Kowanyama Flood Study
Local Drainage Assessment

DEPARTMENT OF ABORIGINAL & TORRES STRAIT ISLANDER PARTNERSHIPS AND KOWANYAMA ABORIGINAL SHIRE COUNCIL

KOWANYAMA TOWNSHIP

Queensland Government

KOWANYAMA ABORIGINAL SHIRE COUNCIL
Place of many waters

LANGTREE CONSULTING

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ACRONYM GLOSSARY

AEP:	Annual Exceedance Probability
AHD:	Australian Height Datum
ARI:	Annual Recurrence Intervals
BOM:	Bureau of Meteorology
DEM:	Digital elevation model
DEM:	Digital Elevation Model
DSDSATSIP:	Department of Seniors, Disability Services and Aboriginal & Torres Strait Islander Partnerships
GIS:	Graphical Information System
KASC:	Kowanyama Aboriginal Shire Council
LiDAR:	Light Detection and Ranging
MESE:	Matters of state environmental significance
QUDM:	Queensland Urban Drainage Manual
RCBC:	Reinforced Concrete Box Culverts
RCP:	Reinforced Concrete Pipes

1.0 INTRODUCTION

Langtree Consulting has been engaged by The Department of Seniors, Disability Services and Aboriginal & Torres Strait Islander Partnerships (DSDSATSIP) and Kowanyama Aboriginal Shire Council (KASC) to undertake a Flood Study at the Township of Kowanyama. The Flood Study consists of both a Regional Flooding Assessment as well as a Local Drainage Assessment. This report outlines the Local Drainage Assessment that was undertaken on the Township of Kowanyama.

The agreed tasks to be completed as part of the Local Drainage Assessment are as follows:

- Undertake a site inspection on site and meet with the key members of the Kowanyama Community and Council;
- Investigate the Township to fully understand the local drainage including:
    - The surrounding low-lying areas;
    - Reviewing access requirements to areas on the outskirts of the community which are inaccessible in the wet, such as adjacent to the airstrip;
    - The current drainage channels and their direction of flow; and
    - The inundation timelines for when and how Magnificent Creek floods back into the community.
- Using the Regional Flood Modelling Mapping, assess the suitability of the proposed locations for future development in Kowanyama;
- Using first principal hydrologic and hydraulic calculations (Rational Method and Manning's Equations) assess areas impacted by local drainage issues observed during the site visit or highlighted by the community and Council;
- Investigate and recommend design strategies to mitigate issues identified to ensure the community is more resilient with respect to local drainage issues. Mitigation measures may consist of regrading/realigning and creating additional drains, making the drains deeper and wider, building detention/storage basins, etc; and
- Prepare a cost estimate of preferred proposals & infrastructure development.

2.0 BACKGROUND

The Kowanyama community includes the Kokoberra, Kokomenjena and Kunjen people who each have their language and cultural differences. The community of Kowanyama is located in the south-west region of the Cape York Peninsula, approximately 25 kilometres from the western coast of the Gulf of Carpentaria and approximately 600 kilometres north-west of Cairns. Kowanyama is positioned on the banks of Magnificent Creek and has landholdings that encompass the Mitchell River and the lower reaches of the Alice River. The nearest town to Kowanyama is Pormpuraaw, to the north-west, which can be accessed by road. Roads into Kowanyama are subject to annual flooding during the wet season. By late December the monsoons leave the community isolated by road. Kowanyama has a weekly road train service from Cairns. This service becomes more frequent leading up to the wet season. Refer to ***Figure 1 and 2*** for the site locality.

During the wet season when the community becomes isolated the only access to Kowanyama is by plane. Airline passenger services to Cairns are maintained throughout the year. The Township is located within the Aboriginal Shire of Kowanyama with a land area of 2,516.1 square kilometres. The Shire's country is characterised by wetlands, coastal plains, lagoons, creeks and thick scrub and is rich in biodiversity. There are many animals and plants that are unique to the area making the environment important at a local and state level. Matters of state environmental significance (MSES) ecological areas are identified in the wetlands of Kowanyama. The topography of Kowanyama is typically uniform, with no mountains within the shire. This distinguishes Kowanyama Aboriginal Shire from other surrounding areas.

The Township of Kowanyama is currently partly developed with a combination of residential, industrial, commercial and community facilities. Development in Kowanyama is guided by the Kowanyama Aboriginal Shire Council Planning Scheme and the Kowanyama Master Plan. The Kowanyama Master Plan seeks to guide future residential, industrial, commercial / tourism, community facilities, and recreation and open space development within Kowanyama, in a way that accords with land use planning objectives and community needs and aspirations.

Figure 1: *Regional Kowanyama, Site locality Plan (Source: Queensland Globe – Not to Scale)*

Figure 2: *Township of Kowanyama, Site Locality Plan (Source: Queensland Globe – Not to Scale)*

One objective of this project is to review the current master plan in retrospect of potential flood events in regard to access, safety and the wellbeing of the Kowanyama community. This review is required to be undertaken in consultation with the Kowanyama community and Council.

The flood study will:

- be an essential tool in assisting with the rectification of the current flooding and drainage issues the community experiences for planning any immediate and long-term future development in and around community; and
- identify requirements and scope for future hydrologic and hydraulic models that will aid Council's emergency and disaster management planning and inform a planning scheme amendment for flood related management, mapping and risks.

As part of the Regional Flooding Assessment, Langtree Consulting in conjunction with Venant Solutions, has prepared both hydrological and hydraulic mapping. The hydrological assessment establishes the rate of flow from the catchment for different size (probability of occurrence) floods, and the hydraulic model uses these flows to establish flood extents, depths, levels and velocities. The hydrology of Magnificent Creek is complex and budgetary constraints means that it will only be possible for this study to approximate these flows which necessitates a conservative approach. Detailed LiDAR data is available to develop a ground surface digital elevation model (DEM) over Kowanyama and surrounds which means that a detailed hydraulic model is able to be developed to estimate flood levels using the flow estimates from the hydrological assessments, noting that the accuracy of the levels will be limited by the accuracy of the flow estimates. This Regional Flooding Assessment is currently contained in a separate standalone Regional Flooding Assessment Report but can be found in **Appendix A**.

The Local Drainage Assessment focused on visiting the Township of Kowanyama to fully understand the local drainage issues. This included meeting with the key members of the Kowanyama Community and Council. Using the regional flood modelling mapping, the suitability of the proposed locations for future development in Kowanyama was assessed. Areas impacted by local drainage issues were reviewed and investigated to determine if alternative design strategies can be used to mitigate the identified issues and to ensure the community is more resilient with respect to local drainage issues.

3.0 EXISTING CONDITIONS

3.1 LAND USE AND ZONING

The Township of Kowanyama is bound by Magnificent Creek to the east and north, with undeveloped sparse bushland to the south and west. The overall area is surrounded by swampy bushland with the main access routes to and from Kowanyama being from Dunbar Kowanyama Road from the west. Access to the east requires the crossing of Magnificent Creek. These crossings are via Kowulhyalalh Road to the north, Shelfo Road to the south-east and Dunbar Kowanyama Road to the south.

By late December, the monsoons leave the community isolated by road. Kowanyama has a weekly road train service from Cairns. This service becomes more frequent leading up to the wet season.

The Township of Kowanyama includes Industrial Precincts, Open Space Areas, a Business Precinct, Airport Precinct and Housing Precincts. The remaining land surrounding the Township is identified as Environmental Management and Conservation Zones. Refer to ***Figure 3*** below for current zoning**.**

Figure 3: *Precinct Map / Zoning (Source: Kowanyama Aboriginal Shire Planning Scheme)*

In accordance with Kowanyama Aboriginal Shire Council Planning Scheme, there is a mixture of proposed future industrial, residential and community facilities located throughout the Township. Refer to ***Figure 4*** for projected zoning of land as per the Master Plan (completed by Cardno in 2019).

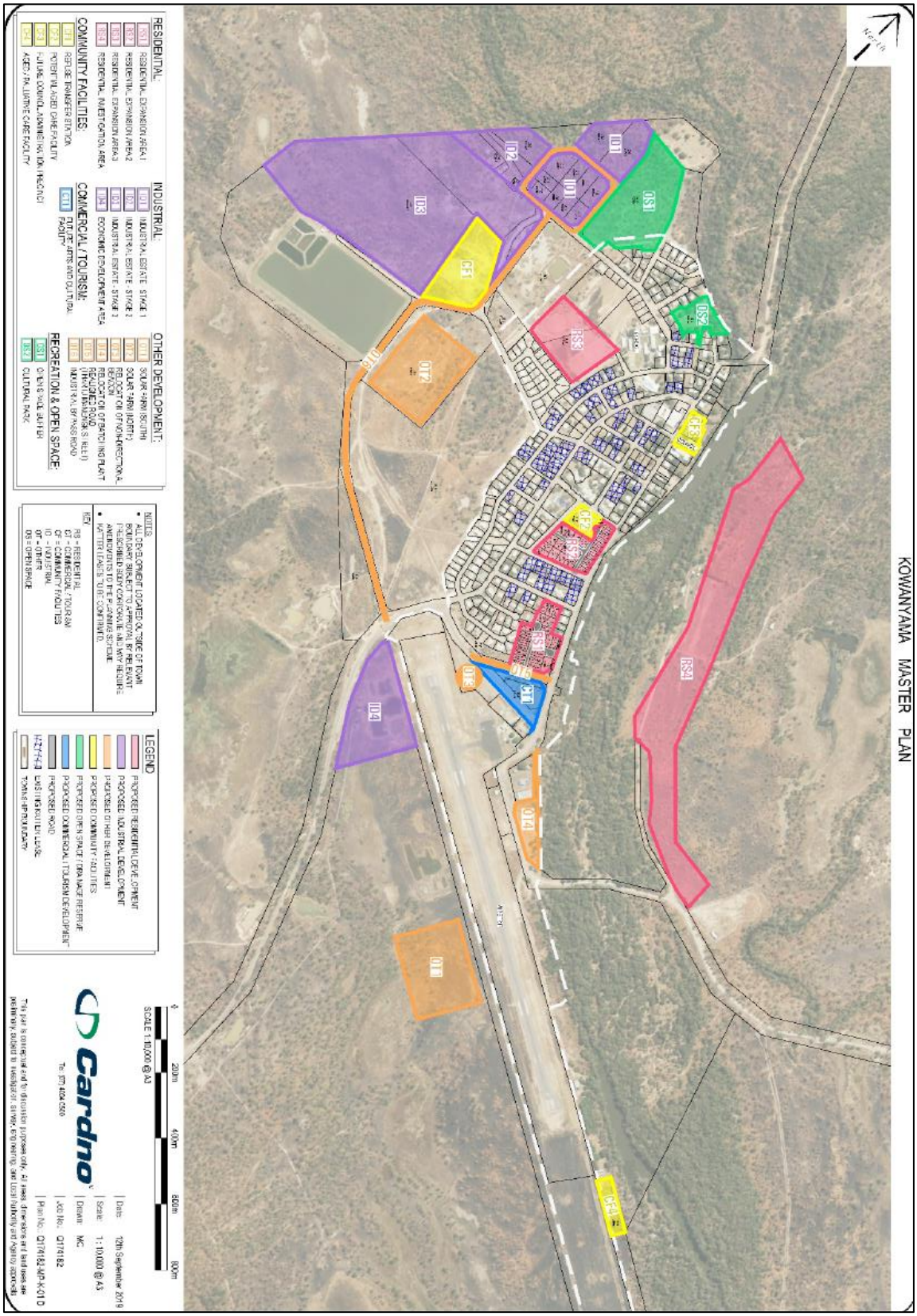


Figure 4: *Master Plan (Source: Kowanyama Aboriginal Shire Planning Scheme)*

3.2 LOCAL DRAINAGE ISSUES

Prior to attending the site inspection on 11th February 2021, Venant Solutions undertook preliminary regional flood modelling and prepared preliminary flood mapping within the Township, so that:

1. The adopted Manning's n values could be given a sensibility check on site. Manning's Roughness Coefficient ('n') is generally referred to as Manning's 'n'. Manning's 'n' is a coefficient which represents the roughness or friction applied to the flow by the channel. Manning's 'n' values are generally selected from Tables, but can be back calculated from field measurements;
2. The existing stormwater infrastructure (i.e. culverts and causeways) locations could be identified so that they could be inspected on site and their geometry recorded; and
3. Flood depth levels could be produced so that an idea of the local flooding areas could be identified and that local drainage issues could be highlighted prior to arriving in the Township.

As the specific Annual Exceedance Probability (AEP) event data is not available for the Township of Kowanyama, this modelling was based on allowing as much flow as possible to flow from the Mitchell River into Magnificent Creek and observing the findings. What was observed was that once the flows in Magnificent Creek exceeded a specific flow rate, any further increases in the flow rate caused breakouts of the Magnificent Creek Catchment within the flood model. It was observed that the increases in flow rate did not significantly affect the localised flooding in the Township of Kowanyama. Refer to ***Figure 5*** below.

The preliminary regional flood modelling mapping identified that there is existing flooding:

- At the State School (Area A);
- In the new residential development on Pindi Street (Area B);
- In the residential houses on the southern area of Kowanyama Street/Arwin Amay Street (Area C);
- At the airport off Shelfo Road (Area D); as well as
- Flooding on Chapman Road, Kowanyama Street, Pindi Street, Uwelkorig Street, Thartj Manengk Street and Shelfo Road.

Figure 5: *Preliminary Regional Flood Modelling Mapping (Source: Venant Solutions)*

4.0 SITE INSPECTION

A site Inspection of the Township of Kowanyama was conducted by Langtree Consulting on 11th February 2021 in conjunction with DSDSATSIP and KASC staff as well as with key members of the Kowanyama Community.

The first thing that was observed flying into Kowanyama was the vastness of the low lying swampy bushland areas that were holding water especially to the west of the Township of Kowanyama.

The following detailed information was gathered during the site inspection:

4.1 FLOOD MAPPING

A general inspection of the Township was undertaken against the areas of flooding indicated on Venant Solutions Preliminary Regional Flood Modelling Mapping (refer to ***Figure 5***). Based on our discussion with KASC staff as well as with key members of the Kowanyama Community it was found that in general the regional flood modelling mapping produced by Venant Solutions is generally accurate for the Township of Kowanyama. **The key finding of the site inspection was discovered through talking with key members of the Kowanyama Community. It was found that that flood waters do not currently flow or overflow from the Mitchell River or Magnificent Creek into Gooseberry Creek.**

4.2 MANNINGS 'n' VALUES

At the time, access outside of the township itself was limited as a flood event had only just occurred in January 2021. Based on our visual inspection it was accepted that the Manning's 'n' values adopted by Venant Solutions were reasonable and reflected the roughness coefficients observed on site.

4.3 STORMWATER INFRASTRUCTURE

All significant stormwater infrastructure was identified, measured and recorded to assist with this Local Drainage Assessment as well as the Regional Flooding Assessment. Refer to ***Table 1*** and ***Figure 6*** below. It was observed that there is limited stormwater infrastructure within the Township of Kowanyama with very little positive underground drainage (i.e. pit and pipe). The majority of the stormwater infrastructure observed is located in the east of the Township near Magnificent Creek.

The existing stormwater infrastructure located in the Township is designed to drain toward Magnificent Creek. There are also existing causeway crossings across Magnificent Creek at Kowulhyalalh Road and Shelfo Road. The main concentration of stormwater infrastructure is located along the open drainage channel in Thartj Manengk Street. The Stormwater Infrastructure allows stormwater to drain from the airport into the open channel and into Magnificent Creek. However, during high rainfall events this open channel also allows backflow from Magnificent Creek to discharge to the western swamp lands. It was noted that the discharge culverts in the Thartj Manengk Street open channel have been installed with flood gates to minimise the backflow that can flow back into the Township from Majestic Creek.

The banks of Magnificent Creek were observed to be scoured and eroded especially surrounding the pipe outlets that discharge to Magnificent Creek. The majority of these discharge pipes have no headwalls, aprons or scour protection.

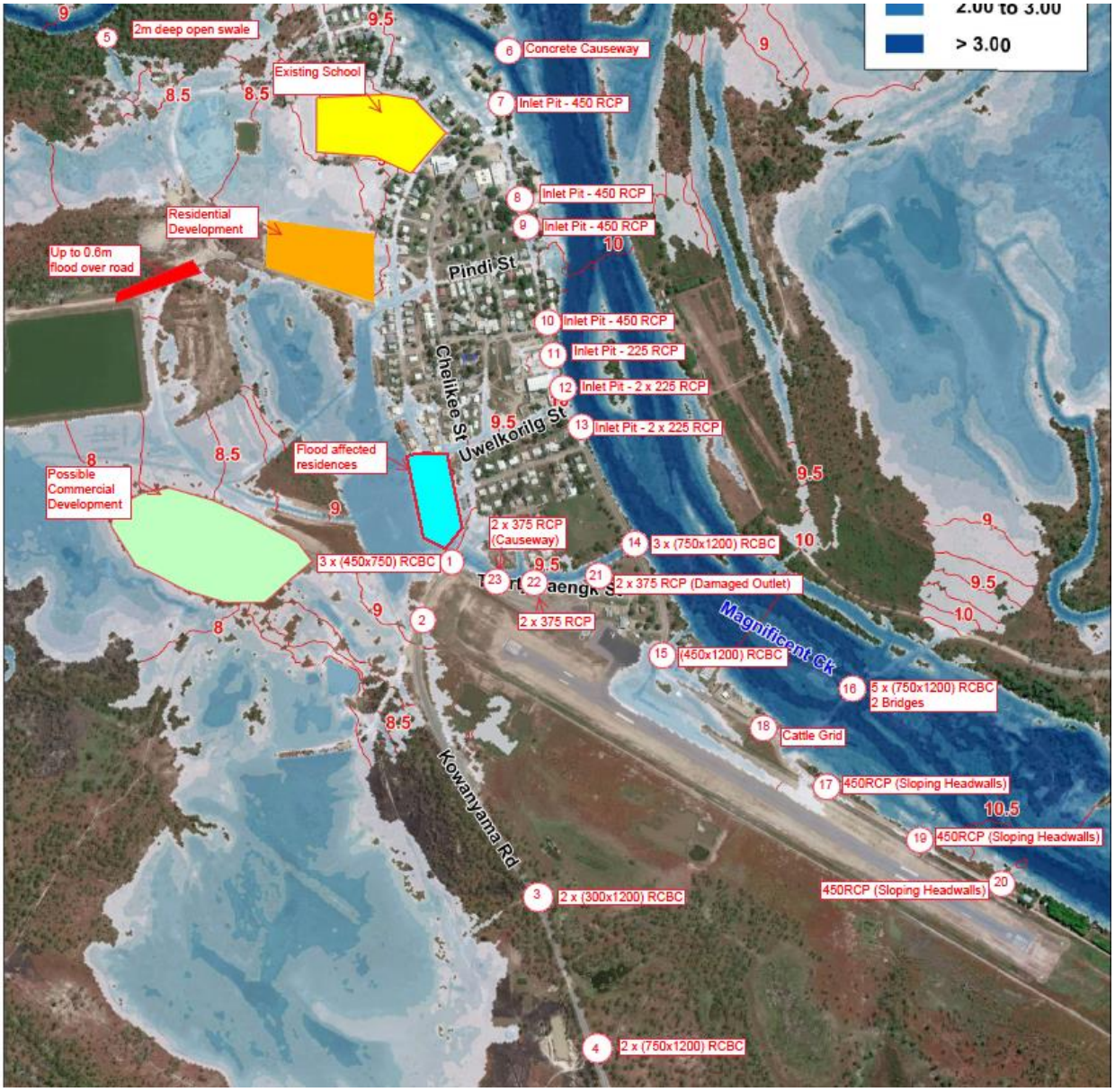


Figure 6: *Key Stormwater Locations (Source: Venant Solutions)*

Table 1. *Significant Stormwater Infrastructure*

ID	Infrastructure type	Location
1	450 x 750 RCBC (3 Cells)	Kowanyama Road
2	No Culvert	Kowanyama Road
3	300 x 1200 RCBC (2 Cells)	Kowanyama Road
4	750 x 1200 RCBC (2 Cells)	Dunbar-Kowanyama Road
5	Open Swale drain up to 2.0m deep	North of Koltmomun Street
6	Concrete Causeway at Creek invert	Kowulhyalalh Road
7	Inlet Pit 450 RCP draining towards Magnificent Creek	Kowanyama Street/Chapman Road
8	Inlet Pit 450 RCP draining towards Magnificent Creek	Gilbert White Street
9	Inlet Pit 450 RCP draining towards Magnificent Creek	Kunjun Street
10	Inlet Pit 450 RCP draining towards Magnificent Creek	Carrington Street
11	Inlet Pit 225 RCP draining towards Magnificent Creek	Between Carrington and Uwelkorilg Streets
12	Inlet Pit 2 x 225 RCP draining towards Magnificent Creek	Uwelkorilg Street
13	Inlet Pit 2 x 225 RCP draining towards Magnificent Creek	Karrenganang Street
14	750 x 1200 RCBC (3 Cells), with three separate flood gates.	Thartj Manengk Street / Chapman Road
15	450 x 1200 RCBC (1 Cells)	Shelfo Road to Airport
16	750 x 1200 RCBC (5 Cells) (2 separate bridges)	Shelfo Road, Across Magnificent Creek
17	450 RCP (Sloping Headwalls)	Shelfo Road – South-east of Airport
18	Cattle Grid	Shelfo Road – South of Airport
19	450 RCP (Sloping Headwalls)	Shelfo Road – South-east of Airport
20	450 RCP (Sloping Headwalls)	Shelfo Road – South-east of Airport
21	375 RCP x 2 pipes (Damaged outlet)	Thartj Manengk Street (East)
22	375 RCP x 2 pipes	Thartj Manengk Street (Middle)
23	375 RCP x 2 pipes (Causeway)	Thartj Manengk Street (West)

4.4 ROAD INFRASTRUCTURE

The key roads within Kowanyama to allow entry/exit and main traffic routes were inspected, assessed and our findings recorded. A record of our finding is contained in ***Table 2*** below.

Table 2. *Key Roads*

Road Name	Location	Purpose	Ownership	Condition
Kowullhyalalh Road	Northbound of Town	Connects to northern river systems	KASC	Sealed - Poor
Shelfo Road	South-East of Town	Connects to eastern river systems	KASC	Sealed – Poor
Kowanyama Road	West side of developed areas (North to South)	Connects main access road, through Kowanyama Town	KASC	Sealed – Poor
Dunbar-Kowanyama Road	South of Kowanyama	Main Access to Kowanyama from Burke Developmental Road	Main Roads/ KASC	Unsealed-OK
Thartj Manengk St	North of airport (East-West)	Local Street to Airport	KASC	Sealed – Poor
Uwelkorilg Str	Centre of Town (East-West)	Local Street	KASC	Sealed – Poor
Pindi St	Centre of Town (East-West)	Local Street from Town to West	KASC	Sealed – Poor
Chapman Road	East side of town (North-South)	Town to Airport	KASC	Sealed - Poor

These roads are typically asphalt sealed with main access track outside of the site being gravel. The majority of roads have no positive underground drainage (i.e. pit and pipe) and are currently in very poor condition.

5.0 FLOODING ASSESSMENT

5.1 PRE-DEVELOPMENT

The findings recorded during the site visit were shared with Venant Solutions to allow them to revise their original preliminary regional modelling mapping. Based on this information Venant Solutions prepared revised flood mapping for the Township of Kowanyama. Refer to the Regional Flooding Assessment Report for more information (**Appendix A**).

As established during the site visit the revised regional flood modelling mapping identified the following Local Drainage Issues within the Township of Kowanyama:

- At the State School;
- In the new residential development on Pindi Street;
- In the residential houses on the southern area of Kowanyama Street/Arwin Amay Street;
- At the airport off Shelfo Road; as well as
- Flooding on Chapman Road, Kowanyama Street, Pindi Street, Uwelkorig Street, Thartj Manengk Street and Shelfo Road.

Based on our modelling and site investigation there appears to be two separate yet connected drainage scenarios at work:

1. **Scenario 1**: is due to the overland flow levels within the Township naturally draining via overland flow paths to the west (to the ocean) and as such it would appear that the low lying swampy bushlands to the west of the Township begin to fill up with the overland flows from the Township. However, as the low lying swampy lands to the west of the Township cannot continue to drain naturally to the west they eventually fill up to a point where they start to back-up and pond water eastwards towards the Township.

   As there is very limited positive drainage within the roads (other than in Chapman Road) especially in the east of the township, the stormwater run-off continues to back-up until it floods the western extents of the Township.

2. **Scenario 2**: is due to the water levels in Magnificent Creek becoming elevated to a point where the roads, drains, culverts, pits and pipe can no longer free drain into Magnificent Creek, the stormwater runoff starts to back-up in the drains, culverts, pits and pipe and the entire Township becomes a pond.

The following scenarios appear to be responsible for the following Local Drainage Issues:

- Flooding at the State School appears to be connected to both Scenarios 1 and 2;
- Flooding in the new residential development on Pindi Street appears to be connected to Scenario 1 only;
- Flooding in the residential houses on the southern area of Kowanyama Street/Arwin Amay Street appears to be connected to Scenario 1 only;
- Flooding at the airport off Shelfo Road appears to be connected to Scenario 2;
- Flooding on Chapman Road and Shelfo Road appears to be connected to Scenario 2 only;
- Flooding on Kowanyama Street, Pindi Street and Thartj Manengk Street appears to be connected to Scenario 1 only; and
- Flooding on Uwelkorilg Street appears to be connected to both Scenarios 1 and 2.

5.2 POST-DEVELOPMENT

While this study has not been undertaken for a particular development, consideration has been given to the KASC Master Plan, 2019 as presented in ***Figure 4*** above. This plan proposes future defined uses and potential development areas that will be impacted by flooding.

This assessment has been carried out with specific attention to the Industrial Bypass Road (OT6 from Master Plan) that would cause potential increase in flooding if not designed to allow water from the eastern catchment to drain to the western catchment of this road. Significant drainage is required through this road to allow the total catchment area to be free draining.

It is also identified in the Master Plan that Thartj Manengk Street will be realigned (OT5), requiring the realignment of the existing open drain along this road. The drainage structure through Kowanyama Road also requires to be increased in size to allow this catchment to free drain towards the east. Please note that this increase in culvert size is independent of the Master Plan

There is significant flooding identified in the proposed Industrial Estate areas where there is an existing open drain discharging to the north (extension of Magnificent Creek). The open drain that currently accommodates flows from the south to the north must also be included as part of the design of OT6. This development will likely require flood mitigation treatment measures within the Industrial Estate area to limit the velocity of flow discharging directly into the creek.

The Master Plan identified a Residential Investigation Area (RS4) which is located on the eastern side of Magnificent Creek and was intended for rural residential development. The Regional Flooding Assessment Report indicated that RS4 was inundated during flood events. Therefore, this area was determined to be unviable for residential use.

The mitigation options presented below allow for significant improvement of the localised flooding issues while allowing for future development.

6.0 MITIGATION OPTIONS

The stormwater infrastructure has been designed for different Annual Recurrence Intervals (ARI). The stormwater infrastructure has been design based on the following ARI's:

- **Swales – 100 ARI Event** (1 in 100 year rainfall event);
- **Culverts – 10 ARI Event** (1 in 10 year rainfall event); and
- **Pits and Pipes – 5 ARI Event** (1 in 5 year rainfall event).

The hydrologic assessment of each catchment and proposed stormwater infrastructure has been analysed using the Rational Method. The guideline utilised for the calculation of the rational method is as per the Queensland Urban Drainage Manual (QUDM) 2017.

$$Q_y = (C_y \,.\, {}^{t}I_y \,.\, A) / 360$$

Where: Q_y = peak flow rate (m3/s) for average recurrence interval (ARI) of ''y' years

C_y = coefficient of discharge (dimensionless) for ARI of 'y' years

A = area of catchment (Hectares)

${}^{t}I_y$ = average rainfall intensity (mm/h) for a design duration of 't' hours and an ARI of 'y' years

t = the nominal design storm duration as defined by the time of concentration

Steps adopted for the peak flow rate calculations have been summarised as follows:

a) Analysis of flow paths based on available contours;
b) Determination of the time of concentration (t_c) for flow paths in accordance with QUDM, 4.6.11;
c) Adoption of the flow path with the longest time of concentration for assessment;
d) Determination of the runoff coefficients; and
e) Calculation of peak flow rate as QUDM, 4.3 (Rational Method).

Each catchment and set of supporting calculations are provided within the **Appendices B-G.**

The catchment mitigations measures have been based on both the proposed development outlined in the Master Plan and what the community currently requires. The locations of each catchment and each proposed mitigation options are identified in **Figure 7** below.

