Mary River Rehabilitation Plan – Gympie Reach

May 2026

alluvium

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for [Mary River Catchment Coordinating Committee]

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1 Introduction

The Mary River Catchment Coordinating Committee (MRCCC) has engaged Alluvium Consulting (Alluvium) to undertake a geomorphic assessment and develop a restoration plan for a reach of the Mary River between the Six Mile Creek and Eel Creek confluences at Gympie. This reach of the Mary River is classified as the M10 Urban River reach, hereby referred to as the 'Urban Reach'. The assessment will determine the trajectory of the river in this region and identify works to rehabilitate the Urban Reach and achieve agreed management objectives for the system.

This study will also build on the existing "Mary River & Tributaries Rehabilitation Plan" (MRTRP) completed by the Mary River Catchment Coordinating Committee (MRCCC) in 2001. The Rehabilitation Plan separated the Mary River into fluvial geomorphic units, which the Urban Reach was classified as 'M10'. The MRTRP outlines specific problems, appropriate recovery strategies and measurable objectives for the MRTRP M10 section of the river. This information was updated in 2026 to reflect current threats to river health in the Urban Reach. The desired outcomes were reviewed from the original MRTRP detailing progress made from on-ground works between 2001 and 2026. New threats from expanding urban development and climate change have been identified and prioritised.

1.1 Study overview and objectives

MRCCC seek a restoration plan, which has the support of a range of stakeholders including Gympie Regional Council, Gympie District Landcare and the local community.

MRCCC has engaged Alluvium to assess the geomorphic condition and trajectory of the study area and develop the restoration plan. The study aims to:

1. Identify historic and contemporary channel change processes
2. Identify features within the alluvial system that will resist lateral and vertical adjustments (i.e. vegetation, bedrock outcrops, valley margins, terraces etc.)
3. Predict the likelihood and location of future channel change
4. Develop management objectives which will guide the development of the rehabilitation plan
5. Develop a restoration plan and estimate costs of implementation

Channel erosion is caused by fluvial geomorphic processes. Understanding these geomorphic processes and their likely future trajectory is important in delivering a cost-effective stream management program. Developing a process of understanding can identify where ongoing channel change is likely, and the scale of intervention required to provide an effective management response.

A 'whole of catchment' approach is required to effectively manage geomorphic processes. Such an approach involves land and water policy and practice, incorporating improved land use and land management practices, as well as effective waterway management activities. The focus of this study is the fluvial processes within the M10 section of the main stem of the Mary River—i.e. the processes that occur in or adjacent to the river channel. Consideration of the processes in tributaries and the broader land management activities are beyond the scope of this study, but may need to be considered by MRCCC and other stakeholders in the long-term management of the system.

1.2 Study area

The Mary River rises in the Conondale Range near Maleny and flows in a northerly direction, through Gympie, and discharges into the Great Sandy Strait near K'gari (Fraser Island). The catchment area is approximately 9,595 km^2, with an approximate stream length of 300 km. The study area is located in the mid reaches of the Mary River at Gympie (Figure 1). The subject area of the river extends approximately 11 km between the Six Mile Creek confluence at the upstream extent to the Eel Creek confluence at the downstream extent.

The study area corresponds to the M10 section of the Mary River (Urban Reach) in the previously developed Mary River and Tributaries Rehabilitation Plan (MRTRP). The M10 is identified as containing important Mary River turtle nesting habitat and habitat for the endangered Mary River Cod and Australian lungfish. The receiving waters of the Mary River include the World Heritage Area listed Great Barrier Reef lagoon and K'gari (Fraser Island), the Internationally recognised RAMSAR Great Sandy Strait RAMSAR Wetland, the Queensland Great Sandy Marine Park under the *Marine Parks Act 2024*, and Declared Fish Habitat Areas under the *Fisheries Act 1994*.

The Mary River in this region has undergone significant land use pressures since European settlement. Riparian and floodplain vegetation was predominately cleared, including historic extraction of the alluvial sands and gravels that dominated the channel and floodplain substrate.

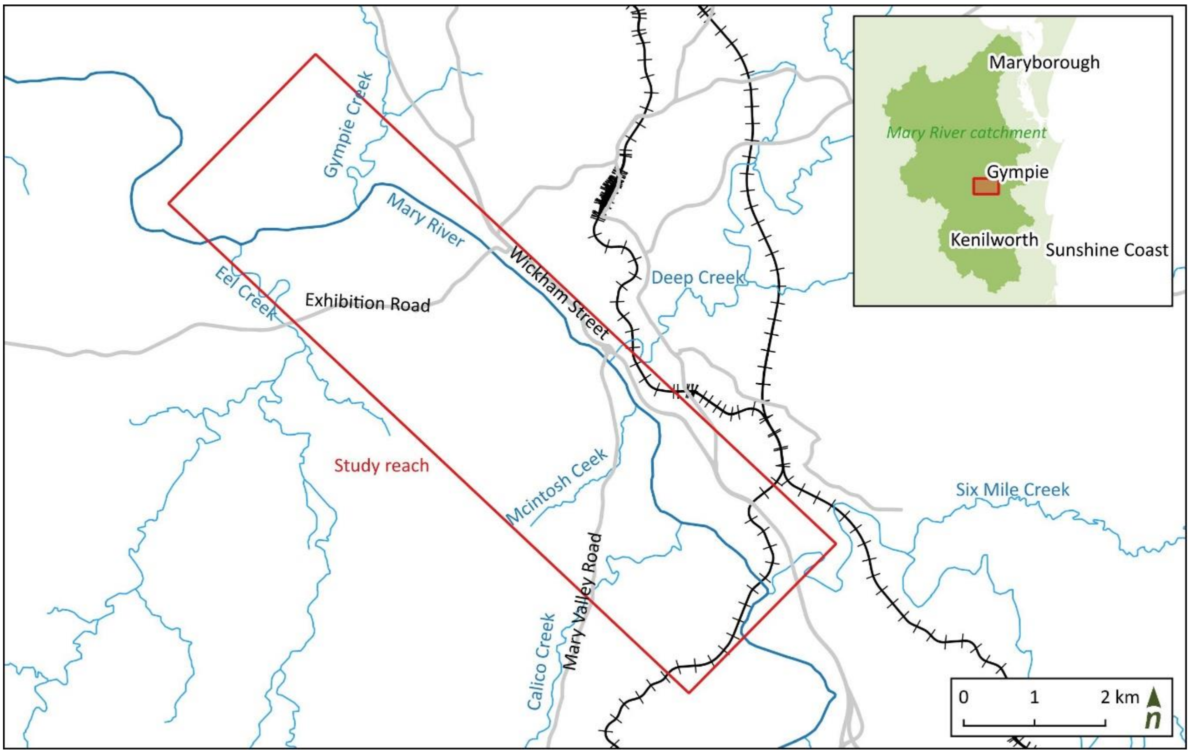


Figure 1. *Study area location map*

1.3 Report structure

The study is presented in a number of sections in this report:

- **Section 2** provides an overview of the study area
- **Section 3** provides an overview of the hydro-geomorphic assessments undertaken
- **Section 4** details the historical processes, existing condition and system trajectory
- **Section 5** details the stream rehabilitation plan, including setting of management objectives for the study area, the determination of erosion potential and recommended works

2 Overview of study area

2.1 Landscape setting

Within the study reach the Mary River is a sand/gravel bed stream with a low sinuosity planform that flows through a partly confined setting. Within a partly confined setting the lateral adjustment of the river is limited by the bedrock along the valley margins. Within the valley margins floodplains are formed in some locations as a result of both lateral and vertical accretion. In many locations terraces are perched above the active floodplains. These terraces are former floodplains abandoned due to changes in base level or shifts in sediment and flow regimes, which resulted in down-cutting. This results in an entrenched compound channel morphology (often called macro-channels) whereby the channel (stream bed) abuts either:

- In-channel bars and benches (1 – 5 m above bed level)
- Alluvial floodplains (5 – 15 m above bed level)
- Terraces (greater than 15 m above bed level)

Each different unit can have a different composition and as a result a different erodibility. While these larger macro-channels are set within broad alluvial floodplains, there is typically minimal lateral planform adjustment of the main channel, as the main channel is 'confined' by the more resistant terrace. A conceptual diagram of a typical valley cross-section with each different major geomorphic unit is shown in Figure 2.

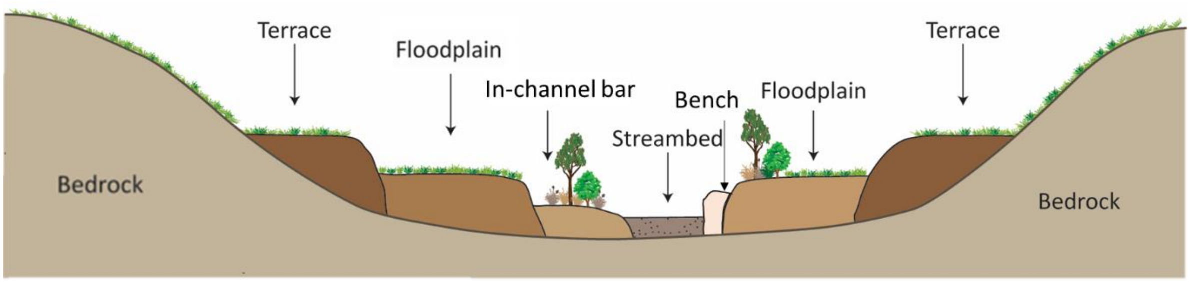


Figure 2. *Conceptual diagram of a typical valley cross-section within the Mary River study area showing bedrock valley margins, terraces, floodplain and stream bed*

An assessment of terrain, channel form and bank morphology was undertaken using 2024 LiDAR data. A terrain assessment provided an understanding to the types of geomorphic units within the reach and the degree of valley confinement, which helps inform where channel instabilities/adjustments are more likely to occur. A Relative Elevation Model (REM) was developed using 2024 LiDAR data to help discern geomorphic units and lateral bedrock or terrace controls, which may limit channel erosion and aid in the assessment of erosion trajectory (Figure 3). The REM, also known as a 'Height Above River' raster, was created by de-trending the baseline elevation of the Digital Elevation Model (DEM) to follow the water surface of the river, rather than having a constant baseline elevation of 0 m (AHD). This allows for better visualisation of channel and floodplain features such as channel planform and the extent of inset geomorphic units, which may be more susceptible to erosion, as well as lateral bedrock/terrace controls, which may limit channel erosion.

The REM highlights that the low flow channel is typically confined on one side in any location by the terrace or occasional bedrock valley margins. There is typically more extensive floodplain development on the southern side of the channel, particularly downstream of the Jones Hill Weir where the active floodplain sits between 8 to 10 m above the channel and is up to 300 m wide in some locations. Much of the northern side of the channel is constrained by the terrace margins however there are some discontinuous floodplains between 50 – 150 m in width. The key geomorphic units across the study reach have been delineated and are presented below in Figure 4.

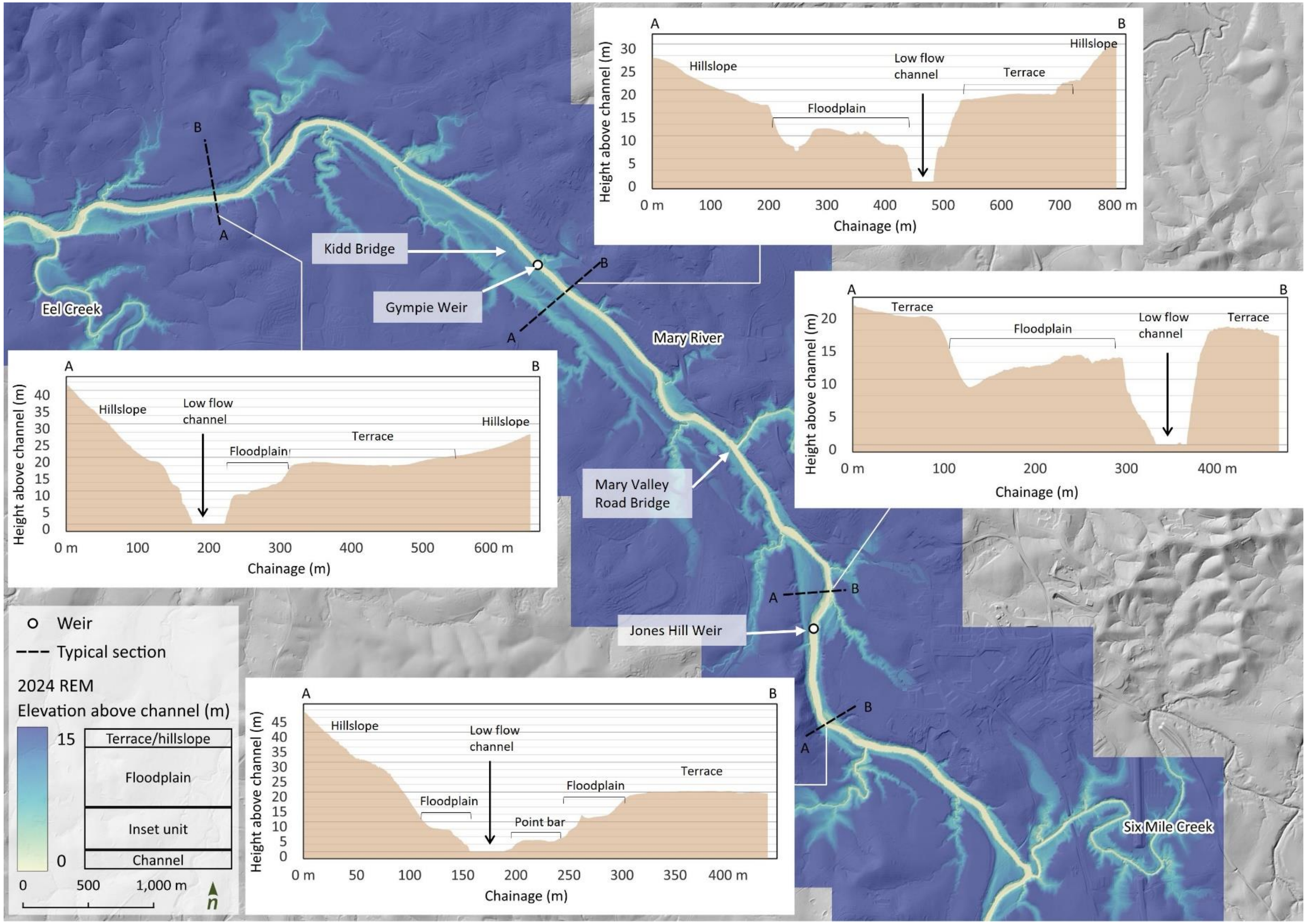


Figure 3. *Relative Elevation Model (REM) highlighting the key geomorphic units in the study reach*

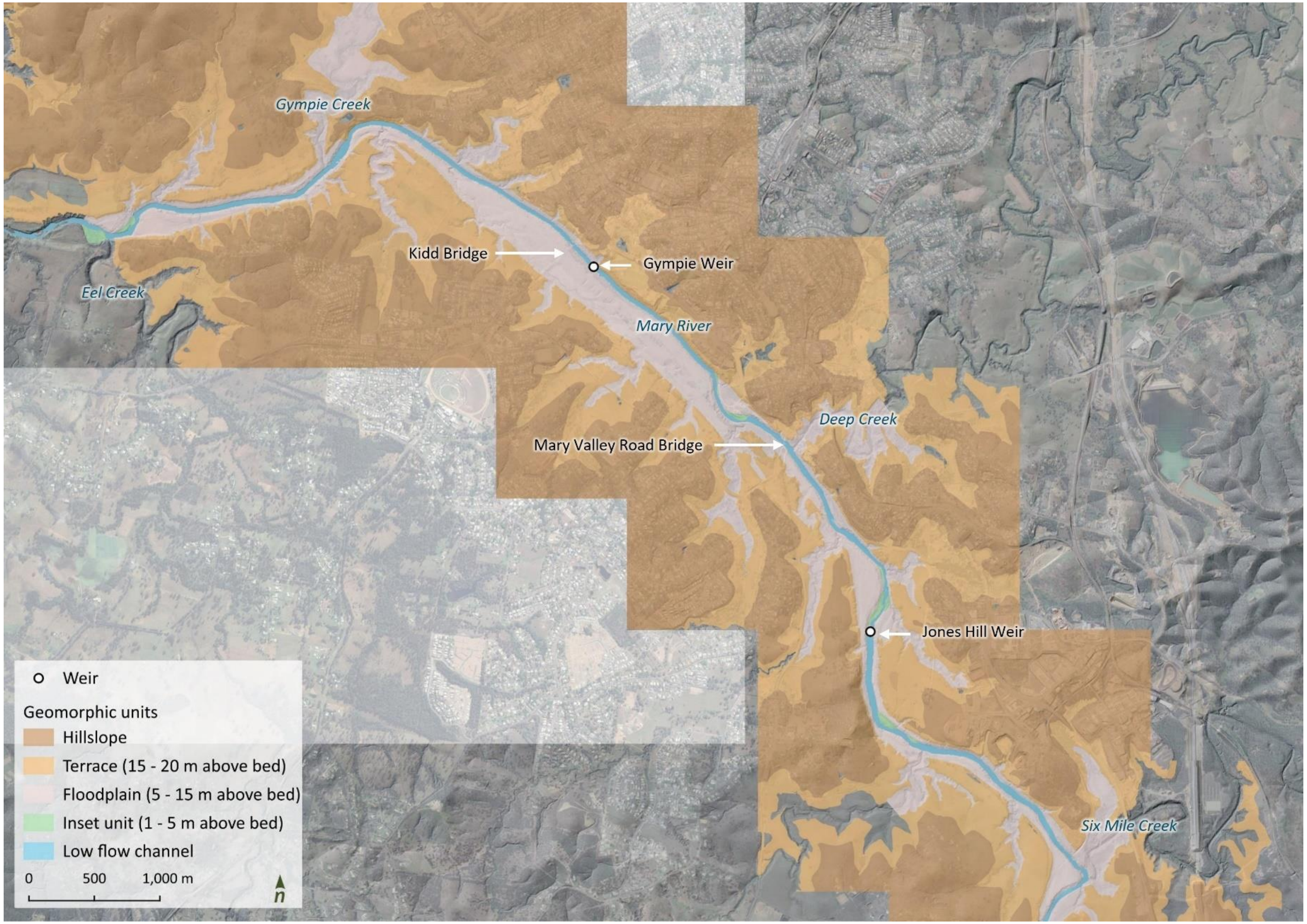


Figure 4. *Geomorphic units adjacent to the Mary River within the study area*

2.2 Geology

The detailed surficial geology across the study reach is presented below in Figure 5. Through the study reach the Mary River dissects a mix of Permian volcanics (eg Highbury Volcanics, Rammutt Formation and Tamaree Formation) and variable meta-sedimentary and sedimentary lithologies (mudstones, sandstones, siltstones, shales and conglomerates) which introduce a variable mix of sands, gravels and clays to the riverbed load. The active floodplain typically comprises of Holocene alluvium comprised of gravels, sands, silts and clays. The upper floodplain/terraces are predominately Pleistocene alluvium comprised of more consolidated clays, silts and sands.

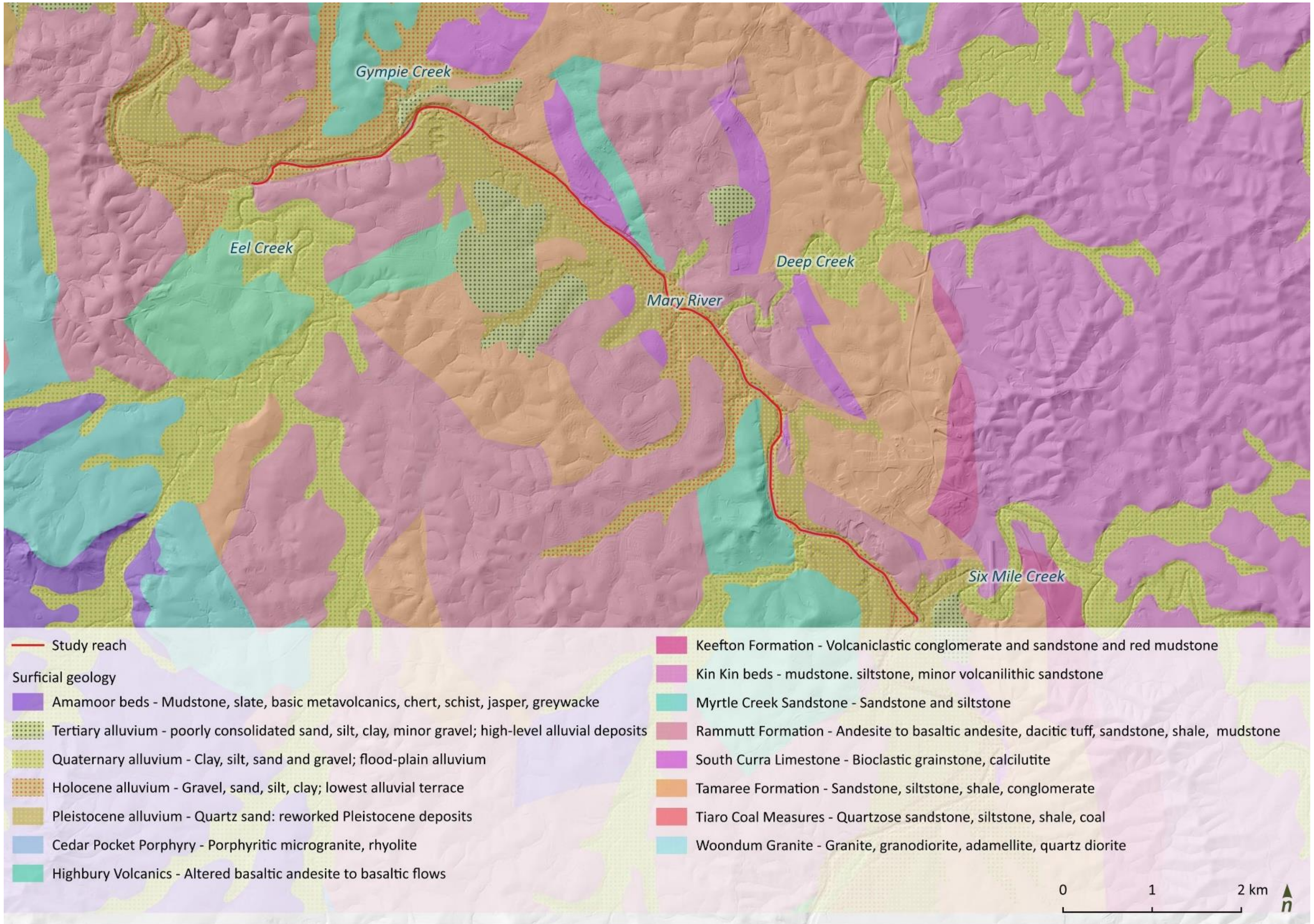


Figure 5. *Detailed surficial geology of the study area*

2.3 Post-European impacts

Prior to European settlement open eucalyptus forests are likely to have grown on the floodplains in the study area. The arrival of European settlers in the 1840s led to significant land use changes. By the late 1840s the Mary River catchment was under pastoral land use, dominated by cattle and sheep (Brizga, 2001).

The morphology of an alluvial stream is primarily defined by its flow regime, sediment supply and riparian vegetation condition. When these factors remain unchanged, a relatively stable stream exists where there is limited adjustment in channel geometry (erosion). The stream is said to be at or near an equilibrium state. In reality due to long and short term variability in climate (rainfall) and sea level, alluvial streams are rarely in a pure equilibrium state as these processes are nearly always adjusting. The term dynamic equilibrium has been used to define such systems that are constantly changing to variable inputs, but whose changes remain within a limited range of variability.

However, when there are sudden changes or disturbances to these inputs they can lead to large changes in channel morphology, and potentially destabilise or move the system towards a new equilibrium state. These processes are further described in Appendix 1.

Within the study area there has been major changes to all three of the primary inputs that can impact on channel change i.e. stream flow, sediment supply and decreased bank strength. Catchment and riparian vegetation has been largely cleared which has increased runoff and hillslope sediment supply and decreased the strength of bed and banks. Unrestricted stock access to the river has further destabilised the system.

Alluvial mining of the channel has also been undertaken throughout the study area. In-channel mining can lead to a reduction in sediment supply and initiate channel incision, which can migrate upstream impacting on bed and bank stability.

The changes to the Mary River were summarised by the local historian Tutt (1994):

(The river has) "changed beyond comprehension to those who knew it even 50 years ago. It has changed from a deep clean stream guarded by shaded scrub (rainforest) which reached back to the ranges, or by the open forest flats saddle high in the native kangaroo grass, to sand clogged watercourse fighting for its life between eroded banks held by thinly scattered trees."

2.4 Land use

There is a variety of land uses within the study area (Figure 6). The mid portion of the study reach on the northern side of the channel includes the township of Gympie and there is a mix of land uses including services, residential/commercial infrastructure, reserves etc. The township infrastructure is largely located on the upper floodplain terraces and hillslopes. The downstream and upstream extents of the study reach are primarily utilised for agricultural production such as grazing and intensive animal production.

The floodplains on the southern side of the channel are primarily used for grazing with a small patch of nature conservation on the hillslope immediately upstream of the Jones Hill Weir.

In the Gympie reach (Urban Reach) of the Mary River, significant historic sand and gravel extraction occurred between the early 1980's and ceased in the late 1980's. Of note, gold mining occurred in the Urban Reach between the 1890's and 1910 approximately.

