Brandy & Water Creek- Investigation & Design of Creek Modification

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Prepared for
Wollongong City Council

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1 Introduction

Cardno undertook a Floodplain Risk Management Study and Plan (FRMSP) for the Allans Creek catchment in 2006 on behalf of Wollongong City Council (Council). The Allans Creek Catchment has a total area of approximately 42 square kilometres, and extends from the Illawarra Escarpment in the west to the Port Kembla Inner Harbour in the east.

This FRMSP investigated a variety of structural and non-structural flood management options to reduce flood damage and risk, and prepared a Flood Risk Management Plan for Council to manage the existing, future and continuing flood risks.

One of the flooding areas identified by the Allans Creek FRMSP is along Brandy and Water Creek in the vicinity of the Darragh Drive, Figtree. This area is shown in Figure 1.1. This FRMSP identified a number of residential properties on the east bank (left bank) of Brandy and Water Creek which experience overfloor flooding in the 1% AEP. The FRMSP recommended a further investigation of options to potentially decrease the overfloor flood risk. One of the options is to lower the west bank (right bank) of the creek opposite these residential properties to increase conveyance and alleviate the potential overfloor flooding as a result.

Cardno was commissioned by Council in 2013 to undertake a further investigation into the creek modification option recommended by Allans Creek FRMSP in this area, and identify the final location and the detailed information regarding the creek modification works. In addition, this project brief included preparation of a concept design suitable for preliminary benefit-cost analysis and community consultation.

1.1 Study Objectives

This study intends to achieve the following objectives:

- Investigate the flood behaviour under the existing conditions by incorporating the additional ground survey data;
- Investigate the flood management options recommended in the Allans Creek FRMSP;
- Undertake an assessment of options to ensure the proposed creek works are consistent with the works proposed in the Allans Creek Catchment Riparian Management Plan (Forbes Rigby, 2002), and maximise the hydraulic and economic benefits.
- Evaluate the restrictions related to the proposed works aimed at reducing the social, environmental and economic impacts of flooding over a range of potential flood events, including 1% AEP, 2% AEP, 5% AEP, 10% AEP, 20% AEP, and the Probable Maximum Flood (PMF);
- Provide a concept design suitable for preliminary benefit-cost analysis and community consultation, and;
- Make a recommendation to Council based on a Multi-criteria assessment.

1.2 Report Outline

In order to achieve the objectives above, the report is outlined as follows:

- Data Inputs (**Section 1.3**);
- Site Investigation (**Section 2**);
- Flood Behaviour under the Current Existing Conditions (**Section 3**);
- Damage Assessment (**Section 4**);
- Floodplain Risk Management Options (**Section 5**); and

- Economic Assessment of Flood Modification Measures (**Section 6**).

1.3 Data Inputs

1.3.1 Previous Studies

A number of studies have been undertaken for the study area previously. These include:

- *Allans Creek Flood Study Addendum 2 – Darragh Drive, Figtree* (Cardno Lawson Treloar, 2009).
- *Allans Creek Floodplain Risk Management Study & Plan – Addendum 1* (Cardno Lawson Treloar, 2008).
- *Allans Creek Flood Study* (Cardno Lawson Treloar, 2006).
- *Allans Creek Floodplain Risk Management Study & Plan* (Cardno Lawson Treloar, 2006).

The Allans Creek Flood Study (Cardno Lawson Treloar, 2006) and the subsequent addendum (Cardno Lawson Treloar, 2008) defined the flood behaviour for the entire Allans Creek floodplain using the one-dimensional (1D) MIKE11 model. In order to explicitly define the breakout behaviour of the flood flows in the Darragh Drive study area, the Council commissioned Cardno in 2009 to construct a more detailed two-dimensional (2D) model, focusing on the Darragh Drive Study area.

The SOBEK model utilised in the Allans Creek Flood Study Addendum 2 (Cardno Lawson Treloar, 2009) as a base model for the current study.

1.3.2 Digital Terrain Model

In the 2009 Darragh Drive Study, A digital terrain model (DTM) was established, based on a mixture of broad scale cross section survey data from the Allans Creek Flood Study as well as the 2005 ALS data from Council.

In the current study, the DTM adopted in the Darragh Drive Study was modified by incorporating the additional ground survey data conducted by KFW in September 2013. It is referred to **Section 2.3** for details.

1.3.3 GIS data

GIS data was provided by Wollongong City Council, and included:

- Cadastre
- 2m LIC contours
- Aerial photograph

2 Site Investigations

2.1 Site Reconnaissance and Rapid Geomorphology Assessment

Cardno Engineers visited the site to gain an appreciation of the topography, geomorphology and built environment for the reach of Brandy and Water Creek extending from George Fuller Drive up to the Hennessy Lane cul-de-sac. Photographs were taken of key aspects of the waterway and surrounding features, a selection of photos is included in **Appendix A**. In addition a Rapid Geomorphology Assessment (RGA) was carried out investigate fluvial behaviour and assess waterway stability. The RGA prompts the user to record observations of the physical characteristics in order to estimate an overall score. The score is indicative of channel stability where scores less than 20 generally indicate stable conditions and scores over 20 indicated unstable conditions. The proforma, its contents and details of the 7 sites recorded are included in **Appendix B**.

The results of the RGA found that scores of greater than 20 were recorded for the reach of creek extending from Darragh Drive down to George Fuller Drive. For the reach adjacent to Darragh Drive scores of between 16–21 were recorded indicating the channel is on the borderline between stable and unstable conditions. The reach upstream of Darragh Drive recorded scores of approximately 15 indicating that it is relatively stable. A gradual decline in stability was recorded in a downstream progression. It is then concluded from the RGA exercise that the Brandy and Water Creek channel was found to have a transition from a moderately stable condition upstream to a degraded and borderline unstable condition downstream. The instability was indicated by the steep exposed channel banks that can be attributed to physical and fluvial modification as a result of urban development.

2.2 Geomorphology Description

The study reach is situated in a transition between a steeper confined valley upstream to a laterally unconfined valley downstream featuring floodplain pockets. Thus it can be expected that the channel geometry changes in response. In upstream areas there is no floodplain. The channel is defined by the walls of the narrow valley and almost no top of bank can be detected in-stream, this is particularly evident adjacent to Hennessy Lane.

For the creek length adjacent to Darragh Drive, the channel appears to have been stabilised and filled on the left bank. Partial to full height rock retaining walls have been built to protect houses backing onto the creek. The opposite bank comprises bushland and a steep valley wall with small floodplain pockets. An irregular shaped channel meanders alongside the backyards of Darragh Drive properties and features an S bend opposite house numbers. Geomorphic units such as sand/gravel point bars, gravel riffles, pools and runs were observed. The sketches shown in **Appendix B** illustrate the geomorphology.

Downstream from the end of Darragh Drive the floodplain expands on the right bank for several hundred meters to a tributary, which has its confluence directly upstream of the George Fuller Drive bridge. The in-set channel appears to have incised and steep exposed banks were observed for the full length of the channel down to the bridge. Some attempts at stabilising the banks in this area appear to have failed as randomly placed rock boulders are slumping on the channel banks. Geomorphic units such as pools, riffles and sand/gravel bars were less prominent downstream of Darragh Drive.

These observations support the findings of the RGA and it can be concluded that the condition of Brandy and Water Creek in the Study Area ranges from poor in the unstable areas downstream to good in the stable areas upstream. Adjacent to Darragh Drive itself the creek condition is good, however there appears to be some ongoing reworking of the lower banks most likely a result of flow confinement by the house foundations/rock walls on the left bank. The creek supports a range of riparian vegetation with mature trees improving the stability of the left bank. The right bank is more densely vegetated and a number of weed species were observed such as Coral Trees, Privet and Lantana.

2.3 Additional Ground Survey

The additional survey undertaken by KFW recorded a range of information to inform the design of creek modification options and floor levels of houses to inform the financial benefit of the options. Creek cross-sections were surveyed at 20m intervals to accurately define the creek channel geometry. In addition trees were surveyed to identify trunk and canopy diameter so ecological impacts of proposed creek modification works could be understood. Other constraints such as fences, sewer mains and rock walls were also surveyed. A copy of the survey is included in **Appendix C**.

2.4 Geotechnical Investigations

Cardno completed geotechnical investigations in September 2013 and an associated report dated 11th October 2013. Four bore holes were drilled at various locations along the Darragh Drive reach to investigate soil properties. It was generally found that a layer of topsoil overlies clayey gravelly sand with refusal of the drill auger being experienced as a result of cobbles and gravel. In some places alluvial deposits of sand and gravel were found. The level of ground water in the boreholes was consistent with the level of the water in the adjacent creek.

Particle Size Distribution testing found that the creek soils are predominantly sand with an approximate proportion of 25% fines indicating that clay and silt is present. These soils are generally loose and prone to erode if they are exposed to flow in the creek. Thus the report recommended that batter slopes should be a maximum of 2Horizontal:1Vertical and protected with overlying topsoil and riparian vegetation. Further recommendations are made in the report for earthworks and foundation strength for construction purposes.

3 Flood Behaviour under the Current Existing Conditions

The creek comprises a variety of geomorphic features such as mature riparian vegetation, pools, riffles, point bars and floodplain pockets. There are also structural elements constructed in the creek such as rock boulder walls and terraced floodplains on the left bank.

An investigation of the flood behaviour under the current existing conditions was undertaken to ensure the hydraulic model is capable of define the creek cross sections, and the topographic features.

The ground survey included detailing of creek cross sections at approximately 20m intervals along with details of the floodplain pockets, structures in the creek channel and adjacent houses. The ground survey was used to update the SOBEK model prepared for Allans Creek Flood Study Addendum 2 (Cardno Lawson Treloar, 2009). No other changes to the model were made.

It is noted that modifications to the Brandy and Water Creek flood behaviour were predicted during detailed design of the George Fuller Drive Bridge (Cardno 2009). Recommendations were made in the flood modelling report to minimise the afflux as a result of the bridge. The bridge is located approximately 1km downstream of Darragh Drive and upon review of the afflux predicted in the flood modelling there would be no implications to the flood behaviour at Darragh Drive. The bridge is location a sufficient distance downstream to eliminate any likelihood of flood affectation to the creek modification works under investigation.

Figure 3-1 shows the elevation differences between the two terrains adopted in the current study and the previous study (Cardno Lawson Treloar, 2009). Most notable areas where ground survey estimates a lower elevation than the ALS is in locations supporting dense low lying vegetation such as floodplains and wetlands. In addition it is possible that the creek channel has experienced erosion since the ALS was recorded in 2005.

3.1 Results Comparison of the Existing Scenarios

It is worthwhile to compare the results based on the current existing case and the previous existing case (Cardno, 2009). **Figure 3-2** shows the flood extent comparison in a 1% AEP event based on these two existing cases, whilst the water level differences are shown in **Figure 3-3**.

It was found that there was generally a reduction in the flood levels for the current existing case. This is not uncommon when updating a hydraulic model using a DTM generated with ground survey compared to ALS. **Figure 3-1** indicates that the terrain elevation difference is generally a 0.1-0.5m lower for the ground survey than the ALS. This foreshadows a reduction in flood level for the study area in the range of 0-0.5m. It is noted that there are some flood level increases of 0-0.1m predicted downstream of Darragh Drive. These are minor increases and most likely the result of either an anomaly in the model or as a result of the increased hydraulic capacity upstream.

3.2 Flood Mapping under the Current Existing Conditions

A range of design events was run under the current existing conditions, including 1% AEP, 2% AEP, 5% AEP, 10% AEP, 20% AEP, and PMF. Figures showing the peak water depths, water levels and velocities for all of the design events under the current existing conditions are listed in **Table 3-1**.

Table 3-1 A List of Figures Showing the Results of the Design Events under the Current Existing Conditions

Design Event	Peak Depths	Peak Water Levels	Peak Velocities
PMF	Figure 3-4	Figure 3-10	Figure 3-16
1% AEP	Figure 3-5	Figure 3-11	Figure 3-17
2% AEP	Figure 3-6	Figure 3-12	Figure 3-18
5% AEP	Figure 3-7	Figure 3-13	Figure 3-19
10% AEP	Figure 3-8	Figure 3-14	Figure 3-20
20% AEP	Figure 3-9	Figure 3-15	Figure 3-21

3.3 Results Discussion

In regard to the flood level contours it can be seen that the creek experiences a water surface profile that is undulating. There is a uniform slope to the flood levels adjacent to properties between 35-41 Darragh Drive. Immediately up and downstream of these properties there is a sharp change in the profile as indicated by the tight contour spacing. This indicates that there is a hydraulic control at the end of Hennessy Lane and directly adjacent to 47-49 Darragh Drive. These are commonly referred to as choke points in the creek channel where there is a narrowing of the valley and reduction in channel area as a result. The choke points throttle flows and the effect on flood levels is described by the observations of the flood level contours above.

Downstream of 47-49 Darragh Drive the profile flattens out into a storage area as flow spreads across the S bend in channel planform with adjoining floodplain pockets. Again a hydraulic control can be identified adjacent to number 73 where the S bend transitions into a less sinuous planform. These hydraulic controls are all caused by a narrow creek channel/valley constricting flow. The slope of the channel banks and valley wall at these locations can range from 30-50% leaving little room for channel expansion.

Table 3-2 summarises the overfloor flooding assessment for properties under the current existing conditions.

Table 3-2 Overfloor Flood Assessment

Event	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding
PMF	7	0.84	2.13	17
1% AEP	2	0.43	0.81	15
2% AEP	1	0.55	0.55	14
5% AEP	1	0.15	0.15	11
10% AEP	-	-	-	9
20% AEP	-	-	-	9

3.4 Flood Risk Precincts

Wollongong City Council utilises flood risk precincts as a part of their planning (*Development Control Plan No. 54 ; Managing our Flood Risks*). There are three precincts, defined below:

- **High Flood Risk Precinct** – This has been defined as the area within the envelope of land subject to a high hydraulic hazard (in accordance with the provisional criteria outline in the *Development Control Plan No.54; Managing our Flood Risks*) in a 100 year flood event together with all the land within a corridor 10 metres horizontally from the top of the creek bank. The high flood risk precinct is where high flood damages, potential risk to life, evacuation problems would be anticipated or development would be significantly and adversely affect flood behaviour. Most development should be restricted in this precinct. In this precinct, there would be a significant risk of flood damages without compliance with flood-related building and planning controls.

- **Medium Flood Risk Precinct** – This has been defined as land below the 100 year flood level (plus 0.5 metres freeboard) that is not within the High Flood Risk Precinct. It is land subject to low hydraulic hazard (in accordance with the provisional criteria outlined the *Development Control Plan No.54*). In this precinct there would still be a significant risk of flood damages, but these damages can be minimised by the application of appropriate development controls.
- **Low Flood Risk Precinct** – This has been defined as all other land within the floodplain (i.e. within the extent of the PMF) but not identified within either the High Flood Risk Precinct or the Medium Flood Risk Precinct. The Low Flood Risk Precinct is that area above the 100 year flood (plus 0.5 metre freeboard) and most landuses would be permitted within this precinct.

The risk precinct mapping under the current existing conditions is provided in **Figure 3-22**.

4 Damage Assessment

4.1 Background

Flooding is likely to cause social and economic damages to the community. Flood damages are classified into different categories as summarised in **Table 4-1**.

Table 4-1 Types of Flood Damages

Type of Flood Damage	Description
Direct	Building contents (internal) Structure (building repair and clean) External items (vehicles, contents of sheds etc)
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social – increased levels of insecurity, depression, stress General inconvenience in post-flood stage

Direct damage costs, as indicated in **Table 4-1**, are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as 'tangible' costs. In addition to this there are also 'intangible' costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDAMAGE or ANUFLOOD or via more generic methods using spreadsheets. For this Study, generic spreadsheets have been used along with the damage curves provided by OEH.

4.2 Floor Level and Property Survey

The study area includes only residential properties, and does not include commercial or industrial land-uses. Floor level survey was undertaken by KFW for properties suspected to be affected by overfloor flooding. The floor survey data includes the ground level and floor level for each property.

4.3 Damage Analysis

A flood damage assessment for the existing catchment and floodplain conditions has been undertaken. The assessment is based on damage curves that relate the depth of flooding on a property to the potential damage within the property.

Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and recourse is generally made to damage curves from other catchments. OEH has carried out research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

The OEH methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW. However, correspondence at the outset of this project with OEH confirmed that the use of the OEH curves was appropriate.

4.3.1 Residential Damage Curves

The draft OEH Floodplain Management Guideline No. 4 Residential Flood Damage Calculation (2004) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet that determines damage curves for three types of residential buildings:

- Single storey, slab-on-ground
- Two storey, slab-on-ground
- Single storey, high-set (i.e. on piers)

All buildings were observed to be single storey slab-on-ground during the site inspection.

Damages are generally incurred on a property prior to any over-floor flooding. The OEH curves allow for a damage of $10,945 (May 2013 dollars) to be incurred when the water level reaches the base of the house (the base of the house is determined by 0.3m below the floor level for slab on ground). Damages of this type are generally direct external damages (sheds, gardens), direct structural damages (foundational damage) or indirect damages (garden amenity and debris clean-up). According to the damage curves this amount of damage remains constant from the base of the house to the floor level of the house.

There are a number of input parameters required for the OEH curves, such as floor area and level of flood awareness. The following parameters were adopted:

- Based on interrogation of the aerial photos a value of 240m^2 was adopted as a conservative estimate of the floor area for residential dwellings for the floodplain. With a floor area of 240m^2, the default contents value is $60,000 (in November 2001 dollars before damage repair adjustment).
- The effective warning time has been assumed to be zero due to the absence of any flood warning systems in the catchment. A long effective warning time allows residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches).
- The study catchment is a small part of the regional area and as such is not likely to cause any post-flood inflation. These inflation costs are generally experienced in remote areas, where re-construction resources are limited and large floods can cause a strain on these resources.

Average Weekly Earnings

The OEH curves are derived for late 2001 and were updated to represent November 2012 dollars. General recommendations by OEH are to adjust values in residential damage curves by Average Weekly Earnings (AWE), rather than by the inflation rate as measured by the Consumer Price Index (CPI). OEH proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data for AWE from the Australian Bureau of Statistics at the time of the assessment was for May 2013. Therefore all ordinates in the residential flood damage curves were updated to May 2013 dollars.

While not specified, it has been assumed that the curves provided by OEH were derived in November 2001, which allows the use of November 2001 AWE statistics (issued quarterly) for comparison purposes. November 2001 AWE is shown in Table D1 of the OEH guidelines, and May 2013 AWE were taken from the Australian Bureau of Statistics website (www.abs.gov.au) as shown in **Table 4-2**. Consequently, all ordinates on the damage curves were increased by 63%.

Table 4-2 AWE Statistics

Month	Year	AWE
November	2001	$676.40
May	2013	$1105.00
Change	63%	

<u>**Average Annual Damage**</u>

Flood damages (for a design event) are calculated by using the 'damage curves' described above. These damage curves define the damage experienced on a property for varying depths of flooding. The total damage for a design event is determined by adding all the individual property damages for that event.

Average Annual Damage (AAD) is an estimation of the flood damage that a floodplain would receive on average during a single year. It is calculated on a probability approach using the flood damages calculated for each design event. A probability curve is developed based on the flood damages calculated for each design event (**Figure 4-1**). For example, the 1% AEP design event has a probability of occurring of 1% in any given year, and as such the 1% AEP flood damage is plotted at this point on the AAD curve (**Figure 4-1**). AAD is then calculated by determining the area under this curve. Further information on the calculation of AAD is provided in Appendix M of the Floodplain Development Manual (NSW Government, 2005).

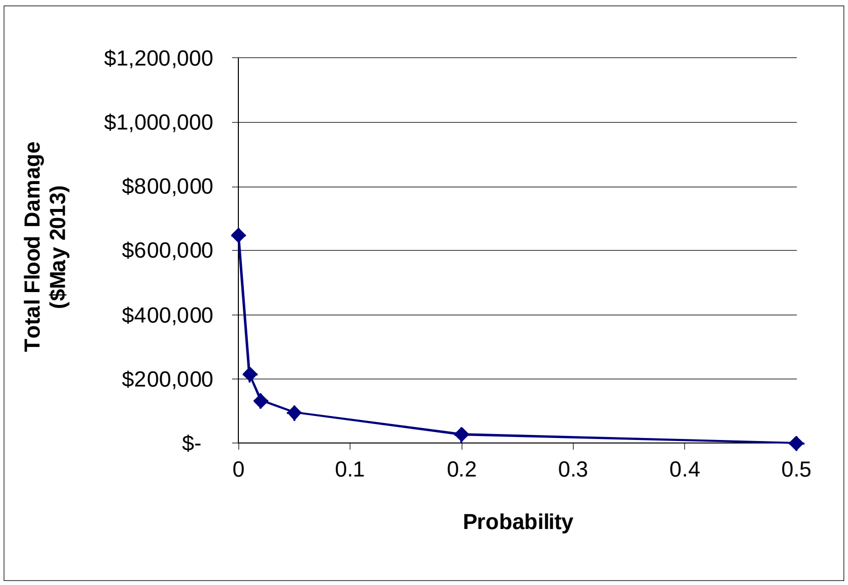


Figure 4-1 Annual Average Damage Curves for the Study Catchment

For this study, the damage resulting from a 50% AEP event (~2 year ARI) was assumed to be zero for the AAD analysis. The value is based on the assumption that flows for the 50% AEP event are contained generally within the channel and thus do not result in inundation with consequent damage to properties.

4.4 Assumptions

Seventeen properties along Darragh Drive were considered in the damage estimation, including nine properties which had a floor survey. **Figure 4-1** shows the locations of these properties. For eight properties without a floor survey (shown in **Figure 4-1**), only over ground flooding occurs at these property lots (Cardno Lawson Treloar, 2009). These properties are not subject to over-floor flooding in this study.

4.5 Results

Table 4-3 shows the results of the flood damage assessments for the modelled storm events. The average annual damage estimated for Darragh Drive under the existing conditions is approximately $20,000.

Table 4-3 Flood Damage Assessment under the Existing Conditions

Event	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($November 2012)
PMF	7	0.84	2.13	17	$648,012
1% AEP	2	0.43	0.81	15	$214,394
2% AEP	1	0.55	0.55	14	$133,431
5% AEP	1	0.15	0.15	11	$96,032
10% AEP	-	-	-	9	$37,945
20% AEP	-	-	-	9	$27,000

It is noted that a property faces a significant overfloor flooding risk since this house and its surrounding levels are depressed in relation to its neighbours. The depth of overfloor flooding is approximately 0.8m in existing conditions and options to reduce flood depths by such an amount would require significant physical works in the creek. Options to reduce the overfloor flooding are then investigated and are discussed in **Section 5**.

4.6 Qualifications

In the calculation of the Annual Average Damage, the damages in the 50% AEP design event are assumed to be zero with a linear increase in damage up to the 20% AEP design event. Assuming a different design event for zero damages can significantly change the AAD (Thomson et al., 2006). Flood modelling was not undertaken for events more frequent than the 20% AEP and a 50% AEP design event was considered to be a reasonable estimate of zero property damage in the catchment.

5 Floodplain Risk Management Options

5.1 Overview

Flood risk can be defined as being existing, future or continuing risk:

- Existing flood risk - the existing problem refers to existing buildings and developments on flood prone land. Such buildings and development by virtue of their presence and location are exposed to an 'existing' risk of flooding.

- Future flood risk - the future problem refers to buildings and developments that may be built on flood prone land in the future. Such buildings and developments may be exposed to a 'future' flood risk, i.e. a risk would not materialise until the developments occur.

- Continuing risk of flooding - the continuing problem refers to the 'residual' risk associated with floods that exceed management measures already in place, i.e. unless a floodplain management measure is designed to withstand the Probable Maximum Flood, it will be exceeded by a sufficiently large flood at some time in the future.

Allans Creek FRMSP (Cardno, 2006) proposed creek modification measures in the study area to decrease the existing, future and continuing risks of flooding for the properties in this area.

The current study investigated a number of preliminary creek modification measures and evaluated the effectiveness of these options. These measures are summarised in **Table 5-1**.

Table 5-1 Preliminary Flood Modification Measures & Qualitative Assessment

Flood Modification Measure	Description	Constraints	Waterway Disturbance	Vegetation Disturbance
FM1	Excavation of the right bank floodplain opposite house numbers 37-45 to a depth of 1m.	Would require removal of 30 trees from the right bank that includes several native species. The depth of excavation has been maximised so that the low flow waterway can be partially retained. Mitigation works would be required to ensure stability of the low flow.	Low	High
FM2	Construction of a secondary flowpath in the floodplain opposite house numbers 37-45.	Would require removal of approximately 10 trees from the right bank that includes several native species. The depth of the flowpath has been set to maximise the hydraulic capacity and retaining the low flow waterway so that is can be partially retained. Mitigation works would be required to ensure stability of the low flow.	Low	Moderate
FM3	Excavation of the right bank floodplain opposite house numbers 37-45 to a depth of 0.5m.	Would require removal of 28 trees from the right bank that includes several native species. The depth of excavation has been minimsed so that the low flow waterway can be retained in full.	Low	High
FM4	Expansion of the channel width opposite no.s 47-51 by excavation of the right bank.	Excavation of the right bank is required and the cut face would be retained with a 2.5m high rock retaining wall. It should be noted that this requires removal of 7 mature native trees from the right bank, being the main factor stabilising the existing outside bend of the meander. Rock lining of the lower bank and low flow channel would also be required.	Low	High

Flood Modification Measure	Description	Constraints	Waterway Disturbance	Vegetation Disturbance
FM5	Removal of sediment from the creek bed opposite house numbers 47-49.	Sediment deposits were observed on the lower left bank in this location that could be excavated to a depth of approximately 0.5m. The sediment deposition would most likely not continue in future if this option is coupled with FM4, because the narrow valley would be widened and flows would naturally continue in a more uniform manner reducing the likelihood of sediment deposition.	Moderate	Low

5.2 A Preliminary Assessment

A preliminary assessment on each of the options was undertaken through modelling with the 1% AEP to test the hydraulic performance of each. Because each of the options involves intrusive works to the creek it was considered appropriate to undertake preliminary testing of this nature to identify the potential of combining options for further assessment of three preferred options. This approach would identify the best performing options that require the least amount of site disturbance.

In terms of FM1 to FM3, these options lower flood levels in the upstream portion of the Darragh Drive reach until a choke point in the channel. The choke point is discussed in Section 3.3 and controls flood behaviour in its vicinity. The results of FM1 and FM3 showed that overfloor flooding remained for two properties on Darragh Drive. Attempts were then made through the investigation of more options to reduce overfloor flooding further. Option FM4 and FM5 target the hydraulic control at the choke point and lower flood levels to a greater extent. The reduction in flood levels is improved further by FM4 and FM5 in combination; however one property remains affected by overfloor flooding.

Further excavation of the banks in the choke point location is not considered feasible both from an environmental and a creek stability perspective. It is noted that the benefit of undertaking further intrusive works would be to alleviate overfloor flooding for one property only. The height of the excavated bank of FM4 is approximately 2.5m and would require stabilisation with a rock boulder retaining wall. Increasing the height of this wall to 3m and beyond is not recommended as the wall would be prone to slumping and slip circle failure, considering that the soils are loose and prone to erode (Cardno 2013). Furthermore excavations for FM5 have been modelled to the greatest extent available without disturbance to the existing low flow channel. The existing rock wall on the left bank is adjacent to property boundaries and reconstruction of the wall, in order to expand the channel to the left, would require excavation in private property and removal of the only established mature trees on the left bank.

It is then concluded that the feasible options to conduct works in channel where the hydraulic control exists have been exhausted. Options to increase hydraulic capacity here would require significant disturbance to in-stream processes, excavation of large bank quantities and construction of very high (>3m) retaining walls.

5.3 More detailed options assessment

Whilst the options investigated to date have success in lowering flood levels by up to 0.5m alongside houses 35-41, there has been limited ability to reduce flood levels for house numbers 43-47 as a result of the narrow channel/valley at this location. FM4 and FM5 have had limited success in lowering flood levels in this location and further works at this location would require expansion of the channel into private property on the left bank. Directly downstream there is a flood storage area, S bend in channel planform, where flood levels are controlled by a narrow channel much further downstream adjacent to house number 73. A significant amount of earthworks would be required to widen the channel opposite number 73, and possibly to include a meander cut-off for the S bend, in order to lower flood levels all the way upstream to houses 43-49. The benefit of undertaking such extensive works is not expected to be viable because it would be undertaken for the benefit of eliminating overfloor flooding for a single property only.

The aim of the options investigated has been to alleviate overfloor flooding through works undertaken in the creek and not within Darragh Drive properties. Flooding of backyards is common for properties along Darragh Drive considering their proximity to the creek. Options to alleviate all property flooding would again require significant expansion of the channel in the narrow valleys and require high retaining structures as a result. The remaining options to further reduce flooding and possibly eliminate overfloor flooding could include:

A. A levee built in private property to prevent flood waters from entering the house of 43-45 Darragh Drive. The length of this levee is expected to extend from 41 – 47 Darragh Drive and would most likely be built in the place of the existing brick wall shown on the survey (**Appendix C**) as a solid red line. The flood impact of this option is not considered to be adverse for properties up or downstream. If this option is included in combination to options 1-3 then the wall would be ~1.5m high, if it is considered independently then the max wall height would be ~2m. Note that this does not include an allowance for freeboard. Residents may oppose this option as a wall built ~2m high would cut off the lower section of their yard backing onto the creek, this is particularly relevant for 47 Darragh Drive, however stairs may be provided from the top of the wall down to ground level or alternatively flood proof doors through the wall.

B. An online retarding basin built adjacent to Hennesy Lane in the form of a detention bund and associated retardation structure. The structure would most likely be an earthen bank with an open slot hydraulic control built from concrete/rock boulders founded on the lower creek bank. The basin would increase upstream flood levels by at least 1m upstream and would expand the flood extent into the open space and into the neighbouring property on the right bank.

These remaining options would include a number of constraints in order to construct and significant consultation with private property owners and environmental agencies in order to approve. As these remaining options would involve a significantly higher amount of constraints in comparison to FM1 to FM5, no further consideration of them was undertaken. Discussion was held with Council and it was decided that three preferred options would be selected from FM1 to FM5 for more detailed modelling and cost benefit analysis.

5.4 Preferred Options

The three options selected for detailed modelling and the cost-benefit analysis are listed in Table 5.2.

Preferred Option	Flood Modification Measures	Waterway Disturbance	Vegetation Disturbance
1	FM1&5	Moderate	High
2	FM2&5	Moderate	Moderate
3	FM2&4&5	Moderate	High

The design layouts of the three preferred options are presented in **Figure 5-1** to **Figure 5-6**. The model results of 100 year ARI for these three preferred options are presented in **Figure 5-7** to **Figure 5-15**.

6 Economic Assessment of Flood Modification Measures

6.1 Damage Estimation for Flood Modification Measures

Damage costs for each of the combined flood modification measures were estimated for the PMF, 1% AEP, 2% AEP, 5% AEP, 10% AEP and 20% AEP events. The results of the damage assessment for the measures are summarised in **Table 6-1**.

The damage costs for each of the flood modification measures were estimated based on the peak flood levels for PMF, 1% AEP, 2% AEP, 5% AEP, 10% AEP and 20% AEP events as detailed in **Section 5**.

Table 6-1 Results of Damage Assessment for Flood Modification Measures

Scenario	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($November 2012)	Reduction of Damage ($November 2012)
PMF						
Existing	7	0.84	2.13	17	$648,012	
FM1&5	7	0.78	2.05	17	$627,957	$20,055
FM2&5	7	0.79	2.02	17	$631,193	$16,819
FM2&4&5	7	0.76	1.97	17	$625,430	$22,582
1% AEP						
Existing	2	0.43	0.81	15	$214,394	
FM1&5	1	0.75	0.75	15	$160,760	$53,634
FM2&5	1	0.72	0.72	15	$177,493	$36,901
FM2&4&5	1	0.66	0.66	15	$139,870	$74,524
2% AEP						
Existing	1	0.55	0.55	14	$133,431	
FM1&5	1	0.50	0.5	12	$117,922	$15,509
FM2&5	1	0.46	0.46	13	$119,671	$13,760
FM2&4&5	1	0.40	0.4	13	$109,849	$23,582
5% AEP						
Existing	1	0.15	0.15	11	$96,032	
FM1&5	1	0.14	0.14	10	$92,720	$3,312
FM2&5	1	0.08	0.08	10	$90,844	$5,188
FM2&4&5	1	0.03	0.03	10	$89,280	$6,752
10% AEP						
Existing	-	-	-	9	$37,945	
FM1&5	-	-	-	9	$37,945	$0
FM2&5	-	-	-	9	$37,945	$0
FM2&4&5	-	-	-	9	$37,945	$0
20% AEP						
Existing	-	-	-	9	$27,000	

Scenario	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($November 2012)	Reduction of Damage ($November 2012)
FM1&5	-	-	-	9	$27,000	$0
FM2&5	-	-	-	9	$27,000	$0
FM2&4&5	-	-	-	9	$27,000	$0

The average annual damage (AAD) for each measure was estimated as described in **Section 4**. **Table 6-2** lists the AAD for each measure and a comparison to the existing AAD of $20,100.

Table 6-2 Average Annual Damage for Quantitatively Assessed Measures

Option ID	AAD	Reduction in AAD due to Option
FM1&5	$19,100	$1,000
FM2&5	$19,200	$900
FM2&4&5	$18,600	$1,500

6.2 Cost Estimation of Flood Modification Measures

A preliminary cost estimate of the potential flood modification measures has been prepared to assist with the comparative assessment. The costs were prepared with reference to the Australian Construction Handbook (Rawlinsons, 2012). **Table 6-3** is a summary of the estimated costs for those measures. Details of these cost estimates are provided in **Appendix D**.

Prior to an option proceeding, it is recommended undertaking a more accurate cost assessment in the light of more detailed analysis.

Table 6-3 Costs of Quantitatively Assessed Measures

Measure	Capital Cost Estimate
FM1&5	$621,900
FM2&5	$258,300
FM2&4&5	$400,000

6.3 Benefit Cost Ratio of Flood Modification Measures

A benefit-cost ratio can be calculated to quantitatively assess the economic benefit of some of the measures (i.e. those which are hydraulically modelled and those with known benefits).

The economic evaluation of each modelled measure was assessed by considering the reduction in the amount of flood damage incurred by various events to the cost of implementing the measure.

Table 6-4 summarises the overall economic assessment for each measure that was able to be economically assessed. The indicator adopted to rank measures on economic merit is the benefit-cost ratio (B/C).

- B/C greater than 1 indicates the economic benefits are greater than the cost of implementing the measure;
- B/C less than 1 but greater than 0 indicates an economic benefit from implementing the measure but the cost is greater than the economic benefit;
- B/C equal to zero indicates no economic benefit from implementing the measure; and

- B/C less than zero indicates a negative economic impact of implementing the measure.

Table 6-4 Benefit-Cost Ratio of Flood Modification Measures

Measure ID	AAD	Reduction in AAD due to Measure	NPW of Benefit	Capital Cost Estimate	Recurrent Cost Estimate	NPW of Measure	B/C Ratio	Rank
FM1&5	$19,100	$1,000	$12,409	$621,900	$0	$621,900	0.020	3
FM2&5	$19,200	$900	$11,168	$258,300	$0	$258,300	0.043	2
FM2&4&5	$18,600	$1,500	$18,614	$400,000	$0	$400,000	0.047	1

NPW – Net Present Worth is calculated using 7% interest over 30yrs.

The benefit-cost analysis shows that all of these measures are not viable because the costs far outweigh the benefits. The reduction in flood damages is insignificant in comparison to the capital cost and therefore the benefit/cost ratio is very low. Generally viability of an option is considered when the benefit/cost ratio is greater than 0.1. As shown in **Table 6-4** the B/C ration is <0.1 for the three preferred options assessed. It is then concluded that the creek modification options proposed are not viable and no further assessment of physical works is feasible for Darragh Drive.

7 Conclusions

The Brandy and Water Creek Modification Study has undertaken detailed flood modelling and design options assessment for the flood affected properties on Darragh Drive. Investigation into the creek modification option recommended by Allans Creek FRMSP for Darragh Drive has found that physical works are not viable. The detailed flood modelling and design options assessment has shown that there are only two properties affected by overfloor flooding in the 1% AEP and that the costs associated with reducing the flood damages outweigh the benefits.

The following tasks have been completed to reach this conclusion:

- Refine the flood behaviour under the existing conditions by incorporating the additional ground survey data;
- Undertake an assessment of options to ensure the proposed creek works are consistent with the works proposed in the Allans Creek Catchment Riparian Management Plan (Forbes Rigby, 2002), and maximise the hydraulic and economic benefits, and;
- Evaluate the restrictions related to the proposed works aimed at reducing the social, environmental and economic impacts of flooding over a range of potential flood events, including 1% AEP, 2% AEP, 5% AEP, 10% AEP, 20% AEP, and the Probable Maximum Flood (PMF);

These tasks involved concept design on a preliminary level to an extent suitable to inform the flood modelling and cost estimation. Once it was identified that the design options were not viable further concept design and investigation was suspended and the following tasks originally identified by the project brief were not undertaken:

- Provide a concept design suitable for preliminary benefit-cost analysis and community consultation, and;
- Make a recommendation to Council based on a Multi-criteria assessment.

It is then recommended that non-structural options for flood risk management are feasible in this location. Some of these may include the below:

- Education of residents regarding the risk of flood at their property;
- Transfer of information to the SES regarding flood risk to these properties, and;
- Development of a Flood Emergency Response plan for the properties affected by overfloor flood in the 1% AEP.

8 References

Cardno Lawson Treloar (2009). Allans Creek Flood Study Addendum 2 – Darragh Drive, Figtree, August, Version 4, prepared for Wollongong City Council.

Cardno Lawson Treloar (2009). Brandy & Water Creek Bridge, Investigation and Concept Design, prepared for Wollongong Council.

Cardno Lawson Treloar (2006). Allans Creek Flood Study, September, Version 6, prepared for Wollongong City Council.

Cardno Lawson Treloar (2008). Allans Creek Flood Study, Allans Creek Floodplain Risk Management Study & Allans Creek Floodplain Risk Management Plan – Addendum 1, September, Version 3, prepared for Wollongong City Council.

