A Design Manual:

Engineering With Nature Using Native Plant Communities

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Semi-arid Riparian Corridor Community, Washington

ABSTRACT

A Design Manual for Engineering With Nature Using Native Plant Communities

Managed lands provide many native plant communities, and incorporating these plants into design features will reduce construction and maintenance costs, while increasing benefits to the environment. Plants are often "keystone" species that hold together entire ecosystems, which are important for many ecological processes to occur. Plant communities in the built environment can provide structure, function, and natural processes to create a sustainable landscape. They are a critical component of energy flow in ecosystems and provide food and habitat for many organisms in an ecological community. Other functions and services include: reduction of wind and water erosion, water storage, regulation of temperature, contribution of atmospheric oxygen, and carbon storage. Using plant communities is a shift in emphasis, away from a fixed design held at a static moment, to a dynamic design allowing for these communities to grow and mature over time. Plant communities not only survive, but are adaptable to changing environmental conditions. Native plant communities have natural resiliency built into them by genetic and species biodiversity, which allows for greater survivability.

This design manual identifies and documents the use of native plants to provide engineered design elements that consider the diverse range of Corps' water resource projects. The goal of this manual is to describe how to utilize plant communities within the built environment to create sustainable landscapes. The first topic addressed by this design manual is why we need to pay attention to our native plant communities and why native plants are important to the Corps' mission. The second topic addressed is understanding how to use the plant resources available on Corps' lands nationwide. This includes how to incorporate native plant communities into projects by describing specific tools and techniques to survey, plan, design, construct, maintain, and monitor projects. Design and scientific components are blended together into a holistic approach, so this manual is accessible to many people with varied professional backgrounds. The third topic addressed is a listing of specific case studies that illustrated well-designed, well-built examples of elements using native plant communities. The advantage of this approach is to reduce construction and operating costs, while increasing benefits to the environment. This manual explores the idea of transforming the way in which native plant communities are thought about and valued by the Corps. Enjoy the journey!

Semi-arid Grassland Community, Washington

CONTENTS

ABSTRACT ..... **iii**

List of Figures ..... **vi**

List of Tables ..... **vii**

INTRODUCTION **1**

Overview 1

Engineering With Nature 1

Goals of this Design Manual 2

Design Manual Provides Guidance 2

Why Protect Native Plants? 3

Conserving Biodiversity 4

Ecological value 4

Economic value 5

Aesthetic value 5

DESIGN **7**

Design Principles 7

Unity 8

Sequence 8

Proportion 8

Rhythm 8

Accent 8

Repetition 8

Variety 8

Elements of Design 10

Color 10

Line 10

Form 10

Mass 10

Texture 10

Perspective 10

Scale 11

Light and Shade 11

Time 11

The Design Process 11

Assessment of needs and constraints 12

Safety 12

Health 12

Welfare 12

Site analysis 12

Existing plants communities 13

Hydrology 13

Man-made environmental aspects 14

Climatic considerations 14

Develop a Site Plan 14

Develop a Planting Plan 14

Develop a Grading Plan 16

Site specific details 17

Construction specifications 17

Monitoring plan 17

Maintenance 19

THE UNITED STATES NATIONAL VEGETATION CLASSIFICATION AND PLANTING TECHNIQUES **21**

Natural Heritage Program 21

The United States National Vegetation Classification 21

The USNVC Survey Methodology 21

NatureServe Explorer 23

Sources to Obtain Native Plant Materials 23

Conservation Methods 23

Ex situ preservation strategies 24

In situ preservation strategies 24

Inter situ preservation strategy 24

Planting Techniques 24

Site preparation 24

Timing 25

Soils 25

Seed Mixes and Seeds 26

Seed mixes 26

Seeds 26

Seed Treatments 28

Interseeding 29

Mosaic seeding 30

Planting 30

Invasive Species Control 30

CASE STUDIES OF IMPLEMENTED DESIGNS **33**

Climate Control – Sun, Shade, Windbreaks, and Energy Conservation 33

Reduce Stormwater Runoff 33

Planting to Stabilize Steep Slopes 34

Bioengineering and biotechnical planting 34

Geocells and geogrids 37

Riparian Corridors, Greenways, and Buffers 40

Riparian Corridors Versus Buffer Strips 40

Riparian buffers 40

Buffer strip 41

Green Infrastructure and Self-sustaining Plantings for Water Conservation in the Environment 43

Permeable pavements 43

Bioretention features or rain gardens 45

Constructed wetlands 46

Wetland Treatment Using Native Wetland Plants fo Filter Discharge 48

Native Plantings for Recreational Features and Aesthetic Enhancement 49

Creating Habitat for Pollinators 50

Planting with Dredged Materials 52

Phytoremediation and Reclamation.....53
Onondaga Lake.....53
Geddes Brook wetland and Ninemile Creek.....54
Carbon Sequestration.....56
Living Shorelines and Nature-Based Protection for Storm Surge.....57
Establishing Native Aquatic Plants to Improve Aquatic Habitat 59

EXISTING DATABASES, SOURCES OF PLANT MATERIALS AND EXPERTISE 63
VegBank.....63
USDA PLANTS Database 63
Natural Resources Conservation Service Plant Materials Center.....63
Native Plant Commercial Nursery Production.....64
Botanical Gardens 64
Plant Conservation Alliance.....65
Native Plant Societies.....66
Native Plant Rescues 66

ACKNOWLEDGEMENTS.....69
POINTS OF CONTACT 69
REFERENCES 71
BIBLIOGRAPHY 77
APPENDIX A. USNVC STANDARD DATA FORM ..81

List of Figures

Figure 1. Combined site plan and planting plan ..15
Figure 2. Site plan area after first year planting..16
Figure 3. Planted area after 3 years with natural vegetation zonation.....16
Figure 4. Important measures indicating plant survivability are species composition and percent cover as part of the monitoring plan 18
Figure 5. Seed from many grasses and flowers can be easily gathered.....26
Figure 6. A no-till drill is used for planting and interseeding an area, and causes minimal disturbance to existing plants.....31
Figure 7. Branch layering technique.....35
Figure 8. Livestaking for a slope or shoreline 35
Figure 9. Turf reinforcement mat with vegetation growing in it.....35
Figure 10. Conceptual and installation details for an anchored reinforced vegetated system, showing a rolled high-performance turf reinforcement mat fixed in place with percussion-driven anchors, and vegetated with hydroseed.....35
Figure 11. Roadbed constructed with geocell at Cunard, a National Park Service boat launch on the New River, West Virginia.....37
Figure 12. Planted geocell stabilizing the same road on the steep down-hill road shoulder.....37
Figure 13. Existing conditions at Site #1 of the proposed biotechnical planting at El Dorado Lake.....38
Figure 14. On-site harvesting of all native plants to be used in the bioengineering project and workshop at El Dorado Lake, Kansas 38
Figure 15. Willow bundles being placed in four trenches running parallel to the shore. 39
Figure 16. Brush layering, which utilizes willows placed perpendicularly into the bank, being implemented at El Dorado Lake, Kansas.....39
Figure 17. New plants sprouting from shoreline treatments 6 months after planting at El Dorado Lake. 39
Figure 18. Riparian corridor with native plant communities. 41
Figure 19. Eroded areas were repaired before planting the drainage channel with native trees, shrub, and the seed mix 42
Figure 20. Tree establishment after two growing seasons within the buffer strip at Dyess Air Force Base.....42
Figure 21. Gravel-filled geogrid parking area at the National Park Service Headquarters in Glen Jean, West Virginia 44
Figure 22. Detail of geogrid 44
Figure 23. Bioretention drainage detail. 45
Figure 24. Constructed wetland at Winfield, West Virginia. 46
Figure 25. The wetland mitigation planting plan at Marmet, West Virginia.....47
Figure 26. Constructed wetland conveying the Burning Springs Branch originating from the hills pictured in the background to the Kanawha River at Marmet 47

Figure 27. Treatment wetland septic system at the Plant Material Center in Alderson, West Virginia. 48

Figure 28. Glade Creek Campground, a popular campground that offers low-impact sites that use existing plant communities to provide privacy and beauty....49

Figure 29. Site detail – a kiosk and handmade stone bench at Glade Creek Campground....49

Figure 30. Volunteers harvesting seed from the adjacent sand prairie, to be planted on the Corps site 52

Figure 31. The sand prairie is a fire-dependant ecosystem and prescribed fire is a management tool used to maintain and restore plant diversity....52

Fiigure 32. The site was a showplace of color after the first prescribed burn in 2013 52

Figure 33. Carbon storage abilities of different habitat types....56

Figure 34. Section of coastal shoreline continuum and living shoreline treatments. 57

Figure 35. Conceptual cross-shore profile of the barrier coast type....58

Figure 36. American water lily flowering and spreading beyound protective closures at a founder colony site....61

Figure 37. Natural Resources Conservation Service. Plant Material Center Locations....64

List of Tables

Table 1. Ecosystem Services Provided by Plants....4

Table 2. Summary of International Vegetation Classification Hierarchy Levels and Criteria for Natural Vegetation 22

Table 3. Classification of Slope Protection and Erosion Control Measures. 34

Table 4. Suitability of Different Soil Bioengineering Methods Based on Soil and Site Conditions....36

Table 5. Summary of Estimated Costs per Impervious Acre Treated for Selected Stormwater Treatments....43

Fresh Water Spring Cypress
Hammock Community, Florida

INTRODUCTION

Engineering With Nature is defined as the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaborative processes.

Overview

Our lands provide many natural plant community palettes. Incorporating native plant communities reduces construction and maintenance costs, while increasing benefits to the environment and to projects. Natural communities are assemblages of species that occur together in space and time. These groups of plants and animals are found in recurring patterns that can be classified and described by their dominant physical and biological features: Red Maple swamp and Pitch Pine/Scrub Oak communities are two examples. This approach will help transform the way in which native plant communities are thought about and valued by the Corps. This design manual identifies and documents the use of native plant communities to provide engineered design elements that consider the diverse range of water resource projects.

Engineering With Nature

Engineering With Nature seeks to apply design in its fullest sense. Engineering With Nature is defined as the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental ,and social benefits through collaborative processes. The essential four principles of Engineering With Nature are as follows (Bridges 2012):

- Use natural processes to maximize benefits, thereby reducing demands on limited resources, minimizing the environmental footprint of projects, and enhancing the quality of project benefits.
- Use science and engineering to produce operational efficiencies supporting sustainable delivery of project benefits.
- Broaden and extend the base of benefits provided by projects to include substantiated economic, social, and environmental benefits.
- Use science-based collaborative processes to organize and focus interests, stakeholders, and partners to reduce social friction, resistance, and project delays, while producing more broadly acceptable projects.

Engineering With Nature is: holistic, a systems approach, sustainable, science-based, collaborative, efficient and cost-effective, socially responsive, innovative, and adaptive.

Careful consideration of alternatives will find the best solution that acts in unison with the sciences of the earth and engineering. Good design ensures the best possible alternative to satisfy the intended objective(s) supporting natural and engineering processes and functions on a particular site. Design should also consider the socio-economic environment; the aim is to align the natural and engineering processes with the socio-economic benefits to lessen the impacts and maximize the benefits of the project. Using native plant communities has many benefits, including their influence on climate, air, and water purification; erosion control; water cycle stabilization; habitat and food for wildlife and pollinators; noise reduction; screening; and increasing property value. For example, businesses have noted that attractively landscaped buildings result in above-average labor productivity, lower absenteeism, and easier worker recruitment. Studies have indicated that people have a basic desire for contact with plants (Bisco Werner et al. 1996, Brethour et al. 2007, Frank 2003, Younis and Qasim 2008). Satisfying this need can have a strong positive influence on human behavior.

A fit environment is defined as one in which the maximum needs of a user are provided by the environment while requiring the least work of adaptation (McHarg 1992). This process is very specific to the site being considered. When done well, the effect can be very subtle, while enhancing the visual aesthetics, and adding multiple functions to the site. Earth, manmade structures, and plants are materials used by designers to define space and to create a designed environment. Choosing a plant palette from a natural plant community that is either present or appropriate for the site (as determined by site conditions) will provide ecological benefits and be adaptable to fluctuating conditions.

The Engineering With Nature concept uses four dimensions including time, and develops its full potential over time. Design changes begin inevitably from the time of planting. This approach allows for the plant communities to maintain their function and natural processes within the environment, while allowing them to evolve over time. This approach is a shift in emphasis, away from a fixed design held at a static moment, to a dynamic design allowing for plant communities to grow and mature over time. Plant communities not only survive, but are adaptable to changing environmental conditions. Native plant communities have natural resiliency built into them by genetic and species biodiversity. Within plant communities, species compatibility has adapted over time. When incorporating native plant communities by designers (landscape architects, engineers, and project planners) in their plans, designs, and specifications, and natural resource managers and maintenance personnel provide self-sustaining features in the landscape that require less maintenance after project implementation, greater survivability, cost savings, and greater ecological benefits to the environment will result.

Goals of this Design Manual

This design manual describes how to utilize plant communities within the built environment to create sustainable projects. The first topic addressed by this design manual is why we need to pay attention to native plant communities and to explain why native plants are important. The second topic addressed is understanding how to use these plant resources available on lands nationwide and how to incorporate native plant communities into projects by describing specific tools and techniques. The third topic addressed is a listing of specific case studies of well-designed, well-built examples of landscape elements using native plant communities.

Design Manual Provides Guidance

This design manual offers instructions on how to use plant communities within the designed environment that will allow for sustainable, resilient features that change over time. There are many opportunities to incorporate

native plants and use them in Corps projects, including:

- Reduction of erosion and sedimentation
- Shoreline stabilization
- Ecosystem restoration
- Mitigation projects
- Riparian buffer projects
- Phytoremediation
- Abandoned mine land remediation
- Wetlands as filters and storage
- Prairie lands as filters to adjacent waterways
- Reduction of storm surge impacts by plant communities
- Watersheds that enhance water quality and maintain quantity
- Climate stabilization
- Carbon sequestration
- Storm surge protection
- Wildlife habitat
- Pollinator food and habitat
- Dredge islands and landscape features with native plant community establishment

Why Protect Native Plants?

Vegetation is often chosen as the basis for a single-factor system for classifying terrestrial ecological systems because it generally integrates the ecological processes operating on a site or landscape more measurably than any other factor or set of factors. Because patterns of vegetation and co-occurring plant species are easily measured, they have received far more attention than those of other components, such as fauna. Vegetation is a critical component of energy flow in ecosystems and provides habitat for many organisms in an ecological community. In addition, vegetation is often used to infer soil and climatic patterns. For these reasons, a classification ... based on vegetation can serve to describe many (though not all) facets of biological and ecological patterns across the landscape (Grossman et al. 1998).

The U.S. National Vegetation Classification (USNVC) and Nature Serve database (2013) has defined more than 800 ecosystem units in the United States and adjacent Canada. Of the 16,100 native flowering plant species in the United States, 5,474 are at risk, making them by far the largest group of organisms at risk. Impacts to native plant communities such as the loss of habitat, fragmentation, invasive plant species, the loss of pollinators, pollution, disease, and changes to the climate will continue to occur, further stressing healthy plant populations and increasing the risks of loss of species.

Plant communities respond to moisture, light, and temperature conditions; therefore elevation and aspect are critical landscape considerations and define where a plant community will likely occur. Although soil is another important requirement, it is water-content within the soil and its structure that determine its chemical nature and water

holding capacity. The plant community responds to site conditions, and is adaptable and resilient to environmental fluctuations. A varying number of plant species within a community are in sync with local conditions responding to the water cycle (precipitation or high-water events). Often different plant species flower at different times throughout the flowering season, which allows for more interactions with the faunal communities including pollinators. Plants provide structure in the environment. Their roots improve soil health, and stabilize soils by limiting erosional forces. Plant growth provides oxygen as a by-product of photosynthesis and they store carbon in their structures. Plants are important to the microclimate because they absorb heat from the air during the transpiration process and release of water in the form of vapor as a major input to the water cycle. They provide shade that reduces solar radiation and reflection, and they also lower wind speed, disperse fog, and influence snow deposition.

Conserving Biodiversity

Conserving biodiversity and the health of native plants and ecosystems is essential to sustain the natural resource base upon which we depend for survival. There is an urgent need to develop effective plant conservation programs before more species and communities become critically endangered. Native plant conservation strategies are not only needed to protect the most imperiled species, but to ensure the long-term survival of all native plant species and plant communities. There is an inherent efficiency with this approach. These communities will provide a range of ecosystem services listed in Table 1, without which we could not exist. No matter how small, all plants play a valuable role in our lives. They provide the following benefits:

Ecological value: Native plants convert the sun's energy into food; thus, they are the source of all food to the animal kingdom. Plants cycle and cleanse fresh water upon which terrestrial animals depend and ensure soil stability for ecosystems. We depend on

Table 1. Ecosystem Services Provided by Plants.

Provisioning services	Regulating services	Habitat services	Cultural services
Food	Air quality regulation	Maintenance of life cycles of migratory species	Aesthetic information
Raw materials	Regulation of water flows	Maintenance of genetic diversity	Spiritual experience
Genetic resources	Moderation of extreme events		Inspiration for culture, art, and design
Medicinal resources	Moderation of climate		Resources for the built environment
Ornamental resources	Maintenance of soil fertility		Opportunities for recreation and tourism
	Waste treatment		
	Erosion prevention		
	Biological control		
	Pollination		

From *The Economics of Ecosystems and Biodiversity (TEEB): The Ecological and Economic Foundations.* (United Nations, European Commission, Germany, and United Kingdom 2009).

plants to provide the oxygen that all living organisms require.

Economic value: Plants are sources of genetic and raw materials that are used to expand or diversify agricultural and industrial products, including foods and medicine. Native plants provide a storehouse of genetic diversity for future exploration, discovery, and use to meet human needs.

Aesthetic value: The beauty of wildflowers is just one of the many aesthetic values of native plants. The presence of plants in their native habitats and in cultivation enhances our world in many ways. Native plant communities and natural areas provide opportunities for people to experience nature.

The variety of plant communities is truly amazing and how these communities adapt to their environment is fascinating. The plant communities pictured at the beginning of each section of this manual are only a small sampling of the diversity of plant communities in the United States. This manual is designed to help readers gain insight into how to use these valuable plant resources, appreciate their diversity, and understand the diverse range of functions and services they can provide.

Sonoran Desert Community, Arizona

DESIGN

There are many functional aspects to utilizing native plant communities to address serious environmental problems in a cost-effective manner within designed and engineered features. For example, a significant problem is the total amount of soil eroded from land and delivered to waterways: estimates of sediment yields in the United States range up to 2 billion tons per year (McDonough and Braungart 2013). One quarter of this sediment load is transported through the system to the ocean, while the remainder is deposited in floodplains, rivers, lakes, and reservoirs (Hardaway et al. 2010). Sediment is considered the number one pollutant for water quality; increased sediment load increases turbidity and decreases oxygen. Additionally, earth and landforms become unstable due to piping, head-cutting, and collapse. Topsoil is also stripped and lost due to water or wind forces, and soil fertility and productivity decrease.

Management of sedimentation and prevention of erosion with native plantings can contribute to protection and restoration of watersheds and large riparian systems. Vegetated buffer zones consisting of native plant communities, including native grasses, herbaceous plants, shrubs, and trees, provide an attractive, cost-effective, and environmentally compatible way to protect riparian, lacustrine, and estuarine waterways from sedimentation, to protect slopes and shorelines against erosion, to control runoff from impervious surfaces, and to provide better storm management practices within the watershed. Native plants are cost-effective, adapt to the environment, and have higher survivability. In severely eroded areas, one could include biotechnical and soil bioengineering stabilization techniques using native plants, such as livestaking, live fascines, brush-layering, and branch-packing (as was used at El Dorado Lake in Kansas, page 38). The use of sustainable design features such as planted concrete pavers, wetland storm culvert and vegetated swale systems, and rolled erosion control products or geotextile fabrics with voids for earth materials and plants can improve soil stability and stormwater management. In some cases, additional armoring is required to stabilize selected critical shoreline areas, though most types of hardening solutions can be interplanted, retrofitted, or combined with bioengineering, vegetation, or other living shoreline techniques to maximize benefits. Such efforts will substantially contribute to improving water quality, protecting upland and shoreline systems, and improving fish and wildlife habitat. While addressing these considerations associated with sustainable design projects, this section provides ideas for enhancing the qualities of the built environment. Attention to details for sustainable design can:

- Improve environmental awareness
- Offer recreational opportunities
- Provide privacy and noise control
- Enhance visual appeal
- Accentuate or diminish adjacent land uses
- Minimize maintenance
- Increase value of real estate

Design Principles

Creating the composition of a design must include the principles of unity, balance, sequence, proportion, rhythm, accent, repetition, and variety. Color, line, form, mass, texture, scale, light, and time are visual elements used in combination to create interest. This interplay of design principles

and visual elements yields a design for a specific site that fulfills its intended purpose.

Unity means that all parts of the composition or landscape go together; they fit. Everything selected for a landscape must complement the central scheme and serve some functional purpose. Unity is obtained by the effective use of components in a design to express a main idea through consistent style and to harmonize the whole. Symmetrical balance is achieved when one side of the design is a mirror image of the other side. Asymmetrical balance uses different elements of interest on either side of the central axis to obtain balance and visual attraction.

Sequence is a successive change of visual perspectives or spatial transition as one moves through a series of spaces. For example, this transition can be obtained by the arrangement of objects with varying textures, forms, or other elements in a sequential order assisting the gradual movement of the viewer's eye through the designed area. Or, it can be a progression of spaces created by combinations of plants, earth, and structures, creating interest and leading one through the area.

