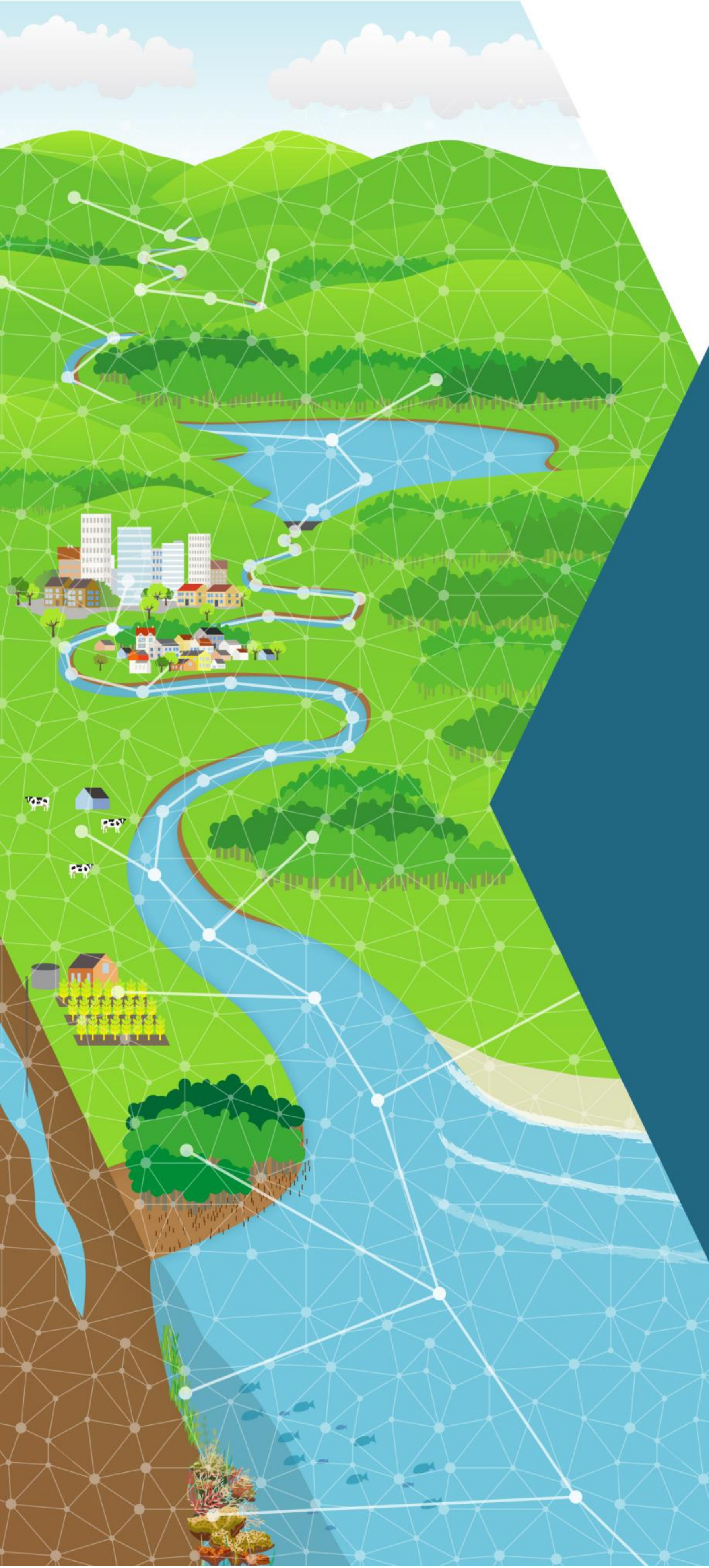
QUEENSLAND WATER MODELLING NETWORK



Landscape restoration and redesign

Review of river reach case studies and Dynamic SedNet model parameterisation

Report prepared by
Alluvium Consulting
For the Queensland Water Modelling Network

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alluvium

Queensland Government

The Queensland Water Modelling Network (QWMN) is an initiative of the Queensland Government that aims to improve the state's capacity to model its surface water and groundwater resources and their quality. The QWMN is led by the Department of Environment and Science in partnership with the Department of Natural Resources, Mines and Energy and the Queensland Reconstruction Authority, with key links across industry, research and government.

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Citation

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Summary

Overview

Stream bank erosion represents a major source of sediment to the Great Barrier Reef (GBR) lagoon. Erosion is a natural and essential process in alluvial systems, however human activities such as land clearing, removal of riparian vegetation or grazing pressure that limit reestablishment of vegetation can result in accelerated rates of stream erosion resulting in damaging channel change.

The Dynamic SedNet model is currently used within the GBR Source Catchment Modelling framework to assess end-of-catchment loads and to estimate pollutant load reductions due to adopted improved management practices. The model, and the data inputs currently utilised, is a reasonable tool for estimating the relative contribution of bank erosion at large whole-of-catchment scales. However, its applicability at smaller spatial scales (i.e. reach or sub-catchment) to estimate erosion rates and undertake prioritisation is limited due to the coarse datasets used, size of the model links and sub-catchment areas, and modelling assumptions. Recent studies have concluded that the Dynamic SedNet model should not be used for stream bank prediction at anything less than the sub-catchment scale, nor to guide reach-scale rehabilitation prioritisation (Brooks et. al. 2014 and Bartley et. al. 2015).

The Stream Bank Erosion component of Dynamic SedNet models bank erosion along stream links represented in the node-link (stream) network. The Stream Bank Erosion component models mean annual sediment supply from bank erosion along a link as a function of bankfull stream power in a hypothetical rectangular channel, the extent of riparian vegetation adjacent to the channel, and the level of bedrock confinement. The bank erosion algorithm calculates the erosion rate over the entire length of the link. Key input variables into the model include channel slope, bankfull flow, bank height, bank substrate, and riparian vegetation condition. The fluvial geomorphology of rivers is a key control on many of these variables.

This study aims to assess the parameterisation of the Dynamic SedNet model in a range of different river types within the GBR. The case study areas have been selected on the basis of good pre-existing data availability in order to assess the geomorphology and hydro-geomorphic processes. This has resulted in all case study areas being located within the coastal fringes as opposed to inland streams in the upper catchments. The objectives of the study objectives:

1. Review the fluvial geomorphology and channel change processes within a range of river types within the GBR catchments
2. Assess the parameterisation and outputs of the Dynamic SedNet model in a range of river types within the GBR catchments

The five case study areas are located within the Mary River catchment, Fitzroy River catchment and Mackay-Whitsundays region. The case studies are shown, and summarised, below.

Stream	Description
Mary River	A 40 km section of Mary River which extends from the Yabba Creek confluence to Six Mile Creek, just upstream of Gympie.
Raglan Creek	A 73 km section of Raglan Creek which transitions through a steeper upper catchment with various degrees of bedrock control before emerging into the estuarine plains. Tortuous and active meandering through lower estuarine reach.
Fitzroy River	A 65 km section of the Fitzroy River upstream of the tidal barrage in Rockhampton.
Murray Creek	A 23 km section of Murray Creek upstream of the Bruce Highway.
O'Connell River	A 17 km section of the O'Connell River which extends from the Andromache River confluence to Bloomsbury.

Results

A summary of the river type, processes, channel erosion and Dynamic SedNet parameterisation in the five case study areas is provided below. Four of the case studies (i.e.all except the Fitzroy) had sections of channel which had an entrenched morphology. These entrenched channels are relics from past sea level, flow and sediment regimes. As a result they do not behave as true self-formed alluvial channels. Within the confines of the alluvial terraces more contemporary alluvial floodplains and benches have formed during the current Holocene period. The case study assessment-identified erosion areas are significantly more prevalent when the channel is bound by inset floodplains and are often concentrated within small areas.

The key erosional processes identified in the case study assessment include:

- The dominant channel erosion processes was fluvial toe scour and subsequent mass failure on the outside of bends within the inset channel. This is part of a meander migration process. This type of erosion is more prevalent in zones where the inset floodplains are more expansive and there is limited woody vegetation coverage.
- Wet flow failures were prevalent in two case study areas. These are assocated with floodplains comprised of alternating fine and coarse sediment layers that control channel bank exfiltration on the recession limb of flood hydrographs. This results in the structural failure of sand layers and the mass failure of the overburden material. The erosion process is driven by the rise and fall of the water level and is not related to boundary shear stress or stream power.
- Meander cutoffs are driving rapid meander development in two case study areas. This increased rate of channel change is the result of localised increases in channel slope and stream power following the meander cutoff.
- Rapid rates of erosion were evident in tidal reaches in two case study areas. This erosion is most likely driven by entrainment of bank sediments (followed by mass failure) due to a combination of fluvial, tidal and wave action. Banks in tidal reaches are often highly erodible as bank vegetation does not establish across the entire tidal range.

Case study area	River type/processes	Channel erosion processes	Dynamic SedNet parameterisation
Mary River	Entrenched sand bed channel with a meandering planform. Lateral adjustment of the entrenched channel controlled by bedrock valley margins and fill terraces. Inset channel flows through more recent inset depositional units (i.e. inset floodplains, benches).	Dominant channel erosion process is fluvial toe scour and subsequent mass failure on the outside of bends within the inset channel. Erosion is more prevalent in zones where the inset floodplains are more expansive and there is limited woody vegetation coverage. There are no examples where there has been significant sediment loss from terrace units. Wet flow failures have historically been prevalent	Longitudinal bed profile accurately estimated. Bank heights assigned to the terraces rather than the active inset channel. Bankfull flow overestimated (by approximately 275-325%) as inset channel not defined. Vegetation buffer correctly assigned to inset channel. Overall good model prediction (84% of actual sediment loss predicted).

		with failure scars clearly visible.	
Raglan Creek	Upper portion consists of partly confined, low sinuosity, gravel bed channel. Middle portion consists of an entrenched channel confined by terraces with a low sinuosity planform. Lower portion consists of an unconfined, meandering tidally influenced, channel.	Downstream meander migration and channel widening driven by fluvial toe scour and mass failure is the dominant channel erosion process in the upper portion. There is limited examples where there has been significant sediment loss from terrace units in the middle portion. Significant meander migration within the lower tidal reach. This erosion is most likely driven by entrainment of bank sediments (followed by mass failure) due a combination of fluvial, tidal and wave action.	Longitudinal bed profile overestimated by an order of magnitude. Bank heights are underestimated by approximately 30 – 60%. Bankfull flow underestimated by approximately 70 – 90%. Vegetation buffer does not cover all erodible areas of the channel boundary Overall good model prediction (86% of actual sediment loss predicted in SC #1766).
Fitzroy River	Partly confined sand bed channel with some bedrock controls. Planform is classified as meandering however it contains several higher-angle bends separated by sections that are near straight. The majority of the case study area sits within the weir pool of the tidal barrage.	The majority of sediment loss is derived from meander migration (i.e. fluvial toe scour and subsequent mass failure) processes. A large meander cutoff is driving increased rates of meander development in one location. Significant sediment loss occurred due to scour of in-channel units such as bars and islands. A significant number of wet flow failures were distributed throughout the case study area.	Longitudinal bed profile overestimated by one to three orders of magnitude. Bank heights are overestimated by approximately 45 - 115%. Bankfull flow overestimated by approximately 100-300%. Vegetation buffer does not cover all erodible areas of the channel boundary. Overall average model prediction (192% of actual sediment loss predicted).
Murray Creek	Upper portion consists of entrenched, low sinuosity, gravel bed channel with discontinuous inset floodplains. Through the mid zone the valley confinement increases, and the	Dominant channel erosion process is the result of lateral meander migration processes (i.e. toe scour and subsequent mass failure) across poorly vegetated inset floodplain units.	Large variations in the longitudinal bed profile are not well represented by the modelled average value. Bank heights are generally well defined.

	channel is significantly confined by bedrock. Lower portion consists of an unconfined, meandering tidally influenced, channel.	There are no examples where there has been significant sediment loss from terrace units. Increased rates of lateral channel change and meander development due a meander cutoff in the lower estuarine reach.	Bankfull flow typically underestimated but varies within the case study area (i.e. bankfull flow is generally underestimated by approximately 30 – 60%, however is over estimated by 30% in the lower reaches). Vegetation buffer generally extends across the key geomorphic units. Overall average model prediction (65% of actual sediment loss predicted).
O'Connell River	Upper portion consists of partly confined, low sinuosity, gravel bed channel. Within this section the channel can abut either bedrock, terrace or inset floodplain units. Middle section consists of an entrenched channel confined by terraces with a low sinuosity planform. Lower portion consists of partly confined, low sinuosity, gravel bed channel with expansive inset floodplains within the broader entrenched channel.	Within the upper portion the dominant channel erosion process is fluvial toe scour and subsequent mass failure on the outside of bends within the inset channel. There are no examples where there has been significant sediment loss from terrace units. Major channel erosion as the result of meander development in the lower portion as the river reworked the coarse sediment deposits and created a defined low flow path.	Longitudinal bed profile are generally well represented by the modelled average values. Bank heights are overestimated by 25-125%. Bankfull flow underestimated by approximately 45-80%. Vegetation buffer generally extends across the key geomorphic units. Overall good model prediction (78% of actual sediment loss predicted).

Summary and key findings

Dynamic SedNet is the primary mechanism for predicting stream bank erosion within the GBR catchments. The purpose of these models is to provide estimates of long term pollutant load reductions, however the model outputs are frequently also used as a source of information to assist in prioritisation of management interventions for stream bank management. This study has shown that using model outputs alone for this prioritisation might not achieve the perceived benefits.

The bank erosion equation used within Dynamic SedNet is an empirical, process-based model that has some key input variables and assumptions. These variables (key input variables shown in bold) and assumptions include:

- **Bankfull total cross-sectional stream power** is a key driver of stream bank erosion. This variable is determined by multiplying **stream slope** by **bankfull discharge.**

- The **height** of the 'bank' (i.e. erosion contributing feature) is directly proportional to the volume of sediment per unit of lateral bank retreat.
- The **proportion of intact riparian vegetation** and **stream bank material erodibility** will impact on the **bank erodibility.**

These assumptions are based on established geomorphic principles. However this study has identified several issues with both how these assumptions are applied, and the datasets used, within the Dynamic SedNet model used for stream bank erosion prediction in Reef Plan models. The key findings of this study are:

1. The case study assessment-identified erosion areas are significantly more prevalent when the channel is bound by certain geomorphic units (i.e. inset floodplains) and are often concentrated within small areas. Within the Dynamic SedNet bank erosion model, only parameters (i.e. bank height and stream bank material erodibility) for one geomorphic unit can be assigned. Given the length of modelled links an understanding of the type and prevalence of channel bounding geomorphic units within each link, and their relative erodibility, would greatly enhance stream bank erosion prediction in Reef Plan models.
2. An understanding of the type and prevalence of channel bounding geomorphic units within each link, and their relative erodibility, would assist in determining the bank height variable within Dynamic SedNet. As an example, within the Mary River case study area the bank height variable was closely aligned to the terrace height however the inset floodplain units are contributing the majority of the sediment.
3. The bankfull total cross-sectional stream power value used to calculate the Dynamic SedNet lateral retreat rate within the case studies assessed is often very inaccurate. The stream slope by bankfull discharge values often had very large variations from actual values. Within the Fitzroy River, and Raglan Creek models the Dynamic SedNet bed slope values are orders of magnitude different from the actual river slopes, and indicate that the Fitzroy catchment scale water quality model requires a thorough review of assigned stream bank erosion parameter values.
4. Overall, the Dynamic SedNet sediment loads are relatively good estimates of sediment loss at the case study scale (i.e. across all links assessed). The overall model performance is similar in case study areas with good parameterisation (i.e. the Mary River and O'Connell River) and case study areas with very poor parameterisation (i.e. Fitzroy River and Raglan Creek). However, at the link scale there is significantly higher variability. How the model is able to predict stream bank erosion results when there are significant errors in the key input parameters is uncertain. The fact that all case studies were located in the coastal fringes where there is generally better data availability for calibration may have assisted the model performance. If the monitoring data and calibration are the key reasons for the good model performance this indicates that the stream bank erosion model has been manipulated as an empirical model for the purposes of predicting the broad distribution of stream bank erosion at sub-catchment scales across large river basins(see point below).
5. This study has identified that the process-based components of the model are not performing as intended at the link/sub-catchment scale in the five case studies assessed (i.e. with bankfull stream power driving erosion, and riparian vegetation and substrate erodibility resisting erosion). Despite the good predictive power of the model there were very large errors in the variables which drive the process-based component of the model in several case study areas. Given there are such large errors in some of the input parameters it is difficult to assess the process-based components of the model performance in the different river types assessed in this study.
6. No observable correlation between bankfull total cross-sectional stream power (or bankfull mean specific stream power) and channel erosion was identified within the five reach scale case studies assessed. Stream power is still likely a major driver of erosion, however the variability in the character and erodibility of the channel boundary sediments overwhelms other controls (i.e. stream power). This aligns with findings of Brooks et.al. (2014).

7. The assessment identified wet flow failures as being prevalent in both the Fitzroy River and Mary River case study areas. These failures are described in Thompson et. al 2013 and are associated with floodplains comprised of alternating fine and coarse sediment layers that control channel bank exfiltration on the recession limb of flood hydrographs. This erosion mechanism requires more variables than are currently included in the Dynamic SedNet stream bank erosion model to identify the sites susceptible to this process. This erosion mechanism can be a major source of sediment in certain river types.

8. Other erosion processes including avulsions and inset floodplain scour are also currently not specifically accounted for within the Dynamic SedNet model (although some of the key variables that drive these processes are within the model i.e. stream power).

9. The tidal reach of Raglan Creek is experiencing active channel erosion. The erosion processes within tidal reaches are often more complex than upstream reaches. Erosion is likely driven by entrainment of bank sediments due a combination of fluvial, tidal and wave action. Banks in tidal reaches are often highly erodible as bank vegetation does not establish across the entire tidal range. These complexities are currently not accounted for within the within the Dynamic SedNet model.

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1. Introduction

1.1. Overview

Alluvium Consulting Australia Pty Ltd (Alluvium) have been engaged by the Department of Environment and Science (DES) to investigate and assess options and opportunities for stream bank erosion modelling within the Great Barrier Reef (GBR) catchments. An initial investigation assessed a range of stream bank erosion modelling approaches and assessed their applicability to GBR streams (Alluvium, 2020). A key finding of this study was the difficulty in accurately predicting stream bank erosion in all river typologies that exist within the GBR catchments.

This study aims to explore the accuracy and parameterisation of the Dynamic SedNet model currently used within the GBR Paddock to Reef Source Catchment Modelling in a range of different river types within the GBR.

1.2. Project background

Stream bank erosion represents a major source of sediment to the GBR lagoon. Erosion is a natural and essential process in alluvial systems; however human activities such as land clearing, removal of riparian vegetation or grazing pressure that limits reestablishment of vegetation can result in accelerated rates of stream erosion resulting in damaging channel change. These erosion processes provide a pathway for sediments and nutrients, such as nitrogen and phosphorous, to enter waterways. Land use changes within the GBR catchments have resulted in significant increases in sediment and nutrient loads to the GBR lagoon. As a result, stream bank erosion has been identified as a major sediment and particulate nutrient delivery process impacting on the GBR (Figure 1, Figure 2 and Figure 3).

Figure 1: *Stream bank erosion along the O'Connell River (left) and Mary River (right)*

The Dynamic SedNet model is currently used within the GBR Source Catchment Modelling framework to assess end-of-catchment loads and to estimate pollutant load reductions due to adopted improved management practices. The Dynamic SedNet is also used to run scenarios to provide comparison of potential reef water quality outcomes arising from a range of theoretical investment strategies.

Bank erosion is currently one of the processes modelled within the Dynamic SedNet model. The main purposes for the modelling are:

1. Estimating the absolute magnitude, and relative sizes, of hillslope, gully and stream bank erosion contributions to overall sediment yield at catchment or basin scale so that management can be apportioned appropriately
2. Spatially prioritising management actions at broad scales of catchments down to several thousand km², helping to target data capture and erosion control projects

3. Quantifying the effect of management actions on site sediment yields which are aggregated to catchment and basin scale for GBR Reef Report purposes

The model, and the data inputs currently utilised, is a reasonable tool for estimating the relative contribution of bank erosion at large, whole-of-catchment scales. However, its applicability at smaller spatial scales (i.e. reach or sub-catchment) to estimate erosion rates and undertake prioritisation is limited due to the coarse datasets used, size of the model links and sub-catchment areas, and modelling assumptions. Recent studies have concluded the Dynamic SedNet model should not be used for stream bank prediction at anything less than sub-catchment scale, nor to guide reach-scale rehabilitation prioritisation (Brooks et. al. 2014 and Bartley et. al. 2015).

Figure 2: *Stream bank erosion along the Mimosa Creek (Dawson River catchment) (left) and Burnett River (right)*

This study aims to assess the parameterisation of the Dynamic SedNet model in a range of different river types within the GBR. The case study areas have been selected on the basis of good pre-existing data availability in order to assess the geomorphology and hydro-geomorphic processes. This has resulted in all case study areas being located within the coastal fringes as opposed to inland streams in the upper catchments.

Figure 3: *Stream bank erosion along the Russell River (left) and Fitzroy River (right)*

1.3. Study objectives

This study has the following objectives:

1. Review the fluvial geomorphology and channel change processes within a range of river types within the GBR catchments
2. Assess the parameterisation and outputs of the Dynamic SedNet model in a range of river types within the GBR catchments, using comparison at a range of scales allowing assessment of i) performance for guiding whole of catchment (river reach scale) management

prioritisation and ii) performance of identifying spatial variability and prioritising management within river reaches.

1.4. Project overview and structure

This study will use five case study areas consisting of either a single Dynamic SedNet-modelled river reach (i.e. link) or a series of consecutive reaches (i.e. 2-4 links). The case study areas have been selected in regions where there is significant data available (i.e. multi-temporal LiDAR data) to assess recent channel change processes and hydro-geomorphic parameters. The areas selected cover a range of river types typical across the GBR catchments with a variety of channel boundary units (i.e. bedrock, terrace and contemporary floodplains) and sediment regimes.

The report has the following structure:

- **Section 2** provides an overview of each case study area, including the location, the fluvial geomorphology and recent observed channel change processes and a range of hydro-geomorphic parameters
- **Section 3** assesses the parameterisation of the Dynamic SedNet model within each case study area
- **Section 4** provides summary and recommendations

2. Case studies

2.1. Overview

The five case study areas are located within the Mary River catchment, Fitzroy River catchment and Mackay-Whitsundays region. The case studies are shown in Figure 4 and summarised in Table 1. Each of the five case study areas are discussed below.

Figure 4: *The location of the five case study areas*

Table 1: Summary of the case study areas

Stream	Description
Mary River	A 40 km section of Mary River which extends from the Yabba Creek confluence to Six Mile Creek, just upstream of Gympie.
Raglan Creek	A 73 km section of Raglan Creek which transitions through a steeper upper catchment with various degrees of bedrock control before emerging into the estuarine plains. Tortuous and active meandering through lower estuarine reach.
Fitzroy River	A 65 km section of the Fitzroy River upstream of the tidal barrage in Rockhampton.
Murray Creek	A 23 km section of Murray Creek upstream of the Bruce Highway.

2.2. Case study 1 - Mary River

Overview

The Mary River case study extends for 40 kilometres, from the Yabba Creek confluence to Six Mile Creek, just upstream of Gympie (Figure 5). The floodplains along this reach support improved pasture for numerous dairies as well as general grazing. The upper slopes support grazing as well as irrigated perennial horticulture, with some quarrying and rural residential development.

The case study area is shown in Figure 6 and Figure 7. In this area the Mary River flows through a spurred valley setting which controls the planform alignment to varying degrees. The extent of alluvial development varies in accordance with valley confinement, but generally ranges from 500 to 2,000 m wide. The alluvial development includes:

- Extensive fill terraces which sit 15-18 m above the channel bed
- Inset floodplain and bench units which sit 10-12 m above the channel bed (mapped in Figure 6 and Figure 7)

Variations in the degree of channel entrenchment and geomorphic units can be seen in the three typical section shown in Figure 8. The main geomorphic units are also visible in Figure 9.

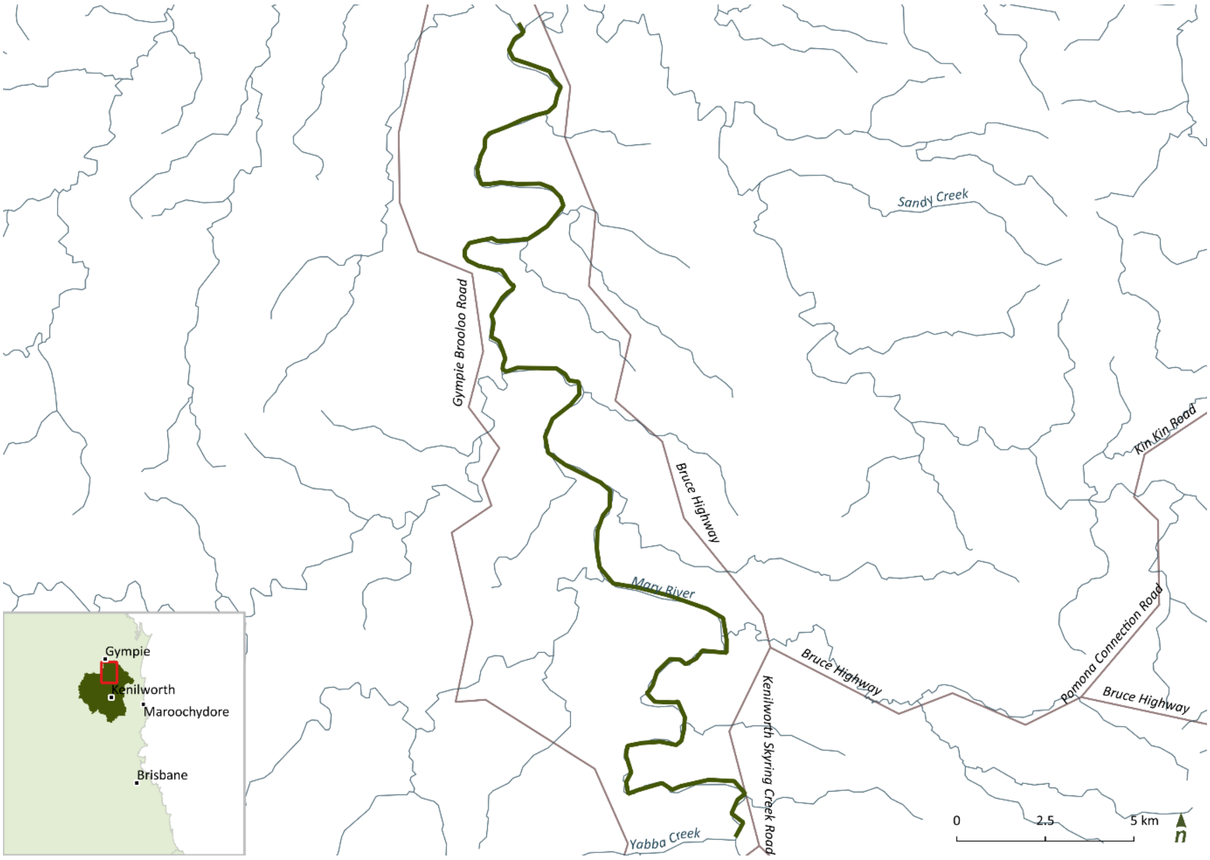

Figure 5: *The Mary River case study area*

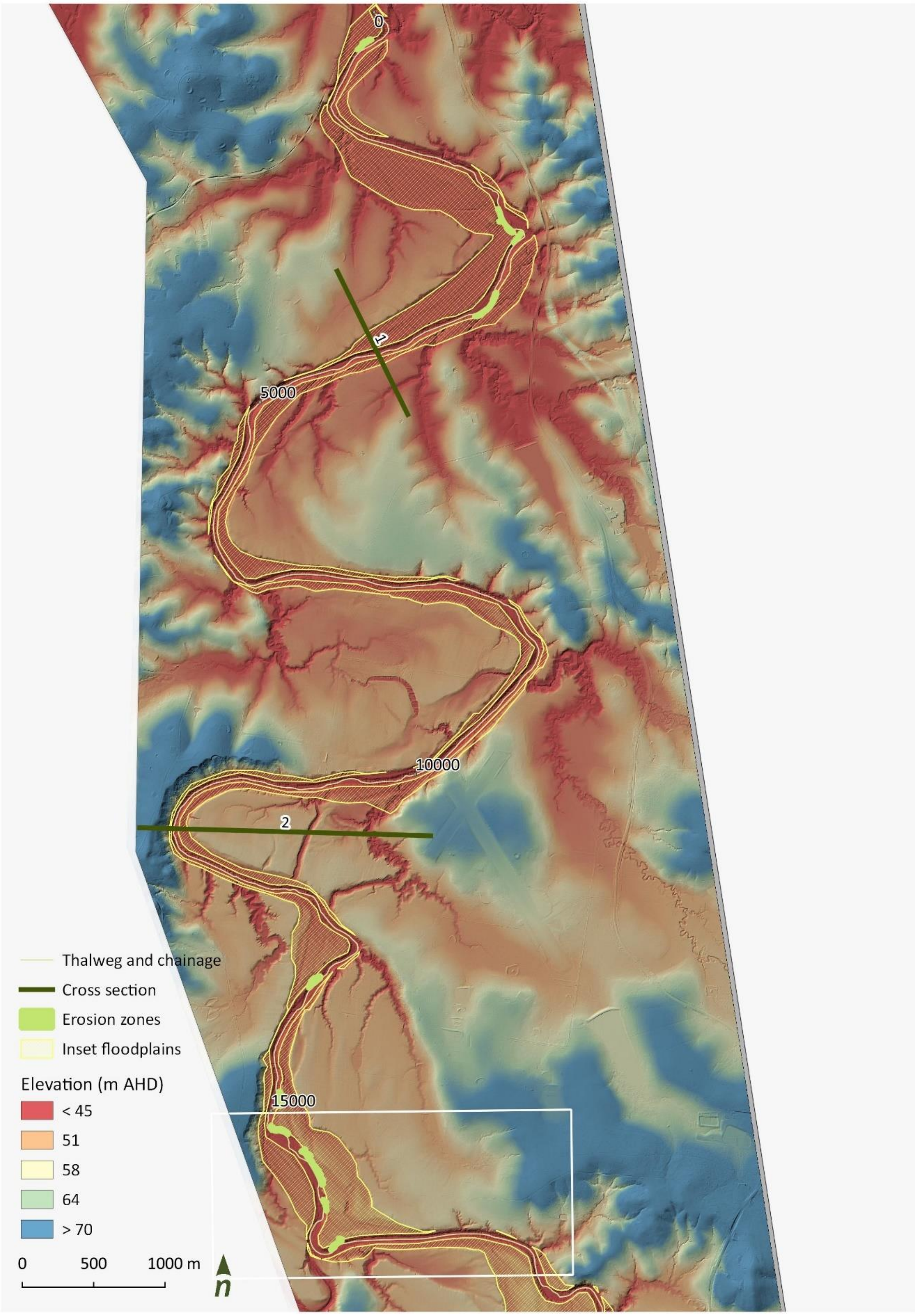

Figure 6: *The downstream portion of the Mary River case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

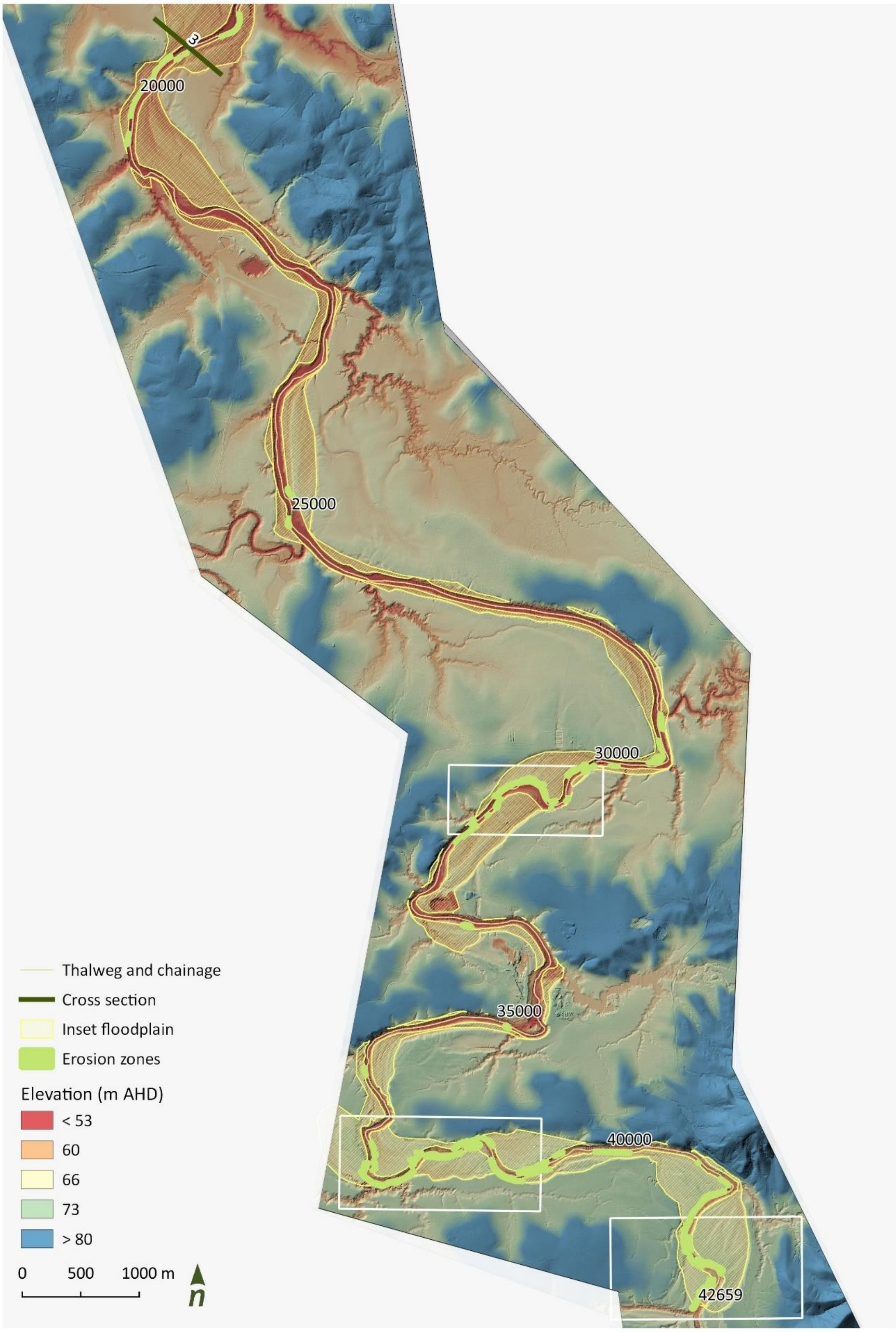

Figure 7: *The upstream portion of the Mary River case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

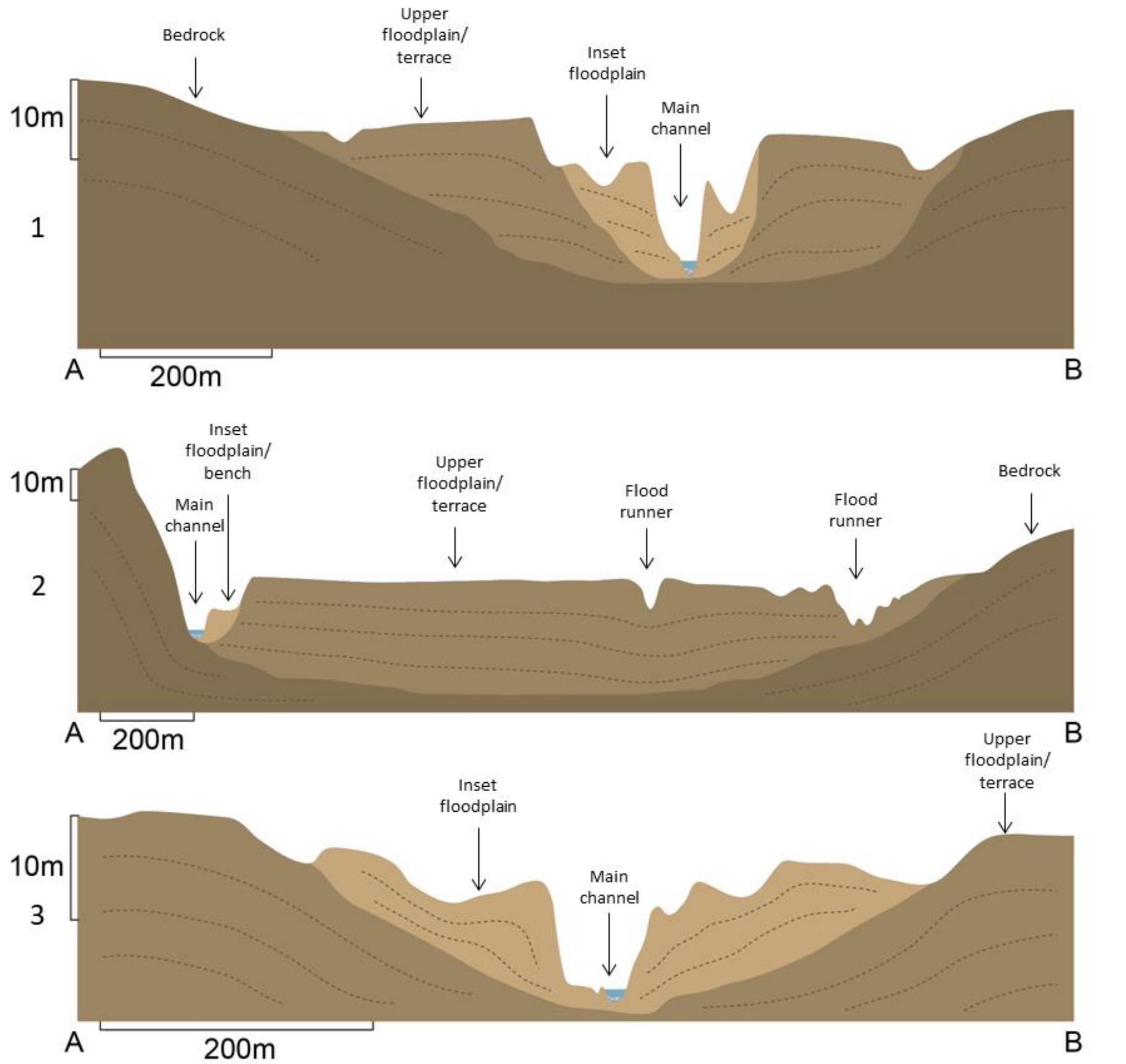

Figure 8: *The three typical sections in the Mary River case study area (shown in Figure 6 and Figure 7) with the key geomorphic units – note the stratigraphy has been estimated as no detailed chronostratigraphic data was available*

Figure 9: *View south along Mary River showing the higher terrace and inset floodplain unit*

The streambed generally consists of sand and gravel deposits while the banks consist of predominately fine sands, silts and clays. The channel forms a series of shallow pools broken by riffles attached to sand and gravel points and bank attached bars and localised instream wood. In-channel bedrock exposures occur where the channel abuts the valley margins (Figure 10).

Figure 10: *Bedrock exposure at the spurred valley margins within the Mary River*

Remnant riparian vegetation mainly comprises of eucalyptus and casuarina fringing woodland. Patchy stretches of gallery rainforest remain within the riparian zone along the upstream two thirds of the case study area. Pockets of remnant eucalyptus ‘Of concern’ woodland also persist on confining valley margins. Regrowth of riparian species is occurring along lower banks where stock access is limited (Figure 12).

Figure 11: *A section of improved riparian longitudinal connectivity in the upper section of the Mary River case study area*

Figure 12: *Establishing riparian vegetation is typically protected where bank slope limits cattle access*

Riparian longitudinal connectivity diminishes in extent towards Gympie. Recent riparian vegetation establishment is predominantly occurring along bank toes where steep bank profiles limit stock access. Where cattle access is facilitated by gentler slopes, riparian vegetation coverage is significantly less, featuring predominantly casuarina regrowth as opposed to the greater species diversity observed in protected areas (Figure 13). Overall, bank condition is severely degraded, with steep, exposed and unstable bank slopes particularly on poorly vegetated inset floodplain and bench units.

Figure 13: *A section of the Mary River downstream of Traveston Crossing Road where there is regeneration along the lower bank on one side and unrestricted stock access on the opposite bank*

Historical and recent channel change processes

Historical aerial imagery analysis indicates that by 1958 the floodplain and riparian zone was predominantly cleared for agricultural activities leaving a narrow riparian zone with poor longitudinal connectivity. The analysis indicates that active meander migration, channel straightening and widening processes have occurred since 1958. The degree of channel widening varies, with more extensive widening where the channel abuts poorly vegetated inset floodplain units (Figure 14 and Figure 15).

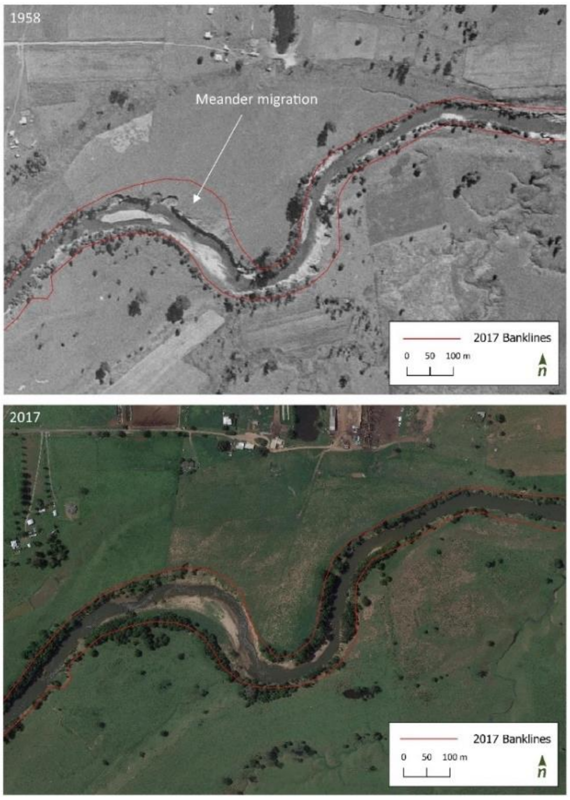

Figure 14: *Meander migration across inset floodplain deposits near the Skyrings Creek Road and Old Bruce Highway intersection within the Mary River case study area (chainage 30,000 m)*

LiDAR data from 2018 and 2009 was available for the Mary River. Flow data for the Mary River between 2009 and 2018 is shown in Figure 15. During this period there were two major flood events in 2011 and 2013 (both events had an average recurrence interval of approximately 15 years). The analysis indicates there has been limited reach-scale channel widening or planform adjustment. However, there are several areas where significant channel erosion has occurred.

The major areas of channel erosion are shown Figure 6 and Figure 7. The multi-temporal LiDAR analysis at a number of areas are shown in Figure 17, Figure 18, Figure 19 and Figure 20. Nearly all the major channel erosion areas occur in zones where the inset floodplains are more expansive and there is limited woody vegetation coverage. Channel erosion within more entrenched sections with narrow inset benches appears to be less prevalent even with poor riparian vegetation. There are no examples where there has been significant sediment loss from terrace units.

The sediment loss is a result of a range of processes including:

- Toe scour and subsequent mass failure as evident on the outside of bends
- Wet flow mass failures as described in Thompson et al. (2013)

The LiDAR indicates wet flow failures have historically been prevalent with failure scars clearly visible along inset units despite no worsening between 2009 and 2018.

