CHAPTER 6

Incorporating Practices into Existing Development - Retrofits / Hydromodification Avoidance

6.1 RETROFIT PLANNING

While new development may be required to manage stormwater on-site, older developments may have been constructed before stormwater management was required or modern criteria were established. Retrofits include new installations or upgrades to existing BMPs in developed areas where there is a lack of adequate stormwater treatment. Stormwater retrofit goals may include, among other things, correcting prior design or performance deficiencies, mitigating flood impacts, disconnecting impervious areas, improving recharge and infiltration performance, addressing pollutants of concern, demonstrating new technologies, and supporting stream restoration activities. Retrofits can be designed to target trash, sediment, nutrients, or other concerns. Common retrofit locations include public open spaces and large parking lots. Often, retrofits can be completed in tandem with other capital projects including roads and parks to achieve multiple benefits and manage cost.

Many grant opportunities for funding retrofit projects exist. Please see Appendix F in this guidance manual for a list of potential grant partners.

While all retrofit sites are unique and no single solution fits all, preferred practices generally provide for increased infiltration, evapotranspiration and rainwater harvesting. Practices such as these reduce stormwater runoff volume while also providing water quality and supply benefits. Retrofits that provide for infiltration (e.g., infiltration basins and trenches, bioretention systems, rain gardens, and swales) where little or no infiltration currently exists are likely to improve site hydrology. Infiltration practices also help to recharge groundwater aquifers, although practices located near public drinking water sources should carefully consider the impact of infiltrating stormwater discharges on drinking water sources. In many cases, retrofits provide an opportunity to remedy past design and/or performance deficiencies.

Depending on the water quality goals for the watershed, communities should also consider retrofitting existing BMPs to maximize pollutant removal. The retrofitting of dry detention ponds, for instance, may provide the most cost-effective approach to capture and treat large drainage areas.

Most of the content in this section is from the EPA Retrofit Guidance.

Table 6-1: Purpose of the Eight Steps in the Stormwater Retrofitting Process

Step and Purpose	Key Tasks
Step 1: Retrofit Scoping Refine the retrofit strategy to meet local restoration objectives.	• Screen for subwatershed retrofit potential • Review past, current and future stormwater • Define core retrofitting objectives • Translate into minimum performance criteria • Define preferred retrofit treatment options • Scope out retrofit effort needed
Step 2: Desktop Retrofit Analysis Search for potential retrofit sites across the subwatershed	• Secure GIS and other mapping • Conduct desktop search for retrofit sites • Prepare base maps for RRI
Step 3 : Retrofit Reconnaissance Investigate feasibility of retrofit sites in the field	• Advanced preparation • Evaluate individual sites during RRI • Finalize RRI sheets back in office
Step 4: Compile Retrofit Inventory Develop initial concepts for best retrofit sites	• Complete storage retrofit concept designs • Finalize on-site retrofit delivery methods • Assemble retrofit inventory
Step 5: Retrofit Evaluation and Ranking Choose the most feasible and cost-effective sites	• Neighborhood consultation • Develop retrofit screening criteria • Create retrofit project priority list
Step 6: Subwatershed Treatment Analysis Determine if retrofits can achieve subwatershed restoration objective	• Compute pollutant removal by storage retrofit • Compute pollutant removal by on-site retrofits • Compare against restoration objective
Step 7: Final Design and Construction Assemble design package to lead to successful retrofit construction	• Secure environmental permits • Obtain landowner approval and easements • Perform special engineering, studies • Put together final design package • Contract and project management
Step 8: Inspection, Maintenance & Evaluation Ensure retrofits are working property and achieving subwatershed objectives	• Construction inspection • Retrofit maintenance • Project tracking and monitoring

Figure 6-1: Adding a Bioretention basin (rain garden) in a municipal park

Figure 6-2: Adding a bioswale at edge of a parking lot

Figure 6-3: Adding a sand filter to treat parking lot runoff

THE STORMWATER RETROFIT PROCESS

1. Evaluate the need and capacity for retrofitting in your community. Determine if your jurisdiction falls within an ongoing or planned Watershed Protection Plan or other Total Maximum Daily Load (TMDL) watersheds and identify your pollutant reduction requirements. If there are redevelopment projects in the planning stage, identify any local requirements for improving on-site stormwater management and assess grant opportunities to support the inclusion of water quality treatment into the project. See Appendix E for a list of potential grant resources.

2. Using Geographic Information System (GIS) software, institutional knowledge, and construction plans as appropriate, identify potential retrofit locations at publicly-owned properties (e.g., parks, schools, and municipal maintenance yards), street rights-of-way, culverts/outfalls, and existing detention practices. Target large parking lots, rooftops, or other impervious areas (public or privately-owned) that lack stormwater management and are considered directly connected to creeks and tidal waters. Identify sites that are prone to flooding, chronic contamination, and/or have a high maintenance burden.

3. Conduct a retrofit investigation by visiting each location to verify current conditions and identify potential retrofit treatment options and constraints. Use this opportunity to verify if impervious cover on site is directly-connected to the streams or tidal waters. Eliminate sites where retrofitting is infeasible or impractical due to existing constraints (e.g., land use, environmental conditions, presence of utilities, or other limitations).

4. Develop an inventory of potential retrofit candidates, with illustrative concept sketches, site photos, and basic drainage calculations. Concept sketches can be done by hand. Once priorities have been identified, concepts can be further advanced to engineering design and construction plans.

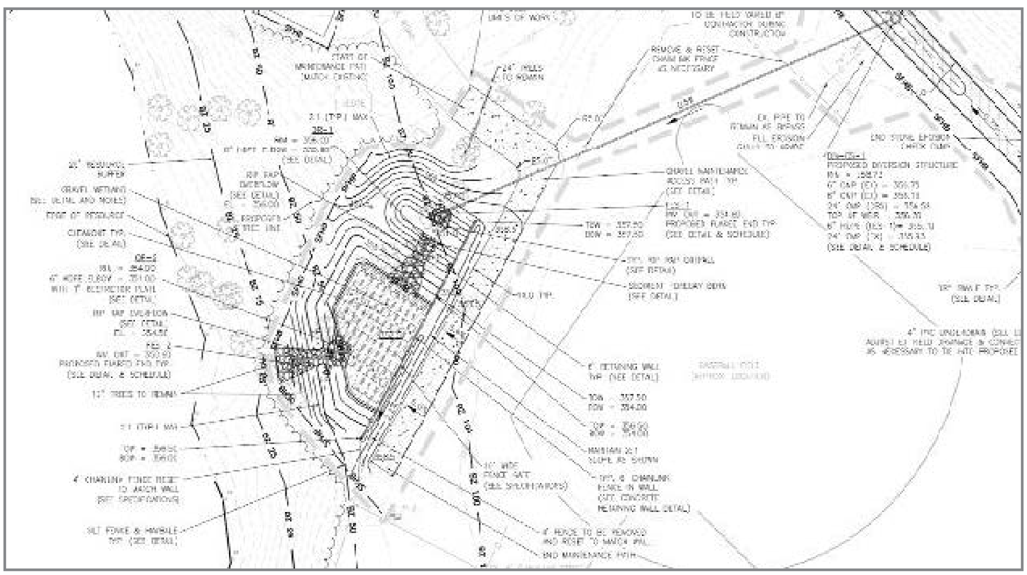

Figure 6-4: Retrofit Concept Sketch

5. Evaluate and rank retrofit concepts based on predetermined factors such as pollutant reduction requirements, BMP feasibility and performance, impervious cover disconnection, cost, visibility, property ownership, and community support. Structural control measures include practices that reduce or disconnect impervious cover, enhance infiltration, or otherwise treat stormwater. Non-structural measures include pollution prevention and source control activities (e.g., street sweeping). Retrofits should also be viewed as demonstration projects to highlight water quality management in your community.

6. Model watershed treatment benefits for various implementation scenarios to help determine the most cost-effective approaches to implementation to maximize pollution management per dollar spent. There are a number of existing public models that could be used to assist in the evaluation of implementation

scenarios including the design guidance found in Chapter 4 in this guidance manual. Other resources include the Harris County LID Manual, the San Antonio River Authority LID Manual, and the Aransas County Storm water Management Design Criteria. **At this point in time, it is appropriate to seek grant funding and/or public private partnerships to help fund the project.**

7. Take the top projects to final design and construction stages. Allow additional time to complete site surveys, necessary State and local permitting, contractor bidding and specifications, and, in some cases, generate public support. The time required to secure implementation funding will likely vary depending on the primary source of funds (i.e., stormwater utility, general or capital budgets, or grants).

