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

Job 2901049.008 & 2901049.009

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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™ method to reflect the Wimmera catchment, which is quite different to the NSW coastal catchments where the River Styles™ 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.

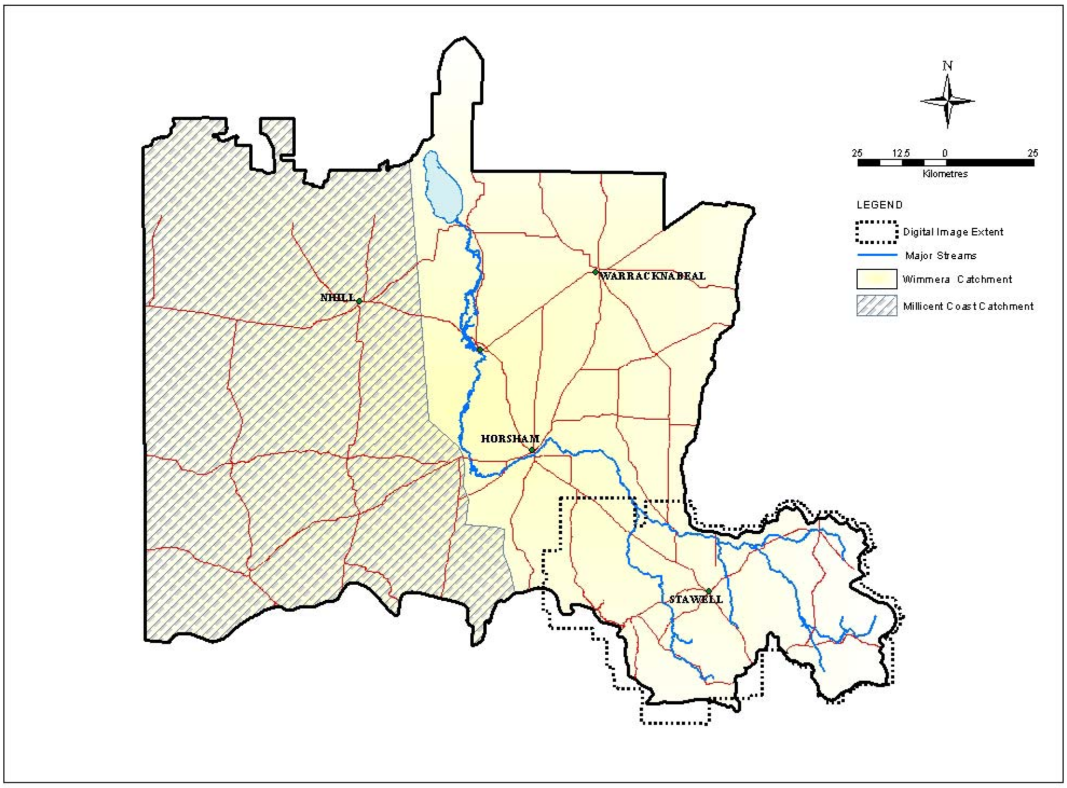

Figure 2.1: Area of the investigation and extent of digital photography

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.