Figure 15: *Meander development within an inset floodplain near Ashton Road within the Mary River case study area*

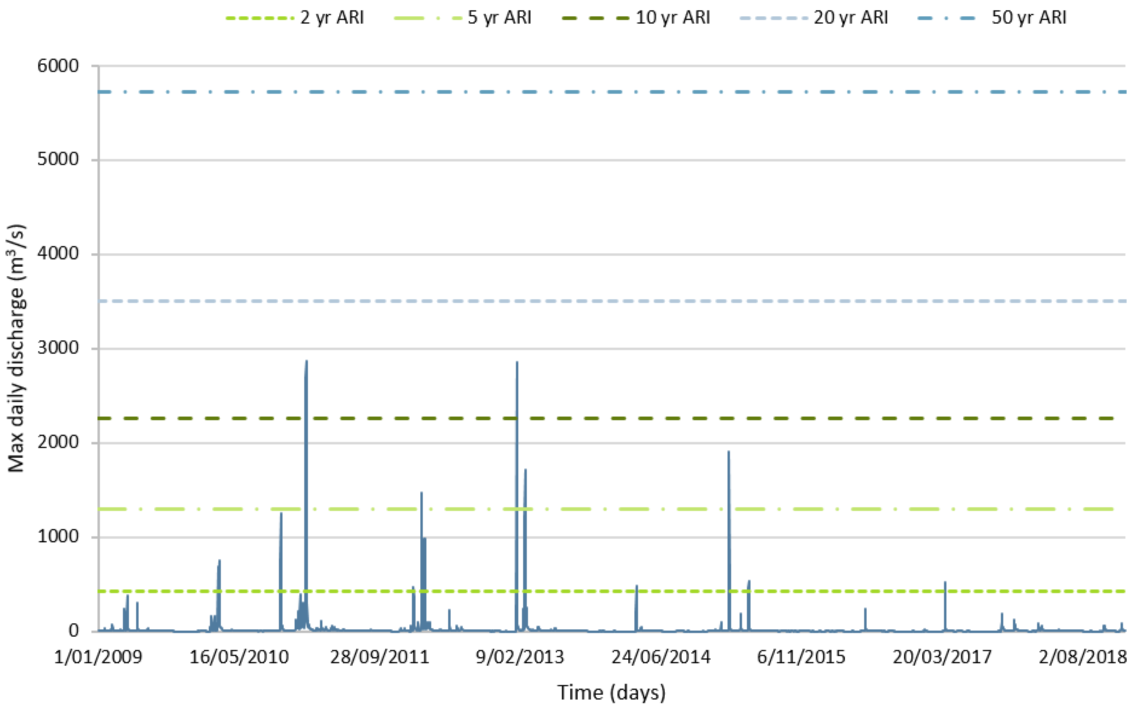

Figure 16: *Maximum daily discharge for the Mary River (Moy Pocket gauge- 138111A) between 2009 and 2018. Showing 2yr, 5yr, 10yr, 20yr and 50yr ARI flows.*

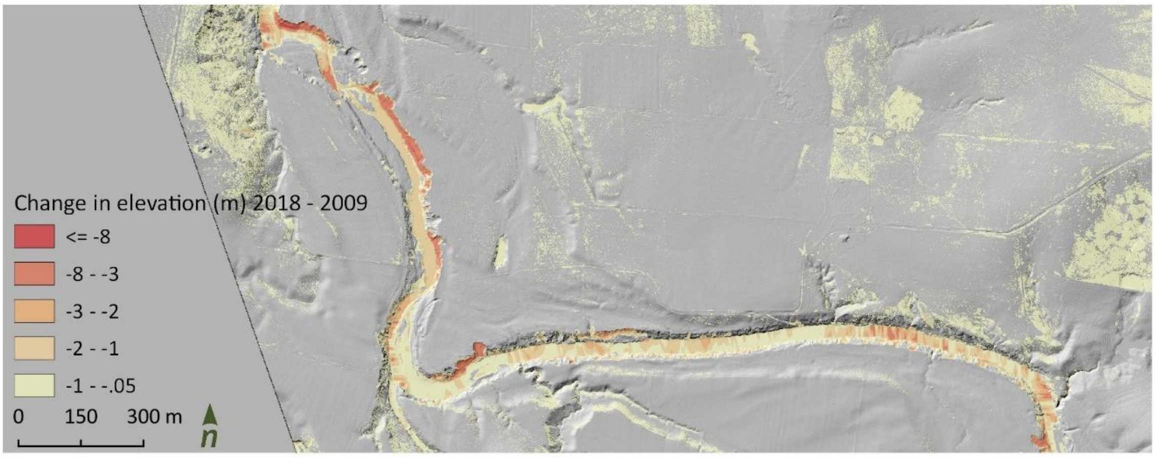

Figure 17: *Bank retreat from an inset floodplain unit through a meander migration process within the Mary River - wet flow failures have also occurred*

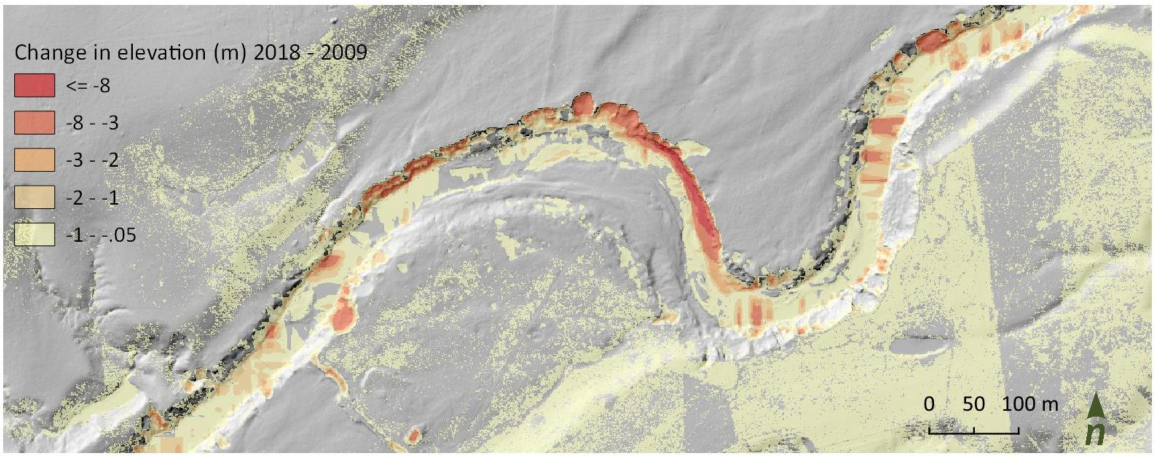

Figure 18: *Bank retreat from an inset floodplain unit through a meander migration process within the Mary River - wet flow failures have also occurred*

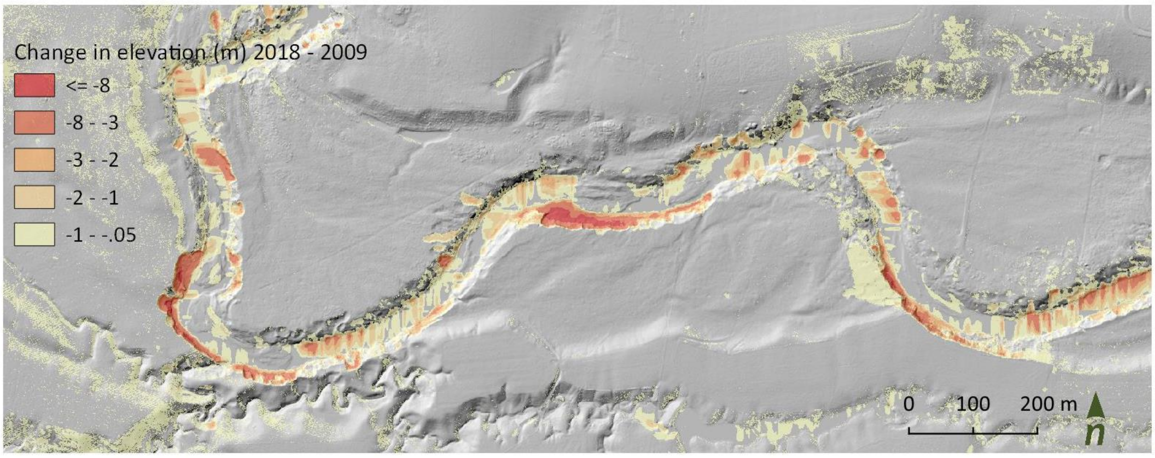

Figure 19: *Bank retreat from an inset floodplain unit through a meander migration process within the Mary River*

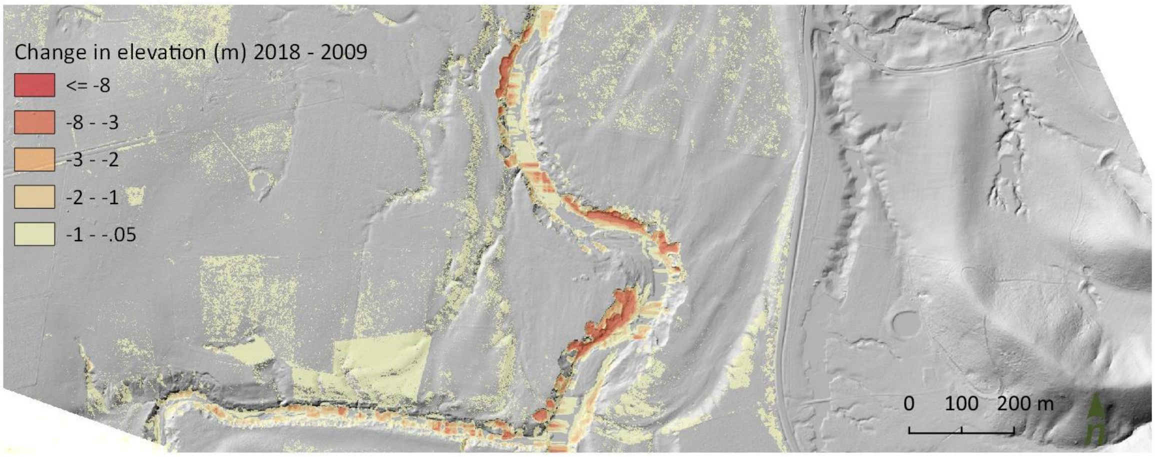

Figure 20: *Bank retreat from an inset floodplain unit through a meander migration process within the Mary River - wet flow failures have also occurred*

Longitudinal profile assessment

The longitudinal bed profile and floodplain and terrace height is shown in Figure 21. The downstream end of the case study area (i.e. below chainage 6,000 m) has a relatively low gradient of 0.000066 m/m. The river flows through an expansive area of inset floodplains through this area (see cross-section 1 in Figure 8). The low gradient and expansive alluvial development are likely partially due to backwater impacts associated with the Six Mile Creek tributary and the bedrock controls near Gympie.

The bed slope steepens substantially between chainage 6,000 m and 16,100 m to 0.0065 m/m. Within this area there is minimal inset floodplain development and the channel is relatively entrenched (see cross-section 2 in Figure 8). Through this section the significant lengths of channel abuts the bedrock valley margins – instream bedrock controls are likely helping to maintain the steeper channel gradient. Upstream of chainage 16,100 m the channel gradient reduces to between 0.00035 -0.00058 m/m. Through this section there are several valley constrictions where the bedrock is likely to result in vertical and lateral control. Upstream of these controls there is often more expansive inset floodplain development.

The bank height of the inset channel is typically 10-11 m however there is a noticeable increase between chainage 3,000 and 9,000 m where the width of inset alluvial units are significantly narrower.

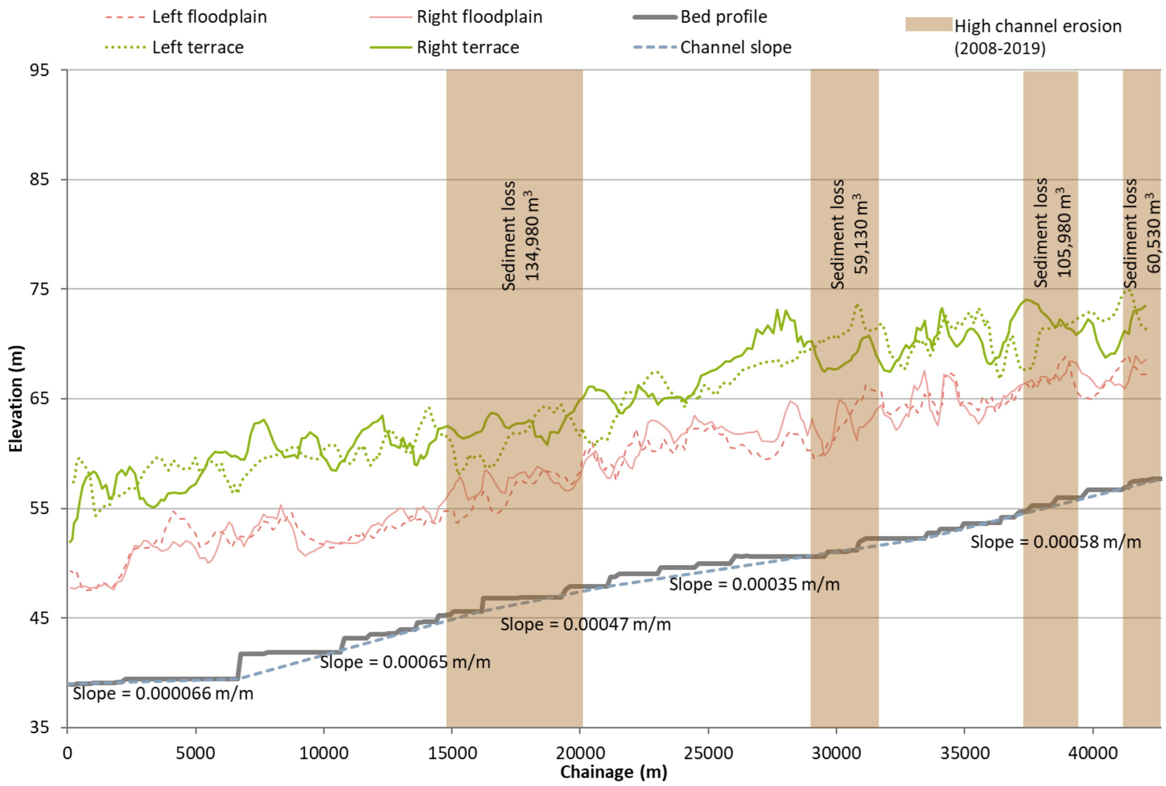

Figure 21: *Longitudinal profile and floodplain and terrace heights within the Mary River case study area*

Bankfull flow assessment

A one-dimensional HEC-RAS model was developed for the study area. The model is uncalibrated; however the hydraulic roughness has been adjusted based on the channel characteristics and sinuosity. A range of flow events were modelled to determine the channel capacity. The water surface for three flow events ranging from 550 m^3/s to 1,000 m^3/s are shown in Figure 22. Representative bankfull flows in three typical cross-section are shown in Figure 23. The channel capacity varies throughout the case study area, however is typically within the 550 m^3/s to 1,000 m^3/s. The return period for these events is between 2 and 3 years (BOM, 2020).

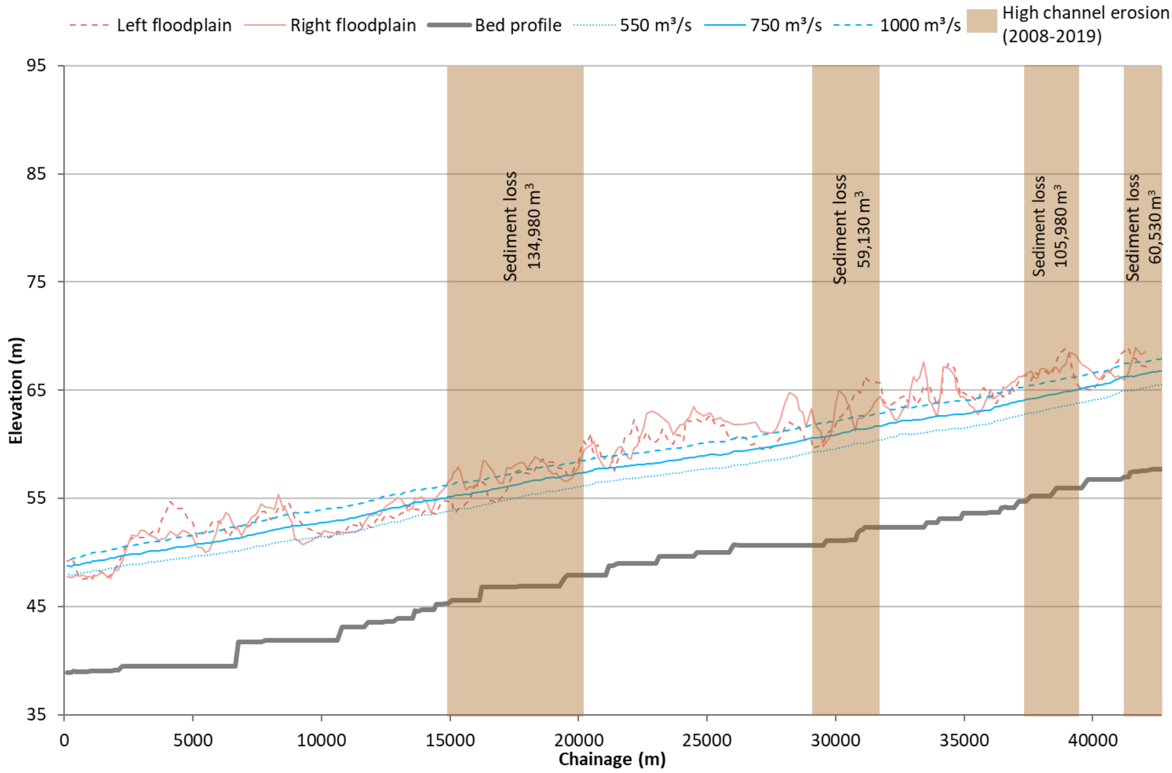

Figure 22: *The water surface elevation for a range of flow events near the bankfull elevation within the Mary River case study area*

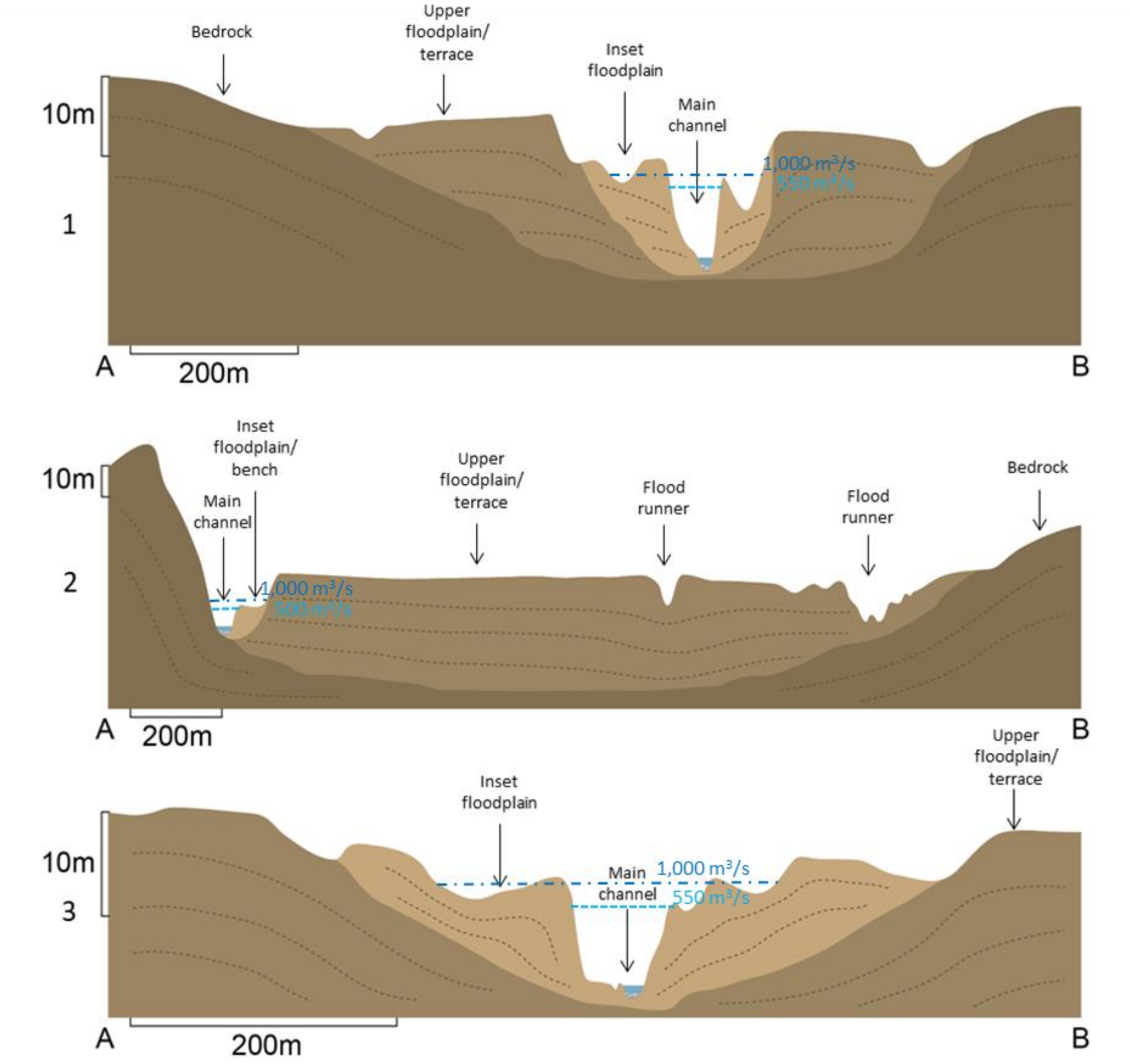

Figure 23: *The three typical sections in the Mary River case study area (shown in Figure 6 and Figure 7) showing the key geomorphic units and representative bankfull flows.*

Stream power assessment

Mean specific stream power was determined from the HEC-RAS model for the three flow events approximating the bankfull flow (Figure 24). Mean specific stream power is the rate of energy loss per unit area of channel boundary (W/m^2). Of all stream power metrics, mean specific stream power is often considered the best indicator of likely channel boundary entrainment.

Bankfull mean specific stream power within the Mary River case study is typically between 25 W/m^2 and 75 W/ m^2. There is no observable correlation between bankfull mean specific stream power and channel erosion within this case study area.

The total cross-sectional stream power results are shown Figure 25. Total cross-sectional stream power is the rate of energy loss per length of channel boundary (W/m). These values were determined by multiplying mean specific stream power by the wetted channel perimeter. Total cross-sectional stream power is the metric used within the SedNet model.

Bankfull total cross-sectional stream power within the Mary River case study is typically between 1500 W/m and 4,000 W/m. Again, there is no observable correlation between bankfull total cross-sectional stream power and channel erosion within this case study area.

The Dynamic Sednet riparian vegetation percentage parameter is also shown on the stream power figures (Figure 24 and Figure 25). This parameter is an indictor of channel resistance, determined by DNRME modellers from analysis of the 2014 Foliage Projective Cover (FPC) layer.

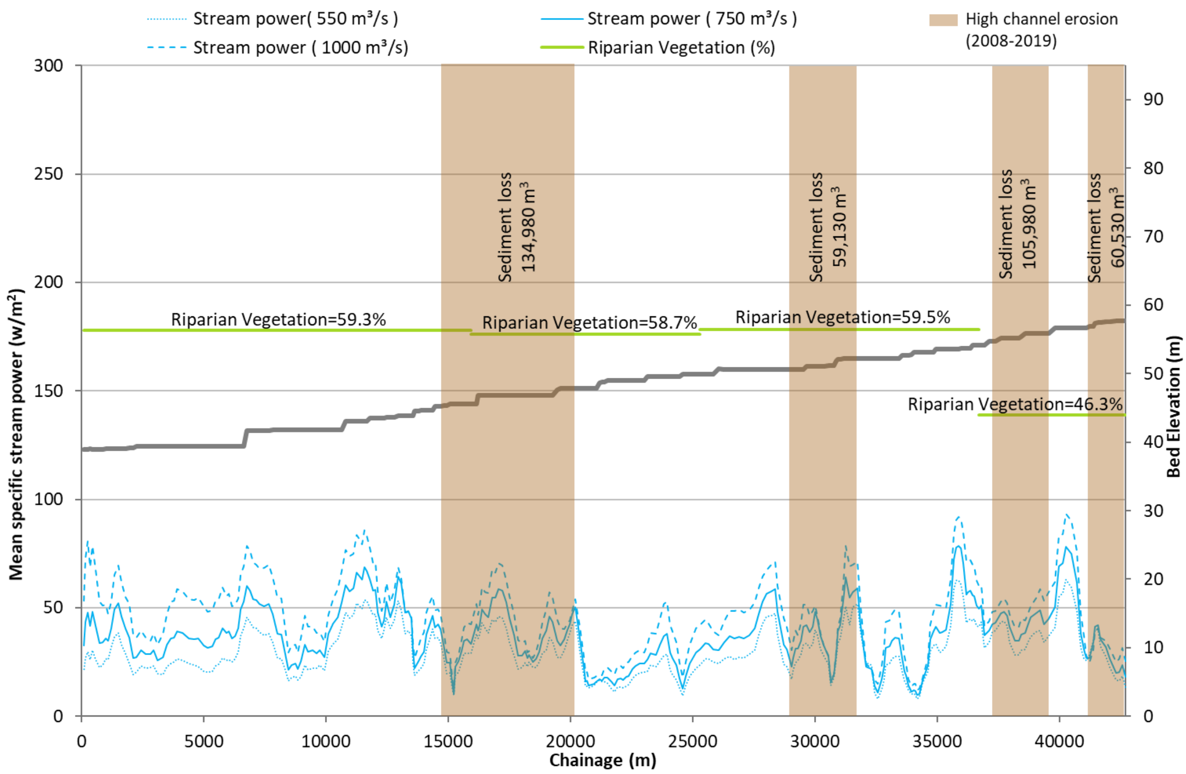

Figure 24: *The mean specific stream power within the Mary River case study area. Longitudinal variability in the SedNet Riparian Vegetation percentage parameter is also shown (note: there is no vertical axis for this metric. Percentage of intact riparian vegetation is shown on figure. Vertical height is relative to percentage of intact riparian vegetation)*

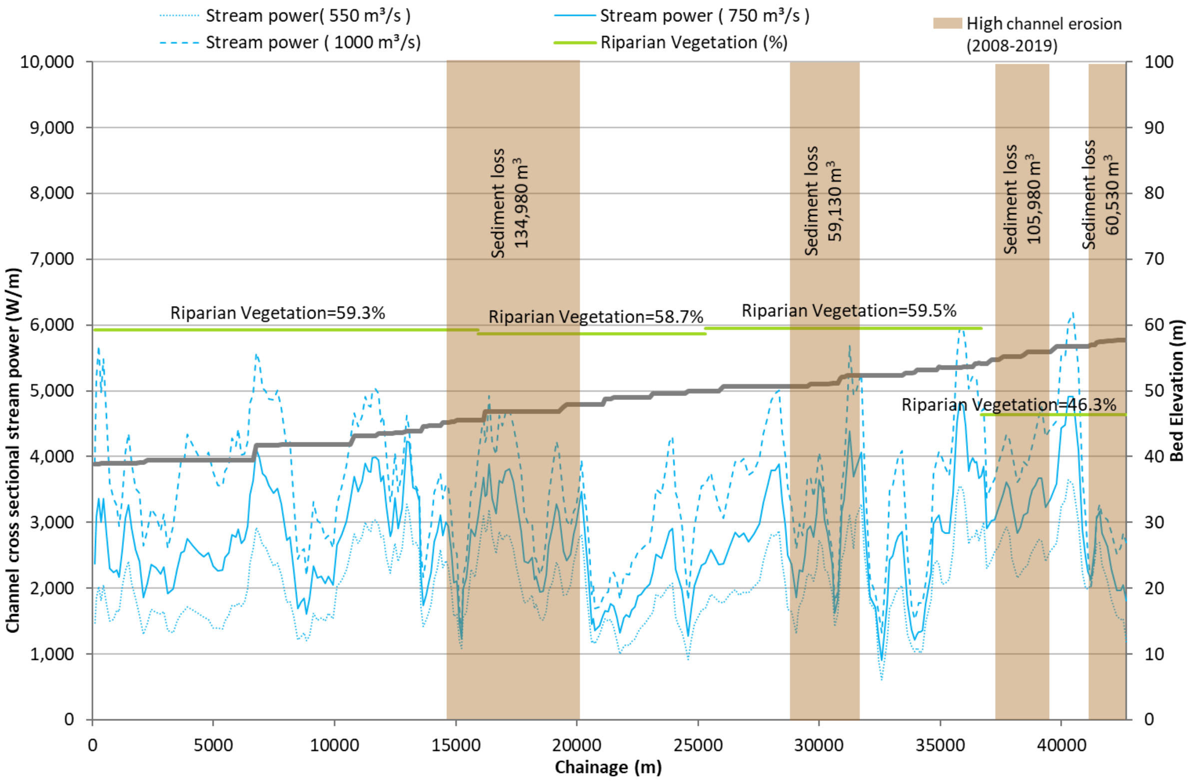

Figure 25: *The cross-sectional stream power within the Mary River case study area. Longitudinal variability in the SedNet Riparian Vegetation percentage parameter is also shown (note: there is no vertical axis for this metric. Percentage of intact riparian vegetation is shown on figure. Vertical height is relative to percentage of intact riparian vegetation)*

Bank sediments

No geotechnical information is available from within the Mary River case studies. The catchment geology consists of a range of volcanic, meta-sedimentary and sedimentary lithologies (mudstones, sandstones, siltstones, carbonaceous shales and conglomerates) which introduce a mix of sands, gravels, silts and clays to the river sediment loads.

2.3. Case study 2 - Raglan Creek

Overview

The tributaries of Raglan Creek rise on the eastern slopes of the Ulma Ranges and flow in a north-easterly direction before draining directly into Keppel Bay, approximately 40 km south-east of Rockhampton. The case study area is approximately 73 km in length, extending from the steep upper catchment to the outlet at Keppel Bay (Figure 26). The reach includes the tributary Six Mile Creek, in the upper catchment. The catchment predominantly supports livestock grazing, except surrounding the tidal flats of the lower sub-catchment, which are marshland/wetlands.

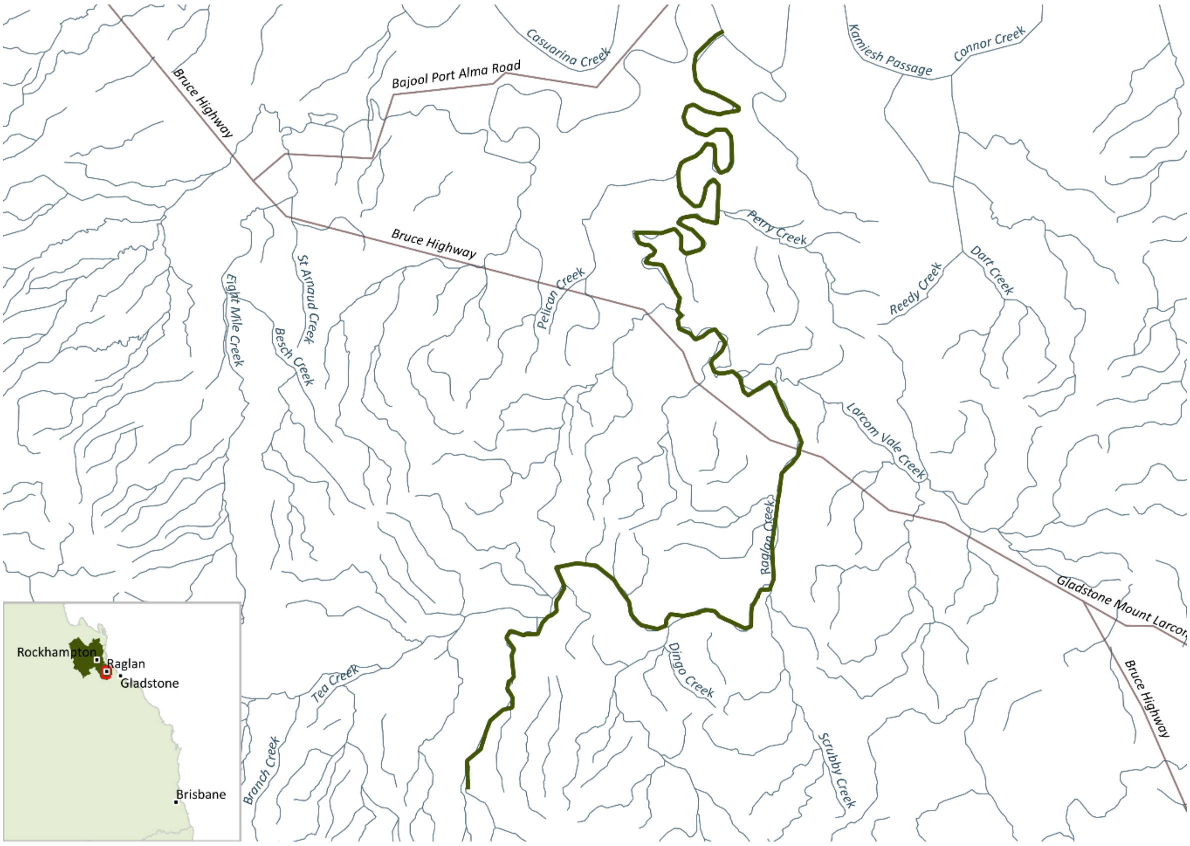

Figure 26: *The Raglan Creek case study area*

Through the upper portion of the case study area, between chainage 60,000 m and 80,000 m, the system flows through a partly confined valley setting, where the system meanders across the floodplain intermittently abutting the valley margins (see Figure 29). Through this section the channel has a wide and shallow morphology with abundant instream gravels (see cross-section 3 in Figure 30). Between chainage 40,000 m and 60,000 m the channel has a low-sinuosity planform and an entrenched channel morphology – through this section the channel has incised into older floodplain units (See Figure 28 and cross-section 2 in Figure 30). The system transitions to an unconfined valley setting downstream of Raglan, where the low relief channel meanders across the tidal flats (Figure 27) within a broader compound channel (see cross-section 1 in Figure 30). Alluvial areas are up to several kilometres wide in the upper reaches (i.e. upstream of chainage 70,000 m), narrowing to 500 m through the mid-reaches (between chainage 40,000 m and 60,000 m), before expanding again surrounding the tidal flats. The lower reaches of Raglan Creek are at or below sea level and hence are subject to tidal influences.

Figure 27: *The downstream portion of the Raglan Creek case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

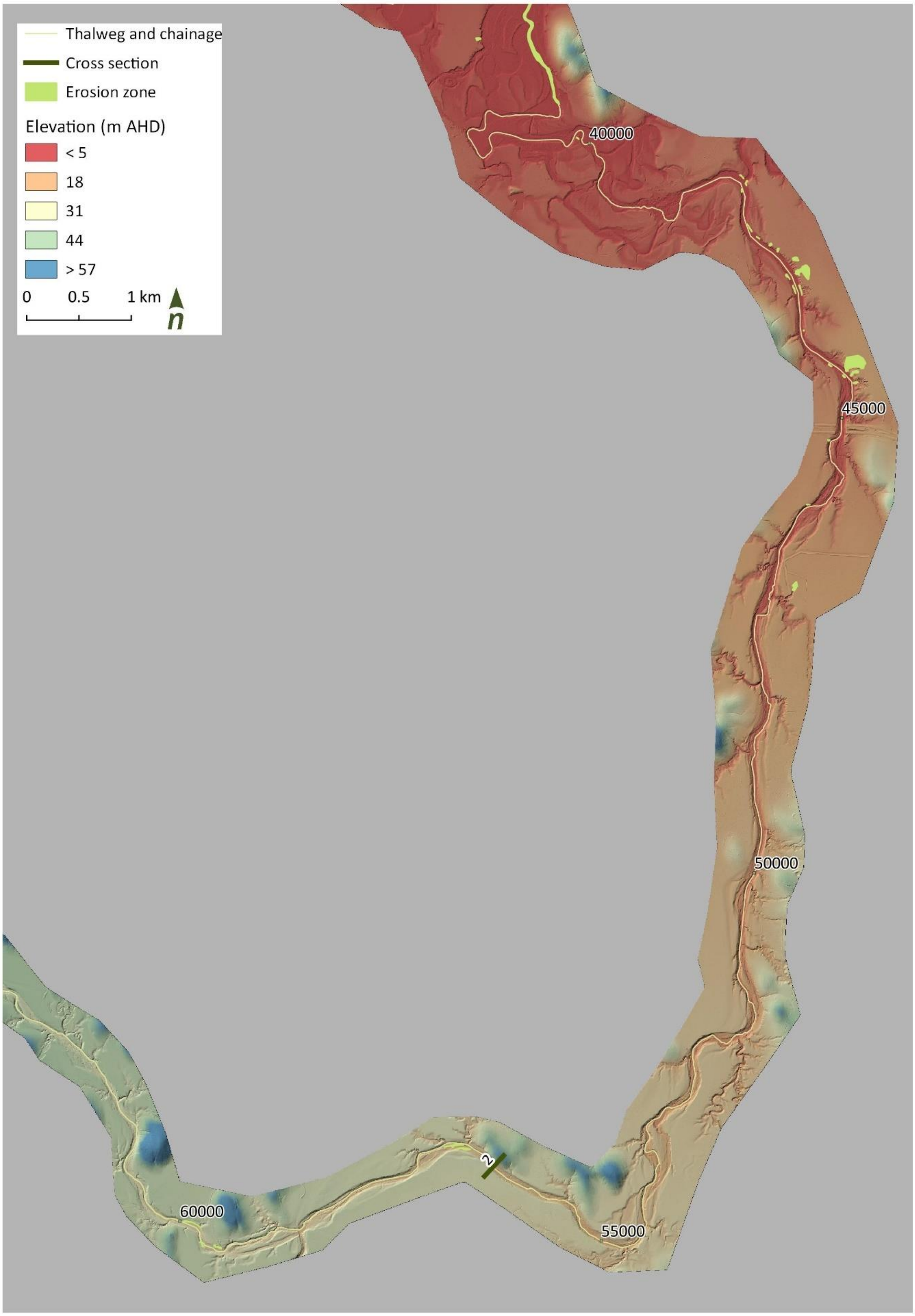

Figure 28: *The middle portion of the Raglan Creek case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

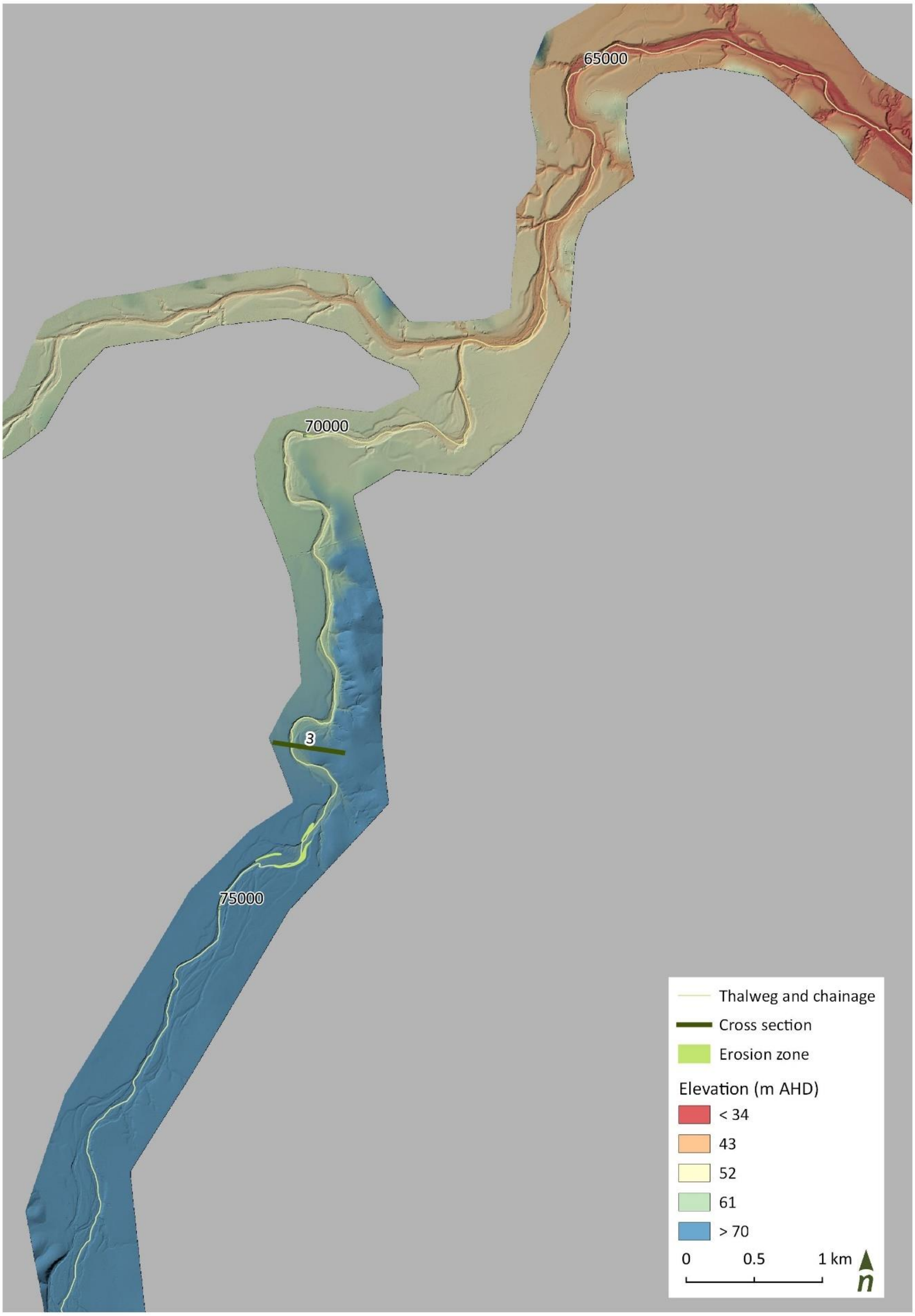

Figure 29: *The upper portion of the Raglan Creek case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

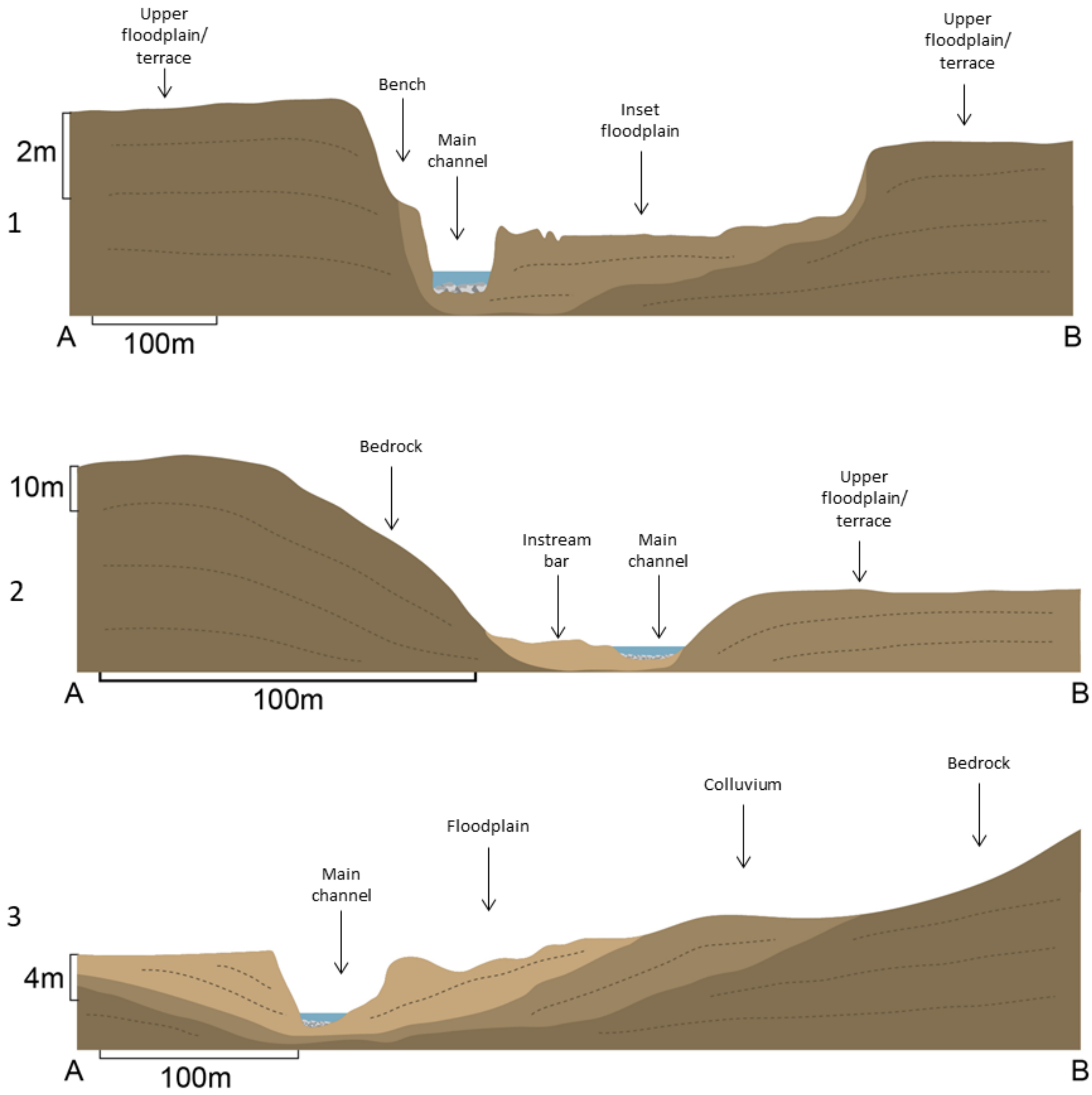

Figure 30: *The three typical sections within the Raglan Creek case study area (shown in Figure 27, Figure 28 and Figure 29) with the key geomorphic units – note the stratigraphy has been estimated as no detailed chronostratigraphic data was available – note the stratigraphy has been estimated as no detailed chronostratigraphic data was available*

Six Mile Creek and the upper reaches of Raglan Creek flow through dispersive sodosol soils. The bed material consists of sands, gravels and cobbles, with occasional bedrock outcrops (Figure 31). Many stream banks within this region have vertical, steep or irregular morphology with exposed soils indicating lateral adjustment. Bedrock outcrops may be limiting large scale vertical and lateral adjustment. Riparian vegetation extent and condition is typically poor and is significantly impacted by cattle grazing (Figure 32 and Figure 33).

The mid reaches (between chainage 40,000 m and 60,000 m) appear to be relatively stable which is likely due to the resistant older floodplain deposits. Reasonable vegetation coverage is typically maintained within the entrenched channel which limits stock access. The reach includes sections in good geomorphic condition, with stable bed and banks and good instream diversity (Figure 34 and Figure 35). The tidal reaches of Raglan Creek contain stream banks that are typically steep/vertical and devoid of vegetation. This is particularly prevalent on the outside of the meanders.

Figure 31: *An example of abundant sandy/gravelly bed material, poor riparian vegetation and cattle impacts within Six Mile Creek which is in the upper portion of the Raglan Creek case study area*

Figure 32: *Limited riparian vegetation, stock impacts and stream bank instabilities in the lower reaches of Six Mile Creek within the Raglan Creek case study area*

Figure 33: *An example of a steep and eroding bank in Raglan Creek*

Figure 34: *An example of a stable section of the mid-reaches Raglan Creek with good riparian vegetation extent and instream diversity*

Figure 35: *An example of good vegetation in the mid-reaches of Raglan Creek*

Historical and recent channel change processes

The earliest aerial imagery available indicates that the catchment was predominantly cleared of native vegetation prior to the 1960s. Changes to channel planform within the case study reach are most prevalent in Six Mile Creek and the upper reaches of Raglan Creek. Major changes include downstream meander migration and channel widening driven by fluvial scour and mass failure (Figure 36). There also appears to be abundant coarse sediments within these reaches which may be contributing to the channel widening.

2019 LiDAR data was available for the whole case study area, however 2009 LiDAR data was only available for the lower third of the case study area. Within the lower third of the case study area an analysis of change in elevation between 2009 and 2019 indicates that significant sediment mobilisation occurred from major erosion zones within the tidal reaches. On the outside of meanders, bank retreat is up to 15 m with erosion scarps up to 1 km in length (Figure 37). This erosion is most likely driven by entraintment of bank sediments due a combination of fluvial, tidal and wave action.

Erosion of a narrow floodplain between two meanders is occurring within the tidal reach. Meander migration has reduced the width of the floodplain between the two meanders by up to 25 m since 2009 (Figure 37). Further erosion may lead to a neck cutoff, and the development of a new flowpath.

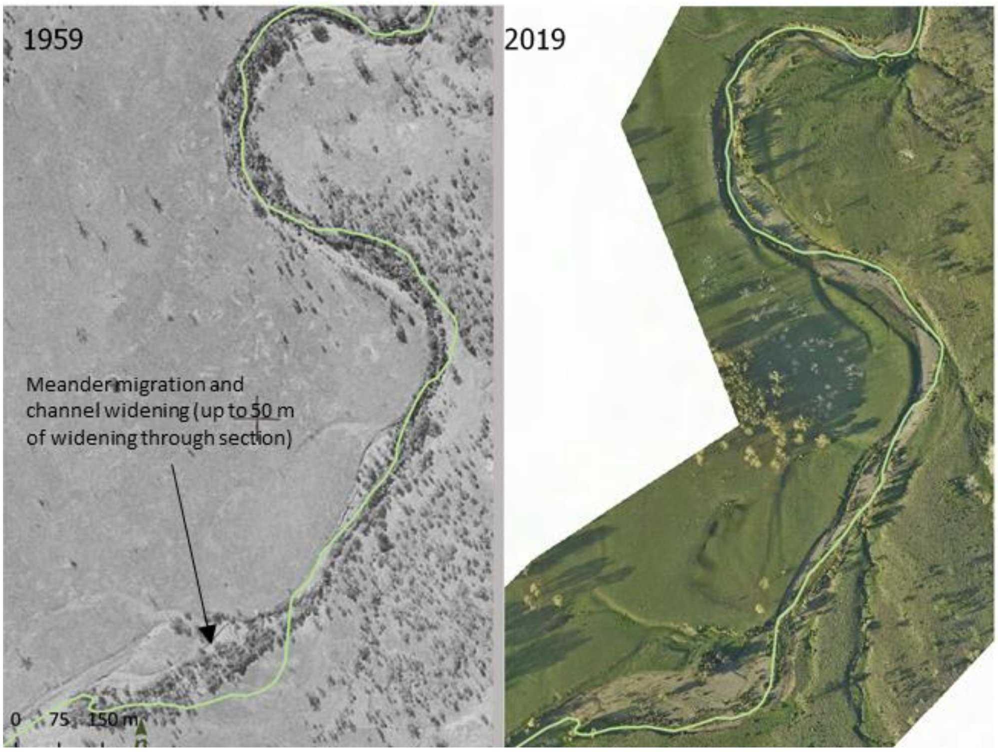

Figure 36: *Comparison of historical aerial imagery within an active zone in Six Mile Creek showing meander migration and channel widening driven by fluvial scour (2019 low flow alignment shown in green)*

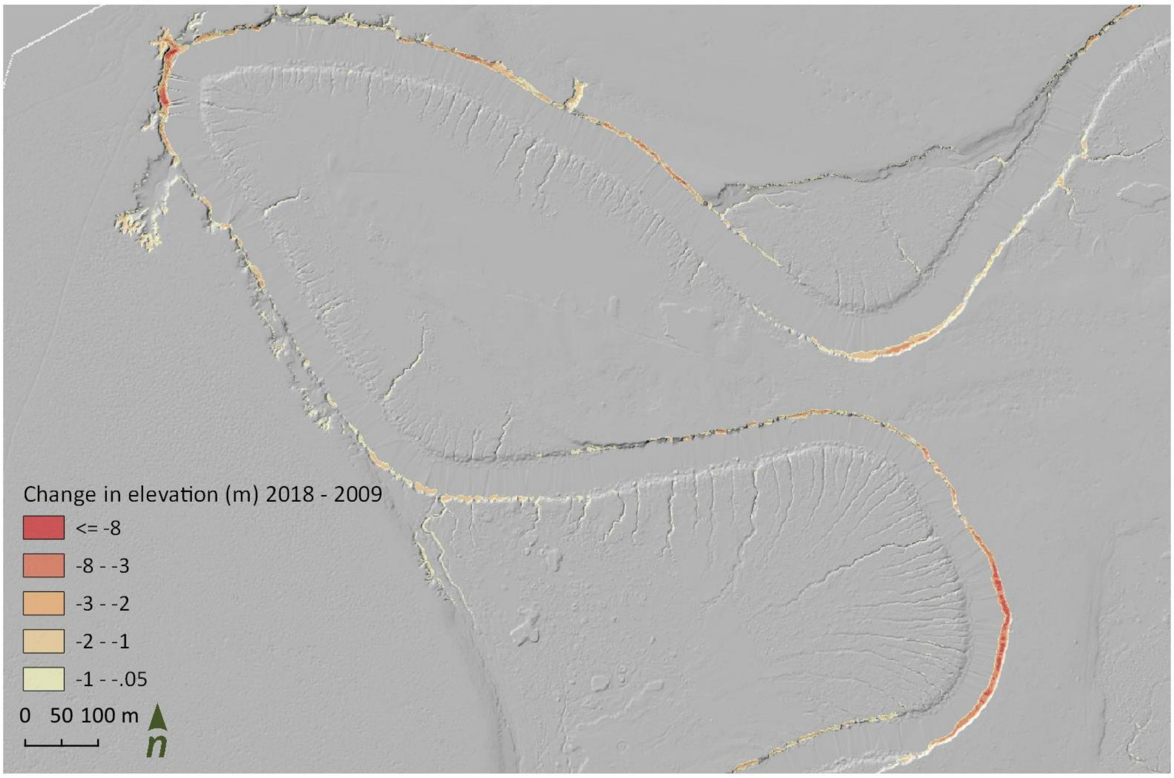

Figure 37: *Meander migration within the tidal reaches of Raglan Creek is likely to lead to a neck cutoff – also note radial floodplain drainage and alluvial gully development*

Longitudinal profile assessment

The longitudinal bed profile and floodplain height is shown in Figure 38. The downstream end of the case study area (i.e. below chainage 35,000 m) has a flat gradient due to the water surface from tidal waters. The LiDAR data has not captured any in-channel features through this zone. Upstream of chainage 35,000 m the tidal influence reduces, and the gradient steepens to 0.0003 m/m. Upstream of chainage 45,000 m the gradient progressively steepens from 0.0012 m/m to 0.0052 m/m.

