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Project Note

To	Fraser White and David Krushka TasWater
From	Suraj Neupane, Bill Cohen and Paul Southcott
Project	P514459-Waratah Dam Replacement Concept Designs
Project reference	E307175-P514459
Document number	ENTURA-FFD9B
Subject	Waratah Dam Replacement Concept Designs

Background

Waratah Dam has been found to be in very poor condition and not to meet dam safety compliance criteria in accordance with ANCOLD guidelines. The dam had a piping incident in 2017 and the reservoir level has been temporarily lowered down below the pipe hole to prevent failure of the dam. The flood capacity of the dam (pre 2017) was assessed to be approximately 1:400 AEP. The piping defect is assessed to be between the 1:2 and 1:5 AEP flood level. Ongoing operation of the dam in its current state is unacceptable due to the risks it poses and given the poor performance of the current dam remedial works are not considered to be good value. One alternative to reduce the risks is to replace the dam with a new structure constructed downstream of the existing dam.

TasWater has requested Entura to prepare concept designs for a compliant replacement embankment dam to the existing full supply level, as well as a design for an alternate concrete gravity weir with a full supply level approximately half the height of the existing dam.

Scope of work

The scope of work for the concept designs includes the following activities:

- Undertake a concept design of replacement embankment dam with the same full supply level (FSL) that would comply with prevailing ANCOLD guidelines, considering the replacement dam to be **High C** consequence category dam.
- Undertake a concept design of approximately 3m high concrete gravity weir that would comply with prevailing ANCOLD guidelines considering the weir to be a **Significant** consequence category dam.
- Prepare concept drawings for the replacement embankment and concrete gravity weir alternatives.

- Undertake high level cost estimates (±50%) for replacement embankment and concrete gravity weir.
- Prepare a brief report on the design (this project note).

Design Basis

Hydrology

Replacement embankment

Previous work on hydrology (Cohen & Southcott, 2018) had modelled inflows up to 1:2000 AEP (Annual Exceedance Probability) flowing into Waratah reservoir. For the replacement embankment, a design 1:10,000 AEP flood event were required to be compliant with **High C** fallback flood capacity requirement based on ANCOLD (2000) adopting the lower end of the required range.

In order to assess the required dam crest level for the proposed dam to safely pass a 1:10,000 AEP flood with the provided spillway, the following approach was applied:

- 1:10,000 AEP design rainfalls were developed:
  - Frequent and rare design rainfall depths (1:2,000 AEP and more frequent) with areal reduction factors (ARF) applied were obtained from the previous hydrology (Cohen & Southcott 2018)
  - Estimates of Probable Maximum Precipitation (PMP) design rainfall depths using the GSAM (Generalised Southeast Australia Method; BOM, 2006) for design storm durations of 24 hours and greater, and the GSDM (Generalised Short Duration Method; BOM 2003) for design storm durations of 6 hours and shorter. PMP depths between these durations were interpolated.
  - Estimates of rare (1:1,000 and 1:2,000 AEP) rainfalls for durations shorter than 24 hours were developed from 1:100 AEP rainfall depths using growth factors obtained from the 24 hour duration storm depths.
  - The 1:10,000 AEP design rainfall depths (Table 1) were interpolated using the method described by Australian Rainfall and Runoff (Book 8 Section 3.5.2.2; Ball et al 2016).
  - Extreme rainfall temporal patterns were obtained for short durations (Jordan et al 2005).
  - Extreme rainfall temporal patterns for longer durations were obtained from BoM (2006).
  - The existing uniform spatial pattern was unaltered.
- Losses developed by Entura (Cohen & Southcott, 2018) were further scaled down to the 1:10,000 AEP resulting in 0.69 mm initial loss and 0.69 mm/hour continuing loss.
- The model developed by Entura (Cohen & Southcott, 2018) was reinstated to run models, including the existing start storage level of RL 606.4m (0.1 m above FSL in the pre-2017 condition) and 0.5 m^3/s base flow

- The model was reconfigured to use the newly designed 10m wide spillway which also has a FSL at RL 606.3m

- The model was run using an ensemble of temporal patterns for a range of design storm durations at the 1:10,000 AEP.

The results of the modelling (given in Figure 1) show that the **critical design storm duration for spill at Waratah Dam using the given configuration is approximately 18 hours or greater**. From visual inspection of results, the median estimates of peak level tend to plateau for longer durations. The worst case of those modelled is a 96 hour design storm, the longest duration modelled. Generally this may indicate that the critical duration may be longer than those analysed. However, given the small size of the reservoir's catchment, and that the median values appear to plateau for durations greater than 18 hours, it is reasoned that if this is the case, the magnitude of increased level would be negligible. There is more variability in peak reservoir level due to temporal pattern than there is to design storm duration.

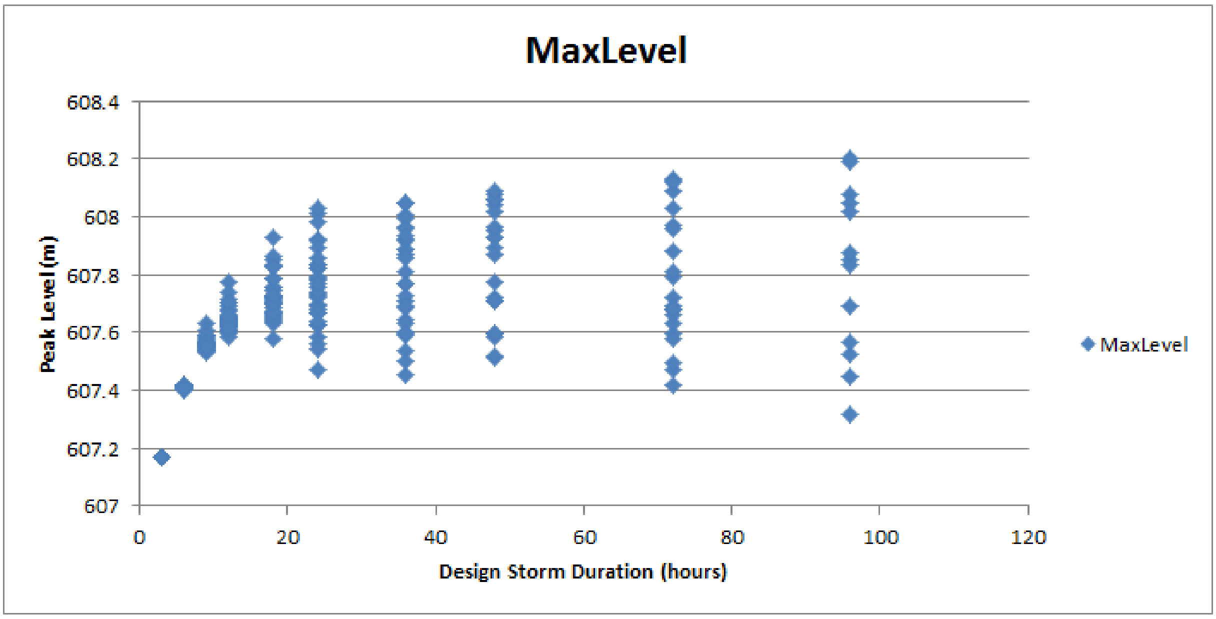

Figure 1 Peak level in Waratah Dam at the 1:10,000 AEP for a range of design storm durations and temporal patterns

For the 1:10,000 design flood, the median estimate of peak level is approximately RL 607.8m (spill of ~35m^3/s). The worst case is RL 608.2 m (spill of ~ 50m^3/s) for a 96 hour design storm simulation. The median spill estimate has been used to size the spillway for the replacement embankment.