Brandy & Water Creek-Investigation & Design of Creek Modification

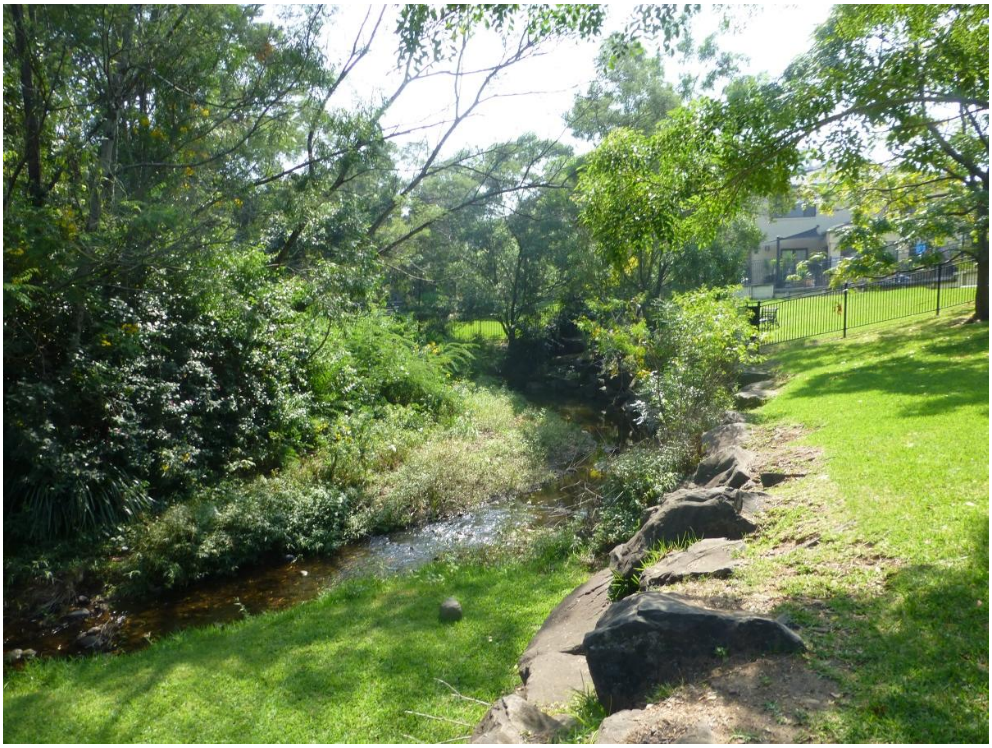
APPENDIX A
PHOTO LOG

Site 0 – Looking downstream at George Fuller Drive bridge

Site 1 – Looking upstream at the creek channel and overland flowpath from Darragh Drive

Site 2 – Looking upstream at the creek channel and tree planting

Site 3 – Looking at the apex of the S bend and sand/gravel point bar



Site 4 – Looking upstream with rock retaining wall in the foreground

Site 5 – Looking downstream with broad floodplain visible in background

Site 6 – Looking downstream left bank is stabilised by rock boulders and gravel comprises the creek bed

Site 7 – Looking at the creek from Hennesy Lane

Site 8 – Looking at the creek with gravel bed

Site 8 – Looking downstream, note the channel banks continue up valley walls and no top of bank is visible

Brandy & Water Creek-Investigation & Design of Creek Modification

APPENDIX B

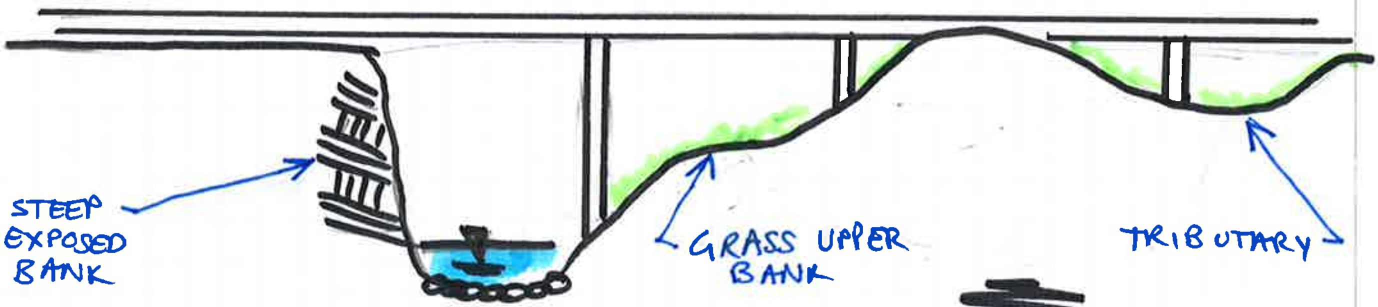
RAPID GEOMORPHOLOGY ASSESSMENT

Site/Station no.	1	1	3	5	6	7	8
Station Description	U/S Red Gum Forest Rd	Overland Flowpath Confluence	S bend in planform	US of S bend	location of bank breakout	hennessy lane	end of hennessy lane
NOTES/COMMENTS	multiple channel crossing		point bar on inside of hairpin bend		rock wall on left side	stormwater outlet on left bank	small inset channel into steep valley
Pattern	Straight	Meandering	Meandering	straight	Straight	meandering	Straight
Primary Bed Material	boulder/cobble	boulder/cobble	boulder/cobble	boulder/cobble	boulder/cobble	boulder/cobble	boulder/cobble
	1	1	1	1	1	1	1
Bed/bank Protection	None	Yes	Yes	yes	yes	yes	yes
	1	0	0	0	0	0	0
Degree of Incision	0-10%	26-50%	26-50%	26-50%	51-75%	26-50%	0-10%
	4	2	2	2	1	2	4
Degree of Constriction	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%	0-10%
	0	0	0	0	0	0	0
Streambank Erosion							
Left	mass wasting	fluvial	fluvial	none	none	fluvial	none
	2	1	1	0	0	1	0
Right	None	fluvial	fluvial	fluvial	fluvial	fluvial	none
	0	1	1	1	1	1	0
Streambank Instability							
Left	51-75%	11-25%	11-25%	0-10%	0-10%	0-10%	0-10%
	1.5	0.5	0.5	0	0	0	0
Right	0-10%	0-10%	0-10%	11-25%	11-25%	0-10%	0-10%
	0	0	0	0.5	0.5	0	0
Established riparian woody-vegetative cover							
Left	0-10%	0-10%	11-25%	11-25%	11-25%	51-75%	76-100%
	2	2	1.5	1.5	1.5	0.5	0
Right	0-10%	11-25%		51-75%	51-75%	51-75%	11-25%
	2	1.5	1.5	0.5	0.5	0.5	1.5
Occurrence of Bank accretion							
Left	0-10%	0-10%	26-50%	26-50%	26-50%	26-50%	26-50%
	2	2	1	1	1	1	1
Right	26-50%	0-10%	0-10%	0-10%	0-10%	11-25%	0-10%
	1	2	2	2	2	1.5	2
Stage of Channel Evolution	III	V	V	VI	VI	VI	III
	2	3	3	1.5	1.5	1.5	2
Composition of adjacent side slope							
Left	Fines	gravel	Fines	Fines	Fines	Fines	Fines
	2	1.5	2	2	2	2	2
Right	Fines	gravel	Gravel	Gravel	Fines	gravel	bedrock
	2	1.5	1.5	2	2	1.5	0.5
Percent of slope (length) contributing sediment							
Left	0-10%	11-25%	11-25%	11-25%	0-10%	11-25%	0-10%
	0	0.5	0.5	0.5	0	0.5	0
Right	76-100%	11-25%	51-75%	51-75%	26-50%	26-50%	0-10%
	2	0.5	1.5	1.5	1	1	0
Severity of side-slope erosion							
Left	High	Low	Low	none	none	none	none
	2	0.5	0.5	0	0	0	0
Right	None	Low	Low	moderate	moderate	low	none
	0	0.5	0.5	1.5	1.5	0.5	0
TOTAL	26.5	21	21	18.5	16.5	15.5	14

Cardno

PROJECT BRANDY + WATER CREEK CROSS SECTION SKETCHES	PROJECT NO. NA49913135 Designed NATHAN EVANS Date Sheet 1 of 5

XS- 0



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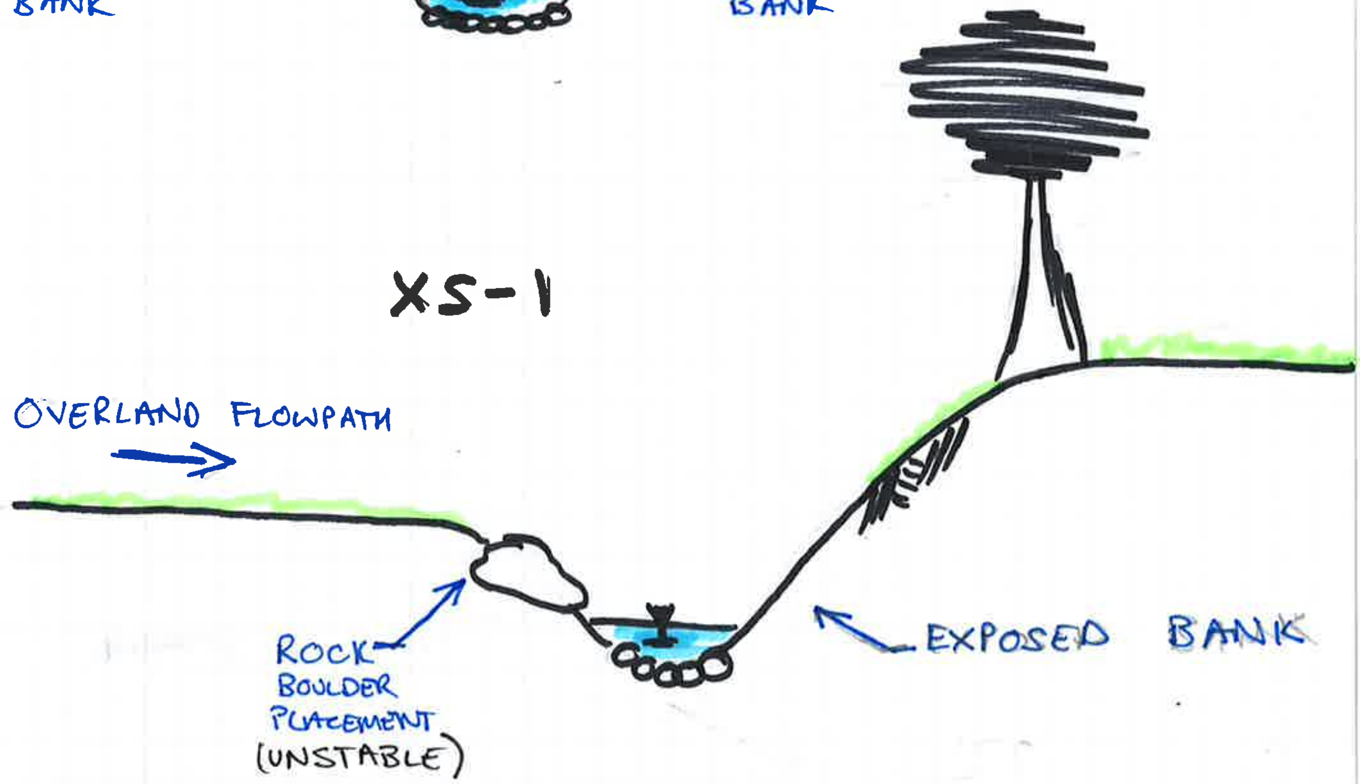

PROJECT BRANDY & WATER CREEK

CROSS-SECTION SKETCHES

PROJECT NO. NA49913135

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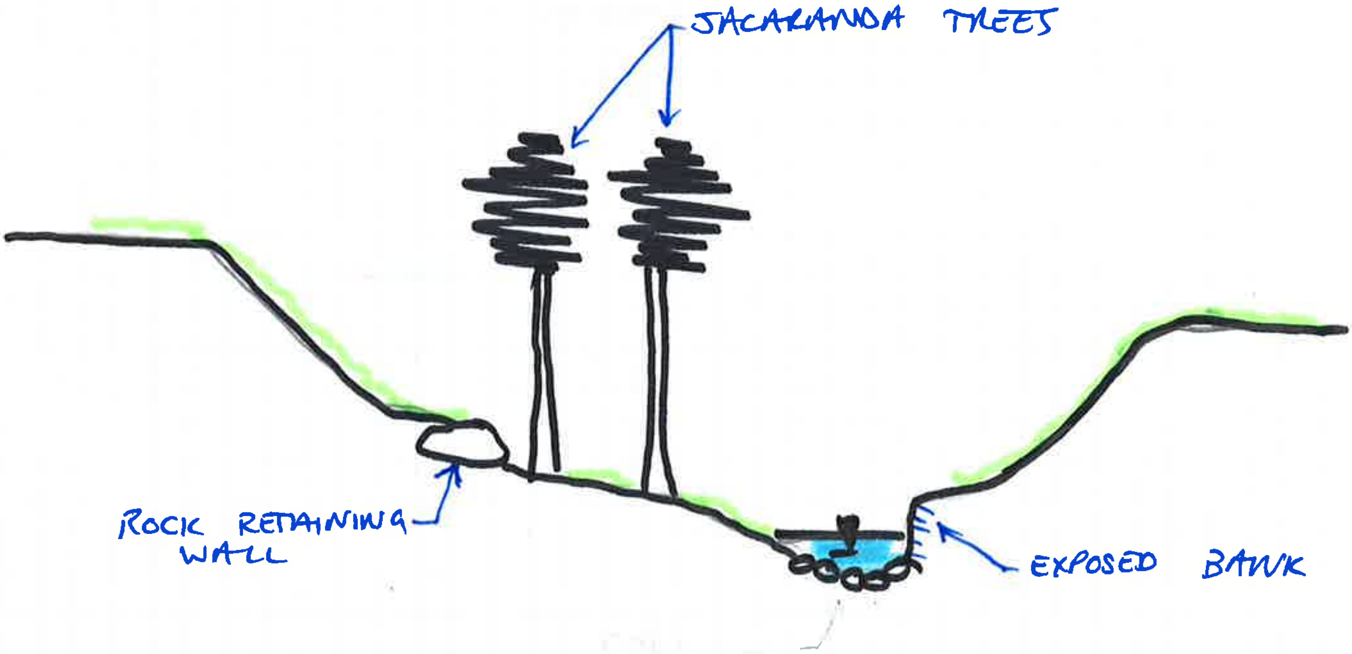
Sheet 2 of 5

XS-2



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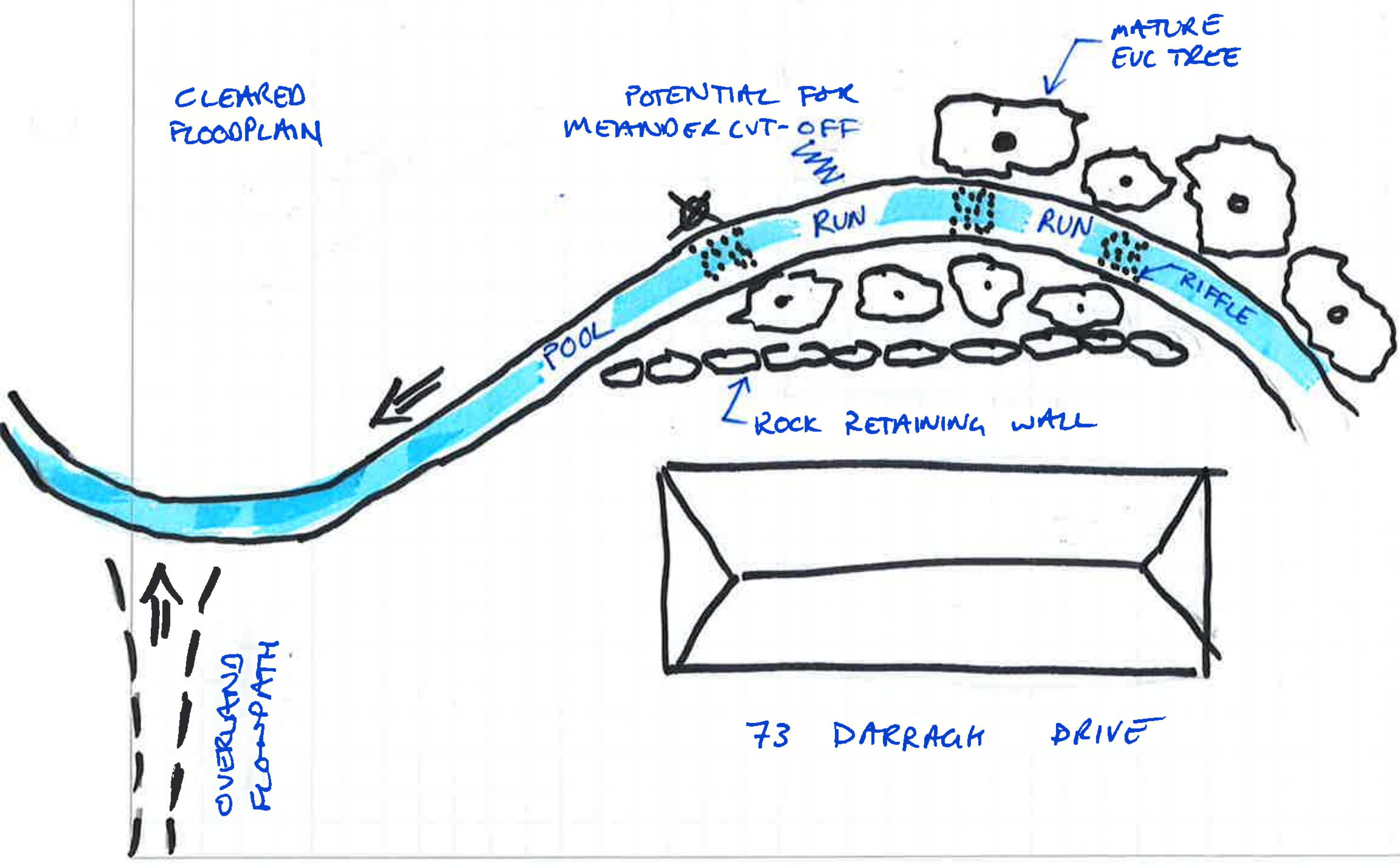

PROJECT BRANDY + WATER CREEK SKETCHES

PROJECT NO. NA49913135
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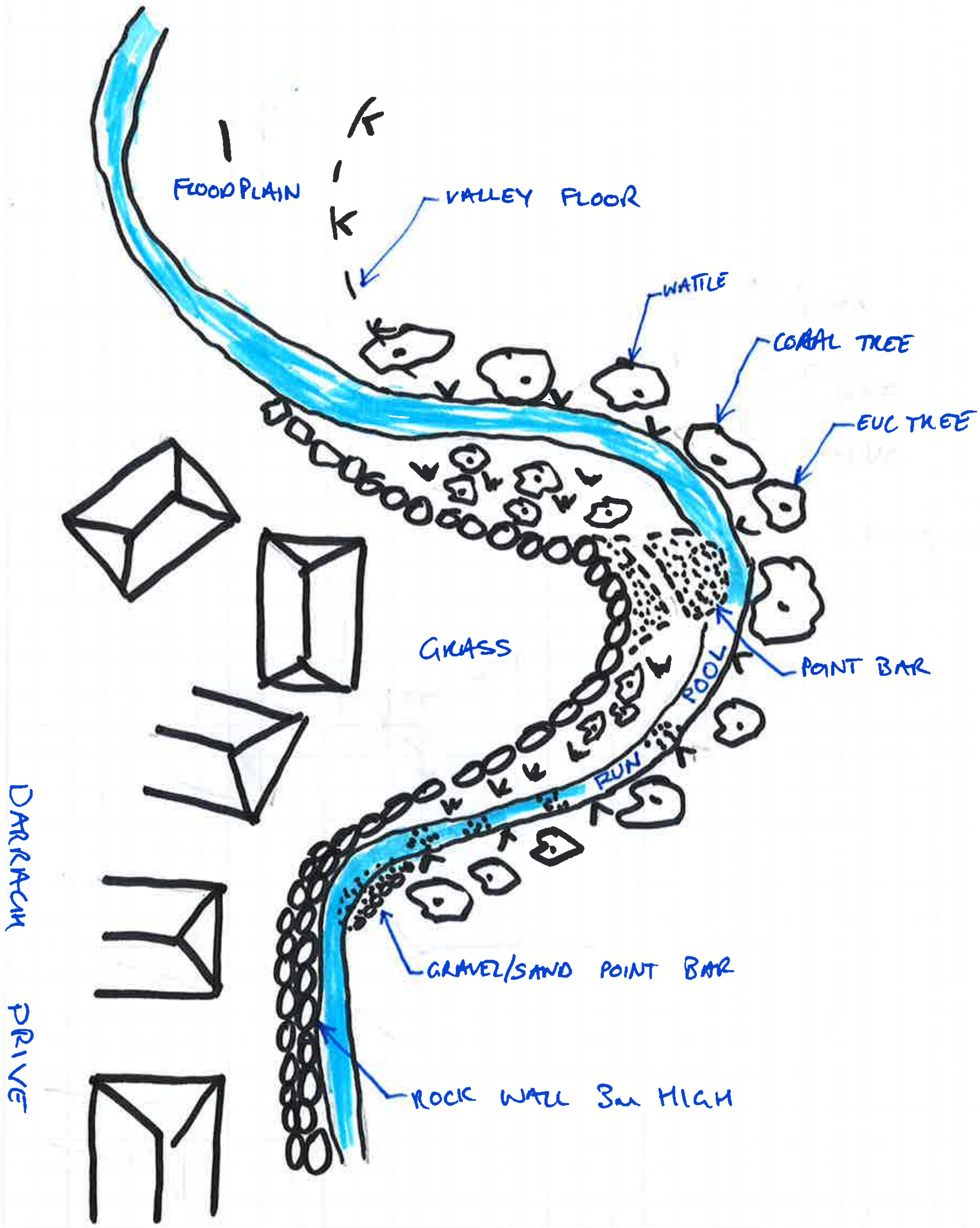
Sheet 3 of 5

XS-3 PLAN

XS-3



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PROJECT BRANDY + WATER CREEK CROSSE SECTION SKETCHES	PROJECT NO. NA49913135 Designed NATHAN EVANS Date Sheet 4 of 5

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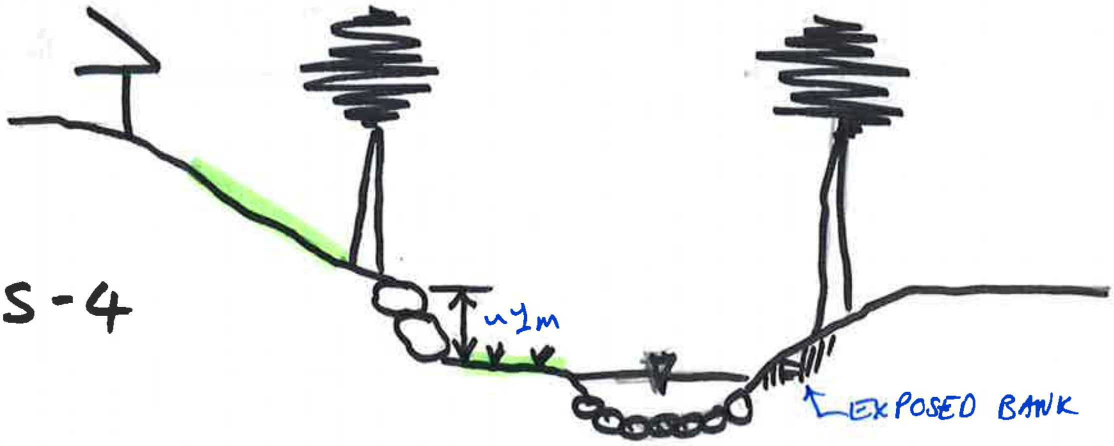

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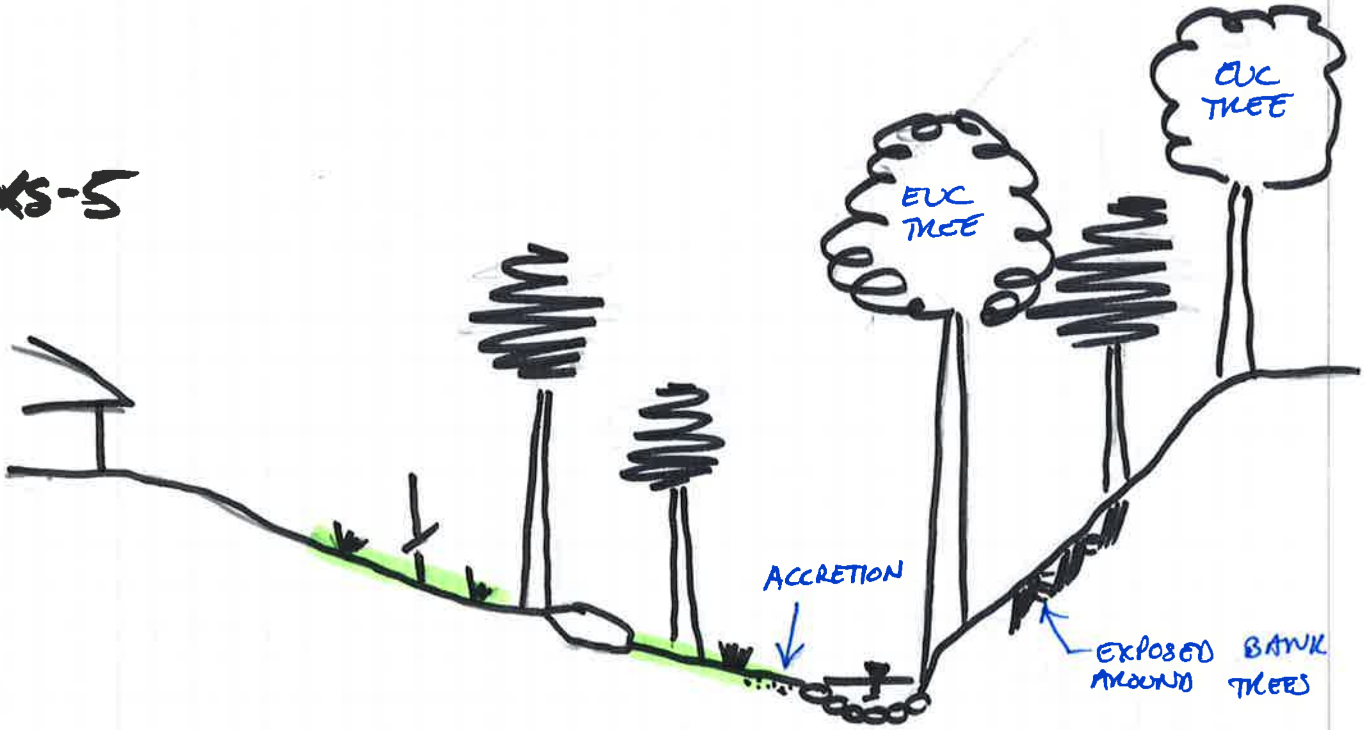

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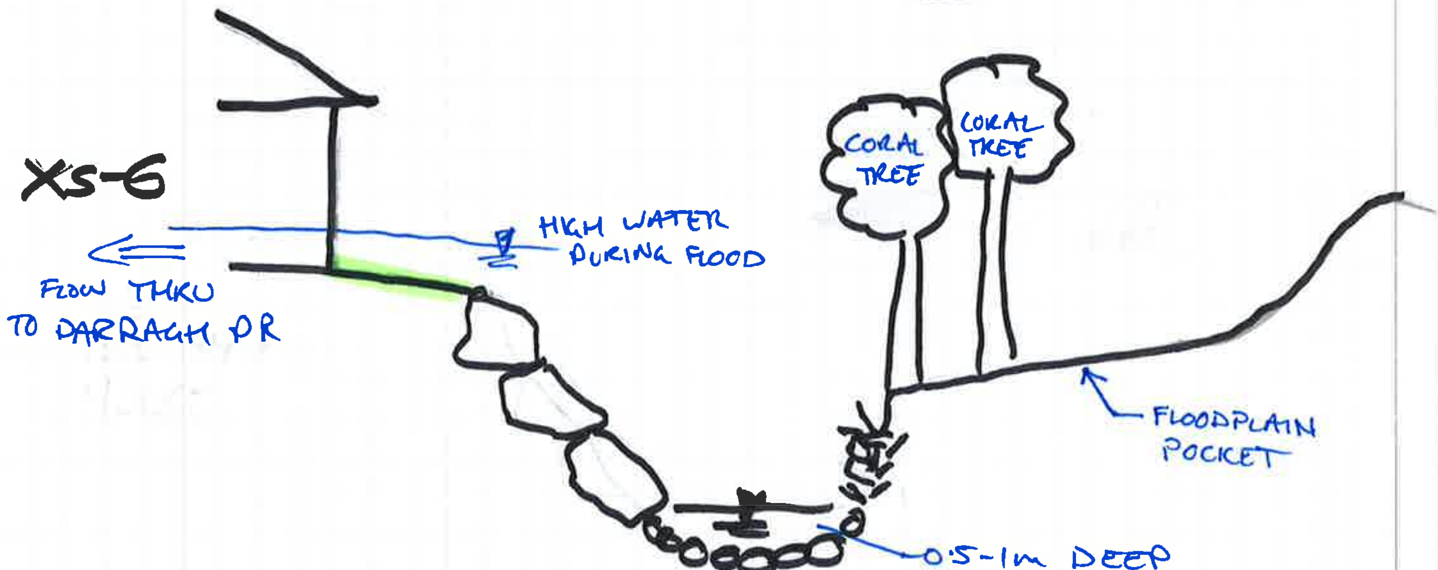

PROJECT BRANDY & WATER CREEK
CROSS SECTION SKETCHES

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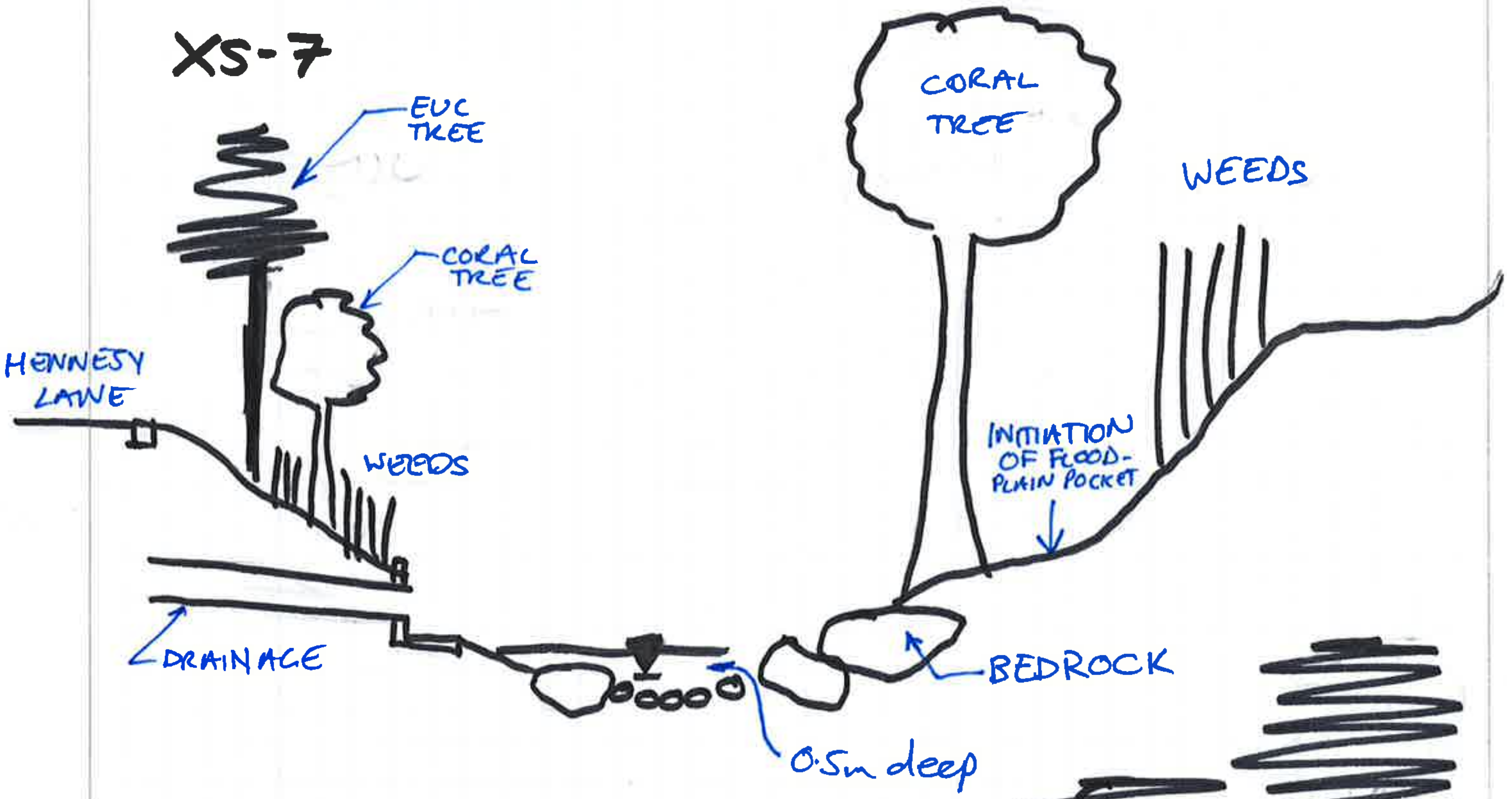
Sheet 5 of 5

XS-7



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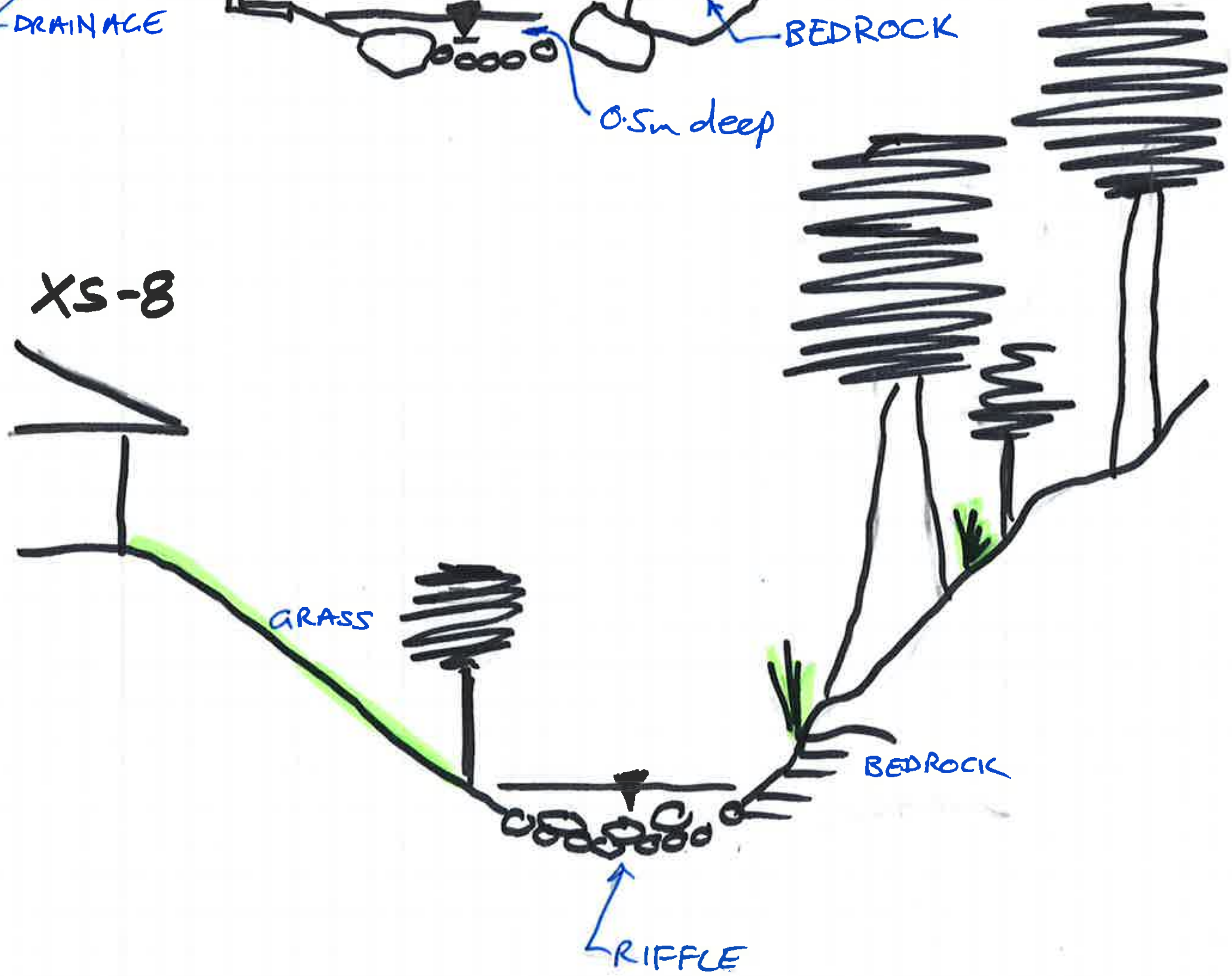

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APPENDIX C
GROUND SURVEY

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Shaping the Future

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SECTIONS 1 TO 10
SCALE 1:200

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EASTING :-	302045.760
NORTHING :-	6187444.927

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LEGEND

- SECTION PROFILE
- HEADWALL
- THW — TOP OF HEADWALL
- KERB
- BRK — BACK OF ROLL KERB
- TK — TOP OF KERB
- FENCE LINE
- BRICK WALL
- ROCKWALL
- PIPE LINE
- TOP OF BANK
- TOE OF BANK
- WATER / CREEK LOCATION
- CONCRETE
- TRACK
- TREE
- CORAL TREE

CAUTION

1. THIS DETAIL SURVEY IS NOT A "SURVEY" AS DEFINED BY THE SURVEYING ACT, 2002. IF ANY CONSTRUCTION AND/OR BUILDING LOCATION/ AREA COMPUTATIONS ARE PLANNED, IT WOULD BE ADVISABLE TO CARRY OUT FURTHER SURVEY WORK TO DETERMINE THE BOUNDARY DIMENSIONS.

2. CADASTRAL BOUNDARIES HAVE NOT BEEN SURVEYED. THEIR LOCATION IS APPROXIMATE ONLY & SHOULD BE VERIFIED BY A SUBSEQUENT SURVEY PRIOR TO THE COMMENCEMENT OF OR ANY CONSTRUCTION.

3. RELATIONSHIP OF IMPROVEMENTS TO BOUNDARIES IS DIAGRAMMATIC ONLY.

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5. CONTOURS ARE INTERPOLATED FROM ACCURATE SPOT LEVELS AS SHOWN AND SHOULD BE USED AS A GUIDE ONLY. DO NOT REINTERPOLATE CONTOURS.

6. THE POSITION OR EXISTENCE OF UNDERGROUND SERVICES HAS NOT BEEN SURVEYED. FULL DETAILS OF THESE SERVICES SHOULD BE OBTAINED FROM THE RELEVANT AUTHORITIES PRIOR TO ANY CONSTRUCTION.

Revision	Amendment or reason for issue	Issue date	Drawn by	Authorised

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Surveyor: M.B./G.L.	Date: 30/08/2013	Drawing Title	Project No. KF111252
Date of Survey: AUGUST 2013	Drawn: Z. DUKLESKI	SURVEY FOR FLOOD STUDY BRANDY & WATER CREEK - FIGTREE DETAIL SURVEY (1 OF 4)	Drawing No. SV01
Height Datum: AHD	Designed		Sheet: 1 Of 7
Origin: S.S.M.101371 R.L.19.445	Checked: C.S.J.		Revision
Horiz. Datum: M.G.A.	Approved	Scale: 1:200 @ A1, 1:400 @ A3	Drawing Status

FILENAME: X:\KF111252\Survey\Drawings\KF111252-SV01-SV07.dwg

PLOTTED BY: zdukleski

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2. CADASTRAL BOUNDARIES HAVE NOT BEEN SURVEYED. THEIR LOCATION IS APPROXIMATE ONLY & SHOULD BE VERIFIED BY A SUBSEQUENT SURVEY PRIOR TO THE COMMENCEMENT OF OR ANY CONSTRUCTION.