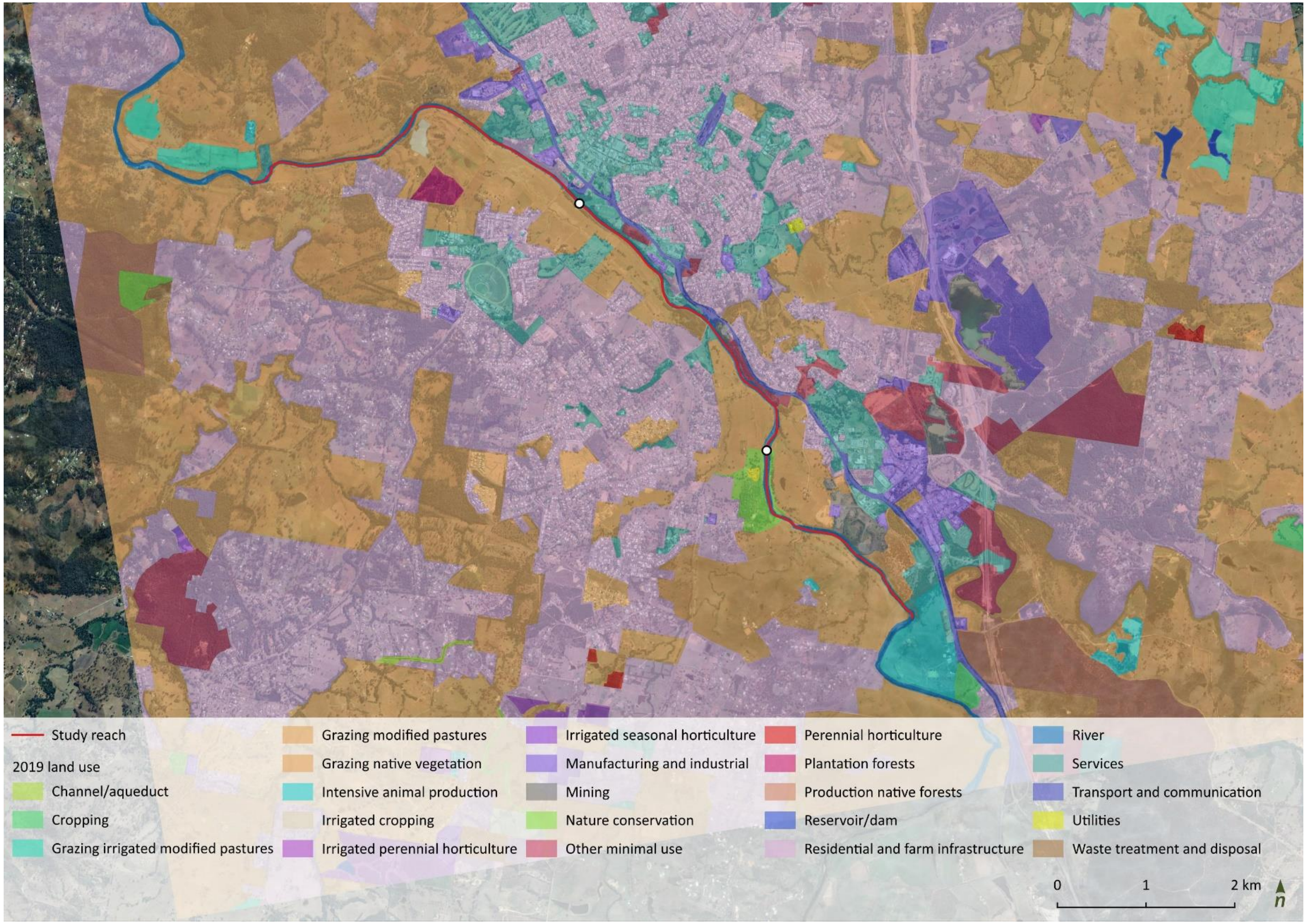


Figure 6. *2019 land use surrounding the study reach.*

2.5 Riparian vegetation

Riparian vegetation can be defined as the land that adjoins, directly influences or is influenced by a river or stream. Since European settlement, riparian vegetation in Australia and within the study area has been substantially degraded. Soils in riparian zones are often the most productive in a catchment and riparian vegetation has historically been cleared for agriculture and grazing on the floodplain. In addition flooding was a concern for many communities and riparian vegetation was perceived to exacerbate floods resulting in the widespread removal of riparian vegetation in many systems across Australia.

It is now generally accepted by waterway scientists, practitioners, and policy makers that high quality, structurally diverse riparian vegetation is important for channel stability and maintaining water quality. Riparian vegetation can improve water quality by reducing pollutants in runoff from adjacent floodplains. Furthermore, riparian vegetation provides geomorphic stability, which reduces the volume of sediment export, which also has a water quality benefit by limiting the mobilisation of bed and bank sediment and their associated nutrients.

The existing Regional Ecosystem (RE) has been mapped across the study reach (Figure 8). The riparian zones within the study area are largely mapped as *Eucalyptus tereticornis* +/- *Eucalyptus siderophloia*, *Corymbia intermedia* open forest on alluvial floodplains (Regional Ecosystem 12.3.11. In the lower reach around the Eel Creek confluence there are patches of simple notophyll fringing forest usually dominated by *Waterhousea floribunda* (Regional Ecosystem 12.3.17) – the Critically Endangered Subtropical Lowland Rainforest threatened ecological community. It should be noted that while these are the mapped ecosystems, there are large portions of the riparian zone, particularly on the southern side of the channel that have limited or no existing riparian vegetation. These riparian communities consist of a range of structural classes including instream vegetation, stream bank ground covers, shrub species and small to large trees. As discussed in Appendix 1, all of these structural classes serve a purpose in the protection of stream banks against erosional channel change. Protection of stream banks against erosion requires a suite of vegetation that includes all these structural elements.

Riparian vegetation within the study area is under threat from weeds, including the vine weeds Cats Claw Vine and Madeira Vine, and Chinese Elm. These infestations are predominately located on the northern side of the channel. The riparian zone, on the southern side in particular, is also under ongoing threat from cattle grazing which can contribute to riparian vegetation degradation and sub-aerial erosion. A map highlighting the known infestations of vine weeds and Chinese Elm is presented below in Figure 7.

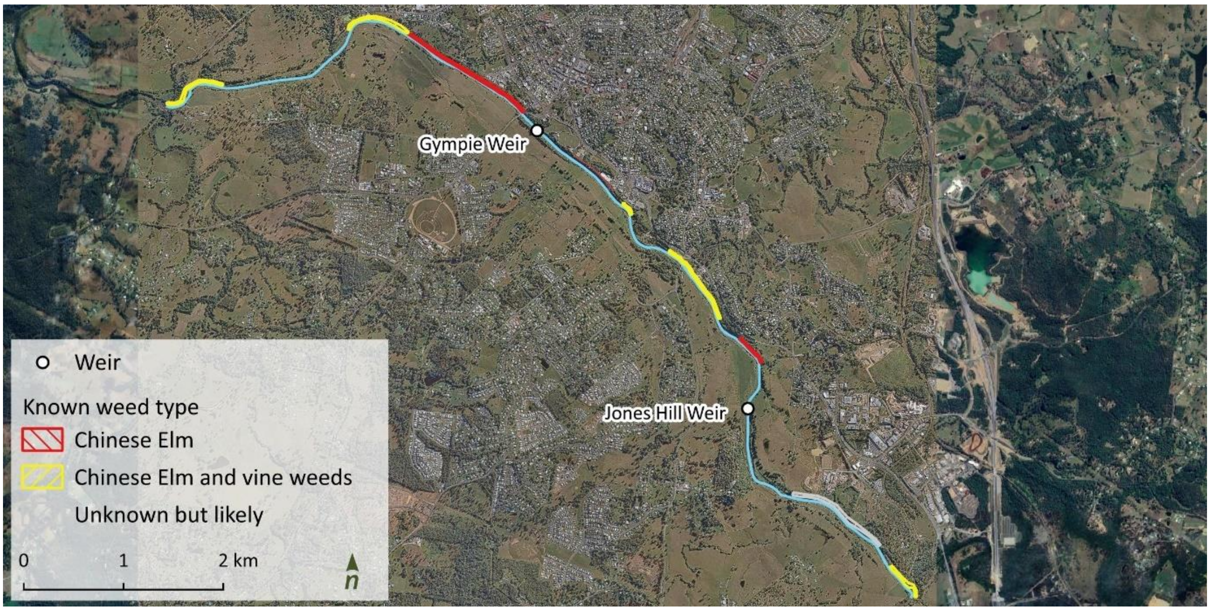


Figure 7. *Known weed presence across the study reach*

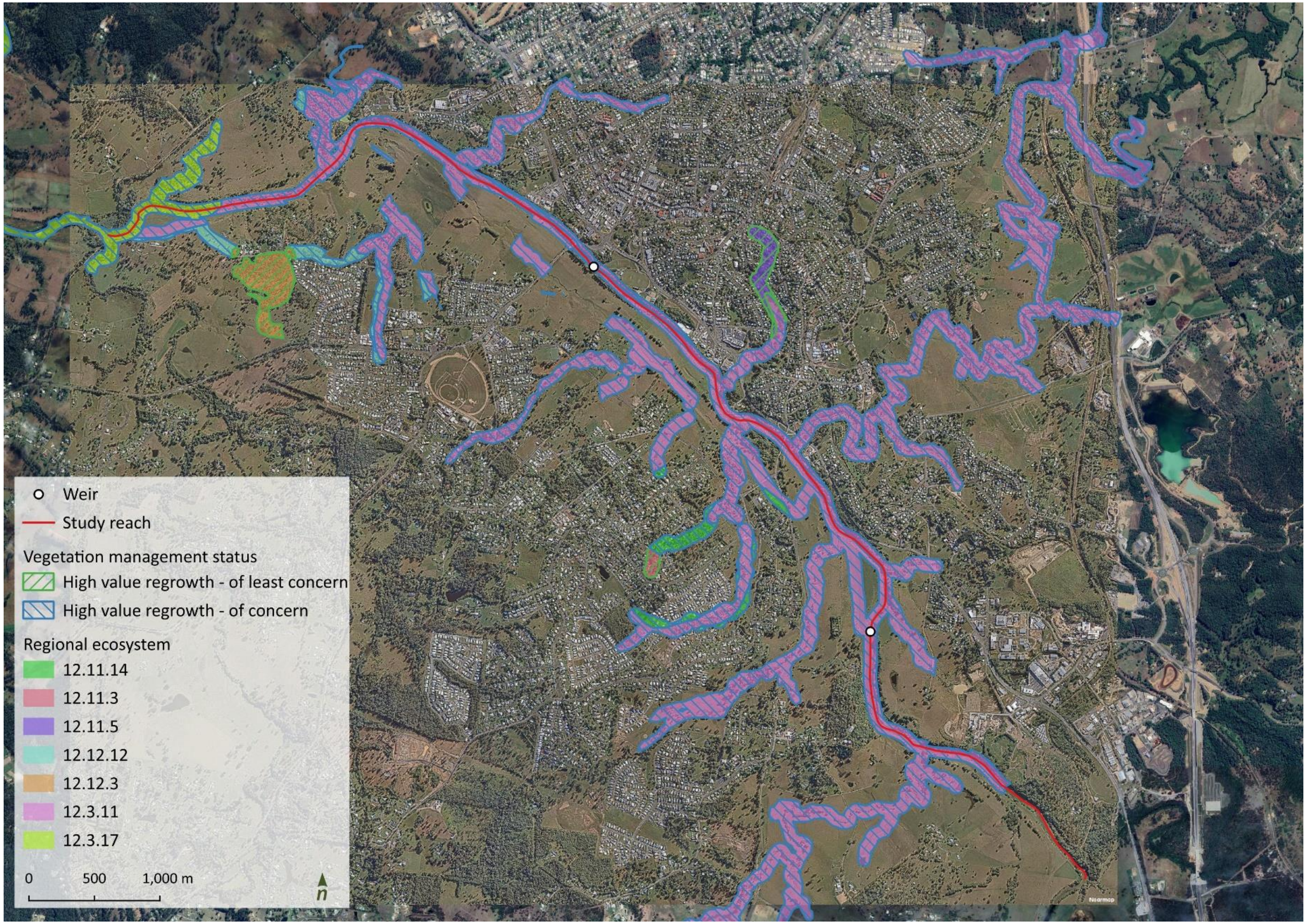


Figure 8. *Remnant vegetation mapping within the study reach*

2.6 Previous works

The Mary River and Tributaries Rehabilitation Plan (MRTRP) was developed by the MRCCC in 2001. Using a Riverstyles™ approach the Plan identified rehabilitation activities that were in line with stakeholder objectives. The MRTRP prioritised actions based on the theory that the protection of natural assets is more cost effective than rehabilitating highly degraded reaches. The M10 area within the study reach was categorised as requiring significant investment required to encourage natural recovery. Stabilisation works were recommended starting in areas with high visibility or next to good remnant patches of vegetation.

There are several publicly owned properties within the reach that are managed by Gympie Regional Council; and these are the areas that have had the most input in terms of rehabilitation works over the last 25 to 30 years. Tree plantings, weed control and ongoing revegetation, by Gympie Regional Council, Gympie District Landcare, community members and MRCCC funded projects, has seen vegetation condition and bank stability improve on the northern bank of the river where it flows through the Gympie CBD. This area is now a well-used community recreation area with a walking trail and picnic areas throughout.

3 Hydro-geomorphic assessment

This section provides an overview of some of the reach-wide assessments of processes within the MRTRP M10 Urban Reach study area. The overview covers historical channel change and changes in recent flood events, bed grade assessment and stream power assessments. For discussion and analysis purposes, the M10 study area has been delineated into three Sub-reaches. The Sub-reach extents are shown in Figure 9 and include:

- Sub-reach 1 'Widgee Crossing reach'- is located at the downstream extent of the study reach between the Gympie Weir and the Eel Creek confluence
- Sub-reach 2 'CBD reach' – is located mid study reach adjacent to the Gympie CBD between the Gympie Weir and Jones Hill Weir
- Sub-reach 3 'Jones Hill reach' – is located at the upstream extent of the study reach between the Jones Hill Weir and the Six Mile Creek confluence

The analysis, assessment and interpretation for each sub-reach is provided in Sections 3 & 4.

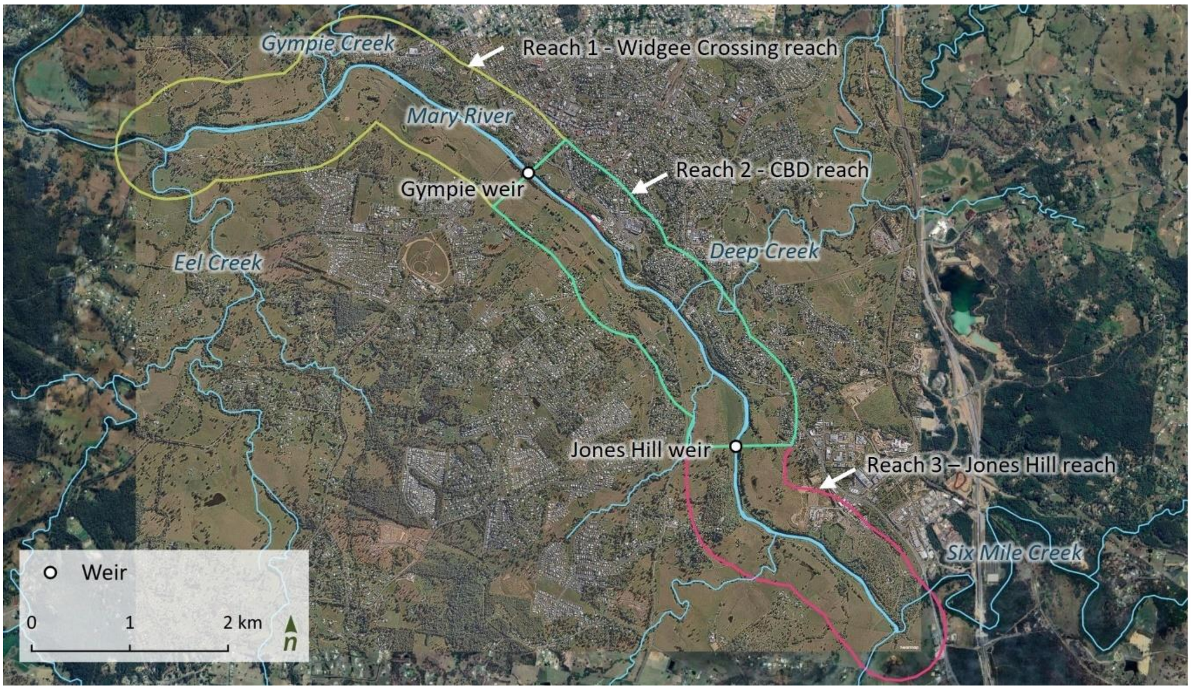


Figure 9. *Sub-reach locations across the study area*

3.1 Temporal aerial imagery analysis

Aerial imagery between 1954 and 2025 was used to assess the historical channel change (see Figure 10, Figure 11 and Figure 12). The analysis of historical aerial photos enabled long-term changes in vegetation condition, channel width and planform to be assessed. Understanding historical rates of change can assist in predicting the future trajectory of the system.

The key observations from the temporal aerial imagery analysis include:

- No significant planform adjustment of the macro-channel boundary – channel adjustment limited to floodplains and inset units within the macro-channel

- Sub-reach 1 – Widgee Crossing reach
    - Channel widening of up to 15 m, and isolated meander migration of up to 30 m in the lower portion of the reach
    - No significant channel adjustment through the upper portion of reach
    - Increase in riparian vegetation along the northern banks
    - Limited riparian vegetation across the southern banks in both 1954 and 2025
    - Widespread urbanisation of adjacent terraces and hillslopes on the northern side of the channel at the upper extent of the reach

- Sub-reach 2 – CBD reach
    - Channel widening of up to 10 m across the reach
    - Meander migration through floodplains and inset units in three locations – retreat of up to 45 m
    - Channel straightening immediately downstream of Jones Hill Weir
    - Significant increase in riparian vegetation along the northern banks and isolated section on the southern banks immediately downstream of Normanby Bridge
    - Generally limited riparian vegetation across the southern banks in both 1954 and 2025
    - Widespread urbanisation of adjacent terraces and hillslopes on the northern side of the channel

- Sub-reach 3 – Jones Hill reach
    - Channel widening of up to 20 m across the mid and upper portions of the reach
    - Significant increase in riparian vegetation along the northern banks at the upstream extent and the southern bank and hillslope immediately upstream of the Jones Hill Weir
    - Widespread urbanisation of adjacent terraces and hillslopes on the northern side of the channel

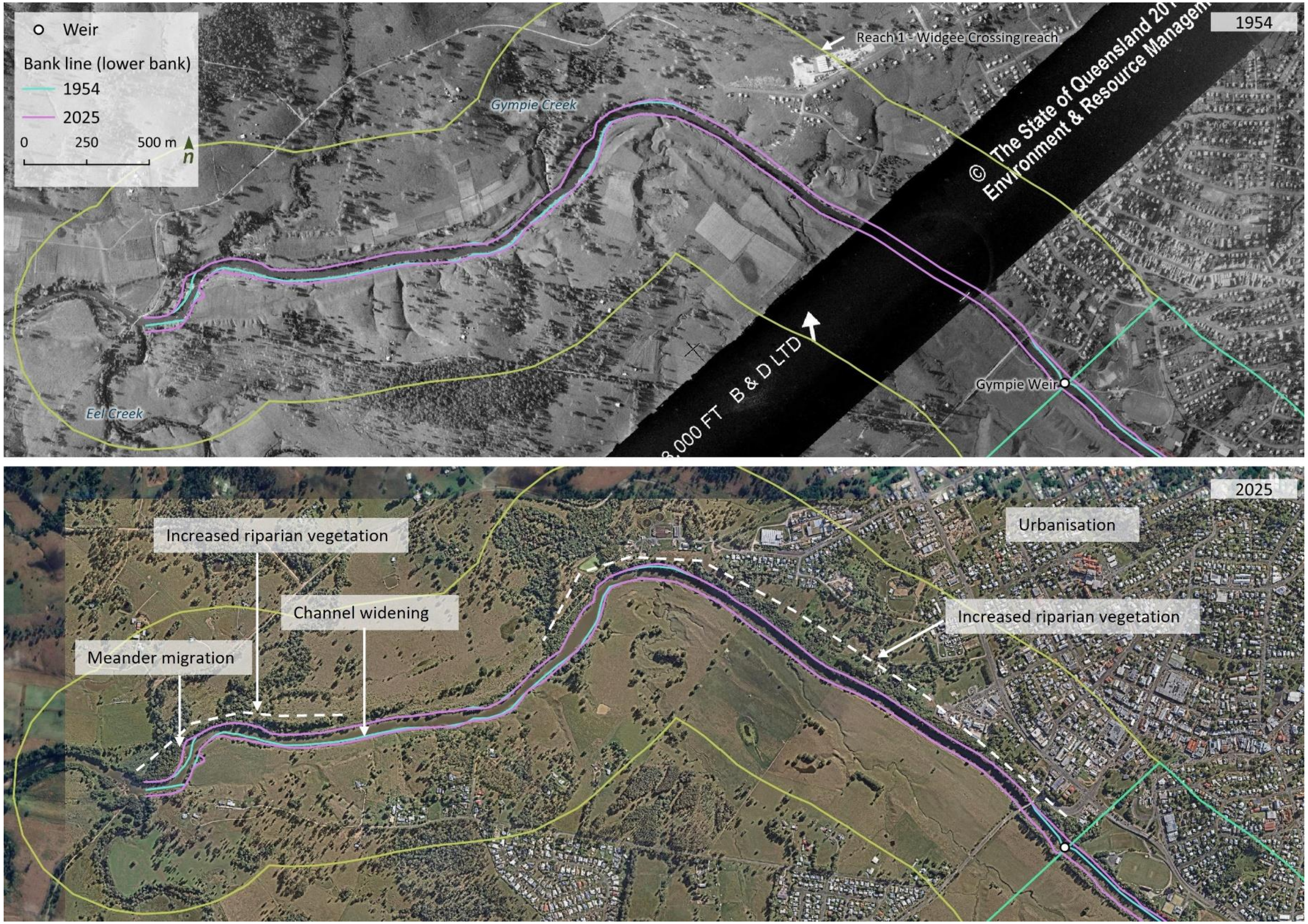


Figure 10. *Multi-temporal aerial imagery analysis at Sub-reach 1 between 1954 and 2025*

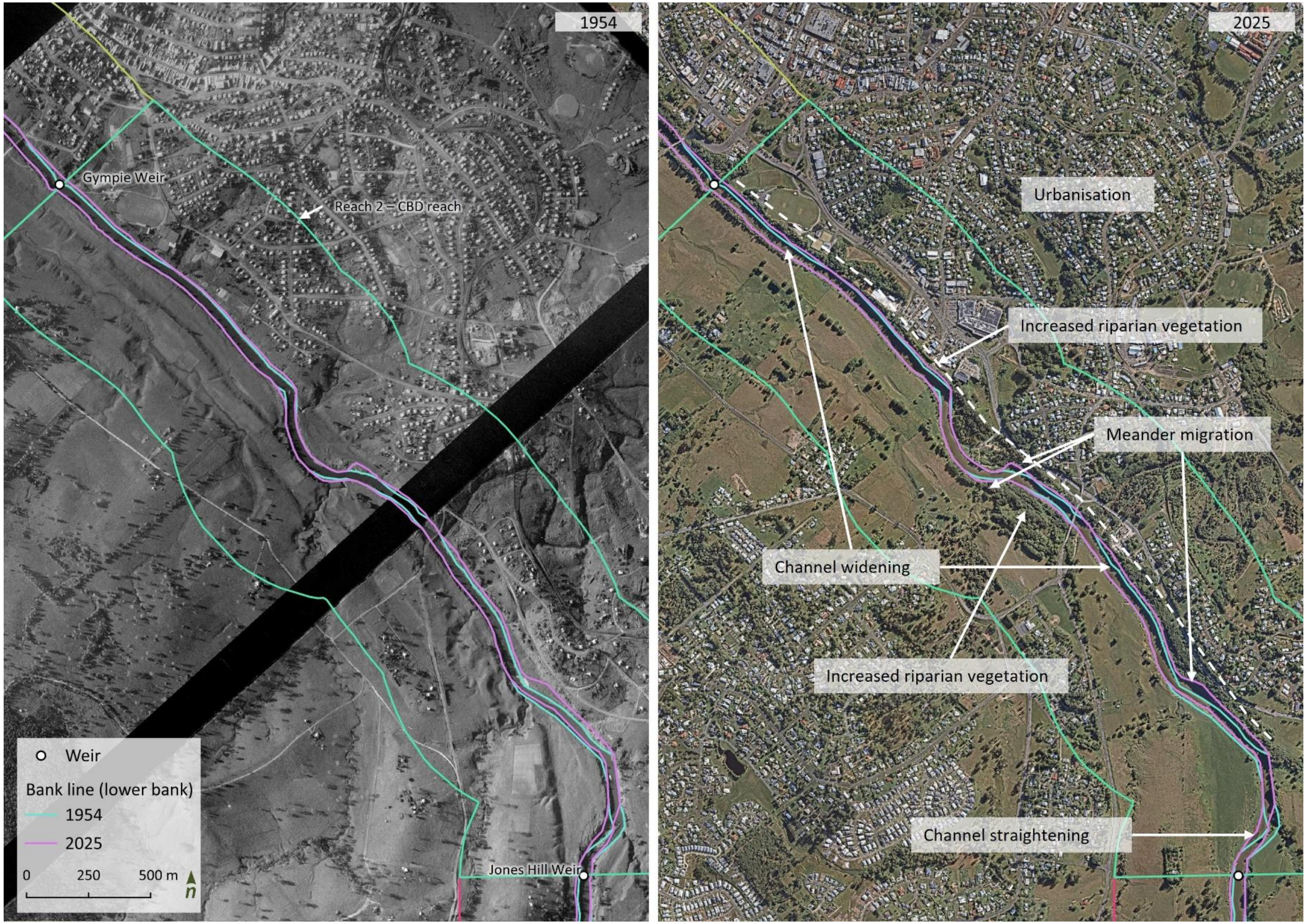


Figure 11. *Multi-temporal aerial imagery analysis at Sub-reach 2 between 1954 and 2025*

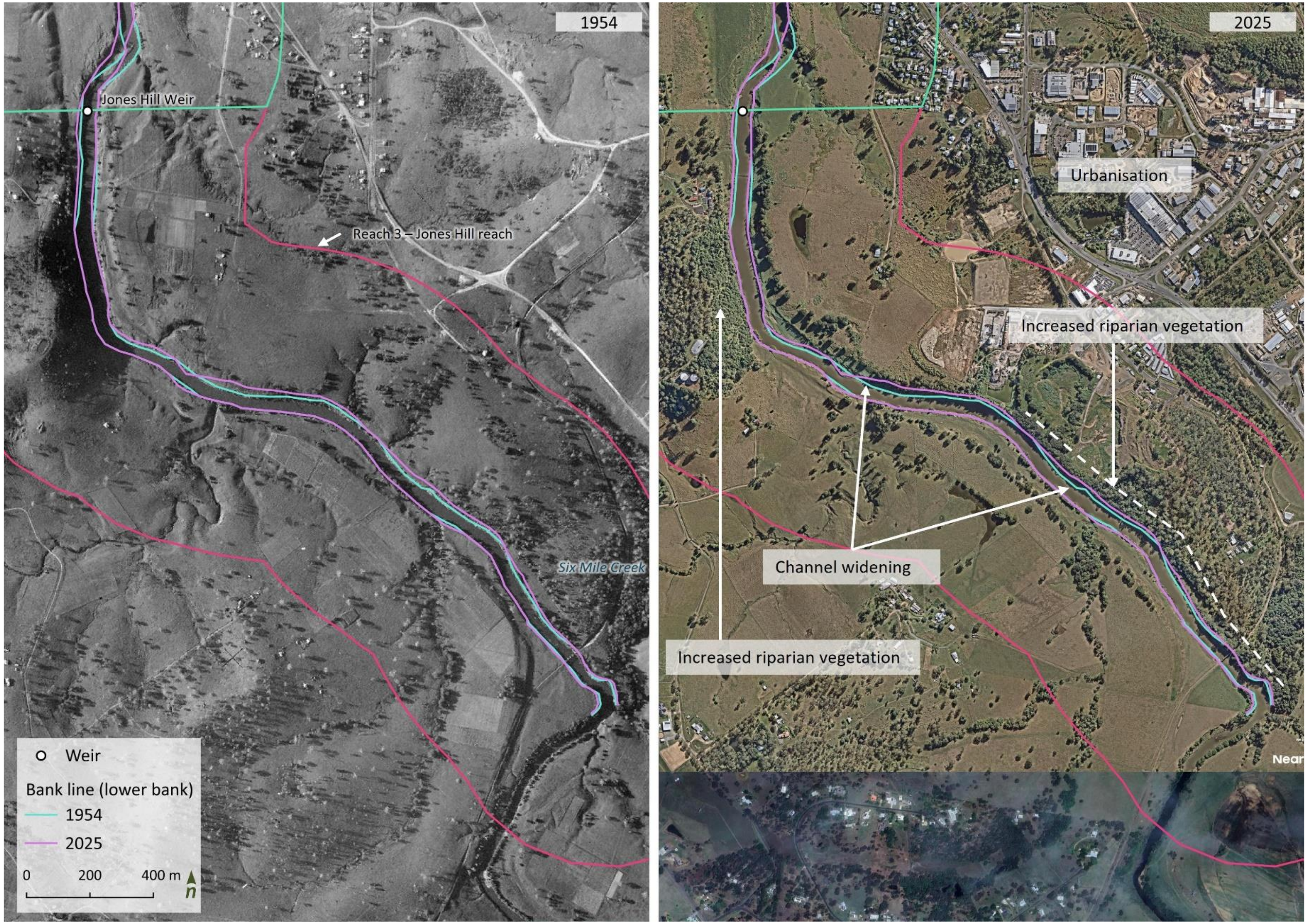


Figure 12. *Multi-temporal aerial imagery analysis at Sub-reach 3 between 1954 and 2025*

3.2 Temporal LiDAR analysis

LiDAR datasets flown in 2009, 2015 and 2024 were available for the study area. From these datasets, Digital Elevation Models (DEMs) were created with one metre grid sizes. The 2009 DEM was compared to the 2015 DEM and the 2015 DEM was compared to the 2024 DEM to assess the changes across the different periods. From each of these comparisons DEMs of Difference (DoD) were developed. A DoD identifies changes in ground surface elevation from two LiDAR datasets captured at various temporal scales. From the DoD the volume of sediment eroded from the banks and the dominant erosional process can be assessed (i.e. meander migration, channel widening etc.). LiDAR cannot penetrate the water surface, as such where there is water in the channel an accurate estimation of bed level, and therefore change in bed level, cannot be determined.

