CHAPTER SEVEN
STAGE FOUR : RIVER MANAGEMENT APPLICATIONS AND IMPLICATIONS IN BEGA CATCHMENT

7.1 Specific lessons learnt from Stages One-Three of the River Styles® framework in Bega catchment that guide management applications in Stage Four

In the past, most river rehabilitation projects in Australia, and elsewhere, have been applied in a piecemeal manner over relatively short reaches (paddock by paddock, or between property boundaries), without a sound understanding of the broader spatial and temporal context. Such reactive strategies are not the most efficient and cost-effective way to achieve broad-scale, catchment-based rehabilitation success in ecological terms. Projects that fail to consider current trends in dominant fluvial processes in each reach and the linkages of biophysical processes within a catchment are likely to require costly maintenance, or fail to achieve their intended goal.

Vision statements must be framed in context of ongoing and likely future 'pressures' that will be experienced, and prospective environmental changes. All too often, however, this intended long-term goal is overlooked or poorly specified. Given that flood prediction and assessment of their geomorphic effects is fraught with uncertainty, interpretation of future river character and behaviour can only be based on the best available knowledge.

Bega catchment comprises a highly variable range of river forms and processes. Four distinct downstream patterns of River Styles have been identified for differing subcatchments, as demonstrated in Chapter 4. Each pattern has recorded differing sensitivity and types of response to human disturbance, with variable off-site consequences. Regardless of these differences, and largely as a consequence of the specific shape and configuration of Bega Catchment, in which all major tributaries join the trunk stream within a short distance just upstream of the lowland plain, the downstream impacts of geomorphic disturbance have resulted in pronounced, cumulative and dramatic changes to river morphology along the lower course of Bega River. Indeed, responses to disturbance rapidly set in train a pattern of geomorphic adjustments that are unlikely to be reversed over management timeframes of 50-100 years (as outlined in Chapters 5 and 6).

Although many other river systems in southeastern Australia have been subjected to similar types and rates of disturbance, the consequences of change are particularly pronounced in Bega catchment. Elsewhere, geomorphic adjustments have been progressive, whereas in Bega catchment geomorphic responses to disturbance were both spatially and temporally distinctive. Spatial distinctiveness reflects the pattern of profound local responses that were conveyed efficiently downstream because of the configuration of the catchment. Temporal distinctiveness reflects the rapid rate of system response to disturbance and the limited potential for geomorphic recovery along the lowland plain, constrained once more by the catchment configuration.

The pervasive nature of human disturbances in all areas other than the uplands and the escarpment zone brought about dramatic cross-catchment changes to river morphology and associated behavioural regimes. As a consequence, there are few remnant reaches of any of the differing River Styles in the middle-lower catchment. Remaining relatively intact reaches tend to be isolated in the catchment, such as intact valley fill and floodout remnants in Wolumla subcatchment.

Seemingly, geomorphic recovery has only recently started across much of the catchment, perhaps within the last few decades (see Chapter 6). This implies that there has been a lag period of around 100 years in which geomorphic responses to disturbance brought about deterioration in river condition. It is intriguing to postulate how this timeframe compares with disturbance responses in other river systems in southeastern Australia.

In Bega Catchment, the primary form of geomorphic disturbance was that associated with removal of riparian vegetation and wood, along with drainage of swamps (whether advertent or otherwise). Once incision was triggered, followed by phases of channel expansion, dramatic river metamorphosis was set in train. This occurred in the late nineteenth and early twentieth century. Catchment configuration, especially the dominance of bedrock-controlled reaches in mid-catchment, ensured river responses to disturbance at the base of the escarpment were rapidly conveyed to the lowland plain.

Other than this prominent, system-wide disturbance, that generally occurred within a decade or so of initial agricultural exploits along valley floors, evidence from archival photographs, air photographs, local knowledge, and field geomorphological investigations indicate that river courses in Bega catchment were not subjected to major adjustments throughout most of the twentieth century. However, after around the 1960s, a secondary phase of disturbance responses became evident, associated primarily with the spread of willows. The choking of various reaches, and the development of near monocultured stands, has profound implications for geomorphic adjustments of channels and associated ecological consequences. These responses will impact greatly on future rates and patterns of geomorphic and ecological recovery.

Analyses of geomorphic recovery potential provide key insights into what management options are realistically River recovery potential must be assessed in context of the baseline information on the diversity of river character and behaviour across the catchment, understanding of linkages of physical processes that drive geomorphic changes and responses, and catchment-wide appraisals of geomorphic condition and the trajectory of change. The recovery potential of rivers in Bega catchment is spatially highly varied. Trends that have emerged, reflect the passage of sediment slugs in different subcatchments (see Chapter 6), influencing the likelihood for rehabilitation success across the catchment.

The catchment-specific nature of human-induced disturbances and their geomorphic responses presents a specific set of considerations within which to frame realistic catchment-framed 'visions' for management activities. This forms the first step in Stage Four of the River Styles framework.

Stage Four of the River Styles framework has three steps (**Figure 7.1)**.

Figure 7.1 Steps in Stage Four of the River Styles framework

Stage Four, Step One: Develop a catchment-framed physical vision
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Stage Four, Step Two: Identify target conditions for river rehabilitation, determining the level of intervention required
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Stage Four, Step Three: Prioritise efforts based on geomorphic condition and recovery potential
⇓
Stage Four, Step Four: Monitor and audit improvement in geomorphic condition

Products produced in Stage Four of the River Styles framework synthesise information derived in Stages One-Three in a way that is readily useable for river management applications. In this chapter, the following products are presented in separate sections for Bega catchment:

Stage Four, Step One

- Tables outlining the catchment-based vision and plan of attack.

Stage Four, Step Two

- Photographs and tables demonstrating target conditions and actions required to move a reach along the recovery trajectory.

Stage Four, Step Three

- Catchment-based prioritisation map showing the priority placed on each reach. Attached to this map are boxes that demonstrate the actions that are required to enhance river recovery in working towards the catchment vision.

7.2 Stage Four, Step One: Develop a catchment framed physical vision

It is recognised implicitly that the River Styles framework is scientifically based, while decision making in river management is a consultative process, driven by a range of agendas among multiple stakeholders. In striving towards a 'shared' physical vision of what is achievable and what is desirable for catchment-framed river rehabilitation programs, application of the River Styles framework provides an initial basis for discussion and a proactive template for management actions (Brierley and Fryirs, 2001). However, recommendations from River Styles analyses must be merged with community aspirations in the development of viable, effective, catchment-framed river management visions and programs. Collective ownership of management plans is required if long-term programs are to achieve sustainable outcomes. For example, empowerment is critical if maintenance of river works is to be sustained following flood events, in strategies such as weed management programs.

A vision statement envisages an improved state for a system that can be achieved at some stage in the future. The mission, goals, and objectives of environmental projects fit into this over-arching vision. This provides a basis to assess the success of management efforts. Generation of a shared vision generates engagement, commitment and focus needed for a successful project. Defining a catchment-framed 'vision' is a critical early step in effective river rehabilitation. In the River Styles framework, derivation of a physical vision is based on information collected and analysed in Stages 1-3 of the framework. Ideally, this scientifically-based physical vision is tightly integrated with community and stakeholder values.

Application of the River Styles framework in Bega catchment has been used to identify an achievable structure and function for river courses across a catchment, maximising the potential to produce a natural, self-adjusting river morphology that minimises the need for invasive management techniques within a specified timeframe. Reach-scale goals can then be framed within this catchment-wide ‘vision’. Through working with the Bega Office of NSW DNR, proactive rehabilitation programs have been developed in a spatially and temporally coherent manner.

The character and behaviour of individual River Styles, and their downstream pattern (analysed in Stage One), provides a physical basis to develop river rehabilitation schemes that fit into a catchment-based vision. Due regard is given to the condition of the river (analysed in Stage Two), and the potential for geomorphic recovery (analysed in Stage Three). For example, it may be pointless to expend significant effort and resources on 'fixing' a downstream reach if a large sediment slug sits immediately upstream, as the future geomorphological behaviour of the downstream reach will reflect river responses to the transfer and/or accumulation of those materials.

In Bega catchment the development of a catchment-based vision was achieved through liaison with managers and the community. In the early 1990's, undue concern was placed on the condition of highly visible reaches close to Bega township, while Landcare groups across the catchment focussed primarily on a range of local issues. This was natural and inevitable given the differing concerns for different sections of river course, and associated variability in land use (and related sets of values). Within this context, river management was dealing with the symptoms rather than the causes of change. Insights generated through application of the River Styles® framework indicated which reaches in the catchment had been most sensitive to change, and how vast volumes of material had been released from these upstream areas. A critical turning point in community and management thinking was achieved through various workshops and field days that discussed these issues. Field visits emphasised the underlying causes of change, placing each reach in context of what processes are occurring upstream. Within a few years, increased emphasis was placed on wider, catchment-scale concerns, allowing for the development of more coherent, proactive strategies. This understanding lead to discussions through the Bega office of NSW DNR about the goals of river rehabilitation in the catchment, and where in the catchment to start. A physical vision was then developed and has been integrated progressively into the Bega Catchment Integrated River Health Package. This vision has incorporated a wide range of environmental (social/economic) values across the catchment within a wide range of communities who have starkly different perceptions of what constitutes an environmental problem (e.g. there is quite a varied sense of what is aesthetically pleasing).