3. RELATIONSHIP OF IMPROVEMENTS TO BOUNDARIES IS DIAGRAMMATIC ONLY.

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- HEADWALL
- THW. TOP OF HEADWALL
- KERB
- BRK BACK OF ROLL KERB
- TK TOP OF KERB
- FENCE LINE
- BRICK WALL
- ROCKWALL
- PIPE LINE
- TOP OF BANK
- TOE OF BANK
- WATER / CREEK LOCATION
- CONCRETE
- TRACK
- TREE
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Surveyor: M.B./G.L.	Date: 30/08/2013	Drawing Title: SURVEY FOR FLOOD STUDY BRANDY & WATER CREEK - FIGTREE DETAIL SURVEY (2 OF 4)
Date of Survey: AUGUST 2013	Drawn: Z. DUKLESKI	
Height Datum: AHD	Designed	
Origin: S.S.M.101371 R.L.19.445	Checked: C.S.J.	
Horiz. Datum: M.G.A.	Approved	Scale: 1:200 @ A1 1:400 @ A3 — Drawing Status

Project No. KF111252
Drawing No. SV02
Sheet 2 Of 7
Revision

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SCALE 1:200

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EASTING :-	302045.760
NORTHING :-	6187444.927

LEGEND

- SECTION PROFILE
- HEADWALL
- THW TOP OF HEADWALL
- KERB
- BRK BACK OF ROLL KERB
- TK TOP OF KERB
- FENCE LINE
- BRICK WALL
- ROCKWALL
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- CORAL TREE

CAUTION

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3. RELATIONSHIP OF IMPROVEMENTS TO BOUNDARIES IS DIAGRAMMATIC ONLY.

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Revision	Amendment or reason for issue	Issue date	Drawn by	Authorised

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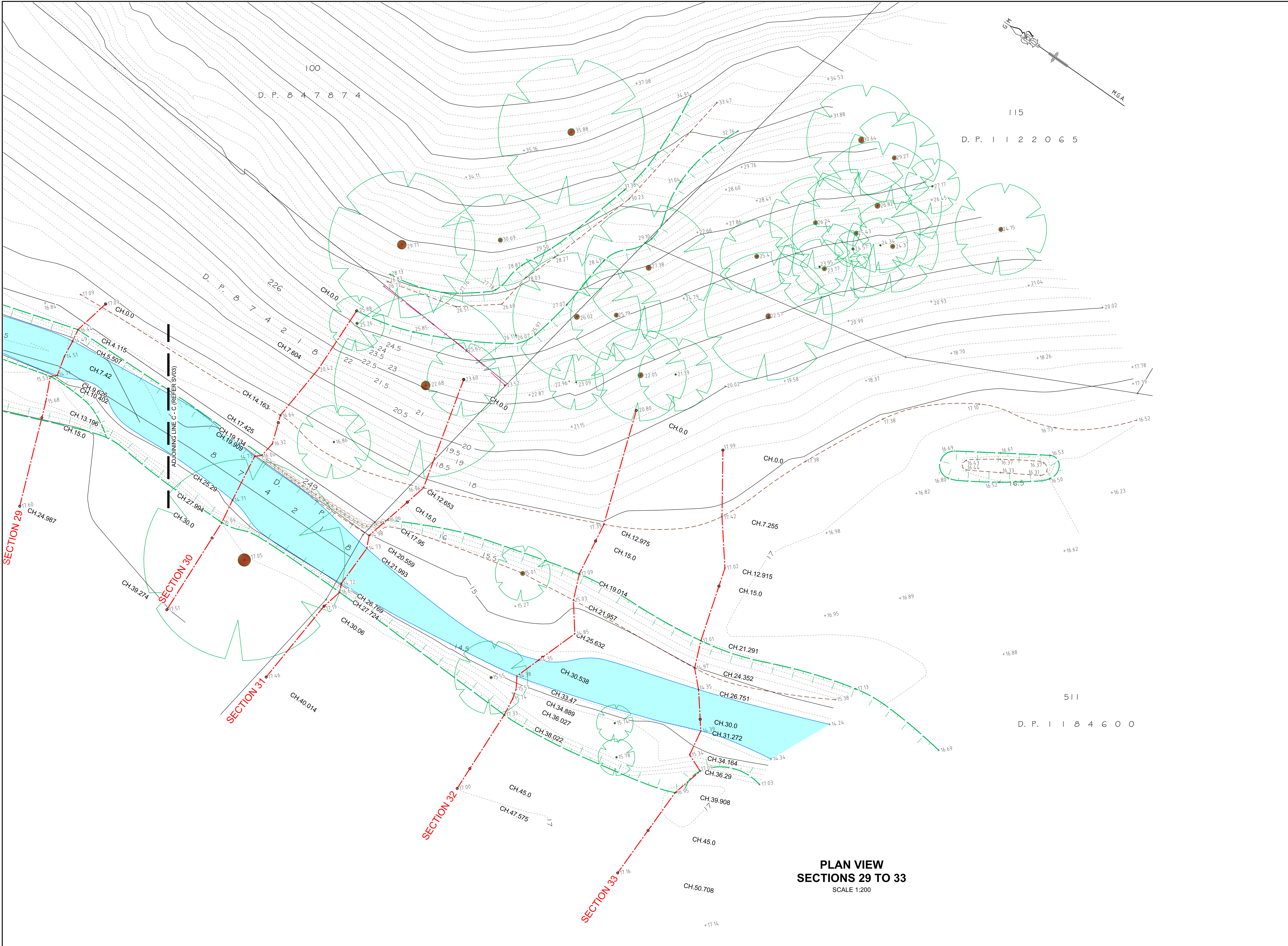
e mail@kfwilliams.com.au
www.kfwilliams.com.au

Surveyor: M.B./G.L.	Date: 30/08/2013	Drawing Title: SURVEY FOR FLOOD STUDY BRANDY & WATER CREEK - FIGTREE DETAIL SURVEY (3 OF 4)	Project No. KF111252
Date of Survey: AUGUST 2013	Drawn: Z. DUKLESKI		Drawing No. SV03
Height Datum: AHD	Designed		
Origin: S.S.M.101371 R.L.19.445	Checked: C.S.J.		Sheet: 3 Of 7 / Revision
Horiz. Datum: M.G.A.	Approved	Scale: 1:200 @ A1, 1:400 @ A3 / Drawing Status	

FILENAME: X:\KF111252\Survey\Drawings\KF111252-SV01-SV07.dwg
PLOTTED BY: zdukleski

DO NOT SCALE



PLAN VIEW
SECTIONS 29 TO 33
SCALE 1:200

ORIGIN OF CO-ORDINATES :-	S.S.M.101371 - R.L.19.445
EASTING :-	302045.760
NORTHING :-	6187444.927

LEGEND

- SECTION PROFILE
- HEADWALL
- THW — TOP OF HEADWALL
- KERB
- BRK — BACK OF ROLL KERB
- TK — TOP OF KERB
- FENCE LINE
- BRICK WALL
- ROCKWALL
- PIPE LINE
- TOP OF BANK
- TOE OF BANK
- WATER / CREEK LOCATION
- CONCRETE
- TRACK
- TREE
- CORAL TREE

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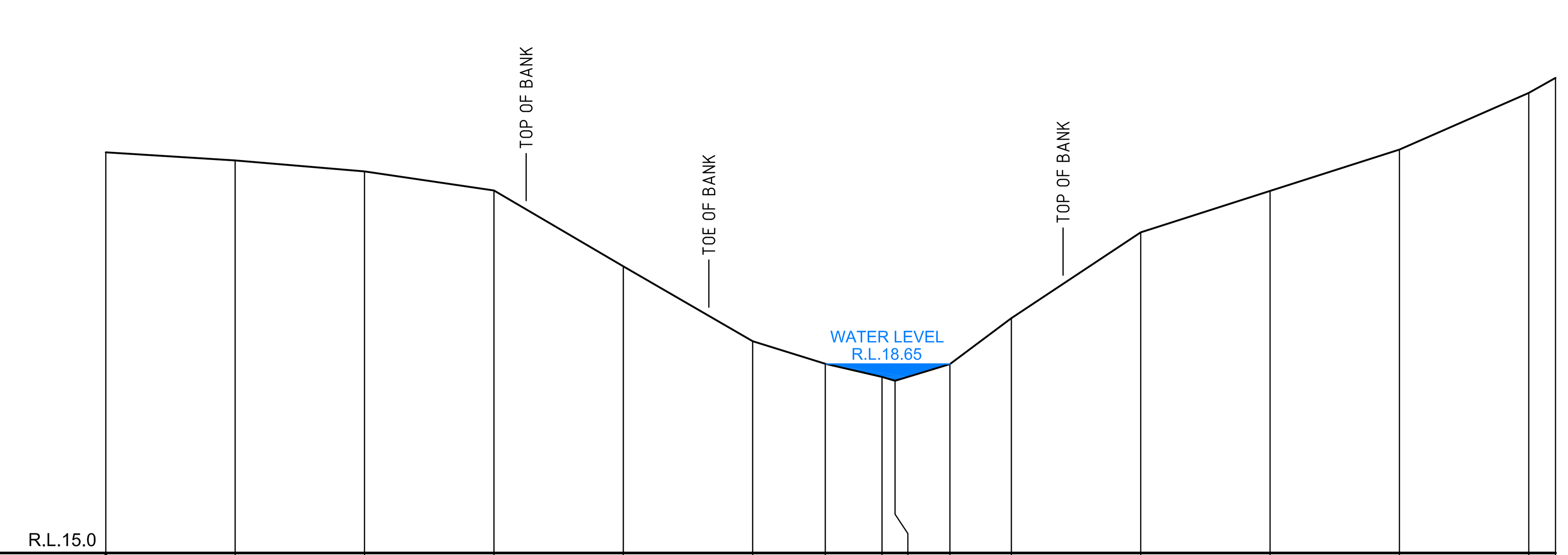
Surveyor: M.B./G.L.	Date: 30/08/2013	Drawing Title: SURVEY FOR FLOOD STUDY BRANDY & WATER CREEK - FIGTREE DETAIL SURVEY (4 OF 4)
Date of Survey: AUGUST 2013	Drawn: Z. DUKLESKI	Project No.: KF111252
Height Datum: AHD	Designed:	Drawing No.: SV04
Origin: S.S.M.101371 R.L.19.445	Checked: C.S.J.	Sheet: 4 Of 7 / Revision:
Horiz. Datum: M.G.A.	Approved:	Scale: 1:200 @ A1, 1:400 @ A3 / Drawing Status:

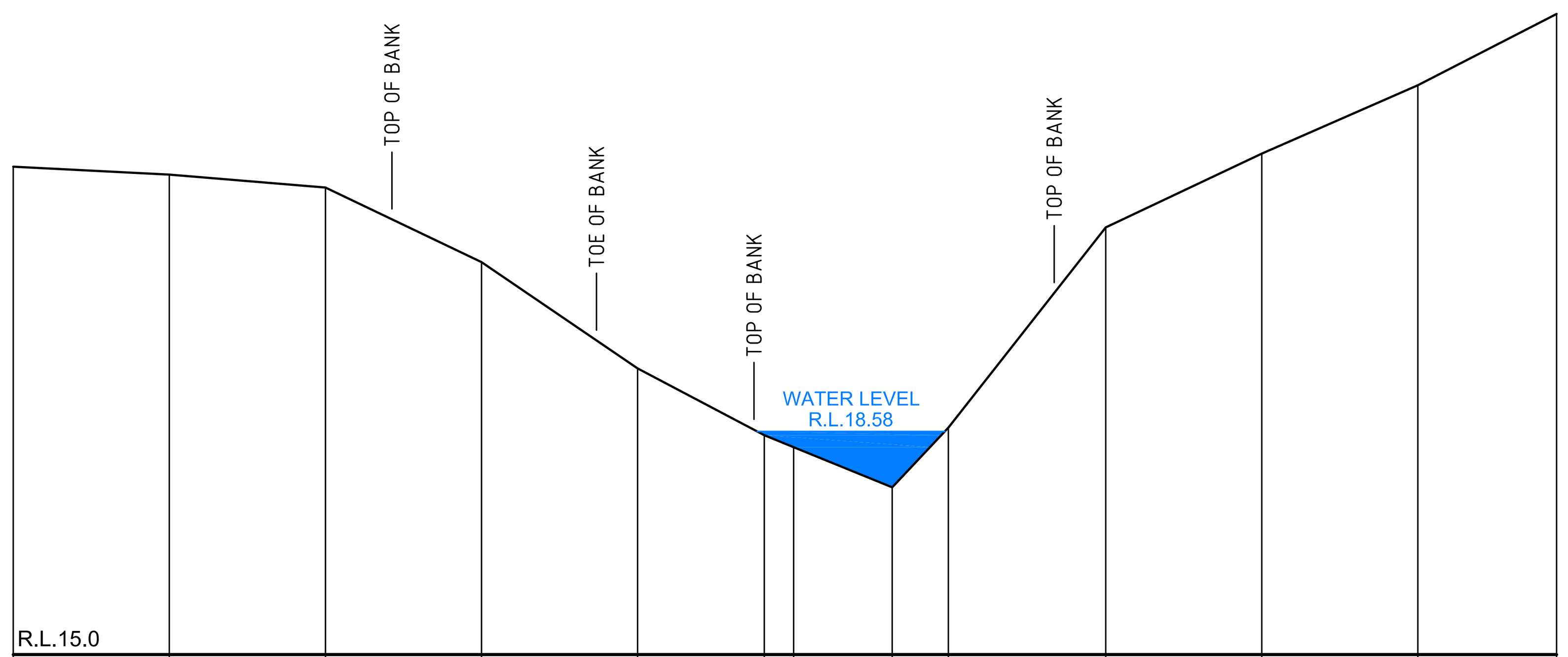
FILENAME: X:\KF111252\Survey\Drawings\KF111252-SV01-SV07.dwg
PLOTTED BY : zdukleski

DO NOT SCALE



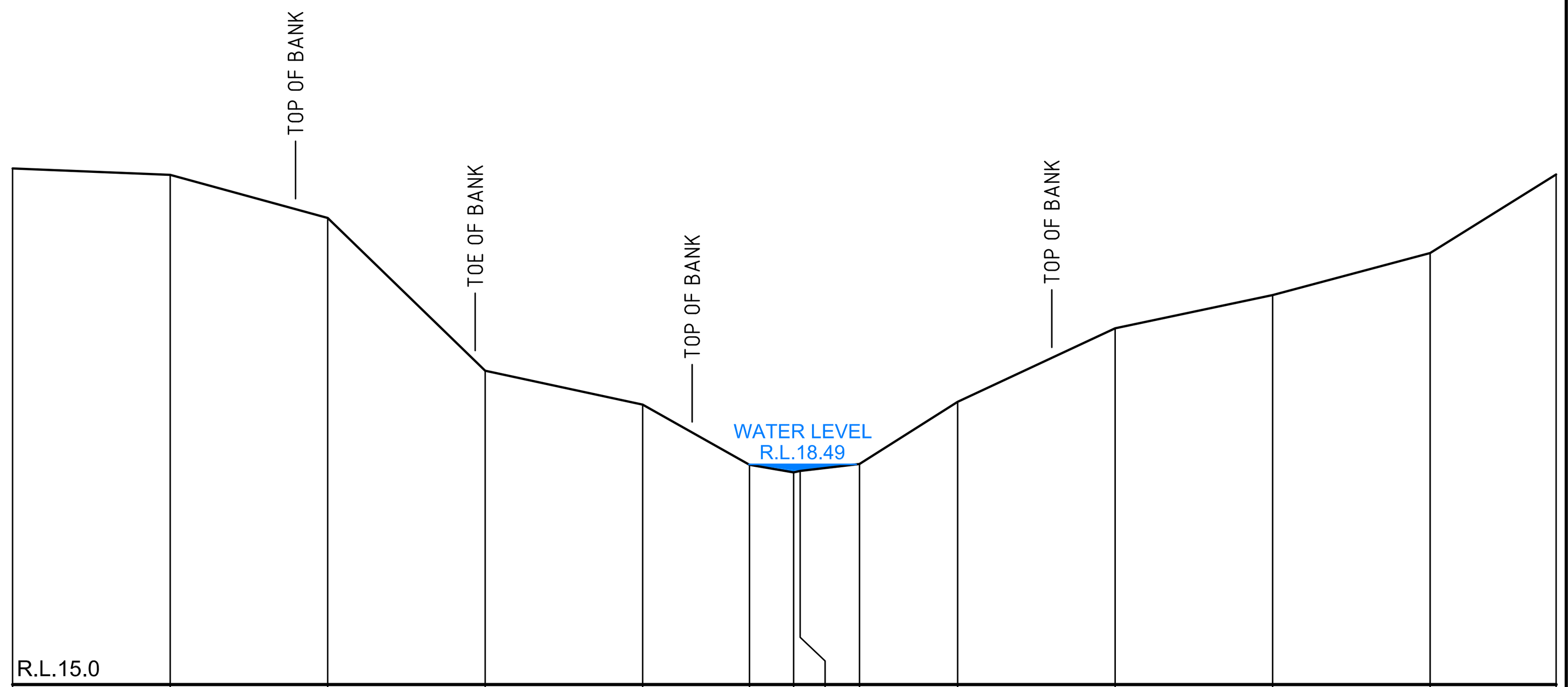
CHAINAGE	EXISTING LEVEL
0	22.736
5	22.579
10	22.367
15	22
20	20.535
25	19.089
27.809	18.653
30	18.399
30.504	18.326
32.626	18.646
35	19.534
40	21.192
45	21.991
50	22.789
55	23.884
56.031	24.173

SECTION No.1
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



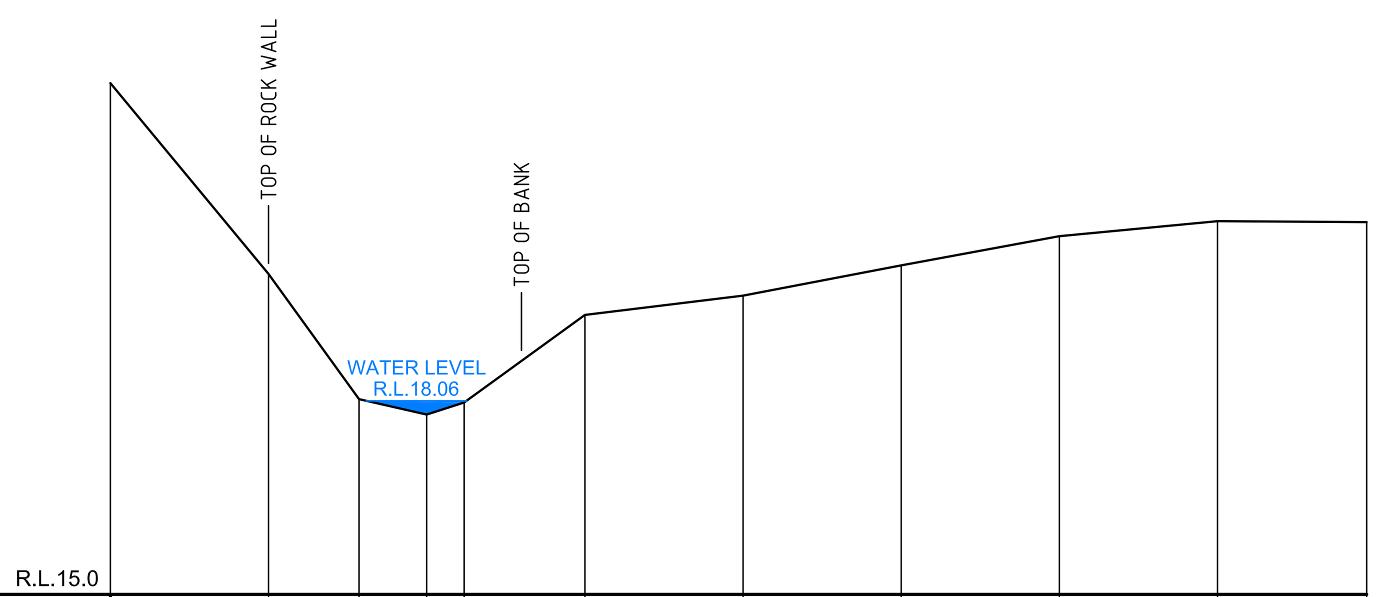
CHAINAGE	EXISTING LEVEL
0	22.822
5	22.696
10	22.488
15	21.292
20	19.588
24.061	18.518
25	18.326
28.157	17.682
29.959	18.638
35	21.849
40	23.032
45	24.128
49.444	25.271

SECTION No.2
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



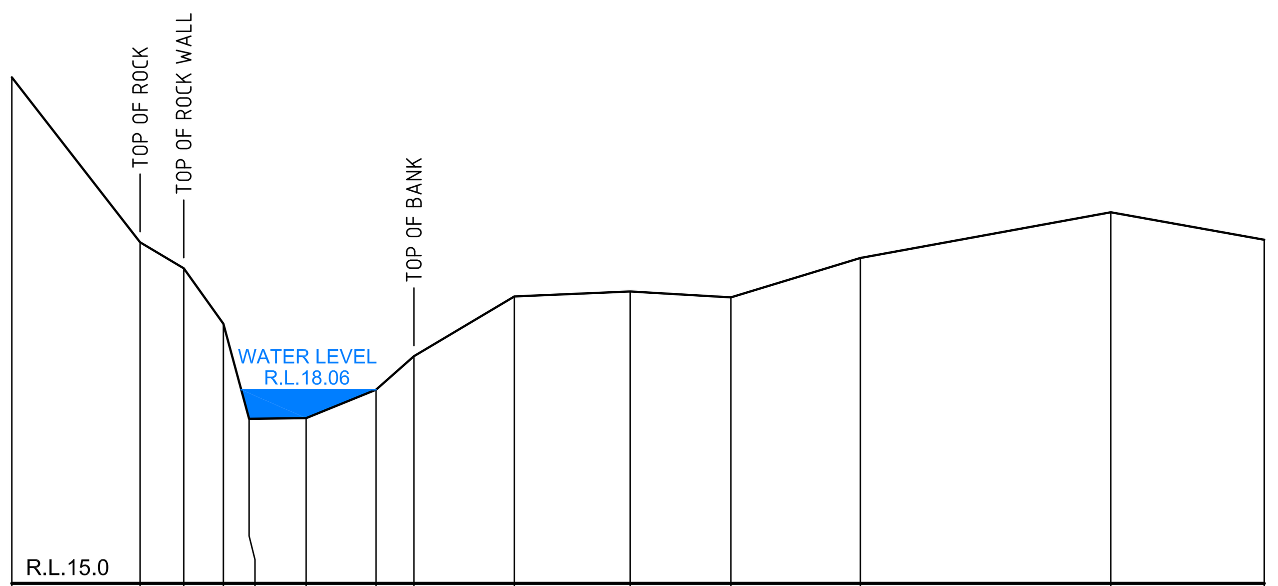
CHAINAGE	EXISTING LEVEL
0	23.187
5	23.085
10	22.401
15	19.978
20	19.44
23.393	18.486
24.793	18.366
25	18.389
26.886	18.498
30	19.485
35	20.651
40	21.179
45	21.845
49	23.091

SECTION No.3
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



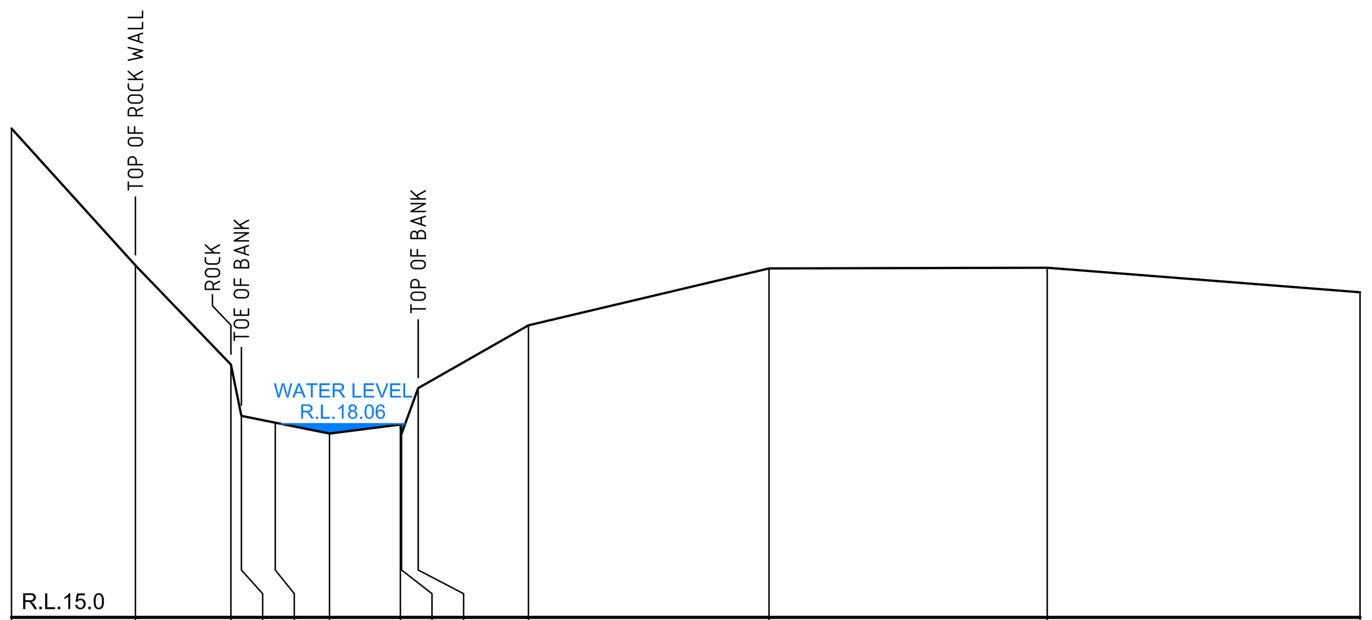
CHAINAGE	EXISTING LEVEL
0	23.081
5	20.065
7.86	18.086
10	17.844
11.185	18.033
15	19.418
20	19.723
25	20.202
30	20.662
35	20.899
39.716	20.884

SECTION No.4
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



CHAINAGE	EXISTING LEVEL
0	22.993
4.057	20.387
5.435	19.977
6.69	19.1
7.502	17.6
9.306	17.611
11.517	18.059
12.712	18.588
15.89	19.533
19.549	19.611
22.735	19.517
26.826	20.139
34.744	20.861
39.597	20.428

SECTION No.5
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



CHAINAGE	EXISTING LEVEL
0	22.728
3.916	20.566
6.936	18.996
7.265	18.187
8.336	18.078
10.051	17.907
12.289	18.049
12.326	17.905
12.851	18.625
16.335	19.617
23.941	20.516
32.733	20.527
42.617	20.14

SECTION No.6
SCALE 1:200 HORIZONTAL
1:100 VERTICAL

ORIGIN OF CO-ORDINATES :-	S.S.M.101371 - R.L.19.445
EASTING :-	302045.760
NORTHING :-	6187444.927

CAUTION

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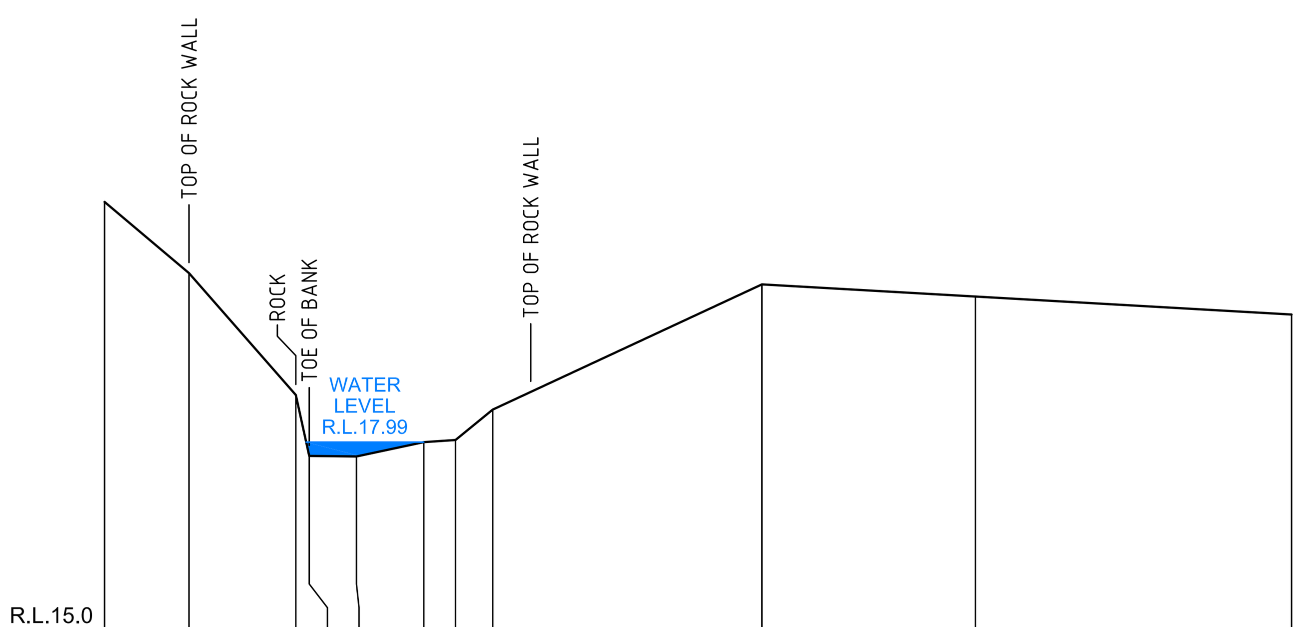
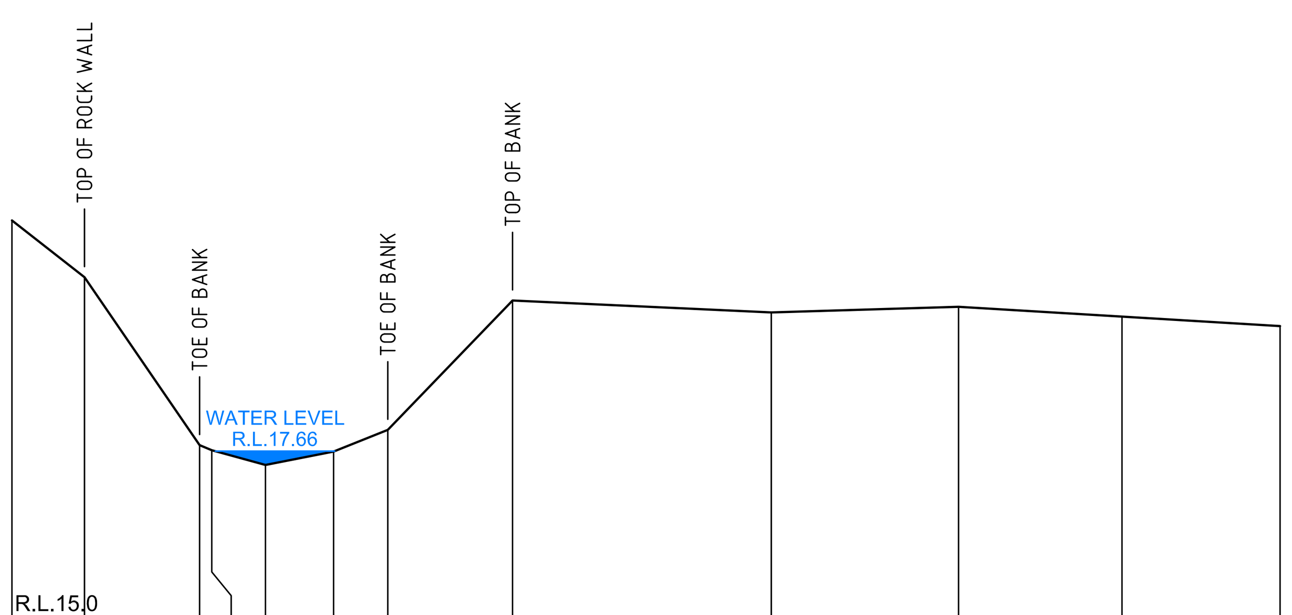


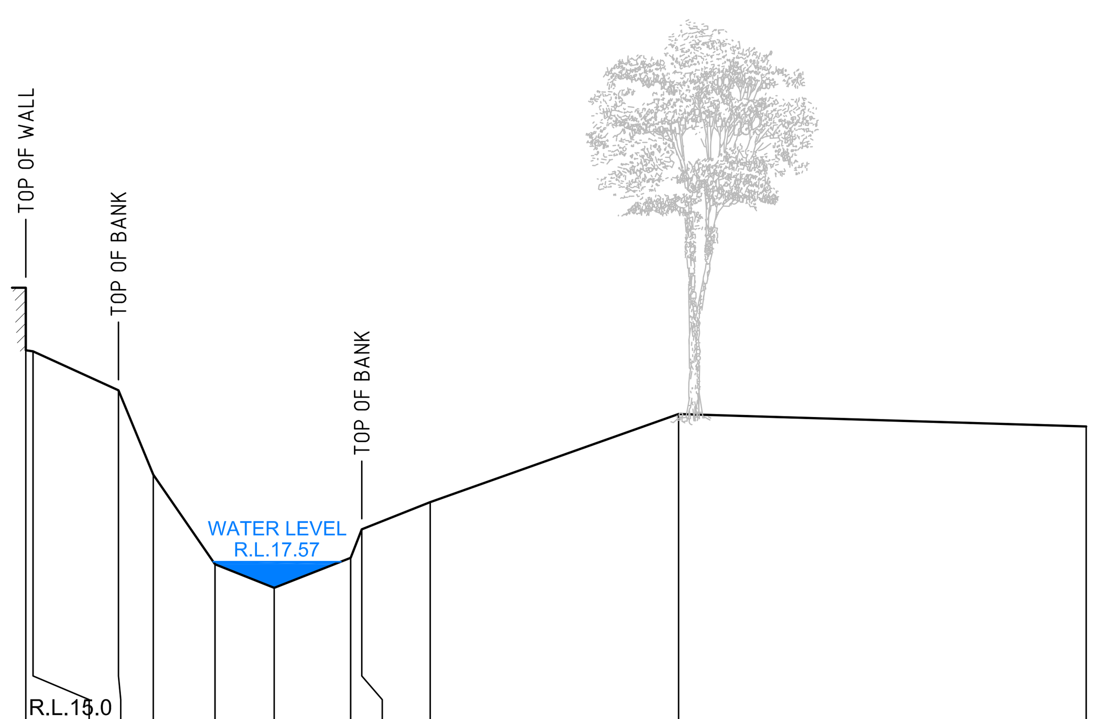
CHAINAGE	EXISTING LEVEL
0	21.788
2.67	20.663
6.047	18.737
6.473	17.774
7.965	17.764
10.095	17.991
11.101	18.025
12.277	18.505
20.789	20.485
27.542	20.293
37.542	20.009

SECTION No.7
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



CHAINAGE	EXISTING LEVEL
0	21.307
2.297	20.408
5.936	17.755
6.321	17.675
8.021	17.442
10.174	17.652
11.889	17.995
15.834	20.04
24.018	19.853
29.942	19.94
35.109	19.787
40.109	19.637

SECTION No.8
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



CHAINAGE	EXISTING LEVEL
0	21.887
0.229	20.88
2.828	20.265
4.027	18.931
5.98	17.516
7.853	17.143
10.269	17.617
10.62	18.067
12.783	18.498
20.636	19.891
33.524	19.693

SECTION No.9
SCALE 1:200 HORIZONTAL
1:100 VERTICAL

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Surveyor: M.B./G.L.	Date: 30/08/2013	
Date of Survey: AUGUST 2013	Drawn: Z. DUKLESKI	
Height Datum: AHD	Designed	
Origin: S.S.M.101371 R.L.19.445	Checked: C.S.J.	
Horiz. Datum: M.G.A.	Approved	

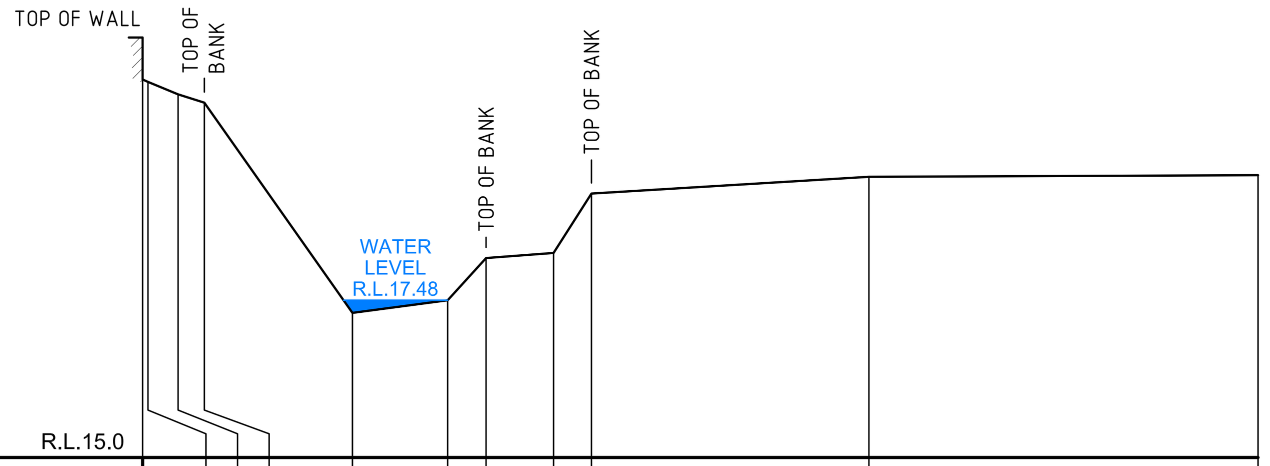
Drawing Title
SURVEY FOR FLOOD STUDY
BRANDY & WATER CREEK - FIGTREE
CROSS-SECTION DETAILS
SECTION 1 TO 9

Scale: AS SHOWN @ A1, AS SHOWN x 2 @ A3
Drawing Status

Project No. KF111252
Drawing No. SV05
Sheet: 5 Of 7
Revision

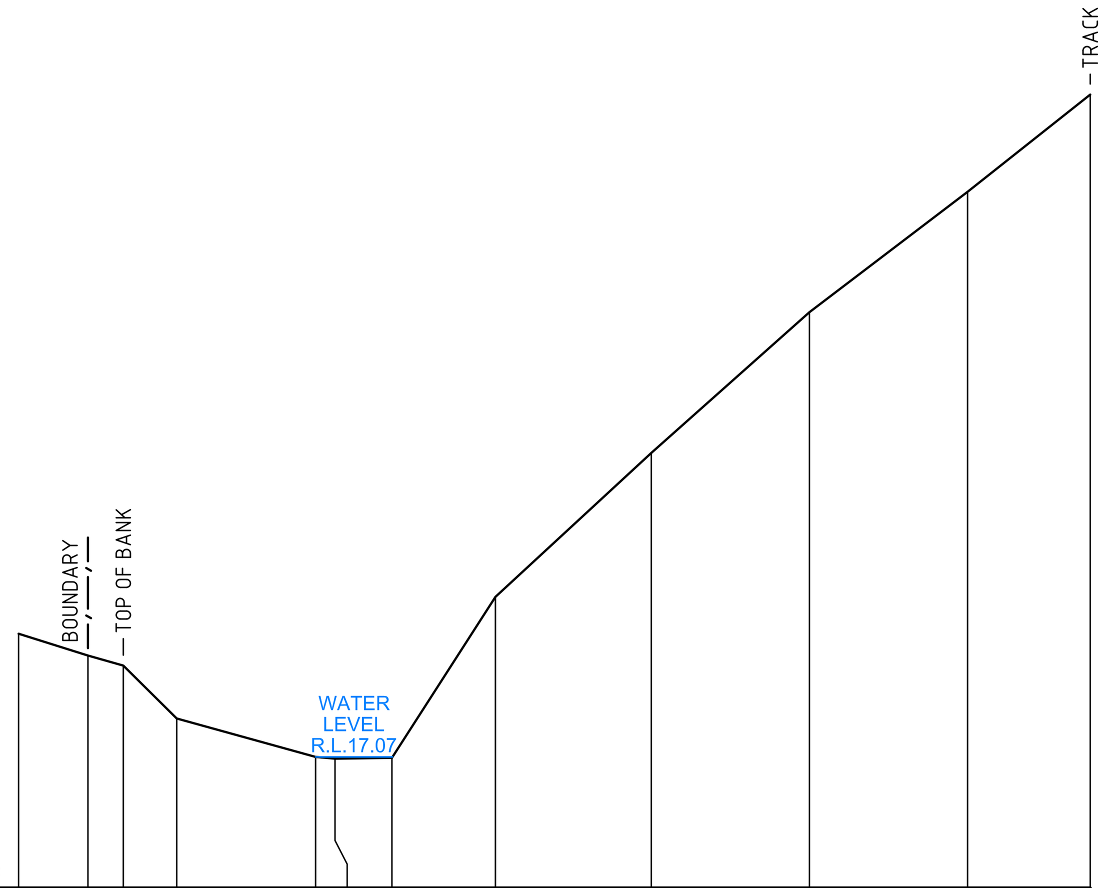
FILENAME: X:\KF111252\Survey\Drawings\KF111252-SV01-SV07.dwg
PLOTTED BY: zdukleski

