Barmah Township Flood Mitigation

Functional Design

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PROJECT DETAILS

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Cover Photo: Murray River at Barmah (July 2005) – Ben Tate.

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1. INTRODUCTION

Water Technology was commissioned to undertake the development of a Functional Flood Mitigation Plan for the township of Barmah in northern Victoria. This Plan was developed for Moira Shire Council and Goulburn Broken CMA, on behalf of the Barmah community. The Plan concentrated on levee options to protect the township.

1.1 Objectives

The key objectives of the study included:

- The development of a functional flood mitigation plan, including:
  - Assessment of economic, social and environmental aspects of proposed levee alignments.
  - Community consultation and communication.
  - Clear and concise documentation for use in future funding applications.
- Involvement of the community in the project:
  - Furthering the community's understanding of the flood mitigation works proposed.
  - Elevating community awareness of flooding issues.

1.2 Approach

The study was undertaken within a risk management context and with reference to the following standards, policies and guidelines:

- Best Practice Principles for Floodplain Management in Australia (CSIRO, 2000)
- Victorian Flood Management Strategy (State Flood Policy Committee, 1998)
- Goulburn Broken Regional Floodplain Strategy (Goulburn Broken CMA, 2002)

Key stakeholders were engaged early in the project by means of a Community based Steering Committee, with representatives from Moira Shire Council, Goulburn Broken CMA, VIC SES, CFA, DSE and the local community. During early meetings including a field inspection by the Steering Committee, the scope of the project was agreed upon, mitigation options were discussed and the preferred levee mitigation option began to take shape.

Water Technology then developed a functional design of the preferred levee option, and had a specialist civil design consultancy, Project Delivery, develop detailed costing and functional design drawings. A number of environmental and cultural issues were investigated at this stage. It was identified that these were important issues that needed to be addressed before progressing further with the functional design. Gaye Sutherland from Goulburn Broken CMA completed a Cultural Heritage Management Plan, with Water Technology ecologists completing a flora and fauna assessment. The results of the functional design were presented to the Steering Committee and the final delivery of the project was discussed.

After gaining positive feedback on the proposed functional design from the steering committee, the report was finalised along with a brochure explaining the functional design in simple terms for use as advertising material for a community information session.

A community information session was held discussing the project and its outcomes.

2. CURRENT KNOWLEDGE

2.1 Previous Studies

GHD (1986) Murray River Floodplain Management Study

This study briefly describes flooding characteristics at Barmah, stating that it is highly influenced by backwater from the Goulburn River and that flood level variations are quite small. The study estimated the 1% AEP flood level at Barmah as 96.9 m AHD, based on the 1975 flood level plus 400 mm. It described the topography as flat with most allotments below the 1% AEP flood level. With most houses built at ground level, it states that flood protection during the 1975 flood event was achieved through sandbagging local low points. Flood durations could last weeks to months. Due to the low lying topography it was suggested that the only mitigation options available included ring levee construction, raising of buildings above flood level and planning controls.

GHD (1994) Barmah Flood Mitigation Study

This study also estimated the 1% AEP flood level at 96.9 m AHD based on a synthetic flood frequency curve. This study questioned the accuracy of historic gauged flood levels at Barmah and so interpolated levels at Barmah, based on more accurate gauged records at Yarrawonga, Toccumal and Echuca. A number of assumptions based on anecdotal evidence were also made. The study also surveyed 106 floor levels within the town, providing a highly valuable dataset. The study found that the town is affected by floods equal to or greater than the 20% AEP flood event and that a ring levee is the most cost-effective mitigation measure. A number of levee alignments were considered. For those that included a crest height equal to the 1% AEP flood level plus 600 mm freeboard, the cost ranged between one to two million dollars. The average annual damage including floods up to the 1% AEP event was estimated to be $76,000 per annum (at that time). The benefit-cost ratio of the proposed levee alignments ranged from around 0.7 to 1.5 assuming a 4% discount rate over a 50 year project life.

Water Technology (2005) Lower Goulburn Floodplain Rehabilitation Scheme – Hydraulic Modelling Report

The Lower Goulburn Floodplain Rehabilitation Scheme was a Goulburn Broken CMA project that investigated the option of returning flood flows to the lower Goulburn River floodplain downstream of Loch Garry. One of the findings of the study was confirmation of the impact of Goulburn River flows on the Murray River at Barmah. It has long been understood that high flows in the Goulburn River could reverse flow in the Murray River at Barmah. This was demonstrated in the calibration of the hydraulic model for the 1993 flood event. Simulating the 1993 flood event with the Lower Goulburn Floodplain Rehabilitation Scheme in place increased the reverse flow in the Murray River by over 100 m^3/s, resulting in a greater backwater effect and increased flood levels at Barmah. Subsequently a further study (SKM 2008) was undertaken to assess the impact of the proposed Lower Goulburn Scheme on the township of Barmah and investigate possible mitigation options. This study estimated the 1% AEP flood level at Barmah to be 96.97 m AHD for existing conditions and 97.13 m AHD (0.16 m increase) with the Lower Goulburn Scheme in place. It is noted that the 1% AEP flood level adopted by Goulburn Broken CMA for planning purposes is 96.9 m AHD, slightly lower than the level estimated from this study. It is considered that some of the assumptions adopted for the design modelling in this study provided a conservative estimate of the 1% AEP flood level at Barmah. These assumptions included a constant 30,240 ML/d flow in the Murray River, and two levee failure scenarios, with one scenario with predominantly north levee failures and the other south levee failures.

SKM (2008) Lower Goulburn Floodplain Rehabilitation Scheme – Assessment of Flood Risk to the Township of Barmah and Preliminary Flood Mitigation Review

This study summarised the flood risk for Barmah, documenting historic flood levels and findings from past projects. Table 1 below summarises the top 10 floods on record at Barmah. One of the key points to take from this analysis is that the 1993 and 1975 flood events were almost identical in the observed flood level at Barmah, but were approximately 400 to 500 mm lower than the 1% AEP flood estimate of 96.97 m AHD from the Water Technology (2005) study and also significantly lower than the 1% AEP flood level estimates of GHD (1986, 1994).

Table 1 Historic and Design Floods at Barmah

Year	1870	1% AEP	1867	1917	2% AEP	5% AEP	1993	1916	1975	1956	1974	1931
Flood Levels (m AHD)	97.3	96.97	96.8	96.7	96.69	96.56	96.51	96.5	96.5	96.3	96.2	96.1

The study identified 133 buildings within the township, most of which had floor level survey from the GHD (1994) study, the remainder were estimated using the available topography and an estimate of height above ground. The study stated that the town was at risk of flooding at water levels of 96 m AHD or greater, confirming that above this level the topography is relatively flat throughout the town.

The study adopted the 1% design flood levels from the Water Technology (2005) study discussed above and undertook a flood damage assessment for Barmah. The average annual damage for Barmah under existing conditions was calculated to be approximately $50,000 and $80,000 with the Lower Goulburn Scheme in place. This is considerably lower than the annual average damage as calculated by GHD (1994). On comparison of the two studies it appears that the SKM (2008) study used a much more rigorous flood damage estimate methodology, with the GHD (1994) study utilising a flood damage estimate from Nyngan in NSW and adjusting it to account for the number and nature of properties impacted and changes to costs.

This study outlined two proposed levee options which could be implemented to mitigate flood damage in Barmah from a 1% AEP design flood event with and without the Lower Goulburn Scheme in place. The proposed levee alignments are presented in Figure 1 below. The levees were approximately between 4 and 4.5 km in length with crest levels equal to the adopted 1% AEP design flood level with and without the Lower Goulburn Scheme in place plus 600 mm of freeboard. The two levee alignments consisted of earthen levees that for the majority of the alignment ran alongside existing roadways. The two levee alignments were estimated to cost just over one million dollars, similar to the GHD (1994) study (not taking inflation into account). These two levee alignments returned a benefit-cost ratio of 0.66 and 0.69 assuming a 4% discount rate over a 30 year project life. These benefit-cost ratios were significantly lower than GHD (1994) due to the lower average annual damage estimate reducing the net benefit of mitigation.

Figure 1 SKM (2008) Proposed Levee Alignments

2.2 Available Data

In addition to the available previous studies described above, a number of other datasets were utilised in this study as described below.

2.2.1 Aerial Imagery

Aerial imagery was available from a number of sources, including Google Maps, Nearmap, DSE Vicmap and infrared photography from the Southern Murray Darling Basin (SMDB) LiDAR Project (Murray Darling Basin Commission, 2001). The DSE Vicmap and Nearmap images were utilised for background mapping for this project. Figure 2 below shows the DSE Vicmap aerial image of Barmah taken in 2009. The imagery was utilised as a mapping background, to identify alternative levee alignments and potential issues along these alignments, and to check the current level of development as compared to that assumed by GHD (1994) and SKM (2008).

2.2.2 Topography

Topography data was available from the Southern Murray Darling Basin (SMDB) LiDAR Project (Murray Darling Basin Commission, 2001). The horizontal accuracy of the data was stated as 0.5 m, with a vertical accuracy of 0.15 m. Figure 3 and Figure 4 below show the LiDAR as both a continuous colour ramp and classified into 0.5 m increments. The LiDAR shows that the majority of the developed floodplain at Barmah is between 96 and 96.5 m AHD, with some low lying areas slightly lower than 96 m AHD and some roads and isolated pockets of land raised above 96.5 m AHD. Of particular note is the low depression that runs through the north and east of town, and the relative height of many of the roads compared to the lower floodplain level.

2.2.3 Floor Level Survey

Floor level survey was obtained from the SKM (2008) study which included the full database from the GHD (1994) study plus a number of additional floor level estimates based on topographic level from the LiDAR and an estimate of the floor level above the ground from a field inspection.

In total, 133 floor levels were available, of which only 13 were non-residential. The building types vary from small fibro-cement construction to large brick veneer buildings, concrete slab on ground and stumps, permanent and temporary structures (annexes and caravans in the two caravan parks in town).

From an analysis of aerial imagery 18 additional buildings were identified requiring a floor level. The same method as that utilised in the SKM (2008) study was employed, estimating the floor levels using the topography and the estimated height above ground. The available and missing floor levels are shown below in Figure 5, with floor levels classified as above and below the 1% AEP flood level.

Figure 2 Aerial Photography of Barmah

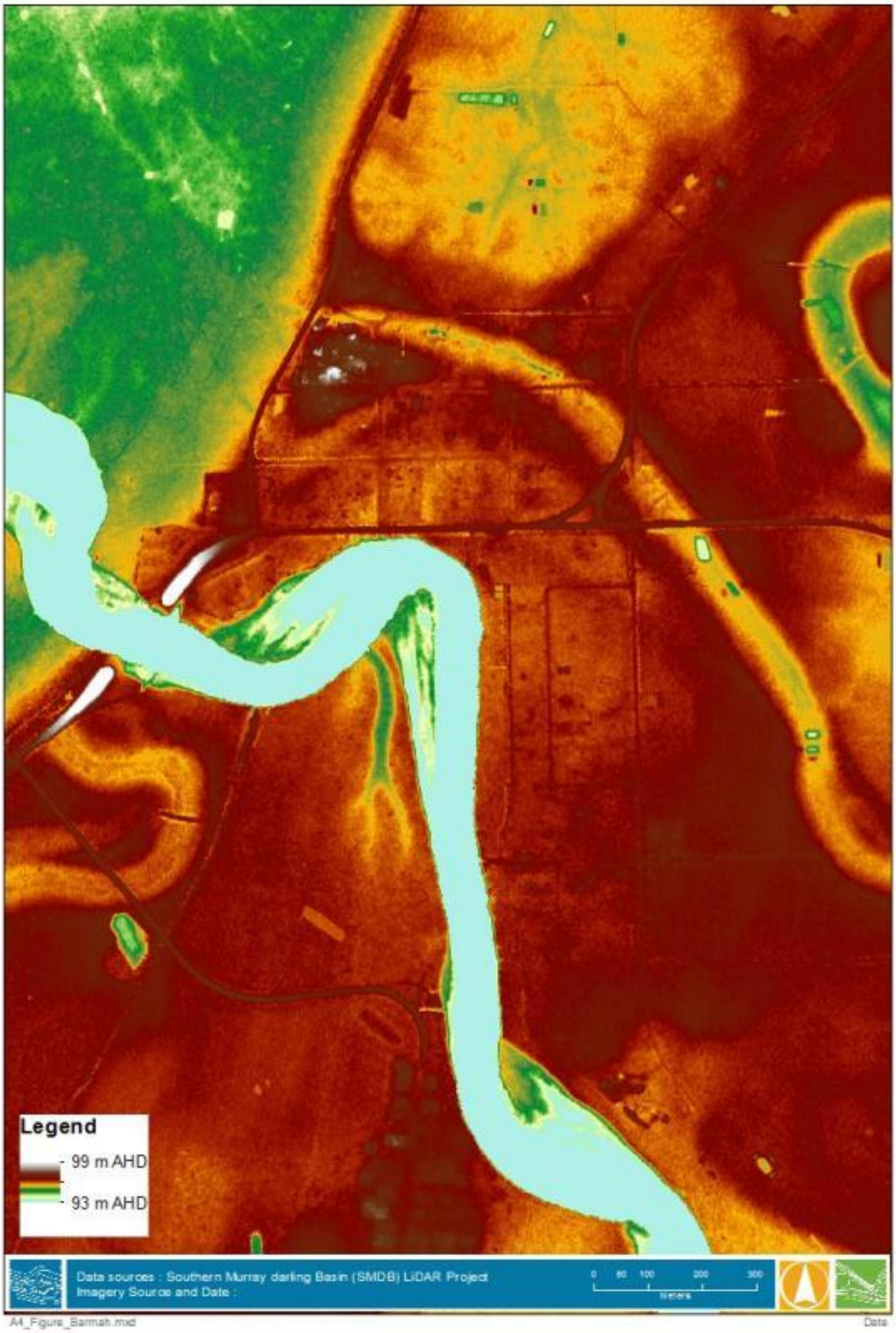

Figure 3 **Available LiDAR (colour ramp) Topography for Barmah**

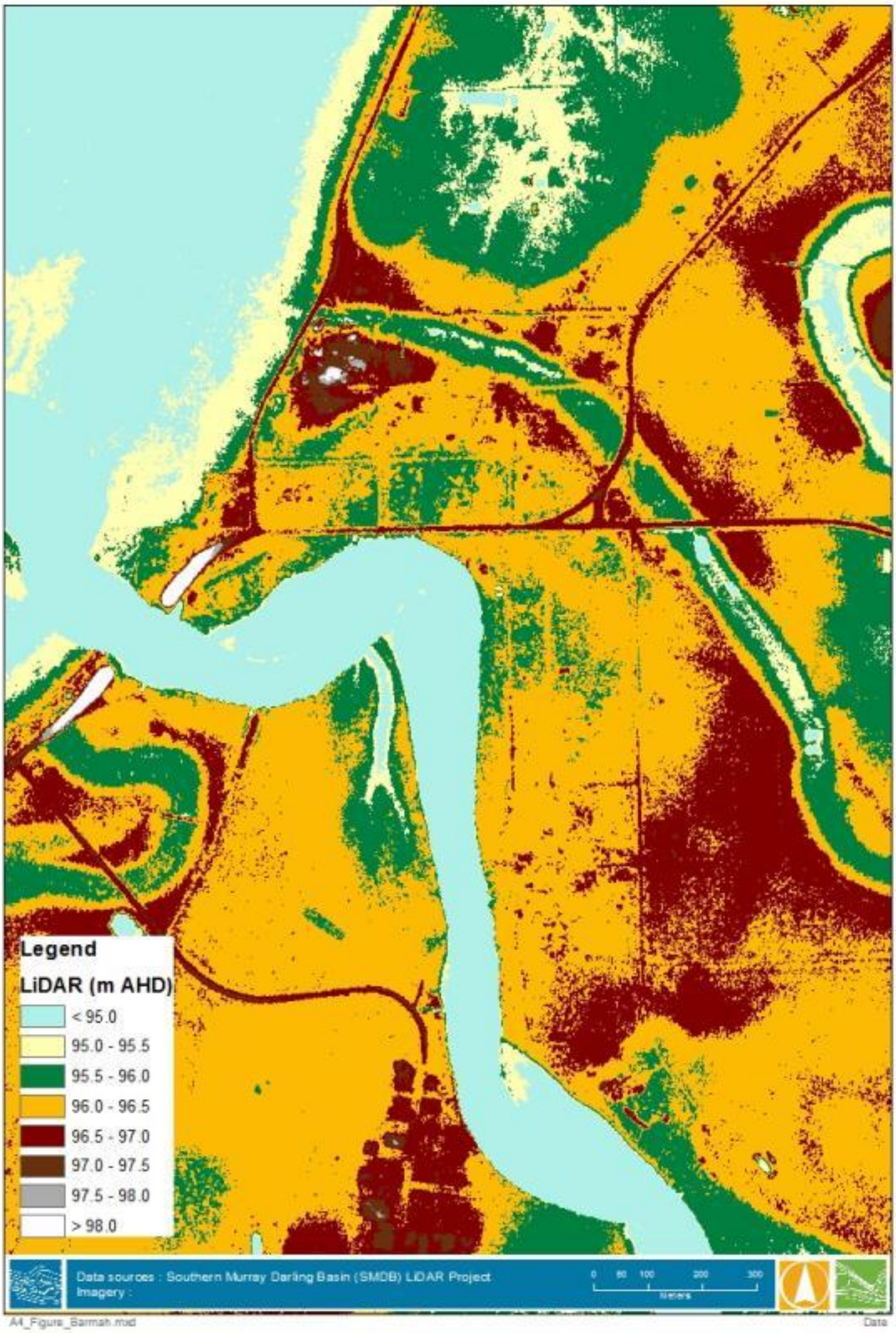

Figure 4 Available LiDAR (classified) Topography for Barmah

Figure 5 Available Floor Level Survey

3. FLOOD MITIGATION OPTIONS

3.1 Potential Options

A number of mitigation options have been considered in the previous studies discussed earlier in this report. The findings from these previous studies and current thinking regarding these options are summarised below.

Do Nothing – This is not considered a long term solution due to the existing flood risk Barmah faces.

Raise Floor Levels – The number of properties at risk of flooding in Barmah is too high to justify raising all floor levels, and the age and construction type of many of the buildings would not allow floor raising to be a feasible option for all buildings.

