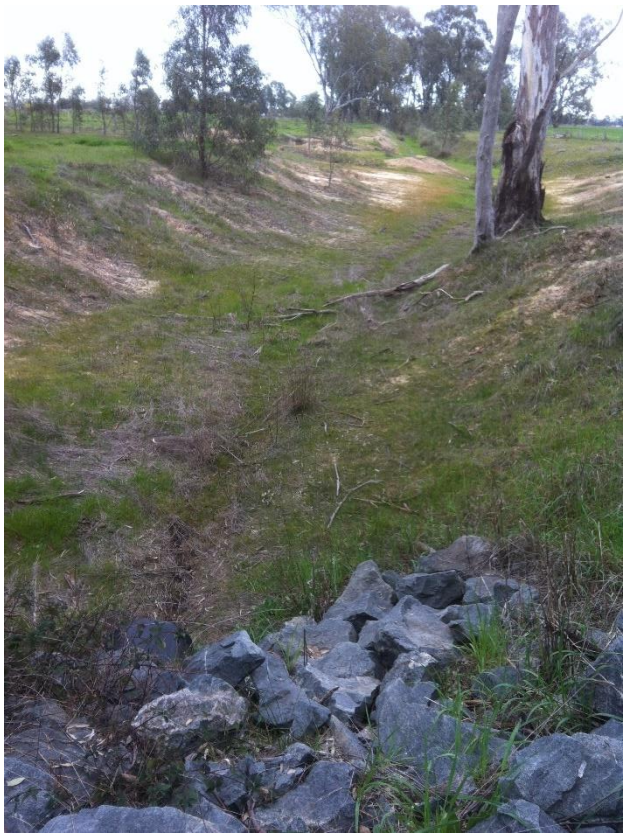
WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Investigation Area 3



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GREATER SHEPPARTON

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Cover Photo: The existing drainage path through Investigation Area 3, looking west from the Broken River breakout

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EXECUTIVE SUMMARY

This report details the flood behaviour of Investigation Area 3, which is bound by the Broken River, Archer Road, Doyles Road and River Road, Kialla. Water Technology was engaged by Greater Shepparton City Council to model the flood behaviour and review its suitability for development in regards to the floodplain management criteria set out by Goulburn Broken Catchment Management Authority (GBCMA). The scope of the project is based on the requirements set out in the GBCMA letter of floodplain management advice for the proposed residential subdivision at Investigation Area 3, Kialla (REF: F-2014-0039). The objectives of this report are in line with these requirements as well as the requirements of Greater Shepparton City Council, and are summarised below:

1. To review relevant information on flood behaviour;
2. To develop an estimate of flood behaviour (levels, extents, velocities) for the 100 year ARI design flood event;
3. To develop a plan of possible development within Investigation Area 3;
4. To assess change in flood behaviour (levels, extents, velocities) for the 100 year ARI design flood event due to the proposed development plan; and
5. Determine a suitable conceptual layout of major collector roads, residential areas, and open space area together with any cut and fill requirements that will have acceptable level of change in floodplain characteristics.

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1. INTRODUCTION

Water Technology was commissioned by Greater Shepparton City Council (GSSC) to prepare a detailed assessment of the existing flood behaviour and potential for development with regards to riverine flooding at Investigation Area 3. The site is referred to as Investigation Area 3, and is being viewed as an area of potential development in both the near and long term future of growth around Shepparton as part of the Kialla and Shepparton South Framework Plan shown in Figure 1-1.

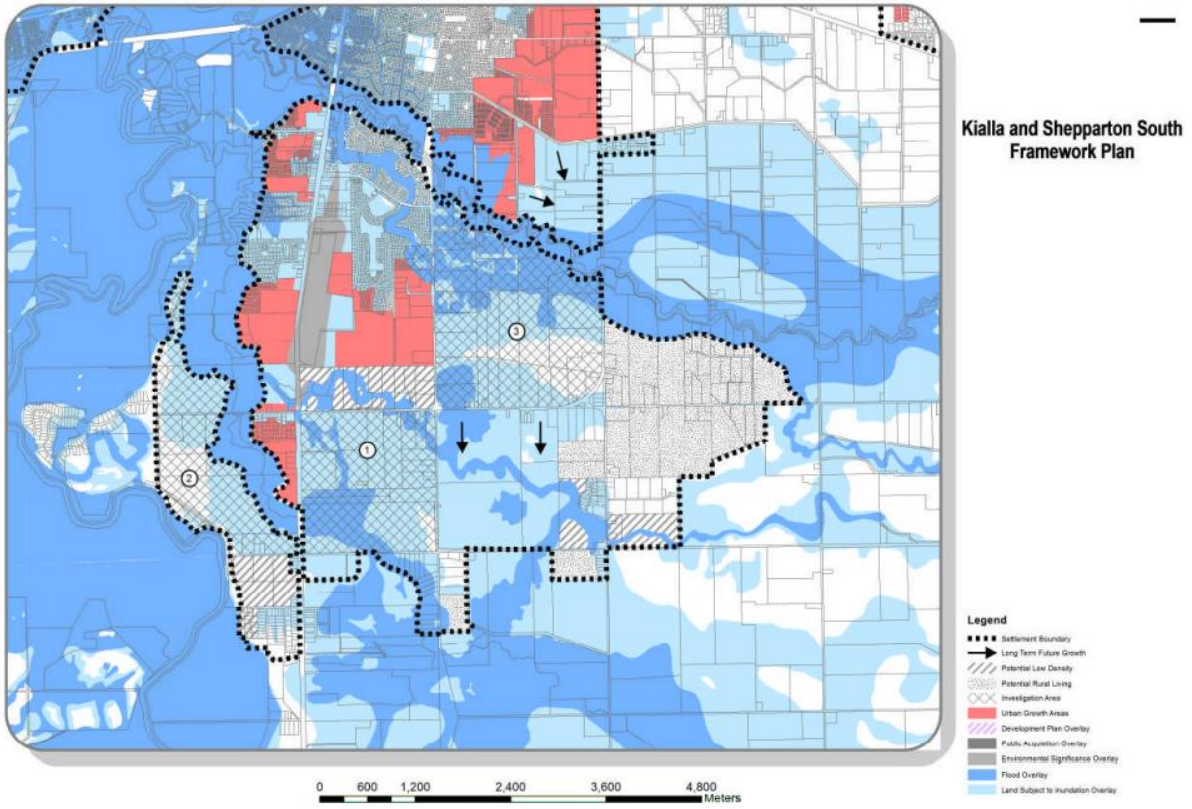

Figure 1-1 Kialla and Shepparton South Framework Plan (Greater Shepparton Planning Scheme)

A Flood Risk Report is generally required for a subdivision when it is located within a floodplain and no Local Floodplain Development Plan exists. The Flood Risk Report must satisfy the following conditions:

- State Planning Policy and Local Planning Policy Frameworks
- Consideration of existing use and development of the land
- Whether proposed development could be located on flood-free land or lower flood hazard
- Susceptibility of development to flooding
- Effect of development on obstructing drainage or reducing flood storage, levels or velocities

This report covers the relevant riverine flooding requirements and flood behaviour for the site. It also includes a recommended development layout which may allow for a future planning amendment, potentially enabling landholders to excise their land for development. Currently the development layouts utilised in this report are conceptual and require more detail in regards to location of services and roadways etc. At a detailed design level, flood behaviour should again be assessed to ensure development is occurring in an appropriate manner with regards to flood risk associated with the Broken River and associated anabranches.

1.1 Study Site

The study site is approximately 459 Ha, located at Kialla on the eastern fringes of the Shepparton township. 410 Ha of the site is zoned as Rural Living Zone with the remainder being zoned as Urban Floodway Zone (UFZ). Much of the site is also covered by either Land Subject to Inundation Overlay (LSIO) or Floodway Overlay (FO) as shown in Figure 1-2. The study site is bound by Broken River, River Road, Archer Road and Doyles Road. A small area to the west of Archer Road was not assessed within the potential development area as the parcels west of Archer Road were identified as reaching their full development potential with two existing houses sitting outside the UFZ. The Broken River runs to the north of the site with a large anabranch dissecting the northern area of the site. The anabranch sits well above the normal water level of the Broken River, but is connected during high flow events. The anabranch travels west towards Archer Road, where it travels through a series of culverts and into the Kialla Lakes system. The site slopes to the north west on a very flat gradient. Currently a number of Goulburn-Murray Water (G-MW) channels traverse the site which form part of the stock and domestic supply channel network. Much of the site is currently used for low density agriculture, equine use and lifestyle farming.