The estimated bank heights below chainage 35,000 m are only 1-2 m however this is due to the lack of bathymetric information. The actual bank heights within the tidal reach are unknown but are likely significantly higher than these estimates. Between chainage 35,000 m and 40,000 m bank heights increase as the tidal influence reduces. Between chainage 40,000 m and 60,000 m bank heights are up to 10 m high as the channel is confined by the older floodplain units. Upstream of chainage 60,000 m bank heights reduce substantially as the channel is less entrenched.

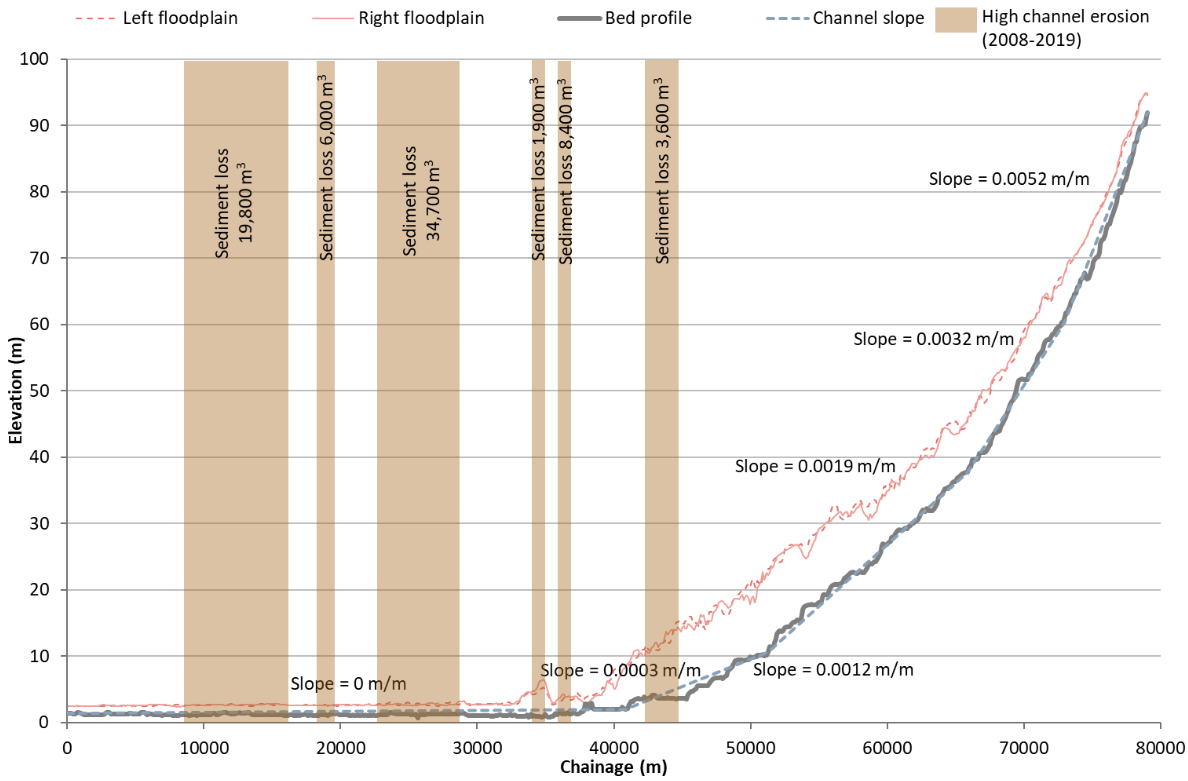

Figure 38: *Longitudinal profile and floodplain heights within the Raglan Creek case study area (note channel erosion areas are not shown in the upstream area due to lack of 2009 LiDAR data)*

Bankfull flow assessment

A one-dimensional HEC-RAS model was developed for the study area. The model is uncalibrated, however the hydraulic roughness has been adjusted based on the channel characteristics and sinuosity. A range of flow events were modelled to determine the channel capacity. The water surface for two flow events, 650 m^3/s and 1,250 m^3/s, are shown in Figure 39.

The channel capacity in the upper reaches is approximately 650 m^3/s, however this increases substantially in the mid reaches to over 1,250 m^3/s. It is not possible to determine the capacity within the tidal reaches due to the lack of bathymetric data. However, capacity within this reach would also vary based on the tidal conditions. Raglan Creek is ungauged so it is not possible to determine return periods for these flow events as part of this study.

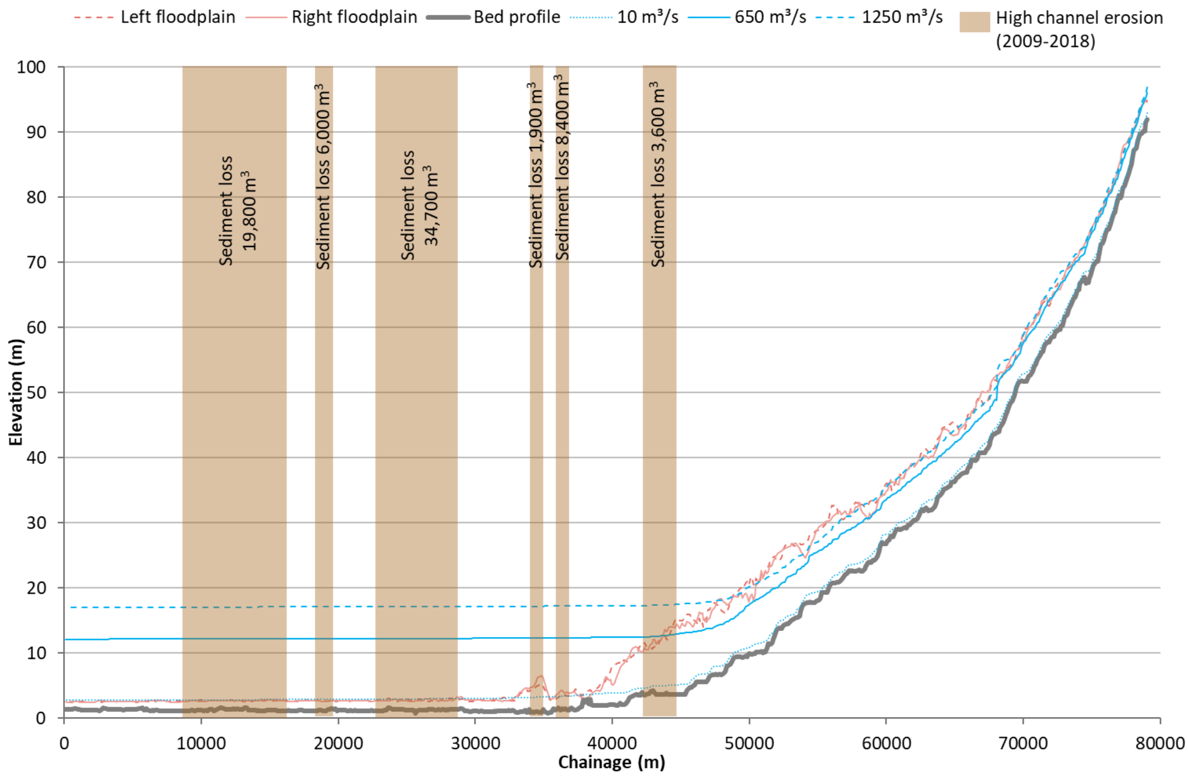

Figure 39: *The water surface elevation for two flow events near the bankfull elevation within the Raglan Creek case study area*

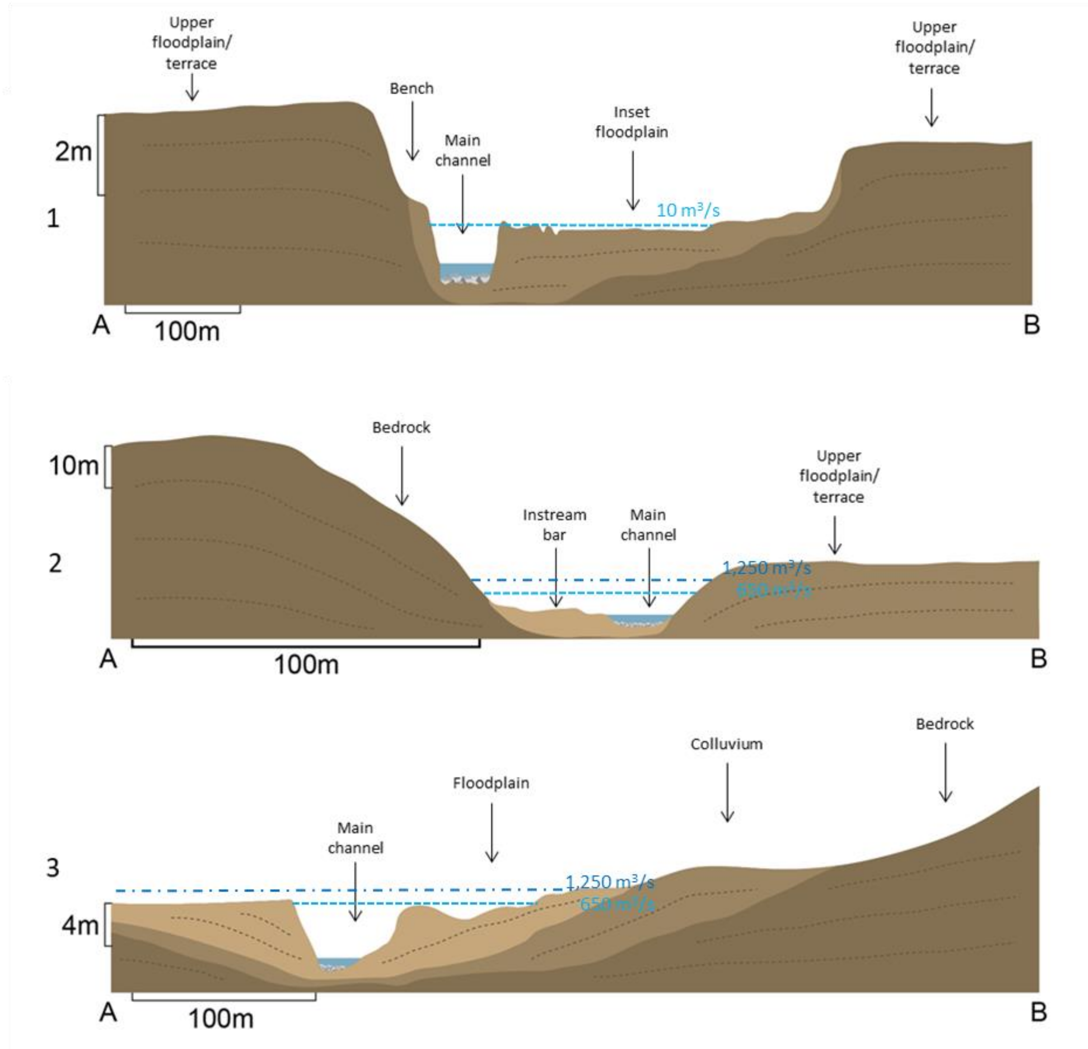

Figure 40: *The three typical sections within the Raglan Creek case study area (shown in Figure 26, Figure 27 and Figure 28) showing the key geomorphic units and representative bankfull flows.*

Stream power assessment

Mean specific stream power was determined from the HEC-RAS model for two flow events, 650 m³/s and 1,250 m³/s, and is shown in Figure 41. Upstream of chainage 70,000 m bankfull mean specific stream power is typically between 200 W/m² and 400 W/ m². No recent multi-temporal LiDAR data was available within this area however historical imagery analysis indicates extensive lateral adjustment through this area.

There is a large spike in the modelled stream power at chainage 67,770 m. This is associated with large widening of the channel downstream of a tributary junction resulting in hydraulic “drawdown”. Inflows from the tributary (which are not modelled) would increase backwater and limit the actual drawdown in this area. As a result, this modelled peak should be viewed with caution.

Between chainages 50,000 m and 65,000 m bankfull mean specific stream power is between 60 -200 W/m². Limited channel change has been observed through this area. Below chainage 45,000 m the stream power results are impacted by the surveyed water surface in the downstream channel and should be disregarded. However, bankfull stream power within the lower tidal reaches is likely to be very low (i.e. less than 5-10 W/ m²) due to the very low gradient.

The total cross-sectional stream power results are shown Figure 42. Upstream of chainage 70,000 m bankfull total cross-sectional stream power is typically between 15,000 W/m and 30,000 W/ m.

Between chainages 50,000 m and 65,000 m bankfull total cross-sectional stream power is typically between 5,000 W/m and 10,000 W/ m.

The Dynamic Sednet riparian vegetation percentage parameter, an indicator of channel resistance, is also shown on the stream power figures.

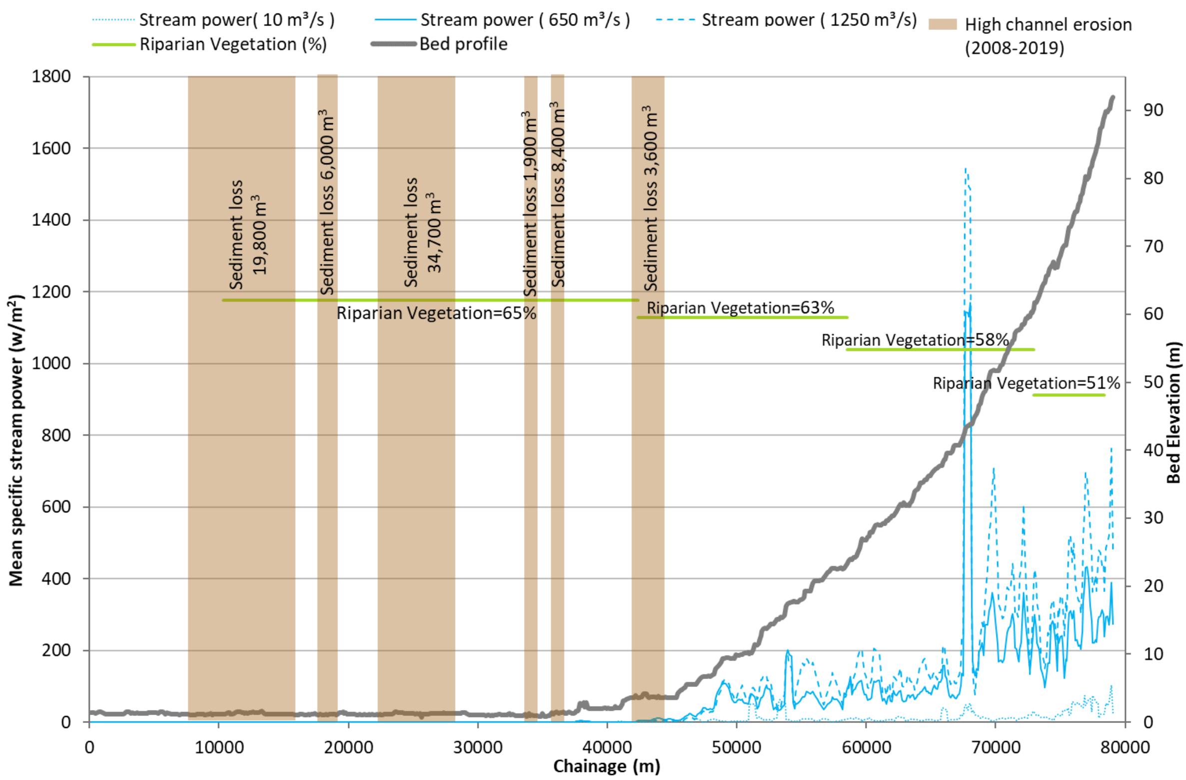

Figure 41: *The mean specific stream power within the Raglan Creek case study area. Longitudinal variability in the SedNet Riparian Vegetation percentage parameter is also shown (note: there is no vertical axis for this metric. Percentage of intact riparian vegetation is shown on figure. Vertical height is relative to percentage of intact riparian vegetation)*

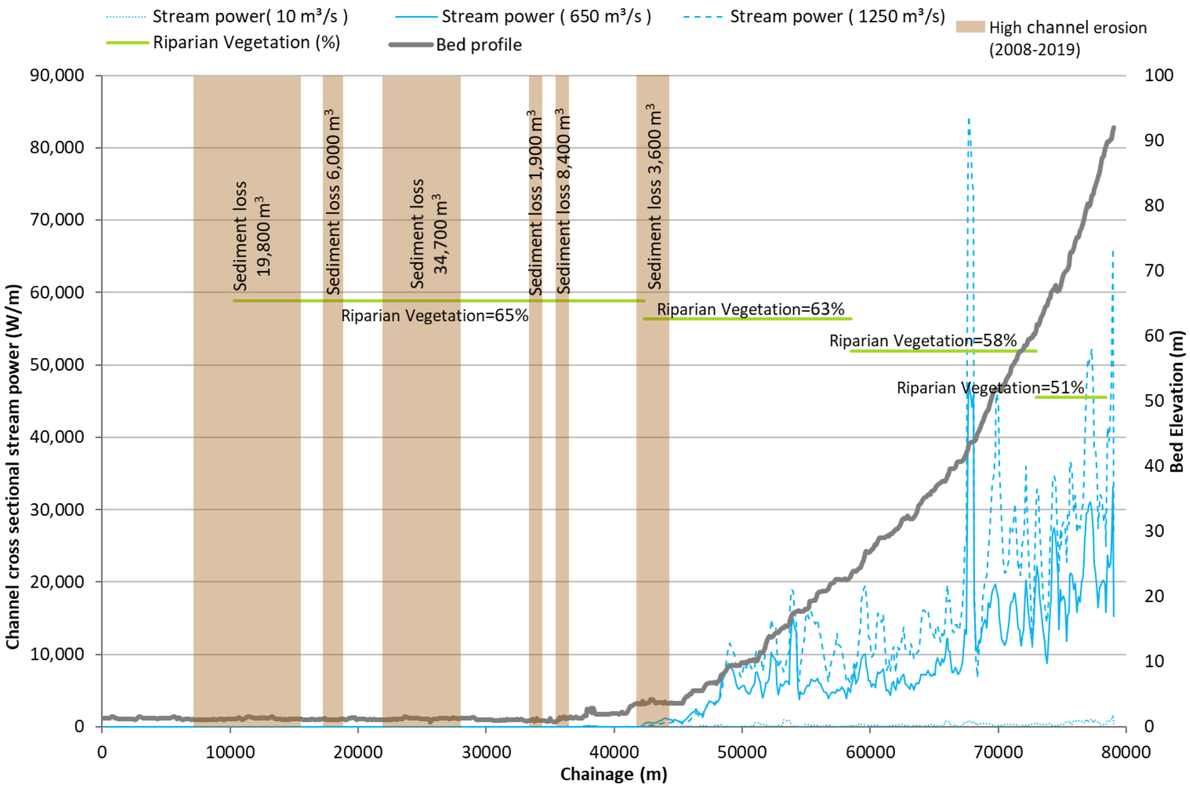

Figure 42: *The cross-sectional stream power within the Raglan Creek case study area. Longitudinal variability in the SedNet Riparian Vegetation percentage parameter is also shown (note: there is no vertical axis for this metric. Percentage of intact riparian vegetation is shown on figure. Vertical height is relative to percentage of intact riparian vegetation)*

Bank sediments

No geotechnical information is available from within the Raglan Creek case studies. The catchment geology consists of a mix of volcanic and sedimentary rocks (predominantly basaltic to andesitic volcaniclastic sandstone and conglomerate, minor silicified siltstone and fossiliferous limestone; rare andesite lava) which introduce a mix of sands, gravels/cobbles and clays to the river sediment loads.

2.4. Case study 3 - Fitzroy River

Overview

The Fitzroy River case study reach extends for 65 km upstream of the tidal barrage in Rockhampton (Figure 43). The upper extent of the reach is approximately 20km downstream of the Eden Bann Weir. The floodplains predominantly support livestock grazing, with some cropping in the lower reaches and the urban centre of Rockhampton.

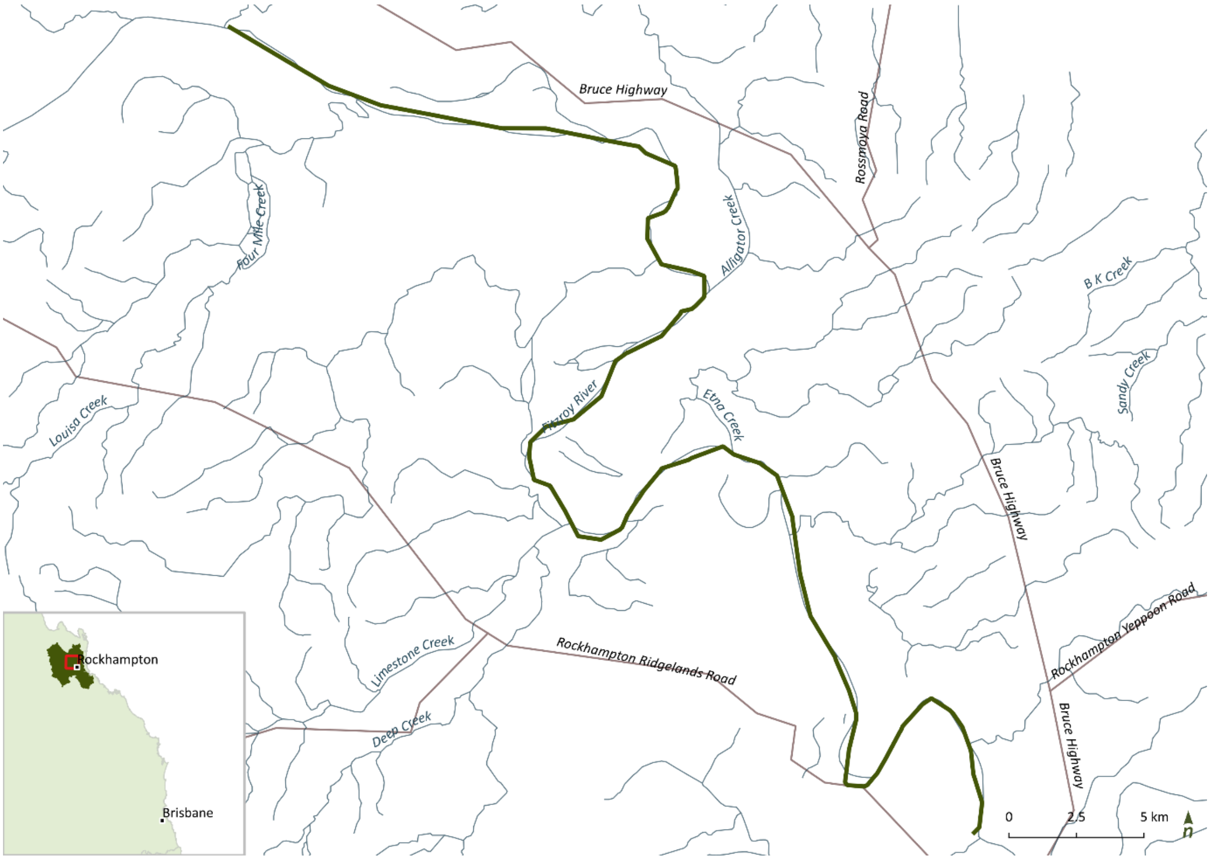

Figure 43: *The Fitzroy River case study area*

The case study area is shown in Figure 44 and Figure 45. The reach flows through a broad floodplain (up to 12 km wide) with thick alluvial deposits that have undergone extensive reworking by the river over geologic time. There are many paleo landforms (including former channel alignments) present that are unrelated to the present-day river but do influence its behaviour (see cross-sections 1 and 2 in Figure 46). The scroll-bar topography in certain locations indicates significant lateral migration of the channel. The reach is partly confined by bedrock valley margins, which limit the ability of the channel to migrate laterally across the valley in some locations. The reach is classified as meandering (Croke et al, 2011), however it contains several higher-angle bends separated by sections that are near straight.

The channel through the reach is wide and extends over 500 m in some locations. Geomorphic units within the channel include:

- wide inset bars, which sit approximately 2 to 5 m above the channel bed (see cross-section 3 in Figure 46, and Figure 47), and
- inset alluvial units including benches, which sit approximately 5 to 10 m above the channel bed (see cross-section 3 in Figure 46).

Both the tidal barrage and the Eden Bann Weir have impacted river hydraulics, sediment transport and bank saturation processes within this area.

The reach is predominantly underlain by quaternary alluvium, comprised of clays, silts, sands and gravels. Riparian vegetation is typically present on the stream banks, but does not extend beyond the top of bank and is generally heavily impacted by cattle grazing. It lacks the structural diversity and density to provide significant erosion protection functions. In-channel bars are typically devoid of vegetation and are impacted by cattle grazing. Riparian vegetation predominantly includes open Acacia forests (R.E. 11.3.1) or open eucalypt woodlands (R.E. 11.3.3).

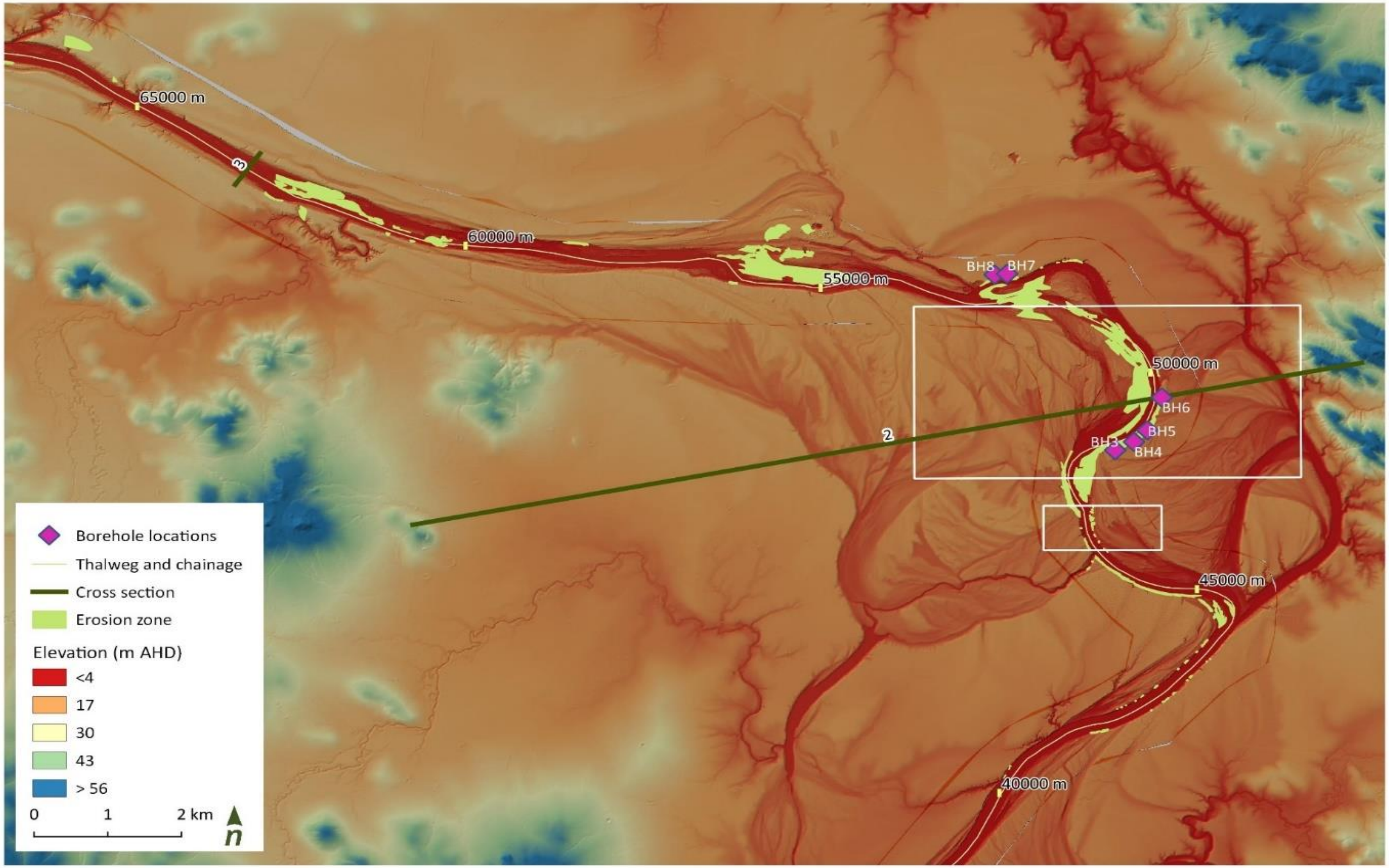

Figure 44: *The upper portion of the Fitzroy River case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

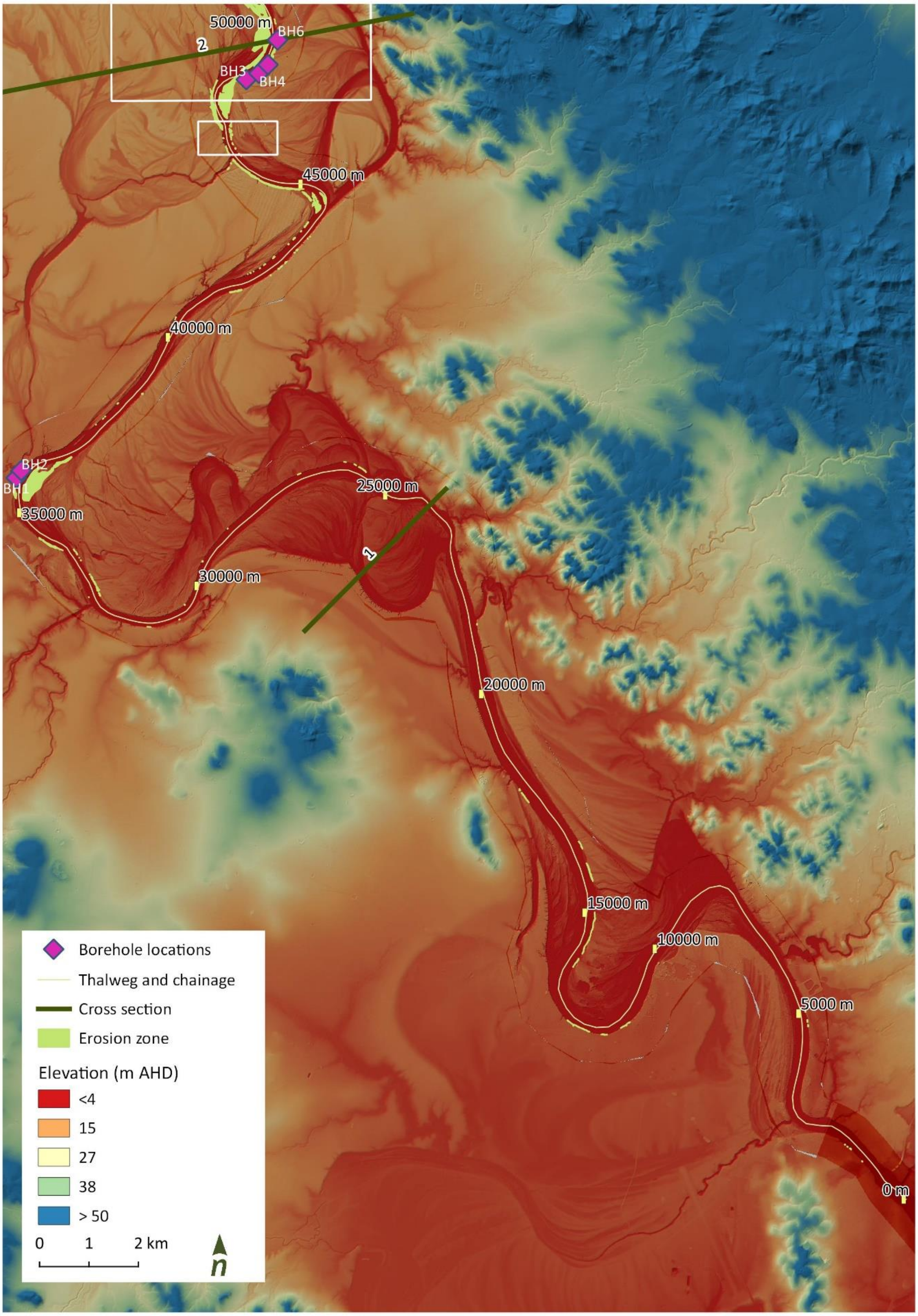

Figure 45: *The downstream portion of the Fitzroy River case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

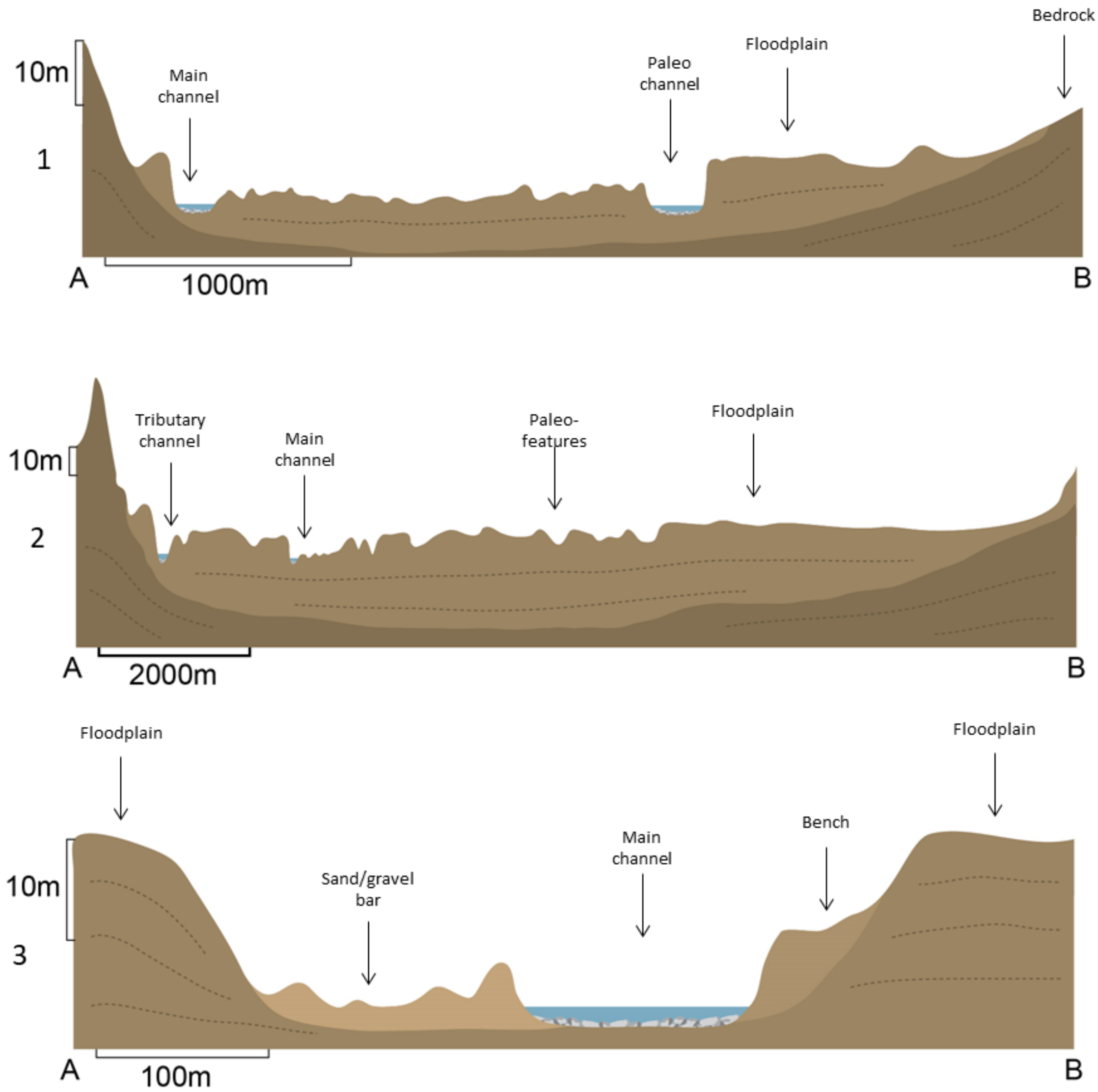

Figure 46: *The three typical sections within the Fitzroy River case study area (shown in Figure 44 and Figure 45) with the key geomorphic units - note the stratigraphy has been estimated as no detailed chronostratigraphic data was available*

Figure 47: *A wide in-channel bar within the Fitzroy River case study area*

Historical and recent channel change processes

The channel alignment through the majority of the case study area has been relatively stable since 1952. The major changes within the reach include downstream migration around several tight bends in the middle of the reach (Figure 48) and the infilling of a paleochannel in the mid to lower reach (Figure 49). The meander migration has resulted in 50 to 300 m of bank retreat on the outside of several meanders. Expansion or contraction of several instream deposits has also occurred.

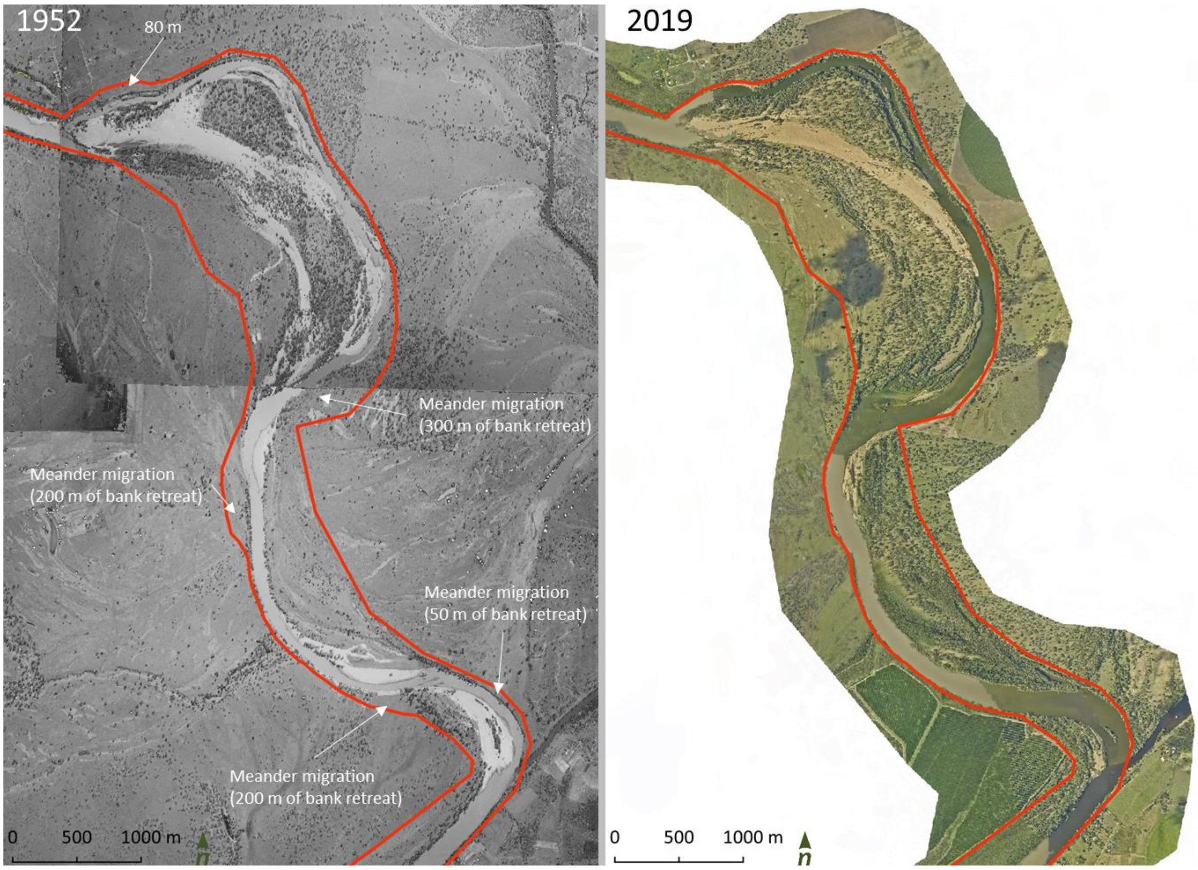

Figure 48: *Comparison of historical aerial imagery within an active zone of the Fitzroy River case study area showing meander migration*

Figure 49: *Comparison of historical aerial imagery within an active zone within the Fitzroy River case study area showing the shutdown of a previous water course*

An analysis of LiDAR between 2009 and 2019 indicated that significant volumes of sediment were mobilised from major erosion zones. Flow data for the Fitzroy River between 2009 and 2018 is shown in Figure 50. The majority of the sediment resulted from meander migration processes at nine major sites (example shown in Figure 51), however significant volumes of sediment were also mobilised from within the channel (Figure 51) and from wet flow failure (Figure 52). Sediment mobilisation was predominantly from the floodplain where erosion of the high banks generates significant volumes of sediment (69 %), however significant volumes of sediment were also eroded from within channel features such as bars.

The major erosion sites were predominantly concentrated in the middle of the study area near the Alligator Creek confluence (between chainage 45,000 and 55,000 m). Within this section several major erosion sites were located on the outside of meanders in addition to in-channel scour. Within this zone significant sediment deposition has also occurred on bars. The accelerated rates of erosion within this area are likely partly attributed to a large meander cutoff that has occurred prior to the 1950s just downstream.

A significant number of wet flow failures were distributed throughout the case study area (Figure 52).

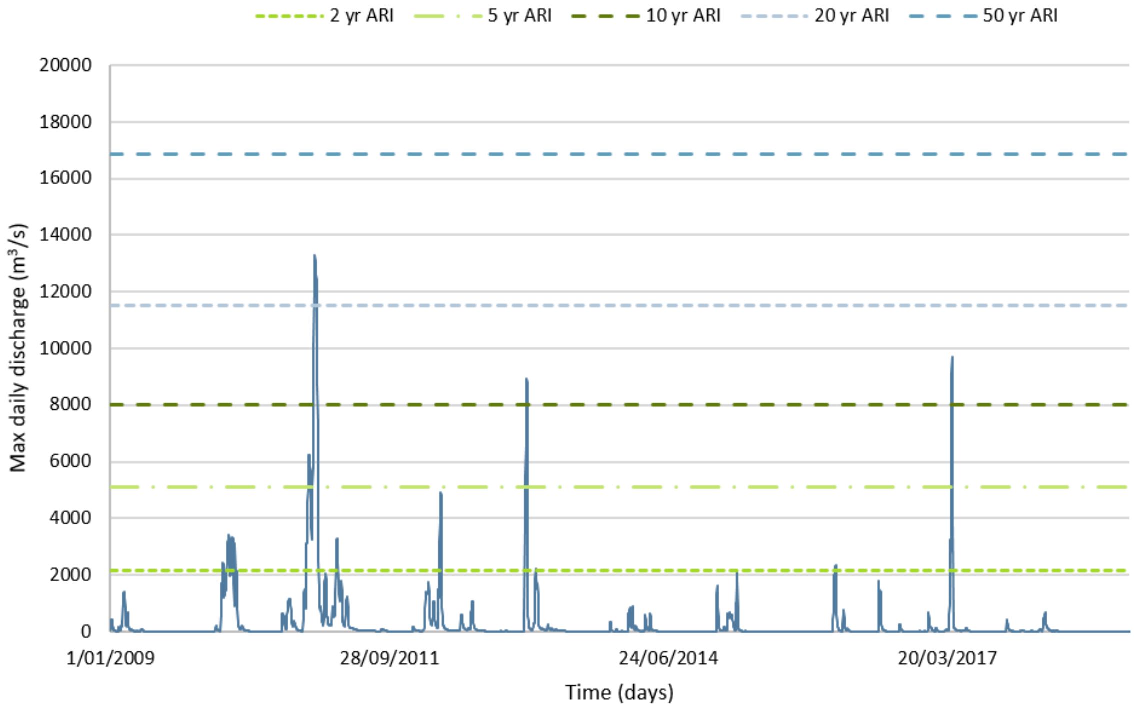

Figure 50: *Maximum daily discharge for the Fitzroy River (The Gap gauge- 130005A) between 2009 and 2018. Showing 2yr, 5yr, 10yr, 20yrand 50yr ARI flows.*

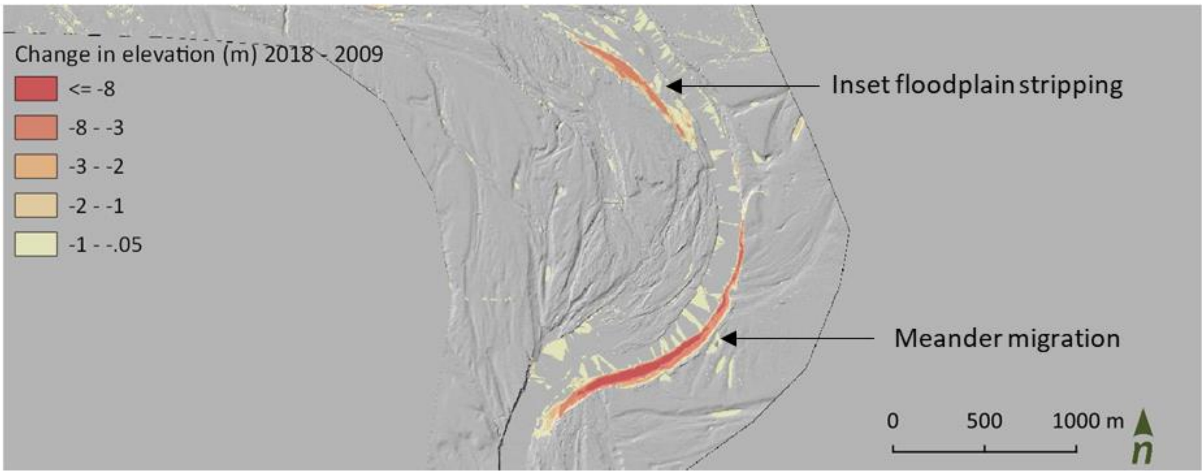

Figure 51: *Change in elevation between 2018 and 2009 within Fitzroy River case study area - showing meander migration and inset floodplain stripping*

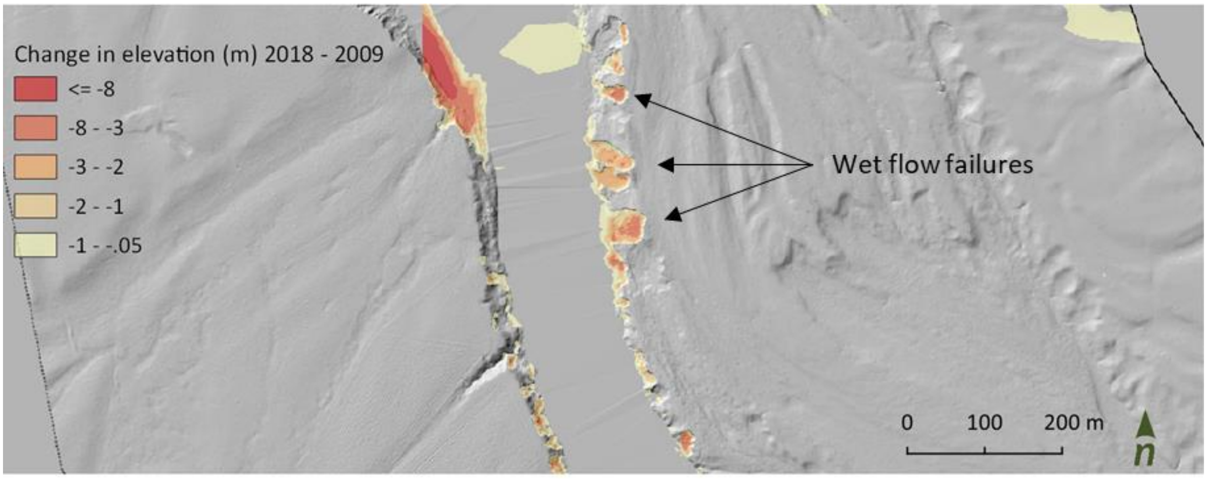

Figure 52: *Change in elevation between 2018 and 2009 within Fitzroy River case study area - showing wet flow failures*

Longitudinal profile assessment

The longitudinal bed profile and floodplain height is shown in Figure 53. The majority of the case study area (i.e. below chainage 53,000 m) has a flat gradient due to the water surface from the tidal barrage. The LiDAR data has not captured any in-channel features through this zone. Upstream of chainage 53,000 m the gradient steepens to 0.0001 m/m.

