



# RIPARIAN REHABILITATION & MONITORING

National Guidelines For Lebanon



## **Editorial**

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## **Reference project**

Sustainable Land Management in the Qaraoun Catchment

## **Executed by**

Ministry of Environment, Service of Natural Resources

## **Funded by**

Global Environment Facility

## **Implemented by**

United Nations Development Programme, Lebanon

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## **Acknowledgements**

During the assessment and implementation phase, the U.S. Forest Service Office of International Programs provided on-site and remote technical support through their riparian rehabilitation expert, Mark Vander Meer. This provided customized rehabilitation plans and preliminary guidelines for the project.

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# CHAPTER 1

## INTRODUCTION

The UNDP Sustainable Land Management in the Qaraoun Catchment (SLMQ) Project aims at embedding sustainability considerations in land use planning and development activities in the Qaraoun Catchment. The project is funded by the Global Environment Facility (GEF) and is implemented in partnership with the Ministry of Environment in Lebanon. The project is intended to reshape land and natural resource management to (i) alleviate land degradation, (ii) maintain existing ecosystem services and (iii) improve livelihoods in the Qaraoun Catchment. LRI has taken part in the design and implementation of rehabilitation activities along the riparian corridor linking Ammiq and Anjar-Kfarzabad wetland extending over more than 25 km in the districts of Zahle and West Bekaa. The works were closely coordinated with the Ministry of Energy and Water (MoEW), Litani River Authority (LRA) as well as with local communities including municipalities under the overall guidance of the Ministry of Environment (MoE).

Rehabilitation plans should reflect a set of goals that aim at improving the ecological functions of the riparian corridor and their sustainability and productivity for the neighboring local communities' benefits.

The main goals for rehabilitation in this project were:

- ▶ Improvement of water quality
- ▶ Conservation of habitat for wildlife (especially endangered species)
- ▶ Stabilization of soil and management of sedimentation movement
- ▶ Revegetation and protection of existing native vegetation

This project aimed to set a baseline for the rehabilitation of the Ghzayel river, that will be monitored for future adjustments and continuation of rehabilitation of this riparian area that stretches over 25 km. Throughout the assessment and implementation phases, the U.S. Forest Service International Programs provided technical support on-site and remotely through their riparian rehabilitation expert Mark Vander Meer, to be able to develop customized rehabilitation plans for the area.

In order to develop cost efficient and sustainable rehabilitation plans adapted to the local conditions of the Ghzayel riparian habitat, a methodological scientific approach was taken into consideration to assess the riparian corridor's health and come up with site-specific rehabilitation plans while taking into consideration all limiting factors. Assessment tools, such as Riparian Quality Index, flood risk assessment and topography assessment conducted under the SLMQ project, will be further discussed in Chapter 5.

## **Riparian Quality Index, flood risk assessment and topography**

Due to the complexity of riparian ecosystems, it is important to follow rehabilitation guidelines that are specific to their ecological conditions. Such guidelines were currently not developed in Lebanon, thus the purpose of the following guidelines is to provide guidance for natural resource managers, land use planners, restoration practitioners from the public and private sectors on 1) identifying riparian zones in Lebanon, 2) assessing quality of riparian zones, 3) developing and implementing targeted rehabilitation plans and 4) monitoring of rehabilitation projects, based on the pilot study of the rehabilitation of the Ghzayel river.

Identifying rehabilitation measures depends on a wide range of factors including environmental, social and economic. The guidelines include:

- ▶ Description and definition of riparian ecosystem in Lebanon
  - ▶ Assessment studies to be completed before developing a rehabilitation plan for a certain riparian area
  - ▶ Importance of sustainable land management in maintaining riparian ecosystems and its impact on ecological and socio-economic functions
- 
- Description of factors (ecological and anthropological) affecting riparian ecosystem degradation in Lebanon
  - Description of rehabilitation techniques that could be integrated in a rehabilitation project depending on all limiting factors on site and level of degradation of the riparian area
  - The development of a sound restoration strategy for degraded riparian areas in Lebanon
  - Effective monitoring guidelines

## CHAPTER 2

# BACKGROUND OF RIPARIAN HABITATS IN LEBANON

Riparian ecosystems are generally defined as being transitional areas between aquatic and terrestrial ecosystems and occur along watercourses and water bodies (U.S. Department of Agriculture NRCS, 1991). Riparian areas are geographically delineated areas with distinctive resource values and characteristics that are comprised of the aquatic and riparian ecosystems, floodplains and wetlands (U.S. Forest Service, 2000). They have distinctive vegetation and physical characteristics, influenced by surface and sub-surface hydrological features of water bodies (Agency of Bureau and Land Management, 1999 and U.S. Fish and Wildlife Service, 1998). Moreover, riparian areas clearly are characterized by gradients in environmental conditions, ecological processes, and species that make it difficult to assign them discrete boundaries (Naiman and Décamps, 1990).

Riparian ecosystems are directly influenced by the type of water body it is adjacent to. Thus, stream classification is important to determine appropriate measures for the rehabilitation of riparian areas. In the following guidelines, riparian habitat classification will be taken into consideration according to stream flow characteristics, a classification system well explained by Zaimes and Emanuel (2014).

- Perennial streams have continuous water flowing in the channel all year round during years of normal rainfall. They are mostly covered with trees, and to a lesser extent shrub that are obligate riparian or non-obligate riparian. Rivers that are permanent in flood plains (like in Akkar and Bekaa or in the south) which means the water is moving slowly and forming meanders. In this case we find more canes, shrubs and other plants that are specific to wet areas, along with obligate riparian trees (Figure 1)
- Intermittent streams have water flowing only part of the year. They have poor tree coverage, either obligate or non-obligate riparian, and are mostly covered with shrubs (Figure 1)
- Interrupted streams have perennial flow in their upper reaches and intermittent flows in their lower elevation reaches
- Ephemeral streams have water flowing only after precipitation events and the streams are above the water table

It is worth mentioning that both perennial and intermittent streams are in direct contact with the water table, which is the boundary between the unsaturated zone and the saturated zone underground ( Zaimes and Emanuel, 2014). The saturated zone below the water table is called an aquifer (U.S. Geological Survey Agency).

Fluvial geomorphology, in simple terms, is the study of the interactions between the physical shapes of rivers, their water and sediment transport processes, and the landforms they create (UMass Extension, 2020). Thus, stream water (perennial, intermittent, interrupted or ephemeral) is an important agent that defines the shaping of a riparian habitat. Alteration of water levels and flow in streams not only impacts transportation of sediments, thus fluvial landforms, but also can impact riparian vegetation and fauna (Zaimes and Emanuel, 2014). While streams try to always reach a state of dynamic equilibrium, where the amount of sediments delivered to the stream is in balance with the capacity of the stream to transport and discharge the sediment, that balance is currently disturbed, leading to erosion and deposition and to unstable streams. Humans had the most negative impact on stream stability, mainly due to land use change leading to extreme change in vegetation cover in riparian areas, such as conversion of lands into agricultural lands, industrial zones, touristic attractions, etc., and to further land degradation, which has been one of the main drivers behind the development of the guidelines.

### Riparian ecosystems in Lebanon

In Lebanon, as in other countries worldwide, riparian ecosystems are more susceptible to declines in biodiversity than other terrestrial ecosystems (Sala et al, 2000). Riparian forests cover a surface area of 58 hectares, representing 0.04% of the total forest cover (MoA/FAO, 2005). Considering the existing number of permanent and seasonal streams and rivers in Lebanon, this percentage can be described as low. The ecological status of many streams and their riparian areas remains largely undocumented (Abboud et al, 2012). Despite their ecological importance, riparian habitats in Lebanon are not listed among the country's known biological hotspots and to date, there are no nationwide assessments on quality of riparian areas and their biodiversity. With Lebanon being home to 404 bird species, including migratory species, 187 species are water dependent bird species and use riparian vegetation as nesting habitat or migration corridors (Strategic Environmental Assessment for the New Water Sector Strategy for Lebanon, 2015). Hunting has aggravated survival of the water dependent bird species, further to the fragmentation of their natural riparian habitats. Hunting has also led to further increase in pollution levels of banks and streams.

Below is an overall description of the current ecological status of rivers and riparian habitats in Lebanon.

- The ecological status of riparian habitats in Lebanon has drastically changed, mainly due to land use changes. The privatization of lands adjacent to riverbanks has led to the noticeable land cover changes in riparian areas. Major areas have turned into intensive agricultural and industrial activities, with a lack of urban planning regulation on important buffer zones and impacting natural resources and functions of riparian areas. Riparian zones/Buffer zones should be identified and according to the Lebanese laws and existing decisions (ex. Law No.77 dated 2018 water law in Lebanon; Law No.444 dated 2002 law of environmental protection in Lebanon; Decision No.144 dated 10/06/1925 related to public properties in Lebanon; Decision No.320 dated 26/05/1926 related to preserving and using water in public property).
- Water pollution has been a major problem in Lebanese rivers and is affecting ecological and socio-economic functions they present, that are discussed in the following chapters. Deterioration in water quality has mainly been due to urbanization, unsustainable agricultural practices and industrialization of areas adjacent or within riparian areas. Thus, Lebanon's rivers

are subject to higher microbial and chemical contamination due to neighboring activities. A study on water quality assessment of eight coastal rivers in dry seasons was done by Houry and El Jeblawi, 2008, and results indicate significant levels of pollution in all eight rivers. The coliform levels were “unacceptably” high, indicating a clear pollution from untreated sewage and wastewater dumping. Haydar C.M et al, (2014) analyzed the water quality in the upper Litani river basin and its seasonal variation, through chemical and physical (pH, T°, TDS, EC) parameters. They have concluded that different seasons revealed the presence of pollution from either mineral or anthropogenic sources or both and for that the degree of pollution is different from one site to another. Pollution caused by human interference was shown to come from municipal wastewater and agricultural purposes discharged into the river. Elevated nutrient level can also cause eutrophication and algal proliferation in the streams, leading to slowing down the water flow and increasing risks of flooding. The table below summarizes main causes of water pollution found in rivers in Lebanon.

Table 1 – Causes of pollution in Lebanese rivers

ACTIVITY	POLLUTION TYPE
Release of untreated sewage	High bacterial contamination levels
Uncontrolled disposal of solid waste	Leaching of chemicals into rivers
Untreated wastewater from industrial discharge	Heavy metals pollution of surface and groundwater
Agricultural runoff from fertilizers and pesticides	Nitrate leaching and contamination of groundwater
Uncontrolled water pumping leading to seawater infiltration into groundwater	High salt levels of groundwater

- Dams are important because they provide water for domestic, industrial and agricultural purposes.

However, in Lebanon, they could present a risk for riparian ecosystems, and threaten a large number of fauna and flora species that are dependent on water habitats, with some being rare and endemic if no accurate assessments were implemented before the planning phase of dams. The NWSS report in 2015 has mentioned the inundation and landform alteration risks that dams ones are prone to cause, and lead to sedimentation and habitat degradation. If proper planning and assessment are conducted, dams could provide benefits to local communities while still conserving natural resources in the area.

