WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Report

Inverleigh Investigation – Manna Gum Estate

Golden Plains Shire

27 April 2023

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EXECUTIVE SUMMARY

Water Technology was commissioned by Goldens Plain Shire to undertake a detailed flood and drainage investigation for the residential area north of the township of Inverleigh. The assessment focused on the performance of the drainage network in Faulkner and Commons Road, which has contributed to flooding of properties and heightened community concerns over the state of the local drainage network.

As part of the investigation detailed flood mapping of a range of design flood events was completed. In addition, the modelling also produced maps based on a simulation of the November 2022 flood event which significantly impacted a number of residential properties along Faulkner Road and King Road. It is noted that during the November event an estimated 80 mm fell between 9pm on 13th and 9am on 14th, with the storm magnitude assessed to be in the order of a 0.5% AEP event or 1 in 200 Yr ARI. The results of the November event mapping were validated against the recollections of the impacted residents and were shown to provide an accurate representation of observed flooding.

Based on the results of the flood mapping an assessment of the functionality of the drainage network was completed. The drainage network within this part of Inverleigh consists of open drains along roadways and easements. These drains, which service a 160ha catchment are designed to outfall to two main locations along Common Road and at the end of King Road. The investigation found that the existing drainage infrastructure is insufficient for the catchment it services due to several factors, such as reduced system capacity (undersized), lack of maintenance (drain sedimentation and vegetation overgrowth), and design issues including network slope and alignment in the lower catchment.

To address the identified drainage deficiencies a number of mitigation options were investigated including:

- **Option 1** – Lowering of the intersection of Argyle Court and Faulkner Road to drain toward King Road.
- **Option 2** – Increases the flood retarding basin size at Gregory Drive by combining the 2 basin footprints into one larger basin.
    - **Option 2a** – Increasing basin size and re-direction of high-flows from the basin toward Common Road directly west out falling via the existing gully and easements.
- **Option 3** - Lowering / re-grading Faulkner Road to Common Road to provide active flow path within the road.
- **Option 4** – Golf Club Diversion, redirecting flows from the upper catchment within a drain on the Golf Club site.

These options were tested individually and in various combinations as part of mitigation schemes, resulting in an improvement to flood conditions within the estate to varying degrees. The most meaningful reduction to flood depth and corresponding flood risk was shown to occur with Option 1 and Option 3. These options focus on reducing the likelihood of excess stormwater breaking out of the existing network and flowing south over properties fronting Faulkner Road towards King Road. These options benefit for additional works including Option 2, 2a and or Option 4 (through Ultimate Scheme 5), all of which address deficiencies within the upper catchment.

Based on the findings of the modelling it is recommended that council proceed with functional design and feasibility assessments of the recommended options, in particular Options 1 and 3. Noting that each of the respective options relies on additional downstream works and broader drain maintenance to ensure that the works can achieve the most beneficial outcome without adversely impacting downstream properties.

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1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by Goldens Plain Shire to undertake a flood investigation and drainage assessment for the residential area north of the township of Inverleigh. The assessment focused on the performance of the drainage network in the area of Faulkner and Commons Road, which has contributed to flooding of properties and heightened community concerns over the state of the local drainage network (Figure 1-1).

This study has been brought about following recent storm events including an event occurring in November 2022 which resulted in flooding to private properties and which ultimately led to council members visiting those impacted. The extensive history of inundation and the impacts of the November event, has led to council engaging Water Technology to provide an extensive analysis of the drainage network, including the identification of mitigation measures. This investigation is an extension of the investigation previously completed by Water Technology in late 2021.

This report outlines Water Technology's investigation which includes:

- History of flooding at the site.
- Development within the estate.
- Impact to residents.
- Known drainage issues and network performance.
- Update of Flood Modelling and Results Analysis.
- Analysis of existing drainage network.
- Identification and analysis of mitigation options.

Figure 1-1 Study Area

1.2 Project Area

The project area is located in the township of Inverleigh, 30km west of Geelong along the Hamilton Highway. Inverleigh is located adjacent to the confluence of the Leigh and Barwon River, with the township lying between the rivers, with residential areas also extended north of the Leigh River. This investigation is focused in the low density residential area north of the Leigh River accessed off Hamilton Highway via Common Road. Consistent with most low-density development areas, the drainage network is predominately open channels within easements and road reserves throughout the estate.

The area of interest is located at the base of the Inverleigh Nature Conservation reserve, with the residential area impacting by a relatively small contributing catchment of roughly 120 ha. This catchment direct flows to south of Common Road, into a defined waterway with a larger catchment from the nature reserve of approximately 1,100 ha.

The catchment area of interest generally falls to the south-west, with a slight variation in gradient across the catchment before out falling over a steep embankment to the incised floodplain and waterway south of Common Road. Due the nature of the downstream floodplain the area of interest and contributing catchment are unlikely to be impacting by flooding in the Leigh River. Once the two catchments are combined the waterway flows (south-easterly) toward the Hamilton Highway before discharging into the Leigh River upstream of the confluence with the Barwon River. A summary of the contributing catchments is presented in Figure 1-2.

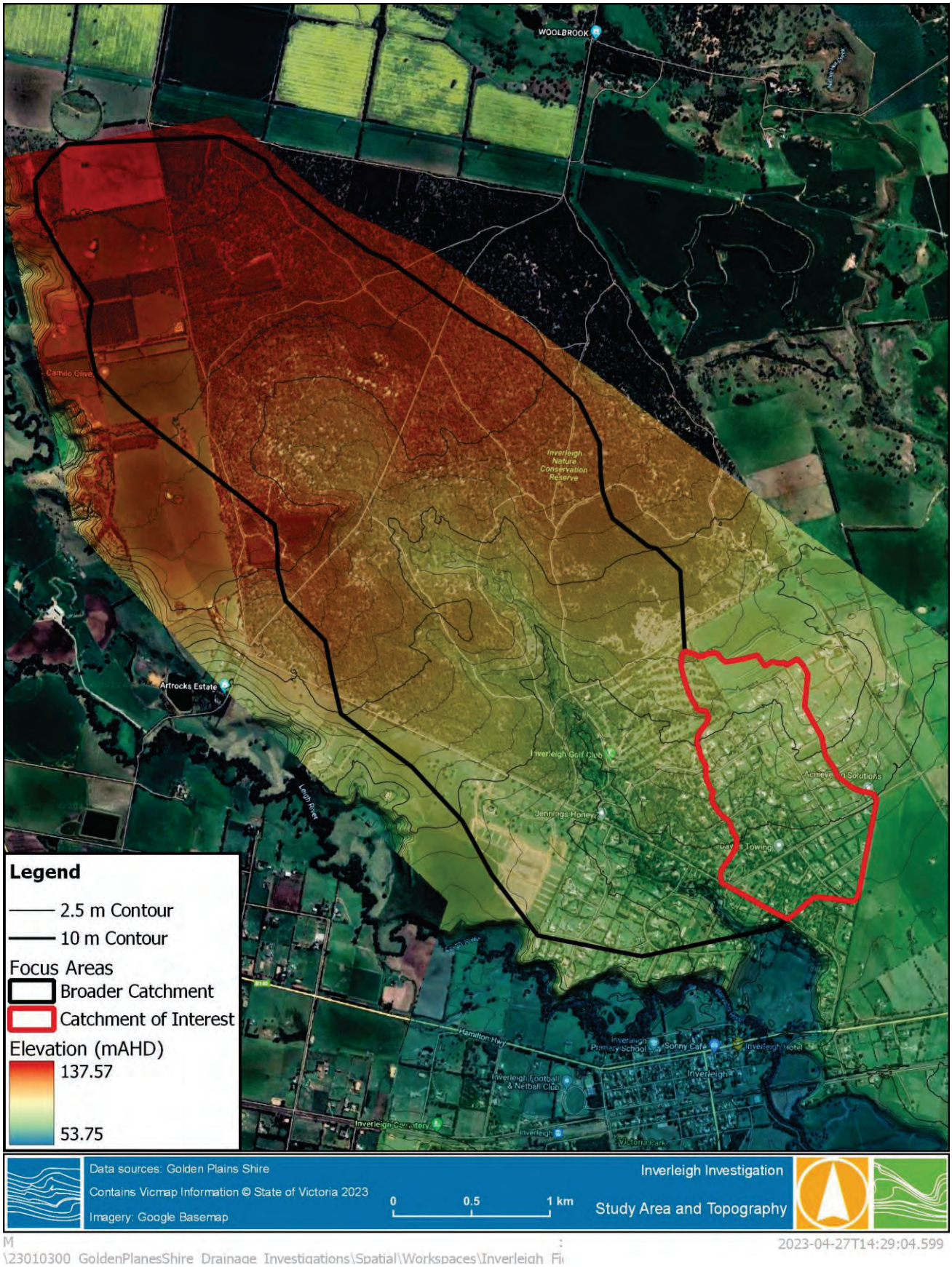

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Figure 1-2 Inverleigh Topography and Catchments

2 FLOODING IN INVERLEIGH

2.1 Overview

The project investigation area has faced persistent drainage issues which are understood to date back to when the original estate was developed. The primary cause for concern lies in the documented cases of above floor flooding in properties neighbouring Faulkner Road and King Road. However, it is understood that throughout this area multiple houses are impacted during significant rainfall events. This section aims to provide a brief description of the development history within the project area and an understanding of the flooding that occurs within the area.

2.2 Development in Inverleigh

Over the course of the last decade, there has been considerable expansion of low-density development within the project area, with several successive subdivisions being carried out. The majority of the new development stages are serviced by the same original drains that were designed to service only a portion of the existing estate. The extent of the development can easily be observed through aerial imagery from 2006 to present, with Figure 2-1, providing a timeline of the areas development.

Based on available Storm Water Management Plans (SWMPs) from the estate, the developments and sub-divisions were designed to reduce the increased run-off from the development back to pre-developed rates at the point at which flows leave the respective development. While this is common practice, there appears to have been inadequate assessment and consideration of the downstream network capacity. This, along with a decline in network capacity due to overgrown vegetation, inadequate maintenance, and driveway crossovers, has worsened the existing issues. The timeline and description of development impacting to study area is provided below:

- Original Development Occurs (1980's - 2006) – This consists of a small number of low-density dwellings located around Faulkner Road, Common Road and Argyle Court. The dwellings are serviced by open drains directed toward Common Road before out falling into the waterway to the south of Common Road and eventually the Leigh River.
- Subdivision of Argyle Court (2006 – 2010) – Additional dwellings are built along Faulkner Road and Argyle Court. These dwellings are located within the original development footprint and are serviced by the same drainage network.
- Barrabool Views Stages 1 to 5 (2010 – 2020) – Approximately 57 dwellings are built north of Faulkner Road. The majority of these dwellings are all designed to drain into the existing network at the following locations:
  - Faulkner Road – dwellings located south of Kincross Drive in general drain to Faulkner Road, upstream of the (new) intersection with King Road. Following works in 2018, undertaken by council, some of the discharge from this development is captured and directed along King Road.
  - Argyle Court – dwellings located north of Kincross Drive and in general west of Falkirk Crescent drain to a basin located upstream at Gregory Drive draining to the existing network (via the Argyle Court Swale).
- King Road Development (2013 – 2020) – subdivision and subsequent development of 23 dwellings south of Faulkner Road. This area drains to the end of King Road away from the existing network, out falling via a small basin which discharges into the neighbouring farmland.
- Manna Gum Estate (2014 – 2020) – Approximately 19 dwellings are built along Gregory Drive, including an additional basin out falling into the Argyle Court Swale and ultimately the existing downstream network.
- Barrabool Views North (2023 – ongoing) – Further development of 58 lots (with dwellings to be built) has been approved adjacent to the golf club. The development has been designed to divert some of the existing upstream catchment to the east away from its natural network, with the remainder of the development draining via a new basin into the existing downstream network.

Figure 2-1 Timeline of Development within the estate

2.3 Drainage Network Overview

The drainage network within this part of Inverleigh consists of predominantly open drains along roadways and easements. These drains are ultimately designed to outfall to two main locations along Common Road and at the end of King Road. The outfalls service a total catchment area of approximately 160 ha. Development within this estate is low-density residential, consisting of residential properties on lots which in general range in size from 1 ha to 2ha. An overview of the drainage network in relation to the design purpose is provided in Figure 2-2.

The network's design falls short in multiple locations, leading to flooding of properties across the estate. It is understood from discussions with the local community, that there is a long history of the network performing issues, with the pre-existing problems exacerbated by ongoing upstream development. Upstream development has resulted in additional run-off being directed toward an already deficient network.

The network is considered to be discontinuous, with multiple underlining factors such as alignment, slope and capacity impacting the efficiency of the open drains. A summary of these network factors is provided below:

- Discontinuous network alignment – throughout the estate easements and open drains have been aligned with consideration of roadways and allotments, likely to maximise development yield. This has resulted in several locations where natural flow paths do not align with drainage assets, meaning that the flow of water is required to change direction or flow through area of reduced grade within the network. A primary example of this is the outfall drain from Gregory Basin, which follows the natural fall of the topography (i.e. the most efficient path), prior to it being diverted along Argyle Court away from the natural flow path leading to breakout flows which continue along their natural alignment in an uncontrolled manner.
- Discontinuous network capacity – the alignment of the network along roadways and allotments has resulted in the capacity of the network reducing from upstream to downstream, throughout the estate. This has occurred for three main reasons:
  - Topographic information indicates that there are several points where the network's capacity decreases as water flows downstream. This can be attributed to the fact that many of the critical drains were cut along contours or against the natural slope of the land. A prominent instance of this occurs on Faulkner Road, which caters to the majority of the catchment and was designed to redirect water toward the Common Road outfall. However, due to the longitudinal fall (or lack thereof) toward Common Road, the capacity of the road-side drainage is lower than the catchment it serves.
  - There is an observed lack of maintenance of open channels/drains resulting in loss of capacity. Throughout the network several of the open channels which were originally designed to convey upstream flows as indicated by defined easements have lost capacity as a result of vegetation growth, erosion and or sedimentation. A site inspection also indicates that many of these drains would now be difficult to access and reinstate due the establishment of vegetation along the banks of the drains.
  - Flows are impacted by road drainage and drive-way crossovers which incorporate relatively small culverts. As a result of the development and subdivision several addition driveway crossovers have been constructed. These crossovers effectively reduce the capacity of the network to that of the culvert crossing which results in breakout flows along roads and through properties in an uncontrolled manner. The issues caused by the crossovers are exacerbated in areas where the network is already inefficient, including along Faulkner Road.

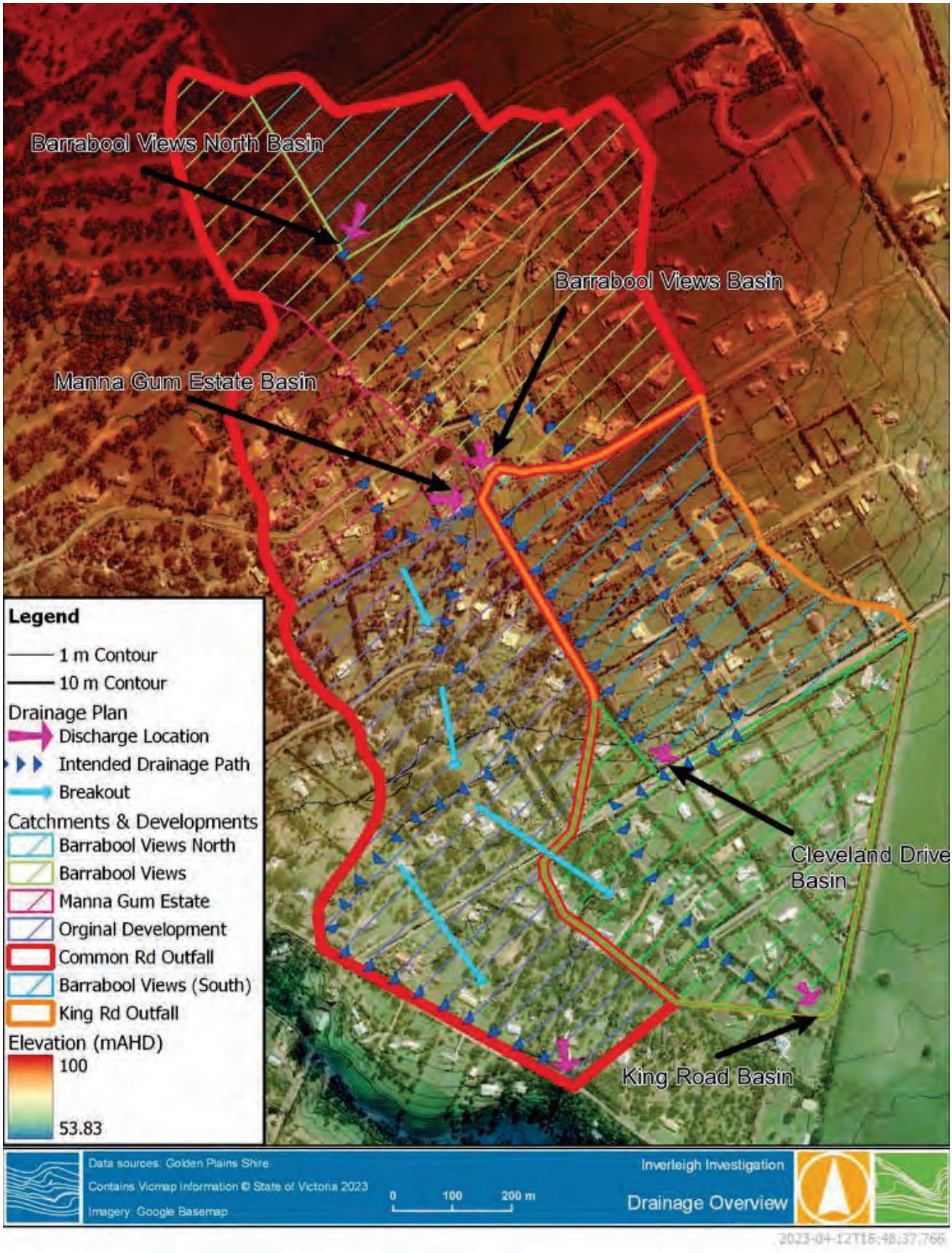

Figure 2-2 Drainage Network Overview

2.4 Past Flooding and November 2022 Event

Over the past decade several rainfall events have led to the exceedance of network (capacity) throughout the study area, with several dwellings and properties inundated. There are a number of mechanisms which contribute to inundation within specific areas including:

- Argyle Court – primarily the result of discharge from the upstream basins at Gregory Drive, exceeding the capacity of the network resulting in inundation of properties on the downstream side of Argyle Court and adjacent to the main swale from the basins.
- Faulkner Road – primarily contributed to by a lack of longitudinal gradient, driveway crossovers and the road crest sitting higher than adjacent properties resulting in inundation of properties downstream.
- King Road – primarily contributed to by the exceedance of the drainage network along and upstream of Faulkner Road, resulting in sheet flow across several properties along King Road.
- Common Road (North – East) – primarily contributed to by a natural gully that drains to Common Road, without an obvious connection to the downstream waterway. It is noted that a dwelling is located directly downstream of the gully's intersection with Common Road.