Table 1: Design rainfall depths at the 1:10,000 AEP for the Waratah Dam catchment

Duration (hours)	Rainfall depth (mm)
3	98
6	138
9	170

Duration (hours)	Rainfall depth (mm)
12	197
18	245
24	287
36	367
48	417
72	474
96	501

Concrete gravity weir

Since the consequence category for the concrete gravity weir is **Significant**, a fallback flood capacity for was taken as 1:1,000 AEP based on ANCOLD (2000) adopting the lower end of the required range. It is assumed that the reservoir will not have any significant attenuation of the inflows due to the much reduced storage volume and that inflows are equal to outflows. The design inflow and outflow is 31.4m^3/s.

Replacement Embankment

Arrangement

A replacement embankment was considered just downstream of the existing embankment. Drawings of the proposed dam can be found in Appendix A. The embankment has the following features:

- Height of the embankment: ~8m
- Upstream slope: 1V:3H
- Downstream slope: 1V:2.5H
- Embankment crest width: 4m
- Embankment crest level: RL 608.3m
- Spillway: 10m long x 2m deep concrete spillway with a broad crested weir around right abutment
- Spillway crest level: RL 606.3m
- Spillway chute: 91m long concrete chute discharging into natural river course
- Outlet work: Ø500mm concrete encased HDPE pipe with a Ø500mm gate valve

Embankment

Embankment crest level was worked out based on the wet freeboard requirements for 1:10,000 AEP flood event and adopting a 0.5m freeboard. Reservoir routing for 1:10,000 AEP flood event for the adopted spillway gave a design flood level of RL 607.8m. Therefore, a final crest level of RL 608.3m was adopted.

The embankment adopted is an earthfill embankment with clay core and 2A filter. It is assumed that the earthfill required for the embankment can be sourced from the reservoir area. The clay core is assumed to be sourced locally. Only one filter, i.e. 2A, has been adopted for chimney filter on the downstream face of central clay core and will be placed between the clay core and the downstream earthfill. However, for blanket filter a 2B filter has also been considered, in addition to 2A filter for higher drainage capacity along the base of downstream earthfill.

The upstream and downstream slope of the embankment was adopted to be 1V:3H and 1V:2.5H respectively. Based on USBR (1987), small dams with proper drainage can have a downstream slope of 1V:2H to 1V:2.5H. Formal stability assessments for different loading conditions have not been undertaken but very limited geotechnical information is available on the site.

Protection of upstream face against wave generated erosion has been provided by incorporating a nominal 1m thick layer of riprap over geofabric for 2/3rd height of the dam from the crest.

Spillway

The full supply level of the replacement embankment has been kept. A free flowing broad crested spillway has been designed for 1:10,000 AEP flood. The dimensions were iterated for the peak outflow and the optimum length and depth were worked out. Based on this, final length and depth was fixed as 10m and 2m respectively allowing for a freeboard of 500mm at the crest.

The chute has a maximum slope of 8.2%. Based on this slope, depth of flow at different sections was worked out for the peak outflow during 1:10,000 AEP flood event. The calculated maximum depth of flow in the chute was 0.86m and adopted maximum height of chute walls on each side was 1.4m allowing for a freeboard of 500mm.

Energy dissipater

An energy dissipater structure has been provided at the end of the spillway chute. The dissipater is USBR Basin II type (USBR, 1986). The dimension of the dissipater is 7m x 10m x 2.1m (L x W x H).

Outlet

A 500mm diameter outlet conduit (HDPE, concrete encased) has been provided for new dam. The outlet meets the requirements for dewatering based on USBR (1990). Note that this does not take into account the inflow into the reservoir during dewatering operation. A trash rack on the head wall at the inlet of new outlet conduit has been included. Similarly, a head wall has been included at the exit. A gate valve (Ø500mm) just upstream of the head wall has also been incorporated in the design. The outlet will discharge slightly downstream of the spillway energy dissipater.

Instrumentation

As the dam is a **High C** consequence category dam, the following instruments have been incorporated in the design to comply with ANCOLD (2003):

- V-notch weir (x 1)
- Manually read reservoir level measuring gauge boards
- Dam deformation survey targets and benchmarks

It is assumed that daily rainfall data will be sourced from a nearby rain gauge via Bureau of Meteorology website.

Access to downstream area

A single lane vehicular bridge over the spillway to the spillway crest has been provided in the design. The adopted bridge is a precast concrete slab supported on spillway chute walls, which would be stiffened as necessary to carry the imposed loads.

Access to outlet works and dam toe is via the bridge over the spillway and crest leading to the left abutment track down to a vehicle parking area near the valve location. An access stairway has been incorporated from the parking area to the valve location.

Concrete Gravity Weir

Arrangement

A trapezoidal concrete gravity weir was considered just downstream of the existing embankment. Drawings of the proposed weir can be found in Appendix B. The concrete gravity weir has following features:

- Height of the weir: 4m from foundation level
- Upstream slope: Vertical
- Downstream slope: 1V:0.55H
- Crest width: 0.8m
- Abutment crest level: RL 604.5m
- Spillway: 27 m long x 1m deep central spillway discharging into an energy dissipater
- Spillway crest level: RL 603.5m
- Outlet: Ø500mm concrete encased HDPE pipe with Ø500mm gate valve

Weir

The parameters chosen for the global stability assessment were slightly conservative as no information is available on the foundation. The assumed parameters are presented below.

