Watershed Restoration White Paper

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1. Introduction and Purpose

Scope and Purpose of this Report

The purpose of this paper is to provide background information regarding watershed restoration science and practice to help guide watershed restoration activities in the Gila basin. Although this document emphasizes ecological aspects of restoration, it is critical that social, economic, and historical conditions are also considered when determining desired outcomes. This report also emphasizes a landscape perspective (systems view) of restoration with an emphasis on clearly defined desirable outcomes and processes for evaluating success.

This report includes brief descriptions of: (1) watershed restoration frameworks with an emphasis on restoration as a function of land use; (2) restoration practices and techniques; (3) assessment and monitoring practices including impacts on water resources; and (4) guidance for how restoration alternatives in the Gila basin can be considered.

This report does not make specific suggestions regarding restoration projects/alternatives, nor does it address issues outside of the physical restoration realm such as administration and project oversight. It is, however, recommended that watershed restoration activities include scientific and administrative oversight. For example, this could include a three to four person panel composed of academic and agency personnel to oversee the planning, implementation, monitoring, and reporting stages of proposed restoration projects. The oversight panel would first develop clear criteria by which the program is evaluated, along with the processes and protocols for evaluating success.

Definition of Watershed Restoration for this Report

It is first necessary to define what is meant by restoration in the context of this report. The following definitions are but a few of those used in the fields of watershed and ecosystem restoration:

- Return an ecosystem to a close approximation of its condition prior to a disturbance (Berger 1990)
- Act of restoring to the original state or a healthy or vigorous state (Bradshaw 1996)
- Historic conditions previously existing on the site will be re-established, including the entire function, structure, and genetic composition (NRC 1992)
- Return of fundamental processes by which ecosystems work, including biological and non-biological elements
- An intentional activity that initiates or accelerates recovery of an ecosystem with respect to its health, integrity and sustainability (SER 2002)

What all of these definitions have in common are elements of restoring the structure and function of the ecosystem to some historical, pre-disturbance condition. Examples of watershed structure include soil condition, hydrology, water quality, and channel morphology.

Examples of watershed functions include water storage, recharge and supply, sediment transport and retention, and transport of organisms, nutrients, and sediments.

Watershed restoration to historic conditions as a goal is typically impractical and prohibitively expensive and there is significant uncertainty and disagreement as to the actual nature of historic or so-called natural conditions. In addition, even if historic or original conditions were better understood, temporal changes in the bio-physical, meteorological (e.g., climate change), and socio-economic (e.g., land uses) and socio-cultural conditions of a watershed or landscape often conspire to drive objectives to alternative outcomes that reflect these realities. More realistically, our goals are to rehabilitate the watershed, which is to return certain functions and structures of the natural ecosystem to a more desirable or beneficial state, but not necessarily to the original condition. In this report, we use the term restoration in a very general sense, where we are considering **restoration and/or rehabilitation of various watershed structures and functions to meet desired ecological and socio-economic needs**.

It is also important to recognize the various '*types*' of restoration that can be pursued in order to reach an end goal. Here we summarize our interpretation of these activities. Different individuals will likely have slightly different connotations depending on their backgrounds.

- **Watershed restoration** is a broad concept that can include a wide range of activities including forest management (e.g. thinning), wetland and riparian restoration, channel alterations, bank stabilization, prescribed burning, and much more.
- **Stream restoration** (or stream corridor restoration) includes efforts to improve any aspect of the stream corridor including the floodplains, riparian zones, and the main channel. This is a subcategory of watershed restoration but is still a broad term.
- **Wetland restoration** includes the rehabilitation of a degraded wetland or reestablishment of a wetland that has been destroyed. This can be considered part of stream restoration if it falls within the stream corridor (e.g. floodplain and riparian wetlands). Hence wetland restoration can have impacts on the stream itself. This will typically be the case in the Gila watershed. However, some wetlands are fed by springs or local water sources and are not located in the stream corridor and hence this would fall under the broader area of watershed restoration.
- **Riparian restoration** involves improvements to the riparian zone of a stream that aims to enhance functionality and structure of the riparian zone and potentially to the stream as well. The *riparian zone* is the region at the interface of the stream and terrestrial zone that serves functions (habitat, flood attenuation, etc.) that are dependent on the characteristics of the stream itself (hydrology, disturbance regime, etc.). Thus, adjustments to the stream (physical alternations, hydro-modifications, etc.) will impact the riparian zone and potentially affect its functionality. Likewise, modifications to the riparian zone that impact its functionality will in turn impact the river (negatively or positively).

- **Floodplain restoration** can include riparian restoration, but can also include non-riparian efforts such as levee setbacks, acquiring vulnerable lands, removing structures, and other activities beyond the riparian zone.
- **Channel restoration** (or in-stream restoration) involves work directly on the stream channel and usually aims to balance channel stability, habitat quantity and quality, and flood control. Examples include channel realignments, bank stabilization, and in-stream habitat or grade control structures.

Connections Between Watershed Processes and Restoration

Watershed restoration is complex because it requires a systems understanding of every land use at the elementary levels of function and process. A watershed is defined as a large land area that may encompass many political jurisdictions and landowner objectives while containing a mix of ecosystems and land uses (forest, agricultural, riparian, wetlands, urban), that drains surface and groundwater to a downstream water body, such as a river, lake or estuary (Schueler, 2005). One view of a watershed is that it is composed of sub-sheds thought of as landforms, and these landforms are closely related in the same way that the health of a stream channel is closely related to the health of its floodplain, terraces and associated flora and fauna communities (Petersen, 1999). Therefore, the restoration of streams and rivers should not be expected to alleviate problems generated throughout a catchment, given that the problems that lead to stream degradation typically are the result of catchment-scale stressors (e.g., large amounts of impervious cover) (Bernhardt, 2011). Unfortunately, most restoration efforts are not coordinated at whole watershed scales to maximize environmental and socio-economic benefits and many are not planned strategically, which results in a patchwork attempt to restore the system (Palmer, 2009). Successful watershed management is dependent upon working at the landscape scale to create and implement a common vision for productive and sustainable watershed conditions (RCN, 2002).

Watershed managers and others engaging in science and restoration activities are increasingly planning restoration activities from a systems perspective. This paradigm shift is an outcome of years of research and practice that has informed the restoration community on what does and does not work. Palmer *et al*. (2005) defined three forms of restoration success: 1) learning from past efforts, 2) meeting stakeholder needs, and 3) ecological improvements. It is well known that success from a stakeholder's perspective is relative to each individual. However, watershed planning and restoration is driven by the goals of those that care for and depend upon the watershed, and so it is desirable to align the efforts and resources of stakeholders towards common goals to the greatest extent possible (Cappiella *et al*., 2006).

