TENTERFIELD CREEK DAM SAFETY UPGRADE

OPTIONS STUDY

Report Number: DC14010

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Executive Summary

Tenterfield Creek Dam is located on Tenterfield Creek approximately 2 km upstream of the town of Tenterfield. The original dam was a concrete gravity structure constructed by the Department of Public Works in 1930 to provide a storage capacity of about 830ML. The storage capacity was increased to 1,150ML in 1974 when the dam was raised by 1.83m and stabilised by a total of 97 post-tensioned ground anchors. Following dredging of the storage a further 240ML was recovered producing a total storage capacity of 1,390ML.

Previous stability assessments undertaken for the dam concluded that the dam did not satisfy the Australian National Committee on Large Dam (ANCOLD) Guidelines for Stability of Gravity Dams and that the situation was likely to deteriorate given the questionable performance of the post-tensioning cables and on the grounds of continuing corrosion and demonstrated loss of load. Additionally, Tenterfield Creek Dam does not meet the current NSW Dams Safety Committee (DSC) requirements for flood handling capacity and hence Council is now faced with having to take substantial steps towards improving the stability of the dam to meet the requirements of the DSC.

Tenterfield Shire Council, as the dam owner, is committed to fulfil its obligations in ensuring the safety of Tenterfield Creek Dam to the relevant requirements of the DSC. As part of this objective, NSW Public Works has been engaged to pursue the following:

- Develop a minimum cost option for bringing Tenterfield Creek Dam up to current DSC requirements, addressing the flood security and structural stability issues with the dam.
- Provide a solution which aims to reduce the impact of the upgrade works on the existing dam’s function since Tenterfield Creek Dam serves as an important water supply function for the local community.

The dam strengthening options which have been selected (deemed feasible) fall into three categories:

- Option 1A: 37 new permanent 27-strand post-tensioned ground anchors (re-stressable, fully corrosion protected with expected design life of at least 100yrs)
- Option 2A: Mass concrete buttressing on the downstream side of the dam
- Option 3: Crest excavated to RL 876.605m (Lower FSL by 1.825m) plus 16 new permanent 27-strand post-tensioned ground anchors

It should be noted that the new permanent post-tensioned ground anchors, proposed for Option 1A, are different to the existing post-tension anchors which are non-restressable and are of the old style anchorage system which does not provide the same level of corrosion protection as the modern anchorage systems now provide. Modern post-tensioned ground anchors are re-stressable, are protected against corrosion by greased sheaths along the entire length, are cement grouted both inside and outside of the sheath and have an expected design life of 100yrs.

Table ES1 below summaries the total project costs (including non-construction intangibles and contingencies) for the options:

Table ES1: Summary of Options Cost Estimates

Option 1A Post-tensioning	Option 2A Concrete Buttressing			Option 3 Lower Storage
	Lower End of Range (Concrete $450/m3)	Middle of Range (Concrete $550/m3)	Upper End of Range (Concrete $650/m3)	
$5.4M	**$5.8M**	**$6.4M**	**$7.0M**	**$4.8M**

As can be seen from Table ES1 above a sensitivity assessment for the mass concrete rate (the cost of which dominates the estimate for concrete buttress strengthening options) has been provided.

Two short term (i.e. approximately 10 years) dam safety solutions (Options 1B and 2B) were also examined, however these options are not favoured since their costs are estimated to be 85% and 93% of the lowest cost long term (i.e. at least 100yrs) dam safety solution Hence, the cost to achieve only approximately 10 years of dam security is considered too high compared with achieving a 100 year solution for a slightly higher cost.

Of the long term dam safety solutions Option 3 can be discounted due to the significant storage loss which is associated with the option. The current storage capacity of the dam would be reduced from 1,390 ML to 740ML (loss of 650ML, 47%) which could significantly impact on Council's ability to provide water to the community in the future, particularly considering the predicted adverse effects of climate change. Option 3 would increase the risk of drought induced water shortages. Additionally, Option 3's estimated cost is still relatively high (89% of the next lowest cost long term dam safety solution) and, when considering the significant storage loss, it is not considered a good long term solution in terms of water supply functionality.

Of the two remaining options, Option 1A (post-tensioning) is the lowest cost solution. However, Option 2A (mass concrete buttressing) could be of similar cost (estimated within 7% of Option 1A) if concrete can be placed at the lower end of the expected cost range which has been presented. Hence Council has requested that both Option 1A (post-tensioning) and Option 1B (mass concrete) proceed to Concept, Detailed Design and Tender Stages to allow the market to reveal which option is in fact the lowest cost solution. Both Options provide feasible long term dam safety solutions for Tenterfield Creek Dam.

The main features of Option 1A are summarised below:

- Storage capacity unchanged
- 37 new x 27-strand permanent post-tensioned ground anchors
- Two new 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators (which are to be controlled by future telemetry system).

The main features of Option 2A are summarised below:

- Storage capacity unchanged
- 6,000m^3 of mass concrete generally sloped at 1V:0.8H on the downstream face.
- Two new 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators (which are to be controlled by future telemetry system).

- Demolition of the outlet pipe and construction of new outlet structure at the downstream toe of the extended dam footprint.

Sketches of the upgrade options are provided at Figure 2 to Figure 5 at Appendix A and full cost estimates are also provided at Appendix B.

It is not expected that there would be any environmental impediments to the project. This however is subject to environmental assessments.

Following the confirmation by Council that both Options 1A and 2A will be taken to tender, the development of the options to Concept and Detail Design stage will proceed.

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LIST OF APPENDICES

1 Introduction and Background

Tenterfield Creek Dam is located on Tenterfield Creek approximately 2 km upstream of the town of Tenterfield. The Flood Consequence Category of the dam is assessed as HIGH A according to NSW Dams Safety Guide Sheet DSC3A (2010). The original dam was a concrete gravity structure constructed by the Department of Public Works in 1930 to provide a storage capacity of about 830ML. The storage capacity was increased to 1,390ML in 1974 when the dam was raised by 1.83m and stabilised by a total of 97 post-tensioned ground anchors.

The dam consists of fourteen blocks/sections separated by vertical movement joints, in which nine of the blocks are post-tensioned with ground anchors. The raised dam has a maximum height of 15m and a crest length of 363 m. The dam has no stilling basin along the overflow section of the dam.

The dam's basic information is as follows:

Dam Owner:	Tenterfield Shire Council
Designed by:	Public Works Department
Constructed by:	Public Works Department
Year of completion:	1931 (original) & 1974 (modification)
Dam Type:	Post-tensioned anchored concrete gravity dam
Crest Length:	363 m
Maximum height:	15 m
Full supply level (FSL):	RL 878.4m
Capacity of reservoir:	1,390 ML
Type of spillway:	Free overfall
Spillway discharge capacity:	800 m^3/s
Spillway length at RL 878.4m:	192 m

In February 1997, lift-off tests were carried out on five of the 97 post-tensioned ground anchors at Tenterfield Creek Dam. The tests indicated loss of post-tensioning loads between 5.1% to 31.4% in the 5 anchors. A stability study of the dam was carried out taking into account the results of the lift-off tests, and Monte Carlo simulation techniques were used to study the variability of the stability factors of 3 chosen blocks of the dam at Chainages 466 ft, 635 ft and 1,000 ft (DPWS 1997).

In March 1998, an extended stability study of the dam was carried out in which the stability of all fourteen blocks of the dam was analysed, and the study went further to include a dam failure risk assessment (DPWS 1998).

In November 2009, a second round of lift-off tests was carried out on 12 post-tensioned ground anchors at Tenterfield Creek Dam (Structural Systems 2009). The NSW Dams Safety Committee (DSC) required Council to arrange for updating the stability study for Tenterfield Creek Dam taking into account the new lift-off test results.

A stability report presented in May 2012 concluded that the dam did not satisfy the ANCOLD Guidelines for Stability of Gravity Dams and that the situation was likely to deteriorate given the questionable performance of the post-tensioning cables and on the grounds of continuing corrosion and demonstrated loss of load (Black & Veitch 2012).

Additionally, Tenterfield Creek Dam does not meet the current NSW Dams Safety Committee (DSC) requirements for flood handling capacity and hence Council is now faced with having to take substantial steps towards improving the stability of the dam to meet the requirements of the DSC.

Tenterfield Shire Council, as the dam owner, is committed to fulfil its obligations in ensuring the safety of Tenterfield Creek Dam to the relevant requirements of the DSC. As part of this objective, NSW Public Works has been engaged to pursue the following:

- Develop a minimum cost option for bringing Tenterfield Creek Dam up to current DSC requirements, addressing the flood security and structural stability issues with the dam.
- Provide a solution which aims to reduce the impact of the upgrade works on the existing dam's function since Tenterfield Creek Dam serves as an important water supply function for the local community.

In general, NSW Public Works' engagement includes the following scope of works:

- Confirmation of initial project components
- Review of all previous reports and dam data
- Revision of the dam's flood hydrology
- Undertaking of an updated dambreak study and review of the dam's Consequence Category
- Development of options for upgrading the dam
- Concept design of the preferred option including cost estimation
- Detailed design and tender documentation.

The focus of this report is the development of options for upgrading the dam.

Revision of the dam's flood hydrology has been completed and a report was issued (WRM September 2013).

An updated Dambreak and Probable Loss of Life (PLL) Study was undertaken in accordance with DSC guidelines and the final version of the report was issued in January 2014 which appended the Hydrology Report (NSW Public Works 2014). The report concluded that the assessments for Tenterfield Creek Dam remained HIGH B for the Sunny Day Consequence Category and HIGH A for the Flood Consequence Category.

In accordance with DSC requirements, the dam is therefore to be upgraded to withstand the PMPDF (Probable Maximum Precipitation Design Flood) and the 1 in 5,000 AEP Maximum Design Earthquake.

This report presents feasible options for upgrading Tenterfield Creek Dam to comply with current DSC guidelines. The options have been developed taking into account updated hydrological and geological considerations as well as condition assessment of the existing structure.

The existing dam arrangement is shown on Figures 1 and 2 at Appendix A and on the 1974 WAE drawings which are provided at Appendix D. Sketches of the upgrade options are provided at Figure 2 to Figure 5 at Appendix A and full cost estimates are also provided at Appendix B.

Following selection of a preferred dam option, it is intended that a more comprehensive Concept Design Report will be produced for the most suitable arrangement.

2 Flood Hydrology

2.1 1996 Flood Hydrology

A hydrology study was carried out by the NSW Department of Public Works in 1996. The analysis followed appropriate methodology given in Australian Rainfall and Runoff, 1987. The analysis was also based on the works undertaken by the Hydrology Group for the 1995 Flood Estimated for Tenterfield Dam. The analysis provides peak inflows for floods with AEP's ranging from 1 in 10 years and 1 in 10^6. The maximum flood inflow independent of storm duration is summarised at Table 2-1 below:

Table 2-1 Summary of Peak Inflows

AEP (1 in x)	Maximum Inflow (independent of storm duration) (m^3/s)
50	118.4
100	150.8
2,000	386.7
50,000	1,020
1,000,000	1,808

2.2 2013 PMF Estimates

As part of design studies currently undertaken by NSW Public Works to upgrade Tenterfield Creek Dam, an estimate of the Probable Maximum Flood (PMF) inflows has been made. These inflows are provided in the Hydrology Report, (WRM 2013).

The Probable Maximum Flood (PMF) discharges along Tenterfield Creek and its tributaries have been estimated using the RORB model which was calibrated and verified against the January 2011 and February 2001 flood events respectively. The calibrated RORB routing parameters (kc =16 and m=0.8) were used for the PMF discharge estimation.

A zero initial loss and a continuing loss rate of 2.5 mm per hour were assumed for the PMF estimation. A sensitivity analysis was also carried out using a continuing loss rate of 1 mm per hour but the results were found to not be sensitive to the adopted continuing loss rate.

Based on the latest hydrological studies, the peak inflow for Tenterfield Creek Dam is 1,199 m3/s which is for a 2 hour critical duration storm.

2.3 Flood Routing Studies

2.3.1 Existing Spillway Arrangement Flood Routing Results

As part of the dambreak and PLL study undertaken by NSW Public Works (2013), the PMF was routed through the storage to determine the Maximum Flood Level (MFL) (Note that the PMF has been adopted for the design flood in lieu of the PMPDF for a High A consequence category dam). As verification, the PMF was re-routed independently using in-house software known as FLROUTE. The two methods produced the same result. The storage capacity curve and spillway discharge rating curve used for the flood routing study are shown at **Figure 2-1** and Figure 2-2 respectively. The spillway rating curve, which was developed and calibrated by DHI (2014) has also verified independently as part of this study. It was found that a discharge co-efficient of 1.85 for all spillway levels produced the same discharge from the dam as when routed using the rating curve developed by DHI (2012).

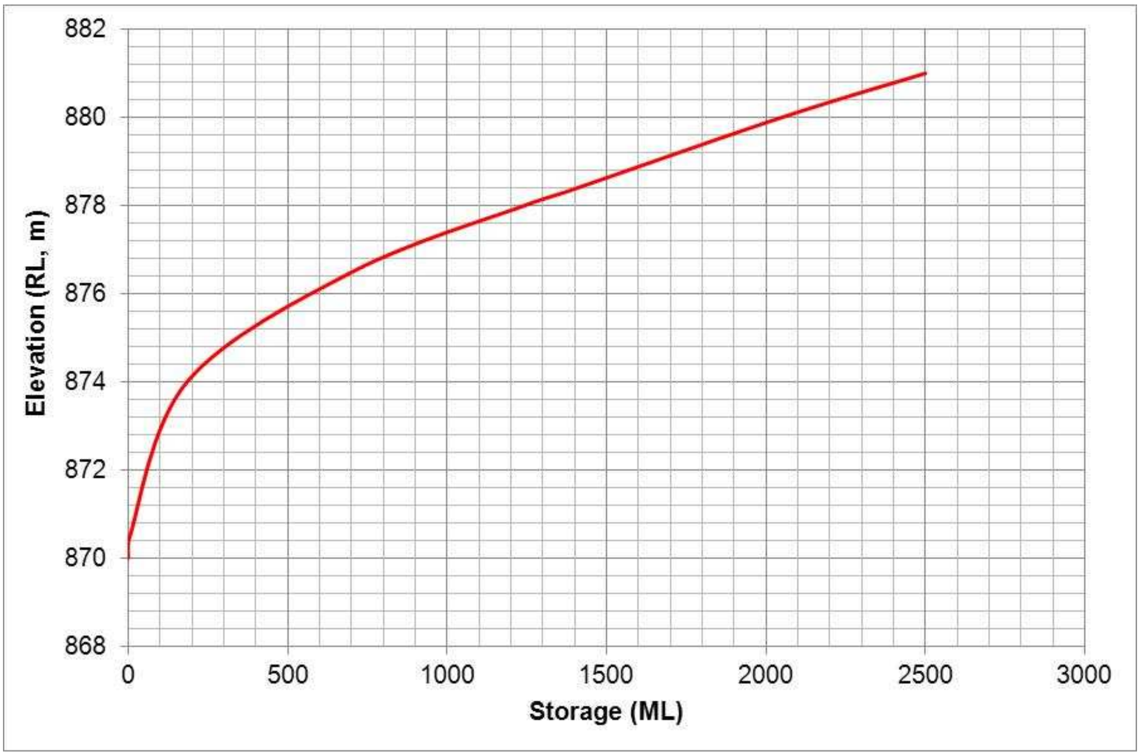


Figure 2-1: Tenterfield Creek Dam Storage Capacity (NUWS, 2014)

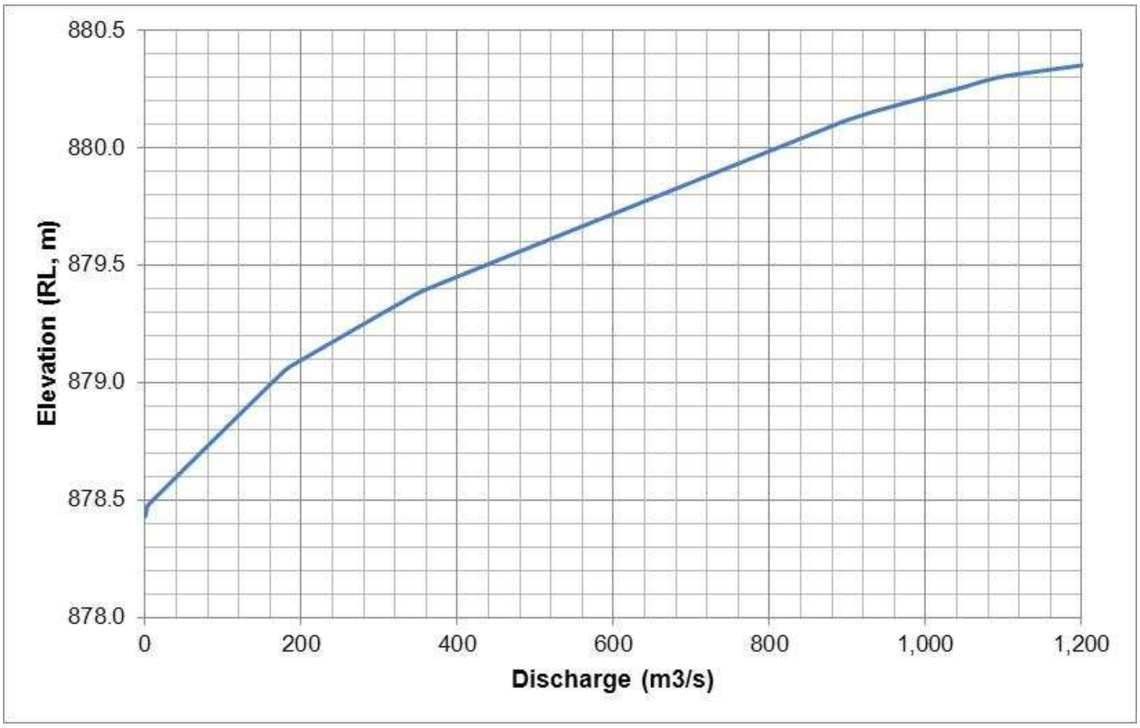


Figure 2-2: Tenterfield Creek Dam Spillway Discharge Rating Curve (DHI, 2012)

The existing Full Supply Level (FSL) of the dam is at RL878.43m. The results of the latest flood routing studies with the above data for the PMF design flood are summarised at below.

Table 2-2 Flood Routing Results for Design Flood (Existing Dam Spillway Arrangement)

Flood	Storm Duration (hrs)	Inflow (m3/s)	Outflow (m3/s)	DFL (RL, m)	Time to Peak (hrs)
PMF (in lieu of PMPDF)	2.0	1,199	1,201	880.35	1.9

Note from Table 2-2 above that the design flood level is RL 880.35m which is approximately 0.24m above the right abutment level and 0.09m above the left abutment level. Therefore, there will be some small overtopping of the dam rock abutments. This has been discussed with NSW Public Works Senior Engineering Geologist and he has indicated that the rock would be expected to handle such overtopping without significant erosion and does not see it as an issue for dam safety especially when considering the frequency of such a rare flood event.

2.3.2 Option 3 (Crest Lowered) Flood Routing Results

In order to assess the flood loading associated with a lower main overflow crest (Option 3), the design flood was routed through the dam with the Option 3 spillway configuration. The results are summarised at Table 2-3 below:

Table 2-3 Flood Routing Results for Design Flood (Existing Dam Spillway Arrangement)

Flood	Storm Duration (hrs)	Inflow (m3/s)	Outflow (m3/s)	DFL (RL, m)	Time to Peak (hrs)
PMF (in lieu of PMPDF)	2.0	1,199	1,195	878.84	1.9

The Full Supply Level (FSL) of the dam for Option 3 is at RL878.84m.

3 Dam Break Studies and Consequence Classification

3.1 Background

A Dam break study was prepared on behalf of Tenterfield Shire Council by the NSW Public Works Department in 1996. From this study it was recommended that the consequence classification for the dam be designated as HIGH for incremental and sunny day dambreak flooding.

The Dams and Civil Section of NSW Public Works was engaged by Tenterfield Shire Council to carry out a revised Dambreak Study and Probable Loss of Life (PLL) Study for Tenterfield Creek Dam in 2013. The following flood scenarios were examined:

1. Sunny Day Dambreak (SDDB);
2. Dam Crest Flood (DCF);
3. DCF Dambreak (DCFDB);
4. PMF; and
5. PMF Dambreak (PMFDB).

In October 2012, Council engaged DHI to carry out a Flood Study for Tenterfield. The study examined a range of flood events from the 1 in 10 AEP event to the Probable Maximum Flood (PMF) event. Information from that study was used to assist with the analysis carried out for the Dambreak and PLL Study.

The main objectives of the study were to determine the existing Sunny Day and Flood Consequence Categories for Tenterfield Creek Dam. These Consequence Categories allowed the Maximum Design Earthquake (MDE) and the Acceptable Flood Capacity (AFC) to be established for the dam.

3.2 Revised Dambreak Study

The Table 3-1 and Table 3-2 summarise the PAR and PLL estimates from the 2013 dambreak and PLL study, which include non-itinerants and itinerants identified along the floodplain downstream of the dam.

Table 3-1 Population At Risk (PAR) Estimates

Event	Sunny Day	DCF	PMF
Total Dambreak PAR	99	451	533
No Dambreak PAR		301	383
Incremental PAR		150	150

Table 3-2 Probable Loss of Life (PLL) Estimates

Event	Sunny Day	DCF	PMF
Total Dambreak PLL	2.34	16.43	22.55
No Dambreak PLL		0.21	0.71
Incremental PLL		16.22	21.84

With the above PLL estimates, the dam's Consequence Categories, MDE and AFC of the dam were determined in accordance with DSC's Publication 3A, 3B and 3C.

Table 3-3– Assessed Dam Consequence Categories and Catering Capacities

Consequence Category	Design Event Capacity
SDCC* = HIGH B	MDE = 1 in 5,000 AEP Earthquake
FCC# = HIGH A	AFC = PMPDF*

*PMF has been used in lieu of PMPDF as expected to be very minor differences beaten floods.

Tenterfield Creek Dam has been assessed at HIGH B for the Sunny Day Consequence Category and HIGH A for the Flood Consequence Category

4 Geology and Material Assessments

An initial inspection of the Tenterfield Creek Dam site was made by NSW Public Works geologists in July 2013. Variable foundation conditions were observed across the valley, leading to a proposal to map different rock zones and record the character of the foundation within each zone. Geological mapping for this second phase of fieldwork was carried out in November 2013. Results have been reported in the Geotechnical Assessment of Foundation Conditions (NSW Public Works, 2014).

4.1 Regional Geology

The Tenterfield area is located on a number of granitic intrusions, interpreted to be Permian in age. Tenterfield Creek Dam and its storage area are located on Bungulla Porphyritic Adamellite (Pab) comprising a very coarsely porphyritic feldspar and spheneric h adamellite. An unnamed granite porphyry (Pp) forms the adjacent higher ground towards the east and north.

4.2 Foundation Geology

Foundation mapping at the Tenterfield Creek Dam site has shown three areas of distinctly differing foundation conditions, as exposed on the surface, including:

- from the start of the spillway section (Ch. 130') to the base of the right abutment (~Ch. 490'), in jointed, slightly weathered, biotitic adamellite of medium to coarse grainsize,
- the valley base and lower left abutment (to ~Ch. 796') in extremely widely jointed slightly weathered and fresh (stained) biotite adamellite, and
- the middle to upper left abutment in extremely widely jointed, highly weathered and moderately weathered biotite adamellite with pegmatitic feldspar phenocrysts, alternating with very widely to extremely widely jointed, slightly weathered biotite adamellite.

Right Abutment (Ch. 0 – 490')

The exposed adamellite in the downstream portion of the foundation trench is predominantly slightly weathered, with some lesser quality seams; however, at the concrete/foundation contact, the foundation rock is interpreted to be (blue) slightly weathered or less weathered rock. The rock substance strength is interpreted to be very strong.

Valley Base to Middle Left Abutment (Ch. 490' – 796')

The exposed adamellite, and some pegmatitic adamellite, at the downstream toe is predominantly fresh (stained); however, at the concrete/foundation contact, the foundation rock is interpreted to be fresh (stained) to fresh. The rock substance is interpreted to be very strong.

Middle and Upper Left Abutment (Ch. 796' to end)

The exposed biotite adamellite, and some pegmatitic adamellite, at the downstream toe is variably weathered. The pegmatitic adamellite is highly/moderately weathered, while the biotite adamellite is predominantly slightly weathered. The rock substance is interpreted to be very strong.

An area of lesser quality foundation was identified during the 1972 construction. The existing dam wall was demolished between Ch's 938' and 997' and the foundation deepened to sound rock to provide a foundation for a gravity section of wall. This deep foundation excavation, (as shown on

1972 foundation photographs) suggests that the foundation is predominantly on slightly weathered rock. The rock substance is interpreted to be very

4.3 Rock Mass Strength

Rock strength parameters are discussed in the Geotechnical Assessment of Foundation Conditions (NSW Public Works, 2014). These parameters have been incorporated in the stability analyses of alternative upgrade options as discussed in following Sections of this report.

4.4 Concrete Strength

Two discarded core samples of concrete from previous anchor cable installation have been tested for unconfined compressive strength (UCS), including Young' Modulus and Poisson's ratio.

A summary of results is tabulated below.

	Sample 1	Sample 2
Length/Diameter Ratio	1.5	2.0
Uniaxial Compressive Strength (MPa)	42.2	29.1
Youngs Modulus (GPa)	30.9	28.0
Poisson Ratio	0.156	0.184
Wet Density (t/m3)	2.36	2.39
Moisture Content (%)	2.66	2.34

Adoption of concrete strength in stability analyses of alternative upgrade options is also discussed in following Sections of this report. It is noted that an Uniaxial Compressive Strength of 20 MPa was used in previous stability assessments of the dam (DPWS 1998).

4.5 Seismicity

A site specific review of the seismicity of Tenterfield Dam has not been carried out. However, the north eastern area of New South Wales is a seismically quiet area. Reviews of seismicity have been carried out at several dam sites in the general area of Tenterfield. The low seismicity of the area and relatively close locations of dams with completed seismicity assessments indicate that a new seismic assessment for Tenterfield Creek Dam is not required. Pindari Dam is the closest dam to Tenterfield Creek Dam and use of seismic assessments for this dam would be appropriate for Tenterfield. Refer Geotechnical Assessment of Foundation Conditions (NSW Public Works, 2014).

5 Dam Safety Upgrade Options Descriptions

5.1 General

In total 5 dam strengthening options have been considered. The options fall within two categories, as follows:

1. Long Term Dam Safety Solution – at least 100 years (assuming existing post-tensioning 0% effective)
2. Short Term Dam Safety Solution – approximately 10 years (assuming existing post-tensioning 50% effective)

This provides Council with a range of short and long term dam safety solutions and enables a sensitivity assessment to me made on the effect of the existing post-tensioning when considering its influence on upgrade options.

The dam strengthening options which have been selected (deemed feasible) fall into three categories:

- New permanent post-tensioned ground anchors (re-stressable, fully corrosion protected with expect design life of at least 100yrs)
- Mass concrete buttressing on the downstream side of the dam
- Lowering of the Full Supply Level in combination with some new permanent post-tensioned ground anchors

Typical arrangements for the three dam strengthening categories are shown at Figure 5-1, Figure 5-2 and Figure 5-3 below.