The floodplain elevation upstream of chainage 53,000 m is approximately 15 m above the channel bed. Downstream of this location the floodplain height above the water surface progressively decreases to 5-8 m at the tidal barrage. The actual bank heights (i.e. above channel bed) within the weir pool (i.e. downstream of chainage 53,000 m) are unknown but are likely between 10 -15 m.

Within the main channel there are often inset units including benches and isolated inset floodplains. These units typically have a height of 5 -10 m above the channel bed.

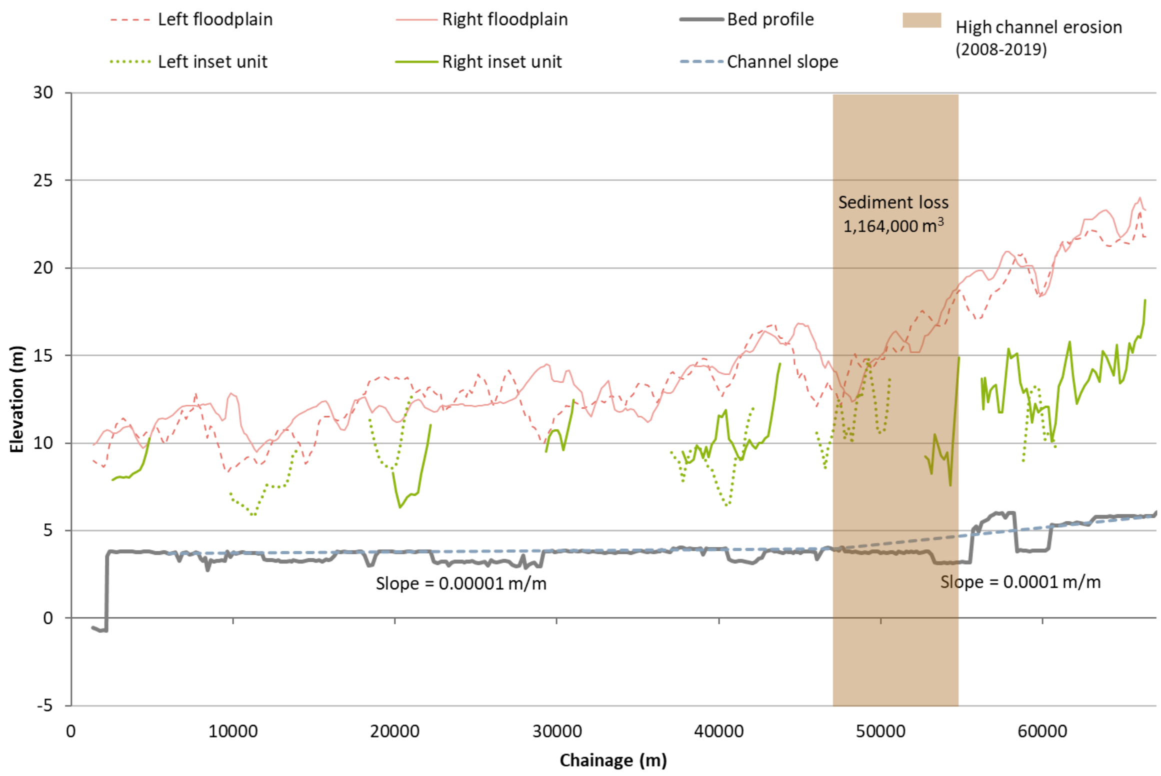

Figure 53: *Longitudinal profile and floodplain heights within the Fitzroy River case study area (note rise in bed elevation at chainage 55,000 m is an error in the LiDAR processing)*

Bankfull flow assessment

A one-dimensional HEC-RAS model was developed for the study area. The model is uncalibrated however the hydraulic roughness has been adjusted based on the channel characteristics and sinuosity. A range of flow events were modelled to determine the channel capacity. The water surface for five flow events between 1200 m^3/s and 5,400 m^3/s are shown in Figure 54. Representative bankfull flows in three typical cross-section are shown in Figure 55.

The channel capacity in the upper reaches is approximately 5,400 m^3/s which has an approximate return period of 5 years. Downstream towards the tidal barrage, channel capacity is closer to 2,900 m^3/s which has a return period of 3 years. It is not possible to determine the actual channel capacity within the weir pool due to the lack of bathymetric data. However, the channel capacity within this reach is unlikely to be significantly different to these modelled estimates.

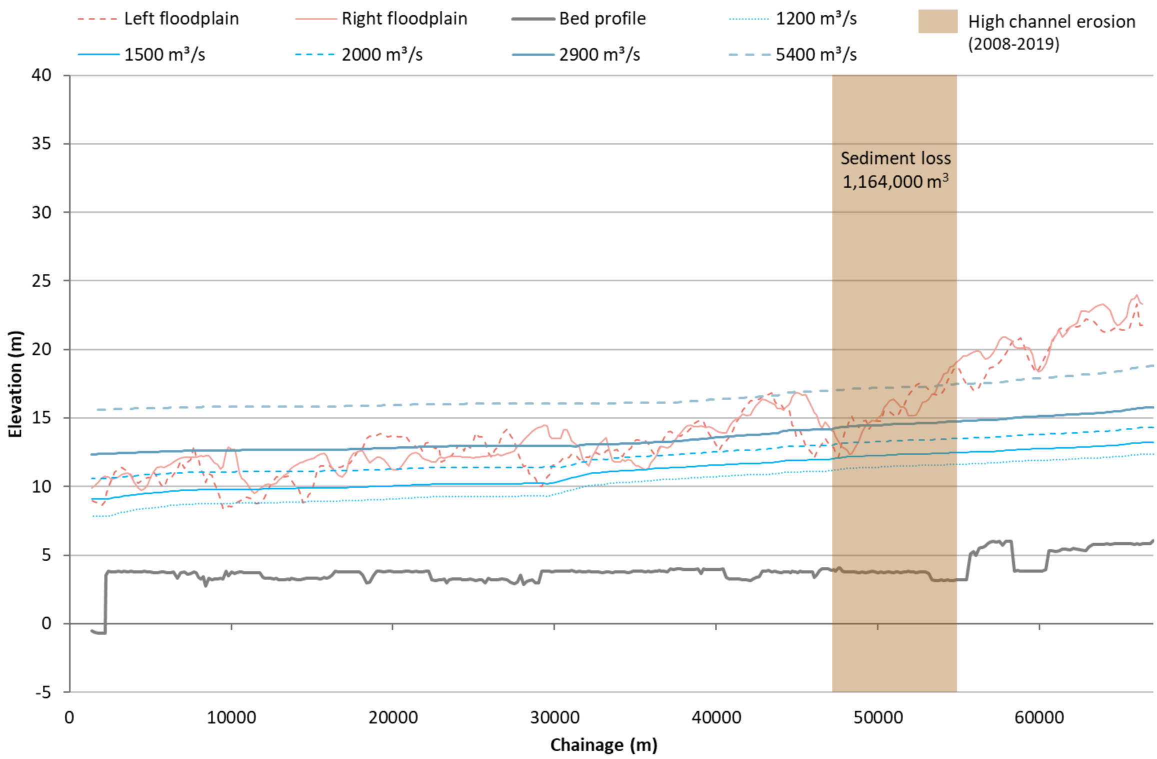

Figure 54: *The water surface elevation for a range of flow events near the bankfull elevation within the Fitzroy River case study area*

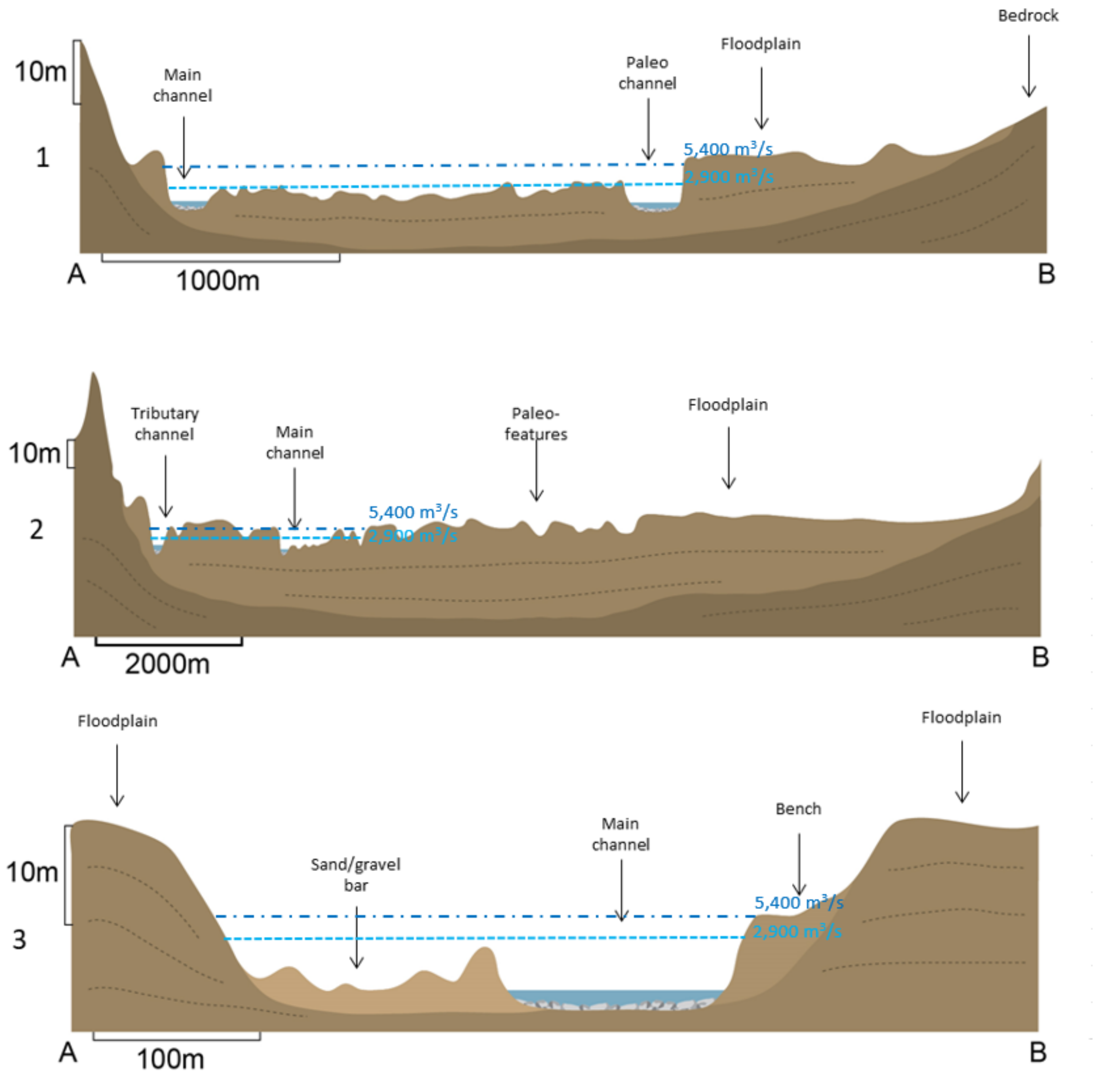

Figure 55: *The three typical sections within the Fitzroy River case study area (shown in Figure 44 and Figure 45) showing the key geomorphic units and representative bankfull flows.*

Stream power assessment

Mean specific stream power was determined from the HEC-RAS model for two flow events, 2,900 m³/s and 5,400 m³/s, as shown in Figure 56. Bankfull stream power is typically less than 10 W/m² although this increases slightly in the upper section of the case study area. The increases in stream power at chainage 30,000 m and 42,000 m are the results of flows transitioning from a narrower zone to a more expansive area. There does not seem to be any correlation between the modelled bankfull stream power and the area of erosion between chainage 48,000 m and 55,000 m.

The total cross-sectional stream power results are shown in Figure 57. Downstream of chainage 28,000 m bankfull total cross-sectional stream power is typically between 500-2,000 W/m. Upstream of chainage 28,000 m it is typically between 2,000-6,000 W/m.

The Dynamic Sednet riparian vegetation percentage parameter, an indicator of channel resistance, is also shown on the stream power figures.

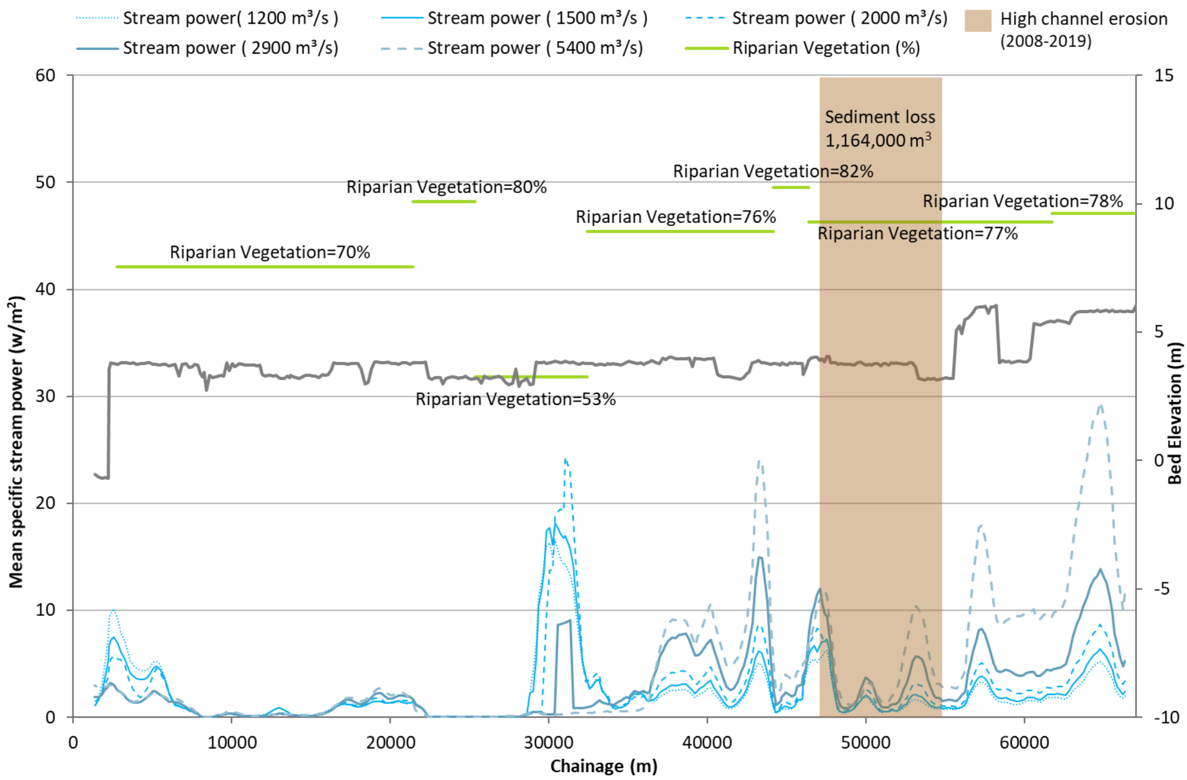

Figure 56: *The mean specific stream power within the Fitzroy River case study area. Longitudinal variability in the SedNet Riparian Vegetation percentage parameter is also shown (note: there is no vertical axis for this metric. Percentage of intact riparian vegetation is shown on figure. Vertical height is relative to percentage of intact riparian vegetation)*

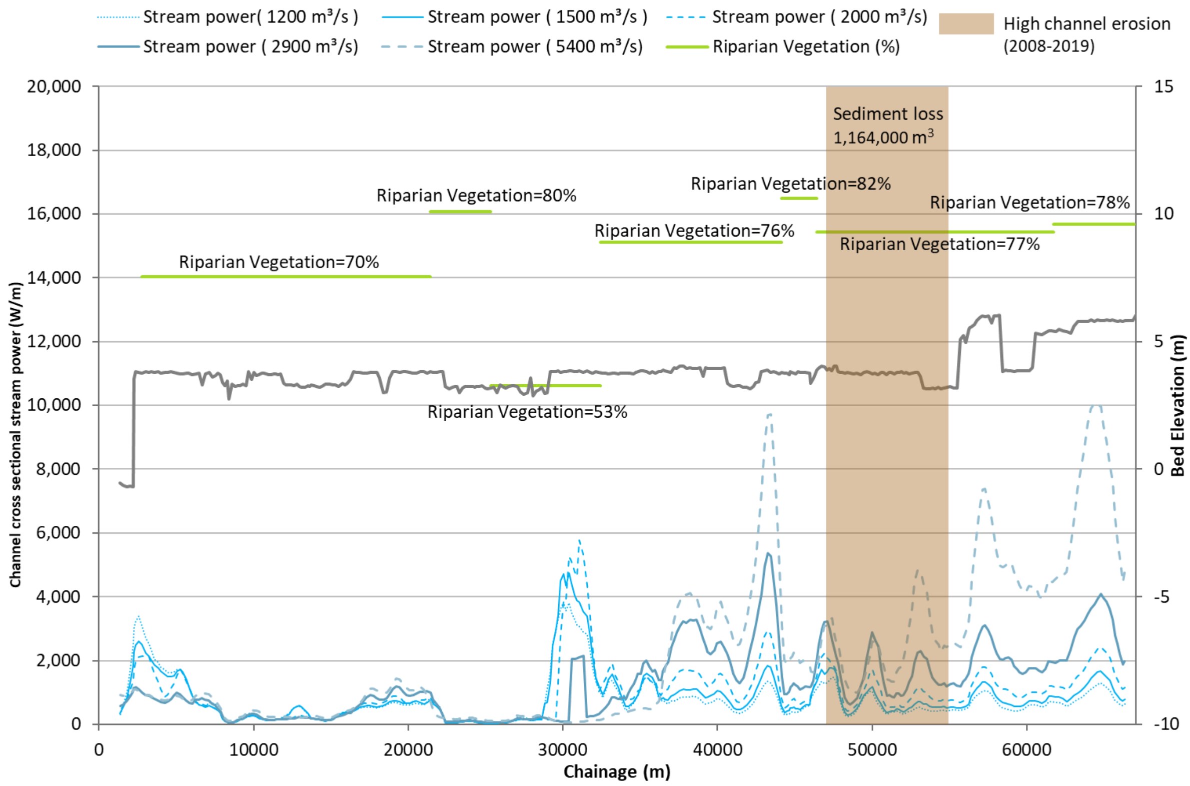

Figure 57: *The cross-sectional stream power within the Fitzroy River case study area. Longitudinal variability in the SedNet Riparian Vegetation percentage parameter is also shown (note: there is no vertical axis for this metric. Percentage of intact riparian vegetation is shown on figure. Vertical height is relative to percentage of intact riparian vegetation)*

Bank sediments

Geotechnical investigations have been undertaken at three sites within the case study area with a total of 8 borehole samples. The results are presented in Table 2. The bank material is a mix of clays and sandy material which varies with depth. There is also significant variation between sites and within sites (see BH5 and BH6). This indicates significant variability in bank composition and erodibility across the case study area.

Table 2: Summary of subsurface conditions at three bank erosion sites within the Fitzroy River case study area (borehole locations shown in Figure 43, Figure 44 and Figure 45)

Site 1		Site 2				Site 3	
BH1	**BH2**	**BH3**	**BH4**	**BH5**	**BH6**	**BH7**	**BH8**
Silty CLAY 0.0-7	**Silty CLAY** 0.0-7	**Silty CLAY** 0.0-2.2	**Silty CLAY** 0.0-3.6	**Silty CLAY** 0.0-2.8	**Silty CLAY** 0.0-5.7	**Sandy Silty CLAY** 0.0-3.45	**Sandy Silty CLAY** 0.0-3.8
Sandy Silty CLAY 7-9.6	**Sandy Silty CLAY** 7-9.6	**SAND** 2.2-7	**Silty SAND** 3.6-7.2	**SAND** 2.8-10	**Sandy Silty CLAY** 5.7-7	**SAND** 3.45-13.5	**SAND** 3.8-7.4
SAND 9.6-13.3	**SAND** 9.6-13.3	**Silty CLAY** 7-8	**SAND** 7.2-14.3	**Silty SAND** 10-17.7	**Silty CLAY** 7-8.7	**Gravelly SAND** 13.5-15.45	**Silty SAND** 7.4-10
Clayey SAND 13.3-14.95 (TD)	**Clayey SAND** 13.3-14.95 (TD)	**Clayey SAND** 8-9.5	**Gravelly SAND** 14.3-14.95 (TD)	**Gravelly SAND** 17.7-19.45 (TD)	**Sandy CLAY** 8.7-9.9		**SAND** 10-15.45

2.5. Case study 4 - Murray Creek

Overview

The Murray Creek case study extends for 23 kilometres, from the Mount Charlton to Jolimont Creek confluence, just downstream of the Bruce Highway (Figure 58). The floodplains along this reach support sugarcane cultivation and grazing. The upper slopes support grazing and rural residential development.

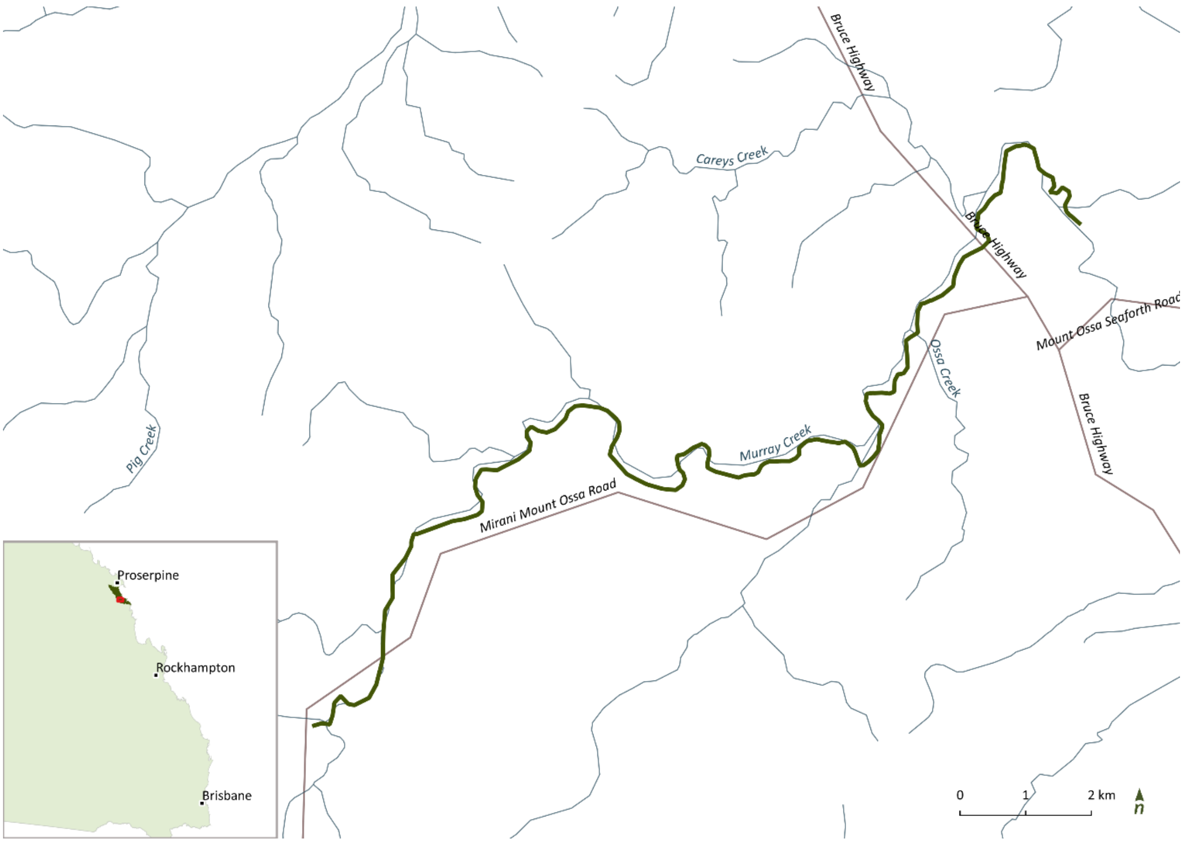

Figure 58: *The Murray Creek case study area*

The case study area is shown in Figure 59, Figure 60 and Figure 61. Through this area Murray Creek flows through varying degrees of bedrock confinement. Within the upper portion of the case study area (upstream of chainage 10,000 m) there are expansive areas of terraces which sit 10-15 m above the channel bed. Within the terraces there are discontinuous floodplains between 50 -250 m in width (see cross-section 3 in Figure 62).

Through the mid zone the valley confinement increases (between chainage 6,000 m and 9,000m), and the channel is significantly confined by bedrock. Downstream of the confined section there are more expansive zones of inset floodplains between 300 -800 m wide (see cross-sections 1 and 2 in Figure 62). The downstream section of the case study area flows through estuarine plains (Figure 63).

Murray Creek is a gravel bed stream with abundant instream gravel deposits including bars and islands in the upper reaches of the case study area (see cross-section 3 in Figure 62). These gravel deposits form pool - riffles sequences within the stream (Figure 64 and Figure 66). In-channel bedrock exposures occur where the channel approaches the valley margins (Figure 65 and Figure 67). Within the lower estuarine portion there are sandy instream deposits.

Riparian longitudinal connectivity is generally poor and diminishes in a downstream direction. Remnant pockets of vegetation exist throughout the system but are particularly prevalent near the forested hillslope and within small inset floodplain units (where clearing was never undertaken). For the majority of the case study area riparian vegetation condition is poor. In many locations the bank condition is severely degraded, with steep, exposed and unstable bank slopes, particularly on outside bends which abut inset floodplain units (see Figure 64).

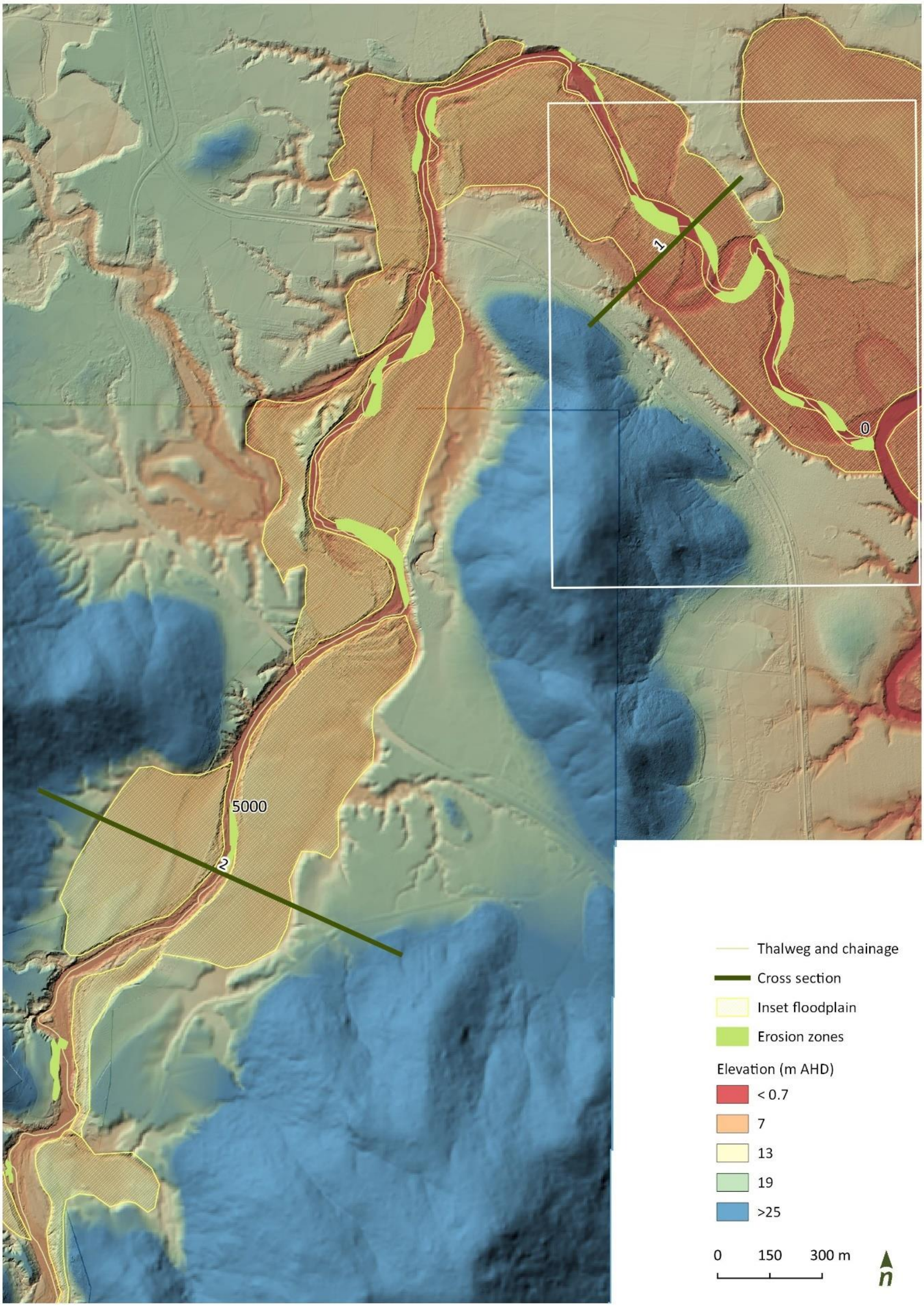

Figure 59: *The downstream portion of the Murray Creek case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

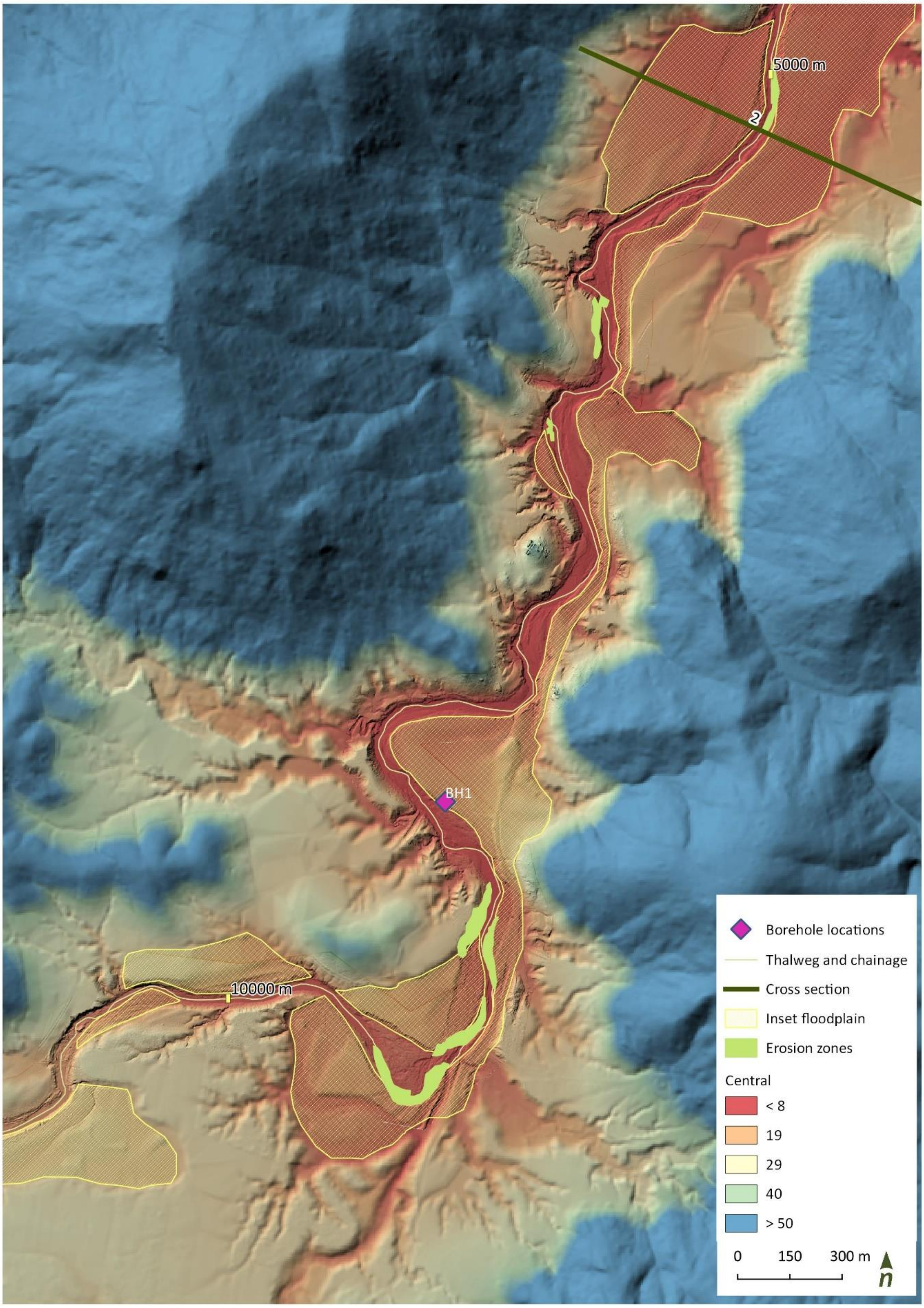

Figure 60: *The middle portion of the Murray Creek case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

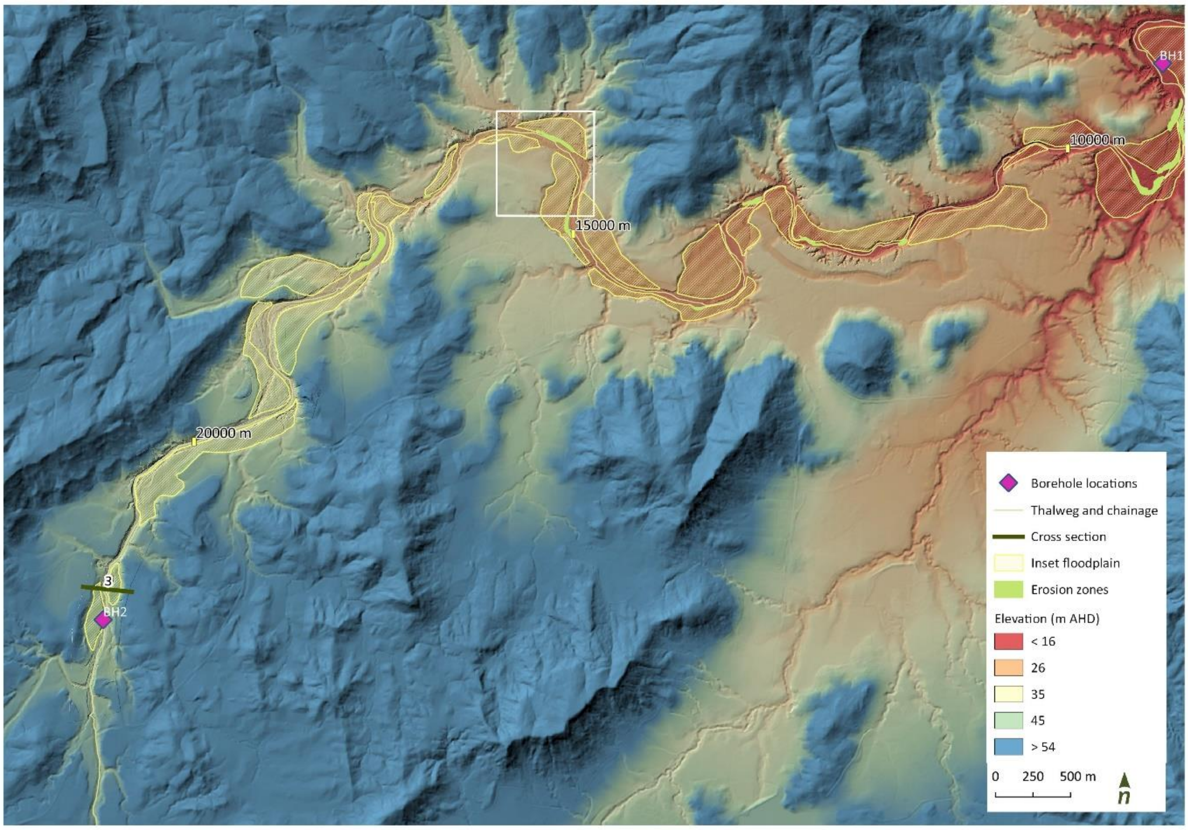

Figure 61: *The upper portion of the Murray Creek case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

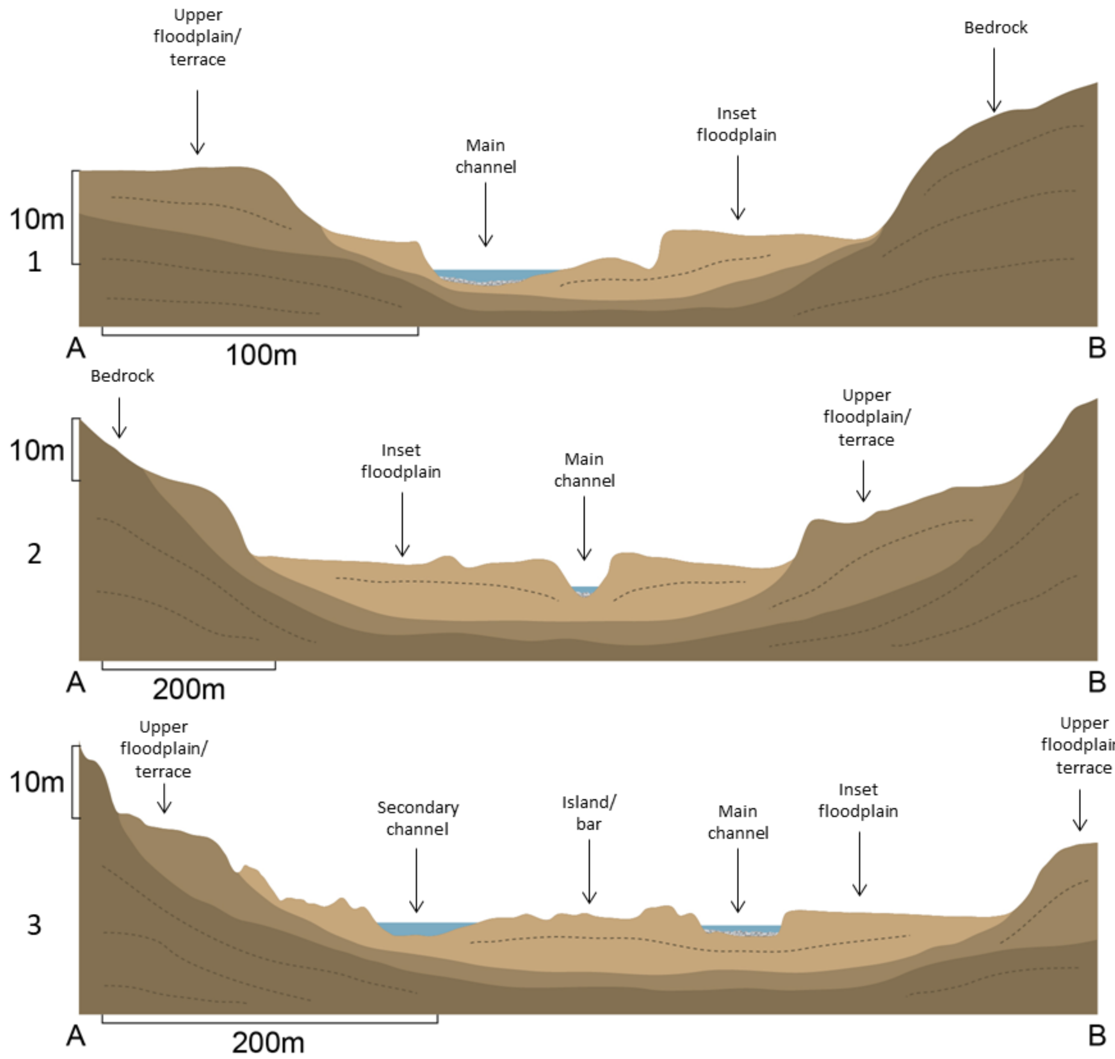

Figure 62: *The three typical sections within the Murray Creek case study area (shown in Figure 59, Figure 60 and Figure 61) with the key geomorphic units. Note the stratigraphy has been estimated as no detailed chronostratigraphic data was available*

Figure 63: *The downstream section of Murray Creek case study area within the estuary where the banks consist of estuarine muds and there are sandy instream deposits*

Figure 64: *Section of Murray Creek downstream of the Bruce Highway*

Figure 65: *Murray Creek through the bedrock-controlled section upstream of the Bruce Highway*

Figure 66: *Bank attached gravel bar and associated riffles within Murray Creek*

Figure 67: *Bedrock control within Murray Creek adjacent to the forested hillslopes*

Historical and recent channel change processes

Historical imagery analysis indicated the lower area of the Murray Creek case study area has undergone significant channel change including a meander cutoff followed by meander development (Figure 68).

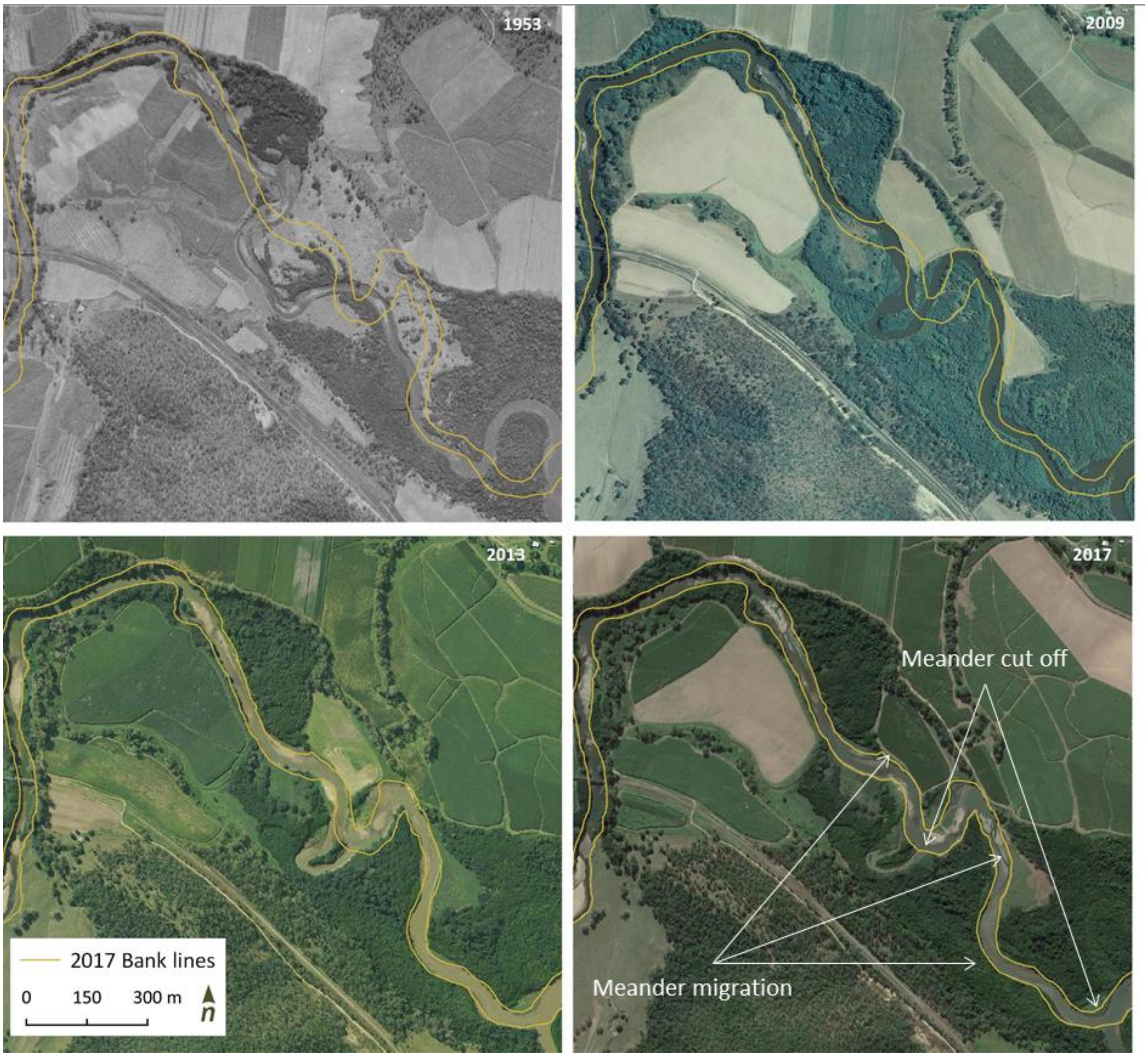

Figure 68: *Historical imagery comparison of the Murray Creek between chainage 0 m and 2,500 m highlighting a meander cutoff and meander development*

LiDAR data from 2018 and 2009 was available for the Murray Creek case study area. During this period there was one major flood event in 2017 and several small to moderate flow events. The analysis indicated significant lateral channel adjustment, predominately through the mid reaches of Murray Creek. The major areas of channel erosion are shown in Figure 59, Figure 60 and Figure 61. The most significant changes occurred adjacent to the inset floodplains where there was limited riparian vegetation.

Aerial imagery assessed between 2009 and 2018 indicates that the most significant channel change occurred between 2009 and 2013 when there were several small flood events in close succession. The analysis indicated that there was only isolated channel change during 2017 despite a major flood event occurring.

The increased adjustment in the earlier years is likely due to a combination of:

- More frequent flow events resulting in more geomorphic work on the channel boundary.
- Less time between events for bank vegetation to recover increasing the geomorphic effectiveness of the next flood event.

- Rates of channel adjustment waning following the rapid adjustment observed between 2009 and 2013.

The multi-temporal LiDAR analysis at a number of areas are shown in Figure 69 and Figure 70. The majority of erosional channel change is the result of lateral meander migration processes (i.e. toe scour and subsequent mass failure) across poorly vegetated inset floodplain units. There are no examples where there has been significant sediment loss from terrace units.

Within the lower estuarine section, a large meander cut-off has occurred since 2009 resulting in a reduction in stream length. This reduction in stream length has resulted in an increase in stream gradient (and as a result stream power). Due to the shortening, the system is adjusting to its new regime which is resulting in increased rates of lateral channel change and meander development.

