DTMR M1 UPGRADE

FLOOD EVENTS OF FEBRUARY AND MARCH 2022
IMPACT ANALYSIS AND RISK ASSESSMENT

Prepared for:

[redacted]

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
620.31045-R01-v0.1	7 October 2022	[redacted]	[redacted]	

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FIGURES

1 INTRODUCTION

1 I refer to the [redacted] letter of instruction of 23 June 2022 in relation to this matter, and subsequent detailed discussions with you and Department of Transport and Main Roads (DTMR) personnel. In accordance with your instructions, SLR Consulting under my direction has completed a comprehensive assessment of the major storm event which occurred on the Gold Coast in late February and early March 2022, and the consequent flooding which occurred in the Tallebudgera Creek catchment. In particular, we have focussed on quantifying the potential impact of construction works on flood levels in this catchment.

2 The flood event which occurred in later March has also been assessed. However, the results of that analysis show substantially lower flood levels, and our primary focus has therefore been on the earlier event.

3 For completeness sake, I note that DTMR is currently constructing the M1 Pacific Motorway upgrade for the Varsity Lakes to Tugun (VL2T) project. The project comprises three packages, being Package A (VL2B), Package B (B2PB) and Package C (VL2T) as per the coloured sections on the plan on the next page.

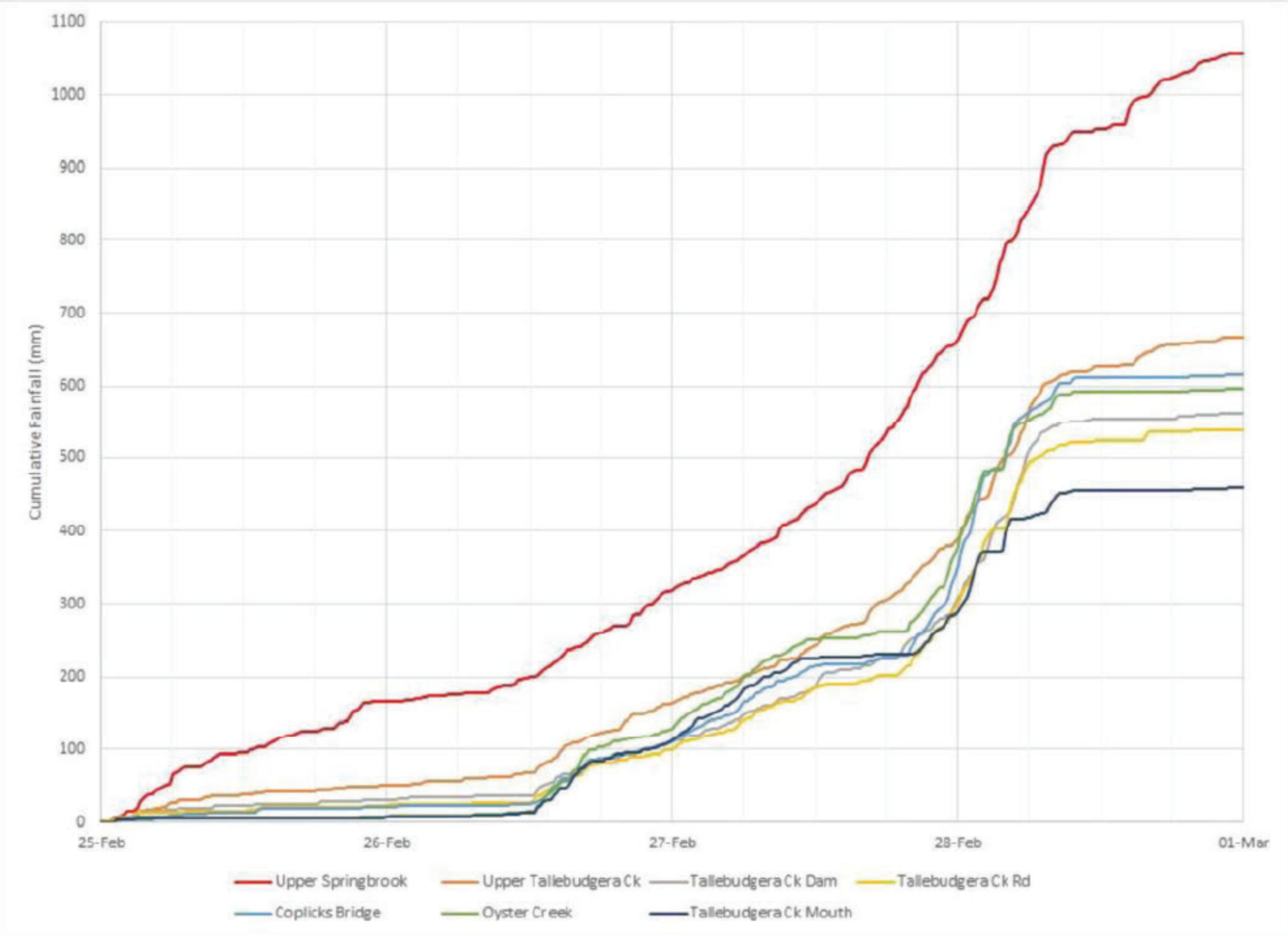
4 The upgrading of the Motorway involves extensive construction works within the floodplains of several local creeks. In this case, the focus is on Tallebudgera Creek and a minor tributary of that system known as Oyster Creek. The major structures in the floodplain which could have impact on flood levels are the new bridges under construction in Tallebudgera Creek itself, as well as the culvert installation a few hundred metres south of the Creek.

2 RAINFALL INTENSITY ANALYSIS

2.1 The Flood Event of Late February and Early March 2022

5 Pluviograph and ALERT rainfall stations record rainfall totals against time, allowing accurate determination of actual rainfall intensities occurring on site. In this case, the Bureau of Meteorology maintains digital records of seven rainfall stations within the catchment as per the following plan:

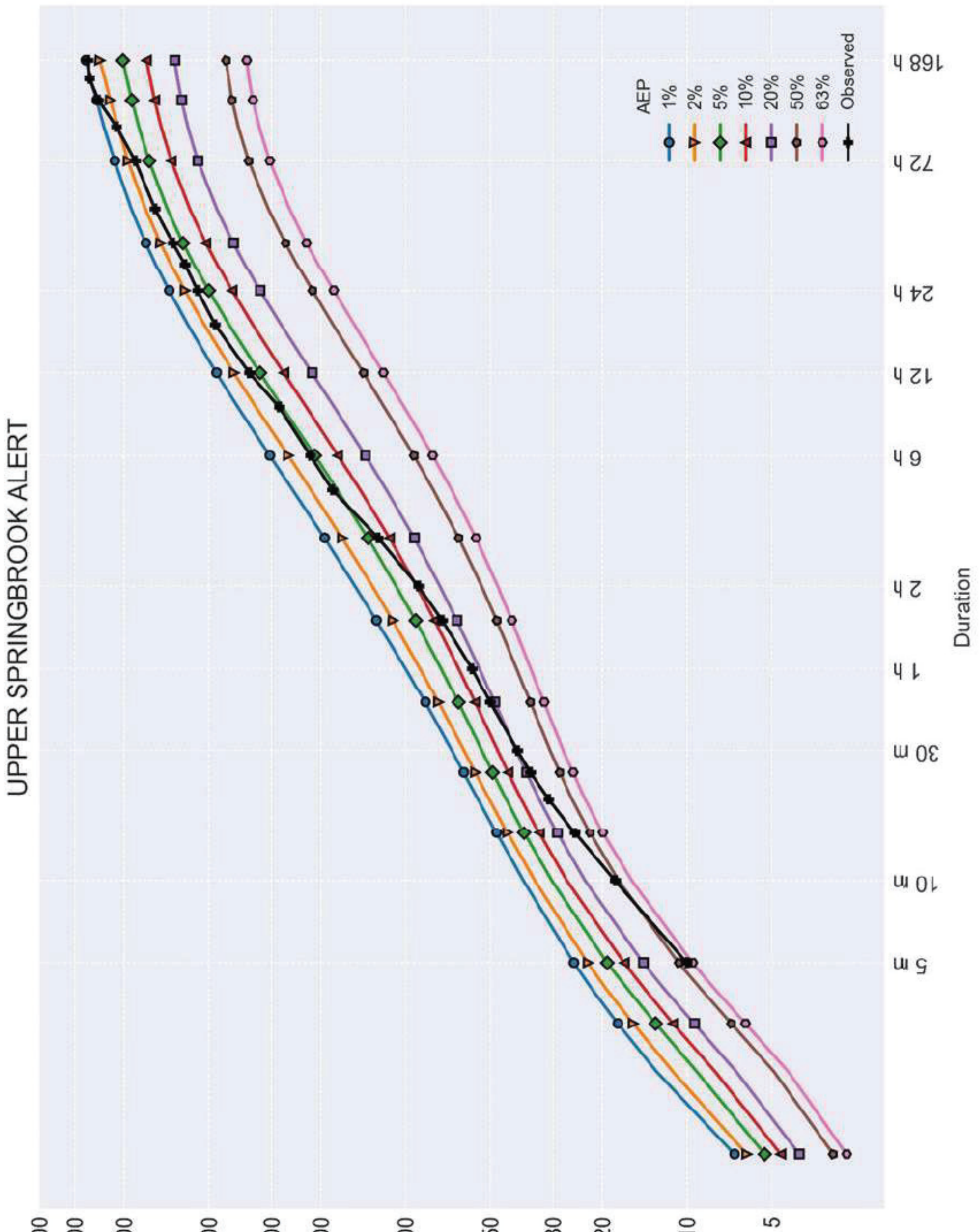
6 The cumulative rainfall totals for the various rainfall stations for the period from 0.00 hours on 25 February to 0.00 hours on 1 March are presented in the following graph. While the total rain event was somewhat longer, this period contains the maximum intensity rainfalls which were recorded at each station. It can be seen that more than 1,000 mm of rain fell at the Springbrook gauge over this period, while the majority of the catchment received between 500 and 700 mm. In comparison, it is noted that the average annual rainfall for at Guineas Creek Road daily rainfall station (which is located in the lower part of the catchment) is 1,587 mm. This was therefore a significant rainfall event

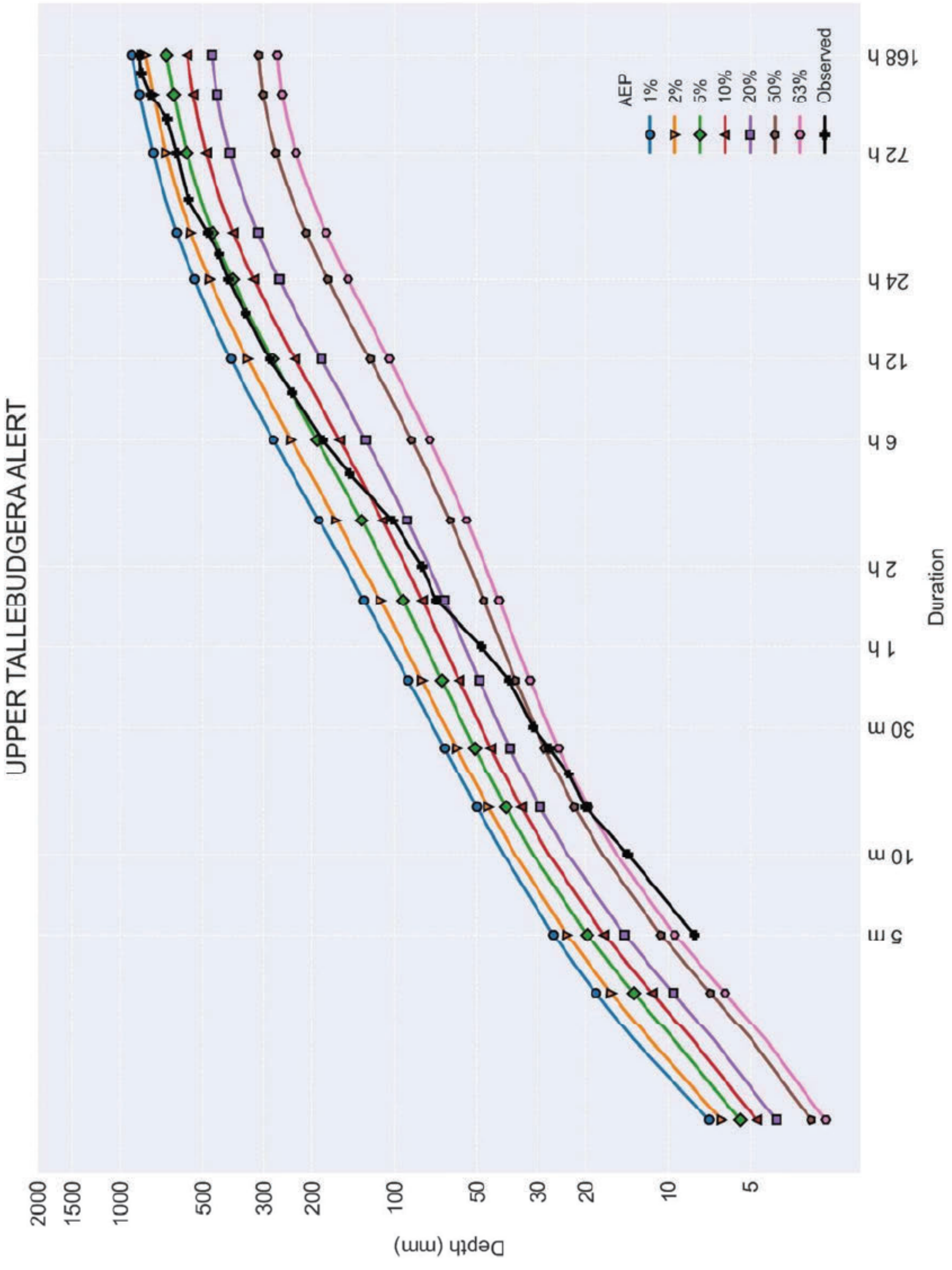


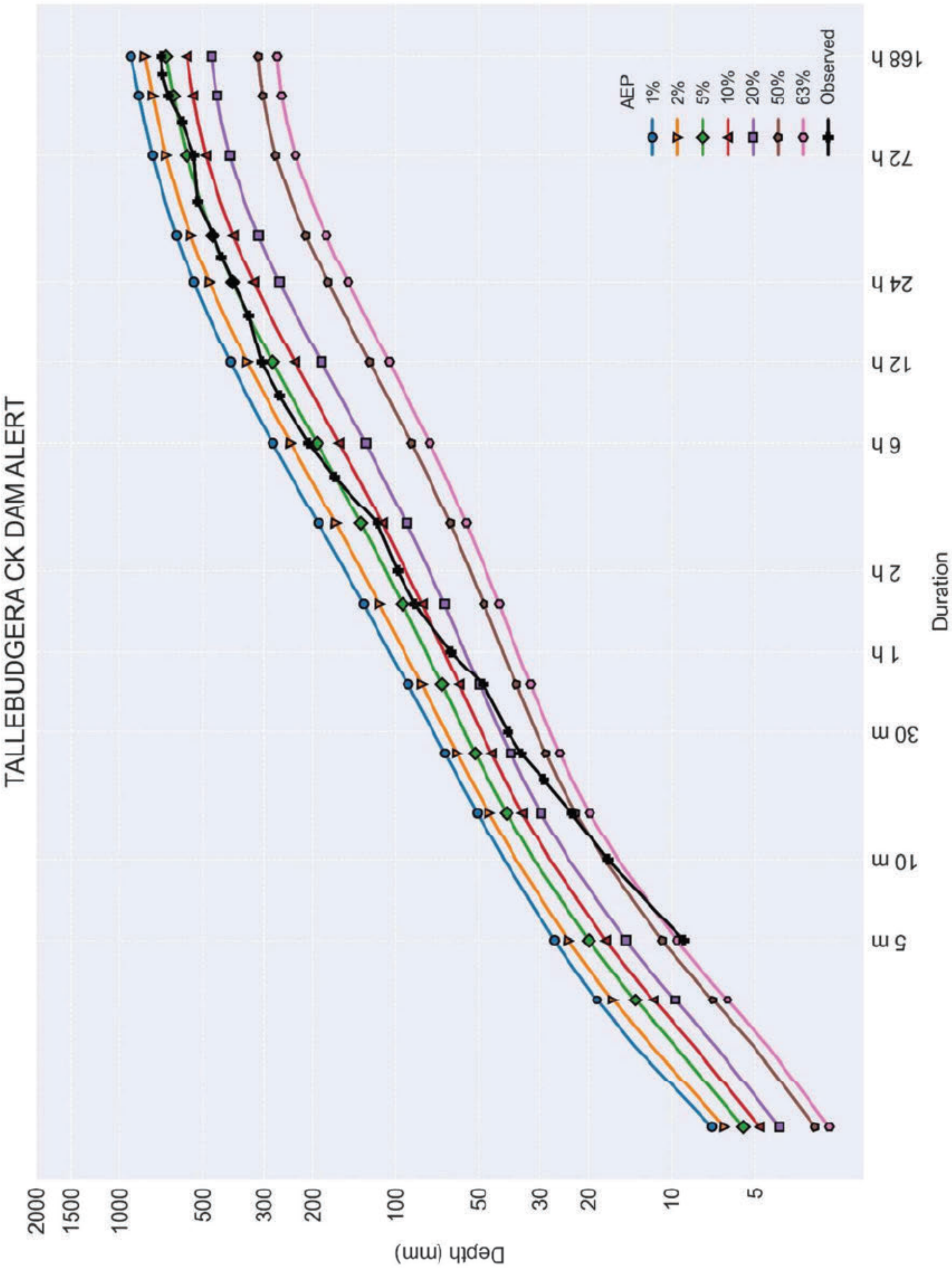
7 Rainfall Depth-Frequency-Duration (DFD) and Intensity-Frequency Duration (IFD) curves are used to estimate the probability of an actual rainfall event, ie how rare the event might be. This probability of a particular storm event varies with the duration of that event, such that shorter durations always provide higher rainfall intensities than longer duration events for the same frequency of occurrence. This simply means that average rainfall intensities decrease with increasing duration.