Table 2: Assumed parameters for stability assessment

Material	Parameter
Friction angle at rock/concrete interface	45°
Cohesion at rock/concrete interface	0 kPa
Concrete tensile strength at rock/concrete interface	0 kPa
Usual loading (assuming outlet is kept closed)	Reservoir level at 200mm above spillway crest

A suitable section was worked out using CADAM software. The factors of safety against sliding and overturning adopted for the stability analysis and the results obtained are as follows:

	Required FOS[1]			Analysed FOS		
	Usual loading	Unusual loading	Extreme loading	Usual loading	Unusual loading	Extreme loading
Sliding	3	2	1.5	3.1	2.6	1.8
Overturning	1.5	1.3	1.1	2.1	1.9	1.8

[1]ANCOLD (2013) and CDA (2007)

Spillway

The spillway was designed for 1:1,000 AEP inflow. A free overflow broad crested weir spillway has been provided in the design. The dimensions were calculated for the peak outflow assuming there is no attenuation in the reservoir. Based on this, final length and depth was fixed as 27m and 1m respectively allowing for a freeboard of 200mm.

Height of the chute walls (0.5m) were determined based depth of flow for peak inflow. A freeboard of 200mm has also been allowed for.

Energy dissipater

An energy dissipater structure has been included at the end of the spillway chute. The dissipater is USBR Basin II type (USBR, 1986). The dimension of the dissipater is 11m x 20m x 1.52m (L x W x H).

Outlet

A 500mm diameter outlet conduit (HDPE, concrete encased) has been provided for the concrete gravity weir. The outlet meets the requirements for dewatering based on USBR (1990). Note that this does not take into account the inflow into the reservoir during dewatering operation. A trash rack with head wall at the inlet of new outlet conduit has been considered. Similarly, a head wall has been included at the exit with a valve just upstream of the head wall has also been incorporated.

Access to weir crest

No vehicular access has been provided for the weir crest.

Access to outlet valve

A single lane vehicular access to outlet valve at the toe of the weir has been provided from the right hand side abutment down to a parking area near the valve location.

Instrumentation

Instrumentation for concrete gravity weir has been incorporated based on the requirements for a **Significant** consequence category dam and are as follows:

- Manually read reservoir level measuring gauge boards
- Dam deformation survey targets and benchmark

It is assumed that daily rainfall data will be sourced from a nearby rain gauge via Bureau of Meteorology website.

Diversion during construction

The existing embankment would be used as a coffer dam during the construction of either replacement embankment or concrete gravity weir.

The existing embankment has a 400 mm diameter outlet conduit with a valve on the downstream side, which was recently refurbished. This conduit will be connected with the new outlet conduit (for replacement embankment as well as concrete gravity weir) to divert the inflows. Considering a construction flood equivalent to 10% percentile flow (i.e. flow that is not exceeded 90% of the time) which is equivalent to 1m^3/s (Pokharel, 2015), the combined capacity of the existing outlet pipe and the new outlet for replacement embankment and concrete gravity weir to divert the inflows was assessed. The maximum outflow that the conduit can discharge is 0.67m^3/s when the reservoir level is 300mm lower than the piping defect in the existing embankment. Therefore, there is a need to operate the existing spillway during construction of the replacement embankment and concrete gravity weir. The current crest level of the existing spillway is approximately RL 605.3m. Therefore, this existing spillway together with the outlet conduit can handle the construction flood.

Diversion for replacement embankment

At the preliminary stages of construction, the existing spillway will have to be used for diverting the inflows. Once the new outlet conduit is in place and connected to the existing outlet conduit, the combined outlet conduit will also be used for diverting the inflows. It should be noted that spillway wall on the left hand side at embankment interface and the spillway chutes will have to be constructed prior to construction of the embankment. This will have a couple of advantages:

- The new spillway can be used for diversion during embankment construction when inflows exceed the outlet capacity;
- Embankment can be compacted against the spillway wall at interface during construction.

The spillway crest wall (top RL of 606.3m) will have to be constructed at the end of construction work when the embankment works are complete.

A small earth and rockfill coffer dam will have to be constructed on the downstream side of the new embankment to protect the works area from back water inundation.

Diversion for concrete gravity weir

The existing spillway can be used for diverting inflows during construction. The existing spillway crest will have to be lowered slightly to prevent the existing embankment being overtopped during the weir construction.

A small coffer dam will have to be constructed on the downstream side of the concrete gravity weir to prevent the works area from back water.

Existing embankment

The existing embankment will have to be kept as is during construction of either the replacement embankment or concrete gravity weir. At the end of construction, the existing embankment will have to be lowered significantly and breached at the deepest section (around the existing outlet) so that water can flow to the replacement embankment or concrete gravity weir intake.

Divers will be required to install and remove a blank plate on the upstream side of the existing outlet conduit, so that this conduit can be connected and disconnected with the new conduit on the downstream side of the existing embankment.

Cost estimate

High level cost estimates (-10% to +30%) for the replacement embankment and concrete gravity weir have been undertaken. Details can be found in Appendix C. A summary of cost estimates is presented below:

Table 1: Cost estimate for replacement embankment (-10% to +30%)

Item	Cost
Preliminaries	$106,000
Excavation work	$494,000
Embankment construction	$1,145,000
Spillway and energy dissipater	$775,000
Instrumentation (telemetered V-notch weir, manual gauge boards and survey markers)	$70,000
Engineering and project management	$633,000
Sub-total	**$3,223,000**
Contingency	$557,000
Total	**$3,780,000**

Table 2: Cost estimate for concrete gravity weir (-10% to +30%)

Item	Cost
Mobilisation, demobilisation and site preparation	$82,000
Earthwork (excavation and removal or existing embankment)	$233,000
Concrete gravity weir, spillway and energy dissipater	$928,000
Instrumentation (manual gauge boards and survey markers)	$31,000
Engineering and project management	$351,000
Sub-total	**$1,625,000**
Contingency	$286,000
Total	**$1,911,000**

Limitations

This report has been prepared based on the currently available information only to a high level concept design for indicative budgeting purposes. The following are noted as significant areas of uncertainty or risks that should be addressed prior to proceeding to feasibility study:

- The only geotechnical information available from site is the geological map of the area. Assumptions have been made that:
  - the local materials are suitable for construction and there is sufficient availability.
  - the permeability and strength at the assumed depth of the foundation is adequate for both options.
  - both of these issues would need to be proven by an appropriate level of geological and geotechnical investigation.
  - significant cost increases in construction cost estimate would occur if either or both of these risks were to eventuate.
- A detailed consequence category assessment for the proposed new dams have not been completed. A detailed assessment may lead to higher consequence categories, leading to higher design standards and increased construction cost estimate to meet these requirements (e.g. higher flood capacity).
- No assessment of the economics of either of the proposed new dams have been undertaken. TasWater should assess the benefits of this development.
- No consideration of potential environmental, cultural or aboriginal heritage impacts have been made.
- No consideration has been made of potential permit requirements may have on the dam design and hence potential construction cost impacts.

