9. Discussion of Floodplain Management Measures

9.1 Overview

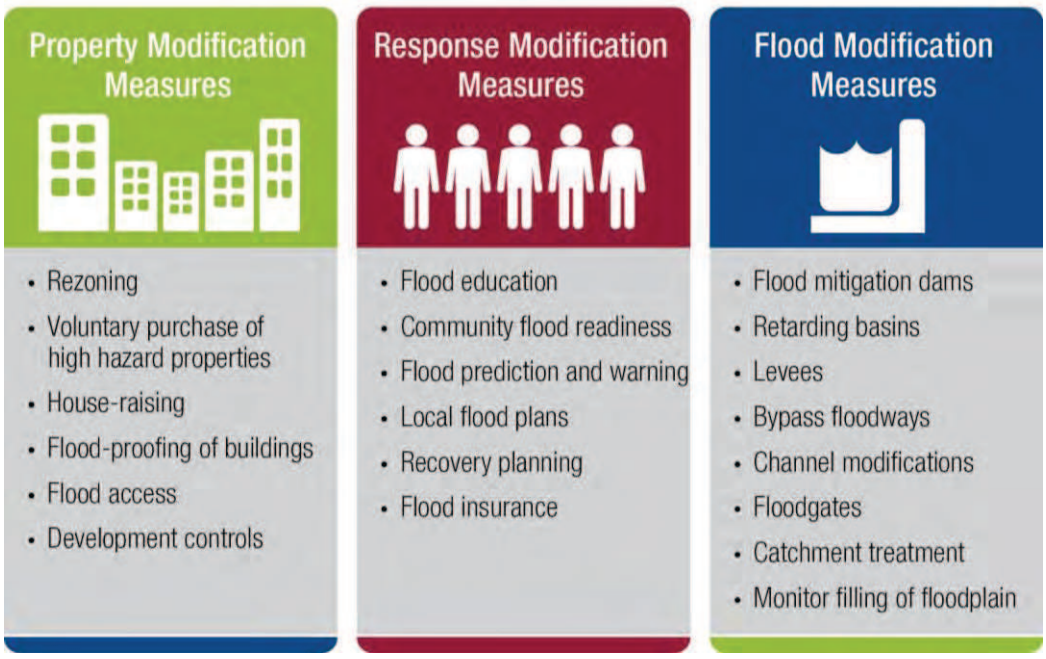
One of the objectives of this Floodplain Risk Management Study was to identify and compare various floodplain risk management options to deal with existing and future flood risk in the study area, considering and assessing their social, economic, ecological and cultural impacts and their ability to mitigate flood impacts.

The *Floodplain Development Manual* (NSW Government, 2005) describes floodplain risk management measures in three broad categories as described below:

- Property modification measures involve modifying existing properties (for example, house-raising) and/or imposing controls on new property and infrastructure development (for example, floor height restrictions);
- Response modification measures involve modifying the response of the population at risk to better cope with a flood event (for example improving community flood readiness); and
- Flood modification measures involve modifying the behaviour of the flood itself (for example, construction of a levee to exclude floodwaters from an area or flood retarding/detention basins to store floodwaters and reduce peak outflows).

Examples of measures falling under the three categories are outlined in Figure 9-1. Some of these measures may or may not be appropriate in a particular catchment, depending on factors such as the flooding behaviour and patterns of development.

Figure 9-1 Floodplain Risk Management Measures *(Source: Floodplain Development Manual, 2005)*



9.2 Flood Modification Measures

A long-list consisting of 28 potential site-based flood modification options were identified based on the broad types of options summarised on Figure 9-1. These were refined to a short-list of ten options for detailed assessment in consultation with Council and the FRMC with consideration of the main problem areas for flooding, likely hydraulic effectiveness and feasibility, site and engineering constraints, land ownership issues and environmental and heritage considerations. The short-listed options consist of drainage upgrade and channel widening options and are discussed in this section. Economic assessment for savings in flood damages by the mitigation options assumes a 50 year design life and a 7% discount rate. A summary of the description and evaluation of the options is provided in Section 9.2.4. The locations of the options are shown on Figure 9-2.

9.2.1 Drainage Capacity Upgrades

This type of flood modification measure involves the upsizing or upgrading of capacity of existing drainage network pipes and road crossing culverts or bridges in order to convey more flood flows in the drainage line, improving flooding conditions upstream and along the upgraded line. Most drainage infrastructure in the catchment was constructed a number of decades ago to a lower design standard. As such existing capacity is typically limited the very frequent flood events, less than, say, the 20% AEP event. Space and cost constraints usually mean that large (e.g. 1% AEP) flood event flows cannot be feasibly catered for by retrofitted drainage upgrades.

Increased flow capacity of drainage structures may improve flooding in upstream areas, but may also result in increased flooding downstream as the flood flows are more efficiently conveyed and discharged into these downstream areas. Additional measures may be required to mitigate these resultant downstream flood impacts.

9.2.1.1 Burns Road crossing (Option D1)

Burns Road is a major road thoroughfare linking Hornsby and Waitara through North Wahroonga to St Ives and on to the City. It crosses Lovers Jump Creek in the mid-section of the catchment. The existing crossing structure consists of a 2.8m x 2.7m box culvert and twin 1.75m diameter pipes.

There is no constrained creek channel downstream of the road crossing. There is a high cliff about 15m downstream of the road, with the creek plunging over a 10m waterfall section. The creek upstream of the road has a defined low flow channel with banks that grade at a gentle slope away from the creek.

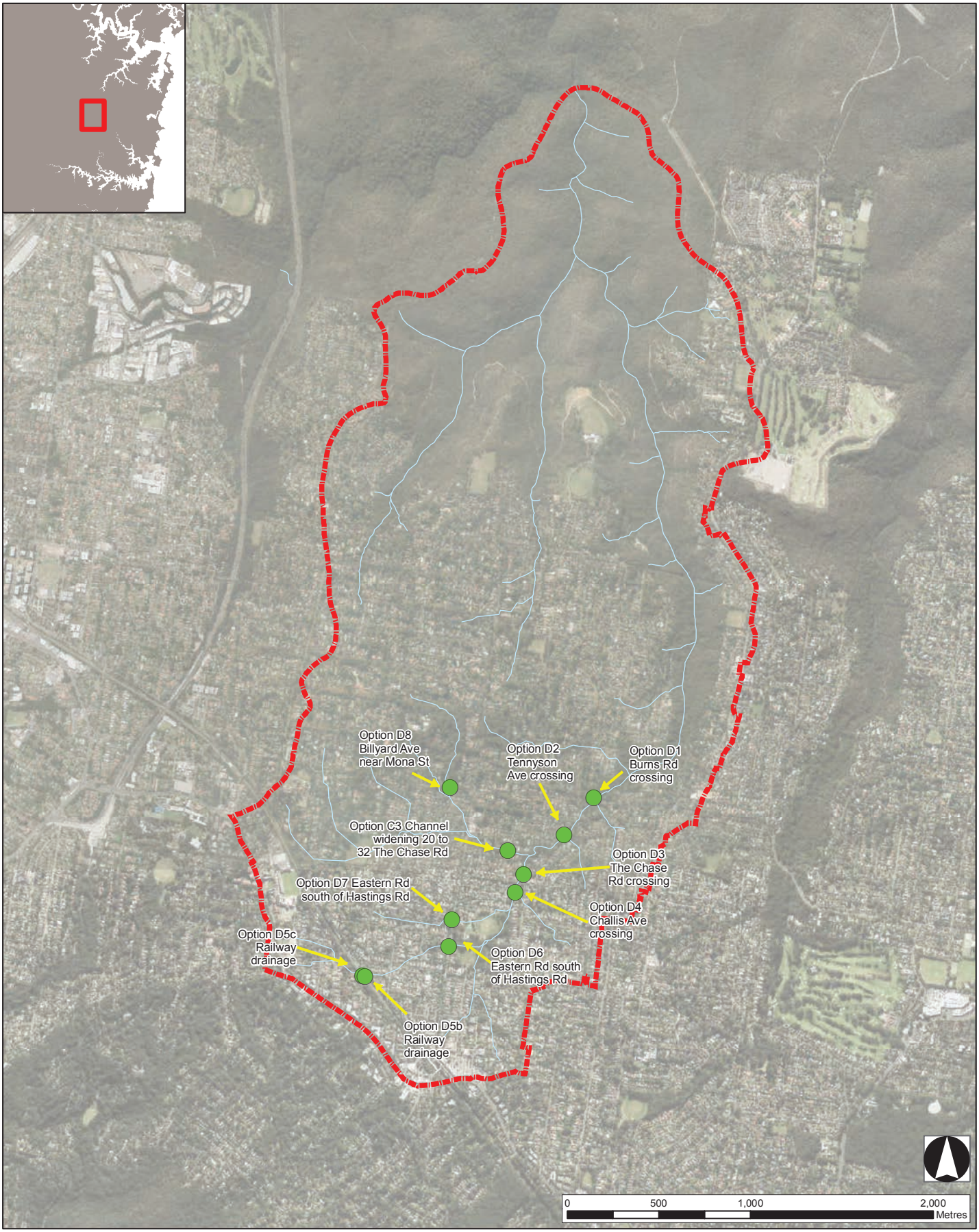
Hydraulic aspects

The road is affected by creek flooding in the 20% AEP event but only to shallow depths. The road is significantly overtopped in the 1% AEP event. Peak flows upstream of the road are summarised in Table 9-1.

Table 9-1: Summary of flows at Burns Road

Flow component	Peak Flow (m^3/s)		
	20% AEP	5% AEP	1% AEP
Road overflow	1.8	17.8	44.0
Box culvert	22.3	23.5	25.3
Twin pipes	17.5	18.9	19.9
Total flow	**40.6**	**60.6**	**89.6**

Increasing the flow capacity at the crossing would improve the flood immunity of Burns Road at this location, meaning that the road would be cut-off in rarer flood events than at present. There may be benefit to flood affectation of up to 2 buildings upstream of the crossing, however this is likely to be localised to near the crossing due to the relatively steep grade of the creek.



Legend

- Mitigation Option Locations
- Study area
- Watercourse

JACOBS

SHEET	Page of	GDA 1994 MGA Zone 56	
TITLE	Mitigation Option Locations		
PROJECT	Lovers Jump Creek Floodplain Risk Management Study and Plan		
DRAWN LC	PROJECT # IA159900	MAP # Figure 9-2	REV 1 VER 1
CHECK AH	DATE 6/03/2019		1:12,000 | A3

Qualitative constraints assessment

While the creek is not particularly constrained downstream of the crossing, the number of additional pipes would be limited by the creek cross section. Two additional 1.75m diameter pipes may fit, one on each side of the existing structures. This needs to be confirmed with further inspection.

Burns Road is a major thoroughfare with one lane in each direction only. Construction of additional pipe crossings would be disruptive but not without precedent. Similar works involving bridge replacement on Eastern Arterial Road, linking East Killara and St Ives (circa mid-1990s), has previously been undertaken with this major arterial being closed for several months. Traffic was diverted to other roads around the closure.

Construction method may be constrained by the limited space downstream between the road and the waterfall. Some trees and vegetation would likely require removal for construction of this option. There are likely to be existing utilities in the road corridor requiring protection or relocation. Existing property driveways may be affected by the construction works. Works are within the road property boundary.

Downstream vegetation and landforms may be locally impacted in the developed case by outlet flows from the additional pipes. There are stands of Sydney Turpentine Ironbark Forest EEC in this location, particularly on the upstream side of Burns Road, which may be impacted by mitigation works.

Other relevant notes

Council is considering the upgrade and widening of Killeaton Road and Burns Road between Link Road, St Ives, and Eastern Road, Wahroonga, in coordination with RMS. The roads are currently single lane each way and are a significant traffic bottleneck. It is appropriate to incorporate any upgrade of the Burns Road crossing of Lovers Jump Creek with this potential road widening project. A concept design of the road widening has not yet been commissioned.

Detailed assessment

Upgrading the hydraulic capacity at Burns Road crossing, assuming two additional 1.75m diameter pipes, was assessed in detail in the hydraulic model. Refer to Figure 9-3 on the next page for layout. It was assumed that the existing drainage structures would be removed and replaced.

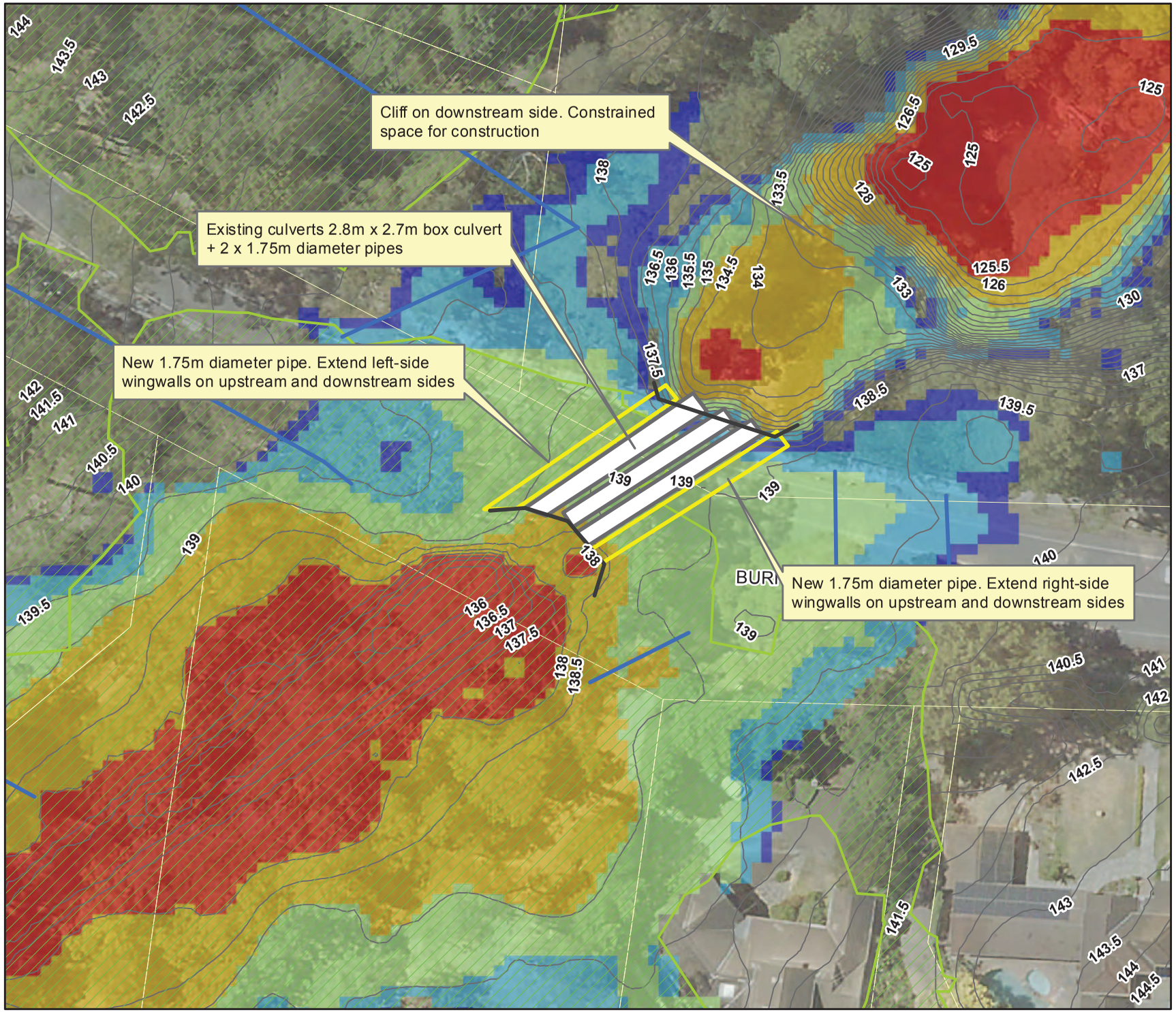
Flooding Impacts

Impacts of the mitigation measure in the 20% and 1% AEP event are presented in Figure 9-4 and Figure 9-5. Change in overall flood behaviour in the study area for the Option D1 are provided below:

- Reductions in flood levels up to -0.7m in 20% event, and -0.2m in 1% AEP, at the road.
- Modest reduction in flood levels at dwellings. Up to -0.1m in 1% AEP at one dwelling only.
- Road flood immunity improved. Now passable (<0.3m depth) in up to at least the 5% AEP (existing flood immunity less than 10% AEP).
- No change in above floor flooding.

