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North West Treatment Hub Review of Environmental Factors

Hydrology and Geomorphology Impact Assessment – Riverstone WWTP Upgrade

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Abbreviations

Term	Abbreviation
Australian Height Datum	AHD
Downstream	d/s
Litres per hectare	L/ha
Manning's roughness coefficient	n
Meters per second	m/s
Mean Annual Precipitation	MAP
Mean Annual Runoff Volume	MARV
Megalitres per day	ML/d
North West Treatment Hub	NWTH
Upstream	u/s
Urban Streamflow Impact Assessment	USIA
Wastewater Treatment Plant	WWTP
Water Recycling Plant	WRP
Standard Deviation	SD

Table of Contents

Appendices

Figures

Tables

1 Introduction

1.1 Project description

The North West Treatment Hub (NWTH) program of works involves the upgrades of two water recycling plants (WRP) at Castle Hill and Rouse Hill, upgrades at Riverstone wastewater treatment plant (WWTP) and the installation of a new sludge pipeline between the plants to transfer sludge to Riverstone WWTP.

Overall project objectives for the NWTH program include:

- Service immediate growth and enable future growth servicing to 2050
- Ensure servicing meets current and future compliance requirements
- Maintain environment and community values.

The location of the water treatment facilities and the proposed sludge transfer lines are shown in Figure 1-1. Also indicated are the three discharge locations:

- Castle Hill WRP: Cattai Creek (tributary to Hawkesbury River)
- Rouse Hill WRP: Seconds Ponds Creek (tributary to Cattai Creek)
- Riverstone WWTP: Eastern Creek (tributary to Wianamatta-South Creek)

1.2 Report objectives

This report covers the hydrology and geomorphology impact assessments for the project components listed in Table 1-1.

Table 1-1 Activities assessed

Location	Proposed activity	Assessment methodology
Riverstone WWTP (Eastern Creek)	Increase treatment capacity from 14.2 ML/d to 36 ML/d	Three sets of criteria have been considered: ■ Relevant eco-hydraulic thresholds (informed by the ecological assessment – ELA, 2021) ■ A bank and bed shear-stress assessment based on empirical sediment transport relationships to assess erosion and deposition risk. Please see Section 2 for more detail.

The study assessing the hydrological and geomorphological impacts associated with the proposed increase in discharge from Rouse Hill WRP, Castle Hill WRP and the construction and operation of the sludge pipelines has been covered in a separate report (Aurecon, 2022).

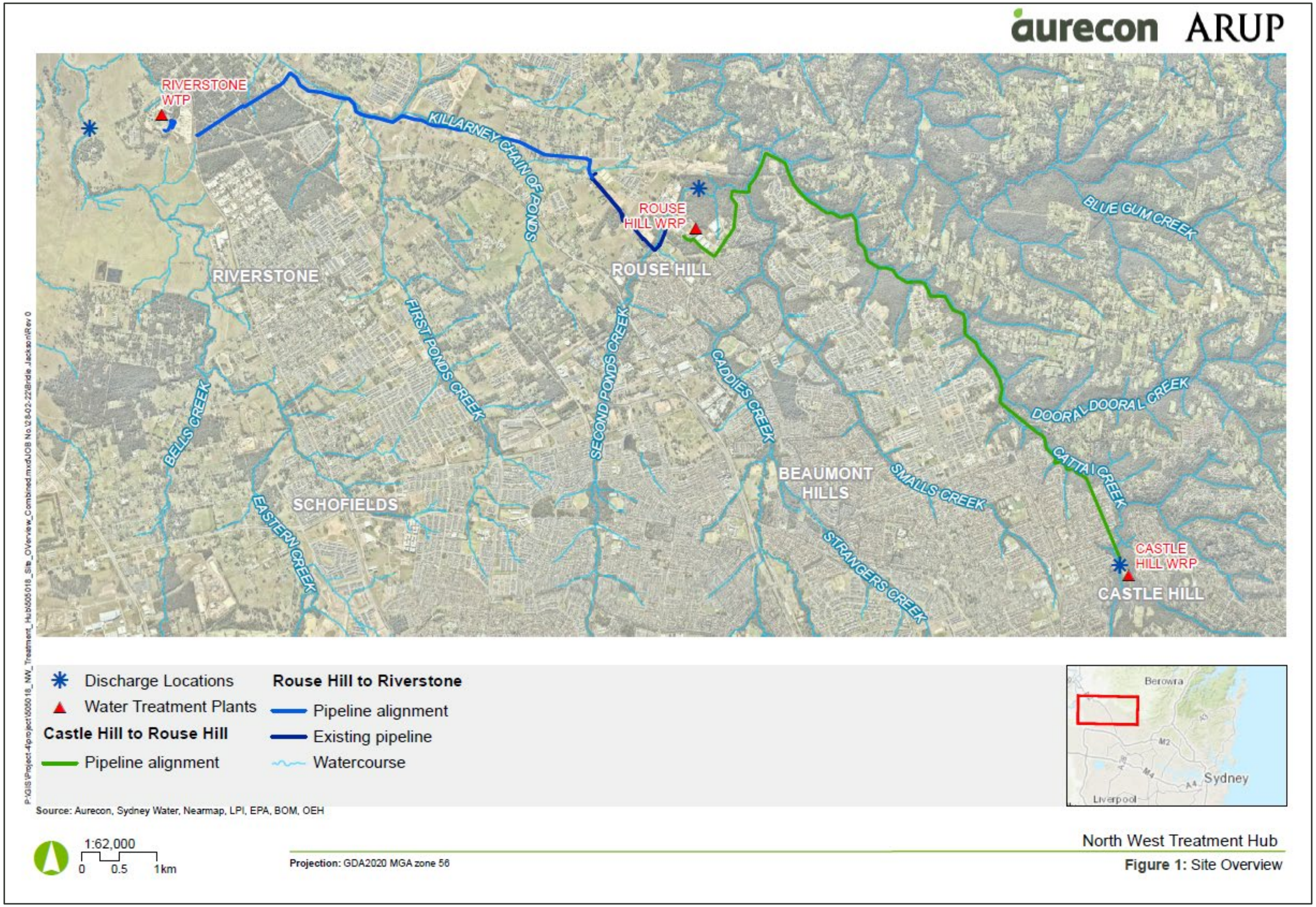


Figure 1-1 Project study area

2 Assessment methodology

2.1 Risk Based Approach

A risk-based assessment has been conducted, examining the potential for increased erosion or habitat loss due to of the proposed increase in wastewater discharge to Eastern Creek.

An indicative reach of creek has been investigated and the potential risks to this reach may also apply to downstream areas until some point in the creek network where the capacity of the waterway can assimilate additional flows.

Criteria considered to inform the assessment include:

- Ecological hydraulic thresholds (methodology detailed in Section 2.1.1) indicate the risk of the waterway becoming impassable to fish types or risk of habitat being washed out
- Bed and bank erosion risk has been assessed by considering the impact of changing shear-stresses expected downstream of the discharge locations (methodology detailed in Section 2.1.2), that may cause alteration of channel geometry or increase the rate of downstream erosion and deposition processes

As the methodology is a risk-based assessment, it is not intended to be a detailed geomorphic investigation of the entire downstream creek system.

2.1.1 Eco-hydraulic thresholds

An assessment of base case (i.e. current) and future case waterflow velocities was conducted to identify potential impact from variations to flow within Eastern Creek. As Eastern Creek feeds into the larger South Creek (which feeds into the Hawkesbury River), the assessment was limited to the confluence of Eastern Creek and South Creek. Any impacts downstream of this confluence is expected to be considerably smaller due to the relative volumes in Eastern Creek versus South Creek.

The ecological hydraulic threshold assessment was conducted in order to quantify potential impacts to aquatic fauna located within Eastern Creek. Aquatic organisms may utilise a variety of hydraulic zones within a watercourse, including high flow (e.g. runs) and lower flow velocity (e.g. edgewaters) zones. The use of velocity thresholds allows for indication of potential impact in any part of the watercourse. Where specific thresholds for invertebrates and macrophytes were not available, scour thresholds were used to qualify potential impact on these receptors. The scour thresholds thus act as a proxy indication of impact on all aquatic biota. In this manner, while individuals might not be predicted to be present within Eastern Creek, assessment of indirect impacts on species such as Platypus, through prey item impacts (on potentially scoured substrates), could be made.

The key thresholds are those considered to reduce ecological stability by indirect (e.g. increase in shear stress causing habitat scour) or direct (e.g. exceedance of velocity threshold for biota favourable condition) impacts.

The assessment was informed by the aquatic physical habitat values that were identified from the North West Treatment Hub – Sensitive Aquatic Habitat Summary (ELA, 2021). It compared the outcomes of the local hydraulic modelling to the identified ecologically driven threshold values (Watson et al, 2019 and Austroads, 2018, respectively) to predict the change in impact to the waterway ecological values from changes to the current hydrological regime.

Direct flow velocities were derived from experimental data informed by the swimming performance of a selection of native Australian fish species (in relation to instream asset structures, as discussed in

Watson et. al 2019). These experimental data were identified as a conservative proxy for appropriation for wild fish and are utilised as a threshold for likely effect on species likely to occur downstream of the discharge. Due to the potential for a variety of fish species to utilise Eastern Creek, a selection of potential fish species across various body shape morphologies were selected for swimming performance (refer Table 2-1). The selection of this was based on physical habitat assessment and potential species (ELA 2021) and an assumption of unknown species utilising the habitat (due to no targeted fish community assessment). As such, a variety of likely species (in terms of both species and general body shapes) were selected to assess the risk of impact to a species which may utilise Eastern Creek.

The conservative nature of experimental testing was identified due to the non-natural setting and laminar nature of the experimental plume (i.e. not simulating natural turbulence zoning) and the focus on small class sizes of the fish species used in the experiment. The specific velocities of concern as predictive prolonged swimming performance speed (*Ucrit 25th percentile* (m/s)), related specifically to fish-swimming performance in a 12 metre flume are presented in Table 2-1. The *Ucrit* performance metric was selected (rather than burst speeds) as the best indicator for identifying prolonged swimming performance due to it being a combination of both sustained and burst swimming performance. As swimming performance is positively geared to body size, relative to capacity to overcome higher velocity (Watson et al. 2019), size of assessed fish are identified in Table 2-1. As such, the assessment then identifies various potential body lengths but also the most vulnerable size classes of fish within Eastern Creek. Larger fish are expected to have higher *Ucrit* capacity than those reported, and used, for the eco-hydraulic thresholds. While prolonged swimming performance for eels is within the *Ucrit* (up to 0.64 m/s; Langdon and Collins 2010), they were not included in this assessment due to capacity to overcome any sustained increases to water velocity through overland travel behavioural responses.

Table 2-1 Relevant potential fish species *U*crit swimming performance data (modified from Watson et al, 2019)

Scientific name	Common name	*Body Shape*	*U*crit size (cm) (Mean ± SD [range])	*U*crit 25th percentile (m/s)
Macquaria novemaculeata	Australian Bass	Compressiform	6.0 ± 0.7 [4.3 - 7.3]	0.53
Trachystoma petardi	Freshwater mullet	Fusiform	7.3 ± 1.0 [5.9 - 8.8]	0.80
Hypseleotris compressa	Empire gudgeon	Compressiform	5.3 ± 0.7 [4.4 - 7.8]	0.34
Hypseleotris galii	Firetail gudgeon	Compressiform	3.8 ± 0.8 [2.4 - 5.4]	0.34
Retropinna semoni	Australian Smelt	Fusiform	4.5 ± 0.7 [2.5 - 6.0]	0.62

Table note:

*U*crit refers to critical velocity threshold where 75 percent of fish are able to maintain prolonged swimming speeds for a defined distance

Hydraulic modelling was undertaken for a portion of Eastern Creek downstream of the WWTP discharge point to assess the impact that increased flow regimes may have on the aquatic fauna in the downstream Eastern Creek environment. The model set up is further detailed in Section 2.3.2 and the critical assessment locations are described in Section 2.3.3. The critical locations are representative of potential key risks that increased flows may have on the local environmental receptors. The output from the hydraulic modelling was used to assess the risk of impacting habitat suitability and fish passage, by considering the expected change to the amount of time the relevant thresholds are exceeded (refer Section 4).

2.1.2 Fluvial geomorphology: Erosion and deposition risk based on shear-stress

Critical tractive force (shear stress) thresholds for various particle sizes and aquatic vegetation were determined using the Technical Guidelines for Waterway Management, Part 6 (DSE, 2007). The particle thresholds were derived using the data presented in Figure 2-1, assuming, based on the local sample collected, that the creek bank material is best represented by the curve for fine sand and has water containing colloids. These assumptions were based on the review of the existing environment as outlined in Section 3.

The use of erosion thresholds for canals is considered appropriate as Eastern Creek typically has slow moving water, is relatively straight and relatively turbid. Guidance material is based on Australian industry practice recommended in waterway restoration manuals.

In adopting shear stress thresholds for various particle sizes, the lower end of the range has been selected for each class i.e. fine sand spans from 0.125 to 0.250 mm, and the threshold has been set based on a size of 0.125 mm. This results in a conservative estimate when presenting the exceedance of these thresholds in Section 4.2.

Thresholds were also adopted for aquatic vegetation and standing macrophytes (tussock and sedge) (DSE, 2007). These thresholds reflect the point of incipient motion of the bank / bed sediment or aquatic vegetation (i.e. the transition from a stationary state to a state of initial motion in response to an increase in the hydrodynamic forces acting on the sediment / macrophytes).

A relationship between shear stress and flow at the critical assessment locations identified along Eastern Creek (refer Section 2.3.3) were derived from the hydraulic modelling results. These relationships were used to determine how often these critical shear stress thresholds are predicted to be exceeded in both current and future scenario flow conditions. The impact assessment is presented in Section 4.

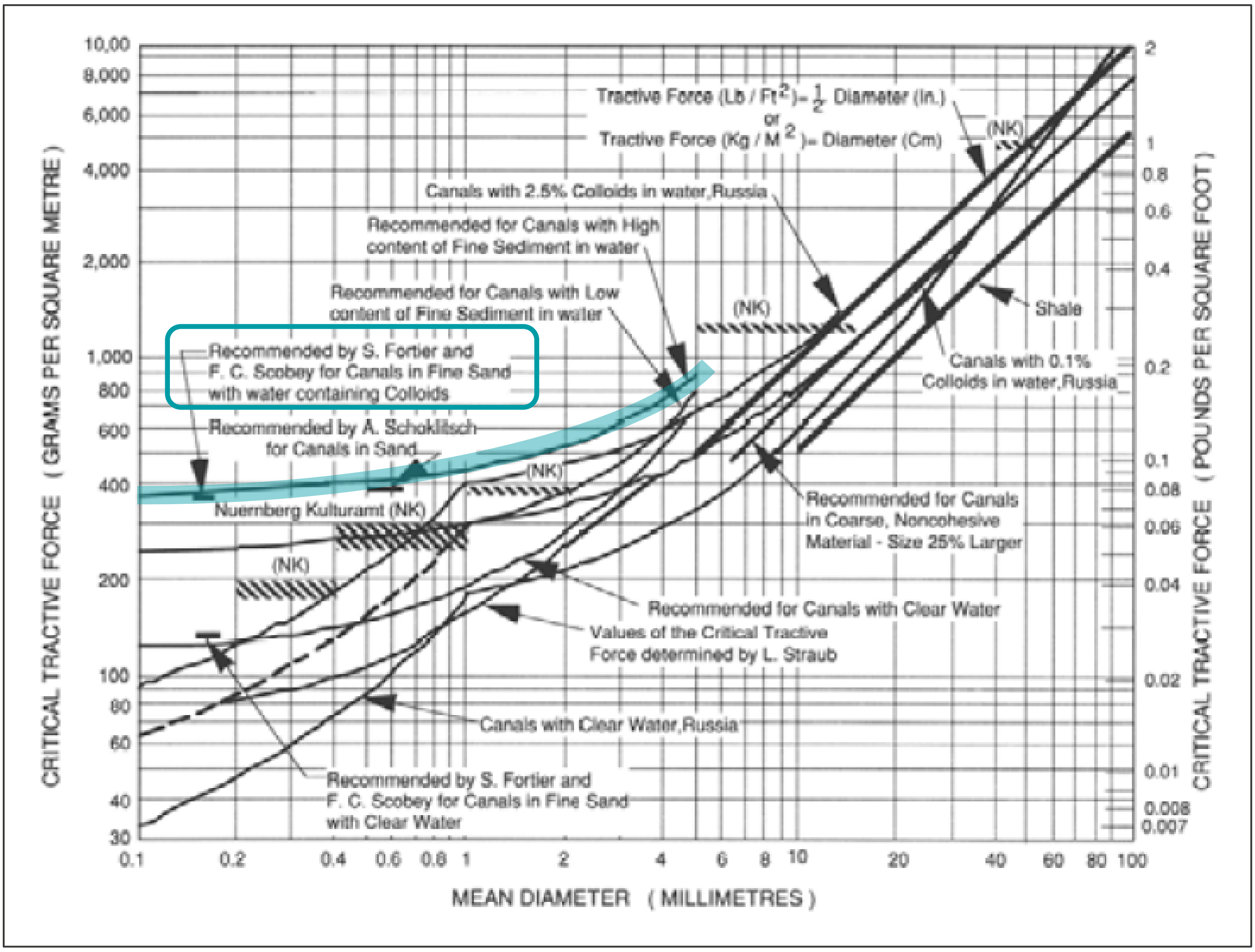


Figure 2-1 Relationships between tractive forces on stream bed and material particle size that will erode (DSE, 2007)

Note: The Canals in Fine Sand with water containing Colloids curve is clouded above and was used for the assessment

By definition, where flows increase erosion it is also implied that there is a deposition risk in downstream waters. Sediment may either drop out locally or be conveyed downstream until the transport capacity it too low and lead to deposition at some point down the system. Our modelling results indicated whether deposition would occur only within the study area and does not include deposition risk in Wianamatta-South Creek or the Hawkesbury-Nepean.

2.2 Impact classification

The significance of any potential project impact on the local surface water resources has been determined by considering the sensitivity of the environment related to the assessed criteria as well as the magnitude of the expected change. The resultant matrix of significance is shown in Table 2-2.

Table 2-2 Impact significance assessment matrix

Magnitude of potential impact	Sensitivity of receiving environment		
	Low	Medium	High
Low	Negligible	Low	Moderate
Medium	Low	Moderate	High
High	Moderate	High	Major

The *Sensitivity of Environmental Values* evaluation is influenced by the following criteria:

- Condition of the environmental value, i.e. how far is it understood to have already been changed from its original natural form or state?
- How unique or rare is the condition or value or it's dependant ecological receptors?
- How sensitive are the dependant receptors to changes?

The *Magnitude of Impact* evaluation is influence by the following criteria:

- If a qualitative assessment has been conducted, how do the results compare to the relevant waterway objectives
- For quantitative assessments the following is considered
- Expected duration of impact: Temporary vs. long-lasting/permanent
- Expected extent of impact: Local vs. regional/widespread
- Estimated degree of change from pre-development conditions

2.3 Input data preparation and modelling

2.3.1 Hydrologic modelling

A hydrological model of the Wianamatta-South Creek system was developed by Sydney Water using the eWater Source platform. This model includes allowance for discharges from the WRP's and WWTP's in the catchment to the waterways. The current and future flows simulated up- and downstream of the Riverstone WWTP were obtained from this model assuming the same climatic conditions (January 2012 to December 2018).

To assess the changes in flow brought about by shifting from the existing to the future land use within the Eastern Creek catchment, four scenarios have been assessed. These are summarised in Table 2-3.

Table 2-3 Scenarios modelled

ID	Landuse	Treatment capacity / ADWF* (ML/d)	Comments
1A	2017 Landuse data	14.2 (2020 Discharge regime)	Current conditions (excluding discharge from the plant)

ID	Landuse	Treatment capacity / ADWF* (ML/d)	Comments
1B	2017 Landuse data	14.2 (2020 Discharge regime)	Current conditions (including discharge from the plant)
2A	2036 Landuse data (low imperviousness / Parkland scenario)	36	Future conditions (excluding discharge from the plant)
2B	2036 Landuse data (low imperviousness / Parkland scenario)	36	Future conditions (including discharge from the plant)

*ADWF = Average Dry Weather Flow

The timeseries datasets of average daily flow rates for each of these scenarios were analysed to estimate the change in flows and associated hydraulic conditions in the receptor waterbody, i.e. in-stream velocities. The datasets were used in conjunction with the hydraulic modelling outputs (Section 2.3.2) to assess the frequency of exceeding the relevant hydraulic threshold values (Section 2.1).

The 2020 and 2036 simulated flowrates (downstream of the discharge location), which have been used in this assessment, are shown in Figure 2-2. The corresponding flow duration curves for all four scenarios across the entire simulated record (2012-2018) is provided in Figure 2-3.