References

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Bureau of Meteorology (2006). *Guidebook to the estimation of PMP: generalised southeast Australia method*, BOM, 2006.

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Jordan, P., Nathan, R., Mittiga, L. and Taylor, B. (2005). *Growth curves and temporal patterns of short duration design storms for extreme events*, Australian Journal of Water Resources, 9(1), pp69-80, 2005.

Pokhrel, P. (2015). *Waratah River yield analysis*, Rev 0.1, ENTURA-95C6A, January 2015.

USBR (1984). *Hydraulic design of stilling basins and energy dissipaters*, A water resources technical publication, Engineering monograph no. 25, United States Department of Interior Bureau of Reclamation, May 1984.

USBR (1990). *Criteria and guidelines for evacuating storage reservoirs and sizing low-level outlet works*, ACER Technical Memorandum No.3, United States Bureau of Reclamation, 1990.

Software:

CADAM (2003), Version 1.4.12, Department of Civil, Geological and Mining Engineering, Montreal, Canada, 2003.

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Appendix A – Embankment option drawings

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NOTES

1. TEMPORARY COFFER DAM IS TO BE CONSTRUCTED SLIGHTLY UPSTREAM OF OF OUTLET PIPE HEADWALL
2. EXISTING EMBANKMENT SHALL BE REMOVED AFTER THE COMPLETION OF REPLACEMENT EMBANKMENT CONSTRUCTION.
3. NEW SPILLWAY SHALL BE CONSTRUCTED FIRST BEFORE THE EMBANKMENT IS CONSTRUCTED TO DIVERT EXCESS INFLOWS EXCEEDING OUTLET PIPE CAPACITY.

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Revision Notes		
Rev.	Date	Approved

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Sheet Size	A1
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PROJECT DETAILS		DESIGN		DATE
Project No.	P 514459	Drawn	B.SHERIFF	04/09/2018
Vault Folder	Projects	Designed	S.NEUPANE	04/09/2018
Discipline	C | M | E | R	Verified	P.SOUTHCOTT	04/09/2018
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WARATAH DAM REPLACEMENT CONCEPT DESIGN
EMBANKMENT AND SPILLWAY PLAN

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Sheet Number: 1 of #
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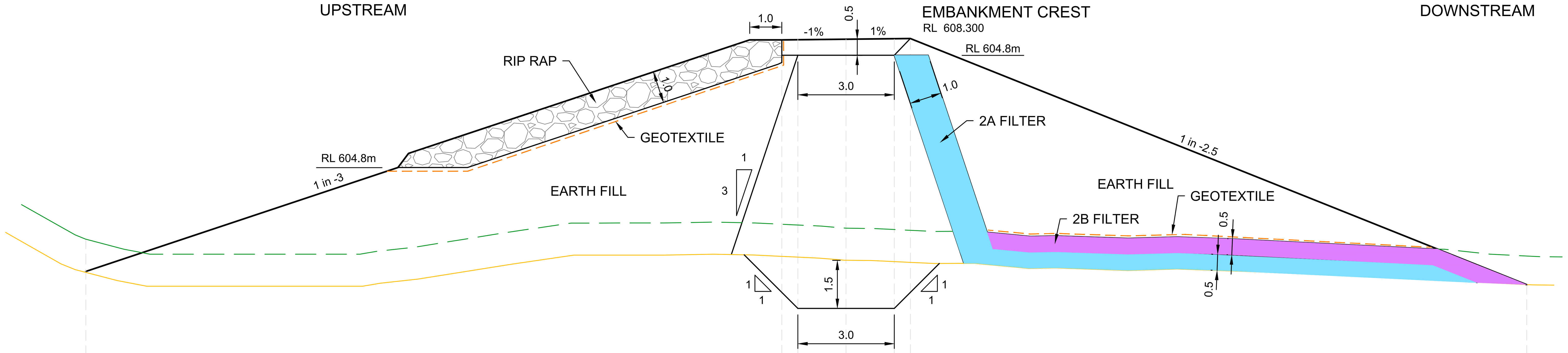

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EXISTING SURFACE	602.064	602.551	602.410	602.020	602.651
OFFSET	-23.649	-2.000	0.000	2.000	21.173

EMBANKMENT SECTION - CHAINAGE 75

A1 HORZ SCALE 1:100
A1 VERT SCALE 1:100

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Vault Folder	Projects	Designed	S.NEUPANE	04/09/2018
Discipline	C | M | E | R	Verified	P.SOUTHCOTT	04/09/2018
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WARATAH DAM REPLACEMENT CONCEPT DESIGN
EMBANKMENT
TYPICAL CROSS SECTION

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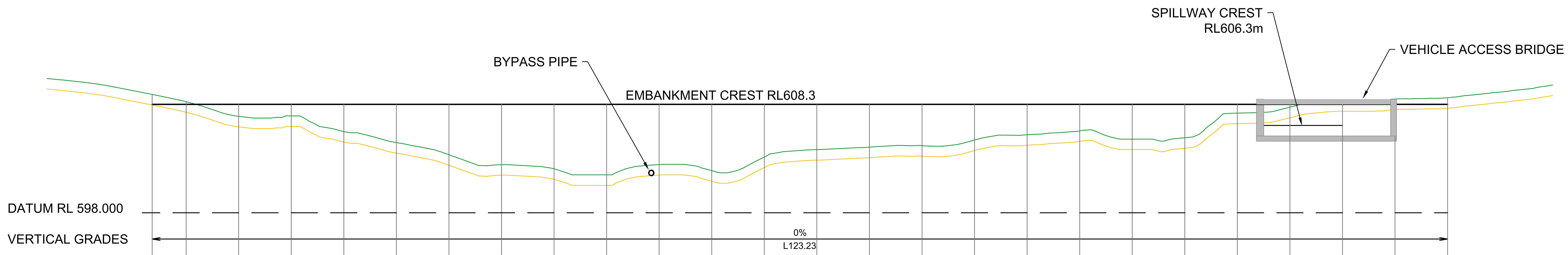

EMBANKMENT	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300
ASSUMED ROCK SURFACE	608.250	607.554	606.166	606.200	604.717	603.667	602.513	601.569	601.184	600.600	601.583	601.002	602.301
EXISTING SURFACE	609.250	608.554	607.166	607.200	605.717	604.667	603.513	602.569	602.184	601.600	602.583	602.002	603.301
CHAINAGE	123.228	120	115	110	105	100	95	90	85	80	75	70	65