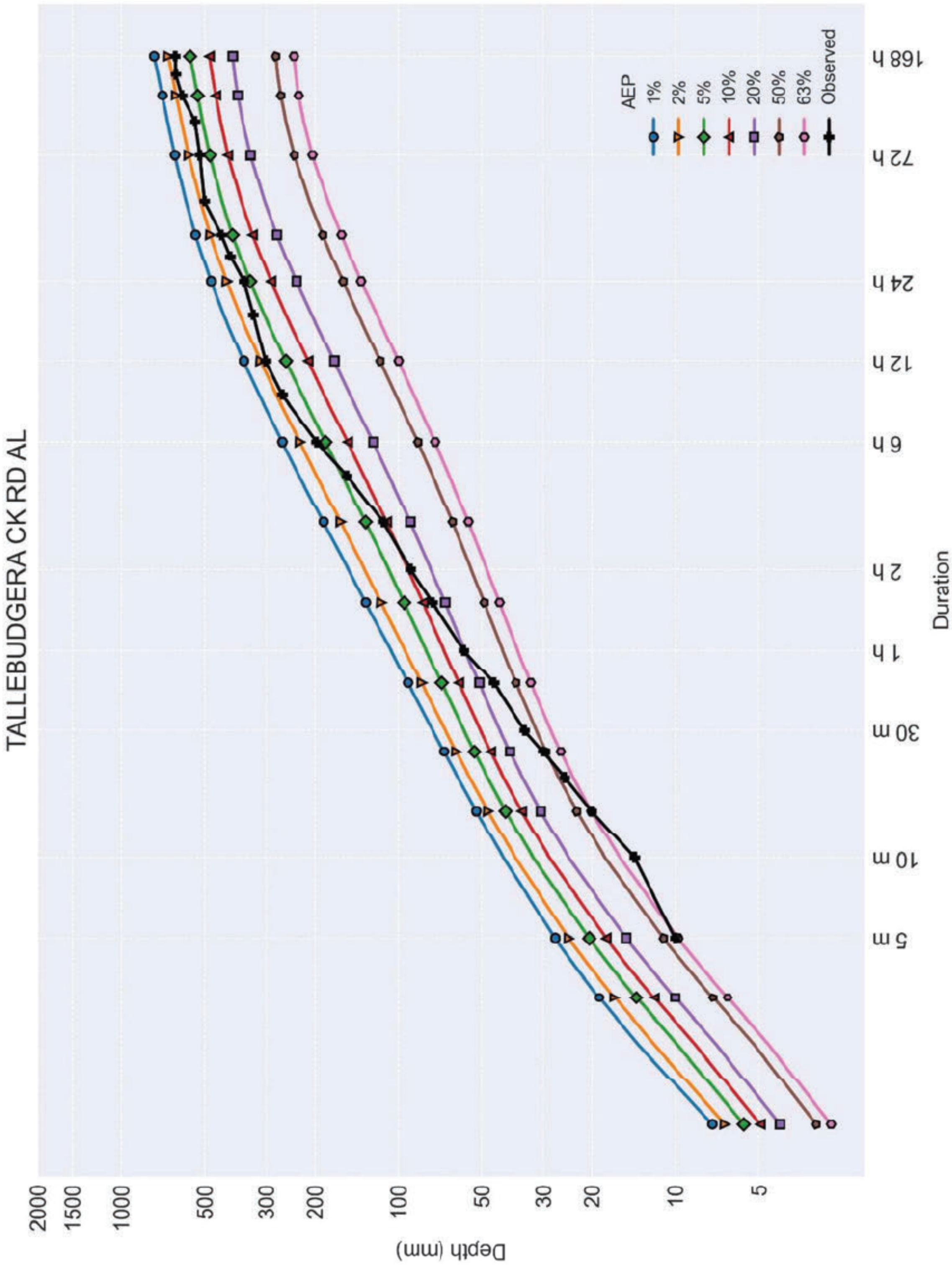
8 In accordance with current engineering hydrological practice, the frequency of a design storm event is now presented as Average Exceedance Probability (AEP), and is always associated with a duration. A 1% AEP storm event of a certain duration (say three hours) has a 1% chance of rainfall with that intensity occurring or being exceeded in any specific year. In layman's terms, this specific AEP event has traditionally been described as the rainfall depth (for that duration) which is predicted (based on an adopted probability distribution) to be equalled or exceeded only once every 100 years on average. However, there is no certainty that such an event will occur within any specific 100 year period because of the stochastic nature of rainfall event. That is, rainfall has a random probability distribution that can be analysed statistically to derive key parameter such as annual average but cannot be determined precisely on any specific day.

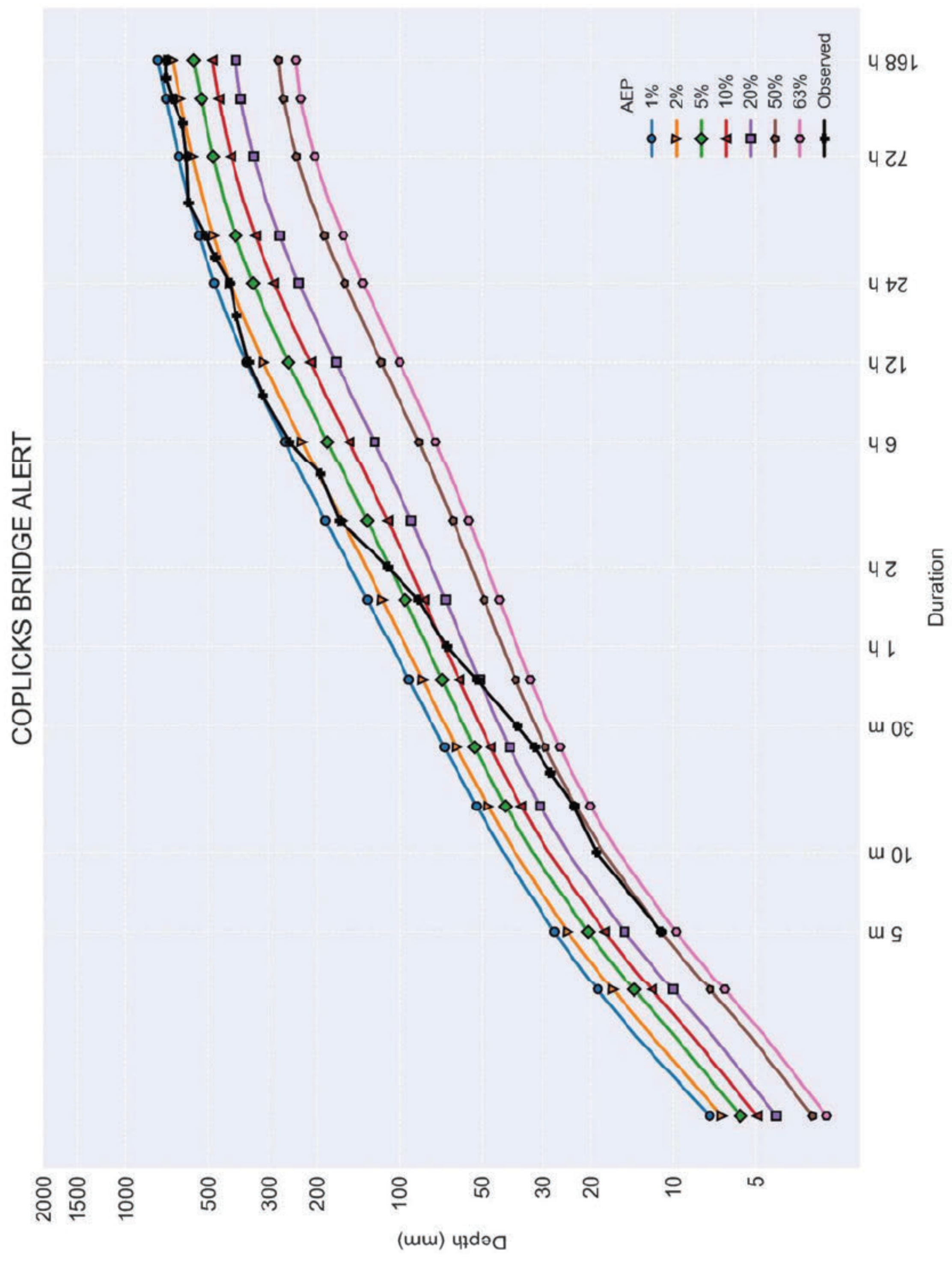
The DFD curves for each of the rainfall stations within the catchment are presented on the next few pages.

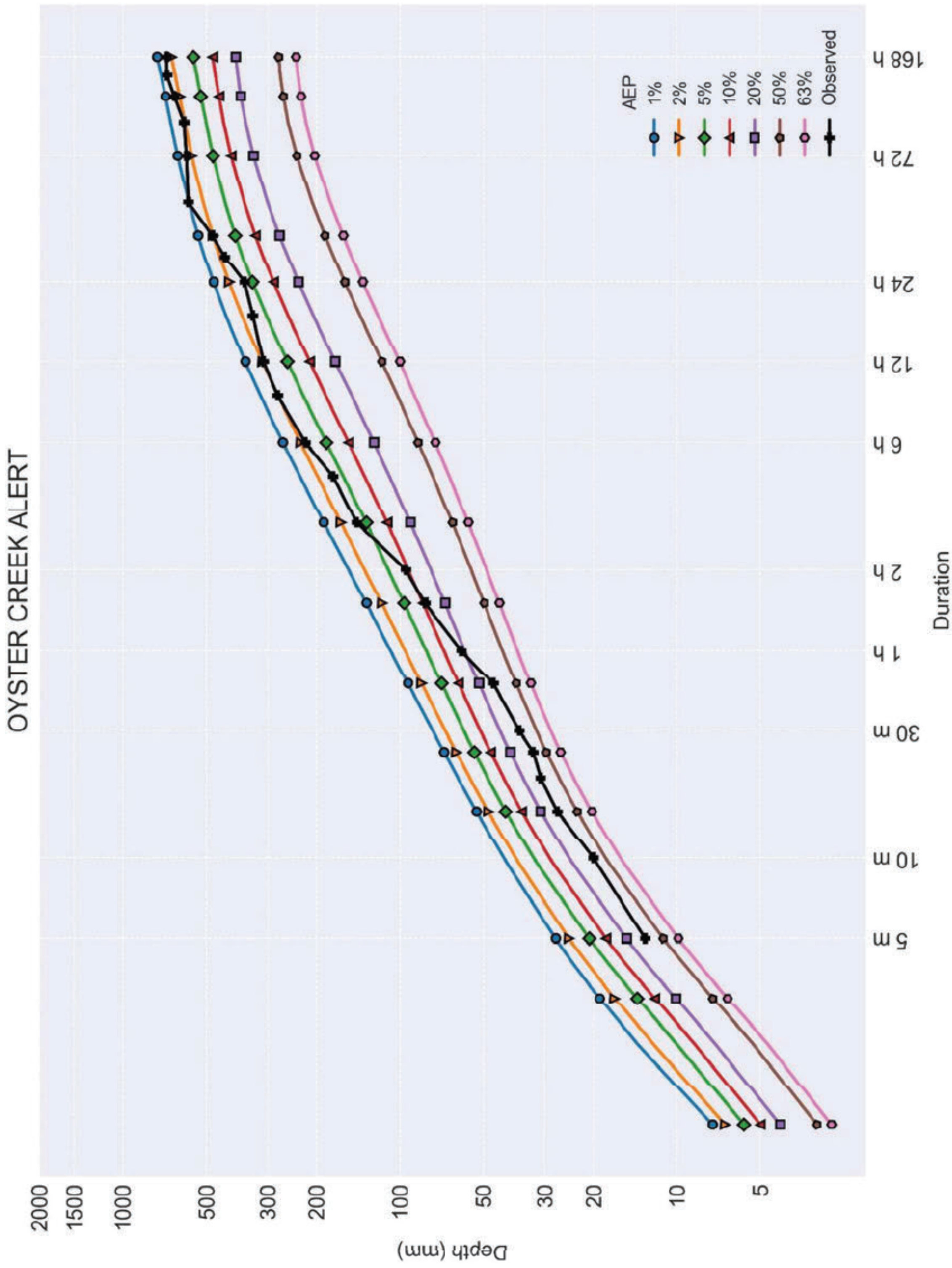

UPPER SPRINGBROOK ALERT
Depth (mm)
2000
1500
1000
500
300
200
100
50
30
20
10
5
Duration
5 m
10 m
30 m
1 h
2 h
6 h
12 h
24 h
72 h
168 h
AEP
1%
2%
5%
10%
20%
50%
63%
Observed

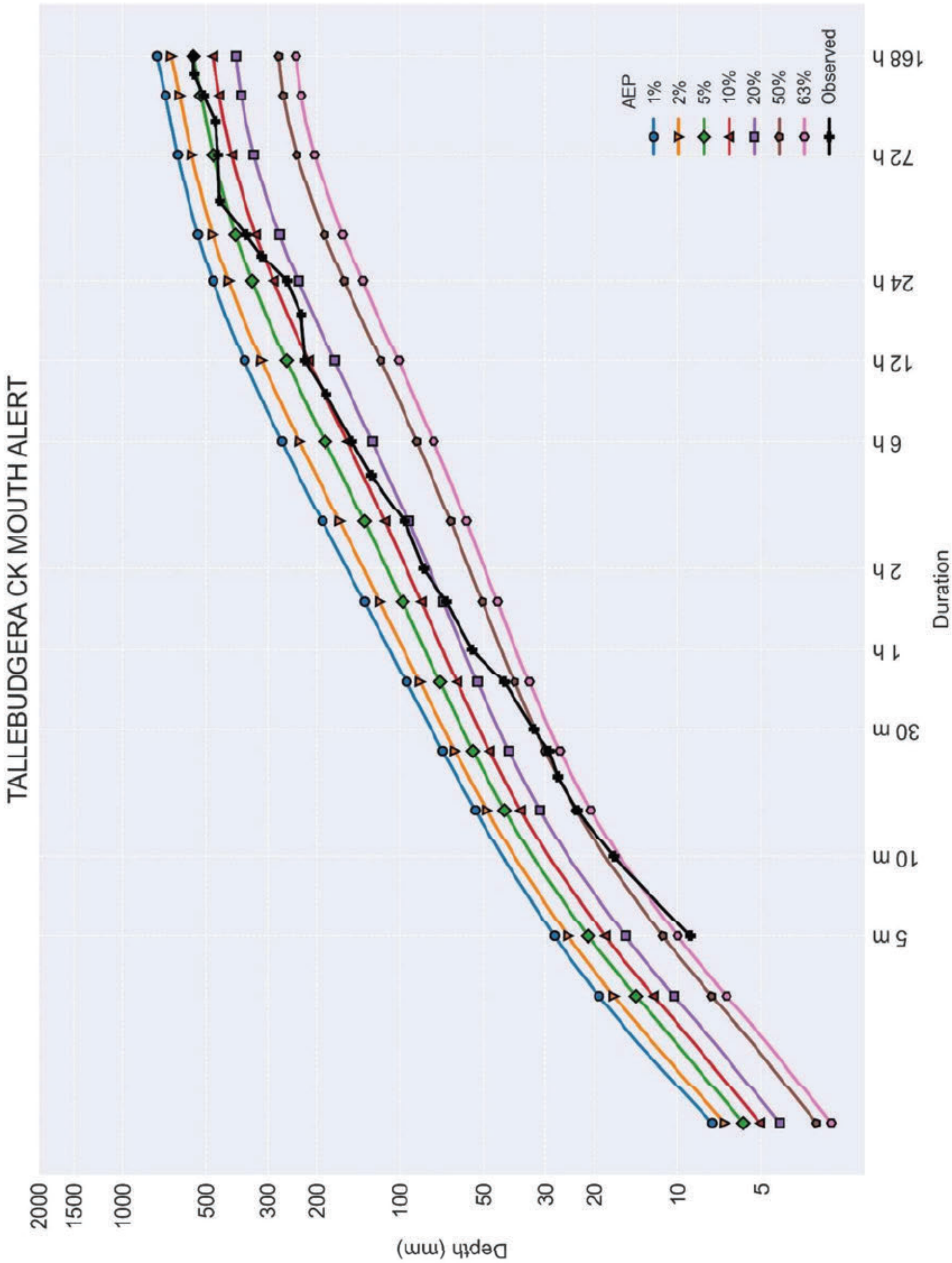

UPPER TALLEBUDGERA ALERT
Depth (mm)
2000
1500
1000
500
300
200
100
50
30
20
10
5
Duration
5 m
10 m
30 m
1 h
2 h
6 h
12 h
24 h
72 h
168 h
AEP
1%
2%
5%
10%
20%
50%
63%
Observed


TALLEBUDGERA CK DAM ALERT
Depth (mm)
2000
1500
1000
500
300
200
100
50
30
20
10
5
Duration
5 m
10 m
30 m
1 h
2 h
6 h
12 h
24 h
72 h
168 h
AEP
1%
2%
5%
10%
20%
50%
63%
Observed


TALLEBUDGERA CK RD AL
Depth (mm)
2000
1500
1000
500
300
200
100
50
30
20
10
5
Duration
5 m
10 m
30 m
1 h
2 h
6 h
12 h
24 h
72 h
168 h
AEP
1%
2%
5%
10%
20%
50%
63%
Observed


COPLICKS BRIDGE ALERT
AEP
1%
2%
5%
10%
20%
50%
63%
Observed
Depth (mm)
2000
1500
1000
500
300
200
100
50
30
20
10
5
Duration
5 m
10 m
30 m
1 h
2 h
6 h
12 h
24 h
72 h
168 h


OYSTER CREEK ALERT
Depth (mm)
Duration
AEP
1%
2%
5%
10%
20%
50%
63%
Observed
5 m
10 m
30 m
1 h
2 h
6 h
12 h
24 h
72 h
168 h
2000
1500
1000
500
300
200
100
50
30
20
10
5


TALLEBUDGERA CK MOUTH ALERT
Depth (mm)
2000
1500
1000
500
300
200
100
50
30
20
10
5
Duration
5 m
10 m
30 m
1 h
2 h
6 h
12 h
24 h
72 h
168 h
AEP
1%
2%
5%
10%
20%
50%
63%
Observed

9 In any actual storm event (such as the February flood), there is a duration which produces rainfall corresponding to the lowest probability. This is not necessarily the duration which has the maximum rainfall intensity or the maximum total depth of rainfall, but rather the duration which corresponds to the rarest storm.

10 In this case, the DFD curve analysis indicates that the February 2022 storm had maximum probabilities of about 5% AEP at the Tallebudgera Creek Mouth and generally 1% AEP for the remainder of the catchment. With the exception of the Coplicks Bridge station, the durations corresponding to these events were generally 24 hours or longer, and in some cases, up to 168 hours (seven days). Overall, this total storm event (durations in excess of 24 hours) would be typified as having an AEP of between 1% and 2%, which is obviously an extreme rainfall event with a corresponding Average Recurrence Interval of 50 to 100 years. However, it is important to note that this description only applies to the longer events with durations of up to seven days.

11 In comparison, the critical storm duration for a catchment will be that duration which produces the maximum flood levels (and generally the maximum flow rates over the length of the catchment). The seven day storm is not the critical duration storm for this catchment, and will therefore not produce the maximum flood levels. The average rainfall intensity for the same frequency storm decreases with increasing duration. That is, a seven day (168 hour storm) with a probability of 2% will have a much lower average rainfall intensity than a six hour storm of the same probability.

12 In contrast to this interpretation of the DFD curve information, the storm durations which cause severe flooding in the Tallebudgera Creek catchment are estimated by technical assessment (based on a catchment area down to the M1 of about 88 km^2 and a stream length of just over 25 km) and review of available records to be generally between six and twelve hours. The longer duration events (up to seven days) noted above do not have sufficiently intense rainfall to cause major flooding in this creek system. Therefore, we are most interested in the probability of storms with durations of six to twelve hours. These can also be read directly from each of the DFD curves above.

13 Therefore, the other general conclusion which can be drawn from the DFD analyses is that the February 2022 rainfall in the six to twelve hour duration range (which are those durations capable of causing the flooding experienced in Tallebudgera Creek) had probabilities as follows:

- Upper Springbrook 5% AEP
- Upper Tallebudgera 5% AEP
- Tallebudgera Creek Dam 3% AEP
- Tallebudgera Creek Road 2% AEP
- Coplicks Bridge 1% AEP
- Oyster Creek 2% AEP
- Tallebudgera Creek Mouth 10% AEP

14 Overall, the February 2022 storm event is considered to correspond to an AEP of between 2% and 5%. That is, it had a recurrence interval of between 20 years and 50 years. This is not withstanding that one local gauge (Coplicks Bridge) recorded rainfall intensities equivalent to a 1% AEP storm event. Since each rainfall station represents less than 20% of the overall catchment, one station recording high does not overly influence the outcome. I will also show in subsequent sections that the flood levels recorded in the catchment in the area of interest upstream of the M1 are also consistent with the 2% to 5% AEP estimate.