The third type of restoration successes listed above (ecological improvements) is the area in most need of improvement. This area is the focus of much current attention and gaining momentum as our society begins to assert a systems framework to problem solving at many levels. Palmer (2009) describes five ways in which ecological knowledge can influence restoration to a far greater extent than at present, including a need to: 1) shift the focus to restoration of process and identification of the limiting factors instead of structures and single species, 2) add ecological insurance to all projects, 3) identify a probabilistic range of possible outcomes instead of a reference condition, 4) expand the spatial scale of efforts, and 5) apply hierarchical approaches to prioritization.

Summary

Watershed restoration is a complex and rapidly evolving field with respect to both research and practice. It is useful to think about restoration in terms of the various types of landforms that can be addressed and the restoration practices that can be employed. However, lessons learned from billions of dollars spent in projects over the past few decades can serve to guide restoration in the Gila Watershed. Specifically, a piecemeal approach to restoration has not produced measureable benefits in most cases. A systematic, basin-wide approach should be employed in the Gila watershed that holistically considers physical, ecological, and socio-economic conditions and aims to build resilience in all of these areas through careful planning and with a solid foundation in science. Restoration efforts should be developed based on clearly defined and measureable desirable conditions and outcomes that are implemented in a systematic fashion.

2. Watershed Restoration Frameworks

Restoration by Land Use

Understanding watershed restoration as a function of land use on a catchment scale has the potential to transform the approach to restoration. Traditionally, restoration projects are conducted on a piecemeal basis with little thought or attention given to the watershed as a whole. Although this piecemeal approach is not very effective from a restoration perspective, it is useful when it comes to determining the types of restoration projects that may be applied to a particular watershed or sub-watershed – especially because watershed restoration projects will typically be implemented on the sub-watershed scale given the challenges associated with restoring an entire watershed in a single effort. The purpose of this chapter is to address the different forms of watershed restoration projects as a function of land use, with particular focus paid to the Gila River watershed. The land uses that will be discussed further are: forest, riparian, wetland, agriculture, and urban.

Forests

Forest restoration has been receiving increased attention throughout the U.S. due to climate change, changing land use practices, increasing populations in the wildland-urban interface and the mismanagement of forests, as evidenced by the number and severity of devastating fires in recent years. Forest restoration activities are often prescribed and implemented at the ownership or forest level and need to be implemented correctly based upon research, socio-economic and socio-cultural realities, landowner objectives, and a solid understanding of how a successful restoration project will be assessed. However, there is often a lack of connectivity among treated forests or a cohesive plan for restoration across a landscape, highlighting the need for a multijurisdictional approach to watershed restoration.

Many forests are in a state of poor health and potential hazard due to recent policies that have resulted in the near elimination of natural fires, lack of active forest management, and widespread drought. In addition, insufficiently aggressive or poorly sited restoration treatments have given some a sense of misguided complacency about the risks of catastrophic wildfire. Aside from the attempt to eradicate naturally-occurring forest fires, lack of thinning and overgrazing by cattle have deteriorated the health and functionality of these systems. The most striking impact of this mismanagement in southwest forests is the large increase in the numbers of trees, as well as the high densities of small trees which fuel hot crown fires in forests that did not experience these types of fires in the past. Therefore, one of the main restoration methods implemented is forest thinning which seeks to decrease the number of trees per acre to a historical state while also reducing fuel loads that have accumulated during the absence of fire.

However, virtually all efforts to restore forests and reduce hazardous fuels will require a long-term plan of successive interventions that accounts for treatment maintenance cycles, evolving science, and changing public values and land uses, including an expanding wildland-urban interface. This is likely to occur sustainably only with the development of a *health forestry sector* that will enable these treatments to occur in the long-term and in the face of contracting public subsidies for forest restoration and hazardous fuel reduction.

Thinning a forest absent a holistic view of the watershed is insufficient if the goal is to return the system to a steady state that can meet the intended goals with a minimum of resource expenditures. "(Physical) restoration also involves changing the structure of the forest, to include an appropriate size and age structure, groupings of trees, decomposing wood on the ground, small or large scattered meadows… and fostering a healthy grass and forb cover, caring for soils and waterways, recovering native species, and protecting wildlife." (Savage *et al.*, 2007). Once accomplished the return of safe "cool" fires may return without threat of the catastrophic fires witnessed during the summer of 2011 and now unfolding in 2012. Mechanical fuel reduction treatments, conducted on a rhythm consistent with a treatment's maintenance cycle, can also result in certain desired conditions, with the added benefit of providing a more sustainable supply of wood products to local forest products businesses.

A second and equally important aspect of forest restoration is the socioeconomic component. Through the management efforts described above, there is an opportunity to enlist local community members in the process. The *New Mexico Collaborative Forest Restoration Program* (CFRP) has begun to implement this often-missed opportunity into all of their restoration projects, as they view physical and socioeconomic restoration as being interdependent. They are in the preliminary stages of identifying the long-term benefits of such programs and socio-economic indicators for forest restoration projects, including those funded by the CFRP, have been systematically developed by the New Mexico Forest and Watershed Restoration Institute housed at New Mexico Highlands University (Egan and Estrada, accepted for publication). Indicators and associated metrics are focused on providing local employment and skills training, while creating new markets for small wood and educating the community about forest health (Estrada *et al*., 2009; Egan and Estrada, in review). The education component is extremely valuable because it has the potential to be passed across and down through generations, thus resulting in a sustainable societal intelligence and valuation of forest lands. In addition, public outreach can also help to develop an understanding and tolerance for the temporary inconveniences associated with prescribed fire and forest thinning – necessary practices if society values hazardous fuels reduction and watershed health.

The Ecological Restoration Institute housed at Northern Arizona University has conducted an abundance of research on the impacts of forest restoration. One outcome of their work is a cost analysis of five scenarios with varying levels of restoration activities for a Ponderosa forest, ranging from full restoration to the "do-nothing" approach. These results show dramatic economic benefits for a restored forest with a steep increase in the monies associated with harvested wood and water as well as a enormous savings associated with the costs of fighting severe wildfires (Friederici, 2006). The proposed increase in harvested water is due to the decreased consumption by trees, which results in greater groundwater storage and an increased contribution to base flows.

