Wimmera Catchment Management Authority

Geomorphic Categorisation and Stream Condition Assessment of the Wimmera River Catchment

Section One – Introduction

Job 2901049.008 & 2901049.009

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List of Abbreviations

Acronym	Definition
CMA	Catchment Management Authority
GIS	Geographical Information System
LWD	Large Woody Debris
Ma	Million years

Geological Time Scales

Table 1.1: Geological time scale used in this report

Era	Period	Epoch	Age
Cainozoic	Quaternary	Holocene	0.01 Ma
		Pleistocene	1.8 Ma
	Tertiary	Pliocene	5 Ma
		Miocene	22.5 Ma
		Oligocene	38 Ma
		Eocene	54 Ma
		Palaeocene	65 Ma
	Cretaceous		144 Ma
Mesozoic	Jurassic		208 Ma
	Triassic		245 Ma
	Permian		286 Ma
Palaeozoic	Carboniferous		360 Ma
	Devonian		408 Ma
	Silurian		438 Ma
	Ordovician		505 Ma
	Cambrian		570 Ma
Proterozoic			2500 Ma

Background to the Investigation

The Wimmera River Geomorphic Investigation, Sediment Sources, Transport and Fate (2001) identified major sediment sources within the Wimmera River catchment and defined priority areas for management. The study identified a number of different stream types and associated processes along the main stem but did not include detailed review of stream types throughout the whole catchment.

The Wimmera River Geomorphic Categorisation and Stream Condition Assessment identifies the stream types throughout the Wimmera River catchment and provides information to assist in determining management regimes for stream types based on the geomorphic characteristics and condition of the stream. The project identifies reference sites for stream types and benchmarks stream condition at those sites. The reference sites provide a template for rehabilitation of similar stream types elsewhere throughout the catchment.

Scope of the Investigation

This project has comprised stream ordering, categorisation and condition assessment of streams within the Wimmera River catchment. The project has been limited to streams of 3rd order and greater. The project has not included the Millicent coast region. For the purpose of this investigation, the Wimmera River was considered to terminate at Lake Hindmarsh. Therefore, the overflow system of Outlet Creek and Lake Albacutya were not assessed with regards to geomorphic condition or stream condition.

Figure 1.1 shows the area of investigation. The hashed area to the west of the Wimmera Catchment is the Millicent Coast catchment, which is part of the Wimmera CMA district but not part of this investigation.

Resources utilised

The following resources were directly relevant to the investigation:

- Wimmera River Geomorphic Investigation (ID&A, 2001).
- Index of Stream Condition data, 1999.
- Aerial photography of the upper catchment at a scale of 1:25,000 in a digital form for the majority of the upper catchment and contact prints in the lower catchment.

GIS information of catchment boundaries and waterways sourced through the Wimmera CMA's existing GIS database.

Location of the Investigation

The investigation was located in the Wimmera River catchment in western Victoria. The Wimmera River is presently a terminal system in the northwest of Victoria. To the north is the Mallee, west is the region known as the Millicent Coast and to the east are the Avon Richardson and Avoca River catchments. In the southern section of the Wimmera River catchment lies the Grampians, the most southern extent of the Great Dividing Range.

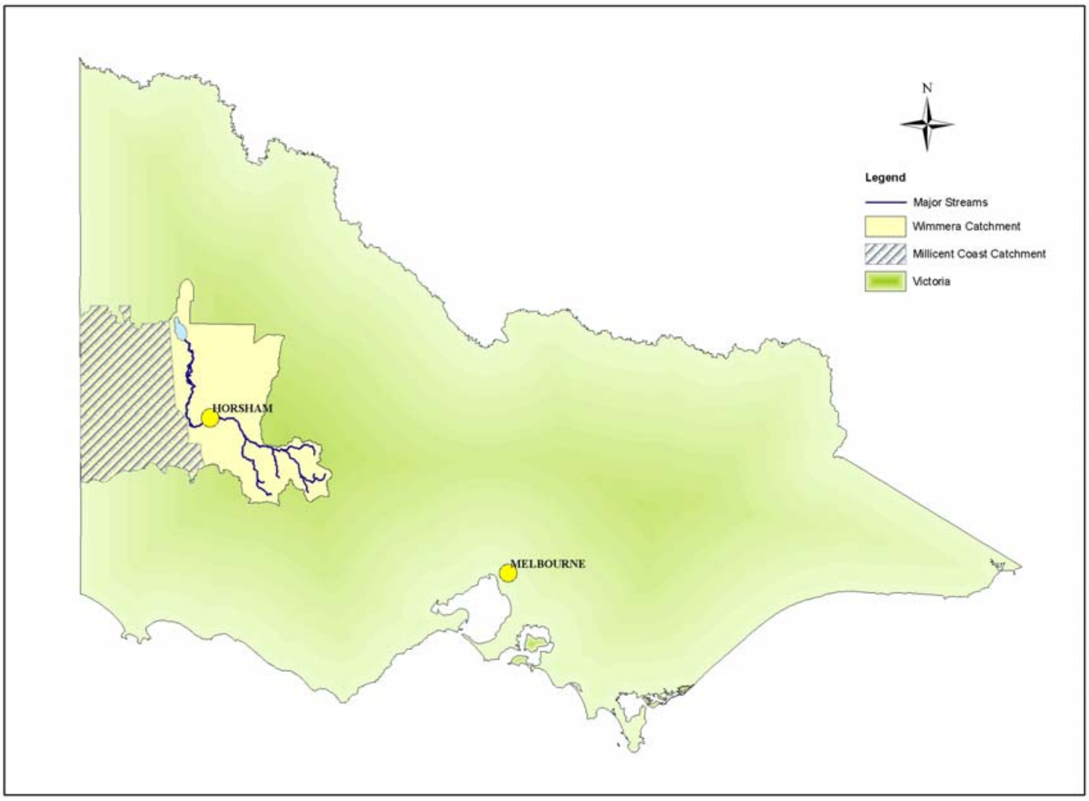

Figure 1.1: Location of the Wimmera Catchment within Victoria

Background to the Wimmera River Region

The Wimmera River catchment rises in the Grampian and Pyrenees ranges of central and western Victoria. The river flows in a northwesterly direction towards Horsham and is joined by several major tributaries that drain the northern slopes of the Grampians. No significant tributaries join after the McKenzie River west of Horsham where the river turns north and flows to Lake Hindmarsh. When Lake Hindmarsh fills, it spills through Outlet Creek to Lake Albacutya. In exceptionally wet periods Lake Albacutya overflows to Wirrengren Plain. The Wimmera River has two major distributaries. The Yarriambiack Creek flows north from Longerenong to beyond Hopetoun. Dunmunkle Creek flows north from Glenorchy and dissipates in the southern Mallee.

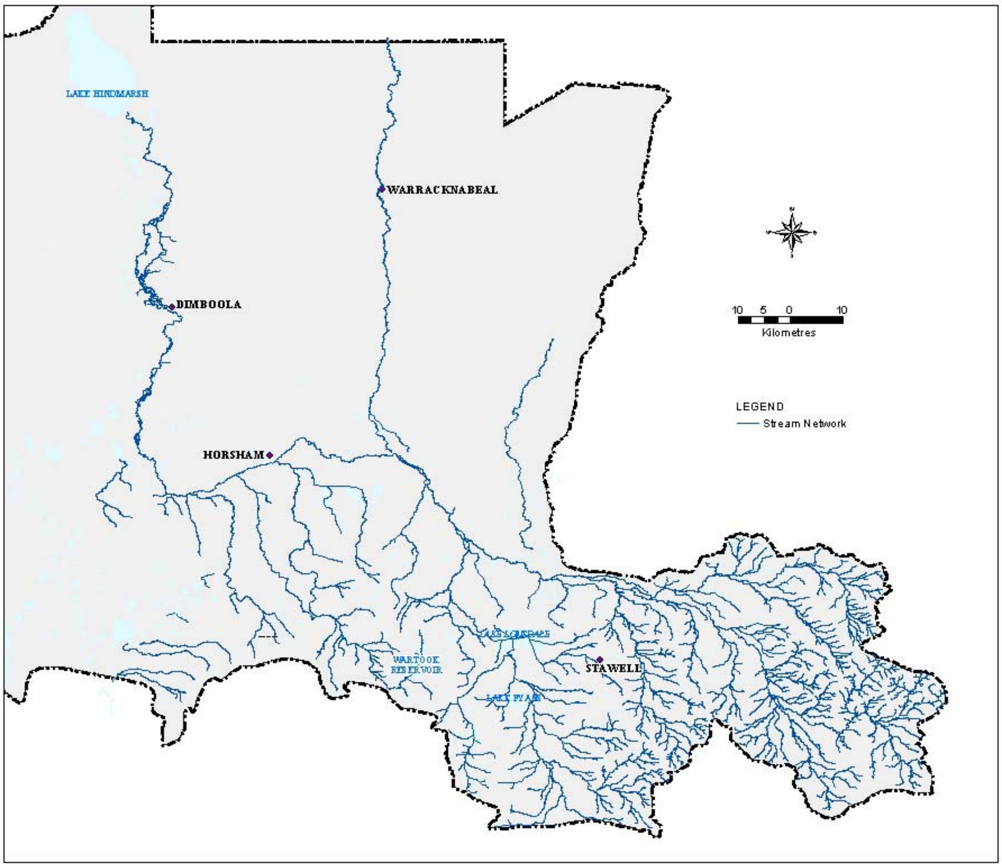

Figure 1.2: Stream Network of the Wimmera River Catchment

Heritage River

In 1991, the Land Conservation Council released their final recommendations for the *'Rivers and Streams Special Investigation'*. The Wimmera River was listed as a Heritage River from Polkemmet Bridge, through Lakes Hindmarsh and Albacutya to Wirrengren Plain.

Hydrology Conditions

The contrasting rainfall and run-off across the Wimmera catchment, being high in the Grampians and Pyrenees ranges and very low on the lowlands, has had a significant impact on the development of the fluvial systems of the catchment. The limited summer run-off means that many smaller streams in the upper catchment are subjected to intermittent flows. In dry periods many of the large streams throughout the catchment are reduced to a series of pools with only tenuous surface links.

The upper catchment of the Wimmera is steeper and the streams generally more confined, though the limited rainfall and runoff has a major effect on the formation of different types of streams. The limited overland flow allows the formation of disconnected channels and other discontinuous fluvial systems, such as intact valley fills and chain of ponds.

The runoff of the Wimmera catchment and the large plains have led to the formation of a single main drainage feature; the Wimmera River. With a dominance of alluvial material in the lower catchment and low relief, the river and the lower reaches of its' tributaries are unconfined. Whilst flows in the Wimmera River may be intermittent during dry periods, the channel system is continuous. Further the low relief has also lead to parts of the Wimmera River being a multi-channel or anabranching system.

The Wimmera-Mallee Stock and Domestic Supply System acts to supply water to the north-west of the catchment over an area of 28 500 square kilometres. The system has had a significant impact on the hydrology of waterways in the catchment.

Streamside Zone Conditions

The Wimmera River and Environs Action Program – Action Plan (Thomson Hay & Associates 1997) and Assessment and Review of Crown Water Frontages in the Wimmera Region (SKM 1998) found that streams in the upper catchment were generally in worse condition than in most other parts of the region. Many of the lower and middle reaches were in good condition as were most streams derived from catchments in the Grampians.

Where present, the riparian zone acts as a wildlife habitat and migration corridor (LCC, 1991). Of particular note within the Wimmera is:

- Widespread native vegetation surrounds the river immediately south from Dimboola and north from Lake Hindmarsh (LCC, 1991).
- There is a site of floristic significance at Dorington Point in Lake Albacutya. The seeds of the river red gums are in international demand due to having a salt tolerance that is higher than usual.
- South from Dimboola, there are six species of flora in the Wimmera River riparian zone which are extremely rare and four species which are endangered or have localised occurrences (LCC, 1991).

- Between Antwerp and Dimboola the vulnerable bottle bluebush (Maireana excavata) is part of an intact understorey.

Geology

The Wimmera catchment can be divided into three major geological areas (Figure 1.3)

1. The Silurian/Devonian sediments of the Grampians in the upper catchment;
2. The Palaeozoic turbidites of the St Arnaud Beds that form the Pyrenees Ranges, and
3. The Tertiary/Quaternary sediments of the Middle and Lower Wimmera.

During the Tertiary period a series of marine transgressions occupied much of the lower Murray Basin. Extensive marine sands, known as the Parilla Sands, were laid down on the Wimmera Plain. The marine transgressions left a series of north - south trending strandline ridges (representing former shorelines). These ridges and associated troughs are now a major influence on catchment behaviour with the Wimmera River, Yarriambiack Creek and Dunmunkle Creek all flowing north in the alignmnet of these troughs. The Parilla Sands became the supply of sediment for the Quaternary Aeolian (windblown landscapes) forms, which now dominate the Wimmera landscape.

A series of global glacial events during the Quaternary period, over the last 50 000 years, have had a significant effect on hydraulic regimes. Alternating periods of wet and dry have played a significant role in the production of the landforms which now dominate the landscape of the south-eastern Australian.

Periods of dry have been influential in the formation of the aeolian forms that cover much of the Wimmera's catchment. These formations include:

1. The Lowan Formation, which makes up the large dune field lobe of the Little Desert National Park;
2. The reddish brown dunes of the Woorinen Formation, which cover much of the Wimmera and Mallee; and
3. The Lunette Lake Basins.

There are also two fluvial formations from the Quaternary.

1. The Shepparton Formation, consisting of fluvial silts and sands which may form erosion resistant terraces along the Wimmera River, and
2. The Coonambigdal Formation, consisting of alluvial units associated with the active channel belt of the Wimmera River. The alluvials are mobile sediments and are currently being reworked by the river within the channel belt.

The sedimentary rocks of the Grampians form a thick sequence of quartzose sandstone, red siltstone and mudstone with occasional lenses and layers of conglomerate. The sediments are predominantly of freshwater origin with occasional thin layers that contain fossils with marine associations. These sediments usually overlie basal acid lavas and pyroclastics.

The Pyrenees Ranges, which are comprised of the St Arnaud beds, generally consist of green mudstones interbedded with graded turbite sandstones and are generally quartz rich. The Grampians and Pyrenees Ranges have been deformed by a series of northwesterly trending high angle faults and *en echelon* folds. The folding and faulting has been attributed to the Tabberabberan Orogeny. The Stawell Granite and the Ararat Granodiorite that postdate the original deformation have also intruded the Grampians and Pyrenees (Douglas and Ferguson, 1988) (see Appendix A).

As the granitic rocks and the sandstones of the Grampians are exposed to weathering there is the development of quartz sands that may form a significant bed load in streams draining these areas, as well as allowing the formation of stream categories such as gorges. This bed load of sand may have a significant influence on the geomorphic form of these streams.

The mudstones and siltstones of the St Arnaud Beds are more prone to weathering and have tended to form confined and partly confined streams (see Geomorphic Categorisation section for a description of stream categorises).

For a more complete description of the Lower Wimmera Geology see Wimmera CMA – Wimmera River Geomorphic Investigation.

Figure 1.3 is a schematic of the different geological zones of the Wimmera catchment. The Lowland Alluvials consist of the Quaternary aeolian sediments and the Tertiary Marine Sands. The Grampians consist of the Silurian Devonian freshwater sandstone and siltstones. The Pyrenees consists of Palaeozoic siltstones and sandstones (turbites).

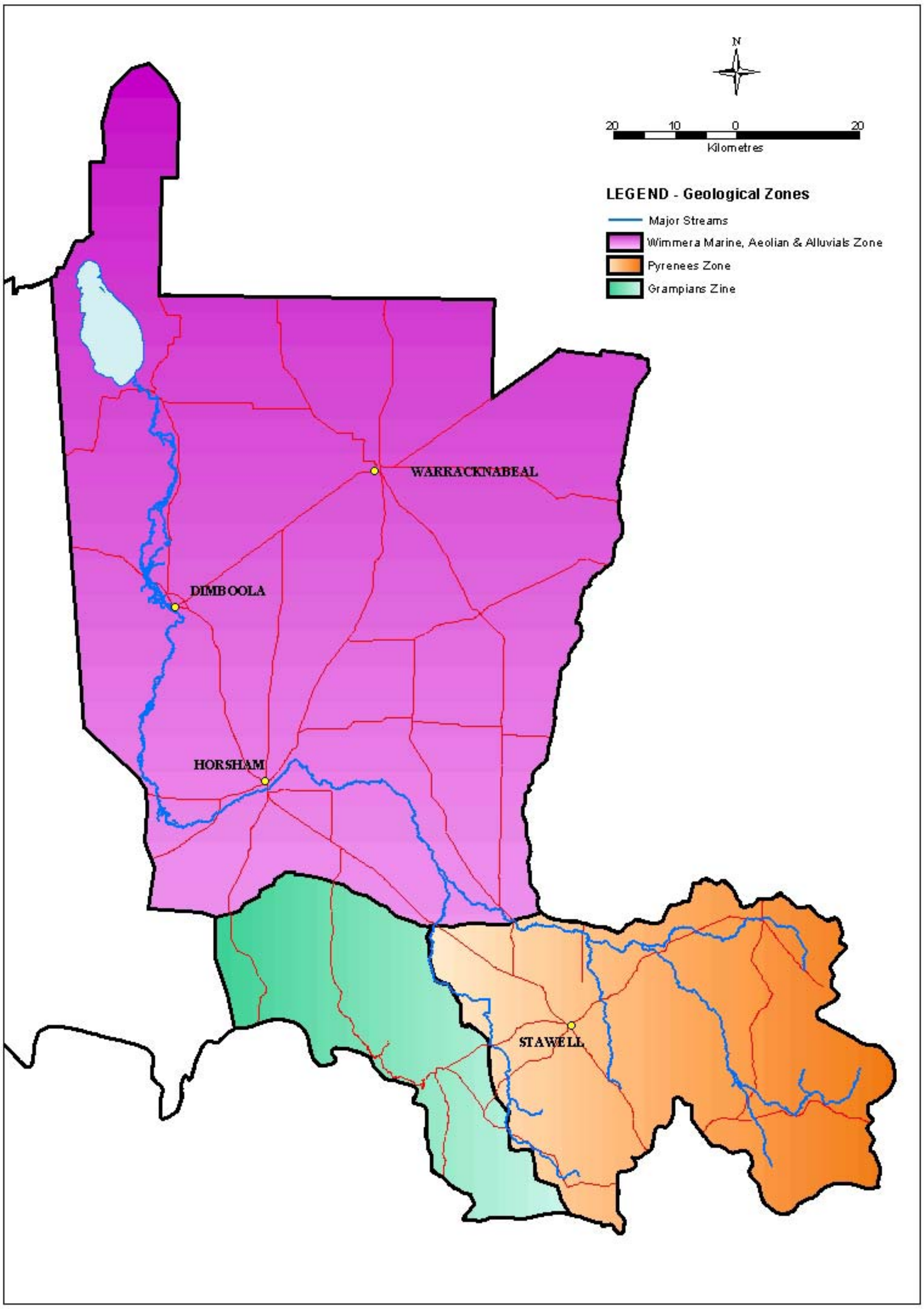

Figure 1.3: Geological zones of the Wimmera River catchment

Topography

The Wimmera catchment is dominated by the western plains of Victoria, which are of very subtle relief. Tertiary marine strandline ridges and Quaternary aeolian dunes and lunettes dominate the topographic features of the plains. The headwaters of the catchment are the western end of the Great Dividing Range and comprise the Grampians and Pyrenees ranges.

The topography of the catchment produces three distinct zones:

1. The highlands of the upper catchment;
2. The transition zone, which occurs between the highlands to lowland plain. This change leads to a drop in stream power and the deposition of most bed material sediment being transported; and
3. The lowland plains, which result in the formation of sinuous channels and multi-channel systems. The channel systems are often complex and vary in activity at differing flow levels.

Structure of the investigation

The project was divided into three distinct phases:

- Phase 1 – Geomorphic Categorisation.
- Phase 2 – Stream Condition Assessment.
- Phase 3 – Management Implications & Recommendations.

Geomorphic Categorisation

The geomorphic categorisation involved:

- Identification of tributaries within the Wimmera River catchment to a third order stream level.
- Categorisation of stream types within the Wimmera River catchment using an approach based on the River StyleTM method.
- Identification of the geomorphic attributes of the stream types to enable categorisation and monitoring, identification of the natural assets of the catchment, and setting of target conditions.
- Providing information on underlying geomorphic processes to assist in developing catchment management strategies.

Stream Condition Assessment

The stream condition assessment involved:

- Use of the previous Index of Stream Condition (ISC) assessments conducted in 1999 to identify the condition of the tributaries within the Wimmera River catchment.
- ISC assessments of an additional 52 sites to increase the number of sites to 89.
- Vegetation cover assessment of all waterways of third order or greater, using aerial photographs and GIS.
- Presentation of the information in a GIS format linked to the geomorphic categorisation information.

Management Implications & Recommendations

The priority stream sections identification involved:

- Identification of representative sections of stream for each stream type for use as a template.
- Corresponding of each stream type with respective condition assessment.
- Determination of priority listing for further study on geomorphically and ecologically significant stream types.
- Identification of objectives for river management.
- Identification of the relative value of conservation and rehabilitation efforts for each stream type and for the overall management of the catchment.

E A R T H T E C H

Wimmera Catchment Management Authority

Geomorphic Categorisation and Stream Condition Assessment of the Wimmera River Catchment

Section Two – Geomorphic Categorisation

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Introduction

The geomorphic assessment of the Wimmera River catchment has been largely based and conducted along the lines of the first stage of the River Styles framework proposed by Brierley and Fryirs (2002). The stream categorisation process involved the interpretation of the different stream categories through the integrated analysis of aerial photos, geology, vegetation, topographical data and stream order. This data was all brought together in a GIS program for simultaneous viewing and analysis.

The stream categories have been adapted from the original River Styles^{TM} method to reflect the Wimmera catchment, which is quite different to the NSW coastal catchments where the River Styles^{TM} method was developed. The streams have been categorised on a reach scale and the reaches have been determined by changes in variables such as stream geomorphology or vegetation cover.

Stream Order

The Wimmera catchment was ordered using the Strahler method of stream ordering. This stream ordering was undertaken after the supplied stream data, mapped at a 1:25000, was checked for connectivity. All anabranching systems where disabled to achieve a single channel. The Wimmera River catchment was ordered by a 'macro' in ArcMap, a GIS computer program.

The Strahler method of stream ordering is a widely accepted system and is commonly used. All small headwater streams are designated as first order. Second order streams are formed at the junction of two first order streams. Third order streams are formed at the junction of two second order streams and so forth.

The Strahler method is limited due to its inflexibility to increase a stream order despite a large number of tributaries increasing its size that are not of the same order of the main stream. This occurs in the Wimmera catchment with a large number of minor low order tributaries intersecting the larger Wimmera River, which significantly changes its size, but without changing its stream order (see Appendix B)

Stream Categorisation

The stream categorisation process involved the simultaneous analysis of three different data sets brought together in a GIS. The data sources used to determine the stream category for each reach included aerial photographs, geology and topography.

Aerial Photography

Aerial photography for the Wimmera catchment existed in a digital format for the majority of the upper catchment (Figure 3). This data was used for a base layer when categorising streams in this area. The resolution of this digital imagery allowed the aerial photographs to be viewed at a 1:5000 scale. The lower part of the catchment was assessed using a variety of aerial photographs. The scale of these photographs varied. Typically, the aerial photography for the lower catchment was at a scale of 1:20 000 or greater, and was not available as stereo pairs thus limiting interpretation. This interpretation limited the ability to define features of the floodplain and the extent of riparian vegetation.

The aerial photography provided a rapid way of assessing large parts of the catchment especially in conjunction with the geology and topographic data. The interpretation was only of limited effectiveness in areas where complete vegetation over storey masked the channel. This typically occurred with the lower order streams in some parts of the upper catchment and the MacKenzie River.

The coverage of digital photography in the Wimmera Catchment is restricted to the southern part of the Wimmera Catchment. Refer to Figure 2.1. The hashed area to the west of the Wimmera catchment is the Millicent Coast catchment, which is part of the Wimmera CMA region but not part of this investigation.

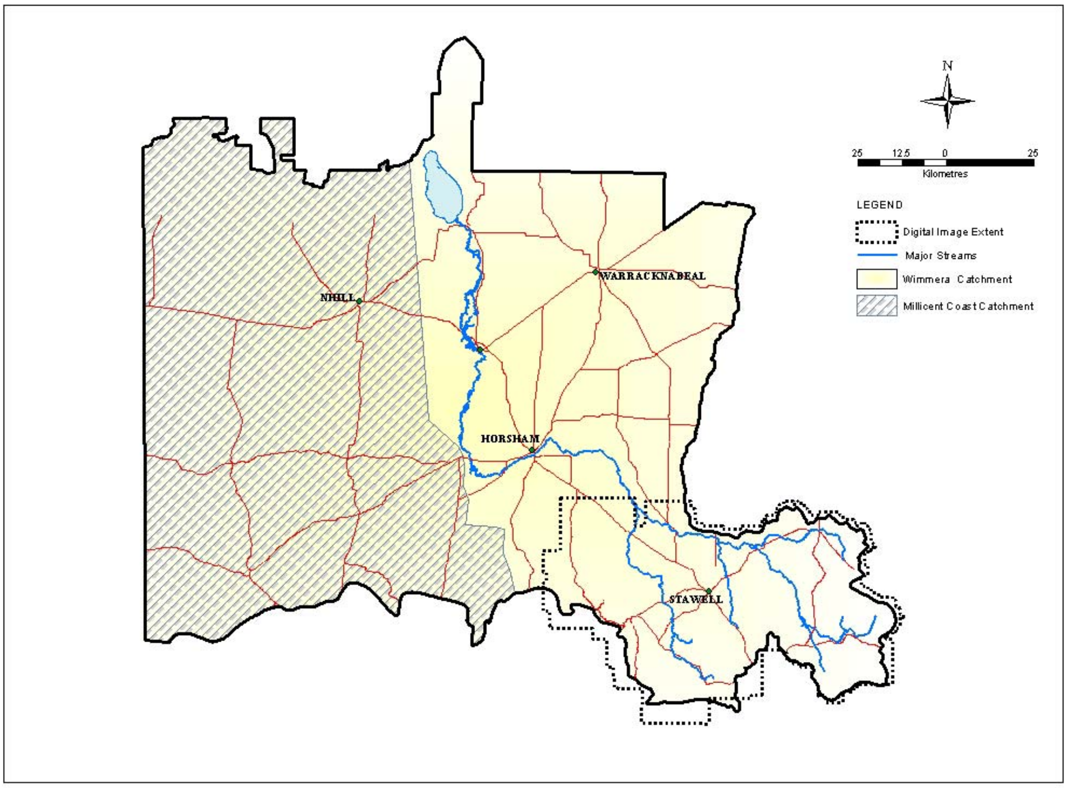

Figure 2.1: Area of the investigation and extent of digital photography

Geology

The Wimmera River catchments stream geomorphology is a reflection of differing geological controls. Different geologies influence hydrology and geomorphology allowing streams of different categories to form in response. Tertiary and Quaternary alluvial sediments dominate and control the middle and lower catchment while the upper catchment is controlled by older and extensively deformed rocks of Cambrian and Ordovician age. The older formations make up the elevated regions of the Grampians and the Pyrenees ranges. The alluvial sediments of the lower catchment are generally more easily reworked, allowing the channels formed to be a result of stream energy, flow, bed load and gradient. This is substantially different in the upper catchment where the harder metasediments of the Grampians and Pyrenees are not easily reworked and stream and channel form is controlled by the geology. This usually results in a confined or partly confined stream. Generally, the confined, partly confined and alluvial discontinuous systems are restricted to the Grampians and Pyrenees ranges.

Topography

Contour data was used in conjunction with geology and aerial photography to determine how confined the different reaches of the stream were as well as giving an indication of the reach and sub catchment gradient.

Stream Categories

Within the Wimmera catchment a total of 18 different stream categories were identified and used. These consisted of 16 natural stream categories, one incising stream category attributed to catchment changes, and one constructed (anthropogenic) stream category.

The sixteen natural styles may be broken down into four different broad classifications.

1. <u>Confined:</u> identified by bedrock (or ancient sediments) being observed in both banks of the channel, over 90% of the channel is in contact with bedrock. The stream has only isolated pockets of floodplain and the channel plan form is imposed by the configuration of the valley.

   The confined stream categories identified within the Wimmera catchment include the Steep Headwater, Confined, and Gorge.

2. <u>Partly confined:</u> 10 to 90% of the streams channel abuts bedrock and valley margins. Floodplains occur as discrete pockets along the channel either on alternate banks or in a semi-continuous manner.

   Partly confined stream categories within the Wimmera catchment include Partly Confined 1, 2 & 3. These categories are dependent on different amounts of bedrock control on the channel and channel sinuosity.

3. <u>Alluvial Continuous:</u> less than 10% of the continuous streams channel(s) abut the valley margin and the floodplain is continuous along both banks of the stream. Classifications change depending on changes in alluvial material, sinuosity and number of channels.

Alluvial Continuous categories within the Wimmera River catchment include Low Sinuosity Fine Grained (Alluvial Continuous 1), Meandering Fine Grained (Alluvial Continuous 4), Meandering Sand Bed (Alluvial Continuous 5), and Anabranching fine grained (Alluvial Continuous 9).

4. Alluvial Discontinuous: alluvial sediments with a discontinuous or absent channel(s).

   Discontinuous Alluvial categories identified within the Wimmera River Catchment include Intact Valley Fill, Cut & Fill, Chain of Ponds, Flood Out, and Anabranching Chain of Ponds.

Two further classifications were used to classify all other reaches of the Wimmera catchment, these are

1. Incised (Discontinuous Channelised): this category of stream has been used to classify any alluvial discontinuous system that was interpreted to have been lost to gullying brought about by post settlement landuse within the catchment.
2. Constructed: this category contains all features that are used to capture and transport water within the catchment and is situated on the natural drainage system or has replaced the natural channel or fluvial form. Features include reservoirs, large farm dams, weir pools and constructed channels and drains.

The results of the remote categorisation and analysis were ground truthed through targeted reconnaissance.

Stream Category Definitions for the Wimmera Catchment

The following descriptions of stream categories have been adapted from the River Styles stream categorisation in conjunction with the desktop review and fieldwork conducted during the project. Seventeen different natural Stream Categories have been identified during the assessment process and a single anthropogenic stream classification was used for channelised systems and other constructed features such as farm dams, weirs and reservoirs etc. The natural stream categories are described below. The relationship of these figures is shown in Figure 2.2.

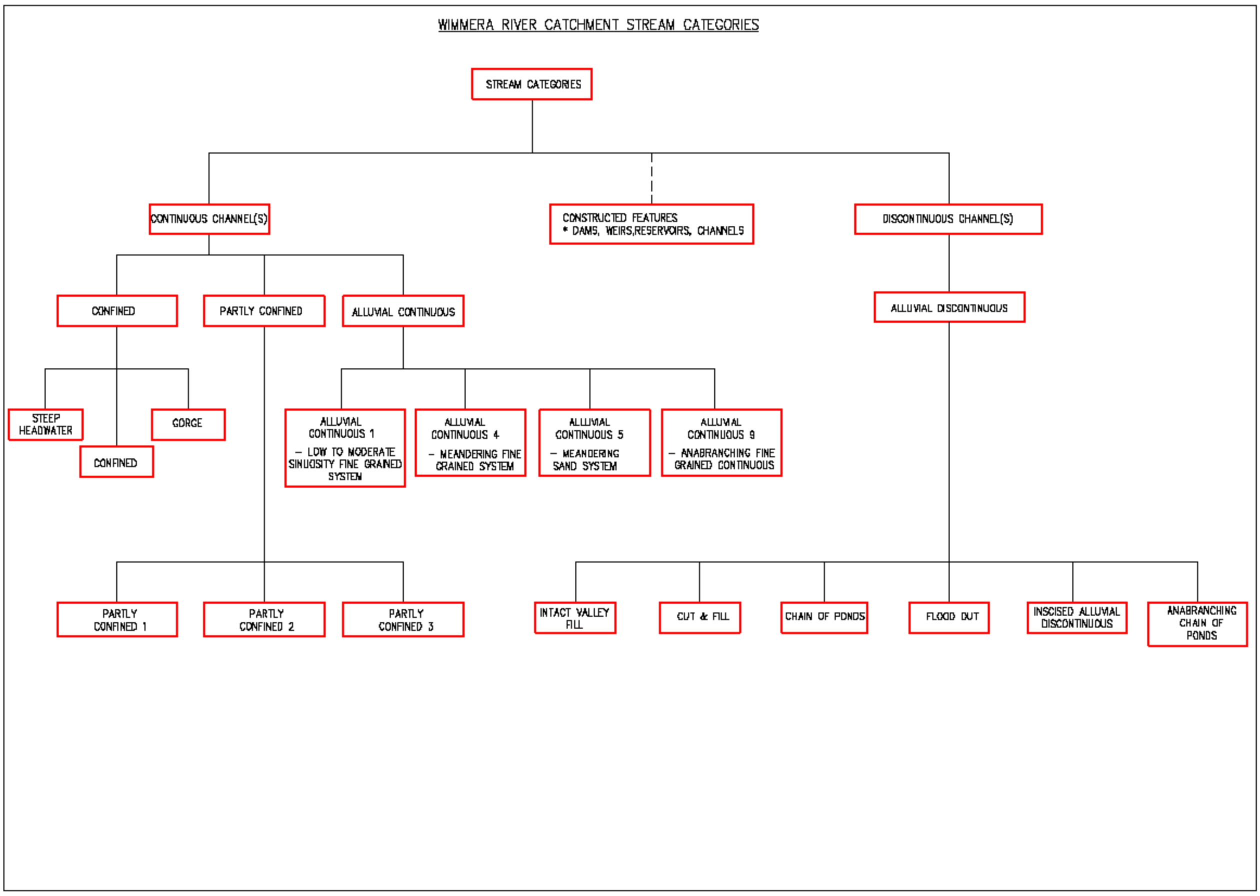

Figure 2.2: Stream Category Definitions for the Wimmera River Catchment

Figure 2.2 shows the relationship between the different individual classifications and their broader classes. For a map of the stream category distribution, refer to Appendix C.

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System: Confined

Stream Type: Steep Headwater

USUAL POSITION	Steep upper parts of catchments, V-shaped valleys, upstream of major falls. Only found within the Grampians geological zone.	
CHANNEL GEOMETRY	Symmetrical to irregular	
CHANNEL PATTERN	Single, controlled by valley shape and pinned to valley margins with isolated floodplain pockets. Flow often around large boulders and rock outcrops.	
GEOMORPHIC UNITS	Channel zone: highly variable but includes pools, steps, falls, riffles, mid-channel and bank-attached bars, small islands	Floodplain zone: small, shallow pockets.
GEOMORPHIC BEHAVIOUR	Steep slope with channels that gravel, boulder or bedrock dominated. Laterally controlled. Small thin floodplains, which can be reworked. May slowly erode valley wall if weathered bedrock or colluvium.	
SEDIMENT TRANSFER BEHAVIOUR	Source zone. Size transported depends on flow energy. Material availability is highly variable from catchment to catchment.	