Economic Evaluation

The cost for the mitigation measures is approximately $820,000. This mitigation option would reduce flood damages at some locations and would save about $22,000 over the 50 years design life. The benefit cost ratio for the Option D1 was estimated at 0.03.



Legend

- Existing Culverts
- New Culverts
- Stormwater pipe
- Existing 0.5m ground contour
- Endangered Ecological Community
- Cadastre

1% AEP Flood Existing Case

Peak Flood Depth (m)

- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

0 5 10 20
Metres

JACOBS®

GDA 1994 MGA Zone 56

TITLE
Drainage Upgrade (Option D1)
Burns Road Crossing

PROJECT
Lovers Jump Creek Floodplain Risk Management Study and Plan

PROJECT # IA159900

MAP # FIGURE 9-3

DATE 24/01/2019

Figure 9-4: Impact of the mitigation Option D1 – Burns Road Crossing in the 20% AEP event

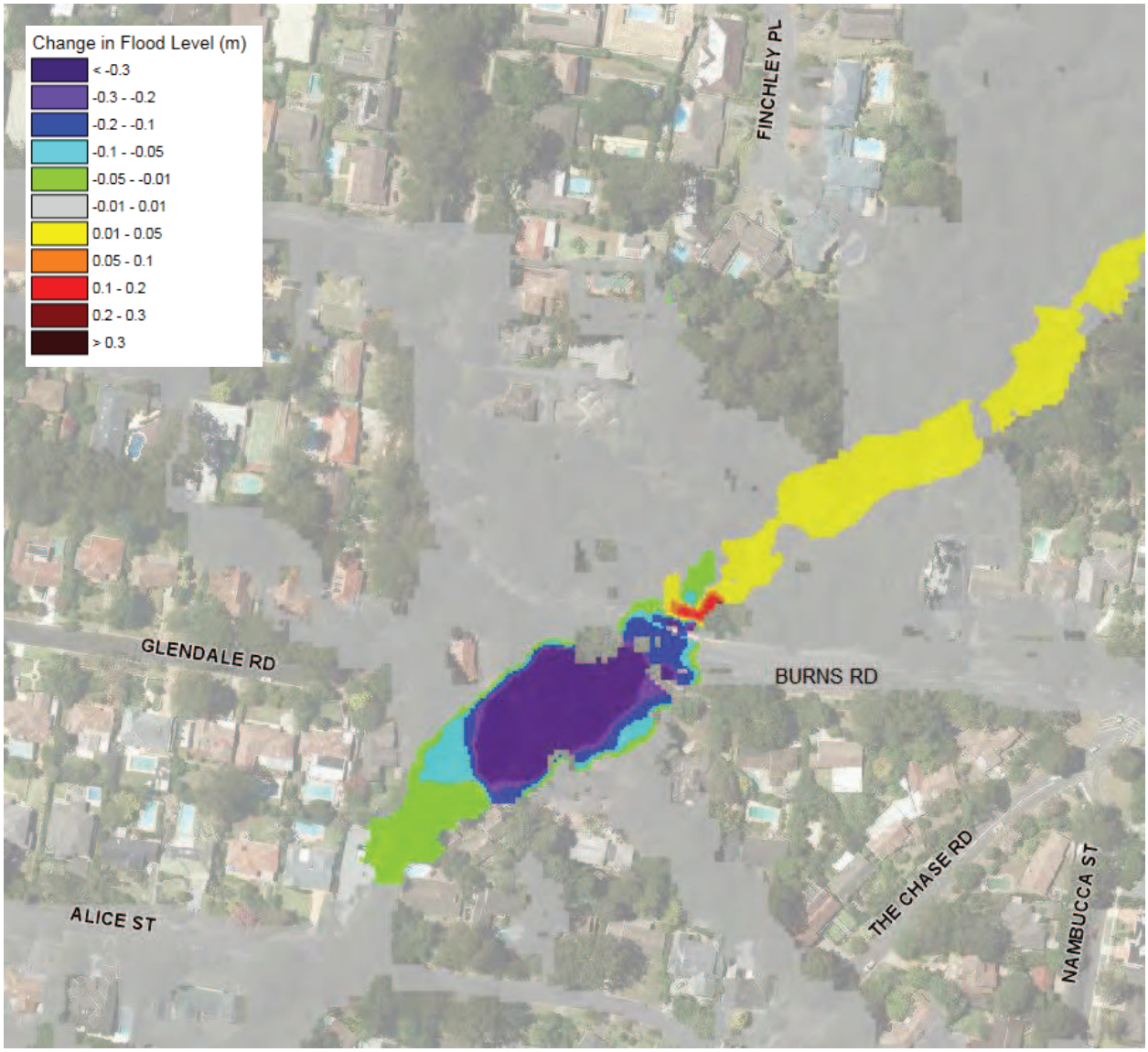
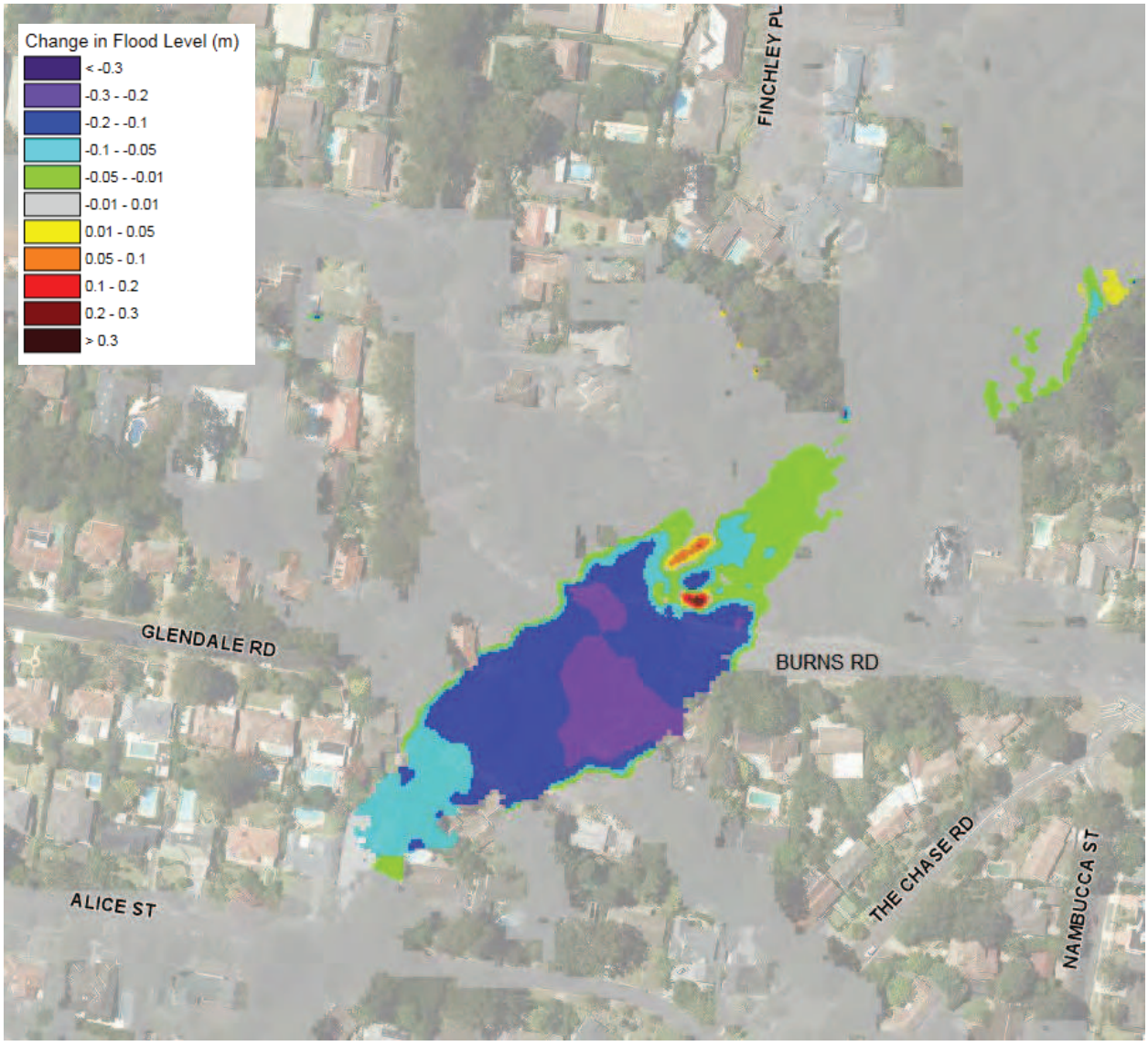


Figure 9-5: Impact of the mitigation Option D1 – Burns Road Crossing in the 1% AEP event



9.2.1.2 Tennyson Avenue crossing (Option D2)

Tennyson Avenue crossing of Lovers Jump Creek currently consists of a slab bridge with two 2.7m wide x 2.4m high rectangular waterway openings, refer to Figure 9-6. Widening of the waterway openings was investigated. This crossing is just downstream of a key flood problem area at the end of Cudgee Street, Turramurra. Increasing the crossing's flow capacity may improve flooding conditions on adjacent properties and improve the flood-immunity of Tennyson Avenue crossing, which is significantly flood-affected (high hazard flooding in 10% AEP and rarer). Tennyson Avenue is a local road which does not form a main thoroughfare.

Figure 9-6 Existing Tennyson Avenue crossing, downstream face

Hydraulic aspects

The road crossing is currently overtopped in the 20% AEP event. Peak flows upstream of the road are summarised in Table 9-2.

Table 9-2: Summary of flows at Tennyson Avenue

Flow component	Peak Flow (m^3/s)		
	20% AEP	5% AEP	1% AEP
Road overflow	7.7	26.0	53.2
Box culverts	29.3	29.3	29.3
Total flow	**37.0**	**55.3**	**82.5**

Qualitative constraints assessment

There are existing utilities crossing the creek at bridge deck level on the downstream side. The upstream and downstream channel would need to be locally widened to accommodate the upgraded crossing. The creek channel downstream is constrained and may restrict flow conveyance.

Localised clearing of Blue Gum High Forest EEC may be required in the vicinity of the crossing upgrade works.

Other relevant notes

Vegetation upstream and downstream of the road crossing is not excessively thick. There is an existing property boundary fence upstream of the culvert inlet which consists of pool-type fencing. This may act as a defacto debris trap during low flows but may become dislodged during flood events and become pinned against the culvert inlets, promoting complete blockage of the inlet.

Recommendation

Council should contact the landowner at property upstream of Tennyson Road crossing to replace the existing pool-type fencing with a design less likely to dislodge during flood events.

Detailed assessment

Upgrading the hydraulic capacity at Tennyson Avenue crossing was assessed in detail in the hydraulic model, assuming that the existing bridge is demolished and replaced with a new bridge with two 4m wide x 2.4m high waterway openings or a single span bridge. Refer to Figure 9-7 on the following page for layout.

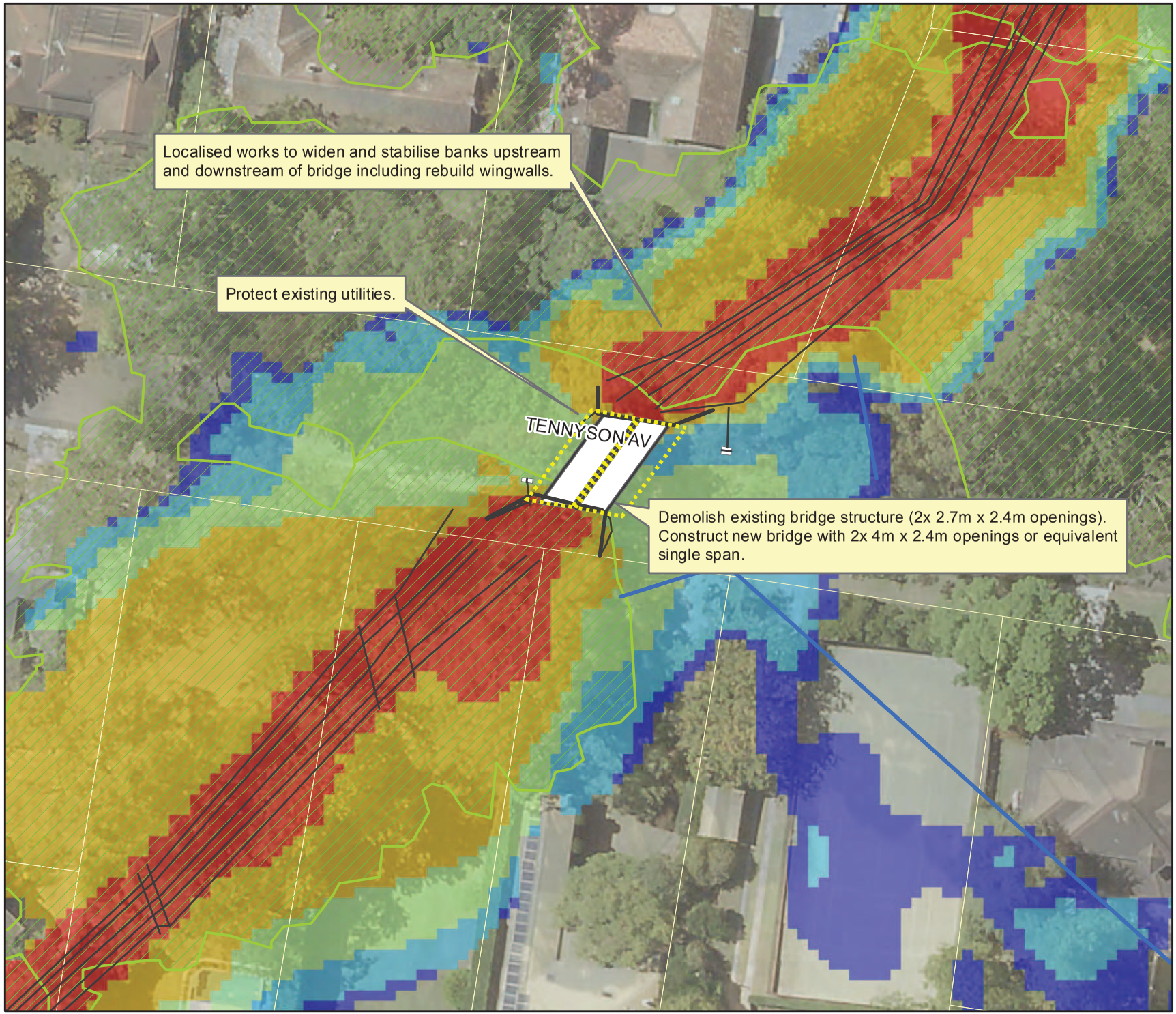
Flooding Impacts

Impacts of the mitigation measures in the 20% and 1% AEP event are presented in Figure 9-8 and Figure 9-9. Change in overall flood behaviour in the study area for Option D2 are provided below:

- Reductions in flood levels up to -0.2m in 20% AEP event, and -0.1m in 1% AEP, at the road
- Modest reduction in flood levels at dwellings. Up to -0.05m in 1% AEP.
- No change in above floor flooding.