The 5 dam strengthening options are as follows:

Long Term Dam Safety Solutions – at least 100 years

- Option 1A: 37 New Permanent Post-tensioned Ground Anchors with Existing Dam Post-tensioning 0% Effective
- Option 2A: Mass Concrete Buttressing on Downstream Side with Existing Dam Post-tensioning 0% Effective
- Option 3: Crest Excavated to RL 876.605m (Lower FSL) plus 16 New Permanent Post-tensioned Ground Anchors

Short Term Dam Safety Solutions – approximately 10 years

- Option 1B: 25 New Permanent Post-tensioned Ground Anchors with Existing Dam Post-tensioning 50% Effective
- Option 2B: Mass Concrete Buttressing on Downstream Side with Existing Dam Post-tensioning 50% Effective

Other common strengthening options have also been considered but have not been pursued as they are either not consider feasible at Tenterfield Creek Dam or they are consider uneconomical when comparing with other options available for the dam. These options include:

- Rockfill buttressing
- Discrete reinforced concrete counterfort walls
- Auxiliary spillway
- Drainage holes in combination with other options

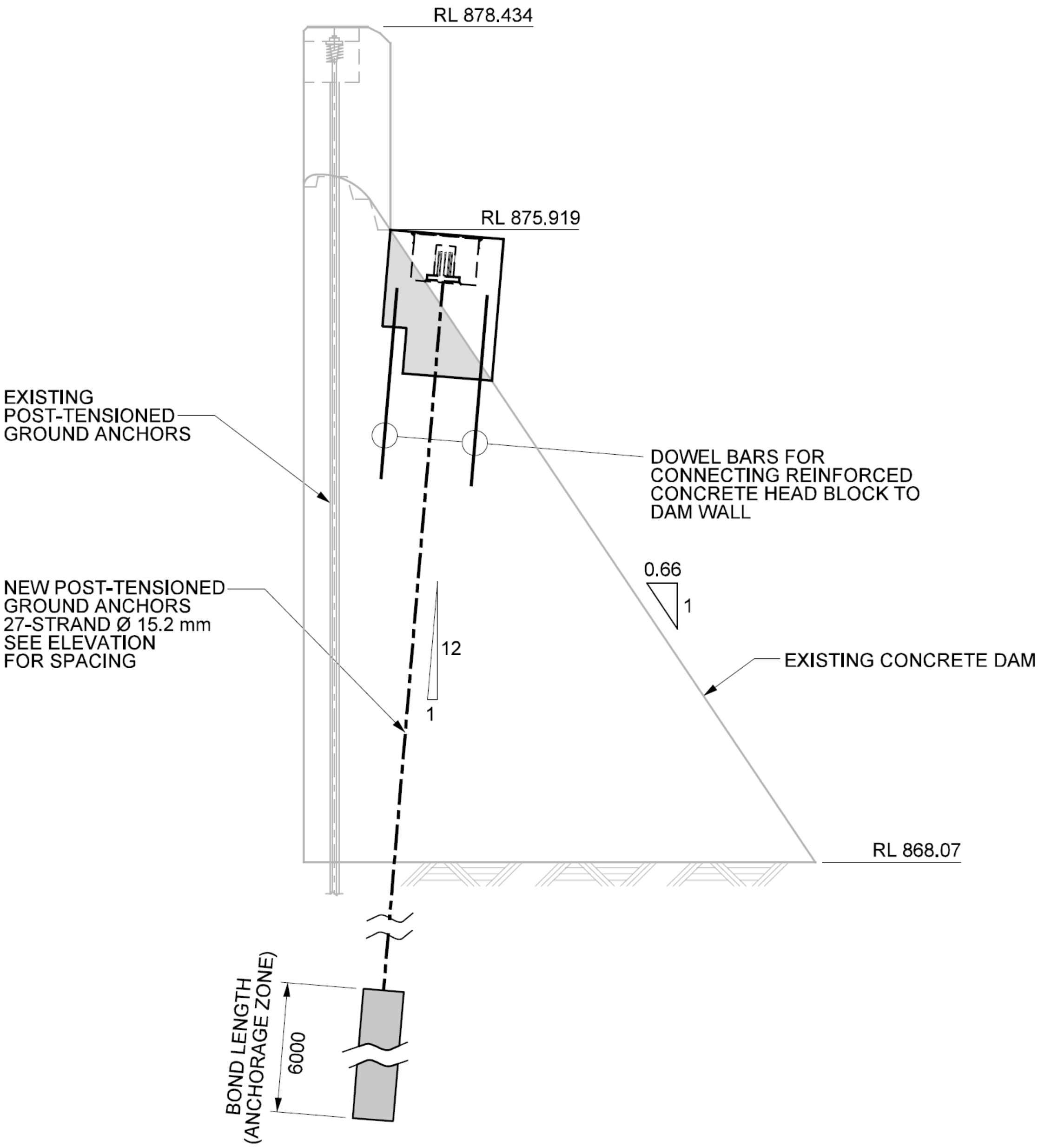


Figure 5-1 Option 1A and 1B Post-tensioning Arrangements – Typical Dam Cross-Section

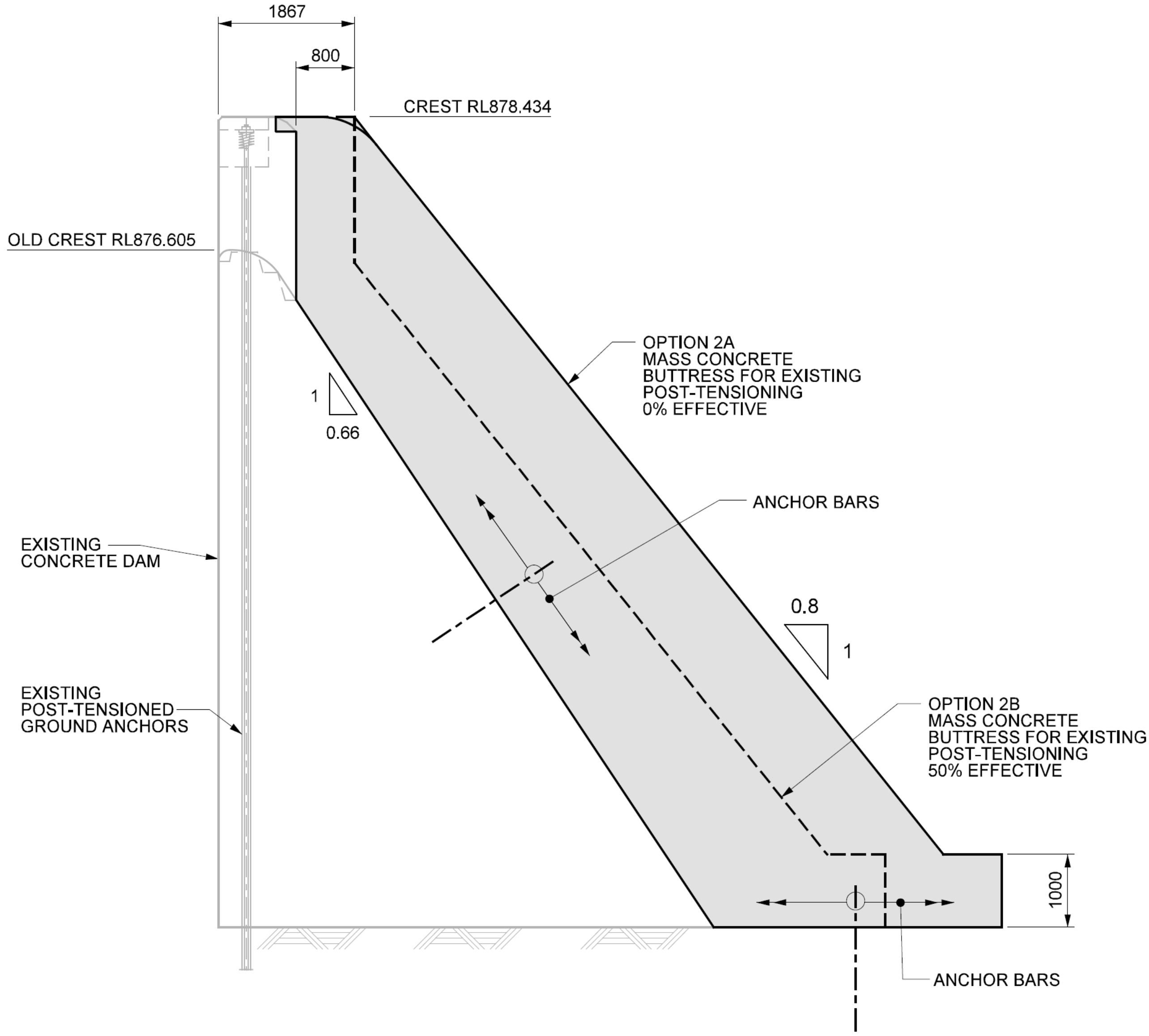


Figure 5-2 Option 2A and 2B Mass Concrete Buttressing Arrangements – Typical Dam Cross-Section

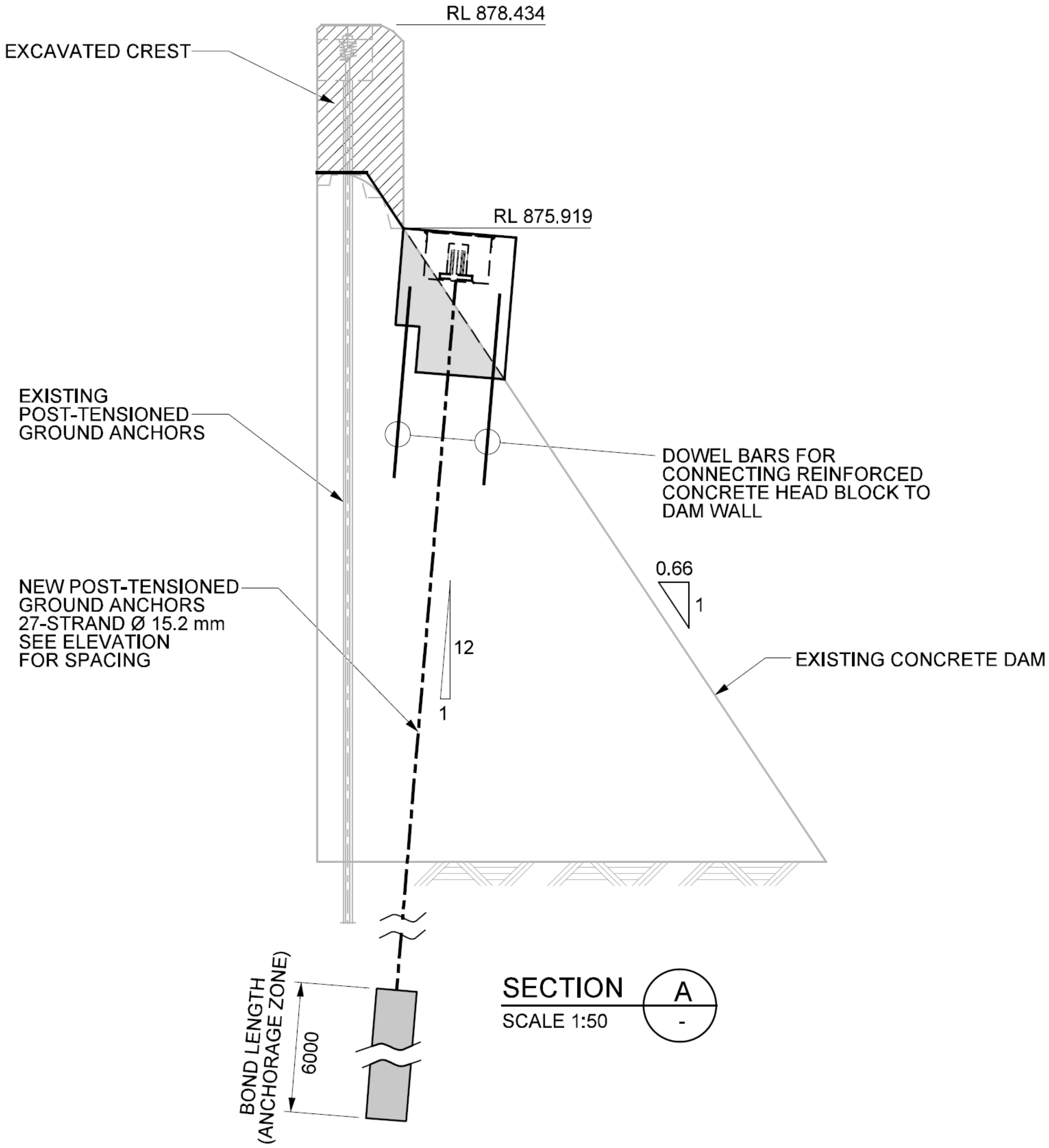


Figure 5-3 Option 3 Crest Lowering plus Post-tensioning Arrangement – Typical Dam Cross-Section

5.2 Long Term Dam Safety Solutions – At Least 100 years

5.2.1 Option 1A Description – Post-tensioning

Option 1A assumes the existing dam post-tensioning is 0% effective. This ensures that the dam safety upgrade solution will be effective for at least 100 years as the existing post-tensioning is not expected to perform adequately beyond another 10 years. The main option features are summarised below:

- Storage capacity unchanged, FSL 878.434, MFL 880.35
- 37 new x 27-strand permanent post-tensioned ground anchors
- Two new 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators (which are to be controlled by future telemetry system).

5.2.2 Option 2A Description – Mass Concrete Buttressing

Option 2A assumes the existing dam post-tensioning is 0% effective. This ensures that the dam safety upgrade solution will be effective for at least 100 years as the existing post-tensioning is not expected to perform adequately beyond another 10 years. The main option features are summarised below:

- Storage capacity unchanged, FSL 878.434, MFL 880.35
- 6,000m^3 of mass concrete generally sloped at 1V:0.8H on the downstream face.
- Downstream outlet house and pipework extend downstream
- Two new 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators (which are to be controlled by future telemetry system)

5.2.3 Option 3 Description – Lower FSL plus Post-tensioning

The main option features are summarised below:

- Storage capacity reduced from 1,390 ML to 740ML (loss of 650ML, 47%), FSL 876.605, MFL 878.84
- Central crest portion (201.85m length) excavated from RL 878.434m to RL 876.605m
- Outlet access bridge and tower lowered (existing bridge piers removed and new piers constructed. Bridge superstructure re-used)
- 16 new x 27-strand permanent post-tensioned ground anchors (for blocks 5 to 11)
- Existing post-tensioned anchors decommissioned in central portion of dam
- Two new 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators (which are to be controlled by future telemetry system).

5.3 Short Term Dam Safety Solutions – Approximately 10 years

5.3.1 Option 1B Description – Post-tensioning

Option 1B assumes the existing dam post-tensioning is 50% effective. Considering that the existing post-tensioning is already lost an average of 11% of load and a maximum of 30% of load, this option is expected to be effective for approximately 10yrs (the existing post-tensioning is not expected to perform adequately beyond another 10 years). The main option features are summarised below:

- Storage capacity unchanged, FSL 878.434, MFL 880.35
- 25 new x 27-strand permanent post-tensioned ground anchors
- Two new 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators (which are to be controlled by future telemetry system).

5.3.2 Option 2B Description – Mass Concrete Buttressing

Option 1B assumes the existing dam post-tensioning is 50% effective. Considering that the existing post-tensioning is already lost an average of 11% of load and a maximum of 30% of load, this option is expected to be effective for approximately 10yrs (the existing post-tensioning is not expected to perform adequately beyond another 10 years). The main option features are summarised below:

- Storage capacity unchanged, FSL 878.434, MFL 880.35
- 3,500m^3 of mass concrete generally sloped at 1V:0.8H on the downstream face.
- Downstream outlet house and pipework extend downstream
- Two new 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators (which are to be controlled by future telemetry system).

5.4 Selection of Preferred Option

This sub-section compares the upgrade options by assessing the advantages and disadvantages of the feasible options which have been assessed. Table 5-1 and
Table **5-2** summarise the total project costs (including non-construction intangibles and contingencies) for the options:

Table 5-1 Summary of Options Cost Estimates (Long Term Solutions)

Long Term Dam Safety Solutions (i.e. at least 100yrs)				
Option 1A Post-tensioning	**Option 2A Concrete Buttressing**			**Option 3 Lower Storage**
	Lower End of Range (Concrete $450/m3)	**Middle of Range (Concrete $550/m3)**	**Upper End of Range (Concrete $650/m3)**	
$5.4M	**$5.8M**	**$6.4M**	**$7.0M**	**$4.8M**

Table 5-2 Summary of Options Cost Estimates (Short Term Solutions)

Short Term Dam Safety Solutions (i.e. approximately 10yrs)	
Option 1B Post-tensioning	**Option 2B Concrete Buttressing (with Concrete $550/m3)**
$4.6M	**$5.0M**

Options 1B and 2B are short term dam safety solutions (i.e. approximately 10yrs) and are not favoured since their costs are estimated to be 85% and 93% of the lowest cost long term dam safety solution (i.e. at least 100yrs). Hence, the cost to achieve only approximately 10 years of dam security is too high compared with achieving a 100 year solution for a slightly higher cost.

Of the long term dam safety solutions Option 3 can be discounted due to the significant storage loss which is associated with the option. The current storage capacity of the dam would be reduced from 1,390 ML to 740ML (loss of 650ML, 47%) which could significantly impact on Councils ability to provide water to the community in the future particularly considering the predicted adverse effects of climate change. Option 3 would increase the risk of drought induced water shortages. Additionally, Option 3's estimated cost is still relatively high (89% of the next lowest cost long term dam safety solution) and when considering the significant storage loss it is not considered a good long term solution in terms of water supply functionality. Note that Option 3 requires a combination of crest lowering and post-tensioning. The post-tensioning was necessary to stabile the dam for the design flood (the design flood has been assumed to be the same as for the existing dam arrangement. The consequence category of the dam may however reduce as a result of a lower FSL. This would need to be assessed if the Option were to progress but has not been assessed at this stage because it is expected that Council would not tolerate storage capacity losses). To eliminate the need for anchors the storage would need to be lowered significantly more than the proposed 1.83m for Option 3 and this was not assessed as the associated loss of storage would not be acceptable to Council.

Of the two remaining long terms options, Option 1A (post-tensioning) is the lowest cost solution. However, Option 2A (mass concrete buttressing) could be of similar cost (estimated within 7% of Option 1A) if concrete can be placed at the lower end of the expected cost range which has been presented. Hence Council has requested that both Option 1A (post-tensioning) and Option 1B (mass concrete) proceed to Concept, Detailed Design and Tender Stages to allow the market to reveal which option is the lowest cost solution.

When assessing the remaining life of the dam in light of the post-tensioning and concrete buttressing options, it is considered likely that it would be the existing dam concrete (which is 84 years old) and not the new concrete or new anchors that would govern the dam's remaining life. From visual inspections during recent site visits the existing concrete appears to be in satisfactory condition considering the dams current age. For the purposes of comparing strengthening options, it has been considered that the post-tensioning and concrete strengthening options have the same expected asset remaining life which would be governed by the existing dam concrete.

Option 1A (post-tensioning) will require some ongoing monitoring and maintenance with some cost associated. The post-tensioned anchors would need to be monitored approximately 5 years after construction and then every 10 years thereafter. Since, the anchors are restressable and some small loss of load over time is expected, the anchors will need to be restressed if found be below design load during monitoring. The cost associated with monitoring and restressing would be in the order of a $50K every 10 years.

During the site inspections of the dam by NSW Public Works personnel, it was noted that there is some dam seepage which accumulates along the toe of the dam particularly in the central portion of the dam. Since the buttress options require widening of the dam footprint in the downstream direction, this seepage may present some construction difficulties where excavation to foundation level along the toe is required. This may lead to some additional costs for dewatering works along the toe during construction.

6 Stability Assessments

6.1 General

The stability analysis has been carried out using an in-house program called DAMSTAB. The program calculates the stress distribution and shear friction factors at various levels within the dam wall and at the foundation considering the dam as a series of 2D cantilevers.

The existing concrete dam is made up of 14 individually constructed blocks of concrete. Three blocks have been selected and modelled on a per-metre unit length basis. Section 6.2 outlines the blocks which have been analysed and discusses the rational of their selection.

For post-tensioning upgrade options, the post-tensioned forces (PTF) were applied as a concentrated force to the block and modified until an acceptable factor of safety for sliding and/or an acceptable amount of cracking was reached. The number of anchors required to provide the resultant PTF was then calculated.

6.2 Sections Analysed

Table 6-1 below summaries the details for the three blocks which have been analysed for this option study. The blocks which have been selected cover the critical features of the dam in terms of post-tensioning, wall height and foundation conditions. The analysis of the three blocks selected for this study is considered sufficient for the development, costing and comparison of dam upgrade options for Tenterfield Creek Dam.

Table 6-1: Summary of Blocks Analysed

Block	Chainage (ft)	Comments
6	466	- Maximum dam height; - 14.8 m from crest to dam foundation interface; - 9.5 m from crest to ground surface at downstream face of dam; - Dam block founded on partly weathered blue granite with sandy seams
8	635	- Maximum exposed dam height; - 10.7 m from crest to dam foundation interface; - 10.3 m from crest to ground surface at downstream face of dam; - Dam block founded on hard solid granite
12	1000	- Left abutment unit without post-tensioned anchors; - 6.8 m from crest to dam foundation interface; - Dam block keyed into sound granite

6.3 Load Cases

In terms of the ANCOLD guidelines on Design Criteria for Concrete Gravity Dams (2013), typical load cases are split into three categories, based on the likelihood of occurrence, allowing different acceptance criteria to be applied to each category. The three categories are: usual, unusual and extreme. In order to assess upgrade options, only the extreme flood load case has been examined for this study. Previous stability analysis studies undertaken for Tenterfield Creek Dam indicate that the extreme flood load case (which is the PMPDF) is most critical in terms of overall stability compared to all other load cases, including the seismic load case (MDE - 1:5,000 AEP). Assessment of upgrade options based on upgrade requirements for the flood loading case is therefore considered acceptable for this study. All load cases will be need to be examined at the concept design stage.

The updated dambreak and probable loss of life (PLL) study (2013) determined that the dam had a HIGH A flood consequence category. A HIGH A flood consequence category requires that the spillway is able to handle the PMPDF (maximum design flood). The 2013 dambreak and PLL study used the PMF and since there is expected to be very little difference between the PMF and the PMPDF, the PMF has been adopted for the design flood. The design flood was routed through the storage as part of the dambreak study and has been verified through further independent routings as part of this study. The critical 2hr duration PMF inflow, when routed through the storage, produces a design flood level of RL 880.35m.

Since the dam has a HIGH B sunny day consequence category, the DSC requires that the dam is able to safety pass the 1:5,000 AEP earthquake (MDE). No site specific seismicity study has been carried out for Tenterfield Creek Dam. Therefore, it is recommended that the seismic study for the nearby Pindari Dam (approximately 80km away) be adopted for the assessment of earthquake load cases. The 2013 geotechnical investigation by NSW Public Works also suggests that using the Pindari Dam seismicity study is acceptable considering that the dams are both located within a low seismic activity area and that due to their proximity, there would be little difference between the two dams in terms of seismic activity.

As indicated in the peer review comments for the Stability Study Report by Black & Veatch (2013), a range of floods between the 1 in 100year AEP event and the PMPDF should be examined (in terms of stability) to determine if the PMPDF is actually the most critical flood loading event for the dam. For the purposes of developing, costing and comparing upgrade options it is not expected that this assessment will have a significant impact on the selection of the preferred option. Hence, the assessment of the critical flood loading will be undertaken in the concept design stage, where the preferred option is refined/optimised.

6.4 Uplift Pressures

The uplift pressure distributions for the dam were calculated using the appropriate uplift pressure profile according to the ANCOLD (2013). Uplift distributions were modified in accordance with ANCOLD (2013) for the section cracked and uncracked cases. Note that the dam is undrained (no drainage holes) and hence uplift pressures are not relieved. This has significant impact on the stability of the dam in that strengthening requirements are more extensive than those which would be required if the dam drained (if the dam had drainage holes).

6.5 Crest Pressures

Sub-atmospheric pressures that act as a destabilising force on the overflow crest can occur during flood events, however it is expected that the lower nappe of the flow will separate at the downstream side of the crest during large flood events. Hence, it is expected that the crest would be naturally aerated and as such negative crest pressures would not develop.

6.6 Lateral Earth Pressure Assumptions

During the site inspection by NSW Public Works personnel on 4th July 2013 it was noted that the much of fill material, which previously existed along the toe of the dam, had been eroded away. Previous stability assessments by DPWS (now NSW Public Works) (1996, 1997, 1999) and Black and Veach (2013) examined the stability of the dam with the silt eroded and not eroded. Due to the new evidence of significant erosion of fill along the toe and the potential for further erosion in the future, the stabilising effect of fill has not been included in the analysis for this options study.

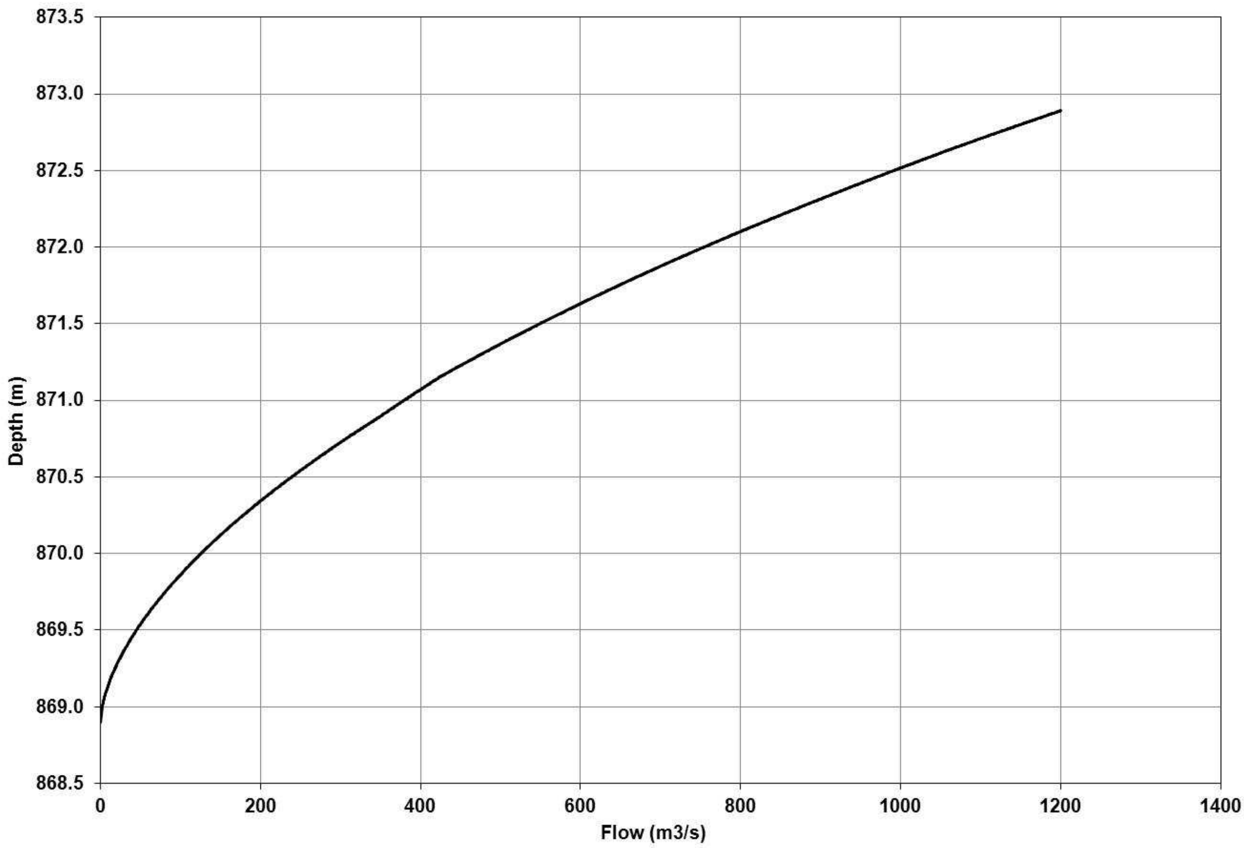
Silt deposited along the upstream side of the dam induces lateral pressure on the upstream face of the dam wall. The approximate silt level marked on the general elevation of the dam in Drawing No. 71112-1X (Appendix D) has been used to estimate the thickness of the silt deposit and corresponding lateral earth pressure loads. It is not expected that the level of silt against the upstream face has changed significantly since it was measured in the 70's.

6.7 Tailwater Levels

A tailwater rating curve was developed from the dambreak study model and is presented at

Figure 6-1 below.

Figure 6-1: Tenterfield Creek Dam Tailwater Rating Curve



From Figure 6-2 above it can be seen that the estimated tailwater level (TWL) in the downstream channel is RL872.8m for the maximum design flood outflow of 1,200m^3/s. The actual tailwater conditions along the toe of the dam may be different to the downstream channel water levels due to flow regime changes as energy dissipates, such as a hydraulic jump. Basic hydraulic calculations were undertaken as part of this study in order to try and determine the appropriate tailwater loading on the dam during the design flood event. The calculations indicate that a submerged hydraulic jump occurs downstream of the dam with a corresponding water level of approximately RL871m occurs against the downstream face of the dam for the design flood loading (DFL).

6.8 Existing Post-tensioning

Tenterfield Creek Dam was raised in 1974 at which time 97 post-tensioning ground anchors were installed. The anchors are therefore 40 years old. The Initial lock-off loads for the 97 post-tensioned ground anchors were recorded on Drawing No. 71112-7X (Refer to Appendix D). Tenterfield Council have had the post-tension ground anchors load tested on two occasions. In February 1997, loading tests were carried out on 5 of the 97 post-tensioning anchors whereas in November 2009, loading tests were carried out on 12 of the 97 post-tensioning anchors with retesting of one anchor at CH151.3ft. The anchor at CH151.3ft was lost permanently when a 3mm extension test was done on the anchor causing slippage of the anchor strands. The results of the loadings tests are summarised in Table 6-2 below.

Table 6-2: Summary of Post-tensioned Ground Anchor Load Testing

Chainage (ft)	Initial lock-off load (Drg. 71112-7X) (kN)	Load Tests					
		February 1997			November 2009		
		Measured Load	Drop in Load		Measured Load	Drop in Load	
			% loss	kN		% loss	kN
151.3	1423	1323	7.0	100	1383		40
216.0	1557	1406	9.7	151			
229.3	1601				1375	14.1	226
281.5	1557				1403	9.9	154
311.6	1601				1497	6.5	104
350.2	1624				1476	9.1	148
389.3	1646	1510	8.3	136			
407.1	1610				1392	13.5	218
437.3	1624				1430	11.9	194
478.2	1579				1463	7.3	116
522.0	1570				1586	-1.0	-16
609.1	1566				1246	20.4	320
617.0	1566	1074	31.4	492			
640.9	1575				1338	15.0	237
911.2	1526	1447.5	5.1	78.5			
923.0	1566				1407	10.2	159
		Mean	12.3	191.5	Mean	10.6	158.3
				Overall	Max	31.4	492
					Mean	11.15	177.1

As can be seen in Table 6-2 above, the average drop in anchor load for the anchors tested is approximately 11% and the maximum loss in anchor load is approximately 31%.These losses are significant.

