Clarrie Hall Dam Raising

Concept Design Report

Report Number: ISR18033

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Document Control

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Cover Image: Clarrie Hall Dam

Executive Summary

This report concerns concept design for the raising of Clarrie Hall Dam. The proposed raised dam will increase the existing storage at Full Supply Level (FSL) from 16,000 ML to 42,300 ML and is expected to meet the additional water security requirements of the Tweed Shire community well into the future.

The preferred dam raising option incorporates increasing the height of the existing concrete faced rockfill embankment and construction of a new concrete lined spillway higher up in the left abutment. The existing intake tower and access bridge will also be raised.

In accordance with NSW Dams Safety Committee (DSC) guidelines, Clarrie Hall Dam has been assigned an EXTREME Consequence Category which requires safe passage of the Probable Maximum Flood (PMF). Studies have identified that the optimum raising of the dam is with FSL at RL70.0m(AHD). The associated maximum flood level is at RL77.0m(AHD).

Concept design for the raised dam and its components has been based on updated hydrological and geotechnical investigations, seismic and structural assessments. This report presents three options for spillway upgrade but provides more detailed concept design for the preferred option and associated raised dam arrangement. Drawings and cost estimate are included as well as discussion on project risks and constructability.

Concept design has been undertaken in full compliance of DSC and ANCOLD requirements and current best practice.

Table of Contents

Glossary of Terms / Abbreviations

Abutment
That part of the valley side against which the dam is constructed.

AHD
Australian Height Datum.
A datum for the recording of elevations. Zero metres AHD approximates mean sea level along the coast.

ANCOLD
Australian National Committee on Large Dams.

Annual Exceedance Probability (AEP)
The probability of a specified magnitude of a natural event being exceeded in any year.

BOM
Bureau of Meteorology

Catchment
The land surface area that drains to a specific point, such as a reservoir.

Computational Fluid Dynamics (CFD)
3D hydraulic modelling program

Consequence
Effects of an action or event (e.g. the potential for loss of life, property or services).

Consequence Category
The scale of adverse consequences subsequent to a dam failure. Refer also Flood Consequence Category and Sunny Day Consequence Category.

Council
Tweed Shire Council (TSC).

Dam Crest Flood (DCF)
The flood event which, when routed through the reservoir, results in a still water reservoir level at the lowest crest level of the dam.

DSC
NSW Dams Safety Committee.

Flood Consequence Category (FCC)
An estimate of the adverse consequences emanating from flood failure of the dam, such as loss of life, property and services damage and environmental effects.

Foundation
The undisturbed material on which the dam structure is placed.

Freeboard
The vertical distance between a stated water level and the top of the non-overflow section of a dam.

Full Supply Level (FSL)
The maximum normal operating water surface level of a reservoir.

H & V
Horizontal and Vertical e.g. 3.5H to 1V describes the steepness of a slope or batter.

Height of Dam

Normally the maximum height from the lowest point of the general foundation area to the top of the dam.

MDE

Maximum Design Earthquake.

ML
Megalitre (measurement of water volume).

MPa
Megapascal (unit of pressure, measurement of strength, equivalent to about 145psi).

OBE
Operating Basis Earthquake.

Probable Maximum Precipitation (PMP)
The theoretical greatest depth of precipitation for a given duration that is physically possible over a particular catchment area.

Probable Maximum Flood (PMF)
The flood resulting from PMP and, where applicable, snow melt, coupled with the worst flood-producing catchment conditions that can be realistically expected in the prevailing meteorological conditions.

Probable Maximum Precipitation Design Flood (PMPDF)

The flood derived from the PMP using AEP neutral assumptions, and as such it is estimated to have the same AEP as the PMP.

PWA
Public Works Advisory (formerly NSW Public Works).

RL
Reduced Level (Survey).

RORB
The software program used to analyse the hydrology (rainfall–runoff processes) of the catchment and calculates hydrographs and peak discharges.

SCADA
Supervisory Control and Data Acquisition, a means of remote access, associated with telemetry.

Sunny Day Consequence Category (SDCC)
An estimate of the adverse consequences emanating from the non-flood (e.g. earthquake) failure of a dam, such as loss of life, property and services damage and environmental effects.

WAE
Work As Executed

1. Introduction

1.1 Background

Tweed Shire Council has engaged Public Works Advisory within the Department of Finance, Services and Innovation to undertake concept design for the proposed raising of Clarrie Hall Dam. The raising of Clarrie Hall Dam seeks to increase the storage level from the current Full Supply Level (FSL) of RL61.5m(AHD) to RL70.0m(AHD). The proposed raised dam will increase the dam's storage capacity from 16,000 ML to 42,300 ML. The project aims to meet the additional water security requirements of the Tweed Shire community into the future.

This report presents discussion of associated investigations and concept designs and includes drawings and cost estimate for the preferred dam raising option. This report has also been prepared as further background information to support the environmental impact assessment process and Council's business case for investment purposes.

Site locality and location plans covering the study area are provided at the end of this section as **Figure 1-1.**

1.2 Project Deliverables

The key deliverables of this project include the following:

- Updated hydrology study including flood hydrographs and flood frequency curves;
- Geotechnical investigations of the site geology and suitability of the rockfill for the raised embankment;
- Separate hydrological, seismic and geotechnical reports produced by sub-consultants which are summarised in this Concept Design Report;
- Computational Fluid Dynamics (CFD) analysis of the preferred spillway option to confirm the dimensions and hydraulic performance; and
- A comprehensive Concept Design Report incorporating discussion of all investigations, analyses and results and including drawings and cost estimate of the preferred dam raising arrangement.

Construction methodology and timing are discussed in **Section 8**. Project risk and cost estimate are presented in **Section 9** and **Section 10** respectively.

1.3 Reference Documents

Reference documents used for concept design of the proposed dam raising and associated works are mentioned in relevant sections of this report and are fully listed in **Section 12.**

It is noted that, because of its historic and close involvement with Clarrie Hall Dam, Public Works Advisory (formerly NSW Public Works and Public Works Department) has maintained in its possession, and therefore made available for this project, all relevant reference documents including from investigation and design of the original dam (completed in 1984) and later upgrade works (completed in 2014) as well as previous dam raising option studies.

1.4 Design Criteria

The dam raising option developed for this concept is based on NSW Dams Safety Committee (DSC) requirements and is also consistent with Australian National Committee on Large Dams (ANCOLD) guidelines. According to the latest Dambreak Study (NSW Public Works, 2007), Clarrie Hall Dam is assigned a HIGH A Sunny Day Consequence Category (SDCC) and a HIGH A to EXTREME Flood Consequence Category (FCC). Generally, concept design of Clarrie Hall Dam Raising has adopted the greatest assessed Consequence Category from the Dambreak study, that is EXTREME.

The Acceptable Flood Capacity (AFC) starting point, as outlined in DSC3B (June 2010) for EXTREME FCC dams, is the PMF flood. The PMF flood has therefore been used as a basis for key design requirements.

The Maximum Design Earthquake (MDE) from DSC3C (June 2010) for HIGH A SDCC dams is assessed to be the 0.01% AEP (10,000 year) event.

Further discussion regarding the AFC and MDE is provided at **Sections 4.1 and 4.2** respectively.

1.5 Concept Design Drawings

Drawings of the existing dam are attached at **Appendix A**.

Concept design drawings which show the key features, dimensions and extent of the Clarrie Hall Dam Raising project are provided at **Appendix B**. These drawings are listed below.

Drawing No.	Drawing Title
Figure 1	Existing Site Plan
Figure 2	Option 1A General Arrangement
Figure 3	Option 1B General Arrangement
Figure 4	Option 2 General Arrangement
Figure 5	Option 1A/1B Spillway Layout and Long Section
Figure 6	Option 1A/1B Spillway Details and Cross Sections
Figure 7	Option 2 Spillway Layout and Typical Sections
Figure 8	Option 2 Spillway and Training Wall Long Sections
Figure 9	Dam Embankment Raising Plan and Long Section
Figure 10	Dam Embankment Raising Typical Cross Section
Figure 11	Intake Tower General Arrangement
Figure 12	Intake Tower Upgraded Work Details
Figure 13	Intake Tower Upgraded Access Bridge Details

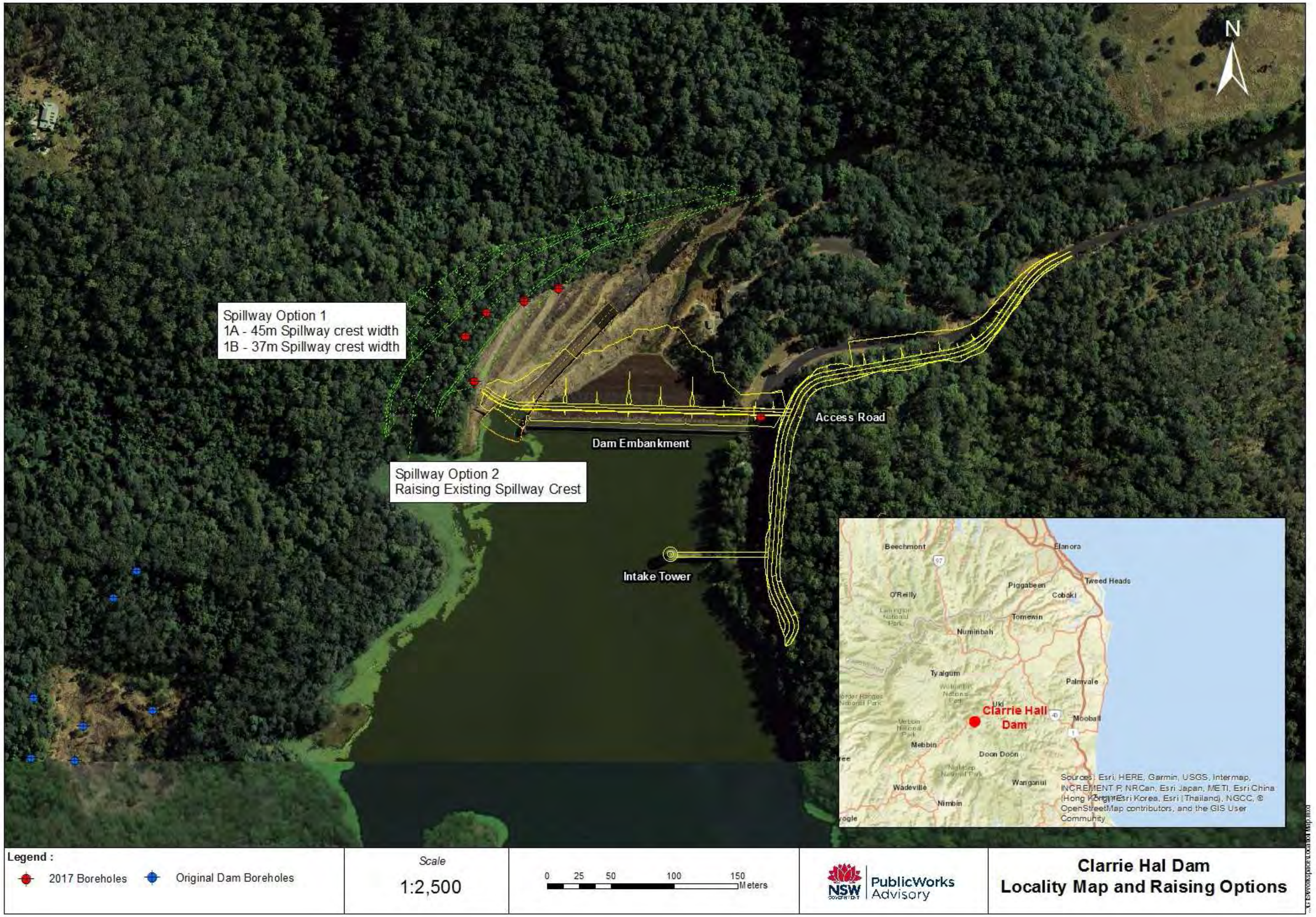


Figure 1-1: Locality and Option Map for Clarrie Hall Dam Raising

2. Description of Existing Dam

Clarrie Hall Dam is located on Doon Doon Creek, some 15 kilometres south-west of Murwillumbah. Doon Doon Creek is a generally north flowing tributary of the South Arm of the Tweed River. Water is released down Doon Doon Creek to the Tweed River, where it is subsequently harvested at the Bray Park weir.

The dam was designed by NSW Public Works (now Public Works Advisory or PWA) and construction was completed in 1984. Clarrie Hall Dam consists of a concrete faced rockfill embankment, a concrete lined spillway, intake and outlet works constructed on a foundation of very hard/strong rhyolite rock (of volcanic origin). The rockfill embankment has a height of 43 metres, crest length of 175 metres and a volume of about 160,000 cubic metres. The crest width is 6 metres; the upstream and downstream slopes are 1V to 1.3H. The upstream slope is covered by a 300mm thick concrete face slab which connects at the top to a wave wall along the embankment crest. Precast concrete parapet wall units are located adjacent to the wave wall which were installed as part of the recent spillway upgrade works. The bottom of the face slab is tied to the embankment's upstream concrete toe slab which also acts as the grout cap. A grout curtain comprising a single line of holes is located under the slab.

The dam is founded on a relatively uniform sequence of hard rhyolite rock with minor welded tuff. Geotechnical investigations have revealed very high to extremely high Uniaxial Compressive Strengths (UCS) for a great part of the rhyolite rock foundation.

Rockfill for construction of the embankment had been sourced from a nearby quarry site located approximately 300m south-west of the dam site.

The embankment profile includes the following zones underneath the upstream concrete face slab described above:

- Zone 1 - a semi permeable zone comprising moderately weathered rhyolite;
- Zone 2 – a permeable intermediate zone comprising slightly weathered to moderately weathered rhyolite;
- Zone 3A – a permeable zone comprising fresh rhyolite; and
- Zone 3B – a downstream mesh and face zone comprising selected fresh rhyolite.

The spillway is an ungated concrete chute with ogee weir and flip bucket located on the left abutment. The spillway chute, and approach area between the dam toe slab and spillway crest, are fully lined and have 6m to 10m high walls. The spillway chute is 110m long. The spillway crest is 36m wide and the chute width narrows to 12m for much of its length. The spillway was upgraded in 2014 (again designed by NSW Public Works), along with placement of precast concrete parapet wall units on the embankment crest, to pass the then probable maximum discharge of 1,355m^3/s.

The intake/outlet system consists of a 34m high, 4m outside diameter reinforced concrete tower of the wet well type situated on a tower base structure at the head of the outlet tunnel which is located under the right abutment.

A concrete lined tunnel through the lower right abutment connects the intake tower with a valve house, located adjacent to the creek approximately 40 metres downstream of the embankment.

The present full supply level (i.e. top water level) of the dam is RL61.5m(AHD) which is 8.9 metres below the embankment wall crest level (i.e. the top of the precast concrete parapet wall on the dam crest). The dam has a catchment area of 60 square kilometres and a storage capacity of 16,000ML.

According to the latest dambreak study (NSW Public Works, 2007), Clarrie Hall Dam is classified as HIGH A Sunny Day Consequence Category and HIGH A to EXTREME Flood Consequence Category.

The existing dam and its components are illustrated on Drawings attached at **Appendix A.**

3. Dam Raising Options Study

A previous study investigating the optimum size and raising options for Clarrie Hall Dam was completed by PWA (NSW Public Works, 2007) and forms the basis of the current concept design. The study assessed five dam raising options:

- Single stage construction to FSL at RL70.0m(AHD);
- Single stage construction to FSL at RL67.0m(AHD);
- Single stage construction to FSL at RL64.5m(AHD);
- Two stage construction, to FSL at RL67.5m(AHD) and then from FSL at RL67.5m(AHD) to FSL at RL70.0m(AHD); and
- Two stage construction, to FSL at RL64.5m(AHD) and then from FSL at RL64.5m(AHD) to FSL at RL70.0m(AHD).

The study showed that the maximum optimum dam size for Clarrie Hall Dam was considered to have a FSL of RL70.0m(AHD). Inundation mapping of the storage levels showed that above a storage level of RL70.0m(AHD) significant breakouts occurred in the upstream storage and would result in the need for saddle dams, significantly increasing the cost of the project. The inundation extent of the dam storage with FSL at RL70.0m(AHD) is provided in **Figure 3-1**.

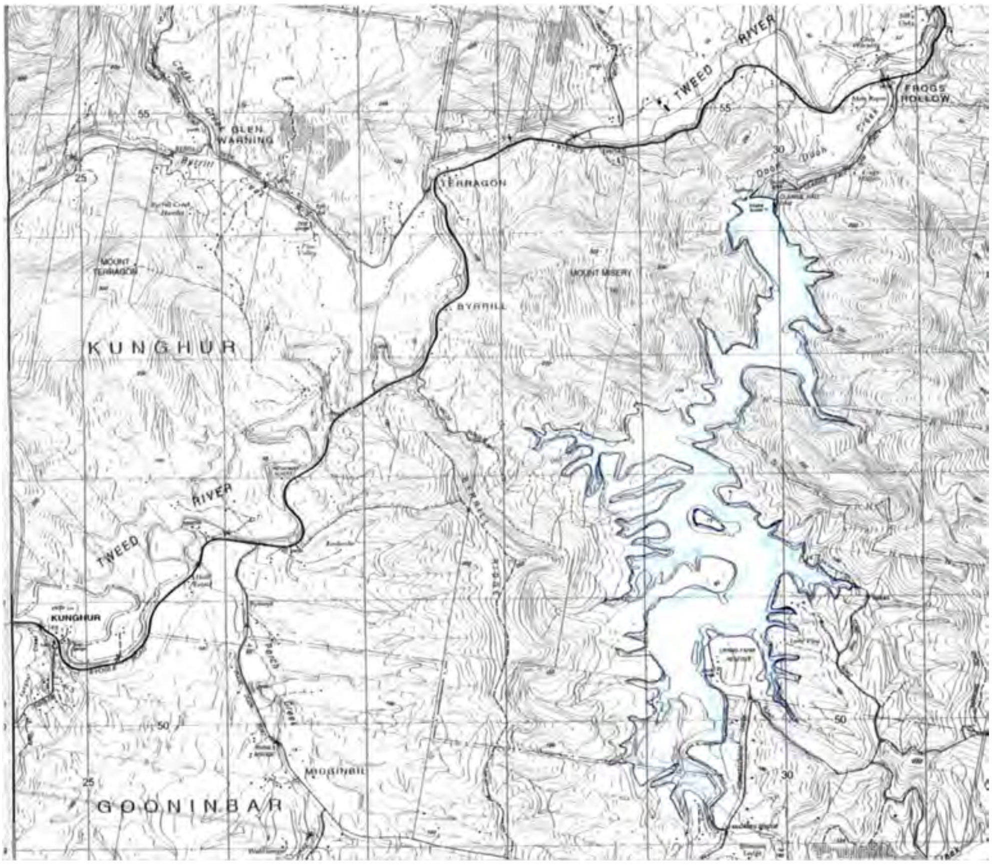


Figure 3-1: Upstream Storage Inundation for FSL 70.0m(AHD)

Cost estimates were completed for each option and they showed that the single construction option was far more economical than raising the dam in stages. It was also noted that single stage dam raising had less impact on the surrounding environment and constructability of the works. Operation of the dam was also disrupted further by staged dam raising. It was therefore a recommendation of the study that single stage construction to FSL RL70.0m(AHD) be adopted for concept design.

4. Dam Safety Design Standards

4.1 Acceptable Flood Capacity

The latest dambreak study carried out by PWA (NSW Public Works, 2007) assigned Clarrie Hall Dam a HIGH A Sunny Day Consequence Category (SDCC) and a HIGH A to EXTREME Flood Consequence Category (FCC). The NSW Dams Safety Committee (DSC) starting point, for any dam assessed as having an EXTREME FCC, is for it to pass the PMF flood event (DSC3B).

WRM Water and Environment Pty Ltd carried out an updated hydrological investigation for the Clarrie Hall Dam (WRM, 2017). The updated hydrological model produced a peak inflow of 3,503 m^3/s for the critical 2-hour PMF storm event. The inflow hydrograph developed in the hydrological study was then used in the concept design for the raising of Clarrie Hall Dam to ensure that the flood was successfully passed. The PMF flood level was used to set the design level of the embankment wall height. See also **Section 5** of this report.

4.2 Design for Earthquake

An updated seismic hazard study was carried out by OZROCKS Geoservices Pty Ltd (OZROCKS, 2017). As Clarrie Hall Dam has been assigned a HIGH A SDCC, the DSC prescribes the maximum design earthquake to be the 0.01% AEP (10,000 year) event (DSC3C). See further discussion in **Section 5** of this report.

4.3 DSC Endorsement of Design Standards

The design characteristics previously outlined in **Section 4** and adopted for this concept design are in accordance with DSC guidelines. The DSC was consulted regarding the determination of the Consequence Category used for Clarrie Hall Dam. The maximum Flood Consequence Category resulting from the Dambreak was HIGH A to EXTREME. The EXTREME Flood Consequence Category was selected in discussion with the DSC and Tweed Shire Council in order to allow for future development in the downstream catchment and potential increase to the Clarrie Hall Dam storage. It is noted that, while the adoption of the EXTREME consequence category assigns the raised dam to withstand a high level of flood impact, it also provides long-term assurance of its integrity and safety.

The concept design as outlined in this report not only satisfies DSC requirements but is also in accordance with all relevant ANCOLD guidelines, Australian Standards and current best practice.

5. Supplementary Investigations and Reports

5.1 Hydrology

An updated hydrological study was undertaken for Clarrie Hall Dam (WRM, 2017). The RORB model was used to develop the hydrological conditions of the Clarrie Hall Dam catchments and the residual Tweed River catchments downstream. The model was successfully calibrated against three flood events; January 2008, January 2012 and January 2013. The calibrated hydrological model was then used to model design flood events for a number of critical storm durations.

The hydrological model became the basis for determining the Clarrie Hall Dam raising options with a varying spillway width. The preferred raised dam arrangement included a new spillway channel higher in the left abutment with sill level at the raised FSL of RL70.0m(AHD) and designed to pass the PMF.

A constant coefficient of discharge (C_D) of 1.8 was used in the hydrological model to equate the actual discharge to the theoretical discharge. The key results are provided in **Table 5-1** and show that a 55m spillway width is required to reduce PMF surcharge levels below RL77.00m(AHD) which is the maximum flood level acceptable by Council (following discussions with the community and surrounding landowners). The results are discussed further in **Section 6.5**.

Table 5-1: Design PMF key reporting hydraulics as reported in the WRM Hydrological Investigation

Spillway Length	Peak PMF inflow (m^3/s)	Peak PMF outflow (m^3/s)	Peak Water Level (m AHD)
40	3,503	1,714	78.27
55	3,503	1,797	76.90

5.2 Survey

Tweed Shire Council carried out a survey of the area of interest for the Clarrie Hall Dam raising project. The area of interest was provided by PWA and is shown in **Figure 5-1**. The survey objectives were to provide the following features:

- 0.5m contours of the area of interest;
- Location of above and underground services within the area of interest;
- Location of any fences within the area of interest; and
- Cadastral layers.

PWA received the 3D survey model in *.dwg (AutoCAD) and *.dgn (MicroStation) format in October 2017. The data was suitable for use in the concept design for the raising of Clarrie Hall Dam.

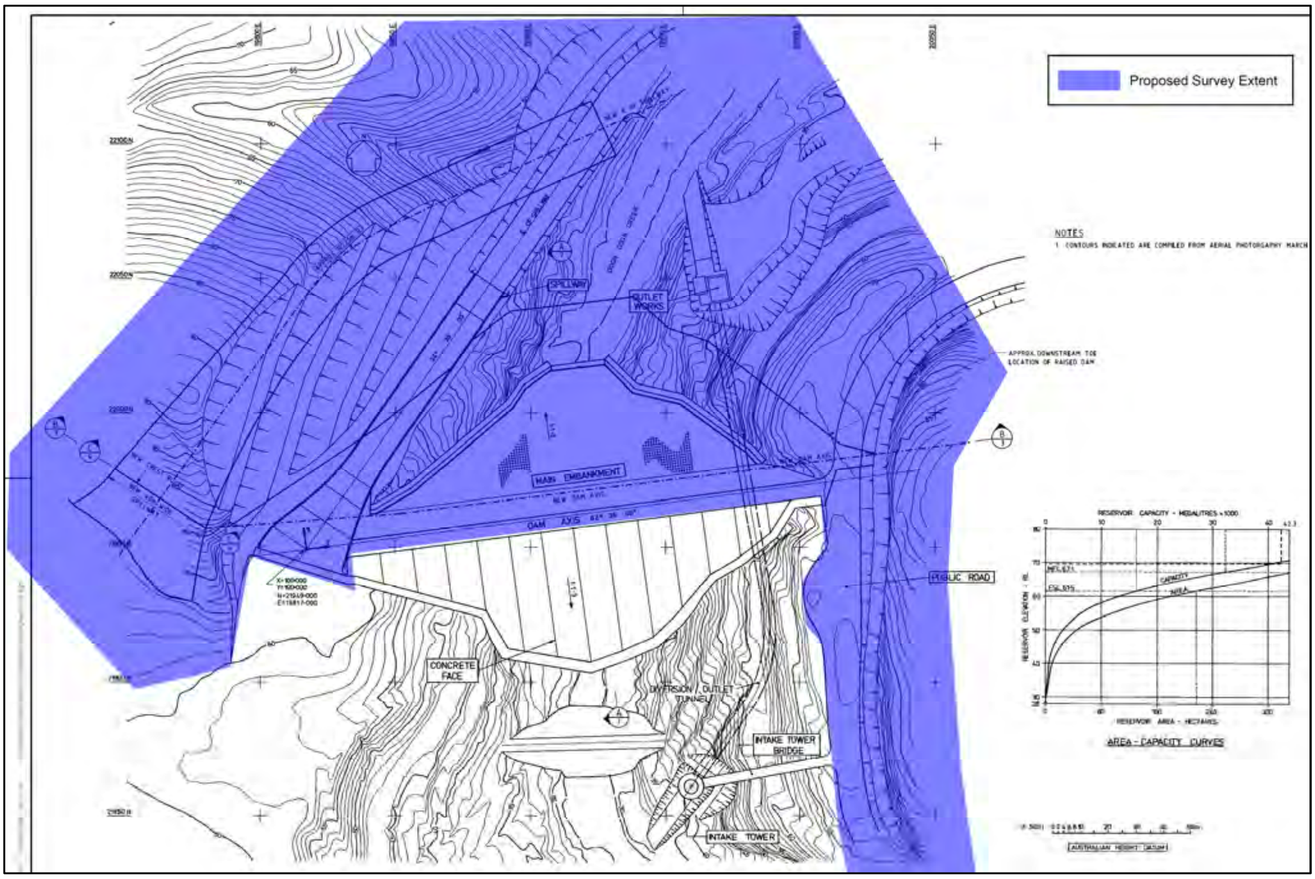


Figure 5-1: Clarrie Hall Dam Survey Extent

5.3 PWA Geotechnical Investigations

The Clarrie Hall Dam site is generally underlain by pink to grey coloured rhyolite. Generally, it is slightly porphyritic, with medium-grained phenocrysts in a fine-grained groundmass. The majority of rhyolite is flow banded to some degree, although there are exposures of welded rhyolitic tuff recorded in the middle third of the left abutment. Essentially, welded rhyolitic tuff has similar engineering properties to flow banded rhyolite.

Substantial geotechnical work was carried out by NSW Public Works (now PWA) before, during and after construction of the original dam. Information and reports from this work have been retained by PWA and have been reviewed as part of this concept design for dam raising. The review has complimented the data provided by recent geotechnical investigations undertaken by PWA.

Geotechnical investigations were carried out between July and September 2017 (PWA, 2018), specifically for the purpose of:

1. developing the preferred raised spillway option (Option 1) on the left abutment of the dam, and
2. assessing the suitability of the excavated material for use as rockfill for the raised embankment.

Investigation at the dam site and adjacent areas included: geological mapping, diamond drilling and laboratory rock testing. The location of boreholes drilled during the investigation is shown in **Figure 5-2**.

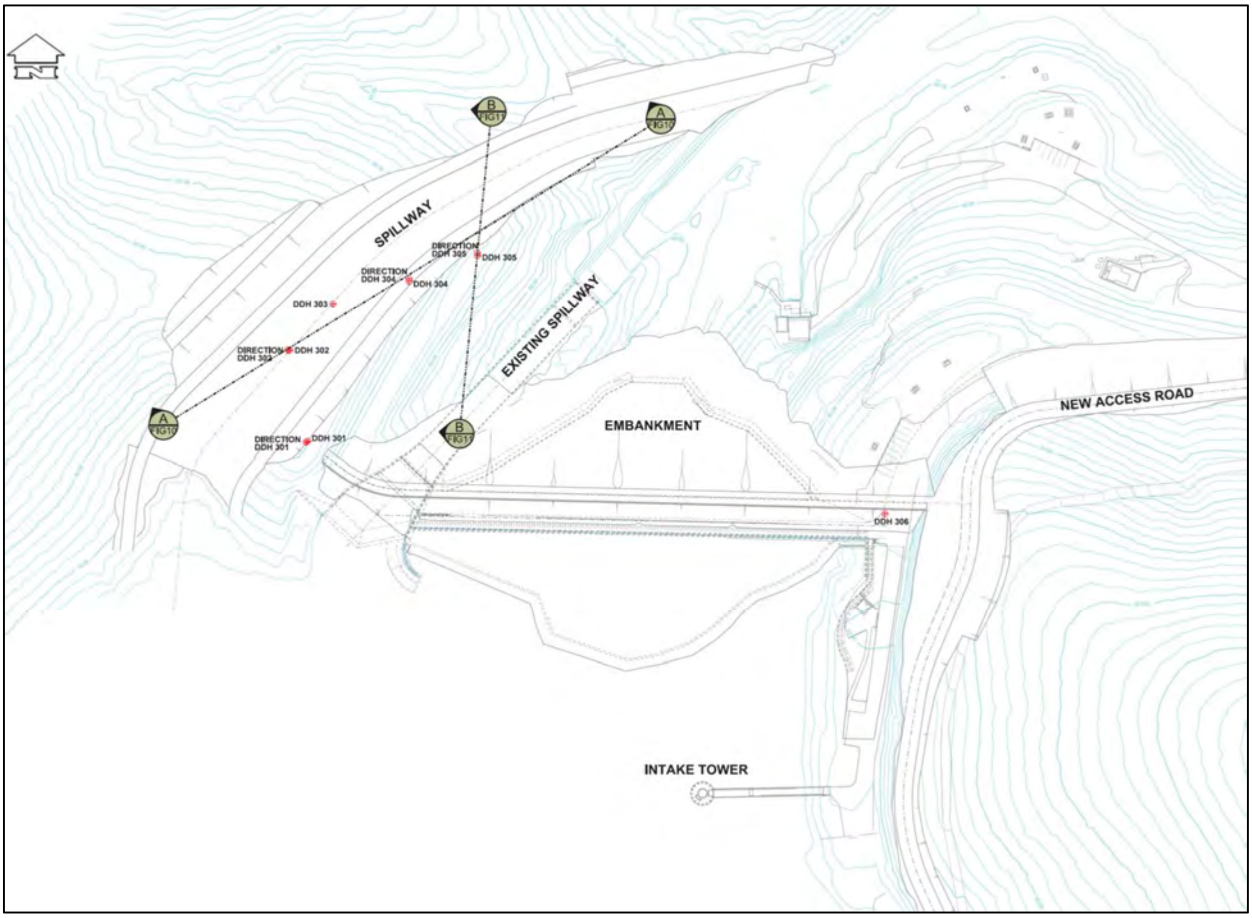


Figure 5-2: Location of Boreholes and Interpreted Geological Sections

The boreholes show that the depth of weathering in the left abutment ridge is deep, with predominately extremely weathered/highly weathered and some moderately weather rhyolite to considerable depth. The moderately weathered rock and slightly weathered rock depths have been targeted to form the foundation conditions of the new spillway channel foundation due to their suitable characteristics for pinned floor linings and wall linings. The extent of weathered rock on the left abutment means that material excavated from the channel has limited use for the dam embankment raising.

The interpreted geology along the Option 1 spillway alignment is shown in **Figure 5-3 and 5-4**. It is anticipated that, of the excavated material from the Option 1 alignment, there is adequate material to be used in the raised embankment Zone 1 (8,000m^3), an unknown quantity could be used in Zone 2 (30,000m^3) and no material could be used in Zone 3A/3B (95,000m^3). Thus, the investigations reveal that the vast amount of material required for use in the raising of Clarrie Hall Dam embankment would need to be sourced from elsewhere. This is likely to come from the existing rock quarry that was used in the original dam construction. An examination of previous geotechnical investigations of the quarry site indicate that sufficient volumes are available.

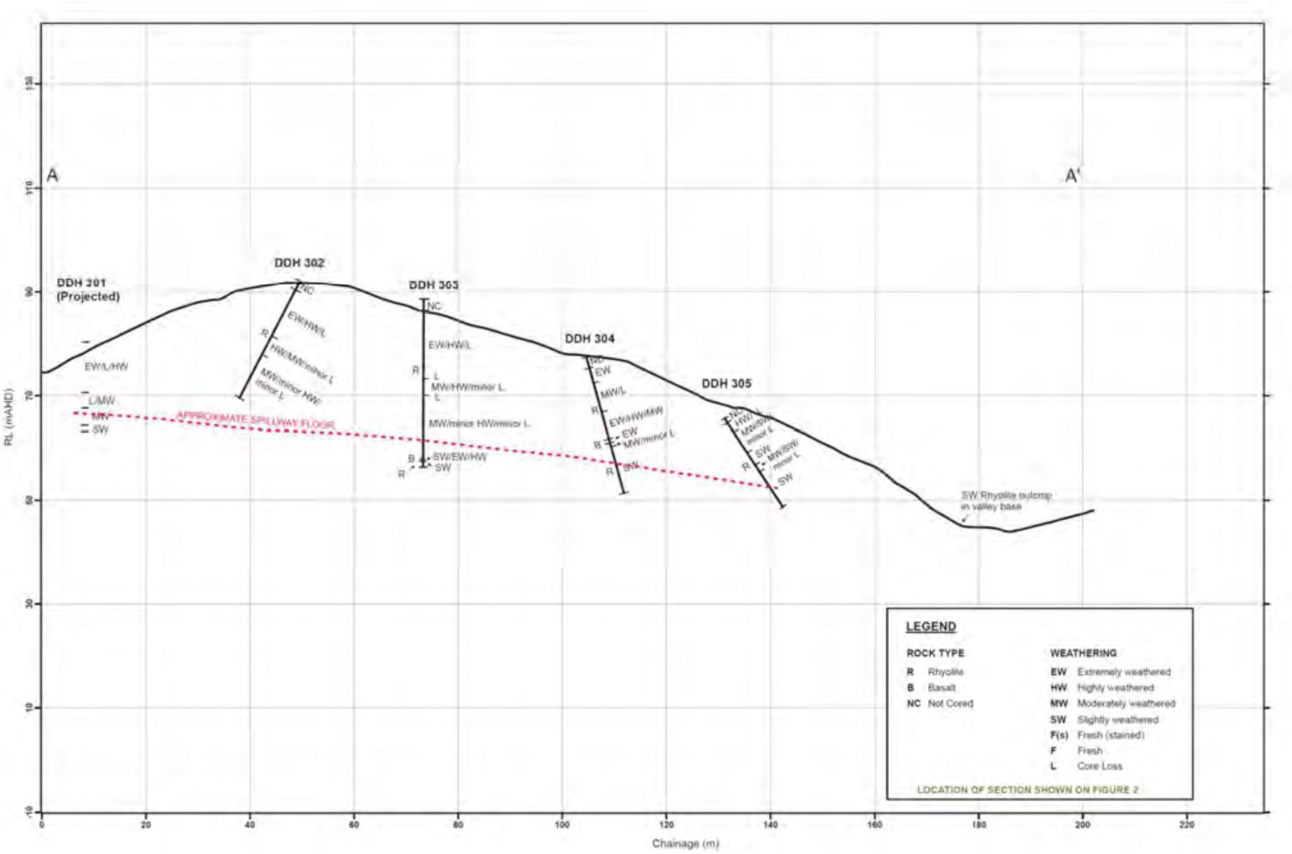


Figure 5-3: Section A Spillway Alignment Interpreted Geology

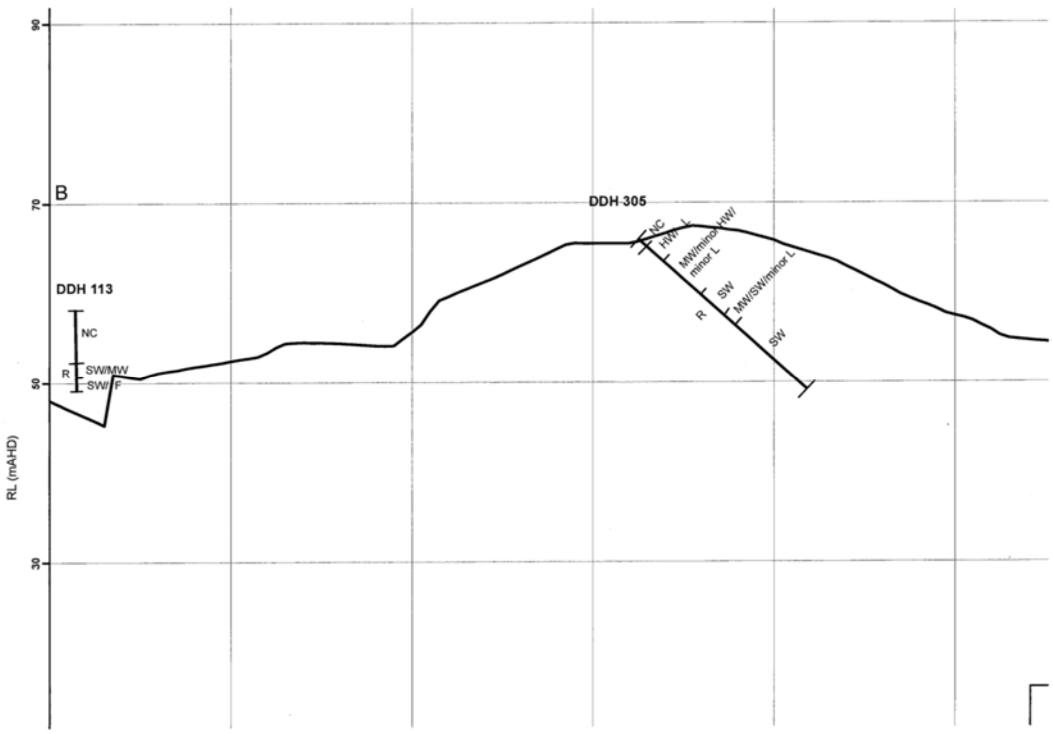


Figure 5-4: Section B Spillway Alignment Interpreted Geology

Investigation of foundation conditions under the proposed raised embankment reveals that the raised portion of the embankment should sit essentially on slightly weathered rhyolite with pockets of moderately weathered rock. Existing loose materials would be removed.

For the extended left abutment upstream toe slab, the majority of the foundation should comprise moderately weathered or moderately weathered/slightly weathered rhyolite, with potential for thin basaltic dykes. For the extended right abutment toe slab, overriding the existing access road, the foundation should comprise essentially slightly weathered rhyolite and a thick, slightly weathered basaltic dyke.

Curtain grouting along the alignment of the extended toe slab will be required to control leakage beneath the raised embankment. Grouting to the pattern and standard of the existing toe slab curtain should be undertaken under the extended toe slab and new spillway crest. Primary and Secondary holes should extend to 10 m depth, with Tertiary and Quaternary holes extending to 5 m. The length of holes may alter depending on actual site conditions found.

The extended intake tower bridge is expected to be found on sound slightly weathered rhyolite.

5.4 Seismic Hazard Assessment

Peak Ground Accelerations (PGAs) for Clarrie Hall Dam have been adopted from the seismic hazard study carried out by OZROCKS Geoservices Pty Ltd (2017). PGA values for a range of AEPs reported by OZROCKS are provided in Error! Reference source not found..

Table 5-2: Peak Ground Accelerations (PGAs) reported for Clarrie Hall Dam

Earthquake (AEP)	PGA (g)
0.2% AEP (500 Year)	0.028
0.1% AEP (1,000 year)	0.047
0.02% AEP (5,000 year)	0.124
0.01% AEP (10,000 year)	0.179
0.002% AEP (50,000 year)	0.363
0.001% AEP (100,000 year)	0.474

The results were used to determine the response spectrum and accelerations for different return periods that provided key important inputs for the seismic design of the raising of Clarrie Hall Dam.

Mean Peak Ground Velocities (PGVs) for a range of AEPs are shown in **Table 5-3** below.

Table 5-3: Peak Ground Velocities (PGVs) reported for Clarrie Hall Dam

Earthquake (AEP)	PGV (mm/sec)
1.39% AEP (72 year)	2.25
0.2% AEP (500 year)	13.2
0.1% AEP (1,000 year)	21.6
0.02% AEP (5,000 year)	59.1
0.01% AEP (10,000 year)	87.0
0.002% AEP (50,000 year)	195.0
0.001% AEP (100,000 year)	266.0

The expected level of ground motion at the Clarrie Hall Dam site in the form of Modified Mercalli Intensity (MMI) was assessed using intensity maps of southeast Australian earthquakes and a MMI hazard curve has been produced. Based on the results, it is expected to have a felt earthquake of MMI 3 every 22 years (vibrations are strong enough to be felt). This parameter might be not interesting for the engineering community; however, it helps in discovering the seismic hazard level in any region. MMI 6 is often used as a comparison to strong shaking that may be experienced by housing, in this case it is expected to be felt approximately every 830 years.

Table 5-4 shows all earthquakes that have occurred surrounding Clarrie Hall Dam within 100 kilometres of the site, with at least a Modified Mercalli Intensity of MMI1+, along with the recorded PGA (in mm/s2). Note there is only one event with MMI3+ in the area that may have been felt.

Table 5-4: Earthquakes Within 100km of Clarrie Hall Dam

Date	Long (deg E)	Lat (deg S)	Depth (km)	Agency	Mag	Dist (km)	MMI	PGA (mm/s2)
23/08/1979	153.49	-28.21	0	BRS	3.2	31	3.8	190.09
12/08/2008	153.37	-28.40	9	MEL	1.7	8	2.7	143.45
5/10/1965	152.55	-28.47	10	BRS	3.4	74	2.2	50.80
8/12/2000	153.46	-28.68	1	SEQW	2.1	31	2.1	78.79
17/01/2008	153.51	-28.34	5	MEL	1.6	22	1.9	79.39
22/09/1976	154.00	-28.00	10	BRS	3.1	83	1.5	32.32
11/06/2008	153.57	-28.25	10	MEL	1.8	33	1.5	53.12
27/08/1977	153.65	-28.29	1	GSQ	1.8	37	1.4	47.69
21/02/1991	153.59	-28.19	6	GSQ	1.8	39	1.2	43.16

6. Dam Raising Concept Design

6.1 General

This concept design builds on previous work investigating the optimum size and raising options for Clarrie Hall Dam (PWA, 2007). Suitable options have been developed from this work with two key requirements determined by Tweed Shire Council:

- FSL of RL70.0m(AHD). This follows on from the 2007 report that determined that the dam's optimum maximum raising height was with FSL at RL70.0m(AHD). This corresponds to a storage volume of 42,300ML that is aligned to meet the ongoing water security of the community; and
- The PMF flood level of the storage be limited to RL77.0m(AHD) to prevent upstream inundation of private land.

The options are based on engineering, social and environmental factors whilst consideration has been given to constructability, efficiency, risks and associated costs.

In association with embankment raising, three spillway options have been investigated as part of this concept design study and are summarised below. All options incorporate construction of a fully lined spillway channel,

6.2 Embankment Raising

Raising of the concrete face rockfilled embankment is proposed as shown on **Figures 9 and 10** at **Appendix B.**

The crest level of the raised embankment will be RL77.0m(AHD) to match the maximum flood level.

In accordance with DSC3B, the dam should accommodate a 600mm freeboard above the maximum flood level. However, following consultation with the DSC, it has been decided that no additional freeboard would be required on top of the maximum flood level since this type of dam would be able to withstand a 600mm depth of overtopping without major failure, in the event of a PMF event occurring.

The proposed raised dam embankment sits well within the local topography and the PMF flood surcharge will not adversely affect upstream private property.

The precast concrete parapet wall units, removed from the existing embankment, will be used on the raised dam embankment and abutting the raised portions of the upstream concrete face.

In terms of the raised embankment's configuration, the crest pavement level behind the parapet wall will be at RL75.5m(AHD), crest pavement width will be 5m, the embankment upstream and downstream slopes will be 1V to 1.3H, matching the existing embankment slopes and considered stable for fresh rockfill construction.

The upstream concrete toe slab would be extended on both left and right abutments. Geotechnical investigations indicate that the upstream toe slab extension would be found on slightly weathered rhyolite. Extension of the grout curtain under the raised embankment into both abutments will also be required in a similar pattern to the existing curtain in order to control leakage beneath the raised embankment. Primary and Secondary holes should extend to 10m depth, with Tertiary and Quaternary holes extending to 5m.

The existing high concrete training walls at the entrance of the current spillway would need to be demolished to make way for the raised embankment fill and upstream face.

The raised embankment fill will continue the current dam zoning profile and comprise:

- a semi-permeable Zone 1 immediately under the upstream concrete face slabs (moderately weathered rhyolite);
- a permeable intermediate Zone 2 (slightly weathered to moderately weathered rhyolite); and
- a permeable fresh rock Zone 3A/3B in the downstream part (slightly weathered rhyolite).

As indicated previously in this report, the majority of material for Zone 1 and Zone 2 would be obtained from the spillway excavations. Zone 3A/3B rockfill would be resourced from the old quarry site.

A new seepage measurement weir will be provided downstream of the raised embankment downstream toe along with a SCADA/telemetry facility to enable continuous monitoring of leakage.

6.3 Spillway Options

As noted previously, three spillway options have been investigated for the raised dam and these are summarised below. All spillway options have been designed to pass the PMF.

Option 1A

Spillway Option 1A general arrangement is illustrated on **Figure 2** at **Appendix B** of this report.

The existing spillway is covered over by the raised embankment and a new spillway channel is proposed higher in the left abutment.

This option was targeted to balance the required volume of rock excavated from the spillway channel and that needed for the raised dam embankment. It was developed under the initial assumption that all of the material from the spillway excavation would be suitable for placing on the raised embankment.

The spillway crest is designed at RL70.0m(AHD) which corresponds to the raised dam's FSL. The spillway crest width is 45m and the channel reduces to 15m wide at the downstream end.

The spillway channel is fully concrete lined channel due to the highly fractured nature of the rock. Although the excavations will be in hard rock, investigations indicate close joint spacings and pockets of weak and fractured rock. The existing spillway was fully lined for this reason. The concrete floor of the new spillway is anchored to the rock and a flip bucket is proposed at the downstream end.

Option 1B

Spillway Option 1B is illustrated on **Figures 3, 5 and 6** at **Appendix B**.

Again, the existing spillway is covered over by the raised embankment and a new spillway channel is proposed higher in the left abutment.

This option was targeted to minimize the amount of rock excavated from the spillway channel excavation when it became apparent during the project that the excavated rock may not be suitable for the raised dam embankment.

The spillway crest is designed at RL70.0m(AHD) which corresponds to the raised edam's FSL. The spillway crest width is 40m and the channel reduces to 15m at the downstream end with a flip bucket and, similar to Option 1A, the spillway channel is fully concrete lined and anchored to a sound rock foundation.

Option 2

Spillway Option 2 is illustrated on **Figures 4, 7 and 8** at **Appendix B**.

This option was developed as an alternative to Option 1B above following awareness that the excavated material from the left abutment under spillway Option 1A would not be suitable for the raised dam embankment.

For this option, the existing spillway is maintained, a new raised crest structure is constructed within the approach channel and the spillway is widened upstream to provide a semicircular 36m spillway crest to provide adequate additional discharge capacity. No excavation is required for this option and the raised dam embankment would meet raised concrete training walls and be covered by a culvert spillway.

6.4 Review of Storage Volume

The original storage volume was calculated using 1:25,000 topographical maps around the time of the original dam construction. PWA carried out a review of the available stage versus storage relationships for Clarrie Hall Dam. Two data sets for Clarrie Hall Dam were found; 1981 storage relationship from the construction drawings and a volume versus area relationship that was used in the 2007 dambreak modelling. The two datasets were compared and the volumes were extracted at key stage points which are provided in **Table 6-1**. The results show that significant differences were found between the two datasets, with the greatest variation occurring at the higher water levels that are now of consequence due to the proposed raising option for Clarrie Hall Dam.

Table 6-1 : Key stage volume comparisons of the original 1981 drawings and the 2007 dambreak

Water Level (m AHD)	1981 Clarrie Hall Dam Construction Drawings Storage Volume (ML)	2007 Dambreak Model Storage Volume (ML)
61.5	16,000	16,721
70.0	41,331	45,750
77.0	64,038	93,006

PWA contacted NSW Lands and Property Information (LPI) to ascertain whether any new topographical surveys of the site have been carried out. LPI were able to provide PWA with data from a recently flown LiDAR of the dam. The data was processed to a Classification Level 1, meaning that verification of height data checks had not been carried out. However, the dataset provides a good basis for estimating relative height information. As the water surface level was known at the time of capture, a relative storage volume was extracted from the DEM above the water surface level. This equates to a re-estimation of the volume between RL 61.5m(AHD) and RL 77.0m(AHD); the stage range over which significant variation was shown to occur between the two datasets previously examined.

The stage relationship above RL 61.5m(AHD) was generated from the DEM using the GIS package ArcGIS 10.2. The storage relationship was then plotted and compared against the two other provided datasets and is shown in **Figure 6-6-1**.

