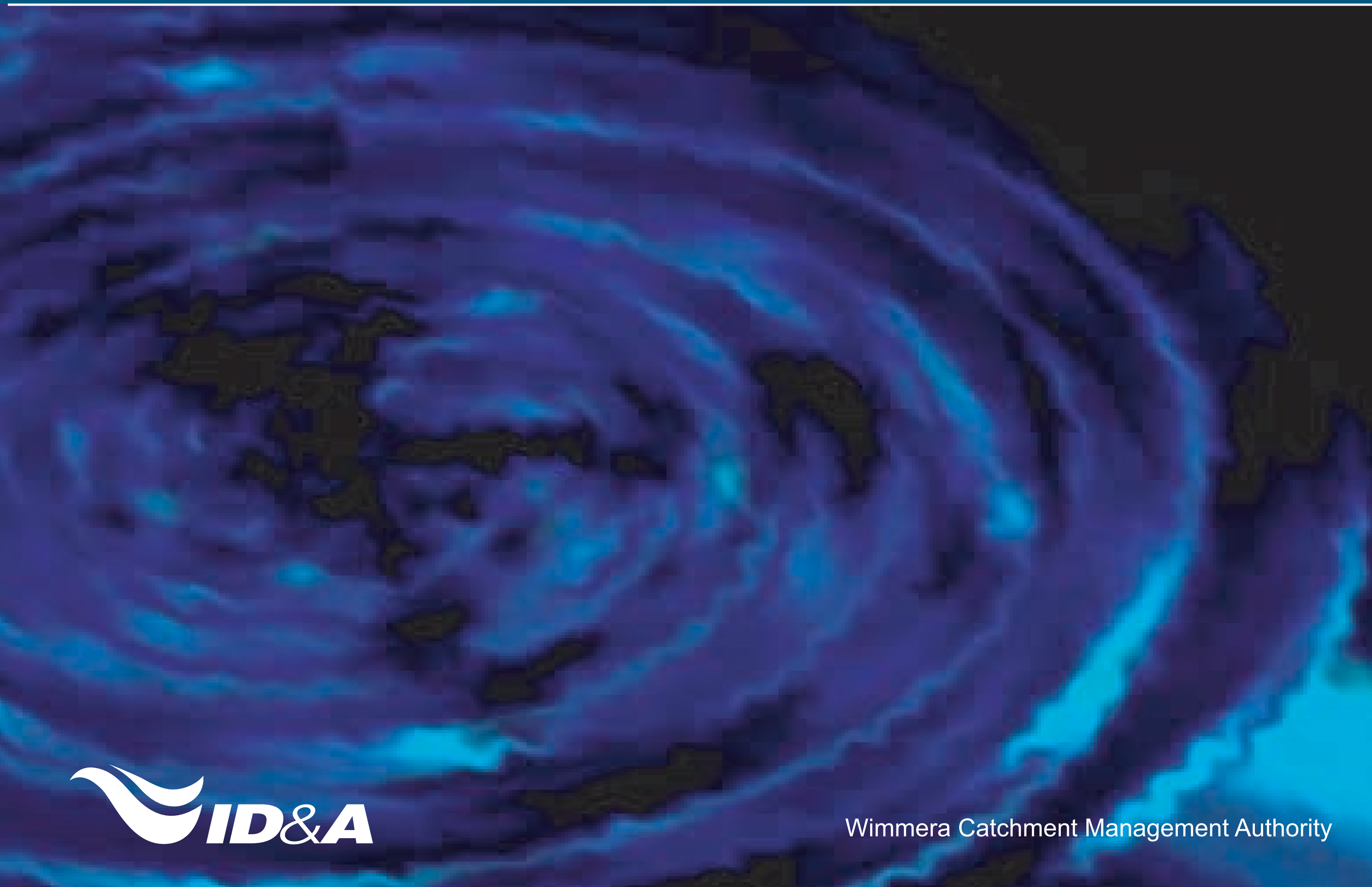


Wimmera River Geomorphic Investigation

Sediment Sources, Transport and Fate



ID&A

Wimmera Catchment Management Authority

Summary

This is an investigation undertaken by ID&A Pty Ltd for the Wimmera Catchment Management Authority. The investigation comprises a revue of and analysis of sediment processes within the Wimmera Catchment. The purpose of the investigation has been to increase the understanding of processes to assist the ongoing management of the Wimmera River and Tributaries.

The focus of the investigation has been on geomorphic processes within the Wimmera River and specific tributaries that are thought to be having an impact on the health of the Wimmera River.

For the purpose of the investigation the Wimmera River has been divided into 20 management reaches. These reaches are based on the geomorphic character and behaviour of the river. Some reaches in the upper catchment have been sub-divided based on contemporary changes in character. The majority of the river is alluvial and continuous. There are however, 3 alluvial discontinuous reaches in the upper catchment. There are also several confined reaches that have controls imposed on them by bedrock and terraces.

The investigation has broadly examined the extent of gully erosion in the upper catchment areas and focussed attention on those tributaries likely to be having an impact on sediment loads in the Wimmera River. It has been found that many tributaries floodout, depositing much of their sediment load, before reaching major streams. There are however, streams that are delivering excess sediment loads to the Wimmera River, such as Glendhu Creek. Given the natural geomorphic character of the river at Glendhu Creek is a Chain of Ponds (Cut and Fill) and the contemporary (anthropogenic) change to a continuous incised channel, the excess sediment loads from gullying in Glendhu Creek may assist in restoring the natural values of this reach (if so desired).

Part of this investigation has analysed the changes that have and are likely to occur in flooding, particularly in the middle reaches of the river. Analysis of hydrology, hydraulics and effective discharge found that the likelihood of overbank flow events is less now then what it was in the early part of last century. This result indicates that works to extract sediment, vegetation and debris from the channel to reduce a perceived increase in flooding may not be warranted. Such work may also be detrimental to stream health.

Reaches 2, 4 and 6, the discontinuous alluvial reaches, are high priorities for management intervention. These reaches are naturally major sediment stores in the river system. Within these reaches there is the potential to preserve rare geomorphic and ecologic features and provide protection for high value downstream reaches. Management works should also be undertaken in those tributaries that are delivering excess sediment loads to the Wimmera River.

The majority of the mid and lower Wimmera River is in good geomorphic condition. Management strategies should be set in place to protect those values. Rehabilitation of stream health in these reaches requires changes to flow management and continuing improvement in land management.

Location	Attribute	Actions
Reaches 2.1 & 2.3, Glenlofty Creek, other tributaries	Intact Chain of Ponds/Freshwater Meadows (Fill Valleys)	Protection through stability assessment, grade control, maintenance of structures, vegetation and stock management works
Reaches 2, 4 & 6	Degraded or recovering fill valleys	Educate community on type of river that naturally exists here. Set objectives for management.
Reach 6.2	Sediment Accumulation Zone	Ensure this continues to function as an effective sediment trap to protect downstream reaches.
Tributaries delivering coarse sediment to river	Degradation of geomorphic function and ecological values	Erosion and transport control measures to reduce coarse sediment inputs to Wimmera River
Reaches 7 to 10	High value habitat	Protection of good condition reaches and rehabilitation works in locally degraded sections
Reaches 14 to 20	Heritage River Corridor	Protection of near intact reaches and rehabilitation of locally degraded sections.

***Table S1** High Priorities for Management of the Wimmera River*

Contents

Introduction

This is a report by ID&A for the Wimmera Catchment Management Authority (WCMA). The report comprises the results of an investigation into geomorphic processes, particularly sediment sources, transport and fate in the Wimmera River Catchment. The purpose of the investigation was to identify sediment processes within the catchment to assist the development of Waterway Management Programs in the region.

This investigation has reviewed a wide range of previous work and information sources on the river and catchment. Investigations have included desktop reviews, targeted field investigations, data collection, modelling and analysis.

This report is intended to provide the WCMA with an understanding of how best to direct efforts for future works programs and community education regarding the geomorphic characteristics and behaviour of the Wimmera River.

Location

The Wimmera River catchment is located in central western Victoria (Figure 1). The catchment headwater areas rise in the Pyrenees Ranges east of Navarre and Elmhurst and the Great Dividing Ranges south of Elmhurst and Stawell. The river flows north westerly to Horsham, receiving several major tributaries from the Northern Grampians. There are no significant tributaries downstream of Mackenzie Creek, west of Horsham, where the river turns north, flowing past Dimboola on its way to termination in Lakes Hindmarsh and Albacutya. The river may on rare occasions terminate in a series of smaller lakes further north into the Mallee.

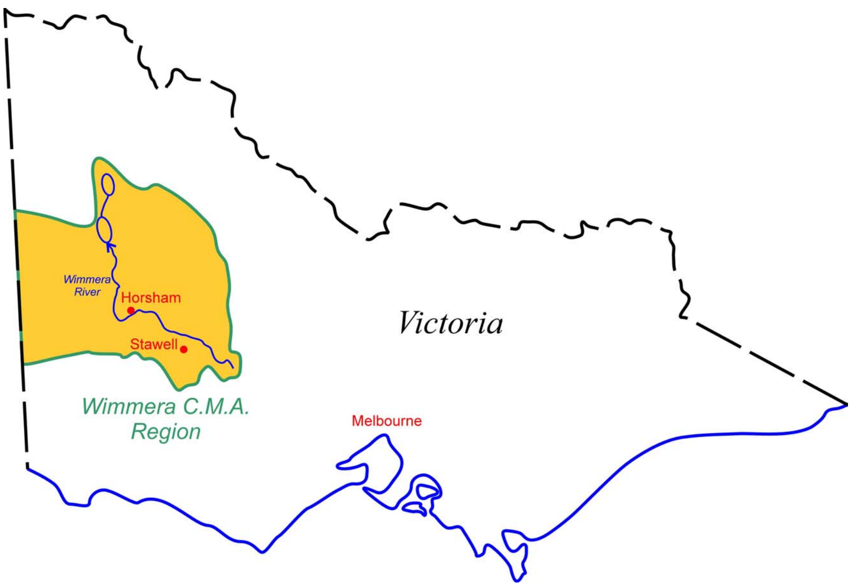


Figure 1 *– Catchment Location*

Scope

The investigation was undertaken to determine sediment sources, transport and fate within the drainage network of the Wimmera River. This investigation involves overview of catchment wide processes that affect specifically the Wimmera River and targeted investigations into tributaries.

A major component of this investigation has been to determine the broad scale character and behaviour of the Wimmera River, both geologically and contemporally. Underlying controls on the river character and behaviour will play a large role in the contemporary sediment source, transport and fate processes.

Geomorphic Investigation Outline

The following exercises were undertaken as components of this investigation:

- Aerial Photo Analysis
- Geological Assessment
- Aerial Inspection
- Field inspections
- Review of historical works on waterways
- 3D Image analysis
- Longitudinal Profile Analysis
- Cross Section Analysis
- Flood Frequency Analysis, pre and post regulation
- Flow Duration/Frequency Analysis
- Effective Discharge Analysis
- Sediment Transport Analysis

The details of these investigations are provided in the plans and appendices accompanying this report. The outcomes and management implications derived from these detailed investigations are provided within this report.

Background Investigations

In August 1997, Thomson Hay & Associates produced a report for the Department of Natural Resources and Environment in Horsham titled: *'Wimmera River and Environs Action Program – Action Plan'*. They carried out a snapshot assessment in April 1996 in terms of the stream health, vegetation, erosion and sedimentation in the Wimmera River.

The report was intended to provide a prioritised strategy for rehabilitation of the Wimmera River's main channel, by quantifying its environmental health. This project was funded by the Murray Darling Basin Commission (MDBC) under the Natural Resource Management Strategy.

According to the assessment carried out in 1996 by Thomson, Hay & Associates:

- upper reaches around Elmhurst are Degraded or Very Degraded
- upstream of Glenorchy, the Wimmera River is considered to be in Moderate or Degraded condition
- between Glenorchy and Horsham, the river is in a Good to Moderate condition.
- just upstream of Horsham and around Natimuk it is considered Degraded.
- downstream of Natimuk, the Wimmera River is in a Moderate to Good condition
- these ratings are based on environmental issues such as remnant indigenous vegetation, sedimentation, erosion, stream health and land use hazard
- Heritage River section – the Wimmera River downstream of the Polkemmet Bridge – is in good to moderate condition

In 1999, Sinclair Knight Merz developed a Wimmera Waterway Management Strategy. The following year, ID&A reviewed and reported on the proposed waterway management field trial sites identified in the Wimmera Waterway Management Strategy. It was recommended in the ID&A report that a geomorphological study of sediment sources, transport and fate would be beneficial to create a greater understanding of stream processes to direct waterway management activities.

Controls on Stream Processes

Geological Timescale Controls

The surficial landforms of the majority of the Wimmera River catchment reflect the events of the most recent geological periods, the Tertiary and Quaternary. The major factors contributing to today's landscape have been the marine incursion during the Tertiary, which laid down a broad sandy plain over the area north of the Grampians and west of the upper catchment bedrock hills. Then, during the Quaternary following marine regression, this surface was reshaped by wind and water (King, 1984).

The upper Wimmera River catchment is within the much older Cambrian/Ordovician sedimentary bedrock hills. These rocks have been extensively deformed through folding and faulting and subjected to long geologic periods of weathering. There are also several granite intrusions with associated metamorphic aureoles in the upper catchment. Most of these areas contain deeply weathered profiles.

The discussion below outlines some of the processes that have occurred as part of catchment evolution and the influences these will have on present day river character and behaviour.

Tertiary

A marine transgression occupied much of the lower Murray Basin during part of the Tertiary. In the Wimmera catchment, this extended as far as the eastern and northern Grampians, which acted as peninsulas into the sea. The sea deposited a broad sandy plain, these sands are known as the **Parilla Sands**. These sands became the supply for the aeolian landforms developed in the Quaternary.

In the late Tertiary, after several marine transgressions and regressions, the final marine regression occurred. This is likely attributable to slight uplift (crustal warping) and/or climate change. During this regression a series of low N-S or NNW-SSE trending strandline ridges (representing shorelines) were deposited as the sea retreated. These ridges and associated troughs have played a major part in the formation of the drainage network of the Wimmera to the present. The north flowing sections of the Wimmera River, Dunmunkle Creek and Yarriambiack Creek flow within the troughs between these ridges. These ridges have also been a major influence on the alignment of the Wimmera – Mallee water supply distribution channels.

The Parilla sands have become partly lithified in most areas, forming a weak sandstone. The upper surface of the sandstone is often ferruginized to a deep red-brown colour, this is seen in the outcrop in the western bank of the Wimmera River through the Duchembeggara – Little Desert National Park reaches.

The retreat of the Tertiary sea may also have played a role in the formation of the deltaic form of lower Mt. William Ck and its anabranches through the Dadswell Bridge to Wimmera River area.

Quaternary

During the Quaternary, global glacial events, especially over the last 50,000 years have played a major role in producing the landforms that dominate the Wimmera region today. These glacial events had substantial impacts on hydrologic regimes, producing alternative periods of wet and dry. These oscillations in hydrologic conditions have played a dominant role in the creation of the semi-arid landforms of southeastern Australia. The last global glacial maximum between about 30,000 and 16,000 years before present was the most recent major landscape forming event (Bowler and Magee, 1978).

The large dune field lobe of the Little Desert National Park is made up of the **Lowan Formation**. This comprises irregular sub-parabolic dunes, reflecting some sense of order owed to the prevailing westerly wind direction that formed them. This dune field is made up of siliceous sands, sourced from the Parilla Sands. Other outcrops of this formation occur where the strandline sandstone ridges have been reworked, such as at Vectis South (reach 12). The pale, whitish coloration of the sands in these dunes, as opposed to the reddish brown coloration of most of the dunes of the Wimmera-Mallee is due to the lack of clay and carbonate in the dunes (Bowler and Magee, 1978). This may make these dunes more susceptible to erosion.

The reddish brown dunes of much of the Wimmera and Mallee are known as the **Woorinen Formation**. These are low discontinuous linear West-East dunes that take a more subdued form (sheet like) in the Wimmera compared to the Mallee. These dunes are most pronounced in the landscape where they are superimposed on the underlying Parilla Sands ridges. The dunes have a relatively high percentage of clay and calcium carbonate. The reddish brown colour of these dunes is owed to the clay rich cutan coating of the quartz grains. The crests of the dunes are coarser grained than the intervening swales, this is expressed in the tree dominated crests and groundcover dominated swales. These dunes are relicts, of which only some have become reactivated following European settlement, these dunes are thought to be more stable than those of the Lowan Formation.

The Woorinen Formation dunes occur along the east side of the Wimmera River alluvial corridor from Vectis East until interrupted by the Lowan Formation and then along both sides north of Dimboola to Lake Hindmarsh.

The formation of the **lunette lake** basins common in southern Australia and in the Wimmera in particular is associated with the oscillations in the hydrologic regime that occurred during the Quaternary and the underlying Tertiary marine strandline ridges. The ridges imposed control on where and the form these lake basins took. The lakes are often kidney shaped, have their long axis oriented parallel with the marine strandlines (N-S or NNW-SSE) and are located in troughs between those ridges.

Crescent transverse dunes, known as lunette ridges, on the eastern side of lake basins are common throughout the mid to lower Wimmera River catchment. The lunettes are made up of multiple units that reflect the oscillations of past hydrologic regimes. Clean quartz sands are associated with wet periods when lakes were large and deep fresh water bodies, the sands were concentrated on the eastern shorelines for contribution to the down wind dune. When the hydrologic regime shifted to dryer (coinciding with global glacial maximums), saline conditions were experienced in the lakes. During these conditions gypseous clay pellets were transported by saltation, to provide the smooth surfaces (Bowler, 1973) characteristic of the dunes in the Wimmera.

The windward (western) margins of the lakes are often a relatively sharp break in slope, representing an ancient or more modern shoreline cliff (Bowler and Magee, 1978). The sandstone cliff is 4m high on the western margin of Lake Hindmarsh.

The Wimmera River intersects several lunette lake basins. The first cuts perpendicular through the lunette ridge of the former lake basin of what is presently known as Dooen Swamp (which has been designated the break between reaches 10 and 11), then several small lake basins between Dimboola and Antwerp (reach 18), before reaching the large lakes Hindmarsh and Albacutya.

Through the middle reaches of the Wimmera River from Glenorchy to Horsham on both sides and downstream of Horsham to Duchembegarra on the left side the channel belt is bordered by terraces of **Shepparton Formation**. These fluvial silts and sands overly or abut higher relief areas of the Parilla sands for the majority of their extents along the Wimmera River. In the terraces of the Shepparton Formation are generally relict surfaces of the Wimmera River floodplain and provide paleo features such as neck cut-offs. The terraces are generally erosion resistant and often mark the limit of the active floodplain in the upper catchment.

The majority of the alluvial units in the active channel belt are known as the **Coonambigdal Formation**. These mobile sediments are presently being reworked by the river within the channel belt.

The western boundary of the Wimmera River surface catchment is due to uplift on the western side of the Hindmarsh Fault which trends north-south immediately west of the river.

Contemporary Changes on Controls

To try and gain a first hand account of what the Wimmera River looked like prior to development of this area, Major Thomas Mitchell was reviewed. Major Mitchell passed through this area in 1836, he crossed the Wimmera River south west of Horsham after crossing the streams he named Mackenzie and Norton. He described the Wimmera River as having banks that were not “water-worn”, but well vegetated slopes and as having a deep, broad channel. No other explorers/settlers accounts of the river have been sourced. Refer to Appendix A for full descriptions.

Following European settlement of the area for gold mining and agricultural activity, much of the forested upper catchment area was cleared. These changes to vegetation and land use had large impacts on the drainage network within the catchment.

Discontinuous Alluvial Rivers

Alluvial rivers do not always have continuous channels, depending on regional factors such as geology (and associated sediment supply and calibre), slope, vegetation composition and cover various discontinuous alluvial river types can be formed. Discontinuous alluvial rivers generally occur in upper and occasionally mid catchment areas. These types of rivers are broadly known as **Cut and Fill**, sub types include **Chain of Ponds** and **Swampy Meadows** (freshwater).

The evolution of Cut and Fill rivers generally involves long periods of sediment accumulation across the entire valley floor (fill phase) under low energy conditions and relatively short periods when a combination of events trigger incision (cut phase). In the fill phase, the river can often host a chain of ponds or freshwater meadow.

Another variant of discontinuous alluvial streams is known as a **floodout**. These streams are characterised by a channel that splays into a fan, deposits sediment and discontinues. These are often seen at the downstream end of gullies or creeks at a change in slope, where the stream no longer has the energy to carry the sediment.

Reaches 2, 4 and 6 of the Wimmera River and many of the tributaries in the upper catchment present the characteristics of discontinuous alluvial streams. Evidence of this can be seen in sediments in the banks of the presently incised stream. The upper layer is often a post European depositional layer of brown silty sand across the whole floodplain, below this are the black silty clays that are indicative of long periods of a low energy environment where fine sediment accumulates. Due to the inefficiency of the drainage network, i.e. no continuous channel, the sediment in these zones is generally waterlogged. Within the black silty clay profile there is often layers of gravels, these are representative of a period when incision occurred through the fill and the energy levels of the drainage network increased. Naturally, such incision events are thought to have occurred in periods such as when catastrophic floods follow droughts or bushfires, which render the valley prone to erosion in such large flow events. These events deposit coarse sediment. When vegetation and a more ‘normal’ hydrologic sequence returns, these reaches of river again become zones of sediment accumulation.

This investigation suggests that many of the discontinuous alluvial reaches of the Wimmera River and tributaries were drained by excavation of a continuous channel, to improve the agricultural potential of these reaches.

The excavation propagated headward erosion through parts of the Wimmera River that are sensitive to change and through many of the tributaries that had these Wimmera River reaches as downstream controls.

Gully Erosion

The upper Wimmera River catchment has one of the highest densities of gully erosion across Victoria according to work recently undertaken by DNRE and CSIRO as part of the Land and Water Resources Audit (see Figure 2.1).

Gully erosion liberates large quantities of sediment that degrades water quality, damages aquatic ecosystems and has the potential to substantially alter the geomorphic character and behaviour of the major streams of the drainage network **if** the sediment is delivered to them. Within the Wimmera River catchment, not all gullies (and subcatchments) are delivering sediment to the river, many of them floodout (see Photo 2.1).

This investigation has sought to identify those subcatchments that are actively delivering sediment to the Wimmera River.

Continuous Alluvial Rivers

The majority of the Wimmera River is a continuous alluvial river. It often has multiple channels (anabranching), generally has low sinuosity and is low gradient. From Glynwylln downstream, the river has low capacity for adjustment, the erosion resistant Shepparton Formation terraces limit lateral migration. Another of the major factors controlling lateral/bank stability is the presence of oblique accretion bars (also known as mud drapes). Mud drapes are the result of deposition of fine sediment, generally silt on and in the grasses and fringing aquatic ground cover species on the banks. The ground cover species roots bind this already cohesive sediment and encourage further depostion. These units build obliquely.

The majority of adjustment that does occur is within the channel belt at very slow rates under natural conditions.

In the lower reaches, the channel belt is often comprised of sand sourced from the aeolian dunes. This will allow the single and multiple channel reaches to be relatively laterally active within the sandy belt.

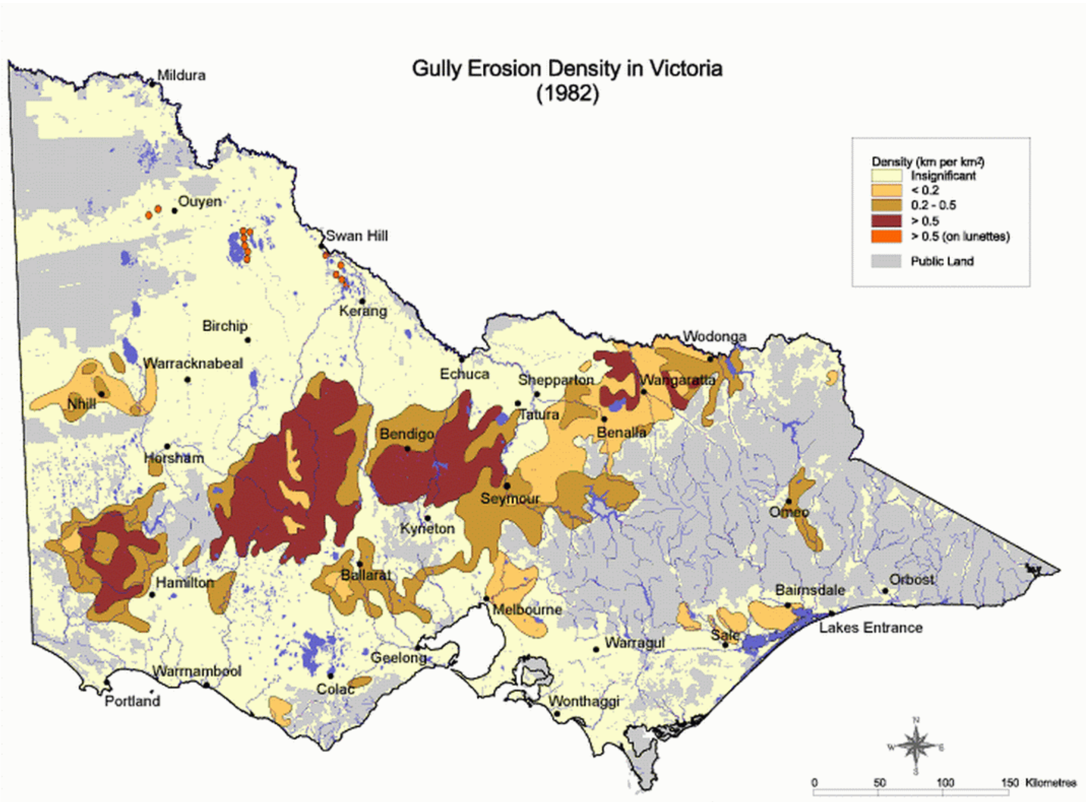


***Figure 2** Gully Erosion Density in Victoria (www.nre.gov.vic.au)*

Severe gully erosion floods out at reduction of slope, depositing sediment

Hydrologic and Hydraulic Changes

This section aims to identify the changes in hydrologic and hydraulic characteristics of the Wimmera River. Hydrologic changes are a result of both natural variations and human intervention. The aim of the investigation is to identify the changes that have occurred in hydrology and channel capacity, the cause of this change, and the extent to which past hydrologic change will further change the hydraulic capacity of the Wimmera River.