Purchase Flood Prone Land – Similar to raising the floor levels, the majority of the township is flood prone, purchasing of flood prone land is not a viable option for all properties.

Planning Controls – It is recommended that planning controls be implemented that set future floor level heights and ensure appropriate development, regardless of whether other mitigation options are implemented. It is noted that a Rural Floodway Overlay and a Land Subject to Inundation Overlay are already in place in the Planning Scheme, these instruments will ensure that appropriate development and finished floor levels are part of any new future development.

Flood Warning – The Bureau of Meteorology provides a flood warning service for the Murray River at Barmah. The Barmah gauge is available live on the Bureau's website and can be monitored for water level in relation to the adopted flood class levels of Minor at 95.28 m AHD, Moderate at 95.79 m AHD and Major at 96.29 m AHD. Barmah has a long flood warning time and the community should receive adequate warnings to enable them to prepare their properties in readiness for flooding and evacuate if required. Similar to planning controls, flood warning should be a mitigation option that is implemented regardless of what other options are considered.

Construct Flood Levees – This was the favoured option of both the GHD (1994) and SKM (2008) studies. Both studies considered a number of different alignments and investigated the benefit-cost relationship using different methods. To protect the Barmah township from flooding with a levee system would require significant works in terms of the levees themselves but also would require upgrades to the local drainage system, roads and driveways. It would require the use of numerous different levee construction types to deal with local constructability issues, and is likely to be costly. This study investigates levee options further, providing a more accurate and current estimate of the cost to construct such a system.

3.2 Options Considered in this Study

3.2.1 Preliminary Levee Alignments

This study refined the previous levee alignments, optimising them to make best use of local topographic features, whilst also minimising disturbance to native vegetation and existing residences. Levee alignments followed existing road infrastructure where possible. The levee alignment was relatively straightforward for much of the area, however the section along the river frontage to the south of the town posed significant challenges. Along this section of the proposed levee two alignment options were presented for consideration. The first option involved following the existing walking track, making use of the cleared space under the canopy of River Red Gum trees. The second option follows property boundaries and could be situated on either side of the property boundaries, however if the levee was situated on the private property side of the fence, this would greatly reduce the impact on River Red Gum, but would most likely require compensation for 23 property owners. Figure 6 illustrates the two preliminary levee alignments.

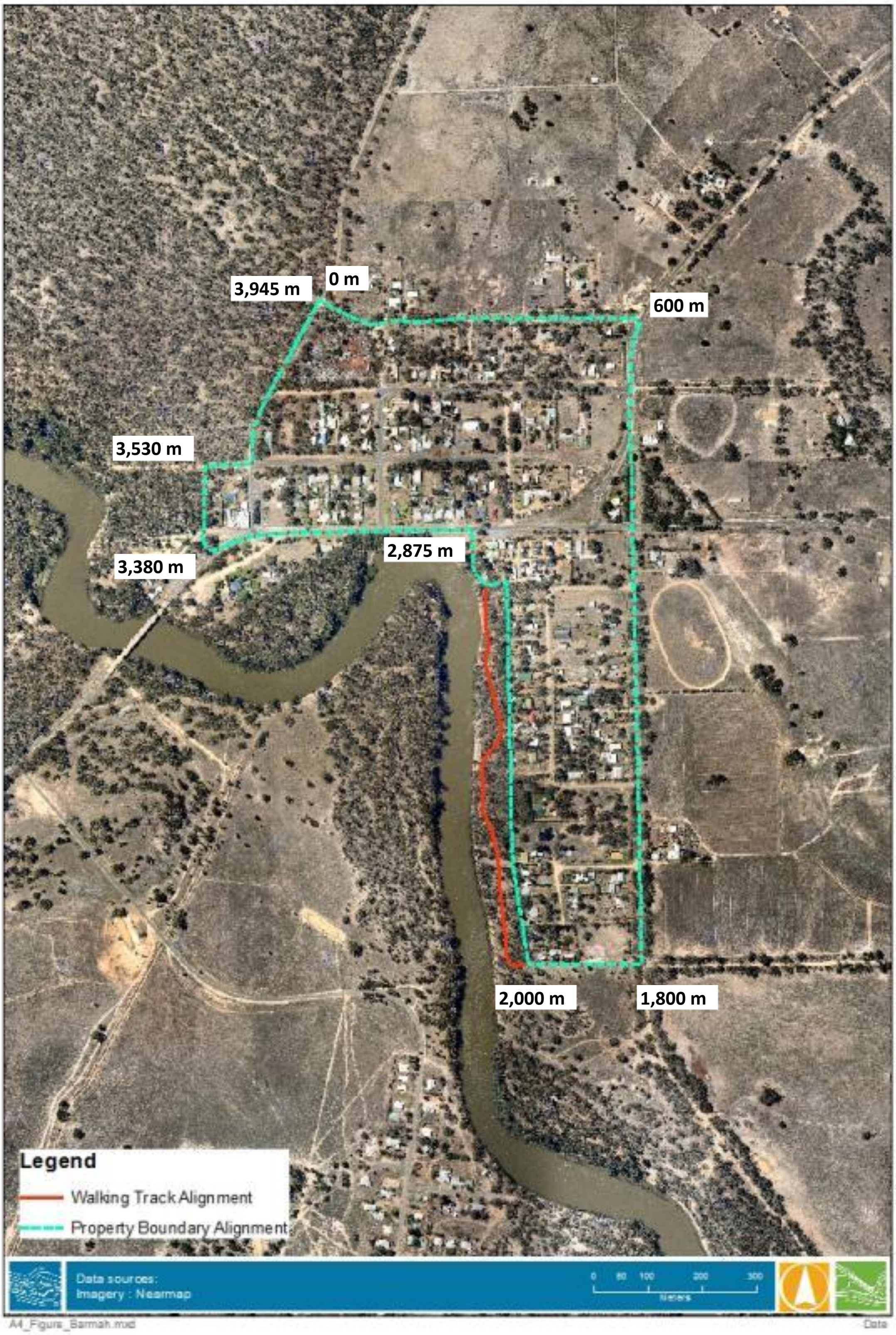

Figure 6 Proposed Preliminary Levee Alignments

The levee from chainage 0 to 1,800, 2,875 to 3,380 and 3,530 to 3,945 m as shown on Figure 11 would be constructed by raising existing roads. The levee from chainage 1,800 to 2,000 m and 3,380 to 3,530 m would be constructed using a typical earthen levee design. The levee between chainages 2,000 and 2,875 m could be constructed using a number of methods:

- Earthen levee
- Crib wall
- Concrete retaining wall
- Temporary flood barrier

These construction methods all have different costs and benefits and are discussed further below.

Figure 12 below shows the longitudinal section of the proposed levee alignments. Note the chainages correspond to those marked on Figure 6. The chainage of the property boundary levee option has been stretched by 11 m through the section between chainage 2,000 and 2,875 m, so that the two levee lengths match for plotting purposes.

As shown on Figure 12, assuming a freeboard of 300 mm, the average levee height along the alignment is approximately 0.8 m, with the maximum height approximately 2 m. With a freeboard of 600 mm these heights obviously increase by a further 300 mm.

These alignments were discussed with the Project Steering Committee which included a number of community representatives and it was felt that they were the best options to consider further.

3.2.2 Levee Construction Methods

As described previously a number of levee construction methods are applicable for Barmah, including raising roads, earthen levees, crib walls, concrete retaining walls and temporary barriers. Figure 11 at the end of this section shows the appropriate construction methods along the two proposed levee alignments.

Raising Roads

The majority of the proposed levee alignment follows the route of existing roads, with approximately 1,875 m of sealed road and 830 m of unsealed road. The cost of resurfacing small urban roads was estimated by Moira Shire Council during the inception meeting at Barmah as being approximately $220,000 per km. It is understood that this is for sealed roads, but may not allow for the required height of raising, in this instance an average height of 0.65 and 1.0 m for the existing sealed and unsealed roads respectively. This assumes that a freeboard of 300 mm is acceptable for a levee constructed by raising roads.

Raising roads requires significant works on approach roads and driveways to ensure permissible grades for access are achieved.

Earthen Levees

Earthen levees have been the traditional flood mitigation construction method adopted in Victoria in the past. Figure 7 depicts the typical cross-section of the proposed earthen levee construction. Major design features of an earthen levee include a top width of 3 m which is indicative of a minimum top width and may be increased to allow for estimated traffic loads. A 2.5:1 batter is proposed to allow mowing and safe public access whilst also minimising the footprint of the levee. A cutoff trench attempts to prevent piping under the levee.

Earthen levees are proposed over a length of approximately 1,240 m with an average height of 1.1 m, allowing for 0.3 m of freeboard. Given 0.3 m has been adopted as the freeboard, a concrete cap has been incorporated along the top of the earthen levee. Using the above 3 m top width and 2.5:1 batters, this gives an average levee footprint of 8.5 m in width.

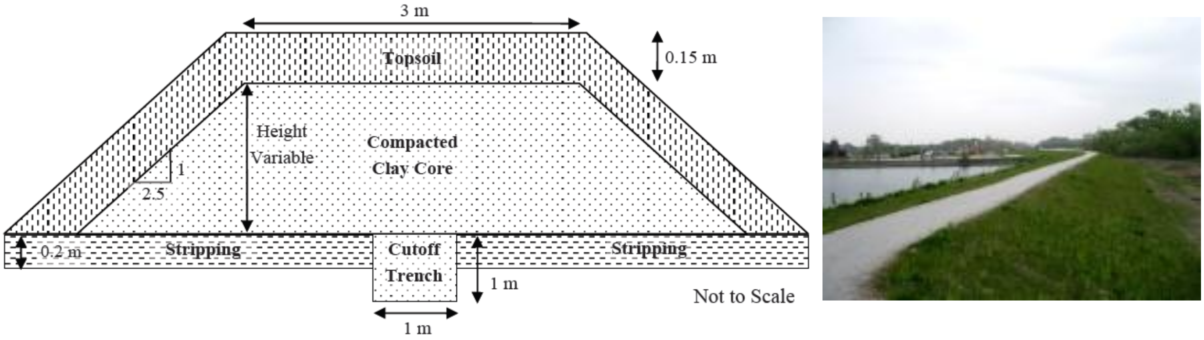

Figure 7 **Proposed Standard Levee Cross-section and example with walking track on crest**

Crib Wall

Along the river frontage to the south of town the area is densely populated by native River Red Gum trees. This means that construction methods in this area could be restricted due to reduced access for heavy machinery. In addition, costly native vegetation offsets would be required if native trees are disturbed or removed. To minimise impact in this area construction should be kept to a minimum footprint.

A crib wall can consist of one or two near vertical walls enclosing a compacted clay core. This alternative provides the opportunity to incorporate vehicular access. It is not common to have a crib wall on the water face of a levee, however it can be achieved utilising a geo-synthetic liner behind the crib wall minimising leakage and the risk of scour damaging the levee. Figure 8 shows an example crib wall levee construction. By reducing the footprint of the levee, the impact on native vegetation and public land may be reduced, thus offsetting the additional cost of construction of the retaining walls along with a reduced maintenance cost.

Figure 8 **Crib Wall levee constructions**

Concrete Retaining Wall

Concrete retaining walls can provide the same level of protection as earthen levees, with a significantly reduced construction footprint. Concrete retaining walls are more expensive to construct. However, significant cost savings may be achieved through the reduction in native vegetation offsets associated with the construction and maintenance of earthen levees. Figure 9 presents an example of a concrete retaining wall levee protecting a residence at a site with limited space.

Figure 9 Concrete Retaining Wall Levee Constructions

Temporary Flood Barrier

Temporary flood barriers are an alternative mitigation method that may be implemented along the river frontage section to minimise vegetation disturbance and maintenance requirements. Stored in containers and mobilised via pallets, temporary flood barriers provide a flexible option for emergency management services for flood protection. Although expensive when compared to construction of basic earthen levees, the zero expenses associated with native vegetation disturbance or private property may make this option competitive. A temporary flood barrier system was recently implemented in Nathalia (March 2012) with great success.

Figure 10 Temporary Flood Wall constructions (Geodesign Barriers, 2011)

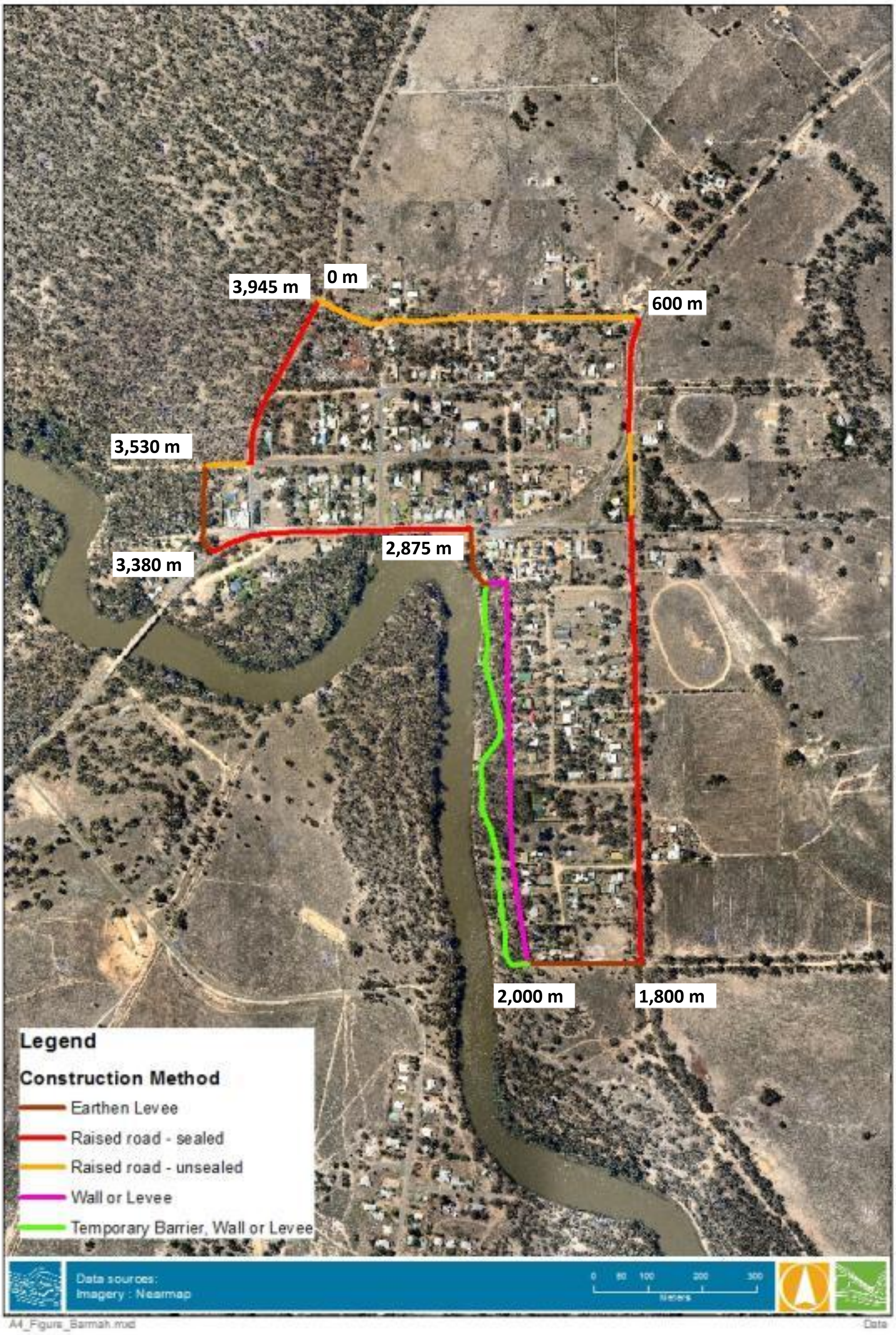

Figure 11 **Location of Appropriate Levee Construction Methods**

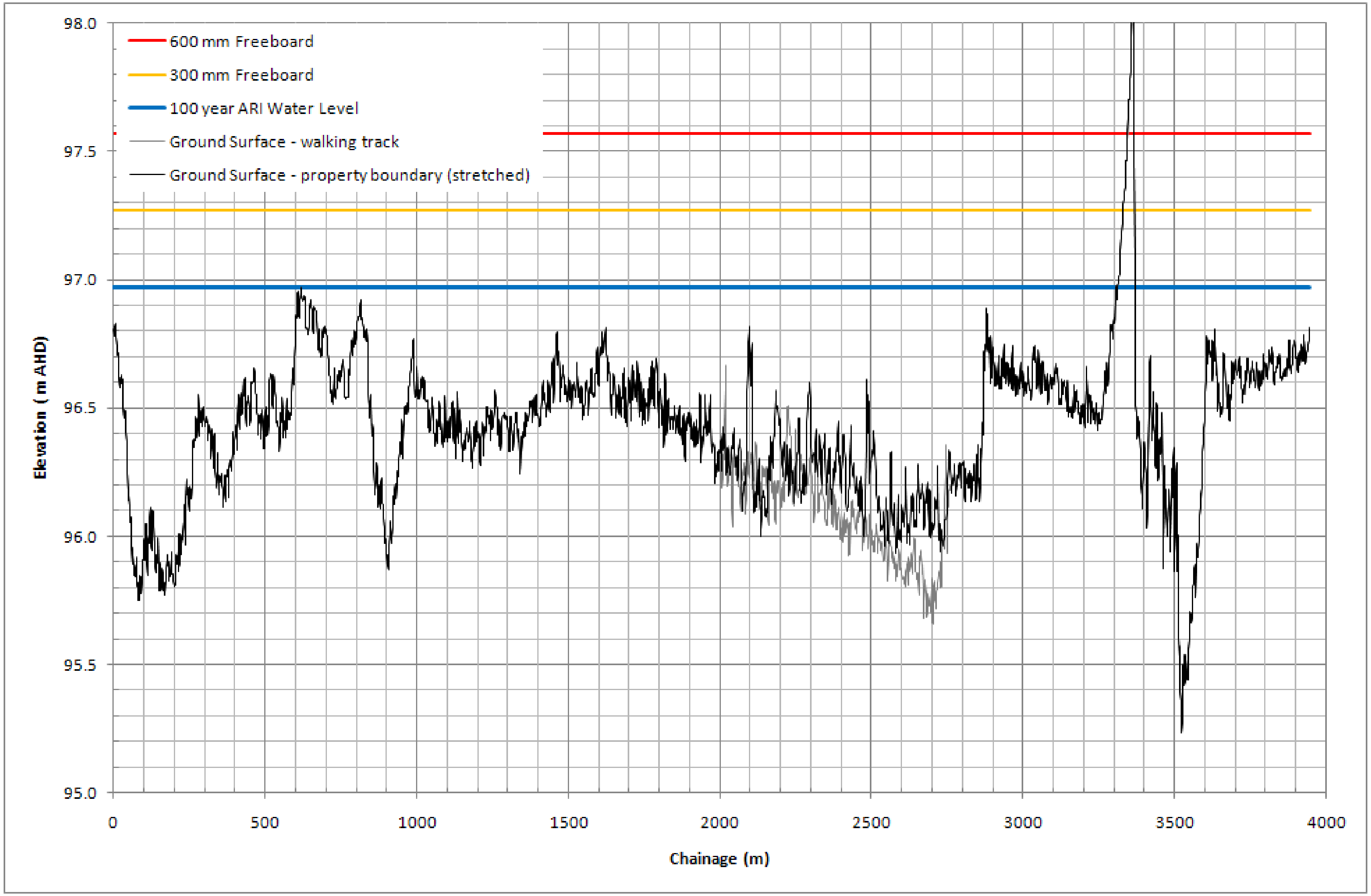

Figure 12 Proposed Preliminary Levee Alignments in Longitudinal Section

3.3 Major Issues with Options

A number of major issues have been identified which contribute to the preferred flood mitigation levee design as discussed below.