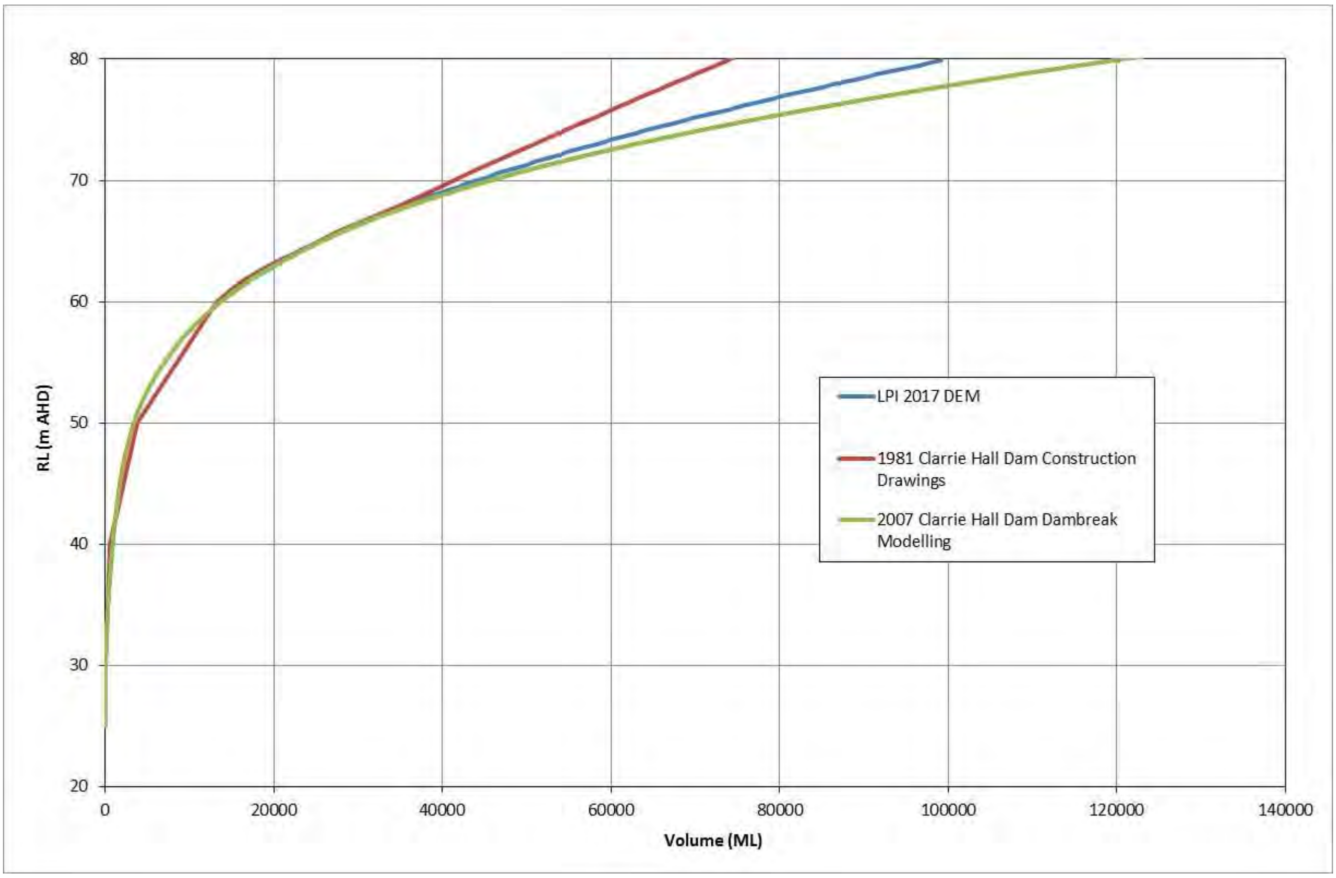


Figure 6-6-1 : Comparison of storage relationships for Clarrie Hall Dam

The result was to combine the 2007 dambreak storage volume estimates below RL 61.5m(AHD) with the 2017 LPI DEM data above this level. The new storage volumes for key reporting stages is provided in **Table 6-2**. The new storage information was then used to update the hydrological analysis, which is discussed in **Section 6.5**.

Table 6-2 : Updated key stage volumes for the merged 2007 dambreak and 2017 LPI DEM

Water Level (m AHD)	Updated 2017 Clarrie Hall Dam Storage Volume (ML)
61.5	16,721
70.0	44,127
77.0	80,727

6.5 Review of the PMF Design Data

Hydrological investigations of the proposed raising were carried out by WRM, which were previously discussed in **Section 5.1** of this report. The hydrological study used a coefficient of discharge (C_D) value of 1.8; equivalent to a typical broad crested weir. The discharge coefficient is influenced by a number of factors such as depth of the approach, relationship between the actual crest shape and the ideal nappe shape, upstream face slope and downstream interferences. The design of the ogee crest of a spillway takes these factors into consideration and attempts to idealise the form in such a way that optimum discharge is achieved. The raised spillway of Clarrie Hall Dam features a nappe-shaped crest profile of the ogee crest in order to maximise discharge over the spillway and reduce the flood protection of the dam. For this reason, the coefficient of discharge will differ significantly as opposed to the value used in the hydrological modelling.

The coefficient of discharge was calculated for a range of upstream water level conditions in accordance with the practises described in the USBR Design of Small Dams (Ref. 26). The calculation used the elements of a nappe-shaped crest profile and approach depth to describe a range of flow rates against upstream water levels.

Inflow hydrographs for the PMF event were modelled using the MIKE 11 hydrodynamic model. The new storage volumes presented in **Section 6.4** were incorporated in the model. In addition, the theoretical spillway rating for each of the options was input to the model. The new spillway rating curve for each option is presented in **Figure 6-6-2**. As the ogee crest has been similarly designed for each option, the spillway discharge differs between the options due to the crest length and to a lesser degree the approach depth. The PMF results with the new spillway discharge characteristics were modelled and the results are provided in **Table 6-3**. The results show that for all the Options tested, the peak PMF water level remains below the surcharge limit of RL 77.0m(AHD). The peak PMF water levels modelled were used as the final design height of each of the Options assessed.

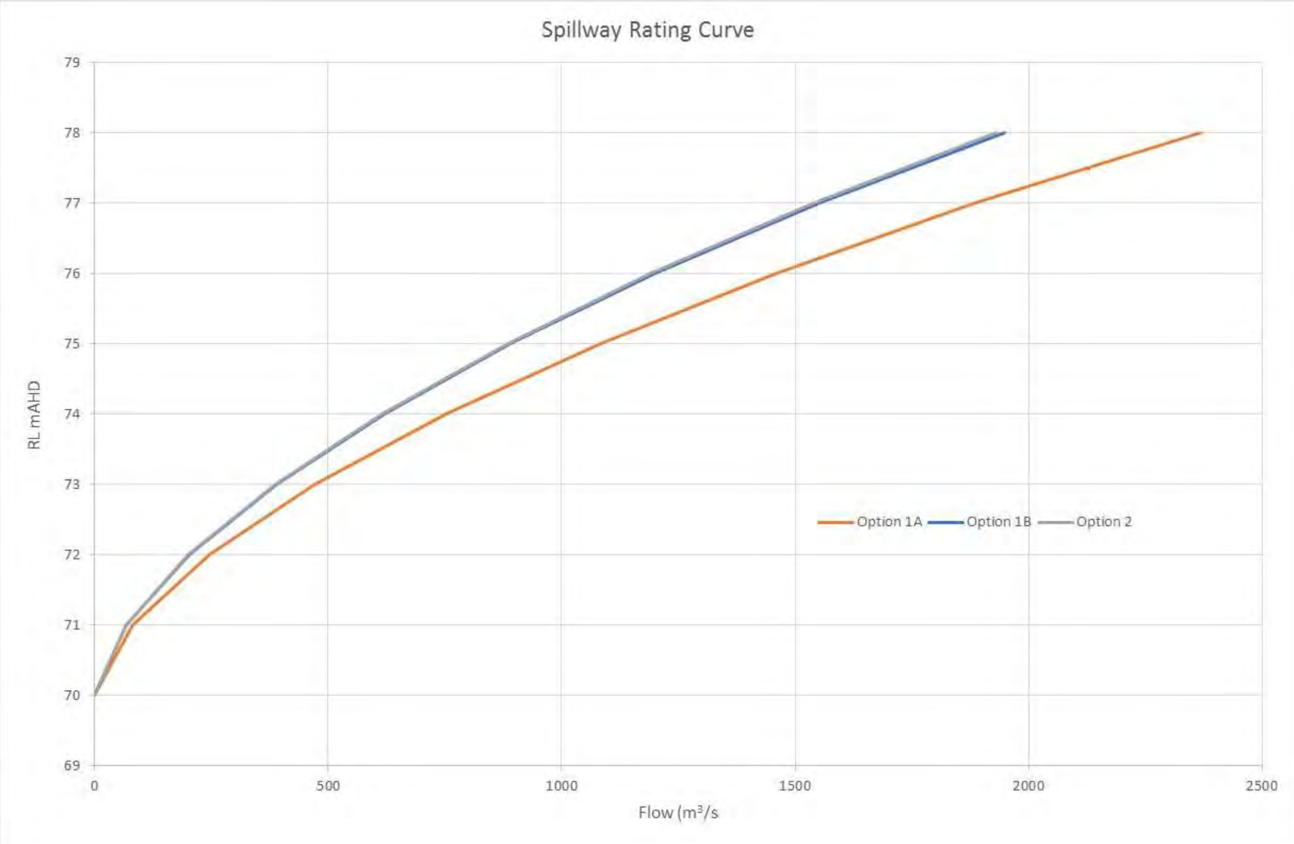


Figure 6-6-2 : Theoretical Spillway Rating Curves for the Options Analysed in this Study

Table 6-3 : Clarrie Hall Dam MIKE 11 Remodelled Results of the PMF Event

Option	Spillway Peak Water Level (m AHD)	Spillway Peak Flow (m^3/s)
Option 1A	76.36	1,609
Option 1B	76.94	1,528
Option 2	76.96	1,524

6.6 The Preferred Spillway Option

As mentioned above, spillway options are illustrated on the Figures at **Appendix B.**

Further analyses and hydraulic modelling have indicated that Option 1B is the preferred option.

Option 1A was not considered further in that it was the optimum arrangement initially considered where all of the excavated material was suitable for embankment raising. Following the geotechnical investigations, which indicated that the majority of excavated material from the spillway channel was not suitable, Option 1B was developed to minimise excavation waste. Option 2 was developed as an alternative to Option 1B.

CFD modelling of the preferred spillway Option 1B was undertaken and is discussed in **Section 7** of this report.

6.7 Intake Tower and Access Bridge

Intake Tower

The existing intake tower is a vertical reinforced concrete circular shaft 33.65m high with internal diameter of 3.2m. The tower is of the wet well type and is situated on a reinforced concrete tower base structure at the head of the outlet tunnel which is located under the dam's right abutment. It has eight water inlet ports to facilitate selective water withdrawal, supporting a series of trashracks and shutters with a crane over the tower deck.

The existing intake tower is proposed to be raised by 8.5m, resulting in the total height of the intake tower to be 42.15m. The raised tower will incorporate three additional water inlet ports.

It is proposed to extend the tower by installing reinforcement bars chemically grouted into the holes drilled at the top of the tower wall. These anchored bars would be installed at spacings to match with the existing reinforcement. The installed anchor bars would then be lapped with reinforcing bars of appropriate length followed by the placement of concrete to the proposed level.

As for the existing arrangement, the raised tower will have radial beams built into the tower wall and a peripheral beam to support the floor slab and the new hoist house super structure. Corbels will be built into the raised tower wall, similar to the existing ones, to support the new access bridge.

The preferred tower raising arrangement is illustrated on **Figures 11 and 12** at **Appendix B.**

Hoist House

A new hoist house similar to the existing is proposed to be constructed on top of the raised intake tower. The raised intake tower will have the radial beams built into its wall and a peripheral beam running on the outer edge of the radial beams (similar to the existing configuration) to support the floor and super structure. The existing compressed AC cladding would be replaced with other suitable material in the new hoist house.

Access Bridge

The current intake tower access bridge consists of two unequal spans 16m and 28m long, supported by a reinforced concrete pier and abutment block. Prestressed girders support an in-situ concrete deck connected by shear connectors and installed on top of the precast prestressed girders.

The existing bridge is to be dismantled, disposed of and replaced with a new bridge to match the raised height of the intake tower.

It is proposed to utilise the existing bridge support pier by raising and strengthening it and introduce one new pier and abutment block to divide the bridge length between the adjoining access road and the tower deck into three unequal spans.

The raised access bridge will incorporate prestressed Closed-Flange Super Tee sections and reinforced concrete deck, similar to the existing arrangement.

The preferred new access bridge arrangement is illustrated on **Figure 13** at **Appendix B**.

7. Raised Dam Analyses

7.1 General

This Section discusses the analyses undertaken in conjunction with the dam raising concept design. These include:

- Embankment stability;
- Intake tower and access bridge structural assessments; and
- CFD modelling with the preferred spillway (Option 1B).

7.2 Embankment Stability

There are no specific design analyses required for a conventional concrete face rockfill dam (CFRD). The concrete face ensures a dry rockfill with no pore pressure. Studies have indicated that horizontal stability is ensured by total vertical loads on any section exceeding total horizontal loads by a factor of at least seven (7). The water load on the concrete face is taken almost entirely by rockfill upstream of the embankment centreline and passes into the foundation upstream of the centreline (Ref. 6).

The NSW Dams Safety Committee notes in guidance sheet DSC3C:
"Concrete Faced rockfill dams of free draining rockfill are often designed empirically on the basis of precedent performance. The DSC will accept such a design basis".

The existing Clarrie Hall Dam embankment comprises fresh to slightly weathered free draining rockfill zones with upstream and downstream slopes of 1V to 1.3H and is founded on a uniform sequence of hard rhyolite rock with minor welded tuff. Geotechnical investigations have also revealed very high to extremely high Uniaxial Compressive Strengths (UCS) for a great part of the rhyolite rock foundation. The 1V to 1.3H embankment slopes are considered acceptable based on precedence and prior research, so no stability analysis was undertaken in the original design of the Clarrie Hall embankment. The slopes were selected without calculations. Trial embankment studies were carried out which confirmed the embankment profile and slope stability.

For the raised embankment, fresh to slightly weathered free draining rockfill is also proposed as outlined in **Section 6.** The batter slopes will be 1V to 1.3H to match the existing profile. As noted above, stability analysis is not required for this type of embankment and was therefore not undertaken.

7.3 Embankment Seismic Considerations

It is widely accepted that the modern compacted CFRD has a high resistance to seismic loadings and this has been confirmed by precedence and theoretical analyses (Ref.7). The high seismic resistance is due to:

- The upstream concrete face providing a dry fill with no possible build up of pore pressures;
- The compacted rockfill developing high frictional resistance.

Clarrie Hall Dam is located in a low seismicity area, as indicated in **Section 6.** In the event of an earthquake, it is expected that the dam embankment would undergo small deformations only during periods of shaking.

Since the entire embankment is dry, earthquake shaking cannot cause pore pressure in the rockfill voids. At Clarrie Hall Dam, the foundation is rock, which does not magnify the incoming acceleration forces. The embankment is well compacted in layers to a dense state with vibrating rollers.

Earthquakes can only cause small deformations during the short period of shaking. After the earthquake is over, the CFRD embankment is as stable as before.

In very strong earthquakes, the concrete face may be cracked, increasing leakage. The potential cracking and leakage cannot threaten the overall safety of the dam because the amount of leakage which can get through the cracks, and the zone of small rock under the face slab, can easily be passed safely through the main rockfill embankment.

The expected effects of a major seismic event (based on previous international observations and studies), such as a CFRD located near the epicentre of a MMI 7.5 earthquake, would be:

- some disturbed slumping of the embankment with a maximum settlement less than 1% of the embankment height, about 50mm for the raised Clarrie Hall Dam;
- some cracking of the upstream face. Cracking of the concrete face slab may produce some increase in leakage but cannot threaten the overall safety of the dam.

Current practice is that no special considerations are required for CFRD's that may be subject to seismic events unless there is close proximity to major faults capable of producing earthquakes of MMI 7.5 or greater (Ref.10). The raised Clarrie Hall Dam embankment is not in this situation and therefore no specific seismic analyses has been undertaken.

7.4 Intake Tower and Access Bridge

Intake Tower

A 3D finite element analysis has been carried out on the existing and raised intake tower taking into account all applicable water and structural loads as well as updated seismic effects.

For the raised intake tower, results show that the tower section is adequately reinforced to handle the base shear for seismic loading up to the required 0.01% AEP (10,000 year) event. However, this is not the case with the design moment. It appears that tower section is likely to handle moment resulting from seismic loadings between the 0.1% AEP (1,000 year) and 0.05% AEP (2,000 year) events. For the 0.02% AEP (5,000 year) and less frequent (but more intense) earthquakes, the tower is likely to experience distress and possible structural damage.

Clarrie Hall Dam has been assigned a HIGH A Sunny Day Consequence Category and is therefore required to withstand the Maximum Design Earthquake (MDE), a 0.01% AEP (10,000 year) event. However, it could be argued that the intake tower could be accepted as having to handle a lower return period earthquake based on the fact that structural damage of the intake tower is not likely to:

- result in an uncontrolled flow of stored dam water downstream; or
- cause damage to valves and pipework. The valves and pipework are expected to remain operational following any earthquake as these fixtures are located downstream of the concrete plug approximately mid-way along the wet/dry outlet tunnel.

Having regard to the above, it is considered acceptable that the raised intake tower withstand an Operating Basis Earthquake (OBE) of much smaller intensity than the 0.01% AEP (10,000 year) event. The acceptance of an OBE for the raised intake tower, between the 0.1% AEP (1,000 year) and 0.05% AEP (2,000 year) events, would not require any additional post-tension strengthening works to be carried out on the structure.

Details of the intake tower structural analysis are included at **Appendix C**.

Access Bridge

As indicated in **Section 6**, for the raised tower access bridge, it is proposed to utilise the existing bridge support pier by raising and strengthening it and introduce one new pier and abutment block. A 3D finite element analysis of the existing and raised pier has been carried out taking into account all applicable water, structural and bridge traffic loads as well as updated seismic effects.

Results show that the existing access bridge pier section is adequately reinforced to handle the base shear for seismic loading up to the required 0.01% AEP (10,000 year) event and bending moment for seismic loading up to the 0.2% AEP (500 year) event. The pier is required to be enlarged in cross section to satisfy code requirements. The enlarged section of the pier, as shown on the attached drawings at **Appendix B,** improves its bending capacity and can handle the bending moment for seismic loading up to the 0.01% AEP (10,000 year) event.

The main dam, having a HIGH A Sunny Day Consequence Category, is required to withstand the Maximum Design Earthquake (MDE), a 0.01% AEP (10,000 year) event. However, it could be argued that the access bridge pier could be accepted as having to handle a lower return period earthquake based on the fact that structural damage of the pier is not likely to:

- cause dam failure resulting in an uncontrolled flow of water downstream
- cause threat to the integrity of the outlet system.

In light of the above facts, it is considered acceptable that both raised access bridge piers (as shown on the drawings at **Appendix B**) withstand an operating basis earthquake (OBE) of much less than the 0.01% AEP (10,000 year) event. The acceptance of an OBE for the piers of 0.1% AEP (1,000 year) would not require any additional post tension strengthening works to be carried out on the pier.

It is also noted that for seismic loading up to the 0.1% AEP (1,000 year) event, the pier foundation (concrete base/rock interface) remains intact for the full base area as stresses remain in compression.

Details of the raised bridge pier structural analysis are included at **Appendix D**.

7.5 CFD Modelling with Preferred Spillway Option

Computational Fluid Dynamic (CFD) analysis has been carried out by Advisian Pty Ltd of the preferred Spillway Option 1B to confirm flow performance and section dimensions. After initial testing of spillway options, as discussed in **Section 6,** Spillway Option 1B was selected as the preferred and most practical option.

The proposed 3D model of the preferred spillway arrangement with the surrounding digital terrain model was provided to Advisian from the civil computer package 12d. The proposed spillway included an excavated ogee crest and entrance channel with a width of 40m. The spillway width decreases downstream of the ogee crest linearly to be 15m wide at the flip bucket. The CFD model was used to check the theoretical rating curve analysis of the spillway and confirm the PMF flood design level. As reported previously, the modelled PMF flood event with a theoretical spillway rating curve yielded the following results:

- Peak water level – RL 76.94 m(AHD)
- Peak flow – 1,528 m^3/s

The CFD model was set up using a multi-mesh block approach that enables the capture of finer details where it is necessary. Mesh sizes range from 2m upstream of the reservoir and up to 0.5m at the spillway. Approximately 4 million cells were used for the overall CFD fluid domain. The CFD model is shown in **Figure 7-1**.

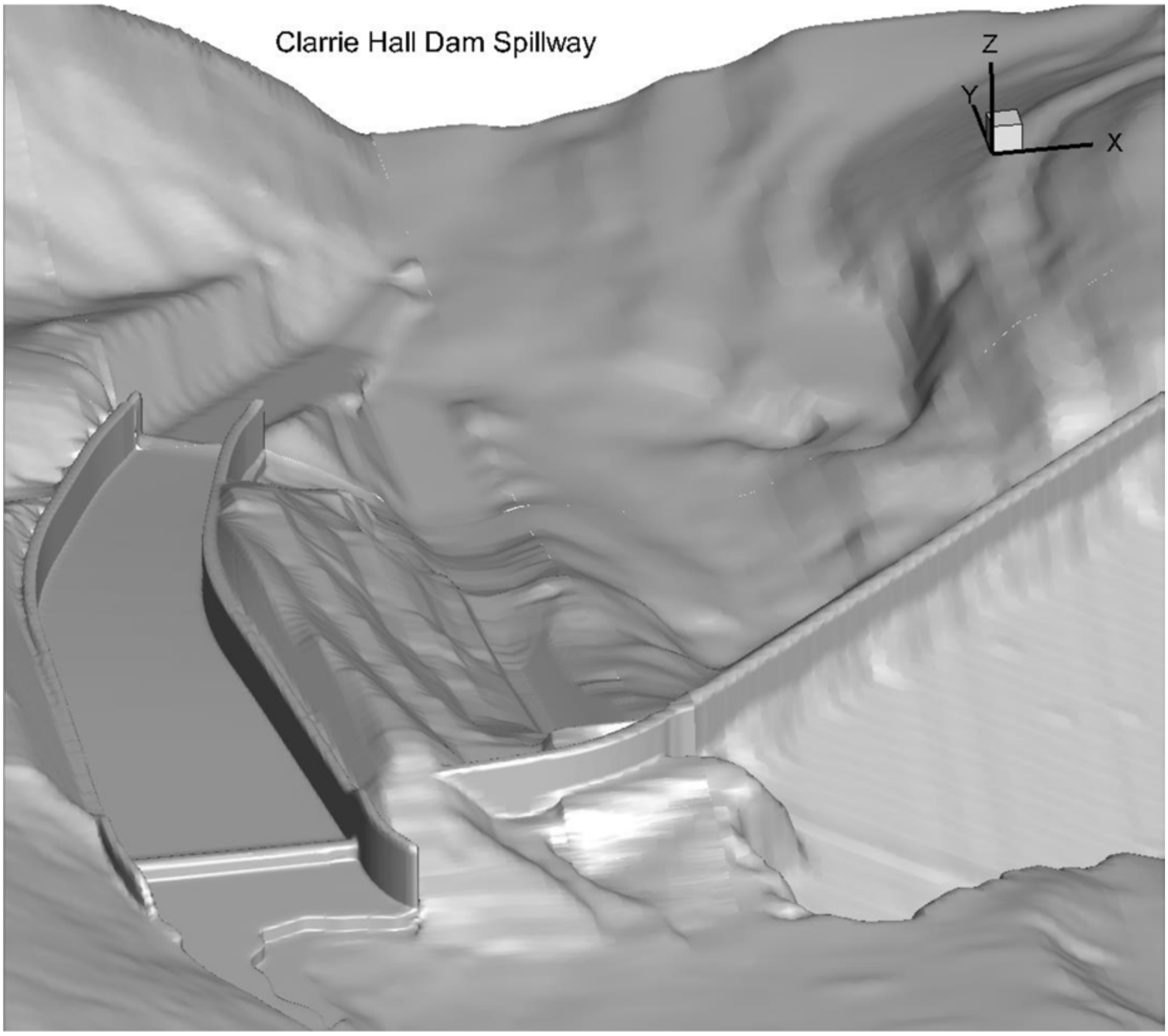


Figure 7-1 – Proposed Raised Dam and Spillway for Clarrie Hall Dam CFD Model, Looking Downstream

The CFD model was first used to confirm that the peak PMF flood conditions were satisfied by the proposed spillway. An upstream water level boundary condition of RL 76.94 m(AHD) was inserted into the CFD model. The discharge measured through the spillway crest in the CFD model was 1,548 m^3/s, which was around one percent more than required to keep the design objective PMF water level below RL 77.0 m(AHD). This result confirmed that the proposed spillway was expected to match the theoretical results for the routed PMF flood event. The CFD model also confirmed some key hydraulic performance characteristics of the proposed spillway option:

- Flow was subcritical upstream of the spillway crest and changed to supercritical immediately downstream of the crest, indicating that the control section was located at the crest. This implies the spillway dimensions are satisfactory in align with the design water levels.

- Negative pressure of -10kPa is observed at the spillway crest but it is unlikely that cavitation will occur. The floor pressure immediately downstream of the flip bucket is reduced to less than 10kPa, whilst the peak pressure where the jet impacts with the downstream channel is 105kPa. The average pressure on the spillway floor is 75kPa. The floor pressures are shown in **Figure 7-2** (at the spillway crest) and **Figure 7-3** (at the flip bucket).

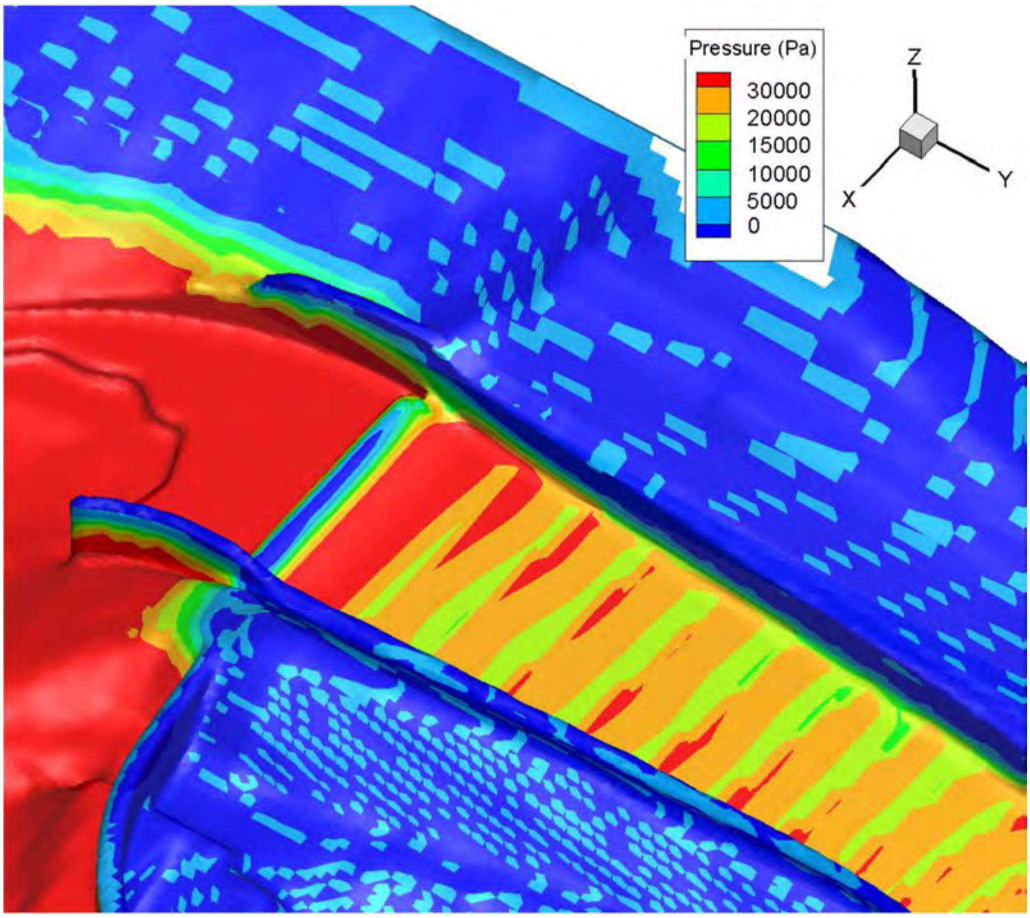


Figure 7-2 – Modelled CFD Floor Pressures of the peak PMF flood event, Spillway Crest

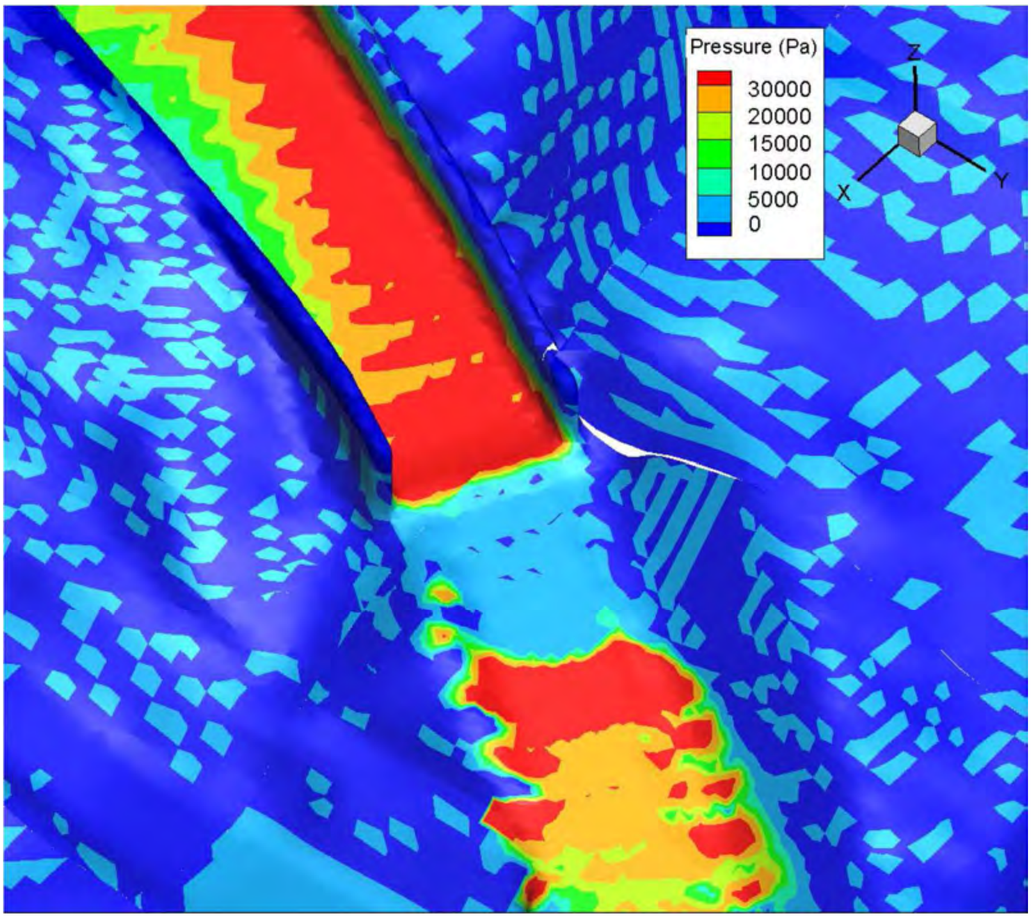


Figure 7-3 – Modelled CFD Floor Pressures of the peak PMF flood event, Flip bucket

The CFD model was then used to produce a new rating curve for the proposed raised spillway option. A continuous rating curve was produced from the rising head model using the computed total flow rate and reservoir water level as a function of time. The new spillway rating curve was then provided and is presented in **Figure 7-4**. The rating curve was then used to re-route the PMF flood event in the one-dimensional MIKE 11 model with the new peak water level of 76.88 m(AHD).

It is noted from the modelling that, at the PMF event, the flow jetted from the flip bucket and impacted on the floor of the downstream channel. There was decrease in the near floor velocity immediately downstream of the flip bucket. This showed that the flip bucket is dissipating the energy of the flow as it travels downstream of the chute.

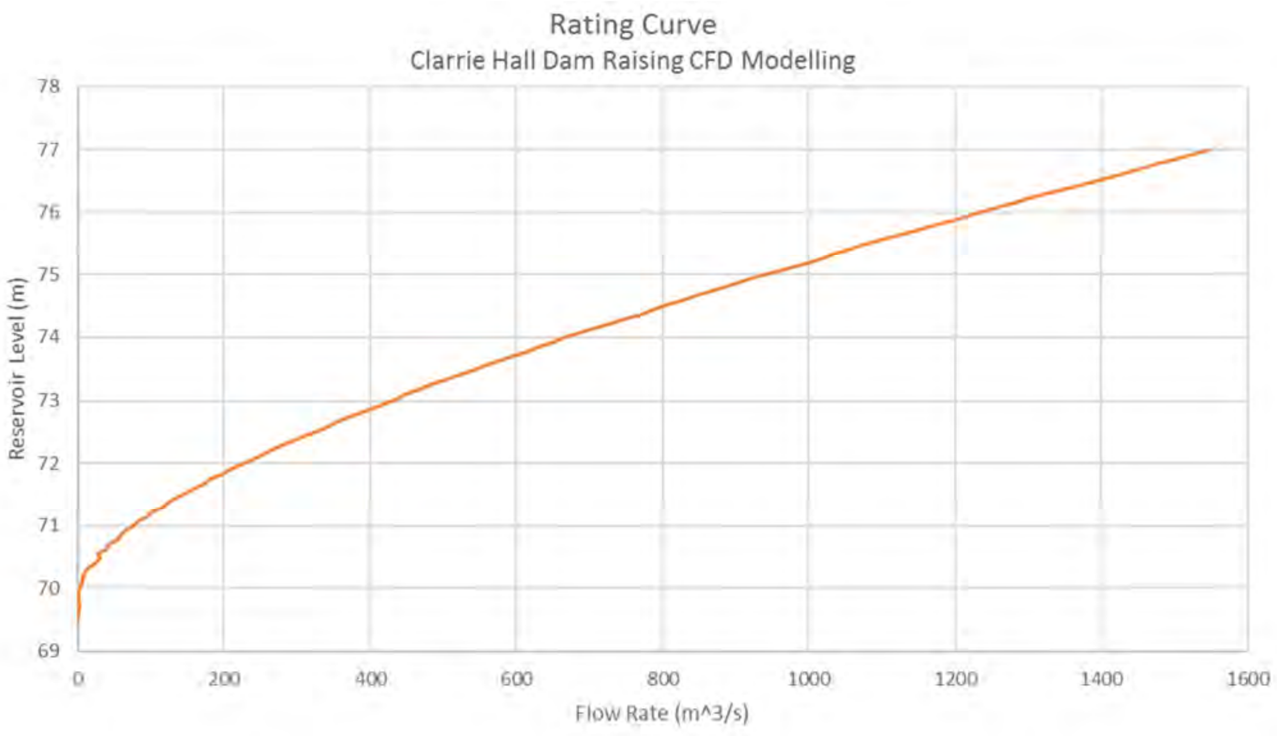


Figure 7-4 – Updated CFD Rating Curve

CFD modelling information above was sourced from *Clarrie Hall Dam Raising: Computational Fluid Dynamics Modelling*, Advisian July 2018 (ref.25).

8. Construction Methodology and Timing

8.1 General

It is proposed to raise the full supply level (FSL) of Clarrie Hall Dam from RL61.5m to RL70.0m. The commensurate maximum flood level will be at RL77.0m. Storage capacity is increased from 16,000ML to 42,300ML.

With the raising of the dam, it is proposed to excavate a spillway channel higher in the left abutment with spillway sill level at RL70.0m(AHD). This is based on the preferred spillway option 1B as described previously in this report.

It was considered originally that material from the raised spillway excavation would be fully utilised as rockfill for the raised embankment. However, geotechnical investigations have revealed that only about 20% of the excavation would be suitable for rockfill construction. As a result, it is proposed to obtain the remaining required rockfill volume from the original quarry site where the rock quality is known and is suitable. The old rock quarry is about 300m upstream of the dam site on the left bank of the storage.

Refer concept drawings attached at **Appendix B** which illustrate the proposed dam raising.

8.2 Lowering of the Storage

Some lowering would be required to allow for construction of the raised embankment including toe slab extension, grout curtain extension and upstream concrete face slab extension. Possibly a 300mm lowering below full supply level would suffice (depends on the Contractor's methodology). Some diversion/dewatering works would also be required to ensure flood free construction, particularly on the abutments of the raised embankment.

8.3 Establishment for Construction

Contractor site facilities, workshops and material storage areas would be established. Suitable sites appear to be downstream of the dam but final locations would depend on the Contractor. Access for construction and environmental protection works would also be required.

Concrete batching plant and concrete material storage will have to be established, again sites downstream of dam seems most suitable.

8.4 Material Transport

Rock would be transported from the new spillway excavation to stockpile (probably downstream of the dam site) and to disposal (could be on or off site depending on Council). As mentioned previously, some 38,000 cubic metres of rock from the spillway excavation would be suitable (and therefore hauled) for fill placement on the raised embankment.

Rock will be delivered progressively to the dam site from the quarry along Contractor's haul roads through the left bank of the storage. It is estimated that approximately 95,000 cubic metres of rock would be transported from the quarry for placement on the raised embankment.

Existing access routes to the site will have to be altered to allow for a new main access road higher in the right abutment and for construction access generally.

8.5 Order of Work

With respect to overall construction approach, the following general order of work is envisaged –

1. Establishment, including environmental and other approvals
2. Removal of the existing concrete parapet wall from the current dam embankment including removal and storage of the recyclable precast concrete panels
3. Removal of the crest pavement from the existing embankment to expose underlying rockfill
4. Excavation of the left and right abutments for the upstream concrete toe slab extension
5. Stripping of the foundation downstream of the existing embankment for the raised embankment footprint including removal of concrete gutter and seepage weir
6. Demolition of the concrete walls at the existing spillway entrance and disposal to waste
7. Excavation for the new spillway channel higher in the left abutment (some blasting may be required in the lower downstream areas)
8. Excavation for the new permanent access road higher in the right abutment
9. Stockpile of suitable rock from the spillway excavation, and suitable disposal of the rest
10. Establishment of haul routes to the old quarry site from the dam site – probably along the edge of the raised storage level in the left bank
11. Construction of the upstream concrete toe slab extension in both the left and right abutments
12. Installation of the grout curtain extension through the upstream toe slab extension on the left and right abutments (no blasting envisaged but slope correction may be required)
13. Stripping of the old quarry site and excavation of suitable rockfill (excavation of the quarry will probably require some blasting)
14. Establishment of a large crane or other means to transfer rock delivered from the quarry across the length of the raised embankment as required
15. Placement and compaction of rockfill on the raised embankment (within configured zones as per the design)
16. Extension of the upstream concrete face slabs (possibly by slip forming)
17. Construction of the concrete sill, floor and walls for the raised spillway (including anchors and drainage)
18. Large rock protection below the flip bucket downstream of the new spillway channel and entry to the creek
19. Installation of precast concrete parapet wall units obtained from the existing embankment on to the raised embankment and connection of the parapet wall units to the raised upstream concrete face slabs
20. Supply and installation of new precast concrete parapet walls on the ends of the raised embankment
21. Removal of the existing intake tower house
22. Demolition of the existing intake tower deck

23. Removal of the existing tower access bridge deck
24. Raising of the concrete intake tower
25. Raising of the existing concrete pier, construction of a new concrete pier and construction of new concrete abutment support
26. Construction of the raised concrete tower deck
27. Construction of the raised bridge deck
28. Construct of a new tower house
29. Installation of all mechanical equipment including additional shutters, trashracks and crane in the raised tower
30. Reinstatement of all electrical supply
31. Construction of a new permanent access road and seal on the right abutment to join the raised tower bridge and down to the new boat ramp location
32. Removal of all temporary access and haul roads
33. Rehabilitation of construction areas (including landscaping)
34. Disestablishment

By excavating for the new spillway channel early in the construction sequence, it will ensure that the dam can safely pass the PMF without overtopping the raised embankment even prior to completion of the works.

8.6 Timing

Based on the above scope of works, an estimated time line for design and construction of the Clarrie Hall Dam Raising project has been prepared and is attached at **Appendix F**.

Essentially, 26 weeks are allowed for detail design and contract documentation (including drawings and specifications) followed by a 6 weeks tender process. Environmental approvals are assumed to run concurrently.

Approximately 70 weeks are allowed for construction of the works following award of contract.

9. Risk Assessment

A risk matrix has been prepared for the Clarrie Hall Dam Raising Project and is attached to this report at **Appendix G.** The matrix has been developed from an earlier version prepared for a risk workshop held at Tweed Shire Council chambers in May 2017.

The matrix covers risk assessment issues under the following general headings:

- Design
- Community Consultation
- Site and Services
- Work, Health and Safety
- Environmental and Site Conditions
- Construction and Programming
- Additional Risks Identified.

Risks identified during both the preconstruction and construction phases of the project are included and risk mitigation strategies are presented.

10. Cost Estimate and Cost Risk Assessment

10.1 General

This section summarises the design and construction cost estimate for the raising of Clarrie Hall Dam as outlined in this report. The estimate is based on predicted construction and project costs as at June 2018.

The cost estimate incorporates a cost risk assessment.

10.2 Rates

The estimate is based on Public Work Advisory's database of rates. These rates are derived from tendered and/or constructed rates from previous projects of a similar nature. Public Works Advisory has developed an extensive database of rates through its involvement in numerous large dam projects at design and construction stages over many years.

10.3 Cost Estimate and Cost Risk Assessment Summary

Cost estimates have been based on the determination of construction methodology, material selection and the substantial experience of Public Works Advisory in the design and construction of dams. Cost risk estimates have been prepared based on estimated 10th percentile (P10), 50th percentile (P50) and 90th percentile (P90) costs.

A cost risk assessment was performed using Version 7 of the Palisade Decision Tools Software, @RISK. The software performs a Monte Carlo simulation with the output "Total Project Cost" generated by letting the computer recalculate our estimate worksheet over and over, each time using randomly selected sets of values for the triangular probability distributions assigned for each of the estimate items.

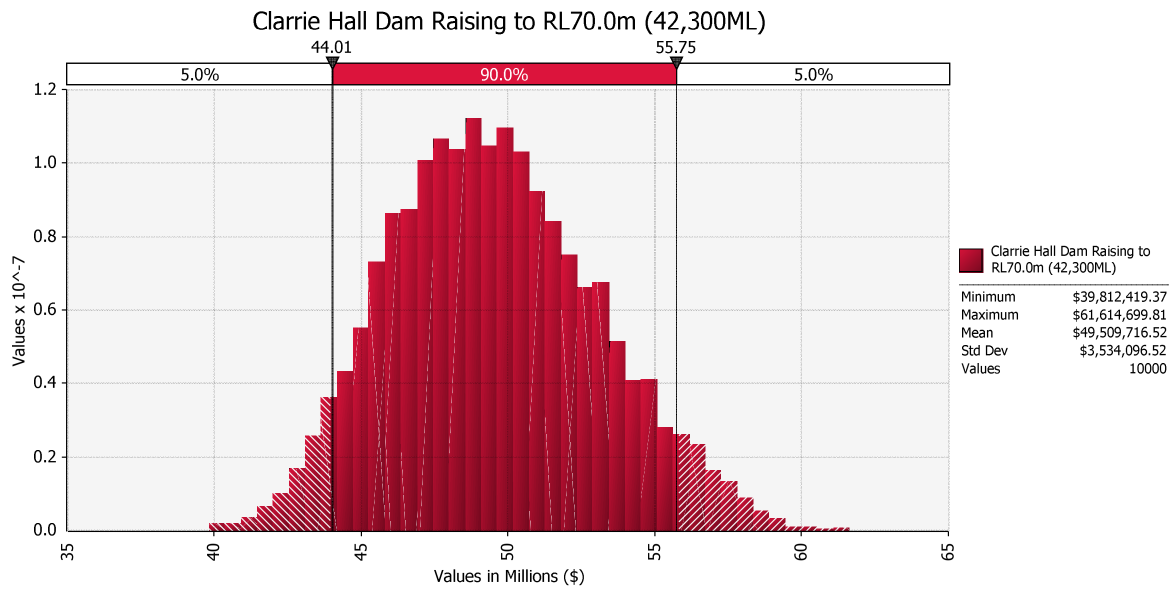
The proposed raising option for Clarrie Hall Dam incorporates FSL70.0m(AHD) with a total storage capacity of 42,300ML. The majority of the rockfill is to be obtained from the old quarry site adjacent to the dam with some smaller volumes extracted from excavation of the new spillway channel higher in the left abutment. The existing precast concrete parapet wall units would be re-used, thus saving on the required number of new units and volume of raised embankment fill.

The dam raising option developed satisfies the NSW Dams Safety Committee (DSC) and the Australian National Committee on Large Dams (ANCOLD) guidelines.

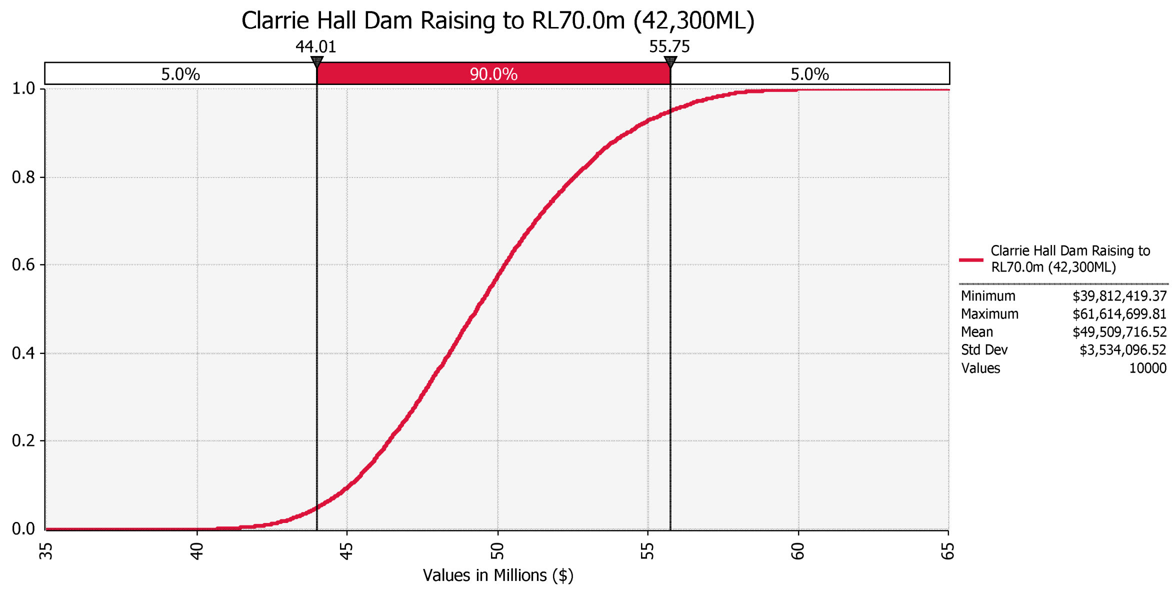
Refer to Error! Reference source not found.**H** for a breakdown of the cost estimates.

From the risk assessment, the total project cost is forecast to be in the range of \$39.8M to \$61.6M, with our estimate of the most likely project cost being \$49.5M. The statistical analysis indicates that there is a 90% probability that the project cost will fall between \$44.1M and \$55.8M.