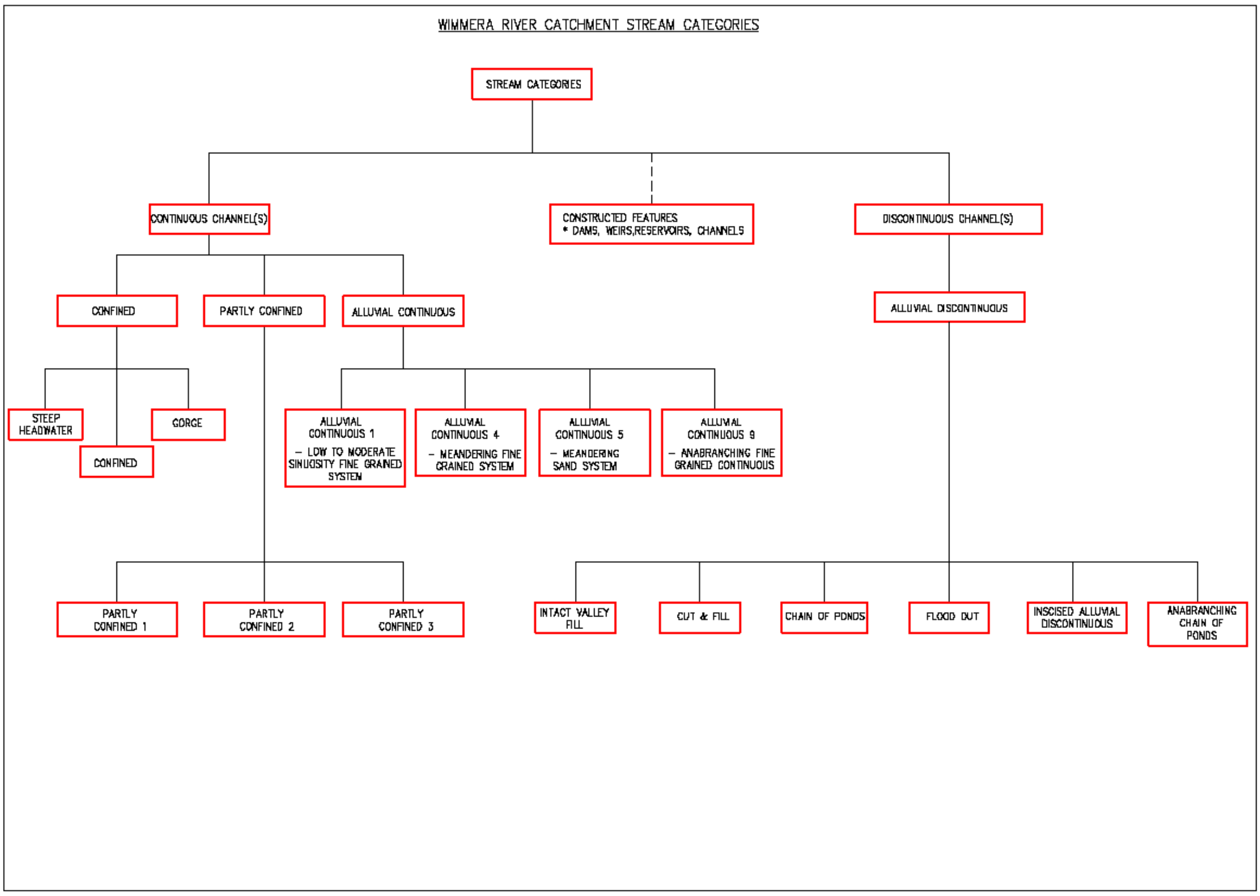

Figure 2.2: Stream Category Definitions for the Wimmera River Catchment

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.	

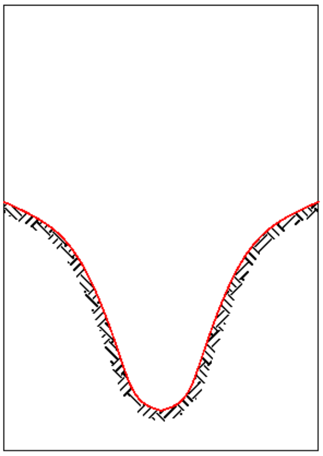

Figure 2.3a: Schematic cross-section of a steep headwater stream

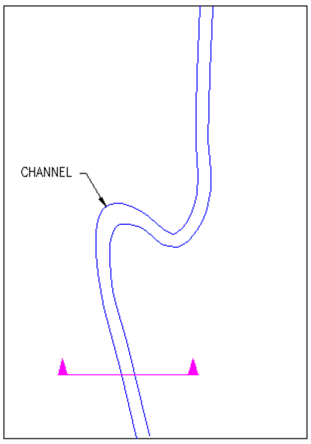

Figure 2.3b: Schematic plan of a steep headwater stream

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.	

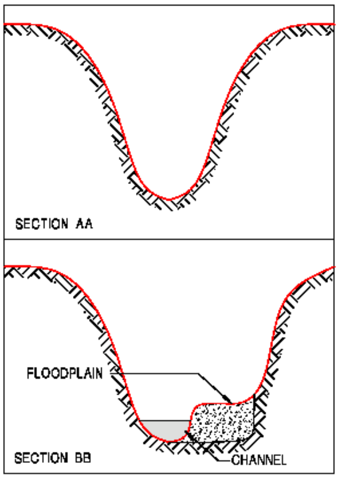

Figure 2.4a: Schematic cross-section of a confined stream

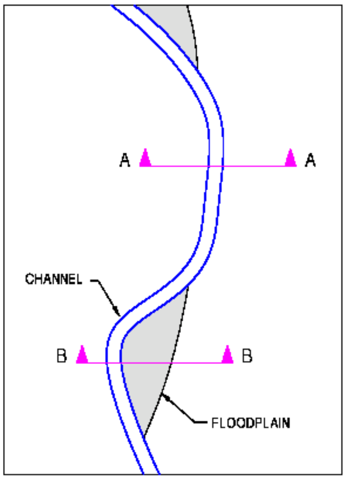

Figure 2.4b: **Schematic plan of a confined stream**

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.	

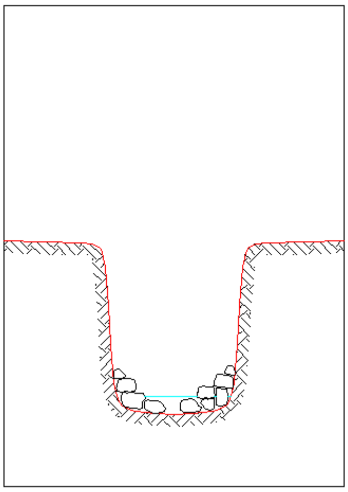

Figure 2.5a: Schematic cross-section of a gorge

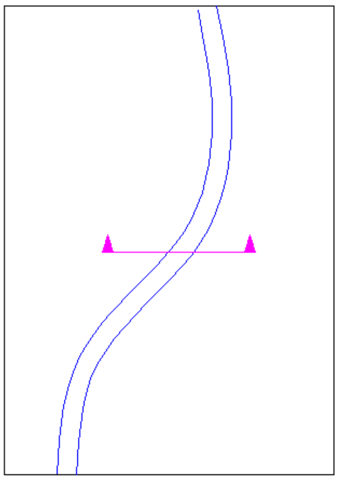

Figure 2.5b: Schematic plan of a gorge

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.	

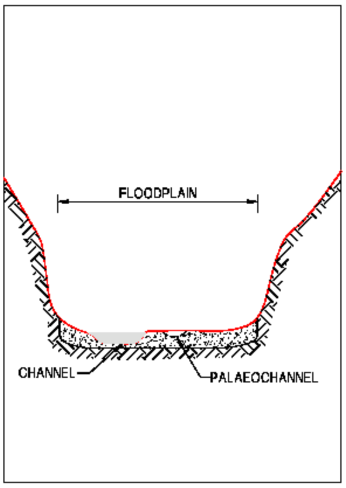

Figure 2.6a: Schematic cross-section of a partly confined 1 stream

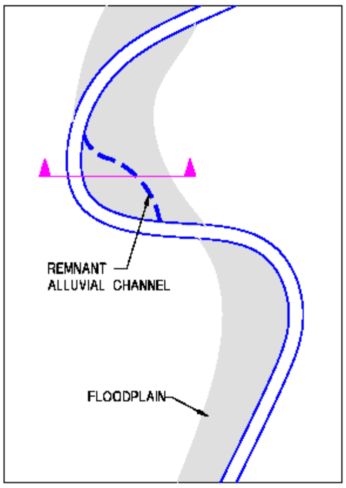

Figure 2.6b: Schematic plan of a partly confined 1 stream

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.	