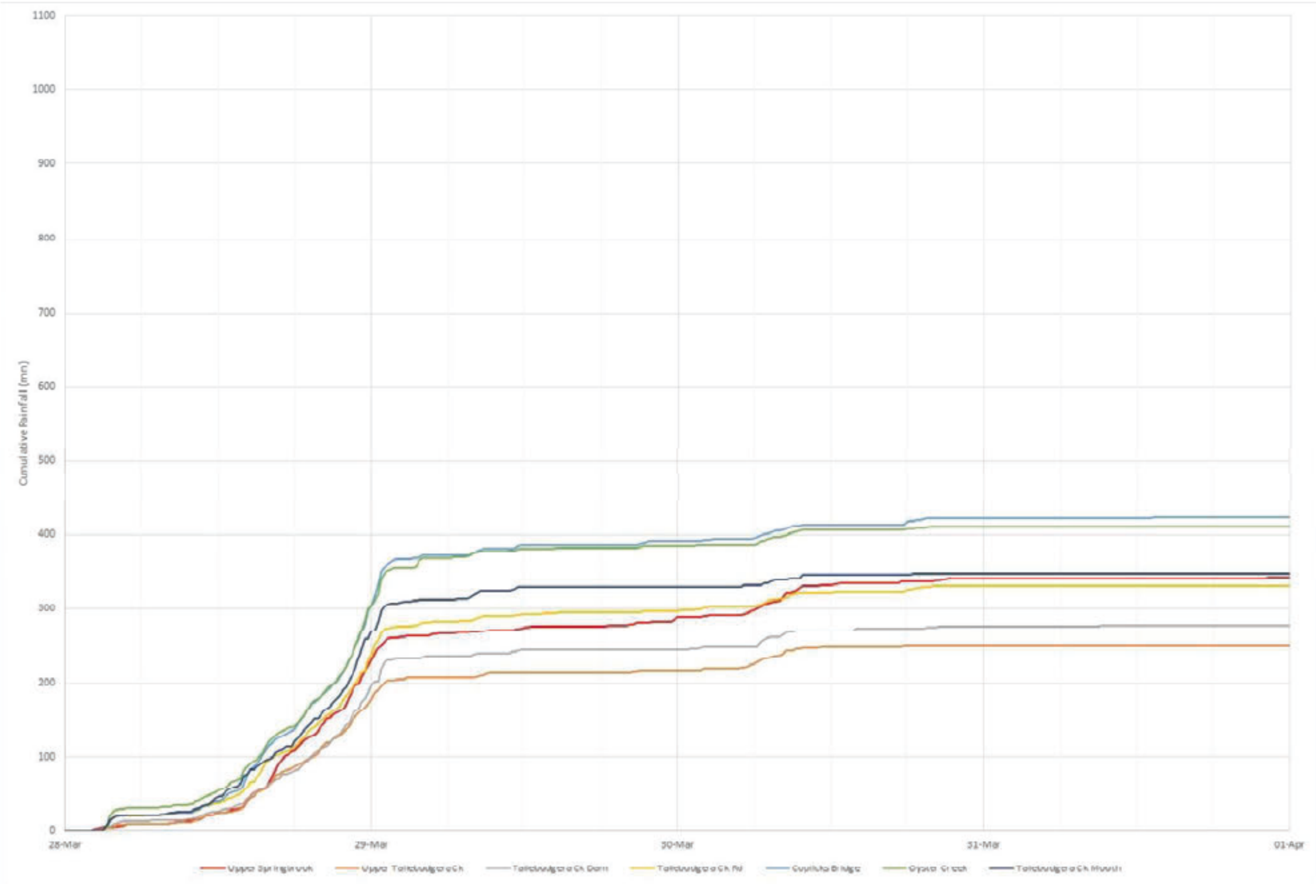
2.2 The Flood Event of 28 to 30 March 2022

15 A similar rainfall intensity analysis was carried out for this event. As I have noted in my introduction above, the flood levels produced by this event were lower than for the February event, and the average intensity information derived from the rainfall records supports the position that the March event was less severe overall. However, this rain was falling on a saturated catchment, so there was at least the potential for flooding.

16 Based on recorded rainfall intensities, and assuming again that the critical storm duration for the Tallebudgera Creek catchment at the M1 is between six and twelve hours, the March 2022 rainfall had the following probabilities at each of the monitoring stations:

- Upper Springbrook 18% AEP
- Upper Tallebudgera 30% AEP
- Tallebudgera Creek Dam 20% AEP
- Tallebudgera Creek Road 10% AEP
- Coplicks Bridge 4% AEP
- Oyster Creek 5% AEP
- Tallebudgera Creek Mouth 8% AEP

17 The cumulative rainfall values for each of the rainfall stations for the March 2022 event are given in the following graph.



18 It is noted that this storm was more variable over the catchment area than the February event. In the upper catchment, the storm was not particularly severe, having an AEP of more than 20% (equivalent to less than a 5 year recurrence interval). In the lower part of the catchment, the storm was significantly more severe, and had perhaps a 5% probability overall. However, it is noted that the February storm was more intense again in these locations. Based on flow rates, the flood in the creek at the gauging station at Tallebudgera Creek Road had about a 14% AEP, which is entirely consistent with the hydrological results listed above.

19 Overall, the March 2022 storm event is considered to correspond to an AEP of between 5% and 10%, perhaps leaning more to the higher figure. That is, it had a recurrence interval of slightly more than 10 years. The results from the hydraulic modelling are consistent with this estimate. In my opinion, it is unlikely that this storm caused any habitable floor flooding.

20 Full details of this modelling, including the hydraulic model results, can be provided if required. However, it is certain that the March 2002 flood event was significantly less severe than the February 2022 event.

3 FLOOD MODELLING

3.1 Introduction

21 In order to determine the potential impact of construction works on flood levels, it is necessary to consider both storm hydrology and catchment hydraulics. In this case, and in accordance with best practice, numerical computer-based models were used for both hydrologic and hydraulic analysis purposes.

22 Gold Coast City Council already has a calibrated flood model of the Tallebudgera Creek system which is used for flooding analysis and development assessment purposes. Council's work uses an URBS hydrologic model (which converts rainfall into flow hydrographs) and a MIKE-21 hydraulic model (which converts those flow rates into water depths and velocities). Relevant information from Council's MIKE-21 hydraulic model was used by the project designers (HDRWSP consortium) to develop a more detailed TUFLOW hydraulic model consistent with best engineering practice. That TUFLOW model was then used as the primary basis for the design of drainage works in the VL2T Motorway project, to ensure that the project would not have unacceptable adverse flooding impacts on other areas in the catchment.

23 It is noted that HDRWSP were not required to utilise the URBS model, since they were dealing with design storm considerations rather than actual flood events. HDRWSP therefore used the design flood hydrographs which were already contained in the MIKE-21 model for their design purposes. HDRWSP developed both pre-development (corresponding to catchment conditions before the commencement of V2LT) and post-development (corresponding to VL2T fully constructed and operational) models.

24 SLR Consulting was provided with HDRWSP's pre-development TUFLOW model, but did not have access to the post development model. We therefore used additional survey and photographic information provided to us by DTMR to set up what I have called the construction phase model. I note that HDRWSP, in its assessment and draft reporting on the February 2022 event, did not set up a specific model of the actual storm event, but used results from the developed case model for comparison purposes.

25 The SLR construction phase TUFLOW model is therefore likely to be a more accurate and robust assessment tool for determination of flooding effects during this event, particularly since we have been able to calibrate that model against recorded flood levels.

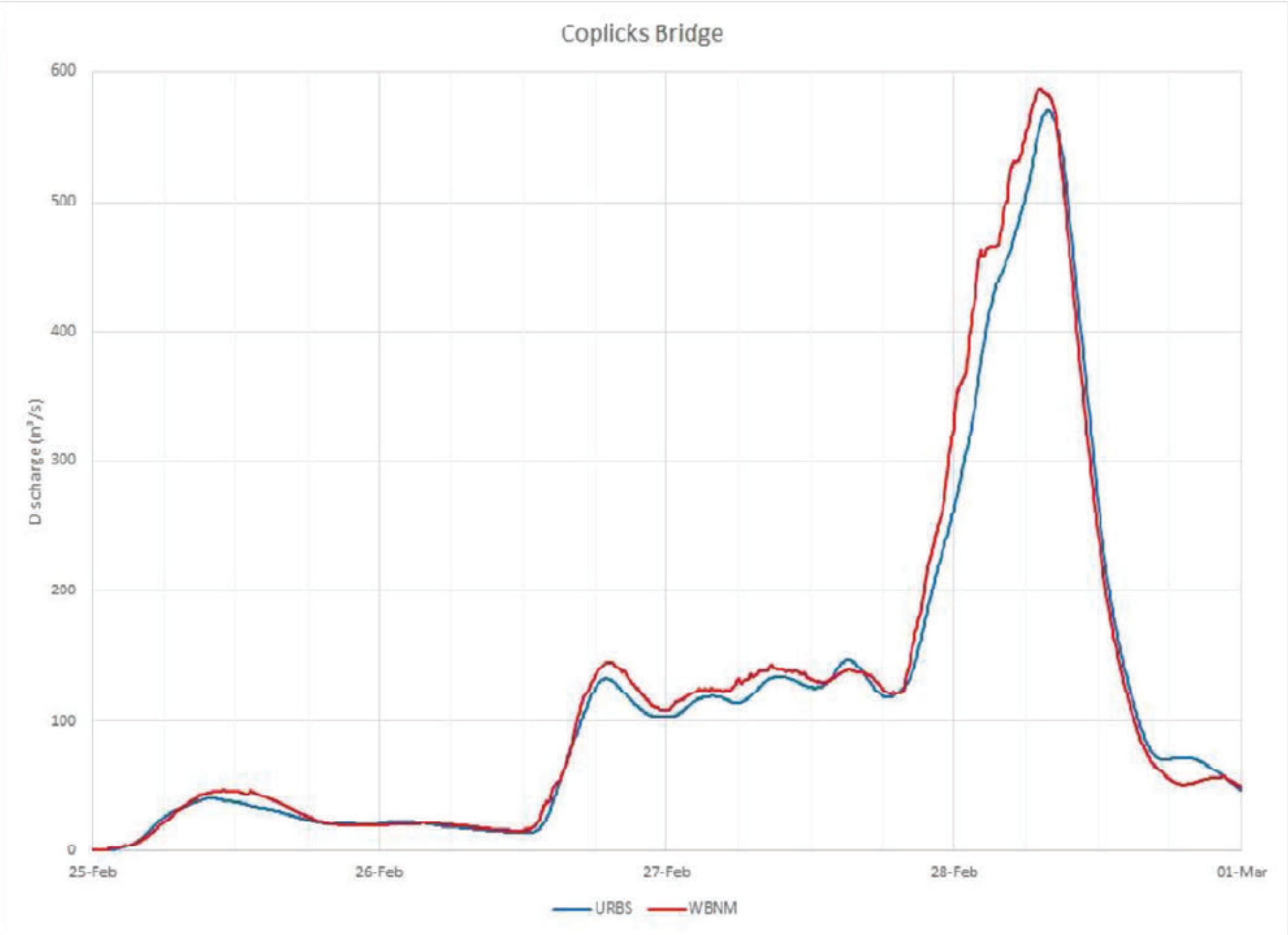
26 It is intended that the construction phase model correspond to the state of construction activity occurring on the site in late February 2022. While this data is not complete (ie we do not have a digital terrain model which represents the entire state of the works in February), I believe that we have sufficient information to have confidence in the modelling results.

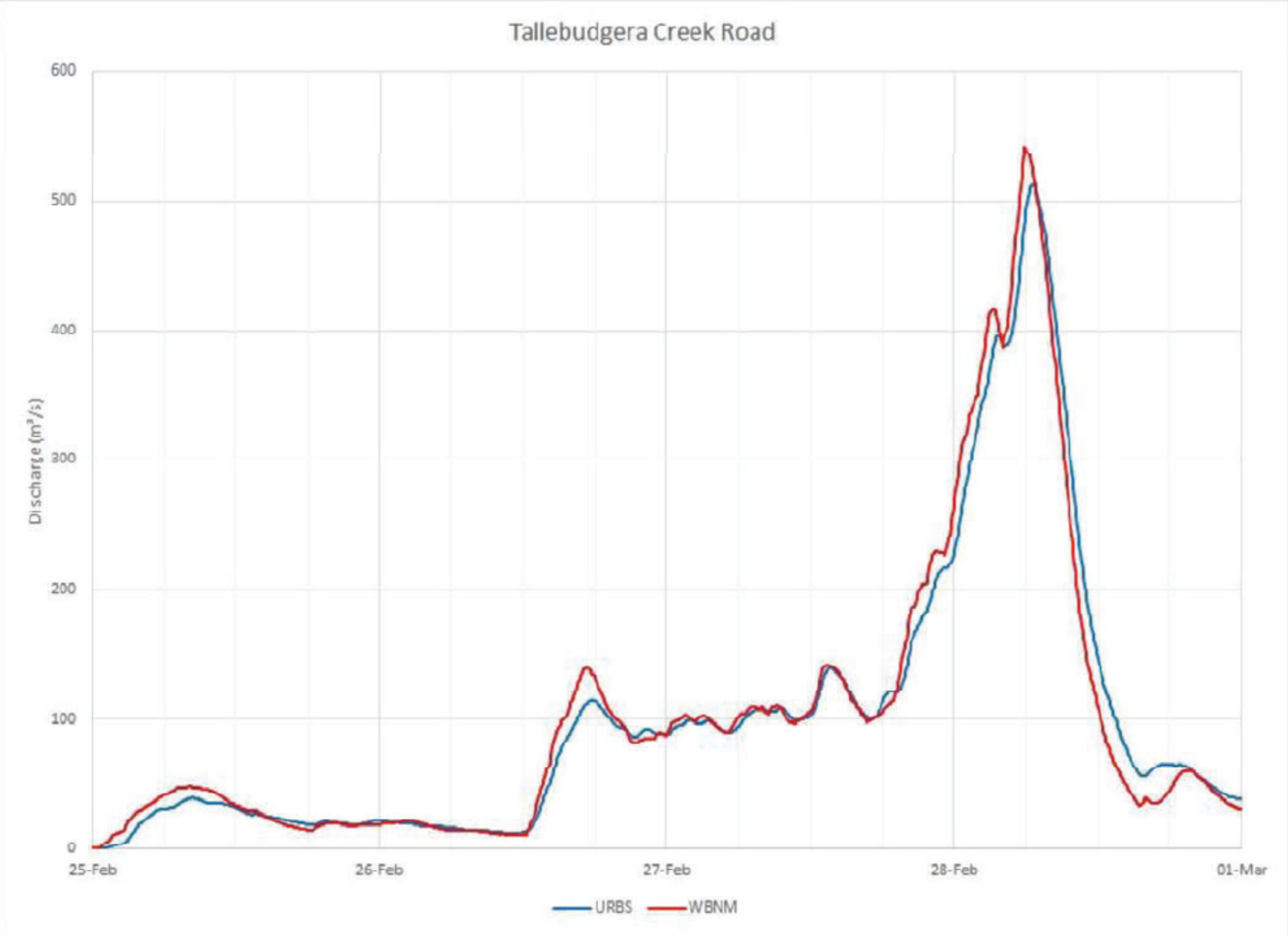
3.2 Hydrologic Model Verification

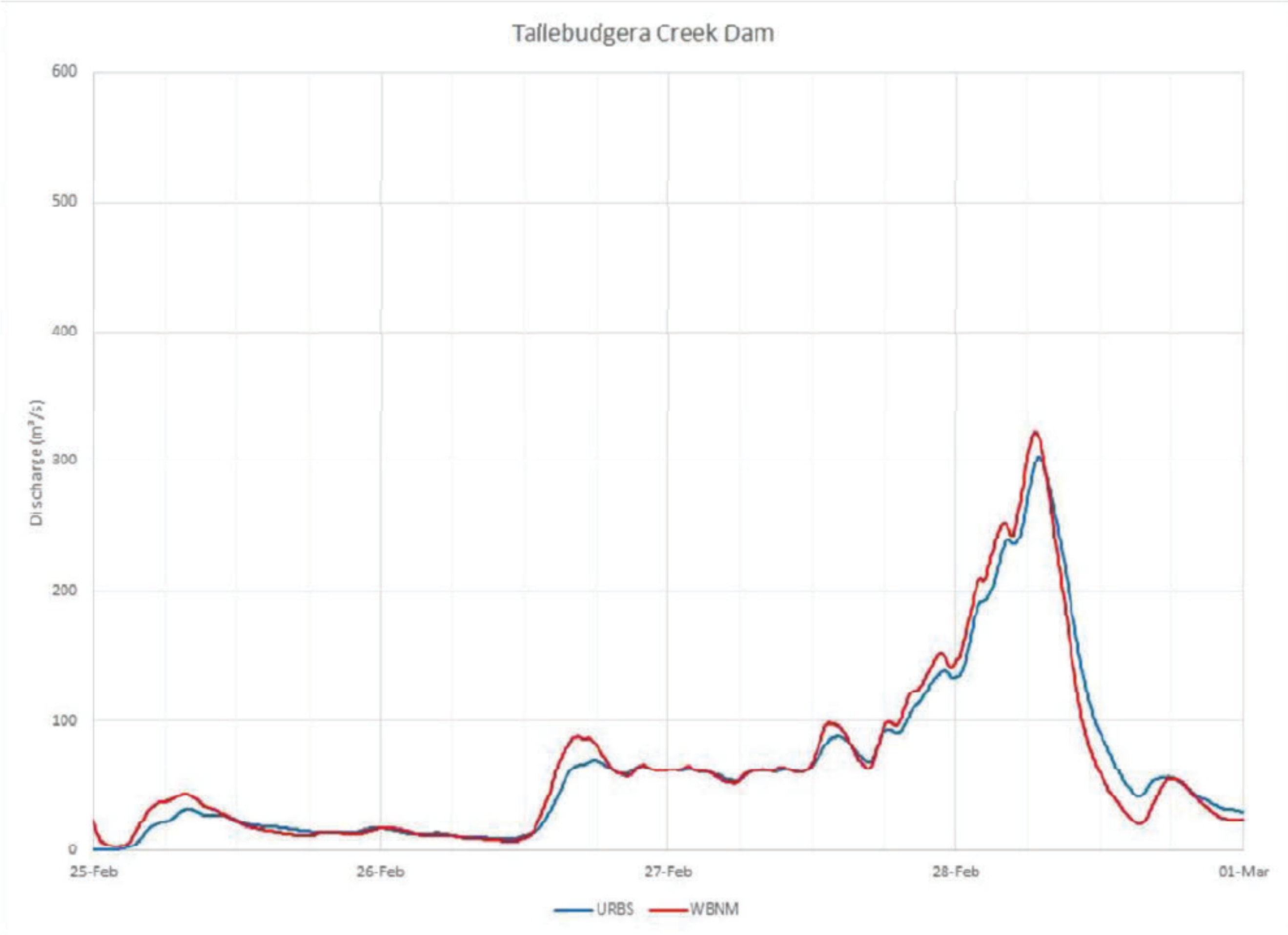
27 Council's Tallebudgera Creek flood modelling is based on an URBS model. In general, we consider the Watershed Bounded Network Model (WBNM) to be a more appropriate tool for subsequent TUFLOW modelling. A WBNM model of the catchment was therefore set up based on available catchment mapping. In this case, therefore, we have access to the results from two hydrologic models (URBS and WBNM) which can be compared for verification purposes.

28 The WBNM model converts rainfall into flow rate based on the intensity of the rainfall, the area of the catchment, and design routing parameters based on the type of stream under consideration. Since there are seven rainfall gauges in the catchment, the apportioning of rainfall into the various sub-catchments in the model is based on what is called a Thiessen Polygon, where the distance between individual stations is used to calculate the influence of each station on the result.

29 This verification was carried out at three station locations in the mid to lower catchment, namely Coplicks Bridge, Tallebudgera Creek Road and Tallebudgera Creek dam. The results are given in the following charts.