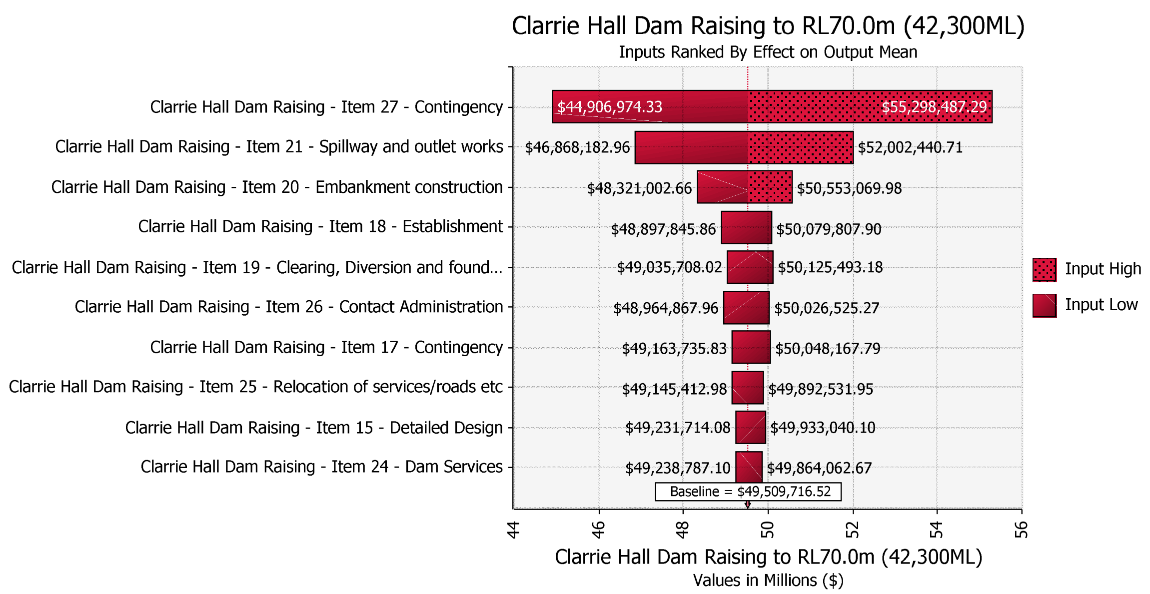
The results of the updated 2018 @RISK analysis are shown on the following page:



Clarrie Hall Dam Raising to RL70.0m (42,300ML)
44.01
55.75
5.0%
90.0%
5.0%
Values x 10^-7
1.2
1.0
0.8
0.6
0.4
0.2
0.0
35
40
45
50
55
60
65
Values in Millions ($)
Clarrie Hall Dam Raising to RL70.0m (42,300ML)
Minimum $39,812,419.37
Maximum $61,614,699.81
Mean $49,509,716.52
Std Dev $3,534,096.52
Values 10000



Clarrie Hall Dam Raising to RL70.0m (42,300ML)
44.01
55.75
5.0%
90.0%
5.0%
1.0
0.8
0.6
0.4
0.2
0.0
35
40
45
50
55
60
65
Values in Millions ($)
Clarrie Hall Dam Raising to RL70.0m (42,300ML)
Minimum $39,812,419.37
Maximum $61,614,699.81
Mean $49,509,716.52
Std Dev $3,534,096.52
Values 10000



Clarrie Hall Dam Raising to RL70.0m (42,300ML)
Inputs Ranked By Effect on Output Mean
Clarrie Hall Dam Raising - Item 27 - Contingency
$44,906,974.33
$55,298,487.29
Clarrie Hall Dam Raising - Item 21 - Spillway and outlet works
$46,868,182.96
$52,002,440.71
Clarrie Hall Dam Raising - Item 20 - Embankment construction
$48,321,002.66
$50,553,069.98
Clarrie Hall Dam Raising - Item 18 - Establishment
$48,897,845.86
$50,079,807.90
Clarrie Hall Dam Raising - Item 19 - Clearing, Diversion and found...
$49,035,708.02
$50,125,493.18
Clarrie Hall Dam Raising - Item 26 - Contact Administration
$48,964,867.96
$50,026,525.27
Clarrie Hall Dam Raising - Item 17 - Contingency
$49,163,735.83
$50,048,167.79
Clarrie Hall Dam Raising - Item 25 - Relocation of services/roads etc
$49,145,412.98
$49,892,531.95
Clarrie Hall Dam Raising - Item 15 - Detailed Design
$49,231,714.08
$49,933,040.10
Clarrie Hall Dam Raising - Item 24 - Dam Services
$49,238,787.10
$49,864,062.67
Baseline = $49,509,716.52
Input High
Input Low
44
46
48
50
52
54
56
Clarrie Hall Dam Raising to RL70.0m (42,300ML)
Values in Millions ($)

11. Discussion and Conclusion

This report concerns concept design for the raising of Clarrie Hall Dam. The proposed raised dam will increase the existing storage at Full Supply Level (FSL) from 16,000 ML to 42,300 ML and is expected to meet the additional water security requirements of the Tweed Shire community well into the future.

The preferred dam raising option involves increasing the height of the existing concrete faced rockfill embankment and construction of a new concrete lined spillway higher up in the left abutment. The existing intake tower and access bridge will also be raised and a new permanent road access will be provided higher in the right abutment.

Concept design for the raised dam and its components has been based on updated hydrological and geotechnical investigations, seismic and structural assessments and is in accordance with NSW Dams Safety Committee (DSC) requirements and Australian National Committee on Large Dams (ANCOLD) guidelines as well as current best practice.

Previous studies undertaken by PWA have identified that the optimum raising of the dam is with FSL at RL70.0m(AHD). The new spillway has been designed such that the maximum flood level in the raised storage does not exceed RL77.0m(AHD).

Clarrie Hall Dam has been assigned an EXTREME Flood Consequence Category (FCC) and a HIGH A Sunny Day Consequence Category (SDCC) which means that it must pass safely the Probable Maximum Flood (PMF) and withstand a 0.01% AEP (10,000 year) Maximum Design Earthquake (MDE).

The existing Clarrie Hall Dam embankment comprises fresh to slightly weathered free draining rockfill zones and is founded on a uniform sequence of hard rhyolite rock with minor welded tuff. Studies have shown that a dam of this type and configuration would be inherently safe even against large magnitude earthquakes and overall stability of the embankment is not threatened.

It was initially envisaged that rockfill for the raised embankment would be sourced from the new spillway excavations higher on the left abutment. However, geotechnical investigations revealed that the majority of the targeted rock was highly to extremely weathered (and highly fractured) which made it unsuitable for embankment rockfill. As a result, the vast amount of material required for use in the raising of Clarrie Hall Dam embankment would need to be sourced from elsewhere. This is likely to come from the existing rock quarry that was used in the original dam construction. An examination of previous geotechnical investigations of the old quarry site indicate that sufficient volumes of suitable material would be available.

Precast parapet wall units from the existing embankment would be stored and used for the raised embankment, thus saving on the number of new units required to be provided across the raised crest.

Three spillway options have been considered as part of the Clarrie Hall Dam Raising project. Spillway Option 1A was developed initially as the optimum arrangement where all of the excavated material would be suitable for embankment raising. Since this was not the case, spillway Options 1B and 2 were then developed. Option 1B is a similar arrangement to Option 1A but narrower overall to minimise excavation waste. Option 2 uses the existing spillway footprint with a raised crest structure and culvert through the raised embankment fill. Following further hydraulic and structural assessments, Option 1B was selected as the preferred spillway option. It is deemed the most practical solution.

CFD modelling of Option 1B has been undertaken which verifies spillway flow behaviour and confirms section dimensions. A summary of results is incorporated in this report.

Analysis has shown that the existing intake tower can be raised without expensive post tensioning techniques, albeit for a smaller earthquake resistance to the main embankment. Similarly, for the raised tower access bridge pier. A three span bridge is envisaged joining the raised intake tower deck level with the new permanent access road in the dam's right abutment.

Concept drawings of the proposed dam raising are attached to this report.

A time line has been developed which shows essentially a 26 weeks design and environmental assessment period followed by 70 weeks construction. Construction methodology suggests that there would be no engineering impediment to construction of the raised dam as outlined.

Risks associated with the Clarrie Hall Dam Raising project have also been identified and a risk matrix has been derived based on an earlier workshop with Council staff and further input from review of precedent projects. Generally, risks are considered manageable and not detrimental to progression of the project.

Cost estimation has included cost risk assessment. The cost risk estimates have been prepared based on estimated 10th percentile (P10), 50th percentile (P50) and 90th percentile (P90) costs. A breakdown of the estimates is presented which cover all aspects of the project.

12. References

1. Geological Survey of NSW, *Tweed District Water Supply Augmentation, Clarrie Hall Dam, Summary of Site Geology,* Report No. GS1981/253, 1981

2. NSW Public Works Department, *Tweed District Water Supply, Clarrie Hall Dam Trial Embankment,* 1983

3. Geological Survey of NSW, *Tweed District Water Supply Augmentation, Clarrie Hall Dam Engineering Geology Report on Construction,* Report No. GS1983/004, 1983

4. NSW Public Works Department, Clarrie Hall Dam, *WAE Drawings,* 1984

5. NSW Public Works Department, *Tweed District Water Supply Augmentation, Clarrie Hall Dam, Final Design Report, Vols. I, II and III,* 1984

6. J.B. Cooke *Progress on Rockfill Dams,* ASCE Journal of Geotechnical Engineering, October 1984

7. G. Bureau, R.L. Volpe, W.H. Roth and T. Udaka, *Seismic Analysis of Concrete Face Rockfill Dams,* ASCE Proceedings, October 1985

8. A. Varty, R. Boyle, E. Pritchard and R. Gill *Construction of Concrete Face Dams, ASCE Proceedings,* October1985

9. J.L. Sherard and J.B. Cooke *Concrete Face Rockfill Dam: I. Assessment,* ASCE Journal of Geotechnical Engineering, October 1987

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11. A. Goyal and A.K. Chopra, *Simplified Evaluation of Added Hydrodynamic Mass for Intake Towers,* ASCE Journal of Engineering Mechanics, July 1989

12. NSW Department of Commerce, *Clarrie Hall Dam, Dambreak Study,* 2007

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16. NSW Public Works, *Clarrie Hall Dam Spillway Upgrade, Concept Design Report*, Report No. DC11079, July 2011

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21. WRM Water & Environment, *Clarrie Hall Dam Flood Hydrology Study*, Report No. 1195-01-B5, February 2017

22. OzRocks Geoservices, *Probabilistic Seismic Hazard Assessment for Clarrie Hall Dam, New South Wales, Australia,* August 2017

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24. Public Works Advisory, *Clarrie Hall Dam Raising, Concept Design Geotechnical Investigation*, Report No, GT32A, January 2018

25. Advisian, *Clarrie Hall Dam Raising: Computational Fluid Dynamics Modelling*, July 2018

26. R. Fell, P. MacGregor and D. Stapledon, *Geotechnical Engineering of Embankment Dams*

27. US Bureau of Reclamation, *Design of Small Dams*

28. ANCOLD, *Guidelines on Concrete Faced Rockfill Dams*

29. NSW Dams Safety Committee, DSC3A, *Consequence Categories for Dams*

30. NSW Dams Safety Committee, DSC3B, *Acceptable Flood Capacity for Dams*

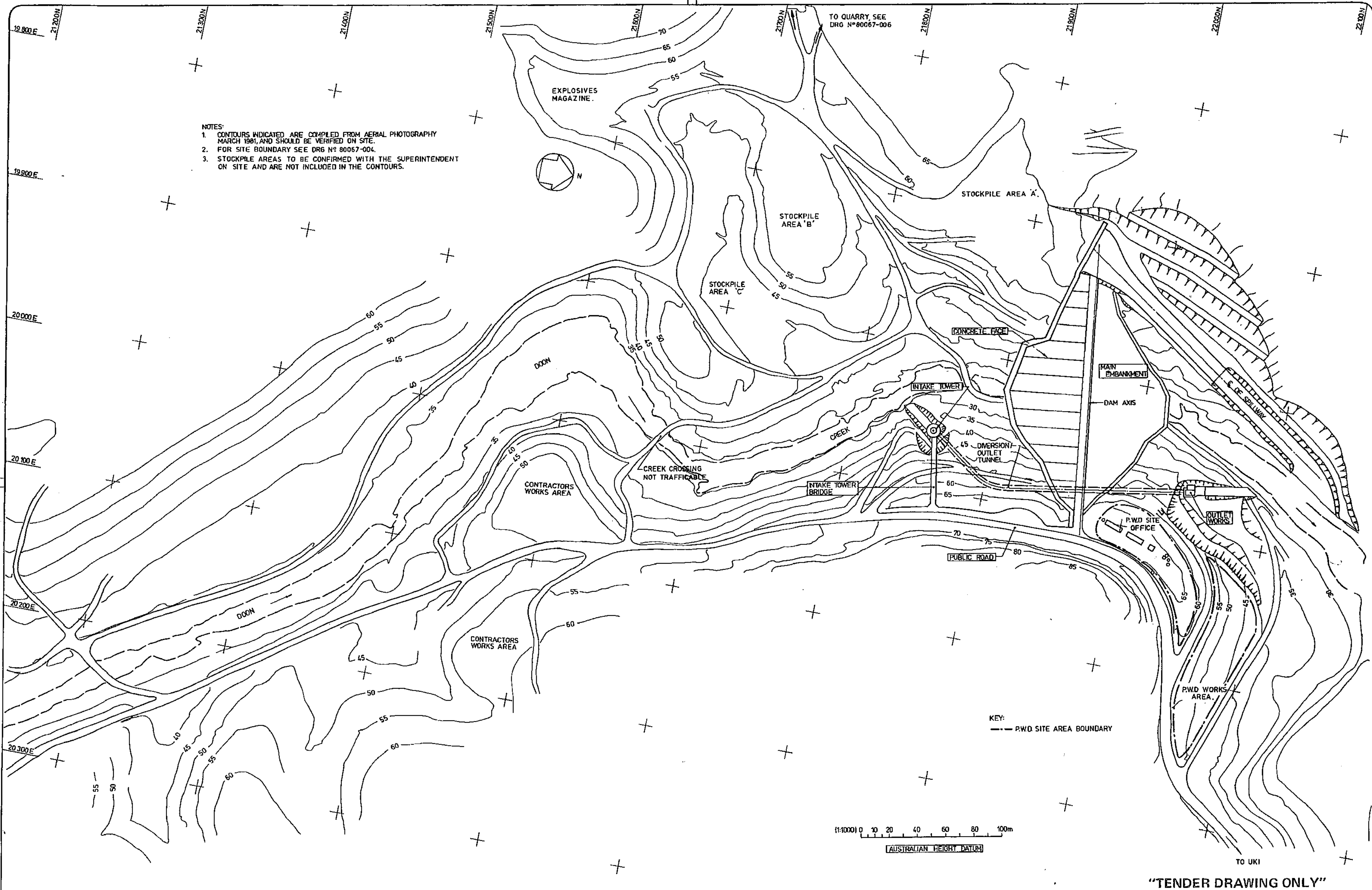
31. NSW Dams Safety Committee, DSC3C, *Acceptable Earthquake Capacity for Dams*

Appendices

APPENDIX A

EXISTING DAM DRAWINGS

80067-002



"TENDER DRAWING ONLY"

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES.
ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

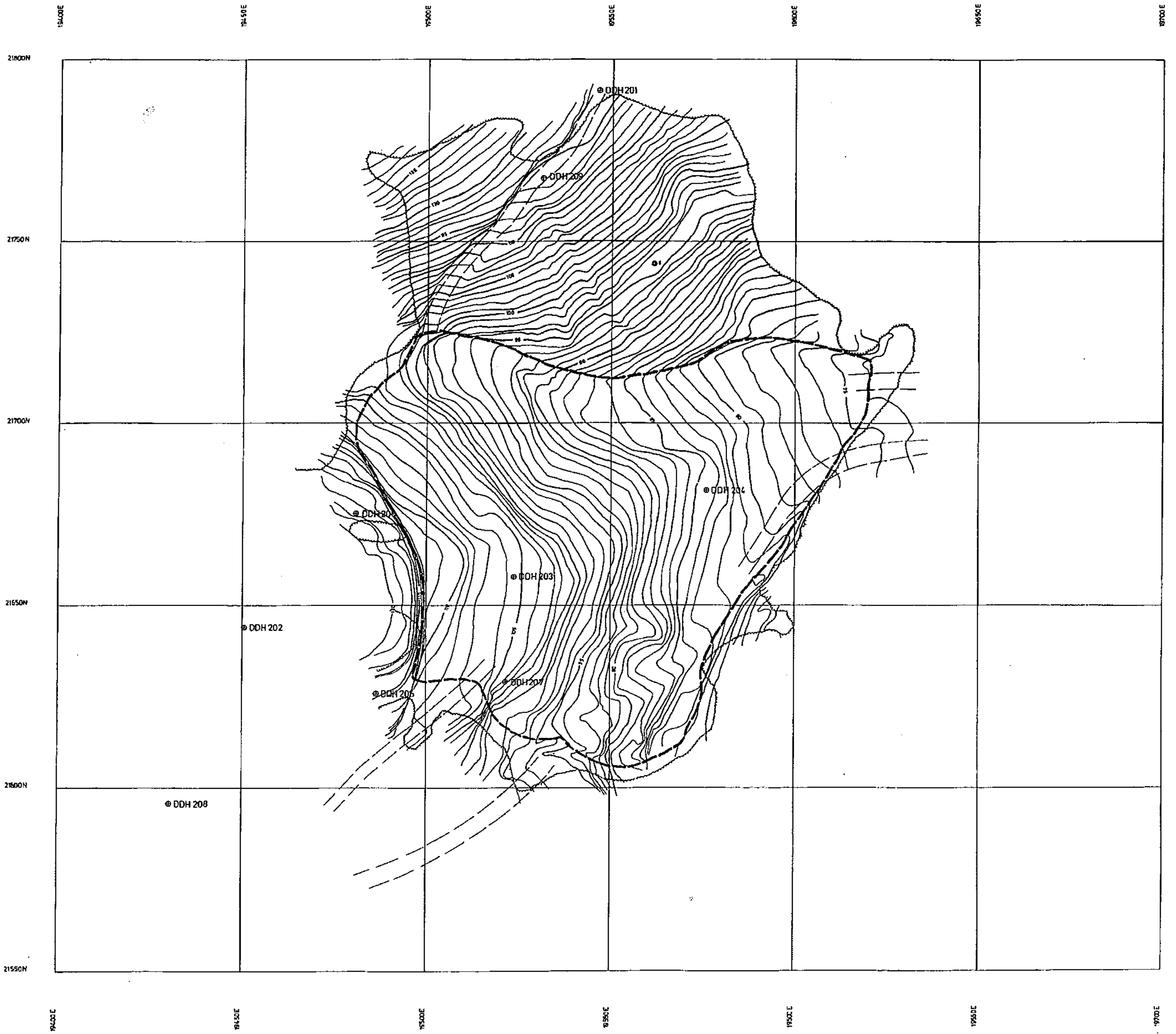
DESIGNED 30.7.81	INSPECTING ENGINEER 30.9.81
DRAWN	PRINCIPAL ENGINEER, WATER SUPPLY 30.9.81
CHECKED 30.9.81	DEPUTY CHIEF ENGINEER 28.10.81

PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PILZ — DIRECTOR OF PUBLIC WORKS
J. P. MESSNER — CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
SITE PLAN

FILE WS 1172/106
DRAWING 80067-002

80067-006



AUSTRALIAN HEIGHT DATUM

SCHEDULE OF BOREHOLE LOCATIONS

HOLE Nº	EAST.	NORTH.	LENGTH	RL. SURFACE
DDH 201	19546	21791	22·60	115
DDH 202	19451	21644	14·21	130
DDH 203	19524	21658	20·35	108
DDH 204	19576	21681	14·90	90
DDH 205	19487	21626	31	116
DDH 206	19481	21675	31	117
DDH 207	19522	21629	25·4	103
DDH 208	19431	21596	31	125
DDH 209	19531	21767	30·5	114

NOTES.

1. CONTOURS INDICATED ARE COMPILED FROM AERIAL PHOTOGRAPHY MARCH 1981, AND SHOULD BE VERIFIED ON SITE. SUBSEQUENT STRIPPING HAS BEEN CARRIED OUT AND SHOULD BE VERIFIED ON SITE BY THE CONTRACTOR.
2. QUARRY OPERATIONS NOT TO EXTEND OUTSIDE STRIPPED AREA UNLESS WRITTEN APPROVAL HAS BEEN GIVEN BY THE SUPERINTENDENT.

KEY:

⊕ DDH 202 VERTICAL DIAMOND DRILL HOLE AND NUMBER.

AREA STRIPPED TO D9 DOZER REFUSAL.

CLEARING LINE TO TREES.

10 5 0 10 20 30 40 50

SCALE 1:500 METRES

"TENDER DRAWING ONLY"

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

DESIGNED [signature] 30.9.81
DRAWN [signature]
CHECKED [signature] 30.9.81

INSPECTING ENGINEER [signature] 30.9.81
PRINCIPAL ENGINEER WATER SUPPLY [signature] 30.9.81
PRINCIPAL ENGINEER DESIGN [signature] 11-10-81

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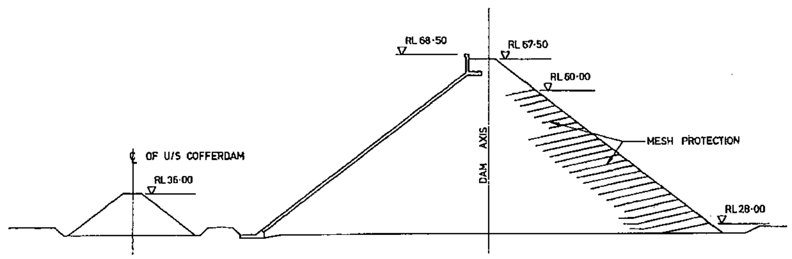
W. K. PILZ DIRECTOR OF PUBLIC WORKS
J. P. MESSNER CHIEF ENGINEER
TWEED SHIRE COUNCIL

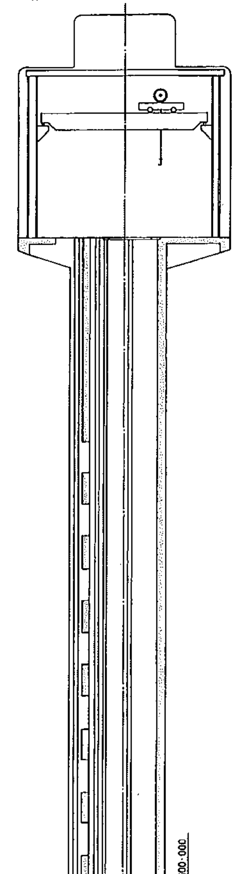
TWEED DISTRICT WATER SUPPLY
C.H. HALL DAM
QUARRY SITE.

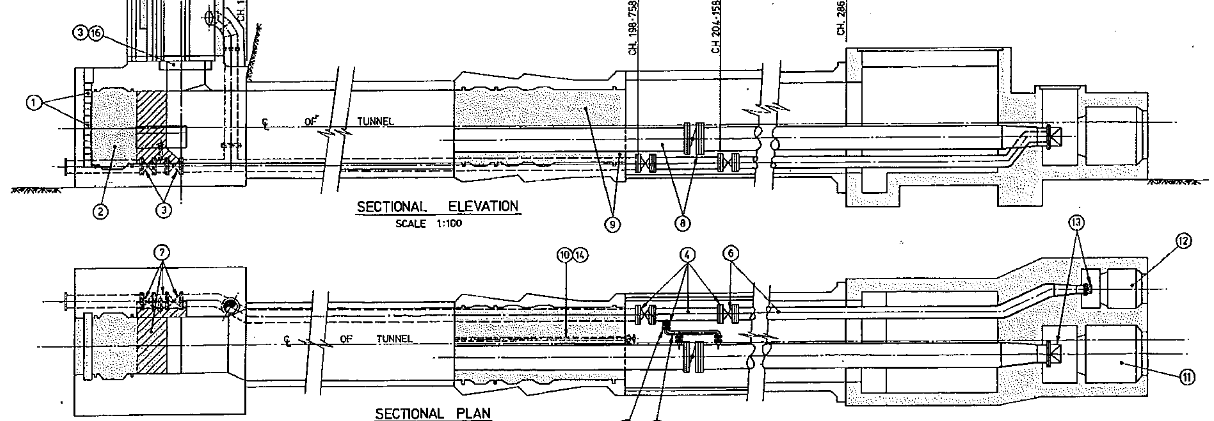
FILE WS 1172/108
DRAWING 80067-006

80067-007



U/S COFFERDAM AND MAIN EMBANKMENT
TYPICAL SECTION
SCALE 1:500





SECTIONAL ELEVATION
SCALE 1:100

SECTIONAL PLAN
SCALE 1:100

WORKS UNDER PREVIOUS CONTRACTS AND BY PUBLIC WORKS DEPARTMENT INCLUDE :-

1. STRIPPING OF EMBANKMENT SITE
2. CONSTRUCTION OF UPSTREAM CONCRETE TOE SLAB
3. SPILLWAY EXCAVATION
4. UPSTREAM AND DOWNSTREAM TUNNEL PORTAL EXCAVATIONS
5. CONSTRUCTION OF CONCRETE LINED TUNNEL, TOWER BASE STRUCTURE, 600ϕ BYPASS PIPE INSTALLATION TO CHAINAGE 198·758.

CONTRACT WORKS

IN THE PERIOD FROM COMMENCEMENT OF CONTRACT TO CLOSURE OF THE DIVERSION TUNNEL THE CONTRACTOR SHALL CARRY OUT THE FOLLOWING WORKS :-

A. EMBANKMENT

COMPLETION OF :-

1. UPSTREAM COFFERDAM
2. STEEL MESHED EMBANKMENT
3. EMBANKMENT CONCRETE FACE AND WAVE WALL, SPILLWAY CONCRETE AND DRAINAGE.
4. INTAKE TOWER AND ACCESS BRIDGE. INSTALLATION OF EQUIPMENT.

B. DIVERSION CLOSURE

1. INSTALL STOPLOGS WITH BULKHEAD GATE IN RAISED POSITION.
2. PLACE STAGE I TOWER BASE PLUG CONCRETE INCLUDING INTERFACE GROUTING.
3. CLOSE 600ϕ GATE VALVES IN TOWER BASE NOT LESS THAN 14 DAYS AFTER PLACING STAGE I CONCRETE AND LOWER BULKHEAD GATE.
4. INSTALL 600ϕ GATE VALVE, 600ϕ PIPE AND TEMPORARY FLANGE TO TUNNEL CHAINAGE 204·158 INCLUDING 150ϕ OFFTAKE AND 150ϕ GATE VALVE FOR CROSS CONNECTION PIPE.
5. COMMENCE RIPARIAN RELEASE OF UP TO 1·1 ML/d THROUGH 150ϕ GATE VALVE AS DIRECTED BY THE SUPERINTENDENT.
6. INSTALL PERMANENT 600ϕ PIPE VALVES AND FITTINGS DOWNSTREAM OF TUNNEL CHAINAGE 204·158.
7. CLOSE 600ϕ GATE VALVES IN TOWER BASE, GROUT BETWEEN VALVES, PLACE STAGE II AND STAGE III TOWER BASE PLUG CONCRETE INCLUDING INTERFACE GROUTING.
8. INSTALL 1200ϕ OUTLET PIPE AND 1200ϕ B.F.V., COMPLETE 150ϕ CROSS CONNECTION PIPE AND FITTINGS.
9. PLACE TUNNEL PLUG CONCRETE INCLUDING INTERFACE GROUTING.
10. OPEN TUNNEL DRAIN VALVE.
11. COMPLETE CONSTRUCTION OF 1200ϕ DISSIPATOR.
12. COMPLETE CONSTRUCTION OF 600ϕ DISSIPATOR.
13. COMPLETE INSTALLATION OF F.D.C. VALVES
14. CLOSE TUNNEL DRAIN VALVE.
15. BALANCE PRESSURE ON BULKHEAD GATE USING 150ϕ CROSS CONNECTION TO FILL 1200ϕ PIPE AND TUNNEL UPSTREAM OF TUNNEL PLUG.
16. RAISE BULKHEAD GATE.

THE SEQUENCE GIVEN ABOVE IS THAT INTENDED BY THE DESIGNERS. WHERE CIRCUMSTANCES REQUIRE THE SUPERINTENDENT MAY APPROVE A DIFFERENT SEQUENCE.

AUSTRALIAN HEIGHT DATUM

1:100 — 2 1 0 2 4 6 8 10 m
1:500 — 10 0 10 20 30 40 50 m

"TENDER DRAWING ONLY"

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES.
ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

DESIGNED 20·9·81 — INSPECTING ENGINEER 6·10·81
DRAWN — PRINCIPAL ENGINEER WATER SUPPLY 17·10·81
CHECKED — PRINCIPAL ENGINEER DESIGN 16·10·81

PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PILZ — DIRECTOR OF PUBLIC WORKS
J. P. MEISSNER — CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
OUTLET WORKS
SEQUENCE OF DEVELOPMENT.

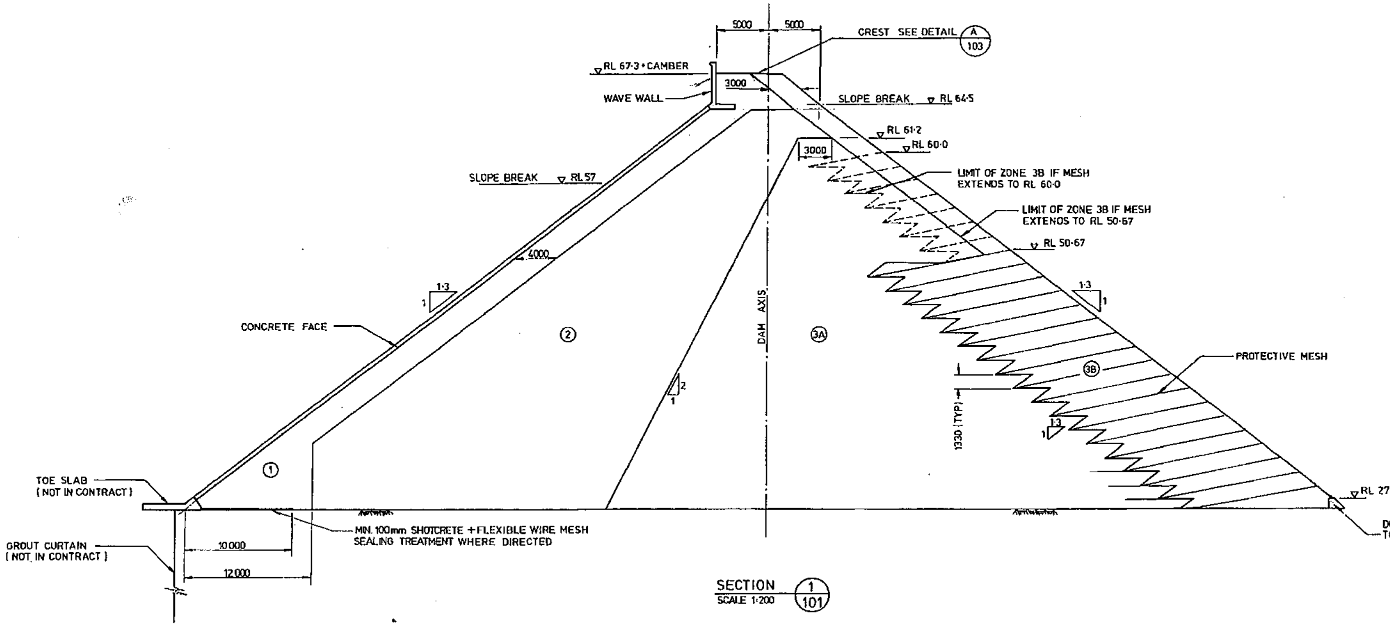
FILE WS 1172/108
DRAWING
80067-007

80067-102

NOTE

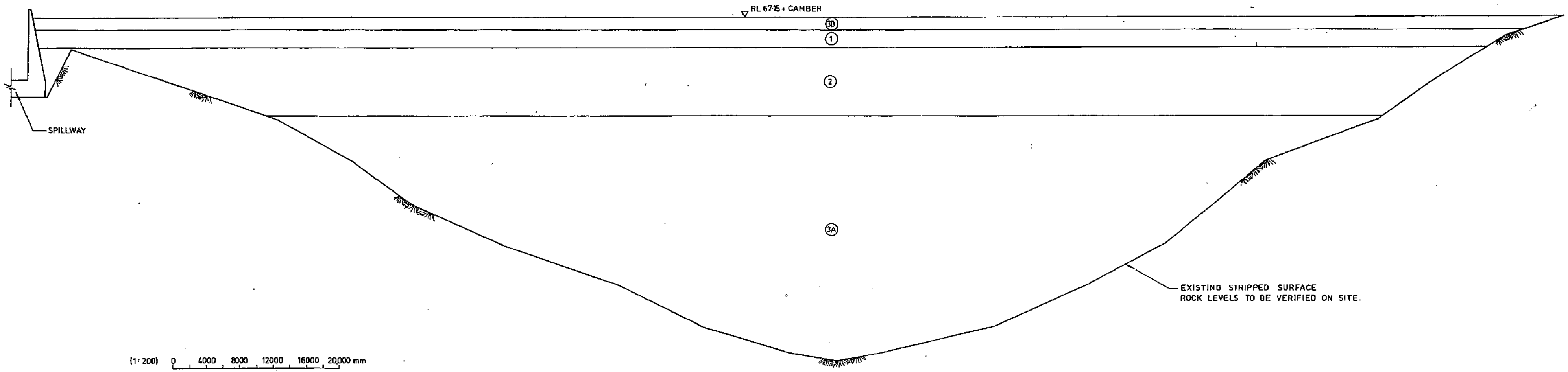
1. FOR GRADATION AND DESCRIPTION OF EMBANKMENT ZONES SEE DRG 80067-104

2. MATERIALS ARE TO BE SELECTED SO THAT ZONE 3A AND 3B MATERIALS ARE COARSER AND MORE PERMEABLE THAN ZONE 2 MATERIAL.



SECTION 1/101
SCALE 1:200

TYPICAL MAXIMUM SECTION



AUSTRALIAN HEIGHT DATUM

SECTION ALONG DAM AXIS

"TENDER DRAWING ONLY"

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES, ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

DESIGNED
INSPECTING ENGINEER 12-10-81
DRAWN
PRINCIPAL ENGINEER WATER SUPPLY 12-10-81
CHECKED
PRINCIPAL ENGINEER DESIGN 16-10-81

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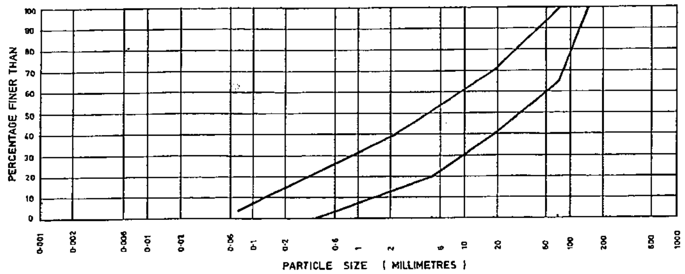
J. P. MESSNER
DIRECTOR OF PUBLIC WORKS
CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
EMBANKMENT DETAILS SHEET 1.

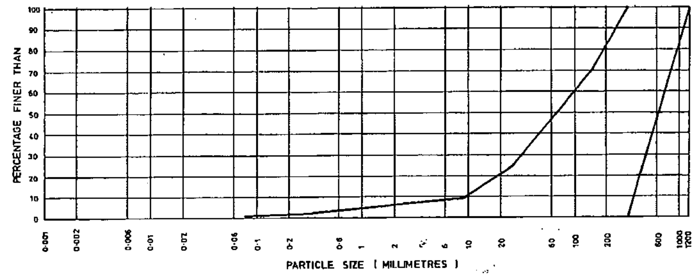
FILE WS 1172/108
DRAWING
80067-102

NOTES:

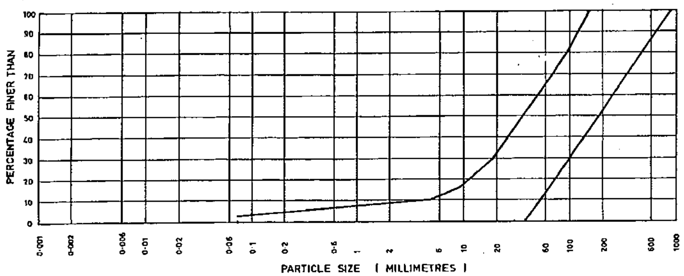
1. THE MATERIAL WITHIN 3m OF THE FACE IN ZONE 3B TO HAVE A SUFFICIENTLY CONSTANT GRADING AND COLOUR TO ENSURE A UNIFORM APPEARANCE TO THE FACE.



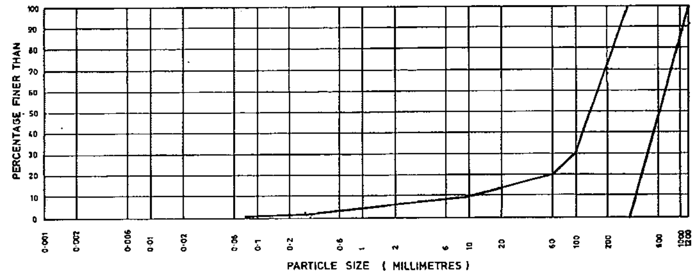
GRADATION LIMITS — ZONE 1



GRADATION LIMITS - ZONE 3A



GRADATION LIMITS — ZONE 2



GRADATION LIMITS - ZONE 3B

ZONE	FUNCTION	DESCRIPTION	LAYER THICKNESS (mm)	COMPACTION EQUIPMENT	Nº OF PASSES PER LAYER	* WATER % BY VOLUME
1.	SEMI PERMEABLE ZONE	MODERATELY WEATHERED RHYOLITE	330	VIBRATORY ROLLER	4 × 10 T	20
2.	PERMEABLE INTERMEDIATE ZONE	SLIGHTLY WEATHERED TO MODERATELY WEATHERED RHYOLITE	1000	VIBRATORY ROLLER	4 × ⊁10 T	20
3A.	FRESH ROCK ZONE	FRESH RHYOLITE	1330	VIBRATORY ROLLER	4 × ⊁10 T	20
3B.	MESH ZONE AND FACE ZONE	SELECTED FRESH RHYOLITE	1330	VIBRATORY ROLLER	4 × ⊁10 T	20
					(T = TONNE)	

* ADDED WATER

EMBANKMENT ZONES

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MK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES. ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

DESIGNED
DRAWN
CHECKED
INSPECTING ENGINEER 6-10-81
PRINCIPAL ENGINEER WATER SUPPLY 12-10-81
PRINCIPAL ENGINEER DESIGN 16-10-81

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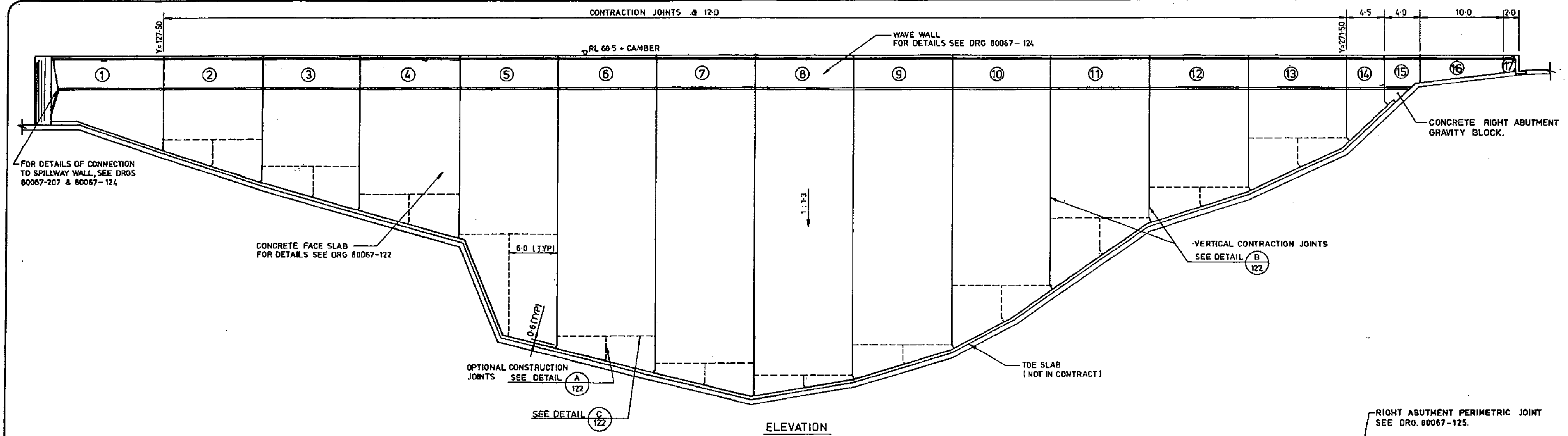
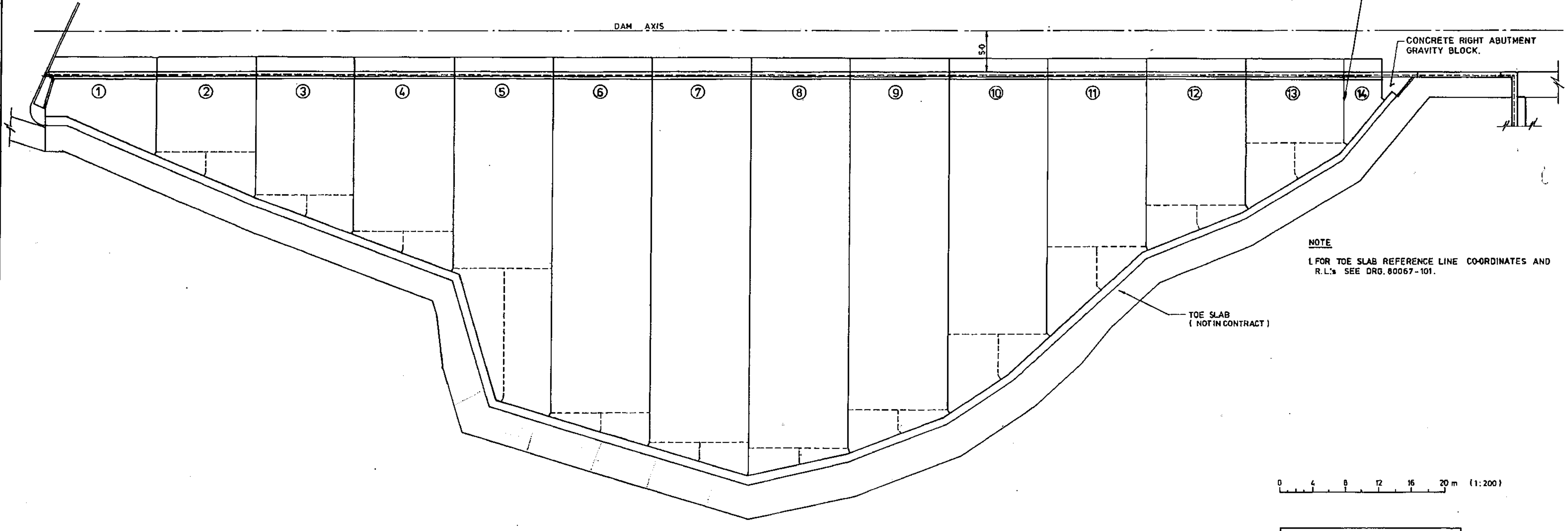
TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
GRADATION AND DESCRIPTION OF EMBANKMENT ZONES

FILE WS1172/108
DRAWING
80067-104

80067-121



ELEVATION
SCALE 1:200



NOTE

1. FOR TOE SLAB REFERENCE LINE CO-ORDINATES AND R.L.'s SEE DRG. 80067-101.

0 4 8 12 16 20 m (1:200)

PLAN
SCALE 1:200

AUSTRALIAN HEIGHT DATUM

"TENDER DRAWING ONLY"

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES.
ALL OTHER DIMENSIONS ARE IN METRES UNLESS STATED OTHERWISE

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DRAWN 28.7.81
CHECKED
INSPECTING ENGINEER 7-10-81
PRINCIPAL ENGINEER - WATER SUPPLY 12-10-81
PRINCIPAL ENGINEER - DESIGN 16-10-81

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J. P. MESSNER CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
CONCRETE FACE AND WAVE WALL
GENERAL ARRANGEMENT

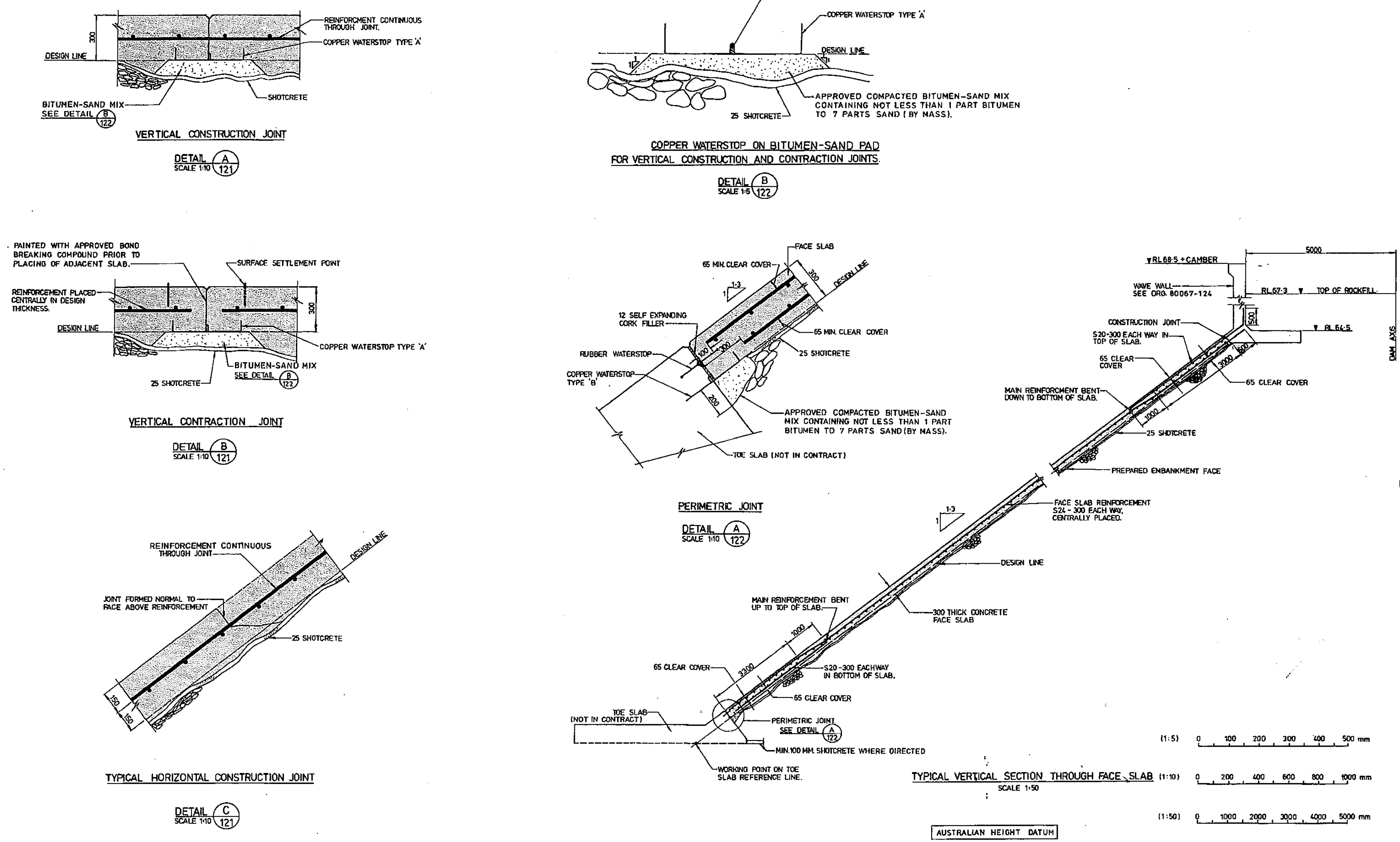
FILE WS1172-108
DRAWING 80067-121

0 100 200 300

NOTES

1. FOR CONCRETE NOTES SEE DRG. 80067-125

2. SPACING AND ORIENTATION OF REINFORCEMENT BARS SHALL BE PARALLEL AND NORMAL TO THE DAM AXIS.



AUSTRALIAN HEIGHT DATUM

"TENDER DRAWING ONLY"

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES.
ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

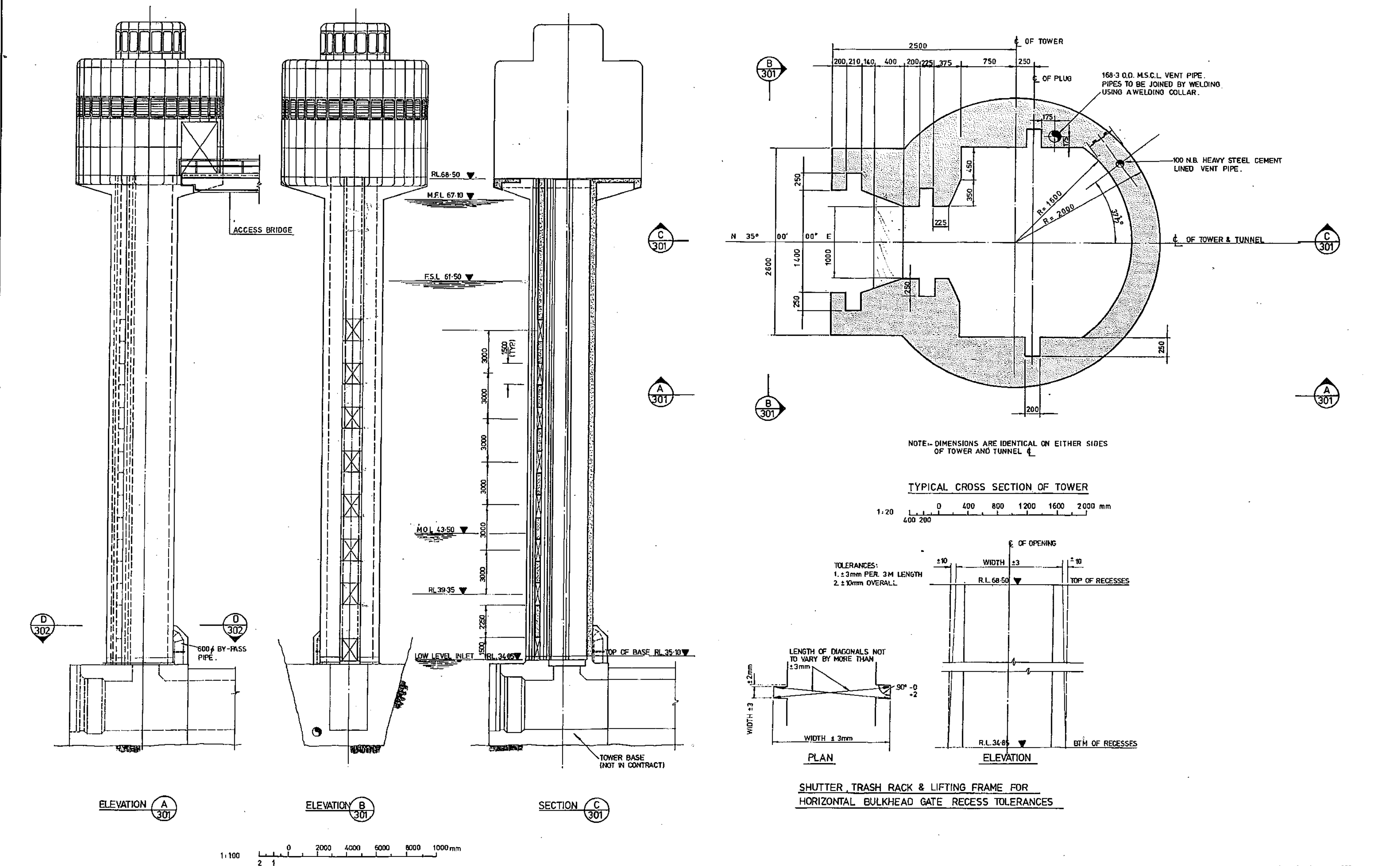
DESIGNED	INSPECTING ENGINEER
DRAWN P. McCALLUM	PRINCIPAL ENGINEER WATER SUPPLY
CHECKED	PRINCIPAL ENGINEER DESIGN

PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PILZ DIRECTOR OF PUBLIC WORKS
J. P. MESSNER CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
EMBANKMENT
CONCRETE FACE DETAILS

FILE WS 1172/108
DRAWING
80067-122

80067-301



"TENDER DRAWING ONLY"

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES. ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

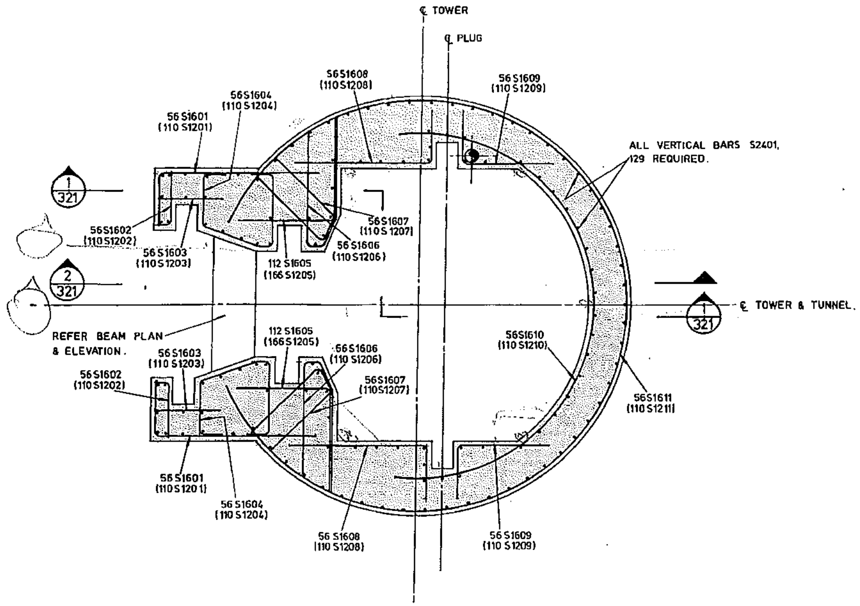
DESIGNED 6·10·81
DRAWN Ian Etherton
CHECKED
INSPECTING ENGINEER R.A. McDonald 6·10·81
PRINCIPAL ENGINEER WATER SUPPLY 12·10·81
PRINCIPAL ENGINEER DESIGN 16·10·81

PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PRZ, J. P. MESSNER — DIRECTOR OF PUBLIC WORKS, CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
GENERAL ARRANGEMENT OF INTAKE TOWER

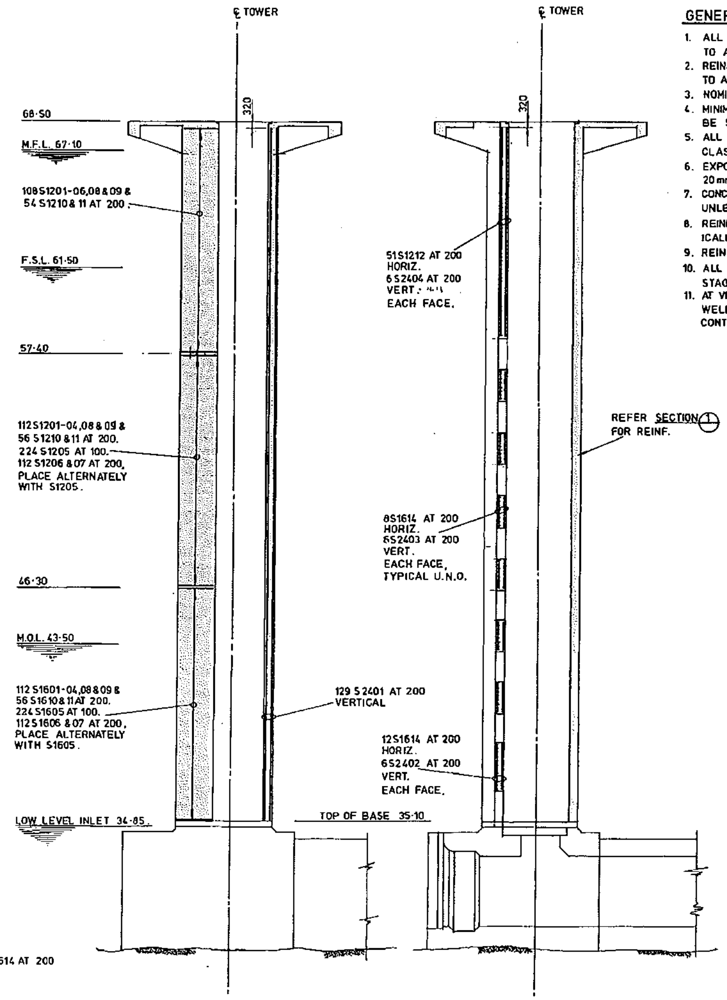
FILE WS 1172/108
DRAWING 80067-301

80067-321.