The erosion zones and mechanisms were analysed across the study reach for both the 2009-2015 period (Period 1) and 2015- 2024 period (Period 2) and the total volume of erosion was calculated and is summarised in Table 1. Analysis of the Mary River at Fishermans Pocket stream gauge (#138007A), approximately 5 km downstream of the urban reach, was undertaken to assess the flow history during the assessment periods (see Figure 13). Between 2009 and 2015 there were two major flood events in 2011 and 2013 where the peak discharge was > 10 year ARI event along with a series of smaller events > 2-5 year ARI. Between 2015 and 2024 there was one major flood event in 2022 where the peak discharge was > 20 year ARI event and some smaller events in that same year where the peak discharge was between a 2 and 5 years ARI event. While the recent period had a larger single flood event, it appears that there was more erosion resulting from a series of consecutive moderate flood events between 2009 and 2015. An overview of the total erosion between 2009 and 2024 is provided in Figure 14, the individual analysis period DoDs for each reach are provided in Section 4. The total estimated volume of sediment loss across the study reach in Period 1 was approximately 102,000 m^3, a rate of approximately 17,000 m^3/year. The total estimated volume of sediment loss across the study reach across Period 2 was approximately 47,000 m^3, a rate of approximately 5,000 m^3/year. The erosion rate in Period 2 was significantly lower than the Period 1 rate.

An analysis of the key erosion mechanisms was also undertaken and an overview provided in Figure 15. During Period 1, almost 40% of the total erosion volume came from mass failures and 60 % from fluvial scour. The spatial extent of the erosion was reasonably evenly distributed across the study reach. During Period 2, the total proportion of erosion from mass failures reduced to approximately 20%, and a large proportion of the erosion occurred through the mid to upper reaches (Sub-reach 2 and Sub-reach 3).

Key areas of deposition were also identified between 2009 and 2024 (see Table 2). The total volume of deposition within the study area was significantly less than the total erosion volume at approximately 21,000 m^3, with almost half of that volume located in Sub-reach 2 between the two weirs.

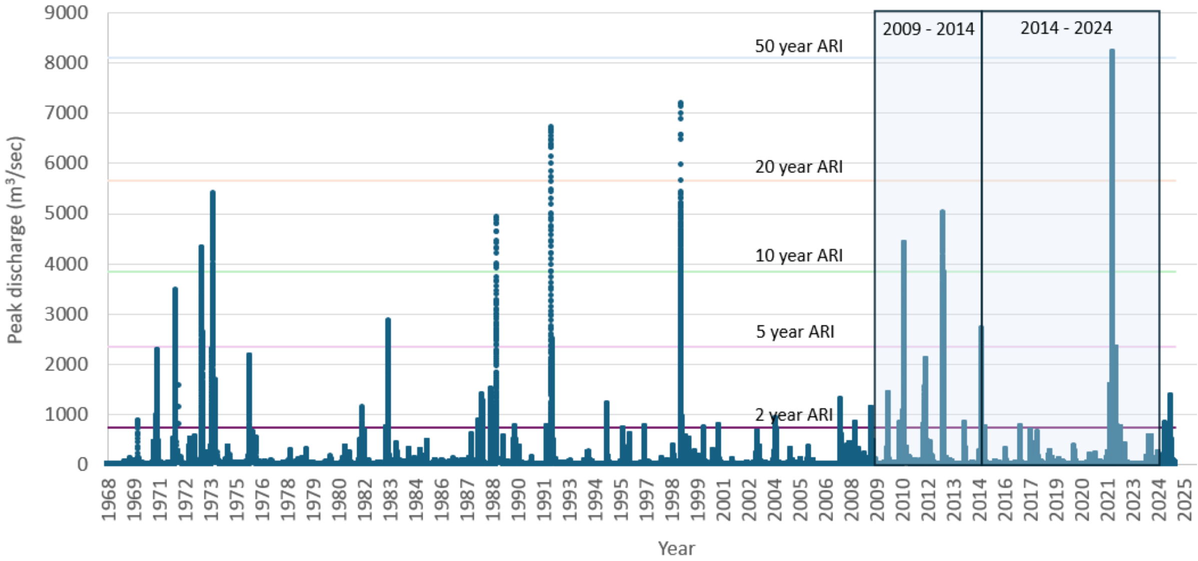


Figure 13. *Peak discharge at the Fishermans Pocket stream gauge (#138007A) with DoD analysis periods highlighted in blue*

Table 1. Estimated sediment loss between 2009 and 2024

		2009 – 2015 (Period 1)			2015 – 2024 (Period 2)		
	Erosion mechanism	**Sediment loss (m^3)**	**Erosion rate (m^3/yr)**	**% of total**	**Sediment loss (m^3)**	**Erosion rate (m^3/yr)**	**% of total**
Reach 1	Floodplain scour	-	-				
	Fluvial scour	19,687	3,281	56	2,662	296	68
	Mass failure	15,388	2,565	44	1,236	137	32
	Total	**35,074**	**5,846**		**3,898**	**433**	
Reach 2	Floodplain scour	1,357	226	4	1,651	183	6
	Fluvial scour	25,882	4,314	71	22,108	2,456	74
	Mass failure	9,097	1,516	25	6,011	668	20
	Total	**36,336**	**6,056**		**29,769**	**3,308**	
Reach 3	Floodplain scour	422	70	1	-	-	-
	Fluvial scour	17,162	2,860	56	11,225	1,247	83
	Mass failure	12,904	2,151	42	2,369	263	17
	Total	**30,488**	**5,081**		**13,594**	**1,510**	**-**
Study area combined	Floodplain scour	1,778	296	2	1,651	183	3
	Fluvial scour	62,731	10,455	62	35,994	3,999	76
	Mass failure	37,388	6,231	37	9,616	1,068	20
	Total	**101,898**	**16,983**		**47,261**	**5,251**	

Table 2. Summary of deposition volumes between 2009 and 2024

	2009 - 2024 deposition volume (m^3)
Sub-reach 1	4,179
Sub-reach 2	10,419
Sub-reach 3	6,471
Total	**21,069**

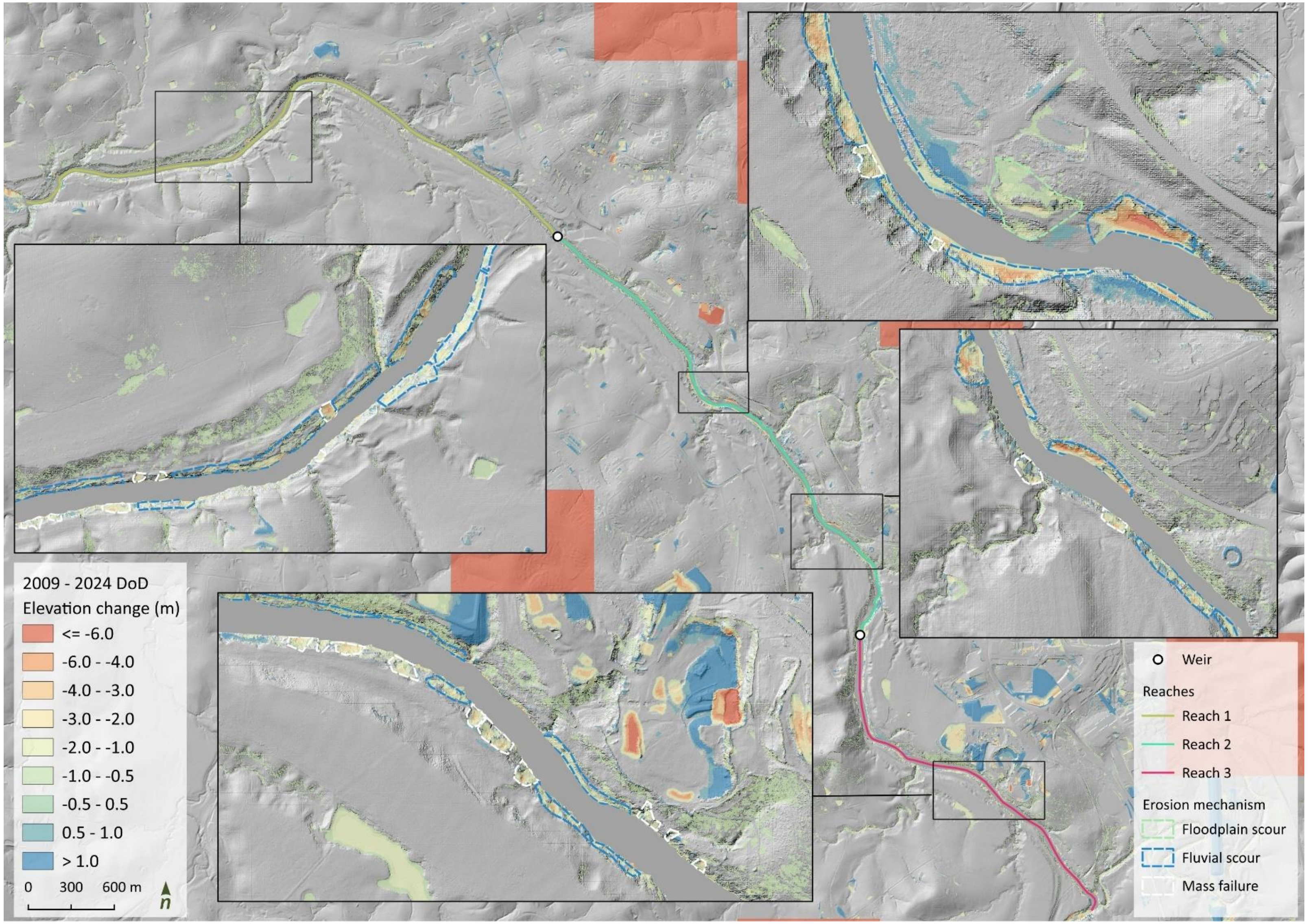
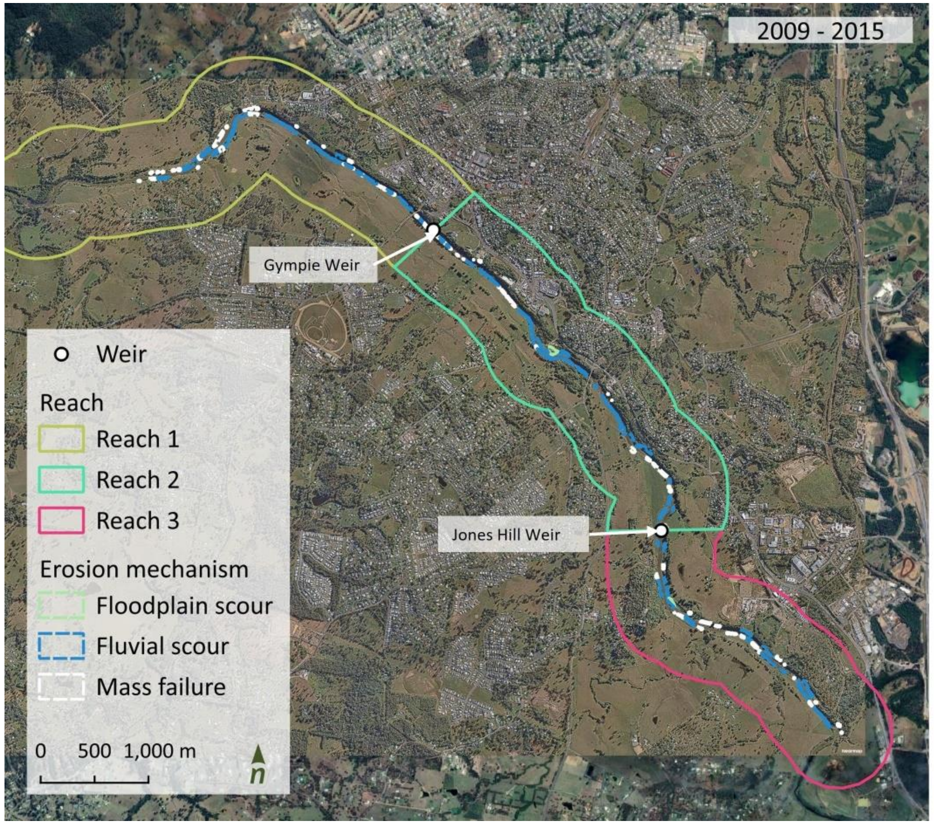


Figure 14. *2009 – 2024 DoD over study area with close up examples within each Sub-reach*



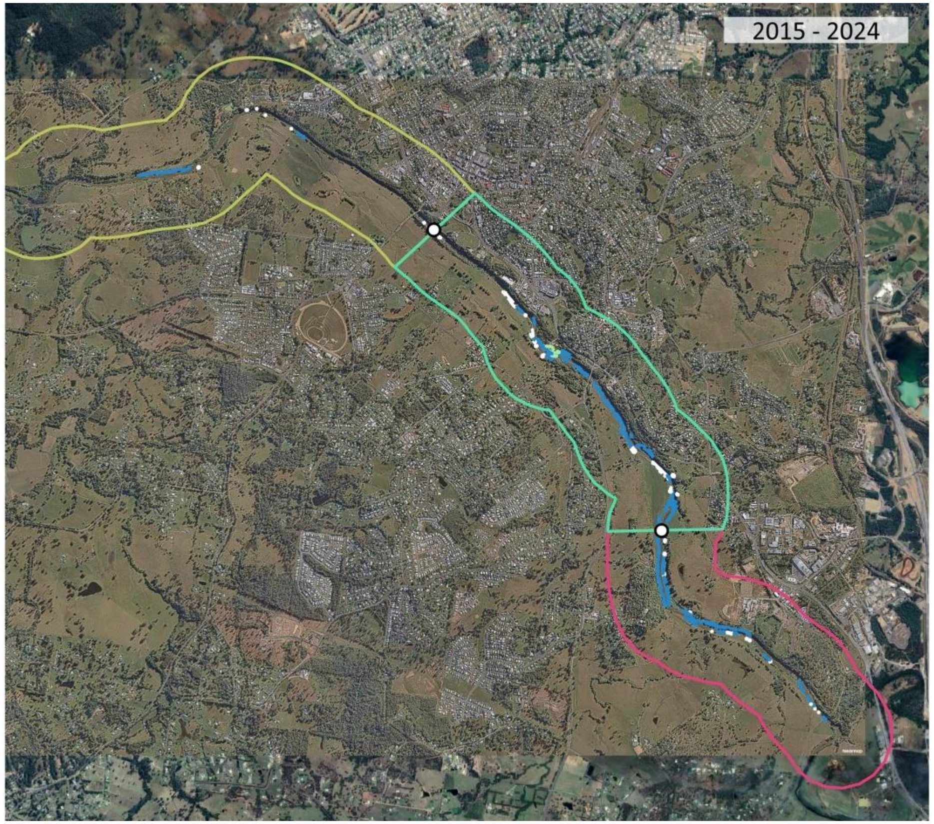
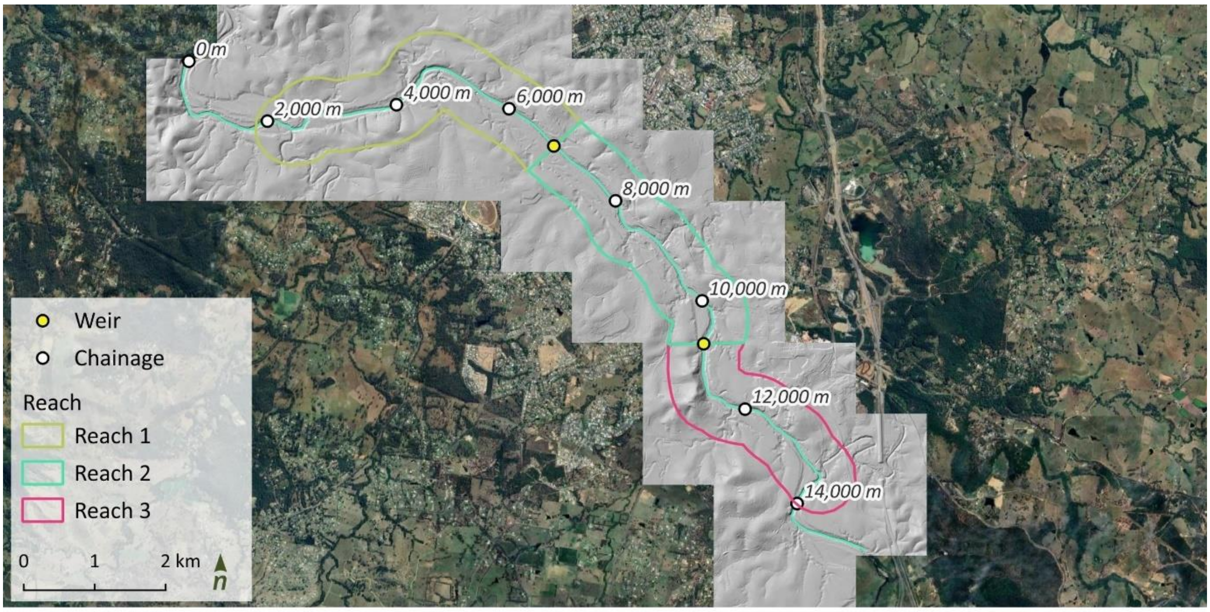


Figure 15. *Erosion mechanisms identified across the study reach between 2009 – 2015 and 2015 - 2024*

3.3 Longitudinal bed grade assessment

A longitudinal profile has been developed using the 2024 DEM (Figure 16). The bed grade across the upper portion of study reach is controlled by the Gympie Weir and Jones Hill Weir. There is a drop in bed elevation downstream of the study area (Chainage 1,000 – 2,000) of approximately 1.2 m, which appears to be a series of riffles and short pools. It is difficult to see the bed material in the imagery across these riffles and whether there is any underlying bedrock control controlling the bed grade in this location. However recent historic imagery analysis does not suggest any significant adjustment of the location of these riffles which indicates they are likely to be relatively stable. Generally, the overall gradient of the entire study reach is relatively low, approximately 0.0004 m/m. The decrease in bed elevation is largely controlled by the weirs, which have created weir pools.



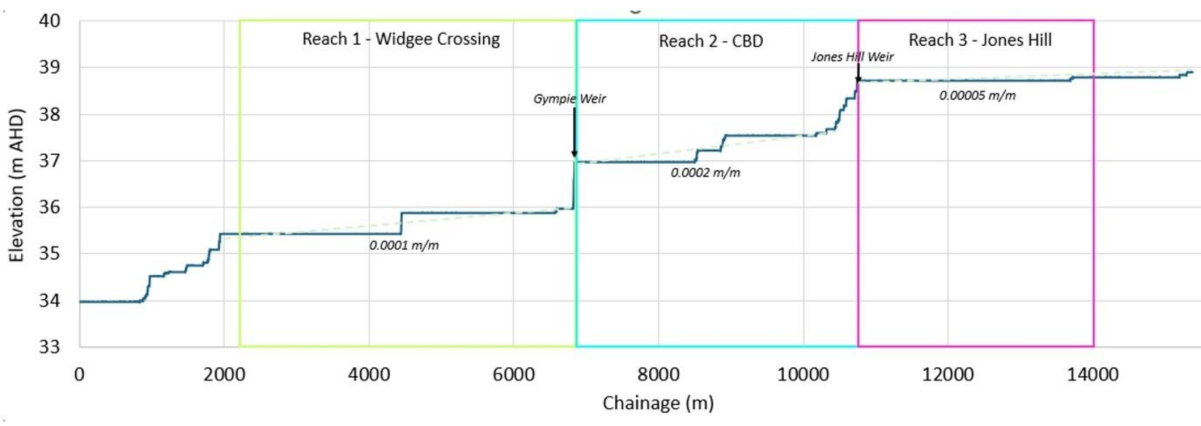


Figure 16. *Longitudinal bed grade within the study area*

4 Existing condition and trajectory – sub-reach summaries

This section provides an overview of the existing condition and trajectory of each of the reaches across the study area. Within each reach, bank sections were assessed and broken up based on the riparian condition and erosion potential. The methodology used for these assessments are provided below.

Method for mapping waterway condition

The different levels of waterway condition include *good condition*, *slightly degraded*, *moderately degraded* and *highly degraded* (Table 3). Woody vegetation extent was used as a proxy for waterway condition because woody vegetation extent is easily assessed with aerial imagery, and is the main attribute responsible for achieving each of the management functions that contribute to enhanced flood resilience, and ongoing provision of ecosystem services, values and functions (Table 4). The outcomes of this assessment are presented in the Sub-reach sections below.

Table 3. Classification of waterway condition used in this project. The classification is based on the degree to which the five management functions are achieved and ecosystem services provided.

Waterway condition	Degree to which management functions are achieved	Degree to which ecosystem services are provided	Woody vegetation extent within the channel and riparian zone*
Good condition	Physical attributes of the waterway are in optimum condition to be achieving *all* five management functions. No improvement is required.	Most ecosystem services are being provided.	More than 80%
Slightly degraded	All management functions are being partially achieved but attributes could be improved.	Most ecosystem services are provided but could be improved.	60-80%
Moderately degraded	Some of the management functions are being partially achieved.	Some ecosystem services are only partially provided.	40-60%
Highly degraded	*None* of the five management functions are being achieved.	Most ecosystem services are not provided.	Less than 40%

*25 m-wide riparian zone is the required width to meet all management functions (Alluvium, 2025).

Table 4. Management functions and corresponding attributes that are influenced by woody vegetation extent.

Function	Attribute
Increase the hydraulic roughness of the channel to help **slow flow velocity**	Hydraulic roughness Vegetation can withstand high flow velocities
Reduce erosion that is occurring at rates above natural background rates of erosion.	Hydraulic resistance and structural protection
Reduce nutrient loads entering waterways from adjacent land and encourage nutrient cycling processes for nutrient removal.	Nutrient uptake by deep-rooted vegetation Shade regulates water temperature Enhanced soil microbial processes Streambank structural protection and hydraulic resistance Sediment and nutrient trapping
Improve the **physical aquatic habitat** for native instream biota	Large wood Shade Hydraulic complexity Streambed heterogeneity
Improve **riparian habitat quality and longitudinal connectivity** through structurally diverse native riparian corridors	Hydraulic roughness to create low flow zones and encourage the formation of depositional units. Hydraulic resistance and structural protection for enhanced streambank and streambed stability Diverse habitat features including protected perches, nest and roost sites (e.g. hollows), leaf litter and large wood Connected riparian corridors

Erosion potential
The likelihood of ongoing erosion at any location can be assessed based on our knowledge of:

- Geomorphic units and an understanding of their erodibility
- Historic erosion rates (Section 3.1 and 3.2)
- Erosion processes (Section 3.1 and 3.2)

Erosion potential across the study reach was assessed and categorised according to the definitions presented in Table 5. The outcomes of this assessment are presented in the Sub-reach sections below.

Table 5. Erosion potential category descriptions.

Erosion potential	Description
Very high	High rates of erosion almost certain in future flood events. Very unlikely the vegetation alone would be able to reduce the likelihood of erosion due to the rate of erosion.
High	High rates of erosion likely in future flood events. Unlikely the vegetation alone would be able to reduce the likelihood of erosion due to the rate of erosion.
Moderate	Some erosion is likely in future flood events. Vegetation may be able to reduce the likelihood of erosion providing favourable flow condition
Low	Low likelihood of erosion in future flood events. Vegetation/bedrock/terrace will be able to limit erosion.