The influence of forest management on hydrologic processes is unique for each watershed and hence observations from other systems may not be transferable across locations. Detailed investigations are necessary in order to estimate hydrologic response of a watershed to a specific restoration scenario. Long-term empirical studies from across the physiographic gradients of the U.S. suggest diverse watershed hydrologic response to forest management, including thinning and controlled burns. However, the following salient trends have emerged from the literature.

(1) Thinning tends to increase water yields due to reduced evapotranspiration. Variability of the hydrologic effects is large due to differences in watershed hydrologic processes, which are controlled by climate, soils, and the stage of vegetation development (Brown 2005). Field and modeling studies suggest that forest impacts on water yield are most pronounced during dry periods (e.g. Burt and Swank, 1992; Swank *et al.,* 1987). Observations in other southwest systems indicate that reduced transpiration following thinning can be offset by increased soil evaporation an understory ET.

(2) The persistence of increased water yields following thinning can vary drastically from only a few years to several decades depending on basin characteristics and climate. Thus, regular maintenance is required in order to maintain increased water yields.

(3) Literature on forestry impacts on floods is more contentious than on annual water yields. It is generally accepted that forest management has effects on small to moderate peak flows but less impact on large floods (Jones and Grant, 1996; Thomas and Megahan, 1998).

Hydrologic response of a specific watershed to various forestry practices can be predicted using study results in similar basins in combination with hydrologic models. Monitoring of change is discussed in Section 3 of this report.

A second, and perhaps more significant, benefit for forest restoration is associated with the reduced risk of severe crown fires which can imperil fish and wildlife species, severely degrade available water resources, and potentially result in catastrophic flooding and debris flows in the event of significant post-fire rainfall events. With respect to the aquatic ecosystem, two possible results of these devastating fires are increased water temperature along with increased sedimentation; which can result in habitat degradation, impact aquatic invertebrates by changing species composition, and reduction in the number and population of aquatic biota (USFWS, 2006). The increased sedimentation due to erosion has the potential to have costly impacts that far outweigh the costs associated with implementing forest restoration. Catastrophic wildfire and subsequent flooding from monsoon rains can severely compromise water availability and quality, while causing damage to forest soils, riparian areas, wildlife habitat and municipal water delivery systems. Such impacts have been repeatedly observed following other wildfires in the southwest, including the 2011 Las Conchas Fire. At the time of this report, the Whitewater-Baldy Complex fire has burned over 200,000 acres in the Gila headwaters and is only 30% contained.

Understanding that treatment effects related to water yield in the Gila are often difficult to predict and further research is needed to elucidate these relationships, for the purposes of this program, the overall goal of any treatment is to address challenges related to downstream water supply and quality. While the full range of appropriate restoration approaches will not be discussed here, examples of forest treatments include hazardous fuels reduction, using mechanical and/or prescribed fire methods, and stream and riparian restoration practices to mitigate the potential impacts of post-fire flooding.

Stream Restoration

As described above, stream restoration includes a wide range of restorative activities that can be undertaken within the stream corridor including in-stream projects, floodplain connectivity, floodplain wetlands, bank stabilization, grade control, hyporheic exchange, and others. Here we focus on in-stream actions and those that restore connectivity within the stream corridor. Riparian and wetland restoration are addressed separately below.

Stream corridors have been heavily degraded worldwide impacting fish and wildlife habitat, water quality, stream stability, and human health. Significant investments have been made in improving environmental conditions over the past several decades. Following passage of the Clean Water Act in 1972, efforts first focused on improved water quality primarily through reduced chemical discharge to streams via the National Pollution Discharge Elimination System (NPDES) permit program. However, it slowly became apparent that physical degradation of stream structure through river engineering, hydro-modifications, water abstractions, and other human activities, also had a profound effect on stream systems. As a result, stream restoration efforts have steadily grown in popularity over the past few decades in an effort to restore stream structure and function. The scale and cost of such efforts vary drastically from local bank stabilization efforts to large-scale river realignments costing tens of millions of dollars.

The field of stream restoration has finally matured to the point that enough data exists to take a critical view of successes, failures, and lessons learned. Successful restoration efforts typically have clear connections between the motivation for restoration, stakeholder goals, and the restoration approach. When these connections are weak or absent, the projects tend to fail or to fall short of expectations. The most common shortcoming of restoration projects is to apply techniques that address the symptoms of degradation rather than the cause. For example, armoring a streambank to prevent bank erosion will typically just shift the erosion to another point in the channel.

A common shortcoming of stream restoration projects in the southwest is the lack of acknowledgment of the profound impacts of hydro-modifications – or the shortsighted attempt to compensate for severe hydro-modifications through structural modifications. In some cases, it might be possible to restore the functions of a channel that has undergone hydro-modifications by “resizing” or “downsizing” the channel for its new reality. In some ways, this experiment is currently underway on the Middle Rio Grande. An alternative approach is currently being investigated on the Rio Chama, where researchers are investigating alternative water management strategies in an attempt to restore processes while still meeting water demands. In the case of the Gila River, hydro-modifications have been relatively small in comparison to other systems in the region -- especially with respect to high flows. The current state and alternative states under various AWSA actions should be carefully considered when investigating stream restoration alterations.

A more effective approach to stream restoration is to start with a comprehensive review of the current conditions (form and function) to inform and formulate clear restoration goals. The restoration goals can then be used to evaluate restoration alternatives within real-world constraints (e.g. water rights, funding, hydro-modifications, right-of-way, etc.). The alternatives can be ranked and selected based on their ability to meet the restoration goals. Because stream systems are complex and dynamic, implementation should be performed within an adaptive management framework if possible. At best, restoration alternatives can be viewed as a series of hypotheses of how the stream will respond to an intervention. Thus, observing the response and testing the underlying hypotheses will lead to improved long-term performance through systematic adjustments to restoration strategies. Long-term monitoring is critical for evaluating success and informing maintenance. Although a self-maintaining system should be the ideal goal, this is impractical in a system that still experiences significant outside stresses.

