Assembly of geomorphic targets for stream rehabilitation - summary of a manual template

David Outhet[1] and Carolyn Young[2]

1 NSW Dept. Natural Resources, POB 3720, Parramatta NSW, 2124. Web: www.dnr.nsw.gov.au, Email: david.outhet@dnr.nsw.gov.au
2 NSW Dept. Natural Resources, POB 189, Queanbeyan NSW, 2620. Email: Carolyn.young@dnr.nsw.gov.au

Abstract

All rehabilitation project stakeholders need to know what their reach will look like and behave like when its recovery is complete. However, selecting a target is complex. We cannot just say "give us a chain of ponds". The physics of the situation may make that an impossible target. Accordingly, we have developed a template for a manual that can be adapted by NSW Catchment Management Authorities for the consistent and objective step-by-step 'assembly' of virtual target reaches. Their manuals will supplement Stage 4 of the River Styles framework and provide geomorphology advisors with thinking tools such as catchment-specific descriptions of each Style's recovery stages and field indicators of their pre-degradation state. There will also be guidance on using place for time substitution and historical information. The assembled virtual target reach must allow for the major irreversible changes in geomorphic controls at both catchment and reach scales such as hydrologic changes from catchment clearing. This type of assembly results in a 'feasible' target reach that is closest to natural rates and types of change, given the present-day controls. That is, a reach that stakeholders can realistically expect to see after recovery is complete. A worked example is given.

Keywords

Rehabilitation, target condition, stream, geomorphology, River Styles

Introduction

This conference paper is a summary of a template for a manual or guideline produced by the NSW Department of Natural Resources (Outhet & Young, 2007) titled: "Assembly of Geomorphic Targets for Stream Rehabilitation" for adaptation and use by NSW Catchment Management Authorities (CMA). Stream rehabilitation project planners/designers need a target. In addition, all stakeholders need to know what their reach will look like and behave like when its recovery is complete. However, selecting a target is complex. To help with the geomorphology aspects of targets, the NSW Department of Natural Resources (DNR) has been compiling a database of real reference reaches for the geomorphic types of stream (River Styles) in NSW (Outhet & Young, 2005). Project planners/designers can visit, observe and measure the real reaches. These reaches integrate all the local controls that affect the processes in the stream at that site. However, we have not been able to find a reference reach for many of the more fragile Styles. In addition, the reach to be rehabilitated may have somewhat different controls from the reference reach. These controls may prevent achievement of the target or the final result may look different from the reference reach. What is required, then, is a 'feasible' target reach that is closest to natural rates and types of change, given the present-day controls. That is, a reach that stakeholders can realistically expect to see after recovery is complete.

This manual template has been written at the request of NSW CMA river rehabilitation staff. Previous target selection guidelines (e.g. Rutherfurd *et al.*, 1999; Brierley & Fryirs, 2005) gave very good descriptions of the process and concept but did not provide enough locally-relevant details related to individual geomorphic types of streams. Each type of stream has very different controls and processes. It is essential that the target be the same River Style (or ancestral River Style) as the rehabilitation reach. This avoids river managers attempting the geomorphic equivalent of 'trying to grow oranges on an apple tree'.

The adapted or assembled target must allow for the major irreversible changes in geomorphic controls that can occur at both catchment and reach scales. Examples are hydrologic changes from catchment clearing and local floodplain changes caused by cropping and flood mitigation. Fortunately, some controls can be changed by on-ground action and these are the ones that designers must identify and use to promote geomorphic recovery by the stream.

To help planners/designers achieve a realistic target, we have developed the following step-by-step guide for the consistent and objective assembly of target reaches. This is a template that can be modified and adapted by each CMA to suit its local conditions by inserting tables, diagrams and photographs. The final manual produced by each CMA will mainly supplement River Styles Stage Four as described in the River Styles book (Brierley & Fryirs, 2005). It is assumed that Stages One to Three have been done by the user (or others) and will only be described briefly in the manual as a reminder to the user. Many catchments in NSW already have maps for those 3 stages. The manual will mainly provide geomorphology advisors (the main manual users) with thinking and observing tools such as locally-relevant descriptions of indicators of pre-degradation state and the extent of degradation or recovery. There will also be guidance on using place for time substitution and obtaining historical information for the catchment and each reach.