4.1 Sub-reach 1 – Widgee Crossing reach

Overview
The Widgee Crossing reach is at the downstream extent of the study area and extends approximately 4.5 km from the Gympie Weir to the Eel Creek confluence. Throughout the Widgee Crossing reach, there are varying degrees of floodplain development. At the upstream extent, up to the meander, there is an extensive floodplain on the southern side of the channel that sits approximately 8-10 m above the channel and between 100 – 300 m in width. On the northern side of the channel, the channel either abuts the terrace or a narrow discontinuous floodplain up to 30 m wide (Figure 17). On the outside of the large meander, the channel abuts the terrace margin immediately upstream of the Gympie Creek confluence. Downstream of here the channel generally abuts a narrow floodplain, less than 50 m in width, which become more expansive and up to 200 m in width at the downstream extent, immediately upstream of the Eel Creek confluence (Figure 18). The key geomorphic units across the reach have been mapped and are presented below in Figure 19 and Figure 20. The adjacent land use throughout Sub-reach 1 is predominately grazing.

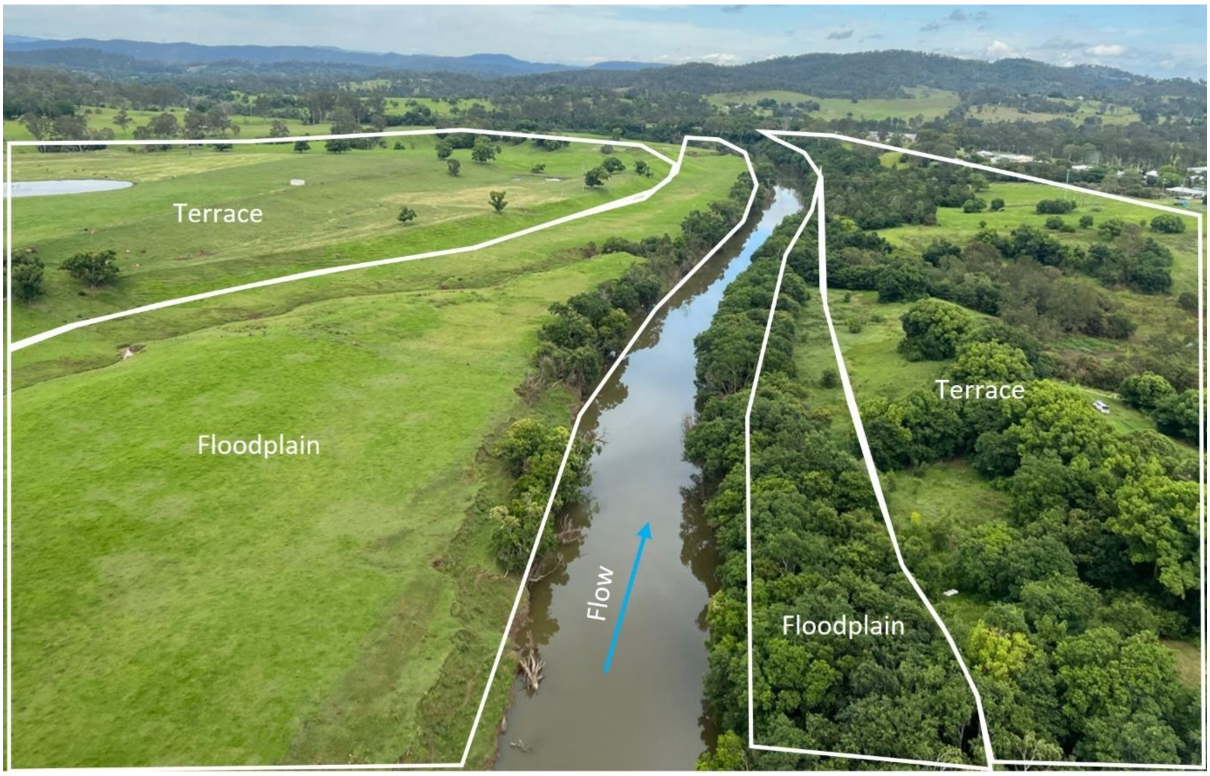


Figure 17. *Geomorphic units across the upper extent of Sub-reach 1*

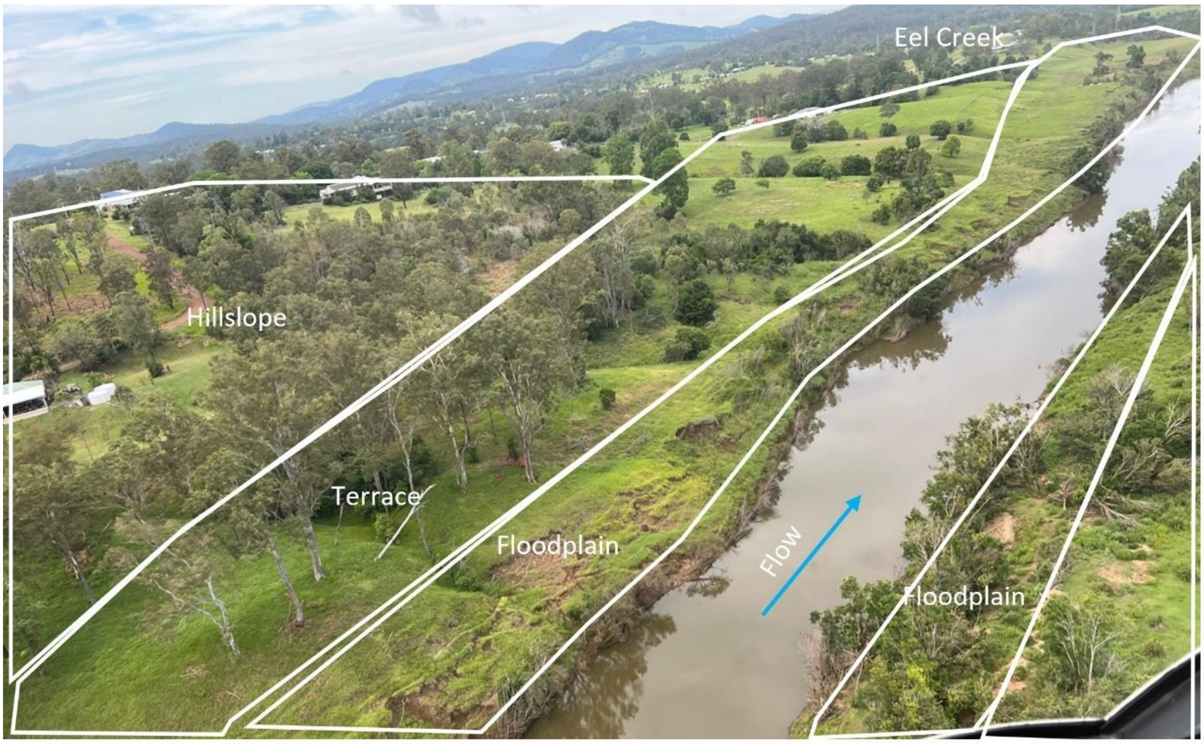


Figure 18. *Geomorphic units in the lower portion of Sub-reach 1*

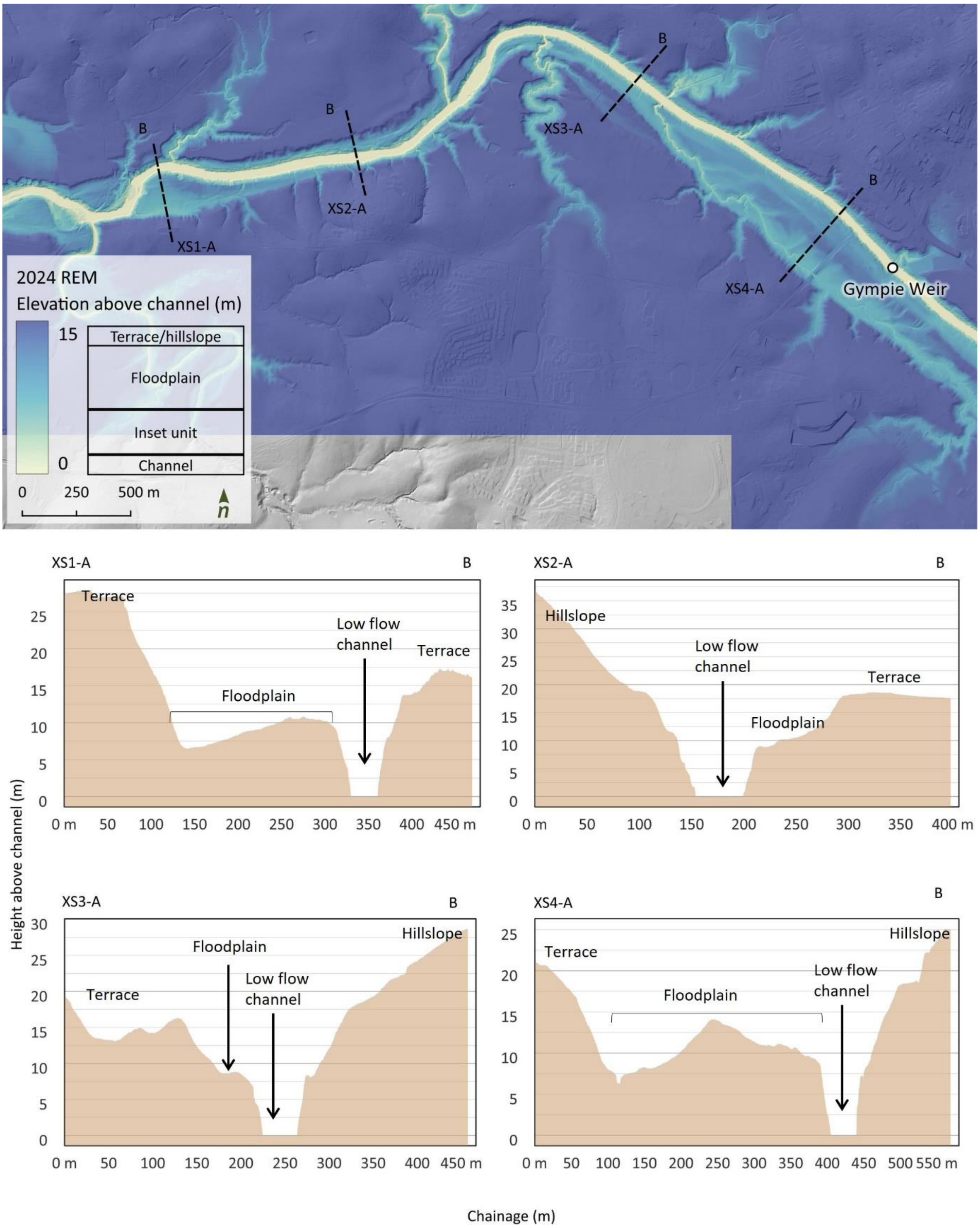


Figure 19. *Relative Elevation Model (REM) highlighting the key geomorphic units in Sub-reach 1*

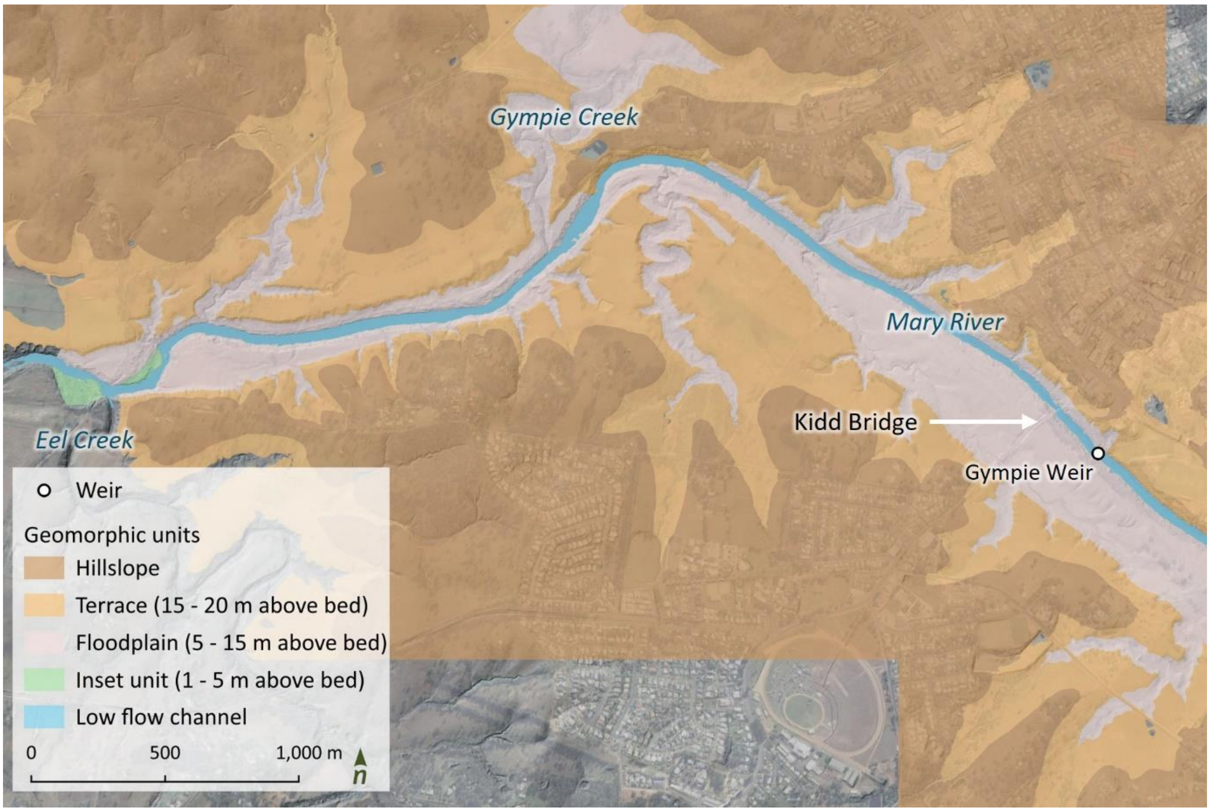


Figure 20. *Key geomorphic units across Sub-reach 1*

Multi-temporal analysis

Multi-temporal LiDAR analysis was undertaken for two periods between 2009 and 2024 (Figure 21). The analysis shows that there was relatively widespread erosion of the floodplain units on the southern side of the channel. The erosion identified was a combination of mass failures or 'wet flow failures' and fluvial scour, there was no significant planform adjustment or bank retreat identified through the reach. Wet flow failures are a type of bank erosion caused by the saturation of bank material followed by a rapid drawdown of floodwaters resulting in geotechnical failure. These failures typically occur on the receding limb of a flood and in areas where the vertical accretion of the floodplain results in banks comprising of alternating layers sandy units and silt or clay units. While these failures often result in significant volumes of sediment being mobilised after the flood event, the failure scars tend to become sediment sinks due to the increased cross-sectional area and resultant low energy zone. As a result, the delivery of sediment to the channel via wet flow failures is typically short lived.

A summary of the erosion rates and mechanisms between 2009 -2015 (Period 1) and 2015 – 2024 (Period 2) is presented below in Table 6. The erosion rate in period 1 (5,846 m^3/year) was significantly higher than in period 2 (433 m^3/year). During period 1 mass failures accounted for approximately 45 % of the total erosion where as in Period 2 accounted for approximately 30%. The fluvial scour identified typically included surficial scour of the exposed lower and mid-banks however, there was minimal significant retreat of the toe of bank.

Table 6. Summary of erosion volumes and mechanisms across Sub-reach 1

	2009 – 2015 (Period 1)			2015 – 2024 (Period 2)		
Erosion mechanism	**Sediment loss (m^3)**	**Erosion rate (m^3/yr)**	**% of total**	**Sediment loss (m^3)**	**Erosion rate (m^3/yr)**	**% of total**
Floodplain scour	-	-				
Fluvial scour	19,687	3,281	56	2,662	296	68
Mass failure	15,388	2,565	44	1,236	137	32
Total	**35,074**	**5,846**		**3,898**	**433**	

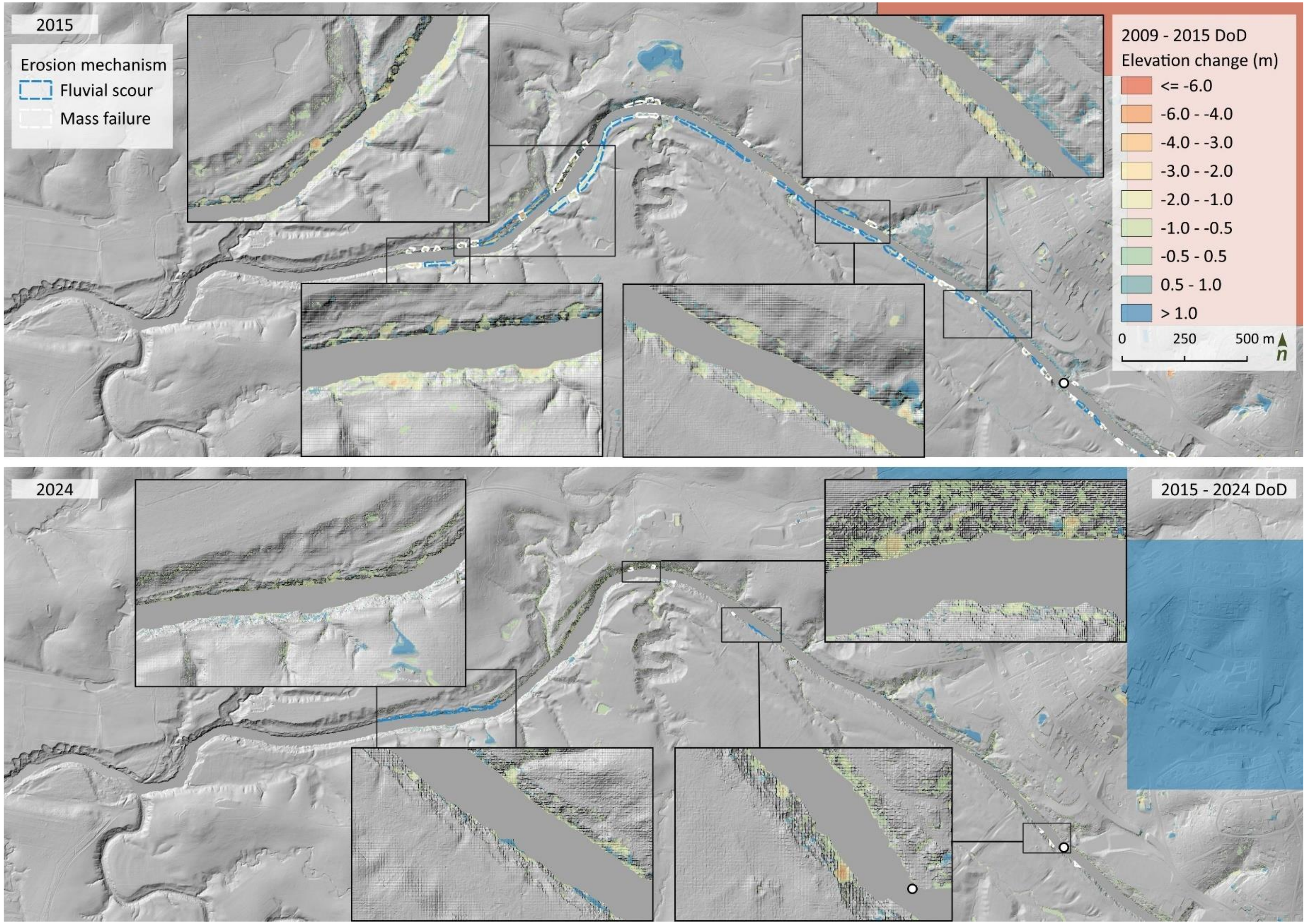


Figure 21. *Multi-temporal LiDAR analysis across Sub-reach 1– 2009 – 2015 DoD (top), 2015 – 2024 DoD (bottom)*

Riparian condition

The riparian condition across Sub-reach 1 is presented below in Figure 22. The riparian condition across the southern side of the channel is highly degraded. The riparian zone is largely devoid of any canopy or shrub species and the bank is either exposed or covered in pasture grasses. The riparian vegetation extent of the northern bank through the upstream half of the reach is typically good; however, it was classified as slightly degraded due to known Cat's Claw vine weed infestations, particularly near the large meander, with Chinese Elm also present throughout. The riparian extent of the northern bank at the downstream end becomes fragmented and has been classified as slightly or moderately degraded. Typical examples of the varying riparian conditions found in Sub-reach 1 is provided below in Figure 23 and Figure 24.

Figure 22. *Sub-reach 1 riparian condition*

Figure 23. *Example of Good riparian condition on the right bank at the upstream extent of Sub-reach 1 (photo looking downstream)*

Figure 24. *Example of slightly degraded riparian condition on the right bank and highly degraded riparian condition on the left bank in Sub-reach 1.*

Erosion potential

The erosion potential across Sub-reach 1 is presented below in Figure 25. The erosion potential was classified as Low on the northern bank at the upstream extent as the channel is significantly confined by the terrace margins, there is reasonable existing riparian vegetation extent and there has been minimal historic erosion. The majority of the southern bank and lower portion of the right bank was classified as moderate erosion potential. The channel abuts the grazed floodplain through these sections and there is limited existing riparian vegetation. There is currently unrestricted stock access to the banks, which can result in increased erosion risk through pre-weakening or sub-aerial preparation and limits the chance of natural vegetation regeneration. Some erosion is likely in future flood events either through wet flow failures or fluvial scour. Vegetation may be able to reduce the likelihood of erosion. An example of a section of the southern bank with a moderate erosion potential is presented below in Figure 26.

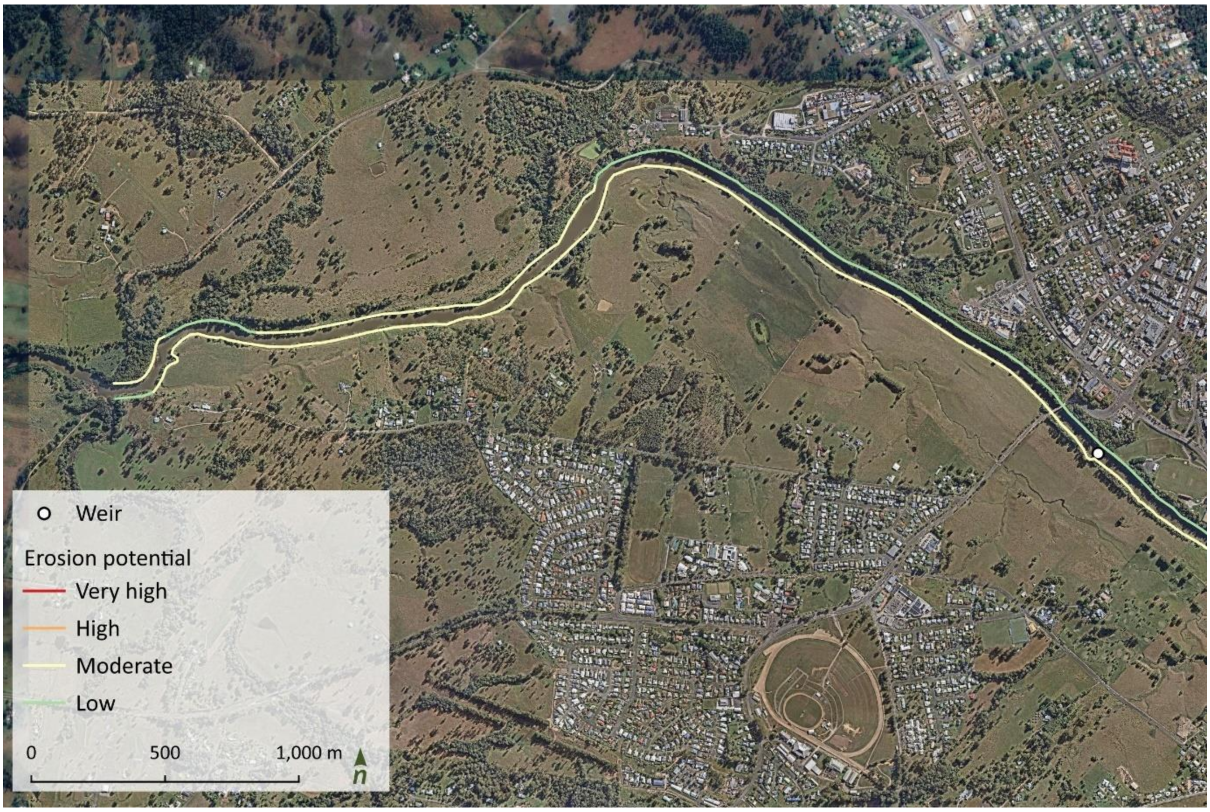


Figure 25. *Sub-reach 1 erosion potential*

Figure 26. *Example of section of bank with a moderate erosion potential in the lower portions of Sub-reach 1.*

Summary and trajectory

Sub-reach 1 is a partly confined stream with a macro-channel morphology. There is varying degrees of floodplain development throughout the Sub-reach but is generally more extensive on the southern side of the channel. The riparian condition is typically highly degraded on the southern side of the channel, which has been heavily impacted by grazing. While there is relatively good riparian vegetation extent across much of the northern side of the channel, there are significant pressures from weeds including Cats claw vine and Chinese Elm. The most significant erosion through Sub-reach 1 was identified on the southern banks where there has been widespread mass failures and some fluvial scour. Without management interventions, some ongoing scour and isolated mass failures would be expected particularly on the highly degraded southern banks. Works should focus on establishing reach scale riparian vegetation limiting the impacts of adjacent pressures and threats such as weed infestations and grazing impacts.

Appropriate rehabilitation options could include riparian fencing for stock management, weed control and widespread revegetation works, which aim to increase the density and width of woody vegetation across the reach, expanding on patches of existing vegetation. Generally, works within highly degraded reaches should be implemented across a significant length of the Sub-reach (i.e. not an isolated site) to help improve recovery potential and desired riparian functions. This requires significant time and financial investment.

4.2 Sub-reach 2 – CBD Reach

Overview

The CBD reach is at the middle extent of the study area and extends approximately 3.8 km from the Jones Hill Weir to the Gympie Weir. On the northern side of the channel, the channel either abuts the terrace or a narrow discontinuous floodplain, typically less than 50 m wide, with the exception of a broader floodplain pocket up to 150 m wide at 'the Sands' reserve (Figure 27). The key geomorphic units across the Sub-reach have been mapped and are presented in Figure 28 and Figure 29. Throughout the CBD Reach, there are varying degrees of floodplain development. There is typically more extensive floodplain development on the northern side of the channel. The floodplains sit approximately 8-10 m above the channel and are up to 200 m in width. The adjacent land use through Sub-reach 1 is predominately grazing on the southern side of the channel and a mix of reserves and public or commercial infrastructure on the northern side.