TYPICAL CROSS SECTION OF TOWER.

SCALE 1:20.

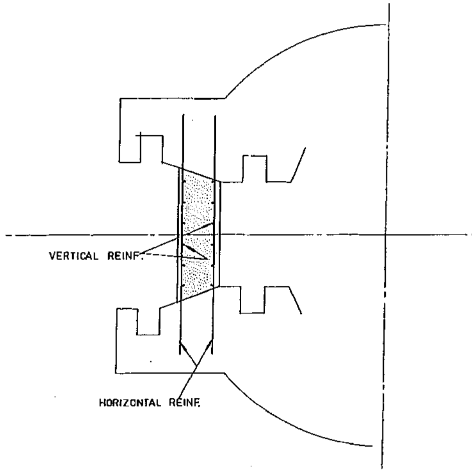


SECTION 1/321 SCALE 1:100

SECTION 2/321

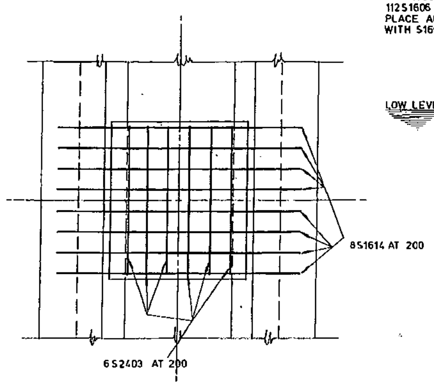
GENERAL NOTES.

1. ALL REINFORCED CONCRETE TO BE GRADE 25 (Fc-25MPa). TO A.S.1480.
2. REINFORCING BARS TO BE GRADE 230S (fsy-230 MPa) TO A.S.1302.
3. NOMINAL AGGREGATE SIZE SHALL NOT EXCEED 40mm.
4. MINIMUM CLEAR COVER TO REINFORCEMENT SHALL BE 50mm.
5. ALL EXPOSED CONCRETE SURFACES SHALL HAVE CLASS F2 FINISH, UNLESS NOTED OTHERWISE.
6. EXPOSED INTERNAL & EXTERNAL CORNERS SHALL HAVE 20mm FILLETS OR CHAMFERS UNLESS NOTED OTHERWISE.
7. CONCRETE LIFTS SHALL NOT EXCEED 2m IN DEPTH UNLESS OTHERWISE APPROVED BY THE SUPERINTENDENT.
8. REINFORCEMENT SHOWN IS REPRESENTED DIAGRAMMATICALLY AND IS NOT NECESSARILY A TRUE PROJECTION.
9. REINFORCEMENT DIMENSIONS SHALL NOT BE SCALED.
10. ALL LAPPED SPLICES IN REINFORCEMENT ARE TO BE STAGGERED.
11. AT VERTICAL SPLICES EACH BAR IS TO BE TIED AND WELDED FOR A MINIMUM RUN OF 15mm FOR ELECTRICAL CONTINUITY.



TYPICAL PLAN OF BEAM.

SCALE 1:20.



ELEVATION OF TYPICAL BEAM .

SCALE 1:20

1:100 — 2 1 0 2 4 6 8 10m

1:20 — 400 200 0 400 800 1200 1600 2000

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MK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES. ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

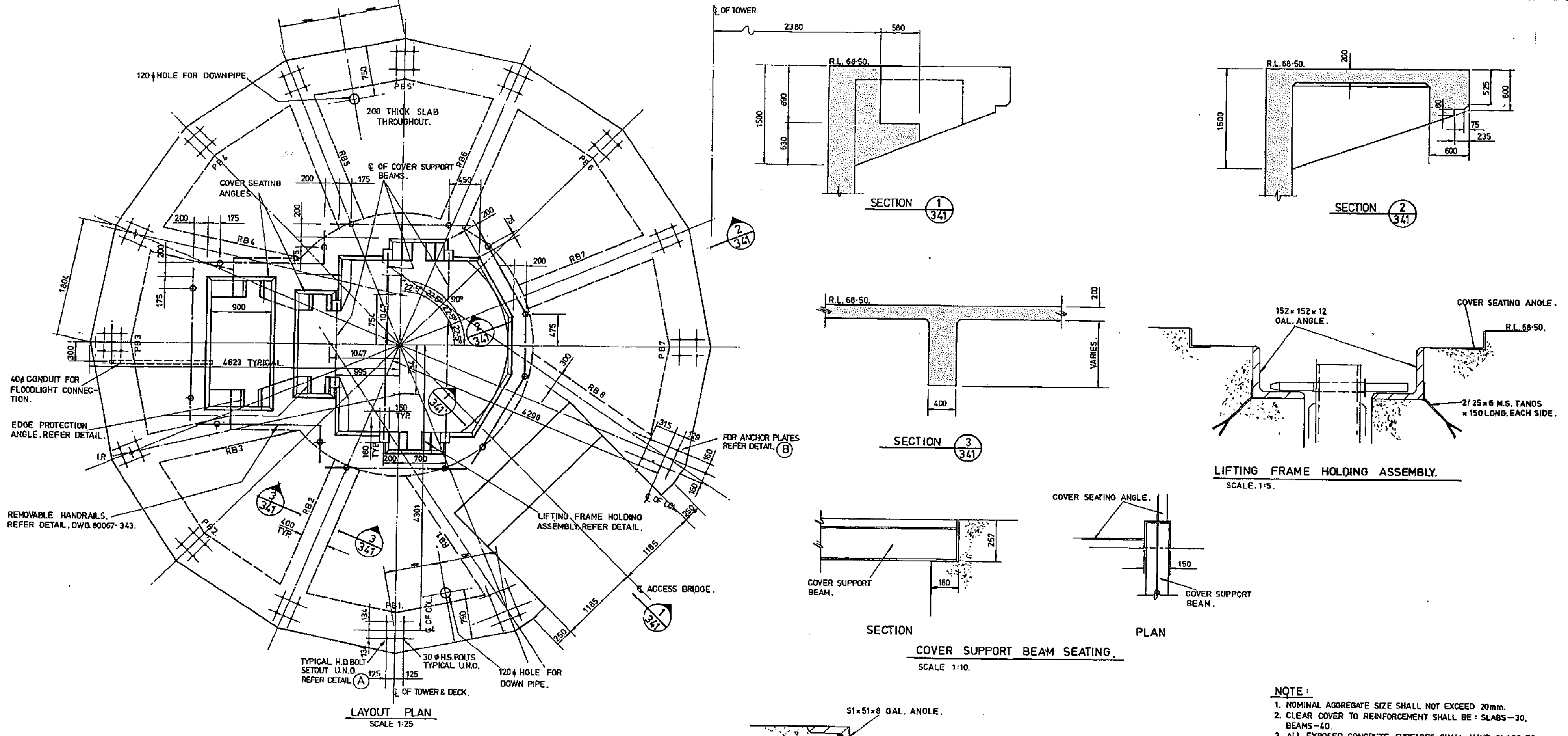
DESIGNED 16.10.81	15-10-81 INSPECTING ENGINEER
DRAWN Ian Etherton.	16-10-81 PRINCIPAL ENGINEER WATER SUPPLY
CHECKED 16.10.81	16-10-81 PRINCIPAL ENGINEER DESIGN

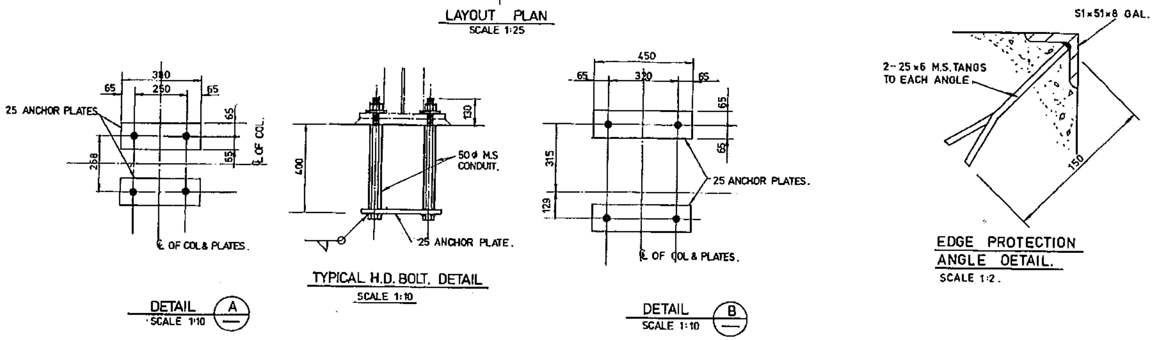
PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PILZ — DIRECTOR OF PUBLIC WORKS
J. P. MESSNER — CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
INTAKE TOWER
REINFORCEMENT DETAILS

FILE WS1172/108

DRAWING 80067-321





NOTE:

1. NOMINAL AGGREGATE SIZE SHALL NOT EXCEED 20mm.
2. CLEAR COVER TO REINFORCEMENT SHALL BE: SLABS–30, BEAMS–40.
3. ALL EXPOSED CONCRETE SURFACES SHALL HAVE CLASS F2 FINISH, UNLESS SHOWN OTHERWISE.
4. REINFORCING BARS SHALL BE GRADE 230R & 230S TO AS1302.
5. EXPOSED INTERNAL & EXTERNAL CORNERS SHALL HAVE 20mm FILLETS OR CHAMFERS, UNLESS SHOWN OTHERWISE.
6. SPLICING OF REINFORCING TO BE CARRIED OUT BY MEANS OF MECHANICAL DEVICES TO A.S.1480.
7. ALL SPLICES TO REINFORCEMENT TO BE STAGGERED.
8. CONDUITS, PIPES & RELATED ITEMS SHALL NOT BE PLACED WITHIN CONCRETE COVER.
9. REMOVABLE HANDRAILS TO BE IN ACCORDANCE WITH A.S.1657.
10. POSTS & HANDRAILS TO BE 48·3 O.D. x 3·2 C.H.S., KNEERAILS TO BE 33·7 O.D. x 3·2 C.H.S. IN ACCORDANCE WITH A.S. 1074.
11. HANDRAILS TO BE 1000 ABOVE FLOOR LEVEL, KNEERAILS TO BE AT MID-HEIGHT.
12. RAILS & POSTS SHALL BE HOT-DIP GALVANISED AFTER FABRICATION & BEFORE PAINTING.

"TENDER DRAWING ONLY"

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES.
ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

DESIGNED 13.10.81 — INSPECTING ENGINEER 15.10.81
DRAWN Ian Etherton — PRINCIPAL ENGINEER WATER SUPPLY 15.10.81
CHECKED — PRINCIPAL ENGINEER DESIGN 16-10-81

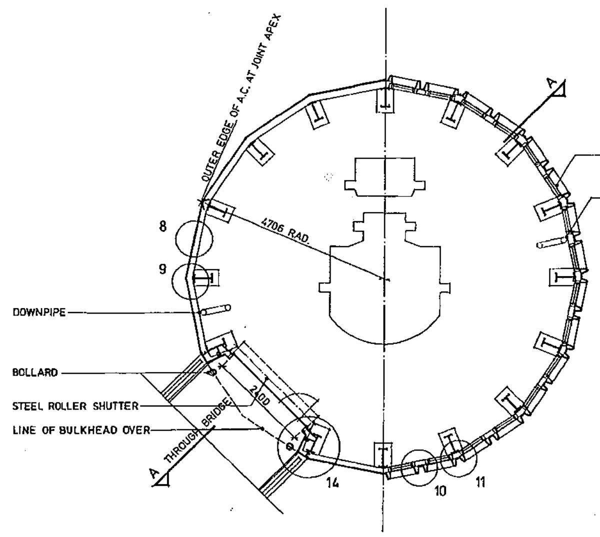
PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PILZ, J. P. MEISSNER — DIRECTOR OF PUBLIC WORKS, CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM.
HOIST HOUSE OPERATING DECK
GENERAL ARRANGEMENT

FILE WS1172/108
DRAWING 80067-341

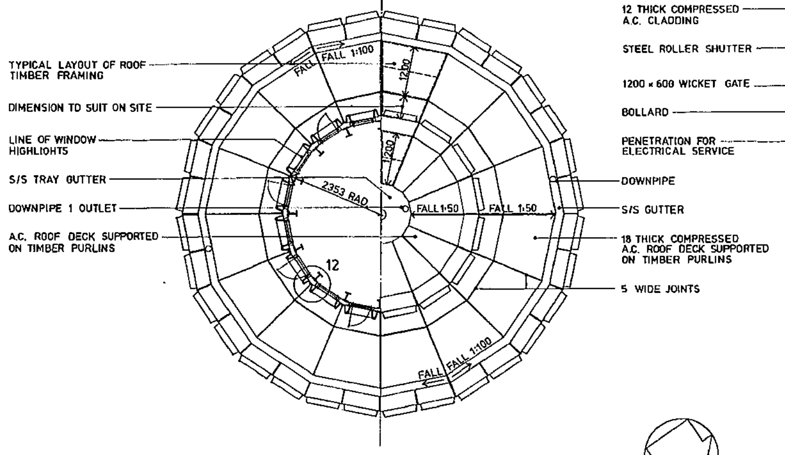
80067-341.

80067-361



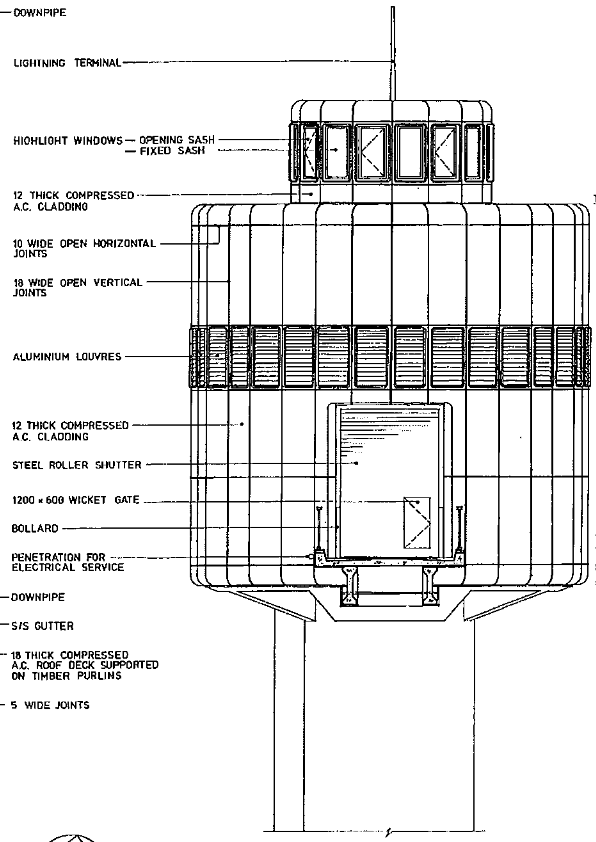
PLAN AT ROLLER SHUTTER
SCALE 1:50

PLAN AT LOUVRES

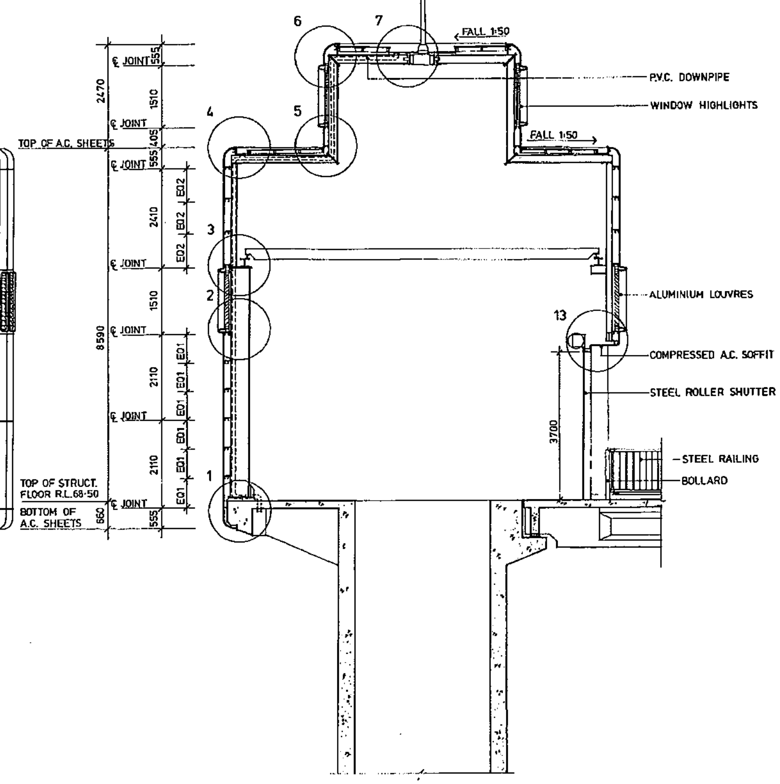


PLAN AT HIGHLIGHTS
SCALE 1:50

ROOF PLAN



ELEVATION
SCALE 1:50



SECTION A-A
SCALE 1:50

NOTE – ACTUAL SITE DIMENSIONS SHALL BE TAKEN IN PREFERENCE TO THOSE SHOWN OR INDICATED ON DRAWING.

"TENDER DRAWING ONLY"

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES.
ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

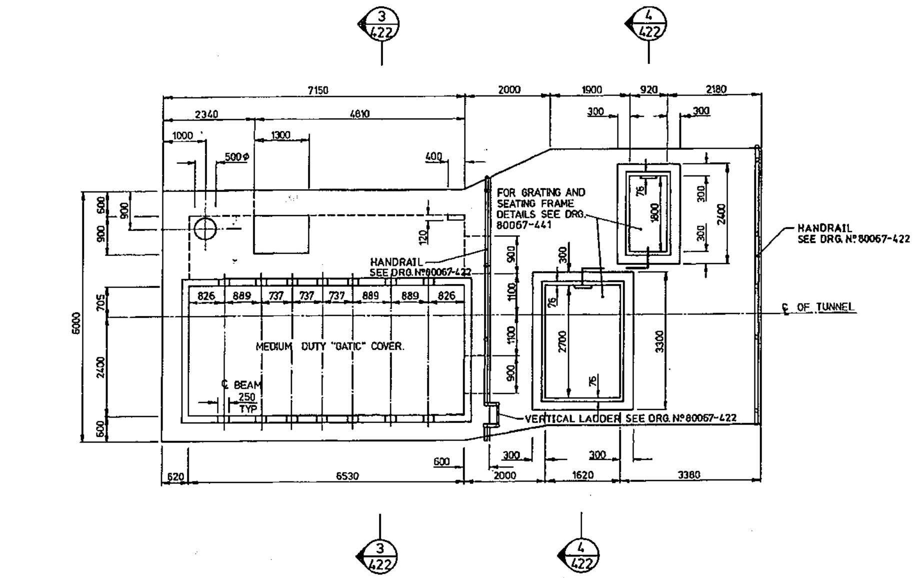
DESIGNED VERA SALTIKOV	[signature] 15-10-81 INSPECTING ENGINEER
DRAWN VERA SALTIKOV KOA HUMPHREYS	[signature] 15-10-81 PRINCIPAL ENGINEER WATER SUPPLY
CHECKED GUY AQUILINA	[signature] 3-7-81 PRINCIPAL ARCHITECT HEALTH

PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PILZ — DIRECTOR OF PUBLIC WORKS
J. P. MESSNER — CHIEF ENGINEER
J. W. THOMSON — GOVERNMENT ARCHITECT
TWEED SHIRE COUNCIL

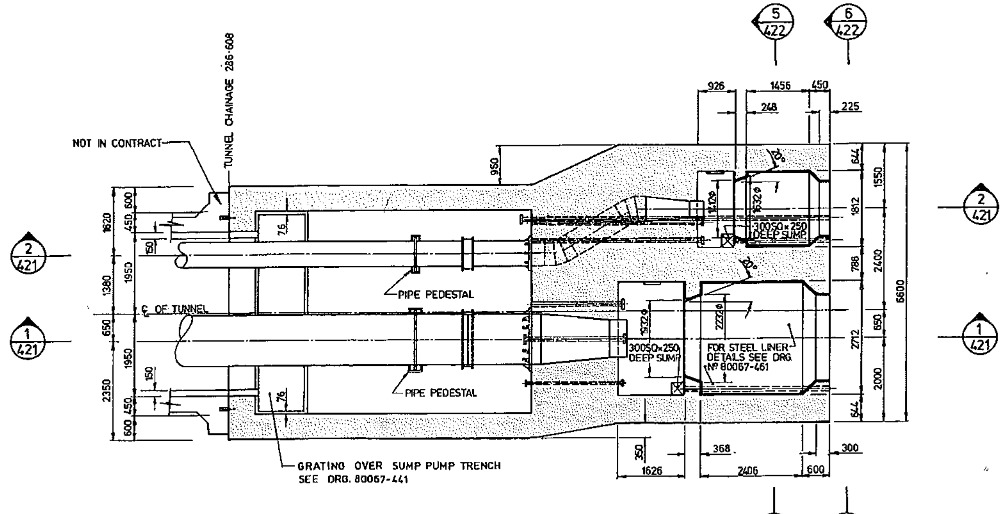
TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
INTAKE TOWER
HOIST HOUSE ARCHITECTURAL DETAILS
SHEET 1

FILE WS 1172/108
DRAWING
80067-361

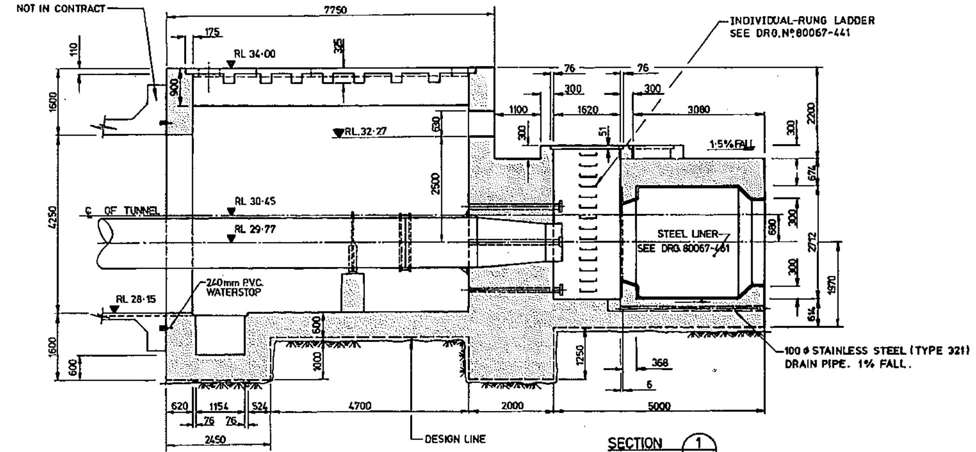
80067-421



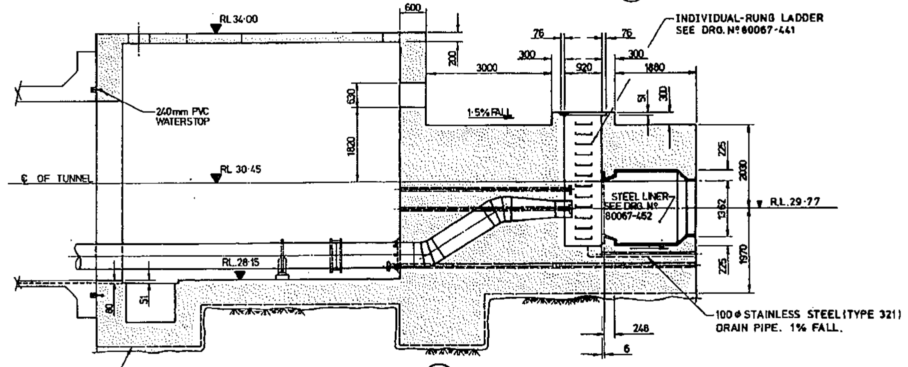
PLAN
SCALE 1:50



SECTIONAL PLAN AT RL 29·77
SCALE 1:50
(FOR PIPE AND SUMP DETAILS SEE DRG.



SECTION 1/421
SCALE 1:50



SECTION 2/421
SCALE 1:50

REFERENCE DRGS:

80067-422
80067-424
80067-425
80067-426
80067-427
80067-471
80067-472
80067-461
80067-462
80067-441
80067-423

NOTES:

1. ALL CONCRETE SHALL BE GRADE 20.
2. AGGREGATE SIZE SHALL NOT EXCEED 40 mm.
3. ALL EXPOSED CONCRETE SURFACES SHALL HAVE A CLASS F2 FINISH UNLESS SHOWN OTHERWISE.
4. THE LOCATION OF CONSTRUCTION JOINTS SHALL BE SUBJECT TO PRIOR APPROVAL OF THE SUPERINTENDENT.
5. FOR PIPEWORK & INSTALLATION ARRANGEMENT SEE DRGS. 80067-451, 80067-452.
6. ALL EXPOSED INTERNAL & EXTERNAL CORNERS SHALL HAVE 20mm. FILLET OR CHAMFERS UNLESS NOTED OTHERWISE.
7. CONCRETE LIFTS SHALL NOT EXCEED 2m IN DEPTH UNLESS APPROVED BY SUPERINTENDENT.
8. ALL REINFORCED CONCRETE SHALL CONFORM TO SECTION C OF THE SCHEDULE TO SPECIFICATION.

AUSTRALIAN HEIGHT DATUM

(1:50) 1000 0 1000 2000 3000 4000 5000 mm

"TENDER DRAWING ONLY"

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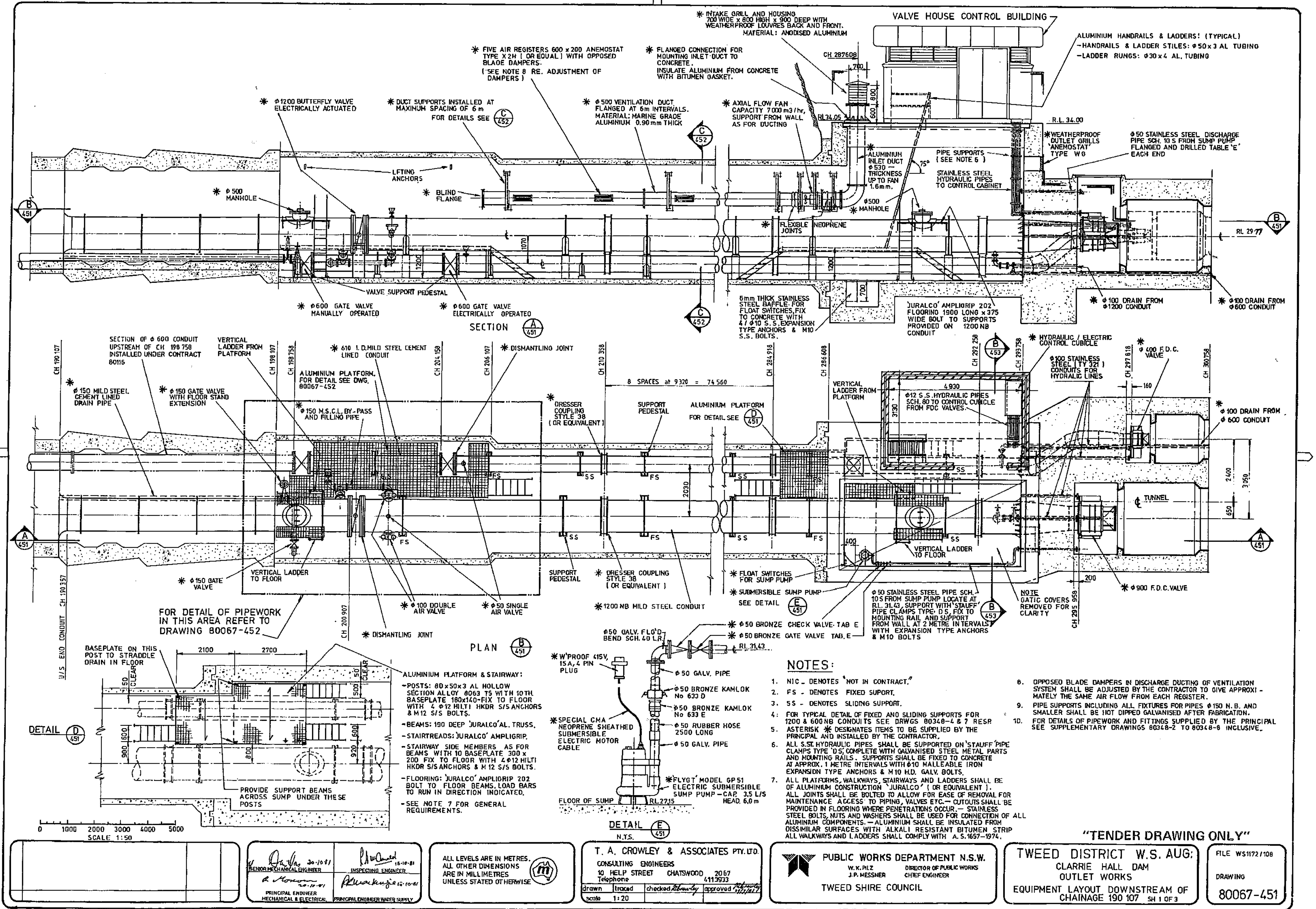
DESIGNED
DRAWN P. McCALLUM
CHECKED
INSPECTING ENGINEER 15·10·81
PRINCIPAL ENGINEER WATER SUPPLY 15·10·81
PRINCIPAL ENGINEER DESIGN 16-10-81

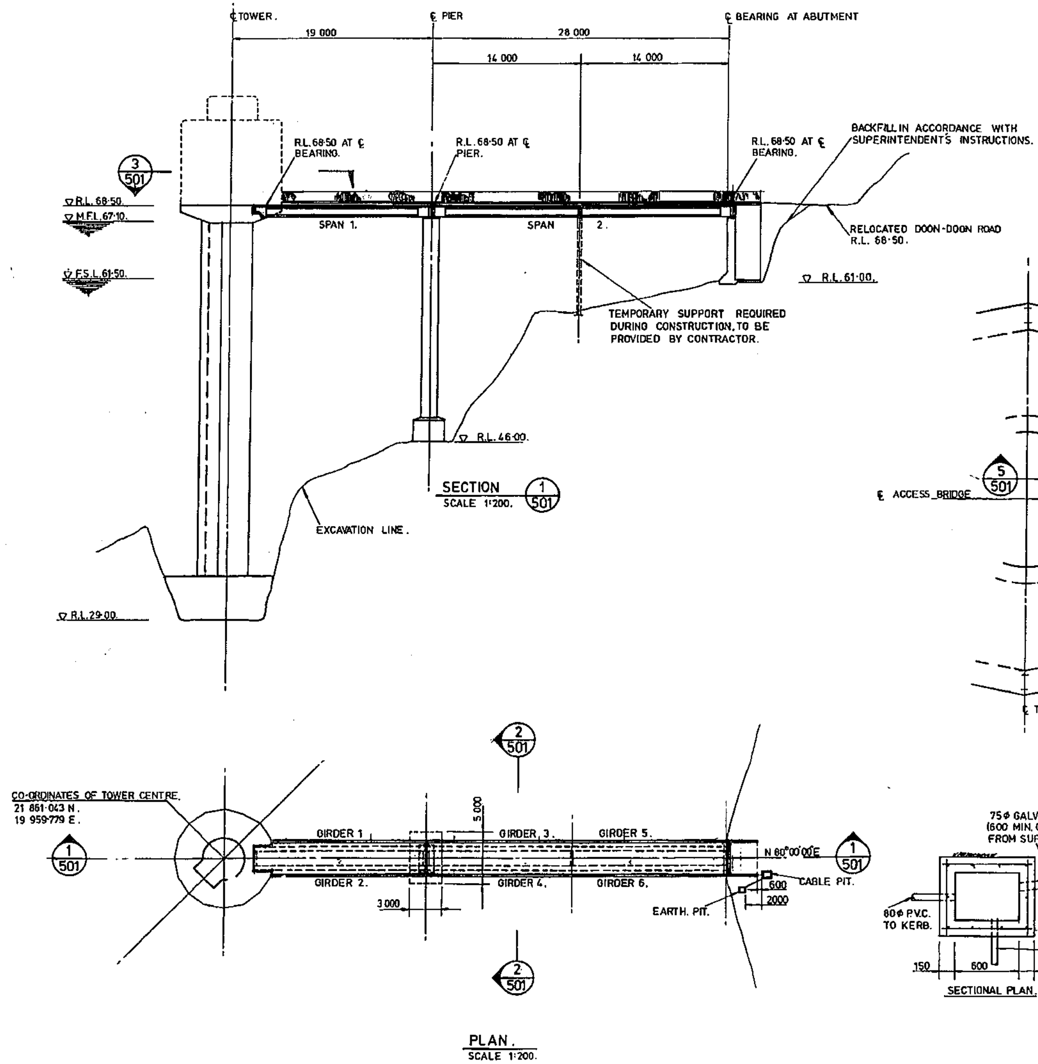
PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PILZ, J. P. MESSNER — DIRECTOR OF PUBLIC WORKS, CHIEF ENGINEER
TWEED SHIRE COUNCIL

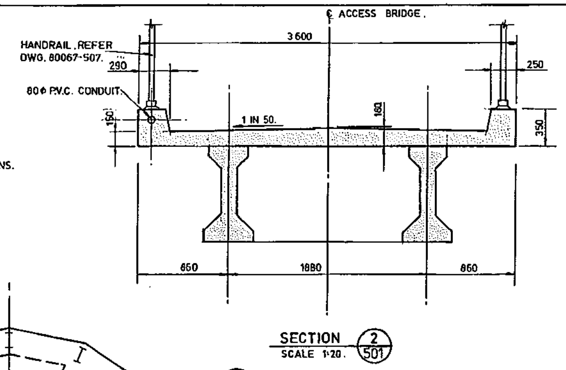
TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
OUTLET WORKS
VALVE HOUSE CONCRETE DETAILS.

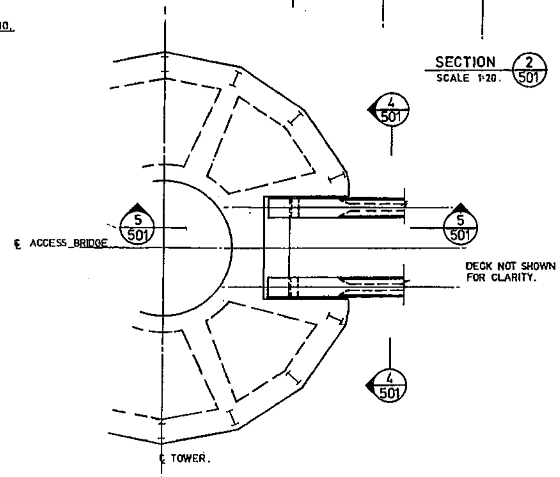
FILE WS 1172/108
DRAWING 80067-421

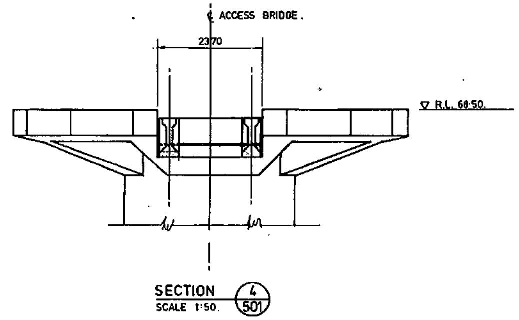


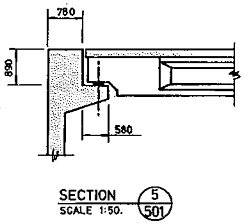
80067-451
VALVE HOUSE CONTROL BUILDING
SECTION (A/451)
PLAN (B/451)
DETAIL (D/451)
DETAIL (E/451) N.T.S.
FOR DETAIL OF PIPEWORK IN THIS AREA REFER TO DRAWING 80067-452
ALUMINIUM HANDRAILS & LADDERS: (TYPICAL)
-HANDRAILS & LADDER STILES: ϕ50x3 AL TUBING
-LADDER RUNGS: ϕ30x4 AL. TUBING
ALUMINIUM PLATFORM & STAIRWAY:
-POSTS: 80x50x3 AL HOLLOW SECTION ALLOY 6063 T5 WITH 10TH. BASEPLATE 180x140-FIX TO FLOOR WITH 4 ϕ12 HILTI HKDR S/S ANCHORS & M12 S/S BOLTS.
-BEAMS: 190 DEEP 'JURALCO' AL. TRUSS.
-STAIRTREADS: 'JURALCO' AMPLIGRIP.
-STAIRWAY SIDE MEMBERS AS FOR BEAMS WITH 10 BASEPLATE 300 x 200 FIX TO FLOOR WITH 4 ϕ12 HILTI HKDR S/S ANCHORS & M12 S/S BOLTS.
-FLOORING: 'JURALCO' AMPLIGRIP 202 BOLT TO FLOOR BEAMS. LOAD BARS TO RUN IN DIRECTION INDICATED.
-SEE NOTE 7 FOR GENERAL REQUIREMENTS.
NOTES:
1. NIC - DENOTES "NOT IN CONTRACT."
2. FS - DENOTES FIXED SUPORT.
3. SS - DENOTES SLIDING SUPPORT.
4. FOR TYPICAL DETAIL OF FIXED AND SLIDING SUPPORTS FOR 1200 & 600 NB CONDUITS SEE DRWGS 80348-4 & 7 RESP.
5. ASTERISK * DESIGNATES ITEMS TO BE SUPPLIED BY THE PRINCIPAL AND INSTALLED BY THE CONTRACTOR.
6. ALL S.ST. HYDRAULIC PIPES SHALL BE SUPPORTED ON 'STAUFF' PIPE CLAMPS TYPE 'DS', COMPLETE WITH GALVANISED STEEL METAL PARTS AND MOUNTING RAILS. SUPPORTS SHALL BE FIXED TO CONCRETE AT APPROX. 1 METRE INTERVALS WITH ϕ10 MALLEABLE IRON EXPANSION TYPE ANCHORS & M10 H.D. GALV. BOLTS.
7. ALL PLATFORMS, WALKWAYS, STAIRWAYS AND LADDERS SHALL BE OF ALUMINIUM CONSTRUCTION 'JURALCO' (OR EQUIVALENT). ALL JOINTS SHALL BE BOLTED TO ALLOW FOR EASE OF REMOVAL FOR MAINTENANCE ACCESS TO PIPING, VALVES ETC. - CUTOUTS SHALL BE PROVIDED IN FLOORING WHERE PENETRATIONS OCCUR. - STAINLESS STEEL BOLTS, NUTS AND WASHERS SHALL BE USED FOR CONNECTION OF ALL ALUMINIUM COMPONENTS. - ALUMINIUM SHALL BE INSULATED FROM DISSIMILAR SURFACES WITH ALKALI RESISTANT BITUMEN STRIP. ALL WALKWAYS AND LADDERS SHALL COMPLY WITH A.S. 1657-1974.
8. OPPOSED BLADE DAMPERS IN DISCHARGE DUCTING OF VENTILATION SYSTEM SHALL BE ADJUSTED BY THE CONTRACTOR TO GIVE APPROXIMATELY THE SAME AIR FLOW FROM EACH REGISTER.
9. PIPE SUPPORTS INCLUDING ALL FIXTURES FOR PIPES ϕ150 N.B. AND SMALLER SHALL BE HOT DIPPED GALVANISED AFTER FABRICATION.
10. FOR DETAILS OF PIPEWORK AND FITTINGS SUPPLIED BY THE PRINCIPAL SEE SUPPLEMENTARY DRAWINGS 80348-2 TO 80348-8 INCLUSIVE.
"TENDER DRAWING ONLY"
SCALE 1:50
ALL LEVELS ARE IN METRES. ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE
SENIOR MECHANICAL ENGINEER
INSPECTING ENGINEER
PRINCIPAL ENGINEER MECHANICAL & ELECTRICAL
PRINCIPAL ENGINEER WATER SUPPLY
T. A. CROWLEY & ASSOCIATES PTY. LTD.
CONSULTING ENGINEERS
10 HELP STREET CHATSWOOD 2067
Telephone 4112933
drawn | traced | checked | approved
scale 1:20
PUBLIC WORKS DEPARTMENT N.S.W.
W.K. PILZ DIRECTOR OF PUBLIC WORKS
J.P. MESSNER CHIEF ENGINEER
TWEED SHIRE COUNCIL
TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
OUTLET WORKS
EQUIPMENT LAYOUT DOWNSTREAM OF CHAINAGE 190 107 SH 1 OF 3
FILE WS1172/108
DRAWING 80067-451

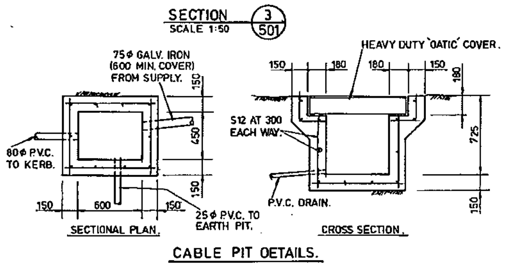


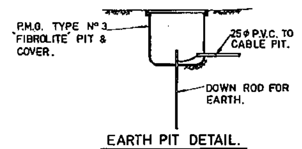










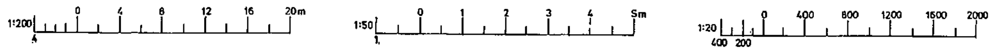


CONSTRUCTION & POST TENSIONING PROCEDURE.

1. CONSTRUCT THE BASE OF THE ABUTMENT UP TO THE CONSTRUCTION JOINT.
2. ERECT THE TEMPORARY SUPPORT AT LOCATION SHOWN. THE SUPPORT SHALL BE DESIGNED TO CARRY A LOAD OF 550 kN AND ENSURE STABILITY DURING CONSTRUCTION.
3. ATTACH PERMANENT BEARINGS AT PIER AND ABUTMENT ENDS. PLACE SPAN 2 GIRDERS IN POSITION AND CONCRETE THE JOINTS BETWEEN THE GIRDERS. CAST SPAN 2 DECK AND CROSS BEAMS. AFTER THE CONCRETE IN THE JOINTS HAS ACHIEVED A STRENGTH OF 35MPa, AND THE CONCRETE IN THE DECK HAS ACHIEVED A STRENGTH OF 25MPa, BUT NOT BEFORE IT IS 14 DAYS OLD, THE POST TENSIONING IS TO BE CARRIED OUT TO THE FOLLOWING PROCEDURE:
   a. POST TENSIONING SHALL BE CARRIED OUT FROM ONE END ONLY.
   b. UPPER TENDONS OF GIRDERS ARE TO BE STRESSED FIRST.
   c. GROUT TENDON DUCTS.
4. ATTACH BEARINGS FOR SPAN 1 GIRDERS AND PLACE GIRDERS IN POSITION. CAST SPAN 1 DECK AND CROSS BEAMS.
5. REFER TO SPECIFICATION FOR POSITIONING OF GIRDERS.

DESIGN LOAD.

