Report

Survey and Design of Demonstration Site Outlet

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1.1 Catchment Map
1.2 Design Area Map
1.3 Introduction

The Buntine–Marchagee Natural Diversity Recovery Catchment is in the northern agricultural zone between Dalwallinu and Coorow. It covers 181,000ha and is the fifth natural diversity recovery catchment declared under the State Salinity Strategy.

Systems of Landcare (Sol) was contracted by the Department of Conservation and Land Management (the Department), through the Buntine-Marchagee Natural Diversity Recovery Catchment (BMRC) to identify water management issues and design appropriate repairs and modifications for where water crosses the Buntine-Marchagee Road and Mamboobie Road for discussion with the Coorow Shire.

The project, to identify water management issues and design appropriate earth works for surface water management at a demonstration site where water crosses the Buntine Marchagee Road and Mamboobie Road.

The demonstration site is 870ha in area and is located on the Buntine Marchagee Road, east of the Mamboobie Road intersection, 14km east of Marchagee.

This analysis focuses on the surveying and designing of appropriate earth works for surface water management at the demonstration site within the Buntine Marchagee Recovery Catchment.

The information for this report was collated and recorded by Systems of Landcare. Martyn Keen, (STO) and Jodie Watts, (RCO) were on site to assist with the collation and recording of data in the surveying process.

Prior to commencement of the project discussions were held with the Recovery Catchment Officer and Senior Technical Officer. Meetings were held on site with the RCO, STO and Peter Gillis, Coorow Shire Works Manager to discuss options for remedial works. A post contract meeting was held with the Coorow Shire, Works Manager and Gary Sherry, Chief Executive Officer (CEO) to present survey result and discusses the preferred options for remediation.
2 Site Assessment

2.1 Defining the Problem

Flooding surface water is being trapped by the road resulting in ponding and extra water logging adjacent and upstream to the Buntine Marchagee Road. Predominantly occurring at the break of slope, a larger area of salinity was observed than had been previously mapped. Surface water is basically uncontrolled, coming off the mid and upper slopes as the existing earthworks have no capacity as such for surface water flows. The red clay flats have a high susceptibility to water logging as a result of this uncontrolled flow from upslope. This was evident with the sunken vehicle tracks across the paddock.

In carrying out the site assessment the problems that were defined in the initial evaluation and report (Sinclair Knight Merz, 2003) were reiterated and reinforced in the surveying process. In carrying out this more detailed site assessment it was found that the area, suffering land management problems is larger than initially identified. This area has pondage, water logging and salinisation whose influence is visible on the surface.

2.2 Drainage Network

The natural drainage network is well defined with second and third order streams until 350m upslope of the Buntine Marchagee Road. At this point the water fans out losing velocity and direction. These well defined channels upslope, are actively eroding and need stabilization as part of a catchment plan. As the water fans out, it is depositing on the flats interrupting and changing further the surface water flows that come in the future.

2.3 Geological Features Affecting Water Hydrology

Numerous dolerite intrusions were identified in the initial assessment and from aerial photography, using a stereoscope. Some of these dolerite intrusions are included in the 1:250,000 Geological Series – Explanatory Notes for Moora. Most of these intrusions have a north south trend except one extending from the area around the large dam, which runs in an east west direction. These intrusions have initially shaped the catchment and are still having an affect on ground water systems in some areas, locally and regionally. Evidence for this was on the western boundary of the key property in the catchment where hillside seepage has expressed itself above the intersection of two geological lineated intrusions. Numerous other hill side seepages were identified using the aerial photography.
Major Hazard Areas

Major land management hazard areas are associated with the natural drainage system beginning at the B-M Road crossing and extend 2kms upstream pass the main catchment break of slope, as indicated on map. Main natural drainage systems are actively eroding and depositing silt above the B-M Road. Water ponding and water logging are occurring up slope of the B-M Road as water is trapped behind this structure. The shallow soil types are conducive to these land management hazards.

Soil and Landscape Information

Soil profile taken from 1:250,000 Geological Series indicates laterite and associated sand along with residual yellow and white quartz sand on the upslope, down to alluvium of clay silt and sand and colluvium of clay and loam at the crossing. The more detailed soil mapping of Stoneman and Kessell show greater detail and confirms the distribution of soils within the demonstration site. With mid and upper slopes averaging 4%, high intensity rainfall events are going to result in water erosion. The sands have high conductivity, thus in low intensity rainfall events, recharge becomes an issue with discharge up against some geology, breaks of slope and reduced porosity at the change of soil types. The break of slope is also where the local hardpans become the shallowest and their effect is increased.