- Streams may transform from perennial to intermittent depending on the stress factors and conditions they are facing, and this is the case of several rivers in Lebanon. However, a full study has not been implemented yet. Moreover, as it will be discussed further in the next chapter, ecological functions and processes along the stream will be negatively impacted due to the urban, agricultural and industrial stressors. The factors that cause streams and streambank degradation have influence on what type of restoration/rehabilitation efforts should be undertaken to be able to restore the stream functionality and natural processes. This part will be covered in the next chapters of this guidelines.

### **Legal considerations:**

Several Multilateral Environmental Agreements are highlighted in the Strategic Environmental Assessment for the NWSS for Lebanon, 2015, emphasizing on the importance of riparian habitats and their conservation:

(1) The Convention on Biological Diversity, Rio de Janeiro (CBD) ratified by Lebanon in 1994 states that by improving the riparian zones, the stream bank erosion can be reduced, the water quality can be improved, and the biodiversity can be supported and conserved.

(2) The Agreement on the Conservation of African - Eurasian Migratory Water Birds (AEWA) calls for improving and restoring riparian woods that would benefit tree-nesting species protected by the Agreement such as Goosander *Mergus merganser* and Goldeneye *Bucephala clangula*.

(3) The RAMSAR Convention on Wetlands considers the riparian areas as part of the wetlands of international importance.

(4) The Convention on International Trade in Endangered Species (CITES) pays attention to the riparian area as a refuge to a variety of species protected by CITES (such as the Otter).

Lebanon's Law for environmental protection is Law #444 /2002. Within this law it states a few important elements that would benefit the conservation and restoration of riparian habitats, such as: (1) Conducting a complete survey about all existing species of the fauna and flora, especially for endangered species, (2) Proposing habitat protection plans for the multiple species of the fauna and the flora and tackling their lives and the means to develop them, (3) Proposing the creation of national parks, natural reserves and protected areas and proposing the conditions for protecting natural sites, (4) Creating a monitoring system to access biological living and genetic resources and use them in accordance with international treaties and conventions ratified by Lebanon (or to be ratified by Lebanon), with the concerned ministries, and (5) Adopting the Environment Impact Assessment principle as a means of planning and managing in order to fight, diminish or reduce to the maximum, the sources of pollution and the deterioration of natural resources. Those environmental legal considerations should be supported by appropriate guidelines, based on internationally recognized scientific approaches, starting from assessment to planning and implementation to monitoring, and accordingly adopted, especially when baseline data is lacking, insufficient or undocumented, as in the case of the riparian habitat conditions in Lebanon. The adoption of the guidelines should lead to the co-habitation of people and riparian natural resources, with a better understanding of the functions provided by riparian habitats.

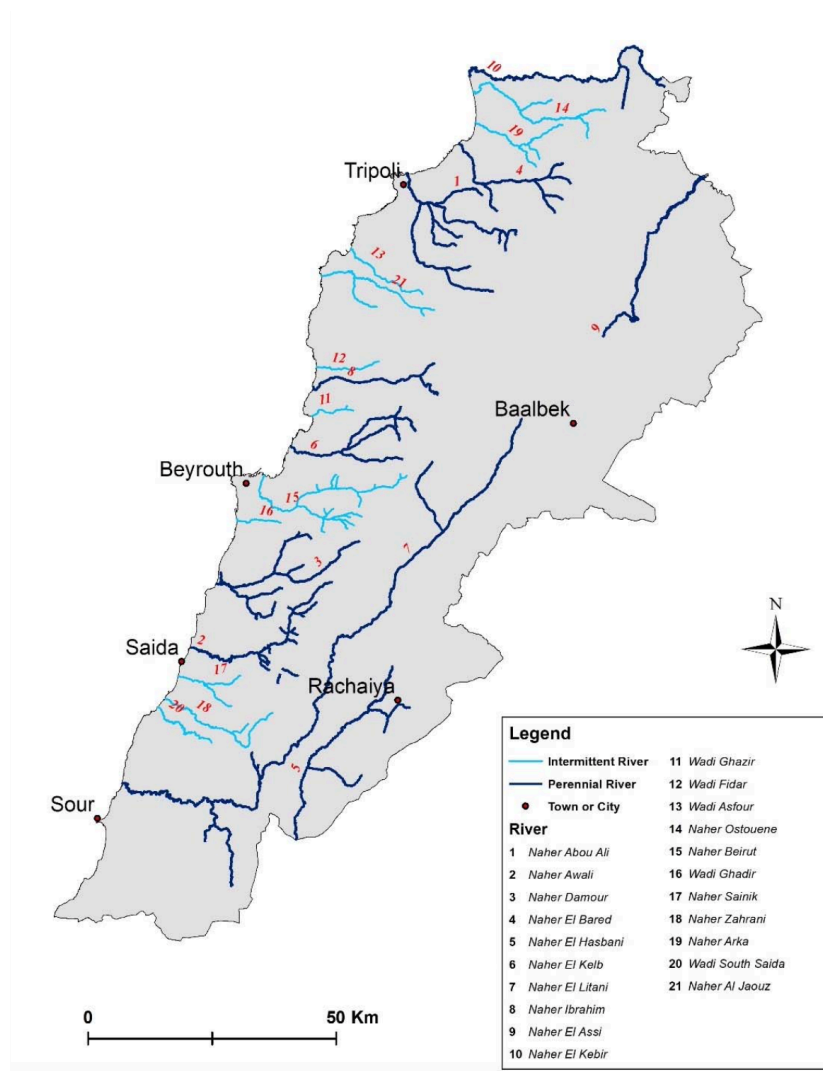
### **Research conducted to date for Lebanon**

In Lebanon, some research has been conducted on developing tools for the overall assessment of riparian habitat quality. George Mitri, PhD, worked on site prioritization for restoration activities along the riparian corridor in the Ghzayel river, between Ammiq and Anjar/Kfar Zabad, using the Riparian Quality Index (RQI) as assessment tool. Stephan and Issa (2017) conducted a study to identify riparian and shrub species around the Nahr Ibrahim river. The study revealed that bioclimatic variability affected species diversity in riparian habitats. Stephan and Issa (2016) also studied the effect of habitat quality and anthropogenic activities on biodiversity and canopy cover in riparian zones. The study helps in identifying priority sites for species conservation depending on habitat quality assessments and anthropogenic activities. Those efforts need to be multiplied and implemented in any riparian habitat rehabilitation planning throughout Lebanon.

Table 2 – Descriptive summary of main intermittent and perennial rivers in Lebanon

	River Name	Governate	Length Km	Geology	Agricultural Activities	Residential/ Non-Residential Structures	Refugee Camps	Roads And Bridges	Flood Risk (Cnrs)	Population Or Vegetation
Intermittent rivers	Wadi South Saida	South			Yes	Moderate	No	Yes		
	Naher Sainik	South			Yes	Moderate	No	Yes		
	Wadi Ghadir	Mount Lebanon			Yes	High	No	Yes		
	Wadi Ghazir	Mount Lebanon			Yes	Moderate	No	Yes		
	Wadi Fidar	Mount Lebanon			Yes	Moderate	No	Yes		
	Naher Ostouene									
	Naher Arka									
	Wadi Asfour									
	Naher Zahrani									
	Naher Beirut									
	Naher el Jaouz	North			Yes	Moderate	No	Yes		
Perennial rivers	Naher el Litani		140							
	Naher el Hasbani		65							
	Naher Awali		48							
	Naher Damour		6.64							
	Naher el Kelb		31							
	Naher Ibrahim	Mount Lebanon	30		Yes	Moderate	No	Yes		
	Naher Abou Ali	North			Yes	High	NA	Yes		
	Naher el Bared									
	Naher el Assi									
	Naher el Kebir		60							

## Main Perennial and Intermittent Rivers in Lebanon



Data Source: SDATL,2004. Classification of rivers modified based on consultation with Dr.Jean Stephan

Figure 1- Main Perennial and Intermittent rivers in Lebanon

## CHAPTER 3

# ECOLOGICAL FUNCTIONS OF RIPARIAN VEGETATION AND HABITATS

Riparian habitats play an essential role in environmental management, particularly in human-altered environments, including but not limited to maintaining biodiversity on a regional scale, offering refuge for prey and predators, and consequently providing corridors for migration. The structures and seral ages of the riparian ecosystem are complex and diverse and, as such, provide an array of functions that are typical only of that habitat (Eubanks and Meadows 2002). Riparian buffers of various types are effective at reducing nitrogen in riparian zones, especially nitrogen flowing in the subsurface; studies around the world have shown that riparian zones remove over 90% of the nitrate from the groundwater that flows through them (Pert, et al. 2010). Mayer, et al. (2007) study shows that, while some narrow buffers (0-25m) remove nitrogen, wider buffers (50m) more consistently removed significant portions of nitrogen most likely by providing more area for root uptake of nitrogen or more sites where groundwater conditions favor denitrification. Moreover, as described by Zaimes and Emmanuel, 2014, streams can be divided into functional zones through their longitudinal profile (Figure 2).

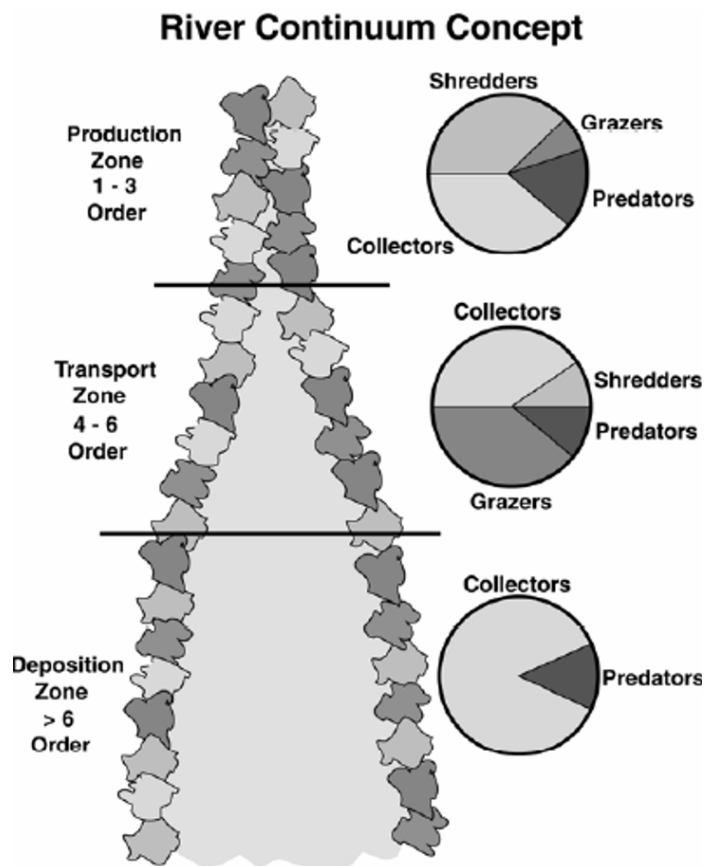


Figure 2: The three zones of the river continuum concept: a. zone of production, b. zone of transfer/ transportation, and c. zone of deposition (Zaimes and Emmanuel 2014).

