6. EXTENDED RIVER TYPOLOGY

6.1 Introduction

In section 4.5, a simple classification of river types was presented, which was based on river channel planform character (number of threads and planform pattern) framed in the context of valley setting (degree of confinement) and was used to delineate reaches using readily-available information, mainly remotely-sensed imagery. The typology defines 7 river types (plus a type 0 for highly altered reaches) (Table 6.1, Figure 6.1).

In this section, an extended classification is proposed, reflecting additional reach properties acquired during the characterisation phase (sections 5.5 and 5.6). Although this extended typology is informed by previous geomorphological research (e.g. Schumm, 1985; Rosgen, 1994; Knighton and Nanson, 1993; Nanson and Knighton, 1996; Church, 2006; Fuller et al., 2013; Nanson, 2013), it is designed for practical application by stakeholders and river managers and it builds explicitly on the simple classification described in section 4.5.

Table 6.1 Simple Classification of River Types based on Confinement and Planform

Type	Confinement	Threads	Planform	*Si* (note 1)	*Bi* (note 2)	*Ai* (note 3)
1	Confined	Single	Straight-Sinuous	n/a	approx. 1	approx. 1
2	Partly confined / Unconfined	Single	Straight	< 1.05	approx. 1	approx. 1
3	Partly confined / Unconfined	Single	Sinuous	1.5 < *Si* < 1.05 *	approx. 1	approx. 1
4	Partly confined / Unconfined	Single	Meandering	>1.5	approx. 1	approx. 1
5	Confined / Partly Confined / Unconfined	Transitional	Wandering		1 < *Bi* < 1.5	*Ai* < 1.5
6	Confined / Partly Confined / Unconfined	Multi-thread	Braided		*Bi* < 1.5	Ai < 1.5
7	Confined / Partly Confined / Unconfined	Multi-thread	Anabranching		*Bi* < 1.5 or *Bi* > 1.5	Ai > 1.5

notes:

1. *Si* (sinuosity index) is the ratio between the distance measured along the (main) channel and the distance measured following the direction of the overall planimetric course (or 'meander belt axis' for single thread rivers).
2. *Bi* (braiding index) is the number of active channels separated by bars at baseflow.
3. *Ai* (anabranching index) is the number of active channels at baseflow separated by vegetated islands (*Ai*

