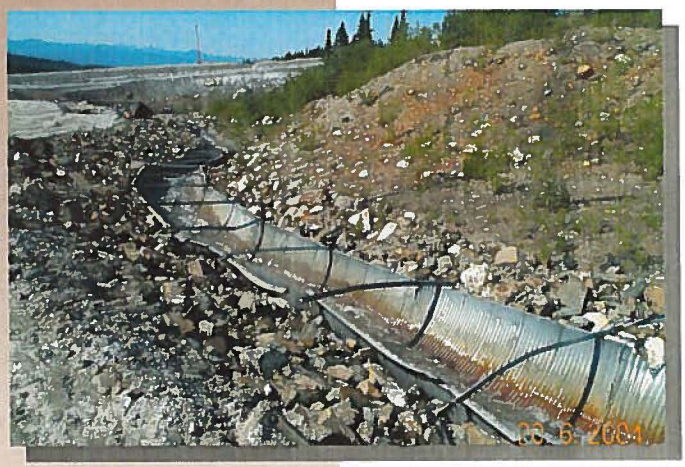
Deloitte & Touche

Vangorda Creek Diversion Design of Emergency Spillway and Recommendations for Flume Upgrade



Prepared for:

DELOITTE & TOUCHE INC.
Interim Receiver of Anvil Range Mining Corporation
Suite 1900, 79 Wellington Street West
Toronto, ON M5K 1B9

Prepared by:

SRK Consulting
Engineers and Scientists

Project Reference Number:
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October 2004

Vangorda Creek Diversion
Design of Emergency Spillway and Recommendations for Flume Upgrade

Deloitte & Touche Inc.

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SRK Project Number 1CD003.62

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1. Introduction

SRK Consulting (SRK) is pleased to submit this report for the design of the emergency spillway to be installed at the headworks of the Vangorda Creek Diversion, Anvil Range Mine, Yukon Territory. The report also provides recommendations for upgrading of the associated 2400mm half-round flume and the plunge pool. Figure 1 provides a vicinity map of the Vangorda Creek diversion system.

SRK completed this work in accordance with a request by Deloitte and Touche (the Interim Receiver of the Anvil Range Mining Corporation) following a major storm event that occurred on June 8, 2004. A report on this event was issued by SRK on July 2004 (SRK, 2004).

This report also provides a summary of the hydrology which formed the basis of the spillway design and flume upgrade. The recommendations provided in this report assume that the flume would remain operational for at the next 10 years and that the remedial measures would provide sufficient security until implementation of the Final Closure and Reclamation plan.

2. Flood Hydrology

The Vangorda Creek diversion was designed to convey the 100-year flood around a lead-zinc ore body that was eventually developed as the Vangorda Pit. The diversion was initially anticipated to have a life span of four years. However, due to the existence of large sources of metal loading in the open pit, the diversion has been retained beyond its originally intended life and is now in its 14th year of operation. At the time of the diversion's design, the 100-year flood was estimated to have an instantaneous peak of 10 m^3/s.

On June 8, 2004, the catchment controlled by the diversion was hit by an intense rainstorm. As a result, the diversion was forced to convey a flow greater than its design discharge. Based on various high water marks along the diversion, the June 8 flood was estimated to peak at about 12 m^3/s, or 20% greater than the design discharge. The methods of estimating the flood magnitude are detailed in an earlier report (SRK, 2004).

The existing diversion will be required to remain in operation for at least another decade, allowing time for a permanent closure measure for the Vangorda Pit to be identified and then implemented. To reduce the risk of overtopping of the headworks embankment and to minimize the impact on the existing flume in the near future, it is proposed to provide an emergency spillway at the headworks to limit the amount of flow that can be diverted down the flume in the event that the diversion experiences another extreme flood event..

Two different options were examined for providing the emergency spillway: i) a surface channel; or ii) one or more culverts. Both options were found to be technically feasible. However, the culvert

option was selected because it would allow the embankment to also continue functioning as a road crossing.

To facilitate the design of the emergency spillway, a spreadsheet was developed to simulate the capacity of the headworks to pass flood events under different configurations for the proposed emergency spillway. The spreadsheet was set up to allow changes to be made to three main variables, namely: the number, diameter and invert elevations of the culverts that would make up the emergency spillway. These three variables were adjusted to meet the design objectives. In selecting values for the variables, 1000mm diameter CMP culverts were selected so that they could be more easily handled using the equipment available at site.

Through a trial and error process, a design for the emergency spillway was selected. The adopted spillway design comprises two 1000 mm diameter culverts set at an invert elevation of 1165 m, or about 3.6 m above the invert of the existing culvert that leads to the flume. Figure 2 shows the estimated rating curve for the headworks with the addition of the two overflow culverts. The blue line on this figure shows how flow through the existing culvert increases as the pond level behind the headworks rises. The red line, on the other hand, shows the combined flow through all three culverts as a function of pond level. If a flood of the same magnitude as June 8 were to occur, then approximately an estimated flow of 10.8 m^3/s would be carried by the flume and about 1.2 m^3/s would be diverted to the open pit via the emergency overflow pipes. The water would rise to an elevation of about 1165.7m.

With the two overflow pipes in place, the system has a capacity to pass a flow of about 21 m^3/s without the embankment being overtopped. Almost 14.7 m^3/s of this total would flow down the flume the remainder would be diverted to the Vangorda Pit via the two overflow pipes. The estimated return period for such an event is several hundreds of years. The design in Section 3 is based on the above parameters.

For discussion purposes only, a second alternative approach was also considered. This alternative considers lowering the invert of the overflow culverts to EL. 1164 (see Figure 19). With this configuration, during an event similar to the one on June 8, 2004, the flume would experience a maximum flow of 9.7 m^3/s while the overflow pipes would see a flow of 2.3 m^3/s. The water level would rise to El. 1165m.

3. Emergency Spillway Design

3.1 Survey

Yukon Engineering Services (YES) completed a survey of the headwork's embankment, the flume, the plunge pool and the drop structure during the week starting July 5, 2004. The survey picked up spot elevations around the headworks of the Vangorda flume and the location of the proposed spillway culvert. YES also picked up elevations of the tops of all the culverts and ran a profile down the centreline of the flume. Cross sections of the key stations along the flume were also surveyed. The survey results were used to develop the 0.5m contour base map.

3.2 Culvert Design

In order to maintain road access over the creek, the spillway will consist of 2 x1000mm diameter corrugated helical culverts. To optimise the flow through the spillway and minimise the flow through the flume, an inlet invert elevation of 1165m was selected. The culvert is designed with a downward gradient of 1 percent, giving the outlet of the culvert an invert elevation of 1164.7m. The culvert will be approximately 24m in length and will have 68x13mm corrugations. Figure 3 and 4 provide plan views of the spillway. Detailed sections of the culvert are provided in Figures 5 to 7.

3.3 Entrance Channel

The alignment of the entrance channel to the spillway is shown on Figure 3. A typical section through the channel is shown in Figure 7. No riprap erosion protection is required for the sideslopes or base of this channel. The base will be 2 metres wide and the sideslopes will be 1.75:1 (H:V). Riprap protection will be placed around both the pipe culvert. A trashrack will be installed at the entrance to the culverts.

3.4 Exit Chute

Figure 3 shows the alignment of the exit chute from the culverts to the original Vangorda Creek Channel. This channel will require riprap protection. The riprap sizing was based on a velocity of 2.8 m/s. Geotextile filter fabric will be laid on the slope and the base prior to placing the riprap. A typical section through the exit channel is shown on Figure 7.

3.5 Quantity Estimates

Table 1 below summarizes quantity estimates of material required to build the spillway.

Table 1: Vangorda Flume Spillway Quantity Estimates

	Quantity
Excavation Volume (m^3):	1500
Rip-Rap Volume (m^3):	200
Bedding Material Volume (m^3):	100
Filter Fabric Area (m^2):	360
Total Culvert Length (m):	48

4. Flume Upgrade

The Vangorda Diversion flume was originally designed for a flow of $10m^3$/sec and consisted of a 2400mm half round CSP flume constructed within a riprap lined open channel. The flume was anchored down by steel plates connected by cables to cross braces laid over the flume. Although the current configuration of the flume performed well during the June 8, 2004 flood, the overflow channel came close to overtopping in a number of places. Furthermore, in many areas the riprap protection was washed away on each side of the flume which put hydraulic pressure on one section of the flume (STA 0+640) causing the flume to lift.

Figures 8 to 12 provide plans and profiles along the flume from the culvert beneath the headworks culvert to the plunge pool.

Using the survey data provided by YES and input from the flood hydrology, a number of sections along the entire flume were developed to assess the hydraulic capacity of the current flume and overflow channel during the 100 year flood event ($Q_{100} = 10m^3/s$). It was found that in most places, as shown in Table 2, that the current configuration of the flume could accommodate the design event while maintaining a freeboard of 0.5m. However, between STA 0+610 and 0+650, the freeboard above the water surface during the peak flow of the 100 year event dropped below 0.5m. Sections along the flume between these stations are shown in Figures 15 to 17.

During an inspection of the flume on June 19, 2004, it was observed that a number of the flume sections and cross braces had been damaged by the flood.

In order to remediate this situation, SRK recommends the following

- Remove the old flume sections between STA 0+460 and 0+640;
- Replace damaged flume sections and cross braces;
- Repair flume sections and replace anchor plates where applicable;

- Top-up the riprap within the overflow channel so that it becomes level with the top of the flume (See Figures 14 to 17)
- Construct a new training berm along the overflow channel from STA 0+610 to 0+650.(See Figure 18)

Photos of the flume sections that will be replaced or repaired are shown in Appendix A.