Record rainfall which fell across spring of 2022 is understood to have impacted the area on multiple occasions, with the worst event occurring as a result of 80 mm of rainfall on 13th of November. The rainfall alone exceeded a 1% AEP event for the 9-hr storm duration which combined with the antecedent catchment conditions caused widespread inundation throughout the estate and township more broadly. This inundation resulted in the inundation of multiple dwellings above floor level.

2.5 Community Recollections

As part of this investigation the project team visited a number of the impacted properties in order to gain firsthand knowledge of the drainage issues present in the area and impacts of the November event on the respective properties. Their key recollections are provided below:

- [redacted]. They provided the following insights on the November event and general performance of the drainage network:
  - During rainfall events, water is supposed to be directed down Argyle Court before drainage behind [redacted] to Common via the existing easement.
  - In actuality, run-off exceeds the capacity of the roadside drains along Argyle Court draining toward Faulkner Road which fails to intercept overland flow resulting in significant sheet flow over Faulkner Road [redacted]. In November they estimate that approximately 90 m of Faulkner Road was overtopping [redacted].
  - [redacted]
  - They contribute the majority of the problems to upstream development not considering the capacity of the existing downstream network.

- [redacted]. The resident provided the following comments while out onsite:
  - Water started flowing [redacted] late on the 13th of November into the early hours of 14th of November 2022, following intense rainfall over the area.
  - The flooding became one large water body very quickly and was flowing [redacted] west to east.
  - The capacity of the drain, [redacted] was overwhelmed with water breaking from its banks. [redacted] no council maintenance has been completed on the drain.
  - The water generally shallow less than 200mm across [redacted]
  - The water flowed slowly towards King Road where it was draining south with a decent flow. Even so the property owner noted between 200-300mm of water over the road.
  - The property owner noted that once the water hits Faulkner Road it has no where to go and effectively fills up the drain and then spills south.
  - [redacted].
  - The property owner considered that in minor events the drainage performed ok, however once the water exceeded the capacity within Faulkner Road there was many houses which become impacted.
- [redacted]. They provided the following comments regarding the event:
  - It was raining very heavily during the evening of the 13th November 2022.
  - Initially water sheeted [redacted] but drained away.
  - It quickly began to rise [redacted] around midnight.
  - The event was a lot worse than previous times [redacted].
  - [redacted] the water was flowing very fast down King Street [redacted].
  - [redacted]
  - [redacted]
  - [redacted]
  - [redacted] there was standing water in the area for days.

2.6 Findings from Previous Investigation

The previous investigation undertaken by Water Technology in late 2021 analysed the performance of the existing network, works undertaken in 2018 and the efficacy of four proposed mitigation measures:

- Option 1 - Raising of the footpath along Faulkner Road to prevent overtopping.
- Option 2 – Raising of footpath along Faulkner Road and re-grading the roadside drain from west [redacted] Faulkner Road in an easterly direction to King Road, with culvert upgrades along Argyle Park.
- Option 3 – A diversion bank along the easement behind [redacted] Faulkner Road and re-grading of the roadside drain from west [redacted] Faulkner Road in an easterly direction to King Road, with culvert upgrades along Argyle Park.
- Option 4 – A combination of Option 2 & 3.

Since the completion of the 2021 investigation, it is understood the following works have been completed by council:

- Re-grading of the Faulkner Road footpath and roadside drainage to direct some water to King Road – see Figure 2-3.
- Rock armouring of the Common Road outfall – See Figure 2-4.

The previous investigation determined that the existing network had a capacity of less than the 10% AEP event, with several properties inundated and breakouts occurring from the drainage network throughout the estate. The capacity issues were discussed in Section 2.3, with the purpose of the previously identified mitigation options to alleviate pressure on the network and reduce nuisance inundation.

A summary of the performance of the proposed mitigation options and recommendations from this assessment is provided below (in order of recommendation). Note additional comments updating the recommendations have also been included:

- Diversion Levee along easement behind [redacted] Faulkner Road (Option 3)
  - While the construction of a levee would likely require additional work to be undertaken at Common Road, to account for additional flows, the inclusion of this levee resulted in the largest reduction in flood conditions and is considered to be a feasible low-cost solution. Noting that it would require the design of additional drainage outlets and or upgrades further downstream. *Update – a similar result could likely be achieved by upgrading or re-establishing the open channel.*
- Re-Grading of Faulkner Road roadside drainage (Option 2)
  - While this option does not have as significant positive impact as other works, it is considered to provide a more efficient drainage network and reduces the amount of flow overtopping at the intersection of Faulkner Road and Argyle Park. *Update – regrading of the intersection to allow overland flow to also drain over the road would improve the performance of this option.*
- Additional Culvert under Argyle Park downstream of the easement [redacted] Argyle Park (Option 2)
  - The inclusion of this culvert allows flow to be split between the roadside drainage along Argyle Park better utilising its capacity.
- Culvert Upgrades along Argyle Park and under Faulkner Road (Option 2)
  - The culvert upgrades improved the efficiency of the roadside drainage network, reduced the overtopping of the road, and reduced the depth & extent of overland flow paths caused by breakouts occurring. It is noted that these upgrades may impact downstream flood conditions if they are not undertaken in combination with the diversion levee. *Update – upgrades would be required to be reflected in the downstream network as well.*

- Raising of Faulkner Road Footpath (Option 1)
  - While this option reduces overtopping and subsequent flow south of Faulkner Road it also presents the most complicated and costly works to undertake due to constraints around driveway cross over and the removal of the existing works. It is also noted that these works don't result in a significant improvement without the inclusion of the additional works to improve drainage performance outlined above.

Figure 2-3 Before and After Photos - Faulkner / King Road Intersection

Before Photos

After Photo

Figure 2-4 Before and After Photos – Common Road Outfall

2.7 Key Drainage Issues

As discussed throughout this section and identified in the previous investigation the drainage network in the estate is deficient for the area it services. The primary factor contributing to the issues is the reduced capacity of the network along Faulkner Road caused by the alignment of the drainage network falling along and against the topography. Additionally, other issues are present throughout the network, and a summary of the key ones is provided below.

- Common Road Southeast Outfall – Servicing Common Road, Faulkner Road, Argyle Court, Barrabool Views and Manna Gum estates. Identified issues include:
  - Planned / Constructed upstream development at Barrabool Views North - While it is noted that this development is proposed to divert some of the upstream catchment away from the Common Road outfall it is considered likely that there will still be an additional volume of run-off directed to the already strained downstream network.
  - Under sizing and design of Gregory Drive Basins – these basins concentrate pre-existing overland flow to the Argyle Court Swale. Based upon the previous investigation these basins provide little retention to flows with minimal impacts to the peak flow rates experienced from the development. Importantly, they also discharge concurrently resulting in higher flows downstream.
  - Inconsistent Capacity along Argyle Swale – this drain does not have a constant cross-sectional area along its alignment and in general is undersized for the upstream network.
  - Intersection of Argyle Swale and Argyle Court – upstream flows are intended to be captured within the roadside drain of Argyle Court, however due to the alignment and a nearby cross over limiting capacity, water overtops the roadway flowing onto the properties on the opposite side of the roadway.
  - Diversion of Argyle Court roadside drain to easement behind [redacted] Faulkner Road – by design water is supposed to be diverted under the roadway via 2 x 900 x 300 box culverts to the easement. The capacity of the culverts exceeds the capacity of the downstream easement due to its longitudinal grade, resulting in overland flow toward Faulkner Road.
  - Faulkner Road Drainage – upstream flows failed to be captured along the easement and from stage 1 of Barrabool Estate are intended by design to drain along Faulkner Road to Commons Road. However, as there is effectively no fall from Argyle Court to Common Road and as a result of several cross overs, water quickly ponds in the roadside drain with upstream flows overtopping the roadway onto downstream properties. It is noted that as a result the majority of the overland flow onto downstream properties outfalls via the King Road catchment and not via Common Road as designed.
  - Common Road Outfall – the outfall into Common Road is understood to have ongoing erosion issues.
- King Road Outfall – Servicing King Road, Casuake Drive, Barrabool Views Stage 1 and excess overland flow overtopping Faulkner Road that the outfall was not designed to convey. Identified issues include:
  - Most of the network in this catchment services its design purpose, with water conveyed along roadways and easements to the outfall.
  - Overland flow from Faulkner Road – as this network was not designed for flows from Faulkner Road easements located around [redacted] King Road, fail to capture the sheet flow from Faulkner Road resulting in inundation of low-lying areas in this vicinity.
  - Outfall from Basin – the King Road basin has no defined outfall with the basin spilling onto the neighbouring farmland.
- Common Road North-East Outfall – Servicing properties south of Gregory Drive and west of Anthony Lane.
  - Outfall to waterway – this area is drained via an existing gully that drains toward the waterway. However, a dwelling is located directly between the gully upstream of Common Road and the waterway downstream. It is understood that this results in water flowing through the property to reach the waterway.

Figure 2-5 provides an overview of the catchments and the location of issues identified above.

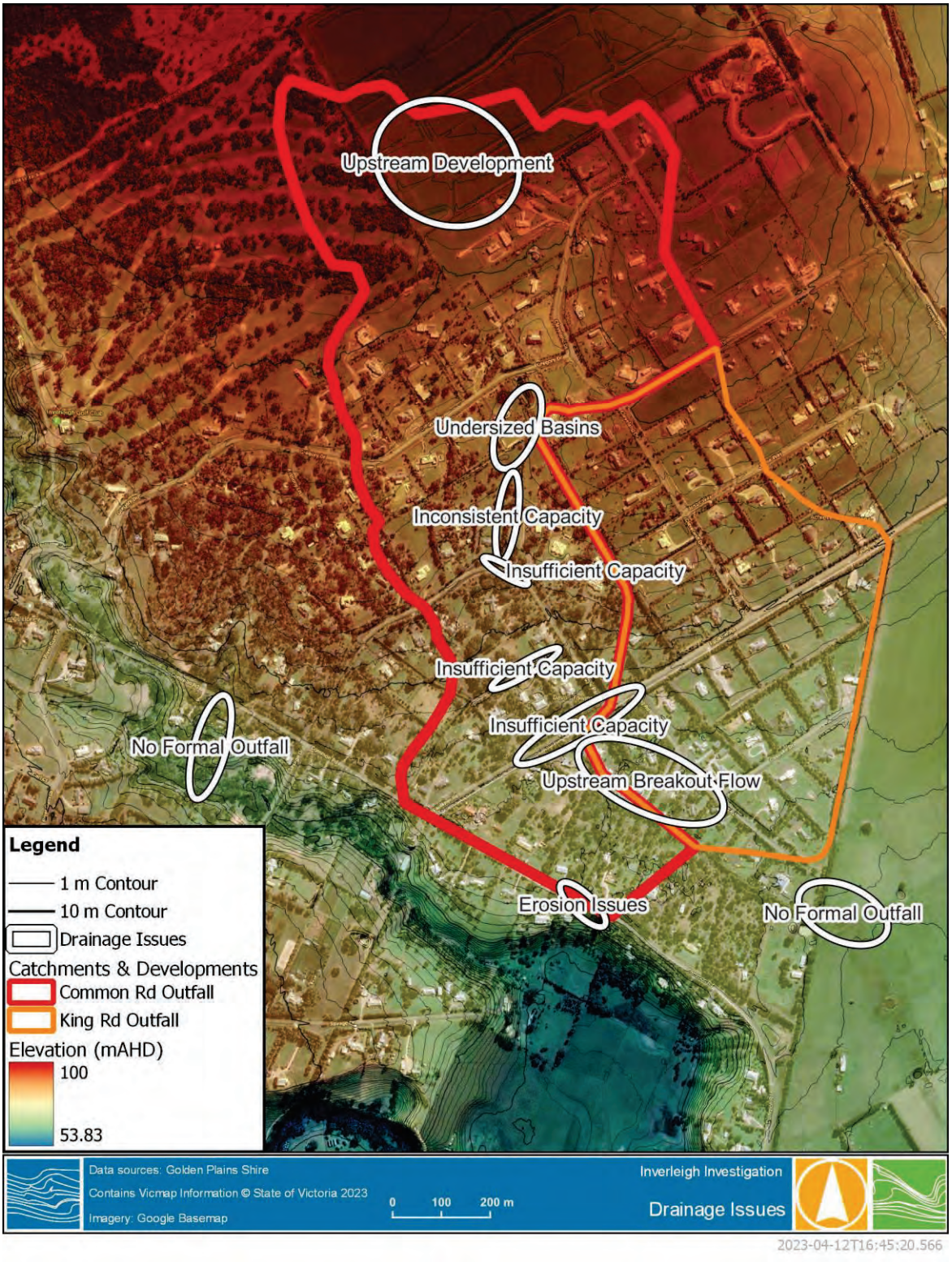

Figure 2-5 Catchments and Drainage Issues

3 FLOOD MODELLING

3.1 Overview

A TUFLOW hydraulic model was previously built for the area as part of the 2021 drainage assessment. The TUFLOW model extent encompassed the northern area of the Inverleigh Township including part of the Leigh River. The model extent captured the entire catchment of interest, while the inclusion of part of the Leigh River floodplain allows for the addition of flows from the Leigh River in future (although not the focus of this assessment). The model adopted a Rain on Grid approach, with a height versus flow (HQ) boundary applied at the downstream end of the model and in locations where water drained toward the model boundary out of the area of interest.

Further information on the model development can be found in the previous investigation[1], a summary of key elements is provided below:

- Topography - was developed based upon two LiDAR datasets (NAP Corangamite 2004 & CEP Geelong 2013), design surfaces of developments, design survey and a created TIN of the roadside drain along Common Road.
- Mannings ‘n’ Roughness – was developed based upon planning layers and aerial imagery. Several roughness values were adopted based on the land-use with rainfall losses varied between surfaces.
- Design Rainfall – rainfall and temporal patterns were extracted from the Bureau of Meteorology (BoM) based on the centroid of the catchment.
- Culverts & Pipes – culvert sizing and locations were provided by Golden Plains Shire. In instances where data was not available estimates based on the surrounding network were adopted.
- Model Grid – the modelled adopted a grid size of 3 m with 1 m Sub-Grid Sampling.

3.2 Model Updates

The adopted TUFLOW model was updated to reflect current catchment conditions, with the following updates undertaken:

- Topography:
  - New CEP Geelong 2021 0.5 m LiDAR was adopted.
  - Additional design surfaces for Barrabool Views were included in the model, provided by Cardno.
- Mannings ‘n’ Roughness – The area of the approved Barrabool Views North was updated from pasture to low density residential development.
- Culverts & Pipes – additional culverts / pipes were included for Barrabool Views and in the downstream network.

The model schematisation including updates is provided in Figure 3-1.

[1] Water Technology 2021, Inverleigh Drainage Assessment – Commons Road, Golden Plains Shire

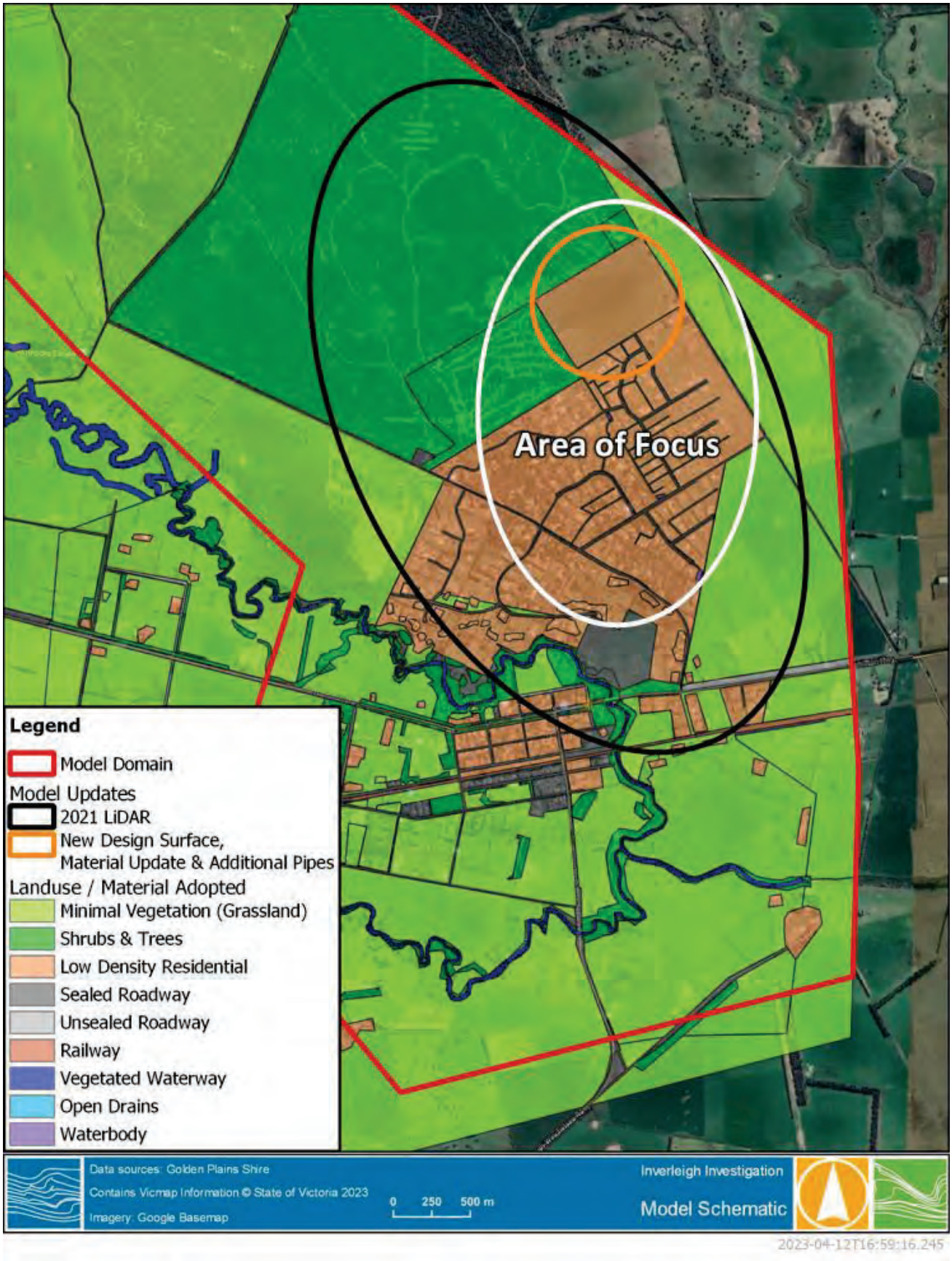

Figure 3-1 Model Schematic

3.2.1 November 2022 Event

With regard to the flooding event which occurred on the 14 November 2022 the Bureau of Meteorology presented the following climate summary:

Rainfall in November was above average across Victoria, with large parts of the state having very much above average rainfall. Maximum temperatures were very much below average across most of Victoria. Minimum temperatures were below average in large parts of the state's north, and above average in the southern half of the South-West district. Some sites had their highest November daily rainfall on record on the 13th and 14th.