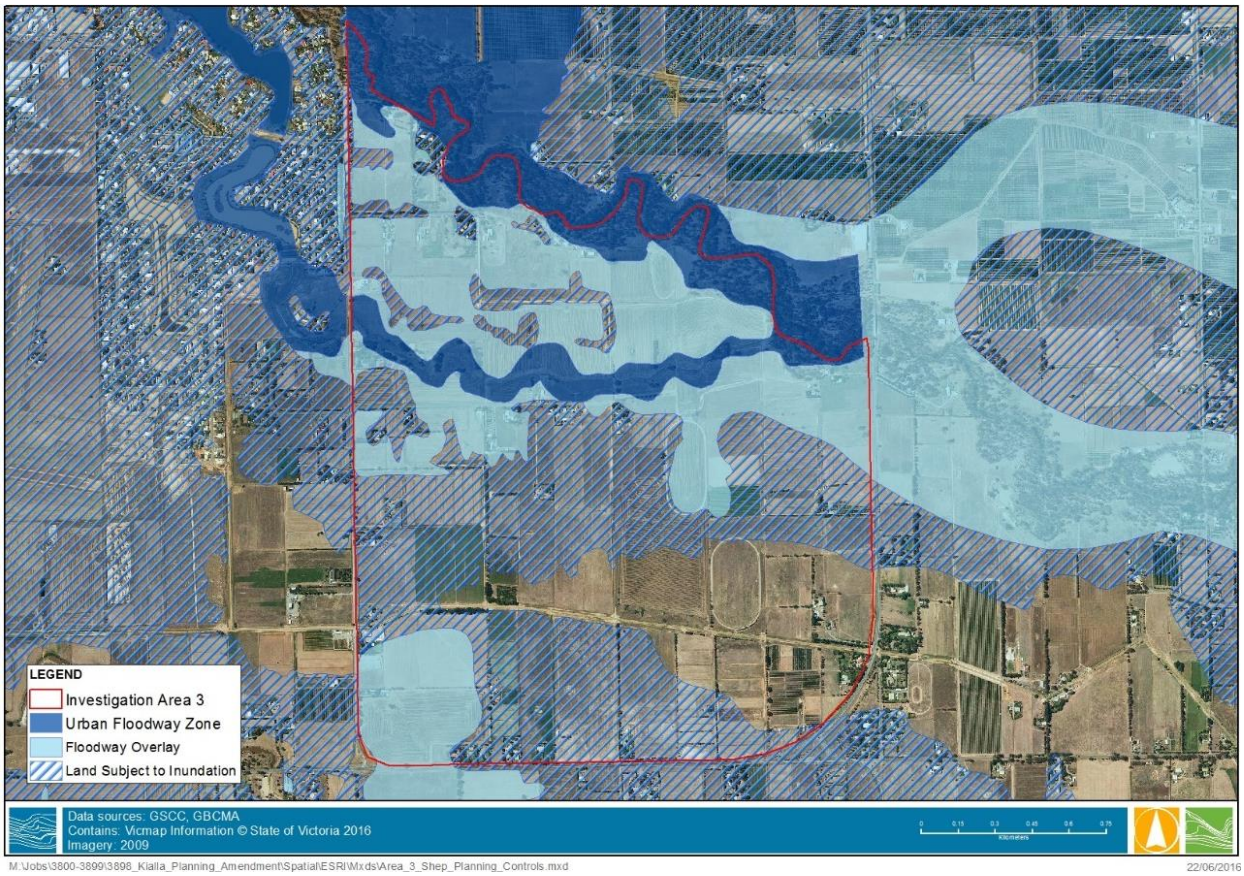

Figure 1-2 Existing Flood Controls in the Greater Shepparton Planning Scheme

1.2 Current Flood Behaviour

Much of the study site is covered by a FO or LSIO, as well as two separate areas zoned UFZ. Under existing flood conditions, water from the Broken River breaks out into the site via an existing anabranch at the eastern end of the site. This breakout area is a natural flow path under high water level conditions. A site investigation found an embankment of rock has been placed in the flow path to restrict the flow through the anabranch under high water levels. This embankment also has a pipe (approx. 450-600 mm diameter) to drain the anabranch after the flood levels in the Broken River have

receded. The pipe has a one way flap valve on the Broken River inlet which does not let water from the Broken River enter the anabranch until the rock embankment is overtopped.

As water overtops the embankment and spreads west through the investigation area, the flood water flows through the anabranch until Archer Road, where a series of culverts convey water beneath Archer Road and into the Kialla Lakes overland drainage path.

As the Broken River levels increase, more water enters the investigation area via the anabranch. Water then spreads out and flows predominately in a north-westerly direction. An existing G-MW channel which runs north-south causes a restriction with an opening of around 180 m, (where the channel is located underground as a subway) constricting the upstream flow extent to 400-450 m through the opening. Upstream of the channel, floodwaters spread south through a localised low area.

Downstream of the channel, as flood levels increase, Archer Road is overtopped and some water flows north along the eastern side of Archer Road back towards the Broken River. Several areas in the north of the study site, which front onto the Broken River are flooded directly from the river. The 1% AEP maximum flood depths are shown in Figure 1-3.

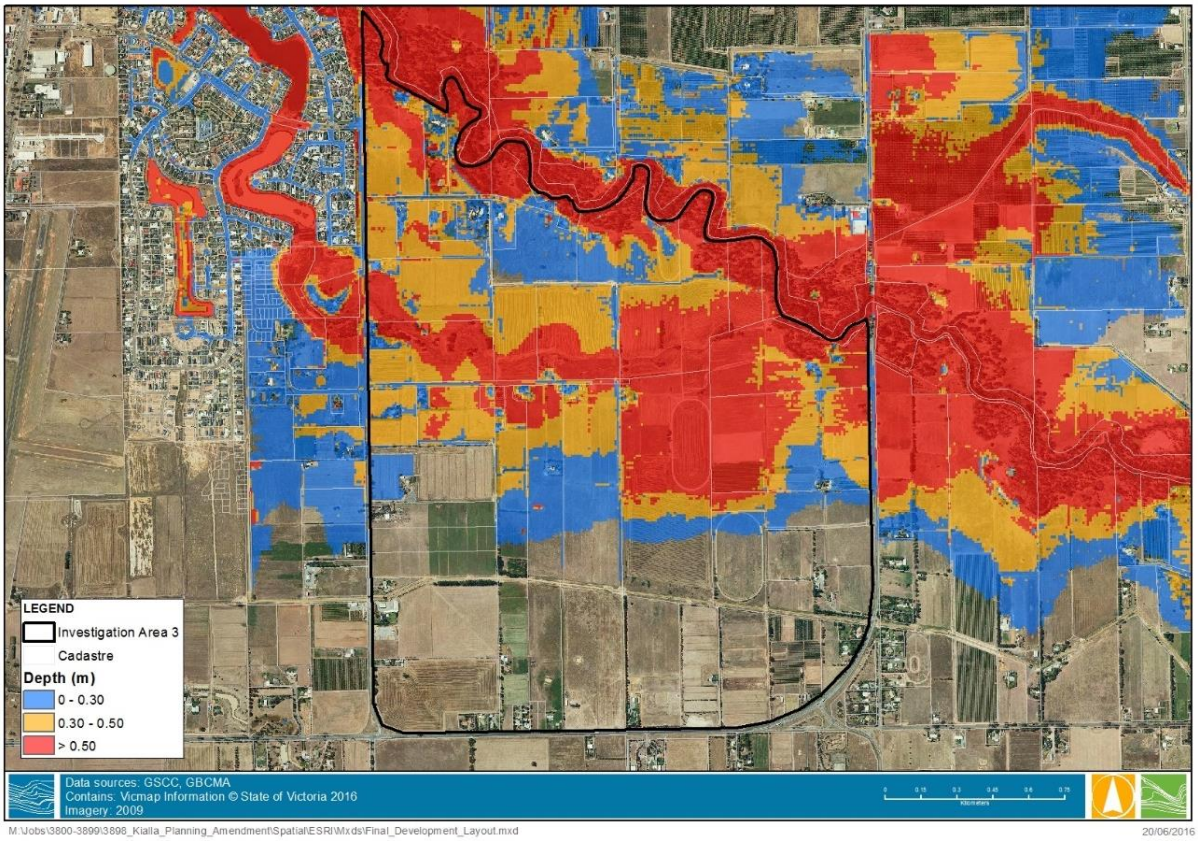

Figure 1-3 1% AEP Maximum Depth Existing Conditions

The 1993 floods are considered the worst in recent history, a number of other flood events have occurred in the area including 1974, 1995 and 2010. A streamflow gauge on Broken River at Orrvale provided information on historical flood events and allows for an accurate estimation of these events to calibrate flood modelling results.

During the 1993 flood event, the flow at the Goulburn River at Orrvale streamflow gauge peaked at 8.23 m with an estimated flow of 42,900 ML/d. The adopted 1% AEP flood event (1 in a 100 year ARI) flow at the Kialla West streamflow gauge is 48,000 ML/d, this was revised during the Shepparton-

Mooroopna Flood Intelligence Study[1]. The results were calibrated to recorded historical flood heights prior to the design flood modelling being undertaken. This is discussed in more detail in Section 1.3.

Local rainfall runoff generated from within the site was not assessed as part of the existing site flooding conditions. Any development plan should investigate local catchment runoff as part of a Stormwater Management Plan.

[1] Water Technology, 2016, Shepparton-Mooroopna Flood Intelligence Study

1.3 History of Flood Investigations

1.3.1 Shepparton – Mooroopna Flood Study (1982)

The Shepparton - Mooroopna Flood Study was undertaken by Sinclair Knight and Partners Pty Ltd was undertaken along with Kinhill Pty Ltd. The study was prepared for the State Rivers and Water Supply Commission of Victoria, the City of Shepparton, the Shire of Shepparton, the Shire of Rodney and the Department of National Development and Energy. The study utilised much of the information gathered from the 1974 Goulburn River flood which caused extensive flooding through Shepparton.

The major study outputs included a flood atlas, mitigation options and a large amount of community feedback regarding the 1974 flood event.

1.3.2 Shepparton Mooroopna Floodplain Management Study (2002)

The Shepparton Mooroopna Floodplain Management Study was undertaken in 2002 by Sinclair Knight Merz in conjunction with Lawson and Treloar Pty Ltd. The study used computational floodplain modelling, using DHI's MIKE 21, to calibrate the flood events of 1974 and 1993 to within +/- 500 mm. The model topography utilised photogrammetry flown in September 1999 and a model grid resolution of 12.5 m for the 'inner area' and a 25 m grid resolution in the 'outer area'. Investigation Area 3 sits in the 'outer area'.

The modelling undertaken in the 2002 flood study formed the basis for the current planning scheme and the existing 1% AEP flood levels for the Investigation Area, these range from 115.0 m AHD in the east of the site to 113.9 m AHD to the north west. These levels were adopted by Goulburn Broken Catchment Management Authority (GBCMA) as designated flood levels.

1.3.3 Flood Warning and Emergency Management Report (2007)

Water Technology completed a Flood Warning and Emergency Management Report for the GSCC in 2007. This involved undertaking a number of recommendations from the 2002 SKM flood study around flood preparedness, flood warning, flood response and the development of improved information management systems. This project developed property specific flood charts for over 6000 properties within the flood risk area, a flood monitoring plan and community flood alerting system.

1.3.4 Archer Road Culvert Investigation (2011)

Following significant flooding across the site in 2010, Water Technology was engaged by GSCC to investigate the impact Archer Road has on the localised behaviour. Anecdotal evidence suggested that the culverts conveying water beneath Archer Road were undersized and were causing a backwater that increased water levels upstream of Archer Road. The investigation found that while the culverts may be undersized, the impact of the culverts and road on the flooding was localised to within the first 500 m given the natural slope of the anabranch. Several scenarios were completed including converting the road to ford crossing and the complete removal of the road. Both showed the impact upstream was relatively localised to the roadway.

1.3.5 Shepparton-Mooroopna Flood Mapping and Intelligence Study (ongoing)

Water Technology are currently undertaking flood modelling of the Shepparton Mooroopna area; this will be used to update existing planning controls within the site. The modelling undertaken for this Investigation Area replicated the modelling being undertaken for the larger flood study. This involved utilising the same model parameters as used in the Shepparton-Mooroopna Flood Study and ensuring existing conditions flood levels matched the larger flood study results. Modelling for the Shepparton – Mooroopna Flood Mapping and Intelligence Study used high resolution Light (LiDAR) and a grid resolution of 10 m. The model was calibrated using surveyed flood height marks from the 1974 and 1993 floods and further validated using aerial imagery from these events. Calibration for these events

was aimed at within +/- 200mm. The use of aerial imagery for validation was taken with some caution as often the timing of the photography does not coincide with the peak of the flood event. Additionally, local rainfall during the event can cause flooding in areas which may not be represented within the floodplain studies. At the time of the investigation, the calibration of the model to the historical events had been undertaken along with 1% AEP design modelling.