In the headwater streams (zone 1), sediments and water are usually produced. It is described as the “production zone”, where vegetation is usually denser, and less sunlight penetrates the stream. The sediments and water are then transported in the mid-level streams (zone 2), known as the “transport zone” where water flow is usually faster and where more sunlight penetrates the stream that promotes algae production. The sediments are finally deposited at the watershed outlet levels, known as the “deposition zone” (zone 3) where nutrient rich water is found. The functional zones are an important habitat for macroinvertebrates, that constitute a critical component of riparian habitats. Those macroinvertebrates are divided into 4 groups: 1) Shredders thrive in the production zone, consuming and shredding the organic matter from the dense vegetation cover and little sunlight penetration; 2) Scrapers thrive more in the transport zone, because they survive more on algae; 3) Collectors are found in the deposition zones, where they filter feed from sediments deposited and 4) Predators feed on the 3 other groups and found in all functional zones. This is known as the river continuum concept and can be used to analyze health of the stream channel. Events affecting negatively stream channels and streambanks resulting in excessive erosion, flooding and slower water flow, will disturb the river continuum concept, and thus ecological processes along the stream. Further functions of seral ages of riparian ecosystems provide are summarized in Table 3.

Table 3 – The structures of riparian ecosystem and their function (Eubanks and Meadows 2002) & their status in Lebanon

STRUCTURAL COMPONENTS	FUNCTION	STATUS IN LEBANON
Roots – Interwoven infrastructure	Capture overland flow and nutrients	Infrequent due to absent or low density of vegetation
	Remove nitrogen from soil	
	Stabilize banks by holding the soil together	
	Trap and retain pollutants	
	Use phosphates adhering to soil and sediments	
Soil	Holds moisture	Either, not present due to accumulation of solid waste or topsoil layers lost due to unsustainable land use
	Offers a growing medium for plants	
	Promotes good water quality by acting as a filter	
Canopy – Trees, shrubs, grasses	Provides food	Fragmented
	Creates microclimates Shade: <ul style="list-style-type: none"> <li>• provides cool forest</li> <li>• provides cool water</li> <li>• shelters wet areas</li> </ul>	
	Creates migration corridors	
	Provides shelter and protection	

Floodplain	Traps sediment and particulate matter during floods	Absence due to anthropological infrastructure and/or unsustainable land use
	Slows velocity of flood waters	
	Holds nutrients and sediments deposited during floods to enrich soil	
Standing and downed vegetation, foliage, branches, leaf litter, uneven ground, and stream substrate	Aids water infiltration by slowing flow	Infrequent due to absent or low density of vegetation
	Provides bank protection—plants lay against banks during high flows	
	Provides habitat	
	Reduces near bank velocity and redirects flow	
	Traps sediment by slowing down and stopping runoff and floodwaters (the sediment drops out)	
Large Woody Debris (LWD) – large trees, tree branches, shrubs caught in streams, and log jams	Aids in floodplain development	Not documented or absent Rare
	Affects: <ul style="list-style-type: none"> <li>• formation of pools and riffles</li> <li>• formation of beaches and seedbeds on lakes</li> </ul>	
	Provides habitat	
	Provides resting and hiding cover for fish	
	Stores sediment and organic matter	
Litter – leaves, twigs, needles, blossoms, seeds, snags, rotting logs, and tree cavities	Provides food and habitat: Benthic and macroinvertebrates feed on litter	Infrequent due to absent or low density vegetation
	Provides food for fish and other aquatic species	
	Insects incubate on plants, then drop into water as food	
	Biodegrades into new topsoil	
Stream, river, lake basin, wetland, vernal pool, and ground water level	Carries away or impounds excess water	Increased water pollution Perennial streams and rivers turning to intermittent
	Provides food and water for animals	
	Water percolates into streams during low flow periods	
	Affects the microclimate	

The severe loss of riparian habitats has led to their substantial degradation and impaired function, which have acute consequences on both the riparian habitats themselves and their associated biota. In Lebanon, there are no continuous riparian habitat along rivers, even in some instances no buffer zones, due to land ownership and hardly any legal enforcement. These fragmented riparian habitats have negative effect on Lebanese biota and surrounding land uses. Lebanon's Mediterranean climate conditions are also a challenge to the biota communities present in riparian habitat, particularly during the hottest months when many surface water sources dry out and food resources become scarce. During summer, watercourses with riparian vegetation are frequently the only places where water can be found, often limited to small pools, making these places essential for biota persistence. They also provide shelter and food and may function as travelling corridors that allow biota to disperse (Santos, et al. 2016). In Lebanon's riparian habitats, not only are they extremely degraded and fragmented, but invasive flora species are replacing native riparian flora species (due to improper revegetation or from adjacent agricultural activities). Riparian habitats in Lebanon are experiencing shifts in species composition and subsequent ecological functions due to all these combined effects (Figure 3).

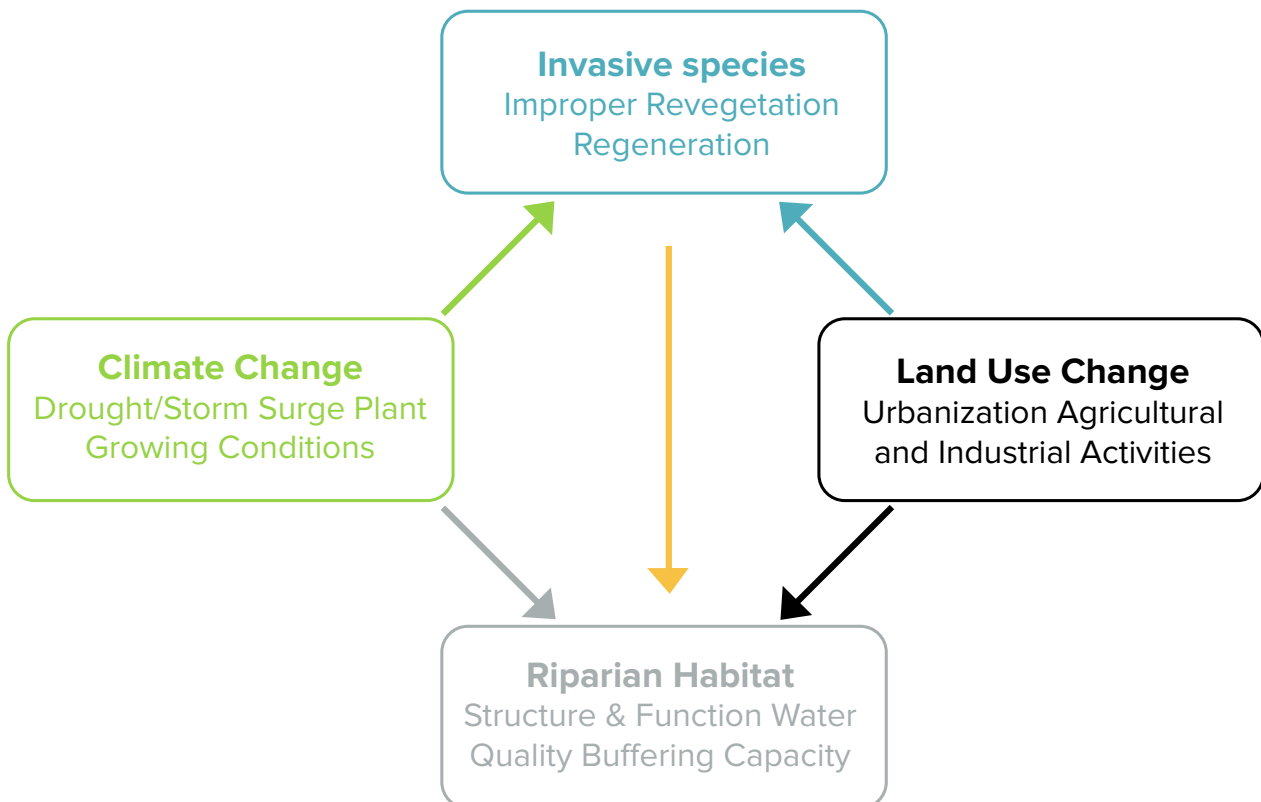


Figure 3: Conceptual model depicting land use change, climate change, and invasive species impacts on riparian habitat along stream corridors (Johnson, et al. 2020).

Riparian habitats harbor greater biological diversity than their adjacent ecosystems despite occupying a much smaller area of the watershed (Sabo, et al. 2005). Even small distributed restored riparian habitats in a fragmented landscape provide suitable habitat for recolonization by community assemblages of invertebrates and pollinators, thus contributing to an increase in local biodiversity and, possibly, the restoration of some of the ecosystem services they originally provided (Araújo, et al. 2018). The Mediterranean Basin is home to approximately 3,300 wild bee species, or approximately 87% of those occurring in the whole Western Palaearctic region. Large as that percentage appears, it is expected to be an underestimate given the insufficient research of the rich bee faunas of Mediterranean Africa and Asia (Herrera 2020). A decline in bee populations, both wild and managed, has been reported worldwide (Klein, Boreux, et al. 2018). Recently it seems there has been an increase of honeybees in some areas of the Mediterranean Basin, due to their honey production as a livelihood for locals. This in turn has a negative impact on wild bees in the long run, by undermining the diversity of wild and cultivated plants (decreasing abundance and quality) and wild bees in the region (Herrera 2020). This is discussed further in chapter 4. Pollinators such as wild bees are also important for the long-term process of habitat restoration and the functioning of ecosystems. Habitats with high biodiversity, such as riparian habitats, are crucial for wild bee population survival. Loss and fragmentation of riparian habitats leads to a decrease in wild bee population and a decrease of habitat conservation and restoration through pollination (Williams 2010). Invasive plants also reduce habitat conservation and restoration through pollination thus, removing invasive plants from riparian forests will bring back pollinators and their benefits. This was tested in Southeastern U.S (approximately five years after removal) and in Eastern North America (two years after removal) studies showed that after removing the invasive shrub Chinese privet (*Ligustrum sinense*) from riparian habitat bees and butterflies returned in abundance and diversity (Hudson, Hanula & Horn, 2013; Hanula & Horn, 2011).

Riparian habitats provide many fruit resources and attract many animals, such as frugivorous birds, which are the main seed dispersers in the Mediterranean basin (Gomes, 2017). Their habitat structure and diversity influence the size of the bird community that inhabits or visits these areas (i.e. migratory avifauna) (Kontsiotis, et al. 2019). In Lebanon, about 80% of the breeding water body dependent bird species nest in riparian habitats (ECODIT, 2015). Conservation of riparian habitats has a crucial importance for successful reproduction in some bat species too (Amorim, et al. 2018). An example in Lebanon is the Savi's pipistrelle bat (*Hypsugo savii*) (Benda, et al. 2016). Kipson, et al. (2018) revealed that these bats have a higher presence in riparian habitats during lactation indicating its importance for successful rearing of young. This could be influenced in the future by increasing droughts and water shortage in the Mediterranean region, which in turn will affect farmers pest control (further discussed in chapter 4).