Economic Evaluation

The approximate cost for the mitigation measures is estimated at $770,000. This mitigation option would reduce flood damages at some locations and would save about $60,000 over the 50 years design life. The benefit cost ratio for Option D2 was estimated at 0.08.



Legend

- Existing Bridge Openings
- New Bridge Openings
- Survey
- Stormwater pipe
- Endangered Ecological Community
- Cadastre

1% AEP Flood Existing Case

Peak Flood Depth (m)

- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

0 5 10 20
Metres

JACOBS®

GDA 1994 MGA Zone 56

TITLE
Drainage Upgrade (Option D2) Tennyson Avenue Crossing

PROJECT
Lovers Jump Creek Floodplain Risk Management Study and Plan

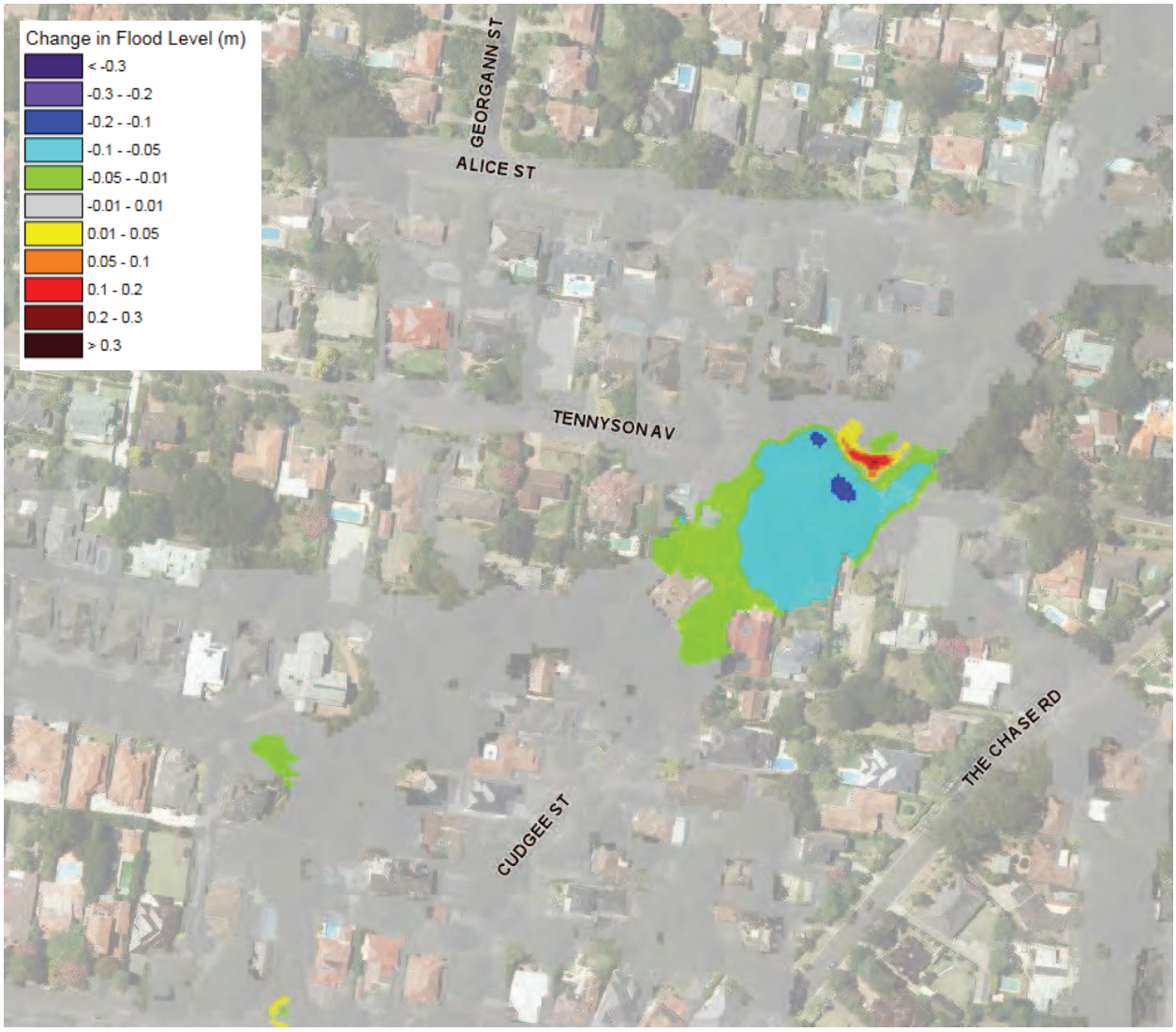
PROJECT # IA159900

MAP # FIGURE 9-7

DATE 24/01/2019

Figure 9-8: Impact of the mitigation Option D2 – Tennyson Avenue Crossing in the 20% AEP event

Figure 9-9: Impact of the mitigation Option D2 – Tennyson Avenue Crossing for in 1% AEP event



9.2.1.3 The Chase Road crossing (Option D3)

The Chase Road crossing of Lovers Jump Creek currently consists of a slab bridge with two 1.5m wide x 2.4m high rectangular waterway openings, refer to Figure 9-10. Widening of the waterway openings is being investigated. Up to four properties which are affected by over-floor flooding in the 1% AEP event may benefit from this drainage upgrade and the flood immunity of the road crossing may also be improved.

Hydraulic aspects

This road crossing appears to be a constraint in the 5% AEP flood and rarer, with floodwaters backing up upstream of the crossing, inundating adjacent upstream properties on The Chase Road with the road overflows then affecting properties on the downstream side. Peak flows upstream of the road are summarised in Table 9-3.

Table 9-3: Summary of flows at The Chase Road

Flow component	Peak Flow (m^3/s)		
	20% AEP	5% AEP	1% AEP
Road overflow	1.1	7.6	20.7
Box culverts	18.4	19.7	20.3
Total flow	**19.5**	**27.3**	**41.0**

Figure 9-10 Existing The Chase Road crossing, downstream face

Qualitative constraints assessment

The existing bridge could be demolished and replaced with a bridge with wider openings equivalent to the channel width.

There is a small stand of Blue Gum High Forest EEC on the upstream side which may be disturbed by construction works, although most vegetation in the vicinity of the crossing appears to be exotic.

There are existing utilities crossing the creek at bridge deck level on the upstream side, and a water mains pipe on the downstream side. The pedestrian footpath crosses the creek on the upstream side via a footbridge separate to the road crossing.

Other relevant notes

Flooding on the upstream side of The Chase Road is also impacted by a footbridge on private property. Floodwaters surcharge the bridge deck in the 20% AEP and rarer and probably exacerbates the flooding impact to the adjacent properties due to the constrained The Chase Road crossing. This footbridge cannot be removed as it is the accessway from the dwelling to the car port on this property.

Creek bank vegetation on the upstream and downstream sides of the crossing appear to be thick stands of exotic vegetation which is likely to impede flows. This thick vegetation is not explicitly represented in the flood model but it would be beneficial if this vegetation were removed and/or managed.

Detailed assessment

Upgrading the hydraulic capacity at The Chase Road crossing was assessed in detail in the hydraulic model, if the existing bridge would be demolished and replaced with a new bridge with two 3m wide x 2.4m high waterway openings, or equivalent single span bridge. Refer to Figure 9-11 on the following page for layout.

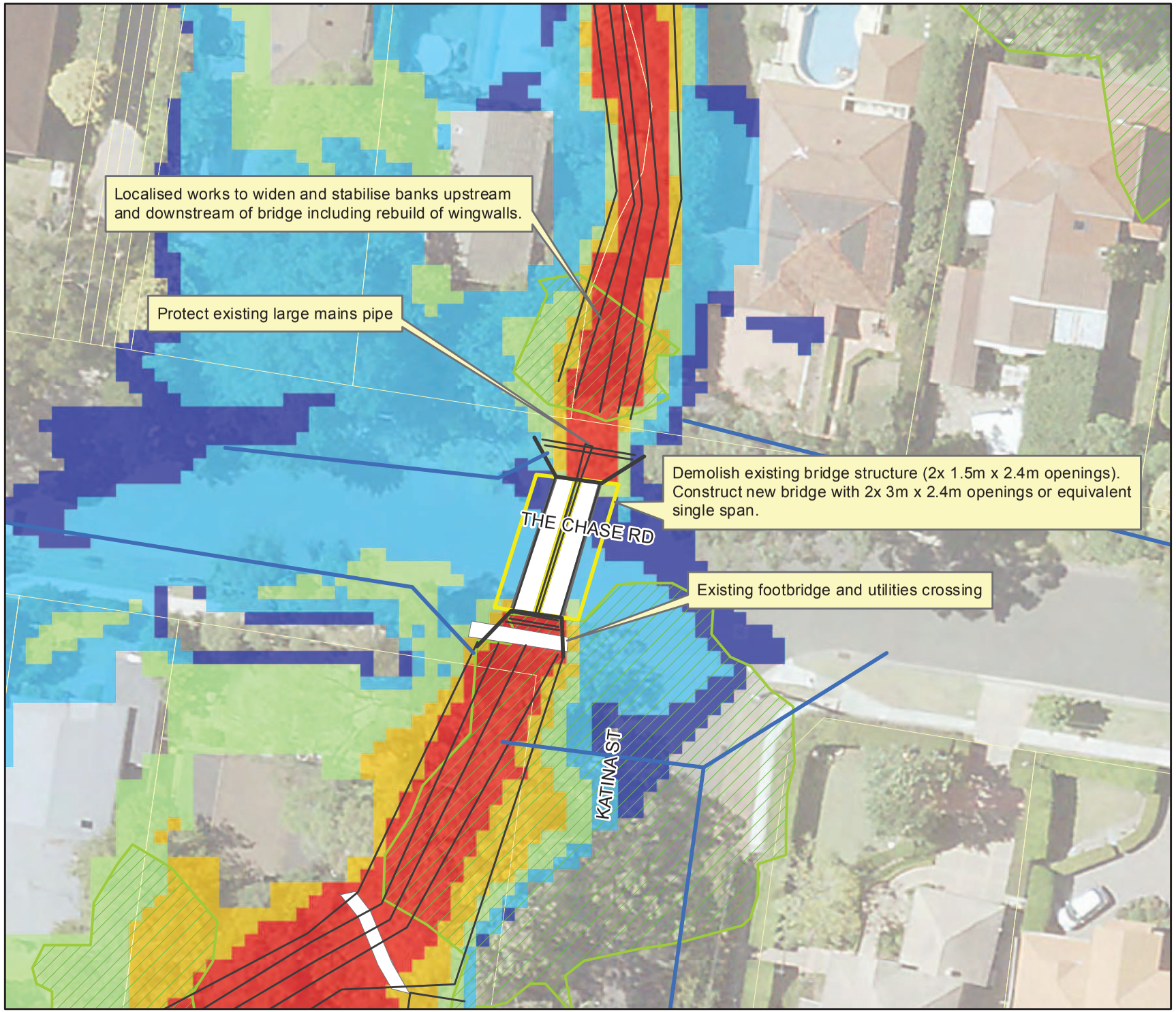
Flooding Impacts

Impacts of the mitigation measure in the 20% and 1% AEP event are presented in Figure 9-12 and Figure 9-13. Changes in overall flood behaviour in the study area for Option D3 are provided below:

- Reductions in flood levels up to -0.8m in 20% AEP event, and -0.3m in 1% AEP, on upstream side of road.
- Reductions in maximum flood levels at three dwellings of up to -0.4m in the 5% AEP and -0.25m in the 1% AEP.
- Increased flood levels in the channel on downstream side of road up to +0.1m with potential minor impacts to dwellings on either side.
- Improvements to trafficability of road crossing in flood events, although already trafficable in the existing case.
- Three less properties with above floor flooding in the 2% AEP event and two less properties with above floor flooding in the 1% AEP event.

Economic Evaluation

The cost for the mitigation measure is approximately $826,000. This mitigation option would reduce flood damages at some locations and would save approximately $500,000 over the 50 years design life. The benefit cost ratio for Option D3 was 0.60.