3.3.1 Environmental Impact

One of the major challenges for the proposed levee systems considered in this study was the reach along the river frontage to the south of town. In this reach there is high value habitat including large River Red Gums which provide habitat for many native species. Water Technology prepared a reported titled *"Barmah Township Flood Mitigation – Flora and Fauna Assessment"* completed in July 2011 which assessed the two proposed alignments. The report is summarised below.

Fauna

A desktop review was carried out prior to the field assessment and incidental fauna sightings were recorded on the day of inspection. Information gathered to date suggests the levee construction is unlikely to have significant impact upon fauna. Although very high quality habitats were not identified, there are certainly opportunities for fauna to occupy the existing proposed alignments. The best habitats observed include small hollows within some of the trees identified. Ground habitats (fallen timber, small shrubs and native grasses) are highly disturbed and are often difficult to maintain in close proximity to housing.

It is recommended that once the alignment and construction methods have been confirmed, a more targeted assessment should occur prior to construction to ensure native fauna is protected or relocated.

Flora

The river frontage and the area behind the pub provides habitat similar to very large forest environments. Should the alignment along the walking track be developed, the clearing will not be wide enough to fragment or split the forest significantly. Adjacent tree canopies should remain untrimmed, where safe to do so, to allow arboreal mammals and other fauna the opportunity to cross the levee more easily. Should the alignment along the property boundary be adopted and cleared, a slight reduction in the width of the riparian vegetation will occur.

A Net Gain assessment was conducted on both alignments and it was found that for Patch Vegetation, the walking track alignment would attract a higher habitat hectare offset if developed. For Trees, the walking track alignment would disturb far less Very Large Old Trees and Large Old Trees attracting far less offset area.

It was found that the walking track alignment provides far less disturbance to large River Red Gums and is the preferred alignment in terms of minimising impact on flora. The levee construction method should consider options that reduce the impact on native vegetation. A Vegetation Offset Management Plan will be required regardless of the alignment chosen. The DSE Regional Native Vegetation Manager should be consulted prior to finalising any alignments during detailed design.

3.3.2 Cultural Heritage

Gaye Sutherland of Goulburn Broken CMA completed a Cultural Heritage Management Plan (Plan Number 11941, May 2012). The Yorta Yorta Nation Aboriginal Corporation is the registered Aboriginal Party for the region and were directly involved in the preparation of the plan.

The site is situated in a riverine area with the most common type of sites commonly recorded in these areas being scarred trees and shell middens. It was also noted that the area has most likely been subject to a high degree of disturbance through logging with the nearby sawmill and the development within the town.

During a preliminary site visit two shell middens were identified along the Murray River bank in close proximity to the activity area. Transects were walked every two metres along the proposed levee alignment with no other Aboriginal cultural heritage evidence observed on the ground surface. Further assessment was undertaken with a series of excavated transects. This further work was justified given the presence of the shell middens, the known Aboriginal activity in the region and the possibility of post European contact archaeological material associated with the period after the Cummeragunja walk-off. The excavations revealed no further Aboriginal cultural material.

The Cultural Heritage Management Plan concluded that there is a low potential for Aboriginal cultural material to be located within the activity area. The recommendation was made that the two shell middens must be protected during any future works using a buffer zone that no contractors should enter, and all contractors should be inducted with regard to the possibility of Aboriginal cultural heritage material. A contingency plan was developed for any future works that may occur and the eventuality that Aboriginal cultural heritage material is discovered.

3.3.3 Constructability

The constructability of the proposed flood mitigation levee is reasonably simple for the majority of the proposed alignment as it follows roads, however the river frontage does pose some challenges due to the requirement to minimise impact on native vegetation. Due to the nature of the habitat it is impossible to avoid disturbing any vegetation, so the design must be based around minimising impact. This approach would favour levee construction methods such as temporary barriers or concrete retaining walls due to their narrow footprint. However these construction methods are very costly as compared to other more conventional methods such as earthen levees.

The section of levee along the walking track close to Murray Road, where the levee would run between the river bend and the water treatment plant is very narrow. In this section serious consideration toward concrete retaining walls was given. The other issue in this section is in regard to the river itself. The outside of the bend is eroding toward the proposed levee, and may require stabilisation to protect the levee.

As mentioned above, the majority of the levee follows roadways. Raising roadways is not without its own challenges. Raising roads requires regrading of intersecting roads and driveways and may also require significant battering out of roads and redesign of roadside drainage.

3.3.4 Cost

Each levee construction method has significantly different costs per unit length and will have different associated costs such as vegetation offsets, etc.

For a flood mitigation scheme to achieve the best chance of receiving funding the scheme should ideally demonstrate a benefit-cost ratio equal to or greater than one. This means that over the life time of the project the benefits of the mitigation (i.e. reduction in flood damages) will equal or exceed the costs of construction and maintenance of such a system. The SKM (2008) study estimated a cost-benefit ratio less than one, and with costs increased in this study due to consideration of more detailed design issues, the benefit-cost ratio is likely to be lower.

A low benefit-cost ratio does not in itself rule out the possibility of constructing mitigation works, however it may result in this scheme having a lower priority relative to other proposed mitigations works and hence, reduce the likelihood of being funded. After higher priority schemes are funded then this scheme may be funded in the future.

As a general rule temporary barriers are more costly than concrete retaining walls, which are more expensive than crib walls, which are more expensive than earthen levees.

3.3.5 Houses Outside Levee

Eleven houses with a known floor level below the 1% AEP flood level are situated outside the proposed levee alignment in close proximity to the township, as shown in Figure 5. Another two houses are located outside the levee with unknown floor levels. To protect ten of the eleven properties the levee could be realigned and would require an additional 400 to 500 m length. The 6 properties close to the bridge and one of the properties to the north of town are situated on fairly low lying topography, requiring high levees to protect them. The properties close to the bridge do have an existing levee which is in poor condition and is not considered high enough or of sufficient integrity to provide any reasonable flood protection at a 1% flood level. At this stage it is not suggested that these additional properties be protected, due to the topographic issue and that a levee would be required to be built on private land. The impact of the levee should be considered in regards to these properties, as it is likely that they may experience slightly elevated water levels as a result of the proposed works.

3.4 Adopted Option

After consideration of the two proposed levee alignments and the major issues discussed above, the walking track alignment was chosen as the preferred alignment. The functional design and the benefit cost assessment of the preferred alignment are discussed in detail below.

The walking track alignment was adopted largely due to the findings of the environmental assessment which strongly favoured the walking track alignment due to the lesser disturbance of large River Red Gum trees. The walking track alignment also avoids the requirement of doing works on private land which would require gaining agreement from all parties, adding a level of strategic risk to the project, as well as the added cost of potential land acquisition or compensation.

4. FUNCTIONAL LEVEE DESIGN

After investigating flood mitigation options for Barmah and consulting with the projects Steering Committee, two alternative levee alignments were developed. Through further investigation into the major issues surrounding the two alignments the walking track alignment was selected as the preferred option.

The objective of the functional flood mitigation levee design was to provide enough information to allow a bid for government funding to be developed for flood mitigation at Barmah. This requires quite detailed information about the alignment, the height and width of the levee, the area of disturbance, what plans and permits need to be developed and sought, etc. These aspects are described in the following sections.

4.1 Preferred Levee Alignment

As discussed above, the walking track alignment was chosen as the preferred alignment with an earthen levee construction method. It is considered that the earthen levee footprint could be accommodated along the walking track alignment without too much disturbance of native vegetation, particularly large River Red Gum trees. The earthen levee method also utilises the least expensive of available construction methods to provide the best possible benefit-cost ratio. With further discussion regarding the levee alignment along the walking track between the river and the water treatment plant near Murray Road, it was felt that an earthen levee with a concrete retaining wall on one side could be accommodated despite the narrow section. Figure 13 shows the preferred alignment and construction type.

4.2 Levee Crest and Freeboard

The flood mitigation levees were designed to a 1% AEP flood level of 96.97 m AHD, with appropriate freeboard. The flood mitigation levee would therefore have a 1% standard of protection.

Consideration was given as to the appropriate level of freeboard for design of the Barmah flood mitigation levees. After discussion with the Steering Committee, specifically Goulburn Broken CMA, it was felt that a freeboard of 300 mm would be satisfactory for the levee alignment where road raising was the construction method employed. This was adopted for two reasons:

1. The construction of a road, with a wide crest and well compacted base, and in some sections a bituminous seal, provides a highly reliable levee, less prone to failure than a conventional earthen levee.
2. The flood levels at Barmah are well understood and show relatively low change over a range of flood events, i.e. there is approximately 280 mm reduction in flood level from the existing 1% to 2% design flood, and a further 130 mm reduction to the 5% design flood level.

Given the second point above, the study team felt that a 300 mm freeboard for the earthen levee components of the system was also appropriate and was adopted for design. The crest level for design of the levee system was therefore 97.27 m AHD.

The 300 mm freeboard was further justified by the fact that the adopted 1% AEP flood level was 7 cm higher than that adopted by the Goulburn Broken CMA for planning purposes.

It should be noted that the purpose of adding freeboard to a levee design is to allow for some uncertainty in estimated flood levels, dynamic impacts of localised hydraulics unable to be modelled and predicted, wear and tear and settlement of the levee over time, and failure of the levee below actual crest level. So whilst a levee with a crest higher than the 1% flood level may protect against floods larger than the 1% flood, it should not be relied upon.

Figure 13 Preferred Levee Alignment and Construction Method

4.3 Levee Design Parameters

The preferred alignment and design crest level was provided to Project Delivery, civil design specialists, to undertake the design drawings and costing of the flood mitigation levees. Project Delivery assisted in the design of the Nathalia Flood Mitigation scheme and so have strong local experience to draw upon in the design phase. The below assumptions regarding the design of the levees were made.

It should be noted that the designs were based on LiDAR as the topographic base. It is recommended that for detail design, site specific feature survey be undertaken to ensure designs are based on the most accurate survey possible.

4.3.1 Road Raising

A full set of design drawings with plans and typical sections of the road raising design is included in Appendix A.

The unsealed gravel roads were designed with a compacted clay core with a 6 m wide (4 m wide for minor road north of the pub), 300 mm deep compacted gravel pavement with a 3% camber. A 1.2 m wide, 100 mm deep compacted gravel shoulder at a 5% slope was included with battered out slopes at 1 in 6 with 150 mm of topsoil and seed.

The sealed roads consisted of a compacted clay core with a 6.2 or 7 m wide, 150 mm deep layer of compacted class 3 crushed rock, and a 150 mm deep layer of compacted class 2 crushed rock at a 3% camber. A 1.5 m wide, 100 mm deep compacted gravel shoulder at a 5% slope was included with battered out slopes at 1 in 6 with 150 mm of topsoil and seed.

4.3.2 Earthen Levee

A full set of design drawings with plans and typical sections of the earthen levee design is included in Appendix A.

The earthen levees assumed a 3 m wide crest with a 1% camber with side slopes at 1 in 2.5. They were comprised of a compacted clay core, assuming 200 mm of stripping, and were dressed with 150 mm of topsoil and seed.

In the section along the walking track between the river and the water treatment plant, a similar earthen levee design as described above was adopted with the batter on the river side replaced by a concrete retaining wall with a very slightly inclined face and a 0.5 m verge between the retaining wall and the 3 m wide crest, with the verge sloped toward the retaining wall at 5%.

4.3.3 Other Design Aspects

As a result of raising roadways, a number of driveways would require regrading and an allowance for 90 driveways was made. These would be regraded at the maximum permissible grade as set out in Moira Shire Councils design guidelines.

An allowance was made for signage, line-marking and fencing but no design drawings were provided. Similarly a number of provisional items were included in the costing regarding alteration to services, kerb and channel and drainage modifications but no design drawings were developed.

5. COST BENEFIT ANALYSIS

5.1 Cost of Mitigation

Following on from the design of the preferred flood mitigation levee works, Project Delivery costed the works including a number of provisional items, as shown below in Table 2.

Table 2 Cost of Preferred Flood Mitigation Levee

Item	Description	Quantity	Unit	Rate	Amount
1	PRELIMINARIES				
1.01	All works necessary to establish and maintain the site inclusive of pedestrian safety and traffic management measures, environmental management, occupational health & safety, protective fencing, for duration of construction period, to conform with Australian Standards	1	Item		$50,000
1.02	Feature survey, detailed design & project management. 5% of construction cost pre contingencies		Item		$165,000
1.03	Setout		Item		$15,000
2	PAVEMENTS AND HARDWORKS				
2.01	Filling including supply, lay, shaping of embankments and compact, as directed and specified at per cubic metre of fill solid.	36,403	m^3	$25	$910,075
2.02	100mm thick concrete paving cast - in situ, including supply, placing and compacting 50mm thick approved bedding material as specified at per square metre.	1,650	m^2	$75	123,750
2.03	150mm compacted depth, Class 3 crushed rock, supplied, laid and compacted.	2,400	m^3	$90	$216,000
2.04	150mm compacted depth, Class 2 crushed rock, supplied, laid and compacted.	2,400	m^3	$100	$240,000
2.05	Prepare pavement for sealing.	15,700	m^2	$2	$31,400
2.06	30mm compacted depth 10mm nominal size type N Asphalt spread and compacted including tack coat.	15,700	m^2	$15	$235,500
2.07	300mm compacted depth Gravel Pavement, supplied, spread and compacted.	2,900	m^3	$60	$174,000
2.08	100mm compacted depth Gravel Shoulder, supplied, spread and compacted.	1,100	m^3	$60	$66,000
2.09	Modifications to existing driveways.	90	No.	$1,500	$135,000
3	SINGAGE, LINE-MARKING and FENCING				
3.01	Erection of permanent signs and posts.		Item		$10,000
3.02	Line-marking		Item		$10,000
3.03	R.R.P.M. Single direction, supplied and placed.		Item		$5,000
3.04	R.R.P.M. Two way direction, supplied and placed.		Item		$5,000
3.05	Supply and placement of Guide Posts and delineators.		Item		$10,000
3.06	Supply and install Type B Guard Fence - Steel Post, as per VicRoads Std. Dwg SD 3661 - with red & white delineators	160	m	$165	$26,400
3.07	Supply and install Breakaway Cable Terminal (BCTA) as per VicRoads Std. Dwg SD 3541	1	No.	$1,500	$1,500
3.08	Supply and install Breakaway Cable Terminal (BCTB) as per VicRoads Std. Dwg SD 3542	1	No.	$1,500	$1,500
4	LANDSCAPING				
4.01	Construct retaining wall	50	m	$350	$17,500
4.02	Topsoil and seed batters	42,500	m^2	$10	$425,000
5	AS CONSTRUCTED DRAWINGS				
5.01	Provide Council with "As Constructed" plans where alterations have been made to the original design plans. (Civil & Landscaping Works)		Item		$15,000

6	MAINTENANCE AND ESTABLISHMENT				
6.01	Allow for annual maintenance		$/yr		$5,000
7	OTHER ITEMS				
7.01	Contractor to note and price any other item that they see as necessary to complete the project		Item		
7.02	Other		Item		
8	PROVISIONAL ITEMS				
8.01	Alteration to services, includes: raising services pits, valves, powerlines, etc.		Item		$300,000
8.02	Remove and dispose of existing trees including removal of root ball.		Item		$20,000
8.03	Plant indigenous trees.	1,000	Each	$10	$10,000
8.04	Construct kerb and channel		Item		$45,000
8.05	Modifications to existing drainage.		Item		$200,000
				SUBTOTAL (excluding maintenance cost)	$3,463,625
				30% Contingencies (excluding maintenance cost)	$1,039,088
				TOTAL (excluding maintenance cost)	$4,502,713

To protect the township of Barmah with a ring levee is an expensive exercise with the estimated cost of works at close to four and a half million dollars, including a number of provisional items and a 30% contingency. The estimated cost is significantly higher than previously estimated levee costs largely due to the method of construction (i.e. raising roads) and also a number of provisional items included at a more realistic cost (realignment of services, drainage works, driveway access, etc.).

5.2 Flood Damage Assessment

A flood damages assessment was undertaken for the study area under existing conditions. The flood damage assessment determined the monetary flood damages for the 20%, 2% and 1% design floods. The flood damage assessment was also undertaken for the preferred flood mitigation levee scheme.

Water Technology has developed an industry leading best practice damage assessment methodology that has been utilised for a number of studies in Victoria, combining aspects of the Rapid Appraisal Method, ANUFLOOD and other relevant flood damage literature. The method utilises GIS software to combine floor levels, property descriptions, ground level topography, property boundaries and infrastructure information with developed stage-damage curves and flood damage estimates. The analysis included properties with buildings inundated above floor, properties with buildings inundated below floor and properties where the building was not impacted but the grounds of the property were (external flooding). In addition to the flood affected properties, lengths of flood affected roads for each event were also calculated within the study area.