2. PROPOSED DEVELOPMENT

A proposed development masterplan, as illustrated in Figure 2-1, was developed by GMR Engineering Services in consultation with GSCC and Water Technology. This initial development layout was implemented in the flood model to assess riverine flooding and was subsequently revised, the results are discussed in Section 3.

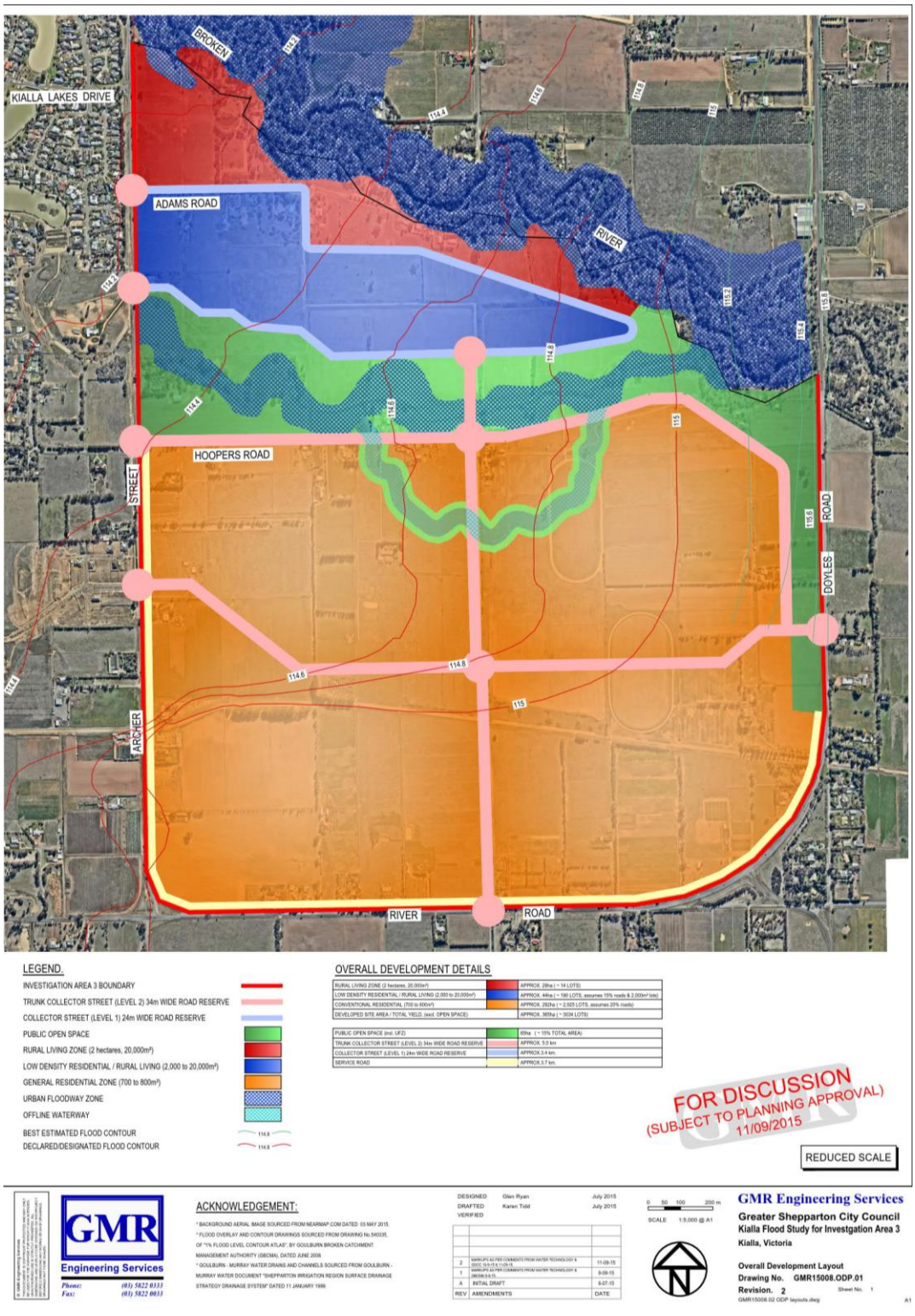

Figure 2-1 Initial Masterplan Layout (GMR Engineering Services)

3. DEVELOPMENT FLOOD RISK

A series of model simulations were undertaken to assess the floodplain management suitability of development. The key criteria assessed included:

- No negative impact to flood levels outside of the study site.
- Any loss of floodplain storage be compensated with the addition of 130% of the floodplain storage volume removed.

To understand the impact the development would have on water levels, depths and extents a direct comparison was drawn between the Water Surface Elevation (WSE) predictions from the 'Base Case' and 'Developed' models. This comparison is calculated as follows:

- *Developed WSE – Base Case WSE = Difference in predicted WSE*

This comparison shows the impact of the development in terms of a change in WSE. A positive change indicates an increase in WSE after development for the 1% AEP flood event. A negative change indicates a decrease in WSE after development during the 1% AEP flood event. The comparison also shows areas which were previous inundated and are now dry after the development and areas which were dry and are now inundated.

3.1 Development Scenario 1

The development layout shown in Figure 2-1 comprises of a large area of General Residential zone land (GRZ), south of Hoopers Road through to River Road. This area was raised above the 1% AEP flood level to make it flood free. The area immediately to the north of the anabranch was proposed to be Low Density Residential Zone (LDRZ), which also requires fill levels above the 1% AEP flood level. The area further north which fronts the Broken River is proposed to be Rural Living Zone (RLZ), which requires a dwelling pad of any new properties to be raised above the 1% AEP flood level. Several areas of floodplain storage were provided within this layout, including the anabranch which was lowered and widened to provide a more efficient flow path. An additional offline waterway in the centre of the site was added as a feature of the development. Additional floodplain storage was located on the eastern side of the study site of the Development Scenario 1 to compensate for the loss of floodplain storage.

Results of the flood modelling using the Development Scenario 1 layout are shown in Figure 3-1, showing the general residential area south of Hoopers Road as flood free. Figure 3-2 shows the difference in flood levels of Development Scenario 1 when compared to existing conditions. The orange and red shading downstream of the study site show that water levels are now higher under the developed scenario compared with existing conditions and would not meet GBCMA requirements.

An iterative process to 'balance' water levels both upstream and downstream of the investigation area while still aiming to meet the development goals within the site resulted in a number of similar development layouts being trialled in the flood model. These iterations are summarised in Table 3-1