Legend

- Existing Bridge Openings
- New Bridge Openings
- Survey
- Stormwater pipe
- Endangered Ecological Community
- Cadastre

1% AEP Flood Existing Case

Peak Flood Depth (m)

- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

0 2.5 5 10
Metres

JACOBS®

GDA 1994 MGA Zone 56

TITLE
Drainage Upgrade (Option D3)
The Chase Road Crossing

PROJECT
Lovers Jump Creek Floodplain Risk Management Study and Plan

PROJECT # IA159900

MAP # FIGURE 9-11

DATE 24/01/2019

Figure 9-12: Impact of the mitigation Option D3 – The Chase Road Crossing in the 20% AEP event

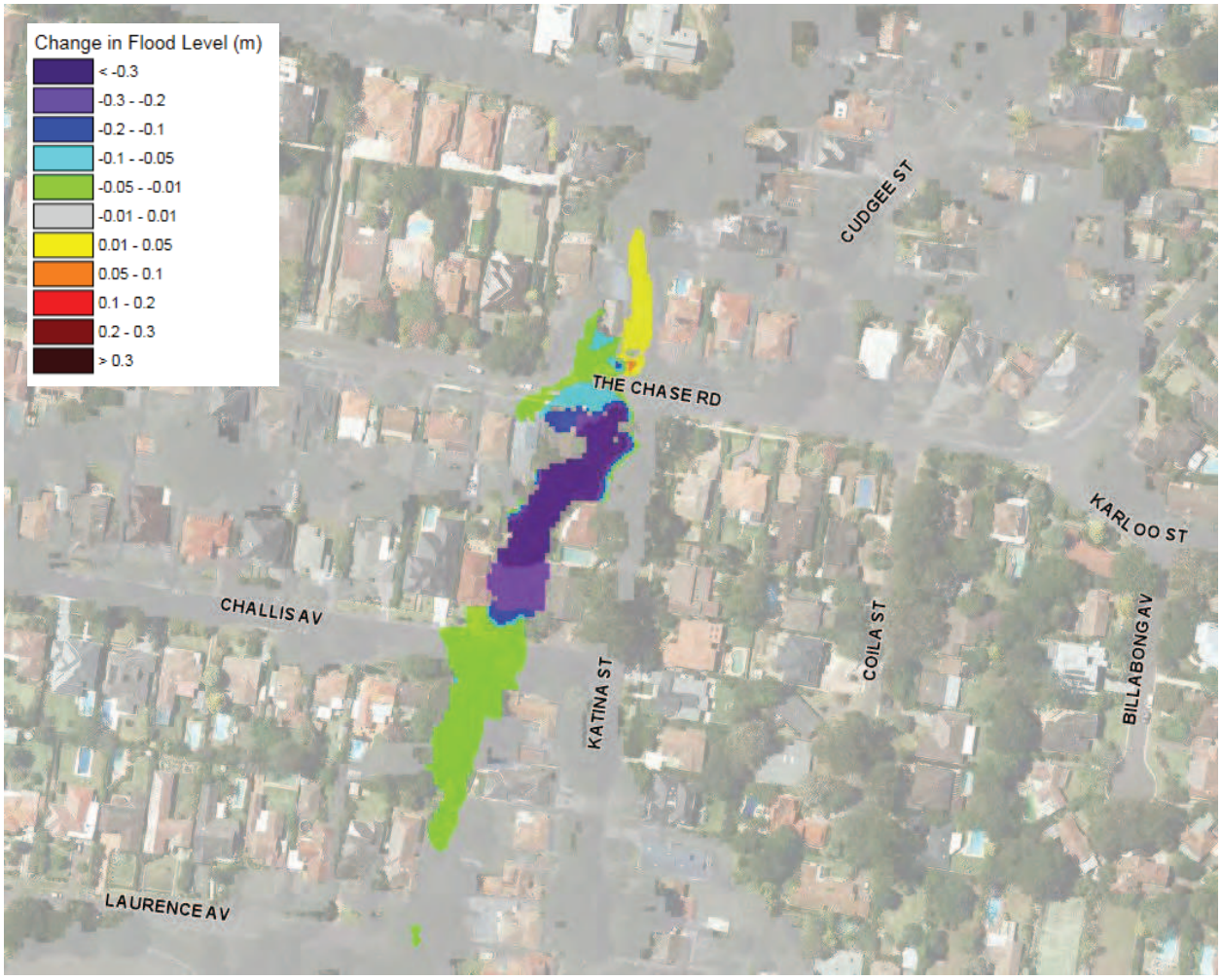


Figure 9-13: Impact of the mitigation Option D3 – The Chase Road Crossing in the 1% AEP event

9.2.1.4 Challis Avenue crossing (Option D4)

The Challis Avenue crossing of Lovers Jump Creek currently consists of a single 3.6m x 1.8m box culvert, refer to Figure 9-14. The culvert discharges into a downstream channel which was recently formalised on its left bank in works undertaken by Council.

Enlargement of the waterway opening was investigated. Two to three properties which are affected by over-floor flooding in the 1% AEP event may benefit from this drainage upgrade. The road crossing flood immunity may also be improved.

Figure 9-14 Existing Challis Avenue crossing, downstream face, looking upstream. Formalised left bank of the creek is on right side of photo, partially complete at time of photo (2014)

Hydraulic aspects

The road crossing is currently overtopped in the 20% AEP event. Floodwaters breaking out and overtopping the road flow onto the downstream properties. Peak flows at this location are summarised in Table 9-4.

Table 9-4: Summary of flows at Challis Avenue

Flow component	Peak Flow (m^3/s)		
	20% AEP	5% AEP	1% AEP
Road overflow	5.4	12.5	25.9
Box culverts	13.3	13.5	13.6
Total flow	**18.7**	**26.0**	**39.5**

Qualitative constraints assessment

The downstream channel appears to be a constraint and a wider waterway crossing cannot fit into the existing channel cross section. Refer to the photo on Figure 9-14. Enlargement of the road crossing would require localised channel widening. There may be scope to combine the road crossing upgrade with channel widening in this section of the creek, which was initially identified in the long-list of options but was deemed to be unfeasible and not considered further as an option.

There is existing Blue Gum High Forest EEC in this location which may be impacted by the works. There are likely to be difficulties with widening the channel through private property, and the works would need to be restricted to the 6m wide easement. Council may have to pay compensation for extending the easement for channel widening on private property.

Detailed assessment

Upgrading the hydraulic capacity at Challis Avenue crossing was assessed in detail in the hydraulic model. For the purposes of this assessment it is assumed that an additional 1.8m x 1.8m box culvert can be accommodated, representing an additional 50% capacity, although it is noted that this would provide flood immunity in the 20% AEP. Localised channel widening at the inlet and outlet would be required. Refer to Figure 9-15 on the following page for layout.

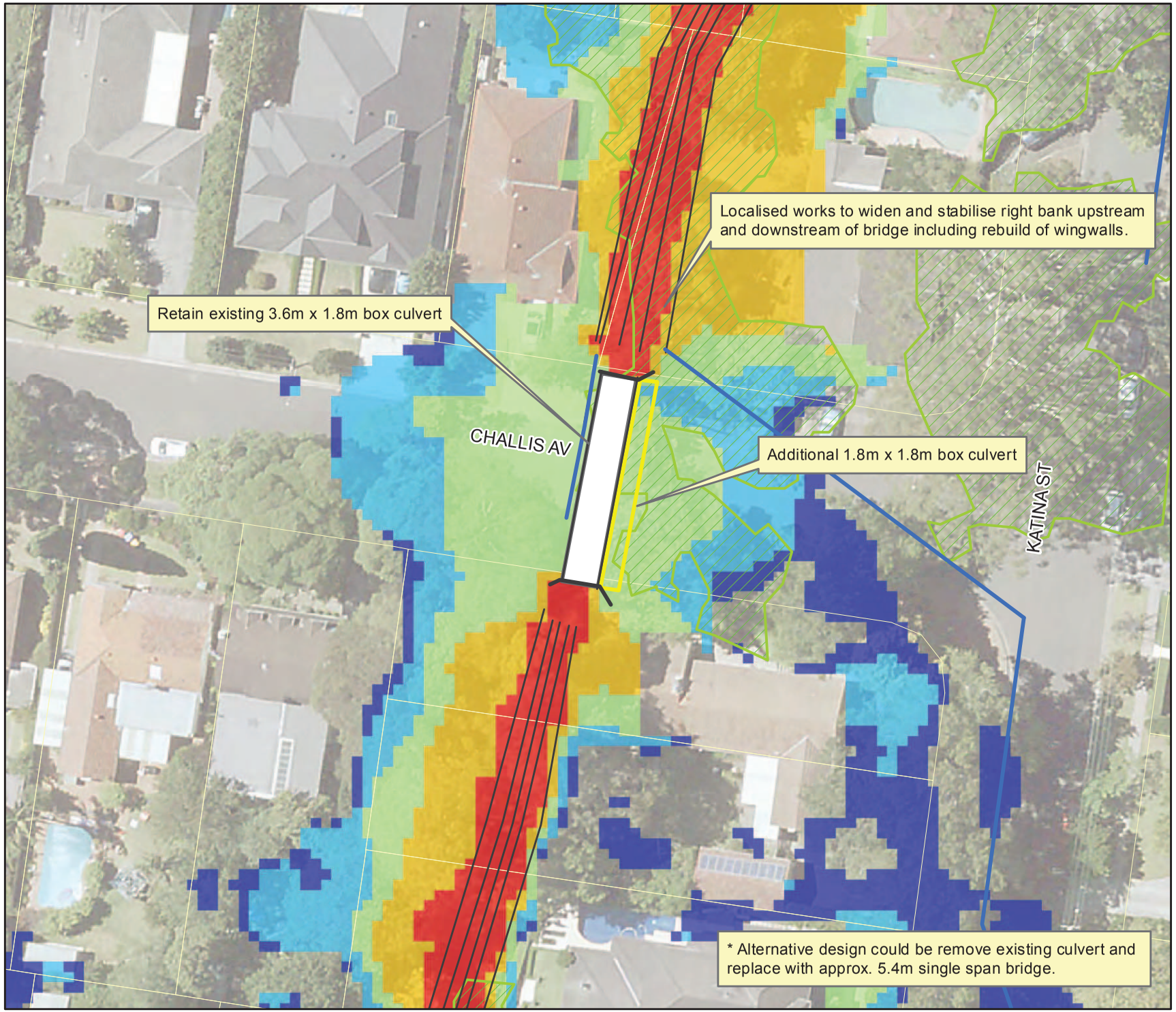
Flooding Impacts

Impacts of the mitigation measure in the 20% and 1% AEP event are presented in Figure 9-16 and Figure 9-17. Change in overall flood behaviour in the study area for Option D4 are provided below:

- Reductions in flood levels up to -0.2m in the 20% AEP event, and -0.06m in the 1% AEP event, on the upstream side of road.
- Minor reductions in maximum flood levels at one dwelling of up to -0.06m in the 2% AEP event and -0.05m in the 1% AEP event. Negligible reductions of -0.02m at three other dwellings.
- Minimal reduction in flooding over road crossing. No improvement in flood immunity.

Economic Evaluation

The cost for the mitigation measures is approximately $340,000. This mitigation option would reduce flood damages at some locations and would save about $100,000 over the 50 years design life. The benefit cost ratio for Option D4 was 0.32.



Legend

- Existing Culvert
- New Culvert
- Survey
- Stormwater pipe
- Endangered Ecological Community
- Cadastre

1% AEP Flood Existing Case

Peak Flood Depth (m)

- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

0 5 10 20
Metres

JACOBS®

GDA 1994 MGA Zone 56

TITLE
Drainage Upgrade (Option D4)
Challis Avenue Crossing

PROJECT
Lovers Jump Creek Floodplain Risk Management Study and Plan

PROJECT # IA159900

MAP # FIGURE 9-15

DATE 24/01/2019

Figure 9-16: Impact of the mitigation Option D4 – Challis Avenue Crossing in the 20% AEP event

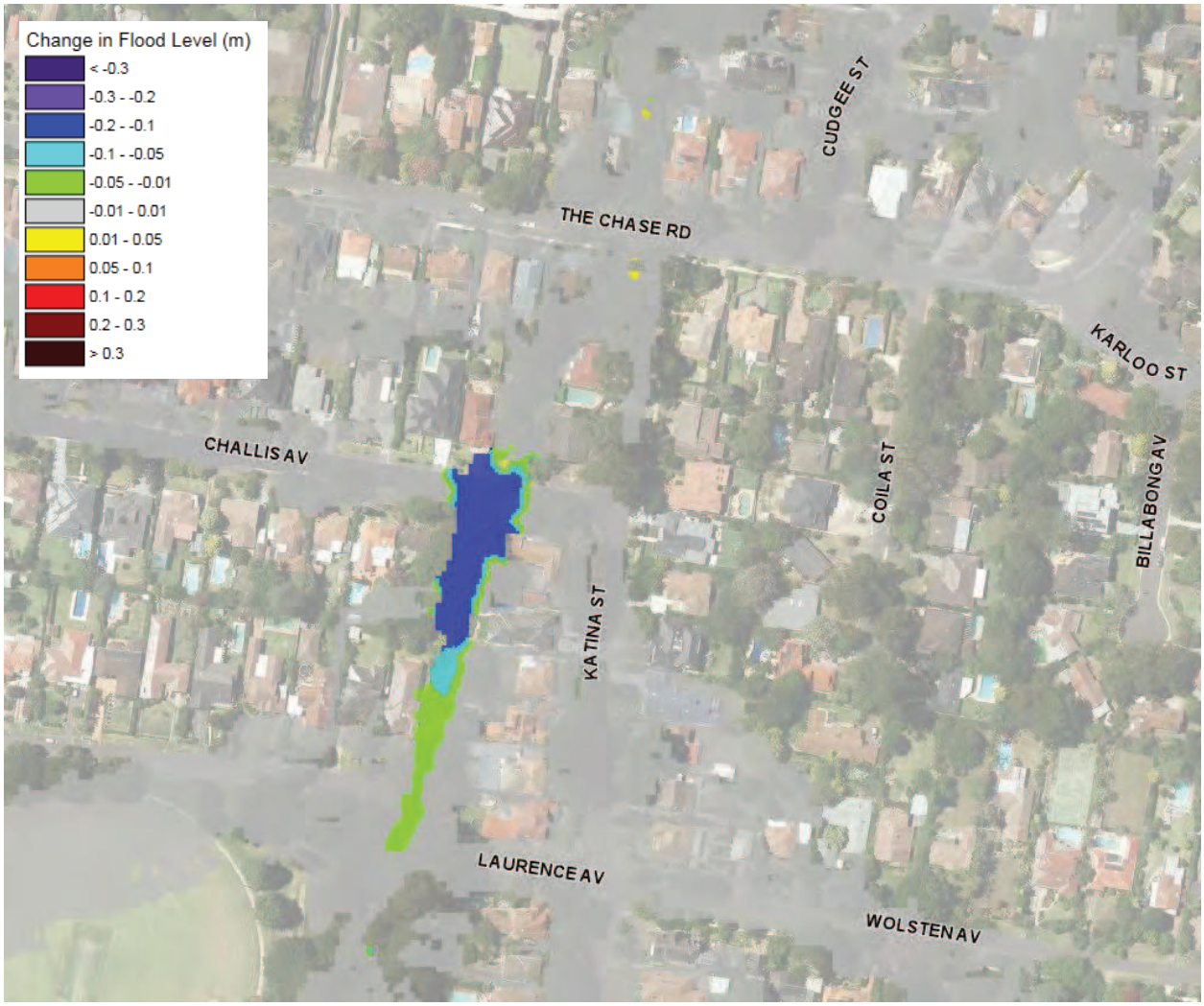
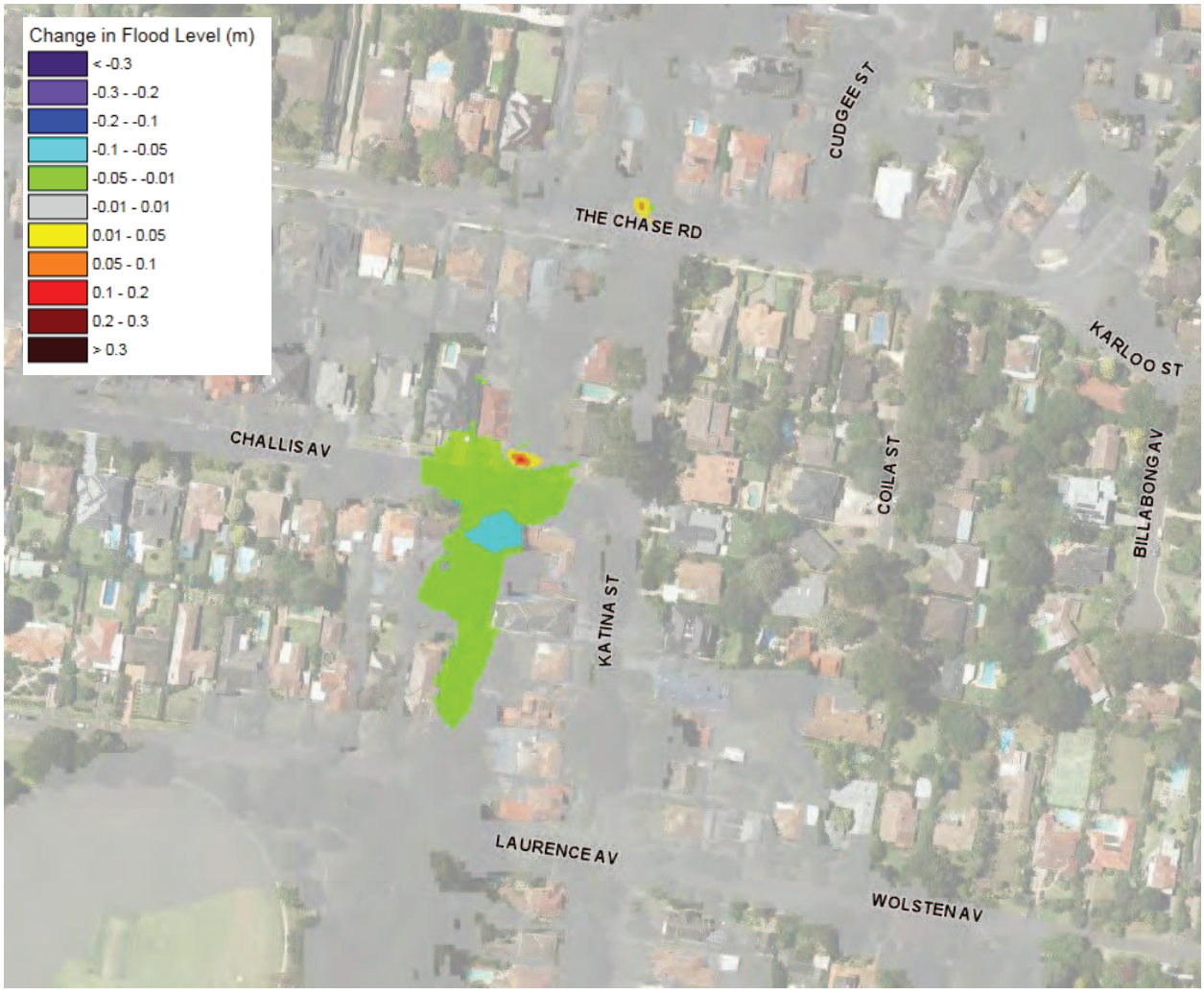