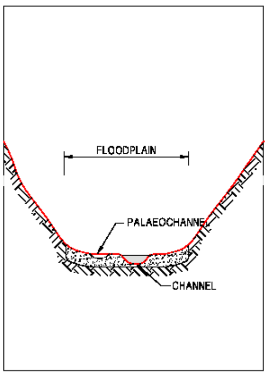

Figure 2.7a: Schematic cross-section of a partly confined 2 stream

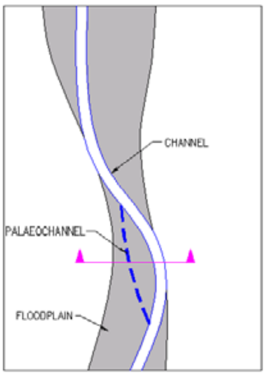

Figure 2.7b: Schematic plan of a partly confined 2 stream

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.	

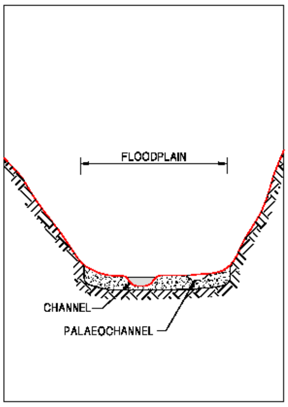

Figure 2.8a: Schematic cross-section of a partly confined 3 stream

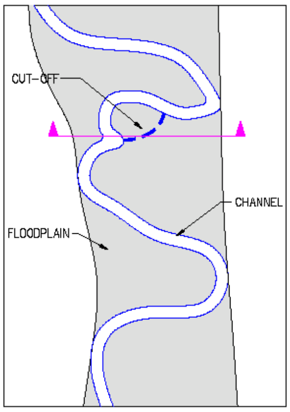

Figure 2.8b: Schematic plan of a partly confined 3 stream

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.	

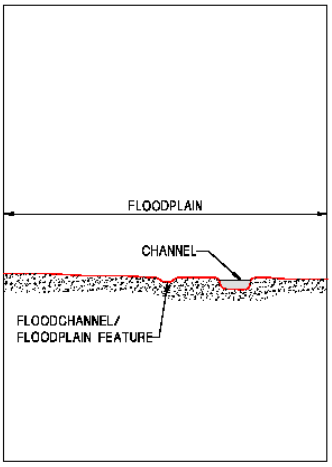

Figure 2.9a: Schematic cross-section of a low to moderate sinuosity stream

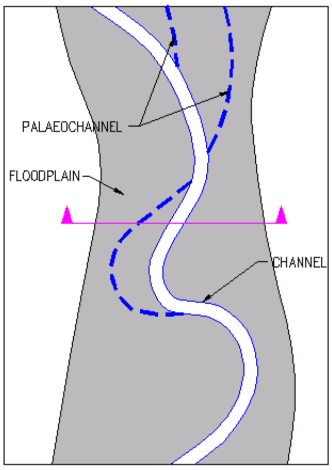

Figure 2.9b: Schematic plan of a low to moderate sinuosity stream

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.	

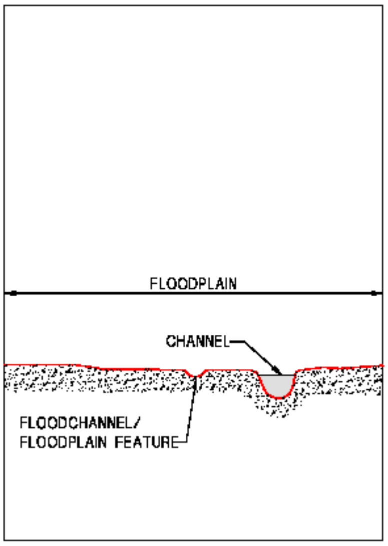

Figure 2.10a: Schematic cross-section of a moderate sinuosity stream

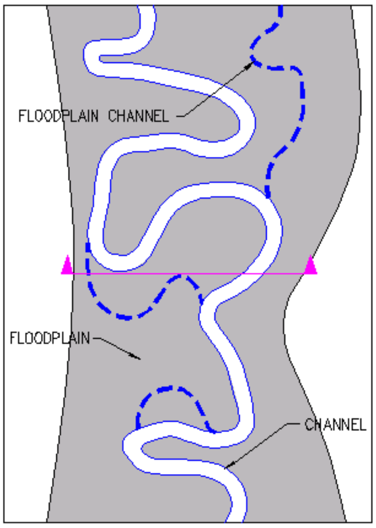

Figure 2.10b: Schematic plan form of a moderate sinuosity stream

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.	