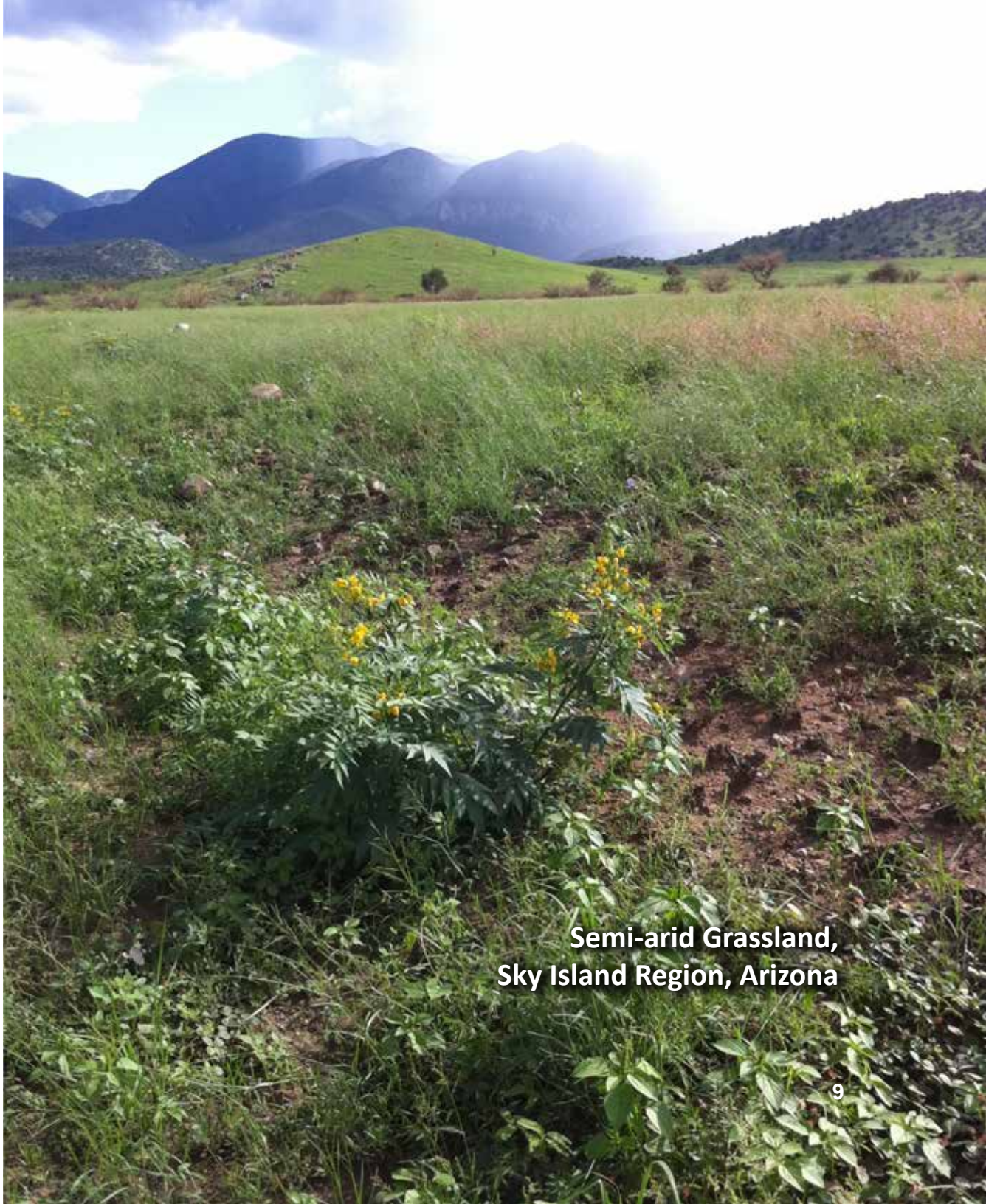
Proportion refers to the size of the parts of the design in relation to each other and to the design as a whole. A three-foot vernal pool, for example, would be lost in a large open greenway, but would fit beautifully into a small opening along a path in a riparian corridor. Proportion in landscape architecture usually refers to the human scale, relating a person to the built environment.

Rhythm is achieved when the elements of a design create a feeling of motion leading the viewer's eye through or even beyond the designed area. Elements like color schemes, line, and form can be repeated to attain rhythm in landscape design. Rhythm reduces confusion in the design and creates a pattern through the designed area.

Accent involves bringing attention to a feature by simplifying the elements around it in space. For example: line can be used to direct visual observation toward a feature as the focal point. In painting or the built environment, the color red is often used as a focal point, to aid the eye in its travel through a canvas or along a route.

Repetition refers to the repeated use of features like plants with identical shape, line, form, texture, and/or color. Too much repetition creates monotony, but when used effectively can lead to rhythm or can bring the attention to an accent. Unity can be achieved by repetition of the same element, while simplifying is achieved by elimination of other elements and unnecessary detail.

Variety can provide interest and diversity in the landscape. A flower garden is a simple example of a designed space reflecting variety. A riparian forest is a diverse natural environment. Biodiversity is associated with the health of a system or natural landscape.



Semi-arid Grassland,
Sky Island Region, Arizona

Color

Line

Form

Mass

In the design of a naturalized landscape or restoration project, replication of the variety of plants growing in an association in that environment would aid in restoring function to the area.

Elements of Design

Color can be used to change perspective. Warm colors and light tints like red, orange, yellow, and white advance an object or area toward the observer. Cool colors and deep shades like blue, green, and black recede and can be used to make objects appear further away. Designers use color to direct attention in the landscape and create a path for the eye to follow. Light colors and tints tend to attract attention, as do bright, vivid colors. Color as an element can strongly influence the emotions and mood. Cool colors are restful, while warm colors express action and excitement.

Line moves the eye visually or the person physically through space. It can be used to create patterns. In the urban landscape, line is inferred by linear features such as streams, riparian corridors, paths and trails, roads, and other infrastructure, and aids in navigating through a space. Horizontal lines generally elicit a restful feeling while vertical lines create a feeling of energy. Straight lines tend to be forceful, structural, and stable, and direct the observer's eye to a point faster than curved lines. Curved or free-flowing lines are smooth and graceful and can be used to create a natural feeling.

Form can be described as a shape or structure of an object or space. For example, the shape of plants can be expressed in terms of their individual growth habits. Plant forms include oval, ball, egg, columnar, cylindrical, pear, vase, spire, mound, and cushion. The branching character of a plant creates the structure, which can be described as ascending, arching, spreading, weeping, or irregular.

Mass is the combination of a group of objects to create perceptions, such as a solid plane or a specific pattern. Mass can be described in terms such asheavy, dense, soft, light, or thin. Plants can be grouped to create three-dimensional space. For example, plants amassed in a woodland or buffer create horizontal and vertical planes or spaces. The canopy or overstory is experienced as a ceiling, elements of the understory such as the shrub layer are experienced as a wall, and ground covers consisting of grasses and herbaceous plants can be interpreted as a floor.

Texture describes the surface quality of an object that can be seen or felt. Texture can be described in such terms as smooth, rough, glossy, or dull. A rough or glossy texture will appear to be in the forefront, whereas a fine or dull texture will fall into the background of a landscape.

Perspective can be created by using materials with different textures to create the sensation of greater depth. A coarse texture can be used in the background, medium texture can be used in the middle, and fine texture

can be used in the foreground. A glossy texture reflecting light will jump out in the foreground, whereas a dull texture recedes.

Scale refers to the size of an object or objects in relation to the surroundings. Size refers to definite measurements, while scale describes the size relationship between adjacent objects. A small scale defines larger areas and conversely a larger scale defines a smaller space. In an urban environment where there are tall buildings adjacent to a stream restoration project, people are attracted to the restoration area in part because the area is at a human scale compared to the surrounding buildings.

Light and shade create a visual pattern in the environment. Light comes forward and shade recedes in perspective. This interplay of light and shade adds visual interest in the landscape. The interplay of light and shade can be an environmental consideration in design. For example, efficient heating can be maximized by utilizing solar radiation and cooling can be maximized by using vegetation to shade an area. Organisms have various tolerances to the amount of light they receive, and this must be considered in the stream restoration project design to allow organisms to live in the area. Plants must be selected to survive in the light condition present at a particular location. Day and night light variations can be used in design to extend interest. For example, in the sun, white flowers and silver plants will brighten any color around them and are visible at night, particularly in moonlight.

Time can be expressed in terms of the seasonal changes or diurnal rhythms. Interest in the landscape can be achieved by adding elements that have different characteristics at different times of the year. For example, deciduous and evergreen plants can be used for different purposes in a planting design. Plant response to seasonal variation can include flowering, fruiting, and foliage color changes that can be utilized to add interest to the landscape.

The Design Process

The design process is one of continual change based on information, refining the design until all the pieces work efficiently together and function as a whole. Several steps and products define the design process for any design to move forward into construction. First is an assessment of needs and constraints and a site analysis of existing conditions. Secondly, the development of a site plan, planting plan, and grading plan is important to define what the site will become. Site details and specifications further define the design and how it will be built. With the design information bound into a contract, a design can be implemented by a contractor. Once construction is complete and the built environment exists, monitoring and maintenance requirements can aid in determining if the design has been

Texture

Perspective

Scale

Light and shade

Time

successful, and what will be needed for future maintenance.

Assessment of needs and constraints. The client and community using a particular place will determine the needs and constraints of the design. Budget and time schedules are also realistic constraints that define the project's scope. To be successful, a design must respond to needs and constraints. In addition to the ecological objectives that normally accompany projects, the designer is responsible for addressing safety, health, and welfare for all participants using the designed area.

Safety can include consideration of flood control measures, erosion control, bank stabilization, and pedestrian safety in the built environment. Appropriate sizing of the channel is an important aspect for flood reduction. Erosion problems need to be identified, thus enabling design solutions to be developed. Stabilization of stream banks may be necessary to provide a safe environment. All public recreational areas and facilities need to be accessible and comply with the Americans with Disabilities Act (ADA) for the safety of the public using the area. This includes walkways, picnic areas or other site amenities, parking lots, and signage used within the project. Signage, lighting, appropriate fencing, and railings may be necessary site amenities to provide for a safe pedestrian experience. Another important consideration is the proper placement of plants that allow for line of sight throughout parking lots, on roadways and pathways to minimize conflicts between vehicular and other types of traffic.

Health considerations include water quality and environmental enhancements. Plants can be selected to aid in the remediation of an area and improve the water quality. Vegetative buffer strips, corridors, and greenways are all ecosystem enhancements that perform a number of functions on a site. A system is healthier with more biodiversity, creating more structure and function in the environment.

Welfare of the public is also considered in looking for opportunities to provide various recreational activities, visual interest, and value to the adjacent land uses. Respite can be found by active and passive forms of recreational activities. Plant communities can enhance the visual aesthetics and natural processes occurring on a site.

Site analysis. A complete survey of the project site is essential and can save time and money. It should include existing vegetation, landform, soils, hydrology, surface water features, views, migration routes for wildlife, transportation corridors, and location of all structures (both onsite and on adjacent property). All of these items should be documented and mapped. Climatic considerations to note are aspect, rainfall distribution, seasonal wind and light patterns, and micro-climatic conditions.

Existing plant communities should be examined by a botanist during the analysis. Tree, shrub, and groundcover names, locations, and conditions should be recorded. Any invasive species should be noted for future treatment. Trees on adjoining property that would affect shade patterns on the site should also be surveyed. This information is essential to designers, as it is their responsibility to blend the project into the natural or existing setting and create a functional setting that complements the proposed activities for the site. Saving existing plants for the project will require protecting them during the construction process. Care must be taken not to change the existing grade by either adding soil or compacting soil in the area under the drip line of a tree.

Land form refers to slope or land elevation changes. It determines surface water drainage patterns and is essential knowledge for the development of a functional grading plan that blends well into the landscape. Any landform that is unique, such as a waterfall, can add to a project. Changes in elevation can provide opportunities to provide views into and out of the site. The knowledge of depth to bedrock is also an important consideration. Slope aspect should be considered because solar gain and precipitation drainage patterns affect plant establishment.

Soil pH, nutrient characteristics, and water holding capacity should be determined by a soil analysis, and used to amend the soil. Existing plants can be clues about the soil condition. For example Chickweed (*Stellaria media)*, Daisy (*Chrysanthemum leucanthemum)*, Dock (*Rumex crispus*.), and Plantain (*Plantago major)* are likely to grow in acidic soils, whereas Lambsquarters (*Chenopodium album)* and the mustard family, often grow in alkaline soils. Plants may also indicate poorly drained soils, e.g., plants that can tolerate wetter soils will grow in poorly drained areas. Plants can also indicate the lack of specific nutrients and fertility; for example, Lupines (*Lupinus spp*.) and Clover (*Trifolium spp*.) grow in nitrogen-deficient soils. A simple examination of the soil by digging a hole can determine its texture, depth of topsoil, and other soil horizons. Soil maps prepared by the Natural Resources Conservation Service (former Soil Conservation Service) will give specific information on soil classification and potentials of the soil. To provide more insight about the soil, testing from various locations on the site and sending to a laboratory will indicate pH and chemical composition and give recommendations.

Hydrology and the condition of the existing surface water features or stream corridors should be assessed. The timing, frequency, magnitude, and duration of flows in a stream influence the makeup of the riparian community, affect aquatic organisms, and influence the stability of constructed features. Water elevations, slopes, and velocities at various discharges and the frequency, duration, timing, and rate of change of those discharges, are elements in determining

stream flows and riparian communities. For all water bodies, water quality, turbidity, temperature, and underlying substrate can affect the dissolved oxygen levels within the water features.

Turbidity, temperature, and available nutrients will determine the aquatic plants within a lake. Lakes form layers called themoclines, which vary in temperature relative to depth. When the temperature of the water at the surface of a lake reaches the same temperature as deeper water, as it does during the cooler months in temperate climates, the water in the lake can mix, bringing oxygen-starved water up from the depths and oxygen down to decomposing sediments. On the lake or pond shore, a natural zonation will occur and be visible within the plant communities. The community is responding to the change in elevation and to the moisture in the soil. In estuarine systems, the depth of water, tidal influence, and salinity will greatly influence the plant communities.

Man-made environmental aspects to be considered in planning and design include noise levels, transportation and utility corridors, property ownership, property lines and easements, surrounding land use, existing buildings and their architectural style, and proposed ingress and egress to accomplish construction and maintenance. Laws and zoning ordinances can determine when permits need to be obtained. Zoning and design ordinances determine the guidance on setbacks, which usually do not apply to plants. However, easements for electric lines and gas lines will restrict plant growth and can introduce concerns regarding herbicide usage.

Climatic considerations such as rainfall distribution can be determined on a regional basis. This is a major factor affecting plant communities. Periods of heavy rainfall can magnify the problems of shallow soils or a hardpan resulting in unwanted standing water. Predominate wind directions differ with the region, the season, and the time of day. Where the wind direction differs in summer and winter, plantings can be arranged to block the cold winter winds from a public use area and direct summer breezes into this same area. All of these factors interact to create micro-climates, and conditions in an isolated spot may differ considerably from the conditions in another area of the landscape. The designer must consider those variations in order to "fine-tune" the plan and plant selection.

Develop a Site Plan

This will combine the information gathered in the site analysis with the programmatic elements of the needs and constraints. Property boundaries, easements, rights of way, and utilities are indicated in plan view. Existing vegetation, buildings, and other features are shown in the drawing. The proposed features are drawn and labeled as proposed, for clarity. Access roads, walkways, trails, water bodies, streams, and any other existing hydrologic features are to be shown and noted. Proposed recreational features, seating, and signage are elements that may be added to the site plan. Adjacent land uses should be noted and the site design should be compatible with the surrounding properties. Notes can be added to clarify the proposed elements or anything of importance that is not graphically represented on the plan.

All plans include standard conventions such as a north arrow for orientation, a bar scale, and a title block indicating the name of the project, client, the designer, and the date. An appropriate scale will be chosen to depict the dimension of elements in a one-to-one unit relationship, visually represented in a way that is easily interpreted by anyone using the plan (Figure 1). If there is a need for a more detailed area, another plan at a different scale can be produced for that specific area.

Develop a Planting Plan

Major features of climate, topography, moisture, and soils shape the region's predominant plant communities. These features are critical in selecting the appropriate plant communities for a site. Site analysis, which is critical to the success of the planting plan, should compare the existing natural conditions (i.e., topography and soil) and plant community to the proposed planting site. Topsoil may need to be stored for use, or brought in to replace the native soil on site. Identifying the dominant plants within the community

(based on number or size within the designated surveyed area) and planting these species will minimize routine care after the establishment of the planting. Given nearby seed sources, other appropriate species may even begin to establish themselves within the planting by natural recruitment. Using the plant community approach will ensure that landscapes will be in relative harmony with their surroundings, and provide structure and function within the ecosystem and the engineered design (Figure 2).

The planting plan incorporates the existing plants to be preserved with the new plants to be planted (Figure 3). Plant selection is based on the specific site conditions identified in the site analysis. Environmental conditions, such as climate, plant zone, soil moisture (mesic, zeric, or hydric soils), and aspect determine what type of communities will be best incorporated. In developing a planting plan, it is important to meet the site criteria and needs such as utilizing plants to provide windbreaks, shade, privacy, and noise screening, or to satisfy other objectives. The plan should address the total site. The planting plan will be within the property boundary of the project. The plant selection process should consider factors such as mature size of the proposed plants, adaptability to local soil and precipitation conditions, exposure to light conditions, wind, U.S. Department of Agriculture (USDA) hardiness zones (based on annual low temperatures), and maintenance

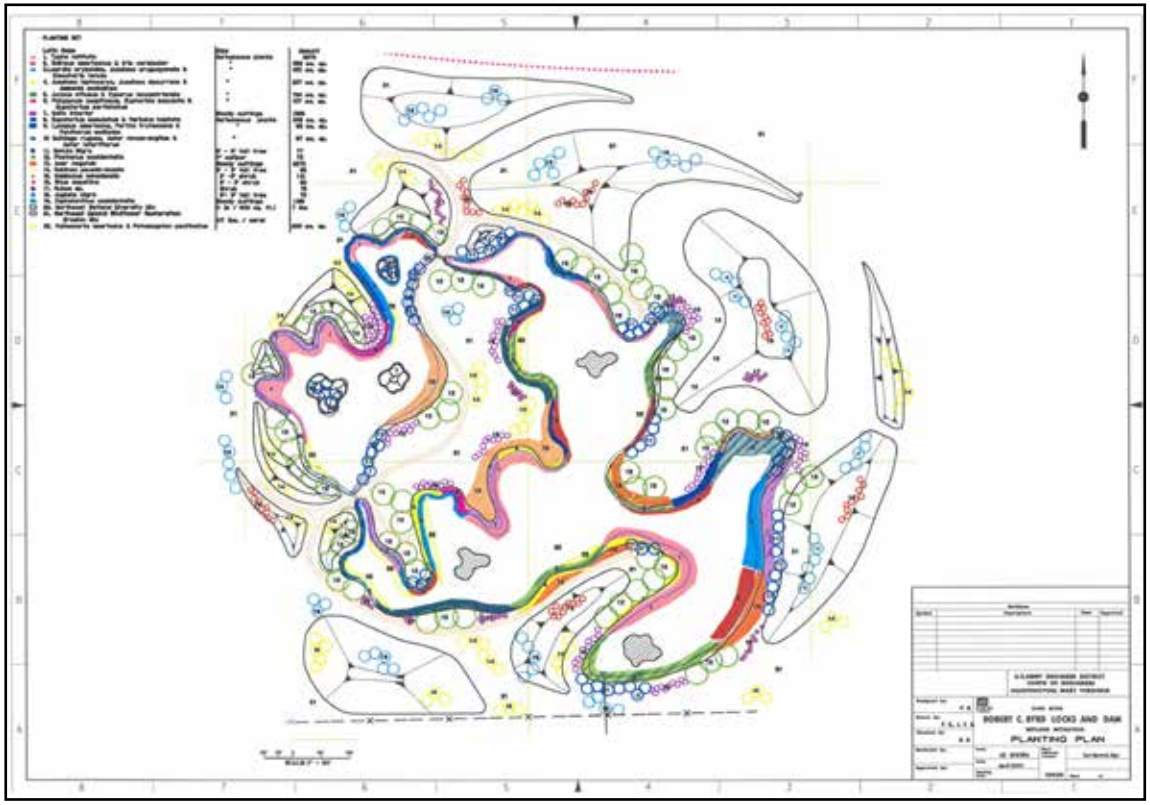


Figure 1. Combined site plan and planting plan.

Figure 2. Site plan area after first year planting.

Figure 3. Planted area after 3 years with natural vegetation zonation.

requirements. Plant texture, foliage color, flowers, and fruit during various times of the year may also be important considerations. Existing invasive species are problematic and may require management or eradication for the success of a planting project. Using native plant communities in their appropriate environment will increase the native wildlife and pollinators adapted to live in the area.

The planting plan will have the standard plan conventions; it will depict areas of existing vegetation labeled as such and plants proposed to be planted labeled with a number or code that is further defined in a key. The key is a table on the plan with plants indicated by the number or code, followed by the botanical name (Latin genus and species), the common name, the size, and how the plant is to be purchased. There may also be a block for notes on the plan. Other specific information will be found in the specifications on how to perform the planting.