Table 3 and Table 4 below show the flood damage cost estimates for existing conditions and with the preferred levee mitigation scheme in place. This demonstrates the potential for large reductions in flood damage cost for Barmah.

Table 3 Flood Damage Estimation – Existing Conditions

Flood Event	1% AEP	2% AEP	5% AEP	20% AEP
Properties flooded above floor	82	34	21	0
Properties flooded below floor	63	106	118	0
Total properties flooded	145	140	139	0
Direct potential damage	$2,435,202	$1,740,856	$1,407,134	$ 0
Direct actual damage	$1,704,642	$1,221,604	$ 985,188	$ 0
Infrastructure damage	$ 336,189	$ 294,991	$ 249,230	$ 0
Indirect damage	$ 477,687	$ 202,381	$ 125,220	$ 0
Total flood damage cost	$2,518,518	$1,718,976	$1,359,638	$ 0
Annual average damage	$ 169,340			

Table 4 Flood Damage Estimation – Preferred Flood Mitigation Levee Scheme

Flood Event	1% AEP	2% AEP	5% AEP	20% AEP
Properties flooded above floor	10	6	3	0
Properties flooded below floor	10	13	16	0
Total properties flooded	20	19	19	0
Direct potential damage	$ 405,555	$ 309,063	$ 283,121	$ 0
Direct actual damage	$ 283,889	$ 216,344	$ 198,185	$ 0
Infrastructure damage	$ 228,188	$ 203,764	$ 169,141	$ 0
Indirect damage	$ 71,709	$ 47,679	$ 27,131	$ 0
Total flood damage cost	$ 583,785	$ 467,787	$ 394,457	$ 0
Annual average damage	$ 47,776			

5.3 Cost Benefit Analysis

A benefit-cost analysis was undertaken using the construction cost estimates and the average annual damage as calculated in the flood damage assessment. A 6% discount rate and a 30 year project life were assumed. Also, the existing building type and land use were assumed in the mitigated conditions. That is, a vacant block of land in the existing conditions was assumed to remain vacant in mitigated conditions. Following the mitigation works, there is potential to re-develop current vacant land in line with the prevailing (residual) flood risk and behaviour which could have additional beneficial economic impacts. An ongoing annual maintenance cost of $5,000 was included in the benefit-cost assessment. It must be noted that it is assumed that Moira Shire Council will make provisions for any ongoing annual maintenance costs.

Table 5 Benefit-Cost Analysis

	With Provisional Items	Without Provisional Items
Average Annual Damage (Existing Conditions)	$ 169,340	$ 169,340
Average Annual Damage (Levee Mitigation)	$ 47,776	$ 47,776
Annual Maintenance	$ 5,000	$ 5,000
Annual Saving	$ 116,564	$ 116,564
Net Present Value (6% over 30 year project life)	$ 1,639,170	$ 1,639,170
Capital Cost	$ 4,502,713	$ 3,755,213
Benefit-Cost Ratio	0.36	0.44

Note: Capital cost assumes the total cost plus contingencies less maintenance costs.

6. COMMUNITY FEEDBACK

INSERT AFTER COMPLETION OF THE COMMUNITY MEETING

7. CONCLUSIONS AND RECOMMENDATIONS

Numerous past studies have considered flood mitigation options for the township of Barmah. All studies have identified that levees are the most appropriate structural solution, with all studies investigating similar alignments. This study investigated two preliminary levee alignments, undertaking a full cost-benefit analysis for the preferred option.

The preferred flood mitigation levee scheme was developed in consultation with the project Steering Committee and was based on a detailed assessment of the site and a consideration of key issues. The preferred option incorporates the raising of roads for the majority of its alignment along with an earthen levee along the existing walking track by the river frontage to the south of town. Through a narrow section between a bend in the river and the water treatment plant near Murray Road the earthen levee is proposed to be supplemented with a concrete retaining wall to narrow the levee footprint.

The preferred flood mitigation levee scheme is proposed to be designed to a 1% AEP design flood level, incorporating 300 mm freeboard. It is noted that the 1% AEP flood level at Barmah is 96.97 m AHD, which is 400-500 mm higher than the 1975 and 1993 flood levels.

Under existing conditions, the average annual flood related damage is approximately $169,340, reduced to $47,776 with the preferred flood mitigation levees. The cost of the preferred flood mitigation levee is estimated at $2,888,625 with another $575,000 of provisional items, a 30% contingency fee of $1,039,088 and an annual maintenance estimate of $5,000. This gives a benefit-cost ratio of approximately 0.4.

Ideally, to achieve the best chance of receiving government funding the benefit-cost ratio should be equal to or greater than 1. The benefit-cost ratio of this flood mitigation levee scheme is obviously significantly lower than this. This low benefit-cost ratio does not rule out government funding for this project, but may mean that it is not a funding priority. It is recommended that a funding bid be submitted with the practical view that the project may not receive funds in the short term, but once other priorities are dealt with then perhaps Barmah may receive funding to allow this project to go ahead.

APPENDIX A DESIGN DRAWINGS

SHEET LIST TABLE

SHEET NUMBER	SHEET TITLE
1	GENERAL LAYOUT
2	TYPICAL CROSS SECTIONS
3	TYPICAL CROSS SECTIONS
4	LAYOUT PLAN
5	LAYOUT PLAN
6	LAYOUT PLAN
7	LAYOUT PLAN
8	LAYOUT PLAN
9	LAYOUT PLAN
10	LAYOUT PLAN
11	LAYOUT PLAN
12	LAYOUT PLAN
13	LAYOUT PLAN
14	LAYOUT PLAN
15	LEVEE LONGITUDINAL SECTION
16	LEVEE LONGITUDINAL SECTION
17	LEVEE LONGITUDINAL SECTION
18	LEVEE LONGITUDINAL SECTION
19	LEVEE LONGITUDINAL SECTION
20	LEVEE LONGITUDINAL SECTION

EARTHEN LEVEE
7m WIDE SEALED ROAD LEVEE
6.2m WIDE SEALED ROAD LEVEE
6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE

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AMENDMENTS

DATE	REVISION	AUTHORISED	DATE	REVISION	AUTHORISED
30-12-11	CONCEPT DRAWINGS	T.McG			

LEGEND

Conduits	Telecom U/G Cable	Telecom Pole	Proposed K & Ch
Existing Drains	Water Main	Telecom Pit	Asphalt Driveway
S.E.C. U/G Cable	Fire Hydrant	Existing Drain Pits	Concrete Driveway
Gas Main	Fire Plug	Proposed Drain Pits	Gravel Driveway
Sewer Main	Valve	Proposed Drains	Tree to be removed
Property Outlet	S.E.C. Pole	Existing K & Ch	Survey Station

Survey by:	LIDAR
Plan by:	J.F.
Checked by:	T.MCGANN
Project Engineer:	
Field book No.:	-
Date:	DEC '11