Figure 9-17: Impact of the mitigation Option D4 – Challis Avenue Crossing in the 1% AEP event



9.2.1.5 North Shore Railway Cross Drainage near Winton Street, Warrawee (Options D5(b) and D5(c))

The railway cross drainage at this location drains a trapped low point on the upstream of the railway embankment. The existing railway drainage structure is a 1.5m x 1.5m arch culvert, which connects to Council drainage pipes including a 0.9m diameter and a parallel 0.6m diameter pipe. These pipes form a trunk drainage branch which ultimately discharge to the northern open channel in Karuah Park, approximately 500m downstream. The Council drainage has approximately 40% the capacity of the railway drainage, resulting in the flows surcharging via a grated pit in the rail corridor onto the surface, contributing to overland flows through downstream properties.

Three properties which are affected by over-floor flooding in the 1% AEP event may benefit from a drainage upgrade in this location. Some downstream properties may also benefit from a drainage upgrade.

Hydraulic aspects

The railway cross drainage is a constriction which results in flooding to depths exceeding 2m at the dwellings upstream of the railway. Peak flows at this location are summarised in Table 9-5.

Table 9-5: Summary of flows at North Shore Railway cross drainage near Winton Street, Warrawee

Flow component	Peak Flow (m^3/s)		
	20% AEP	5% AEP	1% AEP
Upstream inflow	~5	~7	~9
Railway culvert flow	4.5	5.6	6.0
Flow surcharge from pipe to surface, downstream side	0.9	1.4	1.7
Pipe flows, downstream side	3.6	4.2	4.3
Overland flows, downstream side	1.6	2.6	3.6

Qualitative constraints assessment

As previously mentioned, the downstream connected Council trunk drainage pipe line has a lower capacity than the railway cross drainage culvert. This causes piped flows in the culvert to surcharge to the surface. It is not expected that upsizing of the Council system would significantly improve flooding upstream of the railway, but it is likely to reduce the flow surcharging from the pipe system which would improve overland flooding conditions downstream of the railway.

The railway and surrounding development presents a number of constraints to augmentation of the existing railway and downstream trunk drainage:

- Pipe jacking or micro tunnelling construction method would be required to minimise disturbance to the railway embankment. Constraints on maximum pipe size with these methods, particularly pipe jacking.
- Existing residential development is present upstream and downstream of the railway with no direct vehicular access to the drainage low point and culvert location. The existing Council drainage line runs through residential properties. Existing easement width constrained with building structures encroaching on the easement.
- The drainage low point, particularly on the downstream side, is situated relatively low in elevation compared to the nearest roads (Brentwood Avenue and Cherry Street). Pipe depth would need to be exceedingly deep for conventional pipe-laying construction methods (approximately 6m) if an additional culvert line were to be added at the drainage low point and then routed to the nearest road, avoiding residences. Trenchless/tunnelling construction methods would be required.

- A railway electrical substation is situated just to the north of the drainage low point. There are two pipe branches approaching the low point on the upstream side of the railway. The northern branch (with pipe capacity 1.8m^3/s) could be redirected under the railway to Brentwood Avenue, however, this would pass under or close to the substation.
- Railway stakeholders likely to have significant concerns about proposed works to the railway.

Drainage options which improve the flow capacity at and downstream of the railway are likely to increase flooding in the vicinity of the discharge point (Karuah Park) and further downstream.

Detailed assessment

There are a number of potential works options available at this location. The short-listed options which were assessed in detail are summarised below. Other options were initially identified in this location but were deemed to be unfeasible and not considered further as options. Refer to Figure 9-18 on the following page for layout of options.

1) Option D5(b) – Increase culvert capacity, assume additional 1.2m pipe. New additional trunk drainage line downstream of railway to discharge point. Assume some sections through residential properties and then under road. Assume routed to Brentwood Avenue to minimise impact to private property.
2) Option D5(c) – Redirect upstream northern pipe branch (0.9m diameter) from Winton Street, under railway to Brentwood Avenue on downstream side. New additional drainage line downstream of railway to discharge point at Karuah Park.

A new trunk drainage line laid in the roadway is likely to clash with existing utilities which would require protection or relocation.

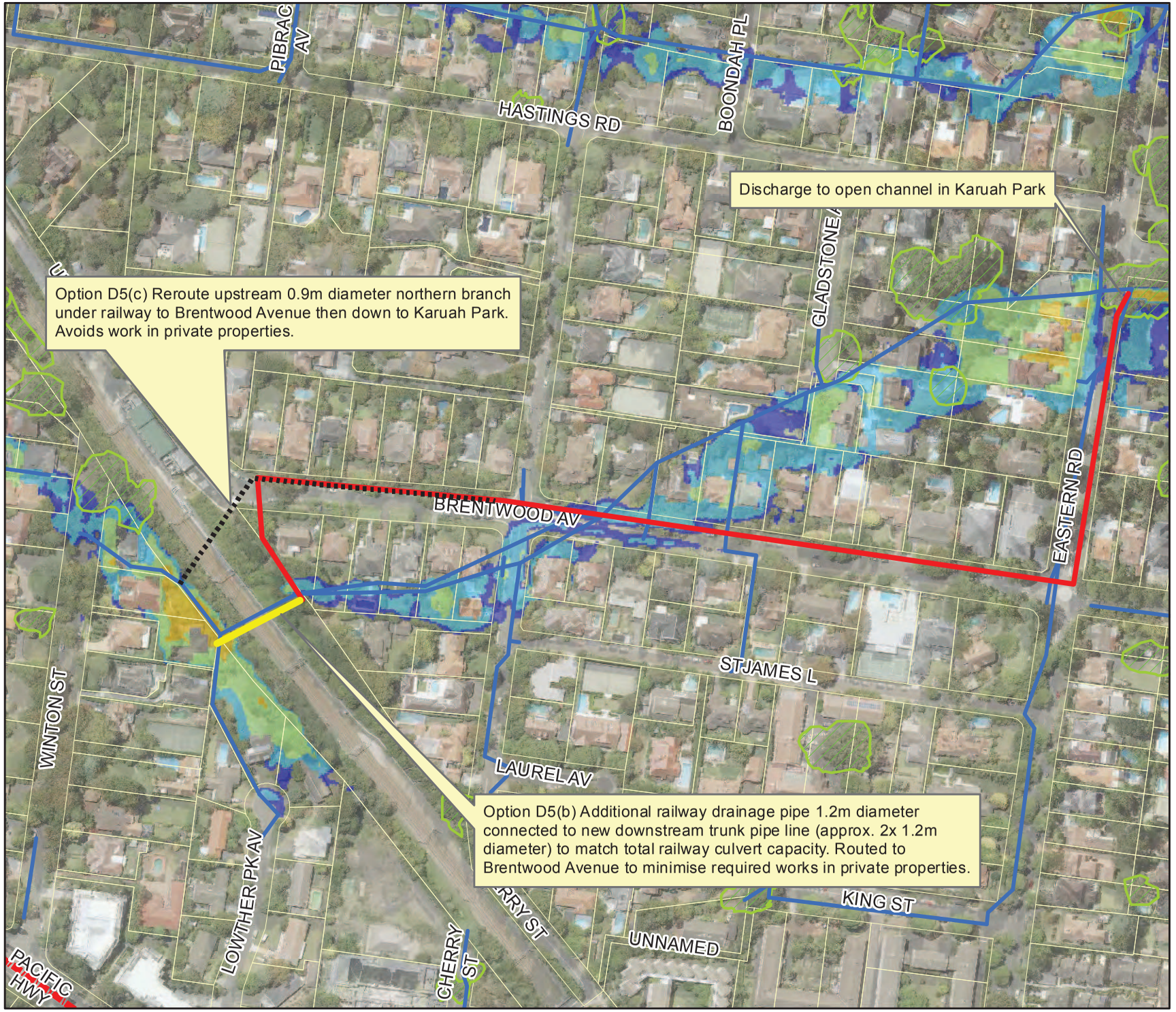
Flooding Impacts, Option D5(b)

Impacts of the mitigation measure in the 20% and 1% AEP event are presented in Figure 9-19 and Figure 9-20. Change in overall flood behaviour in the study area for mitigation measure Option D5(b) are presented below:

- Significant reductions up to -0.9m on properties upstream of railway in 1% AEP. Reduction in maximum flood level at dwelling of -0.4m at worst-affected dwelling
- Reductions up to -0.3m in the 20% AEP and -0.2m in 1% AEP, between railway and Eastern Road
- Increased flood levels +0.05 - +0.25m in creek and on properties downstream of Karuah Road, larger impacts in smaller events. one property with new above floor flooding in 5% AEP as a result.
- One less property with above floor flooding in 1% and 2% AEP.

Economic Evaluation, Option 5(b)

The cost for the mitigation measures was approximately $16,071,000. This mitigation option would reduce flood damages at some locations and would save approximately $400,000 over the 50 years design life. The benefit cost ratio for Option D5(b) was 0.02.



Legend

- Existing Stormwater pipe
- Endangered Ecological Community
- Cadastre

1% AEP Flood Existing Case

Peak Flood Depth (m)

- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

0 25 50 100
Metres

JACOBS®

GDA 1994 MGA Zone 56

TITLE

Drainage Upgrade (Options D5) North Shore Railway Culvert near Winton Avenue to Karuah Park