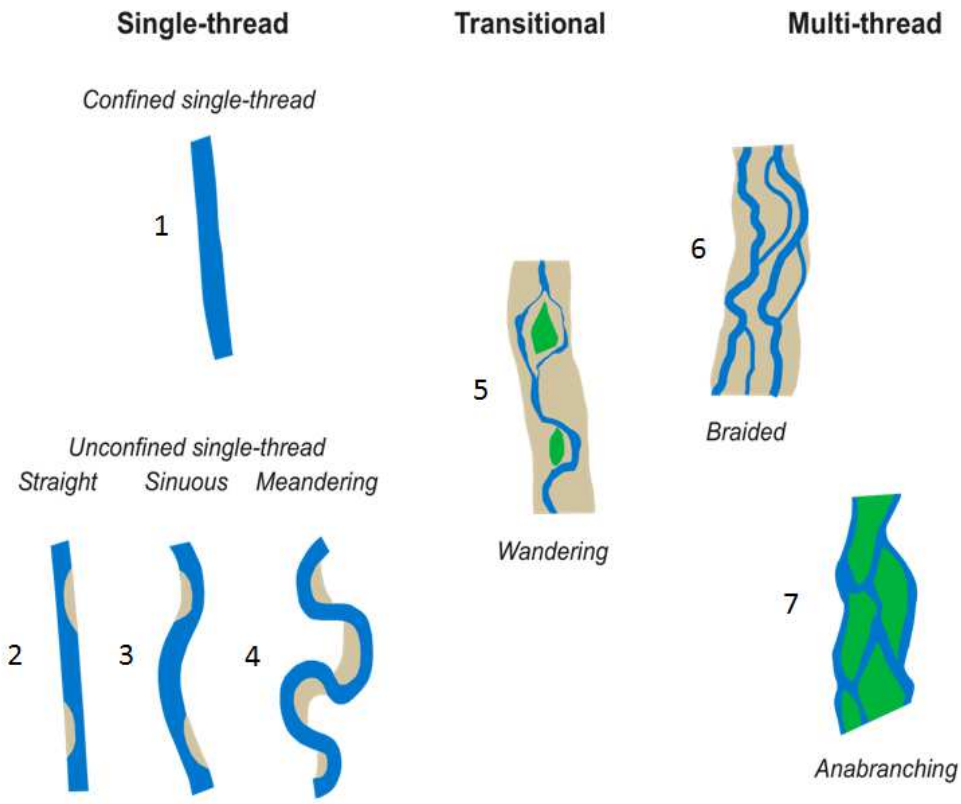

Figure 6.1 Simple River Typology based on Confinement and Planform

6.2. Extended River Typology

The extended typology represents typical associations between channel planform, bed sediment calibre and geomorphic units, framed in context of different valley settings. This typology is built directly onto the simple typology, providing more detailed information on reach character. However, several of the simple types are subdivided when there is a clear distinction within the same simple morphological type, reflecting different bed material calibre and/or morphological units (e.g. different bed material or bed configuration sub-types of confined single thread reaches; a change from a straight / sinuous channel with continuous bars to a straight / sinuous channel with sporadic to absent bars).

Twenty-one extended morphological types are identified (Table 6.2, Figures 6.2 and 6.3) and described (Table 6.3) according to their confinement (confined, partly confined, unconfined), dominant bed material calibre (bedrock, boulder, cobble, gravel, sand, silt) and planform (straight-sinuous, meandering, pseudo-meandering, wandering, braided, island-braided, anabranching). The following points should be noted:

(i) The extended types are intended as ‘naturally-functioning’ types. Therefore type 0 (highly altered) reaches from the simple typology are retained in the extended typology, and any reach with a predominantly artificial bed is allocated to this type.

(ii) Straight and sinuous types are combined in the definitions and descriptions of the extended typology (Tables 6.2 and 6.3), because both planform types are related to similar morphological units when they possess similar bed material and level of confinement. However, to avoid inconsistency between the simple and extended classifications, the combination of, for example, a 'straight' channel (simple classification) with a 'straight-sinuous with alternate bars' (extended classification) should lead to a 'straight with alternate bars' extended type.

(iii) A new transitional type is added to the extended classification: 'pseudo-meandering'. This describes straight or sinuous channels that display large, alternate bars at low flow. While the bankfull channel conforms to a straight or sinuous channel, the low flow channel is so heavily affected by the exposure of alternate bars that it would be defined as meandering if its Si index were to be calculated.

The 21 extended types are not an exhaustive list of possible combinations of planform, morphological units, valley setting and sediment size, but rather an indicative, general framework for identifying catchment- or region-specific ranges of morphologies. The set of distinguishing morphological attributes may vary between regions, but a check-list of the units that may be present within the channel and its generic floodplain is provided in Table 6.3 as a starting point.

Table 6.2 Index of the 21 morphological types in the extended classification

	PLANFORM						
BED MATERIAL CALIBRE **(dominant type in bold)**	Sinuous - Straight	Meandering	Pseudo-meandering (sinuous with alternate bars)	Wandering	Braided	Island Braided	Anabranching
	Bedrock and Colluvial Channels						
Bedrock	1						
Coarse - Mixed	2						
Mixed	3						
	Alluvial (confined *single-thread*)						
Boulder - Cobble	4 (Cascade / Step-pool)						
Boulder - **Cobble** - Gravel	5 (Plane Bed)						
Cobble - **Gravel**	6 (Riffle-pool)						
	Alluvial (partly-confined / confined *single thread*; confined / partly-confined / unconfined *transitional / multi-thread*)						
Cobble - **Gravel** - Sand (gravel-bed rivers)	7	8	9	10	11	12	13
Fine Gravel - **Sand** (sand-bed rivers)	14	15	16		17		18
Fine Sand - **Silt** - Clay (cohesive)	19	20					21
	No exposed bed material						
Entirely artificial bed	0						