DO NOT SCALE



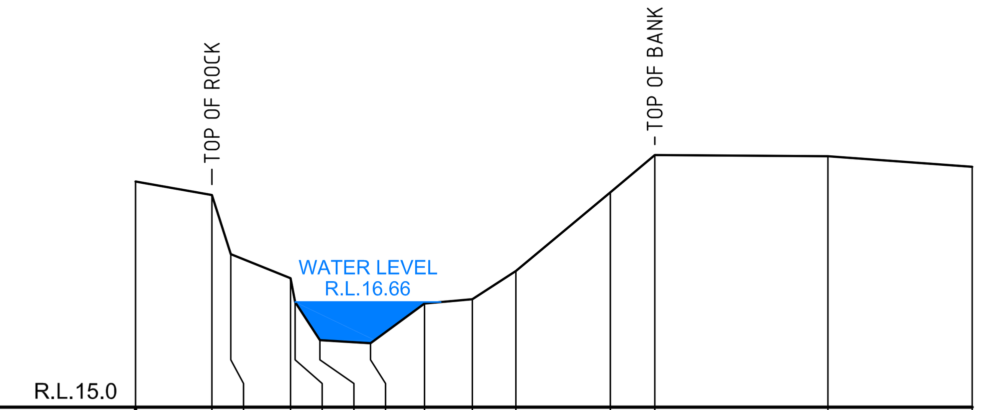
EXISTING LEVEL	21.631	20.93	20.733	20.602	17.283	17.482	18.149	18.229	19.168	19.433	19.457
CHAINAGE	0	0.169	1.122	1.952	6.633	9.64	10.857	12.991	14.189	22.961	35.263

SECTION No.10
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



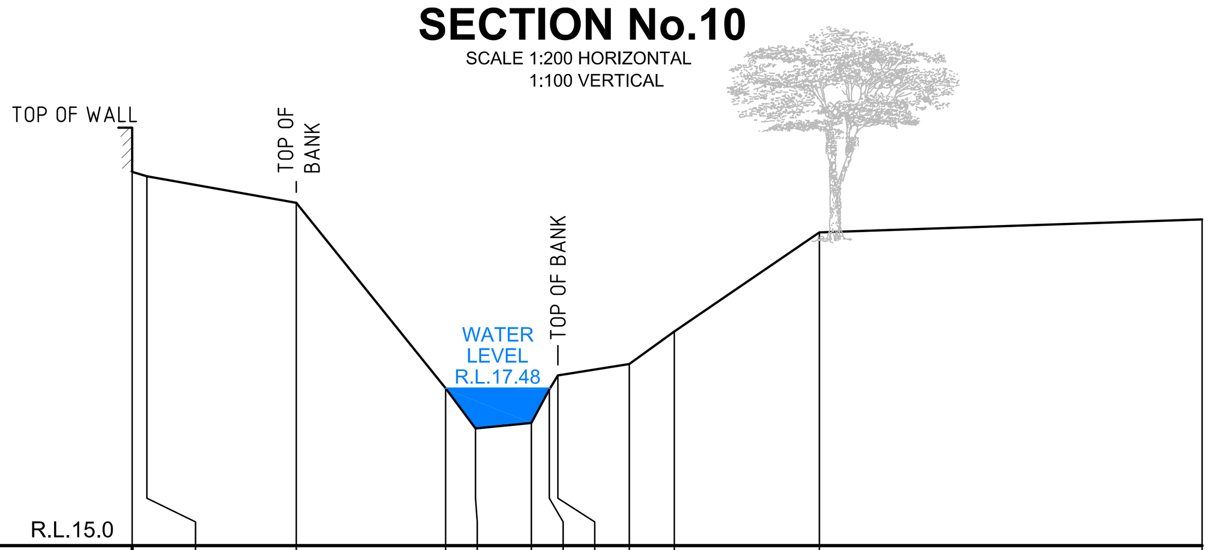
EXISTING LEVEL	19.019	18.674	18.514	17.679	17.072	17.044	17.057	19.601	21.876	24.1	26.004	27.54
CHAINAGE	0	2.191	3.31	5	9.388	10	11.803	15.072	20	25	30	33.876

SECTION No.14
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



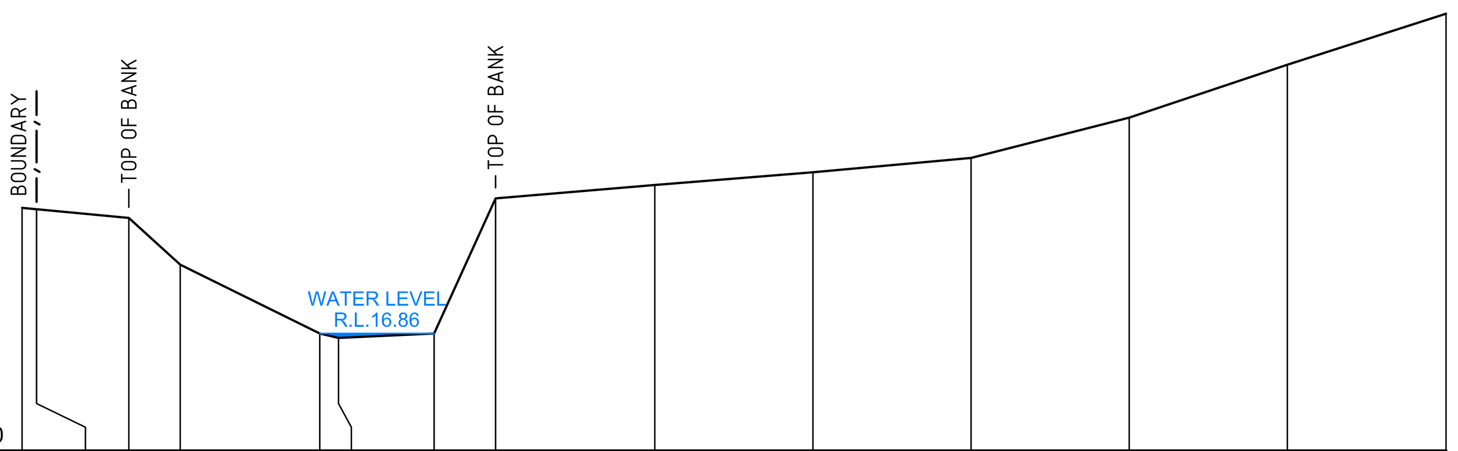
EXISTING LEVEL	18.571	18.358	17.422	17.041	16.663	16.061	16.012	16.64	16.708	17.154	18.4	18.99	18.972	18.804
CHAINAGE	0	2.411	3.009	4.897	5.038	5.822	7.422	9.131	10.642	12.018	15	16.405	21.876	26.435

SECTION No.18
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



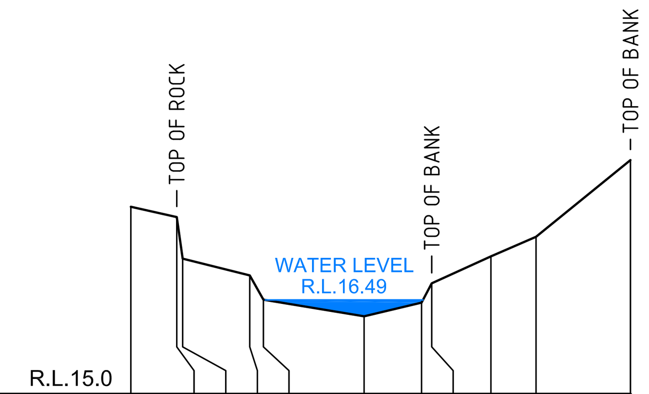
EXISTING LEVEL	21.607	20.839	20.419	17.488	16.853	16.94	17.468	17.691	17.87	18.384	19.952	20.156
CHAINAGE	0	0.466	5.184	9.904	10.847	12.615	13.183	13.453	15.709	17.131	21.717	33.812

SECTION No.11
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



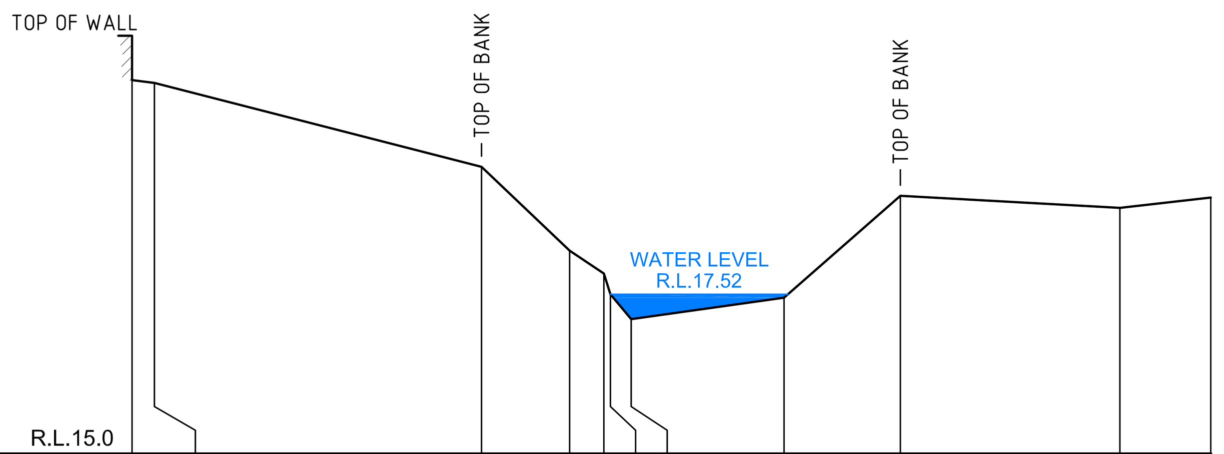
EXISTING LEVEL	18.842	18.82	18.683	17.945	16.857	16.786	16.857	18.992	19.204	19.405	19.631	20.268	21.105	21.911
CHAINAGE	0	0.454	3.371	5	9.41	10	13.023	14.966	20	25	30	35	40	45.017

SECTION No.15
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



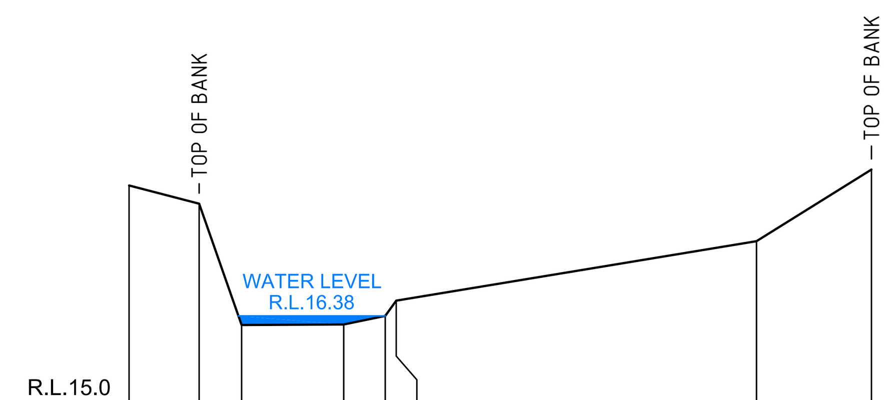
EXISTING LEVEL	17.961	17.799	17.142	16.877	16.495	16.233	16.447	16.752	17.179	17.487	18.699
CHAINAGE	0	1.451	1.641	3.76	4.192	7.376	9.191	9.514	11.385	12.81	15.797

SECTION No.19
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



EXISTING LEVEL	21.604	20.859	19.535	18.211	17.849	17.522	17.13	17.469	19.077	18.887	19.05
CHAINAGE	0	0.706	11.052	13.839	14.923	15.128	15.786	20.621	24.298	31.241	34.116

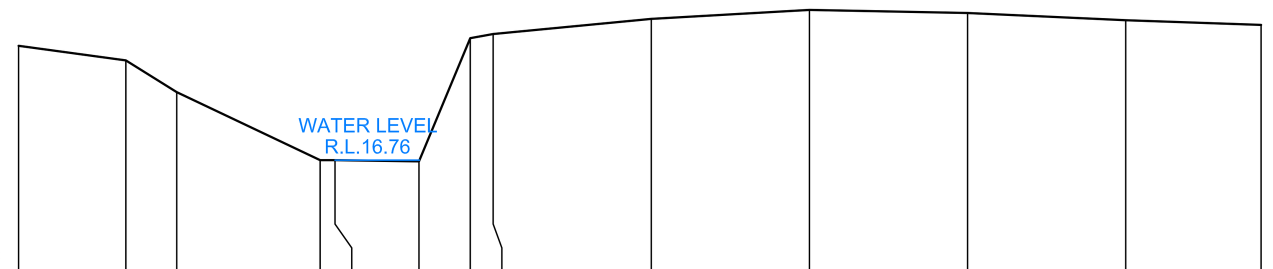
SECTION No.12
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



EXISTING LEVEL	18.445	18.158	16.24	16.248	16.384	16.626	17.565	18.698
CHAINAGE	0	2.215	3.555	6.783	8.095	8.441	19.823	23.458

SECTION No.20
SCALE 1:200 HORIZONTAL
1:100 VERTICAL

ORIGIN OF CO-ORDINATES :-	S.S.M.101371 - R.L.19.445
EASTING :-	302045.760
NORTHING :-	6187444.927



EXISTING LEVEL	18.567	18.338	17.836	16.761	16.76	16.741	18.689	18.755	18.994	19.135	19.086	18.972	18.898
CHAINAGE	0	3.388	5	9.532	10	12.655	14.278	15	20	25	30	35	39.278

SECTION No.16
SCALE 1:200 HORIZONTAL
1:100 VERTICAL

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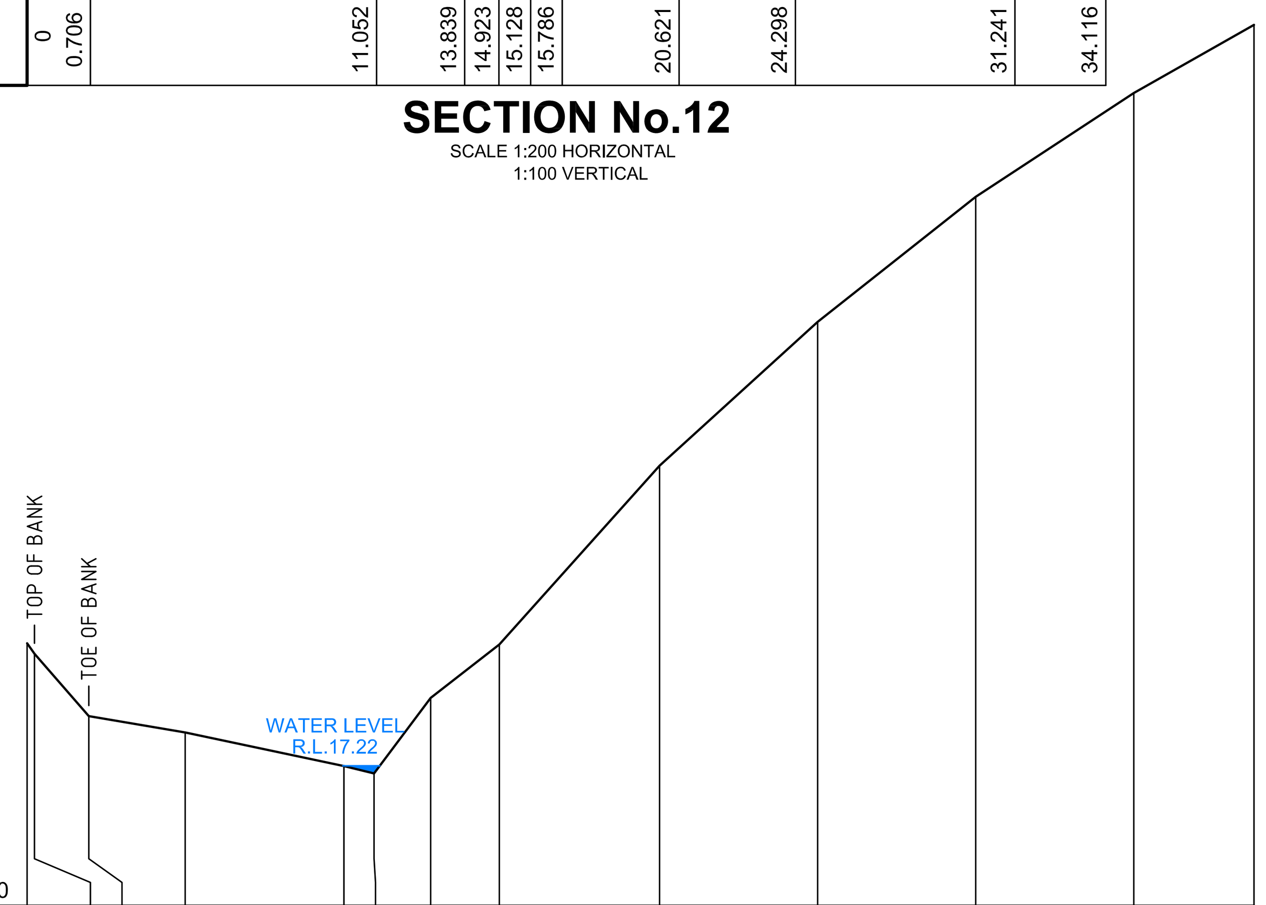
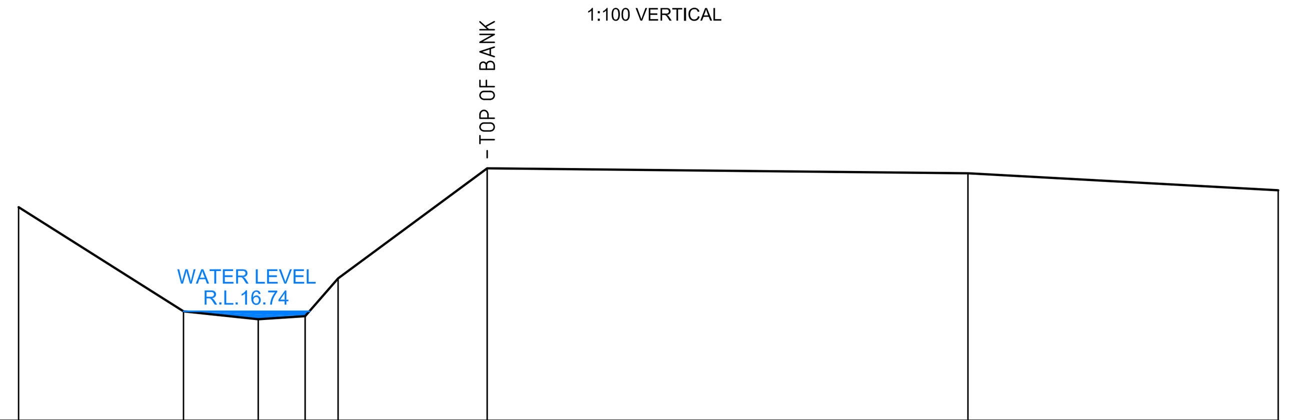


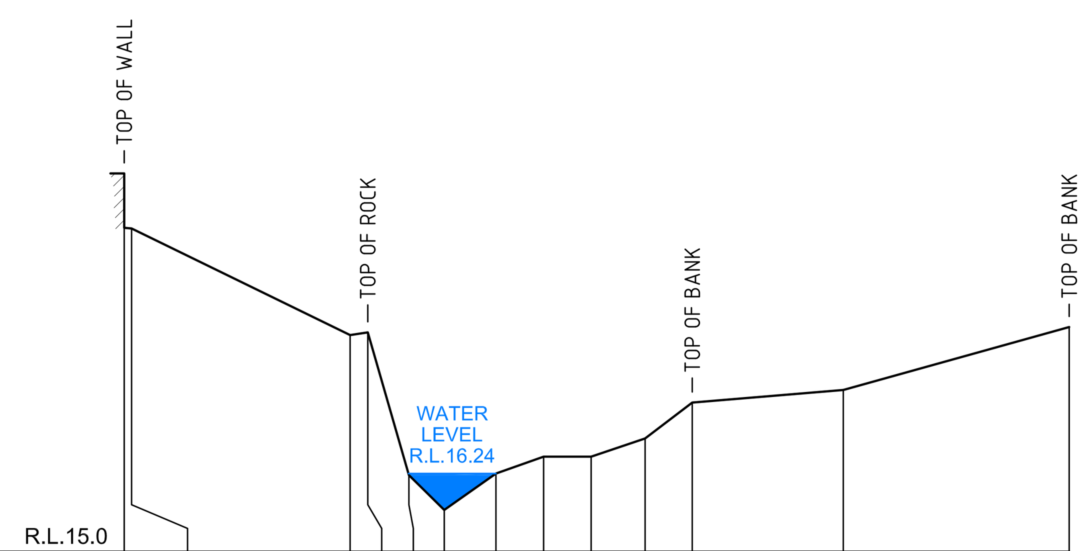
EXISTING LEVEL	19.155	18.99	18.004	17.747	17.216	17.098	18.293	19.137	21.962	24.235	26.213	27.853	28.931
CHAINAGE	0	0.233	1.949	5	10.018	10.972	12.76	14.934	20	25	30	35	38.801

SECTION No.13
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



EXISTING LEVEL	18.384	16.736	16.611	16.66	17.258	18.997	18.919	18.65
CHAINAGE	0	5.208	7.572	9.055	10.095	14.805	30	39.805

SECTION No.17
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



EXISTING LEVEL	20.987	20.117	18.433	18.475	16.218	15.668	16.244	16.51	16.51	16.798	17.365	17.565	18.56
CHAINAGE	0	0.231	7.14	7.699	9	10.115	11.753	13.26	14.761	16.466	17.957	22.731	29.876

SECTION No.21
SCALE 1:200 HORIZONTAL
1:100 VERTICAL

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Revision	Amendment or reason for issue	Issue date	Drawn by	Authorised

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Surveyor: M.B./G.L.	Date: 30/08/2013	Drawing Title: SURVEY FOR FLOOD STUDY BRANDY & WATER CREEK - FIGTREE CROSS-SECTION DETAILS SECTION 10 TO 21	Project No.: KF111252
Date of Survey: AUGUST 2013	Drawn: Z. DUKLESKI		Drawing No.: SV06
Height Datum: AHD	Designed		
Origin: S.S.M.101371 R.L.19.445	Checked: C.S.J.		Sheet: 6 Of 7 / Revision
Horiz. Datum: M.G.A.	Approved	Scale: AS SHOWN @ A1, AS SHOWN x 2 @ A3 / Drawing Status	

FILENAME: X:\KF111252\Survey\Drawings\KF111252-SV01-SV07.dwg
PLOTTED BY: zdukleski

DO NOT SCALE

ORIGIN OF CO-ORDINATES :-	S.S.M.101371 - R.L.19.445
EASTING :-	302045.760
NORTHING :-	6187444.927

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CAUTION

1. THIS DETAIL SURVEY IS NOT A "SURVEY" AS DEFINED BY THE SURVEYING ACT, 2002. IF ANY CONSTRUCTION AND/OR BUILDING LOCATION/ AREA COMPUTATIONS ARE PLANNED, IT WOULD BE ADVISABLE TO CARRY OUT FURTHER SURVEY WORK TO DETERMINE THE BOUNDARY DIMENSIONS.

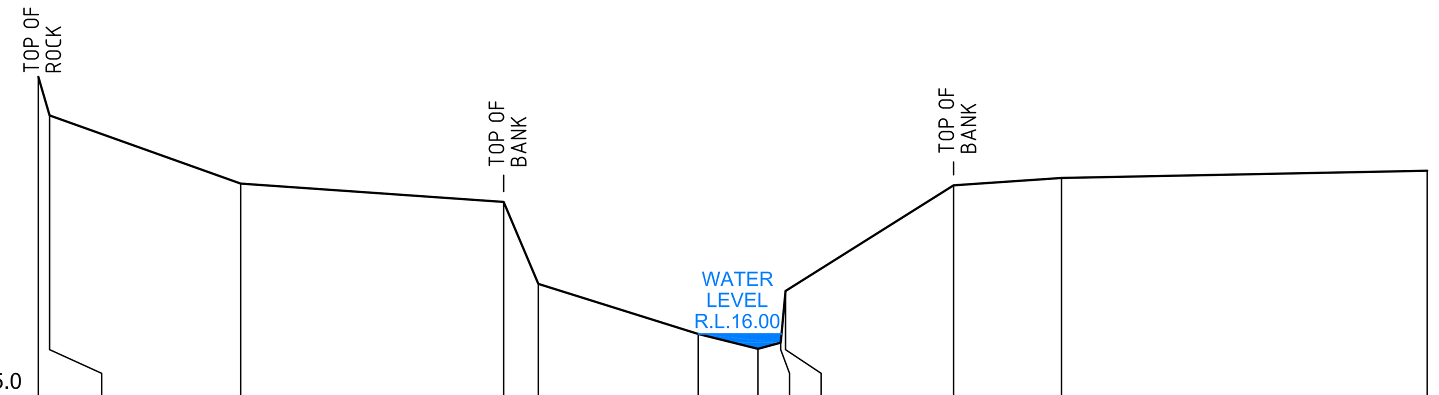
2. CADASTRAL BOUNDARIES HAVE NOT BEEN SURVEYED. THEIR LOCATION IS APPROXIMATE ONLY & SHOULD BE VERIFIED BY A SUBSEQUENT SURVEY PRIOR TO THE COMMENCEMENT OF ANY CONSTRUCTION

3. RELATIONSHIP OF IMPROVEMENTS TO BOUNDARIES IS DIAGRAMMATIC ONLY.

4. WHERE OFFSETS ARE CRITICAL, THEY SHOULD BE CONFIRMED BY FURTHER SURVEY.

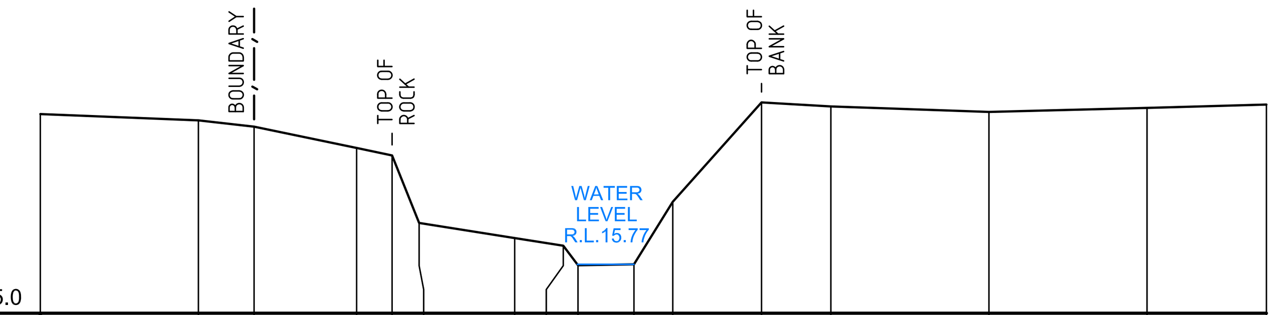
5. CONTOURS ARE INTERPOLATED FROM ACCURATE SPOT LEVELS AS SHOWN AND SHOULD BE USED AS A GUIDE ONLY. DO NOT REINTERPOLATE CONTOURS.

6. THE POSITION OR EXISTENCE OF UNDERGROUND SERVICES HAS NOT BEEN SURVEYED. FULL DETAILS OF THESE SERVICES SHOULD BE OBTAINED FROM THE RELEVANT AUTHORITIES PRIOR TO ANY CONSTRUCTION.



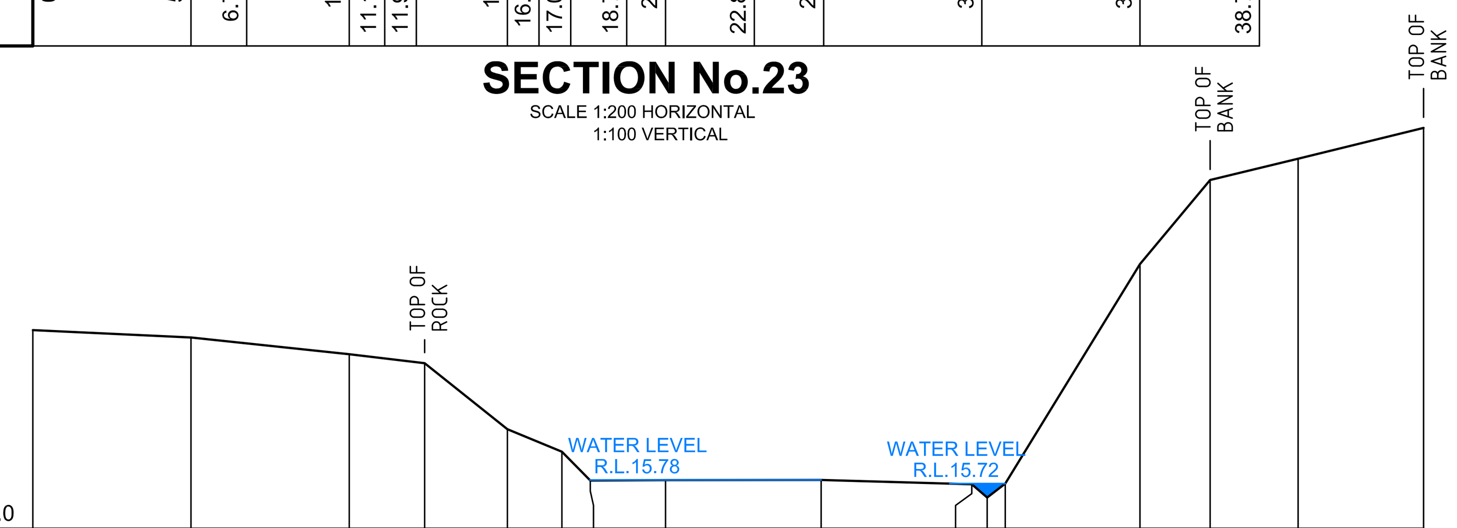
EXISTING LEVEL	20.063	19.453	18.374	18.084	16.789	15.998	15.763	15.861	16.678	18.348	18.463	18.579
CHAINAGE	0	0.353	6.394	14.71	15.807	20.86	22.747	23.47	23.622	28.932	32.346	43.909

SECTION No.22
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



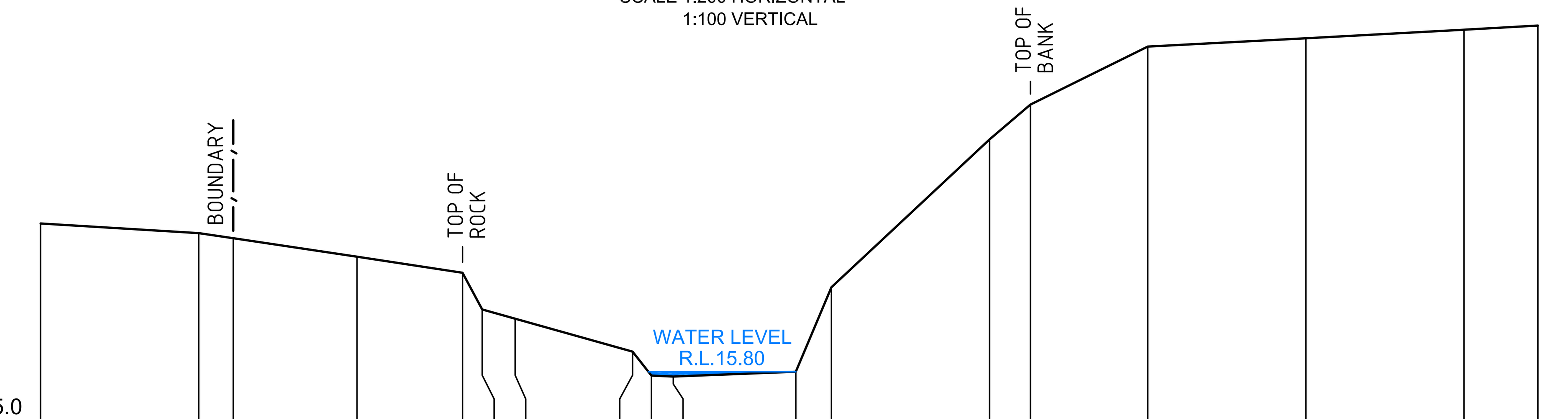
EXISTING LEVEL	18.147	18.047	17.948	17.612	17.493	16.426	16.186	16.066	15.758	15.771	16.76	18.33	18.268	18.18	18.244	18.297
CHAINAGE	0	5	6.76	10	11.123	11.979	15	16.54	17.002	18.773	20	22.809	25	30	35	38.778

SECTION No.23
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



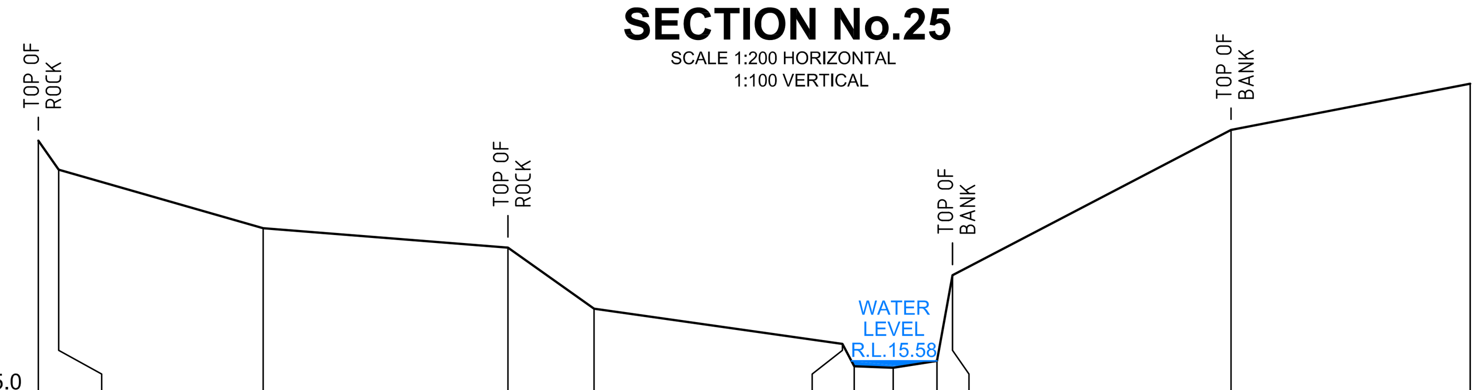
EXISTING LEVEL	18.147	18.029	17.766	17.623	16.581	16.224	15.77	15.775	15.778	15.71	15.5	15.72	19.189	20.519	20.855	21.343
CHAINAGE	0	5	10	12.384	15	16.724	17.623	20	24.921	29.683	30.172	30.743	35	37.219	40	43.967

SECTION No.24
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



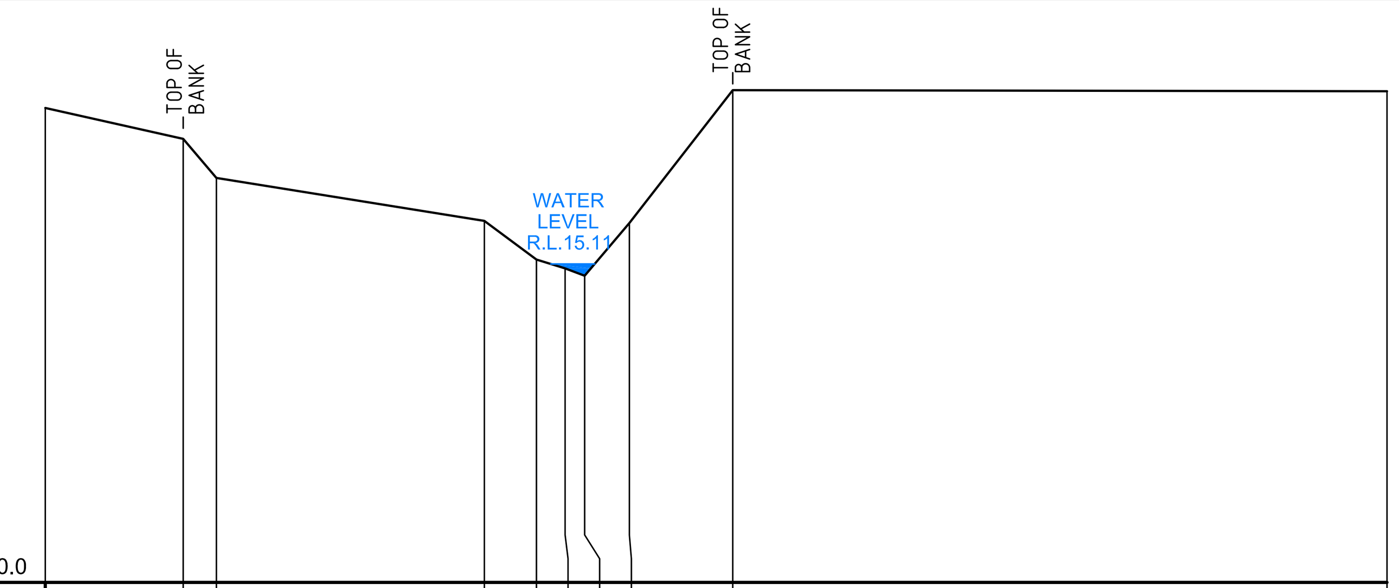
EXISTING LEVEL	18.147	17.995	17.915	17.622	17.368	16.788	16.642	16.123	15.743	15.728	15.804	17.141	19.478	20.028	20.944	21.076	21.21	21.276
CHAINAGE	0	5	6.091	10	13.338	13.962	15	18.713	19.31	20	23.875	25	30	31.29	35	40	45	47.338