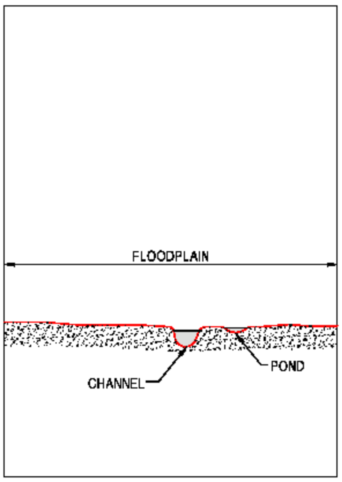

Figure 2.11a: Schematic cross-section of a meandering sand bed stream

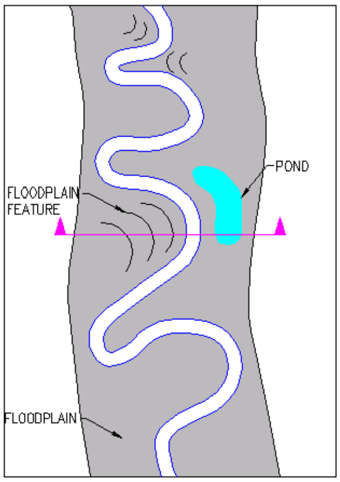

Figure 2.11b: Schematic plan of a meandering sand bed stream

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	

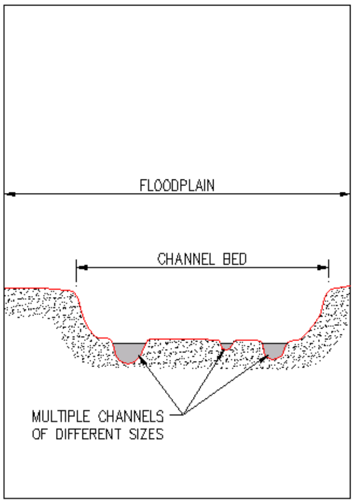

Figure 2.12a: Schematic cross-section of a anabranching fine grained

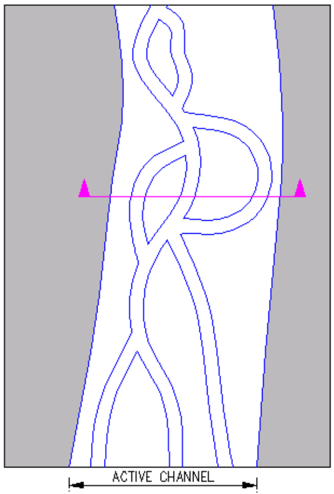

Figure 2.12b: Schematic plan of an anabranching fine grained

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	

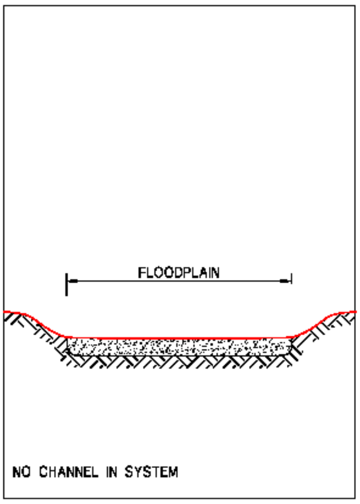

Figure 2.13a: Schematic cross-section of an intact valley fill system

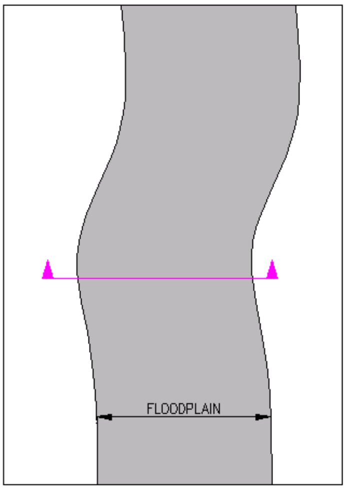

Figure 2.13b: Schematic plan of a intact valley fill system

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)	Channel zone: ponds and/or discontinuous channels	Floodplain zone: swamp or meadow with discontinuous drainage lines
	Incised condition (cut phase)	Channel zone: trench-like channel with insets, bank attached bars, sand sheets & occasional pools. May show signs of swamp redevelopment	Floodplain zone: 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.		

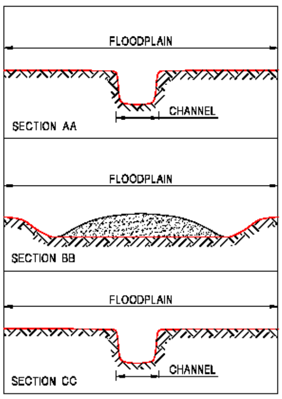

Figure 2.15a: Schematic cross-sections of a cut and fill system

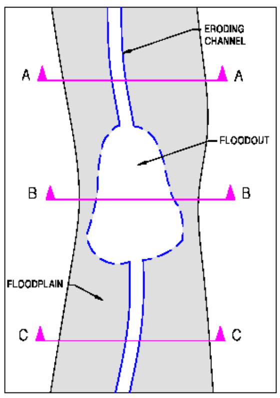

Figure 2.15b: Schematic plan of a cut and fill system

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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