Figure 27. *Example of geomorphic units across the mid extent of Sub-reach 2*

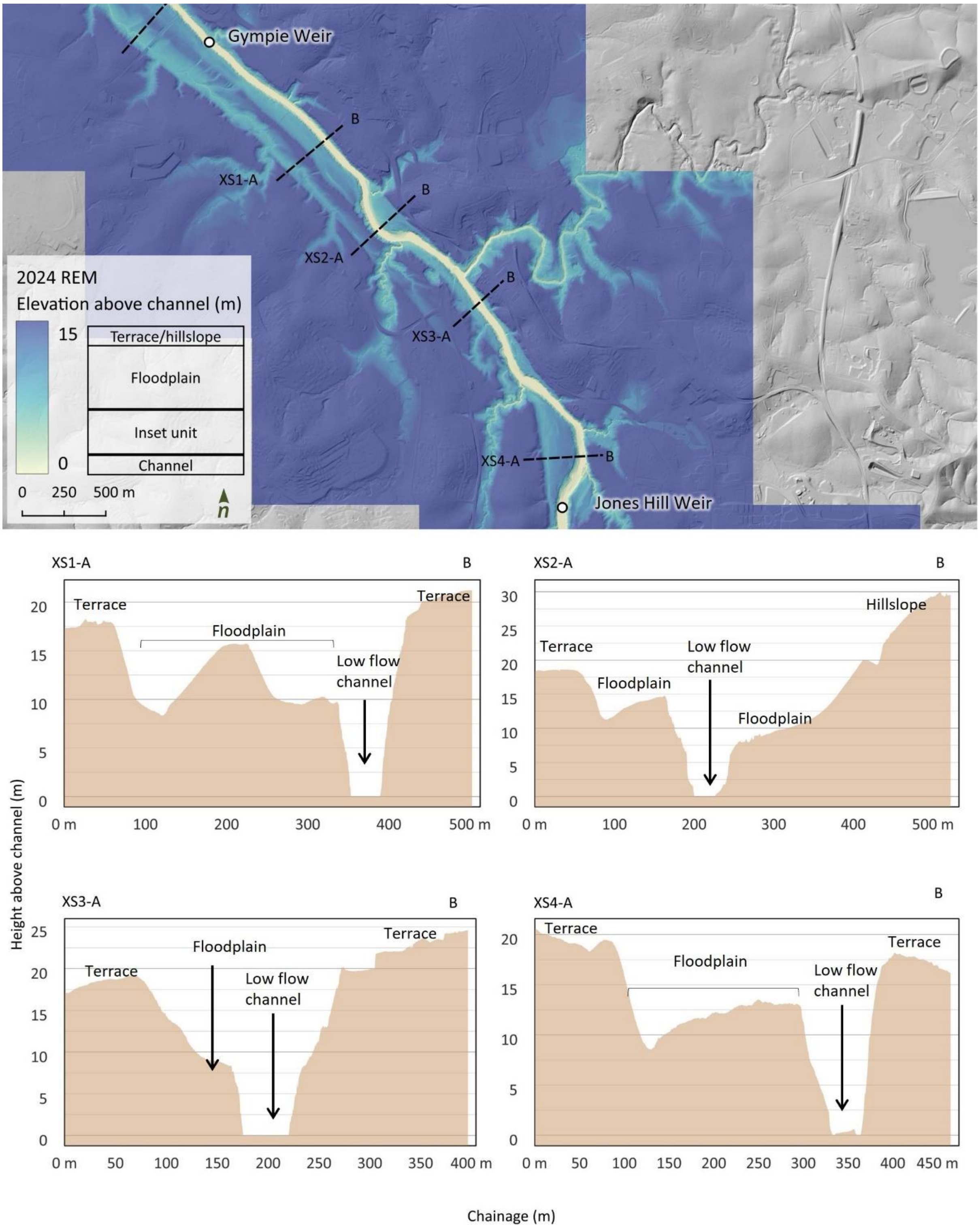


Figure 28. *Relative Elevation Model (REM) highlighting the key geomorphic units in Sub-reach 2*

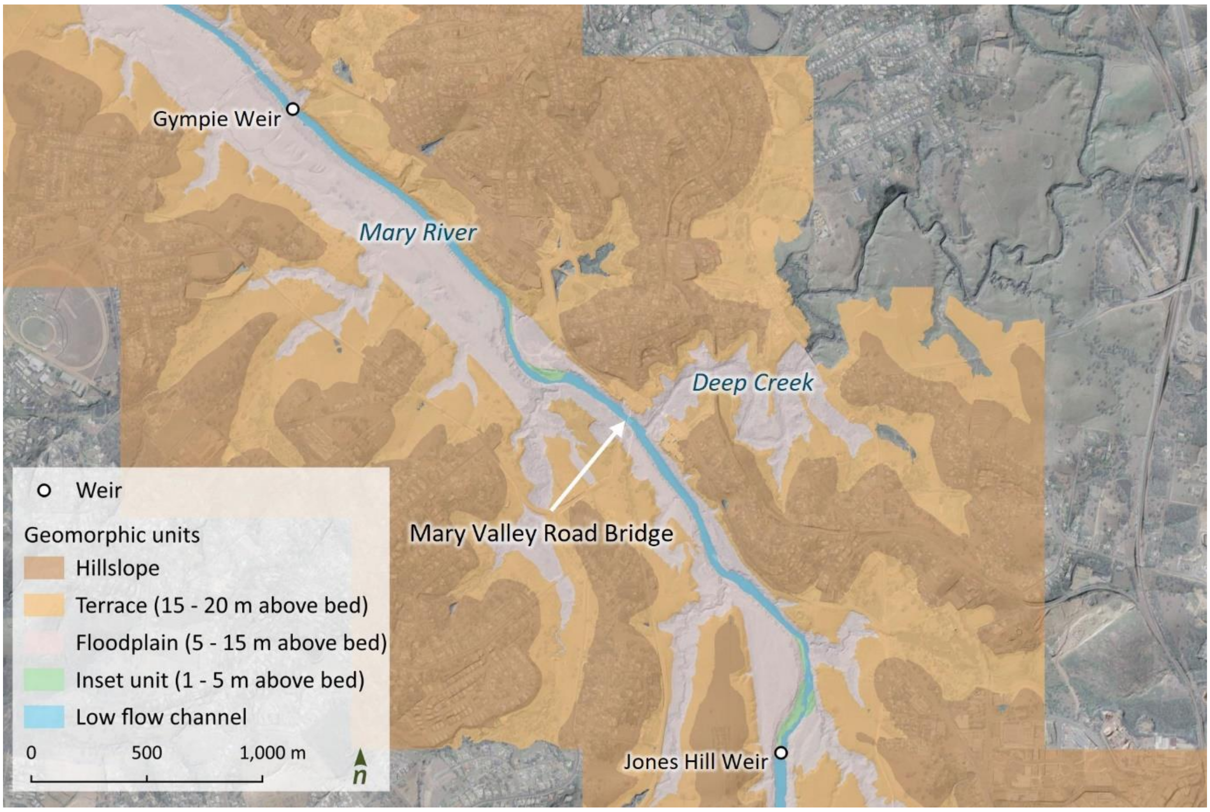


Figure 29. *Key geomorphic units across Sub-reach 2*

Multi-temporal analysis

Multi-temporal LiDAR analysis was undertaken for two periods between 2009 and 2024 (Figure 30). The analysis shows that there was relatively widespread erosion of the floodplain units on the southern side of the channel. The erosion identified was a combination of mass failures or 'wet flow failures' and fluvial scour. The mass failures were largely concentrated on the southern banks. There were two bends on the northern side of the channel where there was significant erosion from meander migration processes. The first site is located approximately 800 m downstream of the Jones Hill Weir (Figure 31). The bank is approximately 10 m high and retreated up to 10 m between 2009 and 2024. The second site is located immediately adjacent to the Sands Reserve and is approximately 12 m high and retreated up to 18 m between 2009 and 2024. Ongoing erosion at this site threatens the adjacent walking track however future erosion will likely be limited to the terrace boundary which is currently approximately 15 m away (Figure 32).

Towards the downstream extent of the reach on the right bank there is a public path that descends down the terrace bank and runs on a narrow bench along the lower bank. There has been some slumping and scour along the bench which threatens to undemine the path (Figure 33). The erosion may also be resulting from concentrated overland flows from the adjacent roads, carparks and netball courts.

A summary of the erosion rates and mechanisms between 2009 -2015 (Period 1) and 2015 – 2024 (Period 2) is presented in Table 7. The erosion rate in Period 1 (6,056 m^3/year) was significantly higher than in period 2 (3,308 m^3/year). Fluvial scour was the dominant erosion process across Sub-reach 2, accounting for approximately 75% of the total erosion volume between 2009 and 2024. It is estimated that approximately 20 % of the total erosion volume across Sub-reach 2 came from the two meander migration sites discussed above.

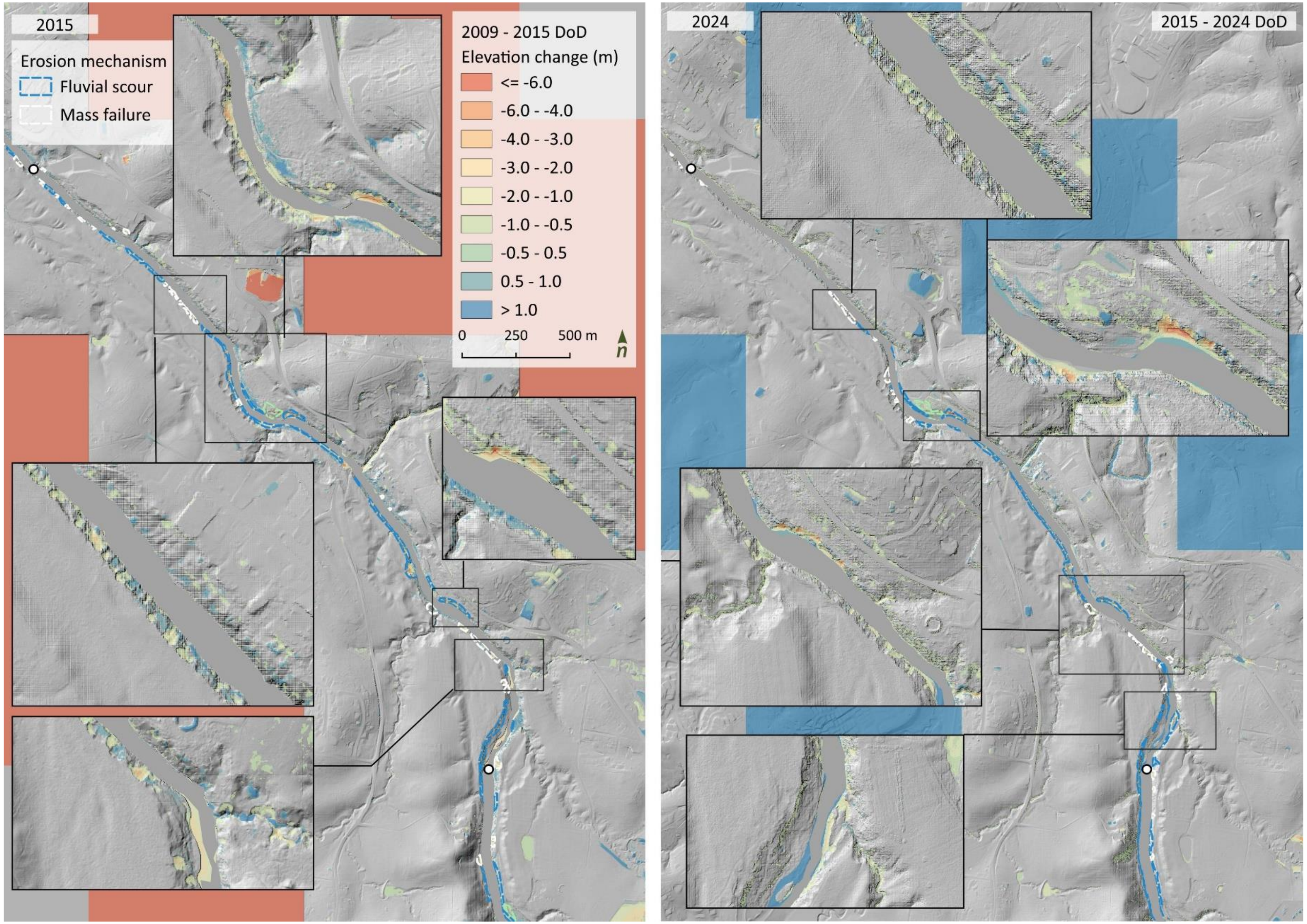


Figure 30. *Multi-temporal LiDAR analysis across Sub-reach 2– 2009 – 2015 DoD (left), 2015 – 2024 DoD (right)*

Figure 31. *Active meander migration on the northern bank approximately 800 m downstream of Jones Hill Weir*

Figure 32. *Active meander migration on the northern bank adjacent to the Sands reserve*

Figure 33. *Erosion of lower bank adjacent to public walking track in the lower portion of Sub-reach 2*

Table 7. Summary of erosion volumes and mechanisms across Sub-reach 2

	2009 – 2015 (Period 1)			2015 - 2024(Period 2)		
Erosion mechanism	**Sediment loss (m^3)**	**Erosion rate (m^3/yr)**	**% of total**	**Sediment loss (m^3)**	**Erosion rate (m^3/yr)**	**% of total**
Floodplain scour	1,357	226	4	1,651	183	6
Fluvial scour	25,882	4,314	71	22,108	2,456	74
Mass failure	9,097	1,516	25	6,011	668	20
Total	**36,336**	**6,056**		**29,769**	**3,308**	

Riparian condition

The riparian condition across Sub-reach 2 is presented below in Figure 34. The riparian condition across the southern side of the channel is typically highly degraded however there are two sections where the vegetation extent increases and has been classified as slightly degraded, these are located immediately downstream of the Mary Valley Road Bridge and immediately upstream of the Gympie Weir. The riparian vegetation extent of the northern bank downstream of the Sands is typically good however is fragmented by the public track along the lower bank. The riparian condition at the Sands is highly degraded with limited existing vegetation. Upstream of the Sands the condition has been classified as slightly degraded as there is known Cat’s Claw vine weed infestations and Chinese Elm throughout. Typical examples of the varying riparian conditions found in Sub-reach 2 is provided below in Figure 35 and Figure 36.

Figure 34. *Sub-reach 2 riparian condition*

Figure 35. *Example of Good riparian condition on the right bank and highly degraded riparian condition on the left bank in Sub-reach 2 – photo looking downstream*

Figure 36. *Example of Slightly Degraded riparian condition on the left bank and highly degraded riparian zone at 'the Sands'' reserve in Sub-reach 2 – photo looking downstream*

Erosion potential

The erosion potential across Sub-reach 2 is presented below in Figure 37. The erosion potential has generally been classified as low on the northern bank except for the two locations where there is active meander migration occurring and the erosion potential has been classified as High or Very High. Outside of these locations the channel is significantly confined by the terrace margins, there is reasonable existing riparian vegetation extent, and there has been minimal historic erosion. The majority of the southern bank and upstream portion of the northern bank was classified as Moderate erosion potential. The channel abuts the grazed floodplain through these sections and there is limited existing riparian vegetation. There is currently some stock fencing on the southern bank downstream of Normanby Bridge however limited riparian fencing upstream of the bridge. In the absence of management intervention erosion is likely in future flood events, either through wet flow failures or fluvial scour. Vegetation may be able to reduce the likelihood of erosion along much of the southern bank. Isolated bank toe stabilisation works will likely be required at meander migration sites to limit ongoing erosion (see Figure 38 and Figure 39).

Figure 37. *Sub-reach 2 erosion potential*

Figure 38. *Example of section of bank with a very high erosion potential in Sub-reach 2*

Figure 39. *Example of bank with high erosion potential in Sub-reach 2*

Summary and trajectory

Sub-reach 2 is a partly confined stream with a macro-channel morphology. There is varying degrees of floodplain development throughout the reach, but is generally more extensive on the southern side of the channel. The riparian condition is typically highly degraded on the southern side of the channel, which has been heavily impacted by grazing. While there is relatively good riparian vegetation extent across much of the northern side of the channel there are significant pressures from weeds including Cat's claw vine weed infestation and Chinese elm. The most significant erosion through the reach was identified on two bends on the northern side of the channel through a meander migration process. Without management interventions, some ongoing scour and isolated mass failures would be expected particularly on the highly degraded southern banks, and ongoing meander migration would be expected on the two bends on the northern side of the channel. Works should focus on establishing reach scale riparian vegetation limiting the impacts of adjacent pressures and threats such as weed infestations and grazing impacts.

Appropriate rehabilitation options could include isolated bank stabilisation works, riparian fencing for stock management, weed control and widespread revegetation works which aim to increase the density and width of woody vegetation across the reach, expanding on patches of existing vegetation. Generally, works within highly degraded reaches should be implemented across a significant length of the reach (i.e. not an isolated site) to help improve recovery potential and desired riparian functions.

4.3 Sub-reach 3 – Jones Hill reach

Overview

The Jones Hill reach is at the upstream extent of the study area and extends approximately 2.8 km from the Six Mile Creek confluence to the Jones Hill Weir. Through the Jones Hill, there is a nearly continuous narrow floodplain on both sides of the channel (Figure 40). The key geomorphic units across Sub-reach 3 have been mapped and are presented below in Figure 41 and Figure 42. The channel does occasionally abut the terrace margins on the northern side of the channel. The adjacent land use throughout Sub-reach 3 is predominately grazing however also includes a large landscape supply yard and publicly-owned land including an old quarry site and AFL grounds on the northern side and the Gympie town water offtake and drinking water treatment plant on the southern side.

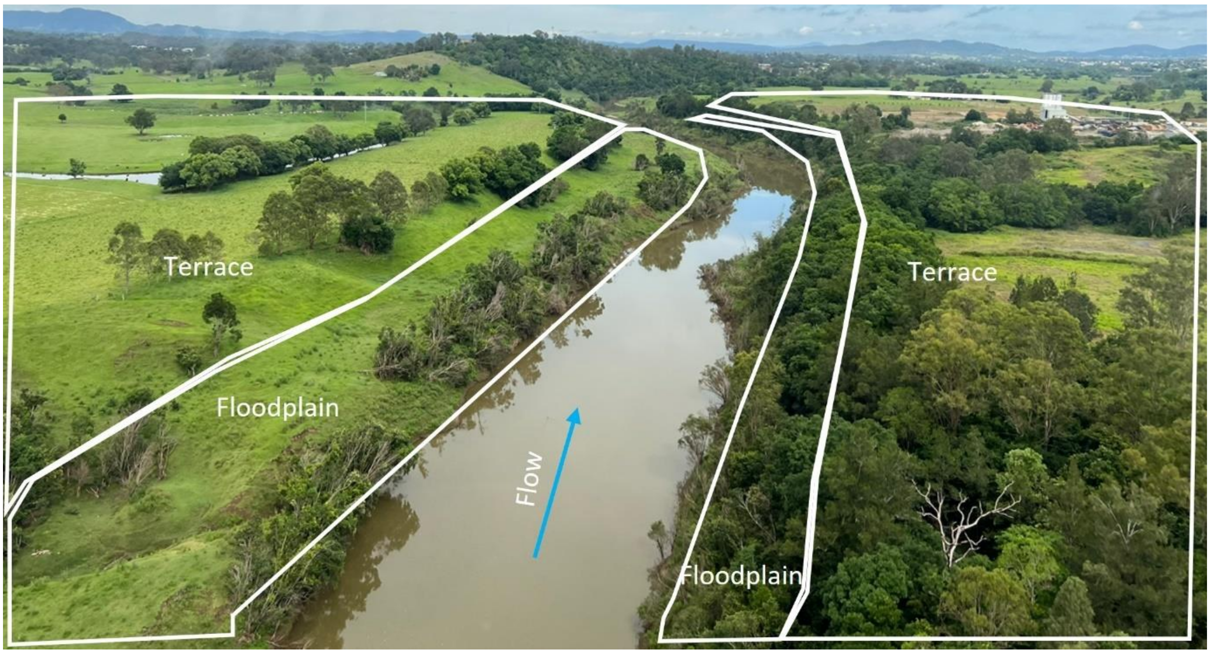


Figure 40. *Example of geomorphic units across the upper extent of Sub-reach 3*

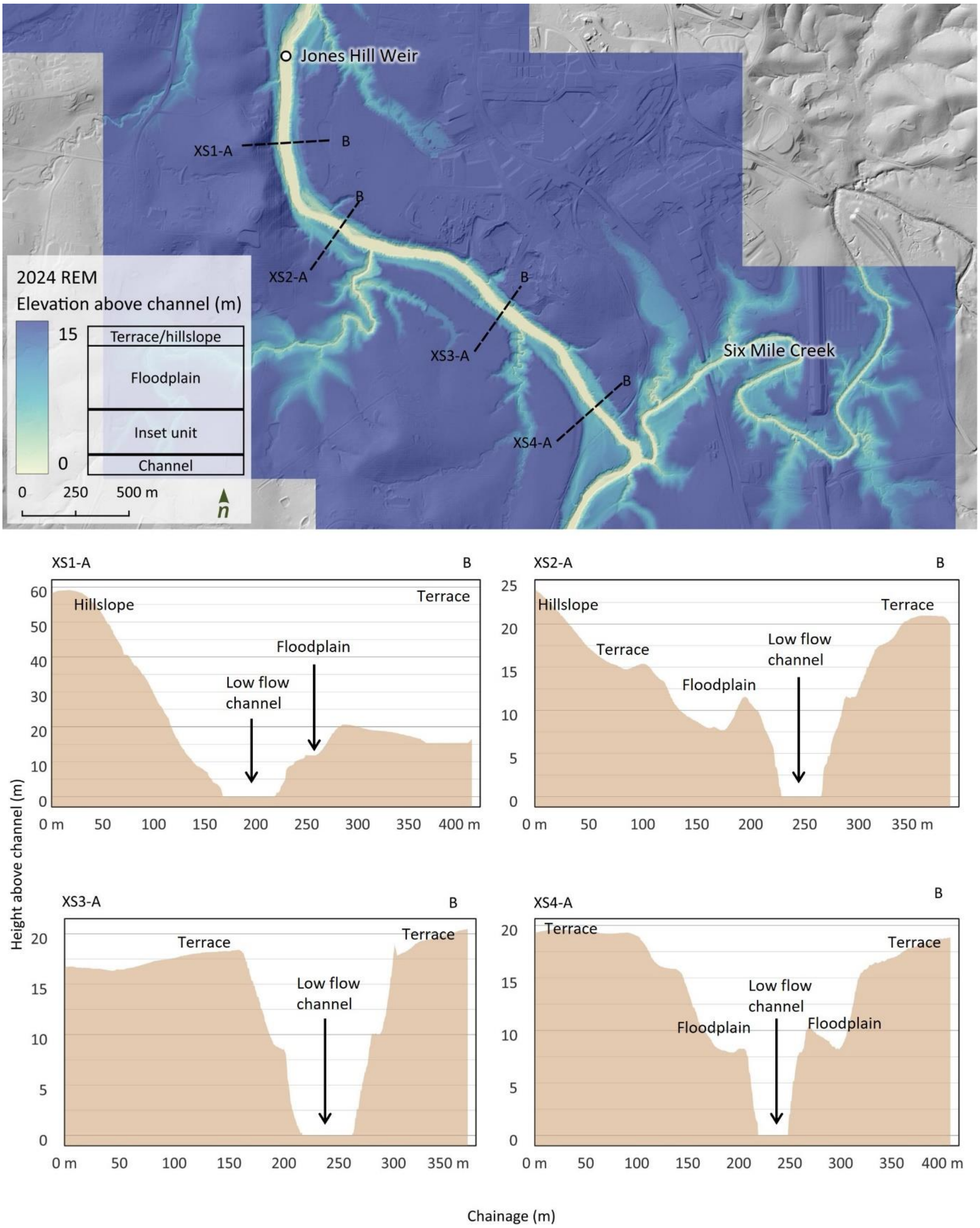


Figure 41. *Relative Elevation Model (REM) highlighting the key geomorphic units in Sub-reach 3*

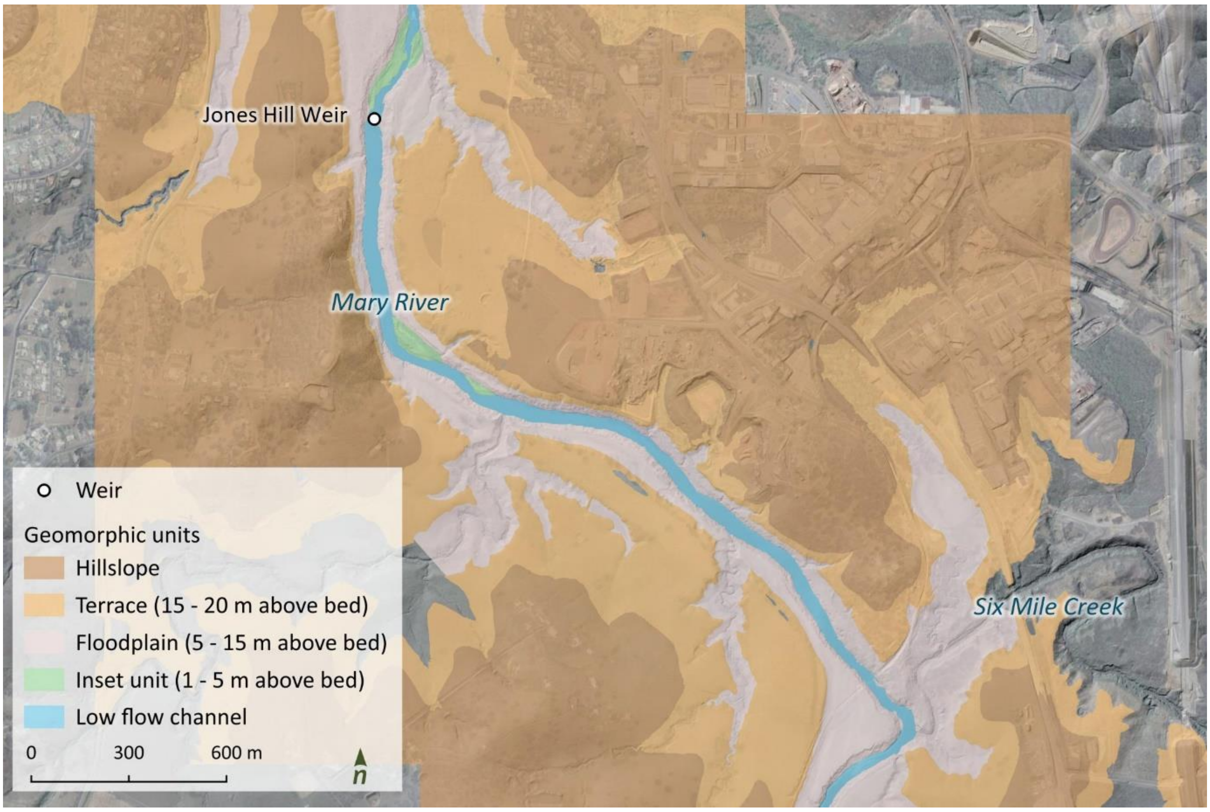


Figure 42. *Key geomorphic units across Sub-reach 3*

Multi-temporal analysis

Multi-temporal LiDAR analysis was undertaken for two periods between 2009 and 2024 (Figure 43). The analysis shows that there was relatively widespread erosion of the floodplain units on both sides of the channel. The erosion identified was a combination of mass failures or 'wet flow failures' and fluvial scour, there was no significant planform adjustment or bank retreat identified through the reach.