SECTION No.25
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



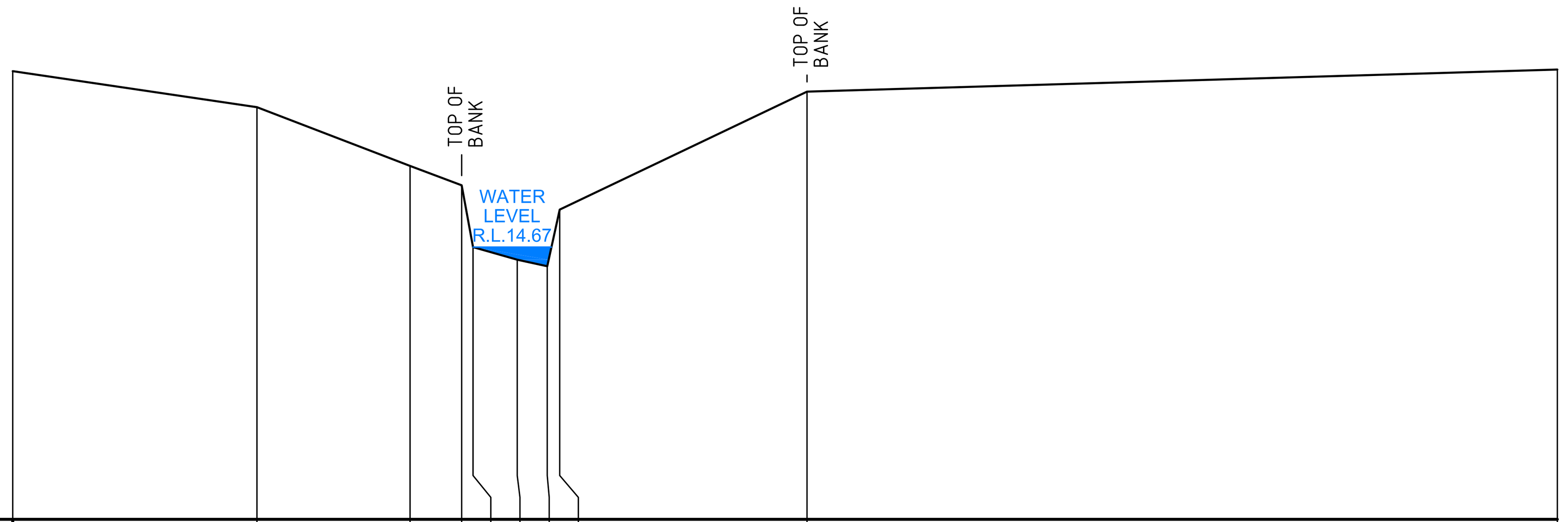
EXISTING LEVEL	19.065	18.605	17.68	17.373	16.409	15.852	15.498	15.474	15.582	16.938	19.234	19.964
CHAINAGE	0	0.641	7.107	14.847	17.567	25.42	25.794	27.024	28.41	28.902	37.707	45.268

SECTION No.26
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



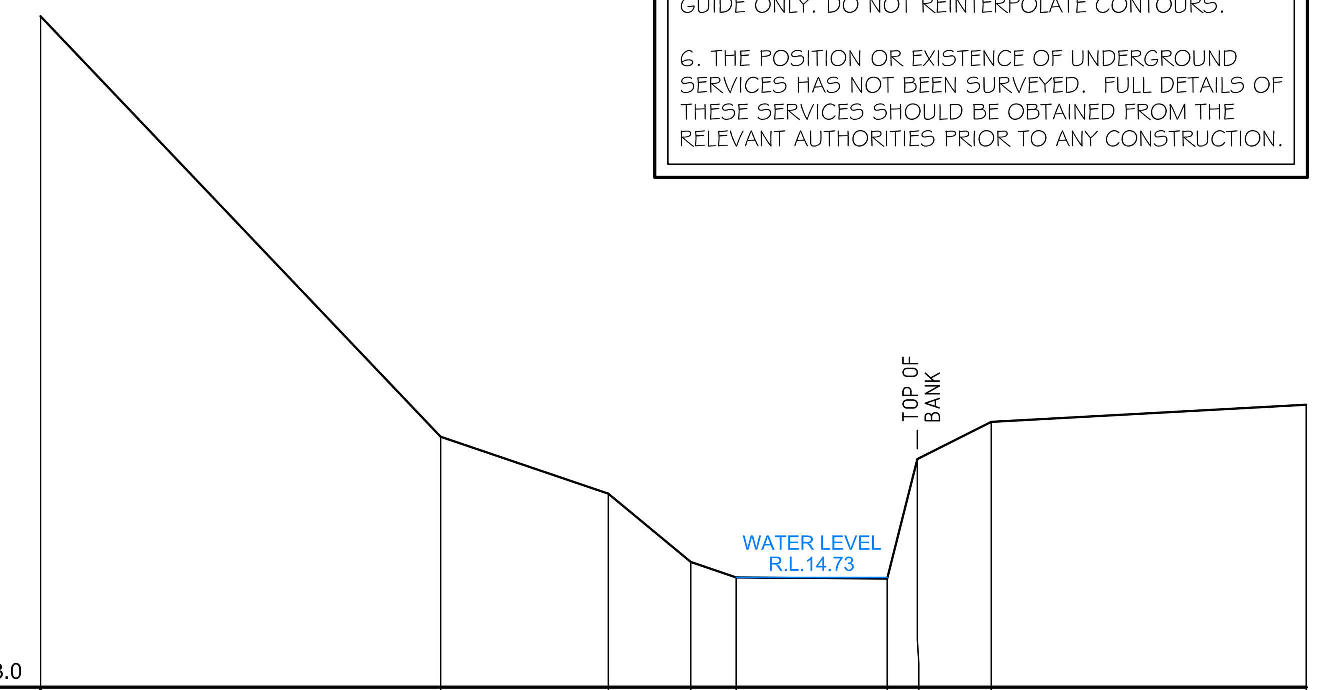
EXISTING LEVEL	17.504	17.016	16.398	15.718	15.107	14.968	14.85	15.685	17.787	17.77
CHAINAGE	0	4.359	5.409	13.879	15.526	16.43	17.051	18.465	21.732	42.415

SECTION No.27
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



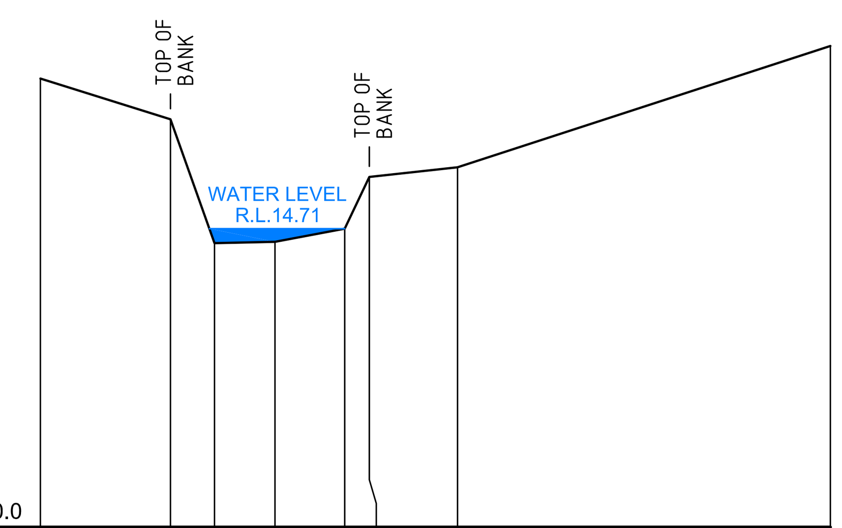
EXISTING LEVEL	17.686	17.069	16.061	15.729	14.669	14.452	14.341	15.311	17.336	17.714
CHAINAGE	0	8.375	13.624	15.393	15.784	17.299	18.327	18.754	27.236	52.961

SECTION No.28
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



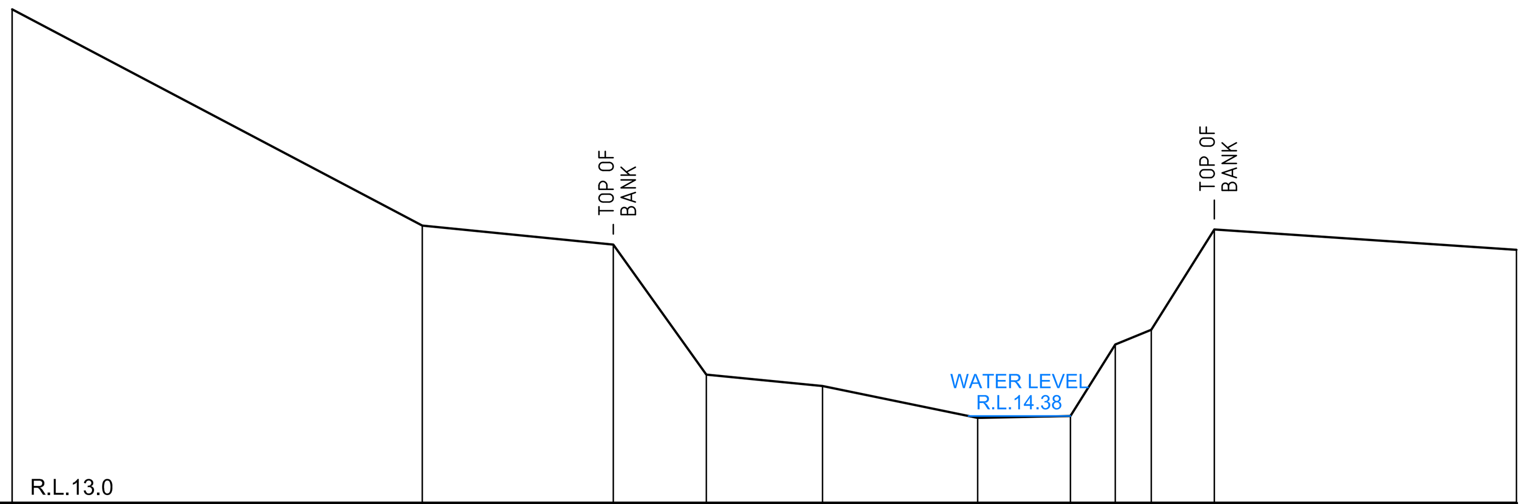
EXISTING LEVEL	23.604	16.959	16.058	14.98	14.733	14.716	16.604	17.193	17.465
CHAINAGE	0	12.653	17.95	20.559	21.993	26.769	27.724	30.06	40.014

SECTION No.31
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



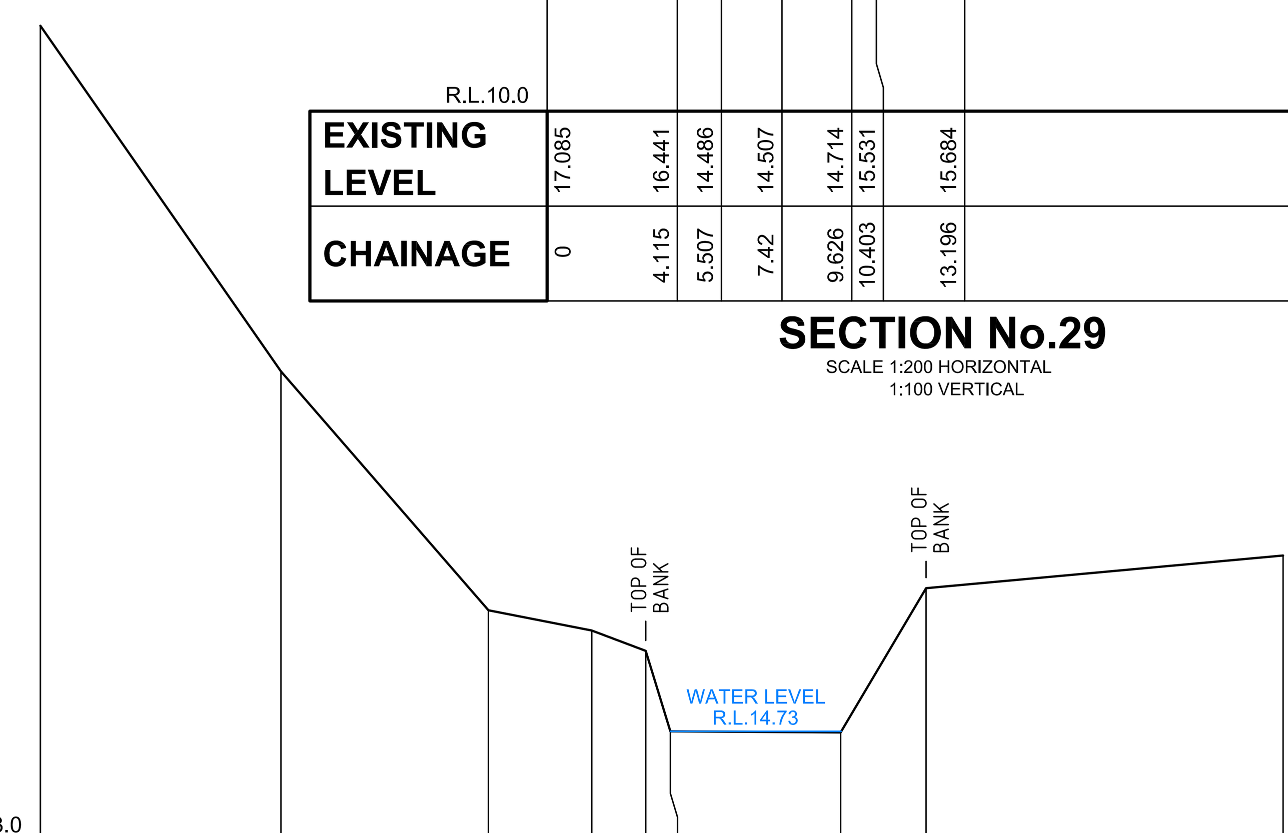
EXISTING LEVEL	17.085	16.441	14.486	14.507	14.714	15.531	15.684	17.599
CHAINAGE	0	4.115	5.507	7.42	9.626	10.403	13.196	24.987

SECTION No.29
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



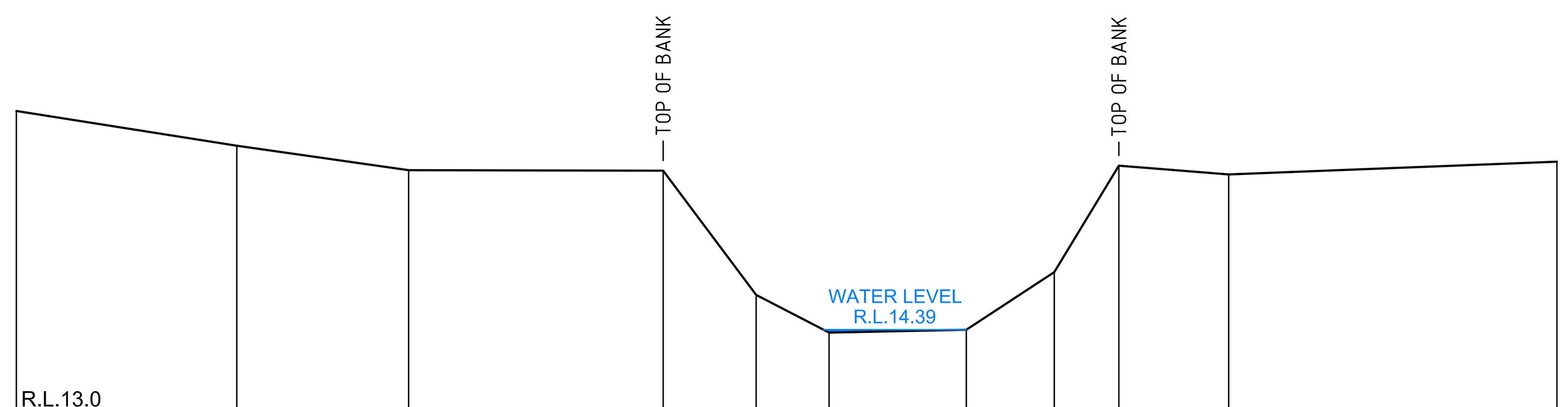
EXISTING LEVEL	20.805	17.388	17.088	15.032	14.852	14.348	14.378	15.508	15.74	17.326	17.004
CHAINAGE	0	12.975	19.015	21.957	25.632	30.538	33.47	34.889	36.027	38.023	47.575

SECTION No.32
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



EXISTING LEVEL	25.883	20.42	16.643	16.324	16.001	14.729	14.713	16.993	17.508
CHAINAGE	0	7.604	14.164	17.425	19.134	19.909	25.29	27.994	39.274

SECTION No.30
SCALE 1:200 HORIZONTAL
1:100 VERTICAL



EXISTING LEVEL	17.992	17.421	17.017	17.009	14.966	14.346	14.393	15.342	17.093	16.948	17.157
CHAINAGE	0	7.256	12.915	21.291	24.353	26.751	31.272	34.164	36.29	39.908	50.708

SECTION No.33
SCALE 1:200 HORIZONTAL

Revision	Amendment or reason for issue	Issue date	Drawn by	Authorised

KFW
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Surveyor: M.B./G.L.	Date: 30/08/2013
Date of Survey: AUGUST 2013	Drawn: Z. DUKLESKI
Height Datum: AHD	Designed
Origin: S.S.M.101371 R.L.19.445	Checked: C.S.J.
Horiz. Datum: M.G.A.	Approved

Drawing Title
SURVEY FOR FLOOD STUDY
BRANDY & WATER CREEK - FIGTREE
CROSS-SECTION DETAILS
SECTION 22 TO 33

Scale: AS SHOWN @ A1, AS SHOWN x 2 @ A3
Drawing Status

Project No. KF111252
Drawing No. SV07
Sheet 7 Of 7
Revision

FILENAME: X:\KF11252\Survey\Drawings\KF11252-SV01-SV07.dwg
PLOTTED BY: zdukleski

Brandy & Water Creek-Investigation
& Design of Creek Modification

APPENDIX D
COST ESTIMATE OF OPTIONS

Cardno
Shaping the Future

NA499-13-135 Brandy Creek Rehabilitation

Scenario 1

Excavate floodplain (1m depth) and remove sedementation

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Allowance for working in creek	1	item		
1.4	Construction setout & survey	1	item		
1.5	Work as executed survey & documentation	1	item		
1.6	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 20% of works cost)				**59,000**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of vegatated areas	6,330	sq. m	10	63,300
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	950	cu. m	25	23,750
2.3	Dispose of excess topsoil (nominal 10% allowance)	95	cu. m	60	5,700
2.4	Removal of large trees	30	item	450	13,500
	SUBTOTAL				**106,250**
3.0	**EARTHWORKS**				
3.1	Excavation of floodplain (1m deep) & sedimentation in creek	4650	cu.m	25	116,250
	SUBTOTAL				**116,250**
4.0	**BANK WORKS**				
4.1	Extend existing rock wall to base of excavation	50	sq. face m	250	12,500
	SUBTOTAL				**12,500**
5.0	**LANDSCAPING**				
5.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	6,330	sq. m	25	158,250
	SUBTOTAL				**158,250**
	CONSTRUCTION SUB-TOTAL				**452,250**
8.0	**CONTINGENCIES**				
8.1	25% construction cost				**113,063**
	CONSTRUCTION TOTAL, excluding GST				**565,313**
	GST				**56,531**
	CONSTRUCTION TOTAL, including GST				**621,844**
	CONSTRUCTION TOTAL, rounded				**621,900**

DISCLAIMER:

1. This estimate of cost is provided in good faith using information available at this stage. This estimate of cost is not guaranteed. Cardno (NSW) will not accept liability in the event that actual costs exceed the estimate.

NOTES:

1. Estimate does not include Consultant's fees, including design or project management
2. Estimate / rates in 2010 dollars and does not allow for inflation

NA499-13-135 Brandy Creek Rehabilitation

Scenario 2

Construct secondary channel and remove sedementation

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Allowance for working in creek	1	item		
1.4	Construction setout & survey	1	item		
1.5	Work as executed survey & documentation	1	item		
1.6	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 20% of works cost)				**24,500**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of vegatated areas	780	sq. m	10	7,800
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	120	cu. m	25	3,000
2.3	Dispose of excess topsoil (nominal 10% allowance)	12	cu. m	60	720
2.4	Removal of large trees	7	item	450	3,150
	SUBTOTAL				**14,670**
3.0	**EARTHWORKS**				
3.1	Excavation of channel & sedimentation in creek	1850	cu.m	25	46,250
	SUBTOTAL				**46,250**
4.0	**BANK WORKS**				
4.1	Extend existing rock wall to base of excavation	50	sq. face m	250	12,500
4.2	Rock lining of secondary channel (incl. provsion and laying of geotextile)	440	sq. m	160	70,400
	SUBTOTAL				**82,900**
5.0	**LANDSCAPING**				
5.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	780	sq. m	25	19,500
	SUBTOTAL				**19,500**
	CONSTRUCTION SUB-TOTAL				**187,820**
8.0	**CONTINGENCIES**				
8.1	25% construction cost				**46,955**
	CONSTRUCTION TOTAL, excluding GST				**234,775**
	GST				**23,478**
	CONSTRUCTION TOTAL, including GST				**258,253**
	CONSTRUCTION TOTAL, rounded				**258,300**

DISCLAIMER:

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Cardno (NSW) will not accept liability in the event that actual costs exceed the estimate.

NOTES:

1. Estimate does not include Consultant's fees, including design or project management

2. Estimate / rates in 2010 dollars and does not allow for inflation

NA499-13-135 Brandy Creek Rehabilitation

Scenario 3

Construct secondary channel, excavate bank and remove sedementation

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Allowance for working in creek	1	item		
1.4	Construction setout & survey	1	item		
1.5	Work as executed survey & documentation	1	item		
1.6	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 20% of works cost)				**37,900**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of vegatated areas	1,020	sq. m	10	10,200
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	160	cu. m	25	4,000
2.3	Dispose of excess topsoil (nominal 10% allowance)	16	cu. m	60	960
2.4	Removal of large trees	12	item	450	5,400
	SUBTOTAL				**20,560**
3.0	**EARTHWORKS**				
3.1	Excavation of channel & sedimentation in creek	2100	cu.m	25	52,500
	SUBTOTAL				**52,500**
4.0	**BANK WORKS**				
4.1	Extend existing rock wall to base of excavation	50	sq. face m	250	12,500
4.2	Rock lining of secondary channel (incl. provsion and laying of geotextile)	440	sq. m	160	70,400
4.3	Trim bank and construct rock retaining wall	130	sq. face m	550	71,500
	SUBTOTAL				**154,400**
5.0	**LANDSCAPING**				
5.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	1,020	sq. m	25	25,500
	SUBTOTAL				**25,500**
	CONSTRUCTION SUB-TOTAL				**290,860**
8.0	**CONTINGENCIES**				
8.1	25% construction cost				**72,715**
	CONSTRUCTION TOTAL, excluding GST				**363,575**
	GST				**36,358**
	CONSTRUCTION TOTAL, including GST				**399,933**
	CONSTRUCTION TOTAL, rounded				**400,000**

DISCLAIMER:

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NOTES:

1. Estimate does not include Consultant's fees, including design or project management

2. Estimate / rates in 2010 dollars and does not allow for inflation

Brandy & Water Creek-Investigation & Design of Creek Modification

FIGURES

Figure 1-1 Study Area

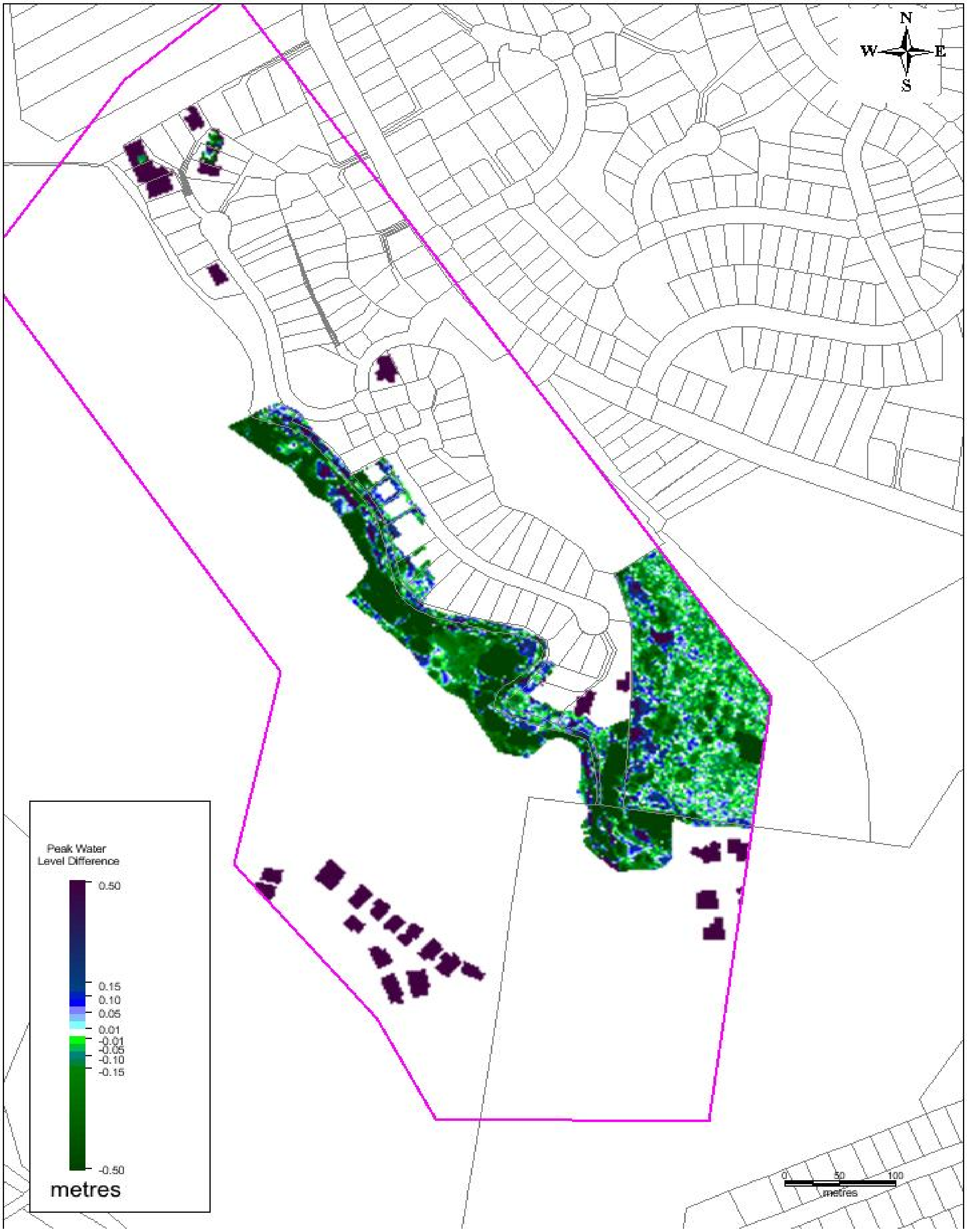

Figure 3-1 Terrain Differences – Current Existing Less Previous Existing

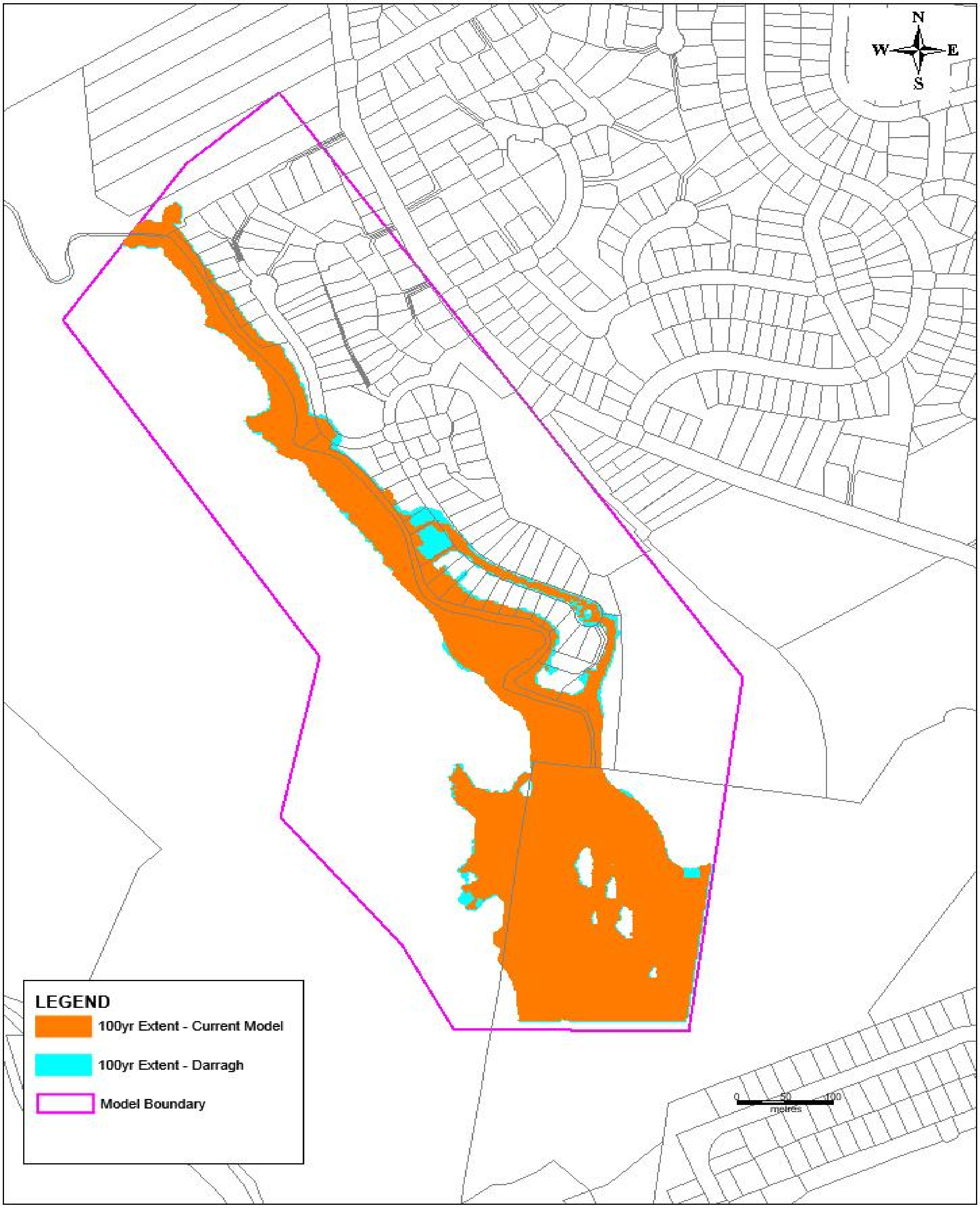

Figure 3-2 Flood Extents – 1% AEP

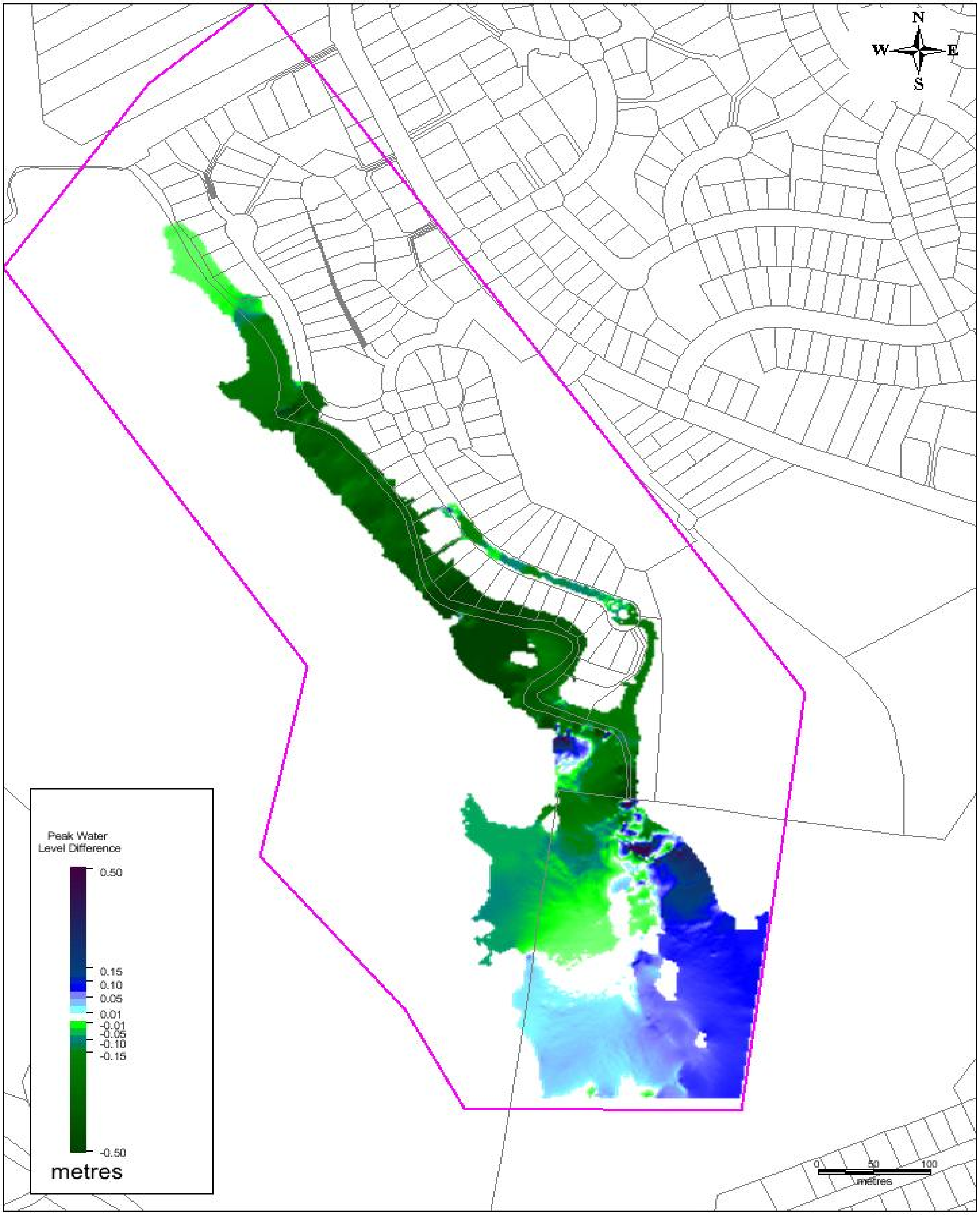

Figure 3-3 Water Level Differences – 1% AEP, 2 Hours Current Existing Less Previous Existing