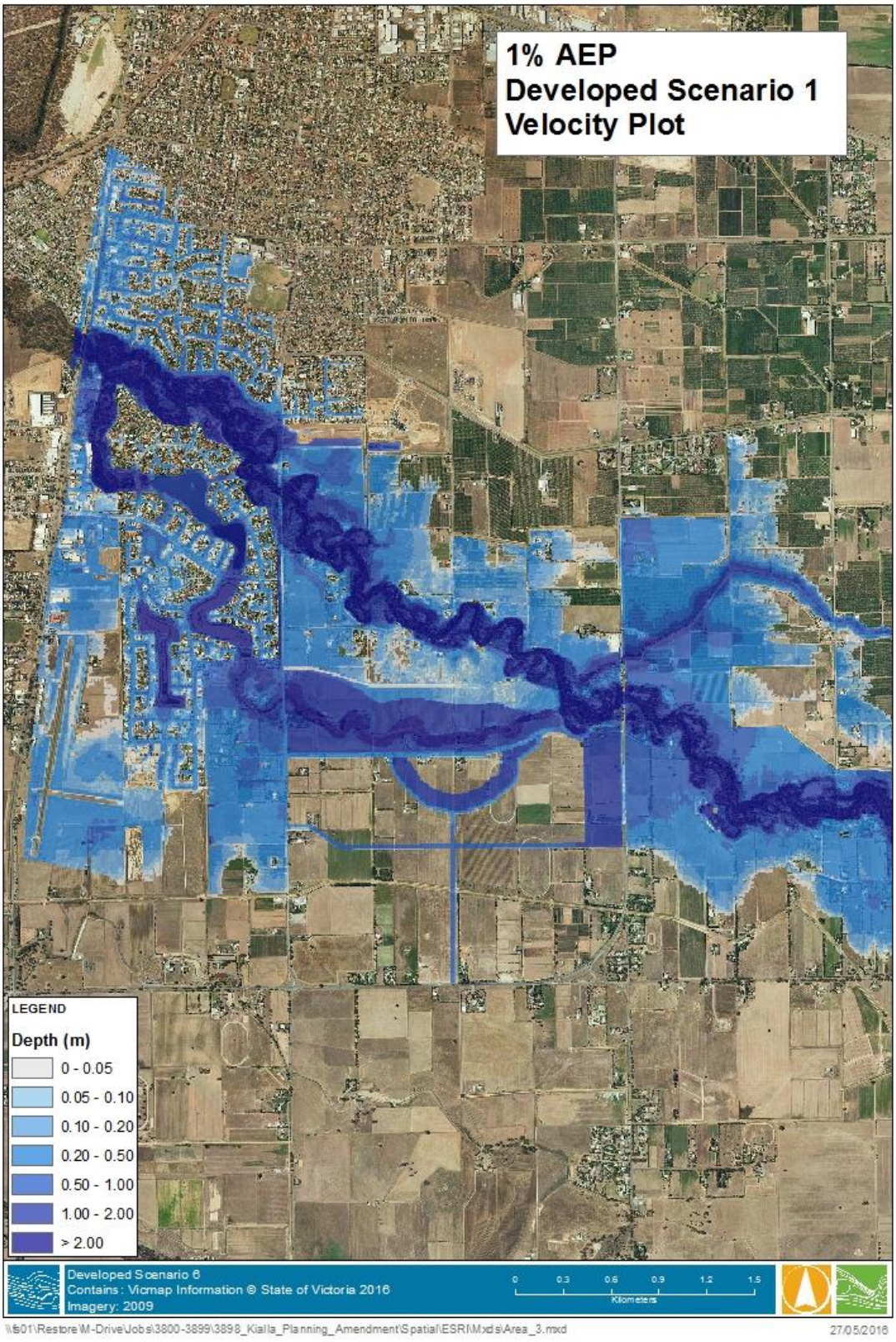

Figure 3-1 Development Scenario 1 - Flood Depth Plot

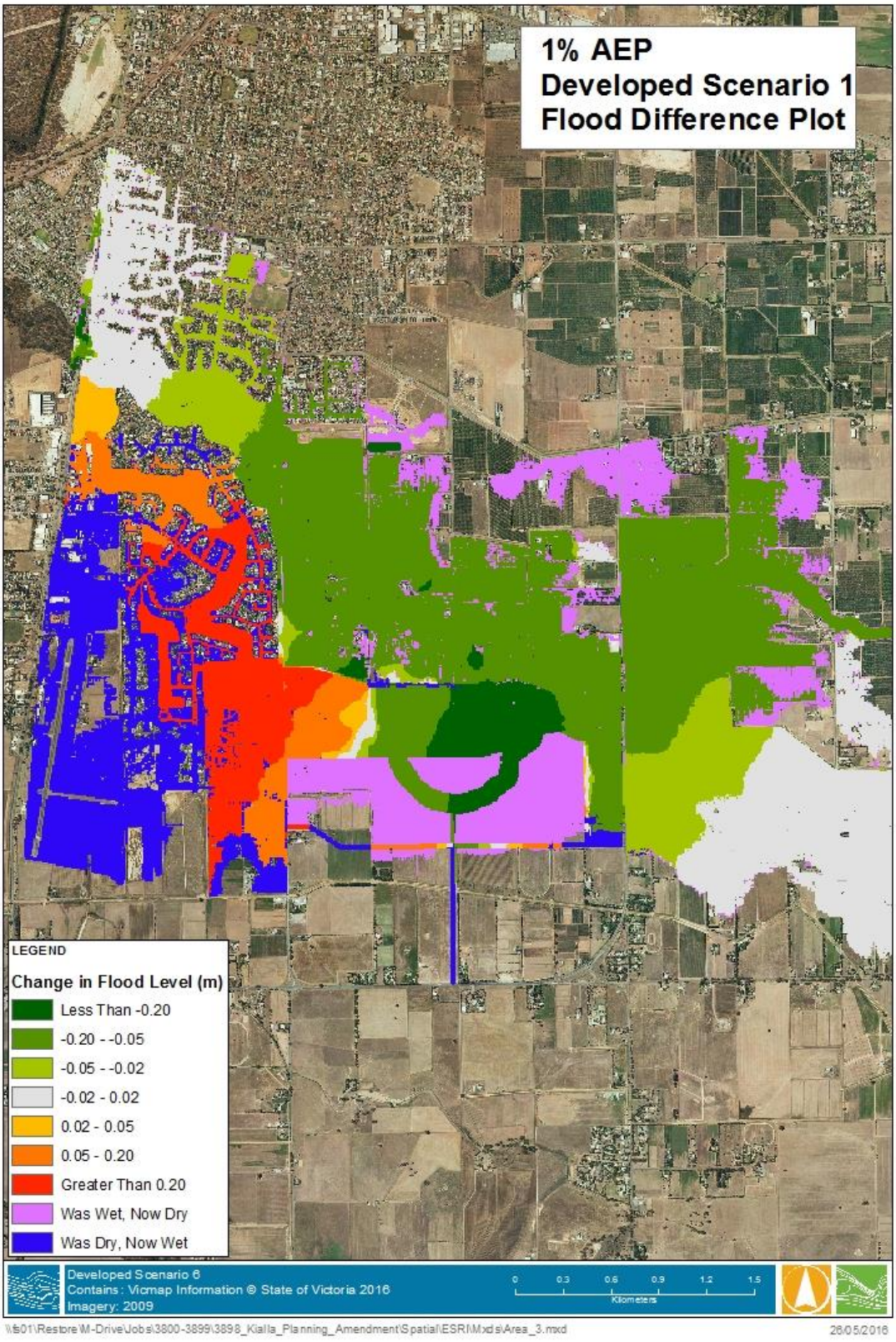

Figure 3-2 Development Scenario 1 - Flood Depth Difference Plot

Table 3-1 Development Iteration summary

Scenario	Changes from Existing Conditions/ Previous developed scenario	Hydraulic model conditions
Development Layout	Residential area (to the south of the anabranch) raised to 116 m AHD, roads set to 114.25 m AHD, offline waterway lowered, Anabranch Deepened to 109 m AHD at the western end of the site, Broken River Offtake lowered from existing levels, G-MW channel to the north of the anabranch leveled to match existing levels either side of the channel.	Increased levels through Kialla Lakes by more than 200 mm. Levels along the Broken River lowered 100-200 mm. The model shows an increase in the flow through the anabranch and Kialla Lakes system.
Iteration 2	As above, additional drain along eastern side of Archers Road added, slight modification of residential land close to Doyles Road. Broken River Offtake raised. Bridgeway over anabranch removed.	Flood depths through Kialla slightly lower than the previous run. Still show an increase of approximately 200mm above existing levels.
Iteration 3	Embankment on the south of Broken River included, Broken River Offtake raised.	Levels through Kialla Lakes still 50-150mm higher than existing conditions, removed flooding from the north of the anabranch through to the Broken River.
Iteration 4	Broken River offtake level raised.	Levels through Kialla Lakes only slightly lowered from previous iteration. Peak flood levels up to 150mm higher than existing conditions through Kialla Lakes
GSCC feedback: Remove the offline waterway as costs to construct bridges/culverts are likely to be expensive. Road levels are to sit above 1% flood level.		
Iteration 5	Broken River Offtake raised Offline waterway removed, floodway (anabranch extended further north), Roadways removed (except roadway around former offline waterway).	Levels through Kialla not increased from existing conditions.
Feedback from GSCC: current earth works show significant 'cut volume' which may make the development economically unviable based on an estimate of $4/m^3 from GSCC. Water Technology proposed to reduce the total cut volume by reducing earthworks in anabranch.		
Iteration 6	Anabranch levels raised from previous iterations. Cut/fill balance reduced to less than 300,000 m^3.	Water levels were increased along the Broken River by approximately 50 mm. levels through Kialla Lakes lowered by more than 200 mm from existing conditions.

Iteration 7	Several properties ring leveed, Archer Road Drain inlet modified, anabranch inlet lowered.	Water levels upstream of Investigation area higher than existing conditions.
GSCC comments: Levels along the Broken River to be adjusted back to existing conditions by balancing more water through Kialla Lakes. Three houses along Hoopers and Archer Road to be protected by ring levees, these were 'glassed walled' around the outside of the houses.		
Iteration 8	Levee along southern bank of Broken River removed, the area between the anabranch and the Broken River is now modelled as RLZ, where fill pads are raised. Three existing houses along Hoopers Road and Archer Road were glass walled.	Levels both upstream and downstream were increased due to change flood conditions. Levels along the Broken River were slightly lowered from existing conditions.
Iteration 9	An additional roadway at the eastern end of the investigation area was added to provide a secondary access road for the RLZ properties. Bridge over anabranch reinstated. Additional floodplain storage added south of the main anabranch.	Improvement upon previous iteration, however water levels downstream of investigation area higher than existing conditions.
Iteration 10	The number of culverts in the roadway were increased in size to allow more flow.	Levels downstream of the investigation area increased compared with existing conditions.
Iteration 11	Minor modifications to the drain along the eastern side of Archer Road. The volume and depth of cut within the anabranch was lowered.	Increased flood levels along Archer Road, flooding of general residential area.
Iteration 12	The Roadway was moved to the centre of the investigation area to mirror the head drop caused by G-MW channel under existing conditions. The GRZ south of Hoopers Road was reduced to RLZ to accommodate the existing conditions flood extent.	Increased flood levels along Archer Road, minor flooding in general residential area.
Iteration 13	Minor modification to bridge over anabranch and raised general residential fill levels to maintain flood free.	No increases of 20mm or greater outside of investigation area,

3.2 Development Scenario 8

Discussions with GSCC and GBCMA found that it was unlikely the area between the Broken River and the anabranch would be suitable for a density of residential development higher than RLZ, based on the existing flow paths through the area in a 1% AEP flood event. The GBCMA also recommended that it was unlikely to support the development of a greenfield site through the use of a levee system and that a levee system should only be utilised where a legacy development within a flood prone area exists. Therefore, this area was reverted back to existing conditions with the addition of a number of

'fill pads' representing RLZ parcels. One requirement being access from Archer Road to these properties in a 1% AEP flood event.