Datum Adopted And Location: A.H.D.
Co-ordinate Datum: MGA

Client: MOIRA SHIRE

BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION

GENERAL LAYOUT

Checked by
Approved
Total No. of Sheets
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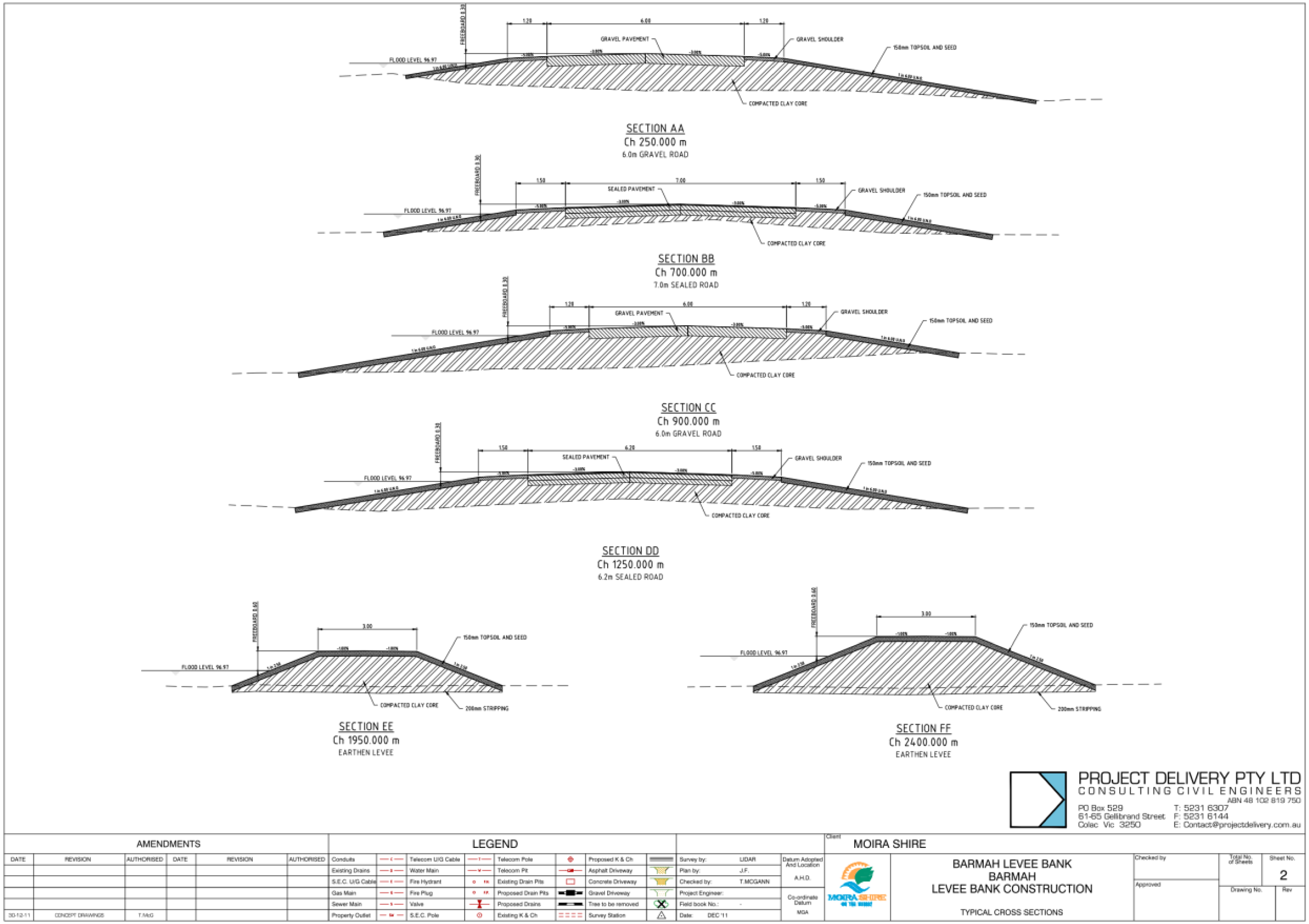
Drawing No.
Rev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SECTION BB
Ch 700.000 m
7.0m SEALED ROAD
SECTION CC
Ch 900.000 m
6.0m GRAVEL ROAD
SECTION DD
Ch 1250.000 m
6.2m SEALED ROAD
SECTION EE
Ch 1950.000 m
EARTHEN LEVEE
SECTION FF
Ch 2400.000 m
EARTHEN LEVEE
FLOOD LEVEL 96.97
GRAVEL PAVEMENT
SEALED PAVEMENT
GRAVEL SHOULDER
150mm TOPSOIL AND SEED
COMPACTED CLAY CORE
200mm STRIPPING
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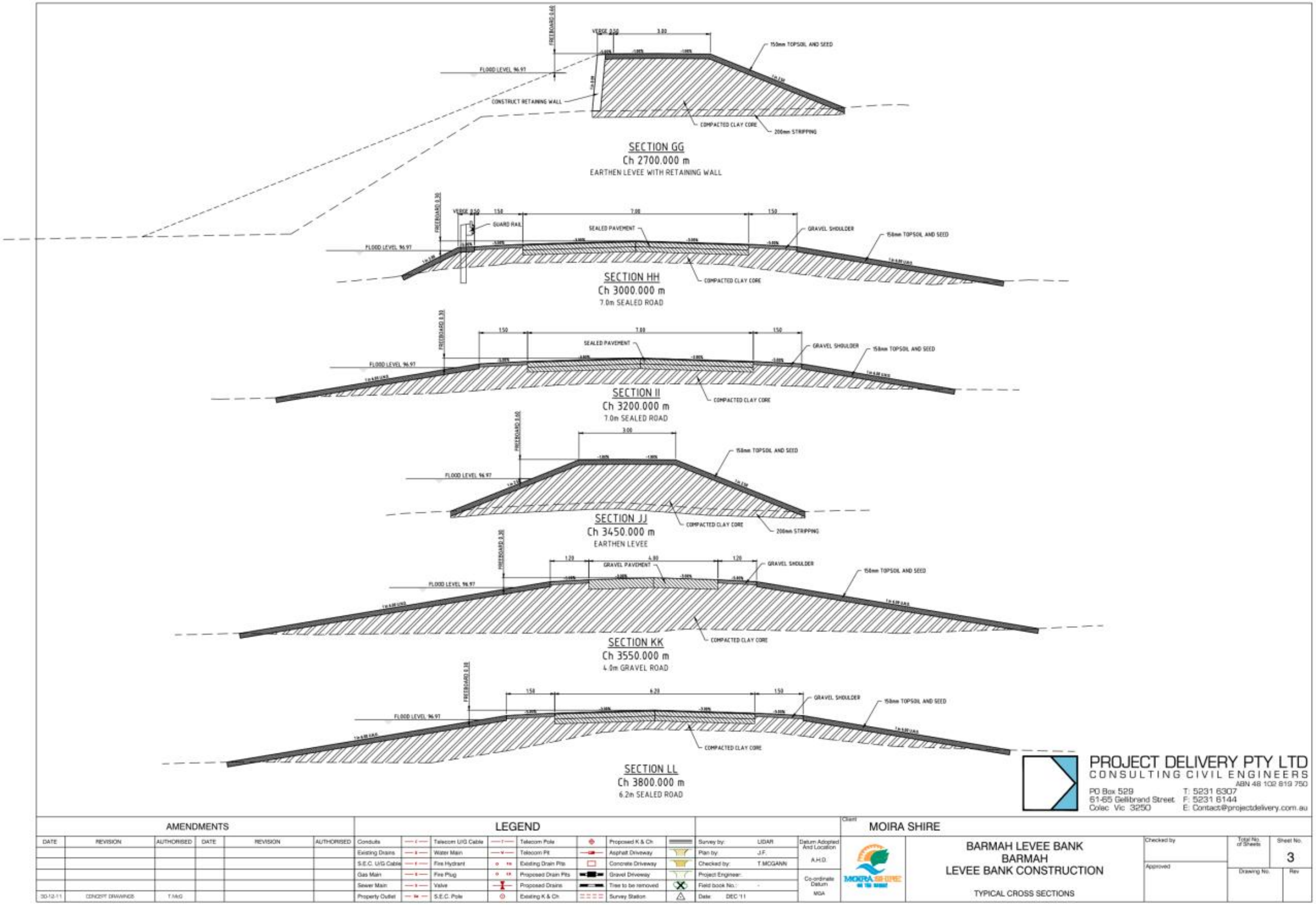
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
TYPICAL CROSS SECTIONS
30-12-11 CONCEPT DRAWINGS T.McG
Survey by: LIDAR
Plan by: J.F.
Checked by: T.MCGANN
Date: DEC '11
A.H.D.
MGA
2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CONSTRUCT RETAINING WALL
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COMPACTED CLAY CORE
200mm STRIPPING
SECTION HH
Ch 3000.000 m
7.0m SEALED ROAD
GUARD RAIL
SEALED PAVEMENT
GRAVEL SHOULDER
SECTION II
Ch 3200.000 m
7.0m SEALED ROAD
SECTION JJ
Ch 3450.000 m
EARTHEN LEVEE
SECTION KK
Ch 3550.000 m
4.0m GRAVEL ROAD
GRAVEL PAVEMENT
SECTION LL
Ch 3800.000 m
6.2m SEALED ROAD
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BARMAH
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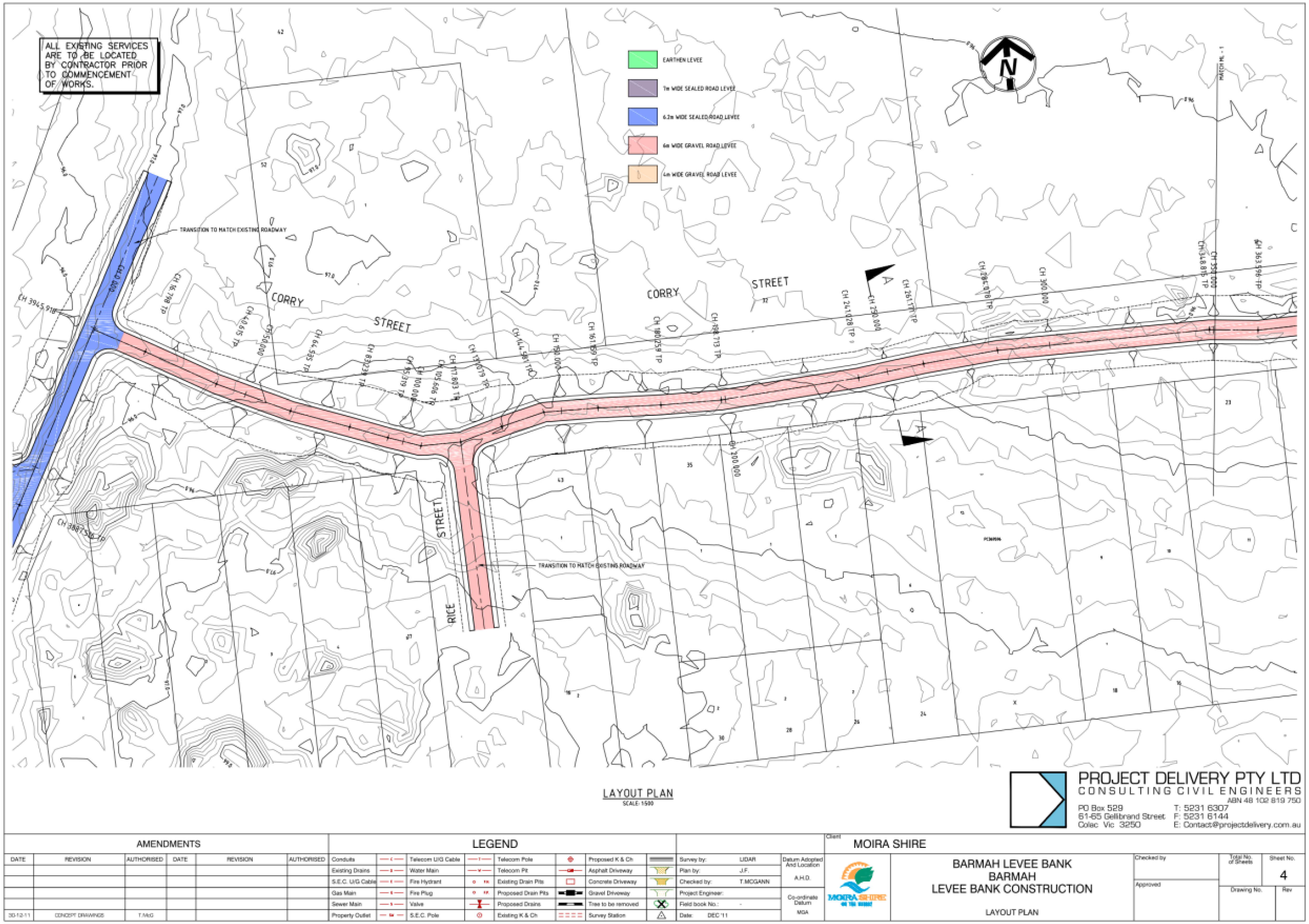
TYPICAL CROSS SECTIONS
3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6.2m WIDE SEALED ROAD LEVEE
6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE
TRANSITION TO MATCH EXISTING ROADWAY
CORRY STREET
RICE STREET
LAYOUT PLAN
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BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LAYOUT PLAN
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Plan by: J.F.
Checked by: T.MCGANN
Date: DEC '11
Sheet No. 4
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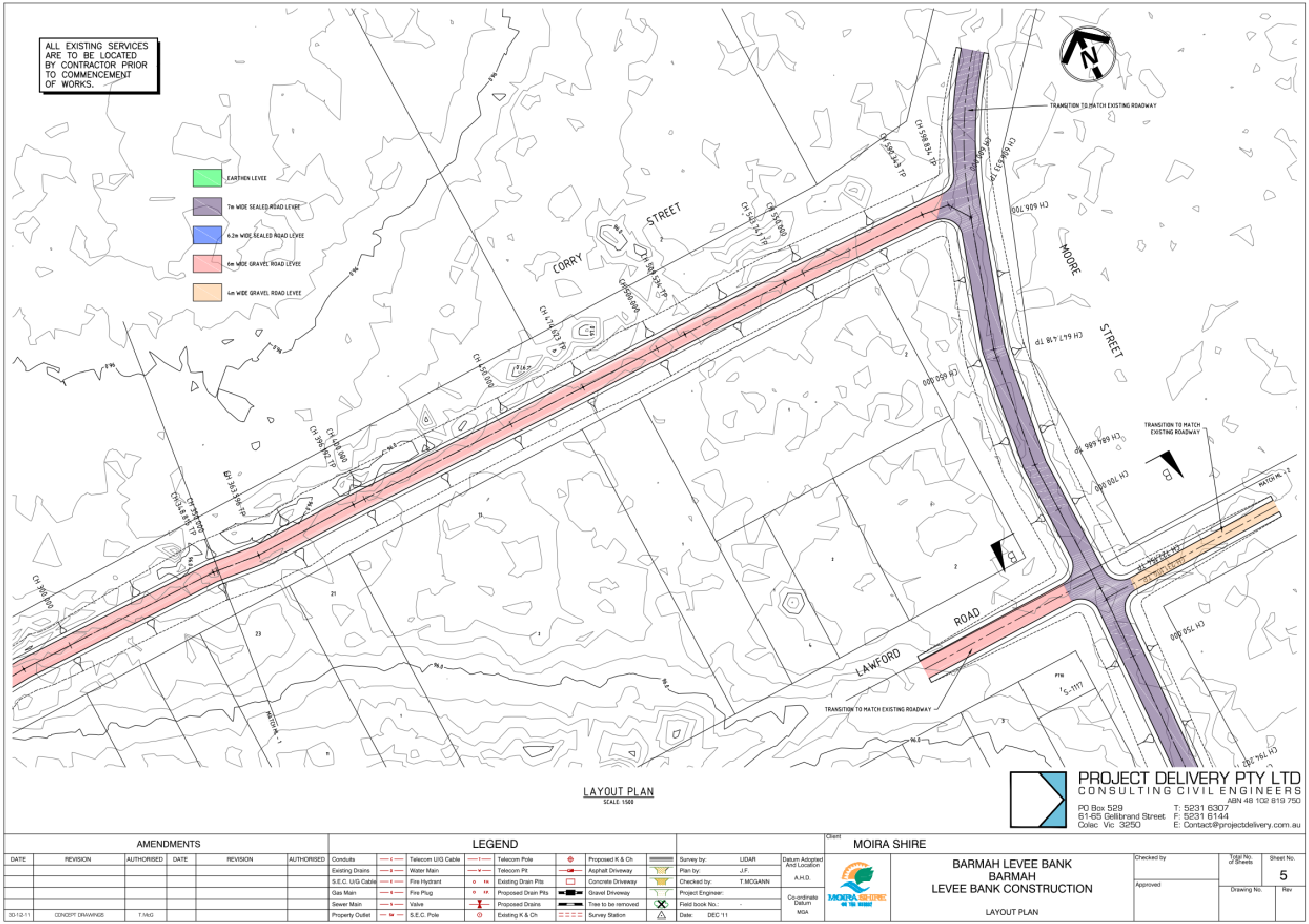
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6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE
CORRY STREET
MOORE STREET
LAWFORD ROAD
TRANSITION TO MATCH EXISTING ROADWAY
LAYOUT PLAN
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BARMAH
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Plan by: J.F.
Checked by: T.MCGANN
Date: DEC '11
A.H.D.
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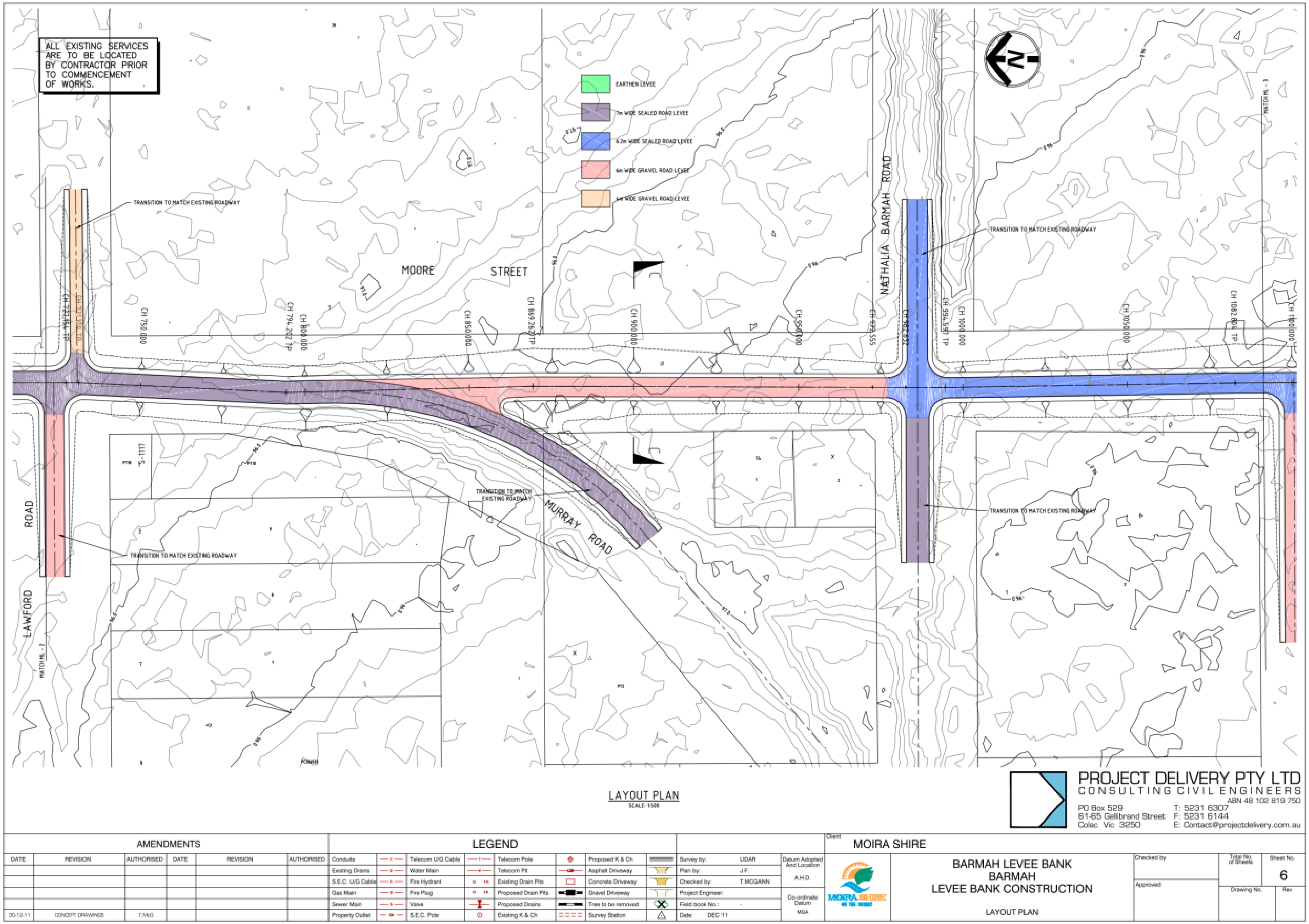
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6.2m WIDE SEALED ROAD LEVEE
6m WIDE GRAVEL ROAD LEVEE
TRANSITION TO MATCH EXISTING ROADWAY
MOORE STREET
NATHALIA BARMAH ROAD
MURRAY ROAD
LAWFORD ROAD
CH 750.000
CH 800.000
CH 850.000
CH 900.000
CH 950.000
CH 1000.000
CH 1050.000
LAYOUT PLAN
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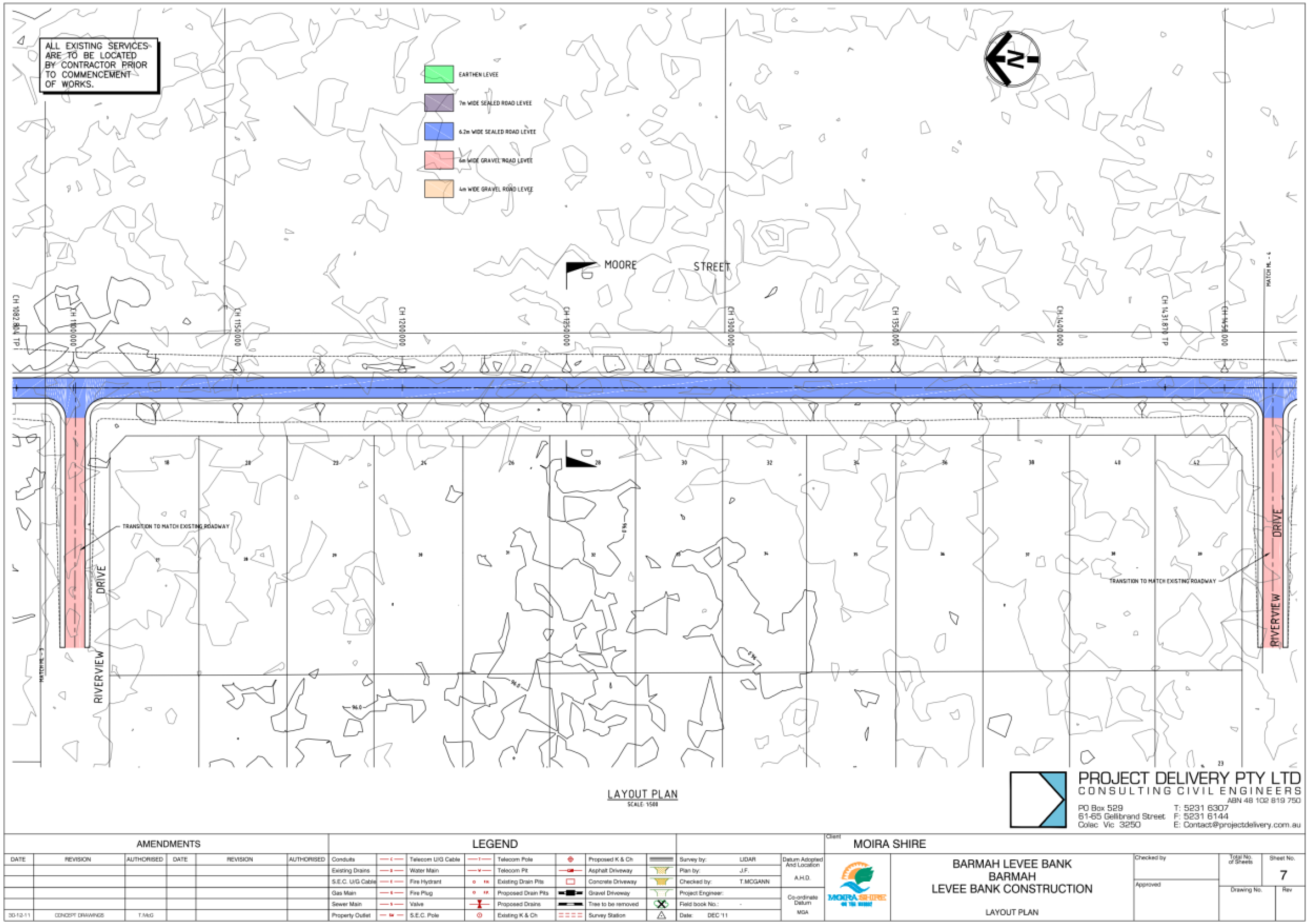
30-12-11 CONCEPT DRAWINGS T.McG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6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE
MOORE STREET
RIVERVIEW DRIVE
RIVERVIEW DRIVE
TRANSITION TO MATCH EXISTING ROADWAY
TRANSITION TO MATCH EXISTING ROADWAY
CH 1150.000
CH 1200.000
CH 1250.000
CH 1300.000
CH 1350.000
CH 1400.000
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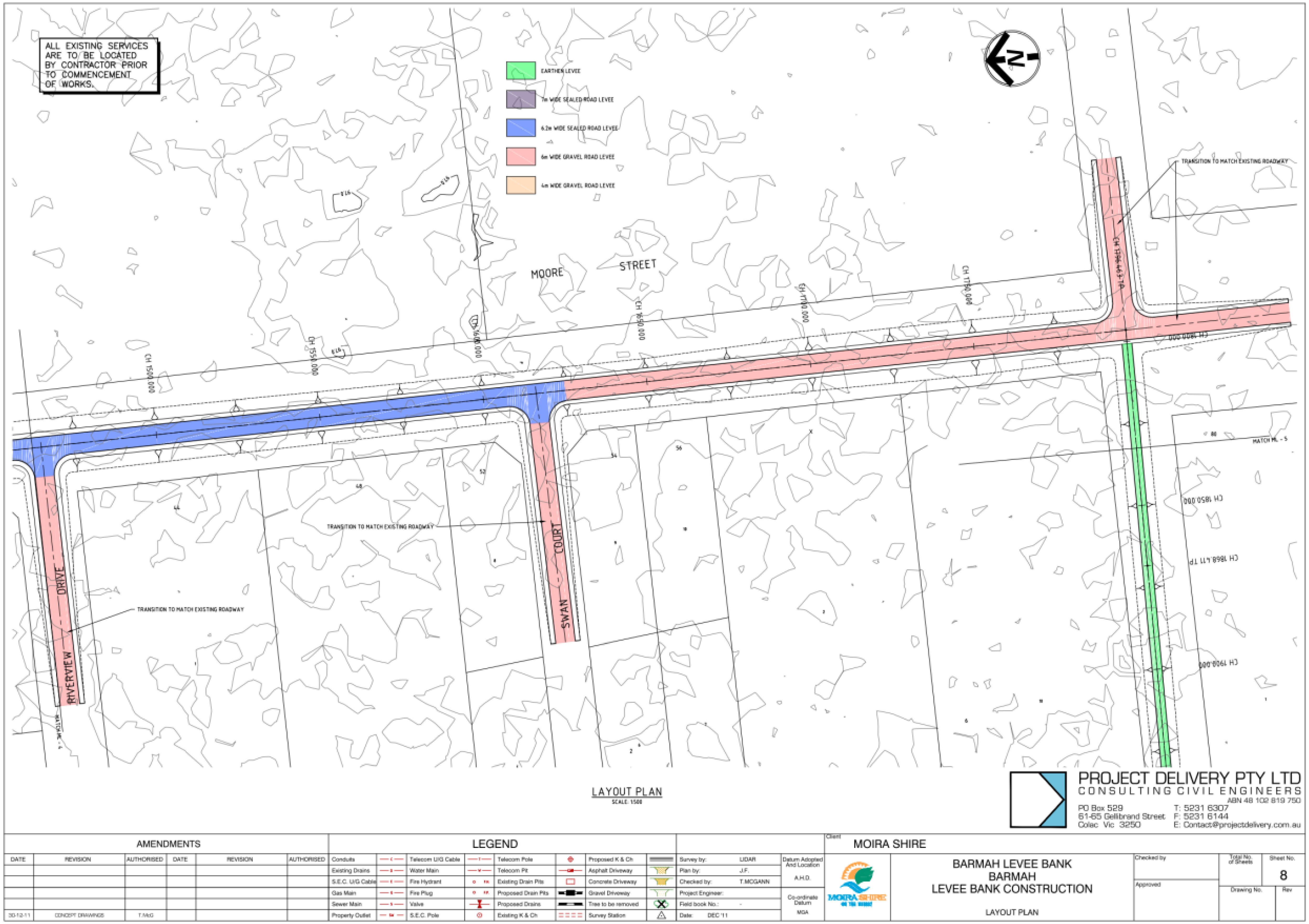
30-12-11 CONCEPT DRAWINGS T.McG
Sheet No. 7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6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE
MOORE STREET
SWAN COURT
RIVERVIEW DRIVE
TRANSITION TO MATCH EXISTING ROADWAY
CH 1500.000
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CH 1850.000
CH 1868.417 TP
CH 1900.000
LAYOUT PLAN
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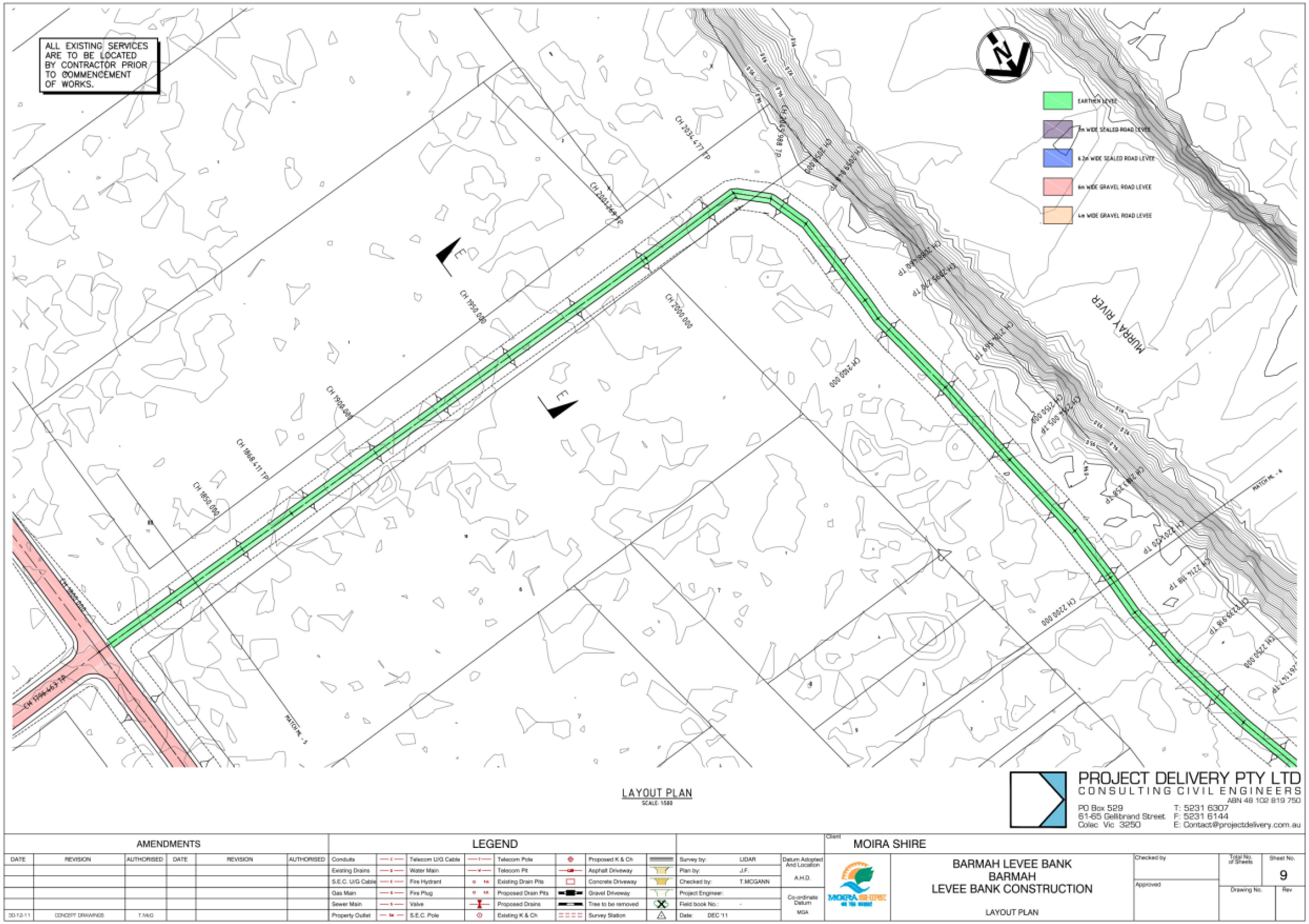
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6.2m WIDE SEALED ROAD LEVEE
6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE
MURRAY RIVER
CH 1850.000
CH 1900.000
CH 1950.000
CH 2000.000
CH 2100.000
CH 2200.000
LAYOUT PLAN
PROJECT DELIVERY PTY LTD
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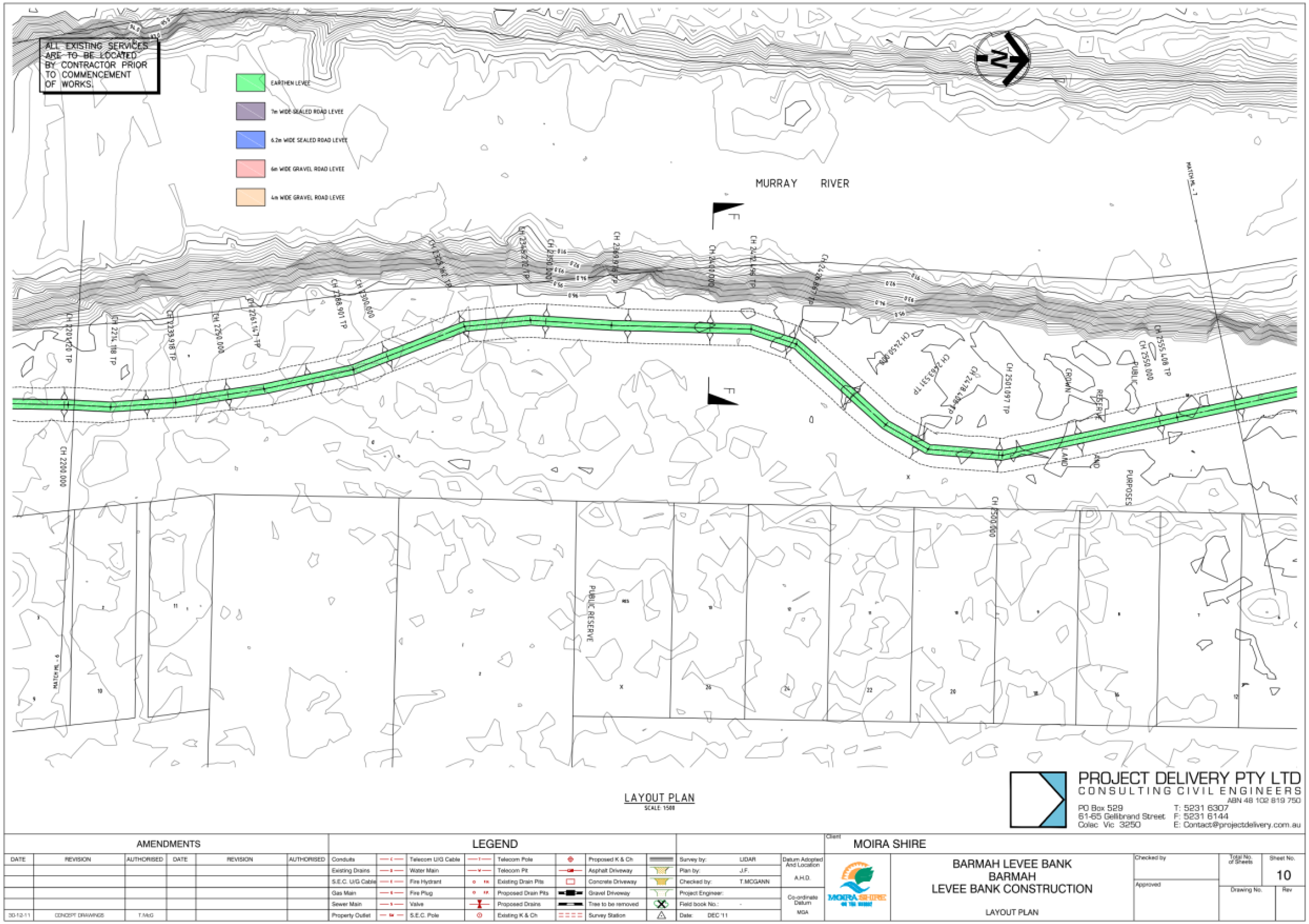
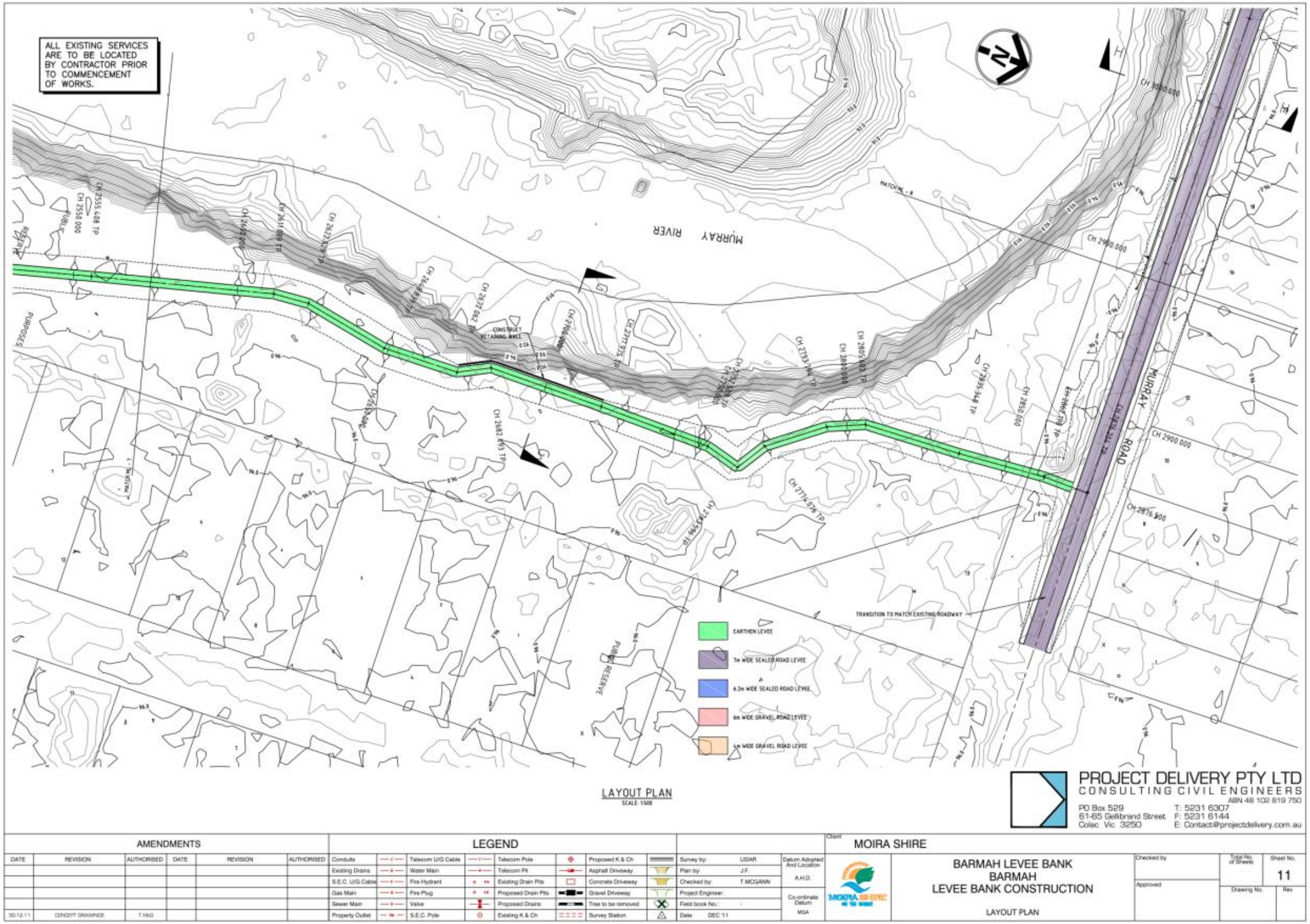
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LAYOUT PLAN
9