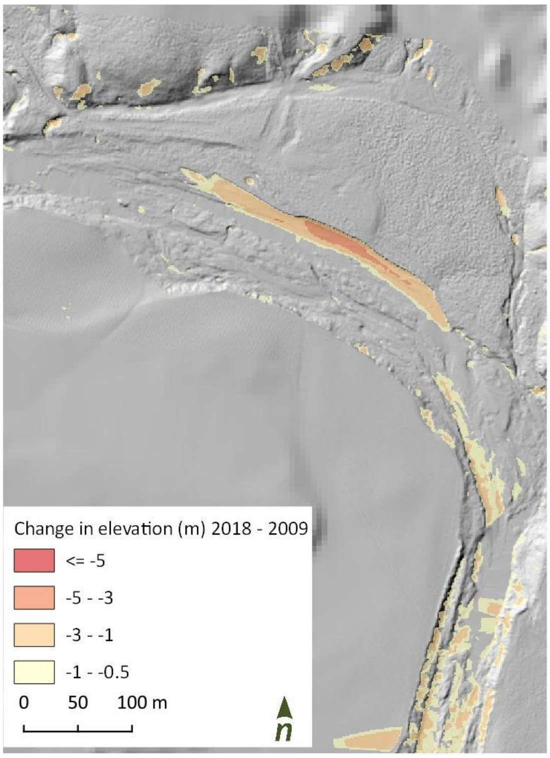

Figure 69: *Bank retreat from an inset floodplain unit through a meander migration process within Murray Creek – chainage 16,000 m see box in Figure 61*

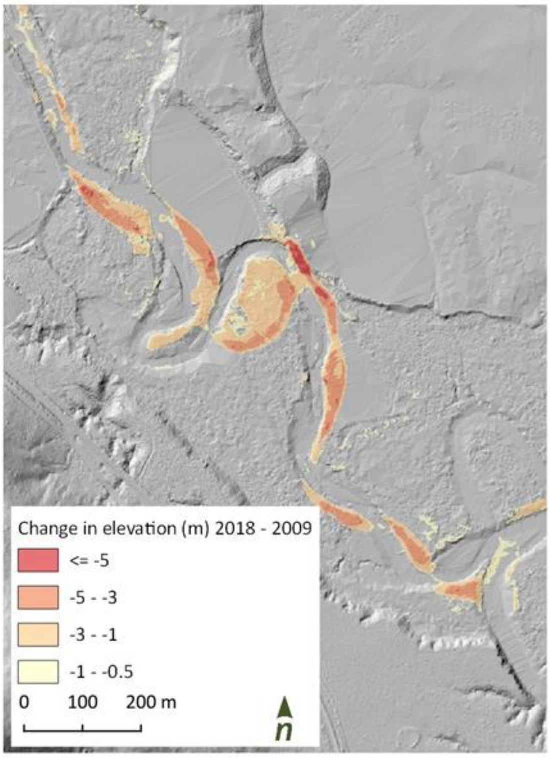

Figure 70: *Bank retreat from an inset floodplain unit through a meander cutoff and development process within lower Murray Creek – chainage 2,000 m see box in Figure 59*

Longitudinal profile assessment

The longitudinal bed profile and floodplain height is shown in Figure 71. Downstream of chainage 10,000 m the channel slope is between 0.0006 m/m and 0.0016 m/m. Between 11,000 m and 10,000 m there is a bedrock outcrop where the bed elevation drops by 3 m. Upstream of the bedrock outcrop the bed profile increases from 0.0002 m/m to 0.0059 m/m.

The bank height is generally between 4-6 m however increases slightly between chainages 6,000 m and 8,000 m where there is more bedrock control and stream banks and floodplains are less well defined.

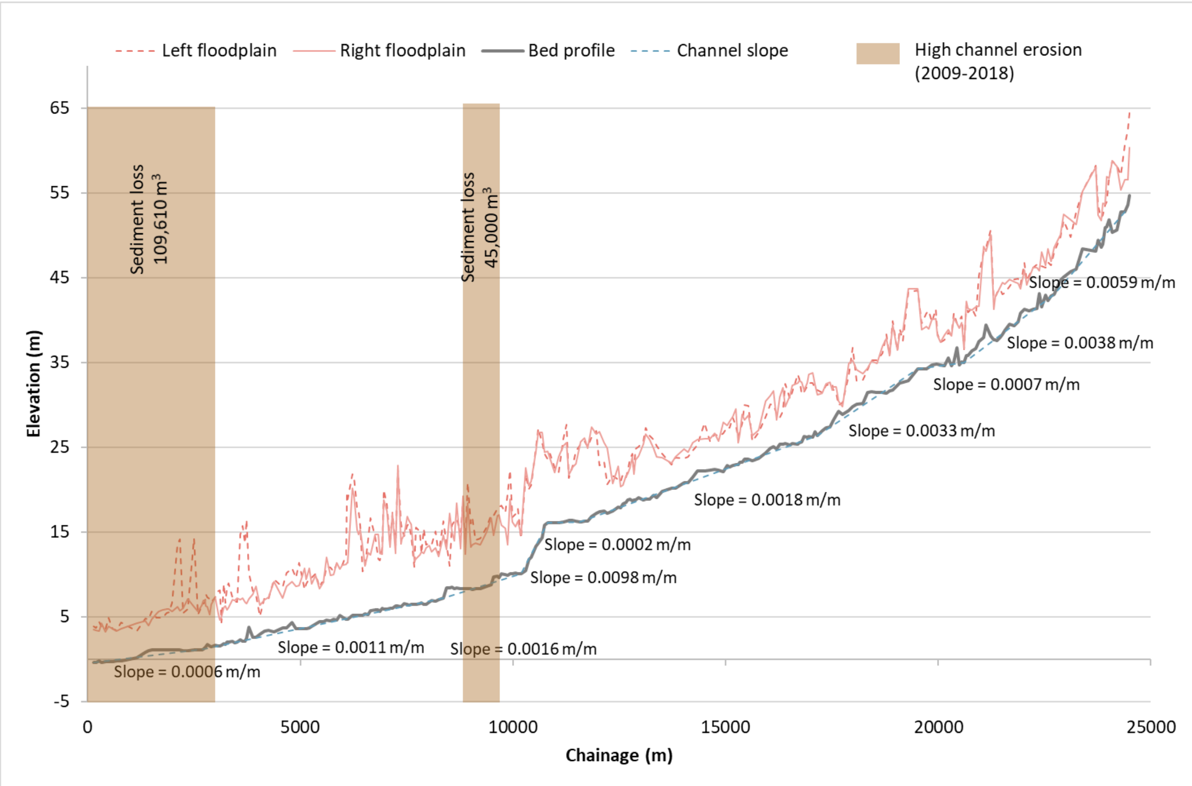

Figure 71: *Longitudinal profile and floodplain heights within the Murray Creek case study area*

Bankfull flow assessment

A one-dimensional HEC-RAS model was developed for the study area. The model is uncalibrated, however the hydraulic roughness has been adjusted based on the channel characteristics and sinuosity. A range of flow events were modelled to determine the channel capacity. The water surface for three flow events, 300 m³/s, 600 m³/s and 1,000 m³/s, is shown in Figure 72. Representative bankfull flows in three typical cross-section are shown in Figure 73.

The channel capacity in the upper reaches is approximately 600 m³/s, however this increases substantially in the mid reaches to over 1,000 m³/s. In the lower reaches channel capacity is closer to 300 m³/s, however this would also vary based on the tidal conditions. Murray Creek is ungauged so it is not possible to determine return periods for these flow events as part of this study.

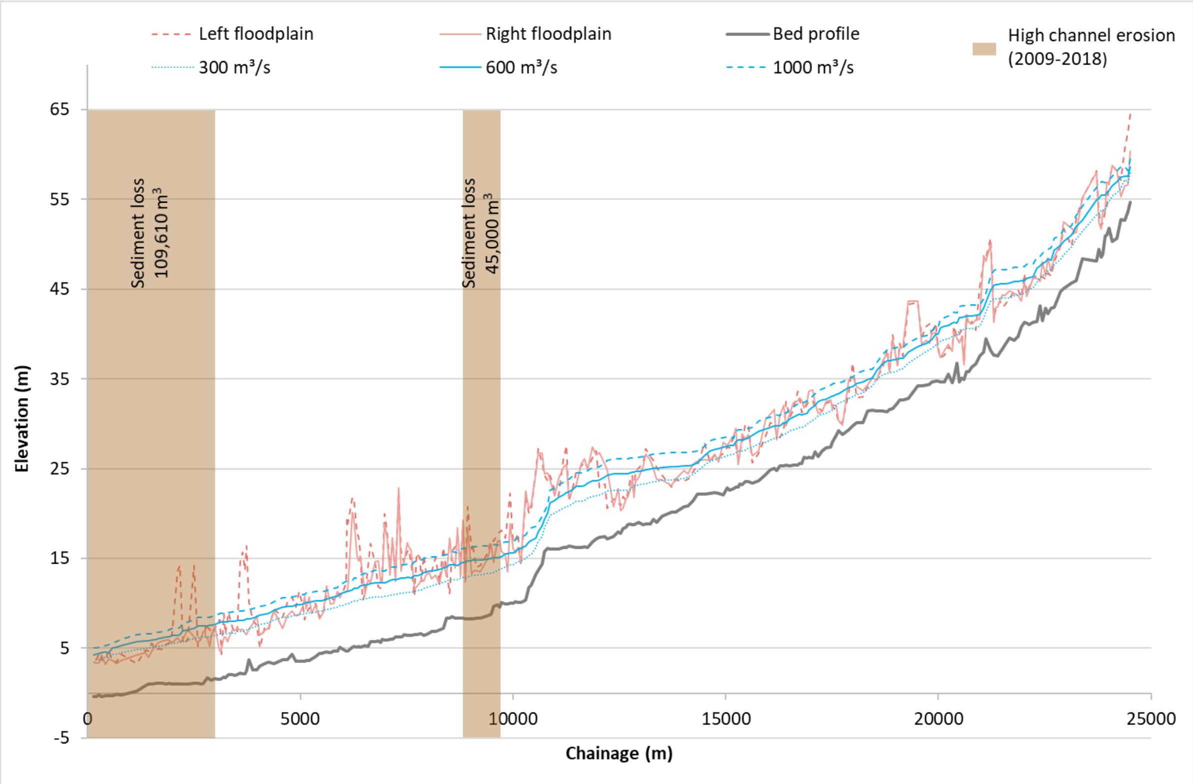

Figure 72: *The water surface elevation for three flow events near the bankfull elevation within the Murray Creek case study area*

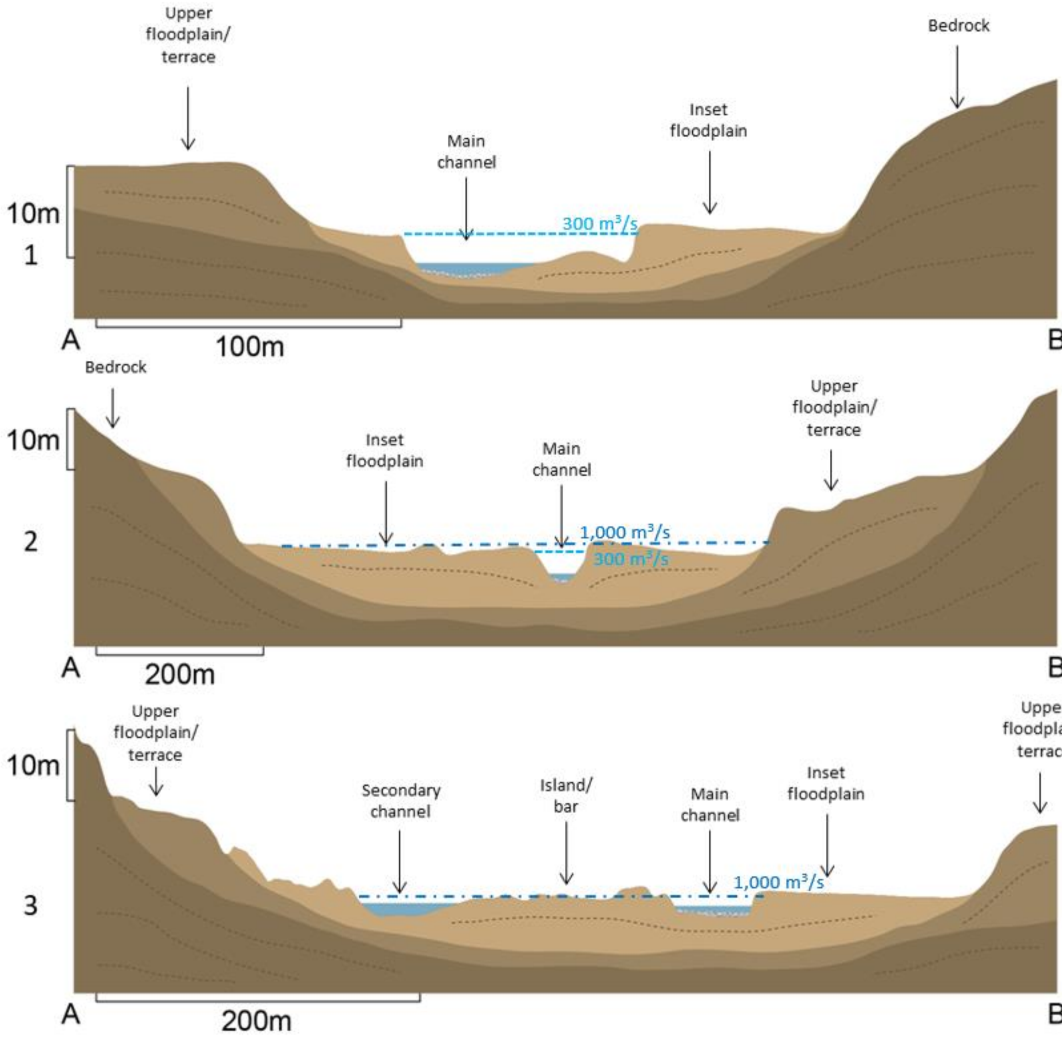

Figure 73: *The three typical sections within the Murray Creek case study area (shown in Figure 59, Figure 60 and Figure 61) showing the key geomorphic units and representative bankfull flows.*

Stream power assessment

Mean specific stream power was determined from the HEC-RAS model for two flow events, 300 m³/s and 600 m³/s, and is shown in Figure 74. Downstream of chainage 8,000 m the bankfull stream power is typically below 100 W/m². There is no observable correlation between stream power and areas of high channel erosion.

Between 8,000 m and 11,000 m there is an increase in bankfull stream power to between 200-1200 W/m² - through this section there are significant bedrock controls. Between chainages 11,000 m and 20,000 m the bankfull stream power is typically between 100- 300 W/m². Upstream of chainage 20,000 m there is a large increase in bankfull stream power which is often within the 200–800 W/m² range.

The bankfull total cross-sectional stream power results are shown in Figure 75. Downstream of chainage 8,000 m the cross-sectional stream power is typically below 10,000 W/m. Upstream of chainage 8,000 m longitudinal variations in total cross-sectional stream power follow a similar pattern to the mean specific stream power results, with values between 10,000-80,000 W/m.

The Dynamic Sednet riparian vegetation percentage parameter, an indictor of channel resistance, is also shown on the stream power figures.

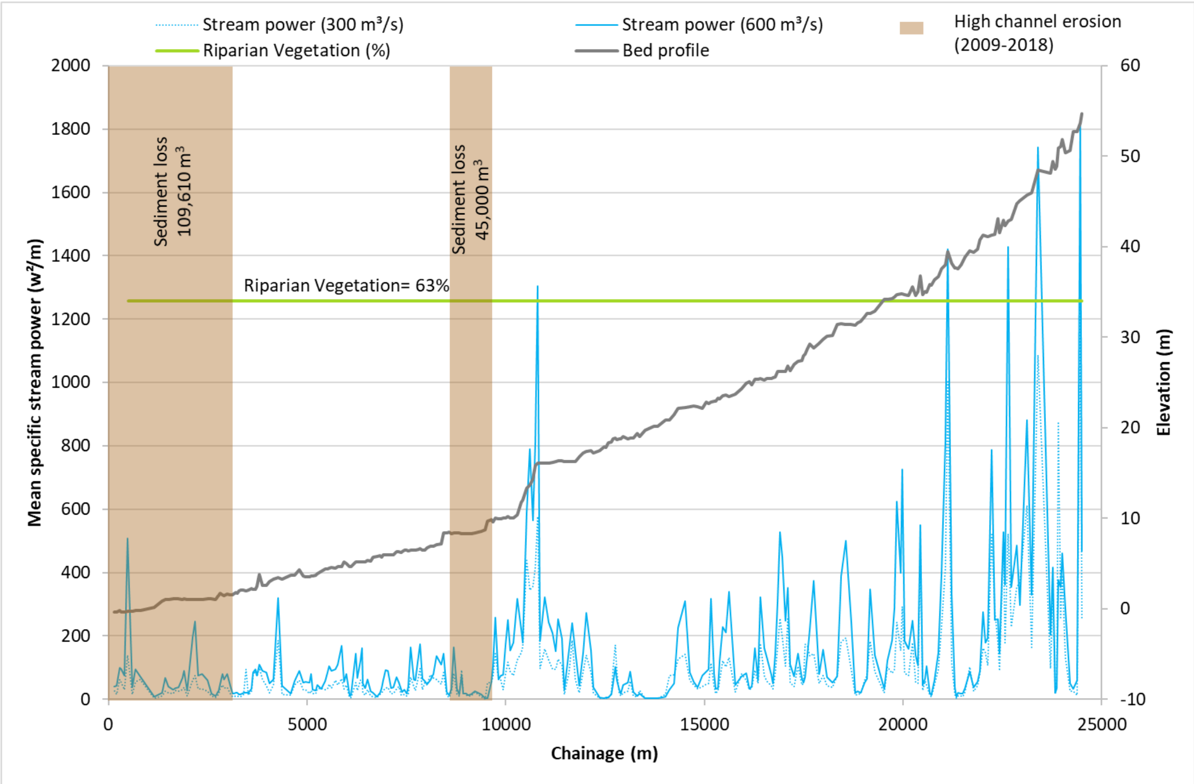

Figure 74: *The mean specific stream power within the Murray Creek case study area. Longitudinal variability in the SedNet Riparian Vegetation percentage parameter is also shown (note: there is no vertical axis for this metric. Percentage of intact riparian vegetation is shown on figure. Vertical height is relative to percentage of intact riparian vegetation)*

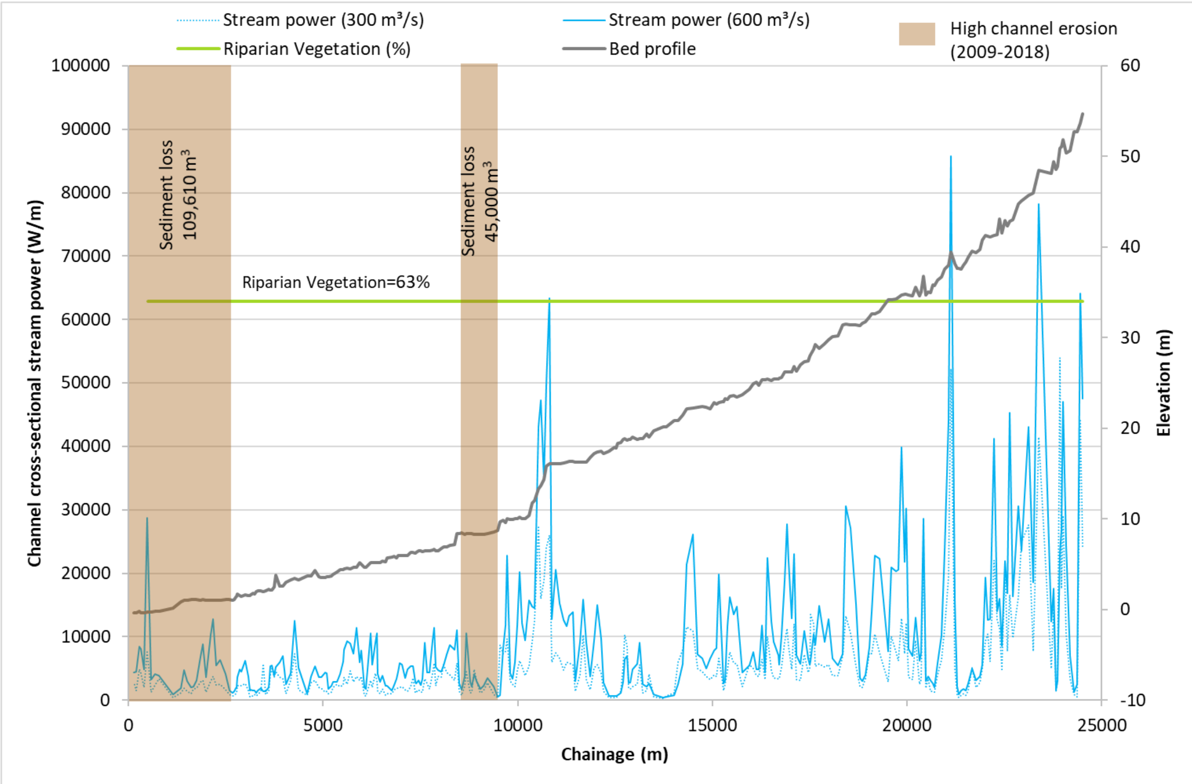

Figure 75: *The cross-sectional stream power within the Murray Creek case study area. Longitudinal variability in the SedNet Riparian Vegetation percentage parameter is also shown (note: there is no vertical axis for this metric. Percentage of intact riparian vegetation is shown on figure. Vertical height is relative to percentage of intact riparian vegetation)*

Bank sediments

Reef Catchments has collected boreholes from two inset floodplain units within the case study area. The results from both boreholes is provided in Table 3. The sediments range from sandy loam to clay. Previous experience within this area indicates the clay content can vary significantly across small areas.

Table 3: Borehole data from the Murray Creek case study area (borehole locations shown in Figure 59 and Figure 60)

BH1	BH2
Fine sandy loam 0-3 m	**Fine sandy clay loam** 0-0.2 m
	Clay loam fine sandy 0.2-1.2 m
	Fine sandy light medium clay 1.2- 3 m

2.6. Case study 5 - O'Connell River

Overview

The O'Connell River case study extends for 17 kilometres, from the Horse Creek confluence to the Andromache River confluence, just upstream of the Bruce Highway (Figure 76). The floodplains along this reach support sugarcane cultivation however there are also some small areas used for grazing.

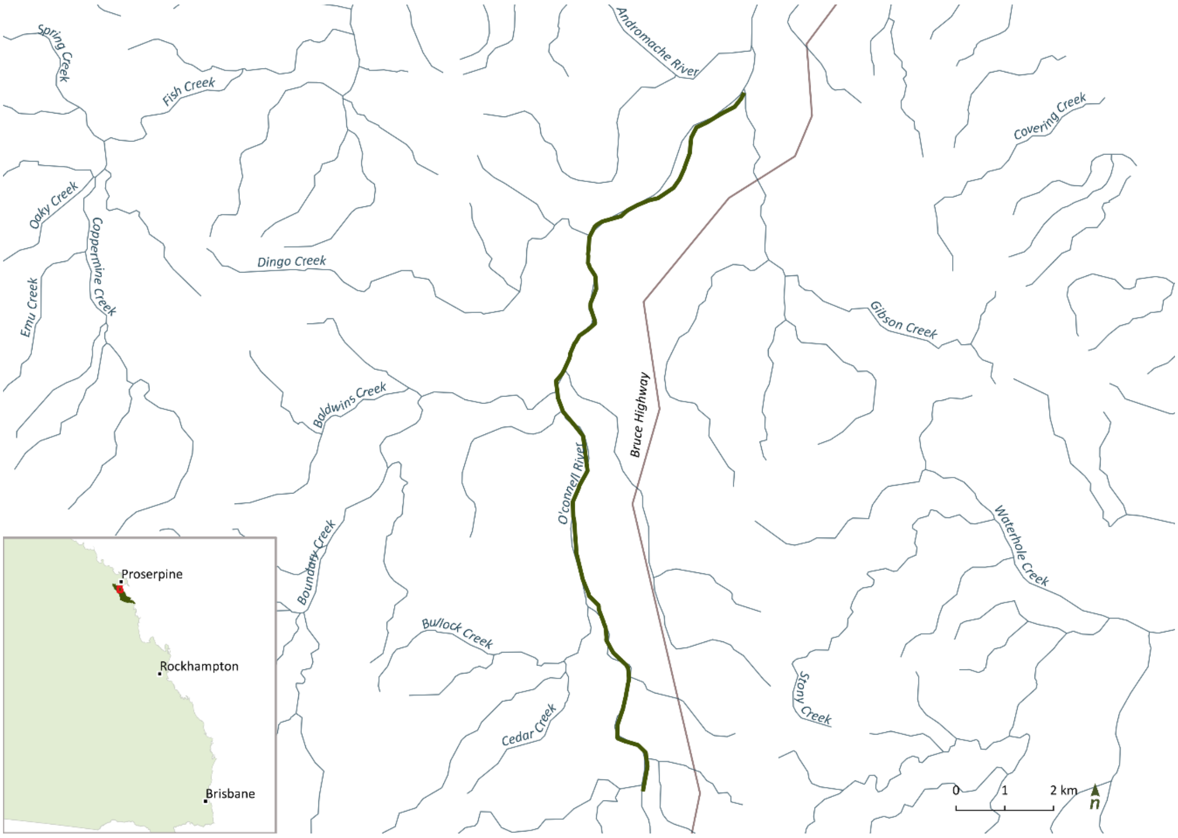

Figure 76: *The O'Connell River case study area*

The case study area is shown in Figure 79 and Figure 80. The upper portion of the case study area (i.e. upstream of chainage 8,000 m) flows through alluvial valley approximately two kilometres in width. The alluvial development includes:

- Fill terrace units which sit 12-15 m above the channel bed, comprised of a red sandy clay (Figure 77).
- Inset floodplain and bench units which sit 3-6 m above the channel bed, comprised of silts, sands, gravels and cobbles (Figure 78).

The inset floodplain units are 200-500 m in width with terraces forming the majority of the alluvial development (see cross-section 3 in Figure 81). Within this section the low sinuosity channel can abut either bedrock, terrace or inset floodplain units.

Approximately 200 m downstream of the Boundary Creek confluence the channel is constricted by both terrace units and bedrock for approximately 3 km (i.e. between chainage 5,000 m and 8,000 m: see cross-section 2 in Figure 81). Within this zone there is very limited inset floodplain development, however there is isolated inset bench development.

Downstream of the Dingo Creek confluence the O'Connell River emerges into a broader zone of inset floodplain development (i.e. downstream of chainage 5,000 m – see cross-section 1 in Figure 81).

Within this section the inset floodplains are typically 300 -500 m wide before confining significantly near the Andromache River confluence.

Throughout the case study area there is a low sinuosity gravel-to-cobble bed channel with some isolated bedrock control. Within the channel are extensive bars which form riffles through the system (Figure 82). Downstream of Dingo Creek confluence as the channel emerges from the confinement there is widespread channel aggradation. The aggradation predominately consists of gravels and cobbles. The O'Connell River transitions to predominantly sandy bed system closer to its mouth.

Figure 77: *Looking across at the left bank immediately upstream of the Boundary Creek confluence – terrace to the left of the image and inset floodplain to the right*

Figure 78: *Looking downstream along the right bank located 1.5 km upstream of the Boundary Creek confluence. Site is subject to meander migration*

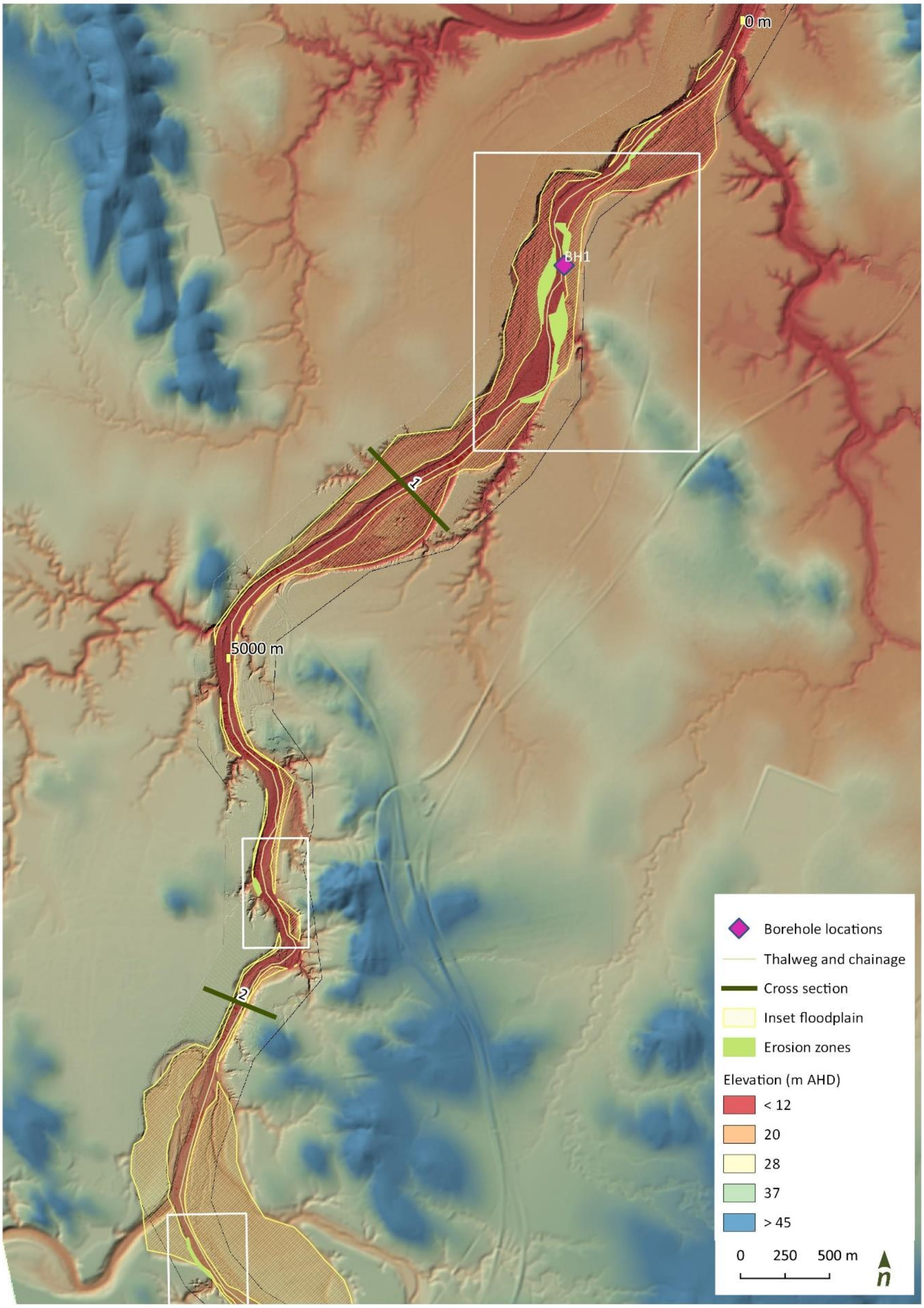

Figure 79: *The downstream portion of the O'Connell River case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

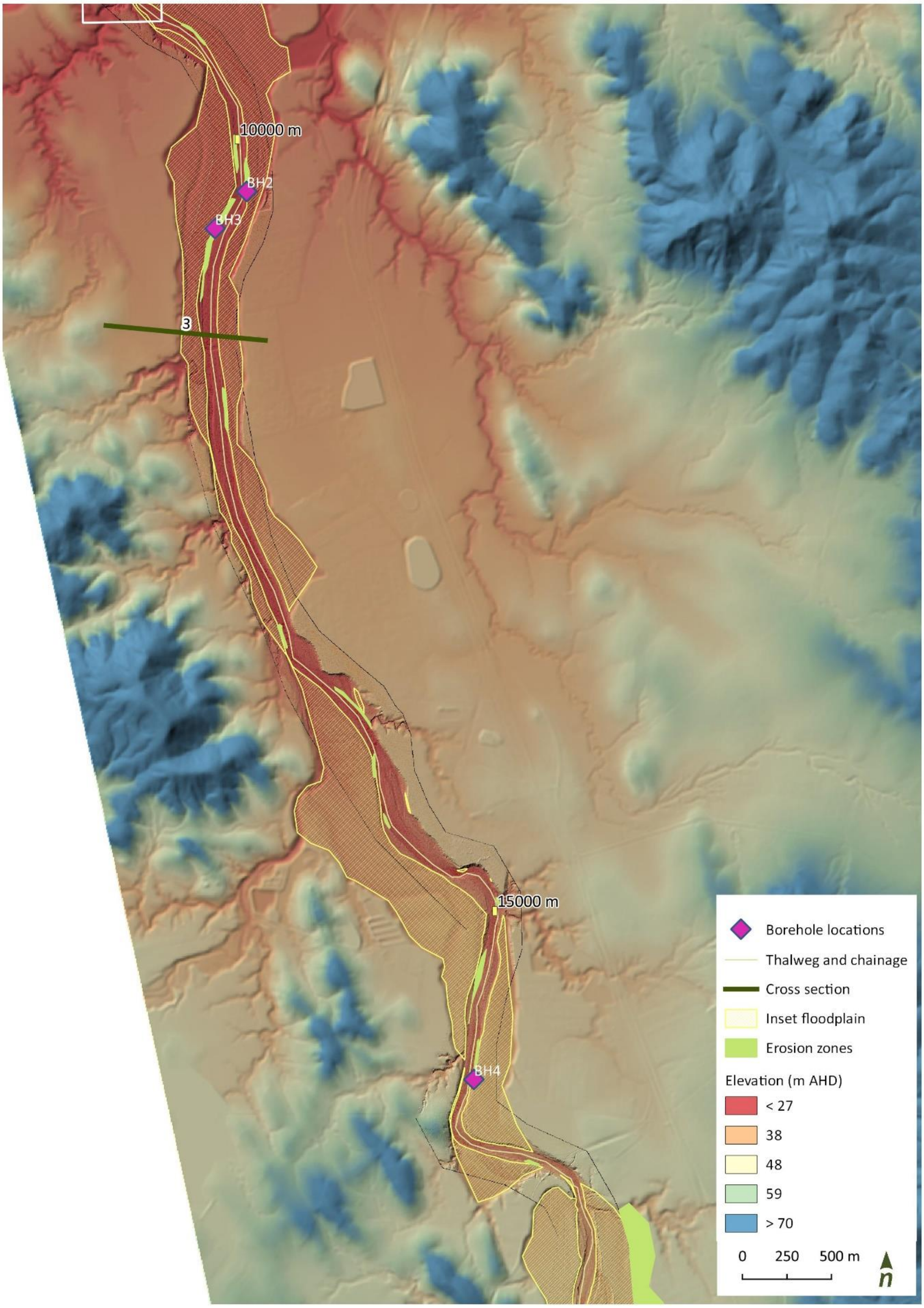

Figure 80: *The upstream portion of the O'Connell River case study showing elevation, inset floodplains, erosion areas and representative cross section locations*

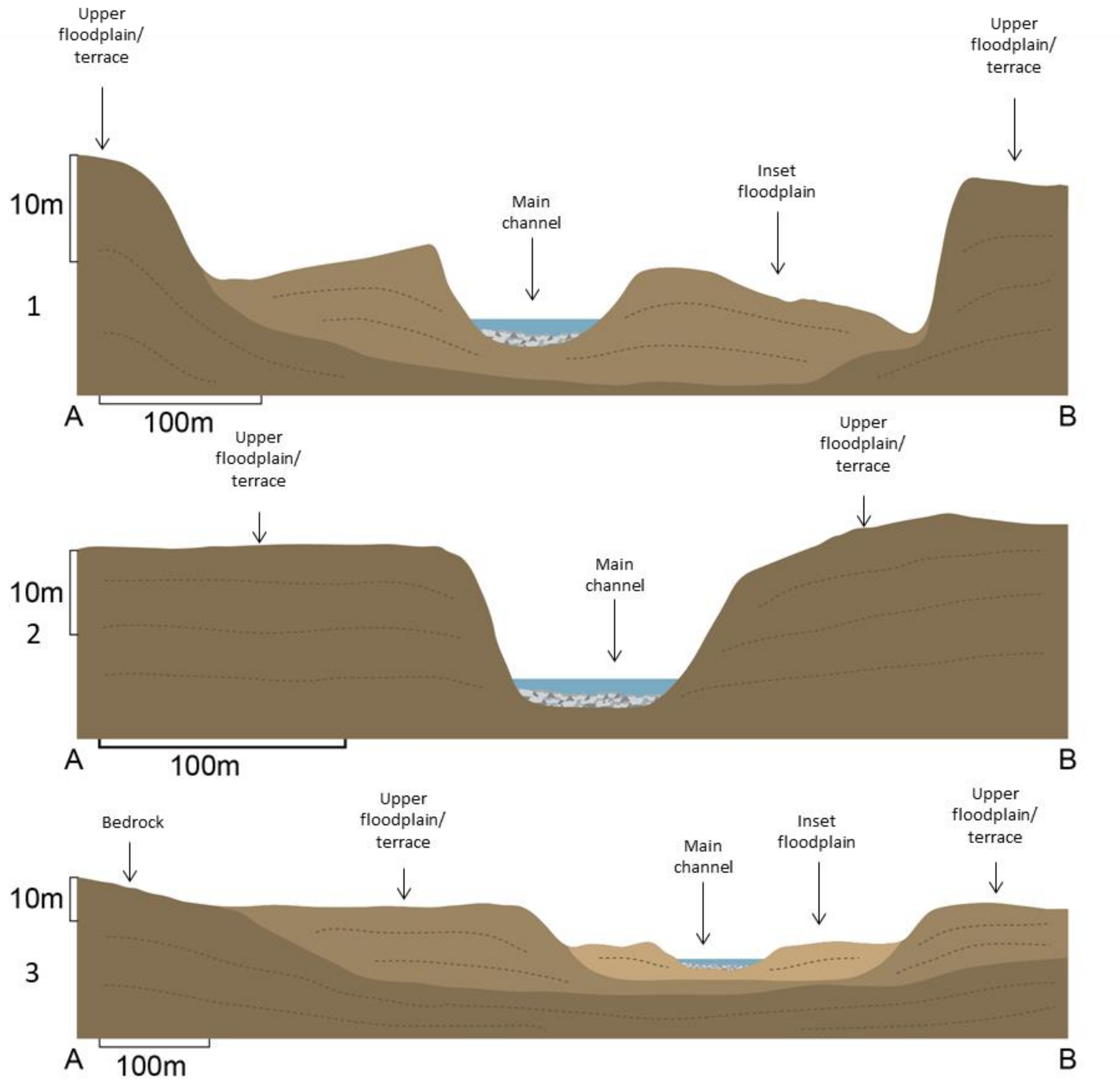

Figure 81: *The three typical sections within the O'Connell River case study area (shown in Figure 79 and Figure 80) with the key geomorphic units. Note the stratigraphy has been estimated as no detailed chronostratigraphic data was available*

Figure 82: *Looking across at the right bank upstream of the Boundary Creek confluence where there are abundant instream gravels*

Riparian vegetation through the case study area is poor, typically ranging from narrow bands of woody vegetation along the channel margins to no woody vegetation. However, there are some more extensive pockets of remnant vegetation within small inset floodplain units and within drainage lines (where clearing was never undertaken).

Historical and recent channel change processes

Historical imagery analysis indicated the lower O'Connell River has undergone significant channel change including an avulsion followed by meander development (Figure 83). LiDAR data from 2018 and 2009 was available for the O'Connell River case study area. Flow data for the O'Connell River between 2009 and 2018 is shown in Figure 84. During this period there was one major flood event in 2017 and several small to moderate flow events.

Downstream of the Dingo Creek confluence extensive channel erosion has occurred between chainage 1,000 m and 2,500 m. Within this zone there has also been significant aggradation. The channel change appears as the result of meander development as the river reworked the coarse sediment deposits and created a defined low flow path (Figure 85). During this process, bank erosion along the inset floodplain has resulted in significant sediment loss. The large volume of sediment loss is partly due to the height of banks which are 6-8 m.

Within the confined section between the Boundary Creek confluence and Dingo Creek there was minimal channel change (i.e. between chainage 5,000 m and 8,000 m). However, one location of significant channel erosion was observed from an isolated inset bench unit (Figure 86).

Upstream of the Boundary Creek confluence there were multiple locations of major bank erosion which resulted in significant soil loss (see Figure 80). The bank erosion predominately occurred where the channel abuts sections of inset floodplain. The sites which contributed the greatest soil loss were on the outside of bends (see Figure 87). The erosion at these sites was due to meander migration – the downstream progression of meanders over time through toe scour and mass failure.

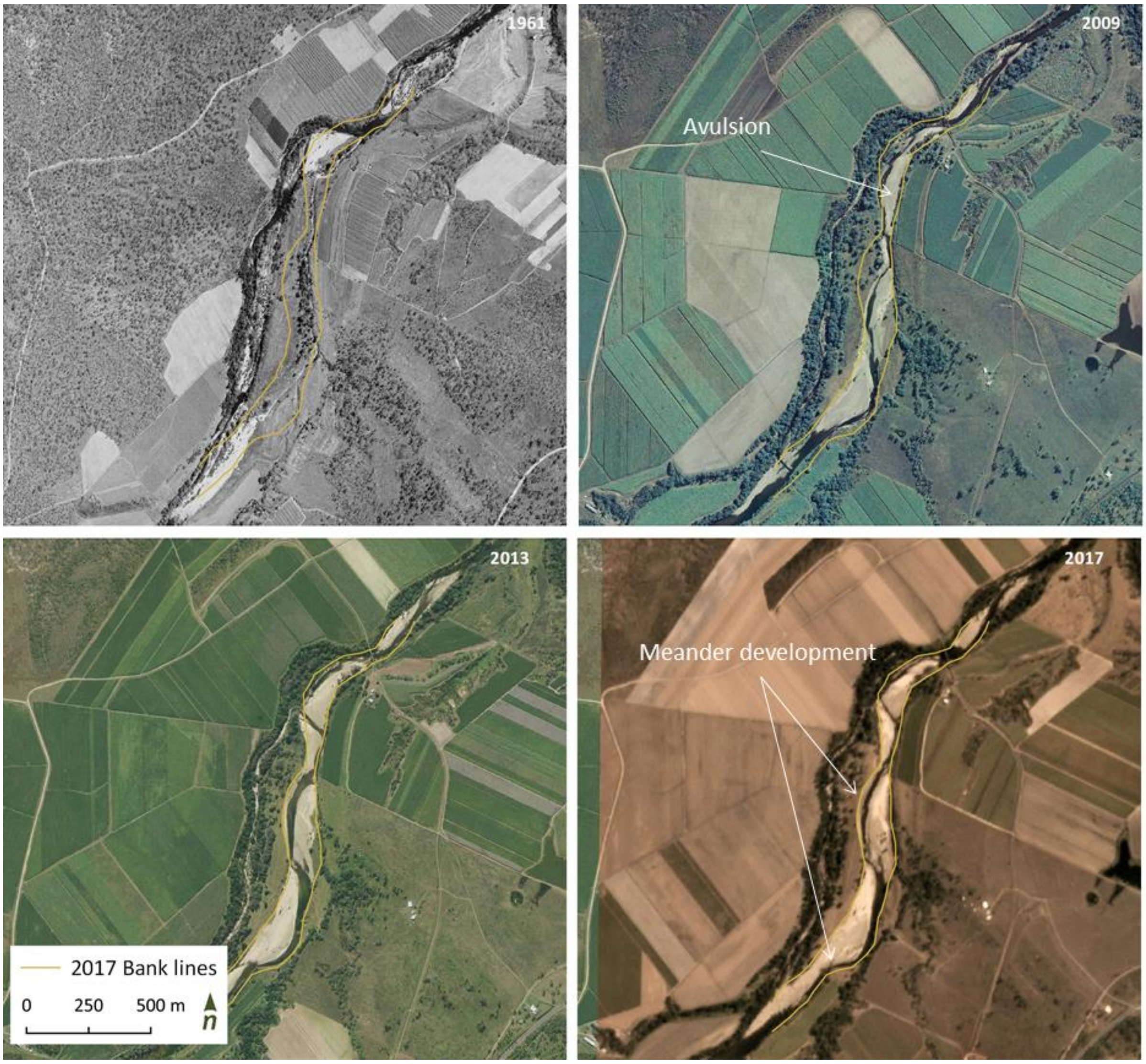

Figure 83: *Historical imagery comparison of the lower O'Connell River between chainage 1,000 m and 2,500 m highlighting an avulsion and meander development*

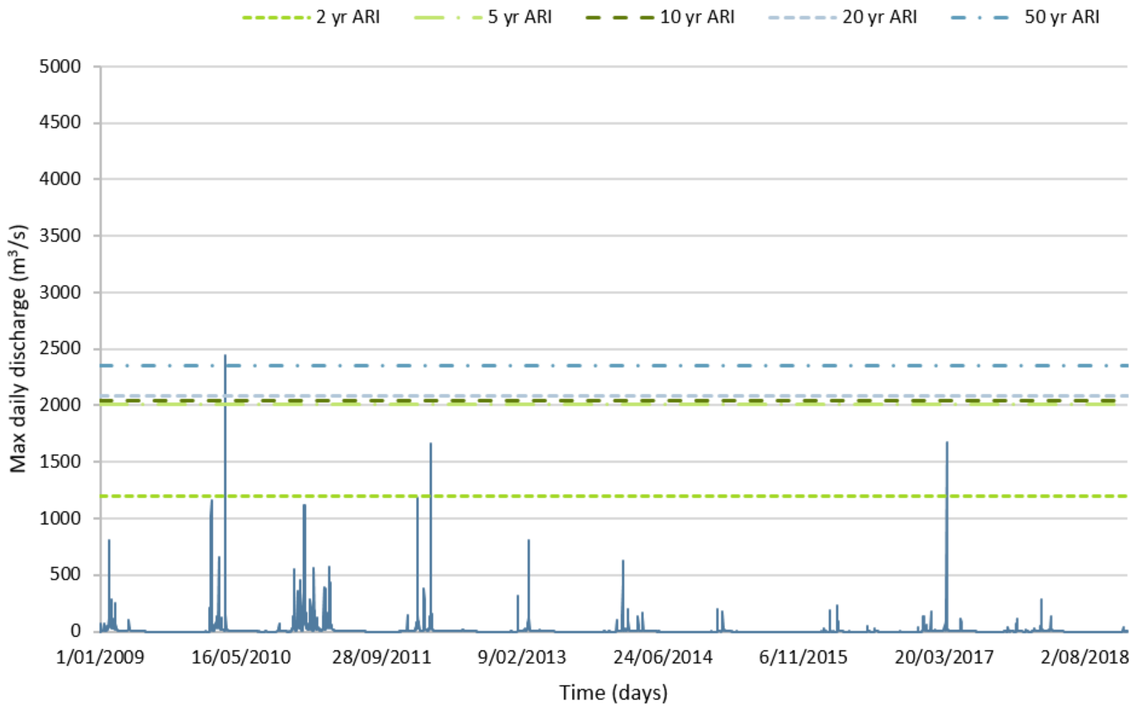

Figure 84: *Maximum daily discharge for the O'Connel River (Stafford's Crossing gauge- 124001B) between 2009 and 2018. Showing 2yr, 5yr, 10yr, 20yr and 50yr ARI flows.*

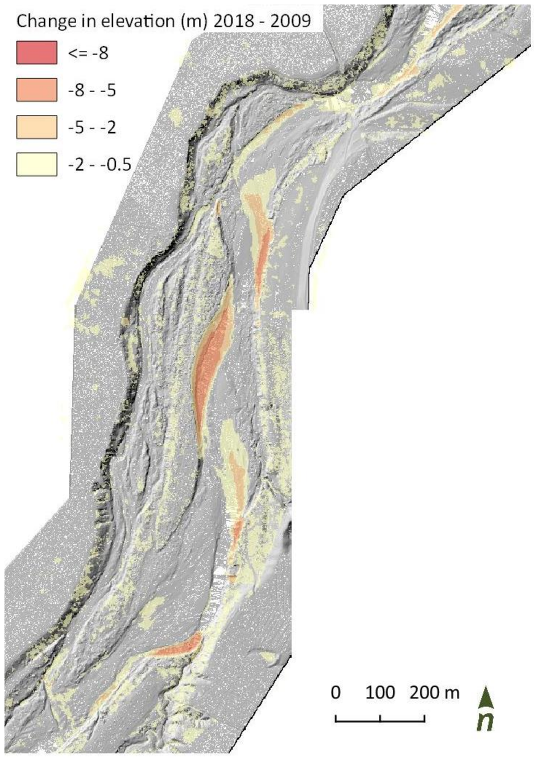

Figure 85: *Significant meander development downstream of the Dingo Creek confluence*

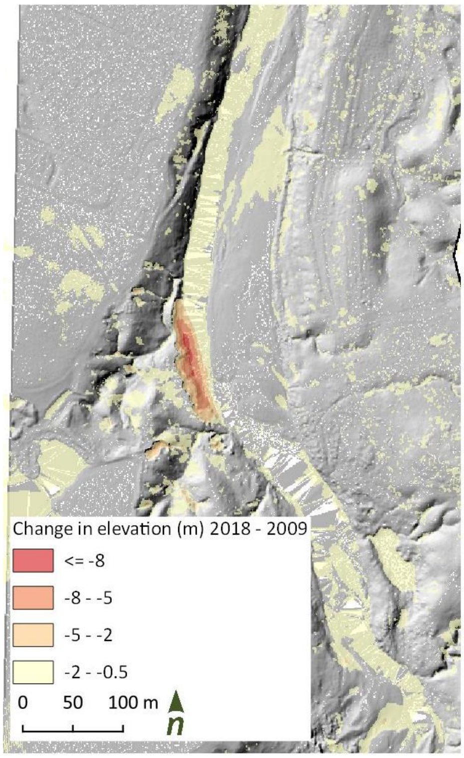

Figure 86: *Erosion of an inset bench unit with the confined section between the Boundary Creek confluence and Dingo Creek*

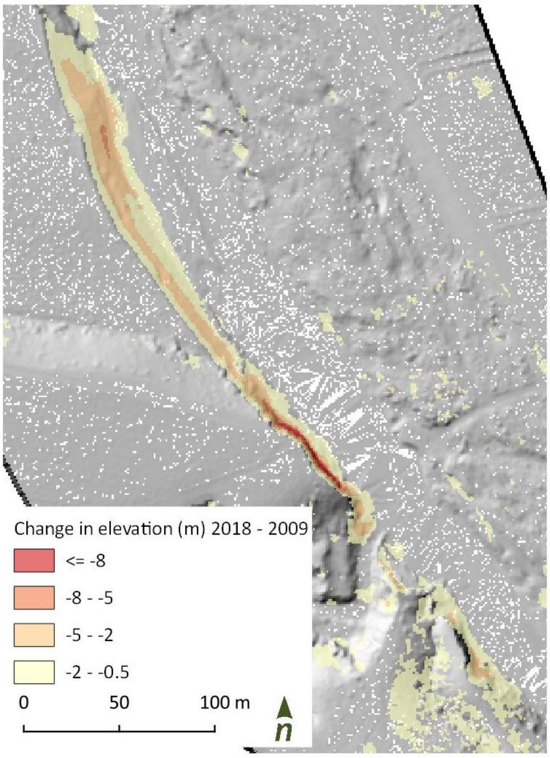

Figure 87: *Bank retreat from an inset floodplain unit through a meander migration process upstream of Boundary Creek*

Longitudinal profile assessment

The longitudinal bed profile and floodplain and terrace height is shown in Figure 88. Downstream of chainage 2,000 m the gradient is approximately 0.002 m/m. However, between chainage 2,000 m and 6,500 m this flattens significantly to 0.0008 m/m – within this area there is substantial instream aggradation and lateral channel adjustment. Within the confined section between the Boundary Creek confluence and Dingo Creek (i.e. between chainage 5,000 m and 8,000 m) the grade steepens to 0.005 m/m where there are bedrock controls within the channel. The significant reduction in grade downstream of chainage 6,500 m results in a reduction in sediment transport capacity and aggradation within this zone.