Development of a 'biophysical vision' for Bega catchment is summarised in **Table 7.1**. The adopted approach has a philosophy of working with natural processes in a realistic way, accepting that some issues will not be resolved and some reaches may have to be 'sacrificed' to achieve the catchment vision. In developing the catchment-based vision for Bega catchment, the precautionary principle has been employed. For example, it unrealistic to expect that willow eradication is a viable option in Bega catchment. Rehabilitation programs need to target strategic reaches in which problem plants are progressively replaced while maintaining due vigilance to ensure that the problem does not escalate.

In creating a catchment vision the following fundamental issues were considered:

- Maintaining or enhancing the diversity of river structure and function throughout the catchment. Remember, channels, floodplains and the estuary are all part of one system.
- Enhancing natural connectivity between channel-floodplain, reach-reach, tributary-trunk where appropriate.
- Achieving a continuous riparian corridor, with native vegetation dominant (and fencing off).
- Weed management and associated maintenance programs.
- Sediment management plans, deciding where in the catchment sediment should be stored or transferred and where available upstream sources are.
- Flow management, tied to water user requirements, while aiming to maintain, whenever possible, the natural hydrological cycle, including natural river and wetland functions and processes. Particular concerns revolve around low flow stage management and maintenance of refugia and associated habitat diversity.
- Concerns for healthy river and habitat availability for fish, macroinvertebrates, macrophytes, frogs, etc., and related biodiversity values, emphasising concerns for issues such as maintenance of unique habitats (e.g. discontinuous watercourses) and reducing barriers to fish passage.
- Recreational activities, focussing on fishing and swimming.
- Aesthetic values.

The over-arching vision for the Bega catchment is to establish "a healthy and diverse river environment that maintains connections of core ecosystem processes in an environmentally sustainable way, balancing the needs of all users". Within this the mission is to enhance geomorphic recovery so that river structure and function are maintained or improved throughout the catchment. Sediment transfer rates, water flow and vegetation associations must 'fit' for each reach, reflecting their River Style and their position in the catchment. To achieve this, the catchment vision seeks to minimise rates of sediment loss from valley floors, improve riparian vegetation cover, and retain base flow conditions for longer durations. In turn, these initiatives will improve ecological associations along river courses. In general terms, strategies aim to minimise erosion and sedimentation problems by locking up sediment as appropriate. Wherever practicable, zones of instability, such as headcuts, are prevented from extending further through the catchment. Riparian vegetation plans are tied to the geomorphic structure of the river, with parallel weed management programs. Trapping of fine grained materials on sand-bed valley floors enhances the retention of base flows, maximising the potential for aquatic ecosystem functioning and improving water quality in receiving basins. To achieve these various goals, reach-based strategies must be appropriate for each River Style.

Table 7.1 A biophysical vision for Bega catchment (modified from Brierley et al., 2002)

Overall vision: Our vision for Bega catchment is to achieve a healthy and diverse river environment that maintains connections of core ecosystem processes in an environmentally sustainable way, balancing the needs of all users.

What are we trying to achieve? Community and government working together, with nature, to improve the health of riverine ecosystems. The Bega Catchment Integrated River Health Package has set priorities for on-ground works that integrate sediment and water storage and delivery issues, exotic weed eradication and planting of native vegetation, water quality objectives, enhancing ecological recovery potential, cost effectiveness and 'demonstration' value.

What are we managing for? The aim is to return the river system to a sustainable (self-maintaining) geomorphic and ecological condition, minimising the need for ongoing (reactive) maintenance. This will be done by enhancing river recovery throughout the catchment and working with the character and behaviour of streams.

What do we want the river to be like? Implementation of management activities strive to work towards a healthier, catchment-wide river system with a natural sediment regime, improved water quality, native vegetation and ecological associations.

Issue	Long term vision	Short term action
Sediment regime	• Lock up sediment in cut and fill River Styles at the base of the escarpment. • Maintain balance between sediment input and output along mid-catchment reaches. • Maintain remnant swamps and floodouts along Frogs Hollow Creek and lower order drainage lines that act as sediment sinks.	**Upper catchment** • Protect remnant swamps and floodouts from headcut retreat. • Cattle exclusion and fencing off. • Revegetate riparian and within-channel geomorphic surfaces to stabilise sediment stores. • Emplace bed control structures to retain sediment in within-channel swamps. **Middle-lower catchment** • Develop riparian revegetation programs to reduce rates of channel expansion, and associated removal of floodplain sediment. • Emplace bank control structures to reduce sediment loss. • Strategically place wood structures to stabilise in-channel sediments and induce pool development. • Establish cattle access points to reduce bank and bed degradation.
Vegetation associations	• Remove willows and re-establish native vegetation associations. • Reinstate a continuous riparian corridor.	• Sustain strategic willow management programs. • Replant native vegetation that suits the riparian environment for each River Style, using species that are indigenous to the region.
Water regime	• Maintain base flow conditions and water storage in remnant swamps and floodouts for drought proofing and ecological refugia. • Reduce time of travel and stream powers by flattening the hydrograph i.e. reduce flood peaks. • Introduce environmental flows within a water management plan that satisfies instream and wetland requirements.	• Conserve and protect swamps and floodouts from headcut retreat. • Undertake riparian and within-channel revegetation programs. • Increase channel roughness through wood placement and revegetation of instream geomorphic surfaces. • Maintain pools under low flow conditions and enhance floodplain wetland connectivity through water allocation and irrigation licensing.
Ecological associations	• Enhance native terrestrial and aquatic ecological associations. • Reinstigate channel-floodplain connections (e.g. between channel habitat and floodplain wetlands). • Improve water quality and organic matter retention. • Maintain and improve the viability of remnant ecological niches in swamps and floodouts.	• Reduce channel capacities to reinstigate channel-floodplain connectivity. This requires sediment storage and revegetation at appropriate places along each River Style. • Protect remnant swamps and floodouts. • Supply and retain organic matter in the system through native revegetation programs. • Reintroduce wood along appropriate streams.

7.3 Stage Four, Step Two: Identify target conditions for river rehabilitation and determine the level of intervention required

One of the underlying premises of the River Styles framework is that river rehabilitation strategies should work with natural trajectories of change, striving to enhance the recovery of rivers. Hence, assessments of geomorphic river condition and recovery potential analysed in Stages Two and Three of the framework are used as a direct guide for the identification of achievable future scenarios. This is a two step process, identifying short-medium term target conditions for river rehabilitation, and ensuring that long term recovery goals fit within the over-arching catchment vision. Moving beyond prescriptive, off-the-shelf management responses, effective river management plans must work with the character and behaviour of each reach, the linkage of biophysical processes that determine the present and likely future behaviour of the reach (i.e. flow and sediment delivery and vegetation issues) and associated assessments of river condition and recovery potential.

Insights into recovery potential indicate how achievable it is to attain a 'good' condition for the reach. Process-based understanding that underpins the River Styles® framework can be applied to determine what actions need to be implemented to achieve this goal. The rehabilitation group then needs to match resources with actions to determine a practical target for the reach (Rutherfurd et al., 2000).

Target conditions are defined as the short-medium term stepping stones that lead towards a recovery goal. The ***recovery goal*** is a defined desirable state (either restoration or creation) that provides a long term goal for river rehabilitation.

Reaches in good geomorphic condition are used to guide target conditions for those in moderate geomorphic condition. Similarly, reaches in moderate geomorphic condition are used as target conditions for those reaches in poor geomorphic condition. Assessment of geomorphic river condition provides a direct indication of the level of intervention required to improve the condition and to enhance river recovery. Specific parameters that require manipulation to enhance recovery and achieve specific target conditions in Bega catchment can be extracted from **Tables 5.13** to **5.25**. This information is used to guide the determination of appropriate river character, geomorphic unit assemblage, channel alignment, vegetation associations and sediment regimes for each River Style. These results are represented visually for selected River Styles in Bega catchment in **Figures 7.2** to **7.5** and the list of good, moderate and poor condition reaches is presented in **Table 7.2**. In conjunction, these figures and the table are used to indicate the degree of geomorphic manipulation required along reaches of different River Styles, and where in the catchment good and moderate condition reaches occur that provide a target condition for poor condition reaches. For example, pool re-emergence is required to move a reach of a Confined valley with occasional floodplain pockets River Style from moderate to good geomorphic condition. A good condition reach occurs along Lower Bemboka River. This reach can be used as a target condition for the reach along Lower Candelo Creek, for example. In contrast, to move a reach of a Partly-confined valley with bedrock-controlled discontinuous floodplain River Style from poor to moderate condition, the formation of channel marginal benches that reduce channel capacity is required. A good condition reach along Upper Tantawangalo Creek can be used as a target condition for reaches along Wolumla Creek, for example.