Since hydrology and hydraulics of river systems are complex there are several ways of assessing changes. Comparisons of pre and post regulation flow conditions have been made using flow duration and flood frequency analysis. The effective discharge technique has been used to identify the likely change in channel hydraulic capacity resulting from changes in the hydrologic regime.

Significant human alterations to the Wimmera River commenced in the 1850's (John Martin pers. comm.) with significant diversions occurring throughout the period from then on, both within the Wimmera River and on the tributaries. Documentation of river works (refer Appendix A) is limited but there was significant removal of vegetation, woody debris and some sand removal on the Wimmera River during the 1960's nearby Horsham and Glenorchy, recorded in the State Rivers and Water Supply Commission files (Refer SRWSC 1970). While there is no defined period of pre and post regulation, the period up to 1935 has been adopted as pre regulation and the period following 1968 adopted as post regulation for the purpose of this investigation.

The natural variation in hydrology for the periods under investigation was assessed for the adjacent Avoca Basin. The Avoca River is considered to be a relatively unregulated river with no major water regulation infrastructure. Flow duration analysis for the Avoca River at Coonooer gauging station (refer Figure A1) reveals higher flows in the period 1970 – 2000 than those in 1900 – 1930. The flood frequency analysis revealed that the Avoca River also experienced higher floods (and more floods of a given magnitude) in the period 1970 – 2000 than the period 1900 – 1930.

Flow duration analysis for the same periods at the Horsham station on the Wimmera River revealed lower flows in the 1970 – 2000 period than the 1900 – 1930 period. Similar results were also obtained for the flood frequency analysis, the frequency of occurrence of floods of given magnitudes has decreased. That is to say that floods of a given Annual Exceedence Probability (AEP) are of a lesser size.

As an example, a flow of 200m^3/s, just in excess of bankfull, downstream of Horsham corresponds to an AEP of 20% (or 1 in 5 years) for the pre regulation period, as opposed to an AEP of 10% (1 in 10 years) for the same flow in the post regulation period. This means that post regulation the occurrence of a flow in excess of 200m^3/s will occur half as frequently.

The analysis confirms that there has been a reduction in flows and flood frequency downstream of Horsham. The comparison with the Avoca River gauge suggests that the reduction in flow and floods on the Wimmera River is the direct result of flow regulation and cannot be attributed to natural variation in stream flow and flood frequency.

A river channel cross section tends to adjust to changes in magnitude, duration or hydraulic characteristics (Tilleard 1999). Tilleard (1999) states that 'Successful river rehabilitation in these situations relies on understanding the direction and magnitude of geomorphic response to hydrologic or hydraulic change'. The 'effective discharge' concept proposes that the size and shape of an alluvial channel will adjust such that the bankfull capacity corresponds to that discharge which, through time, is responsible for moving the most sediment, allowing a prediction of the direction and magnitude of the channel response.

An effective discharge analysis has been undertaken to identify the likely change in capacity of the Wimmera River associated with the flow regulation. Stream power was used as a surrogate for sediment transport for this assessment. On the effective discharge curve there are well defined points where the erosive power of the river 'drops off'. The results of the analysis suggest that the pre regulation effective discharge occurred at a flow of around 15,000 ML/d, or about 174 m^3/s. This value corresponds to a flood frequency between the 50 and 20% AEP's for the 1900 – 1930 period, and compares well with the estimated channel capacity for the reach based on historic cross section data and hydraulic analysis. For the post regulation data the effective discharge is estimated to be approximately 13,000 ML/d (150m^3/s). A reduction in channel capacity is likely to occur as a result of the flow regulation and water extractions.

However the cross section analysis (refer Appendix E) reveals limited reduction in channel capacity upstream of Horsham over the past 30 years. Sediment supply to the subject reach of river is low. This is a result of low transport capacity into the reach and low supply to the reach as a result of upstream geomorphic characteristics and the construction of various weirs (Horsham, Huddleston's and Glenorchy weirs).

Implications for Management

Based on this analysis there appears to have been a period of reduced flood frequency immediately following regulation. Because the process of channel adjustment is slow (dependant on sediment supply) and the introduction of regulation relatively rapid, there has been a period of reduced probability of overbank flooding. The bankfull flow of approximately 175 m3/s has an AEP of 10% on the post regulation flood frequency curve. In essence the large channel is operating within an environment of reduced flow.

Channel adjustments will occur (albeit slowly) and as a result the occurrence of overbank flooding is likely to increase. However review of the flood frequency curve for the post regulation flow regime reveals that the AEP associated with a flow of 150m^3/s, (the post regulation effective discharge) is approximately 20% (i.e. a 5 year ARI event). This is the same as the AEP of the pre regulation effective discharge. In essence, if the channel capacity of the Wimmera River adjusts to the new effective discharge, the occurrence of overbank flooding will not be significantly different to that which occurred prior to regulation.

Management Reaches

The Wimmera River has been divided into 20 management reaches (refer Drawing Nos 2701046_013, 2701046_014 and 2701046_017) in this investigation. These reaches are based on geomorphic characteristics and behaviour. Several reaches have been further divided into sub-reaches based on contemporary adjustments. For the majority, the geomorphic character of the Wimmera River is insensitive to most changes induced by anthropogenic influences on land use and hydrology. Many of the reaches have similar character and behaviour however, they are separated by reaches of markedly or subtly different character and behaviour.

ID&A
N
0 10 20 30 40 50km
KEY
7 Management Reaches
Lake Albacutya
Rainbow
Lake Hindmarsh
Telopea Downs
Brim
Jeparit
20
19
Warracknabeal
Nhill
Kaniva
18
Dimboola
Yarriambiack Creek
Minyip
17
Little Desert National Park
16
Murtoa
Rupanyup
15
14
Goroke
13
Horsham
10
Neuarpur
Natimuk
11
Wimmera River
9
12
Refer to Drawing 2701046-013v1 for detail
Refer to Drawing 2701046-014v1 for detail
8
Glenorchy
7
Navarre
Apsley
Toolondo
Edenhope
Concongella Creek
6
Landsborough
Stawell
Mt. William Creek
Halls Gap
Great Western
5
4
2
3
Elmhurst
1
Wimmera Catchment Management Authority
Waterways for Life.
Wimmera River Geomorphic Investigation
Catchment Map with Management Reaches
Dwg. No. 2701046-017v1

Aerial Photo, Reach 1 of Wimmera River

Reach 1

Reach Description

This headwater reach of the Wimmera River is in a narrow bedrock controlled valley in near intact, forested catchment. Very little fine alluvial material is stored in this reach.

Tributary Stream Issues

No significant tributaries in this reach.

Cross Section Analysis

No historical or current cross section survey has been undertaken in this reach.

Longitudinal Section Analysis

The upper reaches of the Wimmera River are relatively steep, falling from an elevation in excess of 700mAHD to 340mAHD in its upper 7km, a slope of 0.05m/m.

Management Implications

Wimmera River

No management intervention is required in this reach at present. Long term management strategy should incorporate WCMA involvement in the decision making process for management of the surrounding Forest area.

Reach 2

Reach 2 has been divided into sub-reaches based on the contemporary geomorphic characteristics and behaviour that exist at present. Reaches 2.1 to 2.3 are relatively short, occurring in less than 5km, while Reach 2.4 is greater than 10km.

Management Implications, Cross Section and Long Section Analysis are discussed for the whole of reach 2.

Reach 2.1

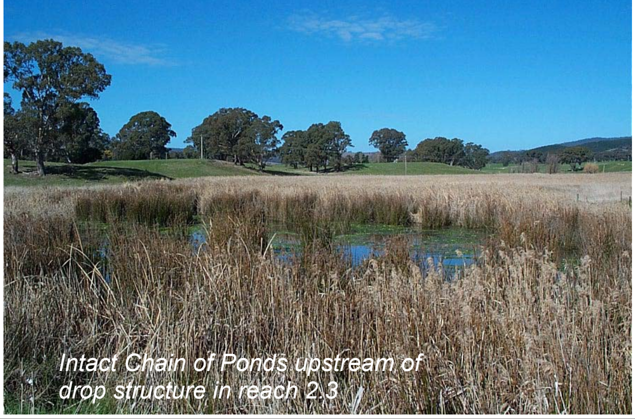
Reach Description

Alluvial discontinuous or not present channel. Intact valley fill containing a freshwater meadow. The downstream boundary of the reach is delineated by several headcuts across the base of the intact fill, which makes up the freshwater meadow, in dense phragmites. The headcuts appear to have been initiated by a small drain cut through the centre of the valley fill downstream of the junction of the Wimmera River with Little Wimmera River and Tom the Tailor Creek. It appears the incision has propagated up Tom the Tailor Creek possibly due to the lower density of in-channel macrophytes compared with the other 2 streams.

Some disturbance may have occurred in the adjoining forest in the past, the impacts on the stream are unknown, but could have resulted in increased rates of sediment inputs to the stream, potentially infilling any ponds.

Aerial Photo, Wimmera River Reaches 2.1 (bottom) to 2.4 (top)

Continuous incised channel, lined with exotic trees


Intact Chain of Ponds upstream of drop structure in reach 2.3

Tributary Stream Issues

Tom the Tailor Creek, the eastern tributary, has experienced substantial gully erosion following draining of reach 2.2. This stream rises in granitic hills that are likely to contribute substantial sand loads to the river. Most of the catchment area has been cleared and is generally grazed.

The Little Wimmera River, the western tributary, like the Wimmera River has remained intact, this is likely due to dense macrophytes, land use and sediment type.

Reach 2.2

Reach Description

Contemporally, this is a continuous alluvial channel. This channel is clearly a man made drain, that has been lined with exotic trees (primarily willow). This reach has the same boundary conditions as the upstream and downstream discontinuous alluvial stream reaches. This reach is likely to have provided increased sediment loads into the Chain of Ponds of reach 2.3 downstream.

Tributary Stream Issues

Tom the Tailor Creek and Little Wimmera River, described above, enter at the boundary between reaches 2.1 and 2.2.

Reach 2.3

Reach Description

Alluvial discontinuous or not present channel. Intact fill containing Chain of Ponds. Downstream boundary of reach delineated by a concrete drop structure that was constructed over the headcut into the valley fill (>3m high). The pools are relatively large open water bodies surrounded by emergent macrophytes and containing submergent macrophytes. The pools are separated by intact fill.

Tributary Stream Issues

No substantial streams or gully erosion issues in this reach.

Reach 2.4

Reach Description

This reach has the same boundary conditions as the upstream discontinuous alluvial Chain of Ponds type stream, however contemporally, this is a continuous alluvial channel. The extents to which this channel has been constructed (see at and downstream of Glenpatrick Creek confluence) or is a result of incision processes initiated by that excavation is not known.


Exotic trees downstream of drop structure


Filling channel downstream of Elmhurst-Landsborough Rd

Anecdotal evidence suggests that many efforts have been made over the last century to maintain this as a continuous reach of channel. Increased rates of erosion on the Wimmera River and in tributaries have provided increased sediment loads that are infilling the channel.

Many tributaries in this reach have undergone incision initiated by the excavation/incision of the Wimmera River and others have also had excavation works undertaken. The infilling of the channel may be viewed as a recovery of the river, though it is with coarser sediment than is characteristic of Chain of Ponds.

This reach has a broad and thick alluvial floodplain where sediment has accumulated due to the downstream controls. The downstream end of this reach is marked by a considerable contraction of the floodplain by bedrock and an alluvial terrace.

Riparian vegetation is missing above ground cover and macrophytes. Stock access is unrestricted throughout.

Tributary Stream Issues

The major left bank tributary in this reach, Hickman Creek, has undergone substantial gully erosion. Changes to its downstream boundary conditions, incision of the Wimmera River and catchment vegetation and land use have lead to the development of a continuously incised over-enlarged stream. This stream has similar characteristics to Reach 2 of the Wimmera River. It is a Cut and Fill stream that while in intact fill state is likely to have contained chain of ponds or freshwater meadows. The development of this gully is likely to have delivered large quantities of sediment to the Wimmera River and floodplain.

The 2 major right bank tributaries upstream of Elmhurst, Sandy and Rocky Creeks flow off granitic hills. Similar adjustments have occurred in these streams as for Hickman Creek, contributing substantial sand loads to the river and floodplain.

The next major right bank tributary, the Glenpatrick/Nowhere Creek system has similar characteristics to the river in this reach. It appears similar adjustments have occurred as with other tributaries, except that continual infilling of a channel within a floodout zone, due to increased rates of sediment inputs, have prompted several attempts at maintaining a continuous defined channel in the mid to lower reaches of these streams, by excavation.

The last major right bank tributary in this reach, shortly upstream of the Elmhurst-Landsborough Road, has experienced severe gully erosion that is contributing substantially accelerated rates of sediment input to the Wimmera River.

Cross Section Analysis

No historical or current cross section survey has been undertaken in this reach. It should be noted the downstream controlling mechanism involved in the formation of this reach is a substantial contraction of floodplain width between a terrace and a bedrock ridge downstream of Elmhurst.

Longitudinal Section Analysis

Reach 2, as expected due to the geomorphic character of the stream is much flatter than reach 1. Elevation ranges 340mAHD to 280mAHD over approximately 16km, giving a stream gradient in this reach of approximately 0.0038m/m.

Management Implications

Wimmera River

The management objective for this reach will need to be determined. The contemporary adjustments to geomorphic character that have occurred due to drainage works and subsequent gully erosion has not altered the geomorphic behaviour of this reach. Due to some of the reach boundary conditions, which have not changed since European settlement, this reach will naturally accumulate sediment and in some sense recreate the swampy environment with a poorly defined/discontinuous channel possibly containing a Chain of Ponds, that befits its setting. Working with these stream processes will be the most effective river rehabilitation strategy.

One of the top priorities throughout the Wimmera River will be to protect reaches that are in good or near intact condition. Reaches 2.1 and 2.3 are intact fill, containing freshwater meadows and chain of ponds, protection of these reaches should be high priority for management. Setting of management objectives for the restoration of Chain of Ponds in reaches 2.2 and 2.4 will be difficult as knowledge of the formation of chain of ponds is limited. However, sensible river management approaches such as restoring native riparian (swampy) vegetation along flow paths and protection against further channelisation/incision should provide the mechanisms that will assist in the recreation of a chain of ponds type stream in the long term.

Tributaries

Objectives for management of the tributaries contains two categories;

- management for processes that impact on stream health and land management within the tributary system
- management for processes that impact on the Wimmera River

Tributaries such as Tom the Tailor, Hickman, Sandy and Rocky Creeks are extensively gullied, they have and will continue to contribute large amounts of sediment (sand from the right bank tributaries) to the Wimmera River. Management strategies here will be to trap the bedload within the tributary system, as coarse sediment is not the dominant size in chain of ponds environments.

The tributary system of Glenpatrick and Nowhere Creek has processes that impact within the tributary system as well as in the river. Given the extensive gully erosion and other contemporary incision that has occurred in this system, sediment supply rates have been greatly increased. Much of this sediment is deposited in the floodout zone where these streams reduce in gradient and/or have downstream floodplain contractions. One such zone is on the Wimmera River floodplain, attempts at maintaining a continuous channel here will prove futile in the long term as the underlying boundary conditions that control the processes dictate that such a reach is a floodout where sediment accumulates.

The excess sediment inputs from gully erosion in the upper catchment exacerbate this process and thus pose many agricultural land use hindrances. Management should therefore be directed at reducing the rate of sediment input from the upper catchment areas, this should be done by trapping sediment within the tributary system which will also help in returning some more natural characteristics in those reaches of the tributaries.


Continuous partly confined channel

Reach 3

Reach Description

This reach is partly confined by valley margins and erosion resistant terraces that restrict lateral migration of the river. The river has incised over a long period to well below a floodplain terrace that contains paleo channels, it is likely that the bed of the river has reached bedrock. The active floodplain is comprised of small pockets, always present on at least one side of the river.

Pre-European, this reach is likely to have had limited sediment inputs due to the storage of most sediment upstream in Reach 2. This may have assisted in the incision of the channel.

Contemporally, there is an increase in lateral processes through point and tributary mouth bar development near tributary confluences, where increased (contemporary) sediment loads are experienced.

Riparian overstorey vegetation is discontinuous, however much more abundant than upstream. Stock access is not controlled, however ground conditions are less favourable for unrestricted access.

Aerial Photo, Wimmera River Reach 3, adjacent Pyrenees Highway

Intact Chain of Ponds, Glenlofty Creek

Tributary Stream Issues

Glenlofty Creek enters the Wimmera River near the upstream end of Reach 3. For the majority of its length it is a near intact Chain of Ponds. The very downstream extent is a continuous partly confined channel.

One of the reasons why this chain of ponds has not been subject to contemporary incision processes is that its downstream controls, the geologically incised Wimmera River, have been relatively insensitive to changes, hence Glenlofty Creek has adjusted to those conditions over a geological timeframe. It also appears no deliberate attempts to drain Glenlofty Creek have been made as yet.

Aerial Photo, Glenlofty Creek

Several other short, steep gully systems from both sides of the river have delivered substantial sediment input to the river channel.

Cross Section Analysis

Cross Section survey comparison was undertaken at the Eversley gauging station (refer Appendix 5, 2701046-003). The historical survey used for comparison with the present cross section is from the under wire survey taken in 1964. Despite the datum's of the two surveys being different, the general dimensions of each of the cross sections indicate some change has occurred. The present cross section appears to be slightly shallower (2.2 to 2.8m) than in 1964 (3.3m) and narrower (23m in 2001 to ~30m in 1964).

It is not possible to imply river evolutionary trends from these sections, except that maybe a slight contraction of cross section has occurred due to increased sediment inputs from the upstream catchment area. It is not known if this is a 'slug' of sediment or a reach wide infilling.

Longitudinal Section Analysis

Reach 3 elevation ranges 280mAHD to 240mAHD over approximately 13km, giving a stream gradient in this reach of approximately 0.003m/m.

Glenlofty Creek

As discussed above and in Reach 6, Glenlofty Creek is rather unique in this area, it has a similar slope to Sheas Creek over the same elevation range, however it has not experienced the gully incision that has occurred in Sheas and many other creeks/gullies in this area.

Distance (m)	Elevation (m)	Slope (m/m)
18750 to 17500	611 to 500	0.08
17500 to 14600	500 to 390	0.037
14600 to 9000	390 to 325	0.01
9000 to 0	325 to 280	0.005

Table 4.1 *Glenlofty Creek Longitudinal Profile Summary*

Management Implications

Wimmera River

Due to the controls on the river in this reach and its capacity to transport sediment, the river has very little scope for adjustment. Localised infilling may occur, but is likely to be only a transitory effect. Bank erosion may occur at some impingements on the terrace, especially where units such as point bars develop in sediment 'slugs'.

The natural geometry of the channel has meant that most of this reach has been less conducive to agricultural pursuits than other reaches, hence has retained more native riparian vegetation and been less disturbed by cattle and sheep. Management efforts should be focused on ecological attributes of the stream on a reach wide basis. Geomorphic processes will largely be managed by rehabilitation of riparian vegetation, it is expected that only localised bank erosion incidences may require structural works to complement vegetation.

Tributaries

Glenlofty Creek, a near intact Chain of Ponds type stream, represents a rare geomorphological feature in this region and across most of Australia. This stream provides the WCMA with the opportunity to preserve (with implementation of some minor vegetation and ecological rehabilitation) a near intact chain of ponds. Undertaking of preservation will also provide the opportunity to use sections of this stream as a benchmark against which comparisons can be drawn for reaches 2, 4 and 6 of the Wimmera River. It will also provide the opportunity to improve understanding of the physical and ecological functioning of this type of stream.

The few other tributaries to this reach come from high relief over short distances, generally directly into the Wimmera River channel. These streams are delivering excess sediment to this reach. Management resources should be directed at reducing the bed material sediment inputs from these streams.

Incised contemporary channel in background through valley fill

Reach 4

Reach Description

Reach 4 is a short, local floodplain expansion that has allowed the formation of a zone of sediment accumulation (Cut and Fill), which is likely to have contained a Chain of Ponds pre European settlement. This reach would naturally be a swampy, waterlogged zone.

This formation of a continuous, incised channel in this reach may have been by excavation of a channel and/or headward incision from downstream in combination with vegetation clearance and land use change. A major tributary sediment input at the downstream end of this reach may contemporally be assisting in the filling of this reach by backwater effects. This tributary (Spring Creek) may have also been the long-term cause of the local floodplain expansion.

There is very little riparian vegetation and the floodplain is cultivated to top of bank.

Aerial Photo, Wimmera River Reach 4

Tributary Stream Issues

Spring Creek is the major tributary in this reach. It has undergone adjustments similar to those experienced by tributary streams in reach 2. Some incision of the Wimmera River which is its downstream boundary control may have been part of the cause for major gully erosion throughout the Spring Creek catchment. Several other smaller tributaries have also been affected and adjusted in the same way. All these streams have delivered large amounts of sediment to the river and floodplain.

Cross Section Analysis

No historical or current cross section survey has been undertaken in this reach.

Longitudinal Section Analysis

Reach 4 elevation ranges 240mAHD to 235mAHD over approximately 5km, giving a stream gradient in this reach of approximately 0.001m/m.

Management Implications

Wimmera River

Management objectives for this reach, as for reach 2, are yet to be determined. Creating an end point or rehabilitation goal for this highly altered reach is difficult.

To attempt to restore this reach to a chain of ponds would be difficult, given land use implications. However, the mechanisms to put in place to trend this reach back toward its former state would be to encourage deposition of fine sediment through reestablishment of dense instream and riparian vegetation. The necessity for any structural works such as LWD installation or bed control structures to assist in achieving the recovery trajectory would require further investigation.

Tributaries

Management objectives for Spring Creek should be aimed at reducing coarse sediment inputs to the river. Allowing some fine sediment inputs to continue may be conducive to any efforts at restoring chain of ponds in reaches 4 and 6.

Sediment extractions from Spring Creek are not recommended. Sediment extractions would result in some headward erosion and may initiate a new phase of tributary incision.

Reach 5

Reach Description

Reach 5 is a partly confined, continuous channel downstream of the Spring Creek confluence. Lateral migration of the channel is restricted by ancient river terraces and valley margins, however outside bend erosion appears active where it impinges on them. Some incision has occurred post European settlement, recovery is now occurring through bench and bar development (assisted by excess sediment inputs from tributaries).

Several flood channels are present on the terrace, coincident with floodplain expansions downstream of tributary confluences.

Riparian overstorey vegetation is discontinuous. Stock access is not controlled, however ground conditions are less favourable for unrestricted access.

Aerial Photo, Wimmera River Reach 5

Tributary Stream Issues

Mt. Cole Creek is one of the major tributaries to the upper reaches of the Wimmera River. It enters from the left bank, coming from headwater areas (such as Ben Nevis) that are underlain by granitic intrusions into metasedimentary rocks. The typical streams that have formed from these materials are cut and fill valleys, when intact they are likely to contain freshwater meadows. Aerial photography has revealed that parts of the stream network may actually still be intact fill. When subjected to gully erosion these streams are likely to produce large amounts of sand. Whether or not this sand is delivered to the Wimmera River is not known, however Mt. Cole Creek has a relatively long distance to deliver this sediment at low gradients. Hence, it is likely much is stored within the tributary system, before reaching the Wimmera River.

Several other left bank gullies with relatively short distances and moderate relief have experienced extensive gully erosion and have and will continue to deliver large volumes of sediment to this reach.

Cross Section Analysis

No historical or current cross section survey has been undertaken in this reach.

Longitudinal Section Analysis

Reach 5 elevation ranges 235mAHD to 227mAHD over approximately 10km, giving a stream gradient in this reach of approximately 0.0007m/m.

Management Implications

Wimmera River

Given that this reach has a relatively low capacity for adjustment at a reach scale, no major structural works are envisaged for this reach. Reestablishment of appropriate riparian and instream vegetation density and composition should be all that is required to manage rates of erosion in this reach. The major threat to this reach is sedimentation due to excess inputs from tributaries or upstream. Abating this threat will require works in those areas. The sediment transport capacity of this reach should enable most fine sediment to be transported through the reach, however a large proportion of coarse sediment is likely to be deposited.

Tributaries

Further investigation in the Mt. Cole Creek catchment is required to determine firstly, if intact freshwater meadows exist and secondly, what proportion of the sediment generated from catchment erosion processes is stored within the tributary system. Protection of intact freshwater meadows should be a high priority for management.

Several short, relatively high relief gullies are delivering excess sediment to the river. Bedload sediment and gully erosion head management is required in these tributaries.

Excavated channel section mid reach 6.1

Remnant pond in reach 6.1

Reach 6

Reach 6 is broken into sub-reaches based on contemporary changes in character and different stages of adjustment and recovery. The whole of reach 6 is a zone where fine sediment has accumulated ubiquitously across the valley floor over long periods of time. This is a Cut and Fill stream type that, while intact fill persists, will often contain a Chain of Ponds.

Reach 6.1

Reach Description

Reach 6.1 is a sediment accumulation zone that is likely to have contained a Chain of Ponds pre European settlement. The channel is now continuous and incised (contemporally in the cut phase). Review of aerial photography and field observations indicates that the channel has been excavated in parts. No historical records have been sourced to determine how much or what volume was excavated. Incision processes caused by the excavation and changes in catchment conditions have enlarged the channel to what it is today.

The draining of these valley fills by creation of a continuous, larger channel was not uncommon as part of agricultural settlement in these types of areas. Draining the valley floor reduced waterlogging of soils, improving the floodplain for agricultural use.

Major sediment inputs from tributaries are assisting in the recovery (to a fill phase) of the channel, forming point and longitudinal bars that are being colonised by macrophytes where not heavily grazed by cattle. The present day channel bed is comprised of sands and gravels and has little morphologic diversity. Banks are generally eroding, though the fine-grained cohesive sediments that have accumulated in this zone control the rate of lateral migration of the channel.

