Cardno
Shaping the Future

Appendix C

Quarantine Flowpath Concept Design

Table of Contents

1 Introduction 3
2 Background 3
3 Concept Design 4
3.1 Option 1 – 13d DTM and concrete ramp 5
3.2 Option 2 – 150m long concrete weir 6
3.3 Option 3 – 250m long concrete weir 8
4 Cost Considerations 9
5 Recommendation 9
6 Qualifications 10

List of Tables

Table 1 Limiting Velocities for Protection Measures
Table 2 Extent of various armouring materials based on 200yr ARI absolute velocity
Table 3 Extent of various armouring materials on 200yr ARI absolute velocity
Table 4 Extent of various armouring materials on 200yr ARI absolute velocity

List of Figures

Figure 1 CHUTE results: roller compacted concrete ramp
Figure 2 Sobek 2D model, 200yr ARI water level comparison
Figure 3 SOBEK 2D model peak velocity results

1 Introduction

Penrith Lakes Development Committee (PLDC) has engaged Cardno to undertake investigations, concept design and analysis of Penrith Lakes and Nepean River under flood. Cardno has undertaken modelling, concept design and cost estimation of various hydraulic control structures and it is the purpose of this report to document the findings for the Quarantine Weir.

The quarantine weir connects the Quarantine Lake and the Main Lake and experiences high energy flows during the initial stages of a flood event. This occurs as there is a high volume of flood water entering Quarantine Lake from the Nepean River once it has broken its banks. As a result flows exceed the level of the quarantine lake spill crest and enter the main lake over a 300m long flowpath. The initial velocities over the weir can increase to a level that can erode natural surfaces i.e. grass. Later when the flood fills main lake a backwater effect is achieved and a more stable flow regime over the flowpath is established. As such it is necessary to design the terrain of the weir and provide surface armouring to resist erosion and sustain the structure. This report summarises the investigations, concept design and analysis undertaken in the proposal of 3 options for the flowpath/weir.

2 Background

Cardno have created SOBEK models to analyse the lakes under flood and investigate various design options. The flood modelling has included:

- Preliminary 1D quarantine weir modelling to test various weir configurations in order to inform more detailed concepts for analysis in a 2D model. The 1D modelling utilised the model established for the flood drainage design.
- Preliminary design scenario 2D using proposed terrain provided by PLDC as revision 13d. This included an indicative size and shape of the quarantine weir. This will be referred to as Option 1 from hereon.
- 2 weir options modelled in 2D to analyse absolute velocity at various locations in order to determine extent of various materials required to armour the weir. Referred to as options 2 and 3.

These models utilised a 15m grid in the 2d cases.

3 Concept Design

The flowpath connecting the lakes in the 13d terrain model is approximately 300m long and 250m wide at the narrowest location and generally takes on the shape of a flume. It is proposed that the flowpath will have a surface of grass for the majority and roller compacted concrete where armouring is required. A spill level of 16.5m AHD exists in the centre at the pinch point and the top of bank is RL 20m AHD on the left bank and RL 25m AHD on the right bank. The left bank flattens to form a bench behind the top of bank down to an approximate level of RL 19m AHD. The current shape promotes velocities to increase along the flowpath, banks and bench to undesirable levels.

The 200yr ARI event results were used for design purposes and are considered suitable for this development considering the size of the design elements and risks associated with possible scouring and erosion. Figures of the results have been provided in the Appendix to this report.

The critical velocities were adapted from scour velocity plots in CIRIA Report 116 (CIRIA, 1987). This plot is included in **Appendix A**. The critical velocities were adopted for selected durations of inundation and are shown in **Table 1**. These points are marked on the graph in **Appendix A**. For the 2hr peak comparison the peak velocity from the model was used, assuming conservatively that the peak velocity occurred over a 2hr period. For the average comparisons, velocities were averaged over 5, 10 and 30 hour periods. These durations were chosen to provide a reasonable range for concept design. It is recommended that these velocities be reviewed in detailed design, with input from appropriate manufactures.