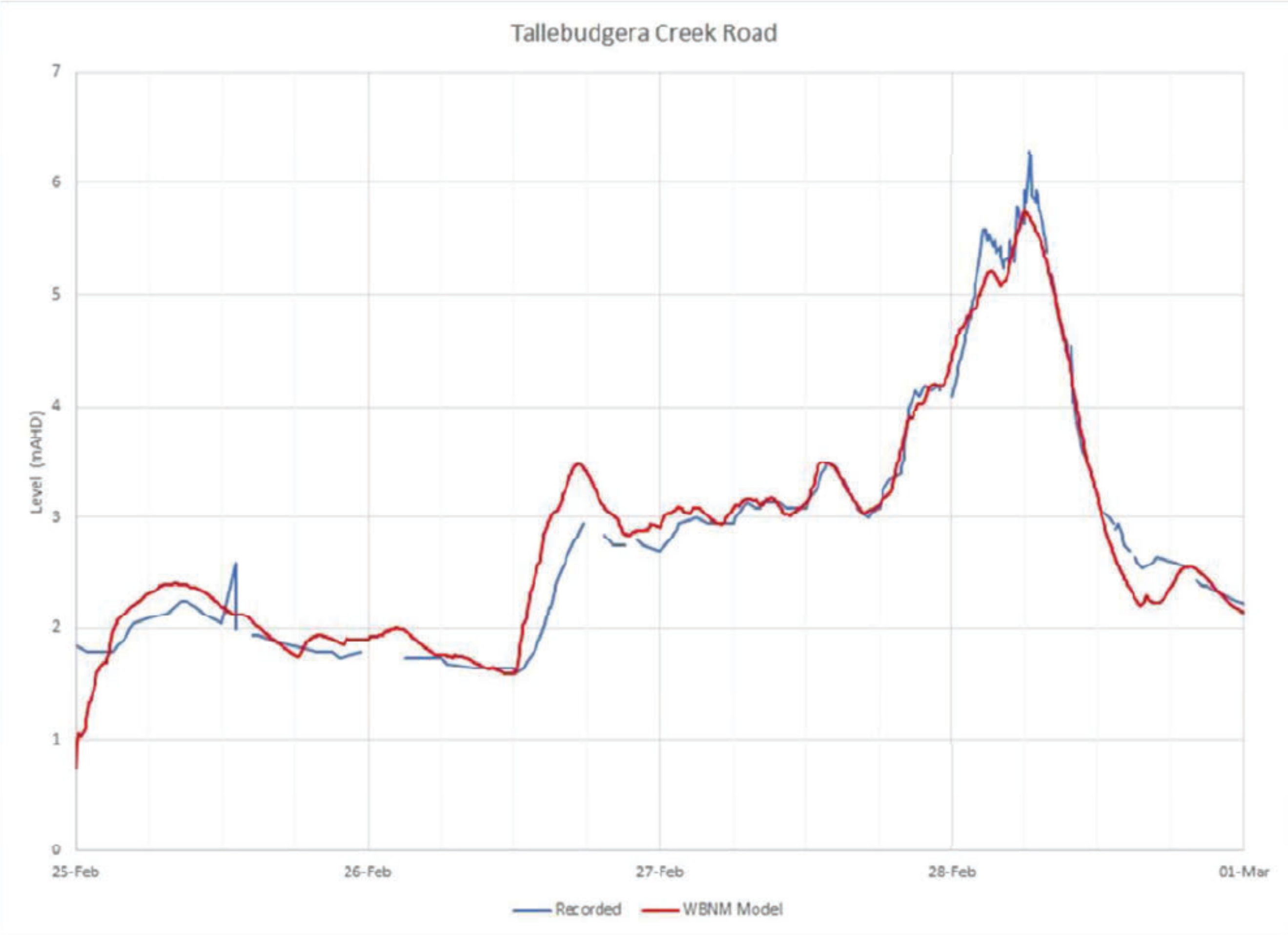



Tallebudgera Creek Road
600
500
400
300
200
100
0
Discharge (m³/s)
25-Feb
26-Feb
27-Feb
28-Feb
01-Mar
URBS
WBNM



30 It can be seen that the verification between the two models is very good at all three stations. While this does not necessarily prove that the models are accurate and correct (eg they might both be wrong to the same extent), it is an important validation, particularly in the context of the following calibration result.

31 There is a flow gauge located in the catchment (at Tallebudgera Creek Road) which enables correlation between flood level and flow rate based on a rating curve applicable to this specific location. The following chart presents the result of this calibration assessment, where the flow rates derived from the WBNM model for the February 2022 flood event are first converted to flood level by way of the rating curve, and then compared with the actual flood levels recorded instantaneously at this location.



32 These results are consistently good. The modelled results closely mimic the recorded levels, providing a high level of confidence that the WBNM hydrologic model is accurately transforming actual rainfalls into measured flow rates.

3.3 Hydraulic Modelling

33 The final piece in this puzzle is to input the February 2022 flow hydrograph into the TUFLOW model to enable calculation of the water depth, and direction and magnitude of flow velocity at every grid point in the model. TUFLOW is an unsteady non-uniform hydrodynamic analysis program which calculates relevant flooding parameters throughout the duration of a flood event. The focus in flood modelling is generally to determine what is known as afflux. Afflux is defined as the increase in maximum flood level as a consequence of development.

34 It is noted that construction phase survey for the Oyster Creek catchment upstream of the new M1 embankment was not available for modelling purposes. While it is clear that substantial earthworks have taken place in this area, it is our opinion that these works will have little, if any, impact on downstream water levels.

35 The TUFLOW model was used to determine peak flood depths, maximum flood levels and maximum flow velocities for the February 2022 event, as well as design flood events with AEPs of 1%, 2% and 5%. These latter analyses are provided solely for comparative purposes in order to demonstrate that the February flood is generally consistent with a 2% to 5% AEP design event. In general, the results indicate that the February flood event had an AEP of slightly more than 2%, corresponding to a Recurrence Interval of somewhat less than 50 years. This finding is entirely consistent with the hydrological assessment based on the recorded rainfall intensities The attached Figures 1 to 14 provide the relevant information in a graphical form.

36 Those Figures provide the following information:

- Figures 1 to 3 Pre-development peak flood levels for the 1%, 2% and 5% AEP events
- Figures 4 to 6 Pre-development peak flood depths for the 1%, 2% and 5% AEP events
- Figure 7 to 9 Pre-development peak velocities for the 1%, 2% and 5% AEP events
- Figures 10 and 11 Pre-development and construction phase peak flood levels for the February 2022 event
- Figure 12 and 13 Pre-development and construction phase peak flood depths for the February 2022 event
- Figure 14 Peak flood level afflux for the February 2022 event

37 By comparing Figure 10 to Figures 1, 2 and 3, it can be concluded that the flood event which occurred in late February 2022 was between a 2% and 5% AEP event, which is consistent with the rainfall and hydrologic analysis reported on above. Figure 14 presents the peak flood afflux for the February 2022 flood event, ie the increase in peak flood level resulting from the construction works.

38 More detailed review of the results for the peak afflux case provides the following conclusions:

- Increase of up to 350mm immediately upstream of the M1 Tallebudgera Creek bridge crossing
- Increase of 180mm at the [redacted] located at [redacted] Tallebudgera Creek Road
- Increase of 100mm upstream of the overflow culverts and around Woolworths
- Increase of 70-90 mm at Larch Street and Daffodil Street at upstream end of model
- No increases in flood level downstream of the M1

3.4 Comparison Between Recorded and Modelled Flood Levels

39 DTMR has supplied a number of surveyed flood levels for the February 2022 event based on debris marks upstream and downstream of the M1 as well as recorded flood levels at a gauging station downstream of the M1. This information is presented in the following table together with relevant model results:

Location	Recorded Level (m AHD)	Calculated Level (m AHD)	Difference (m)
Oyster Creek gauge (downstream of M1)	2.59	2.64	+0.05
Martin Shiels Park (downstream of M1)	2.45 to 2.52 (average = 2.485)	2.43	-0.055
Site Office (upstream of M1)	2.88	2.80	-0.08
Upstream of M1 Overflow Culverts	3.1 to 3.2 (average = 3.15)	3.23	+0.08

40 This comparison demonstrates excellent consistency between measured and calculated flood levels. The TUFLOW model is considered to accurately replicate actual catchment behaviour which validates the hydraulic modelling.

4 POTENTIAL IMPACTS OF CONSTRUCTION PHASE AFFLUX ON EXISTING DEVELOPMENT

41 Figure 14 shows relative widespread low-level impacts (increases in peak flood level of between 50 and 100 mm) in the catchment upstream of the M1, extending to the upstream extent of the model. However, it is noted that there appear to be few impacts on existing residential development. It is noted that the Lidar survey data used in the modelling generally only reflects the average ground and road levels in the model. In particular, it does not pick up floor levels.

42 Normally, house floor levels would be set 225 mm above the allotment ground level. Inundation of an area in the flood model therefore does not necessarily indicate that habitable floors have been flooded. This is particularly relevant to Daffodil Street, where the depth of flooding (Figure 13) on the residential areas is generally less than 250 mm deep.

43 DTMR has provided the following aerial photograph to SLR Consulting, showing the location of flooding complaints received after the February 2022 flood event.

[redacted]

44 A comparison of this photograph with Figure 14 allows the following conclusions to be drawn:

- Flood level increases in the order of 70 to 90 mm occurred in the Larch Street, Daffodil Street and Elm Court vicinities, and it is possible that these increases may have caused over-floor flooding. However, this could only be determined by survey of the actual floor levels which were affected.
- Flood level increases in excess of 125 mm occurred in the vicinity of Heather Street. It is likely that flooding here did inundate existing residences, although this finding would be dependent on the results of site survey of existing habitable floors.
- Similar increases occurred in the vicinity of Kentia Court. Again, detailed site survey of existing floor levels would be required to verify the model results.
- No increases beyond the nominal 10 mm were generally indicated in residential locations downstream of the M1 embankment. However, there are minor impacts in the order of 25 to 75 mm immediately on the downstream side of the embankment. These do not appear to have extended more than twenty metres downstream and seemingly did not impact on any existing residences.
- The model results do not support a finding that the construction works had any impact on buildings or residences in Township Drive, Japonica Drive or Colvillea Court

5 FLOOD RISK ASSESSMENT AND MANAGEMENT

5.1 Introduction

45 I have been asked to specifically address flood risk assessment considerations in respect of the construction works currently taking place in the Tallebudgera Creek floodplain. In the engineering context, flood risk is determined on a probability basis. For example, as far as I am aware, all Queensland local authorities include requirements in their Planning Schemes which effectively require habitable residential floors in new dwellings to be located at or above the peak flood level for a 1% Annual Exceedance Probability (AEP) flood event. The 1% AEP standard is firmly entrenched as a relevant consideration for safety for both persons and property.

46 The hydrologic profession has now adopted AEP as the relevant probability index in determining design rainfall and flood intensities because it was considered that the previous standard (that of Average Recurrence Interval) was misleading to the general public. It is my personal opinion that describing a flood event as having a 100 year design ARI is more evocative in conveying the magnitude of the event than the alternative 1% AEP design event. In this case, however, I will generally use AEP descriptions to describe risk elements.

47 In my experience, it is normal engineering practice for construction projects to adopt lower standards for property damage than the 1% AEP value. The reason for this is a simple economic one. The higher the standard of unacceptable risk which is adopted for a project, the greater the construction cost. I can provide a specific example here in respect of the proposed construction of bridges to cross Tallebudgera Creek. There are a significant number of construction methodologies which could be used in this case to construct the said bridge. However, I need only consider the two extremes to illustrate my point.

48 In the first case, the channel of the creek could be completely closed off by the construction of coffer dams upstream and downstream to exclude water from the workings. While this would minimise construction cost, it would lead to severe risk in that any degree of flooding would likely cause unacceptable flood level increases upstream.

49 In the second case, the construction works could be undertaken entirely out of the channel and above the maximum flood level, somewhat akin to the construction of the Sydney Harbour Bridge where the two ends met in the middle far above the water level. While this would reduce additional flood risk to zero, there would be a much higher construction cost.

50 Construction risk is therefore normally balanced against construction cost in terms of property damage. However, the duration of the works and whether they going to be temporary or permanent are also important considerations. For example, if a dwelling house has an expected life of 50 years, and is designed to a 1% flooding standard, there is actually a 38% chance that the floor level will be inundated during the life of the house. On the other hand, if the construction period for works is three years, then designing for no impacts for a 1% AEP flood during construction returns only a 3% chance that adverse flooding impacts will occur.

51 Finally, the risk assessment should also take account of the likely impacts which would result from the adoption of a specific risk profile. For example, the extent and cost of the likely damage to existing residences must also be a consideration in comparison to the additional cost of the construction works. For example, if protecting to the 1% AEP flood event only spared an additional two houses from damage in comparison to protecting to the 5% level, and the cost of additional construction was $1 million, then it would probably be unlikely that the 1% standard would be adopted.

5.2 Flood Risk Assessment on the B2BP M1 Project

52 In this case, the HDRWSP design consortium produced a specific document to examine flood risk during the construction phase. This document is the Flood Impact Assessment of Temporary Works dated 28 May 2020. The relevant flood impacts expected to arise if major flooding occurred during the construction phase were predicted using the relevant TUFLOW model.

53 Design flood events with the following probabilities were considered:

- 39% AEP (2 Year ARI)
- 18% AEP (5 year ARI)
- 10% AEP (10 Year ARI)
- 5% AEP (20 year ARI)

54 The report stated that ***"Events larger than these four events are rare and thus less likely to occur during the 2 to 3 year period"***, and the following graph was produced.

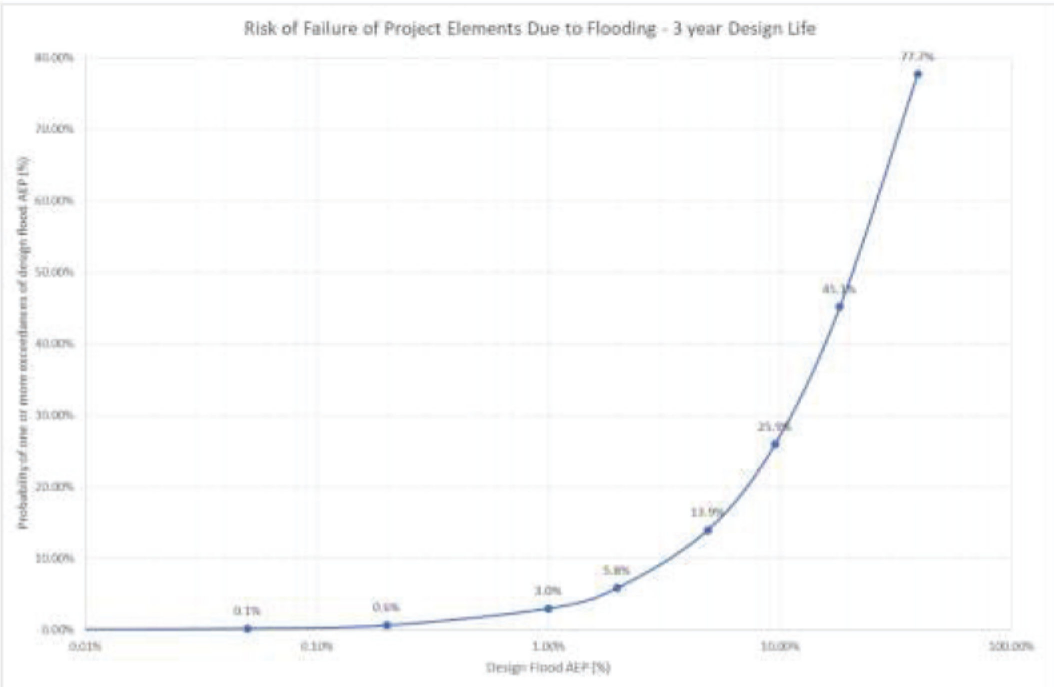


Figure 3: Risk of One or More Exceedances of Design Floods during Construction

55 So an initial decision was made by the project to accept the 5% AEP standard as the maximum which would be considered. The above graph shows that there is a 13.9% chance of a 5% AEP flood occurring during the construction period. In effect, the project was designed to be compliant with this standard. That is, there was approximately a 1 in 7 chance that a flood with an AEP in excess of 5% would occur. In my opinion, this is an acceptable standard for construction purposes, especially compared with the probability of 38% of a house being flooded over a life of 50 years which I outlined in Section 5.1 above.

56 The report guided the adoption of relevant construction methodology based on the likely impact of the relevant works on upstream flood levels. For example, the large rock platform scenario R1 was shown to cause unacceptable upstream flood level increases for even the 38% AEP event. In comparison, the small rock platform scenario R2 produced likely flooding impacts on 109 properties but only two dwellings for the 5% AEP event. The temporary bridge scenario B2 produced similar outcomes, ie 133 properties affected by allotment flood level increases but only two dwellings. I find this analysis to also be consistent with best practice.

57 If there is any criticism of the HDRWSP risk analysis, it is that there was no determination of the likely cost of damage if a flood event with an AEP of less than 5% were to occur in the catchment. This should also have been part of the decision matrix in my opinion. While I don't believe that it would have likely changed the construction methodology or the project fundamentals, the impact of a larger flood could have reasonably been determined with little additional effort. This would have provided more justification for the decision to exclude those floods with AEPs of less than 5%.

58 For example, there is a small, but reasonable chance (5.8%) of a 2% AEP flood event occurring the construction duration. This is close to the flood event which was actually experienced.

59 However, on the basis of the hydraulic modelling which has been undertaken by SLR Consulting, it seems that the number of houses potentially affected at floor level by the February event was still relatively low. In my opinion, both the risk assessment used by HDRWSP and the actual construction methodology used for the bridge works was acceptable. However, I believe that the analysis should also be repeated for at least the 2% AEP storm and the potential damage for this event calculated based on the number of likely affected houses.

6 CONCLUSIONS

60 A detailed hydraulic assessment of the impact of M1 construction works on flood levels in the Tallebudgera Creek catchment during the flood of February/March 2022 has been undertaken. It has been determined that the flood had an Annual Exceedance Probability (AEP) of slightly more (ie less severe) than 2% (a 2% AEP is equivalent to a 50 year Average Recurrence Interval).

61 The flood modelling used for this analysis achieved good correlation with observed and monitored flow rates and flood levels throughout the lower part of the catchment upstream and downstream of the M1 crossing of Tallebudgera Creek.

62 The model showed the following:

- Flood level increases in the order of 70 to 90 mm occurred in the Larch Street, Daffodil Street and Elm Court vicinities.
- Flood level increases in excess of 125 mm occurred in the vicinity of Heather Street and Kentia Court.
- No increases beyond the nominal 10 mm were generally indicated in residential locations downstream of the M1 embankment.