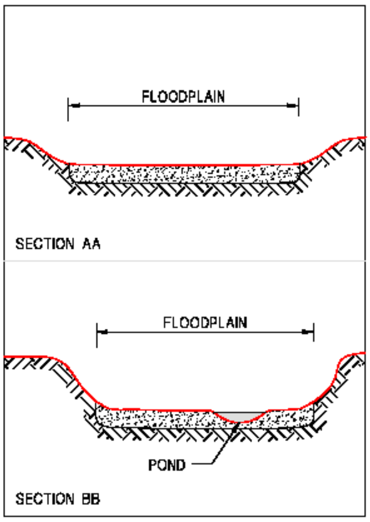

Figure 2.14a: Schematic cross-section of a chain of ponds

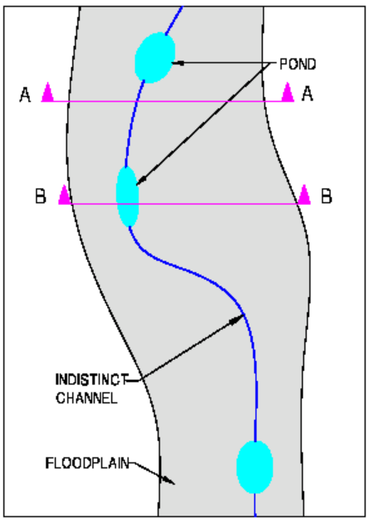

Figure 2.14b: Schematic plan of a chain of ponds system

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	

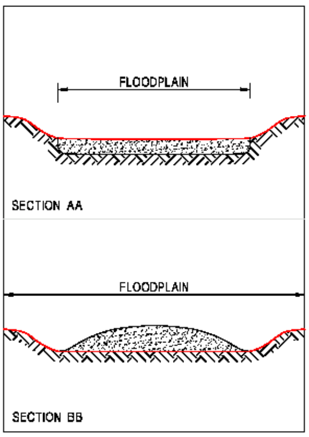

Figure 2.16a: Schematic cross-section of a floodout

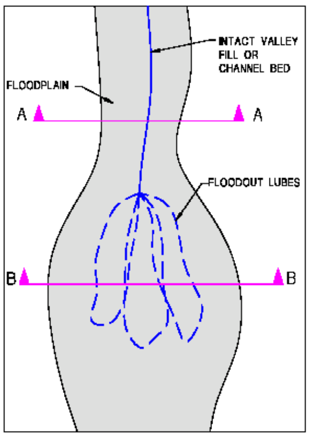

Figure 2.16b: Schematic plan of a floodout

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	

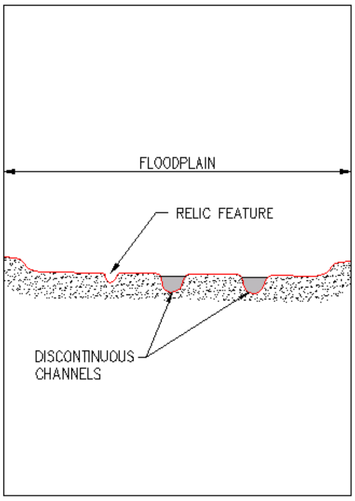

Figure 2.17a: Schematic cross-section of a discontinuous anabranching chain of ponds

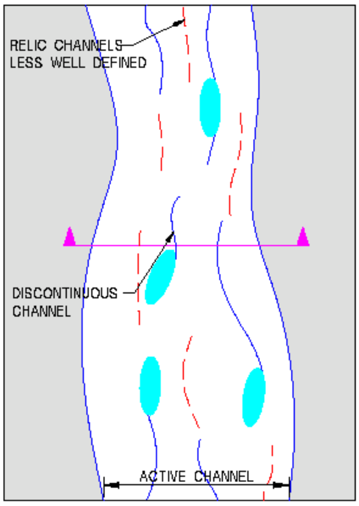

Figure 2.17b: Schematic plan of a discontinuous anabranching chain of ponds

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..	

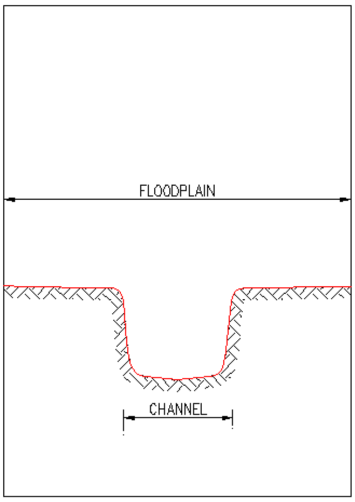

Figure 2.18a: Schematic cross-section of an actively incising alluvial discontinuous system

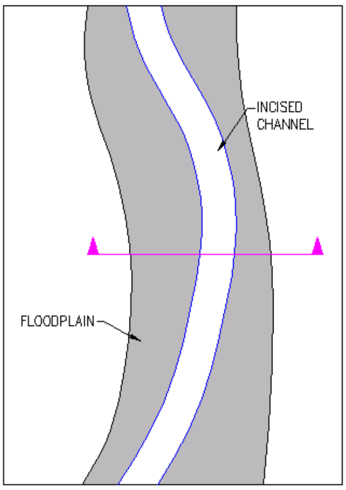

Figure 2.18b: Schematic plan of an actively incising alluvial discontinuous system

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 8th order streams.

The lower order streams, 1st and 2nd 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 3rd to 7th 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 8th order stream for the majority of its length and is extensively longer than the both the 6th and 7th 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 1st and 2nd 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.

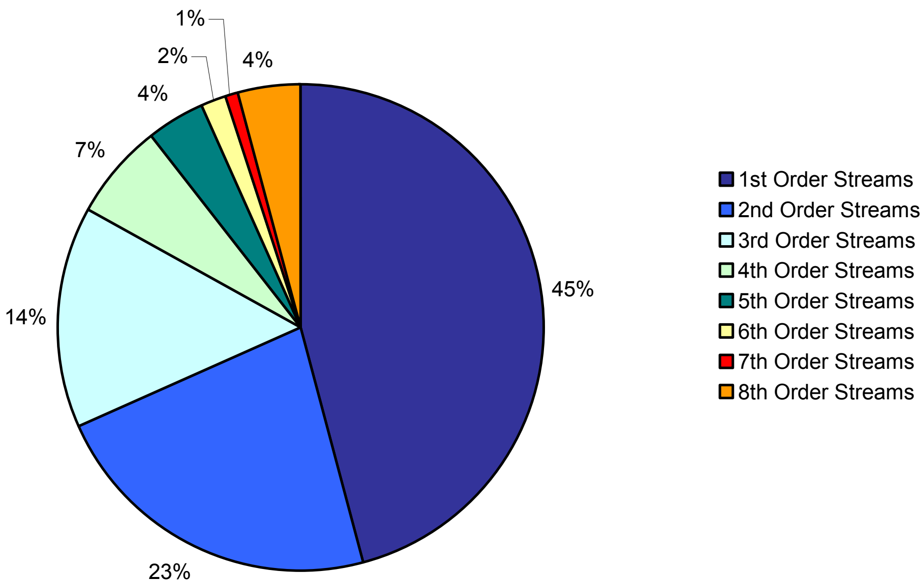

Figure 2.19: A percentage distribution of stream orders within the Wimmera Catchment

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).