The Eurasian Otter (*Lutra lutra*) (Figure 4) is a semi-aquatic critically endangered mammal found in Lebanon (Duplaix and Savage 2018). Their semi-aquatic habitats are extremely vulnerable to land use changes. Canalization of rivers, removal of bank side vegetation, dam construction, draining of wetlands, aquaculture activities and associated man-made impacts are all unfavorable to otter population. Declines in fish biomass result from acidification of rivers and lakes and organic pollution from nitrate fertilizers, untreated sewage, and farm slurry, which in turn reduces the food resources of the otter (Jdeidi, et al. 2010). All the threats mentioned are found across Lebanon and may be the main cause for their decline

and isolation in two known areas in the country: Anjar/Kfarzabad region and Nahr el Kabir. Other semi-aquatic species found in Lebanon are affected by riparian habitat destruction, whether for using the riparian habitat for dispersal between breeding sites, such as Near Eastern Fire Salamander (*Salamandra infraimmaculata*) (Bar-David, et al. 2007) or prey availability such as Dice snake (*Natrix tessellate*); known to feed on amphibians (mainly frogs and their tadpoles), gastropods, insects, reptiles, birds and small mammals (Vlcek and Jablonski 2016) (Figure 4).



Figure 4: Sightings of (a) Eurasian Otter (*Lutra lutra*), (b) Near Eastern Fire Salamander (*Salamandra infraimmaculata*) & (c-d) Dice snake (*Natrix tessellate*) across Lebanon in or adjacent to riparian habitat (Berj Tumberian, 2013 & Lebanese Wildlife, 2019).

Matos, et al. (2009) reflects the importance of riparian habitats in Mediterranean ecosystems for terrestrial mammalian carnivores by showing that carnivore surveys adjacent to riparian habitats consistently had significantly higher species richness than the matrix habitats. The preservation or improvement of riparian habitats would certainly benefit the mammalian carnivore populations and consequently their conservation. Several mammalian carnivores mentioned in the study are found in Lebanon, i.e. Stone (Beech) Marten (*Martes foina*) & Red Fox (*Vulpes vulpes*) (Figure 5). Although mammalian carnivores can persist in several habitat types, their characteristic large ranges and low abundances make them highly vulnerable to human persecution and habitat changes (Terraube and Bretagnolle 2018). Agriculture dominates land use in Mediterranean regions, especially in Lebanon, causing their loss and fragmentation and thus hampering their function. Hence, riparian habitats are frequently the only forest and/or scrub habitat for carnivores at a landscape scale. Thus, conservation planners can easily increase the number of species protected in the region by merely including a river within terrestrial biodiversity reserves.



Figure 5: Sighting of young *Vulpes vulpes* in Lebanon (Lebanese Wildlife, 2019)

## CHAPTER 4

# SOCIO-ECONOMIC FUNCTIONS

As mentioned above, riparian zones perform multiple ecological functions; these ecological functions are directly related to key ecosystem services provided to society (González, et al. 2017). Many of these functions have direct economic relevance, including but not limited supporting agriculture, forestry, industry and several outdoor recreational activities. These examples and others will be addressed further in subsections below, giving examples from around the Mediterranean and internationally as majority of such reports have not yet been conducted in the context of Lebanon.

### **Pest Control**

Every year, vast damage in crop production are caused by herbivorous arthropods (Culliney 2014), as well as rodents (Singleton, et al. 2010). Insectivorous animals have a significant importance to counteract the harmful effects of pests by preying on them, proven with several species such as frogs (Khatiwada, et al. 2016), bats (Baroja, et al. 2019), and birds (Benayas, et al. 2017). Barn owls have been a great success in neighboring countries to control rodent damage on agricultural crops (Peleg, et al. 2018). Furthermore, pest control through integrated pest management systems stands as a very convenient sustainable hazard-free alternative to pesticides, which are a growing global concern if overused. In-stream agricultural pesticide toxicity can influence negatively riparian communities (Graf, et al. 2019). An example of success, in context of riparian habitat adjacent to agricultural lands, is the ability of the soprano pipistrelle bat (*Pipistrellus pygmaeus*) which thrives in riparian habitats (Rachwald, et al. 2016) to control the rice borer moth (*Chilo suppressalis*), which constitutes a major pest of rice around the world (described process in Figure 6) (Puig-Montserrat, et al. 2015). This natural service can be enhanced and replicated in Lebanon by providing bat populations with artificial roosts in riparian habitat adjacent to agricultural lands where some key ecosystem features are present. Caution must be advised as high cases bat deaths from overheating in black-coloured boxes have occurred, it is important to take microclimate characteristics into consideration when setting up a bat-box scheme (Bideguren, et al. 2019). A local example for pest control would be the Lesser horseshoe bat (*Rhinolophus hipposideros*) (Benda, et al. 2016). They perform an ecosystem service as a suppressor of a wide array of agricultural pests in Mediterranean agroecosystems (Baroja, et al. 2019), and need riparian vegetation due to these habitats representing high quality foraging areas for this bat since a major part of its main prey have an aquatic larval development (Jan, et al. 2019).

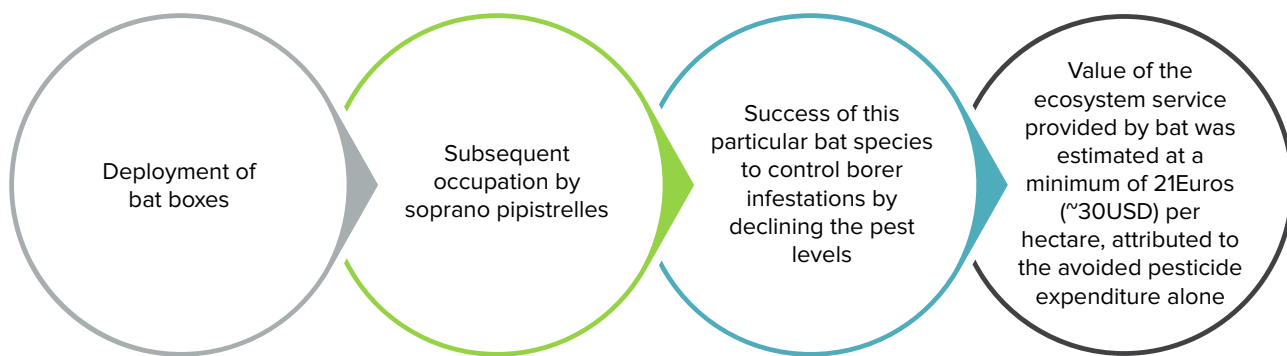


Figure 6: How soprano pipistrelle bat (*Pipistrellus pygmaeus*) controlled the rice borer moth (*Chilo suppressalis*) (Puig-Montserrat, et al. 2015)

### Biophysical/Hydrological

Riparian zones can deliver a range of regulating biophysical/hydrological ecosystem services (Brauman 2015). An example is stream hydraulics and hydrology functions provide (1) longer water residence time, (2) higher retention capacity of organic matter, & (3) higher retention capacity of inorganic matter. These 3 functions provide 2 services, water purification and erosion prevention. The benefits and value for these services are (1) higher water quality, which will reduce/ eliminate cost of water treatment and using the water for irrigation and (2) avoided reservoir sedimentation, which will reduce/eliminate cost of sediment removal (Acuna, et al. 2013).

### Crop Pollination & Seed Dispersal

Bees are especially abundant in Mediterranean ecosystems, where they may represent more than 90% of the pollinating insects (Sanchez, et al. 2020). Pollination is critical for human food supply; 77% of the leading global food crops depend on animal pollinators to produce yield (Klein, Vaissière, et al. 2007). Various farmers rely on managed colonies of the domesticated honeybee (*Apis mellifera*) for crop pollination (Delaplane and Mayer 2000). However, honeybees do not pollinate all crops efficiently and additional pollination may be needed (Garibaldi, et al. 2013). Wild bees have been shown to contribute substantially to the pollination of a variety of crops (Klein et al. 2007) and to provide a safety net in the event of honeybee colony collapses (Winfree et al. 2007). Wild bees crop pollination is an ecosystem service of enormous value, but it is also under increasing threat from agricultural intensification (Ricketts 2004). Grab, et al. (2019) findings reveal that landscape-mediated loss of evolutionary history from bee communities has consequences for current ecosystem functioning and the delivery of ecosystem services to agriculture, such as decreasing abundance and quality of crop production (Figure 7). Specifically, they show that loss of phylogenetic diversity from pollinator communities has a negative effect on pollination services. The diversity of wild pollinator communities can make them more efficient than a single pollinator species (Blüthgen and Klein 2011) and more resistant to environmental changes (Winfree and Kremen 2009). Hence, there are functional benefits attached to conservation of diverse pollinator communities in arable landscapes.

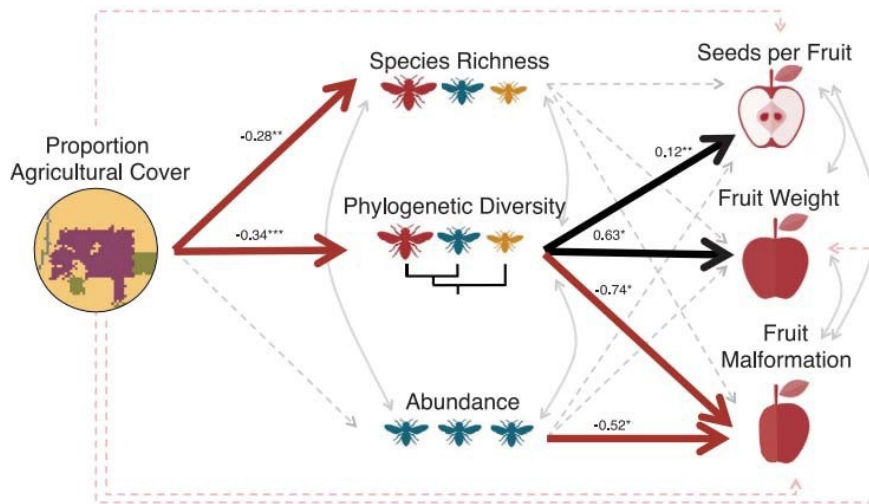


Figure 7: Land-use change has an indirect impact on pollination services and crop production mediated by a reduction in observed mean pairwise phylogenetic distances separating individuals in a community (Grab, et al. 2019).

The stone (beech) marten (*Martes foina*) is known in dispersing native floral seeds contributing to gene flow and forest regeneration (Pereira, et al. 2019). In Lebanon, crop production would be high near riparian areas and could be negatively affected in that case by poorer pollination, poorer seed dispersal, and poorer fruit quality.

In Lebanon it is currently almost impossible to find pristine aquatic ecosystems that have not been altered by human activities. Hence, appropriate restoration practices are needed considering a multi-scale approach. Despite the recognized importance of riparian zones for ecological, economic and social reasons, and the vast amount of scientific literature exploring measures for their conservation, current management is still failing at enabling a proper ecological functioning of these areas (González, et al. 2017). Also, many restoration projects fail to restore wildlife even when the physical environment and vegetation has been restored (Jones and Davidson 2016), probably because of the lack of structural complexity and the critical features required by wildlife (Peipoch, et al. 2015). The conflict between different interests and directives usually leads to the adoption of uncoordinated measures in the management of riparian zones. Conservation of riparian zones will not be possible if technical–ecological, socio-economic, and legal issues are not addressed holistically (González, et al. 2017). The following chapters will cover how to accurately plan riparian rehabilitation projects and develop customized rehabilitation plans targeting fauna and flora conservation and re-establishing riparian functions.