Radar Rainfall records were used to assess the magnitude and distribution of rainfall during the event so that a simulation of the event could be reproduced. Radar Rainfall Depth during the 13 and 14 of November indicated that in the order of 58 mm fell, with the majority of the rainfall occurring between 9pm on 13th and 9am on 14th. Plotting of the observed rainfall against local Intensity Frequency and Duration information indicates that the storm was close to a 0.5% AEP event or 1 in 200 Yr ARI (Figure 3-3).

In accordance with the Infrastructure Design Manual (IDM)[2] minor drainage systems typically comprising of pipe networks and swale drains have the capacity to collect and convey stormwater flows up to the 10% AEP event. Whilst the major drainage system caters for runoff from higher intensity storms up to a 1% AEP event, with these flows nominally contained within the road reserve. Noting that the event in November 2022, was in the order of a 0.5% AEP event.

The radar mapping indicates the localised nature of this storm with the highest intensity falls occurring over the northern part of the Inverleigh township, in the area of the subject estate (Figure 3-4). As the storm was localised the Rainfall Radar records were compared to local (private) rainfall gauges, from Wunderground. The two gauges (IInver239[3] & IVictorI360) are located within the catchment and recorded rainfall totals of up to 80 mm in the same time period, with similar rainfall hyetographs.

As the two gauges hyetograph were similar, the Wunderground data was considered more appropriate and was adopted for the modelling of the November event.

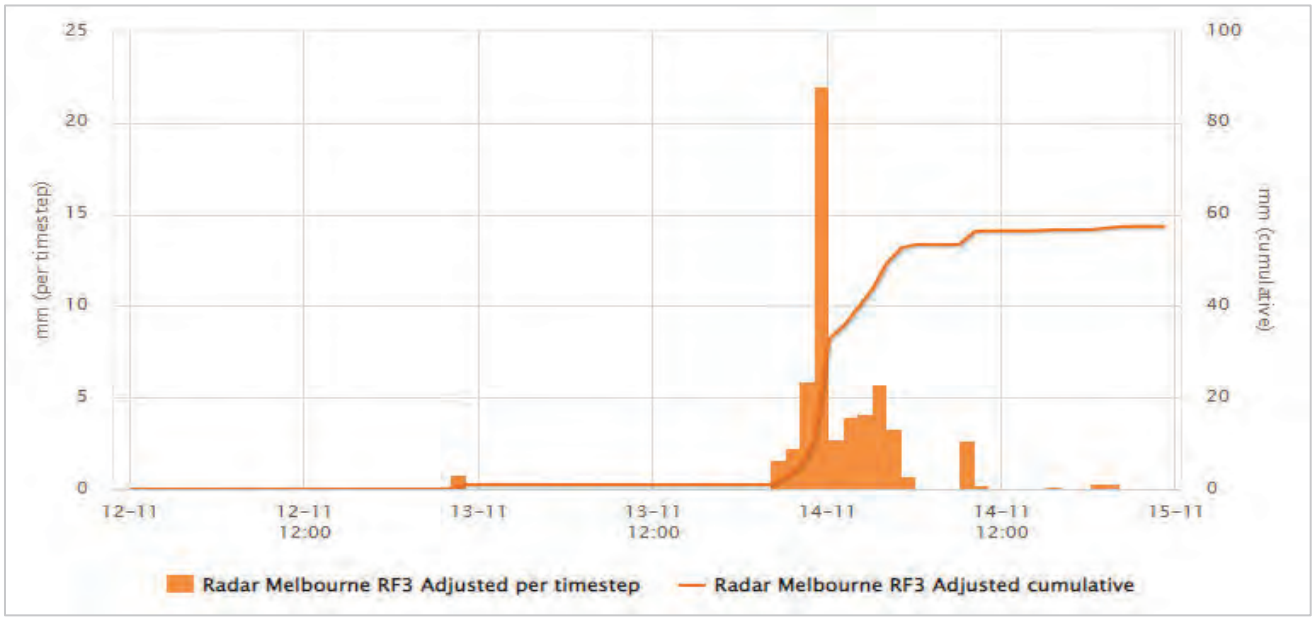

Figure 3-2 Rainfall Distribution and Cumulative Rainfall Total

[2] https://www.designmanual.com.au/assets/files/documents/IDM/IDM_Version_5.4_.pdf
[3] https://www.wunderground.com/dashboard/pws/IINVER239

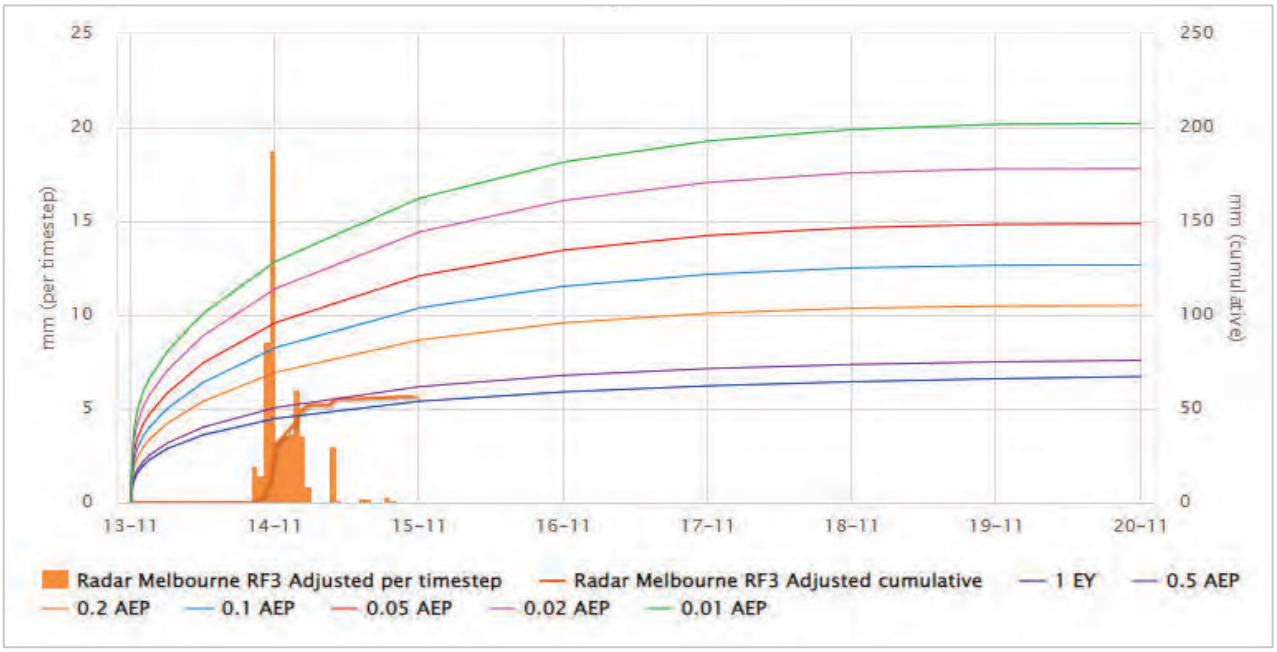

Figure 3-3 Rainfall and IFD Event Plot

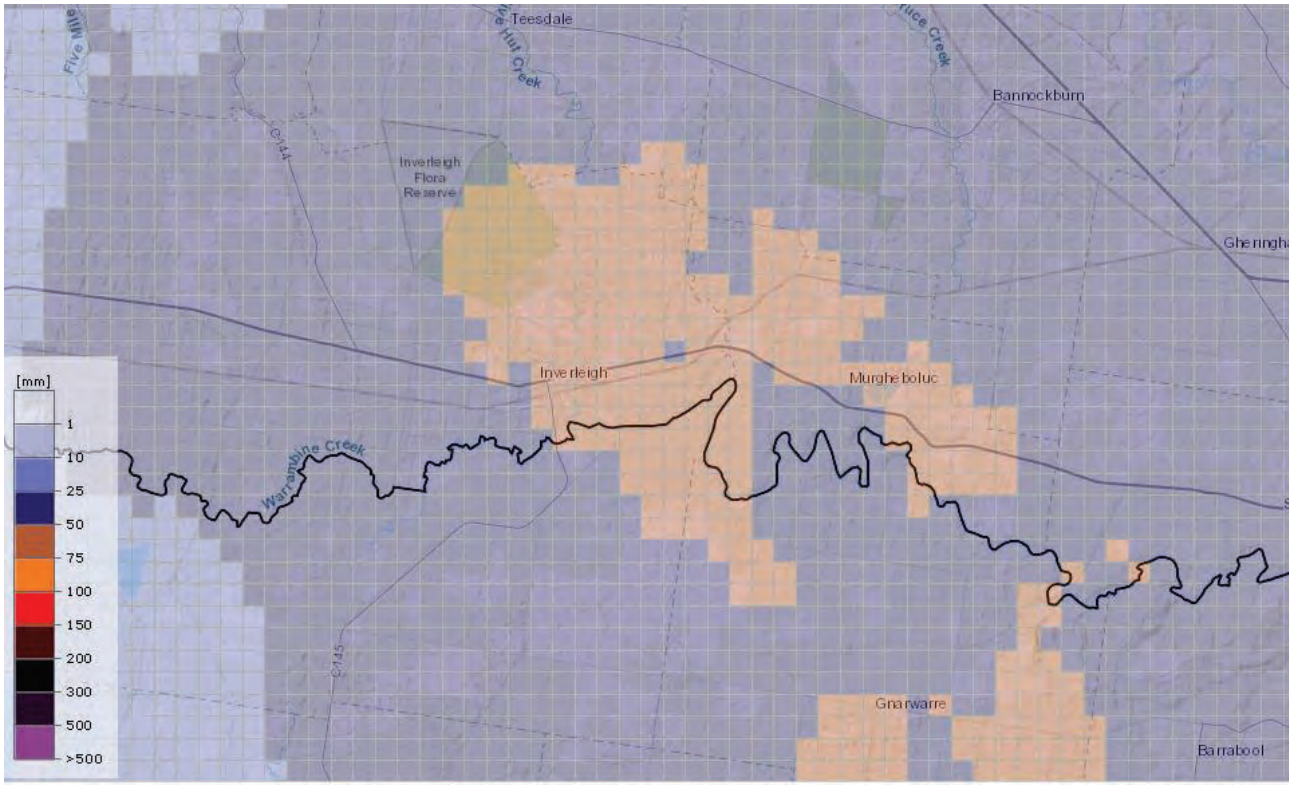

Figure 3-4 Radar Rainfall 13 and 14 November 2022 (HydroNET)

3.3 Model Scenarios

The hydraulic model was run for the following scenarios, incorporating changes listed below:

- Design Modelling – adopted the model updates and was used to assess drainage conditions. The following design events were modelled:
  - 1% AEP 9 hr Storm Duration (TP05)
  - 10% AEP 3 hr Storm Duration (TP05)
  - November 2022 Event (~0.5% AEP event) – with the following changes:
    - No rainfall losses applied – this was considered appropriate due to the antecedent catchment conditions as a result of the rainfall across Spring of 2022.
    - Initial Water Level of Gregory Basins increased – this was considered appropriate as rainfall prior to the main event and the antecedent conditions would have likely seen the basins close to capacity.
- Mitigation Modelling – results and modelling updates are further discussed in Section 6. Mitigation options were assessed for the 1% AEP event and November 2022 event.

4 FLOOD MODELLING RESULTS

The updated hydraulic model was run for the three existing conditions events, with the flood depths presented in Figure 4-1 to Figure 4-3. A summary of the results for each event is presented below:

- 10% AEP Event
  - The majority of overland flow is successfully contained to the drainage network upstream of the Gregory Drive basins.
  - Downstream of the basins along the Argyle Swale and at Argyle Court the capacity of the drainage network is exceeded, with overland flow and inundation experienced on private property along Argyle Court.
  - At the intersection of Argyle Court and Faulkner Road, the drainage network is exceeded resulting in overtopping of Faulkner Road and inundation to properties downstream of Faulkner Road along King Road (upstream of Casuake Drive). Based on community recollections it is understood that this inundates in some dwellings above floor level.
  - Upstream flows exceed the capacity of the easements behind [redacted] Faulkner Road, resulting in overland flow directed toward Faulkner Road, resulting in further overtopping of the roadway and additional inundation.
- 1% AEP Event
  - The majority of overland flow is still directed toward to the Gregory Drive basins, however, in several locations the capacity of the open drains is exceeded. Most notably within Manna Gum estate with overland flow directed south into Argyle Court.
  - The inundation experienced in the 10% AEP event along and within Argyle Court is exacerbated with increases to flood depths and extent.
  - At the intersection of Argyle Court and Faulkner Road, the in overtopping of Faulkner Road and inundation to properties downstream of Faulkner Road along King Road extends below Casuake drive. Based on community recollections it is understood that this inundates multiple dwellings above floor level.
  - The exceedance of the easement behind [redacted] Faulkner Road is exacerbated, resulting in further inundation.
- November 2022 Event
  - Throughout the estates the drainage network is exceeded, with all issues present during the 1% AEP event exacerbated.
  - Based upon community recollections the modelled results are considered consistent with what occurred. The impact to residents throughout the estates but particularly downstream of Faulkner Road, cannot be understated with residents losing possessions and impacting multiple properties (and several dwellings above floor level) as result of the failure of the upstream network.
  - While it is noted that the November event was extremely rare, it does serve as a reminder of the potential impact to residents. It should also be highlight that in response several residents have taken it upon themselves to implement mitigation measures, which will potentially exacerbate conditions on neighbouring residents.

Figure 4-1 10% AEP – Flood Depth

Figure 4-2 1% AEP – Flood Depth

Figure 4-3 November 2022 Event – Flood Depth

5 DETAILED ANALYSIS OF FLOODING AND DRAINAGE ISSUES

5.1 Basin Sizing Analysis

Based on the findings of the previous investigation and corroborated by anecdotal information collected from community consultation, the two basins at Gregory Drive have been determined to provide little retention of flows during major event. To assess the sizing of the basins the following assessment was undertaken:

- Flow rates into the basins were extracted for the 1% AEP and November events modelling. This was used to calculate the rate and volume of water flowing into the basins.
- The capacity of the downstream network was estimated based on manning's calculations of drains at several locations. This information was used to assess the ideal discharge rate from the basins and determine the addition volume that the basins would require to retard flows to the capacity of the downstream network. Based upon the capacity of the downstream network an outlet requirement of approximately 0.6 m^3/s was determined (See Table 5-1 for existing discharge rates). It is noted that this flow is based on the existing drainage network, and if downstream upgrades occurred this value could increase. As such the sensitivity of increasing the downstream capacity to 1.5 m^3/s was tested. It is noted that this value is arbitrary, and its purpose is to provide a comparison to existing conditions should downstream upgrades by undertaken.

A summary of the findings presented in Table 5-1, with the methodology depicted in Figure 5-1. Based upon the analysis undertaken there are two key things to note:

- The existing basin/s are undersized for the catchment and development that it services in large events.
- The existing basin/s could potentially perform adequately for the 10% AEP event, if the basin outlet arrangement was altered. This would involve a similar arrangement to that of the Cleveland Drive basin, it is noted that this may not be feasible as increasing the flow restriction requires additional allowable storage volume. This trade-off between discharge and the volume required is a limitation of the basins within the upper catchment of this estate.
- The existing basin/s could potentially perform adequately for the 1% AEP event, if the basin outlet arrangement was altered and downstream upgrades were performed to increase the capacity of the network to 1.5 m3/s. However, as there is a trade-off between discharge and volume required the feasibility of the outlet arrangement would be required to be tested.
- The existing basin/s are significantly undersized for long duration events with prolonged periods of high flows. For example, for the 1% AEP an additional volume in of 5,200 m^3 would be required to potentially allow for flows to be retarded to the capacity of the downstream network. This is simply because the downstream network has so little capacity that attempting to retard to capacity of the network without additional upgrades is unfeasible.

Table 5-1 Basin Sizing Estimation

Event	Existing Storage Volume Total	Required Discharge Rate (m^3/s)	Actual Discharge Rate (m^3/s)	Maximum Volume Required	Sensitivity Discharge rate	Maximum Volume Required
10% AEP	3,400 m^3	0.6 m^3/s	0.8	Okay	1.5 m^3/s	Okay
1% AEP			2	5,200 m^3		Okay
November 2022			~ 4.9	>20,000 m^3		~ 13,000 m^3

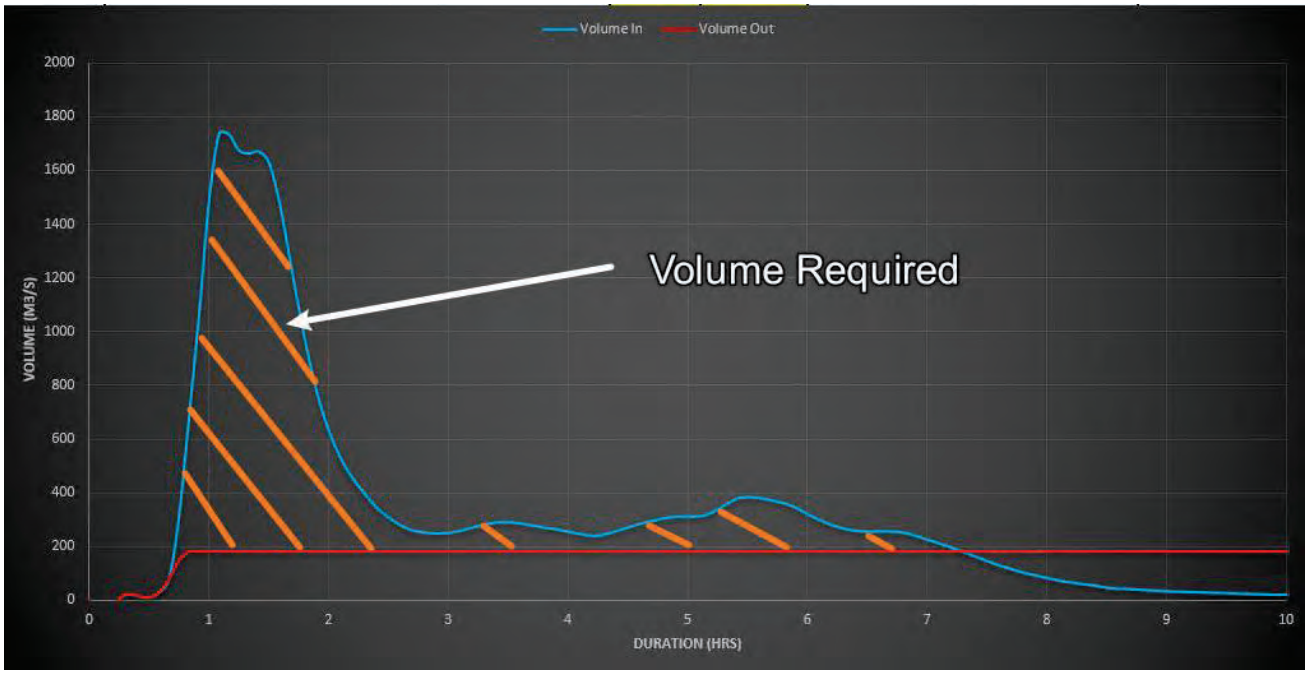

Figure 5-1 Example of Basin Assessment – November Event

5.2 Analysis of Network Deficiencies

As discussed throughout this report, there are several locations within the estate where the drainage network does not have the capacity to pass the flow it receives. Several key locations have been assessed for the 1% AEP event, to quantify the deficiency of the network and help identify potential upgrades or mitigations options. The locations are presented in Figure 5-2, with the assessment presented in Table 5-2.