Summary of each step in the manual template

Step 1. Determine the River Style of the rehabilitation reach (River Styles Stage One)
It is essential that the label for the geomorphic category of the reach is consistent with the labels for the reference reaches to enable comparison of like with like. DNR and the CMA's in NSW have adopted the latest version of the River Styles framework as described in Brierley and Fryirs, (2005).

- Refer to an existing River Styles report/map or, if one has not been done for your catchment;
- Determine the Style using air photos, field observations and the strict rules in the DNR dichotomous key.

Step 2. Determine if the reach Style is one that has an ancestor Style
Some Styles have an ancestor. These reaches have 'evolved' from one Style to another due to major geomorphic change. For example, the Channelised Fill ancestor was Chain of Ponds or Valley Fill because Channelised Fill is caused by the channelisation (natural or artificial) of those two Styles. If a Style has no ancestor then the target for rehabilitation cannot be a different Style from the existing one.

- Refer to the table of Styles and their ancestors that are specific to your catchment.

Step 3. Determine the geomorphic condition of the reach (River Styles Stage Two)
Each reach of stream has its own combination of geomorphic controls (up to 50) that produces the Style and condition of the reach you see today. In the River Styles framework, the geomorphic condition is assessed by comparing your rehabilitation reach with a real or expected reference reach for the Style.

- Refer to an existing River Styles report/map or, if one has not been done for your catchment;
- Consult the DNR River Style Reference Reach Database. If a real reference reach is documented;
- Refer to: 'Field manual for assessing geomorphic condition and trajectory'(Young & Outhet, 2006);
- If a real reference reach is not documented, construct an expected reference by following the procedure in chapter 10 of Brierley and Fryirs (2005) (which will be summarised in the CMA's manual).

Step 4. Assess if the reach is presently degrading or recovering and determine recovery potential (River Styles Stage Three)
Each geomorphic control is likely to be changing at a different rate and extent. For example, the hydrologic regime may have changed quickly and markedly in the past due to catchment clearing but is still changing slowly and subtly due to climate change. The local land use may have changed from dairy cattle grazing to cropping. These control changes can cause the reach to degrade or recover.

- Refer to an existing River Styles report/map or, if one has not been done for your catchment;
- Refer to the table of controls for the Style of your reach and;
- Obtain historical information on any changes in those controls from the list of information sources for your catchment (in addition to the land owner/manager) and;
- Obtain evidence of change from a time series of air photos and;

- Use field observations of change indicators (refer to diagrams and photographs relevant to your catchment). Examples are:
    - Channel
        - Sinuosity – indicators of former path
        - Width/depth ratio – from old channels
    - Bed
        - Indicators of former bed level
        - Indicators of former bed material
        - Effects of artificial bed controls
        - Effects of sediment starvation
    - Banks
        - Indicators of accelerated erosion
        - Effects of artificial bank erosion controls
    - Floodplain
        - Effects of channel expansion on floodplains
        - Effects of channel contraction on floodplains
        - Effects of Artificial Levees
        - Effects of Flood Channel Blockage or Diversion

- Use similar observations of other reaches of the same Style with the same controls but in better condition to substitute place for time to show the future of recovery.