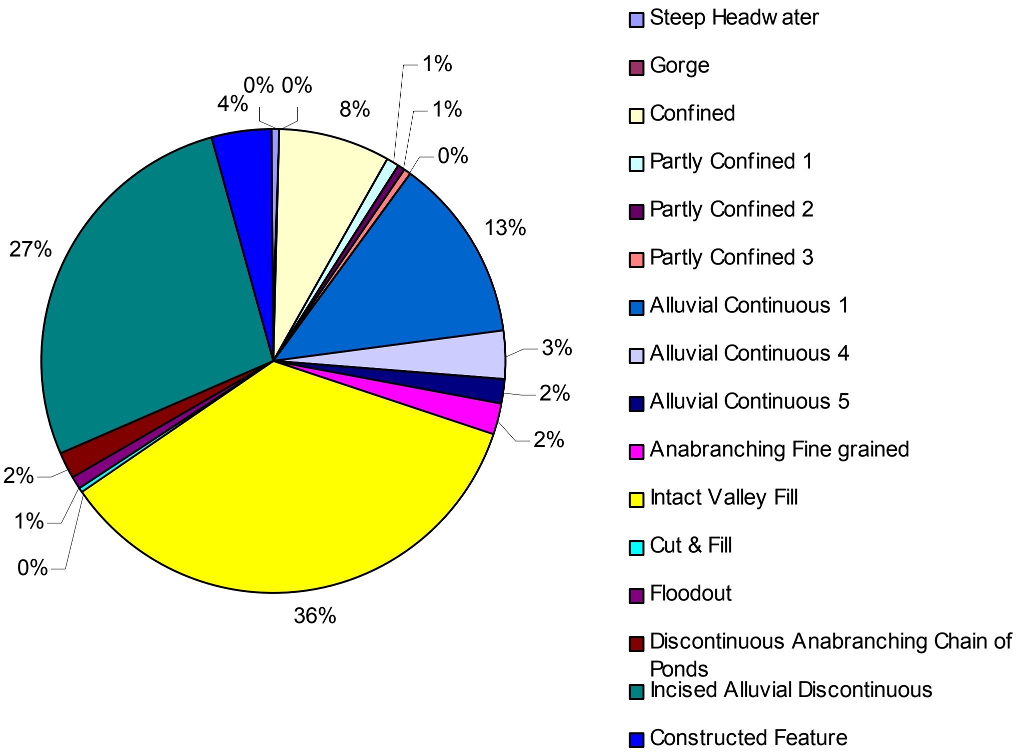

Figure 2.20: The distribution of stream categories in 3rd order streams in the Wimmera Catchment

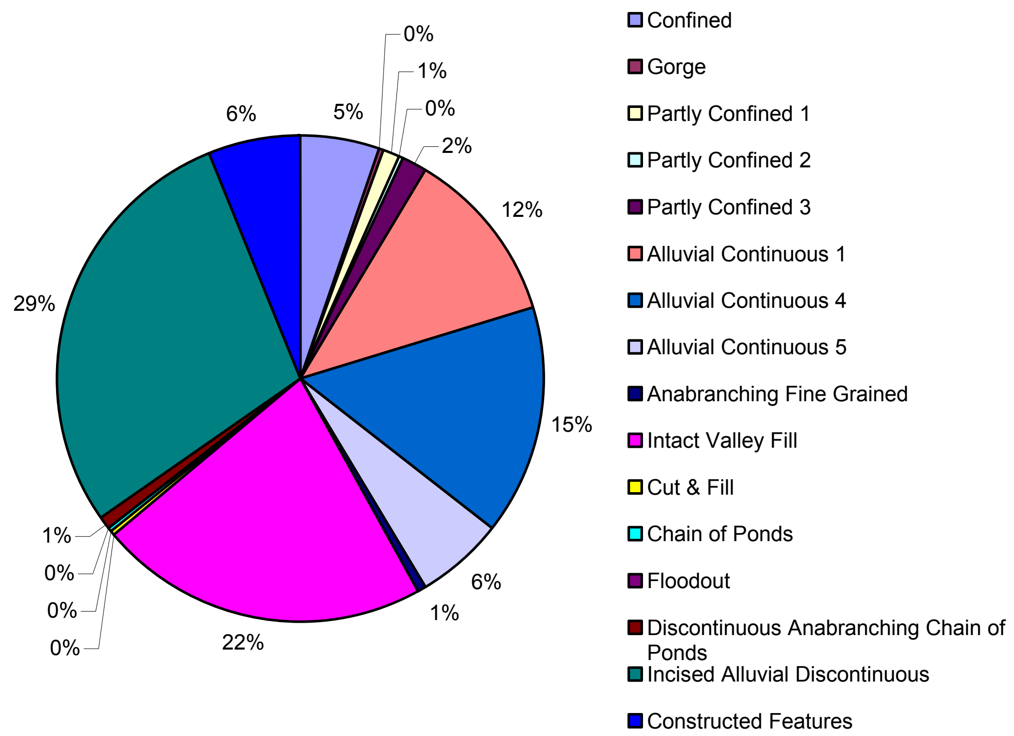

Figure 2.21: The distribution of stream categories in 4th order streams in the Wimmera Catchment