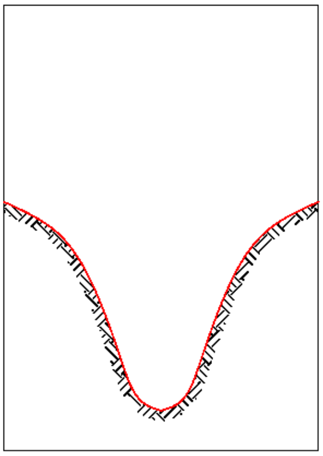

Figure 2.3a: Schematic cross-section of a steep headwater stream

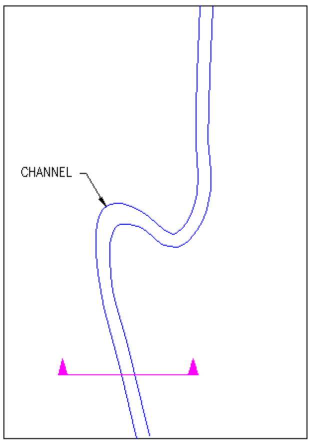

Figure 2.3b: Schematic plan of a steep headwater stream

Figure 2.3c: A steep headwater stream, Grampians National Park (ISC Site 17_5)

Reach near Seven Dials Track. Note the confining valley margins and the boulder and cobble bed of the stream.

Figure 2.3d: A steep headwater stream, Grampians National Park, (Site 20_2)

A steep headwater stream off the Copper Mine track, Grampians National Park. Note the angular boulder bed and the confining valley margins.

Figure 2.3e: A steep headwater stream, Grampians National Park

An aerial view of a steep headwater stream within the Grampians National Park.

System: Confined

Stream Type: Confined

USUAL POSITION	Uplands and mid-catchment. Generally found within the Grampians Geological zone though also occurs in parts of the Pyrenees.	
CHANNEL GEOMETRY	Asymmetrical, symmetrical or compound	
CHANNEL PATTERN	Single. Valley margins dictate the planform of the river. Over 90% of the channel length abuts the valley margin. Occasional discontinuous floodplain pockets at wider sections of valley and tributary inflows, commonly inside of valley bends.	
GEOMORPHIC UNITS	Channel zone: Pools, riffles, cascades, steps, point bars, lobate bars, benches, chute channels and occasional islands	Floodplain zone: discrete floodplain pockets
GEOMORPHIC BEHAVIOUR	Gravel or boulder dominated. Channel not free to migrate downstream or laterally (i.e. is laterally fixed). Reworking of bars and floodplain pockets on inside bends. May slowly erode valley wall if not bedrock. Floodplain may be stripped. Occasional floodplain pockets are localised areas of channel adjustment.	
SEDIMENT TRANSFER BEHAVIOUR	Transfer in balance over the long term, but floodplain pockets accumulate slowly and flush over a short interval.	

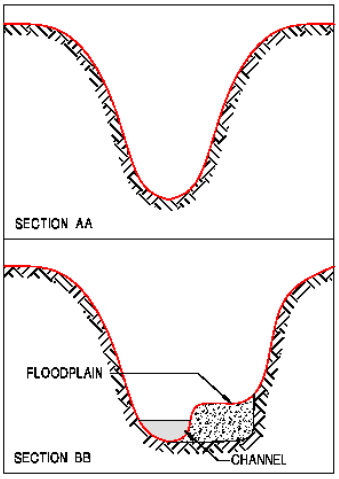

Figure 2.4a: Schematic cross-section of a confined stream

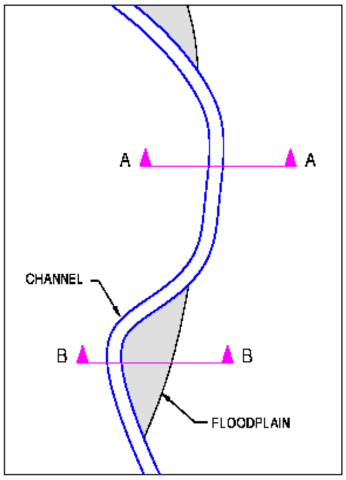

Figure 2.4b: **Schematic plan of a confined stream**

Figure 2.4c: A confined tributary in the Grampians National Park

A confined tributary of the MacKenzie River, note the confining banks and the sub-angular cobble bed-load. (ISC Site 12_5)

Figure 2.4d: A confined upper reach of Glenpatrick Creek.

A confined reach of Glenpatrick Creek, note the confining valley margins. (ISC Site 34_4)

Figure 2.4e: Aerial view of a confined stream Grampians National Park

An aerial view of a confined stream within the Grampians National Park, a headwater of Mt William Creek.

System: Confined

Stream Type: Gorge

USUAL POSITION	Highlands. Only found within the Grampians geological zone.	
CHANNEL GEOMETRY	Bedrock Valley	
CHANNEL PATTERN	Single low sinuosity channel	
GEOMORPHIC UNITS	Channel zone: The channel may contain cascades, rapids, backwater & plunge pools, boulder bars, islands and occasional waterfalls.	Floodplain zone: No floodplain
GEOMORPHIC BEHAVIOUR	Stable geomorphically with only slow change due to the large amounts of bedrock.	
SEDIMENT TRANSFER BEHAVIOUR	Material is transferred through the gorge and not stored.	

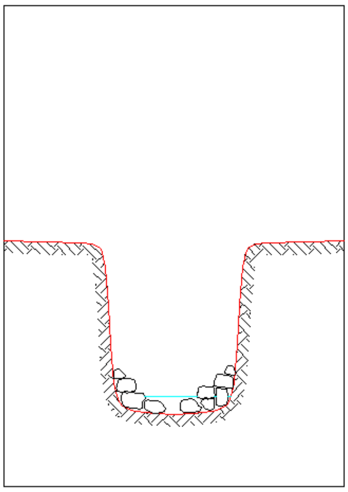

Figure 2.5a: Schematic cross-section of a gorge

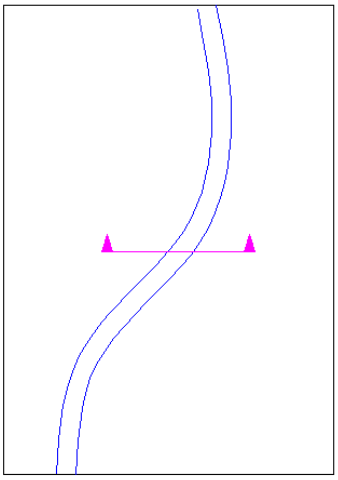

Figure 2.5b: Schematic plan of a gorge

Figure 2.5c: MacKenzie River Gorge

The MacKenzie River gorge contains riffles, cascades, runs and significant water fall, and the channel base is covered with gravels and cobbles. The photo shows a rapid discharging into a typical pool. The Wartook Reservoir controls flows within the gorge. (ISC site14_13)

Figure 2.5d: Golton Creek Gorge

The Golton Creek Gorge is situated within the Grampians National Park. The gorge has a relatively steep bed grade and contains extensive bedrock sections. (ISC site 21_11)

Figure 2.5e: Mackenzie River Gorge Aerial

An aerial view of a MacKenzie River Gorge.

System: Partly Confined

Stream Type: Partly Confined 1: Bedrock controlled discontinuous floodplain.

USUAL POSITION	Uplands. This system is found in the Grampians and Pyrenees geological zones.	
CHANNEL GEOMETRY	Symmetrical and often trench-like or compound channel.	
CHANNEL PATTERN	Single, planform controlled (50 to 90% of the channel length abuts valley margin). Sinuosity dependent on valley shape though tends to be low. Discontinuous floodplain.	
GEOMORPHIC UNITS	Channel zone: Pools, riffles, local bedrock steps, point bars and benches, chute channels.	Floodplain zone: Discontinuous, local terraces, often stripped.
GEOMORPHIC BEHAVIOUR	Gravel or sand dominated. Pattern of behaviour depends on local valley setting, especially in relation to the nature of floodplain pockets. Adjusts through aggradation or degradation of the bed. Local channel expansion and floodplain reworking (stripping) takes place at bends.	
SEDIMENT TRANSFER BEHAVIOUR	Transfer or throughput are in balance over the long term, but may vary from floodplain pocket to pocket.	

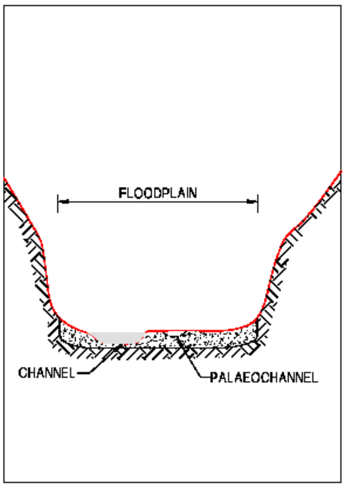

Figure 2.6a: Schematic cross-section of a partly confined 1 stream

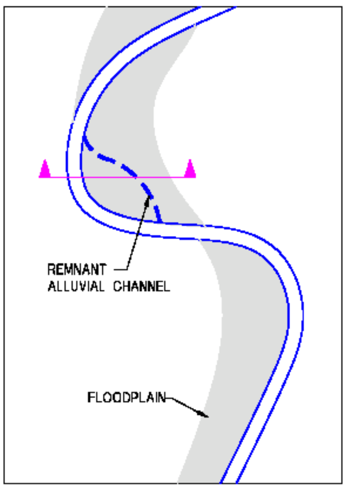

Figure 2.6b: Schematic plan of a partly confined 1 stream

Figure 2.6c: A Partly Confined reach of the Mackenzie River

The partly confined MacKenzie River between the Wartook Reservoir and the MacKenzie Falls and gorge. (ISC Site 15_1)

Figure 2.6d: An Aerial view of Nowhere Creek

An aerial view of a partly confined tributary of Nowhere Creek.

System: Partly Confined

Stream Type: Partly Confined 2: Low sinuosity planform controlled discontinuous floodplain

USUAL POSITION	Mid to upper catchment. This system is generally found with the Grampians and Pyrenees geological zones it is generally found in within alluvial valleys and is not totally bedrock controlled.	
CHANNEL GEOMETRY	Symmetrical and often trench-like or compound channel.	
CHANNEL PATTERN	Single, planform controlled (i.e. the apex of bends and 10 to 50 % of the channel length abuts valley margin). Sinuosity dependent on valley shape. Semi-continuous floodplain.	
GEOMORPHIC UNITS	Channel zone: Planar bed but may contain pools and riffles, point and mid-channel bars and benches.	Floodplain zone: Irregular pockets that may contain shallow levees; flood channels, meander cut-offs.
GEOMORPHIC BEHAVIOUR	The systems tend to be dominated by fine sediments. The pattern of behaviour depends on local valley setting, especially in relation to the nature of floodplain pockets. Adjusts through aggradation or degradation of the bed. Local channel expansion and floodplain reworking (stripping) takes place at bends, bends may migrate downstream.	
SEDIMENT TRANSFER BEHAVIOUR	Transfer or throughput are in balance over the long term, but may vary from floodplain pocket to pocket, sometimes releasing sediment slugs.	

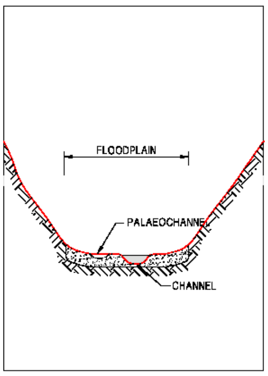

Figure 2.7a: Schematic cross-section of a partly confined 2 stream

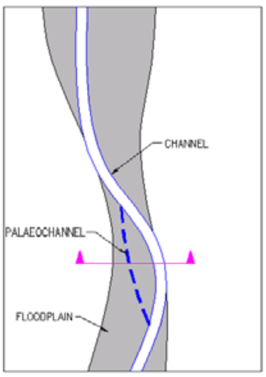

Figure 2.7b: Schematic plan of a partly confined 2 stream

Figure 2.7c: Lower Mackenzie River

A partly confined reach of the MacKenzie River downstream of the MacKenzie Gorge. The water level is due to this part of the MacKenzie River being used to carry water from the Wartook reservoir to Distribution Heads. (ISC Site 13_11)

Figure 2.7d: Glenpatrick Creek

A partly confined reach of Glenpatrick Creek. Note the relatively uniform cobble bed which can be attributed to the past mining of the area (ISC Site 33_5)

Figure 2.7e: An aerial view of Nowhere Creek

An aerial view of a partly confined reach Nowhere Creek.

System: Partly Confined

Stream Type: Partly Confined 3: Meandering discontinuous planform controlled floodplain

USUAL POSITION	Mid to upper catchment. This system within the Grampians and Pyrenees geological zones is generally found within alluvial valleys and does occur in parts of the lower Wimmera River, though only as far as Glenorchy.	
CHANNEL GEOMETRY	Symmetrical and often trench-like or compound channel.	
CHANNEL PATTERN	Single, planform controlled (i.e.10 to 50 % of the channel length abuts valley margin, bend apex's are not necessarily controlled by the valley margin). Sinuosity dependent on valley shape. Discontinuous or semi-continuous floodplain.	
GEOMORPHIC UNITS	Channel zone: Pools, riffles, local bedrock steps, occasional point and mid-channel bars and benches, chute channels.	Floodplain zone: flood channels and associated cut-offs, occasional localised levees;
GEOMORPHIC BEHAVIOUR	Gravel or sand dominated. Pattern of behaviour depends on local valley setting, especially in relation to the nature of floodplain pockets. Adjusts through aggradation or degradation of the bed. Local channel expansion and floodplain reworking (stripping) takes place at bends. In wider reaches, bends migrate downstream.	
SEDIMENT TRANSFER BEHAVIOUR	Transfer or throughput are in balance over the long term, but may vary from floodplain pocket to pocket, sometimes releasing sediment slugs.	

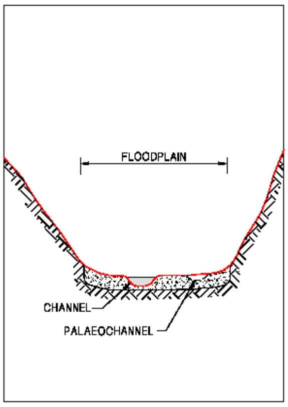

Figure 2.8a: Schematic cross-section of a partly confined 3 stream

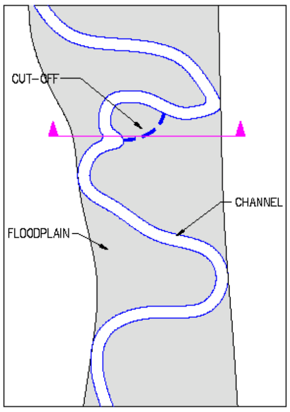

Figure 2.8b: Schematic plan of a partly confined 3 stream

Figure 2.8c: Upper Fyans Creek

A partly confined reach of a Fyans Creek tributary above Lake Bellfield in the Grampians National Park. (ISC Site 16_6)

Figure 2.8d: Wimmera River

A partly confined reach of the Wimmera River in the upper catchment. (ISC Site 46_2)

Figure 2.8e: An aerial view of the Wimmera River

An aerial view of a partly confined reach of the Wimmera River, upper catchment.

System: Alluvial Continuous

Stream Type: Alluvial Continuous 1: Low to moderate sinuosity fine grained continuous system

USUAL POSITION	Lowland plains and western plains, low slope valleys. This system is generally restricted to the Wimmera lowlands.	
CHANNEL GEOMETRY	Deep and narrow symmetrical channels; often low capacity channel	
CHANNEL PATTERN	Single channel with low sinuosity and continuous floodplains along both valley margins.	
GEOMORPHIC UNITS	Channel zone: – levees, pools, runs, benches	Floodplain zone: Continuous channel with flood channels and palaeochannels
GEOMORPHIC BEHAVIOUR	Low rates of meander migration. Floodplain building vertically with fine grained sediments	
SEDIMENT TRANSFER BEHAVIOUR	Sediment transfer in balance, or gradually accumulating fine-grained sediments.	

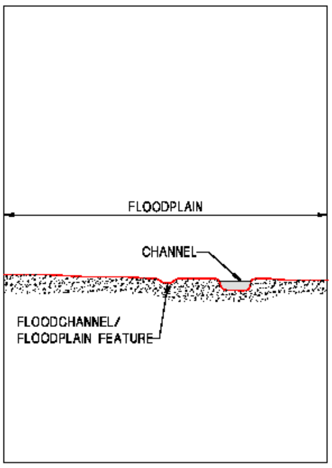

Figure 2.9a: Schematic cross-section of a low to moderate sinuosity stream

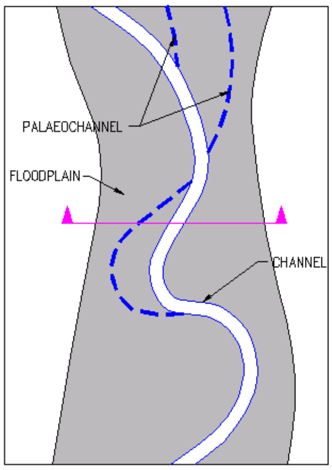

Figure 2.9b: Schematic plan of a low to moderate sinuosity stream

Figure 2.9c: A low sinuosity reach of the MacKenzie River

A low sinuosity reach of the MacKenzie River, the bank full flows are due to this part of the river being used to carry irrigation water from the Wartook Reservoir to the Distribution Heads. (ISC Site 8_3)

Figure 2.9d: Reservoir Creek

A low sinuosity reach of Reservoir Creek (ISC Site 40_10).

Figure 2.9e: An aerial view of the Wimmera River

Aerial view of a fine grained low sinuosity system on the Wimmera River.

System: Alluvial Continuous

Stream Type: Alluvial Continuous 4: Meandering fine-grained alluvial continuous system.

USUAL POSITION	Lowland plains and western plains, low slope valleys. This system is generally confined to the Wimmera lowlands.	
CHANNEL GEOMETRY	Deep and narrow symmetrical channels; often low capacity channel	
CHANNEL PATTERN	Single channel with moderate to high sinuosity and continuous floodplains along both valley margins.	
GEOMORPHIC UNITS	Channel zone: Pools, point benches, benches, point bars, runs	Floodplain zone: Continuous with cut-offs, billabongs, palaeochannels, flood channels, back-swamps, levees
GEOMORPHIC BEHAVIOUR	Low energy mud dominated; with very low rates of meander migration. Floodplain building vertically with fine grained sediments	
SEDIMENT TRANSFER BEHAVIOUR	Throughput in balance, or gradually accumulating fine-grained sediments.	

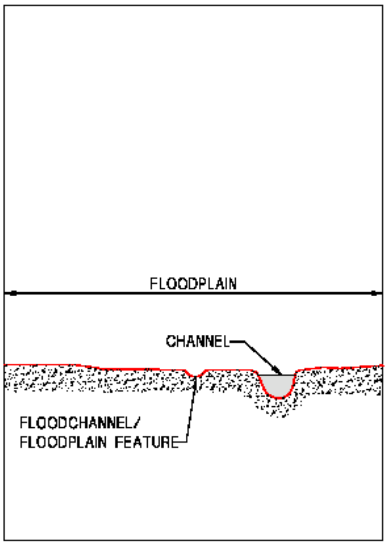

Figure 2.10a: Schematic cross-section of a moderate sinuosity stream

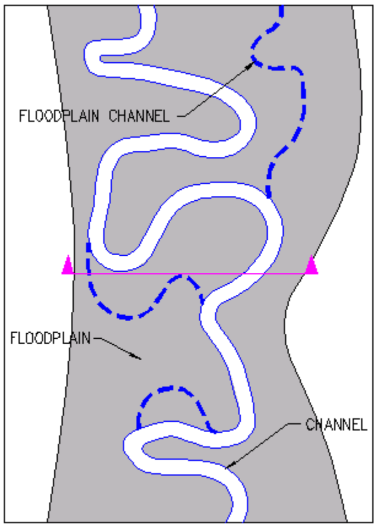

Figure 2.10b: Schematic plan form of a moderate sinuosity stream

Figure 2.10c: Mt William Creek

A typical moderately sinuous reach of Mt William Creek (ISC Site 18_1).

Figure 2.10d: Seven Mile Creek

A moderately meandering reach of Seven Mile Creek (Site 25_6)

Figure 2.10e: An aerial view of Six Mile Creek

Aerial view of a meandering fine grained alluvial continuous system, Six Mile Creek.

System: Alluvial Continuous

Stream Type: Alluvial Continuous 5: Meandering Sand bed

USUAL POSITION	Middle to lower catchment positions in moderately wide valleys. Typically found within the Grampians geological zone or on streams rising in this area for the source of the sand.	
CHANNEL GEOMETRY	Symmetrical channel with high width-depth ratio but can change to asymmetrical through to trench-like (incising) to compound with steps (recovering).	
CHANNEL PATTERN	Single channel with moderate to high sinuosity and continuous floodplains. Low flow channel may locally divide around sand bars	
GEOMORPHIC UNITS	Channel zone: planar sand sheets, lateral bars, point bars, scour pools and benches.	Floodplain zone: Continuous with cut-offs, palaeochannels, flood channels, back-swamps and levees.
GEOMORPHIC BEHAVIOUR	Low energy but laterally active with eroding outside bends and sand depositing inside bends, reworking sandy floodplain. Floodplain building laterally. Meander cut-offs indicate the laterally active and evolving nature of the channel.	
SEDIMENT TRANSFER BEHAVIOUR	Sand transfer in balance, or gradually accumulating.	

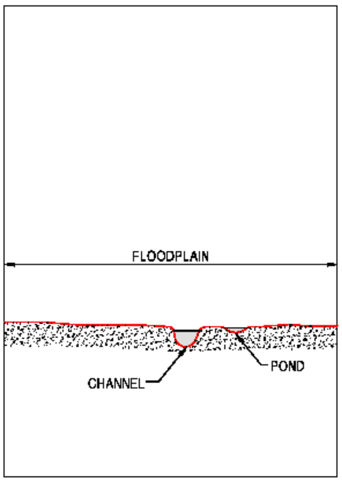

Figure 2.11a: Schematic cross-section of a meandering sand bed stream

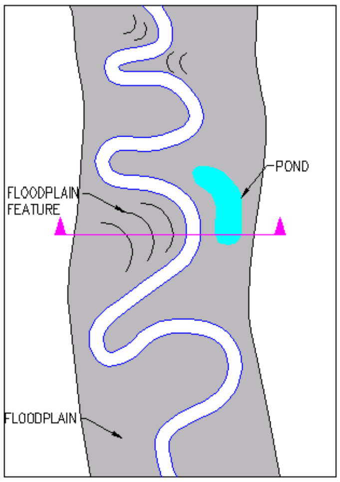

Figure 2.11b: Schematic plan of a meandering sand bed stream

Figure 2.11c: An aerial view of Concongella Creek

An aerial view of a meandering sand bed stream, Concongella Creek

System: Alluvial Continuous

Stream Type: Anabranching Fine Grained

USUAL POSITION	Lower catchment in areas with very low gradients. Typically located within the Wimmera Lowland alluvials, and is a common stream form of the Wimmera River.	
CHANNEL GEOMETRY	Multiple channels,	
CHANNEL PATTERN	Deltaic channels distributing sediment and water	
GEOMORPHIC UNITS	Channel zone: Multiple swamps, ponds, discontinuous secondary channels with multiple low stringers.	Floodplain zone: Continuous flat and generally featureless
GEOMORPHIC BEHAVIOUR	Very low energy and dominated by mud vegetation	
SEDIMENT TRANSFER BEHAVIOUR	Accumulating fine sediments	

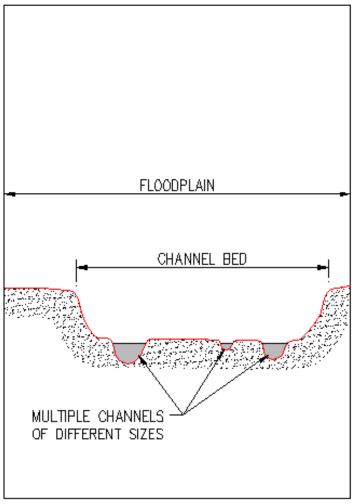

Figure 2.12a: Schematic cross-section of a anabranching fine grained

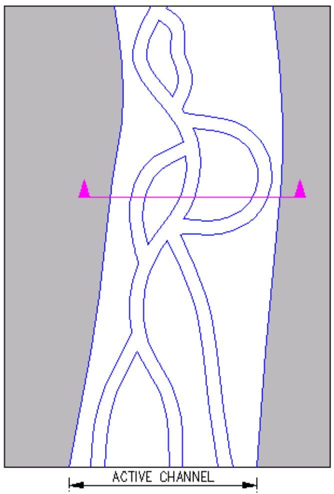

Figure 2.12b: Schematic plan of an anabranching fine grained

Figure 2.12c: The Lower Wimmera River

The main channel of the Wimmera River. The photo shows a pool and thickly vegetated bar that divides it from the next pool. (Site 27b_8)

Figure 2.12d: An anabranch of the Wimmera River

The main anabranch / flood-channel of the Wimmera River, the photo shows splitting of the main subsidiary anabranch into two channels. (Site 27_6)

Figure 2.12e: Mt William Creek and Sheepwash Creek

Aerial views of Anabranching Fine grained, the streams are Mt William Creek and Sheepwash Creek

System: Alluvial Discontinuous

Stream Type: Intact Valley Fill

USUAL POSITION	Upper catchment. Generally found within the lower order streams in the Pyrenees and Grampians geological zones.	
CHANNEL GEOMETRY	No Channel	
CHANNEL PATTERN	Occasional scour points	
GEOMORPHIC UNITS	Channel zone: NA	Floodplain zone: Intact Swamp, occasional scour pools
GEOMORPHIC BEHAVIOUR	Featureless swamp	
SEDIMENT TRANSFER BEHAVIOUR	Accumulating fines	

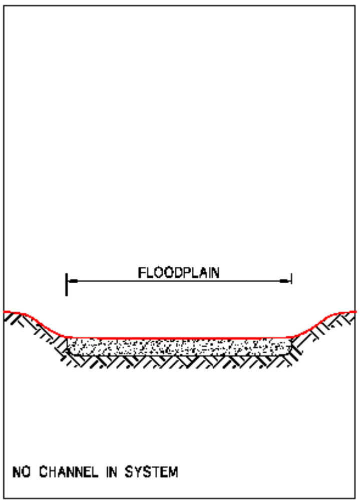

Figure 2.13a: Schematic cross-section of an intact valley fill system

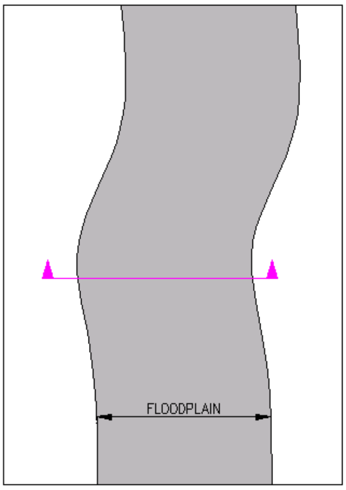

Figure 2.13b: Schematic plan of a intact valley fill system

Figure 2.13c: Intact Valley Fill

An Intact Valley Fill system showing an indistinct preferred flow path. The Intact Valley Fill can be identified in the photo by the indistinct sandy bed and the greener grass (ISC Site 22_4).

Figure 2.13d: Intact Valley Fill, cleared farmland

A typical Intact Valley Fill system in cleared farmland. The system is slightly inset into the surrounding countryside, and is identified by the slightly darker brown grass in the above photo (ISC Site 29_5).

Figure 2.13e: An aerial view of an Intact Valley Fill

An aerial view of an intact valley fill system. The system is a tributary of Glenlofty Creek

System: Alluvial Discontinuous

Stream Type: Cut and Fill

USUAL POSITION	Upper catchment. Generally found in the Pyrenees zone of the catchment on the transition between the highlands and lowlands.		
CHANNEL GEOMETRY	***Incised phase*** = compound channel (i.e. stepped cross-section)	***Filled phase*** = no channel or shallow drainage lines or chain of ponds	
CHANNEL PATTERN	***Incised phase*** = continuous channel	***Filled phase*** = continuous valley fills or swamps or chain of ponds occupying the entire valley floor linked by poorly defined well vegetated channels	
GEOMORPHIC UNITS Note: Individual section of cut and fill/flood out to <100m, if greater logged as flood out and discontinuous gully.	Unincised condition (fill phase)	<u>Channel zone</u>: ponds and/or discontinuous channels	<u>Floodplain zone</u>: swamp or meadow with discontinuous drainage lines
	Incised condition (cut phase)	<u>Channel zone</u>: trench-like channel with insets, bank attached bars, sand sheets & occasional pools. May show signs of swamp redevelopment	<u>Floodplain zone</u>: terraces, range of (dis)continuous valley fill surfaces
GEOMORPHIC BEHAVIOUR	Gravel, sand and/or mud dominated. At any one place, recurrent phases of incision, channel filling and sediment accumulation. Fines and organic matter are occasionally flushed downstream.		
SEDIMENT TRANSFER BEHAVIOUR	Stores large volumes of sediment for long periods and flushes sediments quickly and efficiently when incision is triggered.		

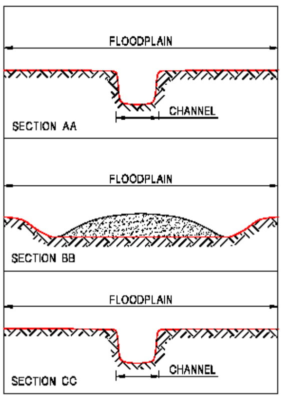

Figure 2.15a: Schematic cross-sections of a cut and fill system

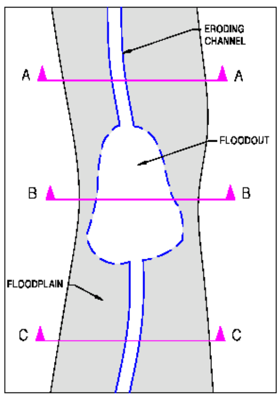

Figure 2.15b: Schematic plan of a cut and fill system

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Figure 2.15c: Lower Cut Phase

Lower reaches cut phase on a minor stream in the Pyrenees. (ISC Site 31_1)

Figure 2.15d: Floodout / Fill Phase

Middle reaches fill phase on a minor stream in the Pyrenees (ISC Site 31_2).

Figure 2.15e: Upper Cut Phase

Upper reaches cut phase on a minor stream in the Pyrenees (ISC Site 31_4).

Figure 2.15f: An aerial view of a cut and fill system.

An aerial view of a cut and fill stream in the vicinity of Crowlands

System: Alluvial Discontinuous

Stream Type: Chain of Ponds

USUAL POSITION	Mid to upper catchment, often plateau streams. Intact forms are only found within the Pyrenees geological zone on the Wimmera River and Glenlofty Creek.
CHANNEL GEOMETRY	Symmetric to irregular ponds and minor or discontinuous channels connecting ponds
CHANNEL PATTERN	Shallow to deep pools (ponds), with steeply dipping banks and shallow dipping ends. Shallow separating channel with little or no defined capacity. Flat flood plain.
GEOMORPHIC UNITS	Channel Zone: deep, long and broad pools, swamps, discontinuous channels, occasional benches Floodplain zone: flat and featureless.
GEOMORPHIC BEHAVIOUR	Mud and organic material dominated, sand in deep pools. Sediment is generally accumulated on floodplain. Pools remain scoured by depth. Vegetation stabilisation of pool separators, otherwise incision may be induced.
SEDIMENT TRANSFER BEHAVIOUR	Sediment accumulation except in deep open water pools

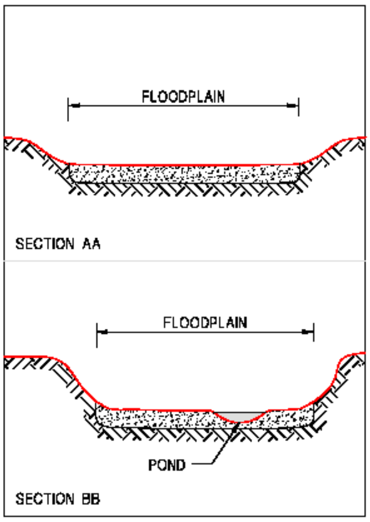

Figure 2.14a: Schematic cross-section of a chain of ponds

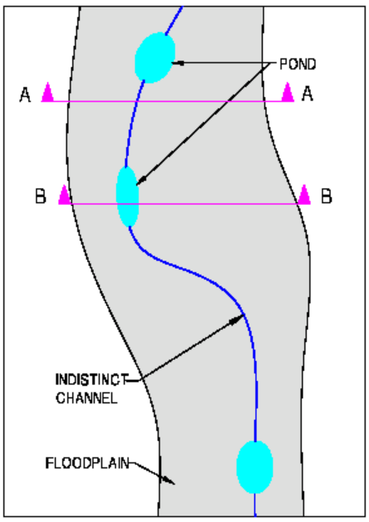

Figure 2.14b: Schematic plan of a chain of ponds system

Figure 2.14c: Glenlofty Creek, chain of ponds.

A view of the Glenlofty Creek chain of ponds system. Note the thick reedy vegetation that surrounds the pond and the large eucalypt associated with the pool. (ISC Site38_3)

Figure 2.14d: Upper Glenlofty Creek

A view of the upper parts of Glenlofty Creek. Note the thick vegetation of the inset channel and the dry scour pool at the base of the bank. (ISC Site 39_2)

Figure 2.14e: Aerial view of Glenlofty Creek.

An aerial view of the Glenlofty Creek Chain of Ponds system. The ponds are the dark round ponds scattered along the channel.

System: Alluvial Discontinuous

Stream Type: Floodout

USUAL POSITION	Upper catchment often associated with changes in gradient such as on the terrace margins and valley floor edges, escarpments and confluences. Generally found in the Pyrenees zone of the catchment on the transition between the highlands and lowlands.	
CHANNEL GEOMETRY	Irregular channels or gullies at upstream end, no channel downstream	
CHANNEL PATTERN	Diverging channels (distributaries) or gullies dissipating onto a fan and/or swamps (on intact valley fill or floodplain). Wide variation in size depending on stream and valley size.	
GEOMORPHIC UNITS	Channel zone: unchannelised, but may have discontinuous scour features and associated small gullies	Floodplain zone: swamps with occasional sand sheet, typically in a fan-shape
GEOMORPHIC BEHAVIOUR	Sand and mud dominated. Sediment supplied from gullies is stored on valley fill downstream. A new distributary forms when an old one is blocked by sediment and/or debris. These lobes shift over the valley fill surface.	
SEDIMENT TRANSFER BEHAVIOUR	Sediment accumulation zone	

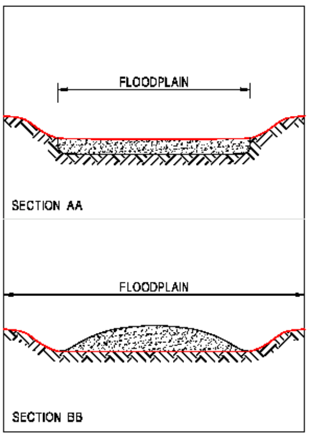

Figure 2.16a: Schematic cross-section of a floodout

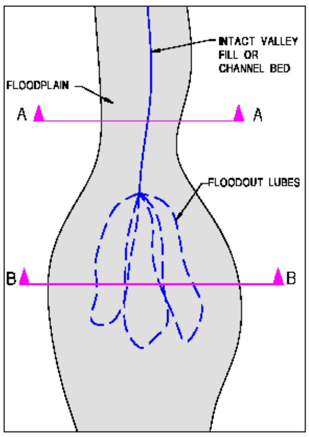

Figure 2.16b: Schematic plan of a floodout

Figure 2.16c: Downstream view of floodout

Looking downstream over flood-out and valley margin. (ISC Site 49_6)

Figure 2.16d: Cross-sectional view of floodout.