A post European settlement floodplain sediment layer of brown sands and silt can be seen in the banks throughout this reach, in stark contrast to the underlying black and grey silty clay sediments indicative of the former swampy environment. An example of a remnant and a contemporary section of channel can be seen behind Joel Joel Hall.

Reach 6.2

This reach is a recovering fill/chain of ponds (see Joel Joel Bridge), it also represents the transition zone into the markedly different character of reach 7. The same sediment layers are present in the banks as in reach 6.1, indicating a swampy environment and contemporary deposition on the floodplain. Lateral migration of the contemporary, continuous channel is more active than in reach 6.1. The recovering form appears to be adopting a pool-riffle sequence (see near Six Mile Creek confluence), with macrophytes colonising the riffles and assisting in aggrading those riffles.

Aerial Photo, Wimmera River Reach 6 (Joel Joel Bridge top left)

Tributary Stream Issues

Sheas Creek

Extensive gully erosion has occurred in this right bank tributary, the cause likely to have been the combined influence of catchment clearing and land use change as well as the incision of the Wimmera River initiating headward erosion. This stream is likely to have delivered substantial volumes of sediment to the Wimmera River prior to the construction of a drop structure (>4m high) at the Joel Joel-Crowlands Road.

This drop structure effectively traps most, if not all bed material sediment upstream, with only a proportion of suspended load passing. A substantial deposit of recent sediment has accumulated upstream of the road. Downstream of the structure, the stream has been diverted, as a straight cut through the Wimmera River floodplain to its confluence. This reach is over enlarged, has near vertical erodable banks and is sediment starved.

Glendhu Creek

This right bank tributary, less than 5km upstream of Sheas Creek has adjusted in the same manner. Extensive gully erosion has and still is contributing large volumes of coarse and fine sediment to the river. Fresh, mobile deposits of gravel and sand are present at and downstream of its confluence in the bed and bars and on benches of the Wimmera River.

Six Mile Creek

This left bank tributary enters toward the downstream end of reach 6.2. Its contemporary character in its lower reaches has been influenced by the incision of this reach of Wimmera River, but not to the same extent as Sheas and Glendhu Creeks. This is due to a much longer low gradient reach towards its downstream end in the Wimmera River floodplain. It has a continuous, low gradient, low capacity channel. Its past sediment inputs appear to be helping the riffle formation in the Wimmera in this area.

Upstream of the Stawell-Landsborough Rd, Six Mile Creek has a natural floodout zone where sediment accumulation occurs. This reach has had a drain excavated through it several times in the last century in attempts to address repeated infilling and local waterlogging associated with the low gradient and excess sediment inputs from upstream.

Cross Section Analysis

Cross sections were taken in both reach 6.1 and 6.2 at Frampton’s Bridge and Joel Joel Bridge respectively.

The historical cross section survey at Frampton’s Bridge was sourced from Vic Roads as constructed bridge plans circa 1965. Direct comparison with the current cross section survey indicates that extensive contraction of the channel has occurred. However, field observation of the channel morphology and sedimentary record at the bridge site contradicts this, indicating that the river is almost the same as that excavated post European settlement of the area. It is therefore likely that the 1965 cross section is a design cross section, not an as constructed cross section.

The historical cross section at Joel Joel Bridge, circa 1970 was also sourced from Vic Roads. Comparison with the present cross section indicates substantial contraction of the channel through aggradation and bench development. Observations at the site would indicate this to be a very likely scenario. This reach of river has good instream and riparian vegetation, giving it the ability to trap a lot of the incoming sediment. The shape of the cross section for the river here from 1970, unlike the neat trapezoidal design section for Frampton's Bridge, actually appears to be how the river would have looked and still does nearby.

Longitudinal Section Analysis

Reach 6 elevation ranges 228mAHD to 208mAHD over approximately 20km, giving a stream gradient in this reach of approximately 0.001m/m.

Sheas Creek

The longitudinal profile of Sheas Creek has been altered substantially following European settlement of the area. The creek has undergone major bed degradation and subsequent adjustments of stream form. This was likely to have been assisted by the bed degradation of the Wimmera River at the confluence initiating headward erosion. A major (>4m high) drop structure has been built at the Joel Joel - Crowlands Road, below this Sheas Creek is now a constructed channel in the Wimmera River floodplain. Refer Appendix 4 for plot of section.

Distance (m)	Elevation (m)	Slope (m/m)
14000 to 9000	350 to 280	0.01
9000 to 4000	280 to 240	0.0075
4000 to 0	240 to 230	0.004

Table 4.2 *Sheas Creek Longitudinal Profile Summary*

Management Implications

Wimmera River

The management of Reach 6.2 for continuing sediment deposition is critical. The potential impacts that increased sediment loads could have on high value reaches downstream make the maintenance of dense instream and riparian vegetation in this reach a high priority for the WCMA. At the moment this reach has accumulated much of the sediment that has been liberated by drainage works and incision processes upstream. Management efforts should be directed toward ensuring all mechanisms are in place that will keep deposited sediment within Reach 6.2 and continuing deposition in this reach of excess sediment delivered from upstream. Vegetation will be the key mechanism, structural works are only likely to be required if any further incision occurs.

The objectives for management of reach 6.1, as with other former chain of ponds type reaches, will require further deliberation with extensive community consultation. The rehabilitation objective for this reach of the Wimmera River will also determine how tributary streams such as Glendhu and Sheas Creek are managed.

Tributaries

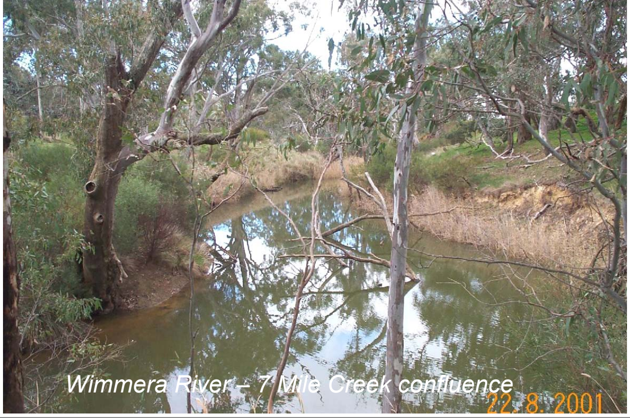
If the objective is to restore the fill in the river valley and possibly a chain of ponds, the contribution of excess sediment loads from tributaries experiencing severe erosion may help accelerate the restoration process. However, it is thought coarse sediment, which does not typify the sediment in chain of ponds stream types, may not be most suitable. The valley fill which forms chain of ponds is believed to be finer than sand. This being the case, management of the tributary stream should aim to reduce coarse sediment inputs, while still allowing some fine sediment to reach the river. This is actually occurring at Sheas Creek as a result of the drop structure, however upstream, Glendhu Creek is delivering all sediment, including substantial volumes of sand and gravel. This sediment is contributing to the infilling of the river in this reach.

If the management objective is to maintain the continuous channel, these sediment inputs from tributaries will continually work against that objective.

The extensive erosion occurring in the **Six Mile Creek** catchment requires management action. The reasons for this are not purely derived from direct geomorphic impacts on the Wimmera River. This creek is not delivering large volumes of sediment to the Wimmera River. The reason for management is to encourage improved management and improved land use conditions in the floodout reaches of the creek that will reduce the threat of future direct impacts on the Wimmera River.

These reaches are naturally floodout zones, however the increased sediment loads being delivered to it from upstream will exacerbate the incompatibility of this reach with agricultural pursuits. The increased sediment loads being deposited in these reaches are likely to increase the waterlogging effects that occur in such zones, hence the likelihood of drainage excavation by landholders to relieve this is higher. To encourage participation in improved management of floodout zones, WCMA should undertake erosion control works to reduce the sediment inputs from upstream.

The priority and order of these works requires more investigation at a sub catchment level and subsequent community consultation.



Wimmera River – 7 Mile Creek confluence

Concongella Creek (left) confluence with Wimmera River (right)

Reach 7

Reach Description

Reach 7 is characterised by a continuous dominant alluvial channel and one or more anabranches/flood channels in parallel. The main channel is similar in character to other reaches downstream, deep, narrow and dominated by vertical processes. The banks of this reach are generally very stable due to the presence of mud drapes (and vegetation), where they are not present banks may be unstable. Some of the outbank erosion observed in this reach may also be attributable to saline groundwater. In channel geomorphic units are generally pools and riffles or runs, there are also occasional lateral and vertical bedrock controls.

Anabranches in this reach may take the form of developing flood channels, decaying paleochannels (often observed as channelised Chain of Ponds) or deferred tributary confluences.

Sheepwash Creek is a flood channel of the Wimmera River. Flood flows from both Concongella Creek and the Wimmera River travel down this channel, which has developed from downstream up. Its capture of the lower reach of Concongella Creek or the Wimmera River has been prevented by the occurrence of interbedded (upward fining sequences of conglomerate to sandstone) sedimentary bedrock at its offtake.

The floodplain widens significantly in this reach as the river leaves the upper catchment area with topographic relief surrounding the floodplain reducing substantially. The last area of relative relief abutting the river occurs at the Glynwylln gauging site. The river is bounded to the north by sedimentary bedrock hills and to the south by a high Shepparton Formation terrace. The extent of geologic incision through this reach of the river and upstream has been controlled here by bedrock.

The first major distributary of the Wimmera River, Dunmunkle Creek, occurs in this reach, flow commences into this system at near bankfull flows in the river. In close proximity to this an inter basin transfer channel has been constructed, this takes flows into Swedes Creek, a tributary of the Richardson River. This channel would commence to flow at approximately 85% bankfull in the Wimmera River. It is possible that high flood flows may have made their way to Swedes Creek under natural conditions anyhow.

Major left bank tributaries in this reach are Seven Mile Creek and Concongella Creek, both relatively long streams, having low gradients at their downstream ends. The major right bank tributary in this reach is Wattle Creek.

The downstream boundary of this reach has been placed after the distributary system, where the river is clearly a single channel system.

Aerial Photo, Wimmera River Reach 7, including Concongella Creek confluence

Tributary Stream Issues

Seven Mile Creek rises in granitic and sedimentary bedrock hills east of Great Western. It follows a north-south lineament until reaching the floodplain of the Wimmera River where it is directed to the west and joins with a paleochannel of the river (which presently takes flood flows only from the river). West of the Glynwylln-Morrl Morrl Road, the creek gradient increases as it cuts down through the high terrace to meet the invert of the Wimmera River.

The majority of the drainage network in the mid to upper Seven Mile Creek catchment has undergone moderate to severe gully erosion. Bank erosion of these incised streams through meander development in the over enlarged channels continues to be active today.

Much of the sediment generated from these contemporary erosion processes appears to have been stored in a floodout zone upstream of the Stawell-Avoca Road, before joining the Wimmera River paleochannel.

Downstream of the Stawell-Avoca Road the creek has extensive growth of typha in the bed, indicating that some sediment has been transported into this reach, possibly coinciding with drainage excavation in the floodout zone near the road. This typha is likely to have trapped most of this sediment. There is no evidence of sediment accumulation at the confluence with the river. Neither is there likely to be due to the high sediment transport capacity of this reach (refer Appendix 6 for results of sediment transport analysis).

Wattle Creek is one of the largest tributaries of the upper Wimmera River. Wattle Creek can also be known as Heifer Station or Howard's Creek, these streams are other major tributaries within the Wattle Creek system.

The upper catchment streams originate in sedimentary rock ridges of relatively high relief, some are forested (eg. Pyrenees State Forest), most are cleared. Extensive gully erosion has occurred through most of the drainage network of upper catchment areas. The trend in this catchment, like many other sub catchments, is for the streams to floodout where relief reduces (stream gradient <0.003) at or before the major streams reach the Wimmera River floodplain level. Hence, much of the sediment generated by contemporary erosion phases has been deposited in the floodout zones before reaching the Wimmera River.

Concongella Creek is a left bank tributary that originates from granitic hills and follows a north-south lineament to the river. The headwater areas are around Stawell and Great Western, the disturbances in these catchment areas include mining as well as agriculture.

Most of the drainage network in this tributary system has undergone gully erosion similar to the other tributary systems. All the major tributary streams to Concongella Creek, including Allanvale, Sandy, Salt, Wattle (another one) and Kirkella Creek's appear to have a lot of contemporary mobile sediment within them. Of particular concern is Kirkella Creek due to its proximity to the Wimmera River.

This release of sediment has translated into Concongella Creek having a sand bed, a slug of which appears to be presently just downstream of the Deep Lead-Granard Park Road. Unlike many of the other major tributaries, Concongella Creek does not appear to have a floodout zone in its downstream extents. It has a continuous, relatively deep and narrow channel that is likely to have a reasonable capacity to transport sediment.

Inspection at the confluence with the Wimmera River revealed that some of this sand is reaching the river, but not enough to have major detrimental impacts. This is likely to be combination of the amount of contemporary sand that is still moving along Concongella Creek and the relatively high sediment transport capacity of the Wimmera River in this reach.

Cross Section Analysis

Two historical cross sections, taken for a Glenorchy component of the Horsham Flood Study circa. 1980 were utilised in this reach. These sections (refer Drawing Nos. 2701046-008 and 2701046-009) indicate very little change has occurred to the present. The upstream section has a track and ford that has slightly altered the natural morphology of the stream.

Inspection of these areas revealed very little sediment storage and no apparent signs of recent channel expansion.

Longitudinal Section Analysis

Reach 7 elevation ranges 208mAHD to 165mAHD over approximately 43km, giving a stream gradient in this reach of approximately 0.001m/m.

Wattle Creek

The Wattle Creek longitudinal profile is typically concave with a long low gradient section in the downstream extents. The Wattle Creek confluence with the Wimmera River is deferred, that is it flows parallel with the river, within the Wimmera River floodplain (close to the opposite floodplain margin) for a substantial length (~6km).

In its upper 10km the streambed slopes range from 0.06 to 0.006, while over the remaining 40km streambed slopes range from 0.002 to <0.001. Refer Appendix 4 for plot of profile.

Distance Range (m)	Elevation Range (m)	Slope (m/m)
49500 to 47200	480 to 325	0.06
47200 to 43500	325 to 280	0.01
43500 to 37850	280 to 250	0.006
37850 to 23000	250 to 220	0.002
23000 to 7000	220 to 200	0.001
7000 to 0	200	<0.001

Table 4.3 *Wattle Creek Longitudinal Profile Summary*

Seven Mile Creek

The longitudinal profile of Seven Mile Creek describes relatively uniform changes in grade throughout its 28km length. Slope ranges from 0.04 in the upper catchment to 0.001 over the lower 10km. Two flat sections of approximately 4km have been interpolated over those last 10km, the upstream one is likely to correspond to a zone where the stream appears to have naturally flooded out in a zone of sediment accumulation. Refer Appendix 4 for plot of profile.

Distance (m)	Elevation (m)	Slope (m/m)
28100 to 27000	347 to 300	0.04
27000 to 25700	300 to 260	0.018
25700 to 22400	260 to 230	0.005
22400 to 16200	230 to 210	0.003
16200 to 0	210 to 190	0.001

Table 4.4 *Seven Mile Creek Longitudinal Profile Summary*

Management Implications

Wimmera River

This reach of the Wimmera River has high environmental values. It is one of the least disturbed and has undergone little adjustment post European settlement. In terms of physical form, vegetation, hydrology and habitat structure it is probably in the best condition of all of the Wimmera River.

Very few rehabilitation actions are required within this reach. The main management objective for this reach should be to preserve and improve its current high environmental values through management actions within upstream reaches and tributaries.

Tributaries

The extensive erosion occurring in the **Seven Mile Creek** and **Wattle Creek** catchments requires management action. The reasons for this are not to address current sediment inputs to the Wimmera River, these creeks are not delivering large volumes of sediment to it. The reason is to encourage improved management and improved land use conditions in the floodout reaches of the tributary streams that will reduce the threat of future direct impacts on the Wimmera River.

These reaches are naturally floodout zones, however the increased sediment loads being delivered to it from upstream will exacerbate the incompatibility of this reach with agricultural pursuits.

The increased sediment loads being deposited in these reaches are likely to increase the waterlogging effects that occur in such zones, hence the likelihood of drainage excavation by landholders to relieve this is higher. To encourage landholder participation in improved management of floodout zones, WCMA should undertake works to reduce the sediment inputs from upstream.

The priority and order of these works requires more investigation at a sub catchment level and subsequent community consultation.

Investigation of the sand slug moving through **Concongella Creek** is required. It is likely some works will be required in the creek to stabilise sand in-place. Gully erosion control works in the upper catchment areas of this system are likely to have little benefit in protection of the health of the Wimmera River, though any opportunities to encourage revegetation within the drainage network will always be beneficial. Gully erosion control works in the Kirkella Creek sub catchment are recommended due to its proximity to the Wimmera River. If any investigations reveal the presence of intact freshwater meadows in the upper catchment, protection of them should be a high priority for management.

Bedrock step between Company's Bridge and Glenorchy

High value habitat and riparian vegetation

Reach 8

Reach Description

Reach 8 is characterised by a continuous, single, deep and narrow alluvial channel dominated by vertical processes (accreting floodplain). In-channel geomorphic units are generally limited to pools, riffles or runs and mud drapes. Near bank full benches may occur on one or both banks, natural levees are often present on both banks. Erosion resistant Shepparton Formation terraces restrict lateral migration of the channel. Flood channels are perched well above channel level, they are often discontinuous channels (decaying paleochannels) containing pools. Some of these channels appear to be experiencing scour.

This reach contains a short section with bedrock controls downstream of Glenorchy, restricting both incision and lateral migration in the Company's Bridge area. It is not known what geologic formation this bedrock belongs to however, it is likely to be a ferruginized layer of Parilla Sands (refer Drawing No.2701046-016). The Parilla Sands are mapped on the surface in this area on the south side of the river where no surface drainage channels are seen on the map (refer Drawing No. 2701046-014). The Parilla Sands will supply quartzose sands to the Wimmera River.

The downstream limit of this reach is the interaction of the river with channels of Mt. William Creek, where the river becomes anastomosing.

Aerial Photo, Wimmera River
Reach 8, Company's Bridge area

Tributary Stream Issues

There are no tributary streams within this reach.

Cross Section Analysis

No historical cross sections were sourced within this reach. Field observation indicates there is very low capacity for adjustment due to the fine-grained sediments and bedrock controls.

Longitudinal Section Analysis

Reach 8 elevation ranges 165mAHD to 150mAHD over approximately 17km, giving a stream gradient in this reach of approximately 0.0009m/m.

Management Implications

Wimmera River

Geomorphic condition, as well as vegetation and habitat structure is in very good in this reach. Management objectives in this reach should revolve around maintaining this condition.

This reach contains the upstream of the substantial hydrologic alterations that occur in the Wimmera River. Water is both exported, from the Glenorchy Weir and imported, from the Mt. William Creek catchment.

Glenorchy Weir will limit the bedload sediment being transported into this reach.

Reach 9

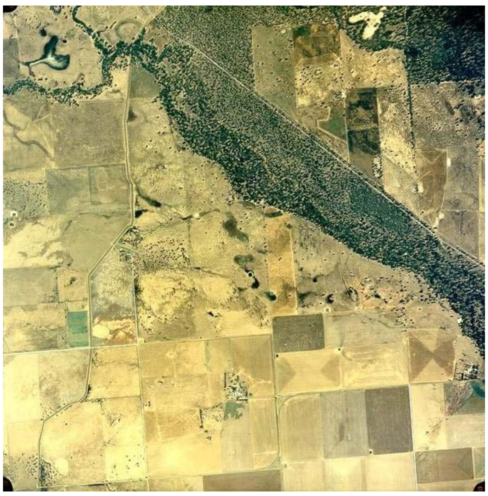
Reach Description

Reach 9 corresponds with the Wimmera River meeting the Mt. William Creek paleo-delta formation, starting about Huddleston's Weir and finishing where Yarriambiack Creek leaves the river. This reach is anastomosing, containing many low capacity channels, including paleo channels often in the form of chain of ponds acting as flood channels.

The wide floodplain has been reworked extensively in recent geological periods, however is contemporally dominated by vertical accretion with fine sediment.

The hydraulic function and to some extent the sediment transport function of this reach are altered by the weir's and the diversion operation. Huddleston's weir harvests all flows up to about half bank full in the main channel, up to 1600Ml/day (the capacity of the diversion channel). Hence, there are no low flows through the majority of this reach. It is expected that the removal of low flows will favour colonisation of the channel with vegetation and slow rates of contraction. Any contraction will be at slow rates due to the lack of bed material sediment supply from upstream and flow events that do occur through this reach are likely to have the capacity to transport most of the suspended sediment through or deposit it on the floodplain.

Some channel form alteration has been observed in some of the anabranches in this reach. Sheepwash (also known as Middle) Creek is experiencing erosion due its use by Wimmera Mallee Water as an escape channel from the diversion channel when its downstream capacity is likely to be exceeded in flood conditions.



Aerial Photo, Wimmera River in Marma State Forest.
Lake Taylor Outlet Channel Syphon top left, then Yarriambiack Creek offtake.

One of the low capacity channels through Marma State Forest

Lake Taylor Outlet Channel syphon, single channel reach shortly upstream of Yarriambiack Creek offtake

Aerial Photo Wimmera River, Horsham – Wal Wal Road, Rocklands Outlet Channel Crossing

Tributary Stream Issues

Where **Mt William Creek** passes through the last of the lateral constraints on its floodplain around Ledcourt it enters the deltaic deposits it formed in the Tertiary period during marine incursion into southeastern Australia. These broad flat deposits now host multiple discontinuous channels where the Mt. William Creek system floods out through the delta and joins with the Wimmera River floodplain.

Since European settlement of the area and the creation of the Wimmera Mallee Water supply system and its infrastructure, many man made alterations to flow quantity and paths and channel form have occurred. Swampy floodout zones of discontinuous channels have been drained by excavation to create continuous channels. Flood flow patterns have been altered by banks, roads and channel crossings.

It is reported by WMW that the majority of low flows in Mt William Creek now flow into the Wimmera River near Huddleston's Weir, instead of near the downstream end of this reach.

Rocklands Outlet channel syphon, Wimmera River

The storages in the upper catchment and the operation of water distribution channels between them have altered hydraulic and geomorphic function and connectivity with the lower catchment. Lake Lonsdale, a swamp formed by the constriction of the floodplain near Ledcourt, has been dammed. This Lake has trapped large amounts of sediment that will partly be sourced from post European gullying.

Mt. William Creek is expected to be a contributor of sand to the Wimmera River owing the sandstones of the Grampians. The amount of sand reaching the river is limited however, by the low capacity for transport in the lower reaches.

Cross Section Analysis

Three historical cross sections of the river were sourced and re-surveyed in this reach, two at channel syphons and one at a bridge.

In the upstream half of the reach a section from the time of construction (1956) of the Rocklands Outlet Channel syphon was sourced. Comparison with the present cross section indicates very little change has occurred here over the last 45 years.

In the central portion of the reach, where Mt. William Creek and the Wimmera River flow in parallel in a channel belt less than 250m wide, a historical section from construction of the Horsham-Lubeck Road bridge (1970) was sourced. The 1970 section is a trapezoidal section, which may be a design section, however comparison with the present cross section reveals little change from this.

At the downstream end of this reach, where Mt William Creek and the Wimmera River have converged into a single channel, just before Yarriambiack Creek departs from the river, a historical cross section at the Lake Taylor outlet channel syphon was sourced. The exact date of this section is unknown, but is likely to be around 1925, the time of construction. Flow conditions at the time prevented survey of the invert in deep water.

Longitudinal Section Analysis

Reach 9 elevation ranges 150mAHD to 130mAHD over approximately 27km, giving a stream gradient in this reach of approximately 0.0007m/m.

Management Implications

Wimmera River

Many interferences with the hydraulic and geomorphic functioning of this reach have occurred, however due to its low capacity for adjustment, little change has occurred in the geomorphic character. With the harvesting of all low flows up to mid bankfull it could be expected that channel contraction may occur, however the harvesting of those flows does not have a significant effect on large flow events, the dominant channel forming events.

The sandy floodplain and in-channel sediment seen in this reach at present have been laid down over the Tertiary and Quaternary geologic periods. Limited bed material sediment from the upper catchment is being delivered to this reach. Much of the fine sediment delivered to the upper Wimmera River due to gullying in the upper catchment may be transported into this reach in suspension in large flow events, however any deposition that occurs will in the majority be on the floodplain.

Tributaries

The Mt. William Creek system was only investigated in broad terms for its interactions with the Wimmera River as part of this investigation, however the many man made alterations that have occurred in this system will be having an impact on stream health. Further investigation is required to assess the functioning of this system. For example, the operation of the Middle Creek overflow requires attention, this channel is experiencing erosion caused by the release of flood flow excesses from the diversion channel.

Wimmera River, downstream of Gross Bridge

Wimmera River cutting through Dooen Swamp lunette ridge

Reach 10

Reach Description

The extents of reach 10 are associated with the Yarriambiack Creek distributary and the Quaternary period landforms associated with its evolution to present day form. The downstream extent of this reach is associated with the boundary between the Tertiary marine Parilla Sands and the Quaternary fluvial Shepparton Formation deposits and the eastern extent of the Quaternary aeolian Lowan Formation dune fields

The Wimmera River transforms from a series of multiple poorly defined channels through Marma State Forest to essentially a single channel across the southern end of a triangular landform, which has Yarriambiack Creek along its eastern boundary and leaving at its northern apex. Associated with this dominant channel are actively developing and decaying flood channels.

The downstream control on this reach is a lunette ridge, which may have temporarily blocked the Wimmera River during the period of land surface evolution dominated by Aeolian processes in this region. The temporary blocking of the Wimmera may have lead to the formation of a lake in the near triangular land surface feature. A series of north-south ridges are present in this depression. Yarriambiack Creek development may have been associated with this transient feature, acting as the escape channel from the Darlot Swamp area.

Aerial Photo, Wimmera River Reach 10 at Dooen Swamp (top)

Wimmera River, upstream of Gross Bridge

Tributary Stream Issues

The are no tributary streams to this reach. Two Mile Creek is associated with the Darlot Swamp and Yarriambiack Creek, functioning essentially as an anabranch of the river. Yarriambiack Creek is a distributary of the Wimmera River, that is, it receives flows from the river and has no further interaction. It terminates over 100km to the north near the town of Hopetoun.