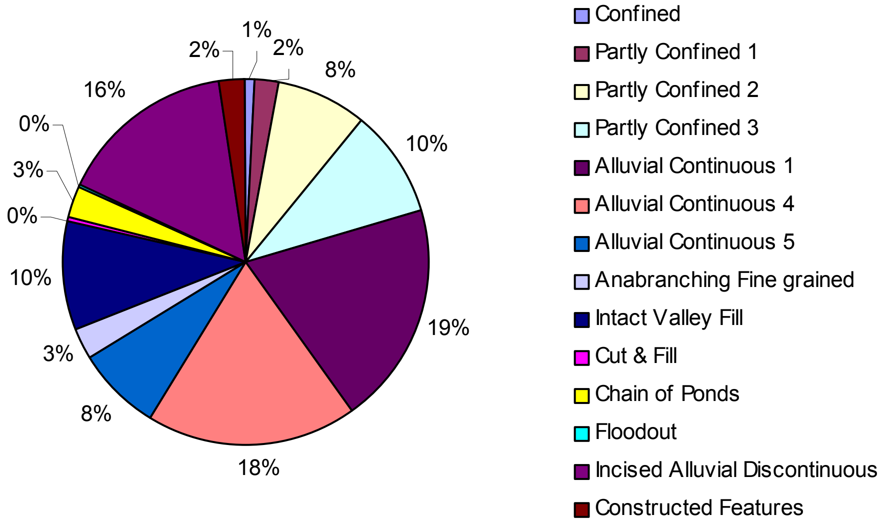

Figure 2.22: The distribution of stream categories in 5th order streams in the Wimmera Catchment

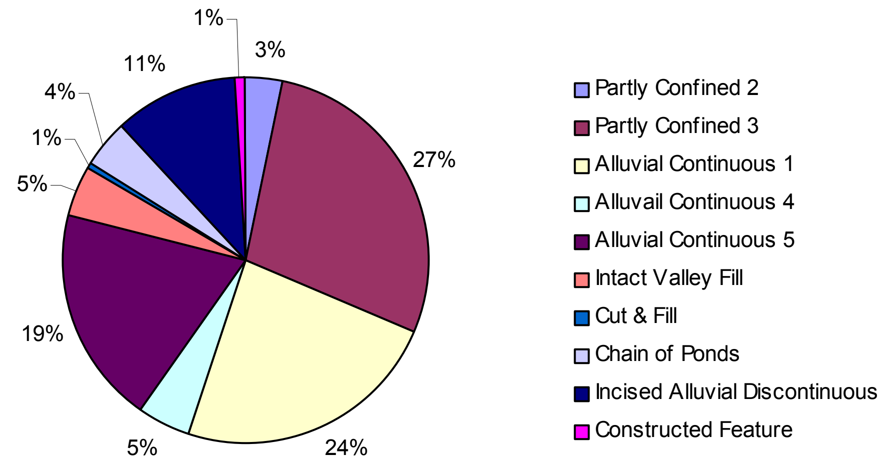

Figure 2.23: The distribution of stream categories in 6th order streams in the Wimmera Catchment

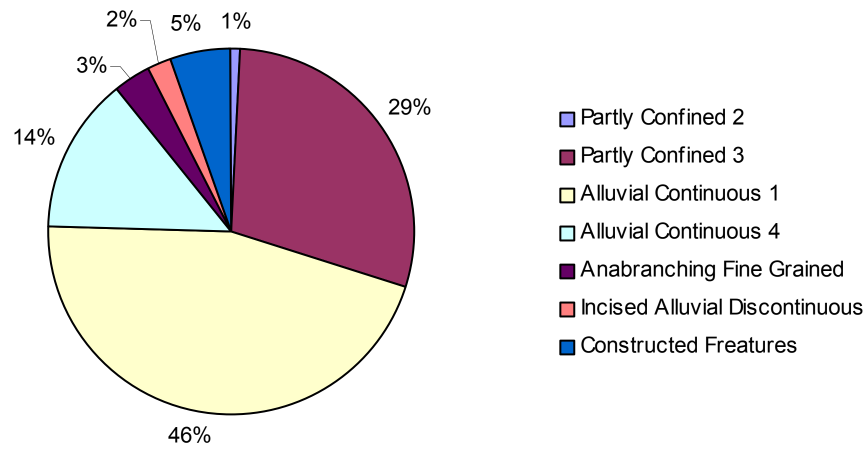

Figure 2.24: The distribution of stream categories in 7th order streams in the Wimmera Catchment

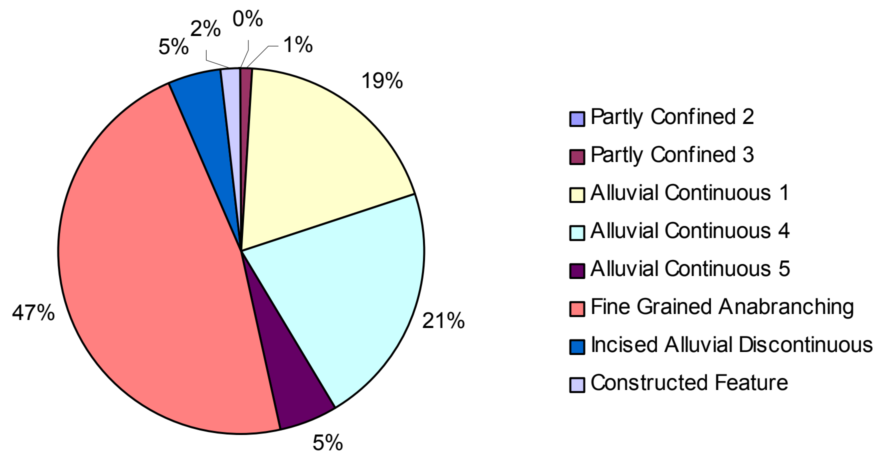

Figure 2.25: The distribution of 8th order stream categories on the Wimmera River from mid-catchment to Lake Hindmarsh