8. Provide frequent and detailed construction inspection to ensure that the project is built per the design plans. Also, maintenance inspection services are necessary for the life of the retrofit to verify performance and identify maintenance issues as needed so that maintenance (mowing, sediment removal, trash collection, etc.) takes place to maximize function and appearance. The community should establish a BMP tracking system to ensure long-term maintenance of existing and retrofitted facilities.

CASE STUDY

TULE CREEK WEST: SEDIMENT TRAP POND, BANK STABILIZATION, AND HABITAT ENHANCEMENT

- Aransas County, 2015.
- Grant funded: 60% federal funds and 40% local match.
- Total Project Cost = $740,000

The Tule Creek watershed drains areas of the City of Rockport and the Town of Fulton. The area population and impervious cover are expected to increase in the next two decades, causing an associated increase in stormwater runoff. Scientists have identified polluted stormwater runoff as a principal cause of declining water quality and loss of wildlife habitat within Little Bay, which Tule Creek joins. Little Bay provides water-based recreational activities for local residents along with important habitat for local wildlife.

Aransas County, working with local communities, developed a stormwater management plan. A range of stormwater BMPs were identified for use in the area.

This project implemented several stormwater BMPs along West Tule Creek. The first project built a sediment trap pond below the confluence of the Upper Tule Creek West with North Tule Creek. Invasive vegetation was selectively removed from riparian areas to allow natural colonization of deep-rooted species for shoreline stabilization, improved wetland functions, reduced erosion, and improved water quality. Two additional projects widened a section of creek bank, stabilized it with riparian vegetation, and monitored water quality after the sediment trap was installed, as well as before and after the bank stabilization. Using this monitoring data to conduct continuous simulation modeling, they documented the effectiveness of the sediment trap and bank stabilization in reducing sediment loading to Little Bay.

6.2 RETROFITTING EXISTING DETENTION BASINS

Modifying existing detention basins may be one of the most cost-effective approaches to enhance water quality treatment. Detention is a common flood prevention requirement for new developments in many areas of the Texas coastal zone. One example is the subdivision in Chambers County, shown in Figure 6-5, which has three detention areas. By modifying the design of these detention basins to include wet pond or wetland characteristics, significant aesthetic and water quality improvements may be achieved.

Figure 6-5: Layout of a high-density single-family residential development. Includes three detention ponds.

Wet ponds can be designed as neighborhood amenities, attracting birds, and allowing opportunities for fishing and canoeing. These visual elements and recreational opportunities, as shown in Figure 6-6 through Figure 6-8 enhance the value of the development. The first two figures illustrate detention incorporated in single family residential developments. In areas with dry detention basins, residents typically install privacy fences because stormwater basins are viewed as unsightly liabilities. On the other hand, residents that back up to a wet pond frequently chose fencing materials that provide a view of the facility, indicating that it is viewed positively, and increases the value of those lots. Figure 6-8 shows a wet pond located at an apartment complex. It is evident that having an open water component makes the detention basin an asset to the development, allowing for higher rents to be charged to apartments that have a view of the pond.

If the use of a wet pond for recreational activities is not desired, the developer may choose to install a wetland detention area instead. Wet ponds include open water in the middle and vegetation around the edges while wetlands detention areas are generally shallow enough to have vegetation throughout. Both of these enhanced detention options are well suited to locations with a high-water table and high average annual rainfall.

Figure 6-6: Enhanced detention wet pond is an amenity (in a subdivision in Chambers County, Texas).

Figure 6-7: Chambers County neighborhood uses wet pond with a fountain for water circulation as a prominent feature in the subdivision.

Figure 6-8: Constructed wet pond provides water quality benefits and an attractive place to recreate for nearby multi-family housing.

6.3 DOWNTOWN REDEVELOPMENT - RETROFITS

Grant funding is often available for projects that incorporate sustainable stormwater components as part of downtown renovation. High density and downtown areas frequently have space constraints that preclude the use of swales and filter strips. However, options such as bioretention and porous pavement are available, used either together or individually, to reduce the impacts of stormwater and improve the performance of the streetscape.

When designing a pedestrian walkway near a busy road, the use of swales or bioretention strips between the sidewalk and road can help the pedestrian feel insulated from nearby traffic and therefore more comfortable walking in groups or with children and pets. As shown in Figure 6-9 and Figure 6-10, the stormwater benefits of these structures are complimented by the use of porous pavement and can be, integrated with the social and aesthetic benefits afforded by the landscaping.

Figure 6-9: Bioretention serves as a buffer between the sidewalk and street. (Photo courtesy of State of Washington Transportation Improvement Board)

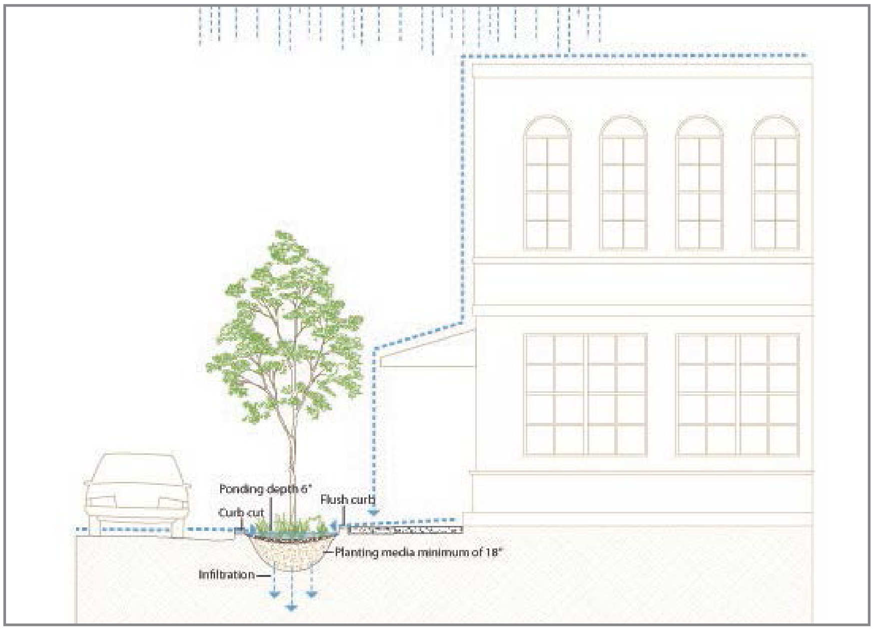

Figure 6-10: Schematic of a bioretention area with no underdrain creating a buffer between the pedestrian zone and the street; stormwater infiltrates into surrounding soils.

Medians and bike lanes afford additional opportunities for stormwater capture and filtration, as in Figure 6-11.

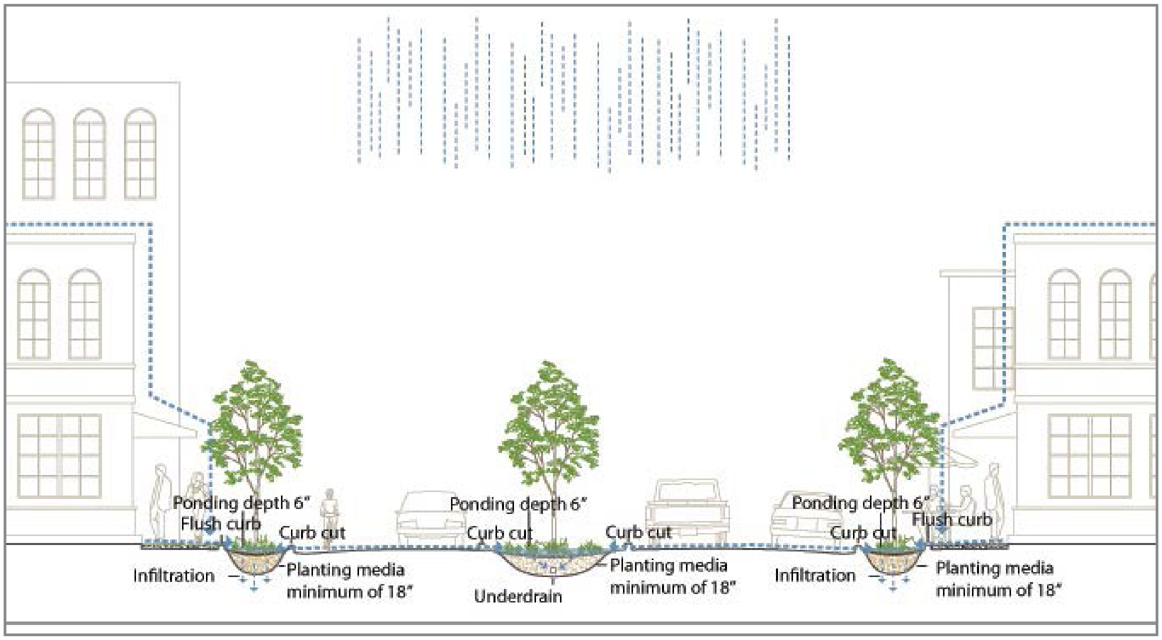

Figure 6-11: Bioretention along streets with a combination of infiltration and underdrain.