While the full range of appropriate restoration approaches will not be discussed here, specific stream corridor restoration approaches could include improvements to diversion structures, restoration or construction of riparian wetlands, levee setbacks, planting of native riparian species, amongst many others. Dozens of restoration techniques are available depending on the restoration objectives and several references are available to guide the process. Examples of these references include:

- NRCS NEH-653: Stream Corridor Restoration Handbook (NRCS, 1998)
- NRCS NEH-654: Stream Restoration Design (NRCS, 2007)
- The River Restoration Centre: Manual of River Restoration Techniques (RRC, 2002)

Riparian Zones

Riparian zones represent the interface between land and streams. They are classified as being comprised of the area that is in direct contact with the stream through ground water. Riparian areas represent a small percentage of total land cover for watersheds, but their productivity and biotic diversity play a critical role in the southwest. However, riparian hydrology has been altered and streamside vegetation has changed as valley bottoms and floodplains across the southwestern U.S. have transformed into urban and agricultural centers. Due to river impoundment, urbanization, agricultural conversion, and hydrologic and ecological changes, the historic condition may no longer represent a realistic desired future condition within the context of riparian restoration activities (Bonfantine *et al.*, 2011). Early settlement in the region centered on watercourses and, as a result, many municipalities in the southwest contain riparian ecosystems. In many areas, native vegetation has declined while exotic species have invaded and matured, thereby affecting the loading and pattern of the riparian fuel complex. Instead of the human community growing into the forest and creating the wildland urban interface, the interface has grown up within the urban area. Protecting communities from the sometimes intense, fast moving fires that occur within these corridors is an important public safety issue for many local communities (Bonfantine *et al.*, 2011). For example, wildfires in the Rio Grande bosque through Albuquerque have motivated intense vegetation clearing and riparian restoration activities.

Fuel reduction is a primary management objective for treating southwestern riparian areas on USFS land (Stone *et al.*, 2006) and riparian sites are frequently identified as priority areas for hazardous fuels reduction in Community Wildfire Protection Plans. However, there is little science available to guide the fuel management process. Riparian areas, despite their ecological importance, have been poorly studied with regard to fire and fuel dynamics. The historic fire regime, vegetation, and fuel conditions are largely unknown. Also lacking are any long-term data comparing the ecological impacts of various treatments (Dwire and Kauffman 2003; Stone *et al.,* 2006). Well-designed monitoring of riparian projects is critical to improving current treatments and modifying future techniques.

The Gila's riparian corridor provides essential habitat for hundreds of species that either occupy the area year-round or use them as migratory stopover points (Soles, 2003). Riparian lands are sensitive to anthropogenic disturbances, because they act as drains for the watershed and therefore display the impact of any and all upland impairments. These zones are typically among the first landscape features to reflect damage from improper management or natural events; however they are also resilient due to the presence of water, which allows for restoration opportunities (RCN, 2002).

A healthy riparian zone provides a plethora of ecosystem services. Aside from the buffering of surface pollutants, riparian areas are vital to the stability and functionality of the system as a whole (Petersen, 1999). Below the surface the roots of riparian plants bind the soil together and protect streambanks from erosion, whereas the above ground portion of the plants absorb energy, slow flow velocity, and filter flood waters during overbank events (Petersen, 1999). Riparian soils also act as a reservoir for streams as a result of their connectivity through the alluvial sediments, and therefore they play an important role in sustaining base flows during dry periods (Chen et al., 2006).

Due to the complex interplay between stream and riparian hydrology, it is impossible to draw general conclusions about the impacts of restoration activities on water budgets. Rather, restoration alternatives must be evaluated on a case-by-case basis. In general, riparian vegetation in the southwest evapotranspires a similar amount of water as traditional crops such as alfalfa (approximately 5 to 10 mm/day during the growth season) (Cleverly *et al.,* 2006). However, crops are most likely to receive water via an irrigation delivery whereas riparian vegetation is more likely to receive water via groundwater uptake. As with forests, thinning of riparian vegetation can reduce water consumption. For example, Cleverly et al. (2006) reported that when salt cedar and Russian olive were removed from a cottonwood understory in the Rio Grande Bosque, water salvaged through reduced ET was 26 cm/yr in relation to ET measured at reference sites. In other words, ET has been shown to be sensitive to vegetation density (e.g. as represented through leaf area index (LAI)), but relatively insensitive to the vegetation type.

There are a variety of restoration projects that have been implemented in riparian areas. California's Wildlife Conservation Board (WCB) details several examples of projects which they have funded including: 1) bank stabilization and revegetation to control excessive erosion and establish a functional riparian corridor, 2) restoration of riparian vegetation on flood-prone land, 3) installation of fencing along the riparian corridor to control and/or manage livestock or wildlife, 4) modification of the existing land form to allow a stream to regain its historic connection with its floodplain (for example, move a levee back away from the stream or remove it), and 5) removal of nonnative invasive plant species and restoration (active or passive) of native riparian vegetation (http://www.wcb.ca.gov/Riparian/). Guidelines for monitoring the outcomes of riparian restoration projects have been developed recently by the New Mexico Forest and Watershed Restoration Institute (Bonfantine *et al.*, 2011). The authors derived protocols from the synthesis of a broad range of existing literature on the assessment of riparian fuels, vegetation, and wildlife habitat into a methodology that is efficient, objective, and appropriate for quantitative summaries. The guidelines are also informed by the experiences of the staff of the New Mexico Forest and Watershed Restoration Institute and its partners and stakeholders and are currently being tested through the Institute's association with the Greater Rio Grande Watershed Alliance.

In the case of the Gila, the occurrence of periodic overbank flooding is a vital event that defines the health of the system. At the same time, these floodwaters that are a result of the Gila's free-flowing nature have the capacity to alter the landscape due to the power and magnitude of flow. A negative consequence is the loss of agricultural lands due to erosion. Evaluating the degree to which riparian restoration can optimize riparian benefits while also protecting property and human welfare would require in depth research of specific alternatives. A goal of riparian restoration activities should be to optimize riparian benefits while protecting property and human welfare. Many floodplains have already been altered by human activity, including development, resulting in concerns about public safety around riparian areas.

Agricultural

Agriculture is a large component of New Mexico's economy. Farmlands exist in every watershed in a variety of ecosystems/biomes. Modern agricultural practices have a noticeable impact on the health of the lands especially when they are implemented near a stream. Additionally, the diversion of water to provide irrigation water has a direct impact on physical and ecological stream processes. Removal of riparian vegetation decreases an important source of habitat while also negating the ecosystem services described above. Due to these historical methods, agricultural lands have become prime sites for restoration activities.

