

Lake Mokoan - Spit Embankment Pre-Feasibility Study



LAKE MOKOAN - SPIT EMBANKMENT OPTION 2B3 CONSTRUCTION STUDY

- Final
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1. Introduction

The Department of Sustainability and Environment commissioned Sinclair Knight Merz (SKM) to investigate technical feasibility of bisecting Lake Mokoan with an earthen embankment known generically as the “spit embankment” option.

This report further develops concepts presented in the Lake Mokoan Study by URS, which investigates future management options for the Lake (November 2003). The proposed embankment will create a smaller storage in the western portion of Lake Mokoan and aims to reduce evaporative water losses and allow the restoration of a wetland complex on the east.

The construction of an embankment was a common component of several URS options, however Option 2B3 was nominated by DSE as the basis for this study. This assessment looks at the practicability of constructing an embankment across the lake from the southern spit to the north shore. This would create a permanent shallow storage with a full supply level of 164.0m AHD, a capacity of 97GL and a surface area of 3080ha (refer *Figure 1*).

Option 2B3 proposed that catchment run-off that would normally be able to pass through the storage from the eastern end of the existing Lake will be passed around the southern side of the storage via a channel/pipeline constructed for this purpose. Material excavated from this channel was proposed to be used in the embankment construction. The viability of the channel construction is also examined.

2. Scope

This study aims to assess the option's practicality and to further quantify and qualify the feasibility, risks and costs associated with such an undertaking based on available information.

Based on a desktop study the approach was to:

- Review existing information from SKM, G-MW and URS and identify any data gaps that would contribute to further refinement of the options assessment;
- Discuss implications of draining the Lake;
- Assess potential construction materials;
- Evaluate implications of foundation preparation and embankment construction including potential environmental issues;
- Consider construction process and timeframe;
- Identify construction risks; and,
- Prepare cost estimates of embankment construction based on available information;

The outcome aims to provide DSE with a technical evaluation of the proposal to enable and promote meaningful discussion with stakeholders.

This report looks at the most practical methods of construction for the proposed spit bank bisecting Lake Mokoan.

Discussions with G-MW indicated their preference for the embankment to be constructed “in-the-dry” to ensure a properly designed and constructed, long life, low maintenance asset is created. Their preference was for the construction of the spit bank between two cofferdams. SKM is in agreement with this aspect as it minimises risks, however alternative construction techniques are also discussed in Section 5 Construction Process.

3. Project Components & Issues

3.1 Storage Water Levels

The proposed operating level of Lake Mokoan in Option 2B3 is EL 164.00m AHD compared to a historical operating level of 166.90. A site inspection was held on 15 January 2004 at which time the water level was EL 163.30.

Advice from G-MW indicates that the dead storage level is at EL 160.65, which results in some inundation of the proposed spit bank site with bed elevations in the area between EL 160.50 and EL 161.00.

The best conditions for the construction of an earthen embankment is in a dry environment where foundation preparation, provision of a cut-off and more efficient delivery and controlled placement of material can be achieved. However, given the dead storage level exceeds the bed level at the proposed site, then alternative construction techniques or dewatering of the site will be required. Potential options for construction of the embankment are discussed in more detail in Section 5.

Factors to consider in assessing the implications of Lake Mokoan water levels on the Spit Bank construction include:

- The potential for catchment inflows from rainfall events
- Operating requirements during construction for supply and diversion of irrigation water
- The cost of dewatering the site versus the cost and (in)effectiveness of construction in wet conditions

3.2 By-pass of Catchment Flows

With the construction of the spit embankment across the natural drainage path, an allowance to pass natural catchment flows across or around the impediment is required. Estimating the magnitude of the inflow rate is outside the scope of this work so the recommendation from the URS study and flood flow estimates provided by G-MW were adopted for the purpose of determining construction feasibility. The URS concept design included a by-pass channel from the Green Swamp wetland area, through the southern end of the spit bank and around the south and western sides of the storage to discharge into the Mokoan outlet channel (*Figure 1*). The cross section of this channel (6m-bed width, 1.1m flow depth) would pass a flow of between 200 to 250ML/d, and would remove water from the wetland area over a period of time.

Preliminary discussions with Goulburn-Murray Water indicated a maximum inflow rate into Lake Mokoan of 7000ML/d, however it is uncertain whether this included flows from the inlet channel as well as natural flows to the west of the proposed embankment. Further hydrological assessments

are required to determine potential catchment run-off rates and the implications this may have on the integrity of the new embankment. Despite this uncertainty the 7000ML/d flow was used as a preliminary flood flow to be accommodated within the new works.

The impact of flood inflow on the proposed spit bank depends on the volume of inflow and the retention capacity of the swamp area for the design storm. As a man-made barrier the embankment design will need to comply with ANCOLD Guidelines which assign the level of protection according to the consequences of failure.

Two options were considered for the by-passing of catchment flows around the new embankment:

- Construction of a bypass channel as proposed by URS;
- Construction of a pump station at the northern end of new embankment and a spillway through the Spit Bank to pass flood flows into the smaller storage as levels permit.

These are discussed in more detail below.

3.2.1 By-Pass Channel

The by-pass channel was proposed to commence with a bed level around EL 161.0 adjacent to the proposed wetland, traversing the southern end of the spit and following the EL165.0 contour within the storage shoreline. The channel would pass across the irrigation inlet channel discharge area via a subway, cross through the southern section of the current embankment and then run parallel with the existing bank to discharge into the existing outlet channel (Refer *Figure 1*).