Table 1: Limiting Velocities for Protection Measures

	RCC, if greater than... (m/s)	Reinforced Grass, if greater than... (m/s)	Good Grass, if greater than... (m/s)
2hr Peak	6.0	5.0	4.0
5hr Average	4.5	3.5	2.0
10hr Average	4.0	3.0	1.5
30hr Average	3.0	2.5	1.0

3 options were investigated that will focus high energy flows to a given location in order to reduce the extent of armouring required in order to reduce visual impact and capital costs. Option 1 includes the preliminary design scenario, being the 13d terrain model, and the other options reconfigure the terrain of the flowpath and include a concrete weir at the edge of the Main Lake. The location of the weir promotes high velocity over the weir and utilises the water level in the Main Lake as a dissipation device. These factors work together to reduce extent of armouring required downstream of the spill crest.

3.1 Option 1 – 13d DTM and concrete ramp

This option includes the 13d terrain as proposed by PLDC with inclusion of a rolled concrete ramp to control high energy flows over the spill crest. The shape of the ramp was designed using the program CHUTE in order to test various ramp configurations. The ramp geometry was not included into the terrain for the 2D SOBEK model as it will be obsolete given a grid size of 15m. It is simply provided to give an indication of the extent of concrete required. As shown in Figure 1 supercritical flow is created over the ramp and a hydraulic jump applied in the dissipation basin at the base of the ramp. This has the effect of reducing flow velocity as it spills over the ramp and continues along the weir flowpath downstream.