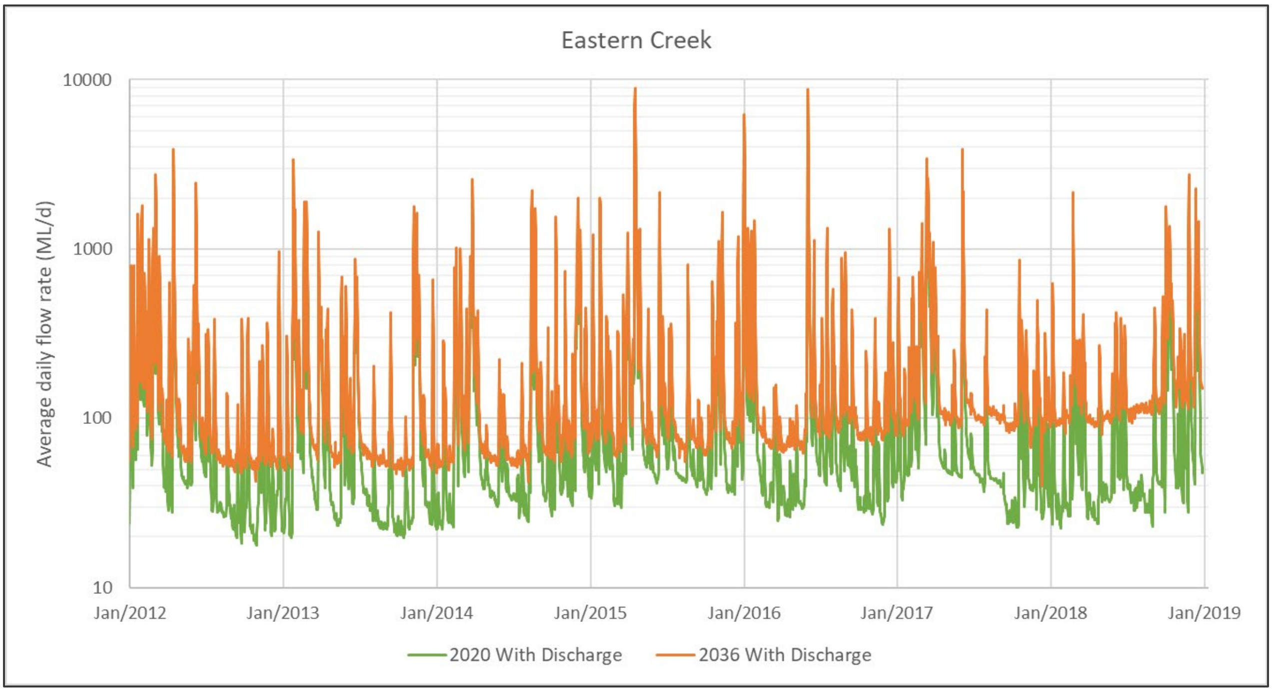


Figure 2-2 Portion of the Eastern Creek simulated flowrates (Jan-Dec 2015)

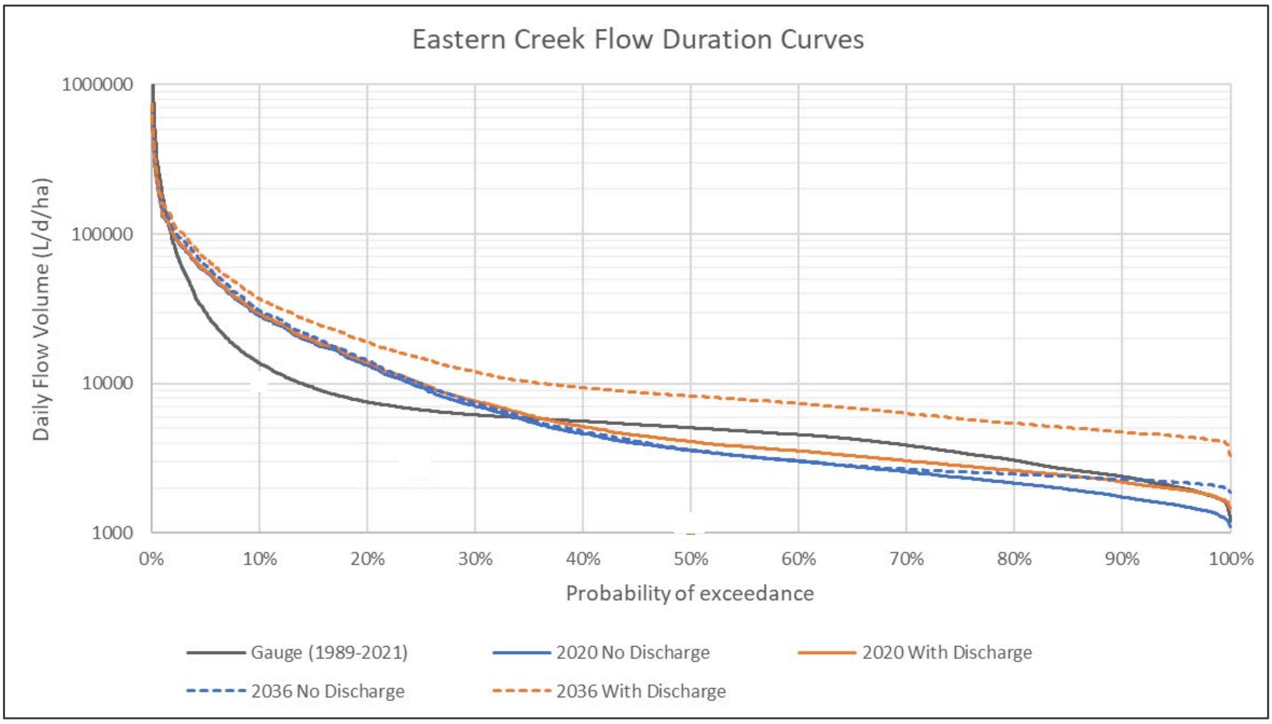


Figure 2-3 Eastern Creek flow duration curves

2.3.2 Hydraulic modelling

Hydraulic modelling was undertaken using a TUFLOW model of the existing and proposed future discharge from the Riverstone WWTP into Eastern Creek. The model was developed for the extent of the site survey (shown in Figure 2-4), with model parameters detailed below. The results are presented in Section 4.1 and 4.2.

Data

Bathymetry and topographic surveys were completed by Marine & Earth Sciences, with cross sections taken every 5m longitudinally along Eastern Creek. Each cross section extended to 20m either side of the creek. More detail was captured for features that may constrict water flow (MES, 2021). The details of the supplied topographic data set used in the hydraulic modelled is shown in Table 2-4. The elevation data was reduced to Australian Height Datum (AHD) using the Ausgeoid 2020 model.

Table 2-4 Topographic data

Data Set	Supplier	Data Type	Resolution & Accuracy
EasternCreek-DTM_xyz-AHD.dat	Marine & Earth Sciences	Bathymetry	+/-2cm vertical and +/-1cm horizontal.
		Topographic survey	+/-2cm vertical and +/-1cm horizontal.

Model parameters

The parameters used to build the TUFLOW model are summarised in Table 2-5. The model setup is shown in Figure 2-4.

Table 2-5 TUFLOW model parameters

Parameter	Eastern Creek TUFLOW Model
Completion date	December 2021

Parameter	Eastern Creek TUFLOW Model
Hydrologic modelling	Source model – refer Table 2-3
Percentile exceedance flow rates modelled	Minimum flow, 95%, 90%, 75%, 50%, 25%, 10%, 5%
Hydraulic model software	TUFLOW HPC module with version 2020-10-AA-iSP-w64
Grid size	2 metres
DEM	EasternCreek-DTM_xyz-AHD.asc
Roughness	0.03 – Creek bed 0.05 – Grassed floodplain and sparse tress
Model boundaries	Upstream – Modelled inflows applied at QT (flow-time) 2D boundary condition. Downstream – Constant mean sea level tailwater of 0.3 m AHD was adopted at HT (stage-time) 2D boundary condition. Refer Section 2.3.3 for discussion.

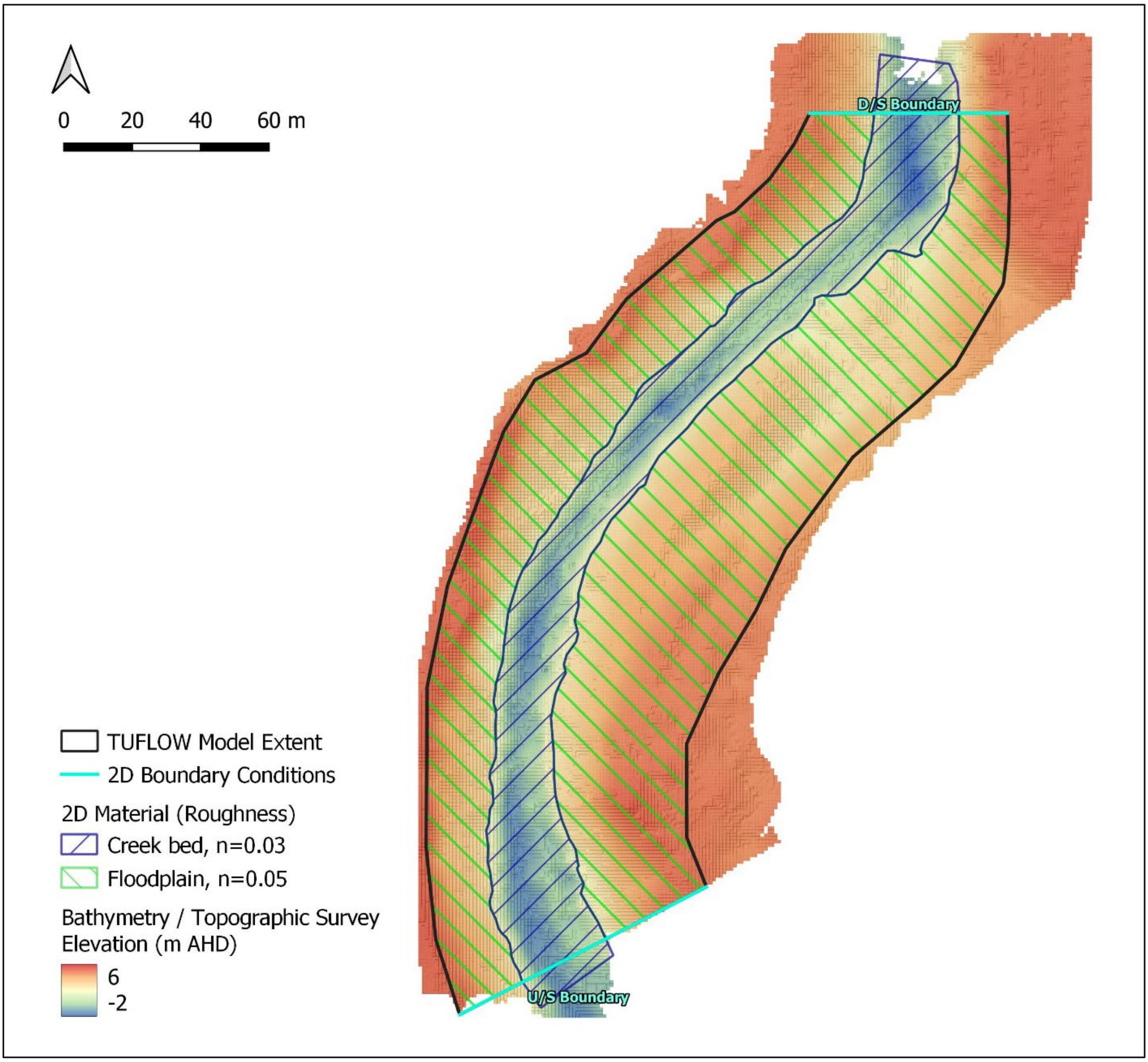


Figure 2-4 TUFLOW Model Domain

2.3.3 Eco-hydraulic and geomorphology assessment locations

Three discrete locations downstream of the WWTP discharge point in Eastern Creek were analysed due to their representation of potential key risks that increased flows may have on the local environmental receptors (refer Figure 2-5 and Figure 2-6). The area selected was previously field-verified by site walkover (refer ELA 2021) and allowed interpretation of potential aquatic environmental receptors. These specific assessment locations were chosen based on the following key risks considered:

- Location A: Representative of key risk #1 **bank erosion.** Site selection informed by visual evidence of bank erosion in this location.
- Location B: Representative of key risk #2: The waterway becomes slightly constricted and may increase water flow velocities leading to **impeded flow and fish passage**.

- Location C: Representative of key risk #3: Emergent macrophytes were observed and the direction of the water flow angle changes. **Macrophyte dislodgement** (i.e. washout of plants due to disruption / removal of bed material around the root system) may occur.

A relationship between flow-velocity and flow-shear stress was determined using the hydraulic modelling results at each location to determine exceedance of eco-hydraulic and fluvial geomorphology thresholds. The cross-sectional average velocity results were used to analyse exceedance of direct eco-hydraulic thresholds. Point results were extracted from water level and velocity timeseries to calculate shear stress against fluvial geomorphology thresholds and to make commentary on risk to fish habitat.

Figure 2-5 Model location downstream of discharge location (Eastern Creek)

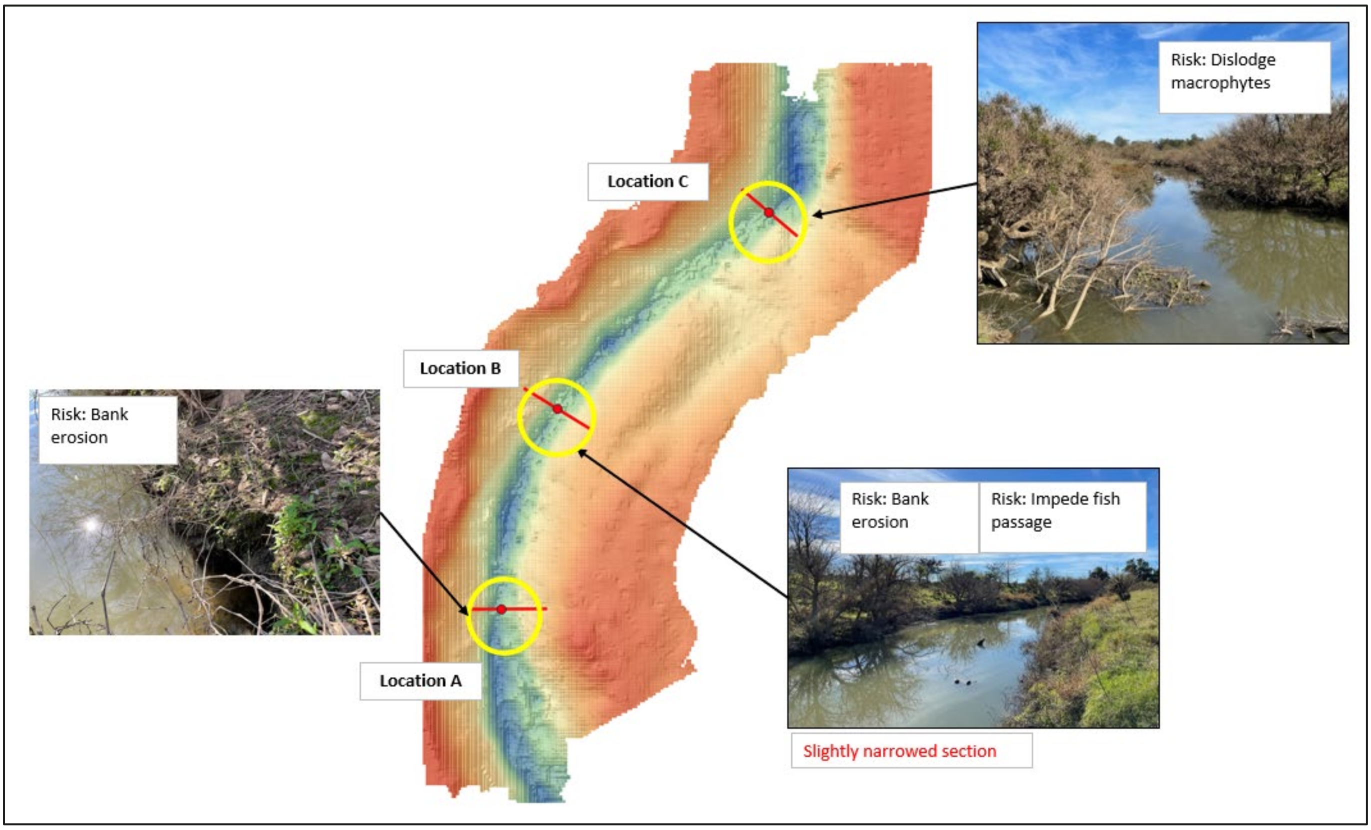


Figure 2-6 Locations modelled for at-risk environmental receptors (Eastern Creek)

2.3.4 Sensitivity analyses

Daily vs hourly flow rates

Hydrologic modelling of the waterway is available at a continuous daily time step. To confirm that daily hydrologic flow rates provided sufficient resolution of sub-daily flow rate fluctuation, daily and hourly flow data was compared at the Eastern Creek gauge 212296 (-33.6821, 150.8529).

A comparison of the hourly and daily flow rates for select percentiles of the data is shown in Figure 2-7. This indicates that the hydrological data at a daily timestep underestimates peak flows for larger events (i.e. 90-percentile flow events) but does provide a reasonable estimate for most of the more common flow rates.

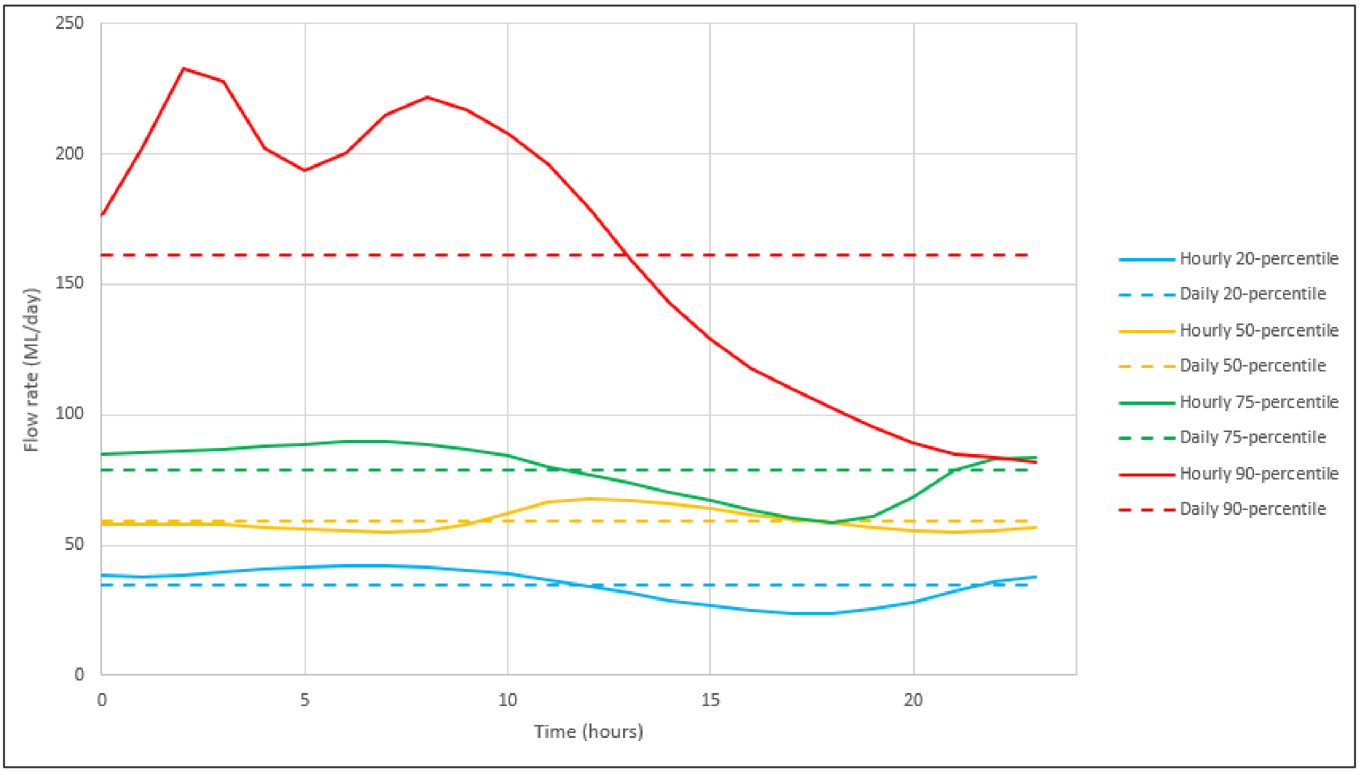


Figure 2-7 Hourly and daily flow rate comparison at gauge 212296

These same daily and hourly percentile flow rates were then run through the hydraulic model to test the sensitivity of velocity predictions (refer Figure 2-8 for an example of the analysis at location C).