Lobate front of flood-out. (ISC Site 49_8)

Figure 2.16e: An aerial view of a floodout

An aerial view of a floodout on the western edge of the Pyrenees ranges.

System: Alluvial Discontinuous

Stream Type: Discontinuous Anabranching Chain of Ponds

USUAL POSITION	Lower catchment in areas with very low gradients. Only found on the Mackenzie River on the lowland alluvial plain.	
CHANNEL GEOMETRY	Multiple interconnecting discontinuous flow paths with channels.	
CHANNEL PATTERN	Discontinuous channels distributing sediment and water set within a shallow trench with a extensive floodplain above the trench.	
GEOMORPHIC UNITS	Channel zone: Multiple swamps, ponds, discontinuous channels with multiple low stringers.	Floodplain zone: Continuous flat and generally featureless existing within the inset trench as well as above the trench.
GEOMORPHIC BEHAVIOUR	Very low energy and dominated by mud vegetation	
SEDIMENT TRANSFER BEHAVIOUR	Accumulating fine sediments	

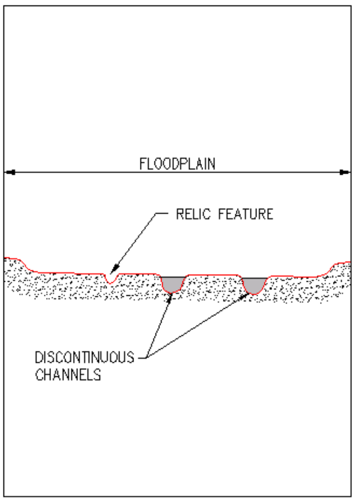

Figure 2.17a: Schematic cross-section of a discontinuous anabranching chain of ponds

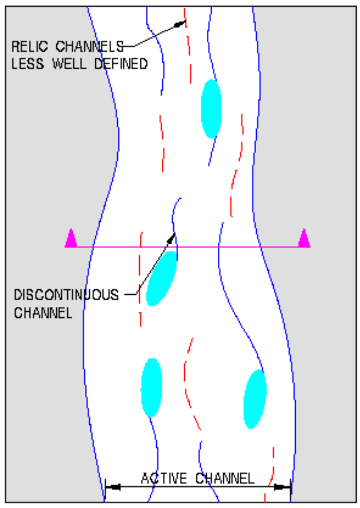

Figure 2.17b: Schematic plan of a discontinuous anabranching chain of ponds

Figure 2.17c: Lower MacKenzie River

A major flow path with ponds of the MacKenzie River above its confluence with the Wimmera River. (ISC Site 6_3)

Figure 2:.17d Lower Mackenzie River, flood channel.

The MacKenzie Rivers floodplain, note one of the numerous associated channels and flood-channels. (ISC Site 6_7)

System: Alluvial Discontinuous

Stream Type: Incised Alluvial Discontinuous (Discontinuous Channelised)

USUAL POSITION	Mid to upper catchment, Found extensively in the Pyrenees and Grampians geological zone, usually in a areas which have been cleared for farming.	
CHANNEL GEOMETRY	Single incised trench	
CHANNEL PATTERN	Straight to low sinuosity	
GEOMORPHIC UNITS	Channel zone: Sand sheets, lateral bars, benches and gravel bed armouring. Inset features may occur in recovering systems.	Floodplain zone: Continuous, flat valley surface/ swamp
GEOMORPHIC BEHAVIOUR	Stable trench with poorly defined low flow channel	
SEDIMENT TRANSFER BEHAVIOUR	Sediment behaviour is dependent on the stage which the systems is at. An immature system which is incising will be actively transferring sediment, however when the system begins to recover sediment will be deposited as bars/features within the channel..	

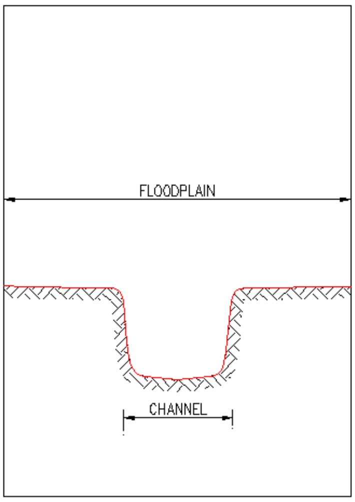

Figure 2.18a: Schematic cross-section of an actively incising alluvial discontinuous system

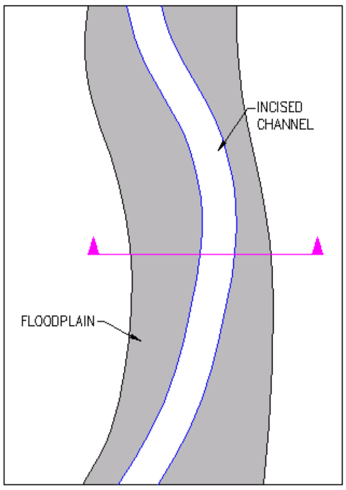

Figure 2.18b: Schematic plan of an actively incising alluvial discontinuous system

Figure 2.18c: A recovering incised system

A stabile incised discontinuous system, note that banks are generally vegetated and at a stable slope in parts and only non-vegetated part of the channel is on the outer bank of the meander bend. (ISC Site 23_1)

Figure 2.18d: An incised system beginning to recover

An actively incising discontinuous system. Note the gravel point bar and bed armouring, derived from in-situ material and the actively eroding over steep bank. (ISC Site 30_7)

Figure 2.18e: An actively incising system

An actively incising discontinuous system in farmland, note the unstable vegetation bare over steep banks and minor gravel bar in the channel. The gravel is derived fro the erosion of in-situ material. (ISC Site 42_8) An actively incising system

Figure 2.18f: An aerial view of an actively incising system

An aerial view of an incising stream in the Wattle Creek catchment

System: Altered Systems

This category consists of constructed features and their associated pools as they affect the Wimmera Catchment. These features include Weirs, Large Farm Dams, Reservoirs and constructed channels. The constructed channels do not include natural streams that have had their capacity expanded to maximise the conveyance of irrigation water.

Results - Geomorphic Categorisation

Introduction

This section firstly discusses the different areas analysed in the geomorphic assessment of the Wimmera catchment. And secondly these sections are discussed independently then in relation to each other. Concluding this discussion is a summary and recommendation of priority areas for work within the Wimmera catchment. The priority areas for work are based on protecting well-preserved systems within the catchment as well as systems that are currently uncommon or rare.

The systems most at threat are alluvial discontinuous systems, which may be either lost though incision or the addition of sediment. The addition of sediment may also have effects on alluvial continuous stream systems overloading their ability to transmit or store the sediment. This may lead to infilling of the channel and subsequent loss of stream values, original form and ecological value.

Spatial Distribution of Stream Orders

The Wimmera catchment has a common stream order distribution for most of its streams. Generally there is a significant reduction in total channel length with each increase in stream order, however this is not true of the 8^{th} order streams.

The lower order streams, 1^{st} and 2^{nd} order streams of the Wimmera River catchment are generally restricted to the highlands and steeper parts of the catchment. However, some of these streams also occur in the lowland plains between the Wimmera River and the northern Grampians. There are also some lower order terminal streams that occur around Natimuk.

Typically streams in the order of 3^{rd} to 7^{th} occur between the generally confined streams of the highlands and the Wimmera River. These streams make up approximately 54% of the total stream length in the Wimmera Catchment. However, the Wimmera River is an 8^{th} order stream for the majority of its length and is extensively longer than the both the 6^{th} and 7^{th} order streams (Table 2). This is due to the Wimmera River having similar sized sub-catchments that have not developed higher order streams required by the Strahler stream ordering system to increase the Wimmera's stream order. Further, after its confluence with MacKenzie River the Wimmera River is joined by no other significant tributaries. This geomorphic assessment of the Wimmera River catchment has assigned geomorphic categories to approximately 32% of the mapped waterways of the region. The remaining 68% of the catchment's streams are of 1^{st} and 2^{nd} order.

Table 2.1: Total length of stream within the Wimmera Catchment and the breakdown of streams by order in terms of total length and percentage of catchment.

Stream Order	Total Length km	% Of catchment stream length
1st Order Streams	4791.38	45.99%
2nd Order Streams	2361.76	22.67%
3rd Order Streams[1]	1514.94	14.54%
4th Order Streams	686.75	6.59%
5th Order Streams	414.92	3.98%
6th Order Streams	165.07	1.58%
7th Order Streams	83.43	0.80%
8th Order Streams[2]	399.39	3.83%
Total length of streams	10417.63km	100.00%

Note:
[1] The amount of 3rd order streams is elevated by both of the distributary channels of Dunmunkle and Yarriambiack creek also being classified as 3rd order.
[2] The elevated length of the 8th order stream (Wimmera River) is a product of the Strahler ordering process and the small catchment area of the Wimmera River which produces a connected overland drainage system in comparison to its total area.

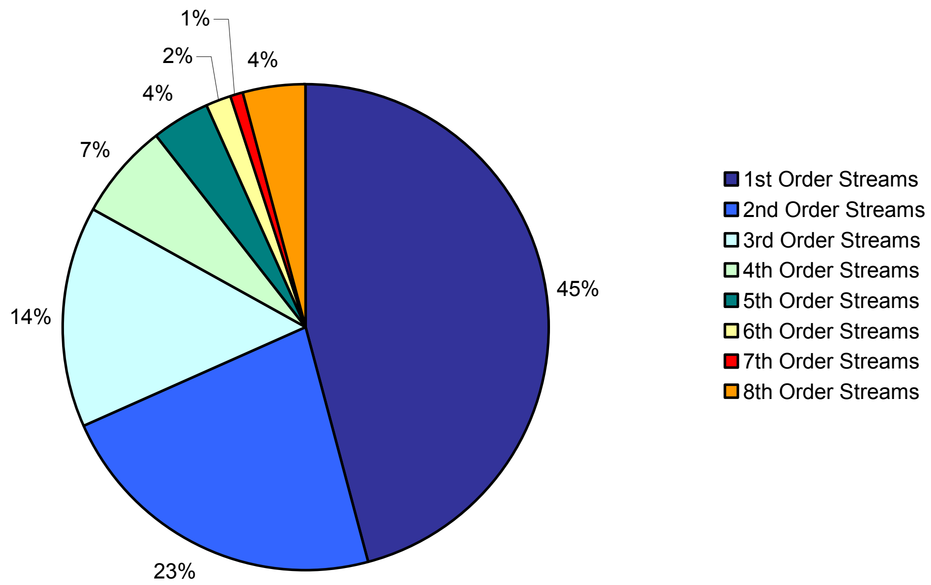

Figure 2.19: A percentage distribution of stream orders within the Wimmera Catchment

Spatial Distribution of Stream Categories

The distribution of stream categories in the Wimmera River catchment is a function of the interaction of geology, topography, flow regimes and vegetation. Therefore, the increased resistance to weathering of the Grampians and other upland areas has led to the formation of confined and partly confined streams. The increased gradients also led to more channelised and active stream systems in lower order streams. Discontinuous systems are common in the foothills, a transitional zone between the elevated highlands and the Aeolian and marine sediment dominated lower catchment. The discontinuous streams typically occur in lower order streams with limited catchments.

The general distribution of the different stream categories is:

- The alluvial continuous streams, of which the Wimmera River is the largest, are most common in the lower catchment, away from the elevated topographic areas of the Grampians and Pyrenees. The multi-channel and more highly sinuous forms such as the anabranching fine grained meandering system need low gradients and are more common at greater distances from the highlands. The higher energy forms of these stream types such as meandering sand beds occur closer to the highlands.
- The alluvial discontinuous streams, which are dominantly intact valley fill systems, are restricted to the upper part of the catchment and the lower order streams. These systems are also more common in regions with overstorey vegetation rather than in the cleared farmland that occurs between the Grampians and the Pyrenees.
- Incised alluvial discontinuous streams are found entirely within the upper catchment and often occur between the intact discontinuous systems and the alluvial continuous systems of the Wimmera River and its major tributaries. These systems are almost exclusively found in cleared catchments, although they do occur within vegetated catchments, usually when associated with past farming or mining activities. The gullied streams of the upper Wimmera River catchment make up most of the incised alluvial discontinuous streams. The reason for this trend is that the incised alluvial discontinuous streams are contemporary systems formed from the gullying of Chains of Ponds and Intact Valley Fills.
- Partly Confined streams occur on the transitional areas between the highlands of the Grampians and Pyrenees and the Lowland Wimmera Plain.
- Confined streams are generally restricted to the Grampians and the Pyrenees.

(See Appendix C for complete stream category distribution maps of the Wimmera River catchment.)

The Wimmera River is dominated by the anabranching fine grained stream that is particularly prevalent in the lower reaches of the river after it has turned north. The second most dominant stream category of the Wimmera River is a fine-grained low sinuosity single channel system that is common where the river and its floodplain are partly restricted by the resistant terraces of the Shepparton Formation and within the middle catchment. Here the river is still being influenced by the joining of tributaries that drain the northern Grampians. The upper reaches of the Wimmera River consist of a variety of partly confined, alluvial discontinuous and confined reaches.

There is a reduction in the variety of stream categories with increasing stream order through out the catchment. With this decrease in stream categories there is also a shift from confined and alluvial discontinuous systems of the lower order streams to a dominance of alluvial continuous and partly confined systems in the higher order streams.

A summary of the different distributions of stream categories by stream order:

3rd Order streams

Contain 16 different stream categories, dominated by Intact Valley Fills and Incised Alluvial Discontinuous systems. Originally, these were interpreted to have been intact alluvial discontinuous systems, prior to European settlement. (Figure 2.20).

4th Order streams

Contain 17 different stream categories and the distribution is similar to the 3rd order streams. The dominant categories are Intact Valley Fills and Incised Alluvial Discontinuous systems, which are originally interpreted to have intact alluvial discontinuous systems (Figure 2.21).

5th Order streams

Contain 15 different stream categories. The dominant categories are Alluvial Continuous 1 and alluvial continuous 4 followed by incised Alluvial Discontinuous and Intact Valley Fills. This stream order marks the change from alluvial discontinuous systems to alluvial continuous systems, which may be either partly confined or unconfined (Figure 2.22).

6th order streams

Contain 10 different stream categories of which Partly confined 3 is the dominant stream category (Figure 2.23).

7th order streams

Contain 7 different stream categories. The dominant stream categories are Alluvial Continuous 1 and Alluvial Continuous 4 (Figure 2.24).

8th order streams

Contain 8 different stream categories. The Wimmera River is the only 8th order stream within the catchment and is dominated by the Anabranching fine grained category (Figure 2.25).

Overall

Of the entire assessed streams within the Wimmera Catchment 75% of the catchment falls into 5 stream categories, Intact Valley Fills 22%, Incised Alluvial Discontinuous Systems 22%, Alluvial Continuous 1 (low sinuosity fine grained) 16%, Alluvial Continuous 4 (meandering fine grained) 10% and Anabranching fine grained 7% (Figure 2.26).

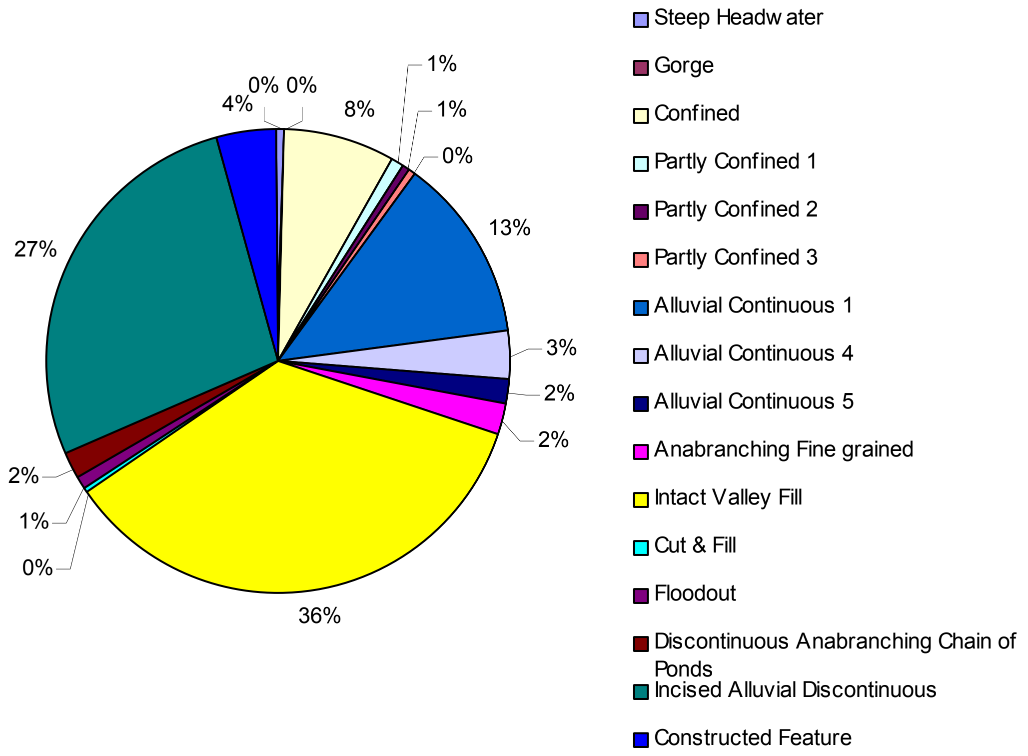

Figure 2.20: The distribution of stream categories in 3rd order streams in the Wimmera Catchment

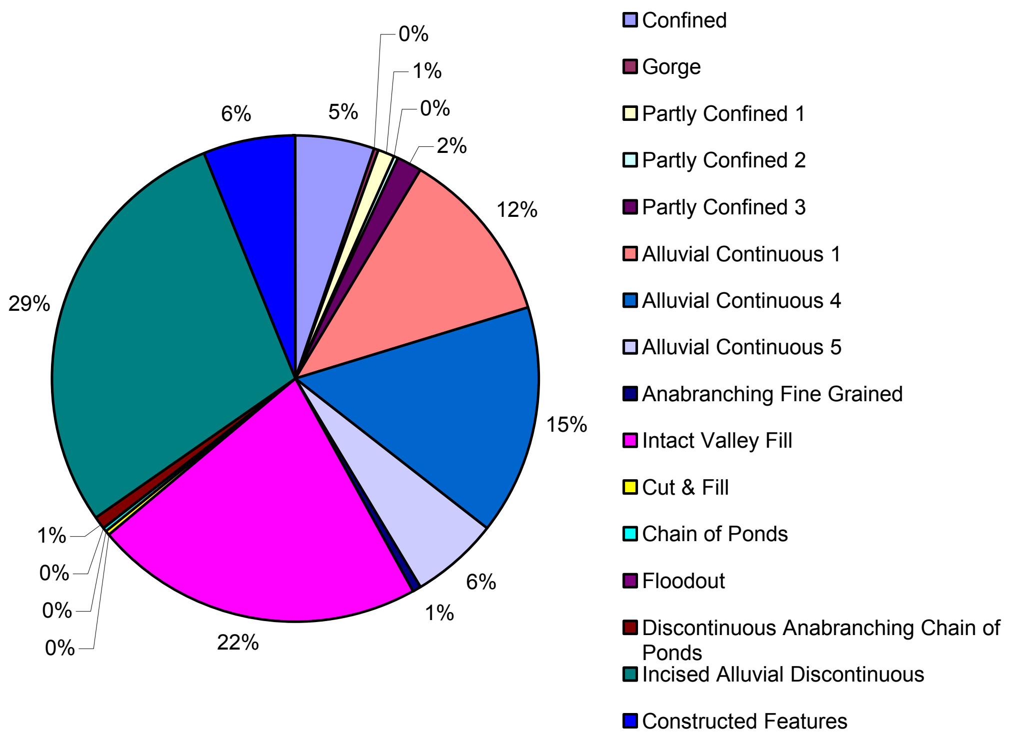

Figure 2.21: The distribution of stream categories in 4th order streams in the Wimmera Catchment

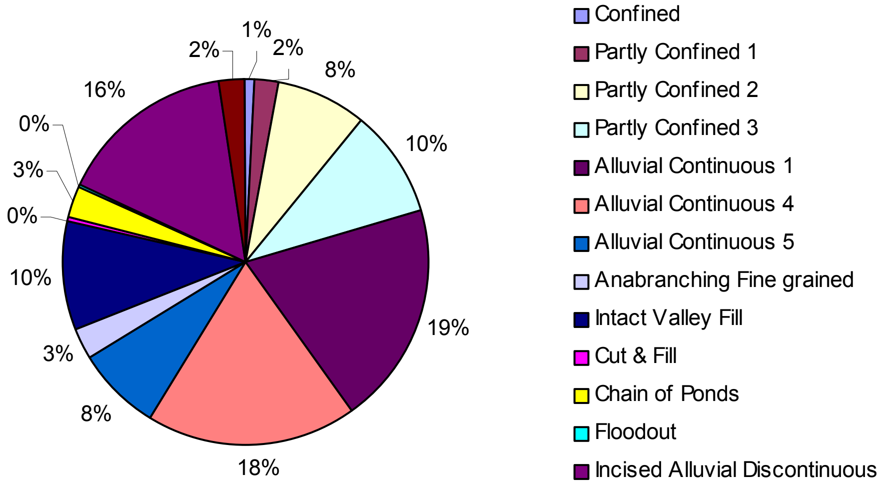

Figure 2.22: The distribution of stream categories in 5th order streams in the Wimmera Catchment

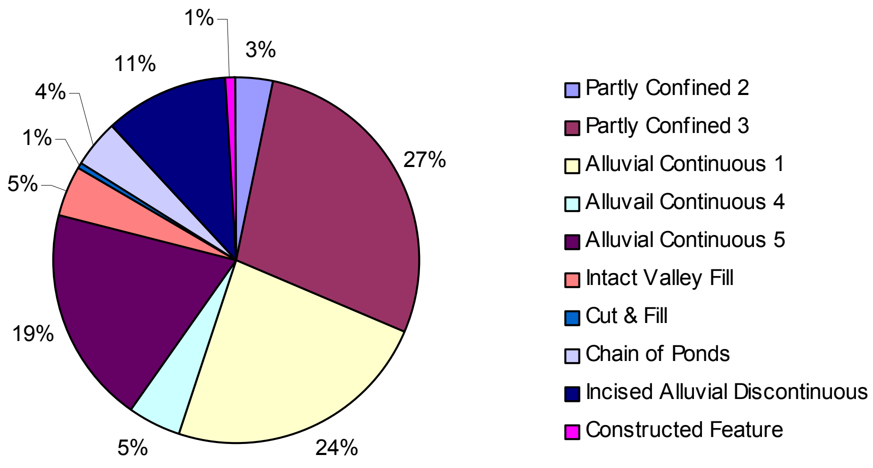

Figure 2.23: The distribution of stream categories in 6th order streams in the Wimmera Catchment

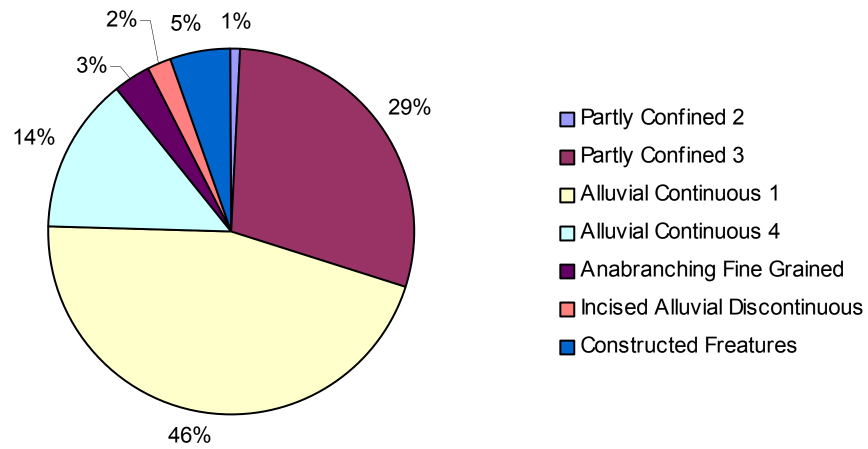

Figure 2.24: The distribution of stream categories in 7th order streams in the Wimmera Catchment

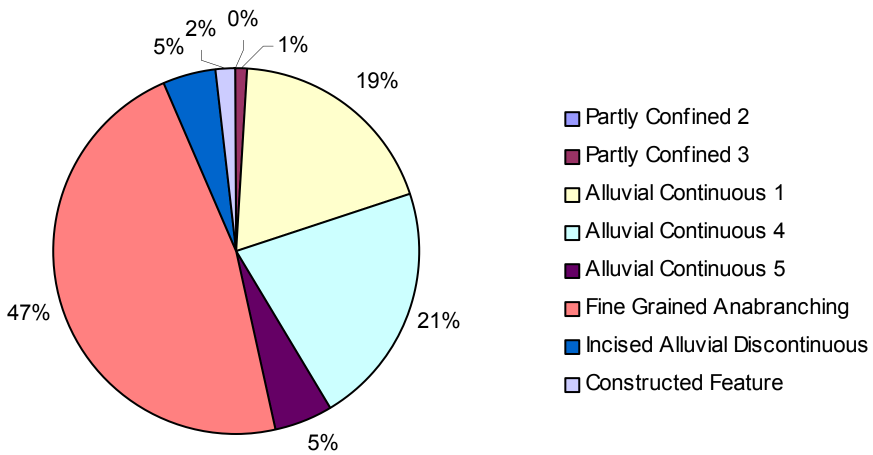

Figure 2.25: The distribution of 8th order stream categories on the Wimmera River from mid-catchment to Lake Hindmarsh

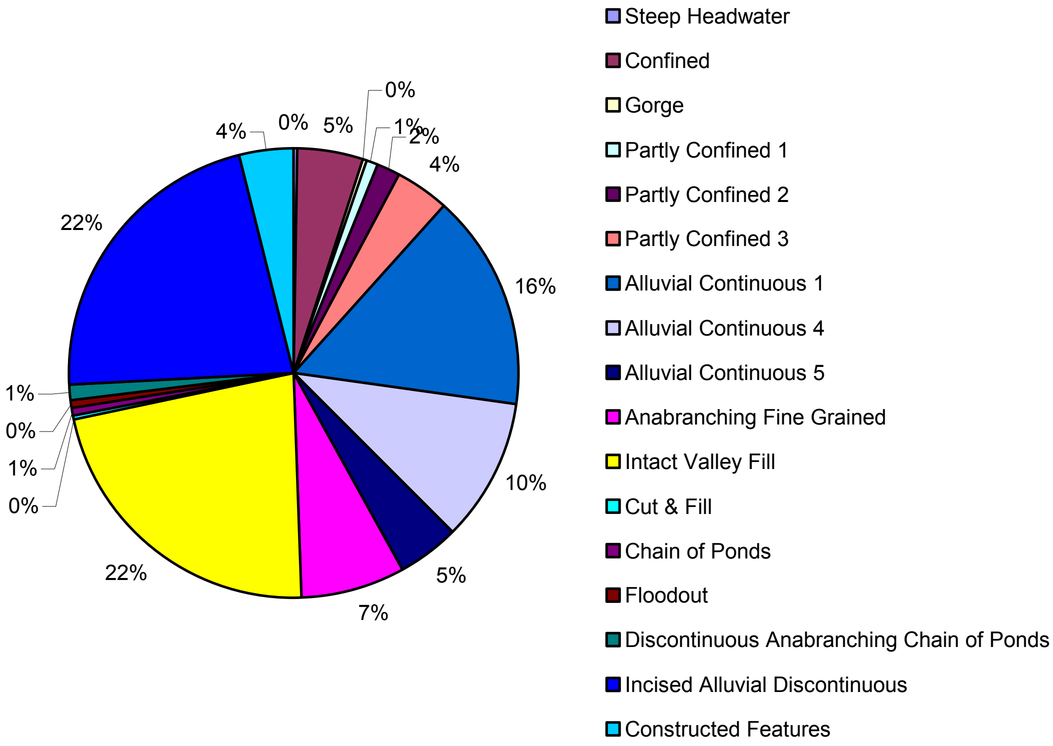

Figure 2.26: The distribution of stream categories in 3rd order and great streams in the Wimmera catchment

Stream Categories by Length

Table 2.2 summarises the lengths of each stream category with regards to stream order rather than the percentages of each stream category as shown in Figures 2.20 to 2.26.

Table 2.2: A summary of stream category length per stream order for the Wimmera River catchment

		Stream Order							
Category		3rd	4th	5th	6th	7th	8th	Total	%
Continuous	**Steep Headwater**	6.8						6.8	0%
Continuous	**Confined**	117.8	35.6	3.3				156.7	5%
Continuous	**Gorge**	3.9	2.8					6.7	0%
Continuous	**Partly Confined 1**	13.4	7.8	9.9				31.1	1%
Continuous	**Partly Confined 2**	9.2	1.9	32.8	5.4	0.7		50.0	2%
Continuous	**Partly Confined 3**	6.0	10.3	39.8	46.5	24.7	4.1	131.3	4%
Continuous	**Alluvial Continuous 1**	196.9	79.9	80.8	39.0	38.3	75.8	510.6	16%
Continuous	**Alluvial Continuous 4**	50.2	106.4	76.6	7.7	11.6	84.5	337.0	10%
Continuous	**Alluvial Continuous 5**	28.9	39.3	31.5	31.5		19.9	151.2	5%
Continuous	**Anabranching fine grained**	34.3	4.4	11.5		2.9	188.4	241.4	7%
Discontinuous	**Intact Valley Fill**	538.9	150.7	40.2	7.5			737.3	22%
Discontinuous	**Cut & Fill**	4.3	2.1	0.9	0.9			8.2	0%
Discontinuous	**Chain of Ponds**		0.7	12.2	6.8			19.7	1%
Discontinuous	**Floodout**	9.1	1.4	0.4				10.9	0%
Discontinuous	**Incised Alluvial Discontinuous**	421.2	196.8	65.8	18.5	1.8	19.4	723.4	22%
Discontinuous	**Discontinuous Anabranching Chain of Ponds**	33.2	5.5					38.7	1%
	Constructed Feature	64.5	41.0	9.4	1.3	4.6	6.3	127.0	4%
							Total	3288.0	100%

* Note that all distances are in km.

Summary of Geomorphic Categorisation

Two discontinuous stream types are dominant within the Wimmera catchment. Intact Valley Fills make up 22% of the total stream length and incised alluvial discontinuous streams make up a further 22%. If the majority of the incised systems were originally intact discontinuous systems, as they have been interpreted, then approximately 44% of the catchments 3rd order and larger streams were alluvial discontinuous systems prior to European Settlement (see figures 2.27 & 2.28 and table 2.2). This demonstrates the vulnerability of these systems with approximately 50% of these systems having been lost in the period since European settlement. The loss of these systems in other areas has been attributed to change in the catchment. The changes that are usually attributed to incision and loss are increased run-off due to catchment clearing and the loss and/or damage to instream vegetation. These changes in the catchment are considered to be a key in the loss of alluvial discontinuous streams such as intact valley fills and chain of ponds.

Due to the exclusion of 1st and 2nd order streams from the assessment, the stream categories such as Intact Valley Fills, Cut & Fills, Floodouts, Steep headwater, Confined and Gorges may be under represented in this investigation.

The relationship between Incised Systems and Intact Discontinuous Systems is further demonstrated by a common distribution on their placement within the catchment. The majority, approximately 90%, of both stream categories are located on streams of 3rd and 4th orders (see figures 2.27 & 2.28). This is further demonstrated by the other similarities of the distribution in the mid order streams and their non-appearance in high order streams.

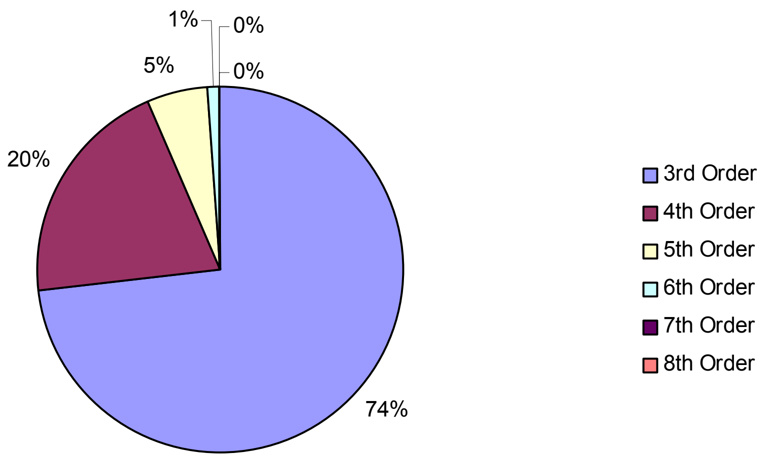

Figure 2.27: Incised systems and their distribution with regards to stream order

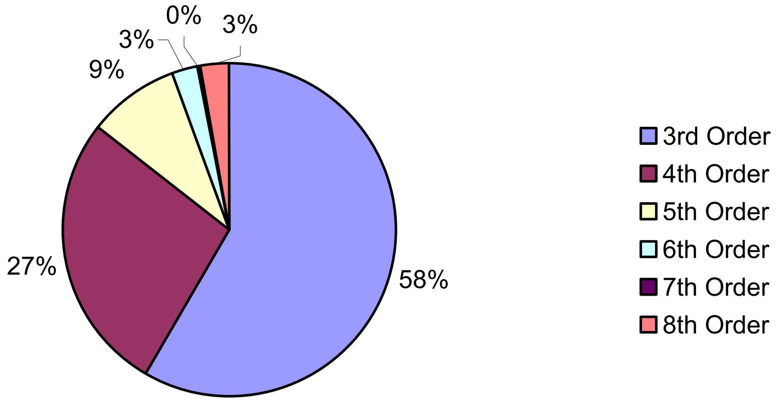

Figure 2.28: Intact Valley Fill systems and their distribution with regards to stream order

There is evidence that the incised systems within the upper Wimmera catchment go through a process of stabilisation to reflect the local contemporary catchment conditions. This stability may be different to their original geomorphic form. Typically this change could be expected to be from an alluvial discontinuous stream to an alluvial continuous stream. This change in stream form may make it difficult to rehabilitate the stream to its original state.

Consequently, rehabilitation within an altered stream type might be a more realistic management option than attempts to return the stream to its pre-European stream type and condition. Recognition of the trajectory of a stream's geomorphic form will assist in planning appropriate management targets. However, in some cases, particularly where rare stream types such as Chain of Ponds are involved, management should recognise and attempt to protect the pre-European form of the waterway.