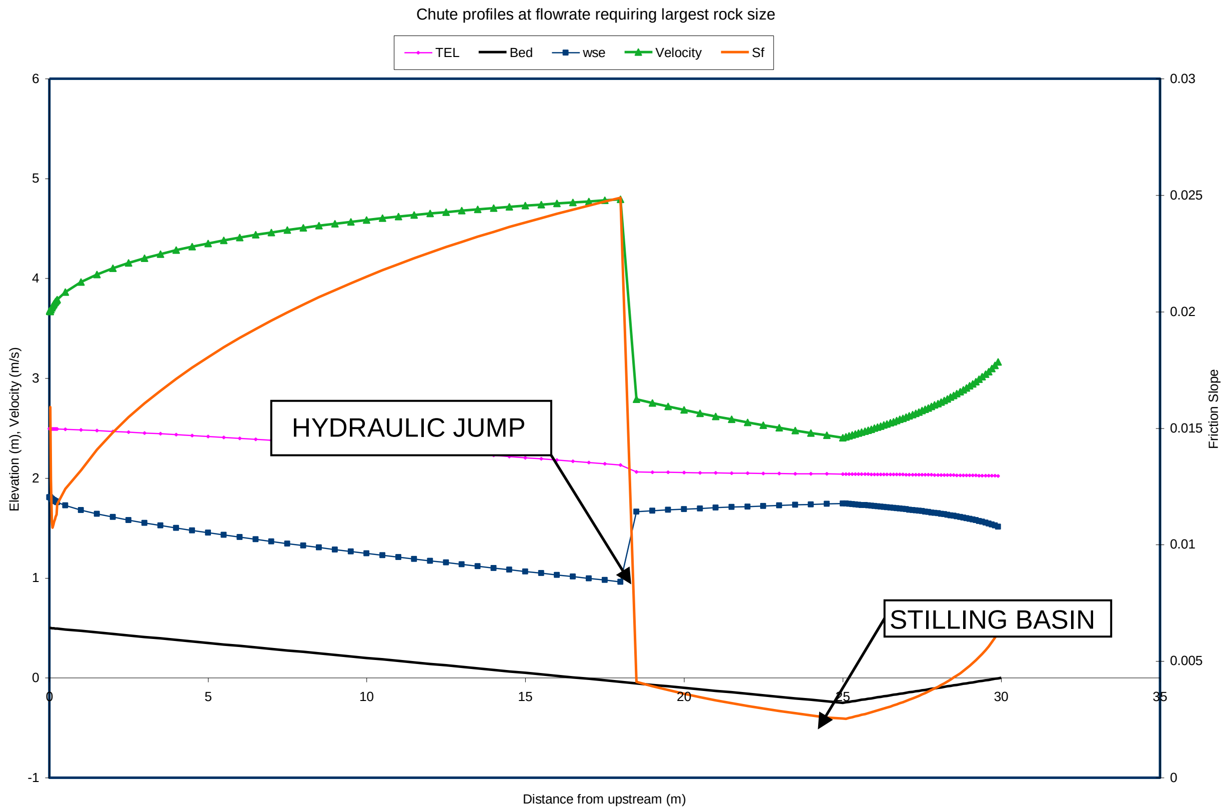

Figure 1 - CHUTE results: roller compacted concrete ramp

It is assumed that the concrete ramp will be sufficient to control velocities greater that 3m/s and reinforced grass may be applied to the up and downslope areas where velocities exceed 2m/s. Analysis of the 2D SOBEK model indicated that the following extents of reinforced grass are required.

It is noted that there will be an area directly upstream of the spill crest where high velocities will exists and a nominal 10m width across the whole ramp lengths has been allowed to armour this. It is assumed that a 1m thick mass of roller compacted concrete will be sufficient to armour the high velocity areas.

Table 2 – Extent of various armouring materials based on 200yr ARI absolute velocity

Treatment Type	Horizontal distance downstream of weir crest	Horizontal distance upstream of weir crest	Vertical Distance	RL (m AHD)
Roller Compacted concrete	0 to 25	0 to 10	0 to 0.5	16-16.5
Reinforced Grass Downstream of crest	25 to 70		0 to 3	13.5-16.5
Reinforced Grass Upstream of crest		10 to 210	0 to 1.25	15.25-16.5
Grass (good cover)	70 to 90	210 to 240	1.25 to 2.5	14.0-15.25

3.2 Option 2 – 150m long concrete weir

In order to reduce the zone of influence for the high velocities it is proposed that the terrain be restructured to provide a spill crest closer to the main lake, in the form of a concrete weir at RL 16.5m AHD, with a gentle grade back to the quarantine lake top of bank level 15m AHD. This will focus the high energy flows onto the weir crest itself in an effort to reduce the extent of armouring. The shape of the weir crest has been created to replicate the shape of the existing lake and to control flows away from the Lake banks.

Shoulders have also been included above the weir crest to provide an area for flows to spill once there is a level of backwater created in the main lake to dissipate flows. This level was chosen when reviewing the time when water levels in Quarentine Lake begin to taper off, signifying that the water level is rising at a slower rate and reducing in velocity as it spills into the Main Lake. The shoulders are proposed at RL 18m AHD, see Figure 2 for details. This design aims to focus the area of armouring to a central location and reduce higher velocities along banks, benches and shoulders of the terrain.