Existing Works

Existing 540ml culvert at the road crossing is below ground level and therefore is not discharging water adequately.

Existing grade banks on upper slopes have no capacity and as such have very limited effect on surface water control. Some of their placement is acceptable but they are not integrated or constructed to industry standards.

Existing creek line channel has insufficient capacity to accommodate a 1 in 20 ARI rainfall event. (See Calculations)
3 Surveying

3.1 Surveying and Setup

An optical laser was used to survey levels along lines running parallel to the Buntine Marchagee Road with levels taken at 50m spacings. The level of accuracy using this equipment is +/- 0.020 metres or better.

Spot heights were taken at 50m intervals along guide lines running parallel to the B-M road lines were at 50m intervals. The lines were spaced at 50m, 200m and along the fence north of the road. Spot heights were taken south of the road, along the fence line at 50m, 250m and at 500m. Heights were also checked along the creek line and waterway. Extra spot heights were taken as deemed necessary with all levels reduced to the TBM.

Distances were measured using a vehicle mounted laser system with accuracy of +/- 0.001 metres.

Spot heights were recorded in a survey book. *(See Appendix 1)*

3.2 Temporary Bench Mark (TBM) for Reducing Levels

A temporary bench mark (TBM) was established near the corner of Mamboobie and Buntine Marchagee Roads using the base of ground water bore 02BMC10 and given an arbitrary figure of 100.00 for reducing levels. This position is 1m west of the northern gate strainer and approximately 1m from the existing north south fence line. This was viewed as a secure position for future reference.

3.3 Invert Levels

Invert levels reduced to the TBM were taken on both ends of the existing culvert pipes under B-M Road.

There are 3 pipes in total. *(See Appendix 1)*
4 Calculations

4.1 Catchment Area above B-M Road

The catchment area above the Buntine Marchagee Road (B-M Rd) was confirmed and marked on the black and white ortho photo. This was carried out through a process of ground truthing.

Area of catchment calculated at 870 ha. This figure came from firstly a dot grid sheet and aerial photo at 1:10000 with clarification from a GIS system.

4.2 Runoff for 2y to 20y Average Recurrence Intervals (ARIs) for Catchment area above B-M Road.

Flood index method of run-off prediction was used for determining 2–20 year average recurrence intervals for confirmed catchment area above B-M Rd.

The area of catchment has been calculated at 870 ha or 8.7km².

Average annual rainfall for the area is 400mm

Loamy soil catchments 75-100% cleared.

\[ Q^5 = 2.77 \times 10^{-6} \times A^{0.52} \times P^{2.12} \]

Frequency factors \( Q_y/Q_5 \) are:

<table>
<thead>
<tr>
<th>ARI (years)</th>
<th>2y</th>
<th>5y</th>
<th>10y</th>
<th>20y</th>
<th>50y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.48</td>
<td>1.00</td>
<td>1.84</td>
<td>3.23</td>
<td>6.10</td>
</tr>
</tbody>
</table>

Substituting figures into the equation:

\[ Q^5 = 2.77 \times 10^{-6} \times 8.7^{0.52} \times 400^{2.12} \]
\[ Q^5 = 2.8m^3s^{-1} \]

Multiplying this figure by the frequency factors returns yields of:

<table>
<thead>
<tr>
<th>2y</th>
<th>5y</th>
<th>10y</th>
<th>20y</th>
<th>50y</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3m^3s^{-1}</td>
<td>2.8 m^3s^{-1}</td>
<td>5.1m^3s^{-1}</td>
<td>9.0m^3s^{-1}</td>
<td>17.08m^3s^{-1}</td>
</tr>
</tbody>
</table>
4.3 Waterway Depth

The recommended maximum velocity for a sandy clay loam as tested on site is $1.25\text{ms}^{-1}$.

Manning’s ‘n’ for average depth of flow 1 to 2 times grass height is 0.03

The slope of the main drainage line is the same north and south of the B-M Rd at 0.006 metres per metre. This area extends 500m upslope and 200m past the B-M Rd.