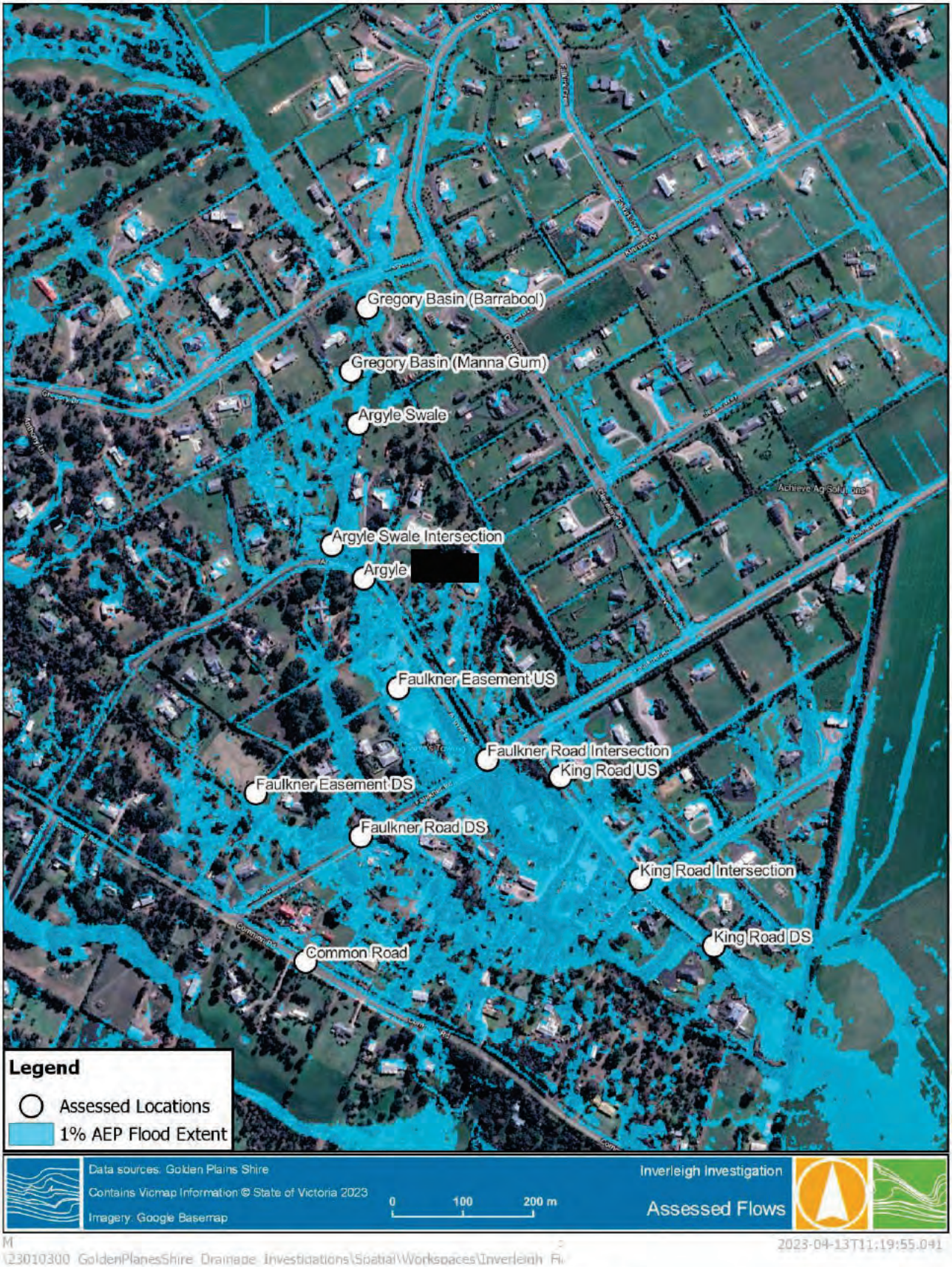

Figure 5-2 Assessed Locations

Table 5-2 1% AEP Event Flow Analysis

Catchment	Location	U/S Flow (m3/s)	Capacity (m^3/s)	Deficiency (m^3/s)	Options / Notes
Common Road Outfall	Gregory Basin (Barrabool)	~ 2.0	At Capacity	N/A	Note basin at capacity and provides little retention or attenuation of flows. Increase basin size or divert upstream flows.
	Gregory Basin (Manna Gum)	~ 0.7	At Capacity	N/A	Note basin at capacity and provides little retention or attenuation of flows. Increase basin size or divert upstream flows.
	Argyle Swale	~ 2.7	~ 1	~ 1.7	Increase drain capacity via re-grading or increasing cross-sectional area. Decrease upstream flow – via diversion or increase in basin size.
	Argyle at Swale Intersection	~ 2.7	~ 2	~ 0.7	Increase capacity of roadway via piping, lowering or roadside drainage upgrades (Inc. crossovers). Decrease upstream flow.
	Argyle [redacted]	~ 2.7	~ 1.5	~1.2	Increase capacity of roadway via piping, lowering or roadside drainage upgrades (Inc. crossovers). Decrease upstream flow.
	Faulkner Road Easement (toward Argyle Crt)	~ 2.7	~ 0.6	~ 2.1	Increase capacity of roadway via piping, lowering, re-grading or roadside drainage upgrades (Inc. crossovers). Increase drain capacity via re-grading or increasing cross-sectional area. Decrease upstream flow via upstream works or roadworks to divert flows to King Road.
	Faulkner Road Easement (toward Common Rd)	~ 1	~ 0.4	~ 0.6	Note U/S flow rate would increase if upstream network performed as designed. Increase drain capacity via re-grading or increasing cross-sectional area. Decrease upstream flow.
	Argyle – Faulkner Road Intersection	~ 2	~ 0.2	> 1.7	Increase capacity of roadway via piping, lowering or roadside drainage upgrades (Inc. crossovers). Decrease upstream flow.

Catchment	Location	U/S Flow (m3/s)	Capacity (m^3/s)	Deficiency (m^3/s)	Options / Notes
	Faulkner Road toward Common	~ 0.5	~ 0.2	~ 0.3	Note U/S flow rate would decrease if easement to north performed as intended. Note U/S flow rate would increase if capacity of roadway upstream was increased. Increase capacity of roadway via piping, lowering or roadside drainage upgrades (Inc. crossovers). Decrease upstream flow.
	Common Road	~0.7	~1	(+) ~0.3	Note U/S flow rate would increase if capacity of y upstream was increased to perform as intended. Increase capacity of roadway via piping, lowering or roadside drainage upgrades (Inc. crossovers). Decrease upstream flow.
King Road Outfall	Cleveland Drive Basin	~0.3	At Capacity	N/A	Note basin is at capacity and performs as designed.
	Faulkner Road (DS Cleveland Basin)	~ 1.2	~1	~0.2	Increase capacity of roadway via piping, lowering or roadside drainage upgrades (Inc. crossovers).
	King Road US	~0.8	~ 2	(+) ~1.2	Utilise capacity and divert upstream flows from Common Road catchment. Note capacity reduces toward Faulkner Road; diversion of upstream flows would have to include drainage upgrades to roadway capacity.
	Casuake – King Road Intersection	~ 2	~ 2	~ 0	Roadway at capacity due to additional flows from overtopping of Faulkner Road. Divert flow from Faulkner Road along King Road within road reserve. Note this would require upgrades to the roadside drainage and crossovers. Upgrade Common Road catchment to prevent overtopping.
	King Road DS	~2.7	~ 2.5	~0.2	As Above

6 MITIGATION OPTIONS AND DRAINAGE UPGRADES

6.1 Identified Mitigation Options

Based on the hydraulic modelling results, community consultation and discussions with council, the following key mitigation options for detailed assessment were identified:

- **Option 1** – Lowering of the intersection of Argyle Court and Faulkner Road to drain toward King Road. This was modelled by creating a TIN of the proposed intersection, with a standard roadway cross-section.
- **Option 2** – Increases the basin size at Gregory Drive by combining the basin footprints into one. This was again modelled by creating a TIN of the proposed basin and a concept design of the outlet based on the arrangement adopted at Cleveland Drive.
  - **Option 2a** – This involves the re-direction of high-flows from the basin toward Common Road directly west out falling via the existing gully and easements. Note to achieve grade from the basin, the height of the basin from option 2 was raised by 250 mm.
- **Option 3** - Lowering / re-grading Faulkner Road to Common Road, with the roadway crest lowered below the surrounding topography. This was modelled by creating a TIN of the proposed roadway, based on a standard roadway cross-section. Note crossovers were removed and not considered as part of this investigation.
- **Option 4** – Golf Club Diversion, this would utilise the easement that runs adjacent to the golf course and direct upstream flows from the upstream development away from the downstream network.

In addition to these mitigation options for the following works are recommended to be considered for immediate action:

- Maintenance of existing drains and/or re-establishment of design cross section.
- Culvert Upgrades along Argyle Park and under Faulkner Road. This was previously proposed and involved upgrading existing 300 mm RCP culverts to 900 x 300 mm box culverts along Argyle Park, including the culvert/s at the intersection with Faulkner Road (where applicable). With the addition of a single 900 x 300 mm box culvert under Argyle Park at the base of the easement adjacent to [redacted] Argyle Park.

Further to this the following major works may also be required to be considered:

- Upgrade of Argyle Court swale downstream of the basins, establishing a consistent cross-sectional area. It is noted that this was modelled as part of the ultimate solution. Note for the ultimate modelled mitigation options this was adopted.
- Outfall design at [redacted] Common Road. The existing gully is understood to drain through this [redacted] waterway), establishing a designed outfall to reduce the inundation [redacted] should be considered.
- Upgrade of the easement/s drain behind [redacted] Faulkner Road. Upgrading these easements will aid in capturing overland flows breaking out from upstream, diverting water away from Faulkner Road.
- Lowering of Argyle Court or increasing of roadside drain capacity (including crossovers) from approximately [redacted] Argyle Court to Faulkner Road. Note this should only be undertaken with subsequent upgrades downstream.

The purpose of the mitigation options and identified additional works is summarised in Table 6-1, with the mitigation options presented in Figure 6-1.

Note the performance of each option and the scenarios tested are discussed throughout this section, with a summary of the performance and recommendations made in sections 7 and 8, respectively.

Table 6-1 Identified Mitigation Options and Additional Works

Option / Work	Assessed (Y/N)	Design Purpose	Estimated Extent of Work[1]	Identified Constraint	Alternative
Option 1 - Lowering intersection of Argyle Court to King Road	Y	Direct overland flow away from [redacted] Faulkner Road down King Road.	Length of works 210 m. 2000 m^3 of cut.	Additional works / upgrades along King Road likely required. Further works required along Faulkner Road to tie into concept design.	Significant upgrading of road-side drainage. Piping of flows from Argyle Court intersection to King Road.
Option 2 - Increasing Basin Size	Y	Increase attenuation and decrease flows downstream	Total Footprint 6,000 m^2 4,950 m^3 of cut 1,600 m^3 fill	Additional land-take and design levels, concept design requires embankment to extend to west along easement.	Maintain existing basin arrangement. Increase downstream capacity to convey current flow regime.
Option 2a - Western Basin Outfall Drain	Y	Divert upstream flows from downstream network for rare events.	Length of drain 850 m. 2,750 m^3 of cut 250 m^3 of fill	Length of works and impact to existing vegetation, most importantly outfall constraint at [redacted] Common Road.	Underground pipes / maintain existing basin arrangement. Increase downstream capacity to convey proposed flow regime.
Option 3 - Lowering Faulkner Road	Y	Direct overland flow away from southern side of Faulkner Road to Common Road and intended outfall.	Length of works 650 m. 8,500 m^3 of cut. Outfall required to be determined.	Extent of works and outfall along Common Road or through private property at end of Faulkner Road. Further works along Common Road required to tie into concept design.	Significant upgrading of road-side drainage. Piping of flows from Argyle Court intersection to Common Road / Outfall. Reduce extent of works if Argyle – King option is adopted.

Option / Work	Assessed (Y/N)	Design Purpose	Estimated Extent of Work[1]	Identified Constraint	Alternative
Option 4 - Golf Club Diversion	Y	Remove upstream flows from downstream network	Length of drain 1000 m. 3,500 m^3 of cut 500 m^3 of fill	Proposed easement doesn't extend all the way to the upstream development. Vegetation removal along easement. Outfall needs to be assessed.	Maintain existing arrangement. Pipe the flows underground to easement.
Maintenance / Upgrading Existing Drains	N	Improve conveyance and capacity of existing network	Not assessed - Length of easements	Resources, Native Vegetation	Maintain existing arrangement
Culvert Upgrades	Previous report Mitigation 2.	Improve conveyance and capacity of existing network	Not assessed	Interference with driveway crossovers & Resources.	Maintain existing arrangement
Argyle Court Swale	Y	Reduce / Mitigate escaping flow from existing swale.	Length of drain 270 m. 950 m^3 of cut	Potential impact to existing vegetation.	Piping of basin flows to Argyle Court Maintain existing arrangement
Outfall through 175 Common Road.	N	Protect 175 Common Road from upstream flow	Not assessed	Existing dwelling and available footprint	Piping or diversion of flows to Savage Drive
Upgrade Easements behind [redacted] Faulkner Road	N – Similar to previous report Mitigation 3	Improve conveyance and capacity of existing network and decrease overland flow reaching Faulkner Road	Not assessed - 450 m of easement	Access / Vegetation removal / Resources	Maintain existing arrangement
Lowering Argyle Court	N	Reduce / Mitigate escaping flow along roadway onto downstream properties	Not assessed - 350 m of roadway.	Extent of works. Requires subsequent downstream works	Piping of flows from Argyle Swale to downstream network

1. Note extent of works and values provided are indicative only based on concept design

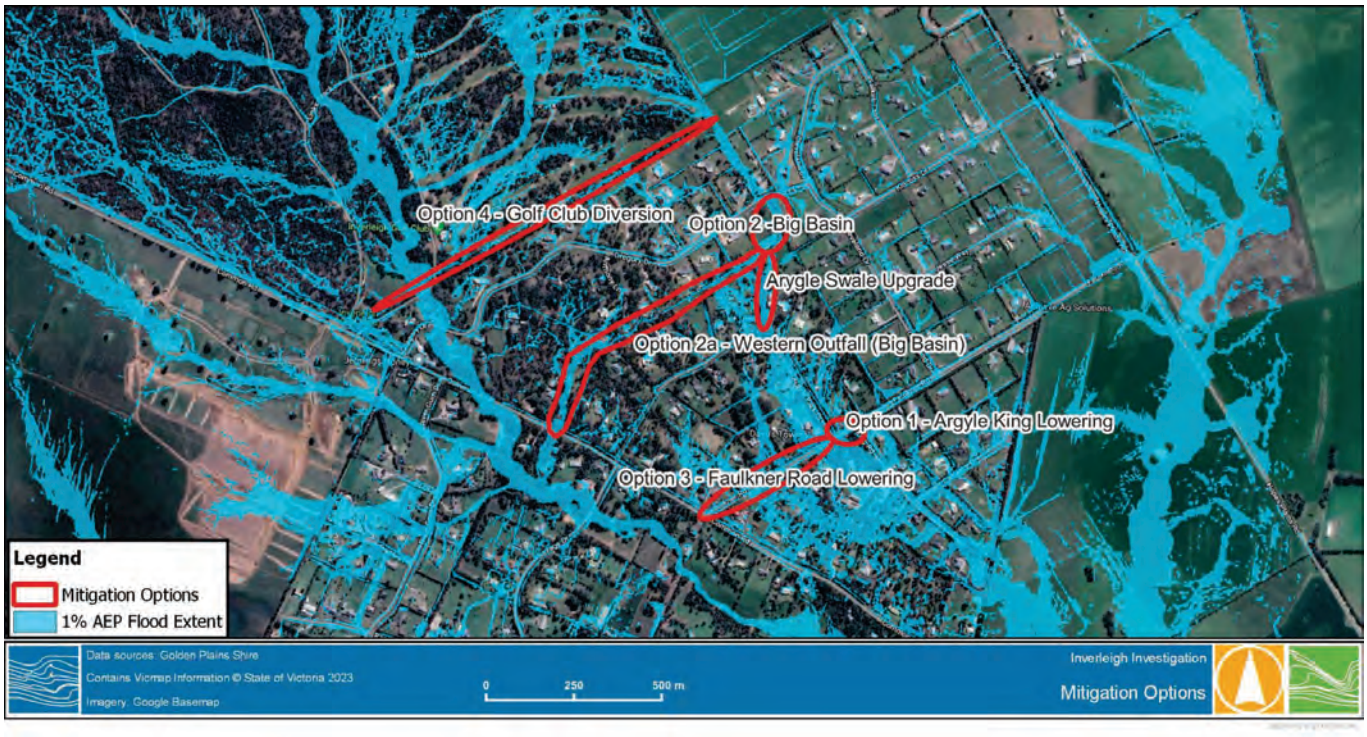

Figure 6-1 Proposed Mitigation Options and Works

6.2 Modelled Scenarios

The TUFLOW model was updated to reflect the proposed mitigation options. It is important to note that whilst each of the mitigation options proposed and modelled produce results which show reductions in flood risk. In isolation no one option is able to adequately address the drainage deficiencies within the catchment due the distributed nature of some of the issues. In response to this a number of **Ultimate Schemes** have been proposed which combine options in order to achieve the best outcome within the catchment.

Having regard to this the following scenarios were modelled (as presented in Table 6-2):

- Each Individual mitigation option separately, and
- Ultimate Scheme 1 & 2 – Which included Option 2, Option 4 and Option 1 or Option 3 (+ Argyle Swale Upgrade)
- Ultimate Scheme 3 & 4 – Which included Option 2 and Option 1 or Option 3 (+ Argyle Swale Upgrade)
- Ultimate Scheme 5 & 6 – Which included Option 2a and Option 1 or Option 3 (+ Argyle Swale Upgrade)

The results of the modelling and assessment of the viability of the options are presented in following sections. Note the ultimate mitigated options were tested for both the 1% AEP event and November 2022 event unless otherwise stated, while the individual options were only tested for the 1% AEP event.