Agricultural restoration can take many forms, and can occur in a range of settings. However, restoration of marginal lands (e.g. land near cut-banks or marshy areas) would contribute substantially to natural diversity in agricultural landscapes (Lefroy *et al*., 1993). Perry (1998) discusses three approaches to agricultural restoration, and emphasizes that a successful project will implement a balance of these as needed. These approaches are: 1) remove land from production and restore natural ecosystems, 2) alter current agricultural practices to reduce the negative impacts of agriculture on the surrounding landscape, and 3) improve the sustainability of agricultural systems to maintain agricultural productivity. Implementing restoration through a process that is guided by these approaches has the potential to improve the natural systems and their associated functions while maintaining agricultural productivity.

The WCB details a series of restoration projects for agricultural lands that seek to mitigate the undesired conditions. These are: 1) habitat restoration and enhancement of water corridors, streams, ditches, canals, tail water and return basins and ponds, 2) construction of vegetated filter strips, hedgerows and other wildlife buffers, 3) development of wetland areas, 4) riparian and floodplain restoration, 5) fencing to protect and enhance native habitats, 6) restoration and enhancement of native grasslands, 7) agricultural habitat management activities that provide significant environmental co-benefits including water quality improvements, greenhouse gas reduction, etc. (http://www.wcb.ca.gov/Riparian/). A theme that is infused through each of these methods is a focus on the restoration of the native flora. A considerable amount of the degradation that has occurred in the environment in all landscapes is a result of changing the composition of plant communities. Thus returning these communities and the conditions they require is a positive step towards restoring agricultural lands.

As is the case for forest restoration, an equally important aspect of agricultural restoration is the socioeconomic component. Restoration must include a balance between beneficial human use of riparian corridors and the needs of the ecosystem. Restoration goals should include aspects of how to improve the sustainability of agricultural systems to maintain agricultural productivity, and the associated way of life, with efforts to improve ecological conditions.

Research and practice related to building the resilience of coupled agricultural and ecological systems are more advanced in other parts of the country including much of the Midwest, Northwest, and Northeast. However, lessons learned in these other regions are largely transferable to the southwest. Effective methods for balancing these priorities can include stream stabilization, riparian buffer strips, distributed detention, water conservation, conservation tillage, chemical controls, and crop rotations. An effective strategy in other states has been to make grants available to landowners that can be invested to make improvements that enhance the value and productivity of their property while also realizing environmental benefits. It is critical that restoration on private lands provide opportunities for the landowners to directly benefit rather than placing a hardship on them to comply.

Wetlands

Wetlands own the nickname of 'the kidneys of the landscape' for their capacity to clean and replenish the water that runs through them. Healthy wetlands are a critical component of a properly functioning watershed. Based upon the *Clean Water Act*, wetlands are defined as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas" (Clean Water Act, 1972). The EPA acknowledges that "wetlands are some of the most biologically productive natural ecosystems in the world, comparable to tropical rain forests and coral reefs in their productivity and the diversity of species they support" (EPA 2001).

There are a variety of functions associated with wetlands relative to their location in the watershed as well as the location of the watershed itself. These include flood attenuation, erosion control, storm protection, groundwater recharge (wetlands retain water within a watershed enabling groundwater recharge), water quality improvements, climate buffering (wetlands can influence local climatic conditions), carbon storage, biomass export, and habitat provisioning (Benstead 2001, Capiella 2006). Important functions associated with wetlands include water quality improvement, floodwater storage, fish and wildlife habitat, aesthetics, and biological productivity (EPA website). It is well documented that wetlands act as a sink for nutrients (Meyer *et al*., 2003).

Loss of wetlands has typically been associated with the drainage of lands for agriculture or for housing development. Capiella (2006) described three main processes associated with land development that significantly alter the hydrology of streams and wetlands. These are: 1) native vegetation that once intercepted rainfall is removed and soils are compacted, 2) impervious cover is created when roads, rooftops, and parking lots are constructed and 3) efficient drainage systems are installed to quickly convey runoff to downstream waters. In the case of the Gila, the major issues pertaining to wetlands are drainage, loss of connectivity, and reduced water availability.

Wetland restoration projects can be motivated by many factors. In the case of the Gila basin, one stakeholder group has proposed using Arizona Water Settlement Act (ASWA) funds to either restore historical wetlands or create new ones altogether. In any case, the ultimate goal is to retrieve the functions and processes described above which are associated with a properly functioning wetland. Whatever the scenario, it is widely recognized that hydrological conditions provide the basic control of wetland structure and functioning (NRC 1992, Benstead 2000). Therefore, restoring the necessary flow regime required for a healthy wetland is an important step in the restoration process.

Zedler (2000) details a series of restoration activities that seek to restore particular wetland functions along with potential actions that may return these functions (Table 1). Zedler emphasizes that the specific hydrological regime is crucial to the restoration of each of the functions listed below.

Table 1: Desirable wetland functions (services) and methods of facilitating their development in restoration sites (Zedler, 2000).

Desired Function	Potential Action
Nutrient removal	Position wetland appropriately, adjust water residence time, and for wastewater treatment wetlands, harvest plants to remove nutrients
Sediment removal	Slow water flow, and provide a basin to trap heavy sediments and allow clean-out
Shoreline-erosion control	Plant vegetation to anchor substrate
Flood-peak reduction	Position wetlands appropriately
Groundwater recharge	Provide sandy substrate and slow water flow

Restoring wetland functions requires a holistic view with attention paid to the cause of the damage and not the associated symptoms. It is a complicated process that is often not achieved due to poor planning or an incomplete understanding of some aspect of the system. For example, out of 40 South Florida wetlands restoration/creation projects reviewed, of the 60% which were deemed failures, the majority of these were attributed to improper hydrologic conditions (Mitsch, 1998). Producing favorable hydrologic conditions for supporting wetland functions is considerably more challenging in the water limited southwest than it is in Florida, and hence caution must be applied when considering wetland restoration in the Gila basin in order to ensure appropriate site conditions and access to water. Wetlands restoration should not occur through an isolated lens, but rather should be seen as a vital component of an integrated water management plan (Benstead, 2001). However, if successful, the creation and restoration of ecosystems in general, and of wetlands in particular, provide important opportunities for enhancing ecosystem services to humans including moderating streamflows improving water quality (Mitsch, 1998).

Wetland development or enhancement is likely to include increased water consumption from background conditions, which must be considered in the planning and monitoring stages of the project. Water consumption is primarily via increased evapotranspiration. Infiltration is likely to contribute to aquifer recharge and increased river baseflows. Specific evapotranspiration rates will vary widely depending on wetland characteristics and can range from values typical for flood irrigation agriculture to as high as open water evaporation (Drexler et al., 2004).