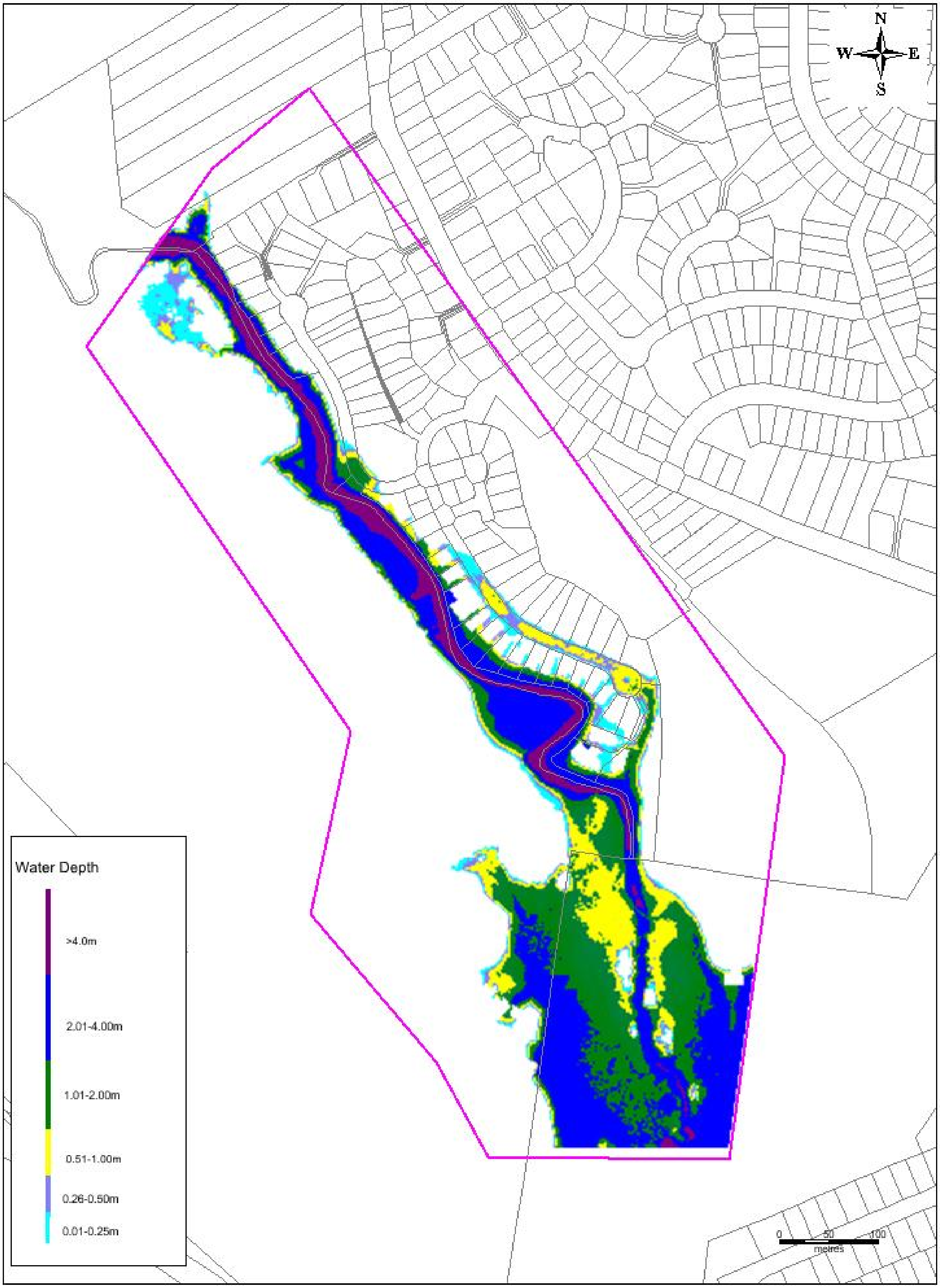

Figure 3-4 Water Depths – PMF, Current Existing Case

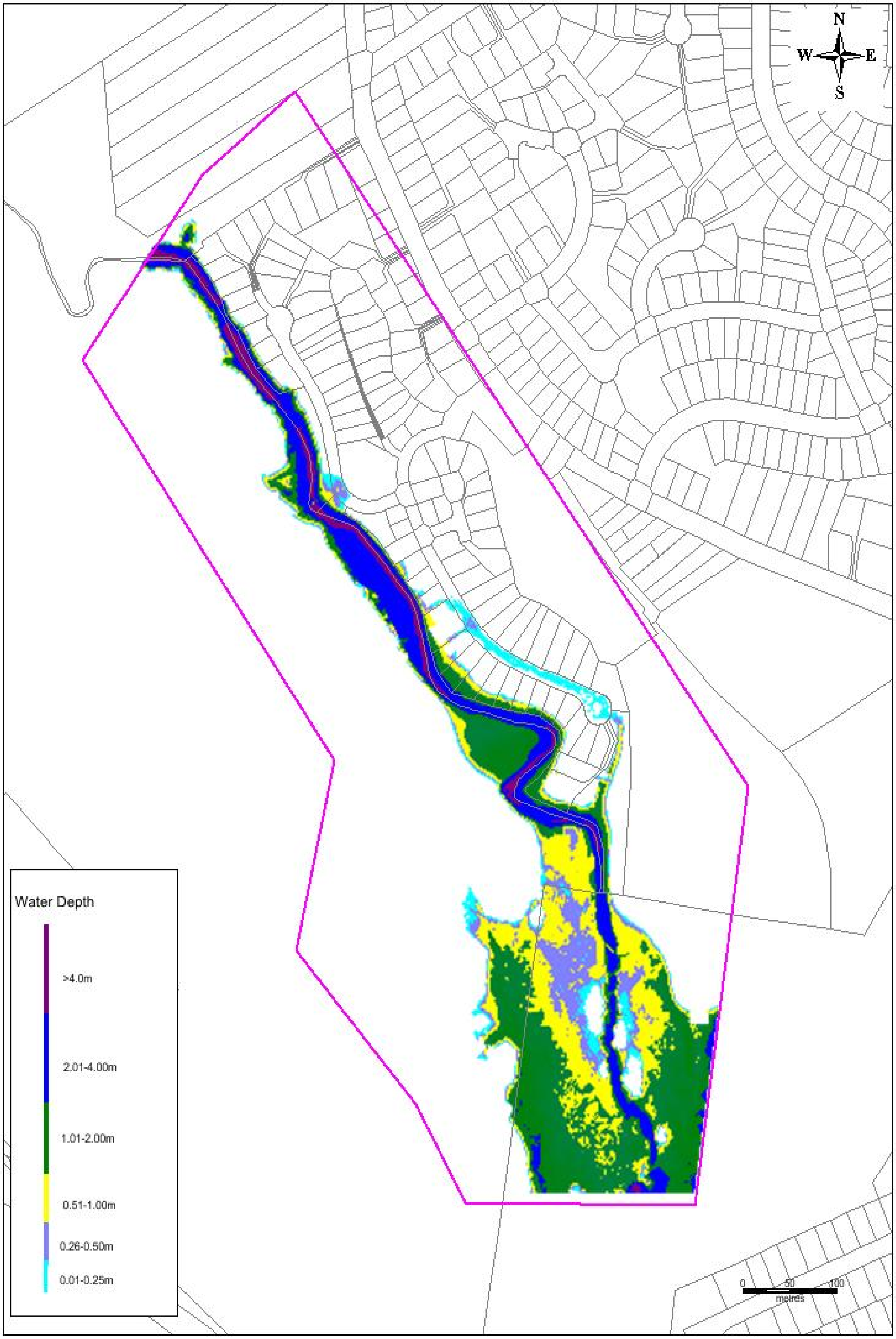

Figure 3-5 Water Depths – 1% AEP, Current Existing Case

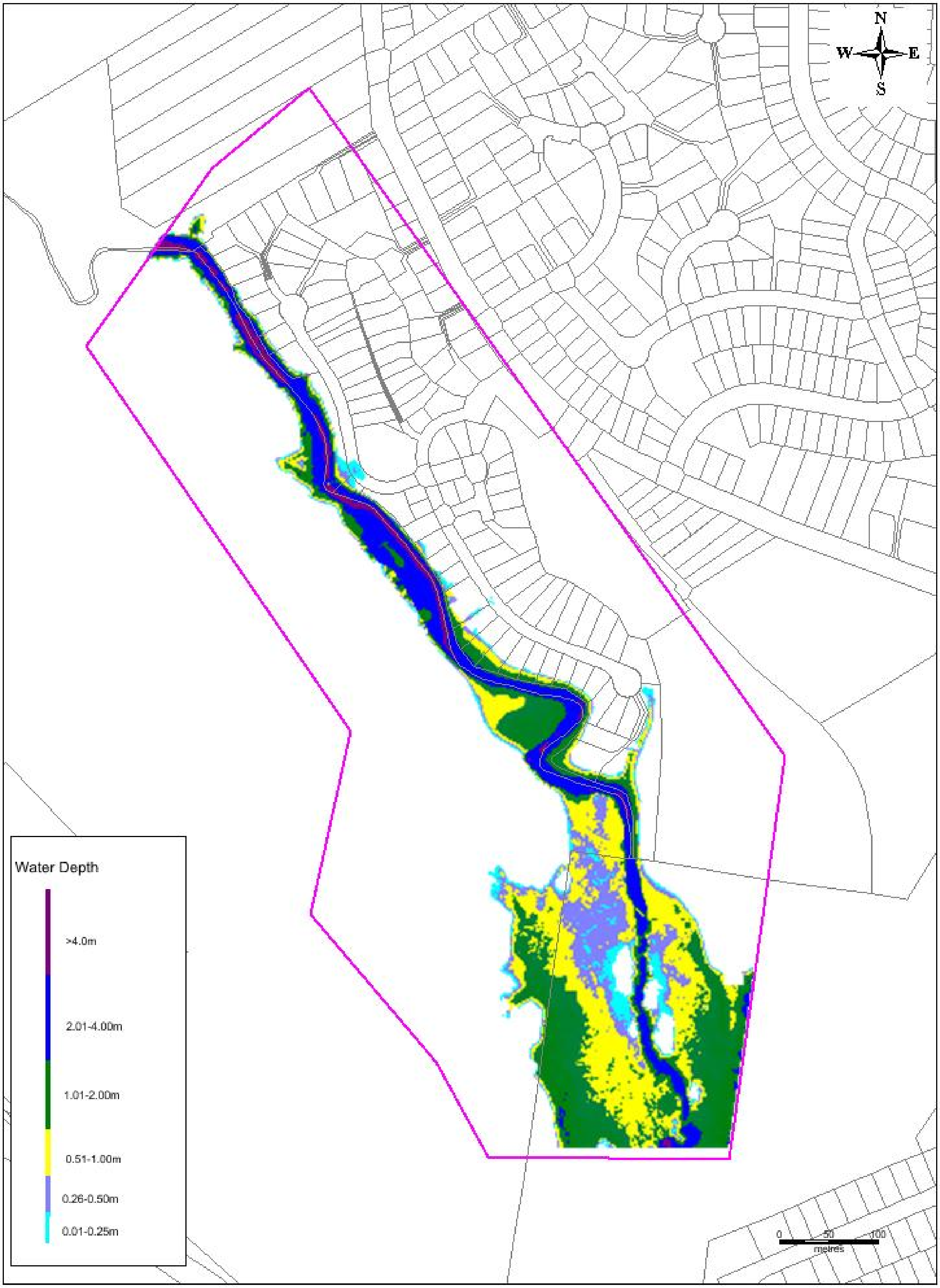

Figure 3-6 Water Depths – 2% AEP, Current Existing Case

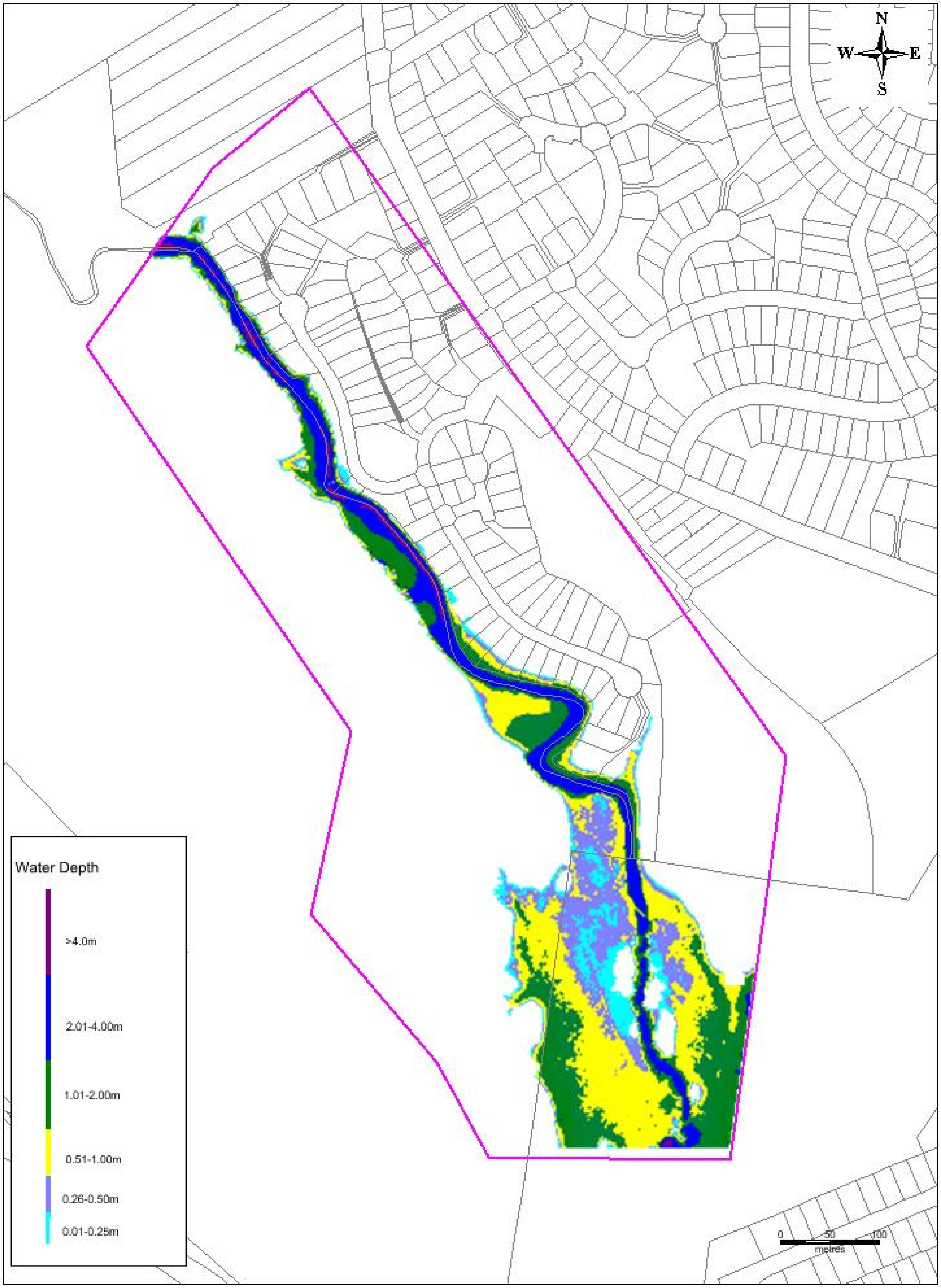

Figure 3-7 Water Depths – 5% AEP, Current Existing Case

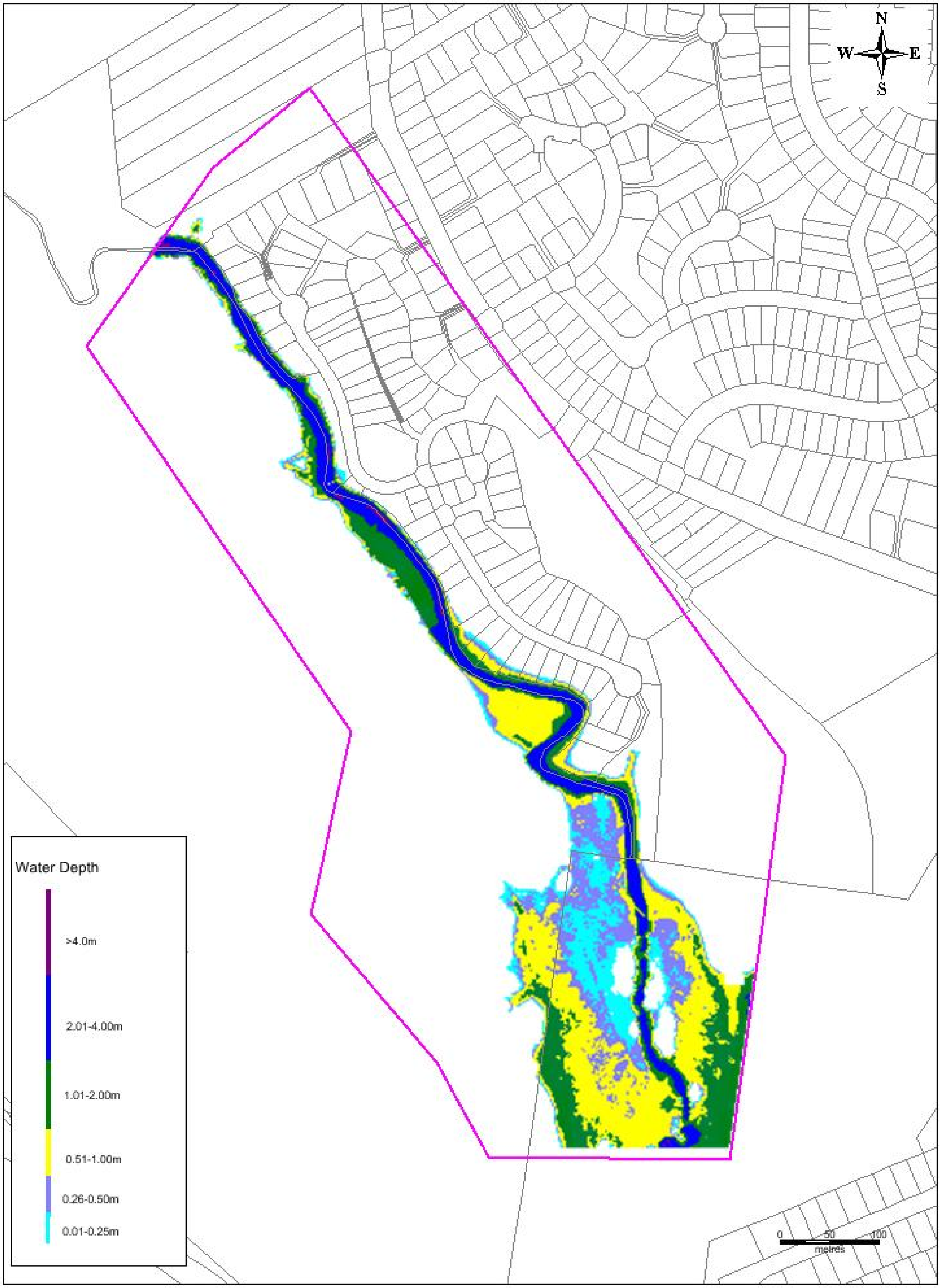

Figure 3-8 Water Depths – 10% AEP, Current Existing Case

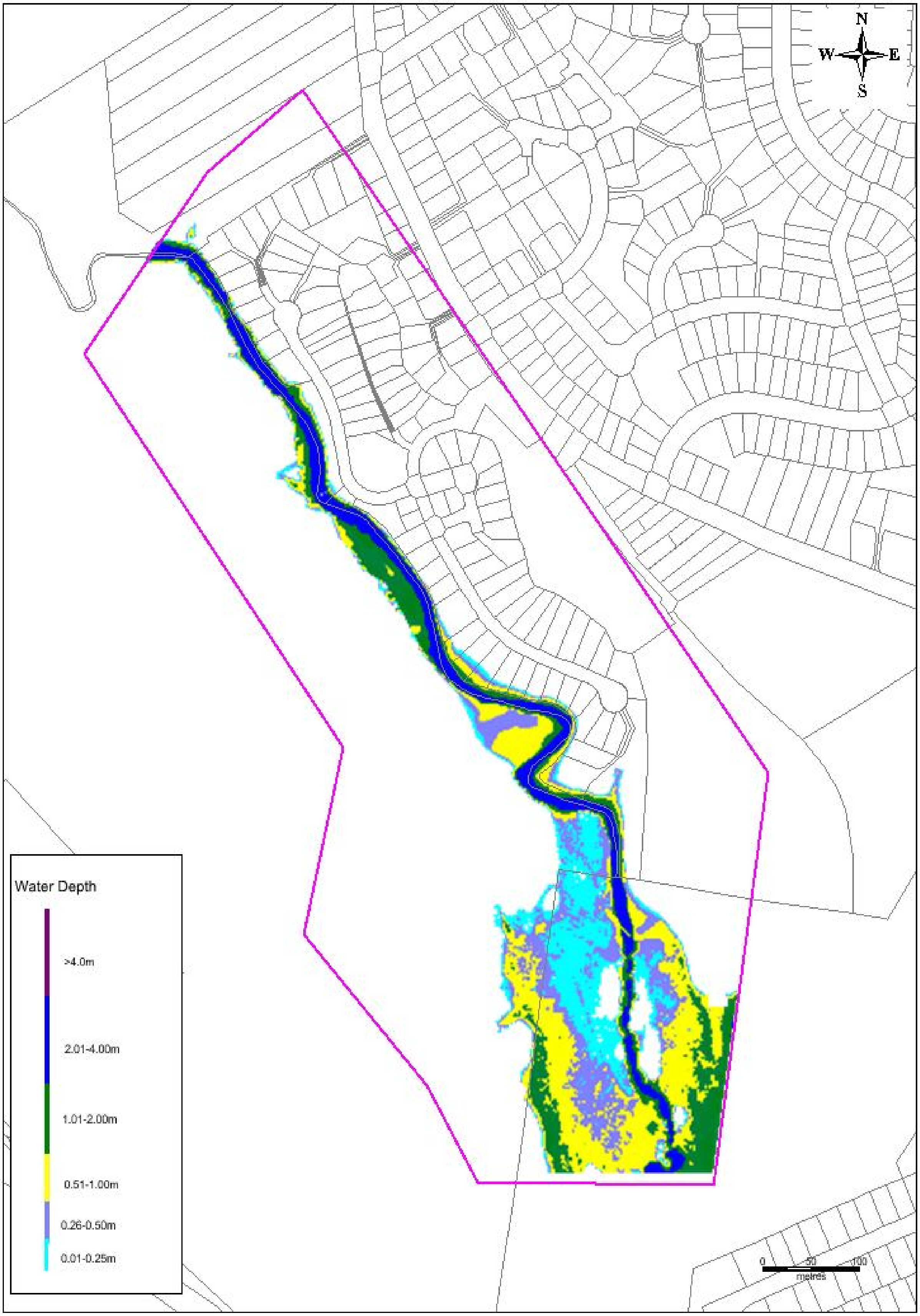

Figure 3-9 Water Depths – 20% AEP, Current Existing Case

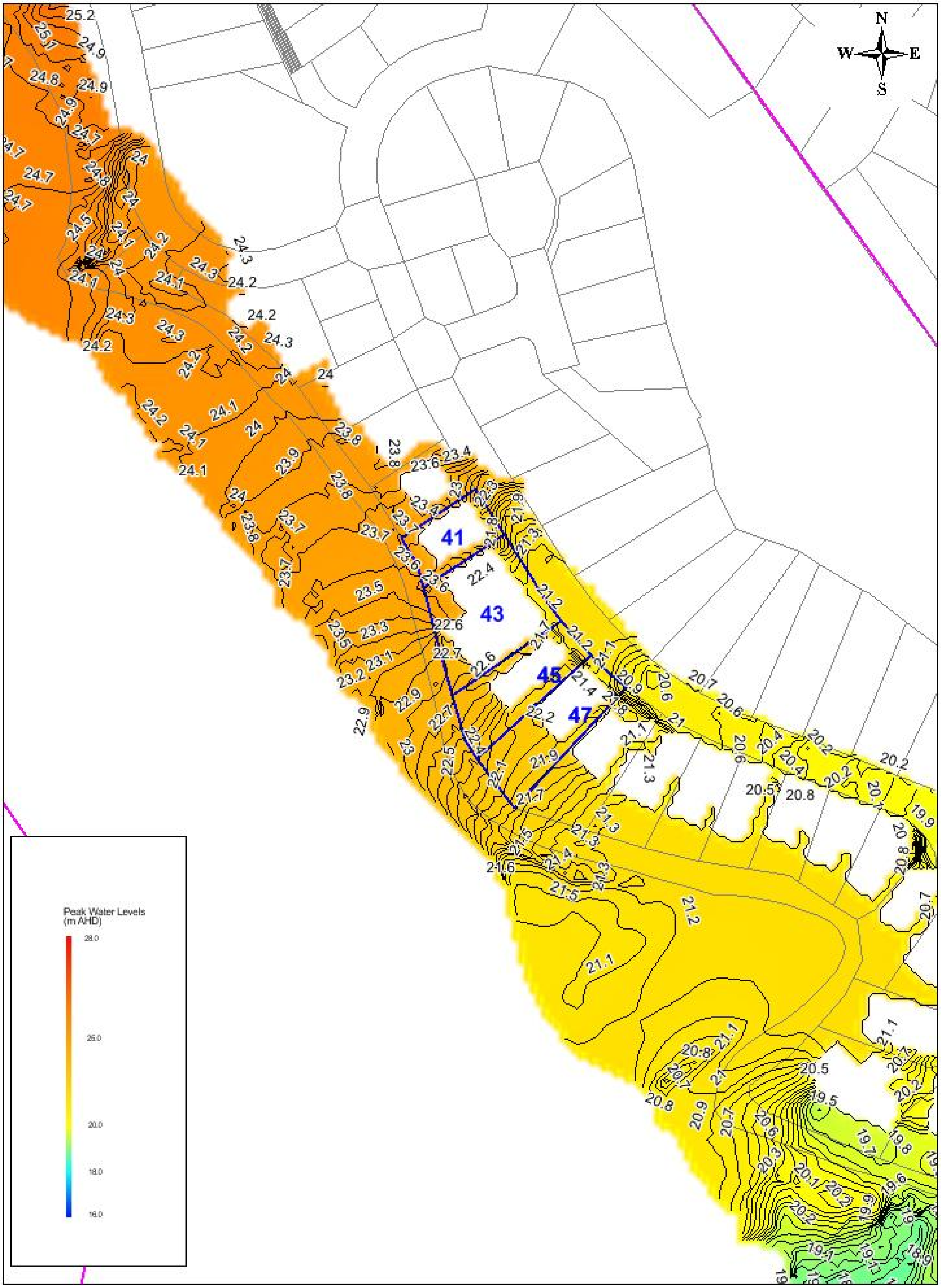

Figure 3-10 Peak Water Levels – PMF, Current Existing Case

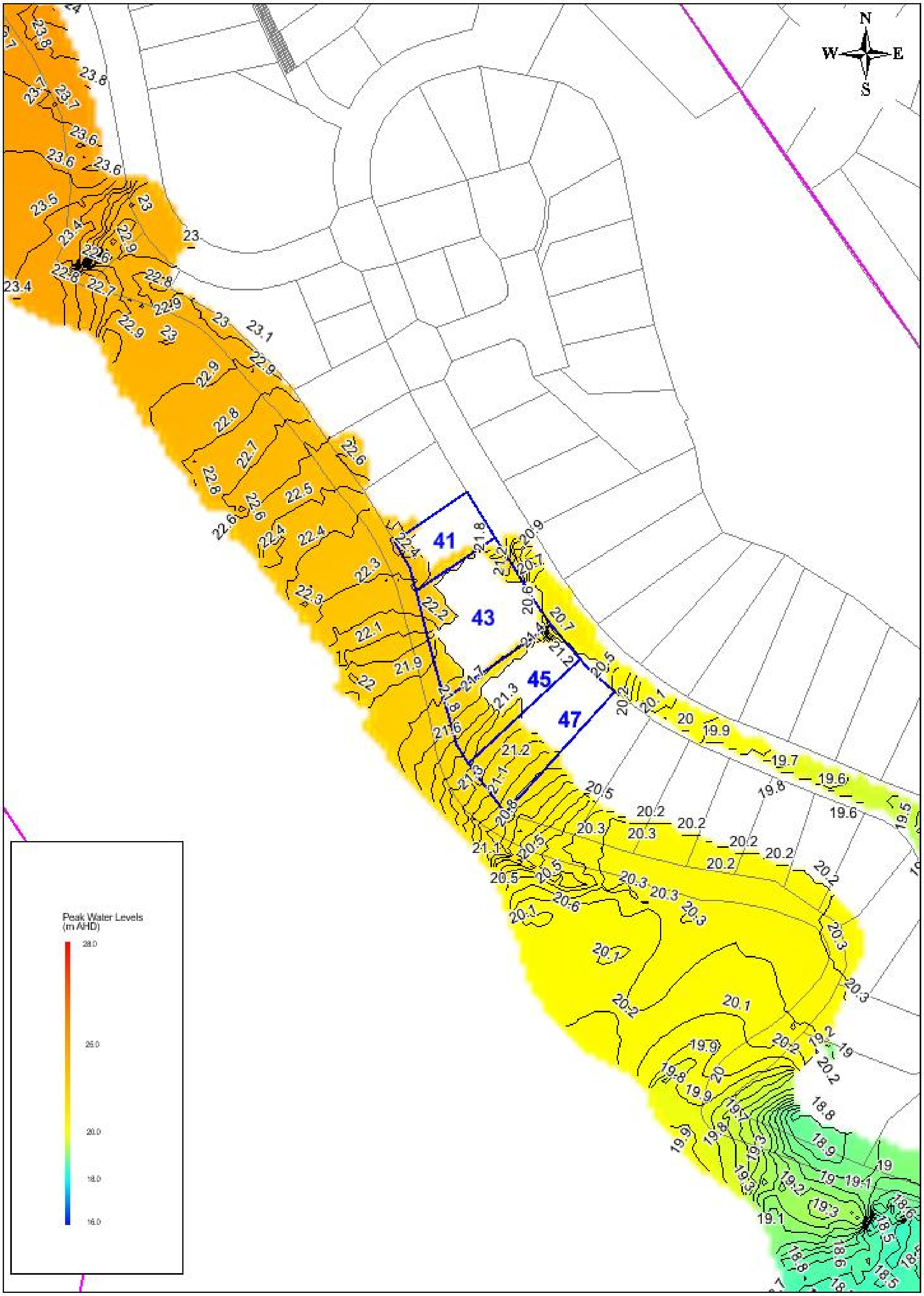

Figure 3-11 Peak Water Levels – 1% AEP, Current Existing Case

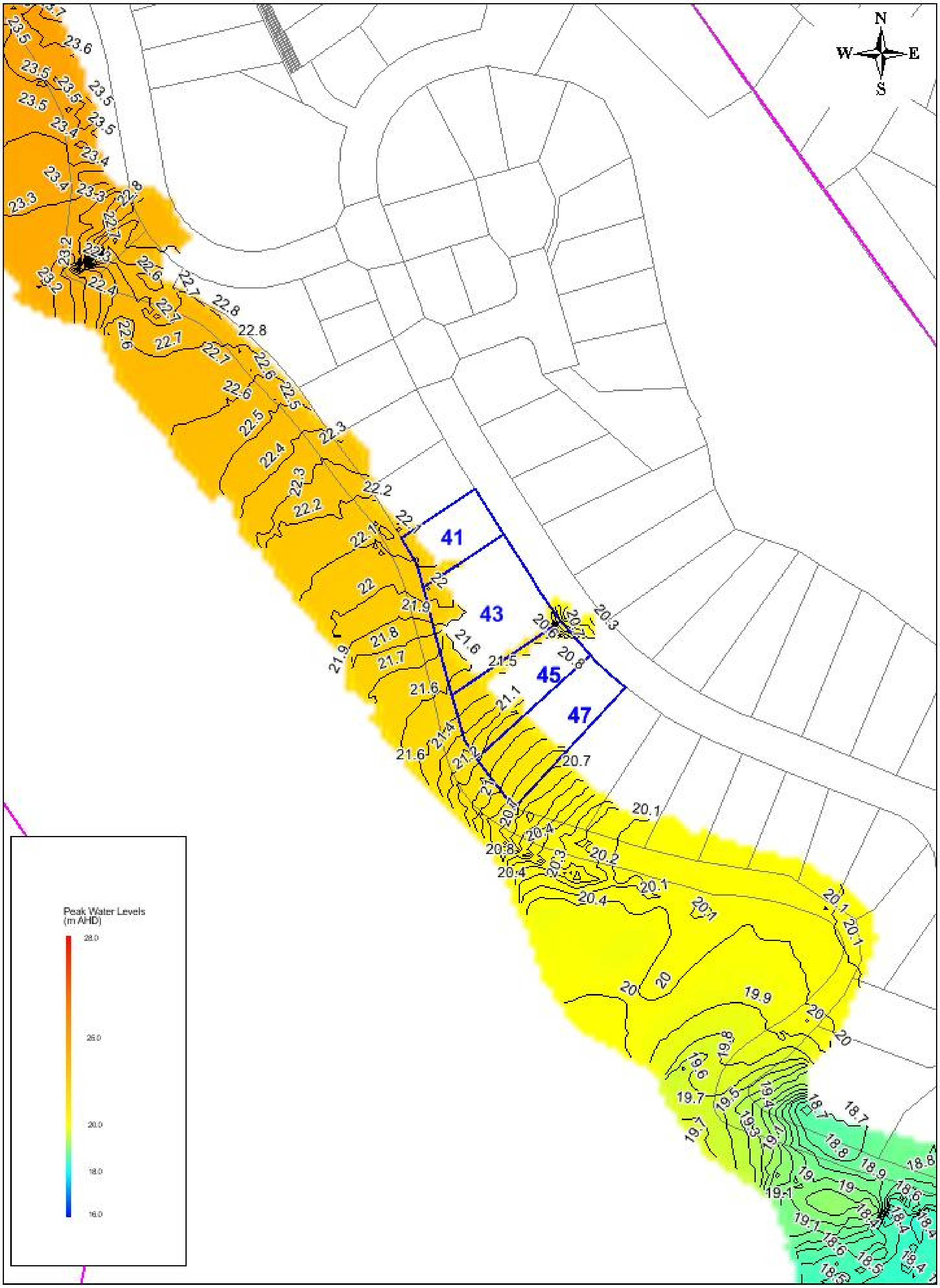

Figure 3-12 Peak Water Levels – 2% AEP, Current Existing Case

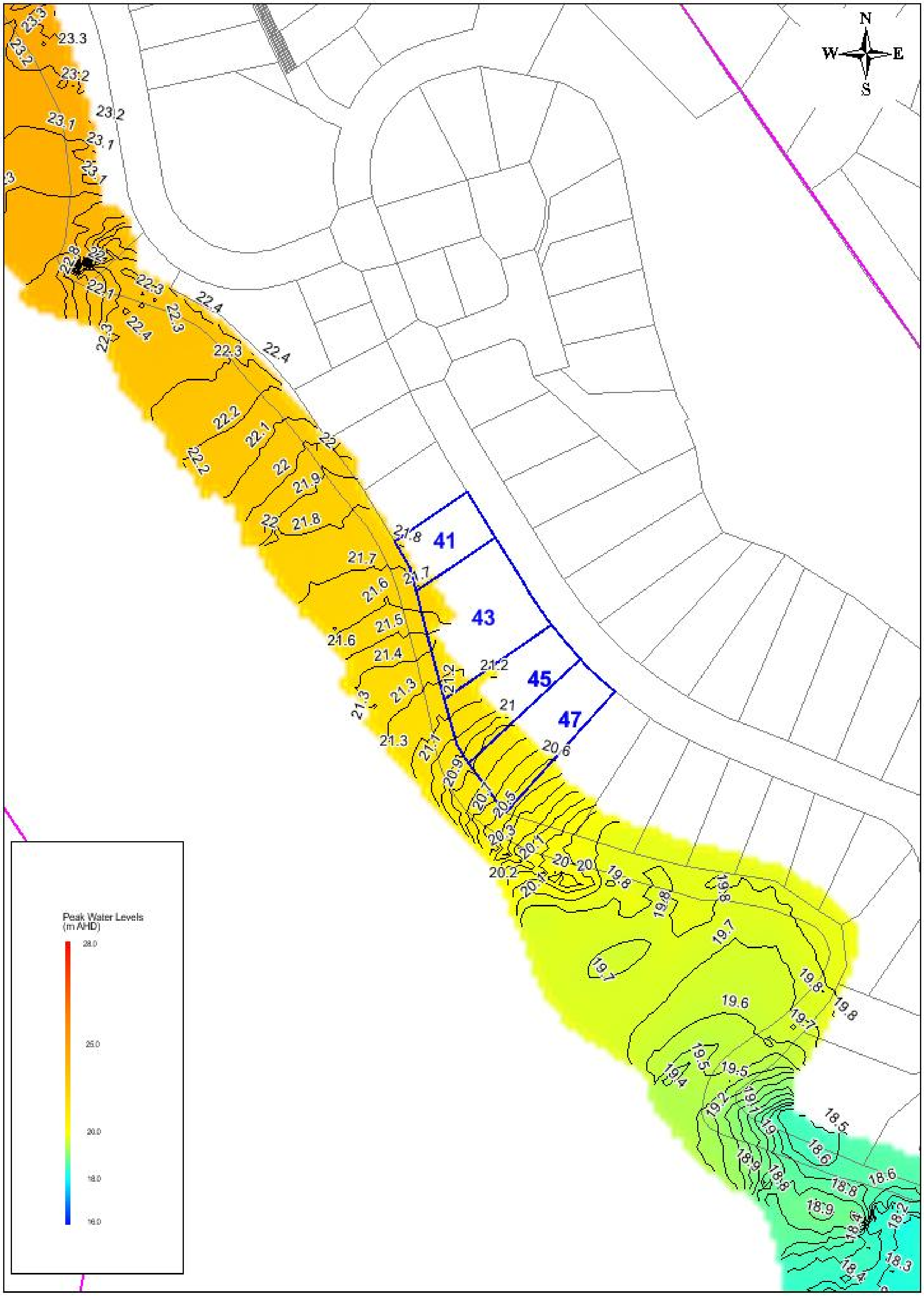

Figure 3-13 Peak Water Levels – 5% AEP, Current Existing Case

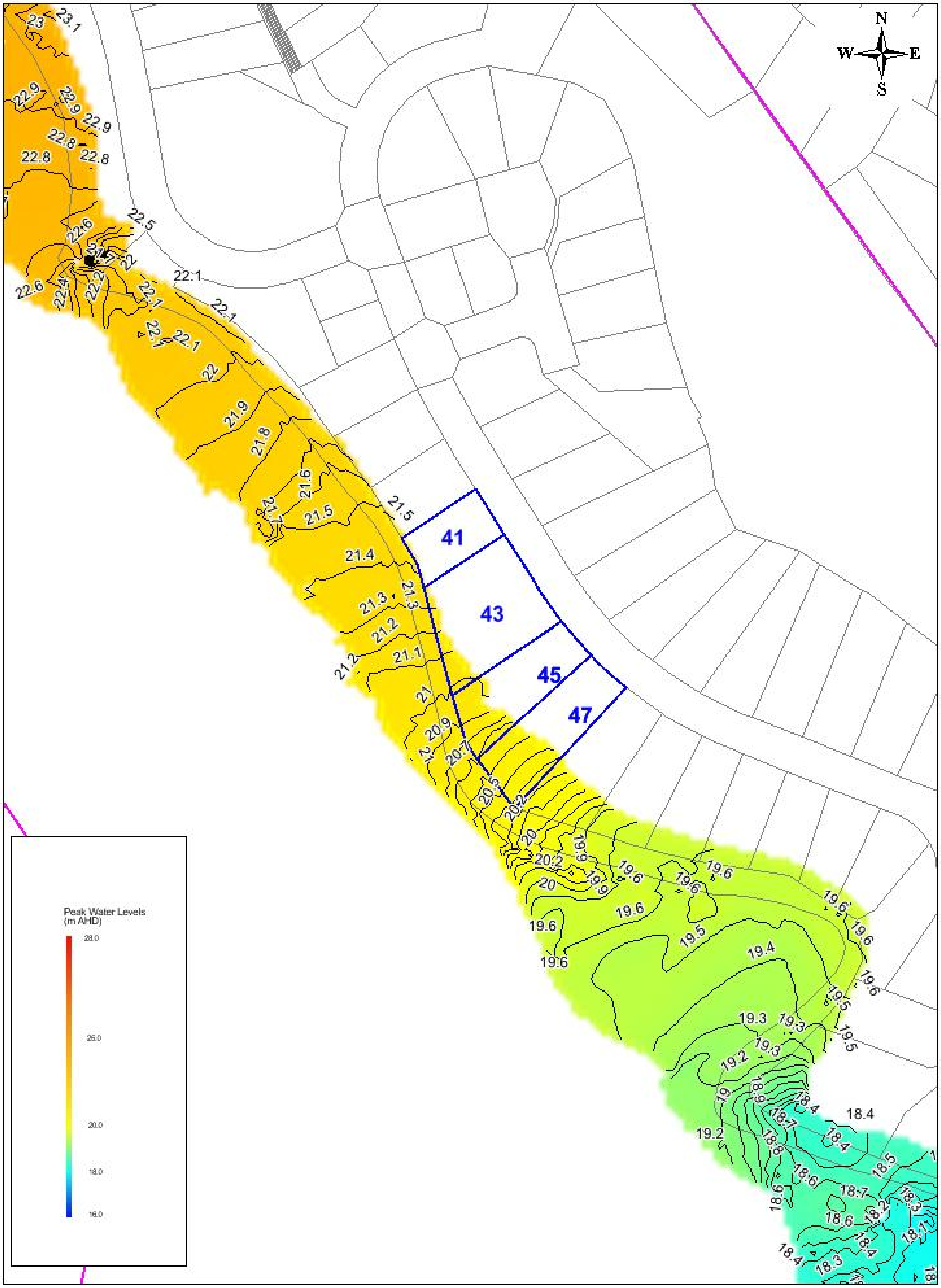

Figure 3-14 Peak Water Levels – 10% AEP, Current Existing Case