Based on contour information available, the average level of the natural ridge at the proposed spit embankment site is approximately EL 160.5. Under pre-dam conditions the water level in the eastern section (wetlands) would be naturally drained to this elevation and further lowering would be from evaporation. Because of this pre-existing condition it is proposed that the channel invert leading from the eastern section be set at EL 160.5.

At the downstream end of the by-pass channel, the design bed of the existing Mokoan outlet channel is EL 158.20. However, a knife-edge measuring-weir in the Mokoan outlet channel has an elevation of EL 159.16 that would dictate the available hydraulic gradient of the by-pass channel unless this weir was modified. (Although the finished bed level would be around EL 158.50 to improve drainage of the channel for maintenance by pumping over the weir). This fall over the by-pass channel length of 14,500-metres gives a bed gradient of 0.092m/1000m, which is considered a very low gradient in hydraulic terms.

Erosion of the channel bed and batters is likely to be an issue as the available soil information identifies dispersive clay soils along the channel alignment. This is also evident from the existing erosion and maintenance problems with the existing irrigation inlet channel. Infrequent flows from

storm events are likely to result in silting of the channel. Weed growth in the channel is also a likely ongoing maintenance problem. To service these potential maintenance issues suitable access with all weather gravelling will be needed along the channel berms. The additional operational issues and costs have not been considered in detail in this report.

The performance of the by-pass channel during high rainfall events is dependent on the water levels at Broken River as these could create backup into the Mokoan outlet channel and thereby restrict discharge from the bypass channel. This aspect requires further hydraulic investigation to assess the feasibility of by-passing flows from the wetland complex. Further assessment of the channels capacity to pass flood flows is also required as the outlet channel is unlikely to take the 7000ML/d flow indicated by G-MW. Increasing the channel's size or providing an additional spillway area in the spit bank may be required.

It will also be necessary to install a structure which will prevent back-flow into the by-pass channel when releases are being made from Lake Mokoan as the outlet channel water depth is around 2.5-metres which would inundate almost the full length of the by-pass channel. Water ponding from backup into the by-pass channel is also likely to promote weed growth.

Other structures required include a subway under the Mokoan irrigation inlet channel and cross drainage subways to pass natural creek flows into Lake Mokoan.

Given the terrain through which this channel will be required to traverse the depth of cut is some five metres deep and therefore an intermediate bench/berm has been proposed to permit maintenance of the channel bed and batters.

The bed width of the channel is proposed to be 6m (supplied by URS) The approximate volume of excavation from the channels construction is estimated at some 1.3 million cubic metres. The cost to construct the channel may be effectively reduced if the material excavated is suitable for use in construction of the proposed embankment.

Further contingencies need to be considered in addition to the high cost of the actual construction of the by-pass channel along the shortest path as shown in *Figure 1*. High voltage power lines run close to the toe of the existing embankment. With a channel cut width over 30-metres wide plus suitable clearance from the toe of the existing embankment the channel will encroach on the power line alignment. This arrangement is not acceptable and the only practical approach is to pass the channel outside the power lines however the cost and complications of land acquisition need to be studied. Land acquisition is also an issue along the toe of the embankment after the divergence of the power lines as the resumption boundary is within 10 metres of the Mokoan embankment toe. It is estimated that the total channel construction along the toe of the existing embankment will need to be within acquired land.

3.2.2 Pump Station

An alternative to the channel arrangement is to install a pumping station at the north end of the spit embankment and pump water from the wetlands over the embankment and into the storage. An earthen channel constructed from Green Swamp to the proposed pump site would serve as the intake to the pumps. A hydrological analysis is required to determine the capacity of the pumps. However if they were to deliver a flow rate similar to that of the by-pass channel as proposed by URS, then their capacity would be in the order of 200 to 250ML/d. It should be noted that the basis for these flow rates is unclear and a hydrological study is needed to confirm inflows from a design storm.

The evaluation and design of the pump station is beyond the scope of this study and would be completed by G-MW. It is envisaged that the pump site would comprise a concrete sump arrangement and platform for the pumps. These pumps are held in reserve by G-MW and would be brought in as required. A smaller permanent pump set could be located at the site to serve irrigators currently sourcing water from the eastern side of the proposed spit embankment. Suction pipes could be either from the storage or the proposed wetlands.

The construction of an inlet channel to the pump site from the wetland area is included in the cost of the proposed works but construction will be scheduled when conditions are suitable to avoid the need for further cofferdam construction. Alternatively the channel may be constructed from a barge but the excavation costs would be high. The cost of the pump station has not been evaluated as it depends largely on the operation and selection of pumps, which has not been assessed in this report.

The bed level of the pump station inlet channel is set at EL 159 which corresponds to the approximate high water mark of Green Swamp as determined from aerial photos taken before construction of Lake Mokoan.

3.2.3 Interconnecting Spillway

In conjunction with the pump arrangement consideration should also be given to constructing a flood spillway across the southern end of the spit. If the flood inflow into the wetland storage level exceeds 164.10 then some flow can be captured within the storage. This will allow inflows exceeding the proposed nominated operating level of the wetland area and the pump capacity to be passed into Lake Mokoan to prevent damage to the proposed embankment (refer *Figure 1*) Water can also be released from the Mokoan outlet works to the river. This requires further investigation of both the potential flow rate and the properties of the in-situ material and their ability to withstand flows without excessive erosion.