EARTH TECH

Wimmera Catchment Management Authority

Geomorphic Categorisation and Stream Condition Assessment of the Wimmera River Catchment

Section Three: Stream Condition Assessment

Jobs 2901049.008 & 2901049.009

April 2003

APPROVED	CHECKED
DATE	DATE

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Contents

Figures and Tables

Introduction

This purpose of this section of the report is to provide an understanding and summary of the current stream condition in the Wimmera River catchment. In order to create an overall picture, data used in this section is a combination of the 1999 Index of Stream Condition (ISC) assessment carried out by the Wimmera Catchment Management Authority (WCMA) and the 2002 ISC data collected by Earth Tech for this project. Aerial photographs of the catchment were also assessed, as detailed in the Approach section.

Approach

The approach to the project included analysis of aerial photographs of the catchment, a review of existing ISC information and completion of ISC assessments of 51 sites in the Wimmera River catchment.

Aerial photographs

Digital aerial photographs were provided by the Wimmera CMA for use in assessment of the geomorphic form and overstorey vegetation cover in selected waterways in the Wimmera River catchment. 3288 km of waterway of third order or greater was assessed for overstorey vegetation cover. Categories included sparse overstorey vegetation (<20%), patchy overstorey vegetation (20-80%) or continuous overstorey vegetation (>80% cover).

Existing information – 1999 ISC

Data from the 1999 assessments of 42 sites in the Wimmera River was provided by the Wimmera CMA for analysis in this project. After the data was assessed, 37 sites were found to have sufficient data for inclusion in this project.

Field assessments – 2002 ISC

Between Monday November 11th and Wednesday November 20th, 52 waterway sites of approximately 430 m were visited in the Wimmera River catchment. An ISC field assessment of the Streamside Zone and Physical Form sub-indices was carried out at each of these sites.

Aerial Photograph Interpretation of Overstorey Vegetation Cover

Background to Aerial Photograph Interpretation

The aerial photograph interpretation included an assessment of the percentage of overstorey vegetation cover along each waterway in the Wimmera River catchment of third order or greater. The three ratings were based on the ISC structural intactness classes, being <20% (sparse), 20-80% (patchy) and >80% (continuous) (Ladson & White 1999a, b & c). Where there was a dam, lake, reservoir or other waterbody, the overstorey vegetation cover was scored as ‘Other’. The results of the assessment are shown in the map titled ‘Overstorey Vegetation Cover and Index of Stream Condition Sites’ in Appendix I.

The aerial photography for the Wimmera catchment existed in a digital format for the majority of the upper catchment (see Figure 2.1). The resolution of this digital imagery allowed the aerial photographs to be viewed at a scale of 1:5000 in the upper Wimmera catchment.

The lower part of the catchment was assessed using a variety of hard copy aerial photographs. The scale of these photographs varied, usually being at a scale of 1:20 000. The hard copy photographs were not available as stereo pairs, which limited the level of interpretation possible. This was particularly evident in the Wimmera River up- and downstream from Dimboola, where the Continuous Anabranching Fine Grained system included 94.9 km of anabranches to the main Wimmera River channel. These sections of waterway were not assessed for overstorey vegetation coverage and are marked on the map as ’Overstorey Vegetation Cover Not Assessed’.

Method of Aerial Photograph Interpretation

The three ratings used in aerial photograph interpretation of overstorey vegetation cover are summarised below. Assessment was based on the woody vegetation in both the riparian zone and floodplain of each reach.

Continuous Overstorey Vegetation

Figure 3.01 - Continuous Overstorey Vegetation (>80% Cover)

Table 3.01: Description of Continuous Vegetation

Longitudinal Continuity of woody vegetation	Width of woody vegetation	Percentage Cover of woody vegetation
>80% continuous woody vegetation in riparian zone	Riparian & Floodplain with continuous woody vegetation	>80% cover woody vegetation (continuous)

Patchy Overstorey Vegetation

Figure 3.02 - Patchy Overstorey Vegetation (20-80% Cover)

Figure 3.03 - Patchy Overstorey Vegetation (20-80%Cover)

Table 3.02: Description of Patchy (20-80%) Vegetation

Longitudinal Continuity of woody vegetation	Width of woody vegetation	Percentage Cover of woody vegetation
Vegetation limited to riparian zone and essentially continuous		
50-80% continuous vegetation in riparian zone	Streamside Zone width at least equal to baseflow width	50 – 80% cover woody vegetation (patchy)
Vegetation patchy and extends beyond riparian zone		
20-50% continuous vegetation in riparian zone	Riparian & Floodplain Streamside Zone width at least 3 times baseflow width	20-50% cover woody vegetation

Sparse Overstorey Vegetation

Figure 3.04: Sparse Overstorey Vegetation (<20% Cover)

Table 3.03 Description of Sparse Vegetation (<20%Cover)

Longitudinal Continuity of woody vegetation	Width of woody vegetation	Percentage cover of woody vegetation
Absent - 20% Continuous	Limited in Riparian zone, sparse in floodplain. Streamside Zone width narrower than baseflow width	<20% cover woody vegetation (sparse)

Using digital photographs provided by the Wimmera CMA in ArcMap 8.1 and hard copy aerial photos provided by the then Department of Natural Resources and Environment, Horsham, 3288 km of waterway in the Wimmera River catchment was assessed for overstorey vegetation coverage. This excluded first and second order streams. There were 6923 segments of waterway, ranging in length from 0.5 m (continuous anabranching fine grained section in the lower catchment) to 9.2 km (Natimuk Creek). The mean length of segments was 474.9 m.

Once each stream segment was assigned an overstorey vegetation coverage, an assessment of the proportion of the catchment within each range of vegetation coverage was carried out This was undertaken with the aid of ArcMap 8.1 and Excel. The results are presented in the next section.

Results of Aerial Photograph Interpretation

The 3288 km of waterway assessed in the aerial photograph interpretation was analysed and is summarised in Tables 3.04 and 3.05. The five categories are:

- Dams & Weirs
- Anabranching Fine Grained (lower catchment only)
- Continuous (>80%)
- Patchy (20-80%)
- Sparse (<20%)

Table 3.04: Summary of statistics of Stream Order vs Overstorey Vegetation Cover.

Stream Order							
	Dams & Weirs	AFG	>80%	20-80%	<20%	Total Length (km)	Percentage
3	27.8	n/a	259.5	346.0	905.1	1538.4	46.8%
4	19.3	n/a	108.3	181.8	377.4	686.8	20.9%
5	8.4	n/a	41.1	168.8	196.5	414.9	12.6%
6	0	n/a	10.6	74.7	79.7	165.1	5.0%
7	3.5	n/a	10.2	36.8	33.9	84.5	2.6%
8	0	94.9	22.3	243.7	37.4	398.3	12.1%
Total Length (km)	59.0	94.9	452.2	1051.9	1630.0	**3288 km**	
Percentage length	1.8%	2.9%	13.8%	32.0%	49.6%		

*AFG is Stream Category 'Anabranching Chain of Ponds'.

The information in Table 3.04 provides an good summary of the vegetation coverage of waterways in the Wimmera River catchment. Of the 3288 km of waterways in the Wimmera River catchment that are of 3rd order or greater, only 13.8% have excellent (>80%) vegetation cover. In the catchment, approximately 32% of the total waterway length has moderate (20-80%) vegetation cover, whilst 49.6% of the 3rd order and greater waterways have poor (<20%) vegetation cover.

The third order streams make up almost half of the waterways in the catchment that are greater than second order. Importantly, 27.5% of the waterways of third order or greater are third order streams with <20% vegetation cover.

59 km (1.8%) of the length of waterway of the streams of 3rd order or greater were assigned as a weir or dam.

There is also 94.9 km (2.9%) of waterway in the lower Wimmera Catchment that is shown on the Vegetation Coverage map, Appendix I, as not having been assessed. This section of the Wimmera River catchment is located both upstream and downstream from Dimboola. These sections of waterway have been assigned a Stream Order of 8 and Stream Style of 'Anabranching Fine Grained' (AFG). The main Wimmera River channel was assessed for vegetation coverage with the aid of aerial photographs and field confirmation. However, as the aerial photographs were at a 1:20 000 scale, it was very difficult to also assess the vegetation cover in the numerous anabranching channels.

Table 3.05 (following page) shows the breakdown of waterway length in the Wimmera River catchment according to stream category. Of the length of waterways assessed as 3rd order or greater, 22.4% is intact valley fill and 22.0% is incised alluvial discontinuous. Of the length of waterway assessed as intact valley fill, 57.9% has an overstorey vegetation cover of <20%. This means that 13.0% of the Wimmera River catchment waterways of 3rd order or greater is intact valley fill with sparse vegetation coverage.

Table 3.05: Summary of statistics of Stream Style vs Overstorey Vegetation Cover.

	Stream Type	Constructed Feature	>80%	20 – 80%	<20%	AFG	TOTAL LENGTH (km)	%
Confined	Steep Headwater	0	6.8	0	0	0	6.8	**0.2%**
	Confined	0	136.6	13.3	6.8	0	156.7	**4.8%**
	Gorge	0	6.7	0	0	0	6.7	**0.2%**
Partly Confined	Partly Confined 1	0	15.8	15.3	0	0	31.1	**0.9%**
	Partly Confined 2	0	4.4	23.8	22.0	0	50.2	**1.5%**
	Partly Confined 3	0	7.0	42.2	82.1	0	131.3	**4.0%**
Alluvial Continuous	Alluvial Continuous 1	0	32.9	276.6	201.1	0	510.6	**15.5%**
	Alluvial Continuous 4	0	62.0	180.9	94.1	0	337	**10.2%**
	Alluvial Continuous 5	0	0.1	75.1	76.0	0	151.2	**4.6%**
	Anabranching Fine Grained	0	7.4	121.1	18.0	94.9	241.4	**7.3%**
	Cut & Fill	0	0.9	0.2	7.0	0	8.1	**0.2%**
Alluvial Discontinuous	Intact Valley Fill	0	166.3	144.0	427.0	0	737.3	**22.4%**
	Chain of Ponds	0	0	0.2	19.5	0	19.7	**0.6%**
	Floodout	0	0	0.5	10.4	0	10.9	**0.3%**
	Incised Alluvial Discontinuous	0	3.5	113.6	606.2	0	723.3	**22.0%**
	Discontinuous Anabranching Chain of Ponds	0	0	38.7	0	0	38.7	**1.2%**
Constructed Features	Dam	46.4	0	0.1	3.3	0	49.8	**1.5%**
	Weir	12.6	0	0.4	11.4	0	24.4	**0.7%**
	Constructed channel	0	1.9	5.8	43.3	0	51	**1.6%**
	Other	0	0	0	1.7	0	1.7	**0.1%**
	TOTAL LENGTH (km)	59.0	452.2	1051.9	0	94.9	**3288 km**	
	Percentage	**1.8%**	**13.8%**	**32.0%**	**49.6%**	**2.9%**		

The information in Table 3.05 shows that, in the Wimmera River Catchment, 5.2% of waterways are confined, 6.4 % are partly confined, 37.8% are Alluvial Continuous, 46.5% are Alluvial Discontinuous and 4.2% are Constructed features.

In the confined reaches, almost 90% of the length has >80% overstorey vegetation cover. In the partly confined reaches, almost 50% of the length has <20% overstorey vegetation cover and 38% has 20-80% overstorey vegetation cover. Just over 50% of the Alluvial Continuous waterways were assigned a vegetation cover rating of 20-80%. The Alluvial Discontinuous stream types were assessed using aerial photographs as having almost 70% of the overall length with overstorey vegetation cover <20%.

Index of Stream Condition in the Wimmera River Catchment

Index of Stream Condition - Background

The Index of Stream Condition (ISC) was developed as a method for assessing the condition of streams in rural and bushland areas. The ISC was created to be a tool to:

- Benchmark stream condition, aiding objective setting and decision making by catchment managers and judging the long-term effectiveness of waterway management programs
- Be used by natural resource managers at local (e.g. CMA implementation groups, Landcare groups), regional (e.g. CMAs), state-wide and national levels

In the mid-'nineties, the State Government of Victoria decided a method was required to assess the overall health of waterways. The Catchment and Land Protection (CALP) Boards and River Management Authorities required a tool to assist with managing and reporting on waterway condition (Ladson *et al*., 1996). In response, the Index of Stream Condition (ISC) underwent its initial development in 1995. The following year saw the method tested on two catchments in eastern Victoria (Ladson *et al*., 1997). An expert panel was involved in the development and review of the method, which continues to undergo improvement (Ladson *et al*., 1997). In 1999, the ISC was applied Victoria-wide by Catchment Management Authorities (CMAs) to gain and combine valuable data about the health of the State's waterways (Batty, 1999).

The ISC is an integrated indicator that assesses a stream's overall condition (Ladson *et al.,* 1997). It involves both desk and field based data collection, which aims to give a reasonable quality, balanced outcome. Within the constraints of acceptable cost and time, it is expected that results satisfy appropriate levels of scientific rigour (Ladson *et al.,* 1999). The ISC consists of five sub-indices including: hydrology, physical form, streamside zone, water quality and aquatic life (Ladson *et al.,* 1996). In a practical sense, the objectives of the ISC are to:

- Report and benchmark the condition of streams in Victoria;
- Aid waterway managers with priority and objective setting in addition to decision making about waterway activities;
- Assist in judging the long-term effectiveness of rehabilitation programs and management intervention;
- Provide a tool for responses from Catchment Management Authorities, a management task necessary due to statutory requirements. (Ladson et al., 1996, 1997 & 1999).

Structure of the Index of Stream Condition

The overall ISC score lies between 0 and 50. A stream with a higher rating is considered more ‘natural’ or ‘ideal’ according to the best professional judgement of the panel of experts who designed the method (Ladson *et al.*, 1997 & 1999). The overall score is made up of five sub-indices. Each sub-index includes an array of indicators that are summed and scaled to ensure they each contribute a score out of ten (Ladson *et al.*, 1999). Following the Victorian State-wide application of the ISC during 1999, a verbal rating system was included, classifying each stream as being very poor, poor, moderate, good or very good in condition.

Limitations of the ISC

The Catchment Managers’ Manual for the ISC (Ladson & White, 1999a) includes a section on limitations of the ISC. They include, amongst other points:

- The ISC has been developed to detect changes in the environmental condition of stream reaches typically 10 to 30 km long over a time period of approximately 5 years. The ISC may not be sensitive enough, or may indeed be overly sensitive, for considerably longer or shorter reaches, or for shorter time periods. Other indicators will generally be required to assess the local effectiveness of works in the short term.
- The ISC was primarily developed for rural streams. Therefore, it may be necessary to modify the ISC if it is to be applied for urban streams

Care should be taken when extrapolating and comparing ISC outputs – for example when comparing ISC outputs for streams in different catchments, or comparing streams of different geometry or character. (Ladson & White, 1999 a).

Index of Stream Condition, 1999

The Wimmera CMA provided the results of the 1999 ISC Assessment. Results for the Physical Form and Streamside Zone scores had been previously summarised for three sites within each reach. One site was selected out of each group of three to represent each reach. There was sufficient data for 37 ISC sites assessed in 1999.

The 1999 ISC results for the 37 selected sites are summarised in Appendix D.

Index of Stream Condition, 2002

Field Assessment

The 52 sites assessed in November 2002 are shown on the map titled *“Overstorey Vegetation Cover and Index of Stream Condition Sites”* , located in Appendix E. A summary of the site details is presented in the table titled *“Summary of ISC Site Locations visited in November 2002”*, (Table E1) located in Appendix E.

Factors of the waterways that contribute to the Physical Form Sub-index include:

- Bank Stability
- Bed Stability
- Instream Physical Habitat
- Impact of artificial barriers on fish migration (Ladson & White, 1999c).

Factors of the waterways that contribute to the Streamside Zone Sub-index include:

- Width of streamside zone
- Longitudinal continuity
- Structural intactness
- Cover of exotic vegetation
- Regeneration of indigenous woody vegetation
- Billabong condition (Ladson & White, 1999c).

Desktop Assessment

In addition to the data collected in the field, there is data required by the ISC method that must be obtained through desktop analysis. One set of data required is an estimation of the "Original Vegetation" structure that is used in a comparison with the current vegetation structure. The Reference Manual (Ladson & White, 1999c) states, "A general knowledge of the structure of the original vegetation community at a measuring site is necessary to evaluate the structural intactness indicator". The Wimmera CMA provided a digital layer of the pre-1750's vegetation community data (EVCs – Ecological Vegetation Communities) for this investigation. The Department of Sustainability and Environment provided detailed definitions of each EVC that were then summarised. Details on the method of assessment are in Appendix F.

The second set of data required is an estimation of the impact of artificial barriers on fish migration. Information was provided by the Wimmera CMA to determine the location of barriers to fish passage such as dams and weirs. However, as discussed in the Analysis of Results section, by the ISC definition all sites assessed had a barrier downstream in the catchment that would not be drowned out at least once per year.

Data from the field assessments and desktop assessments was entered into a Microsoft Access Database created by Melbourne Water Corporation (MWC) and the Department of Natural Resources and Environment (DNRE). The database was provided and approved for use by Paul Wilson at the DNRE in November 2002.

The ISC database generated Physical Form and Streamside Zone scores for each ISC site out of a total possible score of 10. These scores are summarised in Table H1, Appendix H.

Appendix G includes a Report Card for each of the 52 ISC sites assessed in November 200. The information was generated using the Microsoft Access ISC Database. Attached to each ISC site Report Card is a series of photographs that were taken at each site. Photographs were taken facing downstream.

ISC Sites with Poor Physical Form Sub-index Scores

The following photographs are taken facing downstream at four of the 52 ISC sites assessed in 2002. The Physical Form Sub-index scores, which are based on the bank stability, bed stability, instream physical habitat and potential affect of fish barriers, are between 0/10 and 3/10.

FS#30 – Unknown 6

Physical Form Score: 0/10

FS#31 – Unknown 7

Physical Form Score: 3/10

FS#48 – Unknown 12

Physical Form Score: 1/10

FS#51 – Wattle Creek Tributary

Physical Form Score: 1/10

Figure 3.05: Photographs of field sites with Poor Physical Form Sub-index scores

ISC Sites with Good Physical Form Sub-index Scores

The following photographs are taken facing downstream at four of the 52 ISC sites assessed in 2002. The Physical Form Sub-index scores are all 8/10.

FS#12 – Boggy Creek

Physical Form Score: 8/10

FS#14 – MacKenzie Creek

Physical Form Score: 8/10

FS#21 – Golton Creek

Physical Form Score: 8/10

FS#33 – Glenpatrick Creek

Physical Form Score: 8/10

Figure 3.06: Photographs of field sites with Good Physical Form Sub-index scores

ISC Sites with Poor Streamside Zone Sub-index scores

The following photographs are taken facing downstream at four of the 52 ISC sites assessed in 2002. The Streamside Zone Sub-index scores, which are based on the type, abundance and distribution of vegetation in the riparian zone, are all 3/10.

FS#30 – Unknown 6

Streamside Zone Score: 3/10

FS# – 36 – Nowhere Creek

Streamside Zone Score: 3/10

FS#44 – Unknown 11

Streamside Zone Score: 3/10

FS#49 – Unknown 13

Streamside Zone Score: 3/10

Figure 3.07: Photographs of field sites with Poor Streamside Zone Sub-index scores

ISC Sites with Good Streamside Zone Sub-index scores

The following photographs are taken facing downstream at four of the 52 ISC sites assessed in 2002. The Streamside Zone Sub-index scores, which are based on the type, abundance and distribution of vegetation in the riparian zone, are between 8/10 and 9/10.

FS#6 – MacKenzie Creek

Streamside Zone Score: 8/10

FS#17 – Seven Dial Creek

Streamside Zone Score: 9/10

FS#34 – Glenpatrick Creek

Streamside Zone Score: 9/10

FS#40 – Reservoir Creek

Streamside Zone Score: 8/10

Figure 3.08: Photographs of field sites with Good Streamside Zone Sub-index scores

Analysis of the 1999 and 2002 ISC Data

Of the sites assessed using the ISC method in 1999, 37 were selected for inclusion in this report. These are compared in Tables 3.06 and 3.07 to the 52 sites assessed in 2002. Table 3.06 is an overall comparison of the Physical Form Scores and Table 3.07 is a comparison of the Streamside Zone Scores.

Table 3.06: Comparison of the 1999 and 2002 Physical Form ISC scores

Physical Form Scores (/10	No. 1999 sites	% 1999 sites	No. 2002 sites	% 2002 sites	All Sites	% All Sites
0	0	0%	1	1.9%	1	1.1%
1	2	5.4%	3	5.8%	5	5.6%
2	1	2.7%	4	7.7%	5	5.6%
3	6	**16.2%**	3	5.8%	9	**10.1%**
4	10	**27.0%**	5	9.6%	15	**16.9%**
5	9	**24.3%**	8	**15.4%**	17	**19.1%**
6	7	**18.9%**	11	**21.2%**	18	**20.2%**
7	2	5.4%	6	**11.5%**	8	9.0%
8	0	0%	11	**21.2%**	11	12.4%
9	0	0%	0	0%	0	0%
10	0	0%	0	0%	0	0%

There is an overall shift in the Physical Form Sub-index scores from the 1999 and 2002 ISC assessments. In 1999, 66.4% of sites received a Physical Form Sub-index score between 3/10 and 6/10, inclusive. In 2002, 69.3% of sites received a Physical Form Sub-index score between 5/10 and 8/10. When the sites are combined, 66.3% received a Physical Form Sub-index score between 3/10 and 6/10.

Assessment of the 2002 results showed that the median score for both the Streamside Zone and Physical Form Sub-indices is 6/10. The average Physical Form score is 5.3/10 and the average Streamside Zone score is 5.8/10.

Table 3.07: Comparison of the 1999 and 2002 Streamside Zone ISC scores

Streamside Zone Scores (/10)	No. 1999 sites	% 1999 sites	No. 2002 sites	% 2002 sites	All Sites	%All Sites
0	0	0%	0	0%	0	0%
1	0	0%	0	0%	0	0%
2	0	0%	0	0%	0	0%
3	3	8.1%	9	**17.3%**	12	13.5%
4	5	13.5%	8	**15.4%**	13	14.6%
5	11	**29.7%**	8	**15.4%**	19	**21.3%**
6	5	**13.5%**	6	**11.5%**	11	**12.4%**
7	12	**32.4%**	9	**17.3%**	21	**23.6%**
8	1	2.7%	7	13.5%	8	9.0%
9	0	0%	5	9.6%	5	5.6%
10	0	0%	0	0%	0	0%

The majority (75.6%) of the 37 ISC sites assessed in 1999 received Streamside Zone scores between 5/10 and 7/10. In 2002, the results were more evenly spread, with the majority (76.6%) of sites receiving Streamside Zone scores between 3/10 and 7/10. Of the 52 sites assessed, 17.3% received 3/10 and the same percentage received a score of 7/10. The combined scores show that 57.3% of sites received a score between 5/10 and 7/10 for the Streamside Zone sub-index score.

The comparison of the 1999 and 2002 ISC shows that overall there has been very little change in the condition of the catchment. The Physical Form Sub-index scores improved slightly between the two series of assessments, whilst the Streamside Zone Sub-index scores did not change significantly. The comparison was based on limited data and confirms that the Streamside Zone and Physical Form condition of many waterways in the Wimmera River catchment is poor to marginal.

Table 3.08: The Distribution and Median Physical Form and Streamside Zone ISC Scores for each Stream Type

	Stream Type	Physical Form Scores	Median Score	Streamside Zone Scores	Median Score
Confined	Steep Headwater	7, 8	**7.5**	7, 9	**8**
	Confined	6, 8, 8	**8**	3, 4, 9	**4**
	Gorge	8, 8	**8**	7, 9	**8**
Partly Confined	Partly Confined 1	2, 5, 7, 7, 7, 8	**7**	5, 6, 7, 7, 7, 7	**7**
	Partly Confined 2	4, 6, 8, 8	**7**	5, 6, 6, 8	**6**
	Partly Confined 3	3, 4, 4, 5, 6, 6, 8	**5**	3, 3, 5, 5, 5, 6, 9	**5**
Alluvial Continuous	Alluvial Continuous 1	3, 4, 4, 5, 5, 5, 5, 5, 5, 5, 5, 5, 6, 6, 6, 7, 8	**5**	3, 4, 4, 4, 5, 5, 6, 6, 6, 6, 7, 7, 7, 7, 7, 8, 8	**6**
	Alluvial Continuous 4	1, 3, 4, 4, 5, 6, 6, 6	**4.5**	4, 5, 5, 6, 6, 7, 7, 7	**6**
	Alluvial Continuous 5	1, 4, 6	**4**	4, 4, 7	**4**
	Anabranching Fine Grained	4, 5, 6, 6, 6, 7	**6**	5, 5, 7, 7, 7, 8	**7**
	Cut & Fill	3, 3	**3**	6, 7	**6.5**
Alluvial Discontinuous	Intact Valley Fill	4, 5, 5, 6	**5**	3, 3, 8, 9	**5.5**
	Chain of Ponds	4, 6, 6	**6**	3, 5, 5	**5**
	Floodout	5	**5**	3	**3**
	Incised Alluvial Discontinuous	0, 1, 1, 1, 2, 2, 2, 2, 3, 3, 3, 3, 4, 4, 4, 4, 5, 7	**3**	3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 4, 5, 5, 5, 5, 5, 5, 8	**4**
	Discontinuous Anabranching Chain of Ponds	6, 7, 8	**7**	7, 7, 8	**7**

Table 3.08 shows the median Physical Form and Streamside Zone Sub-index scores for the 89 ISC sites. With the exception of the Discontinuous Anabranching Chain of Ponds, the Physical Form Median score generally decreases from the confined waterways to the alluvial waterways. Incised Alluvial Discontinuous waterways have a median Physical Form score of only 2.5/10. Cut and Fill waterways have a median Physical Form score of 3/10, whilst Alluvial continuous 5 waterways score 4/10 for Physical Form.

The stream types of Steep Headwater, Gorge, Partly Confined 1, Anabranching Fine Grained and Discontinuous Anabranching Chain of Ponds have high median Streamside Zone scores. Floodouts have a Streamside Zone median score of 3/10 and Incised Alluvial Discontinuous is 4/10.

Distribution of ISC Sites in the Wimmera River catchment

A total of 89 ISC sites have been used in this analysis. The ISC Catchment Managers' Manual (Ladson & White 1999a) states that:

"The ISC has been developed to detect changes in the environmental condition of stream reaches typically 10 – 30 km long …"

This assessment has covered 3288 km of waterways in the Wimmera River catchment of 3rd order or greater. That means that there is, on average, one ISC site per 37 km in the catchment. With the addition of the ISC sites visited in 1999 for which sufficient data was not available, this distance would be further reduced. Table 3.09 is a summary of the distribution of ISC sites within the catchment.

Table 3.09: The distribution of ISC sites within each Geomorphic Style

	Stream Type	No. sites	TOTAL LENGTH (km)	No. sites per km
Confined	Steep Headwater	2	6.8	**3.4**
	Confined	3	156.7	**52.2**
	Gorge	2	6.7	**3.4**
Partly Confined	Partly Confined 1	6	31.1	**5.2**
	Partly Confined 2	4	50.2	**12.6**
	Partly Confined 3	7	131.3	**18.8**
Alluvial Continuous	Alluvial Continuous 1	17	510.6	**30.0**
	Alluvial Continuous 4	8	337	**42.1**
	Alluvial Continuous 5	3	151.2	**50.4**
	Anabranching Fine Grained	6	241.4	**40.2**
	Cut & Fill	2	8.1	**4.1**
Alluvial Discontinuous	Intact Valley Fill	4	737.3	**184.3**
	Chain of Ponds	3	19.7	**6.6**
	Floodout	1	10.9	**10.9**
	Incised Alluvial Discontinuous	18	723.3	**40.2**
	Discontinuous Anabranching Chain of Ponds	3	38.7	**12.9**
Constructed Features	Dam	0	49.8	**0**
	Weir	0	24.4	**0**
	Constructed channel	0	51	**0**
	Other	0	1.7	**0**
	TOTAL	89	**3288 km**	AVERAGE **36.9**

Discussion of ISC site distribution

Table 3.09 shows the distribution of ISC sites used in this project. Of the 16 Geomorphic Stream Types used, 10 have an ISC site more frequently than the 30 km defined by the method (Ladson & White, 1999a). Five stream types, being Confined, Alluvial Continuous 4, Alluvial Continuous 5, Anabranching Fine Grained and Incised Alluvial Discontinuous, have an average of one ISC site per 40 to 50 km of waterway.

The only stream type with a low frequency of sites per kilometre of waterway is Intact Valley Fill. There is one ISC site per 184.3 km of waterway defined as Intact Valley Fill. The two main reasons for this are in the limitations of the original aerial photograph interpretation.

- Due to the continuous coverage of overstorey vegetation in areas such as the Grampians National Park and the Pyrenees Region, much of the waterway length was attributed a stream type of Intact Valley Fill, as no channel could be seen
- The digital photographs provided were viewed at a 1:5000 scale. In some cases, this was not a fine enough scale to pick out the difference between an Intact Valley Fill waterway and one that has become an Incised Alluvial Discontinuous waterway

Although the aerial photograph interpretation is an excellent method of assessing an extensive length (3288 km) of the geomorphic type and overstorey vegetation cover of waterways in a catchment, there are limitations.

Limitations of the aerial photograph interpretation

Three ISC sites were assigned a stream type of Intact Valley Fill by the aerial photograph interpretation, but were confirmed in the field investigations to have a different stream type. This is due to the difficulty of determining the geomorphic type of a waterway through either patchy (20-80%) or continuous (>80%) overstorey vegetation cover.

As a result, the stream types of several ISC sites originally considered Intact Valley Fill, were changed after field inspections. This meant that the original number of ISC sites allocated to Intact Valley Fill was reduced, as was the average length per ISC site. It also means that there were more Partly Confined 1 and Incised Alluvial Discontinuous ISC sites than originally determined, bringing the averages for these two stream types down to one ISC site per 5.2 km and 40.2 km respectively. Refer Figure 3.09 and Table 3.09.

FS#19 – Unknown 2

Aerial Interpretation – Intact Valley Fill

Field Confirmation – Incised Alluvial Discontinuous

FS#32 – Unknown 8

Aerial Interpretation – Intact Valley Fill

Field Confirmation – Partly Confined 1

Figure 3.09:Two sites that were assigned the incorrect Stream Type using aerial photograph interpretation.

Assessment of the Stream Condition Method

Applicability of the ISC in the Wimmera

There are certain stream types in the Wimmera River catchment for which the ISC method is not appropriate. Although the ISC takes into account most general characteristics of waterways in rural Victoria, it does not factor in some of the stream types that are found in the northwest of the state. For example, stream types such as Chains of Ponds and Intact Valley Fills, where there is no defined channel, are difficult to assess with the standard ISC method. The following photographs show stream types that are found in the Wimmera River catchment that may not be accurately assessed by the current ISC method.

Four ISC sites assessed in 2002 were assessed in the aerial photograph interpretation as being Intact Valley Fills. They are known as Unknown 1, 3, 5 and 8. There were 2 sites on Glenlofty Creek that were defined as Chains of Ponds systems, being field sites 38 and 39.

FS#4 – Unknown 1

Intact Valley Fill

FS#22 – Unknown 3

Intact Valley Fill

FS#38 – Glenlofty Creek

Chain of Ponds

FS#39 – Glenlofty Creek

Chain of Ponds

Figure 3.10: Stream types in the Wimmera that are difficult to assess with the current ISC

Discussion of Applicability

The limitations of the ISC should be recognised in the analysis of results in this investigation. Although the ISC was designed to be a Victorian, statewide assessment, it does not take into account the difference in Geomorphic Categories. For example, the Discontinuous stream categories such as Intact Valley Fill, Chain of Ponds and Floodouts do not have defined channels as used in the ISC. The results of the ISC assessments at these sites should be considered with recognition of their limitations. Further investigation could include the development of an ISC-type assessment specifically focussed on discontinuous systems.

Impact of artificial barriers on fish migration

The ISC Reference Manual (Ladson & White, 1999a) has three ratings as shown in Table 3.10.

Table 3.10: ISC Ratings for the impact of artificial barriers score.

Category	Rating
In a typical year, no artificial barriers in the basin downstream of the reach interfere with the migration of any indigenous fish species endemic to the stream.	4
In a typical year, at least one artificial barrier in the basin downstream of the reach completely blocks the migration of indigenous fish species.	0
Situations where there are artificial barriers in the basin downstream of the reach that do not fit into the above two categories.	2

Source: (Ladson & White, 1999c)

A digital map was created using GIS to show the location of the ISC sites and significant fish barriers in the Wimmera River catchment. The ISC Reference Manual states that the barriers can affect fish passage from any point in the Basin downstream from the site. The 1999 Wimmera ISC data was accessed through the Victorian Water Data Warehouse and the “Impact of artificial barriers on fish migration” score was 0/4 for all sites except Outlet Creek and Natimuk Creek, where the score was 4/4. To remain consistent with the 1999 ISC, the “Impact of artificial barriers on fish migration” scores for the 2002 sites were assigned 0/4.

As stated in the ISC Reference Manual, the Rating Table above:

“…may be refined as the results of further research into the influence of artificial barriers on fish migration become available and the Victorian fish barriers database is developed further” (Ladson & White 1999a).

There are no indigenous native fish species that are migratory in the Wimmera River catchment (Koster & Close, 2001). Therefore, the “Impact of artificial barriers on fish migration” score should technically be 4/4 for all ISC sites. However, there are migratory native fish in the Wimmera River catchment, which are not indigenous to the region, which would be affected by the fish barriers. Whether the score is 0/4 or 4/4 is dependent upon whether the native indigenous or native non-indigenous fish species are considered a priority. If the Wimmera CMA decides to manage the Wimmera River catchment for native indigenous fish species only, the ISC fish migration score should be 4/4. If native non-indigenous fish species are to be included in the management priorities, the ISC score should be 0/4 for fish migration. For consistency in this project, a score of 0/4 was adopted for the fish migration score.

Benefits of the ISC Assessment

One aim of this investigation is to increase the information that the Wimmera CMA holds about the type and condition of its waterways. The ISC data is used by CMAs to populate the recently developed RIVERS database, a program to assist in priority setting. This information is then used in publications such as the Victorian River Health Strategy and the Regional River Health Strategies, which are vital components of the way in which our waterways are managed. With an addition of 52 sites, the Wimmera CMA now has an increased number of ISC sites from which to draw information about the condition of the catchment.

In 2004, the next statewide assessment of the ISC will take place. The Wimmera CMA may use the 2004 ISC results to indicate whether there has been a general change in the condition of the catchment. However, it is more likely that the additional sites assessed in 2004 will further build on the important information that was collected in 1999 and 2002. Such ISC information can be used as a benchmark to define the condition of the Wimmera River catchment.

Hydrologic Assessment

As a broad scale analysis, the Wimmera River catchment can be divided into three hydrologic fields. The aim of the classifications is to identify the systems affected by water harvesting, the natural channels that are used as conduits for the transit of irrigation water and systems unaffected by water harvesting or by the associated distributary systems. The classification system has not attempted to assess the changes in flow regime brought about by changes in land use, vegetation and incision within the catchment.