Develop a Grading Plan

A grading plan is a separate plan noting the existing contours and indicating proposed contours that are to blend into the existing contours on the site. Natural site drainage features and any manmade drainage structures are indicated as existing. The proposed drainage features are indicated and labeled. The correction of any erosion problem is addressed in this plan. Various existing or proposed bank protection treatments will be noted. Handicapped

accessibility requires grading of designed features and spaces (according to the ADA and design guidance) within the design. Another critical consideration is to match the finish grade to the existing grade around all existing trees and existing vegetation that is to be retained (defined by the drip edge of most species of trees). This is true during construction and afterward, because a change in grade over existing tree and shrub roots will often kill them. This includes application of a heavy mulch on top of established tree roots.

Site-specific details. The specific site details can have a major impact upon the overall functionality of the project and can incorporate environmental features into the design. Locate public activity areas, including areas for both passive and active activities. For example, passive usage can be on-site and off-site views into the area, or seating for relaxation. The activity areas can be trails, boardwalks, stream access points for boat launching and fishing, and open areas for play. Kiosks can provide a formal entrance into a natural area informing the visitors of any information that may make their visit to the area more meaningful, fun, and safe (National Park Service (NPS) case study, page 49). Wildlife viewing can be accommodated on site by a path system located away from vehicular traffic and other high-use areas. Nature trails can be developed using interpretive signage. A path system can be developed following the stream corridor in a vegetated buffer along the stream's shoreline. Overlooks can provide visual enjoyment for all using the area. The style of signage can help unite the area within the project bounds and may reflect the style of other signage used by the property owner; for example, signage within a park or nature reserve.

Construction specifications. Instructions for type and quality of materials chosen and methods for installation are written in the specification section. The specifications are complementary to the plans, which show the physical relationship between materials on the site. The construction specifications for a project will vary greatly from one project to the next, and it is therefore impossible to standardize them in the same way as the general conditions of a contract. Specifications are written in a uniform system for organizing and presenting them in a construction contract. The Construction Specifications Institute (CSI) and the American Institute of Architects (AIA) share the credit for the development of a standard specification format, which uses 16 divisions. However, within landscape and planting features; all 16 divisions focus instead is usually on the Site Work Division (Division #2). This can be developed into more detailed sections. For example: 020220 Excavation, filling, and grading; 02550 Site drainage; and 02800 Planting, (including soil requirements, soil amendments, mulches, etc.). One should keep wording in specifications simple and direct, and should avoid easily misunderstood words and phrases.

Monitoring plan. Monitoring of planted sites is necessary to evaluate the planting effort and determine the success of project goals (Figure 4). Vegetative monitoring is best accomplished by establishing permanent plots to record species present and percent cover in order to understand succession, survival of species, and results obtained. As the site develops, maintaining records will aid in understanding how plant communities adapt to site conditions over time. This will be beneficial to a manager in assessing what has been successful and what is cost-effective. This infomation will be valuable in making informed management decisions in the future. A manager should ask the following questions regarding the site:

- Which of the planted species germinated and grew?
- What is the overall percentage of planting survivability?
- Which plants came in from wild sources or specified plantings?
- What is the percentage of native species versus non-native exotic species?
- How are treatment techniques working on any invasive species present?

If the landscape element has been planted to meet a specific goal, such as increasing habitat for a particular animal species, parameters can be added to analyze wildlife and the desired outcome. When threatened or endangered species are present, they

need to be monitored to determine that the population is stable or increasing. If the population declines, a change in management strategy must be undertaken. The timing of the monitoring program will be dictated by the goals and factors, as stated above, and is ideally accomplished at the same time annually or biannually for a series of years. By examining overall successes and failures, one will have a better understanding of the natural processes on the site. Understanding how the plant communities function within the landscape, as a part of the ecosystem in that particular region, is also important. One can make improvements or adjustments to the methodology and maintenance practices.

Figure 4. Important measures indicating plant survivability are species composition and percent cover as part of the monitoring plan.

Seed mixes composed of a variety of grasses, sedges, and herbaceous plants, shrubs, and trees will offer plants with different life histories. Primary succession occurs when early pioneer species colonize mineral substrates or undisturbed soils. Secondary succession occurs as the dominant vegetation reclaims an area after disturbance. A project using native plant communities seeks to restore successional change at some stage and allow the community to grow and adapt. The planting plan can jump-start the succession process to allow for the development of a more diverse and healthier environment that restores function to the natural landscape.

Botanical survey information can indicate successional changes of the site over time.

Replanting may be required if there is a lack of cover (<75% total cover is a general guideline in most ecosystems). However, in arid and semi-arid lands, this will be less (25-30% is more appropriate). Succession will occur and wild plant seed will come into an area by natural means such as animals, wind, and water, to supplement the planting plan, particularly if tracts of existing vegetation were to be preserved on the site.

Project success is determined after construction. A monitoring period can record the development of the planting effort over time. Vegetative components may be more expensive up front, but cost-effectiveness must be evaluated in order to make comparisons to other alternatives. Are the design features functioning as intended? Does the site use the existing resources in an effective way? Does the project meet the needs of the client and community within budget? Stability of the physical structures can be monitored for signs of erosion occurring around buildings and pathways, or within the landscape. Repairing and re-seeding areas in failure is preferred before problem areas become more pronounced.

Maintenance

Long-term functionality and stability must be a consideration in preparing the operations and maintenance (O&M) manual for the local interest. The Corps needs to define its long-tem goals in the maintenance manual for the local cost-share partners.

Maintenance should be as low-cost and efficient, with as little energy use, as possible. Mowing and herbicide usage should not be a realistic management approach if the goal is to restore the natural function of the designed landscape. Succession would be the goal for planted areas, although there may be exceptions to this. One exception is the management and the eradication of invasive species within the project site. Careful application of a systemic herbicide by hand by a specialist who can identify the invasive plant may be acceptable. No widespread spraying of herbicides or pesticides is acceptable because the risks and ramifications to the environment are too great. However, using biocontrols or an integrated pest-management plan and prescribed fire may provide alternative solutions to manage invasive species.

Mowing a path or open spaces intended for recreation is acceptable. However, the use of low-maintenance groundcovers and seed mixes will offer cost savings and be more in keeping with shrinking maintenance budgets. There is beauty in a naturalized grass and wildflower planting, which provides for wildlife and pollinators, and offers a great opportunity to educate the public to appreciate the difference.

Sandhill Prairie Community, Minnesota

THE UNITED STATES NATIONAL VEGETATION CLASSIFICATION (USNVC) AND PLANTING TECHNIQUES

This section provides an overview of the scientific component of EWN. The purpose of this section is to understand the scientific information that currently is available on-line, as well as the methodology of the USNVC.

Natural Heritage Program administers the state databases for each state, from data collected by the USNVC survey process through the Department of Natural Resources or an equivalent state agency. Each state may organize their database in a different format; the USNVC process was used consistently to survey the botanical resources, so the state data collected are consistent. NatureServe holds these data records at: www.natureserve.org/visitlocal/index.jsp. Readers are referred to the individual state heritage plant databases for detailed information on specific plant communities.

The USNVC. Grossman et al. (1998) is currently under development by NatureServe (formerly the Association for Biodiversity Information, ABI), The Nature Conservancy (TNC), and state Natural Heritage programs, in conjunction with the Vegetation Panel of the Ecological Society of America and the Federal Geographic Data Committee. USNVC delivers a comprehensive "single-factor" approach to ecological communities based on a hierarchical classification of vegetation. The USNVC system referred to in this manual is chosen because it provides a nationally and internationally recognized system that has been peer-reviewed and is scientifically defensible.

Divisions within the upper levels of the USNVC hierarchy rely on physiognomic criteria such as vegetation structure and predominant leaf phenology. The two lowest divisions, the *alliance* and the *association*, are based on floristic criteria. The association, constituting the basic unit of inventory and biodiversity assessment, serves as a surrogate for ecological communities. The association level shares definite environmental, structural, and floristic similarities. The system level is based on a gross hydrologic regime and presently includes five divisions: the terrestrial system includes all upland (non-wetland) habitats, while the palustrine system encompasses all non-tidal wetlands dominated by woody plants and herbaceous emergents. The estuarine system includes emergent and floating /submergent tidal wetlands, extending to the upstream limits of tidal influence. The riverine system and the marine system are each represented by a single ecological group. USNVC vegetation mapping is most often done at the subclass level (Corps' Level 1 inventory) or at the more detailed formation level. Table 2 shows the how the USNVC is structured. This system is an appropriate method for managing plant resources and is also used internationally (Anderson et al. 1998). It can be used in the initial botanical survey providing a scientifically defensible baseline. During the design phase, the botanical survey information can be used as planting lists for design plans and specifications. Using the same method for monitoring the project site after construction will provide consistency, which is important in making comparisons and defining success. This is important to determine how the planted landscape project is performing after construction.

The USNVC Survey Methodology. The USNVC utilizes a form, which has been adapted by each state, to capture site, soil, and plant data in a consistent method, so as to build a cohesive database across the country. Data are obtained by using vegetative plots that record all species at all structural levels; canopy, subcanopy, shrub levels, herbaceous plants, and moss or lichen are recorded. Dominant plants within each layer of the plot

Table 2. Summary of International Vegetation Classification Hierarchy Levels and Criteria for Natural Vegetation (Anderson 1998).	
Hierarchy Level	**Criteria**
Upper:	**Physiognomy plays a predominant role**
L1 — Formation Class	Broad combinations of general dominant growth forms that are adapted to basic temperature (energy budget), moisture, and substrate/aquatic conditions.
L2 — Formation Subclass	Combinations of general dominant and diagnostic growth forms that reflect global macroclimatic factors driven primarily by latitude and continental position or that reflect overriding substrate/aquatic conditions.
L3 — Formation	Combinations of dominant and diagnostic growth forms that reflect global macroclimatic factors as modified by altitude, seasonality of precipitation, substrates, and hydrologic conditions.
Middle:	**Floristics and physiognomy play predominant roles**
L4 — Division	Combinations of dominant and diagnostic growth forms and a broad set of diagnostic plant species that reflect biogeographic differences in composition and continental differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.
L5 — Macrogroup	Combinations of moderate sets of diagnostic plant species and diagnostic growth forms that reflect biogeographic differences in composition and sub-continental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.
L6 — Group	Combinations of relatively narrow sets of diagnostic plant species (including dominants and co-dominants), broadly similar composition, and diagnostic growth forms that reflect regional mesoclimate, geology, substrates, hydrology, and disturbance regimes.
Lower:	**Floristics plays a predominant role**
L7 — Alliance	Diagnostic species, including some from the dominant growth form or layer, and moderately similar composition that reflect regional to subregional climate, substrates, hydrology, moisture/nutrient factors, and disturbance regimes.
L8 — Association Or Community	Diagnostic species, usually from multiple growth forms or layers, and more narrowly similar composition that reflect topo-edaphic climate, substrates, hydrology, and disturbance regimes.

are noted, along with the percent coverage for all species. A generic copy of this form is included at the end in Appendix A. Transects are also quite useful in recording how the vegetation and communities change over an elevation gradient. By combining these plot and transect methods and surveying various aspects, elevations, and plant communities, a complete examination of the plant resources in the area can be accomplished. These data can be shared with the Natural Heritage database system and can be entered into the Corps Operations and Maintenance Business Information Link (OMBIL) system. These surveys become the initial baseline, which is scientifically defensible for other design and planning decisions.

NatureServe Explorer is an authoritative source for information on more than 70,000 plants, animals, and ecosystems of the United States and Canada. It is a product of NatureServe and its natural heritage member programs. For species, Explorer includes particularly in-depth coverage for those species that are rare and endangered, and the database can be used to easily find: scientific and common names; conservation status; distribution maps; images for thousands of species; life histories; conservation needs; and more. The International Vegetation Classification (IVC) partners with the USNVC, currently providing detailed content for over 7000 associations and alliances found in the United States. Explorer provides access to the Ecological Systems Classification, which has been used as the map legend for both the US Geological Survey's (USGS's) National Gap Analysis Program and the LANDFIRE Project.

Sources to Obtain Native Plant Materials

A reliable, stable, and economical supply of native plants and seed is essential for planting projects. Regional availability of plant resources is of concern to anyone actively involved in planting efforts. The more obscure plants within the ecosystem are often not commercially available and quantities of available seed can vary from year to year. As the native plant industry expands, more selections become commercially available for different ecosystems; however, there are some other alternative sources and techniques that may be useful for planting purposes.

Finding sources of native and locally adapted seed and plant materials for use on federal lands can be difficult due to unavailability of many species and lack of knowledge about the cultural requirements for many native plants. This manual describes in situ and ex situ conservation strategies with examples of seed and plant applications.

Conservation Methods

Plant conservation methods and techniques, range from ex situ (off site) to in situ (on site) strategies. In addition, the combination of ex situ and in situ methods is referred to as

an inter situ strategy. These strategies are described below.

Ex situ preservation strategies include storage of propagules, seeds, and cryogenically stored tissue off site. Cryopreservation includes seeds, pollen, or tissue frozen in liquid nitrogen at -196 °C. This technique allows for storage of plant species that cannot be stored by conventional means. This method is used for the long-term storage of agricultural and horticultural taxa and is increasingly used for wild species (Guerrant et al. 2004). Specific ex situ methods are as follows:

- Seed banking is the storage of seed in low-moisture and low-temperature conditions, and is used for crop seeds and wild species.
- Tissue culture storage refers to reproductive tissue and seed propagated in vitro under light and temperature conditions controlled for slow growth (Guerrant et al. 2004). Tissue culture propagation is used for the proliferation of clonal plants and controlled seed production.
- Cultivation under a controlled environment (e.g., plants grown in an artificial environment such as a greenhouse) is yet another approach. Commercial cultivation is the production of selected taxa with a focus on profit.
- "Field gene bank" refers to an extensive planting field grown in open air, to maintain genetic diversity within a species. This method is often used for woody species.
- Community gardens refers to the production of plants by a community, family, or tribe as part of the traditional agriculture producing plants used by the group for some purpose (medicinal, food, fiber, etc.).

In situ preservation strategies maintain viable populations of wild plants in a field setting, where they are affected by the natural climatic and ecological processes. However, in situ can also include strategies such as managing wild populations; for example, hand pollinating a wild orchid population. There are also in situ managed wild populations, where wild plants growing in a managed zone are subject to community-level management, such as periodic burning, as in the case of a prairie ecosystem.

An **inter situ strategy** is the combination of ex situ and in situ techniques. An example would be utilizing plants cultivated horticulturally (ex situ) but managed in near-natural conditions (in situ), such as a managed population within restored semi-natural condition. Care should be taken to harvest both seeds and plants sustainably from wild populations. Protocols for harvesting seeds are available at the Plant Conservation Alliance Website (listed in the Bibliography).

Planting Techniques

Site preparation. When preparing an area for planting, it is critical to reduce competition from weeds before planting. Regional differences defined by temperature zones,

aspect, topographic location, and local geomorphology affect timeframes for planting windows and maintenance events. Areas can be tilled in the early spring by shallow disking every three weeks to eliminate weed competition until the area is planted. Follow up with a final disking using a field harrow to level the field and break up clods, and finish by rolling the soil to obtain a firm surface. Rolling the surface parallel to the contour provides the best protection against water erosion when the soil is unprotected by vegetation. Plant or crop residue can be left on the surface to further protect the soil from erosion. Soil tests taken from the area will provide information on fertilizer requirements. If a stand of native plants and grasses exists on the site, consider using a seed drill instead and interseeding rather than cutting the roots of existing plants, which leads to gradual thinning of the grassland (Manske 2003, 2006). Mowing the area before weedy species produce seed will also help control unwanted weed problems. Once established, the native plant community will inhibit weed growth.

Timing. The timing of planting is important and differs from region to region depending on location and type of ecosystem. Successful stands of native plant communities have been planted in the spring, summer, and fall. Most spring-blooming species germinate best when planted shortly after collection while other species do better when planted in early spring, late spring, or early summer. Most warm-season grasses, legumes, and many composites do well in late spring plantings. Planting times will vary by specific regions and the USDA temperature zones across the country. For example, in Kentucky, research has indicated that spring planting is preferred when soil temperatures reach 55 °F, and best germination occurs when soil temperatures reach 65 °F (Barnes 1998). However, in the Midwest, research indicates that fall planting may be more successful and it is increasingly being used in restoration projects in that region (Kurtz 2001). There are a number of reasons to plant in the fall, including less chance of erosion from early spring rains and less competition from weedy species. Another advantage of planting in the fall is that many seeds require cold stratification to germinate, which will occur over the winter as seeds sit dormant until the following spring. Seeding in late October and early November allows a variety of species to become established (Kurtz 2001).

Soils. Understanding site conditions will aid in determining the best plants to be incorporated in a seed mix. Managers should identify the soil type and determine if the area to be planted is wet or dry, and whether it has steep or rolling topography. There will be specific management concerns for rocky and sandy soils. To find out about the soils in a particular area, consult with the Natural Resources Conservation Service (NRCS) soil mapping database (http://www.nrce.usda.gov/wps/portal/NRCS/).

If the soil has been disturbed, many microbiotic organisms may be lost and, in many cases, the soil structure itself is permanently altered. In the event of historical land uses that have resulted in extensive disturbance, managers can only attempt to replicate a facsimile of the original flora that previously occurred on the site.

One hundred and fifty years ago, there was much more topsoil in our country's forests and grassland ecosystems. For example, the prairie ecosystem had 12-16 in. of topsoil. Prairie plants stored carbon within their long root systems, which could be as deep as 15 ft. Now, the topsoil is only 6-8 in. deep and much of the North American prairie lands have been converted to agricultural fields. Tilling has caused loss of soil to wind and water. Forest trees were much larger in diameter and height than they are now. In the United States, topsoil is being lost 10% faster than it can be replenished (McDonough and Braungart 2013). Nutrient loss is also a problem, with nitrogen and other soil nutrients being lost due to erosion processes. Topsoil is not only a valuable commodity, it may contain a viable seed bank. This valuable material should be stockpiled on a construction site until it ican be re-used. It can be properly stored by covering the pile of topsoil with a waterproof tarp to keep the seed and micro-organisms viable. After the construction process, the soil can be spread back onto the site to meet the finish grade. The seed bank can develop and be

Figure 5. Seed from many grasses and flowers can be easily gathered.

augmented by additional planting of seed mixes and plants to provide a biodiversity of plants. However, this material may also contain invasive species propagules, so monitoring the recommended plant community is recommended.

Seed Mixes and Seeds

Seed mixes can be purchased for varying light conditions and moisture and temperature regimes. The manager should consider selecting plants that grow in the local area to ensure a seed mix adapted to that particular environment. Diversity of the seed mix is also an important consideration since many plant communities are highly diverse. When planting is proposed for a local area with an existing plant community, visiting the site and taking notes on the species present and their phenology (e.g., time of flowering and seed production) is highly recommended to help with the design of specific seed mixes. In an area with distinct rain patterns, such as a monsoon season within arid lands, the plant community is adapted to the rainfall pattern of that area and the precipitation will trigger the flowering species. In areas with a more even precipitation distribution pattern, providing species that bloom throughout the growing season will support a greater diversity of wildlife and pollinators.

Seeds are a convenient means of long-term storage; they require little space, are low maintenance, and remain viable for long periods of time depending on species and storage conditions (Figure 5). In general, seeds require low temperatures and desiccation to remain viable (facilities for long-term storage can be expensive to maintain due to the necessity for germination tests, growth trails, and regeneration). The Seed of Success protocol established by the Plant Conservation Alliance (PCA) (2004) recommends care in harvesting and collecting 20% of any particular species from one place. Recommended rates for hand-collected seed depend on the species and site characteristics. For commercial seed mixes that have been tested for germination and purity, the suggested rate generally varies from 10 to 15 lb/acre. The cost for a high-diversity commercial seed mix will be higher. To increase the genetic diversity in hand-collected wild seed, collecting over a period of two seasons is recommended (Kurtz 2001).

Seed mixes are more affordable than transplanting plants when restoring a large area. For example, prairie remnants are suitable seed sources. Remnants can be found in neglected places, including old railroad rights-of-way, old cemeteries, steep areas, and wetland areas not suitable for farming or grazing. Islands in riparian corridors, and old growth forests may be good places to collect seed, due to their isolation. Another obvious place to look for plant species is on project lands slated to undergo construction, when existing native plants will be removed

in the process. Harvesting and returning seed or plants to the site for replanting after construction will reduce project costs and offer genetically diverse ecotypes adapted to the local conditions, thus increasing survivability.

Recent studies have shown the importance of genetics to restoration projects. McKay et al. (2005) identified two main concerns with respect to the genetics of the plants: (1) whether the plants will succeed or fail, and (2) whether the restored populations will be the "same" as the original populations. This involves maintaining the natural genetic structure of the species, as well as ensuring community survival and reproduction. Considerations of ecotopic variation, genetic diversity, and introgression of non-local genes into remnant populations are no longer just academic concerns, but have practical implications for field restoration practitioners (Gustafson et al. 2005).
A growing concern recognizes that the preservation of adaptive genetic variation within and among populations ensures that evolutionary potential is maintained (McKay et al. 2005). One concern is whether locally adapted, novel genotypes will succeed in new environments and how existing populations, adapted to local conditions, will be affected by the introduction of these new genes and genotypes. McKay et al. (2005) make the following recommendations for genetic restoration: (1) collect locally, if at all possible, near or on the landscape feature, and (2) match climatic and environmental conditions and plant communities between the collection site and the design sites. Finally, the idea of using more widely available "coarsely adapted" genetic mixtures that contain genetic variation necessary for further adaptive fine-tuning is a practical approach that may increase the feasibility and economic viability of the landscape features being planted in the greater landscape.