The existing post-tension anchors are non-restressable and are the old style anchorage system which does not provide the same level of corrosion protection as the modern anchorage systems now provide. Modern post-tensioned ground anchors are re-stressable, are protected against corrosion by greased sheaths along the entire length, are cement grouted both inside and outside of the sheath and have an expected design life of 100yrs.

As was outlined in the previous stability analyses by the then Public Works Department (now NSW Public Works) (1996), the existing anchorage system is now regarded by the manufacturer (VSL) as suitable only for temporary/short term conditions. The manufacturer will not guarantee performance of the system against corrosion for beyond a 5 year period following instillation.

Since the anchors are now 40 years old and considering the current loss of load it is not expected that the current anchorage system will perform adequately beyond another 10 years.

6.9 Material Properties

6.9.1 General

Pells Sullivan Meynink Pty. Ltd. (PSM) undertook an assessment of the foundation strength parameters for Tenterfiled Creek Dam in 1998. The assessment was based on a site visit and examination of geotechnical information available for the dam including the dam upgrade construction works undertaken in 1974.

The PSM assessments provided “lower bound”, “best fit” and “upper bound” in accordance with the brief provided by the then Public Works Department (now NSW Public Works). This was to provide sufficient data for the risk based approach which was used to assess the dam failure risk (1999).

NSW Public Works were engaged to undertake a geotechnical investigation for Tenterfiled Creek Dam in 2013/2014. As part of that assessment, Two discarded core samples of concrete from previous anchor cable installation were tested for unconfined compressive strength (UCS), including Young’ Modulus and Poisson’s ratio.

The analyses carried out for this option study is undertaken with the standards based approach and hence lower bound strength parameters from PSM assessments the foundation and test results from the 2014 geotechnical investigation for concrete, have been adopted in combination with the appropriate acceptance criteria outlined in ANCOLD (2013).

The material properties adopted for the stability analyses are summarised in Section 6.9.2.

6.9.2 Summary of Material Properties

Table 6-3 summarises the key material strength parameters which have been used in the analyses. A concrete density of 2.4t/m^3 has been adopted, based on recent tests undertaken on two concrete cylinder samples found at the dam site (two samples: 2.39t/m^3 and 2.36t/m^3).

Table 6-3: Strength Parameters for Latest Analyses

Material	UCS (MPa)	Ø' (degrees)	C' (kPa)	T (kPa)	Comments
Concrete Lift Joint	25	45	0[1]	0	UCS based on 2 sample tests (2014). Shear strength parameters based on lower bound assumption for unbonded concrete lift joints (ANCOLD, 2013).
Concrete Rock Interface	10 (<CH490) 25 (≥CH490)	50	0	0	Based on PSM assessments and assuming the lower of concrete and foundation for UCS values.
Foundation Rock Mass (< CH490ft)	10	55	100	0	Based on PSM assessments
Foundation Rock Mass (≥ CH490ft)	100	64	1850	0	Based on PSM assessments
Foundation Joint (exfoliation joints)	10 (<CH490) 100 (≥CH490)	46	0	0	Based on PSM assessments

Notes: 1. Cohesion = 100kPa adopted for new concrete on buttress options (Options 2A & 2B).

6.10 Foundation Defects

Foundation defects (joint sets) need to be considered when analysing a dam in terms of overall stability as they provide a failure plane within the dam foundation. Near horizontal foundation joint sets are most critical since they provide a continuous plane for sliding and/or lift off during overturning of the dam. The following outlines the critical sub-horizontal foundation characteristics which were outlined in the recently completed geotechnical investigation (2013):

<u>Right Abutment (Ch. 0 – 490')</u>

- There is a near horizontal set (10º to 270ºM).
- Joints are planar to sub-planar, with smooth to semi-rough surfaces.
- Joints are moderately wide to widely spaced (0.2m to 2m)

Valley Base to Middle Left Abutment (Ch. 490' – 796')

- There is a near horizontal set of exfoliation joints (5^o to 105^oM)
- Joints are curved/irregular and outcrop surfaces may be drummy in places.
- Joints are very and extremely widely spaced, with some widely spaced (>2m some 0.6m to 2m)

Middle and Upper Left Abutment (Ch. 796' to end)

- Generally similar to "Valley Base to Middle Left Abutment (Ch. 490' – 796')" above.
- Joints are widely spaced to very/extremely widely spaced (0.6m to >2m)

The above findings suggest that sub-horizontal foundation joints are likely to be present within 0.2m of the base of the dam between chainages CH0' to C490' and within 0.6m of the base of the dam between chainages CH490' to the end of the dam. Therefore the analyses undertaken for this study assumes that a horizontal rock joint is located at the foundation of the dam and hence material parameters corresponding to the foundation joints have been used at this location rather than those for the foundation interface (as described in Table 6-3 above).

6.11 Stability Acceptance Criteria

6.11.1 General

ANCOLD (2013) has been adopted as the acceptance criteria for this study. It is considered the most up to date and appropriate guidelines for concrete gravity dams in Australia.

The MDF load case which has been analysed for this study has been assessed as an "Extreme" load case in accordance with the ANCOLD (2013).

6.11.2 Overturning Stability

The criteria adopted for stability against overturning is outlined below in accordance with ANCOLD (2013):

Position of resultant	=	within the base
Maximum foundation bearing pressure	=	1.5 x allowable
Maximum allowable compressive stress	=	0.8f'c

6.11.3 Sliding Stability

The stability analyses results have been assessed against criteria for peak strength scenarios based on C and Ø "well-defined" in accordance with ANCOLD (2013). The criteria adopted for stability against sliding is outlined in below:

Minimum factor of safety against sliding	=	1.3

6.12 Stability Analyses Results

6.12.1 General

These sub-section summaries the results for the stability analyses which have been undertaken for Tenterfield Creek Dam Safety Upgrade Options. For detailed analyses results refer to Appendix C.

6.12.2 Option 1A and 1B

In order to stabilise the dam for the maximum design flood loading it has been found that the following number of anchors are required for the respective options:

Option 1A (Long Term Safety Solution (i.e. at least 100 years)): Existing Dam Post-tensioning 0% Effective.

- 37 x 27-strand post-tensioned anchors are required.

Option 1B (Short Term Safety Solution (i.e. approximately 10 years)): Existing Dam Post-tensioning 50% Effective.

- 25 x 27-strand post-tensioned anchors are required.

The stability analysis results and post-tensioning requirements for Options 1A and 1B are summarised in Table 6-4 & Table 6-5 below. For detailed analyses results refer to Appendix C. The Option 1A arrangement is shown on Figure 3 at Appendix A.

Table 6-4: Option 1A & 1B Stability Analysis Summary

OPTION 1A & 1B - NEW POST-TENSIONING													
Block No.	**Block Chainages (m)**	**Length of Block (m)**	**PTF Required (kN/m)**	**Analysis Level Location**	**Critical Level of Analysis (RL mAHD)**	**Upstream Stress (kPa)**	**Downstream Stress (kPa)**	**Resultant Location with Theoretical PTF applied**	**Cracking Percentage (if applicable)**	**Minimum SFF with Theoretical PTF Applied**	**No. of 27 Strand Anchors Provided**	**PTF Provided (kN/m)**	**Comments**
Option 1A: Existing post-tensioning 0% effective													
6	391.5' to 481.5'	27.432	735	Concrete	just above 863.65	-18	314	Middle Half	9%	1.30	5	800	Post-tensioning requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	863.65					1.55			
				Foundation Joint	just below 863.65					1.35			
8	571.5' to 661.5'	27.432	550	Concrete	just above 868.38	-22	295	Middle Half	12%	1.30	4	640	Post-tensioning requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	868.38					1.55			
				Foundation Joint	just below 868.38					1.35			
12	928.75' to 1018.75'	27.432	28	Concrete	874.56	4	112	Middle Third	Nil	1.30	1	160	Post-tensioning requirements governed by minimum sliding factor of safety ≥ 1.3. Passive wedge included.
				Interface	873.56					2.46			
				Foundation Joint	just below 873.56					2.13			
Option 1B: Existing post-tensioning 50% effective													
6	391.5' to 481.5'	27.432	466	Concrete	just above 863.65	-7	309	Middle Half	4%	1.30	3	480	Post-tensioning requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	863.65					1.55			
				Foundation Joint	just below 863.65					1.35			
8	571.5' to 661.5'	27.432	332	Concrete	just above 868.38	0	273	Middle Third	Nil	1.30	3	480	Post-tensioning requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	868.38					1.55			
				Foundation Joint	just below 868.38					1.35			
12	928.75' to 1018.75'	27.432	28	As above, no existing post-tensioning for Block 12							1	160	Post-tensioning requirements governed by minimum sliding factor of safety ≥ 1.3. Passive wedge included.

Table 6-5: Option 1A and 1B Summary of Anchorage Requirements

Block No.	Start Chainage (ft)	End Chainage (ft)	Length (m)	Crest level mAHD	Deepest foundation level (mAHD)	Option 1A: Existing Anchors 0% Effective Number of New 27-strand Anchors Required	Option 1B: Existing Anchors 50% Effective Number of New 27-strand Anchors Required	Remark
1	-75	40.00	35.052	880.110	876.300	0	0	Parapet on sound rock.
2	40	130.00	27.432	880.110	876.300	0	0	Parapet on sound rock.
3	130	211.50	24.841	879.348	873.557	3	2	Block with P/T anchors, on weathered rock.
4	211.5	301.50	27.432	878.434	869.747	3	2	Block with P/T anchors, on weathered rock.
5	301.5	391.50	27.432	878.434	864.565	5	3	Block with P/T anchors, on weathered rock.
6	391.5	481.50	27.432	878.434	863.651	5	3	Block with P/T anchors, on weathered rock.
7	481.5	571.50	27.432	878.434	863.803	5	3	Block with P/T anchors, on weathered rock.
8	571.5	661.50	27.432	878.434	867.613	4	3	Block with P/T anchors, on sound rock.
9	661.5	751.50	27.432	878.434	867.156	4	3	Block with P/T anchors, on sound rock.
10	751.5	841.50	27.432	878.434	870.661	4	3	Block with P/T anchors, on sound rock.
11	841.5	928.75	26.594	879.043	872.642	3	2	Block with P/T anchors, on sound rock.
12	928.75	1018.75	27.432	880.262	872.185	1	1	Block without P/T anchors, on sound rock.
13	1018.75	1050.00	9.525	880.262	876.300	0	0	Block without P/T anchors, on sound rock.
14	1050	1110.00	18.288	880.262	878.738	0	0	Parapet on sound rock
				Total Number of Anchors		**37**	**25**	

Each anchor would comprise 27 x 15.2mm diameter super grade steel strands, with each strand having a minimum breaking load (MBL) of 250kN. These modern anchors are significantly better than the old style existing since they are fully restressable, corrosion protected along the entire length and have an expected design life of at least 100 years. 27 strand post-tensioned anchors have commonly been used for strengthening dams of the Tenterfield Creek Dam size and have been selected because they are the most appropriate size considering the range of post-tensioning requirements across the 14 blocks of varying height. Since the dam is separated into 14 separate discrete blocks the analysis assumes that each block is treated as an independent cantilevered member. From the original dam WAE drawings (Refer to Appendix D) it is noted that there is a movement joint between each block. Considering the potential for block joints to open up during cold weather, any distribution of load between blocks has been ignored for the analyses.

A working load of 0.65MBL (4,388kN per anchor) and bond length of 6m has been adopted for the post-tension anchors. The stresses associated with the above arrangement can be accommodated by the foundation.

Post-tensioning Anchorage Design

The anchorage depth for the post-tensioned cables into the foundation rock has been determined from the submerged density of rock in conjunction with 90^{o} inverted pull-out cones extending from the centre of the anchor bond length. The weight of each rock cone, including allowance for the overlap of cones, was compared to the minimum breaking load (MBL). The free length of each anchor and the corresponding submerged cone weight, have been made large enough to exceed the anchor MBL. The above method was basically adopted from an *Overview of Rock Anchorages,* by Littlejohn (UK University of Bradford, undated).

Cable bond lengths have been proportioned in accordance with Cavill (1997) conservatively assuming the foundation is weathered granite with joints spaced at between 0.3m (joints are typically spaced wider) and an ultimate bond strength between the grout and the rock is 2.5MPa. In accordance with the procedure the cable bond length has been proportioned for the design working load in the anchor (65% MBL) with a minimum FOS of 2 on the above ultimate bond strength. This approach produces a required bond length of 6m for the anchors.

Tensile Stresses on the Downstream Face

For Option 1A tensile stresses may be developed at the downstream face of the dam, with maximum stresses at approximately RL869.65m. This is because the post-tensioning provisions required to stabilise the dam assumes that the existing anchors are 0% effective, which will likely be the case at some point in the future, but currently the anchors have lost an average of 11% of load across the dam. Hence, initially the dam is over-stressed until such time as the existing anchors become ineffective. De-stressing of the existing anchors has been considered but it is expected that this would be very difficult and would result in additional cost.

Therefore calculations have been undertaken to ensure that the initial over-stressing can be accommodated by the dam. It has been assumed that the existing anchors are 100% effective for the assessment because it is possible that anchors of an individual block have not lost any load even though other anchors have been found to have lost load. This assumption is probably slightly conservative. The tensile capacity of the concrete lift joints has not been tested and hence zero tensile strength has been adopted for the analyses. Refer to Table 6-6 below of a summary of the maximum potential tensile stresses. It is possible that the dam concrete lift joints has sufficient tensile capacity to handle the stressed outlined below. However if there was a weak plane (lift joint) of concrete, the extent of cracking of the downstream face has been assessed with results also presented in Table 6-6 below.

Table 6-6 Possible Cracking at the Downstream Face (assuming existing anchors 100% effective and Option 1A post-tensioning)

Storage Condition	Max Tensile Stress	Percentage Cracking (Zero Tensile Strength)
Storage at Design Flood Level	Nil	Nil
Storage at Full Supply Level	125kPa	19%
Storage Dewatered	366kPa	48%

Note that if cracking were to occur on the downstream face there may be some minor spalling of concrete which may need to be repaired.

6.12.3 Option 2A and 2B

In order to stabilise the dam for the maximum design flood loading it has been found that the following mass concrete buttressing requirements are necessary for the respective options:

Option 2A (Long Term Safety Solution (i.e. at least 100 years)): Mass Concrete Buttressing on Downstream Side with Existing Dam Post-tensioning 0% Effective.

- 6,000m^3 of mass concrete generally sloped at 1V:0.8H on the downstream face.

Option 2B (Short Term Safety Solution (i.e. approximately 10 years)): Mass Concrete Buttressing on Downstream Side with Existing Dam Post-tensioning 50% Effective

- 3,500m^3 of mass concrete generally sloped at 1V:0.8H on the downstream face.

The stability analysis results for Options 2A & 2B are summarised at Table 6-7 below. For detailed analyses results refer to Appendix C. The Option 2A arrangement is shown on Figure 4 at Appendix A.

Table 6-7: Option 2A and 2B Stability Analysis Summary

OPTION 2A & 2B - MASS CONCRETE BUTTRESSING											
Block No.	**Block Chainages (m)**	**Length of Block (m)**	**Buttress Thickness at toe (m)**	**Analysis Level Location**	**Critical Level of Analysis (RL mAHD)**	**Upstream Stress (kPa)**	**Downstream Stress (kPa)**	**Resultant Location with Buttressing**	**Cracking Percentage (if applicable)**	**Minimum SFF with Buttressing**	**Comments**
Option 2A: Existing post-tensioning 0% effective											
6	391.5' to 481.5'	27.432	4.45	Concrete	just above 863.65	-8	198	Middle Half	8%	1.61	Buttressing requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	863.65					1.42	
				Foundation Joint	just below 863.65					≈1.3	
8	571.5' to 661.5'	27.432	3.81	Concrete	just above 868.38	-7	150	Middle Half	14%	1.57	Buttressing requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	868.38					≈1.3	
				Foundation Joint	just below 868.38					≈1.3	
12	928.75' to 1018.75'	27.432	0.50	Concrete	874.56	11	109	Middle Third	Nil	1.30	Buttressing requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	873.56					2.41	
				Foundation Joint	just below 873.56					2.78	
Option 2B: Existing post-tensioning 50% effective											
6	391.5' to 481.5'	27.432	2.85	Concrete	just above 863.65	41	191	Middle Third	Nil	1.57	Buttressing requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	863.65					1.54	
				Foundation Joint	just below 863.65					1.3	
8	571.5' to 661.5'	27.432	2.22	Concrete	just above 868.38	49	143	Middle Third	Nil	1.62	Buttressing requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	868.38					1.44	
				Foundation Joint	just below 868.38					≈1.3	
12	928.75' to 1018.75'	27.432	0.50	As above, no existing post-tensioning for Block 12							Buttressing requirements governed by minimum sliding factor of safety ≥ 1.3.

Buttress Stability Analysis Method

The analyses for mass concrete buttress options are based on a simplified analysis ignoring induced stresses in the existing dam section and assuming the complete modified base takes all the loading. This is considered satisfactory for these initial assessments in view of the relatively low magnitude of the compressive stresses compared to the compressive strengths of the concrete and foundation. If the option was to proceed, then a check on the stress distribution taking into account the loads on the existing dam and then the incremental loads on the raised dam separately would need to be undertaken. It is however expected that maximum foundation bearing stresses would not vary significantly from those calculated for this options study.

6.12.4 Option 3

In order to stabilise the dam for the maximum design flood loading it has been found that the following combination of crest lowering and post-tensioning is required:

Option 3 (Long Term Dam Safety Solution, i.e. at least 100yrs)

- Crest Excavated to RL 876.605m (Lower FSL)
- 16 x 27-strand post-tensioned anchors are required.

The stability analysis results and post-tensioning requirements for Options 3 are summarised at Table 6-8 & Table 6-9 below. For detailed analyses results refer to Appendix C. The Option 3 arrangement is shown on Figure 5 at Appendix A.

Table 6-8: Option 3 Stability Analysis Summary

OPTION 3 - CREST LOWERED TO RL 786.605 PLUS NEW POST-TENSIONING														
Block No.	**Block Chainages (m)**	**Length of Block (m)**	**PTF Required (kN/m)**	**Analysis Level Location**	**Critical Level of Analysis (RL mAHD)**	**Upstream Stress (kPa)**	**Downstream Stress (kPa)**	**Resultant Location with Theoretical PTF applied**	**Cracking Percentage (if applicable)**	**Minimum SFF with Theoretical PTF Applied**	**No. of 27 Strand Anchors Provided**	**PTF Provided (kN/m)**	**Comments**
Existing post-tensioning removed													
6	391.5' to 481.5'	27.432	425	Concrete	just above 863.65	-10	243	Middle Half	6%	1.31	3	480	Post-tensioning requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	863.65					1.55			
				Foundation Joint	just below 863.65					1.35			
8	571.5' to 661.5'	27.432	320	Concrete	just above 868.38	3	194	Middle Third	Nil	1.30	2	320	Post-tensioning requirements governed by minimum sliding factor of safety ≥ 1.3.
				Interface	868.38					1.55			
				Foundation Joint	just below 868.38					1.34			
12	928.75' to 1018.75'	27.432	Nil	Concrete	874.56	89	34	Middle Third	Nil	3.03	0	0	Nil post-tensioning required
				Interface	873.56					14.66			
				Foundation Joint	just below 873.56					12.69			

Table 6-9: Option 3 Summary of Anchorage Requirements

Block No.	**Start Chainage (ft)**	**End Chainage (ft)**	**Length (m)**	**Crest level mAHD**	**Deepest foundation level (mAHD)**	**Height (m)**	**Existing Anchors Removed Number of New 27-strand Anchors Required**	**Remark**
1	-75	40.00	35.052	880.110	876.300	3.810	0	Parapet on sound rock.
2	40	130.00	27.432	880.110	876.300	3.810	0	Parapet on sound rock.
3	130	211.50	24.841	879.348	873.557	5.791	0	Block with P/T anchors, on weathered rock.
4	211.5	301.50	27.432	878.434	869.747	8.687	0	Block with P/T anchors, on weathered rock.
5	301.5	391.50	27.432	878.434	864.565	13.868	3	Block with P/T anchors, on weathered rock.
6	391.5	481.50	27.432	878.434	863.651	14.783	3	Block with P/T anchors, on weathered rock.
7	481.5	571.50	27.432	878.434	863.803	14.630	3	Block with P/T anchors, on weathered rock.
8	571.5	661.50	27.432	878.434	867.613	10.820	2	Block with P/T anchors, on sound rock.
9	661.5	751.50	27.432	878.434	867.156	11.278	2	Block with P/T anchors, on sound rock.
10	751.5	841.50	27.432	878.434	870.661	7.772	2	Block with P/T anchors, on sound rock.
11	841.5	928.75	26.594	879.043	872.642	6.401	1	Block with P/T anchors, on sound rock.
12	928.75	1018.75	27.432	880.262	872.185	8.077	0	Block without P/T anchors, on sound rock.
13	1018.75	1050.00	9.525	880.262	876.300	3.962	0	Block without P/T anchors, on sound rock.
14	1050	1110.00	18.288	880.262	878.738	1.524	0	Parapet on sound rock
				Total Number of Anchors			**16**	

7 Cost Estimates

7.1 General

This section summarises the estimating methodology and construction costs for each for the dam upgrade options. The estimates are based on predicted construction and project costs as at February 2014.

Cost estimates have been developed for the upgrade options, as attached at Appendix B. The dam upgrade options are as follows:

- Option 1A: 37 New Permanent Post-tensioned Ground Anchors with Existing Dam Post-tensioning 0% Effective (Long Term Dam Safety Solution, i.e. at least 100yrs).
- Option 1B: 25 New Permanent Post-tensioned Ground Anchors with Existing Dam Post-tensioning 50% Effective (Short Term Dam Safety Solution, i.e. approximately 10yrs).
- Option 2A: Mass Concrete Buttressing on Downstream Side with Existing Dam Post-tensioning 0% Effective (Long Term Dam Safety Solution, i.e. at least 100yrs).
- Option 2B: Mass Concrete Buttressing on Downstream Side with Existing Dam Post-tensioning 50% Effective (Short Term Dam Safety Solution, i.e. approximately 10yrs).
- Option 3: Crest Excavated to RL 876.605m (Lower FSL) plus 16 New Permanent Post-tensioned Ground Anchors (Long Term Dam Safety Solution, i.e. at least 100yrs)

7.2 Rates

The estimates are based on NSW Public Work's database of rates. These rates are derived from tendered and/or constructed rates from previous projects of a similar nature. NSW Public Works has developed an extensive database of rates through its involvement in numerous dam projects at design and construction stages over many years. Council has requested that NSW Public Works provide a sensitivity assessment for the mass concrete rate (the cost of which dominates the estimate for concrete buttress strengthening options). Therefore three estimates for Option 2A have been prepared with mass concrete ranging in cost from \$450/m^3 to \$650/m^3.

7.3 Preliminaries and Non-construction Intangibles (NCIs)

The lump sum values adopted for the project preliminaries and NCIs are based on typical values used by NSW Public Works in the preparation of dam and water supply works asset valuations for NSW authorities.

7.4 Contingencies

A nominal contingency value of approximately 30% of the average option total estimated cost has been adopted across all estimates. A 30% contingency value is typically used by NSW Public works for estimates corresponding to option studies and is considered appropriate for the level of assessment done for the study.

7.5 Cost Estimates Summary

Table 7-1 and Table 7-2 summaries the cost estimates which have been prepared for this options study:

Table 7-1: - Cost Estimates Summary (Long Term Options)

Long Term Dam Safety Solutions (i.e. at least 100yrs)					
		Lower End of Range (Concrete $450/m3)	Middle of Range (Concrete $550/m3)	Upper End of Range (Concrete $650/m3)	
Item	**Option 1A Post-tensioning**	**Option 2A Concrete Buttressing**			**Option 3 Lower Storage**
Total Prime Cost	$3,231,740	$3,630,100	$4,230,100	$4,830,100	$2,594,620
Non Construction Intangibles	$960,000	$960,000	$960,000	$960,000	$960,000
Contingencies	$1,250,000	$1,250,000	$1,250,000	$1,250,000	$1,250,000
Total	**$5,441,740**	**$5,840,100**	**$6,440,100**	**$7,040,100**	**$4,804,620**
Rounded Total	**$5.4M**	**$5.8M**	**$6.4M**	**$7.0M**	**$4.8M**

Table 7-2: - Cost Estimates Summary (Short Term Options)

Short Term Dam Safety Solutions (i.e. approximately 10yrs)		
Item	**Option 1B Post-tensioning**	**Option 2B Concrete Buttressing (with Concrete $550/m3)**
Total Prime Cost	$2,423,700	$2,790,200
Non Construction Intangibles	$960,000	$960,000
Contingencies	$1,250,000	$1,250,000
Total	**$4,633,700**	**$5,000,200**
Rounded Total	**$4.6M**	**$5.0M**

Full cost estimate sheets are provided at Appendix B.