The use of alternate material for bike lanes and pedestrian crossings, such as that in Figure 6-12, can increase the safety of those biking or walking. Porous pavement can eliminate standing water on the surface of the area and reduce opportunities for slipping or skidding. Alternate materials also serve to delineate the space, reducing the possibility of a vehicle crossing into the bike lane or failing to stop for a pedestrian.

Figure 6-12: Pedestrian crossing constructed with pervious pavers.

The following renderings (Figure 6-13 through Figure 6-15) illustrate possibilities for downtown redevelopment that incorporates stormwater controls while maintaining the local character of the place and improving the user experience. The renderings are set in Port Isabel, Texas. Given that tourism in Port Isabel is the primary economic driver, the visitor experience can have an appreciable impact on economic growth in the area. The "before" photograph is shown in Figure 6-13.

Figure 6-14 shows pervious pavers on the sidewalks and bioretention areas between the sidewalk and the street that can easily be incorporated into a redevelopment project. These features also provide more shade for pedestrians and parked cars and create a stronger buffer between people on the sidewalk and traffic on the street. Figure 6-15 demonstrates how these stormwater controls can be integrated seamlessly into the fabric of downtown life.

This type of redevelopment can be achieved with very little expense to the city. As redevelopment of private property occurs, stormwater controls can be incorporated into the new design with no cost to the city.

Figure 6-13: Downtown redevelopment BEFORE stormwater controls.

Figure 6-14: Downtown redevelopment. Existing site WITH potential stormwater changes.

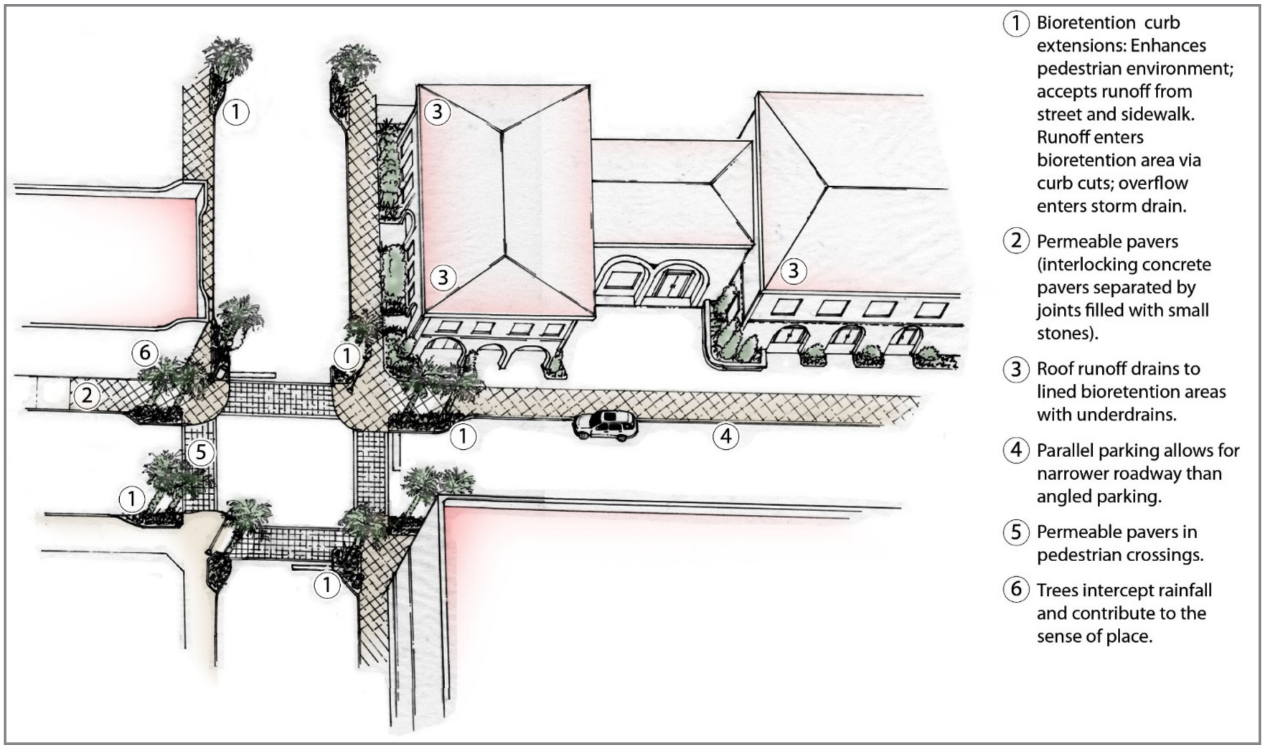

Figure 6-15: Downtown redevelopment. Birds-eye view of stormwater controls.

6.4 HYDROMODIFICATION MANAGEMENT

In some conditions, streams, rivers, and shorelines have been impacted by severe erosion, constructed channels, floodplain encroachment, fill, excavation and removal of native vegetation. In addition, dams have affected the natural flow, habitat, and fluvial processes, thus impacting aquatic habitat, sediment movement, and the natural hydrology, adversely affecting water quality. In the following sections, guidance and references are provided to assist local, state, federal, as well as developers/engineers to restore water resources that have been affected by hydromodification. Please refer to the links in this section, references, and the Texas Hydromodification Best Management Practices Manual, 2008, for additional guidance.

6.4.1 CHANNEL RESTORATION AND NATURAL CHANNEL DESIGN

Streams impacted by natural and un-natural causes can in some cases be restored. Healthy streams enhance habitat, water quality, and provide essential flood mitigation benefits. This section provides excerpts from the San Antonio River Authority, *Natural Channel Design Protocol*, that outlines design considerations, processes, methods, and construction techniques.

While natural channel design is often used in stream restoration projects, it can also be implemented in projects where restoration of ecosystem habitat is not the primary goal, such as flood control projects. Projects that implement restoration and natural channel design techniques are typically part of a holistic, multi-objective plan to improve water quality, restore riparian communities, provide recreation opportunities, and address flooding concerns. Stormwater best management practices (BMPs), Low Impact Development (LID) measures, habitat creation, re-vegetation of stream banks, preservation of natural communities, and trail systems are often incorporated into the project design to meet these multiple objectives. Often, projects implementing natural channel design techniques will do so to address USACE permitting requirements and minimize impacts. Additionally, not all projects may be suitable for a natural channel design approach. Project constraints may preclude a pure natural channel design approach, particularly in urban settings. However, natural channel design elements may still potentially be incorporated into designs. Project goals and constraints must be carefully considered when using the approaches presented in this document.

Goals presented in this manual for incorporating natural channel design into projects include:

- Creating geomorphically stable conditions for appropriate stream reaches;
- Improving and restoring hydrologic connections between the streams and their floodplains;
- Improving aquatic and terrestrial habitat;
- Improving water quality by establishing buffers for nutrient removal from runoff, and by stabilizing stream banks to reduce bank erosion and sediment contribution to stream flows;
- Improving in-stream habitat by providing a more diverse bedform with riffles and pools, creating deeper pools and areas of water re-aeration, providing woody debris for habitat and, reducing bank erosion; and
- Providing storage within a floodplain to retain and attenuate flood flows.

The San Antonio River Authority, Natural Channel Design Protocol, provides detailed guidance to planners, engineers, public works, and maintenance operations staff in the planning, design, permitting, construction, and operations of restored streams. This manual should be used to guide stream restoration and natural channel design in the coastal region and includes the information on the following:

- Watershed assessments;
- Regional flow curves to define hydrologic conditions and design flows;
- Field investigation and base map surveys;
- Geomorphic assessments including bankfull discharge determination, stability, and bedform diversity,

channel evolution, and restoration potential;

- Natural channel design methods including sediment transport analysis;
- Natural channel design within flood control channels;
- In-stream structures and bioengineering;
- Construction plan preparation;
- Technical specifications;
- Permits;
- Construction observation;
- Maintenance; and
- Monitoring and evaluation.