EMBANKMENT	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300	608.300
ASSUMED ROCK SURFACE	603.000	603.235	603.378	603.916	604.415	604.777	604.000	604.132	606.471	607.036	607.657	607.818	607.931
EXISTING SURFACE	604.000	604.235	604.378	604.916	605.415	605.777	605.000	605.132	607.471	608.036	608.657	608.818	608.931
CHAINAGE	60	55	50	45	40	35	30	25	20	15	10	5	0

EMBANKMENT - LONGITUDINAL SECTION

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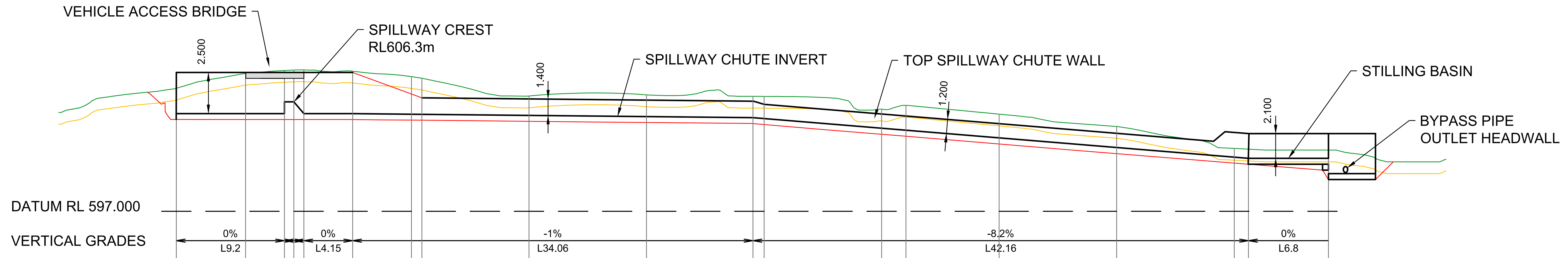
A1 VERT SCALE 1:250



SPILLWAY	605.300	605.300	605.300	606.300	605.300	605.300	605.250	605.241	605.150	605.050
ASSUMED ROCK SURFACE	606.457	607.727	607.967	608.004	608.018	607.905	607.443	607.309	605.800	605.892
EXISTING SURFACE	607.457	608.727	608.967	609.004	609.018	608.905	608.443	608.309	606.800	606.892
CHAINAGE	0	5.888	9.200	10	10.85	15	20	20.892	30	40

SPILLWAY	604.959	604.882	604.061	603.892	603.241	602.420	601.600	601.500	601.500
ASSUMED ROCK SURFACE	605.769	605.764	604.676	605.000	604.257	603.203	601.342	601.276	601.200
EXISTING SURFACE	606.769	606.764	605.676	606.000	605.257	604.203	602.342	602.276	602.200
CHAINAGE	49.056	50	60	62.069	70	80	90	91.214	98.014

SPILLWAY - LONGITUDINAL SECTION

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A1 VERT SCALE 1:250

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Revision Notes

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WARATAH DAM REPLACEMENT CONCEPT DESIGN
EMBANKMENT AND SPILLWAY CHUTE LONGITUDINAL SECTIONS

TASMANIAN WATER & SEWAGE CORPORATION PTY LTD
ABN: 47 162220 653

Drawing Number: P514459-RE-002 | Sheet Number | REVISION

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Appendix B – Concrete weir option drawings

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NOTES

1. EXISTING SPILLWAY CHANNEL SHALL BE USED AS A DIVERSION FOR FLOWS EXCEEDING OUTLET PIPE CAPACITY.
2. EXISTING EMBANKMENT SHALL BE REMOVED AFTER THE COMPLETION OF REPLACEMENT EMBANKMENT CONSTRUCTION.

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PRELIMINARY ONLY
PRINT DATE: 4/09/2018 8:43:26 AM

Revision Notes		
Rev.	Date	Approved

Scale	1:250
Datum H & V	A.H.D.(Tas)
Sheet Size	A1
References	

PROJECT DETAILS		DESIGN		DATE
Project No.	P 514459	Drawn	B.SHERIFF	04/09/2018
Vault Folder	Projects	Designed	S.NEUPANE	04/09/2018
Discipline	C | M | E | R	Verified	P.SOUTHCOTT	04/09/2018
HPRM Folder.	##/#####	© 2018		

DRAWING ISSUE

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WARATAH DAM REPLACEMENT CONCEPT DESIGN
CONCRETE GRAVITY WEIR AND SPILLWAY
PLAN

TASMANIAN WATER & SEWAGE CORPORATION PTY LTD
ABN: 47 162220 653

Consultant Drawing Number: E — Sheet Number: 1 of # — REVISION: A

Drawing Number: P514459-CGW-001

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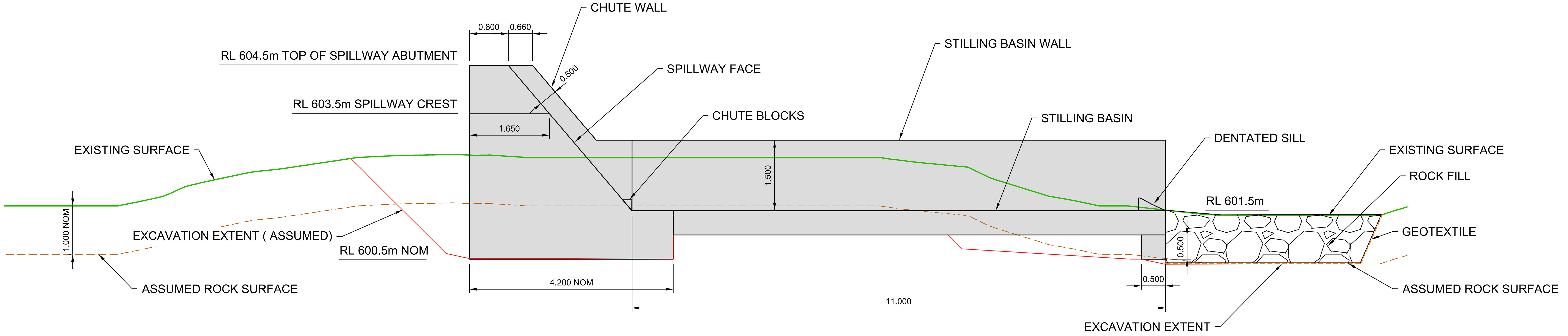

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PRINT DATE: 4/09/2018 10:34:08 AM

SCALE 1:50

Consultant Drawing Number	Sheet Number	REVISION
E	1 of #	A

Revision Notes

Rev.	Date	Approved

Scale	1:50
Datum H & V	A.H.D.(Tas)
Sheet Size	A1

References

PROJECT DETAILS		DESIGN		DATE
Project No.	P 514459	Drawn	B.SHERIFF	04/09/2018
Vault Folder	Projects	Designed	S.NEUPANE	04/09/2018
Discipline	C | M | E | R	Verified	P.SOUTHCOTT	04/09/2018
HPRM Folder.	##/#####	© 2018		