References

1. WAE Drawings of construction and raising of Tenterfield Creek Dam

2. NSW Public Works

   Stability Analysis of Tenterfield Dam
   Report No. DC95038, January 1996

3. NSW Public Works

   Tenterfield Dam Dambreak Study

   Report No. DC96035, July 1996

4. DPWS (NSW Public Works)

   Tenterfield Dam, Review of Stability Analysis

   Report No. DC97055, December 1997

5. DPWS (NSW Public Works)

   Tenterfield Dam, Dam Failure Risk Assessment

   Interim Report

   Report No. DC98039, March 1998

6. Department of Energy, Utilities and Sustainability

   Tenterfield Dam 2005 Audit Report

7. Structural Systems

   Anchor Monitoring, Tenterfield Dam

   November 2009

8. Tenterfield Dam, Dam Safety Emergency Plan

   August 2010

9. Black & Veitch

   Tenterfield Creek Dam, Stability Study Report (Draft)

   May 2012

10. ANCOLD Guidelines on Design Criteria for Concrete Gravity Dams

    February 2013

11. Richard Rodd & Associates
    Review of Tenterfield Creek Dam Stability Study Report (Draft)
    March 2013

12. Black & Veitch
    Response to Review Comments on Tenterfield Creek Dam Stability Study (Draft)
    April 2013

13. Black & Veitch
    Tenterfield Creek Dam, Stability Study Report (Final)
    June 2013

14. WRM Water & Environment (for NSW Public Works)
    Hydrological Modelling for Tenterfield Creek Dam Upgrade Design
    September 2013

15. NSW Dams Safety Committee (DSC)
    Letter to Tenterfield Shire Council re Tenterfield Creek Dam Stability Study and PLL Study
    December 2013

16. NSW Public Works
    Tenterfield Creek Dam, Dambreak and Probable Loss of Life (PLL) Study
    Report No. DC13165, January 2014

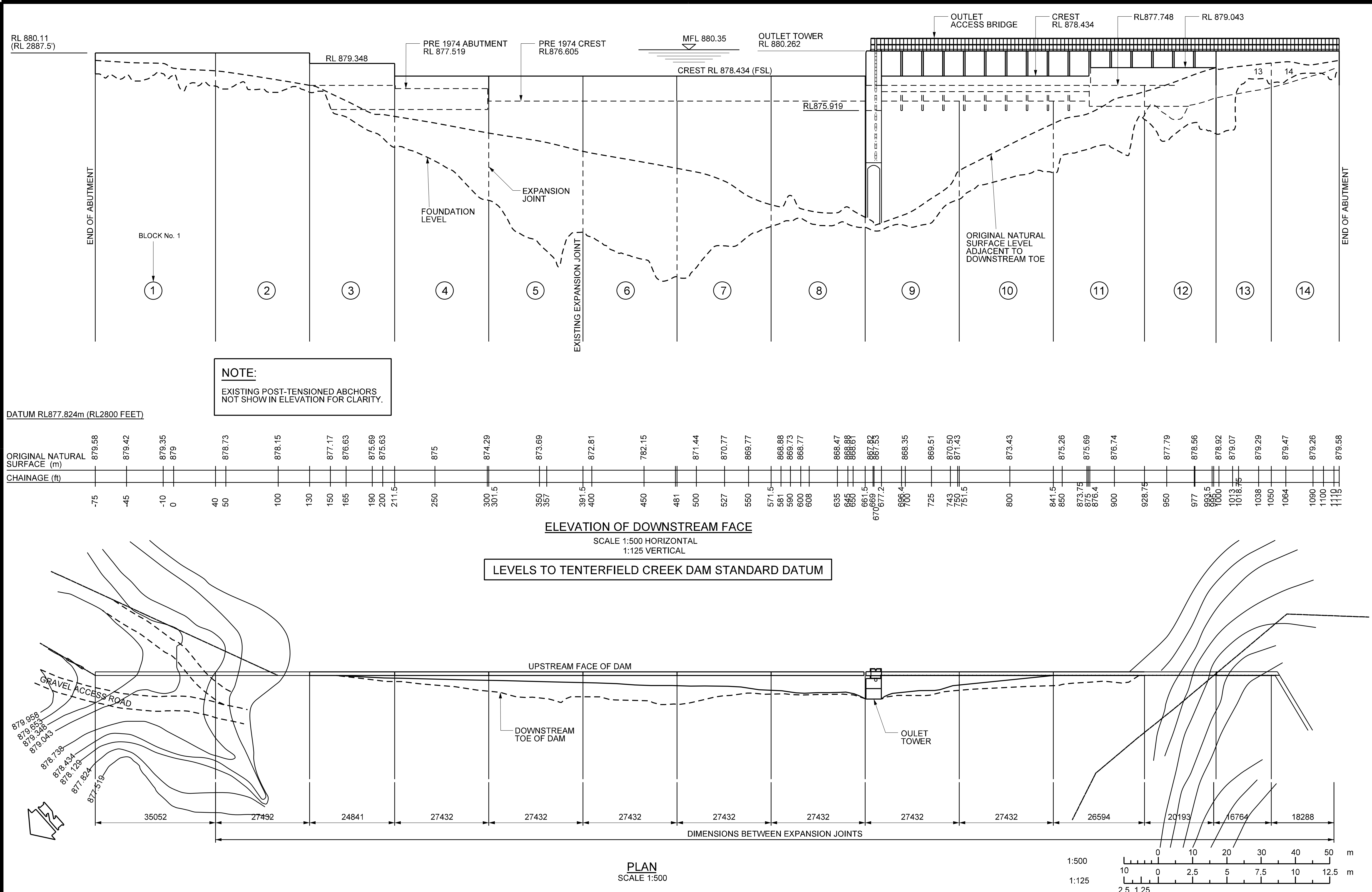
17. NSW Public Works
    Geotechnical Assessment of Foundation Conditions
    Memorandum January 2014

18. NSW Dams Safety Committee Guidelines, DSC3A, DSC3B, DSC3C

19. NSW Urban Water Services
    Tenterfield Water Supply, Tenterfield Yield Study Report
    Report No. 13008 February 2014

Appendices

Appendix A Dam Upgrade Options Drawings



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DESIGNED G.SAMIOS/ D.GUEST
DRAFTED H. LU
CHECKED D. JAMIESON

NSW Public Works
NSW Water Solutions

TENTERFIELD CREEK DAM
SAFETY UPGRADE OPTIONS STUDY

EXISTING DAM
PLAN AND ELEVATION

NO IN SET
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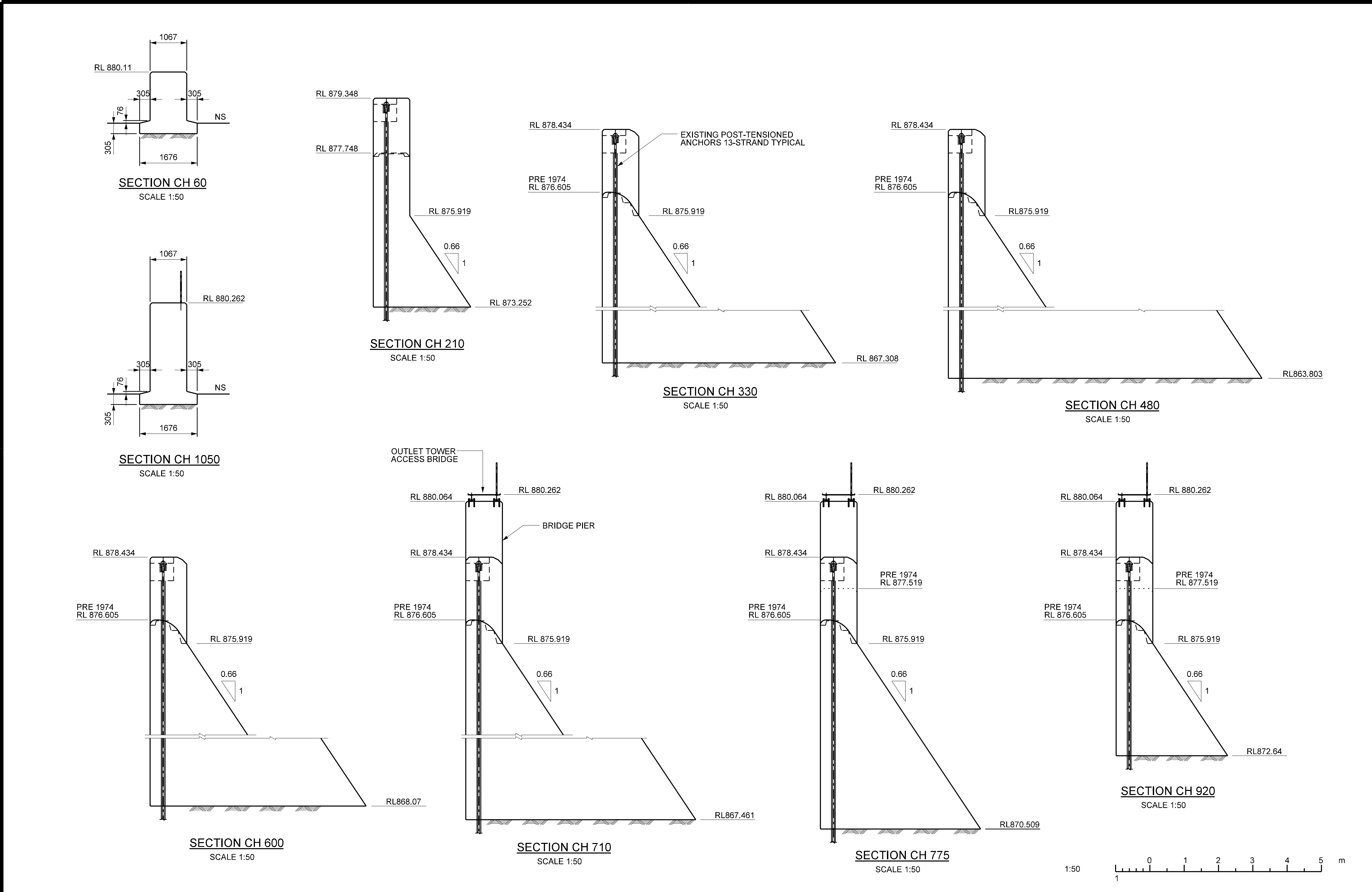

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TENTERFIELD CREEK DAM SAFETY UPGRADE OPTIONS STUDY

EXISTING DAM SECTIONS

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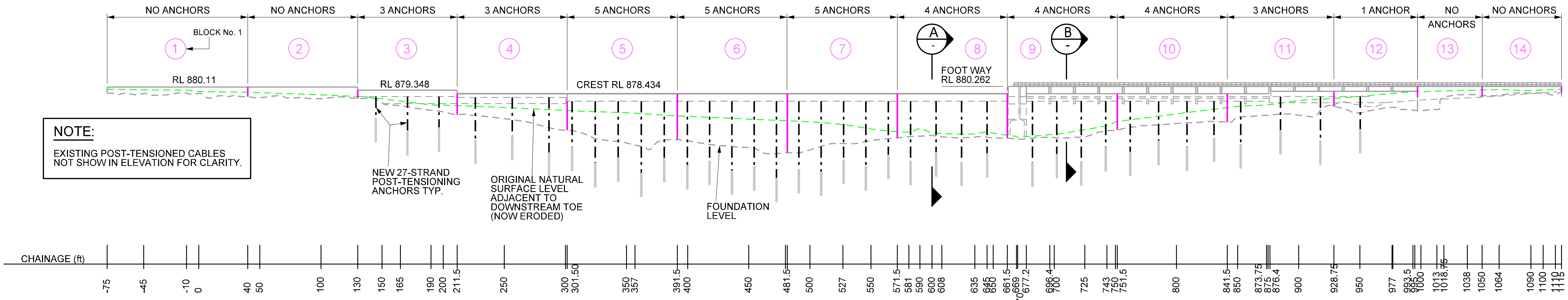

NOTE:

EXISTING POST-TENSIONED CABLES NOT SHOW IN ELEVATION FOR CLARITY.

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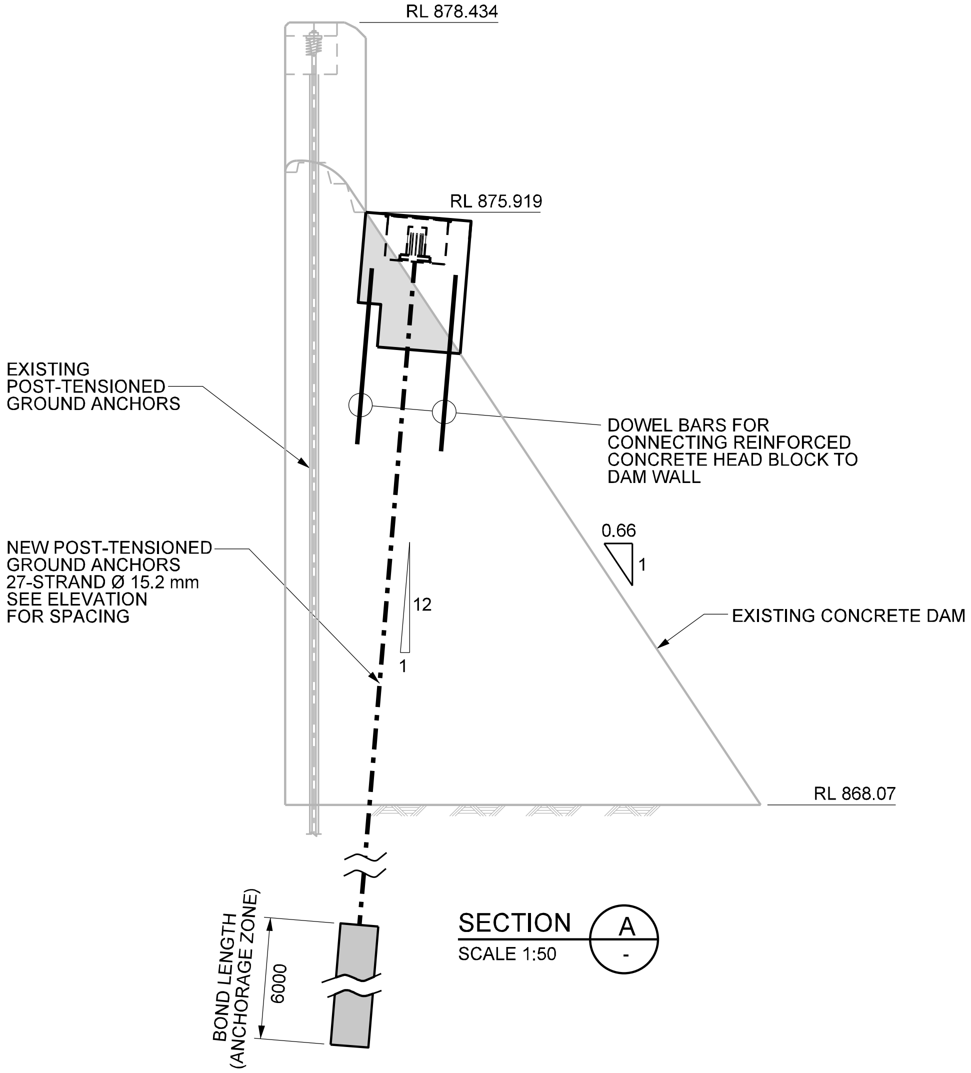
POST-TENSIONING OPTIONS

1A. EXISTING POST-TENSIONING 0% EFFECTIVE
37 ANCHORS (27-STRAND) (AS SHOWN ON THIS DRAWING).

1B. EXISTING POST-TENSIONING 50% EFFECTIVE
25 ANCHORS (27-STRAND) (NOT SHOWN ON THIS DRAWING).



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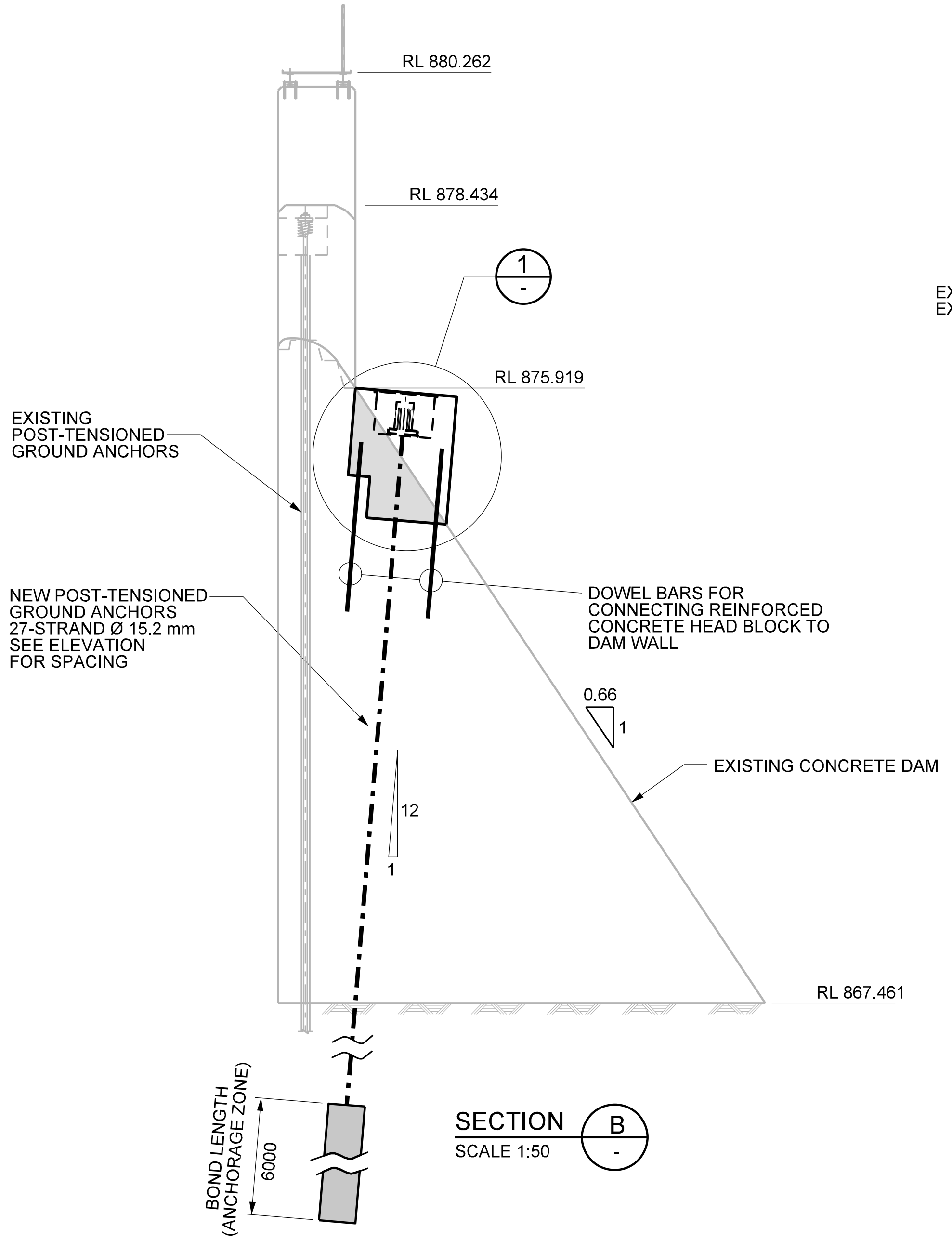

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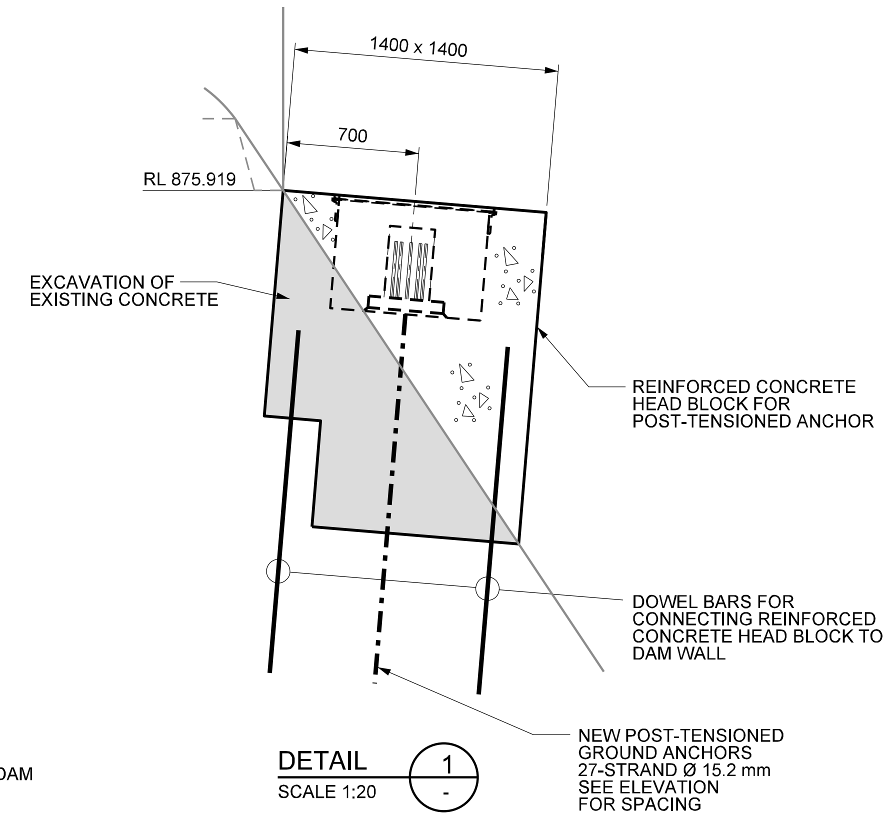

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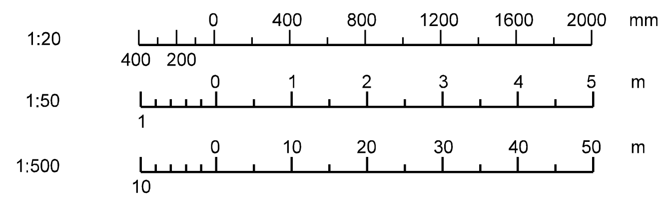

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TENTERFIELD CREEK DAM
SAFETY UPGRADE OPTIONS STUDY

OPTION 1
ADDITIONAL POST - TENSIONING

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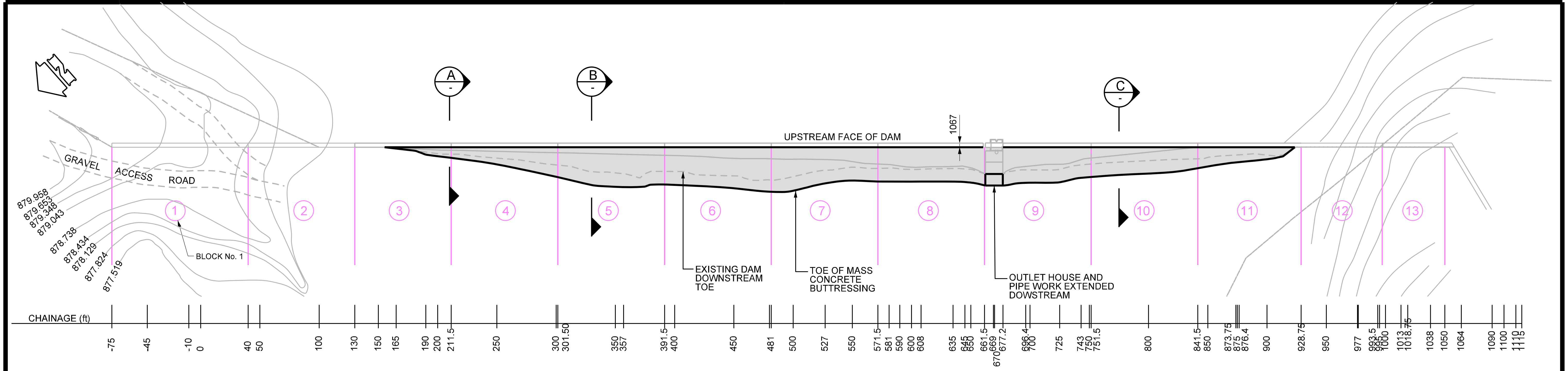

PLAN OF DAM
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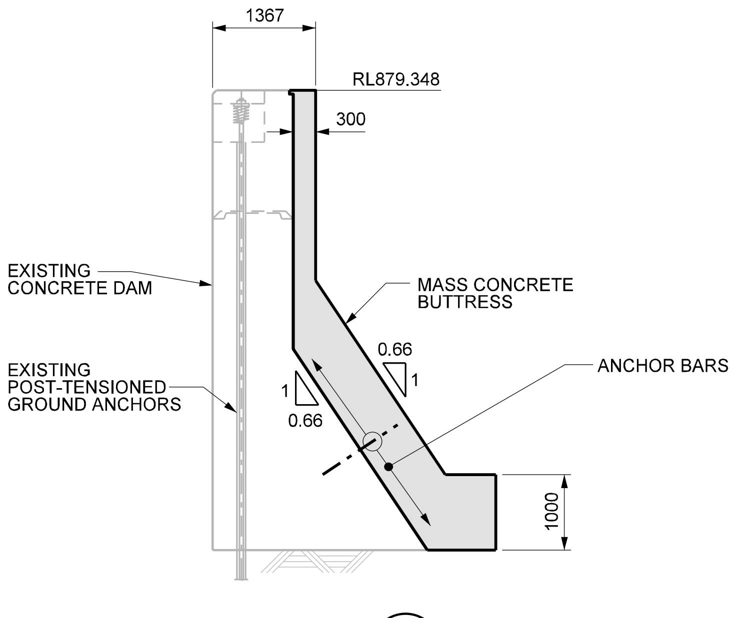

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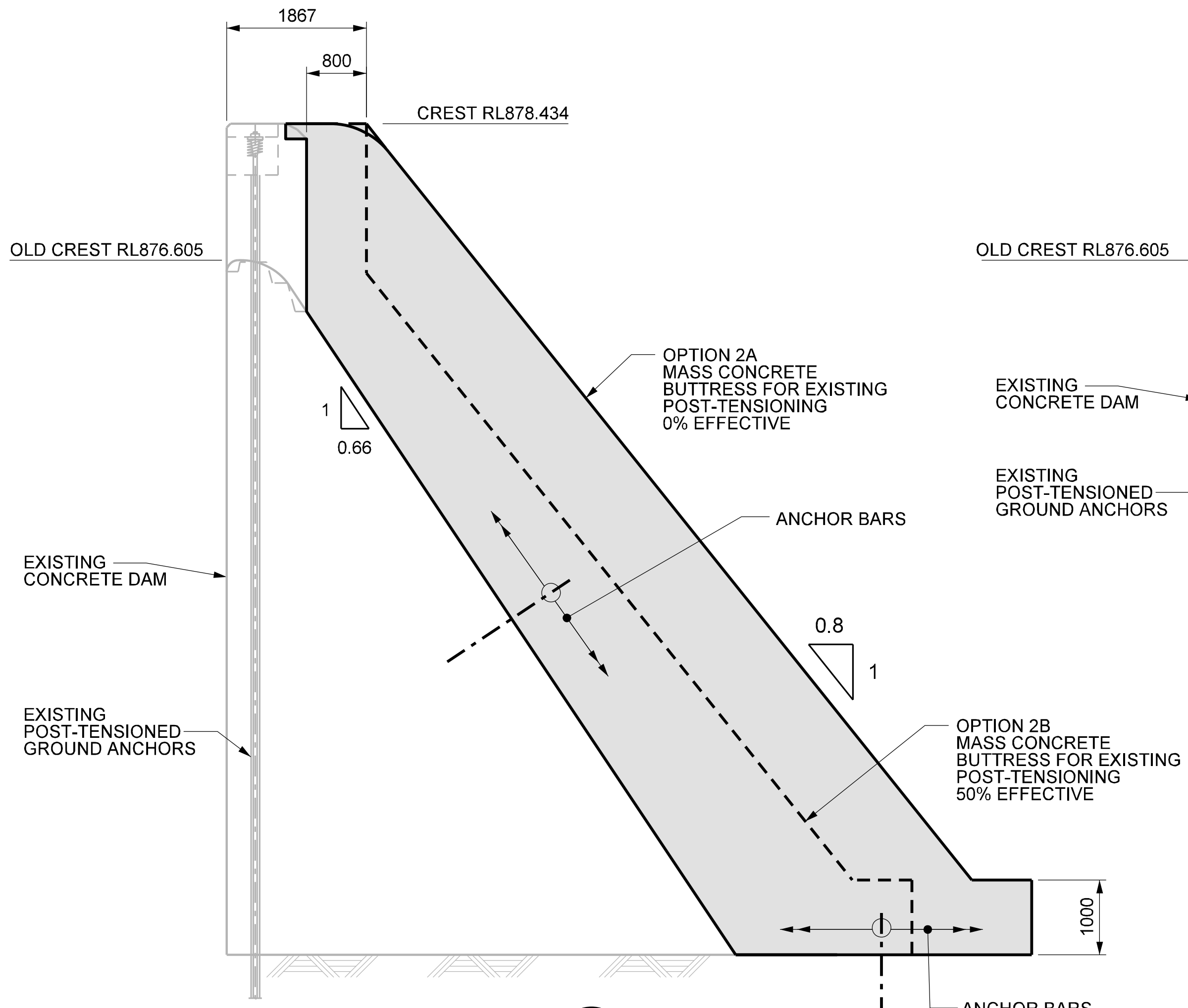

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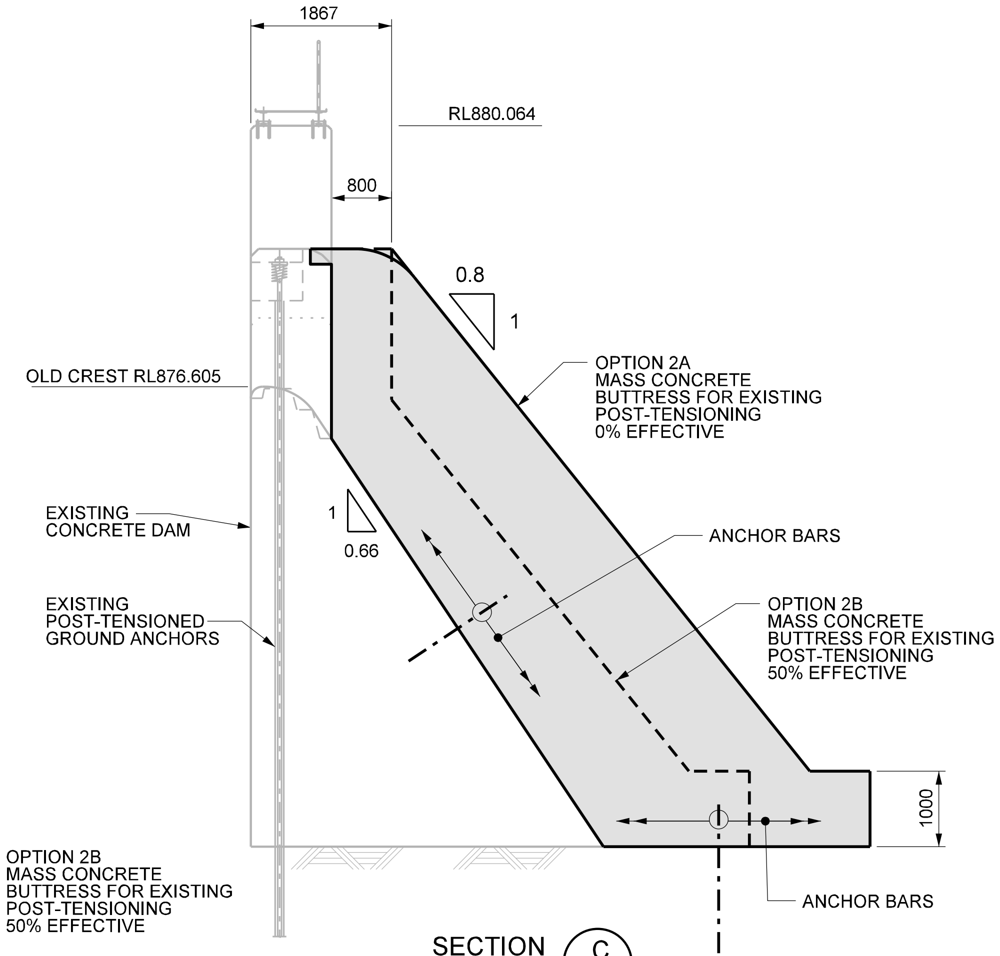

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MASS CONCRETE BUTTRESS OPTIONS

2A. MASS CONCRETE BUTTRESS WITH EXISTING POST-TENSIONING 0% EFFECTIVE (AS SHOWN ON THIS DRAWING).