ALL EXISTING SERVICES ARE TO BE LOCATED BY CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
EARTHEN LEVEE
7m WIDE SEALED ROAD LEVEE
6.2m WIDE SEALED ROAD LEVEE
6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE
MURRAY RIVER
PUBLIC RESERVE
CROWN RESERVE
PUBLIC LAND PURPOSES
LAYOUT PLAN
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
F: 5231 6144
E: Contact@projectdelivery.com.au
AMENDMENTS
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LAYOUT PLAN
Survey by: LIDAR
Plan by: J.F.
Checked by: T.MCGANN
Date: DEC '11
30-12-11 CONCEPT DRAWINGS T.McG
Sheet No. 10


ALL EXISTING SERVICES ARE TO BE LOCATED BY CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
MURRAY RIVER
MURRAY ROAD
CONSTRUCT RETAINING WALL
PUBLIC RESERVE
TRANSITION TO MATCH EXISTING ROADWAY
EARTHEN LEVEE
7m WIDE SEALED ROAD LEVEE
6.2m WIDE SEALED ROAD LEVEE
6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE
LAYOUT PLAN
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
F: 5231 6144
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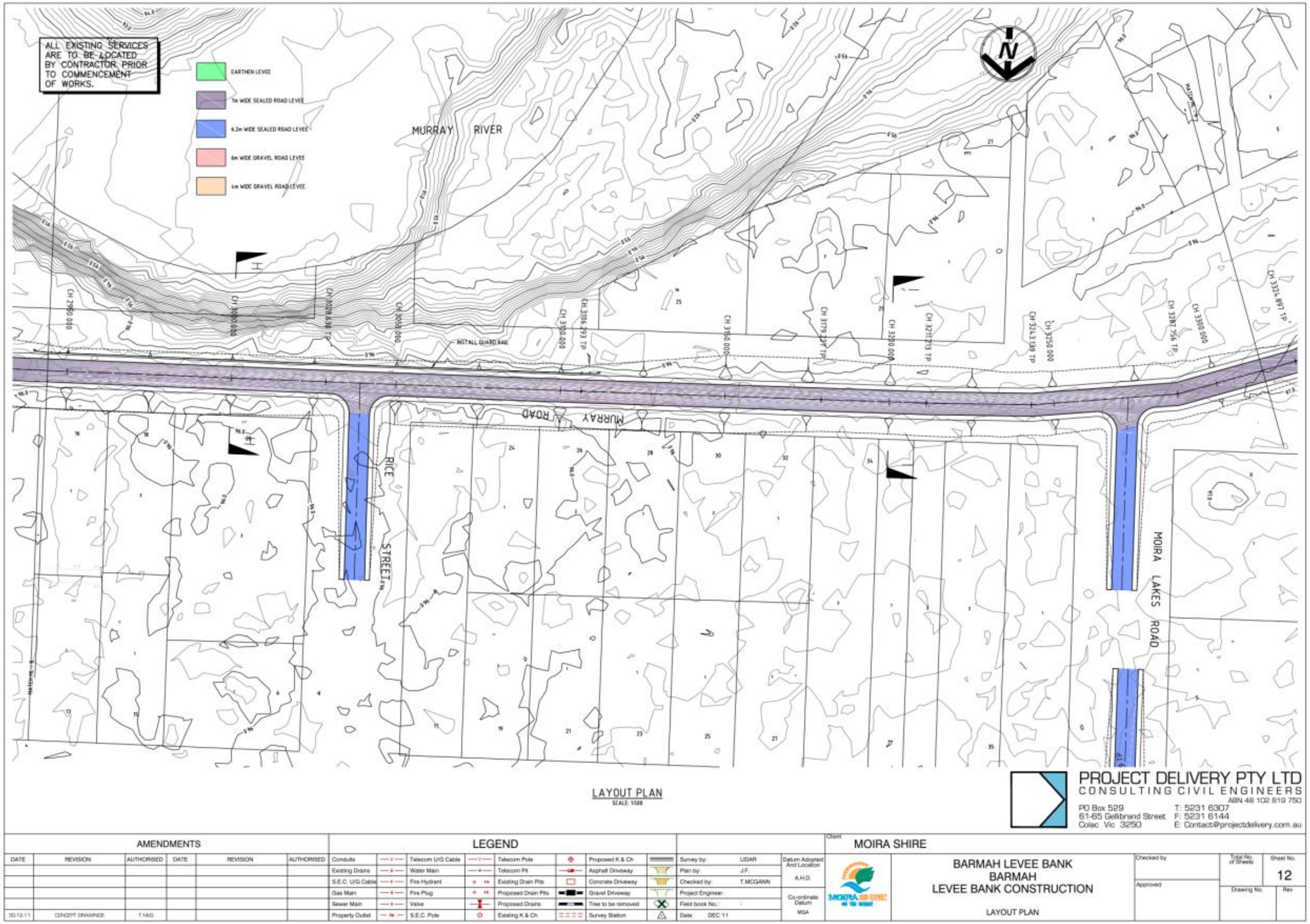
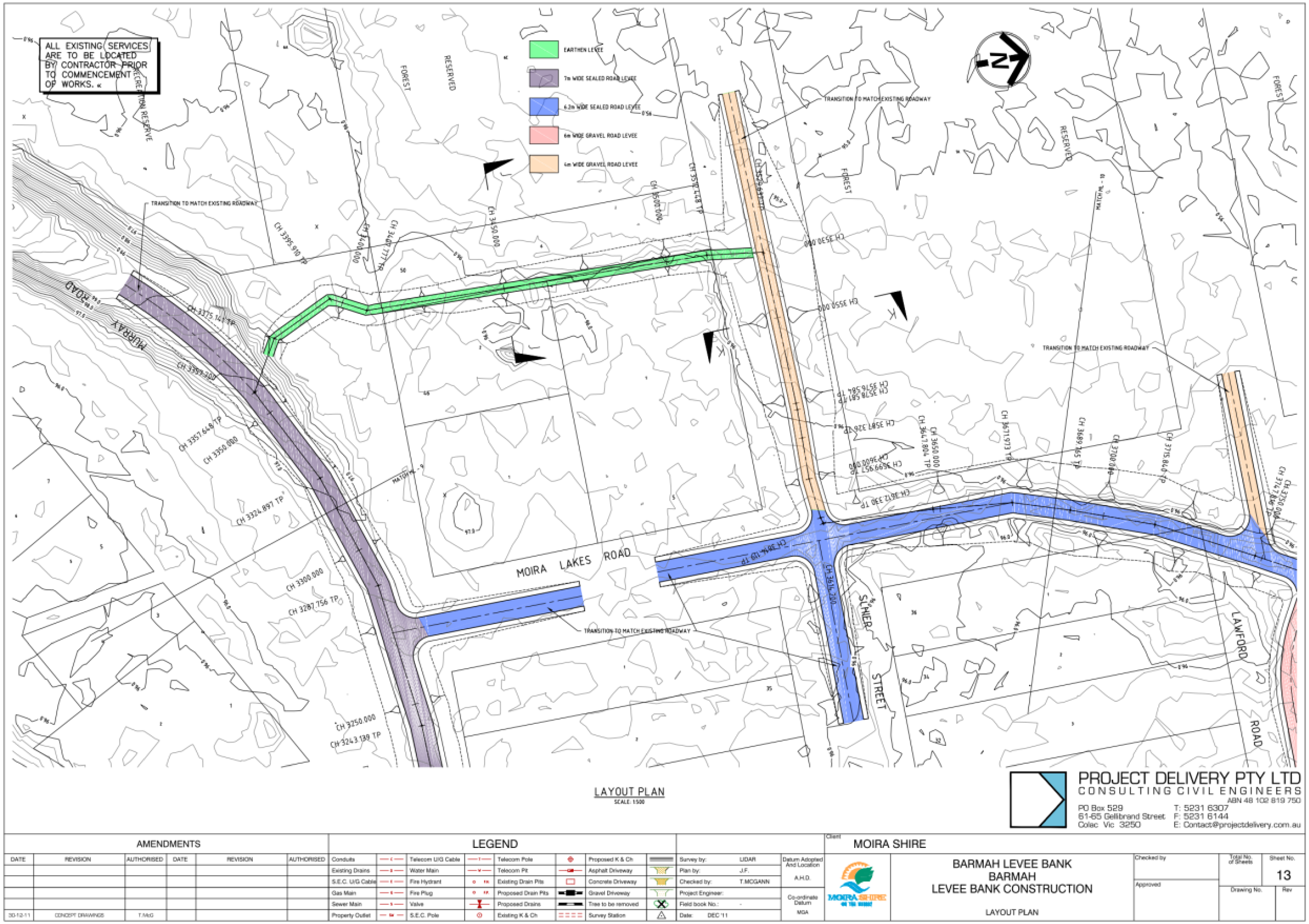
AMENDMENTS
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LAYOUT PLAN
11