Cross Section Analysis

One historical cross section was sourced for comparison in this reach at Gross Bridge on the Drung Drung-Jung Road following construction circa 1962. Comparison with the present cross section indicates that there may have been some deepening (or excavation) by up to 1m over a 15m width of bench in the left hand side of the channel. The cross section comparison shows no sign of infilling over the past 39 years.

Longitudinal Section Analysis

Reach 10 elevation ranges 130mAHD to 128mAHD over approximately 20km, giving a stream gradient in this reach of approximately 0.0001m/m.

Management Implications

Wimmera River

The very low gradient, fine sediments and lack of sediment transport capability into this reach give the river a very low capacity for adjustment. Under the present alterations in hydrologic regime some contraction of the channel may occur, but over long periods of time.

Management objectives within this reach should be to maintain the high value riparian vegetation, rehabilitate any degraded vegetation and address any minor bank erosion issues that may arise. Redundant in-stream structures such as weirs should be assessed for removal.

Reach 11

Reach Description

This reach extends from the lunette ridge of Reach 10 to Francis Swamp. It is characterised by a single (except in Dooen Swamp) well-developed channel. The channel trench is more developed at the downstream end, with an incised compound cross section, containing several floodplain surfaces. The river is laterally inactive, dominated by vertical floodplain accretion processes. The river follows the boundary between Parilla Sands and Shepparton Formation for most of this reach. The downstream extent of the reach is associated with an outlier of the Lowan Formation dune field encroaching onto the floodplain.

Aerial Photo, Wimmera River Reach 11 downstream of Horsham

Wimmera River, shortly downstream of Norton Creek confluence

Tributary Stream Issues

As the **Mackenzie Creek** approaches the Wimmera River it cuts through almost perpendicular the east-west sand dune ridges of the Lowan Formation, intercepting easily mobilised sands. These sands appear to be stored within the dense, intact riparian vegetation corridor that covers the lower Mackenzie channel belt. Within the channel belt the creek takes the form of multiple discontinuous channels.

This lower reach of Mackenzie Creek will be very sensitive to change. Land use or riparian vegetation alterations would pose a high risk of mobilising large quantities of sand.

The lower reaches of **Norton Creek** cut down steeply through fine and cohesive Shepparton Formation and Wimmera River floodplain sediments. The Lowan Formation defers the tributary confluence, though it does not appear to intercept it. There is no evidence of sand storage or transport in this lower reach.

Cross Section Analysis

Two historical cross sections, taken as part of the Horsham Flood Study in 1979/80 were used for comparison with the present in this reach. Both Section 17 and Section 19 are upstream of Horsham at or just upstream of the influence of the Horsham weir pool. Section 19, across a channel syphon, indicates there has been little or no change in the cross section over the last 21 years. Section 17 does not fit perfectly in the horizontal, however the general shape comparison indicates there may have been a slight aggradation of the bed. Section 17, the downstream of these two sections may be under the influence of the Horsham weir pool, where some deposition could be expected at the upstream limits. This slight aggradation of the bed, if it has occurred, is insignificant in terms of overall cross section area.

Longitudinal Section Analysis

Reach 11 elevation ranges 128mAHD to 116mAHD over approximately 27km, giving a stream gradient in this reach of approximately 0.0004m/m.

Management Implications

Wimmera River

There are no substantial geomorphic management issues associated with river processes in this reach. Physical form management issues do arise from human activities within this reach. The extensive recreational use and past clearing and excavation of the Horsham weir pool will be creating morphologic changes, especially from boat wake action on the banks. Where the stream banks are comprised of fine-grained cohesive sediments, bank erosion due to boat wake action will be limited.

The presence of water on the banks of the river due to the weir, has the effect of slaking. Permanent inundation also reduces the extent of instream and riparian vegetation on the lower banks. The combination of these with boat wake action will then move sediment from the banks. The majority of this sediment will be deposited in the bed of the weir pool. Management efforts should aim to maintain a near continuous coverage of macrophytes along the banks at weir pool level.

Recognition needs to be made by the WCMA and community that from this reach downstream the Wimmera River is bounded and often composed of sandy sediments derived from the Aeolian and marine surficial geology of the area. Hence, the river will contain sandy geomorphic units.

Reach 12

Reach Description

Reach 12 through Vectis South begins near Francis Swamp, adjacent where a Lowan Formation outcrop remains on the north side of the river. The floodplain width is substantial in this reach, containing multiple level surfaces creating a compound cross section. There is a dominant channel and one or more flood channels (which are most likely paleochannels), which activate at greater than half bank full flows. One of these channels abuts the floodplain margin against the Lowan Formation. The river is more laterally active than in reach 11.

Aerial Photo, Wimmera River at Vectis South (note Lowan Formation east – west sand dunes)

Tributary Stream Issues

The tributary streams in this reach have small catchment areas and low gradients, flowing north from the plains north of the Grampians. Many are discontinuous and they do not deliver substantial volumes of flow or sediment to the Wimmera River.

Cross Section Analysis

No cross section analysis was undertaken in this reach.

Longitudinal Section Analysis

The overall gradient of the Wimmera River downstream of reach 11 is approximately 0.0003m/m. Local variations may range from less than 0.0001 to 0.0006. It is estimated reach 12 has a stream gradient of approximately 0.0005m/m over 10km.

Management Implications

Wimmera River

No physical form management is required in this reach. It generally has good condition physical form, habitat structure and vegetation associations. As with all the lower reaches of the Wimmera, sandy geomorphic units should be expected in this reach.

Reach 13

Reach Description

Reach 13 contains a single, well-developed channel. The channel belt follows the boundary between Parilla Sands and Shepparton Formation, as per Reach 11. This reach has a sand bed, likely to be sourced from the dune sands upstream and local marine sands. Some meander cut-offs have occurred in this reach, however rates of geomorphic change are very slow. Low sediment supply may also hinder the rate at which infilling of abandoned channels occurs.

Aerial Photo, Wimmera River at Wimmera Highway

Tributary Stream Issues

From reach 13 downstream there are no significant surface water inflows to the Wimmera River.

Cross Section Analysis

No cross section analysis was undertaken in this reach.

Longitudinal Section Analysis

The overall gradient of the Wimmera River downstream of reach 11 is approximately 0.0003m/m. Local variations may range from less than 0.0001 to 0.0006. It is estimated reach 13 has a stream gradient of approximately 0.0001m/m over 8km.

Management Implications

Wimmera River

No physical form management is required in this reach. It generally has good condition physical form, habitat structure and vegetation associations. As with all the lower reaches of the Wimmera, sandy geomorphic units should be expected in this reach.

Wimmera River at reach break (13 to 14)

Wimmera River multi-channelled

Reach 14

Reach Description

Reach 14 is an anastomosing reach with 2 or more channels activated well below floodplain level flows. Rates of channel development and decay appear more rapid than nearby upstream reaches, most likely due to the easily mobilised sands that make up the floodplain. The channels contain short deep pools separated by sandy riffles mostly colonised by phragmites and tea tree. These channels are contained within a relatively broad nearly straight channel belt that follows the boundary of Shepparton Formation sediments and the Aeolian sands of the Woorinen Formation.

Aerial Photo, Wimmera River at Polkemmet Bridge (centre)

Tributary Stream Issues

There are no significant tributaries to this reach.

Cross Section Analysis

No cross section analysis was undertaken in this reach.

Longitudinal Section Analysis

The overall gradient of the Wimmera River downstream of reach 11 is approximately 0.0003m/m. Local variations may range from less than 0.0001 to 0.0006. It is estimated reach 14 has a stream gradient of approximately 0.0002m/m over 6km.

Management Implications

Wimmera River

No physical form management is required in this reach. It generally has good condition physical form, habitat structure and vegetation associations. As with all the lower reaches of the Wimmera, sandy geomorphic units should be expected in this reach.

The Heritage River corridor of the Wimmera River, begins at Polkemmet Bridge in this reach.

Reach 15

Reach Description

Reach 15 is characterised by a single dominant channel in a locally contracted floodplain. The channel is well developed and is substantially larger than channels found in adjoining reaches. The character of this reach is likely to be influenced by the close proximity of lunette ridges at the western floodplain margin.

Aerial Photo, Wimmera River at Duchembegarra

Tributary Stream Issues

There are no significant tributaries to this reach.

Cross Section Analysis

No cross section analysis was undertaken in this reach.

Longitudinal Section Analysis

The overall gradient of the Wimmera River downstream of reach 11 is approximately 0.0003m/m. Local variations may range from less than 0.0001 to 0.0006. It is estimated reach 15 has a stream gradient of approximately 0.0001m/m over 3km.

Management Implications

Wimmera River

The alternation between single and multiple channel reaches in the lower Wimmera River is not fully understood. Surficial geology is the likely control. More investigation would be required into the interaction between these reaches if further understanding of the single and multiple channel reaches' interaction is required.

At this point in time no physical form management is required in this reach. It generally has good condition physical form, habitat structure and vegetation associations. As with all the lower reaches of the Wimmera, sandy geomorphic units should be expected in this reach.

Reach 16

Reach Description

Reach 16 extends from Duchembegarra to Ellis Crossing. It is an anastomosing reach, containing sections of dominant channel and poorly developed or decaying anabranches and sections where all channels are immature or nearly infilled and operate at equal flow levels.

The underlying marine Parilla Sands exert soft bedrock controls on this reach, incision and lateral migration of the channel belt is controlled by the sandstone that is often ferruginized (iron cemented). This is the case at the invert of the offtake of one of the anabranches near Mackleys Road.

Aerial Photo, Wimmera River at Ellis Crossing (top)

Tributary Stream Issues

There are no significant tributaries to this reach.

Cross Section Analysis

No cross section analysis was undertaken in this reach.

Longitudinal Section Analysis

The overall gradient of the Wimmera River downstream of reach 11 is approximately 0.0003m/m. Local variations may range from less than 0.0001 to 0.0006. It is estimated reach 16 has a stream gradient of approximately 0.0005m/m over 10km.

Management Implications

Wimmera River

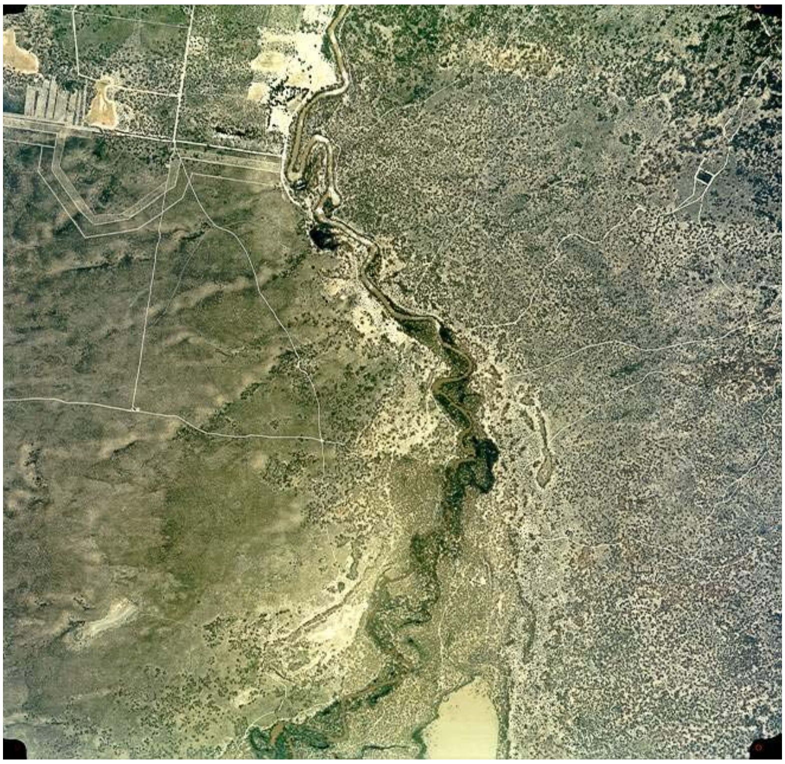
Works have been undertaken near Mackleys Rd by the WCMA in an attempt to prevent an 'avulsion' where it was perceived by landholders that a channel, which flows along the western margin of the channel belt, was developing rapidly. The development of this channel has been influenced by the clearing of riparian and in-stream vegetation, overgrazing and the ford at the end of Mackleys Rd possibly reducing sediment inputs to the downstream section. The WCMA works include the placement of rock and LWD at the upstream end of the anabranch to raise the sill level. These works are not likely to be the solution to the perceived problem. Inspection of the bed of the anabranch channel at its offtake revealed siliceous sands (Parilla Sands, lithified to sandstone), which are resistant to the erosive forces exerted by flows here. The presence of this sandstone is likely to be the reason why this channel had not developed further prior to the works.

More detailed investigation of the geomorphic processes occurring within this reach are recommended to determine if any further works are required. It does not appear that works should be required, the reach generally has good condition physical form, habitat structure and vegetation associations. As with all the lower reaches of the Wimmera, sandy geomorphic units should be expected in this reach.

Reach 17

This reach corresponds with the river cutting through the east-west Lowan Formation sand dunes of the Little Desert National Park. It is characterised by a single, comparatively large (width and depth) channel within a narrow floodplain/channel belt bordered by the sand dunes covered in intact vegetation associations. Cemented Parilla Sands are supplying ‘soft’ gravel size fragments to the stream. Within the channel belt much of the sediment is fine grained and cohesive alluvial material. Sinuosity is irregular, there are long pools or runs, sometimes separated by short high angle bends with sandy point bars on the inside. On the whole geomorphic processes happen at very slow rates. More open water pools are present within this reach than in reaches 13 through 16.

Lateral migration of the Wimmera River in this reach is controlled by the sandstone (Parilla Sands), which has been uplifted on the west side of the river by the Hindmarsh Fault.



Aerial Photo, Wimmera River in Little Desert National Park

Tributary Stream Issues

There are no significant tributaries to this reach.

Cross Section Analysis

No cross section analysis was undertaken in this reach.

Longitudinal Section Analysis

The overall gradient of the Wimmera River downstream of reach 11 is approximately 0.0003m/m. Local variations may range from less than 0.0001 to 0.0006. It is estimated reach 17 has a stream gradient of approximately 0.0006m/m over 20km.

Management Implications

Wimmera River

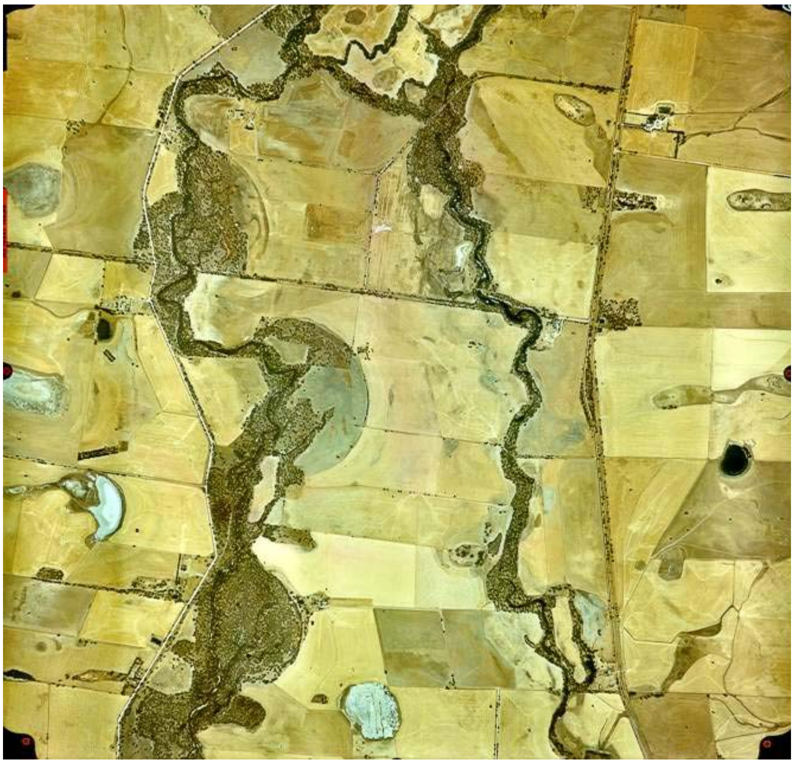
This is a very high value reach of the Wimmera River. It generally has near intact condition physical form, habitat structure and vegetation associations. The management objective for this reach is protection of the existing values. As with all the lower reaches of the Wimmera, sandy geomorphic units should be expected in this reach.

Reach 18

Reach Description

This reach corresponds with the extents of the anabranch known as Datchak Creek, shortly downstream of Dimboola to Antwerp. The anastomosing character of this reach is different to the other anastomosing reaches described here. Distinct from those reaches where the multiple channels are contained within a channel belt less than several hundred metres wide, the main channel and Datchak Creek here are separated by a large island several kilometres wide. The island has aeolian units on its surface, above floodplain level.

The main channel of the river flows through the windward (western) side of several small lunette lakes in this reach, several flood channels are present through the lakes. Lateral migration of the channel is limited in the former lakes by the calcareous clays and sands.



Aerial Photo, Wimmera River and Datchak Creek (note lunette lakes)

Tributary Stream Issues

There are no significant tributaries to this reach.

Cross Section Analysis

No cross section analysis was undertaken in this reach.

Longitudinal Section Analysis

The overall gradient of the Wimmera River downstream of reach 11 is approximately 0.0003m/m. Local variations may range from less than 0.0001 to 0.0006. It is estimated reach 18 has a stream gradient of approximately 0.0005m/m over 28km.

Management Implications

Wimmera River

WCMA has undertaken battering works on the left (outside) bank downstream of Spears Crossing. This work may have been undertaken due to the appearance of the bank, near vertical and devoid of vegetation. Evidence at the site suggests that the rate of migration of this bank is likely to have been very slow, many several hundred year old red gums are located very close to the channel margin on the inside of the bend. A longitudinal bank attached sand bar, slowly being colonised by phragmites and tea tree is immediately below these. Downstream of this, localised channel expansion through slow rates of bank erosion is occurring where tea tree and phragmites have colonised lateral sandy bars, near bank full flows preferentially flow around the outside of these. However, mostly intact riparian vegetation and the fine calcareous sediments ensure this is happening at slow rates.

At this point in time no physical form management is required in this reach. It generally has good condition physical form, habitat structure and vegetation associations. As with all the lower reaches of the Wimmera, sandy geomorphic units should be expected in this reach.

Reach 19

Reach Description

Reach 19 is characterised by a single dominant, well-developed, laterally inactive, low sinuosity channel in a reach with locally variable features. Sandy point and longitudinal bank attached bars are the prevalent instream geomorphic units with long pools and runs. Flood channels (probably paleo channels) are present across the floodplain, which become activated at bank full flows. One flood channel at Tarranyurk is separated by up to a kilometre of floodplain, this channel appears to be decaying at its upstream end.

Occasionally the channel reduces in capacity and splits into 2 channels around vegetatated islands in the channel belt for short (<1km) reaches. There are many benches in these reaches creating a compound cross section.

Aerial Photo, Wimmera River downstream of Tarranyurk

Tributary Stream Issues

There are no significant tributaries to this reach.

Cross Section Analysis

No cross section analysis was undertaken in this reach.

Longitudinal Section Analysis

The overall gradient of the Wimmera River downstream of reach 11 is approximately 0.0003m/m. Local variations may range from less than 0.0001 to 0.0006. It is estimated reach 19 has a stream gradient of approximately 0.0001m/m over 20km.

Management Implications

Wimmera River

At this point in time no physical form management is required in this reach. It generally has good condition physical form, habitat structure and vegetation associations. As with all the lower reaches of the Wimmera, sandy geomorphic units should be expected in this reach.

Reach 20

The last reach of the river before entering Lake Hindmarsh is extensively influenced by backwater effects of either the lake containing water, Jeparit weir and/or the deltaic deposits at the river mouth. The river is sinuous, has many meander cut-offs, billabongs, concave benches, islands and point benches.

Aerial Photo, Wimmera River entering Lake Hindmarsh when full

Tributary Stream Issues

There are no significant tributaries to this reach. Lake Hindmarsh effectively terminates the Wimmera River channel. Outlet Creek flows from the northern end of Lake Hindmarsh to Lake Albacutya, it is effectively a continuation of the Wimmera River. Outlet Creek has not been investigated as part of this report.

Cross Section Analysis

No cross section analysis was undertaken in this reach.

Longitudinal Section Analysis

The overall gradient of the Wimmera River downstream of reach 11 is approximately 0.0003m/m. Local variations may range from less than 0.0001 to 0.0006. It is estimated reach 12 has a stream gradient of 0.0001m/m or less over the 13km to the inlet of Lake Hindmarsh.

Management Implications

Wimmera River

At this point in time no physical form management is required in this reach. It generally has good condition physical form, habitat structure and vegetation associations. As with all the lower reaches of the Wimmera, sandy geomorphic units should be expected in this reach.

Conclusions and Recommendations for Management

This investigation has produced a broad scale understanding of the geomorphic character and behaviour of the Wimmera River. The morphological attributes of the river have been distinguished and the river divided into reaches based on those attributes. The interaction between these reaches has been interpreted.

To generate understanding of sediment sources, transport and fate, the geologic setting of the river and catchment evolution have been investigated. Superimposed on the geologic controls on river character and behaviour are the contemporary (post European) changes that have occurred to the catchment and the river. Some reaches of the river and tributaries have proved sensitive to change or have been directly altered, while others have been insensitive.

The investigations have revealed both new and challenging issues for the management of the Wimmera River, the tributaries and catchment.

Summary of Sediment Sources Transport and Fate in the Wimmera River

Sediment Sources

The geology of the catchment dictates the types of sediment that may become available to the stream network. Following are the main sediment sources within the Wimmera River catchment:

- Permian/Cambrian marine sedimentary bedrock; predominantly siltstone/mudstone, deeply weathered, prone to contemporary gully, rill and sheet erosion when land is cleared. Makes up the majority of bedrock in the upper catchment.
- Devonian Granites; intruded into sedimentary bedrock, weathered, providing sand to streams. May often contain swampy freshwater meadows where not gullied.
- Devonian/Carboniferous marine sandstones; the Grampians are almost completely composed of sand and provide much of the sand to the younger geology, hence to the stream network.
- Tertiary Marine sands; broad plains and ridges from around Glenorchy and downstream, often border the floodplain or channel belt.
- Quaternary Aeolian dunes; primarily sands, often highly erodible, border most of the lower river floodplain or channel belt.
- Quaternary fluvial sediments; clay, silt, sand and gravel deposited within and reworked by the stream network in the most recent geologic periods.

Sediment Transport and Fate

These investigations have included analysis of the sediment transport capacity of the present day Wimmera River at Eversley, Glenorchy and Horsham (downstream of weir). It was revealed that at Eversley and Glenorchy the river has the capacity to transport significant volumes of sediment at bank full flows. In fact, it is likely at these locations the river will be supply limited, that is, it will be able to transport more sediment than is available to it.

The results of this analysis concur with field observations within these reaches. Very little mobile sediment is found in the channel.

In contrast, other reaches of the Wimmera River have low sediment transport capability. Reaches 2, 4 and 6 are natural sediment accumulation zones within the upper catchment. These reaches have over recent geologic time periods, acted as sediment stores. These reaches are cut and fill valleys that most probably contained chain of ponds or freshwater meadows throughout, prior to European settlement of the area. There are still several intact reaches of these stream types, in upper reach 2 and Glenlofty Creek. The majority of reaches 2, 4 and 6 have however undergone channelisation both directly through excavation and through incision processes (headward erosion/gullying) initiated by post European changes within the catchment. Similar adjustments have occurred in most of the upper catchment tributaries, many of which now (over the last 150 years) deliver excess sediment loads to the river.

There are many weirs along the course of the Wimmera River, these structures will trap much of the bedload sediment transported into the weir pool.

One of the major outcomes of this investigation has been to find that many of the upper catchment tributaries experiencing erosion do not deliver <u>coarse</u> sediment to the river. This is generally due to natural mechanisms such as floodouts but may also be due to works undertaken by soil conservation programs (e.g. Sheas Creek).

The majority of the catchments that do deliver coarse sediment to the river are situated in high relief areas close to the river and only travel a short distance within the Wimmera River floodplain (e.g. Glendhu Creek).

Much of the fine sediment generated within the upper catchment and delivered to the river is going to be transported in large flow events and deposited on the floodplain.

One of the other mechanisms affecting sediment transport and fate in the middle and lower reaches of the Wimmera River has been the diversion of large volumes of flow at Huddleston weir into the Wimmera Mallee water supply and distribution system. It could be expected that such a reduction in flow would result in a reduction in channel capacity. However, the supply of sediment into the river downstream of Huddleston weir is limited by upstream morphological attributes and the weirs, hence any contraction of the channel will be very slow. Also, as a result of flow diversions, the magnitude of flow events has declined, further reducing the sediment transport capability within the river system downstream of Huddleston weir.

The impact on the occurrence of overbank flow events has been determined through flood frequency analysis and effective discharge analysis. It has been found that the occurrence of overbank flooding, which has been perceived as increased in recent years, will return to something approaching pre-diversion occurrence.

Recommendations for Management

Based on the understanding developed through investigation a set of ongoing recommendations have been developed. The purpose of these recommendations is to assist the WCMA develop and implement to waterway management program.

Reach 1

Preserve near intact condition, be involved in the decision making processes in forest management.

Reaches 2, 4 and 6

Recognise the natural characteristics of these fill valleys. They are swampy, with discontinuous channels containing Freshwater Meadows or Chain of Ponds.

The WCMA should generate understanding, recognition and acceptance within the community of these characteristics, such that informed management objectives can be determined for these reaches and in tributaries with similar characteristics with the community.

In the interim it is a high priority to ensure no further degradation of those geomorphically intact reaches, 2.1 and 2.3, occurs. High priority should also be given to the rehabilitation of reach 2.2, it is short, between reaches 2.1 and 2.3 and poses a threat to their status.

The management of Reach 6.2 for continuing sediment deposition is critical. The potential impacts that increased sediment loads could have on high value reaches downstream make the maintenance of dense instream and riparian vegetation in this reach a high priority for the WCMA.