1. DESIGN LOAD – 9 TONNE TRUCK.
2. ASSUMED AXLE LOADS.
   72kN 18kN
   4 250



"TENDER DRAWING ONLY"

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

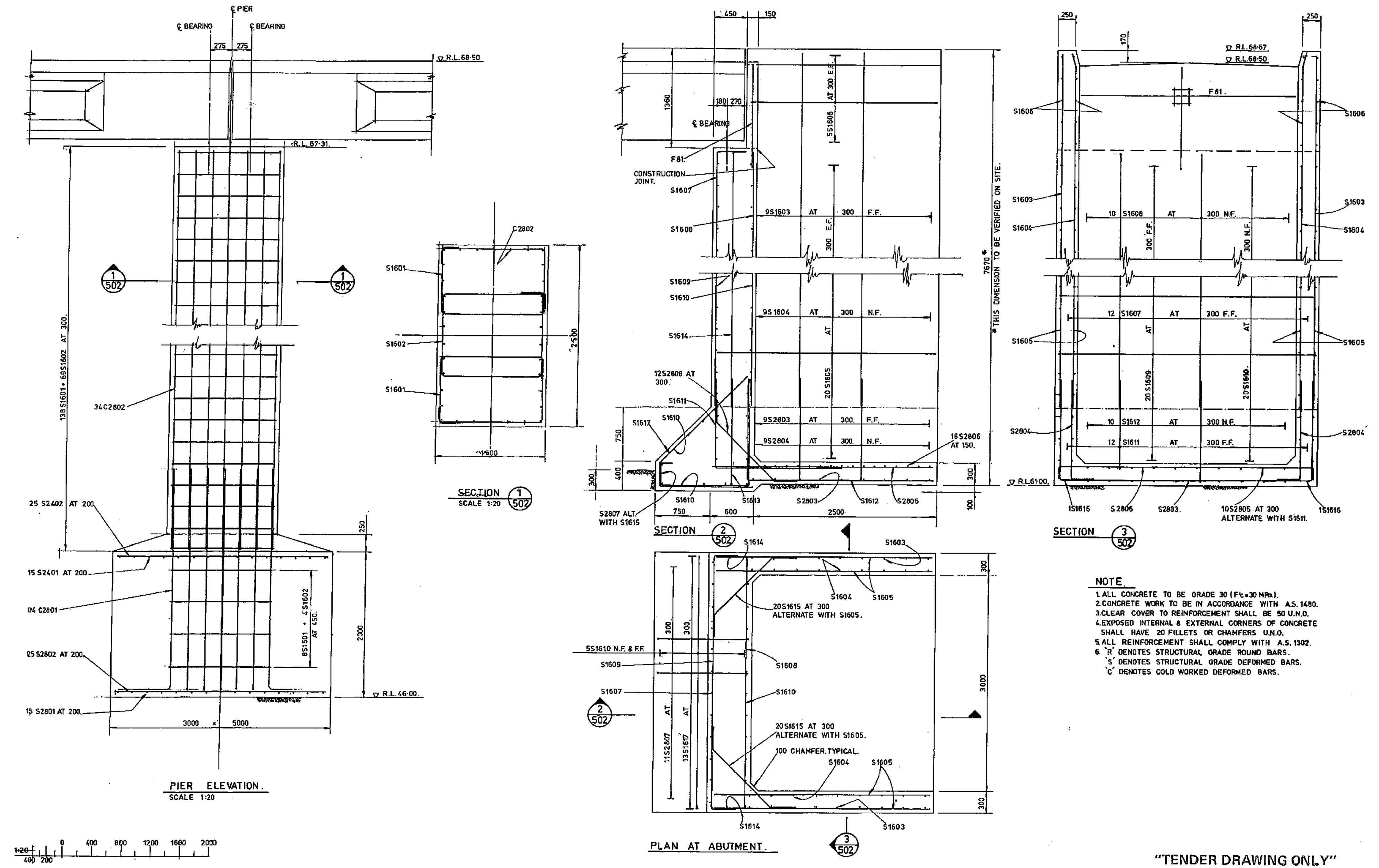
ALL LEVELS ARE IN METRES.
ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

DESIGNED 1-10-81
DRAWN Ian Etherton.
CHECKED 1-10-81
INSPECTING ENGINEER 15-10-81
PRINCIPAL ENGINEER WATER SUPPLY 15-10-81
PRINCIPAL ENGINEER DESIGN. 16-10-81

PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PILZ DIRECTOR OF PUBLIC WORKS
J. P. MESSNER CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
INTAKE TOWER BRIDGE
GENERAL ARRANGEMENT.

FILE WS1172/108
DRAWING 80067-501



NOTE.

1. ALL CONCRETE TO BE GRADE 30 (F'c = 30 MPa).
2. CONCRETE WORK TO BE IN ACCORDANCE WITH A.S. 1480.
3. CLEAR COVER TO REINFORCEMENT SHALL BE 50 U.N.O.
4. EXPOSED INTERNAL & EXTERNAL CORNERS OF CONCRETE SHALL HAVE 20 FILLETS OR CHAMFERS U.N.O.
5. ALL REINFORCEMENT SHALL COMPLY WITH A.S. 1302.
6. 'R' DENOTES STRUCTURAL GRADE ROUND BARS.
'S' DENOTES STRUCTURAL GRADE DEFORMED BARS.
'C' DENOTES COLD WORKED DEFORMED BARS.

"TENDER DRAWING ONLY"

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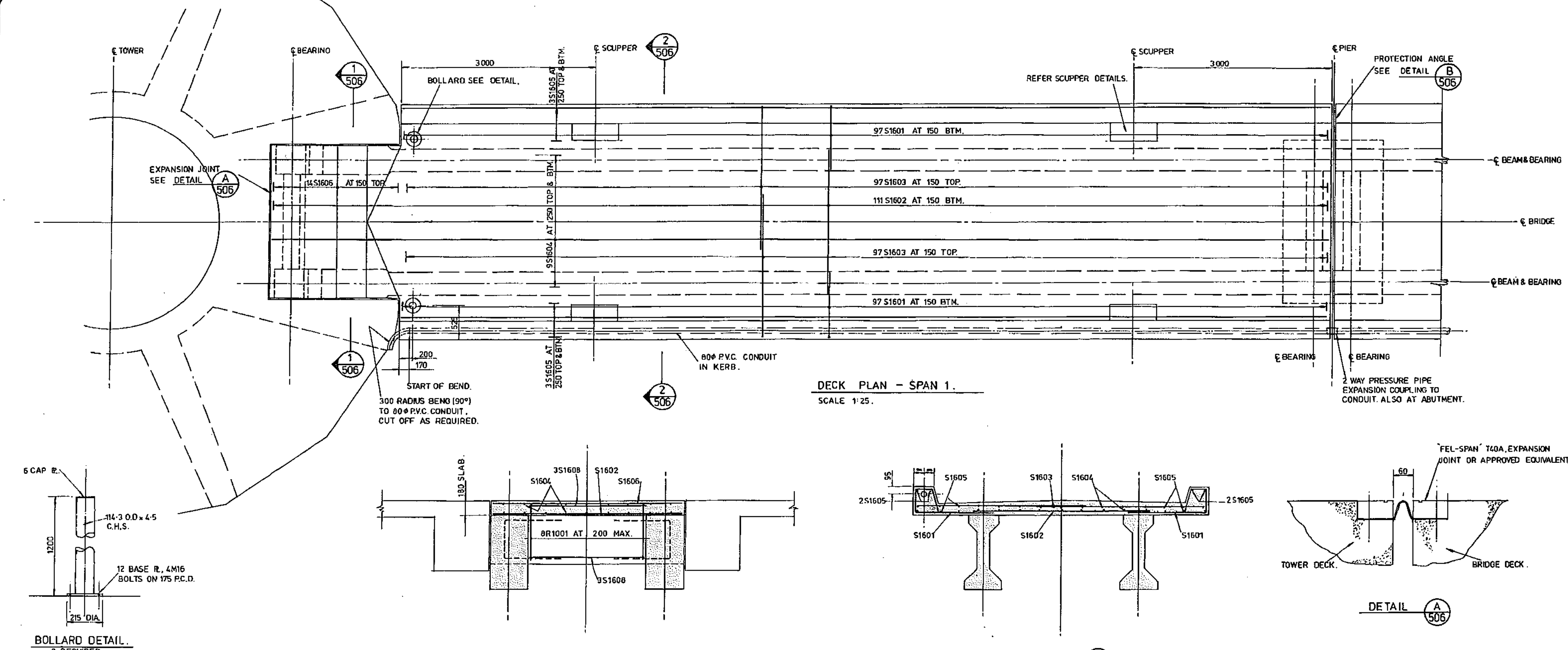
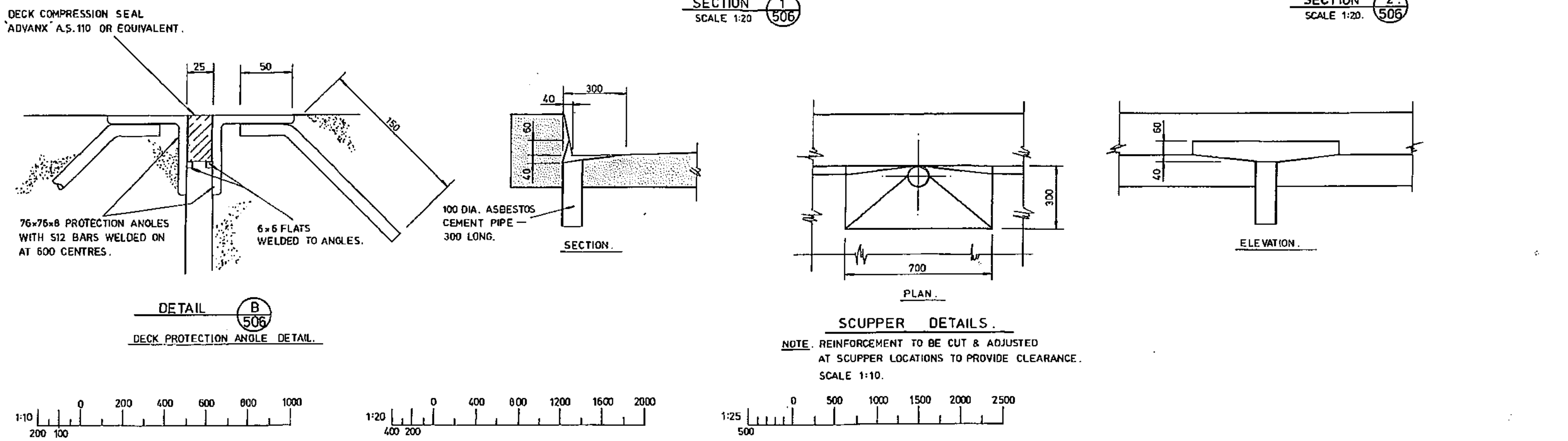
DESIGNED 1.10.81 — INSPECTING ENGINEER 15.10.81
DRAWN Ian Etherton. — PRINCIPAL ENGINEER WATER SUPPLY 15.10.81
CHECKED 1.10.81 — PRINCIPAL ENGINEER DESIGN 16-10-81

PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PILZ DIRECTOR OF PUBLIC WORKS
J. P. MESSNER CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
INTAKE TOWER BRIDGE
PIER AND ABUTMENT DETAILS

FILE WS1172/108
DRAWING 80067-502





GENERAL NOTES.

1. GRADE 30 MPa CONCRETE SHALL BE USED FOR DECK AND KERBS.
2. ALL REINFORCEMENT IN DECK AND KERBS SHALL BE GRADE 230S TO A.S. 1302.
3. CLEAR COVER TO REINFORCEMENT IN DECK AND KERBS TO BE 30 U.N.O.
4. ALL METALWORK EXCLUDING HANDRAILS SHALL BE HOT DIP GALVANISED AFTER FABRICATION TO A.S. 1650 - 1974.
5. ALL EXPOSED CONCRETE SURFACES SHALL HAVE CLASS F3 FINISH.
6. EXPOSED INTERNAL AND EXTERNAL CORNERS OF REINFORCED CONCRETE TO HAVE 20 FILLETS OR CHAMFERS U.N.O.

"TENDER DRAWING ONLY"

No.	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES. ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

DESIGNED 1-10-81	15-10-81 INSPECTING ENGINEER
DRAWN Ian Etherton.	15-10-81 PRINCIPAL ENGINEER WATER SUPPLY
CHECKED 1-10-81	16-10-81 PRINCIPAL ENGINEER DESIGN

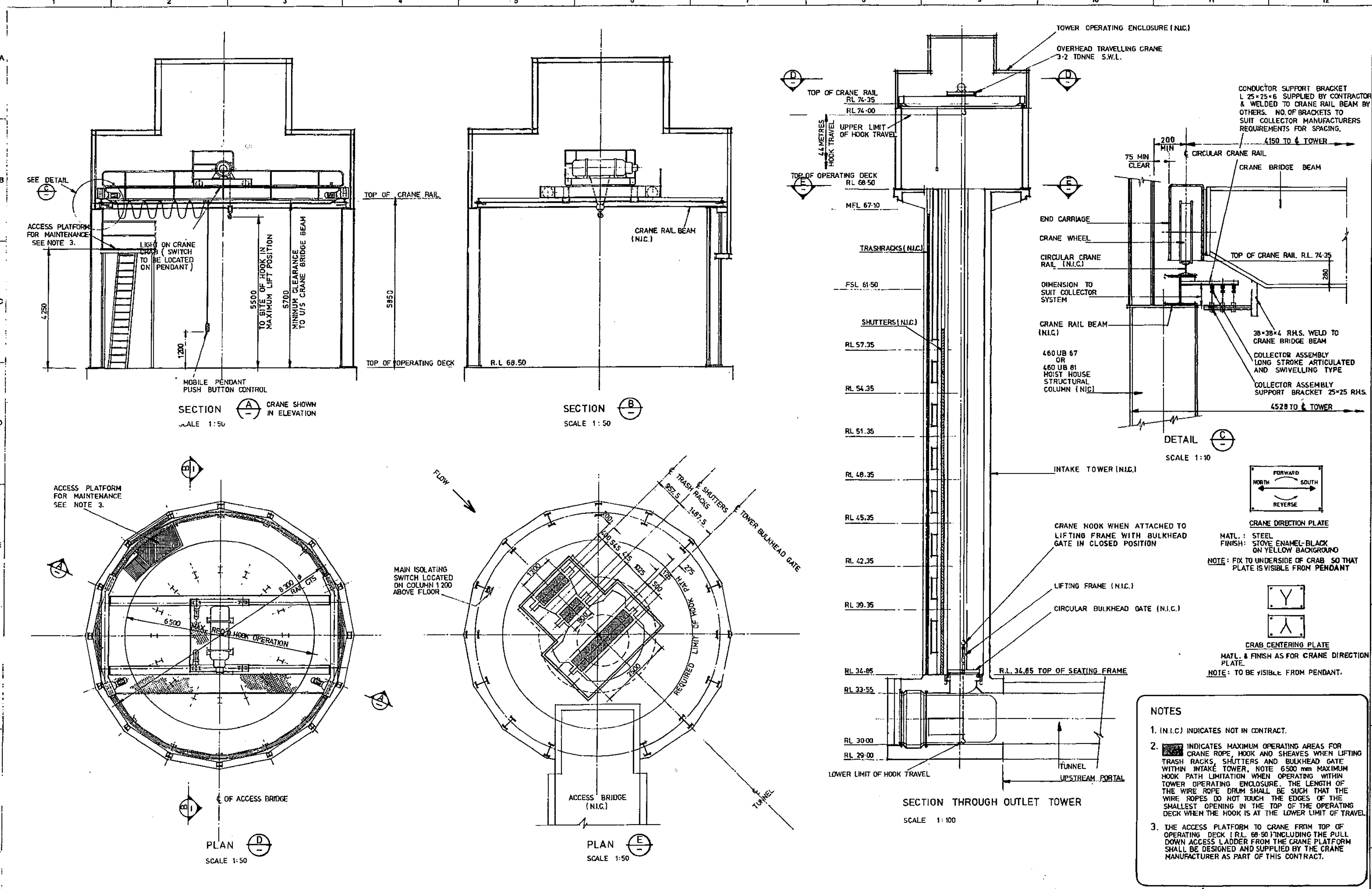
DEPARTMENT OF PUBLIC WORKS N.S.W.
W.K. FILZ DIRECTOR OF PUBLIC WORKS
J.P. MESSNER CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
INTAKE TOWER BRIDGE.
DECK PLAN-SPAN 1.

FILE WS 1172/108.
DRAWING 80067-506

80067-506.

80242-2



NOTES

1. (N.I.C) INDICATES NOT IN CONTRACT.
2. [hatched symbol] INDICATES MAXIMUM OPERATING AREAS FOR CRANE ROPE, HOOK AND SHEAVES WHEN LIFTING TRASH RACKS, SHUTTERS AND BULKHEAD GATE WITHIN INTAKE TOWER. NOTE 6500 mm MAXIMUM HOOK PATH LIMITATION WHEN OPERATING WITHIN TOWER OPERATING ENCLOSURE. THE LENGTH OF THE WIRE ROPE DRUM SHALL BE SUCH THAT THE WIRE ROPES DO NOT TOUCH THE EDGES OF THE SMALLEST OPENING IN THE TOP OF THE OPERATING DECK WHEN THE HOOK IS AT THE LOWER LIMIT OF TRAVEL.
3. THE ACCESS PLATFORM TO CRANE FROM TOP OF OPERATING DECK (R.L. 68·50) INCLUDING THE PULL DOWN ACCESS LADDER FROM THE CRANE PLATFORM SHALL BE DESIGNED AND SUPPLIED BY THE CRANE MANUFACTURER AS PART OF THIS CONTRACT.

HK	DETAILS OF AMENDMENTS	APPROVED	DATE

ALL LEVELS ARE IN METRES
ALL OTHER DIMENSIONS ARE IN MILLIMETRES
UNLESS STATED OTHERWISE

T.A. CROWLEY & ASSOCIATES PTY. LTD.
CONSULTING ENGINEERS
10 HELP STREET CHATSWOOD 2067
TELEPHONE 4113933

DRAWN	TRACED	CHECKED	APPROVED
		[signature]	[signature] 24/7/81

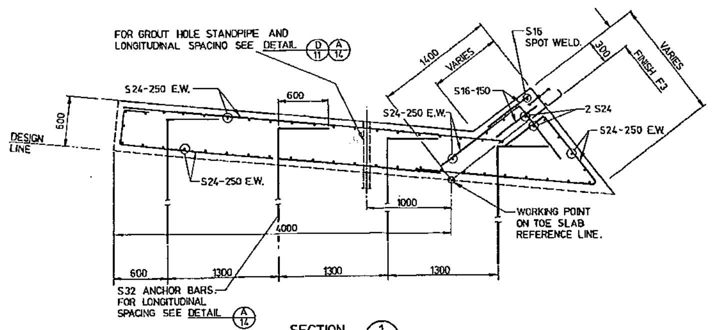
SCALE

PUBLIC WORKS DEPARTMENT N.S.W.
W.K. PILZ DIRECTOR OF PUBLIC WORKS
J.P. HESSNER CHIEF ENGINEER

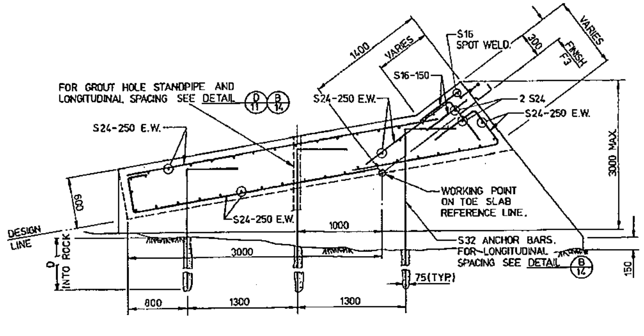
TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
OUTLET WORKS
3.2 TONNE S.W.L. CIRCULAR DOUBLE GIRDER BRIDGE CRANE-GEN. ARRG'T.

FILE WS 1172/108
DRAWING 80242-2

80065-11



SECTION 1 TYPICAL
SCALE 1:25
NORMAL TO REF. LINE



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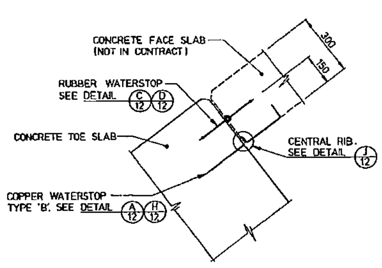
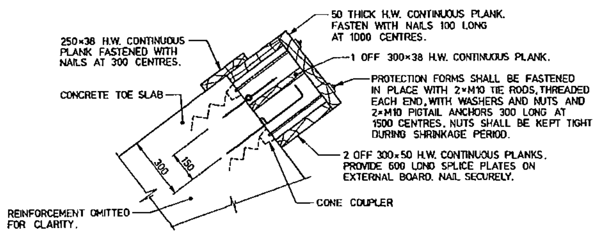
SCALE 1:25
NORMAL TO REF. LINE



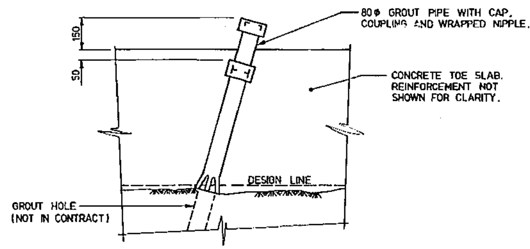
WATERSTOP INSTALLATION AT PERIMETRIC JOINT.

DETAIL B/11
SCALE 1:10



WATERSTOP PROTECTION AT PERIMETRIC JOINT.

DETAIL C/11
SCALE 1:10

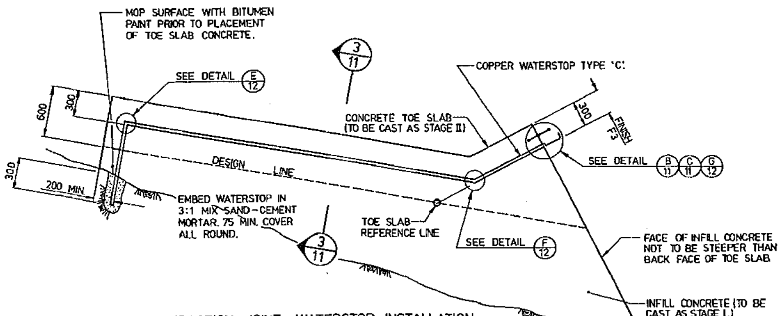


GROUT HOLE STANDPIPE

DETAIL D/11
N.T.S.

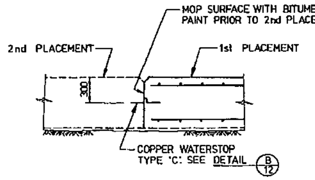
NOTES:

1. CONCRETE SHALL BE GRADE 25 WITH 40 MAX. AGGREGATE SIZE.
2. CLEAR CONCRETE COVER TO REINFORCEMENT SHALL BE 75 UNLESS NOTED OTHERWISE.
3. MINIMUM CLEAR DISTANCE BETWEEN REINFORCEMENT AND WATERSTOPS SHALL BE 50 UNLESS NOTED OTHERWISE.
4. ALL EXPOSED EXTERNAL EDGING (INCLUDING VERTICAL AND PERIMETRIC JOINTS) TO BE CHAMFERED 20×20.
5. CONCRETE FINISH F2 UNLESS NOTED OTHERWISE.
6. THE LOCATION AND ORIENTATION OF ANCHOR BARS SHALL BE AS SHOWN OR AS DIRECTED.
7. THE LOCATION AND INCLINATION OF GROUT HOLE STANDPIPES SHALL BE AS SHOWN OR AS DIRECTED.
8. GROUT HOLE STANDPIPES SHALL BE LOCATED 300 MIN. CLEAR OF ANY CONTRACTION JOINT.
9. ANCHOR BAR DEPTH, 'D', = 5000 BETWEEN REFERENCE POINTS 'A' AND 'H', AND 3000 ELSEWHERE.



CONTRACTION JOINT WATERSTOP INSTALLATION

DETAIL A TYPICAL
SCALE 1:25



CONTRACTION JOINT

SECTION 3/11
SCALE 1:25

1:10 — 0 200 400 600 800 1000 mm
1:25 — 500 0 500 1000 1500 2000 2500 mm

MK	DETAILS OF AMENDMENTS	APPROVED	DATE

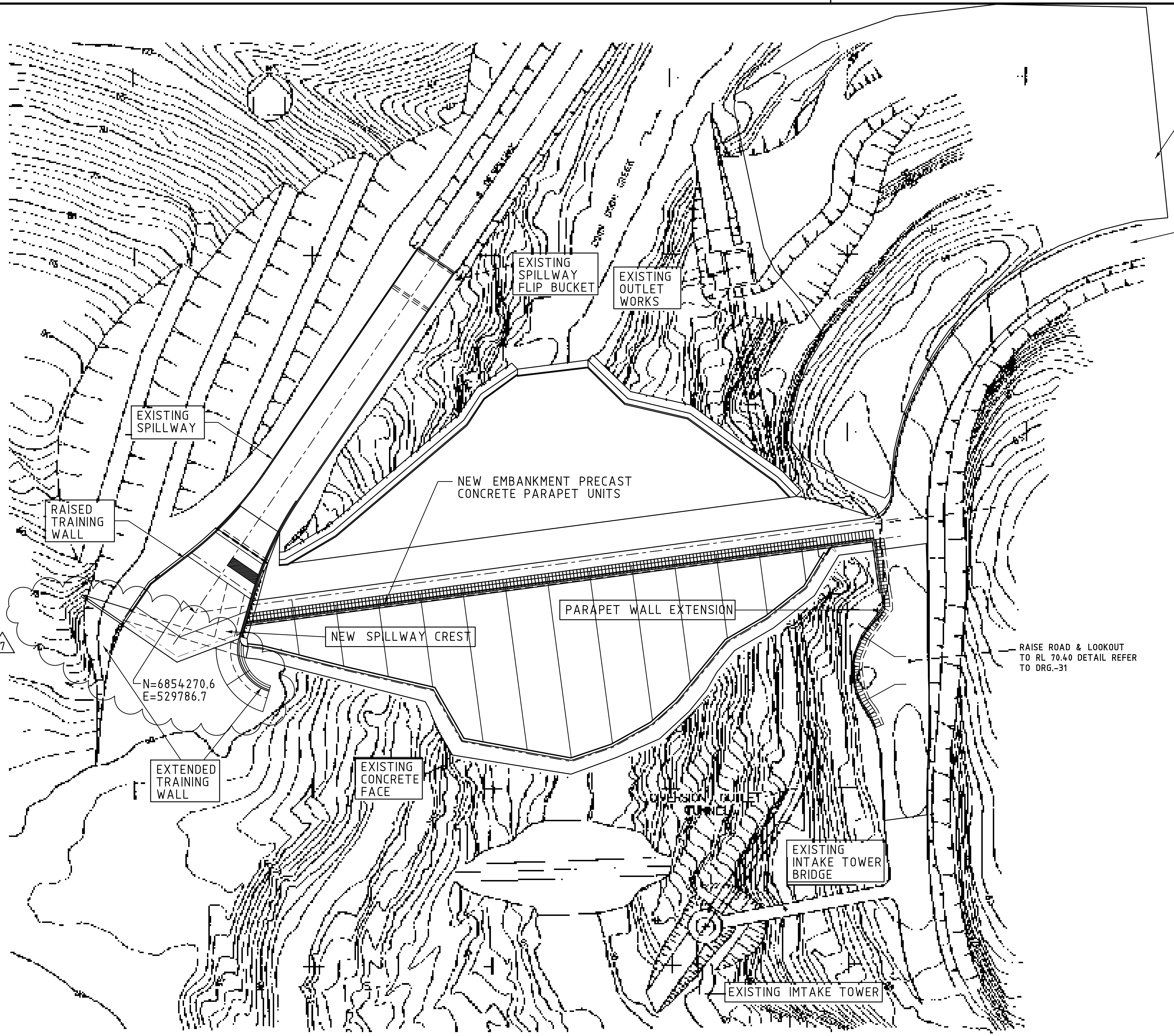
ALL LEVELS ARE IN METRES. ALL OTHER DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE

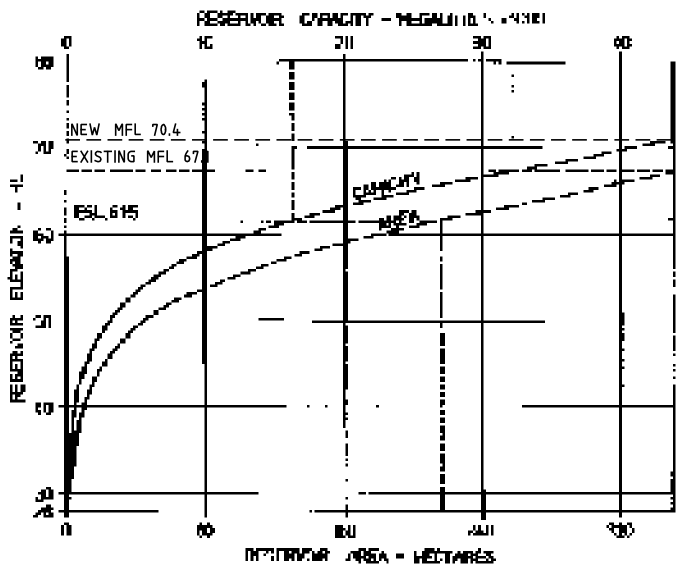
DESIGNED — INSPECTING ENGINEER
DRAWN — PRINCIPAL ENGINEER WATER SUPPLY
CHECKED — PRINCIPAL ENGINEER DESIGN

PUBLIC WORKS DEPARTMENT N.S.W.
W. K. PILZ — DIRECTOR OF PUBLIC WORKS
J. P. MESSNER — CHIEF ENGINEER
TWEED SHIRE COUNCIL

TWEED DISTRICT W.S. AUG.
CLARRIE HALL DAM
CONCRETE TOE SLAB
TYPICAL SECTIONS AND DETAILS.

FILE WS 1172/108
DRAWING 80065-11





AREA - CAPACITY CURVES

NOTES

1. CONTOURS INDICATED ARE COMPILED FROM AERIAL PHOTOGRAPHY MARCH 1981.
2. LEVELS ARE TO AUSTRALIAN HEIGHT DATUM.

1:500 — 10 0 10 20 30 40 50 m

MK	DETAILS OF AMENDMENTS	APPROVED	DATE
A	ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013

MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services

NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, McKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

THE ORIGINAL OF THIS DRAWING WAS SIGNED BY THE PERSONS WHOSE NAMES APPEAR IN THE ADJACENT BLOCK

Y. Bosson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

PLAN RM NO

DESIGNED	S. P. ENGINEER
G.SAMIOS	G.SAMIOS
DRAFTED	A/P. E. DAMS AND CIVIL
C.PANG	D. JAMIESON
CHECKED	
G.SAMIOS	

NSW GOVERNMENT Public Works
NSW Water Solutions

CLARRIE HALL DAM
SPILLWAY FLOOD SAFETY UPGRADE

DAM SITE GENERAL ARRANGEMENT

NO IN SET
CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-01
REVISION A

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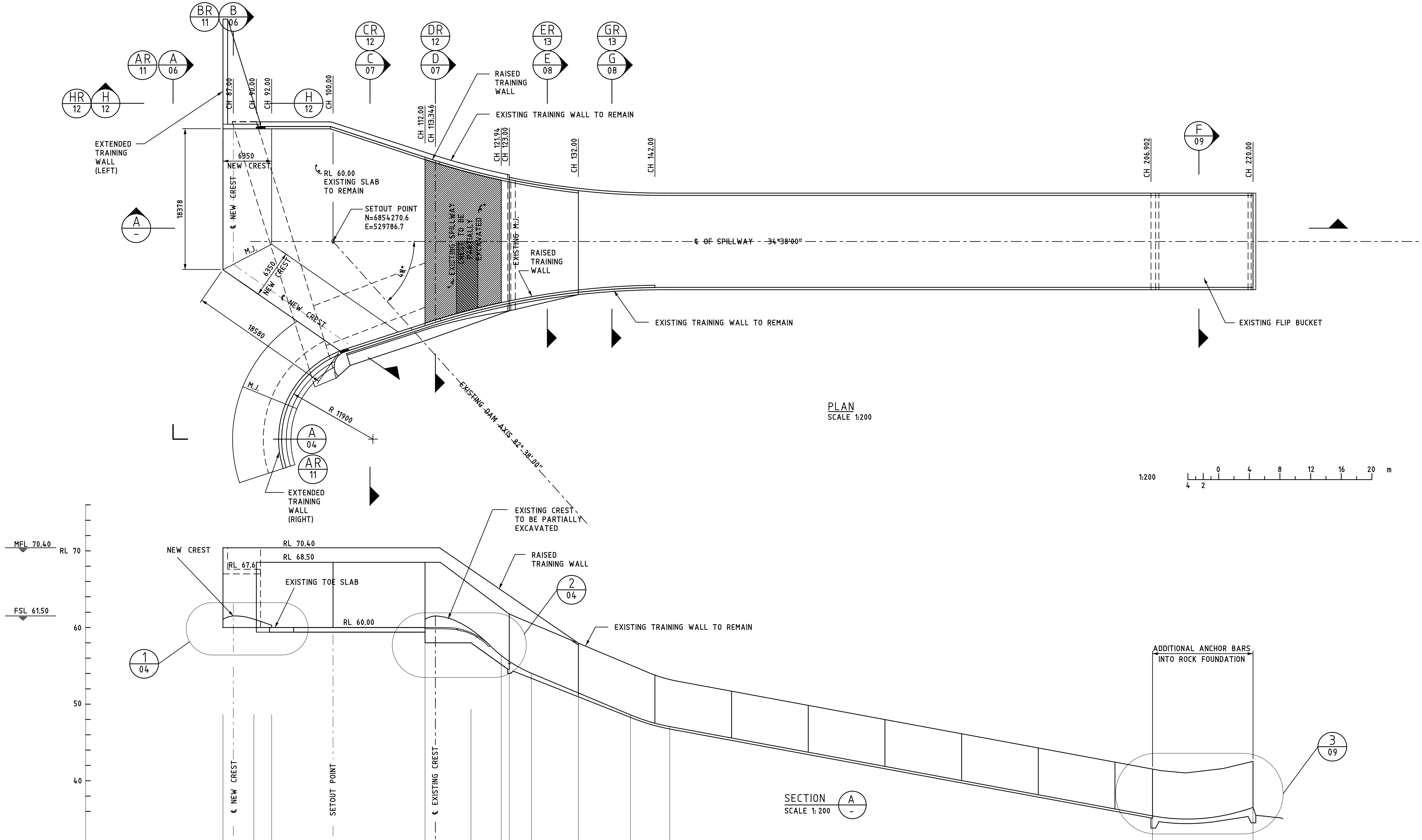
CLHALL_P_001.dgn 13/11/2013 10:45:30 AM



NEW TOP OF CONCRETE FLOOR R.L.	61.07	61.5	61.09 T.P.	60.30		60.0 T.P.		58.68	56.356 T.P.						35.422	36.513
SPILLWAY CHAINAGE	85.65	87.00	89.679	92.00	100.00	112.0	113.346	118.0	121.94	123	125.882 T.P.	132	138.796 T.P.	143.929 T.P.	206.902	220.0
EXIST TOP OF CONCRETE FLOOR R.L.	60.00	60.00	60.00	60.00	60.00	61.07	61.50	59.74	56.356	55.582	54.029	51.46	48.606	47.072	35.422	36.513

MK	DETAILS OF AMENDMENTS	APPROVED	DATE
A	ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013

MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services

NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, McKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

THE ORIGINAL OF THIS DRAWING WAS SIGNED BY THE PERSONS WHOSE NAMES APPEAR IN THE ADJACENT BLOCK

Y. Bosson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

PLAN RM NO

DESIGNED: G.SAMIOS — S.P. ENGINEER: G.SAMIOS
DRAFTED: F.PANG — A/P.E. DAMS AND CIVIL: D. JAMIESON
CHECKED: G.SAMIOS

NSW Public Works
NSW Water Solutions

CLARRIE HALL DAM
SPILLWAY FLOOD SAFETY UPGRADE

SPILLWAY
GENERAL ARRANGEMENT

NO IN SET
CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-02
REVISION A

0 100 200 300

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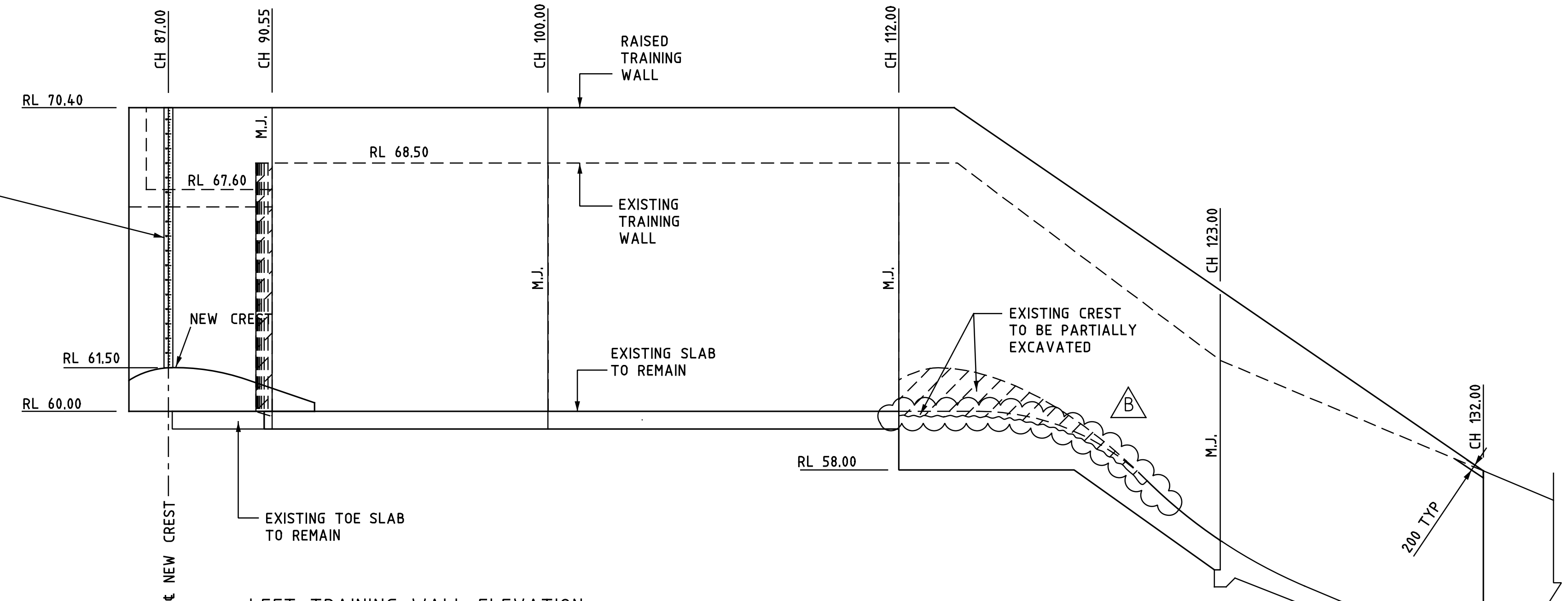
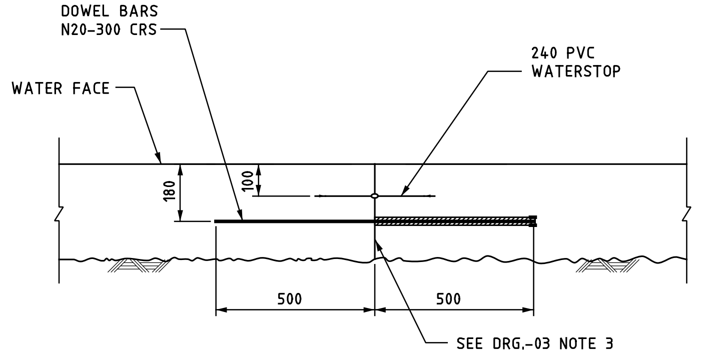
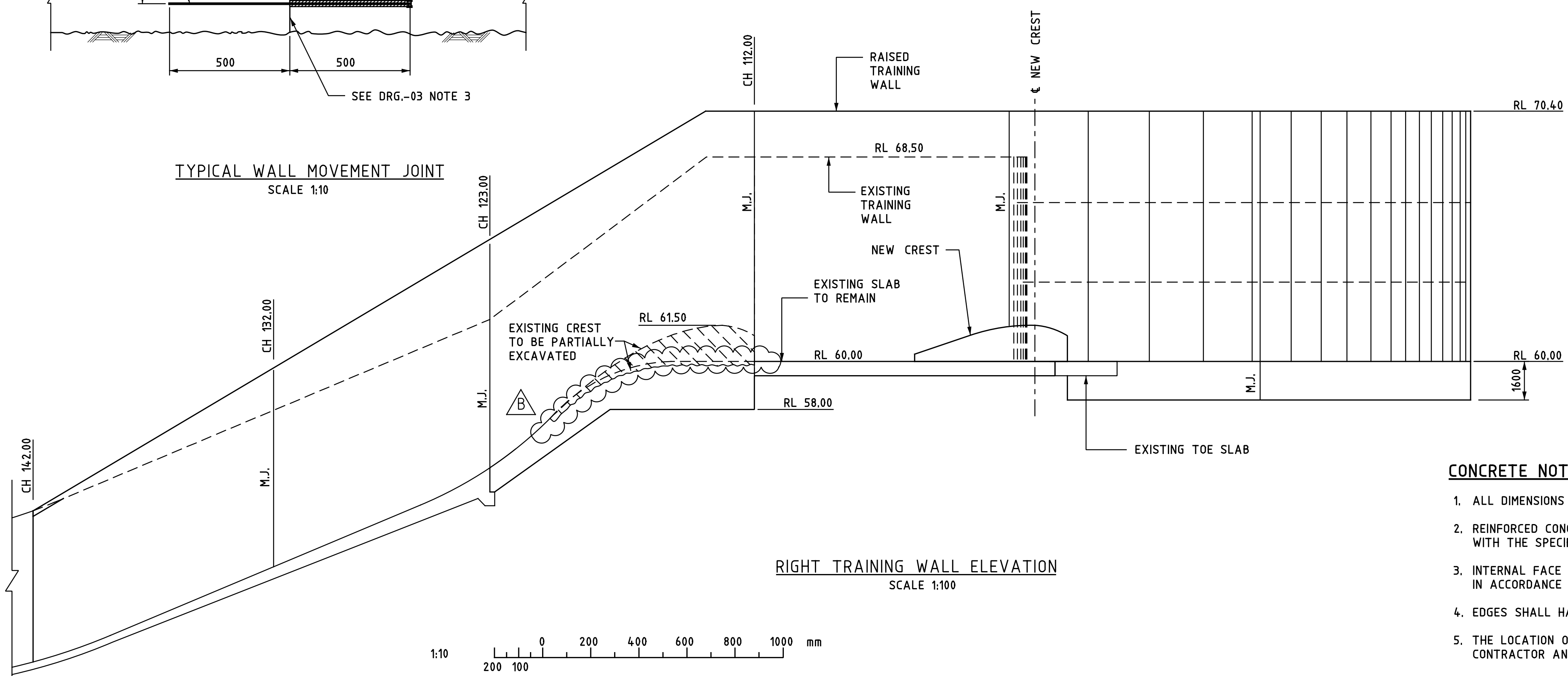


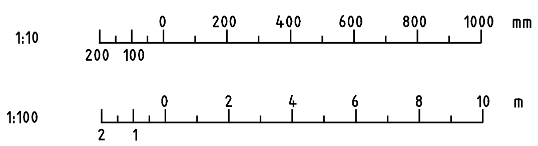
LEFT TRAINING WALL ELEVATION
SCALE 1:100

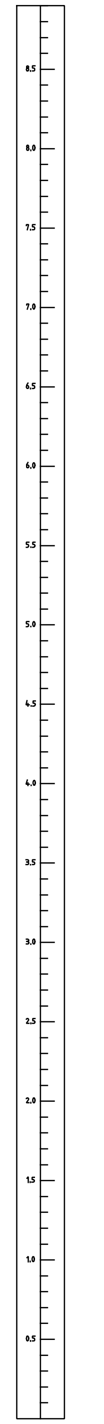


TYPICAL WALL MOVEMENT JOINT
SCALE 1:10



RIGHT TRAINING WALL ELEVATION
SCALE 1:100





DETAIL 1 -
SCALE NTS

CONCRETE NOTES

1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. REINFORCED CONCRETE GRADES SHALL BE S40 (F'c =40MPa) IN ACCORDANCE WITH THE SPECIFICATION.
3. INTERNAL FACE SPILLWAY CREST AND FLOOR SLAB SHALL HAVE F3 FINISH IN ACCORDANCE WITH THE SPECIFICATION.
4. EDGES SHALL HAVE 20mm CHAMFERS UNLESS OTHERWISE NOTED.
5. THE LOCATION OF ANY CONSTRUCTION JOINTS SHALL BE DETERMINED BY THE CONTRACTOR AND SHALL BE SATISFACTORY TO THE PRINCIPAL.
6. FOR ALL CONCRETE POURED ON THE GROUND, PROVIDE 50mm OF N20 BLINDING CONCRETE (F'c=20MPa) IN ACCORDANCE WITH THE SPECIFICATION.
7. ANCHOR BARS SHALL NOT BE LOCATED WITHIN 500mm OF A MOVEMENT JOINT OR CONSTRUCTION JOINT.

MK	DETAILS OF AMENDMENTS	APPROVED	DATE
B	AMENDED EXISTING CREST EXCAVATION PROFILE.	G.S.	12.06.2013
A	ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013

MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services
NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, McKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

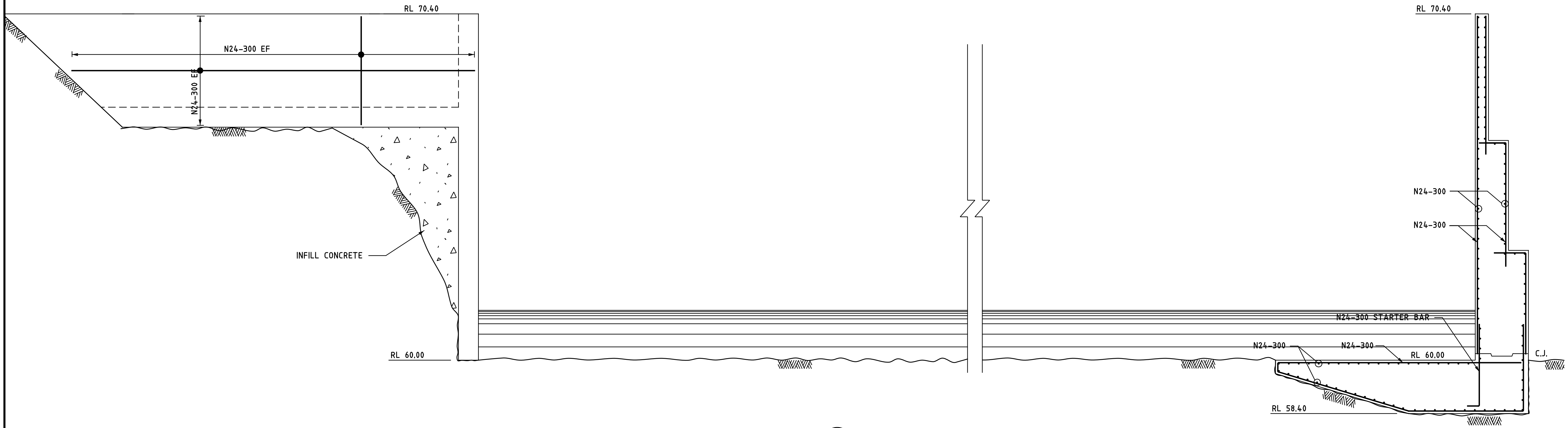
THE ORIGINAL OF THIS DRAWING WAS SIGNED BY THE PERSONS WHOSE NAMES APPEAR IN THE ADJACENT BLOCK
Y. Bosson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

PLAN RM NO	
DESIGNED G.SAMIOS	S.P. ENGINEER G.SAMIOS
DRAFTED F.PANG	A/P.E. DAMS AND CIVIL D. JAMIESON
CHECKED G.SAMIOS	

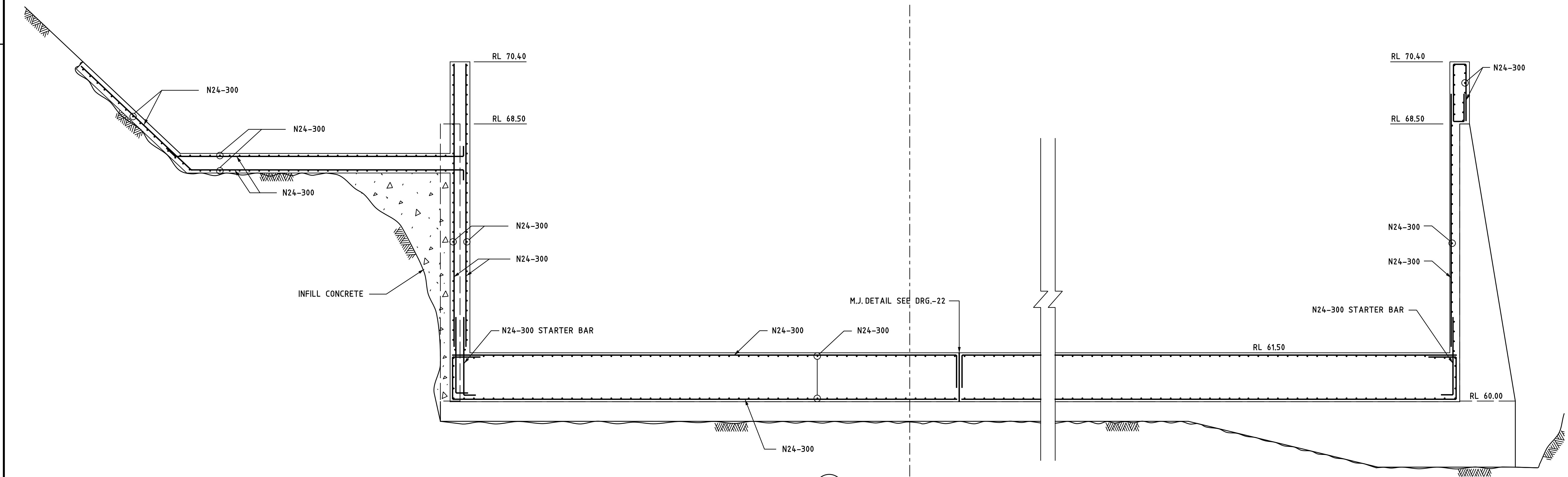
NSW Public Works
NSW Water Solutions

CLARRIE HALL DAM
SPILLWAY FLOOD SAFETY UPGRADE
CONCRETE TRAINING WALL ELEVATION

NO IN SET
CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-05
REVISION B



SECTION AR 02
SCALE 1:50



SECTION BR 02
SCALE 1:50

CH 87.00
(TYPICAL ACROSS SPILLWAY CREST CH 87.00 - CH 92.00)

NOTES

FOR REINFORCEMENT NOTES SEE DRG.-12.