Once the species of grasses, forbs, shrubs, and trees have been chosen for the mix, seeds can be collected or purchased. Hand-gathered seed sources can include collecting local ecotypes that naturally evolved at the site or as close to the project site as possible. Seed that is gathered farther away may be acceptable if there is nothing available closer. However, seed collected from different soil types or climatic regions may have lower survival rates than local seed. Harvested seed can be also be added to commercially purchased seed. Native grass seed is often sold pre-mixed, but it is recommended that individual species lots be purchased and mixed together prior to planting; this will result in the desired mix using the best quality seed. Mixing small quantities of seed is most easily done in a 5-gal bucket or, for larger amounts, on a clean smooth concrete floor, using grain scoops to turn the seed pile. It is easier to keep smooth seeds together in one mix separated from fluffy seed; they can be planted in the same area using different seeding rates.

For purchased seed, using certified seed is recommended because the seed has a known identity and meets certified quality standards for purity and germination (NRCS 2006). This has the best chance of success and the least chance of introducing unwanted seed problems. Varieties of seed have been developed and proven by the NRCS for specific geographic regions of the country. Native grass seed (and often wildflower seed) is sold on a pure live seed (PLS) basis and is recommended because it ensures that the desired product is what is being paid for, and protects against procurement of dead seed or unwanted plant pieces. A pound of pure live seed contains 16 ounces of living seed of the desired species plus additional weight of the other material that has not been removed by the cleaning processes. Using the seed analysis tag, the PLS can be calculated to compare quality of "lots" of seed (NRCS 2006). For example, a seed lot that has a tested germination of 80% and a purity of 90% also has a PLS percentage of 72 (0.80 x 0.90 = 0.72). In 1.0 PLS pound of this seed lot, the gross weight to buy and plant would be 1.39 lb (1.00 divided by 0.72) (NRCS 2006).

Ratios of forbs to grasses will vary in commercial seed mixes; typical mixes include ratios of 50/50 or 60/40 and 66/33 forb/grass seed. The more diverse the seed mix (number of species within the mix), the more stable the planting will become over the long term. For purchased seed, it is better to buy a grass mix and a forb mix separately and create your

own mix to ensure that you acquire the most desired species. If legumes (in nitrogen-fixing plants) are used in the herbaceous plant mix, make certain that the appropriate inoculant is included with the seed.

Seed harvested from native stands may vary considerably from one season to the next in quantity, quality and species diversity. To increase diversity in the planting, it is recommended that the manager use seed that is harvested in two different years (Kurtz 2001). Once gathered, the seed needs to be dried, threshed, separated from the heads, and properly cleaned and stored. Seed should be dried shortly after harvesting to prevent loss during storage. Properly dried seeds have a 5-14% moisture content during storage (Harrington 1972). When seeds are dried out below 5% their cell walls break down and enzymes become inactive, and seeds with a moisture content from 14-30% are often lost to microorganisms and fungi. Moisture levels above 30% will induce germination (Apfelbaum et al. 1997). Seeds often need treatments replicating natural processes to germinate well. Interseeding an area already planted or partially established during the following year will increase the diversity of the planting, because some species do not grow well in an open seedbed. Seeding rates are variable and depend on the species composition of the mix. If the seed is purchased, recommendations are generally provided for the mix. For hand-collected seed, a general guideline for the seeding rate is 10 pounds of clean, pure seed per acre and may be as high as 30 lb per acre for rough, clean, hand-collected seed (Diboll 1997). The rate will vary depending on the species chosen.

Depending on the composition, it can take a number of years for the mix to develop into a mature native plant community, and it will constantly change throughout its development process. Plants do well in soil with a topsoil layer and are able to grow tall and lush once established. However, competition from weeds is greater in more fertile soils and will make the initial establishment more difficult.

Seed Treatments

Various seed treatments may be necessary for proper germination. Treatments include sowing fresh seed, cold-moist stratification, warm-moist stratification, cold-dry stratification, inoculation, scarification, light treatment, and vegetative propagation. Treatment methods are briefly described below:

a. Sowing fresh seed works well for most spring flowering species. Seeds can be sown in flats to be set out when they have developed.

b. Cold-moist stratification can be accomplished by mixing seed with damp sand or vermiculite. The mixture is placed in a plastic bag and put into a refrigerator where the temperature is 34-40°F. Species differ on how much time they need to be stratified; some will require 10 days, while others will require 120 days, but for most species 60-90 days is typical (Kurtz 2001). Once the treatment is achieved, planting should take place in mid-spring when the outdoor temperature is warming up. Species that require stratification can also be sown directly outside in the fall.

c. Cold-dry stratification requires that dry seed be placed in a plastic bag and put into cold storage for a period of time.

d. Warm-moist stratification can be done by mixing seed with damp sand or vermiculite, then placing the seed in a plastic bag and warming it to 68-75°F.

e. Scarification is the process of physically breaking down seed coats, so the plant embryo can take up water and begin to grow. Seeds can be scarified with a piece of sandpaper or by soaking in acid baths, which mimics the natural process of being eaten by an animal and broken down within the digestive system.

f. Inoculation of legumes with nitrogen-fixing bacteria enhances growth (bacteria is applied to wet seed just before it is planted (Steffen 1997)). Full sunlight is needed for some seeds that require light to break dormancy and these species can be sown on the surface of a firm smooth seedbed. Some plant species have complex propagation requirements; for them, the above techniques must be combined in a particular pattern.

g. Vegetative reproduction is the process of dividing roots and planting pieces of the parent plant to create other individuals.

Interseeding. Interseeding refers to the process of planting seed directly into existing vegetation without plowing or herbiciding. This method is preferred where there are many conservation species in an area to be preserved and can serve to increase diversity in the planting. Compared to plowing, plant establishment by overseeding takes considerably longer because of competition from existing plants. A seed mix will develop slowly over 4-5 years when a site is interseeded. A recommended approach for restoring a degraded fire-dependant ecosystem (such as a prairie or long-leaf pine forest) consists of conducting prescribed burns followed by interseeding with an appropriate seed mix (Kurtz 2001). For the Corps' controlled fire management practices, refer to the fire regulations ER, ER 1130-2-540 (http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1130-2-540.pdf) (Corps Lakes Gateway 2005). The primary benefits of interseeding include the relative ease with which many conservation species are restored, improvement in site quality, and the potential contribution to biodiversity conservation (Packard and Mutel 1997).

Mosaic seeding. This technique involves various seeding rates and species mixes for different sites within the restoration

Long Leaf Pine Community, North Carolina

area. It allows for adjusting the planting to correspond to topography and the plant community continuum found along moisture and slope gradients. Additionally, mosaic seeding can be used to increase botanical diversity. For example, planting more forbs in an area may allow species to survive that will not compete well with grasses. Planting in this manner allows for edge unevenness or patches to develop, which mimics a natural site and increases different types of habitat, resulting in greater faunal diversity.

Planting

A no-till drill specifically designed for seeding the fluffy seeds characteristic of native grasses is recommended for areas already established with plant communities (Figure 6). Native grass drills have double disk openers with depth bands and large-diameter drop tubes that don't allow seed to hang up in the tubes (NRCS 2006). Planting the seed at the proper depth is critical for success. Proper seeding depth is ¼ in. to ½ in. maximum (NRCS 2006); it is better to place the seed on the surface of the ground than for seed to be buried too deep. Conventional drills do not have depth bands or feed mechanisms that can handle fluffy seed. Cultipacker type seeders will not meter the fluffy seeds and are not as effective in proper seed placement (NRCS 2006). Soil and Water Conservation Districts rent these drills. A three-point broadcast seeder or a fertilizer spreader can be used and will cover a 6-ft-wide strip. Care should be taken to ensure that the seed is spread uniformly. Once the seed is broadcast or drilled, the site should be harrowed lightly and rolled until the soil is firm; this will prevent the soil from washing away. A less favorable practice is disking the soil because it cuts the root biomass, causing a flush of growth. Then, eventual thinning of the above ground growth opens up the soil to weedy annuals (Manske 2006).

Invasive Species Control

Invasive species are also a concern in planting, maintenance, and management efforts. Executive Order 13112, signed by President Clinton on 3 February 1999, contains policy to prevent the introduction of invasive species, provide for their control, and minimize the economic, ecological, and human health impacts that invasive species cause. The executive order established the National Invasive Species Council (Federal Register 1999). Currently, there are 12 federal agencies on the council. The ramification of this executive order is support in the use of native plant species on federal land. Invasive species are tracked through the Corps' OMBIL process. For the Corps' regulations refer to http://corpslakes.usace.army.mil/employees/policydfm?Id=invasives&Code=All.

Control of invasive species is critical for any type of planting work. Control methods include herbicide application, mowing, brush hogging, use of tree shears, burning, biocontrol, and grazing. If the area to be restored is covered by an invasive species, control of existing stands using applications of an appropriate herbicide should be the first step. Establishing a native planting may require ongoing surveillance and control of the invasive species. The ability to respond quickly, thus eradicating annual weeds before they go to seed, can make a significant contribution to invasive plant control.

During the first year of establishment, plants primarily develop roots and above ground growth is short. By contrast, weeds grow fast and tall in the first year; thus, mowing during this period will help the plants compete for light. However, it is important to set the mower at the correct height, above the top of the seedlings. Setting mower decks to low and scalping the ground with the blade will cause bare spots which open up the soil to erosion. Systemic herbicide treatments can be applied directly to unwanted herbaceous plant leaves or cut stems of brush and invading trees. Most common agricultural weeds that occur in a new planting will become reduced as the grasses and forbs develop.

Figure 6. A no-till drill is used for planting and interseeding an area, and causes minimal disturbance to existing plants (*photo courtesy of Kurt Brownell*).

Tropical Forest Community, Hawaii

CASE STUDIES OF IMPLEMENTED DESIGNS

Each of the chosen design elements will be exemplified by case studies and designs that relate biological, engineering, and socio-economic attributes to each other. The examples chosen provide cost-effective and ecologically sustainable solutions. Examples were taken from projects across the country in multiple ecosystems. Design elements included:

- Climate Control – Sun, Shade, Windbreaks and Energy Conservation
- Reduction in Stormwater Runoff
- Planting that Stabilizes Soil and Slopes
  - Bioengineering or biotechnical planting
  - Geocells and geogrids with plants
- Riparian Corridors, Greenways, and Buffers
- Riparian Corridors versus Buffer Strips
  - Riparian corridors
  - Buffer strips
- Green Infrastructure and Self-sustaining Plantings for Water Conservation in the Environment
  - Permeable Pavements
  - Bioretention Features or Rain Gardens
  - Constructed Wetlands
- Wetland Treatment Using Native Wetland Plants to Filter Discharge
- Native Plantings for Recreation and Aesthetic Enhancement
- Habitat Creation for Pollinators
- Dredged Material Plantings
- Phytoremediation and Reclamation
  - Onondaga Lake
  - Geddes Brook Wetland and Ninemile Creek
- Carbon Sequestration
- Living Shorelines and Nature-Based Protection from Storm Surge
- Plantings for Establishing Aquatic Habitat

Climate Control – Sun, Shade, Wind-breaks and Energy Conservation

iTree is a program produced by David Nowak, a research forester with the U.S. Forest Service. Anyone from urban planners and designers to citizens can enter data into iTree to see what a particular tree contributes to reducing heating and cooling costs, pollution removal, and carbon storage. This program can be scaled up to do this for an urban forest or woodland. For example, the ecosystem services provided by street trees in Minneapolis eauate to a value of $15.7 million per year. At some point, iTree will be able to project future conditions; for example, incorporating future climate conditions and how they will shift the distribution of particular species (DeWeerdt 2013) (http://www.iTreeTools.org).

Reduce Stormwater Runoff

CITYgreen uses the TR-55 model developed by the US Natural Resource Conservation Service (NRCS), which is very effective in evaluating the effects of land cover/land use changes and conservation practices on stormwater runoff. Trees decrease total stormwater volume, helping cities to manage their stormwater and decrease detention costs. CITYgreen assesses how land cover, soil type, and precipitation affect stormwater runoff volume. It calculates the volume of runoff in a 2-year, 24-hr storm event that would need to be contained by stormwater facilities if the trees were removed. This volume multiplied by local construction costs calculates the dollars saved by the tree canopy. For more information go to http://www.Americanforests.org and http://www.davidsuzuki.org.

Planting to Stabilize Soil and Slopes

The Corps, the Agricultural Research Service (ARS), and others including Gray and Leiser (1989), Gray and Sotir (1996), Allen (1992-2002), Shields (1981-2008), and Pollen and Simon (2005) have accumulated a large body of work and research in this area.

Bioengineering, also known as biotechnical planting, utilizes plants in specifically designed features to retain earth and prevent soil loss. This method can be used with plants as the main component or in combination with other earth-retaining structures to create attractive, cost-effective, and environmentally compatible solutions to slope stability. Both biological and structural elements must function together in an integrated and complementary manner. This can be an effective tool for projects on waterways and slopes. Biotechnical slope protection systems are generally more labor-skill intensive than energy-capital intensive, allowing them to be useful in projects that have limited funding. These treatments can be composed of a mix of plants that are components of riparian plant communities and appropriate to the site. Biotechnical structures are used in landscape projects to stabilize the channel or shorelines, and to improve habitat. Structures that prevent degradation are often needed. Many techniques and structure types can be employed to achieve these objectives. It is important to select the techniques that best meet the project's structural requirement (Table 3), site conditions (Table 4), in combination with plants that are locally available in the environment.

Bioengineering and biotechnical planting. Plants are chosen for their ability to produce adventitious roots that can become established relatively quickly to provide a root mat that holds the earth together and prevents erosion. Appropriate riparian vegetation can often be obtained from local stands of species such as willow, alder, dogwood, and others. This stock is already well adapted to the climate, soil conditions, and available moisture in the area, and will therefore have greater survivability. Details illustrating bioengineering techniques using plants are shown in Figures 7, 8, and 9 (Gray and Sotir 1996), and in Figure 10 adapted from Baker (2008).

Table 3. Classification of Slope Protection and Erosion Control Measures.

Category	Examples
Conventional planting	Grass seeding Sodding Transplants
Woody plants used as reinforcements and barriers to water and soil movement	Live staking Live fascines Brushlayering Branchpacking Revetments with slope face plantings Tiered structure with bench plantings
Woody plants grown in openings or interstices of retaining structure	Live crib walls Vegetated rock gabions Vegetated geogrid walls Vegetated breast walls
Conventional structures not using plants	

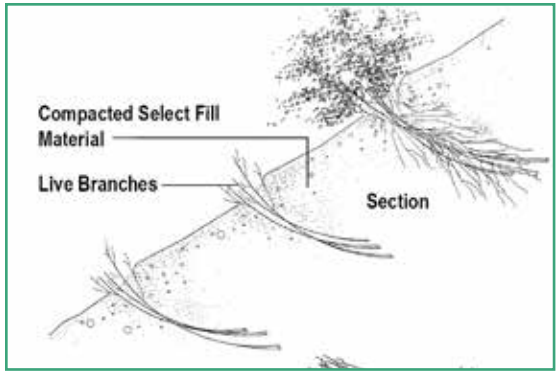


Figure 7. Branch layering technique (Gray and Sotir 1996).

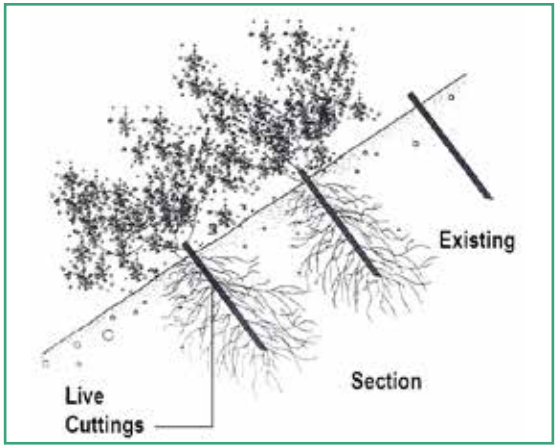


Figure 8. Livestaking for a slope or shoreline (Gray and Sotir 1996).

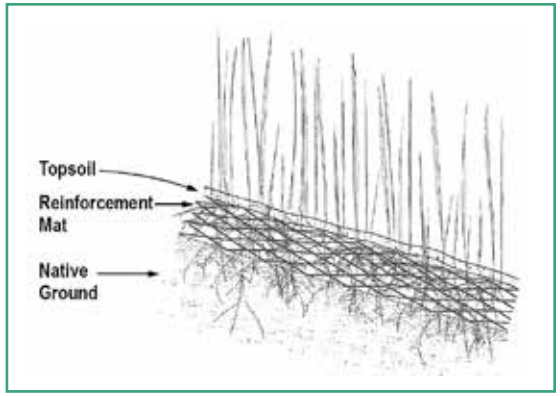


Figure 9. Turf reinforcement mat (TRM) with vegetation growing in it (Gray and Sotir 1996).

Figure 10. Conceptual and installation details for an anchored reinforced vegetated system, showing a rolled high-performance turf reinforcement mat fixed in place with percussion-driven anchors, and vegetated with hydroseed. Holes were cut in HPTRM for existing tree seedlings (Baker 2008).

Table 4. Suitability of Different Soil Bioengineering Methods Based on Soil and Site Conditions (from Gray and Sotir 1996).

Factor or Failure Process	Intensity or Type of Condition	Soil Bioengineering Methods						
		Live Staking	Live Fascine	Bush-Layering	Branch-Packing	Live Crib Wall	Live Slope Grating	Vegetated Geogrid or Geocell
Slope gradient	Steep		X	X	N/A	X	X	X
	Moderate		X	X	N/A	X	X	X
	Gentle	X	X		N/A	X		
Slope height	High	X	X	X	N/A		X	X
	Low	X	X	X	N/A	X	X	X
Soil depth	Deep	X	X	X	X	N/A	N/A	X
	Shallow	X	X			N/A	N/A	
Soil erodibility	High		X			N/A	X	X
	Moderate	X	X	X		N/A	X	X
	Low	N/A	X	X	X	N/A	X	X
Soil strength	Moderate	X	X	X	N/A	N/A	N/A	N/A
	Low	X	X	X	N/A	N/A	N/A	N/A
Slope type	Cut	X	X	X	X		X	
	Fill	X	X	X	X	X		X
Superficial erosion		X	X	X	X		X	
Mass movement	Shallow	X	X	X	X	X		
	Moderate			X				X

N/A = Not applicable.

Geocells and geogrids. An example of using geocell material with plants is shown in Figures 11 and 12. The roadway in these figures uses geogrid cells filled with gravel for the roadbed. However, the roadbed is also constructed on top of geogrid, which is a structural component holding a steep side slope in place on the down-hill side of the road shoulder (Figure 11). The black geogrid cells can be seen in the closeup view (Figure 12) with an assortment of plants growing from local seed recruitment within the wells.

Figure 11. Roadbed constructed with geocell at Cunard, a National Park Service boat launch on the New River, West Virginia.

Figure 12. Planted geocell stabilizing the same road on the steep down-hill road shoulder.

Figure 13. Existing conditions at Site #1 of the proposed biotechnical planting at El Dorado Lake. Note bank retreat landward of existing willows.

Figure 14. On-site harvesting of all native plants to be used in the bioengineering project and workshop at El Dorado Lake, Kansas.

An example of a biotechnical planting project occurred at a workshop held at El Dorado Lake in Kansas. The sponsor of the workshop was the Tulsa District and several local groups volunteered to assist in the project. The first goal of this project was to arrest the erosion of the lakeshore. The shoreline retreat in some years was up to 20 linear feet of shore from the water's edge, caused by erosion from wind fetch and wave action across the lake (Figure 13). The second goal was to demonstrate and install a number of different treatments using a large number of volunteers who learned the treatment methods. Four native tree species and several shrub species were harvested from different locations on the lakeshore, prepared and planted in several days in early March, while the plants were still dormant (Figure 14).

Treatment recommendations consisted of a breakwater constructed 15 ft from shore, which continued parallel to the shoreline in a smooth line to reduce the wave energy. A continuous breakwater could be broken so as to allow limited access to the shore and would serve to control shoreline boating impacts. Sprigging behind the breakwater with Water Willow, *Justicia americana* and Soft Rush, *Juncus effuses* landward also increased emergent plant biodiversity. Several different treatments were used for different reaches within the project. One reach consisted of a series of willow live fascine bundles starting at the land/water contact point for the winter pool, and cut back the slope to a 2H:1V slope,

and continuing with the fascine bundles planted parallel every 4 ft up the shoreline (Figure 15). Another treatment discussed and implemented was a brush mattress, which was livestaked into place with segments of the woody species as described by Allen and Fischenich (2000). The third treatment was brush layering, which utilizes willows placed perpendicularly into the bank, instead of parallel (Figure 16). Combinations of plants within the shoreline treatments consisted of Buttonbush, *Cephalanthus occidentalis*; Black Willow, *Salix nigra;* Sycamore, *Platanus occidentalis*; and Cottonwood, *Populus deltoides*. Other species available on the lake that were used were Alder species, *Alnus spp.*; Rough Dogwood, *Cornus drummondii;* and Boxelder, *Acer negundo*. These were good species to plant at a slightly higher elevation because they mimic the plant zonation that occurs naturally.

Figure 17 is a photo taken in the fall of the same year, after plant establishment. The water level in the lake dropped to expose the cedar breakwater. The breakwater was removed, having served its purpose to dissipate the wave energy and protect the new plantings. Water level fluctuations at flood control reservoirs can vary greatly, so attention to this is critical for a successful project.

Figure 15. Willow bundles being placed in four trenches running parallel to the shore. Cedar trees were staked offshore as a breakwater to dissipate wave energy before reaching the newly planted shoreline.

Figure 16. Brush layering, which utilizes willows placed perpendicularly into the bank (instead of parallel), being implemented at El Dorado Lake, Kansas.

Figure 17. New plants sprouting from shoreline treatments 6 months after planting at El Dorado Lake.