Upstream of the Boundary Creek confluence the grade is between 0.0018 - 0.0021 m/m.

The bank height of the inset channel is typically 4-7 m – however there is significant variability. In many locations, there is no observable inset channel bank as the channel abuts terrace units or the bedrock valley margins. Upstream of the Boundary Creek confluence (i.e. chainage 8,000 m) the terrace height is typically 12-15 m above the channel. Downstream of the Boundary Creek confluence this increase to between 15- 18 m.

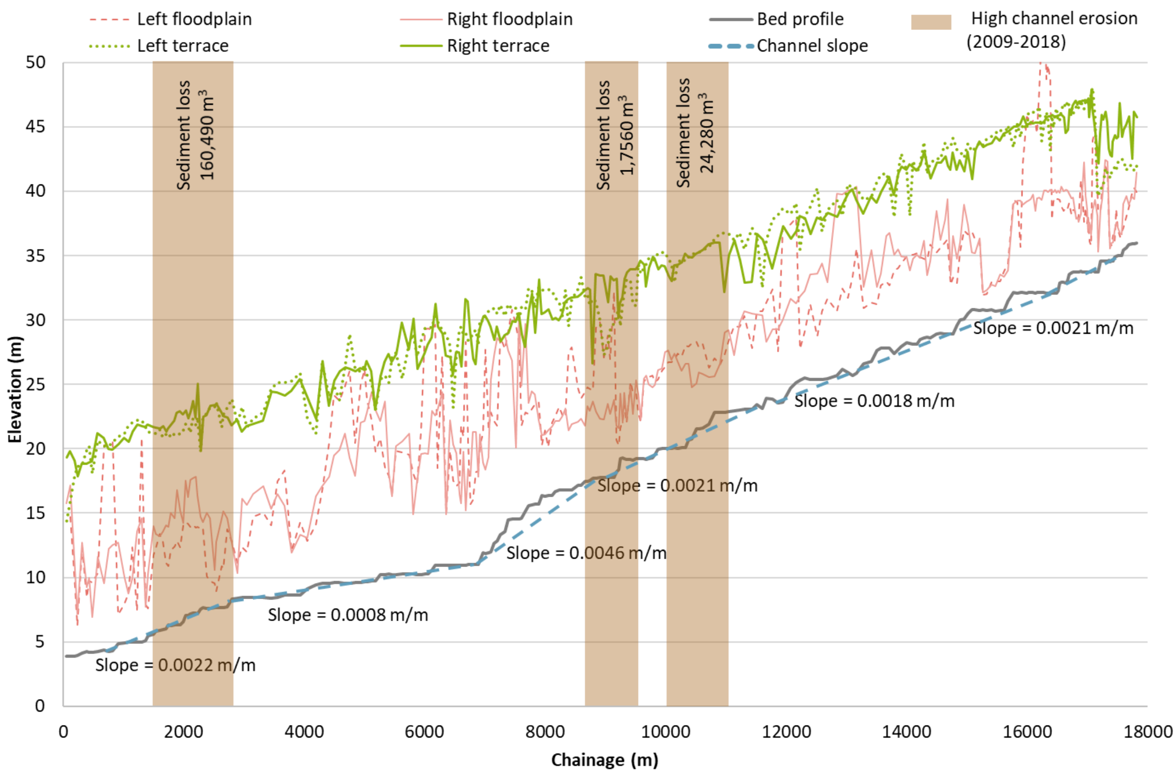

Figure 88: *Longitudinal profile and floodplain heights within the O'Connell River case study area*

Bankfull flow assessment

A one-dimensional HEC-RAS model was developed for the study area. The model is uncalibrated however the hydraulic roughness has been adjusted based on the channel characteristics and sinuosity. A range of flow events were modelled to determine the channel capacity. The water surface for four flow events, 750 m^3/s, 1000 m^3/s, 1500 m^3/s and 3,000 m^3/s, is shown in Figure 89. Representative bankfull flows in three typical cross-section are shown in Figure 90.

Upstream of the Boundary Creek confluence (i.e. chainage 8,000 m) the channel capacity is approximately 750 m^3/s (return period of less than 2 years). Within the confined section between chainage 5,000 m and 8,000 m the channel capacity exceeds 3,000 m^3/s (return period of greater than 50 years). The water surface for the 3,000 m^3/s event is 5 m below the confining terrace surface through this section. Downstream of chainage 5,000 m the channel capacity is approximately 1,500 m³/s (return period between 2- 5 years).

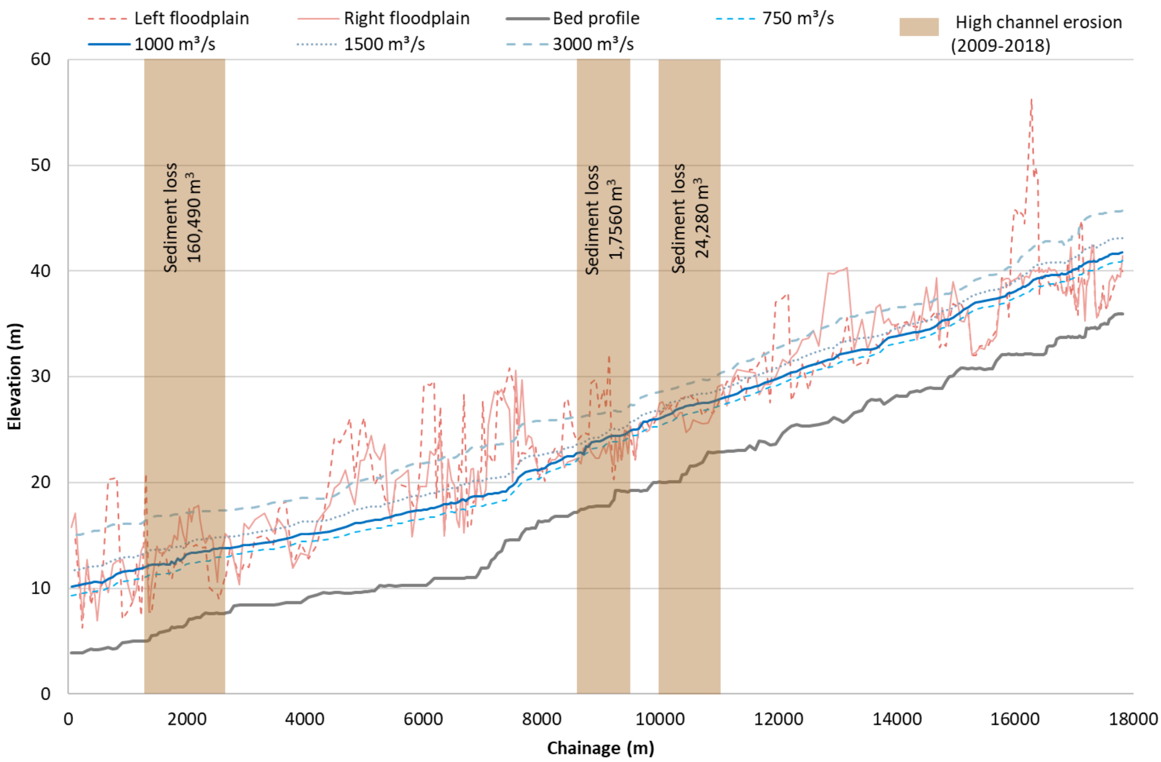

Figure 89: *The water surface elevation for a range of flow events near the bankfull elevation within the O'Connell River case study area*

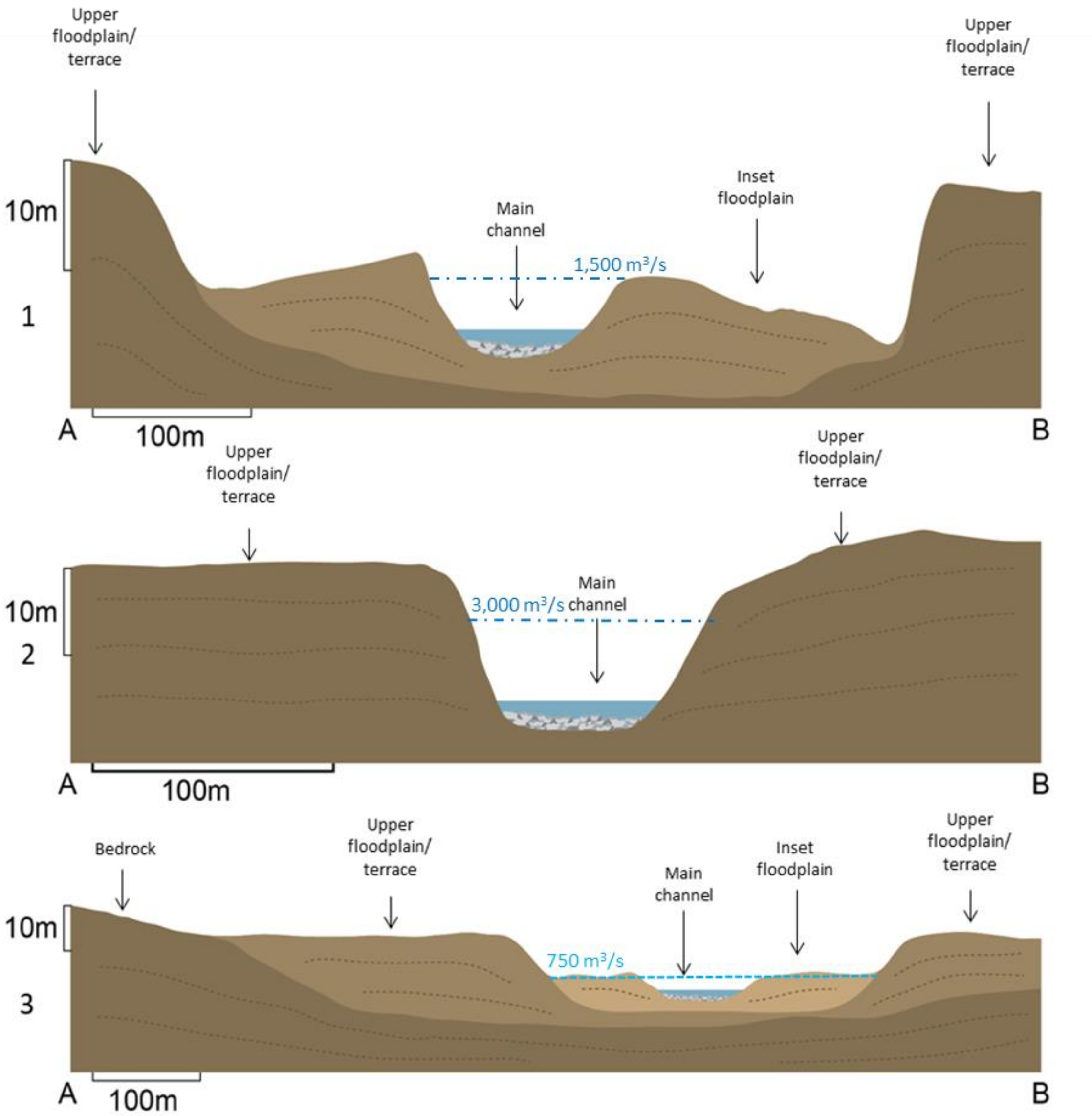

Figure 90: *The three typical sections within the O'Connell River case study area (shown in Figure 79 and Figure 80) showing the key geomorphic units and representative bankfull flows.*

Stream power assessment

Mean specific stream power was determined from the HEC-RAS model for three flow events, 750 m³/s, 1000 m³/s and 1,250 m³/s, is shown in Figure 91. Downstream of chainage 7,000 m the bankfull mean specific stream power is typically between 50 and 200 W/m². There is a large spike in bankfull stream power within the high channel erosion zone however most of the high channel erosion area has comparatively low stream power.

Within the steep, confined section (i.e. between 7,000 m and 10,000 m) mean specific stream power increase to between 100 – 800 W/m². However, this is not bankfull value due to the very high channel capacity through this zone.

Upstream of chainage 10,000 m bankfull mean specific stream power is typically between 100 W/m² and 400 W/ m². There is no observable correlation with the high channel erosion areas within this zone.

The total cross-sectional stream power results are shown in Figure 92. Downstream of chainage 7,000 m bankfull total cross-sectional stream power is typically between 5,000 W/m and 10,000 W/m. Within the confined section the modelled stream power increases to between 10,000 W/m and 60,000 W/m. Upstream of chainage 10,000 m bankfull cross-sectional stream power is typically between 10,000 W/m and 30,000 W/ m.

The Dynamic Sednet riparian vegetation percentage parameter, an indicator of channel resistance, is also shown on the stream power figures.

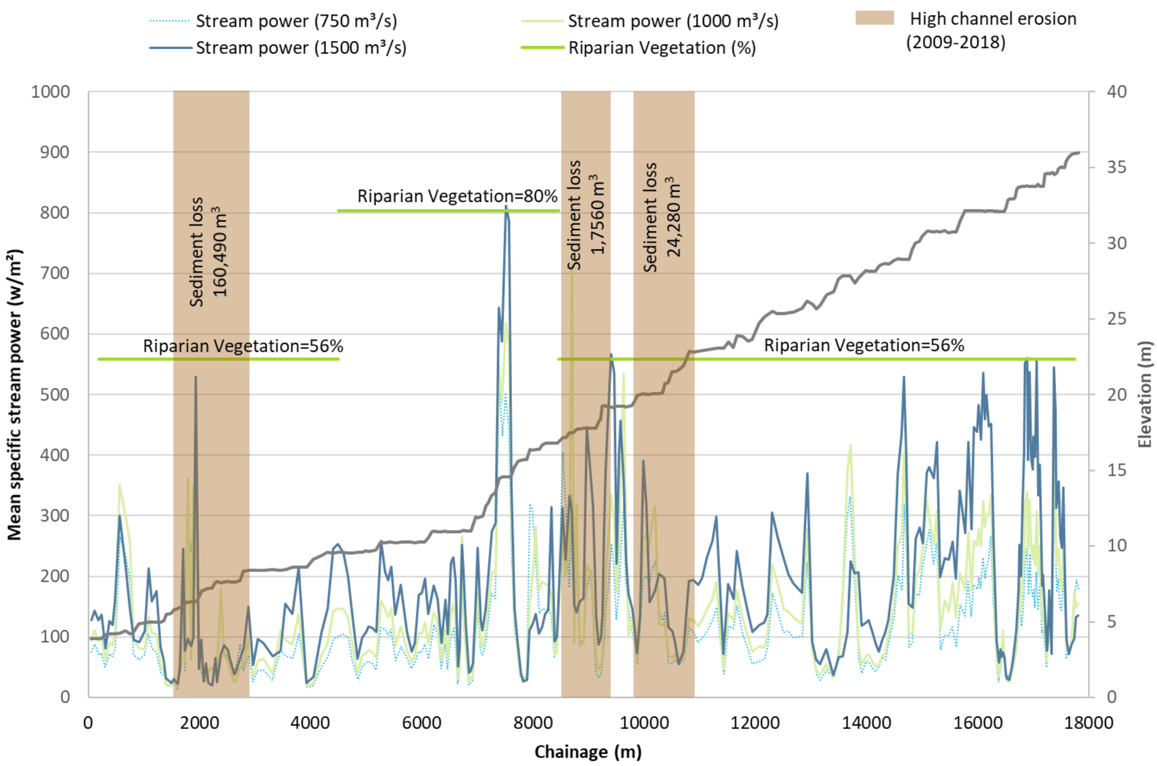

Figure 91: *The mean specific stream power within the O'Connell River case study area. Longitudinal variability in the SedNet Riparian Vegetation percentage parameter is also shown (note: there is no vertical axis for this metric. Percentage of intact riparian vegetation is shown on figure. Vertical height is relative to percentage of intact riparian vegetation)*

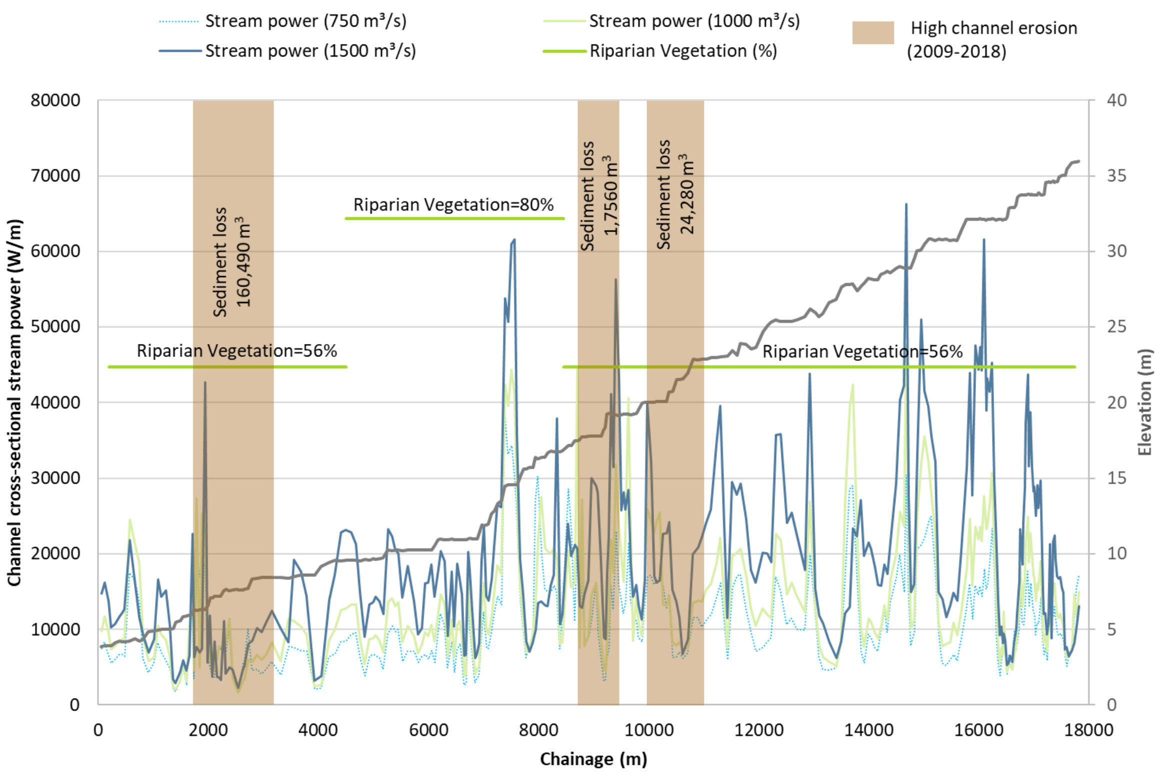

Figure 92: *The cross-sectional stream power within the O'Connell River case study area. Longitudinal variability in the Riparian Vegetation percentage parameter is also shown (note: there is no vertical axis for this metric. Percentage of intact riparian vegetation is shown on figure. Vertical height is relative to percentage of intact riparian vegetation)*

Bank sediments

Reef Catchments has collected boreholes from three inset floodplain units within the case study area. The results from all three boreholes is provided in Table 4. The sediments range from silty clay loam to loamy sand. Previous experience within this area suggests the clay content can vary significantly across small areas indicating significant variability in bank composition and erodibility across the case study area.

Table 4: Borehole data from the O'Connell River case study area (borehole locations shown in Figure 79 and Figure 80)

BH1	BH2	BH3	BH4
Silty clay loam 1-5 m	**Light clay** 1-5 m	**Loamy sandy** 0-2.5 m	**Fine sandy loam** 0-4 m

2.7. Summary of bank erosion processes

A summary of the river type river types, processes and channel erosion in the five case study areas is provided in Table 5. Four of the case studies (i.e. all except the Fitzroy) had sections of channel which had an entrenched morphology. These entrenched channels are relics from past sea level, flow and sediment regimes. As a result they do not behave as true self-formed alluvial channels. Within the confines of the alluvial terraces more contemporary alluvial floodplains and benches have formed during the current Holocene period. The case study assessment-identified erosion areas are significantly more prevalent when the channel is bound by inset floodplains and are often concentrated within small areas.

The key erosional processes identified in the case study assessment include:

- The dominant channel erosion processes was fluvial toe scour and subsequent mass failure on the outside of bends within the inset channel. This is part of a meander migration process. This type of erosion is more prevalent in zones where the inset floodplains are more expansive and there is limited woody vegetation coverage.
- Wet flow failures were prevalent in two case study areas. These are assocated with floodplains comprised of alternating fine and coarse sediment layers that control channel bank exfiltration on the recession limb of flood hydrographs. This results in the structural failure of sand layers and the mass failure of the overburden material. The erosion process is driven by the rise and fall of the water level and its not related to boundary shear stress or stream power.
- Meander cutoffs are driving rapid meander development in two case study areas. This increased rate of channel change is the result of localised increases in channel slope and stream power following the meander cutoff.
- Rapid rates of erosion were evident in tidal reaches in two case study areas. This erosion is most likely driven by entrainment of bank sediments (followed by mass failure) due to a combination of fluvial, tidal and wave action. Banks in tidal reaches are often highly erodible as bank vegetation does not establish across the entire tidal range.

Table 5: Summary of the key river types, processes and channel erosion in the five case study areas

Case study area	River type/processes	Channel erosion processes
Mary River	Entrench sand bed channel with a meandering planform. Lateral adjustment of the entrenched channel controlled by bedrock valley margins and fill terraces. Inset channel flows through more recent inset depositional units (i.e. inset floodplains, benches).	Dominant channel erosion process is fluvial toe scour and subsequent mass failure on the outside of bends within the inset channel. Erosion is more prevalent in zones where the inset floodplains are more expansive and there is limited woody vegetation coverage. There are no examples where there has been significant sediment loss from terrace units. Wet flow failures have historically been prevalent with failure scars clearly visible.
Raglan Creek	Upper portion consists of partly confined, low sinuosity, gravel bed channel. Middle portion consists of an entrench channel confined by	Downstream meander migration and channel widening driven by fluvial toe scour and mass failure is the dominant channel erosion process in the upper portion.

	terraces with a low sinuosity planform. Lower portion consists of an unconfined, meandering tidally influenced, channel.	There is limited examples where there has been significant sediment loss from terrace units in the middle portion. Significant meander migration within the lower tidal reach. This erosion is most likely driven by entrainment of bank sediments (followed by mass failure) due a combination of fluvial, tidal and wave action.
Fitzroy River	Partly confined sand bed channel with some bedrock controls. Planform is classified as meandering however it contains several higher-angle bends separated by sections that are near straight. The majority of the case study area sits within the weir pool of the tidal barrage.	The majority of sediment loss is derived from meander migration (i.e. fluvial toe scour and subsequent mass failure) processes. A large meander cutoff is driving increased rates of meander development in one location. Significant sediment loss occurred due to scour of in-channel units such as bars and islands. A significant number of wet flow failures were distributed throughout the case study area.
Murray Creek	Upper portion consists of entrenched, low sinuosity, gravel bed channel with discontinuous inset floodplains. Through the mid zone the valley confinement increases, and the channel is significantly confined by bedrock. Lower portion consists of an unconfined, meandering tidally influenced, channel.	Dominant channel erosion process is the result of lateral meander migration processes (i.e. toe scour and subsequent mass failure) across poorly vegetated inset floodplain units. There are no examples where there has been significant sediment loss from terrace units. Increased rates of lateral channel change and meander development due a meander cutoff in the lower estuarine reach.
O'Connell River	Upper portion consists of partly confined, low sinuosity, gravel bed channel. Within this section the channel can abut either bedrock, terrace or inset floodplain units. Middle section consists of an entrench channel confined by terraces with a low sinuosity planform. Lower portion consists of partly confined, low sinuosity, gravel bed channel with expansive inset floodplains within the broader entrenched channel.	Within the upper portion the dominant channel erosion process is fluvial toe scour and subsequent mass failure on the outside of bends within the inset channel. There are no examples where there has been significant sediment loss from terrace units. Major channel erosion as the result of meander development in the lower portion as the river reworked the coarse sediment deposits and created a defined low flow path.

3. Parameterisation of the Dynamic SedNet model

3.1. Introduction

Overview of model

Dynamic SedNet is a daily time-stepping sediment budget model which is implemented within the Source integrated modelling system. The model simulates spatial patterns in primary erosion processes at a catchment scale using data relating to terrain, land use, riparian vegetation cover, soils and rainfall. SedNet is used within GBR catchments to model sediment transport processes and the impacts of river management practices.

Dynamic SedNet a is semi-distributed spatial model used to assess end of catchment loads. It is structured around river reaches (described as links) and their associated sub-catchments. Within sub-catchments the model uses Functional Units (FU) to represent different hydrological responses based on land use (Figure 93). Dynamic SedNet uses a daily rainfall-runoff model to predict runoff for each FU in each sub-catchment, and subsequently to predict daily flow and bankfull flow for each stream link (Wilkinson et al., 2014). Flow data is used in the subsequent modelling of daily fine sediment budgets for each link in the river network. SedNet is comprised of multiple models, with each component modelling a specific process (i.e. stream bank erosion, floodplain deposition etc.).

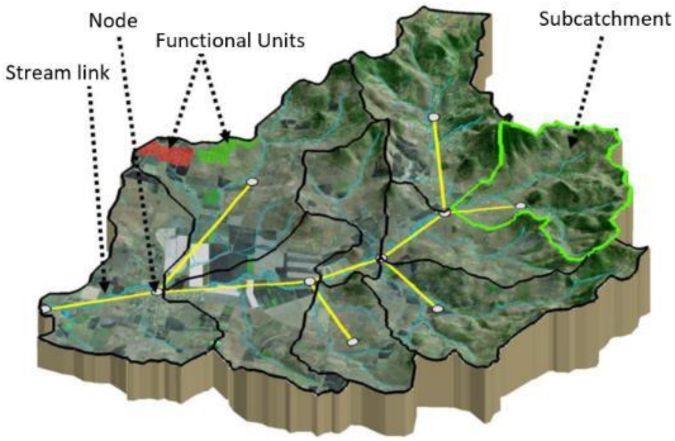

Figure 93: *Example of a Dynamic SedNet functional node and link network implemented within Source (adapted from Hateley, 2014)*

The Stream Bank Erosion component of Dynamic SedNet models bank erosion along stream links represented in the node-link (stream) network. The Stream Bank Erosion component models mean annual sediment supply from bank erosion along a link as a function of bankfull stream power in a hypothetical rectangular channel, and the extent of riparian vegetation adjacent to the channel and level of bedrock confinement as represented by available geological maps (as proxies for erosion resistance) (Figure 94). The bank erosion algorithm calculates the erosion rate over the entire length of the link. The erosion rate is then scaled down based on the proportion on the reach (link) with intact riparian vegetation cover (Prosser, 2018). Mean annual bank erosion (t/y) is calculated as shown in Figure 94.

Mean annual bank erosion (t/y) = Lateral retreat rate (m/y) × Mass Conversion × Bank erodibility

Figure 94: *Mean annual bank erosion equation*

The lateral retreat rate (RR) is the product of total bankfull stream power and calibration and management factors:

$$\mathbf{RR} = (\mathbf{k}\ \boldsymbol{\rho}_{\mathbf{w}}\ \mathbf{g}\ \mathbf{S}_{\mathbf{l}}\ \mathbf{Q}_{\mathbf{bf}})\mathbf{M}_{\mathbf{f}}$$

Where:

$\boldsymbol{\rho}_{\mathbf{w}}$ = density of water (1000 g/m3)

$\mathbf{g}$ = acceleration due to gravity (9.81 m/s2)

$\mathbf{S}_{\mathbf{l}}$ = link stream bed slope (dimensionless)

$\mathbf{Q}_{\mathbf{bf}}$ = bankfull discharge (m3/s)

$\mathbf{k}$ = bank erosion calibration coefficient

$\mathbf{M}_{\mathbf{f}}$ = bank erosion management factor

The bank erosion calibration coefficient is adjusted (according to available monitoring data e.g. measured bank retreat, erosion volumes, end of system loads) to ensure predicted long term erosion rates are comparable with observed bank erosion rates (Wilkinson et al, 2009). Consequently, good quality monitoring data is required to calibrate the model. Previous SedNet studies based in Australia employed K values in the range 0.00001 – 0.0001. The bank erosion management factor, introduced to allow proportional manipulation for Reef Plan, allows for adjustment of retreat rate based on proposed management actions.

Mass Conversion (MC) is determined by bank height and soil density:

$$\mathbf{MC} = \mathbf{F}_{\mathbf{b}}\ \boldsymbol{\rho}_{\mathbf{sh}}\ \mathbf{L}_{\mathbf{l}}$$

Where:

$\mathbf{F}_{\mathbf{b}}$ = proportion is fines in bank materials

$\boldsymbol{\rho}_{\mathbf{s}}$ = stream bank soil dry bulk density (t/m3)

$\mathbf{h}$ = bank height (m) (‘bank’= erosion contributing feature)

$\mathbf{L}_{\mathbf{l}}$ = river length represented by link (m)

Bank erodibility (BE) is considered riparian vegetation cover and bank material erodibility:

$$\mathbf{BE} = (\mathbf{1} - \mathbf{MIN}\ (\mathbf{RipVeg}, \mathbf{MaxVegEffectiveness})) \times \mathbf{SoilErod}$$

Where:

RipVeg = proportion of intact riparian vegetation

MaxVegEffectiveness = cap on the effectiveness of riparian vegetation

SoilErod = stream bank material erodibility (0-1 with 0 for bedrock and 1 for highly erodible alluvial sediments)

MaxVegEffectiveness acknowledges that stream bank erosion occurs in fully vegetated riparian zones. The mean annual erosion is then converted to daily bank erosion using a disaggregation function based on daily stream flow (Figure 95). Daily stream bank erosion is calculated as shown in Figure 95.

$$\text{Daily bank erosion (kg/day)} = \frac{1}{365.25} \times \text{Mean annual bank erosion (t/y)} \times \text{Stream link discharge factor} \times 1000$$

Figure 95: *Disaggregation mean annual bank erosion to daily bank erosion*

$$\textbf{Stream link discharge factor} = \frac{Q_i^b}{\frac{1}{n}\sum_{i=1}^{n} Q_i^b}$$

Where:

Q_i = daily flow rate (m3/s)

n = number of days in the long term historical daily flow record

b = adjustable Daily Flow Power Factor (default 1.4)

Several raster data layers and parameter values are used to build the Dynamic SedNet Bank Erosion model. A Digital Elevation Model (DEM) is used to define both the sub-catchments and the stream network. To determine sub-catchment and stream networks an area threshold for first-order river links must be determined (Wilkinson et al., 2014). Often this area threshold is specified based on computational efficacy and gully erosion mapping. Input raster layers are used to calculate eight raster data sets used in parameterisation (slope, flow direction, contributing area, ephemeral streams, stream order, stream confluences with main channel and stream buffers) (Hateley et al., 2014), although some of these do not contribute directly to stream bank parameterisation. The modelling period is defined by the daily precipitation and potential evapotranspiration data available for input into the daily rainfall-runoff model. Input parameters required for the Dynamic SedNet Bank Erosion component are outlined in Table 6, accompanied with a brief description of data used for GBR Reef Plan model parameterisation.

Table 6: Dynamic SedNet Bank Erosion input parameters and potential data sources

Parameter	Units	Description	Data source
k (bank erosion coefficient)	[0.00001, 0.0001]	Bank erosion calibration coefficient (default 0.00004)	Based on empirical data sets
S_l (river link slope)	m/m	Link stream bed slope	Calculated from DEM
Q_{bf} (bank full discharge)	m^3/s	Bank full discharge (m^3/s) based on the selected ARI (default 1.58 yrs)	Derive ARI discharge (m^3/s) based on long run of hydrology in Source model
ρ_s (soil bulk density)	tonnes/m^3	Stream bank subsoil dry bulk density	http://www.clw.csiro.au/aclep/soilandlandscapegrid/ProductDetails-SoilAttributes.html
h (bank height)	m	Function of catchment area and slope	Dynamic SedNet spatial parameteriser calculates average height at link level. Contributing area inferred from DEM derived sub-catchment and link network.
RipVeg	[0, 1]	Proportion of vegetation in riparian zone (1 for complete cover, 0 for no cover)	Vegetation cover mapping e.g. Queensland 2014 Foliage Projective Cover (FPC) layer. Clipped using a 100 – 200 m stream network buffer
MaxVegEffectiveness	[0, 1]	Sets limit for effectiveness of riparian vegetation in mitigating erosion	Set as 0.95 (Wilkinson et al., 2009)
SoilErod	[0, 1]	The erodibility of stream bank material (0 for rock, 1 for erodible soil). Or based on floodplain width (1 within mapped floodplain area, 0 elsewhere)	Floodplain mapping
p_f (proportion fine)	[0, 100%]	Proportion of fine sediment in bank subsoil	Best available soils data

Summary and proposed approach

A review of comparative studies and assessments of the stream bank component of the Dynamic SedNet model was undertaken in Alluvium (2020). The key findings of this study included:

- Enormous variations in predictive powers of the SedNet bank erosion algorithm. Given the limited number of comparative studies and the large variation in Queensland river types and data availability in these studies it is difficult to draw definitive conclusions on the suitability of the model in different scenarios (i.e. river typologies and data availability). However, comparative studies indicated that greater accuracy between predicted and observed bank erosion rates may be achieved locally through a calibration process and the use of locally relevant slope and bankfull flow data.
- There are limited studies available to assess the accuracy of the bank erosion algorithm used with the SedNet model in each different major river typology found within Queensland.
- The Dynamic SedNet model assumes uniform sediment and vegetation characteristics across the link length. In Queensland streams there are often large variations in erodibility both

longitudinally along the reach and laterally within the strata of floodplains and other depositional units. Alluvial channel boundary erodibility can vary by several orders of magnitude. As a result, it is very problematic to make uniform assumptions of sediment erodibility across the entire link.

Several recommendations were made in Alluvium (2020) which included:

- An assessment of the applicability of the model to the varying river typologies that exist within the Great Barrier Reef catchments.
- Research into the application of the stream power parameter including alternative metrics, parameterisation and application in different river typologies.
- A thorough assessment of bank material erodibility and the development of empirical erodibility datasets within different geomorphic units.
- A framework to assist in developing confidence bands on stream bank erosion prediction results based on the river typology and data availability.

This study aims to assess the parameterisation of the stream bank component of the Dynamic SedNet model in a range of different river types found along the coastal fringes of Queensland. Based on this assessment issues with parameterisation in different river typologies will be identified.

3.2. Mary River

Overview

The Mary River case study area consists of four Dynamic SedNet-modelled links. The four modelled links are shown spatially in Figure 96. Across each link there can be large variations in channel bounding geomorphic units and channel controls. This is particularly evident across the link for SC #503 which covers the lower 16 km of the case study area. The lower section of this link contains an expansive area of inset floodplains while within the upper portion the channel is relatively entrenched with bedrock controls and minimal inset floodplain development.

Key input parameters used in the Dynamic SedNet model for each link within the Mary River case study area are shown in Table 7. A comparison of some of the key modelled parameters to the hydro-geomorphic parameters identified in this study is provided below.

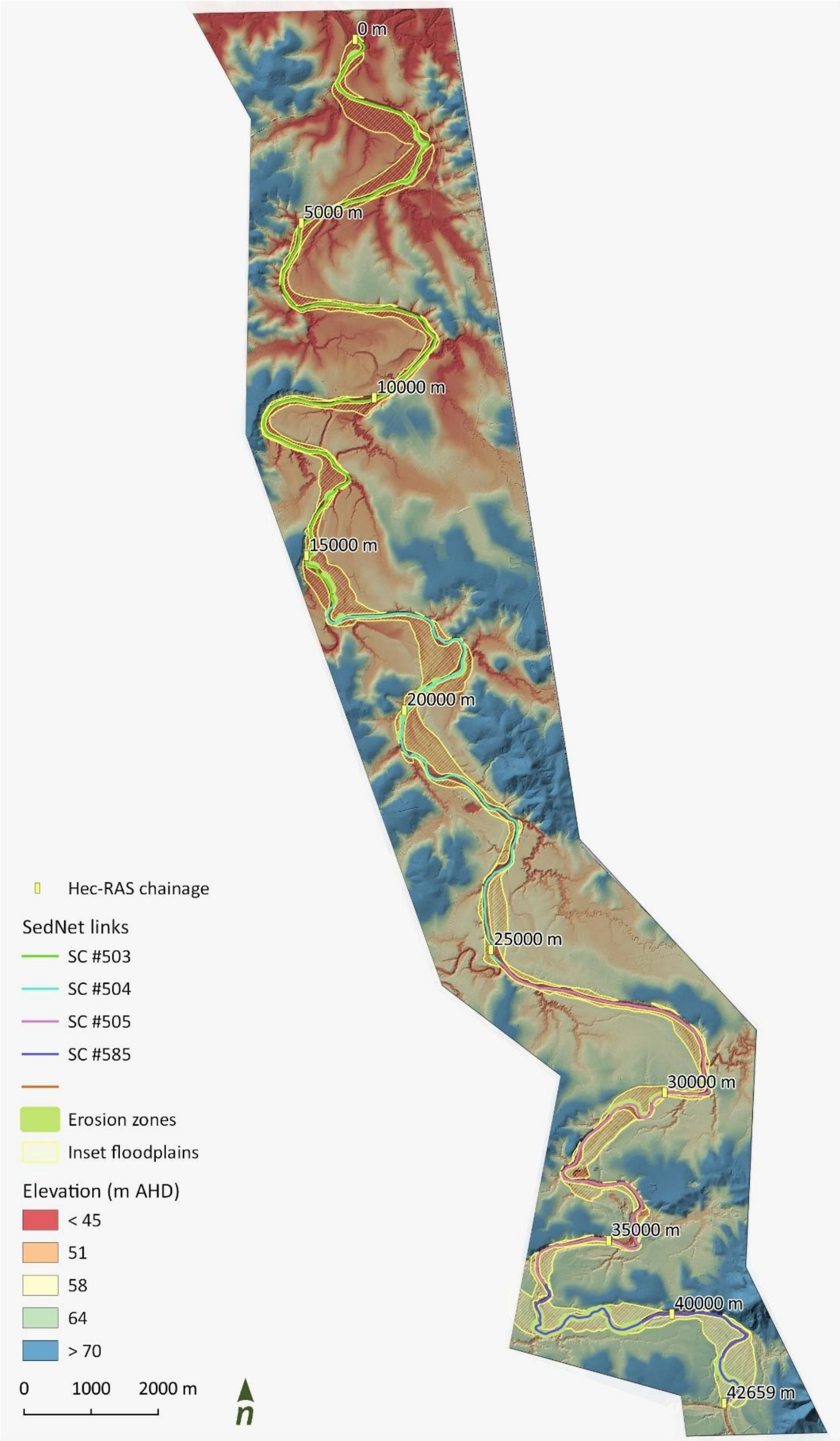

Figure 96: *The Mary River case study area with the Dynamic SedNet links*

Table 7: Dynamic SedNet Bank Erosion key input parameters - Mary River case study reach

Link (Sub-catchment)	Bank Full Flow (m³/s)	Link Slope (m/m)	Link Length (m)	Channel Width (m)	Bank Height (m)	Riparian Vegetation Percentage (%)	Maximum Riparian Vegetation Effect. (%)	Stream bank material erodibility (%)	Bank Erosion Coeff.
SC #503	3744	0.00035	16035	154	16.8	59.3	95	97.7	1.7E-06
SC #504	3543	0.00069	8959	148	16.2	58.7	95	99.0	4.6E-06
SC #505	3209	0.00025	10869	139	15.5	59.5	95	95.4	2.0E-05
SC #585	3232	0.00095	5281	137	15.3	46.3	95	88.8	2.0E-05

Bankfull discharge

Bank full flow used in the Dynamic SedNet modelled links in the Mary River study reach range between approximately 3,200 and 3,750 m3/s. The return period for these events is approximately 10 years (BOM, 2020).

Determining bankfull flow is complicated within this case study area as there are effectively two channels:

- Inset channel which is formed from recent Holocene flow and sediment regime
- Macrochannel which is bound by the outer terraces

The HEC-RAS modelling undertaken in Section 2.2 assessed the inset channel capacity as all the recent observed erosion is occurring within the inset units which bound this channel. The inset channel capacity varies throughout the case study area however is typically between 550 m^3/s to 1,000 m^3/s. The return period for these events is between 2 and 3 years (BOM, 2020). The macrochannel capacity was not modelled as part of this assessment.

Bank heights

The modelled bank heights for the Mary River case study area are shown in Figure 97. The modelled bank heights ranges between 15 – 17 m across the Mary River case study area. The bank heights align with the terrace units within the case study area.

The Dynamic SedNet Component Model Reference Guide specifies the ‘bank’ used to assign bank height should be the erosion contributing feature - not necessarily the channel height or depth. Within the case study area nearly all identified erosion between 2009 and 2018 came from the inset units. These typically have a height of 10-11 m across the Mary River case study area.

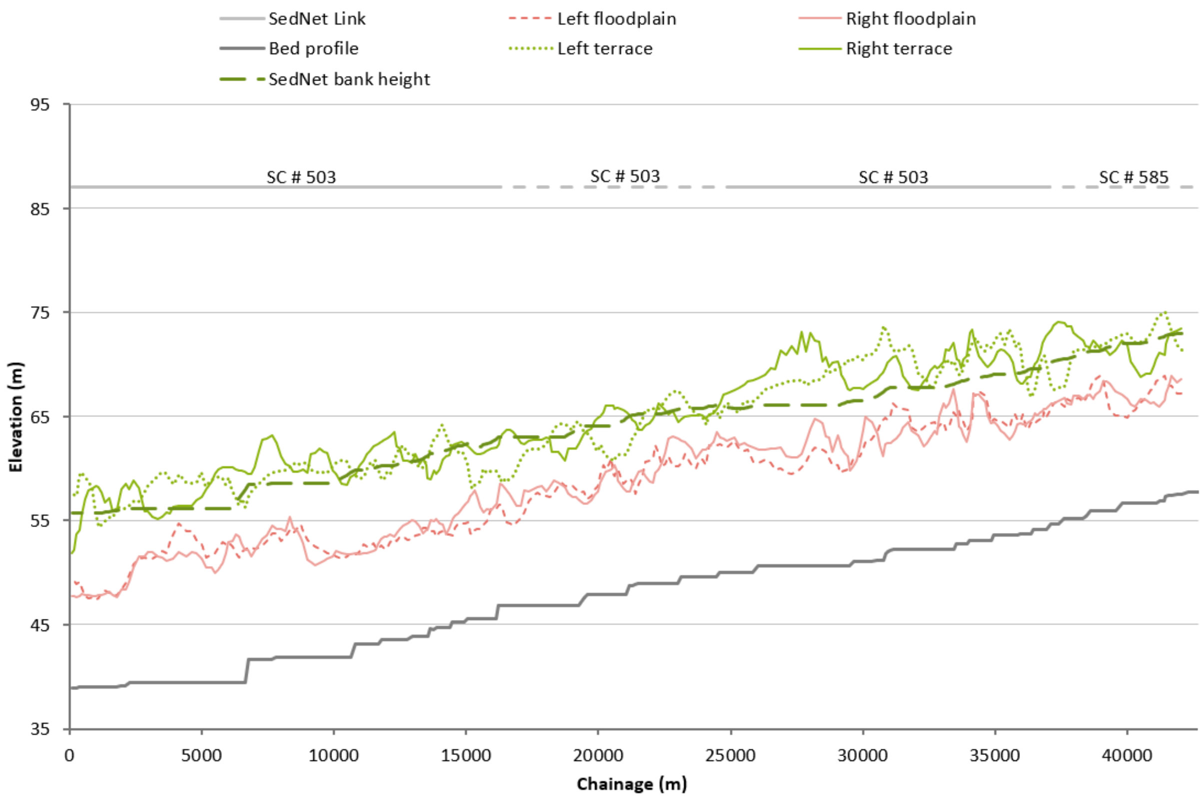

Figure 97: *Modelled link bank height and LiDAR derived bank height within the Mary River case study area*

Bed slope

The modelled bed slopes for the Mary River case study area are shown in Figure 98. Generally, the bed slopes align with the values determined from the LiDAR data. However, across the link for SC #503 the modelled link slope does not represent the major change in slope from 0.000066 m/m to 0.00065 m/m. These two slopes represent the gentlest sloping and steepest sloping sections of the case study area.

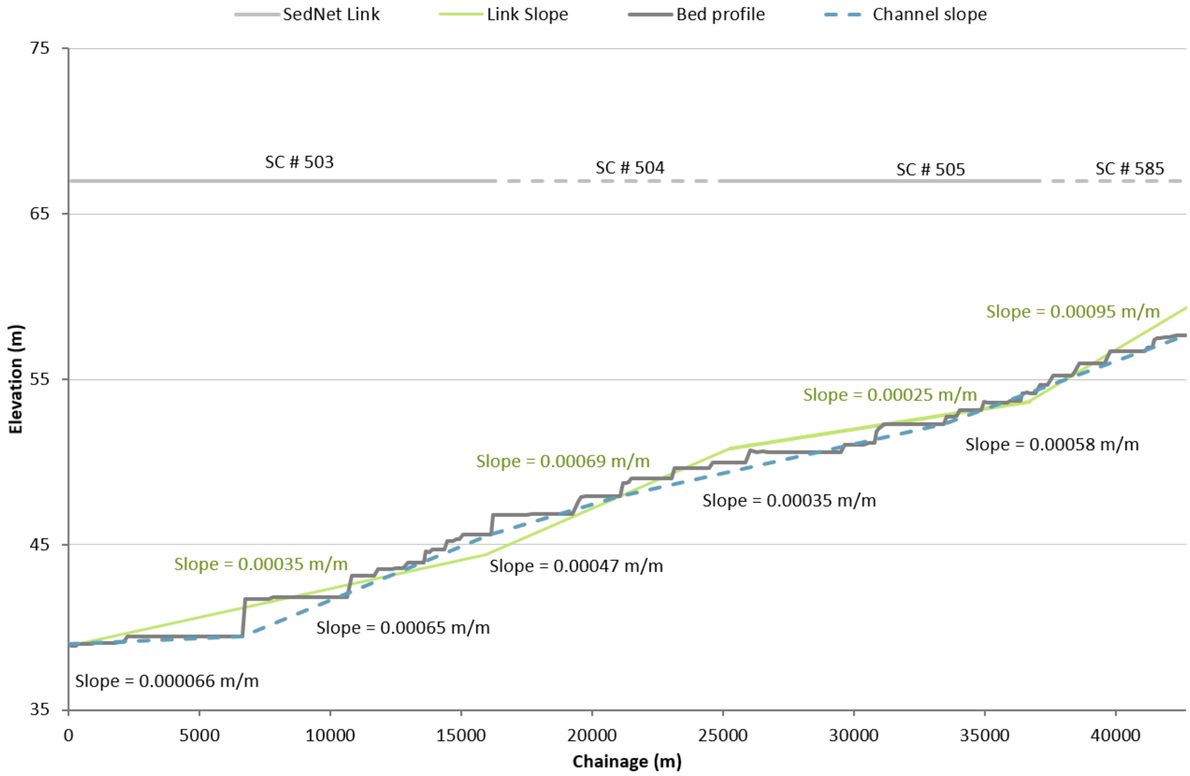

Figure 98: *Modelled link bed slope and LiDAR derived bed slope within the Mary River case study area*

Vegetation condition

Vegetation condition in the Mary River case study reach was assessed by DNRME using the 2014 Foliage Projective Cover (FPC) layer which defines the percentage of ground area occupied by the vertical projection of foliage. The FPC layer was used to delineate woody and non-woody riparian vegetation (within 100 m of stream bank) based on a 12% FPC threshold (i.e. woody vegetation classified as FPC > 12%).