Notes

Type 13 is equivalent to Nanson and Knighton (1996) Types 3, 5, 6

Type 18 is equivalent to Nanson and Knighton (1996) Types 2, 4

Type 21 is equivalent to Nanson and Knighton (1996) Type 1

Types 18 and 21 are often referred to as ‘anastomosing’ rivers

Table 6.3 Descriptions of the 21 morphological types in the extended classification

Extended Channel Type (Simple Channel Type)	Confined / Partly confined / Unconfined	Bed Material Calibre	Planform	Approximate / Typical Slope ($m.m^{-1}$)	Potential Morphological (Geomorphic) Units	Stability	Description
HEAVILY ARTIFICIAL							
0 (1 to 7)	Confined / Partly confined / Unconfined	Artificial	Any	Any	Some superficial bars may be present	Very Stable	
BEDROCK AND COLLUVIAL CHANNELS							
1 (1)	Confined	**Bedrock**	Straight-sinuous	Usually steep	Rock steps Cascades Rapids	Usually strongly confined and highly stable because of the low erodibility of the bedrock bed and bank material	These, sediment supply-limited channels exhibit no continuous alluvial bed, but some alluvial material may be stored in scour holes, or behind flow obstructions such as large boulders
2 (1)	Confined	**Coarse mixed**	Straight-sinuous	Steep	Boulder levées Cascades Sand splays Abandoned channels	Can be highly unstable as water is diverted around and across very coarse bed deposits supplied from hillslopes	Small, steep channels at the extremities of the stream network. Very coarse bed sediment and large wood pieces delivered by debris falls, slides and flows accumulate as colluvial valley fill to form the channel bed. Very low and variable fluvial transport limited by shallow flows
3 (1)	Confined	**Mixed**	Straight-sinuous	Lower gradient than types 1 and 2	Poorly defined, featureless channels.	Very stable, shallow (often ephemeral) channels	Small, relatively low gradient channels at the extremities of the stream network. Mixed bed sediments delivered by less catastrophic hillslope processes than the steep subtype accumulate as colluvial valley fill to form the channel bed. Very low and variable fluvial transport limited by shallow flows

ALLUVIAL CHANNELS							
4 (1)	Confined	**Boulder** - Cobble	Straight-sinuous	> 0.04	Cascades Small pools (do not span the channel, often less than a channel width apart).Step-pools (alternating, channel-spanning, steep sections and pools)	Stable for long periods but occasional catastrophic destabilisation during debris flows.	Very steep with coarse bed material consisting mainly of boulders and local exposures of bedrock that split the flow and allow throughput of bed material finer than the large clasts dominating the bed structure. In some sections, the bed material may show some organisation into channel spanning accumulations of boulders and cobbles (called steps) that support broken, fast-flowing, turbulent, shallow flow threads, separated by pools that frequently span the channel, are usually lined with finer, cobble-sized, material, and support deeper, slower flowing water that is also often turbulent.
5 (1)	Confined	Boulder - **Cobble** - Gravel	Straight-sinuous	> 0.02	Relatively featureless plane bed. Forced bars Forced pools induced by obstructions (boulders, large wood). Occasional: Rapids. Abandoned / active side-channels	Relatively stable for long periods, but floods can induce lateral instability and avulsions, with secondary channels that may be periodically reoccupied, and some channels can be destabilised by debris flows.	Predominantly single thread but secondary channels are sometimes present. Plane bed, composed of predominantly cobble and gravel sized material with occasional boulders or sand patches. Flows are fairly uniform, comprised of glides and runs with occasional rapids. Total sediment transport is low and is supplied mainly by bank erosion / failure and fluvial transport from upstream, but debris flows may occur in some locations.
6 (1)	Confined	Cobble - **Gravel**	Straight-sinuous	> 0.01	Pools Riffles Lateral bars	Subject to frequent shifting of bars.	Coarse cobble-gravel sediments are sorted to reflect the flow pattern and bed morphology. Total sediment transport is low and in mainly as bedload. Sediment is supplied mainly by fluvial transport from upstream and some debris flows.