6.4.1.1 CHANNEL OPERATIONS AND MAINTENANCE GUIDANCE

Each project will have site specific maintenance considerations. A maintenance plan will be prepared as part of the natural channel design report for each project site, and will address both short-term and long-term maintenance items. Maintenance plans should include such aspects as inspections, repairs, replacement, mowing, and vegetation management. In constructed projects, the contractor is typically responsible for coordinating maintenance activities for a specific project area for one year following installation of the project (the warranty period). Example tasks to be considered in the first year following installation for the successful establishment of a project site include:

- Initial inspections including photographs for the first 6-months following construction. The site should be inspected at least twice after storm events that exceed 0.5 inch of rainfall.
- Bare or eroding areas in the project area should be re-seeded to ensure they are immediately stabilized with grass cover.
- Proper fertilization based on soil and vegetation nutrient demands.
- Watering may be needed once per week during the first 2 months and then as needed during the first growing season, depending on rainfall. Under drought or unusual site conditions, watering may be needed for longer periods of time to ensure proper vegetation establishment. Minimum quantities of water should coincide with plant specific needs.
- Since plant stock may die off in the first year, construction contracts should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction. The typical thresholds below which replacement is required are 75% survival of plant material and 90% of planted trees during the first growing season. In later years, the project's defined success criteria for vegetation will dictate whether replanting is necessary.
- Control of invasive and/or exotic vegetation.

Long-term maintenance considerations may include items such as those listed below:

- Allowing for site access in the future to address maintenance needs
- Inspection schedules
- Addressing severe storm damage
- Control of invasive and/or exotic vegetation

- Control of animal activity that may damage planted vegetation or site stability (i.e. beavers, hogs, etc.)
- Vandalism and/or unauthorized site access

Monitoring and evaluation of restoration and natural channel design projects is a useful method to evaluate project performance. A monitoring plan should be developed to determine whether these goals and objectives have been achieved, in order to validate the effectiveness of the project and identify trends, or necessary corrective actions, through the adaptive management process. A common goal when monitoring a natural channel design project is to demonstrate that the restoration activities create a stable functioning stream channel. To ensure that channel stability has been achieved, physical inspections are conducted using a variety of qualitative and quantitative measures. Inspections data are then compared to data and photographs collected prior to restoration and/or during the monitoring previous years.

A qualified or knowledgeable field inspector should walk the entire length of the project with the as-built plans noting any areas of concern. Using a monitoring data sheet, the inspector should describe, in detail, the problem area(s) and take adequate photographs to document the concern and if necessary, provide a recommendation for corrective action. Specific metrics and resolution alternatives should be tabulated in the Monitoring Report. Inspections should be conducted at least once per year. More frequent inspections may be necessary if stability concerns have previously been noted, or there have been frequent/intense storm events. An inspection may be necessary immediately following a significant storm event (bankfull or higher) if it occurs soon after completion of the project and, before bank vegetation has been established in accordance with the plans and specifications. The inspection should evaluate the following:

- Vertical instability
- Lateral instability
- Structural integrity
- Vegetation viability

In the event that the site or a specific component of the site fails to achieve the defined success criteria or project goals, the designer or mitigation provider should work with the owner to develop necessary adaptive management plans and/or implement appropriate corrective actions for the site in coordination with the appropriate agencies and other stakeholders. Corrective action required should be implemented to achieve the success criteria specified in the project design and monitoring plan. The plan should also include a work schedule and monitoring criteria that consider physical (exotic vegetation, beaver dams) and climatic conditions (droughts/floods, long-term hydrology), as well as documenting any significant changes within the watershed.

6.4.2 DAM REMOVAL GUIDELINES AND HABITAT PROTECTION

As an owner of a dam, you may want to remove the dam due to factors such as deterioration and risk of failure, or to return a waterway to its original condition. By performing a dam removal operation, habitat can be restored and natural aquatic functions can return to enhance biological activity. Based on the State of Texas Dam Removal Guidelines, TCEQ, the question of whether to remove a dam is primarily up to the owners and stakeholders of the structure. The Dam Safety Program of TCEQ is not opposed to the removal of dams; however, the Dam Safety Program does want to ensure that the process is conducted safely and in accordance with all the applicable state and federal rules. The guidelines presented here cover the major items that you should consider before beginning the removal process. For the purposes of this document, these items are organized into six general categories:

- Safety Issues
- Erosion Prevention and Sediment Control
- Ecological Issues

- Floodplain Management
- Stakeholder Issues
- Ownership Issues

The safety of downstream residents and the personnel working on the dam are of primary importance. Before engaging in a dam removal, the owner should acquire an approved dam removal plan from the TCEQ Dam Safety Program. This plan should contain the following items:

- Schedule and plan for conducting the phases of the work.
- Description of the method to be used to dewater the reservoir.
- Drawings that illustrate the location and size of the breach.
- Rationale for the sizing and placement of the breach.
- Plan for preventing erosion and sediment loss from the work site, lake bottom, and breach during and after removal.
- Emergency Action Plan that addresses the risks associated with the removal process.

Plans for addressing any relevant items that are noted in these guidelines. There are several important safety issues that must be considered in developing a dam removal plan.

- Construction activity will occur in the vicinity of water.
- Staging and operations will take place on steep inclined slopes.
- Water can flow uncontrollably through a breach, quickly eroding the side walls.
- Removal of material on the downstream slope can cause an increase in the hydraulic gradient within the embankment, which may lead to quickening of the soil.
- Rapid drawdown (lowering of the water level) of the reservoir can create slope instabilities upstream.
- Severe or extreme rainfall events can occur during the removal process.
- Outlet valves may be corroded or inoperable.
- Outlet conduits may be corroded, damaged, or incapable of containing hydraulic pressures or flows associated with drawdown operations.
- Inform the downstream county sheriff before draining, so that emergency management personnel know why a change in stream level is taking place.

By performing the above steps in compliance with the TCEQ Dam Removal Guidelines, minimal water quality impacts can occur and habitat can be protected.

Existing dams and their accompanying reservoirs/water bodies that will not be removed also have the need to practice riparian habitat restoration and maintenance in areas around the impounded water body and in the water body downstream from a dam. Reservoir shorelines are important riparian areas and they need to be managed or restored to realize their habitat and water quality benefits. This management plan must consider fluctuating water levels due to floods and droughts and implement resilient vegetation that can withstand the hot, dry summers but also survive long-periods of inundation. Examples of downstream aquatic habitat improvements include maintaining minimum instream flows, providing scouring flows when needed, providing alternative spawning areas if appropriate for the water body in consideration, protecting streambanks from erosion, and maintaining wetlands and riparian areas.

6.4.3 OPERATION AND MAINTENANCE OF DAMS

Dams are defined as constructed impoundments that are either (1) 25 feet or more in height and greater than 15 acre-feet in capacity, or (2) 6 feet or more in height and greater than 50 acre-feet in capacity. The siting and construction of a dam can be undertaken for many purposes, including flood control, power generation, irrigation, livestock watering, fish farming, navigation, and municipal water supply. Some reservoir impoundments are also used for recreation and water sports, for fish and wildlife propagation, and for augmentation of low flows. Dams can adversely impact the hydraulic regime, the quality of the surface waters, and habitat in the stream or river where they are located. A variety of impacts can result from the siting, construction, and operation of these facilities.

The siting of dams can result in the inundation of wetlands, riparian areas, and land in upstream areas of the waterway. Dams either reduce or eliminate the downstream flooding needed by some wetlands and riparian areas. Dams can also impede or block healthy spawning, migration routes of fish, and any threatened or endangered species. Construction activities from dams can cause increased turbidity and sedimentation in the waterway resulting from vegetation removal, soil disturbance, and soil rutting. Fuel and chemical spills and the cleaning of construction equipment (particularly concrete washout) have the potential for creating nonpoint source pollution. The proximity of dams to streambeds and floodplains increases the need for sensitivity to pollution prevention at the project site in planning and design, as well as during construction.

