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Aesthetic Considerations for Stream Restoration

Stream restoration projects provide social, environmental, and economic benefits which account for the three pillars of landscape sustainability. Of these, EPA focuses on the environmental aspects including water quality protection and restoration.

Anthropogenic activities exacerbate the problems encountered in stream restoration activities. In rural areas nutrients, sediments, and pesticide stream loadings result from agricultural use while urban expansion increases flash flooding and nonpoint pollutant loading (Allan, 2004; Palmer & Bernhardt, 2006).

EPA is exploring the use of stream restoration for water quality protection to promote cooperation with local stakeholders, to encourage sustainable environmental management (RESTORE Partnership, 2013) and to ensure that social and economic considerations be incorporated in environmental planning (National Research Council, 2001; Eden & Tunstall, 2006). Although stream restoration projects may be based on sound science, strong social support is needed if the restoration projects are to be funded, implemented, and sustainably maintained (Kondolf & Yang, 2008). To this end, aesthetics are an integral component of the social and economic benefits of stream restoration and must be considered in stream restoration projects for sustainable management.

Aesthetics in stream restoration

Aesthetics is one of the frequently listed goals for stream restoration in the US (Bernhardt et al., 2005). Besides environmental benefits (in terms of water quality control, flood control, creation of habitat, and biodiversity increase), high quality restoration designs could create attractive aquatic environments and promote economic benefits associated with aesthetics, such as urban regeneration, business growth, and increased land and property values (RESTORE Partnership, 2013). This document introduces the aesthetic considerations for stream restoration. According to literature on landscape aesthetics, visual landscape indicators associated with stream systems (stream channel, riparian wetland or floodplain, and upland landscape) are categorized into three groups as shown in Table 1. Visual indicators with positive, negative, and mixed aesthetic effects are described and case studies illustrate the aesthetic considerations of several restoration projects.

Table 1. Landscape visual indicators associated with stream systems

Positive aesthetic effects	Negative aesthetic effects	Mixed aesthetic effects
Openness and open water	In-channel debris [A]	Man-made features
Water clarity	Reduced proportion of water in channel	Water flow and area
Water movement	Signs of erosion	Trees [B]
Curved or meandering shape	Undesirable plants	Wild systems [C]
Desirable wildlife (e g. birds)		
Colorful plants		

A: There could be exceptions: people in Oregon did not perceive in-channel woody debris negatively (Piegay et al., 2005).
B: Trees generally contribute to aesthetics in a waterscape as long as they don't block views.
C: Designed wild systems, as imitations of natural systems, could provide natural aesthetics. They can be visually pleasing when appropriately designed and managed.

The purpose of this document is to provide information needed to encourage and incorporate aesthetic thinking into stream restoration projects for sustainable management of stream systems. It should be noted that there is no "universal" aesthetic preference to guide restoration designs. The visual indicators presented here are not universally applicable. Each restoration site has its particular site environmental and social conditions that could influence aesthetics. It should also be noted that aesthetic and environmental benefits could not always be aligned in stream restorations. A visually appealing stream landscape might not be an ecologically healthy ecosystem. Based on information provided, project designers could involve the public in design charrettes and survey local opinions to develop designs that meet optimized aesthetics and environmental restoration objectives.

Openness and open water view. People have a general preference for open views in landscapes (Nassauer, 1989; Rogge, Nevens, & Gulinck, 2007) and open water views are desired (Nassauer, 2004). River view was among the most frequently mentioned benefits provided by a stream, in a study on the Chicago River Corridor (Gobster & Westphal, 2004). Figures 1A and B show a stream restoration project with open water views. Designed for aesthetic and habitat value, the stream has a meandering course with sloped (4:1) vegetated banks. Nearly 300,000

plants (including more than 640 trees) were planted to control erosion, soften the hard urban landscapes, buffer noise, cool the water, and enhance wildlife habitat. The improved aesthetics and connectivity for park users could potentially lead to economic benefits. The regional employment increased after project completion during 2008-2012 and there was a four-fold increase (54 to 236) in the number of establishments and a five-fold increase ($10,467,000 to $57,281,000) in total retail sales (Ozdil, Modi, Stewart, & Dolejs, 2013). It should be noted that these changes might not be attributed specifically to the stream restoration project, other factors could be involved.