Table 2: Vangorda Flume Freeboard Calculations

Station	Slope m/m	Left Bank Distance (m)	Right Bank Distance (m)	Culvert Invert El. (m)	Shoulder El. (m)	Depth of Flow (m)	Freeboard (m)
0+070	0.018	1.8	2	1157.945	1160.244	1.25	**1.049**
0+190	0.022	2.1	1.8	1155.407	1157.581	1.203	**0.971**
0+285	0.018	3.6	1.6	1153.676	1155.53	1.25	**0.604**
0+350	0.008	1.9	2.2	1152.594	1155.51	1.44	**1.476**
0+410	0.004	1.1	2.8	1152.125	1154.949	1.64	**1.184**
0+460	0.004	1.1	2.55	1151.732	1153.858	1.65	**0.476**
0+490	0.003	6.25	2.95	1151.456	1153.659	1.61	**0.593**
0+540	0.003	6.5	2.7	1150.812	1152.979	1.61	**0.557**
0+590	0.041	8.3	3.2	1150.177	1151.944	1.01	**0.757**
0+620	0.024	6.05	3.1	1149.51	1151.056	1.17	**0.376**
0+640	0.024	3.25	2.3	1149.04	1150.318	1.17	**0.108**
0+650	0.08	1.75	1.7	1148.3	1149.923	0.83	**0.793**
0+660	0.08	1.75	1.7	1147.5	1149.241	0.83	**0.911**
0+700	0.1	1.05	1.2	1144.244	1146.282	0.793	**1.245**
0+740	0.077	0.6	0.45	1141.13	1143.26	0.85	**1.28**
0+800	0.077	0.6	0.45	1136.299	1138.817	0.85	**1.668**
0+820	0.072	0.7	2.35	1135.16	1137.4	0.86	**1.38**
0+860	0.072	2.8	4.05	1132.164	1134.6	0.86	**1.576**

5. Plunge Pool Upgrade

During the June 8, 2004 flood event, a significant amount of debris accumulated in the bottom of the plunge pool and there was erosion of the sideslopes. SRK recommends that the debris be excavated out of the pool and riprap erosion protection be placed around the sides of the plunge pool to an height of at least 1m above the crown of the 2000mm CSP culvert. The riprap should have a D_{50} of at least 250mm and should be about 0.5m thick. Geotextile filter fabric should be placed on the slope prior to placing the riprap. The slopes should be no steeper than 1.5:1 (H:V). A layout of the plunge pool is shown on Figure 13.

6. Headwater Pool

As for the pool, debris also accumulated in the area immediately upstream of the existing culvert beneath the headworks embankment. Boulders partially block the entrance to the culvert as shown on Photo 13. SRK recommends that the debris in the immediate area above culvert be removed including the bolders.

This report, Vangorda Creek Diversion - Design of Emergency Spillway and Recommendations for Flume Upgrade, 1CD003.62, was prepared by SRK Consulting

Prepared by

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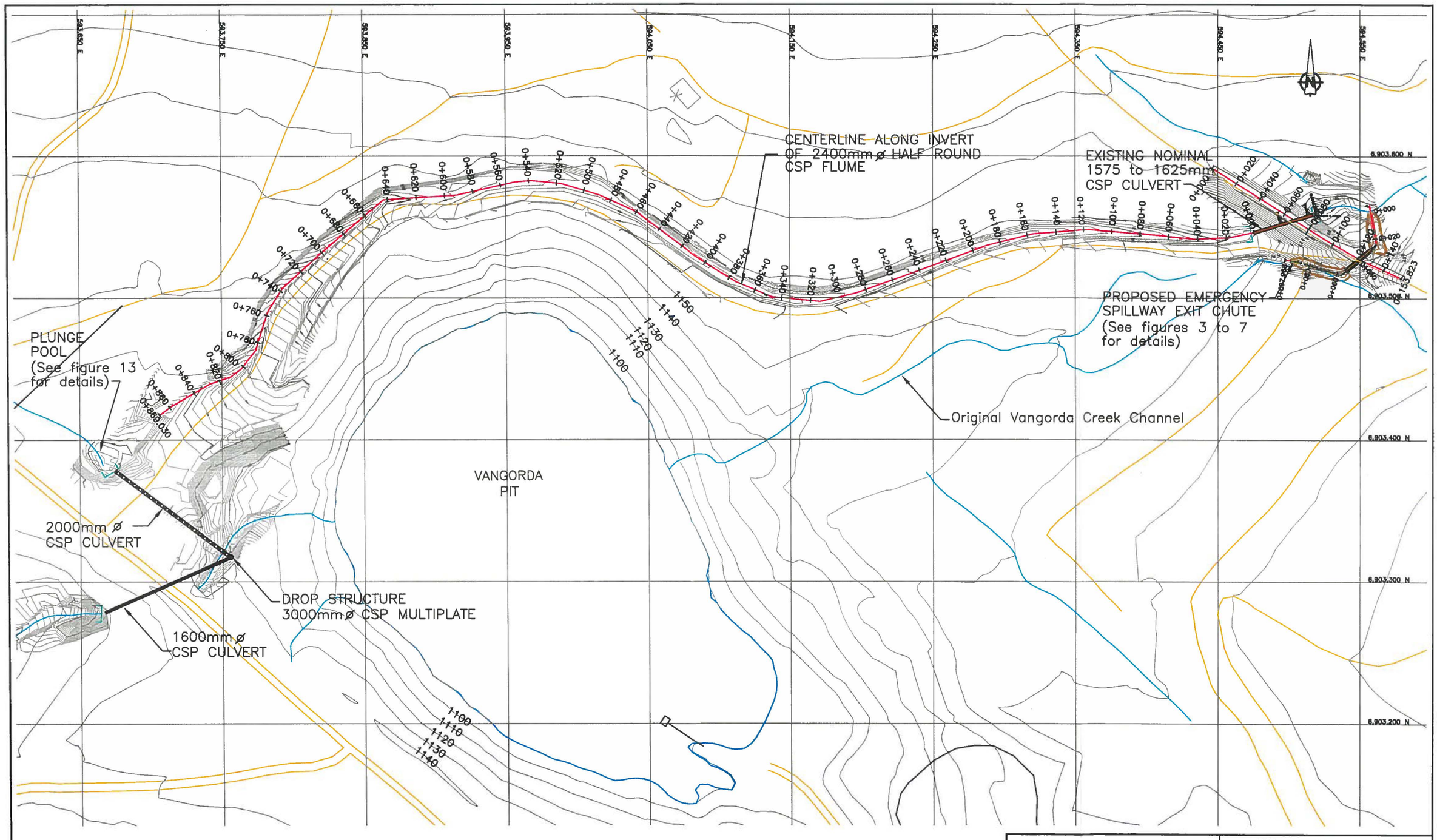
Figures



CONTOUR INTERVAL 0.5m
BASE MAP BASED ON SURVEY
COMPILED BY YES, JULY 5, 2004
CONTOUR INTERVAL 10m BASED ON
MAPPING PREPARED BY ORTHOSHOP,
AUGUST 2004.
DATUM: NAD 27
GRID: UTM

0 20 40 60 80 100 Metres
1:2500

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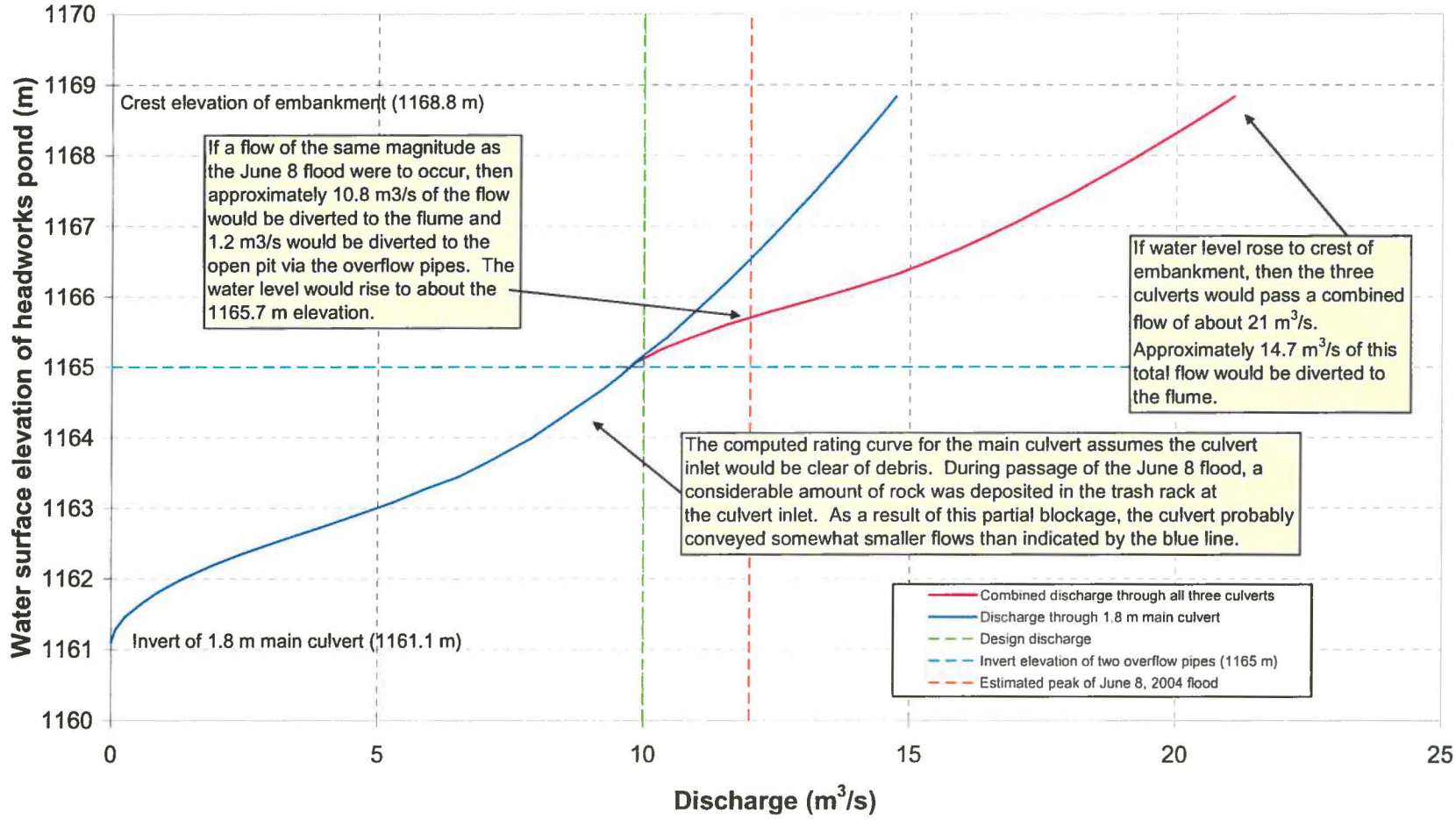
& Touche