As previously mentioned preliminary discussions with Goulburn-Murray Water indicated a maximum inflow rate into Lake Mokoan of 7000ML/d, however it is uncertain whether this included flows from the inlet channel or natural flows to the west of the proposed embankment. For the purposes of this exercise this flow rate has been adopted in a preliminary assessment of the potential spillway. It has been assumed it would consist of a basic concrete spillway with beaching on the upstream and downstream sides to prevent erosion. Assuming a spillway level of 164.10mAHD (100mm above the proposed FSL of Lake Mokoan and a maximum upstream water level of 165mAHD), a spillway width of 60m is required to pass 7000ML/d. Adjustment to freeboard can be provided with temporary boards if required.

Approximately 95,000m³ of earth would need to be excavated from the spillway site. A 16m wide and 3600m long inlet channel would be required from the wetland area to the spillway. If suitable, this material from the inlet channel (approximately 210,000 m³) could be used in the construction of the embankment. The estimated cost of the spillway and channel is in the order of \$1.3million, assuming the excavation of the channel is considered an embankment cost for attaining borrow material. This assessment requires further investigation, particularly in confirmation of the spillway capacity.

4. Geotechnical Design Considerations

4.1 Availability of Suitable Construction Materials

From a review of the available geological and soils information, there does not appear to be material immediately suitable for earthfill embankment construction in the local area. Local soil deposits generally comprise alluvial sand, clay and silt. Clay sourced from these deposits are highly dispersive in nature, as evident in the continuing erosion/piping problems the main dam embankment is subject to (it was constructed using clay sourced from the area). Similarly, rock sourced from the local quarry is not regarded as being suitable for embankment protection as it is sedimentary in origin and degrades significantly upon working/compaction.

Hence, it is recommended that if local clay is used for the embankment's construction, it should be stabilised with lime to reduce the potential for dispersion and to improve its engineering properties. Reducing the potential for dispersion, in addition to appropriate filter materials, will minimise the opportunity of the new embankment to impact on the Lake's turbidity. Furthermore, rock for cofferdam construction or rip rap for the proposed embankment should be sourced from Mawson's quarry at Glenrowan, which is understood to have extensive supply of granite. This would also be the preferred source of sand and gravel material for bedding/filter material.

Potential borrow sites for the embankment material could be located:

- East of the spit, potentially from the spillway inlet channel or the bypass channel, whichever is adopted;
- West of the spit, either from the by-pass channel (if adopted) or from the Lake foreshore above the 165m AHD contour.

Costs for excavating the borrow and delivering material to the embankment site will increase with haulage distance.

The impact of the borrow sites on the turbidity of the main storage and the wetland area needs to be considered as excavation will expose the local dispersive soils. Stripped organic soil and silt should be stockpiled and respread over the borrow area to minimise ongoing turbidity problems.

4.2 Embankment Alignment

The results of the bathymetric survey of the lake bed indicates a natural ridge meandering from the spit on the south side of the lake across to the opposite northern shore. The proposed embankment alignment would follow the ridge to minimise the earthworks required. The lake bed is believed to

comprise organic topsoil overlaying dispersive clay which in some areas may be exposed and contributing to the turbidity of the stored water. There is also likely to be a layer of soft sediment on the floor of the lake, with the depth of this layer unknown at present.

4.3 Foundations

To prepare the foundation of the embankment any soft/organic material should be stripped from the site and a cut-off trench constructed under the centre of the embankment. Probing of the upper soil profile on the shore of the lake to a depth of 500mm during the site inspection did not reveal the depth of organic material. This will need to be confirmed, along with an assessment of the soil profile that may influence the embankment design, during a detailed geotechnical investigation. This could be performed by conducting geotechnical investigations along the proposed embankment alignment as detailed in Section 4.3.

For the purpose of this assessment it has been assumed that a stripping depth of 1.5m beneath the embankment is required.

The implications of placing foundations for a cofferdam or embankment on saturated soils is that lateral displacement/settlement of these soils will occur, with associated deformation in the embankments. If the soft/organic soils on the lake bed extend to a depth of 1.5m, it is anticipated that a cofferdam formed by end dumping rock fill would penetrate this layer to at least this depth, and there would be further settlement of the underlying soil profile. If the main embankment is founded on stripped saturated soils, settlement can also be expected, which may be in the order of 1.0m. A refinement of these figures may be achieved with specific material properties obtained from formal site investigations.

Any material stripped from the embankment footprint may be used to support suitable grass cover for restoration of construction access works and exposed borrow pits.

4.4 Embankment

Once constructed, the embankment will have water on the west side corresponding to the operating level of Lake Mokoan. The east side will be predominantly dry but subject to inundation according to the management of the wetland area and from catchment run-off during infrequent rainfall events. The level and duration of inundation of this eastern batter of the spit embankment will depend on the capacity of the by-pass channel and water levels in the Broken River or the capacity of the alternative pump arrangement. No hydrological assessment has been undertaken to assess the potential water levels on the embankment's eastern side, however this should be undertaken to qualify the potential risks to the embankment.