7 (2 or 3)	Partly Confined / Unconfined	**Gravel** - Sand	Straight-sinuous	< 0.02	Pools Riffles Large alternate (continuous) point bars closely confining the low flow channel	Subject to frequent shifting of bars.	Although dominated by gravel, bed material of varying size in the sand to cobble range may be present. Sediments are usually well sorted to reflect the flow pattern and bed morphology. Total sediment transport is low and is supplied mainly by bank erosion / failure and fluvial transport from upstream, but debris flows may occur in some locations.
8 (4)	Partly Confined / Unconfined	**Gravel** - Sand	Meandering	< 0.02	Pools Riffles Point bars Chutes (on point bars) Cutoffs and abandoned channels (across floodplain) Scroll bars Point benches	Laterally unstable sinuous channels subject to lateral and/or progressive migration	Undulating thalweg reflecting an alternating longitudinal and lateral sequence of pools, riffles and bars. Lateral instability often reflected in sequences of landforms such as point benches and scroll bars, which extend across the floodplain
9 (3)	Confined / Partly confined / Unconfined	**Gravel** - Sand	Pseudo-meandering	<0.04	Large, continuous alternate bars Riffles Pools	Usually highly unstable both vertically, and also when not confined.	Differs from type 8 in its lower sinuosity and very pronounced alternating lateral bar development. Undulating thalweg reflects alternating sequence of pools, riffles and bars.
10 (5)	Confined / Partly confined / Unconfined	**Gravel** - Sand	Wandering	<0.04	Islands Mid channel bars Marginal bars Riffles Pools	Usually highly unstable both laterally (but not when confined) and vertically.	Exhibits switching from single to multi-thread reflecting local changes in slope and/ or sediment supply / calibre and thus exhibits transitional characteristics between other single to multi-thread gravel-bed river types, often with short sections with distinct and different characteristics. Bed material is supplied predominantly by bank erosion / failure and fluvial transport from upstream reaches, but debris flows may occur in confined and partly-confined locations.

11 (6)	Confined / Partly confined / Unconfined	**Gravel** - Sand	Braided	<0.04	Mid channel bars Riffle-pools (particularly noticeable in large braid channels).	Usually highly unstable both laterally and vertically	Occur where sediment supply is relatively higher and/or slopes are steeper and / or sediment is coarser than types 9 and 10. Bed material is supplied predominantly by bank erosion / failure and fluvial transport from upstream reaches, but debris flows may occur in confined and partly-confined locations.
12 (6)	Confined / Partly confined / Unconfined	**Gravel** - Sand	Island-braided	<0.04	Islands Mid channel bars Riffle-pools (particularly noticeable in large channels)	Usually unstable both laterally and vertically	Island braided channels are distinguished from type 11 by > 20% area of active tract covered by islands of established vegetation. Bed material is supplied predominantly by bank erosion / failure and fluvial transport from upstream reaches, but debris flows may occur in confined and partly-confined locations.
13 (7)	Confined / Partly confined / Unconfined	**Gravel** - Sand	Anabranching	<0.01	Islands Riffle-pools (particularly noticeable in large channels)	Most stable of the gravel-sand channel types	Islands covered by mature vegetation extend between channels with only occasional exposured sediment bars Bed material is supplied predominantly by bank erosion / failure and fluvial transport from upstream reaches.
14 (1or 2)	Partly confined / Unconfined	Fine gravel - **Sand**	Straight-sinuous	<0.02	Riffles Pools Point bars Ripples (and Dunes) Occasional: Benches Scroll bars Leveés Backswamps	Laterally unstable sinuous channels sometimes subject to lateral and/or progressive migration	Undulating thalweg reflecting an alternating longitudinal and lateral sequence of pools, riffles and bars.
15 (4)	Partly confined / Unconfined	Fine gravel - **Sand**	Meandering	<0.02	Pools Point bars Ripples (and Dunes) Scrolls Leveés Ridges and Swales Backswamps Abandoned channels	Laterally unstable sinuous channels subject to lateral and/or progressive meander loop progression and extension with cutoffs	Undulating thalweg reflecting an alternating longitudinal and lateral sequence of pools and bars. Lateral instability often reflected in sequences of landforms such as highly sinuous meander bends, point benches and scroll bars, which extend across the floodplain as oxbows, ridges and swales with pronounced wetland development around oxbows, in swales and at the outer extermities of the floodplain