At the moment this reach has accumulated much of the sediment that has been liberated by drainage works and incision processes upstream. Management efforts should be directed toward ensuring that mechanisms are in place that will keep deposited sediment in place and continue the deposition in this reach of excess sediment delivered from upstream. Vegetation will be the key mechanism, structural works are only likely to be required if any vegetation loss and/or incision occurs.

General management objectives for degraded Chain of Ponds and Freshwater meadows should be to encourage regeneration of instream and riparian vegetation.

Management strategies applied to the tributaries of these reaches will be determined once the objectives have been set for the river.

Upper Catchment Tributaries

Those systems which are delivering coarse sediment to the Wimmera River are highest priority for management intervention. e.g. Glendhu, Spring, Sandy and Rocky Creeks. Management strategies should aim to reduce bedload sediment delivery to the river and limit any further headward incision of gullies. Works to achieve this will be both structural and vegetative.

Sediment extraction from tributaries is not recommended, such measures are likely to initiate a new phase of incision and instability.

Within the remainder of the tributaries that are currently not delivering substantial volumes of coarse sediment, any vegetative works are encouraged on an ongoing basis. e.g. Six, Seven, Sheas and Wattle Creeks.

Floodout zones on tributaries

Floodout zones are critical for preventing sediment from upper catchment gully erosion reaching the Wimmera River. Floodout zones occur on major tributaries such as Six Mile, Seven Mile, Wattle and Glenpatrick Creeks and on many other minor streams. Over the last century many of these zones have been drained to improve agricultural land use. Upper catchment gully erosion will have been contributing excess sediment loads that will be infilling these drains returning the floodout zone characteristics.

Management objectives for these reaches should aim to enhance the floodout zone sediment trapping and storage capabilities, while also reducing sediment inputs through gully erosion control upstream.

Glenlofty Creek

This creek has similar characteristics to reaches 2.1 and 2.3 of the Wimmera River, it is a high priority for management to preserve the geomorphically intact chain of ponds. As such a similar approach as recommended for reaches 2.1 and 2.3 should be adopted.

Glenlofty Creek provides the opportunity to increase understanding of Chain of Ponds streams. It is recommended a monitoring program is established and a benchmarking exercise undertaken.

Reaches 7 and 8

Reaches 7 and 8 are very high value reaches of the Wimmera River. They are possibly the least degraded and Reach 7 has one of the least altered hydrology regimes of the whole river. Very little management intervention is required within these reaches. Isolated incidences of bank erosion should be addressed.

There is an imperative to undertake works in tributaries such as Concongella Creek and in upstream reaches and tributaries to protect these reaches.

Reaches 9 and 10

Reaches 9 and 10 are both generally in good geomorphic condition and include high value sections such as the Marma State Forest. Management actions within these reaches should firstly address ecological issues. Localised bank erosion does occur in these reaches, incidences should be identified and considered for future action.

Reach 11

Reach 11 is generally in good geomorphic condition. One exception to this is the Horsham weir pool that is used extensively for recreation and has been extensively altered by 'channel clearing' works. Fortunately the river is relatively insensitive to change, which has kept channel adjustments to a minimum. It is recommended that management of bank erosion within the weir pool be further investigated. Options such as strategic plantings of macrophytes in areas susceptible to bank erosion should encouraged. The community should be informed of the processes occurring in the weir pool and the role macrophytes play in maintaining bank stability.

Grampians Tributaries

The major tributaries to the mid Wimmera River from the northern Grampians have not been investigated in detail, only their impacts at the Wimmera River has been investigated. Mackenzie, Norton and Burnt Creeks are all going to have significant sand loads from the Grampians, management of these streams should be mindful of their sensitivity to disturbance.

Reaches 12 to 20

The majority of the Wimmera River through reaches 12 to 20 (including the Heritage River Corridor) has suffered relatively low levels of disturbance since European settlement. Riparian and instream vegetation, woody debris and geomorphic condition provide excellent habitat structure. The major issue for stream health in these reaches is flow.

Local and isolated geomorphic issues such as bank erosion or anabranch development do exist and should be investigated for potential works. The majority of these reaches simply require protection and improved land management practices.

Perception of flooding in mid to lower reaches

Extraction of sediment, woody debris and vegetation from the river is not an effective use of WCMA resources. The analysis undertaken in this investigation shows that the occurrence of overbank flooding is and will be similar to that which occurred prior to regulation of the river.

The majority of sediment derived from gullying in the upper catchment is not being deposited in the river channel, in fact, the majority is not being delivered to these reaches. Mobile sediment that is seen in the channel in these reaches is in the majority from local sources, such as sand dunes.

Macrophytes such as phragmites do not have any significant impacts on flooding, these plants streamline and provide very little resistance in large flow events.

Priorities for Management

Table 5.1 lists the recommendations for management in priority order, commencing with the reach/tributaries of highest priority. These priorities are based on principles of best practice catchment management:

- preserve areas with near pristine values
- restore areas with high values
- rehabilitate areas that place other values at risk or provide good opportunity for restoring values
- maintain degraded areas to prevent values declining to unacceptable levels

Detailed investigation of the tributaries has not been undertaken. Management priorities may change when further knowledge of these waterways is gained.

Reach/Tributary	Description	Value/Impact	Priority	Actions
Reach 6.2	Discontinuous, recovering chain of ponds	Sediment accumulation zone protecting high value downstream reaches	Very High	Enhance riparian and instream vegetation to ensure this reach continues to function as an effective sediment trap for protection of reaches 7 & 8.
Reach 2.1 and Little Wimmera River	Discontinuous, intact freshwater meadows or chain of ponds	High value reaches of rare geomorphic character	Very High	Stabilise erosion heads at downstream boundaries to these reaches. Protect and enhance riparian and instream vegetation.
Reach 2.3 and Glenlofty Creek	Discontinuous, intact freshwater meadows or chain of ponds	High value reaches of rare geomorphic character	Very High	Maintain drop structure in Wimmera River, protect and enhance riparian and instream vegetation, reduce inputs of coarse sediment.
Reach 1	Intact bedrock controlled valley	High value intact reach with forested catchment	High	WCMA to become involved in management of catchment to ensure protection of this reach.
Tributaries delivering coarse sediment to the upper Wimmera River (e.g. Glendhu, Spring, Sandy, Rocky Creeks)	High relief, short sediment delivery distance tributaries, mostly eroded gullies	Coarse sediment from these tributaries threatens high value reaches of the Wimmera River and hinders recovery of degraded reaches	High	Reduce bedload sediment delivery to Wimmera River. Minimise further headward incision of gullies. Structural and vegetative works required.
Tributaries with floodouts e.g. Glenpatrick, Six Mile, Seven Mile Creeks & many gullies	Mostly drained or incised floodout zones	Sediment from incision process is deposited and stored in floodout zones. Floodout zones are valuable in reducing sediment load to Wimmera River	High	WCMA needs to discuss management of these zones, consult landholders and determine management policy. Best practice management principles suggest these zones should be managed to enhance sediment deposition and storage. Whole of sub catchment plans will be required to address excess sediment supply from erosion processes upstream of floodout zones

Reach/Tributary	Description	Value/Impact	Priority	Actions
Reaches 2, 4 & 6	Continuous, excavated or incised. Recovering Fill Valleys (chain of ponds)	Modified but recovering to a chain of ponds character. This process has potential to impact on current agricultural land usage. Retaining continuous channel will require ongoing sediment extraction and will negatively impact on upstream reaches	High	WCMA needs to discuss management of these reaches, consult landholders and determine management policy. Best practice management principles suggest recommend these zones should be managed to enhance recovery of chain of ponds character
Reaches 7 & 8	Continuous, intact, alluvial	High value reaches with near intact geomorphic condition, riparian vegetation, habitat structure and flow regime	Medium	Protect the high values of these reaches. Enhance riparian vegetation
Reaches 15 – 20	Continuous, near intact, lower Wimmera River	High value, Heritage River section of Wimmera River. Near intact geomorphic condition, riparian vegetation and habitat structure	Medium	Protect the high values of these reaches. Enhance riparian vegetation. Pursue restoration of flow regime
Other tributaries (e.g. Mt Cole, Concongella, Mt William, McKenzie Creeks)	Larger, longer sediment delivery distance tributaries	Further investigation is required to determine the condition and how much sediment is/will be delivered to the Wimmera River by these major tributaries	Medium	Further investigation is required to determine priorities for management
Reaches 9 – 14	Continuous, near intact geomorphic condition	Generally in good geomorphic condition. Some degradation of riparian vegetation and minor bank erosion	Medium	Restore/enhance riparian vegetation. Promote the strategic planting of macrophytes in the Horsham Weir Pool to reduce bank erosion. Pursue restoration of flow regime

Table 5.1 *Recommendations for Management*

Proposed Actions

Further Investigations

This Geomorphic Investigation was undertaken to determine sediment sources, transport and fate within the drainage network of the Wimmera River. Targeted investigations of tributaries were undertaken to determine their geomorphic impact on the Wimmera River. However, detailed investigations of the geomorphic character, condition and processes occurring within tributaries were not part of this investigation.

Further investigation into the tributaries of the Wimmera River is required. The major tributaries of the Wimmera River, such as Mt Cole, Concongella, Mt William and McKenzie Creeks exhibit varying geomorphic characteristics and behaviour. The condition of these tributaries and the potential for them to negatively impact on the high value reaches of the Wimmera River in the future is not known. It is also likely that these tributaries contain reaches of high value and/or rare geomorphic character that warrant protection by the WCMA.

To gain this knowledge it is recommended that a Geomorphic Categorisation of the Wimmera River Catchment be undertaken. The categorisation will expand on the knowledge gained from the Geomorphic Investigation and broaden in focus from the Wimmera River to include the entire catchment. A Geomorphic Categorisation of the catchment would provide the WCMA with the following outcomes:

- identification of geomorphic stream types throughout the Wimmera Catchment
- a thorough stream condition assessment of the Wimmera Catchment
- identification of template reaches for benchmarking and objective setting
- prioritisation of stream reaches with respect to geomorphic stream type and stream condition
- identification of objectives and strategies for stream management and monitoring of priority reaches

Together with the Geomorphic Investigation, the Geomorphic Categorisation will enable informed proactive management of the catchments waterways and facilitate the setting of priorities with targeted outcomes for the Waterway Works Program. It will provide the basis for the implementation of the WCMAs Waterway Works Program into the future.

Promoting Community Awareness

There is potential conflict in the management objectives of many of the reaches of the Wimmera River and its tributaries. The management objectives of these reaches require determination by the WCMA in consultation with the community.

These reaches are generally of two types:

- incised or drained reaches of the Wimmera River, likely to have been chain of ponds prior to European settlement, that are now filling with sediment and recovering towards the chain of ponds character
- Floodout zones of tributaries, incised or drained, re-filling with sediment

To improve the agricultural production value of the floodplains of these natural 'swampy' reaches they were often drained by European settlers. The controls on these reaches in conjunction with increased rates of sediment inputs from upstream erosion means they tend to revert to their natural characteristics, reducing the agricultural values of the adjoining land. There is therefore a benefit to the landholders in retaining the current geomorphic condition of these reaches.

On the other hand maintaining these reaches in their current form is in conflict with best practice catchment management principles. On-going sediment extraction would be required, involving cost and resulting in the incision of upstream reaches, which can lead to loss of agricultural land through gully expansion and/or damage to high value reaches of waterway.

The WCMA should generate understanding, recognition and acceptance within the community of the natural characteristics of these reaches, so that informed management objectives can be determined for these reaches with the community.

The first step in this process is to discuss the management of these reaches within the WCMA (board members, committee members and staff) so that a preferred management policy can be determined. This would be best achieved by undertaking a field day where these sites can be inspected and discussed, and then providing a forum for discussion within the WCMA.

The second step in this process is to involve local landholders and groups in discussion. This would be best achieved by getting the landholders at each site together for a discussion of the natural characters of these reaches and the impacts of management policies on their land use and upstream waterways.

The preferred outcome would be a consensus between the WCMA and landholders for management of these reaches working with rather than against natural processes and characteristics.

Waterway Action Plans

The Geomorphic Investigation has highlighted a number of reaches and tributaries of high geomorphic value that require works for their protection. The development of Waterway Action Plans is recommended for high value reaches that are at threat from processes occurring within them and for reaches/tributaries that are negatively impacting on high value reaches elsewhere. Waterway Action Plans are proposed for the following waterways (in priority order):

1. Glenlofty Creek sub catchment
2. Wimmera River, Reach 6
3. Wimmera River, Reach 2
4. Concongella Creek sub catchment
5. Six and Seven Mile Creek sub catchments
6. Glendhu and Sheas Creek sub catchments

The reaches of highest priority for action (i.e. those listed above) may change when further information becomes available, such as the Geomorphic Categorisation. The WCMA may choose to develop additional Action Plans in the future to include other high priority reaches and tributaries.

These plans will provide an efficient mechanism for involving the community and landholders in the management of these reaches, promoting awareness of the character and condition of the waterways and the processes occurring which are leading to their degradation or the degradation of high value waterways elsewhere.

These plans will involve an assessment of issues and the development of works concepts at a property scale. Landholders will be given an opportunity to discuss the management objectives of the WCMA, the issues affecting them and their property, the activities proposed, and to indicate their willingness to be involved in the activities program.

The Waterway Action Plans will form the basis of activities in these sub catchments and reaches for many years.

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Appendix A

Hydrologic Analysis

Contents

An Indication of Hydrologic Change

The hydrologic and hydraulic analysis comprising this appendix indicates the effects of regulation on the volume and frequency of mean daily flows, therefore giving a better understanding of the flow processes now affecting the river channel.

This appendix also indicates the state of the Wimmera River prior to European settlement and the changes that have altered the River.

Hydrologic comparisons were made for locations on the Wimmera River considered to be upstream of the majority of flow regulations and diversions and for a location on the river considered to be downstream of the major regulations and diversions. Flow information was also obtained for an adjacent catchment to determine the natural variations.

For flow data the location upstream of the human changes was taken as Glynwylln station and Concongella Station combined, the location being upstream of Glenorchy, the location of numerous in channel alterations. For flow data from a location downstream of the changes the Horsham Station, downstream of Horsham but upstream of Mackenzie River, was used.

An adjacent catchment, the Avoca River was included in the analysis to ensure the differences in flow indicated are reflecting human alteration to the flow regime rather than natural variations over the periods. The Avoca Basin runs parallel with the Wimmera/Avon Basin with a similar orientation of a general northerly flow direction. There are no major water storages or diversions in the Avoca River (Department of Water Resources Victoria, 1989) which make variations in flows over time periods a result of natural variation as opposed to human interference.

Gauging station information was obtained from Thiess for the following sites, Table A1.1.

Station no.	Waterway	Location	Data Type	Period of Data
415 206	Wimmera River	Glynwylln – upstream of Glenorchy	Mean daily flow (ML/d)	1946-2001
415 237	Concongella Creek	Stawell – tributary of Wimmera	Mean daily flow (ML/d)	1976-2001
415 200	Wimmera River	Downstream of Horsham – upstream of McKenzie River	Mean daily flow (ML/d)	1889-2001
408 200	Avoca River	Coonooer – upstream of Charlton	Mean daily flow (ML/d)	1889-2001

***Table A1.1**. Gauging stations used in analysis.*

Historical Waterway Changes in the Wimmera River

The Wimmera River Untouched by European Settlement

In 1836 Major Thomas Mitchell and his party became the first Europeans to pass through the Wimmera Region. While Mitchell's party came across the Wimmera River from the south at a location above Horsham the diaries do not give any descriptive indication to the Wimmera River at this location. The following descriptions of the Wimmera River south of Horsham have been summarised from Mitchell (1839);

- *"At a quarter mile from the camp, we crossed a running stream, which also contained deep, and apparently permanent pools. Several pine or callitris trees grew near its banks, being the first we had seen for some time. I named this mountain stream the Mackenzie."*
- *"Beyond it, were grassy, undulating plains, with clumps of casurina, and box trees (eucalypti). At three miles, we came to a deep stream, running with considerable rapidity, over a bed of sandstone rock…. This I named the Norton."*
- *"At nine miles…we soon came once more upon the Wimmera, flowing in one deep channel nearly as broad as the Murrumbidgee, but in no other respect at all similar. The banks of this newly discovered river were not water-worn, but characterised by verdant slopes, the borders being fringed with bushes of mimosae."*

After this point Mitchell and his party abandoned the pursuit of the Wimmera River and headed south-west.

A History of Alteration

From various stated sources an account of dates pertaining to human alterations of the Wimmera River can be formulated, Table A2.1. Channel works in the vicinity of Horsham have been abstracted from the works file of the State Rivers and Water Supply Commission (SRWSC) for the period 1966 to 1970. Apart from the construction of weirs and offtakes works have included snag removal, in-channel and floodplain vegetation removal, alignment training, sand extraction and channel enlargement works.

From the historical investigation it was identified that the years between 1935 and 1968 involved the majority of the river diversions and storages constructed with an effect on the flow in the Wimmera River.

Date	Flow Alteration	References
1857	First weir on Wimmera River used to divert water into Yarriambiack Creek (used until about 1920)	Pers. Comm. John Martin (WMW)
1878	Weir constructed 5km above Glenorchy to divert water into Dunmunkle and Swedes Creeks	WMW (Wimmera Mallee Water) homepage 2001
1887	Construction of Wartook Reservoir, first storage in Wimmera Catchment – Mackenzie River	Pers. Comm. John Martin (WMW)
Late 1800s	Dooen Weir constructed to supply water via pump to Patterson Swamp channel system (towards Dimboola)	
1903	Construction Lake Lonsdale (65,500 ML) – Mt William Creek. Construction Glenorchy Weir and compensation weirs in mid-lower river (i.e. Drung Drung, Dimboola, Antwerp and Jeparit).	WMW 2001, Department of Water Resources Victoria (DWR) Victoria 1989a, Pers. Comm. John Martin (WMW)
1916	Fyans Lake construction (21,000 ML) – Fyans Creek	WMW 2001
1920's	Huddlestons Weir construction for supply of water to Taylors and Pine Lakes (reconstruction early 1980s)	Pers. Comm. John Martin (WMW)
1923	Taylors Lake effective operation (36,000 ML) and Pine Lake (64,000 ML)	Pers. Comm. John Martin (WMW)
1934/35	Green and Dock Lakes construction	WMW 2001
1960's	Construction of low weir in Wimmera River at Yarriambiack Creek offtake to ensure a share of low flows passed to Creek	Pers. Comm. John Martin (WMW)
1966	Lake Bellfield construction (78,500 ML) – Fyans Creek Removal of snags, scrub and obstructions Glenorchy downstream, cut channels across two bends in River near Company's Bridge.	DWR 1989, State Rivers and Water Supply Commission (SRWSC)1970
1967	Removal of snags and vegetation from silt islands within the Wimmera River from Horsham downstream to Kenny's Ford	SRWSC 1970
1968	Construction of low level weir at Glenorchy	Pers. Comm. John Martin
1969	Removal of snags and cumbungi (using bulldozer) from river channel between highway bridge and Drummond St, removal of soil from river bed (inside of bends) From Glenorchy downstream to Faux Bridge (3 miles) removal of trees from bed of river and 'redefine stream through sand banks'.	SRWSC 1970
1970	Horsham Weir construction – Wimmera River (original weir constructed much earlier) Deepening and Widening of Wimmera River throughout Horsham City Riverbed clearing of instream vegetation through Horsham ceased	SRWSC 1970, Pers. Comm. John Martin (WMW)

Table A2.1 *River Alteration Dates*

Hydrologic Change

Since hydrology and hydraulics of river systems are complex there are several ways of assessing changes. Comparisons of pre and post regulation flow conditions have been made using flow duration and flood frequency analysis. The effective discharge technique has been used to identify the likely change in channel hydraulic capacity resulting from changes in the hydrologic regime.

Hydrologic assessments have been undertaken for the Wimmera River near Horsham and the Avoca River (Coonooer Guage). The Avoca River is considered to have not been impacted by flow regulation and provides a usefull comparison for the assessment of regulation versus natural variation in hydrologic regime.

From the historical investigation it was identified that the years between 1935 and 1968 involved the majority of the river diversions and storages constructed with an effect on the flow in the Wimmera River. The flow duration analysis adopted for this investigation requires identical periods of data. For the purpose of pre/post regulation comparisons the periods used for the Wimmera River at Horsham and the Avoca River at Coonooer were 1900-1930 (pre-regulation) and 1970-2000 (post-regulation). The full periods of record outside the period of regulation change (1935 to 1968) were used for flood frequency analysis.

Avoca River – Coonooer Gauging Station (408 200)

The Mean daily flow data for the Avoca River was obtained from Coonooer Gauging Station (408 200), downstream of the Coonooer Bridge and upstream of Charlton. Mean annual streamflow for the Coonooer station is 43,000 ML, compared with 135,000 ML for the Horsham station (Department of Water Resources Victoria, 1989). While there are differences in catchment sizes the stations are worthy comparisons as they are located approximately half way down their respective river systems below most major tributary inputs.

Flow Duration

Flow duration curves indicate the amount of time for which river flows occur within a particular flow range. The duration of time in which flows are within a flow range are indicated by cumulative number of days for which a flow is exceeded over a time period. From the curve the amount of time (number of days) for which mean daily flows are above a particular flow is indicated, for example at the Coonooer gauge post regulation period mean daily flows greater than 15,000 ML/day occurred for 32 days of the 31 year period, Figure A3.1.

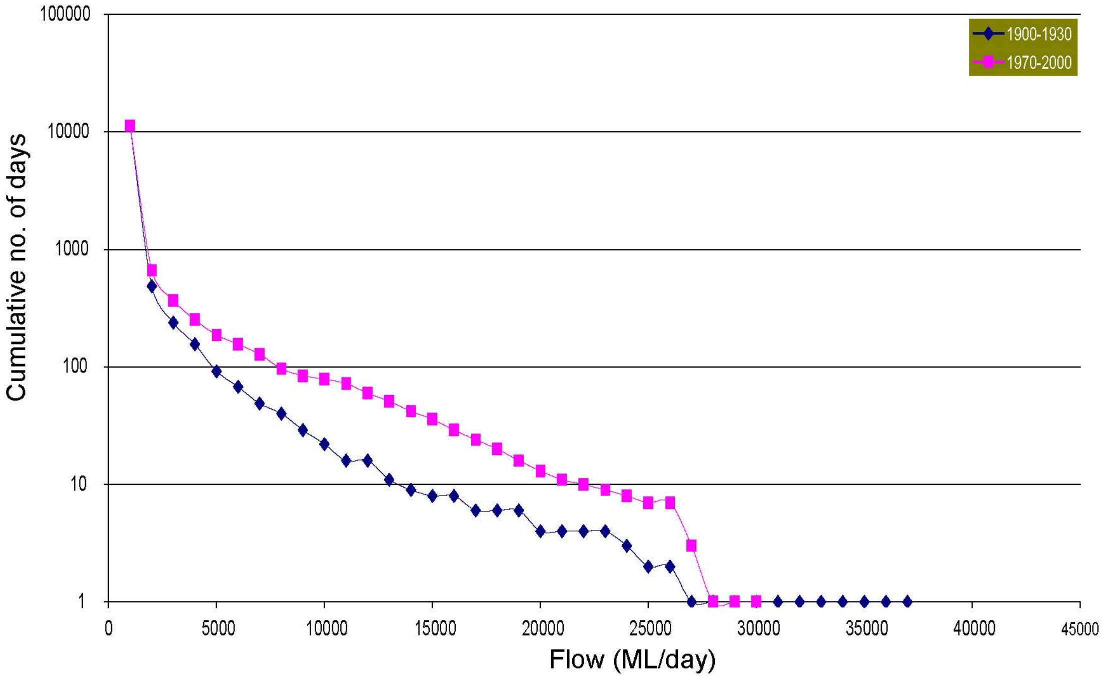


Figure A3.1 *Flow Duration Curves – Avoca River Coonooer Gauge (408 200)*

Flood Frequency

A flood frequency analysis indicates the return period for a flood of a particular magnitude, this can be represented as an Annual Exceedence Probability (AEP). Annual series Log Pearson Type III analysis has been adopted for the investigation.

The variation in flood frequency for the Avoca River at Coonooer station has been assessed for the same periods (pre and post regulation) as that used for the Wimmera River Horsham gauge, Figures 3.2 and 3.3.

The change in flood frequency indicates a general increase in flood frequency magnitude for the equivalent Horsham post regulation period, Table A3.1.

AEP (%)	Discharge (Ml/d) (1900-1930)	Discharge (Ml/d) (1970-2000)	% Change
50	6585	11070	+68
20	14467	21866	+51
10	20698	26621	+29
5	27312	30011	+10

Table A3.1. *Flood Frequency Summary Avoca River at Coonooer Station.*

Note: Results for the 2% and 1% AEP’s are not reliable for 30 year data period and have been excluded from the table.

The results for the Avoca River flood frequency analysis indicate that the floods in the 1970 –2000 period were greater than those in the period 1900 -1930. The flow duration analysis indicates that flows were greater in the 1970 –2000 period than that in the 1900-1930 period.