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WARATAH DAM REPLACEMENT CONCEPT DESIGN
CONCRETE GRAVITY WEIR ENERGY DISSAPATOR
TYPICAL CROSS SECTION

TASMANIAN WATER & SEWAGE CORPORATION PTY LTD
ABN: 47 162220 653

Drawing Number	Sheet Number	REVISION
P514459-CGW-002		

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Appendix C – Cost estimates

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ENGINEERING ESTIMATING SERVICES

ESTIMATE SUMMARY SHEET -10% +30%

JOB No.P-514459

CLIENT: ENTURA

PROJECT: WARATAH DAM REPLACEMENT

REFERENCES: DRAWINGS & INFORMATION PROVIDED BY ENTURA PERSONNEL

OPTION 1 - EARTH FILL EMBANKMENT & CONCRETESPILLWAY

PRELIMINARIES	105,900
EXCAVATION WORK	494,000
NEW EARTHFILL EMBANKMENT	1,145,300
NEW CONCRETE SPILLWAY	774,700
INSTRUMENTATION	70,000
ENGINEERING & PROJECT MANAGEMENT	633,000
BASIC TOTAL	**3,222,900**
CONTINGENCY	557,100
ESCALATION - NOT CALCULATED	
TOTAL ESTIMATED COST OF OPTION 1	**$3,780,000**

ESTIMATED COST RANGE FROM $3,402,000 TO $4,914,000

OPTION 2 - CONCRETE GRAVITY WEIR & SPILLWAY

PRELIMINARIES	82,270
EXCAVATION WORK	232,800
NEW CONCRETE GRAVITY WEIR & SPILLWAY	927,800
INSTRUMENTATION	31,500
ENGINEERING & PROJECT MANAGEMENT	351,000
BASIC TOTAL	**1,625,370**
CONTINGENCY	285,630
ESCALATION - NOT CALCULATED	
TOTAL ESTIMATED COST OF OPTION 2	**$1,911,000**

ESTIMATED COST RANGE FROM $1,720,000 TO $2,484,000

ESTIMATED BY: J.HICKEY (E.E.S.)

DATE: 7-SEPTEMBER-2018

PROJECT / ESTIMATE No.P-514459

ESTIMATE SHEET

DATE: 07-Sep-18

DESCRIPTION	SUMMARY				CONTINGENCY		TOTAL	
	MATERIAL	LABOUR	DES.VARIAT.	SUB TOTAL	%	AMOUNT	COST	COMMENT
OPTION 1 - EARTHFILL EMBANKMENT & CONCRETE SPILLWAY								
PRELIMINARIES	91,400	14,500	0	105,900	15	15,885	121,785	
EXCAVATION WORK	494,000	0	0	494,000	20	98,800	592,800	
NEW EARTHFILL EMBANKMENT	1,143,500	1,800	0	1,145,300	20	229,060	1,374,360	
NEW CONCRETE SPILLWAY	774,700	0	0	774,700	17.5	135,573	910,273	
INSTRUMENTATION	70,000	0	0	70,000	20	14,000	84,000	
ENGINEERING & PROJECT MANAGEMENT	58,000	575,000	0	633,000	10	63,300	696,300	
Contingency Adjustment						482		
BASIC TOTALS	**2,631,600**	**591,300**	**0**	**3,222,900**		**557,100**	**3,780,000**	
CONTINGENCY							INCLUDED	
ESCALATION - NOT CALCULATED							0	
TOTAL ESTIMATED COST OF OPTION 1							**3,780,000**	
OPTION 2 - CONCRETE GRAVITY WIER & SPILLWAY								
PRELIMINARIES	67,770	14,500	0	82,270	15	12,341	94,611	
EXCAVATION WORK	232,800	0	0	232,800	20	46,560	279,360	
NEW CONCRETE WEIR & SPILLWAY	926,000	1,800	0	927,800	20	185,560	1,113,360	
INSTRUMENTATION	31,500	0	0	31,500	20	6,300	37,800	
ENGINEERING & PROJECT MANAGEMENT	26,000	325,000	0	351,000	10	35,100	386,100	
Contingency Adjustment						-231		
BASIC TOTALS	**1,284,070**	**341,300**	**0**	**1,625,370**		**285,630**	**1,911,000**	
CONTINGENCY							INCLUDED	
ESCALATION - NOT CALCULATED							0	
TOTAL ESTIMATED COST OF OPTION 2							**1,911,000**	

PROJECT / ESTIMATE No.P-514459			ESTIMATE SHEET					DATE:	07-Sep-18	PAGE 3 OF 11
DESCRIPTION		**MATERIAL**					**LABOUR**		**TOTAL**	
	QTY	**UNIT**	**RATE**	**COST**		**DAYS**	**RATE**	**COST**	**COST**	**COMMENT**
OPTION 1										
Earthfill Embankment & Concrete Spillway										
PRELIMINARIES										
Mobilisation / de-mobilisation including delivery &	1	Item	20,000	20,000		Included		0	20,000	JH Fig
removal of heavy equipment										
Hire of site hut	35	Week	100	3,500		Included		0	3,500	JH / Cordell
Hire of Portaloo toilet	35	Week	40	1,400		Included		0	1,400	JH / Cordell
Contractor site survey work	1	Item	1,000	1,000		6	1500	9,000	10,000	2m x 3d Survey &
										report
Excavate for Site Offices & Laydown area	300	m3	30	9,000		Included		0	9,000	JH Fig
approx.20m x 50m x 300mm deep										
Spread & compact gravel for Site Huts &	150	m3	40	6,000		Included		0	6,000	JH Fig
Laydown - 50m x 20m x 150mm deep										
Erect temporary barrier - no construction details	100	m	60	6,000		Included		0	6,000	JH Fig
Hire of diesel Generator to service site	175	Day	250	43,750		Included		0	43,750	JH / Cordell
temporary power boards etc.										
Provision of PPE equipment as required on site	1	Item	400	400		N/A		0	400	JH Fig
Allow for Contractor preparation & presentation	1	Item	350	350		5	1100	5,500	5,850	1m x 5d
of various Safety, Environmental, Quality &										JH Fig
Construction Plans as required by the										
Principal										
Sub Total - Preliminaries				**91,400**				**14,500**	**105,900**	