In using Manning’s formula for the planning of this shallow waterways the average depth is to be substituted for hydraulic radius in the calculation, thus Manning’s formula becomes

$$v = \frac{1}{n} \left( \frac{d_{av}}{s} \right)^{1/3}$$

By transposing this formula so that the average depth is the unknown portion of the equation, the formula now reads:

$$d_{av} = \left( \frac{v.n.s^{-1/2}}{1/2} \right)^{3/2}$$

or:

$$d_{av} = v^{1.5} \ n^{1.5} \ s^{-0.75}$$

Where:

- $d_{av}$ = average depth
- $v$ = maximum permissible velocity.
- $n$ = Manning’s roughness coefficient.
- $s$ = slope of channel bed in metres per metre

Substituting values from the demonstration site

$$d_{av} = 1.25^{1.5} \ 0.03^{1.5} \ 0.006^{-0.75} = 0.3368\text{m}$$

The depth of the waterway is to be 0.34m.
4.4 Waterway Width

The peak flow in a waterway channel is expressed as:

\[ Q = A \cdot v \]

Or:

\[ Q = w \cdot d_{av} \cdot v \]

Where:
- \( A \) = cross sectional area and being width (w) by average depth (d)
- \( v \) = maximum permissible velocity
- \( w \) = width
- \( d_{av} \) = average depth

Transposing for the unknown width, the equation now reads:

\[ W = \frac{Q}{D_{av} \cdot v} \]

Where:
- \( W \) = width
- \( Q \) = design peak flow
- \( D_{av} \) = average depth
- \( v \) = maximum permissible velocity

Substituting values for a 1 in 20 ARI

\[
W = \frac{9.0 \text{m}^3/\text{s}^{-1}}{0.34 \text{m} \times 1.25 \text{ms}^{-1}}
= 21.176 \text{m}
\]

Therefore the specifications of the grassed constructed waterway are:

- Width is **21.176 m**
- Depth of flow is **0.34 m**
- Compacted levee height **0.54 m** (flow depth plus 0.2 freeboard)
- Medium density grass cover with a growth height of 0.1 to 0.15 m

Figures have been transferred to a specification sheet (*See appendix 4*).
### 4.5 Waterway Width Options

**Option B**
A depth of 0.24m is substituted into

\[
W = \frac{Q}{D_{av} \cdot v}
\]

\[
w = \frac{9.0 \text{ m}^3/\text{s}^{-1}}{0.24 \text{ m} \times 1.25 \text{ m/s}^{-1}}
\]

\[
= 30 \text{ m}
\]

**Option C**
A depth of 0.29m is substituted into

\[
W = \frac{Q}{D_{av} \cdot v}
\]

\[
w = \frac{9.0 \text{ m}^3/\text{s}^{-1}}{0.29 \text{ m} \times 1.25 \text{ m/s}^{-1}}
\]

\[
= 24.8 \text{ m}
\]
4.6  Gully Characteristic’s

Cross-section of existing creekline at 500m line *(See appendix 14)*

**CROSS-SECTIONAL AREA**

\[ A = bd + Zd^2 \]
\[ = 4.165 \text{ m}^2 \]

**WETTED PERIMETER**

\[ WP = b + 2d \sqrt{Z^2 + 1} \]
\[ = 11.98 \]

**HYDRAULIC RADIUS**

\[ R = \frac{b + Zd^2}{b + 2d \sqrt{Z^2 + 1}} \]
\[ = 0.34 \]

**Manning’s formula is:**

\[ v = \frac{1}{n} r^{2/3} s^{1/2} \]
\[ = \frac{1}{0.025} x 0.34^{2/3} x 0.006^{1/2} \]
\[ = 1.52 \text{ m/s} \]

Peak flow is equal to the cross-sectional area multiplied by the velocity

\[ = 4.165 \times 1.52 \]
\[ = 6.33 \text{ m}^3 \text{s}^{-1} \]

Capacity of existing creekline is not capable of containing a 1in 20 ARI flow of 9 m$^3$ s$^{-1}$

And as such levees are required to stabilize and protect the area.
4.7 Culverts and Road Crossing.