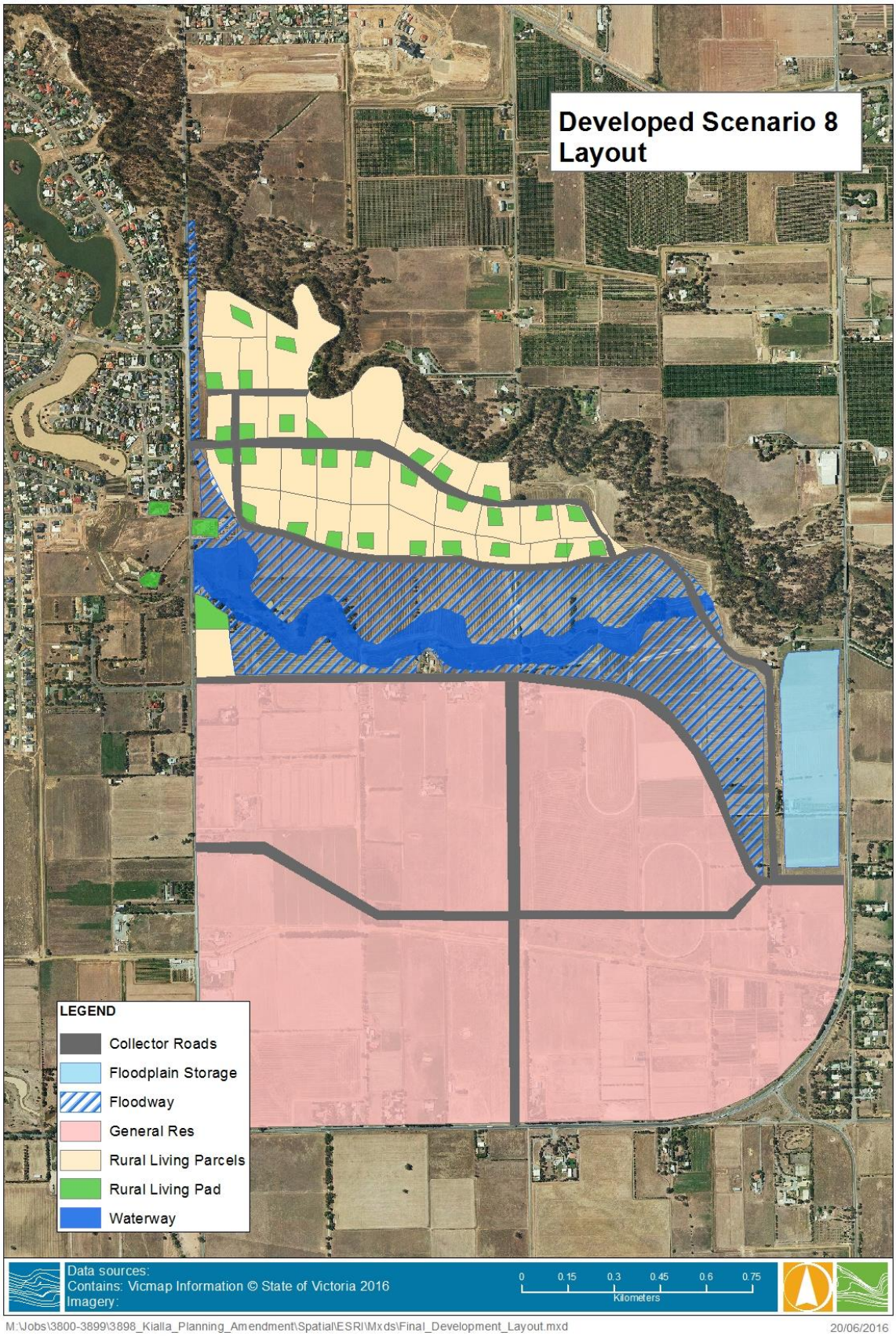

Figure 3-3 Development Scenario 8 Layout

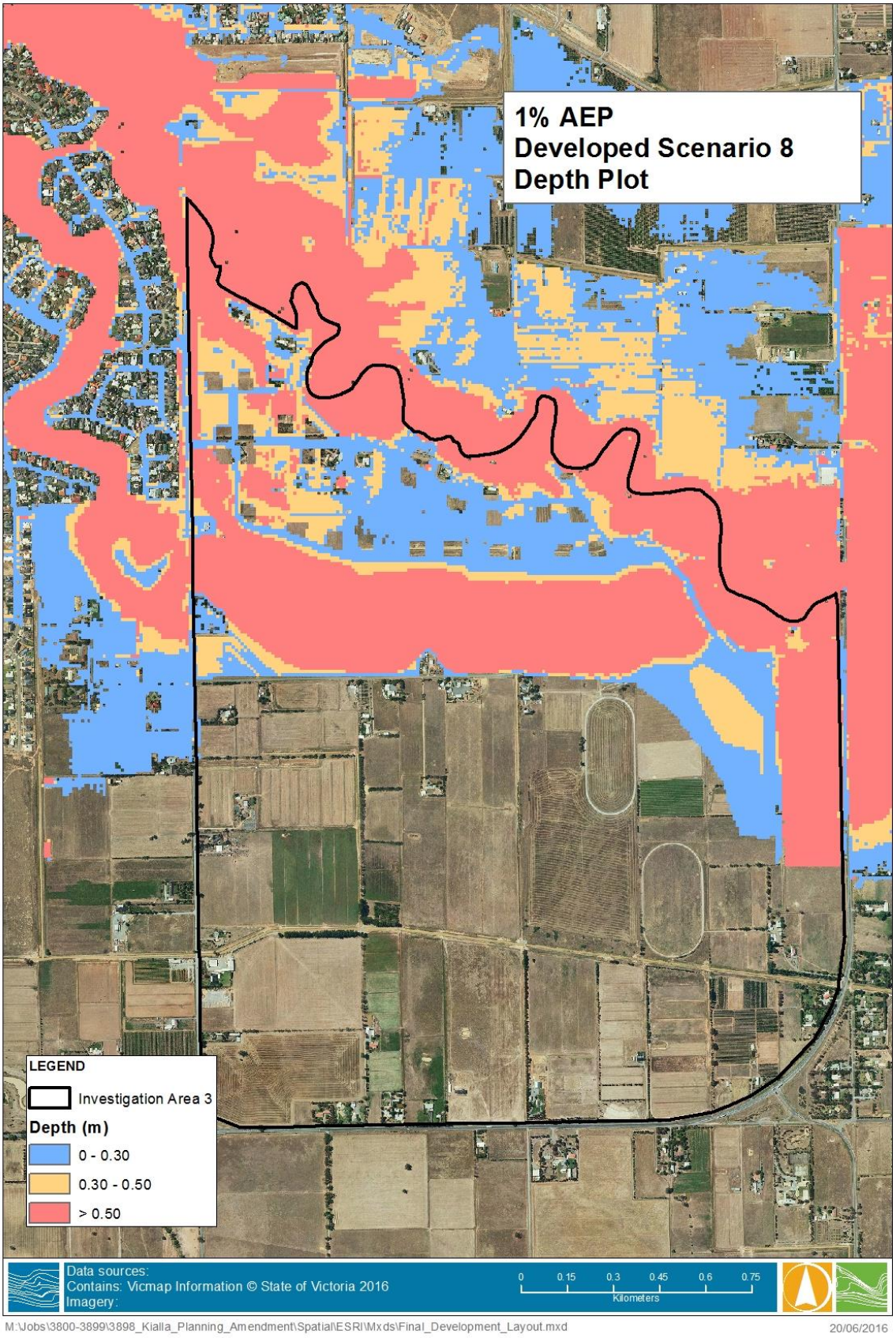

Figure 3-4 Development Scenario 8 - Flood Depth Plot

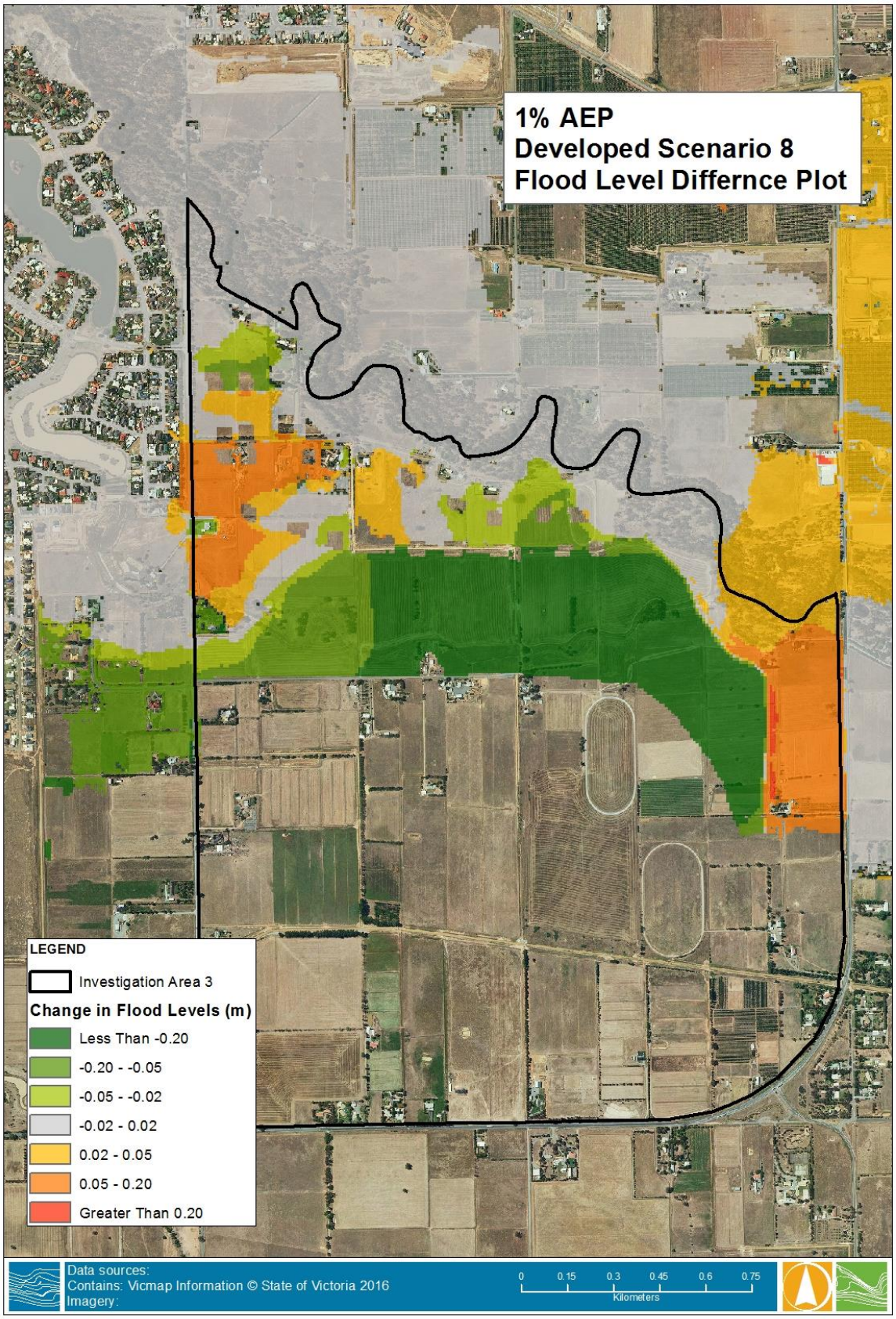

Figure 3-5 Development Scenario 8 - Flood Level Difference Plot

3.3 Development Scenario 9

The bridge over the Broken River anabranch was removed from the initial development layout as it was perceived as an additional benefit to the development. Following discussions with the GSCC, the bridge was reinstated at Development Scenario 10 as a requirement to provide a secondary access route for properties between the Broken River and the anabranch during a flood event. The bridge was located at the eastern side of the study site, immediately downstream of the Broken River offtake. The bridge was allowed to overtop to a maximum depth of 300 mm to ensure safe access during a 1% AEP flood event. The bridge and culverts required for this bridge are significant in size and would likely be a significant expenditure, the culverts were modelled to provide around 30 m width of flow path beneath the roadway similar to the large culvert set on Kialla Lakes Drive. Detailed design would need to ensure conveyance through the culverts does not overtop the bridge by more than 300 mm.

Flood modelling of Development Scenarios 10, 11 and 12 showed that the bridge in east of the site at the Broken River breakout was causing a significant constriction. Pushing water levels upstream of the study site above the existing conditions as a result. When the bridge culverts were increased in an attempt to reduce the impact of flood levels upstream of the site, flood levels downstream of the site were increased above existing conditions.

3.4 Development Scenario 13

Review of the flood modelling results from development Scenario 10, 11 and 12 showed the location of the anabranch crossing to be prohibitive to the development objectives and GBCMA requirements. The location of the bridge was moved to the centre of the study site where the current G-MW channel running north south through the site was located.