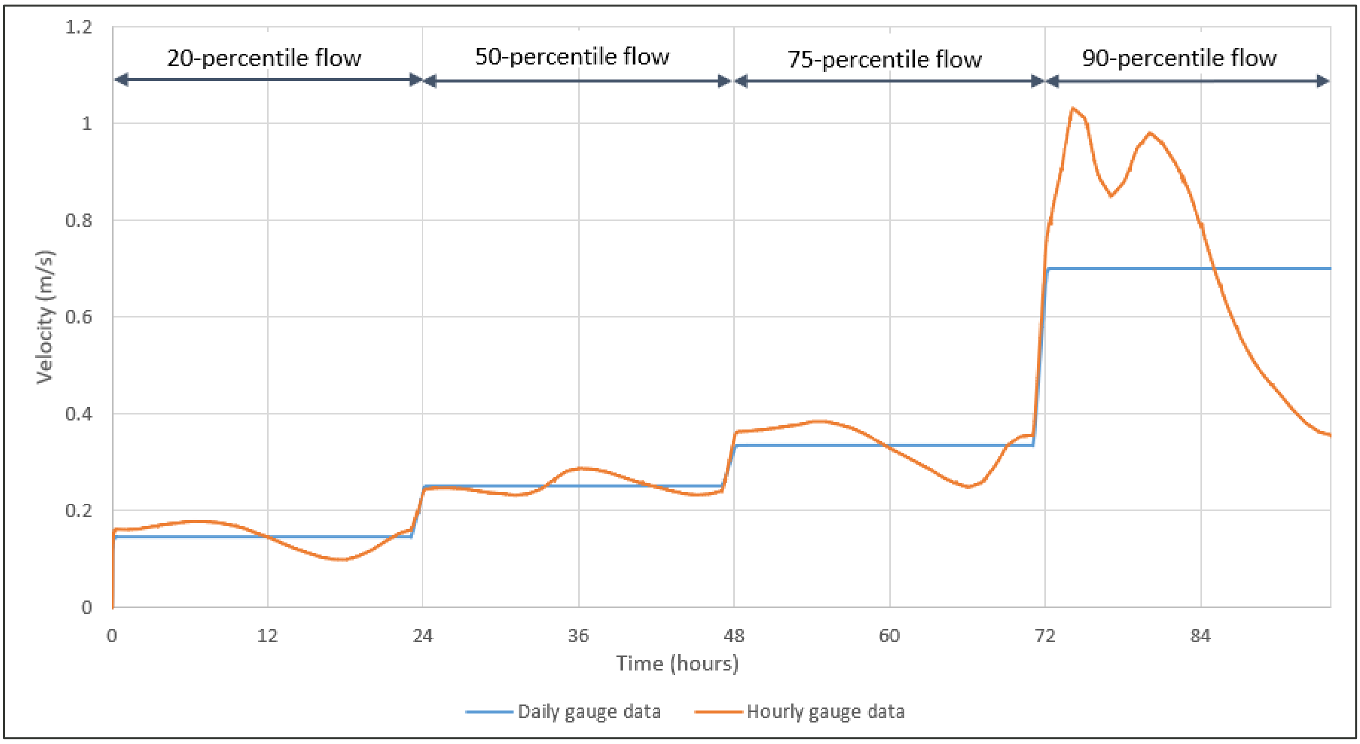


Figure 2-8 TUFLOW output at reporting location C using daily vs hourly gauge inflow data

The modelled results also showed that using daily averaged flows would provide reasonable estimates of velocity for frequent flow events (within 0.05 m/s) but would underestimate peak velocities by up to 0.3 m/s for the higher flow events.

It was determined that simulating daily flows would not affect the accuracy of the outcomes of the eco-hydraulic predictions for frequent flows up to the 90-percentile event. It is also acknowledged that eco-hydraulic predictions should account for the models underestimating peak flow velocities, though these conditions would be short-lived.

Tailwater Level

The Hawkesbury River has a weak freshwater tidal cycle (i.e. non-saline tide) from Wiseman's Ferry (the saline tidal limit) to Yarramundi (approximately 20km upstream from the Wianamatta-South Creek – Hawkesbury River confluence). This influence extends up the lower reaches of Wianamatta-South Creek. The lower reaches of Eastern Creek are subsequently also tidally affected due to the backwater effects from Wianamatta-South Creek and modelling must adopt an appropriate tailwater depth to ensure that velocity predictions in the hydraulic model reflect velocities for a typical range of tailwater conditions.

A sensitivity analysis of tailwater levels was also undertaken to determine the tidal influence on the velocity and shear stress predictions. Table 2-6 displays a range of tidal tailwater levels possible at the Hawkesbury River at Windsor (OEH, 2014). As Eastern Creek experiences backwater effects from Wianamatta-South Creek, it is expected that these tidal fluctuations will propagate upstream and influence the hydraulics at the Riverstone discharge location, approximately 2.5 km upstream from the Eastern Creek – Wianamatta-South Creek confluence.

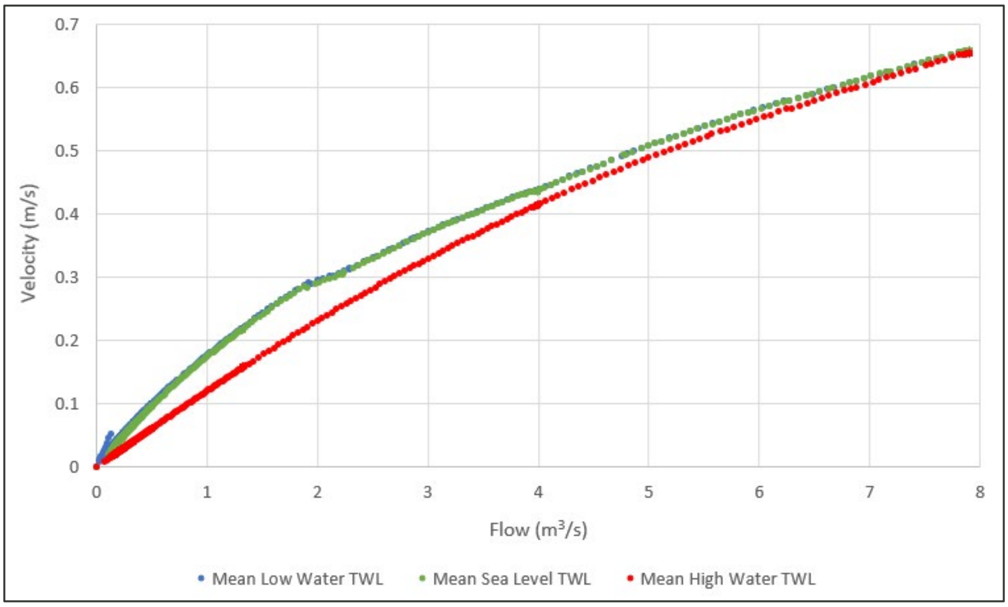
Table 2-6 Tidal levels at Hawkesbury River at Windsor (OEH, 2014)

Tidal condition	Water Level (m AHD)	Comment
Mean Low Water	-0.05	Would result in higher velocities twice a day
Mean Sea Level	0.3	Represents average water level
Mean High Water	0.65	Would inhibit flows several times a day

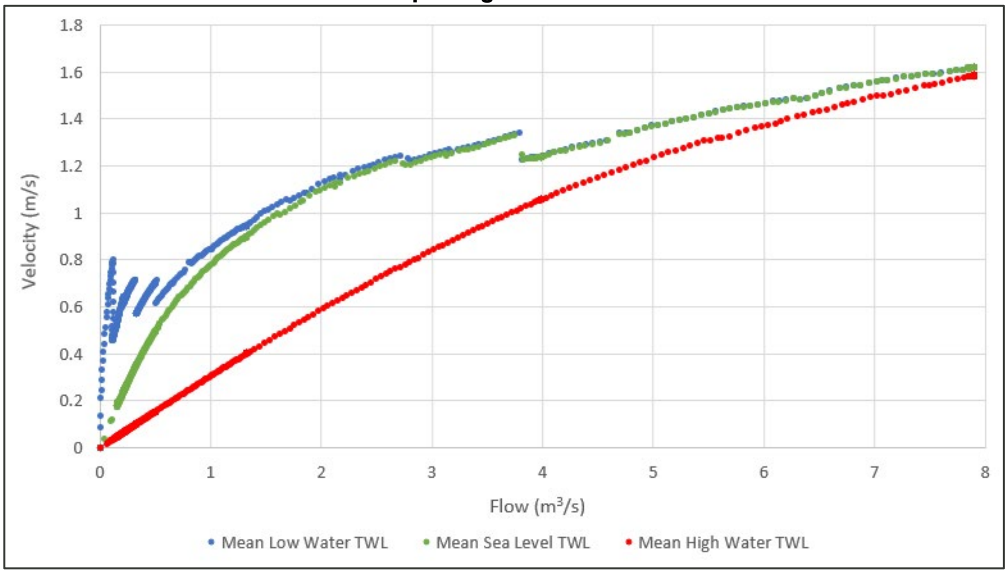
The velocity rating curves at each location under each tailwater condition are graphed in Figure 2-9.

- At Location A, the upstream end of the model, there is little variation between the velocity results for the full range of flows indicating there is not a large tailwater level influence.
- At Location B it can be seen that mean low water and mean sea level result in a very similar velocity rating curve, however velocities would be reduced for a large range of flows under mean high water tailwater level conditions.
- Location C is the closest reporting location to the downstream boundary condition and is shown to have a more pronounced tidal influence. In the lower reach of Eastern Creek, near location C, velocities are expected to be higher during mean low water tide especially for smaller flow events. In contrast, velocities are expected to decrease during high water tide particularly for larger flow events.

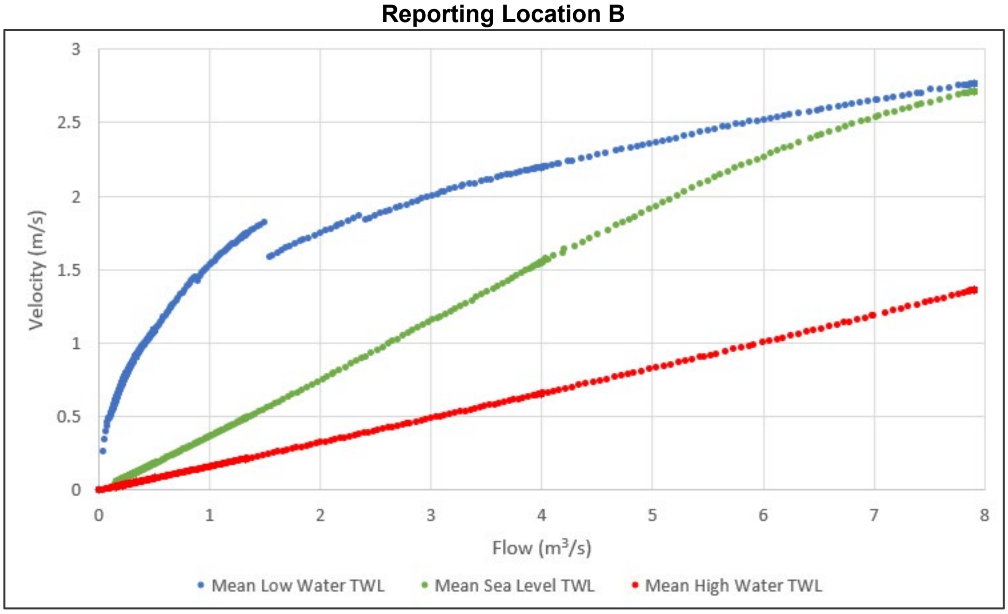
For the purposes of hydraulic modelling in this assessment, the mean sea level tidal condition was selected for the downstream boundary. This was chosen on the basis that the mean sea level would provide the average tailwater condition and average flow velocities typical for a given flow rate across a day. In this way the adoption of a single tail water level would simplify the analysis without losing resolution of the impact of velocity on erosion predictions.



Reporting Location A



Reporting Location B



Reporting Location C

Figure 2-9 Velocity rating curves at each reporting location under each tailwater level condition

3 Existing environment

3.1 Catchment description

Eastern Creek is located within the Hawkesbury-Nepean basin, which encompasses 21,400 square kilometres (km^2), and discharges to Wianamatta-South Creek prior to the confluence with the Hawkesbury River. The Eastern Creek catchment (130 km^2), indicated in Figure 3-1, is comprised of un-zoned, rural and peri-urban land zones. Large areas of the catchment have been designated for urban development (Catchment Simulation Solutions, 2014). The catchment falls within the National Climatic Zone 6 indicating the general climate is considered temperate with no defined dry seasons and warm to hot summers (BoM 2021).

Stream ordering provides an indication of the relative size of a watercourse. Strahler's Stream order system, as prescribed by NSW DPI (2018a), is a simple method of classifying stream segments based on the number of contributing tributaries.

The Strahler stream orders for Eastern Creek at the assessed discharge locations was determined using the available NSW Hydro Line spatial data (NSW DPI, 2018b). Eastern Creek is defined as a Strahler stream order of four (4) indicating inflow from a number of headwater streams.

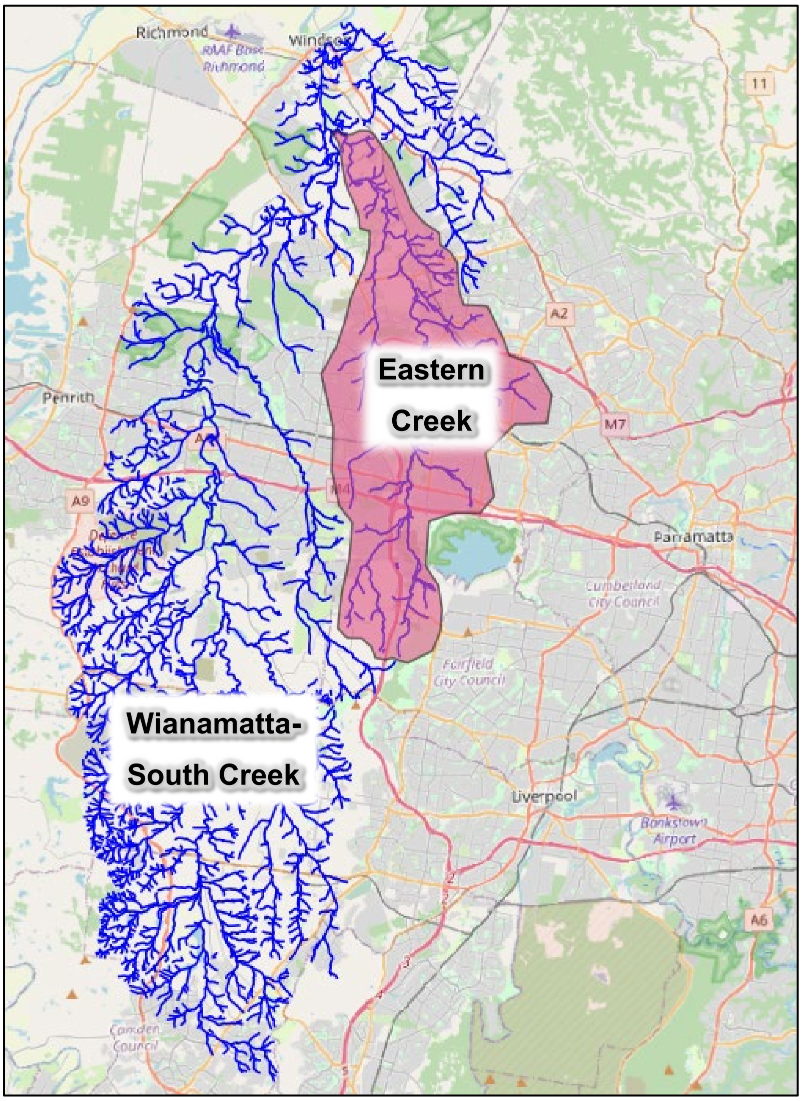


Figure 3-1 Eastern Creek catchment

3.2 Key aquatic features

Eastern Creek aquatic physical habitat values were identified from the North West Treatment Hub – Sensitive Aquatic Habitat Summary (ELA, 2021) (refer Table 3-1). This ELA (2021) summary identified that the assessed section, downstream of the discharge, was likely comprised of silt and clay substrates which have limited resistance to scour. Evidence of bank erosion is present within the channel and the assessment identified that the channel, whilst in typically poor condition, is still suitable for small fish and amphibians.

No species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) *Fisheries Management Act 1994* (NSW) are contained in Eastern Creek. The creek is, however, listed as NSW DPI 'key fish habitat' (NSW DPI, 2013). Changes to the hydrology and geomorphology with Eastern Creek, due to Riverstone WWTP discharge changes, were used to predict impacts to ecology (i.e. fish habitat).

Table 3-1 Key aquatic features of Eastern Creek downstream from discharge

Reach	Hydrology	Physical form	Instream habitat	Streamside vegetation	Overall condition
Eastern Creek Downstream of WWTP discharge point	4th order stream. Predominantly cleared catchment used for agriculture. Continual flows. Evidence of very high previous flows, with flood debris evident in trees No impoundments or significant barriers to flow, apart from a fallen tree across the creek.	Channel up to 10 m wide Banks up to 2 m high, mostly 45° slope. Channel has low grade and low sinuosity and is well defined through a predominantly grassed floodplain. Some bank erosion observed where stock have accessed the creek and where banks have been undercut and a large tree had fallen into the creek. Substrate likely silt and clay	Key fish habitat – Type 1 highly sensitive where native macrophytes are present and Type 2 Moderately sensitive key fish habitat due to continuous flows. Flowing at time of survey 100% run sequence, no pools or riffles observed. Some large submerged woody debris, contributing to habitat. Channel suited to amphibians and small fish, though none observed. Limited macrophytes, mainly in clumps alongside right bank Water relatively turbid.	Poor riparian extent and continuity, typically dominated by Erythrina sp. No evidence of native recruitment. Riparian structure notably absent of a native canopy, midstorey and groundcover 15% tree cover 5% shrub cover 80% exotic grass	Poor condition, stabilised bank only by exotic canopy trees.

Source: ELA (2021)

3.3 Geology and bank composition

Regional surface geology mapping indicates Eastern Creek overlays Quaternary alluvial floodplains which transition to Holocene alluvial floodplain downstream of the Riverstone discharge.

A sample of the bank material (Figure 3-2) was collected downstream of the discharge location. The sampling location (SD03) is shown in Figure 3-10 (Lat -33.653186, Long 150.836072). The particle size distribution is shown in Figure 3-4, which shows the surface of the overbank comprises mainly of silt/clays (<0.063 mm) and sands (0.038 – 2.000 mm).

It is noted that this sample is not necessarily representative of material in the bed. It is expected that material collected in the location represents highly mobilised sediments while heavier and larger particles would comprise bed material, For this reason, a range of particle sizes have been considered in the assessment.

Figure 3-2 Photo of bank material where soil sample was taken

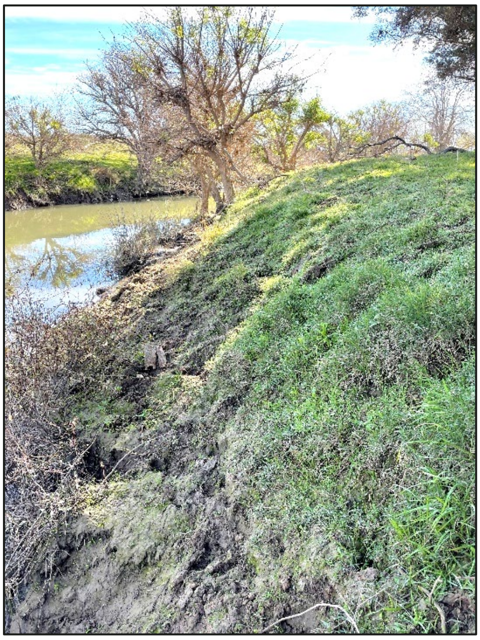


Figure 3-3 Right bank d/s of discharge

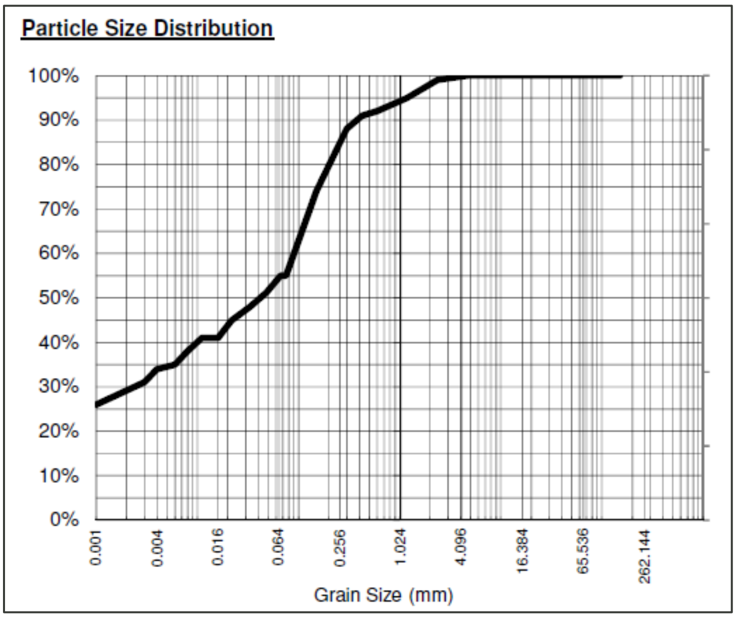


Figure 3-4 Particle size distribution of bank material

3.4 Flow monitoring data

A streamflow gauge is located upstream of the discharge point on Eastern Creek, within Bungarribee Park (Western Sydney Parklands). The gauge was installed in October 1982, however continuous data is only available from 1989. The metadata associated with this stream gauge is indicated in Table 3-2.