Table 6-2 Assessed Combinations of Mitigation Options

Mitigation Option	Ultimate Scheme 1	Ultimate Scheme 2	Ultimate Scheme 3	Ultimate Scheme 4	Ultimate Scheme 5	Ultimate Scheme 6
Option 1 - Lowering intersection of Argyle Court to King Road	✓		✓		✓	
Option 2 - Increasing Basin Size	✓	✓	✓	✓	✓	✓
Option 2a - Western Basin Outfall Drain					✓	✓
Option 3 - Lowering Faulkner Road		✓		✓		✓
Option 4 - Golf Club Diversion	✓	✓				
Argyle Swale Upgrade	✓	✓	✓	✓	✓	✓

6.3 Option 1 – Lowering Argyle Intersection

The results for the 1% AEP maximum depth and comparison to existing conditions, is presented in Figure 6-2 and Figure 6-3 respectively. The modelling results demonstrate:

- The lowering of the intersection directs overland flow from Argyle Court to King Road.
- The works result in no overtopping of Faulkner Road onto downstream properties, east of [redacted]Faulkner Road, with inundation in this location only caused by localised rainfall.
- The diverted flows result in a total of 2.7 m^3/s (an additional 1.9 m^3/s) flowing down King Road (upstream end) exceeding the existing capacity which is estimated to be between 2 – 2.5 m^3/s (See Section 5.2). The additional flow can either be reduced by reducing the extent of upstream works or catering for the additional flow via upgrades to the roadside drainage along King Road (widening and deepening). It is important to note it is expected that major roadworks (i.e. lowering of the road) along the entirety of King Road will not be required.
- The lowering of the intersection has minimal impact on flood conditions west of [redacted]Faulkner Road, as is to be expected.
- The diverted flows result in flood level increases of at most 0.1 m along King Road upstream of Casuake Drive, with depths up to 0.25 m over the road. It is noted that flooding depths above 0.3 m are considered unsafe for vehicle access. Importantly the diverted flows are mostly confined to the road reserve, subsequent upgrades to the road-side drainage (i.e. crossovers) would likely reduce or mitigate adverse flooding to properties fronting King Road.
- The diverted flows result in flood level increases of at most 0.05 m along King Road and along Casuake Drive near the intersection, with depths up to 0.2 m over the road. The impacts near this intersection, demonstrate that the diversion of upstream flows from Argyle Court will require upgrades along King Road.
- The diverted flows result in flood level increases of at most 0.05 m along King Road downstream of Casuake Drive, with depths up to 0.25 m over the road. Again, roadside drainage upgrades to mitigate adverse impacts will be required.
- The diverted flows result in flood level increases of at most 0.03 m to the downstream farmland. This demonstrates that the outfall works to either the existing basin or the addition of a new basin will be required to account for the increased flow regime. Consideration may also need to be given to formalisation of drainage easement through the subject property.

Figure 6-2 Option 1 – 1% AEP Flood Depth

Figure 6-3 Option 1 – 1% AEP Flood Level Difference

6.4 Option 2 – Big Basin

The results for the 1% AEP maximum depth and comparison to existing conditions, is presented in Figure 6-4 and Figure 6-5 respectively. The modelling results demonstrate:

- Increasing the volume of the basin whilst combining the Gregory Basins successfully reduces the overtopping of the Manna Gum estate drains decreasing the flood extent. However, this is because the proposed basin works extend along the downstream side of the main easement, to prevent water backing up along the drain and spilling onto the downstream properties. It is noted that these additional works are a constraint to increasing the basin.
- The works have minimal impact on flood conditions downstream with minor localised increases to flood levels. This is because during the peak of the event the basin spillway (under the current design arrangement) is engaged to a depth of approximately 0.15 m, resulting in a similar discharge to existing conditions. However, the works have a large impact on flow conditions when the basin is operating below the spillway (smaller magnitude events). Prior to the spillway been engaged the discharge from the basin is approximately half of existing conditions. This demonstrates that while increasing the basin size will provide little impact in rare events (i.e. 1% AEP and November Event), it is likely to provide benefit in more common events. The effectiveness of the basin can be improved by increasing the footprint and potentially increasing the spillway height. Though consideration of the Manna Gum Easement levels is required when increasing spillway height.
- The proposed basin increases the storage capacity to approximately 5,300 m^3, 300 mm below the top of bank, this represents an increase of approximately 2,000 m^3 from existing conditions. Based on the analysis presented in Section 5.1, during the 1% AEP event the basin would be sufficient for the capacity of the existing downstream network if a suitable arrangement could be achieved. However, the results demonstrate the trade-off between discharge and volume, as discussed in Section 5.1, as the proposed outlet arrangement is considered realistic but fails to retard flows to the downstream capacity, due to the requirement for a spillway to prevent overtopping of the basin embankment. While increasing the spillway would provide additional volume, it would require an increase in the basin footprint.
- Overall increasing the basin size alone will have improvements during lower events, however, the efficiency of the basin is ultimately still limited to the capacity of the downstream network. As such, depending on the level of protection desired, downstream upgrades should be undertaken prior to increasing the basin size (alone) for rare events.

Figure 6-4 Option 2 – 1% AEP Flood Depth

Figure 6-5 Option 2 – 1% AEP Flood Level Difference

6.5 Option 2a – Big Basin Western Outfall

The results for the 1% AEP maximum depth and comparison to existing conditions, is presented in Figure 6-6 and Figure 6-7 respectively. The modelling results demonstrate:

- The increasing of the Gregory Basins and the western outfall drain results in improvements in the downstream network and within the Manna Gum Estate.
- The works reduce flood levels by up to 0.2 m and reduce to the flow regime to 0.7 m3/s (a reduction of 1.3 m^3/s) along the Argyle Swale. This reduction in flow and flood levels reduces the extent of inundation along the swale, with overland flow largely confined to the swale alignment. However, despite being below the capacity of the swale in certain locations, the inconsistency of the cross-sectional area results in breakout and inundation outside of the drain.
- The works reduce flood levels by up to 0.15 m and the extent of overtopping of Argyle Court [redacted] The reduction in flood levels reduces the extent of inundation on properties on the downstream side of Argyle Court.
- The works have a minor impact to flood levels at and downstream of Faulkner Road [redacted] by up to 0.03 m. Overall the diversion of upstream flows is considered to have little impact on the inundation extent and depth downstream of Faulkner Road. It is noted that the impact may be able to be improved by further reducing the capacity of the low flow arrangement, however, ultimately the capacity of the downstream network is acting as a major constraint. The performance of the network under these conditions demonstrate that the issues present at Faulkner Road, are not solely caused by development upstream of the Gregory Basins.
- The works increase the flow directed west out falling via the existing gully [redacted]. The increased flow results in increases to flood levels of up to 0.03 m [redacted]. The increased flow regime would be required to be addressed via either works [redacted] (and directly upstream) or by the diversion of flows upstream of Common Road. The feasibility of these options would be required to be investigated and is a constraint of this option.
- The works demonstrates that if implemented the works within the downstream network particularly along Argyle Court are reduced. For example, the deficiency at [redacted] Argyle Court would be completely removed should minor upgrades to the cross overs and roadside drainage occur. This is because overtopping under this option is the result of the existing constraints of the crossover and not because the capacity of the roadway is exceeded.
- Overall, the additional works to option 2, improves flood conditions and feasibility of the enlarged basin. However, it is noted that the proposed outfall requires additional works to achieve the drainage direction and the establishment of a formal outfall at [redacted] Common Road. The benefit of implementing the additional works, is that it will significantly reduce the extent of downstream works along Argyle Court (likely confined to road-side drainage) and works required outside of easements.

Figure 6-6 Option 2a – 1% AEP Flood Depth

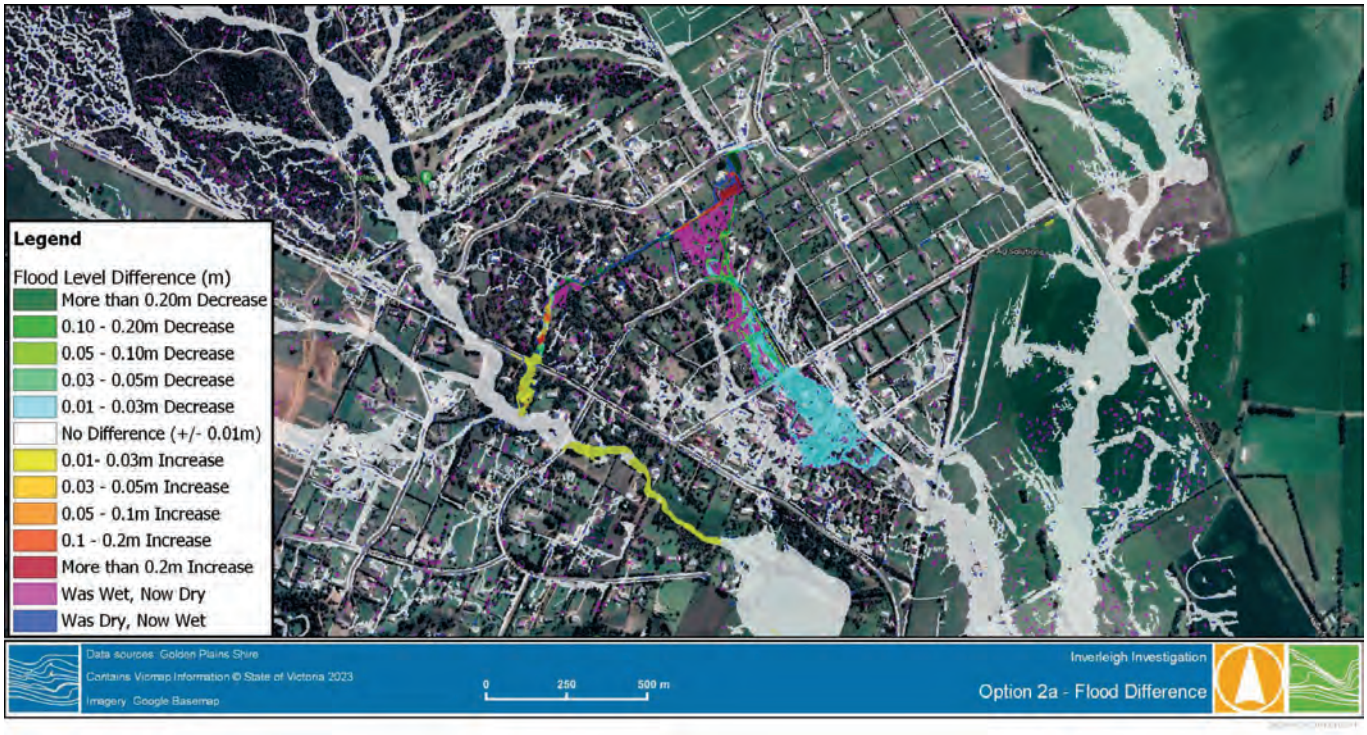

Figure 6-7 Option 2a – 1% AEP Flood Level Difference

6.6 Option 3 – Lowering Faulkner Road

The results for the 1% AEP maximum depth and comparison to existing conditions, is presented in Figure 6-8 and Figure 6-9 respectively. The modelling results demonstrate:

- The lowering of Faulkner Road captures flow from Argyle Court directing it toward and along Common Road.
- The works result in no overtopping of Faulkner Road onto downstream properties, with inundation in this location only caused by localised rainfall.
- The captured flows are conveyed by the proposed concept design with the peak water level ranging between approximately 0.1 m – 0.3 m below the capacity of the roadway along Faulkner Road. Based upon the freeboard, the concept design is considered reasonable for the purposes of this investigation. It is noted that improvement in the upstream easements (behind [redacted] Faulkner Road) could reduce the required works along Faulkner Road.
- The captured flows result in flood depths up to 0.2 m over the road, it is noted that 0.3 m is considered unsafe for vehicle access. It is important to note that this option has been modelled with the roadside drainage free of crossovers, as such additional water would likely be conveyed over the road, potential impacting access via Faulkner Road during flood events.
- The captured flows result in flood level decreases of at most 0.1 m along on the downstream properties along Faulkner Road and downstream along King Road. The subsequent inundation is the result of localised run-off over the natural topography of this area.
- The captured flows result in the exceedance of the capacity of Common Road, resulting in additional inundation on downstream properties. The additional flow will either have to be addressed via further upgrades along Common Road or the establishment of a new outfall. The extent of works and the lack of outfall is a major constraint of this option.
- Overall, the works provide additional protection to Option 1, with the lowering of Faulkner Road protecting all downstream properties. However, the lowering of Faulkner Road requires a significant amount of additional works than Option 1. While it was not assessed it is expected that through the upgrading of easements behind [redacted] Faulkner Road and the implementation of Option 1, a similar result would be achieved. Alternatively, a combination of Option 1 and 3 would likely reduce the extent of lowering required on Faulkner Road.

Figure 6-8 Option 3 – 1% AEP Flood Depth

Figure 6-9 Option 3 – 1% AEP Flood Level Difference

6.7 Option 4 – Golf Club Diversion

The results for the 1% AEP maximum depth and comparison to existing conditions, is presented in Figure 6-10 and Figure 6-11, respectively. The modelling results demonstrate:

- The proposed works implementing a Golf Club Diversion captures overland flow from the upstream development, diverting water along the southern boundary of the Golf Club to the existing flood way.
- The works reduce flood levels by up to 0.1 m and the flow regime to 0.3 m^3/s (a reduction of 0.5 m^3/s) in the downstream drain (upstream of Gregory Drive). This reduction in flow and flood levels reduces the extent of inundation along the existing drain.
- The upstream works reduce flood levels by up to 0.15 m in the (Barrabool Views) basin and 0.1 m in the (Manna Gum) basin, by capturing the upstream flow. This reduction in flood levels results in a discharge from the basins of 1.3 m^3/s (a reduction of 0.6 m^3/s).
- The reduction in discharge from the upstream basins has an impact to flood levels and extent along the Argyle Swale, with levels reduced by up to 0.05 m.
- While the upstream diversion has some minor impacts on levels at [redacted] Argyle Court, downstream of this location the works have negligible impact. Again, highlighted the deficiency that exists in the downstream network.
- Overall, the works alleviate some of the pressure the existing basins are under. For example, based upon the analysis presented in Section 5.1, the works reduce the required storage volume to 3,000 m^3 (a reduction of 2,300 m^3) for the 1% AEP event for a design discharge of 0.6 m^3/s. This combined with the reduction in levels, increases the feasibility of implementing an alternative outlet arrangement. However, it is still noted that achieving the ideal discharge is unlikely within the existing basin footprints and downstream upgrades will not be avoided.

Figure 6-10 Option 4 – 1% AEP Flood Depth

Figure 6-11 Option 4 – 1% AEP Flood Level Difference

6.8 Ultimate Scheme 1 – Option 1, 2 and 4

The results for the 1% AEP and November event for the maximum depth and comparison to existing conditions is presented in Figure 6-12 to Figure 6-15. The modelling results demonstrate:

- 1% AEP Analysis
  - That the combined works do alter the performance of the individual options 1, 2 and 4, with further the reduction in upstream flows improving the performance of the proposed basin.
  - The diversion of upstream flows results in the proposed basin performing better during the entirety of the event. The increase of performance further retards flows, improving conditions downstream. Unlike when implemented alone the new arrangement and increase in basin size improves conditions extending to Faulkner Road. Based on this option the feasibility of designing the outlet arrangement to further retard flows is improved. Though even under the current arrangement required downstream works would be reduced.
  - The performance of the diversion from Argyle to King shows marginal improvement in comparison to when implemented individually, due to the reduction in upstream flows. Though the resulting changes are not significant, with the analysis provided in Option 1 relatively unchanged. It is noted that the reduction in upstream flow likely means the extent of lowering can be reduced.
  - The proposed upgrade to the Argyle Swale captures most of the discharge from the upstream basin.
  - For the 1% AEP event this combined option is considered to be very good. The upstream diversion and increase in basin size alleviates pressure on the Argyle network, while the lowering of the intersection provides protection to properties on the downstream side of Faulkner Road. With additional works to the drainage capacity along Argyle and the easement behind [redacted] Faulkner Road, capturing the majority of overland flow is realistic.
- November Event
  - The combined works demonstrate that they would have significantly improved conditions in November, without fully mitigating inundation to private property.
  - The combined work would have reduced the flood extent and flood levels by 0.15 m downstream of the upgraded basins, while the inundation and overland flow would still have been significant the improvement is evident. It should be stated that the November event as previously discussed was extremely rare, when considering the rainfall and antecedent catchment conditions. As such fully mitigating against these events irrespective of location in Victoria would require a significantly oversized drainage network, well beyond best practice.
  - The performance during the November event also demonstrates the constraint of flow backing up along the Manna Gum estate easement and draining onto downstream properties.