Three categories have been adopted for this investigation:

Stream hydrologically affected – water extracted for the Wimmera Mallee Stock and Domestic Supply System

Stream hydrology has been changed in a significant way due to water harvesting for irrigation and / or domestic supplies.

Stream hydrologically affected – used for water transfer

Stream hydrology is severely affected due to the stream channel being used to distribute water for irrigation, domestic supplies and environmental flows. The use of natural stream channels usually involves a reversal of flows, with high flows during summer and low flows during winter. Flows are also often at bank full levels for extended periods without natural fluctuations, some channels in the Wimmera catchment have also been deepened to allow greater flows down the channel.

Stream not hydrologically affected by the Wimmera Mallee Stock and Domestic Supply System

Stream hydrology is not affected by water harvesting on a large scale for either irrigation or reticulated supplies. If the catchment of these streams is being used as farmland there is a high probability that water harvesting for stock and domestic purposes will be occurring. In uncleared catchments, there maybe some minor water harvesting for fire dams.

Hydrology Results

Streams affected by water harvesting and the distribution of water for stock and domestic water are generally higher order streams that are exclusively continuous in nature. The continuous streams may be Confined, Partly Confined or Alluvial Continuous, depending on their location within the catchment.

As shown in Figures 3.11, 3.12 & 3.13, both the harvesting of runoff and the use of natural streams as distribution channels affect streams as low as 3^{rd} order in the Wimmera Catchment. The length of stream affected generally increases with increasing stream order. This varies from 10% of 3^{rd} order streams being affected to 83% of 8^{th} order streams. There is an average of 8% of waterway length affected across the entire Wimmera Catchment. This assessment does not consider changes to catchment hydrology brought about by changes in land use, clearing and loss of water to farm dams.

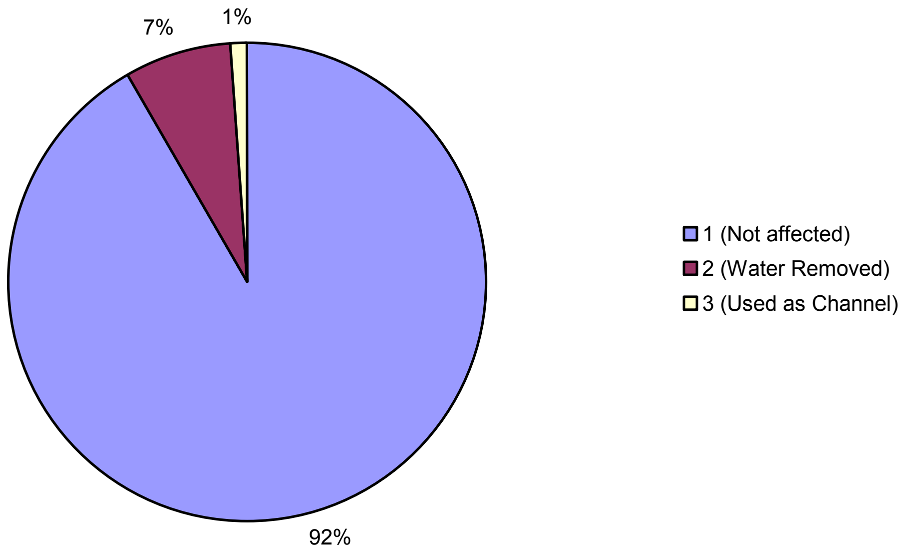

Figure 3.11: The total affected streams within the entire Wimmera catchment.

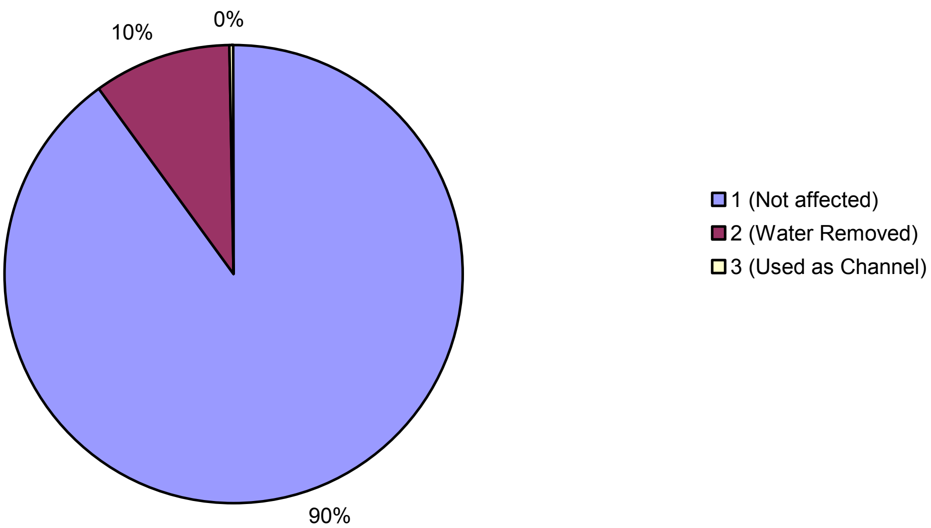

Figure 3.12: The affected streams within 3rd order streams within the Wimmera catchment

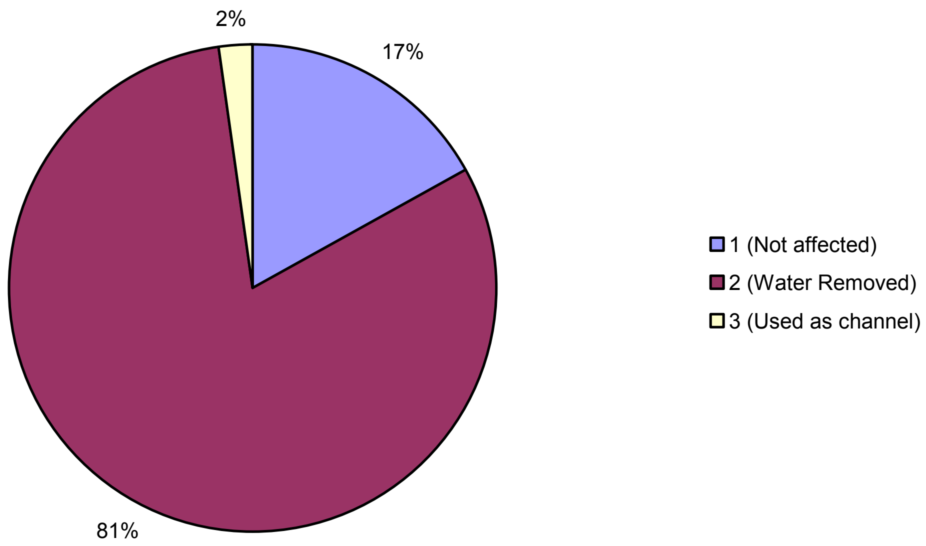

Figure 3.13: The affected break down of the 8th order streams within the Wimmera catchment.

The effects of changes in the Wimmera Catchment brought about by the harvesting and distribution of water are important. Refer to Appendix J for a detailed description and analysis of changes in hydrology within the Wimmera Catchment.

The streams that are required to carry water for irrigation and domestic supplies will adapt to greater flows by increasing channel size and changes in stream alignment at a faster rate than their natural process. The greater flows may have a detrimental effect on stream ecology through:

- The release of cold water
- The removal of in-stream features such as bars and LWD
- Creating areas in the channel of low velocity flow, such as pools, when they are not part of the natural channel character

The length of streams that have been affected by water diversions and used as conduits is quite significant when considered in terms of overall higher order stream length. This is due to water being harvested from lower order streams, which are generally upstream from higher order streams. Extensive harvesting and diversion of water within the Wimmera catchment has left the majority of the lower Wimmera river and its significant tributaries, such as the MacKenzie and Mt William Creek, with low and restricted flows.

Streams with affected hydrological regimes

The streams of the Wimmera River catchment that have undergone significant change in hydrology, due to water harvesting and distribution, since European settlement are summarised in Table 3.11.

These streams are of a generally continuous nature and represent a significant proportion of the larger streams within the catchment. The majority of channel length that has been affected is due to flows being significantly reduced. However, many streams are used at different times of the year to supplement the distribution channel network. Refer to Appendix J for a map of affected streams within the Wimmera River catchment.

The general implications of this assessment are that the lower Wimmera has been severely affected by changes in stream hydrology, the reduction of flows and the upper Wimmera Catchment has been significantly damaged by incision and channelisation (pers comm. Hardie, 2002)

Table 3.11: Streams in the Wimmera River catchment with affected hydrology

Waterway	Way in which waterway is affected
Upper Fyans Creek	Water diverted by WMW (Wimmera Mallee Water) from the headwater streams to the Wannon River
Fyans Creek	Dammed at Lake Bellfield and the stream channel below the dam is used for water distribution
Fyans Creek Diversion	Diverts water to a defined stream below Halls Gap to prevent it bypassing Lake Lonsdale
Mt William Creek	Affected below Lake Lonsdale through the restriction of flow
Sheepwash Creek	Occasionally used to carry regulated flows by WMW
Wimmera River	Used to carry water from Glenorchy to Huddlestones Weir
Wimmera River below Huddlestones Weir	Restricted flows. All water up to 1600ML/day is regulated into the Wimmera Inlet Channel
MacKenzie River	Flows are regulated between the Wartook Reservoir and the MacKenzie Distribution Heads
MacKenzie River below the Distribution Heads	Restricted to between 5 and 10 ML / day of environmental flows. 5 ML/day is a insufficient amount for the river to be fully wetted during the summer month
Potters Creek	Used as a channel for distributing stock and water supplies during the summer as well as for water for Horsham urban storages
Burnt Creek – Distribution Heads to Toolondo Channel	Flows are restricted and environmental flows are not always available during summer periods
Burnt Creek – Toolondo Channel to Wimmera River	Used a distribute water during the summer for dam filling operations
Bungalally Creek	Used as a distribution channel for irrigation water. Stock and Domestic supplies and the lower part of the stream is used to carry Wimmera River environmental flows from Pine Lake to the Wimmera River
Parts of Yarriambiack Creek	Formerly used to carry irrigation water, WMW supplies some water to weir pools at some towns for recreational purposes
Parts of Dunmunkle Creek	Used to carry irrigation as well as stock and domestic water. It has also been excavated in some places for use as a channel or drain for excess irrigation water

Summary of the Stream Condition Assessment

The stream condition assessment has included aerial photograph interpretation, ISC assessments and a review of the hydrology in the Wimmera River catchment.

The aerial photograph interpretation has shown that there are almost 50% of the 3288 km of waterways in the Wimmera River catchment, of 3rd order or greater, with less than 20% overstorey vegetation cover. Only 13.8 % of the waterway length has overstorey vegetation cover of greater than 80%, mostly located in the Grampians National Park, Pyrenees region or the Heritage River section of the Wimmera River.

Waterways which have been identified as Intact Valley Fill make up 22.4% of the total stream length and Incised Alluvial Discontinuous constitute 22.0%. A significant majority of the length of these two types of waterways have overstorey vegetation cover of less than 20%. This means that over 30% of the length of 3rd order streams or greater in the Wimmera River catchment is Intact Valley Fill or Incised Alluvial Continuous with less than 20% overstorey vegetation cover.

The 1999 and 2002 ISC scores were combined to create a set of 89 ISC sites for assessment. The median Physical Form and Streamside Zone scores ranged from 2.5/10 to 8/10. The Confined and Partly Confined systems generally received higher ISC scores than the Alluvial systems. This may be due to the location of the Confined and Partly Confined systems in National Parks and other such protected areas, whilst the Alluvial systems are generally located in agricultural and privately owned areas.

The range of ISC scores may also be affected by the limitations of applying the ISC in the Wimmera River catchment. As discussed in this section, the ISC does not incorporate the unique features of discontinuous systems such as Chain of Ponds or Intact Valley Fill. Analysis of the ISC results for these stream types should consider these limitations.

The Hydrology investigation showed that the majority of waterway length in the entire Wimmera River catchment is not affected hydrologically by the Wimmera Mallee Stock and Domestic Supply System. However, over 80% of the length of 8th order waterways in the catchment is directly affected by water being harvested for irrigation and / or domestic supplies.

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Acknowledgments:

Land Victoria Horsham provided access to the aerial photographs for the part of the catchment that wasn't covered by the digital imagery.

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- Wimmera Waterway Management Strategy (1999)
- Algal Bloom and Nutrient Status of Victorian Inland Waters (1995)

Web Sites

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- Department of Natural Resources and Environment [www.nre.vic.gov.au]
- Victorian Resources Online – Wimmera [via the: www.nre.vic.gov.au site]
- Victorian Water Data Warehouse [www.vicwaterdata.net]
- Waterwatch Victoria [www.vic.waterwatch.org.au]
- Wimmera Catchment Management Authority [www.wca.vic.gov.au]
- Wimmera Mallee Water [www.wmwater.org.au]

Additional Data Sources

Information was collated from the sites on the Internet such as:

- Agriculture, Fisheries and Forestry – Australia [www.dpie.gov.au]
- Department of Natural Resources and Environment [www.nre.vic.gov.au]
- Victorian Resources Online – Wimmera [via the: www.nre.vic.gov.au site]
- Victorian Water Data Warehouse [www.vicwaterdata.net]
- Waterwatch Victoria [www.vic.waterwatch.org.au]
- Wimmera Catchment Management Authority [www.wca.vic.gov.au]
- Wimmera Mallee Water [www.wmwater.org.au]

Texts reviewed include:

- Water Victoria – A Resource Handbook (1989)
- Rivers and Streams – Special Investigation (Final Recommendations) (1991)
- Testing the Waters – The 1996 Review of Victorian Water Quality Monitoring – Technical Discussion Paper (1996)
- The Environmental Condition of Victorian Streams (1990)
- Wimmera Waterway Management Strategy (1999)
- Algal Bloom and Nutrient Status of Victorian Inland Waters (1995)

Wimmera Catchment Management Authority

Geomorphic Categorisation and Stream Condition Assessment of the Wimmera River Catchment

Section Four: Implications for Management & Recommendations

Jobs 2901049.008 & 2901049.009

April 2003

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Introduction

This investigation has identified stream types, their location, length and condition in the Wimmera River Catchment. The investigation provides a greater understanding of geomorphic and ecological processes within the catchment. The output from the investigation can be used to assist in the development of stream management programs within the Wimmera River region. However, any prioritisation of actions first requires a clear and agreed set of objectives for management.

This section of the report provides some recommended actions reflecting both the findings of the stream categorisation and condition assessment process and five recommended waterway management actions.

A Framework for Defining Management Objectives

Wimmera CMA Waterway Action Plans

The Wimmera Catchment Management Authority has prepared Waterway Action Plans (WAPs) for priority waterways identified through previous investigations. The WAPs are based on the regional objectives for stream condition outlined in Table 4.1.

Table 4.1: Wimmera CMA Regional Objectives

Objective	Description
Objective 1	Preserve areas with near pristine values
Objective 2	Restore areas of high value
Objective 3	Rehabilitate areas that place other values at risk or provide good opportunity for restoring values
Objective 4	Maintain degraded areas to prevent values declining to unacceptable levels

Source: Wimmera CMA, 2003

Victorian River Health Strategy

The Victorian River Health Strategy was published in 2002 by the Department of Natural Resources and Environment. The management approach outlined in the Strategy includes the four key elements outlined in Table 4.2.

Table 4.2: Key Elements in the Victorian River Health Strategy's Management Approach

Key Element	Description
Element 1	Protecting the rivers that are of the highest community value from any decline in condition
Element 2	Maintaining the condition of ecologically healthy rivers
Element 3	Achieving an 'overall improvement' in the environmental condition of the remainder of the State's rivers
Element 4	Preventing damage from future management activities

Source: (VRHS, 2002)

The VRHS priorities for protection and restoration are set on the basis of:

- Protection of existing high value areas of areas in good condition
- Restoration of those areas where there is:
    - The highest environmental and community gain for the resources invested
    - Real community commitment towards long term improvement of river health (VRHS, 2002)

Recommended Management Actions

The Wimmera Regional River Health Strategy (RRHS) had not been produced at the time of writing this report. It is anticipated that objectives for management will be developed for the Wimmera River catchment as a component of the development of the Wimmera RRHS. It is expected that the strategies included in the Wimmera RRHS will be consistent with those in the VRHS.

Taking both the Wimmera CMA Regional Management Objectives and the VRHS Key Elements into account, a series of Recommended Management Actions has been developed. Refer to Table 4.3.

Table 4.3: Recommended Management Actions for the Wimmera CMA

Action	Description
Action 1	Protection of Rare Stream Types
Action 2	Protection of Streams in Good Condition
Action 3	Protection of Stream System Function and Diversity
Action 4	Protection of Heritage Rivers
Action 5	Defining Template Reaches using Representative Rivers as a basis

The selected actions listed in Table 4.3 provide a basis for the provision of some preliminary stream management recommendations that can be drawn from the results of this investigation. The list of actions is not exhaustive and is likely to be modified as a component of the development of a Regional RHS.

Action 1: Protection of Rare Stream Types

A number of stream types in the Wimmera River Catchment have been found to be rare and / or unusual both within the catchment and through South East Australia. These stream types are likely to have distinctive ecological communities and are considered worthy of high priority for protection.

Discontinuous Anabranching Chain of Ponds

Comment

The lower MacKenzie River was categorised as a Discontinuous Anabranching Chain of Ponds. This section of waterway has intact geomorphic form, is rare as a stream category within the Wimmera River catchment and is unusual in southeast Australia. The lower MacKenzie River has limited flows downstream from Distribution Heads, upstream from which the Mackenzie River is used as a water transport channel (Refer to the Hydrology Map in Appendix J). At Distribution Heads, water is diverted into the Wimmera Mallee Stock and Domestic Supply System.

The sand-bedded lower MacKenzie River still has an intact channel system. The system shows no evidence of instability, excessive incision or deposition. Similar systems have been identified in the Mt Lofty Ranges of South Australia (see Figure 4.1). The two systems contain similar geomorphic forms and riparian vegetation.

Mt Lofty system Lower MacKenzie River

Figure 4.1: Discontinuous Anabranching Chain of Ponds

The ISC Streamside Zone Sub-index scores for the lower MacKenzie River sites were all 7/10 or 8/10 indicating that the riparian zone is in good to very good condition. The ISC Physical Form Sub-index scores were between 6/10 and 8/10. Hydrology of the lower MacKenzie is seriously affected by water being extracted in some sections and other sections being used for water transfer.

Action 1: Recommendations for Discontinuous Anabranching Chain of Ponds

The hydrology and ecology of the lower MacKenzie River have been severely affected by water harvesting. The condition of this reach of river should be a focus for management and a management plan should be developed. This plan should consider:

- Restoring flows which mimic natural flow regimes
- A detailed assessment to identify any specific risks due to sediment input and / or channel incision
- A monitoring program should be developed to assess changes in the waterway condition and identify risks within the system

The identification of specific threats should then also be treated and managed. An important part of the management program should also be to educate the local landholders and the public about the system.

Distributary Systems

Comment

The distributaries of Yarriambiack and Dunmunkle Creeks are rare hydrological systems within southeastern Australia. These systems distribute floodwaters across the lower Wimmera catchment and into the southern Mallee. Yarriambiack Creek distributary terminates in Lake Coorong, an ephemeral lake that overflows into the southern Mallee. Dunmunkle Creek flows also terminate in the southern Mallee.

The distributaries may once have been Wimmera River channels. They are similar to flood channels associated with the anabranching fine grained systems on the Wimmera River, such as Datchak Creek. However, they do not rejoin the channel. The distributary systems contain similar geomorphic forms to the contemporary Wimmera River. However, both Yarriambiack and Dunmunkle creeks are slowly filling with fine sediment and losing their original geomorphic form.

The intermittent flows associated with these channels may have some rare or distinctive floral and or faunal associations.

Two ISC sites were assessed on Dunmunkle Creek in 2002. The aerial photograph interpretation indicated that Dunmunkle Creek has <20% overstorey vegetation cover. The ISC scores for Physical Form were 5/10 and for Streamside Zone were 4/10 and 6/10.

No sites were assessed on Yarriambiack Creek in 2002. Yarriambiack has overstorey vegetation cover that is mostly <20%, with some sections having 20-80% overstorey vegetation coverage. Three ISC sites were completed in 1999 on Yarriambiack Creek and received 4,5, and 6/10 for Physical Form and 5,8, and 7/10 for Streamside Zone.

Action 1: Recommendations for Distributary Systems

The distributary systems of Yarriambiack and Dunmunkle Creek are a rare hydrological system within southeastern Australia. These systems need to be further studied to gain an understanding of their past flows regimes. This understanding may allow the development of an environmental flow and release program.

These distributary systems also need to undergo further ecological assessment to determine their significance ecologically.

Terminal Systems

Comment

The Natimuk Creek system is a small terminal system that occurs west from Horsham. While Natimuk Creek is part of the Wimmera River catchment, it is an isolated system, which is only connected to the rest of the catchment in the event of very large flows. Geomorphically and hydrologically, Natimuk Creek has more in common with the terminal systems of the Millicent Coast, west from the Wimmera River Catchment. Generally, Natimuk Creek has a poor stream condition.

Action 1: Recommendations for Terminal Systems

The Natimuk Creek system is not a significant system in the Wimmera River catchment as it is not a rare stream type. It is recommended that Natimuk Creek should be managed in conjunction with the terminal systems of the Millicent Coast region.

Chain of Ponds

Comment

The distinctive and uncommon Chain of Ponds fluvial systems of southeastern Australia occur on Glenlofty Creek and on part of the upper Wimmera River. The Chain of Ponds once covered a large proportion of the upper Wimmera River stream length. This investigation has revealed that up to 50 % of stream length in the Wimmera River Catchment was of the discontinuous stream type, a large proportion of which would have been Chain of Ponds. The Chain of Ponds systems have been drained and subjected to incision processes. Only a very limited length (0.6%) of the Chain of Ponds stream type now remains in the Wimmera River catchment.

The 2002 ISC scores for the Chain of Ponds sites are 3/10 to 5/10 for the Streamside Zone Sub-index and 4/10 to 6/10 for the Physical Form sub-index. The relatively low physical form scores can be partly attributed to limitations in the ISC methodology, which does not take into account the unique physical form of the Chain of Ponds system. However, the low physical form score is also a reflection of contemporary infilling of the Chain of Ponds with sediment from upstream erosion and other sediment liberation processes.

Action 1: Recommendations for Chain of Ponds

The Chain of Ponds systems on Glenlofty Creek and the Wimmera River are now rare in the catchment and within SE Australia. The remaining Chain of Ponds systems require protection from ongoing processes. The Physical Form and Streamside Zone Sub-index scores for these sites generally indicate poor to moderate condition. As these sites are geomorphically significant, they should be a priority for management. A management program should aim to monitor the system, improve its condition and inform the public on the nature of the Chain of Ponds and their rarity within the catchment.

Many incised or modified systems in the Wimmera River Catchment were once Chain of Ponds. In some waterways, a process of infilling by sediment is occurring. This is a recovery phase of the process in which the Chain of Ponds systems attempt to return to their original geomorphic form.

FS #38: Glenlofty Creek FS#39 Glenlofty Creek upstream

Figure 4.2: Chain of Ponds examples

Action 2: Protection of Streams in Good Condition

There can be considerable economic advantage in protecting existing streams in good condition as a first step in maintaining and improving the health of rivers in a catchment.

The aerial photograph interpretation highlighted that waterways in the Wimmera River catchment with greater than 80% overstorey vegetation cover are likely to be found in the Grampians National Park, the Pyrenees Region and the Heritage River section of the Wimmera River. High value reaches of waterway are likely to be found in these areas.

Several sites have been highlighted in the ISC assessments as having good Physical Form and Streamside Zone condition. These sites were selected, as both of the ISC Sub-index scores were 7/10 or higher, indicating that the site was in good condition.

A selection of streams with high physical and streamside zone vegetation conditions and with a largely intact hydrologic regime are provided in Table 4.4 and shown in Figure 4.3.

Table 4.4: Sites in the Wimmera River catchment in good condition

Field Site No.	Stream Name	ISC Physical Form Score	ISC Streamside Zone Score
FS#12	Boggy Creek	8	9
FS#17	Seven Dials Creek	7	9
FS#20	Golton Creek	8	7
FS#21	Golton Creek	8	7
FS#34	Glenpatrick Creek	8	9
FS#35	Spring Creek	7	7

FS#12 – Boggy Creek

Streamside Zone Score: 9

Physical Form Score: 8

FS#17 Seven Dials Creek

Streamside Zone Score: 9

Physical Form Score: 7

FS#20 – Golton Creek

Streamside Zone Score: 7

Physical Form Score: 8

FS#21 – Golton Creek

Streamside Zone Score: 7

Physical Form Score: 8

FS#34 – Glenpatrick Creek

Streamside Zone Score: 9

Physical Form Score: 8

FS#35 – Spring Creek

Streamside Zone Score: 7

Physical Form Score: 7

Figure 4.3: ISC Sites with high scores and largely intact hydrology

Action 2: Recommendations

In order that streams in good condition are protected, the following steps should be considered:

- The waterways identified as being in good condition should be monitored regularly to identify any possible threats to their condition
- The land tenure of each waterway should be identified and, where the land is publically owned, the Wimmera CMA should work with the relevant land managers to determine the way in which the waterways should be managed
- Where a private landholder is involved, the Wimmera CMA should provide the landholder with all information available to ensure that the status of the waterway is recognised and managed appropriately. In such a case, the Wimmera CMA should work cooperatively with the land manager to protect the waterway
- The waterways that have been recognised as being in good condition should be used as template reaches for the management and restoration of other waterways throughout the Wimmera River catchment. This concept is discussed in Action 5.

Action 3: Protection of Stream System Function and Diversity

There have been major changes in the hydrologic regime in the Wimmera River catchment associated with water harvesting and use of streams for water supply distribution.

Much more subtle changes in hydrology have taken place in the upper reaches, associated with the conversion of the discontinuous streams into incised alluvial discontinuous streams. The discontinuous systems, including Chain of Ponds, served to store water and release it over a period of time. The gullies result in water being retained for a shorter period in these areas. Consequently, downstream reaches, that once had permanent flow because of the slow release from the ponds, are now more ephemeral and variable in their function.

This has implications for instream ecological processes and water quality:

- Loss of ecological systems due to a loss of the Chain of Ponds
- Loss of ecological systems based on downstream flow regime from the Chain of Ponds
- Reduced nutrient processes through Chain of Ponds and therefore reduced downstream water quality

FS #38: Glenlofty Creek

Figure 4.4: Example of a Chain of Ponds

Action 3: Recommendations

The objectives of managing the Chain of Ponds systems have been largely covered by previous discussions in this report. An important objective to be set is one identifying the length of stream in each stream type and defining the length of each stream order within each stream type that should be in excellent condition.

The assessment of uncommon discontinuous systems, such as floodouts and cut & fills, should be undertaken. Approximately 50% of discontinuous waterways in the Wimmera River catchment have been lost to incision. Floodouts and cut and fills are naturally rare and threatened in the catchment.

Action 4: Protection of Heritage Rivers

Heritage Rivers – Lower Wimmera River

Although riparian and instream vegetation, woody debris and geomorphic condition provide excellent structural habitat in the lower Wimmera River, its hydrology has been significantly affected by anthropogenic activities upstream.

Datchak Creek is a significant anabranch / flood channel of the lower Wimmera River. However, it is under significant pressure from the local agricultural industry as only a limited riparian zone buffers it from surrounding land uses. Datchak Creek retains a good geomorphic condition.

Lake Hindmarsh, Lake Albacutya and Outlet Creek are in reasonable geomorphic condition, though they are suffering from a lack of regular flows. The flooding regimes in these systems have been changed by the significant diversion and harvesting of water in the upper Wimmera catchment. Lake Albacutya is one of Victoria's eleven listed Ramsar wetlands. According to the Victorian River Health Strategy, the status of Lake Albacutya is '…heavily dependent on river condition'. (NRE, 2002).

Action 4: Recommendations

Important considerations for management of the lower Wimmera River include:

- The retention and protection of its current geomorphic form
- Improving and maintaining riparian vegetation
- Improving and maintaining in-stream features such as woody debris

The return of a flow regime similar to the natural regime would significantly increase the ecological value of the river, the terminal system consisting of Lake Hindmarsh and Lake Albacutya and the overflow system of Outlet Creek. It is recommended that the Wimmera CMA investigate the environmental flow requirements of these terminal systems.

The addition of Datchak Creek to the Heritage Wimmera River Corridor may increase the protection of a major geomorphic and hydrologic feature of the lower Wimmera River system.

Action 5: Defining Template Reaches using Representative Rivers as a basis

Representative Rivers

The Victorian River Health Strategy (VRHS) (NRE, 2002) defines Representative Rivers as those that are:

"…rivers in an ecologically healthy condition that can be used to represent the major river classes that once occurred naturally across Victoria."

A statewide target that is set in the VRHS is:

"By 2021, there is at least one major river reach in each of the river regions represented in Victoria that meets the definition of ecologically healthy"

Action 5: Recommendations for Representative Rivers

Although there are no suggested Representative Rivers, as defined in the VRHS, in the Wimmera River catchment, there are two on the Avoca River and two on the Glenelg River. It is recommended that the Wimmera CMA investigate the existing representative rivers and use them as templates for similar waterways in the Wimmera River catchment.

Representative Sites

Representative Sites provide templates for stream condition assessments and for stream rehabilitation efforts. Representative streams provide an opportunity to gain an understanding of the different stream categories that occur within the Wimmera River Basin. Gaining an indication of the features that control the position and formation of such waterways would be a useful outcome.

Action 5: Recommendations for Representative Sites

The identification, assessment and recording of representative sites are recommended. The features that could be assessed to gain this understanding include:

- Catchment area
- Cross section analysis
- Longitudinal profiles
- Flow data (if available)
- Catchment and Riparian vegetation, including exotic and native species

A thorough documentation of those representative sites found in the catchment will capture the diverse and unique nature of the Wimmera Catchment and its streams. This information could then be explored for the establishment of template sites for rehabilitation works in the rest of the catchment.

The identification of representative high value sites in a completely natural state for all stream categories is difficult in the Wimmera River Basin. In particular, suitable representative high value sites for some of the uncommon stream categories are difficult to find.

However, waterways that may contain reaches with representative high value sites are shown in Table 4.5.

Table 4.5: Representative High Value Sites

Stream Type	Waterways
Steep Headwater	Seven Dials Creek and Bovine Creek
Confined	Glenpatrick Creek and Boggy Creek
Gorge	Upper MacKenzie River and Golton Creek
Partly Confined 1	Upper MacKenzie River and Spring Creek
Partly Confined 2	MacKenzie River
Partly Confined 3	Bovine Creek
Alluvial Continuous 1	Sheepwash Creek, Mt William Creek and Lower Wimmera River
Alluvial Continuous 4	Mt William Creek and Lower Wimmera River
Alluvial Continuous 5	Station Creek, Brimpaen
Anabranching fine grained	Lower Wimmera River, Marma State Forest
Intact Valley Fill	Unknown 3 & Unknown 5
Chain of Ponds	Glenlofty Creek
Discontinuous Anabranching Chain of Ponds	Lower MacKenzie River
Cut and Fill	Unknown 7
Floodout	Unknown 13
Distributary Systems	Yarriambiack Creek
Flood Channel	Datchak Creek

It is recommended that the Wimmera CMA further investigate the use of the waterways included in Table 4.5 as template reaches to aid rehabilitation plans in the remainder of the catchment.