The potential for ponded water on both sides of the embankment and the dispersive nature of the potential borrow material has been considered in the embankment design. The proposed bank section consists of a minimum 4-m crest width and 2.5H:1V batters on both the upstream and downstream batters (*Figure 2 – Typical Embankment Section*). A design freeboard of 2m is proposed to provide a finished crest level of 166.0mAHD. Based on the natural surface elevation contours provided by URS, the maximum embankment height is approximately 5.5 metres with a horizontal footprint of around 35m. The crest length of the embankment from the sand spit to the northern shore is approximately 4500 metres

Both the upstream and downstream faces of the embankment will be protected with rip-rap overlaying suitable graded bedding/filter material to prevent erosion of the earthfill through the rip-rap. The crest will be protected with a gravel surface and graded to provide run-off towards the upstream face.

4.5 Recommendations for Further Investigations

If it is decided to progress further with this study, specific geotechnical investigations will be required to define the extent/depth of the lake deposits and to identify suitable materials for embankment construction. Such investigations would include onshore and over-water drilling/cone penetrometer testing (CPT), as well as test pit investigations to investigate borrow sources. Laboratory testing would also be performed on recovered samples to characterise the engineering properties of the soil types encountered.

5. Construction Process

A number of construction methods are available depending on the ability to draw down the storage water level for the construction of the spit bank and the standard of construction required.

A strong preference has been expressed by G-MW for the construction of the embankment between two cofferdams accepting the inability to completely drain the storage.

For this study five options have been considered as follows:

- End dumping into water;
- Dry placement with complete draining of site;
- Dry placement with partial drawdown and provision of cofferdams;
- Dry placement with maximum drawdown and provision of cofferdams;
- Dry placement with maximum drawdown and incorporation of cofferdams into final bank construction.

Costs on preferred options have a contingency inclusion due to the uncertainties of the survey, material properties and the hydrological condition.

5.1 Construction Options

5.1.1 Option1: End Dumping into Water.

This construction process would require the dumping of borrow material directly into the water along the embankment alignment, progressively extending the dam wall across the lake. As the material is placed into water, compaction will not be achievable, hence the embankment section will need to be large to prevent seepage and the batter slopes will be set by the natural angle of repose of the dumped material. Erosion protection material and rip-rap on the batter slopes will need to be dumped into place as work progresses. Crest sealing could be completed after the embankment is trimmed to profile.

Water on the eastern side of the spit bank could be drained when either the by-pass channel or pump station is completed. Erosion protection for the western batter would be required to provide protection from wave action, as the source material is likely to be dispersive.

In submerged conditions the end dump construction method is the only means of construction. However it is not considered an acceptable process as the integrity of the embankment is compromised without any foundation stripping or construction of a cut-off, even though a generous embankment cross section can be provided. There will also be no suitable compaction and based on

the poor performance of the existing Mokoan embankment under dry conditions this method is not recommended.

An additional complication for this method is the presence of submerged dead trees along the southern end of the embankment alignment, which if not removed completely will add further risks to the integrity of the final structure.

This method would result in only minimal disruption to diverters, but will cause an increase in turbidity in the work area even if silt curtains could be used to confine turbidity to the work site. If the rock protection of the batters is placed as work progresses, then silt curtains may only be needed around the exposed area of works.

This is not considered to be a suitable option due to the substantial risks associated with long term embankment integrity.

5.1.2 Option 2: Dry Placement with Complete Drainage of Embankment Site and Dry Placement

The ability to completely expose and dry out the embankment alignment by lowering the water level below the construction site would allow foundation preparation, provision of a cut-off and more efficient delivery and controlled placement of embankment material. However, the ability to achieve this has been questioned, as the dead storage elevation has been quoted at EL 160.65, which is higher than the landform of the embankment alignment.

Drainage of the lake would also impact on the supply of irrigation water to diverters, hence alternative supplies or temporary storage provision would need to be investigated.

Although a better final result from an engineering perspective this is not a practical option due to the advised limit of draw-down for the reservoir exceeding the ridge elevation along the embankment alignment.

5.1.3 Option 3: Partial Drawdown and Dry Placement Within Cofferdams at EL 164, Cofferdam Removal

The construction of cofferdams either side of the spit bank alignment and dewatering the site by pumping over the cofferdam walls is one method of providing a workable site. This process will be considerably more complicated than draining the site and constructing in the dry as per Section 5.2 above. This option assumes that the storage could be drawn down some 2-metres below the proposed new FSL of 164.00 to EL 162.00. Providing 2-metre freeboard would give the cofferdam a crest elevation of 164.00 and allow some small flexibility with the operating level above EL 162.00. Note that this elevation is only 2m below the proposed crest elevation of the proposed spit embankment.

Cofferdams would be constructed by dumping waste quarry material into the water either side of the embankment alignment. Sufficient space would be allowed for construction activities to take place between the cofferdams and the proposed embankment. The cofferdam material will not be treated, compacted or provided with batter protection. Refer *Figure 2* for the arrangement of the embankment and cofferdams (Note the elevation of cofferdams is shown at EL 162.00).

Construction of the dam embankment could then be undertaken within the dry confines of the cofferdams.