A

B

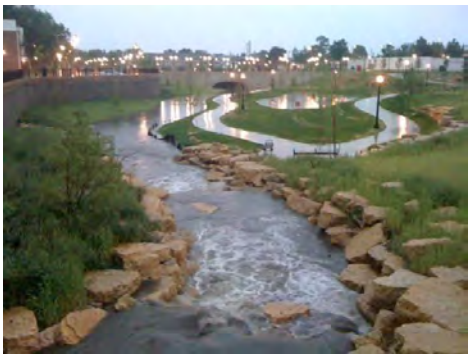
Figure 1. Buffalo Bayou Promenade, Houston, Texas. A) Birdseye view of the site (shows openness and a bridge to increase connectivity); B) Stream riparian area allows water view. Permission from SWA Group.

Water clarity and color. Water clarity and color influence the attractiveness of a waterscape (Gregory & Davis, 1993; Pfluger, Rackham, & Larned, 2010). There is a preference for clear water rather than brown water. Suspended solids, phytoplankton, or substances dissolved in the water could be among factors that influence water clarity. Water clarity and color could indicate tidiness to layman and are often used as indicators of the perceived environmental health (Cottet, Piegay, & Bornette, 2013).

Water movement. People prefer rushing waters than stagnant creeks (Herzog, 1985). Movement (caused by gravity, wind, or both) is an exciting visual aspect of water that contributes to the vividness of a landscape setting. Gravity is the primary factor influencing water movement in streams, which is described as disturbed water surfaces (falling and turbulent) and undisturbed surfaces in a stream channel. Visually desirable water settings could be achieved by creating a mix of disturbed and undisturbed water flow, as shown in Figure 2 (Litton & Tetlow, 1974).

Figure 2. Flow control structures in large rivers provide a more dynamic appeal to the water flow, Uncompahgre River, CO (Rosgen, 2007). Permission from Wildland Hydrology.

Curved, meandering shape. Streams with meandering shapes improve the scenic quality of a landscape (Nassauer, 1989). The meandering channel is a more organic, natural shape that is more aesthetically appealing. The preference for serpentine lines was recognized in the 18th century and this preference was shown in serpentine channels on the English estates designed by a popular 18th century landscape designer, Capability Brown (Kondolf & Yang, 2008). Figure 3A and B show restored streams with meandering channel.



A

B

Figure 3. Boneyard Creek Restoration, Champaign, Illinois. A) Stream meander restored; B) Stream meander and riparian flowerings. Permission from Hitchcock Design Group. Photo source: A: Rob Kowalski with the City of Champaign; B: Hitchcock Design Group.

Desirable wildlife. The presence of desirable wildlife, such as birds, turtles, and butterflies, could enhance visual appeal of a shoreline landscape. The bird species richness indicates habitat value of wetlands. It is positively associated with the attractiveness of wetland landscapes (Hu, 2013; Nassauer, 2004).

Plant color and form. Restored wetlands with flowering plants were perceived as more attractive than ones that aimed to achieve enhanced ecological value only (Nassauer, 2004). Techniques for making a vegetated landscape colorful include selecting plants with showy leaf or flower colors in different seasons, using evergreen species for winter look, and installing a diversity of plant species. Together with other plant characteristics such as size (low height), texture (medium to coarse), and form (clumping plant form with broad leaves), they can make a riparian landscape more visually

pleasing (Hu, 2013). Therefore, using colorful plants in stream riparian wetlands or upland areas could potentially enhance aesthetics of the site. Figure 3-B shows flowering riparian plants in a stream restoration project.

In-channel debris. In-channel woody debris is an important stream restoration measure that provides functions such as increasing water retention time in channel, promoting sedimentation, and enhanced conditions for denitrification. Studies found in-channel woody debris decreases attractiveness of a stream landscape and perceptions toward streams with wood debris are associated with cleanness and human care (Gregory & Davis, 1993; Piegay et al., 2005; Vought & Lacoursiere, 2010). Figure 4 is an example stream restoration project with insufficient consideration for the visual impacts of the use of woody debris; the wood piles indicate a lack of maintenance or care for the landscape (Nassauer, 2004). Gravel bars are also disliked in streams with possible explanation that they reduce the proportion of water in the channel (Le Lay, Piegay, & Riviere-Honegger, 2013). However, large boulders are perceived as more attractive and low-maintenance compared to small size gravel (Le Lay et al., 2013). Logs and large boulders, considered as "native materials", are promoted by Natural Channel Design methods (Lave, 2014; Rosgen, 1997, 2007). Figure 5 shows the use of large boulders for stream flow control.

Figure 4. Latchmore Brook Restoration, Latchmore Brook, UK. Permission from Friends of Latchmore, http://friendsoflatchmore.org/.

Figure 5. Paint Creek, West Virginia. Permission from Decota Consulting Company Inc.; photographer: James Stanton.