Culvert size is limited by the height of the road at 0.53m

Therefore rectangular box culverts (0.9m x 0.450) are the preferred option in conjunction with a constructed floodway for the road crossing

Cross-Sectional Area of 0.9 x 0.450 culvert = 0.405m$^2$

Using a box culvert flow diagram where

$$Q \approx \sqrt{\frac{H A^2}{6.35 n^2 L A^{0.66}} + \frac{0.66}{g}} \text{ m}^3 \text{ s}^{-1}$$

Where

- $A$ = Cross sectional area
- $H$ = Head loss
- $L$ = Length
- $n = 0.013$

The capacity of the 0.9m x 0.450m culvert is $0.4 \text{ m}^3 \text{ s}^{-1}$

$:\therefore$ For the culvert system to handle a 1 in2 ARI flow of $1.3 \text{ m}^3 \text{ s}^{-1}$

4 Box culverts of 0.9 x 0.450 are required.
5 Cross Section Diagrams

5.1 A long-section diagram along the main drainage line.
A Cross Sectional Profile of the Demonstration Catchment was prepared using the reduced levels. (See Appendix 30)

5.2 Slope of main drainage line immediately north and south of B-M Road (design area).
The slope of the main drainage line is the same north and south of the B-M Rd at 0.006 metres per metre. This figure compares to the 0.04 metres per metre slope in the mid and upper catchment areas.

5.3 North of B-M Road
Cross –Sectional Diagrams were prepared for the paddock north of the present culvert site on the B-M road at intervals of:

- Fence line (See Appendix 6)
- 50m (See appendix 5)
- 200m (See Appendix 7)
- Summary (See Appendix 8)

5.4 South of B-M Road
Cross –sectional Diagrams were prepared for the paddock South of B-M Rd at intervals of:

- Fence line (See Appendix 9)
- 50 m (See Appendix 10)
- 250m (See Appendix 11)
- 500m (See Appendix 12)
- Summary (See Appendix 13)

5.5 Creek at 500m
Cross Section Diagram of the Creek Line at 500m, south of the B-M Road was prepared. (See Appendix 14)
5.6 Along B-M Road
Cross sections were completed from the culvert on B-M Road at a distance of 50m in the first measurement then went through in 100m measurements as it was viewed that there was insufficient variation in the elevation through the design area to warrant the extra surveying. This decision was made in conjunction with the Recovery Catchment Officer and is justified in the results.

45m (See Appendix 15)
95m (See Appendix 16)
195m (See Appendix 17)
295m (See Appendix 18)
395m (See Appendix 19)
495m (See Appendix 20)
595m (See Appendix 21)
690m (See Appendix 22)
795m (See Appendix 23)
895m (See Appendix 24)

5.7 Centre Line of Road
Cross Sectional Diagram of the surface level for the centre line of the B-M Rd from Mamboobie East was prepared. (See Appendix 27)

5.8 Shoulders of Road
Cross sectional diagrams for the north and south shoulder of the B-M Rd were prepared.

North Shoulder (See Appendix 26)
South Shoulder (See Appendix 28)

5.9 Toe’s of Road
Cross Sectional Diagrams for both North and South along the toe of the road embankment of the B-M Rd.

North Toe (See Appendix 25)
South Toe (See Appendix 29)

5.10 Fence lines
Cross-Sectional Diagram prepared for inside the private property fence line north and south of the B-M Rd.

North inside fence line (See Appendix 6)
South inside fence line (See Appendix 9)
6 Design Criteria assessed and viewed for the Recommended Structures.

6.1 Criteria

- Site Characteristics
- Soil Types
- Channel Slope
- Catchment run-off peak flow
- Channel cross sectional shape
- Roughness coefficient
- Velocity
- Capacity
- Vegetation cover
- Outlets
- Width
- Channel cross fall between banks or levees
- Levees
- Bank inlets

6.2 Legal Aspects

Waterways must not divert flows from one catchment to another that would not naturally receive that flow.
Flow velocity must not be increased by the inappropriate use of additional free board to provide extra flow capacity.
Due care must be taken during construction and maintenance to halt the loss of disturbed material from the site.

6.3 Environmental Aspects

Poor quality water flows can degrade downstream channels, water course and wetlands. Eroded material from poorly planned, constructed and maintained waterways can reduce flow capacity when deposited in downstream channels.
7 Recommended Works

1. A new floodway with appropriate culverts to be constructed on the B-M road between the properties of Stacy and Muller.

2. This proposed crossing is to be 500m east of the Mamboobie Road intersection and 200m west of the existing culverts. This point is associated with the area of water ponding north of the B-M road.