Figure 7.2 Target conditions for the Confined valley with occasional floodplain pockets River Style in Bega catchment

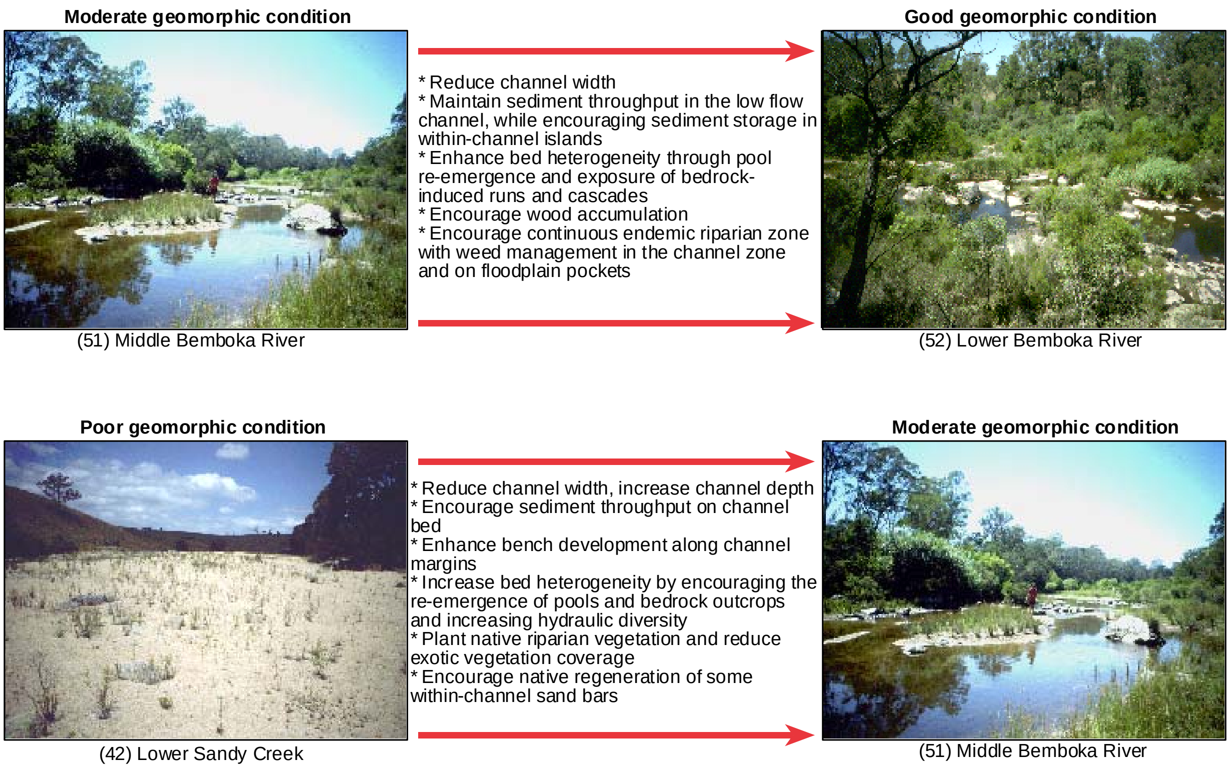


Figure 7.3 Target conditions for Partly-confined valley with bedrock controlled discontinuous floodplain River Style in Bega catchment

Moderate geomorphic condition

(26) Candelo Creek

* Maintain sediment transfer from point bar to point bar
* Enhance pool re-emergence and exposure of bedrock induced runs and riffles
* Encourage sediment storage in within-channel islands and fine grained accumulation in pools
* Encourage wood accumulation
* Encourage continuous endemic riparian zone with an associated weed management program

Good geomorphic condition

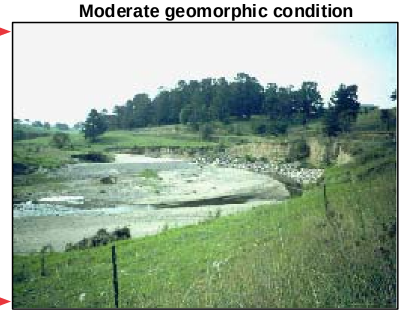
(32) Upper TantawangaloCreek

Poor geomorphic condition

(16) Wolumla Creek

* Reduce channel width by encouraging deposition on benches and point benches
* Reduce rate of concave bank erosion and floodplain reworking
* Encourage re-emergence of pools and bedrock outcrops and increase hydraulic diversity
* Plant native riparian vegetation, and encourage native regeneration on benches and point bars

Moderate geomorphic condition



(26) Candelo Creek

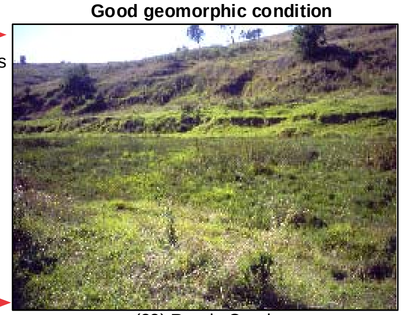
Figure 7.4 Target conditions for the Channelised fill River Style in Bega catchment

Moderate geomorphic condition

(15) Wolumla Creek

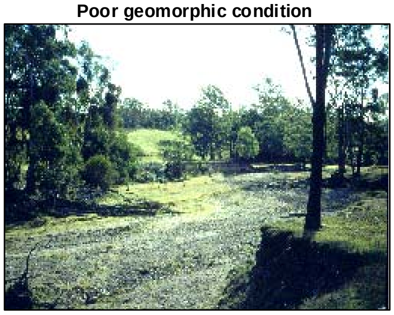
* Encourage vegetation growth on inset features
* Encourage sediment accumulation on the channel bed
* Encourage formation of a discontinuous low flow channel
* Enhance retention of fine grained sediment and organic matter on the channel bed
* Enhance aquatic vegetation colonisation on channel bed
* Encourage continuous endemic riparian zone, tied to a weed management program

Good geomorphic condition



(28) Reedy Creek

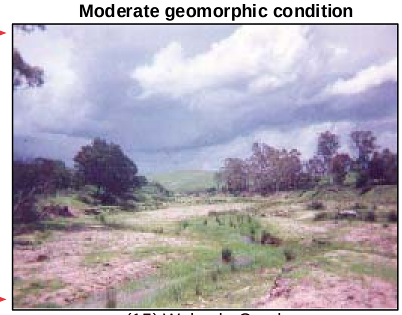
Poor geomorphic condition



Anderson Creek (tributary of Wolumla Creek)

* Reduce channel width through bench formation
* Reduce rate of channel expansion and bank slumping
* Enhance sediment accumulation on the channel bed
* Maintain well-defined low flow channel
* Plant native riparian vegetation, and reduce exotic vegetation coverage
* Encourage regeneration of native vegetation on benches
* Promote aquatic vegetation colonisation on within channel sand sheets

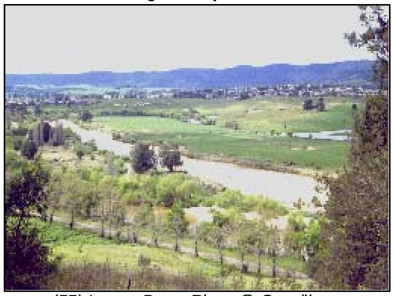
Moderate geomorphic condition



(15) Wolumla Creek

Figure 7.5 Target conditions for the Low sinuosity sand bed River Style in Bega catchment

Moderate geomorphic condition



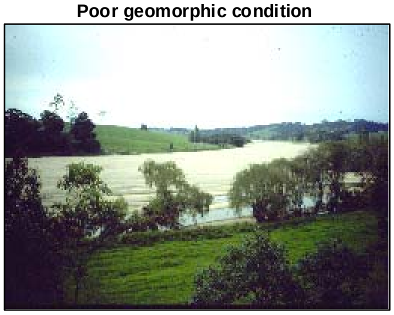
(55) Lower Bega River @ Grevillea

* Increase channel depth via bed material release
* Encourage return of mixed load sediment mix
* Re-align within-channel islands to maintain multiple low flow channels
* Encourage pool and riffle development
* Encourage native vegetation growth on within-channel islands and benches
* Enhance retention of fine grained sediment and organic matter in pools
* Enhance fine grained floodplain deposition and inundation of backswamps
* Encourage continuous endemic riparian zone
* Encourage wood accumulation

Good geomorphic condition

No examples exist in Bega catchment

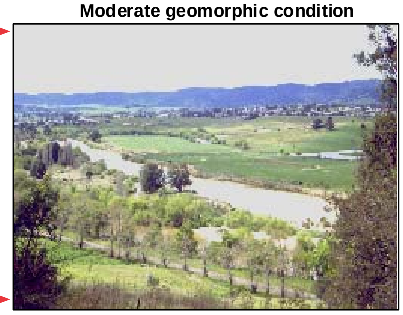
Poor geomorphic condition



Lower bega River @ Wolumla confluence (near (54) Groses Creek)

* Reduce rate of channel expansion by reducing channel width through bench formation
* Increase channel depth
* Enhance sediment accumulation in within-channel islands
* Maintain well-defined, multiple low flow channels
* Replace exotic with native riparian vegetation
* Encourage regeneration of native vegetation on benches
* Promote aquatic vegetation colonisation on within channel sand sheets

Moderate geomorphic condition



(55) Lower Bega River @ Grevillea

Table 7.2 Identifying target conditions for each reach of each River Style in Bega catchment

(Reach numbers correspond with Figure 3.3 and reach names correspond with Tables 5.17, 5.19, 5.21 and 5.23).