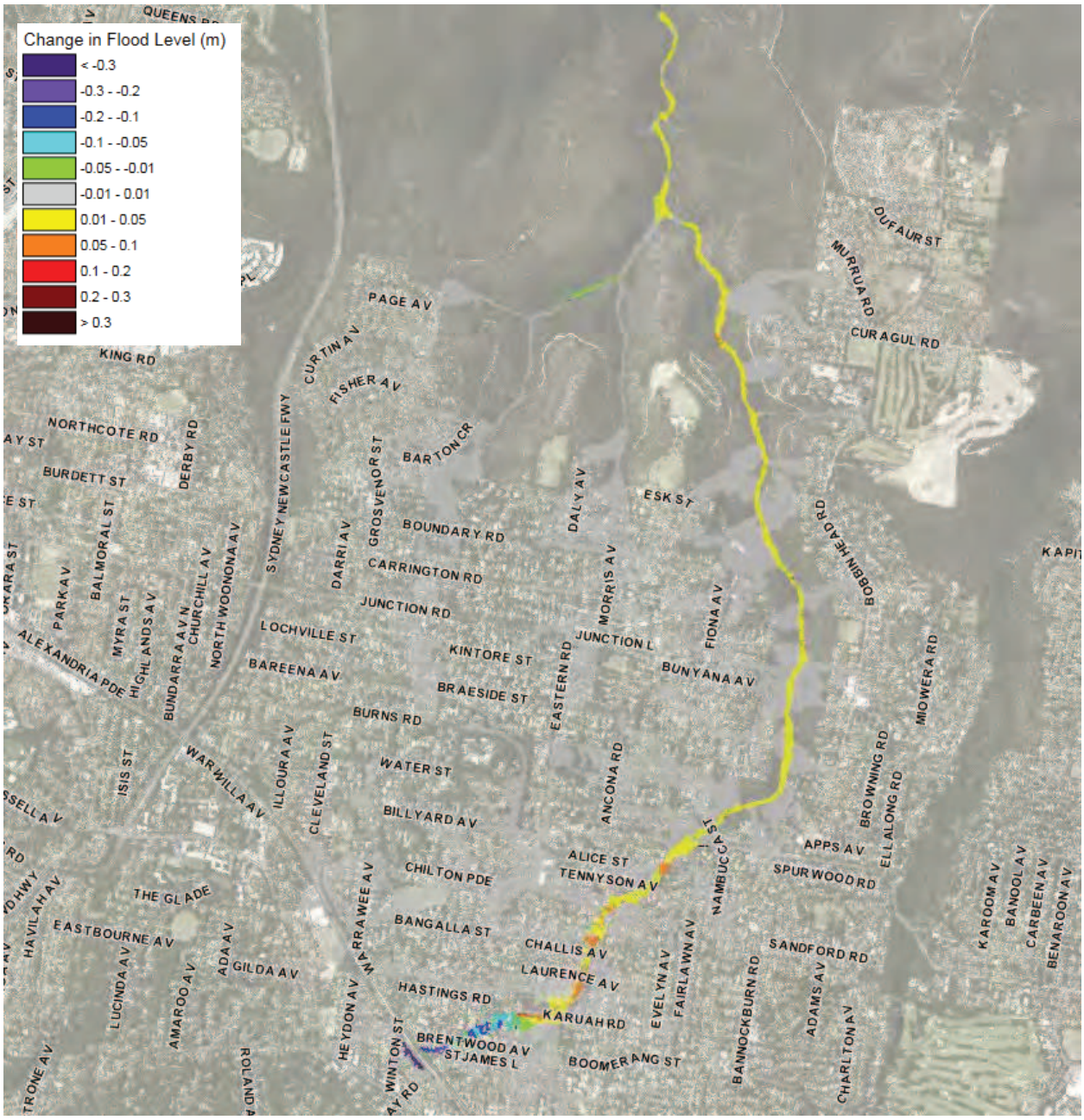
PROJECT

Lovers Jump Creek Floodplain Risk Management Study and Plan

PROJECT #	MAP #
IA159900	FIGURE 9-18
DATE	
24/01/2019	

Figure 9-19: Impact of the mitigation Option D5(b) – North Shore Railway Cross Drainage near Winton Street, Warrawee in the 20% AEP event

Figure 9-20: Impact of the mitigation Option D5(b) – North Shore Railway Cross Drainage near Winton Street, Warrawee in the 1% AEP event



Flooding Impacts, Option D5(c)

Impacts of the mitigation measure in the 20% and 1% AEP event are presented in Figure 9-21 and Figure 9-22. Change in overall flood behaviour in the study area for mitigation measure Option D5(c) are provided below:

- Reductions up to -0.3m on properties upstream of railway in 1% AEP. Reduction in maximum flood level at dwelling of -0.25m at worst-affected dwelling.
- Reductions up to -0.2m in 20% AEP event, typically -0.05 – -0.1m and -0.2m in 1% AEP, between railway and Eastern Road. Negligible reductions of -0.02m in 2% and 1% AEP.
- Increased flood levels +0.05 - +0.12m in creek and on properties downstream of Karuah Road, larger impacts in smaller events. one property with new above floor flooding in 5% AEP as a result.
- One less property with above floor flooding, in 20% AEP event.

Economic Evaluation, Option 5(c)

The cost for the mitigation measures was approximately $13,941,000. This mitigation option would reduce flood damages at some locations and would save approximately $420,000 over the 50 years design life. The benefit cost ratio for Option D5(c) was 0.03.

Figure 9-21: Impact of the mitigation Option D5(c) – North Shore Railway Cross Drainage near Winton Street, Warrawee in the 20% AEP event

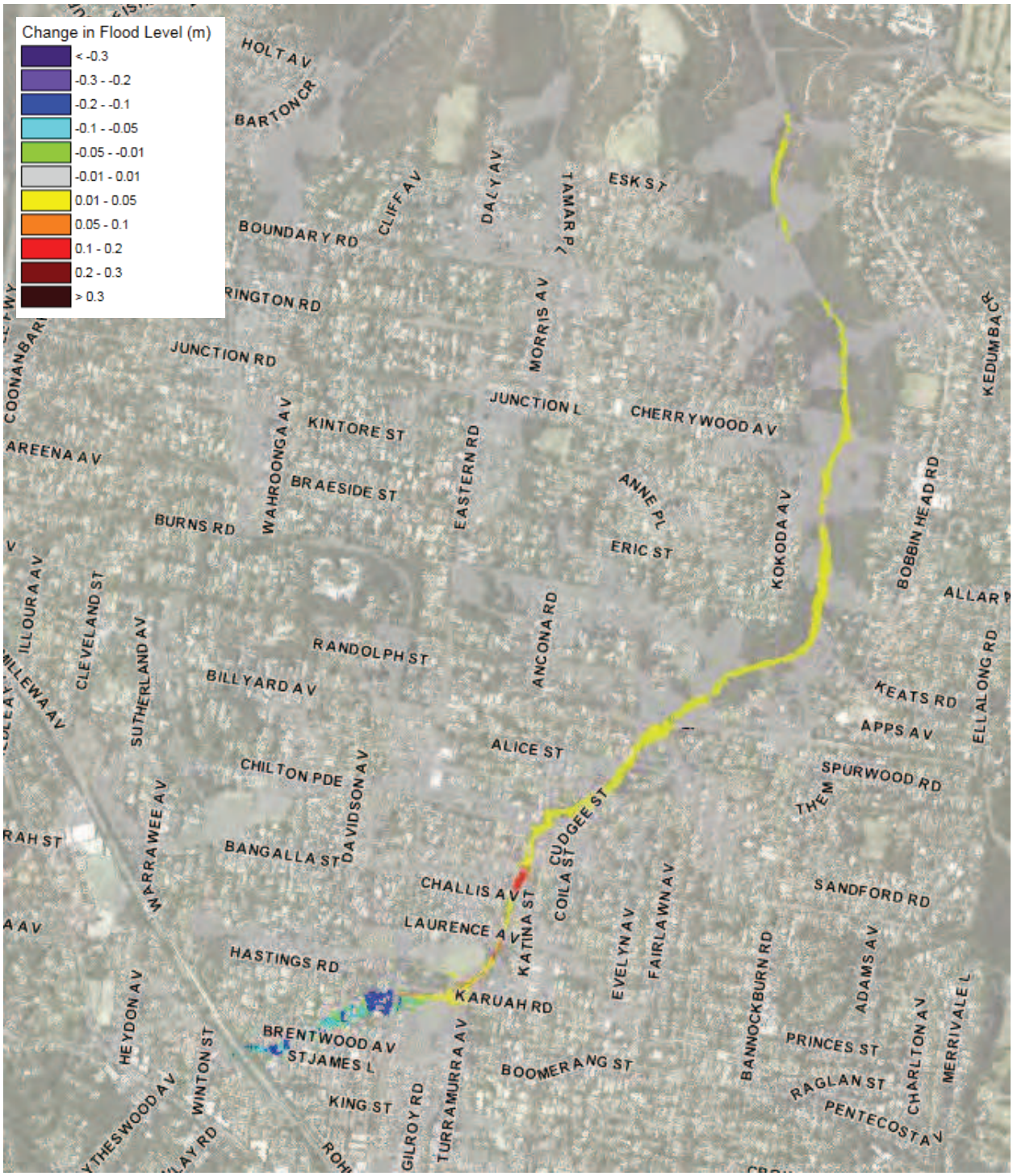
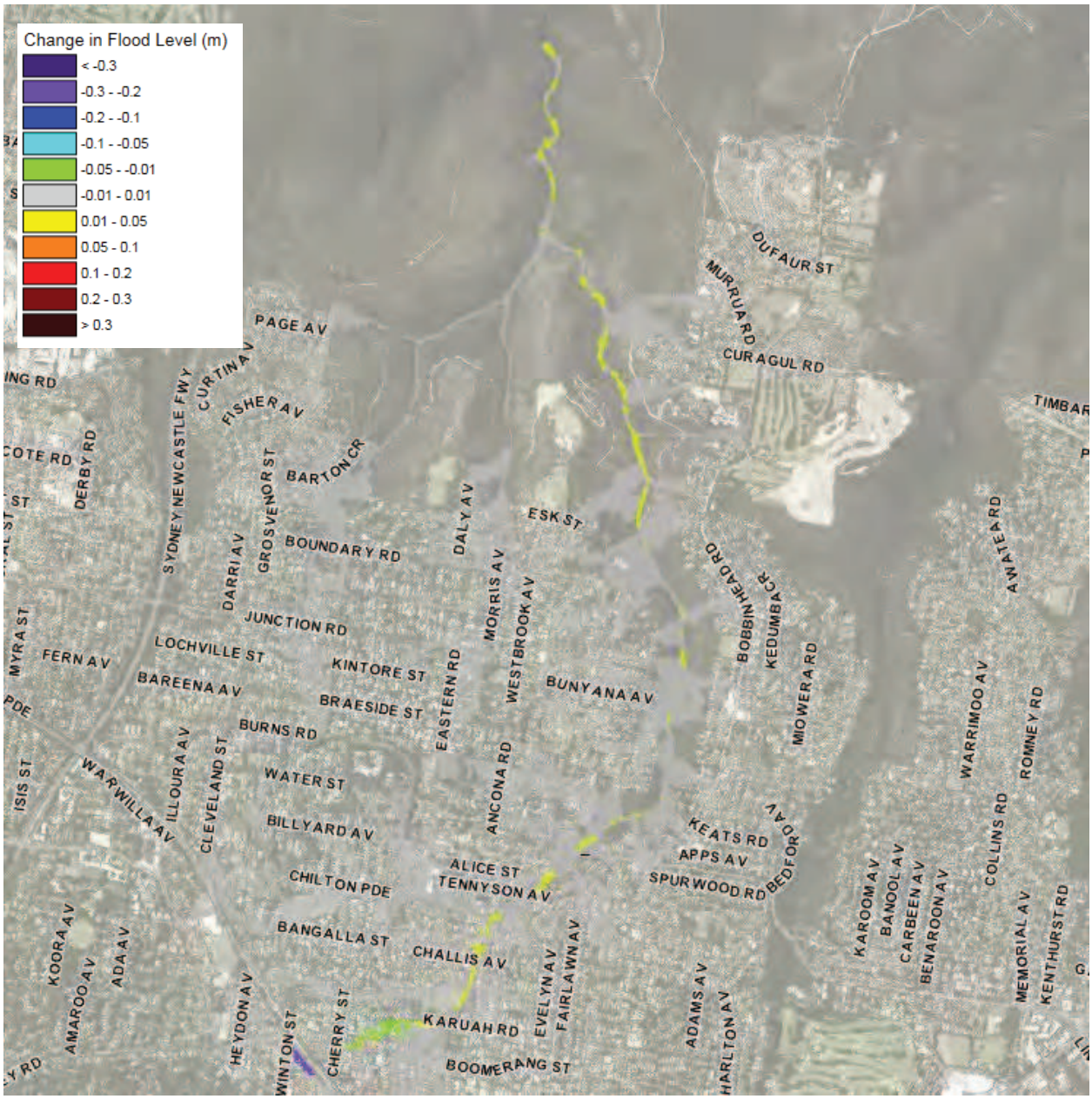


Figure 9-22: Impact of the mitigation Option D5(c) – North Shore Railway Cross Drainage near Winton Street, Warrawee in the 1% AEP event



9.2.1.6 Improved Cross Drainage, Eastern Road south of Hastings Road, Turramurra (Option D6)

Eastern Road is built in fill in this location which forms a drainage low point on residential properties on its upstream western side. Overland flows pond to depths exceeding 1m before overtopping the road. The existing trunk drainage (1.35m diameter) pipe passes under this location but is flowing full due to upstream flows. The northern channel in Karuah Park is located immediately opposite this location over Eastern Road.

Drainage of this low point could be improved by a new drainage line to run the road and then discharge in the northern channel in Karuah Park. The new line would consist of a box culvert, say 3m wide x 0.6m high, which could be laid at a shallower invert depth compared to an equivalent capacity pipe. This may be necessary to achieve adequate cover over the culvert. This option is also preferred over duplicating the existing trunk drainage line, which would require construction works and modification of pit inlets on private property.

The road could be lowered which would reduce upstream ponding depths, however, this is not recommended in order to maintain the existing flood immunity of the road.

Hydraulic aspects

A summary of relevant peak flows in this location is provided in Table 9-6.

Table 9-6: Summary of flows at Eastern Road trapped drainage point, south of Hastings Road

Flow component	Peak Flow (m^3/s)		
	20% AEP	5% AEP	1% AEP
Upstream overland flow	2.4	4.4	6.8

Qualitative constraints assessment

A proposed drainage line is likely to clash with existing utilities in the road corridor, requiring protection or relocation. There may be disturbance to vegetation in the park from construction activities, including Blue Gum High Forest EECs.

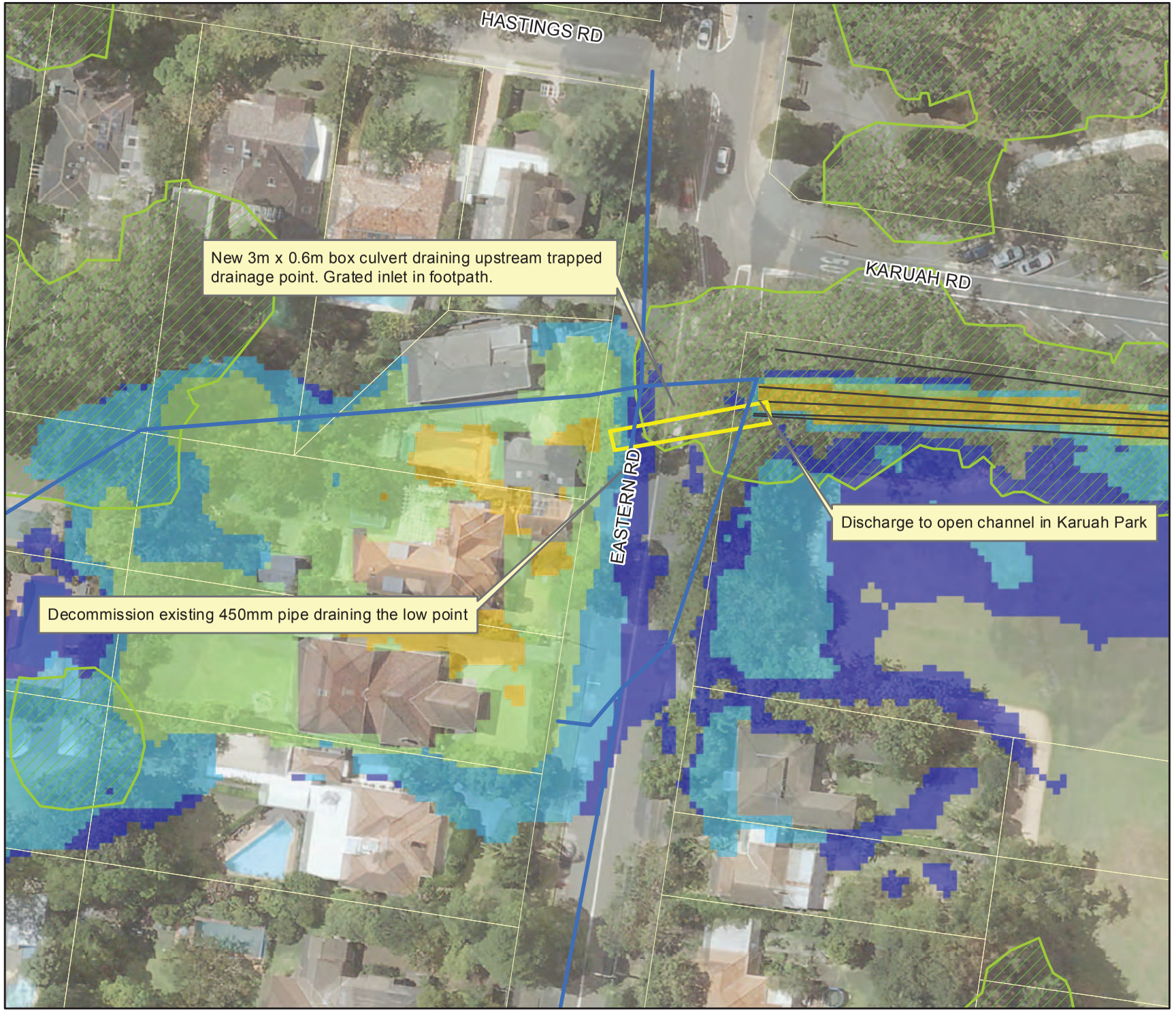
The existing northern channel would need to be amplified to allow discharge of the new culvert.