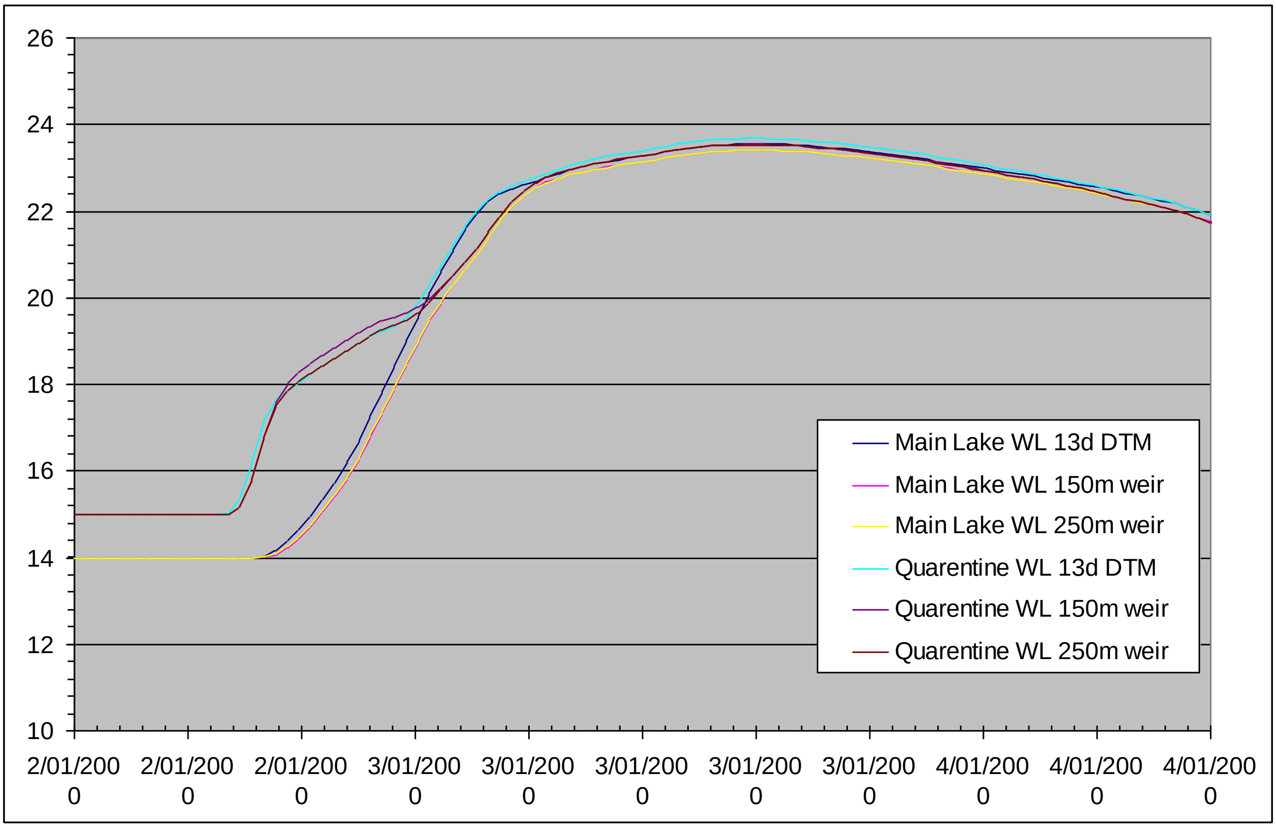

Figure 2– SOBEK 2D model, 200yr ARI Water Level Comparison

Materials for the weir include a reinforced concrete crest and base to withstand hydrodynamic forces and a roller compacted concrete weir body comprising 0.3m thick slabs 3m wide stacked to 3m in height. The slope for the weir will be 1 on 1 and a reinforced concrete strip will be laid 30m upstream for velocities which exceed reinforced grass requirements.

This option caused velocities in the order of 6m/s over the weir crest and velocities greater than 2m/s extending up to 200m upstream of the crest. Velocity did exceed 2m/s of the shoulder of the weir on the right bank.

Table 3 – Extent of various armouring materials on 200yr ARI absolute velocity

Treatment Type	Horizontal distance downstream of weir crest	Horizontal distance upstream of weir crest	Vertical Distance	RL (m AHD)
Roller Compacted concrete	0 to 5	0 to 30	0 to 3	13.5-16.5
Reinforced Grass		30 to 165	0 to 1.0	15.5-16.5
Grass (good cover)		165 to 300	1.0-1.5	15.0-15.5

3.3 Option 3 – 250m long concrete weir

This option utilised similar concept from Option 2 but with a longer spill crest of 250m. As a result velocity over the spill crest was approximately 0.7m/s lower in general. This also allowed for greater containment of high velocities over the weir invert and removal of high velocity of the weir shoulders. This is considered a low risk option as an alternative to Option 2 as it reduces the risk of erosion over the weir shoulder and reduces risk of damage to the concrete weir by high velocity flows.

Table 4 – Extent of various armouring materials on 200yr ARI absolute velocity

Treatment Type	Horizontal distance downstream of weir crest	Horizontal distance upstream of weir crest	Vertical Distance	RL (m AHD)
Roller Compacted concrete	0 to 5	0 to 20	0 to 3	16-16.5
Reinforced Grass		20 to 175	0 to 1.0	15.5-16.5
Grass (good cover)		175 to 300	1.0-1.5	15.0-15.5