River Style	Good condition reaches	Moderate condition reaches	Poor condition reaches
Steep headwater	(47) Bemboka, (30) Tantawangalo, (21) Candelo	None	None
Gorge	(1) Greendale, (4) Frogs Hollow, (11) South Wolumla, (14) Wolumla, (18) Towridgee, (22) Candelo, (27) Reedy, (31) Tantawangalo, (38) Sandy, (43) Colombo, (48) Bemboka, (58) Pollacks Flat, (61) Numbugga, (64) Double, (68) House, (71) Brogo	None	None
Confined valley with occasional floodplain pockets	(1) Lower Frogs Hollow, (24) Upper Candelo, (35) Middle Tantawangalo, (50) Upper Bemboka, (52) Lower Bemboka, (70) House, (66) Upper Double, (72) Brogo, (57) Lower Bega Bottleneck Reach	(51) Middle Bemboka, (34) Upper Tantawangalo, (37) Lower Tantawangalo, (40) Upper Sandy, (63) Numbugga, (67) Lower Double	(17) Wolumla, (9) Upper Frogs Hollow, (20) Towridgee, (25) Lower Candelo, (42) Lower Sandy, (46) Colombo, (53) Bega River, (60) Pollacks Flat
Partly-confined valley with bedrock-controlled discontinuous floodplain	(32) Upper Tantawangalo, (69) House, (65) Double	(23) Upper Candelo, (26) Lower Candelo, (36) Middle Tantawangalo	(45) Colombo, (29) Reedy, (3) Greendale, (13) South Wolumla, (41) Sandy, (16) Wolumla
Intact valley fill	(12) Frogs Hollow	(19) Towridgee	None
Floodout	(7) Frogs Hollow	None	None
Channelised fill	(28) Reedy	(15) Wolumla, (39) Sandy, (2) Greendale, (44) Colombo, (59) Pollacks Flat	(62) Numbugga, (12) South Wolumla
Low sinuosity boulder bed	(49) Bemboka	None	None
Low sinuosity sand bed	None	(55) Lower Bega @ Grevillea, (56) Lower Bega @ Tarraganda, (73) Brogo @ Pearces Ford	(54) Lower Bega @ Groses Creek

The long-term creation and restoration goals for river rehabilitation are based on predictions of the trajectory of change each reach will take (undertaken in Stage Three). They equate to the reference condition for the River Style and can occur on either a creation or restoration trajectory. To identify the restoration or creation goals for rivers in Bega catchment, the trajectory of change diagrams compiled in Stage Three are used. The assessment of river recovery potential is a surrogate measure for the likelihood of recovery towards the goal over management timeframes of 50-100 years. This is appraised in terms of the within-catchment position of each reach, assessment of linkages of biophysical processes and responses to limiting factors operating within the catchment. Hence, reaches with low recovery potential have limited likelihood of reaching the recovery goal over timeframes of 50-100 years. In contrast, reaches with high recovery potential have a high likelihood of recovering towards the goal over a relatively short period of time (e.g. over years or decades). The position of each reach on the recovery diagram indicates the trajectory of change for the reach and how far from the reference condition a reach sits. This provides some indication of the likelihood for recovery over the next few decades.

7.4 Stage Four, Step Three: Prioritise efforts based on geomorphic river condition and recovery potential

In developing catchment-wide river management programs, critical decisions must be made on where in the catchment to start and selection of procedures applied to implement the associated plan of activities. Procedures used to make such decisions should be logical, testable and transparent. While economic, cultural and social values place obvious constraints on how this process is undertaken, a physical template forms a critical basis for decision-making as it can be used to frame what is realistically achievable across a catchment.

Putting aside protection of infrastructure and equivalent site-specific requirements (e.g. rarity of a particular River Style), applications of the River Styles framework emphasise in the first instance the conservation of reaches which remain in good condition (see Brierley and Fryirs, 2000) (see **Figure 3.15**). Identification of unique or rare reaches of a River Style provides a basis upon which to conserve rivers in order to maintain the geodiversity of fluvial landscapes. This has implications for conservation programs at local, catchment, regional or even State/National levels.

The success of rehabilitation programs is maximized by starting with reaches that have a high recovery potential, working out into more degraded parts of the catchment. As recovery is already underway, a 'do-nothing' option may be quite feasible in high recovery potential reaches. Elsewhere, minimally invasive approaches based on riparian vegetation management may facilitate accelerated recovery. Particular attention is given to strategic reaches or point-impacts where disturbances threaten the integrity of remnant or refuge reaches. An example is an actively-retreating headcut. Without strategic actions in these reaches, the potential for degrading offsite impacts is considerable. Irrespective of their geomorphic condition, these reaches must be targeted early in the river rehabilitation process.

In degraded reaches that are experiencing sustained adjustment, inordinate expense on river rehabilitation programs may not yield substantive outcomes, adversely impacting on community confidence in terms of river management efforts. Many low recovery potential reaches are found along laterally-unconfined streams. The pre-disturbance character of these reaches cannot be regained. Concerted efforts would be required to improve their geomorphic and ecologic condition. Management strategies must work with the prevailing boundary conditions to establish (create) a sustainable structure and function that fits the catchment setting. Longer term rehabilitation programs that require invasive rehabilitation techniques would be very expensive, with uncertain outcomes. Rather than spending significant dollars trying to rehabilitate these streams, it may be more expedient to wait for these reaches to adjust to the prevailing environmental conditions before implementing intervention strategies.

7.5 Catchment-wide distribution of reaches with different conservation or rehabilitation status

In general, the pattern of River Styles, the sensitivity to change of each River Style, and the rarity of particular River Styles, have resulted in a fragmented distribution of conservation reaches across Bega catchment (**Figure 7.6**). In addition to Steep Headwater and Gorge River Styles in the uplands and escarpment areas, remnant pre-disturbance conditions only exist for Intact valley fill and Floodout River Styles along Frogs Hollow Creek and Towridgee Creek. These latter reaches maintain base flow and filtering processes, and they provide unique habitats for aquatic fauna. In total, conservation reaches make up around 27 % of river courses in Bega catchment (**Tables 7.3** and **7.4**).