VANGORDA CREEK DIVERSION

VICINITY MAP

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	1



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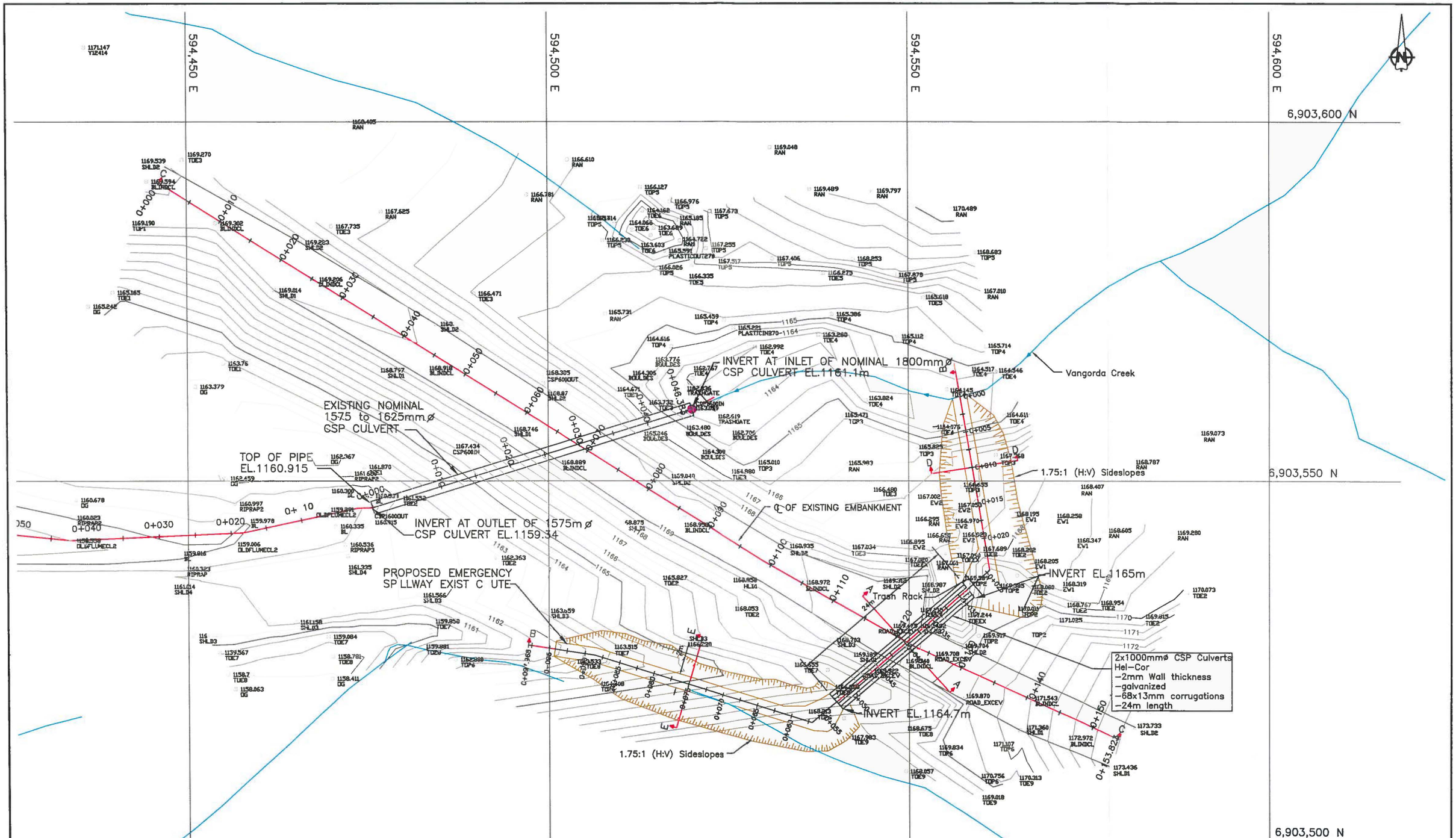
Vangorda Creek Diversion Upgrade

Estimated Discharge Capacity at Headworks with the Installation of two 1000mm diameter Overflow Pipes – El 1165

PROJECT:	DATE:	APPROVED:	FIGURE:
1CD003.62	Oct. 2004		2



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EMERGENCY SPILLWAY LOCATION MAP

PROJECT NO.	DATE	FIGURE
1CD003.56	OCT. 2004	3

INVERT AT INLET OF NOMINAL 1800mmØ CSP CULVERT EL.1161.1m

Vangorda Creek

1.75:1 (H:V) Sideslopes

℄ OF EXISTING EMBANKMENT

OF 1575mmØ
159.34

Trash Rack

INVERT EL.1165m

INVERT EL.1164.7m

1.75:1 (H:V) Sideslopes

2x1000mmØ CSP Culverts
Hel-Cor
-2mm Wall thickness
-galvanized
-68x13mm corrugations
-24m length

0 5 10 15 20 Metres
1:500

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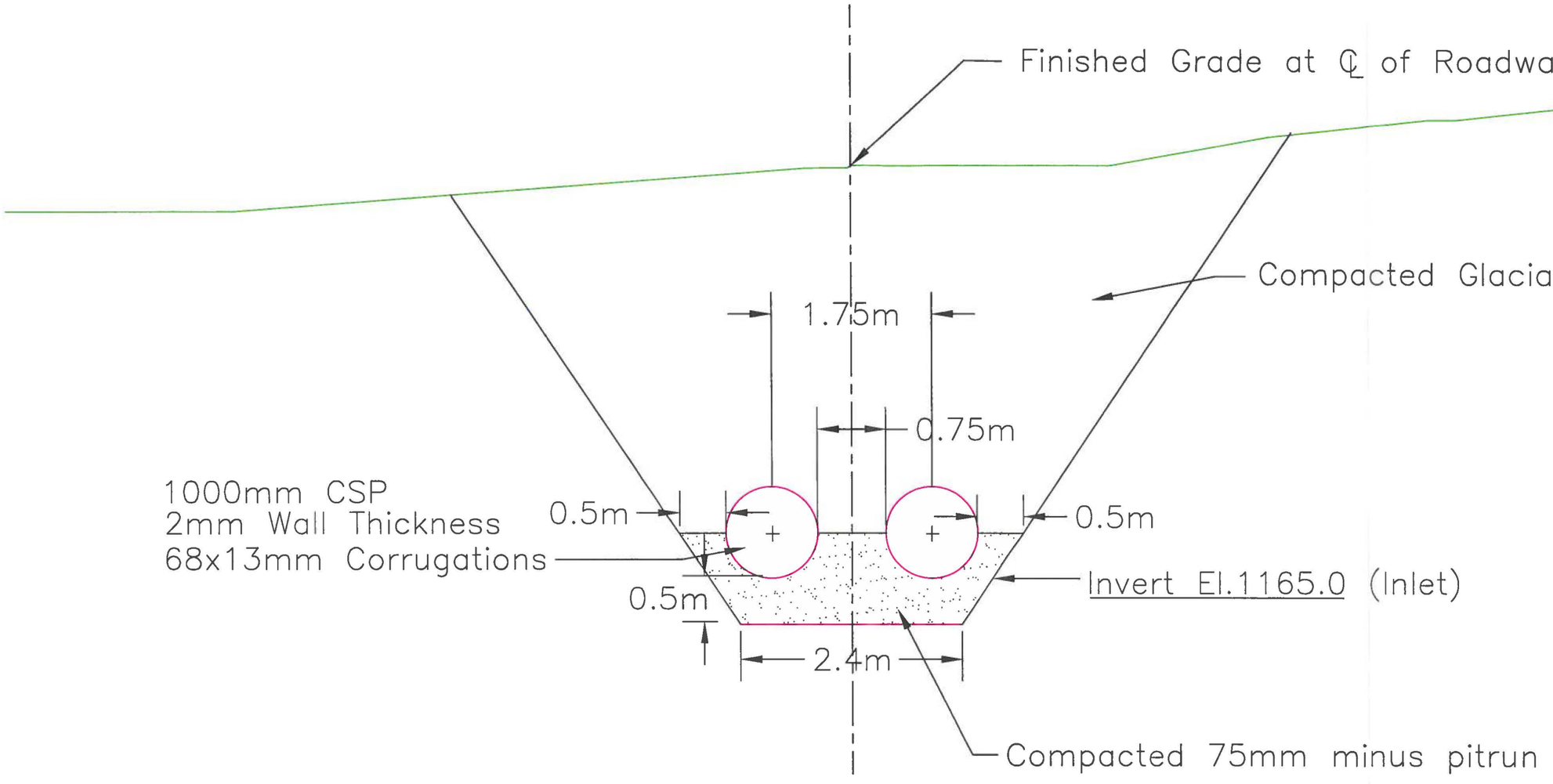
EMERGENCY SPILLWAY SITE PLAN

PROJECT NO.	DATE	FIGURE
1CD003.56	OCT. 2004	4



Section A–A
1:50

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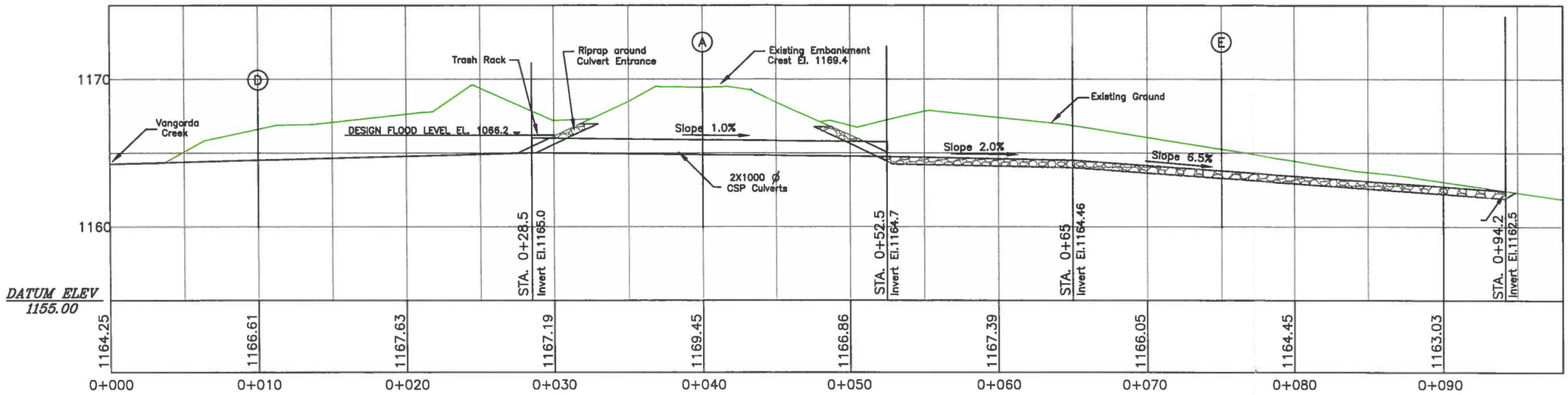
SECTION A–A

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	5



Section B–B
1:300

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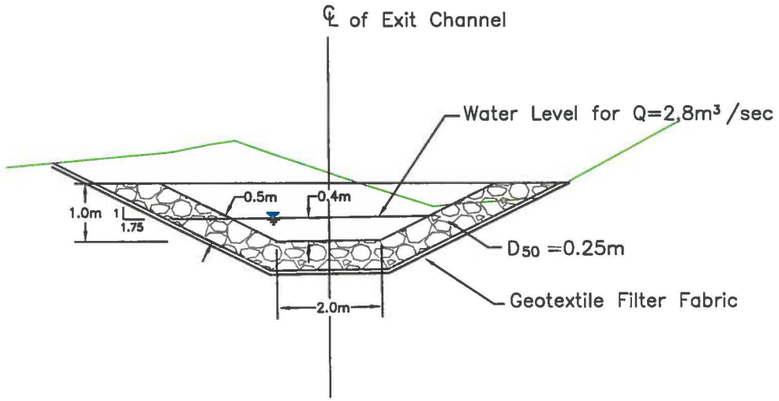
SECTION B–B