Riparian Corridors, Greenways, and Buffers

Riparian corridors and greenways are linear strips of vegetation adjacent to streams and rivers. A greenway can be a vegetated strip along any corridor or protected open space linking one area to another spatially. This linkage can be an important design feature for human use, and is even more critical for wildlife. In an urban stream restoration, the greenway serves different functions, such as protecting water quality by acting as a filter strip, protecting streambanks from erosion, enhancing wildlife habitats, and creating a movement and dispersal corridor. Greenways can play critical long-term roles as floodways. Linking the stream restoration project to a park or other natural area, connecting it to a network of greenways, or reconnecting areas of fragmented habitat, all maximize the potential of the greenway for wildlife usage. It can also provide opportunities for various recreational activities by creating walking or biking trails. Greenways enhance the human communities of which they are a part, enriching the quality of life by providing recreational opportunities, improving aesthetics, and increasing property values.

In a sustainable design, a limited amount of land may be available for the width of the greenway on both sides of the stream and existing incursions of conflicting land uses along the linear run of the project. However, the designer can utilize the principles and elements of design and plant communities to create plans that compensate for disturbances and look for opportunities to make linkages. Generally, the greenway should be a combination of native herbaceous plants, shrubs, and trees. Using a diversity of plants that would naturally occur in a specific native plant community is desirable. A healthy environment is usually the one with the greatest diversity of plant and animal life. One or more diverse plant communities that accommodate differing site conditions, aspects, and elevations can allow for the creation of various habitats and provide diversity. Market research indicates that the value of real estate lots where buffers were present is often 5% or more higher than the value of lots with no buffers present (Palone and Todd 1997).

Riparian Corridors Versus Buffer Strips

Riparian zones occur as transitional areas between aquatic and upland terrestrial habitats. Although not all riparian zones are well-defined, they generally can be described as long linear strips of vegetation adjacent to streams, rivers, lakes, reservoirs, and other inland aquatic systems that affect or are affected by the presence of water. Riparian zones typically comprise a small percentage of landscape, often less than 1%, yet they frequently harbor a disproportionately high number of wildlife species and perform a disparate number of ecological functions when compared to most upland habitats (Fischer and Fischenich 2000). Unfortunately, many riparian zones in North America do not function properly (e.g., they are degraded to the point where they do not protect water quality or provide the resources needed to make them suitable as wildlife habitat or as migration corridors). This degradation also negatively affects many of the other important functions and values these landscape features provide.

What is the difference between buffer strips and corridors? Riparian zones are most commonly referred to as vegetated buffer strips (e.g., riparian buffer strips) or as wildlife movement corridors (e.g., riparian corridors). These titles relate to the recognized purpose of the riparian zones are defined below.

Riparian buffers. A riparian buffer is a strip of vegetation that connects two or more larger patches of vegetation (i.e., habitat), and through which an organism will likely move over time (Figure 18). These landscape features are often referred to as "conservation corridors," "wildlife corridors," and "dispersal corridors." Some scientists have suggested that corridors are a critical tool for reconnecting fragmented habitat "islands." Multiple benefits from planting riparian corridors include:

- Stabilize shoreline by increasing soil holding capacity of plant roots

- Filtration of nutrients and chemicals from runoff from adjacent agriculture and other land uses
- Slows runoff times into stream or river channel
- Can provide for high water storage throughout the system
- Timing of native plant growth closely related to water events in an ecosystem
- Provide cover, habitat, and food for wildlife
- Provide a migratory route for animals, birds, plants, and pollinators
- Provide air drainage along the change of gradient allowing for cooler temperatures

Buffer strip. A buffer strip islinear band of permanent vegetation adjacent to an aquatic ecosystem intended to maintain or improve water quality by trapping and removing various nonpoint source pollutants (NPSP) e.g., contaminants from herbicides and pesticides; nutrients from fertilizers; and sediment from upland soils) from both overland and shallow subsurface flow. Buffer strips occur in a variety of forms, including herbaceous or grassy buffers, grassed waterways, or forested riparian buffer strips. A buffer strip may provide habitat for a variety of plants and animals if sufficient land area is retained to meet the life-history needs of those species. Buffer strips may also function as movement corridors if they provide suitable connections between larger blocks of habitat.

Figure 18. Riparian corridor with native plant communities.

Figure 19. Eroded areas were repaired before planting the drainage channel with native trees, shrub, and the seed mix.

Figure 20. Tree establishment after two growing seasons within the buffer strip at Dyess Air Force Base.

An example of a buffer strip project using a native shrub and tree plantings was completed at Dyess Air Force Base in Abilene Texas. Abilene receives approximately 10-14 in. of rainfall per year. This project had several goals. Dyess staff wanted to improve the water quality of drainage water within ditches intercepted from buildings, roads, and runways. Another goal was to create a native habitat to pull birds of prey away from the flight line, in an effort to eliminate bird/jet collisions. A third goal was to reduce mowing and maintenance within the project bounds. This project included a research component examining the use of hydrophilic compounds in the establishment of native plantings with and without irrigation. Eight species of native tree and shrub species were determined to be appropriate for the area. The trees were planted in rows from the bottom to the top of the drainage channel and are ordered as such in the following list: Eastern Cottonwood, *Populus deltoids*; Black Willow, *Salix nigra*; Texas Walnut, *Juglans microcarpa*; Pecan, *Carya illinoinensis*; Netleaf Hackberry, *Celtis riticulata*; Chickasaw Plum, *Prunus angustifoia*; Western Soapberry, *Sapindus drummondii*; and Plateau Live Oak, *Quercus fusiformus*. Plants, acquired from an NRCS Plant Material Center, were planted on site over two growing seasons in 2005 and 2006.

Existing plants were left on the slope due to the high number of native grasses and herbaceous plants along the drainage ditch. The following seed mix was inter-planted with a tractor and seed drill. This approach controlled soil erosion, and intercepted and absorb sediments and particulate pollutants from surface runoff. The strip width extended to the top of bank. In some areas, erosion gullies were repaired and planted with the seed mix and tree planting (Figure 19). Some of the grass species took several years to become established, and to grow up through the existing vegetation. Green sprangletop (*Leptochloa dubia*), for example, affords temporary cover until other perennial grasses become established. The seeding rate of 18.78 lb/acre was recommended for “normal-use” areas such as those not receiving much traffic. Figure 20 shows plant establishment of cottonwoods and willows on the stream.

Green Infrastructure and Self-sustaining Plantings for Water Conservation in the Environment

Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier environments. Green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, and clean air and water at various scales. At the national or regional level, interconnected networks of park systems and wildlife corridors preserve ecological function, manage water, provide wildlife habitat, and create a balance between built and natural environments. At the urban level, parks and urban forestry are central to reducing energy usage costs and creating clean, temperate air. Lastly, green roofs, walls, and other techniques within or on buildings bring a range of benefits, including reduced energy consumption and dramatically decreased stormwater runoff. At all scales, green infrastructure provides real ecological, economic, and social benefits.

For more information, go to http://water.epa.gov/infrastructure/greeninfrastructure, or http://www.asla.org/greeninfrastructure.aspx.

There are a number of features that offer stormwater retention, water conservation, sediment reduction, and filtering. Small to large stormwater features include permeable pavement, wet swales, bioretention areas, extended detention ponds, and wetlands. Their estimated costs are summarized in Table 5.

Permeable pavements are alternatives to impervious pavement systems. These systems allow stormwater to pass through voids within the pavement surface into an underlying stone reservoir where the water is temporarily stored or filtered and slowly released into the surrounding soil. The design is determined by a structural design analysis, which supports traffic loads. Permeable pavement is typically designed to treat stormwater that falls on the actual pavement surface area, but it may also be used to accept run-off from small adjacent impervious areas, such as impermeable driving lanes or rooftops. However, careful sediment control is needed for any run-on areas to avoid clogging of the down-gradient permeable pavement.

Table 5. Summary of Estimated Costs per Impervious Acre Treated for Selected Stormwater Treatments.[1]

Selected Treatment	Pre-Construction Costs[2]	Construction Costs[3]	Post-Construction Costs[4]	Average Annual Costs over 20 Years[5]
Wet Swale	$12,000	$30,000	$931	$3,031
Bioretention (suburban)	$9,375	$37,500	$1,531	$3,875
Bioretention (urban)	$52,500	$131,250	$1,530	$10,718
Extended Detention Ponds (new)	$9,000	$30,000	$1,231	$3,181
Infiltration Practices w/o sand, vegetation (new)	$16,700	$41,750	$866	$3,788
Wet Ponds and Wetlands (3 acres treated)	$5,565	$18,550	$763	$1,969

[1] Adapted from: Draft Final Report (October 10, 2011), " Costs of Stormwater Management Practices in Maryland Counties;" Dennis King and Patrick Hagan; University of Maryland Center for Environmental Sciences.
[2] Includes cost of site discovery, surveying, design, planning, permitting, etc.
[3] Includes capital, labor, material, and overhead costs, but not land costs.
[4] Combined annual operating, implementation, and maintenance costs.
[5] Does not account for developable land use opportunity costs.

Figure 21. Gravel filled geogrid parking area at the National Park Service Headquarters in Glen Jean, West Virginia.

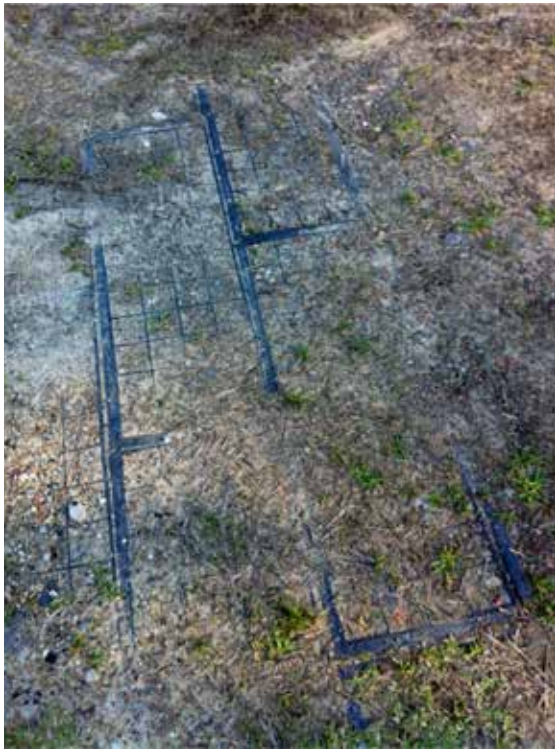


Figure 22. Detail of geogrid.

Permeable pavement has been used at commercial, institutional, and residential sites in spaces that are traditionally impervious. Permeable pavement promotes a high degree of runoff volume reduction and nutrient removal, and it can also reduce the effective impervious cover of a development site.

Designers should evaluate existing soil properties during initial site layout, according to NRCS soil surveys and soil mapping. The structural design of permeable pavements involves consideration of four main site elements:

- Total traffic
- In situ soil strength
- Environmental elements
- Bedding and reservoir layer design

These pavements can be planted with a grass seed mix and maintained by mowing. They can be used in naturalized areas and native plants could be planted around the perimeter of the parking area.

Figure 21 is a small overflow parking lot at the National Park Service, New River Gorge National River Headquarters in Glen Jean, West Virginia. The lot is designated by wood bollards around the perimeter. The surrounding native trees were left in place to provide shade for parked vehicles. The geotextile grid is filled with gravel and compacted (Figure 22) so the bearing capacity is much stonger than compacted gravel alone. This parking lot is approximately 20 years old and is relatively inexpensive compared to pavement.

Wet swales are a linear feature that provide runoff filtering and treatment by planting wetland plant communities that intercept runoff and shallow groundwater (typically less than 6 in. deep). The saturated soil and wetland vegetation provide an ideal environment for biological uptake, microbial activity, and gravitational settling of suspended sediments within water inputs to the system. These features link to other features within the natural or built environment, such as natural or manmade ponds, bioretention feature, and wetlands, etc.

Bioretention features or rain gardens are small water quality treatment channels or ponds used to capture and treat stormwater runoff from discrete impervious areas (e.g., less than 1-acre). These practices typically include natural systems, vegetation, and soils and may be interconnected to create a more natural drainage system (Figure 23). However, the design variants can be distributed throughout a project to provide stormwater management at the source unlike their structural relatives that are typically used as "end-of-pipe" treatment for larger drainage areas. The primary component is the 3-ft to 4-ft filter bed, composed of a mixture of sand, soil, and organic material, which is the planting medium for the wetland plant community. During storms, the runoff temporarily ponds at 6-12 in. above the bioretention soil medium. The plants will take up some of the water, but most will be stored in the gravel underdrain, which serves as a sump. A geotextile filter fabric placed between the layer of the bioretention soil medium and the gravel is necessary to filter fines from the gravel sump, below which a perforated pipe can aid in the transport of water into a larger water feature. The gravel sump will store water until it is slowly released into the undisturbed soil, promoting greater groundwater recharge.

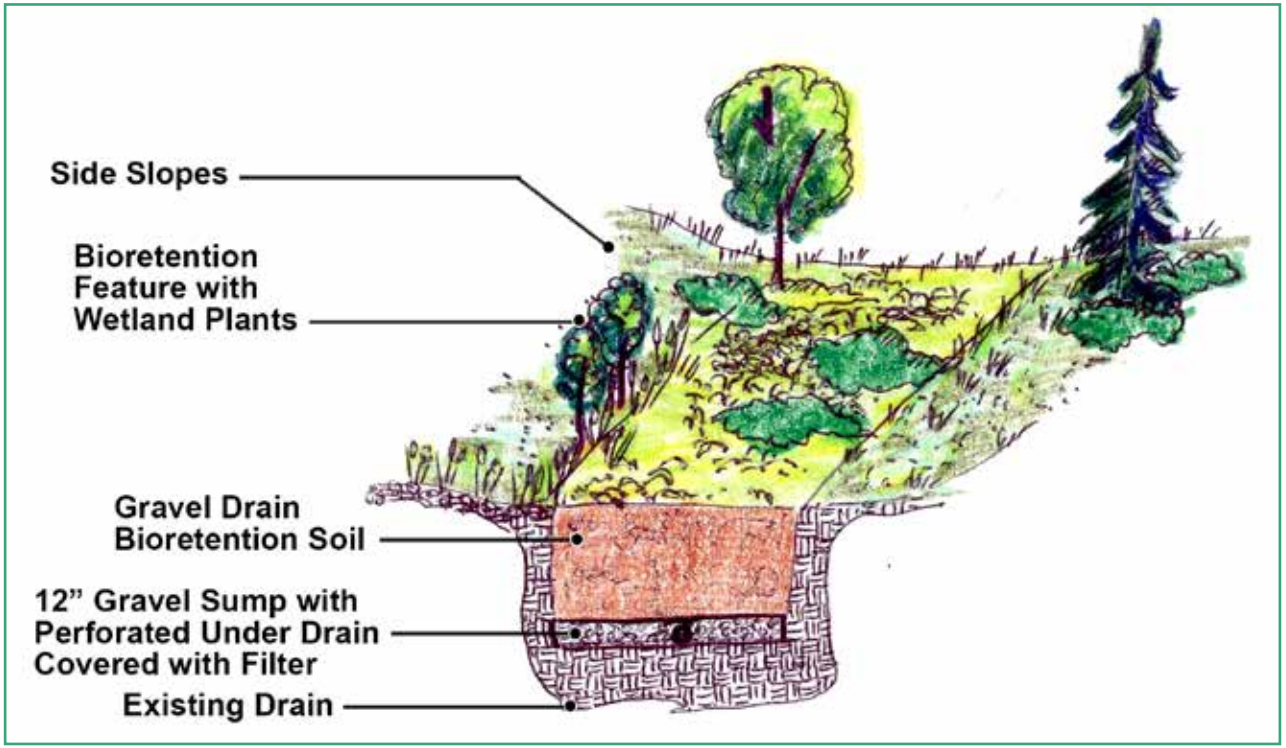


Figure 23. Bioretention drainage detail.

Figure 24. Constructed wetland at Winfield, West Virginia.

Constructed wetlands are water impoundment structures that intercept stormwater run-off and then release it to an open-water system at a specified flow rate. These structures retain a permanent pool and usually have retention times sufficient to allow settlement of some portion of the intercepted sediments and attached nutrients/toxics. Wetlands are typically less than several feet deep and possess variable microtopography to promote dense and diverse wetland plant cover. Runoff from each new storm displaces runoff from previous storms, and the long residence time allows multiple pollutant removal processes to operate. The wetland environment provides an ideal environment for gravitational settling, biological uptake, and microbial activity. Designs can be composed of a series of wetland cells, which provide extended filtering and settling time for wetlands constructed for water quality issues. They can also be considered for use if there is a significant water volume to manage. The Corps has a long history of wetland creation and construction with many fine examples of wetland creation using dredged materials; (Landin et al. 1992), for restoration (Landon 1995), and wetlands as mitigation features (Landin et al. 1992), and wetlands designed by Bailey at Winfield, R.C. Byrd, and Marmet.

A constructed mitigation wetland at Winfield, West Virginia (Figure 24) uses a native riparian plant community, to support a large number of avian species. This wetland was designed and constructed in 2004 as a part of the mitigation package for the Winfield Lock Enlargement Project on the Kanawha River. Tree species that were planted on the wetland shoreline are also found in the wooded riparian area in the background. The native grasses, herbaceous plants, and wetland shrubs were planted from a combination of seed mixes and plants. The wetland shrubs were planted from livestake cuttings from other wetlands in near proximity to this area. This area is monitored by a local birding club, which has maintained records of avian species since the wetland was planted.

Another example of a constructed wetland on a stream occurs at Marmet, West Virginia. This wetland was also part of the mitigation for a larger lock and dam replacement project

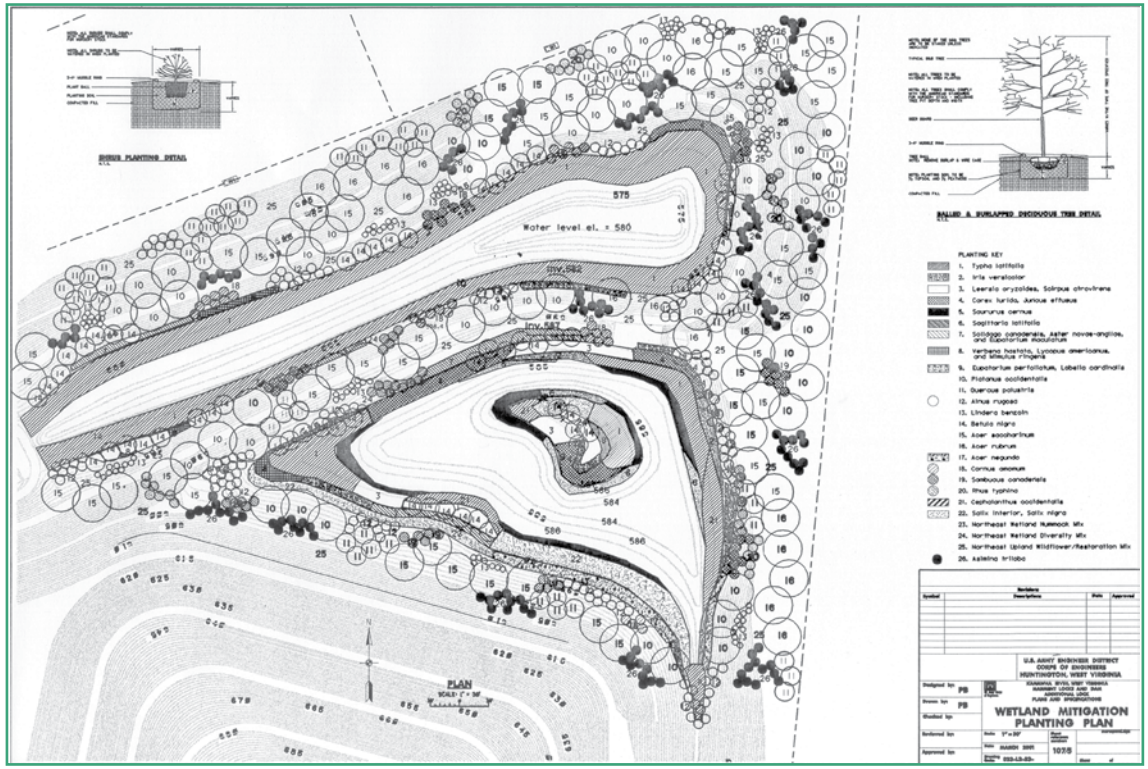


Figure 25. The wetland mitigation planting plan at Marmet, West Virginia. Plan by Pamela Bailey.

(Figure 25). All plantings were to be native trees, shrubs, and seed mixes composed of grasses and herbaceous plants. Initial botanical surveys indicated which species were present and dominant plant species. A plant rescue was undertaken before construction started at Marmet (described on page 66).

An important aspect of this project was that some of the dominant tree and shrub species were also harvested on site as young seedlings and grown at the Alderson Plant Material Center. At the end of the construction phase at Marmet, these plants were returned and planted on the newly constructed landforms on site. The plants that the Plant Material Center grew were not commercially available on the market at the time this project was implemented. Re-introduction of the original genetic diversity of plant stock back onto the project site occurred instead of buying monoculture plant stock from a nursery. These plantings were a cost-effective alternative to planting the site with nursery-available species. A wetland was constructed on the Burning Springs Branch, a small stream that intersects the site (Figure 26).

Figure 26. Constructed wetland conveying the Burning Springs Branch originating from the hills pictured in the background to the Kanawha River at Marmet (2013).

Figure 27. Treatment wetland septic system at the Plant Material Center in Alderson, West Virginia. In the background, the office building is visible to the left and a greenhouse and equipment barn are visible to the right (2013).