2B. MASS CONCRETE BUTTRESS WITH EXISTING POST-TENSIONING 50% EFFECTIVE (SHOWN DOTTED ON SECTIONS).

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TENTERFIELD CREEK DAM
SAFETY UPGRADE OPTIONS STUDY

OPTION 2
DOWNSTREAM BUTTRESSING

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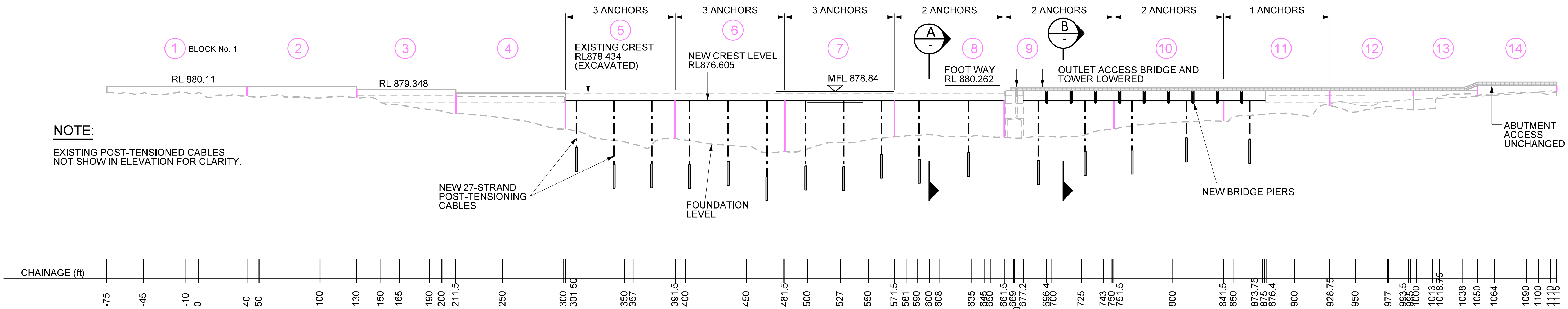

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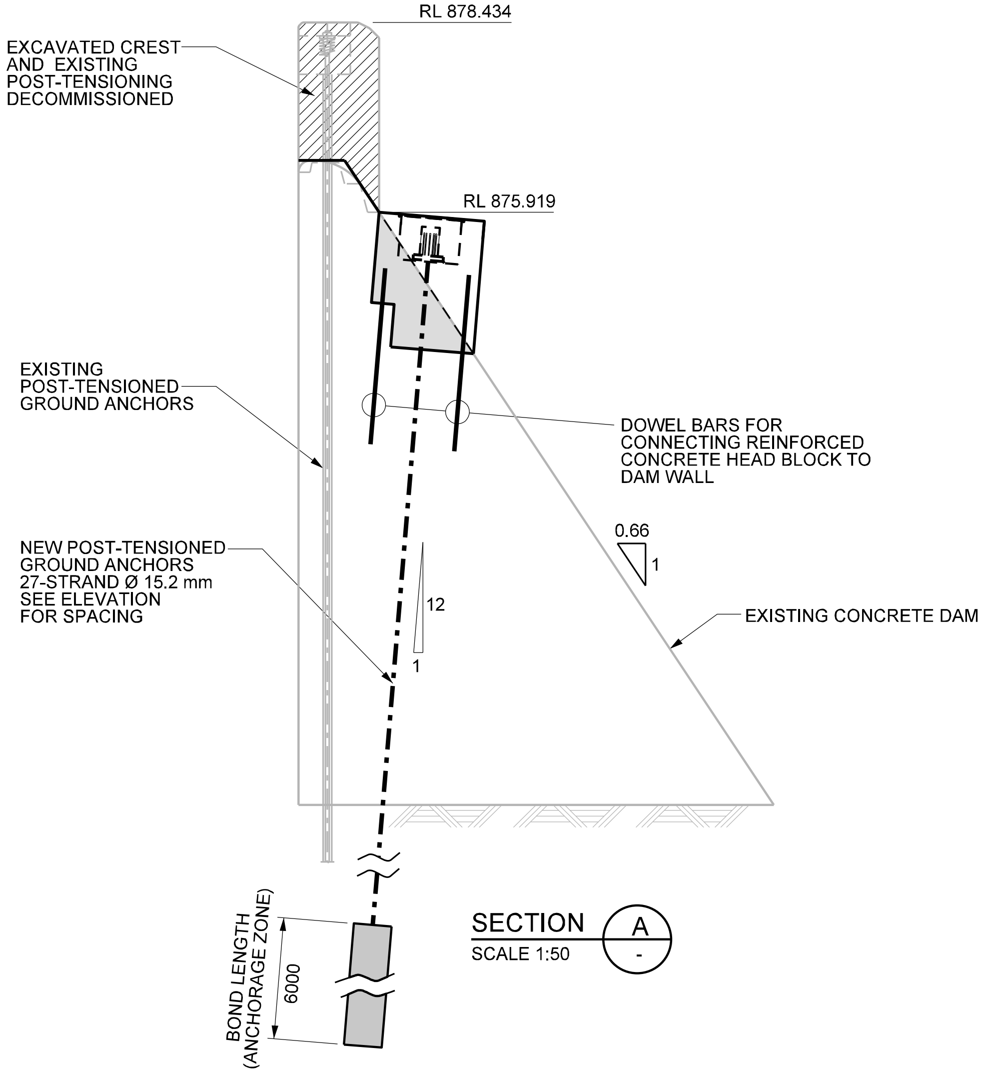
OPTION 3 DETAILS

- CENTRAL CREST PORTION (201.85m) EXCAVATED TO RL 876.605.
- OUTLET ACCESS BRIDGE AND TOWER LOWERED.
- 16 NEW 27-STRAND POST-TENSIONED ANCHORS.



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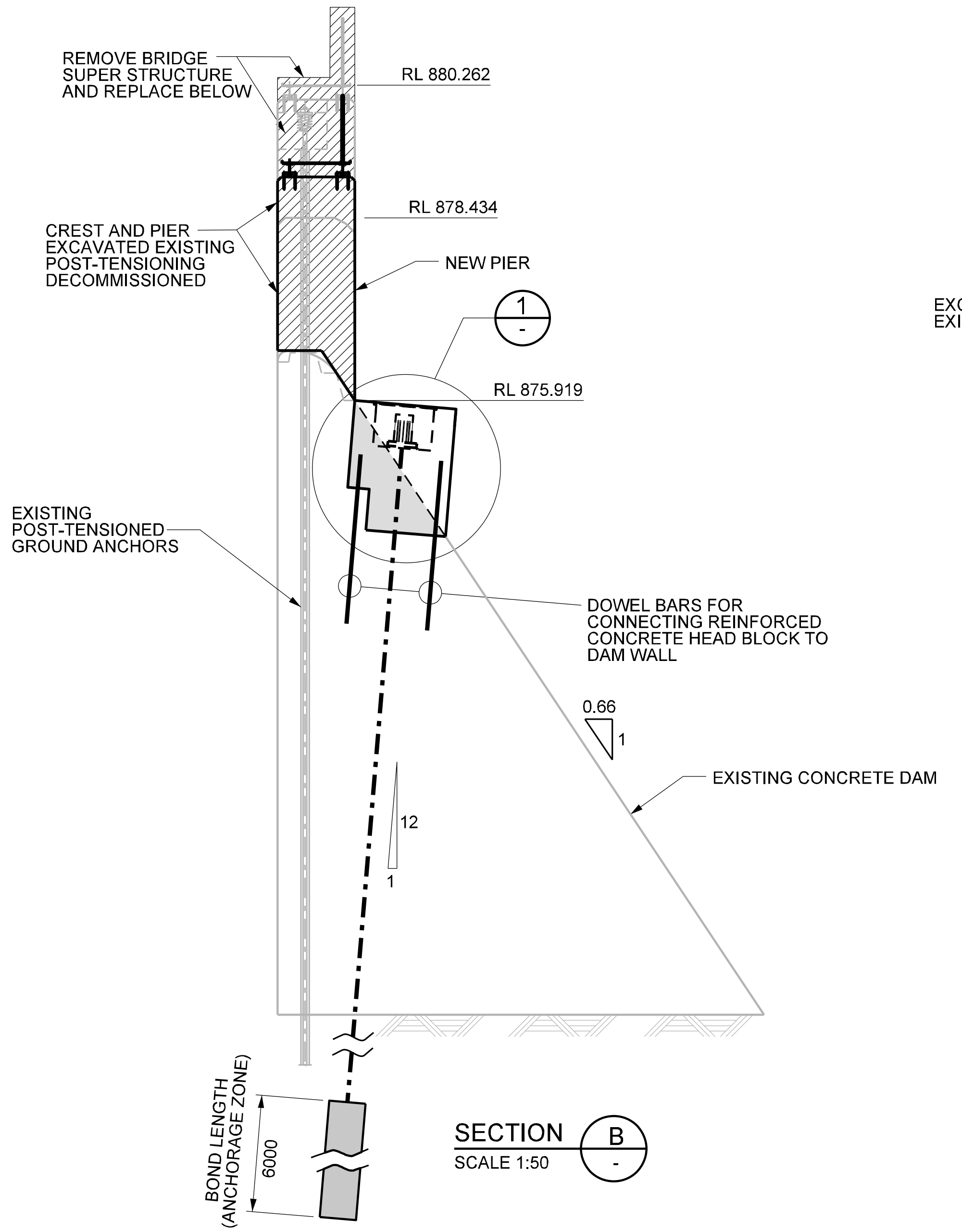

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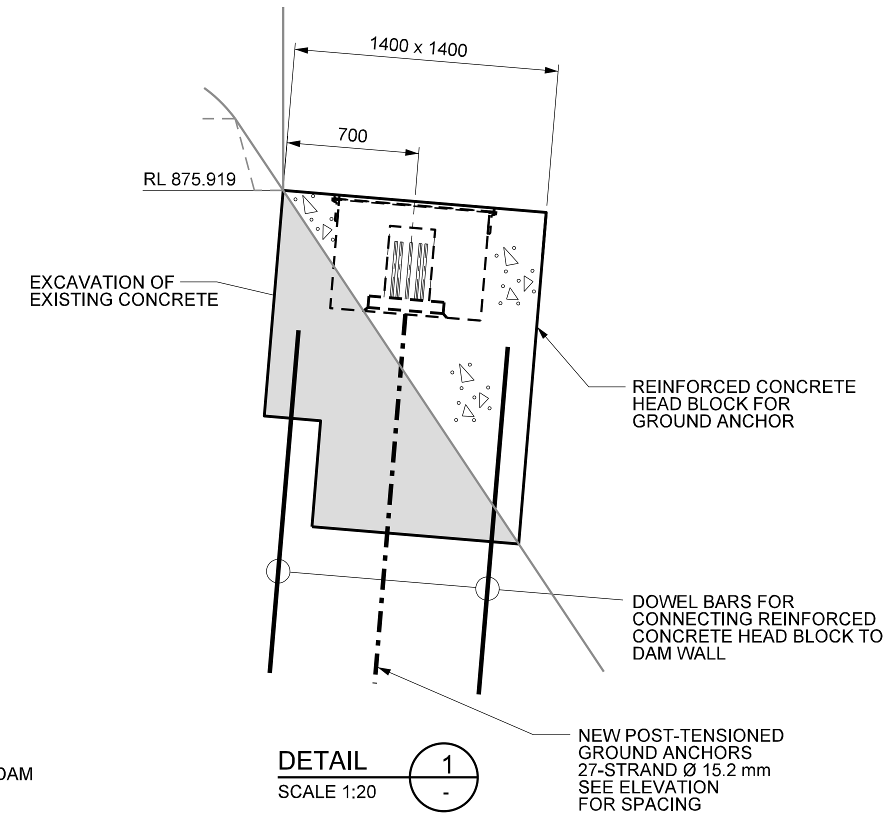

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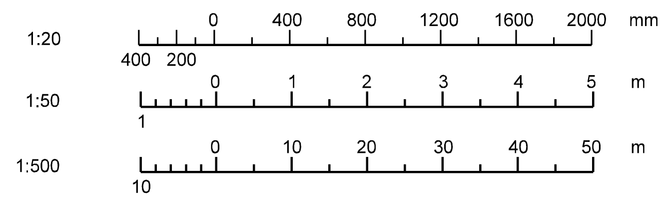

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TENTERFIELD CREEK DAM
SAFETY UPGRADE OPTIONS STUDY

OPTION 3
LOWERING OF DAM FSL

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FIGURE 5
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Appendix B Options Cost Estimates

Tenterfield Creek Dam Options Study

February, 2014

Engineers Estimate

Option 1A: 37 New Permanent Post-tensioned Ground Anchors with Existing Dam Post-tensioning 0% Effective

Long Term Solution (i.e. at least 100yrs)

	Item	Qty	Unit	Rate	Estimate	Sub-total
1.0	**Preliminaries**					
1.01	Establishment and Disestablishment	1	item	$90,000	$90,000	
1.02	Environmental Management	1	item	$80,000	$80,000	
1.03	Safety Management	1	item	$60,000	$60,000	
1.04	Stream Care and General Diversion	1	item	$40,000	$40,000	
1.05	Landscaping and Site Rehabilitation	1	item	$30,000	$30,000	
1.06	Photographic/DVD recording, WAE drgs	1	item	$50,000	$50,000	
1.07	Maintenance of dam access road	1	item	$50,000	$50,000	
	Sub-total 1.0					**$400,000**
2.0	**Post-tensioning Works**					
2.01	Excavation in dam crest for P/T cable headblocks	55	m^3	$2,000	$110,000	
2.02	Reinforced concrete in headblocks	105	m^3	$2,500	$262,500	
2.03	Dowel bars for headblocks - supply and install	370	each	$100	$37,000	
2.04	Establishment of drilling plant	1	Item	$90,000	$90,000	
2.05	Set up for drilling 27 strand P/T cable holes	93	setups	$1,400	$130,200	
2.06	Drilling 215 dia holes through concrete and rock for 27 strand P/T cables	703	m	$280	$196,840	
2.07	Set up for and water testing of P/T cable holes in the foundation	93	each	$250	$23,250	
2.08	Hook ups of waterproof grouting	56	each	$400	$22,400	
2.09	Waterproof grouting of P/T cable holes (20kg bags)	3,160	bags	$20	$63,200	
2.10	Redrilling after waterproof grouting	1,080	m	$225	$243,000	
2.11	Supply and fabricate free length for 27 strand cables	481	m	$780	$375,180	
2.12	Supply and fabricate bond length for 27 strand cables	222	m	$850	$188,700	
2.13	Handle and install 27 strand P/T cables	37	cables	$8,500	$314,500	
2.14	Supply and install anchorage assemblies for 27 strand cables	37	each	$5,500	$203,500	
2.15	Hook-up of grouting for P/T cables	37	each	$760	$28,120	
2.16	Cement for grouting of P/T cables (20kg bags)	1,475	bags	$42	$61,950	
2.17	Stressing 27 strand P/T cables using extended loading sequence	2	cables	$10,500	$21,000	
2.18	Stressing 27 strand P/T cables using normal loading sequence	35	cables	$5,500	$192,500	
2.19	Supply and test load cell and associated equipment	1	Item	$100,000	$100,000	
2.20	Supply, fabricate and maintenance of working platform(s)	1	Item	$35,000	$35,000	
2.21	Supply, fabricate and install metal cover plates and fixings	37	Units	$1,700	$62,900	
	Sub-total 2.0					**$2,761,740**
3.0	**Outlet Works**					
3.01	Replace two 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators	1	item	$50,000	$50,000	
3.02	Miscellaneos metalwork for new access safety provisions	1	item	$20,000	$20,000	
	Sub-total 3.0					**$70,000**
4.0	**Total Prime Cost (PC)**					**$3,231,740**
5.0	**Non Construction Intangibles (NCIs)**					
5.01	Surveys, Concept and Preliminary Investigations	1	item	$150,000		$150,000
5.02	Detailed Design and Documentation	1	item	$240,000		$240,000
5.03	Contract Administration and Supervision (including Procurement)	1	item	$300,000		$300,000
5.04	Project Management and Owner Costs (including Commissioning)	1	item	$180,000		$180,000
5.05	Environmental/Social and Community Studies	1	item	$90,000		$90,000
	Sub-total 5.0					**$960,000**
	Total Estimated Cost - Items 1.0 to 5.0					**$4,191,740**
	Contingency					**$1,250,000**
	TOTAL PROJECT COST					**$5,441,740**

Tenterfield Creek Dam Options Study

February, 2014

Engineers Estimate

Option 1B: 25 New Permanent Post-tensioned Ground Anchors with Existing Dam Post-tensioning 50% Effective

Short Term Solution (i.e. approximately 10yrs)

Item		Qty	Unit	Rate	Estimate	Sub-total
1.0	**Preliminaries**					
1.01	Establishment and Disestablishment	1	item	$90,000	$90,000	
1.02	Environmental Management	1	item	$80,000	$80,000	
1.03	Safety Management	1	item	$60,000	$60,000	
1.04	Stream Care and General Diversion	1	item	$40,000	$40,000	
1.05	Landscaping and Site Rehabilitation	1	item	$30,000	$30,000	
1.06	Photographic/DVD recording, WAE drgs	1	item	$50,000	$50,000	
1.07	Maintenance of dam access road	1	item	$50,000	$50,000	
	Sub-total 1.0					**$400,000**
2.0	**Post-tensioning Works**					
2.01	Excavation in dam crest for P/T cable headblocks	37	m^3	$2,000	$74,000	
2.02	Reinforced concrete in headblocks	71	m^3	$2,500	$177,500	
2.03	Dowel bars for headblocks - supply and install	250	each	$100	$25,000	
2.04	Establishment of drilling plant	1	Item	$90,000	$90,000	
2.05	Set up for drilling 27 strand P/T cable holes	63	setups	$1,400	$88,200	
2.06	Drilling 215 dia holes through concrete and rock for 27 strand P/T cables	475	m	$280	$133,000	
2.07	Set up for and water testing of P/T cable holes in the foundation	63	each	$250	$15,750	
2.08	Hook ups of waterproof grouting	38	each	$400	$15,200	
2.09	Waterproof grouting of P/T cable holes (20kg bags)	2,140	bags	$20	$42,800	
2.10	Redrilling after waterproof grouting	730	m	$225	$164,250	
2.11	Supply and fabricate free length for 27 strand cables	325	m	$780	$253,500	
2.12	Supply and fabricate bond length for 27 strand cables	150	m	$850	$127,500	
2.13	Handle and install 27 strand P/T cables	25	cables	$8,500	$212,500	
2.14	Supply and install anchorage assemblies for 27 strand cables	25	each	$5,500	$137,500	
2.15	Hook-up of grouting for P/T cables	25	each	$760	$19,000	
2.16	Cement for grouting of P/T cables (20kg bags)	1,000	bags	$42	$42,000	
2.17	Stressing 27 strand P/T cables using extended loading sequence	2	cables	$10,500	$21,000	
2.18	Stressing 27 strand P/T cables using normal loading sequence	25	cables	$5,500	$137,500	
2.19	Supply and test load cell and associated equipment	1	Item	$100,000	$100,000	
2.20	Supply, fabricate and maintenance of working platform(s)	1	Item	$35,000	$35,000	
2.21	Supply, fabricate and install metal cover plates and fixings	25	Units	$1,700	$42,500	
	Sub-total 2.0					**$1,953,700**
3.0	**Outlet Works**					
3.01	Replace two 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators	1	item	$50,000	$50,000	
3.02	Miscellaneos metalwork for new access safety provisions	1	item	$20,000	$20,000	
	Sub-total 3.0					**$70,000**
4.0	**Total Prime Cost (PC)**					**$2,423,700**
5.0	**Non Construction Intangibles (NCIs)**					
5.01	Surveys, Concept and Preliminary Investigations	1	item	$150,000		$150,000
5.02	Detailed Design and Documentation	1	item	$240,000		$240,000
5.03	Contract Administration and Supervision (including Procurement)	1	item	$300,000		$300,000
5.04	Project Management and Owner Costs (including Commissioning)	1	item	$180,000		$180,000
5.05	Environmental/Social and Community Studies	1	item	$90,000		$90,000
	Sub-total 5.0					**$960,000**
	Total Estimated Cost - Items 1.0 to 5.0					**$3,383,700**
	Contingency					**$1,250,000**
	TOTAL PROJECT COST					**$4,633,700**

Tenterfield Creek Dam Options Study

February, 2014

Engineers Estimate

Mass Concrete Rate = $450/m^3

Option 2A: Mass Concrete Buttressing on Downstream Side with Existing Dam Post-tensioning 0% Effective

Long Term Solution (i.e. at least 100yrs)

	Item	Qty	Unit	Rate	Estimate	Sub-total
1.0	**Preliminaries**					
1.01	Establishment and Disestablishment	1	item	$90,000	$90,000	
1.02	Environmental Management	1	item	$80,000	$80,000	
1.03	Safety Management	1	item	$60,000	$60,000	
1.04	Stream Care and General Diversion	1	item	$40,000	$40,000	
1.05	Landscaping and Site Rehabilitation	1	item	$30,000	$30,000	
1.06	Photographic/DVD recording, WAE drgs	1	item	$50,000	$50,000	
1.07	Maintenance of dam access road	1	item	$50,000	$50,000	
	Sub-total 1.0					**$400,000**
2.0	**Foundation Preparation Works**					
2.01	Foundation excavation/preparation at downstream toe	1,270	m^3	$20	$25,400	
2.02	Clean-off of foundations for mass concrete at downstream toe	640	m^2	$80	$51,200	
2.03	Dental concrete at downstream toe	70	m^3	$550	$38,500	
	Sub-total 2.0					**$115,100**
3.0	**Mass Concrete Works**					
3.01	Mass concrete for downstream buttressing	6,000	m^3	$450	$2,700,000	
	Sub-total 3.0					**$2,700,000**
4.0	**Concrete Interface Works**					
4.01	Downstream face treatment	2,800	m^2	$50	$140,000	
4.02	Anchor bars (N28 at 2m x 2m grid, 1m long)	700	m	$150	$105,000	
	Sub-total 4.0					**$245,000**
5.0	**Outlet Works**					
5.01	Extend outlet chamber downstream	1	item	$80,000	$80,000	
5.02	Extend pipework downstream	1	item	$20,000	$20,000	
5.03	Replace two 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators	1	item	$50,000	$50,000	
5.04	Miscellaneos metalwork for new access safety provisions	1	item	$20,000	$20,000	
	Sub-total 5.0					**$170,000**
6.0	**Total Prime Cost (PC)**					**$3,630,100**
7.0	**Non Construction Intangibles (NCIs)**					
7.01	Surveys, Concept and Preliminary Investigations	1	item	$150,000		$150,000
7.02	Detailed Design and Documentation	1	item	$240,000		$240,000
7.03	Contract Administration and Supervision (including Procurement)	1	item	$300,000		$300,000
7.04	Project Management and Owner Costs (including Commissioning)	1	item	$180,000		$180,000
7.05	Environmental/Social and Community Studies	1	item	$90,000		$90,000
	Sub-total 7.0					**$960,000**
	Total Estimated Cost - Items 1.0 to 5.0					**$4,590,100**
	Contingency					**$1,250,000**
	TOTAL PROJECT COST					**$5,840,100**

Tenterfield Creek Dam Options Study

February, 2014

Engineers Estimate

Mass Concrete Rate = $550/m^3

Option 2A: Mass Concrete Buttressing on Downstream Side with Existing Dam Post-tensioning 0% Effective

Long Term Solution (i.e. at least 100yrs)

	Item	Qty	Unit	Rate	Estimate	Sub-total
1.0	**Preliminaries**					
1.01	Establishment and Disestablishment	1	item	$90,000	$90,000	
1.02	Environmental Management	1	item	$80,000	$80,000	
1.03	Safety Management	1	item	$60,000	$60,000	
1.04	Stream Care and General Diversion	1	item	$40,000	$40,000	
1.05	Landscaping and Site Rehabilitation	1	item	$30,000	$30,000	
1.06	Photographic/DVD recording, WAE drgs	1	item	$50,000	$50,000	
1.07	Maintenance of dam access road	1	item	$50,000	$50,000	
	Sub-total 1.0					**$400,000**
2.0	**Foundation Preparation Works**					
2.01	Foundation excavation/preparation at downstream toe	1,270	m^3	$20	$25,400	
2.02	Clean-off of foundations for mass concrete at downstream toe	640	m^2	$80	$51,200	
2.03	Dental concrete at downstream toe	70	m^3	$550	$38,500	
	Sub-total 2.0					**$115,100**
3.0	**Mass Concrete Works**					
3.01	Mass concrete for downstream buttressing	6,000	m^3	$550	$3,300,000	
	Sub-total 3.0					**$3,300,000**
4.0	**Concrete Interface Works**					
4.01	Downstream face treatment	2,800	m^2	$50	$140,000	
4.02	Anchor bars (N28 at 2m x 2m grid, 1m long)	700	m	$150	$105,000	
	Sub-total 4.0					**$245,000**
5.0	**Outlet Works**					
5.01	Extend outlet chamber downstream	1	item	$80,000	$80,000	
5.02	Extend pipework downstream	1	item	$20,000	$20,000	
5.03	Replace two 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators	1	item	$50,000	$50,000	
5.04	Miscellaneos metalwork for new access safety provisions	1	item	$20,000	$20,000	
	Sub-total 5.0					**$170,000**
6.0	**Total Prime Cost (PC)**					**$4,230,100**
7.0	**Non Construction Intangibles (NCIs)**					
7.01	Surveys, Concept and Preliminary Investigations	1	item	$150,000		$150,000
7.02	Detailed Design and Documentation	1	item	$240,000		$240,000
7.03	Contract Administration and Supervision (including Procurement)	1	item	$300,000		$300,000
7.04	Project Management and Owner Costs (including Commissioning)	1	item	$180,000		$180,000
7.05	Environmental/Social and Community Studies	1	item	$90,000		$90,000
	Sub-total 7.0					**$960,000**
	Total Estimated Cost - Items 1.0 to 5.0					**$5,190,100**
	Contingency					**$1,250,000**
	TOTAL PROJECT COST					**$6,440,100**

Tenterfield Creek Dam Options Study

February, 2014

Engineers Estimate

Mass Concrete Rate = $650/m^3

Option 2A: Mass Concrete Buttressing on Downstream Side with Existing Dam Post-tensioning 0% Effective
Long Term Solution (i.e. at least 100yrs)

	Item	Qty	Unit	Rate	Estimate	Sub-total
1.0	**Preliminaries**					
1.01	Establishment and Disestablishment	1	item	$90,000	$90,000	
1.02	Environmental Management	1	item	$80,000	$80,000	
1.03	Safety Management	1	item	$60,000	$60,000	
1.04	Stream Care and General Diversion	1	item	$40,000	$40,000	
1.05	Landscaping and Site Rehabilitation	1	item	$30,000	$30,000	
1.06	Photographic/DVD recording, WAE drgs	1	item	$50,000	$50,000	
1.07	Maintenance of dam access road	1	item	$50,000	$50,000	
	Sub-total 1.0					**$400,000**
2.0	**Foundation Preparation Works**					
2.01	Foundation excavation/preparation at downstream toe	1,270	m^3	$20	$25,400	
2.02	Clean-off of foundations for mass concrete at downstream toe	640	m^2	$80	$51,200	
2.03	Dental concrete at downstream toe	70	m^3	$550	$38,500	
	Sub-total 2.0					**$115,100**
3.0	**Mass Concrete Works**					
3.01	Mass concrete for downstream buttressing	6,000	m^3	$650	$3,900,000	
	Sub-total 3.0					**$3,900,000**
4.0	**Concrete Interface Works**					
4.01	Downstream face treatment	2,800	m^2	$50	$140,000	
4.02	Anchor bars (N28 at 2m x 2m grid, 1m long)	700	m	$150	$105,000	
	Sub-total 4.0					**$245,000**
5.0	**Outlet Works**					
5.01	Extend outlet chamber downstream	1	item	$80,000	$80,000	
5.02	Extend pipework downstream	1	item	$20,000	$20,000	
5.03	Replace two 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators	1	item	$50,000	$50,000	
5.04	Miscellaneos metalwork for new access safety provisions	1	item	$20,000	$20,000	
	Sub-total 5.0					**$170,000**
6.0	**Total Prime Cost (PC)**					**$4,830,100**
7.0	**Non Construction Intangibles (NCIs)**					
7.01	Surveys, Concept and Preliminary Investigations	1	item	$150,000		$150,000
7.02	Detailed Design and Documentation	1	item	$240,000		$240,000
7.03	Contract Administration and Supervision (including Procurement)	1	item	$300,000		$300,000
7.04	Project Management and Owner Costs (including Commissioning)	1	item	$180,000		$180,000
7.05	Environmental/Social and Community Studies	1	item	$90,000		$90,000
	Sub-total 7.0					**$960,000**
	Total Estimated Cost - Items 1.0 to 5.0					**$5,790,100**
	Contingency					**$1,250,000**
	TOTAL PROJECT COST					**$7,040,100**