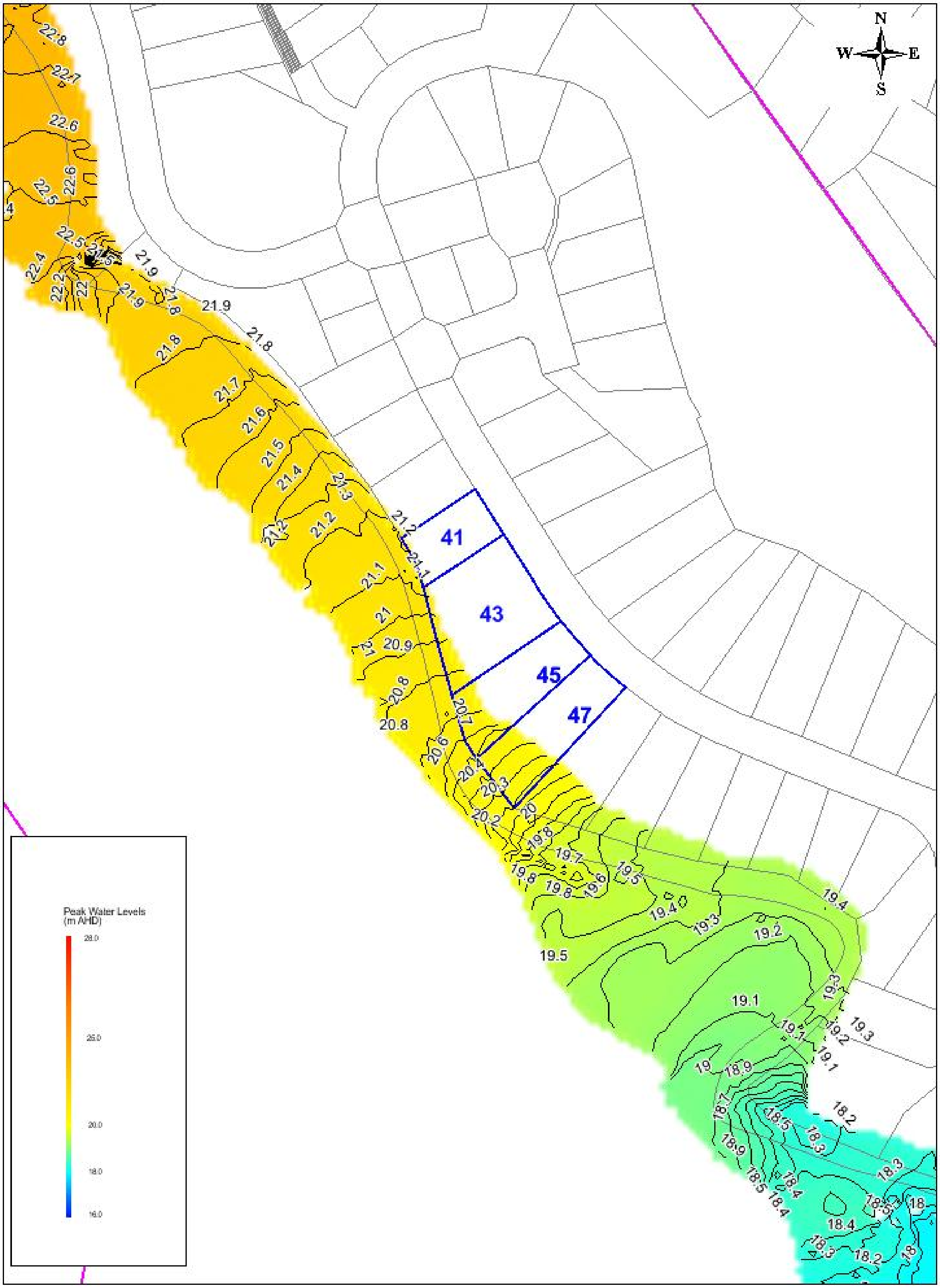

Figure 3-15 Peak Water Levels – 20% AEP, Current Existing Case

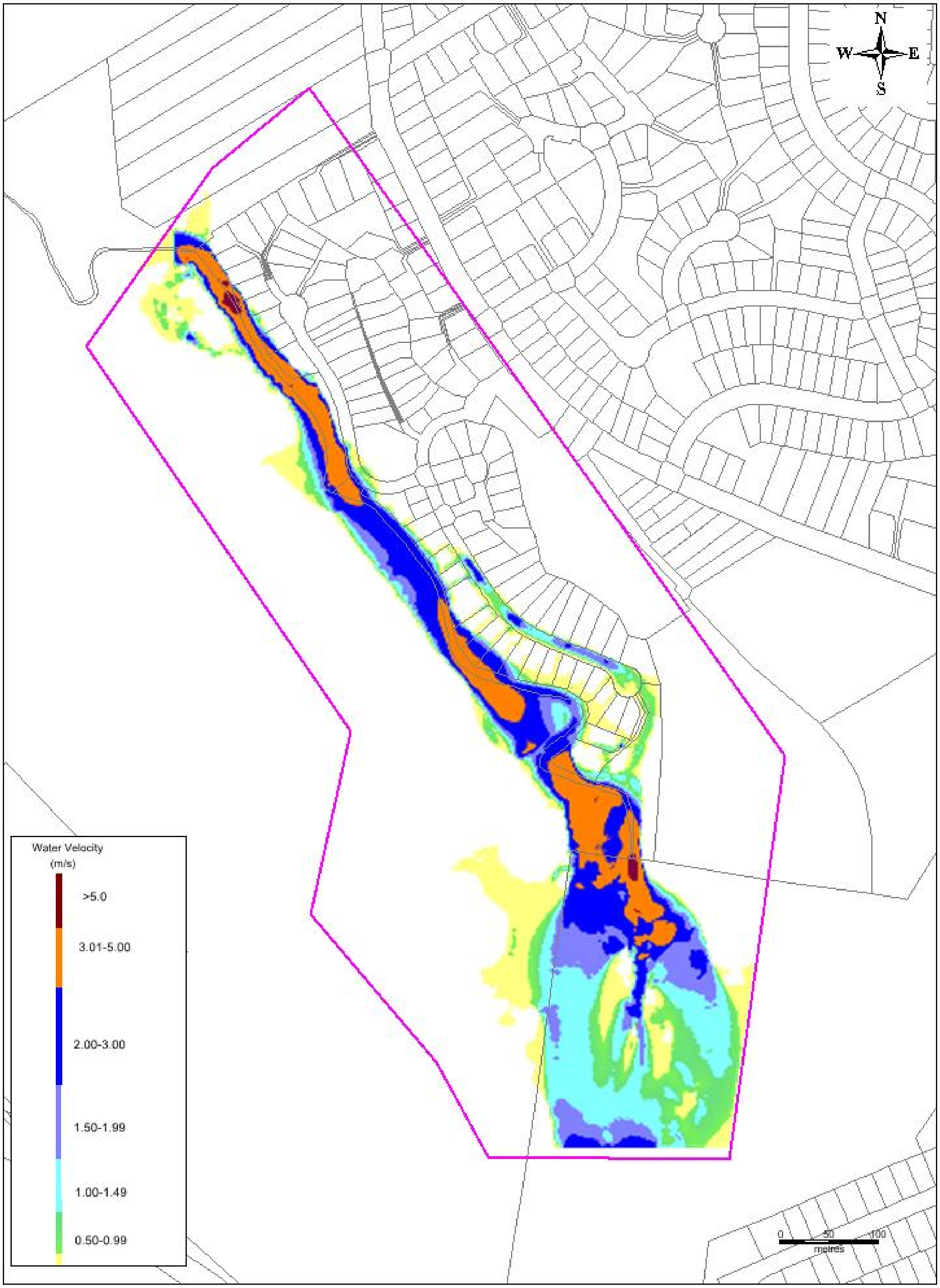

Figure 3-16 Water Velocities – PMF, Current Existing Case

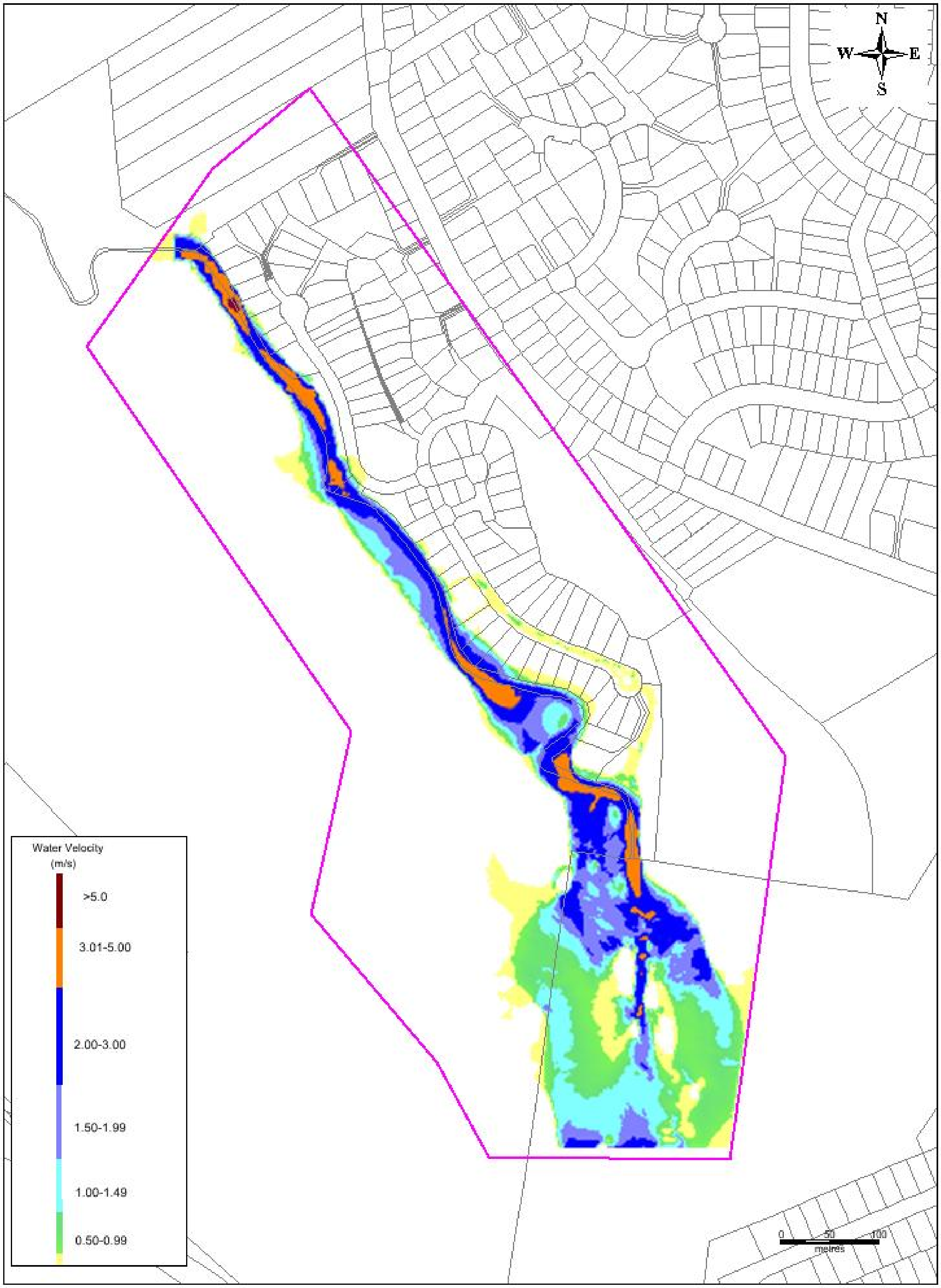

Figure 3-17 Water Velocities – 1% AEP, Current Existing Case

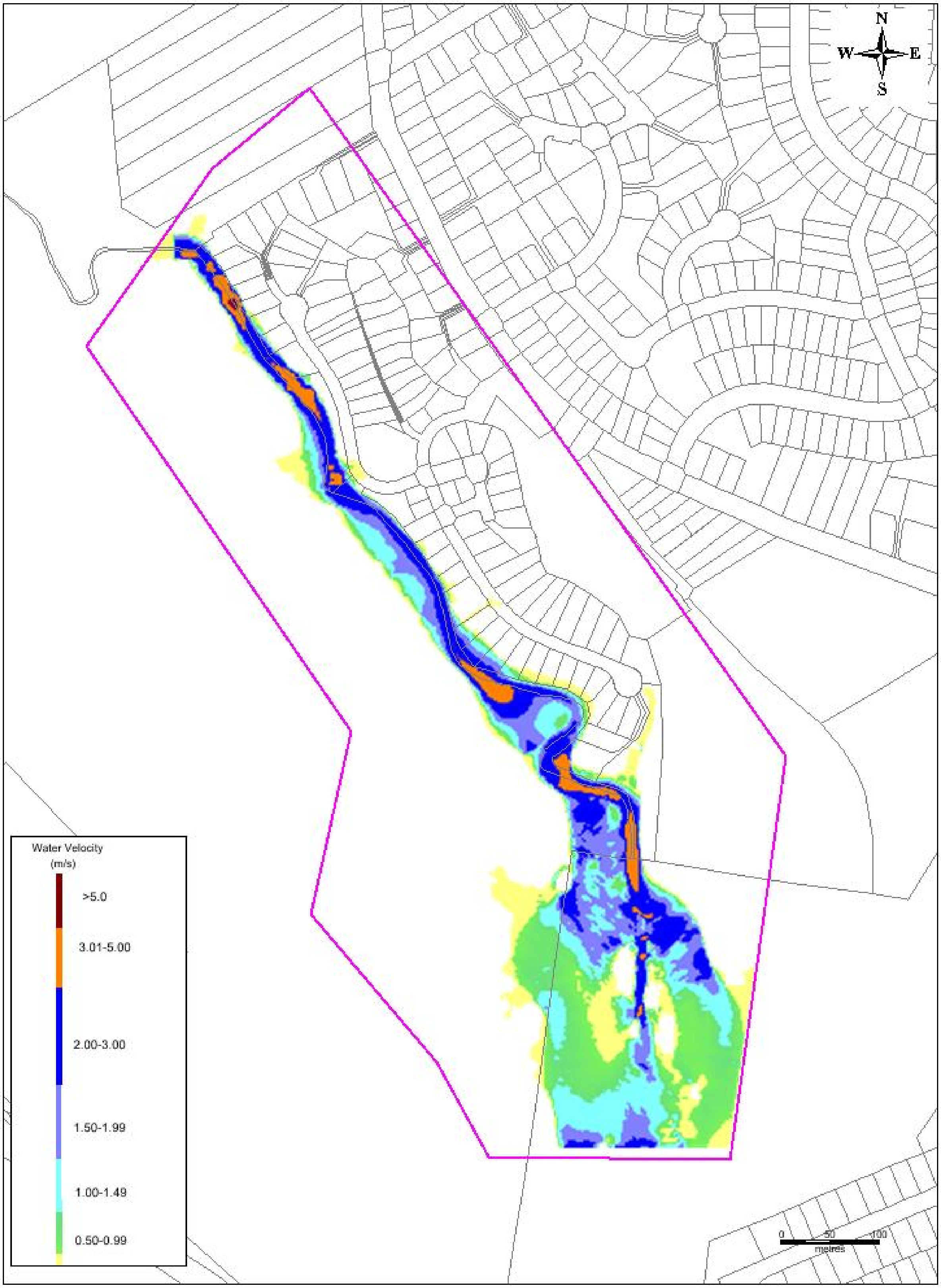

Figure 3-18 Water Velocities – 2% AEP, Current Existing Case

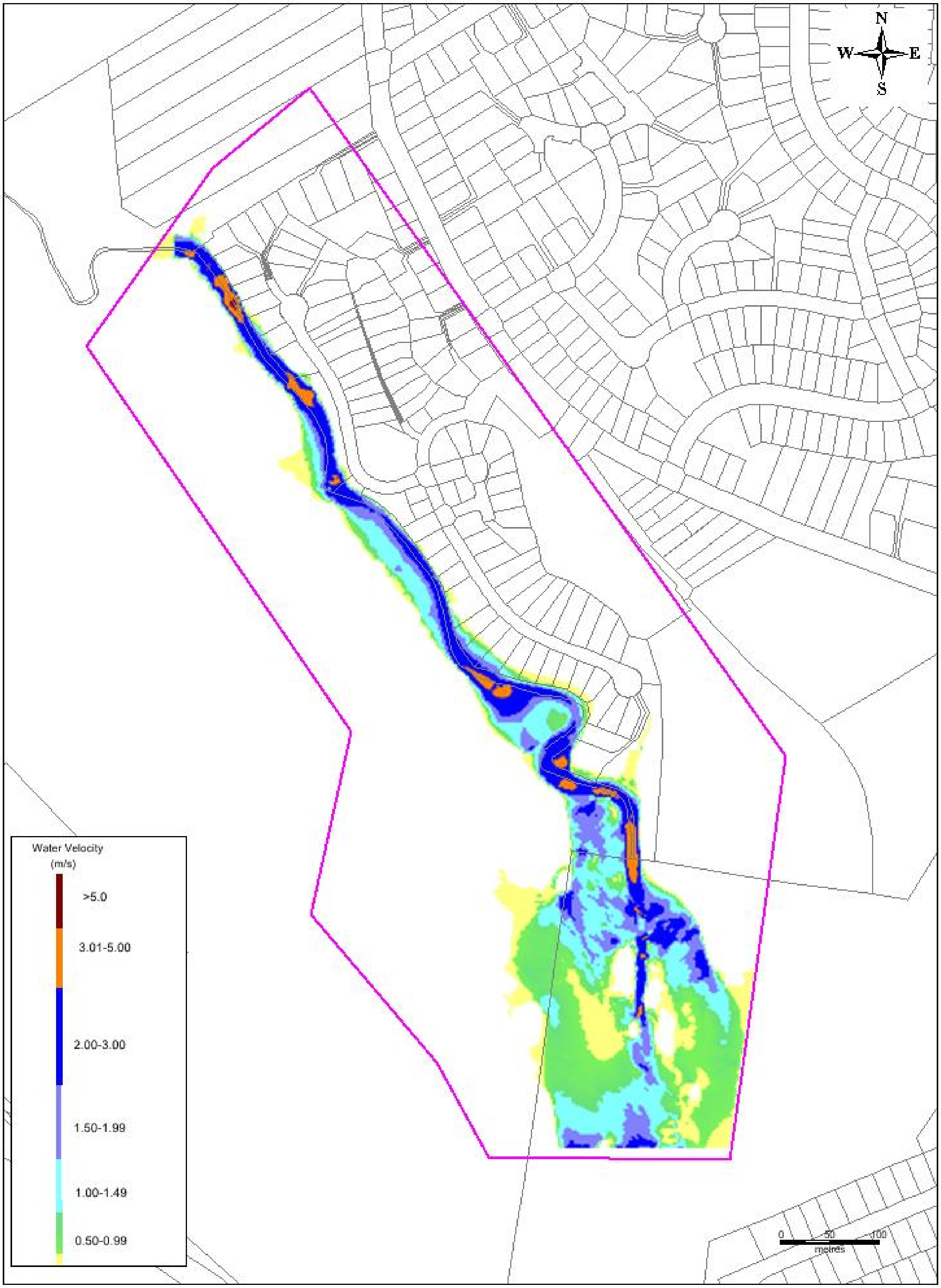

Figure 3-19 Water Velocities – 5% AEP, Current Existing Case

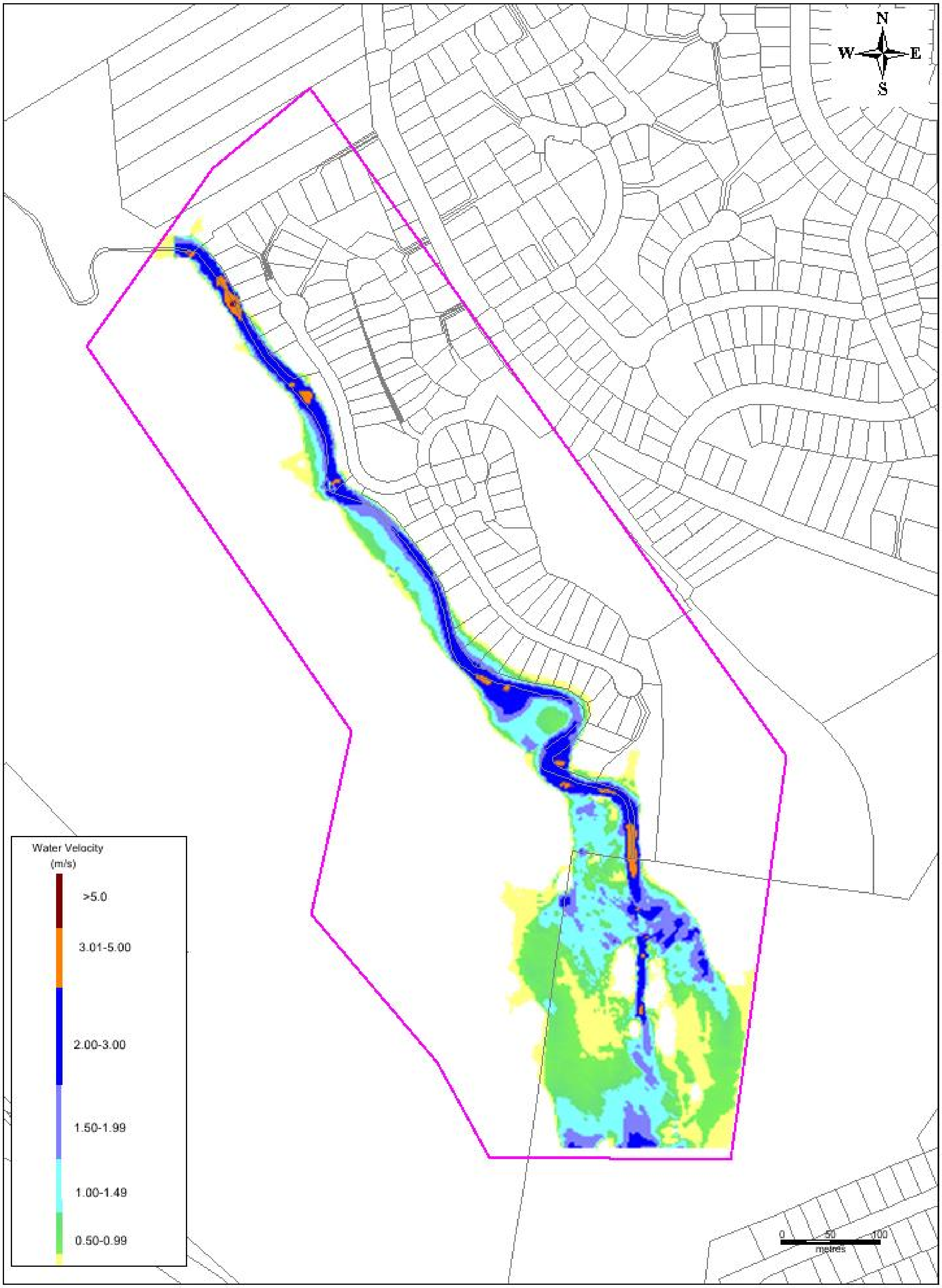

Figure 3-20 Water Velocities – 10% AEP, Current Existing Case

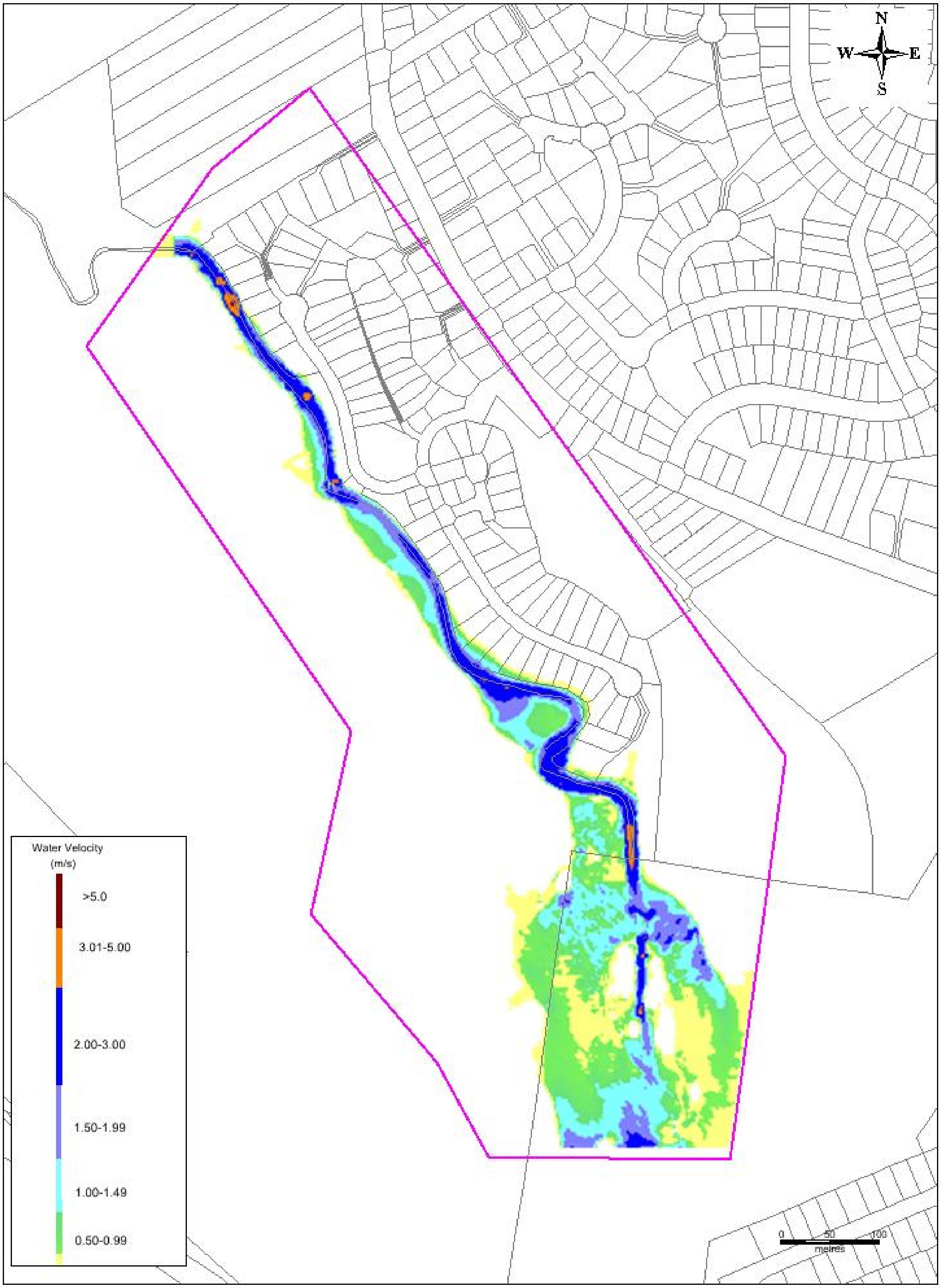

Figure 3-21 Water Velocities – 20% AEP, Current Existing Case

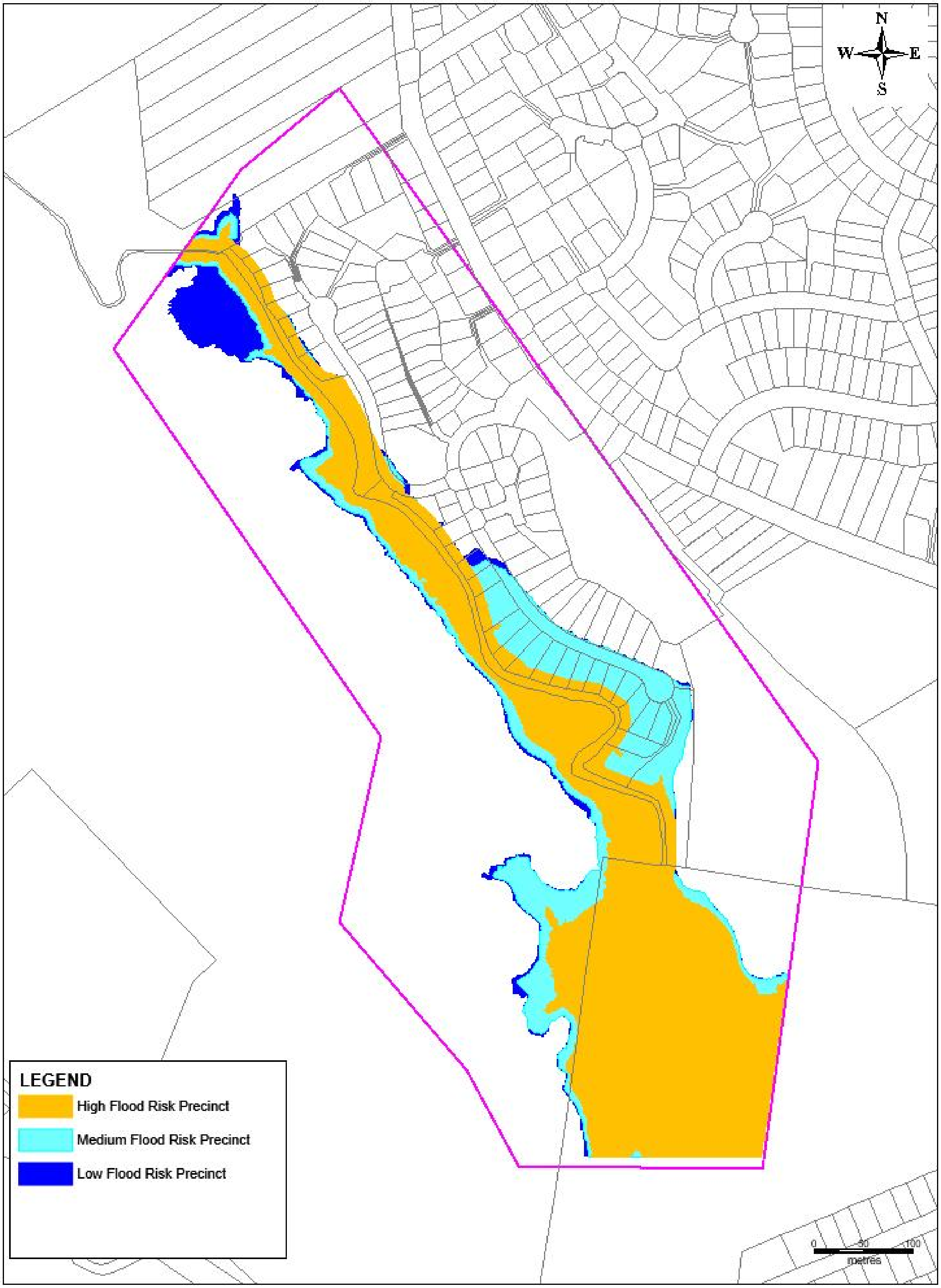

Figure 3-22 Flood Risk Precincts, Current Existing Case

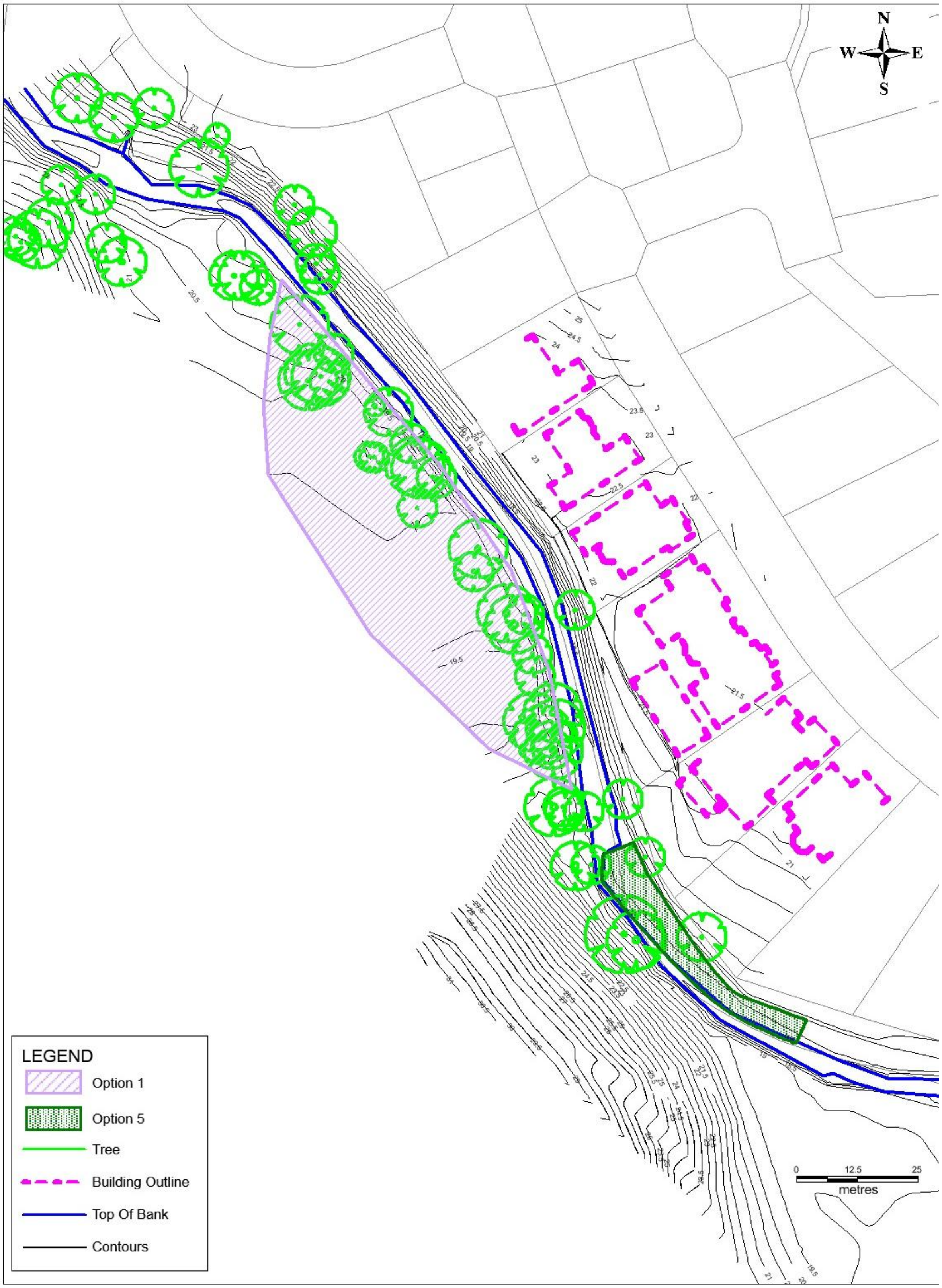

Figure 5-1 FM1 & FM5 Layout

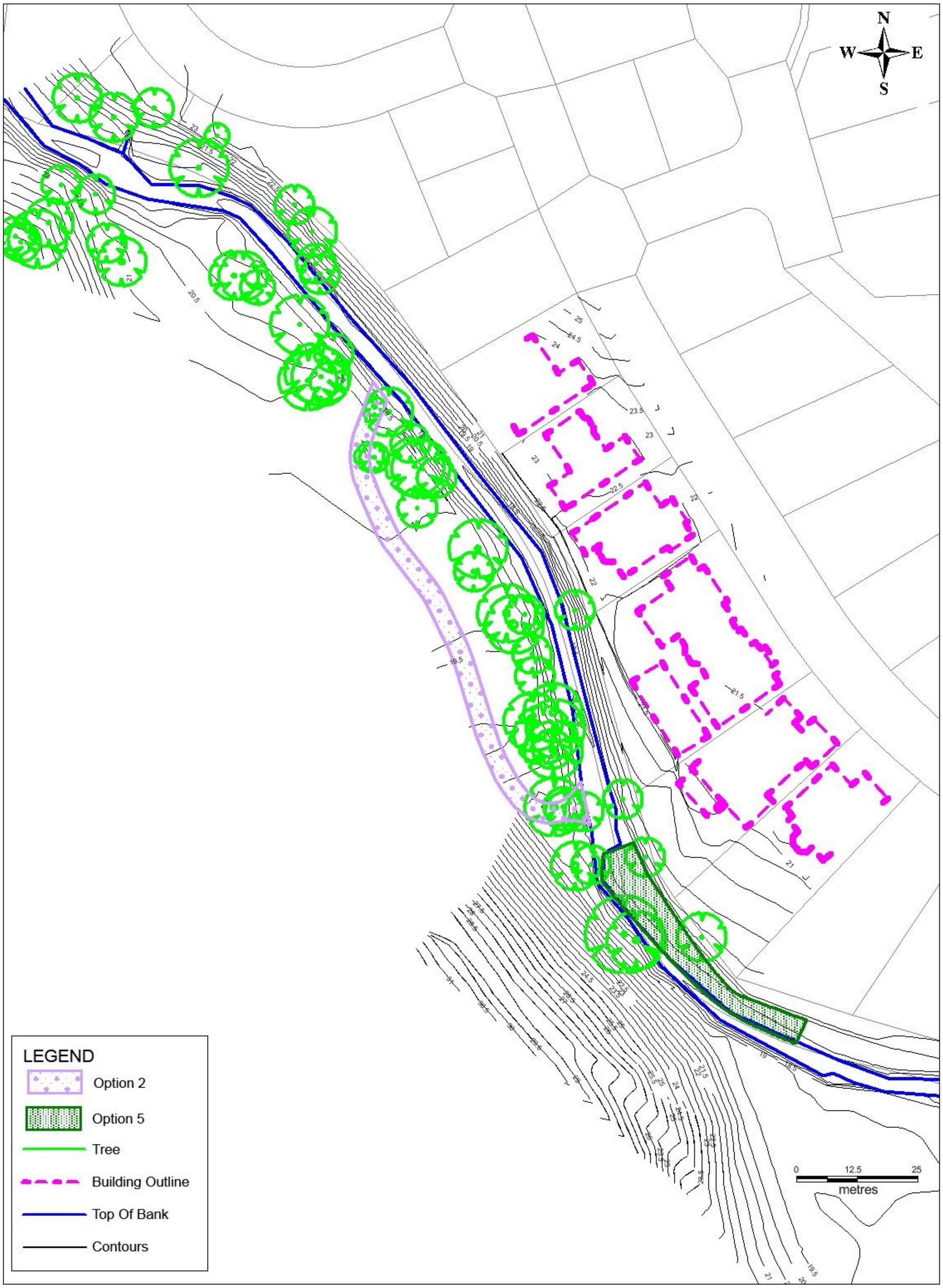

Figure 5-2 FM2 & FM5 Layout

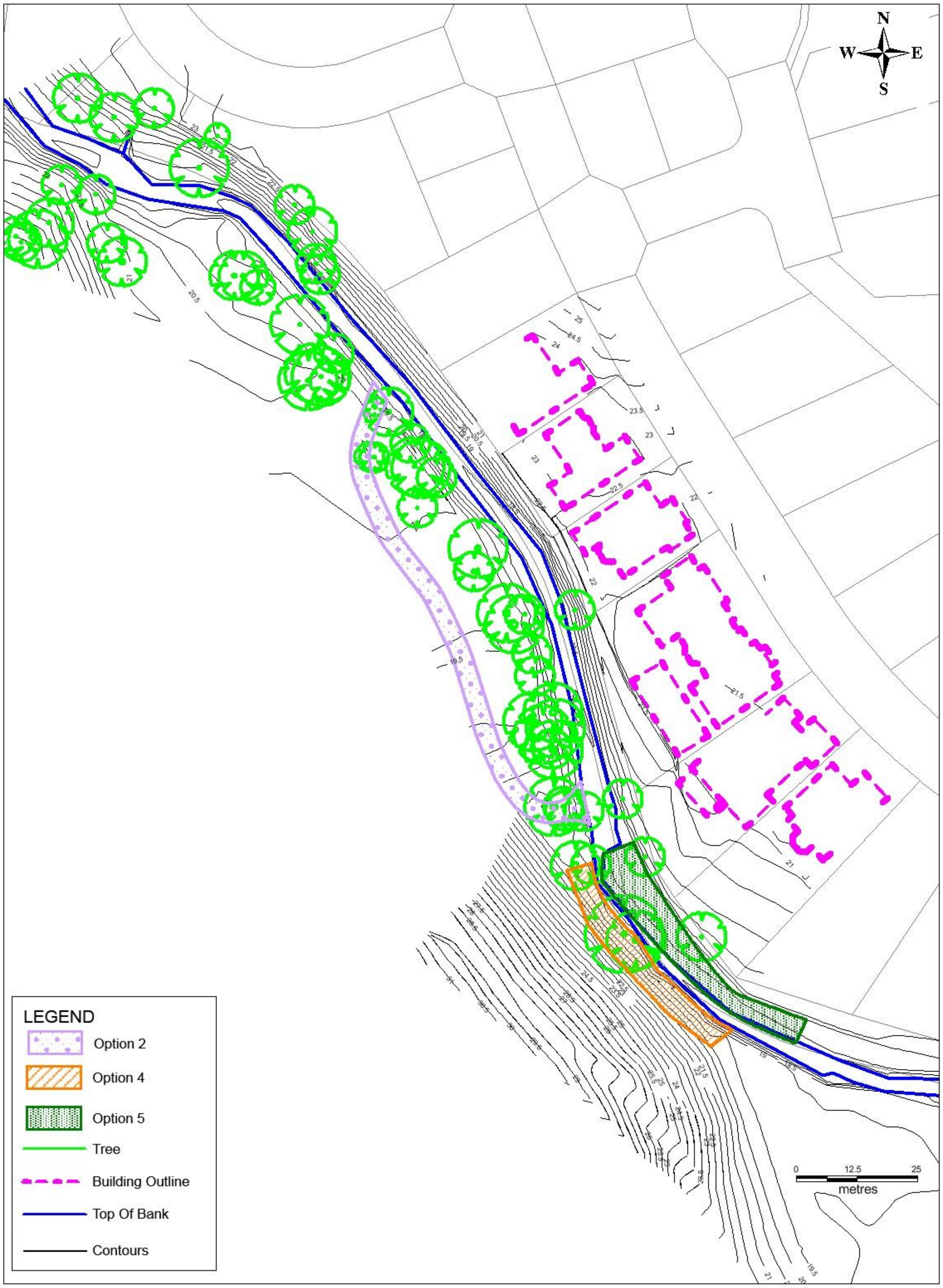

Figure 5-3 FM2 & FM4 Layout

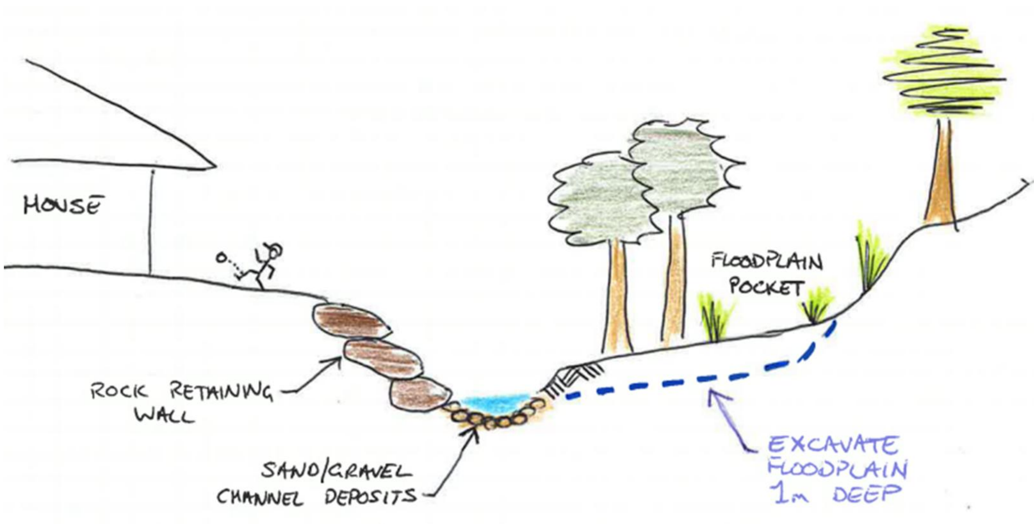