## CHAPTER 5

# PLANNING RIPARIAN AREA REHABILITATION PROJECTS

### A. An Introduction to the Planning Phase

The planning process in natural resource management, and more specifically, riparian area rehabilitation, sets out to establish project goals and objectives and determine appropriate courses of action that best attain these targets (Bettinger et al. 2009). Development of project goals and objectives typically follows problem or opportunity identification and analysis to integrate structural and functional considerations. A comprehensive site assessment performed by skilled observers is essential for developing project goals and objectives. Project goals are designed as broad, general statements that represent the desirable future conditions and outcomes. Goals can be either long-term and strategic in nature or short-term, adaptable, and operational. Objectives are specific, measurable, attainable, realistic, and timely targets that address the constraints of a project while meeting the desired outcomes (FISRWG 1998). While this document focuses on planning for individual rehabilitation projects, a given project may be a part of a larger regional or landscape-scale undertaking or a long-term effort of recovery in an area. The overarching rehabilitation efforts for regional or landscape-scale rehabilitation efforts should have their own set of goals and objectives, with individual projects contributing toward those desirable future outcomes.

Before project goals, objectives, and courses of action can be determined, a substantial amount of assessment and analysis must be performed first. The planning process for riparian rehabilitation projects is characterized by the gathering and interpretation of data and information pertaining to the project site in order to make evidence-based decisions on the rehabilitation approach, at least a year before implementation. This data collection and analysis phase should focus on problem/opportunity identification, site characterization and assessment, stakeholder engagement, and alternatives analyses that compare varying degrees of intervention and rehabilitation. Historical impacts to the site, current conditions (baseline data), socio-economic factors, desired outcomes, and funding availability create both a record and a direction for the project. Understanding the social landscape is a vital element in all rehabilitation projects. Stakeholder engagement early in the planning process is therefore crucial to collaboratively address the problem/opportunity so the subsequent goals, objectives, and courses of action are widely embraced. As such, a well-planned riparian rehabilitation project organizes physical, biotic, economic, and social information in order to develop appropriate interventions. This process is iterative: as new information becomes available and additional stakeholders are involved, the planning phase can adapt to other considerations.

Progressing too quickly from the planning to implementation phase can result in numerous undesirable outcomes. Failing to remove the stressors impacting the system, inability to establish positive ecological trends, unsatisfied or underrepresented stakeholder groups, and budgetary constraints are just a few examples of how inadequate planning can limit the delivery of the intended outcomes. These shortcomings point to the critical nature of the planning phase in setting the stage to achieve success.

## **B. Problem/Opportunity Identification**

Ecological systems are inherently complex. Fluvial ecosystems are especially complex due to the dynamic nature of the hydrologic, geomorphic, biologic, and socioeconomic drivers. However, identifying the problems and/or opportunities for riparian rehabilitation is often visually apparent. Such problems that can be immediately evident upon inspection by a trained restoration professional include:

- ✓ Incised channel beds
- ✓ Collapsing streambanks/ soil erosion
- ✓ Disconnected floodplains
- ✓ Poor riparian cover
- ✓ Anthropogenic litter/ poor waste management
- ✓ High nutrification levels of water
- ✓ Sedimentation
- ✓ Anthropogenic violations on riparian buffer zones (constructions, industrial, etc.)
- ✓ Unmanaged grazing

Unfortunately, once the problems that have caused degradation are identified, correcting them can be difficult and costly.

Because rehabilitation projects are often initiated in response to damage to infrastructure or harm to public health and safety, problem and opportunity identification may not be an explicitly assigned task during the planning phase. Moreover, while an infrastructural or public safety issue may act as the catalyst for a rehabilitation planning project, it may not address all possible problems or opportunities for improvement. Therefore, it is important to fully account for all problems and opportunities characteristic of a project by performing additional assessments as needed. For instance, discrete flooding events may drive a reactionary response in the form of a rehabilitation planning project. While flooding may be the most apparent and influential issue for a particular site, multiple problems or rehabilitation opportunities are not mutually exclusive. A single problem or rehabilitation opportunity may catalyze a response, but additional factors must be considered and addressed throughout the planning phase. This is the point at which a proper site characterization and assessment must be performed, and stakeholder outreach and engagement should commence.

## **C. Site Characterization & Assessment**

This section provides an overview of typical site characterization and assessment efforts for riparian rehabilitation projects. Best management practices are provided to outline common approaches to assessment efforts to progress the planning phase toward implementation. Appendix A displays sample Field Data Collection Forms that, when performed by qualified restoration professional, should adequately address the topics outlined below.

## 1. Overview & Best Management Practices

Site characterization and assessment should identify all the factors contributing to degradation, thereby reducing as many unknowns as possible. Abundant data and information will increase the level of understanding, inform goal and objective development, ensure proper stakeholder engagement, and increase the likelihood of obtaining desirable future outcomes. McDonald et al. (2016) and Gann et al. (2019) outline key concepts of best practice in ecological restoration. These concepts serve as a guide to ensure that the site assessment captures sufficient information and allows for an effective rehabilitation plan to be developed. The following site assessment best practices work to:

### 1) Understand the factors that cause or perpetuate degradation

- a. Agricultural or grazing encroachment
- b. Sediment transport imbalance
- c. Channel confinement
- d. Hydrologic abstraction
- e. Management inefficiencies
- f. Development & land use
- g. Pollution

### 2) Identify the socioeconomic systems associated with the site

- a. Stormwater & wastewater management
- b. Water rights & agricultural users
- c. Hydroelectricity generation
- d. Drinking water supplies
- e. Conservation groups
- f. Public Utilities
- g. Recreation
- h. Fisheries

### 3) Characterize abiotic conditions

- a. Channel & floodplain dimensions
- b. Water quality parameters
- c. Geomorphic evolution
- d. Property boundaries
- e. Hydrologic regime
- f. Soil properties

### 4) Inventory biotic conditions

- a. Catalog species presence & abundance
  - i. Threatened or endangered species
  - ii. Native species
  - iii. Invasive species
- b. Characterize community structure
  - i. Vegetation layers
  - ii. Cover
  - iii. Habitat diversity
  - iv. Wildlife usage

- 5) Determine the level of ecosystem function
  - a. Proper functioning condition
  - b. Limiting factors
  
- 6) Evaluate landscape habitat connectivity
  - a. Upstream – downstream
  - b. Floodplain connectivity
  - c. Groundwater – surface water connectivity
  - d. Habitat connectivity
  - e. Barriers to connectivity

Site characterization and assessments should be performed to coincide with growing seasons to provide the highest degree of similarity between existing and desirable future conditions. It is often necessary to perform multiple site assessments to monitor ongoing changes in site conditions; capture seasonal variability in vegetation, wildlife usage, and flows; and ensure thorough investigations have been performed. Repeat assessments should follow the same methodology as earlier efforts to maximize comparability. It is recommended that a fully developed site characterization and assessment plan, following the assessment forms in Appendix A, in conjunction with appropriate sampling and analysis plans, be developed to ensure continuity over time.

## 2. Community Stakeholder Engagement

Engaging the local community and all public and private stakeholders is one of the most fundamental components to a successful rehabilitation planning process. Too often, planners and project managers proceed through site assessment and restoration design, only to have implementation efforts falter due to a lack of community engagement and stakeholder input. Community members often act as the ‘front lines’ in natural resource management because they live and work on the land, depend on its natural resources, and observe its state of wellbeing on a daily basis. Moreover, stakeholders can have significant authority and jurisdiction related to sites, not limited to property ownership, easements, and liabilities. Therefore, hosting public meetings and performing thorough outreach with all potential parties prior to moving forward with the planning process will greatly bolster the integrity of a project and the likelihood of its success. Stakeholders and community members may offer invaluable resources such as daily observations, volunteer work parties, scientific expertise, cost-sharing, and long-term monitoring and maintenance programs that are crucial to project success. A list of common community members and stakeholders is provided below:

- Private landowners, ranchers, farmers & herders
- Conservation groups and non-profits
- Public and private schools, colleges, and universities
- Community task forces & neighborhood groups
- Public and private utilities
- National and provincial governments and regulatory agencies, including municipalities and union of municipalities
- Recreation, tourism, and commerce groups
- Private industry and wastewater discharge permittees

Overall, a complete community engagement strategy should be adopted prior to project design and implementation. Figure 8 illustrates the strategy adopted by LRI in all project areas. Identifying key stakeholders and influencers in a specific town/village can benefit in well designing the project framework and avoiding implementation challenges. It highlights the influence of decision makers in a specific village and their relationship with local authorities and whether they will positively or negatively influence implementation of any planned activity. The stakeholder analysis could be completed following the below mapping tool (figure 9).