Overall, the implementation of Options 1, 2 and 4 in combination will improve flood conditions during rare events. While for the November event a significant reduction in flooding would have been experienced by residents, however, ultimately not fully mitigated against. This ultimate option would likely require the following works to prevent adverse impacts or prevent existing overland flow:

- Further upgrades increasing the capacity of all options, to prevent exceedance and inundation during the November – considered unrealistic as the level of protection would be beyond best practice.
- Increases to the drainage network along Argyle Court. Noting the extent of works would be significantly reduced as a result of Option 4 – Golf Club Diversion in combination with Option 2 – Big Basin.
- Consideration of removing diversions from Argyle Court to allow majority of water to flow to intersection.
- Upgrades to the easements behind [redacted] Faulkner Road to convey localised run-off and water diverted under Argyle Court.
- Upgrades along King Road to provide capacity for additional flow regime.
- Upgraded of or additional basin at end of King Road to mitigate adverse impacts to downstream farmland.
- Consideration of upgrades to Faulkner Road west [redacted], however, the requirement for this would be removed or reduced should sufficient upgrades occur to the easement behind [redacted] Faulkner Road

Figure 6-12 Ultimate Scheme 1 – 1% AEP Flood Depth

Figure 6-13 Ultimate Scheme 1 – 1% AEP Flood Level Difference

Figure 6-14 Ultimate Scheme 1 – November Event Flood Depth

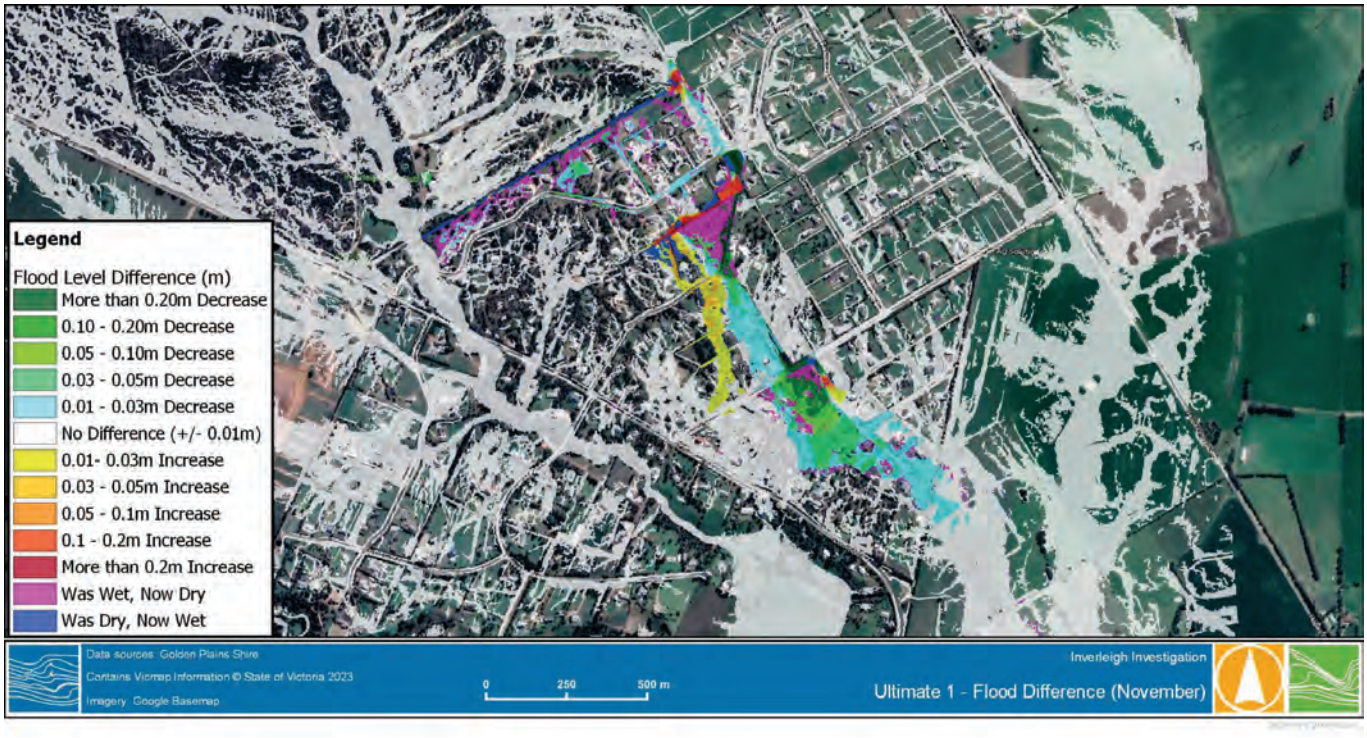

Figure 6-15 Ultimate Scheme 1 – November Event Flood Level Difference

6.9 Ultimate Scheme 2 - Option 3, 2 and 4

The results for the 1% AEP and November event for the maximum depth and comparison to existing conditions is presented in Figure 6-16 to Figure 6-19. The modelling results demonstrate:

- % AEP Analysis
  - That the combined works do alter the performance of the individual options 3, 2 and 4, with further reduction in upstream flows improving the performance of the proposed basin.
  - The diversion of upstream flows results in the proposed basin performing better during the entirety of the event. The increase of performance further retards flows, improving conditions downstream. Unlike when implemented alone the new arrangement and increase in basin size improves conditions extending to Faulkner Road. Based on this option the feasibility of designing the outlet arrangement to further retard flows is improved. Though even under the current arrangement required downstream works would be reduced.
  - The performance of the Faulkner Road lowering improves than when implemented individually, due to the reduction in upstream flows. The reduction in flows would reduce the level of lowering required and reduce the number of upgrades along Common Road and or the required capacity of the alternative outfall at Faulkner Road.
  - The proposed upgrade to the Argyle Swale captures most of the discharge from the upstream basin.
  - For the 1% AEP event this combined option is considered to perform very well and similar to that of option Ultimate 1. This is because the diversion of flows away from the downstream network, would reduce the extent of works along Faulkner Road. The reduction in flow would reduce the required level of lowering, likely making the option more feasible. It should be noted that the overall extent of works for option Ultimate 1 would likely be less but from a flooding perspective alone this option provides more protection. As previously discussed, a combination of Option 1 and 3 or upgrading of the easements behind [redacted] Faulkner Road would likely result in a similar outcome to that presented here.
- November Event
  - The combined works demonstrate that they would have significantly improved conditions in November, without fully mitigating inundation to private property.
  - The combined work would have reduced the flood extent and flood levels by up to 0.3 m downstream of the upgraded basins and would have mitigated the inundation to properties downstream of Faulkner Road (with inundation the result of localised rainfall). As previously noted, designing to such an event, would be providing a level of protection beyond best practice. However, it does demonstrate that the concept design for lowering of Faulkner Road is sufficient for very rare events. This could either mean the concept design provides the desired level of protection or that the lowering and extent of works could be reduced.
  - The performance during the November event also demonstrates the constraint of flow backing up along the Manna Gum estate easement and draining onto downstream properties.

Overall, the implementation of Options 3, 2 and 4 in combination will improve flood conditions during rare events. While for the November event a significant reduction in flooding would have been experienced by residents, however, ultimately not fully mitigated against. This ultimate option would likely require the following works to prevent adverse impacts or prevent existing overland flow:

- Further upgrades increasing the capacity of Option 4, to prevent overtopping during the November – considered unrealistic as the level of protection would be beyond best practice and incur additional construction costs.
- Increases to the drainage network along Argyle Court. Noting the extent of works would be significantly reduced as a result of Option 4 – Golf Club Diversion in combination with Option 2 – Big Basin.
- Consideration of removing diversions from Argyle Court to allow majority of water to flow to intersection.
- Upgrades to the easements behind [redacted] Faulkner Road to convey localised run-off and water diverted under Argyle Court.
- Upgrades along Common Road to the outfall to provide capacity for additional flow regime or the establishment of a new outfall at the intersection of Faulkner Road and Common Road. Noting that the implementation of Option 2a reduces the extent of works required along Common Road or the size of the required outfall.

Figure 6-16 Ultimate Scheme 2 – 1% AEP Flood Depth

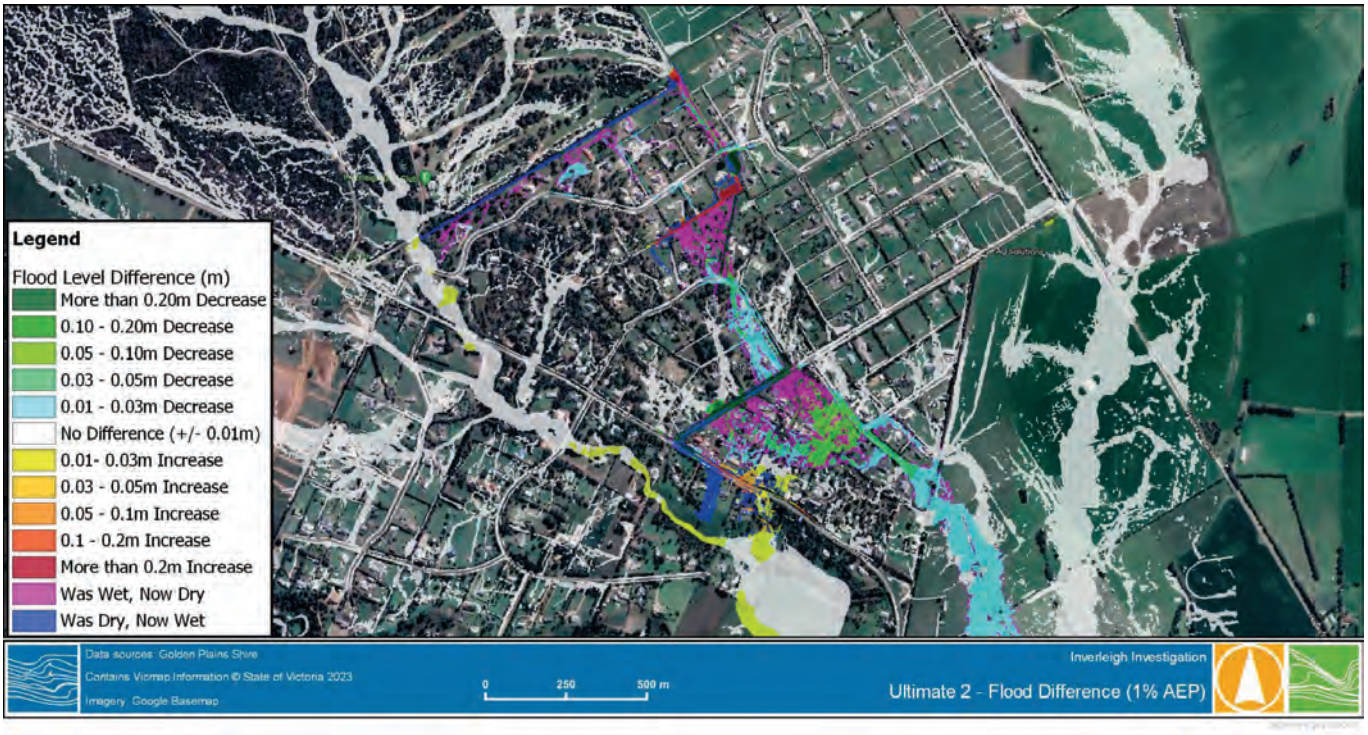

Figure 6-17 Ultimate Scheme 2 – 1% AEP Flood Level Difference

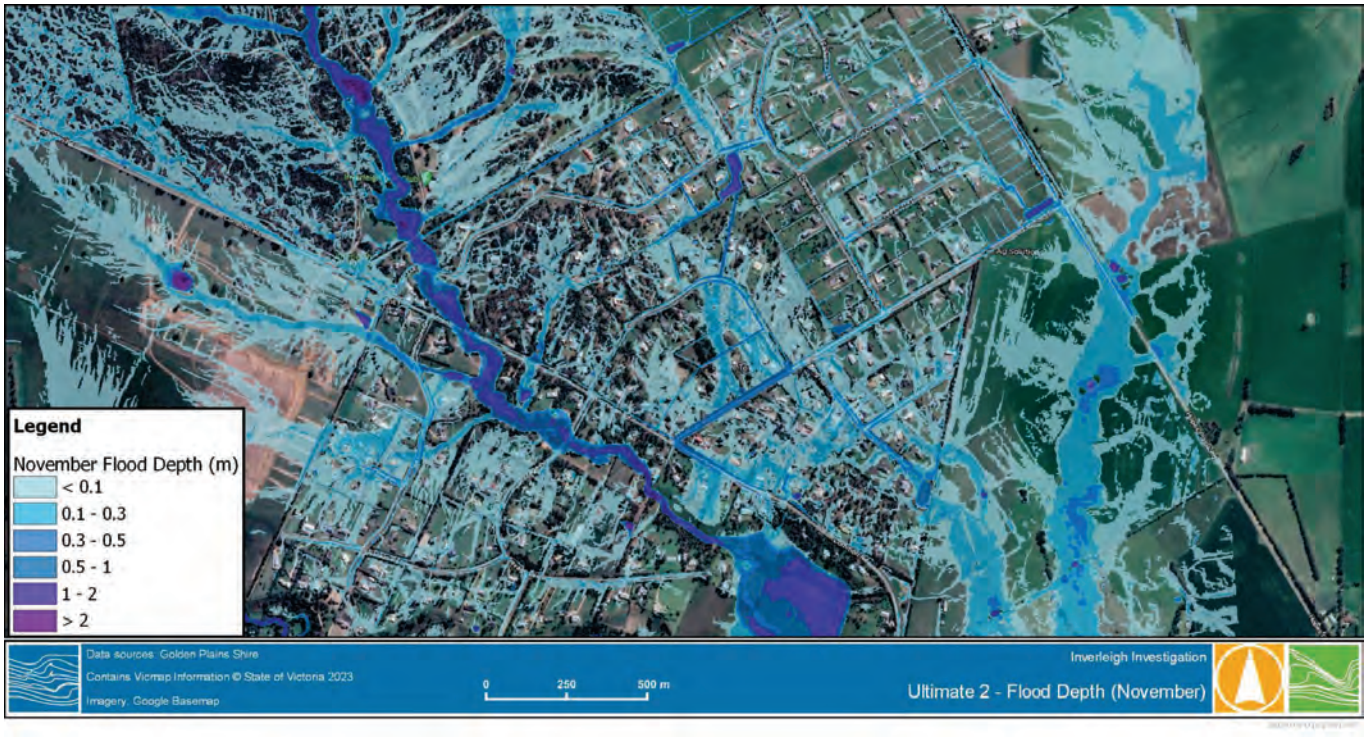

Figure 6-18 Ultimate Scheme 2 – November Event Flood Depth

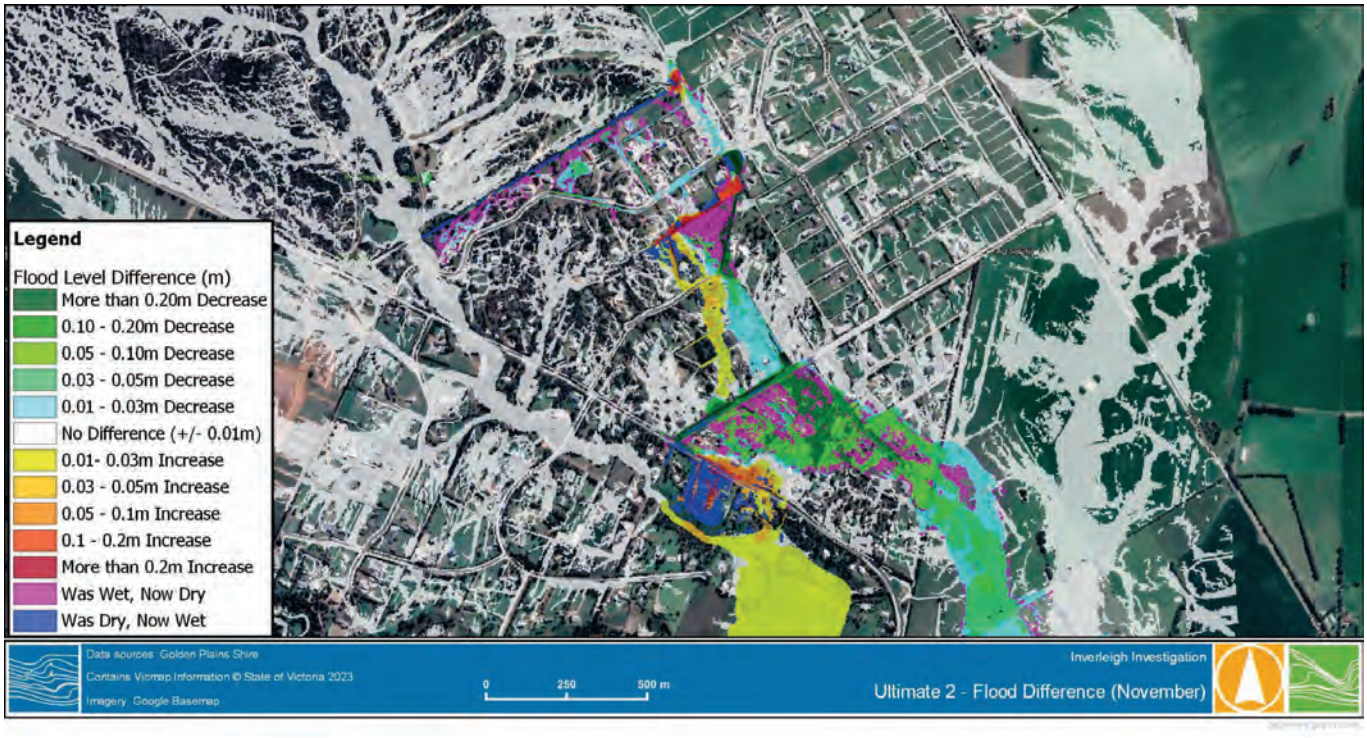

Figure 6-19 Ultimate Scheme 2 – November Event Flood Level Difference

6.10 Ultimate Scheme 3 – Option 1 and 2

The results for the 1% AEP for the maximum depth and comparison to existing conditions is presented in Figure 6-20 and Figure 6-21, respectively. Note this scenario was not tested for the November event as its purpose was to determine the requirement for upstream diversions.

The modelling results demonstrate:

- 1% AEP Analysis
  - That the combined works do not significantly alter the performance of the individual options 1 and 2.
  - The increased basin size has minimal impact to flood levels downstream of the upgraded argyle swale.
  - The diversion from Argyle to King performs the same way it does when implemented individually.
  - The proposed upgrade to the Argyle Swale captures most of the discharge from the upstream basin.
  - The upgraded swale also demonstrates that upgrades throughout the downstream network are required, as the increased flow reaching Argyle Court, results in additional overtopping of the roadway. When compared to the results presented in option Ultimate 1, it demonstrates that to successful convey overland flow from the upstream catchment there is a trade-off between the extent of downstream works required and the diversion of upstream flows away from the downstream network.

Overall, the implementation of Options 1 and 2 in combination will improve flood conditions during rare events. While it was not tested for the November event based upon the performance of option Ultimate 2, it is known that even with upstream diversion, inundation in the lower network is exacerbated. This ultimate option would likely require the following works to prevent adverse impacts or prevent existing overland flow:

- Consideration of upstream diversion via Option 2a - Western diversion or Option 4 – Golf Club Diversion.
- Additional increases in basin size and extent – considered unfeasible without land-take.
- Increases to the drainage network along Argyle Court. Noting the extent of works may be reduced if upstream diversions are implemented.
- Consideration of removing diversions from Argyle Court to allow majority of water to flow to intersection.
- Upgrades to the easements behind [redacted] Faulkner Road to convey localised run-off and water diverted under Argyle Court.
- Upgrades along King Road to provide capacity for additional flow regime.
- Upgraded of or additional basin at end of King Road to mitigate adverse impacts to downstream farmland.
- Consideration of upgrades to Faulkner Road west [redacted], however, the requirement for this would be removed or reduced should sufficient upgrades occur to the easement behind [redacted] Faulkner Road.

Figure 6-20 Ultimate Scheme 3 – 1% AEP Flood Depth

Figure 6-21 Ultimate Scheme 3 – 1% AEP Flood Level Difference (m)

6.11 Ultimate Scheme 4 - Option 3 and 2

The results for the 1% AEP for the maximum depth and comparison to existing conditions is presented in Figure 6-22 and Figure 6-23, respectively. Note this scenario was not tested for the November event as its purpose was to determine the requirement for upstream diversions.

- 1% AEP Analysis demonstrated
  - That the combined works do not significantly alter the performance of the individual options 2 and 3.
  - The increased basin size has minimal impact to flood levels downstream of the upgraded argyle swale.
  - The lowering of Faulkner Road performs the same way it does when implemented individually.
  - The proposed upgrade to the Argyle Swale captures most of the discharge from the upstream basin.