The maximum flood depth plot is shown in Figure 3-6, with the maximum velocity shown in Figure 3-7. Several areas of collector roadway within the development layout have high velocities and may need some minor modifications at detailed design level to provide safe access.

Modelling results showed this development layout meets the GBCMA requirements with flood level increases greater than 10 mm at properties outside of Investigation Area 3. The flood level difference plot in Figure 3-8 shows no negative increase in flood levels of more than 10 mm outside the study site. Figure 3-9 shows an increase in flood velocities on the western side of Archer Road as water is drained out of the Investigation Area.

The final culvert design at the anabranch bridge included 15 box culverts sized at 1800 mm x 1400 mm. The drain running along the east of Archer Road also required a significant set of culverts at Adams Road to convey water during a 1% AEP flood event, and provide safe access along Adams Road. Development Scenario 13 utilised 15, 2000 mm x 1000 mm box culverts, in this case the maximum height of the culverts was limited by the invert level of the drain and the freeboard required from the culvert obvert to the road deck (which was estimated at 1000 mm). Detailed culvert design was outside the scope of this project, but this may be optimised at detailed design stage of any future development.

A number of roadway culverts would also be required to be designed at the detailed design phase of the project. This is to ensure drainage out of the study site following a riverine flood as well as sufficient stormwater drainage.