References

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E A R T H T E C H

Wimmera Catchment Management Authority

Geomorphic Categorisation and Stream Condition Assessment of the Wimmera River Catchment – Appendices

Job 2901049.008 & 2901049.009

April 2003

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Map of the Wimmera River catchment’s Geology

Appendix B:

Maps of Stream Orders in the Wimmera River Catchment 2002

Appendix C:

Maps of Stream Categories in the Wimmera River Catchment 2002

Appendix D:

Summary of selected Wimmera River Catchment ISC Assessments in 1999

Table D1: Summary of selected Wimmera River Catchment ISC Assessments in 1999

Region	Reach	Site Number	Name	Stream Order	Stream Style	Overstorey Vegetation Condition	Hydrology	Physical Form Sub-index score	Streamside Zone Sub-index score	Hydrology Sub-index Score
Just South of Jeparit	2	51	Wimmera River	8	Alluvial Continuous 4	20-80%	Hydrologically Affected – Water Removed	4	6	6
West of Gerang Gerung	3	52	Wimmera River	8	Anabranching Fine Grained	20-80%	Hydrologically Affected – Water Removed	6	7	6
Dimboola	4	53	Wimmera River	8	Alluvial Continuous 4	>80%	Hydrologically Affected – Water Removed	4	7	6
Ellis Crossing to East Natimuk	5	54	Unknown	8	Anabranching Fine Grained	Not assessed due to scale of aerial photographs	Hydrologically Affected – Water Removed	4	5	6
Horsham to Vectis South	6	55	Wimmera River	8	Alluvial Continuous 4	20-80%	Hydrologically Affected – Water Removed	6	6	6
Horsham	7	56	Wimmera River	8	Alluvial Continuous 1	<20%	Hydrologically Affected – Water Removed	6	4	7
Marma State Forest	8	57	Mount William Creek	5	Anabranching Fine Grained	20-80%	Hydrologically Affected – Water Removed	5	7	10
Campbells Bridge	9	58	Wimmera River	8	Alluvial Continuous 1	20-80%	Not Hydrologically Affected	4	7	10
Joel Joel	10	59	Wimmera River	8	Alluvial Continuous 1	20-80%	Not Hydrologically Affected	5	7	10
Crowlands	11	60	Wimmera River	7	Partly Confined 3	<20%	Not Hydrologically Affected	4	3	10
Mount Cole	12	61	Wimmera River	5	Intact Valley Fill	<20%	Not Hydrologically Affected	5	3	10
Wonwondah	13	62	Norton Creek	4	Alluvial Continuous 4	20-80%	Not Hydrologically Affected	5	7	10
Laharum	14	63	MacKenzie River	3	Discontinuous Anabranching Chain of Ponds	20-80%	Hydrologically Affected – Water Removed	7	7	2
Wartook	15	64	MacKenzie River	5	Partly Confined 2	20-80%	Hydrologically Affected – Used For Water Transfer	6	6	2
Jung	17	66	Yarriambiak Creek	3	Anabranching Fine Grained	20-80%	Hydrologically Affected – Water Removed	6	5	10
South Warracknabeal	18	67	Yarriambiak Creek	3	Alluvial Continuous 1	>20%	Hydrologically Affected – Water Removed	5	8	10
North of Warracknabeal	19	68	Yarriambiak Creek	3	Alluvial Continuous 1	>20%	Hydrologically Affected – Water Removed	4	7	10
Dadswells Bridge	21	70	Mt William Creek	2	Alluvial Continuous 1	>20%	Hydrologically Affected – Water Removed	5	7	6
Ledcourt (east Lake Lonsdale)	22	71	Mt William Creek	7	Alluvial Continuous 1	<20%	Hydrologically Affected – Water Removed	5	6	5
Lake Fyans	23	72	Mt William Creek	7	Alluvial Continuous 1	>20%	Not Hydrologically Affected	3	5	10
Moyston	24	73	George Creek	4	Incised Alluvial Discontinuous	<20%	Not Hydrologically Affected	3	5	10
Green Lake	25	74	Golton Creek	5	Alluvial Continuous 1	>20%	Not Hydrologically Affected	5	7	10
Halls Gap	27	76	Fyans Yaloog Creek	5	Partly Confined 1	>80%	Hydrologically Affected – Used For Water Transfer	2	5	10
Campbells Bridge	30	79	Sheepwash Creek	4	Alluvial Continuous 1	>20%	Not Hydrologically Affected	5	4	10

Region	Reach	Site Number	Name	Stream Order	Stream Style	Overstorey Vegetation Condition	Hydrology	Physical Form Sub-index score	Streamside Zone Sub-index score	Hydrology Sub-index Score
Concongella	31	80	Concongella Creek	6	Partly Confined 3	>20%	Not Hydrologically Affected	3	5	10
South West Navarre	32	81	Heifer Station Creek	6	Alluvial Continuous 5	>20%	Not Hydrologically Affected	1	4	10
Navarre	33	82	Wattle Creek	6	Alluvial Continuous 5	20-80%	Not Hydrologically Affected	4	4	10
Barkly	34	83	Wattle Creek	6	Cut & Fill	20-80%	Not Hydrologically Affected	3	6	10
Frenchmans	35	84	Watercourse	5	Alluvial Continuous 4	<20%	Not Hydrologically Affected	1	5	10
Bulgana	36	85	Six Mile Creek	5	Incised Alluvial Discontinuous	<20%	Not Hydrologically Affected	3	5	10
Crowlands	37	86	Mount Cole Creek	6	Partly Confined 3	20-80%	Not Hydrologically Affected	4	5	10
Glenlofty	38	87	Glenlofty Creek	6	Chain of Ponds	<20%	Not Hydrologically Affected	4	3	10
Natimuk	41	90	Natimuk Creek	4	Alluvial Continuous 4	<20%	Not Hydrologically Affected	3	5	10
Brimpaen	42	91	Station Creek	3	Alluvial Continuous 5	20-80%	Not Hydrologically Affected	6	7	10
West Laharum	26	125	Golton Creek	2	Confined	>80%	Not Hydrologically Affected	6	4	10
Halls Gap	28	127	Fyans Creek	5	Partly Confined 1	>80%	Hydrologically Affected – Used For Water Transfer	7	7	10
Glenpatrick	40	139	Glenpatrick Creek	5	Partly Confined 2	20-80%	Not Hydrologically Affected	4	5	10

Appendix E:

Summary of Wimmera River Catchment ISC Assessments in 2002 – Location of Sites

Table E1: Summary of ISC Site Locations visited in November 2002

Field Site ID	Site Number	Reach Number	Stream Name	Site Description
FS #1	WIM1.1	1	Dunmunkle Creek	CFA 279 Property #F22
FS #2	WIM1.2	1	Dunmunkle Creek	East from Stawell - Warracknabeal Road. Closest intersection with Glenorchy - Wal Wal Road, Wal Wal.
FS #3	WIM2.1	2	Sheepwash Creek	Wimmera Park Access Road, off Stawell - Donald Road. Adjacent to property E22, CFA315.
FS #4	WIM3.1	3	Unknown 1	Access from unnamed track on Private Property, south from Laharum Road (Grampians Road). Located west from Laharum 'A' Fire Station.
FS #5	WIM2.2	2	Sheepwash Creek	Flood Channel upstream from Horsham - Wal Wal Road. Nearest intersection is Crutes Road.
FS #6	WIM4.1	4	MacKenzie Creek	Three channel system upstream from Golf Road / Three Bridges Road.
FS #7	WIM4.2	4	MacKenzie Creek	Located adjacent to a fire access track that runs along the right bank and crosses in several places. South from Hickeys Road, Wonwondah.
FS #8	WIM5.1	5	Burnt Creek	Upstream from MacInnes Road, west from the intersection with Staehrs Road.
FS #9	WIM6.1	6	Toolando Tributary	Millicent Coast - Stubgate Road, off Black Range Road. Black Range State Park.
FS #10	WIM7.1	7	Mt Talbot Creek	Upstream from unnamed road. South from Wash Tomorrow Road, off Telangatuk East Road. East from Toolondo Reservoir.
FS #11	WIM8.1	8	Boggy Creek	Downstream from Glenisla Road, east from Schmidt's Road.
FS #12	WIM8.2	8	Boggy Creek	Upstream from Asses Ears Road. Near the intersection with Wallaby Rock Road.
FS #13	WIM4.3	4	MacKenzie Creek	Upstream from the Grampians Road, Wartook.
FS #14	WIM4.4	4	MacKenzie Creek	Gorge. Downstream from MacKenzie Falls.
FS #15	WIM4.5	4	MacKenzie Creek	Upstream from MacKenzie Falls.
FS #16	WIM9.1	9	Bovine Creek	West from Grampians Road (Mt Abrupt Road). Near the intersection with Mt William Road. Downstream end of the reach is its confluence with Fyans Creek.
FS #17	WIM10.1	10	Seven Dials Creek	Adjacent to Seven Dials Track. Access upstream from Redman Road, off Grampians Road.
FS #18	WIM11.1	11	Mt William Creek	South from Redman Road, between Shields Road and Neilds Road.
FS #19	WIM12.1	12	Unknown 2	Upstream from Spears Road.
FS #20	WIM13.1	13	Golton Creek	Upstream from Copper Mine Track, Grampians National Park. Across Copper Mine Track from camping ground. Between Flat Rock Road and Polnners Track.
FS #21	WIM13.2	13	Golton Creek	Golton Gorge, access via Golton Gorge Walking Track.
FS #22	WIM14.1	14	Unknown 3	Intact Valley Fill. Downstream from Lake Fyans Tourist Road. Close to the Ararat - Halls Gap Road.
FS #23	WIM15.1	15	Unknown 4	Adjacent to Rulters Lane, off Bellellen Road. Downstream from Reids Bushland Reserve.
FS #24	WIM16.1	16	Basin Creek	Upstream from the corner of Bellellen Road and Lake Fyans Road. Property owned by Sam Young.
FS #25	WIM17.1	17	Seven Mile Creek	Adjacent to Lynleigh Estate, Landsborough - Stawell Road. Downstream from road.
FS #26	WIM17.2	17	Seven Mile Creek	Downstream from Morrl Morrl Road. North from the intersection with Granard Park Road. Near to the Stawell - Avoca Road.
FS #27A	WIM18.1	18	Wimmera River	Marma State Forest. Downstream from the Horsham - Lubeck Road. Adjacent to property A18 (CFA314).
FS #27B	WIM18.2	18	Wimmera River	Marma State Forest, off Lubek Road. Left Channel.
FS #28	WIM19.1	19	Heifer Station Creek	Upstream from Three Chain Road. Near the intersection with McSparrons Road. North from Stawell Avoca Road. Letter given to CFA 316 E11, J. Bibby - Shed.
FS #29	WIM20.1	20	Unknown 5	A. Supple Road, off Barkly, Navarre Road. Upstream from road.
FS #30	WIM21.1	21	Unknown 6	Behind property E10, upstream from Cross Road, near Barkly - Navarre Road. Letter left at E10.
FS #31	WIM22.1	22	Unknown 7	Unknown Road off Stewarts Road. Near property 354 - 21A. East from Treowen Lane. Old gold workings.
FS #32	WIM23.1	23	Unknown 8	Tributary of Heifer Station Creek. Upstream from Frenchmans Track. Off Mashado Track. Off Stawell - Avoca Road.
FS #33	WIM24.1	24	Glenpatrick Creek	Upstream from Elmhurst - Glenpatrick Road. Mined upstream.
FS #34	WIM24.2	24	Glenpatrick Creek	Upstream from North Glenpatrick Road. Near the corner of Emery Track.
FS #35	WIM25.1	25	Spring Creek	Downstream from Spring Creek Road, off Nowhere Creek Road.
FS #36	WIM25.2	25	Nowhere Creek	Access via Property CFA354F5 (N Powell). Upstream from property.
FS #37	WIM25.3	25	Nowhere Creek	Behind property CFA354F5 (N. Powell). Nowhere Creek Road.
FS #38	WIM26.1	26	Glenlofty Creek	Downstream from Boatmans Road. Off Elmhurst - Landsborough Road.
FS #39	WIM26.2	26	Glenlofty Creek	Adjacent to Warrenmang Road, between Croft & Williamson Road.
FS #40	WIM27.1	27	Reservoir Creek	Off Moyston - Dunkeld Road. West from Gumnut Camp.
FS #41	WIM28.1	28	Unknown 9	Downstream from Rocky Point Bushland Reserve. Off Rocky Point Road (off the Halls Gap - Ararat Road). Downstream from Black Cow Road.

Field Site ID	Site Number	Reach Number	Stream Name	Site Description
FS #42	WIM29.1	29	Tributary of Pentland Creek	Downstream from McGuans Road. Between Polas Road & Killough Road.
FS #43	WIM30.1	30	Unknown 10	Downstream from Property CFA392A 25 - AB & E Graham. Off Brewery Road, access via Military Bypass Road.
FS #44	WIM31.1	31	Unknown 11	Upstream from Sinnots Road. Off Allanvale - Dunworthy Common Road.
FS #45	WIM32.1	32	Spring Creek	Access via property 267 Spring Flat Road. Downstream from a fenced stand of exotics.
FS #46	WIM18.3	18	Wimmera River	Downstream from Bulgana Road. Between Woodlands - Ararat Road & Joel Joel - Crowlands Road. Downstream from Ford.
FS #47	WIM33.1	33	Aston's Scour Tributary	Downstream from Landsborough West - Tulkarra Railway Road. Landsborough West. North from Aston's Scour.
FS #48	WIM34.1	34	Unknown 12	South from T.Vances Road. Near the Joel South - Landsborough Road.
FS #49	WIM35.1	35	Unknown 13	Upstream from Ararat - St Arnaud Road. South from Starts Road.
FS #50	WIM36.1	36	Unknown 14	Downstream from the end of Forestry Road, Landsborough.
FS #51	WIM37.1	37	Wattle Creek Tributary	Downstream from Landsborough Road, Landsborough.

Appendix F:

Original Vegetation Cover Data for 52 ISC sites assessed in 2002

Original Vegetation Cover Data

The Wimmera CMA provided Earth Tech with two GIS layers, one being of the Bioregions in the Wimmera River catchment and the other being of the pre-1750 EVC (Ecological Vegetation Class) information. This information was queried using ArcMap 8.1 to determine the Bioregion and pre-1750 EVC for each of the 52 ISC sites visited in 2002.

Table F1 was sent to the Wimmera CMA as a request for EVC information. The Department of Sustainability and Environment provided the Wimmera CMA with the relevant EVC descriptions, which were then passed on to Earth Tech for interpretation.

Each EVC was given a cover score for each of the three structural layers. The layers are the Overstorey, Understorey and Groundlayer. The cover scores are <20% (sparse), 20-80% (patchy) and >80% (continuous). An example of the interpretation is shown in Tables F2 and F3.

Table F1: The pre-1750 EVCs at the 52 ISC sites visited in 2002

EVC_NEW	Field Site ID	EVC	EVC_TYPE
Sand Ridge Woodland / Damp Sands Herb-rich Woodland Mosaic	6	729	mosaic
Plains Riparian Shrubby Woodland	7	659	EVC
Lateritic Woodland	9	704	EVC
Creekline Sedgy Woodland	10	640	EVC
Damp Sands Herb-rich Woodland / Shrubby Woodland Mosaic	11	672	mosaic
Riparian Scrub Complex	14	17	complex
Cool / Warm Temperate Rainforest Overlap	18	33	complex
Hills Herb-rich Woodland	20	71	EVC
Rocky Outcrop Herbland	21	193	EVC
Riparian Forest	33	18	EVC
Grassy Woodland	42	175	EVC
Grassy Dry Forest	49	22	EVC
Herb-rich Foothill Forest	12, 34, 39	23	EVC
Plains Grassy Woodland	13, 23	55	EVC
Heathy Dry Forest	15, 17	20	EVC
Damp Sands Herb-rich Woodland	16, 40	3	EVC
Shrubby Woodland	19, 22	282	EVC
Drainage-line Woodland	3, 2	679	EVC
Low Rises Grassy Woodland / Alluvial Terraces Herb-rich Woodland Mosaic	31, 29	76	mosaic
Valley Grassy Forest	36, 37, 35	47	EVC
Creekline Grassy Woodland	38,45, 48, 51, 30, 26, 24, 25	68	EVC
Plains Woodland	47, 28, 4, 1	803	EVC
Riparian Woodland	5, 8, 46, 27b, 27a	641	EVC
Alluvial Terraces Herb-rich Woodland	50, 32, 44, 43, 41	67	EVC

Example: Extract of an EVC for interpretation

The relevant sections of the Goldfields Bioregion Creekline Grassy Woodland have been reproduced in Tables F2 and F3.

Table F2: Tree Canopy Cover for Example EVC

%cover	Character Species	Common Name	Total Cover
15%	*Eucalyptus camaldulensis*	River Red-gum	
	Eucalyptus microcarpa	Grey Box	
	Eucalyptus melliodora	Yellow Box	15%

All EVCs have a section on the percentage cover of the overstorey vegetation. In this case, it is 15%, which is equivalent to a structural intactness score of sparse (<20%).

Table F3: Understorey Canopy Cover for Example EVC

Life form	%Cover	Total Cover
Immature Canopy Tree	**5%**	
Medium Shrub	**10%**	
Small Shrub	**5%**	20%
Large Herb	**5%**	
Medium Herb	**15%**	
Large Tufted Graminoid	**15%**	
Medium to Small Tufted Graminoid	**25%**	
Medium to Tiny Non-tufted Graminoid	**5%**	
Bryophytes/Lichens	**10%**	75%

The percentages of cover for those life forms that are considered shrubs have been added up, with a result of 20%. This means that the understorey rating is patchy (20-80%). Similarly, the percentages of cover for those life forms that would make up the ground cover add up to 75%. The ground cover rating is therefore continuous (>80%).

This is a rough interpretation of the EVC data for use in the Index of Stream Condition Streamside Zone Sub-index score. It is not a defined method from the original ISC methodology. Rather, it was developed as a way of integrating the extensive EVC information into the ISC method.

Table F4 is a summary of the interpretation of structural intactness for all EVCs relevant to this project. In some cases, the EVC was not available for a particular bioregion. For example, the Dundas Tablelands Plains Grassy Woodland was not available from the DSE. In its place, the Wimmera Plains Grassy Woodland EVC was used to determine the approximate structural intactness.

The Wimmera Drainage-line Woodland EVC was not available. Based on the Plains Woodland, the structural intactness given to the sites was: overstorey (sparse, <20%), understorey (sparse, <20%) and groundcover (continuous, >80%).

The bioregion and pre-1750 EVC for each of the 52 sites visited in 2002 are summarised in Appendix H, *Table H1: Summary of ISC Assessment in 2002*.

Table F4: The interpretation of the structural intactness for the pre-1750s EVC communities.

BIOREGION	EVC code	EVC Description	BioRegion Used	Overstorey	Understorey	Groundcover
Central Victorian Uplands	18	Riparian Forest		patchy (20-80%)	patchy (20-80%)	continuous (>80%)
Central Victorian Uplands	23	Herb-rich Foothill Forest		patchy (20-80%)	patchy (20-80%)	continuous (>80%)
Dundas Tablelands	55	Plains Grassy Woodland	Wimmera	sparse (<20%)	sparse (<20%)	continuous (>80%)
Dundas Tablelands	640	Creekline Sedgy Woodland		sparse (<20%)	patchy (20-80%)	patchy (20-80%)
Dundas Tablelands	672	Damp Sands Herb-rich Woodland / Shrubby Woodland Mosaic		sparse (<20%)	patchy (20-80%)	continuous (>80%)
Goldfields	22	Grassy Dry Forest		patchy (20-80%)	patchy (20-80%)	continuous (>80%)
Goldfields	23	Herb-rich Foothill Forest	Central Vic Uplands	patchy (20-80%)	patchy (20-80%)	continuous (>80%)
Goldfields	47	Valley Grassy Forest		patchy (20-80%)	patchy (20-80%)	continuous (>80%)
Goldfields	55	Plains Grassy Woodland		sparse (<20%)	sparse (<20%)	continuous (>80%)
Goldfields	67	Alluvial Terraces Herb-rich Woodland		sparse (<20%)	patchy (20-80%)	continuous (>80%)
Goldfields	68	Creekline Grassy Woodland		sparse (<20%)	patchy (20-80%)	continuous (>80%)
Goldfields	76	Low Rises Grassy Woodland / Alluvial Terraces Herb-rich Woodland Mosaic		sparse (<20%)	patchy (20-80%)	continuous (>80%)
Goldfields	175	Grassy Woodland		sparse (<20%)	patchy (20-80%)	continuous (>80%)
Goldfields	282	Shrubby Woodland	Central Vic Uplands	sparse (<20%)	patchy (20-80%)	patchy (20-80%)
Goldfields	641	Riparian Woodland	All Bio Regions	sparse (<20%)	patchy (20-80%)	continuous (>80%)
Goldfields	803	Plains Woodland	Wimmera	sparse (<20%)	sparse (<20%)	continuous (>80%)
Greater Grampians	3	Damp Sands Herb-rich Woodland	Wimmera & CVU	sparse (<20%)	patchy (20-80%)	continuous (>80%)
Greater Grampians	17	Riparian Scrub Complex	All Bio Regions	patchy (20-80%)	patchy (20-80%)	patchy (20-80%)
Greater Grampians	20	Heathy Dry Forest		patchy (20-80%)	patchy (20-80%)	continuous (>80%)
Greater Grampians	23	Herb-rich Foothill Forest	Central Vic Uplands	patchy (20-80%)	patchy (20-80%)	continuous (>80%)
Greater Grampians	71	Hills Herb-rich Woodland		sparse (<20%)	patchy (20-80%)	continuous (>80%)
Greater Grampians	193	Rocky Outcrop Herbland		sparse (<20%)	patchy (20-80%)	patchy (20-80%)
Greater Grampians	282	Shrubby Woodland	Central Vic Uplands	sparse (<20%)	patchy (20-80%)	patchy (20-80%)
Greater Grampians	704	Lateritic Woodland		sparse (<20%)	patchy (20-80%)	continuous (>80%)
Wimmera	641	Riparian Woodland		sparse (<20%)	patchy (20-80%)	continuous (>80%)
Wimmera	659	Plains Riparian Shrubby Woodland		sparse (<20%)	patchy (20-80%)	continuous (>80%)
Wimmera	660	Plains Woodland / Plains Grassy Wetland Mosaic		sparse (<20%)	sparse (<20%)	continuous (>80%)
Wimmera	679	Drainage-line Woodland		No Benchmark Available		
Wimmera	729	Sand Ridge Woodland / Damp Sands Herb-rich Woodland Mosaic		sparse (<20%)	patchy (20-80%)	continuous (>80%)
Wimmera	803	Plains Woodland		sparse (<20%)	sparse (<20%)	continuous (>80%)
All Bioregions	17a	Riparian Scrub Complex		patchy (20-80%)	patchy (20-80%)	patchy (20-80%)

Appendix G:

Data Summary Sheets and Field Assessment Photographs for 52 ISC sites assessed in 2002

Appendix H:

Summary of Wimmera River Catchment ISC Assessments in 2002

Table H1: Summary of ISC Assessment in 2002

Stream Name	Unit id	ISC PF Score	ISC SZ Score	Stream Order	Stream Style	Overstorey Vegetation Cover	Hydrology Type	Bioregion	Pre-1750 EVC
Dunmunkle Creek	FS #1	5	4	3	Alluvial Continuous 1	<20% Cover	Not Hydrologically Affected	Wimmera	Plains Woodland
Dunmunkle Creek	FS #2	5	6	3	Alluvial Continuous 1	<20% Cover	Not Hydrologically Affected	Wimmera	Drainage-line Woodland
Sheepwash Creek	FS #3	7	5	3	Alluvial Continuous 1	20-80% Cover	Not Hydrologically Affected	Wimmera	Drainage-line Woodland
Unknown 1	FS #4	3	4	3	Incised Alluvial Discontinuous	20-80% Cover	Not Hydrologically Affected	Wimmera	Plains Woodland
Sheepwash Creek	FS #5	8	6	8	Alluvial Continuous 1	20-80% Cover	Hydrologically Affected - Water Removed	Wimmera	Riparian Woodland
MacKenzie Creek	FS #6	6	8	4	Discontinuous Anabranching Chain of Ponds	20-80% Cover	Hydrologically Affected - Used for Water Transfer	Wimmera	Sand Ridge Woodland / Damp Sands Herb-rich Woodland Mosaic
MacKenzie Creek	FS #7	8	7	3	Discontinuous Anabranching Chain of Ponds	20-80% Cover	Hydrologically Affected - Water Removed	Wimmera	Plains Riparian Shrubby Woodland
Burnt Creek	FS #8	6	6	5	Alluvial Continuous 1	20-80% Cover	Hydrologically Affected - Water Removed	Wimmera	Riparian Woodland
Toolando Tributary	FS #9	6	9	2	Intact Valley Fill	<20% Cover	Not Hydrologically Affected	Greater Grampians	Lateritic Woodland
Mt Talbot Creek	FS #10	2	3	3	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Dundas Tablelands	Creekline Sedgy Woodland
Boggy Creek	FS #11	7	6	1	Partly Confined 1	<20% Cover	Not Hydrologically Affected	Dundas Tablelands	Damp Sands Herb-rich Woodland / Shrubby Woodland Mosaic
Boggy Creek	FS #12	8	8	3	Confined	> 80% Cover	Not Hydrologically Affected	Greater Grampians	Herb-rich Foothill Forest
MacKenzie Creek	FS #13	8	8	5	Partly Confined 2	20-80% Cover	Hydrologically Affected - Used for Water Transfer	Dundas Tablelands	Plains Grassy Woodland
MacKenzie Creek	FS #14	8	9	4	Gorge	> 80% Cover	Hydrologically Affected - Used for Water Transfer	Greater Grampians	Riparian Scrub Complex
MacKenzie Creek	FS #15	8	7	4	Partly Confined 1	> 80% Cover	Hydrologically Affected - Used for Water Transfer	Greater Grampians	Heathy Dry Forest
Bovine Creek	FS #16	8	9	3	Partly Confined 3	> 80% Cover	Not Hydrologically Affected	Greater Grampians	Damp Sands Herb-rich Woodland
Seven Dials Creek	FS #17	7	9	3	Steep Headwater	> 80% Cover	Not Hydrologically Affected	Greater Grampians	Heathy Dry Forest
Mt William Creek	FS #18	6	7	5	Alluvial Continuous 4	20-80% Cover	Not Hydrologically Affected	Goldfields	Creekline Grassy Woodland
Unknown 2	FS #19	4	8	3	Incised Alluvial Discontinuous	> 80% Cover	Not Hydrologically Affected	Greater Grampians	Shrubby Woodland
Golton Creek	FS #20	8	7	1	Steep Headwater	20-80% Cover	Not Hydrologically Affected	Greater Grampians	Hills Herb-rich Woodland
Golton Creek	FS #21	8	7	3	Gorge	> 80% Cover	Not Hydrologically Affected	Greater Grampians	Rocky Outcrop Herbland
Unknown 3	FS #22	4	8	3	Intact Valley Fill	> 80% Cover	Not Hydrologically Affected	Goldfields	Shrubby Woodland
Unknown 4	FS #23	5	5	2	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Plains Grassy Woodland
Basin Creek	FS #24	7	4	3	Incised Alluvial Discontinuous	20-80% Cover	Not Hydrologically Affected	Goldfields	Creekline Grassy Woodland
Seven Mile Creek	FS #25	6	4	4	Alluvial Continuous 4	20-80% Cover	Not Hydrologically Affected	Goldfields	Creekline Grassy Woodland
Seven Mile Creek	FS #26	5	3	5	Alluvial Continuous 1	20-80% Cover	Not Hydrologically Affected	Goldfields	Creekline Grassy Woodland
Wimmera River	FS #27A	7	7	8	Anabranching Fine Grained	20-80% Cover	Hydrologically Affected - Water Removed	Wimmera	Riparian Woodland
Wimmera River	FS #27B	6	8	5	Anabranching Fine Grained	20-80% Cover	Hydrologically Affected - Water Removed	Wimmera	Riparian Woodland
Heifer Station Creek	FS #28	4	4	4	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Plains Woodland
Unknown 5	FS #29	5	3	3	Intact Valley Fill	<20% Cover	Not Hydrologically Affected	Goldfields	Low Rises Grassy Woodland / Alluvial Terraces Herb-rich Woodland Mosaic
Unknown 6	FS #30	0	3	4	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Creekline Grassy Woodland
Unknown 7	FS #31	3	7	3	Cut & Fill	> 80% Cover	Not Hydrologically Affected	Goldfields	Low Rises Grassy Woodland / Alluvial Terraces Herb-rich Woodland Mosaic
Unknown 8	FS #32	5	7	4	Partly Confined 1	> 80% Cover	Not Hydrologically Affected	Goldfields	Alluvial Terraces Herb-rich Woodland
Glenpatrick Creek	FS #33	8	6	5	Partly Confined 2	20-80% Cover	Not Hydrologically Affected	Central Victorian Uplands	Riparian Forest

Stream Name	Unit id	ISC PF Score	ISC SZ Score	Stream Order	Stream Style	Overstorey Vegetation Cover	Hydrology Type	Bioregion	Pre-1750 EVC
Glenpatrick Creek	FS #34	8	9	4	Confined	> 80% Cover	Not Hydrologically Affected	Central Victorian Uplands	Herb-rich Foothill Forest
Spring Creek	FS #35	7	7	5	Partly Confined 1	20-80% Cover	Not Hydrologically Affected	Goldfields	Valley Grassy Forest
Nowhere Creek	FS #36	5	3	6	Partly Confined 3	20-80% Cover	Not Hydrologically Affected	Goldfields	Valley Grassy Forest
Nowhere Creek	FS #37	6	6	6	Partly Confined 3	<20% Cover	Not Hydrologically Affected	Goldfields	Valley Grassy Forest
Glenlofty Creek	FS #38	6	5	6	Chain of Ponds	<20% Cover	Not Hydrologically Affected	Goldfields	Creekline Grassy Woodland
Glenlofty Creek	FS #39	6	5	4	Chain of Ponds	<20% Cover	Not Hydrologically Affected	Goldfields	Herb-rich Foothill Forest
Reservoir Creek	FS #40	6	8	4	Alluvial Continuous 1	<20% Cover	Not Hydrologically Affected	Greater Grampians	Damp Sands Herb-rich Woodland
Unknown 9	FS #41	1	3	3	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Alluvial Terraces Herb-rich Woodland
Tributary of Pentland Creek	FS #42	2	4	3	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Grassy Woodland
Unknown 10	FS #43	4	4	4	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Alluvial Terraces Herb-rich Woodland
Unknown 11	FS #44	2	3	4	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Alluvial Terraces Herb-rich Woodland
Spring Creek	FS #45	2	3	5	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Creekline Grassy Woodland
Wimmera River	FS #46	6	5	8	Partly Confined 3	20-80% Cover	Not Hydrologically Affected	Goldfields	Riparian Woodland
Aston's Scour Tributary	FS #47	3	5	3	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Plains Woodland
Unknown 12	FS #48	1	4	3	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Creekline Grassy Woodland
Unknown 13	FS #49	5	3	4	Floodout	<20% Cover	Not Hydrologically Affected	Goldfields	Grassy Dry Forest
Unknown 14	FS #50	4	5	2	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Alluvial Terraces Herb-rich Woodland
Wattle Creek Tributary	FS #51	1	5	1	Incised Alluvial Discontinuous	<20% Cover	Not Hydrologically Affected	Goldfields	Creekline Grassy Woodland

Appendix I:

Map of Overstorey Vegetation Cover Assessment from Aerial Photograph Interpretation and Location of 89 ISC Sites Assessed in 1999 & 2002

Appendix J:

Hydrologic Analysis (from Wimmera River Geomorphic Assessment 2001) and Map

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 J1.

Table J1. Gauging stations used in analysis.

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

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 J2. 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.

Table J2: River Alteration Dates

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)

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 useful 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 J1.

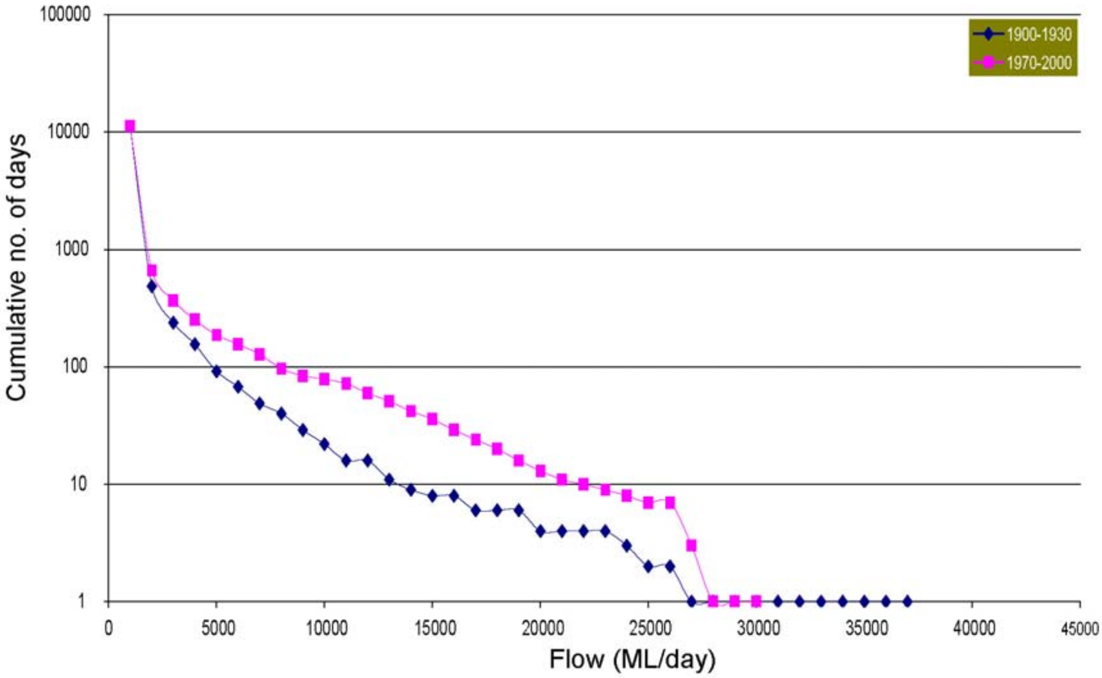


Figure J1 *Flow Duration Curves – Avoca River Coonooer Gauge (408 200)*

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 J2 and J3.

The change in flood frequency indicates a general increase in flood frequency magnitude for the equivalent Horsham post regulation period, Table J3.

Table J3 Flood Frequency Summary Avoca River at Coonooer Station.

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

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.

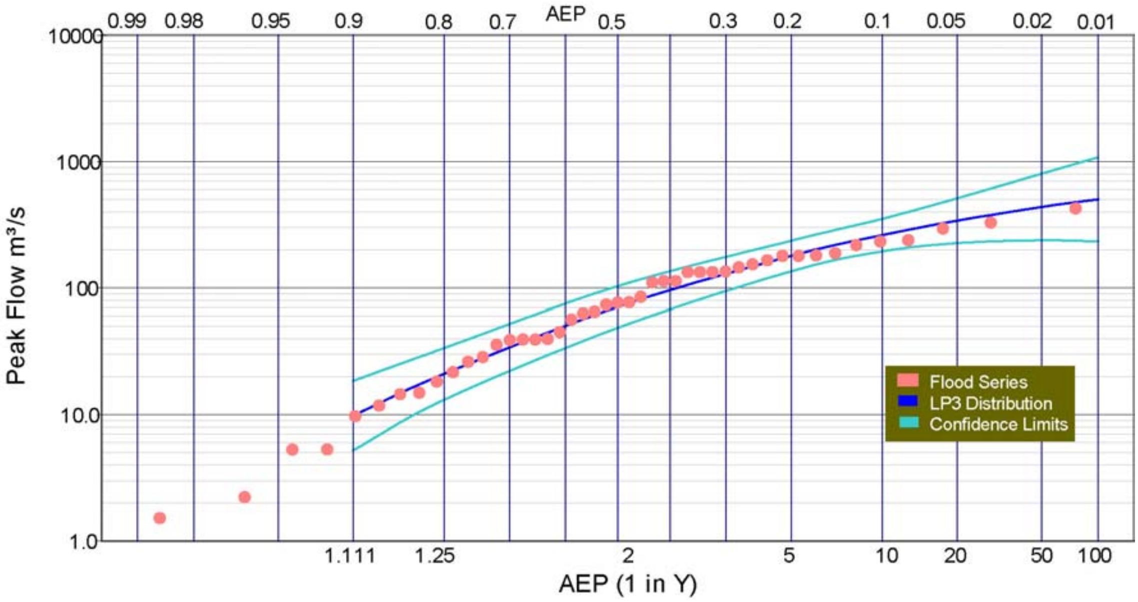


Figure J2 Flood Frequency Curve – Avoca (1900 – 1930)

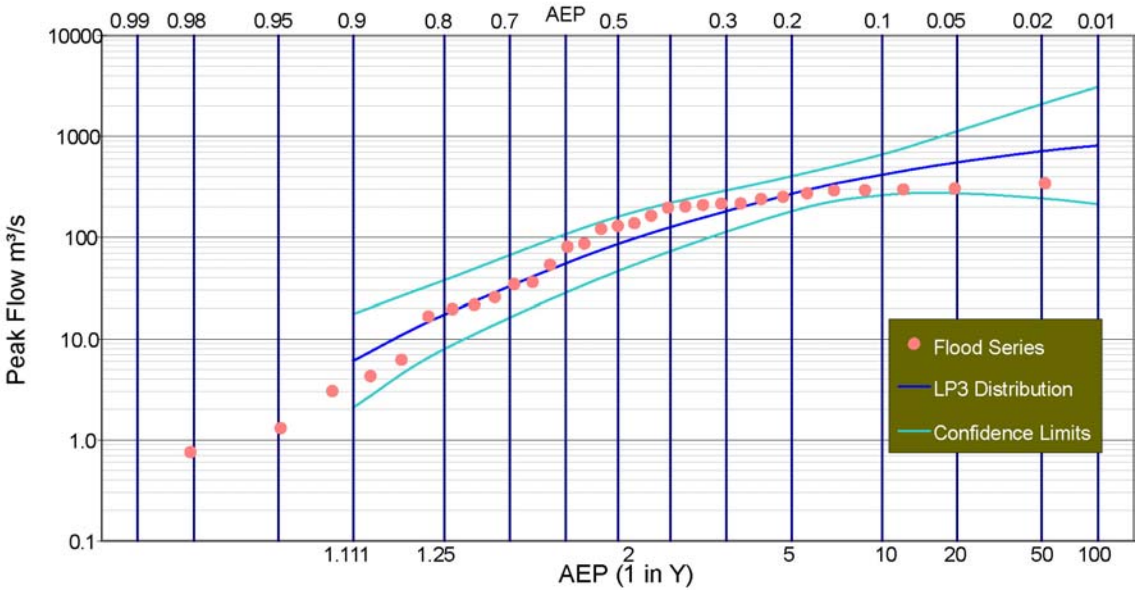


Figure J3 Flood Frequency Curve – Avoca (1970 – 2000)

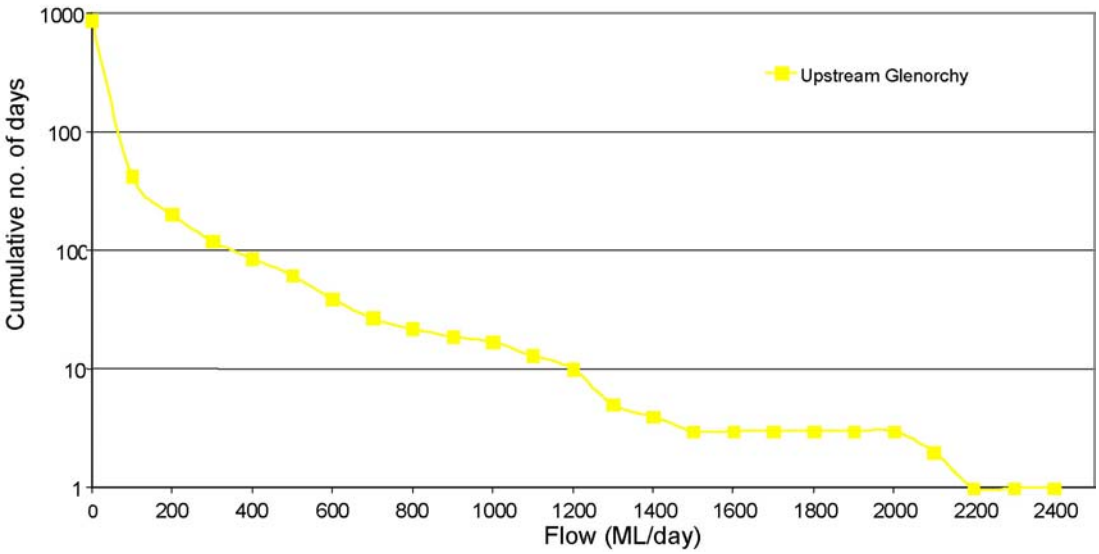
Wimmera River – Glynwylln Station

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 J4. Data has been used for sediment transport investigations



FigureJ4 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 J5.