Step 5. Determine which controls are locked in and which ones can be changed to promote recovery
The geomorphic controls are the limiting factors to recovery. It is impractical to change some so they are considered to be 'locked in'. Others can be changed by management action to promote the reach's recovery processes. Examples are:

- Catchment
    - locked in: rural flow regime (reforesting a whole cleared catchment is impractical)
    - changeable: urban flow regime (using detention basins)
- Adjacent
    - locked in: bank material (impractical to replace a long length of bank with better material)
    - changeable: levee constricting floodplain flow (can be moved)
- Downstream
    - locked in: backwater from valley margin constriction
    - changeable: backwater from a weir (can be lowered or removed)
- Upstream
    - locked in: sediment starvation (impractical to import sediment to catchment)
    - changeable: sediment excess (may only require control of a headcut)

Step 6. Determine if the controls can be changed enough to get the reach back to an ancestor Style or, if beyond the point of no return, to the 'good' condition of the present Style.
This step uses the information obtained in the previous step to assess the effectiveness and practicality of intervention in the changeable controls. A table specific to each catchment must be compiled giving the user information on:

- intervention type (eg structures, revegetation, fencing, land use change) and;
- how each type affects controls and, in turn, reach characteristics (eg size of detention basin needed to reduce urban peak flow by 50% thereby reducing bank erosion rate) and;
- the cost of the different sizes or extent of each type (eg cost of fencing per km).

Step 7. Assemble detailed target characteristics for the rehabilitation reach
This is the final step where the information from the previous steps is used to assemble the targets for the rehabilitation reach. This is where we ask: "which characteristics of the Style's real or expected reference reach can be reasonably achieved in the rehabilitation reach, given the actions we can afford?" For example, structural works may be required to reduce the bank erosion rate back to the Style's reference reach rates but we may only be able to afford revegetation which will only reduce the rate by 50%. So we expect to see bank erosion continuing to happen in the rehabilitated reach but at a slower rate than at present.

Worked example: Toorawandi Creek (Castlereagh River Catchment, NSW – Central West CMA)

Step 1. Determine the River Style of the reach
The River Style of the reach keys out as Channelised Fill. The main characteristics that define this Style are: no valley margin control, floodplain continuous with a flat featureless surface, organic stained bank strata, single channel with a low sinuosity, active sand sheets, lateral bars and a swampy low flow path. Some of these characteristics can be seen in Figure 1.

Figure 1. The rehabilitation reach on Toorawandi Creek before any intervention.

Step 2. Determine if the Style is one that has an ancestor Style
The ancestor Style for Channelised Fill in this catchment is Valley Fill (sand). The sand sub-Style is due to the extensive sandstone bedrock in this part of the Castlereagh catchment. Channelised Fill is caused by the channelisation (natural or artificial) of a Valley Fill reach. The presence of the former Valley Fill (sand) Style is indicated by: sandy bed, flat and featureless remnant fill surface (slightly higher in the centre than at the valley margins), remnants of the swampy meadow tussocks, banks with sand and fine grained strata and an organic-stained darker material near the top formed by swampy meadow vegetation over a long period of time.

Figure 2 shows the assembled appearance of the different stages in the evolution of the Toorawandi rehabilitation reach from Valley Fill (sand) Style to Channelised Fill Style and back again (diagrammatic with vertical exaggeration). It has been compiled by obtaining historical information from long term land owners in the area and from place for time substitution. The land owners say that there used to be many more of the 'swampy' valley bottoms and that the 'gullies' are getting bigger.

A few remnant intact Valley Fill (sand) Style reaches are still found in the area so they were used to assemble the Figure 2 stage 1 pre-disturbance characteristics such as the swampy meadow vegetation (tussocks) on the fill surface. There are no trees due to the permanent swampy conditions. All flows are spread over the whole fill surface and are confined by the valley margins acting as 'banks'. The present situation in the reach is stage 2. Here, the controls have changed, causing degradation and a change to the Channelised Fill Style. A channel is incising into the fill. Both banks are eroding. The swampy meadow is drying out. Stage 3 (future after natural recovery occurs) characteristics were assembled from observing a stable reach well upstream of the major headcuts on Toorawandi Creek: swampy low flow, stable grassed banks and trees starting to grow on the former fill surface (now floodplain). At stage 4 (the assembled target for the reach), bed controls have been installed, causing the channel to fill with sediment and, over time, return the reach to its ancestral Style. All flow is once again spread over the whole fill surface. Swampy meadow tussocks return and the trees die due to the permanent swampy conditions.