Figure 7.6 Prioritisation of management reaches within the Bega catchment vision

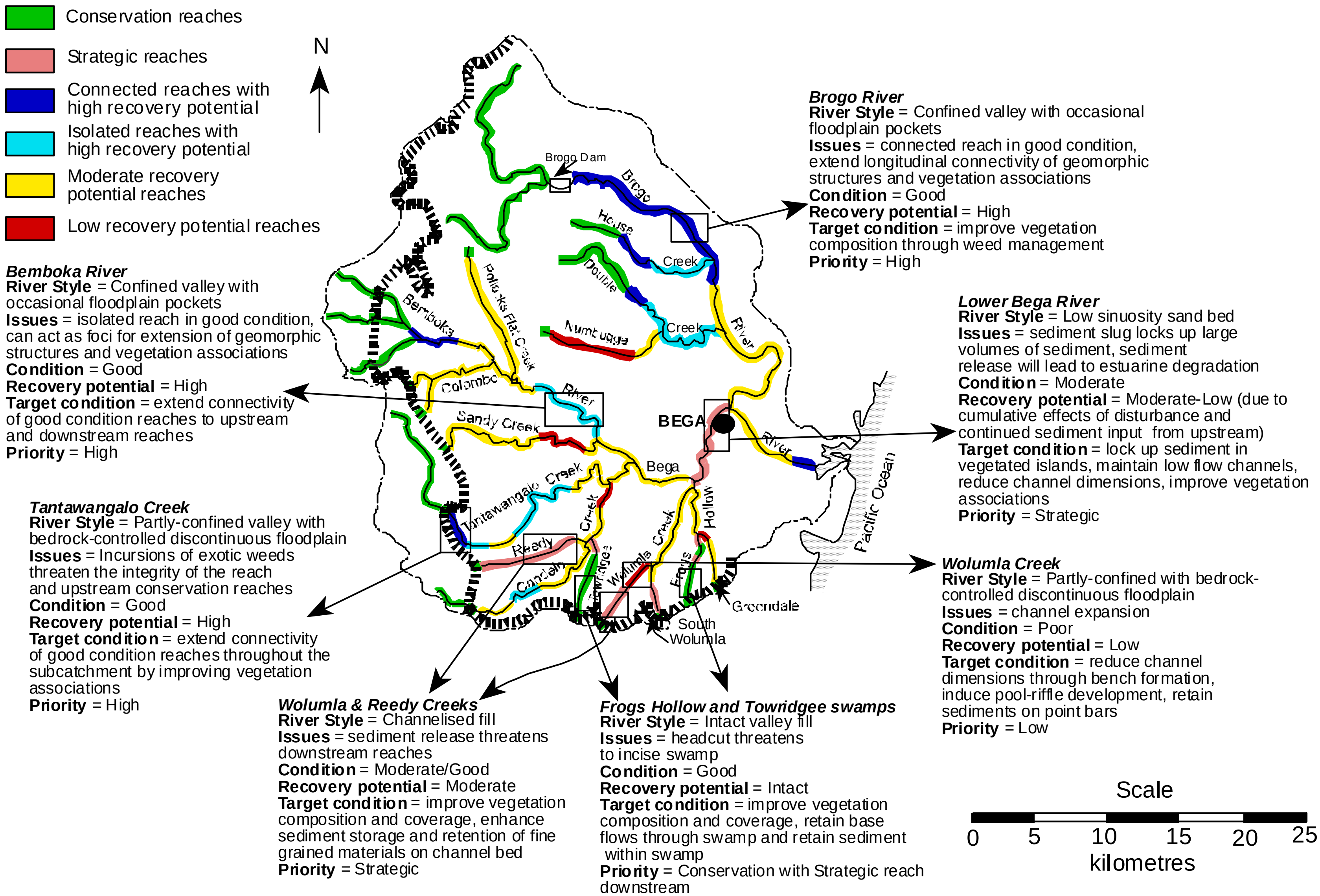


Table 7.3 Stream lengths for reaches of each River Style with different rehabilitation or conservation status

RIVER STYLE	CONSERVATION/ REHABILITATION PRIORITY	Length (km)	% of total stream length in catchment
Channelised fill	Strategic reaches	22	4.4
	Moderate recovery potential reaches	35	6.9
	Low recovery potential reaches	7	1.4
Confined valley with occasional floodplain pockets	Strategic reaches	4	0.7
	Connected reaches with high recovery potential	52	10.5
	Isolated reaches with high recovery potential	50	10.0
	Moderate recovery potential reaches	90	18.0
	Low recovery potential reaches	0	0.0
Floodout	Conservation reaches	2	0.4
Gorge	Conservation reaches	80	16.1
Intact valley fill	Conservation reaches	10	2.0
Low sinuosity boulder bed	Conservation reaches	13	2.7
Low sinuosity sand bed	Strategic reaches	10	2.1
	Moderate recovery potential reaches	36	7.2
Partly-confined valley with bedrock controlled discontinuous floodplain	Connected reaches with high recovery potential	17	3.3
	Moderate recovery potential reaches	19	3.8
	Low recovery potential reaches	21	4.1
Steep headwater	Conservation reaches	28	5.5
Brogo Dam		4	0.8

CONSERVATION/REHABILITATION PRIORITY	Total stream length in catchment (km)	% of total stream length in catchment
Conservation reaches	133	26.9
Strategic reaches	36	7.3
Connected reaches with high recovery potential	69	13.9
Isolated reaches with high recovery potential	50	10.1
Moderate recovery potential reaches	179	36.2
Low recovery potential reaches	28	5.6

Table 7.4 Stream lengths of each reach in each subcatchment with different conservation of rehabilitation status

Subcatchment/ River Style	Priority	Stream length (km)
Greendale		
Gorge	Conservation	0.24
Channelised fill	Moderate	3.93
Bedrock controlled discontinuous floodplain	Low	0.89
Frogs Hollow		
Gorge	Conservation	0.30
Intact valley fill	Conservation	4.04
Confined with occasional floodplain pockets	Strategic	1.17
Floodout	Conservation	1.96
Confined with occasional floodplain pockets	Strategic	1.53
South Wolumla		
Gorge	Conservation	0.25
Channelised fill	Strategic	6.05
Bedrock controlled discontinuous floodplain	Moderate	2.90
Confined with occasional floodplain pockets	Moderate	1.13
Wolumla		
Gorge	Conservation	0.28
Channelised fill	Strategic	6.36
Bedrock controlled discontinuous floodplain	Low	5.15
Confined with occasional floodplain pockets	Moderate	9.03
Towridgee		
Gorge	Conservation	0.25
Intact valley fill	Conservation	5.72
Confined with occasional floodplain pockets	Strategic	1.00
Candelo		
Steep headwater	Conservation	2.30
Gorge	Conservation	0.73
Bedrock controlled discontinuous floodplain	Moderate	4.04
Confined with occasional floodplain pockets	Isolated High	3.38
	Moderate	16.50
Bedrock controlled discontinuous floodplain	moderate	4.00
Reedy		
Gorge	Conservation	0.33
Channelised fill	Strategic	8.74
Bedrock controlled discontinuous floodplain	Moderate	0.83
Tantawangalo		
Steep headwater	Conservation	15.62

Gorge	Conservation	1.33
Bedrock controlled discontinuous floodplain	Connected high	6.79
Confined with occasional floodplain pockets	Moderate	7.12
	Isolated High	12.82
Bedrock controlled discontinuous floodplain	Moderate	8.29
Confined with occasional floodplain pockets	Moderate	8.30
Sandy		
Gorge	Conservation	0.58
Channelised fill	Moderate	8.45
Confined with occasional floodplain pockets	Moderate	4.79
Bedrock controlled discontinuous floodplain	Low	9.11
Confined with occasional floodplain pockets	Moderate	2.94
Colombo		
Gorge	Conservation	0.75
Channelised fill	Moderate	7.33
Bedrock controlled discontinuous floodplain	Moderate	3.94
Confined with occasional floodplain pockets	Moderate	0.84
Pollacks Flat		
Gorge	Conservation	0.27
Channelised fill	Moderate	9.98
Confined with occasional floodplain pockets	Moderate	1.01
Bemboka/Bega		
Steep headwater	Conservation	3.63
Gorge	Conservation	0.59
Low sinuosity boulder bed	Conservation	4.05
Confined with occasional floodplain pockets	Connected High	1.16
	Moderate	12.46
	Isolated High	12.53
	Moderate	15.08
Low sinuosity sand bed	Strategic	7.42
	strategic	3.04
Low sinuosity sand bed (below Brogo River confl.)	Moderate	10.70
Confined with occasional floodplain pockets (Bottleneck reach)	Connected high	9.24
Brogo		
Gorge	Conservation	32.15
Confined with occasional floodplain pockets	Connected High	31.58
Low sinuosity sand bed	Moderate	25.14
House		
Gorge	Conservation	3.52
Bedrock controlled discontinuous floodplain	Connected High	4.05
Confined with occasional floodplain pockets	Isolated High	5.45

Double		
Gorge	Conservation	11.77
Bedrock controlled discontinuous floodplain	Connected High	5.85
Confined with occasional floodplain pockets	Isolated High	15.77
Numbugga		
Gorge	Conservation	0.29
Channelised fill	Low	7.13
Confined with occasional floodplain pockets	Moderate	6.95

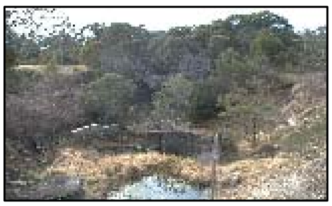
Strategic reaches are located immediately downstream of the conservation priority swamps (the Channelised fill and Floodout River Styles). For example, structural works were completed in Frogs Hollow in October 2002 to arrest a headcut that threatened the intact swamp. Swamp rehabilitation (largely vegetation related) will follow (**Figure 7.7**). Rehabilitation strategies have been implemented to inhibit headcut retreat into these remnant reaches. Strategic reaches are also located along Upper Wolumla and Reedy Creeks, where Channelised fill River Styles have released extensive volumes of sediment since European settlement (around 10 million m^3). Only now are these reaches showing signs of recovery, as sediments are accumulating along their channel beds. Given the relationship between bedload transport and available sediment, a strategic value is placed on these reaches to ensure that rehabilitation occurs through enhancing sediment storage and prevention of reincision, and associated sediment release to downstream reaches. The reach of the Low sinuosity sand bed River Style near Bega township is also given a strategic rating. Although this reach is in poor geomorphic condition and continues to experience the tail effects associated with the passage of the sediment slug, considerable potential exists for sediment release into downstream reaches and the estuary. In total, around 7 % or 36 km of river course in Bega catchment have been given a strategic rating. By conserving or rehabilitating these reaches, significant positive off-site impacts will result, enhancing the recovery of other reaches in the catchment.