Proportion of water in channel. One study found a preference toward stream landscapes with a high proportion of water in the stream channel. Streams with a low proportion of water in the channel were perceived as poorly maintained (Le Lay et al., 2013). The perceived proportion of water in the stream channel could be decreased by the presence of wood debris and deposits.

Signs of erosion. People dislike signs of erosion in shoreline landscapes (Hu, 2013). Signs of erosion (such as un-vegetated substrate on a stream bank) and sediment deposits negatively influence visual appeal of a stream (Cottet et al., 2013). In rural landscapes, no erosion indicates the soil and water conservation work of farmers and is associated with aesthetic quality of a landscape (Nassauer, 1989).

Undesirable plants. Although uncontrolled vegetation could be visually pleasing in undisturbed natural areas, in human modified landscapes people often expect to see landscape settings with well-kept vegetation (even when the organization of landscape settings appears "natural"). Unmanaged vegetation could decrease visual quality in wetland systems, especially when they block water views or cover large areas of water surface. A plant maintenance plan is critical to the long term success of a project. It should be established during the design process and include maintenance responsibilities, weed control protocol, and funding sources (Howley, 2011; Hu, 2013; Nassauer, 2004).

Water flow and area. The aesthetic appeal of a waterscape increases with increasing amounts of visible water (Arriaza, Canas-Ortega, Canas-Madueno, & Ruiz-Aviles, 2004; Dobbie, 2013). However in a stream landscape there is a concave relationship between water flow (amount of water) and landscape aesthetic quality. The attractiveness of water flow in a waterscape increases with increasing flow to a point and then decreases with further flow increases. However, relatively high flows are generally preferred in small streams while flow preferences for large streams are more varied (Brown & Daniel, 1991; Pfluger et al., 2010). Pfluger et al. (2010) suggested exposed stream banks and channel areas could be the reason for low visual appeal at low flows while suspended debris and turbidity might cause the low preference for extremely high flows.

Figure 6 shows a daylighted stream designed to keep sufficient water flow in channel for aesthetic appeal. Water from an adjacent river is pumped to this stream channel for consistent water flow. In-channel boulders make the water in a straight channel more interesting. They can function as flow control structures as well as stepping stones used by park visitors. The aesthetic and recreational (attracts ~64,000 visitors daily) benefits promoted regional economic development. This project achieved a land price (properties within 50 meters of restoration site) increase of 30-50%, double the rates of other areas of the city. It served as a catalyst for ~$1.98 billion US dollar's worth of investment in urban redevelopment (Robinson & Hopton, 2011).

Figure 6. Cheonggyecheon Stream Restoration Project, Seoul, South Korea. Permission from Alexander Robinson.

Man-made features. Man-made features can either positively or negatively affect the visual appeal of a landscape. The presence of built environments could contribute to stream aesthetic appeal in a high-density urban context (Gobster & Westphal, 2004). Man-made elements such as farm houses increase attractiveness of a rural landscape while roads and power lines decrease aesthetic appeal (Arriaza et al., 2004). Well-designed man-made features, such as walking paths and structures for water viewing, enhance aesthetics and people's contact with streams by providing water views (Figure 1A, 3A, and Figure 5).

Trees. Trees have mixed effects on landscape aesthetic quality. Trees can positively affect the appeal of a waterscape. Wetlands with trees are more appreciated than wetlands with no trees (Dobbie, 2013; Nassauer, 2004; van Marwijk et al., 2012). There is a preference for agricultural landscapes with scattered large trees, however, treeless landscapes are disliked (Ives & Kendal, 2013). In urban settings, trees could either positively or negatively influence stream landscape visual quality. A study on restored stream landscapes showed that trees bring visual appeal to the landscapes and provide privacy; but they can also block views of the landscape and caused complaints from local residents (Purcell, Friedrich, & Resh, 2002).

Wild systems (natural aesthetics). Visually mimicking local wild systems is an important approach in restoration landscape design. Natural aesthetics, provided by representations of local natural systems, is emphasized by designers and managers of constructed wetland systems. If not designed or managed appropriately, criticisms can rise due to un-kept looks (Hu, 2013). Indication of human control (mowed grass or trimmed trees) in a landscape is important to enhance aesthetics of a constructed natural system. Figure 7 shows how a restoration project imitates aesthetics of a wild system. In this landscape setting, openness, a curved walkway, boulders, different shades of green, diverse plant species, and appropriate management, are factors that contribute to aesthetics of the landscape. Aesthetics and habitat value are main concerns in the planting design. A pre-vegetated contract-grown (if booking plant materials in advance, nurseries would grow plant materials that will be installed in the long term, so the quantity and quality of plants could be ensured) woody and herbaceous species mix was used to achieve quick establishment, providing aesthetic and habitat value from early time periods and after completion. The project uses 85% native and naturalized plant species and low maintenance was considered in plant selection. This stream daylighting project removed over 4,000 linear feet of culverts. It improved the site's water conveyance capacity from 1,500 cfs (cubic feet per second) to 6,000 cfs (from 28% to 113% of predicted 100-year flood flow). The result of this restoration work is a sustainable constructed natural system that protects water quality of downstream fluvial systems, is resilient to flooding, creates habitat value, serves recreational purposes, and is attractive (Canfield, Koehler, & Cunningham, 2011).