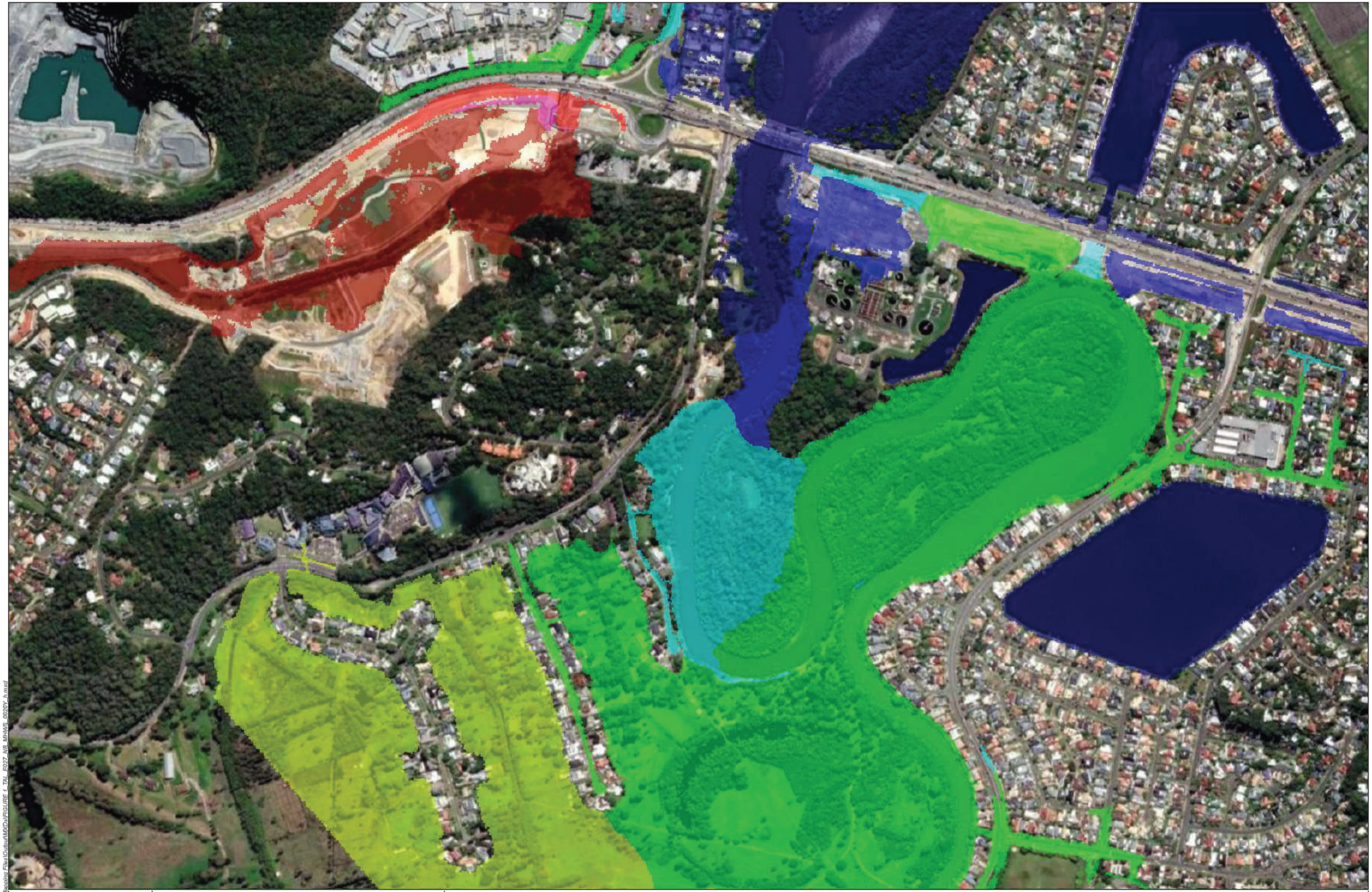
63 Further assessment of the impact of these increases on existing residences and businesses will rely on detailed survey of actual flood levels. The assessment to date has been based on ground surface levels estimated by laser survey.

64 The subsequent flood event which occurred in late March 2022 was significantly less severe, having a probability of exceedance of slightly less (ie more severe) than 10% (a 10% AEP is equivalent to a 10 year average recurrence interval). It is unlikely that the flooding resulting from this event caused inundation of residential floors, although reasonable open space flooding would have been apparent.

65 It has also been determined that the project flood risk analysis upon which the construction methodology was adopted for the bridge crossing of Tallebudgera was sound and acceptable. However, it is recommended that the analysis be revisited to consider at least the potential impact of the occurrence of a 2% AEP flood event. That is, how many houses are likely to suffer damage if such an event were to occur during the construction duration. This finding should be taken into account in determining the on-going bridge construction methodology.

[redacted]

Figures



SLR
www.slrconsultingaustralia.com.au

0 180 360 540 Meters

12-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

Legend

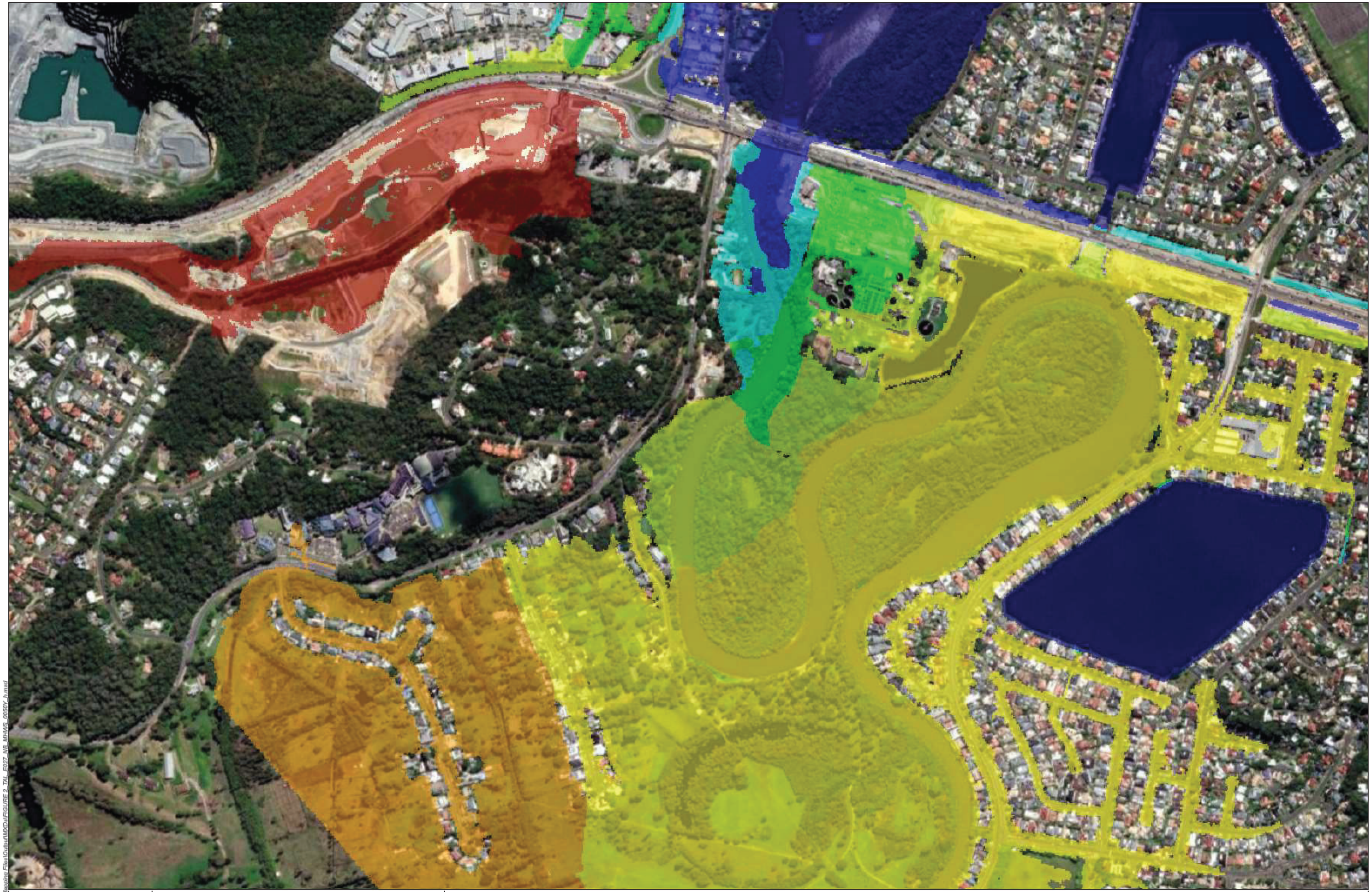
Level (m AHD)

< 2.4	3.0 - 3.2	3 8 - 4.0
2.4 - 2.6	3 2 3.4	> 4.0
2.6 - 2.8	3.4 - 3.6	
2.8 - 3.[illegible]	[illegible]	

M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

Pre-Construction Conditions (E027)
Peak Flood Levels - 5% AEP

FIGURE 1



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0 180 360 540 Meters

12-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

Legend

Level (m AHD)

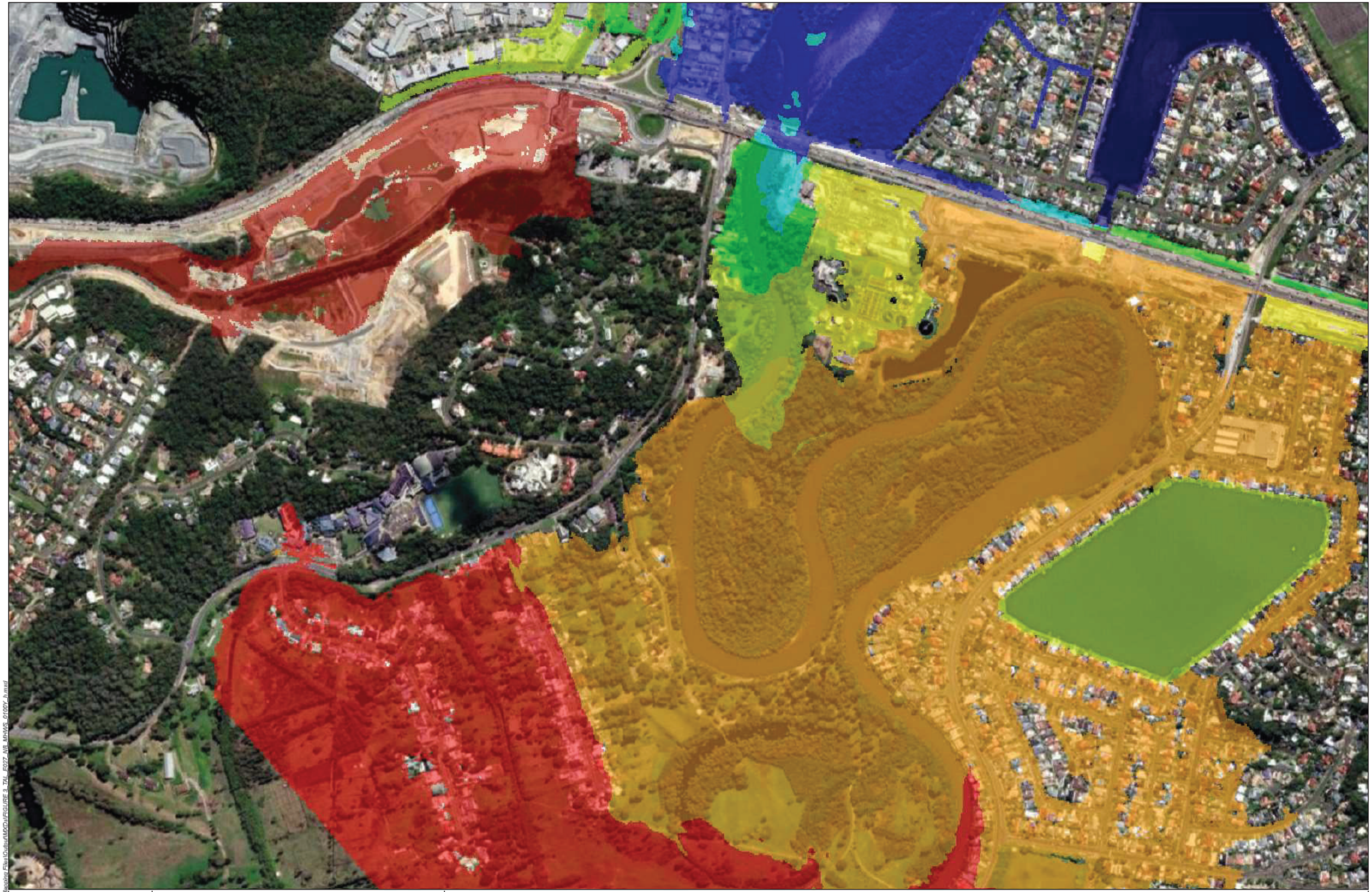
- < 2.4
- 2.4 - 2.6
- 2.6 - 2.8
- 2.8 - 3.0
- 3.0 - 3.2
- 3.2 - 3.4
- 3.4 - 3.6
- 3.6 - 3.8
- 3.8 - 4.0
- > 4.0

M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

Pre-Construction Conditions (E027)
Peak Flood Levels - 2% AEP

FIGURE 2

C:\sesProjects\Tallebudgera\AutoMapping Files\Output\MXDs\FIGURE 2_TAL_E027_NB_MHWS_0050Y_h.mxd



Legend

Level (m AHD)

- < 2.4
- 2.4 - 2.6
- 2.6 - 2.8
- 2.8 - 3.0
- 3.0 - 3.2
- 3 2 3.4
- 3.4 - 3.6
- 3 8 - 4.0
- > 4.0

0 180 360 540 Meters

12-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

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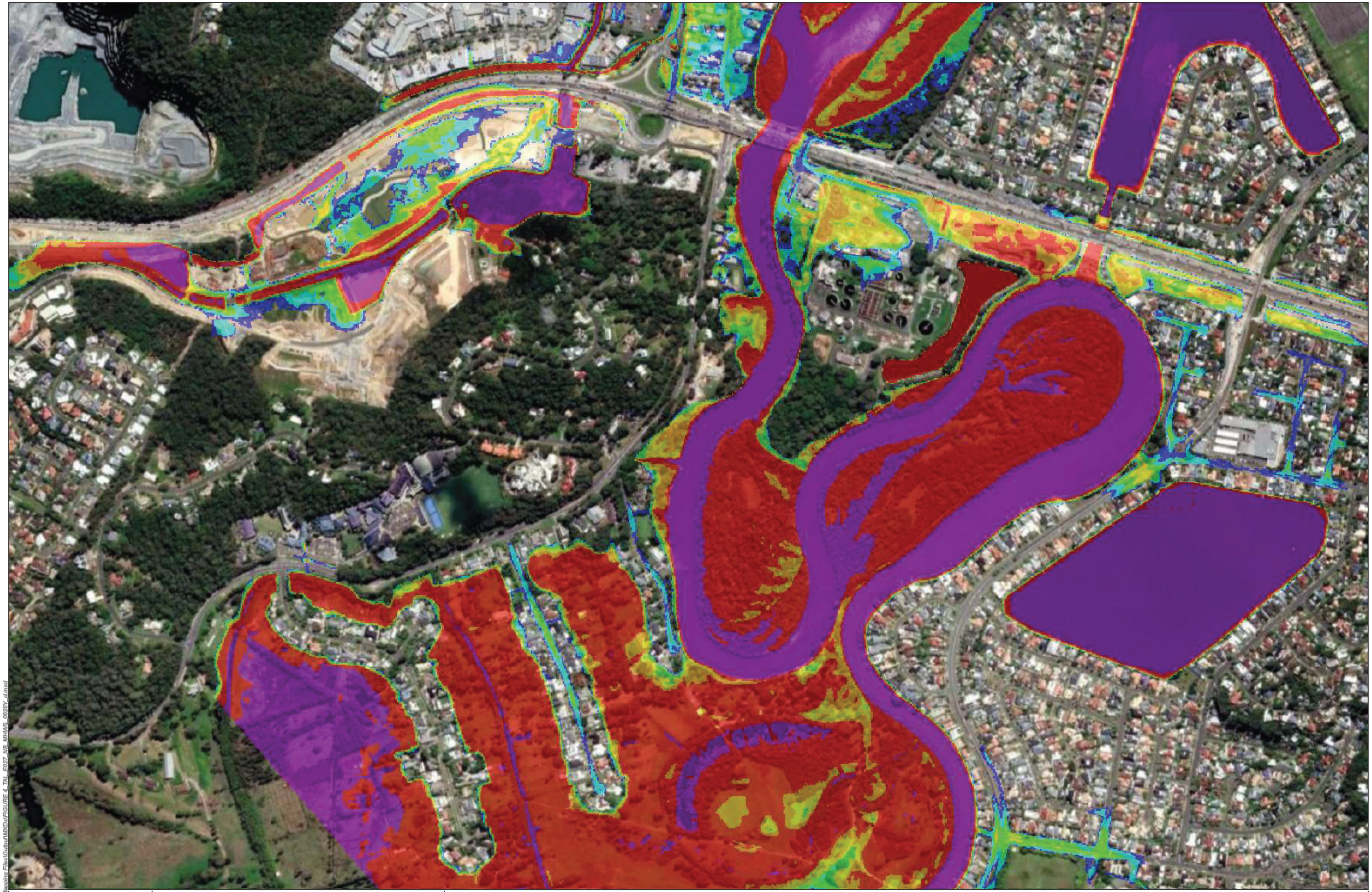
M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