Tenterfield Creek Dam Options Study

February, 2014

Engineers Estimate

Option 2B: Mass Concrete Buttressing on Downstream Side with Existing Dam Post-tensioning 50% Effective

Short Term Solution (i.e. approximately 10yrs)

	Item	Qty	Unit	Rate	Estimate	Sub-total
1.0	**Preliminaries**					
1.01	Establishment and Disestablishment	1	item	$90,000	$90,000	
1.02	Environmental Management	1	item	$80,000	$80,000	
1.03	Safety Management	1	item	$55,000	$55,000	
1.04	Stream Care and General Diversion	1	item	$40,000	$40,000	
1.05	Landscaping and Site Rehabilitation	1	item	$30,000	$30,000	
1.06	Photographic/DVD recording, WAE drgs	1	item	$50,000	$50,000	
1.07	Maintenance of dam access road	1	item	$50,000	$50,000	
	Sub-total 1.0					**$395,000**
2.0	**Foundation Preparation Works**					
2.01	Foundation excavation/preparation at downstream toe	810	m^3	$20	$16,200	
2.02	Clean-off of foundations for mass concrete at downstream toe	400	m^2	$80	$32,000	
2.03	Dental concrete at downstream toe	40	m^3	$550	$22,000	
	Sub-total 2.0					**$70,200**
3.0	**Mass Concrete Works**					
3.01	Mass concrete for downstream buttressing	3,500	m^3	$550	$1,925,000	
	Sub-total 3.0					**$1,925,000**
4.0	**Concrete Interface Works**					
4.01	Downstream face treatment	2,800	m^2	$50	$140,000	
4.02	Anchor bars (N28 at 2m x 2m grid, 1m long)	700	m	$150	$105,000	
	Sub-total 4.0					**$245,000**
5.0	**Outlet Works**					
5.01	Extend outlet chamber downstream	1	item	$70,000	$70,000	
5.02	Extend pipework downstream	1	item	$15,000	$15,000	
5.03	Replace two 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators	1	item	$50,000	$50,000	
5.04	Miscellaneos metalwork for new access safety provisions	1	item	$20,000	$20,000	
	Sub-total 5.0					**$155,000**
6.0	**Total Prime Cost (PC)**					**$2,790,200**
7.0	**Non Construction Intangibles (NCIs)**					
7.01	Surveys, Concept and Preliminary Investigations	1	item	$150,000		$150,000
7.02	Detailed Design and Documentation	1	item	$240,000		$240,000
7.03	Contract Administration and Supervision (including Procurement)	1	item	$300,000		$300,000
7.04	Project Management and Owner Costs (including Commissioning)	1	item	$180,000		$180,000
7.05	Environmental/Social and Community Studies	1	item	$90,000		$90,000
	Sub-total 7.0					**$960,000**
	Total Estimated Cost - Items 1.0 to 5.0					**$3,750,200**
	Contingency					**$1,250,000**
	TOTAL PROJECT COST					**$5,000,200**

Tenterfield Creek Dam Options Study

February, 2014

Engineers Estimate

Option 3: Crest Excavated to RL 876.605 (Lower FSL) plus 16 New Permanent Post-tensioned Ground Anchors
Long Term Solution (i.e. at least 100yrs)

Item		Qty	Unit	Rate	Estimate	Sub-total
1.0	**Preliminaries**					
1.01	Establishment and Disestablishment	1	item	$90,000	$90,000	
1.02	Environmental Management	1	item	$80,000	$80,000	
1.03	Safety Management	1	item	$55,000	$55,000	
1.04	Stream Care and General Diversion	1	item	$40,000	$40,000	
1.05	Landscaping and Site Rehabilitation	1	item	$30,000	$30,000	
1.06	Photographic/DVD recording, WAE drgs	1	item	$50,000	$50,000	
1.07	Maintenance of dam access road	1	item	$50,000	$50,000	
	Sub-total 1.0					**$395,000**
2.0	**Dam Crest Excavation**					
2.01	Excavation of crest concrete (to disposal)	420	m^3	$1,500	$630,000	
	Sub-total 2.0					**$630,000**
3.0	**Crest Access Bridge Works**					
3.01	Remove bridge superstructure (for reuse)	1	Item	$10,000	$10,000	
3.02	Excavation of crest piers (to disposal)	11	m^3	$1,500	$16,500	
3.03	New reinforced concrete bridge piers	12	m^3	$2,000	$24,000	
3.04	Reinstate bridge superstructure	1	Item	$10,000	$10,000	
	Sub-total 3.0					**$60,500**
4.0	**Post-tensioning Works**					
4.01	Excavation in dam crest for P/T cable headblocks	24	m^3	$2,000	$48,000	
4.02	Reinforced concrete in headblocks	45	m^3	$2,500	$112,500	
4.03	Dowel bars for headblocks - supply and install	160	each	$100	$16,000	
4.04	Establishment of drilling plant	1	Item	$90,000	$90,000	
4.05	Set up for drilling 27 strand P/T cable holes	40	setups	$1,400	$56,000	
4.06	Drilling 215 dia holes through concrete and rock for 27 strand P/T cables	320	m	$280	$89,600	
4.07	Set up for and water testing of P/T cable holes in the foundation	40	each	$250	$10,000	
4.08	Hook ups of waterproof grouting	24	each	$400	$9,600	
4.09	Waterproof grouting of P/T cable holes (20kg bags)	1,450	bags	$20	$29,000	
4.10	Redrilling after waterproof grouting	500	m	$225	$112,500	
4.11	Supply and fabricate free length for 27 strand cables	230	m	$780	$179,400	
4.12	Supply and fabricate bond length for 27 strand cables	96	m	$850	$81,600	
4.13	Handle and install 27 strand P/T cables	16	cables	$8,500	$136,000	
4.14	Supply and install anchorage assemblies for 27 strand cables	16	each	$5,500	$88,000	
4.15	Hook-up of grouting for P/T cables	16	each	$760	$12,160	
4.16	Cement for grouting of P/T cables (20kg bags)	680	bags	$42	$28,560	
4.17	Stressing 27 strand P/T cables using extended loading sequence	2	cables	$10,500	$21,000	
4.18	Stressing 27 strand P/T cables using normal loading sequence	14	cables	$5,500	$77,000	
4.19	Supply and test load cell and associated equipment	1	Item	$100,000	$100,000	
4.20	Supply, fabricate and maintenance of working platform(s)	1	Item	$35,000	$35,000	
4.21	Supply, fabricate and install metal cover plates and fixings	16	Units	$1,700	$27,200	
	Sub-total 4.0					**$1,359,120**
5.0	**Outlet Works**					
5.01	Modify/lower outlet tower	1	item	$80,000	$80,000	
5.02	Replace two 600mm dia. scour valves and 250mm dia. suction main valve complete with new actuators	1	item	$50,000	$50,000	
5.03	Miscellaneos metalwork for new access safety provisions	1	item	$20,000	$20,000	
	Sub-total 5.0					**$150,000**
6.0	**Total Prime Cost (PC)**					**$2,594,620**
7.0	**Non Construction Intangibles (NCIs)**					
7.01	Surveys, Concept and Preliminary Investigations	1	item	$150,000		$150,000
7.02	Detailed Design and Documentation	1	item	$240,000		$240,000
7.03	Contract Administration and Supervision (including Procurement)	1	item	$300,000		$300,000
7.04	Project Management and Owner Costs (including Commissioning)	1	item	$180,000		$180,000
7.05	Environmental/Social and Community Studies	1	item	$90,000		$90,000
	Sub-total 7.0					**$960,000**
	Total Estimated Cost - Items 1.0 to 5.0					**$3,554,620**
	Contingency					**$1,250,000**
	TOTAL PROJECT COST					**$4,804,620**

Appendix C Stability Analysis Results

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 1: New Post-tensioning

Damstab Results for MFL Case

Block 6 - Ch: 466'

Storage @ RL 880.35 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Existing Post-tensioning: **0% effective**

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	PTF (kN/m)	C, Phi	File Names		Comments
											Geometry	Forces	
877.65	0	-43	53	18	6	6	0.31	1.07	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
876.65	0	-201	248	49	25	25	0.52	1.07	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
875.65	0	-384	451	90	42	42	0.46	1.25	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
874.65	0	-520	1342	77	786	786	10.19	1.91	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
873.65	0	-52	679	138	808	808	5.85	2.58	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
872.65	0	88	429	209	838	838	4.02	3.25	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
871.65	0	124	325	292	878	878	3.01	3.91	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
870.65	0	120	281	382	920	920	2.41	4.58	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
869.65	0	101	263	473	956	956	2.02	5.25	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
868.65	0	77	262	565	1002	1002	1.77	5.91	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
867.65	0	54	268	657	1057	1057	1.61	6.58	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
866.65	0	32	278	748	1121	1121	1.50	7.25	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
865.65	0	12	290	840	1194	1194	1.42	7.91	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
864.65	0	-4	302	932	1277	1277	1.37	8.58	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
863.65	0	-18	314	1024	1368	1368	1.34	9.25	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
863.65	0	-18	314	1024	1368	1631	1.59	9.25	735	0, 50	TENT466_INTERFACE.DAT	Option1PT_EPT0_NPT735.DAT	Interface
863.65	0	-18	314	1024	1368	1417	1.38	9.25	735	0, 46	TENT466_JOINT.DAT	Option1PT_EPT0_NPT735.DAT	Foundation Joint

Profile 3 - cracking

863.65	9	0	316	1024	1330	1330	1.30	9.25	735	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT735.DAT	Concrete
863.65	9	0	316	1024	1330	1585	1.55	9.25	735	0, 50	TENT466_INTERFACE.DAT	Option1PT_EPT0_NPT735.DAT	Interface
863.65	9	0	316	1024	1330	1377	1.35	9.25	735	0, 46	TENT466_JOINT.DAT	Option1PT_EPT0_NPT735.DAT	Foundation Joint

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 1: New Post-tensioning

Damstab Results for MFL Case

Block 6 - Ch: 466'

Storage @ RL 880.35 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Existing Post-tensioning: **50% effective**

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	PTF (kN/m)	C, Phi	File Names		Comments
											Geometry	Forces	
877.65	0	529	281	18	432	432	24.38	1.07	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
876.65	0	371	476	49	452	452	9.21	1.07	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
875.65	0	232	520	90	468	468	5.19	1.25	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
874.65	0	169	680	112	811	811	7.22	1.91	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
873.65	0	305	341	173	833	833	4.81	2.58	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
872.65	0	300	232	244	863	863	3.54	3.25	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
871.65	0	260	202	327	903	903	2.76	3.91	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
870.65	0	213	200	417	945	945	2.27	4.58	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
869.65	0	167	207	509	981	981	1.93	5.25	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
868.65	0	125	223	600	1027	1027	1.71	5.91	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
867.65	0	89	240	692	1082	1082	1.56	6.58	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
866.65	0	58	259	784	1146	1146	1.46	7.25	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
865.65	0	32	276	875	1219	1219	1.39	7.91	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
864.65	0	10	293	967	1302	1302	1.35	8.58	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
863.65	0	-7	309	1059	1393	1393	1.32	9.25	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT50_NPT332.DAT	Concrete
863.65	0	-7	309	1059	1393	1660	1.57	9.25	332	0, 50	TENT466_INTERFACE.DAT	Option1PT_EPT50_NPT332.DAT	Interface
863.65	0	-7	309	1059	1393	1443	1.36	9.25	332	0, 46	TENT466_JOINT.DAT	Option1PT_EPT50_NPT332.DAT	Foundation Joint

Profile 3 - cracking

863.65	3.6	0	309	1059	1378	1378	1.30	9.25	332	0, 45	TENT466_CONC.DAT	Option1PT_EPT0_NPT332.DAT	Concrete
863.65	3.6	0	309	1059	1378	1642	1.55	9.25	332	0, 50	TENT466_INTERFACE.DAT	Option1PT_EPT0_NPT332.DAT	Interface
863.65	3.6	0	309	1059	1378	1427	1.35	9.25	332	0, 46	TENT466_JOINT.DAT	Option1PT_EPT0_NPT332.DAT	Foundation Joint

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 1: New Post-tensioning

Damstab Results for MFL Case

Block 8 - Ch: 635'

Storage @ RL 880.35 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Existing Post-tensioning: **0% effective**

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	PTF (kN/m)	C, Phi	File Names		Comments
											Geometry	Forces	
878.38	0	-18	2	1	-9	-9	-7.87	1.07	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
877.38	0	-70	91	25	11	11	0.43	1.07	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
876.38	0	-276	334	59	31	31	0.52	1.07	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
875.38	0	-1255	2083	55	592	592	10.68	1.43	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
874.38	0	-322	901	109	607	607	5.56	2.1	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
873.38	0	-69	525	173	631	631	3.66	2.76	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
872.38	0	7	380	246	664	664	2.70	3.43	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
871.38	0	23	322	329	706	706	2.15	4.1	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
870.38	0	15	297	420	744	744	1.77	4.76	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
869.38	0	-2	291	512	784	784	1.53	5.43	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
868.38	0	-22	295	612	832	832	1.36	6.1	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
868.38	0	-22	295	612	832	992	1.62	6.1	550	0, 50	TENT635_INTERFACE.DAT	Option1PT_EPT0_NPT550.DAT	Interface
868.38	0	-22	295	612	832	862	1.41	6.1	550	0, 46	TENT635_JOINT.DAT	Option1PT_EPT0_NPT550.DAT	Foundation Joint
Profile 3 - cracking													
868.38	12.2	0	298	612	798	798	1.30	6.1	550	0, 45	TENT635_CONC.DAT	Option1PT_EPT0_NPT550.DAT	Concrete
868.38	12.2	0	298	612	798	951	1.55	6.1	550	0, 50	TENT635_INTERFACE.DAT	Option1PT_EPT0_NPT550.DAT	Interface
868.38	12.2	0	298	612	798	826	1.35	6.1	550	0, 46	TENT635_JOINT.DAT	Option1PT_EPT0_NPT550.DAT	Foundation Joint

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 1: New Post-tensioning

Damstab Results for MFL Case

Block 8 - Ch: 635'

Storage @ RL 880.35 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Existing Post-tensioning: **50% effective**

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	PTF (kN/m)	C, Phi	File Names		Comments
											Geometry	Forces	
878.38	0	401.15	168.58	1.13	303.95	303.95	270.06	1.07	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
877.38	0	349	258	25	324	324	12.75	1.07	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
876.38	0	144	501	59	344	344	5.78	1.07	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
875.38	0	-282	1109	83	591	591	7.13	1.43	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
874.38	0	93	485	137	606	606	4.44	2.1	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
873.38	0	148	308	200	630	630	3.15	2.76	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
872.38	0	133	253	273	663	663	2.43	3.43	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
871.38	0	101	243	356	705	705	1.98	4.1	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
870.38	0	66	246	447	743	743	1.66	4.76	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
869.38	0	31	257	539	783	783	1.45	5.43	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
868.38	0	0	273	639	831	831	1.30	6.1	350	0, 45	TENT635_CONC.DAT	Option1PT_EPT50_NPT350.DAT	Concrete
868.38	0	0	273	639	831	990	1.55	6.1	350	0, 50	TENT635_INTERFACE.DAT	Option1PT_EPT50_NPT350.DAT	Interface
868.38	0	0	273	639	831	861	1.35	6.1	350	0, 46	TENT635_JOINT.DAT	Option1PT_EPT50_NPT350.DAT	Foundation Joint
Profile 3 - cracking													
Nil													
Nil													
Nil													

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 1: New Post-tensioning

Damstab Results for MFL Case

Block 12 - Ch: 1000'

Storage @ RL 880.35 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Passive Wedge Included
Section has no existing post-tensioning

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	PTF (kN/m)	C, Phi	File Names		Comments
											Geometry	Forces	
879.56	0	43	35	3	42	42	13.64	1.07	28	0, 45	TENT1000_CONC.DAT	Option1PT_NPT28.DAT	Concrete
878.56	0	46	41	16	60	60	3.84	1.39	28	0, 45	TENT1000_CONC.DAT	Option1PT_NPT28.DAT	Concrete
877.56	0	39	44	38	85	85	2.22	2.06	28	0, 45	TENT1000_CONC.DAT	Option1PT_NPT28.DAT	Concrete
876.56	0	26	61	71	119	119	1.68	2.72	28	0, 45	TENT1000_CONC.DAT	Option1PT_NPT28.DAT	Concrete
875.56	0	13	82	113	161	161	1.43	3.39	28	0, 45	TENT1000_CONC.DAT	Option1PT_NPT28.DAT	Concrete
874.56	0	1	105	165	213	213	1.30	4.06	28	0, 45	TENT1000_CONC.DAT	Option1PT_NPT28.DAT	Concrete
873.56	0	4	112	133	275	275	2.06	4.72	28	0, 45	TENT1000_CONC.DAT	Option1PT_NPT28.DAT	Concrete
873.56	0	4	112	133	275	327	2.46	4.72	28	0, 50	TENT1000_INTERFACE.DAT	Option1PT_NPT28.DAT	Interface
873.56	0	4	112	133	275	284	2.13	4.72	28	0, 46	TENT1000_JOINT.DAT	Option1PT_NPT28.DAT	Foundation Joint

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 2: Mass Concrete Buttressing

Damstab Results for MFL Case

Block 6 - Ch: 466'

Storage @ RL 880.35 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Existing Post-tensioning: **0% effective**

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	C, Phi (OLD) & C, Phi (NEW)	File Names		Comments
										Geometry	Forces	
877.65	0	-11	17	18	7	89	5.05	2.49	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
876.65	0	-6	35	49	48	157	3.20	3.29	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
875.65	0	-3	52	90	101	236	2.61	4.09	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
874.65	0	-2	69	141	164	325	2.30	4.89	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
873.65	0	-1	85	202	238	426	2.11	5.69	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
872.65	0	-1	101	273	323	537	1.97	6.49	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
871.65	0	-2	117	356	419	660	1.85	7.29	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
870.65	0	-3	130	446	513	780	1.75	8.09	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
869.65	0	-5	138	537	592	886	1.65	8.89	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
868.65	0	-7	148	629	683	1003	1.59	9.69	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
867.65	0	-9	158	721	784	1130	1.57	10.49	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
866.65	0	-10	169	813	897	1269	1.56	11.29	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
865.65	0	-10	179	904	1020	1419	1.57	12.09	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
864.65	0	-10	189	996	1155	1580	1.59	12.89	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
863.65	0	-8	198	1088	1300	1752	1.61	13.69	0, 45 & 100, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
863.65	0	-8	198	1088	1300	1549	1.42	13.69	0, 50	TENT466BUTTRESS1_INTERFACE.DAT	CF_EPT0.DAT	Interface
863.65	0	-8	198	1088	1300	1346	1.25	13.69	0, 46	TENT466BUTTRESS1_JOINT.DAT	CF_EPT0.DAT	Foundation Joint

Profile 3 - cracking

863.65	8.1	0	199	1088	1249	1665	1.53	13.69	0, 45	TENT466BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
863.65	8.1	0	199	1088	1249	1489	1.37	13.69	0, 50	TENT466BUTTRESS1_INTERFACE.DAT	CF_EPT0.DAT	Interface
863.65	8.1	0	199	1088	1249	1294	1.20	13.69	0, 46	TENT466BUTTRESS1_JOINT.DAT	CF_EPT0.DAT	Foundation Joint

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 2: Mass Concrete Buttressing

Damstab Results for MFL Case

Block 6 - Ch: 466'

Storage @ RL 880.35 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Existing Post-tensioning: **50% effective**

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	C, Phi	File Names		Comments
										Geometry	Forces	
877.35	0	552	-73	26	447	493	18.90	1.87	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
876.35	0	493	3	60	480	528	8.75	1.93	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
875.35	0	402	-32	105	506	574	5.49	2.74	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
874.35	0	323	-16	158	542	631	3.98	3.54	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
873.35	0	262	10	222	590	699	3.15	4.35	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
872.35	0	215	37	296	649	778	2.63	5.15	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
871.35	0	177	64	382	719	868	2.27	5.96	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
870.35	0	146	84	473	780	949	2.00	6.76	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
869.35	0	120	102	565	841	1030	1.82	7.56	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
868.35	0	99	120	657	913	1122	1.71	8.37	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
867.35	0	81	136	748	996	1226	1.64	9.17	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
866.35	0	67	152	840	1091	1340	1.60	9.98	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
865.35	0	56	166	932	1196	1465	1.57	10.78	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
864.35	0	47	179	1023	1312	1602	1.57	11.59	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
863.35	0	41	191	1115	1439	1749	1.57	12.39	0, 45 & 100, 45	TENT466BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
863.35	0	41	191	1115	1439	1716	1.54	12.39	0, 50	TENT466BUTTRESS2_INTERFACE.DAT	CF_EPT50.DAT	Interface
863.35	0	41	191	1115	1439	1483	1.33	12.39	0, 46	TENT466BUTTRESS2_JOINT.DAT	CF_EPT50.DAT	Foundation Joint

Profile 3 - cracking

Nil												
Nil												
Nil												

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 2: Mass Concrete Buttressing

Damstab Results for MFL Case

Block 8 - Ch: 635'

Storage @ RL 880.35 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Existing Post-tensioning: **0% effective**

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	C, Phi (OLD) & C, Phi (NEW)	File Names: Geometry	File Names: Forces	Comments
878.38	0	-18	1	1	-16	47	41.98	1.91	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
877.38	0	-9	22	25	17	107	4.21	2.71	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
876.38	0	-5	40	59	62	178	2.99	3.51	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
875.38	0	-3	57	103	117	259	2.51	4.31	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
874.38	0	-2	73	157	183	352	2.24	5.11	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
873.38	0	-1	89	221	260	455	2.07	5.91	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
872.38	0	-2	105	294	348	570	1.94	6.71	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
871.38	0	-2	121	377	447	695	1.84	7.51	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
870.38	0	-3	131	468	533	808	1.73	8.31	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
869.38	0	-5	140	560	616	917	1.64	9.11	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
868.38	0	-7	150	660	710	1037	1.57	9.91	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
868.38	0	-7	150	660	710	845	1.28	9.91	0, 50	TENT635BUTTRESS1_INTERFACE.DAT	CF_EPT0.DAT	Interface
868.38	0	-7	150	660	710	845	1.28	9.91	0, 50 (best fit)	TENT635BUTTRESS1_JOINT.DAT	CF_EPT0.DAT	Foundation Joint
868.38	14.1	0	152	660	646	927	1.40	9.91	0, 45 & 100, 45	TENT635BUTTRESS1_CONC.DAT	CF_EPT0.DAT	Concrete
868.38	14.1	0	152	660	646	768	1.16	9.91	0, 50	TENT635BUTTRESS1_INTERFACE.DAT	CF_EPT0.DAT	Interface
868.38	14.1	0	152	660	646	768	1.16	9.91	0, 50 (best fit)	TENT635BUTTRESS1_JOINT.DAT	CF_EPT0.DAT	Foundation Joint

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 2: Mass Concrete Buttressing

Damstab Results for MFL Case

Block 8 - Ch: 635'

Storage @ RL 880.35 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Existing Post-tensioning: **50% effective**

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	C, Phi (OLD) & C, Phi (NEW)	File Names: Geometry	File Names: Forces	Comments
878.38	0	406.07	-87.58	1.13	297.31	358.92	318.91	1.87	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
877.38	0	398	-43	25	332	394	15.50	1.87	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
876.38	0	343	40	59	366	429	7.21	1.91	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
875.38	0	279	9	103	391	481	4.65	2.71	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
874.38	0	220	23	157	428	544	3.46	3.51	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
873.38	0	174	46	221	475	618	2.80	4.31	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
872.38	0	138	70	294	534	702	2.39	5.11	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
871.38	0	110	94	377	603	798	2.12	5.91	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
870.38	0	86	111	468	664	886	1.89	6.71	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
869.38	0	66	127	560	725	973	1.74	7.51	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
868.38	0	49	143	660	796	1071	1.62	8.31	0, 45 & 100, 45	TENT635BUTTRESS2_CONC.DAT	CF_EPT50.DAT	Concrete
868.38	0	49	143	660	796	948	1.44	8.31	0, 50	TENT635BUTTRESS2_INTERFACE.DAT	CF_EPT50.DAT	Interface
868.38	0	49	143	660	796	820	1.24	8.31	0, 46	TENT635BUTTRESS2_JOINT.DAT	CF_EPT50.DAT	Foundation Joint

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 2: Mass Concrete Buttressing

Damstab Results for MFL Case

Block 12 - Ch: 1000'

Storage @ RL 880.35 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Passive Wedge Included
Section has no existing post-tensioning

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	C, Phi	File Names		Comments
										Geometry	Forces	
879.56	0	6	19	3	17	17	5.69	1.37	0, 45	TENT1000BUTTRESS_CONC.DAT	CF_PW.DAT	Concrete
878.56	0	18	28	16	43	43	2.73	1.89	0, 45	TENT1000BUTTRESS_CONC.DAT	CF_PW.DAT	Concrete
877.56	0	20	40	38	77	77	2.01	2.56	0, 45	TENT1000BUTTRESS_CONC.DAT	CF_PW.DAT	Concrete
876.56	0	18	56	71	120	120	1.70	3.23	0, 45	TENT1000BUTTRESS_CONC.DAT	CF_PW.DAT	Concrete
875.56	0	13	75	113	172	172	1.53	3.89	0, 45	TENT1000BUTTRESS_CONC.DAT	CF_PW.DAT	Concrete
874.56	0	28	55	165	215	215	1.30	5.22	0, 45	TENT1000BUTTRESS_CONC.DAT	CF_PW.DAT	Concrete
873.56	0	11	109	133	312	312	2.34	5.22	0, 45	TENT1000BUTTRESS_CONC.DAT	CF_PW.DAT	Concrete
873.56	0	11	109	133	312	321	2.41	5.22	0, 50	TENT1000BUTTRESS_INTERFACE.DAT	CF_PW.DAT	Interface
873.56	0	11	109	133	312	371	2.78	5.22	0, 46	TENT1000BUTTRESS_JOINT.DAT	CF_PW.DAT	Foundation Joint

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 3: Crest Lowered to RL876.605

Damstab Results for MFL Case

Block 6 - Ch: 466'

Storage @ RL 878.84 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Existing Post-tensioning removed

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	PTF (kN/m)	C, Phi	File Names		Comments
											Geometry	Forces	
875.65	0	-47	50	25	1	1	0.05	1.24	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
874.65	0	-197	660	25	442	442	18.04	1.91	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
873.65	0	42	321	70	468	468	6.65	2.58	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
872.65	0	105	206	126	504	504	3.99	3.24	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
871.65	0	113	168	195	549	549	2.81	3.91	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
870.65	0	101	159	270	595	595	2.21	4.58	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
869.65	0	81	162	347	637	637	1.84	5.25	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
868.65	0	60	172	424	687	687	1.62	5.91	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
867.65	0	41	186	500	747	747	1.49	6.58	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
866.65	0	25	201	577	816	816	1.41	7.25	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
865.65	0	11	215	654	894	894	1.37	7.91	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
864.65	0	-1	230	731	982	982	1.34	8.58	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
863.65	0	-10	243	808	1078	1078	1.33	9.25	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
863.65	0	-10	243	808	1078	1283	1.59	9.25	425	0, 50	TENT466CUTDOWN_INTERFACE.DAT	Option3PT425.DAT	Interface
863.65	0	-10	243	808	1078	1110	1.37	9.25	425	0, 46	TENT466CUTDOWN_JOINT.DAT	Option3PT425.DAT	Foundation Joint

Profile 3 - cracking

863.65	6.3	0	244	808	1056	1056	1.31	9.25	425	0, 45	TENT466CUTDOWN_CONC.DAT	Option3PT425.DAT	Concrete
863.65	6.3	0	244	808	1056	1256	1.55	9.25	425	0, 50	TENT466CUTDOWN_INTERFACE.DAT	Option3PT425.DAT	Interface
863.65	6.3	0	244	808	1056	1087	1.35	9.25	425	0, 46	TENT466CUTDOWN_JOINT.DAT	Option3PT425.DAT	Foundation Joint

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 3: Crest Lowered to RL876.605

Damstab Results for MFL Case

Block 8 - Ch: 635'