16 (3)	Confined / Partly confined / Unconfined	Fine gravel - **Sand**	Pseudo-meandering	<0.02	Continuous, large alternate bars Pools Ripples (and Dunes)	Laterally unstable through meander loop progression and extension with cutoffs	Continuous, extensive, highly sinuous, bar development within a straight to sinuous channel
17 (6)	Confined / Partly confined / Unconfined	Fine gravel - **Sand**	Braided	<0.02	Bars Ripples (and Dunes)	Unstable both laterally and vertically	Vegetation critical in limiting the lateral extent of the bar-braided channel.
18 (7)	Confined / Partly confined / Unconfined	Fine gravel - **Sand**	Anabranching (sometimes refered to as anastomosing)	<0.005	Islands Ripples (and Dunes) Leveés Vegetation-induced bar and bench forms Ripples Abandoned channels	Stable	Vegetation critical in stabilising bars between channel threads, forming islands that develop by vertical accretion of fine sediment. Little channel bedform development unless stabilised by vegetation
19 (2 / 3)	Partly confined / Unconfined	Fine sand - **Silt** - Clay	Straight-sinuous	<0.005	Levées Backswamps	Very stable	Silt to silt-clay banks often with high organic content are highly cohesive. Little channel bedform development. Bed material is very fine, dominated by silt-sized particles but may also include coarser material, particularly sand. Sediment supply is abundant relative to transport capacity.
20 (4)	Confined / Partly confined / Unconfined	Fine sand - **Silt** - Clay	Meandering	<0.005	Levées Backswamps Point and counterpoint organic benches	Very stable	Silt to silt-clay banks often with high organic content are highly cohesive. Bed material is very fine, dominated by silt-sized particles but may also include coarser material, particularly sand. Sediment supply is abundant relative to transport capacity.
21 (7)	Confined / Partly confined / Unconfined	Fine sand - **Silt** - Clay	Anabranching (sometimes refered to as anastomosing)	<0.005	Islands containing peat swamps, levées crevasse channels, crevasse splays, ponds. Vegetation-induced bar and bench forms Abandoned channels Backswamps	Very stable	Silt to silt-clay banks often with high organic content are highly cohesive. Extensive islands covered by wetland vegetation and separated by multiple stable channels. Little channel bedform development unless stabilised by vegetation. Bed material is very fine, dominated by silt-sized particles but may also include coarser material, particularly sand. Sediment supply is abundant relative to transport capacity.