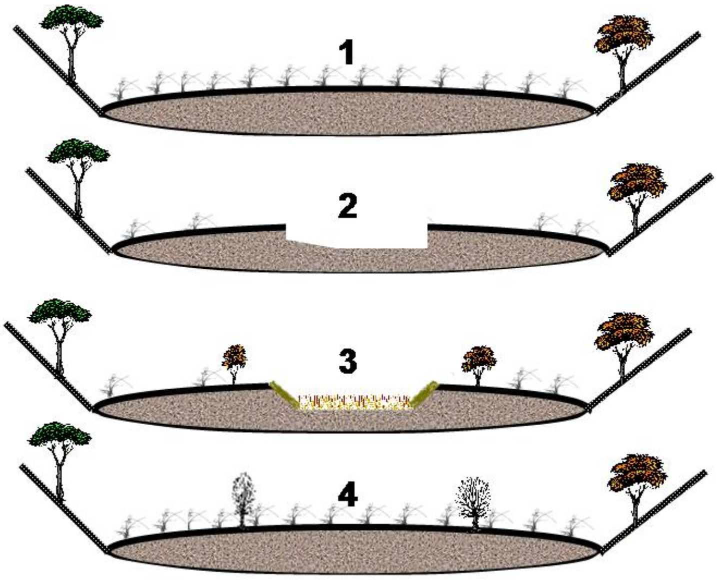

Figure 2. Evolution of the Toorawandi rehabilitation reach Valley Fill (sand) Style to Channelised Fill Style and back again (cross section). (1) – pre-disturbance time - Valley Fill Style. (2) – present time – Channelised Fill Style -degrading. (3) – future - Channelised Fill Style – good condition. (4) – future after intervention – assembled target Valley Fill Style.

Step 3. Determine the geomorphic condition of the reach.
As of the time of writing, there is no documented real reference reach for Channelised Fill. An expected reference was constructed based on a 'stable' (natural rates of change) reach upstream of the major headcuts. Relative to this reach, the rehabilitation reach is in poor condition. This is due to bed lowering causing erosion of both banks (as evident in Figure 1). There is very little bank or bed vegetation to control erosion and there are only small remnants of swampy low flow paths. Cattle access has caused damage.

Step 4. Assess if the reach is presently degrading or recovering and the recovery potential.
The reach is presently degrading due to headcuts as mentioned above. There is a headcut immediately upstream of the reach and another one mid-reach. The lowered bed level has reduced bank support so both channel banks are collapsing. There is insufficient vegetation on the bed or banks for protection and no bedrock in the bed to stop the headcuts progressing upstream.

The history of the catchment and the reach indicates that a combination of major geomorphic control changes has occurred. Extensive forest clearing in the catchment is likely to have increased the frequency of erosive flow events. There has been reduced groundcover on the valley fill surface due to grazing pressure. Finally, some unknown combination of control changes has initiated the headcuts.

To recover to a better condition for the Channelised Fill Style or back to the ancestral Valley Fill (sand) Style, the channel bed needs to aggrade. To achieve Valley Fill (sand) Style the bed must aggrade back to the former valley fill level so that the valley margins become the 'banks'. This will spread the flood flows over a wide area, making them shallow with much lower shear stress than found in deep channels. This must be accompanied by recovery of the swampy meadow tussock vegetation on the surface of the fill which can resist the shear stress of the flood flows. To assess if the reach is recovering to valley fill, the trend should be a decrease in: bankfull discharge return period, flood runner channel size, avulsions and shear stress. In addition, there should be an increase in: width to depth ratio, Manning's n, vegetation cover, and sediment accumulation. Methods for measuring and analysing these indicators are available in Young and Outhet (2006).