Storage @ RL 878.84 m
Tailwater @ RL 871 m
Profile 4 - no cracking

Existing Post-tensioning removed

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	PTF (kN/m)	C, Phi	File Names		Comments
											Geometry	Forces	
874.38	0	-93	421	45	344	344	7.58	2.1	320	0, 45	TENT635CUTDOWN_CONC.DAT	Option3PT320.DAT	Concrete
873.38	0	28	242	94	373	373	3.96	2.76	320	0, 45	TENT635CUTDOWN_CONC.DAT	Option3PT320.DAT	Concrete
872.38	0	55	184	153	411	411	2.69	3.43	320	0, 45	TENT635CUTDOWN_CONC.DAT	Option3PT320.DAT	Concrete
871.38	0	53	171	221	458	458	2.07	4.1	320	0, 45	TENT635CUTDOWN_CONC.DAT	Option3PT320.DAT	Concrete
870.38	0	39	171	297	501	501	1.69	4.76	320	0, 45	TENT635CUTDOWN_CONC.DAT	Option3PT320.DAT	Concrete
869.38	0	21	180	374	545	545	1.46	5.43	320	0, 45	TENT635CUTDOWN_CONC.DAT	Option3PT320.DAT	Concrete
868.38	0	3	194	459	598	598	1.30	6.1	320	0, 45	TENT635CUTDOWN_CONC.DAT	Option3PT320.DAT	Concrete
868.38	0	3	194	459	598	712	1.55	6.1	320	0, 50	TENT635CUTDOWN_INTERFACE.DAT	Option3PT320.DAT	Interface
868.38	0	3	194	459	598	616	1.34	6.1	320	0, 46	TENT635CUTDOWN_JOINT.DAT	Option3PT320.DAT	Foundation Joint
Profile 3 - cracking													
Nil													
Nil													
Nil													

TENTERFIELD CREEK DAM OPTIONS STUDY - STABILITY ANALYSIS

Option 3: Crest Lowered to RL876.605

Damstab Results for MFL Case

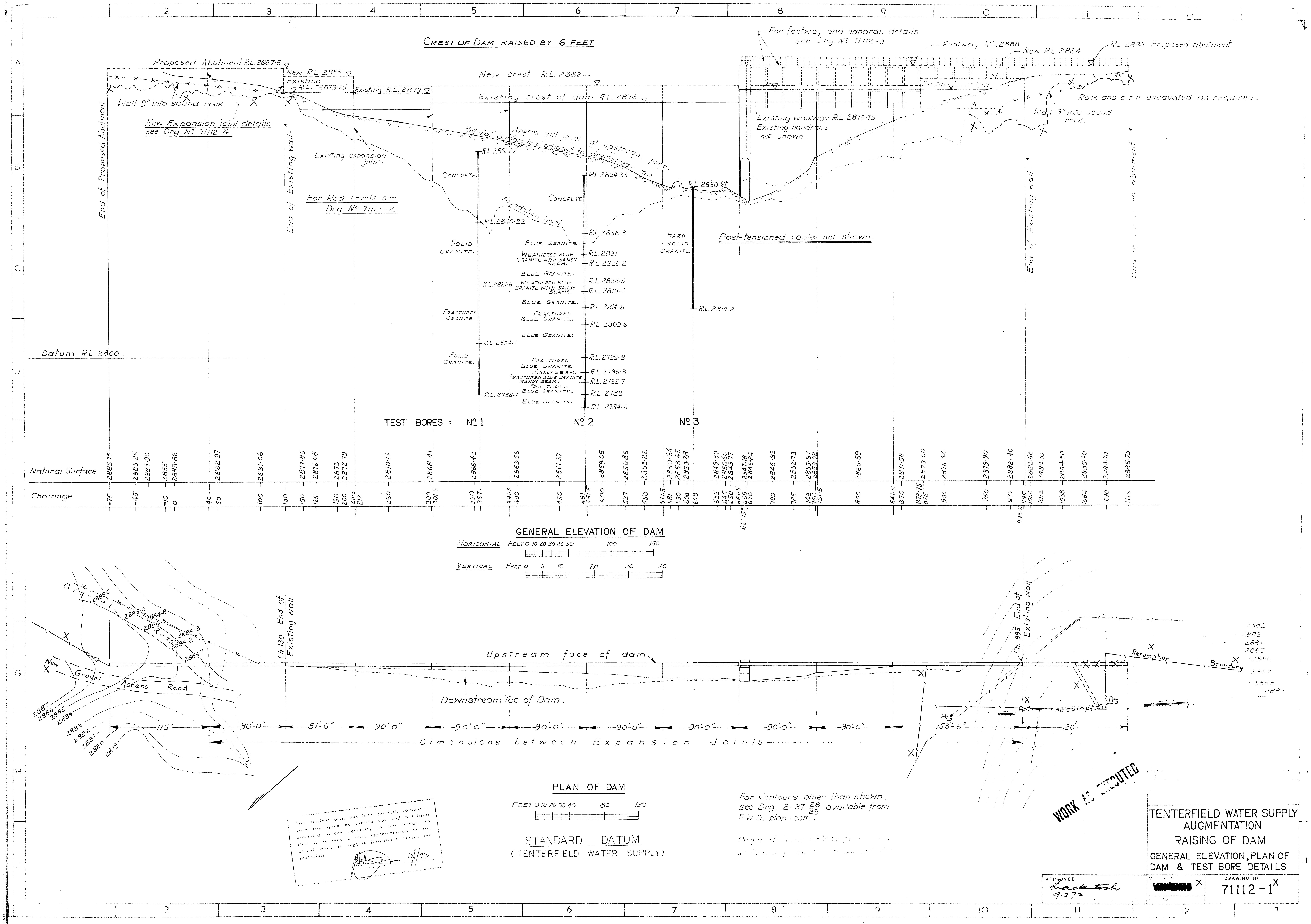
Block 12 - Ch: 1000'

Storage @ RL 878.84 m
Tailwater @ RL 871 m
Profile 4 - no cracking

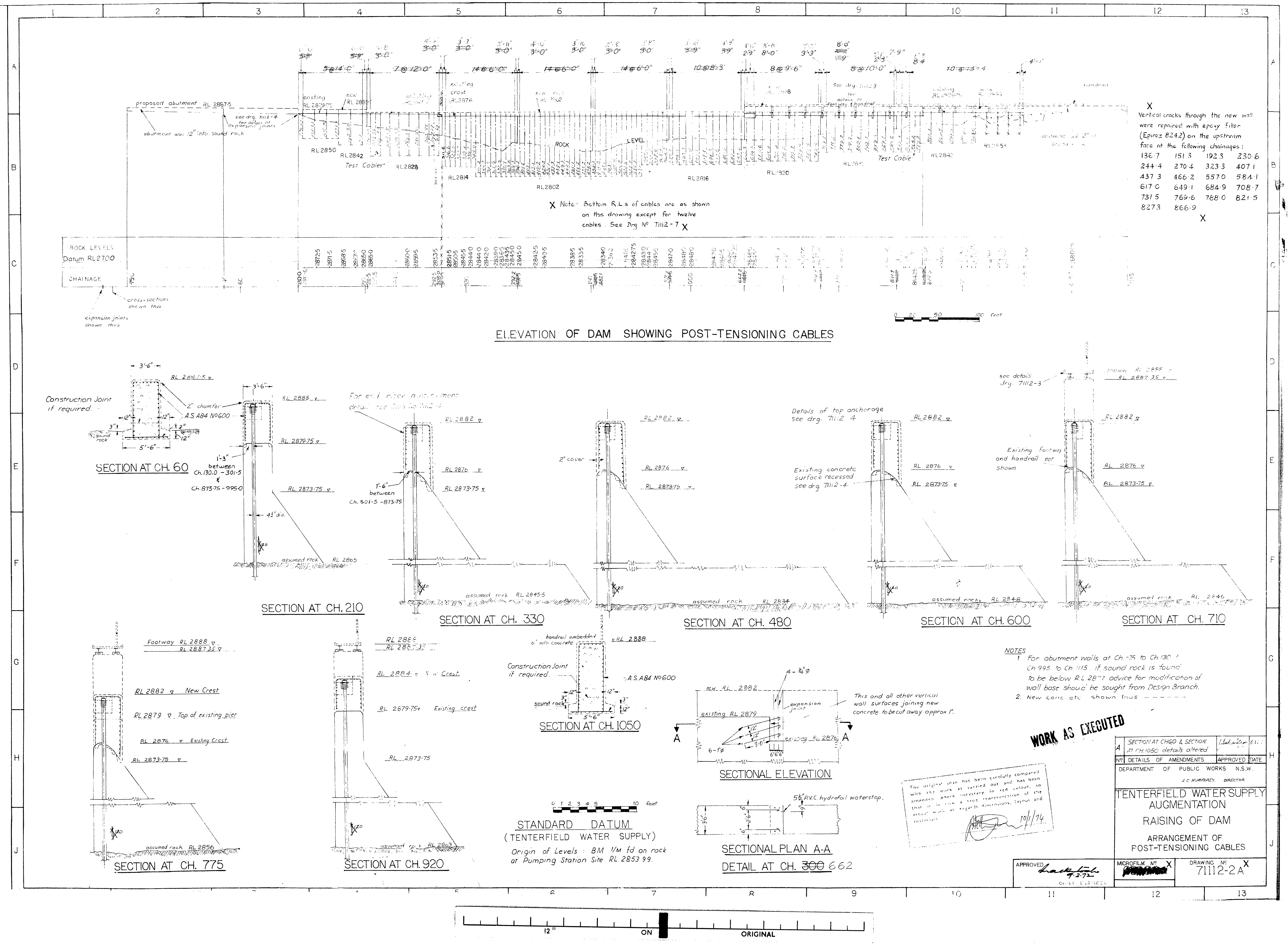
Passive Wedge Included
Section has no existing post-tensioning

RL (mAHD)	Cracking %	Stress U/S (kPa)	Stress D/S (kPa)	Total H (kN)	Total V (kN)	Shear Str. (kN)	SFF	Width (m)	PTF (kN/m)	C, Phi	File Names		Comments
											Geometry	Forces	
879.56	0	17	17	1	18	18	17.67	1.07	0	0, 45	TENT1000_CONC.DAT	CF_PW.DAT	Concrete
878.56	0	51	13	1	45	45	44.59	1.39	0	0, 45	TENT1000_CONC.DAT	CF_PW.DAT	Concrete
877.56	0	70	4	4	76	76	20.22	2.06	0	0, 45	TENT1000_CONC.DAT	CF_PW.DAT	Concrete
876.56	0	77	8	17	116	116	6.73	2.72	0	0, 45	TENT1000_CONC.DAT	CF_PW.DAT	Concrete
875.56	0	79	19	41	165	165	4.07	3.39	0	0, 45	TENT1000_CONC.DAT	CF_PW.DAT	Concrete
874.56	0	77	33	74	224	224	3.03	4.06	0	0, 45	TENT1000_CONC.DAT	CF_PW.DAT	Concrete
873.56	0	89	34	24	291	291	12.32	4.72	0	0, 45	TENT1000_CONC.DAT	CF_PW.DAT	Concrete
873.56	0	89	34	24	291	346	14.66	4.72	0	0, 50	TENT1000_INTERFACE.DAT	CF_PW.DAT	Interface
873.56	0	89	34	24	291	300	12.69	4.72	0	0, 46	TENT1000_JOINT.DAT	CF_PW.DAT	Foundation Joint

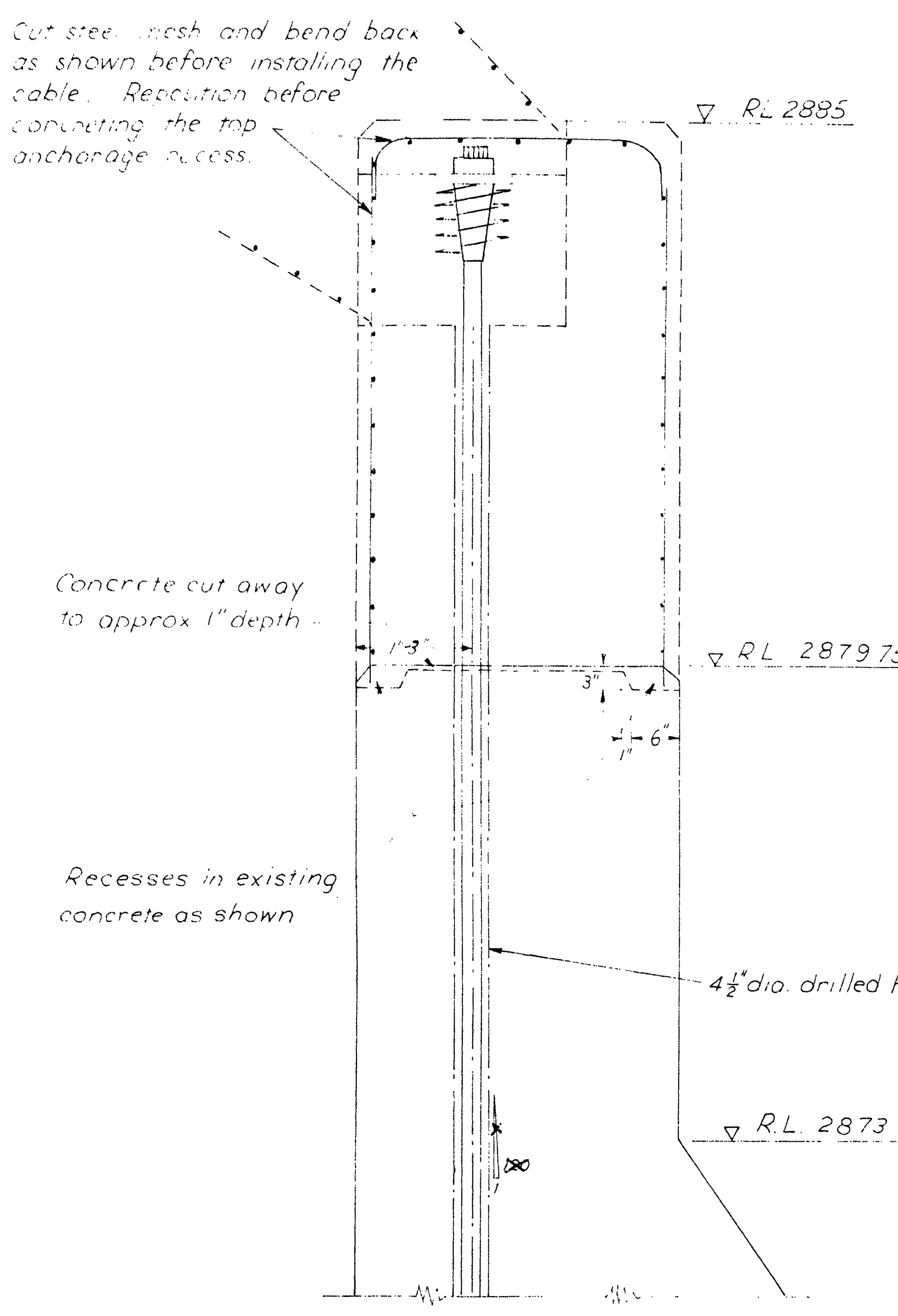
Appendix D Existing Dam Drawings (1974)



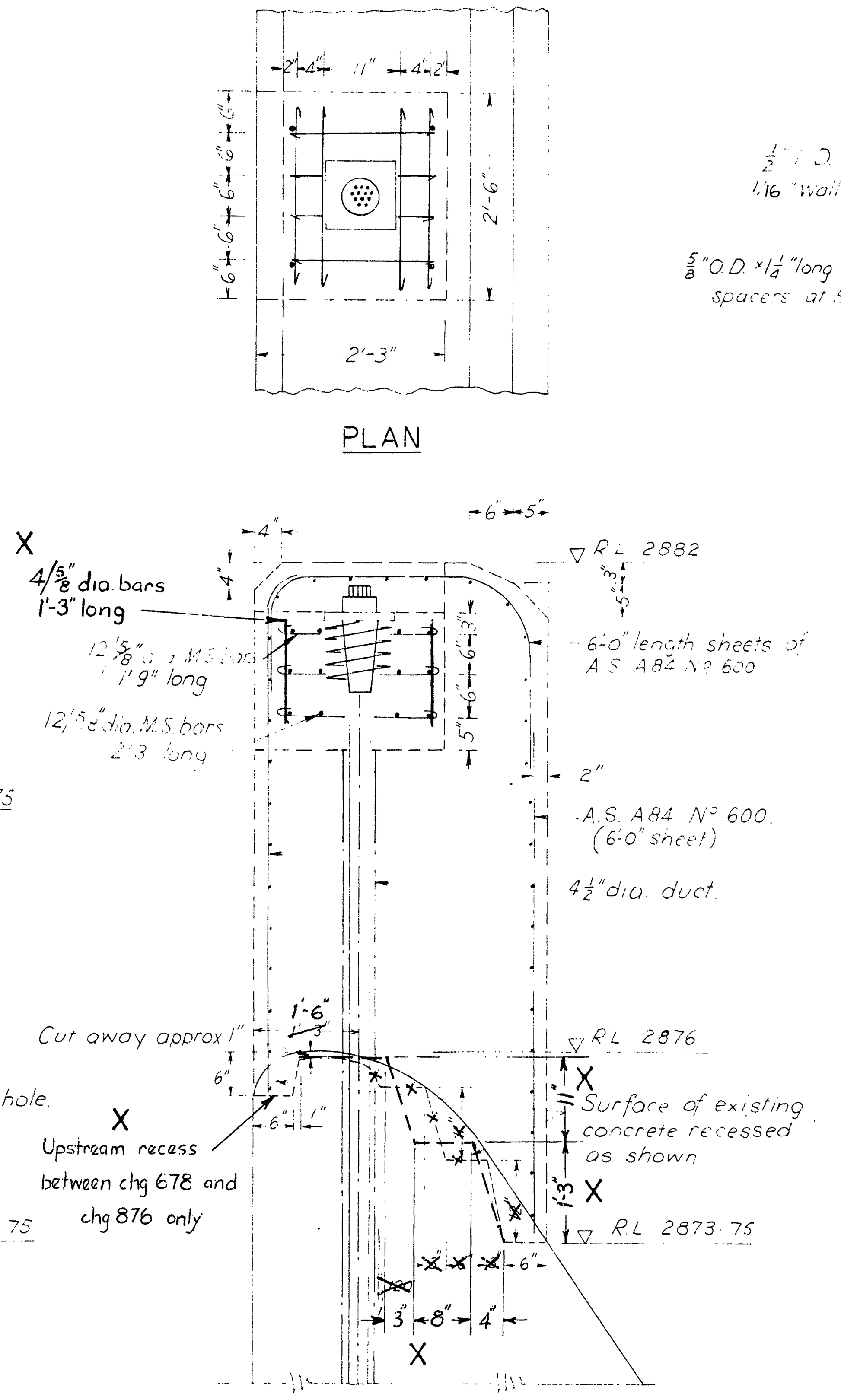
CREST OF DAM RAISED BY 6 FEET
Proposed Abutment R.L. 2887·5
New R.L. 2885
Existing R.L. 2879·75
Existing R.L. 2879
New crest R.L. 2882
Existing crest of dam R.L. 2876
Wall 9" into sound rock.
New Expansion joint details see Drg. Nº 71112-4.
End of Proposed Abutment
End of Existing wall
Existing expansion joints.
Approx silt level of upstream face.
Natural Surface level adjacent to downstream face.
For Rock Levels see Drg. Nº 71112-2.
For footway and handrail details see Drg. Nº 71112-3.
Footway R.L. 2888
New R.L. 2884
R.L. 2888 Proposed abutment.
Rock and o.t.r. excavated as required.
Existing walkway R.L. 2879·75
Existing handrails not shown.
Wall 9" into sound rock.
End of Existing wall
Post-tensioned cables not shown.
Foundation level
R.L. 2861·22
CONCRETE.
R.L. 2840·22
SOLID GRANITE.
R.L. 2821·6
FRACTURED GRANITE.
SOLID GRANITE.
R.L. 2854·33
CONCRETE
R.L. 2836·8
BLUE GRANITE.
WEATHERED BLUE GRANITE WITH SANDY SEAM.
R.L. 2831
R.L. 2828·2
BLUE GRANITE.
WEATHERED BLUE GRANITE WITH SANDY SEAMS.
R.L. 2822·5
R.L. 2819·6
BLUE GRANITE.
R.L. 2814·6
FRACTURED BLUE GRANITE.
R.L. 2809·6
BLUE GRANITE.
FRACTURED BLUE GRANITE.
R.L. 2799·8
SANDY SEAM.
R.L. 2795·3
FRACTURED BLUE GRANITE SANDY SEAM.
R.L. 2792·7
FRACTURED BLUE GRANITE.
R.L. 2789
BLUE GRANITE.
R.L. 2784·6
R.L. 2850·61
HARD SOLID GRANITE
R.L. 2814·2
Datum R.L. 2800.
TEST BORES : Nº 1 Nº 2 Nº 3
Natural Surface
Chainage
GENERAL ELEVATION OF DAM
HORIZONTAL FEET 0 10 20 30 40 50 100 150
VERTICAL FEET 0 5 10 20 30 40
Gravel Road
New Gravel Access Road
Ch. 130 End of Existing wall.
Upstream face of dam.
Downstream Toe of Dam.
Ch. 995 End of Existing wall.
Resumption Boundary
Peg
115' 90'-0" 81'-6" 90'-0" 90'-0" 90'-0" 90'-0" 90'-0" 90'-0" 90'-0" 153'-6" 120'
Dimensions between Expansion Joints
PLAN OF DAM
FEET 0 10 20 30 40 80 120
STANDARD DATUM
(TENTERFIELD WATER SUPPLY)
For Contours other than shown, see Drg. 2-37 28/29 available from P.W.D. plan room.
The original plan has been carefully compared with the work as carried out and has been amended where necessary in red colour, so that it is now a true representation of the actual work as regards dimensions, levels and materials.
10/1/74
WORK AS EXECUTED
TENTERFIELD WATER SUPPLY AUGMENTATION
RAISING OF DAM
GENERAL ELEVATION, PLAN OF DAM & TEST BORE DETAILS
APPROVED
9.2.72
[redacted] X
DRAWING Nº 71112-1X
12" ON ORIGINAL


ELEVATION OF DAM SHOWING POST-TENSIONING CABLES
ROCK LEVELS
Datum RL2700
CHAINAGE
cross-sections shown thus
expansion joints shown thus
proposed abutment RL 2887.5
abutment was 12" into sound rock
ROCK LEVEL
Test Cables
Test Cable
X Note: Bottom R.L.s of cables are as shown on this drawing except for twelve cables. See Drg Nº 71112-7 X
X Vertical cracks through the new wall were repaired with epoxy filler (Epirez 8242) on the upstream face at the following chainages:
136.7 151.3 192.3 230.6
244.4 270.4 323.3 407.1
437.3 466.2 557.0 584.1
617.0 649.1 684.9 708.7
731.5 769.6 788.0 821.5
827.3 866.9
X
SECTION AT CH. 60
SECTION AT CH. 210
SECTION AT CH. 330
SECTION AT CH. 480
SECTION AT CH. 600
SECTION AT CH. 710
SECTION AT CH. 775
SECTION AT CH. 920
SECTION AT CH. 1050
SECTIONAL ELEVATION
SECTIONAL PLAN A-A
DETAIL AT CH. ~~300~~ 662
Construction Joint if required.
A.S.A84 Nº600
Existing concrete surface recessed see drg. 71112-4
Existing Footway and handrail not shown
This and all other vertical wall surfaces joining new concrete to be cut away approx 1".
5½" P.V.C. hydrofoil waterstop.
STANDARD DATUM
(TENTERFIELD WATER SUPPLY)
Origin of Levels: BM 1/M fd on rock at Pumping Station Site RL 2853.99.
NOTES
1. For abutment walls at Ch. 75 to Ch. 130 & Ch. 995 to Ch. 1115 if sound rock is found to be below R.L 2877 advice for modification of wall base should be sought from Design Branch.
2. New conc. etc. shown thus
WORK AS EXECUTED
The original plan has been carefully compared with the work as carried out and has been amended where necessary in red colour, so that it is now a true representation of the actual work as regards dimensions, layout and materials.
10/1/74
A SECTION AT CH. 60 & SECTION AT CH. 1050 details altered
Nº DETAILS OF AMENDMENTS APPROVED DATE
DEPARTMENT OF PUBLIC WORKS N.S.W.
J.C. HUMPHREY, DIRECTOR
TENTERFIELD WATER SUPPLY AUGMENTATION
RAISING OF DAM
ARRANGEMENT OF POST-TENSIONING CABLES
APPROVED 9.2.72
CHIEF ENGINEER
MICROFILM Nº
DRAWING Nº 71112-2A
12" ON ORIGINAL


SIDE ELEVATION
Winch dismantled & replaced as shown
ELEVATION
SECTION A-A
Note: Existing 10" dia flanged steel trunnion pipe extended 8'-3" as shown.
Footway RL 2888.00
New crest level RL 2882
New Crest of Dam RL 2882
Existing RL 2879.75
Existing Pier RL 2879
Existing Crest RL 2876
Existing Crest Level RL 2876
RL 2873.75
Existing Abutment Wall RL 2879.75
Alternative Methods of Pier Construction.
All piers could be constructed either after (as shown in ①) or before (as shown in ②) the raising of crest. In ① the reinforcing bars are grouted into the new concrete. In ② the reinforcing bars are grouted into the old concrete.
Method ① used in all pier construction
PLAN OF WINCH PLATFORM AND FOOTWAY
G.M. 575 galvanized grid mesh in 10'-0" lengths
SECTION SHOWING TRUNNION AND OUTLET PIPES
ARRANGEMENT OF PULLEY BLOCK
DETAILS OF LADDER & CAGE FRAME
DETAIL OF FOOTWAY
C.I. FLANGE FOR HANDRAIL
DETAIL OF U-BOLT
Hot-dip galvanised after fabrication
6 U-bolts per panel of mesh
WORK AS EXECUTED
This original plan has been carefully compared with the work as carried out and has been amended where necessary in red colour, so that it is now a true representation of the actual work as regards dimensions, layout and materials.
10/1/74
DEPARTMENT OF PUBLIC WORKS, N.S.W.
J. C. HUMPHREY, DIRECTOR
TENTERFIELD WATER SUPPLY AUGMENTATION
RAISING OF DAM
ALTERATION & EXTENSION TO FOOTWAY, TRUNNION PIPE & LADDER
APPROVED
7-2-72
DRAWING No
71112 -3X
12" ON ORIGINAL

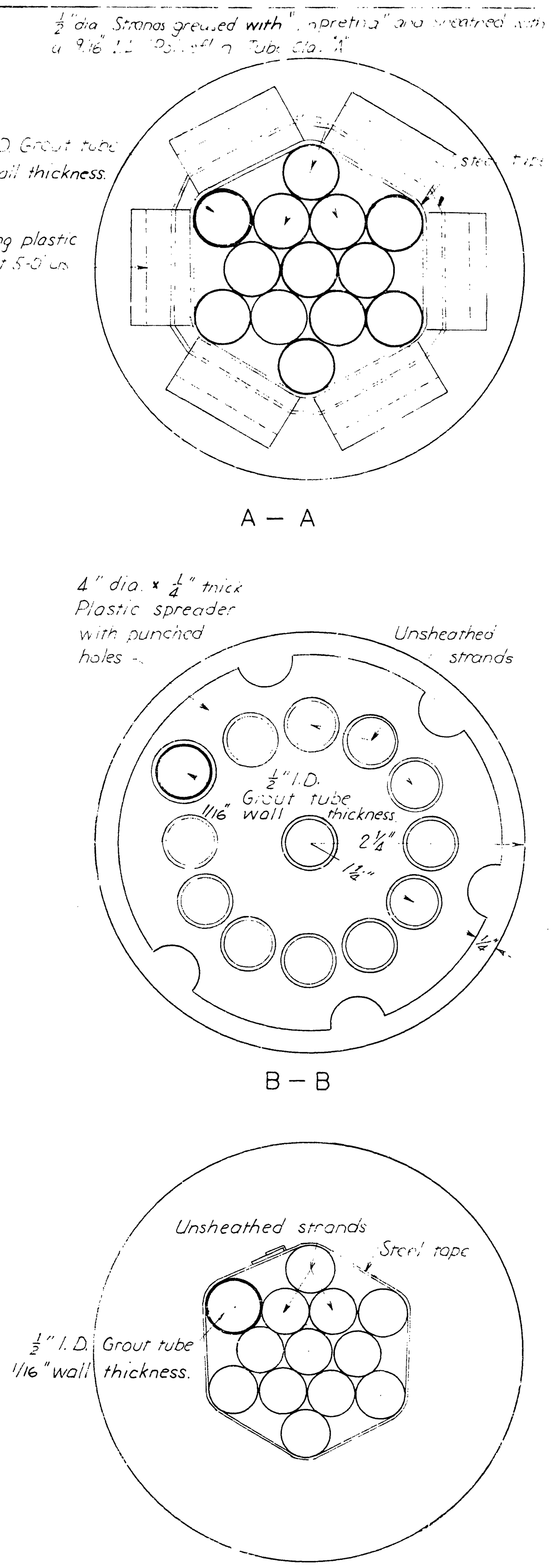


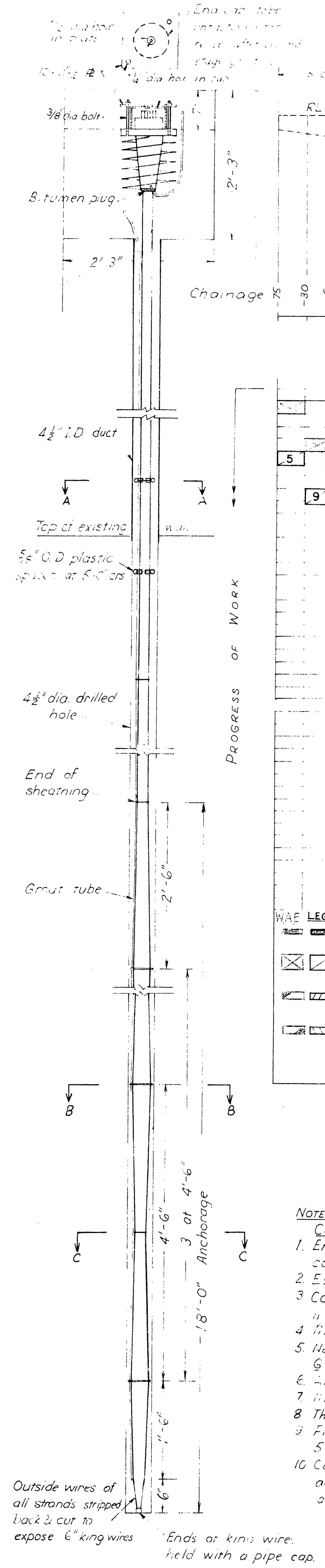
TYPICAL SECTION AT ABUTMENTS SHOWING TOP ANCHORAGE