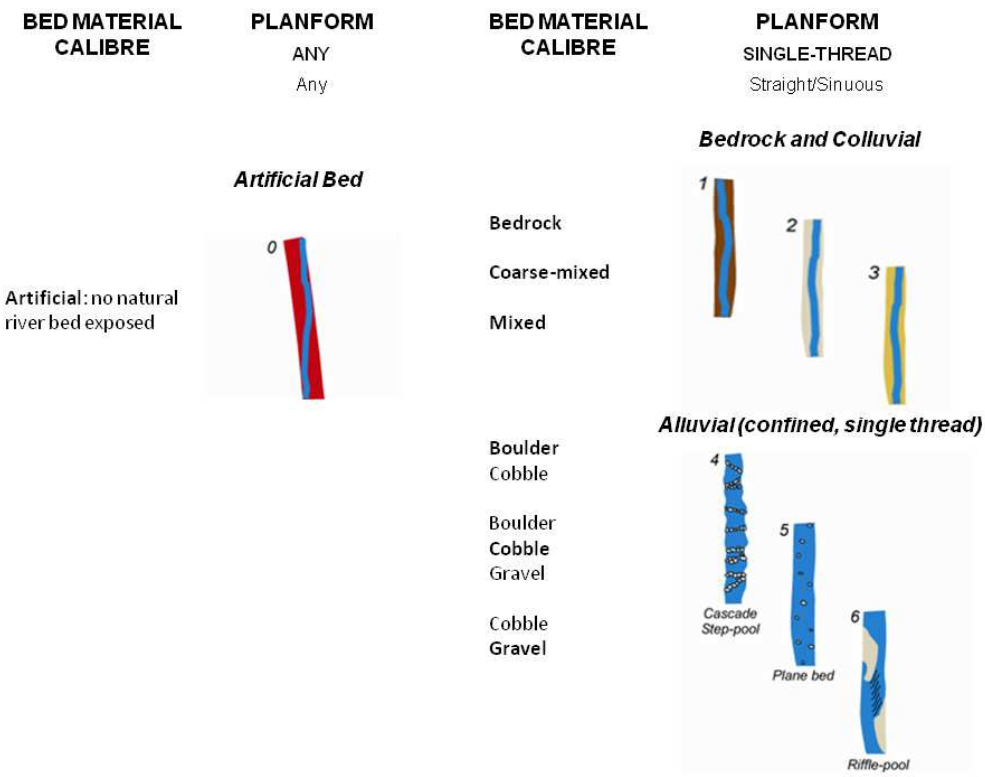

Figure 6.2 Sketches of river types 0 to 6 in the extended typology

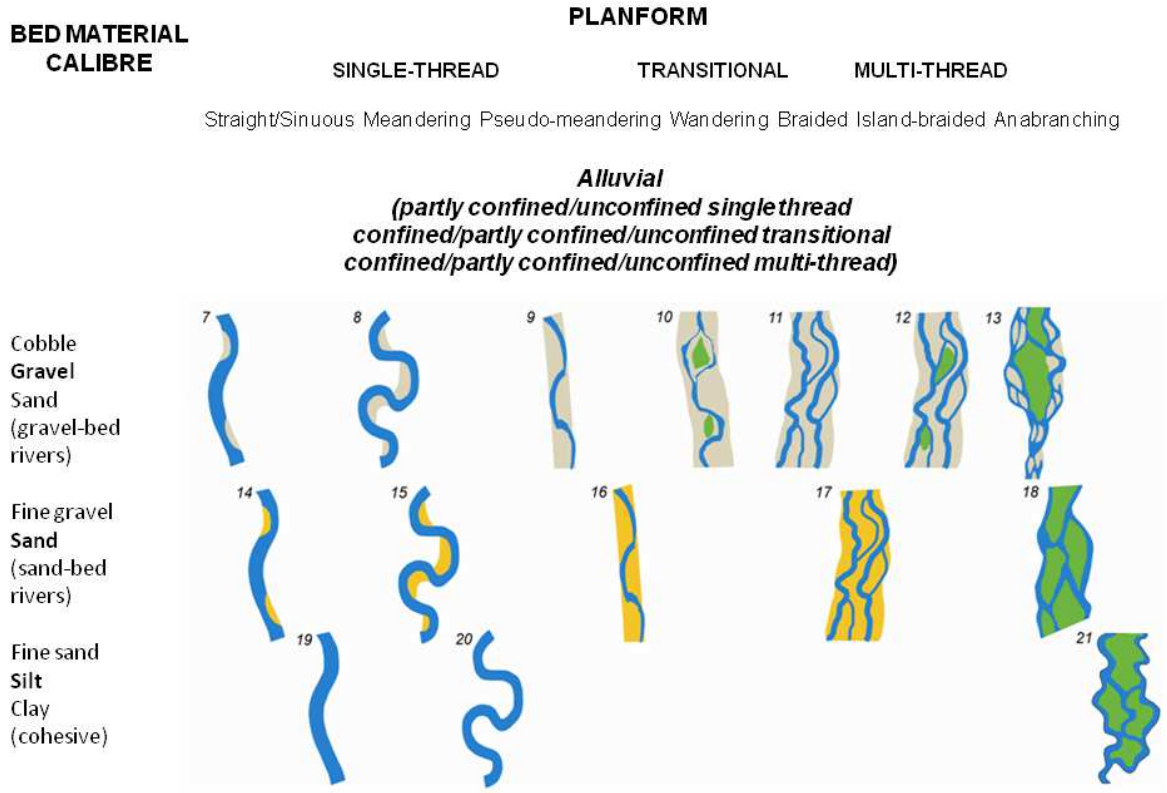

Figure 6.3 Sketches of river types 7 to 21 in the extended typology

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