Connected reaches with high recovery potential are located primarily at the base of the escarpment along the Partly-confined valley with bedrock-controlled discontinuous floodplain and the Confined valley with occasional floodplain pockets River Styles. Given their location downstream of intact or conservation reaches, many of these reaches have the potential to recover quickly with minimal intervention. These reaches make up around 14 % or 69 km of river course in Bega catchment. These reaches occur along Tantawangalo Creek, Bemboka River, House and Double Creeks as well as along the Brogo River. These reaches are in good condition and form good places from which to extend rehabilitation activities into other parts of the catchment.

Isolated reaches with high recovery potential occur along Tantawangalo Creek, Double Creek and Bemboka River. Interestingly, all these reaches are of the Confined valley with occasional floodplain pockets River Style. They are all in good geomorphic condition and make up around 10 % of all river courses in Bega catchment and extend along 50 km of stream length. These reaches are resilient to change and provide ideal foci (or anchor points) from which rehabilitation programs can be extended into more degraded sections of the catchment. These reaches are concentrated along Tantawangalo Creek and Double Creek. There is significant potential for the longitudinal connectivity of good condition reaches to be enhanced and extended along these river courses. Other isolated reaches with high recovery potential occur along Bemboka River and Candelo Creek. These reaches (especially along Bemboka River) present ideal opportunities to extend rehabilitation strategies into the surrounding moderate recovery potential reaches.

Figure 7.7 River rehabilitation works along Frogs Hollow and South Wolumla Creeks

Frogs Hollow swamp - Intact valley fill River Style with headcut



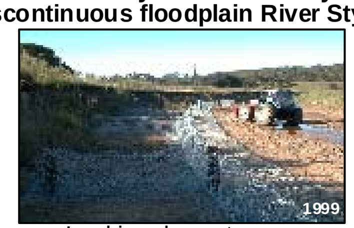
Pre-treatment - looking downstream (Photo C. Massey)

Post-treatment - looking downstream (Photo C. Massey)

Looking upstream - swamp on other side of road (Photo C. Massey)

Ticehurst on Wolumla Creek - Partly-confined valley with bedrock-controlled discontinuous floodplain River Style

Looking upstream Pre-treatment (Photo C. Massey)



Looking downstream - Installation (Photo C. Massey)

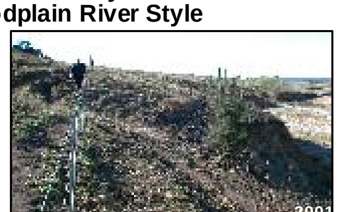
Looking upstream - Post treatment (Photo C.Massey)

Looking upstream - Post treatment (Photo C. Massey)

Looking upstream - Post treatment (Photo C. Massey)

South Wolumla Bridge - Partly-confined valley with bedrock-controlled discontinuous floodplain River Style

Looking downstream - Installation (Photo C. Massey)



Looking downstream - Installation (Photo C. Massey)

The remainder of the catchment is characterised by reaches with moderate or low recovery potential. These reaches are considered to be low rehabilitation priorities. They make up around 42 % of all river courses in Bega catchment.

Overall, strategic reaches are concentrated in the south-east of the catchment and along lower Bega River where the conservation and rehabilitation of Intact swamps and floodouts, and the locking up of sediment stores is considered a high priority for the longer-term geomorphic and ecological functoning of the river system. Beyond this, the subcatchments with the greatest likelihood of rehabilitation success, and the greatest likelihood of achieving a continuous riparian corridor, are in the Brogo system (along Brogo River, House and Double Creeks) and along Tantawangalo Creek. There is also potential for significant success along Bemboka River by connecting reaches with high recovery potential.

7.6 Linking the condition and recovery potential of rivers to the vision and prioritisation of reaches to develop a plan of attack for river conservation and rehabilitation

Key components of land and water management practices that have evolved in association with the development and application of the River Styles framework in Bega catchment include:

1. Determination of management programs that 'work with nature'.
2. Assessment of catchment-scale linkages of biophysical processes and their integration into river management plans.
3. Identification of rare or unique River Styles, such that appropriate conservation measures can be developed and applied.
4. Assessing the geomorphic condition and recovery potential of rivers.
5. Derivation of a catchment-based physical vision.
6. Identification of realistic target conditions for each reach in the catchment that fit within the catchment-based physical vision.
7. Development of a catchment-based prioritisation framework for river management programs.
8. Selection of representative reaches for various biomonitoring programs that are used to audit the impacts of environmental flows, water licensing and water quality.
9. Provision of key information that guides the decision-making processes for various management, policy and licensing issues relating to physical river condition and health (e.g. measures of biophysical stress, environmental flow allocations, habitat assessment, riparian vegetation surveys).

In Bega Catchment, understanding of physical processes has been used to develop proactive rehabilitation strategies that address the causes rather than the symptoms of river degradation. It is hard to imagine how *sustainable* management programs can be designed and implemented *independent from* these insights.

Figure 7.6 details how the physical vision for Bega Catchment can be achieved by implementing the prioritisation framework and concentrating river rehabilitation efforts along specific reaches. These procedures strive to achieve the catchment vision by enhancing river recovery potential. By tackling strategic reaches and rehabilitating reaches with high recovery potential first, there is a greater likelihood of rehabilitation success. In turn, this will increase the connectivity of reaches in good geomorphic condition. Strategies put in place along strategic reaches will have the greatest cost (e.g. through structural work and revegetation strategies). However, in subcatchments with high recovery potential and good foci from which to work out, strategies will be relatively low cost (largely fencing and weed control), low risk and will achieve quick (both locally and off-site). As positive consequences are manifest through the system, reaches with moderate and low recovery potential will increasingly self-adjust without intervention, allowing rehabilitation activities to enhance recovery in the future.

Table 7.5 outlines potential management strategies for each River Style in each different prioritisation category. This table goes further than is normally expected in Stage Four of a River Styles assessment. In this case study, guidance is provided on potential river rehabilitation options. As target conditions are achieved, the priority placed on a reach (and the strategies for rehabilitation) will change. This adaptive process requires recurrent monitoring and revision throughout the implementation and management phase.

Table 7.5 River management techniques for different reaches of River Styles in Bega catchment (modified from Fryirs and Brierley, 1998 c).

Priority	River Style	Reaches in Bega catchment (A/B = implementation program – see Table 7.6)	Comment	Potential risks if no action	Cost level
Conservation	Steep headwater and Gorge	(47) Bemboka, (30) Tantawnaglo, (21) Candelo, (1) Greendale, (4) Frogs Hollow, (11) South Wolumla, (14) Wolumla, (18) Towridgee, (22) Candelo, (27) Reedy, (31) Tantawangalo, (38) Sandy, (43) Colombo, (48) Bemboka, (58) Pollacks Flat, (61) Numbugga, (64) Double, (68) House, (71) Brogo	No changes to river structure are needed. Weed management should be initiated promptly, before problems get out of hand. Stock access management should accompany vegetation management. Commitment to on-going maintenance is required.	Spread of weeds and invasive plants to off-stream locations.	Low - Vegetation maintenance and weed management
	Low sinuosity boulder bed	(49) Bemboka (**A**)	No changes to river structure are needed. Vegetation management is required, focussing on strategies to remove weeds. Stock access management should be initiated promptly, before problems get out of hand. On-going maintenance is required.	Spread of weeds and invasive plants to off-stream locations.	Low - Vegetation maintenance and weed management
	Intact valley fill and Foodout	(12) Frogs Hollow (**A**) (7) Frogs Hollow	Management of the swamps should aim to encourage pre-disturbance vegetation associations, including a range of Melaleuca species and tussock grasses. Proposed rehabilitation strategies aim to maintain or improve this river style. Structural headcut management and a significant riparian vegetation program would achieve great success. Stock exclusion should be encouraged, maximising the potential for native vegetation regeneration. On-going weed maintenance is required.	These sites are extremely vulnerable to headcut retreat into the fills. Hence they pose a significant potential risk. If no action is taken, the potential implications for loss of existing ecological values, the loss of opportunities to rehabilitate these sites, and off-site impacts of downstream sediment transfer will be extensive.	Structural headcut management – high Maintenance (vegetation on swamps and floodouts) – low; Stock access control - low

Table 7.5 (continued)