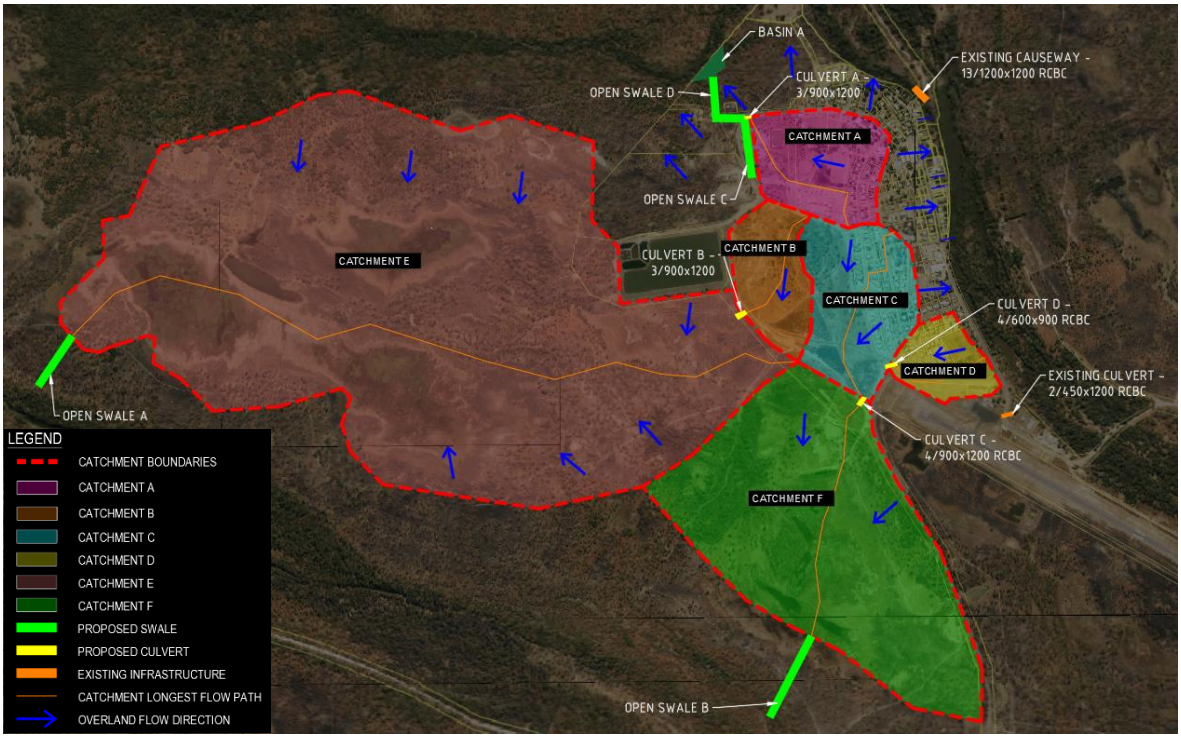


Figure 7: *Catchment Boundaries and Mitigation Options (Refer to* ***Appendix H****)*

6.1 CATCHMENT A

This catchment extends from Pindi Street (south), Chelikee Street (east) to Koltmomun Street (North). The area within these streets appears to currently drain west, toward the existing open drain that discharges into the extension of Magnificent Creek (to the north-west of the Township) (refer to **Appendix H**). The proposed Industrial Bypass Road (OT6) will dissect this catchment and the proposed development will include an Industrial Estate Area to the north-west of the Township where the existing open drain discharges.

To allow flows from the catchment on the eastern side of OT6 to flow toward the western discharge point requires a significant drainage structure through OT6. It is calculated that three (3) 900H x 1200W Reinforced Concrete Box Culverts (RCBC)(**Figure 8**) for a total width of 3.6m, is required to allow drainage through OT6. These culverts (Culvert A) discharge into the existing open drain which is proposed to be realigned to suit the alignment of OT6.

Proposed Open Swale C (Refer to **Figure 9**) along OT6 is calculated to be required to be a minimum of 14.5m wide with base width of 2.5m and a depth of 1m. Swale C discharges into to Swale D (Refer to **Figure 10**) with its dimensions calculated to require a total width 17.2m with a base of 4m and a depth of 1.1m. Open swale D accepts flows from open swale C as well as the RCBC's, discharging the total catchment to a proposed basin

adjoining the extension of Magnificent Creek. This Basin has not been designed for size/capacity as it is reliant on impact imposed the industrial development. Complete build out of the industrial area will have an increased run-off and potential sediment waste which is currently unknown (refer to **Appendix B**).

The size of culverts and open swales have been calculated to allow the flood areas of Catchment A to be free draining to the extension of Magnificent Creek reducing the flood impact on northern residences and allowing future development.

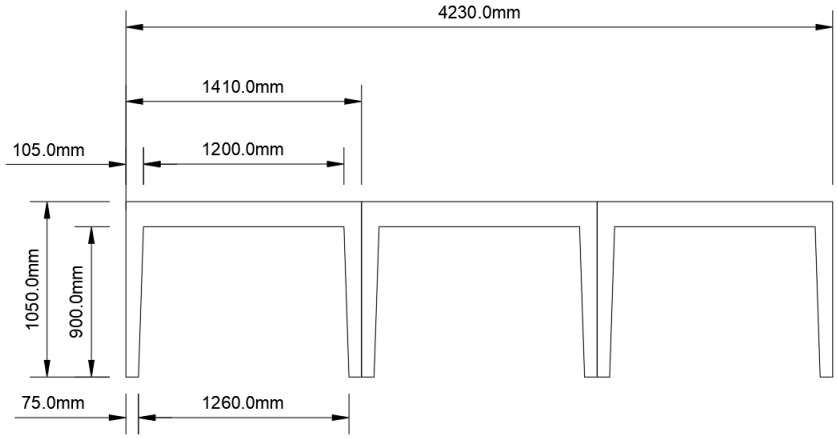


Figure 8: *Culvert A – 3/900x1200 RCBC*

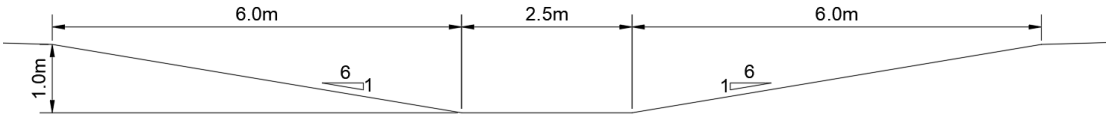


Figure 9: *Open Swale C*

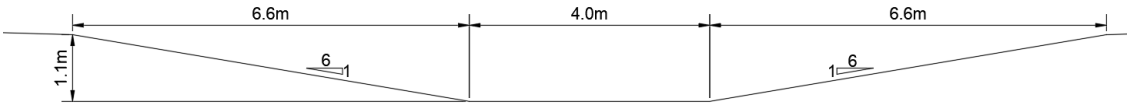


Figure 10: *Open Swale D*

The Budget Estimate Cost of these works is **approximately $590,000.** Refer to **Appendix I**.

6.2 CATCHMENT B

This catchment is bound by Pindi Street to the north, a small ridge to the east and proposed OT6 to the west and south (refer to **Appendix H**). It is noted that there is a proposed Solar Farm (OT2) within this catchment, however this has minimal impact on flooding.

To allow the catchment to drain to the western wetlands, it is calculated that three (3) 900x1200 RCBC's (Culvert B) (Refer to **Figure 11**) are required across OT6, south of the existing treatment pond. These culverts discharge into another analysed catchment area south-west of OT6 which is detailed further in this report (refer to **Appendix C**). Culvert B is suggested to be installed with backflow devices to prevent the build up of the wetland area (Catchment E) from entering Catchment B.

The location of these RCBC's is proposed to align with the existing open swale within the catchment which is evident from contours leading from Pindi St to the existing wetland and other open swales to the south. Sizing of these culverts is dependent on downstream catchments being able to free drain without backflow.

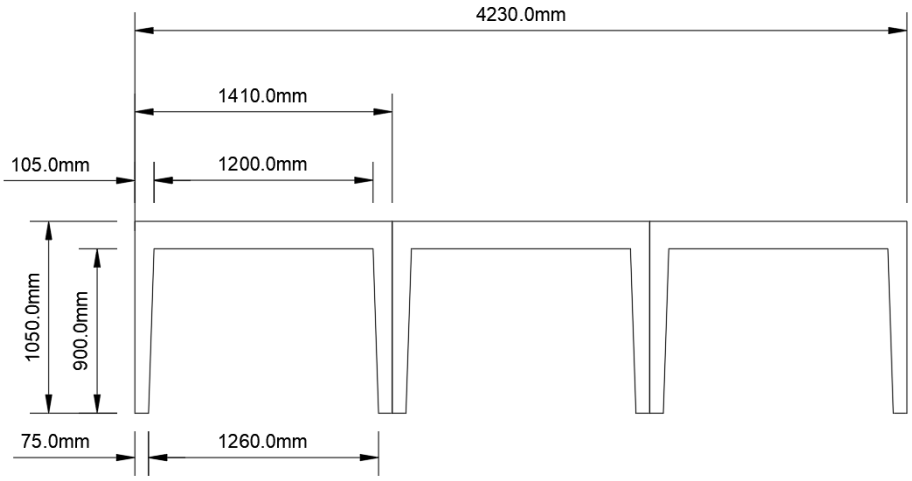


Figure 11: *Culvert B – 3/900x1200 RCBC*

The Budget Estimate Cost of these works is **approximately $185,000**. Refer to **Appendix I**.

6.3 CATCHMENT C

Catchment C includes a high risk flooding area which impacts on residences and also contributes to flooding concerns within Catchment D. The area is bound by the existing ridge line adjoining Catchment B, north to Pindi Street and east to Papulenthrkunt Street. Within the catchment are existing drains that flow in a south-westerly direction to the existing wetlands (refer to **Appendix H**). OT6 impacts the southern boundary of this

catchment and it has been calculated that four (4) 900x1200 RCBC's (Culvert C) (Refer to **Figure 12**) are required to allow the free-drainage of the catchment to the south-west. It is expected that the existing open swale leading from Catchment D (Thartj Manengk Street) will be slightly realigned to divert the overland flows toward the culverts. This design is dependent on downstream Catchment F being free draining, not allowing backup to the culverts (refer to **Appendix D**).

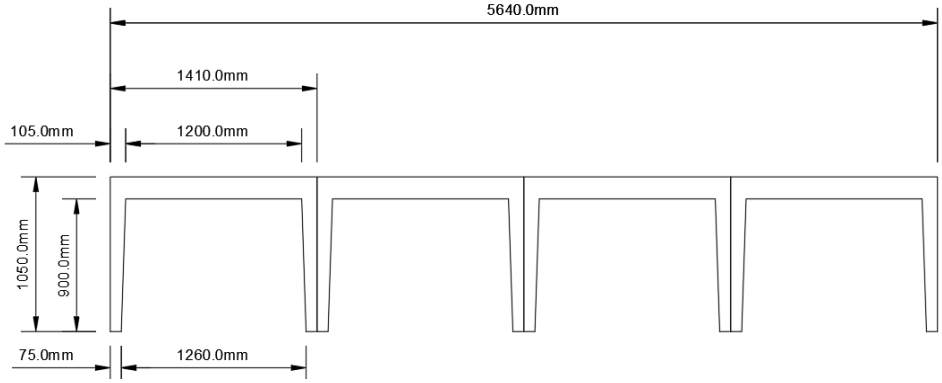


Figure 12: *Culvert C – 4/900x1200 RCBC*

The Budget Estimate Cost of these works is **approximately $226,000**. Refer to **Appendix H**.

6.4 CATCHMENT D

As identified within the Kowanyama Master Plan, Thartj Menangk Street is likely to be realigned (OT5), causing realignment of the existing open drain that adjoins the street. While this drain generally flows toward Magnificent Creek, it is identified within the flood study that significant backup (up to 1.0m) occurs within this drain. Within this catchment are three (3) separate sets of two (2) Reinforced Concrete Pipes (RCP) at 375mm diameter. These RCP's (Culvert D) discharge the airport catchment area into the existing drain (refer to **Appendix H**).

During a rainfall event where Magnificent Creek backs up to Thartj Menangk Street (or the flood gates are closed), this drain needs the ability to overflow to the west (Catchment C). Given the current heights of properties and Kowanyama Road, the crossing of Kowanyama Road is required to accommodate drainage from the existing drain to the west, it is calculated that four (4) 600H x 900W RCBC's (Refer to **Figure 13**), for a total internal width of 3.6m are required for Culvert D (refer to **Appendix E**).

As the existing drain is approximately this width, it would be suitable to maintain the existing drain. For future development, it is understood that these culverts may require widening or

change of location based on the proposed realignment of Thatj Menangk Street (OT5). The existing outlet to Magnificent Creek along Thartj Menangk Street is suggested to be rock stabilised.

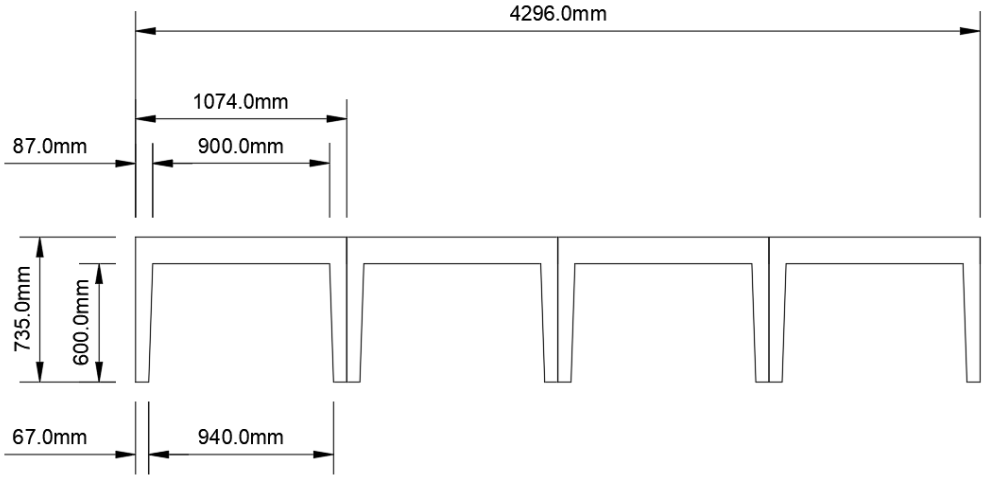


Figure 13: *Culvert D – 4/600x900 RCBC*

The Budget Estimate Cost of these works is **approximately $210,000**. Refer to **Appendix I**.

6.5 CATCHMENT E

This catchment is the largest catchment within the Kowanyama area, accepting flows from Catchment B, and potential overflows from Catchments C, D and F. It is identified within this catchment that there is a slight fall from proposed OT6 and upstream catchments to the south-west. The lowest contour surveyed appears to be 7m Australian Height Datum (AHD), in comparison to typically 8-9m in upstream catchments. This is a minimal change in grade over a catchment length of approximately 3km (refer to **Appendix H**).

Currently, this catchment is bound by a ridge to the west where it is unable to discharge into Gooseberry Creek. As the majority of the upstream catchments are collected within Magnificent Creek, this extension typically runs dry with a high capacity for accepting flows from Kowanyama to the East.

To discharge such a large catchment, and contributing catchments from within Kowanyama, it is proposed to construct an Open Swale A (Refer to **Figure 14**) from the lowest point of the wetland toward Gooseberry Creek. This channel is approximately 280m in length, requiring a base width of 6m (total width 14m) to allow free draining. It is designed to allow for flows to a depth of 1m, reducing the velocity of water discharging into the creek to minimise scour and discharging at a height of 6m AHD (0.35% fall).

It is envisaged that OT6 will be constructed to a flood immune level that will contain any back up of flooding to the western catchment. Culvert B (Catchment B) is suggested to be installed with backflow devices to prevent the build-up of the wetland area from entering Catchment B.

With the above measures, Catchment E will be able to free drain the flood prone areas to the existing creek, improving the impacts of flooding to Kowanyama on a large scale (refer to **Appendix F**). This makes completing these works a priority.

The environmental constraints on this option would also need to be reviewed however, the backflow device could be set at a level that should be able to satisfy any environmental constraints.

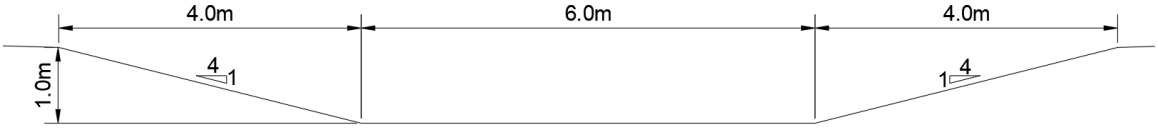


Figure 14: *Open Swale A*

The Budget Estimate Cost of these works is **approximately $236,000**. Refer to **Appendix I**.

6.6 CATCHMENT F

This area is bound by proposed OT6 to the north where contribution catchments C and D enter via proposed Culvert C. (refer to **Appendix H**). Backflow devices are expected to be provided here to limit backflow of Catchment F into Catchment C.

To allow this catchment to be free draining requires a discharge point to the south-west through the existing ridge on the edge of Gooseberry Creek. It is proposed to install Open Swale B (Refer to **Figure 15**) from the lowest point of the catchment (7m AHD) to Gooseberry Creek (6m AHD). To achieve this, the swale is proposed to be approximately 400m in length with a total width of 21.6m (refer to **Appendix G**).

This catchment being free draining is critical to Dunbar-Kowanyama Road as the main point of access to Kowanyama. This road borders the eastern boundary of the catchment and is expected to be at a suitable flood proof height, as there is no flood impact currently expected in this area.

Providing the proposed open swale with upstream culverts allows for the majority of localised flooding in the developed areas of Kowanyama to free drain to the west, where it is unlikely that backflow will occur. The environmental constraints on this option would also need to be reviewed however, the backflow device could be set at a level that should be able to satisfy any environmental constraints.

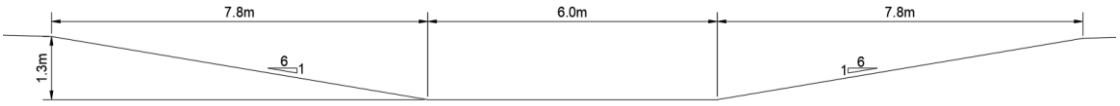


Figure 15: *Open Swale B*

The Budget Estimate Cost of these works is **approximately $440,000**. Refer to **Appendix I**.

6.7 STORMWATER PITS AND PIPES

As part of the proposed mitigation measures, we also considered the installation of additional positive drainage in the roads (i.e. Stormwater Pits and Pit). Without detailed survey it is difficult to exactly calculate the extents of the pit and pipework before it either comes out of the ground or the discharge becomes too low and the flows from Magnificent Creek start blocking off the flow control flaps. Based on LiDAR Survey we have estimated that approximately 1,600m of additional stormwater pipe could be installed with No. 24 inlet pits whilst remaining free draining in a 5 ARI event (1 in 5 year rainfall event) distributed over approximately 8 Streets/Roads:

- Chapman Road;
- Kowanyama Street;
- Gilbert White Street;
- Kunjun Street;
- Pindi Street;
- Carrington Street;
- Uwelkorig Street; and
- Karrengangang Street.

The stormwater pipes would flow from west to east and discharge into Magnificent Creek. Refer to ***Figure 16*** below.

The Budget Estimate Cost of these works is **approximately $700,000**. Refer to **Appendix I**.

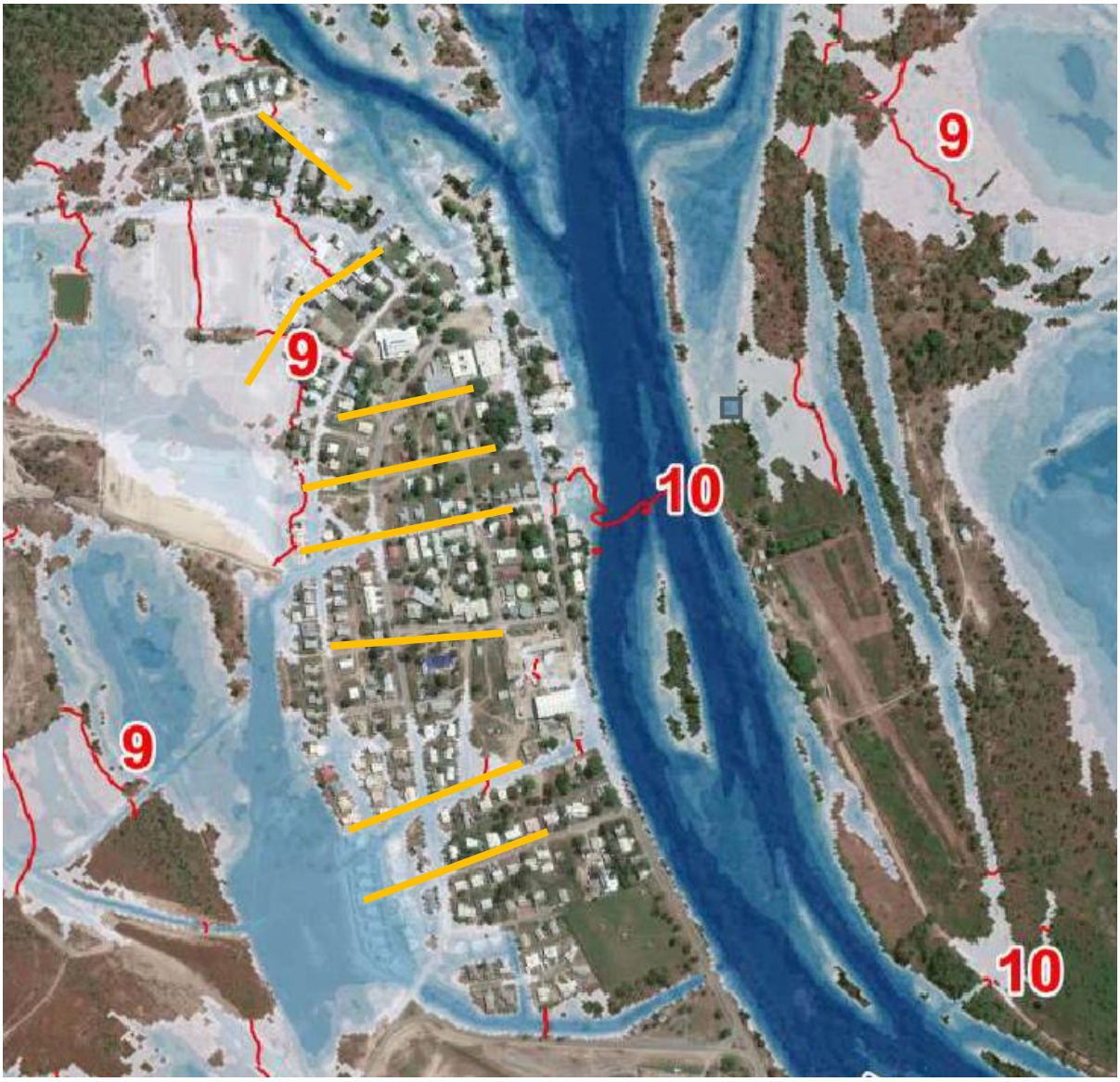


Figure 16: *Possible additional Stormwater Pit Pipe locations shown in yellow*

6.8 ROCK PROTECTION TO THE BANKS OF MAGNIFICENT CREEK

KASC flagged that significant erosion was occurring on the banks of Magnificent Creek and requested that it was captured as part of this flood study. According to KASC, erosion on the banks of Magnificent Creek is impacting fencing on properties that back onto Magnificent Creek. Chapman Road runs parallel to Magnificent Creek and in its southern section it runs in close proximity to its bank. **Figure 17** was provided by KASC and shows erosion occurring behind a property that backs onto Magnificent Creek.

Figure 17: *Erosion occurring on the western bank of Magnificent Creek (Source: KASC)*

To ensure the erosion occurring on Magnificent Creeks banks is controlled, it is proposed that approximately 1200m of dumped rock protection be installed at 3m high on the western bank of Magnificent Creek. Refer to **Figure 18** below for the extent of the dumped rock protection.

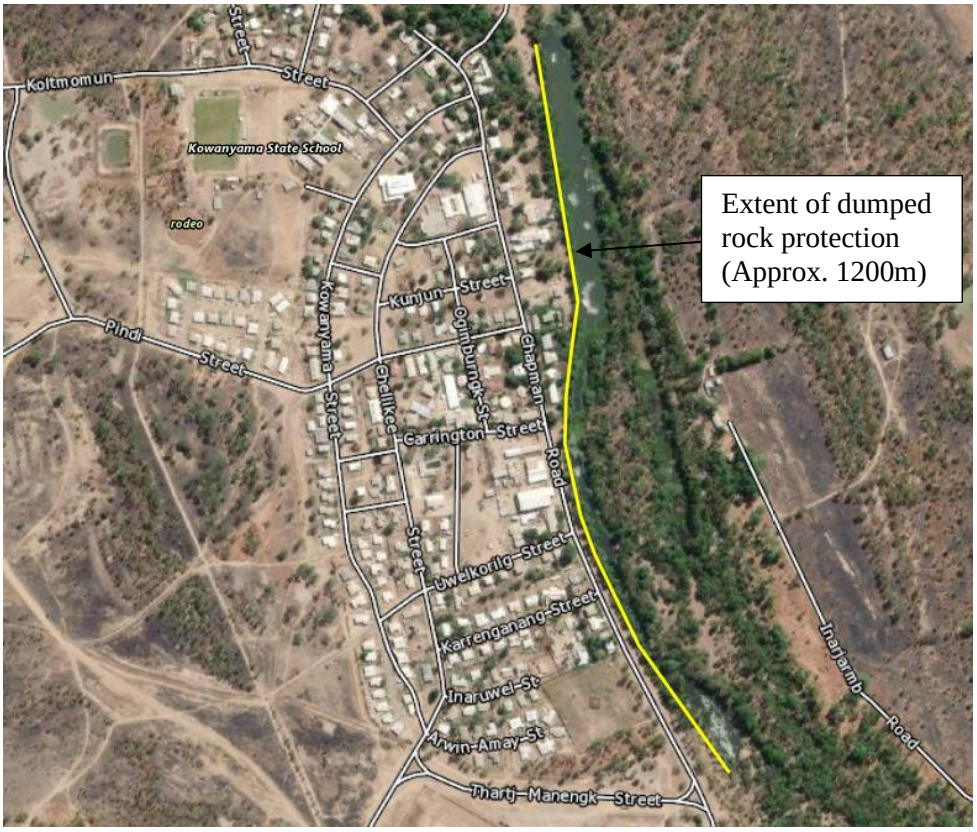


Figure 18: *Extent of dumped rock protection on bank of Magnificent Creek (Source: Q*ueensland *Globe)*

The Budget Estimate Cost of these works is **approximately $340,000**. Refer to **Appendix I**.

6.9 EXISTING CAUSEWAY/FLOODWAY

Please note that as part of the local drainage section of this report we have not addressed the condition of the existing causeways/floodway across Magnificent Creek. As we are not able to use local drainage calculations to determine the requirements for the causeway/floodway it is outside of the abilities of this report. Additional, flood modelling (i.e. with Regional Flooding) would be required to allow us to investigate this Mitigation Option.

7.0 RECOMMENDATIONS

7.1 STORMWATER INFRASTRUCTURE

7.1.1 Discharge to Magnificent Creek

The remaining existing infrastructure within Kowanyama that discharges to Magnificent Creek are recommended to be installed with backflow devices and provided with rock protection to the edge of the creek. The size of the existing RCP's as described in **Table 2** are likely to have minimal capacity for the serviced catchments. With the proposed works undertaken, there is expected to be a relief to the flooding impact and less demand on the existing infrastructure. The eastern portion of the site is expected to maintain drainage to Magnificent Creek, however in the case of extreme flooding (ARI 100), backflow is able to discharge to the west.

Due to backflow devices, Magnificent Creek would be likely to rise higher toward the bank. Rock Protection to the banks and surrounding the outlets of RCP's is recommended to stabilise the creek.

Installing the back flow devices and providing rock protection to the existing infrastructure is deemed a priority over the other recommendations.

7.1.2 Access Across Magnificent Creek (North)

Access across Magnificent Creek to the north via Kowulhyalalh Road is currently via an invert causeway. With expected flood depths to between 1 to 2 m in this area, it is suggested to upgrade the invert causeway to RCBC's. A minimum width of 15m and height of 1.2m is required to allow access through this road, while maintaining the flows through this section of Magnificent Creek.

It is noted that Kowulhyalalh Road does not provide access to other townships, only providing connection to other areas of creek systems. This route does not present a high risk for access restrictions to/from Kowanyama and therefore is not analysed in detail as part of this study and is not deemed a high priority.