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	6



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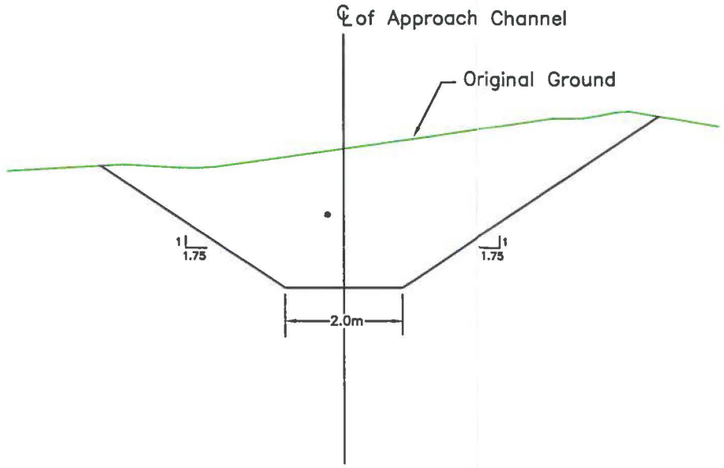

Section D–D

0 1 2 3 4 5 Metres

1:100

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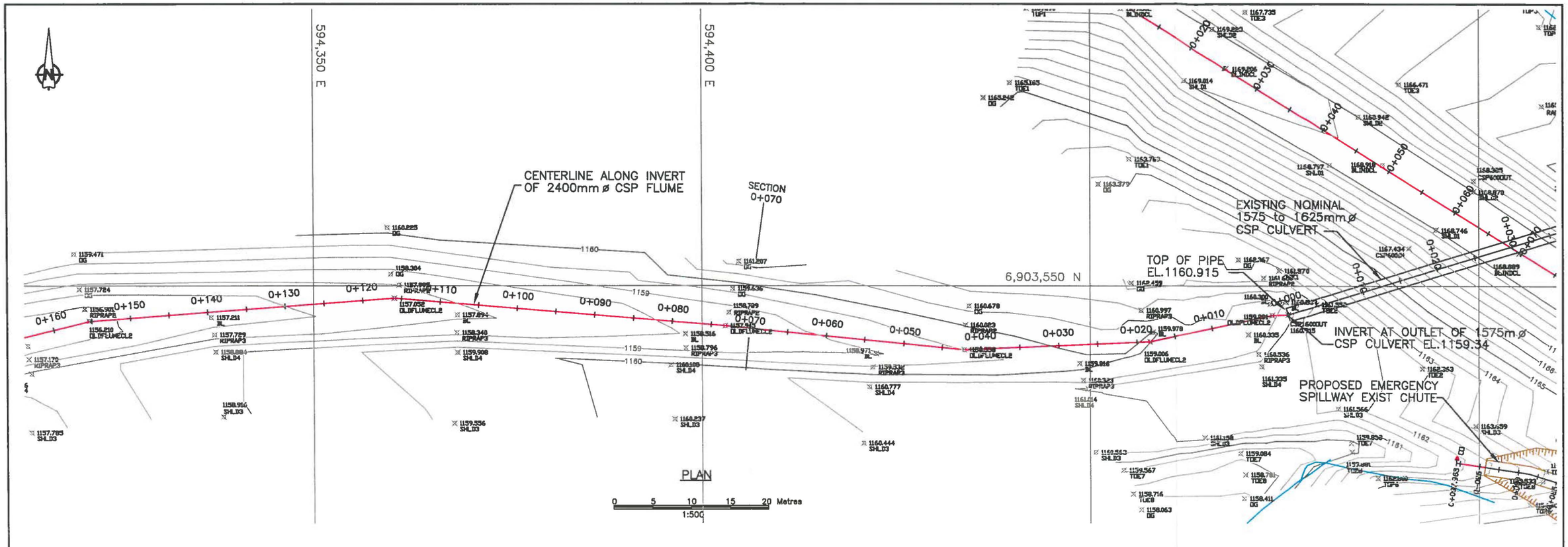
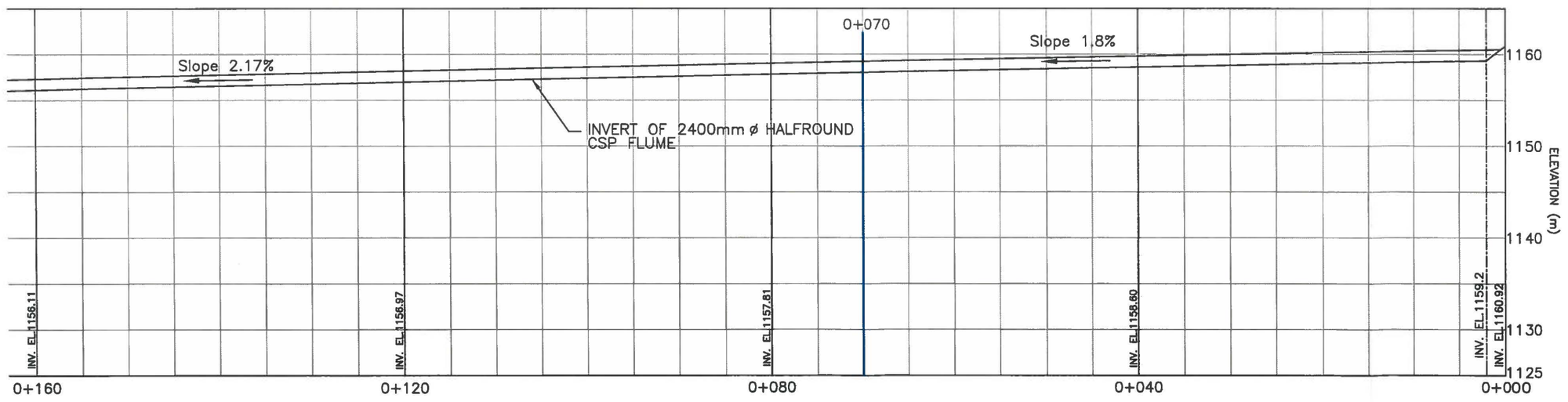
VANGORDA CREEK DIVERSION

EMERGENCY SPILLWAY
TYPICAL SECTIONS

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	7





PROFILE ALONG INVERT OF 2400mm ø HALFROUND CSP FLUME

0 5 10 15 20 Metres
1:500

CONTOUR INTERVAL 0.5m
BASE MAP BASED ON SURVEY
COMPILED BY YES, JULY 2004
DATUM: NAD 27

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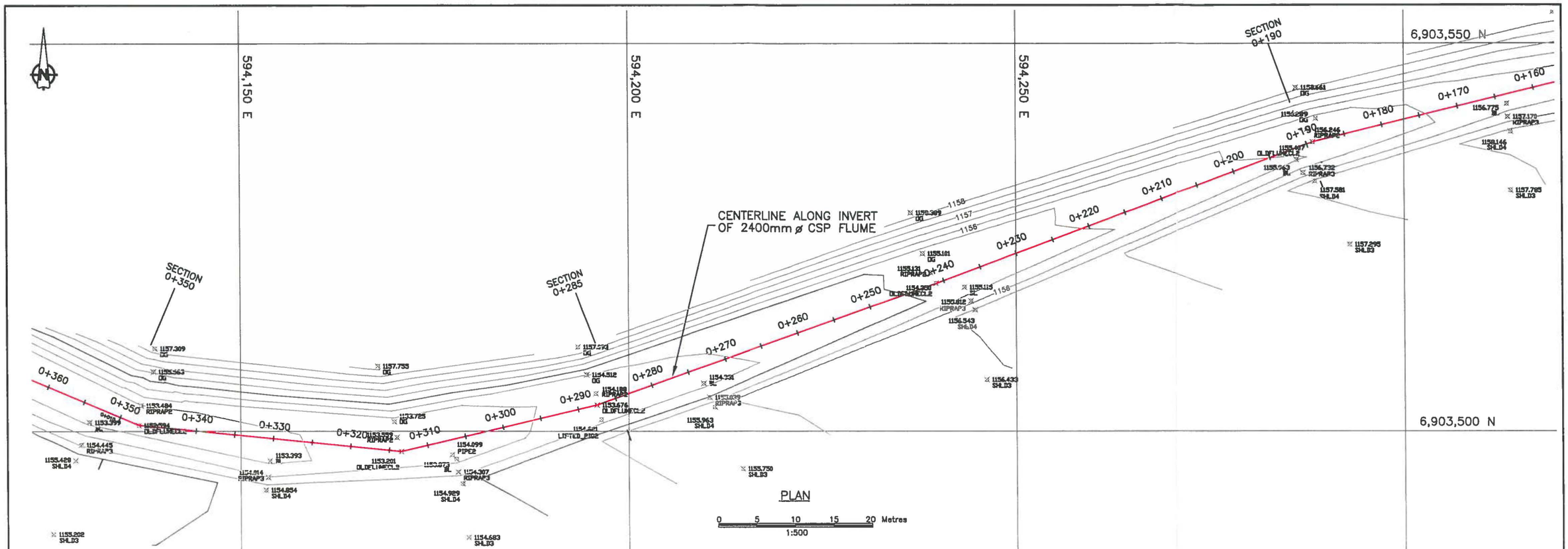
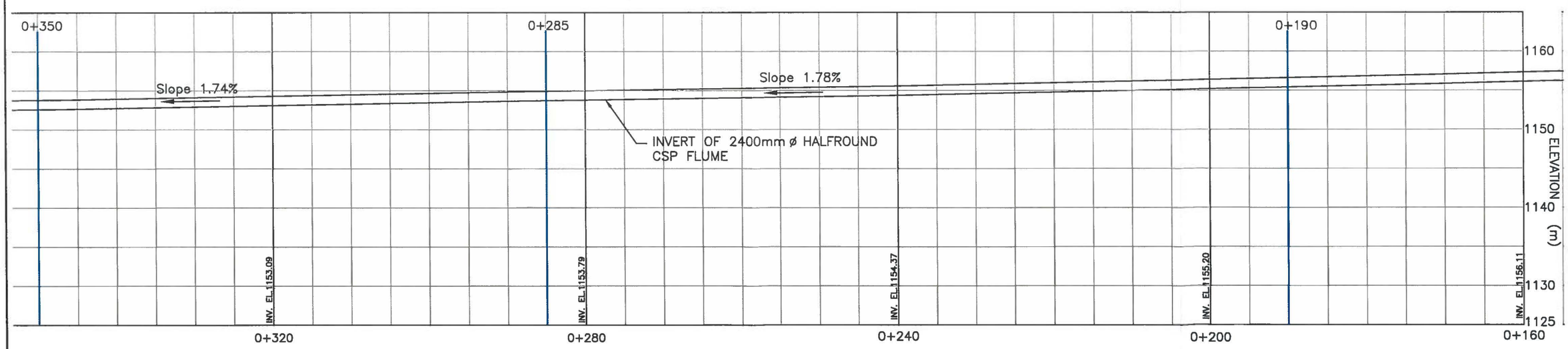
FLUME SITE PLAN AND PROFILE
(0+00 to 0+160)