PROJECT / ESTIMATE No.P-514459 | **ESTIMATE SHEET** | **DATE: 07-Sep-18** | **PAGE 4 OF 11**

DESCRIPTION	MATERIAL					LABOUR			TOTAL	
	QTY	UNIT	RATE	COST		DAYS	RATE	COST	COST	COMMENT
OPTION 1										
Earthfill Embankment & Concrete Spillway (con't)										
EXCAVATION WORK										
Strip Embankment area - approx.3850m2 x 300mm depth	1200	m3	25	30,000		Included		0	30,000	JH Calc
Excavation to assumed rock level - approx 4400m2 x 500mm deep for Embankment	2200	m3	30	66,000		Included		0	66,000	JH Calc
Additional excavation for Embankment Toe - approx 105m length x 5m x 1.5m depth	800	m3	40	32,000		Included		0	32,000	JH Calc
Strip Spillway area - approx.2300m2 x 300mm depth	700	m3	25	17,500		Included		0	17,500	JH Calc
Excavation to assumed rock level - approx 2300m2 x ave 1.7m deep for Spillway	3950	m3	36	142,200		Included		0	142,200	JH Calc
Construct temporary Coffer Dam at Spillway entry end - 20m long x 3m high x 8m wide ave	360	m3	30	10,800		Included		0	10,800	JH Calc
Construct temporary Coffer Dam at Spillway discharge end	150	m3	30	4,500		Included		0	4,500	JH Calc
Remove Coffer Dams after new Embankment & Spillways are constructed	550	m3	20	11,000		Included		0	11,000	JH Calc
Remove existing Embankment after new Embankment has been constructed - approx. 90m length x 16m wide x 4m ave high & dispose of rubble	6000	m3	30	180,000		Included		0	180,000	JH Calc
Sub Total - Excavation Work				**494,000**				**0**	**494,000**	

PROJECT / ESTIMATE No.P-514459		ESTIMATE SHEET						DATE:	07-Sep-18	PAGE 5 OF 11
DESCRIPTION		MATERIAL					LABOUR		TOTAL	
	QTY	UNIT	RATE	COST		DAYS	RATE	COST	COST	COMMENT
OPTION 1										
Earthfill Embankment & Concrete Spillway (con't)										
NEW EARTHFILL EMBANKMENT										
Place new Core material - 100m length x 6m	3200	m3	55	176,000		Included		0	176,000	Ref Mikany dam
depth x 5.3m ave										
Place 2A Filter medium - 100m x 4m x 1000mm	400	m3	230	92,000		Included		0	92,000	Ref Mikany dam
Place 2A Filter medium - 100m x 15m x 500mm	750	m3	230	172,500		Included		0	172,500	Ref Mikany dam
Place 2B Filter medium - 100m x 16m x 500mm	800	m3	160	128,000		Included		0	128,000	Ref Mikany dam
Place Geotextile membrane between 2B Filter &	1500	m2	10	15,000		Included		0	15,000	Ref Mikany dam
Earthfill - 100m x 15m										
Place Earthfill - 270m x 17m x 2m average	3600	m3	80	288,000		Included		0	288,000	Ref Mikany dam
Place Geotextile membrane under Rip Rap on	1500	m2	12	18,000		Included		0	18,000	Ref Mikany dam
U/S face - 100m x 15m										
Place Rip Rap on U/S Face -100m x 11m x 1m	1100	m3	75	82,500		Included		0	82,500	Ref Mikany dam
deep										
Place & compact Gravel Road Base over Earthfill	200	m3	90	18,000		Included		0	18,000	Ref Mikany dam
material & compact to RL 608.3 Approx. 4m wide										
x 500mm deep x 100m										
Install new Bypass Pipe - 70m long x 500mm	70	m	500	35,000		Included		0	35,000	JH Calc
HDPE										
Mass concrete encase Bypass pipe	145	m3	400	58,000		Included		0	58,000	JH Calc
Isolation Gate Valve x 500mm dia	1	No	7,500	7,500		2	900	1,800	9,300	Emerson Budget
Outlet wall & apron	12	m3	1,500	18,000		Included		0	18,000	JH Calc
Construct vehicle access & turnaround area	250	m2	80	20,000		Included		0	20,000	JH Calc
including excavation & preparation										
Timber access stairs to valve location incl.timber	25	m	600	15,000		Included		0	15,000	JH / Cordell
ballastrade										
Sub Total - New Earthfill Embankment				**1,143,500**				**1,800**	**1,145,300**	

PROJECT / ESTIMATE No.P-514459			ESTIMATE SHEET					DATE:	07-Sep-18	PAGE 6 OF 11
DESCRIPTION		MATERIAL					LABOUR		TOTAL	
	QTY	UNIT	RATE	COST		DAYS	RATE	COST	COST	COMMENT
OPTION 1										
Earthfill Embankment & Concrete Spillway (con't)										
NEW CONCRETE SPILLWAY										
Lay FCR or similar under new Spillway - 95m in	340	m3	80	27,200		Included		0	27,200	JH Calc
length x 12m wide x 300mm deep										
Spillway Crest & Entry slab	95	m3	1,100	104,500		Included		0	104,500	JH Calc
Spillway Channel invert slab	385	m3	900	346,500		Included		0	346,500	JH Calc
Spillway Channel walls - 95m x ave 1.3m high x	125	m3	1,600	200,000		Included		0	200,000	JH Calc
500mm thick incl.reo & formwork										
Stilling Basin slab & end wall	40	m3	1,000	40,000		Included		0	40,000	JH Calc
Stilling Basin walls	20	m3	1,600	32,000		Included		0	32,000	JH Calc
Vehicle access Bridge - assume steel frame &	1	Item	11,000	11,000		Included		0	11,000	JH Calc
concrete - 11m wide x 4m wide										
Place Rip Rap at Stilling Basin end of Spillway	50	m3	70	3,500		Included		0	3,500	JH Calc
approx. 100m2 x 500mm deep										
New V-Notch Weir	1	Item	10,000	10,000		Included		0	10,000	JH Calc
Sub Total - New Concrete Spillway				**774,700**				**0**	**774,700**	
INSTRUMENTATION										
Allowance for Survey Targets & Flowmeter at	1	Item	70,000	70,000		Included		0	70,000	JH Calc
V notch Weir,manual Gauge Board & Telemetry										
Sub Total - Instrumentation				**70,000**				**0**	**70,000**	