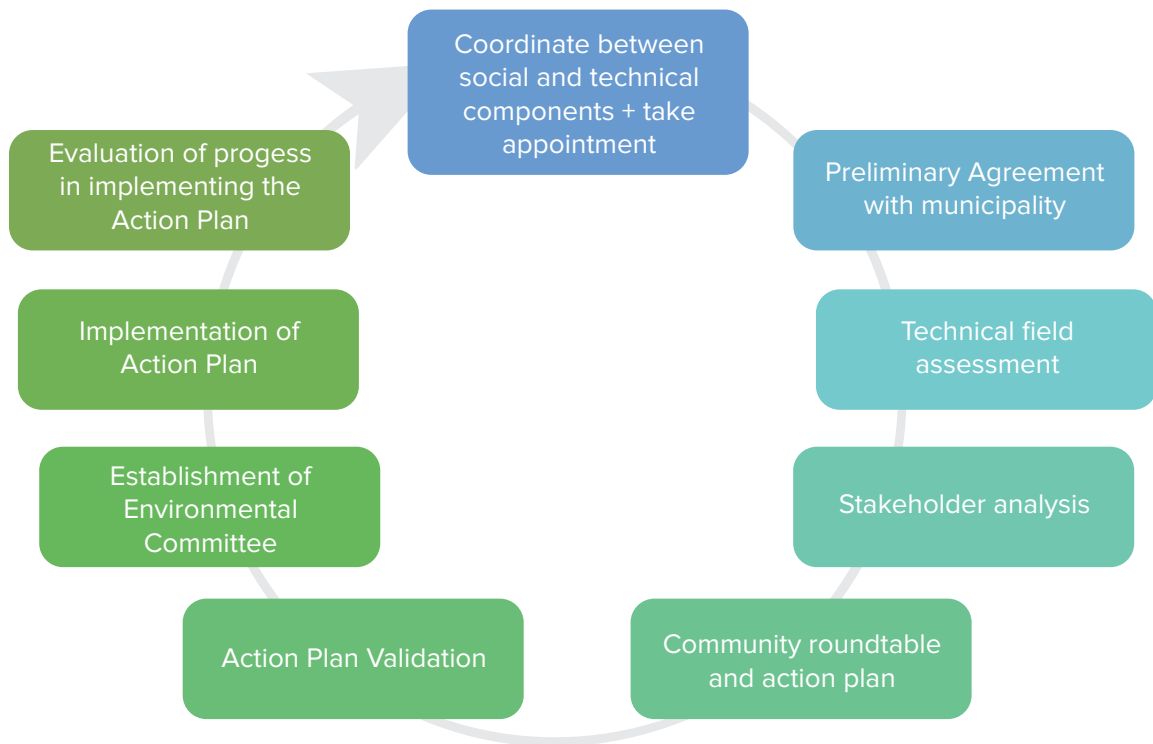


Figure 8 – LRI's community engagement strategy

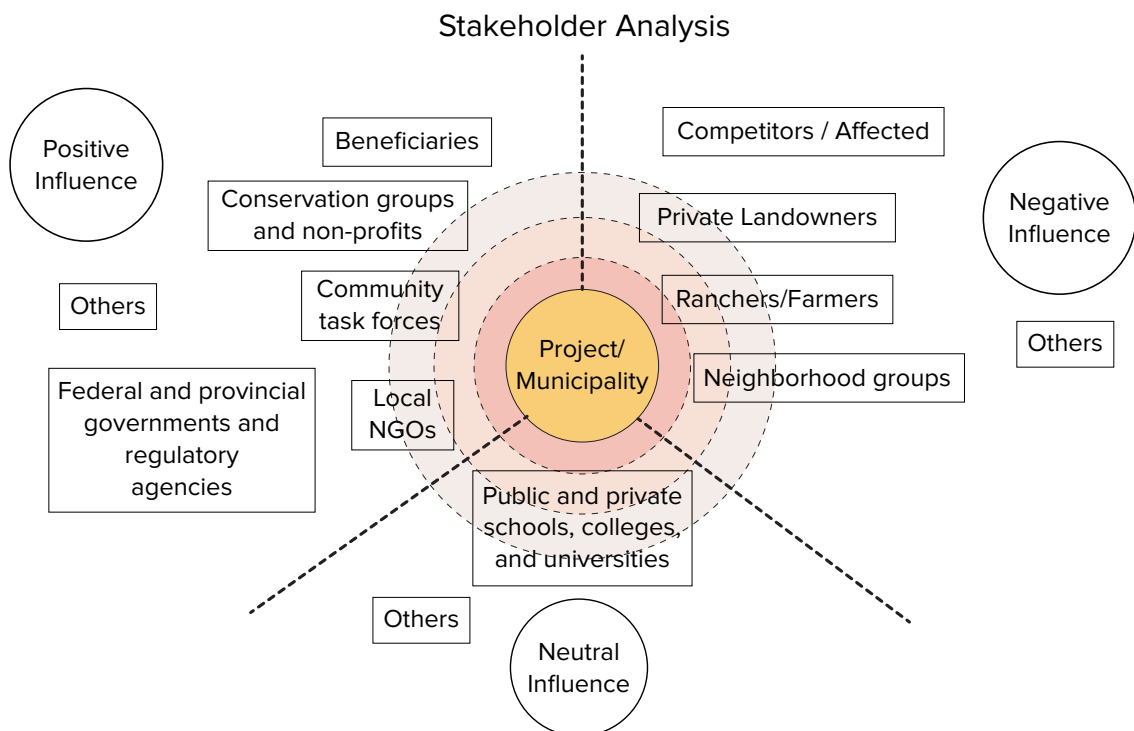


Figure 9 – Stakeholder analysis

### 3. Designing a Site Characterization & Assessment Plan

As the first step in designing site characterization and assessment efforts, planners and project managers should determine the extent of the project area to be addressed. By defining the project area extent, site assessments can focus on the immediate problems and rehabilitation opportunities associated with that area. Delineating realistic and tractable project extents is critical to the feasibility of restoration planning and implementation depending upon the resources available. While property boundaries and legal jurisdictions may ultimately dictate this process, it is important to consider land use and geologic/geomorphic features as project boundaries. As such, field surveys and background assessments need to include evaluations of the surrounding upland areas (well beyond the floodplain) that may be influencing the project site. For larger projects with a phased approach, it is helpful to divide the project extent into operational units, or reaches, to allow for more refined planning and execution.

Once a project area has been defined, planners must formulate specific scientific questions related to the project problems or rehabilitation opportunities that will be addressed through data collection and analysis. These questions can be elementary in nature, such as: How does agricultural land use affect riparian habitat and streambank stability? This simple question will prompt numerous follow-up questions, likely of increasingly technical nature. For instance, observed irrigation withdrawals might lead a planner to ask: How does hydrologic abstraction relate to the ongoing mass wasting of stream banks and the loss of riparian habitat? From there, planners can develop data collection methods that will address the precise question. To address the example question, planners might monitor stream flows, irrigation withdrawals, sediment supply/deficit ratios, bank stability indices, and riparian vegetation communities.

Once the specific scientific questions for each site are formulated, planners must determine what resources are available for site characterization and assessment. This will ultimately dictate the degree of site assessment work that is possible. Budgets for rehabilitation projects are often limited during the planning phase and conserved for implementation efforts. Therefore, this document provides outlines for both lower- and higher-cost assessment approaches (Tables 4 & 5). However, it is imperative that as much data be collected as feasibly possible to inform goals, objectives, and courses of action to meet the desired future conditions. This is especially important for highly degraded systems in which pre-disturbance conditions are not easily identified. For such cases, the use of a reference reach approach is especially helpful. See Box 1 for more information related to reference reach approaches.

Box 1. An overview of utilizing reference reach assessments for riparian rehabilitation planning.

#### The Value of a Reference Reach for Site Assessment & Rehabilitation Planning

An important component of nearly all site assessments is a comparison to an intact – or at least better functioning – system of similar properties. This is often called the reference reach approach. In this approach, an undisturbed (or less-disturbed) system(s) of similar structure and function to the subject system are used as a proxy for baseline comparisons (Rosgen 1996). In degraded systems, it is often difficult to determine what the pre-

disturbance conditions were. By identifying and assessing a system of similar structure and function in a less-disturbed state, planners can acquire an empirical sense of background or baseline conditions for their project area. These reference systems are subjects to emulate or match if possible when determining the future desirable conditions for project areas. Ecological restoration and rehabilitation projects seek to re-establish the historical species composition, community structure, ecosystem functions, and successional trajectories of the ecosystems present prior to degradation. In many cases, a reference reach is the only mechanism to understand what the conditions were prior to degradation.

Identifying intact reference sites is a key element in the rehabilitation planning process and is often difficult in regions of dense development. In areas of wide-spread disturbance, where reference systems cannot be located, the tactic often changes from 'matching' to 'approximating' reference conditions to achieve ecological functional stability. In this case, systems that are assembled primarily on human intuition and incomplete reference reach data are referred to as novel ecosystems but are still restorative in nature. They benefit the environment and human well-being, but they are not 'ecological restoration' in the purest sense because the 'restored state' cannot be directly compared to pre-disturbance conditions. Determining whether the project area has been damaged to a point where restoration or rehabilitation may not be ecologically viable, operationally feasible, or financially possible is an important decision made in the planning process. It is at this crossroad that a team determines whether a project will embrace ecological restoration as its desired outcome or revert to environmental remediation and mitigation as a path towards functional stability.

With an understanding of the available budget and resources for these efforts, planners should develop a site characterization and assessment plan that outlines 1) precisely what data will be collected; 2) standard operating procedures and methodologies for data collection; 3) how often data collection will occur; 4) the personnel responsible for data collection, management, and analysis; 5) equipment, materials, and expertise/training required to perform data collection; and 6) a narrative describing how data will inform the planning process. In addition, sampling and analysis plans should be developed for any projects that aim to perform routine monitoring and laboratory analyses in order to maximize comparability, replicability, representativeness, completeness, precision and accuracy, sensitivity, and spatial and temporal representation.

Table 4 – Strategies for rapid site assessments typically associated with lower costs.

<b>LOWER COST/RAPID ASSESSMENT STRATEGIES</b>	
Literature review	Existing agency, academic, and public reports & data
Regional topographic data	Coarse resolution elevational data
Riparian vegetation survey	Species composition, density, woody debris, & % cover
Fish, bird, & wildlife survey	Direct & indirect observations (presence/absence, tracks, scat, etc.)
Field Stream Assessment	Bank full width, slope, flow, bank erosion hazard index, etc.
Photo-documentation	Establish photo-points for long-term monitoring
Existing violations/non-compliance	Water quality exceedances, illegal dumping, etc.
Recreational use & foot traffic	Direct observations of public and private usage
Herbivory & browse	Characterize wildlife/livestock browse and usage
Industrial	List potential point-source polluters
California Rapid Assessment Methods (SFEI 2020)	Soils, hydrology, vegetation functional quality assessments

Table 5 – Strategies for functional site assessments typically associated with higher costs.

<b>HIGHER COST/FUNCTIONAL ASSESSMENT STRATEGIES</b>	
Topographic survey	LiDAR, photogrammetry, Total Station, RTK
Remote sensing data	Vegetation indices, hydrologic modeling
Riparian quality index (del Tanago & de Jalon 2010)	Quantify riparian habitat quality
Hydrologic & hydraulic modeling	Measure & model discharge & perform flood frequency analyses
Sediment transport	Suspended sediment and bed load measurements & models
Soil & groundwater contamination	Groundwater wells, hydraulic connectivity, chemical analyses
Water quality	Temperature, nutrients, E. coli, Fecal coliform, metals, organics
Proper Functioning Condition (BLM 1998)	Wetland/riparian functional assessments

#### 4. Data Collection, Management & Analysis

The quality and quantity of data must be adequate to answer scientific questions or guide resource management decisions. Quality Assurance (QA) is the overall approach used to ensure that site characterization and assessment produces data of the desired level of quality necessary to meet project goals and objectives and inform the planning process. For instance, QA includes developing necessary sampling and analysis plans, training field staff and volunteers, communicating analytical requirements for any samples taken in the field, and adhering to standard operating procedures and proper methodologies. Quality Control (QC) comprises the technical approaches used to detect and control for bias or error in data collection. For example, QC includes collecting field duplicates, preparing field blanks, reviewing field data collection forms for accuracy, and calibrating equipment. High QC will help to identify problems if they arise and identify the cause of the problem.

Site characterization and assessment efforts require adequate documentation and proper data collection, management, and analysis to produce credible records that accurately represent conditions within the project extent. Data collection should be designed to address the specific scientific questions formulated early in the planning process. The data collection process should clearly document field techniques and site-specific conditions that shape how data are obtained. This includes the collection of metadata to document personnel, weather, hydrologic conditions, data collection methods, sampling procedures and handling, and analytical approaches that will be applied. Analytical methods should be pre-determined to address the specific scientific questions formulated by planners, and efforts should be made to collect all the data required to address these questions.

#### D. Identify Limiting Factors & Stressors to Inform Rehabilitation Planning

After data collection and analysis is complete, planners can begin to identify the limiting factors and environmental or anthropogenic stressors that inhibit proper ecological functions. This is often performed as a prioritization strategy, in which the limiting factors and stressors are ranked according to scores in various categories. From there, the most pressing limiting factors or stressors can be addressed in order of necessity or feasibility. Table 6 provides an example of a limiting factor prioritization approach by ranking problems on a 1-5 scale (1 = low priority; 5 = high priority). In this example, each stressor or limiting factor is assigned a value between 1 and 5 that represents the level of degradation or impairment to each of the categories (ecological, social, and economic). These values are then summed across the three categories, resulting in a cumulative ranking score for prioritization purposes. Adjusting any individual score for stressors will influence the prioritization ranking scores, and thus direct rehabilitation goals and objectives. This approach can be adapted to suit a wide range of projects, limiting factors, or prioritization categories. Data analysis is especially useful when assigning scores for each limiting factor or stressor.