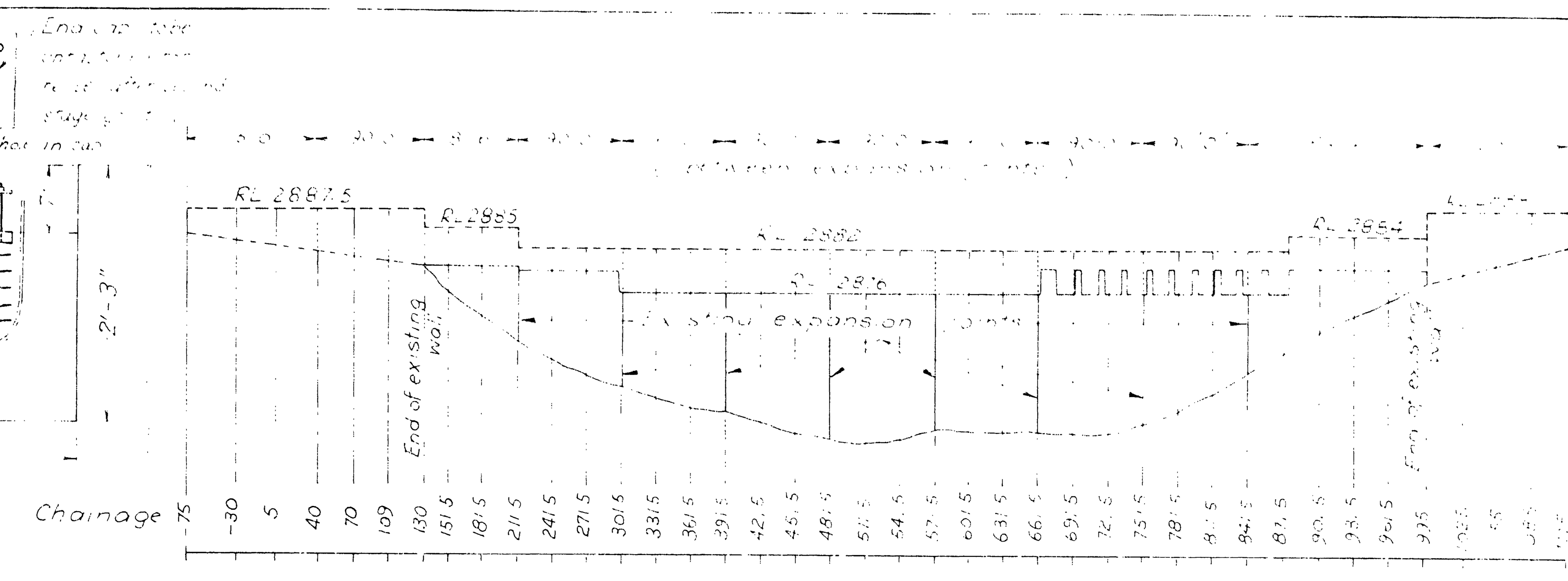
TYPICAL SECTION ALONG CREST SHOWING TOP ANCHORAGE

Inches 12 6 0 1 2 3 Feet

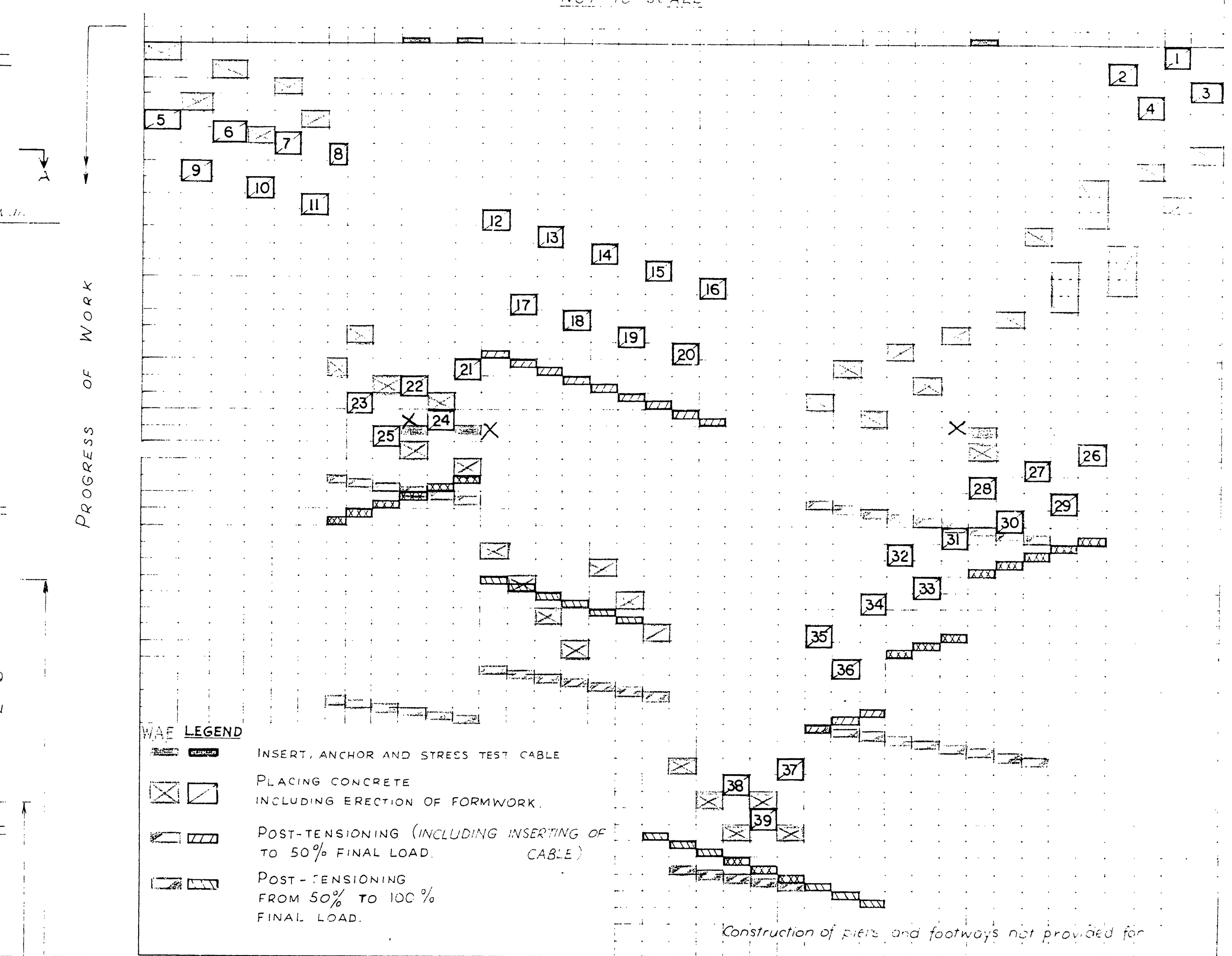




TYPICAL POST-TENSIONING DETAIL



ELEVATION OF DAM
NOT TO SCALE



CONSTRUCTION SEQUENCE FOR CONCRETING AND POST-TENSIONING

Cables shall be stressed in 1 or 2 stages as shown.
Cables stressed in 2 stages shall be tensioned in 1st stage to 50% ± 5% of final load
No alterations to the construction sequence shall be allowed unless approved by the Engineer.

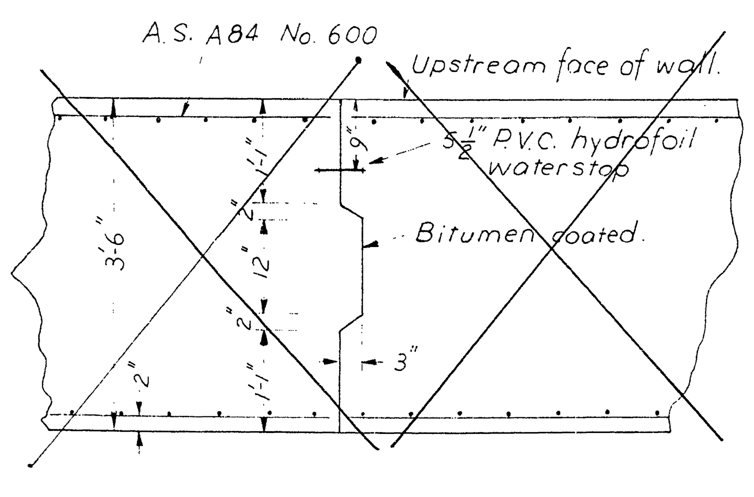
NOTES

Concrete

1. End block concrete shall be Class A 5000 and all other concrete Class A 4000
2. Expansion joints are required where shown.
3. Concrete in each placed length must be cured for a minimum of 14 days before placing adjacent concrete
4. Minimum cover to reinforcement 2"
5. New work shown dotted

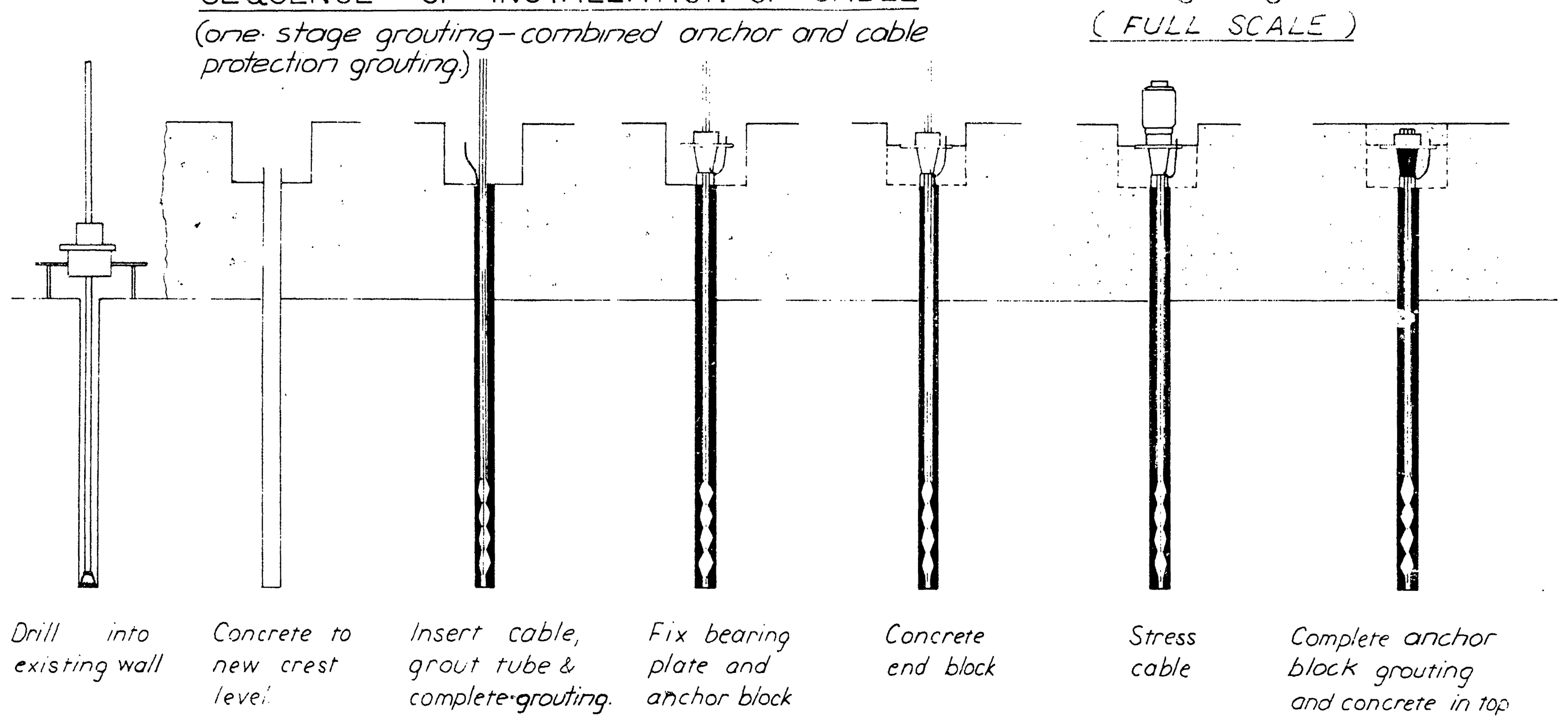
Grouting and Stressing

6. All cables comprise 12-$\frac{1}{2}$" "Supa-7" strands
7. Min ultimate tensile strength of $\frac{1}{2}$" dia strand to be 41300 lb
8. The required load at transfer to be 35000 lb per cable
9. First stage grouting to be carried out not earlier than 5 days after complete concreting to new crest level
10. Cable to be stressed when the end block concrete has achieved a minimum compressive strength of 3500 psi and not earlier than 14 days after grouting.

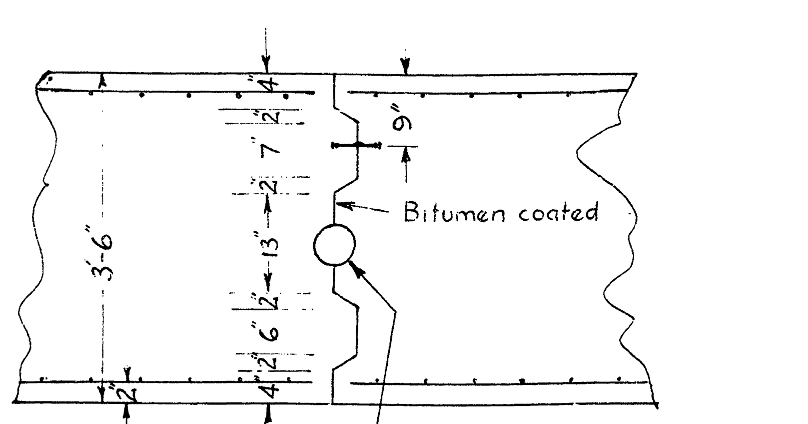


DETAIL OF EXPANSION JOINT

Inches 12 6 0 1 2 3 Feet



SEQUENCE OF INSTALLATION OF CABLE
(one stage grouting—combined anchor and cable protection grouting)



X

$4\frac{1}{2}$" dia hole filled with rubberised hot-poured bitumen continuous with similar in existing wall

The original plan has been carefully compared with the work as carried out and has been amended where necessary to show that it is now a true representation of the actual work as regards dimensions, levels and materials.
10/1/74

WORK AS EXECUTED

DEPARTMENT OF PUBLIC WORKS, N.S.W.

TENTERFIELD WATER SUPPLY AUGMENTATION

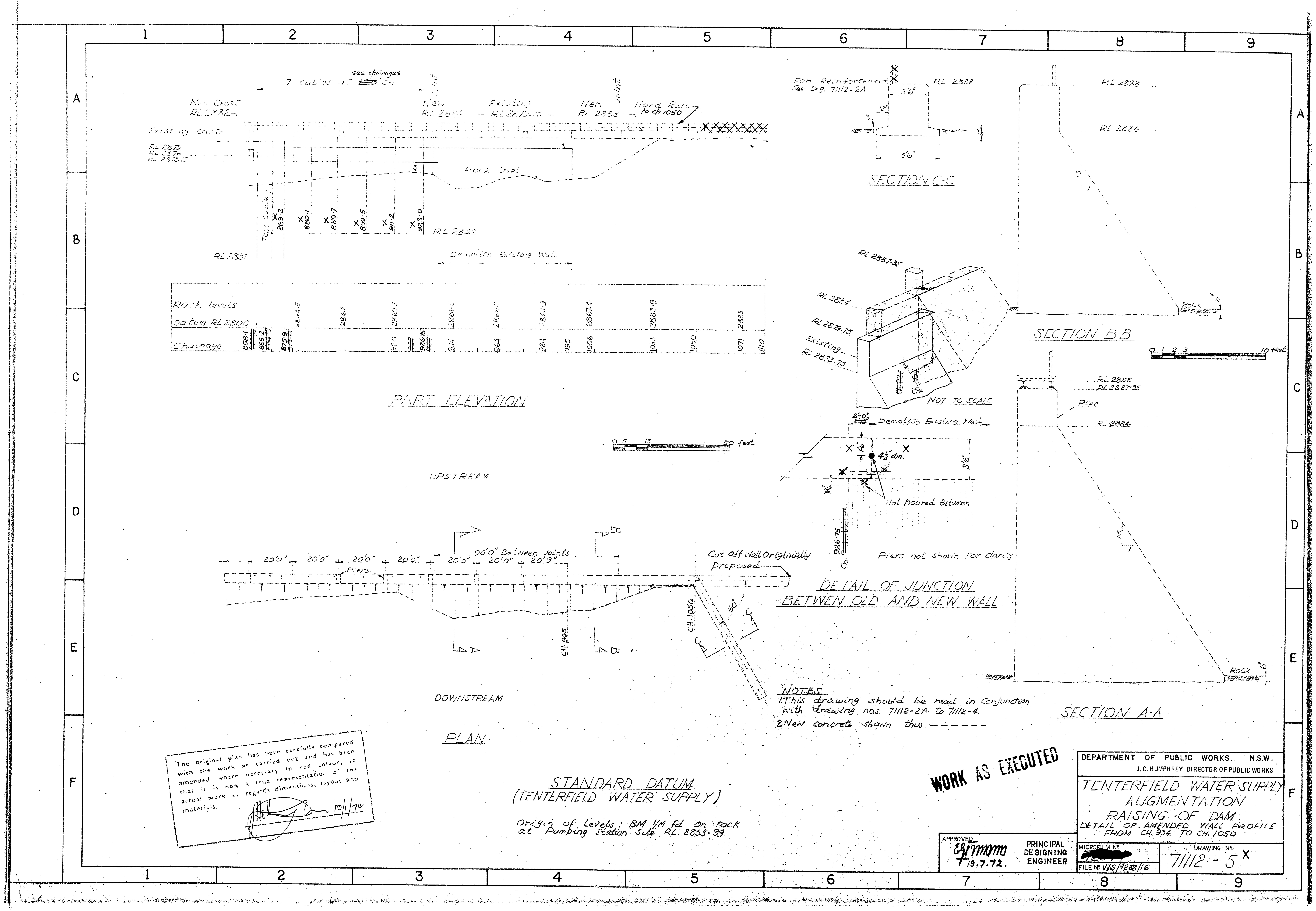
RAISING OF DAM

EXPANSION JOINTS, POST-TENSIONING DETAILS AND CONSTRUCTION SEQUENCE

9.2.72

[redacted]

71112-4X



PART ELEVATION
New Crest RL 2882
Existing Crest
Existing RL 2879.75
New RL 2884
Hard Rails to ch 1050
Rock level
RL 2842
RL 2831
Demolish Existing Wall
Rock levels
Datum RL 2800
Chainage
UPSTREAM
90'0" Between Joints
Piers
Cut off Wall Originally Proposed
CH. 995
CH. 1050
DOWNSTREAM
PLAN
SECTION C-C
For Reinforcement See Drg. 71112-2A
RL 2888
RL 2884
SECTION B-B
NOT TO SCALE
Demolish Existing Wall
4½" dia.
Hot Poured Bitumen
Piers not shown for clarity
DETAIL OF JUNCTION BETWEN OLD AND NEW WALL
RL 2887.35
Pier
Rock
SECTION A-A
NOTES
1. This drawing should be read in conjunction with drawing nos 71112-2A to 71112-4.
2. New concrete shown thus
The original plan has been carefully compared with the work as carried out and has been amended where necessary in red colour, so that it is now a true representation of the actual work as regards dimensions, layout and materials. 10/1/74
STANDARD DATUM (TENTERFIELD WATER SUPPLY)
Origin of Levels: BM 1/M fd on rock at Pumping Station Site RL. 2853.99
WORK AS EXECUTED
DEPARTMENT OF PUBLIC WORKS. N.S.W.
J. C. HUMPHREY, DIRECTOR OF PUBLIC WORKS
TENTERFIELD WATER SUPPLY AUGMENTATION
RAISING OF DAM
DETAIL OF AMENDED WALL PROFILE FROM CH. 934 TO CH. 1050
APPROVED 19.7.72. PRINCIPAL DESIGNING ENGINEER
MICROFILM Nº [redacted]
FILE Nº WS/1288/16
DRAWING Nº 71112 - 5 X

CHAINAGE	R.L. OF TOE	DATE OF STRESSING	LOAD AT JACKING (kips)	ACTUAL ELONGATION AFTER DRAW-IN (mm)	EXPECTED ELONGATION (mm)	LOAD AT TRANSFER (kips)	TOP ANCHORAGE TYPE *	REMARKS
136·7	2850·0	1·8·73	380	43	37	330	M/V	
151·3	2850·0	1·8·73	380	43	37	320	M/V	
165·7	2850·0	1·8·73	380	41	37	345	M/V	
177·7	2842·0	1·8·73	380	55	53	345	M/V	
192·3	2842·0	1·8·73	380	56	53	350	M/V	
206·3	2842·0	1·8·73	380	56	53	350	M/V	
216·0	2828·0	1·8·73	380	73	74	350	M/V	
223·2	2828·0	17-4-73	375				M	Anchorage test cable
229·3	2828·0	1·8·73	380	76	74	360	M/V	
243·0	2828·0	1·8·73	380	71	74	360	M/V	
256·1	2828·0	1·8·73	390	74	74	355	M/V	
269·1	2828·0	1·8·73	390	75	74	355	M/V	
281·5	2828·0	1·8·73	390	71	74	350	M/V	
292·6	2828·0	1·8·73	390	74	74	365	M/V	
297·2	2828·0	17-4-73	375	62	63		M	Anchorage test cable
302·7	2828·0	1·8·73	390	75	74	360	M/V	
311·6	2816·0	1-11-73	390	92	98	360	V	
316·6	2814·0	31-10-73	390	98	102	365	V	
322·0	2814·0	1-11-73	390	98	102	362	V	
327·7	2814·0	1-11-73	390	97	102	365	V	
334·3	2814·0	31-10-73	390	97	102	362	V	
339·2	2814·0	31-10-73	390	98	102	365	V	
345·0	2802·0	1-11-73	390	106	125	367	V	
350·2	2802·0	1-11-73	390	110	125	365	V	
355·8	2802·0	31-10-73	390	117	125	365	V	
361·3	2802·0	1-11-73	390	123	125	367	V	
366·9	2802·0	1-11-73	390	119	125	366	V	
372·5	2802·0	31-10-73	390	121	125	366	V	
378·1	2802·0	1-11-73	390	121	125	365	V	
383·8	2802·0	1-11-73	390	120	125	368	V	
389·3	2802·0	31-10-73	390	119	125	370	V	
396·2	2802·0	1-11-73	390	120	125	365	V	
401·2	2802·0	1-11-73	390	122	125	365	V	
407·1	2802·0	31-10-73	390	95	125	362	V	
413·1	2802·0	1-11-73	390	98	125	364	V	Released + restressed → 84 mm extn, 345 kips at transfer.
419·2	2804·5	1-11-73	390	114	120	365	V	
425·2	2802·0	31-10-73	390	121	125	365	V	
431·1	2807·0	1-11-73	390	116	113	365	V	
437·3	2802·0	1-11-73	390	124	125	365	V	
443·1	2802·0	31-10-73	390	123	125	363	V	
449·1	2802·0	1-11-73	390	126	125	367	V	
455·1	2802·0	1-11-73	390	119	125	365	V	
461·1	2802·0	31-10-73	390	102	125	364	V	
466·2	2803·0	1-11-73	390	117	123	365	V	
473·2	2802·0	1-11-73	390	121	125	365	V	
478·2	2804·0	31-10-73	390	106	121	365	V	Released + restressed → 105 mm extn, 355 kips at transfer.
484·3	2802·0	31-10-73	390	108	125	366	V	
491·2	2802·0	31-10-73	390	115	125	366	V	
497·1	2802·0	31-10-73	390	105	125	362	V	
503·1	2802·0	31-10-73	390	100	125	367	V	Released + restressed → 90 mm extn, 350 kips at transfer.
508·5	2802·0	31-10-73	390	95	125	372	V	

CHAINAGE	R.L. OF TOE	DATE OF STRESSING	LOAD AT JACKING (kips)	ACTUAL ELONGATION AFTER DRAW-IN (mm)	EXPECTED ELONGATION (mm)	LOAD AT TRANSFER (kips)	TOP ANCHORAGE TYPE *	REMARKS
515·2	2803·5	11-12-73	380	115	122	358	V	
522·0	2802·0	11-12-73	380	121	125	353	V	
527·7	2802·0	11-12-73	380	123	125	354	V	
533·7	2802·0	11-12-73	380	123	125	358	V	
539·1	2802·0	11-12-73	380	116	125	356	V	
545·1	2816·0	11-12-73	380	97	98	355	V	
551·2	2816·0	11-12-73	380	95	98	354	V	
557·0	2816·0	11-12-73	380	100	98	352	V	
563·1	2819·0	11-12-73	380	84	92	354	V	
569·2	2817·5	11-12-73	380	93	95	354	V	
575·8	2816·0	11-12-73	380	101	98	354	V	
584·1	2816·5	11-12-73	380	97	97	355	V	
592·5	2816·0	11-12-73	380	97	98	354	V	
600·5	2816·0	11-12-73	380	104	98	356	V	
609·1	2816·0	11-12-73	380	93	98	352	V	
617·0	2816·0	11-12-73	380	81	98	352	V	
624·3	2816·0	11-12-73	380	98	98	360	V	
632·6	2816·0	11-12-73	380	100	98	354	V	
640·9	2816·0	11-12-73	380	98	98	354	V	
649·1	2816·0	11-12-73	380	92	98	354	V	
657·4	2818·0	11-12-73	380	98	94	358	V	
666·2	2814·0	2-8-73	380	100	102	350	M/V	
674·8	2815·0	2-8-73	380	96	100	350	M/V	
683·6	2820·0	2-8-73	380	89	90	352	M/V	
691·9	2820·0	2-8-73	380	90	90	350	M/V	
700·9	2820·0	2-8-73	380	90	90	348	M/V	
710·2	2820·0	2-8-73	380	89	90	360	M/V	
719·7	2820·0	2-8-73	380	91	90	358	M/V	
729·5	2820·0	2-8-73	380	91	90	356	M/V	
739·5	2820·0	2-8-73	380	86	90	350	M/V	
749·5	2820·0	2-8-73	380	92	90	350	M/V	
759·7	2831·0	2-8-73	380	71	68	350	M/V	
770·2	2831·0	2-8-73	380	74	68	343	M/V	
779·8	2831·0	2-8-73	380	75	68	360	M/V	
789·7	2831·0	2-8-73	380	69	68	365	M/V	
800·4	2831·0	2-8-73	380	68	68	350	M/V	
809·8	2831·0	2-8-73	380	69	68	345	M/V	
819·5	2831·0	2-8-73	380	69	68	352	M/V	
829·5	2831·0	2-8-73	380	73	68	340	M/V	
839·6	2831·0	2-8-73	380	71	68	345	M/V	
849·4	2831·0	2-8-73	380	64	68	350	M/V	
858·1	2831·0	2-8-73	380	69	68	348	M/V	
865·2	2831·0	17-4-73	375	69	71		M	Anchorage test cable.
869·2	2831·0	2-8-73	380	67	68	348	M/V	
880·1	2842·0	6-6-73	380	54	52	335	M	
889·7	2842·0	6-6-73	380	53	52	340	M	
899·5	2842·0	2-8-73	380	56	51	348	M/V	
911·2	2842·0	2-8-73	380	54	51	343	M/V	
923·0	2842·0	2-8-73	380	55	51	352	M/V	

* M – Macalloy's system used.
V – V.S.L.'s system used.
M/V – Macalloy's bearing plate, adapted and stressed by V.S.L.

The original plan has been carefully compared with the work as carried out and has been amended where necessary in red colour, so that it is now a true representation of the actual work as regards dimensions, layout and materials.
10/1/74

WORK AS EXECUTED

TENTERFIELD WATER SUPPLY AUGMENTATION

RAISING OF DAM

RESULTS OF CABLE STRESSING

71112-7 X

12" ON ORIGINAL