Wetland Treatment Using Native Wetland Plants to Filter Discharge

Wetlands can absorb nutrients such as nitrogen (N) and phosphorus (P) that run off farmlands in excessive amounts because of fertilizer and manure from livestock. The amount that a wetland can absorb varies depending on the type, size, plants, and soils. These are planting areas installed in shallow basins in which the material is treated by filtering through the constructed bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants. These features are excavated pits backfilled with engineered media, topsoil, mulch, and wetland vegetation designed to reduce the wastewater load due to biological interactions between the soil and plant components (Steiner and Watson 1993).

An example is the wetland treatment system currently in use at Alderson Plant Material Center, designed and constructed in 1998. The engineered design was based on the amount of employees (five people)/hours of use per day for a maximum loading of 160 gal per day, with an overall dimension of approximately 7 by 20 ft. The treatment wetland was originally planted with wetland native plants such as iris, *Iris spp*. and lizard's tail, *Saururus cernus*. Birds have deposited seed and presently other wetland species include Swamp Rose Mallow, *Hibiscus moscheutos*; native Silky Dogwood, *Cornus amomum;* and Water

Smartweed, *Polygonum punctatum*. The system is still functioning as intended and looks like a small patch of wetland shrubs (Figure 27) surrounded by a fence to prevent anything from walking through it.

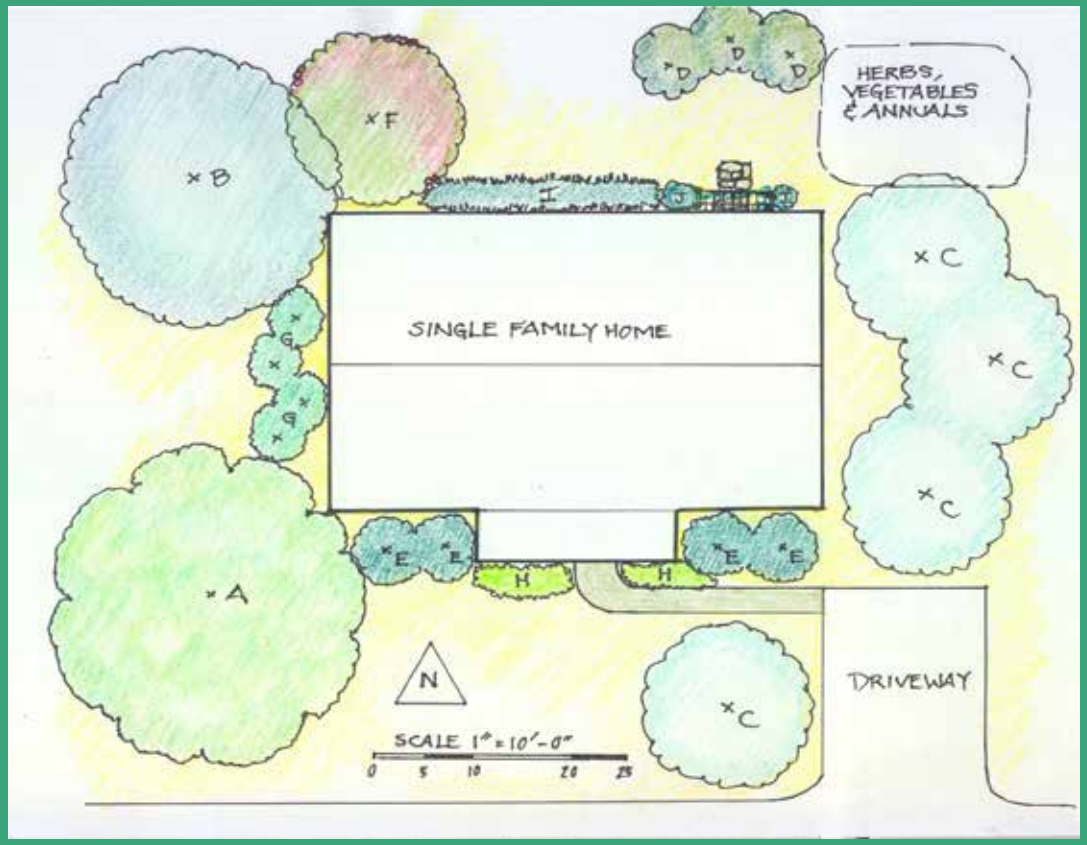
Native Plantings for Recreational Features and Aesthetic Enhancement

The National Park Service (NPS) showcases outstanding sustainable design that is enhanced by the natural environment and developed for recreational purposes. While many of the landscapes are famous, many others are obscure, little-known, and beautiful places. They offer active and passive opportunities for recreation and interpretation of the environment, and they showcase and preserve the natural beauty of their lands, which is the signature of this agency. Many new buildings feature vernacular architecture that blends into its surroundings, by building from local materials, or feature a historic style appropriate to a significant time period. Historic structures are preserved and interpreted to the most significant time period, as accurately as historic records depict. Sustainable and recycled materials are used to a high degree in all park features. Native plants and their communities are valued by the agency and interpretive programs and brochures feature plant information and ecological restoration efforts. NPS plant guidance stresses the use of only native plants and plant communities in design elements, with one exception. That exception is the use of historic plants in an accurate historical context, with the requirement that these plants are not easily spread by natural means so as to prevent any threat of potentially spreading them on lands. NSP also actively manages for invasive species that may be introduced by natural means. Glade Creek Campground was designed and built by NPS maintenance personnel in 1993 (Figures 28 and 29).

Figure 28. Glade Creek Campground, a popular campground that offers low-impact sites that use existing plant communities to provide privacy and beauty.

Figure 29. Site detail – a kiosk and handmade stone bench at Glade Creek Campground. The native plant communities were left intact with as little disturbance as possible during construction.

Residential Landscape for Eastern Broadleaf Forest (Continental) Province



Plan by Pamela Bailey.

PLANT KEY

Latin Name	Common Name	Flowering Period
A. *Tillia americana*	Basswood	April - June
B. *Sassafras albidum*	Sassafras	May - June
C. *Cornus florida*	Flowering Dogwood	May
D. *Viburnum prunifolium*	Black Haw	April - June
E. *Leucothoe catesbaei*	Drooping Leucothoe	April, May
F. *Cercis canadensis*	Redbud	April, May
G. *Lindera benzoin*	Spicebush	March - May
H. *Iris* spp. & *Lilium* spp.	Iris and Lilies	May - Aug.
I. *Vaccinium vascillans*	Lowbush Blueberries	May, June
J. *Lonicera sempervirens*	Trumpet Honeysuckle	June - Aug.

Notes: Trumpet Honeysuckle will need to be planted on a trellis (this is shown as growing around the back entry of the house. Herbs, vegetables, and annual flowers planted in a garden, will extend the flowering season and attract many pollinators.

Creating Habitat for Pollinators

Pollination is defined as the transfer of pollen from one flower to another, which is critical for fruit and seed production in many plants. Plant-pollinator relationships are one of the keystones of healthy ecosystems. The angiosperms, or flowering plants, comprise about one-sixth of all described species and the insects about two-thirds (Wilson 1992). These groups therefore dominate the flora and fauna of the Earth's land surface, and their interactions provide primary ecological services within terrestrial systems. Eighty-eight percent of angiosperms (flowering plants) require pollination, and plant phenology (structural characteristics) has co-evolved with the different types of pollinators (FAO 2008). There are many different pollinator groups, such as bees, butterflies, moths, beetles, flies, birds, and bats. Pollinators transport pollen from the male anthers to female stigma, either of the same flower (autogamy) or different flowers (heterogamy).

About 305 of the world's food production comes from crops that depend on pollinators (Klein et al. 2007). Insect pollination is necessary for most fruits and vegetables including annual crops such as tomatoes, peppers, and strawberries, as well as tree fruits such as apples and peaches. In the United States, the economic value of all pollinator services for agriculture is an estimated $5.7 to $13.4 billion per year (Tang et al. 2005). Honeybees provide about 905 of managed pollination services; however, wild bees also add significant value to crops. For example, the annual contribution of wild pollination services in the United States is estimated at more than $3 billion annually (Losey and Vaughan 2006).

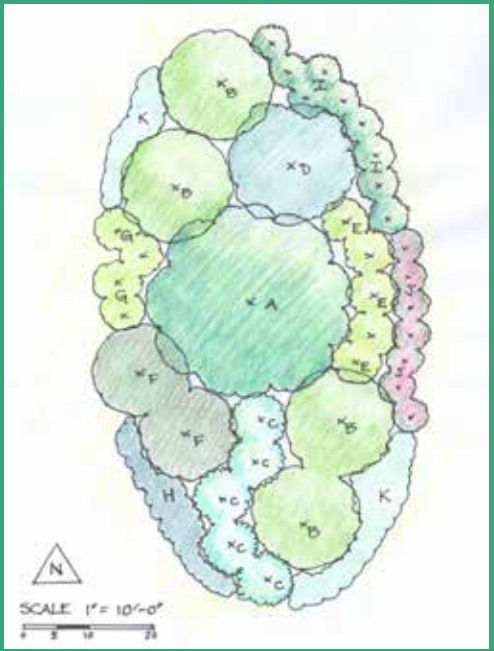
There is growing concern that pollination relationships are imperiled, as exemplified by Colony Collapse Disorder, which has caused recent large, unexplained death in domesticated

honey bees (*Apis mellifera*) – the most important pollinator of domestic crops and many wild plants. Additionally, numerous pollinating insects are listed as threatened or endangered species (TES), including 23 species of butterflies, 2 species of moths, and 1 species of beetle. Loss of species from within networks of co-dependent plants and pollinators can exacerbate decreases in pollination services by triggering vortexes of linked extinctions. Due to the rapid decline in pollinators and the loss of biodiversity of native habitats, it is critical to provide linkages of native species habitats to isolated landform areas (islands). Native plant communities will provide native pollinators with appropriate habitat and food sources on public and private lands.

One can make a difference and increase pollinator habitat by providing plants that create habitat for pollinators. The requirements for pollinators include flowering plants that produce nectar, pollen, and shelter. While pollen is a critical component of pollinators' diets, supplying protein, the market has produced plants that have been genetically altered to minimize pollen because the pollen is "messy" according to some seed suppliers. Companies that sell open pollinated seeds and non-hybridized plants should be sought out when purchasing seeds and plants. Nectar is the carbohydrate source and also a necessary component within pollinator diets. Clean water is another necessary component of pollinator habitat and it should be placed in an area pollinators can access without drowning. Butterflies need mud to obtain minerals from the soil. Shelter is critical in providing pollinators with protection from predators, wind, weather, and roosting and nesting sites. Dead trees and hollow stems of vegetation can provide important shelter.

Anderson et al. (2010) produced a booklet that is a compendium of landscape designs and seed mixes for each of 10 ecoregions across the country. The featured plant lists of native plant species were developed by the Pollinator Partnership and NAPPC (www.pollinator.org) and other regional native plant information in press. Native plants chosen are incorporated into design sketches for plantings around housing, and planted islands for green areas along roadways and on unused land. The design sketches are generic in nature (using generic footprints for the buildings), so a contractor can use the sketches as an appropriate planting and adapt it to existing buildings of varying floor plan footprints. For each area of the country, there is a typical sketch of a housing landscape plan, a typical island planting, and a seed mix suitable for use on larger area plantings or restoration sites. The plans/plantlist and seed mixes also feature native plants that bloom during different months. As an example, the Eastern Broadleaf Forest (Continental) Province Ecoregion was chosen as an illustration.

Island Landscape Plan for Eastern Broadleaf Forest (Continental) Province



Plan by Pamela Bailey.

PLANT KEY

Latin Name	Common Name	Flowering Period
A. *Tillia americana*	Basswood	April - June
B. *Cornus florida*	Flowering Dogwood	May
C. *Sambucus canadensis*	Black Elderberry	June, July
D. *Amelanchier arborea*	Downy Serviceberry	March, April
E. *Physocarpus opulifolius*	Eastern Ninebark	May - July
F. *Cercis canadensis*	Redbud	April, May
G. *Rhus aromatica*	Aromatic Sumac	April, May
H. *Vaccinium macrocarpon*	Cranberry	April, May
I. *Lindera benzoin*	Spicebush	March - May
J. *Rosa rogosa*	Rogosa Rose	June - Aug.
K. Perennial flowers: *Erigeron* spp., *Iris* spp., *Lilium* spp., *Monada* spp., *Phlox* spp., and *Tradescantia virginiana*		May - Sept

Notes: The perennial flowers can extend the flowering season and attract later season pollinators.

Figure 30. Volunteers harvesting seed from the adjacent sand prairie, to be planted on the Corps site. (*Photo by Kurt A. Brownell, natural resource specialist.*)

Figure 31. The sand prairie is a fire-dependant ecosystem and prescribed fire is a management tool used to maintain and restore plant diversity

Figure 32. The site was a showplace of color after the first prescribed burn in 2013.

Planting with Dredged Materials

Another compelling restoration project is located in Kellogg, Minnesota, where the Operations Manager of the St. Paul District developed the concept for constructing a native prairie by using dredged material deposited on a placement site to mimic the natural landforms of adjacent Sand Prairies. The first project, Wabasha Prairie (29 acres), was created in 1999. The second Corps site to use this concept was the West Newton Chute (WNC), a 150-acre site owned by the Corps, adjacent to the Weaver Dunes Scientific and Natural Area. The Weaver Dunes complex includes thousands of acres of sand dunes adjacent to the Mississippi River that are a mix of agricultural lands and native sand prairie communities. Publicly owned areas of the dunes are managed by the Minnesota Department of Natural Resources and The Nature Conservancy.

This WNC project resulted from the need to transfer 1.3 million yd^3 of dredged materials from a temporary placement site within the Mississippi River floodplain to a permanent location. The St. Paul District acquired the 150-acre former agricultural field in the early 1990s and allowed the land to go fallow. The District worked on the dredging, transport, and placement of dredged material to the site. The District Landscape Architect prepared the grading plan for the site and the District Natural Resource Specialist was responsible for the planting of the prairie.

Plant inventories conducted on the project site in the fall of 2002 and spring of 2003 identified more than 50 native sand prairie species that had become established naturally when the site was allowed to go fallow. It was decided to strip the topsoil containing this seed bank and use the soil as containment berms during the hydraulic placement of dredged material. Following construction of the sand dunes, 18 in. of stockpiled topsoil was spread back onto the site. Concurrent with this, the District partnered with The Nature Conservancy to mechanically harvest seeds from their lands as well as hand collect seed using volunteers (Figure 30). First, a total of 32 species of local ecotype seed was acquired for the project. A contractor planted 47 species and an additional 13 species were hand-planted by volunteers, for a total of 60 species. The site was completed in 2005. The West Newton Chute sand prairie is monitored and managed by the St. Paul District. Since being planted, the site has had intrusion by two undesirable species: cow vetch and cottonwood trees. The cow vetch was studied and controlled by a District employee in partnership with DOW Agro Sciences. The cottonwoods seeded in naturally, but were limited to about 30 to 50 trees for the total acreage. The first prescribed burn was conducted last May, after the seventh growing season for the newly established sand prairie (Figure 31). This event restored the natural fire cycle to the prairie, which is a fire-dependant ecosystem. The fire cycle helps to

further control the undesirable species while increasing the diversity within the native plant community. The sand prairie was a showplace of color during the summer of 2013 (Figure 32) and prescribed fire will continue to be used as a maintenance tool in the future.

Phytoremediation and Reclamation

Often the surface soil chemistry must be changed to allow the site to be reclaimed and planted; this series of techniques is referred to as phytoremediation. Phytoremediation is the use of living green plants for in situ reduction and/or removal of contaminants from contaminated soil, water, sediments, and air. Specially selected plants are used in the process. Reduction can be through a process of removal, degradation or containment of a contaminant, or a combination of any of these factors. Phytoremediation is an energy-efficient method of remediating sites with low to moderate levels of contamination and it can be used in conjuction with other more traditional remedial methods. Rhizofiltration is a plant mechanism to allow a plant's root system to clean up contaminated groundwater. The roots are then harvested and disposed of safely. Another method is phytostabilization, which uses certain plants to immobilize poisons in the soil and water. They are accumulated in the roots, absorbed on the roots, or held in the rhizosphere. This prevents migration into the groundwater or air, and also reduces the bioavailability of the contaminant, thus preventing spread through the food chain. Phytodegradation is the breakdown of organic contaminants by metabolic processes driven by the plant. As the plant metabolizes, the organic compounds break down into smaller units that can be absorbed by the plant. Once the soil is cleaned up with phytoremediation techniques, soil amendments can be added (according to soil tests) to adjust the soil before the site can be planted with a native plant community.

Onondaga Lake was chosen as an important case study because it was a superfund site, featuring an extensive cleanup and a number of restoration projects. The lake is roughly 4.5 miles long and 1 mile wide and is located in Central New York, next to the city of Syracuse. Currently, it is going through an extensive process of restoration. Centuries ago, the Seneca, Cayuga, Onondaga, Oneida, and Mohawk Nations were brought together on the shores of Onondaga Lake, where these warring nations accepted a peace treaty between them, and they formed the Haudenosaunee Confederacy – the first representative democracy in the West. The lake became a sacred place, one that must be cared for and respected, and the Onondagas were good stewards of the Lake until New York State took control of the lake and its surrounding areas.

This lake has been polluted since the mid-19th century from industrial sites, including sediments, nutrients, the most prevalent being ammonia and phosphorus, and other toxins including mercury, chlorinated benzenes, BTEX compounds, PCBs, and PAHs. The Solvay wastebeds ring the southwest end of Onondaga Lake. In 1884 Honeywell's predecessors began producing soda ash on the lakeshore. Roughly 6 million lb of salty wastes, made up of chloride, sodium, and calcium were discharged daily to Onondaga Lake from the soda ash facility before it closed in 1986. Additional dumping created the Solvay wastebeds, which continued to leach toxins into the lake. Onondaga Lake was deemed a Super-fund site as a result a lawsuit brought by Atlantic States Legal Foundation, which forced Onondaga County and other parties to clean up the pollution in the lake and surrounding shorelines.

Water quality improvement and many restoration projects have been implemented in this effort to clean up Onondaga lake water quality and shorelines. The Onondaga Lake Habitat Restoration Plan includes new wetlands, shoreline improvements, and a robust habitat layer for the bottom of the lake where remediation is required. Onondaga Lake Park has become the most popular park in Central New York, hosting over 1 million visitors annually. The park features paved, vehicle-free trails; a legacy of history reflecting community growth; special events, sporting competitions, and festivals. A 7-mile stretch of shoreline nooks and crannies provides tremendous options for family picnics, including developed areas

Before being remediated and restored under CERCLA

After being remediated and restored under CERCLA

in Willow Bay and Cold Springs. A current green Infrastructure project includes installing rain barrels to redirect stormwater from the sewage system. The work also includes installing rain gardens meant to soak up extra water and planting trees. In Solvay, a 3.2-acre site at the Solvay Youth Center, the actively eroded hillside will be stabilized and terraced, designed stormwater controls will be installed to manage runoff, and native shrubs and grass will be planted to stabilize soil.

Geddes Brook wetland and Ninemile Creek. Another component is the ongoing restoration at Geddes Brook wetland and Ninemile Creek. This area is being remediated and restored under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The combined area of the restored creek and wetland complex is currently about 22 acres, but will be closer to 40 acres upon completion in 2014. Prior to remediation, the Geddes Brook wetland was a phragmites-dominated elevated wetland with ground surface elevations 2 to 3 ft above the adjacent creek water surface. A utility berm split the wetland in half, isolating the eastern and western portions. Geddes Brook, located on the eastern portion, had been historically dredged and channelized, isolating the stream from the surrounding wetlands.

Remedial efforts completed in 2012 consisted of removing mercury-impacted sediments and restoring the site by creating a diverse wetland complex. The western half of the site was

re-graded to form several shallow and deep emergent pools separated by low-lying ground areas that form numerous edge communities. The water levels in wetland pools are maintained at a relatively constant elevation by retaining precipitation and groundwater using a continuous riparian corridor berm along the bank of Ninemile Creek. The eastern portion was re-graded to create a sinuous Geddes Brook channel that feeds channel grade pools with adjacent shallower perched wetlands. Geddes Brook floods these areas during significant rainfalls and spring snow-melt. The eastern floodplain also has a riparian corridor berm along Ninemile Creek. The entire wetland riparian corridor is designed to be periodically flooded by Ninemile Creek at approximately a once-per-year interval.

Ninemile Creek was restored by creating backwater emergent wetlands and higher ground forested wetlands, surrounded by uplands. The forested wetland was created by channeling stormwater into an elevated depression adjacent to an emergent backwater wetland. Ninemile Creek was rerouted and reconstructed using crib walls and root wads along high erosion banks.

The grading and planting designs for both sites were developed to reduce the potential for phragmites to return as the dominant wetland species. Native persistent and non-persistent plants were installed in the pools. The areas above the water line along the edges were planted with shrubs and trees as well as a native herbaceous plant seed mix. Fast-growing native trees (e.g., black willow) were planted to effectively act as a short-term woody cover to help suppress re-invasion by phragmites while allowing longer-lived hardwoods (e.g., swamp white oak) grow to maturity. A wide variety of native trees and shrubs were planted at a high density to ultimately achieve a closed canopy while still providing the species necessary for early forest succession stages. Species were also selected to lessen the effects of known disease and insect problems, as well as the possibility of future climate change (e.g., bald cypress instead of green ash).