Pre-Construction Conditions (E027)
Peak Flood Levels - 1% AEP

FIGURE 3



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0 180 360 540 Meters

12-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

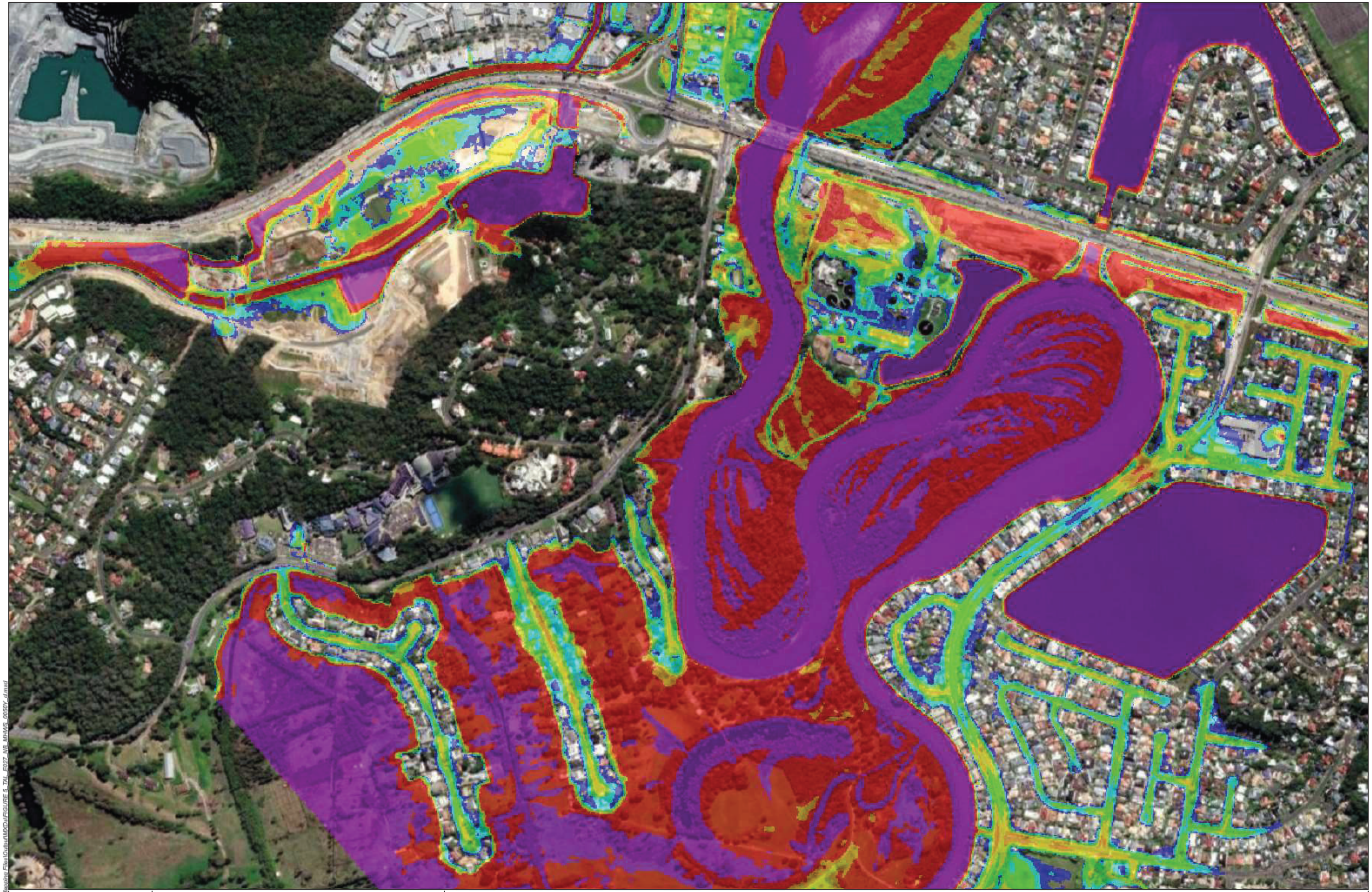
Legend

Depth (m)
- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- > 2

M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

Pre-Construction Conditions (E027)
Peak Flood Depths - 5% AEP

FIGURE 4



0 180 360 540 Meters

12-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

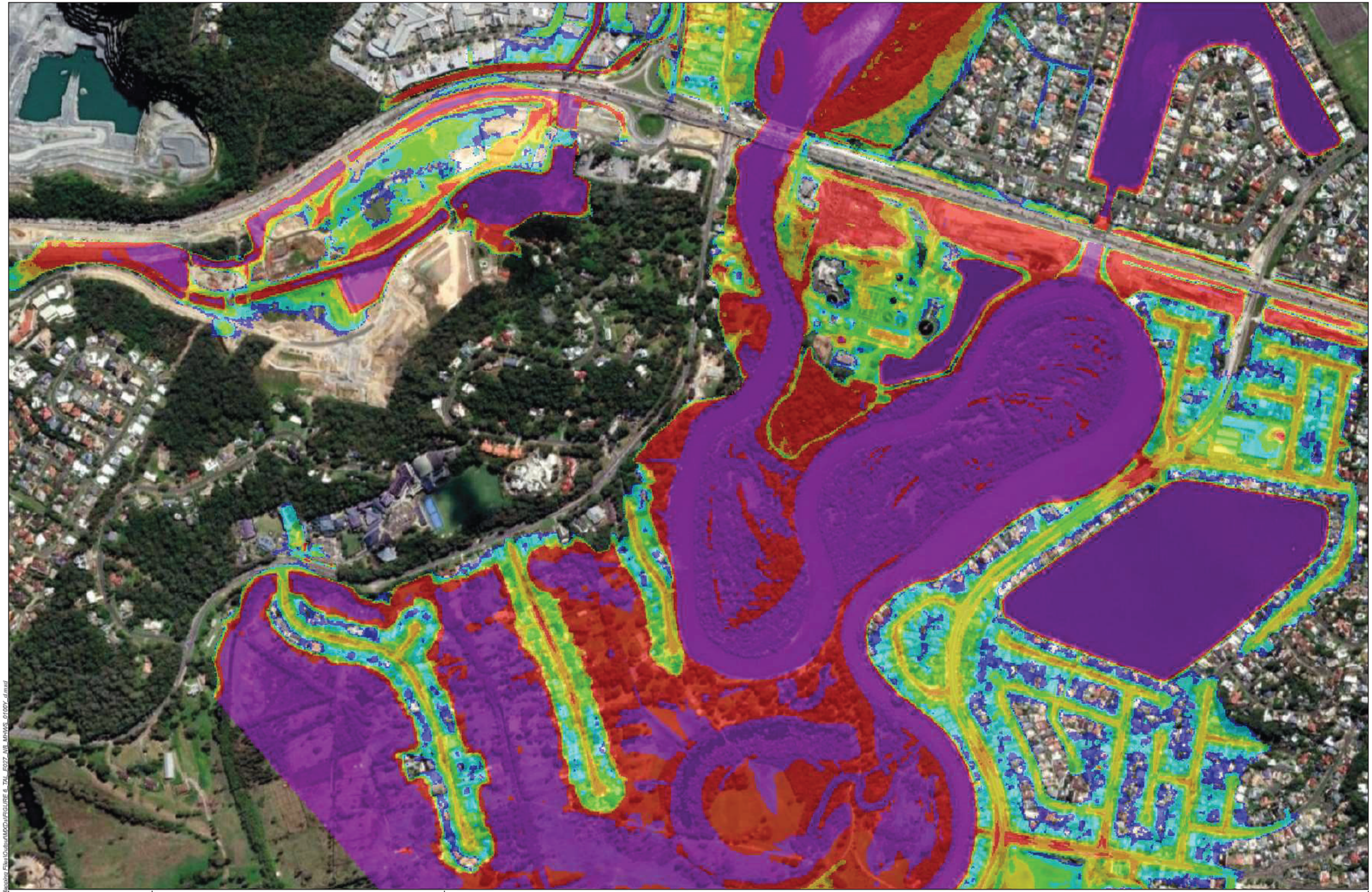
Legend

Depth (m)	
< 0.1	0.75 - 1
0.1 - 0.25	1 - 2
0.25 - 0.5	> 2
0.5 - 0.75	

M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

Pre-Construction Conditions (E027)
Peak Flood Depths - 2% AEP

FIGURE 5



SLR
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0 180 360 540 Meters

12-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

Legend

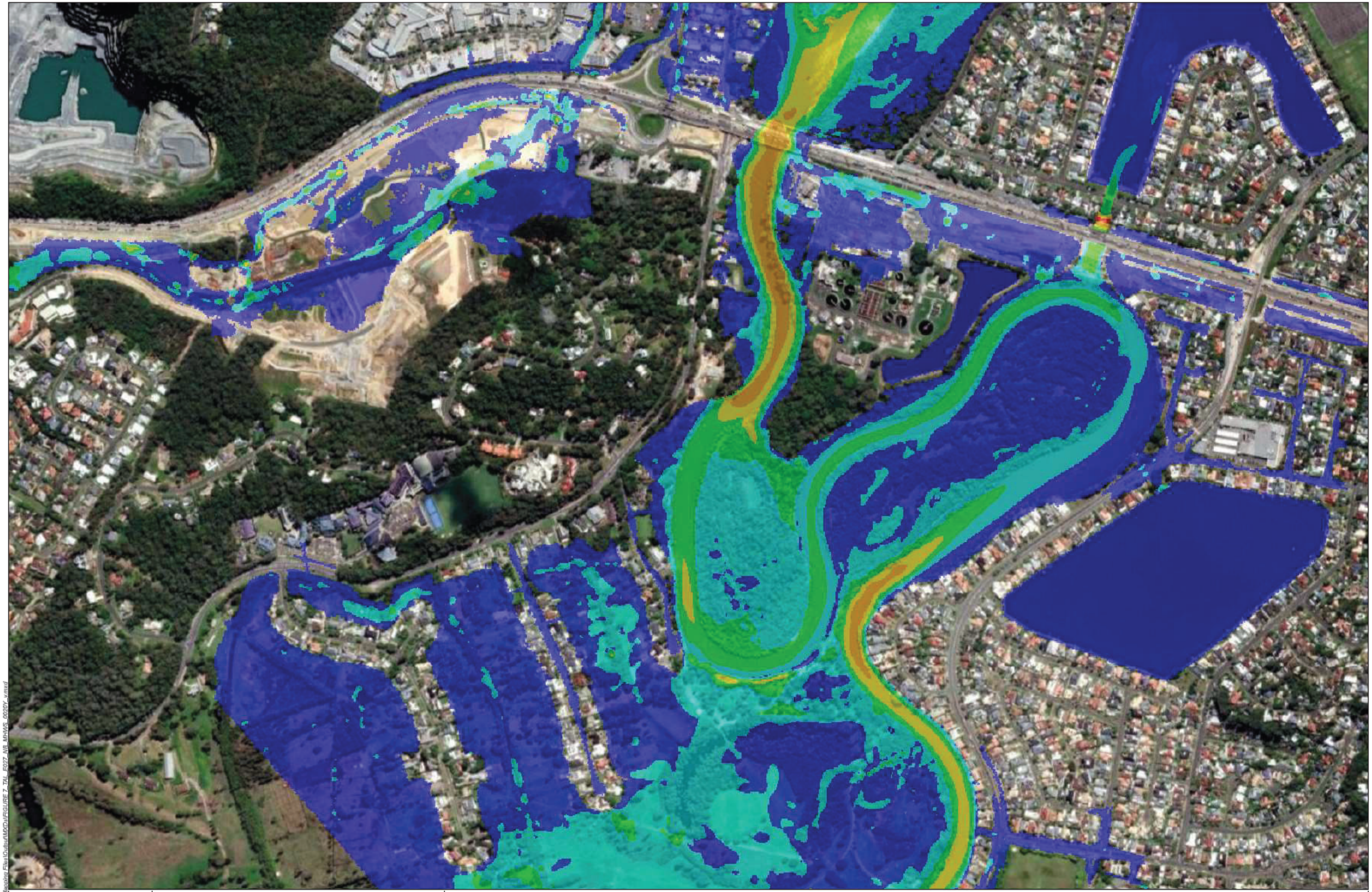
Depth (m)

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- > 2

M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

Pre-Construction Conditions (E027)
Peak Flood Depths - 1% AEP

FIGURE 6



0 180 360 540 Meters

12-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

Legend

Velocity (m/s)

- < 0.5
- 0.5 - 1
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- > 3.0

SLR

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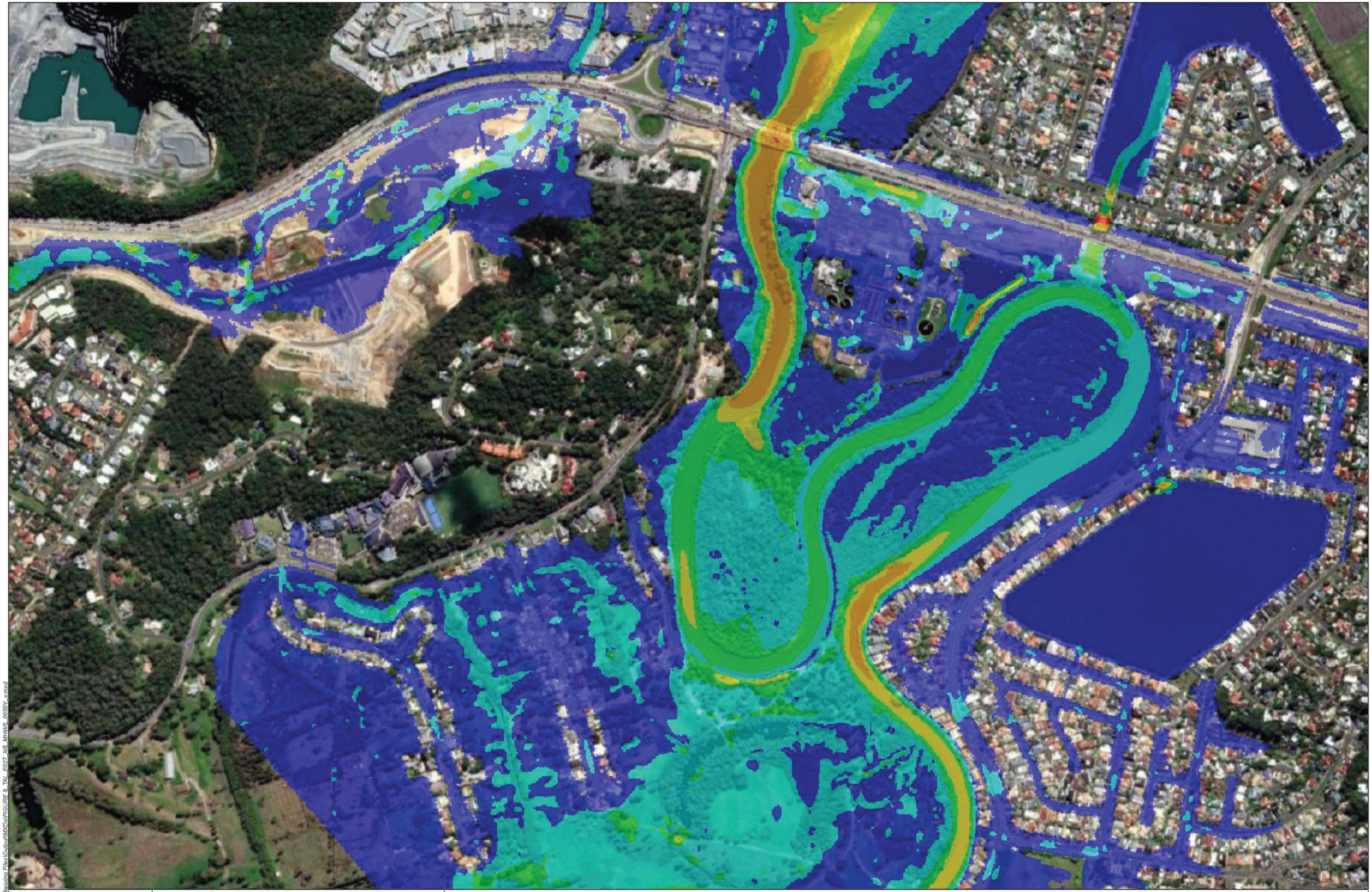
M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

Pre-Construction Conditions (E027)
Peak Flood Velocities - 5% AEP

FIGURE 7



0 180 360 540 Meters

12-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

Legend

Velocity (m/s)

- < 0.5
- 0.5 - 1
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- > 3.0

M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

Pre-Construction Conditions (E027)
Peak Flood Velocities - 2% AEP

FIGURE 8

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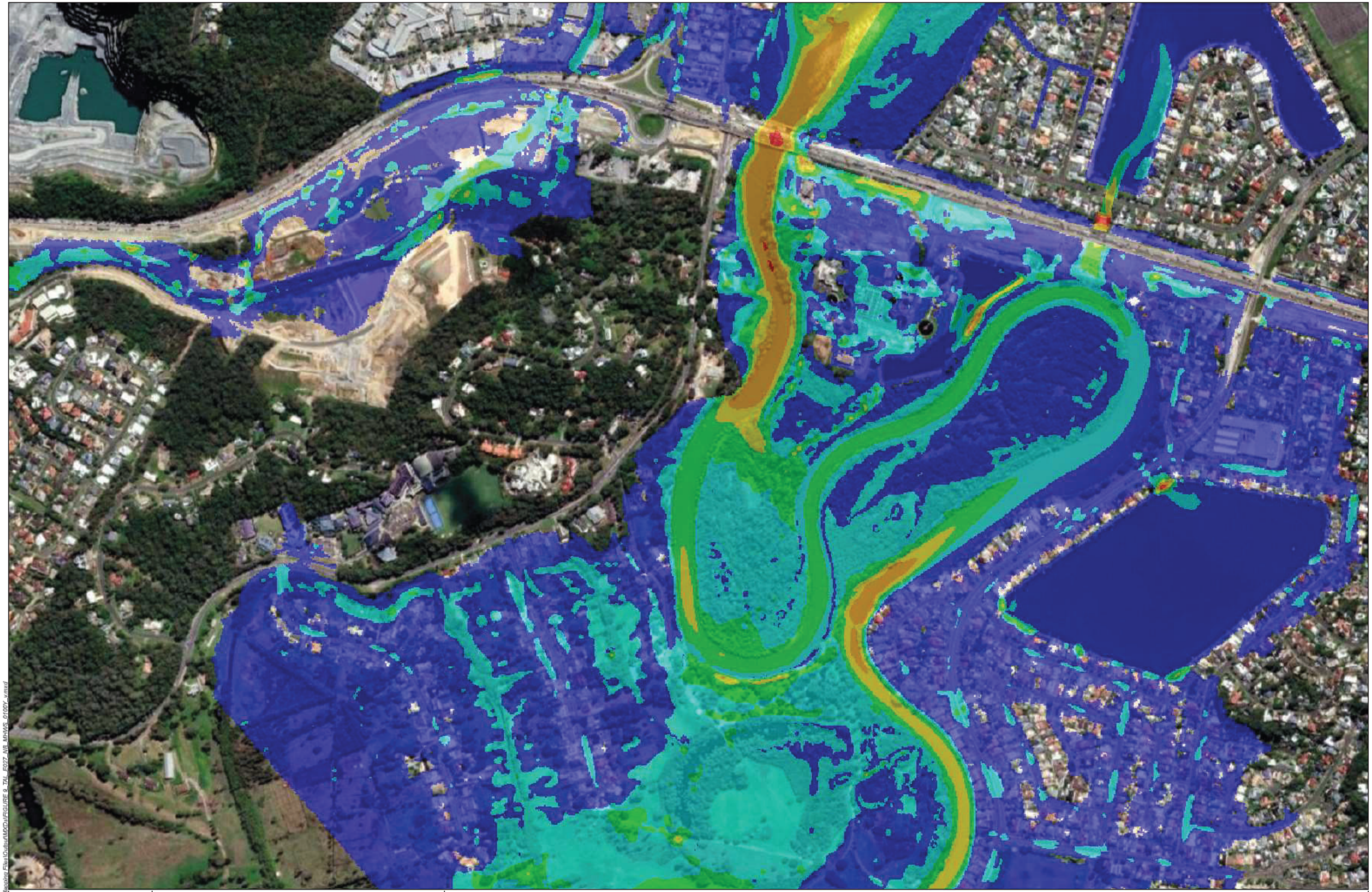
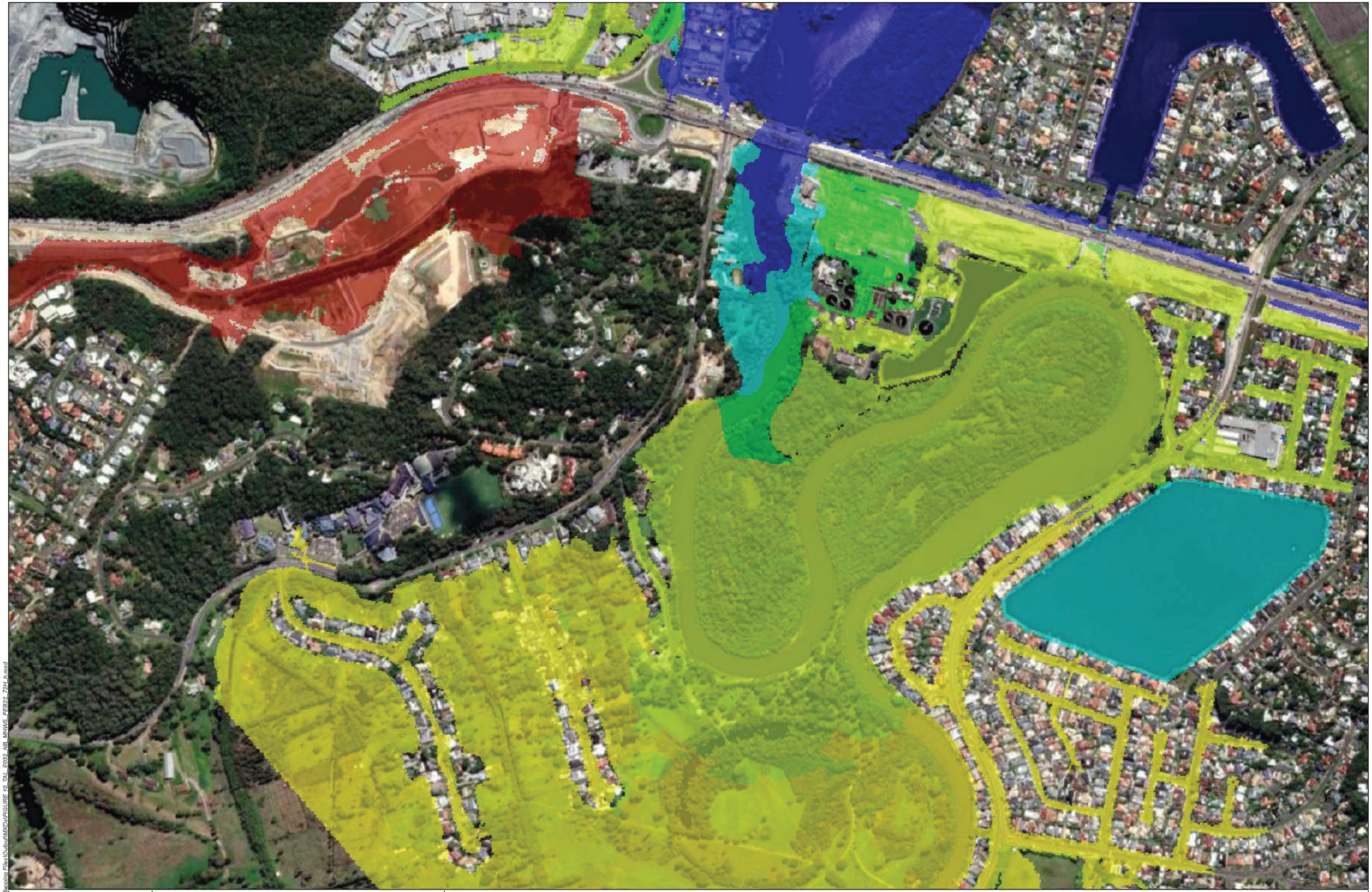