7.1.3 Access Across Magnificent Creek (East)

The existing RCBC cells across Magnificent Creek via Shelfo Road are currently at 750H x 1200W. As the flood depths through this area exceed 1m, it is recommended to increase the size of these cells to 1200H x 1200W. An increase in size will allow for better flow of the creek and improve the flood level of Shelfo Road.

It is noted that Shelfo Road connects only to further creek systems, not providing access to Kowanyama from other townships or such. This route is not considered a high risk for restricting access to/from Kowanyama and is not further analysed as part of this study and is not deemed a high priority.

7.1.4 Access to Airport

The 1% AEP flood mapping indicated that Shelfo Road provides access to the Airport, with a flood depth of approximately 0.1m over the road. If Council wishes to reduce this impact further, it is recommended to duplicate the existing 450x1200 RCBC to allow greater flow through to Magnificent Creek, however this is a low priority as the road is not heavily impacted. Therefore, no further detailed analysis was conducted as part of this study.

7.2 ROAD INFRASTRUCTURE

Through the site inspection it is noted that the existing transport infrastructure is of poor condition. While roads are sealed, there is limited drainage provided, impacting on the overall pavement quality. It is observed in surrounding localities that concrete pavers have been utilised to improve access tracks through the community.

It is highly recommended that road pavements be improved to concrete and designed to a suitable flood immunity level to improve access to all areas throughout Kowanyama.

8.0 COST ESTIMATE

8.1 MITIGATION OPTIONS

Details of cost estimates for each mitigation option in **Section 6.0** above are detailed within **Appendix I**. The rates used have been based on local Cairns rates times a factor of 3 (x3) to represent the rate inflation experienced in Kowanyama.

The culvert structures proposed have been designed and based on standard sizing of pre-cast structures available from several suppliers.

These culverts also require road base material and sealing to support traffic over these areas. As identified within the Kowanyama Master Plan, the Industrial Bypass Road is expected to be designed to a necessary standard for industrial traffic. These costs for pavement design and souring of road materials have not been included within this assessment.

As the recommendations provided are expected to improve the impact of local drainage issues, the further suggested options have not been considered in detail. These optional improvements include:

- Upgrade to causeway along Kowulhyalalh Road;
- Doubling the existing RCBC accessing the Airport;
- Increasing the size of RCBC along Shelfo Road crossing Magnificent Creek; and
- Installing backflow prevention devices.

Detailed cost estimates have only been provided for increasing the size RCBC along Shelfo Road and installing backflow prevention devices as part of this report.

9.0 CONCLUSION

The findings from this Local Drainage Assessment are that the Township of Kowanyama requires substantial stormwater infrastructure improvements to assist in providing increased flood relief to the Community.

An objective of this project was to review the current master plan in retrospect of potential flood events in regard to access, safety and the wellbeing of the Kowanyama community. Based on the current Master Plan and observed local drainage issues, the Township of Kowanyama requires numerous additional stormwater infrastructure at key locations to ensure flooding can free drain away from existing development areas as well as allowing for future development. Langtree Consulting have recommended eight (8) specific mitigation measures with budget estimate costing as well as four (4) other mitigation measures for consideration.

It is hoped that this report assists Council in highlighting the constant flooding issues that they are facing on a regular basis and that sufficient funds can be secured to allow the mitigation measures contained in this report to be designed and constructed.

10.0 CERTIFICATION STATEMENT AND AUTHORISATION

This report has been prepared under the direction of Brett Langtree (RPEQ No 11932), a civil engineer with 24 years' experience in the planning, design and implementation of urban residential, industrial and commercial land development and the provision of infrastructure services to urban and rural communities and the preparation of stormwater assessments for developments.

……..

Brett Langtree – Principal Civil Engineer (RPEQ No 11932), Langtree Consulting

Date: 12 August 2021

APPENDIX A:
KOWANYAMA FLOOD STUDY (REF: R.M00311.001.03)

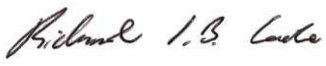
Kowanyama Flood Study

Regional Flooding Report

Reference: R.M00311.001.03
Date: 27 September 2021

Document Control Sheet

Client	Langtree Consulting				
Client Contact	Brett Langtree				
Project Manager	Mark Jempson				
Report Name	Kowanyama Flood Study Regional Flooding Report				
Report Reference	R.M00311.001.03				
Authors	Richard Gale				
Issued to	Version Number				
	0	1	2	3	4
Langtree Consulting	1	1	1	1	

	Name	Signature	Version Number	Date
Prepared by	Richard Gale		3	27/09/2021
Reviewed by	Mark Jempson			27/09/2021

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Executive Summary

Flood modelling of the Magnificent Creek was undertaken to prepare 1% (1 in 100) AEP (annual exceedance probability) flood mapping of Kowanyama. The flood mapping includes depth, flood level, extent, velocity and hazard. The modelling represented flow in the Magnificent Creek but did not include local rainfall over Kowanyama and surrounds. This is noteworthy as during the wet season and in periods of extended rainfall on the town and surrounding areas, water ponds and takes a long time to drain away. A separate report prepared by Langtree Consulting assesses local catchment flooding and drainage. Although flood mapping was only prepared for the 1% AEP event, the assessment established that the flooding would be very similar in more frequent events such as the 5% (1 in 20) AEP event.

Community input was obtained during the model development phase and used to improve and validate the model.

The assessment established that Magnificent Creek flooding is primarily a result of overflows from the Mitchell River and that there is only a small difference in peak flows from more frequent up to rare events. This phenomenon of relatively small increase in peak flood flows is typical for these highly distributed geographical floodplains.

The assessment established that the majority of the town of Kowanyama is not flooded from Magnificent Creek in the 1% AEP event. Areas that do flood include:

- a small section of the airport;
- residential properties at the southern end of Kowanyama Street;
- a number of streets as a result of backflow up stormwater pipes from Magnificent Creek – predominantly sections of Chapman Road, Uwelkorikg Street and Pindi Street);
- the northern end of town near Chapman Road and Koltmomun Street;
- west of Kowanyama where there is significant ponding even without considering local rainfall

The flooding in Kowanyama is a predominantly a result of water backing up channels/drains, backflow through some of the stormwater pipes, and minor overtopping of the riverbank. There are existing manually operated flood gates on the culvert at the outlet of the southern drain into Magnificent Creek. The flood modelling and mapping was done with these culverts both open and closed.

Closing of the gates was found to provide most benefit to properties at the southern end of Kowanyama Street. With the gates open there are a number of properties where the flooding would be classified as unsafe for vehicles, children and the elderly. With the gates closed the hazard is reduced to only being unsafe for small vehicles. Flood level survey was not available to establish if there would be above flood flooding.

A number of mitigation concepts are provided for future consideration.

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Glossary

Annual Exceedance Probability (AEP)	The probability or likelihood of an event occurring or being exceeded within any given year, usually expressed as a percentage
Australian Height Datum (AHD)	The national height datum that approximately corresponds to the mean sea level around Australia. The level is represented by metres above or below this level
BoM	Bureau of Meteorology
Catchment	The area of land that contributes to flooding at a particular location, this includes upstream creeks and tributaries and may cover an area of several hundred or thousand square kilometres
DEM	Digital Elevation Model
Flood Model	A flood model combines both the hydrologic and hydraulic models to represent flooding behaviour at a particular location
Floodplain	The area of land subject to inundation by riverine flooding
GIS	Graphical Information System
LiDAR	Light Detection and Ranging – ground survey captured by an aerial flyover using a laser. The time delay in laser pulse returns provides the distance, the refraction index of the return laser pulse provides information on the properties of the surface struck. For example water, soil, tree/vegetation, metal roofing, road, etc. LiDAR is typically postprocessed to remove spurious information and forms the basis of the DEM
Hydraulic Model	A hydraulic model simulate hydrodynamic flow behaviour of floods. Used to determine extent, level, depth, velocity, hazard of a flood based on flows from the hydrologic model
Hydrologic Model	A hydrologic model simulates catchment response to rainfall. The model simulates the rate of response and timing of the runoff (rainfall excess) and delay or lag to generate flows at a particular locations within the catchment
Manning's n	A roughness coefficient that is used to simulate the hydraulic roughness of a land use or material
Runoff	The proportion of rainfall that is converted to flow after groundwater infiltration has been removed
TUFLOW HPC	A 1D-2D implicit (TUFLOW Classic) or explicit (TUFLOW HPC) solver hydraulic modelling package

1 Introduction

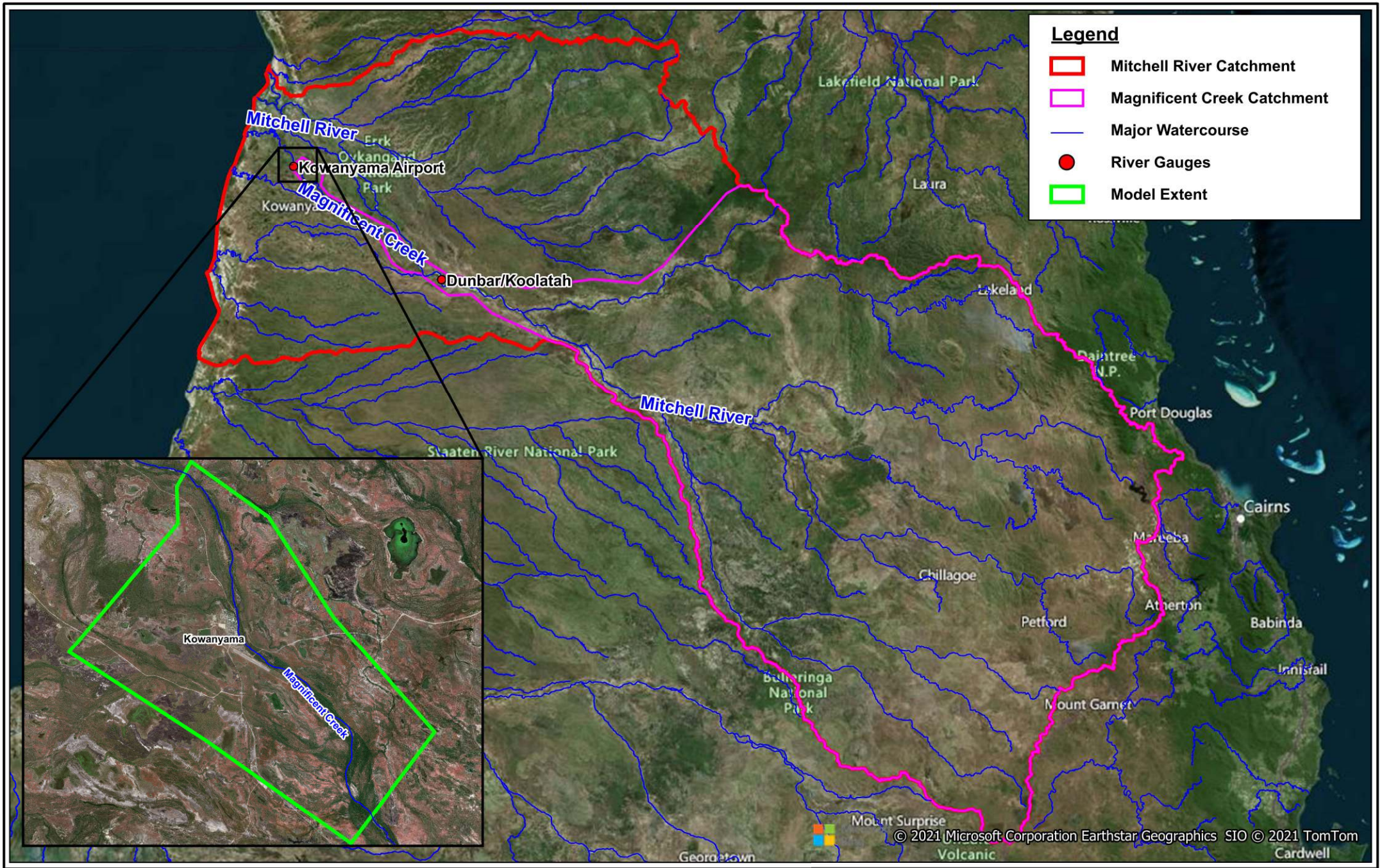
The town of Kowanyama is located on the banks of Magnificent Creek on the western seaboard of Cape York and has a population of approximately 1,000 people. During the wet season the community becomes isolated by road due to widespread flooding across the floodplain and is serviced during these months via the airport. Further, the town suffers from a number of drainage issues from both local runoff as well as back flows from Magnificent Creek which can result in access issues to the airport resulting in further disruptions.

Magnificent Creek is a 'perched' waterway meaning that the banks of the creek are higher than the surrounding floodplain. Kowanyama is built on these elevated perched banks of the creek and hence is flooded when the local watercourses and drains backup as the water level rises in Magnificent Creek. If the water level is sufficiently high in Magnificent Creek the banks themselves may be overtopped.

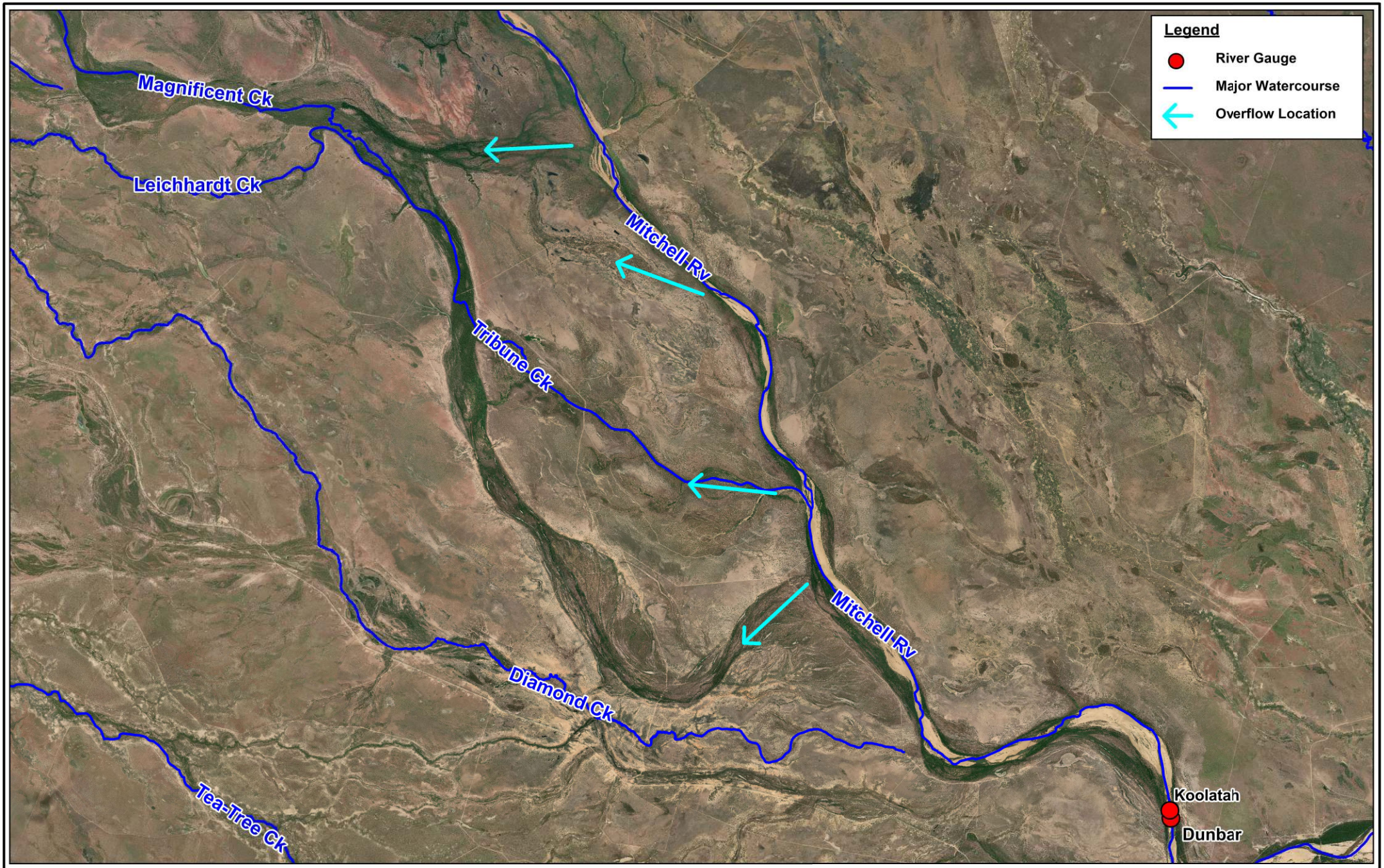
Magnificent Creek is a distributary of the Mitchell River which means that the Mitchell River overflows into Magnificent Creek. Magnificent Creek is also a distributary of Leichhardt Creek which is itself a distributary of the Mitchell River. Therefore, flooding on Magnificent Creek, and hence in Kowanyama, is significantly influenced by the flooding in the Mitchell River catchment. The total Mitchell River basin area is approximately 72,000 km^2, but at the location of the overflow into Magnificent Creek the catchment area is 46,000 km^2. The catchments are shown in Figure 1-1 and the locations of the overflow from the Mitchell River into Magnificent Creek is shown in Figure 1-2.

The overflow point, and hence headwater of Magnificent Creek is approximately 72 km upstream of Kowanyama. Along Magnificent Creek between the Mitchell River and Kowanyama there are a number of watercourse that are distributaries of Magnificent Creek and hence not all of the water overflowing into Magnificent Creek reaches Kowanyama. Downstream of Kowanyama the Magnificent Creek re-joins the Southern Mitchell River approximately 25 km upstream of the outlet to the Gulf of Carpentaria. To establish the magnitude of flooding in Kowanyama caused by Magnificent Creek flooding it is necessary to understand of the hydrology of the Mitchell River and the distributary system.

The Kowanyama Aboriginal Shire Council (Council) has commissioned this flood study to inform the Kowanyama Master Plan. This report by Venant Solutions is one of a number of inputs into the project and focusses on regional flooding in Kowanyama, i.e., flooding from Magnificent Creek. Langtree Consulting and others are assessing local catchment flooding/drainage and Master Plan recommendations. The primary output from this report by Venant Solutions is regional flood mapping including flood extent, depth, height and hazard for the 1%AEP (annual exceedance probability) design flood event. The report documents the methodology and modelling undertaken to prepare the flood mapping.



Title: Kowanyama Flood Study Study Area	Figure: 1-1	Rev: A	N 0 15 30km Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	VENANT SOLUTIONS www.VenantSolutions.com.au
Filepath: S:\Projects\M00311.MJ.KowanyamaFloodStudy\GIS\Drawings\R.M00311.001.00\Fig1-1_StudyArea.WOR				By: RG Date: Jun 2021	



Title: Kowanyama Flood Study Mitchell River Overflow into Magnificent Creek	Figure: 1-2	Rev: A	N 0 3.75 7.5km Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	VENANT SOLUTIONS www.VenantSolutions.com.au
Filepath: S:\Projects\M00311.MJ.KowanyamaFloodStudy\GIS\Drawings\R.M00311.001.00\Fig1-2_Overflow.WOR				By: RG Date: Jul 2021	

2 Methodology Overview

This chapter provides an overview of adopted methodology with further details and assessment provided in subsequent chapters. The key steps in establishing the regional flood mapping were as follows:

- Data collection;
- Hydrological modelling;
- Hydraulic modelling and mapping;
- Reporting.

Hydrological modelling assesses the entire catchment to establish the flow rate for different size floods, and hydraulic modelling is a detailed assessment in the area of interest to establish flood characteristics such as flood extent, depth, height, velocity and hazard. Hydraulic modelling has as an input the flow rates from the hydrological modelling.

There are numerous hydrological modelling approaches techniques available to establish the flow rate from a catchment for different size flood events. Once such approach is a flood frequency analysis (FFA) which requires historical data recorded at river gauges. A river gauge on Magnificent Creek at Kowanyama, Magnificent Creek at Kowanyama Airport (029038) has been recording water levels since February 2007, but fourteen years of record is too short a period to reliably estimate the 1% AEP flood event using a FFA. Further, there is no published rating curve to allow a conversion of the recorded water levels to flow rates (required for a FFA); a rating curve provides a relationship between water level and flow rate. Therefore an alternative approach was required.

As described in the introduction, flooding in Magnificent Creek is significantly influenced by overflow from the Mitchell River. Magnificent Creek being a perched watercourse also means that very little of rainfall falling on the local catchment flows to the creek, rather it mostly flows way from the creek. Therefore key to establishing the design flow rates in Magnificent Creek is establishing the design flow rates in the Mitchell River, and then working out how much of the Mitchell River design flow overflows into Magnificent Creek and arrives at Kowanyama. As noted in the introduction there are a number of distributary watercourses along Magnificent Creek which means that not all of the overflow from the Mitchell River remains in Magnificent Creek at Kowanyama.

Fortunately there is a river gauge on the Mitchell River just upstream of the location where the overflow into Magnificent Creek occurs (see Figure 1-2). The gauge, Mitchell River at Dunbar (919009B) commenced in November 2009 and is still operational. The Dunbar gauge replaced the Mitchell River at Koolatah gauge (919009A) which was located 800 m upstream and commenced operation in 1972. This means there is a continuous record of river heights at this location for 49 years. There is a published rating curve for both gauges and hence flow rates are also published. Therefore the annual maximum flow rate for the 49 year period was used to undertake a flood frequency analysis (FFA) to establish the 1%, 2% and 5% AEP peak flow rates in the Mitchell River.

The next challenge was to quantity the flow reaching Kowanyama. The initial, and ultimately unsuccessful, approach was to develop a regional two-dimensional (2D) hydraulic model, based on the TUFLOW software platform, of the Mitchell River, Magnificent Creek and other tributaries covering an area of approximately 1,800 km^2. The upstream extent of the regional model was located on the Mitchell River at the Dunbar gauge and extended to about 7 km downstream of Kowanyama. A 2D hydraulic model requires a digital elevation model (DEM) to represent ground levels. Detailed LiDAR data is available to develop a ground surface DEM over Kowanyama and

surrounds, however it only covers an area of about 78 km^2 which is well short of the coverage required for the regional hydraulic model. Where the high quality LiDAR was not available SRTM (Shuttle Radar Topography Mission) was used. The SRTM data was compared with Kowanyama LiDAR data and found to be on average 3.9 m high across the floodplains. Therefore the SRTM data was lowered by 3.9 m. In the watercourses it was lowered by a further 2 m based on the comparison with the Kowanyama LiDAR data. The peak flow recorded at the Dunbar gauge in the January 2021 event was run in 2D hydraulic model. The January 2021 flow was used rather than a design event flow to allow a validation with the recorded water level at the Kowanyama Airport gauge. In the model very little flow reached Kowanyama and consequently the water level in the model at the location of the gauge was significantly lower than the recorded level. A number of iterations were made to the model in attempt to improve the distribution of the flow, but to no avail. It was concluded that the vertical accuracy of SRTM data insufficient for reliably representing the overflow from the Mitchell River into Magnificent Creek and the overflows from Magnificent Creek into other tributaries.

Given it was not possible to reliably model the distribution of flows an alternative option to correlate flows at the Dunbar/Koolatah gauges with the Kowanyama Airport gauge was explored and ultimately adopted. The correlation involved plotting historical flows at Dunbar/Koolatah gauges against historical flows from the same event at the Kowanyama Airport gauge. As noted earlier there is no published rating curve for the Kowanyama Airport gauge and hence there are no published flows. Therefore a rating curve for the gauge was derived using the 2D hydraulic model at Kowanyama which allowed the recorded flood level data at the Kowanyama Airport gauge to be converted to flow rates. The rating curve was derived using the detailed 2D hydraulic model developed for Kowanyama, as described below, not the broader scale model described above. Using this correlation, design flows at Kowanyama were derived from the design flows at the Dunbar/Koolatah gauge, the latter being derived from the FFA analysis as described above.

As noted above a detailed 2D hydraulic model was developed covering the township pf Kowanyama and the surrounding floodplains. The model covers approximately 78 km^2 and extends from approximately 9 km upstream of Kowanyama to about 6.5 km downstream. At Kowanyama it is approximately 7 km wide and includes Gooseberry Creek to the south. The model uses the Kowanyama LiDAR data to define ground levels. A computational grid size of 5 m is used which is sufficient to represent the smaller key hydraulic features such as the drain at the southern end of Kowanyama and the channel at the northern end. The 1% AEP event was run on the model and output used to prepare flood extent, depth, height, velocity and hazard mapping.

3 Data

The following data was collated for the hydrological and hydraulic modelling:

- River gauges:
    - Magnificent Creek at Kowanyama Airport (029038) – Water levels from February 2007 to date;
    - Mitchell River at Dunbar (919009B) - Water levels and flows from November 2009 to date;
    - Mitchell River at Koolatah gauge (919009A) – Water levels and flow from July 1972 to November 2010;
- Rainfall
    - Kowanyama Airport (29038) – Daily Rainfall
    - Kowanyama - design rainfall intensity data (IFD) from BoM
- Topographic data:
    - Kowanyama LiDAR DEM;
    - SRTM hydro reinforced 1 second DEM;
- Pipe and culvert dimensions:
    - Field measurements by study team on keys structures influencing hydraulic interactions between drains/floodplains at Kowanyama;
    - Key drainage structures under roads in floodplain as well as crossing of Magnificent Creek.

The river gauge data was obtained from the Bureau of Meteorology (BoM) and the Queensland Government Water Monitoring Information Portal (https://water-monitoring.information.qld.gov.au/). The Kowanyama Airport gauge is manually read and hence are not a continuous record, whereas the Mitchell River gauges are continuous recorders. The Kowanyama Airport gauge data was initially provided by Council but only two years of data was supplied so the full record was obtained from the BoM.

4 Hydrological Assessment

Chapter 2 provided an overview of the hydrological modelling approach involving a FFA analysis at the Mitchell River to establish design event flow rates on the Mitchell River, immediately upstream of the overflow into Magnificent Creek, and the correlation between historical flows at the Mitchell River and at the Kowanyama Airport gauge. This chapter presents these analyses.

4.1 Flood Frequency Analysis

A Flood frequency Analysis was conducted to determine the flood quantiles from the annual maxima flow series for the combined flow series from the Mitchell River gauges at Dunbar and Koolatah. The FFA was performed in accordance with the guidance outlined in Book 3 Chapter 2 of Australian Rainfall Runoff (Kuczera and Franks 2019), using the Bayesian Framework incorporated into the TUFLOW Flike software package (v.5.0251.0).

The Regional Flood Frequency Estimation (RFFE) tool in ARR19 was not applied as the Mitchell River catchment area of approximately 46,000 km^2 at the gauge is considerably larger the recommended upper limit of 1,000 km^2 for this tool. Therefore outputs of the RFFE were not used to inform the priors of the LP3 parameters in the FFA.

The fitting of flood frequency distributions using Flike was undertaken with the following steps:

- Prepare data:
    - Collect gauged streamflow data;
    - Undertake standard data checks on the stream flow data including checking error codes, cataloguing data gaps and undertaking visual inspections;
    - Determine the water year;
    - Extract the annual maximum series and check peaks for independence.
- Using Flike, fit an extreme value distribution to the annual maximum series.

The analysis was done for the hydrological years (October to September) for 1972 to 2021. There were some years of missing record resulting in 42 years of flow data. The following distributions were tested:

- Log Normal
- 2-Parameter Log Normal
- Log-Person III
- GEV
- Generalised Pareto

The Generalised Pareto was considered to provide the best fit to the gauged data. The resulting flood quantiles are displayed in Table 4-1 and the resulting fit of the Generalised Pareto distribution to the flood data is in Figure 4-1. The annual maxima flow and the resulting fit from the other distributions is provided in Appendix.

There is only a small increase in the peak flow rate from the 10% AEP up to the 1% AEP. The likely reason for this is that there is a large overflow into another distributary creek system (Tea Tree Creek) a short distance upstream of the Dunbar gauge. It is possible that there are also breakouts to the north into other distributary creeks The effect of this is that the historical flows peak at around the

6000 m^3/s for the Mitchell River at Dunbar/Koolatah. This phenomenon of relatively small increase in peak flood flows from the 10% to the 1% (and larger) is often the case for these highly distributed geographical floodplains.