Figure 5-4 Typical Section - FM1

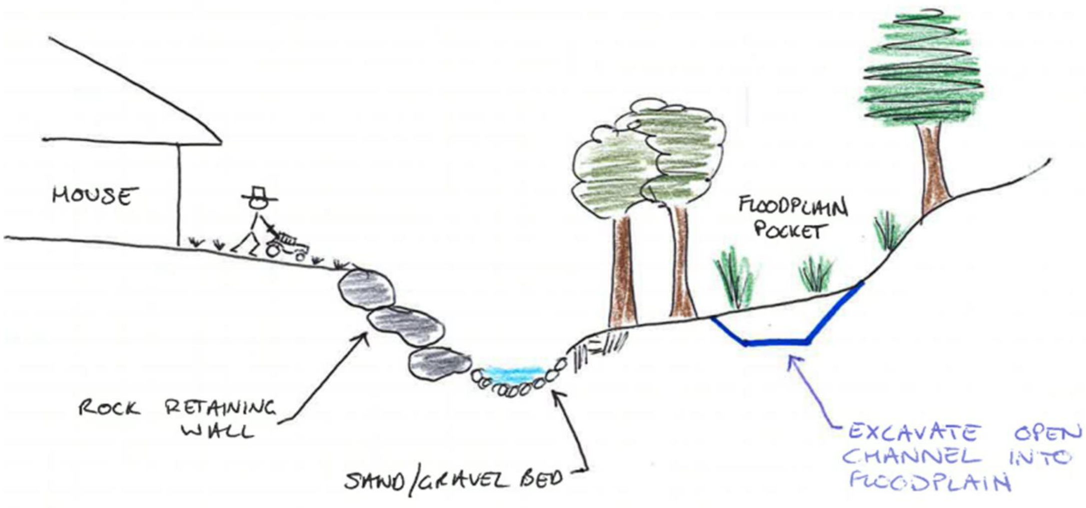

Figure 5-5 Typical Section – FM2

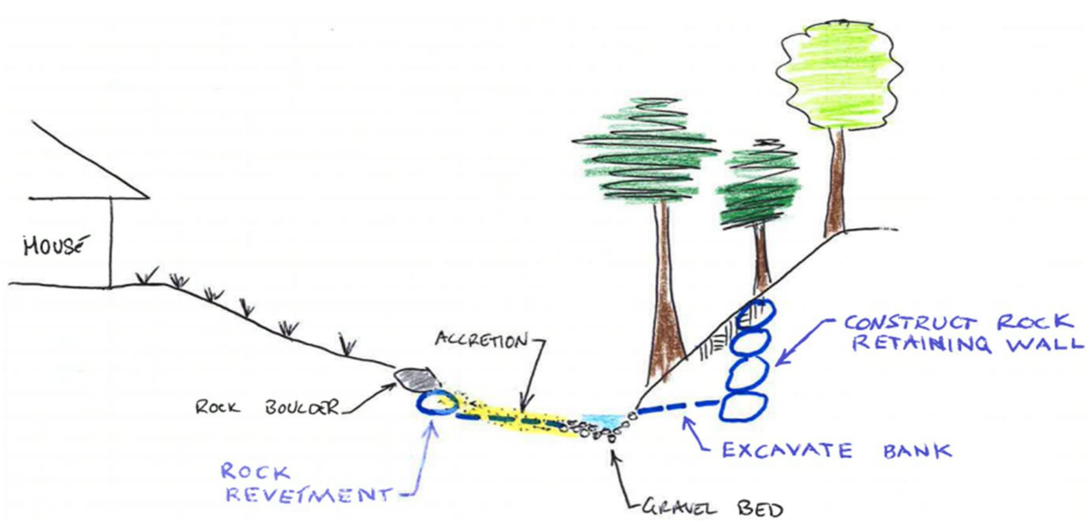

Figure 5-6 Typical Section – FM4 and FM5

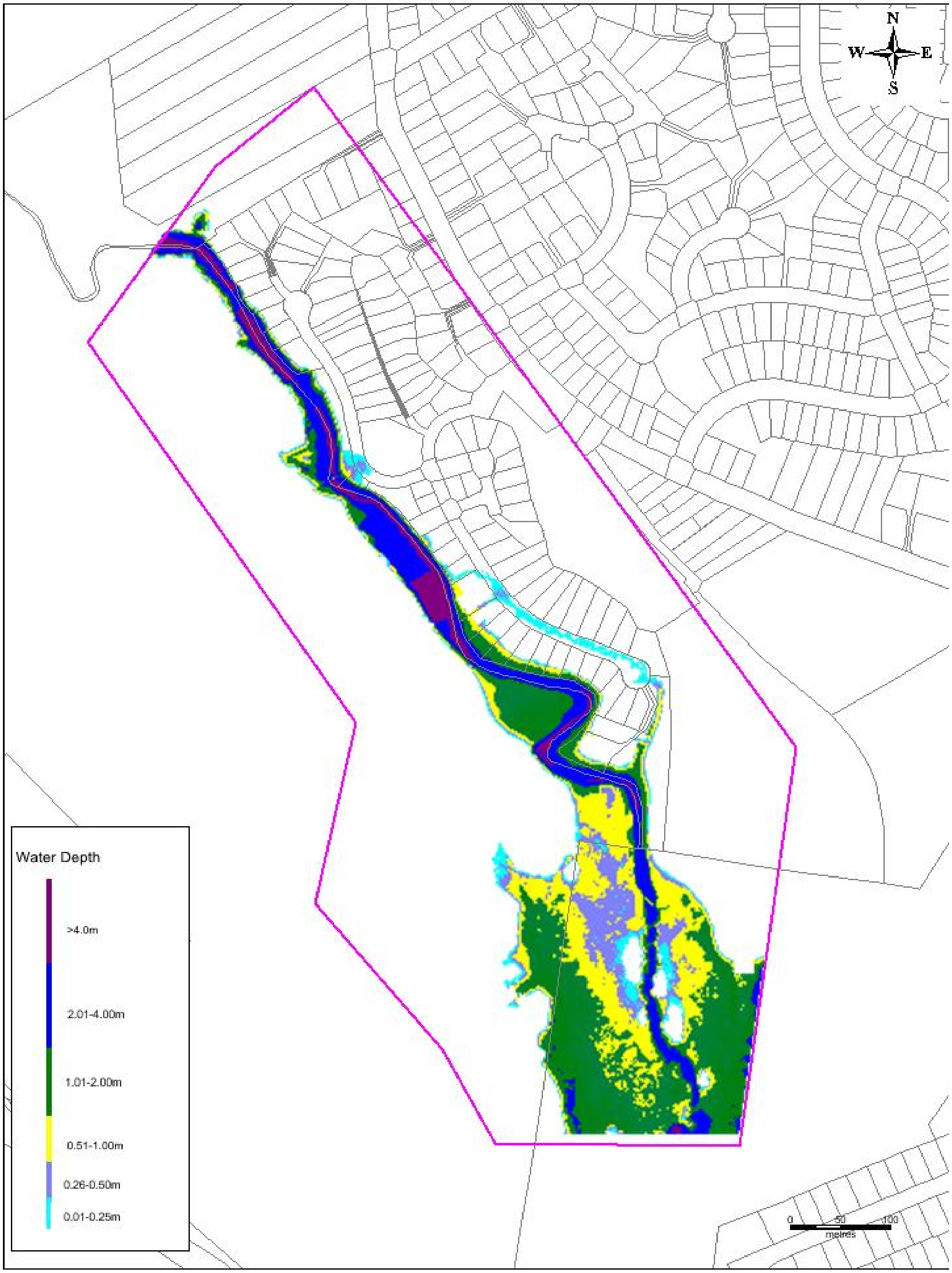

Figure 5-7 Water Depths – 1% AEP of FM1&5

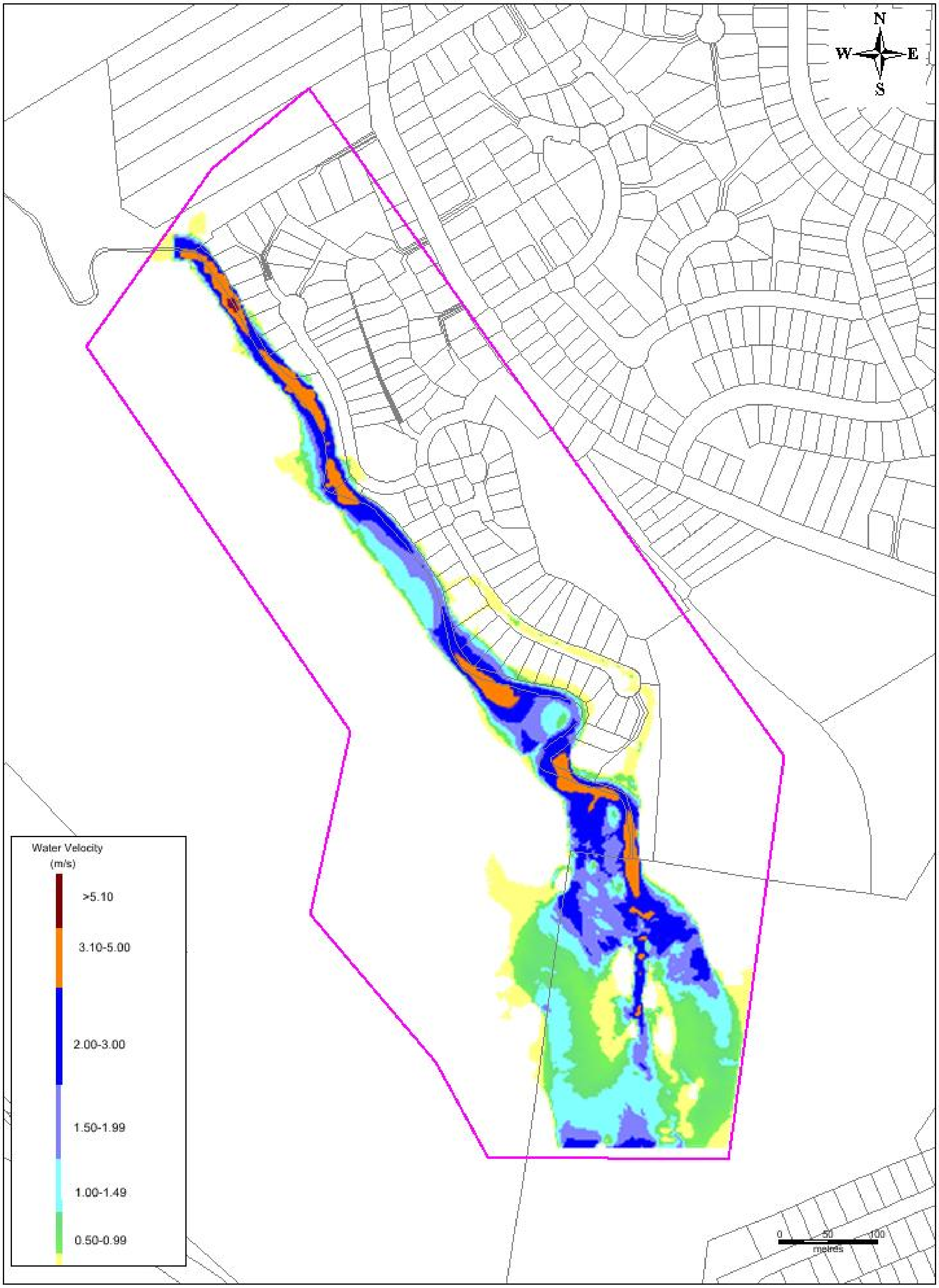

Figure 5-8 Water Velocities – 1% AEP of FM1&5

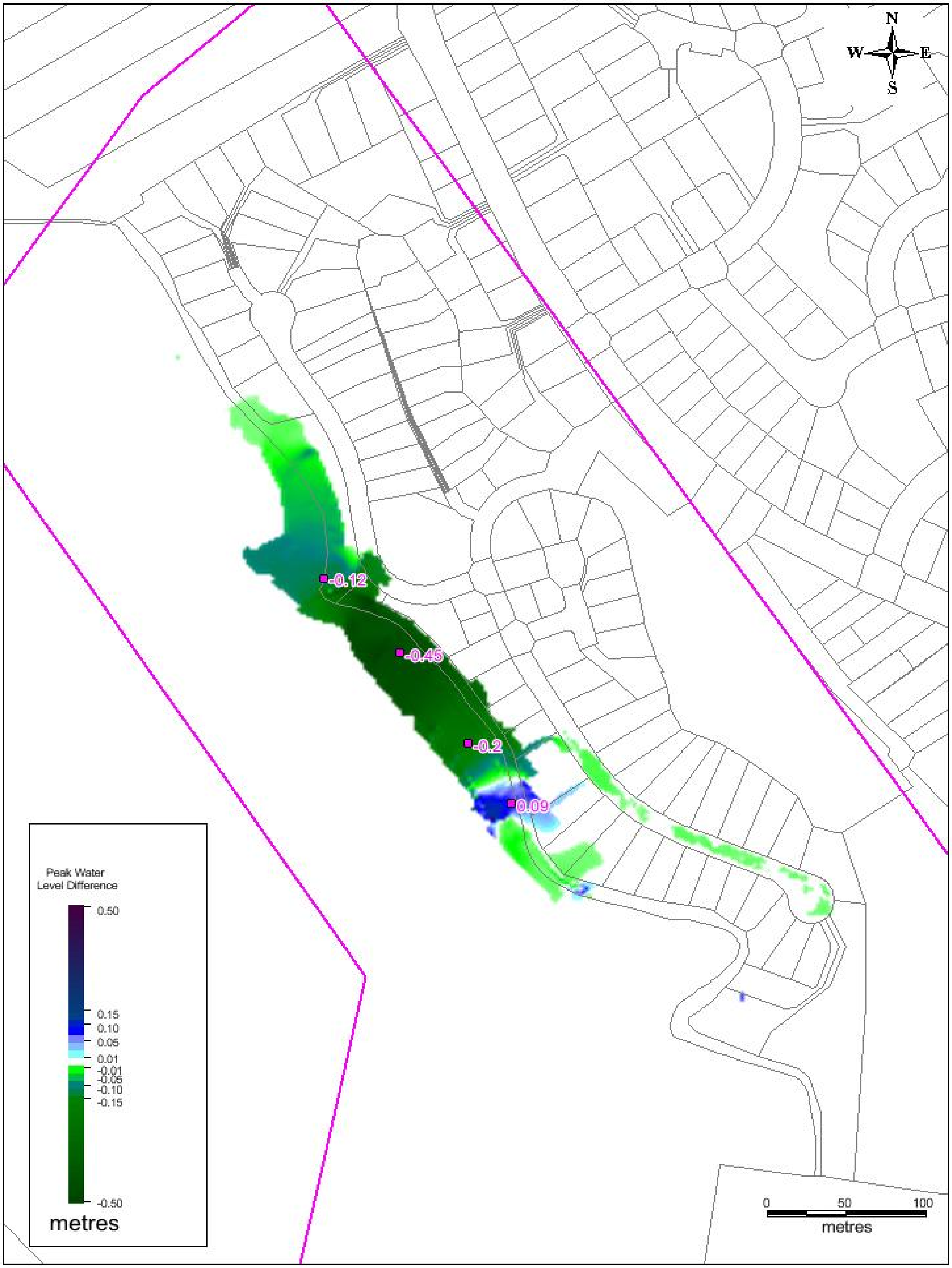

Figure 5-9 Water Level Differences – 1% AEP, 2 Hours of FM1&5 Less Existing

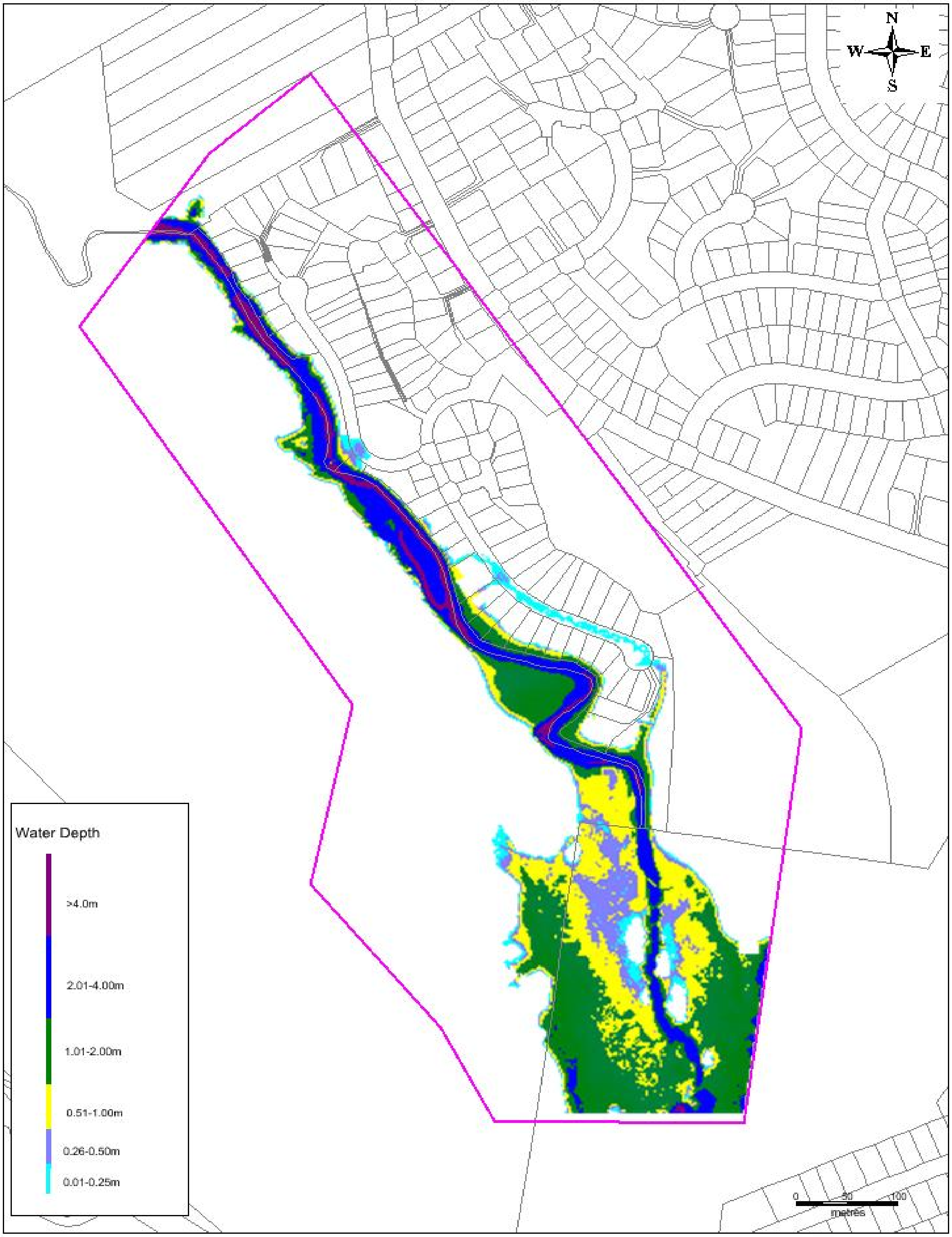

Figure 5-10 Water Depths – 1% AEP of FM2&5

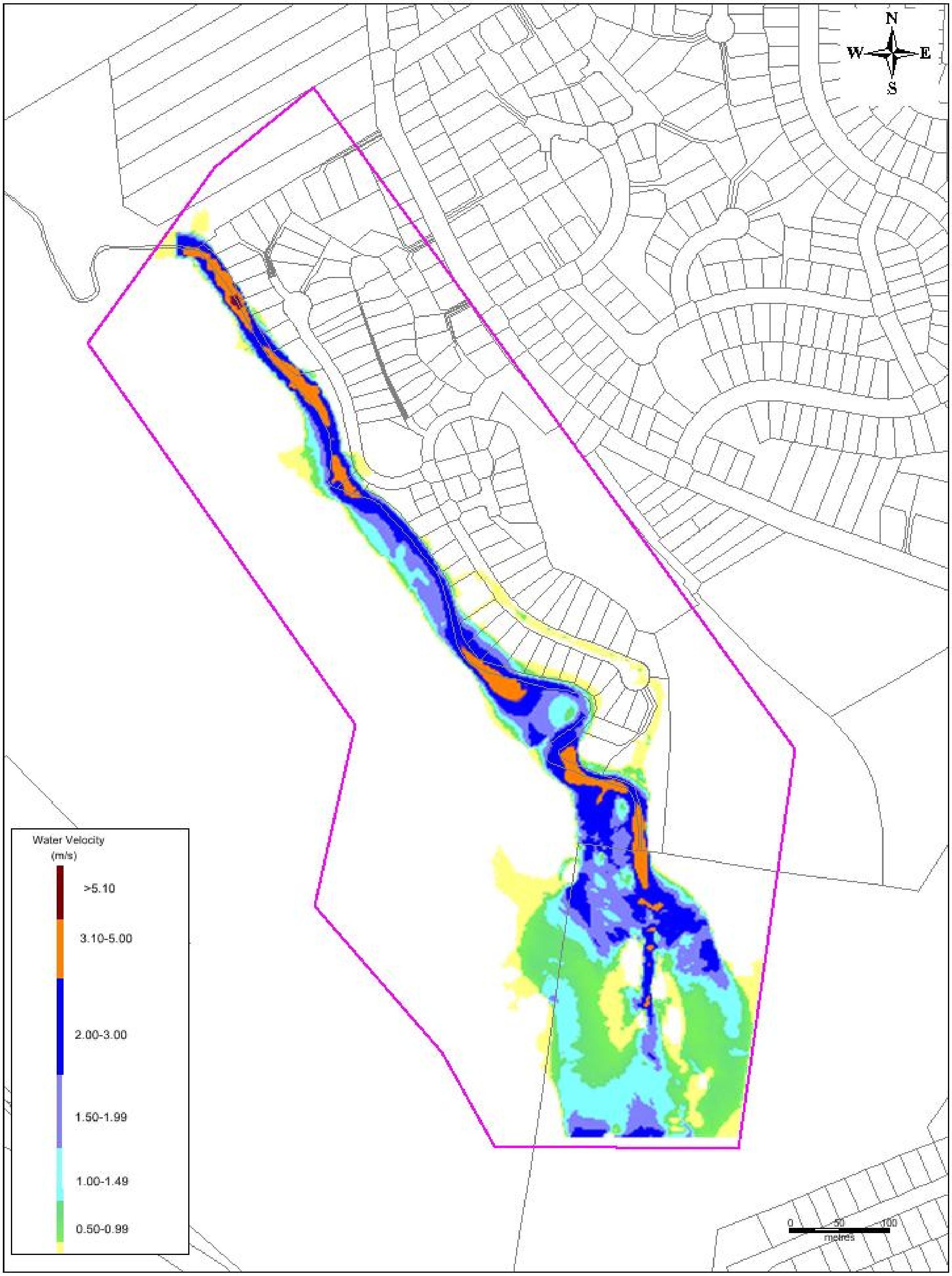

Figure 5-11 Water Velocites – 1% AEP of FM2&5

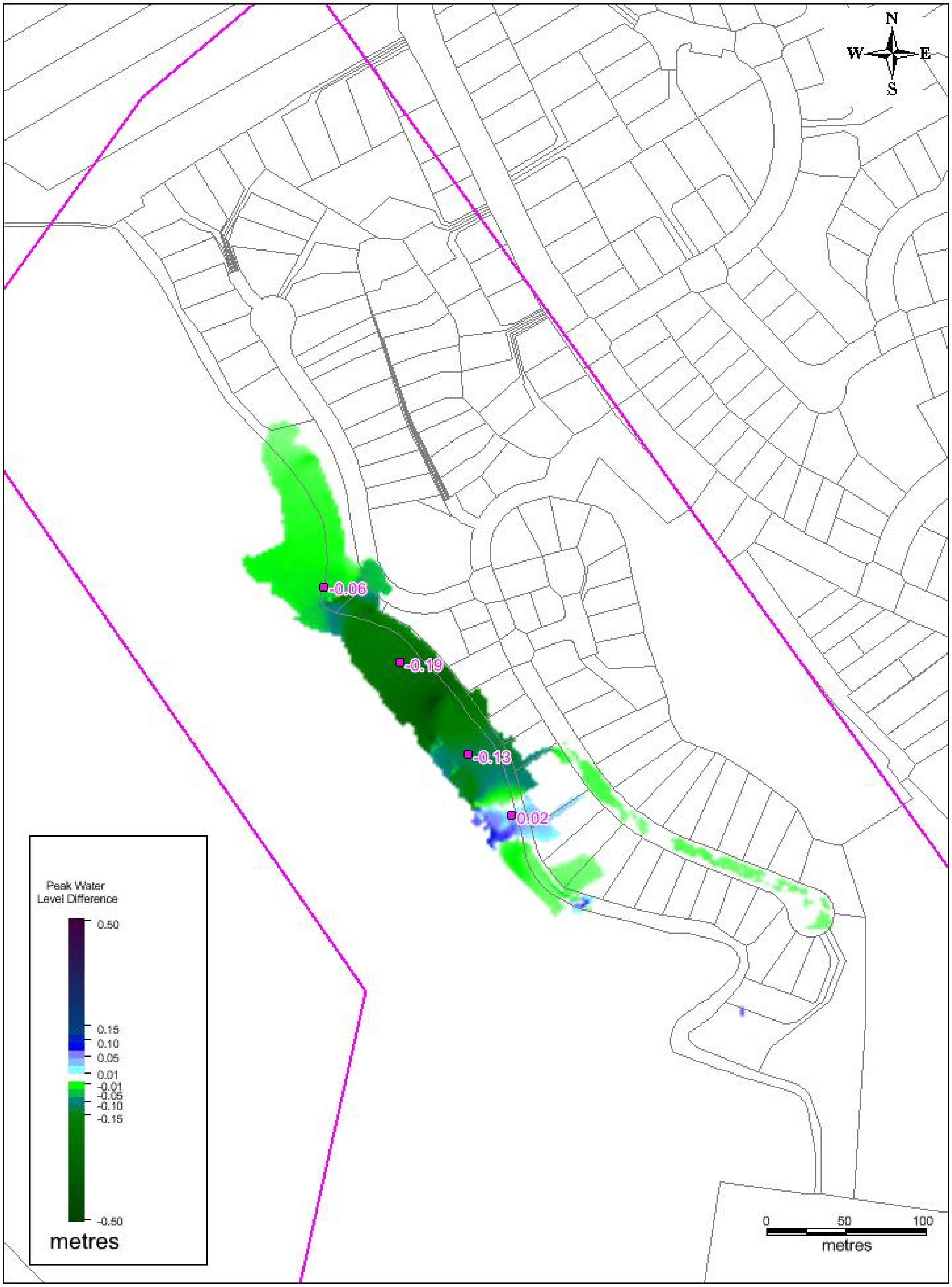

Figure 5-12 Water Level Differences – 1% AEP, 2 Hours FM2&5 Less Existing

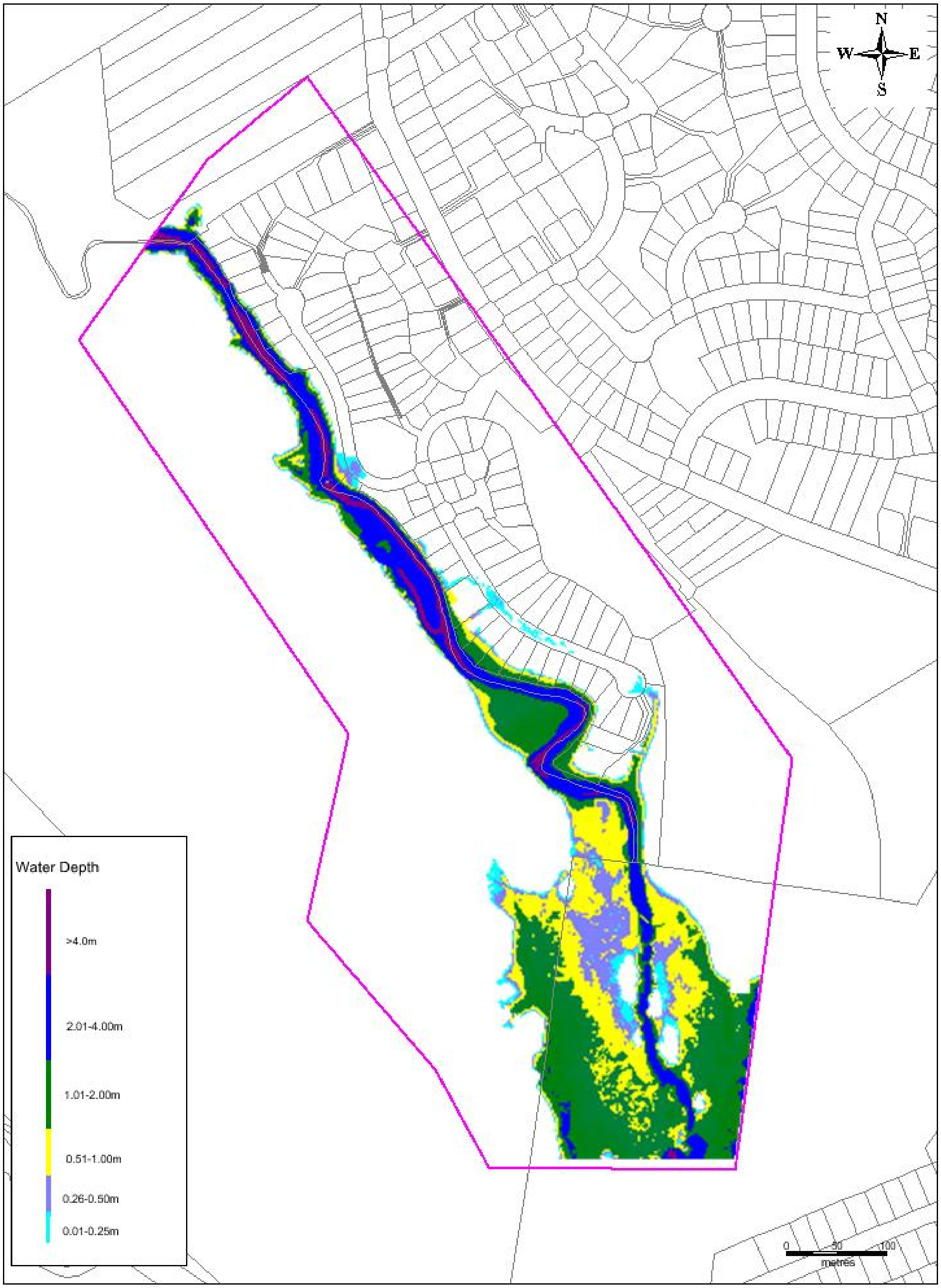

Figure 5-13 Water Depths – 1% AEP of FM2&4&5

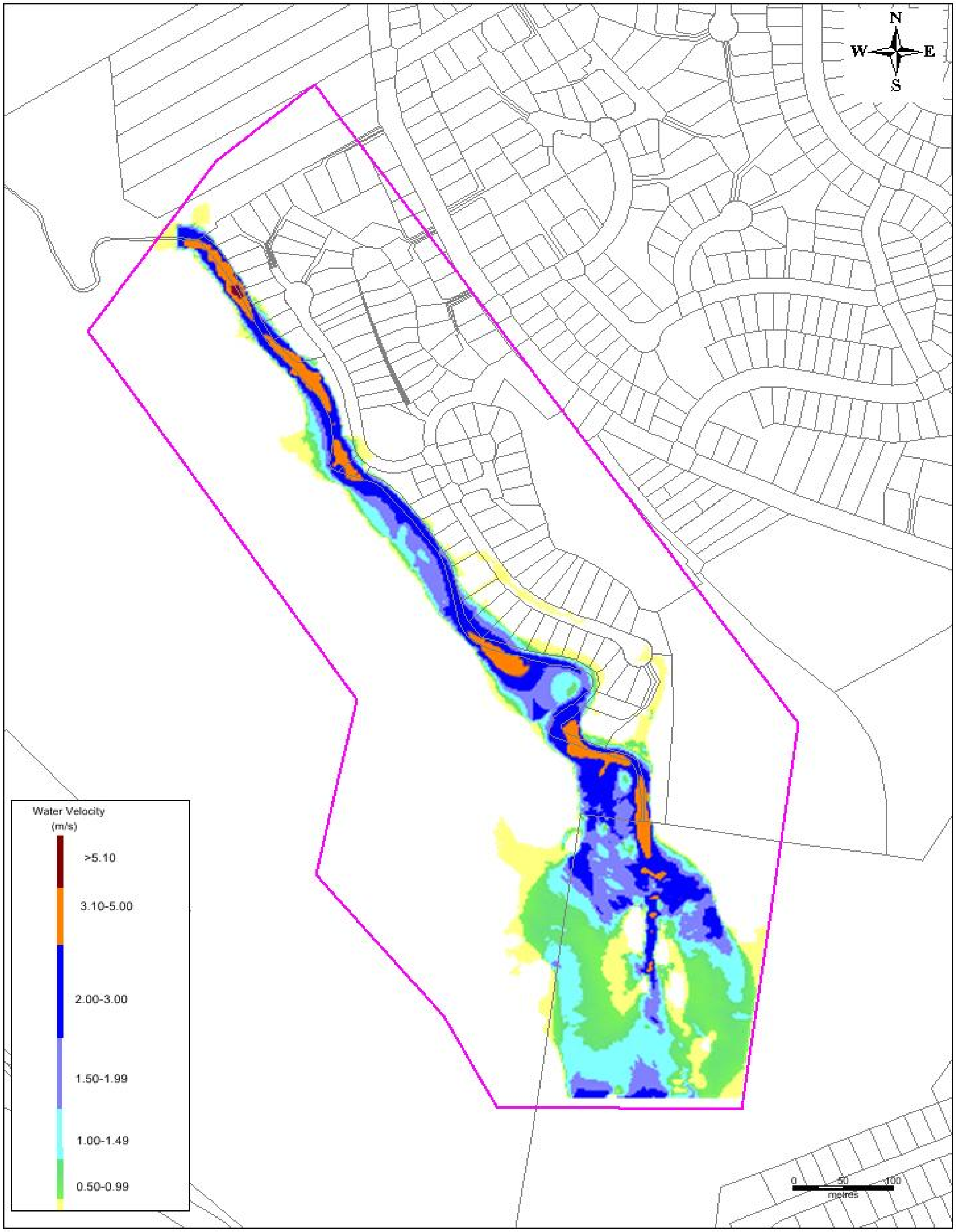

Figure 5-14 Water Velocites – 1% AEP of FM 2&4&5

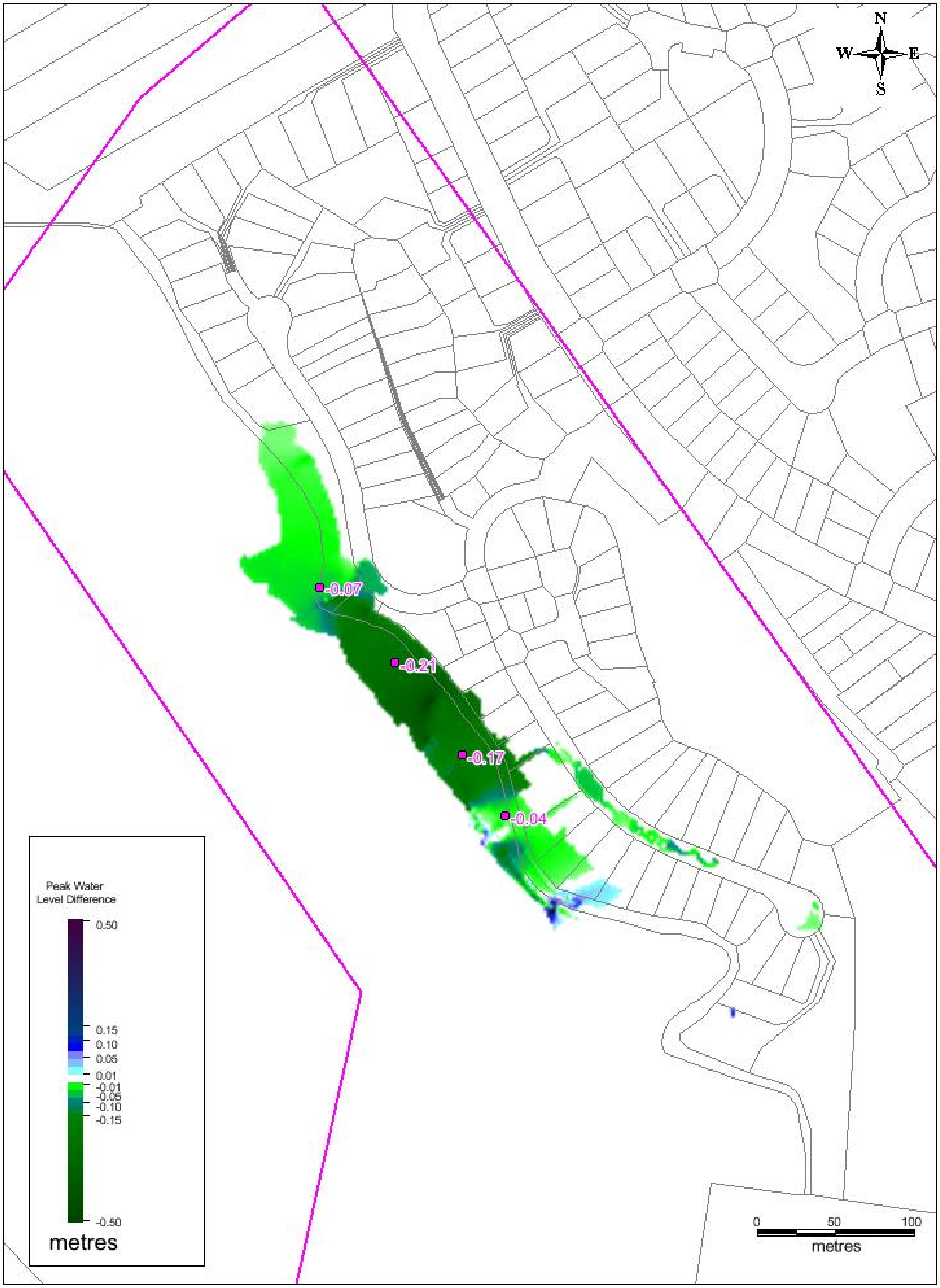

Figure 5.15 Water Level Differences – 1% AEP of FM2&4&5 less existing