Overall, the implementation of Options 2 and 3 in combination will improve flood conditions during rare events. While it was not tested for the November event based upon the performance of option Ultimate 2, it is known that even with upstream diversion, inundation in the lower network is exacerbated.. This ultimate option would likely require the following works to prevent adverse impacts and treat existing overland flow:

- Consideration of upstream diversion via Option 2a or Option 4.
- Additional increases in basin size and extent – considered unfeasible without land-take.
- Increases to the drainage network along Argyle Court. Noting the extent of works may be reduced if upstream diversions are implemented.
- Consideration of removing diversions from Argyle Court to allow majority of water to flow to intersection.
- Upgrades to the easements behind [redacted] Faulkner Road to convey localised run-off and water diverted under Argyle Court.
- Upgrades along Common Road to the outfall to provide capacity for additional flow regime or the establishment of a new outfall at the intersection of Faulkner Road and Common Road.

Figure 6-22 Ultimate Scheme 4 – 1% AEP Flood Depth

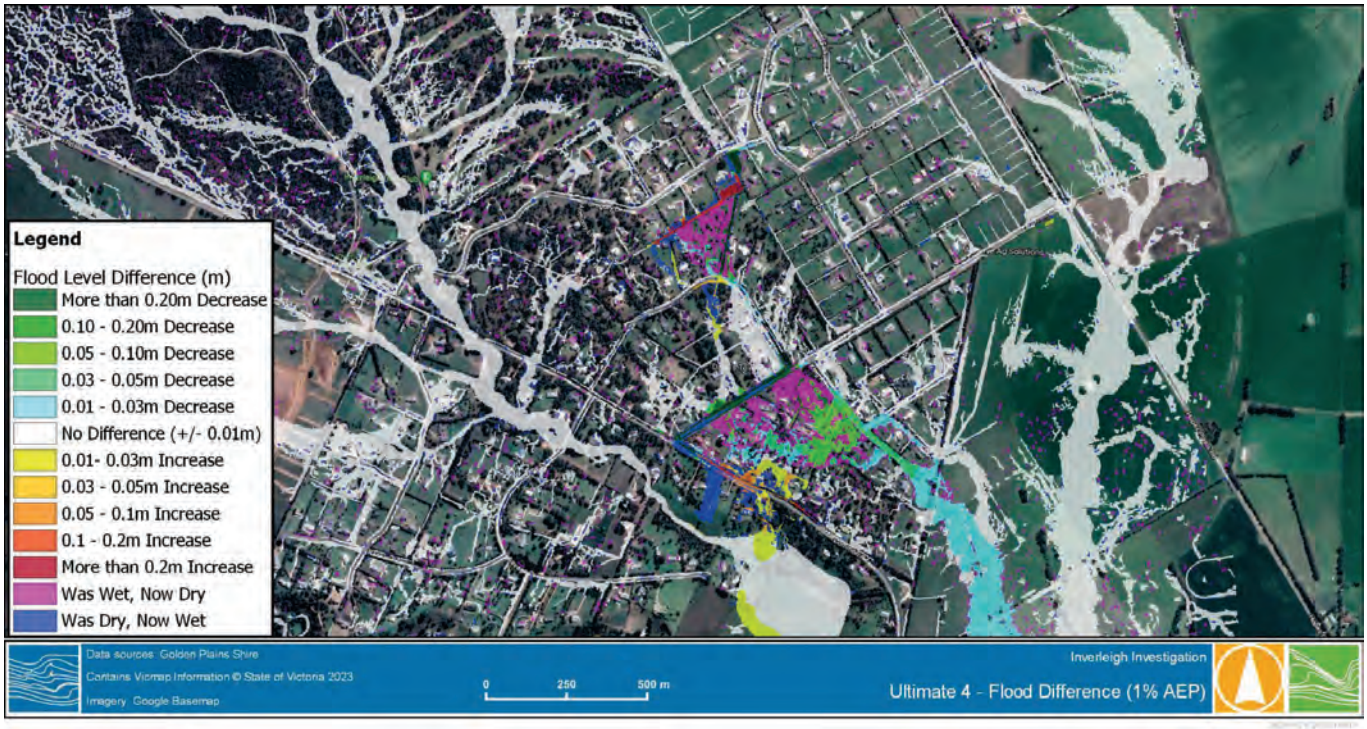

Figure 6-23 Ultimate 4 Scheme – 1% AEP Flood Level Difference (m)

6.12 Ultimate Scheme 5 - Option 1 and 2a

The results for the 1% AEP and November event for the maximum depth and comparison to existing conditions is presented in Figure 6-24 to Figure 6-27. The modelling results demonstrate:

- 1% AEP Analysis
  - That the combined works do alter the performance of the individual options 1 and 2a, with further reductions at the intersection of Argyle and Faulkner Road due to the reduction in upstream flows.
  - The increased basin size and western outfall has a major impact to flood levels and extent downstream of the basins to Faulkner Road.
  - The performance of the diversion from Argyle to King shows marginal improvement in comparison to when implemented individually, due to the reduction in upstream flows. Though the resulting changes are not significant, with the analysis provided in Option 1 relatively unchanged.
  - The proposed upgrade to the Argyle Swale captures most of the discharge from the upstream basin.
  - For the 1% AEP event this combined option is considered to perform better than those previously presented, this is because the proposed western diversion services more catchment than the Golf Club Diversion and allows the upgraded basin to divert high flows away from the downstream network. This diversion of high flows is not possible when the basins are upgraded alone. As such if the basins can be increased in size, Option 2a should be prioritized over Option 4, when considering flood implications alone.
- November Event
  - The combined works demonstrate that they would have significantly improved conditions in November, without fully mitigating inundation to private property.
  - The combined work would have reduced the flood extent and flood levels by 0.2 m downstream of the upgraded basins, while the inundation and overland flow would still have been significant the improvement is evident. As previously noted, designing to such an event, would be providing a level of protection beyond best practice..
  - If the combined works were designed to the November event further upgrades to the western outfall and Argyle-King Diversion would be required. This would result in subsequent upgrades to the outfall at [redacted] Common Road and along King Road.

Overall, the implementation of Options 1 and 2a in combination will improve flood conditions during rare events. While for the November event a significant reduction in flooding would have been experienced by residents, however, ultimately not fully mitigated against. This ultimate option would likely require the following works to prevent adverse impacts or prevent existing overland flow:

- Further upgrades increasing the capacity of Option 1 and 2a, to prevent inundation during the November – considered unrealistic as the level of protection would be beyond best practice.
- Increases to the drainage network along Argyle Court. Noting the extent of works would be significantly reduced as a result of Option 2a.
- Consideration of removing diversions from Argyle Court to allow majority of water to flow to intersection.
- Upgrades to the easements behind [redacted] Faulkner Road to convey localised run-off and water diverted under Argyle Court.
- Upgrades along King Road to provide capacity for additional flow regime.
- Upgraded of or additional basin at end of King Road to mitigate adverse impacts to downstream farmland.
- Consideration of upgrades to Faulkner Road west [redacted] however, the requirement for this would be removed or reduced should sufficient upgrades occur to the easement behind [redacted] Faulkner Road.

Figure 6-24 Ultimate Scheme 5 – 1% AEP Flood Depth

Figure 6-25 Ultimate Scheme 5 – 1% AEP Flood Level Difference (m)

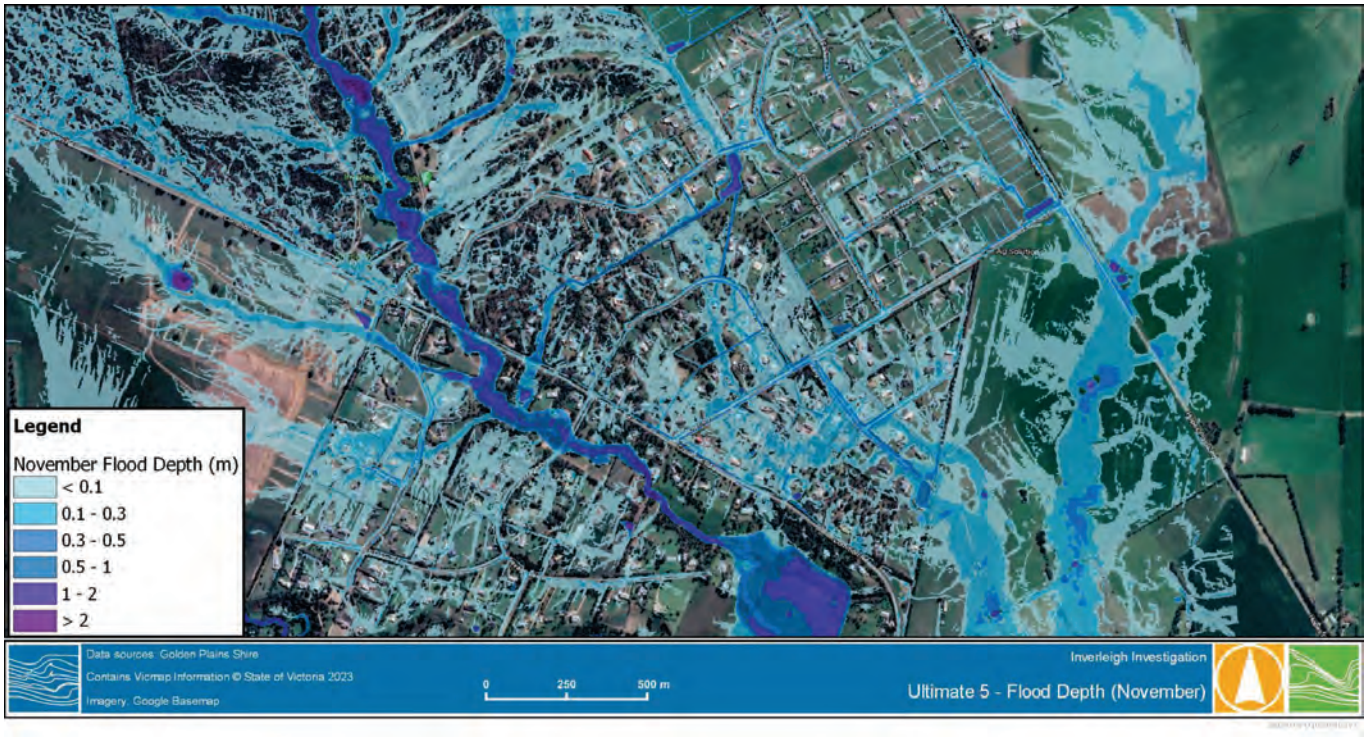

Figure 6-26 Ultimate Scheme 5 – November Event Flood Depth

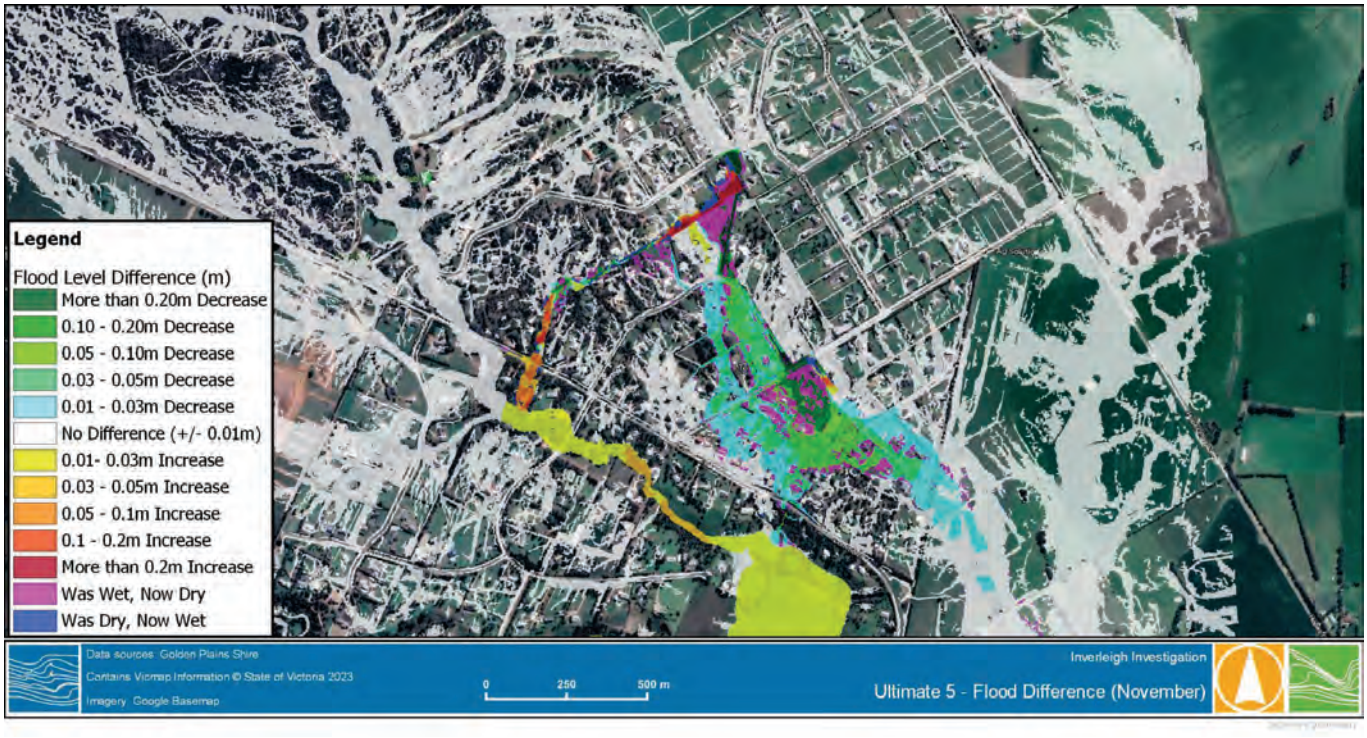

Figure 6-27 Ultimate Scheme 5 – November Event Flood Level Difference

6.13 Ultimate Scheme 6 - Option 3 and 2a

The results for the 1% AEP and November event for the maximum depth and comparison to existing conditions is presented in Figure 6-28 to Figure 6-31. The modelling results demonstrate:

- 1% AEP Analysis
  - That the combined works do alter the performance of the individual options 3 and 2a, with further reductions downstream of Faulkner Road and improvements along Common Road due to the reduction in upstream flows from the western outfall diversion
  - The increased basin size and western outfall has a major impact to flood levels and extent downstream of the basins to Faulkner Road.
  - The performance of the Faulkner Road lowering improves than when implemented individually, due to the reduction in upstream flows. The reduction in flows would reduce the level of lowering required and reduce the number of upgrades along Common Road and or the required capacity of the alternative outfall at Faulkner Road.
  - The proposed upgrade to the Argyle Swale captures most of the discharge from the upstream basin.
  - For the 1% AEP event this combined option is considered to the best when compared to those previously presented. This is because the diversion of flows away from the downstream network, would reduce the extent of works along Faulkner Road. The reduction in flow would reduce the required level of lowering, likely making the option more feasible. It should be noted that the overall extent of works for option Ultimate 5 would likely be less but from a flooding perspective alone this option provides more protection. As previously discussed, a combination of Option 1 and 3 or upgrading of the easements behind [redacted] Faulkner Road would likely result in a similar outcome to that presented here.
- November Event
  - The combined works demonstrates that they would have significantly improved conditions in November, without fully mitigating inundation to private property.
  - The combined work would have reduced the flood extent and flood levels by up to 0.3 m downstream of the upgraded basins and would have mitigated the inundation to properties downstream of Faulkner Road (with inundation the result of localised rainfall). As previously noted, designing to such an event, would be providing a level of protection beyond best practice. However, it does demonstrate that the concept design for lowering of Faulkner Road is sufficient for very rare events. This could either mean the concept design provides the desired level of protection or that the lowering and extent of works could be reduced.
  - If the combined works were designed to the November event further upgrades to the western outfall would be required. This would result in subsequent upgrades to the outfall at [redacted] Common Road.

Overall, the implementation of Options 3 and 2a in combination will improve flood conditions during rare to very rare events. This ultimate option would likely require the following works to prevent adverse impacts or prevent existing overland flow:

- Further upgrades increasing the capacity of option 2a for the November event - considered unrealistic as the level of protection would be beyond best practice.
- Increases to the drainage network along Argyle Court. Noting the extent of works would be significantly reduced as a result of Option 2a.
- Consideration of removing diversions from Argyle Court to allow majority of water to flow to Faulkner Road.
- Upgrades to the easements behind [redacted] Faulkner Road to convey localised run-off and water diverted under Argyle Court.
- Upgrades along Common Road to the outfall to provide capacity for additional flow regime or the establishment of a new outfall at the intersection of Faulkner Road and Common Road. Noting that the implementation of Option 2a reduces the extent of works required along Common Road or the size of the required outfall.