M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

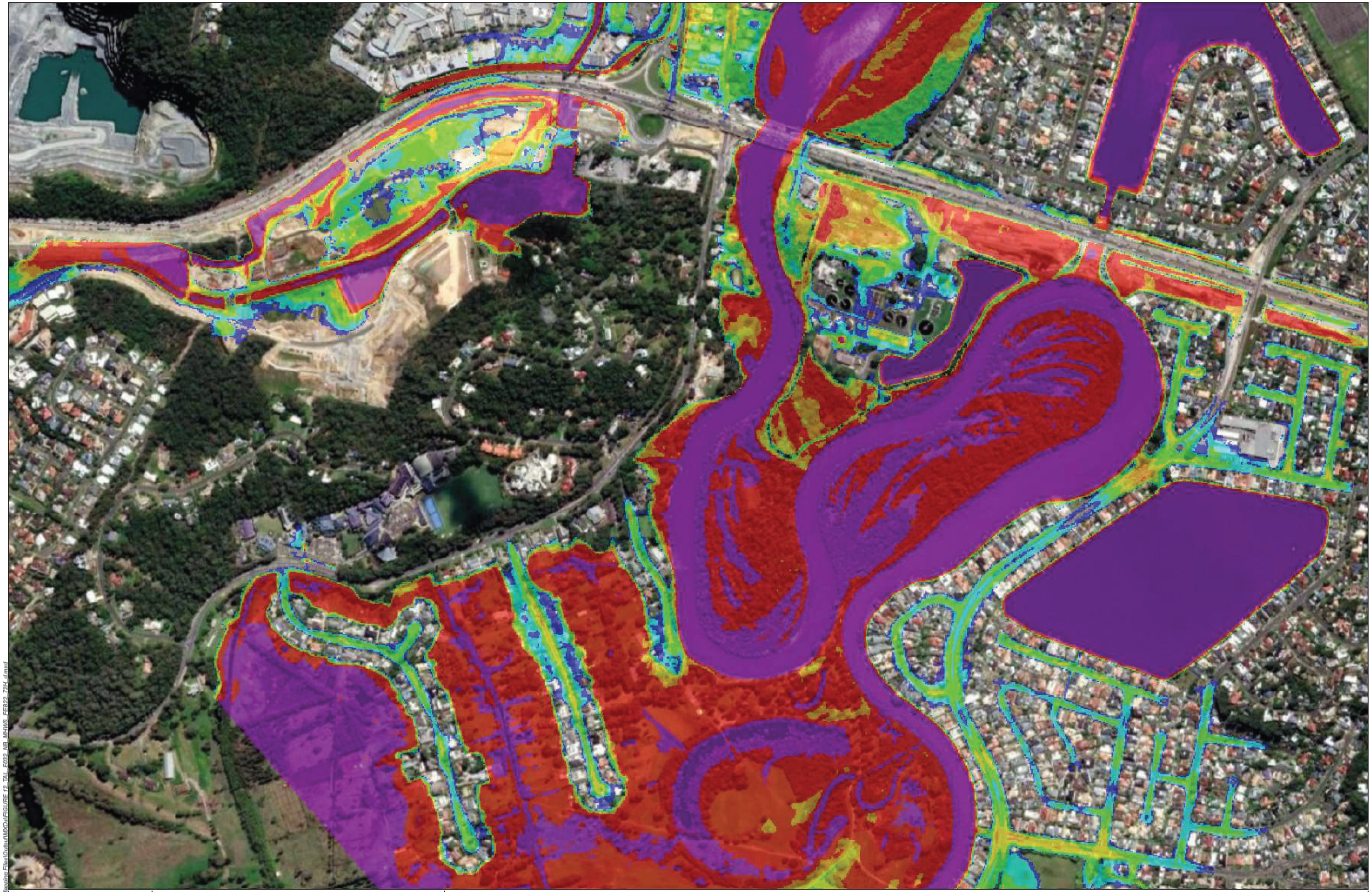
Pre-Construction Conditions (E027)
Peak Flood Levels - February 2022 Event

FIGURE 10

M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

February 2022 Construction Conditions (C007)
Peak Flood Levels - February 2022 Event

FIGURE 11



M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

Pre-Construction Conditions (E027)
Peak Flood Depths - February 2022 Event

FIGURE 12

Legend

Depth (m)

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- > 2

0 180 360 540 Meters

12-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

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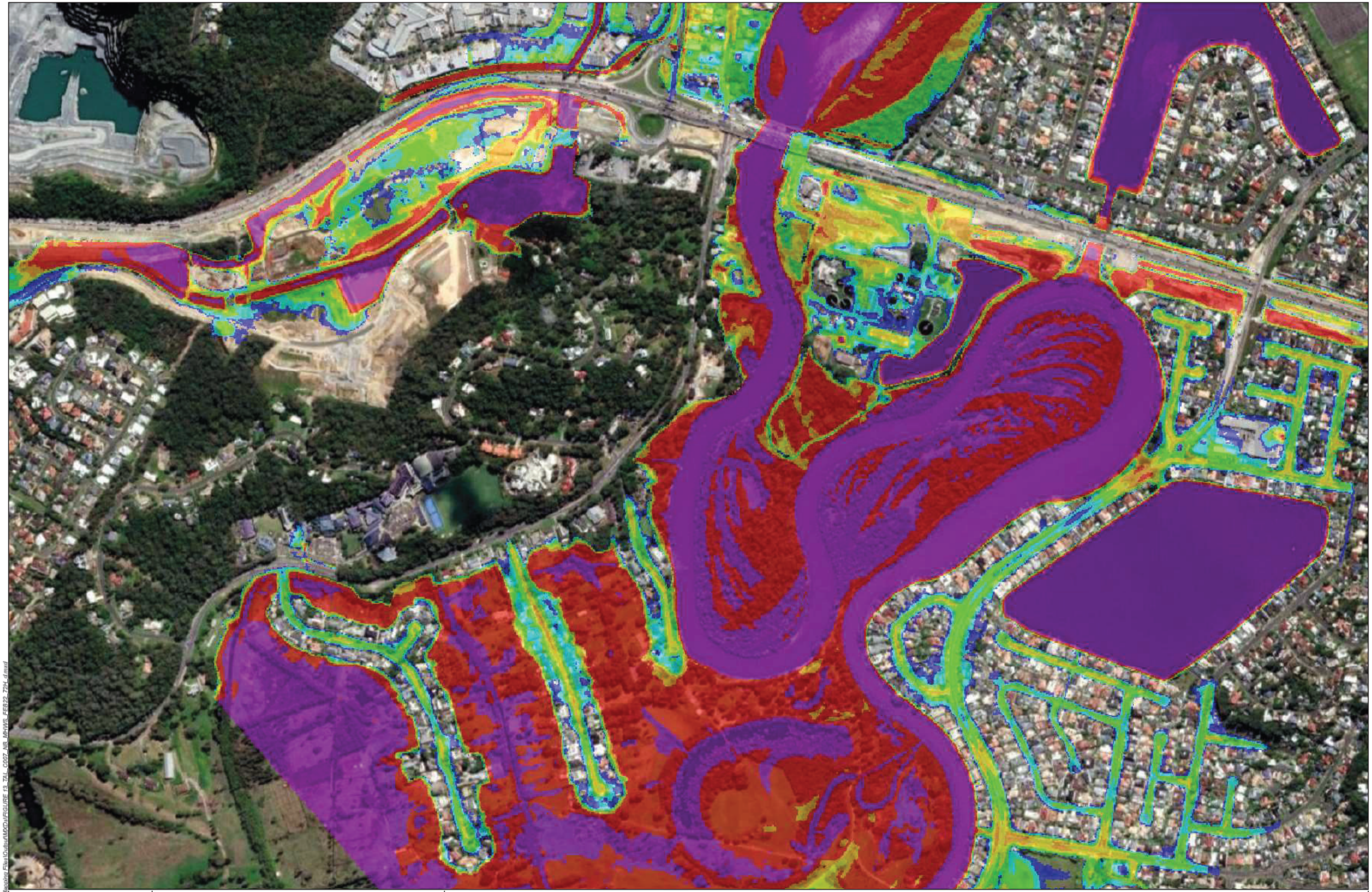

SLR
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0 180 360 540 Meters

12-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

Legend

Depth (m)

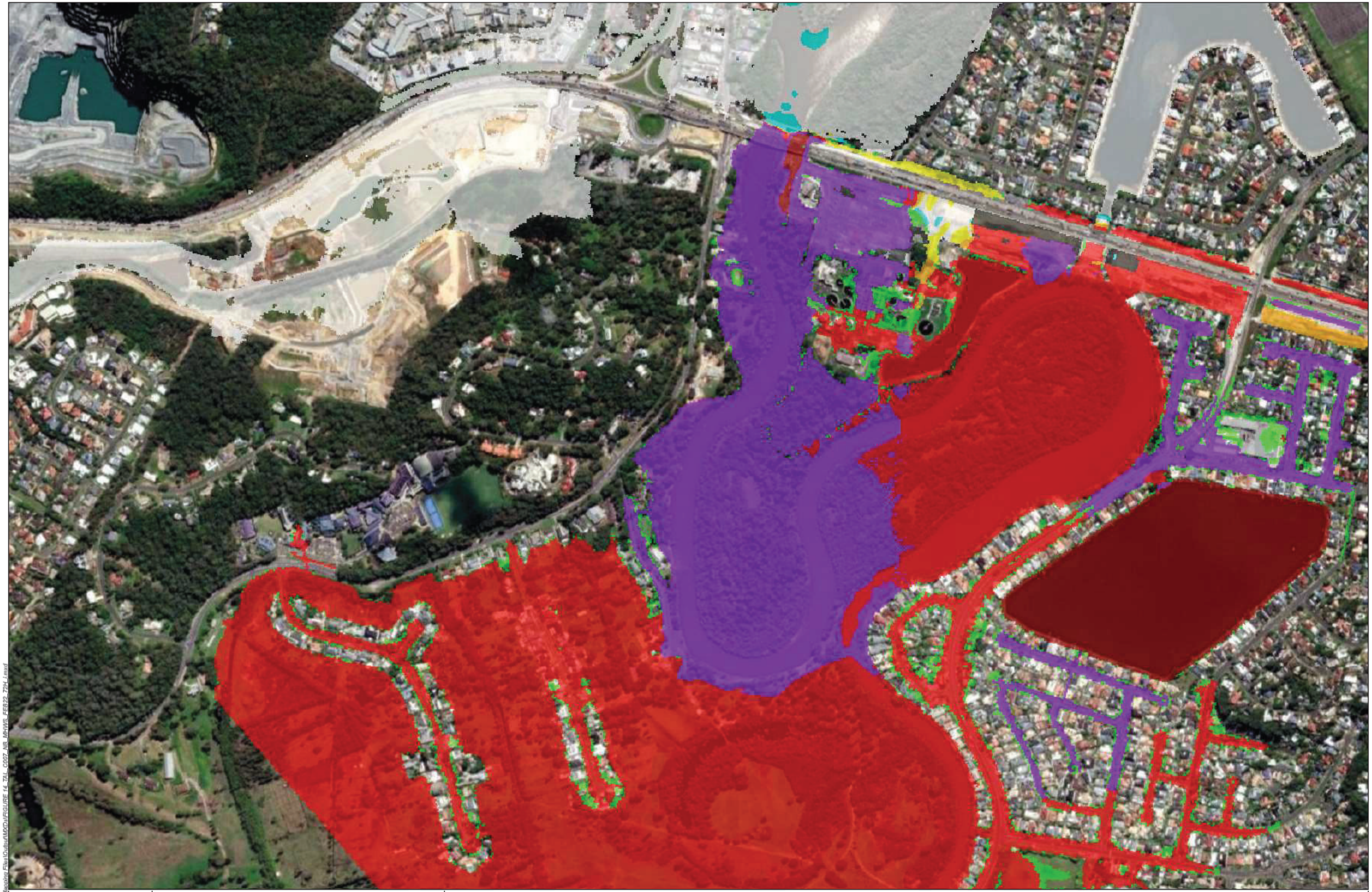
< 0.1	0.75 - 1
0.1 - 0.25	1 - 2
0.25 - 0.5	> 2
0.5 - 0.75	

M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

February 2022 Construction Conditions (C007)
Peak Flood Depths - February 2022 Event

FIGURE 13

C:\sa\Projects\Tallebudgera\AutoMapping Files\Output\MXD\FIGURE 13_TAL_C007_NB_MHWS_FEB22_72H_d.mxd



Legend

Afflux (mm)

< -10
-10 - 10
10 - 25
25 - 50
50 - 100
100 - 250
> 250
Was Wet Now Dry
Was Dry Now Wet

0 180 360 540 Meters

20-Sep-2022 Scale: 1:7,500

Sheet Size : A3 GDA 1994 MGA Zone 56

SLR www.slrconsultingaustralia.com.au

M1 B2PB - Tallebudgera Creek
Construction Flood Impact Assessment

February 2022 Construction Conditions (C007)
Peak Flood Afflux - February 2022 Event

FIGURE 14

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M1 VL2T - TALLEBUDGERA FLOODING COMPLAINTS

Surveying Professional Services

AU213007423.001
1
15 December 2022

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
1	Survey Deliverables Report	[redacted]	[redacted]	[redacted]	20/12/22

Approval for issue

[redacted]	[redacted]	20 December 2022

Prepared by:

RPS

[redacted]

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Ipswich QLD 4305

T [redacted]
E

Prepared for:

DTMR

[redacted]

T [redacted]
E

We acknowledge and pay respects to the people of the Yugambeh language region of the Gold Coast and all their descendants both past and present. We also acknowledge the many Aboriginal people from other regions as well as Torres Strait and South Sea Islander people who now live in the local area and have made an important contribution to the community.

ACKNOWLEDGEMENT OF COUNTRY

Contents

Tables

Pictures

Figures

1 SCOPE

RPS were approached by [redacted] on the 12th October 2022 to provide survey advice into a matter currently under investigation and were provided a letter of instruction outlining the scope of the advice and works required.

The brief of the project was to provide survey advice to the Department of Transport and Main Roads (DTMR) in relation to community complaints received after flood events in February and March 2022, and any impact the Pacific Motorway M1 Varsity Lakes to Tugun upgrade, in particular Packages B (B2PB) and C (PB2T), had on those events.

SLR Consulting had been engaged to undertake an analysis of the implications of the construction works on the 2022 rain events and the preliminary results of the investigations where in the SLR report dated 7th October 2022 and there was a requirement for surveying input identified around efforts to determine floor levels of properties in the following investigation areas.

- Larch Street, Tallebudgera;
- Daffodil Street, Tallebudgera;
- Elm Court, Tallebudgera;
- Heather Street, Tallebudgera;
- Kentia Court, Elanora.

RPS were requested to:

1. Prepare for and attend an initial briefing with the [redacted] team, including a discussion of the available surveying capture options for investigating the floorboard levels of the impacted properties.
2. If applicable, undertake a survey of the floorboard levels of the impacted properties.
3. Prepare for and attend a briefing with DTMR and the [redacted] team to discuss your findings; and
4. Prepare a written note regarding your findings if requested.

Note:

This report is an outline of the approach taken, methodologies, assumptions and measured results and not an interpretation of the impact that those results have on the subsequent reporting

1.1 Initial Review and Advice

An initial review of the available 2018 LiDAR data as supplied by DTMR used was undertaken.

It is worth noting that RPS undertook the LiDAR capture for Gold Coast City Council (GCCC) and the below summary was provided.

1. The reporting that was supplied to GCCC at the time specified vertical accuracy of the data as +/- 0.3m. A city wide verification was carried out that showed the combined dataset achieves an expected accuracy of +/- 0.1m. Although it is important to note that this is an assessment made on the dataset at a city wide level and to accept that level of confidence, local verification would be required.
2. We may be able to use the Mobile Laser Scanning (MLS) capture to do some level of verification locally on the LiDAR data and then utilise the data to determine ground levels adjacent to buildings on properties where the floor level is not identifiable from the MLS capture.
3. The LiDAR data supplied was a DEM sampled to the lowest level within each cell to reduce the size of the data and we would look to source the LAS version of the data which has the individual points classified into ground and non-ground categories.
4. In terms of assessing floor levels of individual properties, MLS is the only viable option for remote capture where there is minimal to no exposure of staff in the local areas of interest, but this will be

limited to the houses where the floor level is visible. (Typically, we will use the front door as a reasonable representation of the habitable floor level).

5. There are a number of properties where there is significant vegetation, structural walls / fences on the front boundary or the door is perpendicular to the road and not visible.
6. Our MLS capture provider is specifying that they should be able to achieve an accuracy of +/- 40mm for our proposed method of capture which is a lesser standard than we would look to supply to DTMR for their typical GFM type surveys but again driven by not having a physical staff presence on site where possible.
7. For any floor levels that can't be determined remotely, and require assessment (based on the LAS version of the 2018 LiDAR) would have to surveyed by direct methods. With cost/time efficiencies a significant consideration escorted access utilising the best available technology of high quality survey grade GNSS with tilt compensation would allow direct measurement to the floor level (again at door) quickly and to an expected accuracy of +/- 20mm.

1.2 Supplied Data

The following information was supplied to RPS (and received date) for the purpose of the survey works:

- [redacted] initial brief (13th October 2022)
- SLR Initial report (13th October 2022)
- GCCC 2018 LiDAR capture data as a DEM (17th October 2022)
- GCCC 2018 LiDAR capture data as Classified LAS (2nd November 2022)

Notes on supplied data:

LiDAR data was captured in 2018 and has been transformed to GDA2020 MGA56 by DTMR. The bounds of each tile conforms to the expected distortion between GDA94 and GDA2020.

2 SURVEY OPTIONS

Typically, there are several survey methodologies that could be utilised to provide floor level information, and these include (in general order of accuracy):

- Conventional digital levelling from a known benchmark
  - Requires access to each property for direct measurement
  - Each house will be tied to a single local benchmark
  - Establishment of the primary level control network is time and cost prohibitive
  - Is the most accurate determination of level and can achieve sub millimetre results
  - Does not provide a horizontal location of the point unless paired with other methodologies
- Conventional total station observations either directly or indirectly via reflectorless
  - Requires access to each property for direct measurement
  - Reflectorless laser measurement can be made but is not discrete and is limited to field of view
  - Establishment of the primary control network could be time and cost prohibitive
  - Determination of level can generally achieve sub 10 millimetre results
  - A horizontal location of the point is also stored
- GNSS direct observations
  - Requires access to each property for direct measurement
  - No primary survey control network is required to be established
  - Checks are made to the existing state control network
  - A local adjustment to AHD can be made
  - Determination of level can generally achieve +/- 15 millimetre results
  - A horizontal location of the point is also stored
  - Modern receivers allow inclined observations meaning for most cases, a direct observation can be made with a high level of confidence
- Airborne drone-based LiDAR systems
  - No physical access required
  - The unit has a 360 degree field of view allowing under eave features to be surveyed
  - Requires line of sight from the drone to the feature
  - CASA restrictions mean flights over properties aren't possible without notification
  - At the optimal flight height, the unit is noisy and may cause issues to residents
  - Determination of level can generally achieve sub 50 millimetre results
- Conventional terrestrial laser scanning
  - No physical access required depending on obstructions from the street
  - Requires line of sight from the scanner to the feature
  - Imagery is captured and used to colourise the point cloud making feature extraction easier
  - Scans would need to be done with direct line of sight to the door or feature being identified
  - Additional scans and ground control would need to be established to co-ordinate and control the accuracy and registration of the resultant point clouds
  - Scans typically take 3 – 5 minutes including photos and largely exposed to public interaction
  - Generates incredibly large data sets that take a considerable amount of time to process

  - Determination of level can generally achieve sub 10 millimetre results
- SLAM based laser scanning
  - No physical access required depending on obstructions from the street
  - Requires line of sight from the scanner to the feature
  - Rapid capture that can be completed as quickly as you can walk the site area
  - Recent technology that has evolved rapidly
  - Accuracy decreases proportional to the distance between control points
  - Testing with our system indicates that accuracies comparable to GNSS are achievable
- Mobile laser scanning systems
  - Most rapid capture available
  - Minimal to no exposure to the public
  - Requires line of sight from the scanner to the feature
  - Accuracy is dependant on co-ordinated ground control
  - Multiple passes of each site are required
  - Determination of level can generally achieve sub 50 millimetre results
  - Higher accuracies can be achieved with additional site control survey

Given the need for the survey to be conducted discreetly there were limited options to complete the survey works and the most appropriate method available was Mobile Laser Scanning in this case.