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	8





PROFILE ALONG INVERT OF 2400mm ø HALFROUND CSP FLUME

0 5 10 15 20 Metres
1:500

CONTOUR INTERVAL 0.5m
BASE MAP BASED ON SURVEY
COMPILED BY YES, JULY 2004
DATUM: NAD 27

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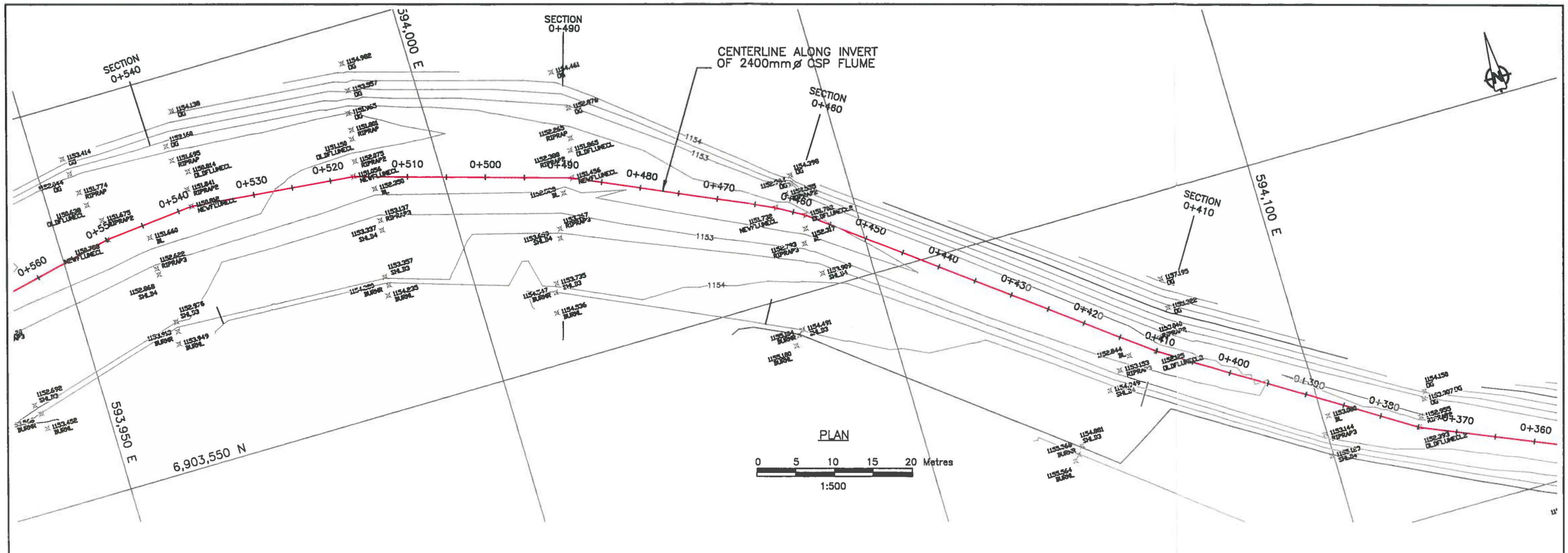
FLUME SITE PLAN AND PROFILE
(0+160 to 0+350)

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	9



CONTOUR INTERVAL 0.5m
BASE MAP BASED ON SURVEY
COMPILED BY YES, JULY 2004
DATUM: NAD 27

PROFILE ALONG INVERT OF 2400mm ø HALFROUND CSP FLUME

0 5 10 15 20 Metres
1:500

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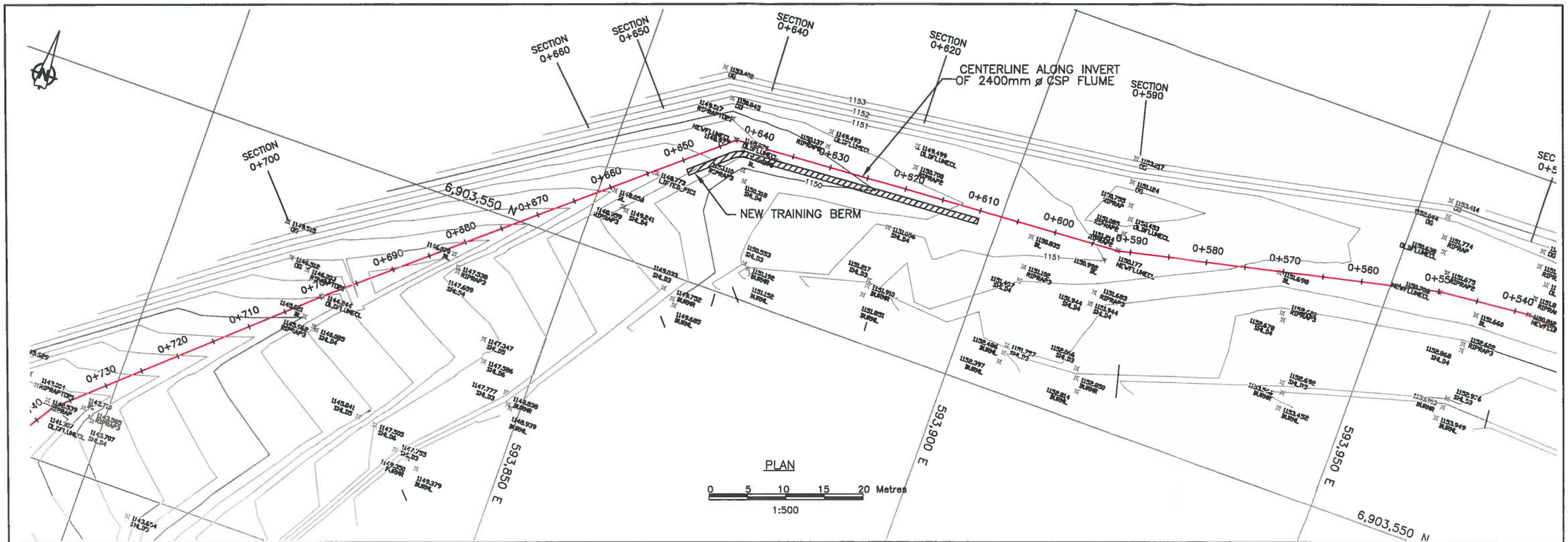
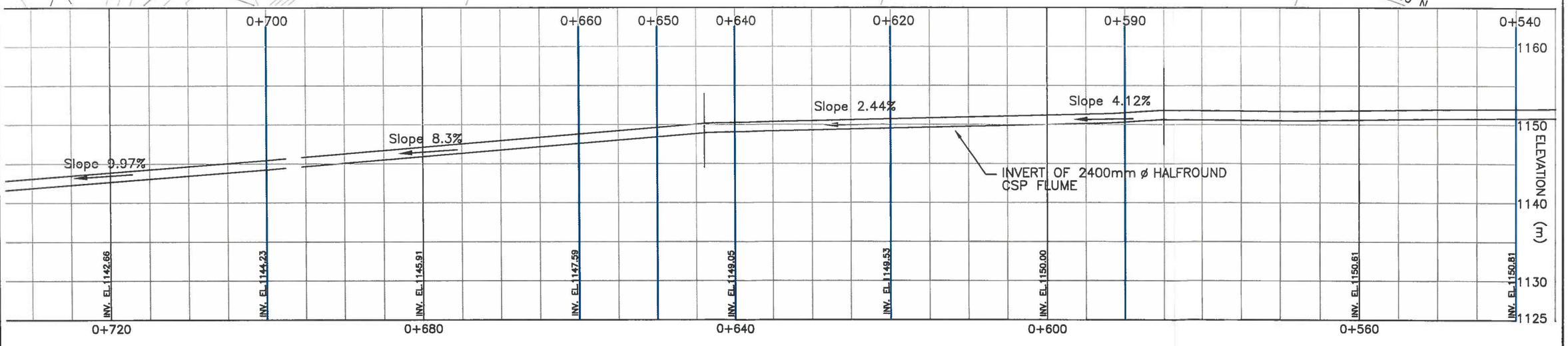
FLUME SITE PLAN AND PROFILE (0+350 to 0+540)

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	10





PROFILE ALONG INVERT OF 2400mm ø HALFROUND CSP FLUME

0 5 10 15 20 Metres
1:500

CONTOUR INTERVAL 0.5m
BASE MAP BASED ON SURVEY
COMPILED BY YES, JULY 2004
DATUM: NAD 27

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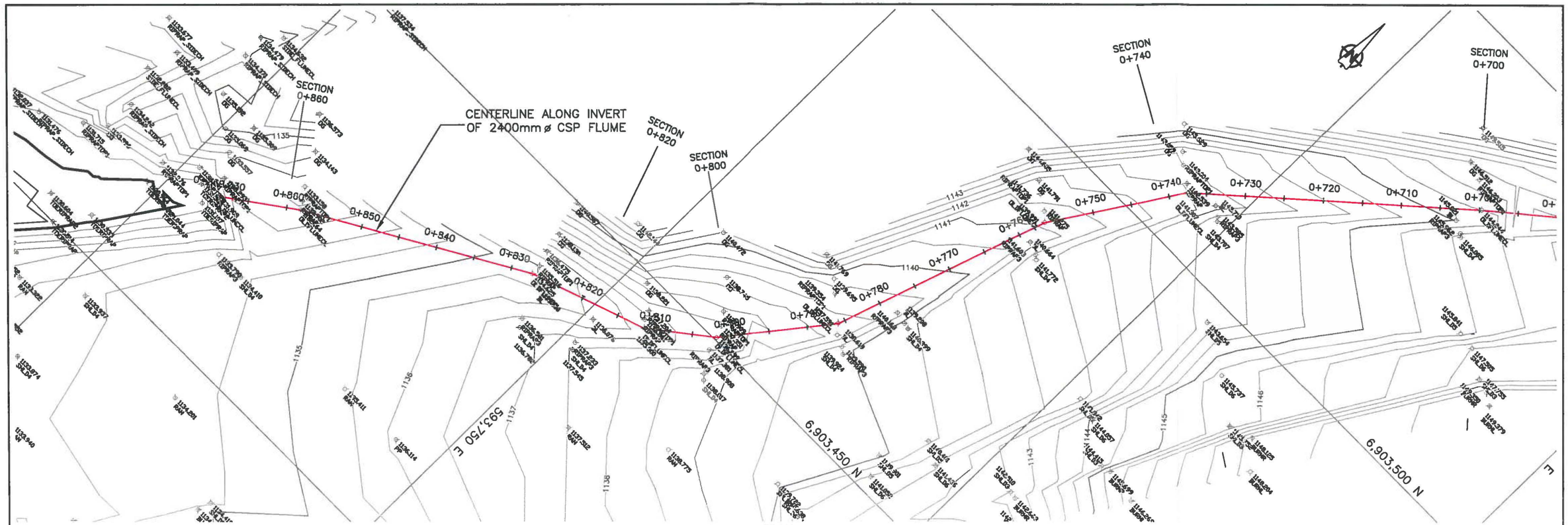
FLUME SITE PLAN AND PROFILE (0+540 to 0+720)