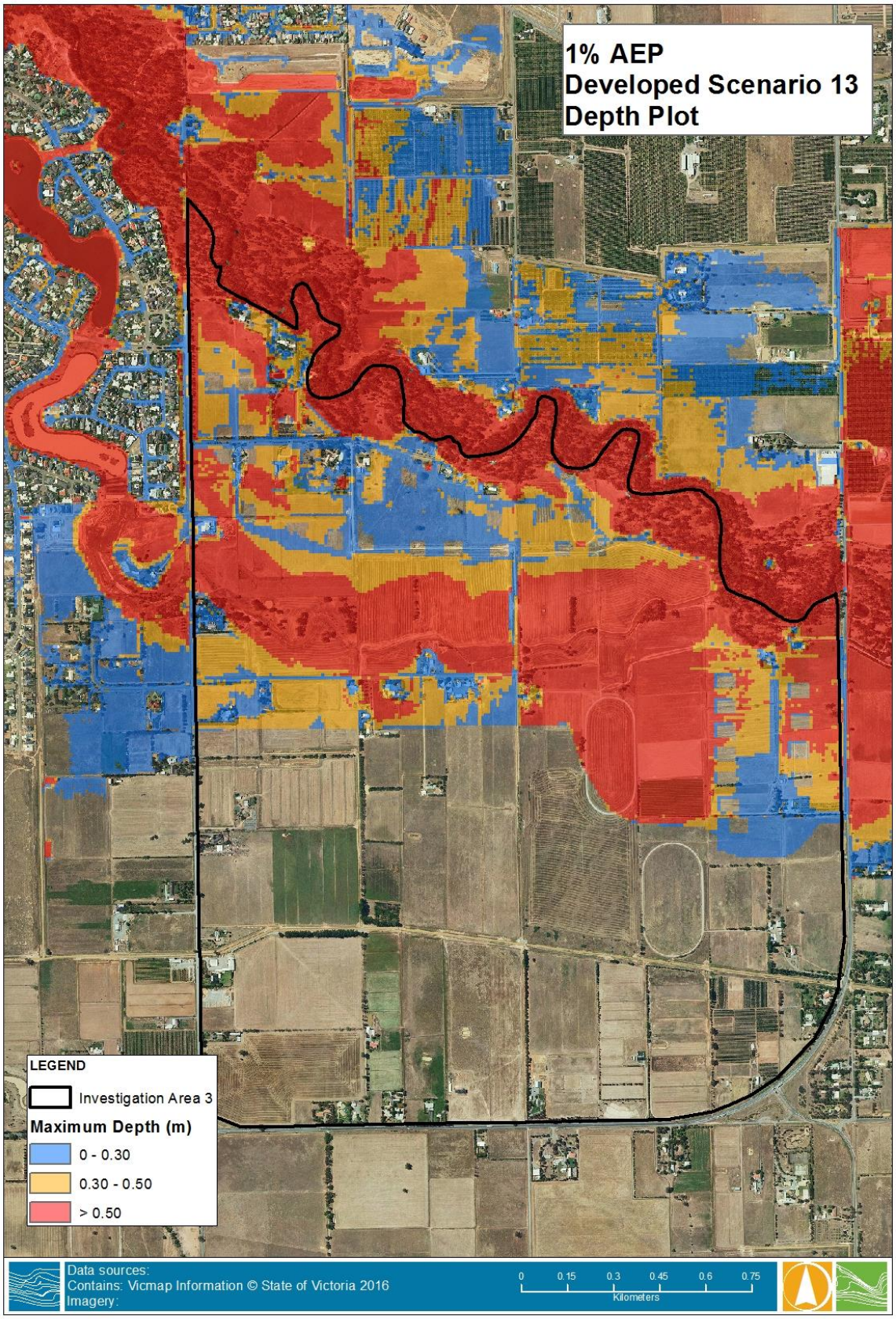

Figure 3-6 Development Scenario 13 – Maximum Flood Depth Plot

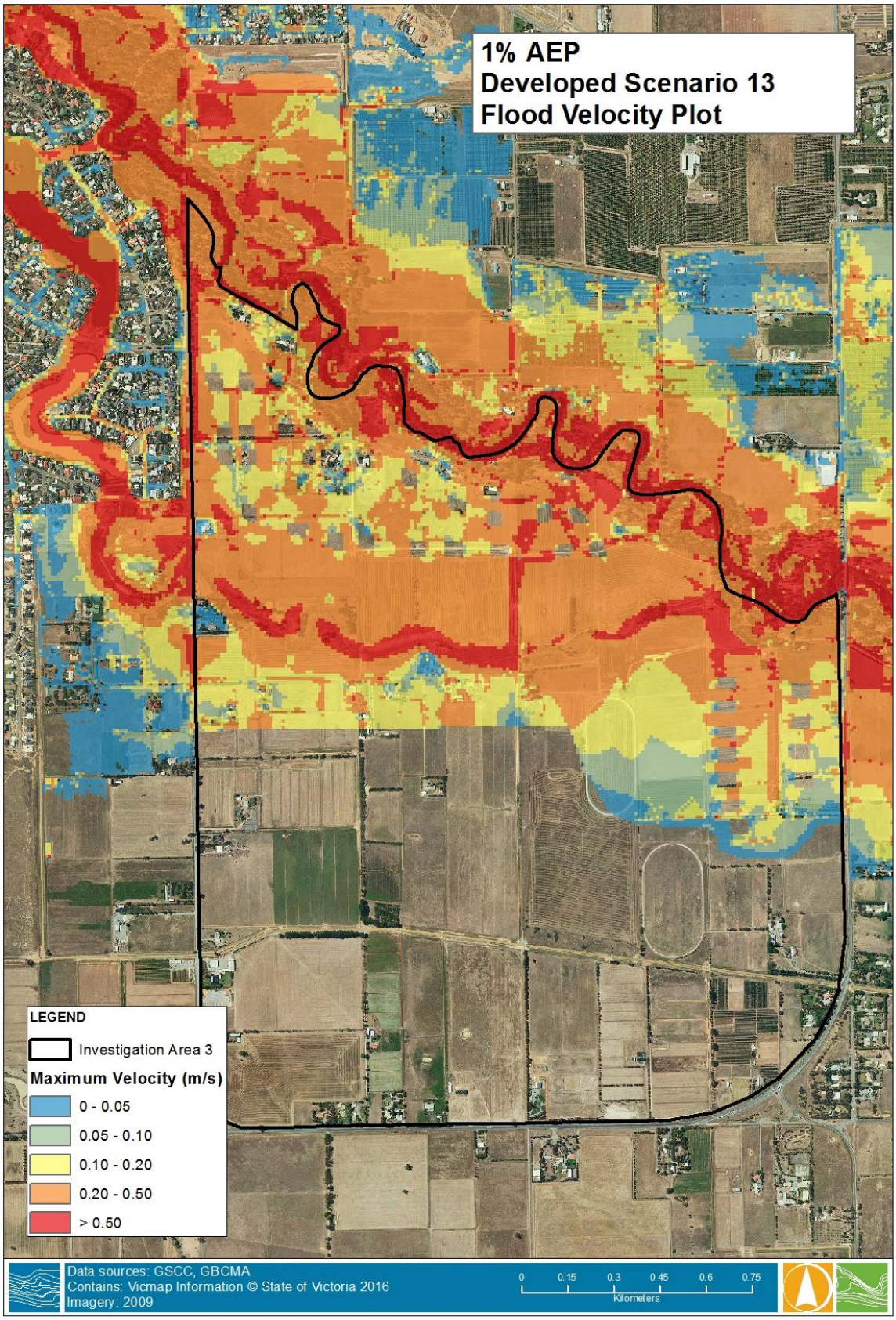

Figure 3-7 Development Scenario 13 - Maximum Velocity Plot

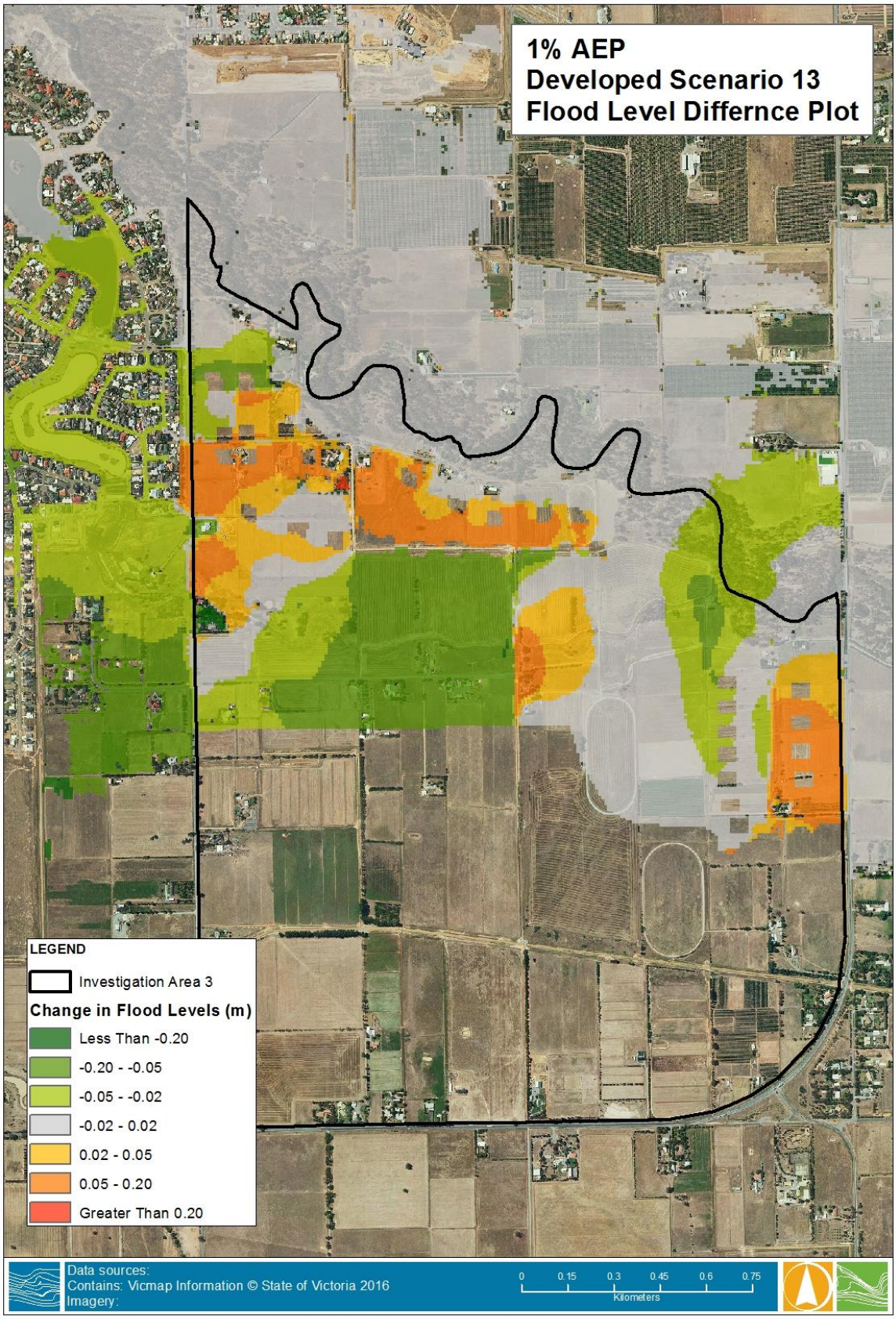

Figure 3-8 Development Scenario 13 - Flood Level Difference Plot

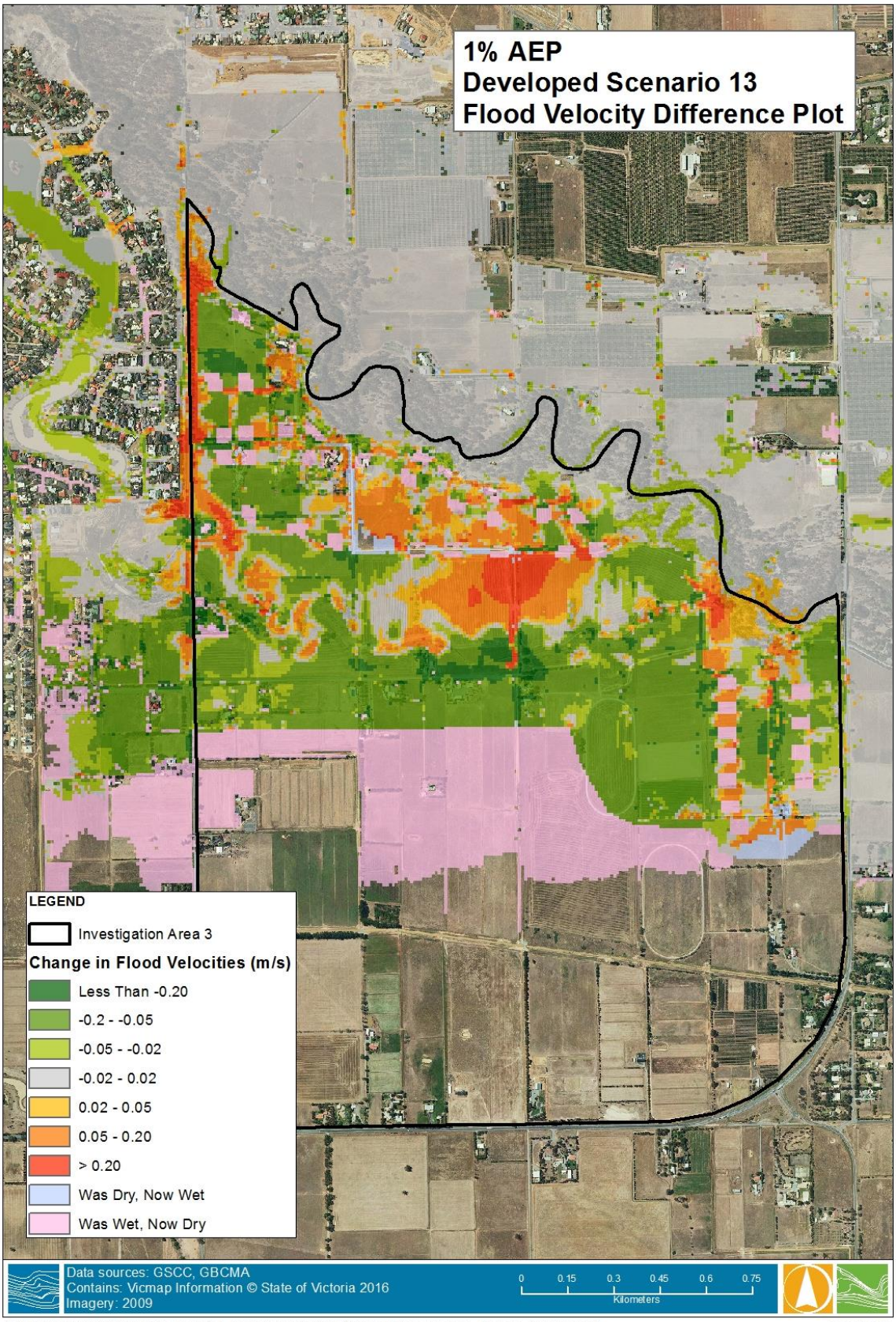

Figure 3-9 Development Scenario 13 - Velocity Difference Plot

A number of iterative layouts were modelled as part of the project to develop a conceptual layout that allows for flood free development while not increasing the flood risk off site. A summary of the iterations undertaken is outlined in Table 3-1. Depth and water level difference plots for each developed scenario are provided in Appendix A. The final development layout is shown in Figure 3-10.

3.5 Land Development

The final developed Scenario (Development Scenario 13) was chosen as the preferred development layout by GSCC. This layout meets GBCMA requirements for no increase in water levels of more than 10 mm outside Investigation Area 3 when compared with existing conditions. This is shown in Figure 3-10.

The floodplain storage lost in the final development layout totalled 211,000 m^3. This was offset through the inclusion of floodplain storage across the site through the deepening of the anabranch, providing an additional 290,000 m^3 of floodplain storage. These meets the GBCMA requirements of 1:1.3 floodplain storage volume loss.

Safe egress throughout the site appears to be achievable with access to the roads to the south and east of the site during a 1% AEP flood event.

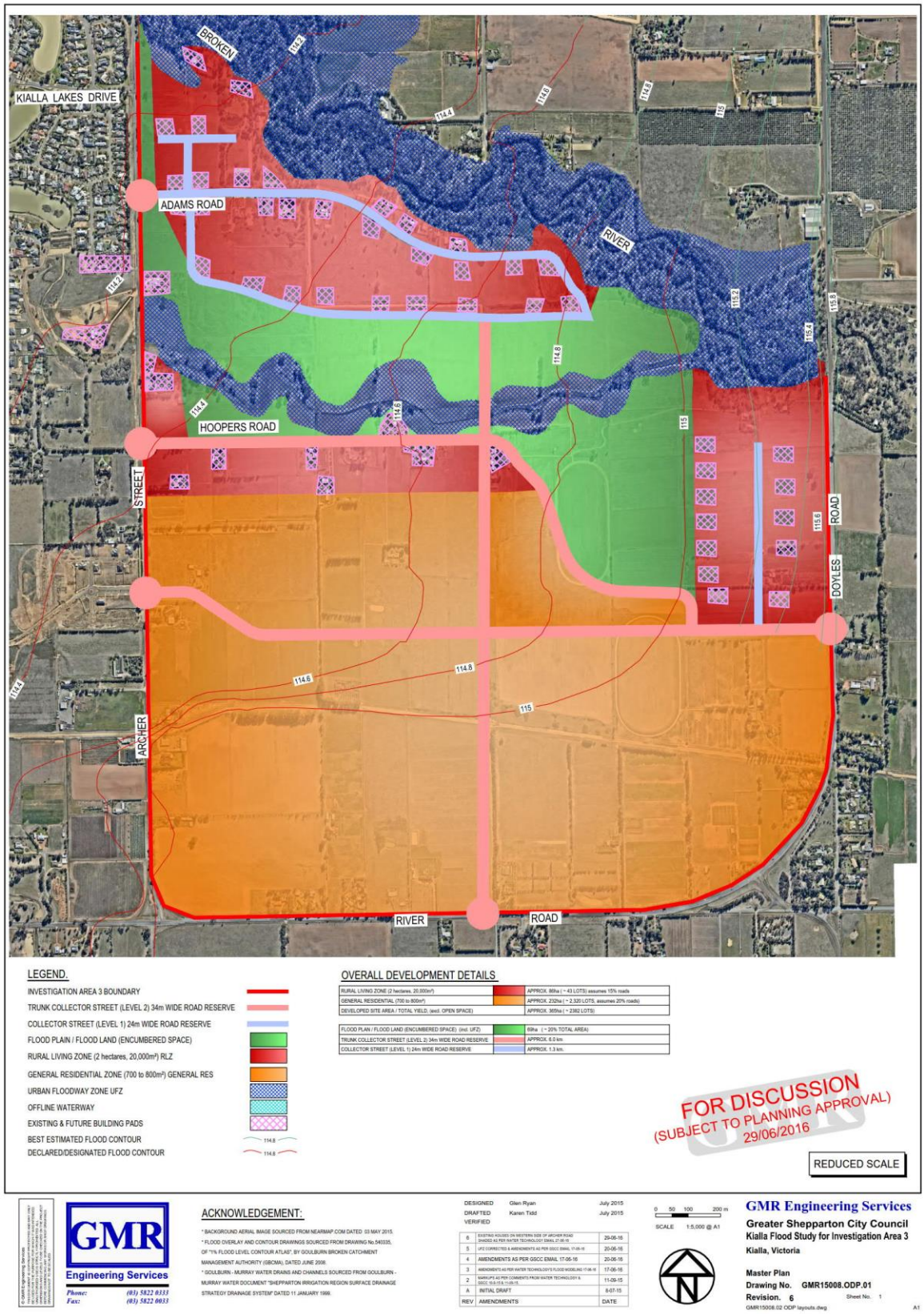

Figure 3-10 Proposed Development Plan (GMR Engineering Services)

3.6 Planning Framework

Based on the flood modelling undertaken for the Shepparton-Mooroopna Flood Mapping and Intelligence Study and Investigation Area 3, one of the recommendations expected to be in the final report will be updating the flood controls in the planning scheme to reflect the most recent flood modelling. Water Technology has prepared an example layout of the expected recommended LSIO and FO for Investigation Area 3 under the final masterplan development layout shown in Figure 3-10. This is based on the Australian Rainfall and Runoff (ARR) guidelines explained below. This map is an example only and does not take into account the frequency at which the area becomes inundated as the previous control criteria did. This overlay example does not include any reference to the Urban Floodway Zone (UFZ)which has not been assessed as part of the ARR guidelines and is used as an example of potential use of flood controls in the planning scheme.