Figure 6-28 Ultimate Scheme 6 – 1% AEP Flood Depth

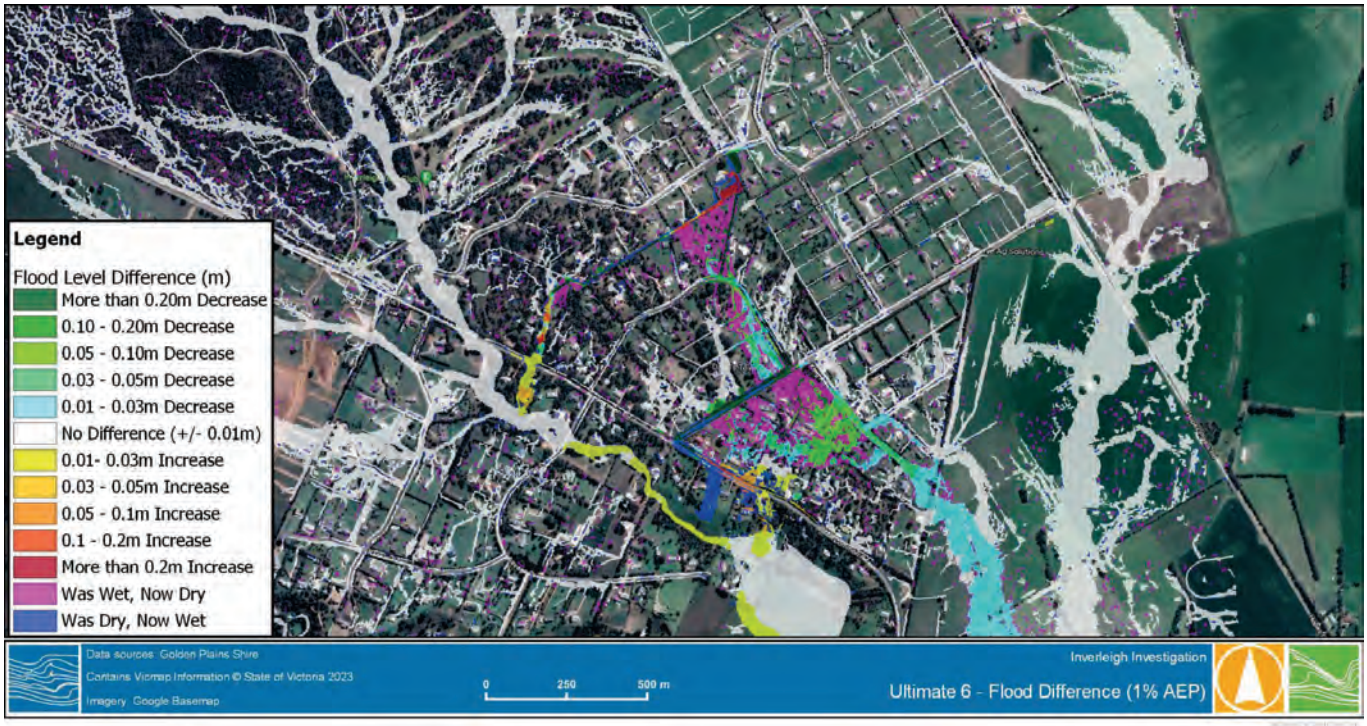

Figure 6-29 Ultimate Scheme 6 – 1% AEP Flood Level Difference (m)

Figure 6-30 Ultimate Scheme 6 – November Event Flood Depth

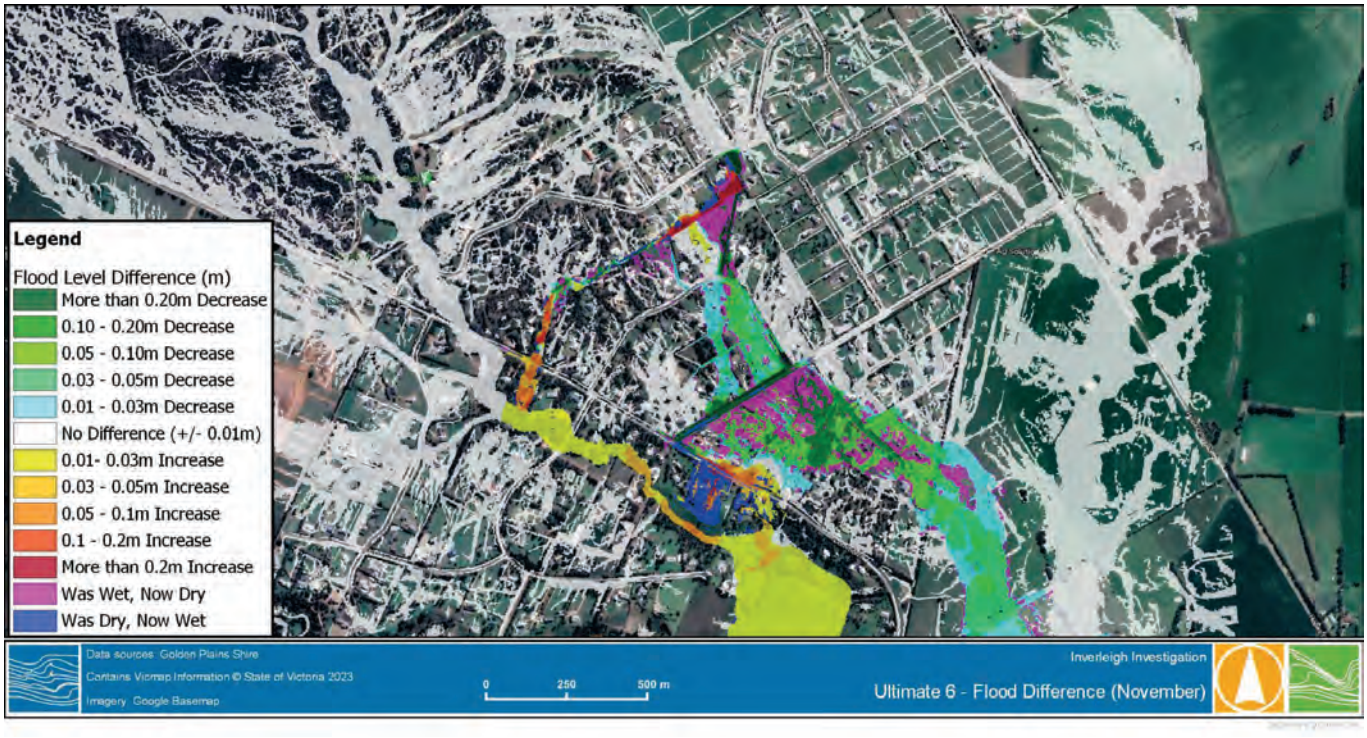

Figure 6-31 Ultimate Scheme 6 – November Event Flood Level Difference

7 OVERALL ASSESSMENT SUMMARY

This investigation represents an extensive analysis of the drainage constraints within Inverleigh in the Common Road development estates. The investigation has aimed to describe the existing network and detail how some of the problems experienced by landowners have worsened as a result of development, lack of maintenance and the shortcomings of the original drainage infrastructure. This investigation has found the existing drainage infrastructure is insufficient for the catchment it services, for the following main reasons:

- Reduction in capacity from upstream to downstream within the drainage network.
- Upstream development designed to pre-developed flow rate and the not capacity of the downstream network.
- Lack of maintenance of existing infrastructure.
- Roadways not designed to carry excess overland flow in key locations.

Following the identification of the cause of the drainage issues in the area, several mitigation measures and drainage upgrades were considered. The identification of mitigation measures and drainage upgrades were constrained by the existing development layout, existing vegetation, the topography and the rural aesthetic the estates aim to achieve. These constraints meant that mitigation measures that improved or alleviated pressure from the existing network, without the requirement for significant land take or vegetation removal were prioritised. However, it was determined that to achieve the desired outcomes minor works along easements and roadside drains, would likely be insufficient.

With consideration of flood modelling of the 10% AEP, 1% AEP and November 2022 event and the existing constraints 5 main mitigation measures and several additional works were identified. The mitigation measures and works identified include:

- Mitigation Options
  - Option 1 – Lowering of the intersection of Argyle Court and Faulkner Road to drain toward King Road.
  - Option 2 – Increases the basin size at Gregory Drive by combining the basin footprints into one.
    - Option 2a – This involves the re-direction of high-flows from the basin toward Common Road directly west out falling via the existing gully and easements.
  - Option 3 - Lowering / re-grading Faulkner Road to Common Road, with the roadway crest lowered below the surrounding topography.
  - Option 4 – Golf Club Diversion, this would utilise the easement that runs adjacent to the golf course and direct upstream flows from the upstream development away from the downstream network.
- Additional Works Required or to be considered
  - Maintenance of existing drains and/or re-establishment of design cross section.
  - Culvert Upgrades along Argyle Park and under Faulkner Road. This was previously proposed and involved upgrading existing 300 mm RCP culverts to 900 x 300 mm box culverts along Argyle Park, including the culvert/s at the intersection with Faulkner Road (where applicable). With the addition of a single 900 x 300 mm box culvert under Argyle Park at the base of the easement [redacted] Argyle Park.
  - Upgrade of Argyle Court swale downstream of the basins, establishing a consistent cross-sectional area. It is noted that this was modelled as part of the ultimate solution. Note for the ultimate modelled mitigation options this was adopted.

- Outfall design at [redacted] Common Road. The existing gully is understood to drain through this [redacted] ([redacted] waterway), establishing a designed outfall to reduce the inundation [redacted] should be considered.
- Upgrade of the easement/s drain behind [redacted] Faulkner Road. Upgrading these easements will aid in capturing overland flows breaking out from upstream, diverting water away from Faulkner Road.
- Lowering of Argyle Court or increasing of roadside drain capacity (including crossovers) from [redacted] Argyle Court to Faulkner Road. Note this should only be undertaken with subsequent upgrades downstream.

The identified mitigation measures were then tested in the hydraulic model for the 1% AEP and November events, with an assessment of the performance of the options individually and together in various combinations used to further discuss and analysis the performance of the drainage network. As no single mitigation options was able to adequately address the range of drainage deficiencies within the catchment, a number of mitigation schemes were proposed. These Ultimate Schemes combine options in order to assess the best outcomes at a catchment scale.

Having regard to the above the following scenarios were run and assessed:

- Each Individual mitigation option separately.
- Ultimate Scheme 1 & 2 – Option 2, Option 4 and Option 1 or Option 3 (+ Argyle Swale Upgrade)
- Ultimate Scheme 3 & 4 - Option 2 and Option 1 or Option 3 (+ Argyle Swale Upgrade)
- Ultimate Scheme 5 & 6 - Option 2a and Option 1 or Option 3 (+ Argyle Swale Upgrade)

The findings of the various scenarios are detailed in Section 6 with each option modelled resulting in an improvement to flood conditions within the estate to varying degrees. Based on the findings of the modelling, it is recommended that council take immediate action to address the identified drainage network deficiencies, including:

- Upgrades to the network to adequately convey flow to the original intended outfall (Commons Road) or alternative outfalls (King Road or natural gully)

  Consideration of the identified constraints and required works will inform the preferred option out of Option 1 – Argyle King Intersection or Option 3 – Faulkner Road Lowering.
- Undertake works the upper catchment to reduce flow discharging to the Faulkner Road drains.

  Consideration of identified constraints of gold club diversion, drain diversion and works will inform choice of option 2a – western diversion or option 4 – Golf Club diversion, both require new drainage alignments but reduce the extent of downstream works required.
- Are alternative measures preferred to those presented?

  For example, all options diverting or conveying flow could be achieved by alternative options. Such as pipes sized to convey a similar flow. The required capacity of any alternatives could be sized to the deficiencies provided in Section 5.2.

Ultimately, any works or upgrades undertaken in the estates and project area should be implemented from downstream to upstream extending from the intended outfalls. This is because any upgrade undertaken prior to a subsequent upgrade downstream will likely result in adverse impacts within the downstream network. Based on this the performance of the proposed mitigation options is provided in Table 7-1, with the options presented in Figure 7-1. It is noted that further information on each option and the individual works is provided in the body of the report.

Table 7-1 Assessment of Mitigation Options

Option / Work	Design Event	Prerequisite	Benefits	Constraints	Extent of Work (estimates)	Comment
Option 1 – Argyle King Intersection	1% AEP	Upgrades or design of new outfall Upgrades along King Road	Significant – mitigates overland flow over intersection on downstream properties. Involves less road lowering than Option 3.	Diverts water to drainage network not designed for additional catchment. As such requires downstream works extending to King Road outfall. Overland flow on King Road prevents access and safe evacuation of development during flood events.	Length of works 210 m. 2000 m3 of cut. Plus, downstream works.	Downstream works reduced when implemented with upstream diversions, such as Option 2a or Option 4.
Option 2 – Big Basin	10% AEP	None	Minor when implemented alone for rare events. Would provide benefit in more common events, likely up to the 10% AEP event.	Available land and design levels.	Total Footprint 6,000 m^2 4,950 m^3 of cut 1,600 m^3 fill Plus outlet design works.	When implemented alone provides little benefit in significant events. If minor events are targeted alteration to existing basin outfall may achieve similar results.
Option 2a - Big Basin Western Outfall	1% AEP	Determination, design and construction of outfall at [redacted] Common Road. Combination of basins.	Utilises existing easements. Significant – mitigates the extent of overland flow downstream of the basins and would reduce the extent of downstream works required.	Likely requires significant vegetation removal. Available land. Requires Option 2 to be built.	Length of drain 850 m. 2,750 m^3 of cut 250 m^3 of fill Plus, outfall works.	The best option for preventing inundation between downstream of the Gregory basins and upstream of Faulkner Road.

Option / Work	Design Event	Prerequisite	Benefits	Constraints	Extent of Work (estimates)	Comment
Option 3 – Faulkner Road Lowering	1% AEP	Upgrades or design of new outfall. Upgrades along Common Road	Significant – mitigates overland flow over Faulkner Road on downstream properties.	Requires extensive roadworks. Requires upgrades downstream. Overland flow on Faulkner Road reduces accessibility of estates during flood events.	Length of works 650 m. 8,500 m^3 of cut. Outfall required to be determined. Plus, downstream upgrades.	Potential works reduced or avoided if implemented with Option 1 and upgrades to the easements behind [redacted] Faulkner Road or Option 2a. A balance between Option 1 and 3 is considered viable but would require further design.
Option 4 – Golf Club Diversion	1% AEP	Determination, design and construction of outfall.	Moderate – alleviates pressure on downstream network, increasing the performance of the existing basins and downstream network.	Easement utilised does not extend to upstream point. Would require vegetation removal or boring to connect upstream and downstream points.	Length of drain 1000 m. 3,500 m^3 of cut 500 m^3 of fill Plus, outfall works.	If the Gregory basins cannot be combined is the only realistic option to divert some upstream flows from the downstream network. If the Gregory basins can be combined Option 2a provides significantly more benefit to downstream network. Not required to be implemented if Option 2a is adopted.

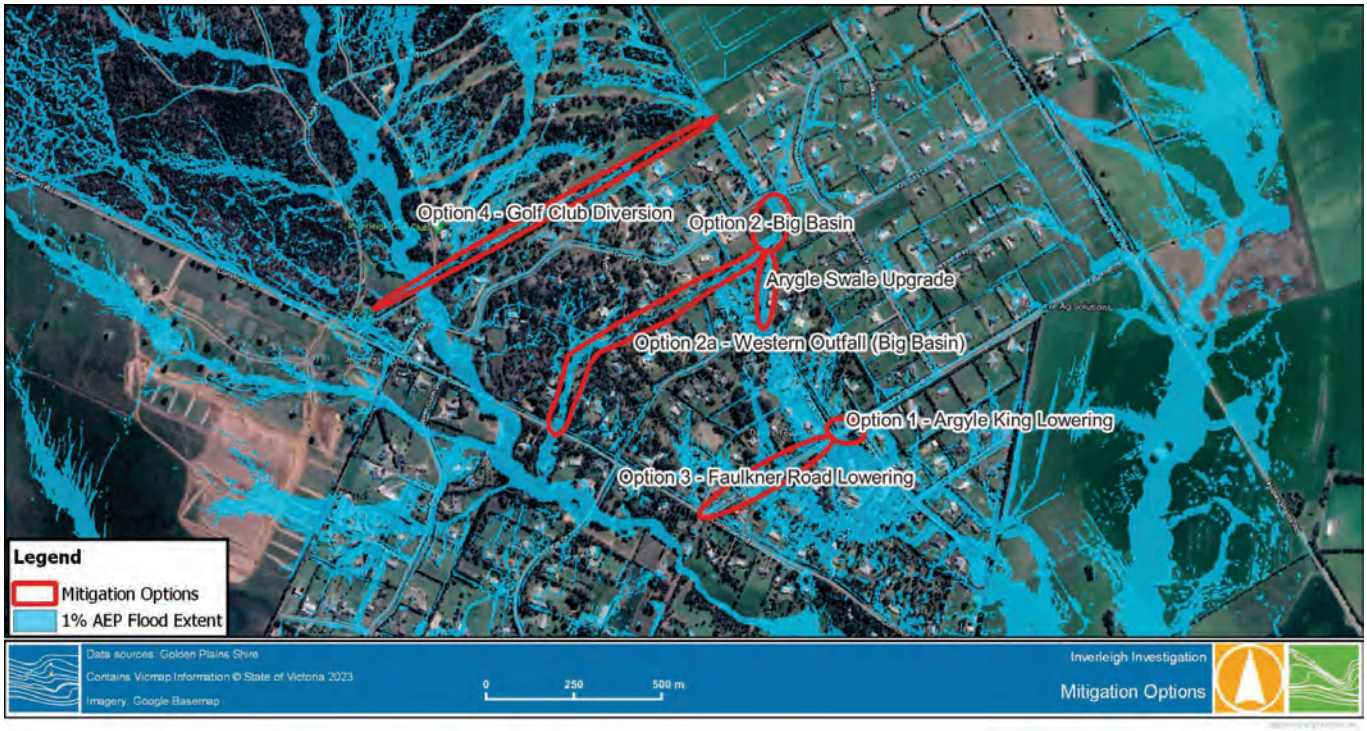

Figure 7-1 Mitigation Options

8 RECOMMENDATION

This investigation has identified several potential mitigation options and works, that if implemented will provide a more efficient drainage network. The performance and constraints of each option have been extensively discussed throughout this report. It is appreciated that there will also be a trade-off between the ideal scenario and the realistic option, once constraints outside of the scope of this investigation are considered (i.e. cost and constructability). As such it is important to note the following recommendations have been made considering with the following criteria:

- Flood protection.
- Required additional works.
- Individual estimated extent of works. Noting no costing has been undertaken.

Based upon the above criteria and the assessed mitigation options, the following recommendations in order of priority are made:

- Implementation of either **Option 1** – Lowering of Argyle Court to King Road intersection or **Option 3** – Lowering of Faulkner Road. Noting the following:
  - Both of these options are within the downstream network and mitigate flooding south of Faulkner Road to varying degrees.
  - ***Option 3*** provides the greatest reduction in flood risk to the Faulkner Rd, King Road area, however will require significantly earth works, and is likely to be the more costly of the two options.
  - Overall ***Option 1*** is considered to be the more realistic solution, yielding similar results to what can likely be achieved by **Option 3**. However it does rely on subsequent works including the following:
    - Upgrading or re-establishment of easements behind [redacted] Faulkner Road. It is noted that maintenance of these easements is recommended for immediate action.
    - Upgrading culvert crossovers and the road-side drainage down King Road.
  - Option 3 would require additional works to the Commons Road drainage connection. It is possible that an additional drainage easement and pipe connection from the corner of Faulkner Rd and Commons Road to the downstream waterway be constructed. This would require council to establish a new easement. Whilst this option does require extensive earthworks it would also offer a potential solution to ongoing erosion issues within the Commons Road Drain.
- Further investigation of viability Option 2a - Big Basin with western outfall.
  - Increasing the basin size alone has minimal benefit for rare events. However, if the increase in basin size can be implemented with the western outfall the increase in basin size and flow diversion significantly improves flood conditions, while also reducing the extent of downstream works required.
- Further investigation of Option 4 – Golf Club Diversion
  - If Option 2a is not viable, the most achievable option that will aid in reducing works downstream becomes Option 4.
  - Option 4 when implemented improves the viability of increasing the basin size and or the feasibility of establishing better outlet arrangements within the existing footprints.

Based on the information provided above it is recommended that an action plan which identifies which of the mitigation options (or their alternatives) are to be implemented. This is crucial as the extent of works for the individual mitigation options are dependent upon which (if any other) option they are coupled with as is indicated by the analysis of the scheme options. *For example, if Option 2a – Big Basin with western outfall is*

implemented with Option 1 – Lowering of Argyle Court to King Road intersection, the required roadway lowering, and downstream works involved with Option 1 is reduced.

Based on the findings of this investigation, Table 8-1, identifies the best combination of mitigation options considering flood protection alone.

Table 8-1 Ideal Combined Options

Option	Option 1	Option 2	Option 2a	Option 3	Option 4
Option 1 - Lowering intersection of Argyle Court to King Road	N/A	✗	✓	○	✓
Option 2 - Increasing Basin Size	✗	N/A	N/A	✗	✓
Option 2a - Western Basin Outfall Drain	✓	Included	N/A	✓	○
Option 3 - Lowering Faulkner Road	○	✗	✓	N/A	✓
Option 4 - Golf Club Diversion	✓	✓	○	✓	N/A

✓ Best Option ○ Similar Option ✓ Second Best Option ✓ Third Best Option ✗ Not Recommended

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