The existing footpath would need to be lowered/modified to accommodate a culvert inlet structure. Property driveways may be impacted for four properties.

This option may benefit up to five properties in terms of flooding of buildings in this location, three of these with over-floor flooding in the 1% AEP event. There are likely to be downstream flood impacts from increased flows if not combined with a detention basin option in the park. Detention basins were initially identified as potential options but were deemed to be unfeasible due to cost, environmental impacts and other factors and were not considered further as an option.

Detailed assessment

Additional drainage consisting of a 3m x 0.6m box culvert was assessed in detail. Refer to Figure 9-23 on the following page for layout.



Legend

- Existing Stormwater pipe
- New Culverts
- Endangered Ecological Community
- Cadastre

1% AEP Flood Existing Case

Peak Flood Depth (m)

- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

0 5 10 20
Metres

JACOBS®

GDA 1994 MGA Zone 56

TITLE

Drainage Upgrade (Option D6) Eastern Road Trapped Drainage Point South of Hastings Road

PROJECT

Lovers Jump Creek Floodplain Risk Management Study and Plan

PROJECT #	MAP #
IA159900	FIGURE 9-23
DATE	
24/01/2019	

Flooding Impacts

Impacts of the mitigation measure in the 20% and 1% AEP event are presented in Figure 9-24 and Figure 9-25. Change in overall flood behaviour in the study area for Option D6 are provided below:

- Reductions of -0.2 to -0.3m on properties either side of Eastern Road particularly in smaller events. Reductions of -0.1 to -0.15m in 1% AEP.
- Increased flood levels +0.02 to +0.07m in creek and on properties downstream of Karuah Road in the 20% AEP, 10% and 5% AEP events particularly around Challis Avenue and The Chase Road.
- Three less properties with above floor flooding in 1% AEP event.

Economic Evaluation, Option 6

The cost for the mitigation measures was approximately $269,000. This mitigation option would reduce flood damages at some locations and would save approximately $170,000 over the 50 years design life. The benefit cost ratio for Option D6 was 0.63.

Figure 9-24: Impact of the mitigation Option D6 – Eastern Road, south of Hastings Road in the 20% AEP event

Figure 9-25: Impact of the mitigation Option D6 – Eastern Road, south of Hastings Road in the 1% AEP event

9.2.1.7 Improved Cross Drainage, Eastern Road north of Hastings Road, Turramurra (Option D7)

Eastern Road is built in fill in this location which forms a drainage low point on residential properties on its upstream western side. Overland flows pond to depths exceeding 1m before overtopping the road. The existing trunk drainage (1.2m diameter) pipe passes under this location but is flowing full due to upstream flows.

Drainage of this low point could be improved by a new drainage line to run south-east across the road and then through Turramurra Memorial Park, discharging into the Lovers Jump Creek channel in the eastern side of the park. The new line would consist of a box culvert, say 2.4m wide x 0.6m high, which could be laid at a shallower invert depth compared to an equivalent capacity pipe. This may be necessary to achieve adequate cover over the culvert to the base of the road pavement.

The road could be lowered which would reduce upstream ponding depths, however, this is not recommended in order to maintain the existing flood immunity of the road.

Hydraulic aspects

A summary of peak flows in this location is provided in Table 9-7.

Table 9-7: Summary of flows at Eastern Road trapped drainage point, north of Hastings Road

Flow component	Peak Flow (m^3/s)		
	20% AEP	5% AEP	1% AEP
Upstream overland flow	~1.5	~2.5	~3.5

Qualitative constraints assessment

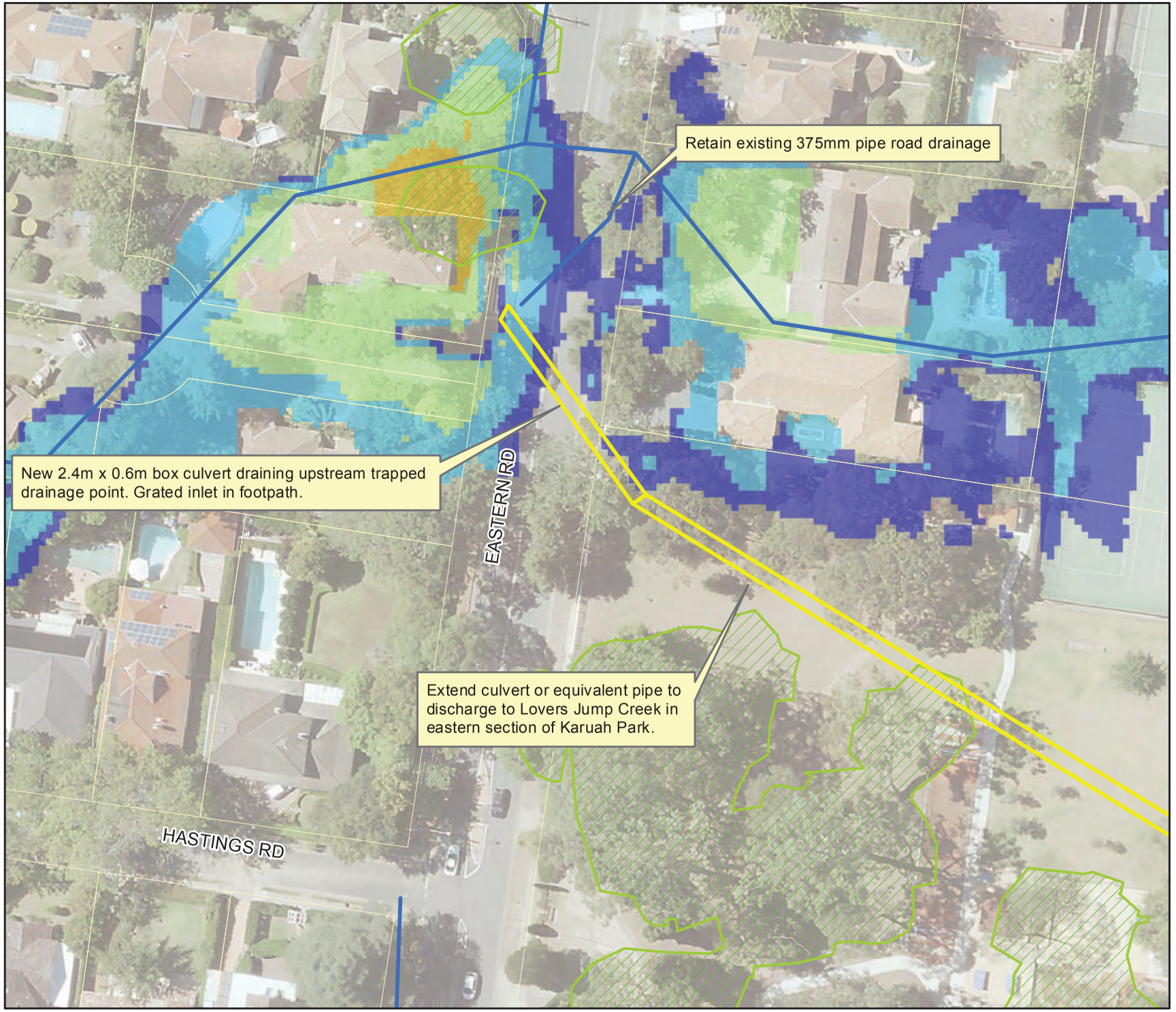
A proposed drainage line is likely to clash with existing utilities in the road corridor, requiring protection or relocation. There would be disturbance to the cricket oval and other parts of the park from construction activities.

The existing footpath would need to be lowered/modified to accommodate a culvert inlet structure. Property driveways may be impacted for four properties.

There are likely to be downstream flood impacts from increased flows if not combined with a detention basin option in the park. Detention basins were initially identified as potential options but were deemed to be unfeasible due to cost, environmental impacts and other factors and were not considered further as an option.

Detailed assessment

Additional drainage consisting of a 2.4m x 0.6m box culvert was assessed in detail. Refer to Figure 9-26 on the following page for layout.



Legend

- Existing Stormwater pipe
- New Culverts
- Endangered Ecological Community
- Cadastre

1% AEP Flood Existing Case

Peak Flood Depth (m)

- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

0 5 10 20
Metres

JACOBS®

GDA 1994 MGA Zone 56

TITLE

Drainage Upgrade (Option D7) Eastern Road Trapped Drainage Point North of Hastings Road

PROJECT

Lovers Jump Creek Floodplain Risk Management Study and Plan

PROJECT #	MAP #
IA159900	FIGURE 9-26
DATE	
24/01/2019	

Flooding Impacts

Impacts of the mitigation measure in the 20% and 1% AEP event are presented in Figure 9-27 and Figure 9-28. Change in overall flood behaviour in the study area for the mitigation measure are provided below:

- Reductions of -0.3 to -0.5m on properties either side of Eastern Road particularly in smaller events. Reductions of -0.1 to -0.4m in 1% AEP.
- Increased flood levels +0.02 to +0.14m in creek and on properties downstream of Karuah Road in the 20%, 10% and 5% AEP events particularly around Challis Avenue and The Chase Road.
- Three less properties with above floor flooding in 1% AEP event.

Economic Evaluation

The cost for the mitigation measures was approximately $1,001,000. This mitigation option would reduce flood damages at some locations and would save approximately $600,000 over the 50 years design life. The benefit cost ratio for Option D7 was 0.60.

Figure 9-27: Impact of the mitigation Option D7 – Eastern Road, North of Hastings Road in the 20% AEP event