ALL EXISTING SERVICES ARE TO BE LOCATED BY CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
EARTHEN LEVEE
7m WIDE SEALED ROAD LEVEE
6.2m WIDE SEALED ROAD LEVEE
6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE
MURRAY RIVER
MURRAY ROAD
RICE STREET
MOIRA LAKES ROAD
INSTALL GUARD RAIL
LAYOUT PLAN
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
F: 5231 6144
E: Contact@projectdelivery.com.au
AMENDMENTS
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LAYOUT PLAN
12


ALL EXISTING SERVICES ARE TO BE LOCATED BY CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
EARTHEN LEVEE
7m WIDE SEALED ROAD LEVEE
6.2m WIDE SEALED ROAD LEVEE
6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE
TRANSITION TO MATCH EXISTING ROADWAY
MURRAY ROAD
MOIRA LAKES ROAD
SCHIER STREET
LAWFORD ROAD
RECREATION RESERVE
FOREST RESERVED
LAYOUT PLAN
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
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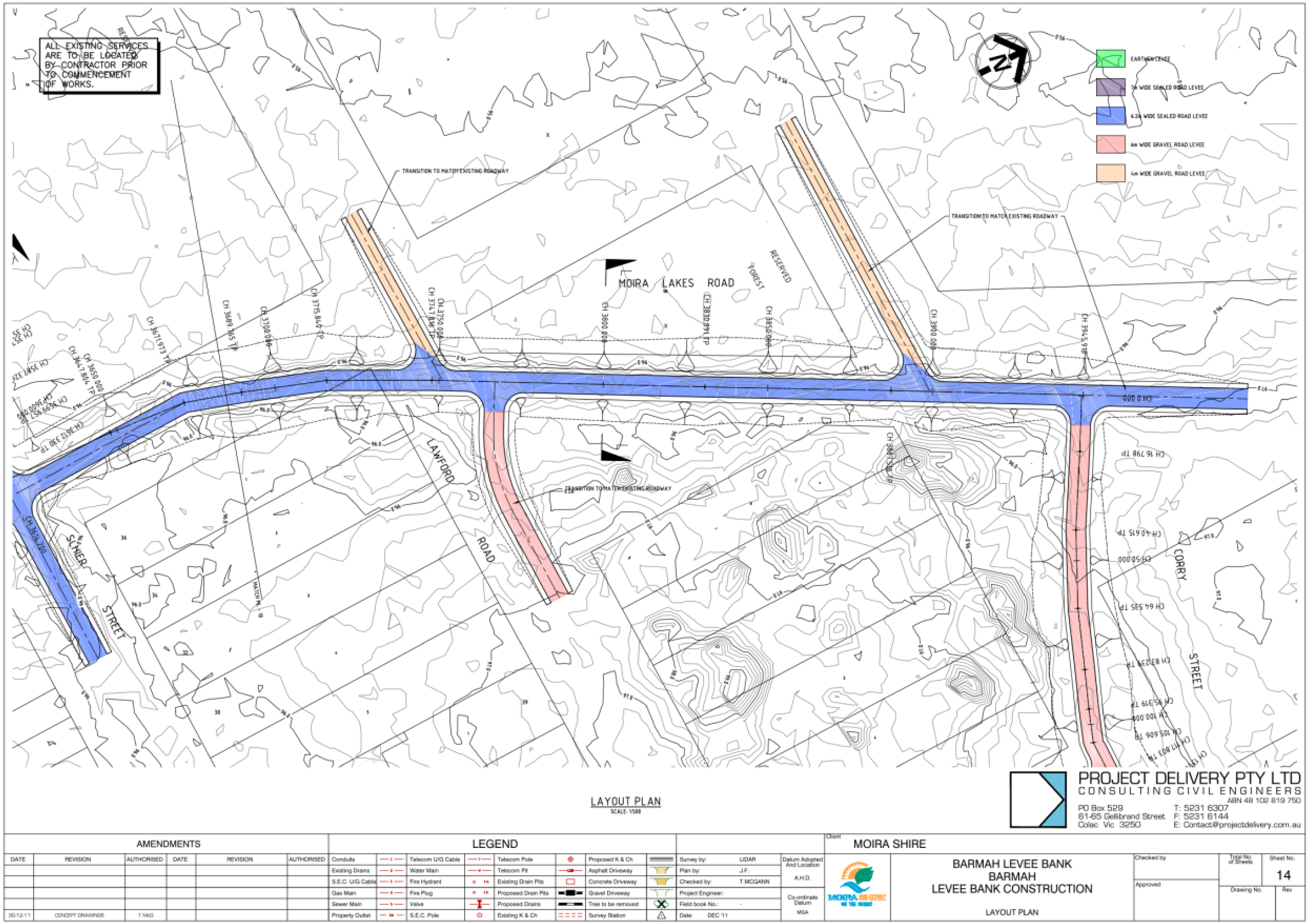
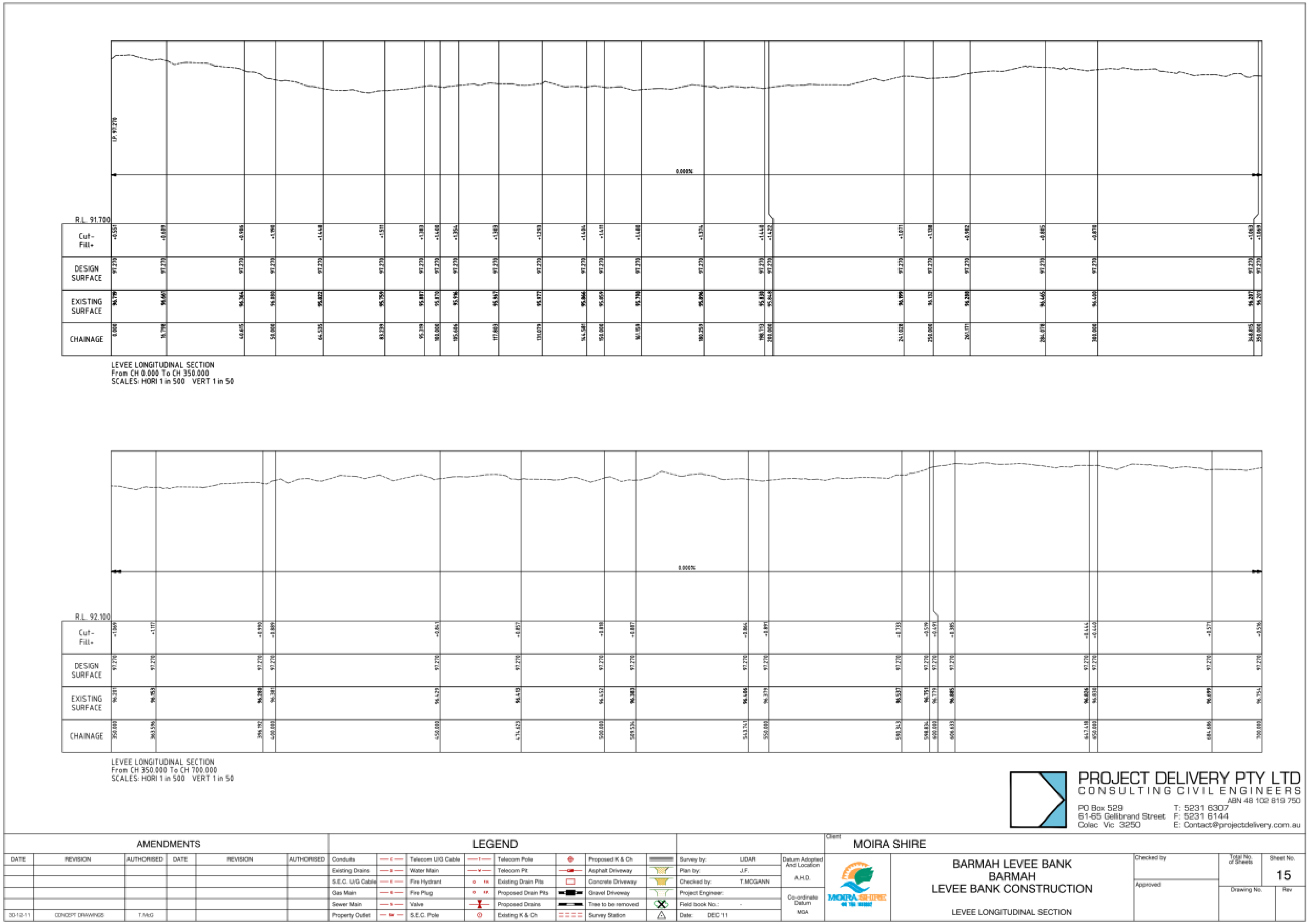
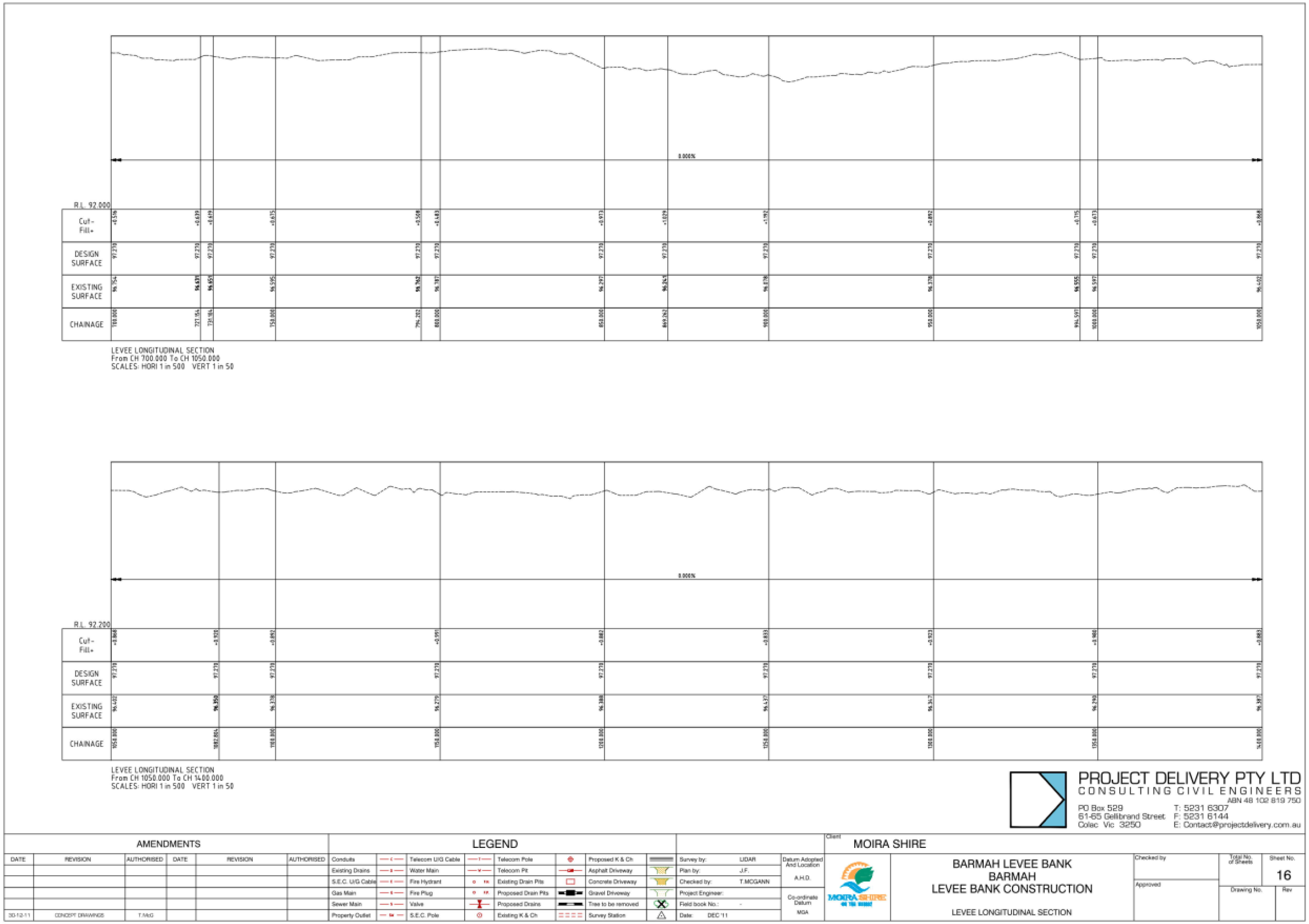
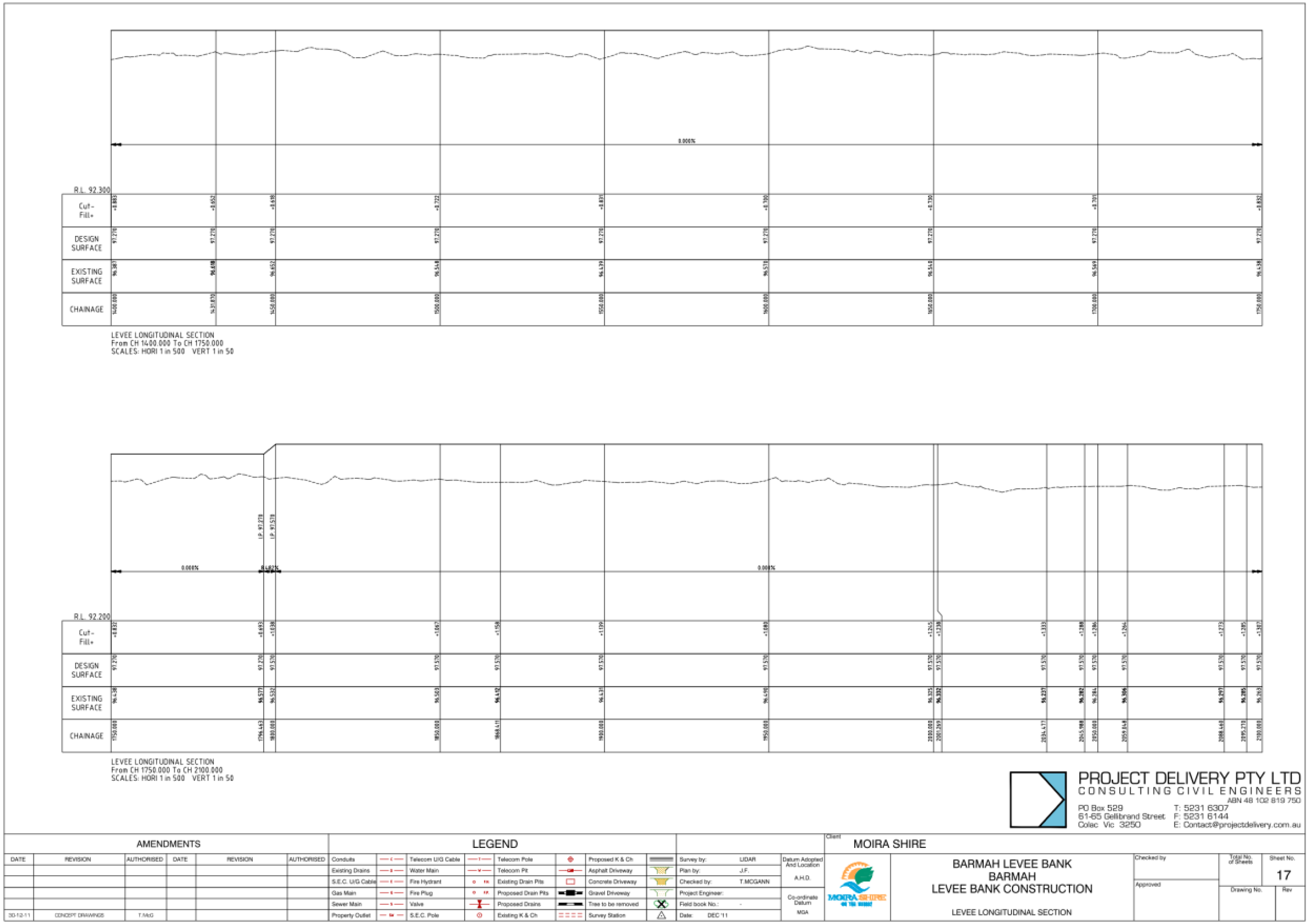
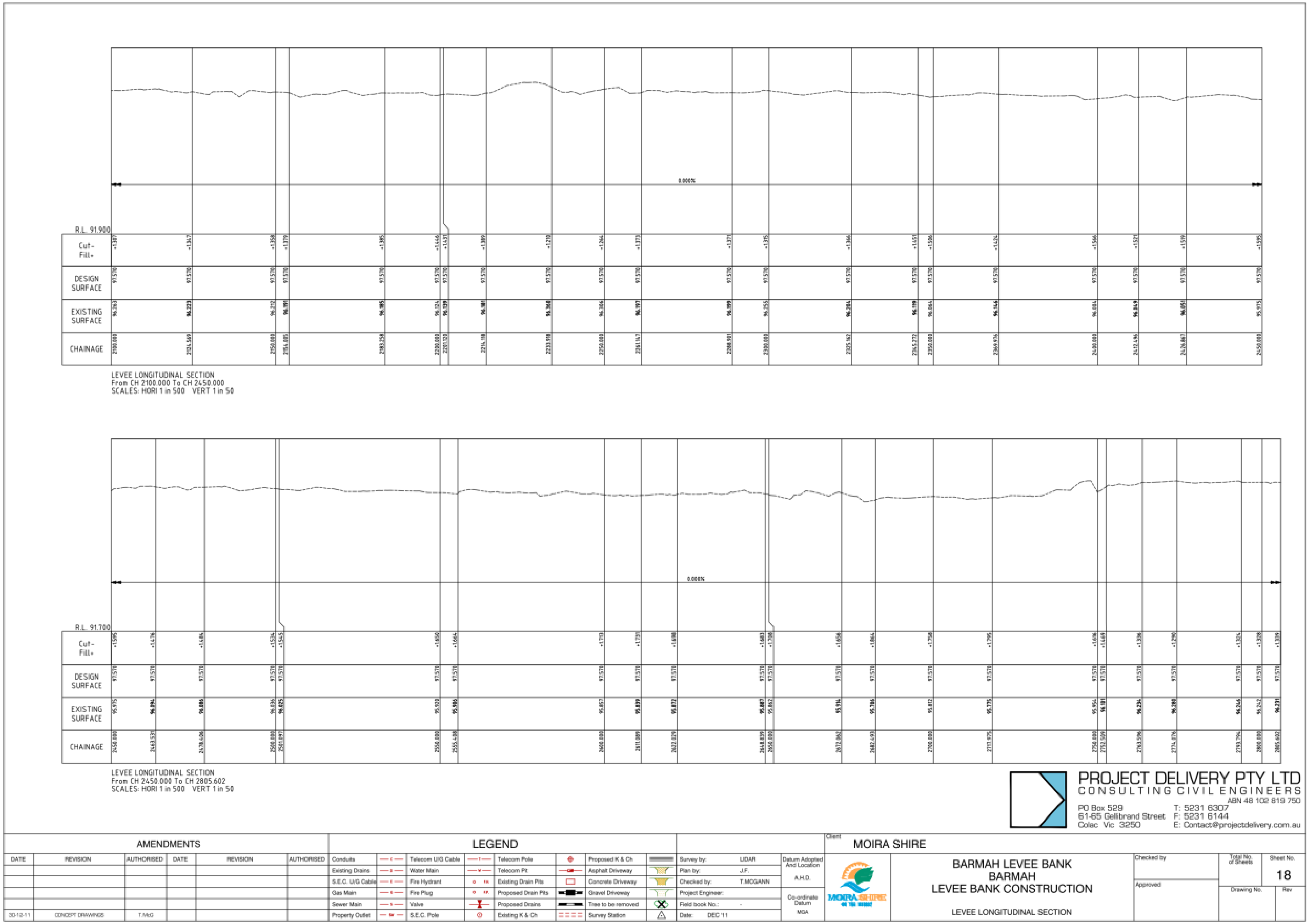
AMENDMENTS
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LAYOUT PLAN
13