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	11



PLAN

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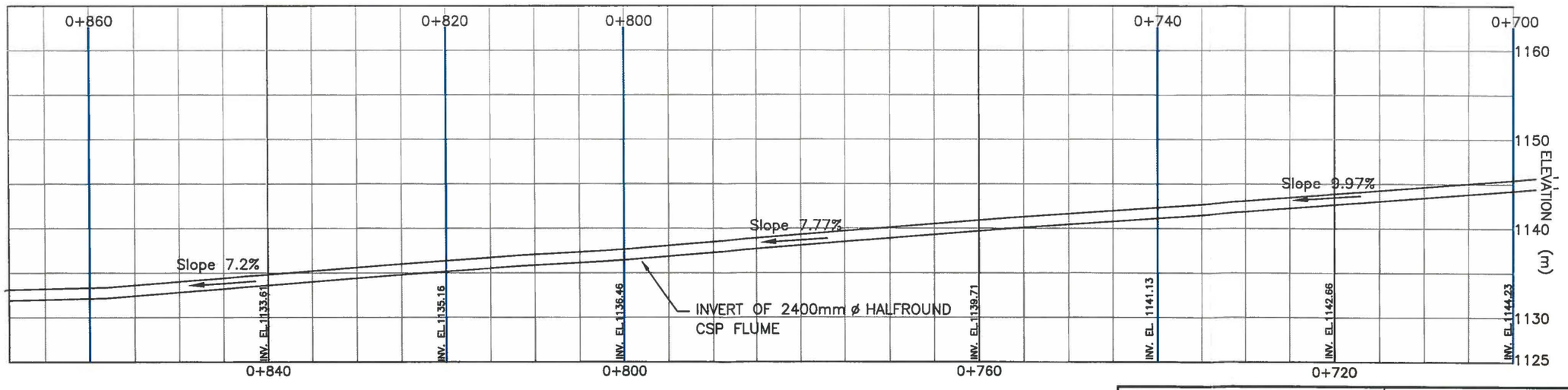
1:500



PROFILE ALONG INVERT OF 2400mm ø HALFROUND CSP FLUME

0 5 10 15 20 Metres
1:500

CONTOUR INTERVAL 0.5m
BASE MAP BASED ON SURVEY
COMPILED BY YES, JULY 2004
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FLUME SITE PLAN AND PROFILE
(0+700 to 0+860)

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	12

UPPER LIMIT OF
RIP RAP EROSION
PROTECTION
AROUND PLUNGE POOL

INVERT OF 2000mm ø CSP
EL. 1128.135

INVERT OF 2000mm ø CSP
EL. 1122.413

593,750 E

6,903,350 N

1124.235
TOP11

1123.313
TOP11

CONTOUR INTERVAL 0.5m
BASE MAP BASED ON SURVEY
COMPILED BY YES, JULY 2004
DATUM: NAD 27
GRID: UTM

0 5 10 15 20 Metres
1:500

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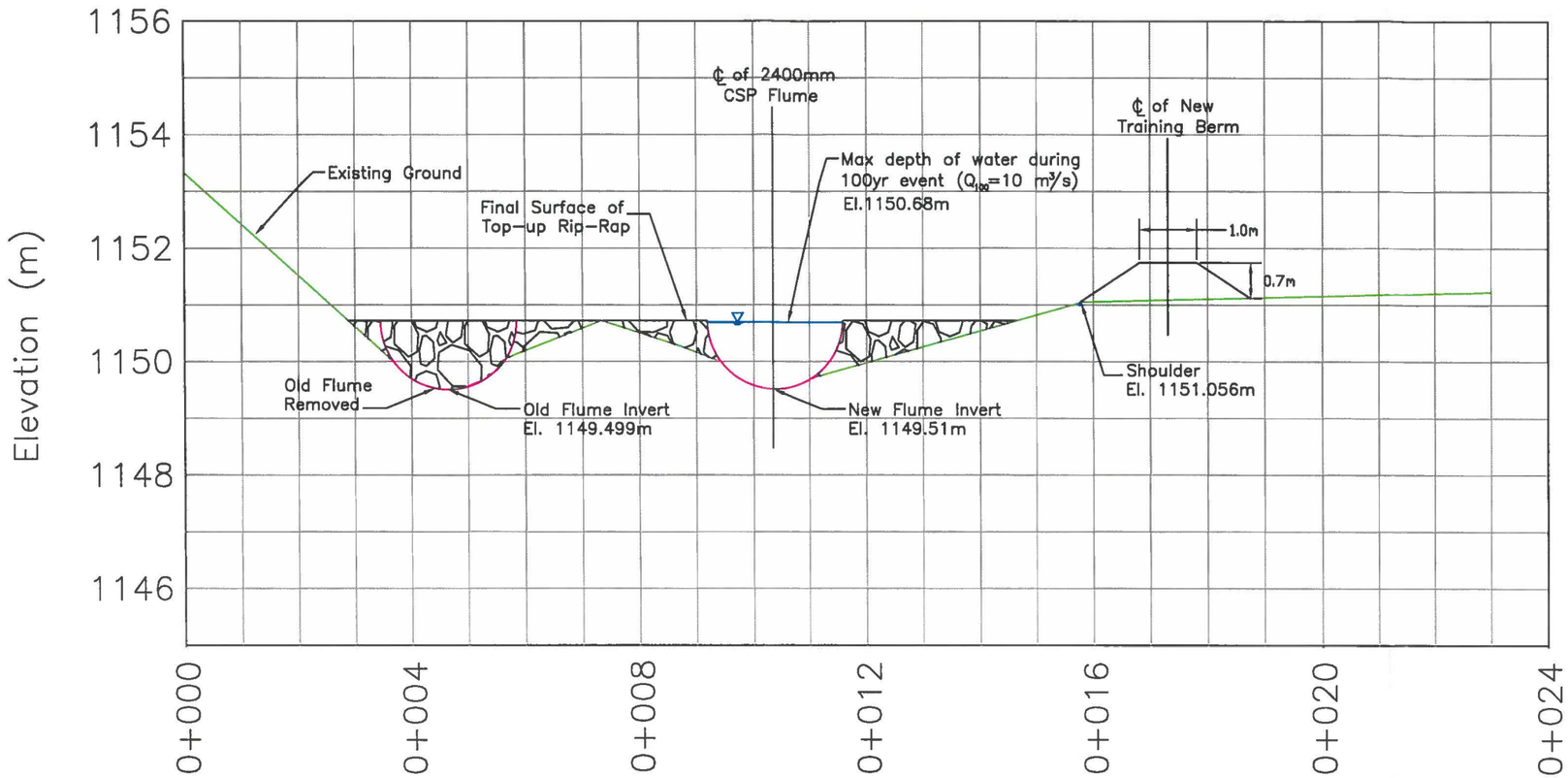
PLUNGE POOL
SITE PLAN

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	13



0+620

1:100

NOTE:
SEE TABLE 2 FOR FLUME DATA

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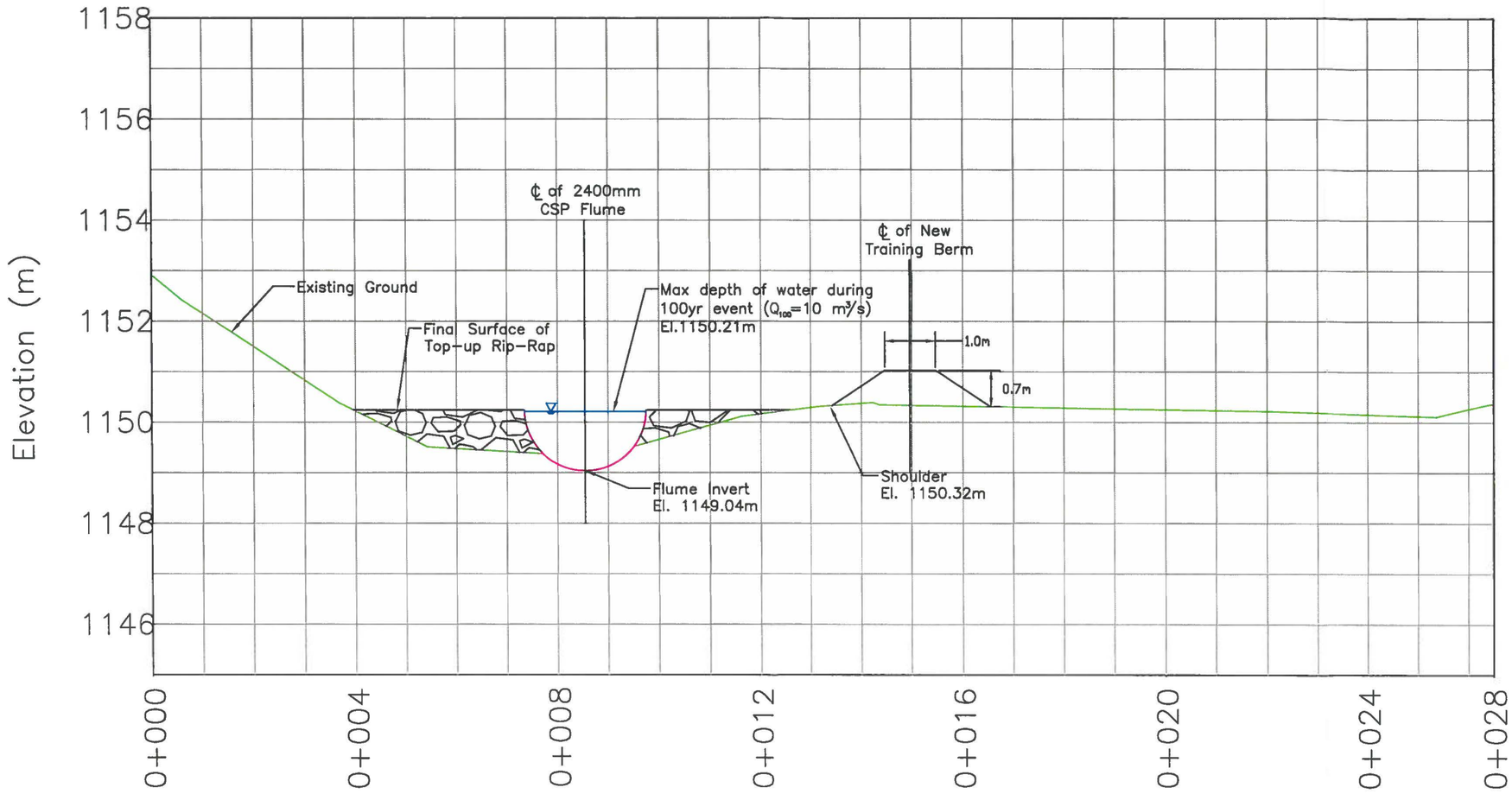
FLUME SECTION
STATION 0+620