A summary of the erosion rates and mechanisms between 2009 -2015 (Period 1) and 2015 – 2024 (Period 2) is presented below in Table 8. The erosion rate in period 1 (5,081 m^3/year) was significantly higher than in Period 2 (1,510 m^3/year). During Period 1, mass failures accounted for approximately 40 % of the total erosion whereas in Period 2 accounted for approximately 15%. The fluvial scour identified typically included surficial scour of the exposed lower and mid-banks however, there was minimal significant retreat of the toe of the bank.

Table 8. Summary of erosion volumes and mechanisms across Sub-reach 3

	2009 – 2015 (Period 1)			**2015 – 2024 (Period 2)**		
Erosion mechanism	**Sediment loss (m^3)**	**Erosion rate (m^3/yr)**	**% of total**	**Sediment loss (m^3)**	**Erosion rate (m^3/yr)**	**% of total**
Floodplain scour	422	70	1	-	-	-
Fluvial scour	17,162	2,860	56	11,225	1,247	83
Mass failure	12,904	2,151	42	2,369	263	17
Total	**30,488**	**5,081**		**13,594**	**1,510**	**-**

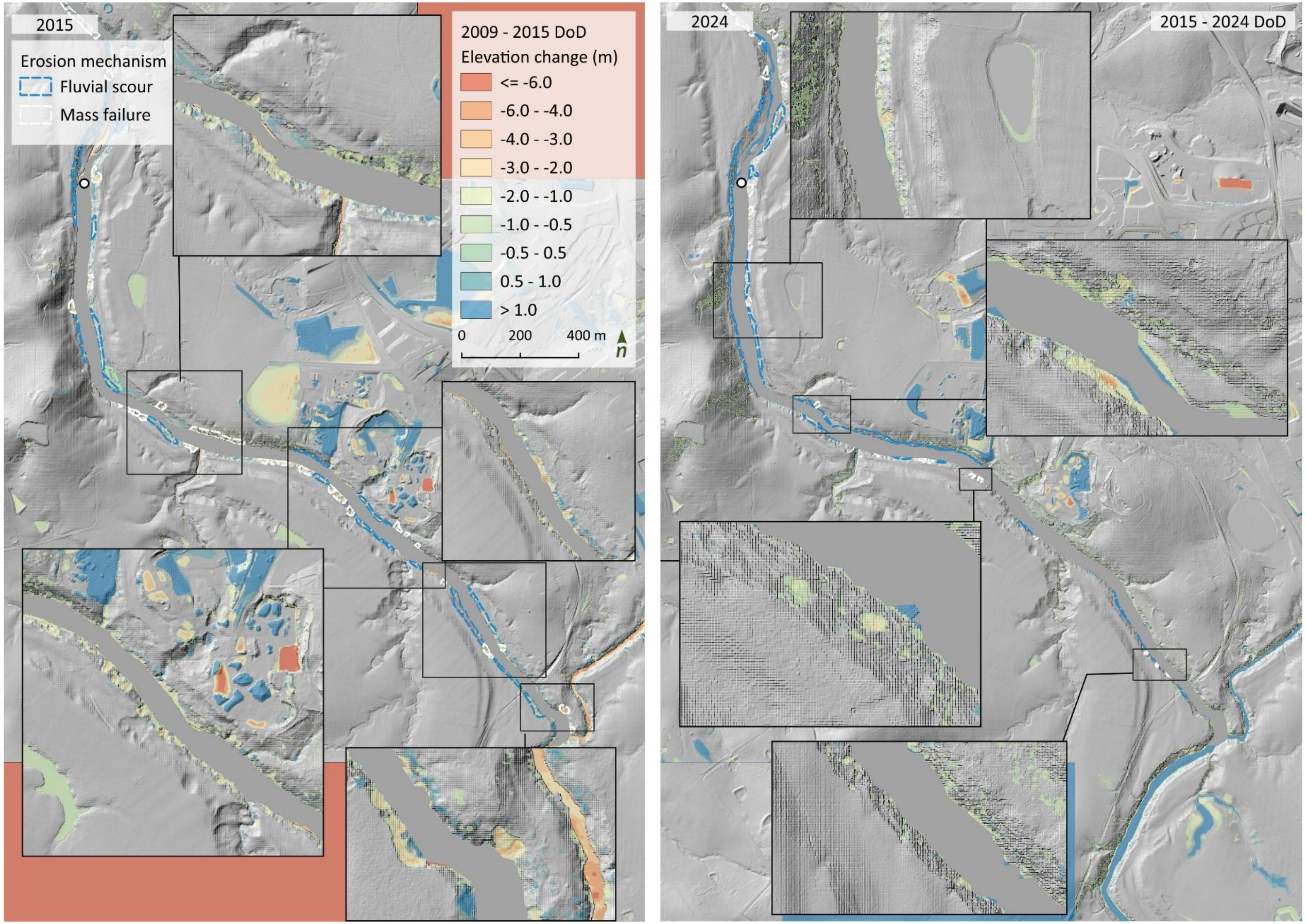


Figure 43. *Multi-temporal LiDAR analysis across Sub-reach 3 – 2009 – 2015 DoD (top), 2015 – 2024 DoD (bottom)*

Riparian condition

The riparian condition across Sub-reach 3 is presented below in Figure 44. The riparian condition across the southern side of the channel is typically highly degraded, however there is a patch of reasonable vegetation at the base of Jones Hill where the Gympie town water supply is extracted and treated (see Figure 45). The riparian vegetation extent of the northern bank upstream of The Sands is typically good through the upper half of the reach however there is a known presence of Cat's claw vine and Chinese Elm near the confluence of Six Mile Creek. The downstream portion of the northern bank is highly degraded with no existing riparian vegetation present (see Figure 46).

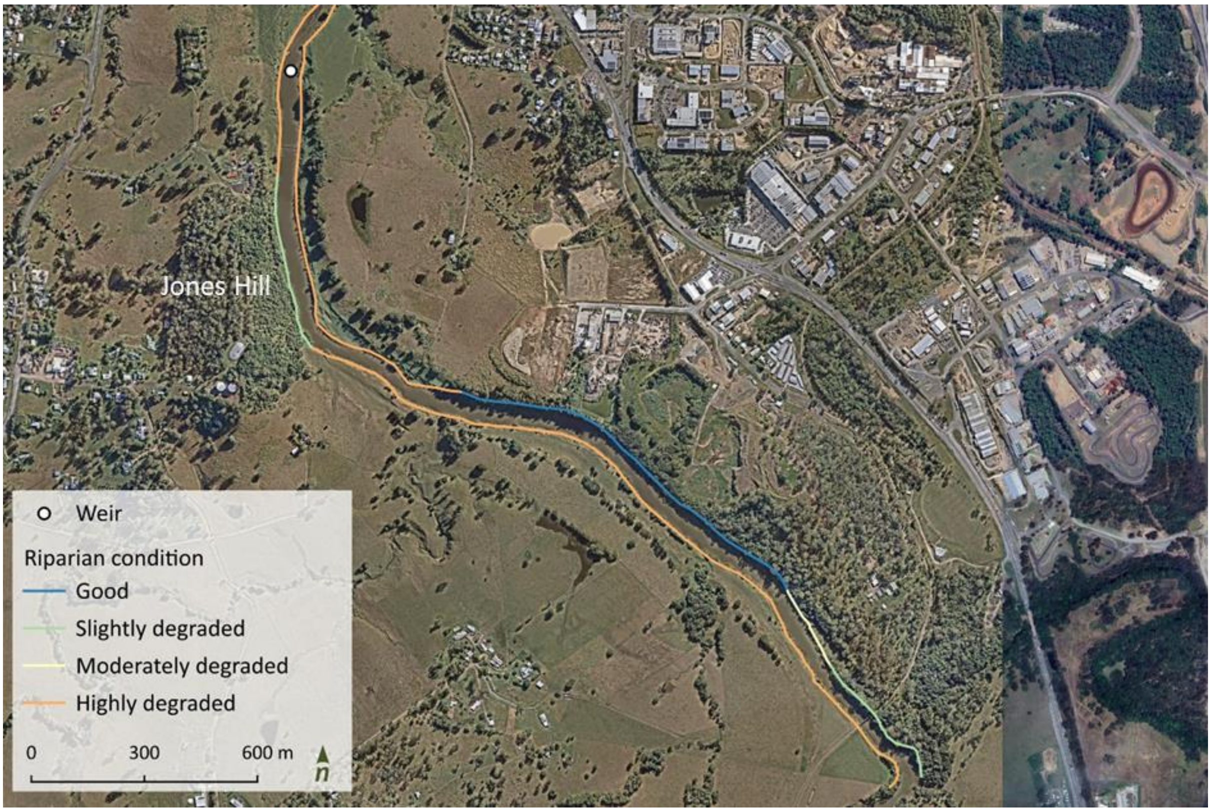


Figure 44. *Sub-reach 3 riparian condition*

Figure 45. *Example of slightly degraded riparian condition on the left bank and highly degraded riparian condition on the right bank in Sub-reach 3 – photo looking downstream*

Figure 46. *Example of good riparian condition on the right bank and highly degraded riparian condition on the left bank in Sub-reach 3 – photo looking downstream*

Erosion potential

The erosion potential across Sub-reach 3 is presented below in Figure 47. The erosion potential was classified as Low on the northern bank at the upstream extent as there is reasonable existing riparian vegetation extent and there has been minimal historic erosion. The majority of the southern bank and lower extent of the northern bank was classified as having Moderate erosion potential. The channel abuts the grazed floodplain through these sections and there is limited existing riparian vegetation. There is currently large areas of unrestricted stock access to the banks, which can result in increased erosion risk through pre-weakening or sub-aerial preparation, and limits the chance of natural vegetation regeneration. Some erosion is likely in future flood events either through wet flow failures or fluvial scour. Vegetation may be able to reduce the likelihood of future erosion. An example of a section of bank with a moderate erosion potential is presented in Figure 48.

Figure 47. *Sub-reach 3 erosion potential*

Figure 48. *Example of section of bank with a moderate erosion potential in Sub-reach 3*

Summary and trajectory

Sub-reach 3 is a partly confined stream with a macro-channel morphology. A near-continuous narrow floodplain occurs throughout the reach that is generally more extensive on the southern side of the channel. The riparian condition is typically highly degraded on the southern side of the channel, which has been heavily impacted by grazing. However, there is a patch of reasonable existing vegetation on the hillslopes and floodplain at Jones Hill. While there is relatively good riparian vegetation extent across much of the northern side of the channel, there are significant pressures from weeds including Cat's claw vine and Chinese elm particularly at the upstream extent. There has been widespread historic erosion including mass failures and fluvial scour of the highly degraded floodplains, however there are limited locations with any significant bank retreat or planform adjustment. Without management interventions, some ongoing scour and isolated mass failures would be expected particularly on the highly degraded banks. Works should focus on establishing Sub-reach scale riparian vegetation, building on the existing patches of good vegetation and limiting the impacts of adjacent pressures and threats such as weed infestations and grazing impacts.

Appropriate rehabilitation options could include riparian fencing for stock management, weed control and widespread revegetation works, which aim to increase the density and width of woody vegetation across the Sub-reach, expanding on patches of existing vegetation. Generally, works within highly degraded reaches should be implemented across a significant length of the Sub-reach (i.e. not an isolated site) to help improve recovery potential and desired riparian functions.

5 Stream rehabilitation plan

5.1 Setting management objectives

Defining clear objectives is an essential step in effective stream rehabilitation planning, as documented in most contemporary stream rehabilitation guides (e.g. Australian Stream Rehabilitation Manual (Rutherfurd et al. 2000), Technical Guidelines for Waterway Management (Department of Sustainability and Environment 2008), Stream Restoration Design Handbook (US Department of Agriculture 2007)). Clear objectives that are reachable, within the constraints and capabilities of the stream and its riparian area, will lead to better designs that perform as intended (US Department of Agriculture 2007).

The perceived success or failure of many stream rehabilitation projects can be as much a function of the selected objectives or criteria for success as the design (US Department of Agriculture 2007). Therefore, the importance of establishing achievable project objectives is critical. Clear, measurable objectives allow stakeholders to evaluate the completed project. Generalities in objectives, such as 'fixing' the stream, can lead to problems (Rutherfurd et al. 2000). Narrowing the objectives reduces ambiguity for designers, management agencies and landholders.

Measureable objectives

As a part of the project, Alluvium met with MRCCC to identify and discuss the key issues within the study area (M10 Mary River Urban Reach) and develop a set of measurable objectives to underpin priority problems identified in MRTRP (see Appendix 2; Appendix 3). The key issues, proposed interventions and long-term goals for the Urban Reach were previously defined in the MRTRP in 2001.

Review of the *Mary River and Tributaries Rehabilitation Plan*

Key stakeholder's workshopped the issues, actions and goals for the M10 in the MRTRP. Priorities were reviewed and refined to reflect the contemporary situation with respect to new information, documentation, actions and activities that have occurred in the reach in the last 25 years.

The prioritised issues identified in the study area include:

- Severe riparian disturbance including historic practices and stock access
- Weed threats to existing riparian vegetation, including:
    - Vine weeds (including Madeira Vine and Cats Claw)
    - Agricultural weeds
    - Environmental weeds (including Chinese Elm)
- Severe bank instability – streambank erosion, sediment mobilisation and bank retreat
- Reduced water quality – urban run-off, increased turbidity, stormwater, increased nutrients, pollution
- Significant depletion of aquatic habitats, instream and riparian connectivity for Threatened Ecological Communities, and iconic and threatened aquatic species including:
    - Critically Endangered Lowland Rainforest of Subtropical Australia; Platypus (*Ornithorhynchus anatinus*); Critically Endangered Mary River turtle (*Elusor macrurus*); Critically Endangered White- throated snapping turtle (*Elseya albagula*); Endangered Mary River cod (*Maccullochella mariensis*); Vulnerable Australian lungfish (*Neoceratodus forsteri*); Vulnerable Grey-headed flying Fox (*Pteropus poliocephalus*); and the Critically Endangered Native Guava (*Rhodomyrtus psidioides*)
- New threatening processes – expanding urban development and climate change impacts
- Riverbed instability and channel widening
- Increased community engagement and awareness of the Urban Reach

Following the recent review of the M10 Urban Reach priorities, measurable objectives and new and updated recovery strategies are provided in Table 9.

Table 9. Proposed rehabilitation objectives for Mary River Urban Reach, Gympie

REACH	PROBLEMS (in priority order)	MEASUREABLE OBJECTIVES	POSSIBLE RECOVERY STRATEGIES / ACTIONS
M10 – Mary 10 Mary River from Six Mile Creek, Gympie to the confluence of Glastonbury Creek, upstream of Bells Bridge.	**1 Severe riparian disturbance** as a result of historic practices and stock access.	Riparian zones and all grazed land (where stock access occurs) is protected through management controls in use by the year 2040	GENERAL **Capacity building:** Continually enhance the capacity of the community to be involved in river rehabilitation through education, extension and motivating people to adopt a culture of care for our waterways and catchment. **Partnerships:** Develop collaborative partnerships with Traditional Owner groups, NRM groups and regulatory agencies including Council. VEGETATION **Riparian management:** Maintain adequate riparian buffers and erect riparian fencing and exclude or actively manage stock access to stream. Include provision for off-stream watering and shade, and stock hardened access points. **Conserve remnants:** Support landholder incentives (i.e. Voluntary Conservation Agreements), advice and encouragement for riparian landholders to retain and manage all existing native vegetation within riparian buffers; actively conserve key areas. **Revegetation:** Implement revegetation initiatives, focussing on building linkages with remnants of conservation significance, or in good condition, and increasing vegetation on floodplains and hillslopes to slow the flow of water and reduce the power of flood events. **Weed management:** Control aggressive environmental weeds, commencing with those threatening reaches of regional or local conservation significance, then good remnant areas, etc. **Assisted regeneration:** Facilitate regeneration and other low cost vegetation establishment techniques (e.g. direct seeding, strategic seed tree planting, cuttings etc) by exclusion of stock, control of weeds and management of access by heavy equipment in riparian zones and channels.
	2 Invasion of woody and vine environmental weeds impacting bank stability and aquatic ecology.	Action to reduce threats from invasive environmental weeds commenced, invasion minimised throughout target reaches by the year 2030 and completely controlled by the year 2050.	
	3 Severe bank instability due to item 1 & 2. Accelerated meander migration, regressive erosion	All banks stabilised prioritising identified areas of high risk by 2040, at a rate of 2% per year	

			Bank stabilisation: Rehabilitation of eroding river banks, to save high value habitat (eg. In-stream habitat), remnant Lowland rainforest and revegetation, or infrastructure (eg. Riverwalk), engage best management practice techniques e.g. appropriate earthworks, rock structures, re-establishment of key fluvial geomorphic features for stabilisation, timber pile fields, intensive riparian revegetation strategies
	4a Moderate water quality problems with respect to a range of parameters and major problems with turbidity and nutrient loads after storms/flooding. State government Mary River WQ objectives that impacts aquatic threatened species **4b Pollution from debris and waste** thrown in river (rubbish from day use visitors, people dumping waste on riverbank, from bridges etc.) tyres, trolleys, wheelie bins,	Support Gympie Regional Council to adopt best management practice that meets accepted water sensitive urban design standards by 2040 Support primary producers to adopt best management practice that meets accepted water quality industry standards by 2040	**Wastewater treatment:** Progressively improve the Gympie treatment plant to the highest standard possible including water reuse to ensure all point source pollution sources meet or exceed Operating Environmental Authority requirement or water quality objectives. **Stormwater management:** Adopt urban stormwater management systems including retrofitting, reuse options from detention ponds, to reduce diffuse source urban pollution through rain gardens and re-instatement of floodplain wetland polishing where possible. **Wetland rehabilitation:** Restore and construct floodplain wetlands in Gympie, including the Lake Alford Duck Ponds to intercept runoff and remove pollutants prior to entering streams, stock wetlands with native macrophytes to assist in this process. **Unregulated flows:** Review water licence conditions in unregulated tributaries feeding M10 reach to improve dissolved oxygen and salinity problems that may result from water abstraction. **Sediment control:** Require all new development applications and infrastructure construction projects (e.g. Main Roads) incorporate the implementation and maintenance of appropriate sediment and erosion control methods into all contracts. **Water quality grants:** Provide incentives to primary producers to upgrade management actions including equipment and fencing incentives to ensure all waste waters are reused and managed in a sustainable manner to minimise nutrients entering streams.

	styrofoam etc (& microplastics) which impacts aquatic threatened species.		
	5 Significant depletion of aquatic habitats and connectivity due to all of the above, and removal of woody debris, regulation of flow, construction of weirs etc. Loss of threatened aquatic species habitat and Lowland Rainforest of Subtropical Australia that supports habitat for aquatic threatened species.	Mary River turtle no longer Critically Endangered by 2040, and resident and breeding throughout the reach. Support/enhance/ protect resident breeding populations and nesting/ general habitat. Mary River cod no longer Endangered by 2040 and is resident and breeding throughout the reach. Support/enhance/ protect resident breeding population and habitat.	**Threatened aquatic species habitat:** Encourage the retention and rehabilitation of key habitats for all threatened aquatic species in the urban reach of the Mary River. Conduct threatened turtle nest protection activities with landholders and active community members. **Fishways:** Construct a fish/turtle way/ramp with rock ramps at the Gympie Weir as a priority, road crossings and other hydraulic jumps, prioritising key habitat connectivity blockages between known cod and lungfish habitat and passage Conduct an inventory of all constructed fish passage blockages on waterways within the Gympie town reach (including tributaries). **Fish passage:** Review existing minor weirs (including the Jones Hill Weir) within the urban reach and to ensure fish passage requirements are met **Improve impediments:** Improve waterway barrier structures in waterways that inhibit fish passage and impact on natural flow regime, or construct fish ladders on productive structures.

	6a Increasing urban development	Loss of catchment terrestrial habitat through urban development and expansion. Increased impervious surfaces leading to greater runoff. Increased pollutants, stormwater (petro-chemicals, nutrients, chemicals, gross pollution, micro-plastics). Increased traffic and human impacts (impacts to wildlife from cats, dogs; road kill etc.	New urban development, point source pollution and stormwater, will meet current best management practice standard and continually adopt improvements e.g. Water sensitive urban design principles so there is no increase in run-off and pollutants Incorporate into GRC Planning Scheme water sensitive urban design, best management practice stormwater and erosion and sediment control for existing and new urban developments Form collaborative partnerships to foster and implement Integrated Catchment Management principles
	6b Climate change impacts	Unpredictable, intensified extreme weather events (drought, rainfall, temperature, storm damage). Environmental flows in this reach will be impacted by urban development,	**Water planning: Future planning** To mitigate against ongoing climate change impacts to the Mary River, GRC to develop, in consultation with the community, climate independent town water supply source to reduce reliance upon the Mary River as its sole water supply source. Refer to Water Security Strategy by GRC Water. **Water use efficiency:** Minimise household water demands by introducing urban and rural water re-use and water use efficiency, and encouraging sustainable water harvesting and off-stream storage.

		increased population and water use and climate change due to increased evaporation and reduced stream flows.	
	7 Bed instability and channel widening due to historic influence and over-extraction of sand and gravel resources. River bed in the reach is likely to be relatively stable due to prolonged absence of bed disturbance from mining and extraction activities in the Mary River and Deep Creek	Historic gold mining and sand and gravel extraction instream led to significant degradation of the Mary River channel and Deep Creek. This severally impacted on habitat for aquatic threatened resulting in diminished population viability of Mary River cod, Mary River turtle, White-throated turtle, lungfish and freshwater mullet	No further sand and gravel extraction due to historic impact on in-stream threatened **within the Urban Rivers Reach.** **Longer-term moratorium based on reach values identified in future URP programs.**
	8 Reach rehabilitation plan reviewed every 5 years.		**Rivercare:** Review The Mary River Rivercare Plan in conjunction with GRC, riparian landholders and Gympie Landcare. Review identify key tributaries that influence the urban reach of the Mary River (Six Mile Ck, Deep Ck, Eel Ck, Gympie Ck, McIntosh Ck.

			Review urban stormwater impacts emanating from the Gympie township run-off for future strategic water quality improvement planning (i.e. Lake Alford, gullies and channelised water systems etc.). Extend River Reach once objectives met in this reach (M10). Progress and provmote programs/project further up and down stream. Council to consider an ICM strategy as part of the approach.

5.2 Recommended works and costs

Overview

Riparian vegetation is the most effective long-term solution to limiting stream bank erosion and helping to achieve the broader management objectives. However, the erosion potential is so great in some zones that waiting for vegetation to reach a level of maturity required to protect stream banks from erosion may not be acceptable and structural intervention may be required.

Vegetation management actions have been devised based on an understanding of the system and processes and the management objectives and are presented below in Table 10. Management zones have been delineated based on an assessment of current condition and erosion potential outlined in Section 4. An overview of the proposed management interventions across the study reach is presented below in Figure 49.

Table 10. Management zones/actions

Management zone description
Riparian revegetation This zone represents areas with an absence of woody vegetation and low threat weeds (i.e. predominantly pasture weeds). These areas can be planted out with minimal site preparation. Areas adjacent to patches of good vegetation should be prioritised to expand the existing riparian corridor where possible. Installation of stock exclusion fencing will also likely be required across many of these zones. Some isolated bank re-profiling where there are steep slopes or erosion scarps to improve access and improve establishment conditions.
Infill planting This zone represents areas with existing native riparian vegetation where the density of vegetation could be improved. Weed management should also be undertaken to improve conditions for establishment and protect existing vegetation.
Maintain/Weed management This zone represents areas in good or slightly degraded condition where weeds can be managed to maintain or improve the condition of native riparian vegetation.
Intensive weed management followed by infill planting This zone represents areas where high threat weed species such as Cats claw and Chinese Elm are present along with native riparian vegetation. While Chinese Elm is a weed, any removal should be accompanied by replacement planting of native species. It should be noted that vegetation management may be limited by steep bank slopes and should only occur where there is feasible and safe access.
Bank stabilisation works This zone represents high threat sites where there is a high or very high erosion potential and revegetation works alone are not feasible. Works are likely to require bank profiling and toe protection such as pile fields or rock revetment to provide slope stability and enable revegetation.