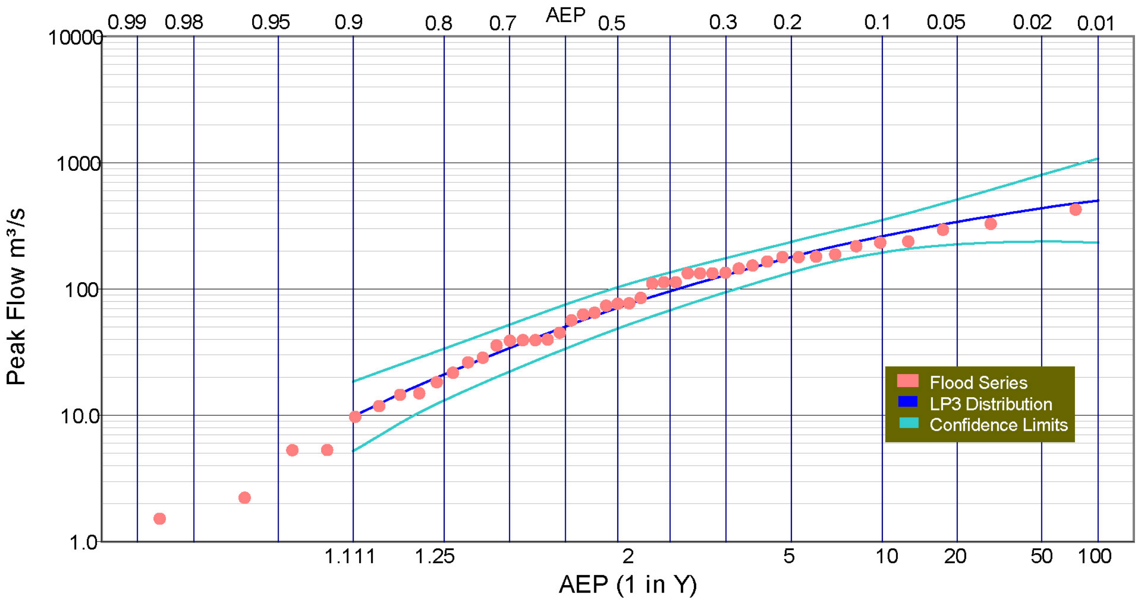


Figure A3.2 *Flood Frequency Curve – Avoca (1900 – 1930)*

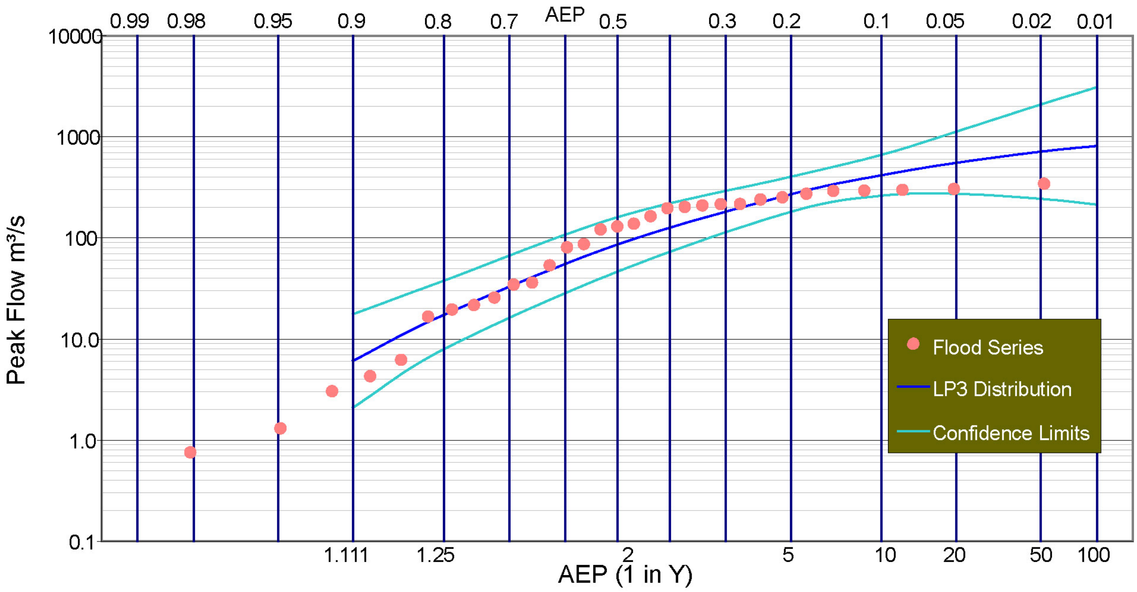


Figure A3.3 *Flood Frequency Curve – Avoca (1970 – 2000)*

Wimmera River – Glynwylln Station

Flow data for upstream of Glenorchy is obtained from the Glynwylln gauge on the Wimmera River and Concongella gauging station on Concongella Creek (415 237).

Flow Duration

The flow duration curve for the section upstream of the main diversions and regulations was obtained from the mean daily flow data by combining the flows from the Glynwylln station with those for Concongella Creek with a day lag. The period is 24 years from 1977 – 2000 inclusive, the longest period of combined record. No pre regulation dates were considered for Glynwylln.

The period of data is not equal to that chosen for the downstream flow duration curve and as such the curve is not for flow comparison purposes between sites but an indication of the trend in flow duration in the upper catchment, Figure A3.4. Data has been used for sediment transport investigations

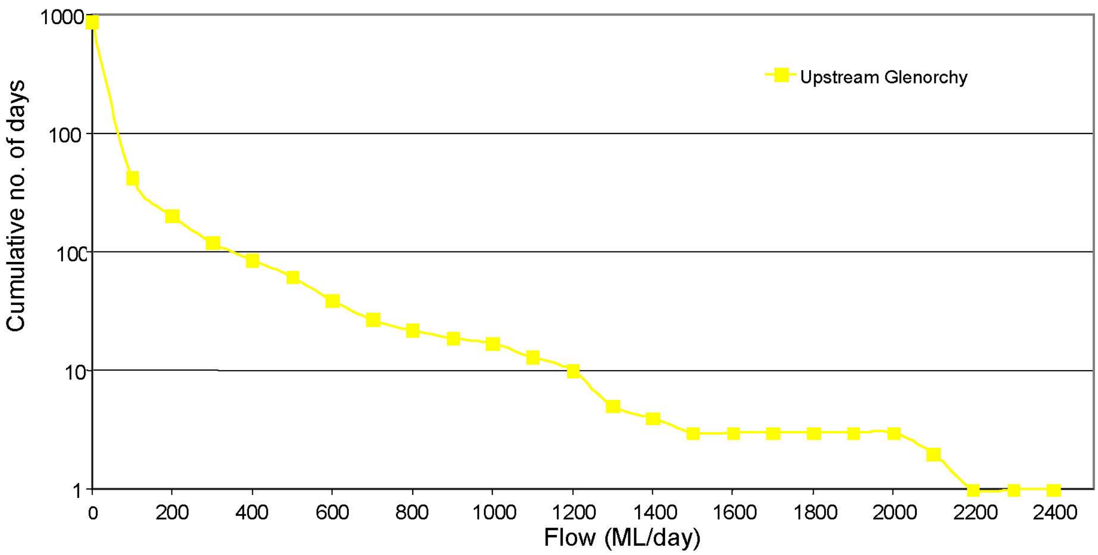


Figure A3.4 *Flow Duration Curve Wimmera River – Upstream of Glenorchy (415 206 and 415 237)*

Wimmera River – Horsham Station

The flow duration curve for the section downstream of the main diversions and storages was taken at the Horsham gauging station (415 200).

Flow Duration

To ensure a relative comparison, periods of equal length were chosen for pre and post conditions. The periods of flow were separated into pre regulation, 1900 – 1930 inclusive and post regulation, 1970 – 2000 inclusive. Both data periods are 31 years, Figure A3.5.

Flood Frequency

Annual series flood frequency curves were produced for pre and post regulation periods for the Wimmera River. Pre regulation curves were for the period 1889 to 1933 inclusive (45 years), Figure A3.6, and post regulation 1970 to 2000 inclusive (31 years), Figure A3.7.

A comparison of discharges for flood frequencies for the Wimmera River upstream and downstream of river alterations reveals a decrease in discharges post regulation, Table A3.2.

AEP (%)	1900-1930 Discharge (m3/s)	1970-2000. Discharge (m3/s)	% Change
50	97	53	-45
20	217	135	-38
10	311	200	-36
5	411	269	-35

Note: Results for the 2% and 1% AEP's are not reliable for 30 year data period and have been excluded from the table.

Table A3.2. *Flood Frequency Summary Wimmera River Downstream of Horsham.*

These results suggest a reduction in flood magnitude in the post regulation period when compared against the pre regulation period. This is in contrast to the results for the Avoca River gauge. The analysis suggests that the reduction in stream flow and flood magnitude in the Wimmera River is likely to be the result of human intervention (flow regulation) alone and not associated with temporal variation in hydrology.

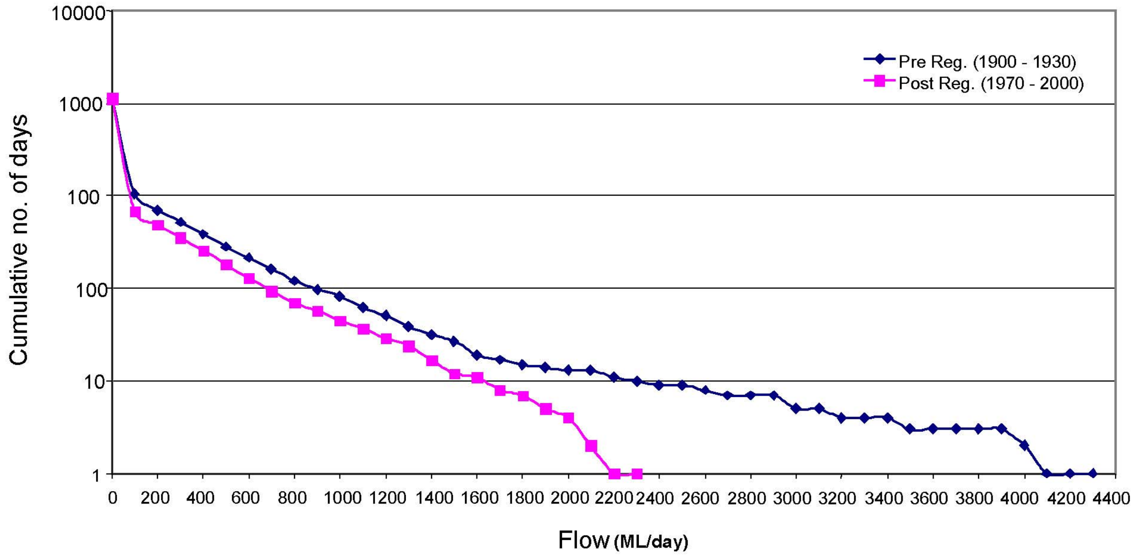


Figure A3.5 *Flow Wimmera River Horsham Gauge (415 200)*

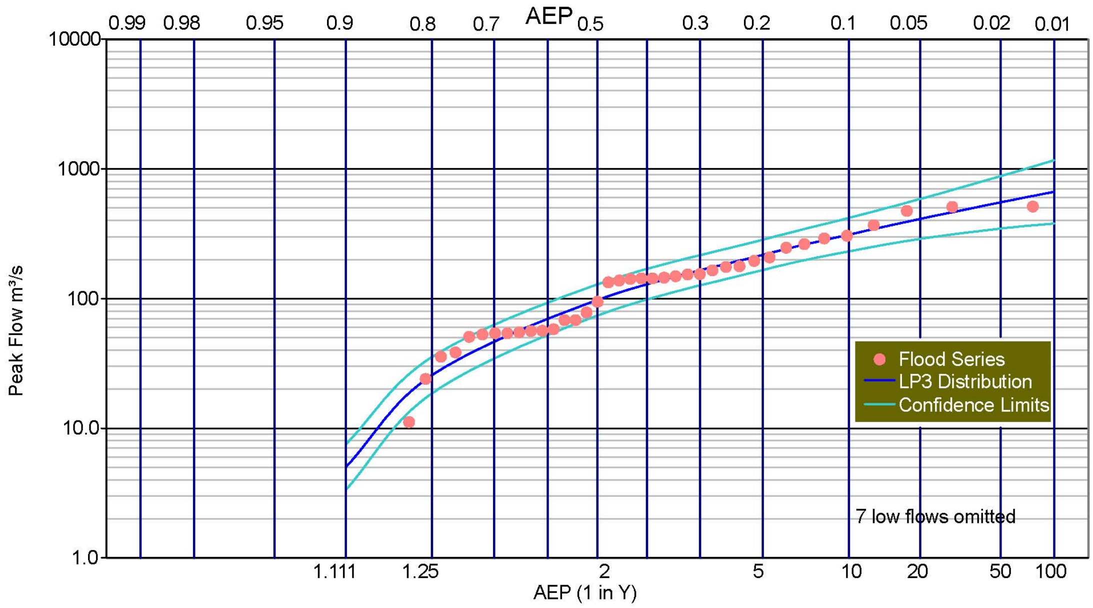


Figure A3.6 *Horsham Pre Regulation 1900 – 1930*

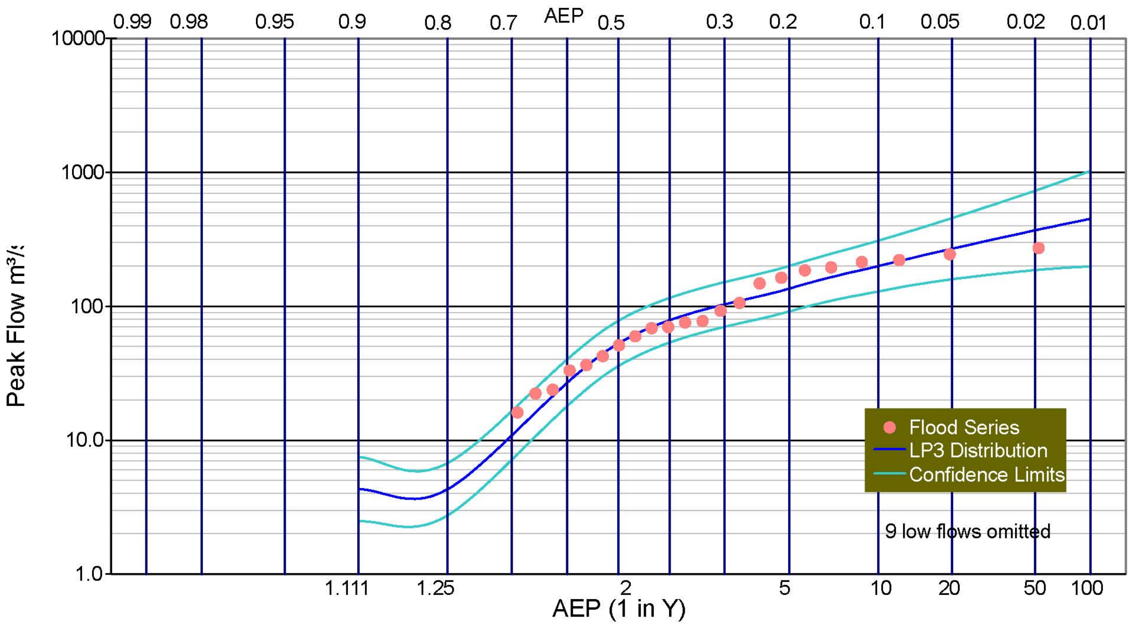


Figure A3.7 *Horsham Post Regulation 1970 – 2000*

Effective Discharge Analysis

The effective discharge technique has been used to identify the likely channel capacity resulting from changes in the hydrologic regime. According to Tilleard (1999) a river channel cross section tends to adjust to changes in magnitude, duration or hydraulic characteristics. Tilleard (1999) states that 'Successful river rehabilitation in these situations relies on understanding the direction and magnitude of geomorphic response to hydrologic or hydraulic change'. The 'effective discharge' concept proposes that the size and shape of an alluvial channel will adjust such that the bankfull capacity corresponds to that discharge which, through time, is responsible for moving the most sediment, allowing a prediction of the direction and magnitude of the channel response.

An effective discharge analysis has been undertaken to identify the likely change in capacity of the Wimmera River associated with the flow regulation. Stream power was used as a surrogate for sediment transport for this assessment. Stream powers were determined using the simple normal depth hydraulic modelling package FLOWMASTER, which assists in basic hydraulic analysis. The input for the model includes;

- Cross section profile
- Discharge
- Channel Roughness (Mannings *n*)
- Channel Slope

Flow data was obtained from the Horsham gauging station (415 200), and cross section data was from downstream of Horsham (upstream of McKenzie River), from survey work undertaken during the Horsham flood study of 1979.

From this analysis the stream power for the channel was determined for various flows, Figure A3.8.

The stream power computations were plotted on and combined with the flow duration curves for the pre and post regulation flow regimes for the Wimmera River gauge near Horsham, (Figure A3.9). The multiplication of the flow duration in terms of a number of days and the stream power produces an effective discharge curve (Figure A3.10).

The results of the analysis suggest that the pre regulation bankfull capacity occurred at a flow of around 15,000 ML/d, or about 174 m^3/s. This value corresponds to an Annual Exceedence Probability (AEP) from the flood frequency analysis of between 50 and 20% for the 1900-1930 period, and compares well with the estimated channel capacity for the reach based on historic cross section data and hydraulic analysis. For the post regulation data the effective discharge is estimated to be approximately 13,000 ML/d (150m^3/s).

The results suggest that a reduction in channel capacity is likely to occur as a result of the flow regulation and water extractions.

However, the cross section analysis (refer Appendix D) reveals limited reduction in channel capacity over the past 20 years. Sediment supply to the subject reach of river is low. This is a result of low transport capacity into the reach and low supply to the reach. Sediment supply has been restricted through the construction of the weirs on the Wimmera Including Glenorchy, Huddlestones and the Horsham Weir.

Because the process of channel adjustment is slow (dependant on sediment supply and transport capacity) and the introduction of regulation relatively rapid, there has been a period of reduced probability of overbank flooding attributable to the flow regulation. The bankfull flow of approximately 175 m3/s has an AEP of 10% on the post regulation flood frequency curve. In essence the large channel is operating within an environment of reduced flow.

Channel contraction should occur (albeit slowly) and as a result it would be expected that the occurrence of overbank flooding is likely to increase. However, review of the flood frequency curve for the post regulation flow regime reveals that the average exceedence probability associated with a flow of 150m^3/s, (the post regulation effective discharge) is approximately 20% (ie a 5 year ARI event). This is the same as the annual exceedence probability of the pre regulation effective discharge. In essence, if the channel capacity of the Wimmera River adjusts to the new effective discharge, the occurrence of overbank flooding will not be significantly different to that which occurred prior to regulation.

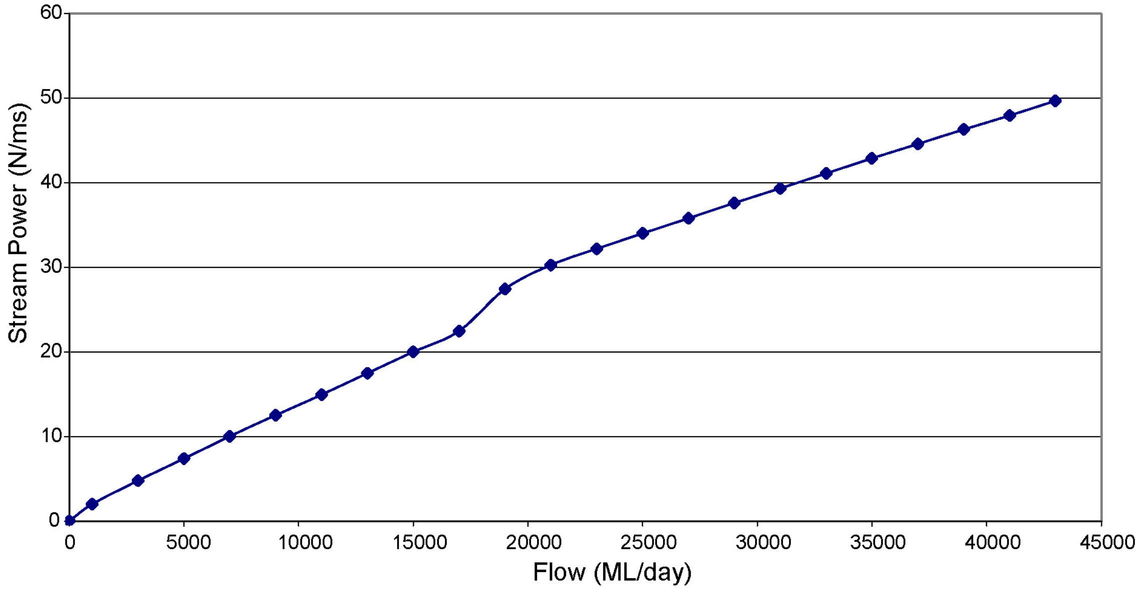


Figure A3.8 *Stream Power – Downstream Horsham*

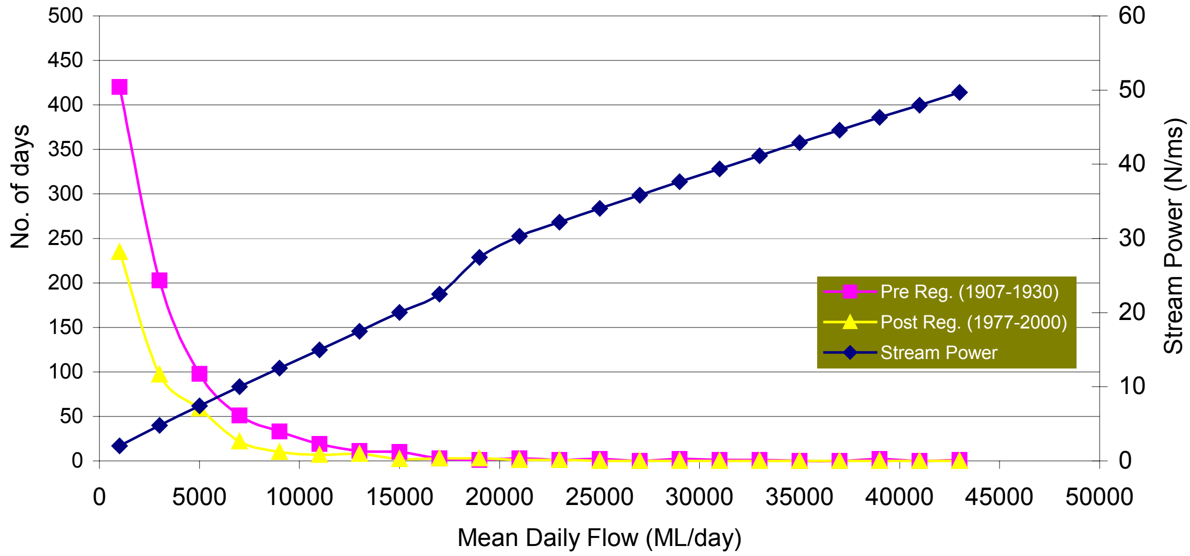


Figure A3.9 *Flow Duration versus Stream Power – Downstream Horsham*

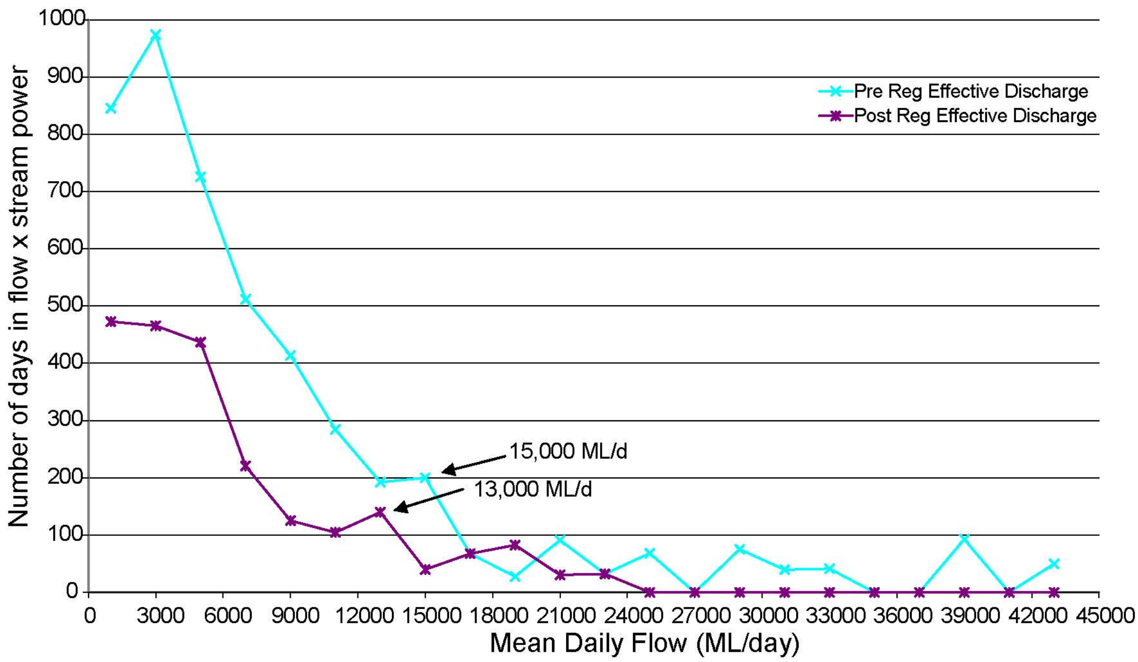


Figure A3.10 *Effective Discharge Analysis – Downstream Horsham*

Appendix B

Aerial Photo Analysis

Aerial Photo Analysis

One of the initial steps in a geomorphic investigation of a large scale is to gather as much information on the characteristics of the catchment and river from available aerial photography. For the Wimmera River catchment several sources of aerial photography were sourced. Firstly, a recent history perspective was gained through the review of black and white photo mosaics assembled from aerial photography taken in 1946 and prepared in 1950. Table B1 lists the characteristics of various identifiable streams by Photo Mosaic Sheet. Characteristics listed relate mainly to erosion and sedimentation, these photos were also used to assist in determining reaches.

Following review of recent history aerial photography, the most recent aerial photography available was reviewed. Photography reviewed was taken in 2000 for the catchment upstream of Glenorchy and various dates in the 1990's for the remainder of the river.

This photography was reviewed to determine reaches of the Wimmera River that could then be confirmed or adjusted on the ground. Reaches were based on characteristics such as sinuosity, continuity of channel(s), floodplain features (presence/absence of developing or decaying channels), lateral or vertical controls, single or multiple channels (anabranches or flood channels) and in the lower reaches in particular surficial geological features.