The operation of dams can also generate a variety of types of nonpoint source pollution in surface waters. Controlled releases from dams can change the timing and quantity of freshwater inputs into coastal waters. Dam operations may lead to reduced downstream flushing, which, in tum, may lead to increased loads of BOD, phosphorus, and nitrogen; changes in pH; and the potential for increased algal growth. Lower instream flows, and lower peak flows associated with controlled releases from dams, can result in sediment deposition in the channel several miles downstream of the dam. The tendency of dam releases to be clear water, or water without sediment, can result in erosion of the streambed and scouring of the channel below the dam, especially the smaller-sized sediments. One result is the siltation of gravel bars and riffle pool complexes, which are valuable spawning and nursery habitat for fish. Dams also limit downstream recruitment of suitably-sized substrate required for the anchoring and growth of aquatic plants. Finally, reservoir releases can alter the water temperature and lower the dissolved oxygen levels in downstream portions of the waterway.

To guide the safe and effective operation and maintenance of dams, this document references the TCEQ "Guidelines for Operations and Maintenance of Dams in Texas." All dam owners and operators should follow this guidance to ensure safe operations and high-water quality management in the daily operations and maintenance of their dams. Some key items noted in the document include:
Establish a schedule for both day-today tasks and tasks performed less frequently throughout the year. The schedule should formalize inspection and maintenance procedures so that even an inexperienced person can determine when a task is to be done.

- Operation Plan Guidelines
- Establishing an operation procedure or plan calls for detailed
- Data on the physical characteristics of dam and reservoir
- Descriptions of dam components
- Operating instructions for operable mechanisms
- Instructions for inspections
- Instrumentation and monitoring guidelines
- Guidelines for maintenance
- Guidelines for emergency operations

MAINTENANCE GUIDELINES

A sound maintenance program will protect a dam against deterioration and prolong its life. A poorly maintained dam will deteriorate and may fail. Nearly all the components of a dam and the materials used for its construction are susceptible to damaging deterioration if not properly maintained. A well-prepared maintenance program protects not only the dam owner, but the general public as well while considering and providing good habitat preservation and enhancement. The cost of a proper maintenance program is small compared to the cost of major repairs or the loss of life and property and resultant litigation. A basic maintenance program based primarily on systematic and frequent inspections is necessary. Inspections, as noted in Chapter 5 of the Guidance, should be carried out monthly and after major floods or earthquakes. During each inspection, fill out a checklist of items requiring maintenance and ensuring that the dam operators are aware of the latest reports and findings to enhance operations and water quality protection.

Preventing erosion and soil loss within the impoundment and dam failures protects water quality and lives. When dams fail, extensive amounts of soil and debris are released into the receiving stream. Further, the large volume of water and sediment washes away streamside trees and vegetation and generates additional erosion and scour, significantly altering habitat and the natural aquatic and nearby terrestrial areas. Additionally, streamside homes and businesses can be swept away. Thus, the proper operations and maintenance of dams is essential in protecting lives, property, habitat, and water quality.

6.4.4 STREAMBANK AND SHORELINE EROSION GUIDANCE

Streambank erosion is used in this guidance to refer to the loss of land along nontidal streams and rivers. Shoreline erosion is used in this guidance to refer to the loss of beach or land in tidal portions of coastal bays or estuaries. Erosion of ocean coastlines is not regarded as a substantial contributor of NPS pollution in coastal waterbodies and will not be considered in this guidance.

The force of water flowing in a river or stream can be regarded as the most important process causing erosion of a streambank. All of the eroded material is carried downstream and deposited in the channel bottom or in point bars located along bends in the waterway. The process is very different in coastal bays and estuaries, where waves and currents can sort the coarser-grained sands and gravels from eroded bank materials and move them in both directions along the shore, through a process called littoral drift, away from the area undergoing erosion. Thus, the materials in beaches of coastal bays and estuaries are derived from shore erosion somewhere else along the shore. Solving the erosion of the source area may merely create new problems with beach erosion over a much wider area of the shore.

The erosion of shorelines and streambanks is a natural process that can have either beneficial or adverse impacts on the creation and maintenance of riparian habitat. Sands and gravels eroded from streambanks are deposited in the channel and are used as instream habitat during the life stages of many benthic organisms and fish. The same materials eroded from the shores of coastal bays and estuaries maintain the beach as a natural barrier between the open water and coastal wetlands and forest buffers. Beaches are dynamic, ephemeral landforms that move back and forth onshore, offshore, and along shore with changing wave conditions. The finer-grained silts and clays derived from the erosion of shorelines and streambanks are sorted and carried as far as the quiet waters of wetlands or tidal flats, where benefits are derived from addition of the new material. There are also adverse impacts from shoreline and streambank erosion. Excessively high sediment loads can smother submerged aquatic vegetation (SAV) beds, cover shellfish beds and tidal flats, fill in riffle pools, and contribute to increased levels of turbidity and nutrients. .

Management measures for eroding streambanks and shorelines should include the following:

- Where stream bank or shoreline erosion is a nonpoint source pollution problem, streambanks and shorelines should be stabilized. Vegetative methods are strongly preferred unless structural methods are more cost-effective, considering the severity of wave and wind erosion, offshore bathymetry, and the potential adverse impact on other streambanks, shorelines, and offshore areas.
- Protect streambank and shoreline features with the potential to reduce NPS pollution.
- Protect streambanks and shorelines from erosion due to uses of either the shorelands or adjacent surface waters.

The following practices are described for illustrative purposes only. Local governments need not require the implementation of these practices. However, as a practical matter, the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above. Preservation and protection of shorelines and streambanks can be accomplished through many approaches, but preference in this guidance is for nonstructural practices, such as soil bioengineering and marsh creation, natural systems, that are resilient, sustainable, require minimal maintenance once established, avoid catastrophic failures such as concrete wall collapse, and can enhance water quality and habitat.

6.4.4.1 SOIL BIOENGINEERING AND VEGETATIVE PRACTICES

Soil bioengineering is the installation of living plant material as a main structural component in controlling problems of land instability where erosion and sedimentation are occurring (USDA-SCS, 1992). Soil bioengineering largely uses native plants collected in the immediate vicinity of a project site. This ensures that the plant material will be well adapted to site conditions. While a few selected species may be installed for immediate protection, the ultimate goal is for the natural invasion of a diverse plant community to stabilize the site through development of a vegetative cover and a reinforcing root matrix (USDA-SCS, 1992). Soil bioengineering provides an array of practices that are effective for both prevention and mitigation of NPS problems. This applied technology combines mechanical, biological, and ecological principles to construct protective systems that prevent slope failure and erosion. Adapted types of woody vegetation (shrubs and trees) are initially installed as key structural components, in specified configurations, to offer immediate soil protection and reinforcement. Soil bioengineering systems normally use cut, unrooted plant parts in the form of branches or rooted plants. As the systems establish themselves, resistance to sliding or shear displacement increases in streambanks and upland slopes. Specific soil bioengineering practices include:

Live Staking. Live staking involves the insertion and tamping of live, rootable vegetative cuttings into the ground as shown in Figure 6-16. If correctly prepared and placed, the live stake will root and grow. A system of stakes creates a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. Most willow species are ideal for live staking because they root. This is an appropriate technique for the repair of small earth slips and slumps that are frequently wet.