Goulburn-Murray Water has indicated that the cofferdams are to be removed after construction of the embankment in order to reduce long-term turbidity impacts. However their removal will undoubtedly contribute to increased turbidity at the time and require double handling of the material. Minimal interruption is expected to divert supplies under this construction method, although alternative supplies may be required depending on the water level in the wetland area during the construction period. The use of silt curtains will be required to confine turbidity to the work site over the entire length of embankment.

The estimated cost of this option is approximately \$51.2million (40% contingencies).

The volume of quarry waste required for the cofferdams alone is approximately 500,000m³, allowing for 1.5m of settlement into the organic subgrade and 40% contingency. The estimated volume of earthfill for the embankment is 750,000m³ (40% contingency).

Although a suitable option for controlled embankment construction the size of the cofferdams is high and will require double handling. The construction program is expected to run over two consecutive summer periods.

5.1.4 Option 4: Full Drawdown and Dry Placement Within Cofferdams at EL 162, Cofferdam Removal

This option involves the drawdown of the water level to the dead storage EL of 160.65. Cofferdams would then be constructed by dumping waste quarry material into the water either side of the embankment alignment. Sufficient space would be allowed for construction activities to take place between the cofferdam and the proposed embankment. The cofferdam height of 162mAHD would provide 1.35m of freeboard above the dead storage and possibly allow some small flexibility with the operating level above this.

Cofferdams would be constructed by dumping waste quarry material into the water either side of the embankment alignment. Sufficient space would be allowed for construction activities to take place between the cofferdams and the proposed embankment. The cofferdam material will not be treated, compacted or provided with batter protection.

Construction of the dam embankment could then be undertaken within the dry confines of the cofferdams.

Goulburn-Murray Water has indicated that the cofferdams are to be removed after construction of the embankment in order to reduce long-term turbidity impacts. However their removal will undoubtedly contribute to increased turbidity at the time and require double handling of the material.

Some interruption is expected to divert supplies under this construction method due to the reduced water level and alternative supplies may be required depending on the water level in the wetland area during the construction period. The use of silt curtains will be required to confine turbidity to the work site over the entire length of embankment.

The estimated cost of this option is approximately \$31.7million (40% contingencies).

The volume of quarry waste required for the cofferdams is approximately 150,000m³, allowing for 1.5m of settlement into the organic subgrade and 40% contingency. The estimated volume of earthfill for the embankment is 750,000m³ (40% contingency).

The construction risks for this option are higher than that of Option 3 due to the lower cofferdam but there are significant cost savings with this construction method.

5.1.5 Option 5: Full Drawdown and Dry Placement between Cofferdams ultimately Incorporated into the Toe of the Embankment

This option has been presented in addition to previously discussed construction methods as a potentially more environmentally acceptable and cheaper option.

This option involves the draw-down of the water level to the dead storage EL of 160.65. Cofferdams would then be constructed by dumping waste quarry material into the water either side of the embankment alignment as per Options 3 & 4. However, instead of allowing space between the cofferdam and the proposed embankment, these cofferdams would be separated only so far apart as to allow the embankment to be constructed within the cofferdams. The cofferdams ultimately forming the toes of the completed embankment (Refer *Figure 2* – Integrated Cofferdam Embankment Cross Section). The cofferdam height of 162mAHD would provide 1.35m of freeboard above the dead storage and possible allow some small flexibility with the operating level above this.

This option negates the need for the cofferdams to be removed following construction and reduces the volume of earthfill required as the cofferdams provide some of the embankment volume. The estimate cost of this option is \$27million.

The volume of quarry waste required for the cofferdams is approximately 150,000m³, allowing for 1.5m of settlement into the organic subgrade and 40% contingency. The estimated volume of earthfill for the embankment is 650,000m³ (40% contingency).

5.2 Preferred Option

Based on the above discussion the preferred option is Option 5 - Full Drawdown and dry placement between cofferdams ultimately incorporated into the toe of the embankment.

Key advantages of this option are:

- Reduced overall material volume;
- Minimal environmental disturbance;
- Least cost option;
- Avoids double handling of cofferdam material

As with all options there are identified risks associated with this option. A key risk identified is the potential differential settlement of the cofferdams compared to the main embankment.

This Option is presented in Figures 1 & 2.

5.3 Construction Stages

Construction stages for the preferred Option 5 using integrated cofferdam protection is likely to be as follows:

- Lower storage level sufficient to minimise cofferdam height;
- Form access roads suitable for sourcing and delivery of materials.
- Construct temporary cofferdams using end dump method, removing dead trees as required;
- Pump out water contained within cofferdams;
- Allow period for drying out of embankment site;
- Stripping and excavation of borrow areas;
- Treat borrow material for lime stabilisation;
- Strip embankment foundations and stockpile spoil material to extent of staged progress to avoid unnecessary foundation exposure;
- Excavate under bank cut-off trench;
- Transport, place and compact embankment material at optimum moisture content.
- Deliver and place batter slope bedding material

- Deliver and place batter slope rip-rap;
- Deliver and place crest gravel seal;
- Reinstate borrow areas with stockpiled stripping;

For embankment construction ‘in the dry’ it has been assumed that a cut-off trench will suffice, however pre-construction drilling or exposure of the site may dictate a modified cut-off arrangement. Options for this include a deeper key trench, heavy gauge sheet piling or grouting, all of which would add to the cost of the works.

Should a decision be made to pursue Options 3 or 4, then the cofferdam removal task needs to be added to the above list.