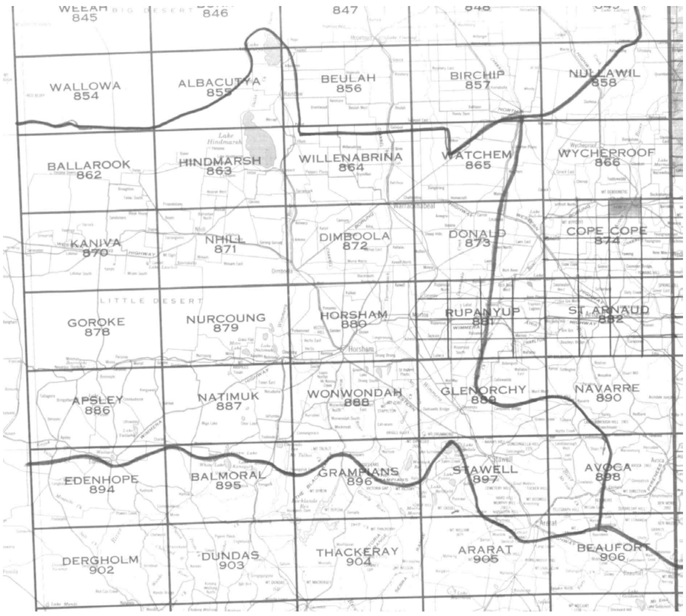


Figure B1 – *Index of historical photos*

Sheet	Stream	Status
Avoca A2	Sheas Creek & tributaries	Extensive active gully erosion in cleared catchment.
	Howards Creek	Cut & Fill sections adjacent St. Arnaud-Ararat Rd. Cut sections have active bank erosion, immediately u/s of Landsborough
Avoca A3	Gully	Adjacent Sheas Ck system, E683000 N589300. Major sediment accumulation u/s and d/s of road from major headward gully erosion u/s. Appears to have and still is delivering relatively large sediment loads to Wimmera River. Re-incision is likely.
	Sheas Creek	Major sediment accumulation u/s and d/s of road from major headward gully erosion u/s. Appears to have and still is delivering relatively large sediment loads to Wimmera River. Re-incision is likely.
	Wimmera River	Km 273-282. Active bank erosion associated with excessive sediment inputs creating point and bank attached longitudinal bars throughout. These bars are actively migrating. Over expanded channel, low sinuosity north-south trench, being infilled by sediment from tributaries. Little or no riparian vegetation.
Avoca A4	Glenlofty Creek	Discontinuous alluvial channel, with some intact Chain of Ponds, other sections incising. Relatively low sediment inputs from forested tributaries.
	Spring Creek	Cut and Fill stream almost continuously incised. Relatively steep relief, extensive gully erosion. No riparian vegetation.
	Tributary	N5891000. Very active gully incision and trunk stream bank erosion. Its Wimmera River confluence on Avoca A3 has major sediment accumulation.
Avoca C1	Spring Creek	A drain has been constructed through sediment accumulation (floodout) zone on Wimmera River floodplain. Possibly causing mobilisation of u/s bed sediment.
	Wimmera River	Km 281-292. Straight incising channel through a sediment accumulation (fill) zone km 286-292 with no remaining riparian overstorey vegetation. No depositional features in the new channel in this reach. From km 282-286 have a low amplitude, low sinuosity continuous channel with many point bars from excess sediment inputs increasing lateral migration. Partial riparian cover.
	Mt. Cole Creek	Downstream of St. Arnaud-Ararat Rd maybe sediment accumulation zone. Mostly intact riparian overstorey. All lower tributaries are actively eroding, contributing increased sediment loads.

Sheet	Stream	Status
	Gully	Tributary @ km281 of Wimmera River. Acitve gully erosion, lot of sediment stored at floodout onto Wimmera River floodplain d/s of Woodlands - Ararat Rd (E682250,N5888800).
	Six Mile Creek	Upper reaches are discontinuous alluvial (Cut & Fill). Partially cleared riparian zone.
Avoca C2	Spring Creek	Continuous alluvial, excess highly mobile bedload.
	Glenlofty Creek	Discontinuous alluvial channel (Cut & Fill, some Chain of Ponds) all the way to Wimmera River confluence @ km 307. Sparse riparian overstorey. Must be very fine grained, low gradient and have good ground cover.
	Wimmera River	Km 291-314. From km 301-314; relatively broad upper catchment floodplain, with few features (uniform cross section) indicating a Cut and Fill stream where vertical process dominate. Appeared to be continuously incised, low sinuosity, occasionally impinging on valley margins. Should be silt dominated with some gravels. Possible sand inputs from u/s of Elmhurst. Km 292-301; Floodplain contracts, continuous channel with more aggressive lateral processes expressed through bank erosion and bars. Sparse riparian overstorey vegetation.
	Tributaries	Confluent between km302-306, from Rock Hill, Reserve Hill and from south of Highway. Very active gully erosion. Substantial sediment slugs at confluences with Wimmera.
	Tributaries	From north between Glenpatrick and Glenlofty Creeks. Very active gully erosion. Substantial sediment slugs at confluences with Wimmera. Some recovery evident with revegetation/regeneration on filled sections.
	Nowhere/Glenpatrick Creek	Downstream reach on floodplain is similar in character to Wimmera River.
Avoca C3	Mt. Cole Creek	Good riparian overstorey vegetation continuity and width, controlling rates of lateral migration. Sand bed is likely.
	Gullies	Incision had reached top of catchments. Excessive sand and/or silt loads in trunk streams. Most overstorey vegetation cleared.

Sheet	Stream	Status
Avoca C4	Mt. Cole Ck & tributaries	Sand bed coming off Ben Nevis. Almost continuous riparian overstorey vegetation on Mt. Cole Ck. Active gully erosion in tributaries. May be some intact fill sections on Mt. Cole Ck u/s of Eversley Rd, d/s of Warrak.
Glenorchy C2	Wimmera River	Weir, township, etc.
Glenorchy C3	Mt. William Creek	Downstream of Lake Lonsdale Dam. Flow and sediment starved. Implications not discernible. Good riparian overstorey vegetation.
Glenorchy D3	Concongella Ck	Km 0-14; moderate sinuosity, low amplitude, active meander migration and point bar/bench development. Incising local gully tributaries.
	Sheepwash Creek	This stream is an effluent of Concongella Creek on the Wimmera River floodplain, also acting as a Wimmera River flood channel (developing? Anabranch). The channel is discontinuous, also impacted by road and railway.
	Wimmera River	Relatively straight, low amplitude, long wavelength meanders. Vertical processes dominate. Almost continuous riparian overstorey cover. Minor bank erosion apparent.
Glenorchy D4	Wimmera River	Km 243-259; anabranching with tributary confluents. More laterally active, building point bars.
	Heifer Station Creek	Vertically accreting, laterally stable.
	Seven Mile Creek	Cut and Fill/Chain of Ponds. Has since had a drain cut downstream of Glynwylln-Morrl Rd, which has initiated incision through fill. Active post 1950, sediment may not be reaching river.
Horsham A1	Wimmera River	Km 73-85; Very slow rates of lateral processes, vertical floodplain accretion is dominant process. Most meander cut-offs infilled. Long straights separated by relatively short high angle bends. In Wail State Forest
Horsham C3	Wimmera River	Quantong Rail and Road Bridges.
Horsham C4	Wimmera River	Km132-146; 2 bridges and weir through Horsham
	McKenzie River (or creek?)	Confluence
Horsham D3	Wimmera River	Km149-166; no evidence of lateral migration, vertical processes dominate. Moderate sinuosity ancestral course entrenched into Shepparton Formation terraces. Occasional flood channels.
	Two Mile Creek	Broad swale, no defined channel
Horsham D4	Yarriambiack Creek	Effluent offtake
	Wimmera River	Km 166-178; Anastamosing u/s of Yarriambiack Ck offtake, 2 or 3 channels, one dominant. Good riparian overstorey, Marma State Forest.

Sheet	Stream	Status
Nhill B4	Wimmera River	Km 39-50; Bank confined?, vertical processes dominate, little evidence of lateral migration. Alignment influenced by lunette ridges (see km 43-45)
Nhill D2	Wimmera River	Km 50-59; Some lateral migration evident, especially upstream of the Northwest Railway bridge where point bars and benches are apparent. Flood channels and distributaries connected to terminal lakes.
Nurcoung B4	Wimmera River	Km 85-94; floodplain expands and contracts, influencing benches likewise. Anastamosing in wider floodplain reaches
Nurcoung D2	Wimmera River	Km 94-103; long run sections in straights separated by pools on short high angle bends. Polkemmet Bridge – Heritage River Corrider.
Nurcoung D4	Wimmera River	Km 103-112; long runs/poos separated by short riffles as lateral clay bars. Several high angle bends, short wavelength, high amplitude meanders and long straights. Flood channels.
Stawell B1	Concongella Creek	Km14-25; Partly confined in either very fine grained alluvium or very weathered bedrock. No evidence of lateral migration apparent. Very low sinuosity, narrow channel in narrow floodplain. Near continuous riparian overstorey.
	Eastern tributaries	Active gully erosion, much sediment stored where gullies floodout onto Concongella Ck floodplain. Very little riparian overstorey.
	Wattle Creek	Km0-5; Excess sediment loads from upstream apparent in vertically accreting stream. Low sinuosity, short wavelength, low amplitude meanders.
Stawell B2	Wattle Creek	Multiple actively eroding gullies in cut & fill streams in headwater zone. Not all full incised at time of photos (are **now**).
	Seven Mile Creek	Partly confined stream in north-south lineament. Active bank erosion, very little riparian overstorey vegetation. Continuously incised channel, excess mobile bedload. Extensively gullied western tributary contributing sediment loads that are likely to reach Wimmera River.
	Surridge Creek	Floods out onto Seven Mile Creek floodplain (drain constructed through this **since**). Continuously incised, active gully erosion upstream.

Sheet	Stream	Status
	Six Mile Creek	Most d/s western tributary stream, extensive incision through fill.
	Wimmera River	Km259-265; large point bars d/s of Six Mile Ck confluence, increasing lateral migration rates of bends. These bars are **now** colonised with vegetation. Joel Joel Bridge
Stawell B3	Concongella Creek	Km 25-33; semi-continuous (**now** continuous), active bank erosion, excess mobile bedload. Scattered riparian overstorey.
	Salt Creek	Km 0-9; Up and downstream of Salt Creek Rd was discontinuous Cut & Fill (**now** drained and continuous). Sandy Creek tributary similar.
	Eastern Concongella Ck tributaries, north of Salt Ck	Cut and Fill streams, discontinuous channels (**now** continuously incised). Shallow single or multiple swales on relatively flat floodplain.
Stawell B4	Salt Creek	Km 10-14; continuous sand bed, active bank erosion, partly confined. Sparse riparian overstorey.
	Seven Mile Creek	Active gully erosion in tributaries, nearly all continuously incised channels.
	Surridge Creek	Active gully erosion, continuously incised channel.
	Six Mile Creek	Semi-continuous channel, poorly defined/infilled. Scattered riparian overstorey.
Stawell D1	Concongella Creek	Km 33-42; Continuous, partly confined or alluvial low amplitude, long wavelength meanders. Active bank erosion, likely excess sand bed load (u/s granites). Most riparian overstorey cleared.
Stawell D2	Allanvale Creek	Continuously incised to top of catchment (**now** infilled near Allanvale-Tuckershill Rd).
	Salt Creek	Continuously incised to top of catchment (in granites)
	Six Mile Creek	Discontinuous Cut & Fill channel in upper catchment zone (**now** continuous)
Stawell D4	Concongella Creek	Dispersive soils in gullies, not all continuously incised to top of catchment, nor is main channel near Armstrong.
Wonwondah A1	Wimmera River	Km 114-131; appears more laterally active than adjoining reaches. Meander cut-offs, flood channels, billabongs, ephemeral wetlands. Moderate sinuosity, infrequent point bars.
	Darragan Creek	Unchanneled swale, low gradient, low run-off. Riparian overstorey corridor approx. 200m wide and continuous.
	Nortons Creek	Poorly defined sinuous channel in broad shallow swale, vertically accreting.
Wonwondah A2	Nortons Creek	Continuously defined channel, laterally restricted by terraces and incised over long time, low amplitude and wavelength meanders. Some local gully tributaries from terraces.

Sheet	Stream	Status
	Mackenzie River	North-south lineament parallel with Nortons Creek incised into Shepparton Formation terrace. Very low sinuosity, long wavelength, and low amplitude. Excellent riparian overstorey.
	Bungally Creek	Continuously defined channel, laterally restricted by terraces and incised over long time, low amplitude and wavelength meanders. Some local gully tributaries from terraces.
	Burnt Creek	North-south lineament incised into Shepparton Formation terrace. Very low sinuosity, long wavelength, and low amplitude. Almost continuous riparian overstorey.
Wonwondah A3	Darragan Creek	Swampy in upper reaches, shallow poorly defined channels in broad swales merging to single swale.
	Francis Swamp area tributaries	Lateral gullies perpendicular to trunk stream from terrace, appear active and frequent.
Wonwondah A4	Nortons Creek	Chain of Ponds near and downstream of Butts Rd. Vertical processes dominate. Near continuous riparian overstorey.
	Mackenzie River	Possibly chain of ponds as well
	Bungally Creek	Semi-continuous sinuous low flow channel inset in long wavelength, low amplitude meander trench. Part of Burnt Creek system.
Wonwondah B2	Wimmera River	Km 178-189; Anastamosing with Mt William Ck to and after confluence. Broad floodplain.
Wonwondah B3	Burnt Creek	North-south lineament incised into Shepparton Formation terrace. Very low sinuosity, long wavelength, low amplitude. Almost continuous riparian overstorey.
Wonwondah B4	Mt William Creek	North-south lineament incised into Shepparton Formation terrace. Very low sinuosity, long wavelength, low amplitude. Almost continuous riparian overstorey.
	Wimmera River	Rocklands channel crossing (sediment trap and water extraction) and Faux Bridge
Wonwondah C1	Darragan Creek	Headwater area contains lunette lake (Darragan Swamp)
	Norton Creek	Rocklands Channel crossing, implications for flow and sediment transport.
Wonwondah C2	Norton Creek	Generally defined shallow channel in trench. Locally active gully tributaries of the terrace. Semi continuous riparian overstorey.

Sheet	Stream	Status
	Mackenzie River	Low sinuousity channel belt with inset low flow channel, incised into Shepparton Formation terrace. Rocklands Channel crossing, implications for flow and sediment transport.
	Burnt Creek	Generally defined shallow channel in trench. Locally active gully tributaries of the terrace. Semi continuous riparian overstorey.
Wonwondah C4	Norton Creek	Generally defined shallow low flow channel inset in trench. Locally active gully tributaries of the terrace. Continuous and wide riparian overstorey.
Wonwondah D1	Burnt Creek	Generally defined shallow channel in trench. Locally active gully tributaries of the terrace. Scattered riparian overstorey.
Wonwondah D3	Burnt Creek	Effluent of Mackenzie River. Generally defined shallow channel in trench. Locally active gully tributaries of the terrace. Scattered riparian overstorey.
	Mackenzie River	Low sinuousity channel belt with inset low flow channel, incised into Shepparton Formation terrace.

Table B1 *- Review of 1946 Aerial Photography (by sheet)*

Appendix C

Further Components of Geomorphic Investigations

Aerial Inspection

To gain a rapid catchment wide perspective, inspect features in question from aerial photography review and identify further attributes of the river system, low-level aerial reconnaissance was undertaken over the catchment. Inspection included viewing of nearly the whole length of the Wimmera River channel and parts of upper catchment sub-catchments. This exercise was undertaken in a light aircraft by Wayne Erskine, Rohan Lucas and Paul Atherton.

Geological Assessment

Undertaking an assessment of the geological controls that play an important part in catchment evolution is one of the initial steps in most fluvial geomorphological investigations. Geological data sources for this project include the following maps and various referenced articles:

- digital geological data for the Wimmera CMA area, made available by WCMA for this project (see Drawing No 2701046-016)
- Geological Survey of Victoria 1:250,000 Geological Map Sheets (Horsham, St. Arnaud and Ballarat)

These data sources were used to assess the distribution of geological units and structural features that make up the catchment and to understand the likely effects these units will have on stream character and behaviour.

A detailed discussion of the Tertiary and Quaternary geology of the mid to lower Wimmera River area is located in Section 2 of this report.

Field inspections

Field inspections of the Wimmera River and targeted sub-catchments were undertaken to equivocate all findings made to this point of the investigation. The following were the major objectives of field inspections:

- more accurately delineate reach boundaries/transitions
- description of the geomorphological units and their associations that define the characteristics and behaviour of the stream within a reach
- appreciation of the catchment as a whole

3D Image analysis

A terrain model and 3D image of the catchment were developed to assist with the visualisation of the catchment and identification of sub catchments with significant relief in close proximity to the Wimmera River i.e with the capacity to deliver sediment to the Wimmera River.

Appendix D

Longitudinal Profile Analysis

Longitudinal Profile Analysis

The longitudinal profiles of the Wimmera River and a number of major tributaries were analysed. Assessment comprised the development of the profiles from the state digital topographic data and the extraction of stream bed grades.

Wimmera River

The Wimmera River is a very low gradient river. The river begins at elevations of around 700mAHD and finishes in Lake Hindmarsh, over 300km of river channel away, at less than 100m AHD (see Figure D5). Over 400m of the elevation drop occurs in the first 10km of river upstream of Elmhurst.

Stream gradient reduces by an order of magnitude from 0.05 in Reach 1 to 0.004 in Reach 2. From Reach 2 to Reach 7 stream gradient ranges from 0.003 to 0.0007. The overall gradient of the Wimmera River downstream of Glenorchy is approximately 0.0005. Local variations may range from less than 0.0001 to 0.0006.

Wattle Creek

The Wattle, Howard's and Heifer Station Creek catchment, which will be known in this report as the Wattle Creek catchment, enters the Wimmera River floodplain at the area known as Greens Creek. The Wattle Creek confluence with the Wimmera River is deferred, that is it flows parallel with the river, within the Wimmera River floodplain (close to the opposite floodplain margin).

Upper catchment (upper 10km) stream gradient ranges from 0.06 to 0.006. Over the remaining 40km stream gradient range from 0.002 to <0.001 on the Wimmera River floodplain (see Figure D1).

Distance Range (m)	Elevation Range (m)	Slope (m/m)
49500 to 47200	480 to 325	0.06
47200 to 43500	325 to 280	0.01
43500 to 37850	280 to 250	0.006
37850 to 23000	250 to 220	0.002
23000 to 7000	220 to 200	0.001
7000 to 0	200	<0.001

Table D1 *– Wattle Creek Longitudinal Profile Data Summary*

Sheas Creek

The longitudinal profile of Sheas Creek has been altered substantially following European settlement of the area. The creek has undergone major bed degradation and subsequent adjustments of stream form. This was likely to have been assisted by the bed degradation of the Wimmera River at the confluence initiating headward erosion. A major (>4m high) drop structure has been built at the Joel Joel - Crowlands Road, below this Sheas Creek is a constructed channel in the Wimmera River floodplain. Refer Figure D2.

Distance (m)	Elevation (m)	Slope (m/m)
14000 to 9000	350 to 280	0.01
9000 to 4000	280 to 240	0.0075
4000 to 0	240 to 230	0.004

Table D2 – *Sheas Creek Longitudinal Profile Data Summary*

Seven Mile Creek

The longitudinal profile of Seven Mile Creek describes relatively uniform changes in grade throughout its 28km length. Slope ranges from 0.04 in the upper catchment to 0.001 over the lower 10km (see Figure D3). Two flat sections of approximately 4km have been interpolated over those last 10km, the upstream one is likely to correspond to a zone where the stream appears to have naturally flooded out in a zone of sediment accumulation.

Distance (m)	Elevation (m)	Slope (m/m)
28100 to 27000	347 to 300	0.04
27000 to 25700	300 to 260	0.018
25700 to 22400	260 to 230	0.005
22400 to 16200	230 to 210	0.003
16200 to 0	210 to 190	0.001

Table D3 – *Seven Mile Creek Longitudinal Profile Data Summary*

Glenlofty Creek

Glenlofty Creek is rather unique in this area, it has a similar slope to Sheas Creek over the same elevation range, however it has not experienced the gully incision that has occurred in Sheas and many other creeks/gullies in this area. The reason for this is thought to be the difference in geologic downstream controls. Glenlofty Creek joins the Wimmera River in a partially confined reach where the channel is continuous, narrow and relatively incised when compared to some of the other reaches of the upper Wimmera River. The reach of The Wimmera River downstream of the confluence with Glenlofty Creek is naturally incised there has been no post European effort to channelise the reach. Hence, Glenlofty Creek has had downstream controls that have not changed under post European conditions. Sheas Creek's downstream controls, geologically a discontinuous channel in a sediment accumulation zone (Cut and Fill) have changed to a continuous incised channel. Refer Figure D4.

Distance (m)	Elevation (m)	Slope (m/m)
18750 to 17500	611 to 500	0.08
17500 to 14600	500 to 390	0.037
14600 to 9000	390 to 325	0.01
9000 to 0	325 to 280	0.005