3. The bottoms of the culverts are to be positioned to drain as much as possible of the water ponding area. The dimensions for the floodway of 30m wide and 0.25m deep are the minimum dimensions required for a 1 in 20 year average return interval.  
   *(See Specification Sheet – Appendix 2)*

4. The floodway is to have two box culverts at each end 0.9m x 0.45m that will cater for small rainfall events, along with the initial flow from larger rainfall events.  
   *(See Specification Sheet – Appendix 2)*

5. A waterway is to be constructed from a point 400m upslope of the BM road to the proposed new crossing. The levees are to be compacted to a height of 0.54m with a base width of 4m. This height includes 0.2m of freeboard.  
   *(See Specification Sheet – Appendix 4)*

6. The levee system will need to continue back up slope along the creek line ensuring that the capacity of this channel meets the requirements of 9m$^3$.

7. Option of a levee system or shallow relief drain is to be constructed north of B-M road, capable of 9m$^3$ conveying the flow from the floodway to the regional drainage system. This channel will need to pass into and through the revegetated area to ensure safe disposal into the regional drainage system. Waterway is to cross into revegetation 300m from Mamboobie road.
8. Width and depth for the shallow relief drain will be the same as for a waterway. *(See Specification Sheet – Appendix 4)*

9. The leveed waterways north and south of B-M Road need to follow the small shallow parabolic hollow that is available. This small depression does not have capacity to handle the volumes associated with the peak flows emanating from this catchment but provides a good foundation and base to construct a leveed waterway system upon.

10. A total water management plan with grade banks and waterways designed and constructed to industry standards is required across the catchment.

11. A grade bank is suggested for the eastern side to help keep the area dry from water ponding and water logging. This area is highly susceptible to salinisation as there is a major break of slope at this point. The soil profile contains a shallow lateritic hardpan that increases surface runoff but severely restricts groundwater flows.

12. The proposed grade bank will need to be constructed to industry standards to ensure 1:20 ARI reliability.

13. It is further recommended that the area beneath the proposed grade bank is revegetated so as to control the local perched water table. This will also aid and protect the B-M road at this position.

14. Recommended that maintenance of proposed earthworks be carried out within five years of construction. Repair any damage to earthworks from large rainfall events as soon as possible after occurrence.

**Detailed specification sheets for each recommended work have been prepared as part of this Assessment and Report.**
SPECIFICATIONS FOR ROAD CROSSING

EXCAVATED AREA 30M WIDE X 0.25 DEEP

2 BOX CULVERTS
0.9m x 0.45m AT EACH END OF THE FLOODWAY

Top of road surface

Specification Sheet Road Crossing
Prepared for:

<table>
<thead>
<tr>
<th>Original</th>
<th>Up dated</th>
<th>Up dated</th>
</tr>
</thead>
</table>

Prepared by:
Date
SPECIFICATIONS FOR GRADE BANK

Grade bank cross section

Side slope 1:4
Side slope 1:3
Water Level
Channel Depth 0.25 metres
Channel 3.5 metres wide
Freeboard 0.2 metres
Original Ground Level

Construction Specifications
Alignment of bank is surveyed on correct grade using optical or laser level. Level to an accuracy of +/-0.050m or better and place alignment marks (pins or pegs). Survey interval, to establish alignment marks, should be no greater than 25mts. Extra alignment marks are required on tight bends, particularly when crossing ridges and small depressions. When no level sill is constructed, extra grade is included at the bank outlet to allow the grade bank channel to return to ground level. Construction machinery should have suitable capacity, horsepower and appropriate attachments. Both bulldozers and graders are suitable.

Maintenance
Grade bank channel, bank and or side slopes damaged by stock or run-offs are to be repaired to original construction standards as soon as practicable. Breached banks are to be repaired as soon as run-off event has passed. Breaches are to be filled with compacted material of the same quality or better than that used in the original bank construction. Correctly constructed banks with adequate channel capacity, correct side slopes and adequate bank compacted freeboard, may only need reconstructive maintenance at greater than 5 yearly intervals. However, all grade banks should be reconstructed when capacities are less than the original construction.
SPECIFICATIONS FOR WATERWAY

Waterway Cross Section

Levee Height: 0.54 metres
Depth of Flow: 0.34 metres
Freeboard: 0.2 metres

CONSTRUCTION SPECIFICATIONS

Alignment and width of the waterway are to be pegged, as detailed on the plan, using appropriate survey techniques. Cross sections are to be surveyed and cut and fill pegged as required.

Topsoil to be stockpiled when filling or shaping and re-spread over disturbed areas.

Allow machinery weight to compact fill or shaping.

Levees to be constructed from outside the channel, using appropriate techniques, resulting in the levees being compacted to the correct height including freeboard.