Substantial large woody debris was also installed in the Geddes Brook and Ninemile Creek restoration areas to further enhance habitat value. The woody debris was anchored with boulders and was partially buried to prevent floating. Floating debris piles were constructed by installing closely-spaced vertical logs and dropping crossed logs between them. The lateral resistance and friction between the vertical and horizontal logs successfully retain these woody debris piles during flooding without the use of cables or anchors. This project is a collaborative effort by a number of researchers and scientists from the State University of New York College of Environmental Science and Forestry (SUNY-ESF); Exponent; Terrestrial Environmental Specialists, Inc.; and Anchor QEA, and Parsons.

Geddes Brook Wetland

Before construction, Photo by Ray D. Hollander

During construction, Photo by Ray D. Hollander

After construction, Photo by Mark A. Arrigo

Carbon Sequestration

Carbon sequestration is the capture and long-term storage of carbon dioxide (CO^2). CO^2 naturally captured from the atmosphere by biological, chemical or physical process, and measured as a rate of carbon uptake per year. The long-term storage of carbon in plant-materials or sediment, is measured in terms of the total weight of carbon stored. Carbon sequestration through biological processes affects the world's carbon cycle and includes peat formation, agricultural plants and soils, re-forestation, wetlands, coastal blue carbon, and other ocean processes. Plants incorporate atmospheric CO^2 into biomass through photosynthesis and plant growth.

A carbon sequestration model such as CITYgreen's carbon module quantifies the role of urban forests in removing atmospheric carbon dioxide and storing the carbon. Based on tree attribute data on trunk diameter, CITYgreen estimates the age distribution of trees within a given site and assigns one of three age distribution types. Type I represents a distribution of comparatively young trees. Type 2 represents a distribution of older trees. Type 3 describes a site with a balanced distribution of ages. Sites with older trees (with more biomass) are assumed to remove more carbon than those with younger trees (less biomass) and other species. For forest patches, CITYgreen relies on attribute data on the dominant diameter class to calculate carbon benefits. Each distribution type is associated with a multiplier, which is combined with the overall size of the site and the site's canopy coverage to estimate how much carbon is removed from a given site. The program estimates annual sequestration, or the rate at which carbon is removed, and the current storage in existing trees (reported in tons). Economic benefits can also be associated with carbon sequestration rates using whatever valuation method the user feels appropriate http://www.Americanforest.org.

Another example is coastal blue carbon which is carbon captured by living coastal and marine organisms and stored in coastal ecosystems, such as salt marshes, mangroves, and seagrass beds (http://www.habitat.noaa.gov/coastalbluecarbon). These types of habitat are known as carbon sinks because they absorb large quantities of CO^2 and contain large stores of carbon accumulated over hundreds to thousands of years. Current studies suggest that mangroves and coastal wetlands annually sequester carbon at a rate two to four times greater than mature tropical forests and store three to five times more carbon per equivalent area than tropical forests (Figure 33). Most coastal blue carbon is stored in the soil, not in above-ground plant materials (biomass), as is the case with tropical forests. Although coastal habitats provide a great service in capturing carbon, their destruction poses a great risk. When these habitats are damaged or destroyed, not only is their carbon sequestration capacity lost, but stored carbon is released and contributes to increasing levels of greenhouse gases in the atmosphere. As a result, damaged or destroyed coastal

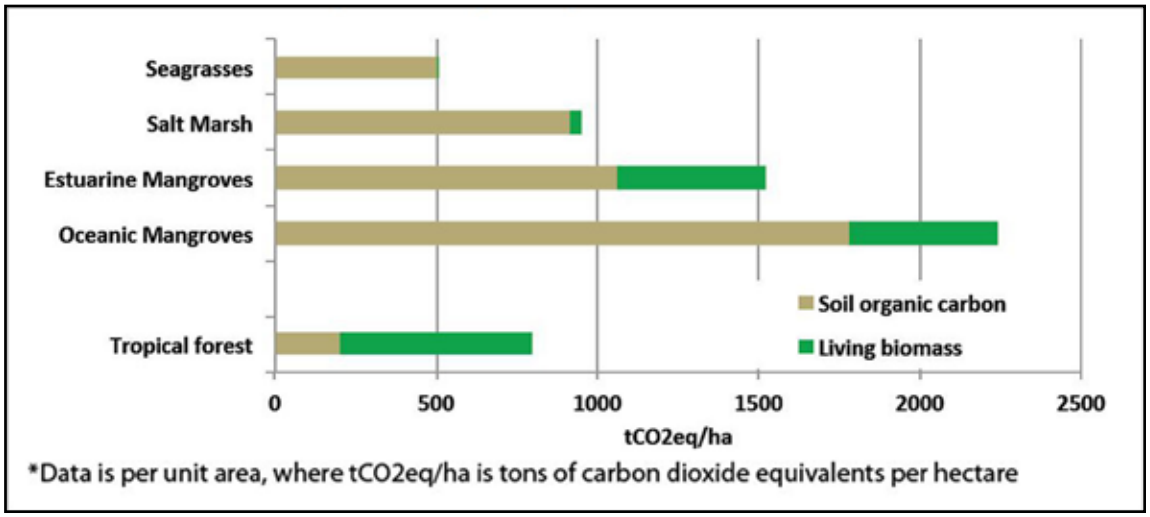


Figure 33. Carbon storage abilities of different habitat types (Source: Murray et al. 2011).

habitats change from being net carbon sinks to net carbon emitters (Murray et al. 2011). Unfortunately, coastal habitats around the world are being lost at a rapid rate, largely due to coastal development.

Living Shorelines and Nature-Based Protection from Storm Surge

Biological structures such as salt marshes, sea grass beds, and coral reefs attenuate waves and as a result, provide coastal protection from the damages caused by flooding and storm events (Koch et al. 2009). This is becoming a critical service in many regions because of the increased risk of flooding and storm events – both in terms of frequency and severity. Salt marshes play a leading role in intertidal areas, dissipating wave and tidal energy, thereby reducing the cost of flood defense measures. They also absorb huge amounts of water when inundated and then slowly release it afterwards, which can also prevent flooding.

The Coastal and Hydraulics Laboratory at ERDC has published many papers and models, which address storm surge issues as a result of recent hurricanes and coastal catastrophes. One paper describes how wetlands can significantly reduce storm surge (Wamsley et al. 2010). Another paper examines storm surge and wave reduction benefits of different environmental restoration features (marsh restoration and barrier island changes), as well as the impact of future wetland degradation on local surge and wave conditions (Wamsley et al. 2009). A recent study (U.S. Army Corps of Engineers 2013) provided nature-based shoreline solutions as a response to Hurricane Sandy.

Shorelines are often stabilized with hardened structures, such as revetments and concrete seawalls. However, these structures often increase the rate of coastal erosion, remove the ability of the shoreline to carry out natural processes, and provide little habitat for estuarine species. NOAA is working to implement a more natural bank stabilization technique called "living shorelines." Living shoreline projects utilize a variety of structural and organic materials, such as wetland plants, submerged aquatic vegetation, oyster reefs, coir fiber logs, sand fill, and stone (Luscher and Hollingsworth 2005, Moon 2007, Hardaway et al. 2010). This approach provides shoreline protection and reduces erosion, maintains valuable habitat, improves water quality and clarity, provides an attractive natural appearance, and can provide recreational use areas (Figure 34). For more information, go to http://www.habitat.noaa.gov.

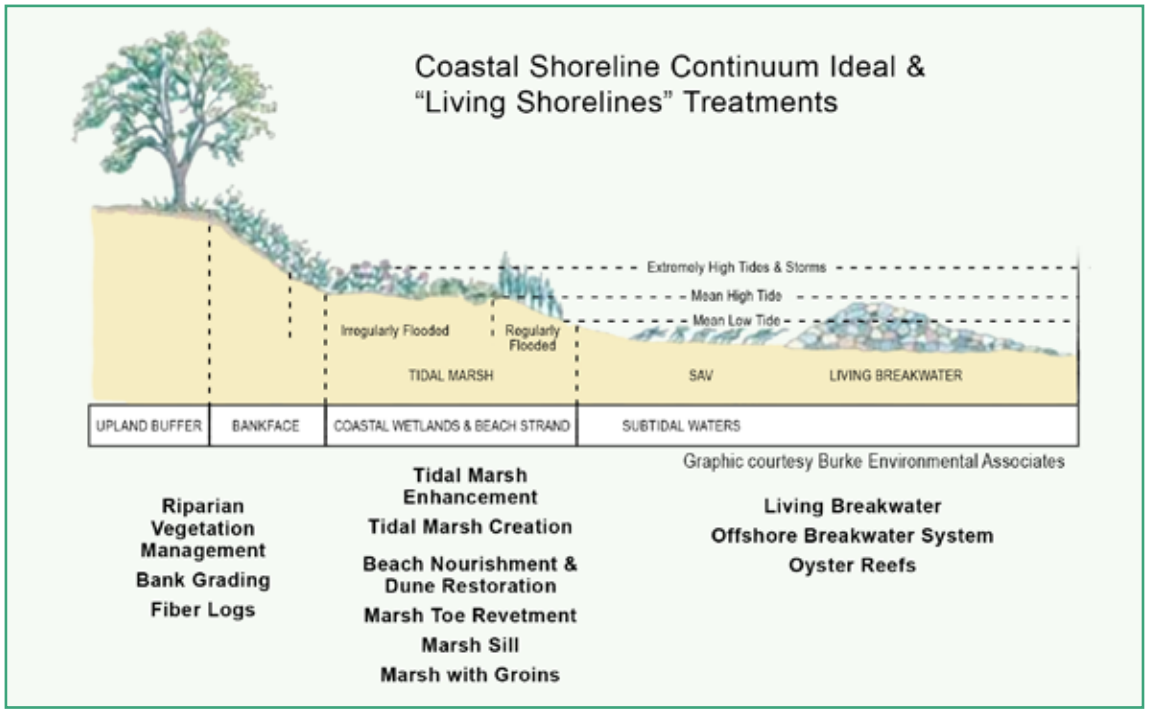


Figure 34. Section of coastal shoreline continuum and living shoreline treatments. Adapted from Burke Environmental Associates.

Interest in this topic has recently increased as a result of climate change. Parameters to measure storm impacts include: 1) shoreline change rate, 2) dune height, 3) beach width, and 4) combined geomorphology index. Under the Shepard classification system (1948), coastlines are classified according to the physical and geological processes responsible for the formation and present configuration of the coast. These processes also continue to act on and shape both natural and manmade features in the coastal environment. Understanding these processes and combining them with detailed descriptions of the plant community associations located in the appropriate landform and at the correct elevation, will be important to engineers and scientists involved in the design and construction of nature-based solutions for coastal storm protection (Figure 35). Protective coastal landscape features include barrier islands, shorelines, dune complexes, wetlands, and maritime forest communities.

Dune complexes are formed in the supratidal zone along wide sandy beaches with significant wind action to blow sand landward, where it accumulates generally above the spring high tide level. Well-developed dune complexes may include foredunes immediately adjacent to the beach, secondary and even tertiary dunes, and interdunal areas that may trap water, creating small wetland and/or open-water areas. Typically the dune complex is characterized only by natural or artificial foredunes possibly bordered to the landward side by a small marshy area. Above the spring high tide level, vegetation can colonize the sand accumulations, reducing the wind shear and leading to further accumulation of wind-blown sand. Vegetation stabilizes the sand deposits, creating higher and steeper dunes than if no vegetation were present (Bird 2008). Dune heights vary parallel to shore depending on variations in wind or sediment supply, frictional elements such as vegetation, or structures such as fencing. Dunes tend to migrate landward under the constant influence of coastal winds and occasional storms that can produce surge and wave runup that exceed the high tide level. If runup is significant, the foredunes and/or dune complex may be overwashed or breached, leading to a washover fan.

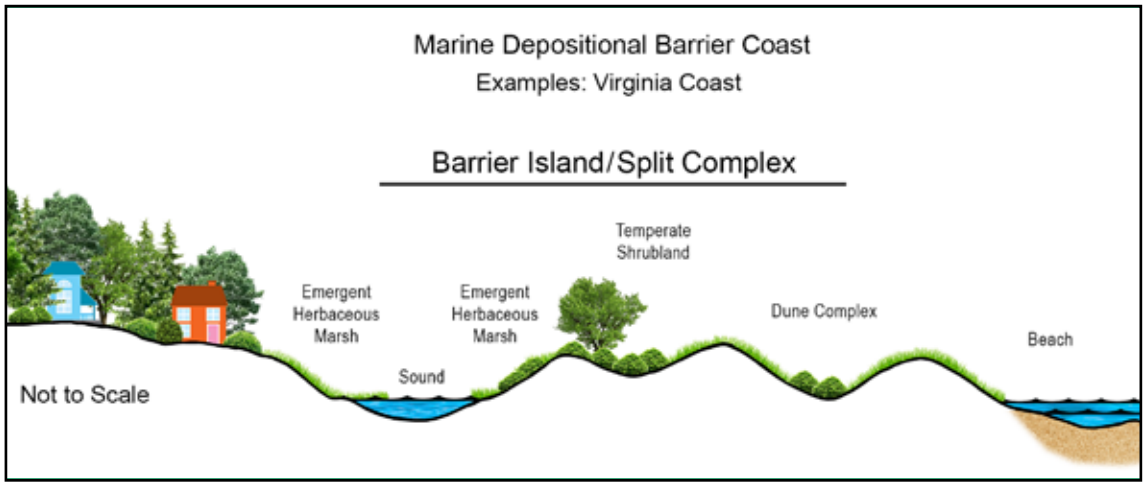


Figure 35. Conceptual cross-shore profile of the barrier coast type. Note the barrier feature can be a barrier island or a spit.

Islands offer protection to the coast and coastal inland development. Islands can occur in all coast types excluding the beach plain. However, the origins of islands differ for each coast type and the different settings lead to differing drivers of form and function. The islands are natural features; however, properly placed and constructed artificial islands can perform the same functions and behave as natural islands. The barrier island is one of the defining features of barrier coast types. Natural barrier islands are characterized by seaward to landward progression of beaches, dune complexes consisting of foredunes and perhaps secondary and tertiary dunes with interdunal areas that may contain small wetland and/or open-water areas, finally transitioning to a barrier flat area that is typically vegetated

with grass and shrub communities. Estuarine fringe wetlands dissected by tidal creek networks occur at lower elevations. Dunes are stabilized by native beach grasses and shrub communities. Since barrier islands/spits are dynamic systems, planting native dune plants, such as grasses and shrubs will allow for the adaptive capacity of these systems and make them far more resilient to coastal storms and sea level rise.

Establishing Native Aquatic Plants to Improve Aquatic Habitat

The following case study was provided by Gary Owen Dick and Lynde L. Dodd,USACE ERDC EL,Lewisville Aquatic Ecosystem Research Facility, Lewisville, Texas. Aquatic plants are often overlooked as critical components of healthy aquatic ecosystems. Aquatic and riparian plants provide valuable habitat (food and cover for invertebrates, fish, and other wildlife), improve water clarity and quality, reduce shoreline erosion and sediment resuspension, and help prevent spread of nuisance exotic plants (Engel 1988, James and Barko 1990, Killgore et al. 1991, Doyle and Smart 1993, Thorp et al. 1997, Barko and James 1998, Dick et al. 2004). These qualities contribute significantly to ecosystem health and function, which in turn improve the value of the waterbody as a natural resource.

Inland waterbodies in the United States include reservoirs, large and small lakes, permanently inundated wetlands, ponds, and riverine systems. Waterbodies exhibiting poor ecosystem health often exist in one of three conditions interrelated to aquatic plants: (1) they completely lack native aquatic plants, (2) they support native plant communities that are insufficient to provide system-wide benefits, or (3) they are infested with nuisance species that cause both environmental and water use problems. Corrective measures can be undertaken through a combination of management techniques (as needed to address specific issues) that may require introductory establishment of plants, enhancement of existing plant communities, and management of nuisance species.

An example of the third condition occurred in Lake Lamar, Texas, located on a Texas Army National Guard (TXARNG) training site in Lamar County, Texas. The lake was constructed in 1942, has a surface area of 43 acres, and is filled by runoff from a small, forested watershed with potentially long retention time. Much of the lake is littoral, with aquatic vegetation occurring in about 30 acres, historically dominated by several beneficial native species. However, infestations of two nuisance species, Eurasian watermilfoil (*Myriophyllum spicatum*) and American lotus (*Nelumbo lutea*), occurred in the mid-2000's and required management. Watermilfoil, an introduced species, has plagued U.S. water bodies since its introduction in the 1940's. Lotus, while native, can become aggressive in shallow waterbodies, and sometimes requires management. As surface canopy-forming species, these two have the potential to deleteriously alter ecosystems, resulting in degraded aquatic habitat (Smart et al. 2009).

A combination of two survey methods was employed in early 2007 to accurately assess the lake's vegetation community: surface observation GPS (SOG) (Dodd-Williams et al. 2008) and point intercept rake sampling (Madsen 1999). The survey revealed that nuisance plants dominated over 95% of the vegetated acres. A management plan was then designed to shift vegetation community dominance from nuisance to beneficial native species, thereby increasing diversity, improving aquatic habitat, and increasing resilience against ecological disturbances.

Herbicides, biological control agents, mechanical controls, and other management tools were considered for controlling watermilfoil and lotus. Emphasis on management tool selection was placed on minimizing damage to existing beneficial aquatic vegetation and species to be established in the lake. Herbicides (for both species) and mechanical management (for lotus) were selected because of the challenges of managing multiple nuisance species, especially when considering the need to minimize impacts on beneficial native species, and a lack of availability of reliable

biological control agents for either nuisance species.

Ultimately, an aquatic formulation of triclopyr, a systemic, broad-leaf herbicide was selected due to its ability to target undesirable species in the lake with minimal effect on desirable plants. It was also determined that post-herbicide biomass (dead plant material) and any regrowth of lotus would be mowed using a boat-mounted sickle mower to improve light penetration and promote recovery of volunteer beneficial plants.

Volunteer beneficial plants present in the lake included coontail (*Ceratophyllum demersum*) and American pondweed (*Potamogeton nodosus*), but these dominated less than 5% of the vegetation community. It was anticipated that triclopyr application would not impact these plants, and that removal of watermilfoil and lotus would reduce competitive interactions and enable growth and spread of the beneficial species. However, considering the low diversity of the existing assemblage and its susceptibility to invasion by undesirable plants, addition of beneficial species to the plant community was included in the project. Submersed, floating-leaved, and emergent aquatic plants native to the general area but not found in the lake were selected, collected locally, and produced guidelines developed by ERDC (Dick et al. 2013).

The lake was too large to apply full-scale plantings, so the project utilized the founder colony approach for establishing additional beneficial species (Smart et al. 1998). The approach is designed to accelerate natural processes of aquatic plant establishment and spread by planting colonies at strategic locations within a waterbody. The function of the colony is to overcome a major impediment to aquatic vegetation establishment: availability of propagules for natural spread. Continual provision of propagules (seeds, fragments, etc.) from founder colonies ensures that they are present when conditions are suitable for natural spread to occur. Founder colonies also provide immediate, localized habitat improvement (Figure 36). Exclosures are commonly used to protect founder colony plantings from herbivores such as waterfowl and turtles, and multiple plantings triggered by changes in water elevation are sometimes made to counter the effects of water level fluctuation (Dick et al. 2013).

Test plantings were made at three locations in the lake in early 2007, with 16 species of plants installed with and without protection to ascertain which of the additional plantings, if any, would require protection from herbivores. These test plantings formed the basis for founder colonies during later plantings. Triclopyr applications were made in September 2007, resulting in substantial removal of watermilfoil and lotus with little impact on volunteer and planted beneficial species.

Watermilfoil was not detected in surveys conducted in spring 2008, although some lotus recovery from tubers and seed was observed. A boat-mounted sickle mower was used to cut surface growth. Additional plantings were made in founder colonies using information from test plantings, with most emergent species not requiring protection and most submersed species requiring protection, an occurrence common in aquatic restoration projects (Dick et al. 2013). By the end of the 2008 growing season, watermilfoil had still not been observed and lotus was found in less than 10 acres (with coverage in those acres less than 10%). Remaining lotus was spot-treated with triclopyr. Most importantly, the ecosystem responded to management as anticipated, with beneficial native volunteers and founder colony plantings spreading to fill the niches left open by nuisance plant removal.

Low levels of recovery of watermilfoil and lotus occurred in 2009 and 2010, but never exceeded 1 acre coverage and never dominated in any areas during that period. This was partly due to early detection/early response management: when infestations were noted, plants were removed by hand (in very shallow water) or spot-treatment with triclopyr. During the same period, beneficial native vegetation through maintained its dominance, and by the end of 2010 had grown to cover the previously vegetated acreage (30 acres) occurring in the lake.

The project showed the value of incorporating ecological principles into aquatic ecosystem management (an ecological approach): removal of nuisance plants coupled with filling the niche left open by planting beneficial plant species. While longer-term monitoring will provide more information regarding methods used in the project and the sustainability of results, it nonetheless demonstrated the feasibility of replacing nuisance species with beneficial species.

Figure 36. American water lily flowering and spreading beyond protective exclosures at a founder colony site. Stands of beneficial American pondweed (volunteer) and Illinois pondweed (planted) combine with lilies to dominate the vegetation community.

Sagebrush Steppe Community, Washington

EXISTING DATABASES, SOURCES OF PLANT MATERIALS, AND EXPERTISE

This section provides other resources of native plant data and other sources of plants for projects. The many other federal agencies and the Plant Conservation Alliance (PCA), which have different roles in the conservation of native plant communities, are briefly explained herein.

VegBank is the vegetation plot database of the Ecological Society of America's Panel on Vegetation Classification. VegBank consists of three linked databases that contain (1) the actual plot records, (2) vegetation types recognized in the U.S. National Vegetation Classification and other vegetation types submitted by users, and (3) all plant taxa recognized by Intergrated Taxonomic Information System (ITIS)/U.S. Department of Agriculture (USDA) as well as all other plant taxa recorded in plot records.