PROJECT / ESTIMATE No.P-514459			ESTIMATE SHEET					DATE:	07-Sep-18	PAGE 7 OF 11
DESCRIPTION		MATERIAL					LABOUR		TOTAL	
	QTY	UNIT	RATE	COST		DAYS	RATE	COST	COST	COMMENT
OPTION 1										
Earthfill Embankment & Concrete Spillway (con't)										
ENGINEERING & PROJECT MANAGEMENT										
Engineering Design, Drafting, Geotech &	1	Item	23,000	23,000				375,000	398,000	JH Fig
Environmental Studies at 12.5% of Direct Costs -										
on $3,186,000										
Project Management, Site Supervision, Meetings,	1	Item	35,000	35,000				200,000	235,000	JH Fig
Contractor & Client Liaison at 7.5% of Direct Costs										
on $3,186,000										
Sub Total - Engineering & Project Management				**58,000**				**575,000**	**633,000**	

PROJECT / ESTIMATE No.P-514459			ESTIMATE SHEET					DATE:	07-Sep-18	PAGE 8 OF 11
DESCRIPTION		MATERIAL					LABOUR		TOTAL	
	QTY	UNIT	RATE	COST		DAYS	RATE	COST	COST	COMMENT
OPTION 2										
Concrete Gravity Weir & Spillway										
PRELIMINARIES										
Mobilisation / de-mobilisation including delivery & removal of heavy equipment	1	Item	20,000	20,000		Included		0	20,000	JH Fig
Hire of site hut	18	Week	100	1,800		Included		0	1,800	JH / Cordell
Hire of Portaloo toilet	18	Week	40	720		Included		0	720	JH / Cordell
Contractor site survey work	1	Item	1,000	1,000		6	1500	9,000	10,000	2m x 3d Survey & report
Excavate for Site Offices & Laydown area approx.20m x 50m x 300mm deep	300	m3	30	9,000		Included		0	9,000	JH Fig
Spread & compact gravel for Site Huts & Laydown - 50m x 20m x 150mm deep	150	m3	40	6,000		Included		0	6,000	JH Fig
Erect temporary barrier - no construction details	100	m	60	6,000		Included		0	6,000	JH Fig
Hire of diesel Generator to service site temporary power boards etc.	90	Day	250	22,500		Included		0	22,500	JH / Cordell
Provision of PPE equipment as required on site	1	Item	400	400		N/A		0	400	JH Fig
Allow for Contractor preparation & presentation of various Safety, Environmental, Quality & Construction Plans as required by the Principal	1	Item	350	350		5	1100	5,500	5,850	1m x 5d JH Fig
Sub Total - Preliminaries				**67,770**				**14,500**	**82,270**	

PROJECT / ESTIMATE No.P-514459 | **ESTIMATE SHEET** | **DATE: 07-Sep-18** |

DESCRIPTION		MATERIAL					LABOUR		TOTAL	
	QTY	UNIT	RATE	COST		DAYS	RATE	COST	COST	COMMENT
OPTION 2										
Concrete Gravity Weir & Spillway (con't)										
EXCAVATION WORK										
Strip Weir area - approx.850m2 x 300mm depth	260	m3	25	6,500		Included		0	6,500	JH Calc
Excavation to assumed rock level - approx 1000m2 x 700mm deep for Embankment	700	m3	35	24,500		Included		0	24,500	JH Calc
Remove existing Embankment after new Embankment has been constructed - approx. 90m length x 15m wide x 5m ave high & dispose of rubble	5600	m3	30	168,000		Included		0	168,000	JH Calc
Construct vehicle access & turnaround area including excavation & preparation	400	m2	80	32,000		Included		0	32,000	JH Calc
Allow for pedestrian access from Vehicle access road to Outlet Valve - approx.15m x 1.2m wide gravel	18	m2	100	1,800		Included		0	1,800	JH Calc
Sub Total - Excavation Work				**232,800**				**0**	**232,800**	

PROJECT / ESTIMATE No.P-514459			ESTIMATE SHEET					DATE:	07-Sep-18	PAGE 10 OF 11
DESCRIPTION		MATERIAL					LABOUR		TOTAL	
	QTY	UNIT	RATE	COST		DAYS	RATE	COST	COST	COMMENT
OPTION 2										
Concrete Gravity Weir & Spillway (con't)										
NEW CONCRETE GRAVITY WEIR & SPILLWAY										
Lay FCR or similar under new Spillway - 850m2	340	m3	80	27,200		Included		0	27,200	JH Calc
x 400mm deep										
Gravity Walls	65	m3	1,800	117,000		Included		0	117,000	JH Calc
Abutment Blocks	8	m3	1,200	9,600		Included		0	9,600	JH Calc
Spillway section	370	m3	1,600	592,000		Included		0	592,000	JH Calc
Chute Walls	12	m3	2,000	24,000		Included		0	24,000	JH Calc
Stilling Basin Walls	20	m3	1,800	36,000		Included		0	36,000	JH Calc
Dentated Sill & Chute Blocks	6	m3	1,400	8,400		Included		0	8,400	JH Calc
Stilling Basin Slab	65	m3	1,000	65,000		Included		0	65,000	JH Calc
Bypass Outlet Headwall & Apron	6	m3	1,500	9,000		Included		0	9,000	JH Calc
Install new Bypass Pipe - 20m long x 500mm	20	m	500	10,000		Included		0	10,000	JH Calc
HDPE										
Mass concrete encase Bypass pipe	42	m3	400	16,800		Included		0	16,800	JH Calc
Isolation Gate Valve x 500mm dia	1	No	7,500	7,500		2	900	1,800	9,300	Emerson Budget
Place Rip Rap at Stilling Basin end of Spillway	50	m3	70	3,500		Included		0	3,500	JH Calc
approx. 100m2 x 500mm deep										
Sub Total - Concrete Gravity Weir & Spillway				**926,000**				**1,800**	**927,800**	

PROJECT / ESTIMATE No.P-514459			**ESTIMATE SHEET**					**DATE:**	**07-Sep-18**	**PAGE 11 OF 11**
DESCRIPTION		**MATERIAL**					**LABOUR**		**TOTAL**	
	QTY	**UNIT**	**RATE**	**COST**		**DAYS**	**RATE**	**COST**	**COST**	**COMMENT**
OPTION 2										
Concrete Gravity Weir & Spillway (con't)										
INSTRUMENTATION										
Allowance for Survey Targets & Level Gauge at Weir	1	Item	31,500	31,500		Included		0	31,500	JH Calc
Sub Total - Instrumentation				**31,500**				**0**	**31,500**	
ENGINEERING & PROJECT MANAGEMENT										
Engineering Design, Drafting, Geotech & Environmental Studies at 12.5% of Direct Costs - on $1,561,000	1	Item	20,000	20,000				175,000	195,000	JH Fig
Project Management, Site Supervision, Meetings, Contractor & Client Liaison at 10% of Direct Costs on $1,275,000	1	Item	6,000	6,000				150,000	156,000	JH Fig
Sub Total - Engineering & Project Management				**26,000**				**325,000**	**351,000**	

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