In order to determine woody riparian vegetation percentage for each Dynamic SedNet sub-catchment the following steps were taken:

- A 20 m buffer was applied to the stream centreline (buffer distance based on stream order i.e. 7)
- The classified FPC layer was then clipped to a 100 m buffer outside of the channel
- Finally, the woody/non-woody cover polygon was intersected with sub-catchment layers to determine woody riparian vegetation percentage for each sub-catchment/link (Figure 99)

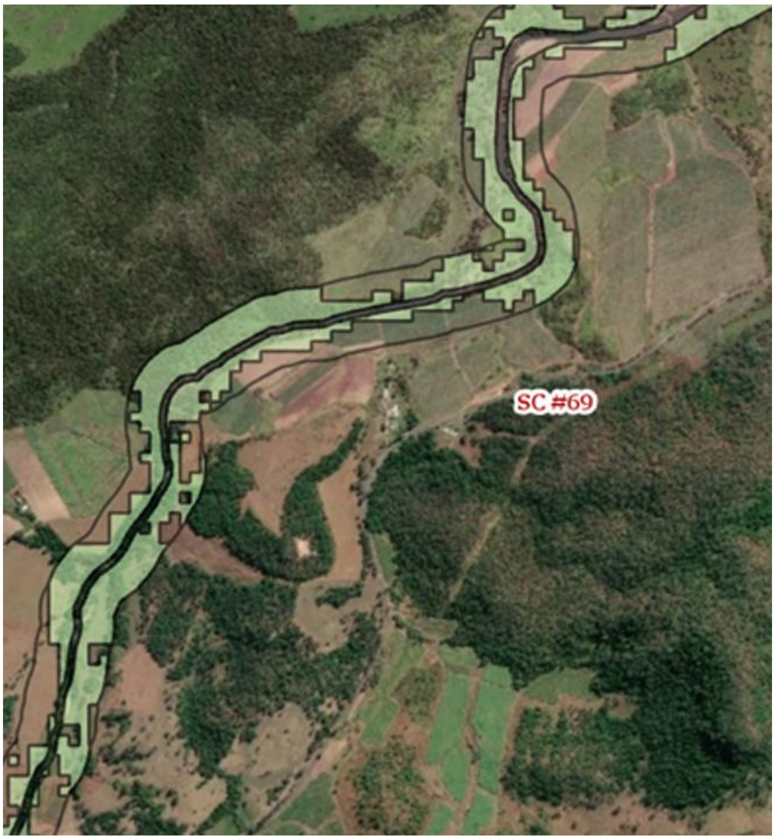

Figure 99: *Woody riparian vegetation within 100 m stream bank buffer (green area delineates FPC > 12%) (DNRME)*

A summary of buffer distances applied to case study reaches (based on stream order and region) is provided in Table 8.

Table 8: Summary of buffer distances based on stream order and region (DNRME)

Stream Order	Buffer Distance (from centreline)
1-3	5 m (FI, BM), 5-10 m (MW)
4-5	10 m (FI, BM, MW)
6	15 m
7-8	15 m (FI, BM, MW)
9	25 m (FI, BM)
Canals and small anabranches	5m
Notes:	FI denotes Fitzroy region BM denote Burnett-Mary region MW denotea Mackay-Whitsunday region

The Mary River typical sections with key geomorphic units and the SedNet riparian vegetation percent buffer zones are shown in Figure 100. In the areas assessed the 100 m buffer generally extends across the key geomorphic units which are generating sediment (i.e. the inset floodplain and bench units). However, there are some critical areas of exposed unit within the channel that are not covered by the buffer areas.

The buffer zones do not always cover the higher terraces which are the modelled bank height units (see bank height discussion above).

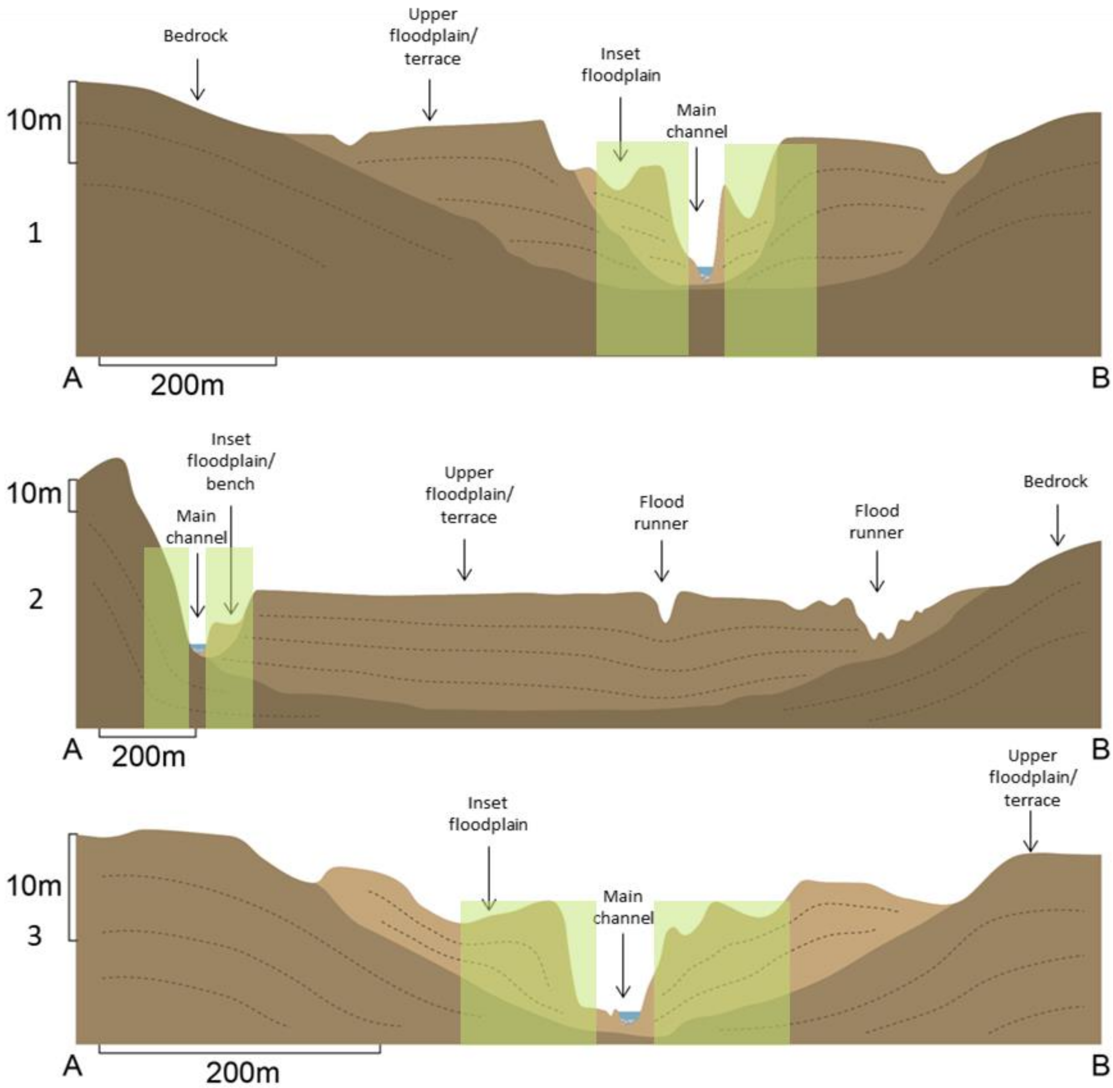

Figure 100: *The three typical sections in the Mary River case study area (shown in Figure 6 and Figure 7) with the key geomorphic units and 100 m riparian vegetation zones*

Stream bank material erodibility

The Dynamic SedNet soil stream bank material erodibility parameter ranges between approximately 89% and 98% across the Mary River case study area. No stream bank boundary erodibility data is available within the case study area. However, for the lower link at least, erodibility would vary substantially across the link due to the varying geomorphic units which form the channel boundary. It is understood these parameters are estimated by modellers based on a range of techniques (e.g. soil mapping, erosion rates, calibration).

Sediment loss

The Dynamic SedNet modelled daily flows, Mean Annual Bank Erosion (MABE), and long-term average flows for each link were used to determine the volume of stream bank erosion in the Mary River case study reach between 2009 and 2018. The modelled sediment loss (coarse and fine) between 2009 and 2018 was 465,677 m3 (Table 9).

Temporal analysis of LiDAR data between 2009 and 2018 has allowed accurate assessment of sediment release from major erosion sites; there is a high degree of confidence that when there is large variation in elevation near stream banks the majority of this is due to stream bank erosion.

Estimating the cumulative sediment release from all minor stream bank erosion (i.e. less than 0. 5-1 m of difference) can be misleading due the differences in water surface and the position of pools on the day of survey, differing accuracy of datasets and differing ability to penetrate vegetation foliage. As a result, only sediment release from major erosion sites has been estimated in this study.

LiDAR analysis between 2009 and 2018 indicated that over 551,641 m³ of sediment was mobilised from major erosion zones within the case study reach (Table 9). However, total sediment release from stream bank erosion is likely to be higher than these estimates. The total Dynamic SedNet sediment loss volumes are slightly less (16%) than sediment loss volumes derived from the LiDAR data. However, at the link scale the variability is much greater although still within +/-100% of the actual values.

Table 9: Comparison between Dynamic SedNet modelled and LiDAR derived sediment mobilisation volumes in the Mary River case study reach

Volume of sediment mobilised (m3)			Modelled percentage of actual (LiDAR) (%)
Link (Sub-catchment)	**SedNet (2009 – 2018)**	**LIDAR (DoD) (2009 – 2018)**	
SC #503	25,613	171,726	15%
SC #504	73,205	99,049	74%
SC #505	112,688	95,807	118%
SC #585	254,171	174,934	145%
Total row	**465,677**	**551,641**	**84%**
Note: in 2018 Dynamic SedNet data was only available from January to June			

Calibration

A summary of calibration processes applied to the Mary River Dynamic SedNet model were provided by DNRME catchment modellers. The model within the case study area has recently utilised improved stream bank erodibility data (source unknown) and Digital Elevation Model for bed slope. Furthermore, bank erosion coefficients for SC #503 and SC #504 have been calibrated to closely match bank retreat rates estimated (using historical aerial imagery and satellite imagery) by Binns et. al. (2017).

3.3. Raglan Creek

Overview

The Raglan Creek case study reach consists of four Dynamic SedNet modelled links. The four modelled links are shown spatially in Figure 101. The four links align relatively well with the geomorphic features and degree of channel entrenchment identified within this case study area within Section 2.3.

Key input parameters used in the Dynamic SedNet model for each link within the Raglan Creek case study area are shown in Table 10. A comparison of some of the key modelled parameters to the hydro-geomorphic parameters identified in this study is provided below.

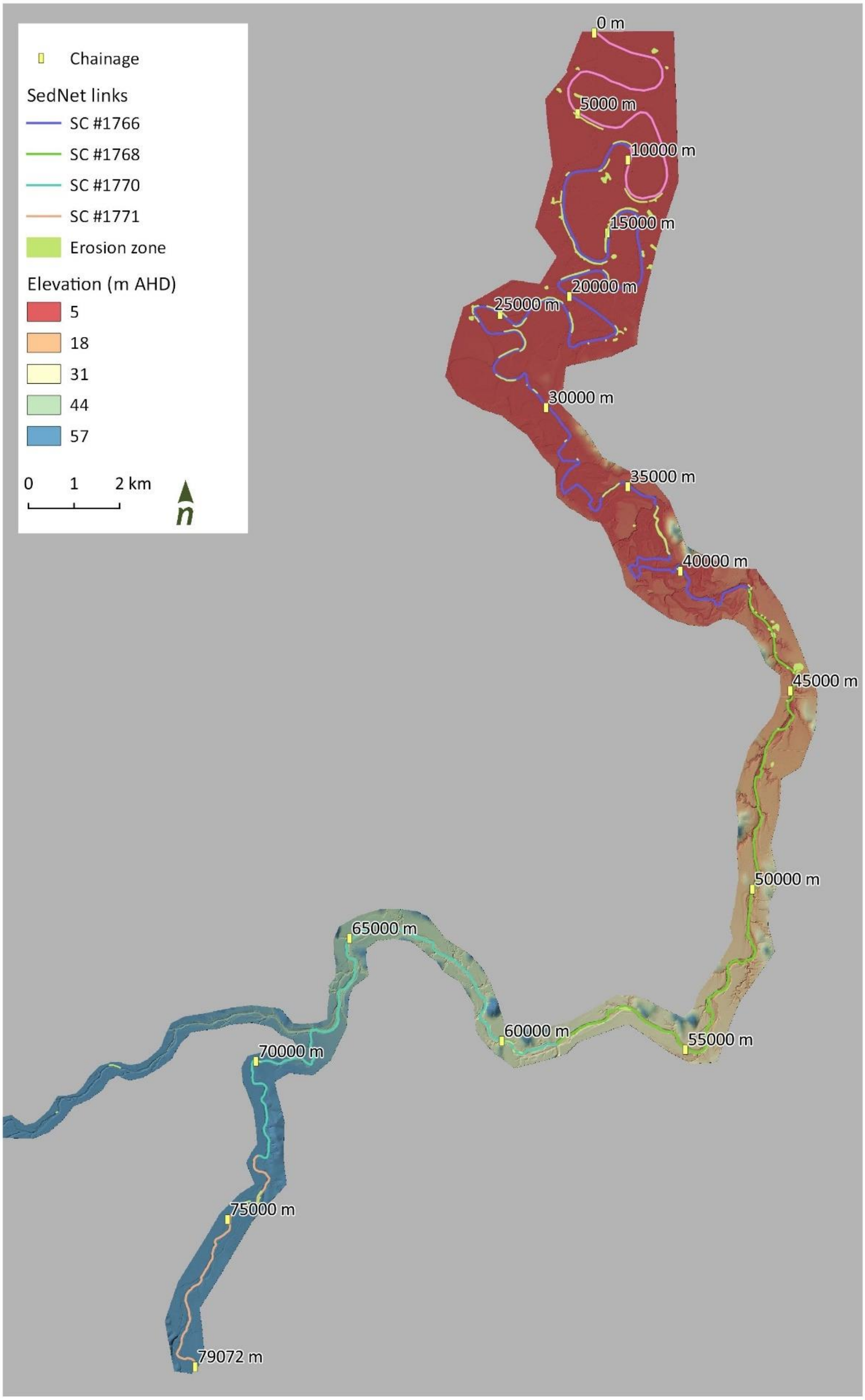

Figure 101: *The Raglan Creek case study area with the Dynamic SedNet links*

Table 10: Dynamic SedNet Bank Erosion key input parameters – Raglan Creek case study reach

Link (Sub-catchment)	Bank Full Flow (m^3/s)	Link Slope (m/m)	Link Length (m)	Channel Width (m)	Bank Height (m)	Riparian Vegetation Percentage (%)	Maximum Riparian Vegetation Effect. (%)	Stream bank material erodibility (%)	Bank Erosion Coeff.
SC #1766	880.5	0.0036	31199	60	5.0	65.3	95	75	2.0E-06
SC #1768	220.7	0.0186	15720	43	4.4	62.6	95	50	2.0E-06
SC #1770	182.8	0.0202	15041	25	3.8	57.7	95	75	2.0E-06
SC #1771	58.04	0.0110	5296	20	2.5	50.6	95	75	2.0E-06

Bankfull discharge

Bankfull flow used in the Dynamic SedNet modelled links in the Raglan Creek case study area increases from 60 m3/s in the upstream link to 880 m3/s within the downstream link. This assessment was unable to determine the channel capacity within the downstream link (i.e. the tidal reach) due to the lack of bathymetric data.

The HEC-RAS modelling undertaken in Section 2.3 identified the channel capacity in the upper reaches is approximately 650 m^3/s (SC #1770 and #1771). Within the entrenched section between chainage 40,000 m and 60,000 m (i.e. SC #1768) the HEC-RAS modelling identified that the channel capacity is over 1,250 m^3/s. This indicates bankfull flow is significantly higher than the Dynamic SedNet modelled values.

Bank heights

The modelled bank heights for the Raglan Creek case study area are shown in Figure 102. The SedNet bank heights in the upper reaches (SC #1770 and #1771) are 3.8 m and 2.5 m respectively. The bank heights assessed from the LiDAR data within these reaches was approximately 7 m. Within the entrenched section between chainage 40,000 m and 60,000 m (i.e. SC #1768) the Dynamic SedNet bank heights were 4.4 m which is less than the 10 m height derived from the LiDAR data. For the lower tidal reach, the SedNet bank height is 5 m. It is not possible to determine the actual bank heights within the tidal reaches from LiDAR data due to the lack of bathymetric information.

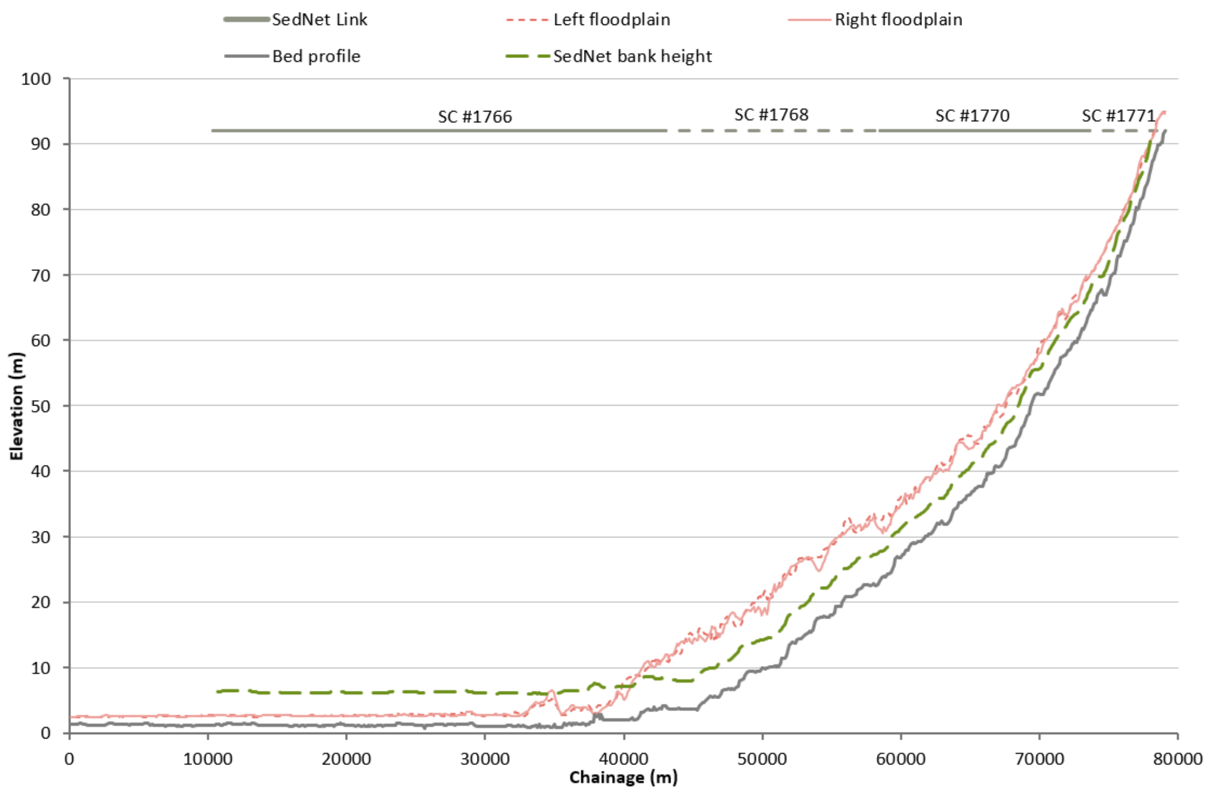

Figure 102: *Modelled link bank height and LiDAR derived bank height within the Raglan Creek case study area*

Bed slope

The modelled bed slopes for the Raglan Creek case study area are shown in Figure 103. The Dynamic SedNet modelled bed slope in the downstream tidal reach is 0.0036 m/m compared to the water surface gradient of 0.000017 m/m. The modelled bed slope for the remaining three links upstream are typically an order of magnitude steeper than the gradients derived from the LiDAR data.

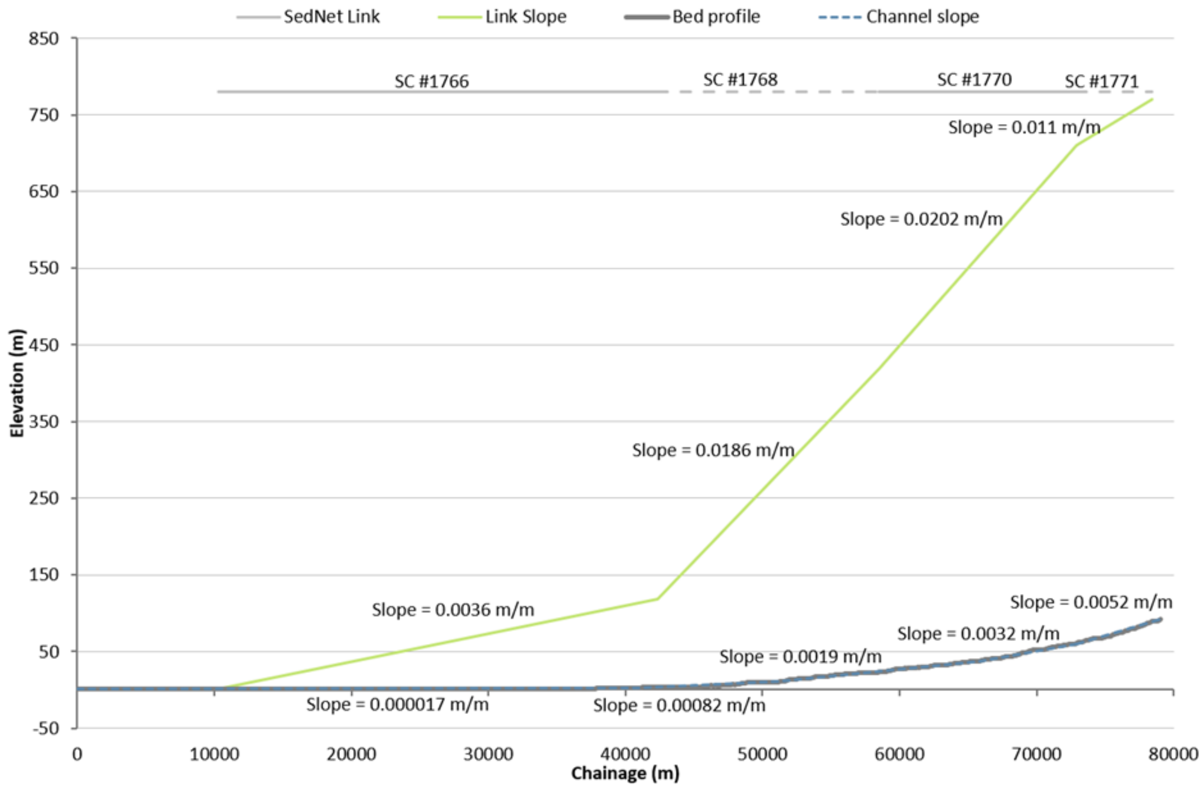

Figure 103: *Modelled link bed slope and LiDAR derived bed slope within the Raglan Creek case study area*

Vegetation condition

Vegetation condition in the Raglan Creek case study reach was assessed using the 2014 FPC layer as per the methodology outlined in the Mary River case study (Section 3.2). The stream order of the Raglan Creek study area ranges from 4 to 6, therefore a 10 - 15 m buffered was applied to the stream centreline.

The Raglan Creek typical sections with key geomorphic units and SedNet riparian vegetation percent buffer zones are shown in Figure 104. In the areas assessed the 100 m buffer generally extends across the key geomorphic units which are generating sediment (i.e. the inset floodplain units). However across all three cross-sections shown in Figure 104 there are areas of exposed unit within the channel boundary which are not covered by the buffer area.

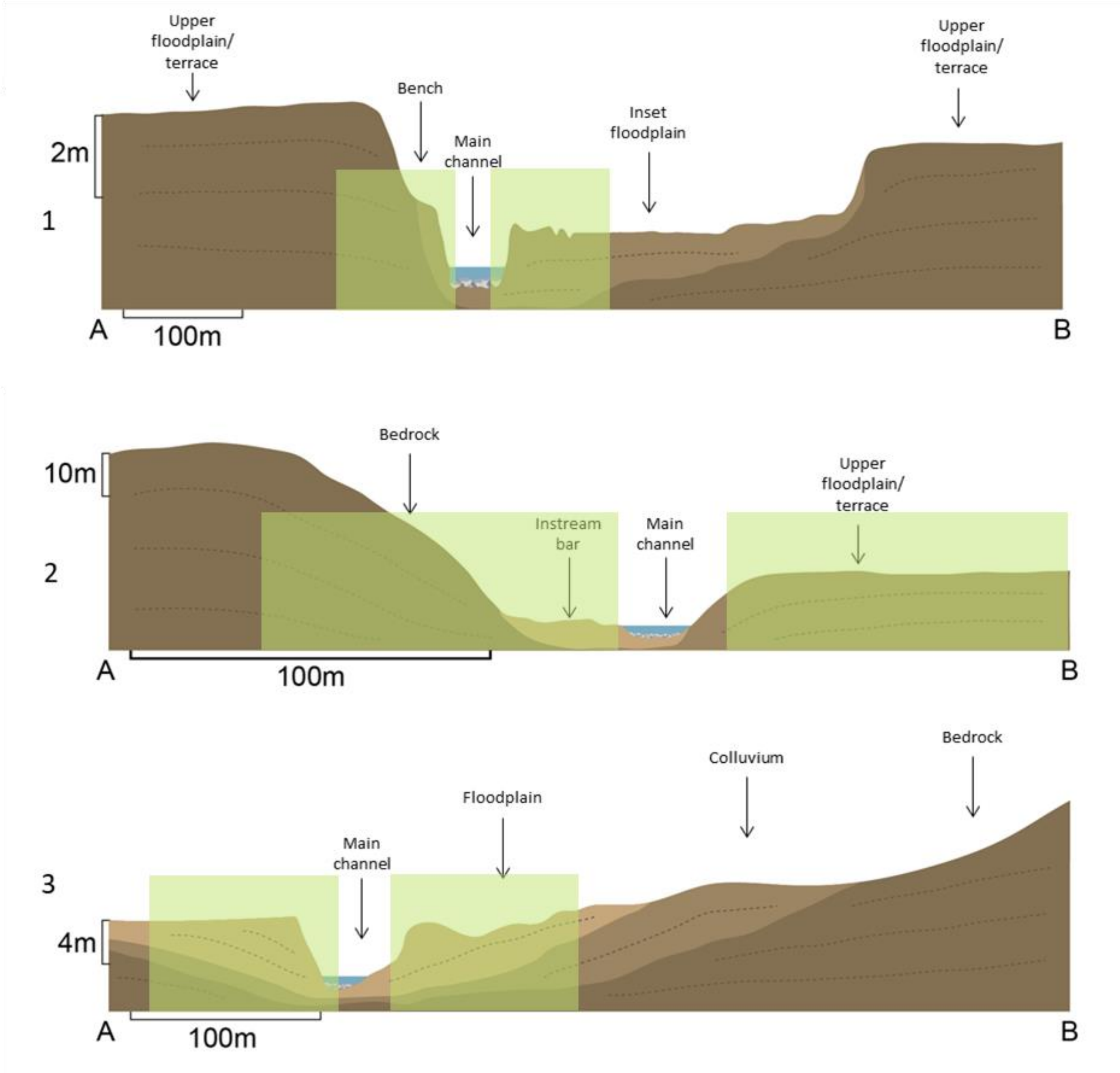

Figure 104: *The three typical sections in the Raglan Creek case study area (shown in Figure 27, Figure 28 and Figure 29) with the key geomorphic units and 100 m riparian vegetation zones*

Stream bank material erodibility

The Dynamic SedNet stream bank material erodibility parameter ranges between 50 and 75% across the Raglan Creek case study area. No stream bank boundary erodibility data is available within the case study area. However, it would be expected that the terrace units which confine the channel between chainage 40,000 m and 60,000 m (i.e. SC #1768) would have a lower erodibility than the more contemporary deposited units. This is reflected within the stream bank material erodibility parameter with SC #1768 having an erodibility value of 50% compared to 75% in the other three links (see calibration discussion below).

Sediment loss

The Dynamic SedNet modelled daily flows, MABE, and long-term average flows for each link were used to determine the volume of stream bank erosion in the Raglan Creek case study reach between 2009 and 2018. The modelled sediment loss (coarse and fine) between 2009 and 2018 was 111,513 m3 (Table 11).

LiDAR analysis between 2009 and 2018 was only available for the downstream area (i.e. SC #1766). The analysis indicates that over 67,053 m3 of sediment was mobilised from major erosion zones within the case study area (Table 11). Total sediment release from stream bank erosion is likely to be higher than these estimates given the lack of bathymetric information in this area. However, the Dynamic SedNet sediment loss volumes are comparable to sediment loss volumes derived from the LiDAR data in this area.

Table 11: Comparison between Dynamic SedNet modelled and LiDAR derived sediment mobilisation volumes in the Raglan Creek case study reach

Volume of sediment mobilised (m3)			Modelled percentage of actual (LiDAR) (%)
Link (Sub-catchment)	**SedNet (2009 – 2018)**	**LIDAR (DoD) (2009 – 2018)**	
SC #1766	57,745	67,053	86%
SC #1768	23,360		
SC #1770	29,029		
SC #1771	1,379		
Total	**111,513**		
Note: in 2018 Dynamic SedNet data was only available from January to June			

Calibration

A summary of calibration processes applied to the Raglan Creek Dynamic SedNet model was provided by DNRME catchment modellers.

Stream bank material erodibility was adjusted from the default value of 100% (i.e. alluvium) to values based on a qualitative assessment of the presence, and severity, of stream bank erosion within each sub-catchment/link. Field data and aerial imagery analysis were used to categorise the severity of stream bank erosion within each sub-catchment. Stream bank erosion classes range from no evidence of stream bank erosion to very high erosion (i.e. at least one bank actively eroding along most of the modelled link) (Table 12). These qualitative erosion classes were then converted to a stream bank material erodibility percentage for each link (DNRME, 2020, pers. comm., April).

Table 12: Stream bank erosion classes and allocated stream bank material erodibility values

Proportion of stream bank erosion	Stream bank material erodibility
No bank erosion	5%
Low	25%
Moderate	50%
High	75%
Very High	100%

3.4. Fitzroy River

Overview

The Fitzroy River case study reach consists of seven Dynamic SedNet modelled links (river reaches). The seven modelled links are shown spatially in Figure 105. The seven links align relatively well with the geomorphic features and degree of channel confinement identified within this case study area within Section 2.4.

Key input parameters used in the Dynamic SedNet model for each link within the Fitzroy River case study area are shown in Table 13. A comparison of some of the key modelled parameters to the hydro-geomorphic parameters identified in this study is provided below.

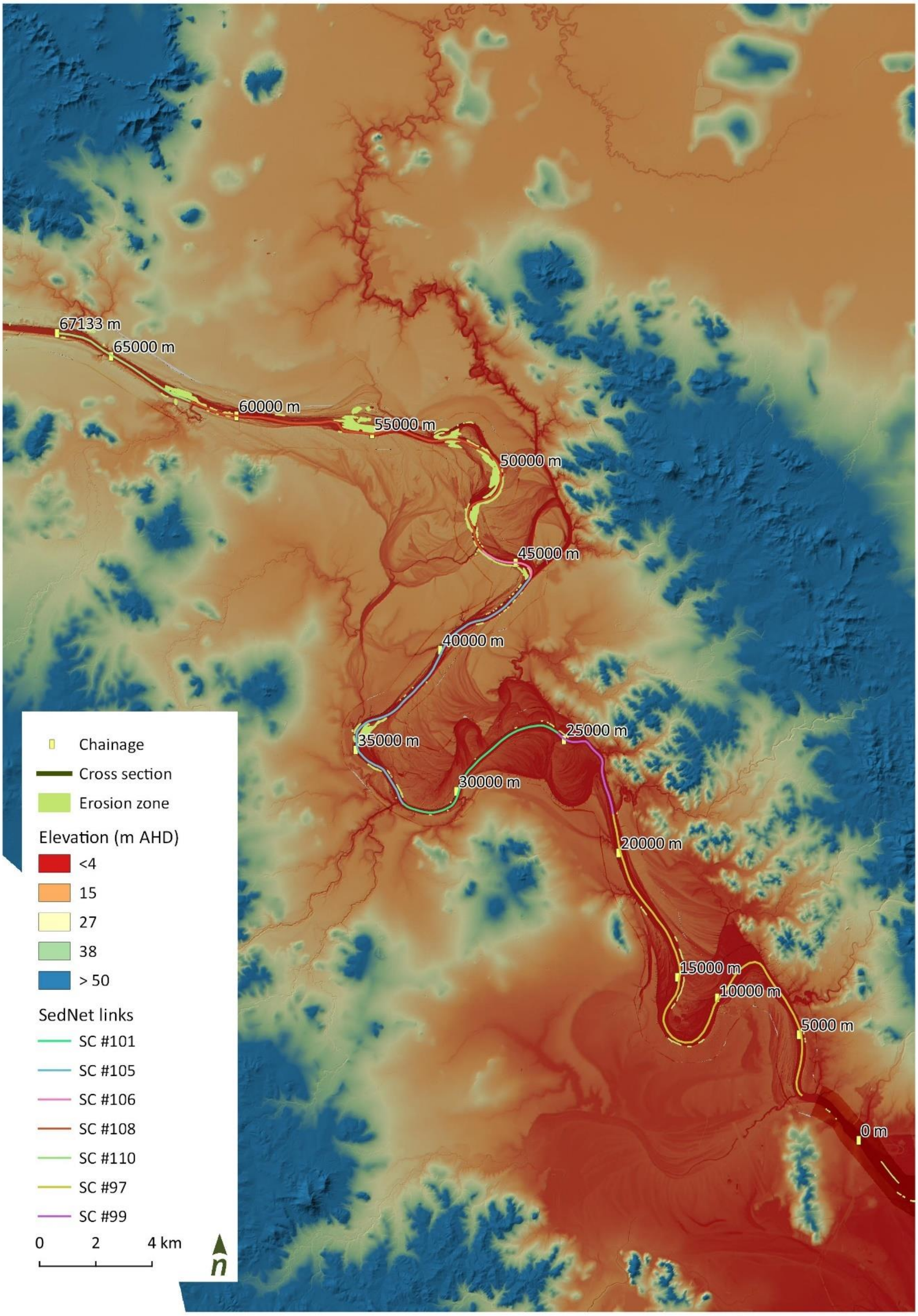

Figure 105: *The Fitzroy case study area with the Dynamic SedNet links*

Table 13: Dynamic SedNet Bank Erosion key input parameters - Fitzroy River case study reach

Link (Sub-catchment)	Bank Full Flow (m³/s)	Link Slope (m/m)	Link Length (m)	Channel Width (m)	Bank Height (m)	Riparian Vegetation Percentage (%)	Maximum Riparian Vegetation Effect. (%)	Stream bank material erodibility (%)	Bank Erosion Coeff.
SC #97	11,560	0.0026	19,690	307	21.5	70	95	5	2.0E-06
SC #99	11,132	0.0281	5,029	165	21.5	80	95	25	2.0E-06
SC #101	11,077	0.0046	7,134	206	21.5	53	95	25	2.0E-06
SC #105	10,973	0.0018	12,687	195	21.5	76	95	38	2.0E-06
SC #106	10,451	0.0161	2,956	172	21.5	82	95	25	2.0E-06
SC #108	10,444	0.0073	18,464	214	21.4	77	95	50	2.0E-06
SC #110	10,435	0.0374	5,710	269	21.4	78	95	75	2.0E-06

Bankfull discharge

Bankfull flow used in the Dynamic SedNet modelled links in the Fitzroy River case study area range between approximately 10,500 and 11,500 m3/s, which have return periods of 17 and 20 years respectively (Table 13). Comparatively, the HEC-RAS modelled bankfull flow is approximately 5,400 m3/s in upper reaches (SC#110 and upper SC# 108), and approximately 2,900 m3/s in downstream reaches (Figure 54). Overall, the bankfull flows applied in the Dynamic SedNet model for the Fitzroy River case study reach are considerably higher than the HEC-RAS bankfull flow estimates. Even when channel roughness is reduced from 0.035 to 0.01 the Dynamic SedNet input bankfull flows exceeds the channel capacity (i.e. channel capacity is approximately 7,500 m3/s in downstream reaches). Due to the lack of bathymetric data within the weir pool (downstream of chainage 53,000 m) it is not possible to definitively determine the actual channel capacity (and therefore bankfull flow). However, channel capacity is unlikely to be significantly different to the HEC-RAS modelled estimates. As a result, the bankfull flow used in the Dynamic SedNet modelled links are higher than actual bankfull flow.

Bank heights

The modelled bank heights for the Fitzroy River case study area are shown in Figure 106. The Dynamic SedNet input link bank heights are approximately 21.5 m across the entire case study area. The floodplain elevation upstream of chainage 53,000 m is approximately 15 m above the channel bed. Downstream of this location the floodplain height above the water surface progressively decreases to 5-8 m at the tidal barrage. The actual bank heights (i.e. above channel bed) within the weir pool (i.e. downstream of chainage 53,000 m) are unknown but are likely between 10 -15 m.

The Dynamic SedNet bank heights are significantly higher than bank heights derived from the LiDAR data.

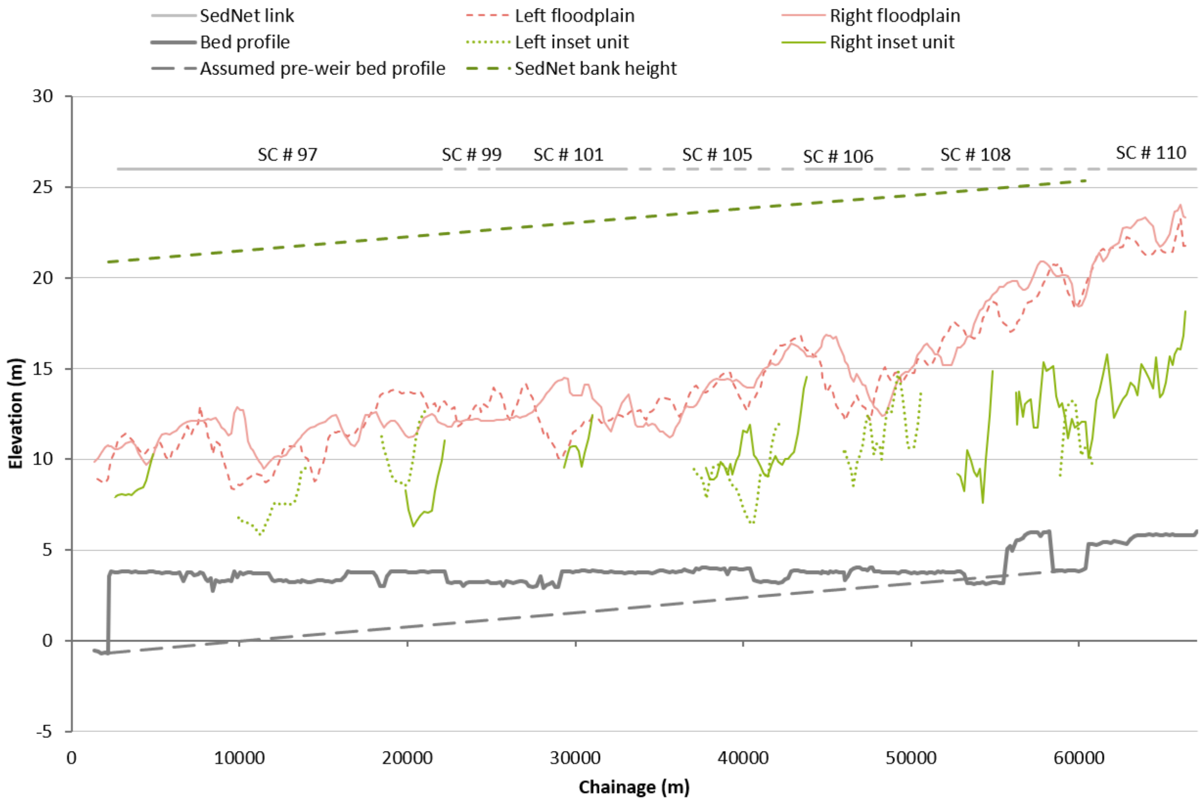

Figure 106: *Modelled link bank height and LiDAR derived bank height within the Fitzroy River case study area*

Bed slope

The modelled bed slopes for the Fitzroy River case study area are shown in Figure 107. The Dynamic SedNet link bed slopes range from 0.00183 to 0.03737 m/m. However, the majority of the case study area (i.e. below chainage 47,250 m) has a flat gradient (≈ 0.00001 m/m) due to the water surface from the tidal barrage. Through this zone LiDAR data captured the water surface (rather than in-channel features). The LiDAR derived bed slope data is only accurate for SC #110. Overall, the SedNet input link slopes are between one and three orders of magnitude greater (i.e. steeper) than LiDAR derived bed slopes.

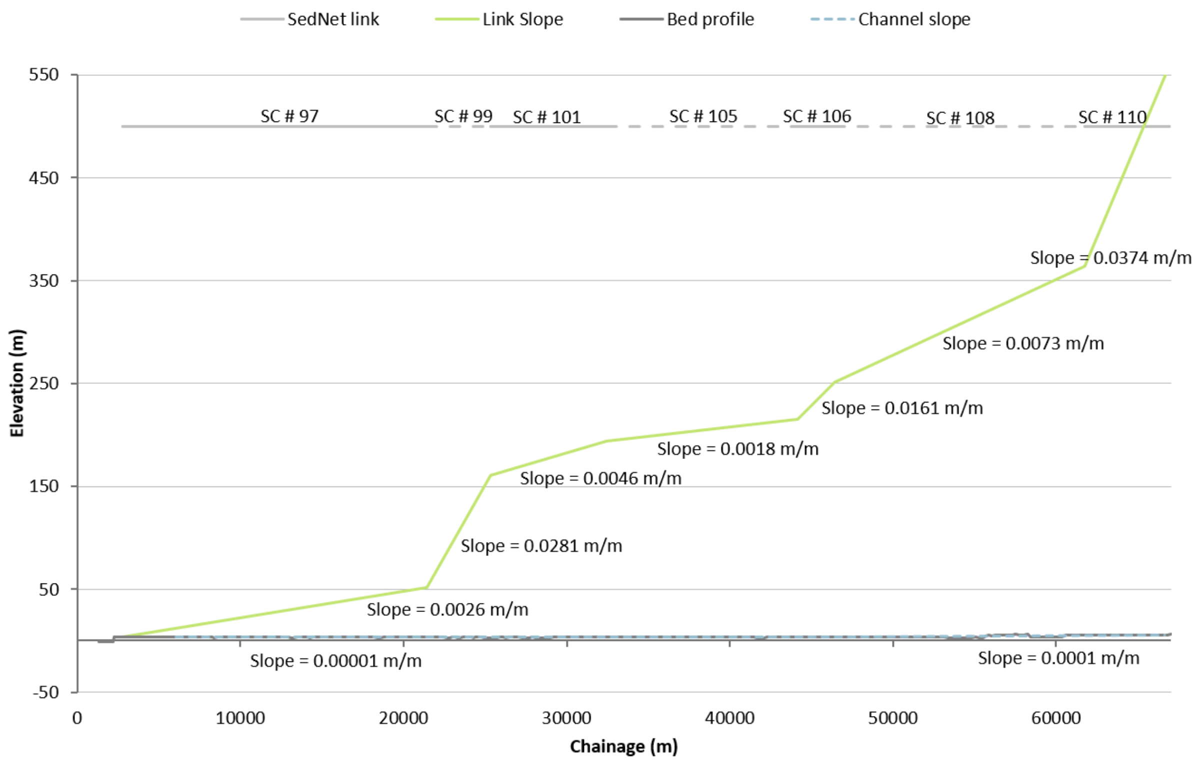

Figure 107: *Modelled link bed slope and LiDAR derived bed slope within the Fitzroy River case study area*

Vegetation condition

Vegetation condition in the Fitzroy River case study reach was assessed using the 2014 FPC layer as per the methodology outlined in the Mary River case study (Section 3.2). The stream order of the Fitzroy River study area is 9, therefore a 25 m buffer was applied to the stream centreline.

The Fitzroy River typical sections with key geomorphic units and Dynamic SedNet riparian vegetation percent buffer zones are shown in Figure 108. In several areas within the Fitzroy case study reach the 100 m buffer does not extend across the key geomorphic units which are generating sediment (i.e. the floodplain and bench units on exposed stream banks). In cross-section 3, for example, the buffer extends across the bench on the right side of the channel (looking downstream), but does not cover the full extent of the vegetated sand/gravel bar and floodplain on the left of the channel (Figure 109).