Table 3-2 Stream flow gauge related to Riverstone WWTP

Station name	Station number	Catchment area (km^2)	Data owner	Number of records (years)	Record commenced
Eastern Creek at Riverstone	212296	118	Sydney Water	+20	01/01/1989

The flow regime in Eastern Creek can be studied by plotting the flow duration curves (refer Figure 3-5). The three curves represent the following datasets:

- Gauge (1989 – 2021): The full record of flow data available at the gauge
- Simulated (2012 – 2018): The simulated flows under current conditions, excluding any discharge from the plant (i.e. Scenario 1A in Table 2-3)
- Gauge (2012 - 2018): Gauge data for the period corresponding to the available simulated synthetic record

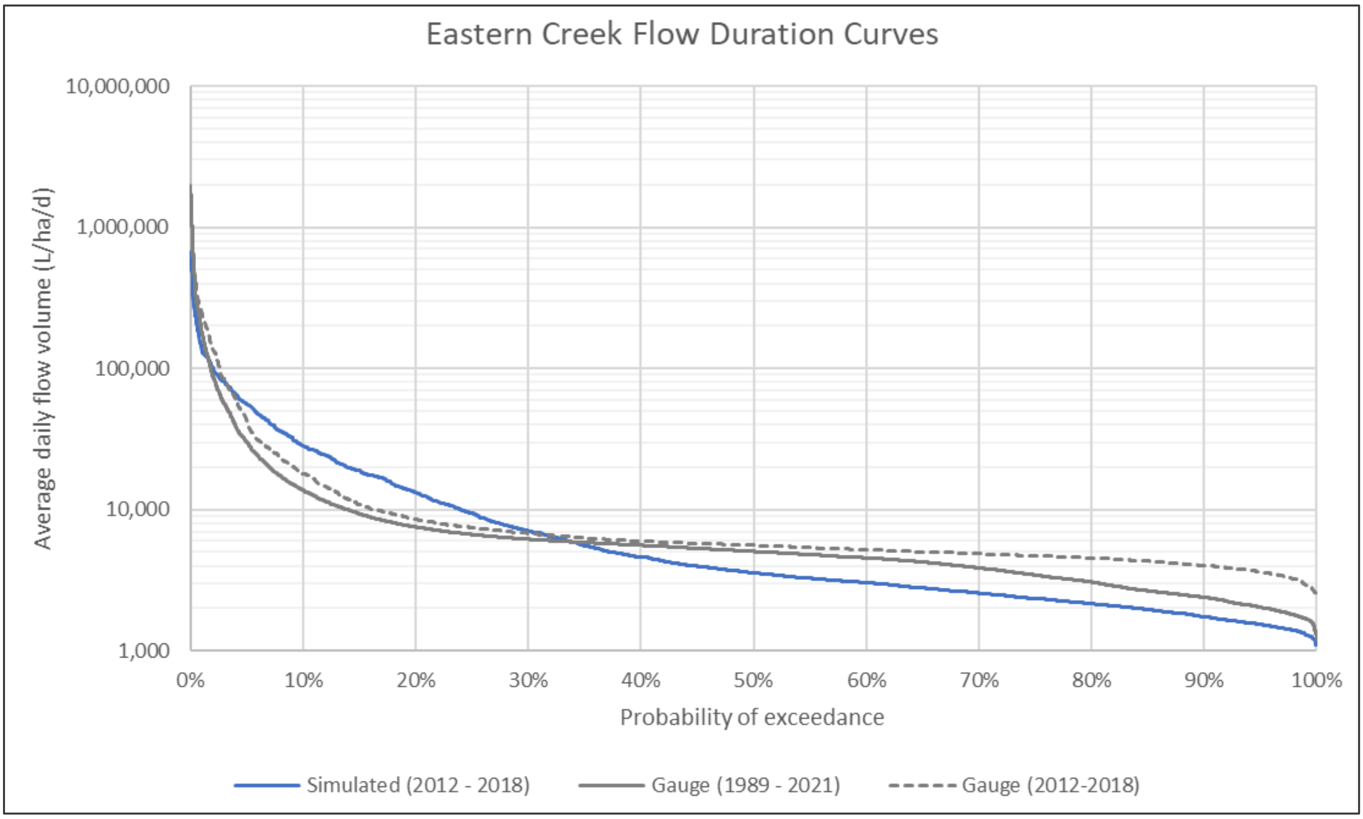


Figure 3-5 Flow duration curves – Measured vs simulated flow data

Flow duration data (in ML/d) for Eastern Creek are presented in Table 3-3. Key percentiles for the gauge data are summarised below:

- 25th: Representation of high flows, 25% of the time the flowrates exceeded 88 ML/d
- 50th: Median flow rate of 66 ML/d. This is significantly different from the average flow rate of 193 ML/d due to excessive flood conditions influencing the average more than the median value

- 75^{th}: Representation of low flows, 25% of the time the flowrate is below 56 ML/d
- 90^{th}: Representation of very low flows, 10% of the time the flowrate is below 48 ML/d.

Table 3-3 Summary statistics for Eastern Creek flow duration curves

Dataset	Percentile exceedance flow rate (ML/d)					Average flow (ML/d)
	20^{th}	25^{th}	Median	75^{th}	90^{th}	
Gauge (2012-2018)	101	88	66	56	48	193
Simulated: No discharge (2012-2018) Scenario 1A	161	115	43	29	21	160
Simulated: With discharge (2012-2018) Scenario 1B	169	122	50	34	27	168

3.5 Fluvial geomorphology

The River Styles framework is used to characterise geomorphic river conditions of rivers and identifies the sensitivity to change (fragility) and likelihood of recovery. The framework provides for a high-level, qualitative assessment of the general geomorphic condition. The river styles characteristics for Eastern Creek are identified in Table 3-4.

The upstream and downstream reaches of Eastern Creek indicate limited differences in typical geomorphology with the exception of noted bank erosion zones downstream of the discharge (refer Figure 3-6) and a higher recovery potential, upstream. Based on the fragility characteristic, both sections have limited resilience to changes indicating the potential for a change to shape, location or condition under disturbance. The change in recovery potential between the reaches is likely linked to upstream land use practices.

Table 3-4 Eastern Creek River Styles characteristics (after Brierley and Fryirs 2005)

Watercourse	River style	Stream condition	Recovery potential	Fragility	Comments
Eastern Creek d/s of discharge point	Laterally unconfined valley setting, continuous planform channel with low sinuosity and fine-grained bed (River Styles, 2022).	Moderate	Moderate	Moderate	Minor bank erosion in parts
Eastern Creek u/s of discharge point			High		-

Figure 3-6 Eastern Creek – Bank erosion

Limited evidence of lateral movement of the creek channel is noted from historical aerial imagery between 1947, 1965 and 2005 and the latest available imagery from 2021 (Nearmap, 2021) (Figure 3-8, Figure 3-7 and Figure 3-9). The hydrology in the upstream catchment would have changed over this period due to partial urbanisation as well as treated effluent discharges.

The limited lateral movement of the watercourse between 1947 and 2005 imagery suggests resilience to significant geomorphological changes. This, combined with low sinuosity in the river channel, demonstrates that lateral migration is low - creek banks are not actively being eroded with this material deposited further downstream on point bars.

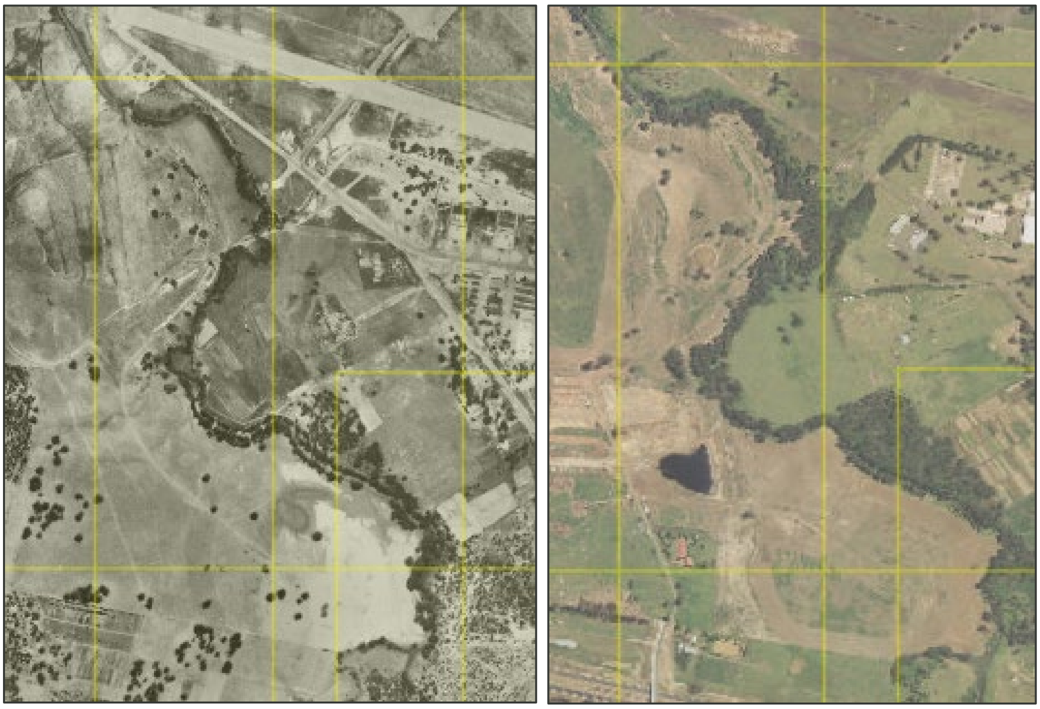


Figure 3-7 Eastern Creek upstream [~2.5 km upstream of discharge] (1947 *vs.* 2005)

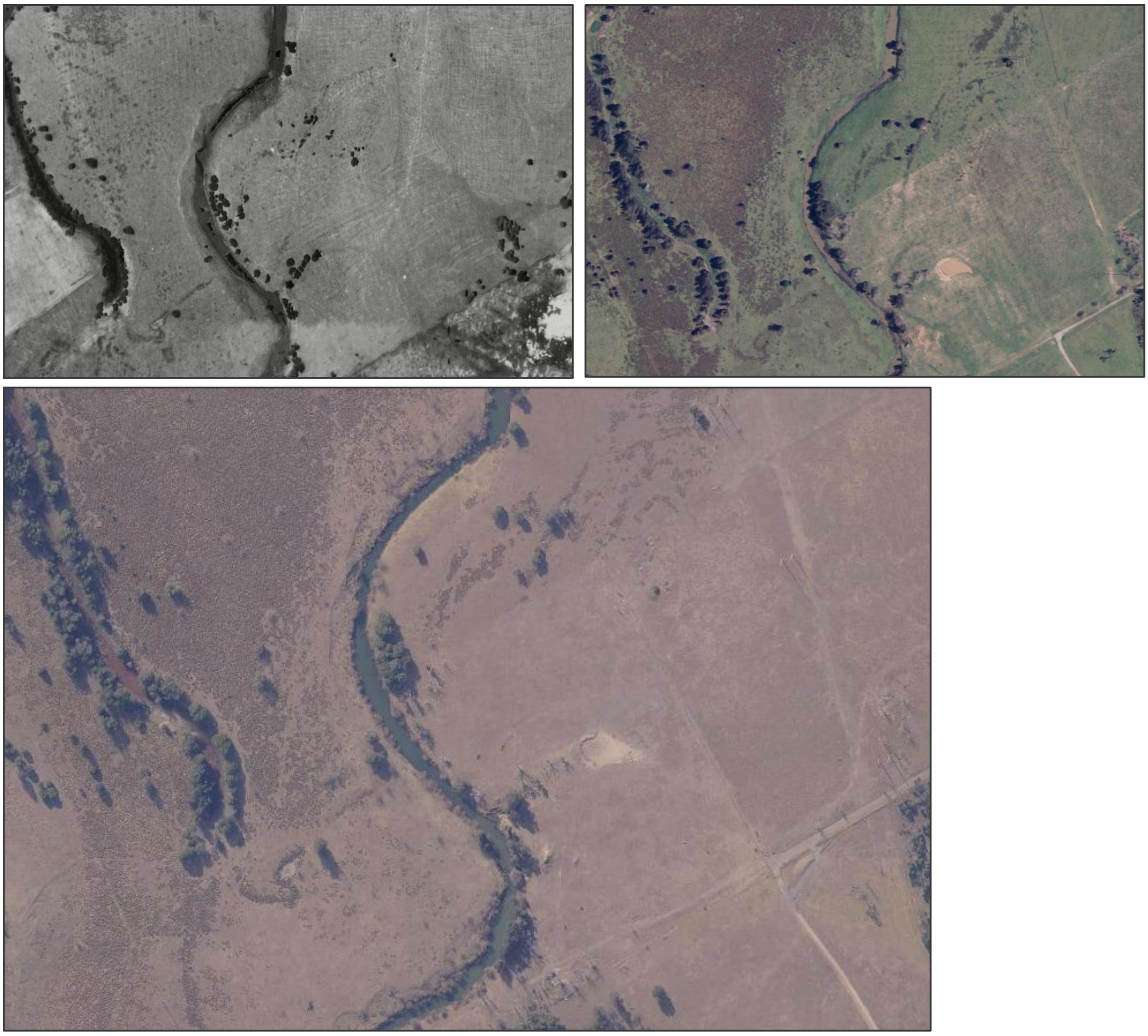


Figure 3-8 Eastern Creek at discharge (1947 vs. 2005 vs 2021)

Figure 3-9 Eastern Creek downstream [~ 2 km downstream of discharge] (1965 *vs.* 2005)

A limited snapshot assessment of bank sediment particle size distribution (SD03, refer Figure 3-4) indicates a particle size distribution (PSD) ranging from 0.001 millimetre (mm) to 4.75 mm (PSD provided in Figure 3-4). The median particle size (D50) was 0.042 mm, which lies in the silt-size range. Principal components of the sediment are clays / silts (<0.063 mm) and fine sands (0.063 – 0.125mm), medium sands (0.125 – 0.500 mm) and coarse sands (0.500 – 2.000 mm). The presence of this material indicates the floodplain is a deposition zone.

Contour mapping of a limited section (190 metres) of Eastern Creek, approximately 300m downstream of the Riverstone discharge point indicates some incision of the channel in the surrounding landscape (refer Figure 3-10). Within the assessed reach, the watercourse is typically three to five metres below the surrounding floodplain, indicating the potential for intermediate flow regimes (relative to over-topping events) to have a considerable impact on watercourse geomorphology via vertical accretion.

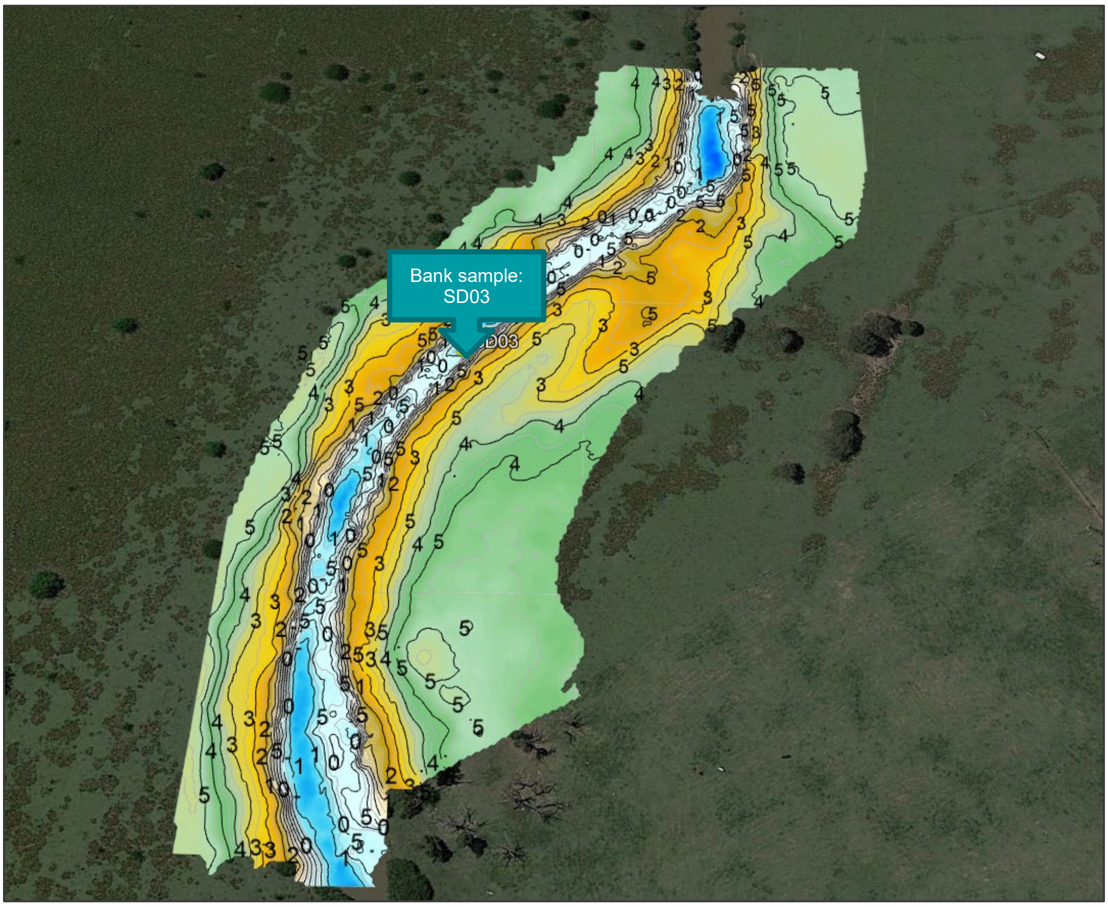


Figure 3-10 Floodplain and channel survey of study area

The existing bathymetry gathered in 2021 (described in Table 2-4) also shows there are several raised sediment bars and deeper pools along the creek long section, as seen in Figure 3-11. The extent of the bathymetry shown is for the length of the hydraulic model (upstream boundary at chainage 0m, downstream boundary at ~304m).

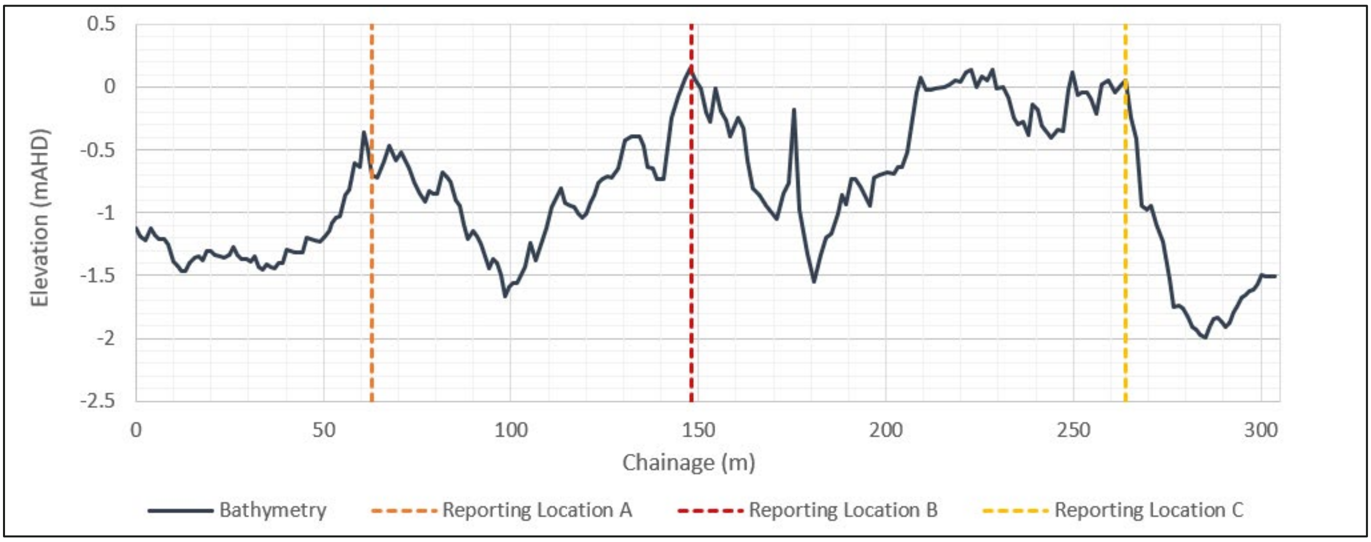


Figure 3-11 Bathymetry along creek thalweg

The raised zones may be 'slugs' of sediment moving north to the Hawkesbury River or may be natural formed bars adjacent to pools, forming a pool and riffle sequence. The composition of these slugs is not known but is expected to be historical sediment deposition from the upstream catchment and these are subject to erosive forces during critical flow events. Reporting locations were selected to coincide with these bars or slugs because:

- The shallower zones on top of the bars are the critical locations where flow velocity dictates the rate of erosion and downward migration of sediment.
- These shallower zones are also likely to be the zones where fish would find fish passage to be more difficult and these zones pose the greatest risk to upstream movement.

The selection of these locations are deemed conservative, as the deeper pools are expected to exhibit lower velocities and proportionally would be less prone to erosion but would conversely be subject to deposition if the rate of erosion or frequency of erosion should increase. If acceptable changes to erosion rates over the bars are found, then the same would be the case in the deeper pools . Insufficient data is available to determine whether erosion is potentially beneficial to the system in this reach.