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	14



0+640
1:100

NOTE:
SEE TABLE 2 FOR FLUME DATA

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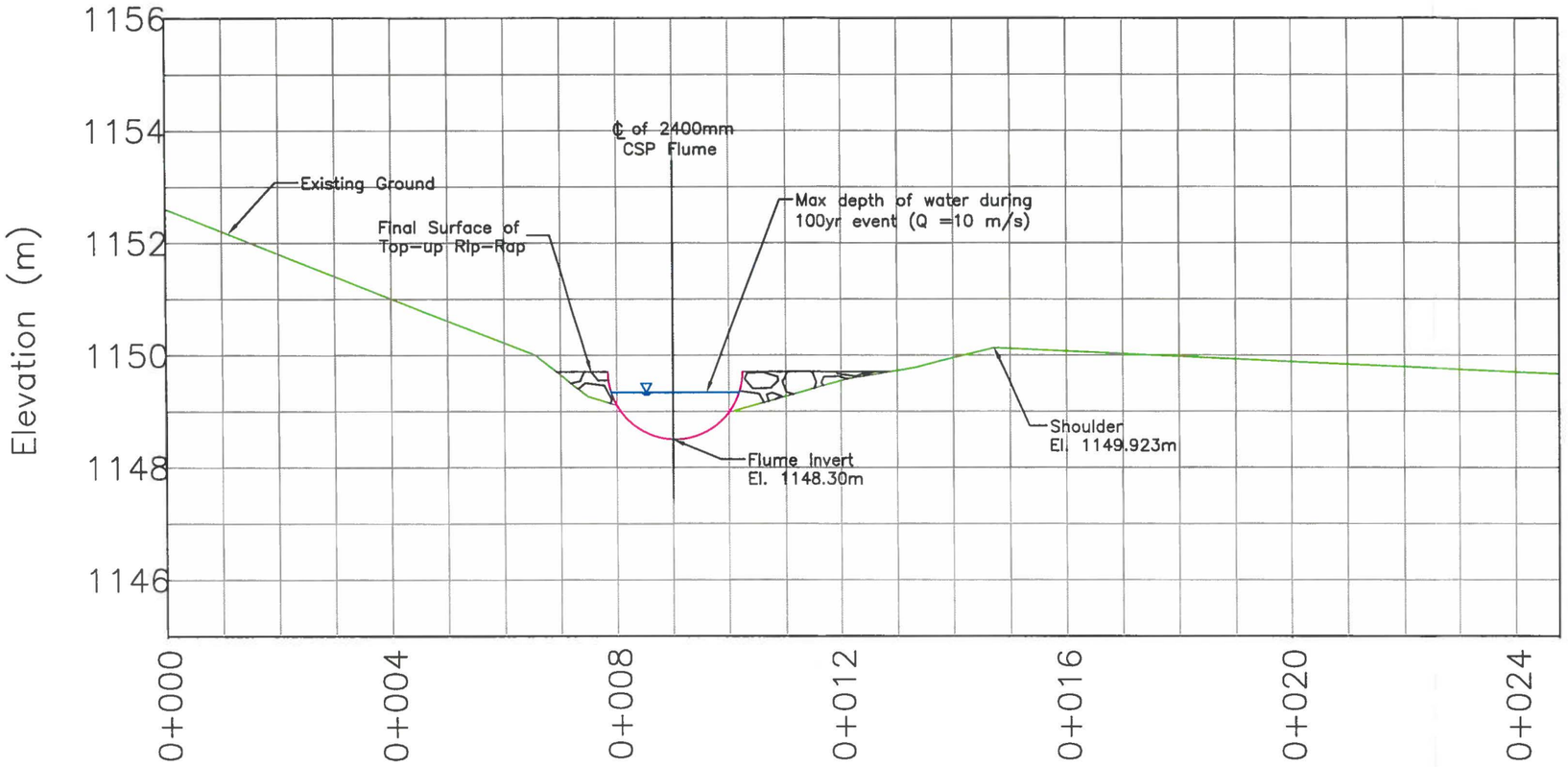
VANGORDA CREEK DIVERSION

FLUME SECTION
STATION 0+640

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	15



0+650

1:100

NOTE:
SEE TABLE 2 FOR
FLUME DATA

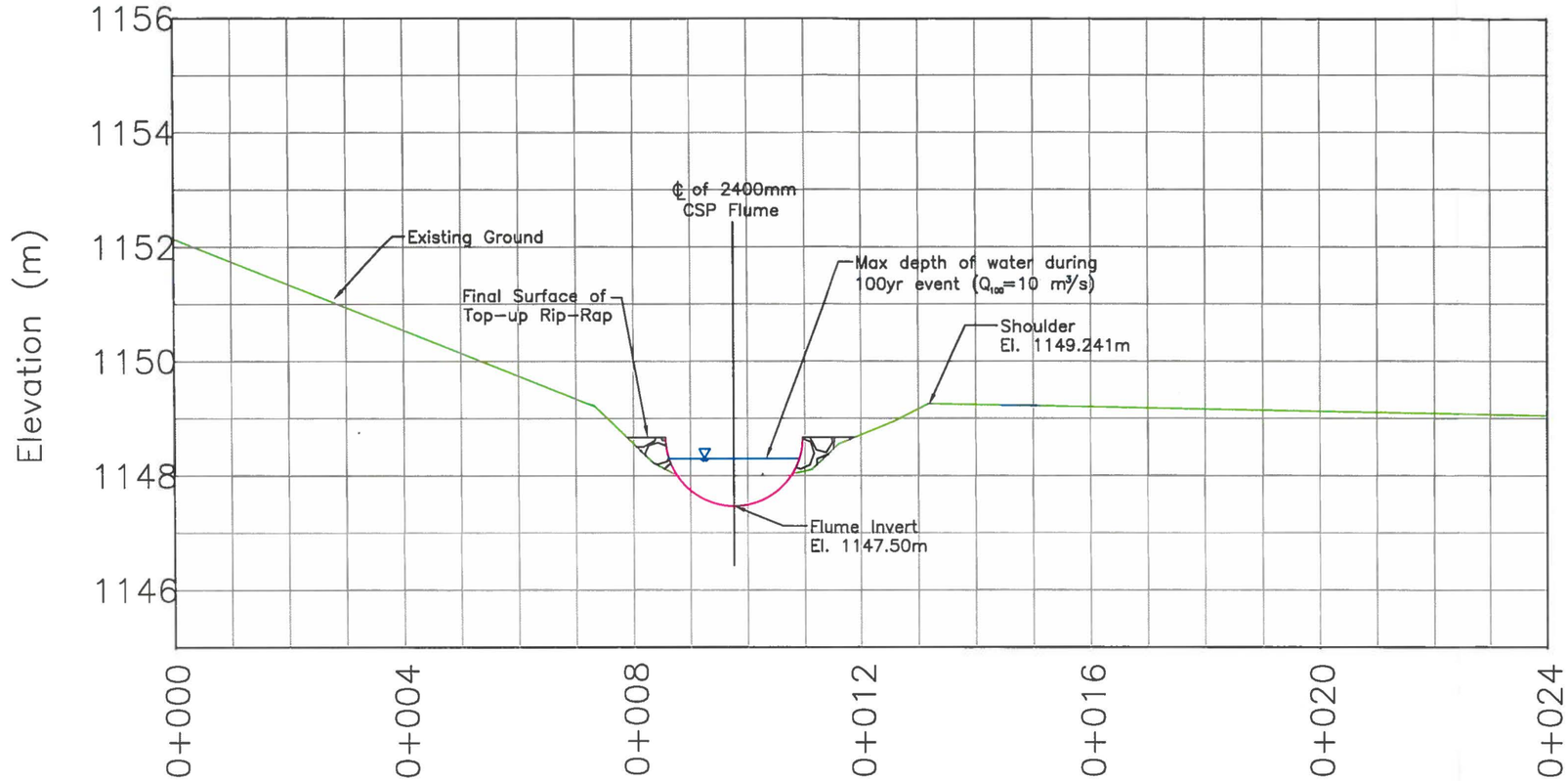
SRK Consulting
Engineers and Scientists

Deloitte & Touche

VANGORDA CREEK DIVERSION

FLUME SECTION
STATION 0+650

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	16



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NOTE:
SEE TABLE 2 FOR
FLUME DATA

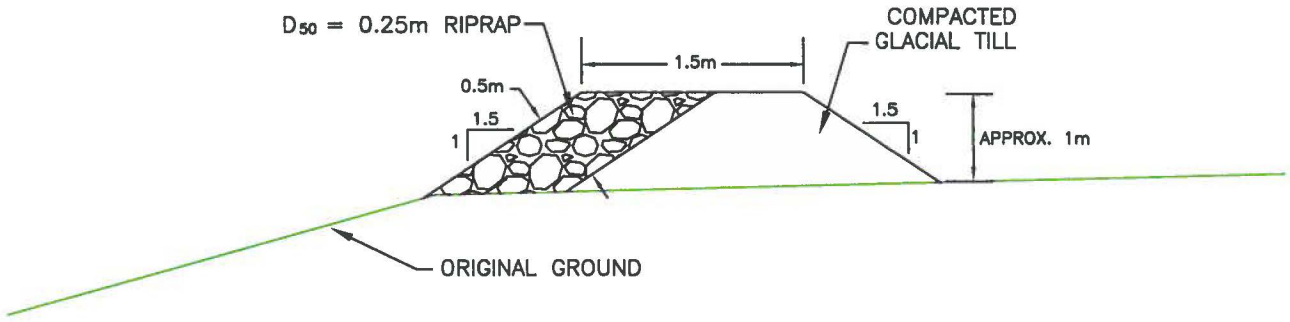
SRK Consulting
Engineers and Scientists

Deloitte & Touche

VANGORDA CREEK DIVERSION

FLUME SECTION
STATION 0+660

PROJECT NO.	DATE	FIGURE
1CD003.62	OCT. 2004	17



SCALE
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SRK Consulting
Engineers and Scientists