1:50 0 1 2 3 4 5 m

MK	DETAILS OF AMENDMENTS	APPROVED	DATE
A	ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013

MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services

NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, McKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

THE ORIGINAL OF THIS DRAWING WAS SIGNED BY THE PERSONS WHOSE NAMES APPEAR IN THE ADJACENT BLOCK

Y. Bosson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

PLAN RM NO

DESIGNED	S.P. ENGINEER
G.SAMIOS	G.SAMIOS
DRAFTED	A/P.E. DAMS AND CIVIL
C.PANG	D. JAMIESON
CHECKED	
G.SAMIOS	

Public Works
NSW Water Solutions

CLARRIE HALL DAM
SPILLWAY FLOOD SAFETY UPGRADE

SPILLWAY REINFORCEMENT
Sheet 1 of 4

NO IN SET
CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-11
REVISION A

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13/11/2013

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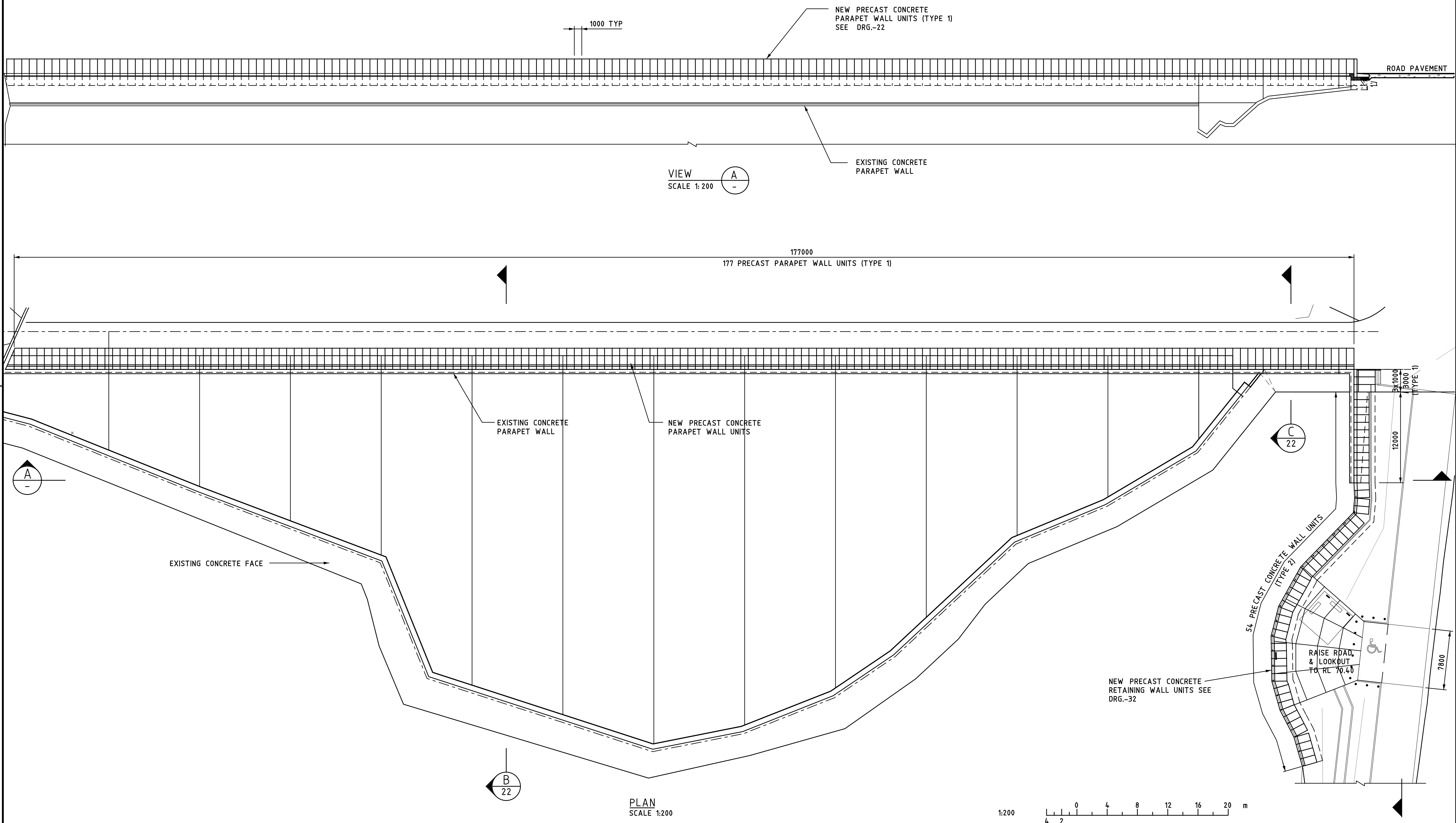


MK	DETAILS OF AMENDMENTS	APPROVED	DATE
A	ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013

MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services

NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, McKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

THE ORIGINAL OF THIS DRAWING WAS SIGNED BY THE PERSONS WHOSE NAMES APPEAR IN THE ADJACENT BLOCK

Y. Bosson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

PLAN RM NO

DESIGNED	S.P. ENGINEER
G.SAMIOS	G.SAMIOS
DRAFTED	A/P.E. DAMS AND CIVIL
C.PANG	D. JAMIESON
CHECKED	
G.SAMIOS	

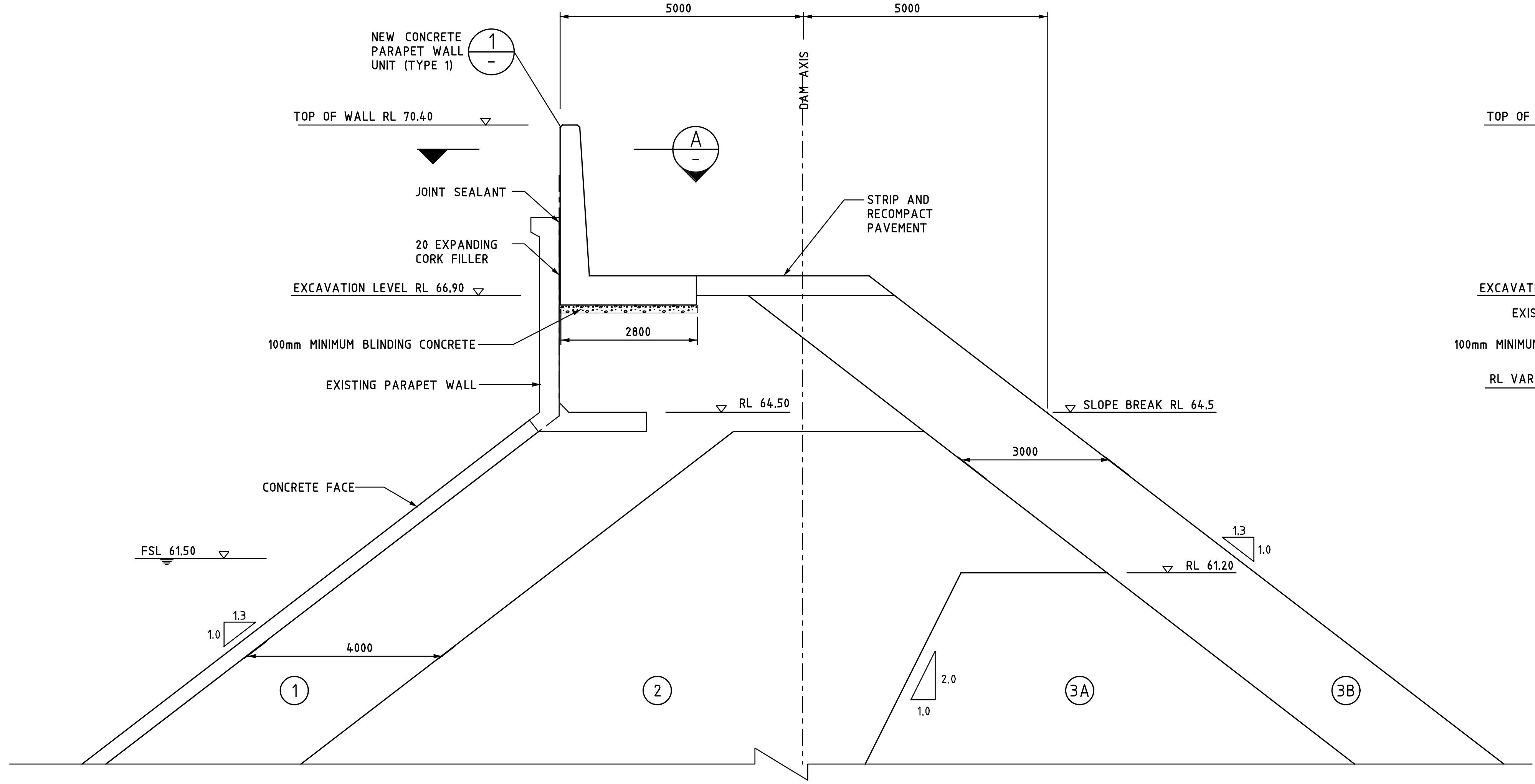
NSW GOVERNMENT Public Works NSW Water Solutions

CLARRIE HALL DAM SPILLWAY FLOOD SAFETY UPGRADE

EMBANKMENT PLAN SHOWING NEW PARAPET WALL UNITS

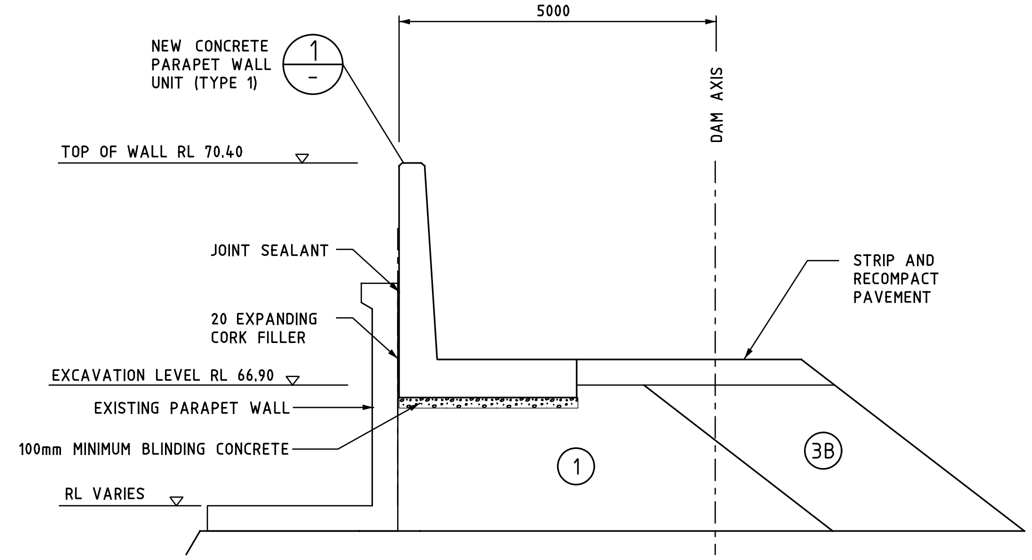
NO IN SET
CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-21
REVISION A

10:39:20 AM G:\Pcad\CLARRIE HALL SPILLWAY UPGRADE\DETAIL DESIGN 2012\CLHALL_P_021.dgn 13/11/2013



SECTION B
SCALE 1:50 21

TYPICAL EMBANKMENT SECTION

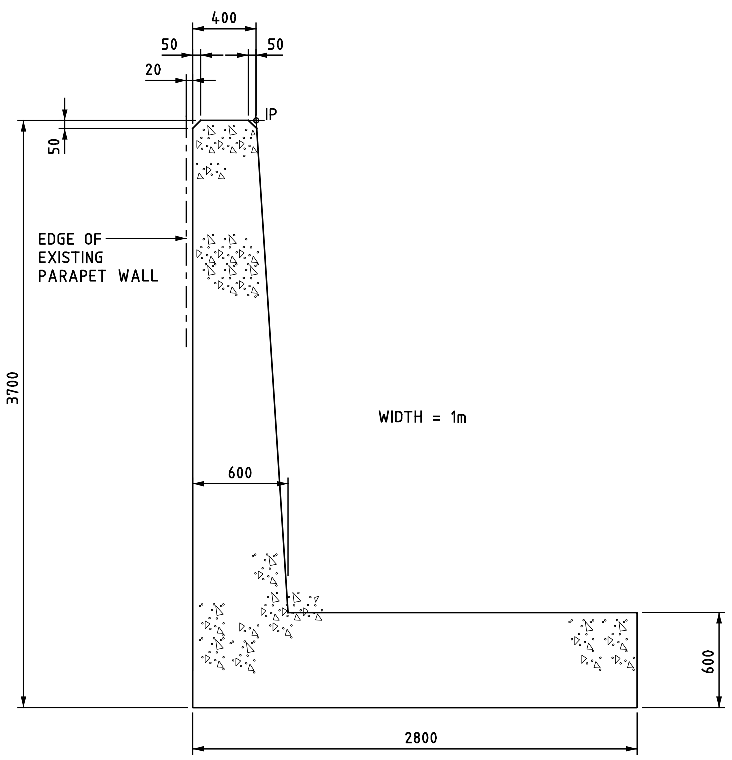


EMBANKMENT RIGHT ABUTMENT SECTION

SECTION C
SCALE 1:50 21

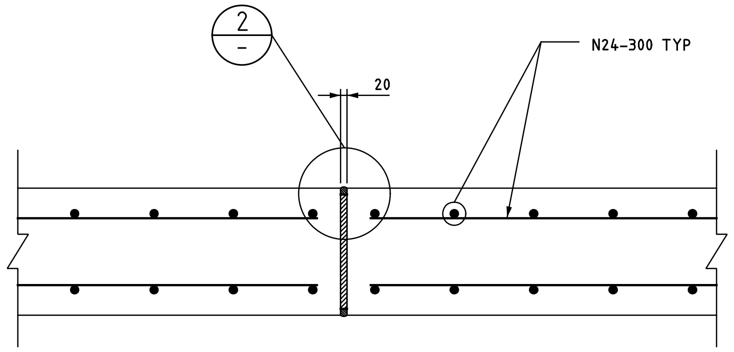
LEGEND

	FUNCTION	DESCRIPTION
1	SEMI-PERMEABLE ZONE	MODERATELY WEATHERED RHYOLITE
2	PERMEABLE INTERMEDIATE ZONE	SLIGHTLY WEATHERED TO MODERATELY WEATHERED RHYOLITE
3A	FRESH ROCK ZONE	FRESH RHYOLITE
3B	MESH ZONE AND FACE ZONE	SELECTED FRESH RHYOLITE



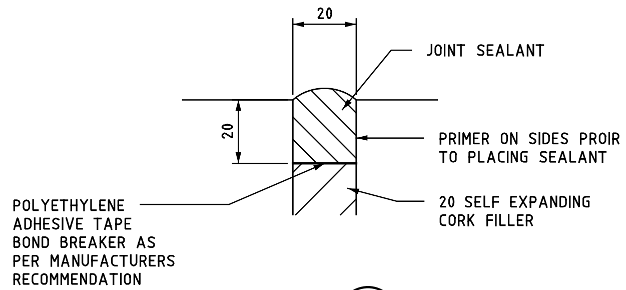
PARAPET WALL UNIT (TYPE 1)

DETAIL 1
SCALE 1:20

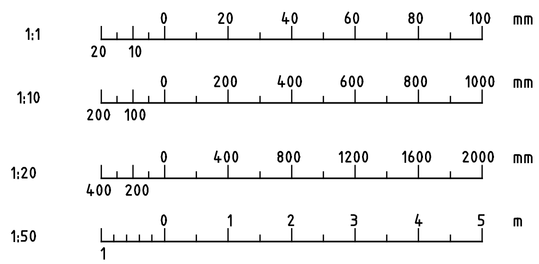


TYPICAL JOINT BETWEEN UNITS

SECTION A
SCALE 1:10



DETAIL 2
SCALE 1:1



MK	DETAILS OF AMENDMENTS	APPROVED	DATE
A	ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013

MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services
NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
LEVEL 13, McKELL BUILDING
2-24 RAWSON PLACE
SYDNEY 2000
PHONE (02) 93727808

THE ORIGINAL OF THIS DRAWING WAS SIGNED BY THE PERSONS WHOSE NAMES APPEAR IN THE ADJACENT BLOCK

Y. Bosson
TECHNOLOGY CONTROLLER
WATER TECHNOLOGIES

PLAN RM NO
DESIGNED G.SAMIOS | S.P. ENGINEER G.SAMIOS
DRAFTED F.PANG | A/P. E. DAMS AND CIVIL D. JAMIESON
CHECKED G.SAMIOS

NSW Public Works
NSW Water Solutions

CLARRIE HALL DAM SPILLWAY FLOOD SAFETY UPGRADE

PARAPET WALL CROSS SECTIONS

NO IN SET
CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-22
REVISION A

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13/11/2013

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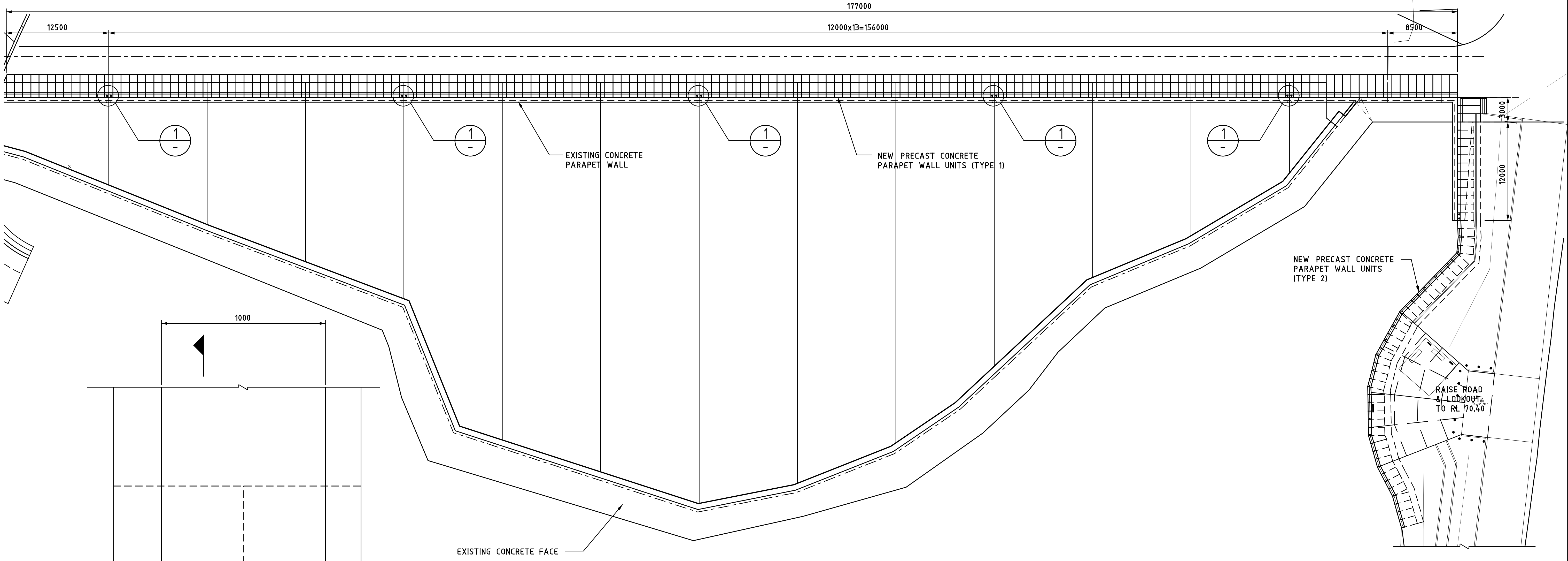
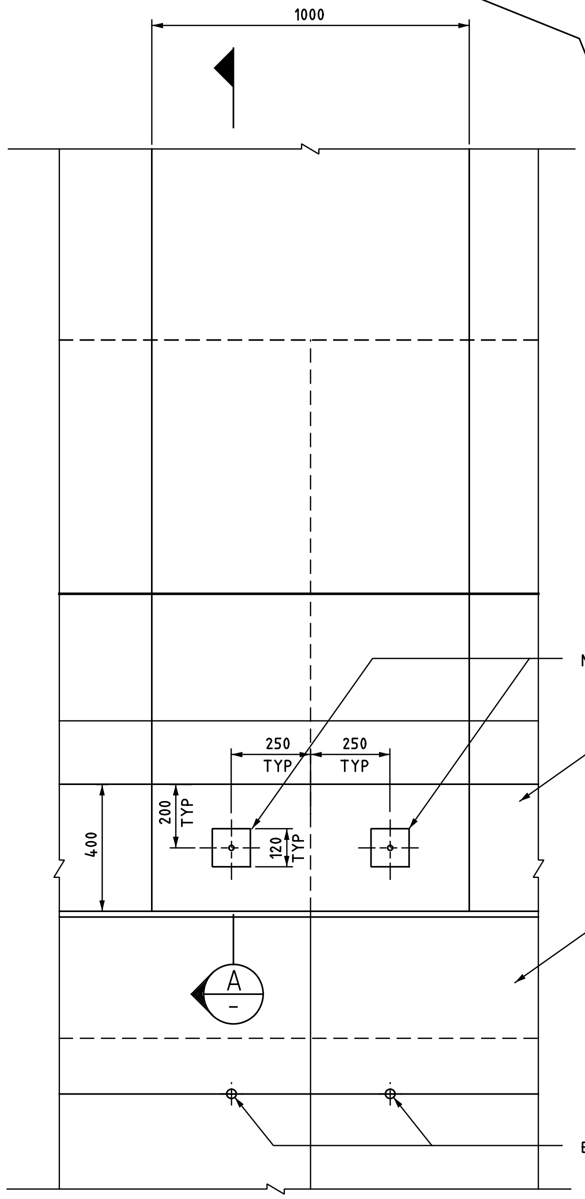
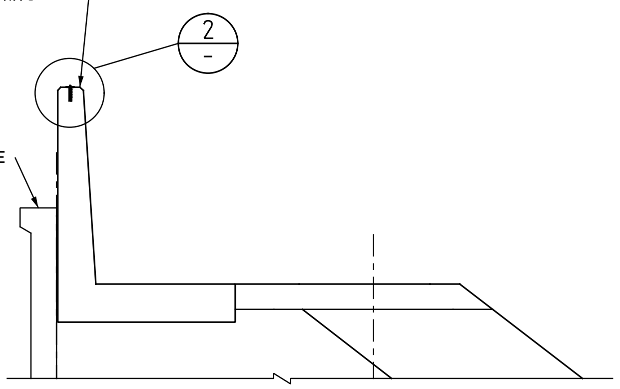


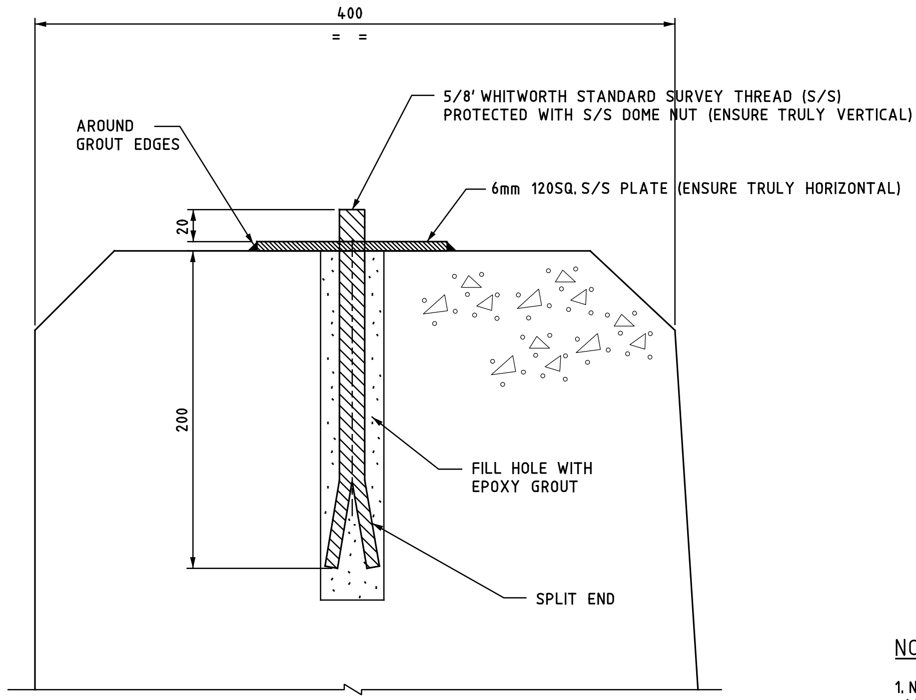
SURVEY MARKER LAYOUT
SCALE 1:200



DETAIL 1 – TYPICAL
SCALE 1: 10



SECTION A
SCALE 1: 20



DETAIL 2 – SURVEY MONITORING PIN
SCALE 1: 2

NOTE

1. NEW SURVEY MARKERS TO BE INSTALLED IN LINE WITH EXISTING MARKERS.

1:200 — 4 2 0 4 8 12 16 20 m

MK	DETAILS OF AMENDMENTS	APPROVED	DATE
A	ISSUED FOR CONSTRUCTION.	G.S.	05.03.2013

MICHAEL COUTTS-TROTTER - Director General
Department of Finance and Services
NSW WATER SOLUTIONS
DAMS AND CIVIL TECHNOLOGIES
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2-24 RAWSON PLACE
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TECHNOLOGY CONTROLLER
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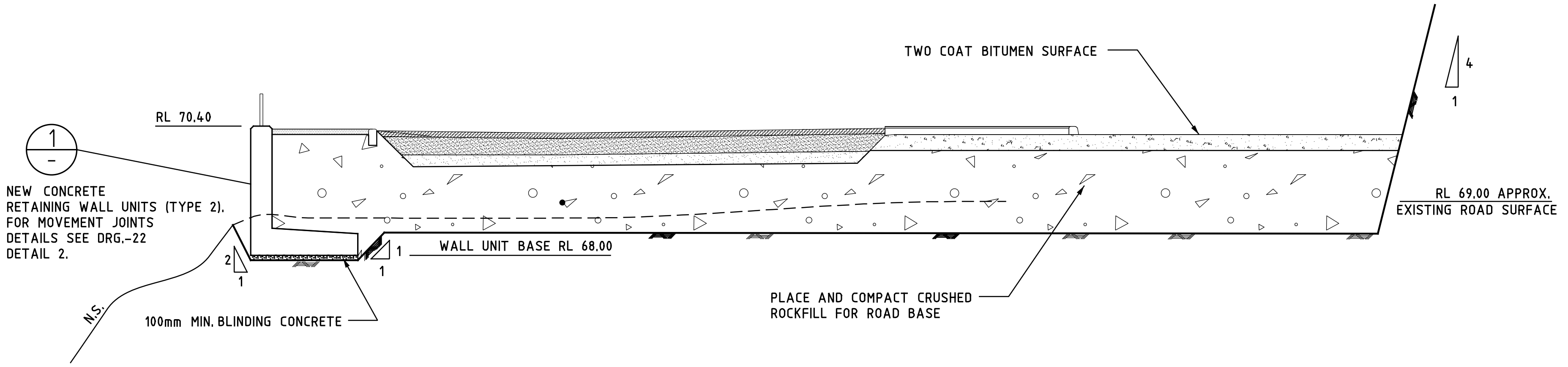
DESIGNED G.SAMIOS	S.P. ENGINEER G.SAMIOS
DRAFTED F.PANG	A/P.E. DAMS AND CIVIL D. JAMIESON
CHECKED G.SAMIOS	

Public Works
NSW Water Solutions

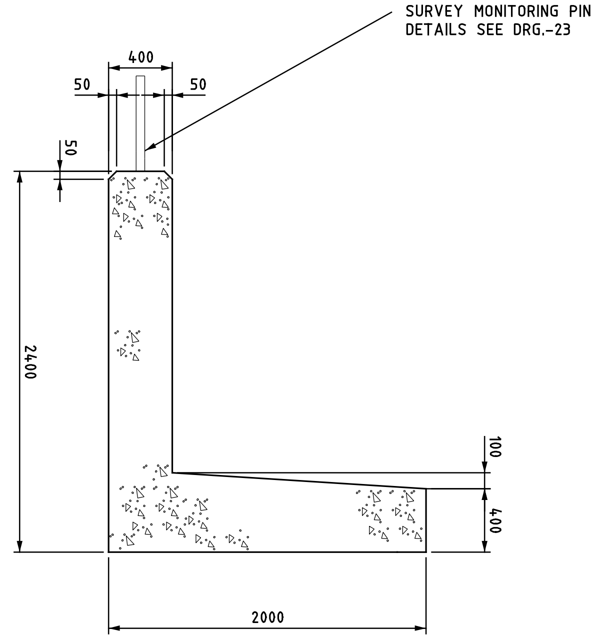
CLARRIE HALL DAM
SPILLWAY FLOOD SAFETY UPGRADE

SURVEY MARKER
LAYOUT AND DETAILS

NO IN SET
CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-23
REVISION A

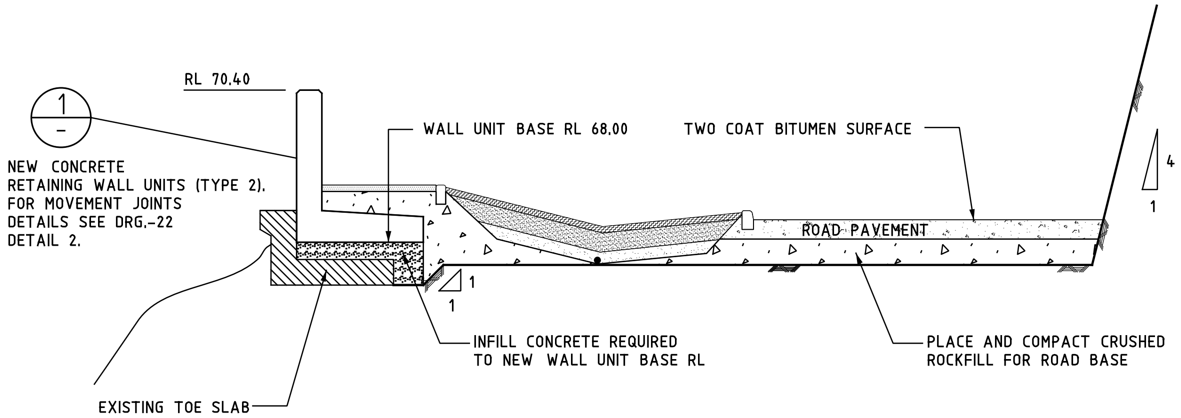


SECTION A
SCALE 1:50



RETAINING WALL UNIT (TYPE 2)

DETAIL 1
SCALE 1:20

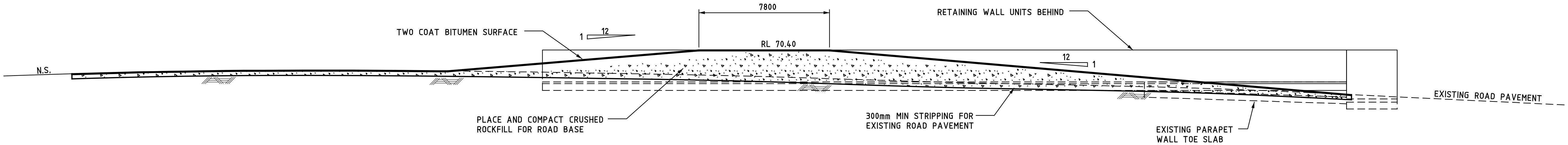


SECTION C
SCALE 1:50

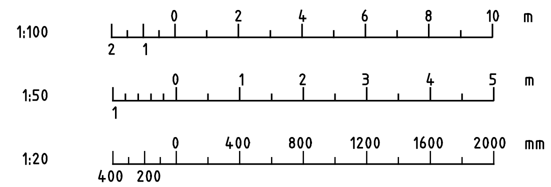
FOR ACTUAL ROAD WIDTH AND DETAILS OF LOOKOUT AND ASSOCIATED FURNISHINGS SEE LANDSCAPE DESIGN DRAWINGS.

NOTE:

1. FOR CONCRETE GENERAL NOTES, SEE DRAWING -05.
2. FOR REINFORCEMENT OF WALL UNITS, SEE DRAWING -14.
3. FOR SURVEY MARKER DETAILS REFER TO DRG.-23.



SECTION B
SCALE 1:100



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CHECKED G.SAMIOS	

Public Works
NSW Water Solutions

CLARRIE HALL DAM
SPILLWAY FLOOD SAFETY UPGRADE

RAISED ROAD & LOOKOUT SECTIONS

CONTRACT NO. EC2012-191
DRAWING NO. EC2012-191-32
REVISION A

APPENDIX B

PROPOSED RAISED DAM DRAWINGS

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CLARRIE HALL DAM
RAISING OPTIONS

EXISTING SITE PLAN

PROJECT/CONTRACT No. ?
A1 SCALE @ A1 1:1000
DRAWING No. FIGURE 1 REV 0

CONFIRM SCALE — 100mm ON A1 ORIGINAL

G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG01-ClarrieHall-exSITE.dgn zhangc2 4:06:33 PM 31/01/2018

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CLARRIE HALL DAM
RAISING OPTIONS
OPTION 1a
GENERAL ARRANGEMENT

PROJECT/CONTRACT No.	?
A1	SCALE @ A1 1:1000
DRAWING No. FIGURE 2	REV 0

CONFIRM SCALE — 100mm ON A1 ORIGINAL

G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG02-ClarrieHall-opt1a.dgn zhangc2 12:07:15 PM 1/06/2018

G:\Waterfec\Poad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG03-ClarrieHall-opt1b.dgn

14/03/2018 5:10:47 PM zhangc2

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CLARRIE HALL DAM
RAISING OPTIONS

OPTION 1b
GENERAL ARRANGEMENT

PROJECT/CONTRACT No. ?

A1 SCALE @ A1 1:1000

DRAWING No. FIGURE 3 REV 0

CONFIRM SCALE — 100mm ON A1 ORIGINAL

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CLARRIE HALL DAM
RAISING OPTIONS

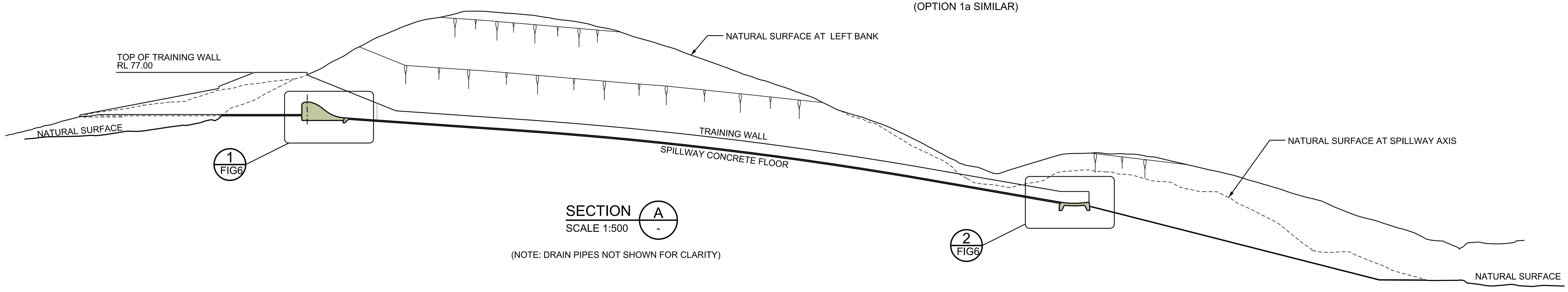
OPTION 2
GENERAL ARRANGEMENT

PROJECT/CONTRACT No.	?
A1	SCALE @ A1 1:1000
DRAWING No. FIGURE 4	REV 0

CONFIRM SCALE — 100mm ON A1 ORIGINAL

G:\WatertecPcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG04-ClarrieHall-opt2.dgn ZHANGC2 2:58:46 PM 15/03/2018

PLAN (OPTION 1b)
SCALE 1:500
(OPTION 1a SIMILAR)



SECTION A -
SCALE 1:500

(NOTE: DRAIN PIPES NOT SHOWN FOR CLARITY)

1:500 0 10000 20000 30000 40000 50000 mm
10000

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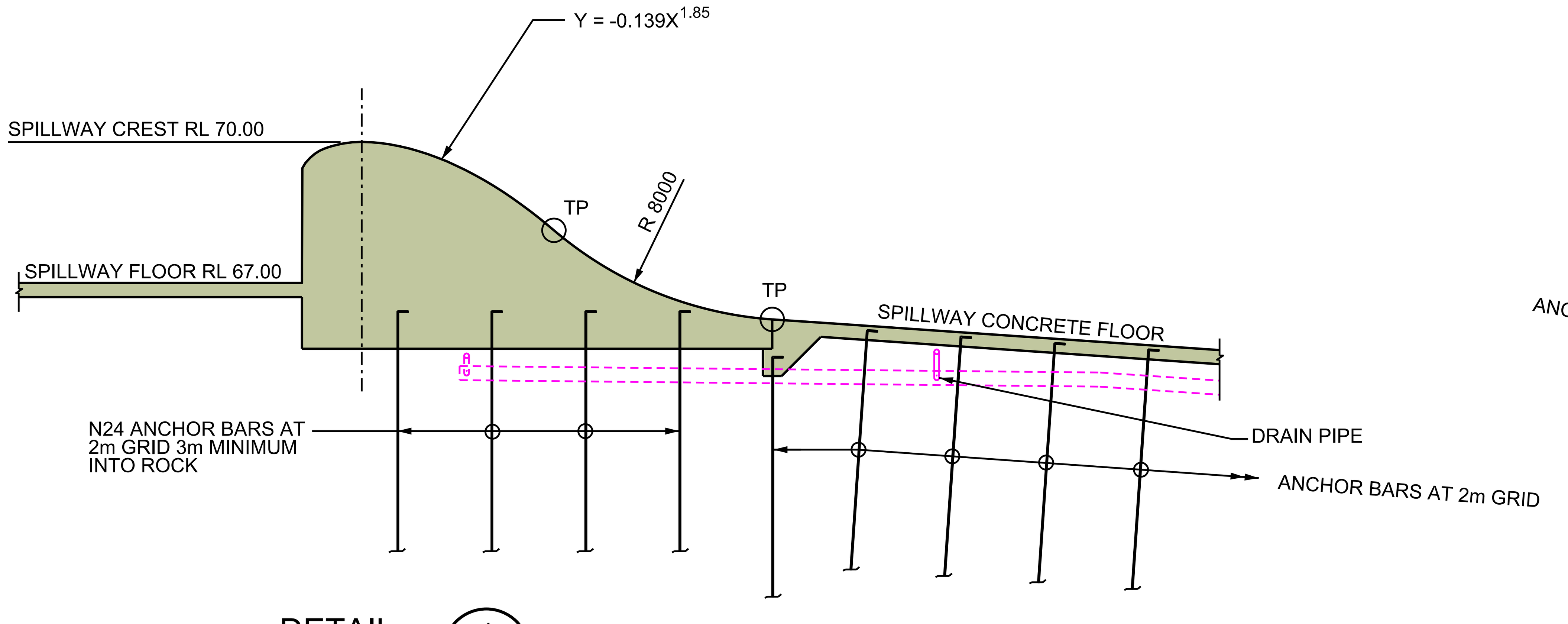
CLARRIE HALL DAM
RAISING OPTIONS

OPTION 1a/1b
SPILLWAY LAYOUT
AND LONG SECTION

PROJECT/CONTRACT No. ?
A1 SCALE @ A1 1:500
DRAWING No. FIGURE 5 REV 0

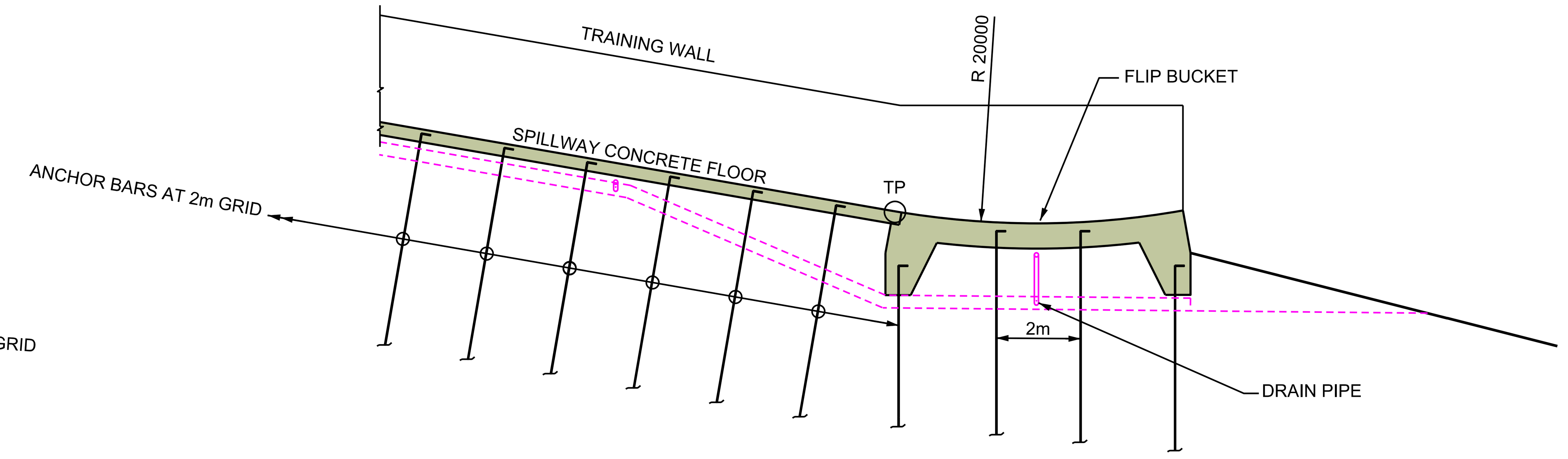
CONFIRM SCALE 100mm ON A1 ORIGINAL

G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG05-ClarrieHall-opt1b.dgn zhangc2 14/03/2018 4:40:58 PM

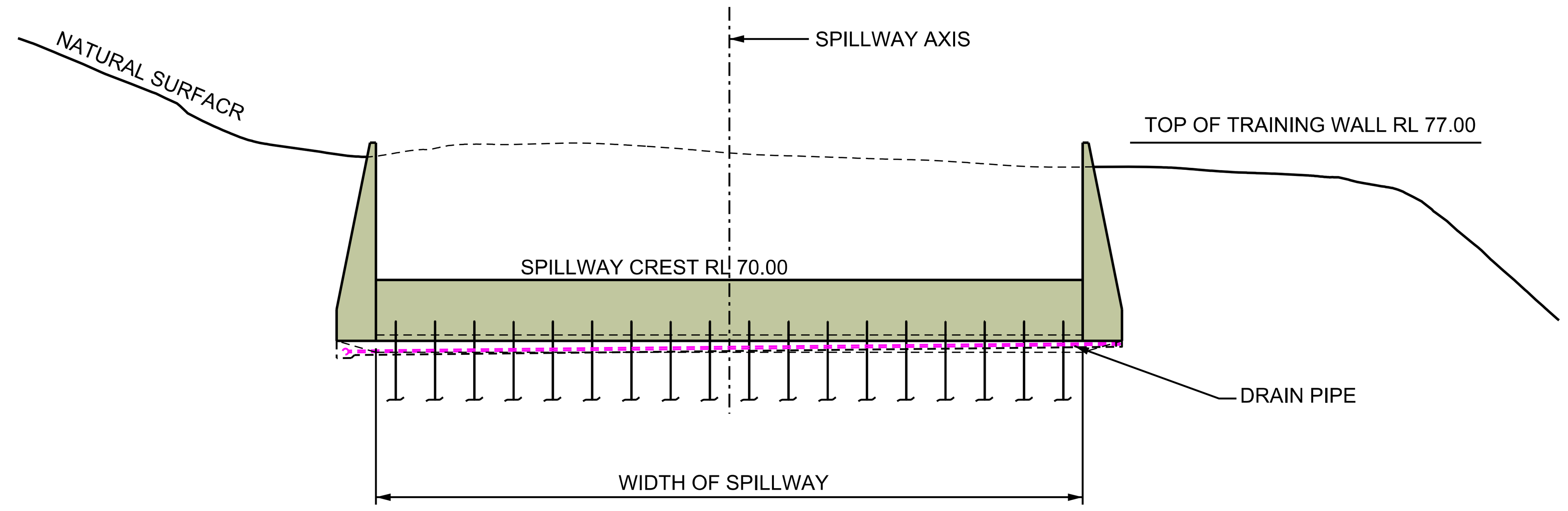


DETAIL 1 FIG5
SCALE 1:100

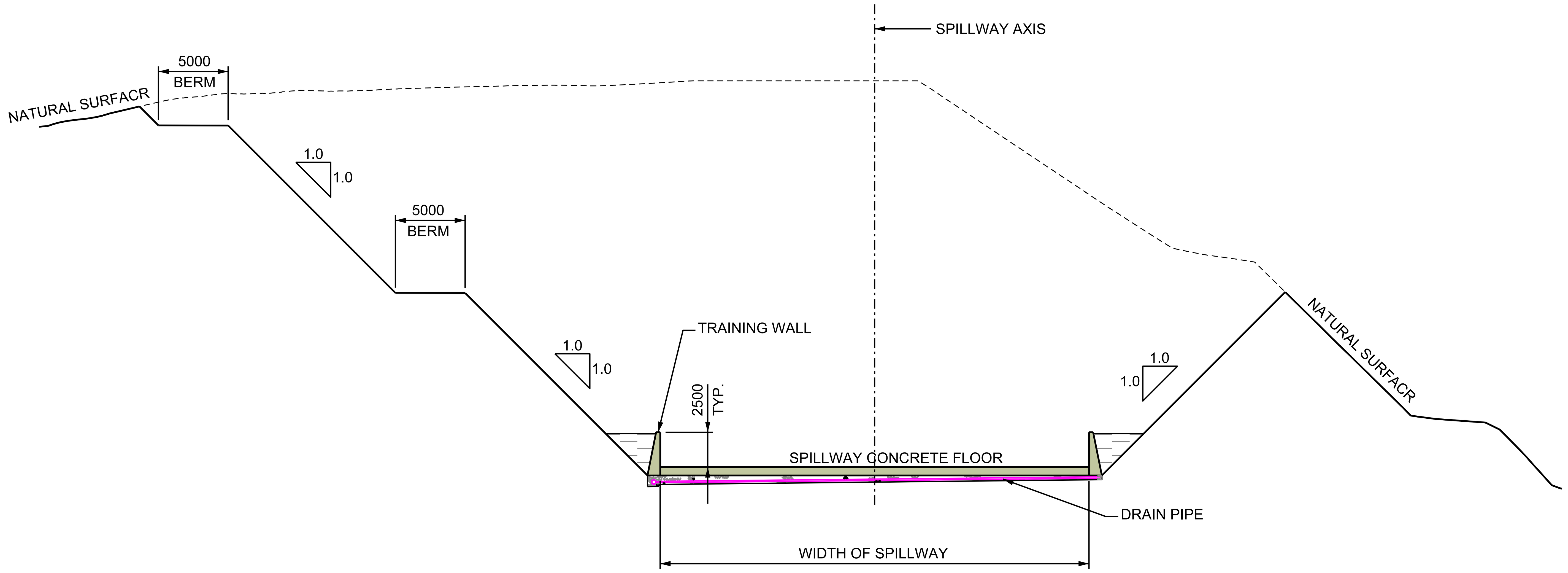
NOTE: TRAINING WALL NOT SHOWN FOR CLARITY



DETAIL 2 FIG5
SCALE 1:100

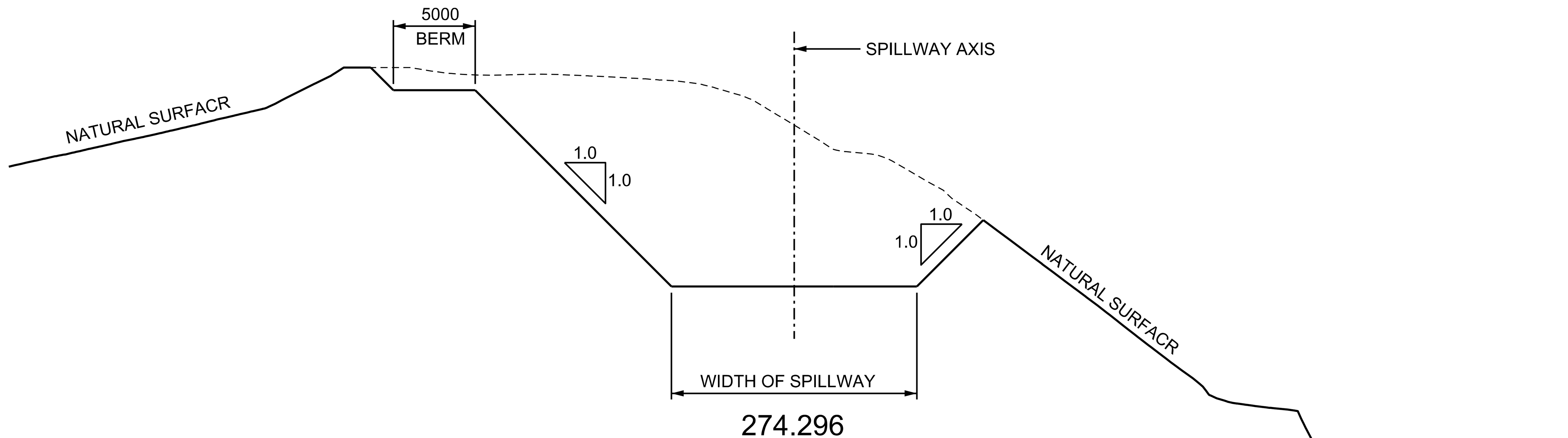


SECTION B FIG5
SCALE 1:250

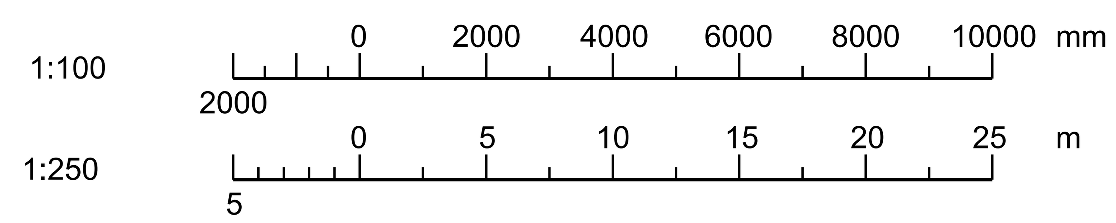


SECTION C FIG5
SCALE 1:250

ANCHOR BARS NOT SHOWN FOR CLARITY



SECTION D FIG5
SCALE 1:250



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CLARRIE HALL DAM
RAISING OPTIONS