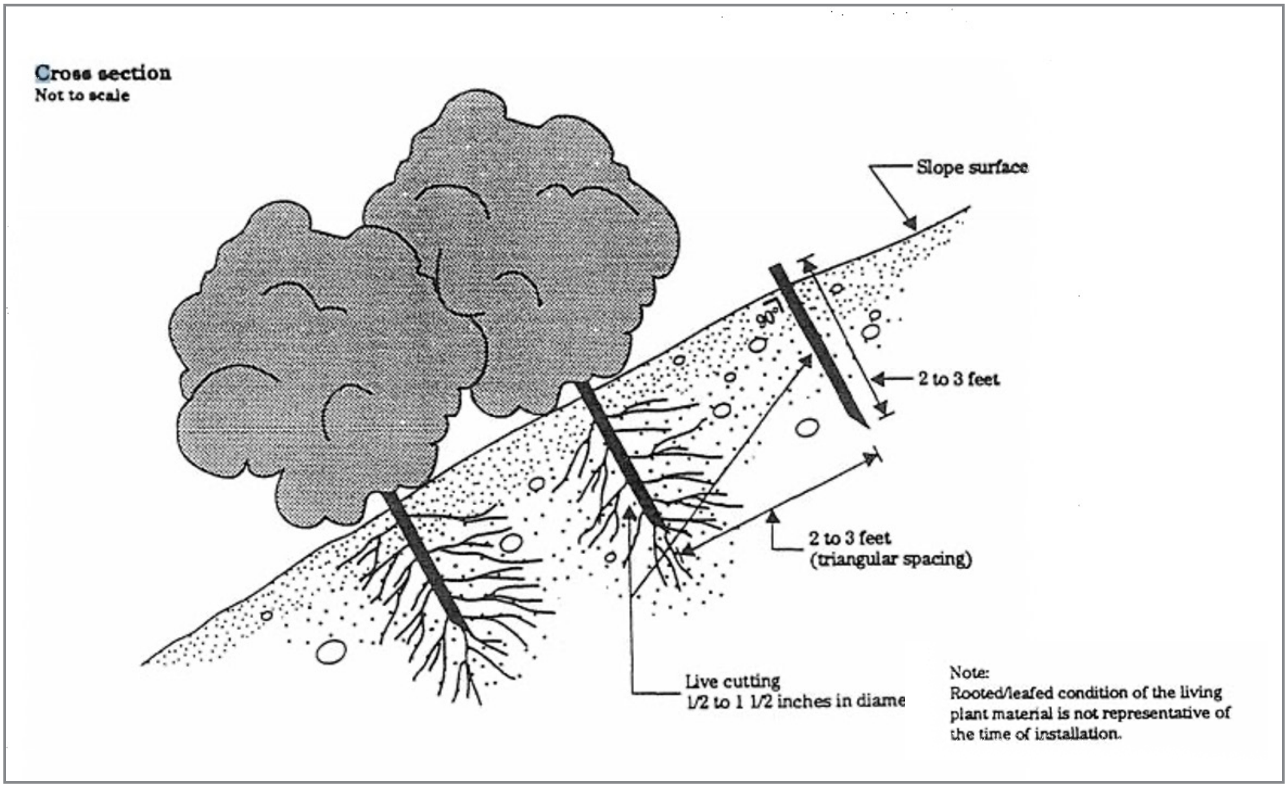

Figure 6-16: Live Staking (Source: EPA)

Live Fascines. Live fascines are long bundles of branch cuttings bound together into sausage-like structures (Figure 6-17). When cut from appropriate species and properly installed, they will root and immediately begin to stabilize slopes. They should be placed in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow face sliding. This system, installed by a trained crew, does not cause much site disturbance.

Joint Planting. Joint planting (or vegetated riprap) involves tamping live cuttings of rootable plant material

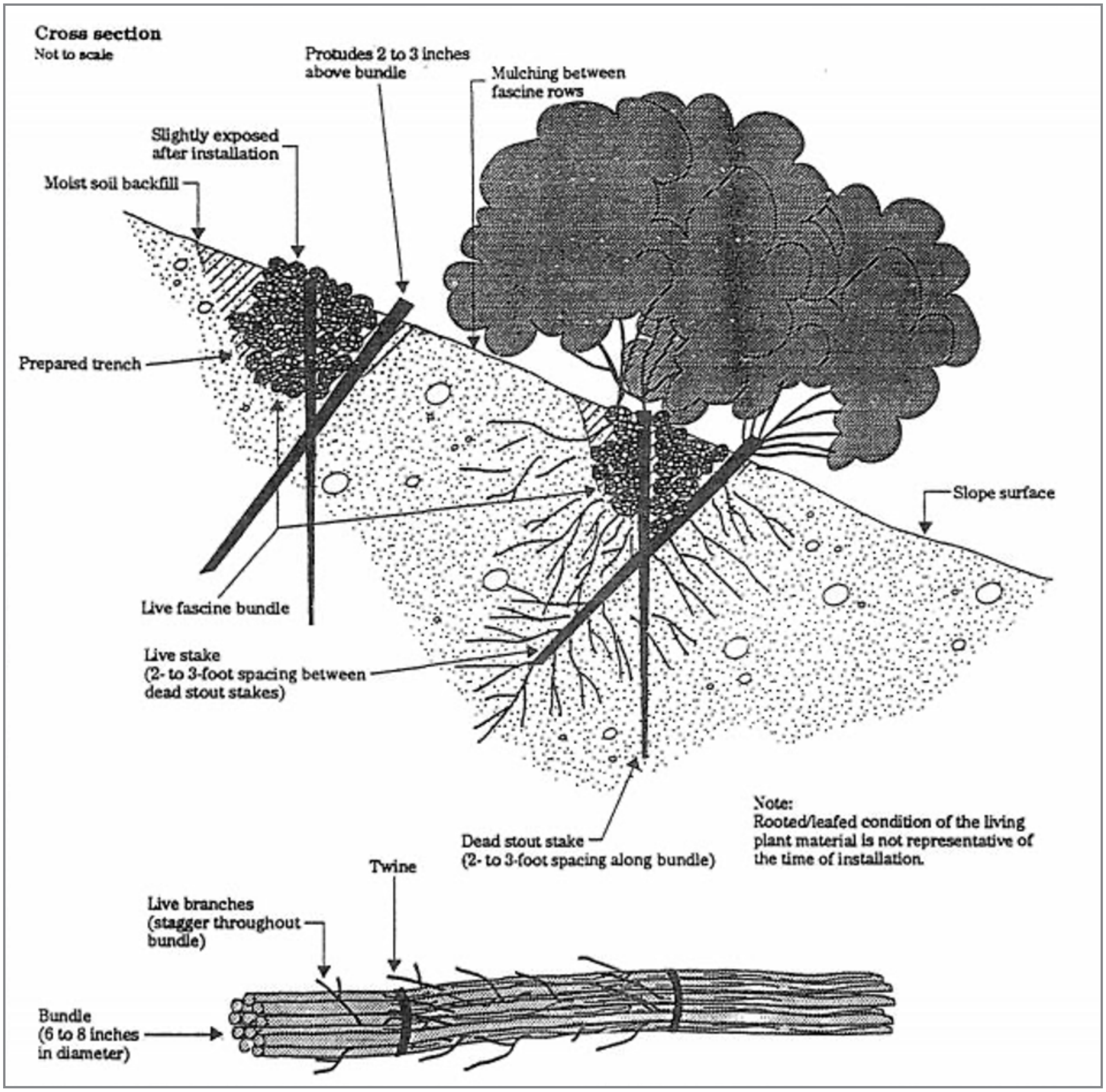

Figure 6-17: Live Fascines (Source: EPA)

into soil between the joints or open spaces in rocks that have previously been placed on a slope (Figure 6-18). Alternatively, the cuttings can be tamped into place at the same time that rock is being placed on the slope face.