***Table D4** – Glenlofty Creek Longitudinal Profile Data Summary*

Figure D1
Wattle Creek Longitudinal Profile

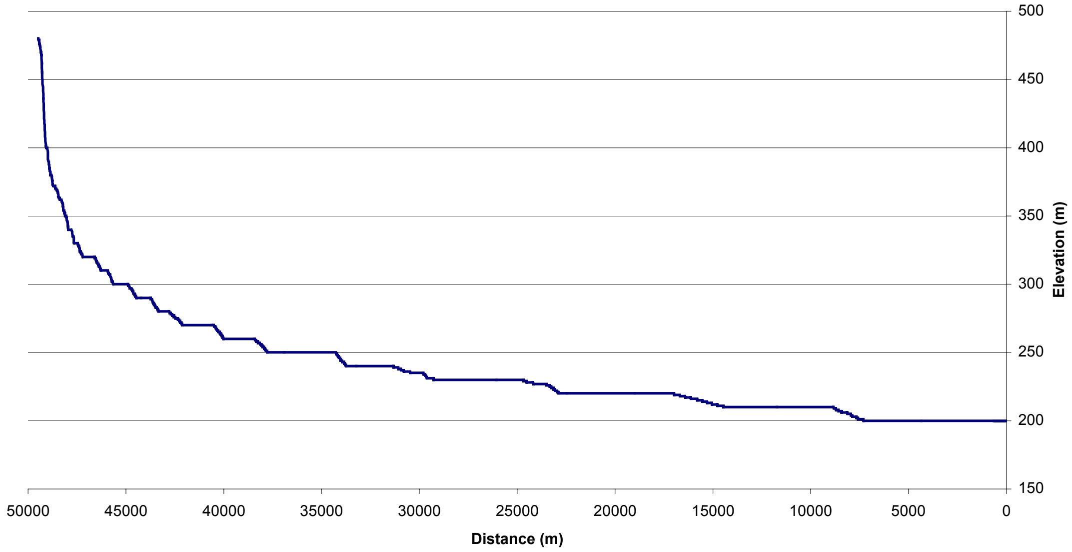


Figure D2
Sheas Creek Longitudinal Profile

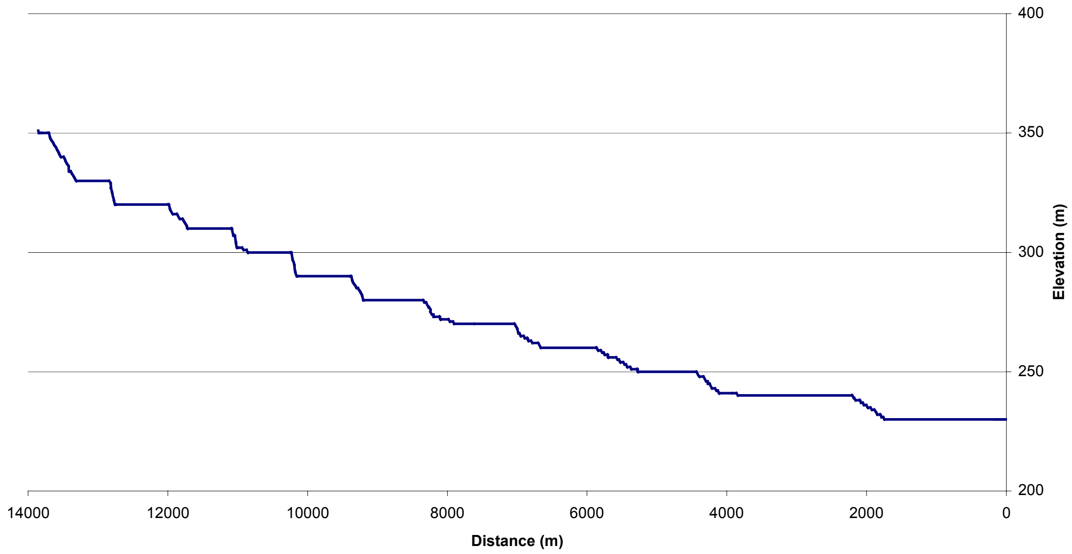


Figure D3
Seven Mile Longitudinal Profile

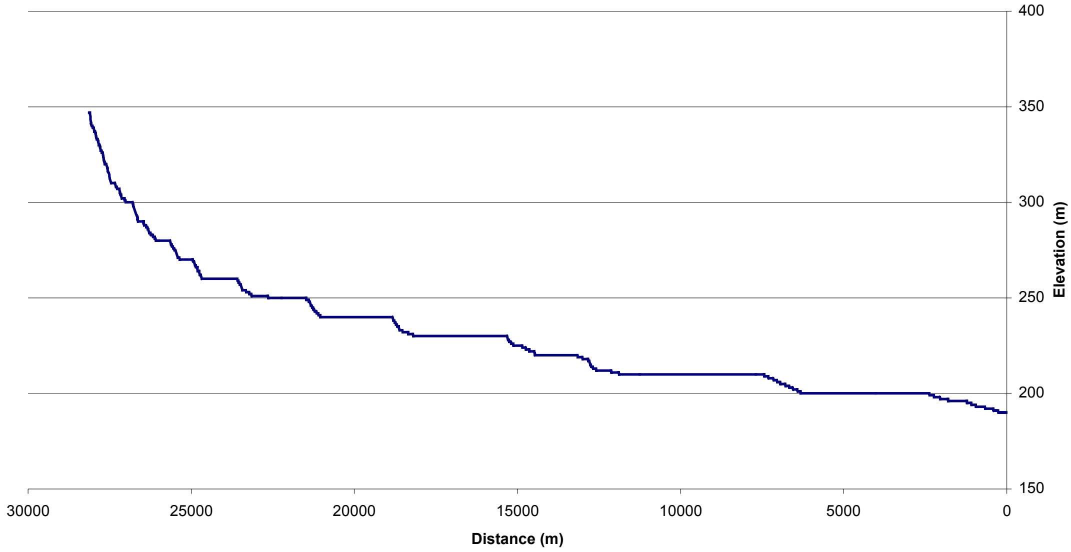


Figure D4
Glenlofty Creek Longitudinal Profile

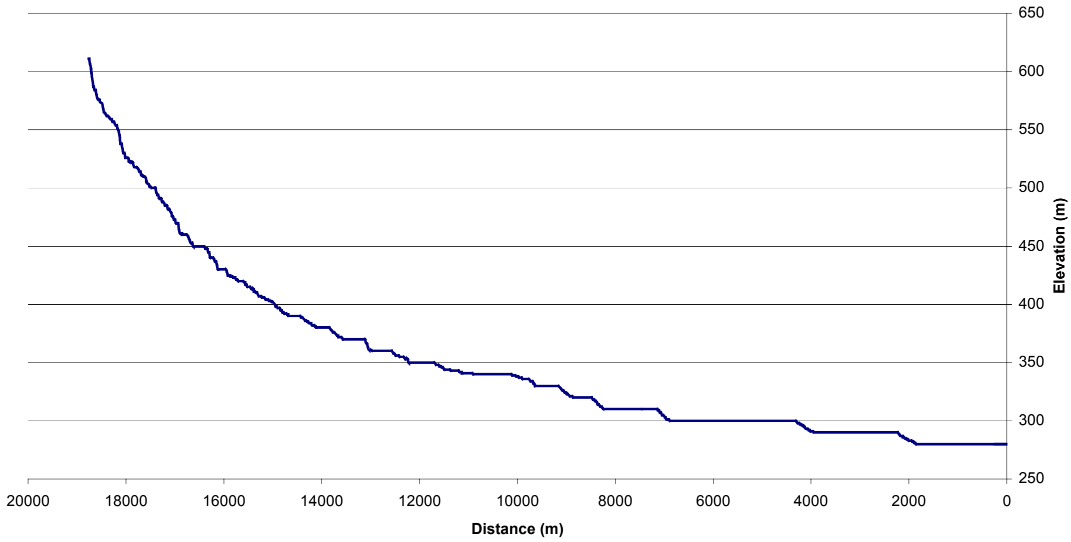
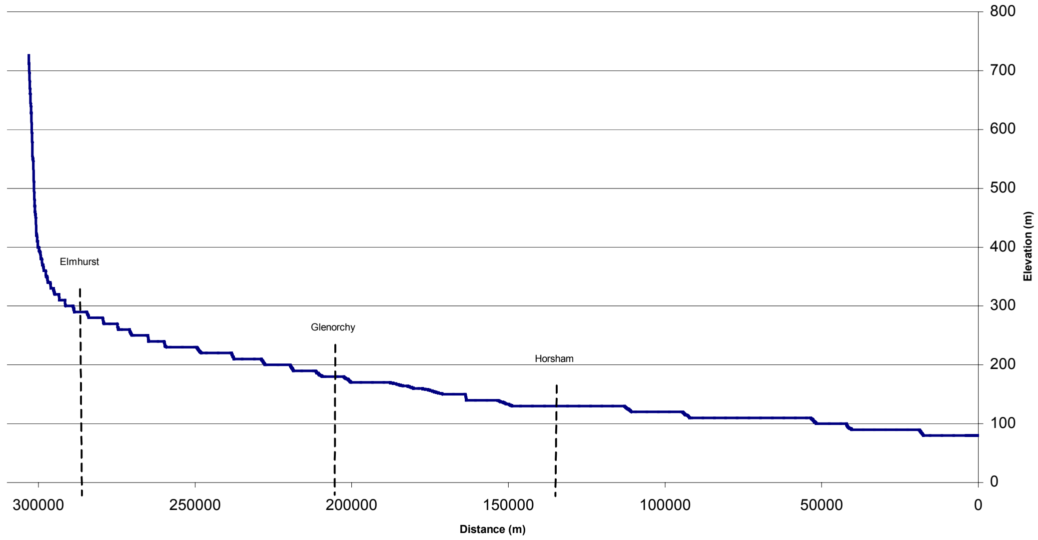


Figure D5
Wimmera River Longitudinal Profile



Appendix E

Cross Section Analysis

Wimmera Geomorphological Investigation Cross Section Surveys

No.	Site	Cross Section Type	Location	Old	Source	New	Source
1	Old Eversley Crosswire (L10919)	Gauging Station	300m downstream of Eversley recorder	1964	Thiess	2001	Survey
2	Framptons Bridge	General Arrangement	Stawell – Joel South Rd	1965	Vic Roads	2001	Survey
3	Joel Joel Bridge	General Arrangement	Landsborough	1970	Vic Roads	2001	Survey
4	Section 25	Glenorchy Flood Study	220.8km – Glenorchy plan	1980	NRE	2001	Survey
5	Section 24	Glenorchy Flood Study	219.7km – Glenorchy plan	1980	NRE	2001	Survey
6	Rocklands Channel Syphon	Syphon	200m d/s Faux's Bridge	1956	State Rivers and Water Supply Commission	2001	Survey
7	Lubeck Road Bridge	General Arrangement	Lubeck Road (bridge over Wimmera not anabranch)	1970	Vic Roads	2001	Survey
8	Lake Taylor Outlet Channel	Syphon	NW of Lake Taylor off Burnt Clay Rd (~200m u/s Yarriambiack Ck)	?	State Rivers and Water Supply Commission	2001	Survey
9	Gross Bridge	General Arrangement	Drung Jung Road	1970?	Vic Roads	2001	Survey
10	Section 19	Horsham Flood Study	146.3km – Horsham plan	1979	NRE	2001	Survey
11	Section 17	Horsham Flood Study	144.8km – Horsham plan	1979	NRE	2001	Survey

Appendix F

Sediment Transport Analysis

Sediment Transport Analysis

An analysis of the sediment transport capability of the Wimmera River has been undertaken firstly for an assessment on the geomorphic processes and secondly to answer the question of a perceived increase in flooding due to sediment deposition.

This component of the geomorphic investigation is a brief account of the sediment transport capability of the Wimmera River. The sediment transport capability is the amount of sediment that could be transported by flows if the sediment was available to be mobilised by the river. Sediment supply to the river is not quantified in this investigation. It is recognised that supply to the river has dramatically increased over the last 150 years. Field observations were made checking that analysis held true.

Three sites on the Wimmera River were included in the sediment transport analysis; downstream of Horsham, upstream of Glenorchy (using Glynwylln gauging data) and upstream of Eversley. Discharges for the gauging stations were obtained for the longest period available. For the Horsham gauge regulation has impacted on the flows and consequently pre and post the data for Horsham was also analysed for the periods 1900 to 1930 and 1970 to 2000.

Sediment samples were taken from each of the three sites and a grading analysis undertaken. Due to the proportion of fines in the Horsham and Glenorchy samples being greater than 50 percent these samples were further analysed to determine the proportion of sediment less than 75 micron.

Site details are indicated in Table F.1.

Site	Gauging Station	Bankfull Discharge (cumecs)	Slope (m/m)	D50 (mm)	% finer than 0.062 mm
Horsham downstream	415 201	200	0.00036	0.17	25
Glenorchy upstream	415 206	210	0.0096	0.036	60
Eversley upstream	415 207	50	0.0058	2.8	1

Table F1

The sediment particle size analyses indicate that the material from Horsham is fine sand, from Glenorchy sandy silt and from Eversley is sandy gravel.

The hydrology and sediment data is input for the dos interface computer model called SEDDISCH (public domain software available from the United States Geological Survey).

The data is analysed by the following established bed material sediment transport relationships:

- Laursen
- Engelund and Hanson
- Colby
- Ackers and White (using D50)
- Yang Sand (using size fractions)
- Einstein
- Toffaleti

The mean of the equations was then utilised and discharge dependant sediment loads (tons/day) plotted against discharges of 5, 10, 20, 50, 100, and 200 m3/s where required, the highest discharge within the bankfull capacity.. A first to fifth order linear regression was fitted to determine an equation, Figures F.1 to F.3.

The linear equation was corresponded to the mean daily flow data and sediment transport capacities determined for every day of available data. The loads were summed and a yearly transport capacity load determined, the results are indicated in Table F.2.

Site	Period	Sediment Transport Capacity (tons/year)
Horsham downstream	Average	69,000
	1900 – 1930	101,000
	1970 – 2000	56,000
Glenorchy upstream	Average	320,000
Eversley upstream	Average	83,000

Table F.2

The results indicate that there is considerable difference between the sediment transport capacities of Eversley and Horsham, and Glenorchy. Glenorchy has a considerably higher sediment transport capacity of 320,000 tons/year. This is explained by the large flow capacity channel and the fine sediment (50 % of material is less than 75 microns). The other two sites are similar as a result of the Eversley experiencing a steeper bed grade than Glenorchy but a reduced flow capacity, while the Horsham gauge experiences a reduced bed grade but greater flow capacity.

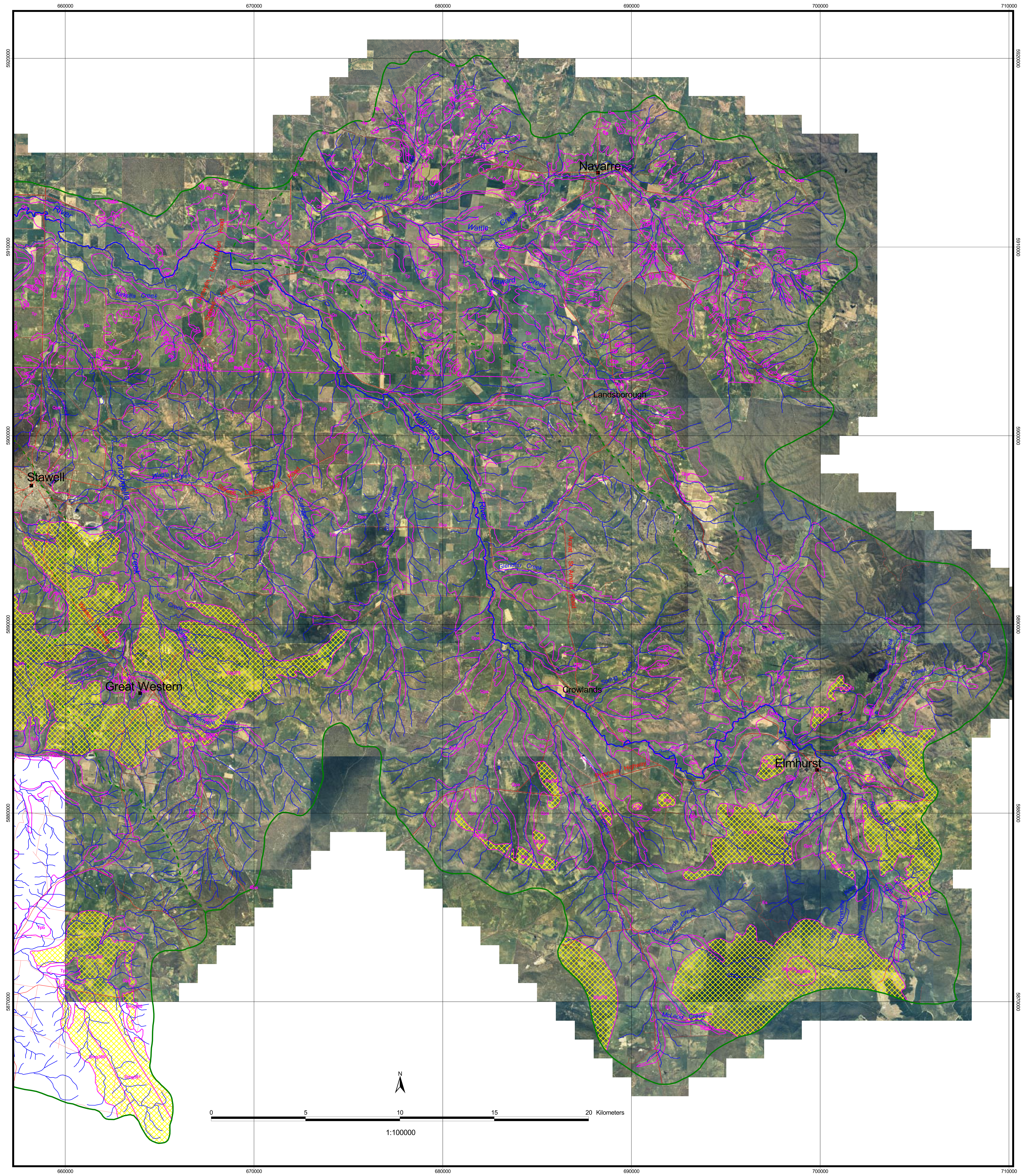
Pre and post sediment transport capacities for Horsham are as expected, with a reduced flow post regulation resulting in almost half the capacity for transporting sediment.

Appendix G

Drawings

Wimmera River Geomorphic Investigation
Lower Wimmera River Catchment
Dwg. No. 2701046-013v1
N
0
5
10
15
20 km
1:75000
LEGEND
Cross section location
Reach Boundary
Sub-Reach Boundary
River chainage (km)
Major road
Secondary road
Channel
Major waterway
Secondary waterway
Gauging Station
Sub-catchment boundary
WCMA Boundary
20m Contour
ID&A
Wimmera Catchment Management Authority
Waterways for Life.
Lake Hindmarsh
Jeparit
Tarranyurk
Antwerp
Speirs Crossing
Dahchik Creek
Borung Highway
Dimboola
LITTLE DESERT NATIONAL PARK
Ellis Crossing
Wimmera River
Duchembegarra
Natimuk
Vectis South
Wimmera Highway
Horsham
Horsham Weir
Francis Swamp
Horsham - Noradjuha Road
Norton Creek
McKenzie Creek
Western Highway
Henty Highway
Dooen Swamp
Section 19 (146.3km)
Section 17 (144.8km)
Gross Bridge
Warracknabeal
Yarriambiack Creek
Murtoa
Darlot Swamp
Lake Taylor outlet channel syphon
Marma State Forest
Horsham - Lubeck Road Bridge
Horsham - Wal Wal Road
Rocklands outlet channel
Burnt Creek
Golton Creek
Sheepwash (Middle) Creek
Mt. William Creek
Hudleston Weir
20
19
18
17
16
15
14
13
12
11
10
9

LEGEND
Cross section location
Reach Boundary
Sub-Reach Boundary
River chainage (km)
Major road
Secondary road
Channel
Major waterway
Secondary waterway
Gauging Station
Sub-catchment boundary
WCMA Boundary
20m Contour
ID&A
Section 24 (219.7km)
Section 25 (220.8km)
Glenorchy
Glenorchy Weir
Hudleston Weir
Mt. William Creek (old course)
(new course)
Middle Creek
Dunmunkle Creek
Wimmera River
Sheepwash Creek
Bunyip Creek
Western Highway
Kirkella Creek
Glenorchy - Moyston Road
Stawell - Avoca Road
Navarre
Hefer Station Creek
Morrows Creek
Wattle Creek
Greens Creek
Howard Creek
Friends Creek
Landsborough
Lake Lonsdale
Lake Wartook
Jerrywell Creek
Stawell
Concongella Creek
Wattle Creek
Stawell - Landsborough Road
Seven Mile Creek
Sunday Creek
Six Mile Creek
Joel Joel Bridge
Frampton Bridge
Sheas Creek
Glendhu Creek
Ararat - St Arnaud Road
Grampians Road
Salt Creek
Sandy Creek
Lake Fyans
Mt. William Creek
Halls Gap
Great Western
Allanvale Creek
Lake Bellfield
Crowlands
Spring Creek
Pyrenees Highway
Eversley Area
Elmhurst
Sandy Creek
Rocky Creek
Hickman Creek
Mt. Cole Creek
Shepherds Creek
McLeod Creek
Little Wimmera River
Wimmera River
Tysh the Lake Creek
Moyston
Wimmera Catchment Management Authority
Waterways for Life.
N
0 5 10 15 20 km
1:75000
1
2
2.1
2.2
2.3
2.4
3
4
5
6
6.1
6.2
7
8
Wimmera River Geomorphic Investigation
Upper Wimmera River Catchment
Dwg. No. 2701046-014v1



Geology Key

KEY	PERIOD	TIME_SCALE	FORMATION	LITHOLOGY DESCRIPTION
Qc	Quaternary	< 2 mill years	Coonambidgal Formation	Fluvial, lacustrine: clay, sand, sandy clay
Ql	Quaternary	< 2 mill years	Lowan Formation	Aeolian: dune sand, fine to medium grained
Qo	Quaternary	< 2 mill years		Aeolian: source-bordering dune deposits: sand, silt, clay
Qpa	Quaternary	< 2 mill years	NA	Fluvial: gravel, sand, silt
Qra	Quaternary	< 2 mill years		Fluvial: alluvium, gravel, sand, silt
Qrc	Quaternary	< 2 mill years		Fluvial: "gully" alluvium, colluvium: gravel, sand, silt
Qrd	Quaternary	< 2 mill years		Aeolian: coastal and inland dunes: dune sand, some swamp deposits
Qrl	Quaternary	< 2 mill years		Fluvial: alluvial terraces: gravel, sand, silt
Qrm	Quaternary	< 2 mill years		Paludal: lagoon and swamp deposits: silt, clay
Qs	Quaternary	< 2 mill years	Shepparton Formation	Fluvial: silt, sand, minor gravel
Qu	Quaternary	< 2 mill years		Aeolian: lunette deposits: sand, silt, clay
Qvn	Quaternary	< 2 mill years	Newer Volcanics	Extrusive: tholeiitic to alkaline basalts, minor scoria and ash
Qw	Quaternary	< 2 mill years	Woorinen Formation	Aeolian: dune sand, calcareous, clayey, palaeosols
Qy	Quaternary	< 2 mill years	Yamba Formation	Aeolianites and evaporites: fine-grained gypsum
Tp	Tertiary	65-2 mill years	undifferentiated	Fluvial: gravel, sand, silt
Tpb	Tertiary	65-2 mill years	Brighton Gp/ Moorabool Viaduct Sd/ Hanson Plain Sand	Fluvial: gravel, sand, silt
Tpb	Tertiary	65-2 mill years	Brighton Gp/ Moorabool Viaduct Sd/ Hanson Plain Sand	Fluvial: gravel, sand, silt
Tpl	Tertiary	65-2 mill years		Deflational??: laterite
Tpp	Tertiary	65-2 mill years	Parilla Sand	Marine: sand, silt
Dlg	Devonian	395-345 mill years	Early Devonian granite,unnamed	
Dlg365	Devonian	395-345 mill years	Tailor Creek Tonalite	Intrusive: hornblende tonalite, medium to coarse grained, pale green
Dlg372	Devonian	395-345 mill years	Glenlogie Granodiorite	Intrusive: mafic biotite -hornblende granodiorite, medium grained, grey
Dlg373	Devonian	395-345 mill years	Elmhurst Granite	Intrusive: biotite granite, fine to medium grained, cream to pale grey
Dlg374	Devonian	395-345 mill years	Ben Nevis Granite	Intrusive: biotite granite, medium to coarse grained, cream to pale grey
Dlg376	Devonian	395-345 mill years	Langi Ghiran Granite	Intrusive: biotite granite, medium grained, pale grey
Dlg378	Devonian	395-345 mill years	Mount Cole Adamellite	Intrusive: biotite -hornblende adamellite, coarse grained, pale grey to pink
Dlg379	Devonian	395-345 mill years	Stawell Granodiorite	Intrusive: zoned pluton consisting of adamellite, granodiorite, diorite
Dlg383	Devonian	395-345 mill years	Dunneworthy Granodiorite	Intrusive:
Dlg384	Devonian	395-345 mill years	Hickman Creek Granite	Intrusive: felsic biotite adamellite, coarse grained, pale grey to pink
Dlg396	Devonian	395-345 mill years	Mafeking Tonalite	Intrusive: hornblende tonalite, medium to coarse grained, slightly porphyritic
Dlg397	Devonian	395-345 mill years	Epacris Hills	Intrusive:
Dlg398	Devonian	395-345 mill years	MacKenzie River Granodiorite	Intrusive: hornblende granodiorite, fine to medium grained, pale pink
Dlvr	Devonian	395-345 mill years	Rocklands Rhyolite	Extrusive: rhyolite lava, flow-banded, ignimbrite
Dmg380	Devonian	395-345 mill years	Ararat Granite	Intrusive: biotite two -feldspar granite, contains hornfels
Dmg381	Devonian	395-345 mill years	Burrumbeet Adamellite	Intrusive: biotite hornblende granodiorite, medium grained granophyric
SDr	Silurian-Devonian	395 mill years	Grampians Group	Marine, fluvial: sandstone, minor conglomerate, siltstone
Eg	Cambrian	600-500 mill years	Glenelg River Group	Marine: sandstone, siltstone
Es	Cambrian	600-500 mill years	Saint Arnaud Group	Marine: sandstone, siltstone, biotite schist
Ev	Cambrian	600-500 mill years	various	Extrusive, intrusive: basalt, andesite, boninite, rhyolite, gabbro, lithic sandstone, chert, shale, breccia

Legend

- Waterway
- Road
- WCMA catchment boundary
- Sub-catchment boundary
- Dlg376 Geological boundary & key
- Granitic outcrops

ID&A

Wimmera Catchment Management Authority

Waterways for Life.

Wimmera River Geomorphic Investigation

Upper Wimmera River Catchment Geology

Dwg. No. 2701046-015v1

Geology Descriptions

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Dlg398	Devonian	395-345 mill years	MacKenzie River Granodiorite	Intrusive: hornblende granodiorite, fine to medium grained, pale pink
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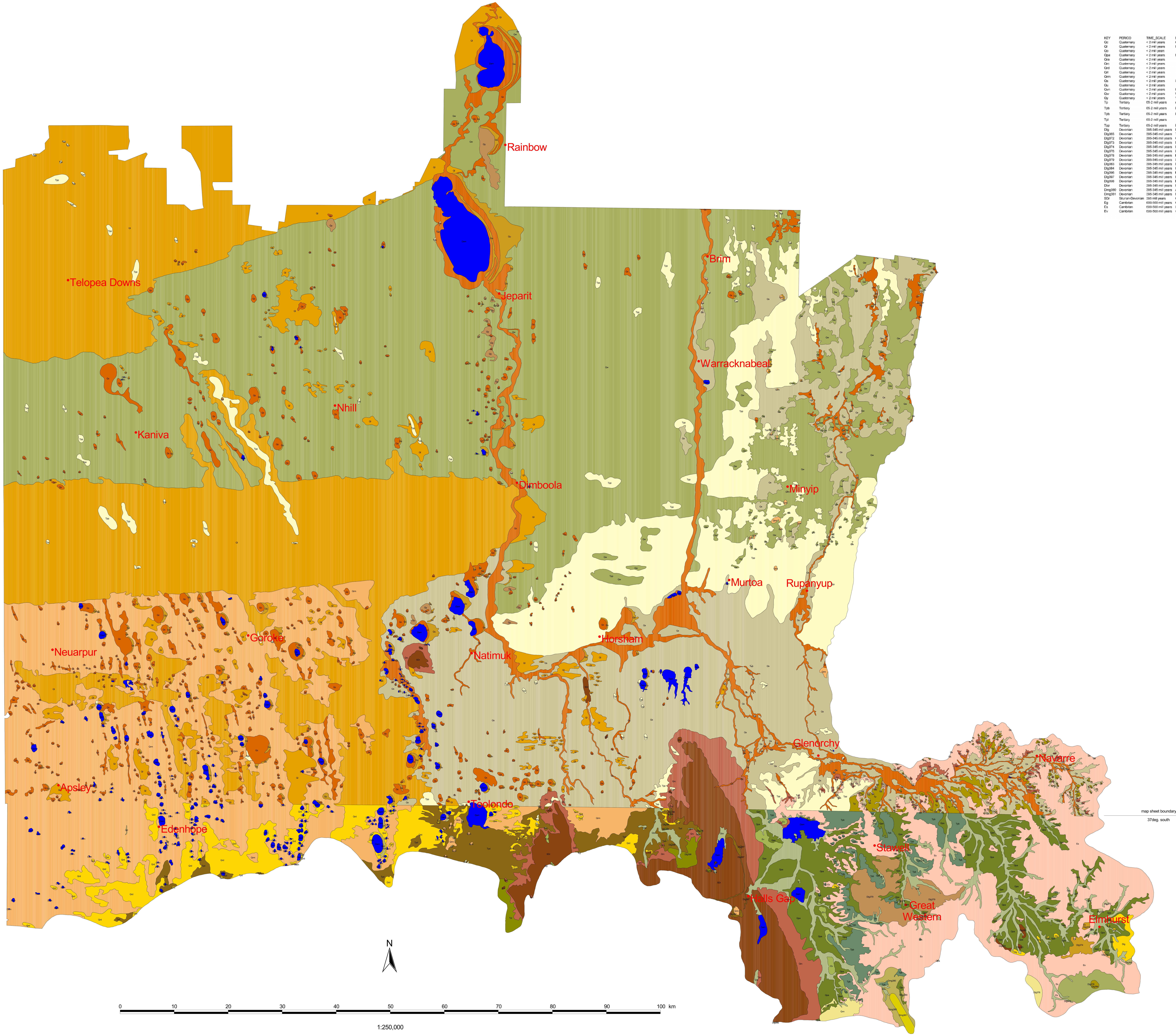

Legend

Town
Water Body

Geology

Qc
Ql
Qo
Qpa
Qra
Qrc
Qrd
Qrl
Qrm
Qs
Qu
Qvn
Qw
Qy
Tp
Tpb
Tpd
Tpl
Tpp
Dlg
Dlg365
Dlg372
Dlg373
Dlg374
Dlg376
Dlg378
Dlg379
Dlg383
Dlg384
Dlg396
Dlg397
Dlg398
Dlvr
Dmg380
Dmg381
SDr
Eg
Es
Ev

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Wimmera River Geomorphic Investigation

Wimmera C.M.A. Region Geology

Dwg. No. 2701046-016v1