Bank inlet positions to be surveyed for correct spacings and positions. Set the ends of the inlet to eliminate back flow out of the waterway.

Check level of the waterway channel surface to determine the accuracy of construction. Use levelling to confirm the levee freeboard.

Vegetation cover on waterway channels and banks to be a mixture of annual and perennial grasses, clover and medics, dependant on soil type. Seed at double pasture and fertilizer rates.

MAINTENANCE

Vegetation covers to be maintained at a height between 0.1 and 0.2 metres.
Mow or periodically graze vegetation to maintain flow capacity.
Damaged channel floor and levees are to be reconstructed to original specifications.
Do not use waterway as an access track or firebreak.
Control noxious weeds.

Waterway Width: 21.8 metres
Side Slope: 6:1
Side Slope: 2:1
APPENDIX 5

Cross-Section Along 50m line Parallel to and North of B-M Rd from TBM Mamboobie Rd

Distance (metres)

Elevation

Reduced Level

0 12 62 112 162 212 262 312 362 412 462 512 562 612 662 712 762 812 862 912 962 1012

98.5 99 99.5 100 100.5 101 101.5 102

Elevation (metres)
Cross-Section along 200m line Parallel to and North of B-M Rd from TBM Mamboobie Rd

APPENDIX 7
Summary of Cross-Sections North of B-M Rd from TBM Mamboobie Rd
APPENDIX 9

Cross-Section along Fence Line Parallel to and South of B-M Rd from TBM Mamboobie Rd

Distance (metres)

Elevation (metres)

- Elevation
- Reduced Level

0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 875

98 99 100 101 102 103 104
APPENDIX 10

Cross-Section along 50m line Parallel to and South of B-M Rd from TBM Mamboobie Rd

![Graph showing elevation and reduced level over distance](image-url)
Appendix 11

Cross-Section along 250m line Parallel to and South of B-M Rd from TBM2 Laneway
Cross-Section of Creek Line at 500m Line South of B-M Road
APPENDIX 15

Cross-Section at 45m from T-Section of Mamboobie Rd and B-M Rd

Distance (metres)
APPENDIX 16

Cross-Section at 95m from T-Section of Mamboobie Rd and B-M Rd

Distance (metres)

Elevation (metres)
APPENDIX 17

Cross-Section at 195m from T-Section of Mamboobie Rd and B-M Rd

![Graph of elevation versus distance]
APPENDIX 18

Cross-Section at 295m from T-Section of Mamboobie Rd and B-M Rd

[Diagram showing elevation changes over distance]
APPENDIX 19

Cross-Section at 395m from T-Section of Mamboobie Rd and B-M Rd

![Graph showing elevation changes over a distance of 16 metres, with peaks and valleys indicating changes in terrain.](image-url)
APPENDIX 20

Cross-Section at 495m from T-Section of Mamboobie Rd and B-M Rd

Distance (metres)

Elevation (metres)
**APPENDIX 22**

Cross-Section at 690m from T-Section of Mamboobie Rd and B-M Rd

![Graph showing elevation changes over distance](image-url)
APPENDIX 23

Cross-Section at 795m from T-Section of Mamboobie Rd and B-M Rd

Distance (metres)

Elevation (metres)

Elevation
APPENDIX 24

Cross-Section at 895m from T-Section of Mamboobie Rd and B-M Rd
Cross-Section of North Toe of B-M Rd from Mamboobie East
APPENDIX 26

Cross-Section of North Shoulder of B-M Road from Mamboobie East

Distance (metres)

Elevation (metres)

Shoulder North Elevation
Cross-Section of Centre of B-M Rd from Mamboobie East

Distance (metres)

Elevation (metres)

APPENDIX 27
APPENDIX 28

Cross-Section of South Shoulder of B-M Rd from Mamboobie East

- Distance (metres)
- Elevation (metres)

**Shoulder South**
Cross-Section of South Toe of B-M Rd from Mamboobie East

APPENDIX 29
APPENDIX 30

Cross Sectional Profile along the Main Stream

Elevation (metres)

Distance (metres)

Series 1

0 500 1000 1500 2000 2500 3000 3500 4000 4500

270 280 290 300 310 320 330
REFERENCES:


Keen, MG 1998, *Common Conservation Earthworks used in Western Australia*, Agriculture Western Australia, Geraldton, Western Australia.


Pilgrim, DH 1987, *Australian rainfall and runoff*, The Institution of Engineers Australia, Barton, ACT.