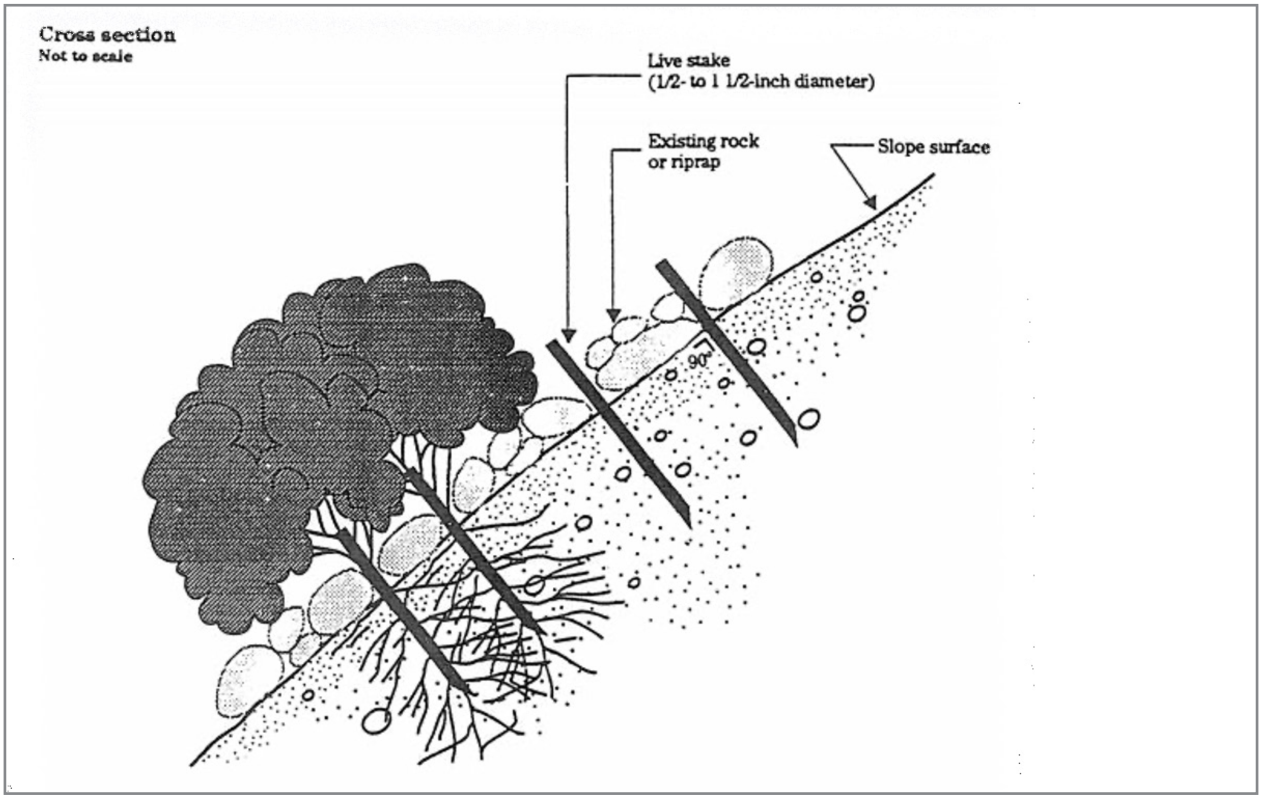

Figure 6-18: Joint Planting (Source EPA)

Marsh creation and restoration is another useful vegetative technique that can be used to address problems with erosion of coastal shorelines, Figure 6-19. Marsh plants perform two functions in controlling shore erosion. First, their exposed stems form a flexible mass that dissipates wave energy. As wave energy is diminished, both the offshore transport and longshore transport of sediment are reduced. Ideally, dense stands of marsh vegetation can create a depositional environment, causing accretion of sediments along the intertidal zone rather than continued erosion of the shore. Second, marsh plants form a dense mat of roots (called rhizomes), which can add stability to the shoreline sediments.

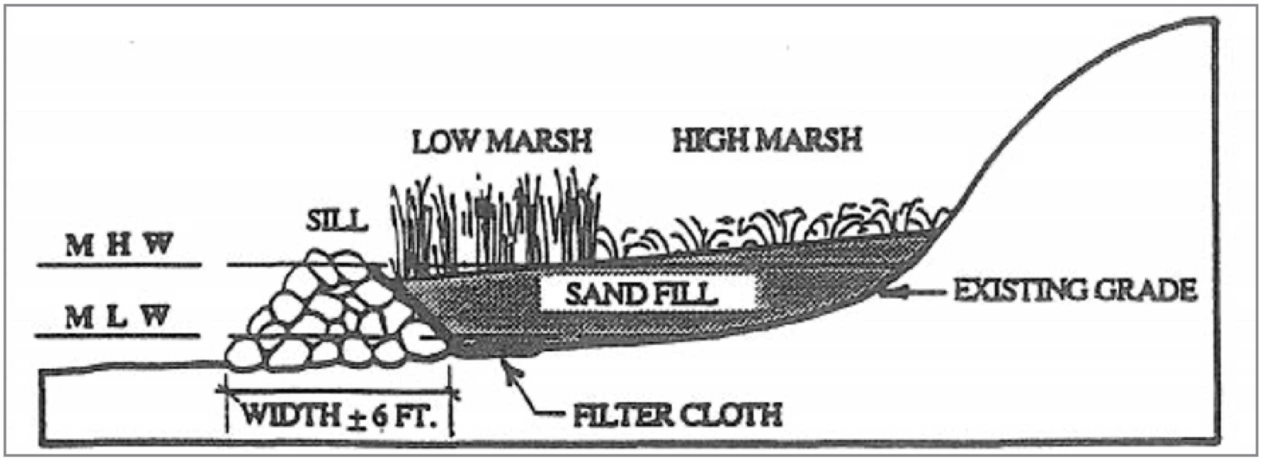

Figure 6-19: Shallow Marsh Creation (Source: EPA)

6.4.4.2 ROCK RIPRAP AND STRUCTURAL TECHNIQUES

For sites where soil bioengineering and marsh creation would not be an effective means of streambank or shoreline stabilization, a variety of engineering approaches can be considered. One approach involves the design and installation of fixed engineering structures and rock rip rap. Bulkheads and seawalls are two types of wave-resistant walls that are similar in design but slightly different in purpose (Figure 6-20). Bulkheads are primarily soil-retaining structures designed also to resist wave attack. Seawalls are principally structures designed to resist wave attack, but they also may retain some soil. Both bulkheads and seawalls may be built of many materials, including steel, timber, or aluminum sheet pile, gabions, or rubble-mound structures.

Although bulkheads and seawalls protect the upland area against further erosion and land loss, they often create a local problem. Downward forces of water, produced by waves striking the wall, can produce a transfer of wave energy and rapidly remove sand from the wall. A stone apron is often necessary to prevent scouring and undermining. With vertical protective structures built from treated wood, there are also concerns about the leaching of chemicals used in the wood preservatives.

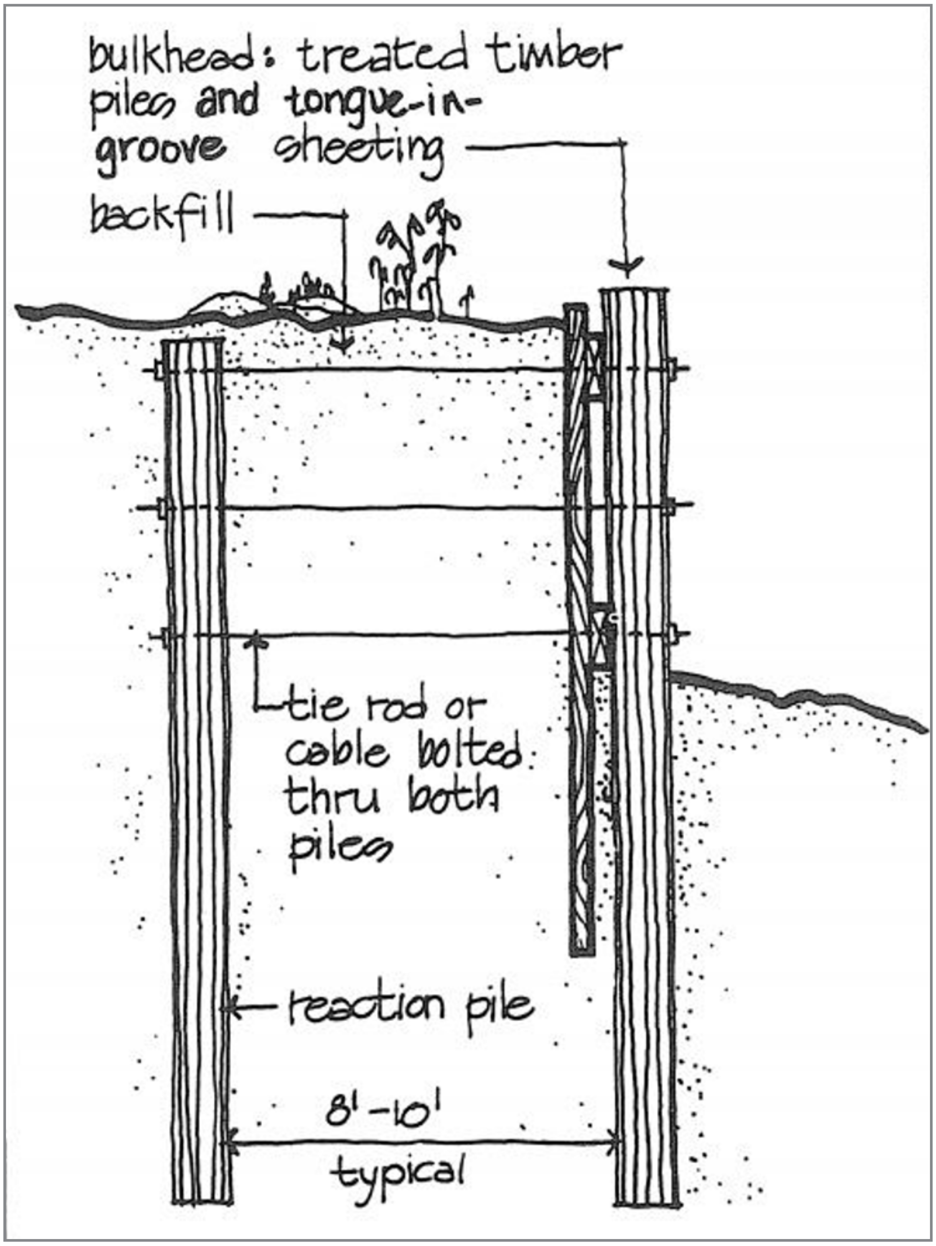

Figure 6-20: Schematic Bulkhead Example (Source: EPA)

Toe Protection for vertical bulkheads has a number of qualitative advantages. Toe protection usually takes the form of a stone apron installed at the base of the vertical structure to reduce wave reflection and scour of bottom sediments during storms (Figure 6-21). The installation of rubble toe protection should include filter cloth and perhaps a bedding of small stone to reduce the possibility of rupture of the filter cloth. Ideally, the rubble should extend to an elevation such that waves will break on the rubble during storms.