5.4 Construction Timeframe

Construction time frame is dependent on suitable weather conditions however the attached program is an indicative program for the works without undue delays.

A placement rate of 1500m³/day has been assumed for the embankment construction work whilst a placement rate of 1800m³/day has been adopted for the cofferdam construction.

On this basis the placement of the cofferdams requires some 85 days and the embankment requires approximately 435 working days – a total of 470 days or about 79 six-day weeks. This does not include site establishment nor the time required to dewater and dry out the construction site between the cofferdams which will vary depending on previous water levels and weather conditions.

5.5 Construction Risks

Construction risks are:

Issue	Possible Problem	Control Measure
Exposure of poor or inconsistent foundation material	<ul style="list-style-type: none"> ■ Modification of cut-off arrangement required ■ Suitable compaction cannot be achieved 	<ul style="list-style-type: none"> ■ Thoroughly investigate site conditions using exploratory drilling to identify likely problems ■ Option Sheet piling or modified cut-of arrangement

Issue	Possible Problem	Control Measure
Depth of silt layer	<ul style="list-style-type: none"> ▪ Deeper excavation required 	<ul style="list-style-type: none"> ▪ Investigative drilling prior to commitment to works.
Flood Event	<ul style="list-style-type: none"> ▪ Inundate and saturate work site ▪ Scour of placed material 	<ul style="list-style-type: none"> ▪ Defer construction work until site is suitable ▪ Limit exposed areas ▪ Construction process to limit obstruction of waterways ▪ Place sacrificial material if pre-warned of flood event
Wet weather conditions during construction	<ul style="list-style-type: none"> ▪ Limited access for plant ▪ Damage to access provisions 	<ul style="list-style-type: none"> ▪ Provide access roads suitable for moderate rainfall conditions.
Dry conditions	<ul style="list-style-type: none"> ▪ Dusty work environment ▪ Placement of dry soil ▪ Dust blowing onto adjacent lands 	<ul style="list-style-type: none"> ▪ Provide water cart for dust ▪ Provide suitable moisture content testing on material placed by contractor
Environmental Damage	<ul style="list-style-type: none"> ▪ Damage to flora and fauna 	<ul style="list-style-type: none"> ▪ Prepare Environmental Management Plan
Occupational Health and Safety	<ul style="list-style-type: none"> ▪ Unsafe work practices 	<ul style="list-style-type: none"> ▪ Prepare a site safety plan
Plant movement	<ul style="list-style-type: none"> ▪ Accidents with other plant ▪ Accidents with vehicles 	<ul style="list-style-type: none"> ▪ Control procedures for safe plant movement ▪ Restrict access to work site
Traffic control in/out of site	<ul style="list-style-type: none"> ▪ Accidents with traffic or plant entering leaving/site 	<ul style="list-style-type: none"> ▪ Warning signs and site induction procedures

6. Cost Estimates

A summary of the cost estimates for each of the options is provided below. More detail is documented in Appendix A.

Spit Embankment Costs

Embankment Option	Estimated Cost (includes 40% contingency on quantities)
Option 1: End Dumping	Not costed as not technically feasible
Option 2: Complete drawdown to construct in dry conditions	Not costed as dead storage level is above construction area elevation
Option 3: Partial Drawdown and construction between 164mAHD cofferdams which are then removed	\$51.2m
Option 4: Full Drawdown and construction between 162mAHD cofferdams which are then removed	\$31.7m
Option 5: Full Drawdown and construction between 162mAHD cofferdams which are integrated into embankment	\$27m

Catchment By-pass Flow Costs

Catchment By-pass Flow Option	Estimated Cost (includes 40% contingency on quantities)
Option A: By-pass Channel	\$9.4m¹
Option B: Pump Station and Spillway	\$1.6m excluding pump and civil/structural works

Notes:

1. A reduction in cost of \$3.8million is possible if the material is suitable for embankment construction (and hence would be allocated to earthfill costs).

7. Summary

This report finds that the construction of the spit embankment to bisect Lake Mokoan is technically feasible based on the information identified during this study.

The preferred option identified in this report is Option 5, which consists of full drawdown of Lake Mokoan and dry placement of the spit embankment between cofferdams, which are ultimately incorporated into the toe of the embankment

This study identified that local materials are dispersive clays that will require conditioning before placement in the embankment to allow proper compaction and long term integrity of the structure.

A significant issue is the provision of drainage for the eastern section of the lake to cope with local catchment discharge. The impact of the proposed works on hydrological conditions have not been investigated in detail and this is recommended before further consideration can be given to a drainage system.

It is recommended that the next stage of work incorporates geotechnical field investigations and detailed hydrological studies to establish the design parameters and further refine the design elements.

The estimated capital cost for Option 5 is \$27M as discussed in Section 5 of this report. This capital cost includes a 40% contingency, which is appropriate at this level of study. This cost does not include the proposed by-pass channel or pump station and spillway options, which may increase this estimate by up to 30% depending on the drainage strategy chosen.

Estimated construction time for the preferred option is in the vicinity of 470 working days or two construction seasons assuming favourable (dry) climatic conditions. More detailed investigations may refine the design and construction technique to reduce the overall construction period.