Figure 7. Westerly Creek Restoration, Denver, Colorado. Permission from Forest City Stapleton; photographer: Ken Redding.

Educational signs. Although not directly associated with aesthetics of a landscape, educational signs could increase people's knowledge of streams and potentially promote their visual acceptance for restorations (Figure 8). Educational techniques, such as onsite signs or local social media, could be used to improve people's ecological understanding and guide perceptions of in-channel wood debris (Chin et al., 2008). Guided on-site educational tours could be used to explain project objectives to local property owners, and to strengthen their emotional affinity for in-stream elements like wood debris and gravel bars (Le Lay et al., 2013).

Figure 8. On-site sign delivering educational message on stream restoration, Dunes Creek, Indiana. Permission from Dan Mecklenburg

Maximizing synergies

Restorations should consider incorporating visual thinking into projects and maximize synergies among aesthetic considerations and environmental benefits. Table 2 summarizes visual and environmental influences of some commonly used restoration measures, including construction of woody debris dams, creation of meandering channels, channel widening and bank grading, and restoration of riparian wetlands and bank vegetation. These restoration measures have a range of functions, such as reducing peak water velocity, increasing base flow, increasing water retention time, and increasing biodiversity (Craig et al., 2008; Vought & Lacoursiere, 2010). The visual quality information of the measures is generated based on visual indicators mentioned previously. For example, the construction of debris dam increases in-channel debris (decrease visual quality), results in decreased proportion of water in channel (decrease visual quality), and increase stream water flow (increase visual quality). It provides environmental functions such as to increase groundwater-surface water exchange, promote sedimentation and nutrient cycling, and enhance

conditions for denitrification. Considering the potential aesthetic and environmental alternatives for stream restoration, eclectic planning measures and options including; dam construction, debris removal, riparian wetlands restoration, and buffer zone initiation, must be coordinated to achieve maximal community benefits as well as landscape sustainability.

Conclusions

Aesthetics is an important aspect of sustainable stream restoration. It is often associated with recreational and economic benefits in urban settings. Water aesthetics (interrelated with a variety of landscape elements, including riparian plantings, bank slope, and manmade features) is a key concern in promoting the aesthetics of stream-wetland systems. The environmental functions streams provide (flood control, water quality control, and creation of wildlife habitats) also influence aesthetics of stream landscapes (water flow, water clarity, and desirable wildlife). Connectivity of the site can be increased with bridges, pathways, and overlooks to promote people's contact with the stream landscape and help them learn more and care more about water systems. Besides design techniques, other factors affect the long-term aesthetic performance of a restoration site, such as use of a maintenance plan, public involvement and education, and funding support.

Table 2. Stream restoration measures and associated visual quality and environmental functions ("+" represents positive aesthetic effects; "-" represents negative aesthetic effects; "+/ -" represents mixed aesthetic effects; "*" represents environmental functions provided)

Visual and environmental considerations associated with restoration measures		Restoration Measures			
		Construction of woody debris dam	Creation of channel meanders	Channel widening and bank grading	Restoration of riparian wetlands and buffer
Visual indicator-negative	In-channel debris	-			
	Reduced proportion of water in channel	-			-
	Signs of erosion			+	+
	Undesirable plants				-
Visual indicator-positive	Water view			+	-
	Meandering shape		+		
	Colorful plants				+
	Desirable wildlife				+
Visual indicator-mixed	Water flow	+	+	+	+
	Trees				+/-
	wild systems				+/-
Environmental functions	Reduce (peak) water velocity	*	*	*	*
	Increase base flow				*
	Increase water retention time in stream valley	*	*	*	*
	Increase groundwater-surface water exchange	*	*		
	Erosion control			*	*
	Reduce nutrients and sediment entering stream			*	*
	Promote sedimentation	*			*
	Nutrient recycling	*			*
	Increase retention of organic matter	*	*		*
	Enhance conditions for denitrification	*	*		*
	Increase biodiversity and support wildlife	*			*

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