Table 6 – An example prioritization table for limiting factors and stressors in a riparian rehabilitation setting.

LIMITING FACTOR OR STRESSOR	ECOLOGICAL PRIORITY	SOCIAL PRIORITY	ECONOMIC PRIORITY	TOTAL SCORE	PRIORITY RANKING
Hydrologic abstraction	2	3	5	<b>10</b>	<b>2</b>
Livestock browse	5	1	5	<b>11</b>	<b>1</b>
Anthropogenic litter	5	5	1	<b>11</b>	<b>1</b>
Water quality	2	4	1	<b>7</b>	<b>3</b>
Soil conditions	4	1	1	<b>6</b>	<b>4</b>

### E. Rehabilitation Project Alternatives Analysis

The use of data analyses and prioritization approaches enable planners and project managers to develop a suite of rehabilitation alternatives. Typically, an alternatives analysis is an analytical comparison of the operational suitability, effectiveness, and life-cycle cost of different rehabilitation alternatives to suit the needs of a project. Different alternatives are selected based on their capacity to solve the problem(s) associated with rehabilitation projects and provide perspective as to the costs and benefits of each alternative.

Alternatives should represent a gradient of intervention intensity, from No-Action to full riparian reconstruction. Alternatives may vary greatly among and within riparian rehabilitation projects and are guided by the site characterization and assessment work, ranked prioritization approaches, and the insight of experts and planners. Alternatives can address one or more of the identified problems or rehabilitation opportunities affecting a project. Ideally, alternatives analyses should include an analytical comparison of effectiveness for each of the identified problems/opportunities, including a narrative of the suitability for the project, inherent risks, life-cycle costs, and a clear pros-cons chart to help planners determine the most appropriate alternative.

### F. Selection of Appropriate Rehabilitation Strategies & Activities

With a clear picture of the site attributes, social landscape, and budget allocation, determining appropriate implementing activities for the project becomes a less challenging endeavor. McDonald et al. (2016) offer three broad options for approaching implementation that are inherently linked to the intensity, scale, and nature of the degradation.

## 1. Passive measures and strategies

When disturbance is low, the remaining biotic community will likely deviate little from reference site examples. In these minor-disturbance scenarios, natural communities have an ability to rebound on their own through natural regeneration once the source of degradation has been removed, provided that removing the cause does not jeopardize project area habitat integrity, such as in large-scale earthwork. Passive restoration can also be a viable approach when the site has been subjected to intermediate disturbance. In these cases, recovery might be prolonged, but can be an acceptable trade off in remote areas or when funding is limited.

Short-term overgrazing is one example where a passive strategy can be employed. If soils have not been severely compacted, the simple installation of a fence is all that is required to remove the source of degradation. With no other human inputs, the plant community can re-sprout or germinate from the seed bank, and wildlife can recolonize from nearby habitats. Another instance of passive restoration is where a biotic system is choked by weeds but is, by and large, intact. The removal of the exotic pest problem can allow for native colonization and release existing suppressed native vegetation.

Passive restoration techniques tend to be less expensive relative to other approaches.

## 2. Soft-engineering measures and strategies

Ecological systems have a threshold from which they can recover. When that threshold has been exceeded, i.e. when the disturbance is beyond the point from which the system is able to self-recover, additional human intervention is required to establish a positive recovery trend. In these cases, the removal of the root cause is not enough to initiate desirable successional development. Soft engineering measures are implemented in situations where the degradation is intermediate. These measures are often referred to as assisted regeneration because some external assistance, but not complete reconstruction, is needed to initiate successional processes. Simple revegetation efforts such as tree and shrub plantings are an example of this approach. Some riparian bank stabilization and bio engineering techniques can also be considered “soft-engineering”.

Low-tech process-based techniques are quickly gaining recognition and popularity. This approach is used in rivers and streams that lack structural complexity. This strategy is very cost effective and usually applied without machinery. Structures are built in the water and on floodplains with small logs and branches. Structures aggrade incised channels, enhance stream access to flood plains, and improve floodplain stability. Utah State University, USA, Restoration Consortium, provides an excellent manual and training program to implement these techniques; “The Low-Tech Process Based Restoration of Riverscapes Design Manual” (Wheaton et.al. 2019).

Soft-engineering is relatively inexpensive compared to hard-engineering described below. However, costs can be surprisingly high if large trees are planted or the effort necessary to establish plants is excessive.

## 3. Hard-engineering measures and strategies

In scenarios where the level of disturbance is high, ceasing the degrading activities and minor interventions will not suffice. Thus, a larger effort is required to reconstruct the site and make it suitable for a biotic community to either establish itself or develop after planting activities.

Complexity of the project often increases with higher levels of disturbance. This complexity necessitates more attention being placed on the sequencing of project phases.

Examples of hard-engineering include recreating landforms such as riparian flood plains and riverside terraces, stream and river channel construction, removing contaminated soils, road obliteration and mine and quarry reclamation.

### **Restoration Technique Selection.**

Depending on the size, complexity, and heterogeneity of disturbance at the site, these three approaches can be blended and incorporated in different sections of the project or in distinct habitats. The next step is selecting specific restoration techniques within these key strategies. Because opportunities for ecologic restoration cover an enormous variety of damaged ecosystems and severity of damage, selecting a specific technique requires planners and practitioners to consider a complex matrix of interrelated social, biophysical, and budgetary factors. It is at this point in the planning and design process that overarching guidelines become less useful and technique selection is performed by experienced restoration professionals. Allowing these specialists and other team members to contribute their knowledge, experience, and creativity will lead to project success.

Building a team of qualified professionals is essential to the success of the project. Often project managers will need to enlist engineers, stream geomorphologists, hydrologists, GIS specialists, contracting specialists and other professionals to assist in technique selection and design.

Because of the complexity associated with specific technique selection and design, these topics will not be covered in these guidelines. That said, there are many sources of in-depth information for this portion of project planning. The Society for Ecological Restoration (SER) is a good place to begin to research on specific restoration and revegetation techniques. SER offers a wide range of services and publications. Restoration professionals in Lebanon are currently active participants within this organization. In addition, there are hundreds of region-specific restoration and revegetation guidelines available.

## **G. Restoration & Rehabilitation Plan**

The culmination of the planning phase is the creation of a restoration and rehabilitation plan to guide project implementation, monitoring, and adaptive management. A well-developed plan will contain all the elements necessary to document, justify, implement, and manage a rehabilitation project. Box 2 provides an outline of a typical restoration and rehabilitation plan.

Box 2. A generalized template for typical riparian restoration and rehabilitation plans

### Restoration & Rehabilitation Plan Outline Template

- 1) Introduction
  - a. Acknowledgements
  - b. Purpose & scope of plan
  - c. Project history & collaborators

- 2) Background Information
  - a. Site location
  - b. Climate & precipitation
  - c. Geology & soils
  - d. Water & wetland resources
  - e. Vegetation
  - f. Fish & wildlife
  - g. Socioeconomic factors
  - h. Maps if available
  
- 3) Restoration Goals & Objectives
  - a. Goals
  - b. Objectives
  
- 4) Proposed Restoration & Rehabilitation Alternative
  - a. Justification for selected alternative from A-A
  - b. Narrative of proposed restoration and rehabilitation actions
  
- 5) Proposed Alternative Suitability
  - a. Justification for selected alternative as suitable to meet goals and objectives
  
- 6) Restoration Designs
  - a. Conceptual restoration designs
  - b. Final design plans & specifications
  - c. Anticipated costs
  
- 7) Monitoring & Adaptive Management Plan
  - a. Site management agreements
  - b. Monitoring program
    - i. Monitoring parameters & methodologies
    - ii. Performance standards to determine success or failure
  - c. Reporting Requirements
    - i. Agency or funding body reporting requirements
  - d. Adaptive Management Plan
    - i. Short term management
    - ii. Long term management
    - iii. Management decision-making process & partners
    - iv. Anticipated costs & funding sources
  
- 8) References/Literature Cited
  
- 9) Appendices
  - a. Field data collection forms
  - b. Analytical results
  - c. Technical reports and memos
  - d. Supporting research and documentation
  - e. Photos

## CHAPTER 6

# PROJECT IMPLEMENTATION

### A. Overview

Project implementation typically begins as soon as a rehabilitation plan has been approved by the planners. However, implementation can often begin earlier as a result of phased-execution projects, preliminary construction efforts, or emergency stabilization work. Implementation involves logistical management, stakeholder coordination, materials sourcing and procurement, contract bidding and awarding, and project execution and close-out.

Because each project can differ, implementation requirements will vary substantially depending on the scope of work and project constraints. Logistical hurdles range from permit limitations and site access requirements to contracting issues and seasonal work constraints. Stakeholder coordination can include maintaining respectful and reciprocal landowner relations, collaborating with agencies for permit modifications, fundraising for implementation efforts, or maintaining public presence and involvement. Sourcing adequate native plant materials is often a challenge for regions where restoration industries have not fully developed. Implementation projects that go to public bid also exhibit myriad challenges associated with contractor interest, capabilities, expertise, and cost. To handle these challenges, project managers should have a strong background in the region and consider implementation requirements throughout the planning phase to reduce the likelihood of unforeseen circumstances.

Physical implementation efforts include organizing and overseeing personnel for material procurement and delivery, site preparation, installation, and project close-out. How these elements come together is determined by the scope of work and the level of planning involved throughout the process.

### B. Factors to Consider

Factors to consider prior to and during implementation include:

1. Timing and sequencing
  - a. Climate, weather, and flooding
  - b. Plant phenology and dormancy
  - c. Native plant nursery operations
  - d. Contractor availability
  - e. Hydrographs and seasonal water tables
  - f. Work constraints related to threatened or endangered species

2. Personnel
  - a. Staff training
  - b. Contractor expertise and relevant work experience
  - c. Communication pathways
  - d. Implementation observation and inspection
  
3. Unforeseen circumstances
  - a. Change orders
  - b. Delays in material delivery
  - c. Equipment down-time
  
4. Equipment & Materials
  - a. Proper equipment availability and functionality
  - b. Specifications and standards

## CHAPTER 7

# MAINTENANCE, MONITORING, & ADAPTIVE MANAGEMENT

This section is provided to outline management agreements, strategies for monitoring project success, and implementing an adaptive management plan for riparian rehabilitation projects.

### A. Site Management Agreements

Prior to implementation, an agreement should be made between the project stakeholders, local authorities and greater community as to the responsibility of long-term site management. This agreement should specify 1) which parties will assume the long-term management role, 2) how management decisions will be made, and 3) how management costs and operations will be executed. Many rehabilitation projects occur on publicly owned land and management may be assumed by municipalities. In contrast, projects that occur on agricultural lands are typically privately owned, and some form of cost sharing or external management actions may be required to prevent the landowner from assuming all responsibility.