Appendix A Cost Estimates

Spit Embankment Costs

Embankment Option	Estimated Cost (includes 40% contingency on quantities)
Option 1: End Dumping	Not costed as not technically feasible
Option 2: Complete drawdown to construct in dry conditions	Not costed as dead storage level is above construction area elevation
Option 3: Partial Drawdown and construction between 164mAHD cofferdams which are then removed <ul style="list-style-type: none"> Cofferdams \$17.1m Stripping \$2m Earthfill \$11.2m Filter Material \$3.7m Riprap \$2.7m Silt Curtains \$25k Cofferdam removal \$9.8m G-MW Management and Design \$4.7m Total \$51.2m 	
Option 4: Full drawdown and construction between 162mAHD cofferdams which are then removed <ul style="list-style-type: none"> Cofferdams \$5.2m Stripping \$2m Earthfill \$11.2m Filter Material \$3.7m Riprap \$2.7m Silt Curtains \$25k Cofferdam removal \$3m G-MW Management and Design \$3.9m Total \$31.7m 	
Option 5: Full drawdown and construction between 162mAHD cofferdams which are integrated into embankment <ul style="list-style-type: none"> Cofferdams \$5.2m Stripping \$1.8m Earthfill \$9.8m Filter Material \$3.7m Riprap \$2.7m Silt Curtains \$25k G-MW Management and Design \$3.8m Total \$27m 	