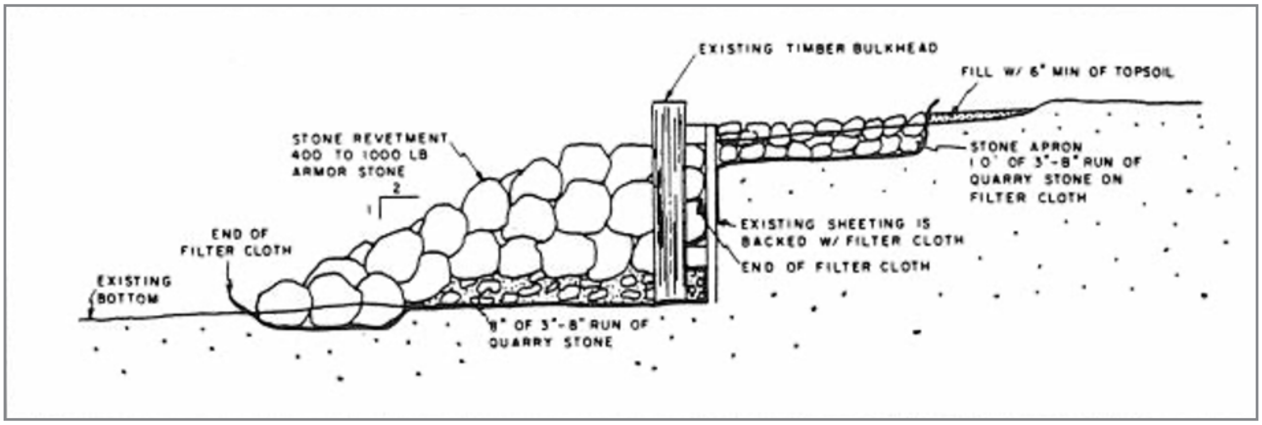

Figure 6-21: Schematic Toe Protection (Source: EPA)

Rock riprap is another type of vertical protective structure used for streambank and shoreline protection. One rock rip rap design contains several layers of randomly shaped and randomly placed stones, protected with several layers of selected armor units or quarry stone (Figure 6-20). The armor units in the cover layer should be placed in an orderly manner to obtain good wedging and interlocking between individual stones. The cover layer may also be constructed of specially shaped concrete units.

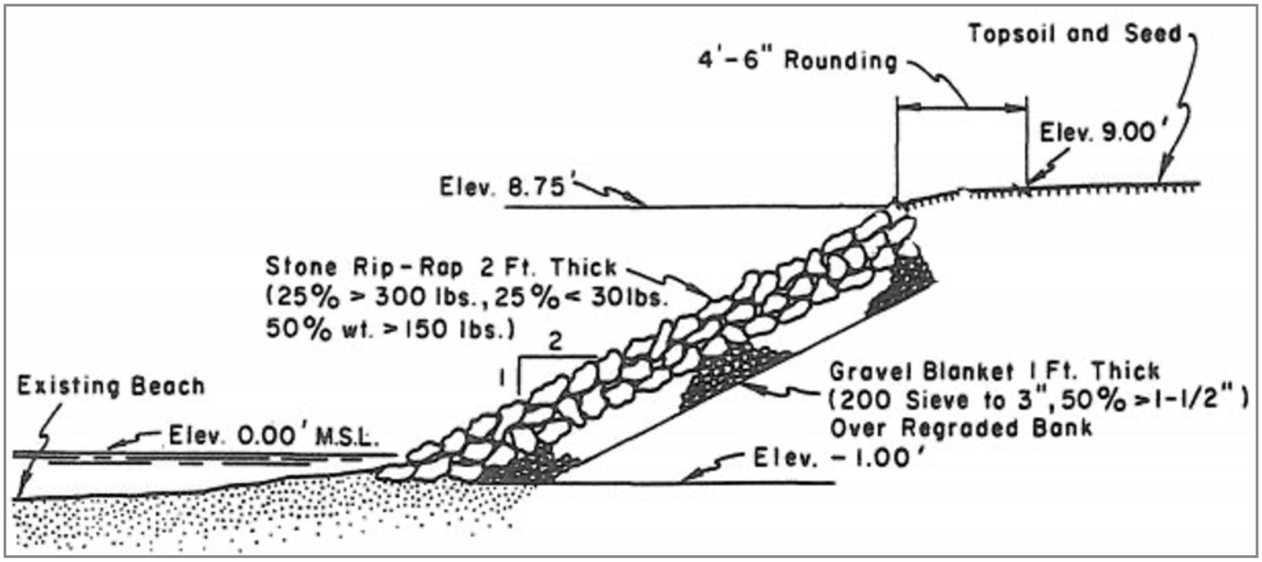

Figure 6-22: Rock Rip Rap Schematic Cross Section (Source: EPA)

Structures of various types can be used to protect the shoreline and streambanks. Some examples include:

Gabions (stone-filled wire baskets) or interlocking blocks of precast concrete are used in the construction of revetments. In addition to the surface layer of armor stone, gab ions, or rigid blocks, successful revetment designs also include an underlying layer composed of either geotextile filter fabric and gravel or a crushed stone filter and bedding layer. This lower layer functions to redistribute hydrostatic uplift pressure caused by wave action in the foundation substrate. Precast cellular blocks, with openings to provide drainage and to allow vegetation to grow through the blocks, can be used in the construction of revetments to stabilize banks. Vegetation roots add additional strength to the bank. In situations where erosion can occur under the blocks, fabric filters can be used to prevent the erosion. Technical assistance should be obtained to properly match the filter and soil characteristics. Typically blocks are hand placed when mechanical access to the bank is limited or costs need to be minimized. Cellular block revetments have the additional benefit of being flexible to conform to minor changes in the bank shape.

Groins are structures that are built perpendicular to the shore and extend into the water. Groins are generally constructed in series, referred to as a groin field, along the entire length of shore to be protected. Groins trap sand in littoral drift and halt its longshore movement along beaches. The sand beach trapped by each groin acts as a protective barrier that waves can attack and erode without damaging previously unprotected upland areas. Unless the groin field is artificially filled with sand from other sources, sand is trapped in each groin by interrupting the natural supply of sand moving along the shore in the natural littoral drift. This frequently results in an inadequate natural supply of sand to replace which is carried away from beaches located farther along the shore in the direction of the littoral drift. If these "downdrift" beaches are kept starved of sand for sufficiently long periods of time, severe beach erosion in unprotected areas can result.

Maintenance of Rock RipRap and Structures is necessary to repair the damage from storms and winter ice and to address the effects of flanking and off-shore profile deepening. The maintenance varies with the practice type, but annual inspections should be made by the property owners. For stone revetments, the replacement of stones that have been dislodged is necessary; timber bulkheads need to be backfilled if there has been a loss of upland material, and broken sheet pile should be replaced as necessary. Gabion baskets should be inspected for corrosion failure of the wire, usually caused either by improper handling during construction or by abrasion from the stones inside the baskets. Baskets should be replaced as necessary since waves will rapidly empty failed baskets. Steel, timber, and aluminum bulkheads should be inspected for sheet pile failure due to active earth pressure or debris impact and for loss of backfill. For all structural types not contiguous to other structures, lengthening of flanking walls may be necessary every few years. Through periodic monitoring and required maintenance, a substantially greater percentage of coastal structures will perform effectively over their design life.