Table 4-1 FFA results for Mitchell River at Dunbar/Koolatah

AEP	Expected Quantile (m^3/s)	Lower 90% Quantile Confidence Limits (m^3/s)	Upper 90% Quantile Confidence Limits (m^3/s)
20%	5350	TBC	TBC
10%	5940	TBC	TBC
5%	6210	TBC	TBC
2%	6360	TBC	TBC
1%	6410	TBC	TBC

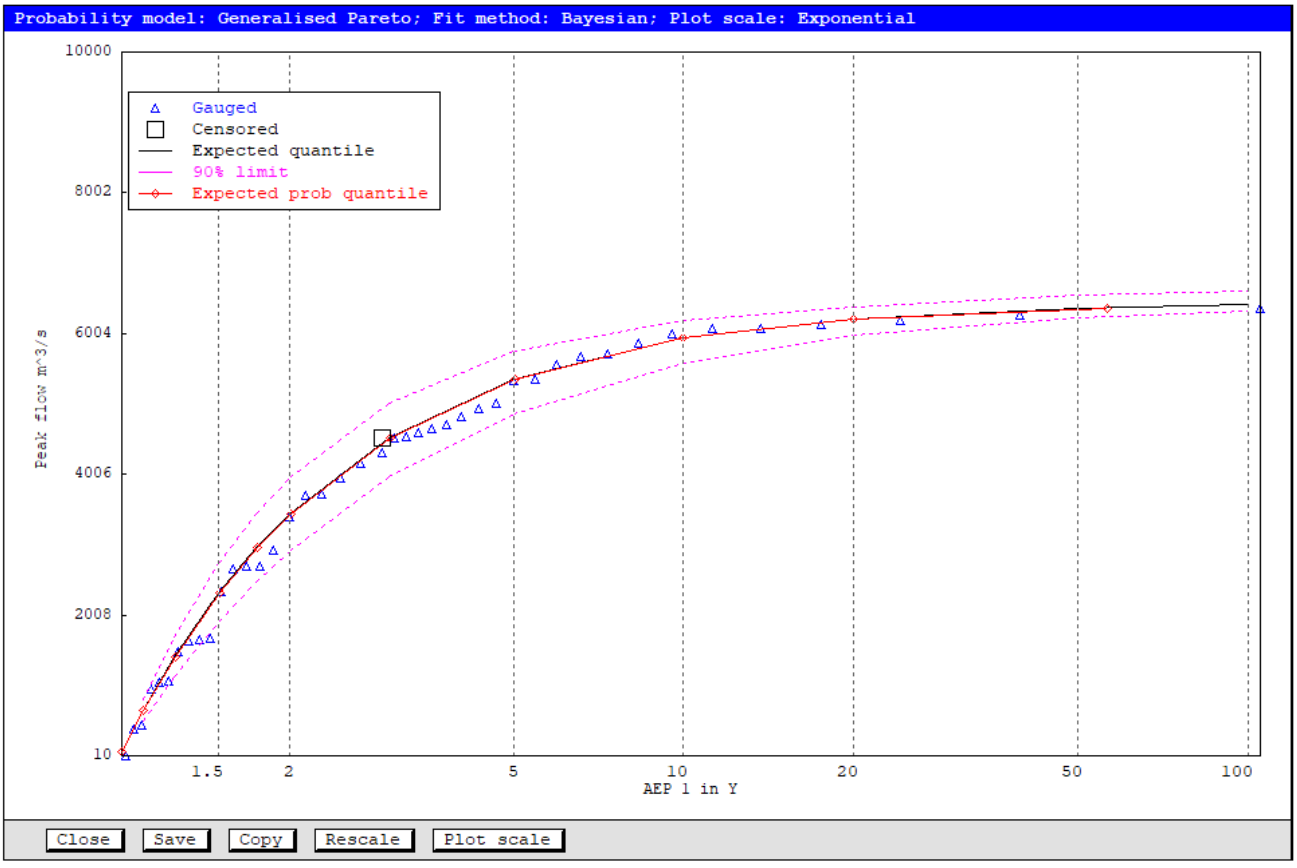


Figure 4-1 Flood frequency curve for the Mitchell River at Dunbar/Koolatah based on FFA

4.2 Kowanyama Gauge Correlation to Dunbar Gauge

As detailed in Chapter 2 a correlation between the flows in the Mitchell River at the Dunbar gauge and flows in Magnificent Creek at the Kowanyama Airport gauge was undertaken using historical flow data. The correlation was required to establish the design flows in Magnificent Creek at the Kowanyama Airport gauge. Also as detailed in Chapter 2 the Kowanyama Airport gauge does not have a published rating curve and hence only water levels are available. Therefore a rating curve was derived using the 2D hydraulic model run using a range of flow inputs; details of the hydraulic model setup are provided in Chapter 5.

Table 4-2 lists the recorded gauge height and peak flow (from the derived rating curve) at Magnificent Creek at the Kowanyama Airport gauge and the corresponding flows at the Dunbar/Koolatah gauges on the Mitchell River. As evident in the table there can be a delay of many days between the peak flow rate on the Mitchell River and the peak flow rate in Magnificent Creek at Kowanyama. This is because it is over 100 km between the gauges but also the size of the Mitchell River catchment means the floods are typically slow rising and stay elevated for many days. It is also noted that in 2010 when both Dunbar and Koolatah gauges were both still operating there is about a 7% difference in the reported flow at the gauges. The Dunbar gauge is the lower flow and it is located 800 m further downstream. There does not appear from the aerial photography to be an obvious overflow channel between the two gauges and based on the depth of flow recorded and the channel depth from the SRTM DEM it is unlikely that bank was overtopped. Therefore the difference in flow is likely a result of a difference in the respective rating curves rather than an actual difference in flow.

The values for each flood event in Table 4-2 are plotted in Figure 4-2. This indicates there is generally a reasonable correlation, except above 5000 m^3/s on the Mitchell River there is what could be considered two separate correlations. The reason behind this has not been explored further, but a possibility is that there the higher flows are a combination of local catchment runoff and Mitchell River overflow. For the purposes of this study a more conservative (higher flow) correlation is adopted.

The other exception is the February 2014 flood which plots as an outlier, but is also the highest level recorded at the gauge.. The flow in the Mitchell River was comparatively small but it is the largest event recorded at the Magnificent Creek at Kowanyama Airport gauge. This event was investigated further as follows:

- Flows were reviewed from gauges further up the Mitchell River and found to be consistent with the record at Dunbar indicating there was not an error in the Dunbar gauge. The quality reading at the gauge was fair thereby also supporting this conclusion);
- The daily rainfall records at Kowanyama were reviewed and compared with the design rainfall data for this location. The results of this analysis are presented in Table 4-3 which shows that over a 7-day period the total rainfall was greater than a 1 in 2000 event. This in combination with the comparatively small flows in the Mitchell River indicates that this was a very large event within the Magnificent Creek catchment. Because it was an event considerably larger than a 1% AEP, it has been ignored for the correlation.

Table 4-2 Flow Correlation between Magnificent Creek and Mitchell River

Magnificent Creek at Kowanyama Airport Gauge			**Dunbar/Koolatah Gauges**	
Date	**Recorded Gauge Height (m)***	**Peak Flow (m^3/s)**	**Date**	**Peak Flow (m^3/s)**
15/01/2021	4	312	8/01/2021	4508
27/02/2021	3.85	300	25/02/2021	5065
17/03/2020	2.4	127	12/03/2020	1676
10/02/2019	4.3	352	6/02/2019	5352
15/03/2018	3.6	278	13/03/2018	3708
22/01/2017	3.4	262	19/01/2017	2920
16/03/2016	2.9	195	14/03/2016	2151

Magnificent Creek at Kowanyama Airport Gauge			Dunbar/Koolatah Gauges	
9/02/2014	4.47	490	9/02/2014	1733
30/01/2013	3.89	303	27/01/2013	5554
25/03/2012	4.05	316	23/03/2012	4532
15/03/2011	4.34	367	12/03/2011	5685
5/02/2010	4	312	2/02/2010	5675/6072
14/02/2009	4.17	325	9/02/2009	6399
26/02/2008	4.4	374	22/02/2008	6162
14/02/2007	4.07	318	11/02/2007	6005

*Zero metres (gauge zero) on the Kowanyama Airport gauge is at 5.465 m AHD

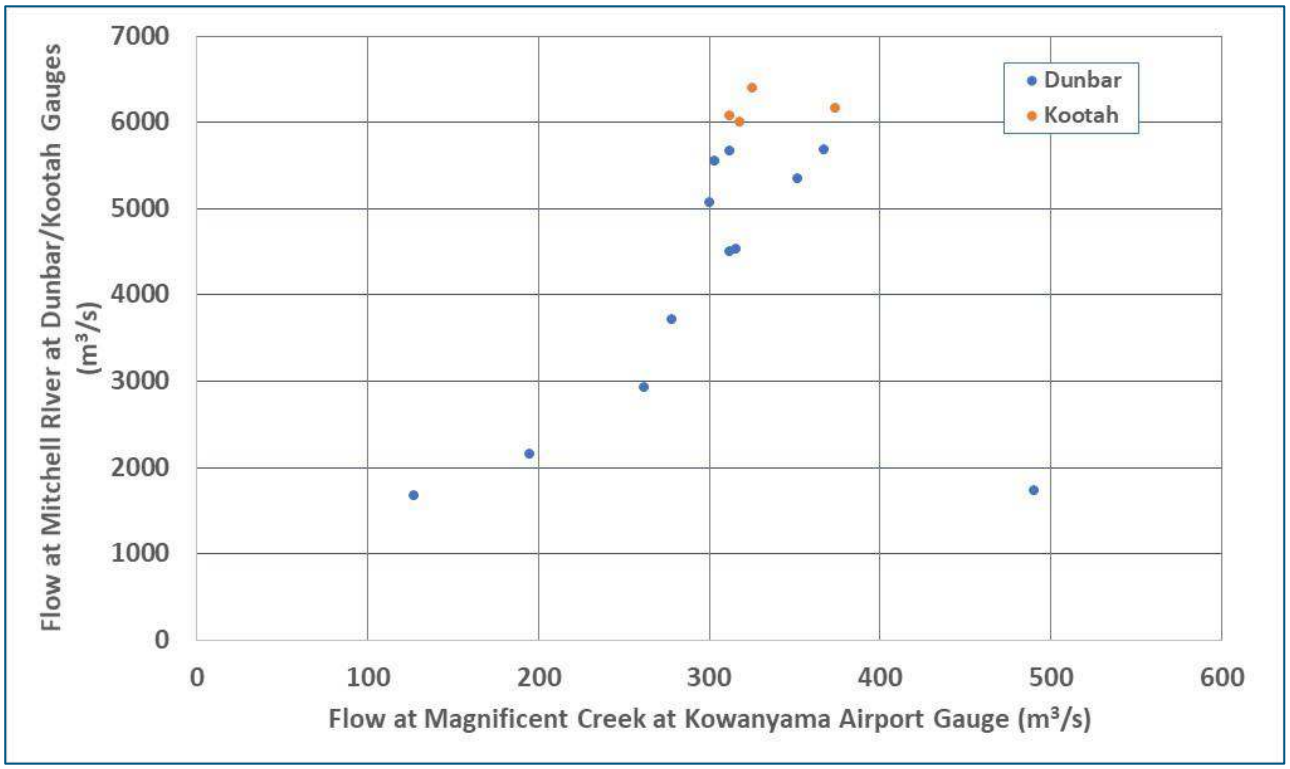


Figure 4-2 Flow Correlation between Mitchell River and Magnificent Creek

Table 4-3 Analysis of February 2014 Rainfall at Kowanyama Airport

Storm Duration (hrs)	Recorded Rainfall Total (mm)	Approximate AEP of Recorded Rainfall
24	361	1% (1 in 100)
48	536	0.5% (1 in 200)
72	726	0.33% (1 in 300)
96	879	0.13% (1 in 750)
120	1046	0.06% (1 in 1700)
144	1218	Rarer (larger) than 0.05% (> 1 in 2000)

4.3 Adopted Design Flows

Using the correlation in Figure 4-2 and the Mitchell River design flows from Table 4-1 the design flows in Magnificent Creek were derived and are summarised in Table 4-4. Like the Mitchell River there is no significant difference between the 5% and 1% AEP flows and is not unexpected for the hydrology and geographical conditions around the perched condition of Magnificent Creek.

Table 4-4 Magnificent Creek Design Flows

AEP	Mitchell River at Dunbar/Koolatah Design Flow (m^3/s)	Magnificent Creek at Kowanyama Airport Design Flows (m^3/s)
5%	6210	380
2%	6360	390
1%	6410	400

5 Hydraulic Modelling

This section documents the development of the hydraulic model and the calibration and validation process undertaken for this study.

5.1 Hydraulic Model Development

To produce the various mapping outputs required for the study, specifically flood extent, flood depth, velocity, and hazard, a two-dimensional (2D) hydraulic model was developed. A linked 1D/2D hydraulic model was developed using TUFLOW Highly Parallelised Computing (HPC). TUFLOW HPC solver uses an explicit finite volume solution scheme.

Within the TUFLOW HPC model the waterway and floodplain were represented in the 2D domain, with culverts represented as embedded 1D elements. The benefits of modelling the waterways and floodplain in the 2D domain include:

- Explicitly represents the spilling and remerging of flows between the waterway and the floodplain;
- Explicit modelling of bend losses;
- Accounts for contraction and expansion losses through constrictions; and
- Better representation of velocity across the waterway by providing cell-by-cell velocities across the waterways rather than limited to a horizontally averaged velocity.

The model only represented flow in the Magnificent Creek flooding Kowanyama which, as noted in Section 4, is predominantly flow from the Mitchell River system. This means that no local catchment rainfall was applied to the model domain. This is noteworthy as during the wet season and in periods of extended rainfall on the town and surrounding areas, water ponds and takes a long time to drain away. As this local rainfall ponding is separate to flooding from Magnificent Creek it was not modelled.

5.2 TUFLOW Model Version

Model runs were performed with the latest version (at time of assessment) build of TUFLOW HPC, specifically, 2020-10-AA-iSP-w64.

5.3 Design Events

For this draft hydraulics report, the hydraulic model was run for the 1% AEP event. The 5% and 2% AEP events were not run because of the insignificant difference in design flows (refer Table 4-4).

5.4 Model Extent

The extent of the hydraulic model was determined by the available Kowanyama LiDAR data. The model extent is shown in Figure 5-1.

5.5 Topography

The geometry of the 2D floodplain and watercourses were established by reading in a uniform grid of square elements from the DEM. This grid (or zpt layer) forms the basis of the hydraulic model. The DEM used in the hydraulic model was based on the Kowanyama LiDAR data.

5.6 Grid Resolution

One of the key considerations in hydraulic modelling is the selection of an appropriate grid element size. Grid element size affects the resolution, or degree of accuracy, of the representation of the physical properties of the study area as well as the size of the computer model and its resulting run times. Selecting a smaller grid size will result in both higher resolution and longer model run times.

To ensure accurate representation of flooding within the catchment a grid resolution of 5 metres was adopted for model. Sub-grid Sampling (SGS) was used, with heights sampled at 1 metre intervals along the side of each cell.

Sub-Grid Sampling

TUFLOW 2020-01-AA introduced a new method of representing topography in TUFLOW. Sub-grid Sampling uses curves representing the sub 2D cell terrain data to construct the model instead of each 2D cell and each 2D cell face having one elevation. The curves are made from heights sampled at set intervals (for example 1 metre) along the side of a 2D cell. SGS is only available in a model that is using TUFLOW HPC.

There are two main benefits to using SGS, both ameliorating the difficulties inherent in modelling on a grid with constant size and orientation. Firstly, SGS mitigates the effects of grid resolution. In sampling multiple points along the face of each cell variations in terrain can be represented in a single cell that would have previously taken several cells to accurately represent. Secondly, SGS is adept at representing a defined channel running at an angle to the grid. In the traditional method of topographical representation this would produce a pronounced 'saw-tooth' effect that incurred significant additional losses as the flow was forced at right angles. With SGS these losses are eliminated as the jagged edges to the mesh are effectively smoothed out. Whilst SGS is an important tool in improving the resolution of the representation of the terrain, it is important to recognise that the two-dimensional computations still occur at the grid resolution not the SGS resolution. Therefore in areas of complex two-dimension flow it is still important to adopt an appropriate grid resolution.

When compared to TUFLOW HPC, which treats each square grid element in the same way as TUFLOW Classic, SGS differs only in the topography, sampling from the DEM many times across the width of the cell. This allows SGS to have even more defined control of hydrodynamic elements, such as flood depth, volume and spilling at a sub-grid scale. The surface resistance to flow (Manning's 'n' value) is still sampled at ½ the grid resolution.

More information on the processes involved in the selection of cell heights and the benchmarking of SGS can be found in the TUFLOW 2020-01 Release Notes (BMT, 2020).

While SGS does have many advantages, models that use SGS have a slower run time than equivalent (same grid resolution) standard HPC models and a considerably higher RAM draw on start up.

Watercourses

The Magnificent Creek watercourse is at minimum 100 m wide (bank to bank) and much wider in many locations. The proposed grid size of 5 m means that there will be a minimum of 20 grids cells across the watercourse. The smallest of the important watercourses in the model is the drain at the southern end of Kowanyama. This drain is typically around 20 m to 25 m bank to bank which means that it will be represented by 4 to 5 grids. The TUFLOW manual suggests that key watercourses should preferably be represented by a minimum 3 to 4 grids, and hence the 5 m grid size is considered suitable for this model. As noted above the application of SGS provides additional resolution.

Viscosity

TUFLOW 2020-01-AA introduced a new approach to modelling sub grid scale turbulence (eddy viscosity) for HPC. Eddy viscosity is the turbulence that occurs at a scale that is impractical to model. The losses caused by this turbulence must be represented in hydraulic modelling in some manner. Previously, TUFLOW used the Smagorinski approach to determine these losses. While this is fine on large scale models with coarse grid sizes, as cell sizes are reduced and the cell size to flood depth ratio decreases it becomes less accurate. This is because the Smagorinski approach is proportional to cell size. The result of this is that the Smagorinski coefficients can end up becoming important calibration parameters. The latest TUFLOW release introduced the Wu eddy viscosity formulation as the default. This approach differs from that proposed by Smagorinski as it takes in to account both 2D and 3D effects and is not dependent on cell size.

5.7 1D Hydraulic Structures

Small, sub-grid sized, hydraulic structures such as culverts were modelled as 1D elements dynamically linked to the 2D domain. The culvert sizes were measured by Langtree Consulting during the field trip and inverts were set to match the ground level in the DEM. The location of each of the culverts is shown in Figure 5-1 and Figure 5-2.

The southern drain outlets to Magnificent Creek via a 3/1200 x 750 RCBC under Chapman Road. This RCBC has manually controlled gates that can be closed during flooding in Magnificent Creek to prevent backflow up the drain. Being manually closing gates it is plausible that there may be times when the gates are not closed or not closed in time. Therefore the model was run with and without the gates closed to understand the flood risk under both scenarios.

5.8 Boundary Conditions

The model requires both inflow and outflow boundaries. The locations of these boundaries are shown on Figure 5-1. The inflow boundary represents the flow in Magnificent Creek at the location of the upstream extent of the hydraulic model. The adopted 1% AEP design flow presented in Table 4-4 are at the location of the Kowanyama Airport gauge. To achieve this flow at the gauge required a higher inflow to account for the flow that spills out of the creek between the boundary and the gauge. Most of this outflow occurs only a short distance downstream of the boundary and hence well upstream from Kowanyama and into distributary channels to the west and east of Kowanyama. Ideally the model extent, and location of the inflow boundary, would be located further upstream to better present these outflows, but no LiDAR data was available to extend the model. Therefore the flood levels in the vicinity of the boundary and these overflow locations should be used with caution. Importantly this does not affect the flood mapping in Kowanyama, which is the primary focus of the assessment, because the model inflows were adjusted to achieve the 1% AEP flow at the gauge. To achieve the 1% AEP flow of 400 m^3/s at the gauge required an inflow of 800 m^3/s which indicates that approximately 50% of the flow spills into the distributary channels.

Because only peak flow estimates were available from the hydrologic assessment rather than a hydrograph (flow vs time) it is necessary to run the model in steady state. Normally where there are large floodplains, such as around Kowanyama, the volume of water as well as the peak flow is important in establishing flood levels and hence the model is run in unsteady state using a hydrograph inflow boundary. Running in steady state is normally conservative, i.e. it will produce higher flood levels. However, historically at Kowanyama the floods are relatively slow rising and over multiple days which means that a steady state analysis is appropriate. Further to develop

hydrographs for the design events was beyond the scope of works and would add considerably to the project cost without providing a significant benefit.

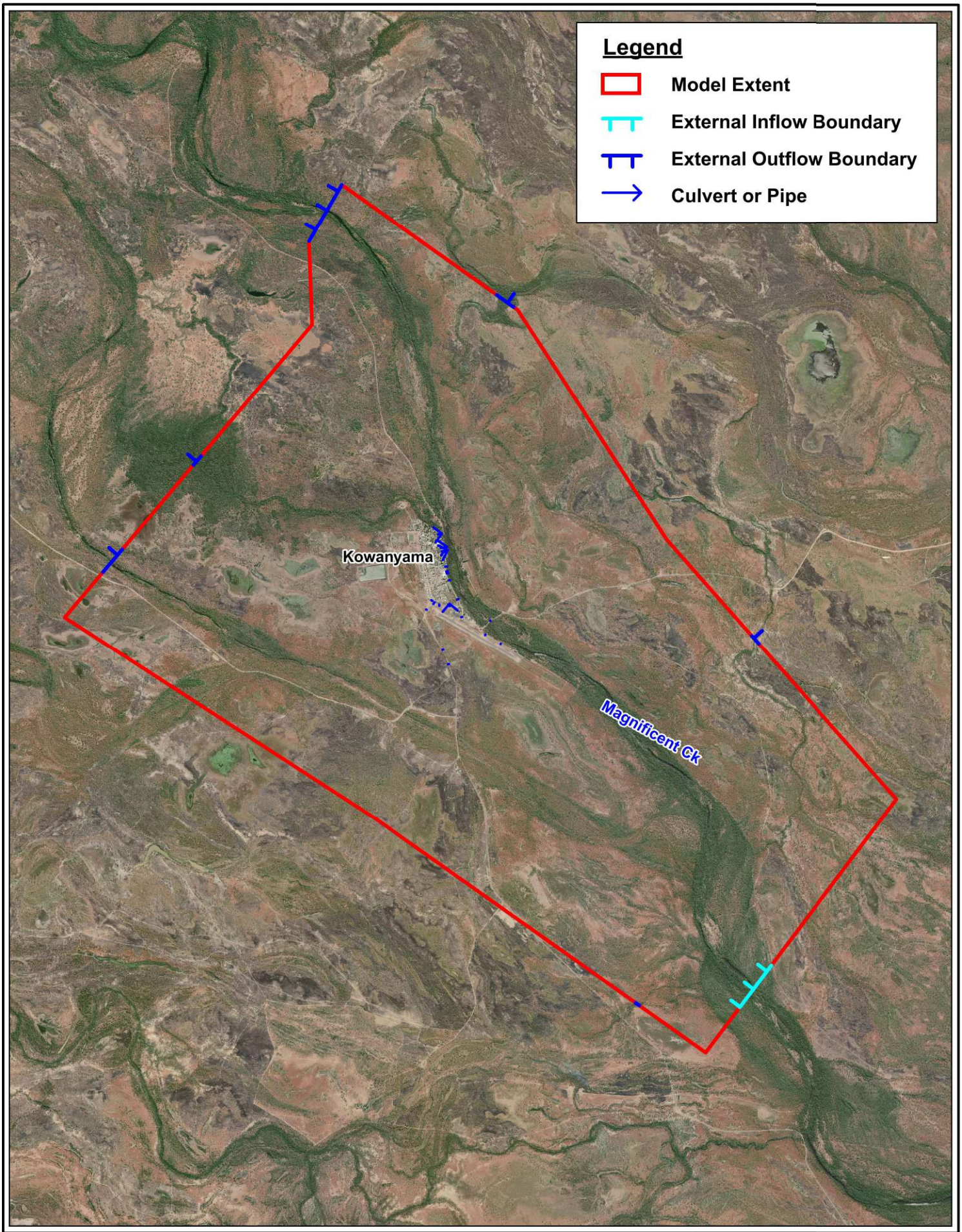
The outflow boundaries were represented as a stage discharge (HQ) boundary with the slope selected based on the general bed profile. A review of the flood surface output from the model confirmed that the outflow boundaries are not influencing flood levels in Kowanyama.

5.9 Surface Roughness

The surface roughness layer, or Manning's 'n' layer, for the floodplain were based on areas of different land-use type as indicated in the planning scheme, aerial photography and during the site inspections. The adopted manning's values are shown in Table 5-1 and the surface roughness layer is shown in Figure 5-3 and Figure 5-4.

Table 5-1 Surface Roughness Values

Land Use	Manning's 'n'
Roadways (including reserve)	0.025
Low Density Residential Areas	0.100
Farm Zones	0.050
Open Channel	0.033
Dense Vegetation	0.14



Title: Kowanyama Flood Study
Hydraulic Model Schematisation

Figure:	Rev:			By: RG
5-1	A	N 0 1.25 2.5km Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	Date: Jun 2021

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Title:
Kowanyama Flood Study
Hydraulic Model Schematisation - Zoom View

Figure:	Rev:			By:	
5-2	A	N	0 1.25 2.5km Approx. Scale	Date:	Jun 2021

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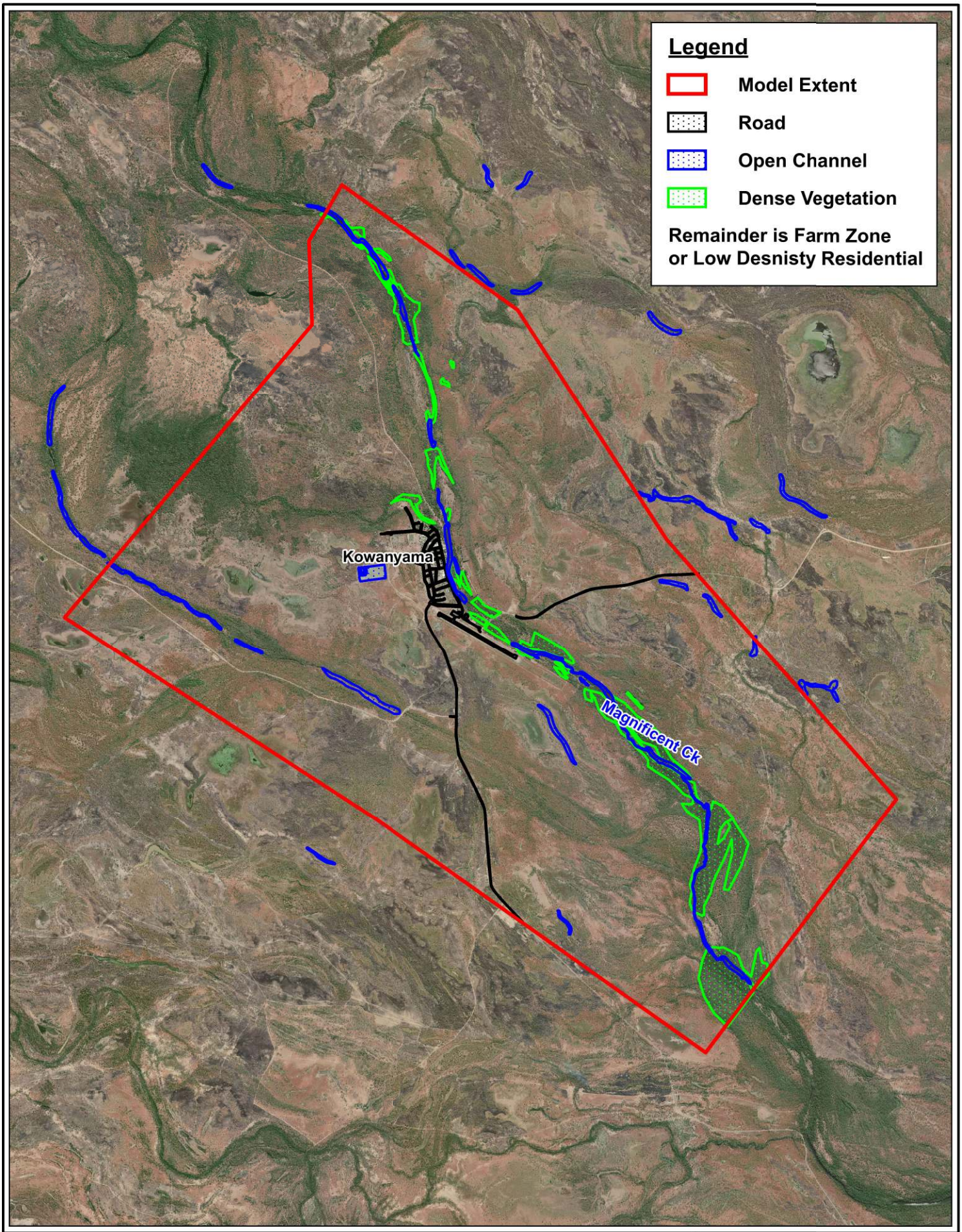

Title: Kowanyama Flood Study
Surface Roughness Distribution

Figure:	Rev:			By: RG
5-3	A	N	0 1.25 2.5km Approx. Scale	Date: Jun 2021

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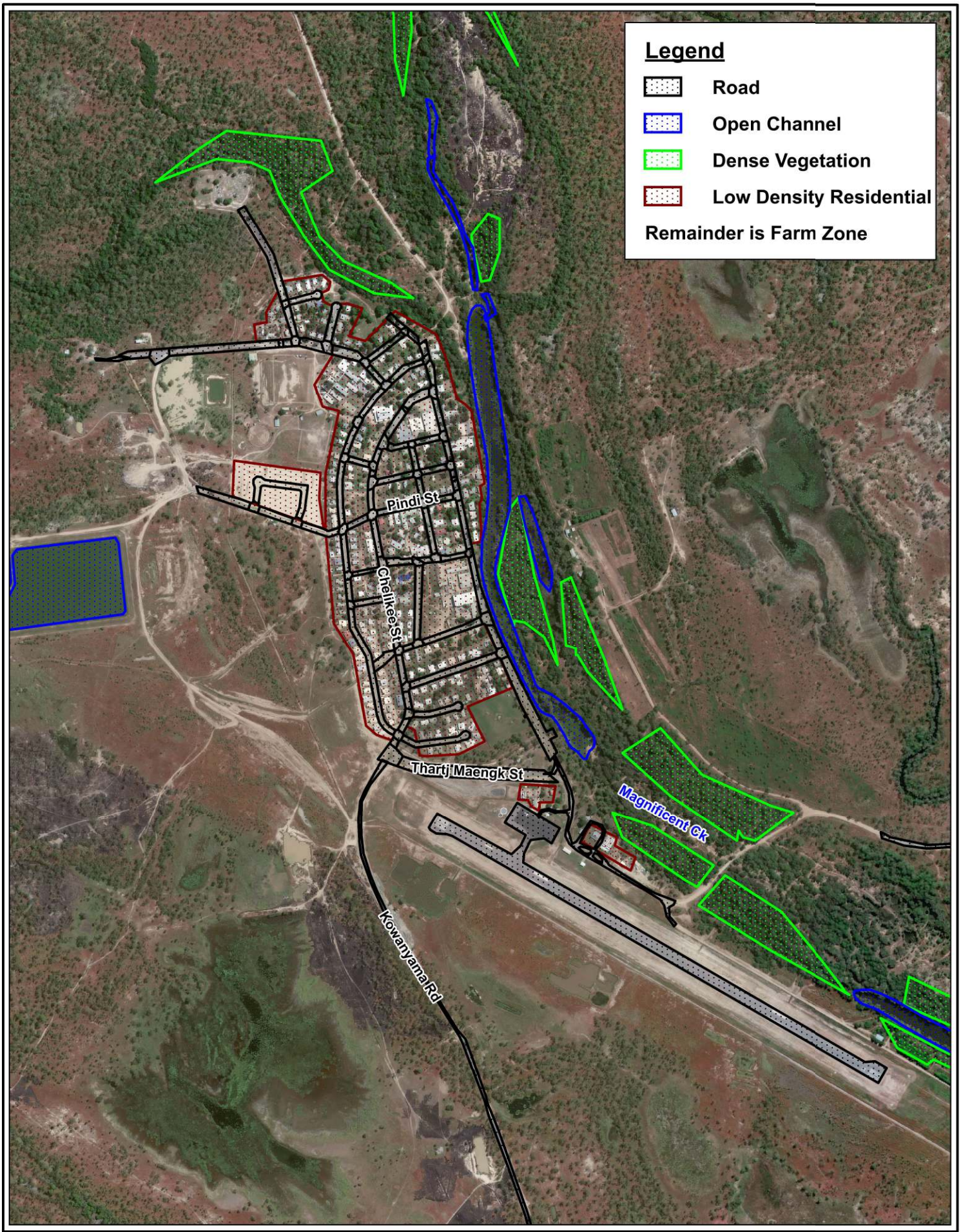

Title: Kowanyama Flood Study
Surface Roughness Distribution - Town

Figure:	Rev:			By: RG
5-4	A	N 0 250 500m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	Date: Jun 2021

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5.10 Hydraulic Model Calibration & Validation

Calibration of the hydraulic model refers to the process by which historical flood events are run through the model and the model outputs are compared to historical data such as gauge levels, surveyed flood marks and anecdotal information obtained from community members and photographs. To undertake a calibration of a hydraulic model requires a reliable estimate of the flow in the system during the historical flood event. As documented earlier in this report the hydrological regime in Magnificent Creek is complex and significantly more data and budget would be required to quantify the historical flows. Therefore calibration of the hydraulic model was not undertaken.

However, at the commencement of the project and prior to the development of the design hydrology a preliminary hydraulic model was setup and run with an arbitrarily selected large flow. Mapping was produced from this model run and used in the community consultation to obtain feedback on general flooding patterns and flood extents. At the time the Kowanyama Airport gauge data was not available to obtain an understanding of the size of the modelled event in comparison with historical flood events. The selected flow for this analysis was larger than the flow that was ultimately adopted for the 1% AEP event. Feedback from the community indicated that the model was representing typically observed flood extents well in and around Kowanyama. Feedback was provided that overflow from Magnificent Creek into Gooseberry Creek to the south had not been observed as was indicated on the preliminary mapping. Subsequently when the gauge data became available the inflow was lowered so that the water level in the model matched with the peak February 2021 gauge level. In this model run there was no overflow into Gooseberry Creek which was consistent with the local community observations.

Although anecdotal in nature, the feedback from the community on the initial modelling and mapping provided confidence that the model was generally consistent with community observations.

5.11 Design Event Modelling

As noted in Section 5.8 the inflow boundary was iteratively adjusted until the flow in the model at the Kowanyama Airport gauge location approximately matched the 1% AEP design flow of 400 m^3/s. Output from the model was then used to prepare the following mapping:

- Flood gate open
    - 1% AEP Flood depth, Extent and Height - Figure 5-5 and Figure 5-6;
    - 1% AEP Flood Velocity - Figure 5-7;
    - 1% AEP Flood Hazard - Figure 5-8;
- Flood gates closed
    - 1% AEP Flood depth, Extent and Height - Figure 5-9;
    - 1% AEP Flood Velocity - Figure 5-10;
    - 1% AEP Flood Hazard - Figure 5-11.

The flood hazard mapping is based on the H1 to H6 hazard classification in accordance with ARR19 as follows:

- H1 – generally safe for people, vehicles and buildings;
- H2 – unsafe for small vehicles;
- H3 – unsafe for vehicles, children and the elderly;

- H4 – unsafe for people and vehicles;
- H5 – unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure;
- H6 – Unsafe for vehicles and people. All building types considered vulnerable to failure.

5.11.1 Flood Gates Open

Figure 5-5 shows significant breakout flow to the north and south of Magnificant Creek upstream of Kowanyama. This is consistent with the feedback from the community consultation. Figure 5-6 shows that the majority of the town of Kowanyama is not flooded from Magnificent Creek in the 1% AEP event. The flooding that does occur is a predominantly a result of water backing up the southern channel combined with overtopping of the riverbank and backflow through some of the stormwater pipes. Areas that do flood include:

- a small section of the airport;
- residential properties at the southern end of Kowanyama Street;
- a number of streets as a result of backflow up stormwater pipes from Magnificent Creek – predominantly sections of Chapman Road, Uwelkorikg Street and Pindi Street);
- the northern end of town near Chapman Road and Koltmomun Street;
- west of Kowanyama where there is significant ponding even without considering local rainfall.

There is a new residential area off Pindi and Kowanyama Streets which the mapping shows as partially flooded. However the LiDAR was flown prior to the development of this area and hence the flood model may not accurately represent the ground levels within the development. Therefore results should be used with caution in this area.

Figure 5-7 shows that the flood velocity is highest in the channels and is generally below 0.5 m/s on the floodplain and in Kowanyama.

Figure 5-8 shows that all the flooding in Kowanyama is in the H1 – H3 categories with the majority of the flooding around the town classified as H1, which should be safe for all people and vehicles. However, there is an area of H3 classification on the houses at the southern end of Kowanyama Street. As H3 is classified as unsafe for vehicles, children and the elderly the occupants of these houses are potentially at risk during a flood event. Floor level survey data is not available to establish of the flooding would be above the floor level of these houses.

5.11.2 Flood Gates Closed

Assuming the flood gates are closed does not significantly influence the flood level in Magnificent Creek as can be seen by comparing the flood level contours in Figure 5-6 and Figure 5-9. Within Kowanyama the flood extent and levels are lower with the flood gates closed as would be expected as backflow up the southern drain is prevented. However the modelling indicates that there would still be flooding in the same areas listed above for the gates closed scenario.

At the southern end of Kowanyama Street there is still flooding at some of the residential properties albeit at a lower level (~8.75 m AHD compared with ~9.25 m AHD). There is also less extensive flooding at the new residential area off Pindi and Kowanyama Street, but as noted above the results from the flood model should be used with caution in this area.

The flooding at the northern end of town and in Chapman Road, Uwelkorikg and Pindi Streets is the same regardless of whether the gates are open or not.

Like the scenario with the flood gates open, the flood velocity is highest in the channels and is generally below 0.5 m/s on the floodplain and in Kowanyama (Figure 5-7).

With regards to flood hazard the main difference between the flood gates open and closed is at the houses at the southern end of Kowanyama Street. With the gates open the hazard classification around the houses is H3, but with gates closes the hazard is reduced to H2.

More detailed information on the flooding mechanisms affecting these locations and potential mitigation options is provided in Section 6.

Mapping shows inundation from Magnificent Creek flooding only. Inundation from rainfall on the town and surrounding areas is not included in this mapping.

Legend

- Inflow Boundary
- Outflow Boundary
- Model Extent
- 10.0 Flood Height (m AHD)

Flood Depth (metres)

- 0.00 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- 0.50 to 1.00
- 1.00 to 2.00
- 2.00 to 3.00
- > 3.00

8.5
9
9.5
10
10.5
11
11.5
12
12.5
13

Kowanyama

Magnificent Ck

Title: Kowanyama Flood Study - Whole Model
Flood Extent, Depth and Height Mapping - 1% AEP

Figure:	Rev:				
5-5	A	N	0 1 2km Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	By: RG Date: June 2021

Filepath: S:\Projects\M00311.MJ.KowanyamaFloodStudy\GIS\Drawings\R.M00311.001.00\Fig5-5_100y_Depth.WOR

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Mapping shows inundation from Magnificent Creek flooding only. Inundation from rainfall on the town and surrounding areas is not included in this mapping.

Model does not represent new residential development at this location

Legend

- Inflow Boundary
- Outflow Boundary
- Model Extent
- 10.0 Flood Height (m AHD)

Flood Depth (metres)

- 0.00 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- 0.50 to 1.00
- 1.00 to 2.00
- 2.00 to 3.00
- > 3.00

Title: Kowanyama Flood Study - Town Area - Gate Open
Flood Extent, Depth and Height Mapping - 1% AEP

Figure:	Rev:				
5-6	A	N	0 200 400m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	By: RG Date: June 2021

Filepath: S:\Projects\M00311.MJ.KowanyamaFloodStudy\GIS\Drawings\R.M00311.001.00\Fig5-6_100y_Depth_Town.WOR

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Mapping shows inundation from Magnificent Creek flooding only. Inundation from rainfall on the town and surrounding areas is not included in this mapping.

Model does not represent new residential development at this location →

Legend

- Inflow Boundary
- Outflow Boundary
- Model Extent

Flood Velocity (m / s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Title: Kowanyama Flood Study - Town Area - Gate Open
Flood Velocity - 1% AEP

Figure:	Rev:			By:
5-7	A	N	0 200 400m Approx. Scale	RG

This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.

Date: June 2021

Filepath: S:\Projects\M00311.MJ.KowanyamaFloodStudy\GIS\Drawings\R.M00311.001.00\Fig5-7_100y_Velocity_Town.WOR

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Mapping shows inundation from Magnificent Creek flooding only. Inundation from rainfall on the town and surrounding areas is not included in this mapping.

Model does not represent new residential development at this location

Legend

- Inflow Boundary
- Outflow Boundary
- Model Extent

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Title: Kowanyama Flood Study - Town Area - Gate Open
Flood Hazard Mapping - 1% AEP

Figure:	Rev:				By:
5-8	A	N	0 200 400m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	RG
					Date: June 2021

Filepath: S:\Projects\M00311.MJ.KowanyamaFloodStudy\GIS\Drawings\R.M00311.001.00\Fig5-8_100y_Hazard_Town.WOR

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Mapping shows inundation from Magnificent Creek flooding only. Inundation from rainfall on the town and surrounding areas is not included in this mapping.

Model does not represent new residential development at this location

Legend

- Inflow Boundary
- Outflow Boundary
- Model Extent
- 10.0 Flood Height (m AHD)

Flood Depth (metres)

- 0.00 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- 0.50 to 1.00
- 1.00 to 2.00
- 2.00 to 3.00
- > 3.00

Title: Kowanyama Flood Study - Town Area - Gate Closed
Flood Extent, Depth and Height Mapping - 1% AEP

Figure:	Rev:				
5-9	A	N	0 200 400m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	By: RG Date: June 2021

Filepath: S:\Projects\M00311.MJ.KowanyamaFloodStudy\GIS\Drawings\R.M00311.001.00\Fig5-9_D02_100y_Depth_Town.WOR

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Mapping shows inundation from Magnificent Creek flooding only. Inundation from rainfall on the town and surrounding areas is not included in this mapping.

Model does not represent new residential development at this location →

Legend

- Inflow Boundary
- Outflow Boundary
- Model Extent

Flood Velocity (m / s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Title: Kowanyama Flood Study - Town Area - Gate Closed
Flood Velocity - 1% AEP

Figure: 5-10 | Rev: A | N | 0 200 400m Approx. Scale

This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.

By: RG
Date: June 2021

Filepath: S:\Projects\M00311.MJ.KowanyamaFloodStudy\GIS\Drawings\R.M00311.001.00\Fig5-10_D02_100y_Velocity_Town.WOR

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Mapping shows inundation from Magnificent Creek flooding only. Inundation from rainfall on the town and surrounding areas is not included in this mapping.

Model does not represent new residential development at this location →

Legend

- Inflow Boundary
- Outflow Boundary
- Model Extent

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

Title: Kowanyama Flood Study - Town Area - Gate Closed
Flood Hazard Mapping - 1% AEP

Figure:	Rev:				By:
5-11	A	N	0 200 400m Approx. Scale	This mapping product is based on techniques and data in accordance with the study scope. Users should consider the mapping in the context of the report. No two floods are the same and care should be taken in the use and interpretation of the results presented.	RG
					Date: June 2021

Filepath: S:\Projects\M00311.MJ.KowanyamaFloodStudy\GIS\Drawings\R.M00311.001.00\Fig5-11_D02_100y_Hazard_Town.WOR

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6 Flood Mitigation Considerations

Assessment of options to mitigate Magnificent Creek flooding in Kowanyama is beyond the scope of this study, but some considerations in this regard are provided. None of the options presented here have been tested in the flood model to demonstrate their suitability or otherwise. It is recommended that this be undertaken as a preliminary investigation before adopting such measures for detailed design and construction.

Figure 6-1 shows a zoomed in view of the flood depth and extent mapping at the southern end of Kowanyama. The red lines on the maps are the existing culverts and stormwater pipes. At this location there are a number of houses on Kowanyama Street that are in floodwater that is classified as unsafe. Potential mitigation options are shown on the figure as follows:

1. Construct a levee across outlet of the drain from the airport and provide a culvert with a flap gate to prevent backflow. This will eliminate the backwater flooding at the airport from Magnificent Creek.
2. The modelling has shown that the existing manually operated flood gates provide some benefit in Kowanyama, particularly to the houses at the southern end of Kowanyama Street. It is recommended that these gates are maintained and ensure that robust operational procedures are in place so that the gates are closed as required.
3. Provide a levee on the riverbank to prevent overtopping into Uwelkorilg Street as well as protecting the houses along the riverbank on Chapman Road. There is also a small backflow from the creek through the stormwater pipe into Uwelkorilg Street. The mapping indicates that the flooding along Uwelkorilg Street is not impacting on the properties, but it does contribute volume to the flooding that is impacting on houses on Kowanyama Street. The backflow through the pipe is considerably less than the flow over the riverbank, but it is included for future consideration.
4. Widen the outlet channel to west. It is evident from the modelling and mapping that the current channel is restricting the outflow to the west and causing the water to pond and flood the properties.

Figure 6-2 shows a zoomed in view of the flood depth and extent mapping at the northern end of Kowanyama. At this location there are a small number of flooded properties as a result of backflow up a small gully and overtopping of a bank. There is also shallow flooding in Chapman Road and Pindi Street as a result of backflow through the stormwater pipes from Magnificent Creek. Potential mitigation options are shown on the figure as follows:

5. Levee to prevent flooding into properties on riverbank. Flap gates on the two stormwater pipes to prevent backflow flooding into Chapman Road and Pindi Street.
6. Levee along riverbank and new culvert with flap gate. The culvert and flap gate would be required as the levee would cross the small gully thereby preventing runoff from local rainfall events flowing into the creek.

If further consideration is given to the levee options it is recommended that riverbank survey be obtained and the flood model updated to confirm that overtopping does occur and if it does that the full extent is properly understood. This is recommended because the modelling is based on LiDAR data and the levels in the LiDAR along the riverbanks may be affected by vegetation.

Figure 6-1 Excerpt 1 from Flood Model (Gates Open) – Southern End of Kowanyama

Figure 6-2 Excerpt 2 from Flood Model (Gates Open) – Northern End of Kowanyama

7 Summary

A hydrological assessment and hydraulic modelling of the Magnificent Creek was undertaken to prepare 1% AEP flood mapping of Kowanyama. The flood mapping includes depth, flood level, extent, velocity and hazard. The modelling represented flow in the Magnificent Creek but did not include local rainfall over Kowanyama and surrounds. This is noteworthy as during the wet season and in periods of extended rainfall on the town and surrounding areas, water ponds and takes a long time to drain away. A separate report prepared by Langtree Consulting assesses local catchment flooding and drainage. Although flood mapping was only prepared for the 1% AEP event, the assessment established that the flooding would be very similar in more frequent events such as the 5% (1 in 20) AEP event.

The hydrological assessment established that Magnificent Creek flooding is primarily a result of overflows from the Mitchell River catchment and that flow in Magnificent Creek overflows into separate watercourses before reaching Kowanyama. Because of the distributary nature of the rivers and creeks there is only a small difference in peak flows from the 10% AEP to the 1% AEP events. This phenomenon of relatively small increase in peak flood flows from the 10% to the 1% (and larger) is often the case for these highly distributed geographical floodplains.

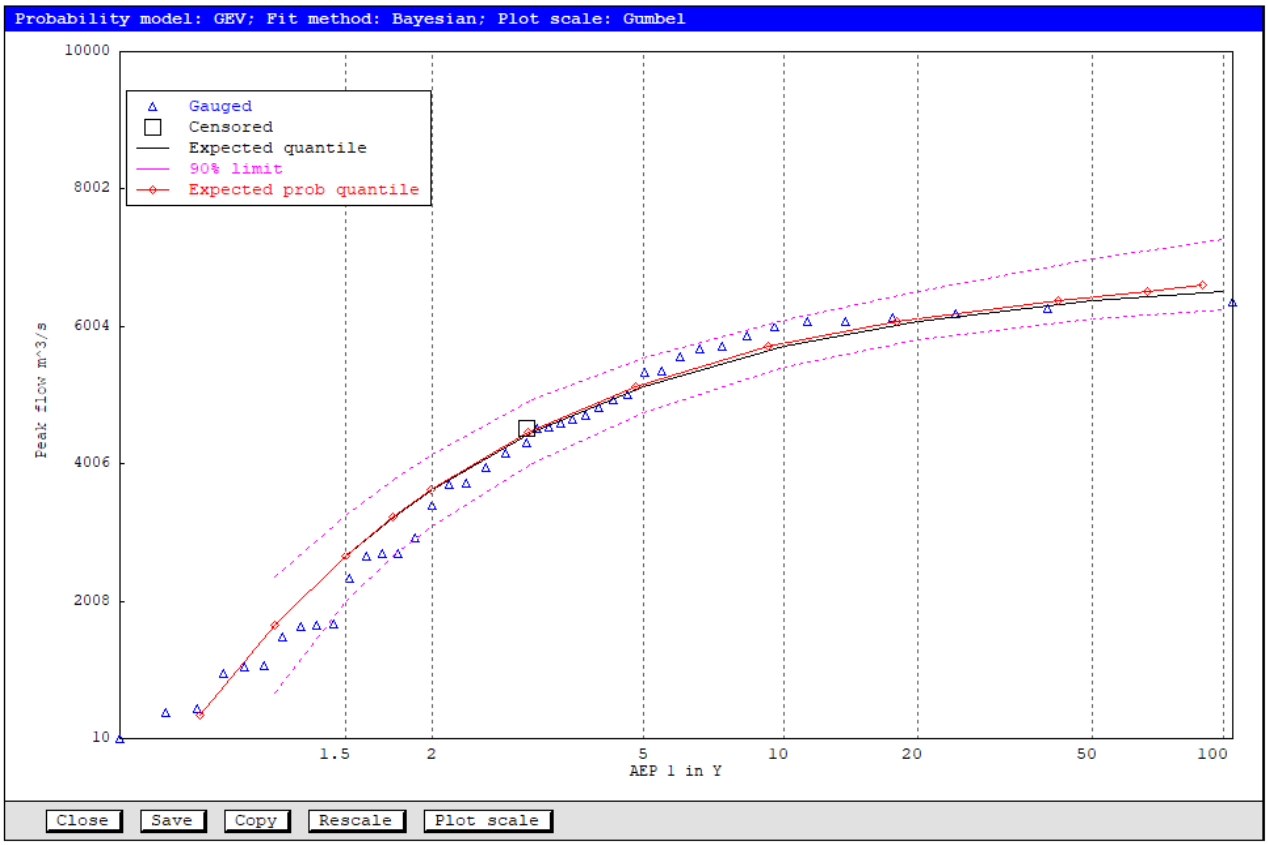
There is a stream gauge on the Mitchell River immediately upstream of the breakout into the Magnificent Creek. A flood frequency analysis at this gauge established design event flow rates on the Mitchell River and this was correlated to historical flows at the Kowanyama Airport gauge to provide design flow rates on the Magnificent Creek at Kowanyama.

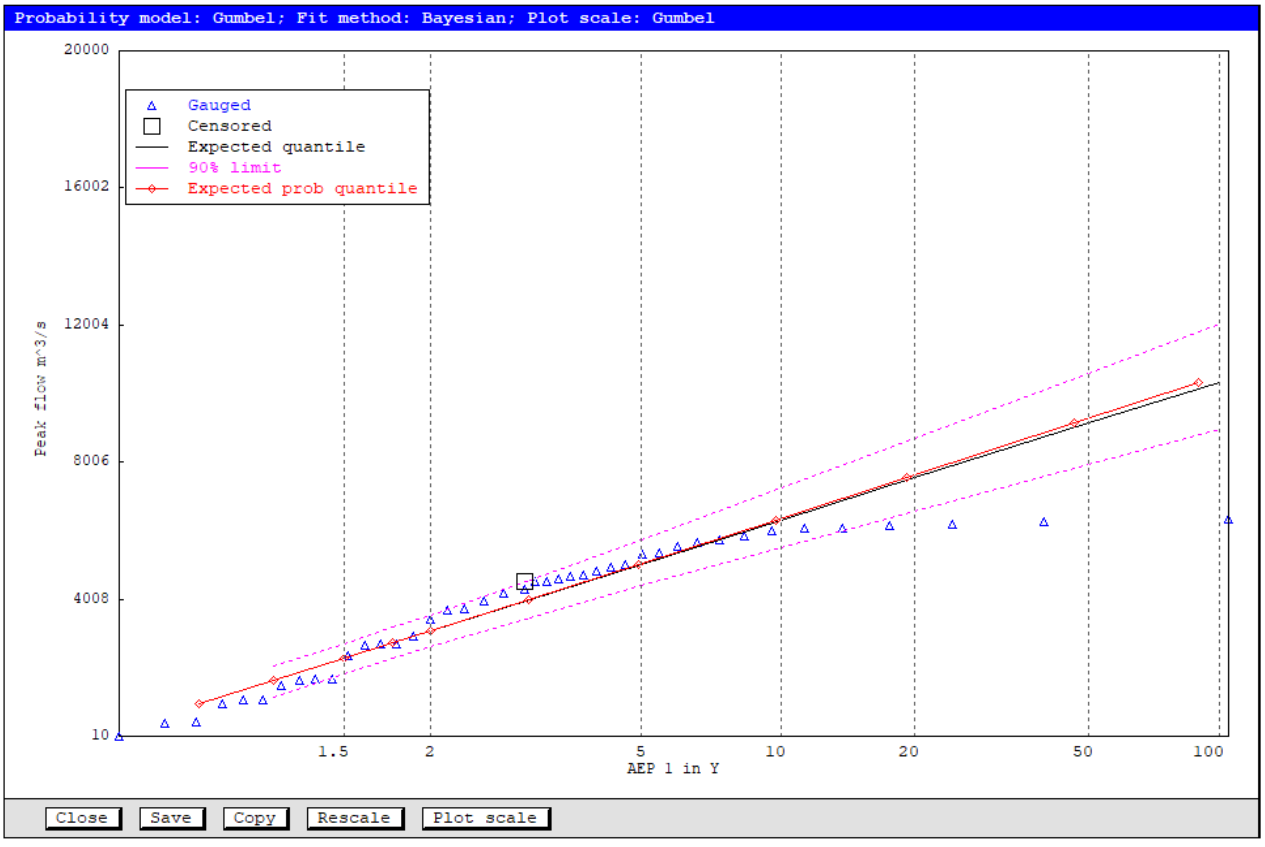
A TUFLOW 2D hydraulic model of Magnificent Creek was developed to allow a detailed understanding of the flooding characteristics at Kowanyama and surrounds. The 1% AEP design flow established from the hydrological analysis was input into hydraulic model. The model outputs were used to generate the mapping. Community input was obtained during the model development phase and used to improve and validate the model.

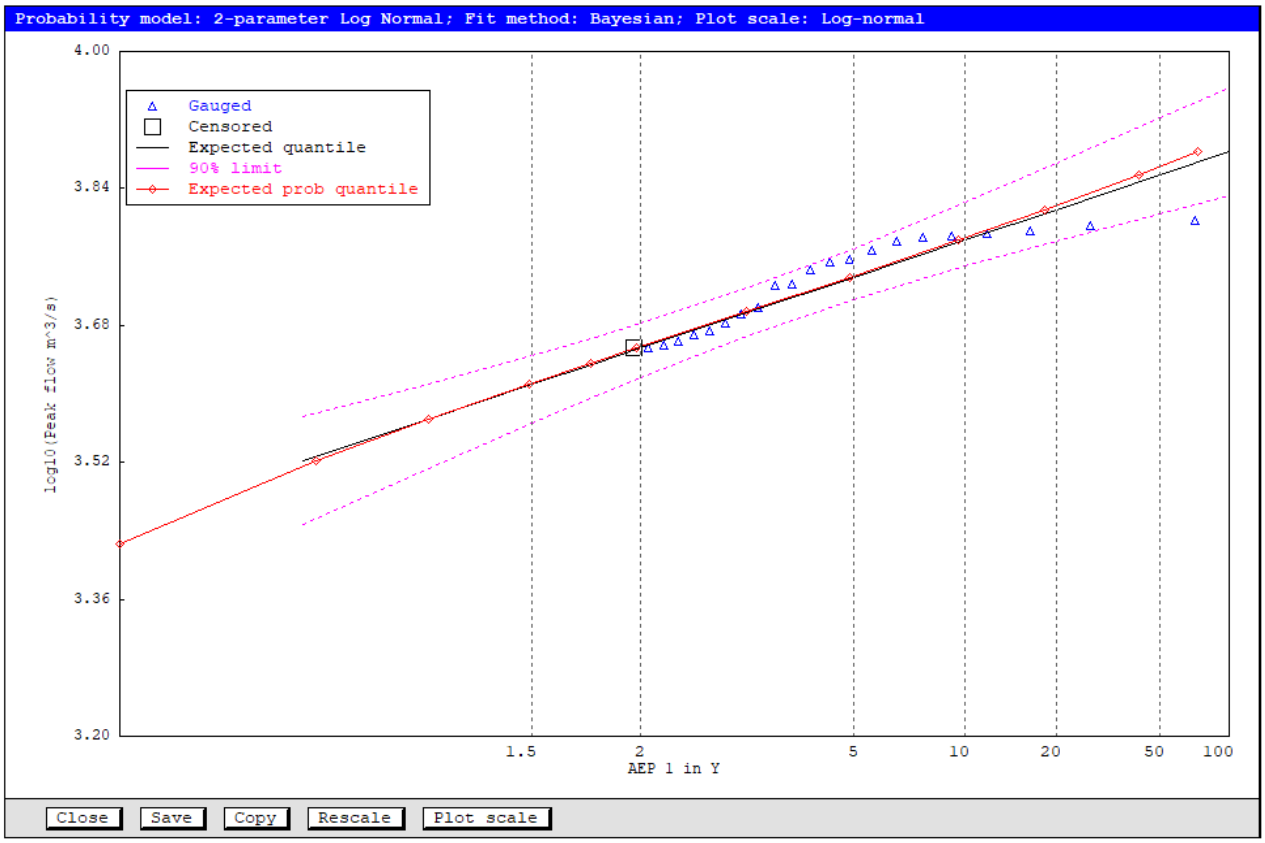
The assessment established that the majority of the town of Kowanyama is not flooded from Magnificent Creek in the 1% AEP event. The flooding that does occur is a predominantly a result of water backing up the southern channel, minor overtopping of the riverbank, and backflow through some of the stormwater pipes. There are a number of flood prone properties at the southern end of Kowanyama where the flooding was classified as unsafe.

A number of mitigation concepts were provided for future consideration.

Appendix A – FFA Outputs



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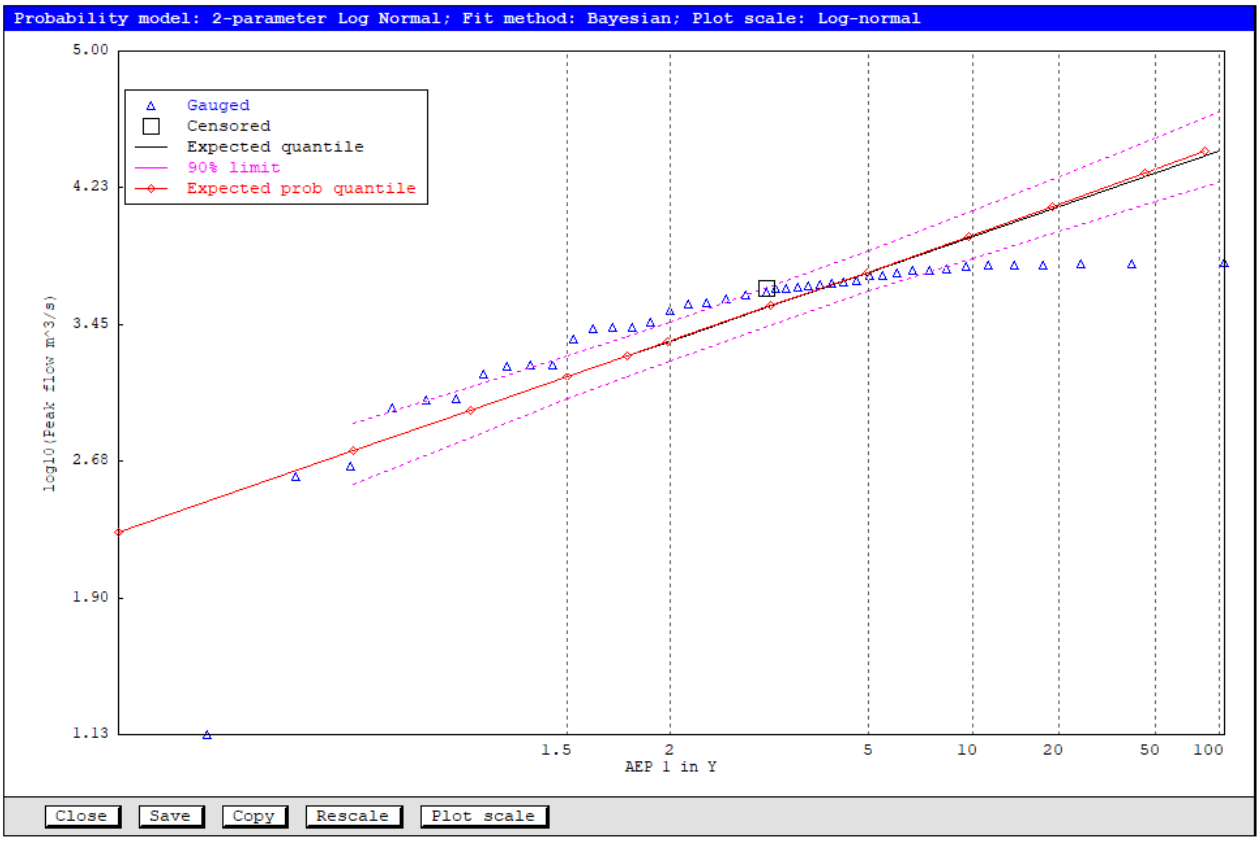
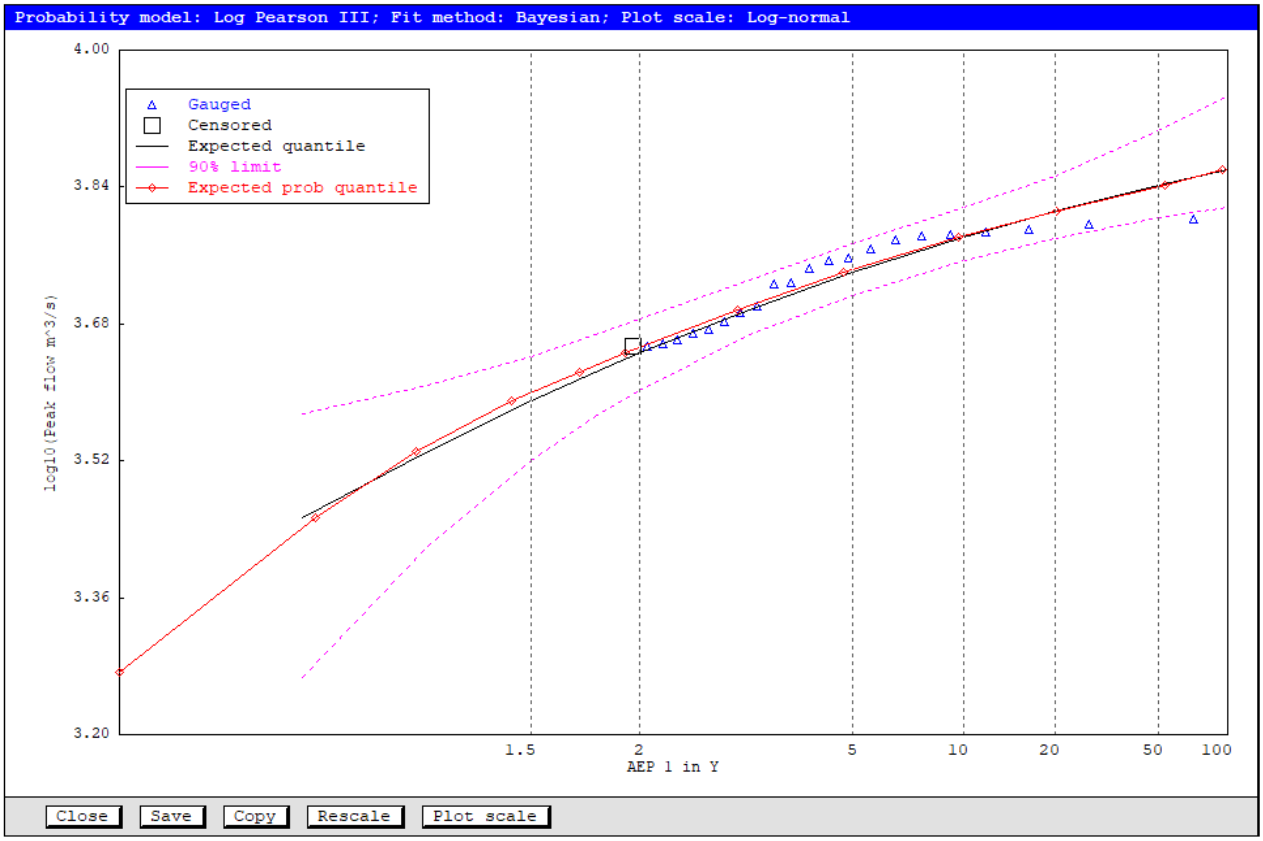
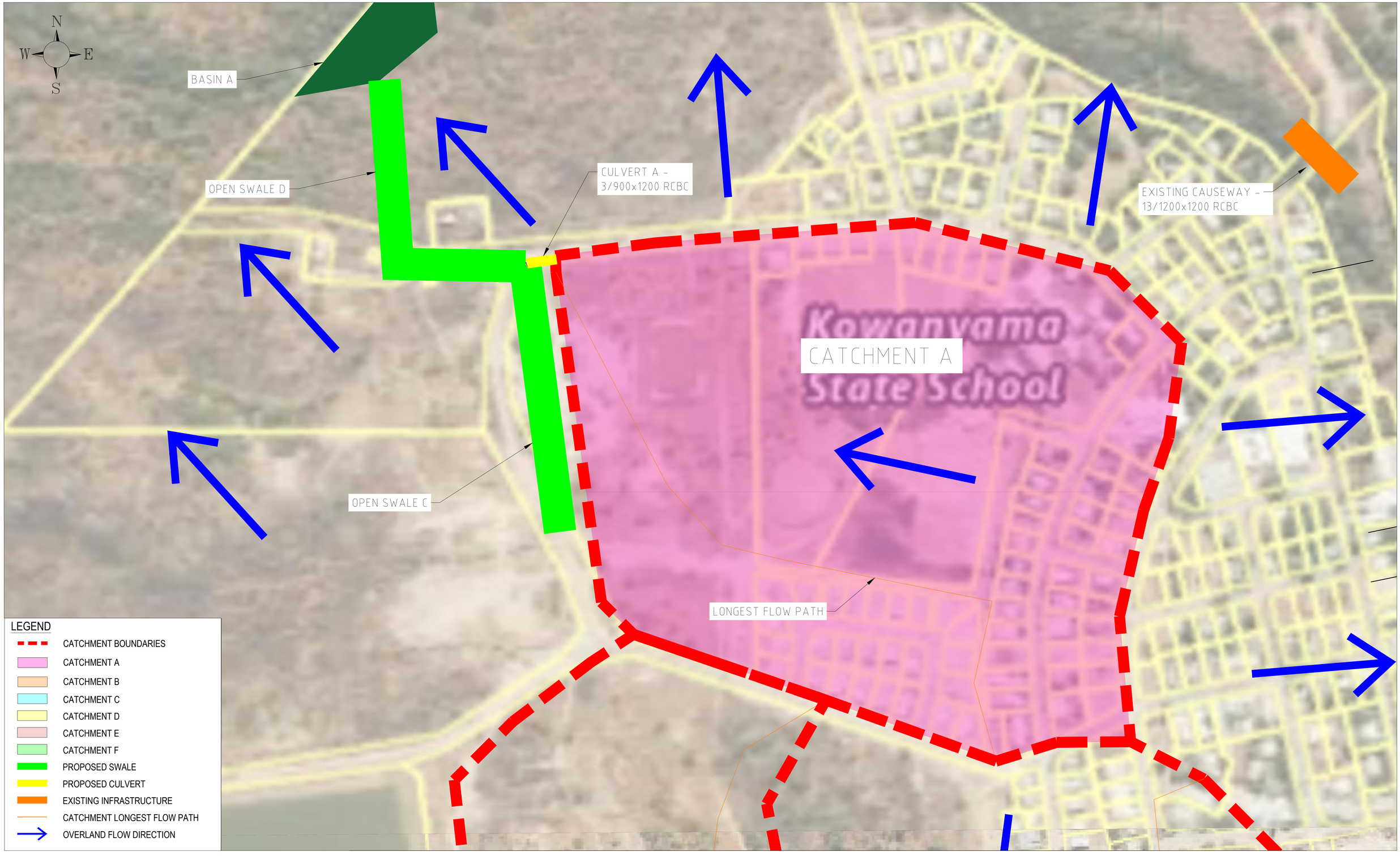
Gauged
Censored
Expected quantile
90% limit
Expected prob quantile
log10(Peak flow m^3/s)
4.00
3.84
3.68
3.52
3.36
3.20
1.5
2
5
10
20
50
100
AEP 1 in Y
Close
Save
Copy
Rescale
Plot scale


Probability model: 2-parameter Log Normal; Fit method: Bayesian; Plot scale: Log-normal
Gauged
Censored
Expected quantile
90% limit
Expected prob quantile
log10(Peak flow m^3/s)
5.00
4.23
3.45
2.68
1.90
1.13
1.5
2
5
10
20
50
100
AEP 1 in Y
Close
Save
Copy
Rescale
Plot scale


Probability model: Log Pearson III; Fit method: Bayesian; Plot scale: Log-normal
Gauged
Censored
Expected quantile
90% limit
Expected prob quantile
log10(Peak flow m^3/s)
4.00
3.84
3.68
3.52
3.36
3.20
1.5
2
5
10
20
50
100
AEP 1 in Y
Close
Save
Copy
Rescale
Plot scale

APPENDIX B:
CATCHMENT A STORMWATER ASSESSMENT



CATCHMENT A PLAN

NOT TO SCALE

REVISIONS

No.	BY	DATE	DESCRIPTION
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HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

CERTIFICATION

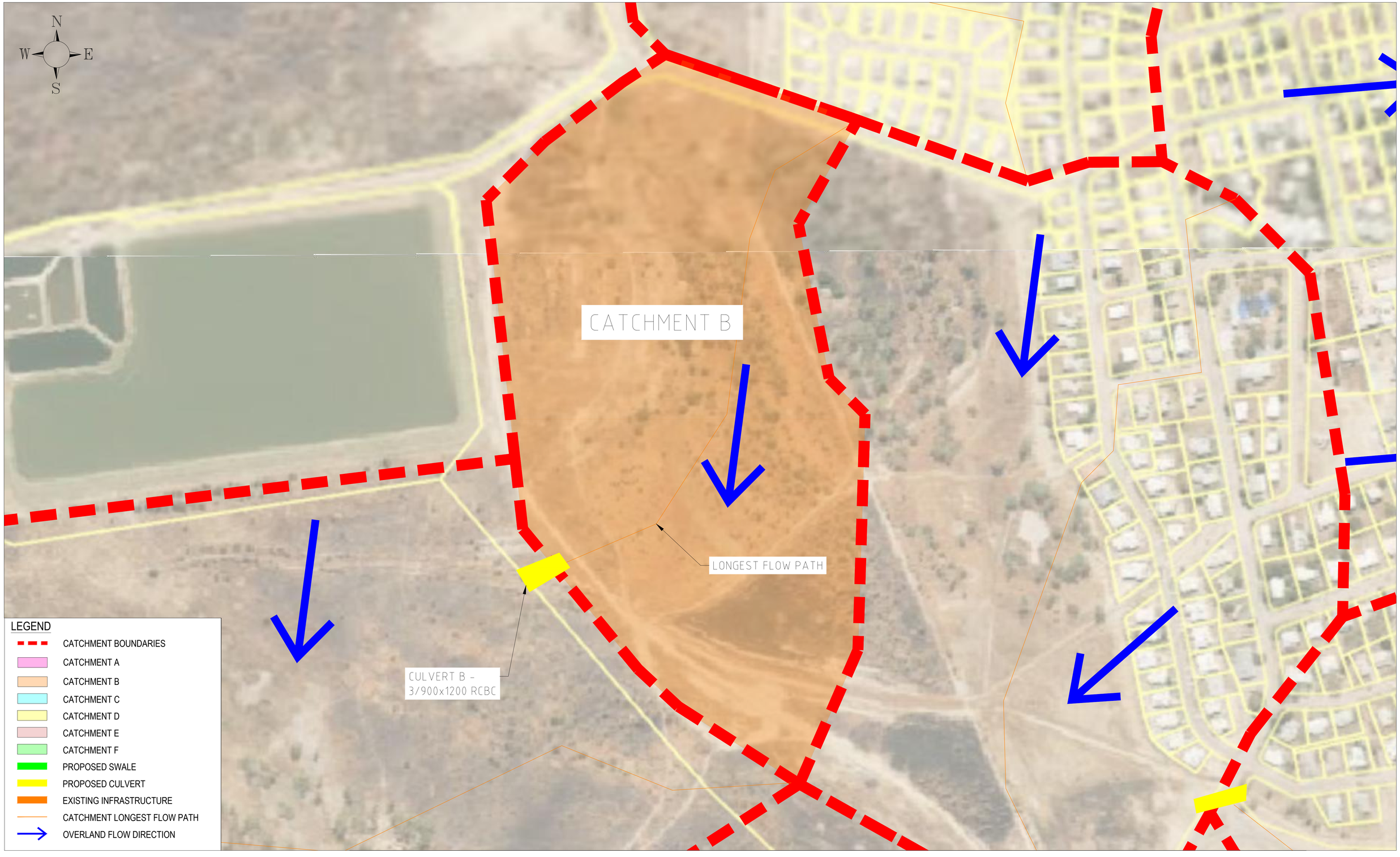
Langtree Consulting

KOWANYAMA ABORIGINAL SHIRE COUNCIL

KOWANYAMA QLD 4892
KOWANYAMA FLOOD STUDY
CATCHMENT A PLAN

SCALE	NTS
SHEET	SHEET 2 OF 7
REVISION	A
DRG No.	0489–002

APPENDIX C:
CATCHMENT B STORMWATER ASSESSMENT



CATCHMENT B PLAN

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HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

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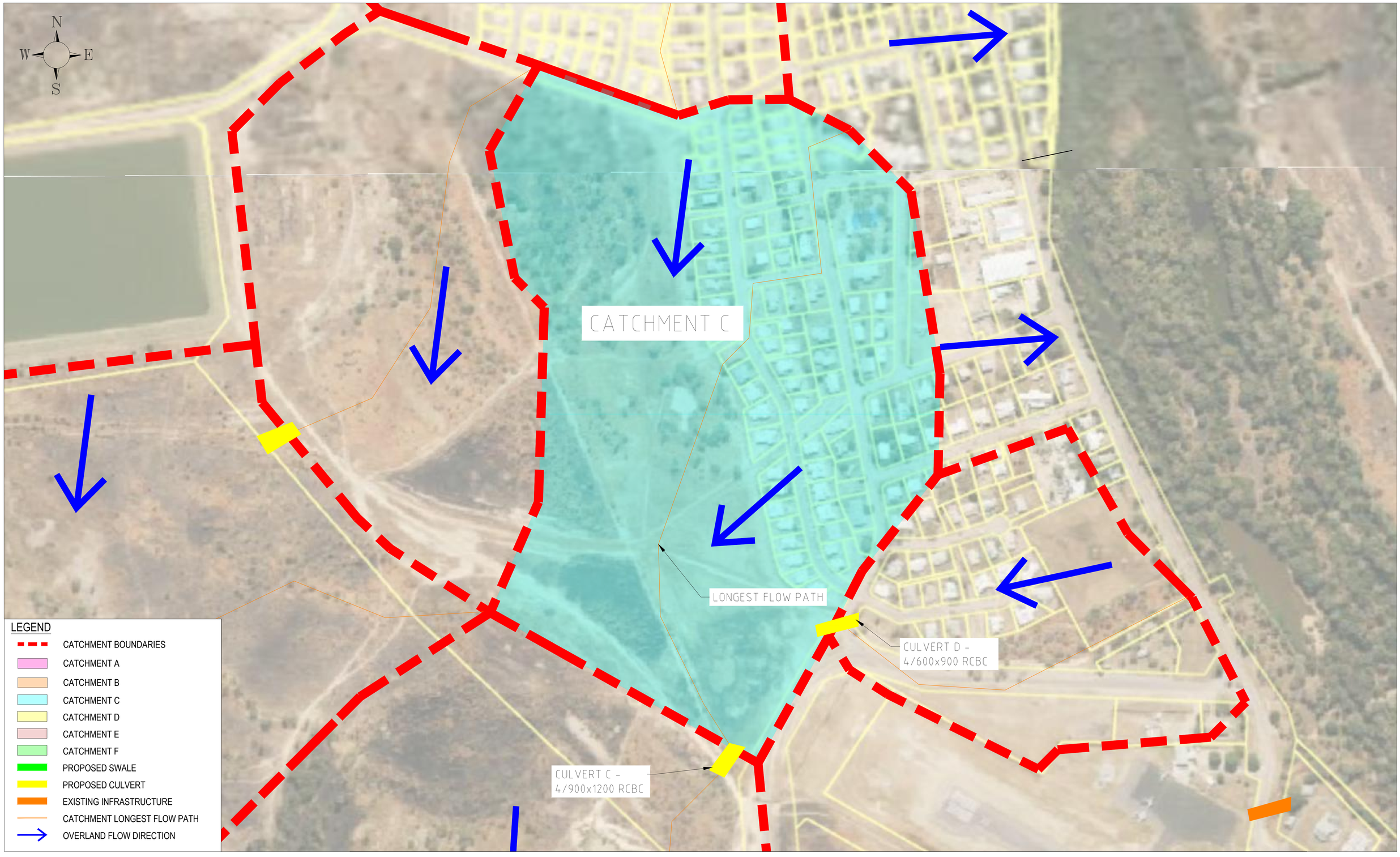
CATCHMENT B PLAN

SCALE	NTS
SHEET	SHEET 3 OF 7
REVISION	A
DRG No.	0489–003

APPENDIX D:
CATCHMENT C STORMWATER ASSESSMENT



CATCHMENT C PLAN

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VERT. DATUM	AHD		
DRG. FILE		DATE	
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DRAWN	A.R	29/07/21	

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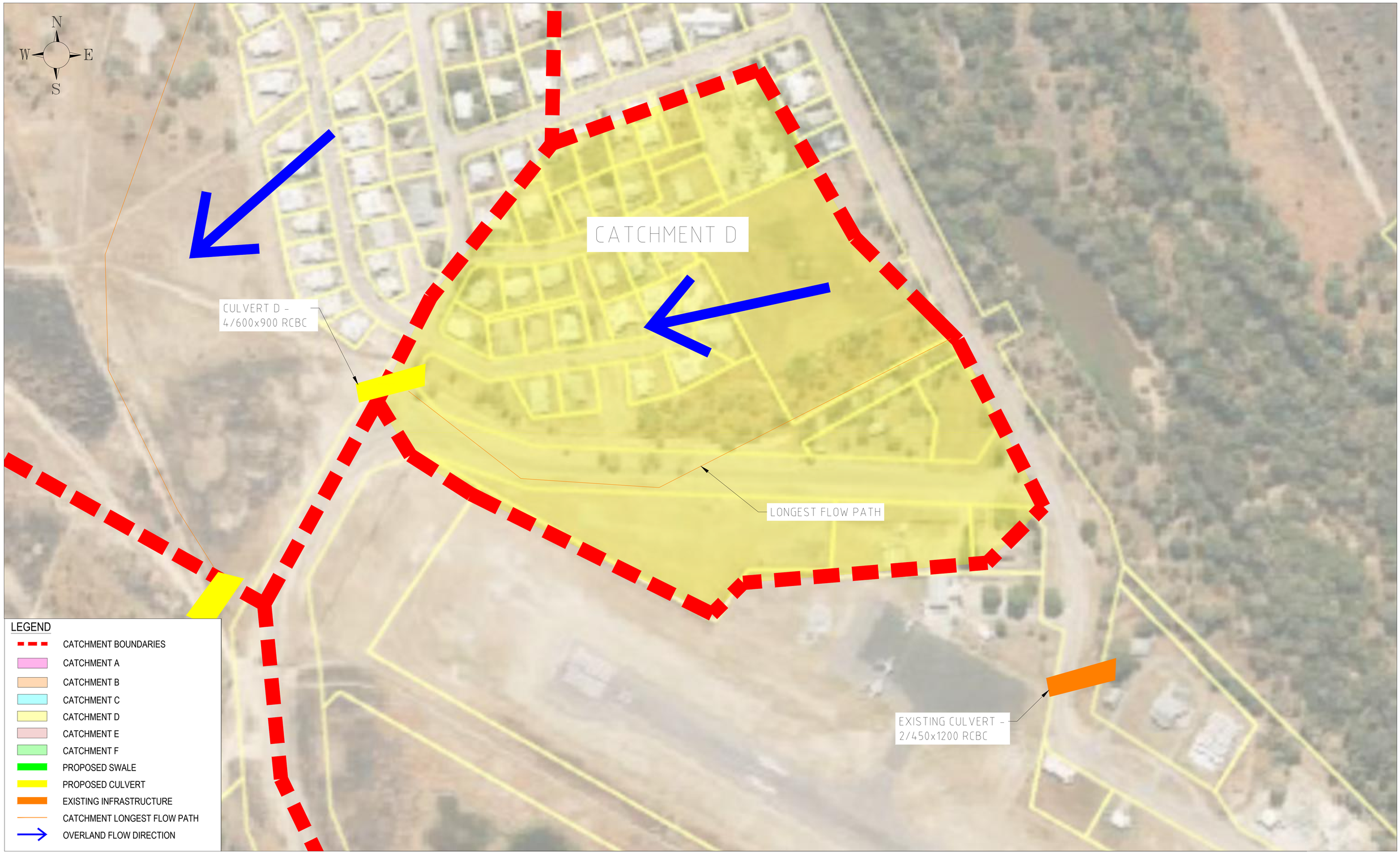
CATCHMENT C PLAN

SCALE	NTS
SHEET	SHEET 4 OF 7
REVISION	A
DRG No.	0489-004

APPENDIX E:
CATCHMENT D STORMWATER ASSESSMENT



CATCHMENT D PLAN

NOT TO SCALE

REVISIONS

No.	BY	DATE	DESCRIPTION
A	A.R	29/07/21	FOR INFORMATION

HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

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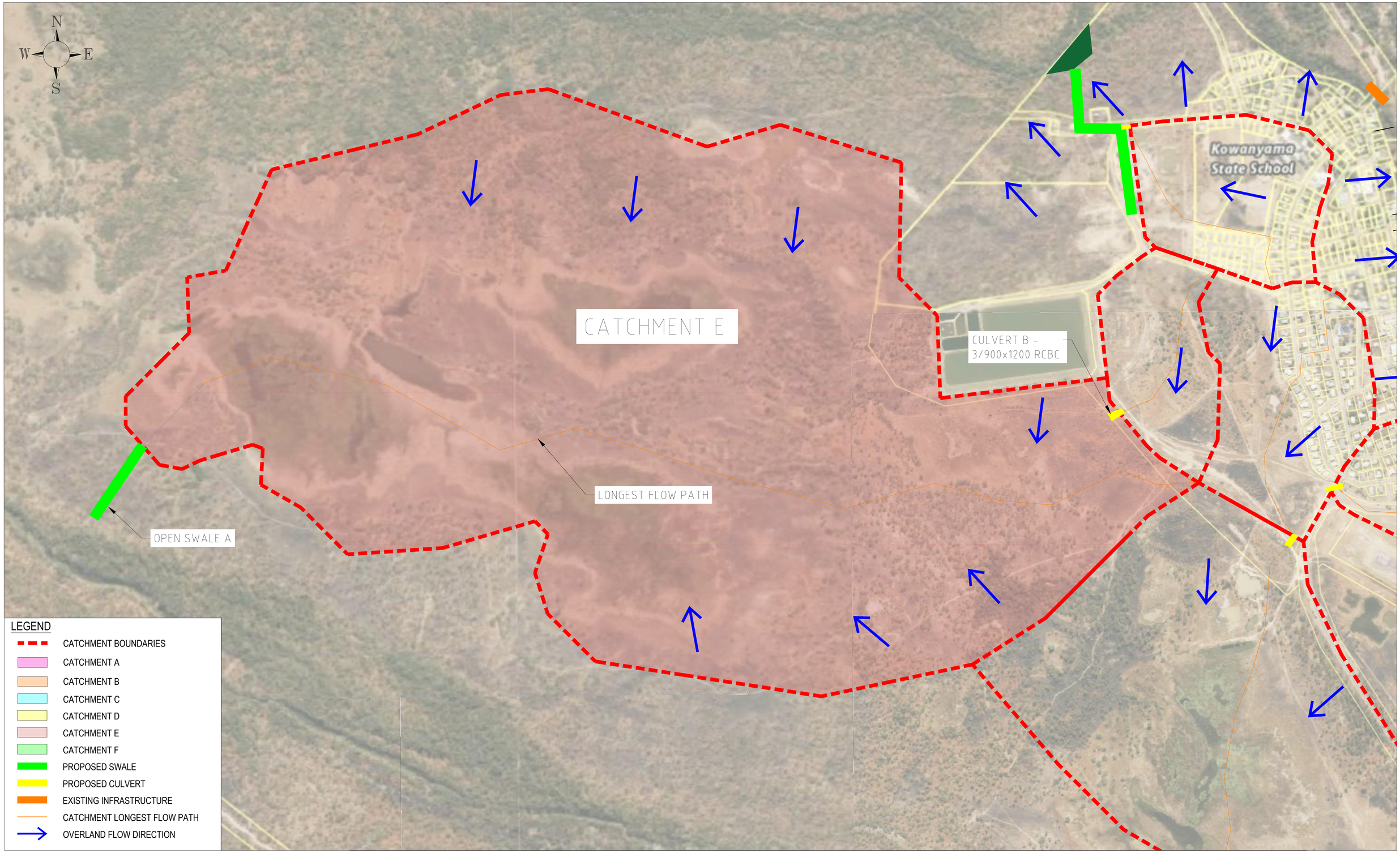
CATCHMENT D PLAN

SCALE	NTS
SHEET	SHEET 5 OF 7
REVISION	A
DRG No.	0489-005

APPENDIX F:
CATCHMENT E STORMWATER ASSESSMENT



CATCHMENT E PLAN

NOT TO SCALE

REVISIONS

No.	BY	DATE	DESCRIPTION
A	A.R	29/07/21	FOR INFORMATION

HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

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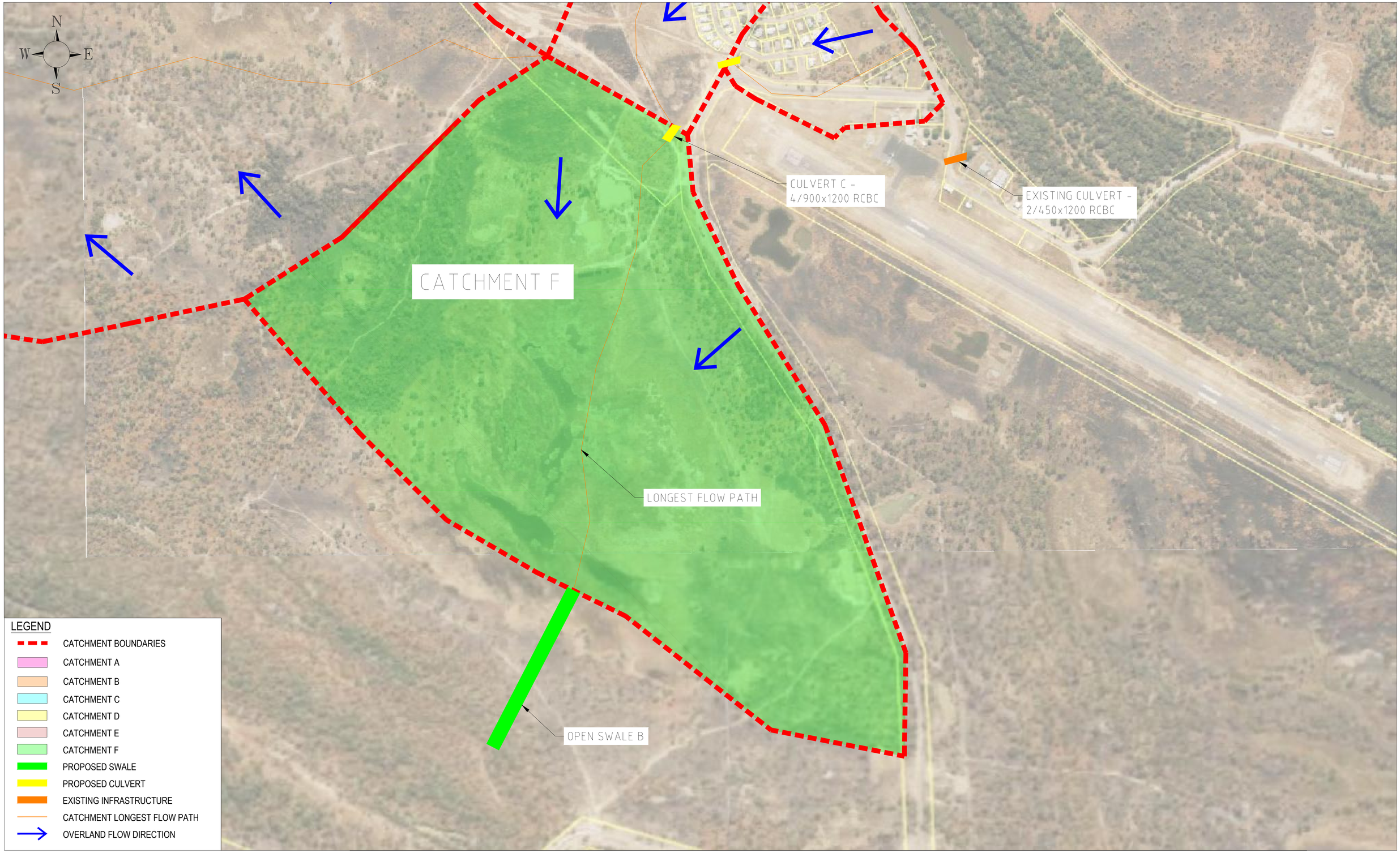
KOWANYAMA FLOOD STUDY

CATCHMENT E PLAN

SCALE	NTS
SHEET	SHEET 6 OF 7
REVISION	A
DRG No.	0489-006

APPENDIX G:
CATCHMENT F STORMWATER ASSESSMENT



CATCHMENT F PLAN

NOT TO SCALE

REVISIONS

No.	BY	DATE	DESCRIPTION
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HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

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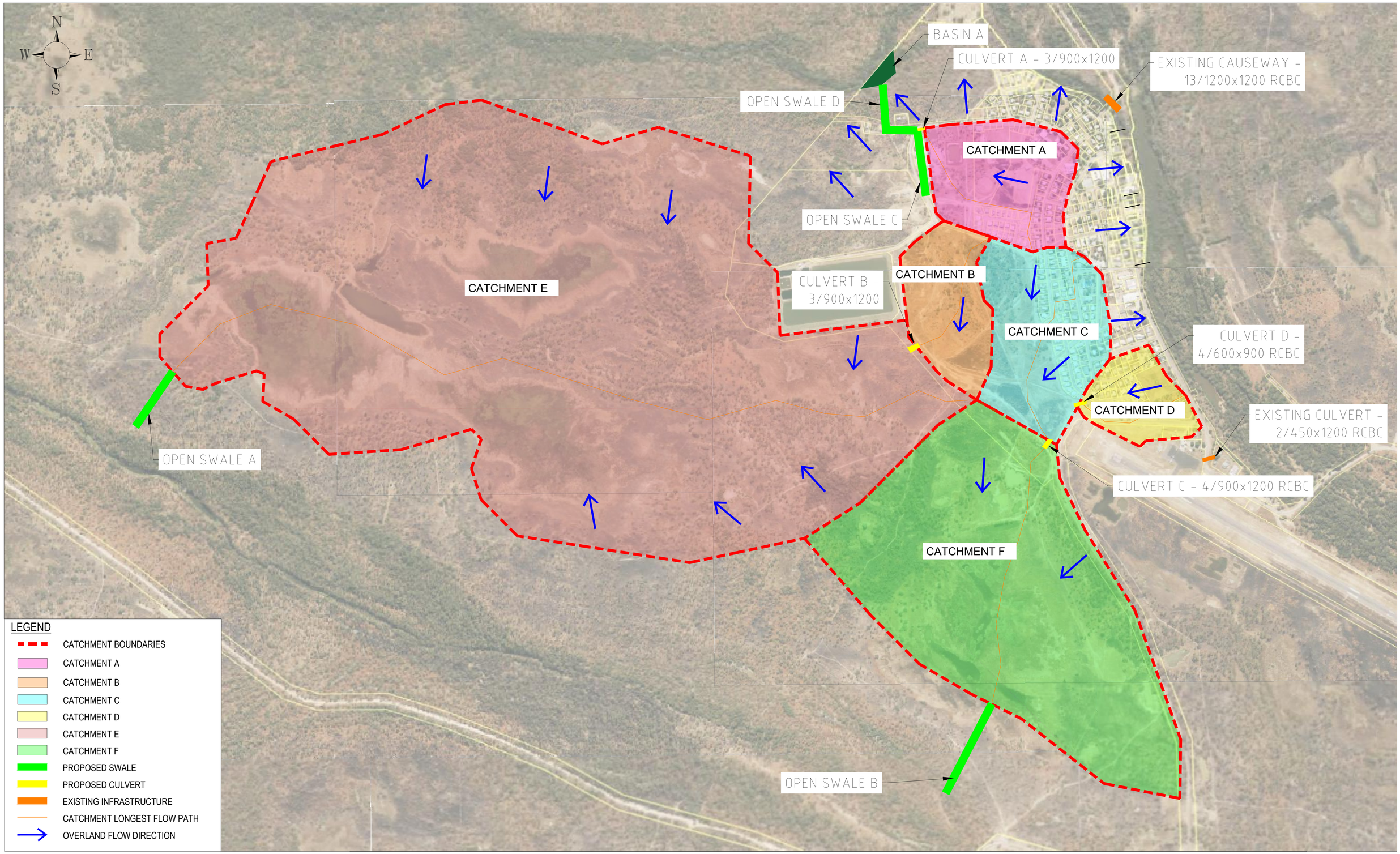
KOWANYAMA FLOOD STUDY

CATCHMENT F PLAN

SCALE	NTS
SHEET	SHEET 7 OF 7
REVISION	A
DRG No.	0489–007

APPENDIX H:
CATCHMENT PLANS



OVERALL CATCHMENT PLAN

NOT TO SCALE

REVISIONS				
A	A.R	29/07/21	FOR INFORMATION	
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HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

CERTIFICATION

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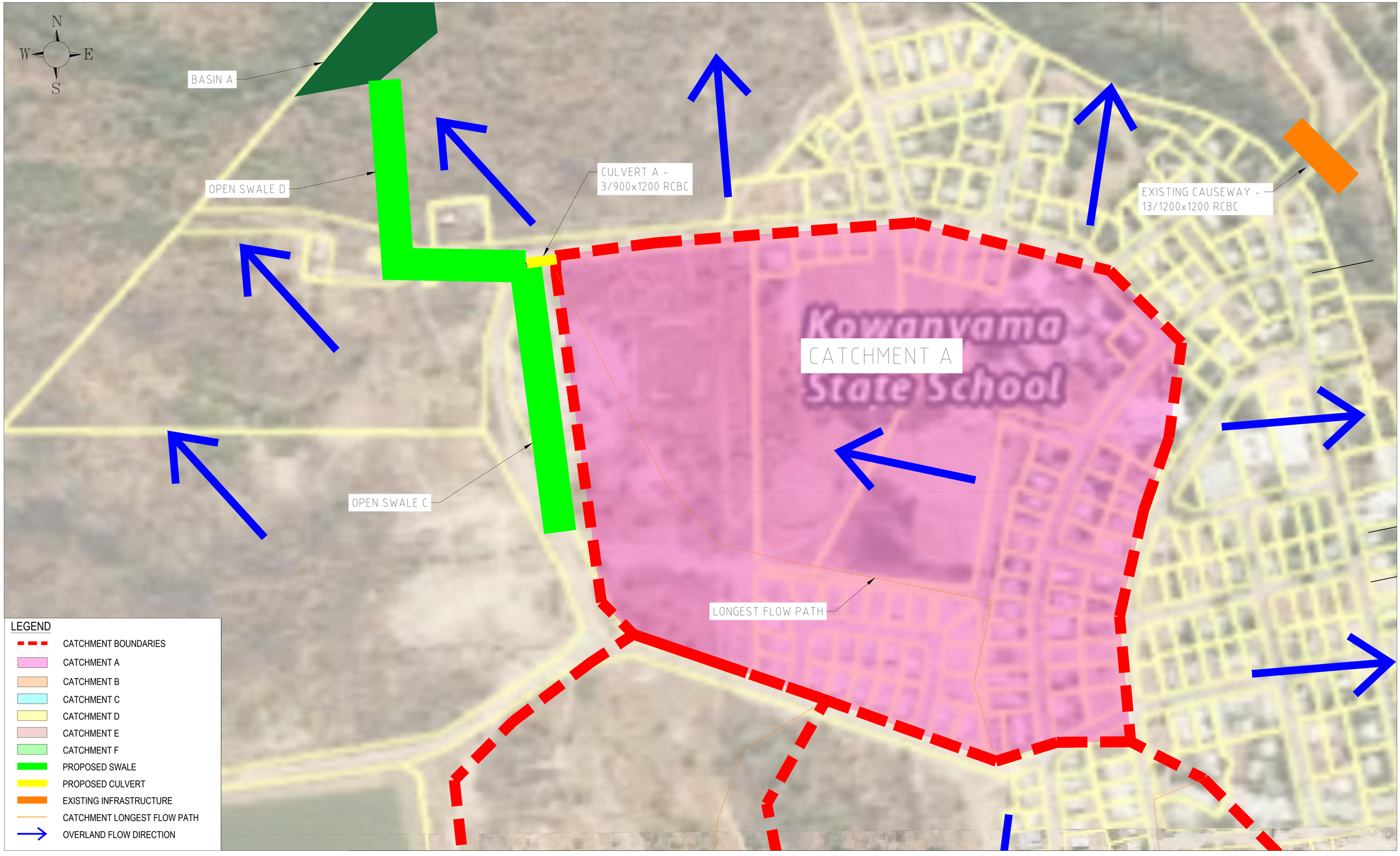
KOWANYAMA ABORIGINAL SHIRE COUNCIL

KOWANYAMA QLD 4892

KOWANYAMA FLOOD STUDY

OVERALL CATCHMENT PLAN

SCALE	NTS
SHEET	SHEET 1 OF 7
REVISION	A
DRG No.	0489-001



CATCHMENT A PLAN

NOT TO SCALE

REVISIONS

No.	BY	DATE	DESCRIPTION
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HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

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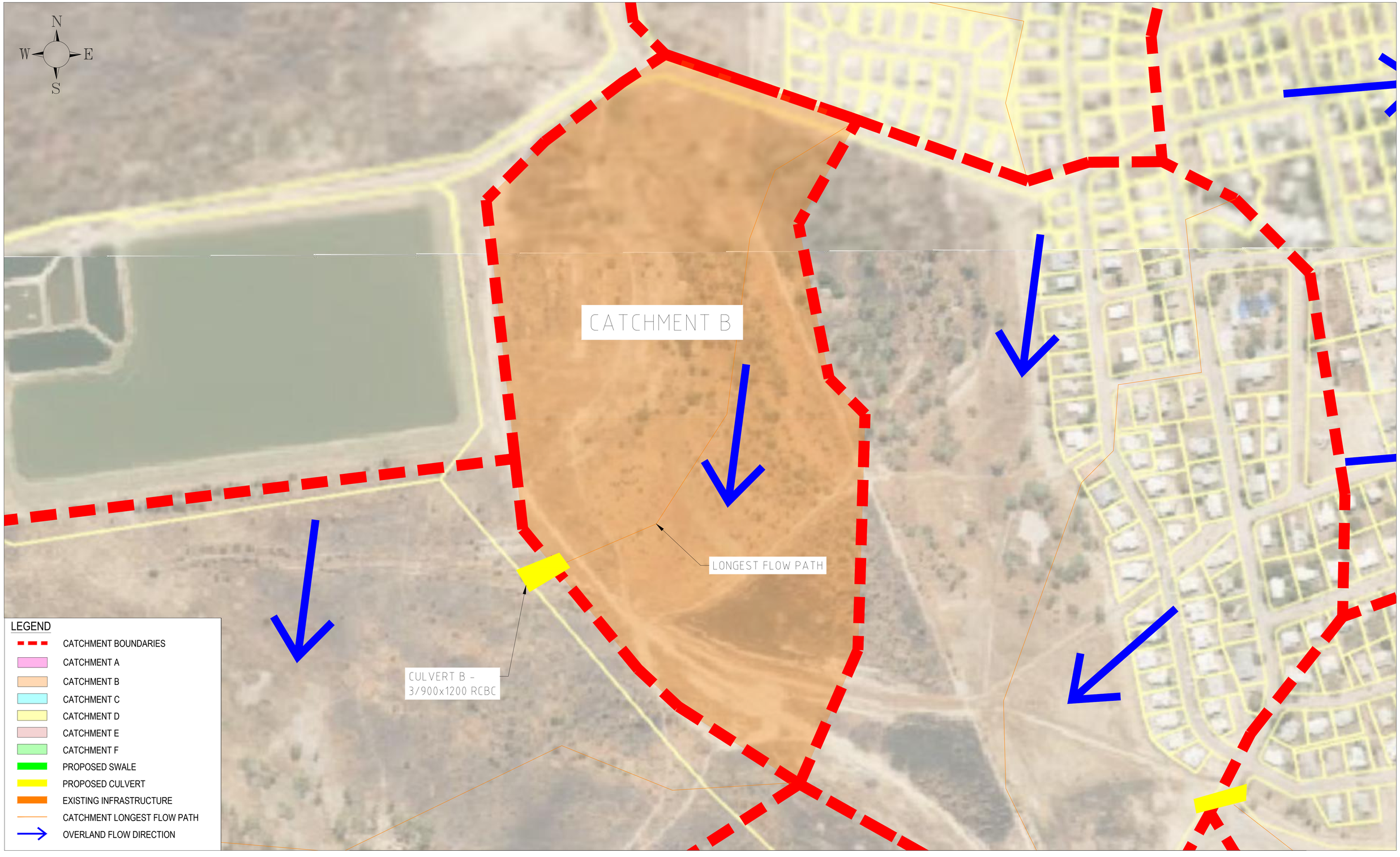
KOWANYAMA FLOOD STUDY
CATCHMENT A PLAN

SCALE	NTS
SHEET	SHEET 2 OF 7
REVISION	A
DRG No.	0489–002



CATCHMENT B PLAN

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HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

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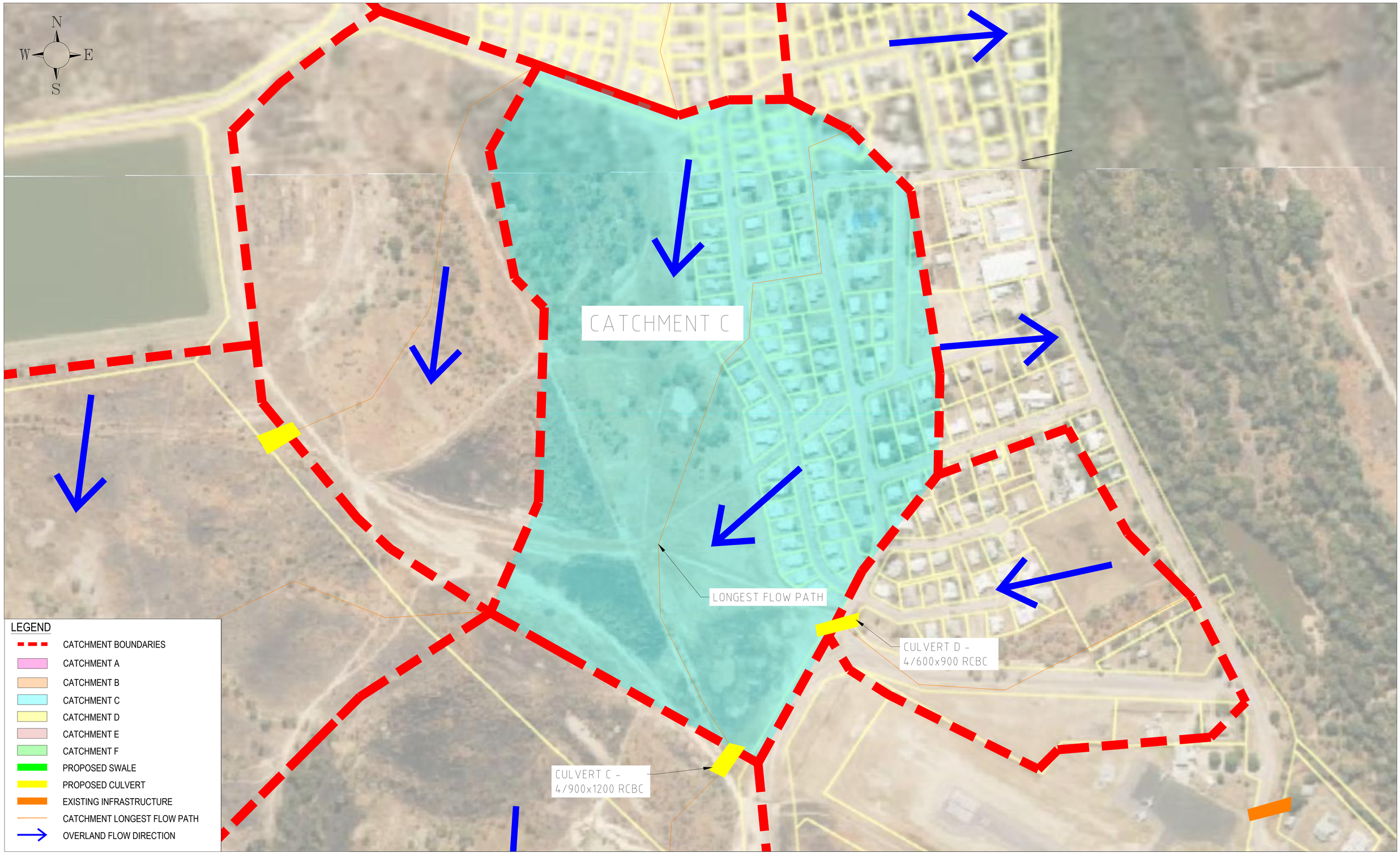
CATCHMENT B PLAN

SCALE	NTS
SHEET	SHEET 3 OF 7
REVISION	A
DRG No.	0489–003



CATCHMENT C PLAN

NOT TO SCALE

REVISIONS				
A	A.R	29/07/21	FOR INFORMATION	
No.	BY	DATE	DESCRIPTION	

HORIZ. DATUM	MGA		
VERT. DATUM	AHD		
DRG. FILE		DATE	
DESIGN	A.R	29/07/21	
DRAWN	A.R	29/07/21	

CERTIFICATION

Langtree Consulting

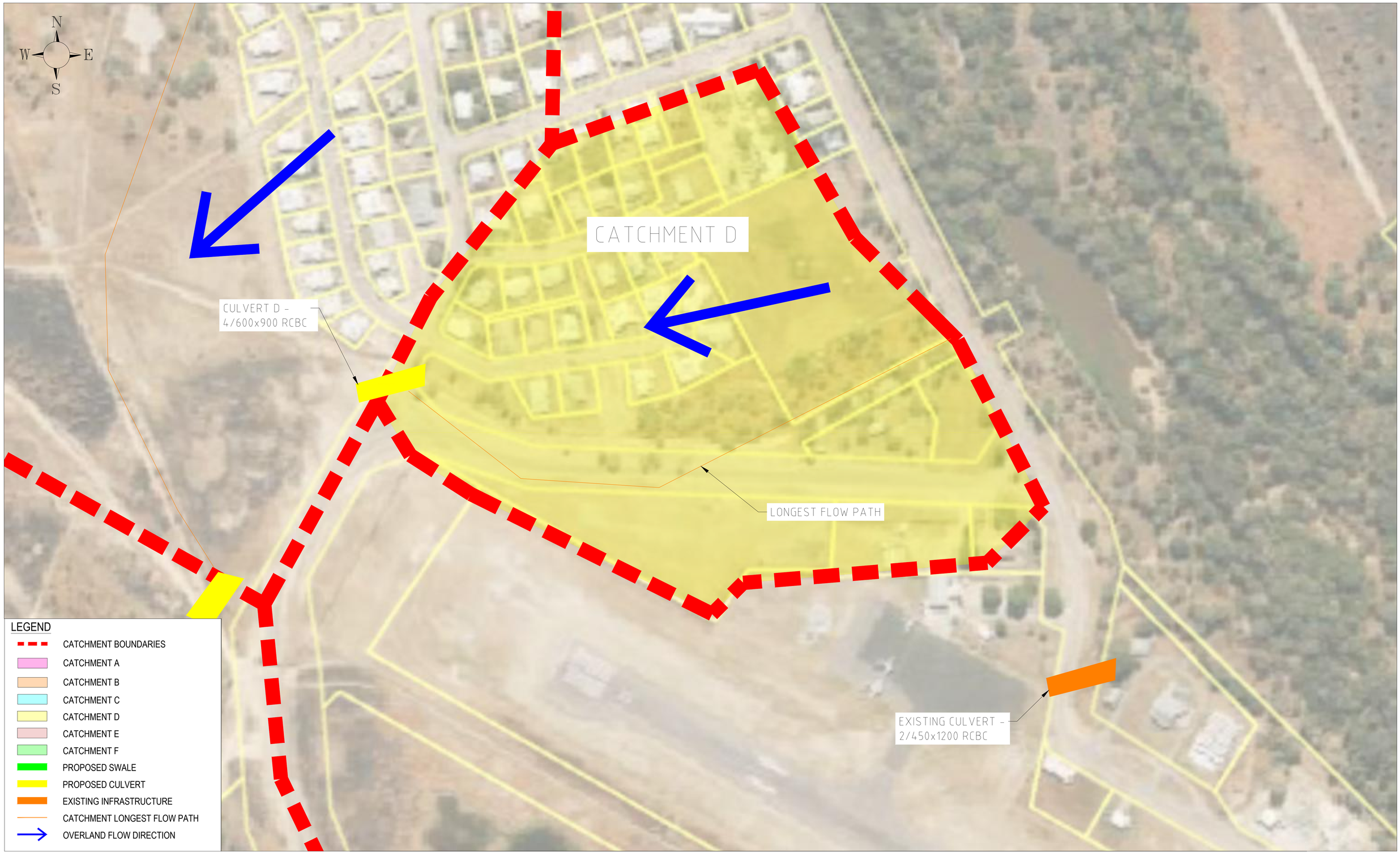
KOWANYAMA ABORIGINAL SHIRE COUNCIL

KOWANYAMA QLD 4892

KOWANYAMA FLOOD STUDY

CATCHMENT C PLAN

SCALE	NTS
SHEET	SHEET 4 OF 7
REVISION	A
DRG No.	0489-004



CATCHMENT D PLAN

NOT TO SCALE

REVISIONS

No.	BY	DATE	DESCRIPTION
A	A.R	29/07/21	FOR INFORMATION

HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

CERTIFICATION

Langtree Consulting

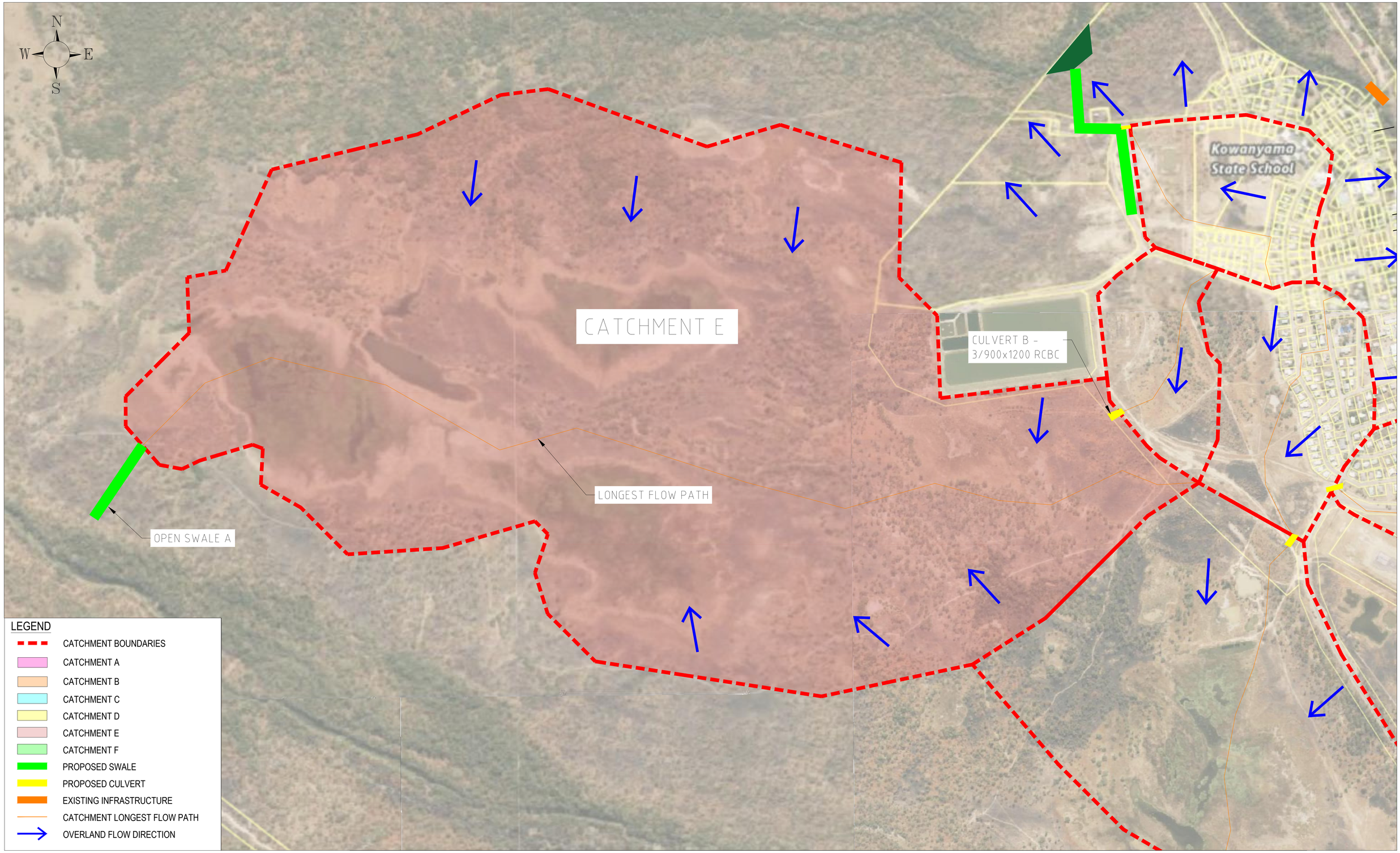
KOWANYAMA ABORIGINAL SHIRE COUNCIL

KOWANYAMA QLD 4892

KOWANYAMA FLOOD STUDY

CATCHMENT D PLAN

SCALE	NTS
SHEET	SHEET 5 OF 7
REVISION	A
DRG No.	0489-005



CATCHMENT E PLAN

NOT TO SCALE

REVISIONS

No.	BY	DATE	DESCRIPTION
A	A.R	29/07/21	FOR INFORMATION

HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

CERTIFICATION

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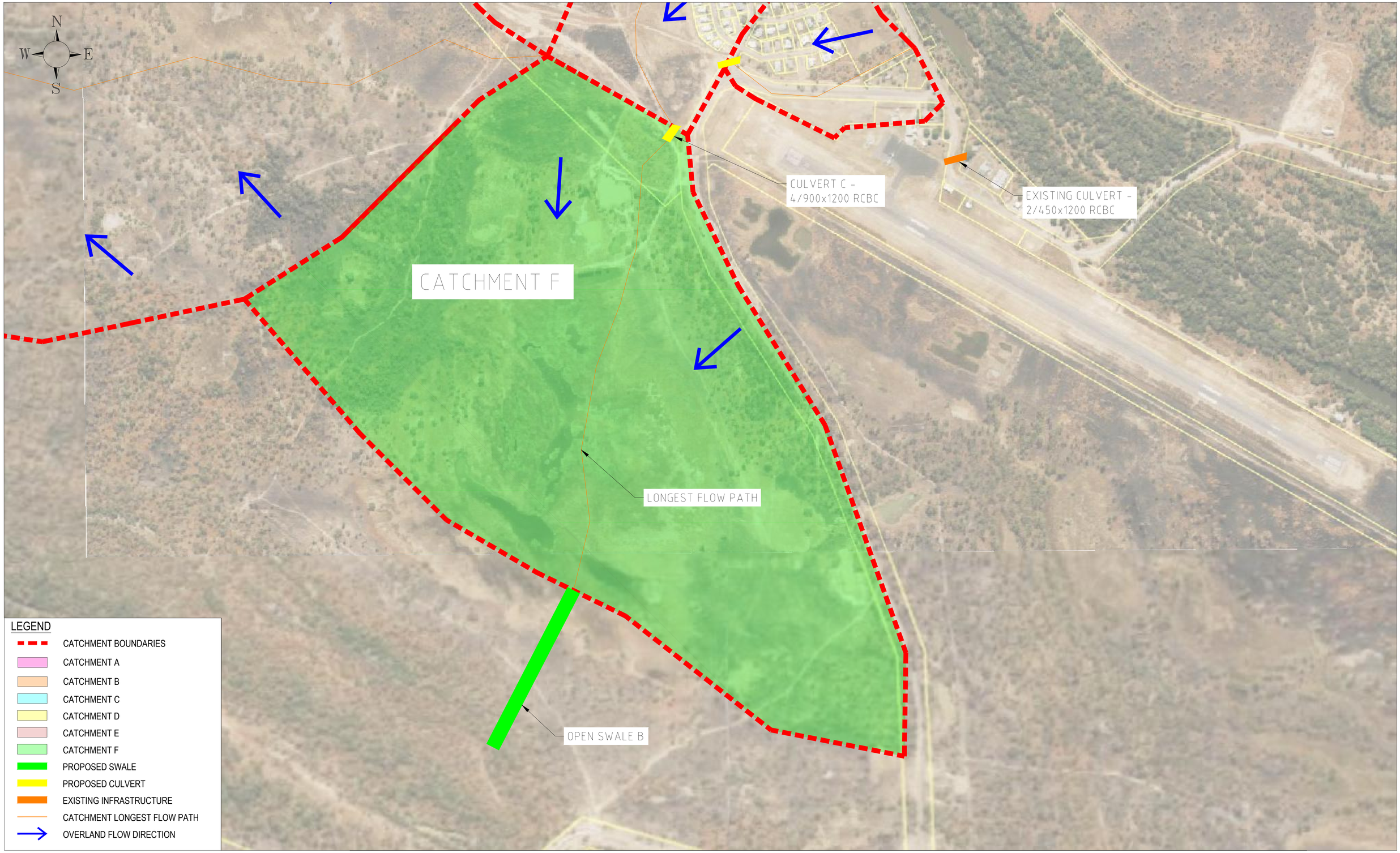
KOWANYAMA ABORIGINAL SHIRE COUNCIL

KOWANYAMA QLD 4892

KOWANYAMA FLOOD STUDY

CATCHMENT E PLAN

SCALE	NTS
SHEET	SHEET 6 OF 7
REVISION	A
DRG No.	0489-006



CATCHMENT F PLAN

NOT TO SCALE

REVISIONS

No.	BY	DATE	DESCRIPTION
A	A.R	29/07/21	FOR INFORMATION

HORIZ. DATUM	MGA	
VERT. DATUM	AHD	
DRG. FILE		DATE
DESIGN	A.R	29/07/21
DRAWN	A.R	29/07/21

CERTIFICATION

Langtree Consulting

KOWANYAMA ABORIGINAL SHIRE COUNCIL

KOWANYAMA QLD 4892

KOWANYAMA FLOOD STUDY

CATCHMENT F PLAN

SCALE	NTS
SHEET	SHEET 7 OF 7
REVISION	A
DRG No.	0489–007

APPENDIX I:
COST ESTIMATE

Bill of Quantities

Culvert A and Swales C and D

Job No. 0489
Ref No. BM0009
Date. 24/06/2021

ITEM	DESCRIPTION		TOTAL
1	SCHEDULE A - PRELIMINARY		$36,000.00
2	SCHEDULE B - EARTHWORKS		$309,700.00
3	SCHEDULE C - STORMWATER		$120,460.00
	CONTINGENCY	20%	$69,140.00
		SUBTOTAL	**$535,300.00**
		10% GST	**$53,530.00**
		CIVILWORKS CONSTRUCTION TOTAL	**$588,830.00**

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**SCHEDULE A - PRELIMINARY**				
1.1	Site Establishment/Dis-establishment	Item	1.0	$5,000.00	$5,000.00
1.2	Provision for traffic	Item	1.0	$10,000.00	$10,000.00
1.3	Environmental management plan	Item	1.0	$5,000.00	$5,000.00
1.4	Erosion and Sediment Control Measures	Item	1.0	$10,000.00	$10,000.00
1.5	Public consultation (notification to residents/property owners)	Item	1.0	$1,000.00	$1,000.00
1.6	As-constructed documentation	Item	1.0	$5,000.00	$5,000.00
				SCHEDULE A - PRELIMINARY (EXCL. GST)	**$36,000.00**
2	**SCHEDULE B - EARTHWORKS**				
2.1	Clearing and grubbing	m^2	8800.0	$5.00	$44,000.00
2.2	Removal of trees (Provisional Qty)	m^2	0.0	$10.00	$0.00
2.3	Stripping of topsoil (50mm)	m^3	440.0	$15.00	$6,600.00
2.4	Earthworks:				
	(a) Cut to fill	m^3	0.0	$15.00	$0.00
	(b) Imported fill	m^3	0.0	$25.00	$0.00
	(c) Removal of unsuitable material (Provisional Qty)	m^3	5700.0	$35.00	$199,500.00
2.5	Trim, water and compact road subgrade (compaction 95% MDD)	m^2	40.0	$5.00	$200.00
2.6	Compact and final trim of batters	m^2	7350.0	$4.00	$29,400.00
2.7	50mm topsoil and grass seed to verges, batters and disturbed areas	m^2	3000.0	$10.00	$30,000.00
				SCHEDULE B - EARTHWORKS (EXCL. GST)	**$309,700.00**
3	**SCHEDULE C - STORMWATER**				
3.1	Supply and install of drainage structures complete including excavation, bedding, backfill, compact and dispose of surplus materials:				
	(a) 3/900x1200 RCBC	m	18.0	$5,000.00	$90,000.00
	(b) Blinding Concrete	m^3	2.0	$800.00	$1,560.00
	(c) Reinforced Concrete Culvert Base Slab	m^3	10.0	$1,800.00	$18,000.00
	(d) Reinforced Concrete Headwall	m^3	0.8	$1,800.00	$1,440.00
	(e) Reinforced Concrete Apron including footing	m^3	2.7	$1,800.00	$4,860.00
	(f) Reinforced Concrete Wingwall	m^3	1.0	$1,800.00	$1,800.00
	(g) Reinforced Concrete Cut Off Wall	m^3	1.0	$1,800.00	$1,800.00
3.2	Dumped rock protection including excavation, geofabric under, supply and place of rock (300mm thick d_{50} = 200mm)	m^2	10.0	$100.00	$1,000.00
				SCHEDULE C - STORMWATER (EXCL. GST)	**$120,460.00**

Bill of Quantities

Culvert B

Job No. 0489
Ref No. BM0009
Date. 24/06/2021

ITEM	DESCRIPTION		TOTAL
1	SCHEDULE A - PRELIMINARY		$36,000.00
2	SCHEDULE B - EARTHWORKS		$3,550.00
3	SCHEDULE C - STORMWATER		$120,460.00
	CONTINGENCY	20%	$7,910.00
		SUBTOTAL	**$167,920.00**
		10% GST	**$16,792.00**
		CIVILWORKS CONSTRUCTION TOTAL	**$184,712.00**

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**SCHEDULE A - PRELIMINARY**				
1.1	Site Establishment/Dis-establishment	Item	1.0	$5,000.00	$5,000.00
1.2	Provision for traffic	Item	1.0	$10,000.00	$10,000.00
1.3	Environmental management plan	Item	1.0	$5,000.00	$5,000.00
1.4	Erosion and Sediment Control Measures	Item	1.0	$10,000.00	$10,000.00
1.5	Public consultation (notification to residents/property owners)	Item	1.0	$1,000.00	$1,000.00
1.6	As-constructed documentation	Item	1.0	$5,000.00	$5,000.00
			SCHEDULE A - PRELIMINARY (EXCL. GST)		**$36,000.00**
2	**SCHEDULE B - EARTHWORKS**				
2.1	Clearing and grubbing	m^2	100.0	$5.00	$500.00
2.2	Removal of trees (Provisional Qty)	m^2	0.0	$10.00	$0.00
2.3	Stripping of topsoil (50mm)	m^3	50.0	$15.00	$750.00
2.4	Earthworks:				
	(a) Cut to fill	m^3	0.0	$15.00	$0.00
	(b) Imported fill	m^3	0.0	$25.00	$0.00
	(c) Removal of unsuitable material (Provisional Qty)	m^3	50.0	$35.00	$1,750.00
2.5	Trim, water and compact road subgrade (compaction 95% MDD)	m^2	50.0	$5.00	$250.00
2.6	Compact and final trim of batters	m^2	50.0	$4.00	$200.00
2.7	50mm topsoil and grass seed to verges, batters and disturbed areas	m^2	10.0	$10.00	$100.00
			SCHEDULE B - EARTHWORKS (EXCL. GST)		**$3,550.00**
3	**SCHEDULE C - STORMWATER**				
3.1	Supply and install of drainage structures complete including excavation, bedding, backfill, compact and dispose of surplus materials:				
	(a) 4/900x1200 RCBC	m	18.0	$5,000.00	$90,000.00
	(b) Blinding Concrete	m^3	2.0	$800.00	$1,560.00
	(c) Reinforced Concrete Culvert Base Slab	m^3	10.0	$1,800.00	$18,000.00
	(d) Reinforced Concrete Headwall	m^3	0.8	$1,800.00	$1,440.00
	(e) Reinforced Concrete Apron including footing	m^3	2.7	$1,800.00	$4,860.00
	(f) Reinforced Concrete Wingwall	m^3	1.0	$1,800.00	$1,800.00
	(g) Reinforced Concrete Cut Off Wall	m^3	1.0	$1,800.00	$1,800.00
3.2	Dumped rock protection including excavation, geofabric under, supply and place of rock (300mm thick d_{50} = 200mm)	m^2	10.0	$100.00	$1,000.00
			SCHEDULE C - STORMWATER (EXCL. GST)		**$120,460.00**

Bill of Quantities

Culvert C

Job No. 0489
Ref No. BM0009
Date. 24/06/2021

ITEM	DESCRIPTION		TOTAL
1	SCHEDULE A - PRELIMINARY		$36,000.00
2	SCHEDULE B - EARTHWORKS		$3,000.00
3	SCHEDULE C - STORMWATER		$158,270.00
	CONTINGENCY	20%	$7,800.00
		SUBTOTAL	**$205,070.00**
		10% GST	**$20,507.00**
		CIVILWORKS CONSTRUCTION TOTAL	**$225,577.00**

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**SCHEDULE A - PRELIMINARY**				
1.1	Site Establishment/Dis-establishment	Item	1.0	$5,000.00	$5,000.00
1.2	Provision for traffic	Item	1.0	$10,000.00	$10,000.00
1.3	Environmental management plan	Item	1.0	$5,000.00	$5,000.00
1.4	Erosion and Sediment Control Measures	Item	1.0	$10,000.00	$10,000.00
1.5	Public consultation (notification to residents/property owners)	Item	1.0	$1,000.00	$1,000.00
1.6	As-constructed documentation	Item	1.0	$5,000.00	$5,000.00
			SCHEDULE A - PRELIMINARY (EXCL. GST)		**$36,000.00**
2	**SCHEDULE B - EARTHWORKS**				
2.1	Clearing and grubbing	m^2	70.0	$5.00	$350.00
2.2	Removal of trees (Provisional Qty)	m^2	0.0	$10.00	$0.00
2.3	Stripping of topsoil (50mm)	m^3	35.0	$15.00	$525.00
2.4	Earthworks:				
	(a) Cut to fill	m^3	0.0	$15.00	$0.00
	(b) Imported fill	m^3	0.0	$25.00	$0.00
	(c) Removal of unsuitable material (Provisional Qty)	m^3	35.0	$35.00	$1,225.00
2.5	Trim, water and compact road subgrade (compaction 95% MDD)	m^2	40.0	$5.00	$200.00
2.6	Compact and final trim of batters	m^2	50.0	$4.00	$200.00
2.7	50mm topsoil and grass seed to verges, batters and disturbed areas	m^2	50.0	$10.00	$500.00
			SCHEDULE B - EARTHWORKS (EXCL. GST)		**$3,000.00**
3	**SCHEDULE C - STORMWATER**				
3.1	Supply and install of drainage structures complete including excavation, bedding, backfill, compact and dispose of surplus materials:				
	(a) 4/900x1200 RCBC	m	24.0	$5,000.00	$120,000.00
	(b) Blinding Concrete	m^3	2.6	$800.00	$2,080.00
	(c) Reinforced Concrete Culvert Base Slab	m^3	13.3	$1,800.00	$23,940.00
	(d) Reinforced Concrete Headwall	m^3	1.0	$1,800.00	$1,800.00
	(e) Reinforced Concrete Apron including footing	m^3	3.3	$1,800.00	$5,850.00
	(f) Reinforced Concrete Wingwall	m^3	1.0	$1,800.00	$1,800.00
	(g) Reinforced Concrete Cut Off Wall	m^3	1.0	$1,800.00	$1,800.00
3.2	Dumped rock protection including excavation, geofabric under, supply and place of rock (300mm thick d_{50} = 200mm)	m^2	10.0	$100.00	$1,000.00
			SCHEDULE C - STORMWATER (EXCL. GST)		**$158,270.00**

Bill of Quantities

Culvert D

Job No. 0489
Ref No. BM0009
Date. 24/06/2021

ITEM	DESCRIPTION		TOTAL
1	SCHEDULE A - PRELIMINARY		$36,000.00
2	SCHEDULE B - EARTHWORKS		$2,550.00
3	SCHEDULE C - STORMWATER		$143,186.00
	CONTINGENCY	20%	$7,710.00
		SUBTOTAL	**$189,446.00**
		10% GST	**$18,944.60**
		CIVILWORKS CONSTRUCTION TOTAL	**$208,390.60**

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**SCHEDULE A - PRELIMINARY**				
1.1	Site Establishment/Dis-establishment	Item	1.0	$5,000.00	$5,000.00
1.2	Provision for traffic	Item	1.0	$10,000.00	$10,000.00
1.3	Environmental management plan	Item	1.0	$5,000.00	$5,000.00
1.4	Erosion and Sediment Control Measures	Item	1.0	$10,000.00	$10,000.00
1.5	Public consultation (notification to residents/property owners)	Item	1.0	$1,000.00	$1,000.00
1.6	As-constructed documentation	Item	1.0	$5,000.00	$5,000.00
			SCHEDULE A - PRELIMINARY (EXCL. GST)		**$36,000.00**
2	**SCHEDULE B - EARTHWORKS**				
2.1	Clearing and grubbing	m^2	55.0	$5.00	$275.00
2.2	Removal of trees (Provisional Qty)	m^2	0.0	$10.00	$0.00
2.3	Stripping of topsoil (50mm)	m^3	27.5	$15.00	$412.50
2.4	Earthworks:				
	(a) Cut to fill	m^3	0.0	$15.00	$0.00
	(b) Imported fill	m^3	0.0	$25.00	$0.00
	(c) Removal of unsuitable material (Provisional Qty)	m^3	27.5	$35.00	$962.50
2.5	Trim, water and compact road subgrade (compaction 95% MDD)	m^2	40.0	$5.00	$200.00
2.6	Compact and final trim of batters	m^2	50.0	$4.00	$200.00
2.7	50mm topsoil and grass seed to verges, batters and disturbed areas	m^2	50.0	$10.00	$500.00
			SCHEDULE B - EARTHWORKS (EXCL. GST)		**$2,550.00**
3	**SCHEDULE C - STORMWATER**				
3.1	Supply and install of drainage structures complete including excavation, bedding, backfill, compact and dispose of surplus materials:				
	(a) 4/600x900 RCBC	m	24.0	$5,000.00	$120,000.00
	(b) Blinding Concrete	m^3	1.7	$800.00	$1,360.00
	(c) Reinforced Concrete Culvert Base Slab	m^3	6.5	$1,800.00	$11,700.00
	(d) Reinforced Concrete Headwall	m^3	0.9	$1,800.00	$1,692.00
	(e) Reinforced Concrete Apron including footing	m^3	2.1	$1,800.00	$3,834.00
	(f) Reinforced Concrete Wingwall	m^3	1.0	$1,800.00	$1,800.00
	(g) Reinforced Concrete Cut Off Wall	m^3	1.0	$1,800.00	$1,800.00
3.2	Dumped rock protection including excavation, geofabric under, supply and place of rock (300mm thick d_{50} = 200mm)	m^2	10.0	$100.00	$1,000.00
			SCHEDULE C - STORMWATER (EXCL. GST)		**$143,186.00**

Bill of Quantities

Stormwater Drains to Roads

Job No. 0489
Ref No. BM0009
Date. 24/06/2021

ITEM	DESCRIPTION		TOTAL
1	SCHEDULE A - PRELIMINARY		$31,000.00
2	SCHEDULE B - STORMWATER DRAINAGE		$497,300.00
	CONTINGENCY	20%	$105,660.00
		SUBTOTAL	**$633,960.00**
		10% GST	**$63,396.00**
		CIVILWORKS CONSTRUCTION TOTAL	**$697,356.00**

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**SCHEDULE A - PRELIMINARY**				
1.1	Site Establishment/Dis-establishment	Item	1.0	$5,000.00	$5,000.00
1.2	Provision for traffic	Item	1.0	$5,000.00	$5,000.00
1.3	Environmental management plan	Item	1.0	$3,000.00	$3,000.00
1.4	Erosion and Sediment Control Measures	Item	1.0	$15,000.00	$15,000.00
1.5	Public consultation (notification to residents/property owners)	Item	1.0	$1,000.00	$1,000.00
1.6	As-constructed documentation	Item	1.0	$2,000.00	$2,000.00
				SCHEDULE A - PRELIMINARY (EXCL. GST)	**$31,000.00**
2	**SCHEDULE B - STORMWATER DRAINAGE**				
2.1	Clearing and grubbing	m^2	1600.0	$5.00	$8,000.00
2.2	Remove and dispose of existing culvert end structures complete:				
	(a) 450 dia. RCP (8 locations)	No.	8.0	$350.00	$2,800.00
2.3	Supply and install new culvert complete including excavation, bedding, backfill, compact and dispose of surplus materials:				
	(a) 450 dia. RCP (Class 2) (8 locations)	m	8.0	$450.00	$3,600.00
2.4	Supply and construct headwall complete:				
	(a) 450 dia. RCP (8 locations)	No.	8.0	$1,200.00	$9,600.00
2.5	Supply and construct drainage along roadside:				
	(a) 450 dia. RCP	No.	1600.0	$250.00	$400,000.00
	(b) Stormwater Inlet Pits	No.	24.0	$1,200.00	$28,800.00
2.6	Dumped rock protection including excavation, geofabric under, supply and place of rock	m2	250	$50.00	$12,500.00
2.7	50mm topsoil and grass seed to verges, batters and disturbed areas	m^2	1600.0	$20.00	$32,000.00
				SCHEDULE B - STORMWATER DRAINAGE (EXCL. GST)	**$497,300.00**

Bill of Quantities

Rock Protection to Magnificent Creek

Job No. 0489
Ref No. BM0009
Date. 24/06/2021

ITEM	DESCRIPTION		TOTAL
1	SCHEDULE A - PRELIMINARY		$31,000.00
2	SCHEDULE B - EARTHWORKS		$224,800.00
	CONTINGENCY	20%	$51,160.00
		SUBTOTAL	**$306,960.00**
		10% GST	**$30,696.00**
		CIVILWORKS CONSTRUCTION TOTAL	**$337,656.00**

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**SCHEDULE A - PRELIMINARY**				
1.1	Site Establishment/Dis-establishment	Item	1.0	$5,000.00	$5,000.00
1.2	Provision for traffic	Item	1.0	$5,000.00	$5,000.00
1.3	Environmental management plan	Item	1.0	$3,000.00	$3,000.00
1.4	Erosion and Sediment Control Measures	Item	1.0	$15,000.00	$15,000.00
1.5	Public consultation (notification to residents/property owners)	Item	1.0	$1,000.00	$1,000.00
1.6	As-constructed documentation	Item	1.0	$2,000.00	$2,000.00
				SCHEDULE A - PRELIMINARY (EXCL. GST)	**$31,000.00**
2	**SCHEDULE B - EARTHWORKS**				
2.1	Clearing and grubbing	m^2	3600.0	$5.00	$18,000.00
2.2	Stripping of topsoil (50mm)	m^3	180.0	$10.00	$1,800.00
2.3	Dumped rock protection including excavation, geofabric under, supply and place of rock	m^2	3600.0	$50.00	$180,000.00
2.4	50mm topsoil and grass seed to verges, batters and disturbed areas	m^2	1250.0	$20.00	$25,000.00
				SCHEDULE B - EARTHWORKS (EXCL. GST)	**$224,800.00**

Bill of Quantities

Open Swale A

Job No. 0489
Ref No. BM0009
Date. 24/06/2021

ITEM	DESCRIPTION		TOTAL
1	SCHEDULE A - PRELIMINARY		$31,000.00
2	SCHEDULE B - EARTHWORKS		$147,500.00
	CONTINGENCY	20%	$35,700.00
		SUBTOTAL	**$214,200.00**
		10% GST	**$21,420.00**
		CIVILWORKS CONSTRUCTION TOTAL	**$235,620.00**

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**SCHEDULE A - PRELIMINARY**				
1.1	Site Establishment/Dis-establishment	Item	1.0	$5,000.00	$5,000.00
1.2	Provision for traffic	Item	1.0	$5,000.00	$5,000.00
1.3	Environmental management plan	Item	1.0	$3,000.00	$3,000.00
1.4	Erosion and Sediment Control Measures	Item	1.0	$15,000.00	$15,000.00
1.5	Public consultation (notification to residents/property owners)	Item	1.0	$1,000.00	$1,000.00
1.6	As-constructed documentation	Item	1.0	$2,000.00	$2,000.00
				SCHEDULE A - PRELIMINARY (EXCL. GST)	**$31,000.00**
2	**SCHEDULE B - EARTHWORKS**				
2.1	Clearing and grubbing	m^2	4000.0	$5.00	$20,000.00
2.2	Stripping of topsoil (50mm)	m^3	200.0	$10.00	$2,000.00
2.3	Earthworks:				
	i) Imported fill - Select Fill (CBR10 materials)	m^3	0.0	$80.00	$0.00
	ii) Removal of unsuitable material	m^3	3000.0	$25.00	$75,000.00
2.4	Trim, water and compact road subgrade (compaction 95% MDD)	m^2	0.0	$10.00	$0.00
2.5	Compact and final trim of verges	m^2	2020.0	$5.00	$10,100.00
2.6	50mm topsoil and grass seed to verges, batters and disturbed areas	m^2	2020.0	$20.00	$40,400.00
				SCHEDULE B - EARTHWORKS (EXCL. GST)	**$147,500.00**

Bill of Quantities

Open Swale B

Job No. 0489
Ref No. BM0009
Date. 24/06/2021

ITEM	DESCRIPTION		TOTAL
1	SCHEDULE A - PRELIMINARY		$31,000.00
2	SCHEDULE B - EARTHWORKS		$302,850.00
	CONTINGENCY	20%	$66,770.00
		SUBTOTAL	**$400,620.00**
		10% GST	**$40,062.00**
		CIVILWORKS CONSTRUCTION TOTAL	**$440,682.00**

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT
1	**SCHEDULE A - PRELIMINARY**				
1.1	Site Establishment/Dis-establishment	Item	1.0	$5,000.00	$5,000.00
1.2	Provision for traffic	Item	1.0	$5,000.00	$5,000.00
1.3	Environmental management plan	Item	1.0	$3,000.00	$3,000.00
1.4	Erosion and Sediment Control Measures	Item	1.0	$15,000.00	$15,000.00
1.5	Public consultation (notification to residents/property owners)	Item	1.0	$1,000.00	$1,000.00
1.6	As-constructed documentation	Item	1.0	$2,000.00	$2,000.00
			SCHEDULE A - PRELIMINARY (EXCL. GST)		**$31,000.00**
2	**SCHEDULE B - EARTHWORKS**				
2.1	Clearing and grubbing	m^2	8700.0	$5.00	$43,500.00
2.2	Stripping of topsoil (50mm)	m^3	435.0	$10.00	$4,350.00
2.3	Earthworks:				
	i) Imported fill - Select Fill (CBR10 materials)	m^3	0.0	$80.00	$0.00
	ii) Removal of unsuitable material	m^3	7200.0	$25.00	$180,000.00
	iii) Road subgrade replacement material - Select Fill (CBR10 materials)	m^3	0.0	$80.00	$0.00
2.4	Trim, water and compact road subgrade (compaction 95% MDD)	m^2	0.0	$10.00	$0.00
2.5	Compact and final trim of verges	m^2	3000.0	$5.00	$15,000.00
2.6	50mm topsoil and grass seed to verges, batters and disturbed areas	m^2	3000.0	$20.00	$60,000.00
			SCHEDULE B - EARTHWORKS (EXCL. GST)		**$302,850.00**