Strategic	Channelised fill	(28) Reedy (15) Wolumla (12) South Wolumla	Bed stability should commence before bank stabilisation in these settings. To stabilise the bed and promote sediment retention and channel infilling, bed control structures may be required. Proactive rehabilitation strategies can accelerate the processes of natural channel recovery (through channel infilling) that appear to be evident at these sites (today, and over the past few decades). Cattle should be excluded from the incised trench and inset features and valley fill surfaces/banks revegetated. This will restrict erosion rates. Where inset features are not present, their formation (or installation) should be encouraged to promote sediment storage. Increased vegetation cover would trap sediments. Swamp vegetation associations should be encouraged along the channel bed. Ongoing maintenance is required over a medium term (decadal) timeframe. Channel expansion is a difficult (and expensive) process to counteract.	Significant potential remains for this site to supply large volumes of material downstream via valley fill erosion. The strategies suggested are low risk, but potentially vital.	Bed control - moderate to high. Stock access control and revegetation - moderate
	Confined valley with occasional floodplain pockets	(9) Upper Frogs Hollow (20) Towridgee	Address headcuts that are retreating into the fills, by either direct work on the nickpoint and incised channel immediately downstream, or protection of floodplain remnants (along lower order drainage lines) that inhibit incisional processes. Immediate action is required at these strategic sites.	These sites are the location of headcuts retreating into into valley fills and floodouts. Hence they pose a significant potential risk.	Bed control – high; Maintenance (vegetation on swamps and floodouts) – low; Stock access control - low
	Low sinuosity sand bed	(55) Bega River @ Grevillea (54) Bega River @ Groses Ck	Sediment management and maintenance of suitable channel geometries must be considered before vegetation improvement. In downstream reaches, effective rehabilitation is contingent on what happens upstream, requiring a long term perspective. Maintenance of present low flow channels is essential. This may require the clearance of some vegetation and selective removal of islands. This will encourage continued sediment throughput, but not sediment release which could impact directly on downstream and estuary reaches. The 'target' river structure should maintain the linkage between the channel and floodplain, and hence the backswamps, while reducing sand deposition atop the floodplain. This may be enhanced by deepening of the low flow channels. This process may be facilitated naturally if vegetation is removed from the low flow channel. Visible results at these sites could be achieved within a decade, but this site requires a long term strategy and maintenance (over decades).	High. Further vegetation establishment within the low flow channel will restrict sediment throughput, and island erosion will cause sedimentation problems downstream, potentially choking the channel and leading to avulsion into floodchannels (e.g. at Tarraganda). If sediment and vegetation choking extends downstream, where the channel is narrower, the channel may expand or avulse into floodchannels that are etched into the lowland floodplain.	Moderate

Table 7.5 (continued)

Connected high recovery potential	Partly-confined valley with bedrock-controlled discontinuous floodplain	(32) U. Tantawangalo (**B**) (69) House (65) Double	Vegetation management plans are required which exclude exotic species but encourage native regeneration. This strategy has a high likelihood of success given the good condition of the adjoining conservation sites which contain good seed sources. Vegetation in the riparian zone and on mid-channel bars needs maintenance. Lomandra and aquatic species should be encouraged around pools, but riffles should be kept free of vegetation so as to not obstruct flow and cause erosion of adjacent vegetated bars and floodplain. This strategy will also maintain sediment throughput. Ongoing weed management and vegetation maintenance are required. Should this be effectively emplaced, and weed problems are minimised, stock exclusion should be considered, aiming to achieve self-regeneration. Visible improvement can occur over a few years.	None. Strategies strive to maintain the present river style, but improve vegetation associations.	Low – largely vegetation related
	Confined valley with occasional floodplain pockets	(50) U. Bemboka (**A, B**) (72) Brogo (**A, B**)	Maintenance and improvement of vegetation structure is all that is required. Removal of exotics will likely allow natural seed sources to regenerate the riparian and within-channel zone. Native species presently colonising these zones are good. However, the extension of exotics into adjacent conservation priority sites must not occur. Sediment movement must be maintained as choking of the channel is undesirable. Local vegetation removal may be required. Visible improvement can occur in a few years.	None. Rehabilitation strategies aim to maintain the present river structure, but improve vegetation associations.	Vegetation removal – moderate. Vegetation maintenance and stock access control - low
Isolated high recovery potential	Confined valley with occasional floodplain pockets	(24) Upper Candelo (35) Mid Tantawangalo (**B**) (70) House (66) Upper Double (57) Bottleneck Reach (67) Lower Double (52) Lower Bemboka	These sites have the potential to recover with a well developed vegetation management plan and maintenance. These sites require exotic vegetation removal and direct planting and seeding to improve their vegetation and ecological character. To ensure continued sediment throughput, some vegetation clearance from the within-channel zone may be required, as numerous sections of these reaches are choked with vegetation which is largely exotic in character. Some sites would be rehabilitated successfully with moderately quick and visible results. Long-term strategies aim to connect these reaches with upstream high recovery potential and conservation reaches. Given their position, these reaches cannot be the highest priority for outlay of expenditure and effort, as upstream consequences must be dealt with first. Results could be achieved over a few years, as there is a relatively good basis to work upon.	None. Rehabilitation strategies aim to maintain the present river structure, but improve vegetation associations.	Moderate

Table 7.5 (continued)

Moderate recovery potential	Confined valley with occasional floodplain pockets	(1) Lower Frogs Hollow (34) Upper Tantawangalo (37) Lower Tantawangalo (40) Upper Sandy (63) Numbugga (17) Wolumla (25) Lower Candelo (42) Lower Sandy (46) Colombo (53) Bega River (51) Middle Bemboka (60) Pollacks Flat (**A**)	At present, vegetation management is all that can be readily achieved in these reaches. Sediment throughput is occurring naturally. These reaches are isolated from good seed sources and riparian strips are scattered or absent providing a limited platform upon which strategies could build. These sites will require longer term vegetation management and fencing off. Improvement of riparian vegetation structure will require seeding and planting programs to encourage native vegetation cover. Visible results should occur in years. A long-term, decadal timeframe is required for development, given limited sediment availability from upstream, and that much of this sediment will be locked up in the future.	Little risk, as vegetation improvement can only be beneficial.	Moderate
	Partly-confined valley with bedrock-controlled discontinuous floodplain	(23) Upper Candelo (36) Middle Tantawangalo (45) Colombo (29) Reedy (13) South Wolumla (**BVSC, DLWC**)	Self-adjusting channels with reduced channel dimensions and lower rates of lateral adjustments can likely be achieved by building on the contemporary pattern of river changes to decreased sediment loads. Minimal structural works at problem bends will encourage sediment accumulation along concave banks. To encourage success with vegetation strategies, stock access control is required. Results at these sites could be achieved within a decade.	These sites are sensitive to change, and will adjust naturally.	Moderate
	Channelised fill	(39) Sandy (**A**) (2) Greendale (44) Colombo (59) Pollacks Flat	Bed stabilisation must occur before bank stabilisation. In most instances, the channel has incised to bedrock or a local base level (e.g. gravel lag) and is now stabilising. Inset features are often already well vegetated and stabilising the channel marginal zone, indicating that the sites are rehabilitating naturally. As such, management strategies should encourage and build on these natural recovery processes. As these sites adjoin conservation sites, there are good upstream sources of native seed, increasing the likelihood of success of riparian vegetation rehabilitation. Stock exclusion and weed management are required to maximise this potential. Vegetation management strategies are required to minimise lateral channel expansion. Emplacement of small bed control structures, along with vegetation regeneration and the reintroduction of wood, would promote sediment retention and infilling of the channel, promoting conditions to facilitate swamp development. The retention of mud and organic material is essential for swamp re-establishment. Hence, the roughness of the channel bed must increase (through vegetation and wood strategies). Reconstruction of intact valley fill surfaces is not attainable over the short to middle term (i.e. decades). However, formation of a swamp within the incised trench may be relatively quick (years).	Potential for sediment release. Weed management should be considered.	Bed control and wood - moderate to high. Stock access control and vegetation - moderate

	Low sinuosity sand bed	(56) Bega @ Tarraganda (**A, BVSC**) (73) Brogo @ Pearces Ford	Sediment management and maintenance of suitable channel geometries must be considered before vegetation improvement at this site. As the downstream part of the catchment, effective rehabilitation is contingent on what happens upstream and requires a long term perspective and maintenance approach. Maintenance of present low flow channels is essential. This may require selective clearance of vegetation and removal of islands. This will encourage continued sediment throughput, but not sediment release which would impact directly on downstream and estuary reaches. 'Target' conditions for river structure should maintain the linkage between the channel and floodplain, and hence the backswamps, while reducing sand deposition atop the floodplain. This may require the deepening of the low flow channels, which will occur naturally if vegetation is removed from the low flow channel to a width that enables maintenance of sediment throughput. Visible results at these sites could be achieved within a decade, but this site requires a long term strategy and maintenance (over decades).	High. Further vegetation establishment within the low flow channel will restrict sediment throughput, and island erosion will cause sedimentation problems downstream, choking of the channel and possible channel avulsion into floodchannels (e.g. at Tarraganda).	Moderate