The Mobile Laser Scanning was also to undertaken utilising GNSS corrections only through the subject area to further reduce the need for staff / public interaction.

3 METHODOLOGY

3.1 Review of Site Constraints

RPS have reviewed the area of interest and determined that the areas marked on Figure 1 are suitable for MLS capture. Within these corridors, the MLS system will capture multiple passes of scan data and 360° imagery.

Our sub-contractor Land Surveys will capture multi-pass (at least two passes) mobile scan data and 360° imagery. Capture will be limited to public roads and car parks. Private properties (for example, retirement villages) will be excluded from capture.

As a line-of-sight technology, it is to be noted that physical obstructions including parked vehicles, barriers, vegetation, topography, etc. may restrict the ability to capture accurate floor levels. Similarly, reduced density through angle of incidence and increased range from scanner will reduce the ability to extract features from the point cloud.

Figure 1 – MLS Capture Area and GCP Locations

3.2 Co-ordinate Systems

To allow integration into existing data sets, the capture of and data supplied will be on the MGA2020 co-ordinate system as defined by GNSS observations with local checks to existing state survey control benchmarks as appropriate.

3.3 Site Conditions

The following streets were captured as part of the MLS survey:

- Larch Street, Tallebudgera;
- Daffodil Street, Tallebudgera;
- Elm Court, Tallebudgera;

- Heather Street, Tallebudgera;
- Kentia Court, Elanora.

Additional over capture was completed along Nineteenth Avenue and Tallebudgera Creek Road to connect to ground control marks placed away from the primary areas of interest.

The locations were typical suburban streets and as such a variety of obstructions were encountered including vehicles, vegetation, fences and boundary walls/structures.

3.4 Weather

The weather conditions on the day of capture were favourable.

3.5 Mobile Laser Scanning

RPS engaged Land Surveys to complete the capture component of the survey. Data capture will be undertaken using the Riegl VMX based system with a minimum of two passes per carriageway, staying in the leftmost lane to capture MLS data as close to the properties as possible.

The VMX system collects measurements using a combination of laser scanning, inertial measurement unit, GNSS rover receiver and spherical camera. The configuration is calibrated on site to couple the scanner, IMU and GNSS receiver position.

Traffic Management is not required to operate the VMX system on public roads.

The VMX system consists of two Riegl VUX 1-HA line scanners capturing up to 1,000,000 points per second tracing a helix 30° from the vehicle trajectory. Capture is conducted on two angles which results in a criss-cross pattern of data. This allows for maximum coverage behind fixed objects. The scanners are mounted high above the vehicle to maximises angle of incidence to the scanned road and allows sight over obstructions to an extent.

At all times, scanning is conducted in accordance with the rules of the road, including driving at the gazetted speed when safe. “U-turns” are avoided where possible and any need to stop the vehicle is done in safe locations with appropriate use of warning lights/beacons.

To reference the scan capture to the project area, the system will utilise corrections from nearby CORS network with valid Reg 13 certificates.

All MLS data was captured during daytime conditions.

The typical point cloud density from an MLS survey will vary with the number of passes, the speed of the vehicle and the distance from the scanner head on the vehicle. For a single pass at 30km/h, the point cloud density is approximately 1700 points per square metre.

Imagery is captured with the LadyBug 5 camera system and will be captured at 10m intervals.

The MLS capture was completed on the 7th November 2022.

3.5.1 MLS Survey Equipment

The system used by Land Surveys uses only the highest quality survey equipment, with rigorous checking and calibration regimes.

The MLS equipment used on the project is as follows:

- Scanning Vehicle using Riegl VMX system.
- Dual Riegl VUX 1HA scanners.
- FLIR Ladybug 5 spherical 360° imagery camera.
- Applanix IMU
- Trimble GNSS Rover.

3.6 Ground Control

MLS positioning and datum have been derived from Ground Control Points (GCP's) observed utilising nearby CORS network bases. GNSS receivers measured a minimum of 180 epochs of data for each control station in accordance with industry standards. Prior to the observation of the GCP's, independent checks were made to PSM54318 on Tallebudgera Creek Road with published MGA2020 co-ordinates of E542582.638 N6889068.446 and AHD value of 7.922m.

Checks prior to and at the conclusion of the GCP observations confirm that the system and corrections applied resulted in acceptable co-ordinate accuracies for the project.

The final GCP co-ordinates are listed below in Table 1

GCP04	543950.900	6888527.086	2.409
GCP03	544299.491	6889348.092	2.657
GCP02	542413.752	6889127.110	3.700
GCP01	543098.213	6889323.625	5.396
54318QA	542582.593	6889068.436	7.945

Table 1 – GCP Co-ordinates

MLS control has been placed at a few of locations spread out over the project area to ensure the accuracy of the resultant point cloud data. These have been placed along Tallebudgera Creek Road and Nineteenth Avenue as indicated in Figure 1 and are per Photos 1 and 2 below.

Land Surveys and RPS will utilise provided control to remove any (height) bias in the system and for general QA purposes.

Picture 1 – Examples of Ground Control GCP01 & GCP02 as placed and observed

3.7 MLS Data Processing

A raw vehicle trajectory is calculated, coupling the GNSS rover with IMU data against the CORS network. The multiple passes along the route will be vertically and horizontally averaged against the reference line/s. Processing is completed using RiProcess processing software. The software provides quality assurance plots and reporting.

To retain full point cloud resolution, the point cloud will not be thinned.

3.8 Project Point Cloud

The point cloud shall cover all public carriageways, as indicated. As a minimum the project point cloud shall cover the entire paved surface (edge to edge and side roads), the ground surface to 20m outside the edges of pavement (unless site lines are restricted by structures / vegetation) and 20m above the paved surface.

3.9 Floor Level Extraction

Once the point cloud is produced, RPS extracted the floor levels. Staff from our office will determine a floor level for every property within the scanned extents, as far as these can be determined with confidence. Floor levels can be extracted / derived from direct extraction of floor level from garage / car port floor level if car port level and house level are the same.

Some floor level extraction has also been completed based on the top of door, assuming a standard door height of 2040mm and these shall be considered less accurate than a direct observation to the floor.

4 RESULTS

4.1 Google Street View v MLS Imagery

A review of the sites was undertaken using Google Street View prior to the commencement of the project and advised there were a number of properties that visibility to the floor or door would be obstructed in some manner.

Imagery taken at the time of capture shows that several additional properties had installed fencing or block walls on boundary and / or had vehicles obstructing the view to the door.

4.2 Review of Supplied MLS Data

The data supplied by Land Surveys was reviewed and compared to the GCP's. An adjustment of 0.102m was applied to ensure that the MLS point cloud data was consistent with the fixed constraints of the site. This was the only adjustment made to the data supplied.

4.3 Comparison of MLS to LiDAR

As part of the QA process and to confirm that the MLS data and supplied LiDAR data were suitable to be integrated together, a comparison between the two data sets was undertaken. The results tabulated below show that the LiDAR conforms well locally to the ground control and the MLS and LiDAR agree within expected tolerances

[redacted]

4.4 Features Identified

Features identified from the MLS data were:

- Street Address
- Lot and Plan
- MLS extracted levels being Direct, Top of Door, Garage, Eave as appropriate
- Surface Level from 2018 LiDAR adjacent to building
- Single or Double storey
- Relevant comments

4.5 Example Point Cloud View

The features were extracted as points in Trimble Business Centre for tabulation and an example of resulting point cloud is displayed in the images below.

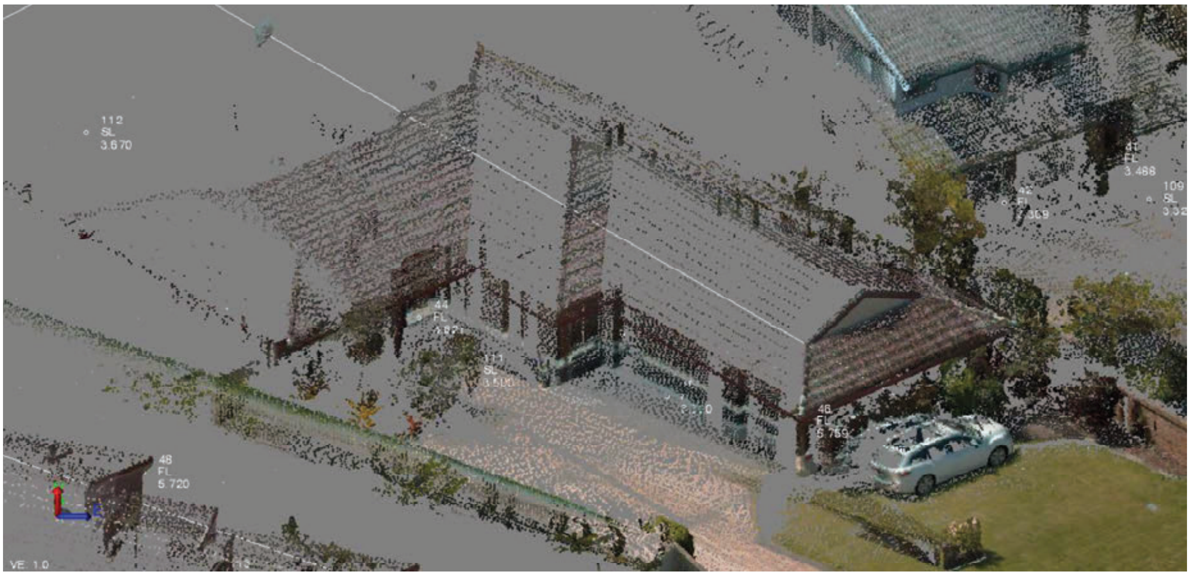

Figure 2 – Example point cloud [redacted]

Figure 3 – Top down view [redacted] **showing exemplar door and garage**

4.6 Tabulated Results

Refer to results annexed to the rear of this report.

4.7 Assumptions

In most cases, the direct observation for the floor level is at the location of the door and is typically at the landing at the front of the door and as such may be subject to some small level of variability between the described level and the actual level of the floor noting that in general this will result in the floor level reported being slightly lower than actual.

Floor levels derived from the top of door are assuming a standard door size of 2040mm and can be affected by screen door and particular door frames.

Attached garage levels are typically obtained at the front of the roller door and would expect to typically be lower than the habitable floor level of the main dwelling.

Detached garage levels are obtained in the same manner as the attached, however these are typically separate buildings or enclosed carports removed from the main dwelling

Surface Levels derived from LiDAR at the front and rear of the properties are taken from 2018 GCCC LiDAR data as supplied from DTMR and is a representation of the ground levels adjacent to the buildings and structures on site at the time of the original capture and may not be representative of the actual levels on site at the time of the investigation events.

4.8 Expected Accuracies

The expected accuracy of the MLS capture is +/- 50mm based on the system configuration and the method used to control the horizontal, vertical position and trajectory.

The extraction of the feature information is a manual process and based on the best representation of the feature identified in the point cloud. Typically, we would expect the feature extraction to be the same accuracy as the MLS capture but the interpretive nature of the feature extraction means that this could approach +/-100mm in some instances where the density of the point cloud capture is affected by 1) the distance from the scanner, 2) obstructions in the field of view, 3) poor colourisation due to objects between the scanner and the resulting point cloud.

Eave levels have been derived directly of the soffit where possible, however for a number of properties the location and level of the gutter has been used as the most reliable representation of the eave level and the accuracy of the extracted points will be consistent with other extracted points.

Floor levels can be approximated from eaves, but we would typically expect the result of such and exercise to be somewhere around +/- 300mm

4.9 Possible Additional Approaches

The approach of using MLS capture and feature extraction is really the only potential option for discrete capture of features.

The only sure way to obtain the floor levels is via direct survey either by conventional total station / levelling or by GNSS receiver.

The GNSS receiver would be the most time effective whilst maintaining an acceptable level of accuracy. The floor level would need to be taken at front, rear or side door that had the least obstruction from the eave.

5 DELIVERABLES

Deliverables consisted of:

- 12d and 3d DWG of MLS ground surface
- Spreadsheet of resulting feature extraction
- SHP file information of the MLS and LiDAR feature extraction
- Web view link of data and imagery [redacted]
- Survey Report

6 INDUSTRY TERMINOLOGY AND ABBREVIATIONS

12da	12d Software Data File Extension
3d	3 Dimensions
AHD	Australian Height Datum
CASA	Australian Civil Aviation Safety Authority
CORS	GNSS Continually Operating Reference Station
DTMR	Department of Transport and Main Roads (Queensland)
DWG	AutoCAD Software Drawing File Extension
FLIR	Forward Looking Infrared (Company)
GCCC	Gold Coast City Council
GCP	Ground Control Point
GNSS	Global Navigation Satellite Systems
IMU	Inertial Measurement Unit
LiDAR	Light Detection and Ranging
MGA	Map Grid of Australia
MLS	Mobile Laser Scanning
QA	Quality Assurance
RL	Reduced Level
SLAM	Simultaneous Localisation and Mapping

Table 3 - Industry Terminology and Abbreviations

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

DTMR M1 UPGRADE - BURLEIGH TO PALM BEACH

FLOOD EVENTS OF FEBRUARY AND MARCH 2022
HOUSE AND PROPERTY FLOODING ASSESSMENT

Prepared for:

[redacted]

SLR Ref: 620.31045-R02
Version No: -v0.1
January 2023

SLR

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with [redacted] (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
620.31045-R02-v0.1	19 January 2023	[redacted]	[redacted]	

HOUSE AND PROPERTY FLOODING ASSESSMENT

1 SLR Consulting has previously completed a detailed flooding assessment for DTMR in respect of this project (***DTMR M1 Upgrade - Flood Events of February and March 2022 – Impact Analysis and Risk Assessment, SLR Consulting, 7 October 2022***). SLR Consulting has subsequently been requested by DTMR to prepare this current report to estimate the likely impact of this flooding on existing residences in the Tallebudgera Creek catchment. It is noted that the upstream extent of all existing flood models corresponds to an imaginary line running north-west to south-east approximately 200 m west of Larch Street. The model could be extended upstream relatively easily based on existing survey information. If the model were to be extended to cover other parts of the catchment, we would recommend that it be extended at least up to Coplicks Bridge so that we could use the monitored flood levels at that gauging location for additional calibration of our hydraulic model.

2 DTMR has provided SLR Consulting with survey data relating to various ground and floor levels collected in affected streets. This level information was collected by a road-based monitoring system incorporating LIDAR (light detection and ranging) technology. While this process enables rapid collection of accurate data, it is adversely affected by fences, gardens, road furniture and parked vehicles. In effect, the system can only estimate levels for points that it has a clear line of sight to. Hence, the equipment is only able to pick up relevant floor levels when it can “see” a point on that floor. The habitable floor level of a dwelling is obviously a key parameter (together with the predicted or measured peak flood level) when attempting to determine whether over-floor flooding has occurred during a storm event.

3 In many cases, the habitable floor level of a particular residence therefore cannot be picked up because of interference with the line of sight. In those cases, the assessment has been based on other data. For example, some garage floor levels were able to be taken in circumstances where the habitable floor level was unavailable. Similarly, front yard levels were available in most instances. In these circumstances, it has been assumed that the habitable floor level is either 100 mm above the measured garage level or 225 mm above the front yard allotment level.

4 All of these assumptions and measurement tolerances lead, of course, to a degree of uncertainty about the accuracy of the assessment. The only foolproof way to accurately determine habitable floor levels of any affected property is to carry out detailed terrestrial survey using suitable equipment and methods. However, in the absence of this level of investigation, the approximate methods utilised here can still provide relatively good guidance over wide areas and within a compressed time frame.

5 Based on the various analysis and modelling tolerances built into the assessment, it is considered that an accuracy of ±200 mm will generally be applicable. This uncertainty must be recognised when considering a number of the conclusions which I have reached, and it is stressed that these conclusions are based solely on the level data set which has been provided. That is, we have not been provided with any detailed information from landowners or Gold Coast City Council as to the extent and depth of any flooding which may have occurred.

6 The determination of whether a house was likely flooded or not in the February event in this analysis is based solely on comparing the derived floor levels with the modelled flood level. It is clearly possible that some houses which were flooded in that event have not been identified in this assessment. However, so long as the accuracy of the method of analysis is taken into account, it is considered that this over-floor flooding assessment provides a useful summary of likely urban flooding impacts in the Tallebudgera Creek catchment resulting from the February storm.

7 The following table presents a detailed summary of the habitable floor, garage floor and front yard levels adopted in our analyses, as well as comments on likely flooding impacts throughout the areas of interest. A statement of Direct in the Method column means that the actual habitable floor level was measured during the data collection phase. Similarly, Garage in the Method column indicates that the actual garage floor level was determined by LIDAR for the lot in question. Consequently, the value given in the Floor Level column is either the actual measured habitable floor level, the actual measured garage level, or the estimated habitable floor level based on adding 225 mm to the front yard level when either of the other two levels were not available.

8 The conclusions of our analyses are designated in the table using the following colour code:

- Green — Direct habitable floor levels where the house was flooded during the event, but would not have flooded if the temporary construction works were not underway. A total of 6 houses.
- Blue — Garage was flooded by the event, but would not have flooded if the temporary construction works were not underway. House unlikely to have been flooded during this event as a consequence of the temporary construction works. A total of 8 houses.
- Yellow — Garage flooded by the event, but would have flooded anyway if the temporary construction works were not underway. That is, the only impact was an increase in depth of flooding. Estimated house floor levels are possibly affected by flooding, ie these entries would possibly be green if the floor level was determined accurately. A total of 19 houses.

9 To summarise then, our analysis of the results indicates that there were 25 houses in the catchment which actually, or possibly, flooded during the February 2022 event, and where over-floor flooding may not have occurred if the temporary construction works were not in place at the time of the event. Of these, only 6 houses have had their habitable floor levels accurately measured, with floor levels being only estimated from other measurements for the remaining 19 houses.

10 The majority of the flood-affected properties are in Kentia Court and Daffodil Street.

11 While I note that caution should be applied when drawing conclusions from this information because of measurement and computational uncertainty, I believe that the findings provide a reasonable assessment of the quantum of impact resulting from the temporary construction works.

12 Further assessment can be made of this information if required. For example, locations where yards were notionally flooded could be determined. The focus to date has been on identifying properties which may have suffered damage during the flood event. In that regard, the next step in this process should probably involve determination of actual habitable floor levels from the 19 properties where that value has been indirectly estimated from other measurements.

13 The detailed table is presented following.

[redacted]

[redacted]

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