Urban Areas

For the purpose of watershed restoration, urban land areas are typically classified as areas containing at least 10% impervious cover (Schueler, 2005). The intensive process of urbanization has a profound impact on the hydrology, morphology, water quality, and ecology of surface waters (Horner *et al.,* 1996). Research has shown that stream conditions are directly related to the amount of impervious cover in the watershed and as a result there has been a lot of attention paid to the impact impervious cover has on streams (CWP, 2003). As urbanization increases, streams handle increasing amounts of runoff, which degrades headwater streams as well as major tributaries (CWP, 1998). These impairments result in streams that are severely degraded, sometimes to the point where they cannot support the assemblages, which once called the stream home.

As a result of the degradation of our nation's streams, particularly in the urban setting, there has been an upwelling of support for the creation of watershed protection groups. The number, sophistication, and expectations of urban watershed groups have all increased sharply in recent years, and these groups can exert considerable pressure to influence watershed management. The Center for Watershed Protection (CWP) has developed an "Integrated Framework to Restore Small Urban Watersheds", and in this document they detail eight major alterations to the landscape as a result of urbanization that are significant from the standpoint of restoration. These are: 1) conversion to impervious cover, 2) construction of sewer, water, and storm water infrastructure, 3) intensive management of pervious areas, 4) fragmentation of natural area remnants, 5) interruption of the stream corridor, 6) encroachment and expansion in the floodplain, 7) increased population density, and 8) increased density of storm water hotspots (Schueler, 2005). A detailed description of these is outside the scope of this paper, given the minimal role the urban setting currently plays on the Gila Watershed. For further details refer to the CWP report mentioned above.

There are numerous techniques that may be used to restore urban watersheds. Upon a review of watershed restoration projects the CWP found at least 130 urban restoration practices that have been used which they grouped into 7 main categories of restoration practices (Schueler, 2005). The 7 groups are: 1) storm water retrofit practices, 2) stream repair practices, 3) riparian management practices, 4) discharge prevention practices, 5) watershed forestry practices, 6) pollution source control practices, and 7) municipal practices and programs (Schueler, 2005).

Summary

Watershed restoration is an evolving field of practice composed of professionals that continue to learn from past efforts in order to improve our watersheds through future work. The integration of a diverse stakeholder group in the restoration process is important aspect of these projects, but can pose serious obstacles that may be too great to overcome. "Politics and social agendas will always influence the desired endpoints of a restoration effort, but the process by which restoration is done should be science driven" (Palmer, 2009). Currently, the science states that nature's functions and subsequent ecological services are best provided when natural processes (hydrologic, geologic, and ecologic) are mostly in control and are given room to operate (Mitsch, 1998), and therefore watershed restoration should focus on processes rather than interventions reliant on structural solutions (Roni *et al*., 2002).

Restoring watersheds requires both an intimate connection to the land and a labor force. As described above the economic contribution of restoration may result in a long-term sustainable workforce depending upon the scale of the work. “Whether removing a road, upgrading a culvert, or stabilizing a stream bank, restoration activities are labor-intensive. These jobs contribute to the socio-economic conditions of the communities in which the restoration occurs, and this linkage of job creation to environmental conservation can powerfully motivate people to support restoration activities” (Hurd, 2009). Community involvement in watershed restoration is important if the restoration is to be a success. The overall benefits provided by restoration are shared throughout the community. “Healthy watersheds and riparian-wetland areas are critical to providing communities with the economic, ecological, and social benefits that come from the reliable availability of adequate supplies of clean water” (RCN, 2002).

3. Implementation of Restoration Projects

Done properly, implementation of restoration at the watershed scale is an extremely complex and non-linear process that cannot be simply summarized in a guidance document. Here we have included a brief description of the major elements that have been found to be successful when undertaking restoration projects. Elements like *identifying baseline conditions* are fairly straightforward (assuming adequate resources exist) -- whereas elements like *setting restoration goals* can be extremely challenging and often require the support of seasoned professionals.

Identifying Baseline Conditions

It is critical that a sound understanding of baseline conditions be in place before considering restoration strategies. Baseline conditions include the current state of hydrologic, geomorphic, ecologic, and socio-economic conditions in the basin. Further, historical conditions as a function of time and landscape activity should also be considered. This activity should be completed at the watershed scale -- although detail can be added in areas of interest or concern. A detailed '*Baseline Conditions Plan'* should be formulated in advance to identify exactly what types of data will be gathered and to what end. The final product should not only include relevant data, but also a narrative of how the watershed has changed, what caused those changes, and what are the consequences of such changes (positive and negative). The data should focus on quantifying changes in landform form and function.

If feasible, it is best to consider baseline conditions in two stages. In the first stage, basic watershed characteristics are described such as: census data including population and economic trends; land use patterns; legislation and designations (e.g. wilderness designation); climatology; stream hydrology; channel modifications; forest management; and zoning and planning documents. In the case of the Gila Watershed, much of this data already exists and is readily available. Thus, the main activities would include compiling the relevant information, forming a narrative, and identifying data gaps.

The second stage of this process is more detailed and is informed by the first screening stage. The goal is to develop a sound understanding of watershed processes in order to describe connections between watershed stressors and degradation. This information can be used to guide restoration goals in a way that stressors can be reduced to restore watershed functions. For example, relationships between streamflow, groundwater, riparian regeneration, and primary productivity will likely be needed in order to evaluate channel modifications and alternative streamflow management. Another example would be to investigate the role of forest thinning on watershed water yields.

Several techniques exist for conducting physical and ecological functional assessments including the Hydrogeomorphic Assessment technique (Brinson *et al*., 1995) and the New Mexico Rapid Ecological Assessment Methodology (NHNM, 2010). These and other techniques can be used to guide more detailed analyses depending on the types of questions that need to be addressed and the range of restoration alternatives being considered. As specific alternatives arise, it is necessary to conduct more detailed studies to support design and management decisions. For example, it would be necessary to investigate how a diversion structure is expected to impact fish habitat availability and connectivity.

Hydrologic Considerations

Baseline data collection should also include gathering hydrologic data and collecting new data as specific questions arise. For example, a watershed restoration alternative could include mechanical thinning or prescribed burns, which in turn would have the potential to increase annual water yields. In order to understand the degree to which changes in water yields are expected, managers need a baseline dataset. In essence, managers need to understand the water budget for each landscape feature and then be able to predict and describe how the water budget changes as a result of restoration activities. This can be accomplished using field measurements, remote sensing data, and hydrologic models.