The Victoria Planning Provisions (VPPs) contain a number of controls that can be employed to provide guidance for the use and development of land that is affected by inundation from floodwaters. These controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO).

Section 6(e) of the Planning and Environment Act 1987 enables planning schemes to 'regulate or prohibit any use or development in hazardous areas, or likely to be hazardous'. As a result, planning schemes contain State planning policy for floodplain management requiring, among other things, that flood risk be considered in the preparation of planning schemes and in land use decisions.

Guidance for applying flood controls to Planning Schemes is available from the Department of Environment, Land, Water and Planning (DELWP) Practice Note on Applying Flood Controls in Planning Schemes.

Planning Schemes can be viewed online at http://planningschemes.dpcd.vic.gov.au/home. At the completion of the Shepparton-Mooroopna Flood Mapping and Intelligence project, it is recommended that the planning scheme for Greater Shepparton be amended to reflect the flood risk identified by the most recent flood mapping.

The method used to delineate the proposed FO is broadly based on the new Australian Rainfall and Runoff Project 10 'Appropriate Safety Criteria for People'. Criterion for delineating the FO considers both vehicle and people safety, and are as follows, based on the 1% AEP flood:

- Depth > 0.3 m
- Velocity > 1.5 m/s
- Depth x velocity > 0.3 m^2/s.

Goulburn Broken CMA may approve development guidelines which adopt a depth threshold of 0.30 m for safety requirements, and as such the example FO has been defined using the above criteria. This is currently under consideration and may change. Previously a threshold of 0.5 m was adopted across the floodplain management industry, but based on new research the industry is moving towards the lower depth threshold.

The LSIO includes the area outside of FO and bounded by the 1% AEP flood extent. The example overlay plot is shown in Figure 3-11.

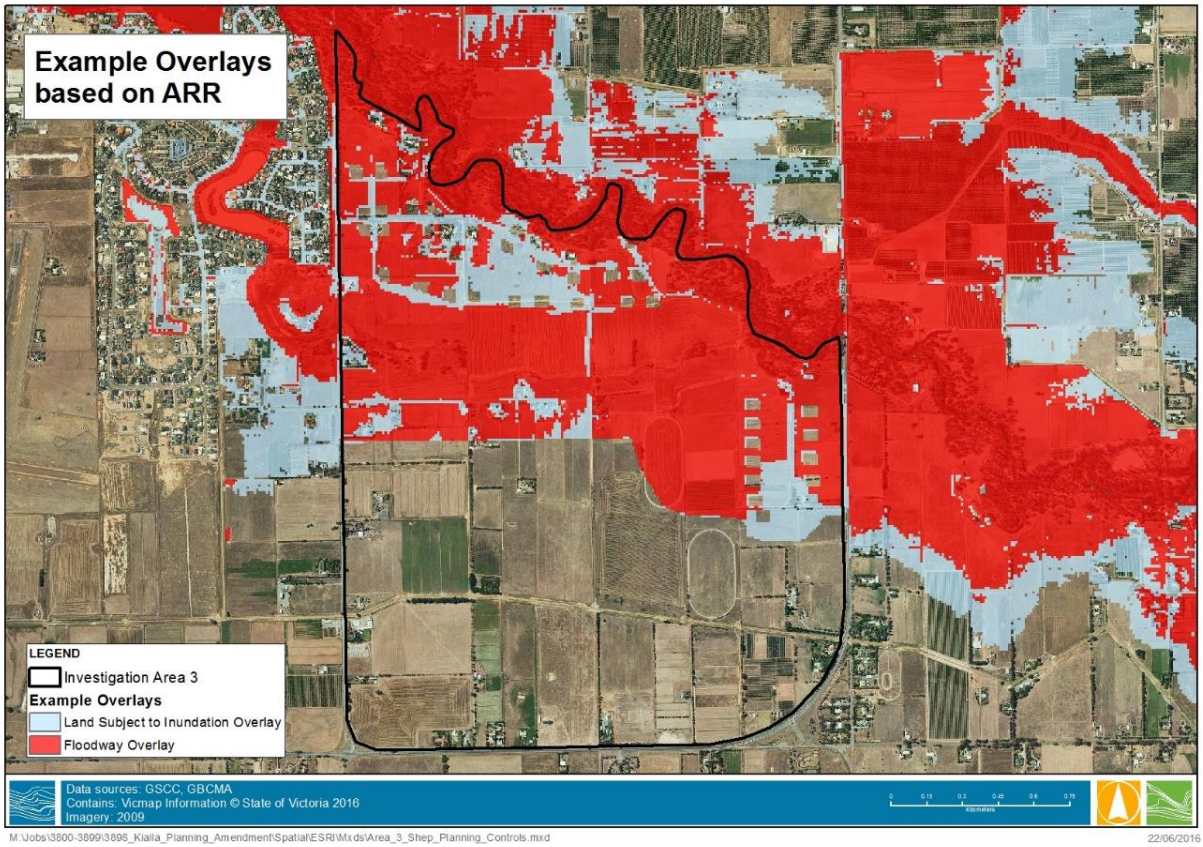

Figure 3-11 Example Overlays based on ARR guidelines

*Please note Figure 3-11 does not include delineation of UFZ and is an example of the LSIO and FO delineation based on ARR guidelines

3.7 Potential Flood Risk with Development

Modelling of flood behaviour developed by Water Technology has shown that areas within Investigation Area 3 may be suitable for residential development. A large portion of land to the south of Hoopers Road sits above the 1% AEP flood level, while smaller parts of the remaining site may be suitable to a lower density level of development. The existing G-MW channel running north-south through the site was shown to be an important hydraulic control and changes to crest levels are likely to have a negative impact on properties downstream of the channel and downstream of the Investigation Area.

3.7.1 Flood Warning Time

Investigation Area 3 has considerable flood warning time from a Broken River flood. There are currently a number streamflow gauges on the Broken River including Orrvale, Gowangardie, Benalla and further upstream at Lake Nilma. These gauges provide a good indication of expected peak flooding as well as estimated flood levels at the Orrvale gauge and the Investigation Area.

Flood peak travel times from the gauge upstream of Benalla to the Orrvale gauge is estimated at 24-48 hours based on historical floods including 1993, 1995 and 2010.

3.7.2 Site Egress

Currently two of the three roads surrounding the site provide site access/egress, with flood depths not exceeding 0.30 m in a 1% AEP flood event. Archers Road to the north of Hoopers Road does not provide safe egress to and from the study site as Kialla Lakes Drive and Archer Road north of the

Broken River are overtopped in a 1% AEP flood event at depths greater than 0.30 m. River Road and Doyles Road provides safe egress to and from the study site, the addition of the bridge across the anabranch provides safe egress to the Rural Living Zone properties in the north of the Investigation Area.

Collector roads were modelled in the final development layout as raised roadways at this conceptual stage of the project. The results show the maximum flood depth over the collector roadways are raised to ensure safe egress for several rural living and equine living properties, with no depths above 300 mm. Further investigation of the flood behaviour at a detailed design level which utilises final road levels and adequate stormwater drainage for the roadways would be required to show safe egress to all properties within the Investigation Area.

3.7.3 Flood Conveyance and Storage

Flood conveyance across the site was maintained by locating fill sites in areas with the least impact on the main flow paths across the site.

Floodplain storage across the site has been reduced through an increase in the fill levels at the areas identified within the masterplan layout as GRZ, the fill pads of RLZ as well as the main collector roads within the site. A total volume of 211,000 m^3 of floodplain storage was reduced through the raising of the GRZ area south of Hoopers Road and the fill pads in the RLZ above the 1% AEP flood level.

A net balance of flood storage was achieved across the site with the deepening and widening of the anabranch and the inclusion of floodplain storage south of the anabranch. 130% of compensatory storage needs to be replaced for any floodplain development fill. This was achieved as shown in Table 3-2. The floodplain storage added to the study site through the deepening of the anabranch is around 15,000 m^3 more than the GBCMA required value of 130%.

Table 3-2 Floodplain Storage Summary

Area	Floodplain Storage Reduced (m^3)	Floodplain Storage Added (m^3)
General Residential Zone	164,000	0
Rural Living Zone (North)	30,000	0
Rural Living Zone (East)	17,000	0
Anabranch	0	290,000
Total	**211,000**	**290,000**

3.7.4 Earthworks

The total earth works differ from the floodplain storage summary provided above. These earthworks are based on the final development layout which includes the GRZ area 2,500m^2 fill pads within the RLZ raised above the 1% AEP flood level. These are summarised in Table 3-3 and were separated into the four areas; the GRZ, RLZ north of the anabranch, RLZ in the east of the investigation area and the anabranch and floodplain storage. This shows a net balance of around 66,000 m^3 of additional fill required to meet the final masterplan development layout. Collector roadways were modelled as raised from the existing topography and were included in this calculation. Final road levels for other smaller roads were not set at this conceptual stage of the project. It would also be assumed that the suitable fill material required for the roadways would be sourced offsite.

Table 3-3 Earthworks Summary

Area	Total Cut (m^3)	Total Fill (m^3)
General Residential Zone	30,000	290,000
Rural Living Zone (North)	0	62,000
Rural Living Zone (East)	0	30,000
Anabranch & Floodplain Storage	300,000	0
Total	**335,000**	**395,000**

4. CONCLUSION

Based on the information provided by GSCC, the final development layout meets the requirements of the GBCMA in regards to the Broken River floodplain management. Should development occur, the fill pad areas identified within the final development layout should be raised above the 1% AEP flood level.

Further detailed design may modify the layout of a development and therefore cause a change to flood levels and floodplain storage volumes quoted within this report. Further investigation of the flood behaviour should be addressed at detailed design stage of the development.