Low recovery potential	Partly-confined valley with bedrock-controlled discontinuous floodplain	(26) Lower Candelo (3) Greendale (41) Sandy (16) Wolumla	Sediment transfer from point bar to point bar should be maintained, while striving to reduce channel capacity and the rate of lateral migration. In all instances, bed stability must be addressed prior to bank concerns. In severe cases, channel realignment may be required with bed and/or bank control structures. Within-channel vegetation establishment on point bars and benches is required to stabilise sediment stores and encourage channel contraction. Riparian vegetation to establishment is required reduce bank erosion and channel expansion. Results at these sites will require a longer term rehabilitation strategy.	These sites are sensitive to change and risks of strategies failing are high.	Moderate to high depending on selected works
	Channelised fill	(62) Numbugga	Bed stability should commence before bank stabilisation. Development of inset features should be encouraged. Existing features should be revegetated so that sheer valley fill banks are protected and channel width is narrowed. Where inset features are not present, vegetation strategies could trap sediment at the base of shear valley fill banks. Sediment should be retained whenever possible through promotion of in-channel sedimentation and localised swamp development. Bed control structures may be required, such as log drops or weirs. Results at these sites will require long term works and maintenance.	Significant potential remains for these sites to supply large volumes of material downstream, and for further valley fill erosion to occur.	Moderate to high depending on works chosen

7.7 Stage Four, Step Four: Monitor and audit improvement in geomorphic condition

Based on the information in **Table 7.5**, the Bega Office of NSW DNR have undertaken, or are in the process of implementing and monitoring, a range of river conservation and rehabilitation strategies in different parts of the catchment. These are outlined in **Table 7.6** and include:

- Design and implementation of headcut retardation structures for strategic reaches of the Intact valley fill River Style.
- Reaches of the Channelised fill have been fenced off to reduced the impact of cattle. Sediment accumulation is now occurring on the channel bed.
- Reaches of the Partly-confined valley with bedrock-controlled discontinuous floodplain River Style in Wolumla Catchment have had a mix of structural and vegetation rehabilitation works completed as a demonstration of how to 'work with' river character and behaviour and implement appropriate strategies that enhance river recovery.
- Weed management is underway along the good reaches of the Confined valley with occasional floodplain pockets River Style in Bemboka subcatchment. This will provide a focal point from which rehabilitation of reaches upstream and downstream can occur.
- Strategies to maintain sediment storage and improve vegetation composition along the lowland plain are underway. Wood is being emplaced to improve bed structure and induce pool development.

Each of these reach-scale strategies fits within the catchment vision, recognising explicitly the catchment-scale linkages of geomorphic processes and the natural character and behaviour of each River Style. Although encouraging results have been achieved thus far, long term success will require sustained commitment to monitoring and maintenance programs.

Table 7.6 Ongoing river conservation and rehabilitation works in Bega Catchment (as of December, 2002).

Background
The NSW DLWC is developing and coordinating a range of plans and on-the-ground works that are currently being implemented through the (**A**) Bega Integrated Sediment Management Project and (**B**) The Bega-Towamba Catchments River Rehabilitation Incentive Scheme. Other parties include Landcare Groups, the Bega Valley Shire Council (**BVSC**), the National Parks and Wildlife Service (**NPWS**) and the local dairy industry. Significant funds from the Natural Heritage Trust (NHT) have been used to implement the strategies on-the-ground. These programs are designed to achieve the goals set out within the catchment-framed vision and are based on the findings presented through the application of the River Styles framework throughout the catchment. NSW DLWC are providing technical advice and planning assistance, works management and extension. The Far South Coast Catchment Management Association (FSCCMA) have been the principle body in planning and submitting the funding applications.

The first priority for works in Bega catchment is to protect sediment sinks from incision and sediment removal (i.e. protecting intact valley fill and floodout River Styles). All potential sediment sources are being targeted and stabilisation options outlined. Broader ecological issues such as willow (*Salix spp.*) control and native vegetation replanting form part of the approach to rehabilitate priority areas and river reaches.

Community Participation
Using the River Styles framework has provided a basis to educate community groups on the use of geomorphic knowledge as a basis to improve river/catchment health. In addition, communities need to be aware of methods of sustainable options for riparian and riverine management, and the necessity to undertake remedial works. The catchment plan involves rehabilitating strategic and high recovery potential reaches by applying a range of rehabilitation techniques. All reaches entail rehabilitation techniques that fit with the natural character and behaviour of the River Style. Re-vegetation programs form part of their respective recovery plans. Some sites are located in high profile areas, close to major roads, which have good demonstration and community education potential.

Project Title/ Subcatchment/ River Style	Aim/Geomorphic achievements	Description of remedial works/ cost/ status
Wolumla Catchment Sediment and Rehabilitation Rivercare Program		
Ticehurst (Wolumla) Partly-confined valley with bedrock controlled discontinuous floodplain	• Stabilise sediment stores along a 500 m reach of Wolumla Creek. • Good demonstration site to show how rehabilitation works with the natural processes of the River Style.	• 150 m mesh fence and bays • 150 m rock revetment wall • rock flume on small headcut • fencing and revegetation • $61,000 completed 1999
Sarjents Swamp (Wolumla) Intact valley fill	• Apply rehabilitation measures to minimise impacts from a headcut that is retreating into an intact tributary fill, in an area suffering from grazing pressure.	• bed level cattle crossing • log weir • fencing and revegetation of swamp • $2,900 completed 1999
Frogs Hollow Swamp (Frogs Hollow) Intact valley fill	• Protect an intact, high conservation priority remnant swamp from a retreating headcut and potential release of large volumes of material. • Protect the ecological attributes of this wetland (ongoing).	• concrete flume to arrest headcut • fencing and revegetation on swamp • $80,000 completed October 2002
South Wolumla Bridge (Wolumla) Partly-confined valley with bedrock controlled discontinuous floodplain	• To prevent channel expansion and undermining of bridge. • To trap and stabilise sediment in bench and bar features. • To reduce channel capacity. • To re-instigate ecological functioning along the reach. • To demonstrate the geomorphic function of wood in trapping river sediments and the role of vegetation in stabilising that sediment. • To compliment works completed at the downstream Ticehurst site.	• timber or mesh wire bank protection structures have been constructed • Fencing and revegetation. Bank protection bays have been planted with native swamp and riparian vegetation species. Riparian strip replanted. • $75,000 completed 2001
Wolumla catchment All River Styles	• To target smaller, but strategically important, sediment sources.	• over 9000 locally grown trees and shrubs planted on intact swamps,

	• To enhance the ecological integrity of the catchment.	river banks and other sensitive areas • some minor gully control works • $25,000 ongoing
Bega Integrated Sediment Management Projects		
Sediment control projects (Throughout catchment)	• 12 sediment control projects aimed at stabilising sediment stores in strategic locations throughout Bega catchment.	• minor structural (wood, wire training etc.) some non-structural (vegetation) • management contracts set up with landowners to maintain works for 11 years • $130,000 completed
Sand sheet stabilisation (Wolumla and Tantawangalo)	• To stabilise sediments stored in sand sheets on the channel bed, reducing material movement to the Bega trunk stream.	• Revegetation techniques being designed. • Storing local species that have high establishment success rates. • Trialling direct seeding. • $22,500, ongoing design phase
Wood along Bega River (Lower Bega River near Brogo confluence) Low sinuosity sand bed	• To induce pool formation and scour on the channel bed. • To provide aquatic habitat for fish.	• Wood structures designed • $19,500, 2003, design phase
Bega-Towamba Catchments Stream Rehabilitation Incentive Program		
Weed control and stock management (Throughout catchment)	• 22 projects to target strategic reaches throughout Towamba and Bega catchments. • Upper Bemboka River and 11 other reaches are key in Bega catchment.	• Weed control, stock management (fencing and water troughs) • Management contracts set up with landowners to maintain works for 11 years • $208,000, ($150,000 community, $58,000 DLWC), completed
Miscellaneous Landcare projects	• Numerous projects funded and ongoing.	
Additional initiatives to achieve the catchment vision Additional initiatives are in the process of development to meet the South East Catchment Management Board Blueprint (NSW DLWC, 2002). This document summarised priority work targets up to the year 2012.		

7.8 Concluding comments

River management must continue regardless of limitations of knowledge. There will always be some level of trial and error involved and mistakes will be made. However, in all instances, it is advisable that the precautionary principle is observed, and best use is made of available information in a conservative manner. If effective monitoring and reporting procedures are put in place, we can learn from successes and failures, ensuring effective transfer of knowledge elsewhere.

Many Rivercare and Landcare groups, as well as individuals in NSW and across Australia, have shown considerable ingenuity in the design of river rehabilitation plans. So long as these plans work with the behaviour of the river, the local group takes ownership of the experimental designs, and appropriate auditing procedures are put in place (and documented), these developments are to be encouraged. Collective commitment to a process of learning will yield significant advances in rehabilitation measures. Application of the River Styles framework provides a rational basis by which lessons learnt in one reach can be meaningfully applied elsewhere (i.e. for an equivalent type of river character and behaviour). However, in all these applications, appropriately documented procedures for rigorous auditing and post-project appraisal are critical if the best environmental outcomes are to be achieved both now and into the future.