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 J6, and post regulation 1970 to 2000 inclusive (31 years), Figure J7.

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 J4.

Table J4. Flood Frequency Summary Wimmera River Downstream of Horsham.

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.

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.

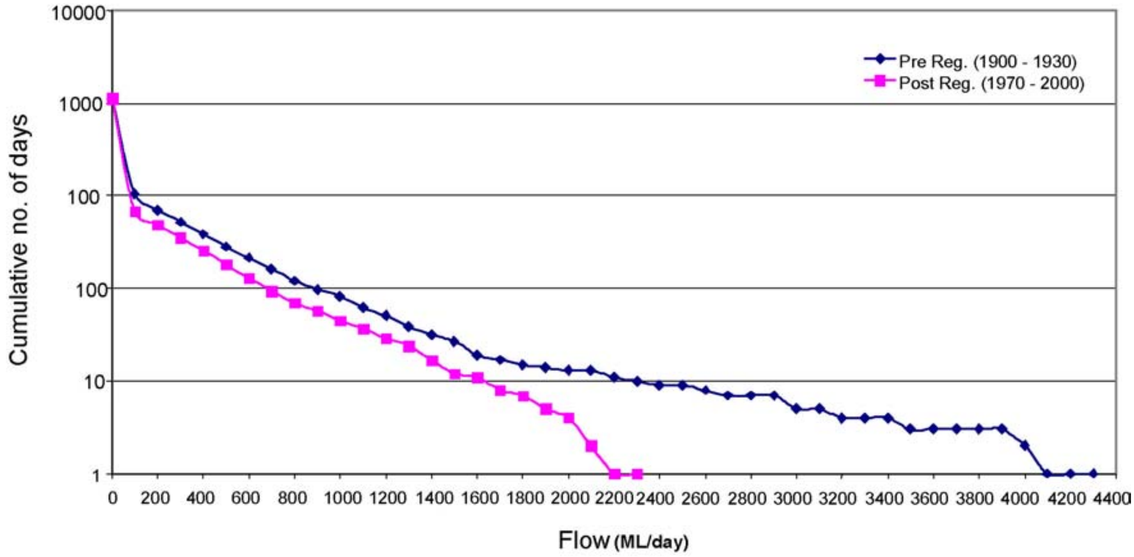


Figure J5 Flow Wimmera River Horsham Gauge (415 200)

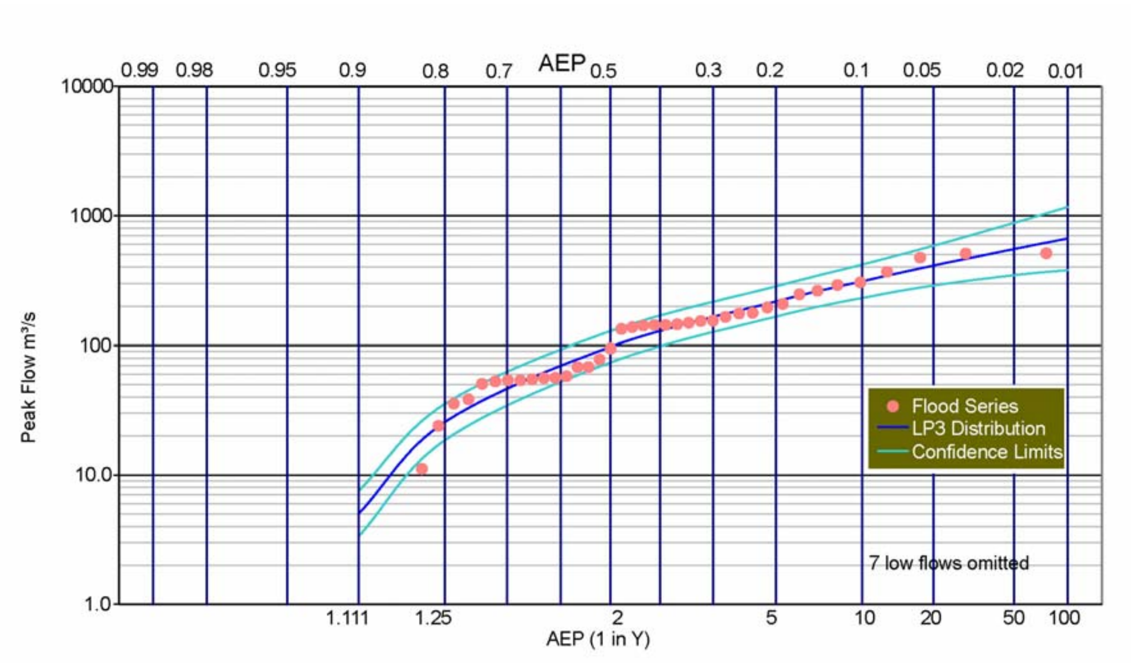


Figure J6 Horsham Pre Regulation 1900 – 1930

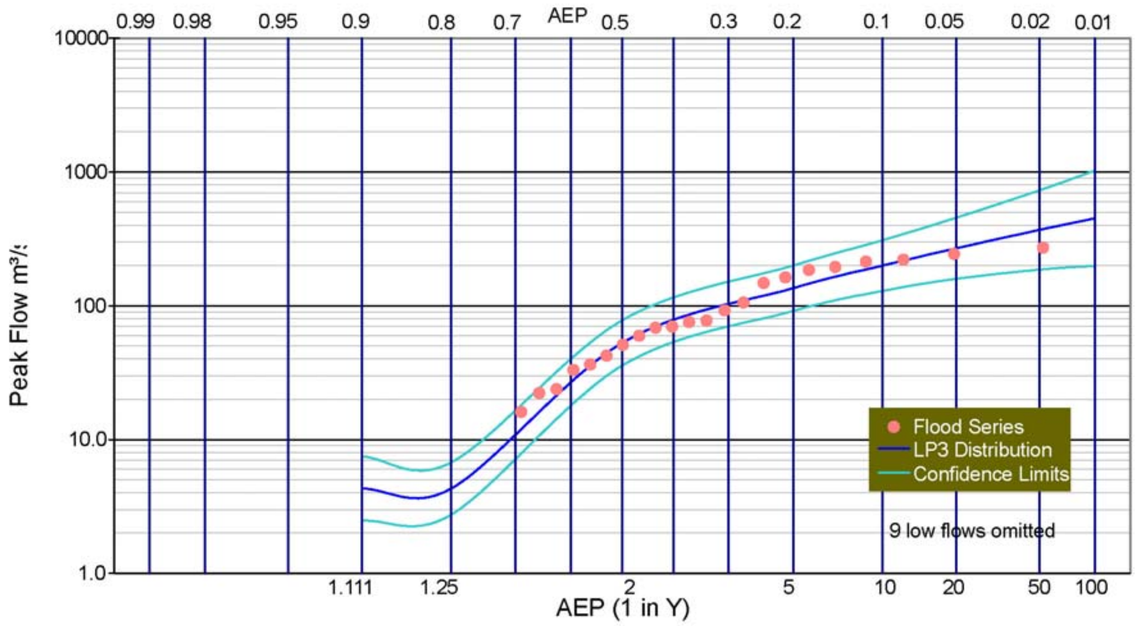


Figure J7 Horsham Post Regulation 1970 – 2000

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 J8.

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 J9). The multiplication of the flow duration in terms of a number of days and the stream power produces an effective discharge curve (Figure J10).

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 Wimmera Geomorphic Investigation 2001) 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.

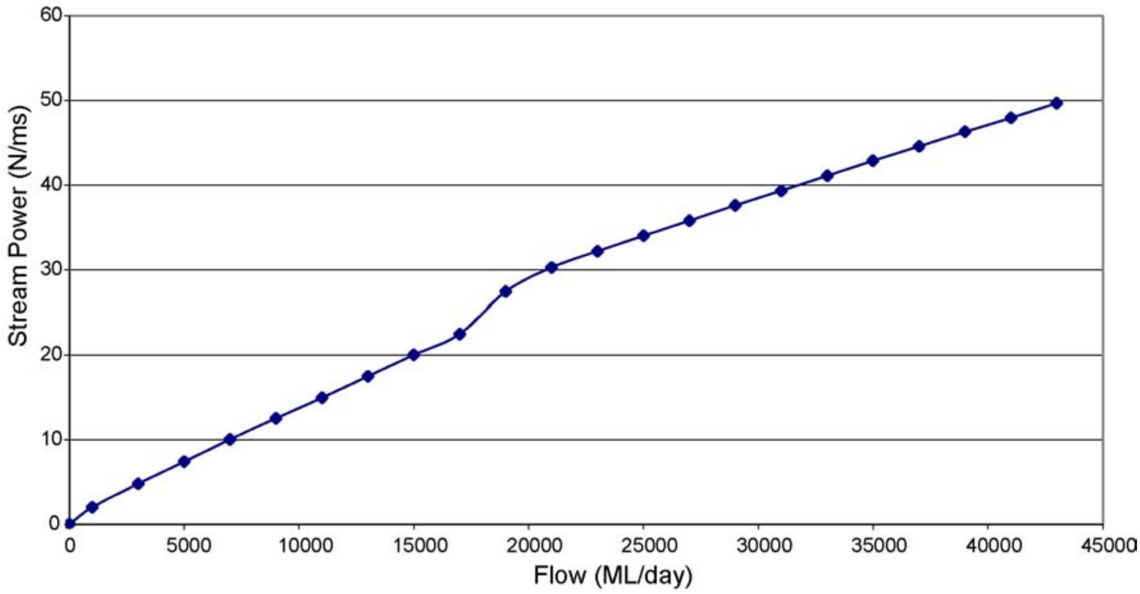


Figure J8 Stream Power – Downstream Horsham

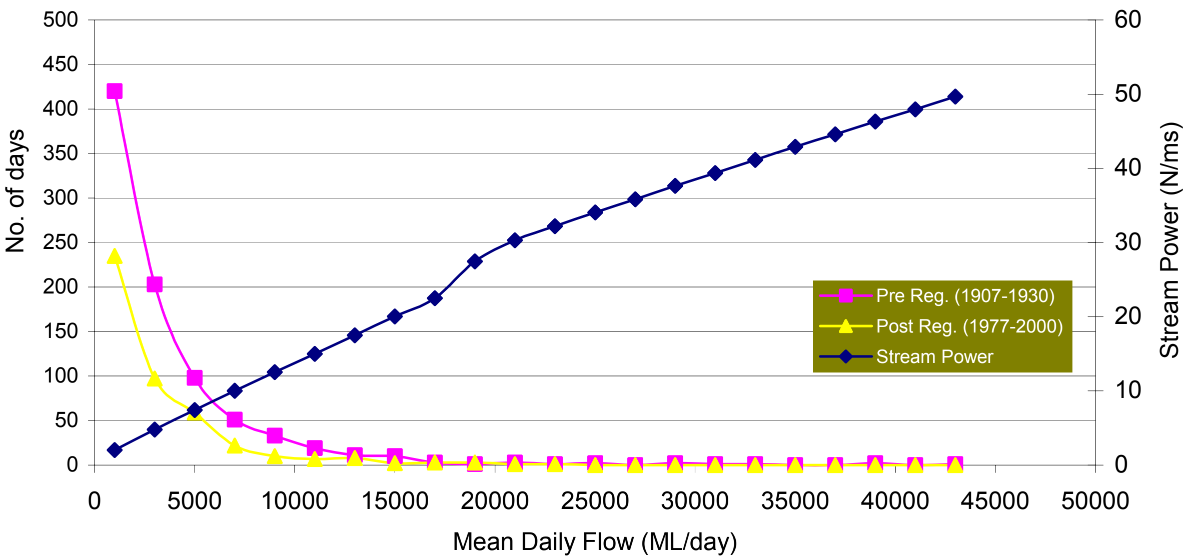


Figure J9 Flow Duration versus Stream Power – Downstream Horsham

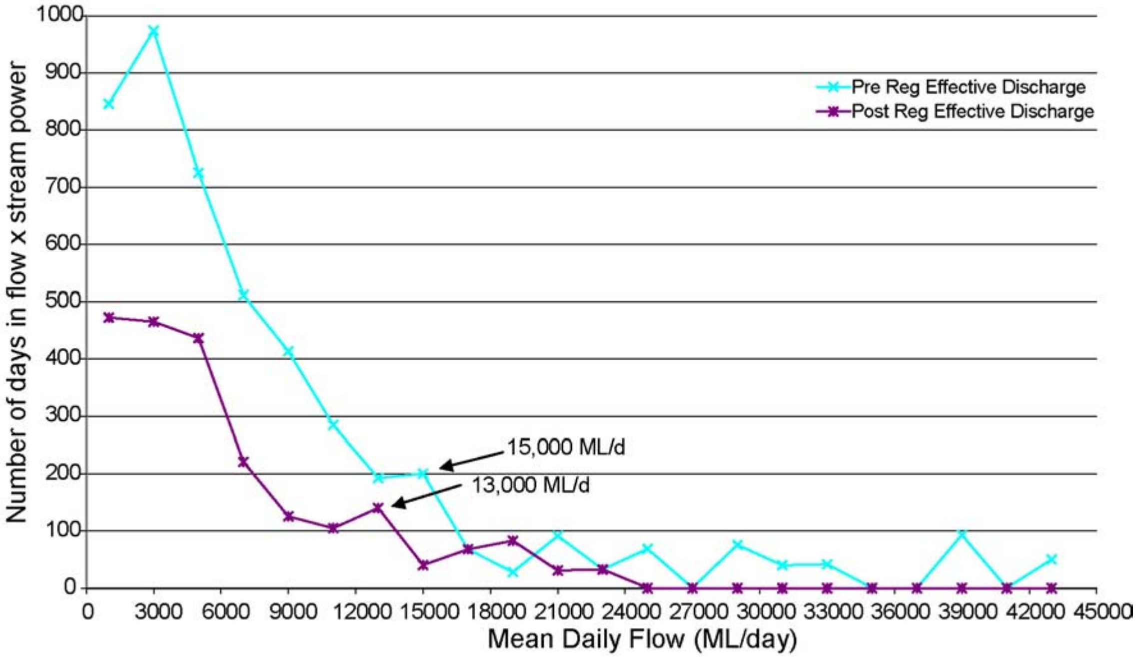


Figure J10 Effective Discharge Analysis – Downstream Horsham

Appendix K

Geomorphic summaries from Field Assessments at 52 sites in the Wimmera River Catchment in 2002

FS#1: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	2.5m	0.5m	>100m
Grade Slope	Very Low		
Sediment Type	Clay		
Stability	Very Stable	Very Stable	
Manning's	Low		
Reach Evolution	Stable		
Erosion	None noted		
Sedimentation	Depositional System		
Cut-offs/Avulsions	None		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Very Stable		
Water Present & Depth	No		
Existing Stream Works	None		
Land use	Cropping & Grazing		
Stock Access & Type	Yes – Sheep		
Stream Style Mapped	AC4		
Stream Style Observed	AC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The creek channel has been excavated in a minor way to a depth of about 0.5m with the spoil forming a low levee on one or both of the banks. See photos. There were no features noted on the floodplain.

FS#2: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	2 to 3m	1.5m	>100m
Grade Slope	Very Low		
Sediment Type	Clay and Silt		
Stability	Stable		
Manning's	Very Low		
Reach Evolution	Stable/mature		
Erosion	None		
Sedimentation	Depositional		
Cut-offs/Avulsions	None		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Stable		
Water Present & Depth	Yes 0.2m at gauging station retained behind gauging station drop structure, water is currently not flowing		
Existing Stream Works	Yes, drop structure at gauging station		
Land use	Road side reserve changing to grazing and cropping on the floodplain		
Stock Access & Type	No Transect 3, Yes Transects 1&2 (transect from ISC)		
Stream Style Mapped	AC1		
Stream Style Observed	AC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Dunmunkle Creek, has been deepened and may also being used as a irrigation channel or drain from irrigated pastures/paddocks

FS#3: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	12 to 15m	3 to 4m	>100m
Grade Slope	Very Low		
Sediment Type	Cemented Conglomerate changing to sand silt and clay down stream	Silts and clays	
Stability	Very Stable		
Manning's	Low		
Reach Evolution	Stable		
Erosion	Scour in channel bed around Conglomerate and trees	Minor erosion on parts of the bank probably to do with stock access in the past.	
Sedimentation	Loose gravel in the channel bed often associated with conglomerate bars and trees that also occur in the channel bed and banks		
Cut-offs/Avulsions	None		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Stable - no evidence of lateral migration		
Water Present & Depth	No flow, pools up to 1m deep?		
Existing Stream Works	None		
Land use	Grazing & Cropping		
Stock Access & Type	Yes - Most likely sheep		
Stream Style Mapped	AC1		
Stream Style Observed	Flood-channel - AC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Sheepwash Creek is a major flood-channel of the Wimmera River. It also acts as a collection points for tributaries draining the northern slopes of the Grampians. The channel is in good condition with regards to geomorphology.

FS#4: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	3m	0.5m	>100m
Grade Slope	Very Low		
Sediment Type	Silt and Clays		
Stability	Low Stability, the channel is currently incising		
Manning's	Very Low, Open Paddock		
Reach Evolution	The system is currently incising		
Erosion	Formation of scour pools in the channel and associated bank erosion		
Sedimentation	None system is eroding		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Very low		
Number of Channels	1		
Lateral Stability	Stable, no evidence of lateral movement or of channel straightening		
Water Present & Depth	None		
Existing Stream Works	None		
Land use	Cropping and Grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	Incised alluvial discontinuous (minor scale)		
Vulnerability (Intact Valley Fills only)	Highly vulnerable to incision		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The system is currently unstable and may become an active gullying system. The entire system is covered with the pasture of the paddock. A loss of this vegetation would severely destabilise the system. The grassy cover has masked the scouring during the aerial photograph survey.

FS#5: Geomorphic Field Assessment Notes

Channel Zone	Bed	Banks (Height)	Floodplain
Width	14-16m	3-4m	>100m
Grade Slope	Low		
Sediment Type	Clay & silt dominant, with minor sand bars, mid channel	Clay & Silt	
Stability	Very Stable, no evidence of channel incision		
Manning's	Low to moderate		
Reach Evolution	Stable flood channel not undergoing any current geomorphic change.		
Erosion	None noted		
Sedimentation	Transporting system		
Cut-offs/Avulsions	None noted, though scour holes occur at trees bases		
Channel Sinuosity	Low		
Number of Channels	Single channel, however is a subsidiary channel to the Wimmera River		
Lateral Stability	Stable, no evidence of lateral movement		
Water Present & Depth	No		
Existing Stream Works	None		
Land use	Reserve changing to cropping & grazing		
Stock Access & Type	Yes, none present though probably sheep		
Stream Style Mapped	AC1		
Stream Style Observed	Flood-channel - AC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Well preserved channel geomorphically. The channel is predominantly single though splays to a multi-channel in one part with low islands that are well vegetated.

FS#6: Geomorphic Field Assessment Notes

Channel Zone	Bed	Banks (Height)	Floodplain
Width	6-8m	1-2m	>100m
Grade Slope	Low Gradient		
Sediment Type	Sand		
Stability	Moderate		
Manning's	Moderate		
Reach Evolution	Mature reach		
Erosion	None evident		
Sedimentation	Pre dominantly a depositional system		
Cut-offs/Avulsions	Yes - Multi channel system		
Channel Sinuosity	Moderate		
Number of Channels	Approximately 3		
Lateral Stability	Moderately stable		
Water Present & Depth	No		
Existing Stream Works	None noted		
Land use	Reserve		
Stock Access & Type	No		
Stream Style Mapped	AC5		
Stream Style Observed	Discontinuous Anabranching Chain of Ponds		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The channels consist of scour pools (often associated with channel bends) separated by runs. The channels seem to be fairly stable showing no signs of lateral movement. However there are common scours in the floodplain which may link up with the currently channels in floods allowing the river to evolve.

FS#7: Geomorphic Field Assessment Notes			
Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	3-5m	1-2m	100m
Grade Slope	Very Low		
Sediment Type	Sand & Silt	Silt & Clay	
Stability	Stable		
Manning's	Moderate		
Reach Evolution	Mature - no current geomorphic change		
Erosion	None noted		
Sedimentation	Transporting system		
Cut-offs/Avulsions	None		
Channel Sinuosity	Moderate		
Number of Channels	1		
Lateral Stability	Stable - Minor Point Bars and Meanders		
Water Present & Depth	No		
Existing Stream Works	None noted		
Land use	Reserve		
Stock Access & Type	No		
Stream Style Mapped	AC9		
Stream Style Observed	Discontinuous Anabranching Chain of Ponds		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		
Comments: Low sinuosity channel with minor point bar and bench development on some meander bends. Banks and floodplain thickly vegetated with shrubs.			

FS#8: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	3-4m	0.2m	>100m
Grade Slope	Very Low		
Sediment Type	Clay	Clay	Silt and Clay
Stability	Stable		
Manning's	Moderate		
Reach Evolution	Stable - though may have changed as the creek is currently used as a channel for the transportation of irrigation water		
Erosion	None noted		
Sedimentation	Eroding / transporting system		
Cut-offs/Avulsions	Possible 1 meander cut-off, very old. Occurs as a swamp on the outer side of a meander bend.		
Channel Sinuosity	Very Low		
Number of Channels	1		
Lateral Stability	Stable no movement noted		
Water Present & Depth	Yes, 1m+		
Existing Stream Works	Used as a distribution channel		
Land use	Cropping & grazing		
Stock Access & Type	Yes, sheep		
Stream Style Mapped	AC9		
Stream Style Observed	AC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Burnt Creek is a low sinuosity channel that is used as a channel for the distribution of irrigation water. There are a few very minor scours and possible flood channels on the floodplain, though these are very straight and may be anthropogenic.

FS#9: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	150m	NA	NA
Grade Slope	Low		
Sediment Type	Sand & Silt		
Stability	Very Stable		
Manning's	Moderate - would usually be higher but the vegetation is still recovering form being burnt.		
Reach Evolution	Mature		
Erosion	None Noted		
Sedimentation	Depositional		
Cut-offs/Avulsions	NA		
Channel Sinuosity	NA		
Number of Channels	NA		
Lateral Stability	NA		
Water Present & Depth	None		
Existing Stream Works	None		
Land use	Reserve		
Stock Access & Type	No		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	Intact Valley Fill		
Vulnerability (Intact Valley Fills only)	Not vulnerable		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: An intact valley fill system, that looks very stable despite having been recently burnt. No evidence of scour or channel development was noted.

FS#10: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	2-3m	2-3m	>100m
Grade Slope	Low		
Sediment Type	Clay & Silt		
Stability	Low stability, system is currently incising		
Manning's	Very Low - Open Paddock		
Reach Evolution	Immature, actively evolving		
Erosion	Currently incising in bed eroding banks		
Sedimentation			
Cut-offs/Avulsions	Abandoned meander loop which has now become vegetated with pasture		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Stable, no signs of lateral migration or channel straightening		
Water Present & Depth	No		
Existing Stream Works	None noted		
Land use	Grazing		
Stock Access & Type	Yes, sheep		
Stream Style Mapped	Incised alluvial discontinuous		
Stream Style Observed	Incised alluvial discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	Immature, just beginning to incise		

Comments: A recently incised Intact Valley Fill. The system is currently unstable with very little vegetation in the channel or on its actively eroding banks.

FS#11: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	1-2m	3-4m	>100m
Grade Slope	Low		
Sediment Type	Sand	Sand & Silt	
Stability	Stable - no active evidence of channel evolution		
Manning's	Moderate		
Reach Evolution	Mature		
Erosion	Very limited – Outer bends of some meanders and scour around fallen trees etc		
Sedimentation	Transporting system		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low to moderate		
Number of Channels	1		
Lateral Stability	Stable, minor scouring and migration associated with some meander bends		
Water Present & Depth	No		
Existing Stream Works	None noted		
Land use	Reserve		
Stock Access & Type	No		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	PC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: A moderately sinuous channel that is partially controlled by the foothills of the western Grampians. There is minor development of meander bends and benches in arts of the channel.

FS#12: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	1.5-2m	1.0m	Very Limited to RHB
Grade Slope	Moderate		
Sediment Type	Rock - Cobbles approximately 100-150mm		
Stability	Very stable		
Manning's	High		
Reach Evolution	Mature		
Erosion	None noted		
Sedimentation	Incising system		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Very Low		
Number of Channels	1		
Lateral Stability	Very Stable		
Water Present & Depth	Yes 150mm		
Existing Stream Works	None		
Land use	National Park		
Stock Access & Type	National Park		
Stream Style Mapped	Confined		
Stream Style Observed	Confined		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: A confined stream in the Grampians National park. The system is intact.

FS#13: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	4-5m	3m	~200m
Grade Slope	Low to Moderate		
Sediment Type	Sandy Clay, the clay has a plastic texture		
Stability	Stable		
Manning's	Moderate		
Reach Evolution	Mature		
Erosion	Minor scouring on the outer banks of meander bends		
Sedimentation	Transporting system		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low to Moderate		
Number of Channels	1 – Occasional very minor abandoned channel relics or flood scours on the floodplain		
Lateral Stability	Stable - no evidence of lateral migration		
Water Present & Depth	Yes – 600mm+		
Existing Stream Works	The creek channel is used to transport water from the Wartook Reservoir		
Land use	Reserve left bank, grazing property right Bank		
Stock Access & Type	Yes on the right bank, most likely sheep or cattle		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	PC2		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Meandering stream that is partly confined by the foothills of the Grampians. Minor scouring is noted on the outer parts of some meander bends. These bends are also usually associated with fallen trees that have been undermined.

FS#14: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	2-14m	0.5m	NA
Grade Slope	Steep		
Sediment Type	Cobbles to boulders to country rock. Minor gravel		
Stability	Very Stable		
Manning's	Moderate to high		
Reach Evolution	Mature		
Erosion	NA		
Sedimentation	Transport /erosion		
Cut-offs/Avulsions	NA		
Channel Sinuosity	Very Low		
Number of Channels	1		
Lateral Stability	Very Stable		
Water Present & Depth	Yes. 100mm to 2m+ in pools		
Existing Stream Works	Wartook Reservoir upstream		
Land use	National Park		
Stock Access & Type	No		
Stream Style Mapped	Confined		
Stream Style Observed	Gorge		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Classic Gorge

FS#15: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	3-20m	1m	60m in pockets
Grade Slope	Moderate to steep		
Sediment Type	Cobbles, boulders & bed rock		
Stability	Stable		
Manning's	High		
Reach Evolution	Mature		
Erosion	None noted		
Sedimentation	Transporting/eroding system		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Very stable		
Water Present & Depth	Yes, $600mm^+$ in pools		
Existing Stream Works	Wartook Reservoir upstream		
Land use	National Park		
Stock Access & Type	None noted		
Stream Style Mapped	Confined		
Stream Style Observed	PC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: A partly confined stream on an upland plateau above the MacKenzie Falls. The stream seems in good geomorphic condition apart from changed natural flows due to water being released or withheld in the Wartook reservoir upstream.

FS#16: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	1-1.5m	1-1.5m	50-80m
Grade Slope	Moderate		
Sediment Type	Gravels to boulders - 25mm to 500mm		
Stability	Stable		
Manning's	High		
Reach Evolution	Mature		
Erosion	None noted		
Sedimentation	Eroding / Transporting		
Cut-offs/Avulsions	None		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Stable with no evidence of lateral migration		
Water Present & Depth	Yes, 100-300mm		
Existing Stream Works	Bridge just upstream		
Land use	National Park		
Stock Access & Type	No		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	PC3		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Minor tributary of Fyans Creek consisting of pools and riffles and logjams. Scour is associated with major logjam and channel bification. There is minor scour/erosion on the outer bank of some meander bends.

FS#17: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	0.5-1.5m	<1.0m	NA
Grade Slope	Steep		
Sediment Type	Gravels to boulders and bedrock - 15mm+		
Stability	The system is stable though the colluvium and alluvial material will be moved and reworked with large flows the channel is controlled by the bedrock bars.		
Manning's	Very High		
Reach Evolution	Mature		
Erosion	Minor unstable banks in the colluvial material		
Sedimentation	Transporting and eroding system		
Cut-offs/Avulsions	NA		
Channel Sinuosity	Very Low		
Number of Channels	1		
Lateral Stability	Very Stable		
Water Present & Depth	Yes - 10mm on riffles and rock bars to 600mm in pools		
Existing Stream Works	None		
Land use	National Park		
Stock Access & Type	NA		
Stream Style Mapped	Confined		
Stream Style Observed	Steep headwater		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The reach consists of bedrock bars and alluvial material that has a channel cut into it. The bars seem to be 'damming' the alluvial material. Pools are scoured into the colluvial material around LWD or at the base of rock bars. Pools have also been eroded into the bedrock as 'whirl pools' these still contain the grindstones.

FS#18: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	3-8m	2-3m	>100m
Grade Slope	Very Low		
Sediment Type	Sand	Sandy silt	
Stability	Moderately stable		
Manning's	Low to Moderate		
Reach Evolution	Mature		
Erosion	Minor instability on the outer banks on some channel bends.		
Sedimentation	Sand bars occur mid-channel and there is scouring around LWD		
Cut-offs/Avulsions	Yes, minor channel on floodplain		
Channel Sinuosity	Moderate		
Number of Channels	1		
Lateral Stability	Moderate - Abandoned channel on flood plain indicates that the river does evolve laterally though there is no evidence of new movement.		
Water Present & Depth	Yes, up to 1m in pools though not flowing and the pools are isolated		
Existing Stream Works	None		
Land use	Riverside reserve, maybe grazed? Not currently being grazed		
Stock Access & Type	?		
Stream Style Mapped	AC1		
Stream Style Observed	AC4		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Large amount of leaf litter in the channel. Sand bed channel. Scour holes in channel are often associated with meander bends, though also occurs in straighter sections of the channel and around LWD.

FS#19: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	2-3m	3-4m	>100m
Grade Slope	Very Low		
Sediment Type	Sand	Silty Clay with minor sand	
Stability	The channel currently evolving and therefore is unstable		
Manning's	High		
Reach Evolution	The channel currently seems to be stabilising after a period of incision		
Erosion	The channel is currently eroding on the outer banks of all meander bends.		
Sedimentation	The base of the channel seems to be accreting with lateral and mid-channel bars being deposited. Vegetation is also being to gain a foothold on these new sand bars		
Cut-off/Avulsions	None noted		
Channel Sinuosity	High		
Number of Channels	1		
Laterale Stability	The channel is currently eroding on the outer banks of all meander bends.		
Water Present & Depth	Yes, 100mm max apart from the rare pools		
Existing Stream Works	None noted		
Land use	Reserve?		
Stock Access & Type	No		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	The system seems to be in a recovery stage with vegetation beginning to gain a foothold in the channel banks and bed.		

Comments: Banks seem to becoming revegetated more so on the inner banks of bends and in straight section of the channel as well as some of the recently deposited sand bars. The area seems to be recovering from past clearing or mining, unsure?

FS#20: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	1m	NA	NA
Grade Slope	Steep		
Sediment Type	Gravels to cobbles	Sand silty soil overlying country rock	
Stability	Stable system		
Manning's	High		
Reach Evolution	Mature		
Erosion	None noted		
Sedimentation	Eroding / transporting system		
Cut-offs/Avulsions	None		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Very Stable		
Water Present & Depth	No, dampness in some of the scour/pools of the channel bed, probably from the rain 2 days prior to the survey		
Existing Stream Works	None		
Land use	National Park		
Stock Access & Type	No		
Stream Style Mapped	Steep Headwater, a 1st order stream was assessed		
Stream Style Observed	Steep Headwater		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Signs of overland flow around the stream, probably during the rain 2 days prior to the survey. Steep headwater stream, which is bedrock, controlled with areas section of gravels, cobbles and boulders occupying the channel. There is a large amount of vegetation in the channel. The area has been burnt previously. Minor duplication of channel at the confluence of a very minor tributary or gully/ or pocket of floodplain all is still very controlled. The area has been cleared and maybe mined (access road s the copper mine track uncertain of the location of the mine).

FS#21: Geomorphic Field Assessment Notes

Channel Zone	Bed	Banks (Height)	Floodplain
Width	1m Base flow 10m high flow	NA	NA
Grade Slope	Very Steep		
Sediment Type	Bedrock & boulders		
Stability	Very Stable		
Manning's	Moderate		
Reach Evolution	Mature		
Erosion	None		
Sedimentation	Eroding/transporting system		
Cut-offs/Avulsions	None		
Channel Sinuosity	Very low		
Number of Channels	1		
Lateral Stability	Very stable		
Water Present & Depth	Yes, 1 mm seeps and 1m+ in pools		
Existing Stream Works	None		
Land use	National Park		
Stock Access & Type	None		
Stream Style Mapped	Confined		
Stream Style Observed	Gorge		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Classic gorge though very steep access very difficult.