USDA PLANTS Database provides standardized information about the vascular plants, mosses, liverworts, hornworts, and lichens of the United States and its territories. It includes names, plant symbols, checklists, distributional data, species abstracts, characteristics, images, crop information, automated tools, other Web links, and references. This information primarily promotes land conservation in the United States and its territories, but academic, educational, and general use is encouraged. PLANTS reduces government spending by minimizing duplication and making information exchange possible across agencies and disciplines. PLANTS is a collaborative effort of the USDA NRCS National Plant Data Center (NPDC), the USDA NRCS Information Technology Center (ITC), The USDA National Information Technology Center (NITC), and many other partners.

The Natural Resources Conservation Service (NRCS) Plant Material Centers provide native plants that can be used to restore sites and help solve natural resource problems. Scientists at these centers seek out plants that show promise for meeting an identified conservation need and test their performance. A conservation need may include erosion reduction, water quality improvement, streambank protection, or pollinator habitat (Natural Resources Conservation Service 2005). Twenty-six Plant Material Centers located across the country (Figure 37) develop seed mixes and grow plants adapted to a particular region. After seed mixes and plants are certified through testing, they are released for commercial production. The work is carried out cooperatively with federal and state agencies, commercial businesses, and seed and nursery associations.

The NRCS Plant Material Centers are willing to assist in development and storage of locally adapted seed mixes at a reasonable cost. For example, a successful partnership occurred during the Marmet Locks and Dam Replacement Project in West Virginia. The partners were the U.S. Army Corps' Huntington District and the NRCS Plant Material Center in Alderson, West Virginia. A Memorandum of Under-standing (MOU) through the Economy Act, was signed by both agencies to harvest plants and propagules from six native plants on the proposed construction site at Marmet. These plants were grown at the plant material center for two growing seasons, and the 2-year-old young trees and shrubs were provided to the contractor for replanting at the Marmet site. The six chosen species were dominant native plant species within a riparian plant community on the Kanawha River, as indicated by initial botanical survey work, and all were unavailable commercially at the time. By growing the six species and

returning these local ecotypes to their original site, genetic integrity was maintained after construction.

Native Plant Commercial Nursery Production is increasing in areas around the country in an expanding market. For seed or plant sources, consider collecting or buying as close as possible to the restoration site, because these sources would be adapted to the soil, water, and climate of the region. Ask the grower about the location of the sources of the seeds or plants and maintain this information in records on the restoration project. Sometimes seeds and plants may not be available locally and it may be necessary to buy plants and seeds at a greater distance, but within the same ecosystem and having similar climatic conditions. If purchased plant stock is derived from tissue culture propagation, the genetic variability may be limited. It is necessary to ensure that the seed collection and propagation techniques allow for genetic variation for the seed to survive and reproduce.

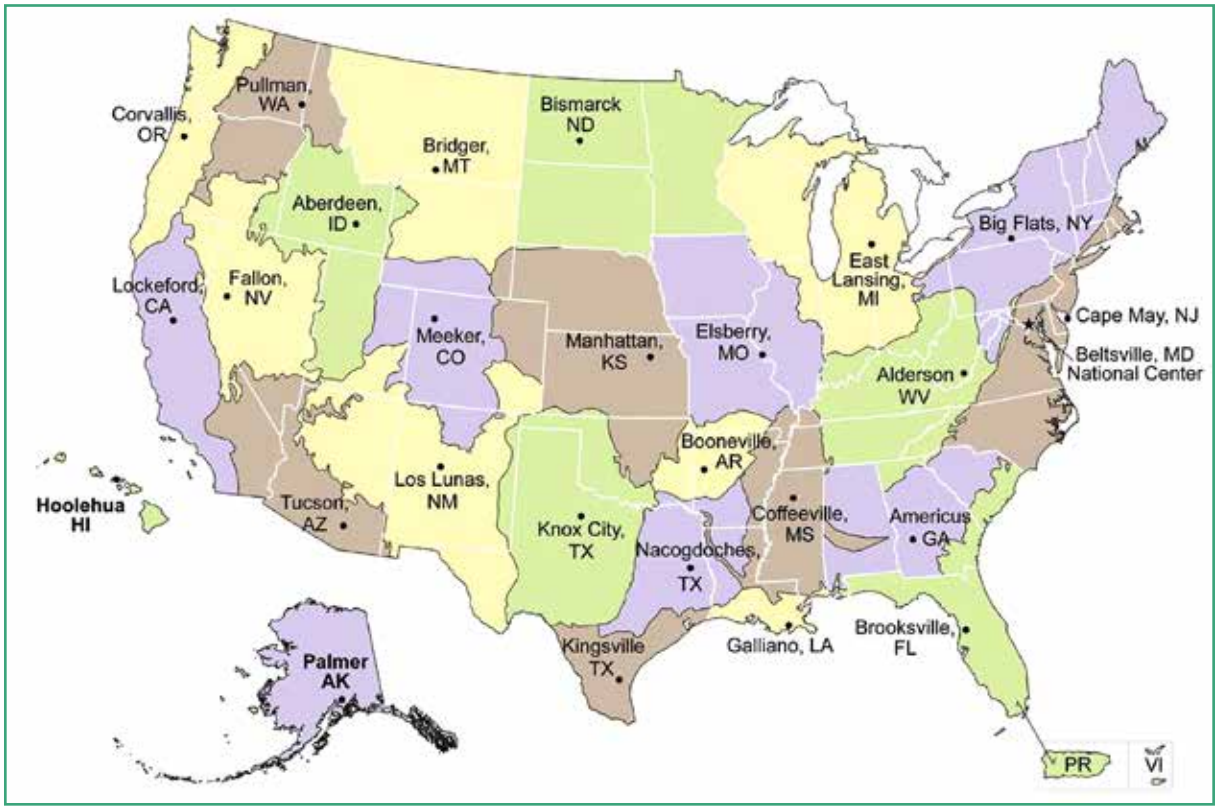


Figure 37. Natural Resources Conservation Service. Plant Material Center Locations (from http://plant-materials.nrcs.usda.gov/centers).

A Public Works Technical Bulletin entitled, "Sources of Plant Materials for Land Rehabilitation" (USACE 2005) has been compiled. The US Forest Service has compiled the "Eastern Resource Directory for Native Plants," which lists commercial nurseries for native plants (Dagnan 2004). The intent of these documents is to provide a listing of vendors; neither agency promotes a particular vendor.

Botanical Gardens and other ex situ facilities, such as seed banks, are artificial centers of species diversity and are among the most concentrated sites of species richness available (Guerrant et al. 2004). Botanic Garden Conservation International (BGCI) is a non-profit organization founded in 1986 to curb the threat to plant diversity worldwide. It is composed of 2,200 botanical gardens worldwide (Shepard 2005), representing 148 countries. These botanic gardens hold 80,000 species (Wyse 2001).

Botanic gardens in many countries have developed seed banks for the storage of seeds, mainly wild species. As of 1998 there were 200 botanic gardens with seed banks (Botanic Garden Conservation International 2005) maintained in long-term storage. Several botanic gardens have developed the capacity to store tissues under cryopreservation.

Within the United States, there are 76 botanic gardens. The Missouri Botanical Garden hosts the nonprofit Center for Plant Conservation (CPC), a national network of community-based institutions providing professional hands-on assistance to prevent extinction and achieve recovery of imperiled plants. The activities and scientific approach of the CPC have generated productive debate on the conservation role of botanic gardens (McMahan 1995) and the adoption of plant genetics as the guiding tool for botanic garden conservation activities (Center for Plant Conservation 1991, McMahan and Guerrant 1991). More information can be found at the CPC website: www.centerforplantconservation.org (CPC 2006).

A large network of 3,240 herbaria located in 165 countries are listed in *Index Herbariorium*, a compilation of herbaria available through the New York Botanical Garden (New York Botanical Garden 2006). In the United States, herbaria are associated with botanical gardens and universities. These collections are invaluable to botanists because they provide species information that can be used to verify specimens, location data of the specimen collected to compile range data for the species, and historic records of the species. Several herbaria offer on-line collections.

The Plant Conservation Alliance (PCA) is a consortium of 10 federal agencies (including Department of Defense) and over 290 cooperating private organizations involved with native plant restoration and conservation in North America. The PCA provides a collaborative framework for linking resources and expertise in the development of sound, scientific projects. The organization responds to the World Conservation Union (ICUN) on the status of native plants in North America (World Conservation Union 2006). Its vision is "For the enduring benefit of the Nation, its ecosystems, and its people; to conserve and protect our native plant heritage by ensuring that, to the greatest extent feasible, native plant species and communities are maintained, enhanced, restored, or established on public lands, and that such activities are promoted on private lands." More information about the PCA is available on their website at www.nps.gov/plants.

The Memorandum of Understanding (MOU) for Federal Native Plant Conservation was originally signed on 25 May 1994, then extended until 30 September 2003 and now is being renewed at the turn of its 20th year. The U.S. Fish and Wildlife Service, U.S. Forest Service, National Park Service, Federal Highway Administration, Bureau of Land Management, USDA Agricultural Research Service, USDA Natural Resources Conservation Service, U.S. Geological Survey, and Department of Defense have signed the MOU in the past. The MOU represents the federal branch of the PCA, which is the Federal Native Plant Conservation Committee. PCA is a public/private partnership that accomplishes conservation by: (1) clearly communicating a broad-based, inclusive

message that encourages partnerships at all levels; (2) effectively leveraging the contributions of cooperators to accomplish on-the-ground projects for native plant restoration and conservation; and (3) actively consulting with partners in the development of sound, scientific projects conducted by communities for communities.

One such project is the "Seeds of Success," an interagency program coordinated by the PCA that supports and coordinates seed collection of native plant populations in the United States to increase the number of species available for use in stabilizing, rehabilitating, and restoring federal lands. This is the first program in the United States to support long-term conservation storage of all common native plant species. PCA supports three types of seed collection: (1) collection of seed for the Royal Botanical Gardens, Kew Millennium Seed bank; (2) collection of seed for the Agriculture Research Service Native Plant Germplasm Collection; and (3) collection of seed locally for specific rehabilitation and restoration projects. In each case, seeds are collected at the population level following the Seeds of Success protocol (U.S. Bureau of Land Management (BLM) 2004). Additionally, the BLM is quite active in the western states and operates a warehouse in Boise, Idaho with storage capacity for 1 million pounds of seed (PCA 2006). A number of native species of prairie grasses and sagebrush seed are available for restoration on their land and used for restoring areas within the Great Basin, including the endangered Great Basin Sagebrush ecosystem.

Native Plant Societies are located in each state and memberships are often composed of professional and amateur botanists with knowledge of the state's flora. The Eastern Resource Directory for Native Plants (US Forest Service 2004) also lists Native Plant Societies in each state and provides contact information. Most of these societies offer memberships at a minimal fee and have a number of scheduled events including field trips to various natural areas to view native plants. These various societies may be interested in entering partnering opportunities on restoration projects.

Native Plant Rescues. The purpose of participating in the native plant rescue is to save native plants from destruction. The event can be 1-day event or longer and be covered by a Memorandum of Agreement (MOA) if conducted with another agency or entity. If the site to be developed contains a number of plants that will be bulldozed, a plant rescue allows the Corps to have others come onto Corps lands to dig up plants that will be transplanted to another site with similar environmental conditions. An example of a successful native plant rescue was held at Marmet, West Virginia. The West Virginia Department of Natural Resources (WVDNR) was the entity that signed the MOA with the Corps. WVDNR came and harvested the plants from the site, and was responsible for transferring the plants to two school systems. The first school was Doddridge Middle School, at which a wetland mitigation project was planted on 5 acres of school grounds. The second school was Buffalo Elementary, which developed and planted a nature trail. Both of these school projects were education-based projects that students were involved in; they planted the harvested plants at their respective schools. These projects were incorporated as components within the science curriculum. These plant resources are valuable resources, and they should not be carelessly destroyed. Plant rescues are a very cost-effective way of acquiring native plant communities for planting purposes.

Dune Community, Hawaii

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Semi-arid Riparian Community,
Snake River, Washington

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Glacial Stream in Sub-alpine
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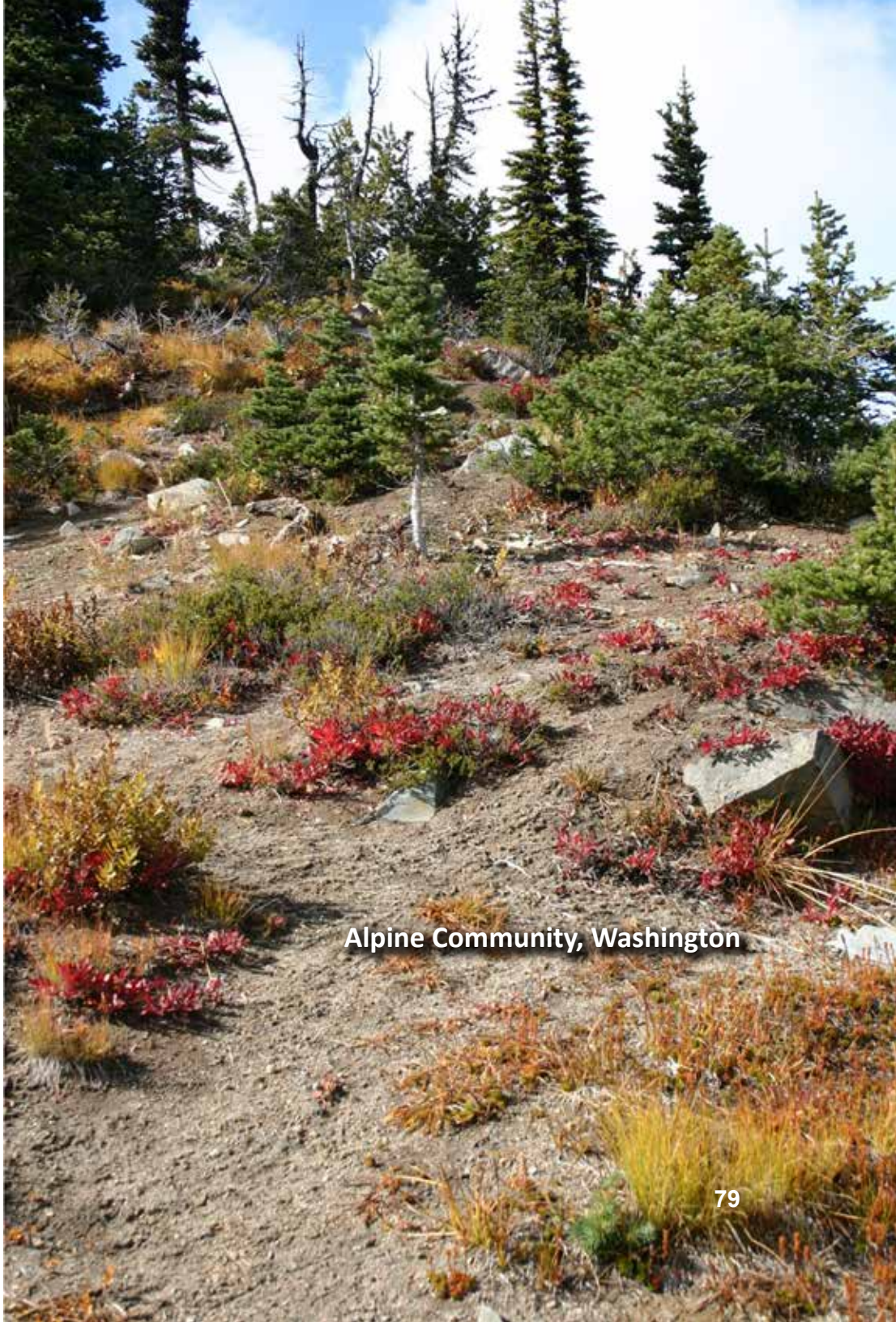
Alpine Community, Washington

Chihuahuan Desert, Arizona
Looking into Mexico

APPENDIX A
Standard Field Form
National Vegetation Classification System, Nature Conservancy 1988

Identifiers / Locators

Plot Code_____ Polygon Code_____
Provisional Community Name_____
State_____ Site Name_____
Quad Name_____

GPS file name_____ Field UTM X_____UTM Y_____
Corrected UTM X_____UTM Y_____ mN UTM Zone_____

Survey Date_____ Surveyors_____
Directions to Plot:

Plot length_____ Plot width_____ Photo #s_____ Plot Permanent (y/n) _____
Plot representativeness:

_____

Environmental Description

Elevation_____ Slope_____ Aspect_____
Topographic Position_____
Landform _____
Surficial Geology_____

Cowardian System	Hydrologic Modifiers		Salinity Modifiers
___Upland	___Semi-permanently flooded	___ Intermittently flooded	___Saltwater
___Estuarine	___Seasonally flooded	___Permanently flooded	___Brackish
___Riverine	___Saturated	___Tidally flooded	___Freshwater
___Palustrine	___Temporarily flooded	___Permanently flooded tidal	
___Lacustrine			

Environmental Comments:

Soil Taxon/ Description

Unvegetated surface

___Bedrock
___Large rocks (>10 cm)
___Small rocks (0.2-10 cm)
___Sand (0 – 0.2 cm)
___Wood
___Litter
___Bare soil
___Other

Soil Texture			Soil Drainage	
___Sand	___Loamy Sand	___Sandy Loam	___Rapidly Drained	___Well Drained
___Silt	___Clay Loam	___ Silty Clay	___Moderately Drained	___Somewhat Poorly Drained
___Clay	___ Peat	___Muck	___Poorly Drained	___Very Poor Drained
___Loam	___Silt Loam			

Vegetative Description

Leaf Phenology (of dominant stratum)	Leaf Type	Physiognomic Class	Cover Scale for Strata & Unvegetated Surface		Height Scale for Strata	
Trees and shrubs	___Broad leaf	___Forest	1	<5%	1	<0.5 m
___Evergreen	___Needle-leaved	___Woodland	2	5-15%	2	0.5-1 m
___Cold-deciduous	___Mycrophyllous	___Shrubland	3	15-25%	3	1-2 m
___Drought-deciduous	___Graminoid	___Dwarf Shrubland	4	25-35%	4	2-5 m
___Mixed evergreen	___Forb	___Herbaceous	5	35-45%	5	5-10 m
cold-deciduous	___Pteridophyte	___Nonvascular	6	45-55%	6	10-15 m
___ Mixed evergreen		___SparselyVegetated	7	55-65%	7	15-20 m
drought-deciduous			8	65-75%	8	20-35 m
___Herbs			9	75-85%	9	35-50 m
___Annual			10	85-95%	10	>50 m
___Perennial			11	95-100%		

Strata	Height Class	Cover Class	Diagnostic species (if known)
T1 Emergent	____	____	_____
T2 Canopy	____	____	_____
T3 Sub-canopy	____	____	_____
S1 Tall Shrub	____	____	_____
S2 Short Shrub	____	____	_____
S3 Dwarf Shrub	____	____	_____
H Herbaceous	____	____	_____
Grass	____	____	_____
Forb	____	____	_____
Fern	____	____	_____
N Non-vascular	____	____	_____
V Vine/ liana	____	____	_____
E Epiphytic	____	____	_____

Animal Use Evidence:

Natural and Anthropogenic Disturbance Comments:

Other Comments:

Species / percent cover. Starting with uppermost strata, list all species.
For forest and woodlands, list all DBH of all trees above 10-cm diameter (separate measurements with a comma). Put * next to any species that are known diagnostics for a particular community in the classification.
List species outside the plot at the end of the table and designate with a 0 in a cover class column.

Species Names	Cover	Species Names	Cover
		Cover Scale for Species	
		1 <1%	
		2 1-5%	
		3 5-25%	
		4 25-50%	
		5 50-75%	
		6 75-100%	

From the Author: Dr. Pamela Bailey

I have 28 years of professional expertise, as a landscape architect and botanist. Besides conducting botanical surveys, I combined both professions into sustainable design and restoration projects. In the past, I have worked in the private and public sectors; for The Nature Conservancy, the National Park Service, and the U.S. Army Corps of Engineers. Currently, I conduct research and reimbursable projects for the Military and Civil Works Programs, as a research botanist with the Environmental Laboratory at the U.S. Army Engineer Research and Development Center. I use plants in technical applications including bioengineering, shoreline stabilization, and pollination biology to examine insect/plant interactions using network science. I hope that this book will inspire people to see the value of incorporating native plant communities into sustainable designs, and to create opportunities to Engineer With Nature.

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Photo By Mike Butler

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About EWN

The U.S. Army Corps of Engineers (USACE) initiative known as Engineering With Nature (EWN) is the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaborative processes. EWN seeks to align science with engineering to improve the decision-making process and expand the range of benefits that can be achieved through USACE projects. EWN projects and tool development directly support a number of USACE plans and directives, including the USACE Civil Works Strategic Plan, the USACE Campaign Plan, and the USACE Environmental Operating Principles. As a leading practice, EWN is being pursued through innovative research, field demonstrations, communicating lessons learned, and active engagement with field practitioners and USACE partners and stakeholders. For more information on EWN, please contact Dr. Todd Bridges at Todd.S.Bridges@usace.army.mil and Cynthia Banks at Cynthia.J.Banks@usace.army.mil or visit www.Engineering-WithNature.org.

EWN promotes triple-win outcomes

WHAT IS THIS? On your mobile device, download a Quick Reference (QR) code reader of your choice and visit the EWN website.

EWN 2014

A Design Manual:

Engineering With Nature Using Native Plant Communities