The specific techniques for measuring baseline hydrologic conditions and changes due to restoration will need to be customized for each restoration alternative. Standard methods exist for many of the key processes and emerging technologies are available for others. To evaluate watershed response to forest management, data will be required to describe precipitation, runoff, evapotranspiration, recharge, and baseflow. This will require installation of experimental flumes to measure stream discharge; weather stations to gather meteorological data (precip., temp., relative humidity, wind speed and direction, and solar radiation); soil moisture sensors; and groundwater monitoring wells. This information should be combined with information about vegetation structure (tree species, heights, and diameter, etc.) in order to understand the relationships between forest condition and water yield. Finally, hydrologic models can be used to further describe and predict components of the water budget under existing and future conditions.

Another important activity that will require careful consideration of water budgets is wetland restoration. In most cases, wetlands will consume additional water from background conditions due to increased evapotranspiration. This is particularly true if the design includes significant periods of time with open water. In this case, accurate estimates of ET will be important and many methods exist for estimating and measuring ET in a wetland environment (Drexler *et al.,* 2004). It will also be helpful to monitor groundwater elevations and soil moisture conditions to describe impacts on groundwater recharge. All of these methods can also benefit from the use of remote sensing data such as vegetation indices.

Setting Restoration Goals

NEH-653 identifies the following components for the process of identifying restoration goals: 1) Define the desired future condition, 2) Identify scale considerations, 3) Identify restoration constraints and issues, and 4) Define goals and objectives.

Watershed planning and restoration is often informed by the diverse, sometimes competing, objectives of a broad array of stakeholders—from scientists and restoration practitioners to business interests and concerned citizens. While finding agreement among disparate points of view may be a laudable goal of collaborative restoration processes (Cappiella *et al*., 2006), to be effective, proposed projects cannot lose sight of that which science and experience informs us about strategies and practices that are actually *effective* in achieving the ultimate goal of a sufficient and sustainable supply of clean water. Among the lessons learned from the Track Fire near Raton, for example, was that pre-fire thinning likely was not aggressive enough, in part because there were those at the table who wanted to thin aggressively – generally consistent with the science – and those who didn't want *any* trees cut. As a result, a process of compromise among diverse stakeholders led to fuel reduction practices that were out of the range of residual stand stocking that is consistent with *effective* fuels reduction. Given an objective of hazardous fuels reduction to mitigate the occurrence of or cool down severe wildfire in order to protect the city's water supply, this project failed – even before there was a fire. When the city of Raton engineer was later asked what, in retrospect, he might have done differently, he responded – *cut more trees*. Outreach efforts designed to educate stakeholders about the range of treatments that science and experience have demonstrated are effective to meet objectives, then, will be critical to developing consensus around proposed treatments.

The scale of a restoration project can vary greatly, and hence so will the budget. In the case of the Gila, the entire area considered under AWSA should be considered as a starting point. However, the geographic extent will likely need to be narrowed due to financial constraints. Funding is an obvious constraint, but other technical constraints, federal and state regulations, land-use conflicts, etc. must also be explicitly recognized. This information can then be combined to develop feasible, implementable, and measureable restoration goals and objectives.

Organizational Structure and Process

The following is a suggested template for an organizational structure and process that can be used to consistently and accurately describe the effort to stakeholders and fairly and effectively allocate resources to proposed projects.

1. Define the critical issue(s)/challenges – e.g., delivering sufficient and sustainable supply of clean water to …

2. Articulate a mission/objective that is consistent with these issues and institutional/program values – e.g., to develop strategies and implement projects that will result in a more sustainable flow of clean water to …

3. Describe strategies for achieving the mission/objective that include specific operational approaches – e.g., the organization will develop mechanisms for soliciting and funding project proposals that are consistent with its mission/objective. This will be accomplished by ...

4. Base organizational decisions (e.g., funding of projects) on their conformance to the mission/objectives and best available science.

5. Form a decision-making Steering Committee comprised of those who are knowledgeable of and have demonstrated support for the mission/objectives.

6. Provide for mechanisms for broader input (e.g., general meetings of citizens, stakeholders), with the understanding that (a) the outcomes will be used to inform, not drive, Steering Committee decisions; and (b) while public input will be considered, decisions will ultimately be made based on conformance with the mission/objective and best available science.

Design of Physical or Management Actions

The design stage is the main technical aspect of the restoration process. This activity will obviously vary greatly depending on the nature of activities identified through the alternative analysis. Every effort should be made to include experienced professionals and to base all design and management actions on sound science. There will be uncertainty in any activity that involves natural systems. Rather than designing uncertainty out of the system, it should be addressed by developing hypotheses of how the system will respond to activities. This is further addressed below under adaptive management.

Implementation

Implementation is the process of making on-the-ground changes. The most challenging aspect of implementation will likely be permitting and other human dimensions of the project. However, working in a natural system also means dealing with nature and flexibility must be built into the implementation plan to allow for unpredicted events. For example, land disturbance will likely require seeding and follow up seeding should be expected in the event that precipitation patterns do not encourage germination.

Adaptive Management Plan

An adaptive management plan (AMP) is a systematic process for dealing with the uncertainties that implicit in working with a coupled natural and human system. If the restoration goals and strategy are based on scientific understanding of the underlying processes, alternatives can be developed to reflect this understanding. However, such systems can never be perfectly understood because they are the product of complex, non-linear, and are a function of countless interdependent processes. Within the AMP framework, science-based conceptual models initiate a sequential process of prediction, implementation, monitoring, evaluation, and adaptive improvement that will result in successful restoration activities over time.

Monitoring Needs

Restoration treatments impose changes to a target ecosystem, forest, watershed or landscape, and community. Treatment effectiveness and other outcomes are monitored over time, generally with baseline pre-treatment assessments providing a measure of reference conditions. For forest restoration, re-measurement is often conducted immediately before and immediately after treatment, then every five years thereafter. Examples of this approach may be found in the CFRP long-term monitoring reports posted at www.nmfwri.org/collaborative-forest-restoration-program/cfrp-long-term-monitoring.

Monitoring protocols may vary, depending on treatment objectives and the scope of the project. Examples of common protocols developed for the southwest US can be found at: http://www.nmfwri.org/collaborative-forest-restoration-program/cfrp-long-term-monitoring, for forest restoration projects; http://www.nmfwri.org/collaborative-forest-restoration-program/cfrp-long-term-monitoring, for riparian restoration projects; and http://www.nmfwri.org/collaborative-forest-restoration-program/cfrp-long-term-monitoring, for socio-economic monitoring.