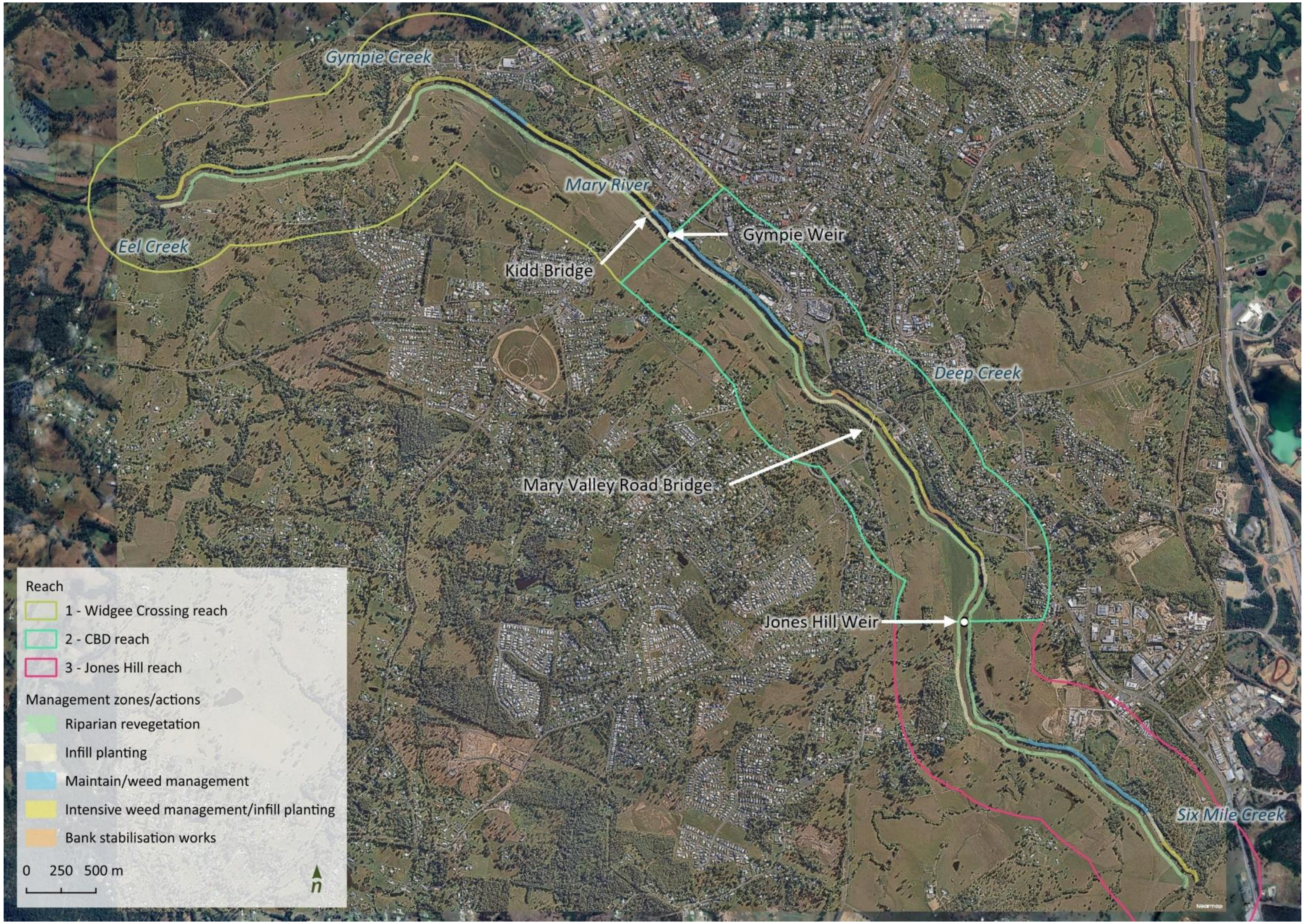


Figure 49. *Management zones/actions across the study reach*

Cost estimates

High level costs have been included for the proposed management actions outlined above based on recent stream rehabilitation works in the Mary River region. It should be noted these costs are provided as a guide only and more detailed site investigations will be required to determine factors such as fencing requirements, available planting extents, bank profiling requirements, weed types and extents. These are provided below in Table 11. Note that the costs could be significantly reduced by limiting structural intervention. Further bank retreat and sediment mobilisation would occur in zones with a high or very high erosion potential with banks that are too steep for planting, however the banks may reach a stable grade and adequate vegetation coverage if a wide enough riparian buffer zone is planted.

Table 11. Cost of implementing bank stabilisation works within the study area

Recommended works and cost	Unit	Cost ($)
Active revegetation – assuming 1 plant per1.5 m x1.5 m	m^2	8 – 10
Infill planting (depending on required density)	m^2	3 - 8
Maintenance (assuming 3 yrs including watering if required)	m^2	10 - 20
Maintain/weed control	m^2	3 - 6
Fencing	m	20
Bank stabilisation works (including earthworks and toe protection)	m	2,000 - 4000

5.3 Summary

The Mary River through the study area has undergone significant geomorphic change since European settlement. The analysis undertaken in this study indicates that ongoing channel change is likely to present further threats to water quality, private assets and significant river health values that exist in the catchment. These processes present significant economic, social and environmental risks to the broader community (Appendix 1).

This plan recommends a program of work that aims to increase the natural resilience of the system through the establishment of high quality, structurally diverse riparian vegetation. Alluvium (2011) found where very similar reaches of stream experience large floods, the reaches that have been cleared of native vegetation experience much greater erosion damage than corresponding reaches that have been revegetated over several years. Revegetating historically cleared stream systems can significantly reduce the economic costs of flood events.

Appendix 2 provides an overview of the objectives, Mary River and tributaries Rehabilitation Plan and Environmental Values.

Appendix 3 details the rehabilitation prioritisation approach developed to guide rehabilitation focus efforts in the future, based on connectivity of sites in the M10 urban reach of the Mary River.

The establishment of high quality, structurally diverse riparian vegetation through the study area will have substantial economic and environmental benefits. However, as discussed in this plan associated management interventions including structural works and stock control will be required to aid vegetation establishment.

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Appendices

Appendix 1 Factors Affecting Erosion

Erosion processes in alluvial rivers

Rivers that flow through unconsolidated sediments are known as alluvial rivers. These rivers are shaped by their flow regime, base level, sediment inputs and boundary strength. The boundary strength refers to the resistance of the bed and banks of the stream to scour, and is controlled by the characteristics (size) of the bed and bank sediments and the riparian vegetation condition.

The erosion, transport and deposition of sediment in alluvial river systems has been the subject of much scientific research. The study of the interactions between the physical forms and sediment transport processes is known as fluvial geomorphology (geomorphology for convenience in this study).

The sediment processes are of particular interest to the Mary River stakeholders. Excessive rates of erosion have an impact on river health, water supply, public and private infrastructure and ultimately the Great Barrier Reef.

Sediment yield

The amount of sediment delivered to the outlet (or any other location in a catchment) is controlled by the rate of erosion and by the rate of sediment transport. A catchment can be considered in three broad zones: sediment supply, sediment transport and sediment storage (Figure 50).

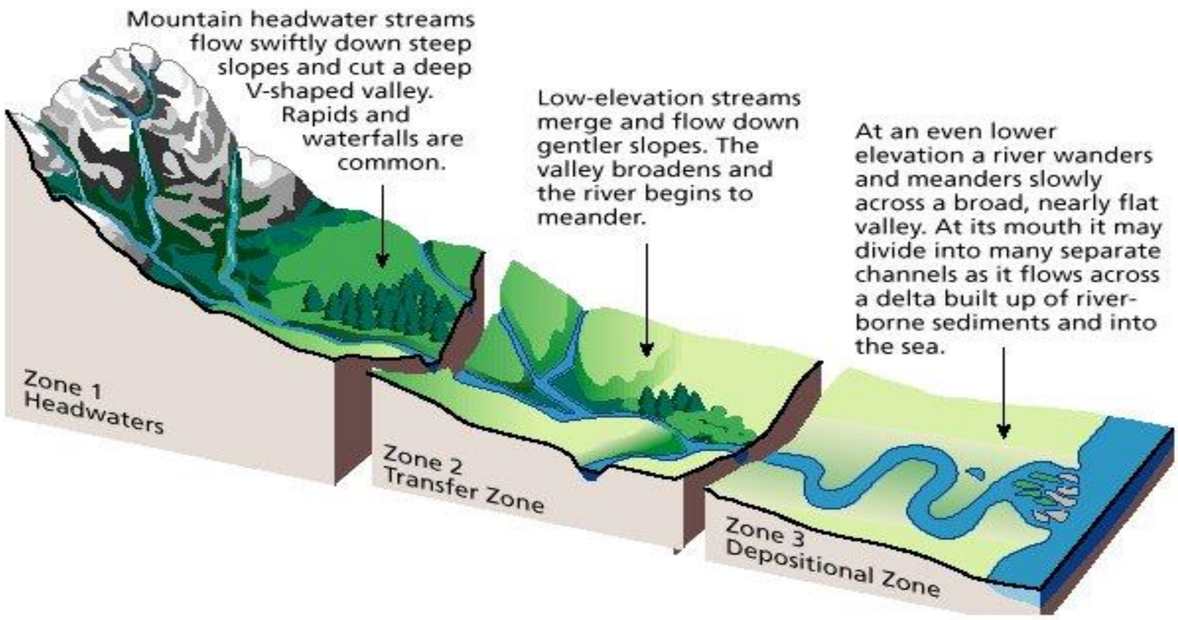


Figure 50. *Sediment zones in a typical catchment. Image reproduced from the Federal Stream Corridor Restoration Handbook (USDA 1997)*

The sediment yield to a location in a catchment is a function of the rate of erosion from source area and the rate of transport of that liberated sediment to the location of interest. Sediment is generated by erosion of hillslopes and headwaters in the upper catchment, and transferred downstream through the channel network.

The form of a channel is largely a function of the water and sediment supplied to it. Adjustments to channel form occur as a result of relationships that exist between channel form, flow and sediment transport. At the reach-scale, the type of adjustment that can take place is constrained by the valley setting, the nature of bed and bank materials, and riparian vegetation. This gives rise to a wide diversity of different channel forms.

Channel bed and bank erosion throughout the catchment contributes to the sediment entering a river system. The rate of channel erosion is controlled by factors including the flow regime (channel erosion can increase dramatically during floods), the supply of sediment to a reach, the size, shape and slope of the channel, and the strength of the bed and banks. Riparian vegetation influences a number of these factors. Tree root systems increase the strength of bank material, and above ground vegetative structures slow the flow of water and shield bank sediment from erosion. The valley width also constrains channel erosion by limiting the lateral extent of erosion.

The driving variables and boundary conditions that influence channel form and geomorphic processes are illustrated schematically (Figure 51).

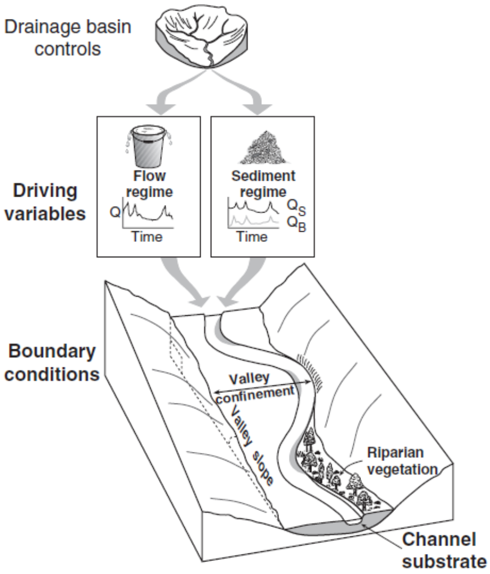


Figure 51. *Schematic representation of the factors influencing channel form and geomorphic process in alluvial rivers (reproduced from Charlton 2008)*

The rate at which sediment is transported through a river system is controlled by

- the flow regime (more sediment is transported if there are a sequence of large flows than during a long drought),
- the energy (or stream power) in the system (a steep, powerful river will transport more sediment faster than a flat, slow flowing system –straightening rivers can increase the stream energy) and
- the size of the sediment (fine sediment in suspension is transported more quickly than gravels or cobbles).

A small proportion of the sediment eroded typically leaves a catchment, because a significant volume of the sediment is stored in transient sediment sinks as it is deposited throughout the catchment. These sediment sinks include in-channel islands, bars and benches or floodplains (vegetation can help lock sediment into these sinks). Sediment can be released from storage, when it is re-eroded at a later stage, and an individual particle of sediment can be stored and remobilised many times as it is transported through a river system. Changes to land management practices (clearing or loss of riparian and catchment vegetation) can significantly increase the proportion of sediment that leaves a catchment.

The geomorphic processes that drive sediment transport operate across different spatial scales, from drainage basin or catchment to individual particles of sediment. The relationship between different spatial scales can be considered schematically (Figure 52).

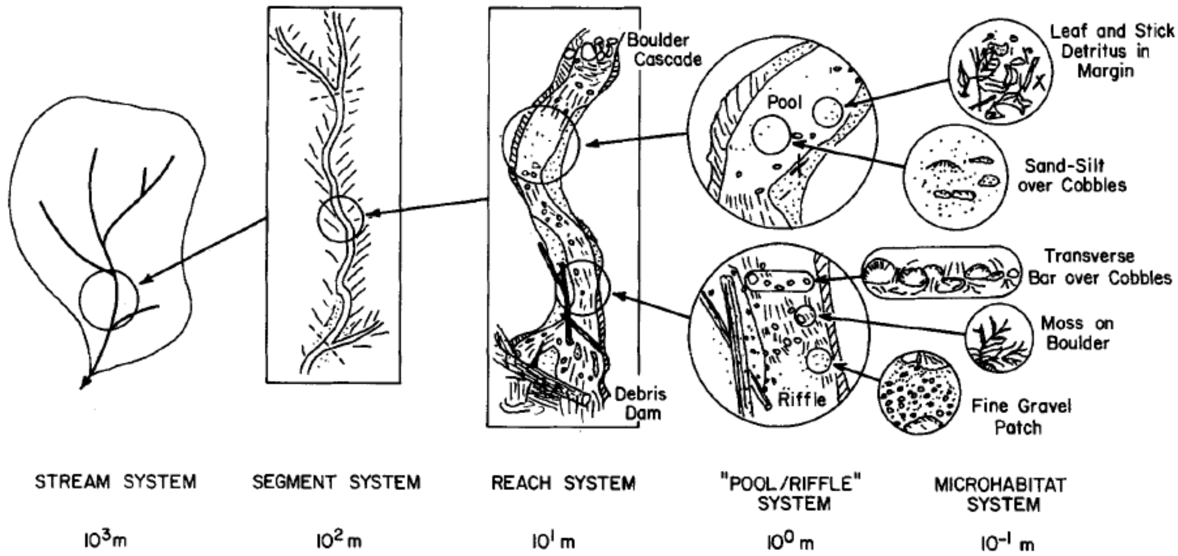


Figure 52. *Hierarchical organization of a spatial scales in a stream system (from Frissell et al 1986).*

Understanding sediment erosion and transport processes is critical to developing a rehabilitation plan that will reduce sediment yield to a receiving environment. The spatial scales most relevant to managing sediment yield are catchment to reach-scale. A range of fluvial geomorphic processes operate across these scales (see boxes below). Understanding the location of these processes in a catchment, what's driving them, and their likely future magnitude is central to effectively reducing sediment yield.

Bank erosion is a ubiquitous geomorphic process in alluvial channels. Limited rates of bank erosion is important in the development of channel forms and the functioning of a healthy stream system. The migration of channels across their floodplains involves a combination of bank erosion on one side and deposition on the other (which is often expressed through meander migration) However accelerated rates of bank erosion and bank erosion that threatens infrastructure can also create management problems when bridges, buildings, agricultural lands and roads are undermined or destroyed. Large volumes of sediment can be generated and made available for transport to downstream reaches and receiving waters.

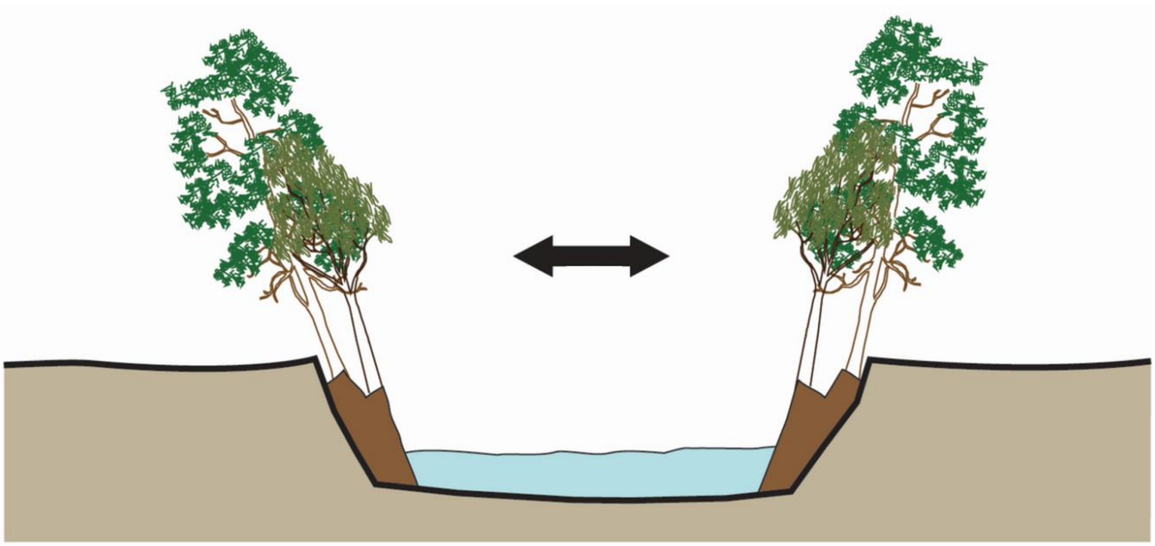
Bank erosion is often caused by a number of different geomorphic processes that can operate separately or in combination, and can be considered in three groups:

1. Pre-weakening processes such as repeated cycles of wetting and drying or cattle trampling of the substrate, which 'prepare' the bank for erosion.
2. Fluvial processes, where individual particles of sediment are directly entrained (mobilised) by flowing water.
3. Processes of mass failure, which include the collapse, slumping or sliding of bank material into the channel.

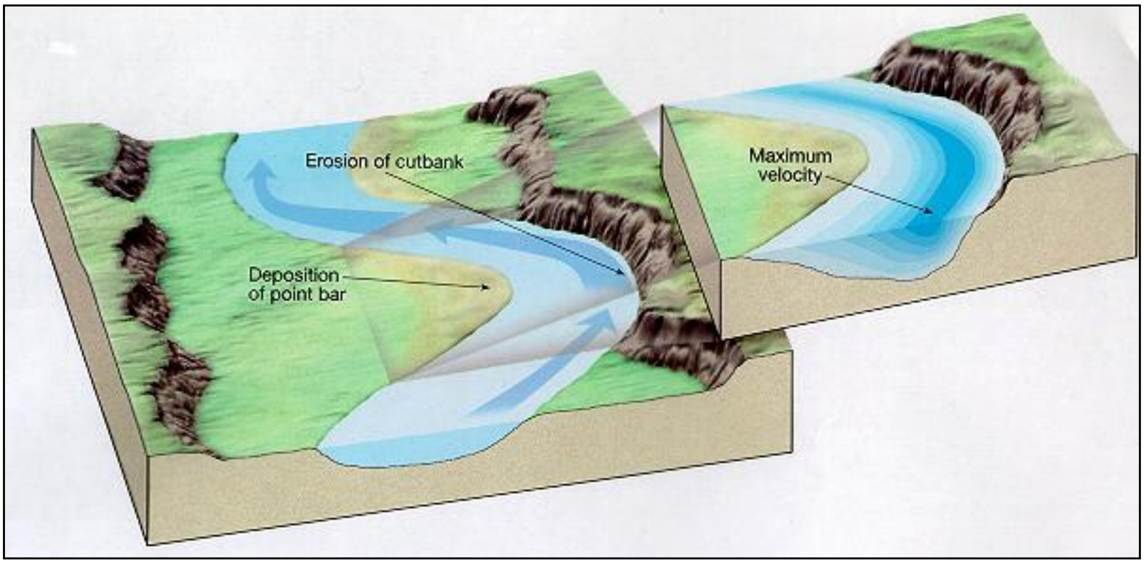
Bank erosion is an important contributor to geomorphic related management issues due to the amount of sediment it can release, and its direct impact on floodplain assets and property.

Bank erosion can be accelerated when stream power is high, sediment supply is low and suitable riparian vegetation is absent or in poor condition.

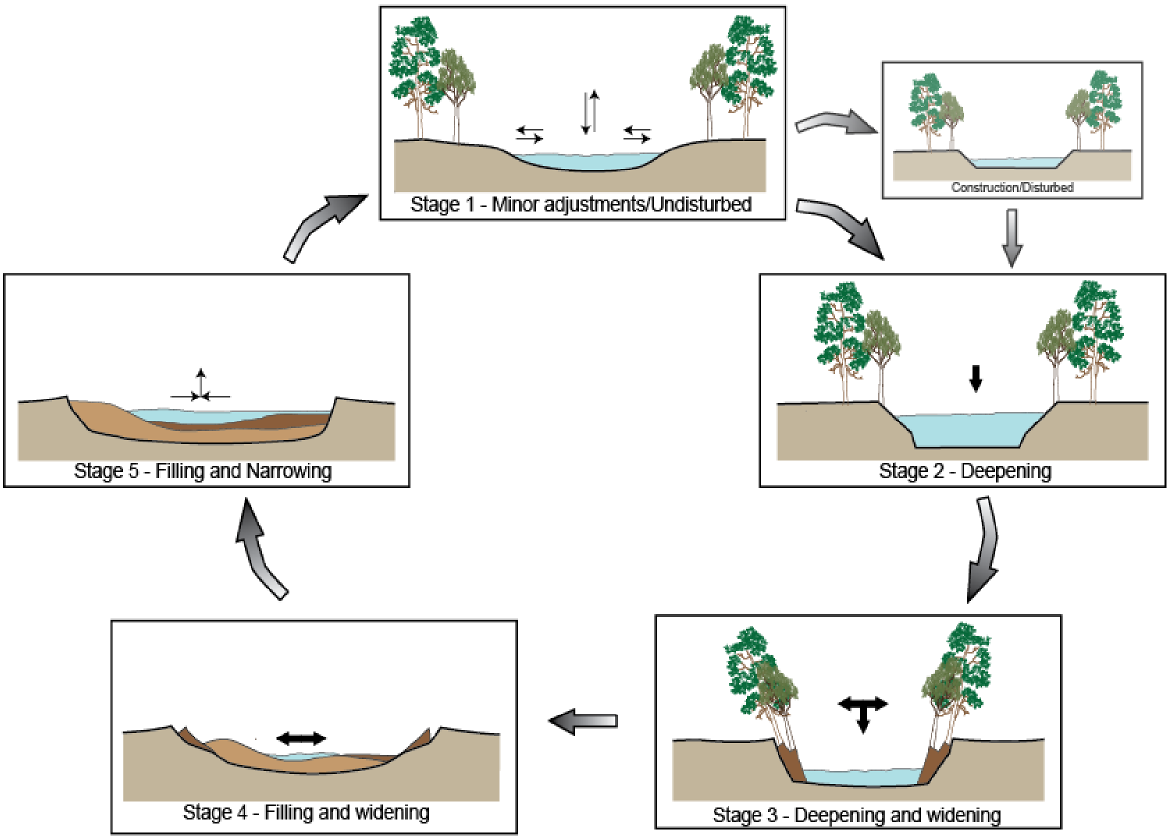
Channel widening occurs when river banks erode on both sides of a channel. Channel widening is often a symptom of a wider scale process, such as an increase in in-channel flow, arising from river regulation, channelisation, deforestation urbanisation or channel incision.



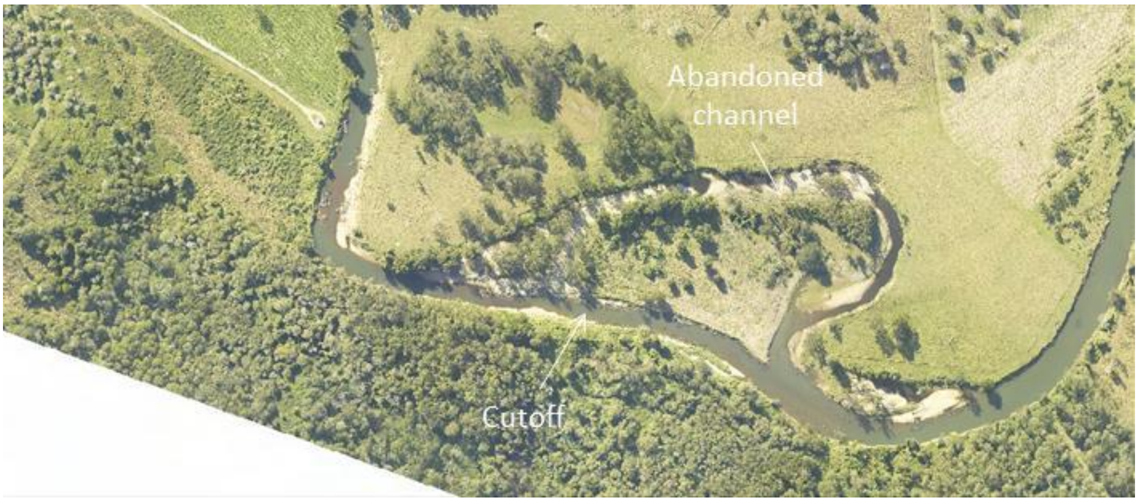
Channel migration is often associated with **meander migration**, and is driven by erosion on one bank and deposition on the other.



Channel incision occurs when the bed of the channel cuts down and causes reach-scale deepening of the channel. The deepening is then normally followed by widening. If the there is sufficient sediment supply from upstream then the widening may be followed by filling and channel contraction. Five stages of channel incision are shown conceptually in the diagram below.



Avulsions and meander cut-offs are both floodplain processes where a new, often shorter, channel is scoured leaving the previous course abandoned.



The influence of riparian vegetation on erosion – the processes at work

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 erosion resulting in damaging channel change. As discussed earlier there is a range of erosional processes that can occur independently or in unison resulting in channel change. Abernethy and Rutherfurd (1999) define three erosion categories as:

1. **Subaerial erosion –** erosion by processes external to the stream (i.e. cattle pugging, desiccation, groundwater seepage)
2. **Fluvial scour –** erosion resulting from the entrainment of bed and bank sediments due to hydraulic forces exceeding the resistance force (e.g. cohesion, gravity etc.)
3. **Mass failure –** erosion caused when large volumes of bank material slide or topple from the bank into the channel.

Riparian vegetation plays an important role in minimising the rates of erosion in each of these three erosional categories. However, for each category different types of vegetation impact on the processes differently. Furthermore as highlighted by Abernethy and Rutherfurd (1998), the means by which different types of vegetation impact on erosional channel change is also dependant on the location within the catchment. A summary of how different vegetation types limit each of the three erosion categories is given in Table 12.

Table 12. Vegetation and its influence on each of the three erosional processes (adapted from Abernethy and Rutherfurd, 1998)

Erosion process	Vegetation interaction
Mass failure	Root reinforcement – Riparian trees strengthen bank substrate and tend to resist mass failure. The extent of reinforcement is dependent on root strength and the density of the root structure. The effect of the roots is to increase the effective cohesion of the sediments. The longer and more extensive the root network the greater the degree of reinforcement. As a result, smaller shrubs and grasses are less effective at limiting mass failure. (Abernethy and Rutherfurd 2000) Bank moisture – Saturated banks are less stable than unsaturated banks as water increases the weight of the bank, encouraging mass failure. All vegetation types decrease the level of bank saturation by intercepting precipitation and by transpiration (Abernethy and Rutherfurd 2000)
Fluvial scour	Resistance of bank material – Vegetation on the bank increases cohesion and bank strength through the root networks. Smaller shrubs and grasses, which have limited impact on mass failure processes, are more effective at limiting the ability of bank sediments to be entrained due to their more extensive coverage of the bank surface area (Blackham 2006). Near bank velocities – Vegetation increases hydraulic roughness, which reduces near bank velocities. The shear force exerted against the bank is thus reduced. The impact of vegetation on hydraulic roughness is complex and varies with type of vegetation and discharge. At low flow, grasses and shrubs that stand rigid have a high wetted surface area and provide hydraulic resistance (Blackham 2006). As discharge increases, the herbaceous vegetation often cannot withstand the force and is flattened against the bank. Hydraulic resistance is reduced but the vegetation protects the bank substrate from erosion (Abernethy and Rutherfurd 1999). Large trees provide minimal resistance during low flow but as discharge increases their large trunks and branches provide the majority of the resistance once the herbaceous vegetation has been flattened.
Sub-aerial preparation	Piping – Seepage of water can lead to leeching and softening of the bank material making the bank more susceptible to mass failure. Vegetation can reduce the onset of saturated flow through evapotranspiration. However, cavities from decomposed roots can encourage subsurface flow. The risk of this can be reduced with an appropriate suite of riparian vegetation. Desiccation – Dry and cracking banks are more susceptible to mass failure. Vegetation can reduce desiccation by binding the substrate together. (Wynn and Mostaghimi 2006).