FS#22: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	10-15m	NA	>100m
Grade Slope	Very Flat		
Sediment Type	Silty clays		
Stability	Very stable		
Manning's	Moderate to High		
Reach Evolution	Mature		
Erosion	Minor canalisation with small eroding head <0.5m and a minor scour hole		
Sedimentation	Accreting system, erosion scare also seem to be infilling		
Cut-offs/Avulsions	NA		
Channel Sinuosity	NA		
Number of Channels	NA		
Lateral Stability	NA		
Water Present & Depth	No		
Existing Stream Works	None		
Land use	Reserve		
Stock Access & Type	No - though probably in the past		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	Intact Valley Fill		
Vulnerability (Intact Valley Fills only)	System moderately vulnerable to change		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: System seems to be quite stable and the erosion scars seem to be infilling and recovering with vegetation being established on the erosion scar and new growth on clear areas (grassed areas) of the system.

FS#23: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	1-2m	1m	30-40m
Grade Slope	Moderate		
Sediment Type	Sand Bed	Silty Clay	Silty Clay
Stability	Moderate		
Manning's	Low		
Reach Evolution	The reach is infilling and stabilising		
Erosion	Erosion is occurring in some part of the bed	Erosion is occurring on some of the meander bend outer banks	
Sedimentation	The channel is accumulating sand		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Stable, minor erosion on some bends and banks		
Water Present & Depth	None noted		
Existing Stream Works	None noted		
Land use	Grazing, though the stream has been generally fenced off.		
Stock Access & Type	Yes, though probably only as drought feed. Sheep		
Stream Style Mapped	Incised alluvial discontinuous		
Stream Style Observed	Incised alluvial discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	In a stable phase		

Comments: The system seems to be recovering, though not to the original discontinuous system. Stream seems to be very similar to Ian Rutherfurd's study near Euroa with sand beds in eroded old discontinuous systems.

FS#24: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	1.5-2.5m	0.5-1.0m	20m each bank
Grade Slope	Moderate		
Sediment Type	Sand with minor cemented Sandstone	Silty clay with minor sand	
Stability	Moderate		
Manning's	Low		
Reach Evolution	Either a recovering Channelised discontinuous (Most likely) or a PC3.		
Erosion	Minor erosion, (bare banks) on meander bends		
Sedimentation	Minor sand bars in mid channel		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Stable no evidence of migration		
Water Present & Depth	No		
Existing Stream Works	None noted		
Land use	Grazing		
Stock Access & Type	Yes, Sheep most likely, none present		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	System seems to be recovering		

Comments: The system seems to have evolved into a semi-stable meander sand stream; benches have begun to form on each bank. There is only limited erosion occurring and this is associated with meander bends.

FS#25: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	1.0-1.5m	1m	~500m
Grade Slope	Low		
Sediment Type	Silty sand with minor gravels		
Stability	Stable		
Manning's	Low to moderate		
Reach Evolution	Mature		
Erosion	None noted, in channel some associated with meander bends		
Sedimentation	Fines are infilling scour holes and pools		
Cut-offs/Avulsions	None noted.		
Channel Sinuosity	Moderate		
Number of Channels	1		
Lateral Stability	No sigh of lateral movement		
Water Present & Depth	Yes, No flow, though pool depth varied from 0.1m to 1m+		
Existing Stream Works	None noted		
Land use	Cropping and grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	AC4		
Stream Style Observed	AC4		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	Systems has reached a stable form		

Comments: Pools silting up according to farmer. Erosion is limited meander bends. The streambed consists of sand and gravel bars. According to the farmer the stream no longer has fish in any of its pools. Benches exist in the channel on both banks and are sparsely vegetated.

FS#26: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	10m	2-2.5m	>100m
Grade Slope	Low		
Sediment Type	Silt and clay bed, banks and floodplain. Minor sand and gravel bars in channel bed		
Stability	Moderate		
Manning's	Low		
Reach Evolution	Mature		
Erosion	Yes, Minor erosion on meander bends and some straight channel sections		
Sedimentation	Sand and gravel bars in stream		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Very Low		
Number of Channels	1 - Seven mile creek is also a flood channel for the Wimmera River		
Laterale Stability	No evidence of lateral movement		
Water Present & Depth	Yes, in pools to an approx depth of 1.5m		
Existing Stream Works	None noted - Bridge 50m upstream of transect 1		
Land use	Grazing		
Stock Access & Type	Yes, sheep		
Stream Style Mapped	AC1		
Stream Style Observed	Flood-channel – AC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: All erosion noted is just non-vegetated banks, which do not seem to be actively retreating. Channel consists of pools and benches with minor gravel and sand bars.

FS#27 Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	8-14m	2-3m	>500m
Grade Slope	Very Low		
Sediment Type	Silts and Clays		
Stability	Stable		
Manning's	Moderate		
Reach Evolution	Mature		
Erosion	Very Minor erosion on some banks		
Sedimentation	Minor fine sand bars in the channel bed and Scour holes around LWD, trees and Meander bends		
Cut-offs/Avulsions	Yes, the system is an anabranching system		
Channel Sinuosity	Moderate		
Number of Channels	1 main and multiple minor channels of anabranches and high flow channels		
Laterale Stability	No evidence of current lateral migration though the system is prone to channel changes		
Water Present & Depth	Yes, in pools up to 1m in depth		
Existing Stream Works	None noted		
Land use	Marma State Forest		
Stock Access & Type	No		
Stream Style Mapped	AC9		
Stream Style Observed	AC9 (Anabranching Fine Grained)		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Single main channel with multiple cut-offs and islands within the major Anabranching system which occurs about 400m west of the current active Wimmera River channel at low flow levels.

FS#27b: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	10-12m	2-3m	>500m
Grade Slope	Low		
Sediment Type	Fines, mainly silts and clays, minor sand in bars in channel		
Stability	Stable		
Manning's	Moderate		
Reach Evolution	Mature		
Erosion	None noted		
Sedimentation	Accumulating fines		
Cut-offs/Avulsions	Yes – the system is an anabranching system with a single main channel with multiple cut-offs and minor anabranches and a major anabranch or flood channel with is on associated cut-offs -see site 27.		
Channel Sinuosity	Moderate		
Number of Channels	2		
Laterale Stability	Currently stable though the ?		
Water Present & Depth	Yes, 1m+		
Existing Stream Works	None noted		
Land use	River reserve - Marma State Forest		
Stock Access & Type	No		
Stream Style Mapped	AC9		
Stream Style Observed	AC9 (Anabranching Fine Grained)		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The Wimmera River's main channel is a series of reed-fringed pools separated by vegetated bars, which are usually reed, and scrub dominated. The system seems to be in good condition geomorphically. Te pools in the system seem to contain permanent water.

FS#28: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	4-8m	1-1.5m	50m RB, >200m LB
Grade Slope	Low		
Sediment Type	Silty Soils with minor gravel lenses and minor cemented conglomerate exposed in channel bed		
Stability	Low to moderate		
Manning's	Very Low		
Reach Evolution	Stabilising after incision, Channel hasn't changed in 50 years, A Bibby Landholder		
Erosion	Grass in parts of the channel and some bare banks, though there is no evidence of current activity erosion		
Sedimentation	Minor gravel bars forming generally as point bars in the channel		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low to moderate		
Number of Channels	1		
Laterale Stability	Stable no signs of lateral movement		
Water Present & Depth	None noted		
Existing Stream Works	None noted		
Land use	Cropping and grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	Current systems seems to be stable		

Comments: Comment form landholder:' Scour hasn't changed since the property was acquired in 1952.' The Current channel seems to be bedrock controlled, with bars forming knick points in the channel. The bedrock is close to the surface according to the landholder. Gravel bars are common in current channel usually on meander bends and there is a series of benches in the channel that may have been formed by a second period of incision. The channel has a tighter meander than the original channel, which contains the benches.

FS#29: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	2-6m		30m in pockets
Grade Slope	Low to moderate		
Sediment Type	Clayey silt with minor coarse sand		
Stability	Stable		
Manning's	Very Low		
Reach Evolution	Mature		
Erosion	Yes, though minor and restricted to the outer part of one bend and a small section of bank/valley side about 5m from the Intact Valley Fill		
Sedimentation	Accreting		
Cut-offs/Avulsions	NA		
Channel Sinuosity	Low		
Number of Channels	NA		
Laterale Stability	NA		
Water Present & Depth	Stable		
Existing Stream Works	Major farm dam across channel		
Land use	Cropping & grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	Intact Valley Fill		
Vulnerability (Intact Valley Fills only)	Moderate		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Minor bare (vegetation free patches) in the channel but these are usually associated with stock tracks. The system seems to be fairly stable; All bar patches more susceptible to erosion are on the channel sides. The Dam at the upstream end of the reach will help to mitigate large flows and potential scouring events.

FS#30: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	4-8m	2-3.5m	20-30m in pockets
Grade Slope	Moderate		
Sediment Type	Silty clay with minor sand and gravel bars		
Stability	Unstable		
Manning's	Low		
Reach Evolution	Evolving, the reach is still deepening		
Erosion	Both the channel and banks are still actively eroding		
Sedimentation	The system is still eroding though there are gravel bars (point bars) in the channel. The gravel is derived form insitu gravels from the eroded material		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Moderate		
Number of Channels	1		
Laterale Stability	Highly stable		
Water Present & Depth	Yes 0.5m in a single pool		
Existing Stream Works	None noted		
Land use	Cropping and grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	The system is still eroding and incising and is currently unstable and actively evolving.		
Comments: The system is highly unstable			

FS#31: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	1-3m	0.2-3m	~50m
Grade Slope	Moderate		
Sediment Type	Gravel Bed		
Stability	Moderate		
Manning's	Low to moderate		
Reach Evolution	The system seems to be in recovery phase, though it is still eroding in places		
Erosion	Yes		
Sedimentation	Gravel bars are often associated LWD		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	Single main channel, there are many subsidiary channel but theses are relics of past mining activity		
Lateral Stability	Stable, no evidence of lateral; migration		
Water Present & Depth	None noted		
Existing Stream Works	None noted		
Land use	Reserve		
Stock Access & Type	No		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	Cut & Fill		
Vulnerability (Intact Valley Fills only)	Moderate		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: Area has undergone extensive mining in the past; there are many shafts and trenches cut into the surrounding area/floodplain? these workings show many patches of minor erosion. Both cut sections of the assessed reach have gravel beds. It is unclear if the cut and fill morphology is 'natural' or a response to the past mining activity. The gravel bars/channel bed may also either be due to erosion of the insitu material or may be another relic of the historic mining activity. GEOLOGY: Silty clay material with frequent layers alluvial gravel layers.

FS#32: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	1-2.5m	0.2-3m	NA
Grade Slope	Low to moderate		
Sediment Type	Silty Clay with minor gravel pars in channel bed		
Stability	Moderate		
Manning's	Moderate		
Reach Evolution	Stabilising		
Erosion	Yes, minor erosion on some channel bends and in parts of the channel		
Sedimentation	Minor gravel Bars		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Moderate		
Number of Channels	1		
Lateral Stability	Stable - no signs of lateral migration		
Water Present & Depth	None noted		
Existing Stream Works	None noted		
Land use	Pyrenees State Park		
Stock Access & Type	No		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	PC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	System is stable, may be returning to Intact Valley Fill		

Comments: The stream is now a PC1, though in the past it may have been an Intact Valley Fill prior to the mining activities that have affected the channel. Parts of the channel are very straight and regular and may have been constructed during the mining period. Also the channel becomes indistinct in some places where the gully floor/floodplain widens and more distinct in more confined parts of the channel.

FS#33: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	6-8m	1-2m	80-120m
Grade Slope	Moderate		
Sediment Type	Gravel to cobble stream bed with cobbles being dominant, 25mm-800mm with average being 200mm. Minor bedrock bars are also exposed in the channel bed. The floodplain and channel banks consist of similar gravels and cobbles but with a silty matrix.		
Stability	Stable		
Manning's	Moderate to high		
Reach Evolution	The channel alignment seems to be mature though it lacks the bed forms of a mature channel.		
Erosion	None noted		
Sedimentation	A slowly incising system, though generally should be considered a transporting system		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Laterale Stability	Moderate		
Water Present & Depth	None noted		
Existing Stream Works	None noted		
Land use	Reserve		
Stock Access & Type	No		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	PC2		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The channel is very monotonous with very few bed forms such as scour pools. The channel just seems to be one long riffle. This seems to indicate that the channel is in some stage of evolution and recovery. The current channel generally lacks old LWD, the little that does exist is associated with the only scour in the river channel. There is a large amount of new LWD in channel which may result in more scour and channel features.

FS#34: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	1-3m	0.5-1.5m	Minor pockets
Grade Slope	Moderate		
Sediment Type	Alluvial gravel to cobble streambed with cobbles being dominant. Minor bedrock bars are also exposed in the channel bed. The floodplain pockets and channel banks consist of similar gravels and cobbles but with a silty matrix.		
Stability	Stable		
Manning's	Moderate		
Reach Evolution	Restabilising after past mining activity		
Erosion	Yes though only on banks cutting into valley sides		
Sedimentation	Eroding		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Stable,		
Water Present & Depth	Yes, single pool which may be associated with a spring for there was a minor over flow of damp channel a few meters down stream of the pool		
Existing Stream Works	None noted		
Land use	Pyrenees State Park		
Stock Access & Type	No		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	Confined		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The channel seems fairly stable though currently seems to be in the later stages of recovery and stabilisation. The channel contains very little in the way of pools and in stream features. The channel may have incised after the mining activity and is now recovering may have originally been and Intact Valley Fill though unlikely considering the gravels in the floodplain.

FS#35: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	1.5-2m	0.5-1.5m	Pockets with a maximum width of 30m
Grade Slope	Moderate		
Sediment Type	The channel bed is dominated in parts by cobbles, though other areas these seem to be being covered with fines. The channel is also thick with vegetation		
Stability	Stable		
Manning's	Moderate to High		
Reach Evolution	Mature?		
Erosion	No		
Sedimentation	Transporting system, minor fines accumulating, may be in response to increasing vegetation in channel		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low to moderate		
Number of Channels	1		
Lateral Stability	Stable		
Water Present & Depth	Yes, stagnant pools		
Existing Stream Works	Ford, constructed of concrete for light vehicle access, is acting as an artificial knick point and sediment has built up to its level on the upstream side.		
Land use	Recovering cleared land?		
Stock Access & Type	No		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	PC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The system seems to be in a recovery phase after a possible period of incision, with vegetation and associated sedimentation occurring in some parts of the channel. There is also no evidence of any active incision or erosion. The area may be recovering from being cleared.

FS#36: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	10-15m	2-3m	100-200m
Grade Slope	Low		
Sediment Type	Cobble bed, banks and floodplain consist of silty clay with gravel and cobble lenses.		
Stability	Stabilising		
Manning's	Low		
Reach Evolution	Stabilising after a period of possible incision.		
Erosion	Minor erosion present on meander bends		
Sedimentation	Gravel bars are forming on channel sides and meander bends		
Cut-offs/Avulsions	Minor cut-offs are present within the incised channel on some of the benches		
Channel Sinuosity	Moderate		
Number of Channels	1		
Lateral Stability	Moderate		
Water Present & Depth	No		
Existing Stream Works	None noted		
Land use	Grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	PC3		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The system seems to be in a recovery phases after a period of incision and active widening of its original channel bed. Bars, point bars and vegetation are establishing themselves in the inset channel, There still seems to be a lack of in channel features though scour pools do exist on some of the meander bends in the reach assessed.

FS#37: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	6-8m	2-3m, though laid back rather than sub vertical	100-150m
Grade Slope	Moderate		
Sediment Type	Cobble bed, banks and floodplain consist of silty clay with gravel and cobble lenses.		
Stability	Stabilising		
Manning's	Moderate		
Reach Evolution	Stabilising		
Erosion	Very minor and is only associated with where the channel comes into contact with valley side.		
Sedimentation	Transporting/eroding system		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Stable		
Water Present & Depth	None noted		
Existing Stream Works	None noted		
Land use	Former grazing land though now fenced from stock access		
Stock Access & Type	No, though the fenced area is gated so may be used for drought feed.		
Stream Style Mapped	Intact Valley Fill		
Stream Style Observed	PC3		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The banks of the reach have been revegetated with over storey species within the last 8 to 10years. Also a levee has been constructed to divert flow form meander bend and associated unstable bank. The system and channel seem to be in a recovering phases with the channel minus bars, pools and LWD.

FS#38: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	20-40m	NA	60m in pockets
Grade Slope	Very Low		
Sediment Type	Fine grained		
Stability	Stable		
Manning's	Moderate		
Reach Evolution	Mature		
Erosion	None noted		
Sedimentation	Accreting system		
Cut-offs/Avulsions	NA		
Channel Sinuosity	NA		
Number of Channels	1		
Lateral Stability	NA		
Water Present & Depth	Yes, 2m+ in pools?		
Existing Stream Works	None noted		
Land use	Cropping and grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	Chain of Ponds		
Stream Style Observed	Chain of Ponds		
Vulnerability (Intact Valley Fills only)	The vegetation of the system is under threat from the stock access though no physical threat such as headward erosion or sediment source was noted. However the ponds maybe receiving excess sediment from the cleared land around the channel.		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The numbers of ponds in the system seem to be limited, all also seem to be associated with large trees (both living and dead). The channel and ponds are choked with vegetation. Some of the ponds seem to be infilling which ay be due to sediment reaching the ponds from the cleared farmland that surrounds the channel. This infilling doesn't seem to be occurring where the fringing bank vegetation is wider. The ponds are better developed around living trees rather than the dead ones.

FS#39: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	4-12m	Up to 3m	20m in pockets
Grade Slope	Moderate		
Sediment Type	Fines		
Stability	Stable		
Manning's	Moderate		
Reach Evolution	Mature		
Erosion	Some very minor erosion assorted with some of the banks, generally just bar patches		
Sedimentation	Accreting system, very slow		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	NA		
Number of Channels	1		
Lateral Stability	None noted		
Water Present & Depth	No		
Existing Stream Works	None noted		
Land use	Grazing		
Stock Access & Type	Yes Cattle		
Stream Style Mapped	Chain of ponds		
Stream Style Observed	Chain of ponds		
Vulnerability (Intact Valley Fills only)	Minor threats due to excess sediment from the cleared land and the damage to the ponds due to stock access.		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The chain of bonds system occurs in a channel that is sunk below the floodplain. The ponds usually occur on the upstream parts of bends within the channel. The ponds seem to be quite stable and where dry during assessment. The system seems to be in a fairly robust state and not under any immediate threats.

FS#40: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	8-10m	3-4m	~400m
Grade Slope	Low		
Sediment Type	Sandy bed with silty sand banks and floodplain		
Stability	The bed of the stream seems stable though the banks are sub-vertical and only moderately stable		
Manning's	High		
Reach Evolution	Recovering		
Erosion	The banks of the channel are over steep and susceptible to erosion.		
Sedimentation	Sedimentation is occurring with in the current inset channel		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Moderate		
Number of Channels	1		
Lateral Stability	Stable		
Water Present & Depth	Yes in pools with a depth of ~0.3m		
Existing Stream Works	None noted		
Land use	Scrubland, maybe recovering form being cleared or burnt		
Stock Access & Type	No		
Stream Style Mapped	AC1		
Stream Style Observed	AC1		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The channel has incised but now seems to recovering with lateral and point bars occurring in the channel and vegetation now becoming very established on incised gully floor and on some of the bars. The bars mainly consist of sand. There is still some minor instability on the outer parts of some bends. The original floodplain above the current channel level may now be to high to be flood easily.

FS#41: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	3-4m	2-3.5m	~15m
Grade Slope	Moderate		
Sediment Type	Sandy silt bed and banks		
Stability	System is still actively eroding.		
Manning's	Low		
Reach Evolution	Immature with active erosion still occurring in channel		
Erosion	Both bed and banks are still eroding		
Sedimentation	No		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Moderate		
Water Present & Depth	Yes, very minor flows and very limited pools to a depth of 150mm		
Existing Stream Works	Concrete forward at the head of accessed reach which has also acted as a stop on the headward erosion		
Land use	Grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	Still actively eroding		

Comments: The system is actively eroding bed and banks; scour holes exist in some parts of the channel. There seems also to be some very minor infilling of some scour holes, which might be attributed to low flows?

FS#42: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	4-5m	1-1.5m	30-50m
Grade Slope	Low		
Sediment Type	Gravel bed, with the banks consisting of a silty sand alluvial material with gravel beds and lenses		
Stability	Moderate		
Manning's	Low		
Reach Evolution	Reach stabilising after a period of incision		
Erosion	No active erosion though the banks are unstable in some places		
Sedimentation	Minor accumulation of gravel in stream bed		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Moderate		
Water Present & Depth	Yes, minor pools to a depth of 0.5m		
Existing Stream Works	Ford acting as a erosion barrier		
Land use	Grazing		
Stock Access & Type	Yes, cattle		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	The system is being to stabilise after a period of incision		

Comments: The channel seems to reaching a point of stabilisation with the formation of some gravel bars and the establishment of some vegetation. The gravel is also being to bury some LWD, which may indicate a change from an erosional system to an accreting system. System is still in an unstable state and would be likely to incise in a large flow event. The source of the gravel is form the erosion of the insitu material.

FS#43: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	1-1.5m	2-3m	~20m
Grade Slope	Moderate		
Sediment Type	A gravel and sand bed stream with banks consisting of sandy silt with gravel lenses		
Stability	Moderate		
Manning's	Moderate		
Reach Evolution	Recovering?		
Erosion	None noted		
Sedimentation	Gravel and sand bars in the channel		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Moderate		
Number of Channels	1		
Lateral Stability	?		
Water Present & Depth	None noted		
Existing Stream Works	Large farm dam upstream, erosion control drop structure.		
Land use	Fenced of grazing land		
Stock Access & Type	None noted		
Stream Style Mapped	AC5		
Stream Style Observed	Incised alluvial discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The system seems to have reached a point of stabilisation, with the channel now being thickly vegetated, though the farm dam and drop structure seems to protect a completely different system of an Intact Valley Fill.

FS#44: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	4-5m	1m	25m
Grade Slope	Low		
Sediment Type	Minor gravel bed system with silty clay banks containing quartz gravels. Minor bedrock out crops in the channel bed		
Stability	Low		
Manning's	Low		
Reach Evolution	Reach is being to recover		
Erosion	Some parts of the channel still seem to be eroding, and sections of bank are still being undercut.		
Sedimentation	Sedimentation is occurring behind the rock bars and in the more highly sinuous parts of the channel		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low to moderate		
Number of Channels	1		
Lateral Stability	Moderate		
Water Present & Depth	Yes, single pool with a depth of 150mm		
Existing Stream Works	None noted		
Land use	Grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	System is recovering to a stable position		

Comments: System seems to be in a recovery phase with the channel beginning to infill in the lower reach and benches appearing in the upper parts of the reach. The lower part of the reach channel has also become vegetated. The infill isn't due to the bridge below the reach for the channel has in filled on both sides of the bridge,

FS#45: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	3-4m	2-3m	20m
Grade Slope	Low		
Sediment Type	Gravel bed		
Stability	Moderate		
Manning's	Low		
Reach Evolution	Stream is still recovering though seems to be reaching a stable point		
Erosion	There is some minor erosion on the channel banks		
Sedimentation	Point and lateral gravel bars are developing in the channel and associated pools		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Moderate		
Number of Channels	1		
Lateral Stability	Moderate		
Water Present & Depth	Yes, 25mm flows and pools to ~0.3m		
Existing Stream Works	None noted		
Land use	Grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	Systems seems to have also most reached a stable form		

Comments: The stream seems to have incised in the past and now seems to be reaching a stable gravel bed form. Vegetation is well established on channel banks and is becoming established on channel bars and in the channel is some places. System will still be susceptible to floods but will more likely act in the way of a gravel bed stream. System may restabilise as a gravel bed stream rather than the probable original form of an Intact Valley Fill.

FS#46: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	5-10m	3m vert, 3-15m horizontally	~200m
Grade Slope	Low		
Sediment Type	A sand and gravel bed stream with a silty clay bank		
Stability	Very Stable		
Manning's	Moderate		
Reach Evolution	Mature		
Erosion	None Noted		
Sedimentation	Yes		
Cut-offs/Avulsions	None Noted		
Channel Sinuosity	Low to moderate		
Number of Channels	1		
Lateral Stability	Very Stable		
Water Present & Depth	Yes, 0.1m to 2m+ in pools		
Existing Stream Works	None Noted		
Land use	Grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	PC3		
Stream Style Observed	PC3		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The Wimmera River channel consist of large pools separated by vegetation-choked bars, The system appears to be stable.

FS#47: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	1.5-2m	1.5-0.5m, lessens downstream	~30m
Grade Slope	Low to Moderate		
Sediment Type	Silty sand banks and bed with minor gravel lenses, also minor gravel lenses in the lower part of the reach.		
Stability	Moderate		
Manning's	Low		
Reach Evolution	Recovering		
Erosion	Yes in the upper parts of the reach		
Sedimentation	Yes, gravel bars are forming in the lower pars of the reach.		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Stable		
Water Present & Depth	None noted		
Existing Stream Works	None noted		
Land use	Grazing, though the scour has been fenced		
Stock Access & Type	None noted		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	System is recovering though is probably still unstable		

Comments: The systems seem to be recovering though still probably unstable and easily effected by large flows. There are some minor benches in the channel but seem to be relics of older channel floor.

FS#48: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (Height)**	**Floodplain**
Width	10m	3m	NA
Grade Slope	Moderate		
Sediment Type	Silty Clay with very minor gravel (<25mm)		
Stability	Low		
Manning's	Low		
Reach Evolution	Still incising		
Erosion	Yes in banks and bed		
Sedimentation	Very minor gravel bars formed of eroded insitu gravel in parts of the channel		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Moderate		
Water Present & Depth	None noted		
Existing Stream Works	None noted		
Land use	Grazing - though fenced from stock		
Stock Access & Type	No		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)			
Evolutionary Stage (Incised Systems Only)	System is still evolving, though has reached bedrock, which is helping to stabilise the channel.		

Comments: The system seems to be still evolving and has not reached a stable form yet, Above the rock bar in the accessed reach the channel seems to gravel bed with a meandering form, though it may still be immature with limited channel features, below the rock bar the gravel has been removed and the channel is occurring bare sediment.

FS#49: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	10-100m	NA	NA
Grade Slope	Moderate to high		
Sediment Type	Fines		
Stability	Stable		
Manning's	Low		
Reach Evolution	Mature		
Erosion	None noted		
Sedimentation	Accreting		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	NA		
Number of Channels	NA		
Lateral Stability	NA		
Water Present & Depth	None noted		
Existing Stream Works	Yes, a series of diversion bars have been but across the floodout and Intact Valley Fill to divert water out of the channel and across the paddock to prevent erosion.		
Land use	Grazing		
Stock Access & Type	Yes, Sheep		
Stream Style Mapped	Floodout		
Stream Style Observed	Floodout		
Vulnerability (Intact Valley Fills only)	Stable, not vulnerable		
Evolutionary Stage (Incised Systems Only)	NA		

Comments: The system is fairly stable and protected form down stream headward erosion by two diversion levees. The floodout is fairly indistinct with a steep lobate front.

FS#50: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	2-10m	0-2m	NA
Grade Slope	Moderate		
Sediment Type	Alluvial gravels with silty matrix		
Stability	Low		
Manning's	Low		
Reach Evolution	Still evolving with headward erosion		
Erosion	Yes – tunnel erosion on banks and headward erosion at gully head		
Sedimentation	None Noted		
Cut-offs/Avulsions	None Noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Stable		
Water Present & Depth	None Noted		
Existing Stream Works	None Noted		
Land use	Grazing		
Stock Access & Type	Yes, Sheep though none currently in paddock		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)			
Evolutionary Stage (Incised Systems Only)	Still evolving with headward erosion, and unstable banks		

Comments: The upper part of the system is still expanding with via headward erosion and the banks are highly unstable and eroding in many places, the lower part of the system the channel is stabilised by some very large over story vegetation though incision is still occurring with there roots very exposed. The channel banks are more stable in the lower reach and there are some minor gravel bars. THE HEADWARD EROSION NEEDS TO BE CONTROLLED.

FS#51: Geomorphic Field Assessment Notes

Channel Zone	**Bed**	**Banks (height)**	**Floodplain**
Width	10m	2-6m	NA
Grade Slope	Mod		
Sediment Type	Silty Clay		
Stability	Very Low		
Manning's	Low		
Reach Evolution	Still evolving		
Erosion	Yes Channel and Banks		
Sedimentation	No		
Cut-offs/Avulsions	None noted		
Channel Sinuosity	Low		
Number of Channels	1		
Lateral Stability	Moderate		
Water Present & Depth	No		
Existing Stream Works	Yes, the CMA has conducted major erosion control works.		
Land use	Wattle Creek Bushland reserve		
Stock Access & Type	No		
Stream Style Mapped	Incised Alluvial Discontinuous		
Stream Style Observed	Incised Alluvial Discontinuous		
Vulnerability (Intact Valley Fills only)	NA		
Evolutionary Stage (Incised Systems Only)	The system is still evolving.		

Comments: The system has under gone extensive rehabilitation works. The banks are still failing in places and there is also some tunnel erosion present in the banks. Would be interesting to monitor to see how successful the work rehabilitation works have been.

Appendix L

Metadata for the Wimmera River Catchment Geomorphic Categorisation and Stream Condition Assessment Database

Dataset Information

Title

WimmeraRCatch2002.mdb

Custodian

Wimmera Catchment Management Authority

Jurisdiction

Wimmera Catchment Management Authority Management Area

Description

Abstract

This dataset contains data primarily representing the waterways in the Wimmera Catchment Management Authority Management Area. All features of the dataset are uniquely identified by ID fields specified in Tables *** to ***. Updates to these datasets are to be determined at the discretion of the Wimmera Catchment Management Authority.

Datasets in the series are listed below:

- Stream Order
- Stream Style
- Stream Condition
- Hydro Type
- Wimmera ISC Field Sites 1999
- ISC Field Sites 2002

Geographic Extent

Wimmera Catchment Management Authority Management Area, Wimmera Region, Victoria, Australia

Coordinate System

GDA 94, AMG Zone 54

Dataset Currency

Beginning Date

Ending Date

Current as of March 2003

Dataset Status

Progress

Complete as of March 2003 data delivery

Maintenance and Update

To be determined at the discretion of Wimmera Catchment Management Authority

Dataset Access

Stored Data Format(s)

CD

Available Format Type(s)

To be determined at the discretion of the Wimmera Catchment Management Authority

Access Constraints

To be determined at the discretion of the Wimmera Catchment Management Authority

Data Quality

Lineage

The 1:25 000 digital hydrology layer was amended by Earth Tech to allow the connection and ordering of streams within the Wimmera River Catchment. The connection process involved removing breaks within the digital layer and joining the discontinuous fluvial systems to the Wimmera River system. Once all the waterways were connected, a complete stream ordering of the catchment was carried out.

Positional Accuracy

A GPS was used to locate the ISC sites in the field in 2002.

Attribute Accuracy

Completeness

Waterways of third order or greater were assigned a Stream Order, Geomorphic Categorisation, an Overstorey Vegetation Cover rating and an Hydrology Rating.

Contact

Contact Organisation

Wimmera Catchment Management Authority

Contact Position

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Other

Metadata Date

March 11th, 2003, by Earth Tech

Additional Metadata

Additional documents that provide significant data history and descriptive information:

- Wimmera Catchment ISC 1999 data – provided to Earth Tech by the Wimmera CMA in 2002.
- Wimmera River Catchment Geomorphic Categorisation and Stream Condition Assessment Report
- Wimmera River Geology

Name:	Geology of Victoria
Scale:	1:250 000
Spatial Extent:	Victoria (GIS format)
Owner:	Geological Survey of Victoria
	Minerals and Petroleum Victoria
	Department of Primary Industries
	(Department of Natural Resources and Environment)
Access:	General
Abstract:	The dataset contains the line, point & polygon feature delineating the Geology of Victoria.

WimmeraRCatch2002.mdb

Table 1: WimmeraRCatch2002

Code	Description
FID	Each waterway segment has an unique ID
Shape	Polyline / Polygon
Length	Length (metres) of each waterway segment
Object ID	Each waterway segment has an unique ID
Name	Waterway name – where known
Type Code	0-6 and 999 ***
Stream Order	Range 0 – 8, 0 being no order assigned and 1-8 representing stream orders .lyr_Files\WimmeraRCatch_2002_order.lyr
Stream Style	Refer to Table 2 .lyr_Files\WimmeraRCatch_2002_style.lyr
Stream Overstorey Vegetation Cover	Refer to Table 3 .lyr_Files\WimmeraRCatch_2002_cond.lyr
Hydro Type	Refer to Table 4 .lyr_Files\WimmeraRCatch_2002_Hydro.lyr

Table 2: Stream Style Definitions

Code	Description
0	None
1	Intact Valley Fill
2	Cut & Fill
3	Confined
4	Partly Confined 1
5	Partly Confined 2
6	Partly Confined 3
7	Alluvial Continuous 1
10	Alluvial Continuous 4
11	Alluvial Continuous 5
15	Anabranching Fine Grained
18	Chain of Ponds
20	Steep Headwater
21	Gorge
22	Floodout
28	Incised Alluvial Discontinuous
30	Dam
31	Weir
32	Constructed Channel
33	Other
66	Discontinuous Anabranching Chain of Ponds
999	First and second order streams

Table 3: Overstorey Vegetation Cover Definitions

Code	Description
0	No Overstorey Vegetation Cover assigned – likely to be a dam or constructed feature
1	Overstorey Cover >80%
3	Overstorey Cover 20 – 80%
5	Overstorey Cover <20%
77	Anabranching Fine Grained – not assigned an overstorey vegetation cover rating due to lack of detailed aerial photographs at the time of the investigation
999	First and second order streams

Table 4: Hydrology Data

Code	Description
1	Stream not hydrologically affected by the Wimmera Mallee Stock and Domestic Supply System
2	Stream hydrologically affected – water extracted
3	Stream hydrologically affected – used for water transfer

Table 5: ISC Sites 1999 – Wimmera Field Sites 1999 (Reach No.)

Code	Description
FID	Unique ID for ISC site
Shape	Point
Reach	WCMA reach from 1999 ISC Assessments
Region	WCMA region from 1999 ISC Assessments
Easting1	Upstream Easting
Northing 1	Upstream Northing

Table 6: ISC Sites 2002 – ISC Field Sites 2002 (Field Site No.)

Code	Description
FID	Unique ID for ISC site
Shape	Point
MW Unit ID	Field Site Number (FS#)
Stream Name	Waterway Name
Reach Number	2002 ISC Reach Number
Site Number	Site Number grouped by Reach
Start Easting	Upstream Easting
Start Northing	Upstream Northing
End Easting	Downstream Easting
End Northing	Downstream Northing
MW ESMAP	CFA Region 51*** Map Reference
Index PF	ISC Physical Form Score (out of 10)
Index SZ	ISC Streamside Zone Score (out of 10)