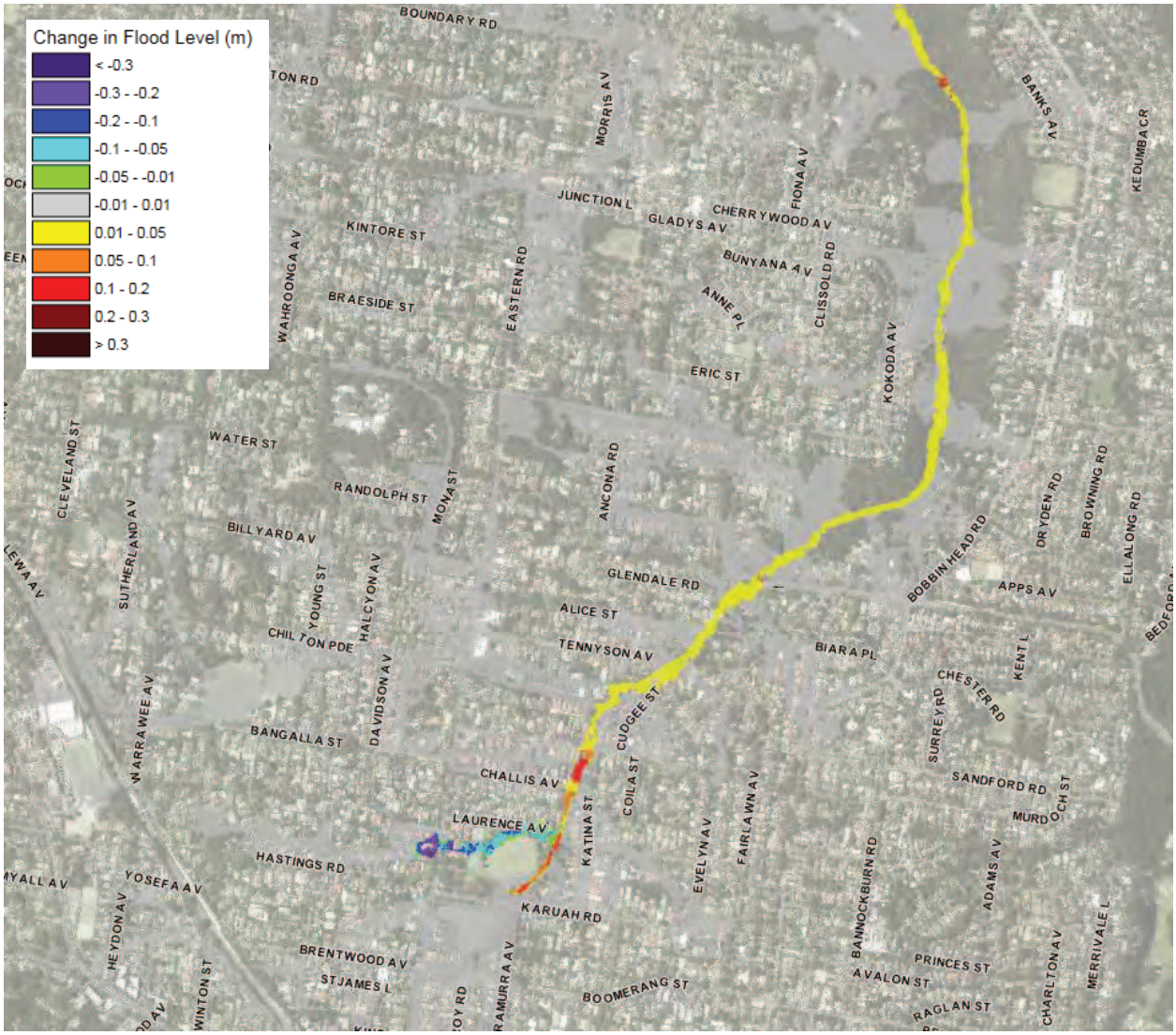
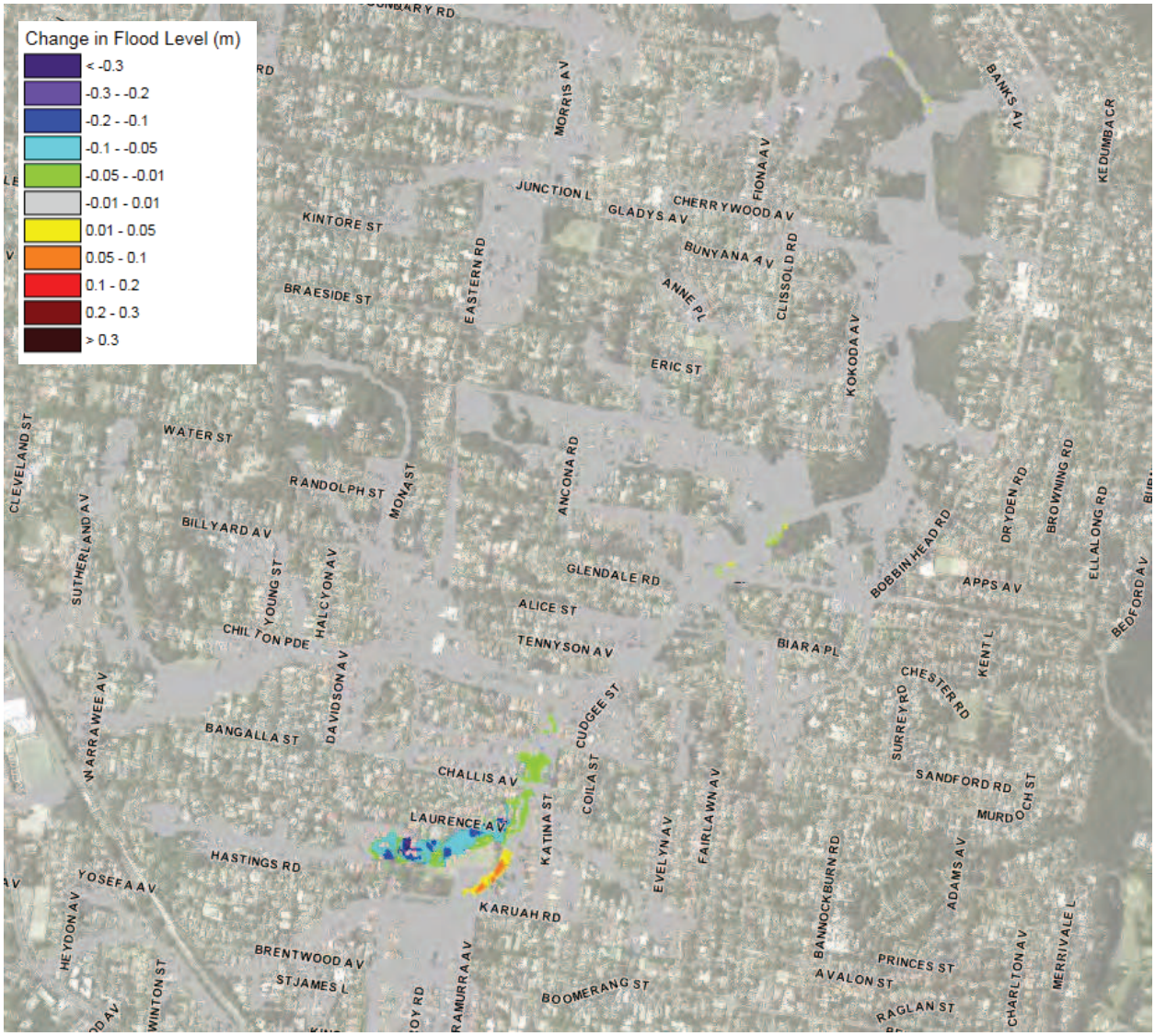


Figure 9-28: Impact of the mitigation Option D7 – Eastern Road, North of Hastings Road in the 1% AEP event



9.2.1.8 Augmented Drainage Line, Billyard Avenue at Mona Street to Lovers Jump Creek, Turramurra (Option D8)

Overland flows from two flow paths north of Billyard Avenue are partially intercepted by a pipe network which then crosses under Billyard Avenue and south-east through private properties to Worcester Place and Eastern Road before discharging to a branch of Lovers Jump Creek. The overland flows converge in the private properties and then flow south-east to the creek. A drainage capacity upgrade may improve flooding to approximately 12 dwellings with above-floor flooding in the 1% AEP.

Hydraulic aspects

A summary of relevant peak flows in this location is provided in Table 9-8.

Table 9-8: Summary of flows at Billyard Avenue near Mona Street

Flow component	Peak Flow (m^3/s)		
	20% AEP	5% AEP	1% AEP
Overland flow	<1	4.4	8.1

Qualitative constraints assessment

A proposed drainage line is likely to clash with existing utilities in the road corridor, requiring protection or relocation. There are already a significant number of existing main stormwater lines through this area, which may pose difficulties in placing a new pipeline. Works would be disruptive to traffic in Eastern Road, which is a significant arterial road. There may also be space constraints in the road and at the discharge point.

This option would increase flows discharged to the creek branch, likely impacting on properties adjacent to the creek, which is already a flooding trouble spot.

Detailed assessment

A 1.35m new pipe line was assessed in detail to increase the interception of flows. The pipe would run east under Billyard Avenue and then south down Eastern Avenue, discharging to the creek opposite Hastings Street. The works were assumed to include rationalising with the existing drainage lines along the route to resolve likely clashes. Refer to Figure 9-29 on the following page for layout.

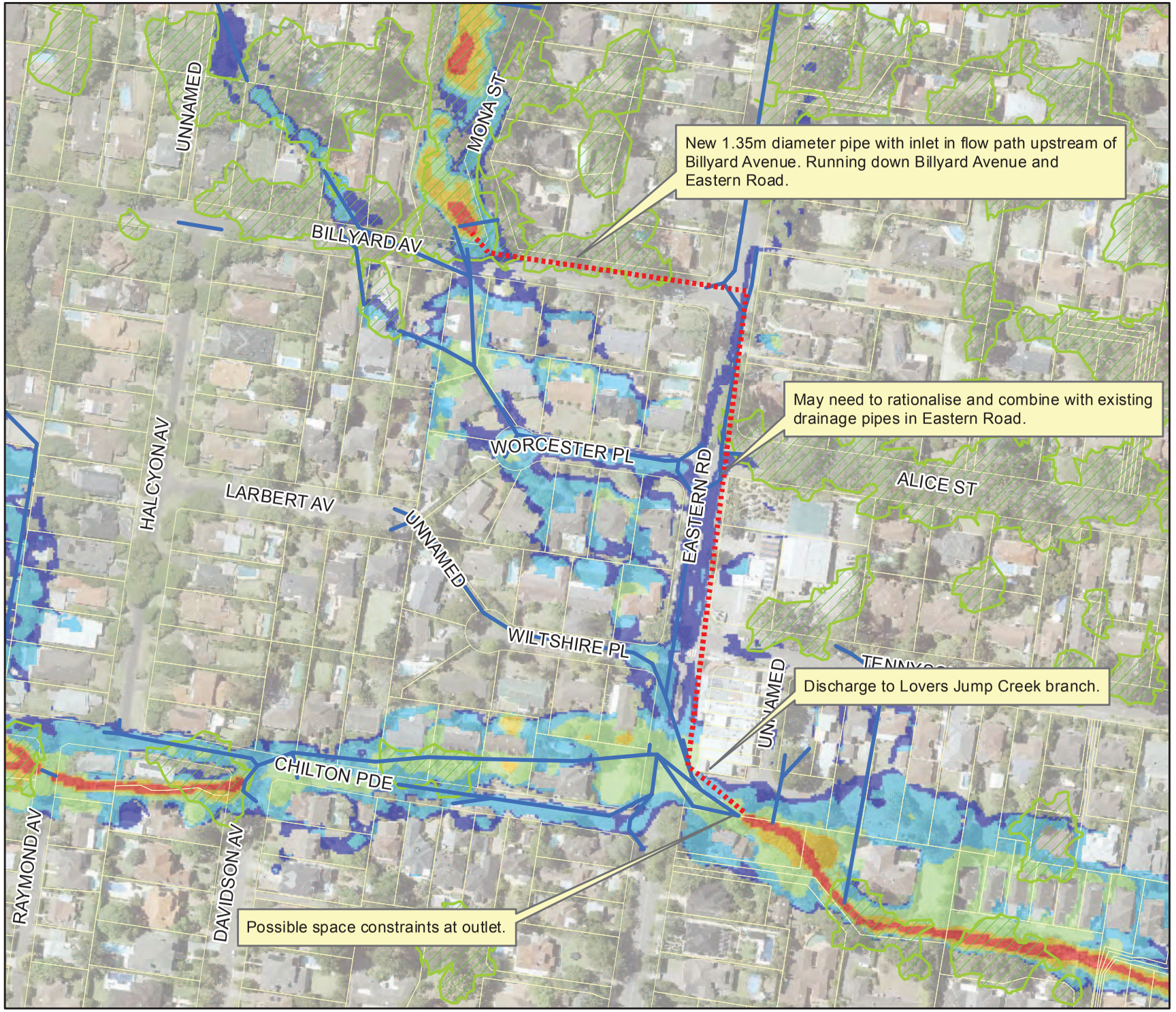
Flooding Impacts

Impacts of the mitigation measure in the 20% and 1% AEP event are presented in Figure 9-30 and Figure 9-31. Change in overall flood behaviour in the study area for mitigation measure Option D8 are provided below:

- Reductions of up to -0.4m in the 2% and 5% AEP, and up to -0.25m in the 1% AEP on properties between Billyard Avenue and Eastern Road.
- Increased flood levels +0.02 to +0.06m in creek and on properties downstream of Eastern Road in the 20% and 10% AEP events. Increases typically +0.02m and localised up to +0.1m in the 5% AEP.
- Five less properties with above floor flooding in 1% AEP event.

Economic Evaluation

The cost for the mitigation measures was approximately $2,261,000. This mitigation option would reduce flood damages at some locations and would save approximately $184,000 over the 50 years design life. The benefit cost ratio for Option D7 was 0.08.



Legend

- Existing Stormwater pipe
- New drainage line
- Endangered Ecological Community
- Cadastre

1% AEP Flood Existing Case

Peak Flood Depth (m)

- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

0 25 50 100
Metres

JACOBS

GDA 1994 MGA Zone 56

TITLE
Drainage Upgrade (Option D8) Billyard Avenue at Mona Street to Lovers Jump Creek Branch

PROJECT
Lovers Jump Creek Floodplain Risk Management Study and Plan

PROJECT # IA159900

MAP # FIGURE 9-29

DATE 24/01/2019

Figure 9-30: Impact of the mitigation Option D8 – Billyard Avenue near Mona Street in the 20% AEP event

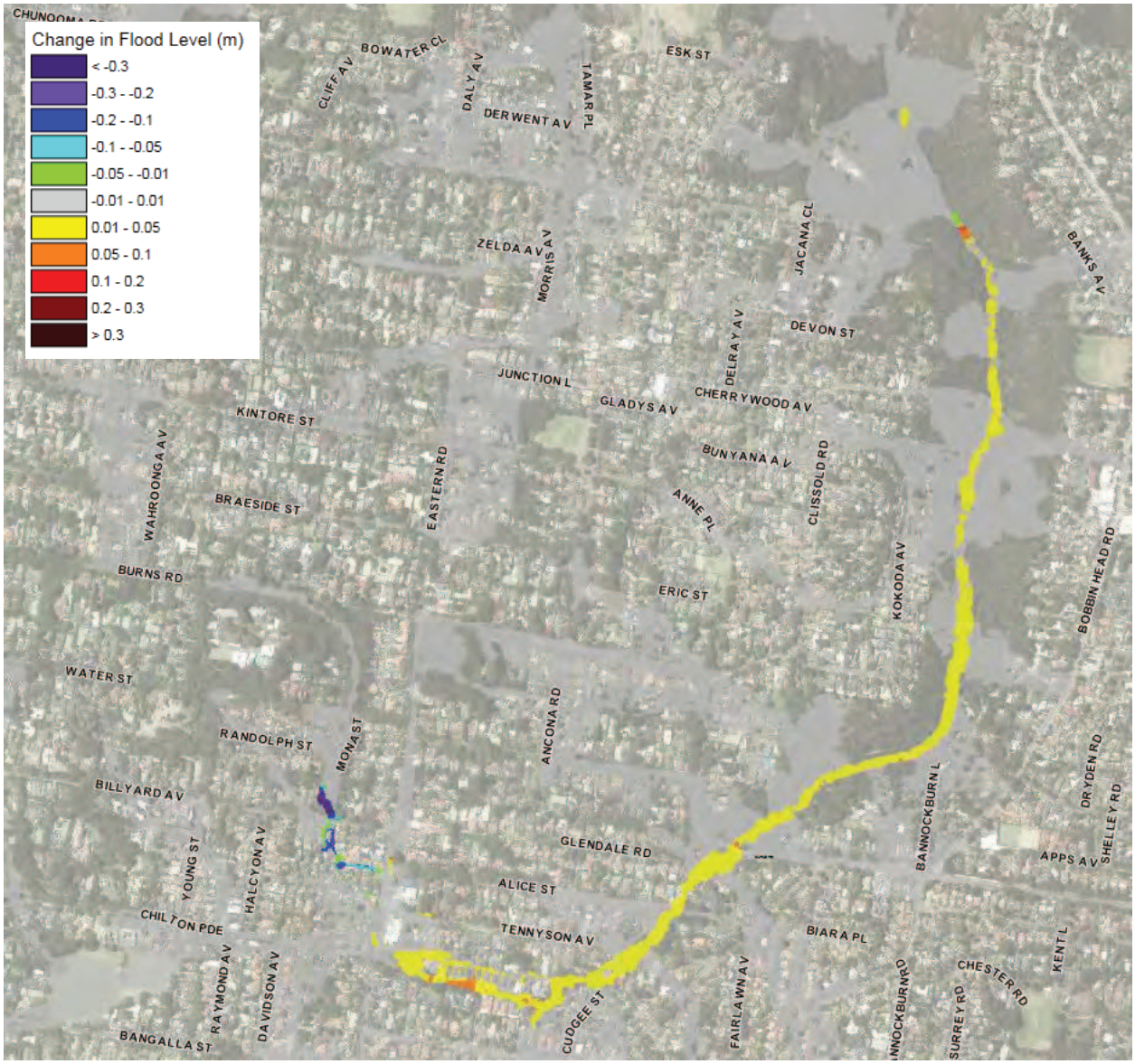


Figure 9-31: Impact of the mitigation Option D8 – Billyard Avenue near Mona Street in the 1% AEP event