The recovery potential was assessed as moderate. As can be seen in Figure 1, there appears to be a large active load of sand in the bed. An estimate of active bed load volumes upstream of the rehabilitation reach indicates that there is enough to fill the channel back to valley fill level over a short period of time (decade or less, depending on flow occurrence). However, intervention works (bed controls) must be constructed to promote the aggradation process and achieve recovery.

Step 5. Determine which controls are locked in and which ones can be changed to promote recovery.
The locked in controls for this example are flow regime and sediment supply.

The controls that can be changed for rehabilitation are the headcuts (by installing bed control structures) and the vegetation (by establishing vegetation as the main long term bank and valley fill protection).

Step 6. Determine if the controls can be changed enough to get the reach back to an ancestor Style, or if beyond the point of no return, to the good condition of the present Style
Bed controls have been designed to cause bed aggradation back to valley fill level so that the channel is completely filled, returning the reach to Valley Fill (sand) Style as shown in stage 4 of Figure 2. As mentioned in step 4 above, the sediment influx appears to be adequate for completely aggrading the bed in a decade or so (depending on flow occurrence). The land owners and the CMA are willing to rehabilitate the stream and undertake maintenance. They see many benefits coming from stopping sediment getting into the Castlereagh River (where there are sediment slug problems), from having water stored in the valley fill and from the extended time for plant growth on the swampy meadow in dry periods. The stock access will have to be controlled and some revegetation carried out. The works have been costed and funding is available.

Step 7. Assemble detailed target characteristics for the rehabilitation reach
By referring to stage 4 in the evolution diagram in Figure 2, we assembled the following target characteristics for the rehabilitation reach of Toorawandi Creek:

- Geomorphology: no channels so all flow is spread over the whole fill surface with the valley margins acting as 'banks';
- Sediment regime: accumulation of sand across the whole valley fill surface. No sand leaving the reach;
- Vegetation: dense native grasses (as close to 100% ground cover as possible) such as Poa tussock. The existing trees will die due to the permanent swampy meadow conditions.

Conclusion

We have produced a user-friendly step-by-step manual template to guide the assembly of geomorphic targets for stream rehabilitation. The steps are designed to allow geomorphology advisors to assemble feasible targets, regardless of whether a suitable reference reach exists. The method builds on previous target selection guidelines by relating to individual geomorphic types of streams, providing locally-relevant details, and enabling a consistent and objective approach to stream rehabilitation. The steps are summarised and an example is provided to demonstrate the thinking behind each step. The manual template can now be adapted and published by each NSW CMA.

Acknowledgements

We gratefully acknowledge the River Styles framework by Gary Brierley and Kirstie Fryirs plus the information on Toorawandi Creek from Michael Longhurst.

References

Brierley, G. J., & Fryirs, K. A. (2005). *Geomorphology and river management - applications of the River Styles framework.* Carlton, VIC.: Blackwell Publishing.
Outhet, D. N., & Young, C. (2005). Using reference reaches to suggest causes of poor river geomorphic condition. In I. D. Rutherfurd *et al.* (Ed.). *Proc. 4th Australian Stream Management Conference: linking rivers to landscapes* (pp. 470-476). Hobart TAS.: Department of Primary Industries, Water and Environment.
Outhet, D. N., & Young, C. (2007). *Scientific and technical operating procedures: Assembly of Geomorphic Targets for Stream Rehabilitation.* Parramatta, NSW: Department of Natural Resources (intranet)
Rutherfurd, I. D., Jerie, K., & Marsh, N. (1999). *A rehabilitation manual for Australian streams volume 1.* Canberra, ACT: Land and Water Australia.
Young, C., & Outhet, D. N. (2006). *Scientific and technical operating procedures: Geomorphic reference reaches – field manual*. Parramatta, NSW: Department of Natural Resources (intranet).