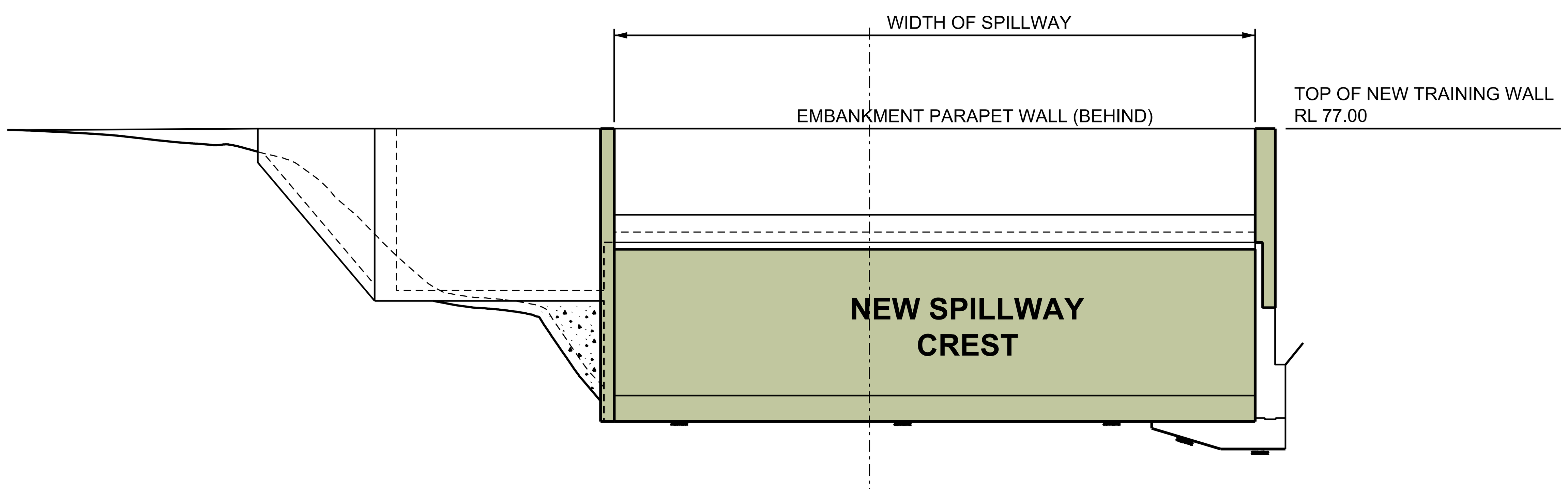
OPTION 1a/1b
SPILLWAY DETAILS
AND CROSS SECTIONS

PROJECT/CONTRACT No. ?
A1 | SCALE @ A1 1:100, 1:250
DRAWING No. FIGURE 6 | REV 0

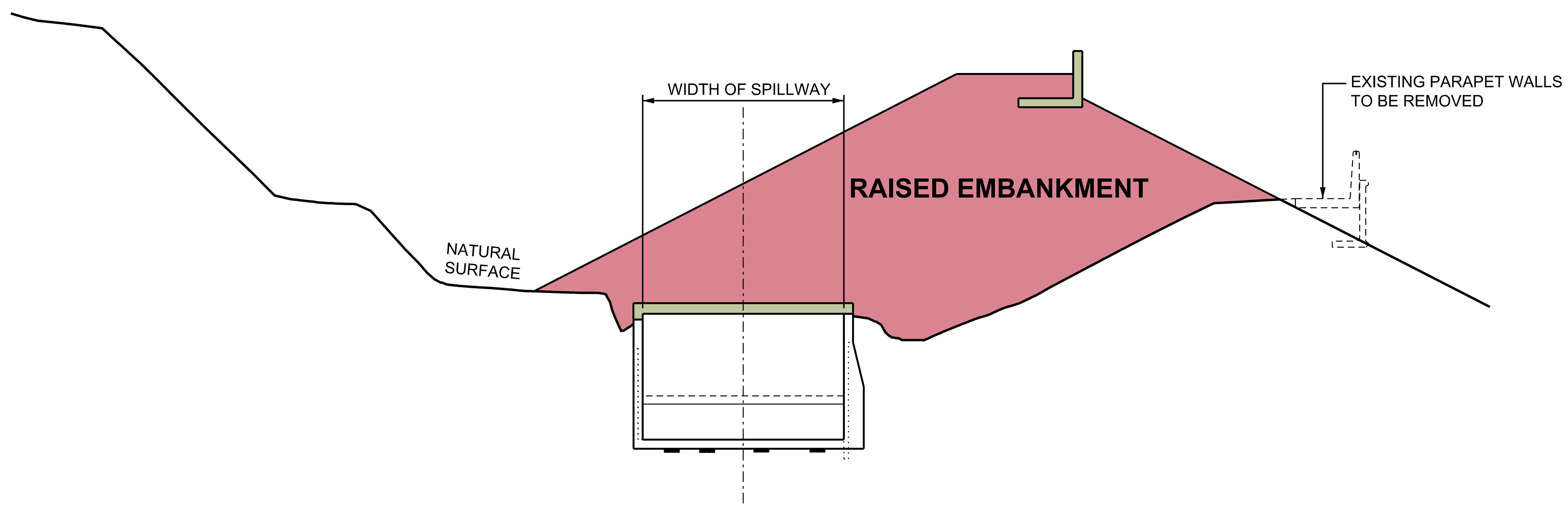
CONFIRM SCALE — 100mm ON A1 ORIGINAL

G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG06-ClarrieHall-opt1b.dgn zhangc2 11:41:38 AM 16/03/2018

PLAN
SCALE: 1:250



SECTION C
SCALE 1:250



SECTION D
SCALE 1:250

1:250 0 5 10 15 20 25 m

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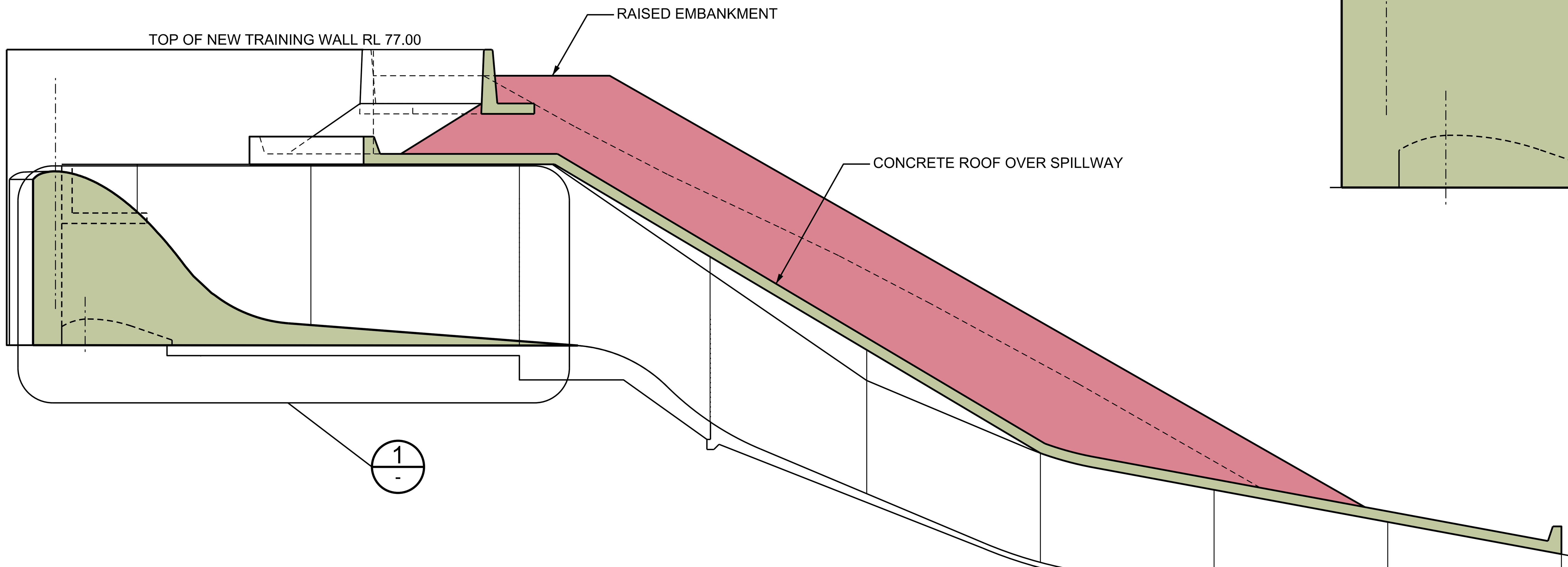
CLARRIE HALL DAM
RAISING OPTIONS

OPTION 2
SPILLWAY LAYOUT
AND TYPICAL CROSS SECTIONS

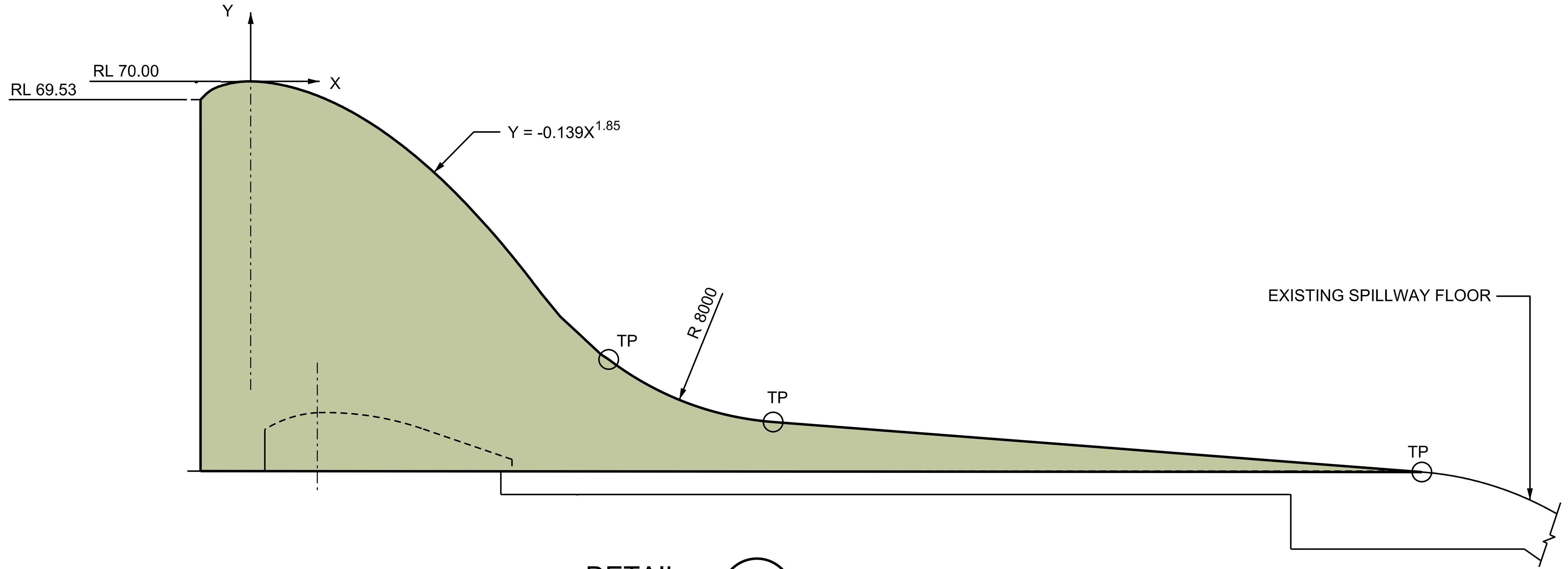
PROJECT/CONTRACT No. ?
A1 SCALE @ A1 1:250
DRAWING No. FIGURE 7
REV 0

CONFIRM SCALE — 100mm ON A1 ORIGINAL

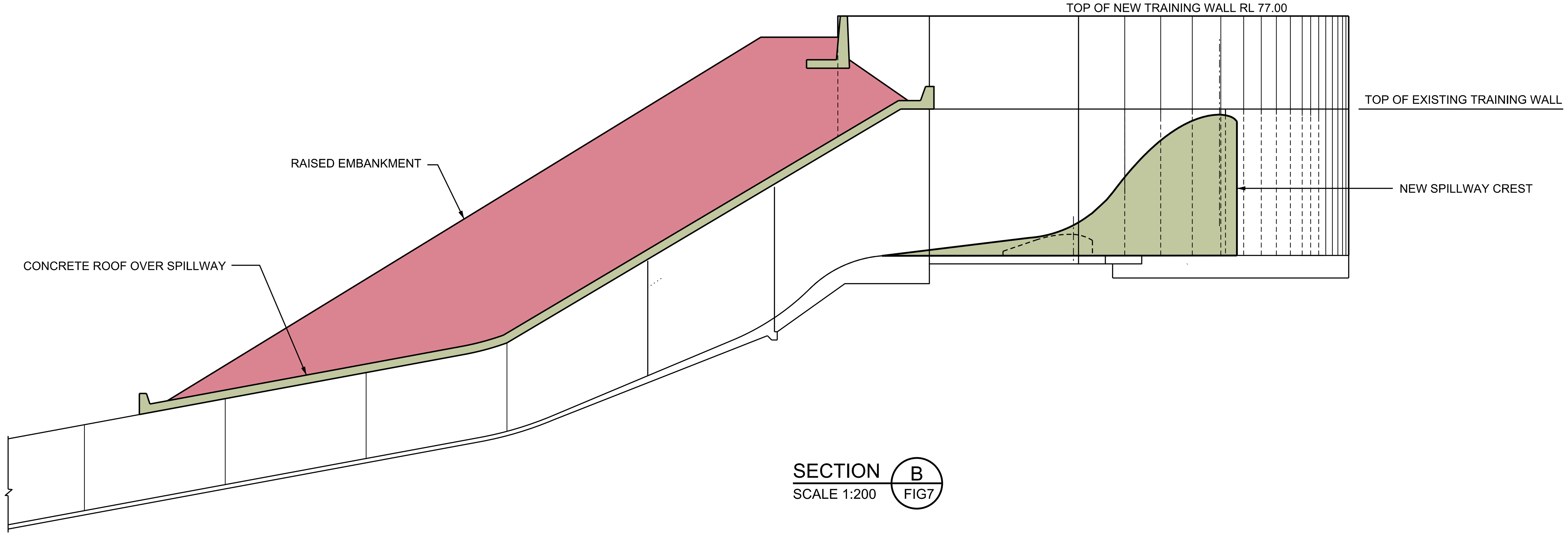
G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG07-ClarrieHall-opt2.dgn ZHANGC2 3:08:57 PM 15/03/2018



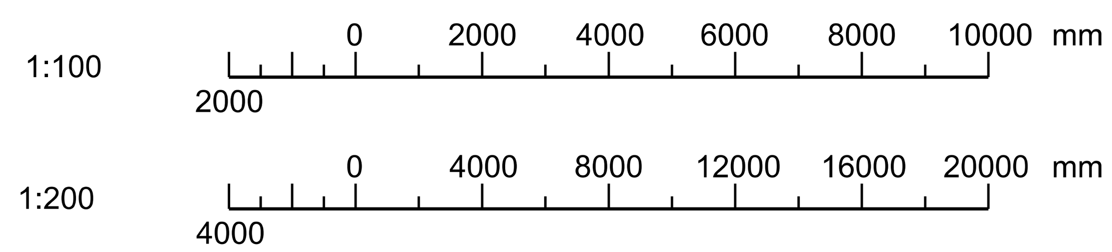
SECTION A
SCALE 1:200
FIG7



DETAIL 1
SCALE 1:100



SECTION B
SCALE 1:200
FIG7



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CLARRIE HALL DAM
RAISING OPTIONS

OPTION 2
SPILLWAY AND
TRAINING WALL LONG SECTIONS

PROJECT/CONTRACT No. ?
A1 SCALE @ A1 1:100, 1:200
DRAWING No. FIGURE 8
REV 0

CONFIRM SCALE — 100mm ON A1 ORIGINAL

G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG08-ClarrieHall-opt2.dgn
zhangc2
12:26:33 PM
19/02/2018

PLAN - RAISED EMBANKMENT (OPTION 1b)

SCALE 1:500

(NOTE: OPTION 1a AND OPTION 2 SIMILAR)

SECTION A

SCALE 1:500

1:500 10 0 10 20 30 40 50 m

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CLARRIE HALL DAM
RAISING OPTIONS

DAM EMBANKMENT RAISING
PLAN AND LONG SECTION

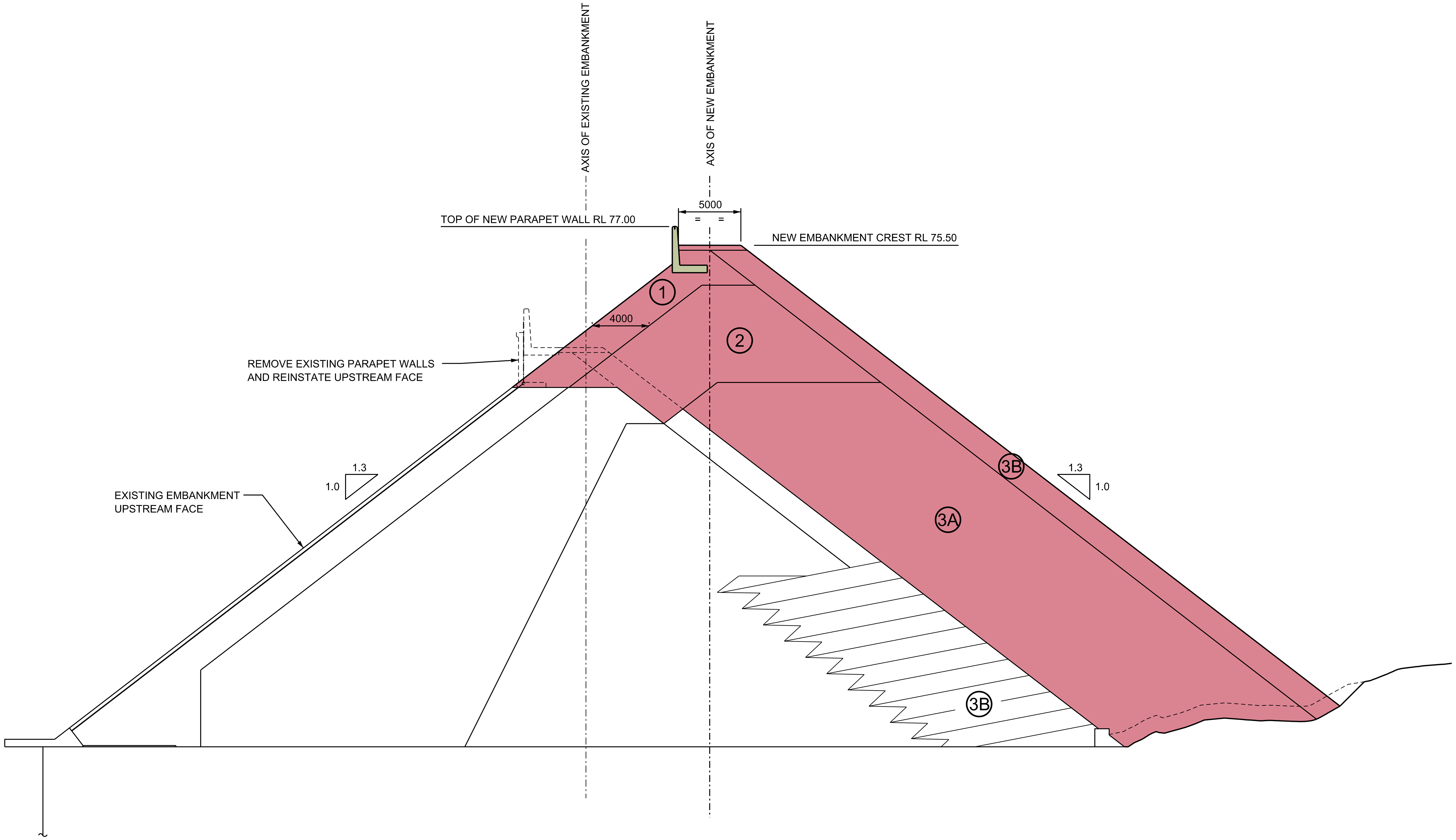
PROJECT/CONTRACT No. ?

A1 SCALE @ A1 1:500

DRAWING No. FIGURE 9 REV 0

CONFIRM SCALE — 100mm ON A1 ORIGINAL

G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG09-ClarrieHall-opt1b.dgn zhangc2 11:40:09 AM 16/03/2018



SECTION B/FIG9
SCALE 1:200

ZONE	FUNCTION	DESCRIPTION
1	SEMI-PERMEABLE ZONE	MODERATELY WEATHERED RHYOLITE
2	PERMEABLE INTERMEDIATE ZONE	SLIGHTLY WEATHERED TO MODERATELY WEATHERED RHYOLITE
3A	FRESH ROCK ZONE	FRESH RHYOLITE
3B	MESH ZONE AND FACE ZONE	SELECTED FRESH RHYOLITE

1:200 4000 0 4000 8000 12000 16000 20000 mm

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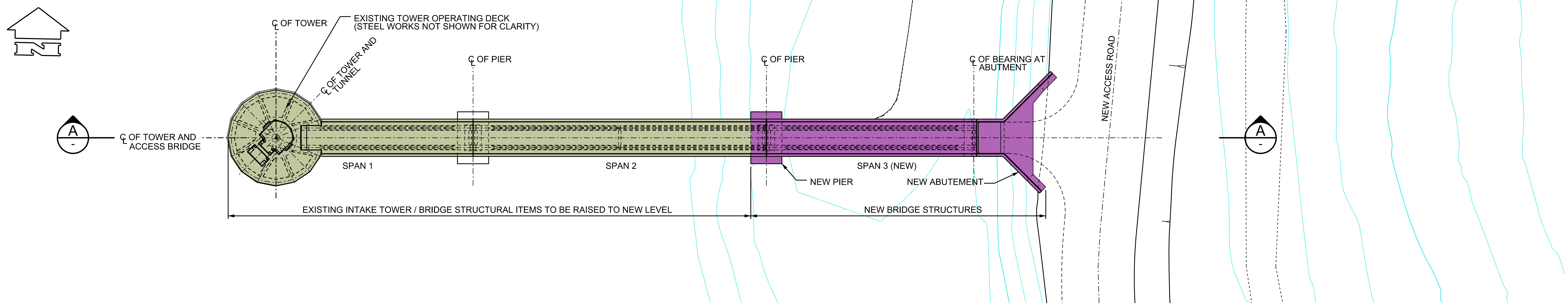
CLARRIE HALL DAM
RAISING OPTIONS

DAM EMBANKMENT RAISING
TYPICAL CROSS SECTION

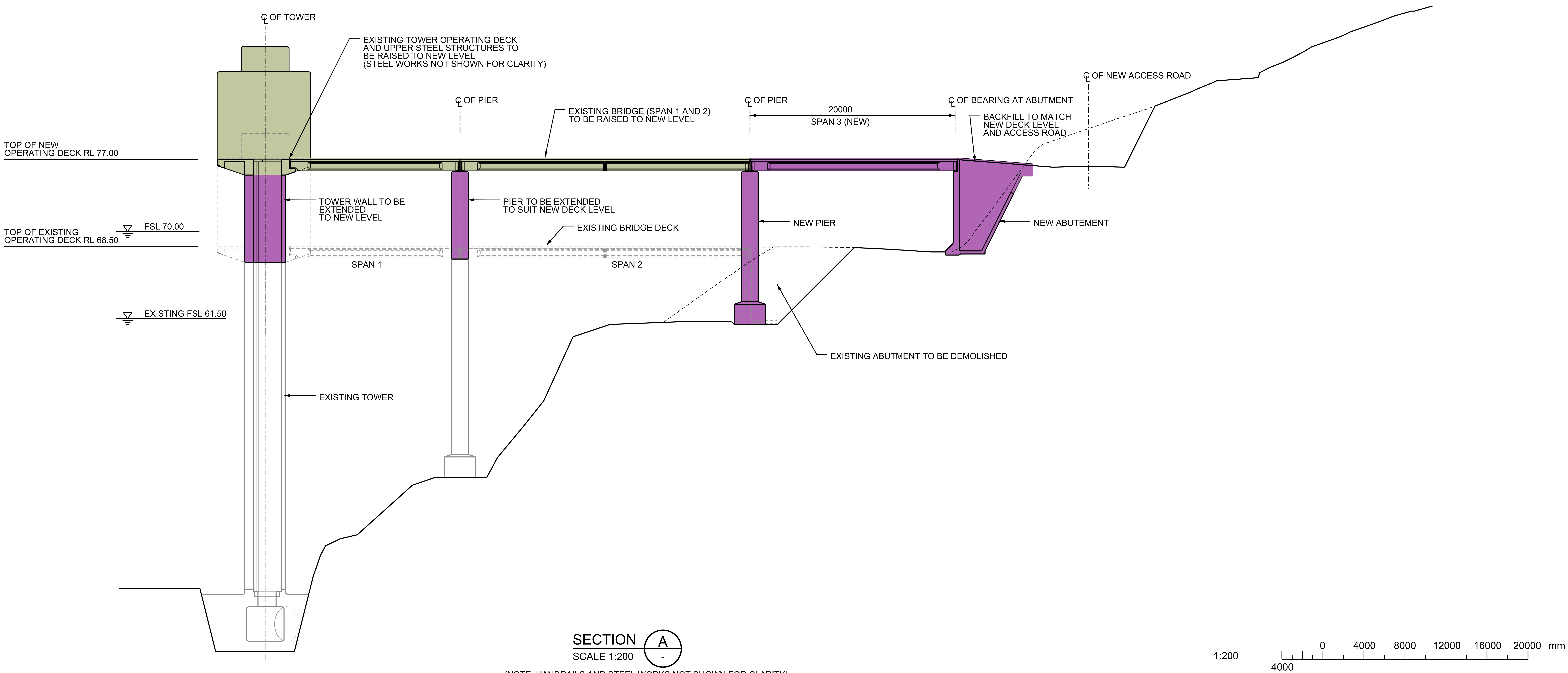
PROJECT/CONTRACT No. ?
A1 SCALE @ A1 1:200
DRAWING No. FIGURE 10 REV 0

CONFIRM SCALE 100mm ON A1 ORIGINAL

G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG10-ClarrieHall-opt2.dgn
zhangc2 6:48:01 PM 22/02/2018



PLAN
SCALE 1:200



SECTION A -
SCALE 1:200

(NOTE: HANDRAILS AND STEEL WORKS NOT SHOWN FOR CLARITY)

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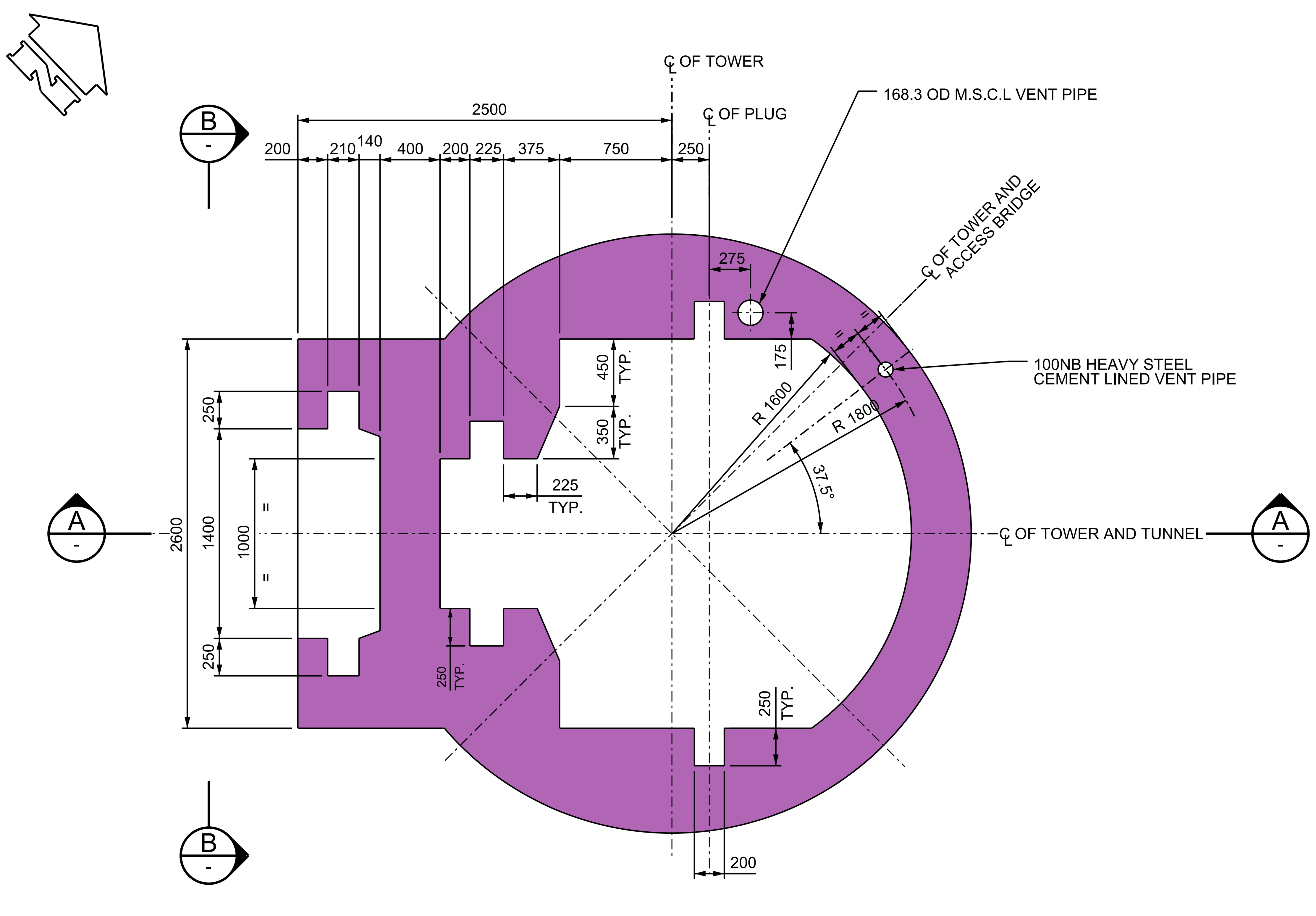
CLARRIE HALL DAM
RAISING OPTIONS

OPTION 1a
INTAKE TOWER
GENERAL ARRANGEMENT

PROJECT/CONTRACT No. ?
A1
SCALE @ A1 1:200
DRAWING No. FIGURE 11
REV 0

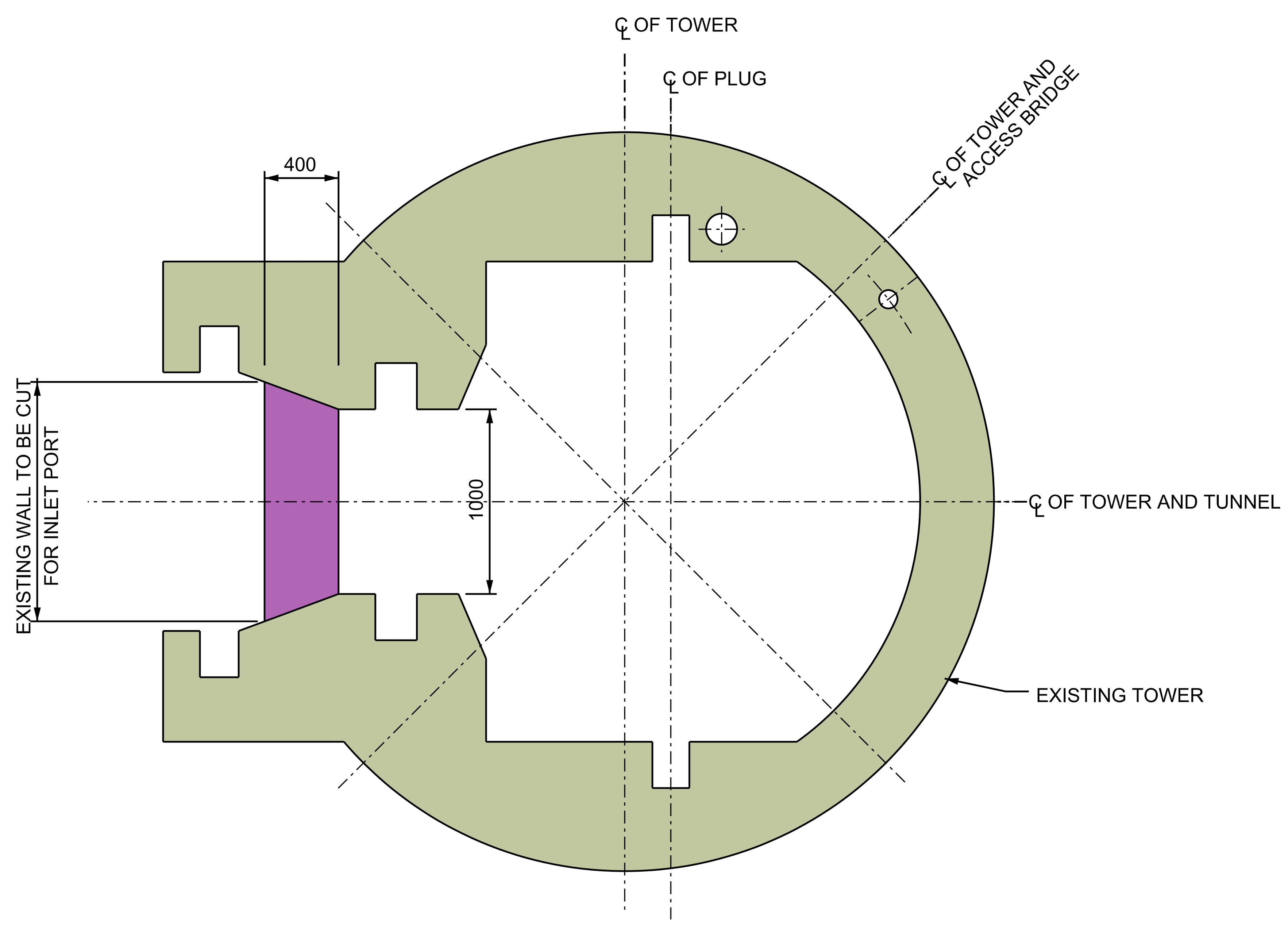
CONFIRM SCALE — 100mm ON A1 ORIGINAL

G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG11-ClarrieHall-opt1a.dgn
zhangc2
3:45:28 PM
6/06/2018



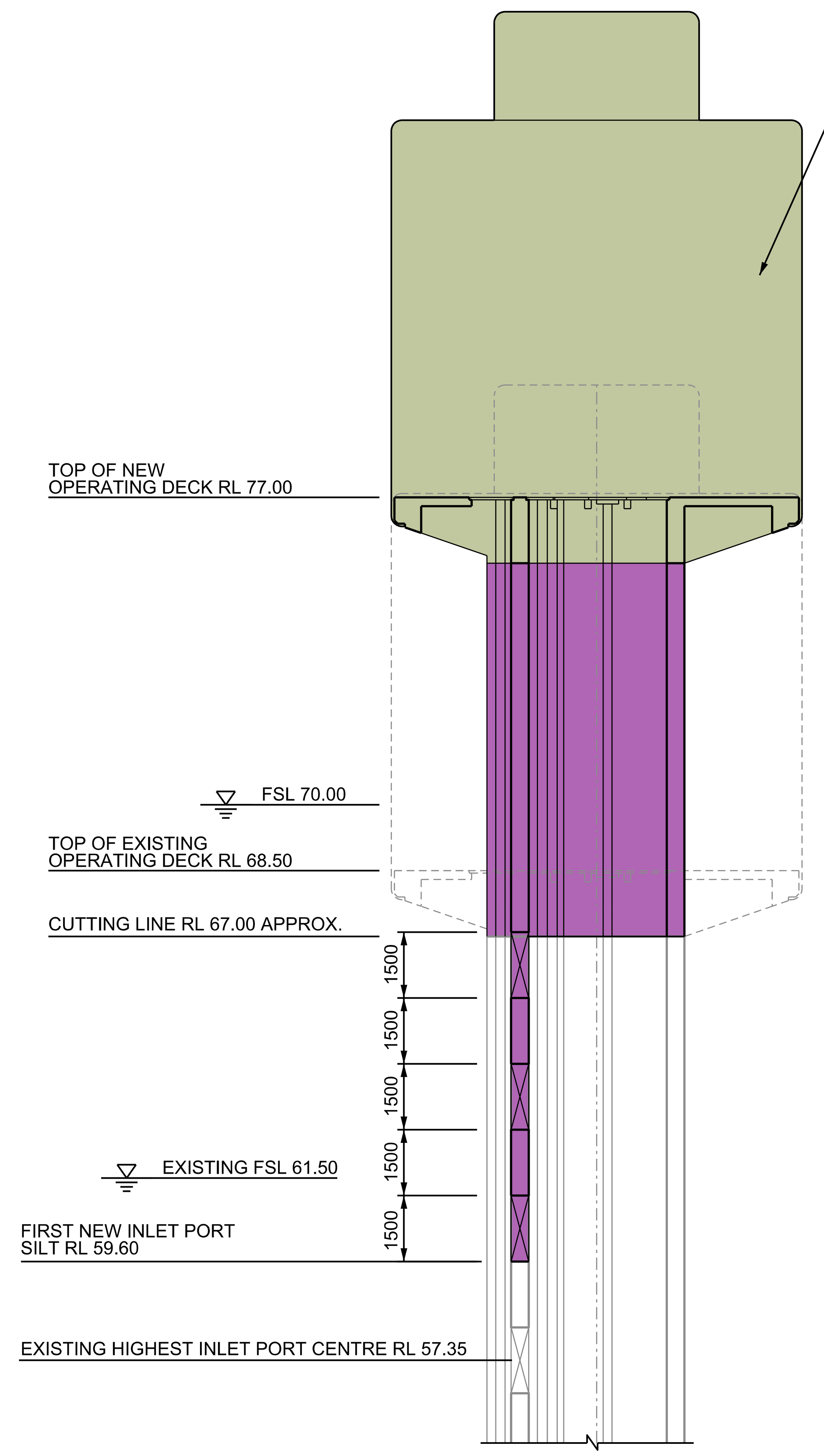
SECTIONAL PLAN - TYPICAL EXTENDED TOWER PORTION (ABOVE RL 67.00)

SCALE 1:25



SECTIONAL PLAN - EXISTING TOWER UPGRADED PORTION (RL 59.60 TO RL 67.00)

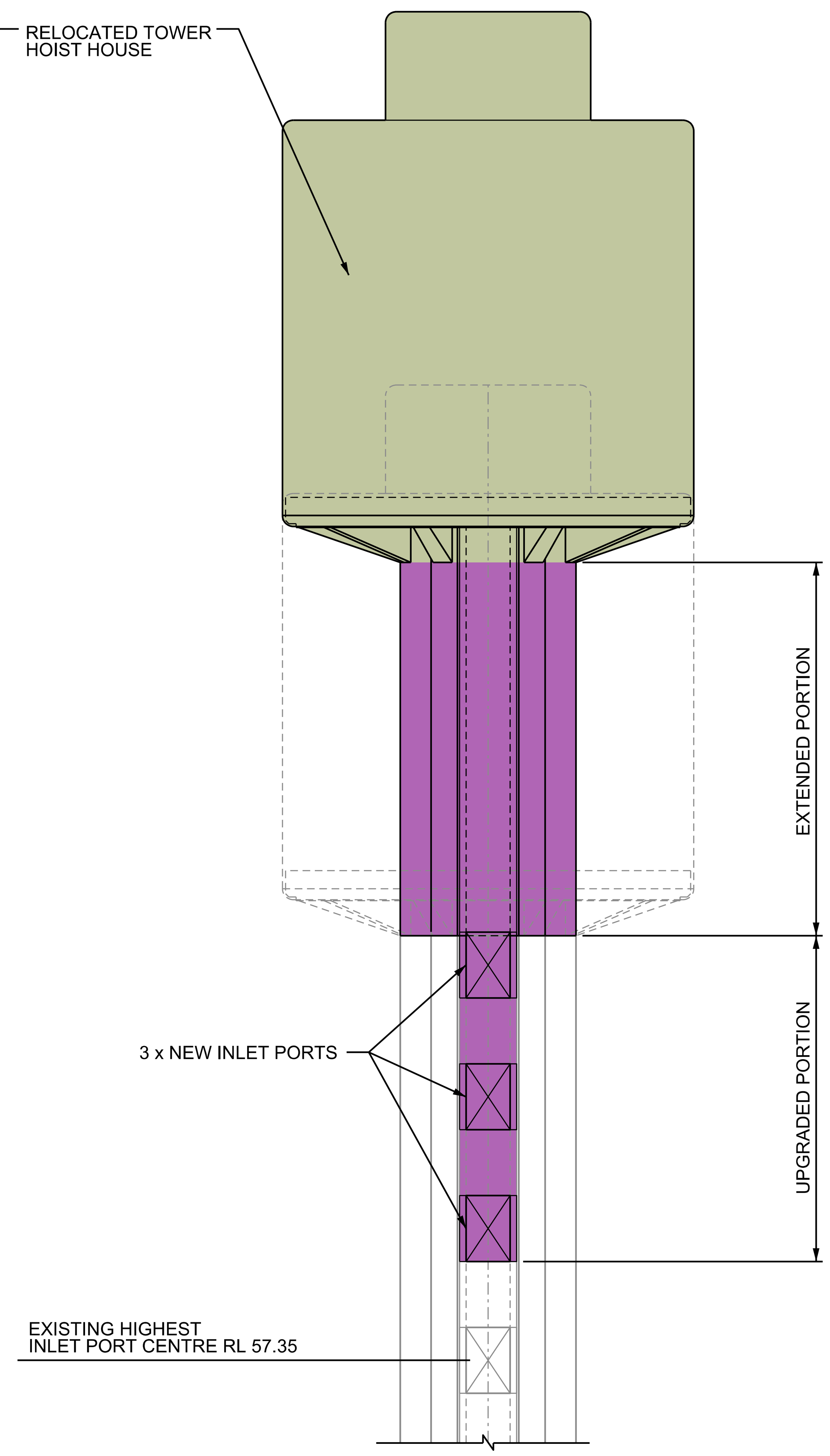
SCALE 1:25



SECTION A

SCALE 1:100

(NOTE: STEEL WORKS NOT SHOWN FOR CLARITY)



VIEW B

SCALE 1:100

(NOTE: STEEL WORKS NOT SHOWN FOR CLARITY)

1:25 — 500 0 500 1000 1500 2000 2500 mm

1:100 — 2000 0 2000 4000 6000 8000 10000 mm

REV	AMENDMENT DETAILS	APPROVED	DATE
0	ISSUED FOR REVIEW	XX	XX

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NSW GOVERNMENT — Public Works Advisory

DESIGNED	B. CLARK
CHECKED	G. SAMIOS
DRAFTED	C. ZHANG
PRINCIPAL ENGINEER	G. SAMIOS

CLARRIE HALL DAM

RAISING OPTIONS

OPTION 1a

INTAKE TOWER

UPGRADED WORK DETAILS

PROJECT/CONTRACT No. ?

A1 — SCALE @ A1 1:25, 1:100

DRAWING No. FIGURE 12 — REV 0

CONFIRM SCALE — 100mm ON A1 ORIGINAL

6/06/2018 11:46:27 AM zhangc2 G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG12-ClarrieHall-opt1a.dgn

REV	AMENDMENT DETAILS	APPROVED	DATE
0	ISSUED FOR REVIEW	XX	XX

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DESIGNED	B. CLARK
CHECKED	G. SAMIOS
DRAFTED	C. ZHANG
PRINCIPAL ENGINEER	G. SAMIOS

CLARRIE HALL DAM
RAISING OPTIONS

OPTION 1a
INTAKE TOWER
UPGRADED ACCESS BRIDGE DETAILS

PROJECT/CONTRACT No. ?
A1 SCALE @ A1 1:20, 1:100, 1:200
DRAWING No. FIGURE 13 REV 0

CONFIRM SCALE 100mm ON A1 ORIGINAL

G:\Watertec\Pcad\Clarrie Hall Dam Raising 2018\FIGURES-DRAWINGS\FIG13-ClarrieHall-opt1a.dgn zhangc2 5:07:44 PM 6/06/2018

APPENDIX C

RAISED INTAKE TOWER ANALYSIS

C.1 General

The existing intake tower is a vertical reinforced concrete circular shaft 33.65m high with internal diameter of 3.2m. It has eight water inlet ports to facilitate selective water withdrawal.

The existing intake tower is proposed to be raised by 8.5m resulting in the total height of the intake tower to be 42.15m. The raised tower will incorporate two additional water inlet ports.

It is proposed to extend the tower by installing reinforcement bars chemically grouted into the holes drilled at the top of the tower wall. These anchored bars would be installed at spacings to match with the existing reinforcement. The installed anchor bars would then be lapped with reinforcing bars of appropriate length followed by the placement of concrete to the proposed level.

As for the existing arrangement, the raised tower will have radial beams built into the tower wall and a peripheral beam to support the floor slab and the new hoist house super structure. Corbels will be built into the raised tower wall, similar to the existing ones, to support the new access bridge.

C.2 Structural Analysis

Procedure

- Linear static analysis for gravity loads.
- First four natural frequency modes for tower (frequency analysis).
- Spectral response analysis for response accelerations having 10,000, 5,000, 1,000 and 500 year return periods. Response accelerations applied in two directions, orthogonal to each other (X and Y directions) as the tower is not symmetrical.
- Linear combination of results from linear static and spectral analysis.
- Extraction of results to determine demand (base shear and moments) in the X and Y directions using square root of sum of squares (SRSS) method.
- Evaluation of tower capacity and comparison with demand.
- Determination of stresses at the tower/base connection.

Finite Element Model

A 3D model of the raised tower (Figure 1 at **Appendix C**) was developed using the Strand7 finite element computer program. The model was assigned the following parameters:

Material	Concrete
Young’s modulus	27460 MPa
Compressive strength	25MPa
Density	2400 kg/m^3

Boundary Conditions

The tower was assumed to be fixed in all directions (translation and rotation) at its connection to the base. The tower was assumed to behave as a cantilever column fixed at the base when subjected to the design loading.

C.3 Loading

Hydrodynamic Loading Determination

As the tower is always likely to be submerged in water, the critical loading would be the hydrodynamic loading being generated onto its inner and outer walls whilst these try to push water as a result of the movement of the tower base caused by an earthquake.

The hydrodynamic loading, caused by the inertia of the water mass, attached to the inside and outside wall faces, was approximated using paper titled “Simplified Evaluation of Added Hydraulic Mass for Intake Towers” by Goyal and Chopra published in ASCE Journal of Engineering Mechanics (1989).

A 1m water differential depth considered between the outside and the inside of the tower ie. water inside the tower 1m below the water outside the tower.

Water level outside the tower was considered at FSL (RL 70.00mAHD).

Gravity Loading

Gravity loading include self-weight of the tower and weight of the hoist house at the top of the tower.

Load Combinations

- Gravity load (Self-weight + Hoist House weight) + Hydrodynamic load

Results

- Base shear and moments for different earthquake return periods are presented at **Table C-1**.
- Maximum tensile stresses at the tower/base connection are presented at **Table C-2.**
- Comparison of section capacity versus demand is presented at **Table C-3.**

Table C-1 Base Shear & Bending Moment about CG of the Section for Different Return Periods

Return Period (yrs)	Fx (kN)	Fy (kN)	Mx (kNm)	My (kNm)	Comment
10,000	**1130**	0	0	**18257**	Seismic direction vector in X direction
	0	1120	17938	0	Seismic direction vector in Y direction
5,000	**780**	4	20	**12398**	Seismic direction vector in X direction
	0	774	12179	0	Seismic direction vector in Y direction
1,000	**289**	0	0	**4435**	Seismic direction vector in X direction
	0	286	4348	0	Seismic direction vector in Y direction
500	99	0	0	3037	Seismic direction vector in X direction
	0	**103**	**3155**	0	Seismic direction vector in Y direction

Table C-2 Maximum Stresses (MPa) at Tower/Base Connection along the Height of the Section - ZZ axis (Gravity ± Spectral (SRSS))

Return Period (yrs)	Tensile	Compressive	Comment
10,000	3.70	7.29	Seismic direction vector in X direction
	3.37	6.25	Seismic direction vector in Y direction
5,000	2.07	5.54	Seismic direction vector in X direction
	1.84	4.72	Seismic direction vector in y direction
1,000	0.75	3.16	Seismic direction vector in X direction
	Nil	2.62	Seismic direction vector in Y direction
500	Nil	2.72	Seismic direction vector in X direction
	Nil	2.38	Seismic direction vector in Y direction

Table C-3 Demand Vs Estimated Section Capacity

Bending Moment

Return Period (yrs)	Demand (kNm)	Estimated Section Capacity - ΦMu (kNm)	Comment
10,000	18,257	8,835	Section Inadequate - NG
5,000	12,398	8,835	Section Inadequate - NG
1,000	4,420	8,835	Section Adequate - OK
500	3,155	8,835	Section Adequate - OK

Base Shear

Return Period (yrs)	Demand (kN)	Estimated Section Capacity – Φvuc (kN))	Comment
10,000	1130	1022	Section Inadequate - NG
5,000	780	1022	Section Adequate - OK
1,000	289	1022	Section Adequate - OK
500	103	1022	Section Adequate - OK

Findings

Results show that the raised tower section is adequately reinforced to handle the base shear for seismic loading up to the 0.01% AEP (10,000 year) event. However, this is not the case with the moment. It appears that tower section is likely to handle moment resulting from seismic loadings between 0.1% AEP (!,000 year) and 0.05% AEP (2,000 year) events. For the 0.02% AEP (5,000 year) and lower frequency occurrences (but more intense earthquakes), the tower is likely to experience distress and possible structural damage.

APPENDIX D

RAISED INTAKE TOWER BRIDGE PIER ANALYSIS

D.1 General

Access to the intake tower hoist house is from the right side of the dam via a public road leading to an access bridge which connects the public road to the hoist house.