4 Impact assessment

4.1 Eco-hydraulic thresholds

As described in Table 2-5 (Section 2.3.2), the full range of expected flow rates were run through the hydraulic model and velocity, depth and water levels corresponding to each of these flow rates have been analysed.

Cross-sectional results were output for each of the three assessment locations described in Section 2.3.3. For the eco-hydraulic velocity thresholds, Location B was identified as the critical location for assessment, where there was risk of impeding fish passage. Location B is an area where the waterway is slightly constricted and may increase water flow velocities and impede flow. The Manning's coefficient was set to 0.03 within the creek to represent the minimal environmental substrate roughness inhibiting water velocity.

A relationship between velocity and flow (i.e. a velocity rating curve) was established at Location B to determine the portion of the time these thresholds would be exceeded for each hydrologic scenario. The velocity exceedance curve and tabulated results for Location B are presented below.

This analysis has assumed that fish use the edges of the channel for refuge habitat whilst fish passage would be sought on an opportunistic basis wherever in the channel cross-section there was space and suitable flow velocities to enable swimming upstream. This is shown in Figure 4-1 and Figure 4-2 indicating discrete areas within the creek that exceed the eco-hydraulic thresholds (i.e. prolonged swimming performance) for the 50th percentile flowrates. As the threshold assessment indicates unhindered fish passage along the edge of the channel, fish behaviour is expected to be altered as an impact of increased velocity at the 50th percentile flowrate. Figure 4-3 and Figure 4-4 show that there is some change to fish passage along the edge of the channel at the 75th percentile flow and this may impact the passage of slower swimming fish such as Gudgeon under 2036 discharge conditions where it was unhindered in the 2020 conditions. At the 90th percentile flow conditions shown in Figure 4-5 and Figure 4-6, fish passage is impacted at several sections of the creek for fish of all assessed swimming abilities in the 2020 discharge conditions and remain as such in the 2036 discharge conditions.

Comparison maps between velocity results under 2020 and 2036 discharge conditions are presented in Figure 4-7 through Figure 4-9 to show the overall velocity impact along the creek under the 50th, 75th and 90th percentile flowrates respectively.

The velocity mapping shows that zones of the waterway are likely to be impassable to fish under current day conditions, but generally fish could use the outer banks to migrate upstream up to the 90th percentile flow event.

Under the 2036 discharge scenario, the same zones of high velocity will form and the creek centre line will become impassable for most species in the 50th and 75th percentile event. Again, modelling indicates that the outer banks of the waterway are likely to remain passable up to the 90th percentile flow event. Thus the extent of habitat is not likely to be impacted by worsening or preventing upstream fish migration.