Additional hydrologic monitoring is necessary to evaluate whether the restoration projects are performing as expected, and in many cases to inform maintenance and adaptive management. In most cases, the ongoing monitoring will be very similar to the baseline monitoring described above. Example questions to address are, "Did water yields change as expected after forest thinning and have the increased yields persisted over time? If not, why did the restoration project fail and how can restoration be adjusted to meet targets?"

Critical to the success of any monitoring effort are adequate field and data analysis training, as well as data archiving. Long-term monitoring will not succeed unless reference data are collected with the appropriate level of methodological rigor. This is one of the most challenging aspects of so-called multi-party or citizen monitoring, since not all citizen participants have an adequate level of training, expertise and commitment to the project (Egan 2011).

The results of monitoring will inform the AMP process by comparing expected outcomes to actual changes to the system. This information is then used to update and improve restoration approaches.

Maintenance

Among other benefits, monitoring informs the question of treatments' maintenance cycles – the period of time between successive treatments in order to maintain their effectiveness. Effectiveness is defined by the objective of the restoration treatment, and can include water yield, mitigation of severe wildfire, or issues related to forest health and productivity – or some combination of these or other possible project outcomes. Developing a better understanding of maintenance cycles should be part of the long-term monitoring process.

Potential for Gila Watershed Restoration under AWSA

Watershed restoration projects in New Mexico have typically assumed one of several project objectives:

- Hazardous fuels reduction that has a positive impact on water yield, supply and quality.
- Riparian restoration, typically addressing challenges related to invasive plants, as well as the mitigation of severe wildfire (see Bonfantine *et al*., 2011 for an elaboration of this).
- Projects that focus on the socio-economic dimensions and outcomes of restoration, especially so-called utilization projects that focus on building restoration-based infrastructure that do not result in ecological changes (see Egan and Estrada (in review) for an elaboration).
- Planning projects aimed at subsequently implementing broad, strategic watershed-scale restoration.

In addition, stream restoration projects in New Mexico have addressed another set of issues:

- Channel and floodplain modifications to improve or create habitat for endangered species (e.g. Middle Rio Grande).
- Bank stabilization and channel realignment to reestablish lateral or streamwise connectivity or to increase channel stability (e.g. Rio Puerco, Pecos River, Santa Fe River).
- Riparian vegetation and riparian wetland restoration to increase habitat (e.g. Bosque del Apache National Wildlife Refuge (NWR), Bitter Lake NWR).

Restoration projects in the Gila watershed could include these or additional approaches as discussed in Chapter 2. The most appropriate restoration approaches should be based on clear objectives combined with the gathering and analysis of high quality data and guided by science.

Potential criteria for evaluating restoration alternatives

Land managers and funding agencies are typically faced with an array of possible alternatives, suggesting a need for developing filters and priorities to identify the most important projects to implement or fund. There are several criteria and questions to consider during this prioritization process. These include:

1. Is the proposed project consistent with the organization's mission/objectives? Is the project supported by the best available science?
2. Are the proposed implementations connected spatially to other restoration projects on the landscape? The connectivity of some restoration efforts across a watershed or landscape should be a criterion for prioritization and funding. Isolated restoration efforts, while perhaps laudable in their intent, generally don't carry the same benefits as those that purposefully attempt to connect with other efforts in a more strategic way.

3. Is the location and scope of the restoration treatment strategic? That is, is the project not only connected spatially to other projects, but is it positioned spatially relative to its effectiveness in achieving its objectives and the organization's mission?
4. What will be monitored and how? Important sub-questions include:
   - *Will both ecological and socio-economic outcomes/effects be monitored?* Many restoration projects focus only on their ecological outcomes/consequences, ignoring the important socio-economic dimensions of the project. See Egan and Estrada (in review) for guidance on socio-economic monitoring of forest restoration projects.
   - *Will long-term monitoring be conducted (e.g., every five years for 20 years)*, or just short-term? Some outcomes/consequences, such as treatment maintenance cycles, won't be apparent until sometime after the implementation of the project. Are there mechanisms in place (e.g., local funding/commitment; data archiving) to account for this?
   - *How will the data/results be used?* Will monitoring results be used to assess effectiveness or inform future projects?
   - *What monitoring protocols will be used* and are they sufficiently rigorous to provide reliable interpretations of the results? Data quality is a major challenge in some watershed restoration programs, especially those emphasizing collaboration and citizen involvement. Important questions to resolve in this regard include: Are grantees, or their contractors, sufficiently trained to collect information that accounts for sampling and measurement error? Is there an appreciation for errors around estimates of key attributes? See Egan (2011) for elaboration.
   - *What are the objectives of the restoration treatment?* Are they clearly articulated and are they consistent with broader watershed needs/goals? Are they related to, for example: improving watershed health; mitigating the potential for catastrophic wildfire; economic development; securing water supply to a municipality? Because of the funding constraints under the AWSA, are there clear links between the proposed project/project objectives and water yield?
5. *Is there a plan to maintain the (effectiveness of) treatments?* All restoration and/or hazardous fuel reduction treatments have a maintenance cycle – that is, they must be "renewed" every, say, 10-20 years (for low thinnings), depending on the site and how aggressive the treatments are.
6. What are the potential impacts of the proposed project on local economic development?
7. What is the level of community support for the project? For example, is the town, county or other community entity or organization willing to support the project, even with matching funding?

Summary

Watershed restoration is not an exact science and every situation is unique. Although no 'one size fits all' approach exists for implementing restoration, there are several key elements that should be considered when developing and implementing watershed restoration. As described here, it is important to have a clear understanding of baseline conditions including knowledge of how the functionality of the system has changed over time. Clear watershed restoration goals should be developed based on best available science with input from stakeholders. This is particularly important when the original source of revenue has a finite duration (e.g. Will the community continue to support the project after the original funding has expired?). Restoration alternatives should be considered with respect to their ability to reach the restoration objectives, and criteria for success should be identified in advance to keep the process transparent and unbiased. Adaptive management should be incorporated from the get-go in order to accommodate uncertainty in natural systems and to improve upon assumptions throughout the process. Maintenance and monitoring must be incorporated from the onset in order to ensure that there's a clear plan for these vital activities. Clear milestones and metrics for success should be identified. Maintenance and monitoring activities should be used to evaluate project success. Data and information gathered should be used to inform adaptive management actions and ensure long-term progress and success.

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