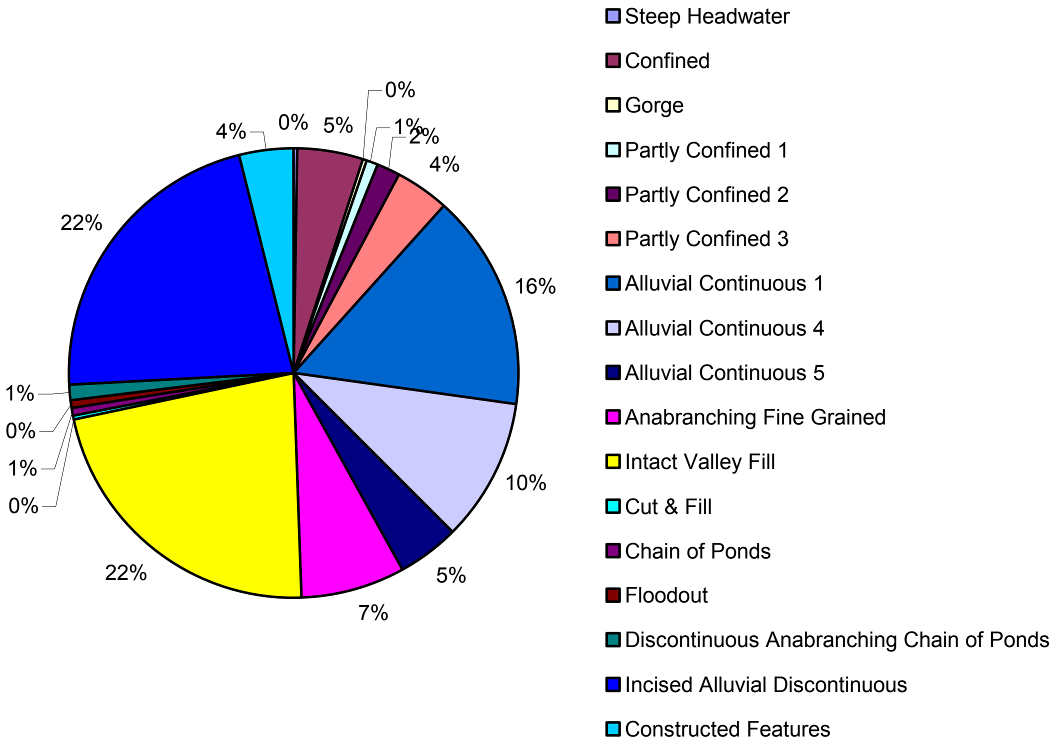

Figure 2.26: The distribution of stream categories in 3rd order and great streams in the Wimmera catchment

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.

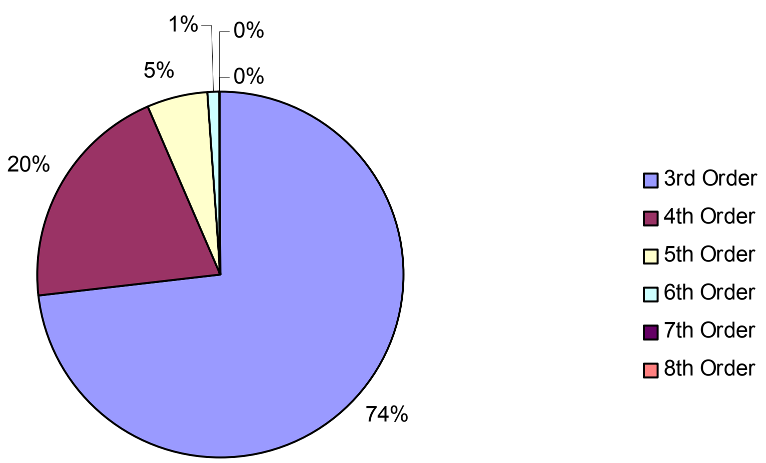

Figure 2.27: Incised systems and their distribution with regards to stream order

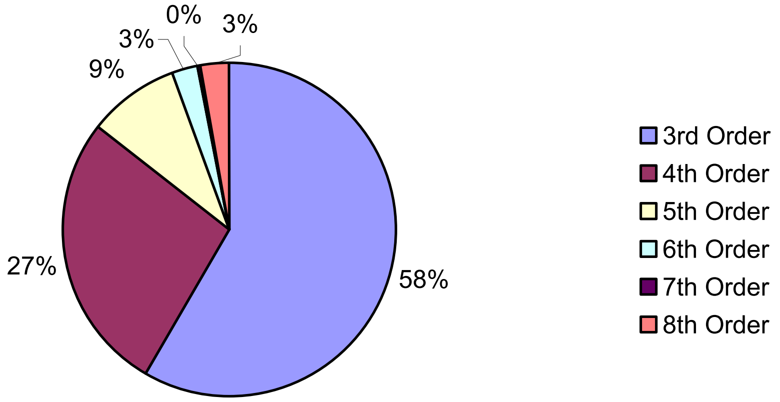

Figure 2.28: Intact Valley Fill systems and their distribution with regards to stream order

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.