The access bridge consists of two unequal spans supported by a reinforced concrete pier. Short and long spans are 16.5m and 28m long respectively, shorter span being close to the entrance to the hoist house.

The pier supporting the access bridge girders is a rectangle column 1500mm X 2500mm and 19.06m high. The access bridge would need to be raised by 8.5m to match the top of the raised intake tower.

The pier has a base 2m thick, 3m wide and 5m long.

D.2 Structural Analysis

Slenderness Check of Existing and Raised Pier

The access bridge girders sit on the pier through bearing pads and are not structurally connected to the pier. The slenderness of the existing pier was checked assuming it behaved as a cantilever column with built in connection at the base (effective length factor Ke=2.2).

The slenderness ratio of the existing pier was estimated to be 93 which satisfied the maximum limit of 120 as per the requirement of AS3600.

However, by increasing the height of the pier, the slenderness ratio increases to 140, exceeding the maximum limit of 120.

It was therefore decided to increase the cross section of the existing column to bring its slenderness ratio less than 120 to comply with AS3600.

The existing column was enlarged in dimensions to 2000mm X 3000mm for the increased height of 27.56m. The slenderness ratio of column with increased dimensions dropped to 101 satisfying the AS3600 limit of not greater than 120.

Procedure

- Linear static analysis for gravity loads.
- First four natural frequency modes for tower (frequency analysis).
- Spectral response analysis for response accelerations having 10,000 year, 5,000 year and 500 year return periods. Response accelerations applied in two directions orthogonal to each other (X and Y directions) as pier is not symmetrical.
- Linear combination of results from linear static and spectral analysis.
- Extraction of results to determine demand (base shear and moments) in X and Y directions using square root of sum of squares (SRSS) method.
- Evaluate capacity of upgraded pier and compare with the demand.
- Determination of stresses at the foundation (concrete base/rock interface).

Finite Element Model

A 3D model of the upgraded and raised pier (Figure 1 at **Appendix D**) was developed using finite element program Strand7. The model was assigned the following parameters:

Material	Concrete
Young’s modulus	27460 MPa
Compressive strength	25MPa
Density	2400 kg/m^3

Boundary Conditions

The pier was assumed to be fixed in all directions (translation and rotation) at its connection to the base. The tower was assumed to behave as a cantilever column when subjected to the design loading.

D.3 Loading

Hydrodynamic Loading Determination

As the main pier is always likely to be submerged in water, the critical loading would be the hydrodynamic loading being generated onto its faces whilst these try to push water as a result of the movement of the pier base caused by an earthquake.

The hydrodynamic loading, caused by the inertia of the water mass attached to the pier faces, was approximated using Engineering Manual by USACE, titled “Structural Design and Evaluation of Outlet Works” which, in turn, refers back to the paper titled “Simplified Evaluation of Added Hydraulic Mass for Intake Towers” by Goyal and Chopra published in ASCE Journal of Engineering Mechanics (1989).

Water level around the pier was considered at FSL (RL 70.00 mAHD).

Gravity Loading

Gravity loading include self-weight of the pier and weight of the bridge.

Load Combinations

Gravity load (Self-weight + access bridge weight) + Hydrodynamic load

Results

- Base shear and moments at the column/base connection for different earthquake return periods are presented at **Table D-1**.
- Comparison of section capacity of existing pier versus demand is presented at **Table D-1**.
- Comparison of section capacity of enlarged pier versus demand is presented at **Table D-2**.
- Maximum stresses at the pier base/foundation interface are presented at **Table D-3.**

Table D-1 Base Shear & Bending Moment about CG of the Section

Return Period (yrs)	Fx (kN)	Fy (kN)	Mx (kNm)	My (kNm)	Comment
10,000	**553**	0	0	**6561**	Seismic direction vector in X direction
	0	**638**	**10472**	0	Seismic direction vector in Y direction
5,000	**381**	0	0	**4460**	Seismic direction vector in X direction
	0	**438**	**7152**	0	Seismic direction vector in Y direction
1,000	**140**	0	0	**1600**	Seismic direction vector in X direction
	0	**162**	**2650**	0	Seismic direction vector in Y direction
500	**85**	0	0	**965**	Seismic direction vector in X direction
	0	**98**	**1604**	0	Seismic direction vector in Y direction

Table D-2 Demand Vs Estimated Section Capacity (Existing Pier)

Bending Moment Capacity of Existing Pier Section

Mx (kNm) = 2490   My (kNm) = 2562

		Return Period (Years)			
		10,000	**5,000**	**1,000**	**500**
Demand (kNm)	Mx (kNm)	10,472	7,152	2,650	1,604
	My (kNm)	6,561	4,460	1,600	965
		Section Inadequate	Section Inadequate	Section Inadequate	Section Adequate

Shear Capacity of Existing Pier Section

Fx (kN) = 1059   Fy (kN) = 898

		Return Period (Years)			
		10,000	**5,000**	**1,000**	**500**
Demand (kN)	Fx (kN)	553	381	140	85
	Fy (kN)	638	438	162	98
		Section Adequate	Section Adequate	Section Adequate	Section Adequate

Table D-3 Demand Vs Estimated Section Capacity (Enlarged Pier)

Bending Moment Capacity of Enlarged Pier Section

Mx (kNm) = 5552 My (kNm) = 6263

		Return Period (Years)			
		10,000	**5,000**	**1,000**	**500**
Demand (kNm)	Mx (kNm)	10,472	7,152	2,650	1,604
	My (kNm)	6,561	4,460	1,600	965
		Section Inadequate	Section Inadequate	Section Adequate	Section Adequate

Table D-4 Max. Stresses (MPa) at Pier Foundation (Gravity + Spectral (SRSS))

Return Period (yrs)	Tensile	Compressive	Comment
10,000	0.75	1.84	Seismic direction vector in X direction
	0.65	1.45	Seismic direction vector in Y direction
5,000	0.34	1.43	Seismic direction vector in X direction
	0.32	1.1	Seismic direction vector in Y direction
1,000	Nil	0.86	Seismic direction vector in X direction
	Nil	0.67	Seismic direction vector in Y direction
500	Nil	0.74	Seismic direction vector in X direction
	Nil	0.58	Seismic direction vector in Y direction

Findings

Results show that the existing access bridge pier section is adequately reinforced to handle the base shear for seismic loading up to the 0.01% AEP (10,000 year) event and bending moment for seismic loading up to the 0.2% AEP (500 year) event. The pier is required to be enlarged in cross section to satisfy code requirements. The enlarged section of the pier improves its bending capacity and the enlarged pier can handle the seismic loading up to the 0.1% AEP (1,000 year) event.

It is also noted that, for seismic loading up to the 0.1% AEP (1,000 year) event, the pier foundation (concrete base/rock interface) remains intact for the full base area as stresses remain in compression.

APPENDIX E

CFD MODELLING OF PREFERRED SPILLWAY OPTION (1B)

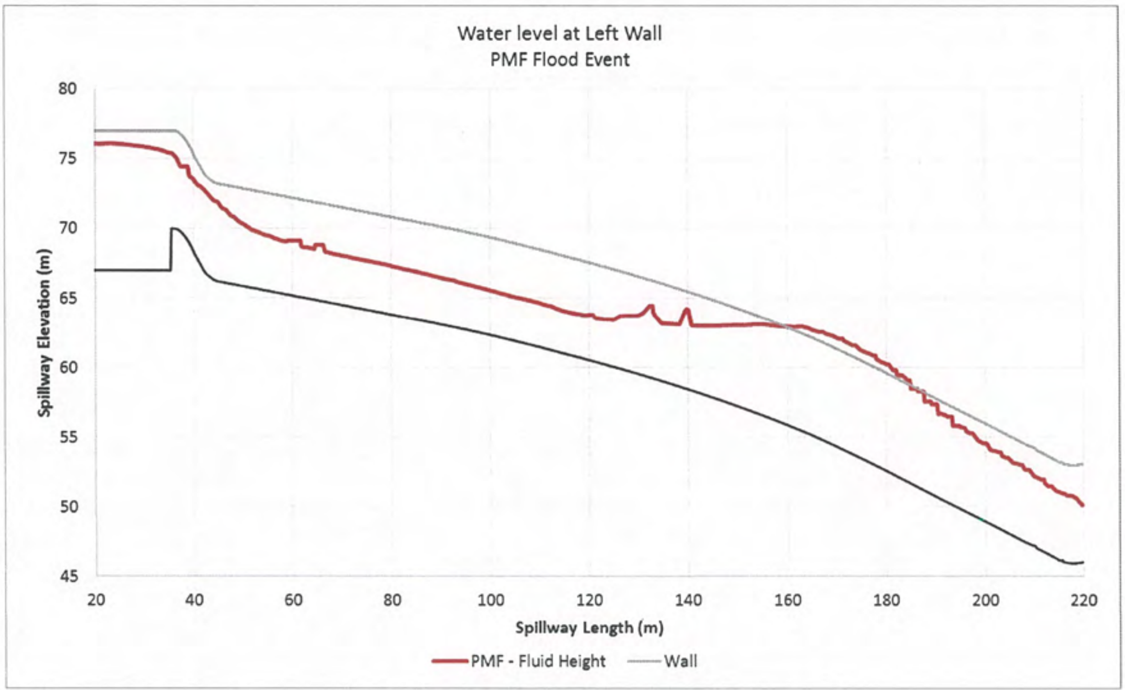


Figure 3-25 Graph showing water level at the Left Wall at PMF event

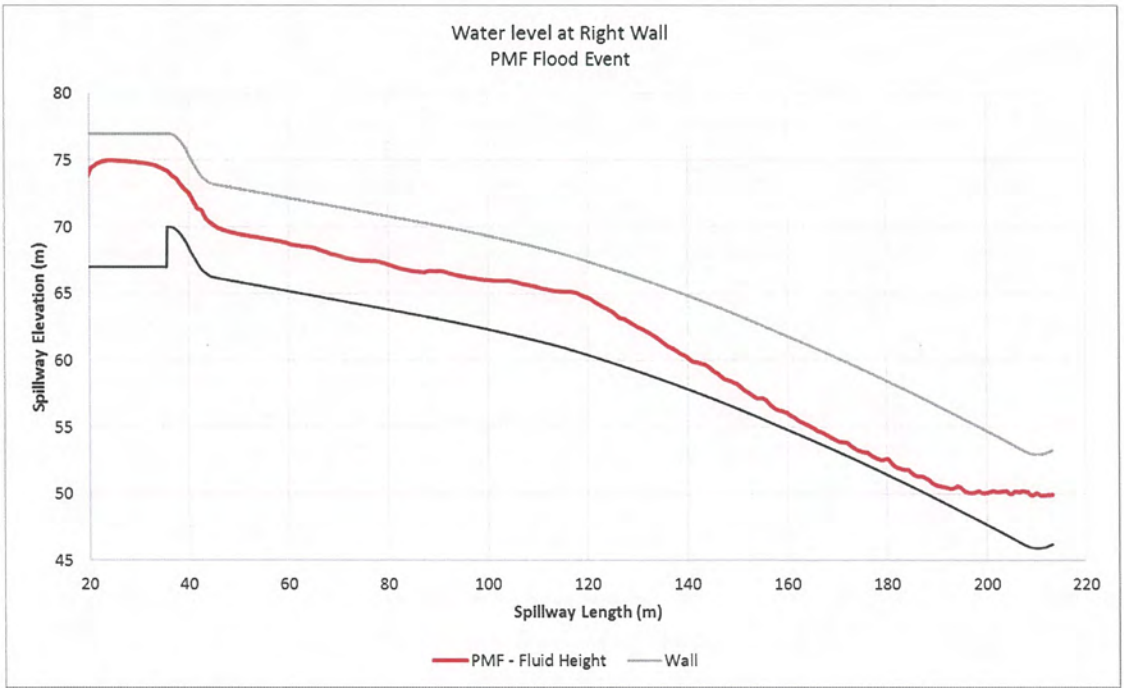


Figure 3-26 Graph showing water level at the Right Wall at PMF event

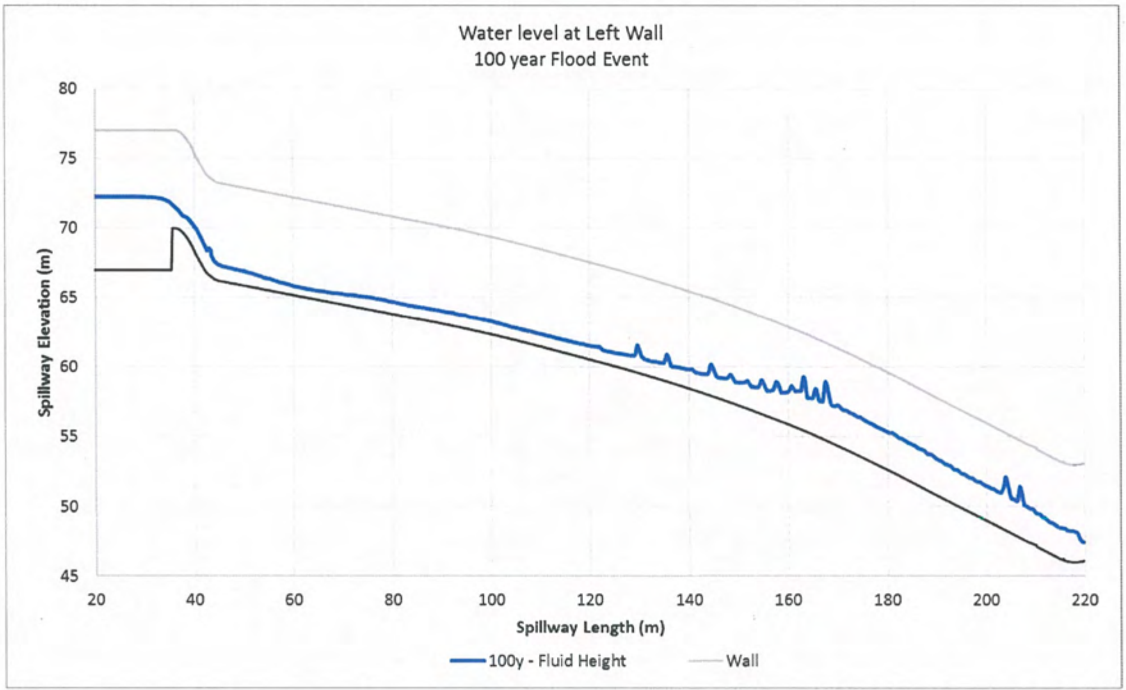


Figure 3-46 Graph showing water level at the Left Wall at 100 year event

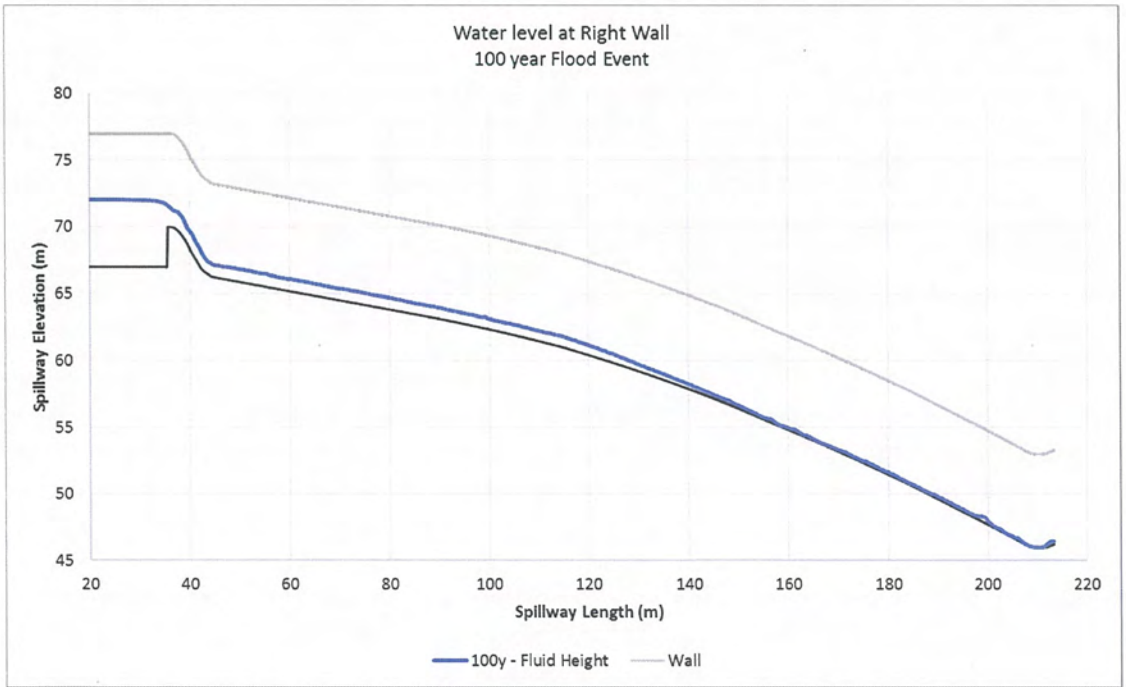


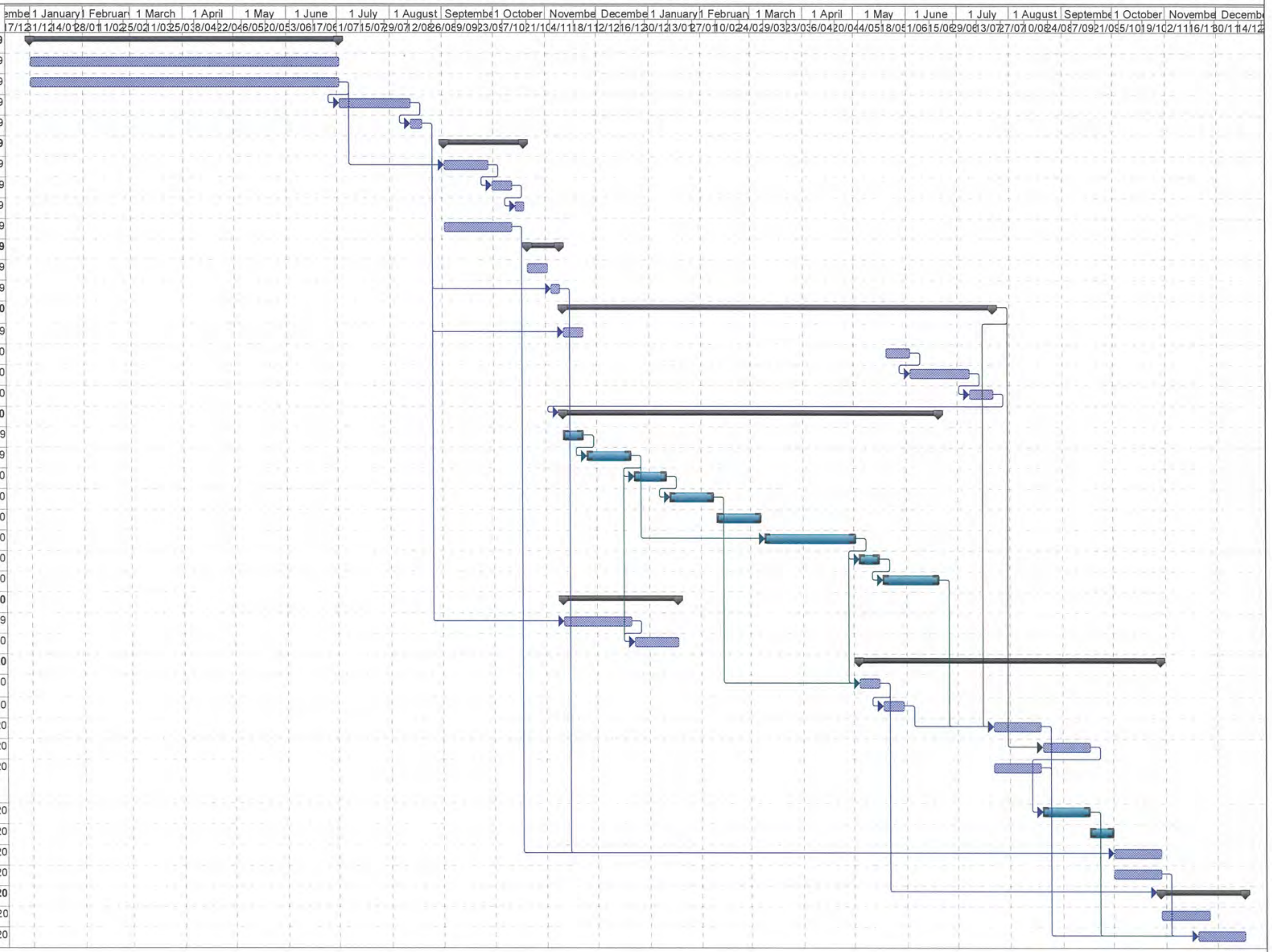
Figure 3-47 Graph showing water level at the Right Wall at 100 year event

APPENDIX F

PROJECT TIME LINE

CLARRIE HALLI DAM RAISING PROJECT

ID		Task Name	Duration	Start	Finish
1		**Preconstruction**	**26 wks**	**Tue 1/01/19**	**Mon 1/07/19**
2		Detail design and contract documentation	26 wks	Tue 1/01/19	Mon 1/07/19
3		Environmental approvals	26 wks	Tue 1/01/19	Mon 1/07/19
4		Call tenders and tender review	6 wks	Tue 2/07/19	Mon 12/08/19
5		Award tender	1 wk	Tue 13/08/19	Mon 19/08/19
6		**Site Establishment**	**7 wks**	**Mon 2/09/19**	**Fri 18/10/19**
7		Site facilities	4 wks	Mon 2/09/19	Fri 27/09/19
8		Temprorary access and haul roads	2 wks	Mon 30/09/19	Fri 11/10/19
9		Quarry establishment	1 wk	Mon 14/10/19	Fri 18/10/19
10		Environmental management	6 wks	Mon 2/09/19	Fri 11/10/19
11		**Flood Protection**	**3 wks**	**Mon 21/10/19**	**Fri 8/11/19**
12		Flood protection/dewatering/diversion works	2 wks	Mon 21/10/19	Fri 1/11/19
13		Storage lowering (Council dependency)	1 wk	Mon 4/11/19	Fri 8/11/19
14		**Spillway**	**36.4 wks**	**Mon 11/11/19**	**Tue 21/07/20**
15		Stripping/excavation works	2 wks	Mon 11/11/19	Fri 22/11/19
16		Anchors and drainage	2 wks	Wed 20/05/20	Tue 2/06/20
17		Concrete works	5 wks	Wed 3/06/20	Tue 7/07/20
18		Downstream protection works	2 wks	Wed 8/07/20	Tue 21/07/20
19		**Embankment**	**32 wks**	**Mon 11/11/19**	**Fri 19/06/20**
20		Parapet all and crest road removal	2 wks	Mon 11/11/19	Fri 22/11/19
21		Foundation stripping/excavation	4 wks	Mon 25/11/19	Fri 20/12/19
22		Demolition of existing spillway training walls	3 wks	Mon 23/12/19	Fri 10/01/20
23		Uostream toe slab and grout curtain	4 wks	Mon 13/01/20	Fri 7/02/20
24		Material from spillway and embankment raising	4 wks	Mon 10/02/20	Fri 6/03/20
25		Quarry excavation and embankment raising	8 wks	Mon 9/03/20	Fri 1/05/20
26		Upstream concrete face	2 wks	Mon 4/05/20	Fri 15/05/20
27		Parapet wall	5 wks	Mon 18/05/20	Fri 19/06/20
28		**New Permanent Right Abutment Access Road**	**10 wks**	**Mon 11/11/19**	**Fri 17/01/20**
29		Excavation	6 wks	Mon 11/11/19	Fri 20/12/19
30		Roadworks and sealing	4 wks	Mon 23/12/19	Fri 17/01/20
31		**Intake Tower and Deck**	**25.6 wks**	**Mon 4/05/20**	**Wed 28/10/20**
32		Demolition of tower deck	2 wks	Mon 4/05/20	Fri 15/05/20
33		Removal of bridge deck	2 wks	Mon 18/05/20	Fri 29/05/20
34		Raising of tower stem concrete	4 wks	Wed 22/07/20	Tue 18/08/20
35		Raised tower deck	4 wks	Thu 20/08/20	Wed 16/09/20
36		Raising of bridge pier and construction of new piers	4 wks	Wed 22/07/20	Tue 18/08/20
37		Raised bridge deck	4 wks	Thu 20/08/20	Wed 16/09/20
38		New tower house	2 wks	Thu 17/09/20	Wed 30/09/20
39		Supply and install mechanical works	4 wks	Thu 1/10/20	Wed 28/10/20
40		Power supply	4 wks	Thu 1/10/20	Wed 28/10/20
41		**Disestablishment**	**7 wks**	**Thu 29/10/20**	**Wed 16/12/20**
42		Site clean up and removal of temporary works	4 wks	Thu 29/10/20	Wed 25/11/20
43		Site rehabilitation	4 wks	Thu 19/11/20	Wed 16/12/20



Project: Revised_Proposal_Program
Date: Thu 5/07/18

Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Progress
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Deadline

APPENDIX G

PROJECT RISK MATRIX

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
	DESIGN RISKS		
D1	Design	• Designs will be undertaken fully in accordance with NSW Dams Safety Committee (DSC) requirements, Australian National Committee on Large Dams (ANCOLD) guidelines and all relevant AS standards.	• Designs will be in accordance with current best practice and subject to independent peer review.
D2	Items salvageable for reuse	• The crest parapet walls can be reused for the raised embankment crest, however additional walls will be required as the raised dam crest length is longer than existing dam. • It is expected that the existing tower bridge deck and crane support structure can be reused.	• There will be some risk from the time the parapet walls are removed until the embankment is raised about the new spillway. Flood protection during construction needs to be considered carefully. • Car parking and history/aboriginal/learning information to be reinstated. • Areas for storage will be required including storage of the pre-cast parapet walls before reinstatement on the raised crest. • Sequence of construction to keep old spillway operational as long as possible during construction. • Access to site, closed for 2 years – part of contract specification • Existing embankment mesh protection will just be left there and covered over with rock. All agreed.
D3	Construction program and sequencing	• The existing dam configuration and constraints around the continued operation of the dam will impact significantly on the construction sequencing and approach. A preliminary construction program will be prepared with input from construction industry specialists. This will be a cost-critical exercise because flood diversion and construction of the embankment and spillway structures in a staged manner at an existing large dam in operation is a complex undertaking.	
D4	Cost estimating	• Accurate cost estimates are required to inform Council and other key stakeholders in terms of budget planning. To provide understanding and test uncertainty, a probabilistic risk based cost estimate using analysis using Monte Carlo techniques (@RISK) will be utilised.	
	COMMUNITY CONSULTATION		
C1	Advice to landowners	• Council will need to inform landowners of the works. • The Contractor will be responsible for providing landowners with contact details and of the specific times works will be undertaken that may impact vehicle movement or produce noise/vibrations or other disturbance. • Council will need to inform affected landowners when manual water releases occur from outlet works.	• Need to check downstream users again when we start using automatic valve releases. Ensure we have their mobile numbers to send SMS's to. • Notification of causeways on Tweed River downstream. • Signage at entrance to dam and advertising of dam closure to locals and public in general. • Advice of blasting operation during construction will need to be provided to affected landholders • Temporary flood due to valve opening during construction will need to be communicated to affected residents
C2	Access to site through adjacent landowner	• Early consultation with affected landholders will need to be undertaken by Council to ensure that access is granted where necessary	
C3	Land owner access via Clarrie Hall Dam Rd	• The Contractor will be responsible for providing landowners with contact details and of the specific times works will be undertaken that may impact vehicle movement or produce noise/vibrations or other disturbance.	
C4	Discovery of an Aboriginal artefact	• The Principal assumes the risk if an artefact is found. The Contractor is to notify the Principal and the Principal assumes the risk for any additional costs.	

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
S	**SITE AND SERVICES**		
S1	Site access and access Roads	• Site access will be via Clarrie Hall Dam Rd from the Kyogle – Murwillumbah Road. • Site is not accessible in times of flood. Non accessibility due to flood will be a risk that the Contractor needs to consider. Flooding of Kyogle – Murwillumbah Road and alternative roads can occur depending on spatial variation of rainfall. The Contractor will need to plan transport and deliveries to avoid delays. • Maintenance of access and all internal roads to be with Contractor. Dilapidation survey's will be required • Traffic control, dust control and speed control will be the responsibility of the Contractor	
S2	Access across dam embankment and spillway walls and intake tower bridge	• Load bearing capacities for embankment, spillway walls and bridge will be calculated by the designers. Design values will be given to the Contractor, but 30yr old structure so the Contractor will need to take this into account. • The Contractor will be responsible for meeting loading requirements and performing ongoing maintenance. Dilapidation surveys will be required	• Confirmation that no Annual or 5 yearly Surveillance inspections required during dam upgrade. Complete one before and one on first fill. • Confirmation of survey requirements just before raising, at end and once filled. • Include Cadastral of existing services in site survey. • The downstream seepage weir will need to be re-instated early after lower embankment placement to enable continued monitoring
S3	Construction impacts on dam wall	• The Principal will need to carry out EPOCH survey and compare data before, during and after construction. • Vibration monitoring will be required • Dilapidation surveys will be required.	• New seepage weir monitoring point required. Pipe from existing location. Do very early in construction to maintain seepage record
S4	Unexpected encounter with existing underground services not shown or incorrectly shown on the design and contract drawings.	• The Contractor must carry out a complete services search prior to commencing excavation works and is responsible to check and confirm the existence and location of any services in the design are correct.	
S5	Encountering materially adverse site conditions	• The Principal bears the risk of materially adverse site conditions. Relevant geological reports will be provided to the Contractor.	
S6	Site services for construction, water supply, sewerage, power	• The Contractor will need to make arrangement for services and ensure appropriate use in consultation with the Principal.	• What is capacity of existing services? – power, no drinking water, no sewerage capacity for construction – very minor public facility only. These aspects need to be considered.
S7	Use of Dam water for construction works	• The Contractor will likely be permitted to use dam water free of charge only for the purpose of carrying out the works (responsible use). The location and method of water extraction must avoid the risk of dam water contamination, and must be approved by the Principal. Dam water is non potable.	
S8	Working in an operational storage Dam	• The Contractor will need to manage this risk and fully understand Council's operational requirements. Daily liaison and regular meetings will be necessary.	• Temporary telemetry provisions need to be made for the construction, once the existing telemetry locations are affected by the raising works. Must maintain seepage monitoring during construction
S9	Construction may limit operational access	• Close coordination between the Contractor and Council operators required to ensure site access restrictions are minimised and managed with adequate notification provided.	
S10	Illegal site access and vandalism	• It will be the Contractor's responsible for securing work site. It is noted that the public have previously accessed the spillway to body board or skate down the cute.	• Video surveillance - could be permanent and handed over to Council at completion of construction. Require monitoring of works, photo, video record by contractor
S11	Site Office Establishment including fenced compound	• The Contractor will need to propose a suitable location for site office with approval from the Principal	• Only limited amenities exist on-site with a pump out tank. Won't be appropriate for larger workforce.

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy		Comments
		• It will be the Contractor's responsibility to provide and maintain site office for Council staff.		• Accommodation. Contractor may approach Council to have a person(s) housed onsite for security. We may support for mutual benefits.
S12	Delivery, storage and protection of materials	• The Contractor will need to ensure adequate processes for delivery, storage and protection of materials are implemented		
	WORK HEALTH AND SAFETY			
W1	Identified WHS Construction Risks	• Working at Heights • Working over and near water • Flooding • Excavation works • Drilling works • Grouting works • Concrete works • Rockfill haulage, placement and compaction • Overhead Electricity • Scaffolds and work platforms • Hazardous substances • Moving Plant • Hazardous Equipment • Traffic and vehicular movement • Access and egress	• Public access • Demolition activity • Formwork • Vibration • Hydraulic pressure • Power tools • Manual handling • Underground services • Confined Spaces • Solar radiation • Dust • Noise • Bushfires	• Public access restricted for entire period of construction • FCD Valve will letting water through the site most of the time. This flow will need to be allowed to flow through. • Large snakes are regularly found in the vicinity of the dam. • FCD Valve is remotely operated and warning needed for opening, ALARM. • Biggest risk for us is walking around the rocky areas – Slippery and uneven surfaces. • Operational access to all parts of the new dam need to be thought of in the design. Including both sides of spillway for inspection and viewing spillway from certain points. • Rock falling is a risk to workers. • Blasting - alarm and notification to landholders. Consider use of Non-Explosive Controlled Demolition Agent for rock excavation if geotechnical conditions are suitable. • Security cameras required • Communication during construction needs to be adequate
W3	Management of WHS on site during construction	• The principal Contractor will be responsible for the management of WHS for themselves, subContractors and all associated construction personnel, including any Council personnel. • Council's operations staff will be inducted into and work under the Contractor's WHS system • Coordination will be needed to ensure the Contractor's site procedures and Council adopted procedures do not contradict. • Council's dam management operations and emergency procedures will need to be provided for inclusion in the principal Contractor's safety management plan.		
W4	Falls from height / Working over water	• It will be the Contractor's responsibility to comply with all WHS requirements. Selection of appropriate subbies, implementation of appropriate management plans and SWMS.		
W5	Bushfires	• The Contractor will need to prepare evacuation plans to ensure that adequate procedures are in place in case of bushfires		
W6	Working below a coffer dam or water retaining structure, and working within a stream bed / flood prone area	• It will be the Contractor's responsibility to comply with all WHS requirements. Selection of appropriate subbies, equipment, construction techniques, implementation of appropriate management plans, SWMS, early warning and evacuation.		

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
W7	Control of jointly occupied site with Contractor/s and Council.	• The Contractor will need to manage entry of all personnel to site. (Site control system for all people entering/leaving/transiting site will need to be developed). This should include allowance for emergency night time entry by Council staff.	
W8	Control of landholders with access via Clarrie Hall Dam Rd	• The Contractor will need to manage safe access for all landholders.	
W9	Remotely activated outlet valve	• The Principal will need to ensure audible and visual alarm prior to release and the Contractor will need to consider valve operation in its safety management plan	
W10	Presence of H_2S gas adjacent to outlet works when water is discharged.	• It is unclear whether construction personnel stationed on site would be at risk. It is currently not an issue since Council staff are not stationed at the dam. Gas released disperses but is not measured and smell is present. The Contractor will need to account for the presence of H2S gas in its safety management plan.	
W11	Presence of asbestos during construction.	• The intake tower contains asbestos and therefore the contactor will need to manage the risk and use appropriate methods of removing the asbestos as required for the raising works.	
W12	Independent certification for coffer dams or other flood mitigation constructions with a structural component or potential impact on water flows to or through the spillway	• The Contractor will need to engage an independent certifier for coffer dams or other flood mitigation constructions. The Contractor will need to arrange, provide and pay all costs for certification.	
W13	Independent certification for formwork	• The Contractor will need to engage an independent certifier for the formwork. The Contractor will need to arrange, provide and pay all costs for certification.	
	ENVIRONMENTAL AND SITE CONDITIONS		
E1	Identified Environmental Risks	• Dewatering Management • Erosion and sediment control • Contamination of dam water • Contamination of Doon Doon Ck • Effects of flooding events and potential for pollution storage of fuels and oils, and other hazardous substances • Flora and Fauna • Cultural and Heritage Issues e.g. Indigenous items found during excavation • Impact of Construction Traffic • Weed Control • Mitigation Measures identified in Review of Environmental Factors • Contractors risk (except for Indigenous items found during construction)	• Particularly in dam and downstream • Blasting dust, noise, vibration to be considered. • Construction noise and dust. • Waste materials need adequate management of disposal • Tree clearing? V's Water quality – generally Council to determine through Environmental Assessment phase • Water turn over in dam risk increased if lowering dam and no flow through. • Sediment from upstream clearing etc. entering Tweed River. Need to stage the catchment clearing so large areas are no left bear when dam fills. • Can the storage filling be controlled to any extent to allow fauna to migrate – consider. • Raised storage rim - can there be some shallow areas at the back of the storage but steeper slopes elsewhere to limit weed growth • De-stratification needs to be determined, current project to speed-up to get results that can be included in the environmental assessment.
E2	Contamination of water / management of runoff Protection of Dam, Doon Doon Ck and groundwater water	• Contractor will need to address in Construction Environmental Management Plan (CEMP) • Contamination of water could result significant impact of flora and fauna in Doon Doon Creek - which is an unacceptable outcome.	• If there is low water level there is an increased risk of turn-over

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
		• The Contractor will need to use appropriate controls and systems to ensure no issues and will need to manage risk of pollution from the works due to flooding events also. • Work methods, materials and sequencing to allow for effects of flooding events and potential for pollution. Appropriate storage / treatment of runoff	
E3	Noise and Vibrations	• The Contractor will need to comply with Environmental Assessment/Approval (EA) requirements and consult with affected residents. • Vibration monitoring will be required on dam during the construction period	
E4	Disposal of surplus material	• The Contractor in consultation with the principal will need to undertake appropriate disposal of surplus materials, identifying item for salvage.	
E5	Discharge of dewatering water (and treatment)	• The Contractor will need to obtain approvals for discharge to receiving waters and outlined in CEMP	
E6	Management of Acid Sulfate Soils & Groundwater	• ASS risk is considered unlikely, however the Contractor will need to abide by the EA and geotechnical provisions and obtain approvals for discharge to receiving waters as required.	
E7	Upstream inundation areas	• Environmental assessment will need to be undertaken on new upstream inundation areas, including for flood surcharge inundation e.g impact on significant vegetation may influence raising height decision	• Council's flora and fauna study to consider further with some additional research.
E8	Tree clearing	• Areas subject to inundation that were previously unaffected will need to be assessed for tree removal and the associated environmental impact.	• Trees on the rim of the new dam catchment. Desire to have deeper drop-off but retain dedicated flat areas for lilies and bird habitat. Need to sort this out soon so we can complete clearing in areas needed. • We don't want too many trees dead in water • Consider water quality risk in terms of leaving trees in the storage, as part of Environmental Assessment
E9	Early identification of ancillary sites	• Design stage to identify all potential ancillary works areas (including rock borrow areas, materials set down areas etc.) that need to be assessed and included into project environmental assessment and approval	• PWA to provide construction disturbance footprints for flora and fauns assessments as soon as they are available
E10	Breach of Project condition of approvals	• Contractor will need to ensure all project approvals, commitments, and monitoring requirements are included into CEMP • Environmental reporting during construction (including management of complaints / incident register) • Auditing of environmental compliance during construction	
E11	Vegetation clearing	• Early initiation of environmental monitoring commitments • Pre-clearing (inundation) surveys and flora/fauna translocation activities	• What areas are to be cleared? This needs to be provided by PWA as input for environmental assessment.
CONSTRUCTION and PROGRAMMING			
CP1	Time Period for Construction and Working Hours	• An estimate construction schedule will be developed with input from a construction Contractor.	

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
		• Considering of seasonal rainfall valuations to be considered regarding proposed commencement date for construction works • Council to decide acceptable working hours so that estimated construction program can be developed. (For the spillway upgrade project the following working hours applied: Monday – Friday 7am – 6pm. Saturday 8am – 1pm. No work on Sundays or Public Holidays) • The Contractor may need to operate temporary works such as dewatering equipment outside normal working hours but pumps will need to meet EA noise restrictions.	
CP2	Lowering of the Storage During Construction	• Council need to make a decision on whether any storage lowering during the construction is acceptable and if so to what extent. The timing of the construction may influence the requirements set across the construction period. i.e. lowering may be permitted during "wet season" for example. • Implications to threatened species needs to be considered when determining the timing of any water lowering activities. This needs to be assessed early in the design stage to mitigate an impact at construction stage.	• Expected that lowering of storage by approximately 1m will be required during construction works for a period of approximately 3 months. Levels to be detailed in design and these progressed through ETI and Tender process. • There is threatened water birds (Jacana) that need to be considered in relation to storage lowering.
CP3	Damage to/ loss of works/equipment occurring from flooding and overtopping of spillway or other construction areas.	• The Contractor is responsible for all personnel and equipment and should have insurance for flooding events. • Council consider lowering the storage during the works (to say RL61.30m AHD, as was adopted for the spillway upgrade project) and control flooding from minor inflows via releases through the outlet works. This will not in any way absolve the Contractor from full responsibility for the impacts of flooding. • The Contractor will need to demonstrate how it will manage flooding risks and recover from events. (eg. nightly removal of equipment with hazardous substance or large enough to cause damage, no instream temporary works components that could get caught in spillway etc.)	
CP4	Construction sequence / scheduling of works	• The Contractor is best placed to determine the construction sequence and will be responsible for all construction sequence risks. • The construction of works will need to be sequenced such that there is no increased risk of damage to overall dam structure as a result of flooding during the construction works (in accordance with NSW Dam Safety Requirements • The works sequence will need to be agreed with by the designers • The Contractor will need to show how they will control risks through sequencing.	• Provide justification for the sequencing of works in the concept design report
CP5	Potential site isolation due to flooding	• The Contractor must plan for flooding events that can isolate the site and ensure that their equipment can be quickly and safety removed from flood areas, as necessary • There will be a time delay associated with such an event and the Contractor can request an extension of time, but there will be no price variation for such a delay. Contractor's insurance should cover for such eventuality.	
CP6	Damage to Dam's structural integrity during flooding	• The construction of works will need to be undertaken and sequenced such that there is no increased risk of damage to overall dam structure as a result of flooding during the construction works (in accordance with NSW Dam Safety Requirements • Temporary structures must be able to be removed quickly to ensure they do not restrict spillway flow capacity in-situ or through failure, if flooding occurs	

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
		• Independent certification of coffer dam and instream structures will be required	
CP7	Dam Safety Procedures	• There will need to be an interim Dam Safety Emergency Plan (approved by the NSW DSC) for the construction period taking into account the changed conditions and operation of the dam during the works. • The Contractor will need to comply with DSEP requirements and the Principal will be in charge of DSEP activities.	• Interim DSEP to be prepared by PWA at conclusion of design
CP8	Water Release	• Contractor will need to be conscious of resulting sprays, odours and other associated consequences. • Releases may occur with limited warning.	
CP9	Contamination of water	• Contamination of water could result in the Principal being unable to continue to provide water supply to the Shire - which is an unacceptable outcome. • The Contractor will need to use appropriate controls and systems to ensure no issues and will need to manage risk of pollution from the works due to flooding events also.	
ADDITIONAL RISKS IDENTIFIED			
A1	Hydrographic Survey		• Council considering getting a hydrographic survey now to determine silt build-up because it will be harder to do when dam is deeper.
A2	Existing Concrete Face Condition		• Concrete face wall detailed inspection – Considering doing this now to determine useful life of concrete, condition and alignment. It will be harder to do when deeper and we won't see this concrete anymore. PWA to provide details of suggested diving consultant. Suggest using remotely operated vehicle (ROV).
A3	Concrete Admixtures		• Concrete specification needs to ensure cheaper additives do not compromise the quality of the concrete. Need to let contractor know early about % of additives etc. allowed.
A4	Fish Passage		• Design options to mitigate fish passage will need to be included in environmental assessments if they have construction elements that are outside current study footprints
A5	Operational water quality management		• Flooding of vegetation has the potential to impact on water quality associated with rotting vegetation.
A6	De-stratification		• De-stratification requirements post-construction need further assessment and investigation.
A7	Flooding of aquatic vegetation		• Further exploration of opportunities such as habitat translocation, manipulating filling rates of dam post construction (if possible), construction of temporary farm dams for supplementary habitat. Action: • David Hannah to explore opportunities as part of flora and fauna assessment
A8	Flora and fauna study area		• Flora and fauna study will need to assess areas associated with extended embankments, new spillway, new access road and boat ramp design, construction ancillary areas etc. Public Works to provide general footprint of extent of works. David Hannah to provide scope of additional flora fauna assessment to Rob Siebert

CLARRIE HALL DAM RAISING - RISK MATRIX

No	Identified Risk/Issue	Initial Consideration/ Comment/ Strategy	Comments
A9	EIS requirements		• Additional requirements not planned or expected may have implications to project programming. e.g. biodiversity pathway may change
A10	Brief for site survey		• PWA to provide to Council. Survey plans to include property boundaries and existing services
A11	Communications on-site		• Ensure adequate communications on-site during the works - site has poor mobile phone coverage in certain locations at certain times
A12	Photography and videography		• Construction works should be recorded using photography and videography
A13	Amenities		• The contractor will need to provide own amenities as existing site amenities will be insufficient
A14	Site offices on adjoining land		• Contractor will need to identify early if site offices are required on adjoining land. Discuss with contractors at ETI stage
A15	Storage during construction		• Areas for storage will be required including storage of the pre-cast parapet walls before reinstatement on the raised crest.
A16	Filling rate after construction		• Filling rate will impact upon flora and fauna. Likely that storage will fill rapidly after raising. Valve releases will have little impact on storage if high flood inflows.
A17	Consultation with Lot 1 DP118944		• This land owner is not to be approached. Current ongoing issue. Owners: Brian and Lesley Hill. Property on western side of CHD Road
A18	Blasting of rock		• Consider use of Non-Explosive Controlled Demolition Agent for rock excavation if geotechnical conditions are suitable. • Consider impact on existing adjacent structure • Vibration limits
A19	Stockpiling of materials		• Location, management, haul roads - needs to be determined early
A20	Concrete batching plant		• Location and approach needs to be determined early
A21	Existing rock cores		• PWA can view the old rock cores as part of their geotechnical assessments. Peter Haywood can arrange viewing at Bray Park.
A22	Loss of survey infrastructure surrounding the dam and the monitoring pins in the existing dam		• Many marks as possible need to be preserved to allow the existing survey control to be adequately connected to the new structure
A23	Changes in PWA staff on this project		• PWA staff has specialist knowledge of Clarrie Hall Dam due to involvement from the original and design and construction and in the spillway upgrade project. This experience should be retained on the project.

APPENDIX H

PROJECT COST ESTIMATE AND COST RISK ASSESSMENT

Clarrie Hall Dam Raising to RL70.0m (42,300ML)

Item	Description	P10	P50	P90	Risk Distribution	Expected Price	Comments
	Preconstruction						
1	Flood Hydrology	$48,620	$48,620	$48,620	Pert	$48,620	Completed
2	Survey	$70,103	$70,103	$70,103	Pert	$70,103	Completed
3	Flora and Fauna Studies	$190,000	$190,000	$190,000	Pert	$190,000	Engagement
4	Cultural Heritage	$128,000	$160,000	$240,000	Pert	$168,000	Engagement but will be subject to additional costs
5	Environmental Flows	$152,000	$190,000	$210,000	Pert	$187,000	Engagement of K Bishop, P Cloke and EcoLogical. May go to $210,000
6	Concept Design	$794,000	$794,000	$794,000	Pert	$794,000	NSW PW engagement
7	Preliminary Environmental Assessment	$80,000	$100,000	$100,000	Pert	$96,667	To be done internally. Cost not expected to exceed $100,000
8	Application for SEARS	$16,000	$20,000	$20,000	Pert	$19,333	To be done internally. Cost not expected to exceed $20,000
9	Agency Consultation	$16,000	$20,000	$20,000	Pert	$19,333	To be done internally. Cost not expected to exceed $20,000
10	EIS Consultant	$640,000	$800,000	$1,200,000	Pert	$840,000	Engagement of consultant to do the EIS incl of further studies beyond those above if needed
11	Exhibition and Workshops	$16,000	$20,000	$30,000	Pert	$21,000	Public advertisement, production of documents etc
12	Response to Submissions Report	$48,000	$60,000	$90,000	Pert	$63,000	Engagement of consultant to prepare the Response to Submissions
13	Determination	$16,000	$20,000	$30,000	Pert	$21,000	Admin costs for sending to Minister etc
14	Planning Approvals	$32,000	$40,000	$60,000	Pert	$42,000	To be completed by Designer
15	Detailed Design	$960,000	$1,200,000	$1,800,000	Pert	$1,260,000	PWA Assessment (would include some further geoech) NSW PWA can provide estimates
16	Project Management	$320,672	$373,272	$490,272	Pert	$384,006	Assume 10%
17	Contingency	$320,672	$746,545	$1,470,817	Pert	$796,278	Range of contingency assumed; 10% - 20% - 30%
	Total Pre Construction	**$3,848,068**	**$4,852,540**	**$6,863,812**		**$5,020,340**	
	Construction						
18	Establishment	$725,000	$1,450,000	$2,900,000	Pert	$1,570,833	Includes Site Estab, disestablishment, flood protection, dewatering, Env mngt during construction
19	Clearing, Diversion and foundations	$500,000	$1,000,000	$2,000,000	Pert	$1,083,333	included in items 42 and 43 based on PWA estimate
20	Embankment construction	$5,600,250	$7,467,000	$8,960,400	Pert	$7,404,775	from PWA estimate
21	Spillway and outlet works	$12,000,000	$16,400,000	$20,000,000	Pert	$16,266,667	$16,400,000 (spillway) + $1,800,000 (intake tower) from PWA estimate
22	Intake Tower	$1,600,000	$1,800,000	$2,200,000	Pert	$1,833,333	from PWA estimate
23	Fish Elevator	$0	$0	$0	N/A	$0	As per page 18 of the Fine Screen Report, it is assumed that is is unlikely that a fishway would be required.
24	Dam Services	$400,000	$600,000	$1,000,000	Pert	$633,333	Ok. This cost may include any adjustment to current outlet valves operation and power requirements
25	Relocation of services/roads etc	$1,200,000	$1,600,000	$2,000,000	Pert	$1,600,000	Suggest allow new right abutment road cost $1,400,000 from PWA estimate + say $200,000 for general services relocation
26	Contact Administration	$2,202,525	$3,031,700	$3,906,040	Pert	$3,039,228	from PWA estimate (10%)
27	Contingency	$4,845,555	$10,004,610	$21,483,220	Pert	$11,057,869	Range of contingency assumed; 20% - 30% - 50%
	Total Construction	**$29,073,330**	**$43,353,310**	**$64,449,660**		**$44,489,371**	
	Total Project	**$32,921,398**	**$48,205,850**	**$71,313,472**		**$49,509,712**	

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