### B. Monitoring Program

A monitoring program should be implemented to fulfill all performance monitoring and reporting requirements that were outlined in a project's Restoration and Rehabilitation Plan. This section describes suggested monitoring parameters and assessment methods, performance standards and success criteria, and documentation and reporting requirements for riparian rehabilitation projects. Habitat restoration and rehabilitation will be considered achieved if all success criteria are met or exceeded by the end of the stated monitoring period for respective projects.

#### 1. Monitoring Parameters & Methods

##### *Containerized Plant Survival*

For riparian planting efforts, a representative number of containerized tree and shrub plantings shall be monitored for five years following project completion to assess plant survival across all species. For truly representative monitoring, at least 10% of all containerized plants installed as part of restoration and rehabilitation efforts shall be monitored for survival (including replacement plantings). Monitoring shall address at least 10% of the plantings for each species and annual monitoring efforts shall revisit the same individual plants throughout the entire monitoring period. This repeat monitoring is best achieved using GPS locations or tagging plant stems with durable labels. Those individual plants chosen for monitoring (10% subpopulation) shall be randomly selected and distributed across the rehabilitation area.

The lack of aboveground viable growth, based on both leaf and branch/stem tissues, will result in a plant being recorded as dead. Natural recruitments (i.e. volunteer plants) or existing trees and shrubs shall not be included in - this monitoring procedure, it is covered in a separate survey (see below 'Native and Invasive Vegetative Cover').

By monitoring the survival rates of individual plants and species, planners can identify the most dominant and tolerant species for specific site conditions. Survival rates for each species will be based on the proportion of living plants to the number of individuals selected for monitoring (based on the

10% minimum requirement). The total survival rate for each species will be estimated by multiplying the original number of plants (of that species) installed during restoration and rehabilitation efforts by the 10% subpopulation survival rate. For those species that do not meet the performance standards, the project stakeholders shall coordinate to determine whether that species requires expanded monitoring - replacement plantings, or substitution with another species.

#### *Containerized Plant Vigor*

The vigor of planted trees and shrubs shall be monitored for five years. Those same plants selected for survival monitoring (10% subpopulation) will be used to monitor plant vigor. Plant vigor shall be determined through visual inspection for the following indicators: herbivorous browse, fungal disease, leaf discoloration, low-density or diseased foliage, desiccation, insect infestations, and vandalism. Plant vigor shall be assessed using a rating scale (good = 3; fair = 2; poor = 1; dead = 0), with scores assigned to each plant based on visual inspection. Vigor ratings are described below:

- Good (3): less than 25% of aboveground growth exhibits one or more of the factors listed above
- Fair (2): 25%-75% of aboveground growth exhibits one or more of the factors listed above
- Poor (1): more than 75% of aboveground growth exhibits one or more of the factors listed above
- Dead (0): a plant that does not appear capable of growth

Total vigor ratings for each species shall be calculated as the average of all vigor scores from the monitored subpopulations. For those species that do not meet the performance standards, the project stakeholders shall coordinate to determine whether that species requires expanded monitoring efforts or replacement plantings. Plant community vigor ratings shall be reported by combining the average ratings for all species to represent the plant community vigor rating overall. These standards will help inform management to address issues related to hydrology, browse, trampling, pests, and disease.

#### *Native and Invasive Vegetative Cover*

Percent cover of both native and invasive plant species shall be monitored to track plant colonization and recruitment of both the native community and non-native infestations. Percent vegetative cover shall be visually estimated in no fewer than 20 representative plots distributed throughout the project area. The cumulative area of the 20 (or more) representative plots shall be greater than or equal to 25% of the total project area. Completely randomized sampling procedures can miss certain areas or habitat types of a project by chance alone. Stratified sampling places sample plots within each of several established reaches, zones, or habitats and thus ensures the entire range of habitats is included within the sampling protocol.

This method is referred to as randomized block design. In each plot, percent cover by species and status (native vs. invasive) is estimated across both canopy and understory communities. The 20 or more plots will be used to calculate average percent vegetative cover for native species as well as invasive species within the respective habitat types. These performance standards will provide information that will inform management concerns related to noxious and invasive weed control, plant community trajectories, and habitat quality and complexity.

*Habitat Area and Extent*

The areal extent (i.e. m<sup>2</sup>) of each riparian restoration and rehabilitation project shall be measured to document the expected and realized benefits over time. Areal extent may be measured using up-to-date aerial imagery (within 12 months) or ground surveys employing GPS equipment. Monitoring shall record

the changes in riparian areas over time and note the convergence of discrete habitat units through vegetative infill.

**2. Performance Standards**

Performance standards for riparian restoration and rehabilitation will invariably span many diverse ecological communities. Riparian restoration and rehabilitation success will be considered independently for each habitat type. Depending on the reporting requirements outlined in a project’s Restoration and Rehabilitation Plan, performance standards may need written notification of completion to meet grant, permit, or jurisdictional requirements.

Riparian restoration and rehabilitation projects often include the preservation of existing vegetation alongside the establishment of containerized native plantings or seed. The monitoring results of containerized plantings shall be compared annually to the performance standards to assess success relative to survival, vigor, cover by native species, cover by invasive species, and areal extent of riparian habitat. Table 7 provides example performance standards and success criteria for riparian rehabilitation projects.

Table 7 – 5-year performance standards for riparian rehabilitation monitoring efforts.

MONITORING PARAMETER	MONITORING YEAR	PERFORMANCE STANDARD	SUCCESS CRITERIA
Plant Survival, by species	1	90%	≥70%
	2	85%	
	3	80%	
	4	75%	
	5		
Plant Vigor, by species	1	>1.0	≥2.0
	2	>1.0	
	3	>1.0	
	4	>1.5	
	5		

Vegetative Cover; natives	1	Demonstrate increasing native coverage >25% >33% >50%	≥50% or equivalent to reference conditions
	2		
	3		
	4		
	5		
Vegetative Cover; invasives	1	Demonstrate decreasing invasive coverage <75% <50% <33%	≥20% or equivalent to reference conditions
	2		
	3		
	4		
	5		
Riparian Habitat Extent	1	Demonstrate increase in habitat area >25% >33% >50%	>60% or equivalent to reference conditions
	2		
	3		
	4		
	5		

### C. Reporting Requirements

Depending on the terms and conditions of a rehabilitation project, annual monitoring reports may be required to document the results of implementation, management, and monitoring activities. Reports shall directly address monitoring results as they pertain to the performance standards and success criteria outlined in a project's Restoration & Rehabilitation Plan. Monitoring reports shall include the following information as a minimum:

- Permit numbers on the cover/title page
- Names, titles, and affiliations of report authors and monitoring staff
- Project location
- Monitoring methods & any modifications made to methodology
- Site conditions during monitoring efforts; observations and findings relevant to habitat rehabilitation
- Summary, analysis, and discussion of monitoring results
- Discussion of adaptive management efforts and ongoing issues
- Future management recommendations to meet performance criteria
- Appendix containing photographic documentation and supporting documents

Photographic documentation of rehabilitation progress shall be a substantial component of monitoring efforts and reporting. It is highly recommended that permanent photo-point stations be established throughout the project area during implementation and be used repeatedly to provide long-term visual comparisons that supplement monitoring efforts. Photo-point locations and orientation shall be recorded in the field and mapped for reference in annual monitoring reports.

## D. Adaptive Management

Riparian rehabilitation projects do not tend to be a one-and-done task. As dynamic systems subject to numerous environmental and anthropogenic stresses, riparian corridors require keen management efforts that constantly evolve over time. To this end, adaptive management shall be employed to ensure project goals and objectives – particularly performance criteria – are met. Adaptive management should be established in perpetuity within the constraints of normal environmental conditions and natural processes, and thus should be discussed during the site management agreement phase. The overarching goal of this approach is to establish and maintain quality functional habitat by responding to unforeseen changes in site conditions, natural recruitment, succession, anthropogenic stresses, and climate variation. The adaptive management plan provides for site managers to monitor, manage, maintain, and report on the trajectory of rehabilitation efforts and ecological progress. Adaptive management is designed to allow for modifications and substitutions to management expectations as a result of annual monitoring reports. Annual monitoring reports will inform each successive year's management and maintenance priorities to provide for a dynamic, self-sustaining approach. It is imperative that site management agreements establish clear roles, responsibilities, expectations, and decision-making frameworks to ensure the success of adaptive management practices.

### 1. Adaptive Habitat Management

Site managers shall perform regular visits to the site during the first year following implementation. In subsequent years, monitoring reports can be used to inform adaptive management strategies that work toward meeting performance standards and success criteria. A substantial portion of these metrics relate to vegetative community composition and cover. To that end, adaptive management efforts shall aim to optimize browse-protection and soil-moisture conditions to meet performance standards and project goals and objectives. Because conditions vary significantly across sites, adaptive management for habitat quality includes a broad range of strategies. The following is a list of common maintenance and management efforts for riparian rehabilitation projects:

- Irrigation
- Individual plant browse protectors
- Wildlife & livestock exclosure fencing
- Fertilization
- Seeding
- Scarification
- Soil aeration & decompaction
- Litter removal
- Fence repair
- Pruning & limbing
- Noxious and invasive weed control

### 2. Adaptive Management Process

The adaptive management process provides site managers with the flexibility and executive power to respond to problems that arise during short-term maintenance efforts or from long-term monitoring reports. Typically, site managers shall respond and perform actions to ensure performance standards and success criteria are met without consultation from the greater community of stakeholders. However, there may arise situations in which the site managers may opt to seek outside consultation, and situations in which outside consultation is mandatory.

The steps below provide an example process by which site managers may implement adaptive management to address issues that are both foreseen and unforeseen at various scales. The four steps are as follows:

- 1. Adaptive management trigger:** An incident which alerts the site manager to a problem that requires investigation.
- 2. Investigative actions:** Mandatory actions the site manager must take following a trigger. Mandatory actions include identifying the issue; mapping the problem area; investigating potential contributing factors.
- 3. Management response plan:** The site manager develops a plan to respond to the findings from the investigation. This plan may manifest as a simple memo to stakeholders or as a multipage document that requires review and expert consultation.
- 4. Reporting:** The management response plan must be documented in that year's monitoring report to be disseminated to the stakeholders

This protocol is designed to provide site managers with the flexibility and decision-making power to execute routine management activities. For management issues that arise over long-term monitoring efforts or manifest as complex issues with the potential to thwart achievement of restoration goals and objectives, site managers shall request consultation from stakeholders or experts for guidance on the following activities:

- Proposed changes to performance standards
- Proposed changes to success criteria
- Additional earthwork, regrading, or sediment removal
- Additional plantings, seeding, or public access work
- Any action that requires permit approvals

Adaptive management may also be required in the event of foreseen or unforeseen factors that limit the ability to meet performance standards. While the adaptive management process is the same, below is a list of conditions that may initiate the adaptive management process:

- Failure to meet performance standards
- Invasive species
- Hydrologic changes
- Wildfire
- Wildlife herbivory
- Site degradation

Regardless of the conditions that result in adaptive management actions, site managers shall initiate contact with stakeholders to re-evaluate project goals and objectives and restructure monitoring and management plans to reflect new information and conditions.

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