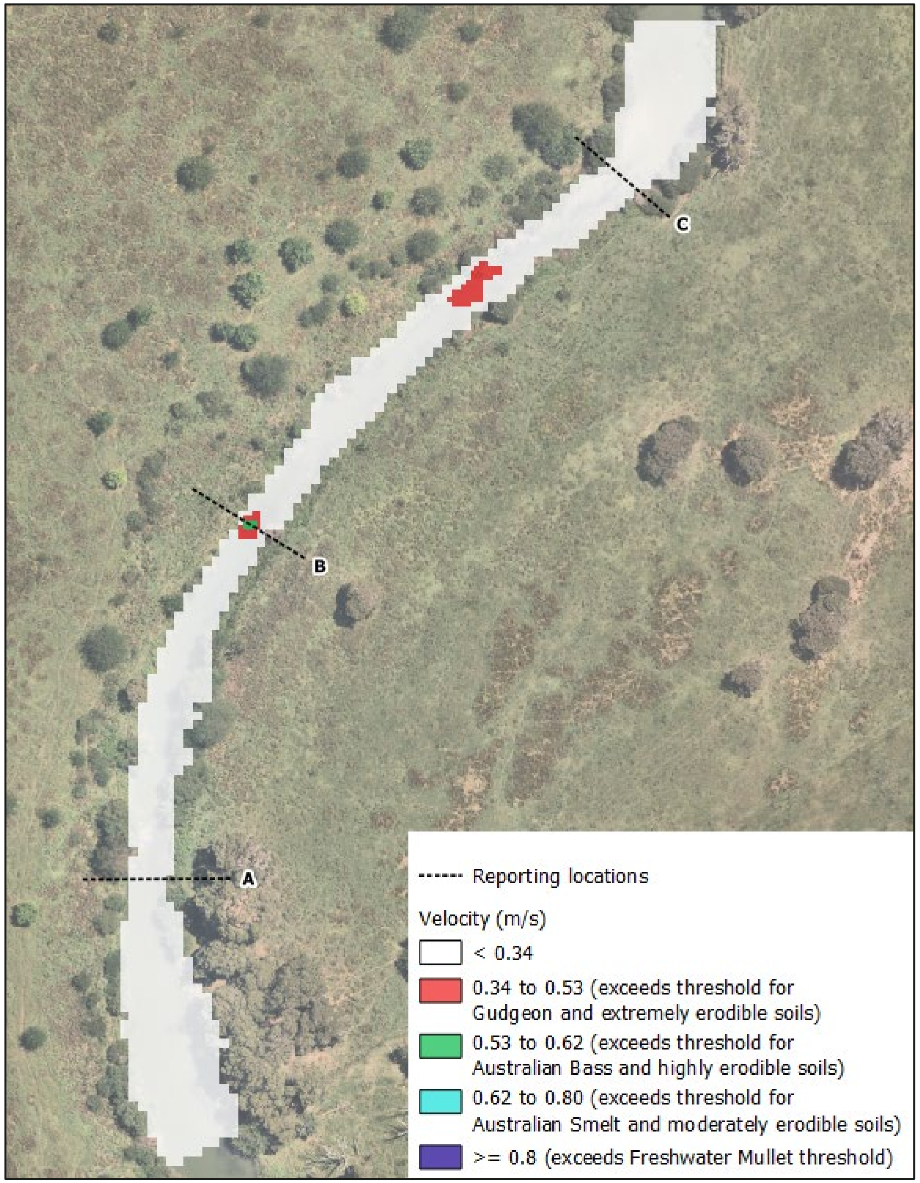


Figure 4-1 2020 Discharge scenario velocity at 50th percentile flow

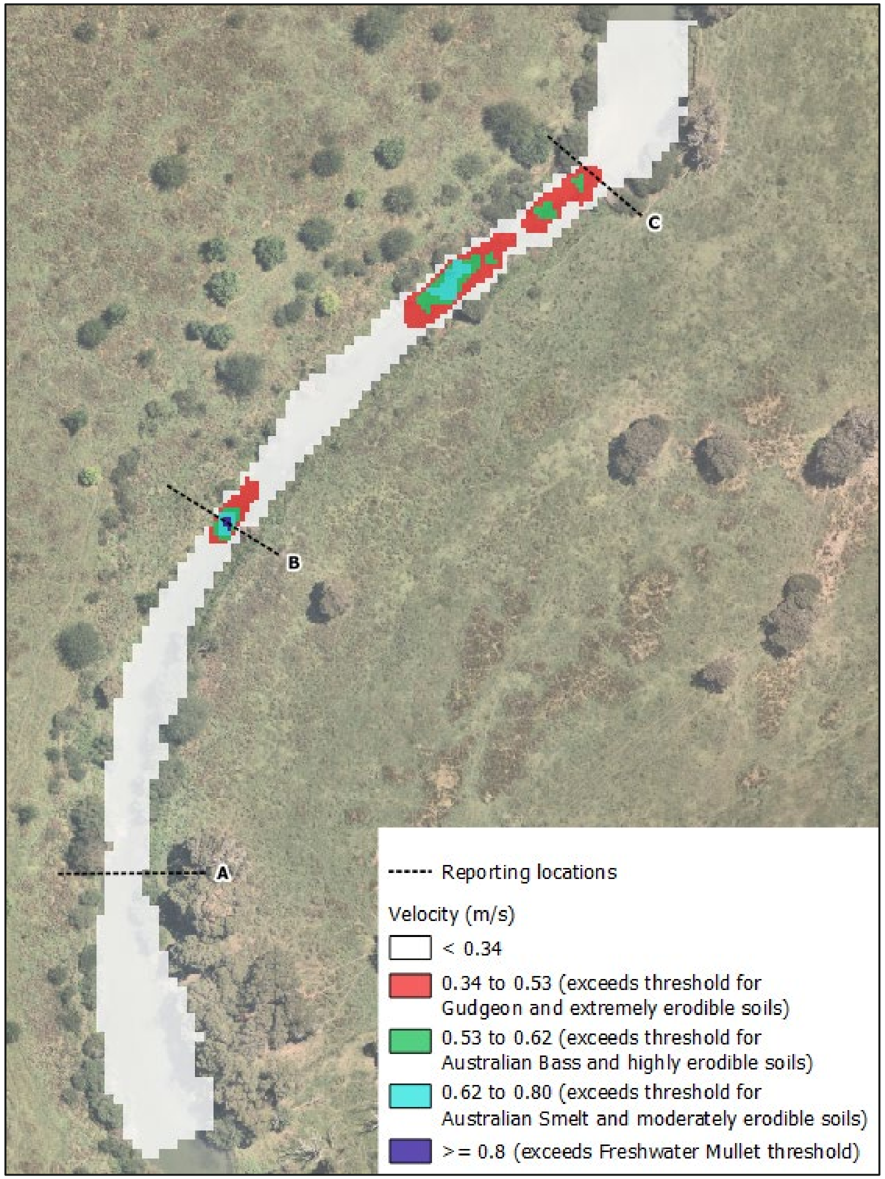


Figure 4-2 2036 Discharge scenario velocity at 50th percentile flow

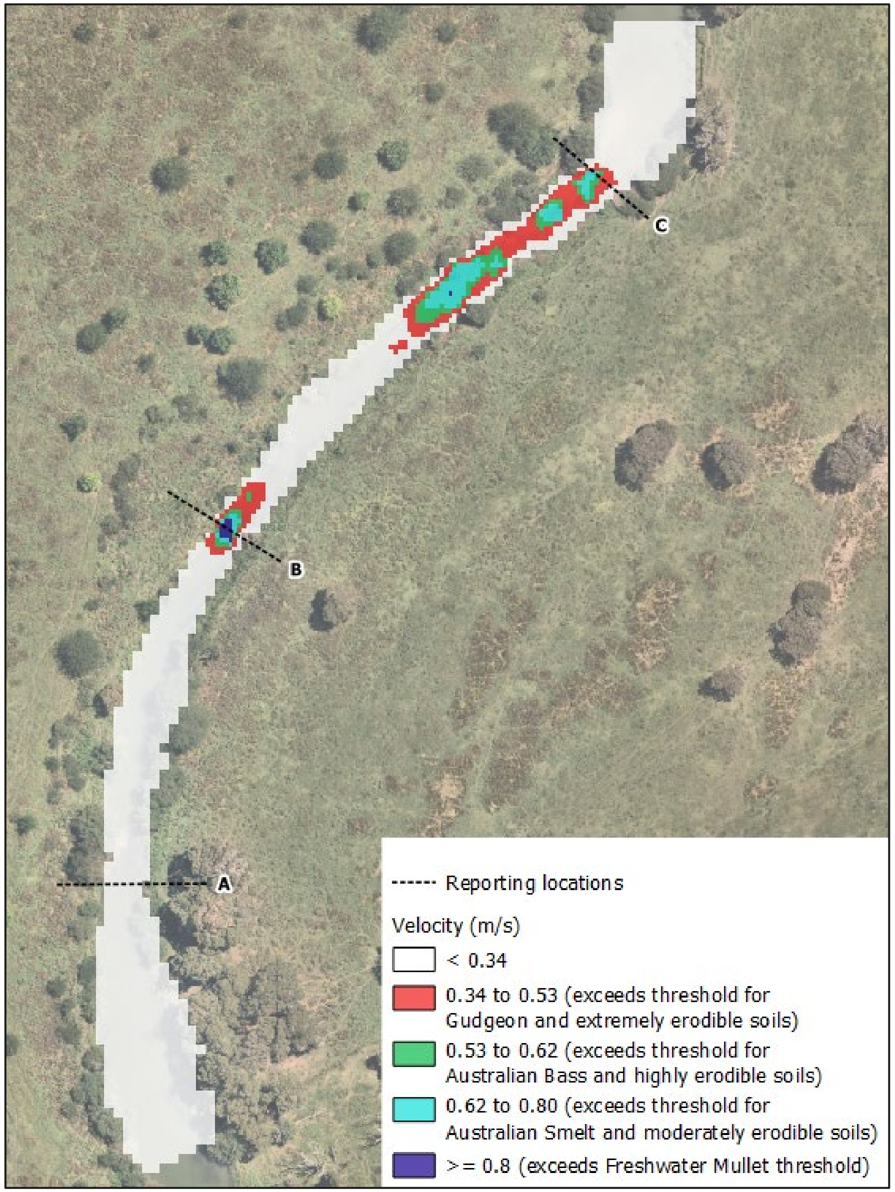


Figure 4-3 2020 Discharge scenario velocity at 75th percentile flow

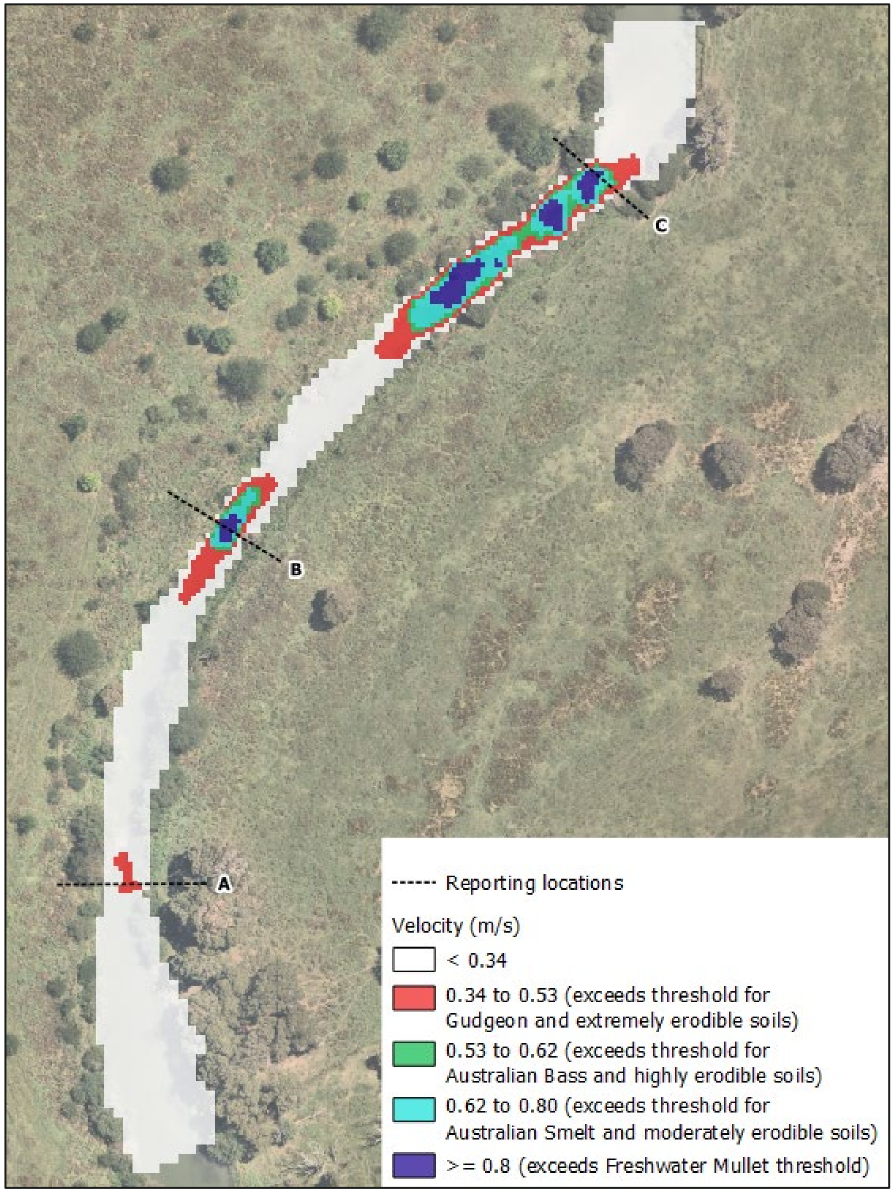


Figure 4-4 2036 Discharge scenario velocity at 75th percentile flow

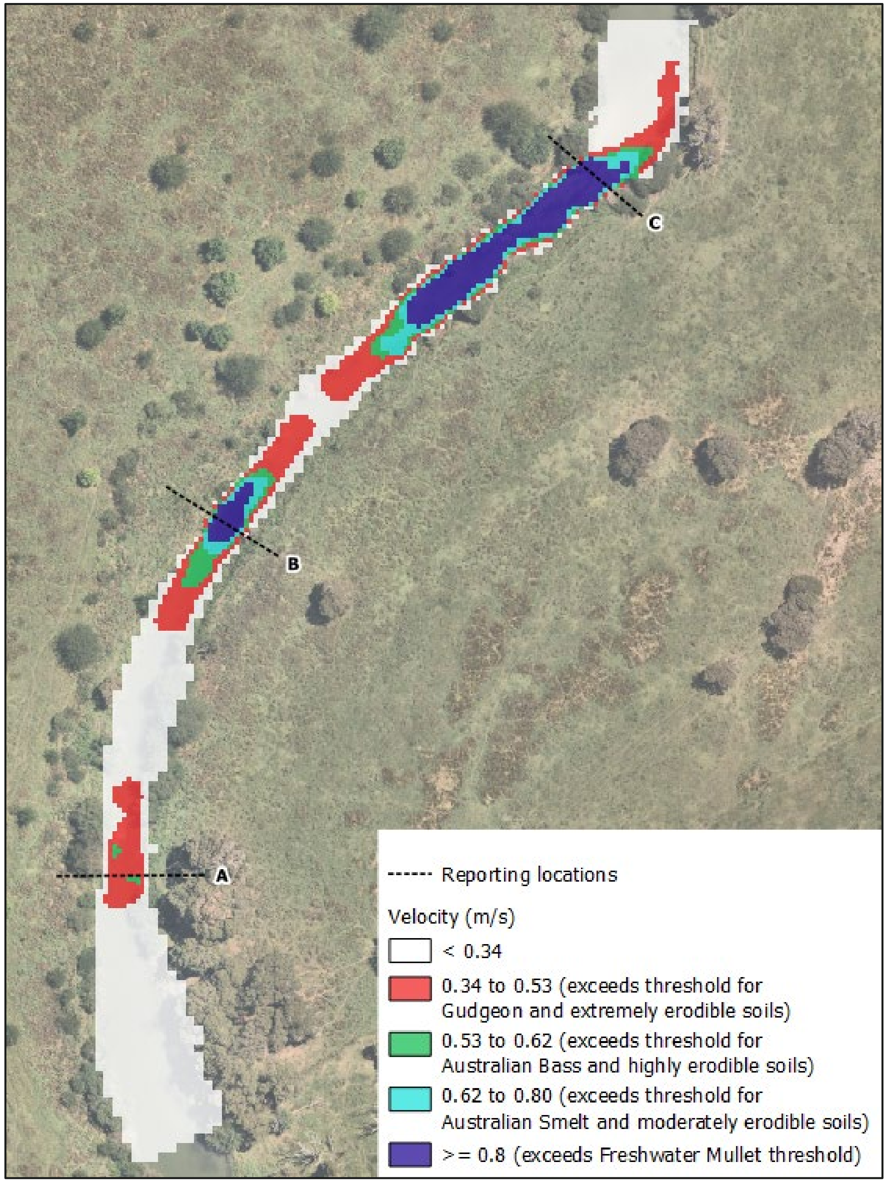


Figure 4-5 2020 Discharge scenario velocity at 90th percentile flow

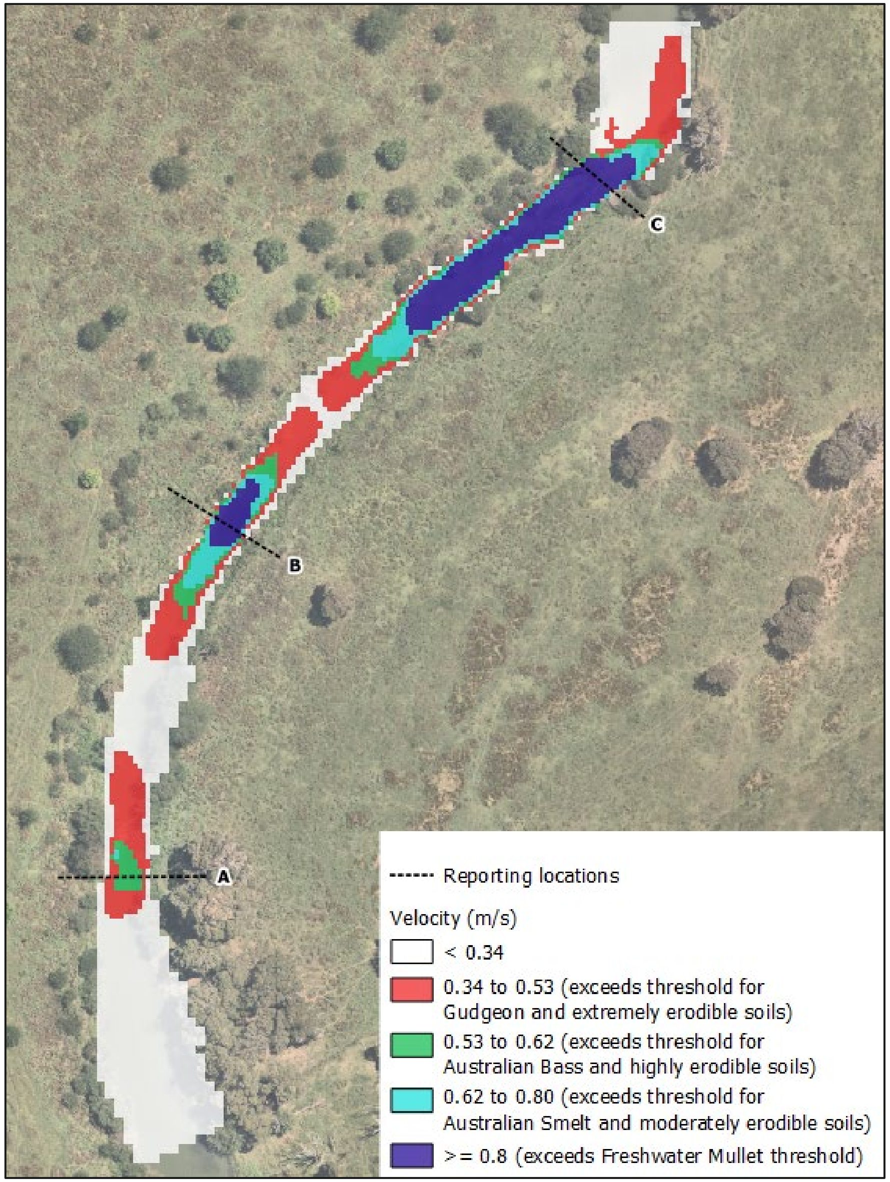


Figure 4-6 2036 Discharge scenario velocity at 90th percentile flow

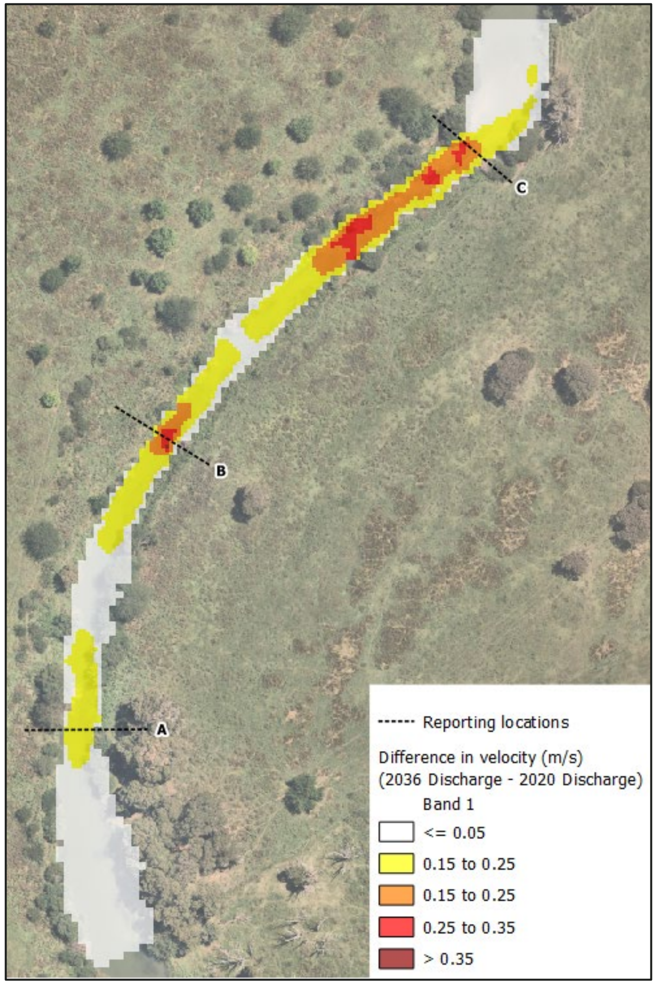


Figure 4-7 Velocity difference map at the 50th percentile flowrate (2020 vs 2036)

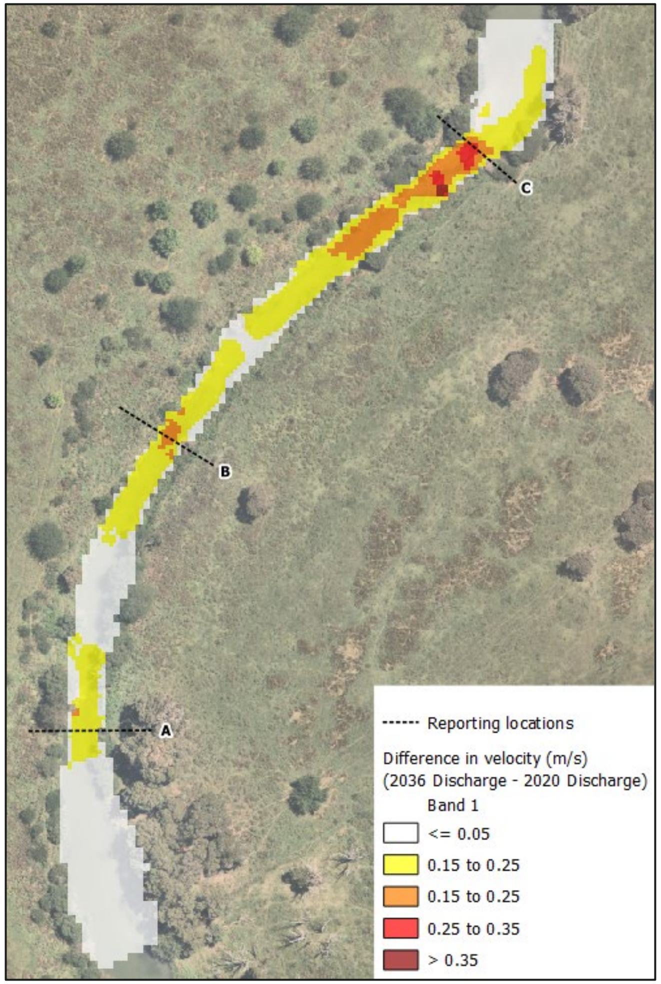


Figure 4-8 Velocity difference map at the 75th percentile flowrate (2020 vs 2036)

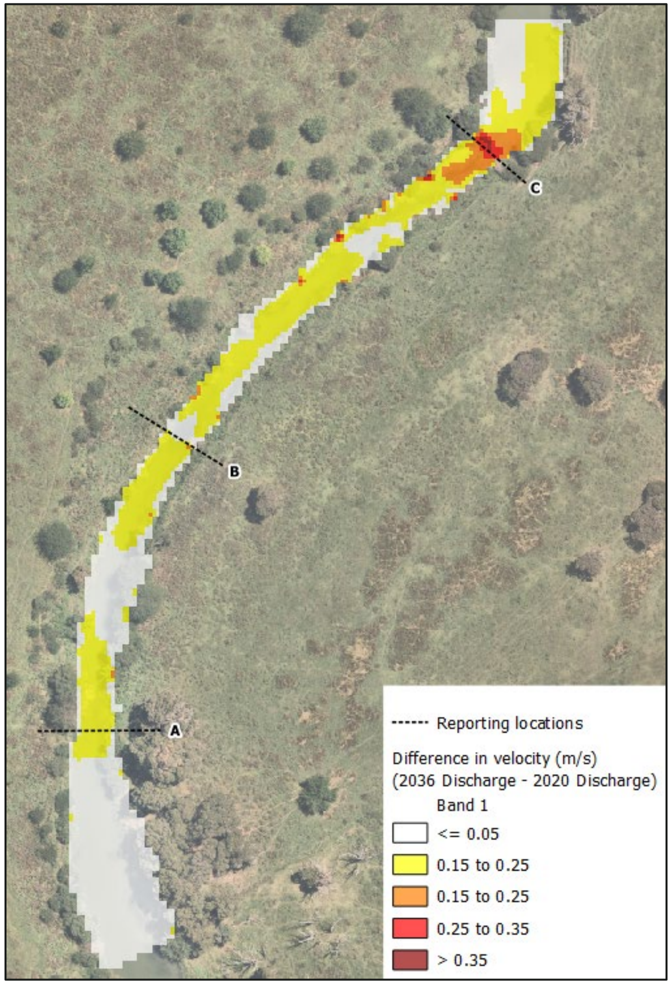


Figure 4-9 Velocity difference map at the 90th percentile flowrate (2020 vs 2036)

4.1.1 Erosion and fish passage impact risk at Location B

Within the 2020 scenario, modelling indicates that at Location B (a narrow section that creates an area of increased velocity), impact to the selected fish species that prefer slower moving waters (i.e. Empire and Firetail Gudgeon) is potentially occurring (refer Table 4-1 and Figure 4-10). These represent a portion of time where continual swimming performance is exceeded and represent existing potential impact, limiting habitat use. This portion of time of potential impact is reduced for those fish which are stronger swimmers (i.e. Freshwater Mullet and Australian Smelt) and is typically exceeded less than 50% of the time.

While the cross-sectional average velocities exceeded the swimming performance, it is considered that impact would not be substantial with the presence of instream structures (e.g. large woody debris) that slow down velocities and provide refuge within the creek. As such, flows during the 2020 scenario are not expected to impact fish swimming performance as impact is typically below 50% of time and it is expected that in-stream structures observed within Eastern Creek would provide some protection from high downstream velocities.

Within the 2036 discharge scenario, the creek centreline velocities exceed the threshold for several species such as the Empire and Firetail Gudgeon and Australian Bass for the full range of flow rates. This portion of time of potential impact is reduced for those fish that are stronger swimmers (i.e. Freshwater Mullet and Australian Smelt) however is exceeded more than 50% of the time. As this is considered a potentially impactful change, various cross-section points (i.e. east bank/west bank and channel centre) provided in Appendix B were interrogated to identify if impact was mitigated within different parts of the waterway channel. At this cross-section, velocities are not significantly reduced at the banks for the 50th percentile flow (approximately 100 ML/day) and would be exceeding these velocity thresholds more than 50% of the time across all points of the creek section.

Modelling indicates that the outer banks of the waterway are likely to remain passable up to the 90th percentile flow event. Thus, the study reach shows that while impassable conditions are likely to result, this is not significantly worsened by additional wastewater discharge.

Table 4-1 Portion of time average velocity exceeding aquatic ecology zone thresholds (Location B)

Impact receptor / Risk	Velocity required for impact (m/s)	% of time that velocity is exceeded			
		2020 No Discharge	2020 With Discharge	2036 No Discharge	2036 With Discharge
Empire Gudgeon	0.34	77%	89%	92%	100%
Firetail Gudgeon	0.34	77%	89%	92%	100%
Australian Bass	0.53	45%	51%	46%	100%
Australian Smelt	0.62	38%	41%	39%	87%
Freshwater Mullet	0.80	29%	31%	30%	61%

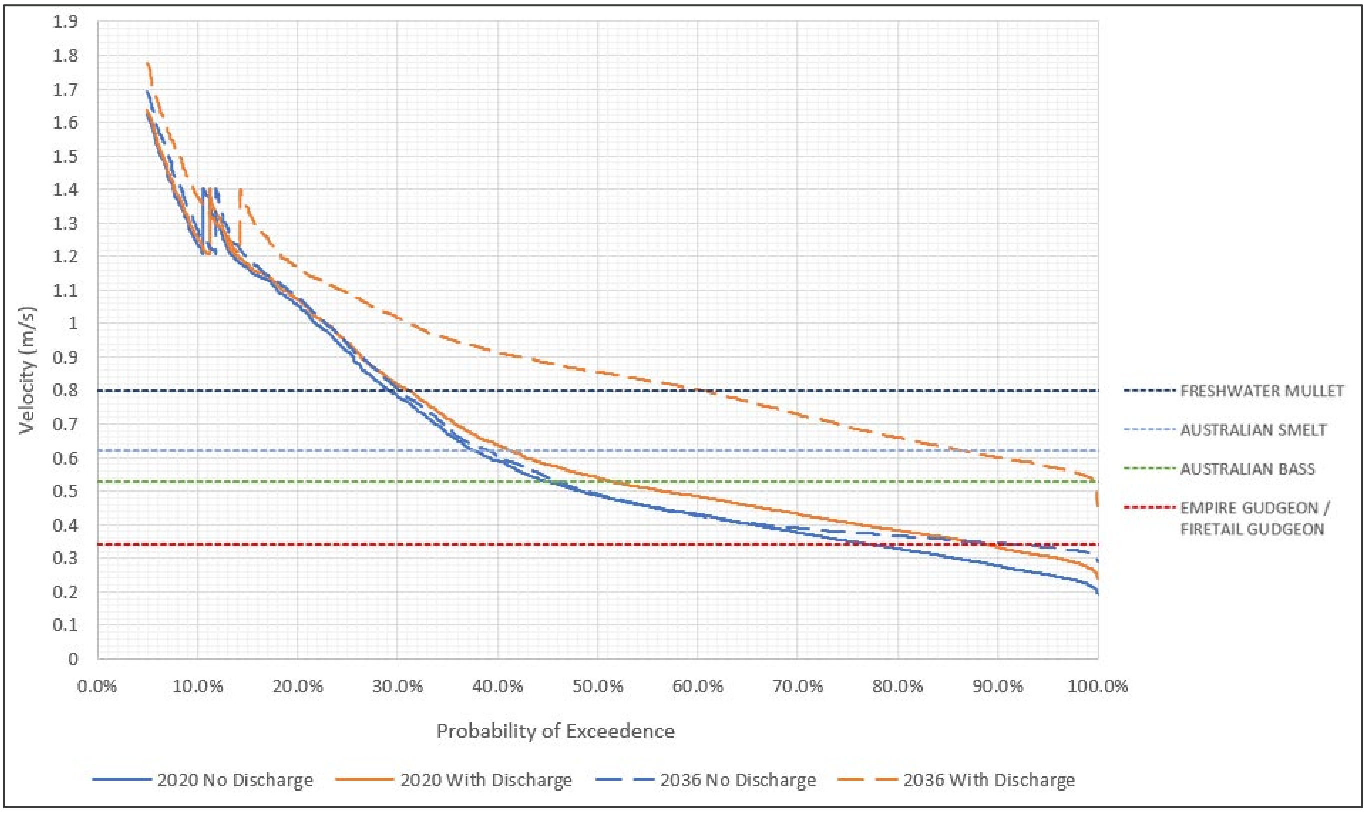


Figure 4-10 Location B velocity exceedance curve

Note: There is a distinct change in the velocity rating curve at 327 ML/day, partially due to a section of sub-critical flow directly downstream at these flowrates. As such, there are two representative relationships above and below this flow on the velocity exceedance curve. Velocities will likely transition over this range.

4.2 Fluvial geomorphology: Erosion risk based on shear-stress

Locations A, B and C (refer Section 2.3.3) were used to model shear stress to determine risk to bank erosion and macrophyte dislodgement. Bank erosion was predominantly discussed with respect the creek geomorphology, but also has indirect implications to channel stability and may cause deterioration of fish habitat, including submerged / emergent macrophytes.

The velocity and water level time series results were extracted at a single point on the cross-section and converted to bed shear stress using Equation 4-1.

$$\tau_{bed} = \frac{\rho g V^2 n^2}{y^{\frac{1}{3}}}$$

$\rho = density\ \left(\frac{kg}{m^3}\right)$ $V = velocity\ \left(\frac{m}{s}\right)$ $y = depth\ (m)$

$g = gravity\ (\frac{m}{s^2})$ $n = Manning's\ coefficient$

Equation 4-1. Bed shear stress calculation in TUFLOW hydraulic model (BMT, 2018)

Point results were used rather than cross-sectional averages, as Equation 4-1 varies with, and is sensitive to, depth. A sensitivity analysis was undertaken (presented in Appendix B) comparing point results from the creek centre and from the eastern and western banks. It was determined that the centre point both exceeds the various critical tractive force thresholds more often than at the banks and identifies the greatest risk of change in conditions between 2020 and 2036 flow conditions. Bed shear stress at the creek centre point also presents a better indicator of erosion risk compared to the bank erosion in this reach of Eastern Creek and it was deemed more appropriate to present results from the creek centre point for a conservative comparison. While localised bank erosion was noted in photos, aerial photos do not show significant alteration in channel migration.

Figure 4-11 and Figure 4-12 also show how these bed shear stress results vary spatially across the creek for the 2020 and 2036 discharge scenarios under the 50-percentile flow.

A comparison map between bed shear stress results under 2020 and 2036 discharge conditions under the 50-percentile flow has been presented in Figure 4-13 to show the scale of change overall to bed shear stress impact along the creek.

The shear stress exceedance curves and tabulated results for the locations at risk of erosion impacts are presented below.