ALL EXISTING SERVICES ARE TO BE LOCATED BY CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
EARTHEN LEVEE
7m WIDE SEALED ROAD LEVEE
6.2m WIDE SEALED ROAD LEVEE
6m WIDE GRAVEL ROAD LEVEE
4m WIDE GRAVEL ROAD LEVEE
TRANSITION TO MATCH EXISTING ROADWAY
MOIRA LAKES ROAD
FOREST RESERVED
LAWFORD ROAD
SLAVIER STREET
CORRY STREET
LAYOUT PLAN
SCALE: 1:500
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
F: 5231 6144
E: Contact@projectdelivery.com.au
AMENDMENTS
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LAYOUT PLAN
Sheet No. 14
Survey by: LIDAR
Plan by: J.F.
Checked by: T.MCGANN
Date: DEC '11
30-12-11 CONCEPT DRAWINGS T.McG


LEVEE LONGITUDINAL SECTION
From CH 0.000 To CH 350.000
SCALES: HORI 1 in 500 VERT 1 in 50
R.L. 91.700
Cut-
Fill+
DESIGN SURFACE
EXISTING SURFACE
CHAINAGE
LEVEE LONGITUDINAL SECTION
From CH 350.000 To CH 700.000
SCALES: HORI 1 in 500 VERT 1 in 50
R.L. 92.100
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
F: 5231 6144
E: Contact@projectdelivery.com.au
AMENDMENTS
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LEVEE LONGITUDINAL SECTION
Survey by: LIDAR
Plan by: J.F.
Checked by: T.MCGANN
Date: DEC '11
Datum Adopted And Location A.H.D.
Co-ordinate Datum MGA
Sheet No. 15
30-12-11 CONCEPT DRAWINGS T.McG


0.000%
R.L. 92.000
Cut- Fill+
DESIGN SURFACE
EXISTING SURFACE
CHAINAGE
LEVEE LONGITUDINAL SECTION
From CH 700.000 To CH 1050.000
SCALES: HORI 1 in 500 VERT 1 in 50
0.000%
R.L. 92.200
Cut- Fill+
DESIGN SURFACE
EXISTING SURFACE
CHAINAGE
LEVEE LONGITUDINAL SECTION
From CH 1050.000 To CH 1400.000
SCALES: HORI 1 in 500 VERT 1 in 50
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
F: 5231 6144
E: Contact@projectdelivery.com.au
AMENDMENTS
DATE
REVISION
AUTHORISED
30-12-11
CONCEPT DRAWINGS
T.McG
LEGEND
Conduits
Existing Drains
S.E.C. U/G Cable
Gas Main
Sewer Main
Property Outlet
Telecom U/G Cable
Water Main
Fire Hydrant
Fire Plug
Valve
S.E.C. Pole
Telecom Pole
Telecom Pit
Existing Drain Pits
Proposed Drain Pits
Proposed Drains
Existing K & Ch
Proposed K & Ch
Asphalt Driveway
Concrete Driveway
Gravel Driveway
Tree to be removed
Survey Station
Survey by: LIDAR
Plan by: J.F.
Checked by: T.MCGANN
Project Engineer:
Field book No.: -
Date: DEC '11
Datum Adopted And Location
A.H.D.
Co-ordinate Datum
MGA
Client
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LEVEE LONGITUDINAL SECTION
Checked by
Approved
Total No. of Sheets
Sheet No.
16
Drawing No.
Rev


LEVEE LONGITUDINAL SECTION
From CH 1400.000 To CH 1750.000
SCALES: HORI 1 in 500 VERT 1 in 50
LEVEE LONGITUDINAL SECTION
From CH 1750.000 To CH 2100.000
SCALES: HORI 1 in 500 VERT 1 in 50
CHAINAGE
EXISTING SURFACE
DESIGN SURFACE
Cut- Fill+
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
F: 5231 6144
E: Contact@projectdelivery.com.au
AMENDMENTS
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LEVEE LONGITUDINAL SECTION
17


R.L. 91.900
Cut-
Fill+
DESIGN SURFACE
EXISTING SURFACE
CHAINAGE
LEVEE LONGITUDINAL SECTION
From CH 2100.000 To CH 2450.000
SCALES: HORI 1 in 500 VERT 1 in 50
R.L. 91.700
LEVEE LONGITUDINAL SECTION
From CH 2450.000 To CH 2805.602
SCALES: HORI 1 in 500 VERT 1 in 50
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
F: 5231 6144
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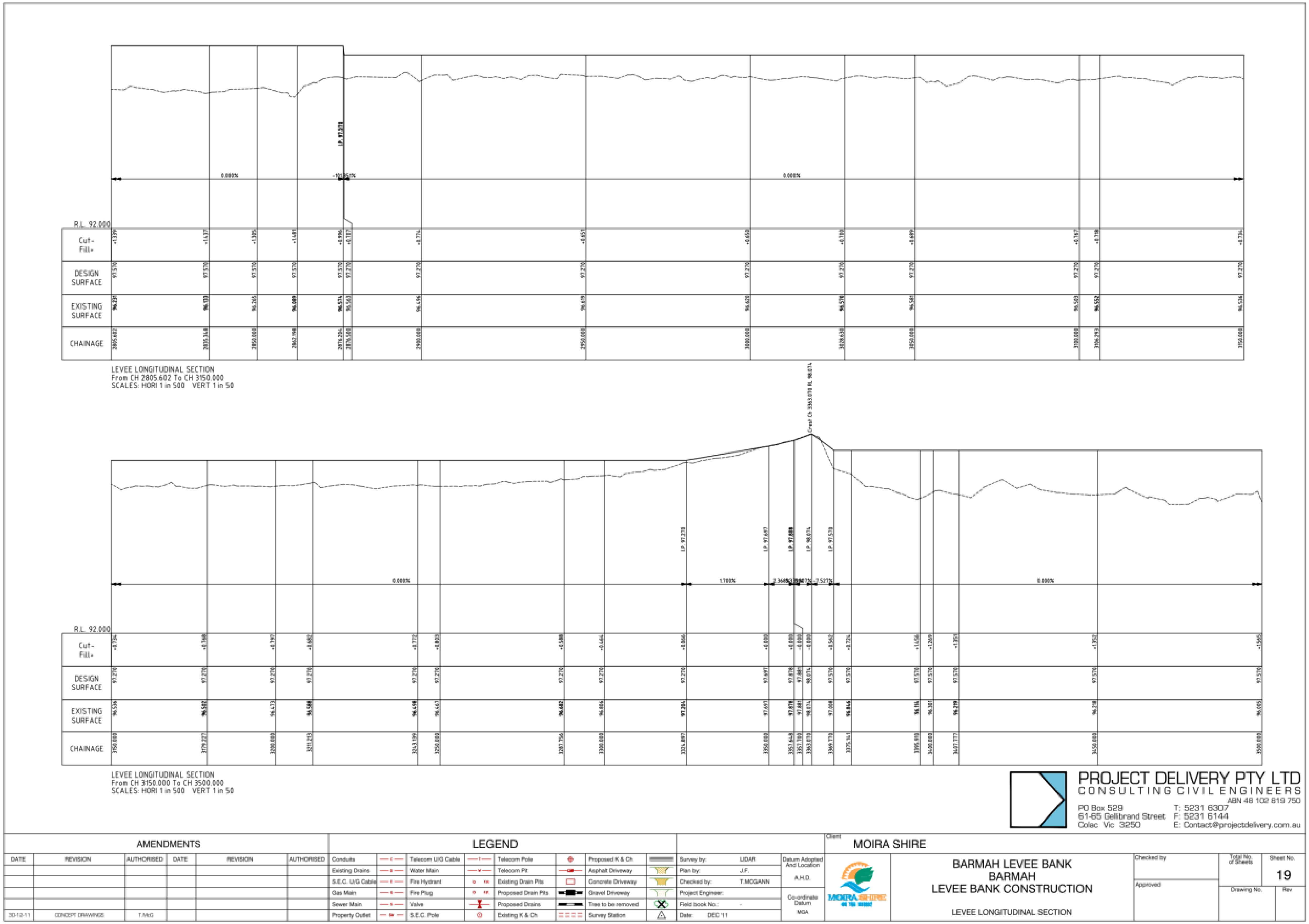
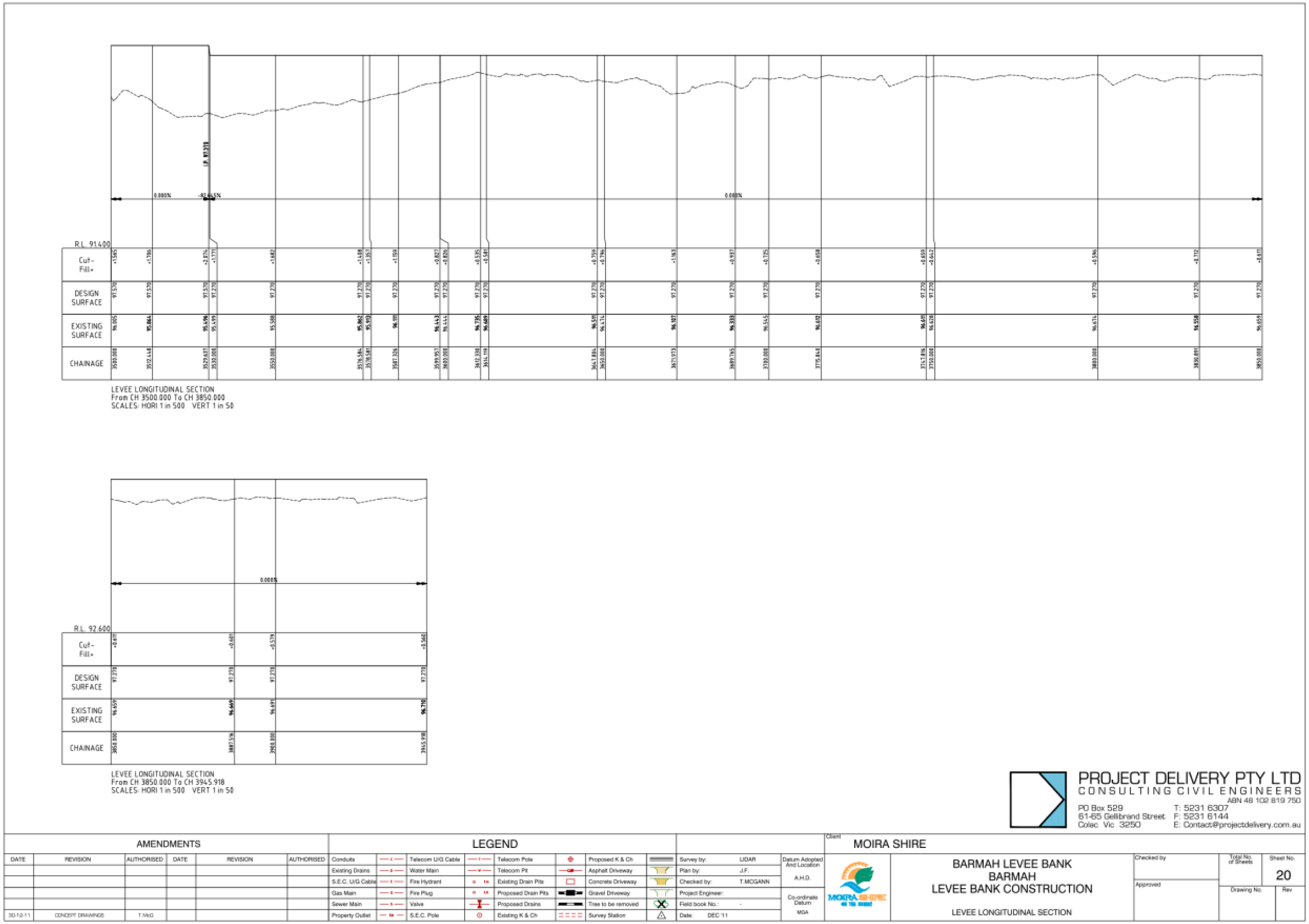
AMENDMENTS
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LEVEE LONGITUDINAL SECTION
Survey by: LIDAR
Plan by: J.F.
Checked by: T.MCGANN
Date: DEC '11
Sheet No. 18
30-12-11 CONCEPT DRAWINGS T.McG


LEVEE LONGITUDINAL SECTION
From CH 2805.602 To CH 3150.000
SCALES: HORI 1 in 500 VERT 1 in 50
LEVEE LONGITUDINAL SECTION
From CH 3150.000 To CH 3500.000
SCALES: HORI 1 in 500 VERT 1 in 50
R.L. 92.000
Cut- Fill+
DESIGN SURFACE
EXISTING SURFACE
CHAINAGE
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
F: 5231 6144
E: Contact@projectdelivery.com.au
AMENDMENTS
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LEVEE LONGITUDINAL SECTION
Survey by: LIDAR
Plan by: J.F.
Checked by: T.MCGANN
Date: DEC '11
30-12-11 CONCEPT DRAWINGS T.McG
19


R.L. 91.400
Cut-
Fill+
DESIGN SURFACE
EXISTING SURFACE
CHAINAGE
LEVEE LONGITUDINAL SECTION
From CH 3500.000 To CH 3850.000
SCALES: HORI 1 in 500 VERT 1 in 50
R.L. 92.600
Cut-
Fill+
DESIGN SURFACE
EXISTING SURFACE
CHAINAGE
LEVEE LONGITUDINAL SECTION
From CH 3850.000 To CH 3945.918
SCALES: HORI 1 in 500 VERT 1 in 50
PROJECT DELIVERY PTY LTD
CONSULTING CIVIL ENGINEERS
ABN 48 102 819 750
PO Box 529
61-65 Gellibrand Street
Colac Vic 3250
T: 5231 6307
F: 5231 6144
E: Contact@projectdelivery.com.au
AMENDMENTS
LEGEND
MOIRA SHIRE
BARMAH LEVEE BANK
BARMAH
LEVEE BANK CONSTRUCTION
LEVEE LONGITUDINAL SECTION
Survey by: LIDAR
Plan by: J.F.
Checked by: T.MCGANN
Date: DEC '11
A.H.D.
MGA
30-12-11 CONCEPT DRAWINGS T.McG
Sheet No.
20