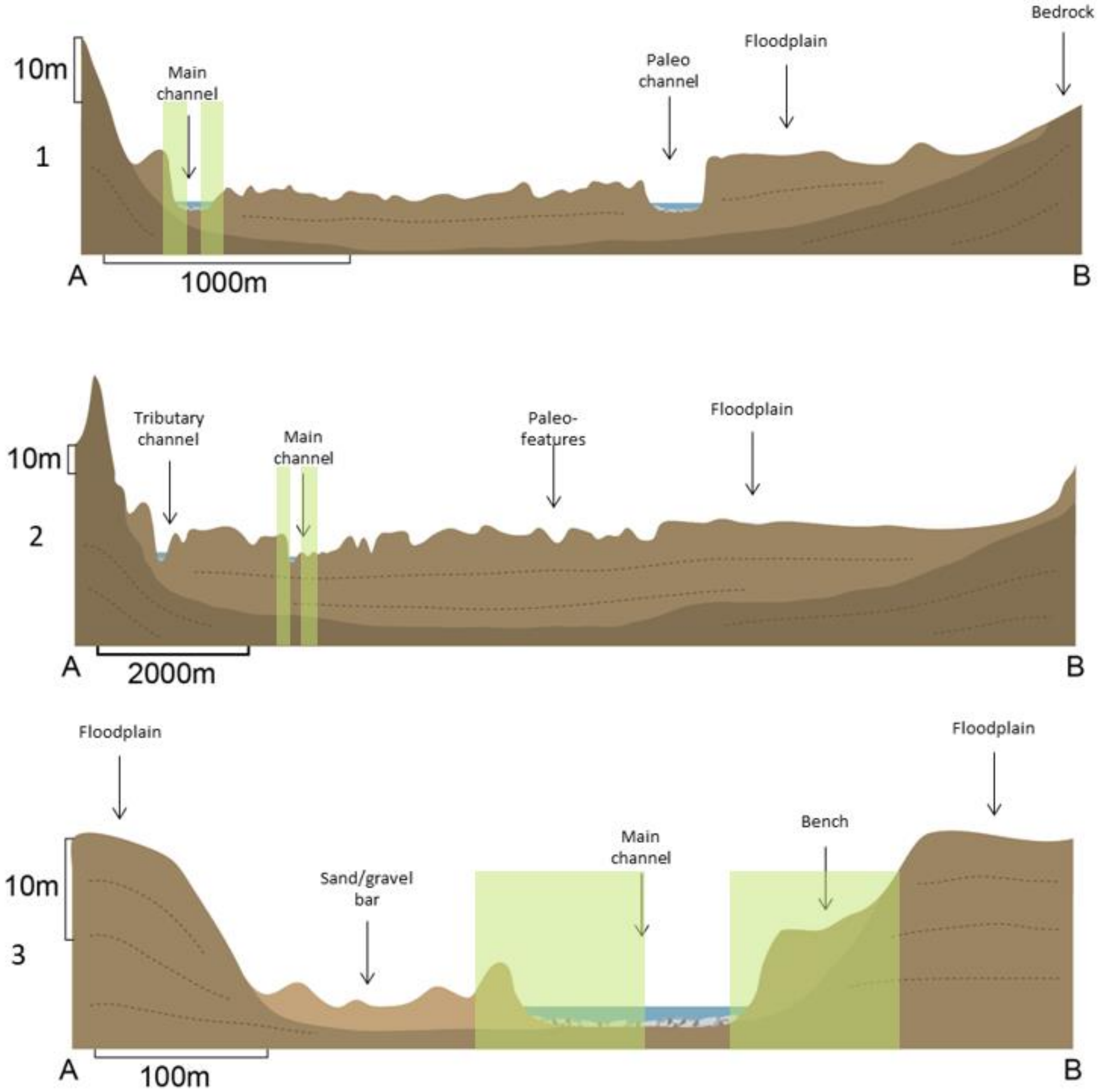

Figure 108: *The three typical sections in the Fitzroy River case study area (shown in Figure 44 and Figure 45) with the key geomorphic units and 100 m riparian vegetation zones*

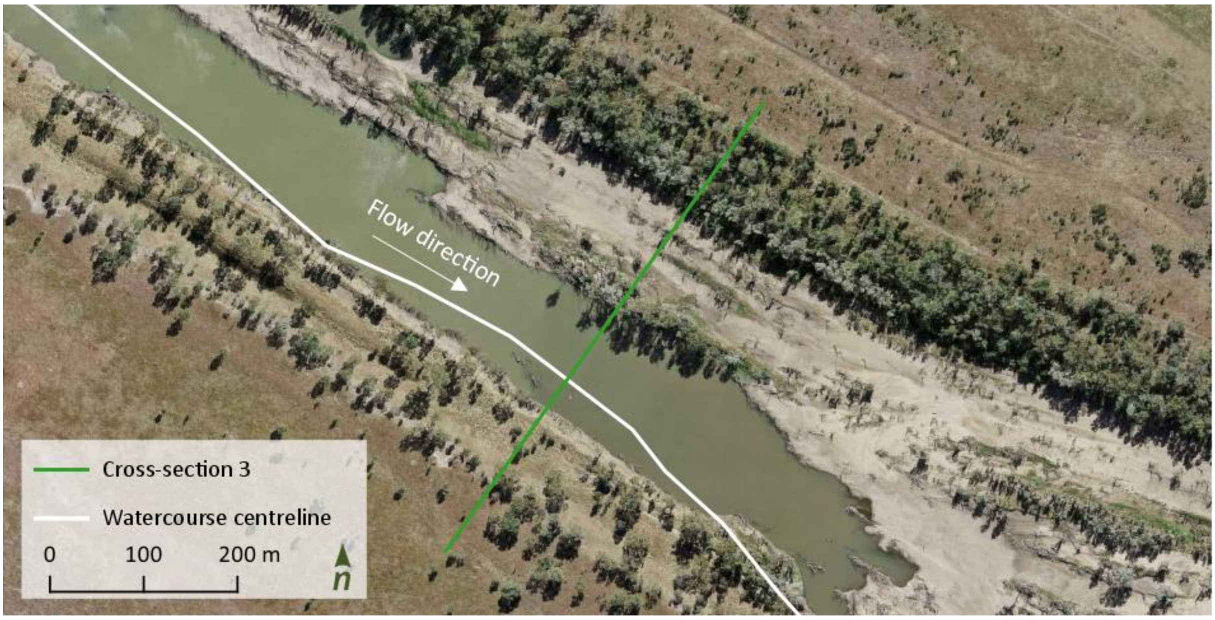

Figure 109: *Riparian zone on left bank of Cross-section 3 (approximately 100 m wide) is not captured within the SedNet riparian vegetation percentage buffer zone*

Stream bank material erodibility

The Dynamic SedNet stream bank material erodibility parameter is highly variable in the Fitzroy River case study area, ranging between 5% and 75%. The values have been adjusted to account for observed bank erosion using the same approach discussed in Section 3.3 (only the models within the Fitzroy catchment have been calibrated with this approach).

Stream bank boundary erodibility data is not available within each link, however the geotechnical data available for the Fitzroy River case study area indicates significant variability in bank composition and erodibility. As a result, large variations in stream bank material erodibility would be expected.

Sediment loss

The Dynamic SedNet modelled daily flows, MABE, and long-term average flows for each link were used to determine the volume of stream bank erosion in the Fitzroy case study reach between 2009 and 2018. The modelled sediment loss (coarse and fine) between 2009 and 2018 was 4,419,195 m3 (Table 14).

LiDAR analysis between 2009 and 2018 indicated that over 2,300,943m3 of sediment was mobilised from major erosion zones within the case study area (Table 14). Total sediment release from stream bank erosion is likely to be higher than these estimates.

The Dynamic SedNet sediment loss volumes are 92% higher than sediment loss volumes derived from the LiDAR data. However, at the link scale there is significantly more variability – particularly links SC #99, SC #101 and SC #110 where the sediment loss was between approximately 30 and 150 times the observed values.

Table 14: Comparison between Dynamic SedNet modelled and LiDAR derived sediment mobilisation volumes in the Fitzroy River case study reach

Volume of sediment mobilised (m3)			Modelled percentage of actual (LiDAR) (%)
Link (Sub-catchment)	**SedNet (2009 – 2018)**	**LIDAR (DoD) (2009 – 2018)**	
SC #97	81,919	50,452	162%
SC #99	483,317	3,379	14304%
SC #101	265,478	8,231	3225%
SC #105	147,351	145,893	101%
SC #106	142,277	140,524	101%
SC #108	1,074,928	1,881,897	57%
SC #110	2,223,925	70,566	3152%
Total	**4,419,195**	**2,300,943**	192%
Note: in 2018 Dynamic SedNet data was only available from January to June			

Calibration

A summary of calibration processes applied to the Fitzroy River Dynamic SedNet model were provided by DNRME catchment modellers. The Fitzroy River model was calibrated in 2020. The data provided by DNRME for this study (Table 13) are post the 2020 calibration.

Stream bank material erodibility was adjusted from the default value of 100% (i.e. alluvium) to values based on a qualitative assessment of the presence, and severity, of stream bank erosion within each sub-catchment/link (see approach outlined in for Raglan Creek in Section 3.3).

In 2020, sediment loss results (2009 - 2019) from the Lower Fitzroy River morphology assessment and restoration plan (Alluvium, 2019) were used for model calibration in the Fitzroy River case study area. However, the total volume of sediment loss (estimated from the LiDAR analysis) was compared against the Dynamic SedNet predicted fine (rather than total) sediment loads. Therefore, bank erosion results are not equivalent.

Prior to 2020 calibration, stream bank material erodibility was adjusted based on input from local hydrographers, Fitzroy Basin Association (FBA) staff, and local residents who provided expert opinion regarding the proportion of stream bank erosion along Fitzroy River. As a result, the Fitzroy River was given a stream bank material erodibility value of 75% indicating high stream bank erosion (this classification was not supported by aerial imagery analysis). Post 2020 calibration, stream bank material erodibility values were replaced with those derived from the aerial imagery analysis method.

At gauging stations, the estimated bankfull flow height was derived from a combination of techniques including (i) the inflection point of the discharge curve, (ii) gauging station cross-sectional profiles, and (iii) hydrographer estimates. The resulting bankfull flow height was used to extract both bankfull flows and ARIs from Hydstra (a time-series data management system). A variable ARI was applied to sub-catchments within gauge-contributing area where more than one bankfull ARI existed (based on hydrographer estimates).

To determine bankfull flows for sub-catchments/links between gauging stations the model was run with a range of ARIs. The model ARI which resulted in a near bankfull flow at the downstream gauging station was then applied to the sub-catchment/linklink upstream of the gauge (DNRME, 2020, pers. comm., April).

Post 2020 calibration the higher (rather than lower) range of the estimated bankfull flow heights derived from these techniques was used resulting in an increase in the estimated bankfull flows.

3.5. Murray Creek

Overview

The Murray Creek case study area consists of one Dynamic SedNet modelled link. The modelled link is shown spatially in Figure 110. As discussed in Section 2.5 there is significant variability in the geomorphic form of this case study area which includes a gently sloping tidal reach and steep bedrock controlled gorge sections.

Key input parameters used in the Dynamic SedNet model for each link within the Murray Creek case study area are shown in Table 15.

A comparison of some of the key modelled parameters to the hydro-geomorphic parameters identified in this study is provided below.

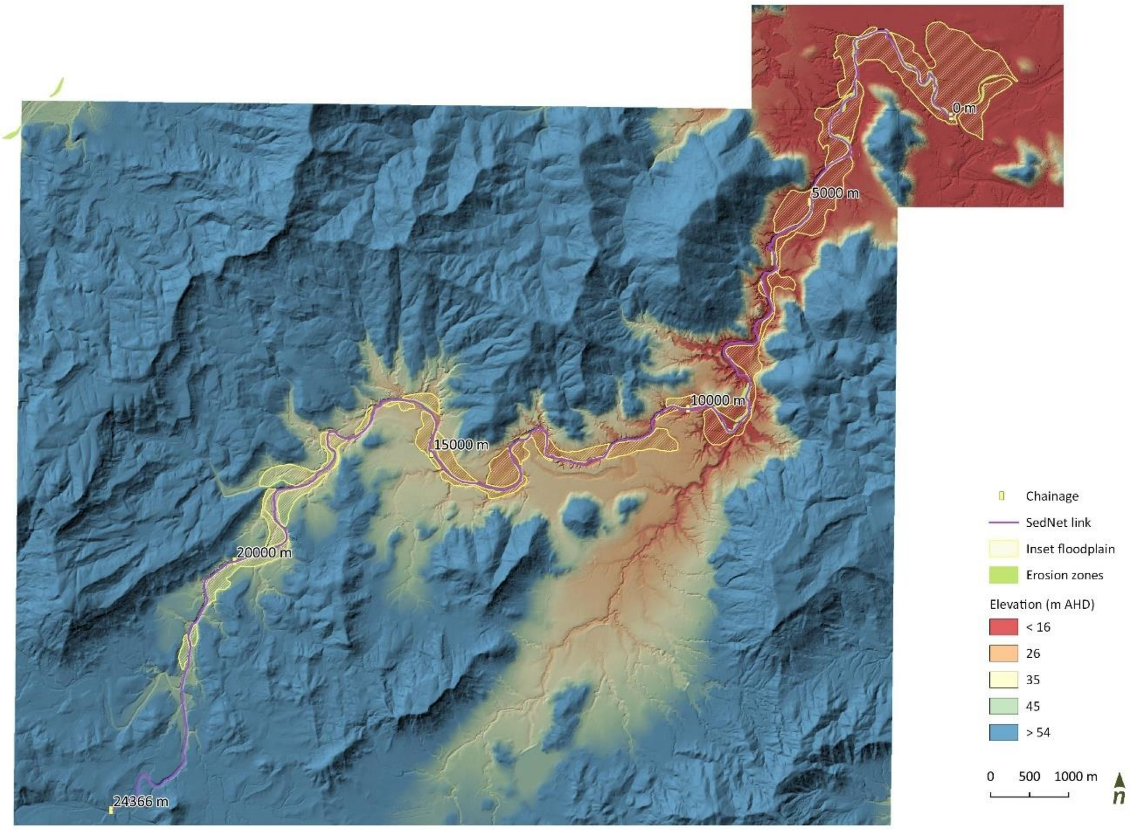

Figure 110: *The Murray Creek case study area with the Dynamic SedNet links*

Table 15: Dynamic SedNet Bank Erosion key input parameters – Murray Creek case study reach

Link (Sub-catchment)	Bank Full Flow (m^3/s)	Link Slope (m/m)	Link Length (m)	Channel Width (m)	Bank Height (m)	Riparian Vegetation Percentage (%)	Maximum Riparian Vegetation Effect. (%)	Stream bank material erodibility (%)	Bank Erosion Coeff.
SC #69	400	0.00225	22894	35	5.9	63	95	93	0.000035

Bankfull discharge

Bank full flow used in the Dynamic SedNet modelled link in the Murray Creek case study area is 400 m3/s. The HEC-RAS modelling identified the channel capacity in the upper reaches is approximately

600 m³/s however this increases substantially in the mid reaches to over 1,000 m³/s. In the lower reaches channel capacity is closer to 300 m³/s however this would also vary based on the tidal conditions. This indicates bankfull flow is generally higher than the SedNet modelled values.

Bank heights

The modelled bank heights for the Murray Creek case study area are shown in Figure 111. The SedNet bank height across the case study area is 5.9 m. The bank height derived from LiDAR data is generally between 4 - 6 m, however increases slightly between chainages 6,000 m and 8,000 m where there is more bedrock control and stream banks and floodplains are less well defined.

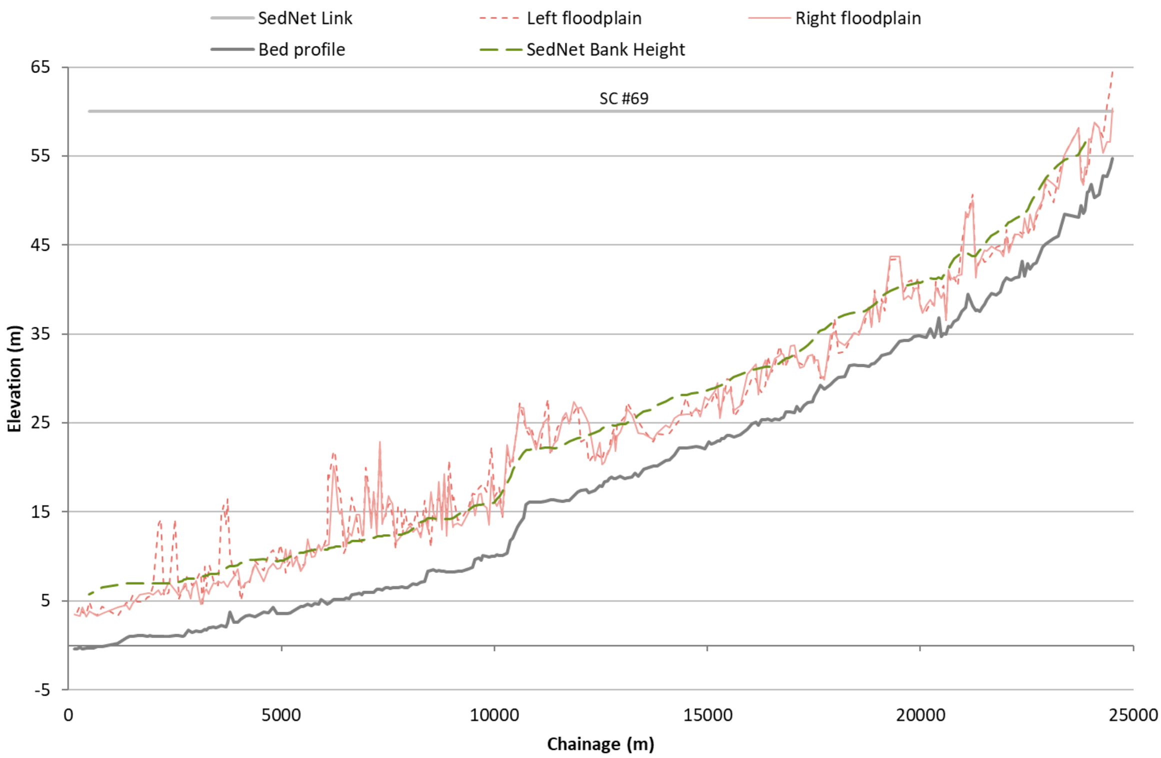

Figure 111: *Modelled link bank height and LiDAR derived bank height within the Murray Creek case study area*

Bed slope

The modelled bed slope for the Murray Creek case study area is shown in Figure 112. The Dynamic SedNet link has a slope of 0.00225 m/m, which aligns with the bed slope in some sections within the upper case study area. However, within the case study area there are large variations in bed slope which are not well represented by this average value.

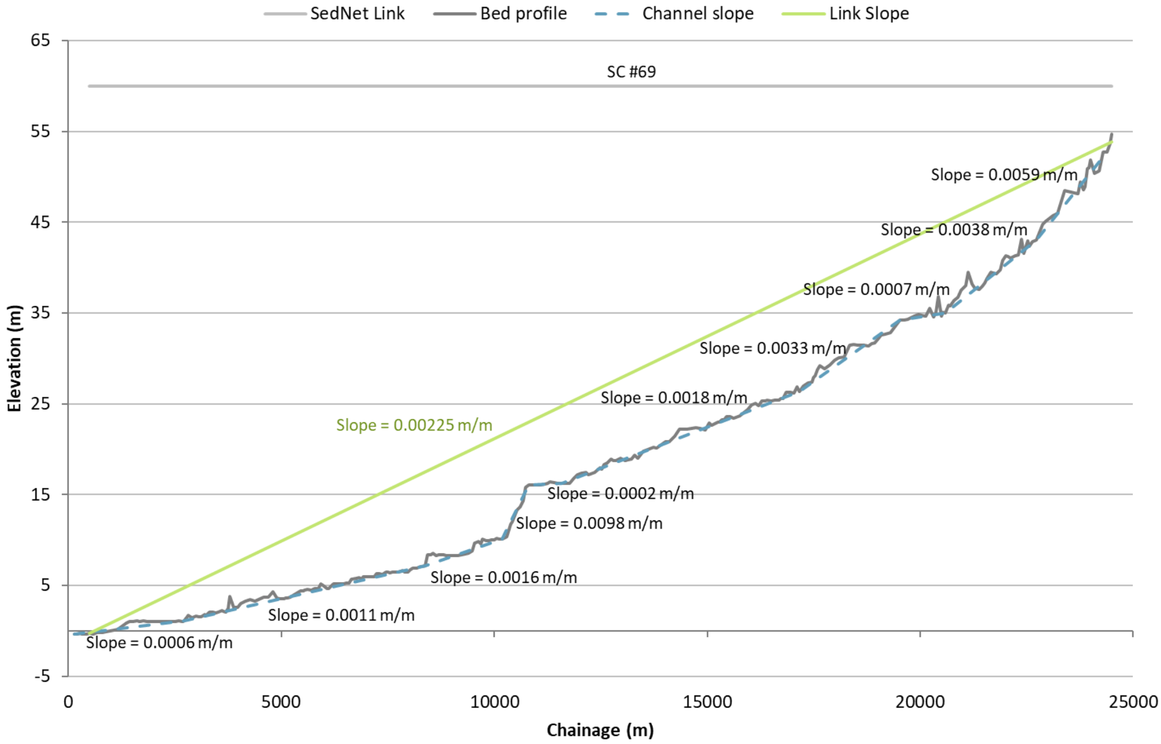

Figure 112: *Modelled link bed slope and LiDAR derived bed slope within the Murray Creek case study area*

Vegetation condition

Vegetation condition in the Murray Creek case study reach was assessed using the 2014 FPC layer as per the methodology outlined in the Mary River case study (Section 3.2). The stream order of the Murray Creek study area is 4, therefore a 10 m buffered was applied to the stream centreline.

The Murray Creek typical sections with key geomorphic units and SedNet riparian vegetation percent buffer zones are shown in Figure 113. In the areas assessed the 100 m buffer generally extends across the key geomorphic units which are generating sediment (i.e. the inset floodplain units). However across all three cross-sections shown in Figure 113 there are areas of exposed channel boundary which are not covered by the buffer area.

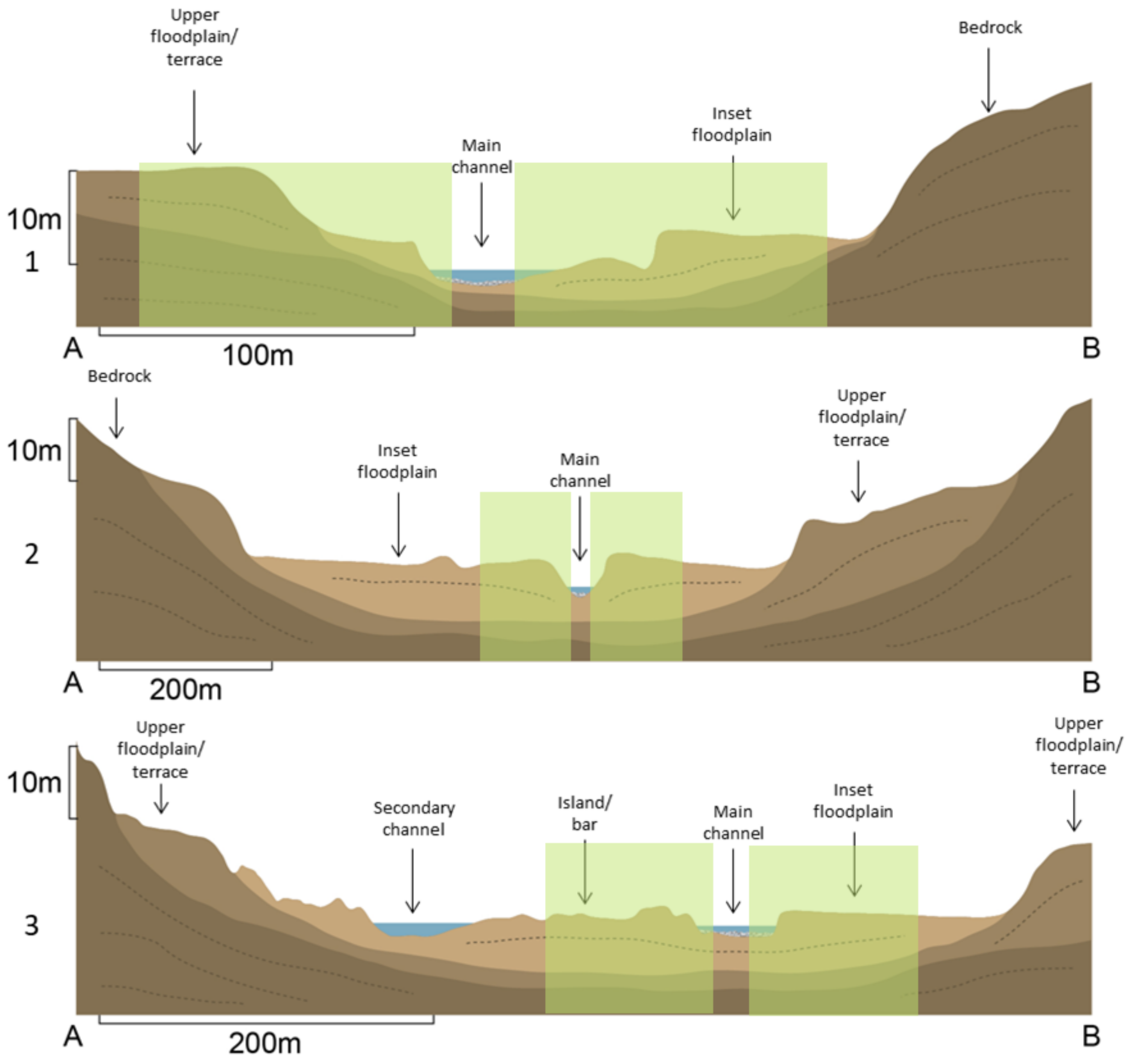

Figure 113: *The three typical sections in the Murray Creek case study area (shown in Figure 59, Figure 60 and Figure 61) with the key geomorphic units and 100 m riparian vegetation zones*

Stream bank material erodibility

The Dynamic SedNet stream bank material erodibility parameter is 93% in the Murray Creek case study area. Geotechnical data from the two boreholes within this area identified that the sediments range from sandy loam to clay. The loam soils are likely to have high stream bank material erodibility.

Sediment loss

The Dynamic SedNet modelled daily flows, MABE, and long-term average flows for each link were used to determine the volume of stream bank erosion in the Murray Creek case study area between 2009 and 2018. The modelled sediment loss (coarse and fine) between 2009 and 2018 was 176,848 m3 (Table 16) LiDAR analysis between 2009 and 2018 indicated that over 273,000 m3 of sediment was mobilised from major erosion zones within the case study reach (Table 16). Total sediment release from stream bank erosion is likely to be higher than these estimates.

The Dynamic SedNet sediment loss volumes are slightly less (35%) than sediment loss volumes derived from the LiDAR data.

Table 16: Comparison between Dynamic SedNet modelled and LiDAR derived sediment mobilisation volumes in the Murray Creek case study reach

Volume of sediment mobilised (m3)			Modelled percentage of actual (LiDAR) (%)
Link (Sub-catchment)	**SedNet (2009 – 2018)**	**LIDAR (DoD) (2009 – 2018)**	
SC #69	176,848	273,123	65%
Note: in 2018 Dynamic SedNet data was only available from January to June			

Calibration

A summary of calibration processes applied to the Murray Creek SedNet model were provided by DNRME catchment modellers. Based on information provided there has been no recent calibration bankfull flow or stream bank material erodibility.

3.6. O'Connell River

Overview

The O'Connell River case study area consists of three Dynamic SedNet modelled links. The three modelled links are shown spatially in Figure 114. The three links align relatively well with the geomorphic features and degree of channel entrenchment identified within this case study area and discussed within Section 2.6.

Key input parameters used in the Dynamic SedNet model for each link within the O'Connell River case study area are shown in Table 17. A comparison of some of the key modelled parameters to the hydro-geomorphic parameters identified in this study is provided below.

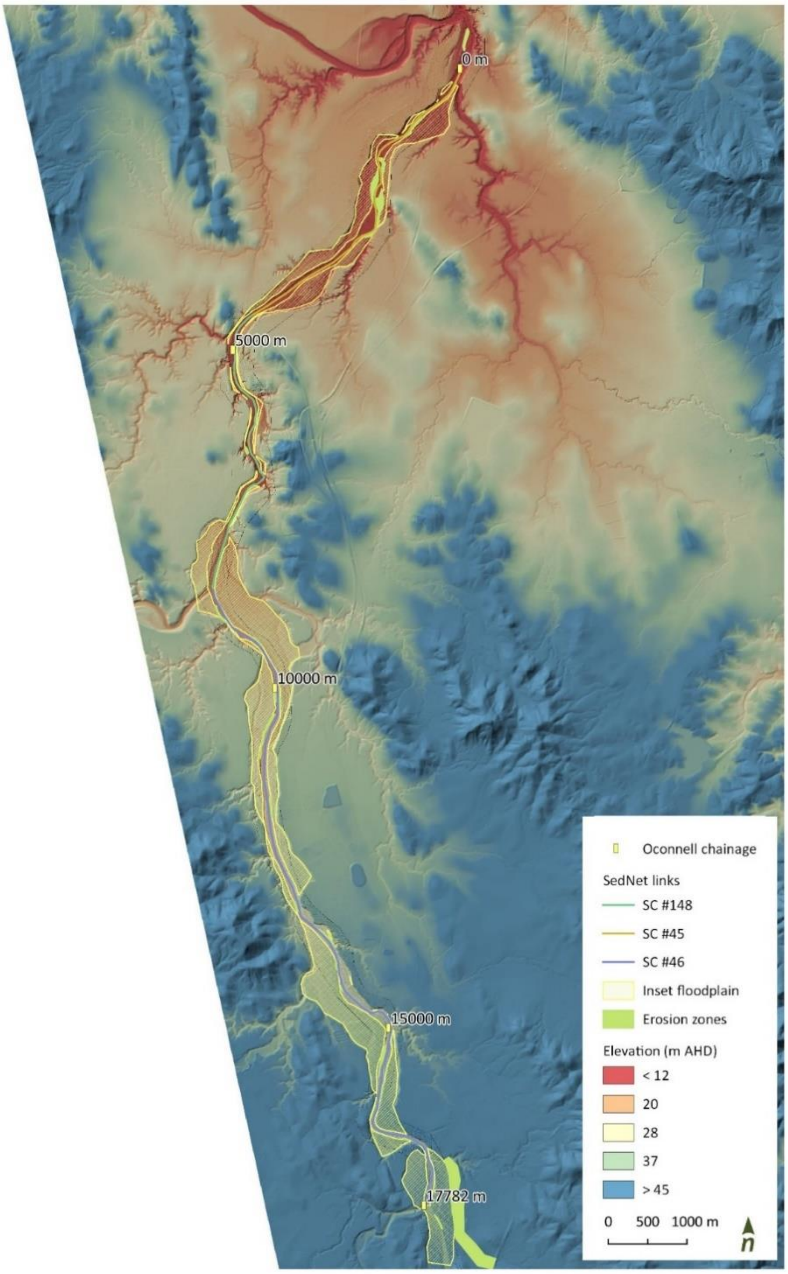

Figure 114: *The O'Connell River case study area with the Dynamic SedNet links*

Table 17: Dynamic SedNet Bank Erosion key input parameters – O'Connell River case study reach

Link (Sub-catchment)	Bank Full Flow (m^3/s)	Link Slope (m/m)	Link Length (m)	Channel Width (m)	Bank Height (m)	Riparian Vegetation Percentage (%)	Maximum Riparian Vegetation Effect. (%)	Stream bank material erodibility (%)	Bank Erosion Coeff.
SC #45	594	0.0017	4230	82	8.9	56	95	100	5.0E-05
SC #148	627	0.0008	3961	74	8.8	80	95	98	5.0E-05
SC #46	405	0.0019	9351	56	7.0	56	95	99	5.0E-05

Bankfull discharge

Bankfull flow used in the Dynamic SedNet modelled link in the O'Connell River case study area ranges between approximately 400 and 630 m3/s. The HEC-RAS modelling identified the channel capacity upstream of the Boundary Creek confluence (i.e. chainage 8,000 m) to be approximately 750 m^3/s (return period of less than 2 years). Within the confined section between chainage 5,000 m and 8,000 m the channel capacity exceeds 3,000 m^3/s (return period of greater than 30 years). Downstream of chainage 5,000 m the channel capacity is approximately 1,500 m^3/s (return period of 5 years). This indicates bankfull flow is higher than the Dynamic SedNet modelled values.

Bank heights

The modelled bank heights for the O'Connell River case study area are shown in Figure 115. The Dynamic SedNet bank heights across the case study area are between 7 m and 8.9 m. The inset floodplain units, where the majority of sediment loss is occurring from, typically have a height of 4-7 m - however there is significant variability.

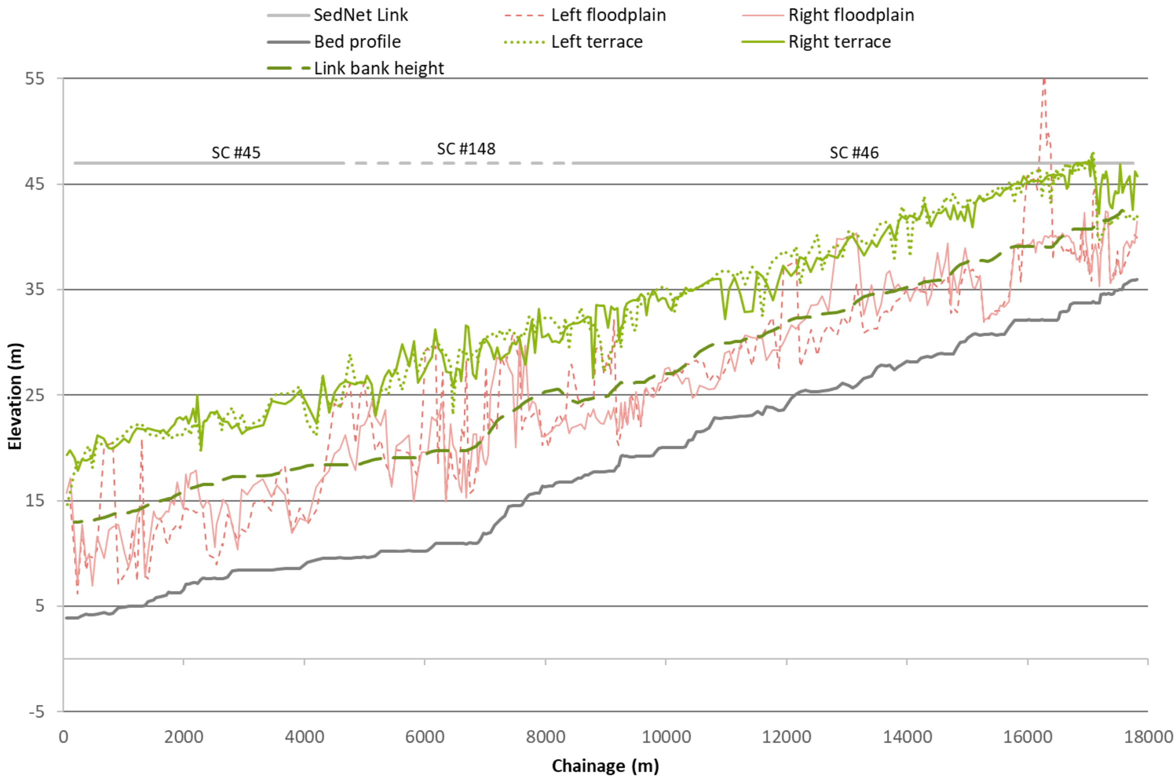

Figure 115: *Modelled link bank height and LiDAR derived bank height within the O'Connell River case study area*

Bed slope

The modelled bed slopes for the O'Connell River case study area are shown in Figure 116. Generally, the bed slopes align with the values determined from the LiDAR data. However, across the link for SC #148 the modelled link slope does not represent the major change in slope from 0.0008 m/m to 0.0046 m/m. These two slopes represent the gentlest sloping and steepest sloping sections of the case study area.

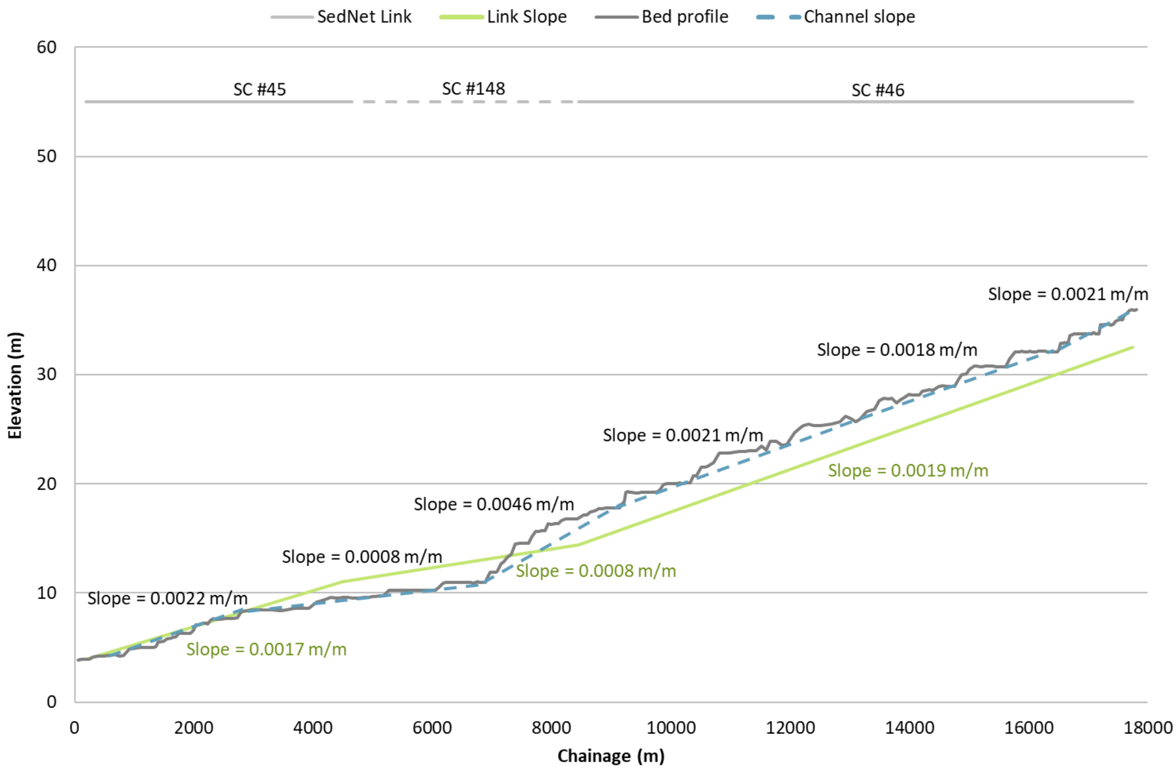

Figure 116: *Modelled link bed slope and LiDAR derived bed slope within the O'Connell River case study area*

Vegetation condition

Vegetation condition in the O'Connell River case study reach was assessed using the 2014 FPC layer as per the methodology outlined in the Mary River case study (Section 3.2). The stream order of the O'Connell River study area is 6, therefore a 15 m buffered was applied to the stream centreline.

The O'Connell River typical sections with key geomorphic units and Dynamic SedNet riparian vegetation percent buffer zones are shown in Figure 117. In the areas assessed the 100 m buffer generally extends across the key geomorphic units which are generating sediment (i.e. the inset floodplain units).

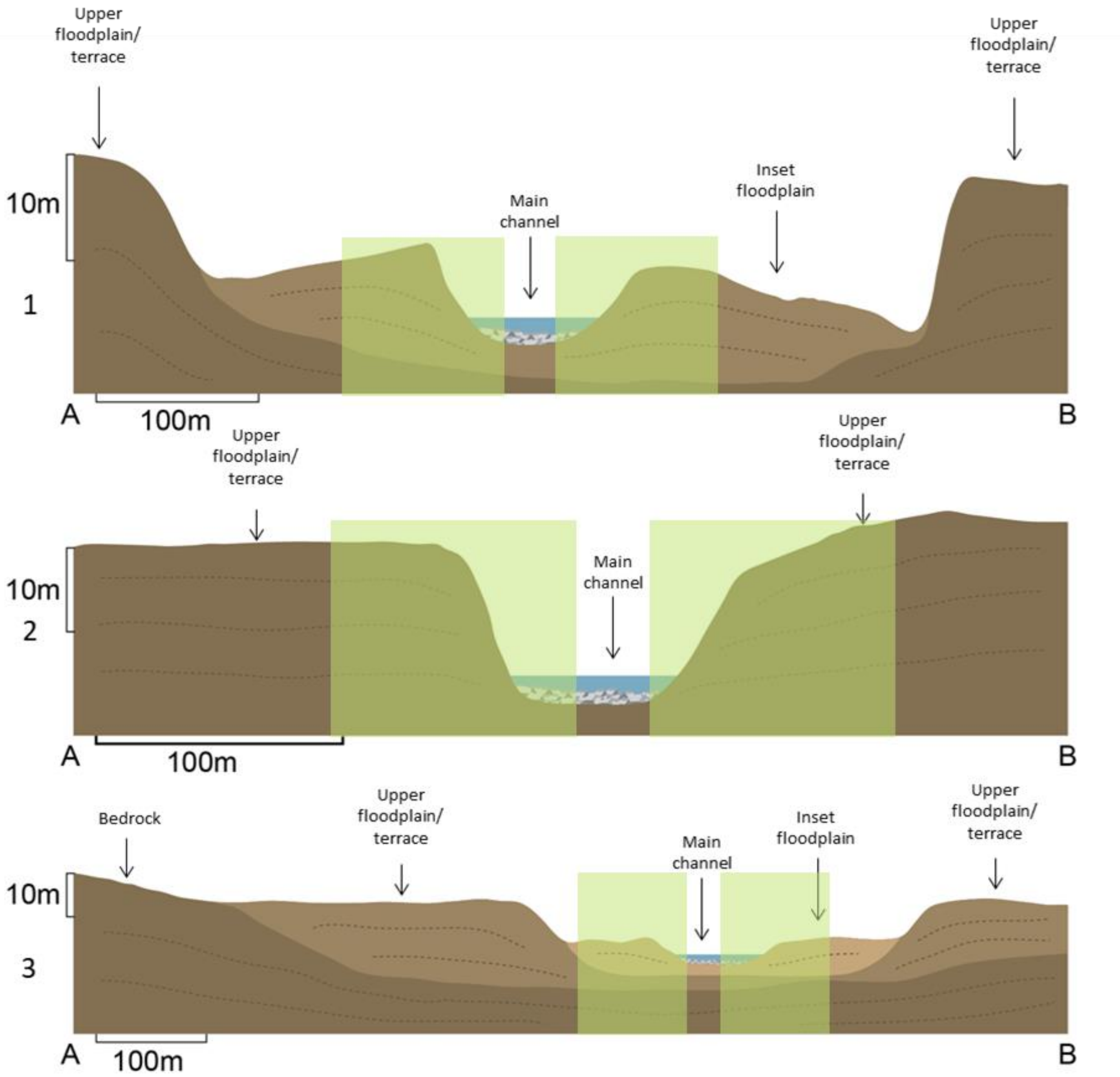

Figure 117: *The three typical sections in the O'Connell River case study area (shown in Figure 79 and Figure 80) with the key geomorphic units and 100 m riparian vegetation zones*

Stream bank material erodibility

The Dynamic SedNet stream bank material erodibility parameter ranges between 98% and 100% across the O'Connell River case study area . Geotechnical data from the three boreholes within this area identified that the sediments range from silty clay loam to loamy sand. No geotechnical data is available for the entrenched section of channel between the Boundary Creek confluence and Dingo Creek (i.e. between chainage 5,000 m and 8,000 m – SC #148). However, this link is likely to have much lower stream bank material erodibility than the other links due to the confining terraces and bedrock control.

Sediment loss

The Dynamic SedNet modelled daily flows, MABE, and long-term average flows for each link were used to determine the volume of stream bank erosion in the O'Connell River case study reach between 2009 and 2018. The modelled sediment loss (coarse and fine) between 2009 and 2018 was 217,464 m³ (Table 18).

LiDAR analysis between 2009 and 2018 indicated that over 279,200 m^3 of sediment was mobilised from major erosion zones within the case study area (Table 18). Total sediment release from stream bank erosion is likely to be higher than these estimates.

The Dynamic SedNet sediment loss volumes are slightly less (22%) than sediment loss volumes derived from the LiDAR data. At the link scale variations in the modelled estimates are greater for SC #46.

Table 18: Comparison between Dynamic SedNet modelled and LiDAR derived sediment mobilisation volumes in the O'Connell River case study reach

Volume of sediment mobilised (m3)			Modelled percentage of actual (LiDAR) (%)
Link (Sub-catchment)	**SedNet (2009 – 2018)**	**LIDAR (DoD) (2009 – 2018)**	
SC #45	82,456	175,652	47%
SC #148	17,820	19,085	93%
SC #46	117,188	84,466	139%
Total	**217,464**	**279,203**	**78%**
Note: in 2018 Dynamic SedNet data was only available from January to June			

Calibration

A summary of calibration processes applied to the O'Connell River SedNet model were provided by DNRME catchment modellers. The information indicated there has been no recent calibration of bankfull flow.

The Bank erosion coefficient for the O'Connell River links were calibrated against GBRCLMP loads estimates at O'Connell River at Caravan Park (end-of-system) site (DNRME, 2020, pers. comm., April). Previously the bank erosion coefficient for these reaches was calibrated against bank erosion estimates provided in the O'Connell River bank stability assessment Alluvium (2014). However, the bank erosion coefficient data provided by DNRME indicate a value of 0.000002 is adopted for all three links.

4. Summary and key findings

Dynamic SedNet is the primary mechanism for predicting stream bank erosion within the GBR catchments. The purpose of these models is to provide estimates of long term pollutant load reductions, however the model outputs are frequently also used as a source of information to assist in prioritising management interventions for stream bank management. This study has shown that using model outputs alone for this prioritisation might not achieve the perceived benefits.

The bank erosion equation used within Dynamic SedNet is an empirical, process-based model that has some key input variables and assumptions. These variables (key input variables shown in bold) and assumptions include:

- Bankfull total cross-sectional stream power is a key driver of stream bank erosion. This variable is determined by multiplying stream slope by bankfull discharge.
- The height of the 'bank' (i.e. erosion contributing feature) is directly proportional to the volume of sediment per unit of lateral bank retreat.
- The proportion of intact riparian vegetation and stream bank material erodibility will impact on the bank erodibility.

These assumptions are based on established geomorphic principles. However this study has identified several issues with both how these assumptions are applied, and the datasets used, within the Dynamic SedNet model used for stream bank erosion prediction in Reef Plan models. The key findings of this study are:

1. The case study assessment-identified erosion areas are significantly more prevalent when the channel is bound by certain geomorphic units (i.e. inset floodplains) and are often concentrated within small areas. Within the Dynamic SedNet bank erosion model, only parameters (i.e. bank height and stream bank material erodibility) for one geomorphic unit can be assigned. Given the length of modelled links an understanding of the type and prevalence of channel bounding geomorphic units within each link, and their relative erodibility, would greatly enhance stream bank erosion prediction in Reef Plan models.
2. An understanding of the type and prevalence of channel bounding geomorphic units within each link, and their relative erodibility, would assist in determining the bank height variable within Dynamic SedNet. As an example, within the Mary River case study area the bank height variable was closely aligned to the terrace height however the inset floodplain units are contributing the majority of the sediment.
3. The bankfull total cross-sectional stream power value used to calculate the Dynamic SedNet lateral retreat rate within the case studies assessed is often very inaccurate. The stream slope by bankfull discharge values often had very large variations from actual values. Within the Fitzroy River, and Raglan Creek models the Dynamic SedNet bed slope values are orders of magnitude different from the actual river slopes, and indicate that the Fitzroy catchment scale water quality model requires a thorough review of assigned stream bank erosion parameter values.
4. Overall, the Dynamic SedNet sediment loads are relatively good estimates of sediment loss at the case study scale (i.e. across all links assessed). The overall model performance is similar in case study areas with good parameterisation (i.e. the Mary River and O'Connell River) and case study areas with very poor parameterisation (i.e. Fitzroy River and Raglan Creek). However, at the link scale there is significantly higher variability. How the model is able to predict stream bank erosion results when there are significant errors in the key input parameters is uncertain. The fact that all case studies were located in the coastal fringes where there is generally better data availability for calibration may have assisted the model performance. If the monitoring data and calibration are the key reasons for the good model performance this indicates that the stream bank erosion model has been manipulated as an

empirical model for the purposes of predicting the broad distribution of stream bank erosion at sub-catchment scales across large river basins(see point below).

5. This study has identified that the process-based components of the model are not performing as intended at the link/sub-catchment scale in the five case studies assessed (i.e. with bankfull stream power driving erosion, and riparian vegetation and substrate erodibility resisting erosion). Despite the good predictive power of the model there were very large errors in the variables which drive the process-based component of the model in several case study areas. Given there are such large errors in some of the input parameters it is difficult to assess the process-based components of the model performance in the different river types assessed in this study.

6. No observable correlation between bankfull total cross-sectional stream power (or bankfull mean specific stream power) and channel erosion was identified within the five reach scale case studies assessed. Stream power is still likely a major driver of erosion, however the variability in the character and erodibility of the channel boundary sediments overwhelms other controls (i.e. stream power). This aligns with findings of Brooks et.al. (2014).

7. The assessment identified wet flow failures as being prevalent in both the Fitzroy River and Mary River case study areas. These failures are described in Thompson et. al 2013 and are associated with floodplains comprised of alternating fine and coarse sediment layers that control channel bank exfiltration on the recession limb of flood hydrographs. This erosion mechanism requires more variables than are currently included in the Dynamic SedNet stream bank erosion model to identify the sites susceptible to this process. This erosion mechanism can be a major source of sediment in certain river types.

8. Other erosion processes including avulsions and inset floodplain scour are also currently not specifically accounted for within the Dynamic SedNet model (although some of the key variables that drive these processes are within the model i.e. stream power).

9. The tidal reach of Raglan Creek is experiencing active channel erosion. The erosion processes within tidal reaches are often more complex than upstream reaches. Erosion is likely driven by entrainment of bank sediments due a combination of fluvial, tidal and wave action. Banks in tidal reaches are often highly erodible as bank vegetation does not establish across the entire tidal range. These complexities are currently not accounted for within the within the Dynamic SedNet model.

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