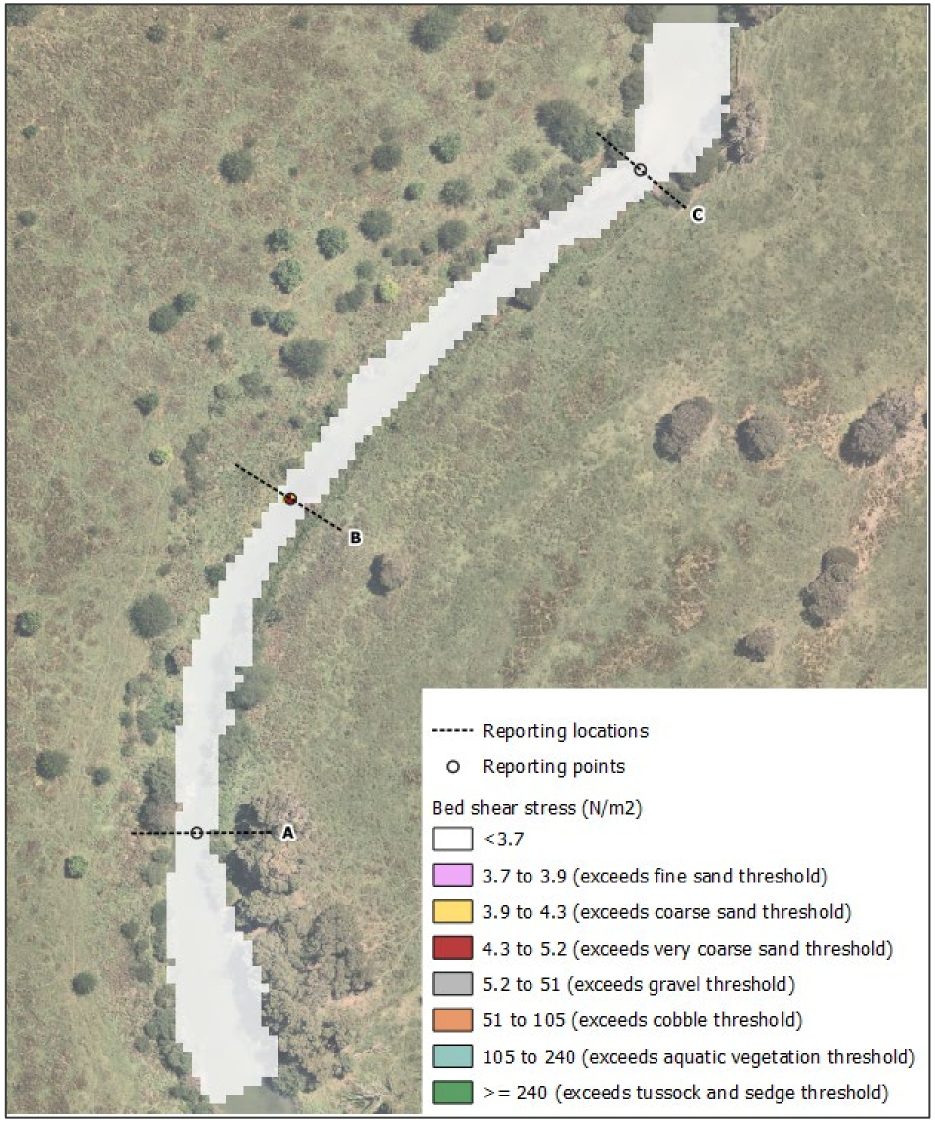


Figure 4-11 2020 Discharge scenario bed shear stress at 50th percentile flowrate

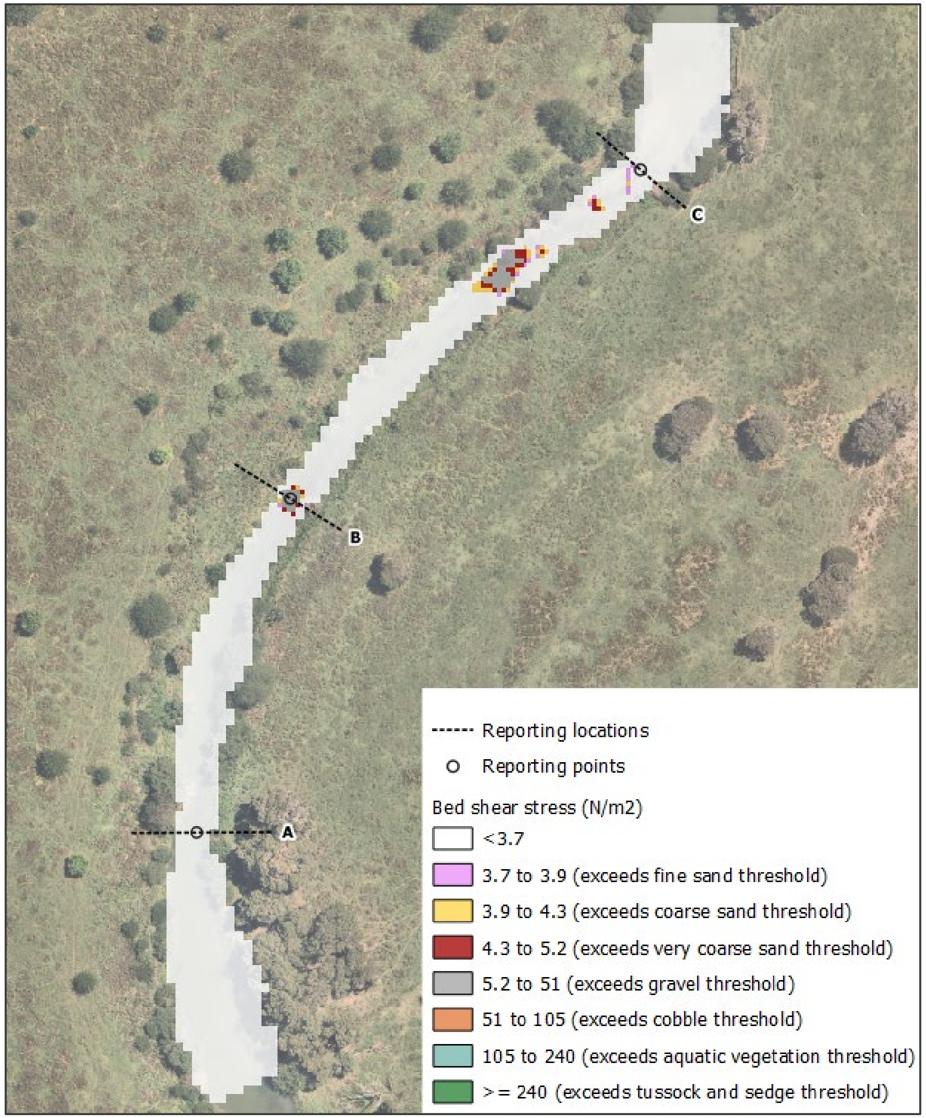


Figure 4-12 2036 Discharge scenario bed shear stress at 50th percentile flowrate

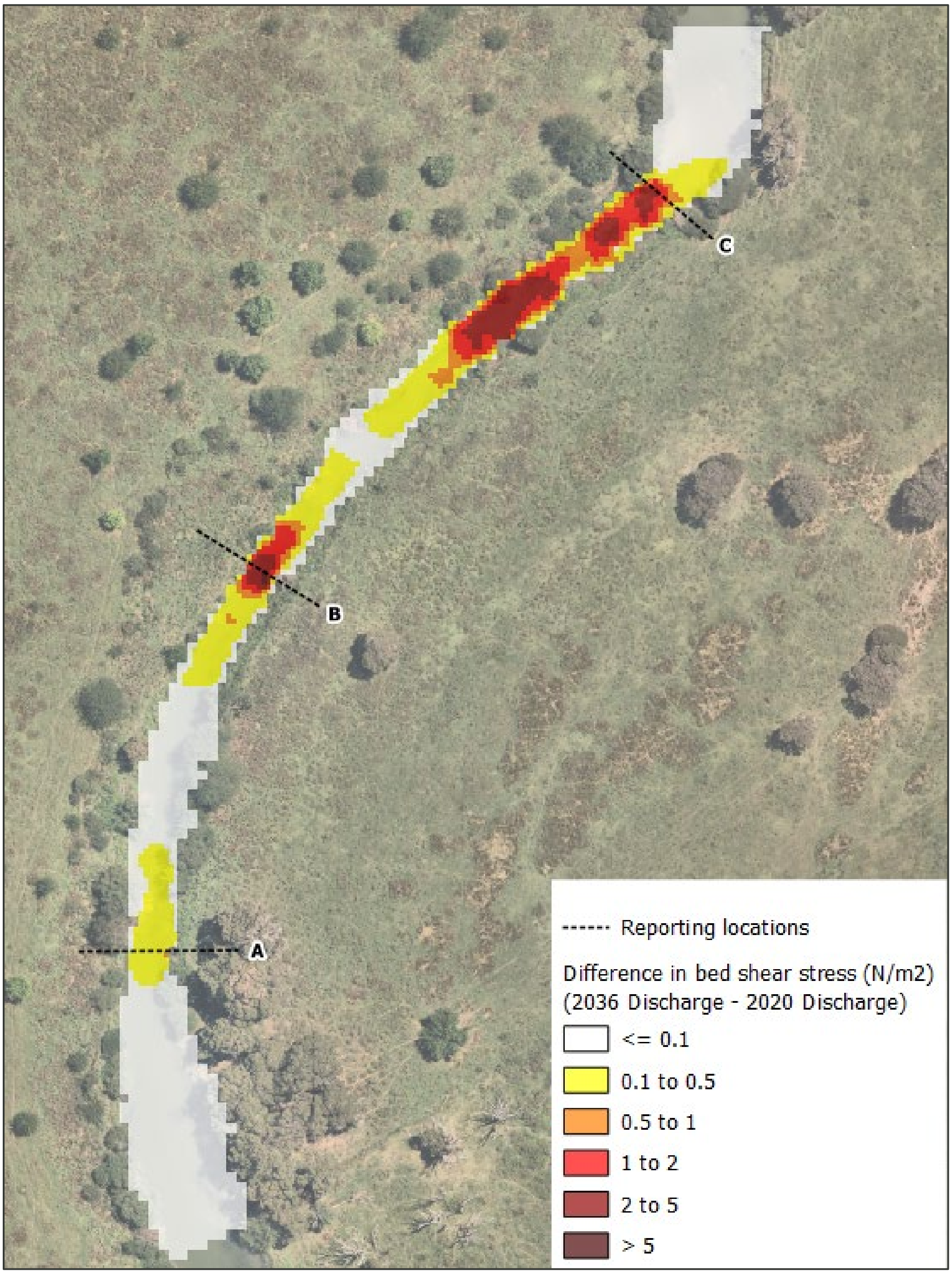


Figure 4-13 Bed shear stress difference map at the 50th percentile flowrate (2020 vs 2036)

4.2.1 Bank erosion risk at Location A

An analysis of shear stress changes at Location A, presented in Table 4-2 and Figure 4-14, indicates that existing sediment transport rates tend to be low and will stay low under the proposed 2036 discharges.

Under the 2020 discharge conditions:

- Shear stresses would periodically transport particles classified as very coarse sand and anything smaller (Table 4-2, Figure 4-14). This would occur up to 6% of the time for fine sand and up to 5% of the time for very coarse sand.

- Shear stress is not likely to transport particles larger than very coarse sand where they may exist in the creek bed or any vegetation.

Applying 2036 discharge conditions:

- The amount of time that fine to very coarse sand particles may be transported increases by 2% or less.
- Any gravels may be transported 5% of the time. No exceedances have been modelled for the current conditions (and will likely only take place during flooding conditions).

Existing bathymetry of the area shows this long section of the creek appears to have several deposition zones, for which this location sits at the peak of one such raised crest (~chainage 63m, Figure 3-11). If the creek often experiences sufficient shear stress where these deposition zones exist, the creek system will likely find a new equilibrium whereby the creek section will either deepen or widen until these critical flow events will no longer result in such high shear stresses. As such, these submerged areas of deposited material will gradually shift downstream in a stochastic fashion, responding to the increases and decreases in shear stress acting upon the mass. Equally, new material will be supplied to the reach from upstream mobilisation as it does not appear that this reach is in 'sediment deficit'.

This location was identified as being at risk of bank erosion based on in-field observations. The results indicated that the banks likely do experience some erosion but only during large and relatively infrequent flow events and the frequency / magnitude of these 'channel shaping events do not significantly differ between 2020 and 2036 flow scenarios. Figure 4-14 shows a convergence of the scenarios at high flow rates which all exceed the critical shear stress thresholds to the same degree. This demonstrates that the system will either transport all available sediments in the channel or none at all. It is unknown how the bank material differs from the bed material, but it is likely these same large flow events will see the peak of this deposition zone slowly migrate downstream over time.

Therefore modelling at Location A indicates that shear stresses under 2036 discharges from the treatment plant will most likely accelerate sediment transport in the creek channel by a very minor amount resulting in minor localised change in erosion patterns in that location.

Table 4-2 Portion of time bed shear stress exceeds geomorphology thresholds (Location A)

Impact receptor / Risk	Critical Tractive Force (N/m^2)	% of Time That Critical Tractive Force is Exceeded				Risk of altered sediment transport
		2020 No Discharge	2020 With Discharge	2036 No Discharge	2036 With Discharge	
Fine sand (0.125mm)	3.7	6%	6%	7%	8%	Low
Coarse sand (0.5mm)	3.9	6%	6%	7%	8%	Low
Very coarse sand (1mm)	4.3	5%	5%	6%	7%	Low
Gravel (2mm)	5.2	0%*	0%*	0%*	5%	Low
Cobble (64mm)	51	0%*	0%*	0%*	0%*	Negligible
Aquatic vegetation	105	0%*	0%*	0%*	0%*	Negligible
Tussock and sedge	240	0%*	0%*	0%*	0%*	Negligible

*Only during flooding conditions (not modelled)

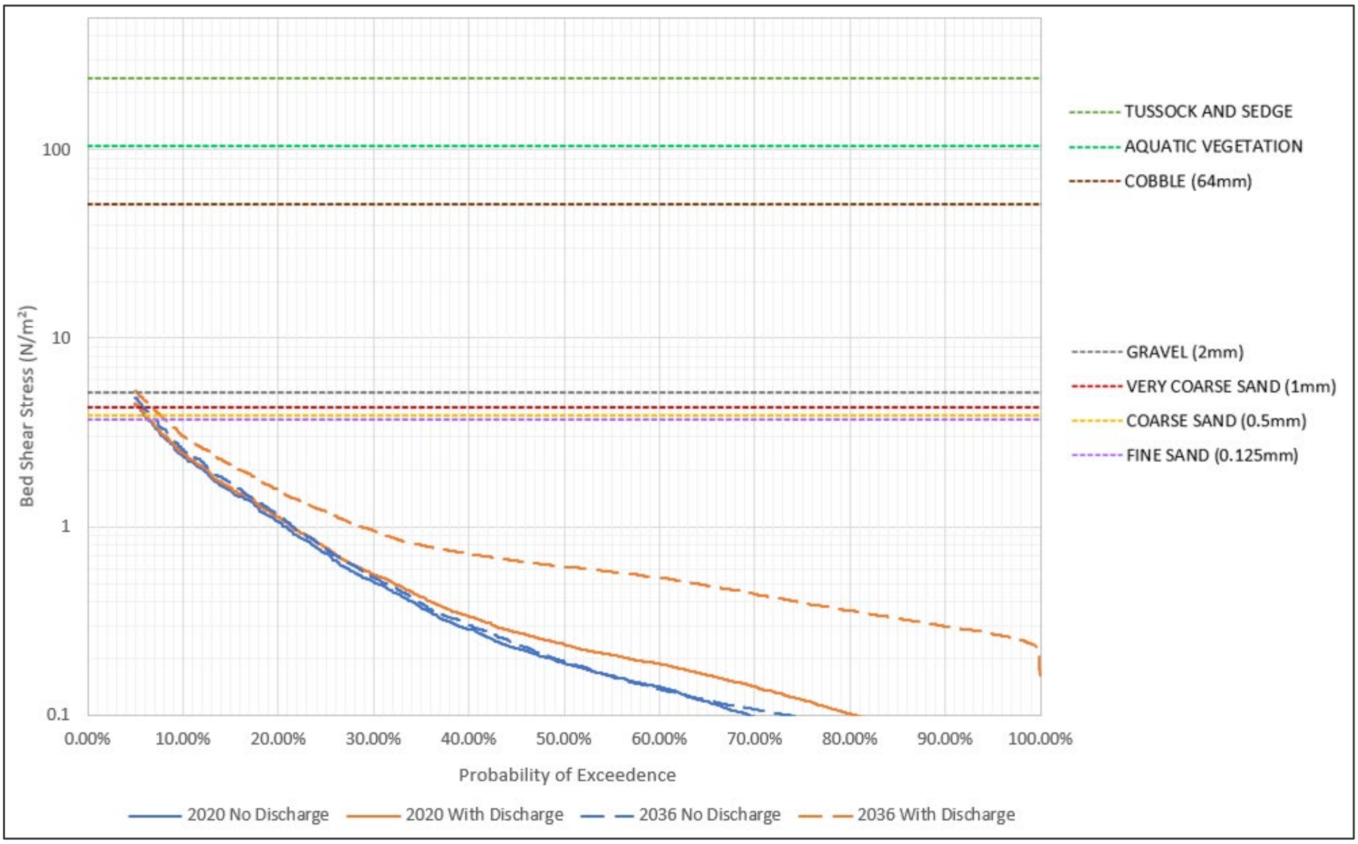


Figure 4-14 Location A shear stress exceedance curve

4.2.2 Erosion and fish passage impact risk at Location B

Modelling at Location B shows comparable frequencies of exceeding the assessed shear stress thresholds when considering the current and 2036 no discharge scenarios (i.e. reflective of catchment changes). However, when considering the wastewater discharge scenario in 2036, the frequency of exceeding these same shear stress thresholds increases such that they would be exceeded consistently. This is expected to increase local erosion at Location B for some time until a new equilibrium is reached.

Modelling of the channel at Location B under the 2020 conditions indicates that:

- Shear stress thresholds are exceeded 72% of the time for sand and 51% of the time for gravel (where it may exist in the creek bed). This suggests that there is already frequent erosion occurring at this section and the channel is in a regular state of change. (Table 4-3, Figure 4-15).
- Flows do not prevent the growth of macrophytes which indicates channel stability due to survival of individual stands and longevity of the deposited material that the plants are rooted into. Indeed, the macrophytes themselves may stabilise the channel in these locations by reducing water velocities due to friction loses, manifesting in a decrease in shear stress acting upon the bed.

The conditions are predicted to be marginally different for the 2036 discharges.

Under 2036 discharge conditions:

- Shear stress thresholds for sand are exceeded 100% and up to 100% of the time for gravel (where it may exist in the creek bed). This suggests that the channel will respond by deepening and widening over a reach of waterway to a point downstream where the channel has capacity to accommodate the additional flows.
- Flows would not prevent the growth of macrophytes

Modelling results show that increased discharge from the plant in 2036 will lead to increased shear stress in the creek. Assuming that there is not sufficient stabilisation of the banks from vegetation, with all particle sizes up to gravel experiencing near constant exceedance of shear stress thresholds, it would be expected that this creek section would find a new equilibrium as discharge from the plant increased up to the 2036 scenario.

Location B is at what appears to be a deposition zone along the creek (~chainage 148m, Figure 3-11). Similar to discussion for Location A, the composition of overbank bank material is very fine, and it may be expected that the creek deepens or widens at this location. If the creek bed comprises of more gravel sized particles than sampled at the bank, the modelling suggests these gravel particles will become more easily transported in the 2036 conditions. This has the potential to lead to armouring of the creek bed in sections where these larger particles settle out. This may affect the natural geomorphology of the creek.

Modelling also indicates that the considered flow events under the current creek geometry do not cause any disturbance to particles larger than gravels or to vegetation under any scenario. Potential impact to fish habitat depends on whether macrophytes are present at this location and how much structure is present at edge waters. While in-stream habitat is considered to mitigate a portion of the impact to aquatic fauna the impact to substrate may result in temporary mobilisation and scour risk to Eastern Creek. This may result in an indirect impact to local aquatic fauna due to reduced predator-prey interactions and loss of foraging resource for higher-order aquatic fauna within the system.

Table 4-3 Portion of time bed shear stress exceeds geomorphology thresholds (Location B)

Impact receptor / Risk	Critical Tractive Force (N/m^2)	% of Time That Critical Tractive Force is Exceeded				Risk of altered sediment transport
		2020 No Discharge	2020 With Discharge	2036 No Discharge	2036 With Discharge	
Fine sand (0.125mm)	3.7	62%	72%	61%	100%	High
Coarse sand (0.5mm)	3.9	58%	69%	58%	100%	High
Very coarse sand (1mm)	4.3	53%	63%	53%	100%	High
Gravel (2mm)	5.2	45%	51%	46%	100%	High
Cobble (64mm)	51	0%	0%	0%	0%	Negligible
Aquatic vegetation	105	0%	0%	0%	0%	Negligible
Tussock and sedge	240	0%	0%	0%	0%	Negligible

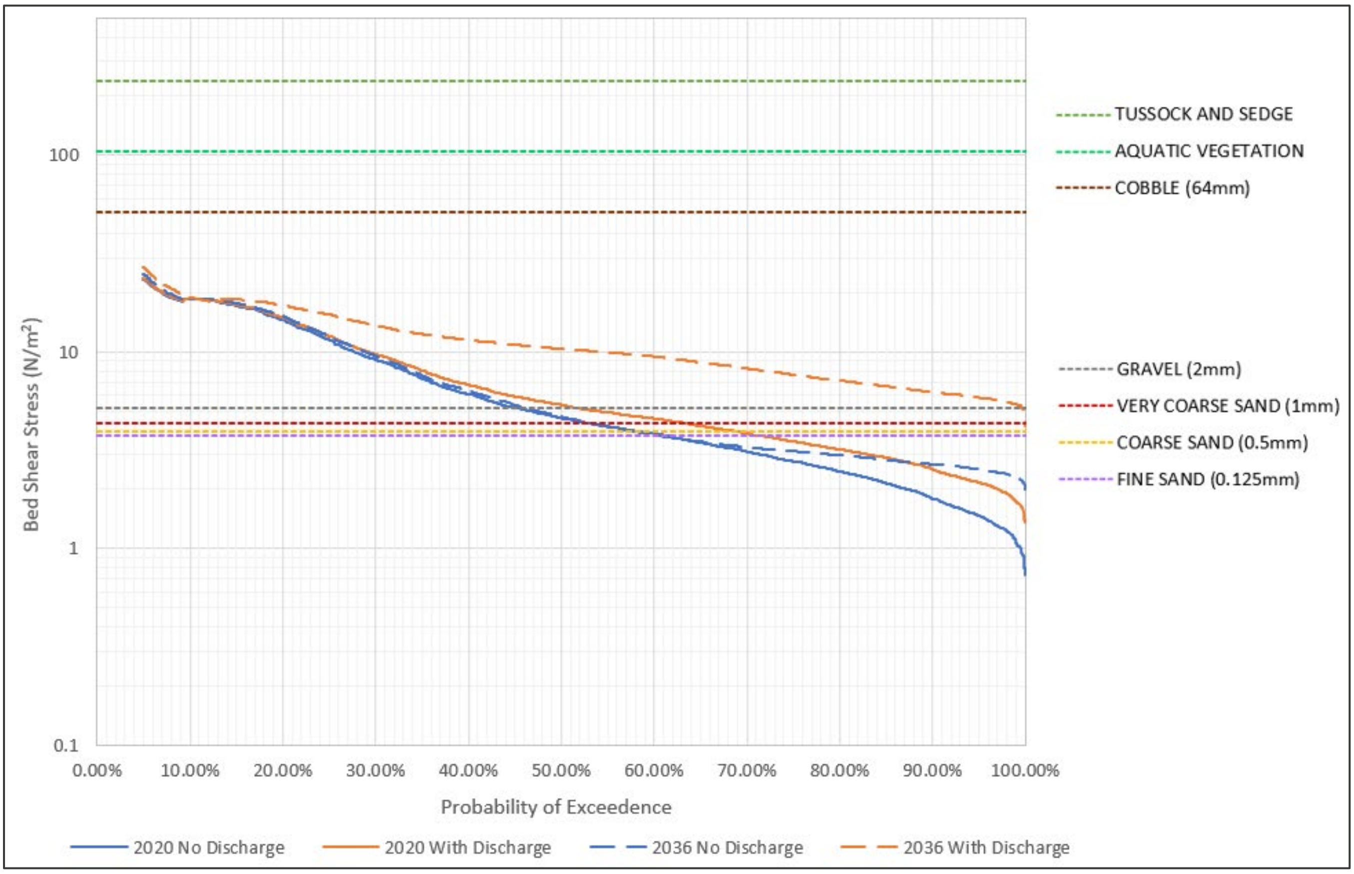


Figure 4-15 Location B shear stress exceedance curve

Note: There is a distinct change in the shear rating curve at 380 ML/day. As such, there are two representative relationships above and below this flow on the shear stress exceedance curve.

4.2.3 Macrophyte dislodgement risk at Location C

Modelling at location C shows that high shear stresses occur under current day conditions with high shear stresses to occur 2-5% more often in 2036. Moderate shear stresses would occur 20% more frequently in 2036.