Importantly, and as outlined in Table 12, for these different forms of erosion, vegetation plays two critical roles in limiting channel change:

4. **Hydraulic (frictional) resistance**: **According to** Anderson and Rutherfurd (2003) riparian vegetation adds additional resistance elements in the main channel and on the floodplain of waterways such that flow velocity and conveyance are reduced. As a result:

   - In-channel stream power is lower in vegetated reaches compared to systems with bare banks, and
   - near bank stream velocity is lower in vegetated reaches compared to systems with bare banks
   - Flood wave speed is also reduced through vegetated channel networks

5. **Structural protection to the stream bank**: The vegetation provides structural reinforcement to the bank material increasing the cohesive properties of the soil.

A single vegetation species will generally not limit erosion and downstream flood wave speed; a suite of vegetation types is required. This suite of vegetation includes instream vegetation, stream bank ground covers, shrub species and trees. This suite of vegetation is typical of south east Queensland's remnant native riparian vegetation.

Appendix 2 Objectives, MRTRP Strategies and Environmental Values

Objective	MRTRP recommended recovery strategies/ actions	Values protected
Increase the erosion resistance of channel bed, banks and floodplain so they have a greater probability of withstanding flood events with a similar magnitude as 2022 (i.e. approx. 50 year ARI event) without major channel change.	• PA: Channel recovery • PE: Bank stabilisation	• Reduce the loss of public assets (water offtake, Jones Hill Water Treatment Plant, parks, roads/paths, utility infrastructure, and private land and assets • Reduce sediment and nutrient loads to downstream receiving waters
Protect and where possible increase threatened species populations through habitat protection and enhancement	• FG: Cod habitat	• Mary River turtles • White Throated Snapping turtles • Lungfish • Mary River Cod • Grey Headed Flying Fox • Other river health values (i.e. water quality, fish, macroinvertebrates etc.)
Protect and where possible increase riparian vegetation condition extent (laterally and longitudinally)	• VA: Riparian management • VB: Conserve remnants • VC: Revegetation • VD: Weed management • VE: Assisted regeneration • PE: Bank stabilisation	• Ecosystem values of a riparian vegetation zone • Habitat values • Other river health values (i.e. water quality, fish, macroinvertebrates etc.) • Reduce sediment and nutrient loads to downstream receiving waters
Protect and where possible improve water quality through bank stabilisation and riparian management	• VA: Riparian management • VB: Conserve remnants • VC: Revegetation • VD: Weed management • VE: Assisted regeneration • PE: Bank stabilisation	• Water supply • Stormwater discharge • Sewage treatment discharge

Riparian vegetation establishment

The riparian zone can be defined as the land that adjoins, directly influences or is influenced by a river or stream. Riparian vegetation protects instream biota from poor water quality by reducing pollutants in runoff from adjacent areas. The shade provided to the waterway by riparian vegetation provides stable water temperatures which is important for native animals, particularly Mary River Cod breeding. Detritus supplied by riparian vegetation is an important source of food and energy to the in-stream ecosystem and wood is an important source of shelter and habitat for instream biota. Riparian vegetation also provides geomorphic stability which also has a water quality benefit.

The establishment of high quality, structurally diverse riparian vegetation within the study area can achieve or assist to achieve all the management objectives for this reach of the Mary River. This includes the following strategies:

1. Increase the erosion resistance of channel bed, banks and floodplain as described in Appendix 1
2. Create stable and diverse bank morphology which can provide nesting habitat for Critically Endangered Mary River turtles, white-throated snapping turtles and other terrestrial and aquatic fauna
3. Increase and enhance instream physical form and diversity
4. Trap lateral inflows of sediment and nutrients from adjacent floodplains

However, this vegetation will take time to reach a level of maturity, structural diversity and robustness that allows it to perform the desired functions outlined above. The change in the function provided by vegetation (e.g. erosion resistance) through time is referred to as its trajectory of change, or trajectory, and is illustrated conceptually below in Figure 53. In the following sections recommendations relating to riparian vegetation establishment along the banks, within the channel and along the floodplain are outlined. These recommendations reflect the risk (likelihood and consequence) of erosion occurring during the vegetation establishment phase.

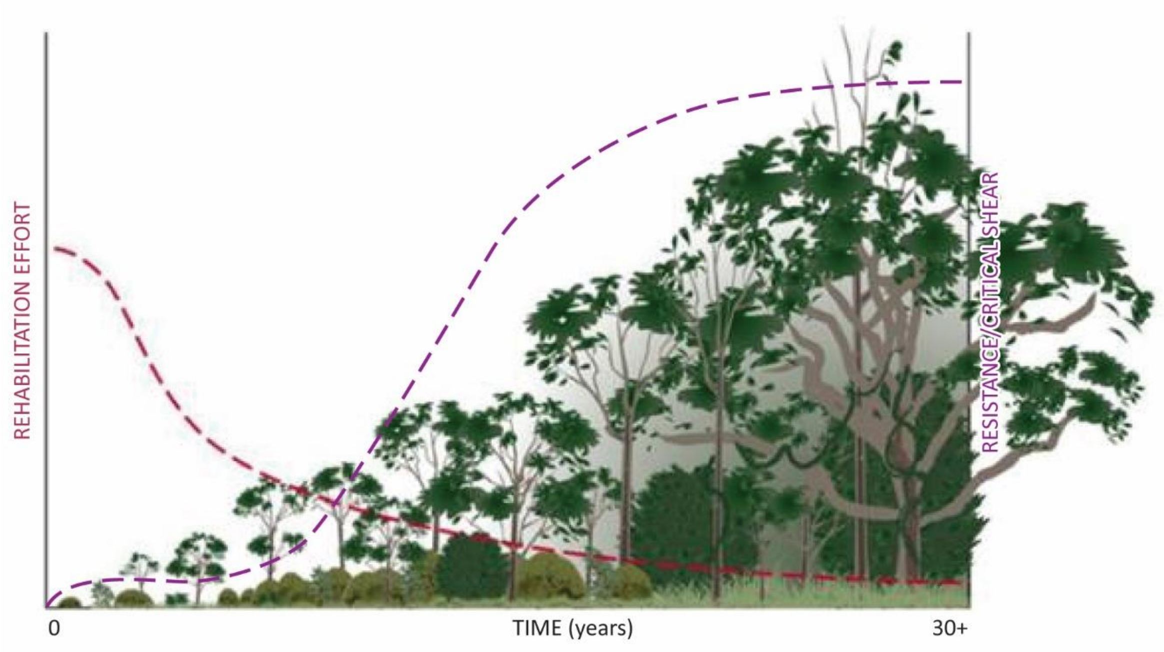


Figure 53. *Progressive long-term improvement in river health and erosion resistance with gradual reduction in rehabilitation effort (source: Department of Sustainability and Environment (2004)).*

Within the study area the riparian area contains a variable extent of riparian vegetation, including sections with moderate to good riparian vegetation. However, the vegetation is under threat from Cat's claw creeper and other weedy vines. The climbing weed can overtop and kill mature trees, opening up the canopy and allowing weeds to establish in the understorey. This can lead to further degradation in the structure and composition of the native vegetation community. Cat's claw creeper threatens the remaining native vegetation community, particularly along the northern banks which could result in increased rates of erosion and sediment export.

5.4 Prioritisation approach

A prioritisation approach was developed to help guide where to focus the rehabilitation efforts within the study reach. The approach is summarised below.

Summary

In order to increase a river corridor's capacity to absorb the impact of floods and continue to provide associated ecosystem services, it is important to (see **Figure 54**):

1) identify which biophysical characteristics of a river corridor contribute to the capacity to absorb the effects of floods (i.e. ***what***)
2) establish how these characteristics can be maintained or enhanced through waterway management interventions (i.e. ***how***) and finally
3) identify where in a river network such interventions will be most effective (i.e. ***where***).

Further details of each of these points and how they are incorporated into the strategy is provided below.

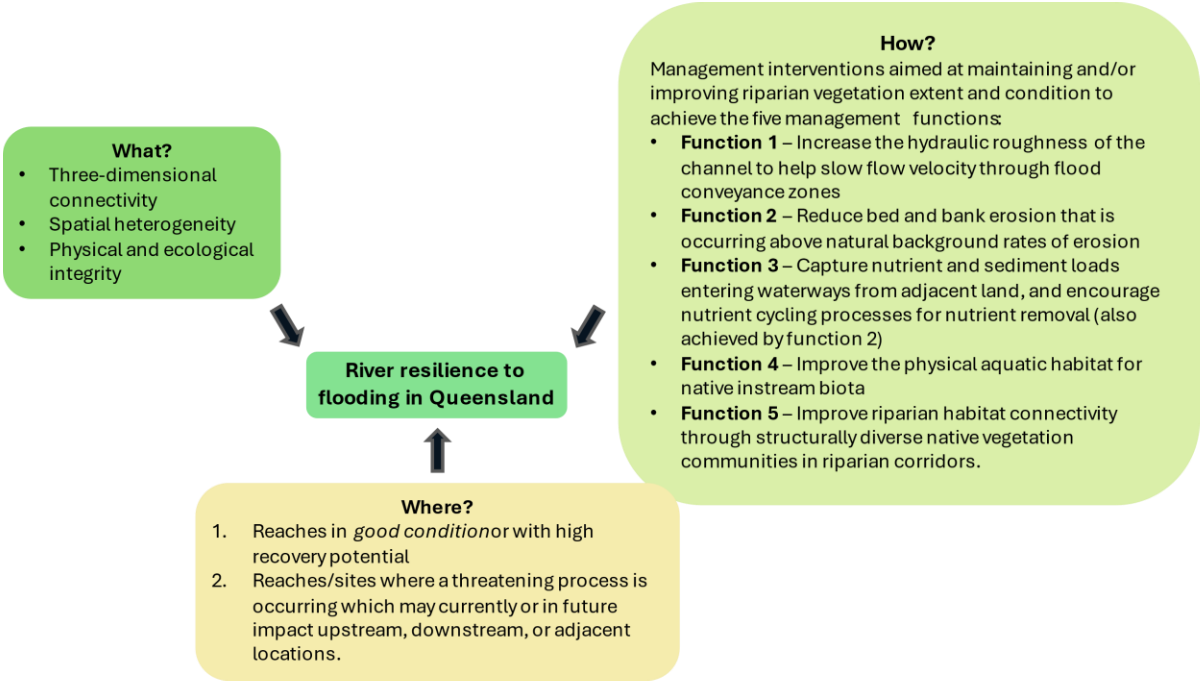


Figure 54. *Schematic showing the factors influencing river resilience to flooding in Queensland (adapted from Wohl (2024)).*

What biophysical characteristics of a river corridor contribute to its capacity to absorb flood events?

The biophysical characteristics that contribute to the absorbing capacity of a river corridor include (Wohl, 2024; Rahel, 2012):

- three-dimensional connectivity - the ability for materials and organisms to move up and downstream, between the channel and floodplain and between the surface and subsurface.
- spatial heterogeneity – diversity within the river corridor, providing storage for materials moving downstream and refugia for organisms during and after the flood event, and
- physical and ecological integrity - the degree to which the physical characteristics and biological communities in the river corridor are natural, rather than altered by humans.

How can these characteristics of a river corridor be maintained and enhanced?

- Management interventions: Vegetation (both riparian and floodplain vegetation) is the primary attribute that we can influence to enhance river resilience and achieve the biophysical characteristics described above. A range of waterway management approaches can be employed to maintain or enhance vegetation extent and condition, including weed control, riparian revegetation, increasing riparian buffer width, streambank stabilisation works to enable successful vegetation establishment and protect adjacent vegetation, bed control works to limit channel incision processes and promote vegetation recovery, and increasing floodplain roughness with vegetation.
- Management objectives: The biophysical characteristics of three-dimensional connectivity, spatial heterogeneity, physical and ecological integrity (see above) increase the capacity for a river corridor to absorb the effects of flooding. These three biophysical characteristics can be maintained and enhanced by improving riparian vegetation extent and condition. Improving the riparian vegetation extent and condition can help the delivery of key ecosystem services, cultural values and functions. We have identified five key reach-scale management functions aimed at improving the extent and condition of riparian vegetation to enhance ecosystem service delivery (Table 13). We believe that these five functions optimise the ecosystem services provided by riverine-floodplain ecosystems affected by floods, and hence allow us to prioritise actions across the reach to optimise these services, and increase resilience to flooding. Achieving these five management functions will help achieve river resilience and the management objectives outlined in Table 9.

Table 13. Management functions (achieved through riparian revegetation works) to enhance riverine ecosystem service delivery.

Management functions	Riverine ecosystem services enhanced
1. **hydraulic roughness** of the channel to help slow flow velocity through flood conveyance zones	• Surface water supply • Ground water supply • Regulation of baseline flows and extreme events • Reduce erosion (next objective)
2. **Bed and bank erosion** that is occurring at rates above natural background rates of erosion.	• Regulation of baseline flows and extreme events • Food production • Water quality regulation • Recreational activities • Aquatic habitat • Surface water supply
3. **Capture nutrient and sediment loads** entering waterways from adjacent land, and encourage nutrient cycling processes for **nutrient removal** (also achieved by function 2)	• Surface water supply (for consumptive uses) • Water quality regulation
4. **Physical aquatic habitat** for native instream biota	• Aquatic habitat • Water quality regulation
5. **Riparian habitat quality** and longitudinal connectivity through structurally diverse native vegetation communities in riparian corridors.	• Water quality regulation • Local climate regulation • Recreational activities • Aesthetic appreciation • Intellectual and representative interactions with natural environment

If these five management functions are achieved, a river corridor is more likely to maintain a self-adjusting regime of processes, functions, and set of feedback mechanisms that sustain and/or improve river ecosystem health and, therefore, allow that corridor to better absorb the impacts of flood events. Therefore, by achieving these functions, ecosystem services, cultural values and other functions of the river system are more likely to be maintained in the event of a future flood.

Where in a river should be targeted for management interventions?

This prioritisation approach adopted for this strategy expands on a 'prioritisation protocol' developed by Agnew and Fryirs (2022) for NSW rivers to ensure it is relevant to the QLD context. Similar to the approach outlined by Agnew and Fryirs (2022) (and the River Styles© Framework more broadly), this approach identifies different types of interventions within three types of Sub-reaches, which have been defined based on an understanding of the existing condition, recovery trajectory and geomorphic processes occurring within a reach:

- **Protection** reaches refers to reaches that are currently in 'good condition'. The condition of these reaches should be *maintained* by firstly identifying where these reaches are located and then ensuring that over time, external pressures and threats are reduced. They may not require any active rehabilitation at present. These reaches will serve as a focal point from which to expand rehabilitation efforts, if adjacent reaches have high recovery potential.
- **Recovery** reaches refer to reaches that are 'degraded' to some degree. Management intervention within these reaches aim to improve the condition of the reach removing pressures and threats (e.g. through fencing and weed management) and active riparian revegetation to enhance resilience.
- **High threat** reaches or sites refer to reaches/sites in which a threatening process is occurring, which may currently or in future impact upstream, downstream, or adjacent locations. Examples of threatening processes include an imminent meander cut-off, head cut migration, bank retreat occurring above natural rates of erosion. High threat reaches/sites often require civil works to address the threatening process.

Method for identifying threat reaches/sites

Throughout the study reach high threat sites have also been identified where there is active geomorphic adjustment. Intervention is often required in areas where accelerated rates of erosion and/or sediment pulses are impacting adjacent areas and/or upstream and downstream reaches. Often this type of intervention is expensive and requires extensive earthworks, and/or structural toe protection to support native riparian vegetation establishment and river recovery. Areas with extensive existing vine weed infestations have also been classified as high threat zones as it threatens existing stands of good vegetation.

Prioritisation of reaches/sub-reaches and actions

Protection and *recovery* reaches (described above) should be prioritised based on the following procedure:

- Priority 1 – maintain reaches in *good condition*, classified Protection Reaches. Protection Reaches already provide flood resilience and support ecosystem services and must be maintained*;* sometimes High Threat Reaches/Sites within, upstream or downstream will have to be managed to maintain the existing condition of these reaches.
- Priority 2 – *Slightly degraded* Recovery Reaches connected to reaches in *good condition*. These reaches are likely to have high recovery potential and their location next to reaches in *good condition* means recovery can be accelerated by natural exchange, dispersal, and migration processes, making rehabilitation more sustainable. Targeting these reaches expands and strengthens the length of corridor in *good condition*.
- Priority 3 – *Slightly degraded* Recovery Reaches not connected to reaches in *good condition*. These reaches are likely to have high recovery potential. Over time, these reaches will serve as a new focal point from which to expand corridors in *good condition*.
- Priority 4 – *Moderately degraded* Recovery Reaches connected to reaches in *good condition*. These reaches are likely to have lower recovery potential and more intensive interventions are likely to be required. Risks associated with implementation of management interventions (i.e. erosion rates, hydraulic forces, bank stability/slopes and weed pressures) must be understood for successful implementation to occur. Being adjacent to reaches in *good condition*, recovery may be accelerated once the pressures and threats are managed.
- Priority 5 – All other areas. These reaches are likely to have lower recovery potential, and more intensive interventions are likely to be required. Risks associated with implementation of management interventions (i.e. erosion rates, hydraulic forces, bank stability/slopes and weed pressures) must be understood for successful implementation to occur.
- Prioritisation of High Threat reaches. Threatening processes can occur anywhere within a catchment. The prioritisation of *High Threat* reaches and/or sites should be based on an assessment of the threatening erosional process and its trajectory, identification of the pressures or threats contributing to the threatening process, identification of impacts of the threatening process, and an assessment of cost effectiveness (in terms of flood resilience) of the proposed management intervention.

The prioritisation approach is summarised in Figure 55, with the approach for *protection* and *recovery* reaches on the left, and the approach for *high threat* reaches on the right. Historically, there has been a strong emphasis on investing in the rehabilitation of high threat sites/reaches to manage the threatening process within a short timeframe. In future, equal emphasis should be placed on investing in protection and recovery reaches to enhance the natural recovery processes of river systems. Whilst it is important to manage high threat reaches/sites, investing in protection and recovery reaches promotes broader, reach-scale recovery and is a more cost-effective approach to enhancing resilience to future flood events and encouraging the ongoing provision of ecosystem services.

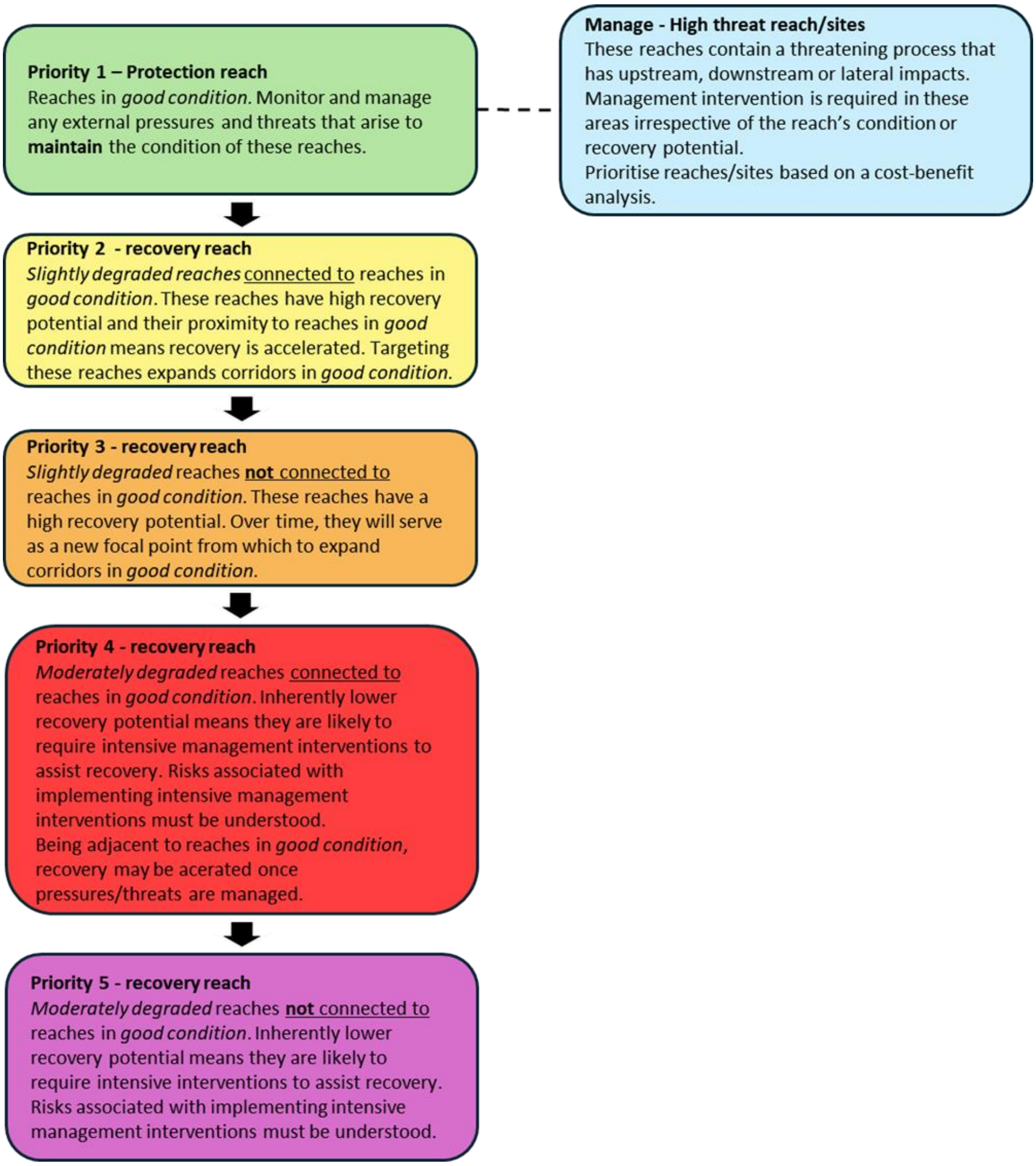


Figure 55. *Prioritisation approach for implementing on-ground reach-scale rehabilitation works to increase the resilience of QLD waterways to flooding.*

The prioritisation approach was applied to the Sub-reaches delineated above based on the existing riparian condition. The results of the prioritisation for rehabilitation works across the study reach is presented below in Figure 56.

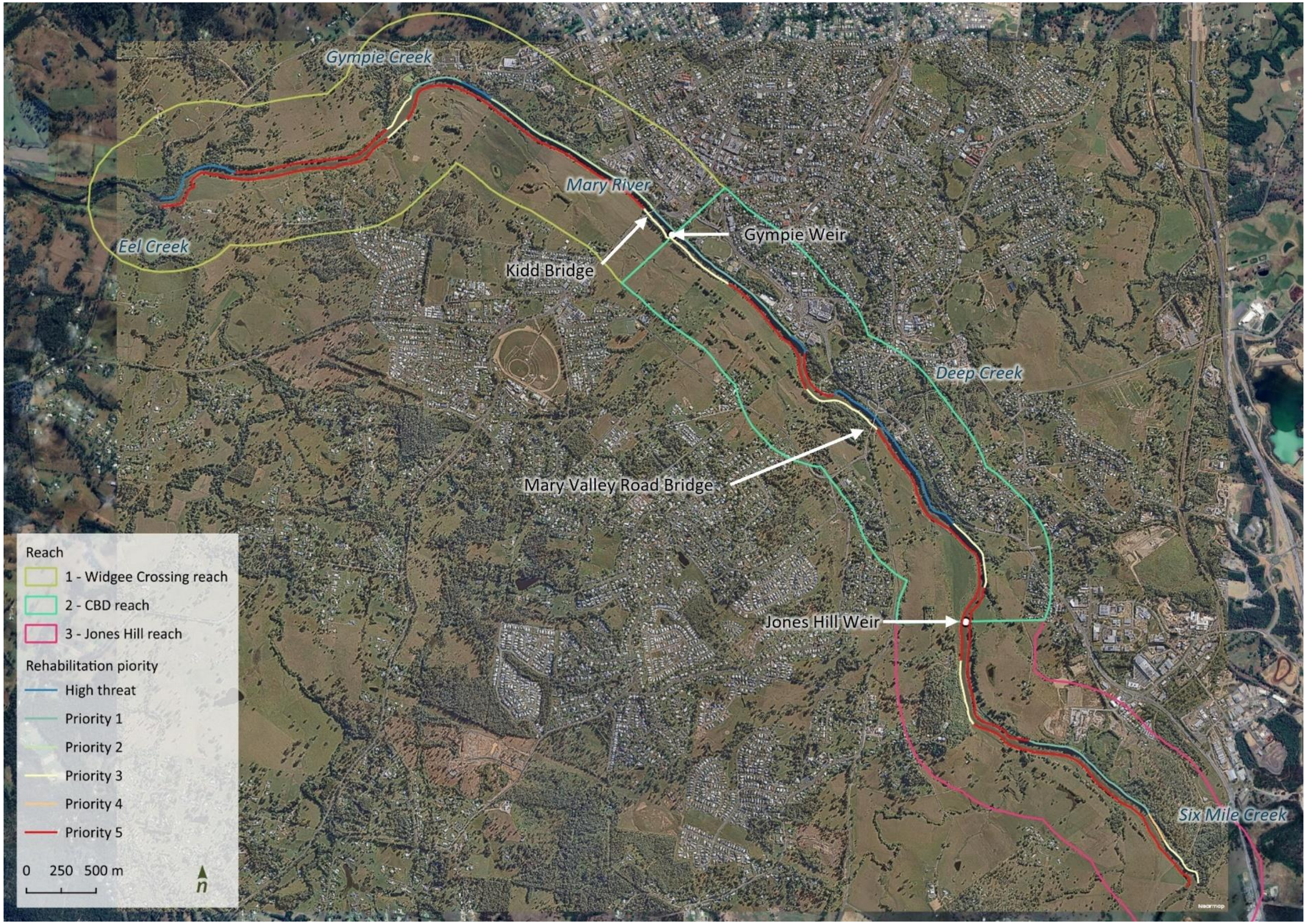


Figure 56. *Overview of rehabilitation prioritisation across the study reach*