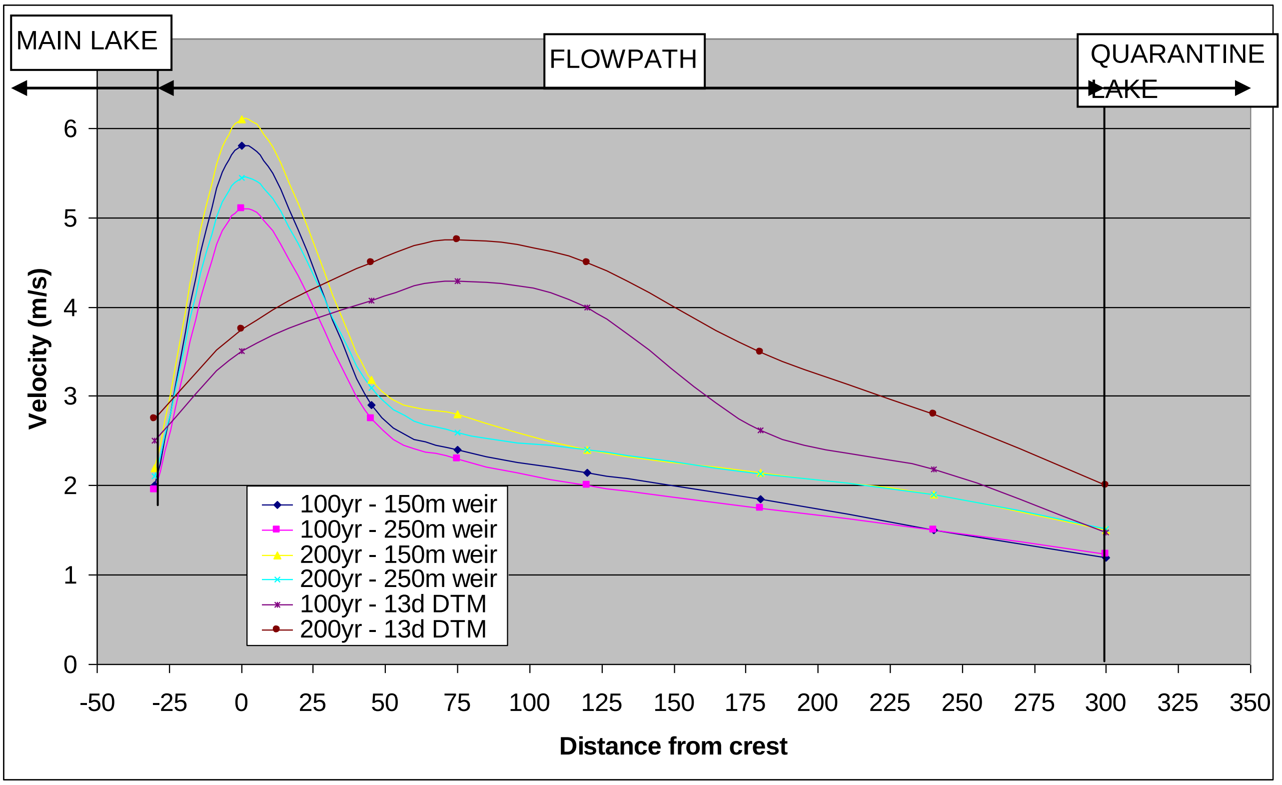

Figure 3 – SOBEK 2D model peak velocity results

4 Cost Considerations

The factors that will likely have the greatest impact on cost will be the concrete armouring and the volume of earthworks. Given this, option 1 is likely to be the most expensive, by a significant margin, due to the great amounts of both concrete and earthworks required to construct it. Option 2, being the shortest weir will be the cheapest option to construct. Option 3 will be more expensive than option 2.

5 Recommendation

It is clear from the investigations, concept design and estimation that regrading of the 13d terrain to force the spill crest adjacent to the main lake will assist with confining the spread of high velocity. This in turn reduces the volumes of armouring required and cost savings are clear.

It is recommended that Option 2 be adopted for detailed design. Whilst option 3 resulted in slightly lower velocities, this reduction was not significant enough to reduce the required amount of protection. Option 2 still provides sufficiently low velocities across the weir, and its reduced length results in cheaper construction.

6 Qualifications

- This concept design has been completed base of the information provided for the Penrith Lakes development
- All modelling and design is conceptual and must be analysed further during detailed design
- Should any of the hydraulic controls or terrain of the Penrith Lakes Development change then the results of this report are invalid and shall be recalculated.