Location C was identified as a location that may experience disturbance to standing macrophytes due to the meander in the creek and the potential increase in shear stresses along the outside bend where these macrophytes exist. This is seen in the modelling of the 2020 no discharge scenario as the shear stress threshold is exceeded 8% of the time for aquatic vegetation and 5% of the time for tussock and sedge as shown in Table 4-4. These vegetation results are comparable in the 2020 discharge and 2036 no discharge conditions and only increase by up to 2% of the time for the 2036 discharge scenario. This indicates that macrophyte habitat is unlikely to be adversely impacted in 2036 conditions.

While impacts to standing macrophytes are not substantial in the 2036 conditions, the largest impact of the 2036 discharge increase can be seen in the exceedance of the particle thresholds (Figure 4-16). These thresholds for particle erosion are exceeded much more frequently in 2036 discharge conditions and exceeds 50% of the time for fine and coarse sand (the dominant components in local bank material). This may have implications to the banks in which these macrophytes grow. While the macrophytes may provide additional stability to the banks, the increased flow and resulting shear stress may cause undercutting of the bank just prior to the bend apex on the outer bank of the meander bend. It should be noted however, that the banks in this area have been modelled with a Manning's roughness value of 0.03. It is likely that localised velocities will decrease in areas of macrophyte growth and further reduce the localised shear stress. As such, these results present a conservative estimate but are realistic for zones that have missing vegetation and are exhibiting erosion.

The modelling indicates that Location C will experience more frequent flow events that transport gravels and cobbles (where they may exist in the creek bed) in the 2036 discharge scenario.

In order to reach a new equilibrium, it is likely that the creek channel will undergo some widening or deepening. Due to the velocities, shear stress and geometry of the creek at this section, widening and possible undermining of the bank is more probable than deepening of the creek.

Table 4-4 Portion of time bed shear stress exceeds geomorphology thresholds (Location C)

Impact receptor / Risk	Critical Tractive Force (N/m^2)	% of Time That Critical Tractive Force is Exceeded				Risk of altered sediment Transport
		2020 No Discharge	2020 With Discharge	2036 No Discharge	2036 With Discharge	
Fine sand (0.125mm)	3.7	27%	29%	28%	52%	Moderate
Coarse sand (0.5mm)	3.9	27%	28%	28%	50%	Moderate
Very coarse sand (1mm)	4.3	26%	27%	27%	46%	Moderate
Gravel (2mm)	5.2	25%	26%	26%	40%	Moderate
Cobble (64mm)	51	11%	11%	12%	14%	Moderate
Aquatic vegetation	105	8%	8%	9%	10%	Low
Tussock and sedge	240	5%	6%	6%	7%	Low

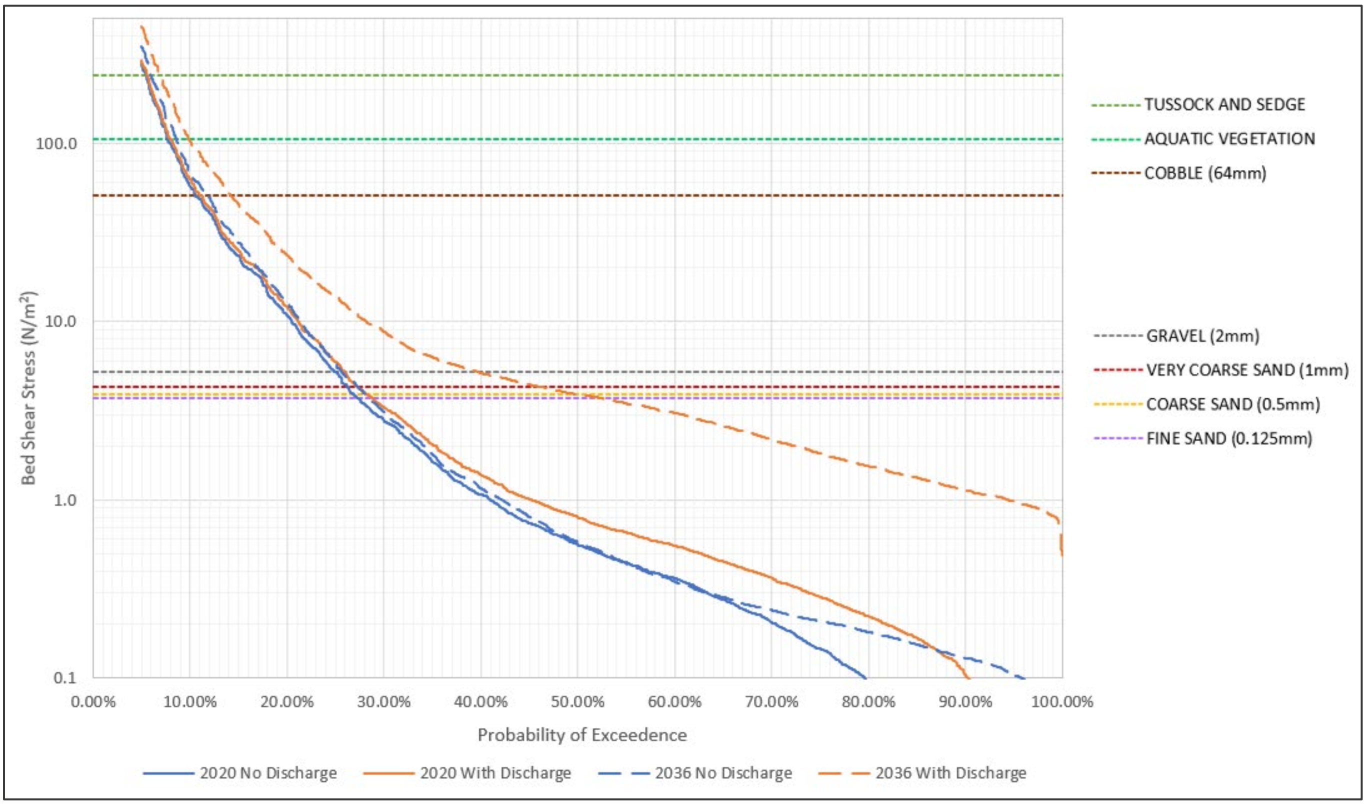


Figure 4-16 Location C shear stress exceedance curve

4.3 Impact Assessment Outcomes

4.3.1 Summary of potential impacts, proposed mitigation measures and management

The average discharge rate at the Riverstone WWTP is projected to increase from 7.7 to 36 ML/day. This results in a considerable change in flow regime where this discharge outlets into Eastern Creek. The following potential impacts to geomorphology and hydrology from the increased treatment plant discharge, have been considered:

- Increased erosion of the creek banks and bed and accelerated sediment transport processes
- Periodic flow conditions resulting in barriers to fish passage
- Redistribution of macrophyte habitat.

A summary of the key outcomes is provided in Table 4-5.

Table 4-5 Summary of potential impacts, proposed mitigation measures and management

Potential impact	Analysis	Discussion	Impact severity			Mitigation measures recommended
			Sensitivity	Magnitude	Significance	
Redistribution of macrophyte habitat	Comparison of potential shear stresses with published limits for macrophyte stability		Low	Low	Low	■ An adaptive management plan is recommended to ameliorate any observed impacts. This could include maintenance / planting of riparian vegetation along the creek banks, providing addition protection / stabilisation to creek features that are impacted ■ Armour creek banks to prevent erosion extending upstream. Selection of an appropriate calibre rock material to withstand the predicted velocity / shear stress increases for the 2036 discharge scenario. ■ Introduction of wood revetments/large woody debris
Increased erosion risk and resultant increased deposition risk further downstream	Erosion risk based on shear-stress	Low risk over the majority of the waterway High risk in shallow and narrow sections	Low	Low to High	Moderate	
Impeding fish passage	Eco-hydraulic thresholds	High flows (90th percentile) are likely to cause impediments to fish migration under current day conditions. This is likely to be worsened by future catchment and wastewater discharges. Based on the study reach, it is unlikely that projected 2036 treatment plant discharges will impede upstream fish migration for majority of the time (50%ile and 75%ile flows).	Low	Medium	Low	

4.3.2 Cumulative impact assessment

The Eastern Creek catchment upstream of the discharge location is expected to undergo major changes within the coming years, specifically urbanisation of large areas which are currently agricultural lands as part of the North West Growth Area (DPE, 2022). This includes:

- Colebee - 1,000 new homes
- Riverstone - 9,000 new homes, three new primary schools and a new K-12 school, the Vineyard and Schofields neighbourhood centres, a new community services hub and upgrades to major roads
- Schofields - 2,950 new homes, retail space in three neighbourhood centres, a potential public transport corridor linking Schofields station to Rouse Hill and upgrades to key roads

These catchment changes are reflected in the hydrologic changes shown above.

To account for these changes, the land-use data within the catchment was adjusted in the Source model (see Table 2-3), and thus the simulated flows for the 2020 and the 2036 scenarios differ. The assessed 2036 scenarios with discharge from the treatment plant thus account for both the proposed treatment plant discharges as well as the expected catchment changes. It is possible to apportion the predicted impacts to either the proposed project or the external changes, by considering the 2020 versus 2036 results without the treatment plant discharge (i.e. representative of the flows upstream of the discharge location).

In general, the anticipated risk of eco-hydraulic and geomorphological impacts in Eastern Creek resulting from the proposed increase in treatment plant discharge is much greater than the risks of impacts expected as a result of upstream catchment changes alone. This inference is based on the comparison of the four flowrate scenarios and the portion of time the assessment thresholds were exceeded at the critical assessment locations.

5 Conclusion

To continue to service the local communities, as the population grows in the western areas of Sydney, Sydney Water needs to increase treatment capacity of their existing Wastewater Treatment facilities. A portion of this work has been grouped into an amalgamated project, known as the NWTH. One of the plants that will be upgraded is the Riverstone WWTP, which currently discharges treated effluent to Eastern Creek.

Eastern Creek downstream of the plant discharge location currently meanders through agricultural land until it discharges to Wianamatta-South Creek about 2.3km further downstream. The flow regime in the creek has already been affected by urbanisation in the catchment.

The treatment capacity at the plant is proposed to be increased from the current 14.2 ML/d to 36 ML/d by 2036. This is expected to result in an increase in average discharge rate from 7.7 ML/d to 36 ML/d (including wet weather flows).

The risk based assessment has considered a short reach of the Eastern Creek and finds that within this reach there is potential for the following impacts:

- Localised increases in velocities within the centre of the channel
- An increase shear stress, especially within the centre of the channel, increasing the frequency of erosive events and increasing the rate of sediment migration downstream. In some locations (location B for instance) the increase in shear stress would likely lead to widening and deepening of the channel. There is a risk that this would extend from the study area to the confluence with Wianamatta-South Creek, with localised areas eroding more than others
- A small reduction in the amount of time local fish species are able to swim upstream, with velocities expected to exceed some of the species' swimming speed within the channel centre on a constant basis (Figure 4.9) but remain acceptable along the channel edges.
- Macrophyte habitat is unlikely to be adversely impacted in 2036 conditions.

The waterway is already significantly impacted by human activities upstream of the plant, the proposed increase in discharge will likely exacerbate these conditions until a new equilibrium is reached, i.e. adjusted shape and size of the channel, following which velocities will likely reduce leading to the return of more frequent fish passage and slowing of any fluvial geomorphological migration. A buffer to allow for lateral migration of the channel is recommended downstream from the treatment plant discharge.

The potential hydrological and geomorphological impacts have been deemed low to moderate, and where moderate these will likely only be temporary in nature. The extent of these impacts downstream of the study reach has not been determined in this study.

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Appendix A – Sediment sample and particle size distribution lab reports

Certificate of Analysis

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Mayfield West, NSW 2304
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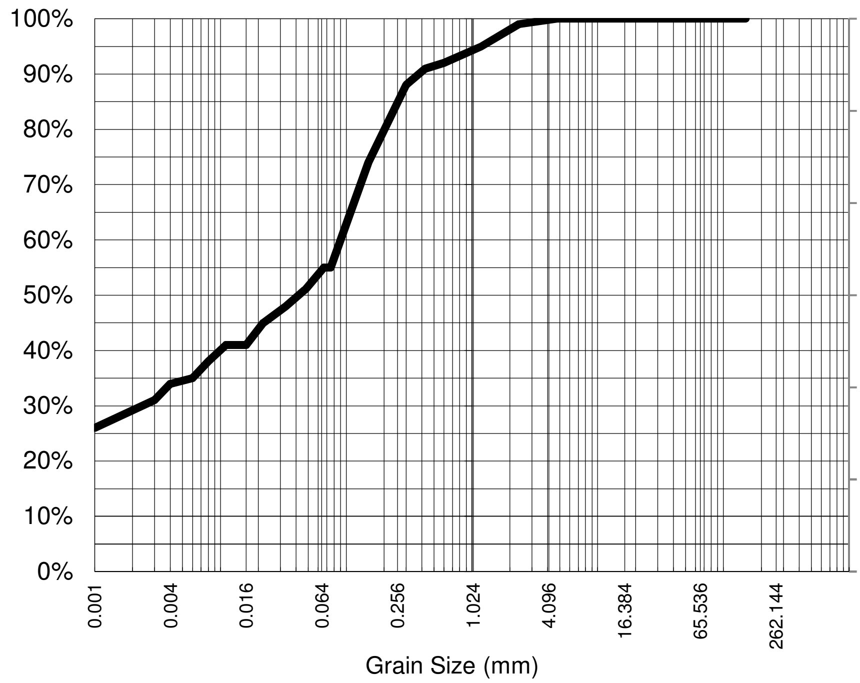
fax 02 4968 0349
samples.newcastle@alsenviro.com

ALS Environmental

Newcastle, NSW

CLIENT:	AMELIA BASSON	**DATE REPORTED:**	22-Jun-2021
COMPANY:	AURECON AUSTRALASIA PTY LTD	**DATE RECEIVED:**	11-Jun-2021
ADDRESS:	PO Box 538 Neutral Bay NSW, Australia	**REPORT NO:**	ES2121996-003 / PSD
PROJECT:	505018	**SAMPLE ID:**	505018_NWTH_SD03_010621

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	95%
0.600	92%
0.425	91%
0.300	88%
0.150	74%
0.075	55%
Particle Size (microns)	
47	51%
33	48%
22	45%
16	41%
11	41%
8	38%
6	35%
4	34%
1	26%

Median Particle Size (mm)*	0.042

Analysis Notes

Samples analysed as received.
** Soil Particle Density required for Hydrometer analysis according to AS 1289.3.5.1—2006 was not requested by the client . Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 18-Jun-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description: FINES, SAND

Dispersion Method Shaker

Test Method: AS1289.3.6.2/AS1289.3.6.3

Soil Particle Density (<2.36mm) #N/A

NATA Accreditation: 825 Site: Newcastle
This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025. This document shall not be reproduced, except in full.

WORLD RECOGNISED ACCREDITATION

Aleksandar Vujkovic
Laboratory Supervisor
Authorised Signatory

Template Version PKV8.0 180919

Appendix B – Hydraulic modelling sensitivity analyses

Bank vs side channel

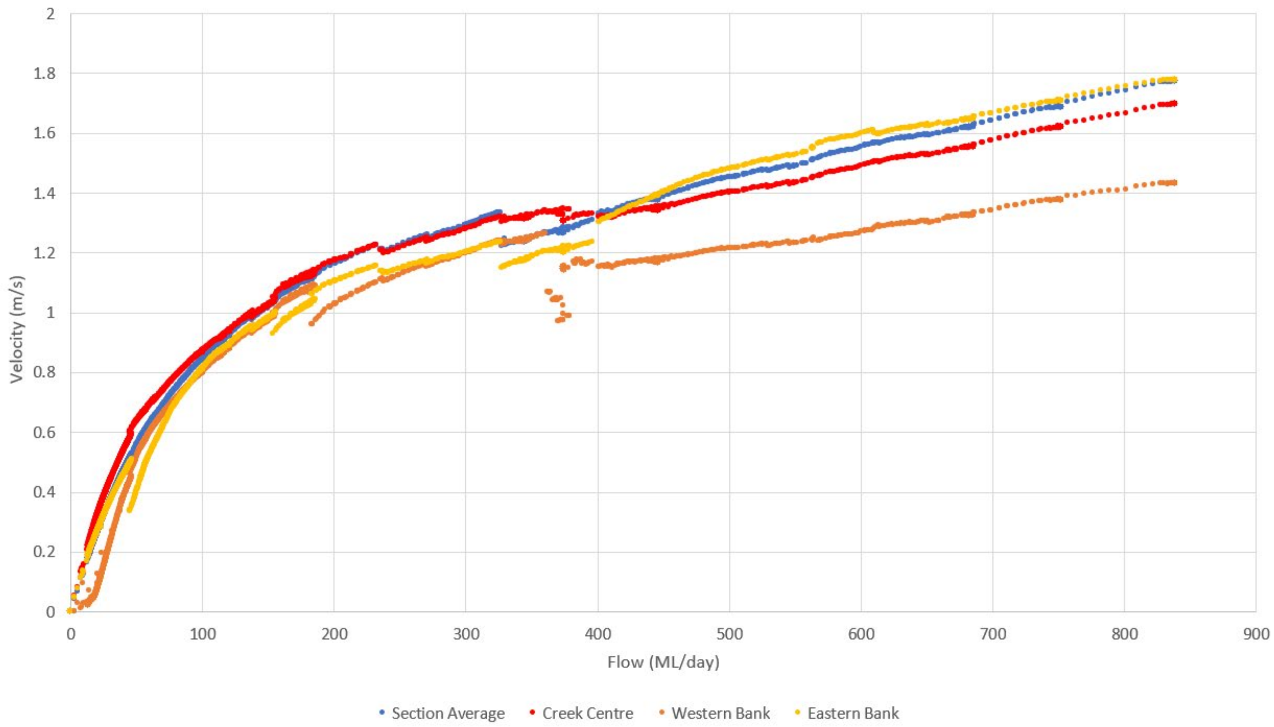


Figure B-6-1 Velocity rating curve at Location B for various locations across the creek section

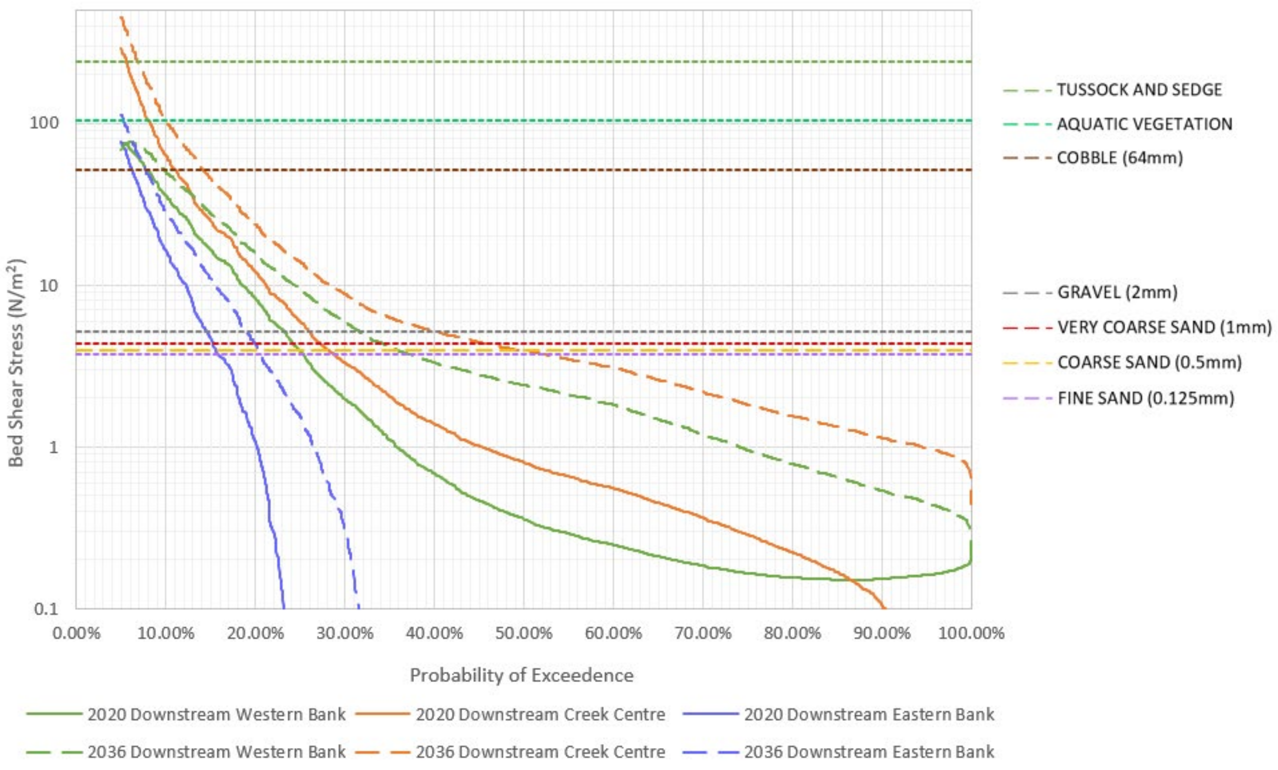


Figure B-6-2 Location C shear stress exceedance curves at various points on the cross-section