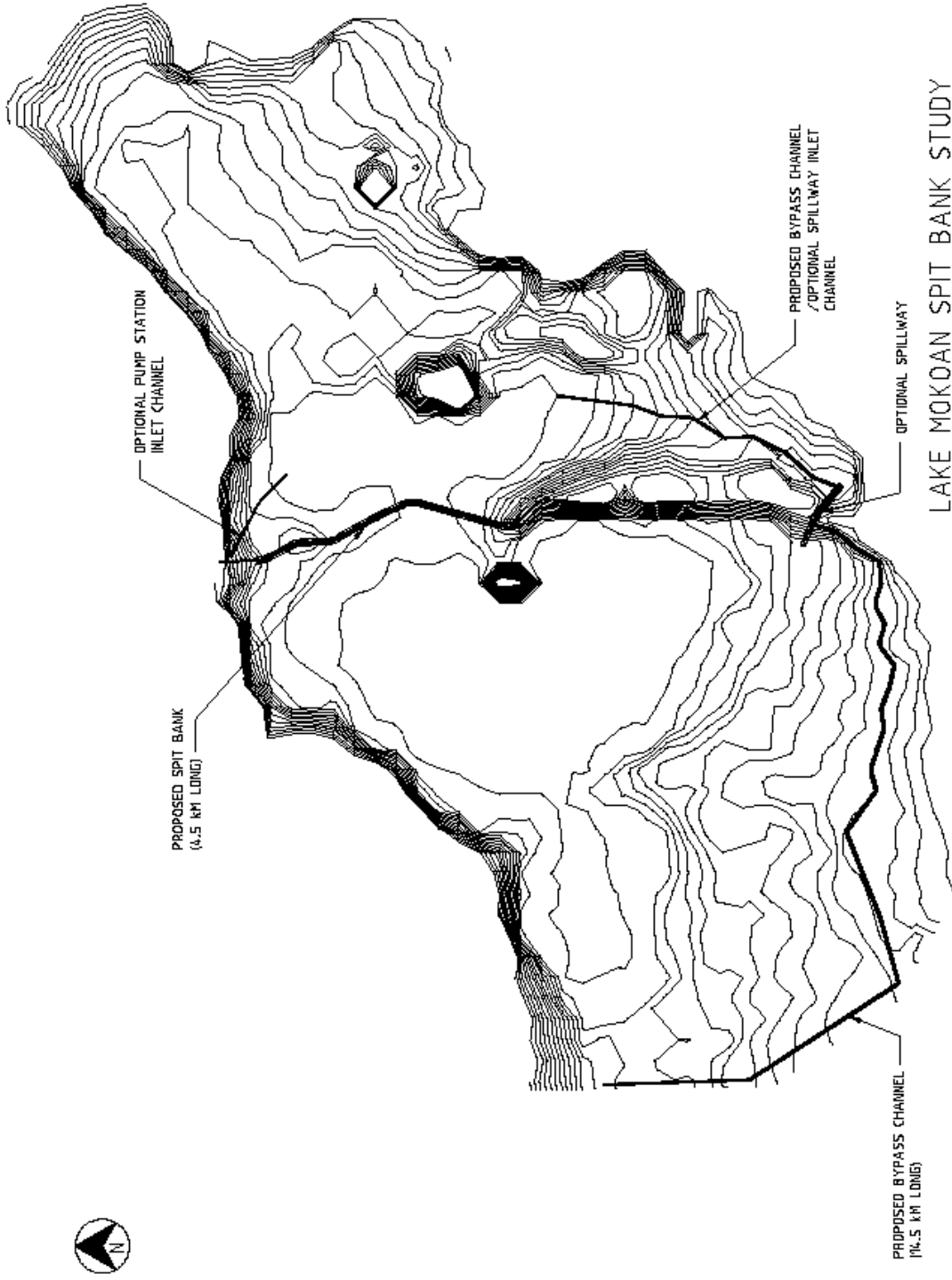


Catchment By-pass Flow Costs

Catchment By-pass Flow Option	Estimated Cost (includes 40% contingency on quantities)
<p>Option A: By-pass Channel</p> <p>By-pass channel – including spoil disposal/placement (with 210,000m³ including in embankment earthfill costs)¹</p> <p>Gravelling Channel access</p> <p>30m spillway in Spit (for 7000ML/d flow)²</p> <p>Drainage subways (3 No)</p> <p>Subway under Mokoan Inlet channel</p> <p>Backflow structure</p> <p>Total</p>	<p>\$8.1m</p> <p>\$200k</p> <p>\$720k</p> <p>\$162k</p> <p>\$120k</p> <p>\$120k</p> <p>\$9.4m</p>
<p>Option B: Pump Station and Spillway</p> <p>Pumps</p> <p>Pump Station Civil Works</p> <p>Pump Station inlet channel (including disposal/placement of spoil)</p> <p>60m spillway in Spit (for 7000ML/d flow)²</p> <p>Spillway inlet channel</p> <p>Total</p>	<p>Provided by GMW</p> <p>To be costed by GMW</p> <p>\$300k</p> <p>\$1.3m</p> <p>Including in embankment earthfill costs</p> <p>\$1.6m plus pump civil/structural works</p>

Notes:

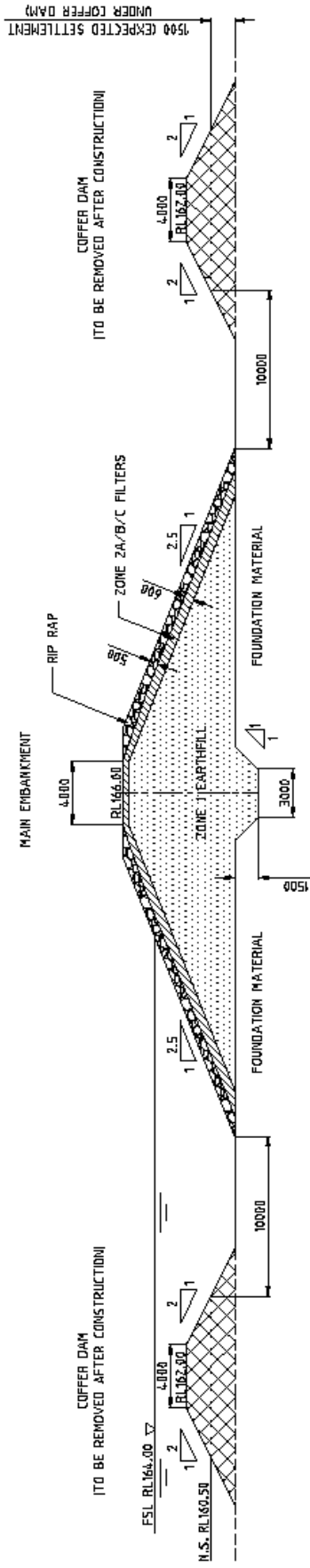
1. A reduction in cost of \$3.8million is possible if the material is suitable for embankment construction (and hence would be allocated to earthfill costs).
2. Flow rate of 7000 ML/d is estimate only (G-MW) and requires confirmation by hydrological assessment.



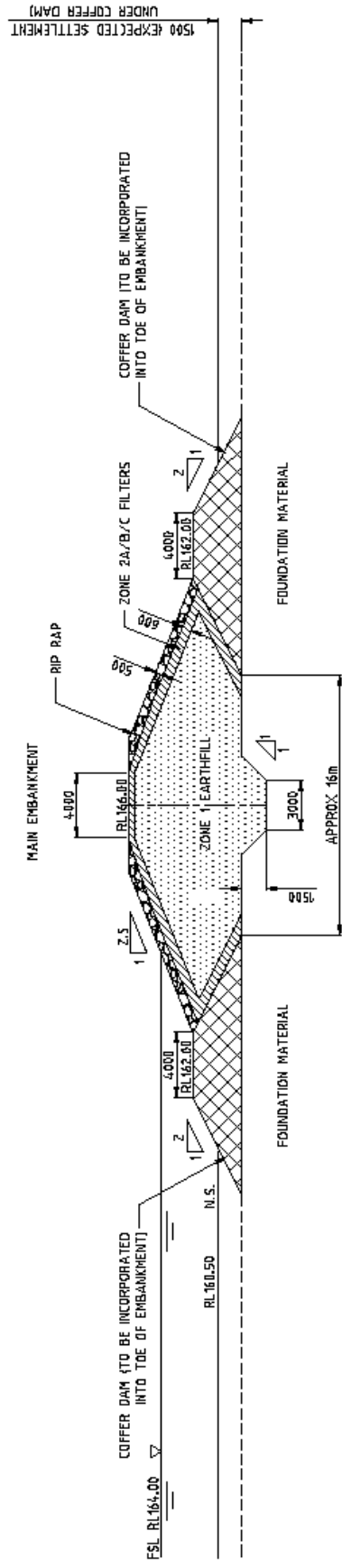
NOTE:
CONTOURS PROVIDED BY URS

LAKE MOKOAN SPIT BANK STUDY
GENERAL ARRANGEMENT

FIGURE 1



EXTERNAL COFFER DAM EMBANKMENT CROSS SECTION



INTEGRATED COFFER DAM EMBANKMENT CROSS SECTION

FIGURE 2