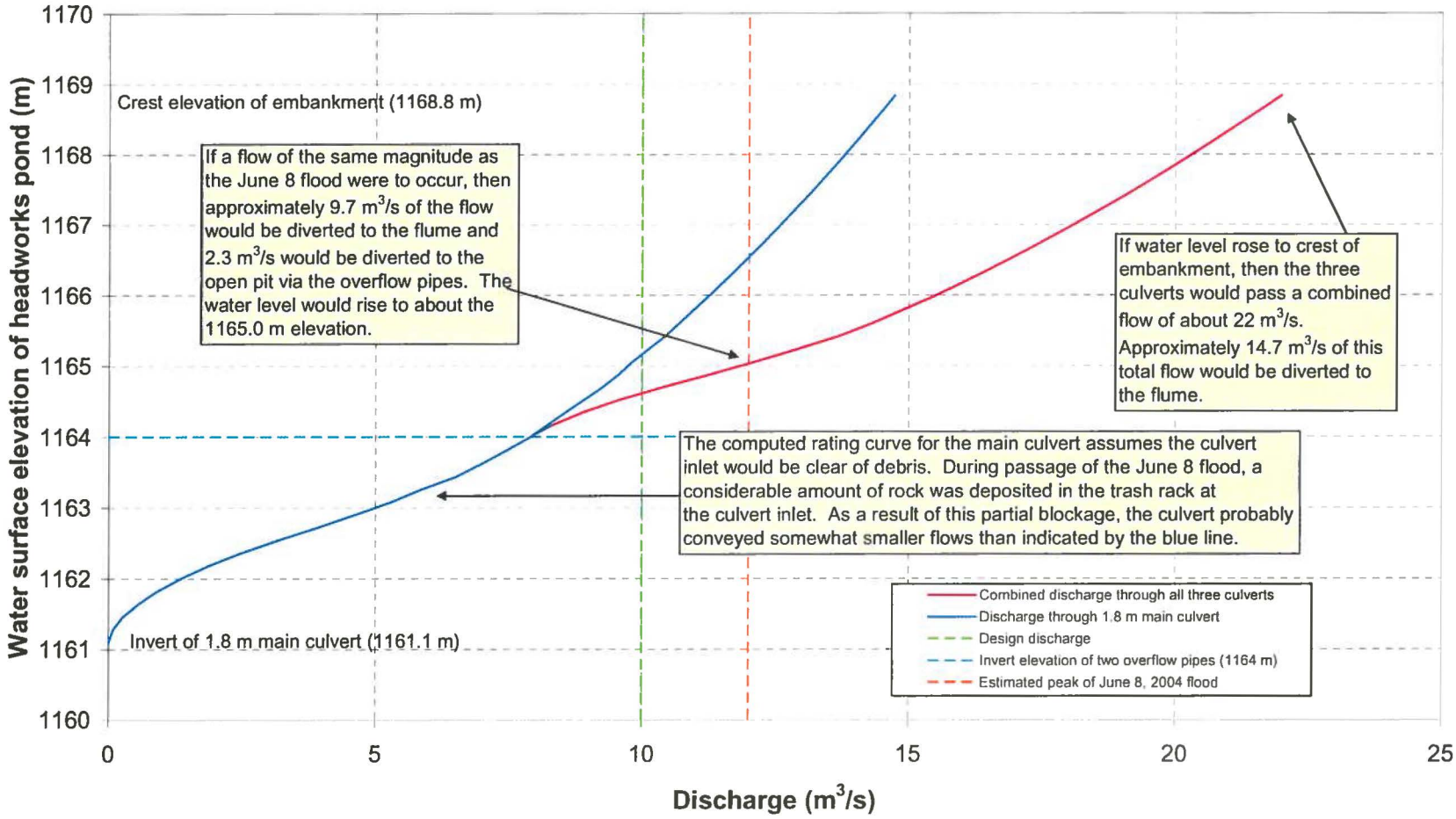
Deloitte & Touche

VANGORDA CREEK DIVERSION

TRAINING BERM
TYPICAL SECTION

PROJECT NO.	DATE	APPROVED	FIGURE
1CD003.62	OCT. 2004		18

Dwg Ref: Mdwg



SRK Consulting
Engineers and Scientists

Deloitte & Touche

Vangorda Creek Diversion Upgrade

Estimated Discharge Capacity at Headworks with the Installation of two 1000mm diameter Overflow Pipes – El 1164

PROJECT:	DATE:	APPROVED:	FIGURE:
1CD003.62	Oct. 2004		19

Appendix A
Photos

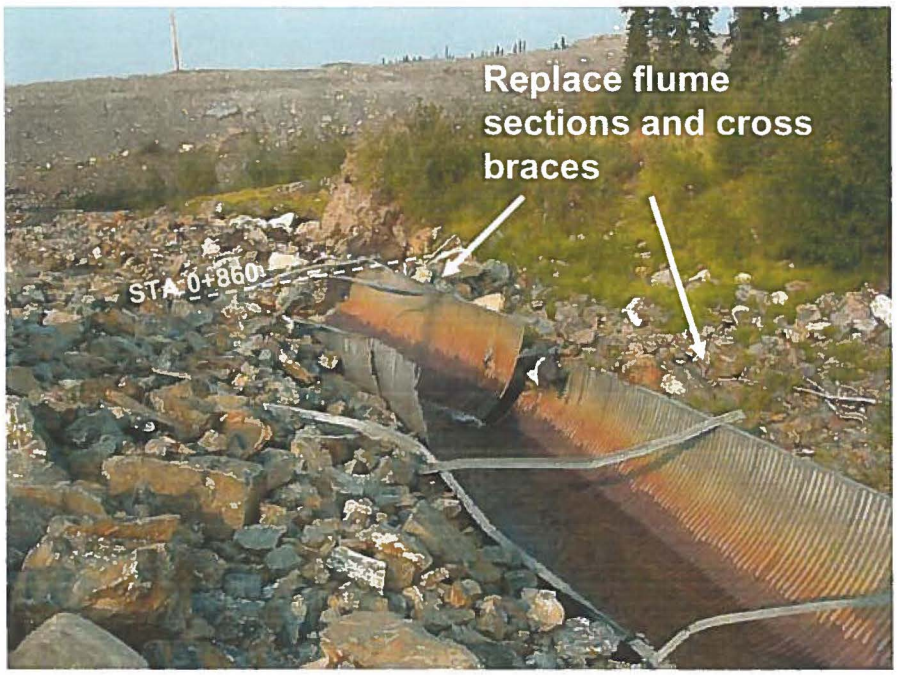


Photo 1: STA 0+860

Photo 2: STA 0+780

Photo 3: STA 0+770

Photo 4: STA 0+640

Photo 5: STA 0+640

Photo 6: STA 0+642

Photo 7: STA

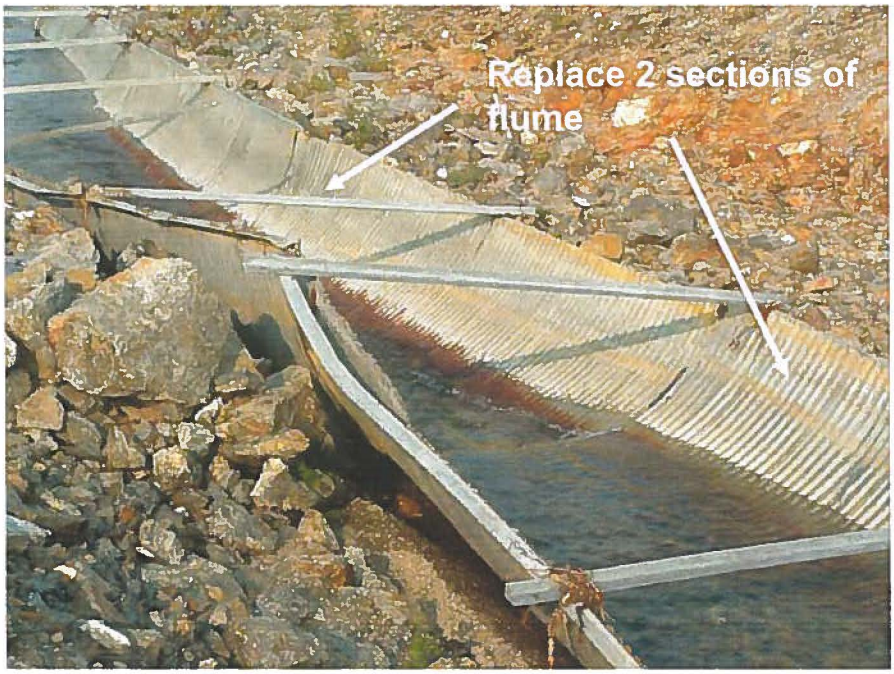


Photo 8: STA

Photo 9: STA 0+630

Photo 10: STA 0+590

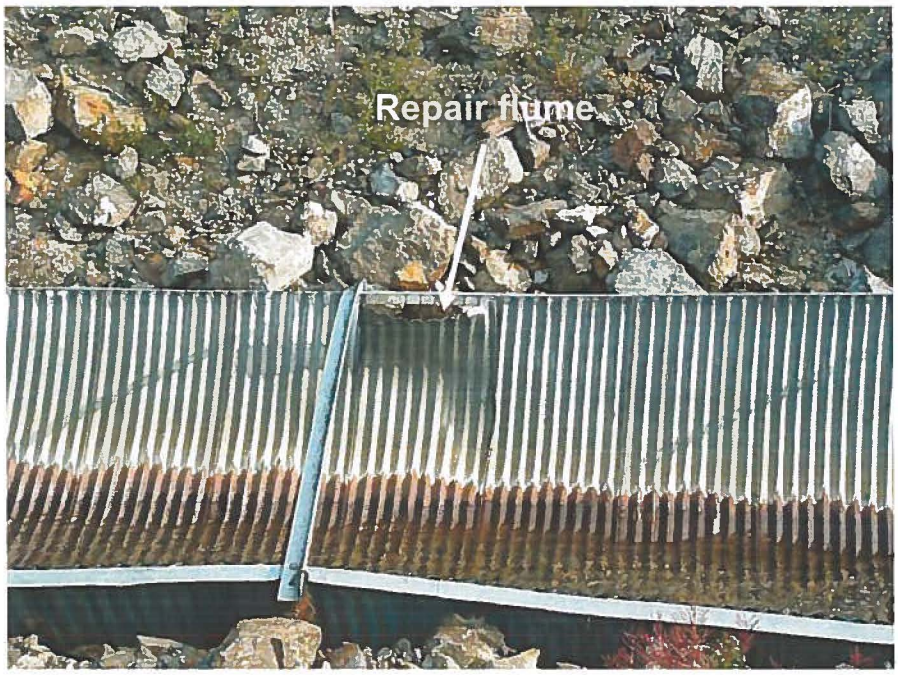


Photo 11:

Photo 12: STA 0+520

Photo 13: