Flood Model Report

Kununurra Stormwater Study

CW992700

Prepared for

Shire of Wyndham - East Kimberley

Cardno

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1 Introduction

Cardno was commissioned by Shire of Wyndham - East Kimberley (SWEK) to undertake flood modelling to better understand the frequency and severity of flooding within the Kununurra township. Recent storm events have exceeded the capacity of the town's drainage system causing flooding in the Townsite, the adjacent Nulleywah Community and within the adjacent Ord Irrigation Scheme (OIC).

The aim of the project is to:

1. Assess and map the performance of the existing drainage system within the study area and provide a complete set of drainage data,
2. Provision of a detailed long term, overall drainage management strategy; and
3. Provision of a long-term capital works program to be implemented to mitigate flooding in the townsite and minimize damage to Shire, Water Corporation and Ord Irrigation Asset Mutual Cooperative (OIAMC) infrastructure.

Proposed actions aim to reduce risk by ensuring a targeted flood response; reducing exposure; reducing flood volumes; focusing maintenance on critical assets and the strategic construction of flood mitigation measures.

The extent of the hydrological study proposed extends 4 km north of the Townsite as shown in Figure 1. The catchment plan for the flood study and external catchments draining to the Study Area is shown in Figure 2.

1.1 Study Objective

As detailed in the brief, the objectives of the study are to:

- Prepare and calibrate hydraulic flood models to observed flood behaviour for recent flood events and define flood behaviour for the 63.2%, 20%, 5% and 1% Annual Exceedance Probability (AEP) flood events;
- Assess the existing drainage infrastructure capacity and performance and highlight potential problem areas of the system and high priority areas for attention;
- Understand the severity of flood risk posted to properties, infrastructure and areas susceptible to flooding;
- Prepare flood risk mapping and flood level contours which can be readily used by SWEK, OIAMC and Water Corporation for infrastructure and development planning purposes;
- Develop costed indicative, draft capital works program for the drainage system under SWEK management which is broken into annual stages to the approximate value of $1M;
- Develop an indicative, draft annual maintenance program for the drainage system under SWEK Management; and
- Provide a report on the outcomes of the study outlined above.

1.2 Scope of Works

In order to achieve the objectives outlined in Section 1.1, Cardno developed a site-specific methodology that involved:

- Desktop assessment of the available data to aid in identification of data gaps;
- Development of 1D-2D coupled model for the Study Area;
- Determination of the flood extents and depths for the design 63.2%, 20%, 5% and 1% AEP flood events;
- Establishment of the functionality of the drainage infrastructure; and
- Development of a priorities list for maintenance/ work with associated cost estimate.

2 Background

2.1 Study Area

Kununurra is a town in far north Western Australia located at the eastern extremity of the Kimberley Region, approximately 37 kilometres from the Northern Territory border (Figure 1). It is the largest town in Western Australia north of Broome with the closest town being Wyndham, 100 kilometres away. Kununurra is 3,040 kilometres from Perth via the Great Northern Highway.

The town is situated in amongst the scenic hills and ranges of the far north-east Kimberley Region, having an abundance of fresh water, conserved by the Ord River Diversion dam and main Ord River Dam, Lake Argyle.

The catchment area is approximately 21 km^2 (herein referred to as the Study Area), predominantly comprised of residential developments, industrial/commercial developments with areas of parks and public open spaces spread throughout the township and large areas of major open space to the north and north-eastern side of the catchment.

Runoff from the Study Area generally drains south and south-westerly towards Lily Creek Lagoon and north-westerly towards the M1 channel.

2.2 Original Drainage System

The original drainage system proposed for Kununurra relied heavily on overland flow with little underground stormwater pipes. Houses were built off the ground using stilts typically with chain-linked fencing so as not to impede surface flows. Cut-off drains were installed upstream of the town to limit flows entering residential areas and diverting it around rural properties (SWEK, 2013). Over time, as the Kununurra township has expanded, leading to an increase in impervious area runoff, the original overland drainage system has proven to be exceeded in capacity.

The source of a significant proportion of the flow through the townsite is the runoff from Mirima National Park, located north-east of the townsite and containing rocky impervious features. It was intended for these flows to be captured and contained in cut-off drains and discharged south to Lily Creek Lagoon. However, due to the runoff from the National Park conveying silt and causing siltation of the cut-off drains, their capacity has been reduced diverting additional water to the M1.

2.2.1 Drainage Catchments

The original Townsite was divided into 6 catchments as shown in drawing 48531-0-1-A in Appendix B. These catchments discharge to either Lilly Creek Lagoon or the M1 channel. Failure of the drainage function of a single catchment meant flows would enter into an adjacent catchment causing the subsequent catchment drainage infrastructure to fail. This cascading is noted to be commonplace (SWEK, 2013).

2.2.2 Cut-off Drains

Two major cut-off drains were constructed on the north-east side of town to divert overland flow from the Mirima National Park and land surrounding Kelly's Knob away from the Townsite. Both drains were constructed in very light sandy soil and it is clear from available documentation that considerable effort was applied to protect the drains from erosion. The use of drop structures throughout the drains ensured flows were not hindered and erosion was reduced. This drainage design results in the system being sensitive to changes and requiring frequent maintenance (SWEK, 2013).

Further, it has been suggested levees or berms for flood control previously existed east of Weaber Plain Road, north of the townsite, to help minimise flood impacts downstream. As-constructed Public Works Department of Western Australia (PWDWA) should be reviewed to confirm if this was indeed the case.

2.2.3 Ord Irrigation Project: Irrigation Channels, Drains, Associated Structures and On-Farm Structures Design Manual

A proportion of the stormwater flow from the Kununurra townsite drains to M1 Channel. The M1 was originally designed to be able to receive stormwater runoff from the townsite and also the wastewater treatment plant (WWTP) owned and operated by Water Corporation. The channel is designed to handle drainage from town for a storm event equivalent to 240mm / 48 hours.

The system was designed to move water slowly through the system, thus limiting erosion and dangerous velocities and minimising environmental impacts when ultimately discharging to the Ord River. Based on OIC's Design Manual (1974), originally created by Public Works Department, the design flow velocities in the main channels are 0.3 m/s (minimum) and 0.75 m/s (preferred maximum), with an absolute maximum of 1.0 m/s. To operate effectively, drainage catchments utilising the M1 should ideally be designed with consideration of the design parameters in the Design Manual

The design flow of the M1 Channel is approximately 26 m^3/s. In comparison, the environmental flow for the nearby Ord River is approximately 45 m^3/s in non-drought conditions.

2.3 Previous Studies

2.3.1 Hydrologic Study of Weaber Plains Road Flooding and Viable Mitigation Strategies (JDA, 2013)

In January 2003, JDA was commissioned by SWEK and Water Corporation to undertake a hydrological investigation to assess and provide flood mitigation options for a 256 ha area of land located between the M1 channel and Weaber Plains Road. The study was undertaken in response to several properties being inundated in the area over three consecutive wet seasons (1999/2000 through to 2001/2002).

2.3.1.1 Modelling Results

The flood assessments results identified locations where flooding affected the study area. The results of the study noted:

- Due to flatness of the topography within the study area, the extent of flood inundation for the 50 year Average Recurrence Interval (ARI) storm event was only marginally greater than the extent of flooding for the 5 year ARI storm event;
- The existing properties located within the study area have different levels of protection against flooding. A number of existing houses are located above the 50 year ARI flood level, while other houses are below the 2 year ARI flood level;
- For events greater than the 5-year ARI, flooding of Weaber Plains Road towards the northern extent of the study area was noted. In this area, the flood results identified that the 50 year ARI volume was less than the 10 year ARI flood volume as the critical duration was noted to be less (6 hours compared to 24 hours); and
- For events greater or equal to the 5 year ARI, overtopping of the M1 channel eastern embankment near the southern extent of the study area was noted.

The estimated accuracy of flood levels by JDA was considered to be in the order of +/- 0.1 m for the 2 year ARI and to +/- 0.2 m for the 50 year ARI.

2.3.1.2 Flood Mitigation Options

Seven options for flood mitigation were identified and analysed by JDA:

- Option A – House protection bunds
- Option B – Increase capacity of D2 culverts, D2 drain and research station road culverts
- Option C – Construct gated outlets to M1
- Option D – Construct gated outlet to M1C2
- Option E – Onsite detention basins in the catchments
- Option F – Raising house pads
- Option G – Diverting flow from one catchment to another

An evaluation of all options was performed based on technical, environmental, social and capital cost criteria, with a qualitative assessment performed with options ranked within each selected category. Based on this evaluation, Option A was the preferred option. Option A also provided the highest level of protection (50 year ARI).

2.3.2 Flood Risk Assessment Kununurra (GHD, 2013)

GHD was commissioned by SWEK in February 2013 to undertake a flood risk assessment for two areas in Kununurra (residential areas north-east and commercial areas south-west of township) to identify drainage

and flood characteristics of the areas. The purpose of the study was to identify problem areas and propose flood mitigation options. DHI Mike Flood was the software utilised to build and run the 5, 10 and 100-year ARI storm events.

2.3.2.1 Results

The flood assessment results identified locations where flooding affected the study area. Locations identified by GHD in the townsite where inundation had occurred are discussed in the proceeding sections with advised flood mitigation options.

2.3.2.2 North – Ironwood Drive and Weaber Plain Road East

Modelling results indicated that in larger events (5 year ARI or greater), stormwater ponds on Weaber Plain Road just south of the intersection with Ironwood Drive. This was noted to be due to substantial sediment deposited in the drain from scouring in areas east of Kelly's Knob.

Proposed Mitigations Options

- Where water overtops the road, provide floodway to protect the road (intersection of Poincettia Way and Weaber Plain Road);
- If Ironwood Road is not lowered, an outlet for water from Mangaloo Street is required (intersection of Iroonwood Drive and Konkerberry Dr);
- Some Roads to be lowered (intersection of Nutwood Cres and Konkerberry Dr);
- Drain and culvert sizes to be upgraded (north of intersection of Leichhard St and Konkerberry Dr);
- Construct levee to prevent water overtopping the drain system (Ironwood Drive); and
- Clear and reconstruct drain to re-grade the drain from north to south (intersection of Ironwood Drive and Weaber Plain Road).

2.3.2.3 South – Park Along Messmate Way, Ivanhoe Road

Runoff volume from direct rainfall inundated the park along Messmate Way. The park has underground drainage that ultimately discharges to Lily Creek Lagoon, but inadequacy in the drainage system fail to prevent overtopping of the park in even a 5-year ARI storm event. Due to the lack of a levee or embankment between the park and the commercial properties to the north east, high water tail levels cause extensive flooding through the commercial areas.

The combination of limited culvert and pipe capacity downstream of Ivanhoe Road and high tail water levels causes extensive flooding upstream through the commercial area.

Proposed Mitigation Options

- Constructing a levee on the south side of the park north of Messmate Way will prevent water from overtopping the road;
- An increase in the size of the culverts under Ivanhoe Road to ease the ponding against the road and flooding the commercial area. It was also noted that the capacity of this drain should be investigated.

General Maintenance

During a site visit, GHD noticed most driveways used standard 300 mm diameter pipes, which were either blocked or broken. Some drains were noted to grade in the wrong direction. It was recommended that clearing out and re-grading the drains and culverts will help convey water during lower flows and increase discharge and decrease flood duration after heavy storm events.

2.3.3 Rejuvenation of Kununurra Township Drainage Stage 1 (2013)

The report prepared by SWEK (2013), which also utilised results from the GHD report, highlighted the intent of the original town drainage system was to favour overland flow. Flooding in town was attributed to alteration of the Towns intended design, including removal of drainage structures, which has caused the system to fail to perform as was designed.

It was noted that over time, the overland flow component has been compromised by activities within the catchment such as houses not always been built on stilts and wire fences being replaced with solid structures. To counter this, some roads have been lowered to act as drainage pathways but this has not been completed in its entirety and therefore not completely effective.

The main conclusion of the report is that current flooding caused by the cut-off drains needs to be resolved in the first instance allowing other flooding issues within the town to be resolved.

SWEK proposed the following works as part of Stage 1 works:

- Drain A: along Weaber Plain Rd
  - Restoration of drain to return to original design parameters with shallower batter profiles suitable to soil structure;
  - Replacement of Hidden Valley Caravan Park crossover to a single span bridge as it is currently impeding flow; and
  - Reinstatement of downstream drop structures (which were removed) to restore grade.
- Drain B: along Ironwood Dr
  - Restoration of drain to return to original design parameters with shallower batter profiles suitable to soil structure;
  - Re-establish grade lines between Speargrass Rd and drop structure opposite Cajuput St; and
  - Replacement of the drop structure - and possibly increase capacity to match that of the culverts in Speargrass Rd.

3 Model Input Data

3.1 Digital Elevation Model (DEM)

A 1m resolution digital elevation model (DEM) of the study area has been supplied by Geoscience Australia using LiDAR data captured in February 2017, which has vertical accuracy of ± 0.2m. It is understood that at the time of data capture, the drains in the study area were dry.

As part of Quality Assurance checks, it was found that the bed levels of the M1 Channel were not represented in the LiDAR data, suggesting there was water in the drain and a portion of the D1 drain was not captured. An alternative DEM of the M1 Channel was created utilising land survey data for these sections provided by OIC. These datasets were used to develop a terrain for the 2D overland model used for this study.

3.2 Drainage Network

The existing drainage network in the study area was surveyed by McMullen Nolan Group (MNG) in June 2017. The survey data was then imported into GIS software and reviewed to identify data gaps and discrepancies. The infill techniques outlined in Table 3-1 below were then used to modify the dataset to be suitable for use.

Table 3-1 Drainage Network Modification Techniques

Data gap / discrepancy	Resolution
Disconnected network	Manually connecting pipe ends in GIS software
Incorrect pipe direction (some pipes digitised downstream to upstream)	Pipes re-orientated based on topography and overall position in the drainage network.
Missing pipe diameters	Diameters estimated based on adjacent pipes and position in the system.
Missing invert information	Missing invert values have been infilled by subtracting the pipe diameter and cover from the DEM ground level. A cover value of 600 mm was assumed.
Pipes deemed to have erroneous invert information (i.e. pipes with extreme slope, disconnects to upstream / downstream levels)	Manual adjustments made where necessary whilst ensuring the network remained underground.
Network discontinuity	Clarification from SWEK was sought for the drainage arrangement at various locations, particularly on Messmate Way. Some locations in the network were missing outlets. These were digitised manually, with diameters estimated from the immediate upstream pipe and invert levels based on the DEM ground level at the outlet location.

3.2.2 M1 Structure Information

The M1 Channel contains a series of radial gates, which are controlled in the event of a storm. The gates are opened 300mm to maximise flow down the D1 drainage channel. Detailed design drawings of these gates were provided by the Water Corporation, which assisted in modelling these structures. In addition, flow and level data were also supplied (provided in Appendix B), such that the gate parameters (eg. losses) could be calibrated.

Outlet structures at the D1 drain were not included in the drainage network survey. The details for these structures were provided by the OIC (2017) as CAD drawings.

3.3 Land Use

The spatial distribution of land use categories for the study area were supplied by SWEK (2017). These categories used to inform the hydraulic roughness and rainfall losses for use in the hydraulic model. The technique used to derive rainfall losses from the land use categories is outlined in section 5.2.6.

3.4 Rainfall

3.4.1 Design rainfall

The design rainfall data was sourced from ARR Data Hub, which include the 2016 Intensity Frequency Duration (IFD) data developed by the Bureau of Meteorology (BoM). This included rainfall depths for the durations ranging from 30 minutes to 72 hours for the 1%, 5%, 20% and 63.2% AEP storms and corresponding temporal patterns. Each duration exhibits 10 temporal patterns to account for the temporal variation in rainfall distributions.

The rainfall depths generated from IFDs relate to points in a catchment rather than the whole catchment area and therefore need to be adjusted to represent the areal average rainfall rather than point rainfall. This is done through an aerial reduction factor (ARF), which uses the catchment area, storm duration and storm frequency to derive a ratio between the aerial average rainfall and point rainfall. It was noted that using the entire study area for the ARF calculation would lead to an overestimation of the ARF for shorter duration storms, which are likely to be critical to flooding in the townsite. Therefore, the study area was divided into a 'Rural' and a 'Townsite' area for the purposes of calculating ARFs. This ensured that shorter duration storm depths at the townsite were not underestimated by the ARF.

3.4.2 Historical rainfall

Kununurra has been subject to several severe storm events in its history. The rainfall data from a storm event which occurred between 6th and 8th of February 2014 were sourced BoM (Station ID: 002056) at a daily resolution and the Department of Water and Environmental Regulation (DWER) (Station ID: 502062) at 30-minute resolution. The BoM gauging station is located at Kununurra Airport; approximately 1.5 km west of the townsite and the DWER gauging station is located at Abney Hill, approximately 6 km north of the townsite, as shown in Figure 1. This rainfall event was chosen due to the available observations and photographs from the corresponding flood event, which assisted in model validation outlined in section 5.3.

Rainfall data for this event was later sourced from DWERs townsite rain gauge and was found to have recorded a similar rainfall depth and temporal pattern as the Kununurra Airport over the same period.

3.5 Rainfall losses

Rainfall losses were sourced from the ARR Data Hub in the form of initial and continuing loss values. The application of the losses is limited to rural areas only and therefore, a methodology was developed to determine losses for the urban areas, which is discussed in section 5.2.6. It was noted that these losses were representative of the wider regional catchment and did not necessarily reflect the losses for the study area. Therefore, engineering judgement and understanding of the region soils was made to adjust the ARR losses accordingly.

3.6 Anecdotal Observations

The flood event of February 2014 received media attention due to its severity and widespread damage to infrastructure. Photographs of flooding at locations in the townsite were available from the ABC News website (Collins, Mills 2014). Additional photos of the flooding were provided by SWEK and OIC, shown in Plates 1 to 4 on the following page. Anecdotal observations were used to assist in validating the hydraulic model, discussed in section 5.3.

Plate 1 Barringtonia Ave (Source: ABC News, 2014)

Plate 2 - Barringtonia Ave and Weaber Plains Rd Intersection (Source: SWEK,2014)

Plate 3 – Messmate Way (Source: SWEK,2014)

Plate 4 – M1 Channel (Source: OIC, 2014)

3.7 Site Visit

Cardno undertook two site visits; 14 to 15 March 2017 and 15 to 16 May 2019 which included inspections with Shire Officers. Key information noted during the site visits are provided in the proceeding sections.

3.7.1 Ivanhoe Road drains (IRD):

- The industrial site drains to IRDs and to the Main Ivanhoe Road Drain (MIRD) which ultimately discharges to Lily Creek Lagoon;
- No issues with the IRD and MIRD;
- Drain outlet to Lily Creek Lagoon has a bund across to prevent lagoon coming back up the MIRD;
- Minimal silt issues observed;
- Majority of land southwest of Messmate Way flows towards Ivanhoe;
- Approximately in line with the Mental Health Centre Rd along Ivanhoe Rd is the catchment split with half going to Lily Creek Lagoon and the other half towards the M1; and
- Bio-retention basin is not designed correctly. Control structure does not control any flows and does not store water for treatment.

3.7.2 Bandicoot Drive

- Open swale drains and drive way crossovers;
- Major silt, vegetation growth and drain degradation visible.
- Lack of maintenance;
- Land owners fill spoon drains;
- Majority of cross overs blocked or broken;
- Bandicoot Drive earmarked to be rebuilt, drainage upgrade to be incorporated;
- Coates Hire and neighbouring property floods;

Plate 5 – Roadside drain no longer defined on River Gum

- Lake view apartments example of land owners filling drains; and
- Bandicoot drive can drain into the drain located adjacent to Kimberley Grand (open drain, silt, impeded by landowners in spots), a 450mm culvert besides BP (pipe blocked) and to IRD.

3.7.3 Poinciana Street

- Two swale outlets only typically get half full;
- Poinciana St to be upgraded;
- Silt and low vegetation in both drains. Veg most likely acts as a stabiliser for silts and allows it to drop out; and
- Like Bandicoot, people are filling in spoon drains. Crossovers are damaged.

3.7.4 Subway building

- Sandbags blocking doors to prevent water entering buildings;
- Water fills up to kerb height along Banksia St then overflows to other street drainage;
- Drains are connected to the Messmate Swale; and
- Most likely top water level in the swale equals the water level being noticed behind Subway.

3.7.5 Messmate Swale

- Pipe system (twin 600mm) with above ground grassed swale connected via BUPs;
- Generally works well; and

- Some subsidence issues due to old pipes (40 + years) and connections failing.

3.7.6 Barringtonia Ave/Weaber Plains Rd

- Connected to a 450mm outlet to Lily Creek lagoon; and
- Flooding has been reported up to the keep left sign (~800mm).

3.7.7 Weaber Plains Rd Hillside Drain

- Outfall under Barringtonia Ave hasn't overtopped road (likely due to overtopping of the drain banks upstream of the road);
- Observations that the drain D/S of Barringtonia only fills up half way;
- Hillside drain has broken bank approx. opposite 43 Weaber Plain Rd previously;
- Large amount of silt (3-4ft) within the drain;
- Large amount of bank erosion evident. Some mitigation works have been completed utilising rock to minimise erosion; and
- Silt removal has not occurred for a number of years.

Plate 6 – Weaber Plain Hillside Drain erosion and silt

3.7.8 Weaber Plain Road

- Road has no kerbs with road falling towards properties;
- No defined spoon drain evident with runoff sheet flowing towards Victoria Hwy and via Bubble in structures; and
- Majority of Bubble-ins impacted by silt.

3.7.9 Cnr Ironwood Dr and Weaber Plain Rd

- Main confluence of industrial area drain and Weaber Plain Rd runoff;
- Hillside drain is separate to industrial drain. Hillside drain has a higher invert than the road and road spoon drain in this location; and
- Look at potentially connecting industrial drain to Hillside Drain further down Weaber Plain Road.

3.7.10 Outlet under Ironwood adjacent to St Martins

- Has overtopped the road in this location previously;
- Drain both upstream and downstream unmaintained with vegetation and silt; and
- Land from old Shire offices drains across oval towards this drain. Connects via 300mm pipe underneath Coolibah. Evidence of standing water and high flows at oval.

3.7.11 Industrial area (north of town)

- No pit and pipe drainage, road and kerb;
- Drainage flows south through two drains to along Weaber Plain Road;
- Lots of sand coming in off the National Park through the drains;
- Swale full of silt and vegetation; and
- Potential for the swale to grade away from town and enter the M1 from the north.

Plate 7 – Sand from the National Park across Salacca Loop

3.7.12 Lakeside

- Combination of kerb breaks, pipes and swales;

- Some minor silting and vegetation build-up in drains; and
- Drainage appears to be functioning well, with the main issues arising due to high groundwater.

3.7.13 General notes

- Large sediment/silt issue from undeveloped land; and
- Road lowering to help with surface flow is intercepting the groundwater causing the road pavement to fail. Recommend subsoils are laid in all trenches with drainage pipe. Potentially, lowering the drainage system along Messmate Way will allow groundwater control to be installed, preventing groundwater from damaging infrastructure such as the pool.

4 Hydrology

4.1 Overview

A hydrologic model of the Mirima National Park was constructed to determine the flows contributing to the study area from the escarpment. The modelling package XP-RAFTS was used to simulate flows generated by the 1%, 5%, 20% and 63.2% AEP storm events. XP-RAFTS uses the Laurenson Runoff Routing method to generate streamflow hydrographs from rainfall excess in rural and urban settings. The model requires the discretisation of the catchment into sub-catchments and the following inputs: area, vectored slope, loss rates and Manning's roughness, which are used to calculate the storage delay coefficient for each sub-catchment. The resulting hydrographs were used as inflows into the hydraulic model.

4.2 Model Development

4.2.1 Catchments

The National Park catchment is approximately 6.2 km^2, which was discretised into 53 sub catchments using the DEM and GIS tools. Major streamlines were also developed through geo-processing of the DEM. The sub-catchments are mostly homogenous, with the exception of the downstream catchments, which are smaller. The catchment delineation is shown in Figure 3.

4.2.2 Rainfall

Design rainfall hyetographs were sourced from the ARR Data Hub using the centroid of the National Park catchment (Lon: 128.8º, Lat: -15.8º). Durations between 30 minutes and 72 hours for the 1%, 5%, 20% and 63.2% AEP events, including ten temporal patterns for each duration were downloaded.

An ARF was calculated using the total catchment area and was applied to the design rainfall depths.

4.2.3 Input parameters

The area and vectored slope of the streamline for each sub-catchment was calculated using the DEM and GIS tools. Due to the homogeneity of the sub-catchments (rocky terrain), a uniform Manning's 'n' value of 0.05 was used.

An initial loss (IL) / continuing loss (CL) scheme was used to model rainfall losses, the values for which were sourced from the ARR Data Hub. The loss parameters obtained were IL= 64 mm and CL = 8 mm/hour. Due to the rocky terrain attributing to impervious surfaces, it was deduced that these values would need to be adjusted by 50%. Hence, initial loss and continuing loss values of 32 mm and 4 mm/hour were used respectively.

A hydrograph lag time was used for each streamline to account for channel routing, using an average wave celerity of 2 m/s.

Model input parameters are presented in Appendix C.

4.3 Rational Method Validation

Peak flow results from the XP-RAFTS model were checked against flows calculated using the Rational Method to ensure the hydrological model is robust and produces reliable results. Two upstream sub-catchments (Cat_03 and Cat_08) were lumped, and the generated peak flows were compared to that from the Rational Method for the 1% AEP event. The time of concentration for the sub-catchments were calculated using the Barnsby-Williams method (QUDM, 2013). The findings of the comparison are presented in Table 4-1. It can be seen that the peak flow rate generated by XP-RAFTS is a close match to the Rational Method calculation, making the model suitable for use.

Table 4-1 Rational Method Verification for XP-RAFTS Model

Parameter	Value
Area (ha)	55.69
Slope (%)	2.62
Fraction impervious - f_i	0.0
Time of concentration- t_c (min)	41.67
$^1I_{10}$ (mm/hr)	63.5
Coefficient of discharge - C_{10}	0.3
Frequency factor - F_{100}	1.2
Coefficient of discharge - C_{100}	0.36
Average rainfall intensity – $^tI_{100}$ (mm/hr)	109.00
Peak flow - Q_{100} (m^3/s)	**6.07**
XP-RAFTS Peak flow (m^3/s)	**5.87**

4.4 Results

Sixteen durations (between 30 minutes and 72 hours) with an ensemble of 10 temporal patterns per duration were modelled in XP- RAFTS for each event frequency. The median peak flow for each ensemble was then calculated before calculating the maximum of the 16 median peak flows. This yielded the design flow rate for each event, presented in Table 4-2. Note that results are reported for the model outlet at Cat_36. The results for each modelled storm where used as boundary inflows in the hydraulic model.

Table 4-2 XP-RAFTS Model Results

AEP Event	Peak flow (m^3/s)
63.2 %	11.0
20%	33.8
5%	51.5
1%	75.3

5 Hydraulic Model

A 1D/2D linked rain-on-grid hydraulic model of the study area was constructed using the modelling package TUFLOW to simulate overland, channel and pipe flows in the study area. TUFLOW is a grid-based 2D hydrodynamic free-surface solver capable of simulating floods, tide, storm tide and coastal hydraulics. It can incorporate a 1D scheme through dynamic linking with the 2D overland component. In this study, the pit and pipe network, along with major hydraulic structures such as culverts and gates were modelled as 1D and the surface topography modelled as 2D, representing overland flow paths.

The TUFLOW Heavily Parallelised Computing (HPC) solution scheme was used to utilise the quicker model run times when being run on a GPU graphics card as opposed to being run on a single CPU core as is the case with TUFLOW Classic. This allowed for the modelling of ensembles of different rainfall temporal patterns using the hydraulic model without excessive run times. The HPC scheme uses adaptive timestepping to progress through the simulation, where the timestep is adjusted such that it complies with the stability criteria of the numerical solution.

5.1 Methodology

The ARR 2016 recommendation for design assessments involves the modelling of an ensemble of different rainfall temporal patterns for each storm duration to model the variability in observed patterns. When modelling multiple durations to determine the critical duration for a site or multiple sites in a 2D hydraulic model, this becomes an extremely time consuming step. To mitigate this issue, the steps outlined below were undertaken in the modelling process. These steps are based on the recommendations provided in ARR 2016 (ref: Book 2, Chapter 5, Section 5.9.2).

1. An initial hydraulic model (E01) of the study area was constructed with a ‘coarse’ grid size (10m x 10m) and only key hydraulic structures where included as a 1D component.
2. The E01 model was used to run all rainfall durations and temporal patterns ranging from 30 minutes to 72 hours, equating to 160 runs for each AEP event.
3. The median flood surface elevation for each duration was calculated for the ensembles.
4. Five critical locations in the townsite were chosen for assessment. These are shown on Figure 4.
5. The durations which exhibited the maximum median flood level at the critical locations were identified. Note that this could reveal up to 5 different critical durations and temporal patterns.
6. The ensemble results for these durations were inspected to determine which storm temporal pattern produced the median flood surface elevation.
7. A final detailed hydraulic model (E02) was constructed with a ‘fine’ grid (3m x 3m) which contained the pit and pipe system as well as key hydraulic structures as a 1D component.
8. The critical storm duration(s) and temporal pattern(s) identified in step 6 were then run as E02.
9. The combined maximum flood surface elevation of these runs are calculated and adopted as the design flood surface.

This methodology was used to prepare floodplain maps for the 63.2%, 20%, 5% and 1% AEP events.

5.2 Model Development

5.2.1 Model Domain

The model domain, shown in Figure 4, has a total area of 21 km^2 and encompasses the Kununurra townsite and the rural area to the north. This area was included due to contributing flows to the M1 Channel, which affects the flows generated from the townsite entering the channel. The northern boundary was extended approximately 0.5 km along the M1 Channel, north of the M1C1 gates to avoid numerical errors associated with an open boundary propagating upstream. The western boundary was chosen to include the runoff generated by the agricultural land west of the M1 Channel flowing into the channel. The southern boundary was chosen as Victoria Highway and the southern end of the townsite south-east of Lily Creek Lagoon. The eastern boundary was chosen as the western ridge of the National Park. The DEM was also used to assist in determining the catchment for the hydraulic model.

5.2.2 Topography

The model topography was developed using the DEMs described in section 3.1. Modifications were made to the topography to ensure it was suitable for hydraulic modelling. For example, the very steep topography could potentially lead to instabilities or excessive time step lowering as velocities increase. Therefore, very steep areas representing some buildings and large rocks/hills were manually lowered and the corresponding Manning's roughness increased to alter the flow paths. In addition, some drains were not captured in the LiDAR (potentially due to water or vegetation) were manually modified using survey data. The model topography is shown in Figure 5.

5.2.3 Grid size

The grid size was chosen such that it was able to represent topographical features without excessive model run times. Model E01, which was used to identify critical durations and storm temporal patterns, was made using a grid size of 10m. Model E02, which was used for the final design runs, was made using a gird size of 3m, which was sufficient to model the major drains, roads and road kerbs.

5.2.4 Rainfall

The design rainfall described in section 3.5.1, was applied to the model using direct rainfall method. This was an appropriate method to use for modelling localised flooding generated by runoff in the townsite.

For very steep areas shown in Figure 4, particularly near the National Park, Kelly's Knob and Mount Cyril, rainfall was deactivated and the equivalent rainfall hyetograph applied downstream, specifying the area deactivated and the losses applied. This was done to avoid numerical instabilities arising from high velocities caused by rainfall falling directly on these areas. It is a reasonable assumption that the routing effects from these steep areas are negligible.

It is understood that approximately one third of the Kununurra Airport drains into the M1 Channel. Due to the absence of the airport from the LiDAR data, a similar equivalent area technique as the one described above was adopted to account for the runoff generated by the eastern part of the airport.

5.2.5 Resistance

The hydraulic resistance values were applied to the hydraulic model as Manning's 'n' roughness coefficients as presented in Table 5-1. These values for the overland domain were based on the land use categories described in section 3.4, with some additions. The land use distribution across the model domain is provided in Figure 6. A uniform Manning's 'n' value of 0.014 was used for the pipes and culverts modelled in 1D.

Table 5-1 Hydraulic Roughness Values

Land Use	Manning's 'n'	Land Use	Manning's 'n'
Drains	0.01	R15	0.2
Caravan/ aboriginal site	0.2	Public purposes	0.03
Water authority	0.01	Parks- Rocky terrain	0.025
Town center	0.3	Parks and recreation	0.03
Tourist	0.2	Mixed business	0.5
Rural industrial	0.3	Major roads	0.018
Rural living	0.05	Light industrial	0.3
School/Church	0.3	Industrial	0.5
Rural agriculture	0.03	Hospital	0.5
Road reserve	0.045	Channel (medium	0.045
New developments	0.35	Sand quarry	0.05
R50	0.35	Rural developed	0.08
R30	0.3	Lily Creek flood plain	0.05
R20	0.2	Townsite roads	0.03

5.2.6 Rainfall losses

An initial loss and continuing loss scheme was used to model rainfall losses. The distribution of initial and continuing losses were based on the supplied land use distribution shown in Figure 6. The rainfall losses across the model domain were calculated based on a fraction impervious estimate for each land use category. The fraction impervious estimates were made from inspection of aerial imagery, geological mapping and calculating an areal weighted average. These were then used to calculate the losses for each category by proportioning the initial and continuing losses obtained from the ARR Data Hub for pervious surfaces and making an assumption on the losses for impervious surfaces, which are shown in Table 5-2. The calculated loss rates for each land use category applied in the model are shown in Table 5-3.

Table 5-2 Pervious and Impervious Surface Loss Rates

Surface type	Initial loss (mm)	Continuing loss (mm/hr)
Pervious (from ARR Data Hub)	64	8
Impervious	1	0.1

Table 5-3 Fraction Impervious and Loss Rates Used in Model

Land Use	Initial loss (mm)	Continuing loss (mm/hr)
Drains	57.7	7.21
Caravan/ Nulleywah Community site	32.5	4.05
Water authority	57.7	7.21
Town center	7.30	0.89
Tourist	7.30	0.89
Rural industrial	19.9	2.47
Rural living	25.0	7.21
School/Church	19.9	2.47
Rural agriculture	25.0	7.25
Road reserve	19.9	2.47
New developments	26.2	3.26
R50	10.5	1.29
R30	10.5	1.29
R20	16.8	2.08
R15	26.2	3.26
Public purposes	57.7	7.21
Parks- Rocky terrain	1.00	2.50
Parks and recreation	27.7	7.21
Mixed business	7.30	0.89
Light industrial	19.9	2.47
Industrial	7.30	0.89
Hospital	7.30	0.89
Channel (medium vegetation)	57.7	7.21
Sand quarry	25.0	8.00
Rural developed	12.8	1.60
Lily Creek flood plain	57.7	7.21
Townsite roads	1.00	0.10

5.2.7 Inflows

The discharge generated by the runoff from the National Park described in Section 4 were included as an external inflow into the model. This was applied on the upstream end of Lily Creek as shown in Figure 4.

5.2.8 Boundary conditions

The model contains four outlets as shown in Figure 4. The Lily Creek outlet was specified a constant water level boundary condition of 41.75 mAHD for all AEP events. This was adopted based on advice from the Water Corporation that the water level may occasionally exceed the normal operating level to 41.75 mAHD.

The outlet south of Victoria Hwy was specified a 'HQ' boundary type, with a specified slope of 1%. This slope was used to generate a rating curve for the open boundary. At this stage, it is assumed that there is no tail water condition in the drain south of Victoria Hwy.

In a similar manner HQ boundaries were specified at the open boundaries along the D1 drain and the M1 Channel, with slopes of 15% and 0.02% (M1 Channel design slope) respectively. The high slope at the D1 boundary is due to a drop structure just downstream of the boundary.

5.2.9 1D network and structures

5.2.9.1 Pit and Pipe network

The pit and pipe network for the townsite was modelled as a 1D component and linked to the 2D component using source links at the pits. Pipes below 0.3m in diameter were excluded from the network as it was assumed that they would be blocked or ineffective during a major storm event. This network also included manholes at some junctions and along the network.

Two types of pits were specified as is on the ground within the townsite. Side entry pits were given dimensions of 1.0m length and 0.2m height. Grated pits were assigned an inlet curve shown in Plate 8. This was calculated based on grate dimensions of 0.6m x 0.9 m.

The modelled pipe network for the townsite is shown in Figure 7.

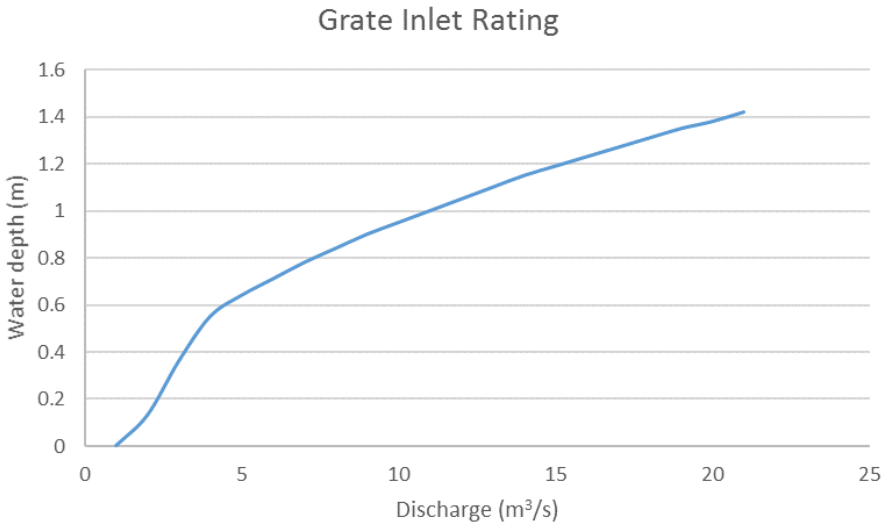

Plate 8 – Grated pit inlet rating curve

5.2.9.2 Structures

Major structures such as culverts were included as part of the 1D domain. In cases where the culvert invert level was below the DEM level, the DEM level was modified such that it matched the culvert invert levels, or a drain was manually included in the model topography. Culverts smaller than 0.3m in diameter were excluded, as they would likely be blocked or ineffective in a major event. Many of these smaller culverts are road crossing pipes which are overgrown with vegetation.

The M1C1 gate structure is located in the northern part of the model and has been modelled as part of the 1D domain. It consists of three radial gates, each 3.65 m wide. It is understood that the gates are opened by 0.3m in a storm event to allow water to discharge downstream (pers comm. Mat Dear, OIC) and has been modelled as such for design events. A discharge coefficient of 0.6 was used.

5.3 Model Validation

In order to determine whether the model is producing reasonable results, a historic rainfall event was modelled and the results compared to anecdotal observations. The event chosen was the February 2014 event occurring between the 6th and the 8th of February. This event was chosen due to its severity and available photographs of flooding in the townsite caused by the event, which allowed water levels to be derived.

5.3.1 Validation rainfall

The obtained rainfall data indicated the rainfall depth from Abney Hill station was 73 mm greater than that from Kununurra Airport over the same period (6th to 8th of February 2014). This suggests that the northern part of the catchment received more rainfall than the townsite. This spatial variation in rainfall was accounted for by applying the Abney Hill rainfall data to the northern part and the Airport data to the southern part of the model. Due to the Airport data being only available at a daily resolution, the temporal pattern from the Abney Hill data was used to distribute the Airport rainfall data. The validation rainfall hyetograph adopted is shown in Plate 9.

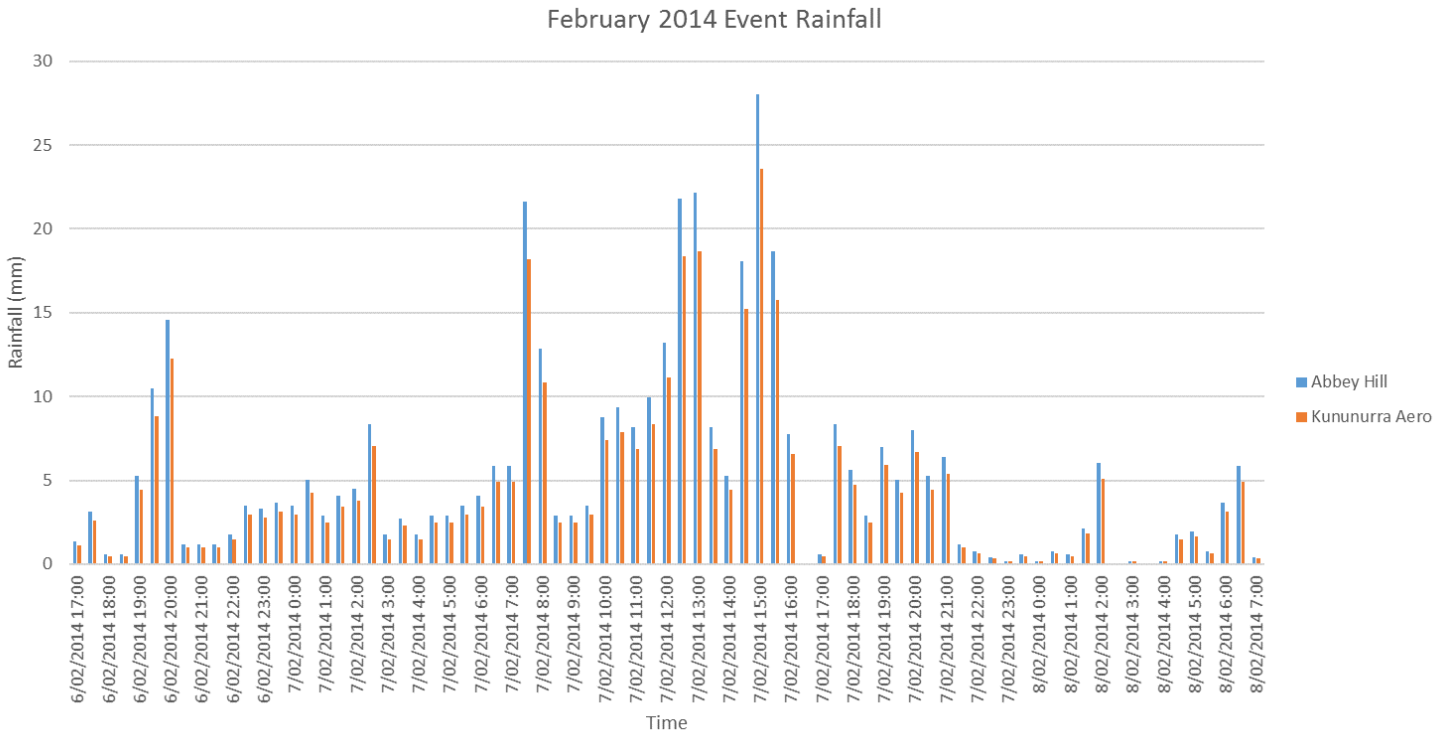

Plate 9 – Rainfall hyetographs used for validation.

5.3.2 Validation results

The results of the validation run are shown in Figure 8. It should be noted that the rainfall event of February 2014 was prior to the constriction of the large swale drain along the eastern side of the M1 Channel, which was installed in 2016, however, the swale drain is present in the LiDAR and hence model topography, making that area incomparable for the purposes of validation. It was noted however that water was breaching the banks and entering the M1 Channel from the east as was observed on the ground during the event.

In the townsite however, the modelled and observed flood levels are comparable. Assessing the photograph locations at Messmate Way and Barringtonia Ave revealed that the flood levels at these locations are approximately 47.35 mAHD and 49.23 mAHD. At both locations, the modelled water level was within 0.1m of the observed water level, indicating that the model is representing the flood characteristics of the townsite with a reasonable level of accuracy.

The validation results provide a good level of confidence in the model's ability to predict the flood levels and extents of design events.

5.4 Volume Check

A volume check was conducted to ensure that the correct volume of water was being input into the model. The input volume was calculated using the following equation:

$$V_{input} = [(Rainfall\ depth - Losses) \times Area\ ] + V_{inflows}$$

An areal weighted average of the losses across the domain was used to calculate the excess rainfall depth, which was then used to obtain the volume to rainfall over the catchment. $V_{inflows}$ represents the volume of water entering the model domain from external catchments. V_{input} was then checked against the volume input reported by the model. This check was done for the 1% and 20% AEP events and revealed a relatively low volume error (<5%) as shown in Table 5-4.

Table 5-4 Input Volume Error for the 20% and 1% AEP Events

Event frequency	Input volume error
1% AEP	1.92 %
20% AEP	4.87 %

6 Results

6.1 Floodplain mapping

Floodplain maps for the 63%, 20%, 5% and 1% AEP events were developed and are shown in Figures 10 to 13. This was done by calculating the maximum depths of the critical durations and temporal patterns for each AEP event. A depth filter of 0.05 m was applied to eliminate very shallow areas of flooding.

6.2 Flow hydrographs

Flow hydrographs were reported for the locations shown in Figure 9. The peak flow across these lines are presented in Table 6-1.

Table 6-1 Peak Flows Across Reporting Lines for 1%, 5%, 20% and 63.2% AEP Events

Reporting line	1% AEP	5% AEP	20% AEP	63.2% AEP
RP1	18.93	9.64	4.52	0.01
RP2	5.06	4.38	3.45	1.96
RP3	3.49	2.47	1.86	0.65
RP4	1.75	1.45	1.17	0.48
RP5	11.83	9.38	7.61	4.63
RP6	12.86	9.17	5.88	2.08
RP7	1.13	0.82	0.60	0.20
RP8	52.02	38.76	29.03	11.62
RP9	12.52	8.44	5.49	2.50
RP10	15.86	10.44	6.00	1.65
RP11	11.16	7.48	4.99	2.33
RP12	10.33	6.03	2.95	1.23
RP13	23.01	11.63	5.48	1.00
RP14	0.41	0.30	0.24	0.10
RP15	1.22	0.86	0.63	0.24
RP16	6.58	0.86	0.63	0.24
RP17	8.73	6.74	5.44	3.50
RP18	1.36	1.15	0.83	0.39
RP19	2.10	1.56	1.18	0.60
RP20	11.29	6.76	4.08	1.08
RP21	8.40	6.25	4.90	2.42
RP22	1.68	1.35	1.18	0.78
RP23	39.56	15.17	7.77	2.03
RP24	9.36	6.84	4.36	2.48
RP25	1.25	1.00	0.74	0.44
RP26	9.62	5.32	4.22	1.97
RP27	0.75	0.40	0.20	0.09
RP28	0.88	0.59	0.45	0.19
RP29	1.48	1.27	0.76	0.22
RP30	1.15	0.56	0.38	0.13

Reporting line	1% AEP	5% AEP	20% AEP	63.2% AEP
RP31	6.29	3.05	2.30	1.5

6.3 Flooding hotspots

Model results indicated that several flood hotspots were present in the townsite. These are discussed in detail below:

6.3.1 Barringtonia Ave

The intersection of Barringtonia Ave and Weaber Plain Road experiences flood depths of up to 0.75m as shown in Plate 7. This flooding is caused by overtopping of the Weaber Plain Road cut-off drain south of Mount Cyrill with flow proceeding to the west, down Barringtonia Ave, and the low point at the intersection with Weaber Plain Road. This is illustrated by the black arrows in Plate 10. The flow within the cut-off drain at RP16 (Figure 9) for the 1% AEP is 6.58m^3/s with the maximum capacity of the culvert under Barringtonia Ave calculated as being 2.22 m^3/s.

It was found that the footbridges across the cut-off drain south of Barringtonia Ave create a tailwater effect in the drain as the 2100 mm diameter pipes are insufficient in conveying the flows. This combined with the undersized 1200 x 1200 RCBC under Barringtonia Ave plays a major part in the drain overtopping and flows west.

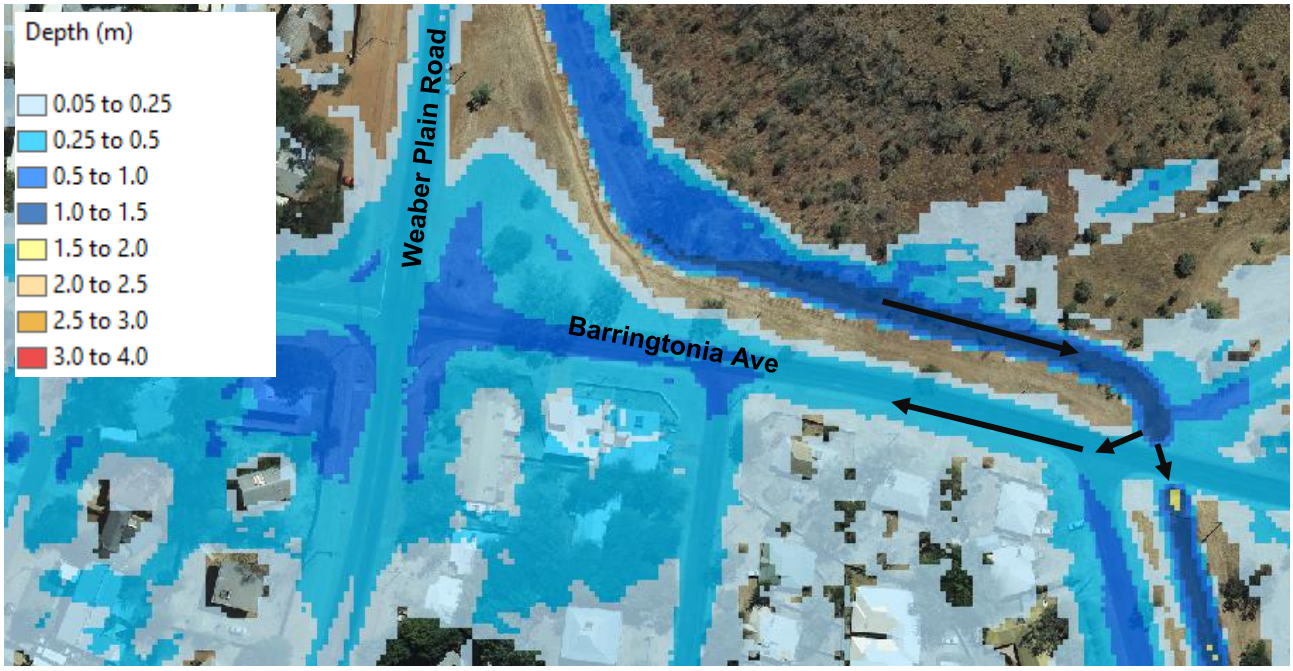

Plate 10 – Flooding at Barringtonia Avenue.

6.3.2 Industrial area

Flooding in the industrial area, shown in Plate 11 is attributed to direct rainfall at the site and occasional breakouts of some open channel drains. This location contains a network of open channel drains, which convey water to the roadside drain along Ivanhoe Road, eventually draining to Lily Creek Lagoon. Although not modelled with a tailwater, the outlet pipes under Victoria Hwy which drain the water out of the industrial area is potentially affected by a tailwater level from the downstream Water Corporation infiltration basin as was reported by GHD (2013). The tailwater exacerbates the flooding in the industrial area and needs to be considered.

Plate 11 – Flooding in the industrial area.

6.3.3 Nulleywah Community

The flooding experienced at the Nulleywah Community housing is shown in Plate 12. This flooding is attributed to the flows from Kelly's Knob directly east and breakouts of the drain to the north and south.

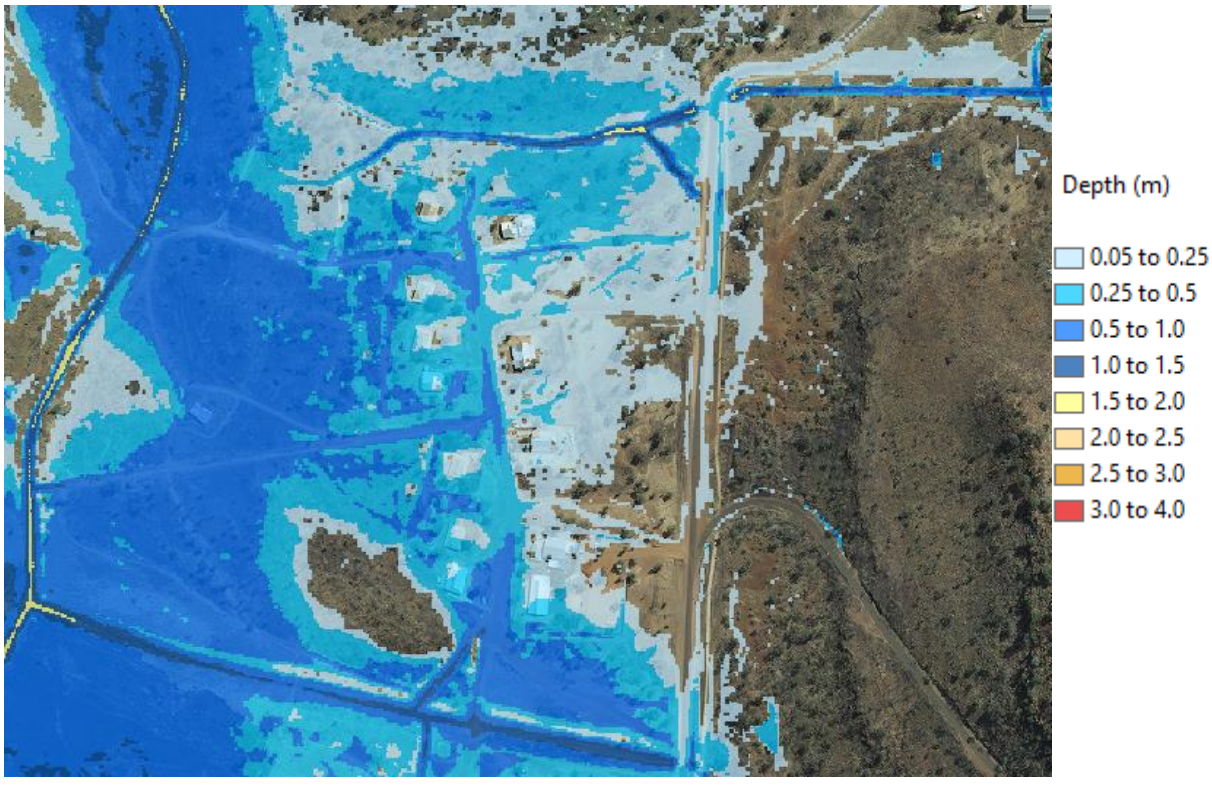

Plate 12 – Nulleywah Community

6.4 Comparison with Previous Studies

The modelled flood levels and extent have been compared to the findings of the Flood Risk Assessment (GHD, 2013). Due to the differences in modelling techniques between this study and the GHD study, the results exhibit some major differences. With respect to the 'North' study area as referred to in the GHD study, the flood extent is similar to the modelled extent in this study, with flooding along Leichhardt St and at the intersection of Nutwood Cr and Konkerberry Dr. Flood levels are greater in the GHD study due to the larger catchments draining into the 'North' study area. These catchments were represented as part of the direct rainfall model in this study, which identified alternate flow paths directing water away from the 'North' study area and hence less flooding in the area.

With respect to the 'South' study area representing the industrial area just north of Victoria highway, exhibits a similar flood extent to the modelled extent of this study. The overtopping of the park along Messmate Way and flow into the industrial area is observed in both studies. The flood levels are generally higher in the GHD study, potentially due to different tailwater levels for the culvert under Victoria highway, which drains a large proportion of the industrial area towards Lily Creek Lagoon. The ponding of water against Victoria Highway around Lakeview apartments in the GHD study is due to the absence of culverts in the model, which drains this area to Lily Creek Lagoon.

6.5 Sensitivity Analysis

A sensitivity analysis was conducted to determine the sensitivity of the modelled flood levels on a selection of inputs. The hydraulic roughness and rainfall losses were varied by 30%. The results were then compared to the base case scenario (E02) to obtain a water level afflux. The sensitivity scenarios are presented in Table 6-2.

Table 6-2 Sensitivity Analysis Scenarios

Scenario	Description
S01	Increase Manning's 'n' by 30%
S02	Decrease Manning's 'n' by 30%
S03	Increase initial and continuing loss by 30%
S04	Decrease initial loss by continuing loss by 30%

Results indicated that the flooding in the townsite is relatively insensitive to changes in roughness and rainfall losses. Slight increase in flood levels were observed for scenario S01 along the drain located south of Kelly's Knob and areas in the floodplain in the rural part of the study area. Conversely, the same areas experience a decrease in flood levels in scenario S02. Both outcomes are expected as the Manning's 'n' affects the velocity and discharge.

A majority of the study area is also insensitive to changes in the rainfall loss values. A slight decrease in flood levels is observed in the agricultural area west of the M1 Channel and in the channel itself for scenario S03. Conversely, the same areas experience an increase in flood levels for scenario S04.

The sensitivity results suggest that the choices for the roughness and loss parameters for the design events are reasonable estimates. It is recommended that a sensitivity analysis of the boundary conditions be conducted, particularly at the outlet south of Victoria Highway.

6.6 Stakeholder Engagement

A stakeholder engagement was conducted with representatives from:

- The Shire of Wyndham East Kimberley (SWEK);
- Ord Irrigation Cooperative (OIC);
- Department of Water and Environmental Regulation (DWER); and
- Water Corporation (WC)

The outcomes of the stakeholder engagement identified the need to investigate six critical flood areas, which were believed would help alleviate flooding in the townsite. These measures are outlined in Table 7-1. The issue of siltation of the major cut-off drains around Kelly's Knob and Mount Cyril from runoff sourced from the National Park was discussed, with suggestions that re-instating the drop structures in the cut-off drains will

mitigate the issue to some extent. Further discussion with the state governing body for the national parks will need to be made to create a strategy for reducing siltation.

DWER expressed the need for water quality monitoring at stormwater outlets discharging to Lily Creek Lagoon, as pollutants from the industrial area upstream may affect the water quality in the lagoon. The outlet which discharges west alongside Ivanhoe Road, discharges to a borrow pit before overflowing to the lagoon. The pit itself is overgrown with vegetation and is located in the Kununurra Water Reserve, which is classified as a P1 protection area as gazetted in 2004 under the *Country Areas Water Reserve Act 1947*. The tailwater level from Lily Creek Lagoon in this area is likely significant for the draining of the industrial area. Furthermore, DWER identified the need to incorporate Water Sensitive Design (WSD) for future drainage plans.

There is concern over the use of the M1 Channel for stormwater storage and conveyance during storm events. The OIC has expressed its concerns over the structural damage to the channel during major storm events as well as pollutants carried by overland flow entering the channel. WC have a shared in the view that the stormwater drainage system should be less reliant on the channel.

The meeting minutes from the stakeholder engagement workshop are attached in Appendix D.

7 Options Analysis

Upon presentation of the results to stakeholders, several management options for flood mitigation were discussed. It was concluded that the six options would be modelled and the impacts assessed. These options are presented in Table 7-1 and shown in Figure 15. During the modelling process, two further scenarios where modelled and impacts assessed (as presented in Table 7-1) to help minimise flooding.

Table 7-1 Summary of Flood Mitigation Options Investigated.

Code	Description
D01	▪ Widening of the D1 drain to 20m (base width). ▪ Increasing capacity of the swale running parallel to the M1 Channel- 30m base, 1.5m depth and 1:4 side slopes. ▪ Re-grading the swale to run from south to north. ▪ Including a siphon (12 x 1200 x 1200 RCBC) at the downstream end of the swale, which drains directly to the D1 drain. ▪ Altering the roughness coefficient of the swale and the major drains from the townsite to Manning's n=0.01, assuming that the swale and drains will be well maintained.
D02	▪ Increasing the capacity of the pipes under the Messmate Way public open space to 2 x 900 RCP.
D03	▪ Including 2 x 900 RCP along Weaber Plain Rd from Leichhardt St to Barringtonia Ave and upgrading the pipes from Barringtonia Ave to the outlet to 2 x 900 RCP. ▪ Including a detention basin at the north-eastern corner of the intersection. ▪ Upgrading the culvert under Barringtonia Ave to 3600 x 1200 RCBC. ▪ Removal of the footbridges over the drain, which are causing a tailwater effect for the culvert under Barringtonia Ave. ▪ Re-grading the drain downstream of Barringtonia Ave to 0.5% to further mitigate tailwater effects.
D04	▪ Clearing and re-grading the drain east of the Kimberley Grande Resort, with a Manning's n=0.01. ▪ Addition of 600 RCP under the drain and 900 RCP downstream of Victoria Hwy, flowing out to Lily Creek lagoon. ▪ Addition of two additional pits, one at each end of the drain.
D05	▪ Extending the 2 x 1050 RCPs along Coolibah Dr up Ironwood Dr to discharge in the drain upstream of Ironwood Dr. ▪ Including three additional pits along Ironwood Dr. ▪ Lowering the road level of Ironwood Dr at this location to 43 mAHD to act as an overflow. ▪ Altering the roughness coefficient of the drain to Manning's n=0.01.
D06	▪ Removal of the caravan park crossings across the cut-off drain running parallel to Weaber Plains Rd (Drain A) which act as a restriction to flows. ▪ Altered the roughness of the drain to 'Manning's n = 0.03. Increased the capacity of basin north of Poincettia Way. ▪ Re-directed the drain north of Kentia Way to flow north instead of south and increased the capacity of the swale running north parallel to Weaber Plain Rd. ▪ Increased the capacity of the culverts under Cocus Way and the unnamed road between Cocus Way and Kentia Way to 3 x 900 RCP. ▪ Included 3 x 1200 x 600 RCBCs under Weaber Plains Road north to discharge the re-directed flow west.
D07	▪ All options D01 to D06 combined.
D08	▪ As option D01, with the addition of a levee at 43.5 mAHD on the eastern side of the M1 swale and extension of the swale south towards the townsite.

7.2 Options Analysis Results

The options detailed in Table 7-1 were modelled with the 1% AEP and 20% AEP event critical storms. The maximum water level at each grid cell from the critical storms was then calculated to yield the design flood surface elevation for each option. These were then compared with the design flood surface elevation for the

existing case (E02) by calculating the difference between E02 and the design flood surface of each option. The resulting 'afflux' maps are shown in Figures 16 to 31, with positive values reflecting reductions in flood levels and negative values reflecting an increase in flood levels. The results of the options analysis are discussed in the proceeding sections.

7.2.1 Option D01

The afflux maps for Option D01 are shown in Figures 16 and 17. They present a slight reduction in flooding around the Nulleywah Community and further south towards the townsite on Ironwood Dr. However, the reductions do not extend beyond Ironwood Dr, suggesting that maintenance and/or upgrades are required further upstream in the townsite itself to allow flows in the townsite to reach the swale. In addition, the M1 water level is reduced by 1.2m as a result of the expansion of the swale and D1 drain and the inclusion of the siphon.

7.2.2 Option D02

The afflux maps for Option D02 are shown in Figures 18 and 19. Reductions of flood levels in the Messmate Way open space is evident, however, reductions are limited beyond Messmate Way. Areas north of Coolibah Dr experience slight reductions as a result of the changes. The car park west of Messmate Way experiences slight reductions in the 1% AEP event. The extra capacity provided by the pipe upgrade to 2 x 900 RCPs allows for the pipes along River Fig Ave to be upgraded (from a single 600 RCP), which will allow water from the north-east towards Barringtonia Ave to drain via Messmate Way.

7.2.3 Option D03

The afflux maps for Option D03 are shown in Figures 20 and 21. The re-grading, clearing and removal of the footbridges in the drain downstream of Barringtonia Ave was extremely effective in reducing the tailwater effect evident in the existing case. The pipe upgrade under Barringtonia Ave to 3600 x 1200 RCBC was also effective in conveying the flows from the cut-off drain. This resulted in reductions of flood levels of up to 0.2 m in the intersection of Barringtonia Ave and Weaber Plain Rd and reductions extending west all the way to Ironwood Dr in both the 1% AEP and 20% AEP events.

The detention basin north-east of the Barringtonia Ave and Weaber Plains Rd intersection is effective in storing water from road runoff in both events. However, the main purpose is to allow stormwater from all events to pond off the road rather than within the intersection.

7.2.4 Option D04

The afflux maps for option D04 are shown in Figures 22 and 23. The additional pipes and regraded drain are effective in reducing flood levels by up to 100mm on Bandicoot Dr, Poinciana St, Bloodwood Dr and a proportion of the industrial area north of Victoria Hwy. The reductions are less prevalent in the 20% AEP.

7.2.5 Option D05

The afflux maps for Option D05 are shown in Figures 24 and 25. Flood level reductions are localised in the immediate surrounding area and range between 50 to 100 mm at the TAFE and primary school. The negative afflux downstream of the Ironwood Dr culvert is due to greater flows through the culvert from the extension of the pit and pipe network and alteration of the flow path over Ironwood Dr as a result of the lowering of the road. The additional pits are also effective in reducing flood levels on Ironwood Dr.

7.2.6 Option D06

The afflux maps for Option D06 are shown in Figures 26 and 27. The positive afflux north of Kelly's Knob is attributed to diverting the drain north of Kentia Way to flow north. Stormwater then flows through the culverts under Weaber Plains Rd before continuing west towards the M1 Channel. The expanded basin is also effective in storing stormwater in smaller events. The removal of the caravan park crossings increases conveyance in Drain A in and hence a reduction in water breaking out of the drain and flowing across Weaber Plains road to the cut-off drain south of Kelly's Knob (Drain B), as reflected by the flow through RP20 in Figure 9, being reduced by 6.82 m^3/s. This in turn reduces the flow through Drain B and reduces flooding in the properties south of Kelly's Knob by 60 - 80mm.

7.2.7 Option D07

The afflux maps for Option D07 are shown in Figures 28 and 29.

The outcome for the combined scenario shows similar reductions as described in the preceding sections.

7.2.8 Option D08

The inclusion of the levee along the eastern side of the swale prevents overland flow from the east entering the swale and ultimately increasing the capacity in the M1. When compared to Option D01, the inclusion of the levee has decreased the water level by approximately 300mm the M1.

The afflux maps in Figures 30 and 31 show localised flood reductions in the Nulleywah Community when compared to the existing case. The reductions however did not extend beyond Ironwood Dr in the north-western part of the town again suggesting that the flows are restricted at this location, which is a major outlet for the water in the townsite. This option in conjunction with clearing, maintenance and upgrades of the drains and culverts in the townsite itself will likely result in greater flood level reductions upstream. Furthermore, this option allows for more capacity downstream in the M1 than option D01 for future drainage works in the townsite.

8 Short Term Management Options

Considering the condition of the drainage infrastructure observed during the site visit and as documented in the 2013, Rejuvenation of Kununurra Township Drainage Stage 1 Report, Cardno have documented five key areas to be considered as part of short-term management options:

1. Preparation of an Asset Management Plan (AMP);
2. Preparation of an Operations and Maintenance Strategy;
3. Planning Controls;
4. Maintenance of existing drainage infrastructure; and
5. Rejuvenation of existing drainage infrastructure.

8.1 Preparation of an Asset Management Plan

Cardno are unaware of the Shire having any formal drainage Asset Management Plan (AMP) in place for council's drainage assets.

As described in IPWEAs Condition Assessment & Asset Performance Guidelines (2016), an AMP should allow for:

- Works orders to initiate reactive maintenance activities of those defects requiring attention as part of the current maintenance program, including timelines for completion.
- Capital expenditure projects for both renewals/replacement and new/upgrade, that address, project planning criteria including:
  - Priorities based on risk;
  - Bundling of projects into annual works programs;
  - Smoothing expenditures to avoid "lumpiness" in the budget allocations over future years, where possible.
- Liaison with other stakeholders on potential impacts of drainage asset works to ensure coordination of projects;
- Addressing new capital works impacts arising from both drainage projects and development projects to make sure they are incorporated into the organisations asset management programs for ongoing operation, maintenance and financial management.

The indicative cost associated with preparation of an AMP (assuming initial data collection/review) is presented in Table 8-1.

Table 8-1 Cost of Works - AMP

Task	Cost (ex GST)
Preparation of an AMP (and initial data collection)	$100,000[1]

1- Works assumed to be carried out by a consultant rather than the Shire

8.2 Preparation of an Operations and Maintenance Strategy

The majority of current maintenance is reactive which ultimately leads to asset deterioration, which costs more in the long term to rectify. The development of an Operations and Maintenance (O&M) Strategy has been identified as a priority to reduce the risk to the Townsite and reduce reactive maintenance needed. The Maintenance strategy should be designed to:

- Describe the systems and procedures to be used to plan and manage maintenance and replacement works;
- Specify the types of maintenance to be carried out;
- Establish the order of priority for maintenance activities; and
- Describe inspection regimes and responsibilities.

8.2.1 Example Maintenance of Drainage Infrastructure

1. Inspect drainage infrastructure during the following periods:
    a. During construction to determine whether machinery, falling trees or construction activity has damaged any components of existing drainage infrastructure. If damage has occurred, repair it.
    b. After each run-off event. Inspect the erosion damage at flow entry and exit points. If damage has occurred, make the necessary repairs.
    c. At least weekly during the nominated wet season (if any) otherwise at least fortnightly.
2. Clean out accumulated sediment when it reaches the marker board/post, and restore the original storage volume.
3. Do not dispose of sediment in a manner that will create an erosion or pollution hazard.
4. Check all visible pipe connections for leaks, and repair as necessary.

Table 8-2 presents example Operation and Maintenance Guidelines.

Table 8-2 Drainage Infrastructure – Operation and Maintenance

INSPECTION	
1.	**Routine Inspection**
1.1	Routine inspection should be carried out, as a minimum, on a regular monthly basis. The purpose of the inspection is to indicate when maintenance of drainage infrastructure is required.
1.2	Inspections should consider accumulation of sediment, condition of vegetation, ponded water.
1.3	Inspect following each rainfall event. Inspect drainage infrastructure following rainfall events to ensure that runoff \ has not caused damage or accumulation of sediment to a level where it must be removed. If damage has occurred, make the necessary repairs. If necessary, remove the accumulated sediment and restore the original storage volume. Remove all trash and debris from the basin.
1.4	Maintenance is required if: Excessive erosion has occurred. Excessive sediment accumulation has occurred. Vegetation is over grown. Water is ponding for excessively long periods of time. Inlets or outlets are damaged or blocked.
2.	**Annual Inspection**
2.1	Once a year, the condition of drainage infrastructure should be closely inspected. Any damage or problems should be noted on a Maintenance Form for action.
ROUTINE MAINTENANCE	
3.	**Purpose**
3.1	Routine maintenance of drainage infrastructure involves removal of accumulated sediment and restoration to original storage volume.
4.	**Sediment control**
4.1	Clean out sediment accumulated in the basins and drains when it reaches the top of the indicator post.
4.2	Check material in the basins and drains for excessive settlement, slumping of slopes, or piping between the conduit and the embankment; make all necessary repairs.
4.3	Sediment should not be disposed in a manner that will create an erosion hazard.
5.	**Litter Management**
5.1	Remove and dispose of trash and other debris from drainage infrastructure.

The costs associated with preparation of an O&M Strategy is presented in Table 8-3.

Table 8-3 Cost of Works – O&M Strategy

Task	Cost (ex GST)
Preparation of an O&M Strategy	$30,000[1]

1- Works assumed to be carried out by a consultant rather than the Shire.

8.3 Planning Controls

There exists a set of historical documents, rules and decision making that has led to the present level of development within Kununurra. Originally, it was assumed that cadastral boundaries enclosed reasonably permanent areas suitable for developing residential and commercial assets ad-infinitum. The notion that the land and assets within these boundaries is now vulnerable (or becoming vulnerable) to flooding, leads to the need for careful planning to determine future development directions flood risk areas.

8.3.1 Planning Instruments

The Shire should consider incorporating planning instruments into their planning framework as a preventative tool to limit future flood risk to residents and property. Some suggested planning instruments are as follows:

Structure Planning. Local structure plans typically indicate future proposed zoning, and the expectation is that once a structure plan has been implemented to a stage that the boundaries of the proposed zoning are set and not going to be changed, they then be incorporated into the planning scheme as a standard amendment.

In areas where development or redevelopment of land is proposed, all structure plans should properly consider the flooding extents presented in this report, to account for flood risks and ensure an appropriate buffer to flooded areas is included. This instrument may have limited effect in the context of the Shire, given much of the land identified as vulnerable is already developed. However, current agreed and draft local structure plans within flooded areas should be reviewed to identify any areas of concern, particularly with regards to providing permanent public/private infrastructure. The Shire will need to consider the implications of any such conflicts, and actions required to avoid the exposure of additional assets to risk from flooding processes where land remains undeveloped.

It is noted that in accordance with Section 27 of the Deemed Provisions of the Planning and Development (Local Planning Schemes) Regulations 2015, the effect of a structure plan is that: where the WAPC has approved a structure plan for an area, the decision maker is to have due regard to, but is not bound by, the structure plan when deciding the application (emphasis added). Currently approved structure plans have a life of 10 years from the date of approval, unless they have been revoked earlier. The local government or the landowner is able to request the WAPC to revoke approval of a structure plan under a number of circumstances, including when implementation is complete, or if effective implementation is not possible due to change in legislation or a state planning policy.

Notifications on Title**,** to inform current and future landholders of flood hazard risk should be considered.

Assessment Criteria**,** to ensure consistency when assessing applications for development proposed in hazard areas, for inclusion into a Local Planning Policy.

Development applications for subdivision and zoning beyond existing scheme allowances, within flood hazard areas, should not be encouraged or approved.

Theoretical Instruments include ‘transferable development rights’, ‘leaseback of land’, ‘land swaps’ and ‘rolling easements’. These instruments remain conceptual in the WA planning context and are not provided for under the State’s planning framework at present. These concepts require more research to determine how they would be practically implemented, but may be considered by the Shire in future.

Development Criteria/Controls where future development is allowed, a set of development criteria and controls should be considered to ensure existing drainage infrastructure is not further burdened by for instance; the addition of higher flows and altering flow paths (such as cross overs) unless an assessment of the external system has been undertaken and/or appropriate onsite controls have been provided.

8.3.2 Cost of Implementing Planning Controls

The costs associated with implementation of Planning Controls is presented in Table 8-4. The costings assume that the Shire will undertake the majority of work with input where required by a consultant.

Table 8-4 Cost of Works – Planning Controls

Task	Cost (ex GST)
Preparation of Planning Controls	$30,000[1]

1- Works assumed to be carried out by a consultant rather than the Shire.

8.4 Maintenance of Existing Infrastructure

As noted in Section 3.7, a large proportion of the towns infrastructure is lacking maintenance with maintenance activities generally being reactive (unplanned) rather than proactive (planned).

It is considered that there is a large backlog of maintenance, which should be undertaken to improve drainage performance.

The Shire's drainage assets comprises of the estimate of infrastructure presented in Table 8-5 and Table 8-6.

Table 8-5 Existing Shire Infrastructure – Main Townsite

Task	Unit	Total Amount
Pipe	Length (m)	14,955
Drain	Length (m)	13,791
Structures (i.e. gully and side entry pits)	Individual Unit	355
Drainage Basin	Area (m^2)	13,760

Table 8-6 Existing Shire Infrastructure – Lakeside

Task	Unit	Total Amount
Pipe	Length (m)	4,478
Drain	Length (m)	3,056
Structures (i.e. gully and side entry pits)	Individual Unit	106

The costs associated with undertaking the backlog of maintenance is provided in Table 8-7. Costs of backlog maintenance are based on:

- Pipe work flushing and clearing, including structures- $81/m.
- Drain maintenance, assumed grader - $25/m.
- Drainage basin, assumed laser bucket - $10/$m^2$.

Table 8-7 Existing Shire Infrastructure – Costs of Backlog Maintenance Activities

Task	Cost (ex GST)
Main Townsite Backlog Maintenance	$1,687,000
Lakeside Backlog Maintenance	$437,000

It is important to note, due to such a large cost, backlog maintenance is likely to be spread over 4 years based on a spend of $500,000 per year maintenance budget. It is important to undertake proactive maintenance on infrastructure once backlog maintenance has been undertaken to ensure infrastructure remains effective.

8.5 Rejuvenation of Existing Infrastructure

As noted in Section 2.3.3, the main conclusion of the Rejuvenation of Existing Infrastructure Stage 1 report by SWEK (2013), the cut-off drains along Weaber Plains Road and Ironwood Drive need to be resolved in the first instance so that other flooding issues within the town can be resolved.

Based on limited information provided in the report, the works detailed in Section 8.5.1 and 8.5.2 are proposed.

8.5.1 Cut-off Drain A – Weaber Plains Road

1. Sediment removal along length of drain. Assumed to be 1m deep for costing purposes
2. Installation of three drop structures in locations shown on Public Works Department of Western Australia (PWDWA) drawing number 44786-4-1 Rev B[1].
3. Re-grading of drain as shown on shown on PWDWA drawing number 44786-4-1 Rev B.

8.5.2 Cut-off Drain B – Ironwood Drive

1. Sediment removal along length of drain. Assumed to be 1m deep for costing purposes
2. Installation of one drop structure adjacent to Cajuput Street as shown on PWDWA drawing number 44786-5-1.
3. Re -grading of drain as shown on shown on PWDWA drawing number 44786-5-1.

8.5.3 Cost of Rejuvenation of Existing Infrastructure

The costs associated with the works in cut-off Drain A and B and existing infrastructure is presented in Table 8-8 with a costing breakdown provided in Appendix E. Assumptions of costings are discussed in further detail in Section 9.

Table 8-8 Cost of Works – Rejuvenation of Existing Drainage Works

Task	Cost (ex GST)
Cut-off Drain A – Weaber Plains Road	$110,000
Cut-off Drain B – Ironwood Drive	$52,000

8.6 Summary of Short Term Management Options

Proposed short-term management options and associated costs are presented in Table 8-9 based on assumed five year roll out, equivalent of $500,000 per year.

Table 8-9 Short Term Management Options Cost Estimate Summary

Task	Cost (ex GST)				
	Year 1	Year 2	Year 3	Year 4	Year 5
Preparation of an AMP	$100,000				
Preparation of an O&M Strategy	$30,000				
Planning Controls	$30,000				
Backlog Maintenance of Existing Infrastructure	$259,000	$419,000	$500,000	500,000	446,000
Cut-off Drain A – Weaber Plains Road	$55,000	$55,000			
Cut-off Drain B – Ironwood Drive	$26,000	$26,000			
Total	**$500,000**	**$500,000**	**$500,000**	**$500,000**	**$446,000**

[1] The report notes that metric drawings are available in Appendix B of the report. The drawings could not be sourced by Cardno and should be reviewed and updated prior to works.

9 Capital and Maintenance Cost Estimates

Cost estimates were developed for each of the explored flood mitigation options in Section 7. The rates used were obtained from construction rates for similar projects and provide a high-level estimate of construction and maintenance costs. Quantities have been based on plan measurements of distance and area, with volumes estimated using the ground surface levels from the LiDAR data.

9.1 Cost Risk

The following cost risk items have been identified as part of this study:

- Construction timeframes are not staged. Staged construction will incur extra preliminary costs.
- De-watering costs are not considered in the estimates. Construction is assumed to take place in the summer period.
- Underlying ground conditions are unknown and may impact construction methods and equipment requirements.
- Construction rates used in developing cost estimates have been based on:
  - Pervious projects in the area
  - Competitive rates
  - Client provided rates

9.2 Assumptions

The following over-arching assumptions were made in determining cost estimates for each option:

- Due to the level of available information and times which have not been investigated, an accuracy of +/- 30% have been applied.
- Existing ground surface will be earth worked to achieve desired surface levels.
  - Cut material to be used as fill to construct drains and channels.
  - Excess cut over fill material to be carted to stockpile. Excess stockpile material remaining after channel construction to remain as is. There is no allowance for respreading.
  - Excess fill over cut material to be obtained from surrounding areas within the site by further stripping earthworks.
- Where relevant rates have not been available for the area, a factor of 1.65 has been applied.

The cost estimate for the mitigation options are presented in Table 9-1. Details of the quantities and rates used for each option are provided in Appendix E.

Costing for option D04 has not been included as it was undertaken by SWEK prior to the finalisation of this report.

Table 9-1 Cost Estimates for Remaining Flood Mitigation Options

Option	Construction cost
D01	$11,372,000
D02	$ 1,426,000
D03	$ 1,998,000
D05	$ 668,000
D06	$ 790,000
D08	$12,760,000

10 Recommendations

Cardno has used the data and information obtained from this study to prioritise the assessed mitigation options. This prioritisation considers the effectiveness of the option in terms of reducing flood risk throughout the Kununurra townsite and the cost estimates of the options presented in Table 9-1. Cardno's recommended prioritisation is presented in **Error! Reference source not found.**:

Table 10-1 Prioritisation of Flood Mitigation Options

Priority	Option	Location of Works
1	D03	Weaber Plain Road and Barringtonia Ave upgrades
2	D06	North Industrial area – inc. Caravan Park culverts
3	D01/ D08	M1 siphon and flood levee
4	D05	Ironwood Drive works
5	D02	Messmate Way upgrades

Cardno recommends the implementation of D08, while more expensive, be constructed as opposed to D01 to further alleviate flood risk for the townsite and M1 and associated infrastructure.

Further Cardno recommends:

- The short term management options detailed in Section 8 be implemented in addition to the above options for optimised performance of the town's stormwater drainage system.Review of as constructed PWDWA drawings for additional information on further flood levees or berms previously constructed.
- Future drainage plans, structure plans and local planning schemes incorporate best water management practices, in line with guidelines and recommendations from DWER. A water quality program be established for the stormwater outlet at Ivanhoe Road due to the location of the environmentally significant wetlands located south of the townsite (Lake Kununurra and Lily Creek Lagoon). The discharge from this outlet passes through the light industrial area upstream and has the potential to compromise water quality of these wetlands. Structural controls to manage water quality should be considered for the townsite.
- Water quality monitoring should be conducted at stormwater outlet discharge points and further downstream in Lily Creek Lagoon.

11 References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia (Geoscience Australia), 2016.

Collins B, Mills V. *Kununurra flooding with more rain forecast*, ABC Kimberley, 7 February. Available at: http://www.abc.net.au/local/photos/2014/02/07/3940293.htm?site=kimberley (Accessed: 6 May 2019).

Davies J, Rogers A, Martens S, O'Donnell M, *Hydrologic Study of Weaber Plains Road Flooding and Viable Mitigation Strategies*, JDA Consultant Hydrologists, 2003.

GHD*, Flood Risk Assessment Kununurra*, 2013.

Hammond N, Shire of Wyndham East Kimberley, *Rejuvenation of Kununurra Township Drainage*, 2013.

Institute of Public Work Engineering Australasia Queensland, *Queensland Urban Drainage Manual,* 2017.

Institute of Public Works Engineers Australasia, *Condition Assessment & Asset Performance Guidelines*, 2016.

Webber, *M., Runoff Generation: Laurenson*, XP Drainage Help Documentation, 2015.

APPENDIX A

FIGURES

LOCALITY MAP

Kununurra

Perth

N

0 450 900 km

Abney Hill

Mills Rd

D1 Drain

M1 Channel

Kelly's Knob

Mirima National Park

Mt. Cyril

Kununurra Airport

Lily Creek Lagoon

Ord River

Legend

- Rainfall gauges
- Study area

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N

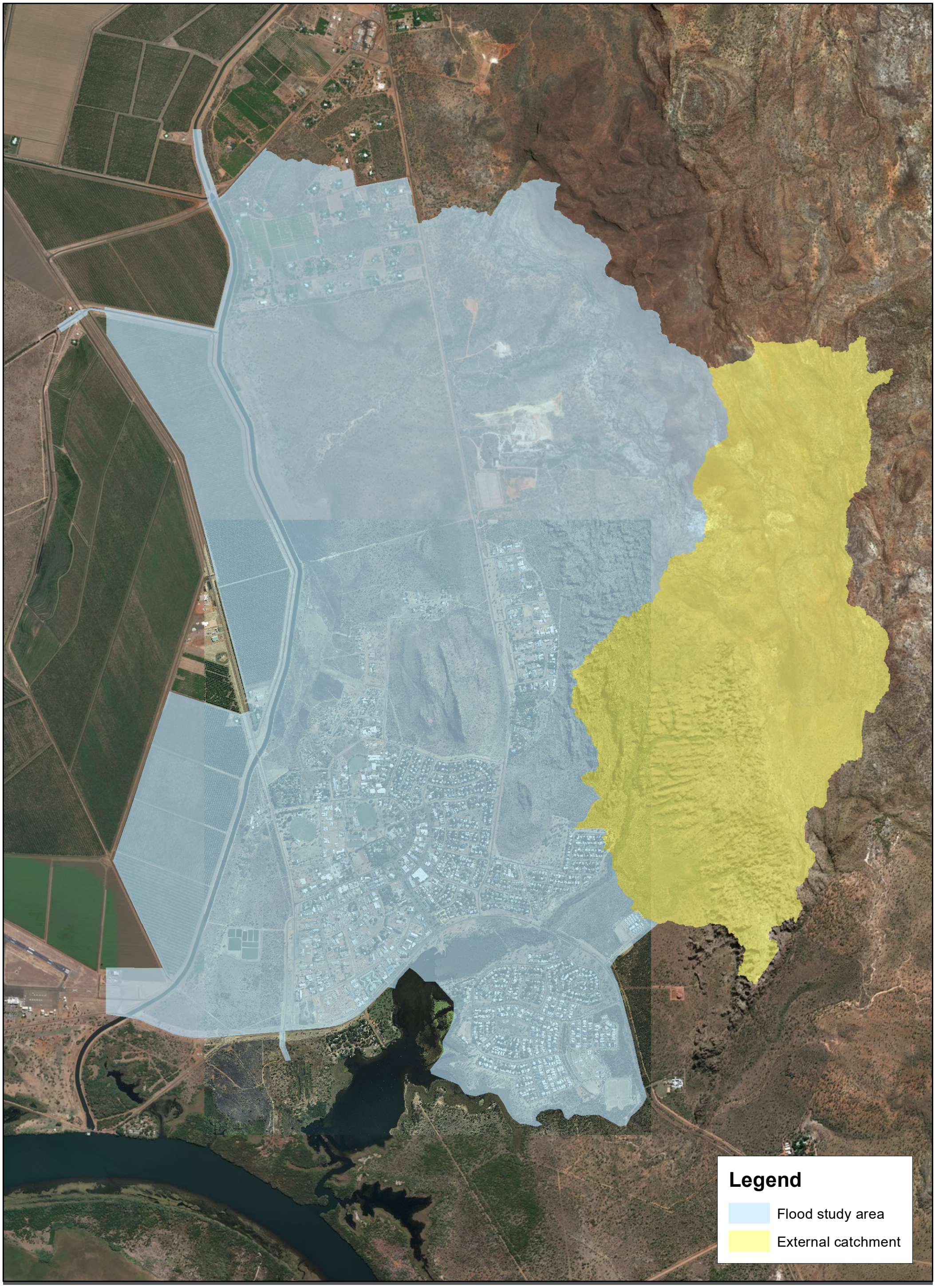
Date
3/05/2019

Size
A3

0 0.150.3 0.6 0.9 Km

STUDY AREA

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 1
CW992700-GS-001- STUDY AREA 01



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Date
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Size
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CATCHMENT PLAN

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 2

CW992700-GS-002- CATCHMENT PLAN 01

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Cat_53
Lily Creek

Legend

- Streamlines
- Flood study area
- Hydrology catchment plan

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Date
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Size
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0 0.05 0.1 0.2 0.3 Km

MIRIMA NATIONAL PARK CATCHMENTS

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 3
CW992700-GS-003-HYDROLOGY CATCHMENTS 01

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Date
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Size
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0 0.1 0.2 0.4 0.6 Km

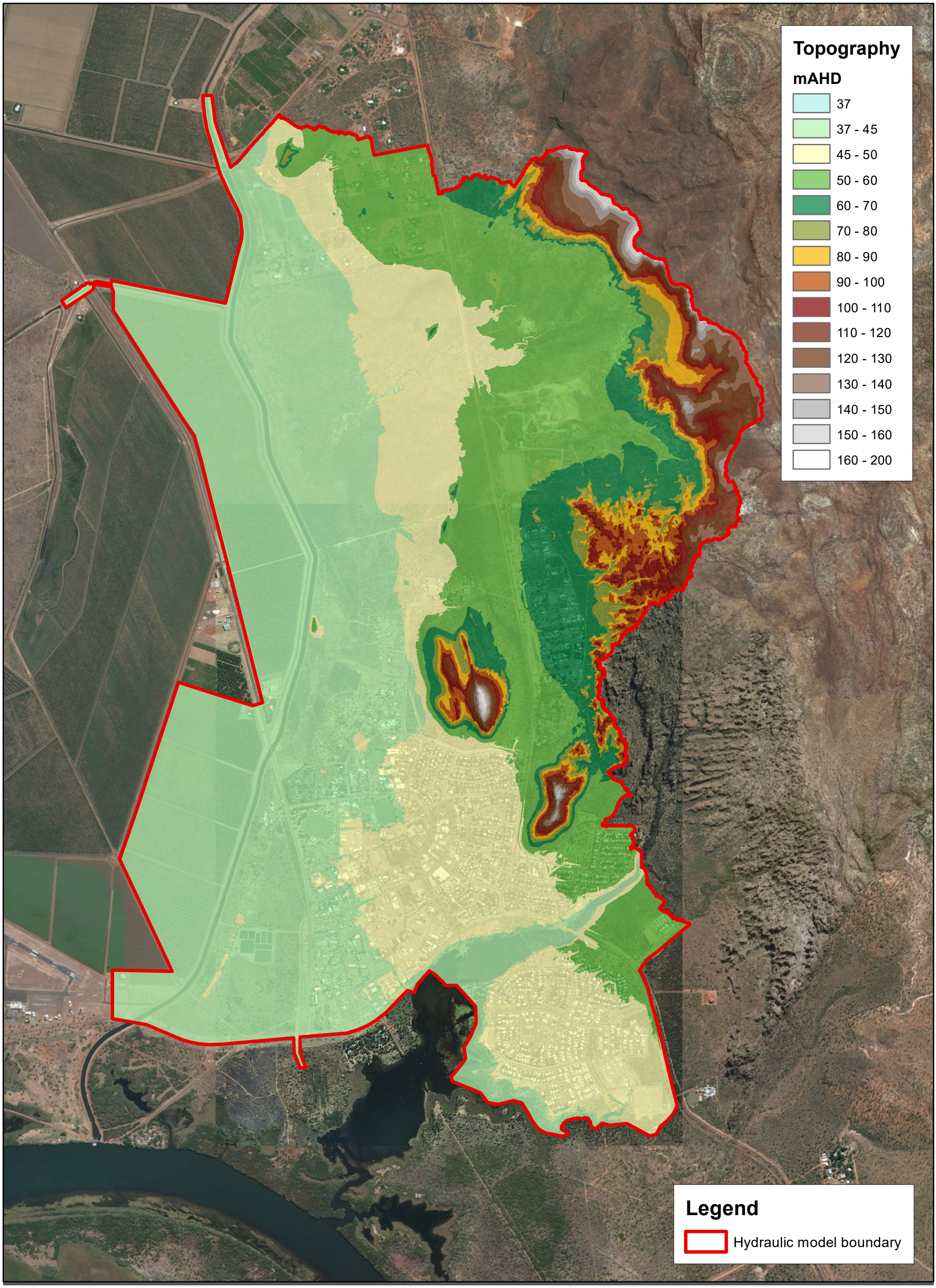
HYDRAULIC MODEL SETUP

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 4

CW992700-GS-004-HYDRAULIC MODEL SETUP 01



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Date
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Size
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0 0.1 0.2 0.4 0.6 Km

MODEL TOPOGRAPHY

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 5

CW992700-GS-005-MODEL TOPOGRAPHY 01

Legend

- Hydraulic model boundary

Land use

- Caravan' aboriginal site
- Channel- vegetated
- Drains
- Hospital
- Industrial
- Light industrial
- Lily creek flood plain
- Mixed business
- New developments
- Parks and recreation
- Parks- rocky terrain
- Public purposes
- R15
- R20
- R30
- R50
- Road reserv
- Roads
- Rural Industrial
- Rural Living
- Rural agriculture
- Rural developed
- Sand
- School/ church
- Tourist
- Town centre
- Water authority

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N

Date
3/05/2019

Size
A3

0 0.1 0.2 0.4 0.6 Km

LAND USE

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 6
CW992700-GS-006-LAND USE 01

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Legend

- Pipe network
- Hydraulic model boundary

1D MODEL NETWORK

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 7

CW992700-GS-007-1D NETWORK 01

Date
3/05/2019

Size
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0 0.050.1 0.2 0.3 Km

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Barringtonia Ave/ Weaber Plains Rd
Modelled Water Level: 49.13 mAHD
Observed Water Level: 49.23 mAHD

Messmate Way
Modelled Water Level: 47.41 mAHD
Observed Water Level: 47.35 mAHD

Legend

- Study area

Depth (m)

- 0.05 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 4.0

FEBRUARY 2014 - MAXIMIUM FLOOD DEPTH

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 8
CW992700-GS-008-VALIDATION DEPTH 01

Date
3/05/2019

Size
A3

N

0 0.1 0.2 0.4 0.6 Km

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RP1
RP13
RP10
RP8
RP23
RP24
RP9
RP12
RP26
RP25
RP11
RP22
RP21
RP6
RP20
RP7
RP27
RP31
RP29
RP28
RP16
RP15
RP5
RP19
RP18
RP4
RP2
RP3
RP14

Legend

- Reporting lines
- Study area

Depth (m)

- 0.05 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 4.0

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Tel: 9273 3888
Fax: 9486 8664

N

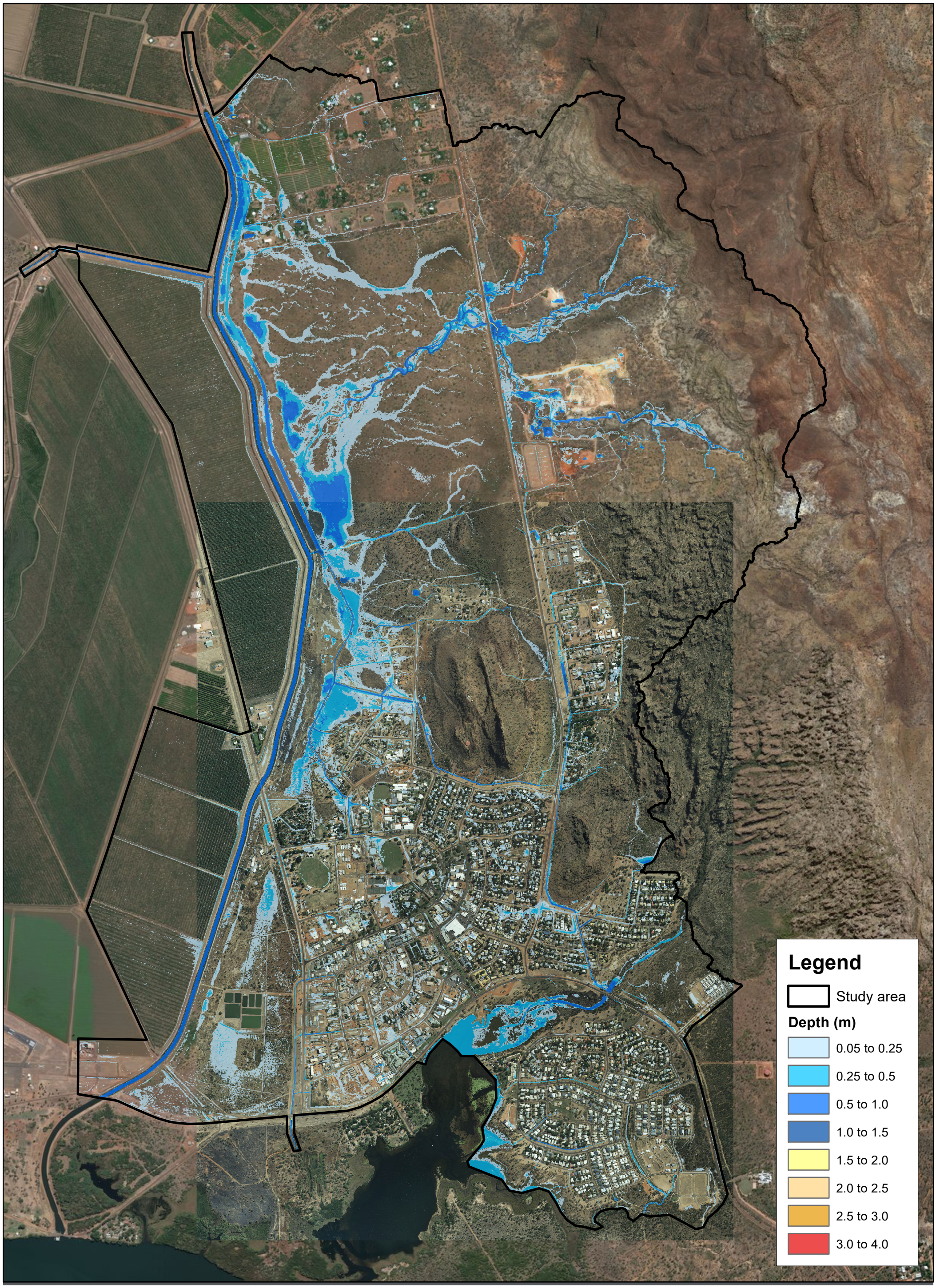
Date
3/05/2019

Size
A3

0 0.1 0.2 0.4 0.6 Km

REPORTING LOCATIONS

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 9
CW992700-GS-009-PLOTOUTPUTS 01



63.2% AEP MAXIMUM FLOOD DEPTH

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 10

CW992700-GS-010-63.2% AEP MAX DEPTH 01

Date
3/05/2019

Size
A3

N

0 0.1 0.2 0.4 0.6 Km

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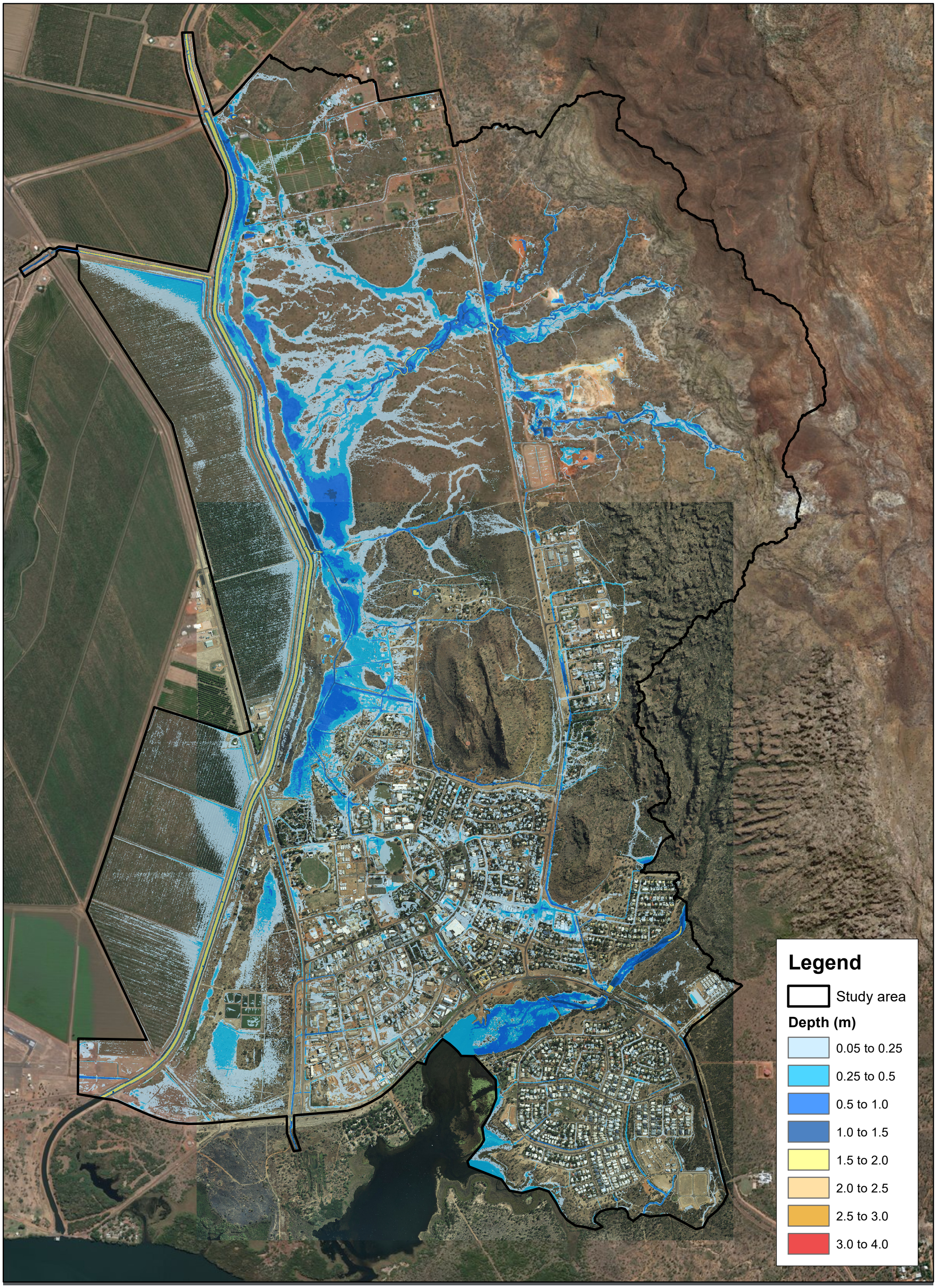

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Date
14/05/2019

Size
A3

0 0.1 0.2 0.4 0.6 Km

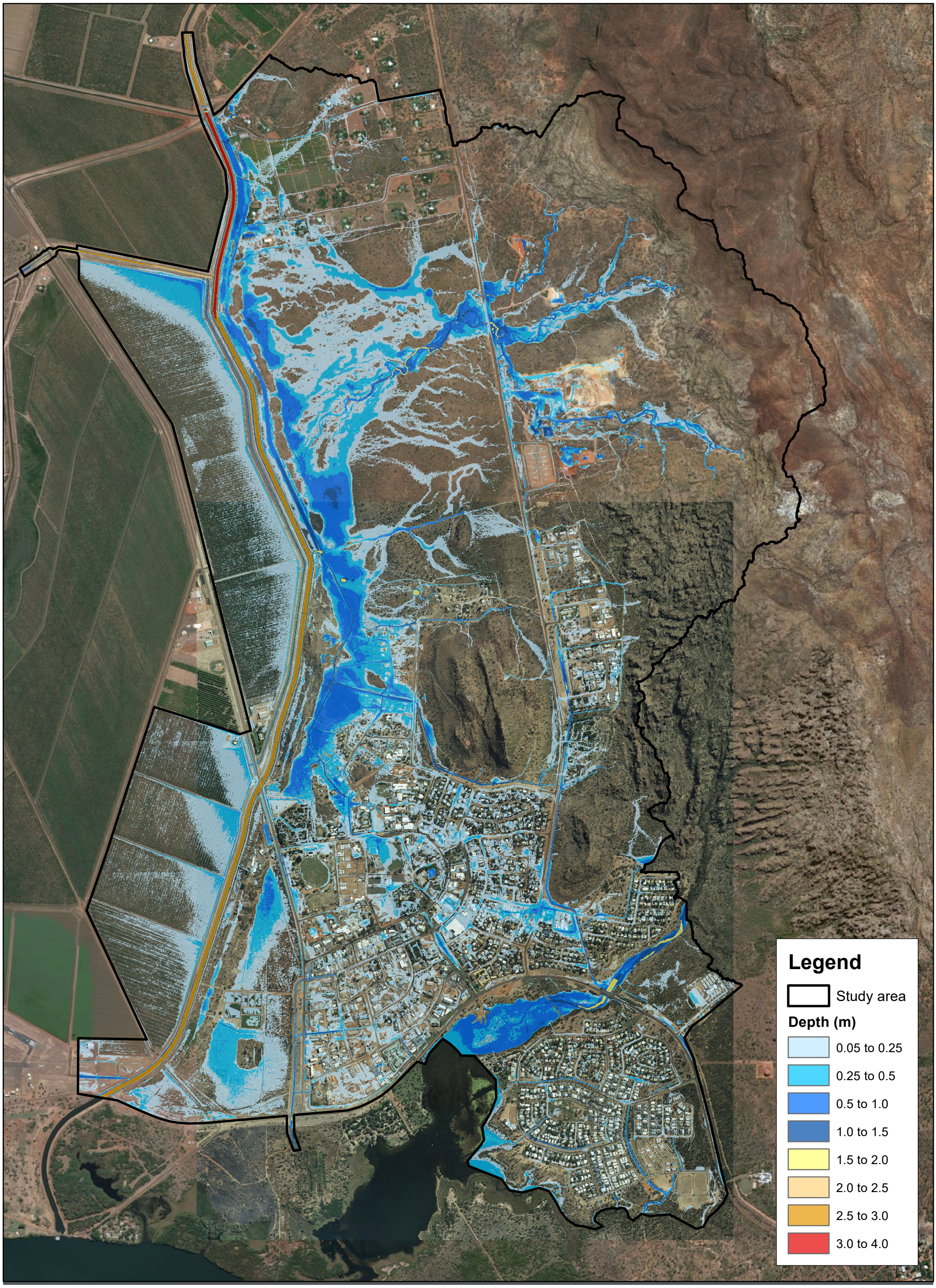
20% AEP MAXIMUM FLOOD DEPTH

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 11

CW992700-GS-011-20% AEP MAX DEPTH 01



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Date
14/05/2019

Size
A3

0 0.1 0.2 0.4 0.6
Km

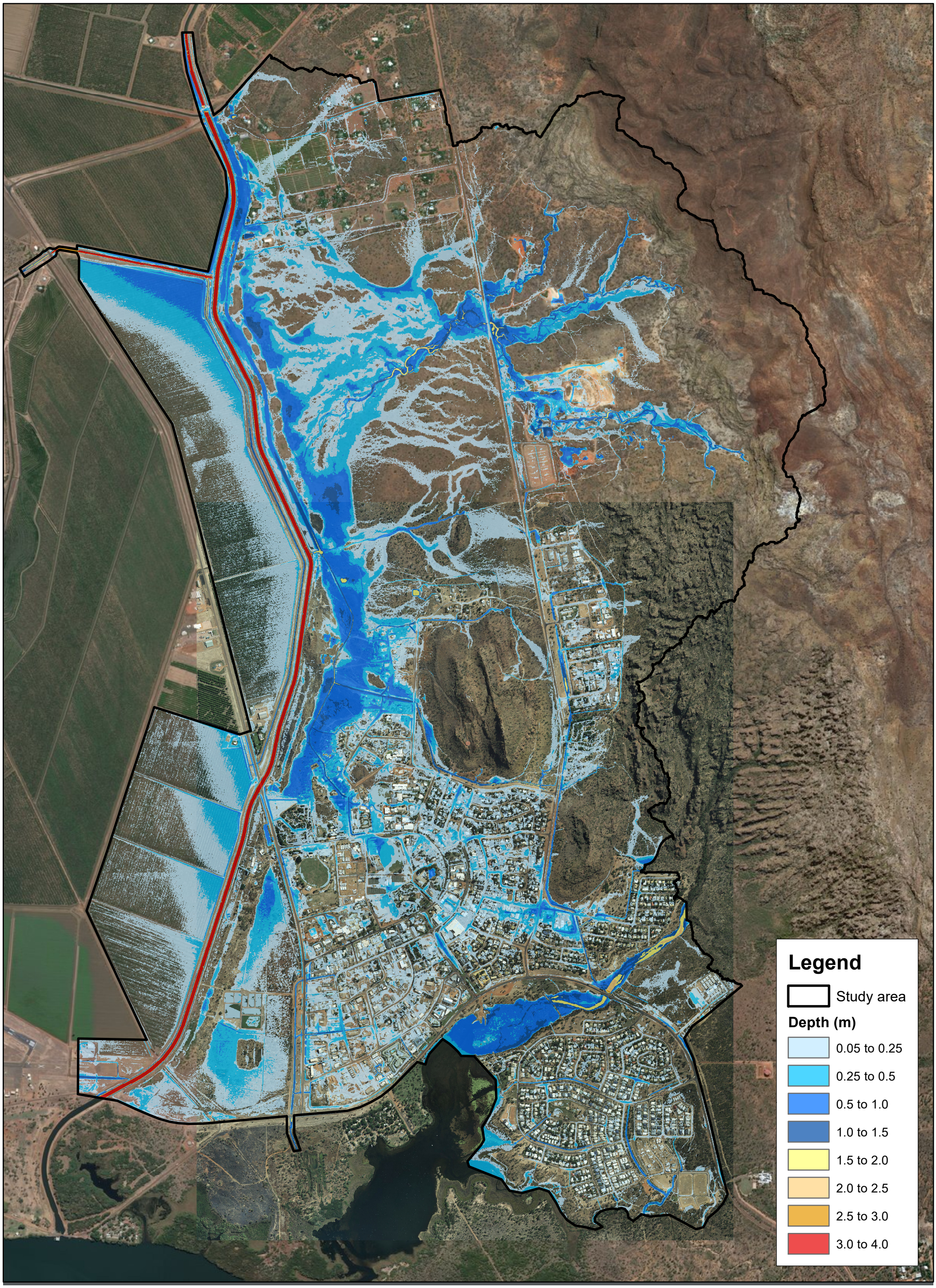
5% AEP MAXIMUM FLOOD DEPTH

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 12

CW992700-GS-012- 5% AEP MAX DEPTH 01



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Date
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Size
A3

0 0.1 0.2 0.4 0.6 Km

1% AEP MAXIMUM FLOOD DEPTH

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 13

CW992700-GS-013-1% AEP MAX DEPTH 01

S01

S02

S03

S04

Legend

Study area

Afflux (m)

-0.34 to -0.20

-0.20 to -0.10

-0.1 to -0.05

-0.05 to 0.05

0.05 to 0.10

0.10 to 0.20

0.20 to 0.30

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Size
A3

0 0.2 0.4 0.8 1.2 Km

SENSITIVITY AFFLUX

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 14

CW992700-GS-014-1% AEP SENSITIVITY AFFLUX 01

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Legend

- Additional pits
- Re-graded drain
- Levee
- Upgraded pipes
- Additional pipes
- Existing pipes
- D1 Expansion
- Basin/swale
- Study area

Option D01

D1 expanded: 20m base, 4m depth, 1V:4H side slopes
Ivanhoe Rd bridge removed

Option D08 Levee. Crown at 43.5 mAHD

Option D08 levee culverts:
4 x 1200 x 600 RCBCs

Siphon: 12 x 1200 x 1200 RCBCs
Upgraded pipes: 6 x 1200 x 1200 RCBCs

Swale parallel to M1 expanded:
30m base, 1.5m depth, 1V:4H side slopes

Option D06

Culverts upgraded:
3 x 900 RCPs

Culverts added:
3 x 1200 x 600 RCBCs

Drain redirected north
and re-graded

Basin expanded

Caravan Park crossings
removed

Option D05

Road level lowerd to 43 mAHD
to act as overflow

Additional pipes (2 x1050 RCPs)
and 4 additional pits

Option D03

Pipe network extends north
to Leichhardt St and south
to outlet (2x900 RCPs)
with 3 addional pits

Pipe upgraded to
3600 x 1200 RCBC

Proposed detention basin

Drain regraded: 0.5% slope
and footbridges removed

Option D04

Drain regraded and
crossing removed

Additional pipes: 2x900 RCPs

Option D02

Pipes upgraded to 2 x 900 RCPs

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Size
A3

0 0.10.2 0.4 0.6
Km

OPTIONS ANALYSIS

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 15
CW992700-GS-015- OPTIONS ANALYSIS 01

Legend

Study area

E02-D01 Afflux (m)

- Below -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to 0.03
- 0.03 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- 0.5 to 1
- 1 to 2

Note: Positive values indicate flood level reductions

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Size
A3

0 0.05 0.1 0.2 0.3 Km

D01 - 1% AEP AFFLUX

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 16
CW992700-GS-016- 1%AEP D01 AFFLUX 2 01

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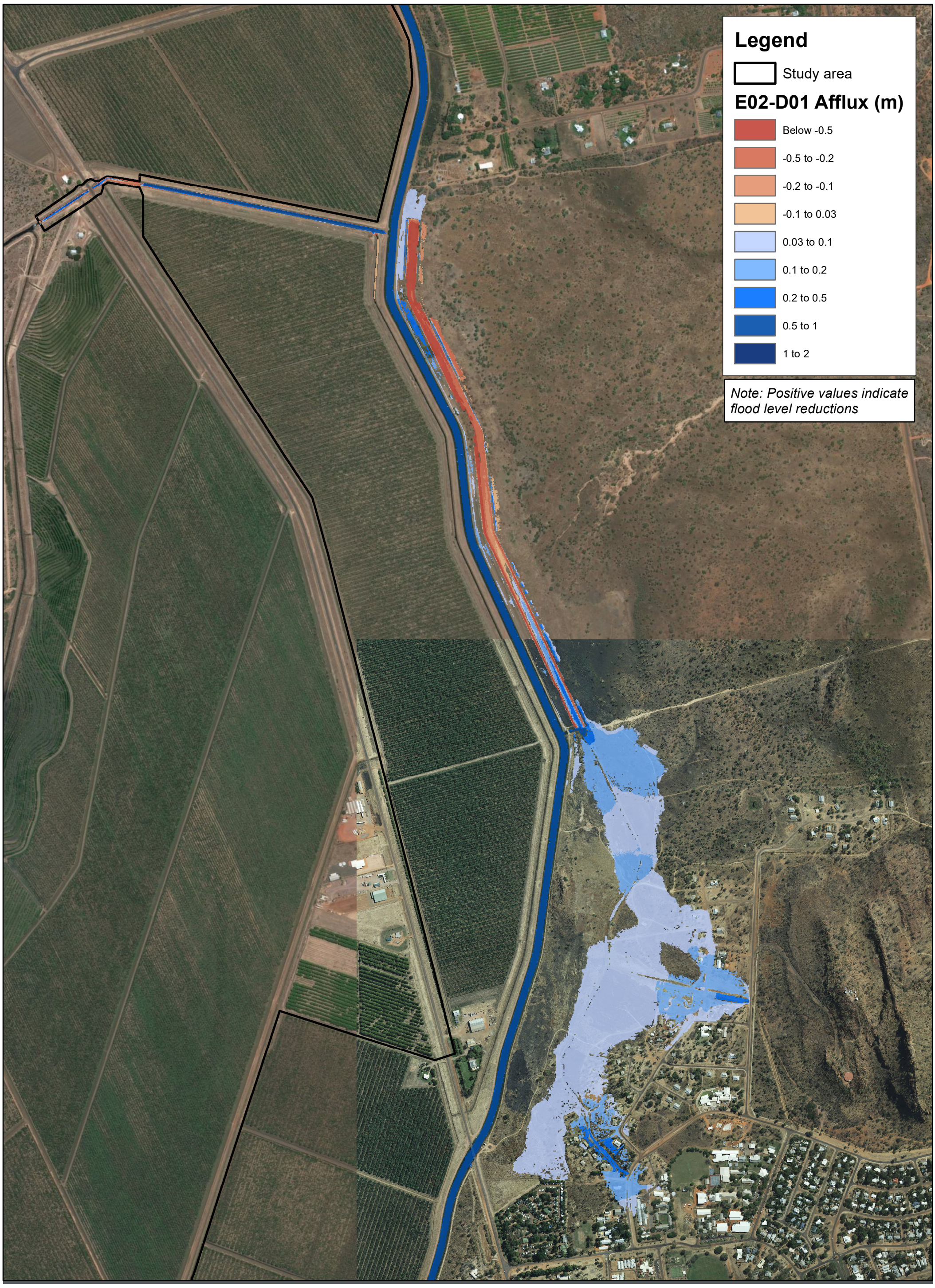

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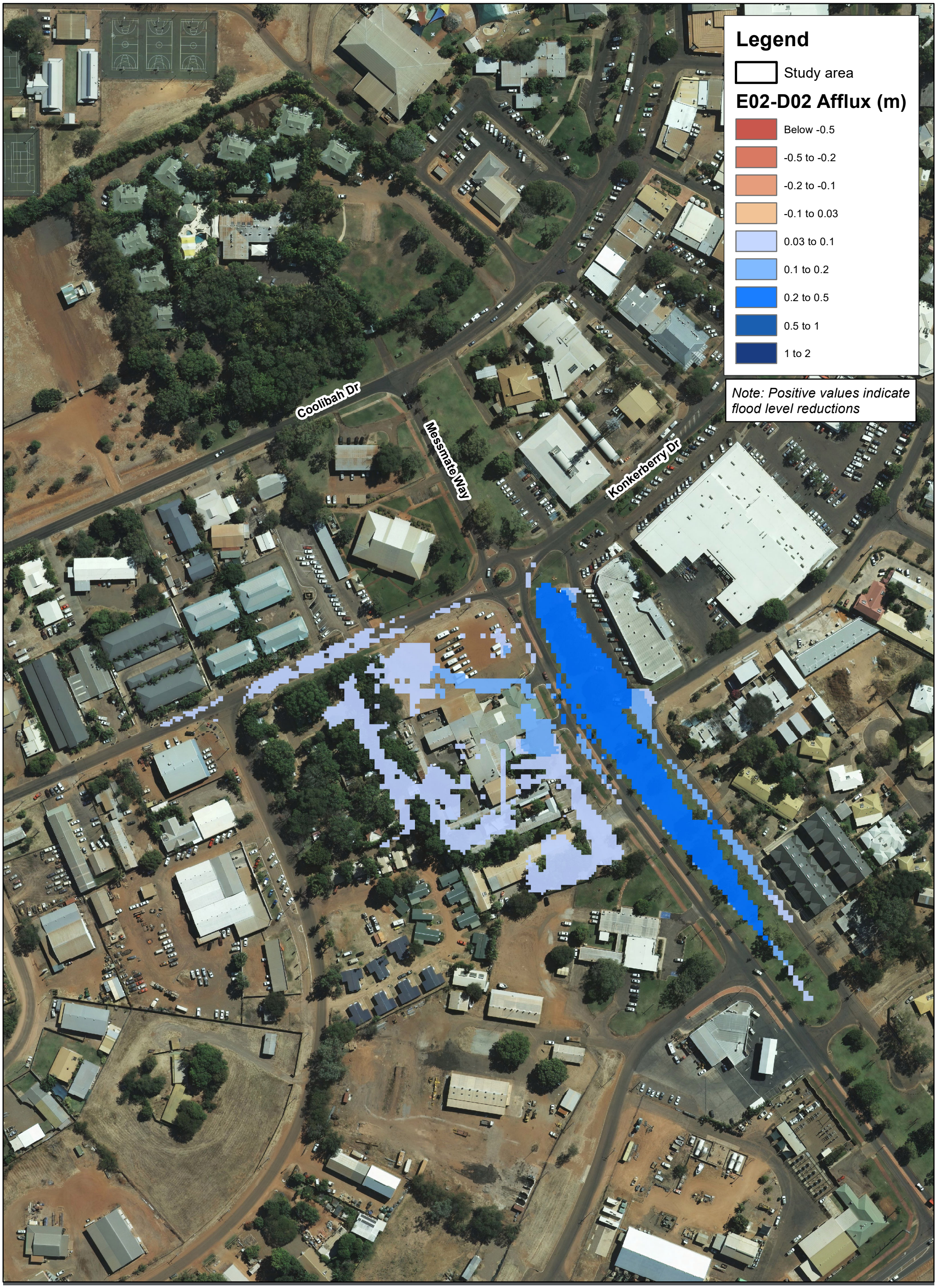
Size
A3

0 0.05 0.1 0.2 0.3 Km

D01 - 20% AEP AFFLUX

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 17
CW992700-GS-017- 20%AEP D01 AFFLUX 01



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Date
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Size
A3

0 0.01 0.02 0.04 0.06 Km

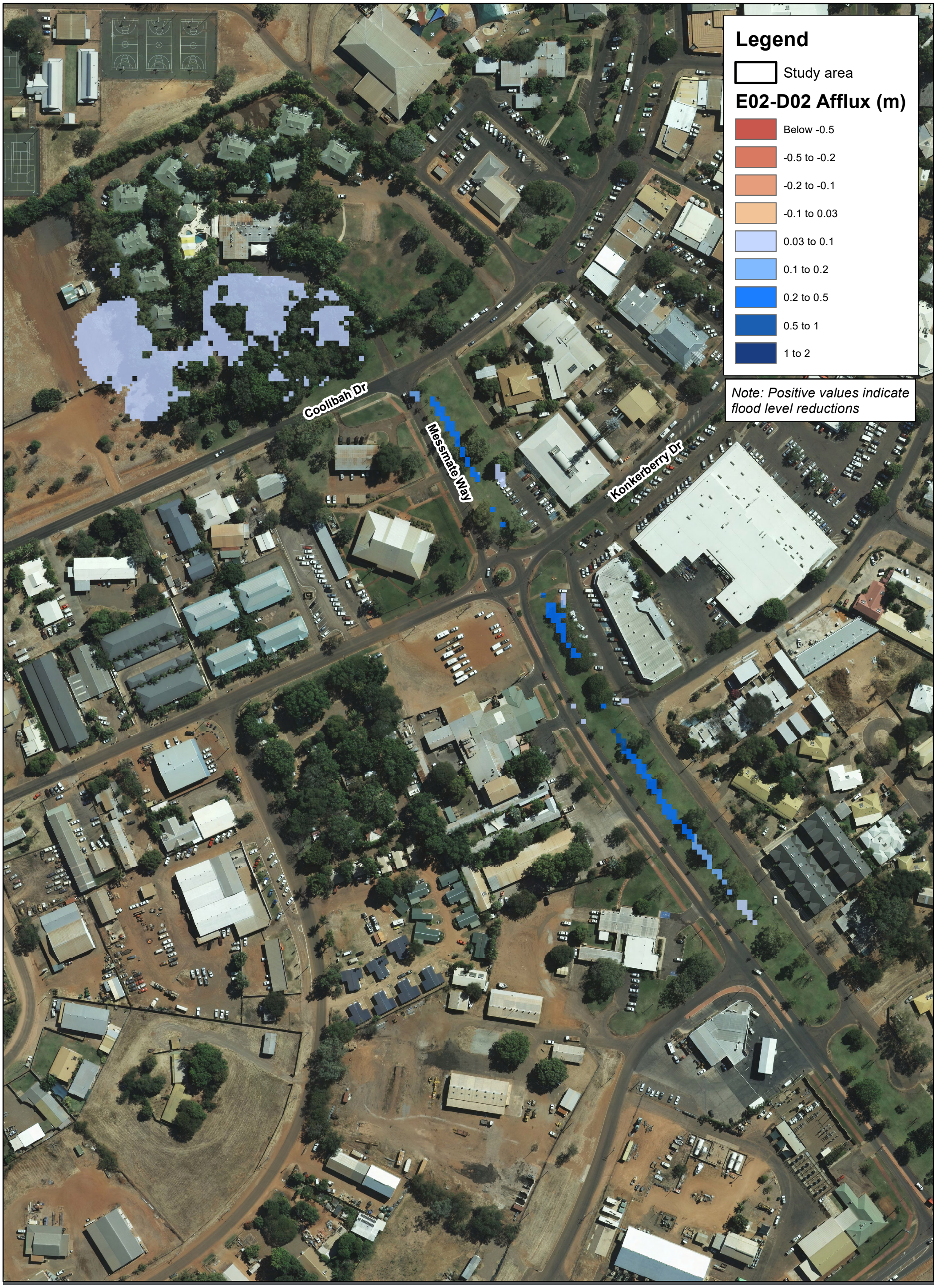
D02 - 1% AEP AFFLUX

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 18

CW992700-GS-018- 1%AEP D02 AFFLUX 01



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Date
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Size
A3

0 0.01 0.02 0.04 0.06
Km

D02 - 20% AEP AFFLUX

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 19

CW992700-GS-019- 20%AEP D02 AFFLUX 01

Legend

Study area

E02-D03 Afflux (m)

- Below -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to 0.03
- 0.03 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- 0.5 to 1
- 1 to 2

Note: Positive values indicate flood level reductions

D03 - 1% AEP AFFLUX

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 20

CW992700-GS-020- 1%AEP D03 AFFLUX 01

Cardno

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Date
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Size
A3

0 0.045 0.09 0.18 0.27
Km

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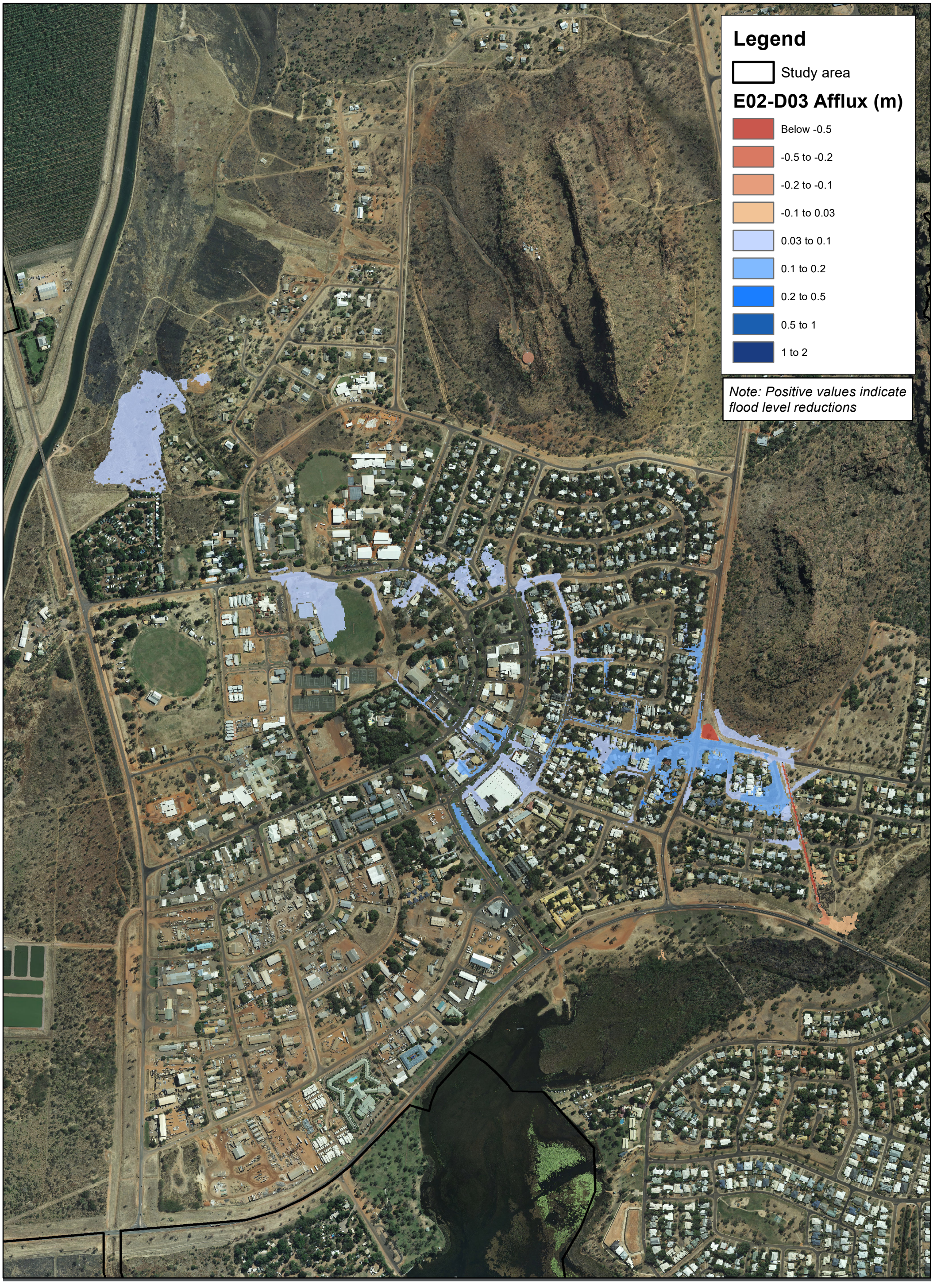

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N

Date
8/07/2019

Size
A3

0 0.045 0.09 0.18 0.27
Km

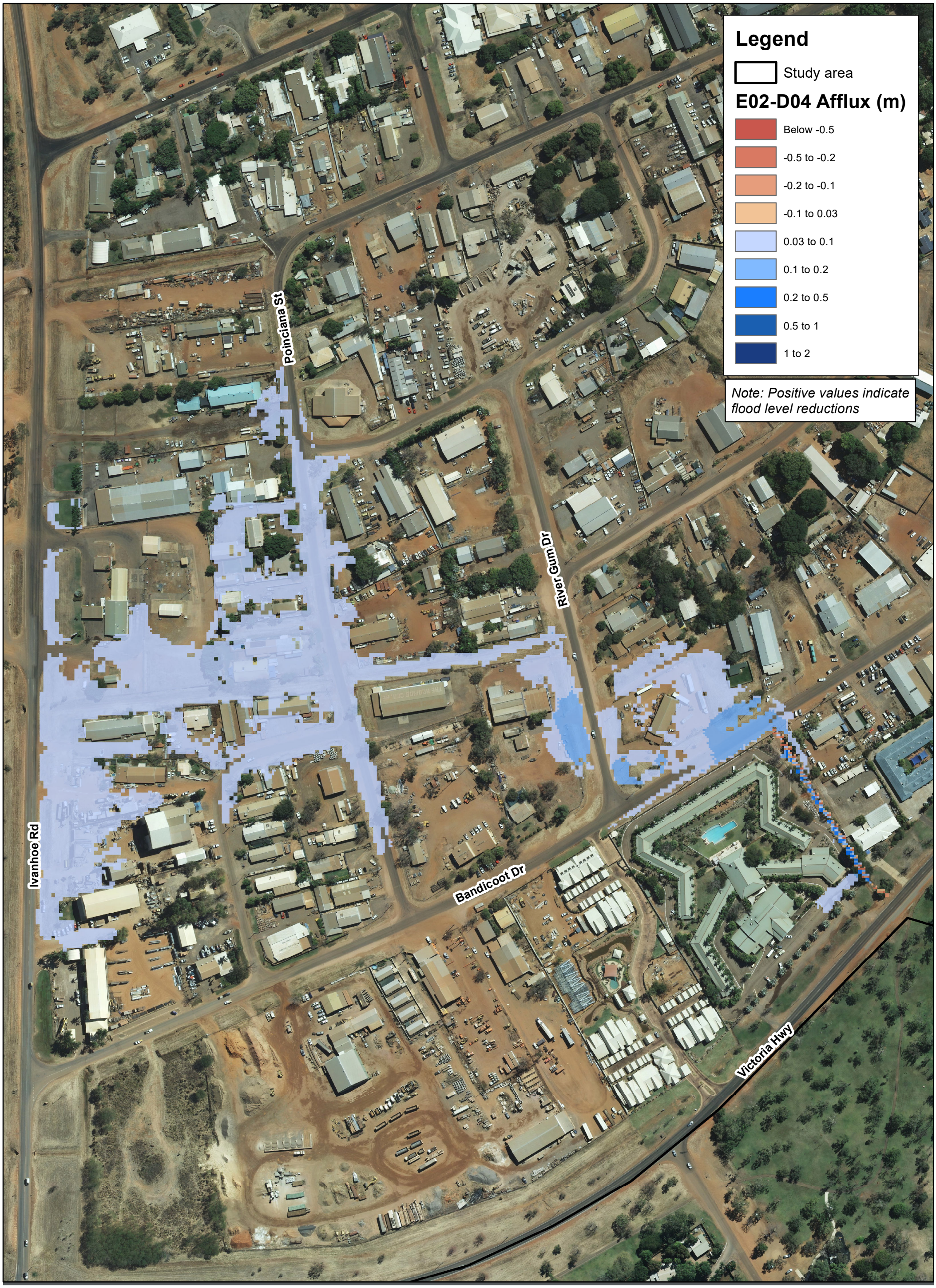
D03 - 20% AEP AFFLUX

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 21

CW992700-GS-021- 20%AEP D03 AFFLUX 01



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Date
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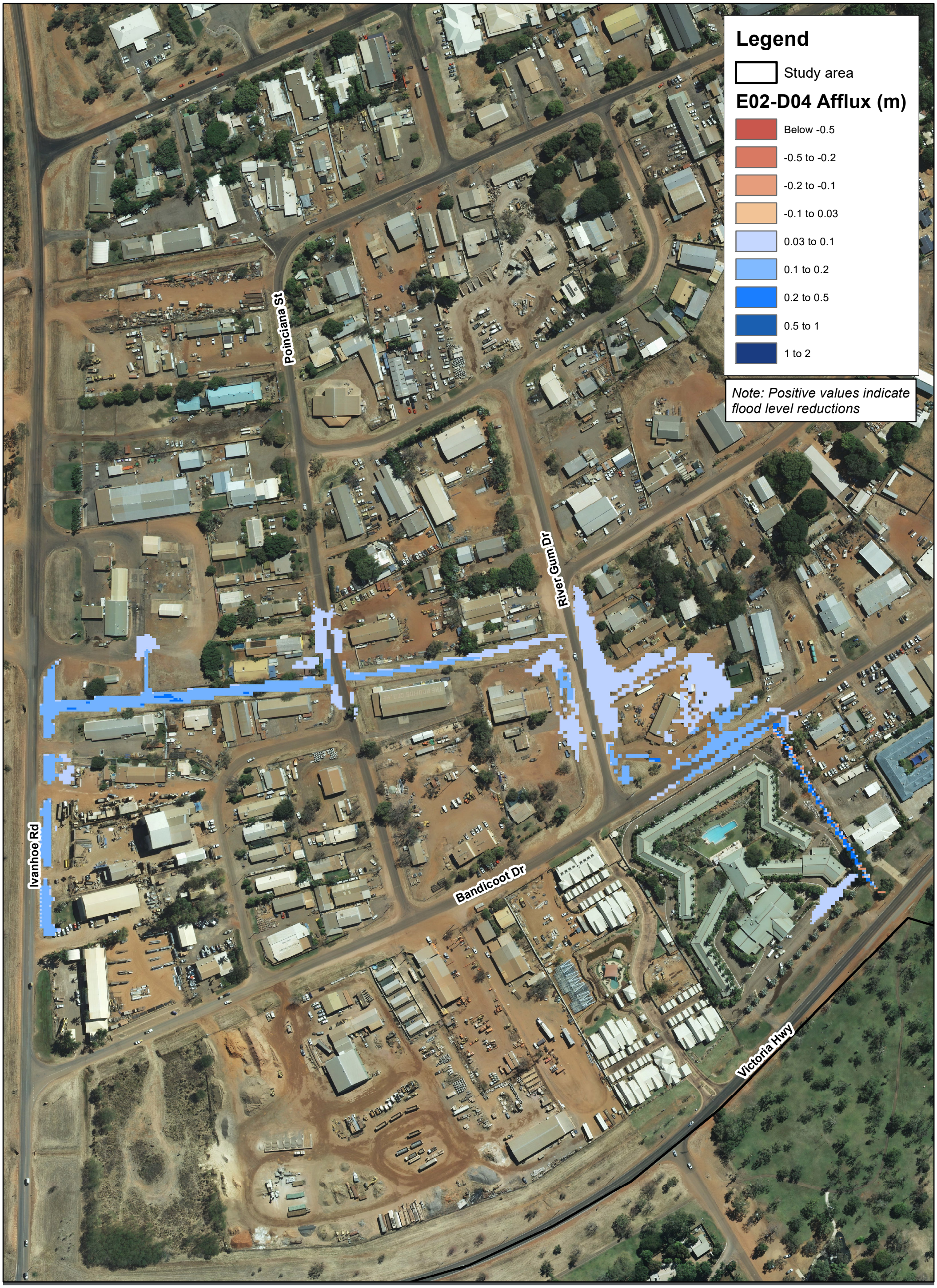
Size
A3

0 0.0125 0.025 0.05 0.075
Km

D04 - 1% AEP AFFLUX

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 22
CW992700-GS-022- 1%AEP D04 AFFLUX 01



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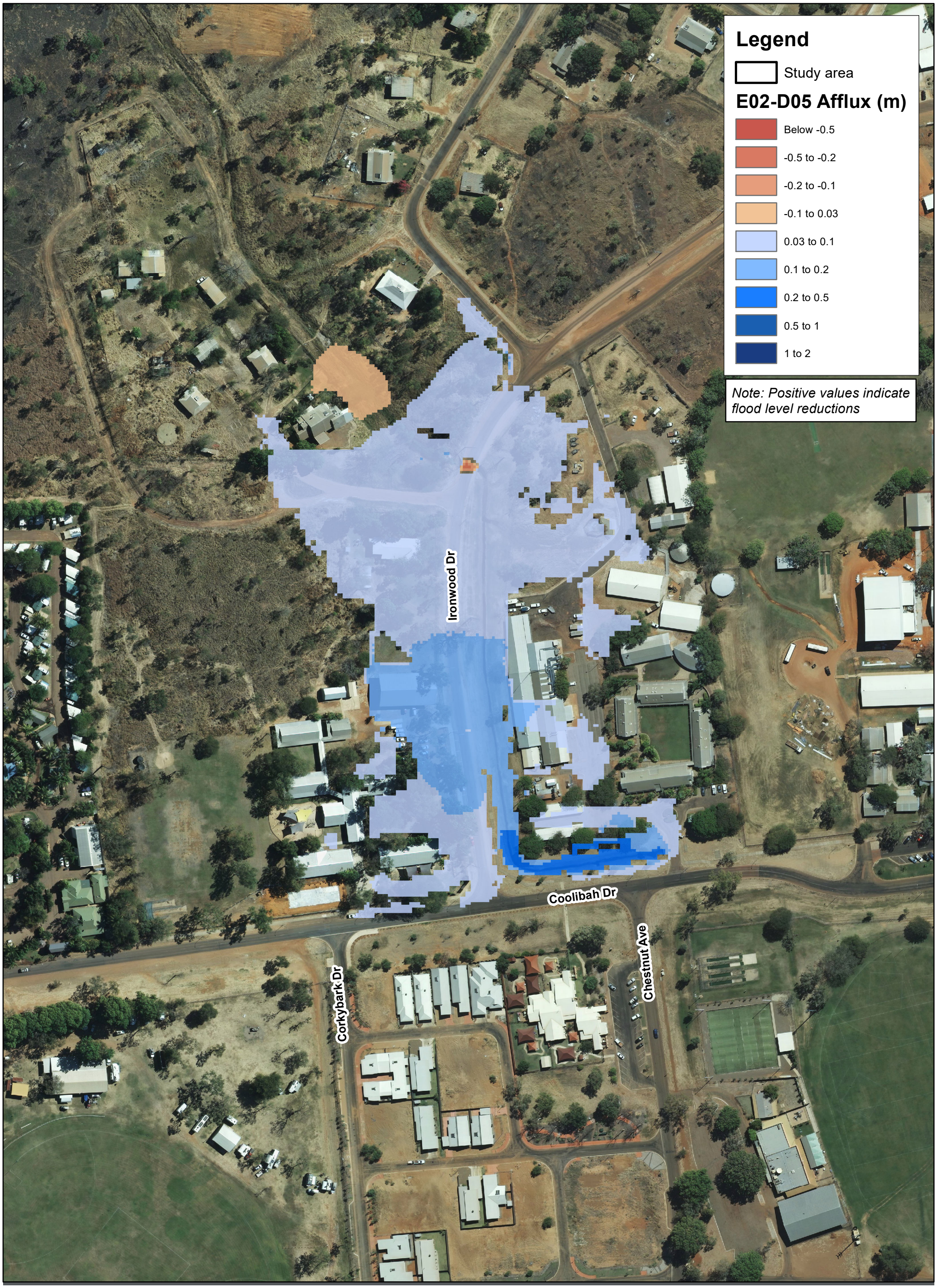
Size
A3

0 0.0125 0.025 0.05 0.075
Km

D04 - 1% AEP AFFLUX

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 23
CW992700-GS-023- 20%AEP D04 AFFLUX 01



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Date
3/07/2019

Size
A3

0 0.01 0.02 0.04 0.06 Km

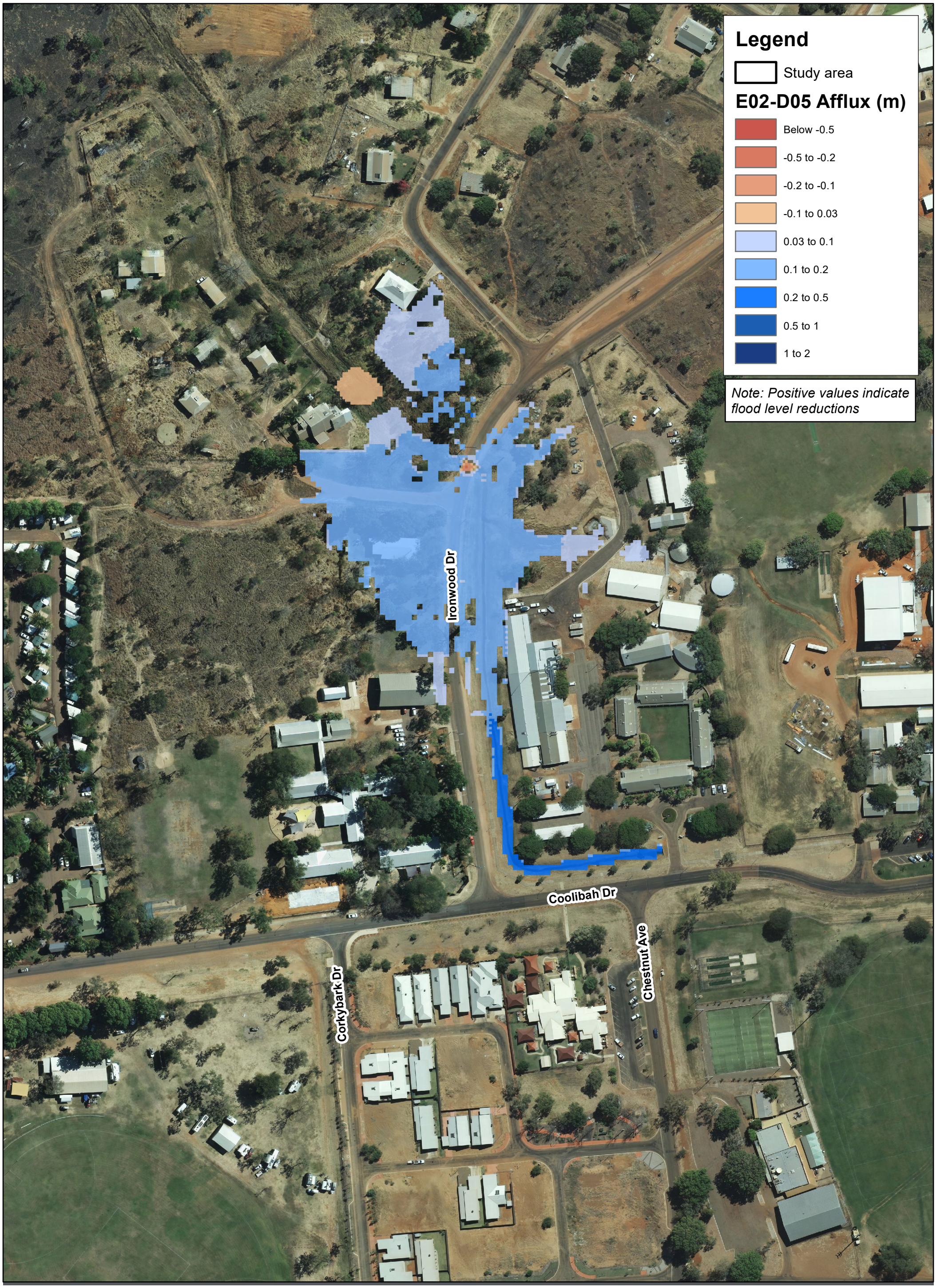
D05 - 1% AEP AFFLUX

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 24

CW992700-GS-024- 1%AEP D05 AFFLUX 01



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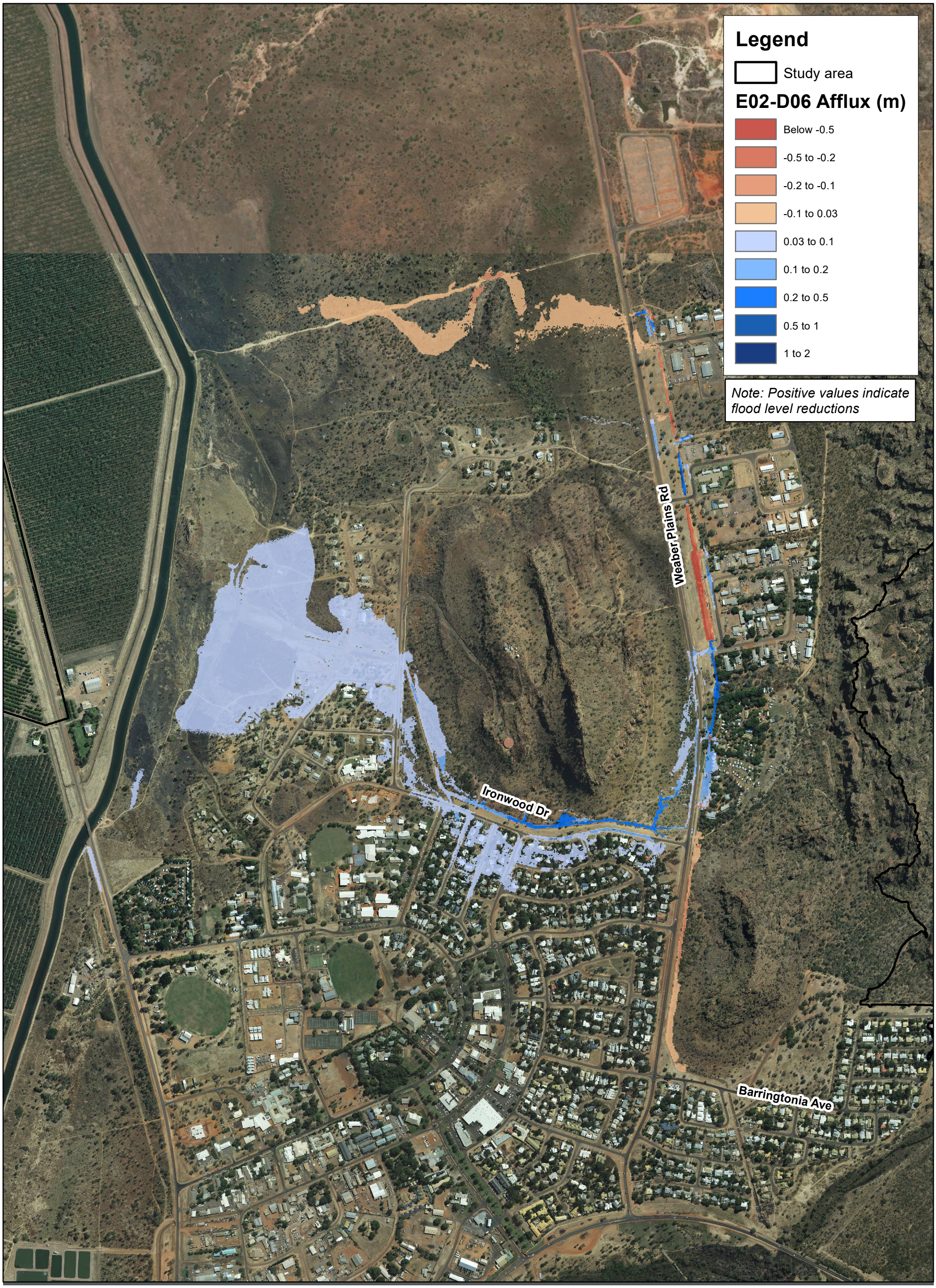
Date
8/07/2019

Size
A3

0 0.01 0.02 0.04 0.06 Km

D05 - 20% AEP AFFLUX

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 25
CW992700-GS-025- 20%AEP D05 AFFLUX 01



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Date
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Size
A3

0 0.050.1 0.2 0.3
Km

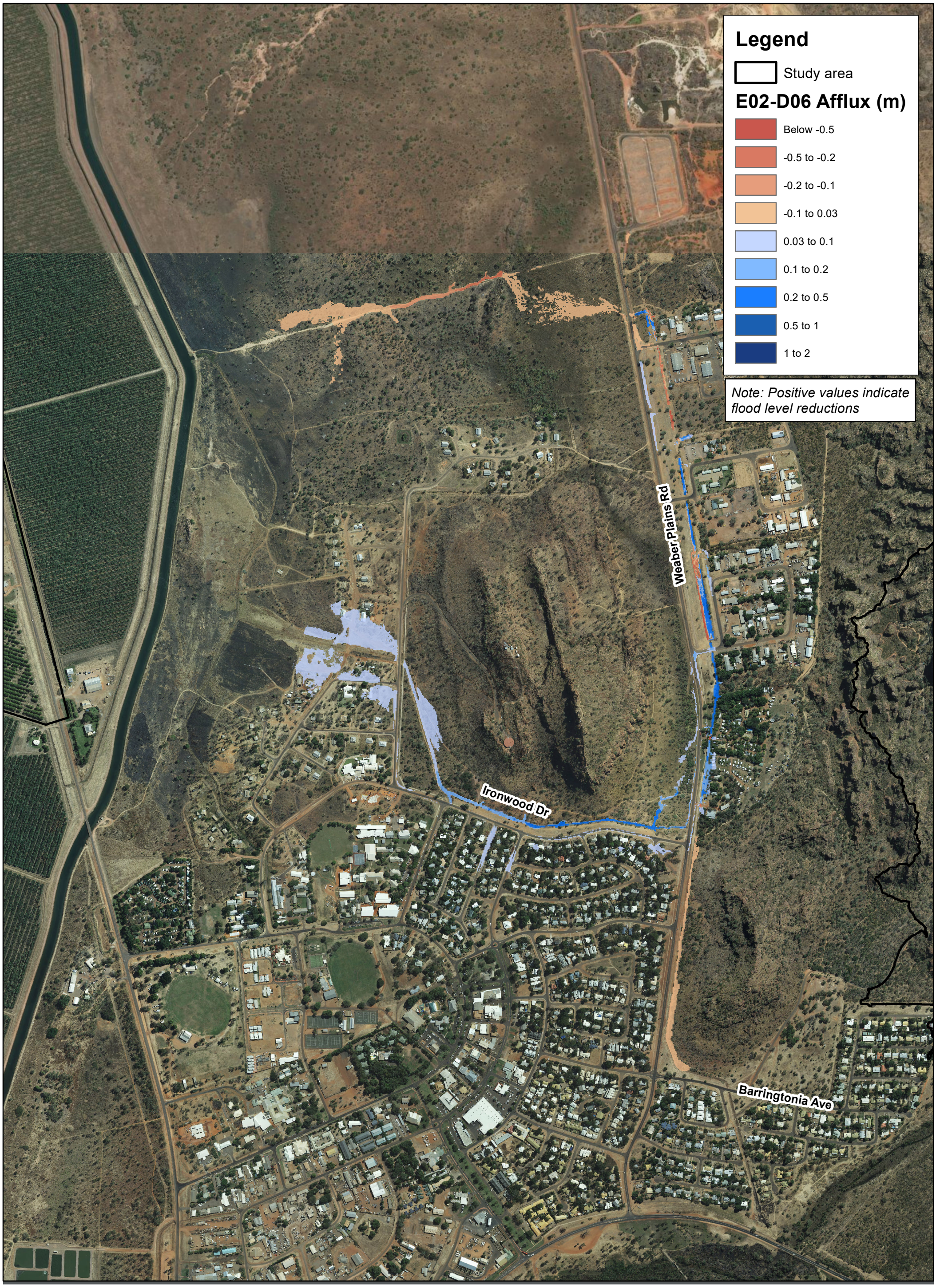
D06 - 1% AEP AFFLUX

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 26

CW992700-GS-026- 1%AEP D06 AFFLUX 01



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Date
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Size
A3

0 0.050.1 0.2 0.3
Km

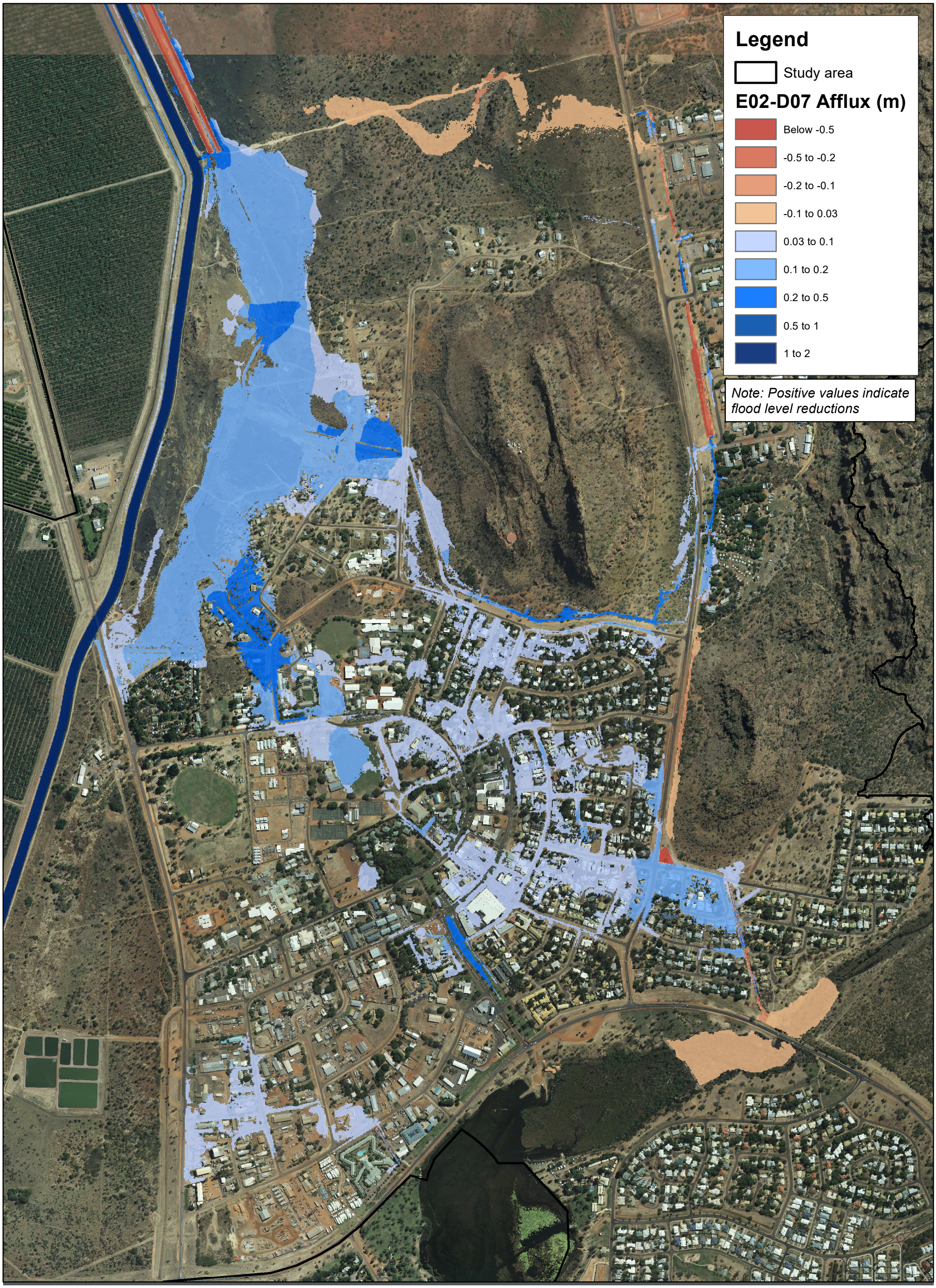
D06 - 20% AEP AFFLUX

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 27

CW992700-GS-027- 20%AEP D06 AFFLUX 01



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Date
8/07/2019

Size
A3

0 0.050.1 0.2 0.3
Km

D07 - 1% AEP AFFLUX

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 28
CW992700-GS-028- 1%AEP D07 AFFLUX 01

Legend

Study area

E02-D07 Afflux (m)

- Below -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to 0.03
- 0.03 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- 0.5 to 1
- 1 to 2

Note: Positive values indicate flood level reductions

Cardno

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Date
8/07/2019

Size
A3

0 0.050.1 0.2 0.3 Km

D07 - 1% AEP AFFLUX

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 29

CW992700-GS-029- 20%AEP D07 AFFLUX 01

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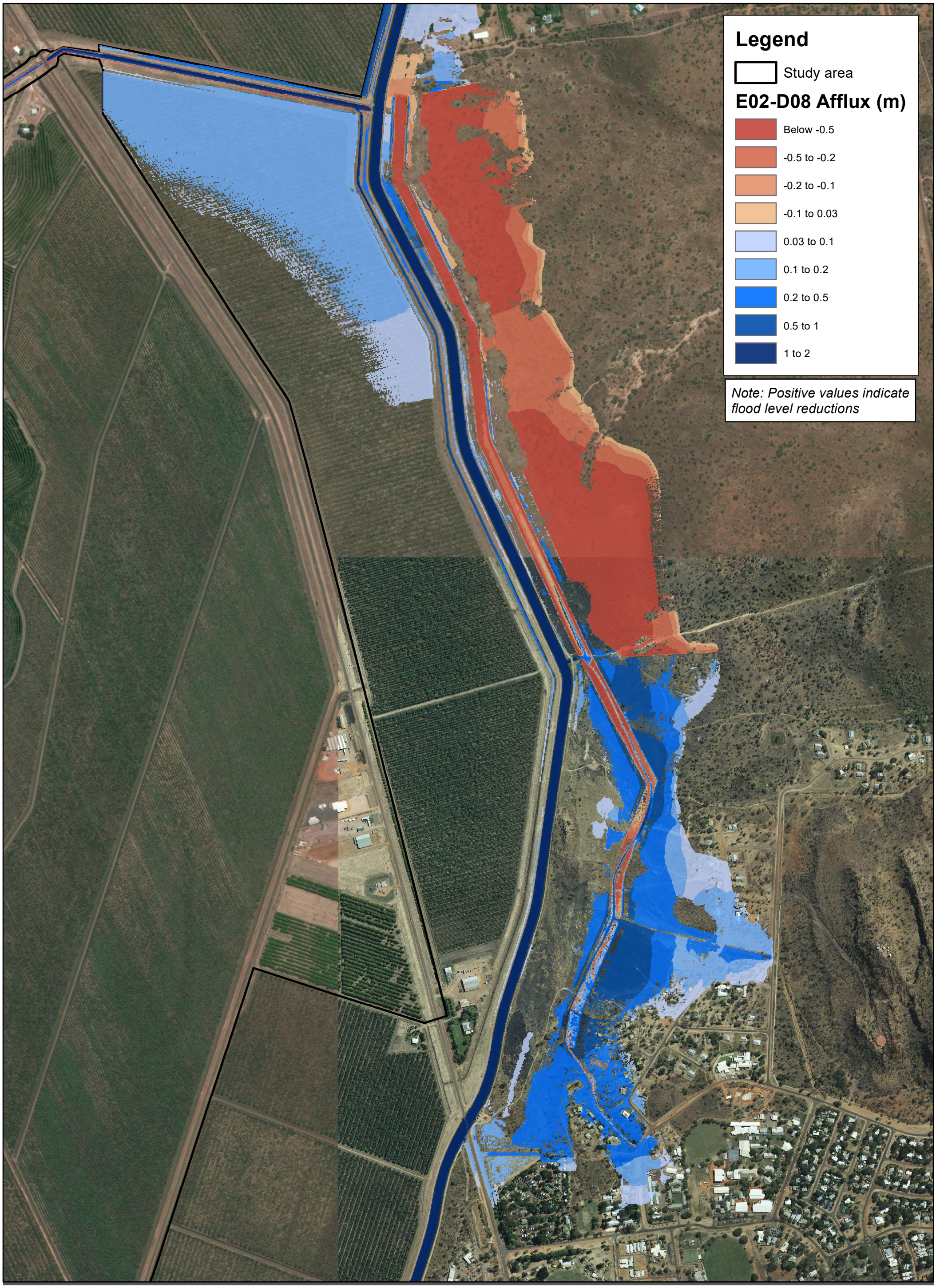

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Date
8/07/2019

Size
A3

0 0.050.1 0.2 0.3 Km

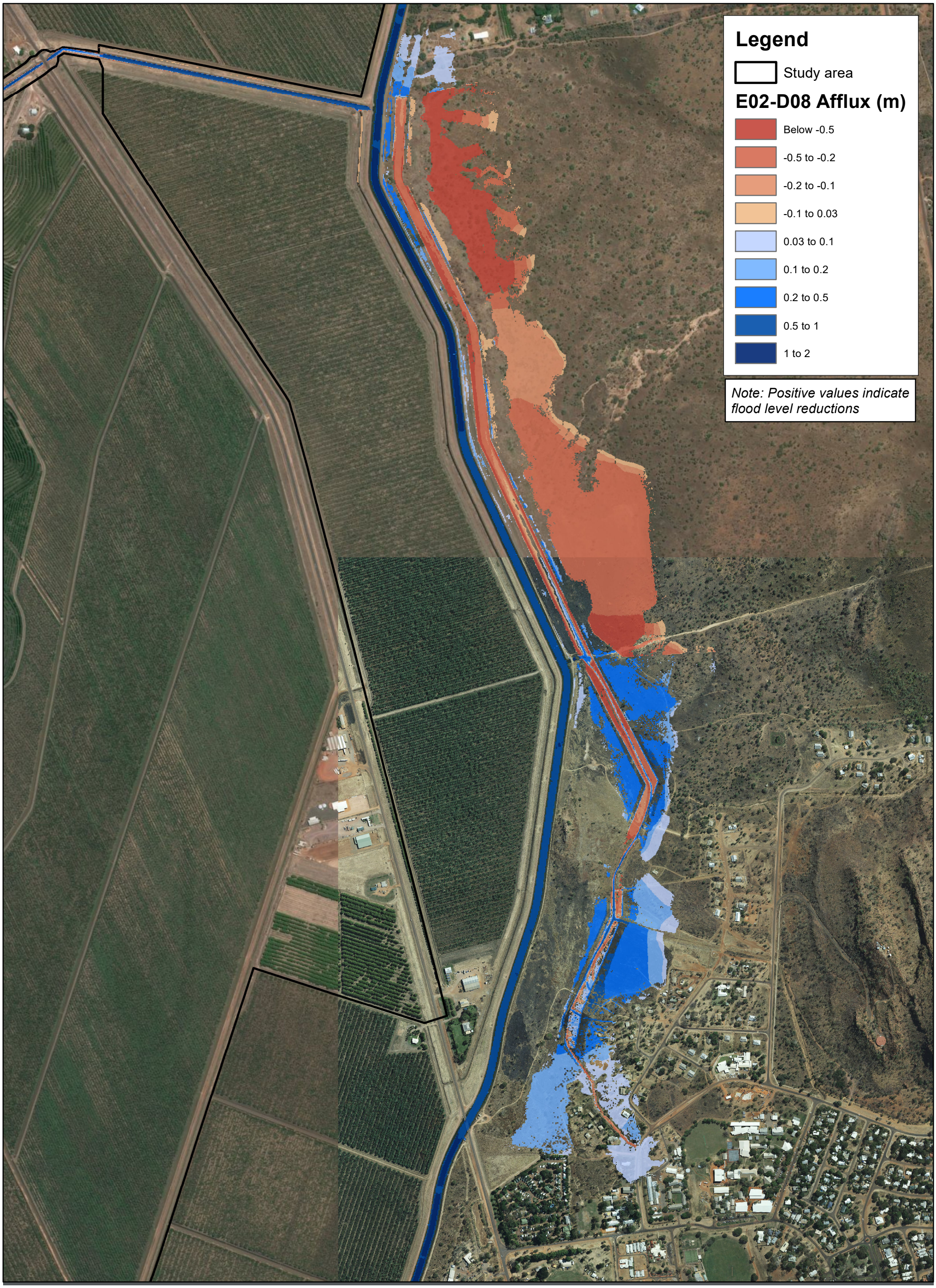
D08 - 1% AEP AFFLUX

KUNUNURRA STORMWATER STUDY

CW992700

FIGURE 30

CW992700-GS-030- 1%AEP D08 AFFLUX 01



DATE PLOTTED:8/07/2019 12:09:30 PM BY: SAJIDUL HAQUE
FILE: K:\Projects\CW992700_Shire_of_Wyndham-East_Kimberley_Kununurra_Stormwater_Study\5_Technical\Water and Environment\Comps_Drawings_File_Notes\Build\Report\CW992700-GS-031- 20%AEP D08 Afflux.mxd

Cardno
11 Harvest Terrace
West Perth, WA 6007
Tel: 9273 3888
Fax: 9486 8664

N

Date
8/07/2019

Size
A3

0 0.050.1 0.2 0.3
Km

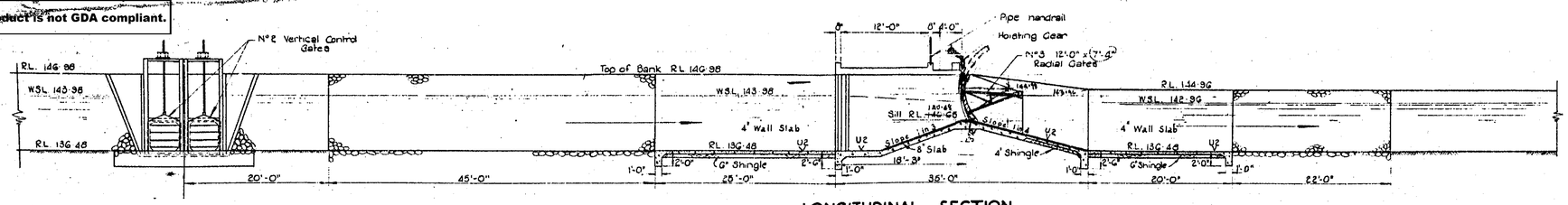
D08 - 20% AEP AFFLUX

KUNUNURRA STORMWATER STUDY
CW992700
FIGURE 31
CW992700-GS-031- 20%AEP D08 AFFLUX 01

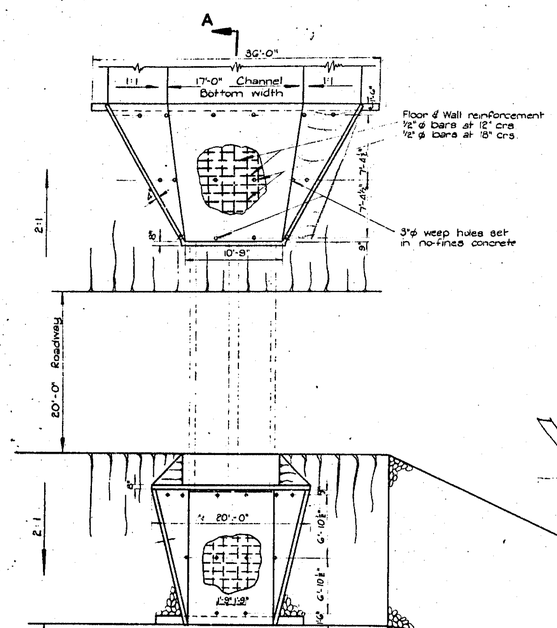
APPENDIX

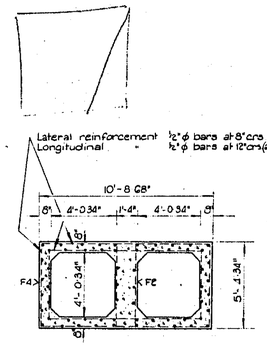
B

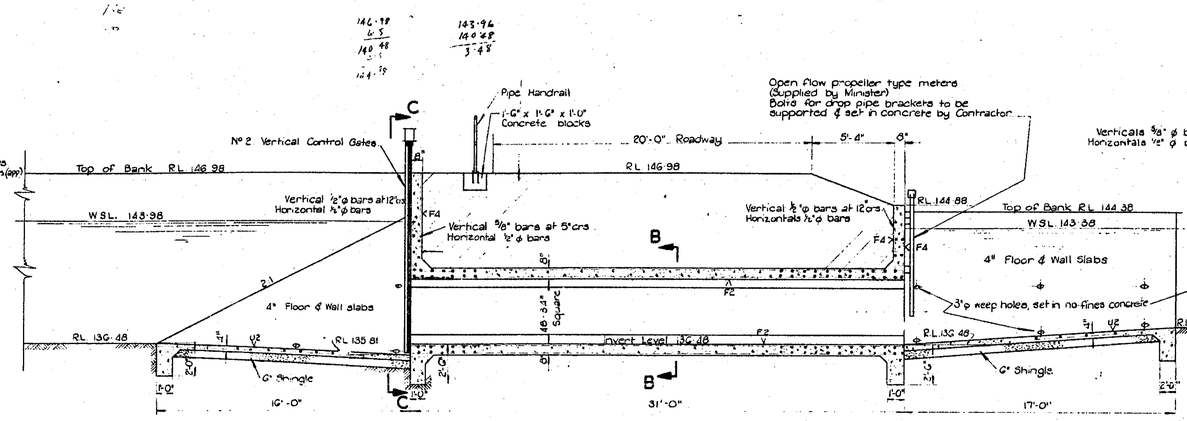
PUBLIC WORKS DEPARTMENT DRAWINGS



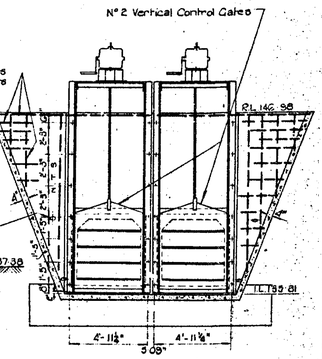
LONGITUDINAL SECTION



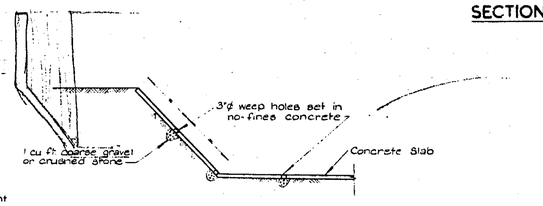




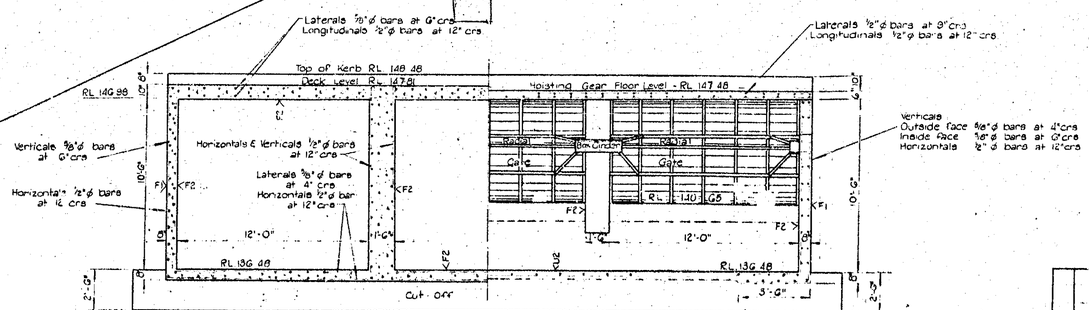
SECTION A-A



SECTION C-C



PLAN



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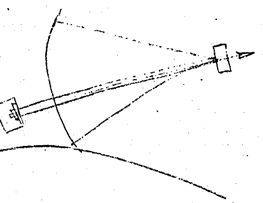
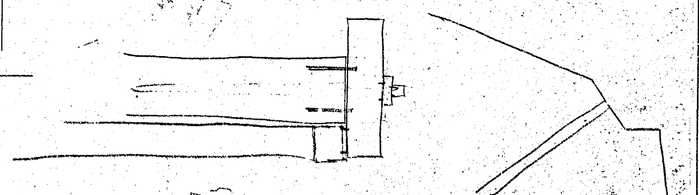


NOTES:-

1. All concrete to be Class 5
2. Concrete finishes and placing of mild steel reinforcement to be in accordance with the specification
3. Minimum cover to reinforcement to be 1½ inches unless otherwise shown
4. Vertical lift gates, radial gates and propellor type meters to be supplied by the Minister



NO	DATE	REVISIONS	REVD	APP'D

REFERENCE DRAWINGS

P.W.D. WA. 36654 Drg 3 Sheet 2

PUBLIC WORKS DEPARTMENT — WESTERN AUSTRALIA

ORD RIVER PROJECT
IRRIGATION AREA
CONTROL STRUCTURE MIC1 AT 24300 FT.
GENERAL ARRANGEMENT

File: F.B. 8

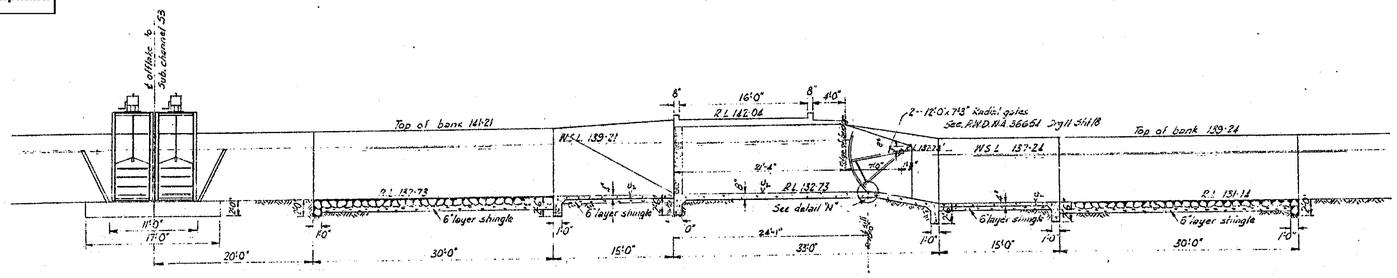
Scales:-
⅛ Inch : 1 Foot
14 Inch : 1 Foot

Drawn by C.C.J 28.11.61
Examd by K.C.W. 13.12.61
Traced by A.G. 2.12.61
Examd by C.C.J 18.1.62

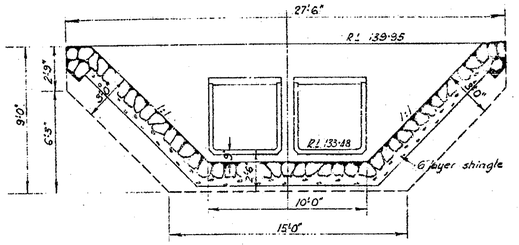
Recommended 24/1/62 — J. Hydraulic Design
Approved: 24/1/62 — Hydraulic Engineer

DRG. NO. 4 SHT. NO. 7

P.W.D.W.A. 36654



LONGITUDINAL SECTION A-A
Scale: $\frac{1}{8}$"=1'0"



SECTION C-C
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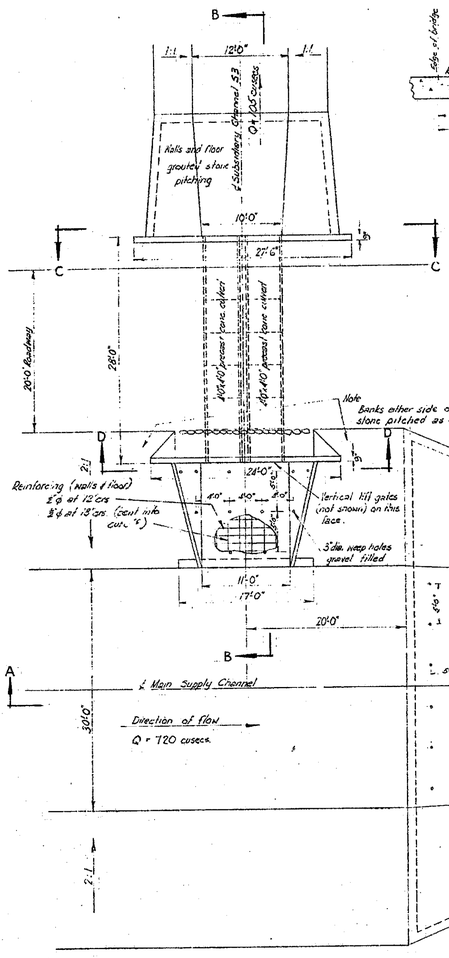
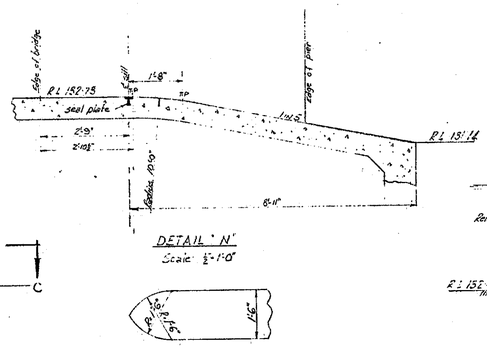
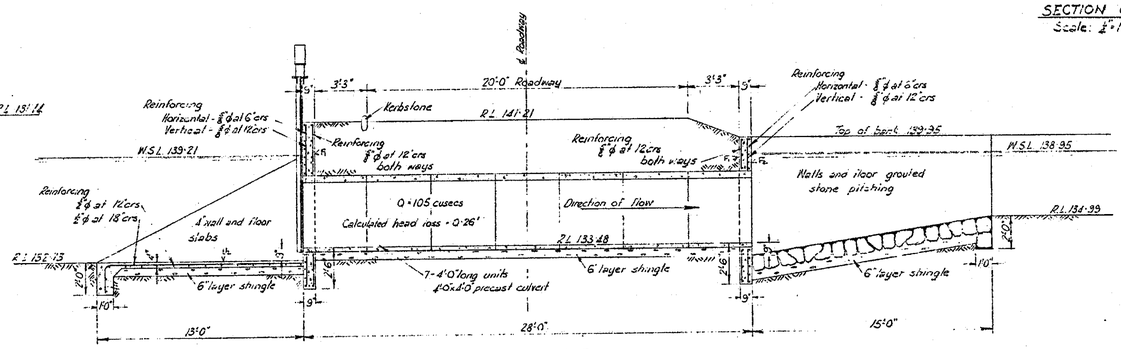




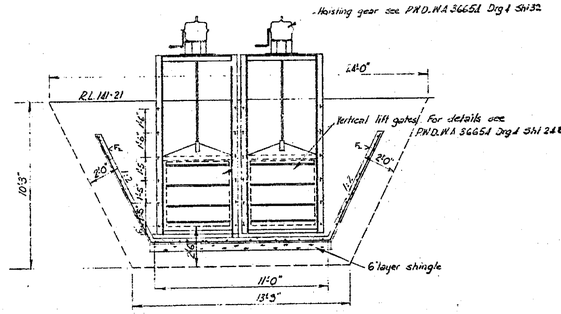
DETAIL 'N'
Scale: $\frac{1}{2}$"=1'0"

DETAIL OF PIER NOSE
Scale: $\frac{1}{2}$"=1'0"



SECTION B-B
Scale: $\frac{1}{4}$"=1'0"

PLAN
Scale: $\frac{1}{8}$"=1'0"



SECTION D-D
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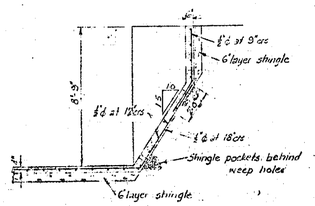

SECTION E-E
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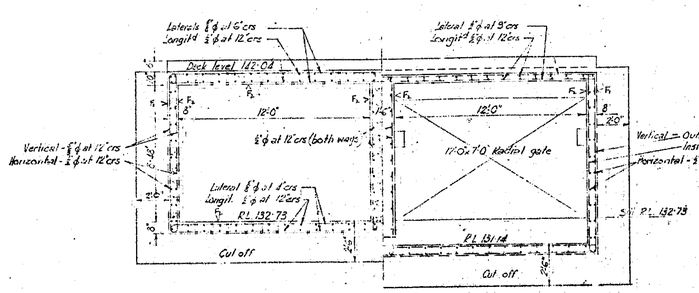

SECTION F-F
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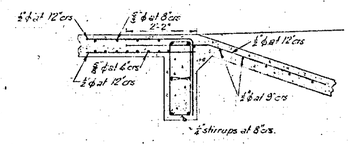

DETAIL "M"
Scale: $\frac{1}{2}$" = 1'0"

Notes.
1. All concrete to be class 5
2. Concrete finishes and placing of mild steel reinforcing to be in accordance with the Specification.
3. Minimum cover to reinforcement to be 1½" unless otherwise shown.
4. Vertical lift gates radial gates and embedded metal works other than reinforcing to be supplied by the Minister.

1	11-2-65	REDRAWN	H.M.W.
No.	DATE	REVISIONS	REV'D JOB'D

REFERENCE DRAWINGS
P.W.D.W.A. 36654 DRG 3 SHEET 24 B
P.W.D.W.A. 36654 DRG 4 SHEET 32

PUBLIC WORKS DEPARTMENT - WESTERN AUSTRALIA
ORD RIVER PROJECT
IRRIGATION AREA
CONTROL STRUCTURE MIC2 AT Gm. 68c
GENERAL ARRANGEMENT

FILE	F.B.	SCALES	$\frac{1}{8}$"=1'0" $\frac{1}{4}$"=1'0" $\frac{1}{2}$"=1'0"
	L.B.		
DRAWN	H.M.W. 14-2-63	RECOMMENDED for [illegible]	APPROVED for [illegible]
EXAMINED	R.C.W. 1-3-63	[signature]	[signature]
TRACED		ENGINEER M&I	DIRECTOR CONSTRUCTION
EXAMINED			
DRAWING	4.	SHEET	8A

P.W.D.W.A. 36654

FG-1370-1273

Gate Radius	1273	mm			
Height of Gate Fully Open	212	mm	Height of Gate Fully Closed	1232	mm
Gate Internal Width	1273	mm			
Gate External Width	1370	mm			

Upstream Level (mm)	Downstream Level (mm)											
	0	100	200	300	400	500	600	700	800	900	1000	1100
0	0											
100	0	0										
200	0	0	0									
300	6	6	6	0								
400	19	19	19	18	0							
500	36	36	36	35	31	0						
600	56	56	56	55	52	47	0					
700	80	80	80	78	76	71	64	0				
800	105	105	105	104	102	98	92	81	0			
900	133	133	133	132	130	126	121	113	100	0		
1000	163	163	163	162	160	156	151	145	135	120	0	
1100	195	195	195	194	192	188	184	178	170	159	141	0
1200	229	229	229	228	226	222	218	212	205	196	183	162

RUBICON

GENERAL NOTES
UNLESS OTHERWISE SHOWN ALL DIMENSIONS ARE IN

SCALES AS SHOWN
PHOTONEGATIVE
PHOTOPROJECTION
DATUM

DESIGN CALC — BOOK —
CHECKED G.L. — BOOK —
DRAWN D.M.M. CHECKED J.C.D.
TRACED CHECKED

SUBMITTED DATE
for ENGINEER DESIGN OFFICE

APPROVED DATE
ENGINEER I/C

PUBLIC WORKS DEPARTMENT – WESTERN AUSTRALIA

KUNUNURRA TOWNSITE
STORMWATER DRAINAGE
GENERAL PLAN SHOWING SYSTEMS

P.W.D.WA. 48531 - 0 - 1

REVN. A

A				
ZONE	DATE	REVISION	DRN	APPD

SURVEY BOOKS — FILE No P.W.S 740/67

APPENDIX

C

XP-RAFTS MODEL PARAMETERS

Catchment ID	Area (ha)	Average Slope (%)	Manning's 'n'
Cat_01	11.24	2.89	0.05
Cat_02	21.74	1.95	0.05
Cat_03	16.98	3.37	0.05
Cat_04	15.59	1.82	0.05
Cat_05	12.35	0.97	0.05
Cat_06	9.84	3.46	0.05
Cat_07	12.35	0.57	0.05
Cat_08	38.71	1.11	0.05
Cat_09	15.75	2.75	0.05
Cat_10	25.66	1.30	0.05
Cat_11	12.93	1.70	0.05
Cat_12	7.19	2.40	0.05
Cat_13	3.92	4.07	0.05
Cat_14	6.63	2.63	0.05
Cat_15	16.12	3.72	0.05
Cat_16	14.92	1.70	0.05
Cat_17	16.96	1.92	0.05
Cat_18	11.42	0.83	0.05
Cat_19	5.45	3.59	0.05
Cat_20	8.28	1.51	0.05
Cat_21	15.27	1.74	0.05
Cat_22	5.68	1.21	0.05
Cat_23	23.67	2.90	0.05
Cat_24	8.97	1.73	0.05
Cat_25	6.15	10.86	0.05
Cat_26	12.30	4.08	0.05
Cat_27	3.40	1.21	0.05
Cat_28	9.36	1.83	0.05
Cat_29	18.28	2.40	0.05
Cat_30	20.13	1.03	0.05
Cat_31	3.45	0.06	0.05
Cat_32	23.37	3.21	0.05
Cat_33	14.97	7.70	0.05
Cat_34	11.62	5.03	0.05
Cat_35	10.33	1.98	0.05
Cat_36	21.36	0.15	0.05
Cat_37	4.68	2.80	0.05
Cat_38	5.11	2.78	0.05
Cat_39	5.91	7.09	0.05
Cat_40	27.13	0.52	0.05
Cat_41	1.09	1.03	0.05

Catchment ID	Area (ha)	Average Slope (%)	Manning's 'n'
Cat_42	4.48	4.65	0.05
Cat_43	3.47	1.05	0.05
Cat_44	4.17	4.62	0.05
Cat_45	3.35	1.56	0.05
Cat_46	4.27	2.42	0.05
Cat_47	3.12	6.45	0.05
Cat_48	11.91	1.60	0.05
Cat_49	5.40	8.18	0.05
Cat_50	4.65	1.42	0.05
Cat_51	19.26	1.97	0.05
Cat_52	5.99	0.81	0.05
Cat_53	11.32	0.88	0.05

APPENDIX

D

STAKEHOLDER WORKSHOP MINUTES

Meeting Minutes

Project Title	Kununurra Stormwater Study		
Client	Shire of Wyndham East Kimberley (SWEK)		
Date	16/05/2019	**Meeting No.** -	**Project No.** CW992700
Location	SWEK Main Offices – 20 Coolibah Drive, Kununurra, WA 6743		
Recorded By	Cardno		

Attendance	**Distribution**
Riccardo Divita (RD) **Saj Haque (SH)** **Matt Dear (MD)** **John Piercey (JP)** **Susie Williams (SW)** **Stuart Dyson (SD)** **Dave Hawkins (DH)** **George Jannings (GJ)**	Attendance list
Apologies	

Item	Description	Action
1	**Modelling description**	

	• Brief overview of modelling undertaken by Cardno provided by RD.
	  ○ Model setup
	  ○ Data used
	  ○ Methodology
	• Model should only be used for impact assessment and not in determining floor levels for new developments due to issues with the DEM supplied by Geoscience Australia.
	• Model report review done by DWER. Comments from SW	

1.1	Further Comments	
	• Modelling approach is sound -SW • Land use division used in model is excessive -SW • Historical data is available from gauge at DWER office in the town -SW	• SW to provide Cardno with rainfall data from their gauge for the 2014 event. • Cardno to run calibration event with this data and observe differences.
2	**Model results**	
	• Corner of Barringtonia Ave and Weaber Plains Rd: Bank overtopping at culvert 220m east of intersection, causing water to flow west to the intersection.	

	• Industrial area adjacent to Ivanhoe Road: Stormwater from this area discharges to drain along Ivanhoe Road. Tailwater level of drain likely has an impact on flooding in this area. Industrial area adjacent to Weaber Plain Rd: Crossing under access road to Caravan park is undersized. Stormwater overflows across Weaber Plain Rd and down towards cutoff drain south of Kelly's Knob	
2.1	Further Comments	
	• Water quality monitoring should be considered being undertaken by SWEK at Ivanhoe drain outlet before discharging to Lily Creek Lagoon – SW • Ivanhoe drain discharges into borrow pit south of Victoria Hwy, which is overgrown with vegetation. It is unclear whether is in a P1 groundwater area and hence if maintenance can be conducted on the area.	• Cardno to add water quality monitoring as a recommendation in final report. • SW to confirm the P1 boundary south of Victoria Hwy.
3	**Mitigation Measures**	
	Six mitigation measures have been agreed upon to be modelled to assess impacts: 1. Expansion of the D1 drain, reversing the swale and including a siphon. 2. Increasing pipe capacity under Messmate Way to 2 x 900 RCP all the way along the park. 3. Weaber Plain Rd and Barringtonia Ave intersection: update culvert under Barringtonia Ave, with a retention basin on the north-east corner of intersection. 4. Ironwood Dr: continue 2x600 RCP from the TAFE up to drain just north of St Martins Way and include a swale over the top, similar to Messmate Way. Double the capacity of the culverts under Ironwood Dr and lower the road at that location to act as a flood way for larger events. 5. Increase size of outlets under Victoria Hwy to 2x900 RCP adjacent to Lakeview Apartments. 6. Industrial area (for discussion pending modelling results) Options may include: a. Revert drain along Weaber Plains Rd and Ironwood Dr back to original design, including drop structures. b. Maintenance of Industrial area retention basin. c. Replacement of potentially undersized culverts i.e. caravan park. d. Formalise drainage across Weaber Plains Rd for discharge into M1.	• RD to provide SWEK with an updated timeline. • Cardno to model mitigation measures and present the results to SWEK on a staged basis. • Cardno to determine preliminary costings for mitigation options and a schedule. • The results are planned to be presented in the July council meeting.
4	**General Discussion**	

	• Sedimentation caused by runoff from the National Park is causing siltation in the cut-off drains and drain adjacent to Weaber Plains Road -RD • Department of Parks and Wildlife (DPAW) have installed drop structures at the foothills of the National Park. Yet to see if they are effective in reducing sedimentation during a large storm event. • Water Corporation's position is against the use of the M1 Channel for stormwater conveyance- DH. • Future drainage plans should incorporate Water Sensitive Urban Design (WSUD), which may require inclusion in planning regulations – SW. • There is concern over pollutants and hazardous material (eg syringes) being found in M1 Channel, which is believed to be carried from overland flow from storm events. – MD	

APPENDIX

E

MITIGATION MEASURE COSTINGS

Feasibility - Opinion of Cost

Kununurra Stormwater Study

Option D01

Rev: 1

Item	Description	Quantity	Unit	Rate	Amount

1.0	Preliminaries	Quantity	Unit	Rate	Amount
	Site Establishment (Mobilisation and demobilisation)	1	Item	$ 8,500	$ 8,500
	Security	1	wks	$ 5,000	$ 5,000
	QA, Safety, Environmental Management Plans	1	Item	$ 2,000	$ 2,000
	General Conditions, Insurances etc	1	Item	$ 5,000	$ 5,000
	Locate Existing Services	1	Item	$ 10,000	$ 10,000
	Construction/Environment management Plans and approvals	1	Item	$ 1,000	$ 1,000
	As Constructed Drawings for Earthworks, Roadworks, Drainage, Water and Sewers as required by SWEK, Water Corporation and Western Power	1	item	$ 2,000	$ 2,000
	Site Supervision and Survey	16	wks	$ 2,000	$ 32,000
				SUB-TOTAL	$ 65,500

2.0	Siteworks and Demolition	Quantity	Unit	Rate	Amount
	Remove and dispose existing RCBCs from M1 to D1	75	m	$ 120	$ 9,000
	Remove and dispose existing culverts along D1 under Ivanhoe Rd.	45	m	$ 120	$ 5,400
				SUB-TOTAL	$ 14,400

3.0	Drainage	Quantity	Unit	Rate	Amount
	Supply and lay box culverts, including precast base slabs				
	1.2m x 1.2m	1,146.0	m	$ 1,617	$ 1,854,000
	Clearing existing drains				
	Clear vegetation and detritus out of existing drainage channels	33,958.0	m2	$ 10	$ 340,000
	Drainage earthworks				
	Siphon earthworks- cut to spoil, channels and new drainage pipework and culverts alignments	30,350.0	m3	$ 19	$ 583,000
	D1 Drain - cut to spoil and channels	40,940.0	m3	$ 19	$ 787,000
	M1 Swale- re-grading swale and cut to spoil	40,887.0	m3	$ 19	$ 786,000
	Reinforced concrete slabs	432.0	m2	$ 140	$ 61,000
				SUB-TOTAL	$ 4,411,000

5.0	Other items	Quantity	Unit	Rate	Amount
	Ivanhoe Rd bridge over D1	1	-	4,500,000	$ 4,500,000

6.0	Contingency	Quantity	Unit	Rate	Amount
	Contigency	-	-	30%	$ 1,347,270
				SUB-TOTAL	$ 1,347,270

TOTAL (ex GST)	**$**	**10,338,170**
GST (10%)	**$**	**1,033,817**
TOTAL (inc GST)	**$**	**11,372,000**

Opinion of Cost - Disclaimer

1. This document is produced by Cardno (WA) Pty Ltd solely for the benefit of and use by the client, in accordance with the retainer, if agreed to. Cardno (WA) Pty Ltd does not and shall not assume any responsibility or liability whatsoever to any third party arising out of any use or reliance by any third party on the content of this document.
2. This opinion of costs is an engineering estimate only and has not been completed by a qualified Quantity Surveyor. The rates used are based on rates based on similar projects. It is advised that the client review the rates used against rates used on similar projects.
3. It is understood that this opinion of costs is indicative. We accept no liability or responsibility for interpretations made or use of the information for any other purpose. It should also be noted that the opinion of costs may be affected by a number of factors outside the control of Cardno (WA) Pty Ltd and we cannot warrant the accuracy of the information provided and recommend a further review of the information contained herein be undertaken by the client prior to use.
4. This opinion of costs has only been based on the civil design as per the items listed above.
5. A contingency has been applied as per above.
7. This assessment has been based on information available at this time.
8. No allowance for de-watering, assumed construction is taking place during summer period.
9. No allowance for alteration, relocation or protection of existing services.
10. No allowance for contamination and Acid Sulfate Soils works.
11. This opinion of cost is for construction costs only, consultant fees are not included.
12. Prices based on 2018 Customer Price Index, estiamte does not include CPI increase at time of construction.
13. No allowance for demolition/alterations of adjacent land owner's structrues if required.
14. No allowance for adjacent land acquisitions.
15. No allowance for the reinstatement of turf, vegetation and landscaping.
16. No allowance for removal and/or reinstating of existing trees that may be affected by the construction.

Feasibility - Opinion of Cost

Kununurra Stormwater Study
Option D02
Rev: 1

Item	Description	Quantity	Unit	Rate	Amount
1.0	**Preliminaries**	**Quantity**	**Unit**	**Rate**	**Amount**
	Site Establishment (Mobilisation and demobilisation)	1	Item	$ 8,500	$ 8,500
	Traffic Management	8	wks	$ 3,000	$ 24,000
	Security	1	wks	$ 5,000	$ 5,000
	QA, Safety, Environmental Management Plans	1	Item	$ 2,000	$ 2,000
	General Conditions, Insurances etc	1	Item	$ 5,000	$ 5,000
	Locate Existing Services	1	Item	$ 10,000	$ 10,000
	Construction/Environment management Plans and approvals	1	Item	$ 1,000	$ 1,000
	As Constructed Drawings for Earthworks, Roadworks, Drainage, Water and Sewers as required by SWEK, Water Corporation and Western Power	1	item	$ 2,000	$ 2,000
	Site Supervision and Survey	8	wks	$ 2,000	$ 16,000
	Temporary fencing	1196	m	$ 17	$ 19,734
				SUB-TOTAL	$ 93,234
2.0	**Siteworks and Demolition**	**Quantity**	**Unit**	**Rate**	**Amount**
	Remove and dispose existing pipe crossing under Messmate Way (road)	51	m	$ 250	$ 12,750
	Remove and dispose existing pipes (open space)	595	m	$ 60	$ 35,700
	Removal and disposal of existing pits	3	no.	$ 2,000	$ 6,000
				SUB-TOTAL	$ 54,450
3.0	**Roadworks**	**Quantity**	**Unit**	**Rate**	**Amount**
	Earthworks				
	Box Out and Subgrade Preparation, Trim and Compact	152	m2	$ 6	$ 877
	Sub-Base Course				
	150mm limestone sub-base in place, compacted, waterbound and graded	151.9	m2	$ 11	$ 1,729
	100mm crushed rock basecourse	151.9	m2	$ 18	$ 2,756
	Asphalt				
	Primerseal	151.9	m2	$ 6	$ 877
	Asphalt seal, 40mm first lift, compacted thickness	152	m2	$ 25	$ 3,859
	Extruded Concrete Kerbing (including 35% ggbfs)				
	Semi-Mountable Kerb (SMK) adjacent to bitumen	8	m	$ 31	$ 239
	Singage & Linemarking				
	Install all linemarking and road marking including RRPM's	1	item	$ 5,000	$ 5,000
	Supply and install street name signs	1	item	$ 3,750	$ 3,750
	Median Strip Island				
	Re-installing kerb and bricks for median strip	22	m2	$ 120	$ 2,640
				SUB-TOTAL	$ 21,726
4.0	**Drainage**	**Quantity**	**Unit**	**Rate**	**Amount**
	Excavate and backfill in all classes of material to depths or all depths as shown				
	0m - 2m	660.0	m	$ 108	$ 71,438
	Supply and lay reinforced concrete stormwater pipe, rubber ring joint, class 2				
	DN600	270.0	m	$ 250	$ 67,587
	DN900	1052.0	m	$ 511	$ 537,751
	Supply and Install Rocla precast concrete headwalls to suit:				
	DN900	2.0	no.	$ 3,081	$ 6,162
	Side Entry Pit (SEP)/ Junction Pit (JP) (brick chamber)				
	200mm thick cast insitu base	74.0	m2	$ 362	$ 26,781
	Brick liner	16.53	m	$ 4,662	$ 77,069
	250mm thick cast insitu conversion slab	44.4	m2	$ 563	$ 25,011
	Concrete lid	22	No.	$ 726	$ 15,972
				SUB-TOTAL	$ 827,771
5.0	**Contingency**	**Quantity**	**Unit**	**Rate**	**Amount**
	Contigency	-	-	30%	$ 299,154
				SUB-TOTAL	$ 299,154
				TOTAL (ex GST)	**$ 1,296,335**
				GST (10%)	**$ 129,634**
				TOTAL (inc GST)	**$ 1,426,000**

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Feasibility - Opinion of Cost

Kununurra Stormwater Study
Option D03
Rev: 1

Item	Description	Quantity	Unit	Rate	Amount
1.0	**Preliminaries**	**Quantity**	**Unit**	**Rate**	**Amount**
	Site Establishment (Mobilisation and demobilisation)	1	Item	$ 8,500	$ 8,500
	Traffic Management	8	wks	$ 3,000	$ 24,000
	Security	1	Item	$ 5,000	$ 5,000
	QA, Safety, Environmental Management Plans	1	Item	$ 2,000	$ 2,000
	General Conditions, Insurances etc	1	Item	$ 5,000	$ 5,000
	Locate Existing Services	1	Item	$ 10,000	$ 10,000
	Construction/Environment management Plans and approvals	1	Item	$ 1,000	$ 1,000
	As Constructed Drawings for Earthworks, Roadworks, Drainage, Water and Sewers as required by SWEK, Water Corporation and Western Power	1	item	$ 2,000	$ 2,000
	Site Supervision and Survey	8	wks	$ 2,000	$ 16,000
				SUB-TOTAL	$ 73,500.00
2.0	**Siteworks and Demolition**	**Quantity**	**Unit**	**Rate**	**Amount**
	Remove and dispose existing pipe crossing under Barringtonia Ave	15	m	$ 250	$ 3,750
	Remove and dispose existing pipes (Weaber Plains road)	480	m	$ 60	$ 28,800
	Remove and dispose existing pathways	50	m	$ 50	$ 2,500
	Remove existing footbridges	2	no.	$ 4,000	$ 8,000
	Removal and disposal of existing pits	10	no.	$ 2,000	$ 20,000
				SUB-TOTAL	$ 63,050
3.0	**Roadworks**	**Quantity**	**Unit**	**Rate**	**Amount**
	Earthworks				
	Box Out and Subgrade Preparation, Trim and Compact	100	m2	$ 6	$ 600
	Sub-Base Course				
	150mm limestone sub-base in place, compacted, waterbound and graded	100.0	m2	$ 11	$ 1,100
	100mm crushed rock basecourse	100.0	m2	$ 18	$ 1,800
	Asphalt				
	Primerseal	100.0	m2	$ 6	$ 600
	Asphalt seal, 40mm first lift, compacted thickness	100	m2	$ 25	$ 2,500
	Extruded Concrete Kerbing (including 35% ggbfs)				
	Semi-Mountable Kerb (SMK) adjacent to bitumen	86	m	$ 30	$ 2,580
	Singage & Linemarking				
	Install all linemarking and road marking including RRPM's	1	item	$ 5,000	$ 5,000
	Median Strip Island				
	Re-installing kerb and bricks for median strip	10	m2	$ 120	$ 1,200
	Pathways	433	m	$ 60	$ 25,980
				SUB-TOTAL	$ 41,360
4.0	**Drainage**	**Quantity**	**Unit**	**Rate**	**Amount**
	Excavate and backfill in all classes of material to depths or all depths as shown				
	0m - 2m	1600.0	m	$ 105	$ 168,000
	Supply and lay reinforced concrete stormwater pipe, rubber ring joint, class 2				
	DN900	1600.0	m	$ 500	$ 800,000
	Supply and lay box culverts, including precast base slabs				
	1.2m x 1.2m	47.0	m	$ 1,600	$ 75,200
	Supply and Install Rocla precast concrete headwalls to suit:				
	DN900	2.0	no.	$ 3,000	$ 6,000
	DN1200	6.0	no.	$ 3,200	$ 19,200
	Detention basin				
	Cut to spoil, including drainage basin and new drainage pipework and culverts alignments	3000	m3	$ 10	$ 30,000
	Open Channel Drain				
	Regrade existing drain (Including Clear vegetation and detritus out of existing drainage channels)	400	m	$ 50	$ 20,000
	Side Entry Pit (SEP)/ Junction Pit (JP) (brick chamber)				
	200mm thick cast insitu base, brick liner, 250 mm thick cast insitu conversion slab and grated/concrete lid	10.0	no.	$ 10,000	$ 100,000
				SUB-TOTAL	$ 1,218,400
5.0	**Contingency**	**Quantity**	**Unit**	**Rate**	**Amount**
	Contigency	-	-	30%	$ 418,893
				SUB-TOTAL	$ 418,893
				TOTAL (ex GST)	**$ 1,816,000**
				GST (10%)	**$ 181,600**
				TOTAL (inc GST)	**$ 1,998,000**

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Feasibility - Opinion of Cost

Kununurra Stormwater Study
Option D05
Rev: 1

Item	Description	Quantity	Unit	Rate	Amount
1.0	**Preliminaries**	**Quantity**	**Unit**	**Rate**	**Amount**
	Site Establishment (Mobilisation and demobilisation)	1	Item	$ 8,500	$ 8,500
	Traffic Management	5	wks	$ 3,000	$ 15,000
	Security	1	wks	$ 5,000	$ 5,000
	QA, Safety, Environmental Management Plans	1	Item	$ 2,000	$ 2,000
	General Conditions, Insurances etc	1	Item	$ 1,000	$ 1,000
	Locate Existing Services	1	Item	$ 10,000	$ 10,000
	Construction/Environment management Plans and approvals	1	Item	$ 1,000	$ 1,000
	As Constructed Drawings for Earthworks, Roadworks, Drainage, Water and Sewers as required by SWEK, Water Corporation and Western Power	1	item	$ 2,000	$ 2,000
	Site Supervision and Survey	5	wks	$ 2,000	$ 10,000
	Temporary fencing	323	m	$ 17	$ 5,491
				SUB-TOTAL	$ 59,991
2.0	**Siteworks and Demolition**	**Quantity**	**Unit**	**Rate**	**Amount**
	Remove headwall and existing pits	3	m	$ 2,000	$ 6,000
				SUB-TOTAL	$ 6,000
3.0	**Roadworks**	**Quantity**	**Unit**	**Rate**	**Amount**
	Earthworks				
	Box Out and Subgrade Preparation, Trim and Compact	136	m2	$ 6	$ 785
	Sub-Base Course				
	150mm limestone sub-base in place, compacted, waterbound and graded	136.0	m2	$ 11	$ 1,548
	100mm crushed rock basecourse	136.0	m2	$ 18	$ 2,468
	Asphalt				
	Primerseal	136.0	m2	$ 6	$ 785
	Asphalt seal, 40mm first lift, compacted thickness	136	m2	$ 25	$ 3,456
	Extruded Concrete Kerbing (including 35% ggbfs)				
	Semi-Mountable Kerb (SMK) adjacent to bitumen	75	m	$ 31	$ 2,327
	Concrete pathways				
	Reinstatement of concrete pathways	120	m2	$ 100	$ 12,000
				SUB-TOTAL	$ 23,370
4.0	**Drainage**	**Quantity**	**Unit**	**Rate**	**Amount**
	Excavate and backfill in all classes of material to depths or all depths as shown				
	0m - 2m	325.0	m	$ 108	$ 35,178
	Supply and lay reinforced concrete stormwater pipe, rubber ring joint, class 2				
	DN1050	325.0	m	$ 785	$ 255,078
	Supply and Install Rocla precast concrete headwalls to suit:				
	DN1050	1.0	no.	$ 3,303	$ 3,303
	Re-aligning drain along Ironwood Dr.				
	Cut to fill, including open channell drain and alignments with existing drains	2300	m3	$ 19	$ 44,160
	SEP and JP (brick Chamber)				
	200mm thick cast insitu base, brick liner, 250mm thick cast insitu conversion slab	4.0	no	$ 10,000	$ 40,000
				SUB-TOTAL	$ 377,719
5.0	**Contingency**	**Quantity**	**Unit**	**Rate**	**Amount**
	Contigency	-	-	30%	$ 140,124
				SUB-TOTAL	$ 140,124
				TOTAL (ex GST)	**$ 607,203**
				GST (10%)	**$ 60,720**
				TOTAL (inc GST)	**$ 668,000**

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15. No allowance for the reinstatement of turf, vegetation and landscaping.
16. No allowance for removal and/or reinstating of existing trees that may be affected by the construction.

Feasibility - Opinion of Cost

Kununurra Stormwater Study
Option D06
Rev: 1

Item	Description	Quantity	Unit	Rate	Amount
1.0	**Preliminaries**	**Quantity**	**Unit**	**Rate**	**Amount**
	Site Establishment (Mobilisation and demobilisation)	1	Item	$ 8,500	$ 8,500
	Traffic Management	3	wks	$ 3,000	$ 9,000
	Security	1	wks	$ 5,000	$ 5,000
	QA, Safety, Environmental Management Plans	1	Item	$ 2,000	$ 2,000
	General Conditions, Insurances etc	1	Item	$ 5,000	$ 5,000
	Locate Existing Services	1	Item	$ 10,000	$ 10,000
	Construction/Environment management Plans and approvals	1	Item	$ 1,000	$ 1,000
	As Constructed Drawings for Earthworks, Roadworks, Drainage, Water and Sewers as required by SWEK, Water Corporation and Western Power	1	item	$ 2,000	$ 2,000
	Site Supervision and Survey	8	wks	$ 2,000	$ 16,000
				SUB-TOTAL	$ 58,500
2.0	**Siteworks and Demolition**	**Quantity**	**Unit**	**Rate**	**Amount**
	Remove existing culvert crossings to Caravan Park	2	no.	$ 2,000	$ 4,000
	Remove and dispose existing pipe crossing under Unnamed road and Carpentaria St.	31	m	$ 250	$ 7,750
				SUB-TOTAL	$ 11,750
3.0	**Roadworks**	**Quantity**	**Unit**	**Rate**	**Amount**
	Earthworks				
	Box Out and Subgrade Preparation, Trim and Compact	159	m2	$ 6	$ 918
	Sub-Base Course				
	150mm limestone sub-base in place, compacted, waterbound and graded	159.0	m2	$ 11	$ 1,810
	100mm crushed rock basecourse	159.0	m2	$ 18	$ 2,886
	Asphalt				
	Primerseal	159.0	m2	$ 6	$ 918
	Asphalt seal, 40mm first lift, compacted thickness	159	m2	$ 25	$ 4,040
				SUB-TOTAL	$ 10,573
4.0	**Drainage**	**Quantity**	**Unit**	**Rate**	**Amount**
	Excavate and backfill in all classes of material to depths or all depths as shown				
	0m - 2m	61.0	m	$ 108	$ 6,603
	Supply and lay reinforced concrete stormwater pipe, rubber ring joint, class 2				
	DN900	93.0	m	$ 511	$ 47,539
	Supply and lay box culverts, including precast base slabs				
	1.2m x 0.6m	90.0	m	$ 1,529	$ 137,610
	Supply and Install Rocla precast concrete headwalls to suit:				
	DN900	12.0	no.	$ 3,081	$ 36,972
	DN1200	6.0	no.	$ 3,440	$ 20,642
	Detention basin				
	Cut to spoil, including drainage basin and new drainage pipework and culverts alignments	2513	m3	$ 19	$ 48,250
	Clearing existing drains				
	Clear vegetation and detritus out of existing drainage channels	15932	m2	$ 10	$ 159,320
	Open Channel Drain				
	Regrade existing drain (Including Clear vegetation and detritus out of existing drainage channels)	580	m	$ 25	$ 14,500
				SUB-TOTAL	$ 471,435
5.0	**Contingency**	**Quantity**	**Unit**	**Rate**	**Amount**
	Contigency	-	-	30%	$ 165,677
				SUB-TOTAL	$ 165,677
				TOTAL (ex GST)	**$ 717,935**
				GST (10%)	**$ 71,793**
				TOTAL (inc GST)	**$ 790,000**

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Feasibility - Opinion of Cost

Kununurra Stormwater Study

Option D08

Rev: 1

Item	Description	Quantity	Unit	Rate	Amount
1.0	**Preliminaries**	**Quantity**	**Unit**	**Rate**	**Amount**
	Site Establishment (Mobilisation and demobilisation)	1	Item	$ 8,500	$ 8,500
	Security	1	wks	$ 5,000	$ 5,000
	QA, Safety, Environmental Management Plans	1	Item	$ 2,000	$ 2,000
	General Conditions, Insurances etc	1	Item	$ 5,000	$ 5,000
	Locate Existing Services	1	Item	$ 10,000	$ 10,000
	Construction/Environment management Plans and approvals	1	Item	$ 1,000	$ 1,000
	As Constructed Drawings for Earthworks, Roadworks, Drainage, Water and Sewers as required by SWEK, Water Corporation and Western Power	1	item	$ 2,000	$ 2,000
	Site Supervision and Survey	18	wks	$ 2,000	$ 36,000
				SUB-TOTAL	$ 69,500
2.0	**Siteworks and Demolition**	**Quantity**	**Unit**	**Rate**	**Amount**
	Remove and dispose existing RCBCs from M1 to D1	75	m	$ 120	$ 9,000
	Remove and disose existing culverts along D1 under Ivanhoe Rd.	45	m	$ 120	$ 5,400
				SUB-TOTAL	$ 14,400
3.0	**Drainage**	**Quantity**	**Unit**	**Rate**	**Amount**
	Supply and lay box culverts, including precast base slabs				
	1.2m x 0.6m	320.0	m	$ 1,529	$ 489,280
	1.2m x 1.2m	1,146.0	m	$ 1,617	$ 1,853,082
	Clearing existing drains				
	Clear vegetation and detritus out of existing drainage channels	33,958	m2	$ 10	$ 339,580
	Drainage earthworks				
	Installing siphon- cut to fill, channels and new drainage pipework and culverts alignments	30,350	m3	$ 19	$ 582,720
	D1 Drain - cut to spoil and channel	40,940	m3	$ 19	$ 786,048
	M1 Swale- cut to spoil and regrade swale	40,887	m3	$ 19	$ 785,030
	Reinforced concrete slabs	432.0	m2	$ 140	$ 60,588
				SUB-TOTAL	$ 4,896,328
5.0	**Other items**	**Quantity**	**Unit**	**Rate**	**Amount**
	Ivanhoe Rd bridge over D1	1	no.	$ 4,500,000	$ 4,500,000
	Levee along swale	32,557	m3	$ 19	$ 625,094
6.0	**Contingency**	**Quantity**	**Unit**	**Rate**	**Amount**
	Contigency	-	-	30%	$ 1,494,069
				SUB-TOTAL	$ 1,494,069
				TOTAL (ex GST)	**$ 11,599,391**
				GST (10%)	**$ 1,159,939**
				TOTAL (inc GST)	**$ 12,760,000**

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Feasibility - Opinion of Cost

Kununurra Stormwater Study

Maintenance Costs

Rev: 1

Item	Description	Quantity	Unit	Rate	Amount
1.0	**Pipe cleaning**	**Quantity**	**Unit**	**Rate**	**Amount**
	Main townsite	14,955	m	$ 81	$ 1,204,476
	Lakeside	4,478	m	$ 81	$ 360,658
				SUB-TOTAL	$ 1,565,134
2.0	**Drain Maintenance**	**Quantity**	**Unit**	**Rate**	**Amount**
	Main Townsite	13,791	m	$ 25	$ 344,775
	Lakeside	3,056	m	$ 25	$ 76,400
				SUB-TOTAL	$ 421,175
3.0	**Drainage basins**	**Quantity**	**Unit**	**Rate**	**Amount**
	Main Townsite	13,760	m2	$ 10.00	$ 137,600
				SUB-TOTAL	$ 137,600
5.0	**Drain clearing**	**Quantity**	**Unit**	**Rate**	**Amount**
	Cutoff Drain A	1,350	no.	$ 25	$ 33,750
	Cutoff Drain B	1,051	m3	$ 25	$ 26,275
				SUB-TOTAL	$ 60,025
7.0	**Drop Structures**	**Quantity**	**Unit**	**Rate**	**Amount**
	Cutoff Drain A	3	no.	$ 25,000	$ 75,000
	Cutoff Drain A	1	no.	$ 25,000	$ 25,000
				SUB-TOTAL	$ 100,000
				TOTAL (ex GST)	**$ 2,284,000**

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4. This opinion of costs has only been based on the civil design as per the items listed above.
5. A contingency has been applied as per above.
7. This assessment has been based on information available at this time.
8. No allowance for de-watering, assumed construction is taking place during summer period.
9. No allowance for alteration, relocation or protection of existing services.
10. No allowance for contamination and Acid Sulfate Soils works.
11. This opinion of cost is for construction costs only, consultant fees are not included.
12. Prices based on 2018 Customer Price Index, estiamte does not include CPI increase at time of construction.
13. No allowance for demolition/alterations of adjacent land owner's structrues if required.
14. No allowance for adjacent land acquisitions.
15. No allowance for the reinstatement of turf, vegetation and landscaping.
16. No allowance for removal and/or reinstating of existing trees that may be affected by the construction.

About Cardno

Cardno is a professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

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