restoration design guidelines for

texas hill country riparian areas

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contents

introduction


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2015 saw two exceptional rainfall events in central Texas and especially within the Blanco River watershed. In May, above average rainfall had resulted in saturated soils with conditions coming together during the Memorial Day weekend for extreme rainfall which produced 10-13" within a time frame of 12 hours near southern Blanco county. This resulted in record river levels that produced catastrophic flood damage to property and people along the Blanco River. The Fort Worth National Weather Service Office reported May 29, 2015 that this singular event produced 35 trillion gallons of water, enough to cover the entire state in 8" of water. Residents of the Blanco barely had time to process this event and its far-reaching effects, when a second 500 year rainfall hit again on October 30, 2015.

The intensification of extreme weather patterns has clearly been documented over the past three decades, and the trend demonstrates an increase in heat waves, drought, intense rain events, and floods, among other weather events. Resilient landscapes help mitigate the effects of these intense events and can even offset some of the outcomes. This resilience emanates from the prolific amount of species that once covered over 15,000,000 acres in central Texas. Land use is the most important driver of global biodiversity change in the twenty-first century (Sala et al. 2000), and the reduction of diversity can alter, reduce, or eliminate ecosystem services such as air cleansing, carbon sequestration, temperature moderation, freshwater provision and cleansing, and slowing the flow of stormwater runoff (Cardinale et al. 2012). Simply put, common development practices and residential property construction and maintenance have considerably reduced the land's capacity to absorb and minimize adverse impacts by compacting soils, reducing native plant communities, introducing invasive species, and increasing impervious

surfaces. Damaged soils increase rainwater runoff conveying excessive amounts directly into our creeks, streams, and rivers and the resulting flood damage can alter the hydrologic system.

The good news is that we can control how our landscapes function and ultimately choose to design our surroundings so that they retain important qualities that cumulatively mitigate the disruptive effects of inadequately planned and poorly managed development. If we accept and embrace the fact that landscapes are inherently dynamic, then we can accommodate natural processes into our designs. For riparian areas, this means understanding that disturbance events such as floods are integral to many organisms that are dependent upon these events for regeneration. Nature has provided us with a means to address both people's needs and natural processes; we simply need to observe our surroundings and be aware that our actions significantly impact our surroundings for better or worse. We should not concern ourselves with "curbing the influence of human occupancy." Rather, we should create a better understanding of landscape management and prevent damage to the environment, maintaining healthy conditions so that we may enjoy and thrive within wildlands, cities, and their interface. By doing so we will "fulfill the responsibilities of each generation" to preserve the land (Leopold 1933). As President and Mrs. Johnson said, we should not relegate nature to a weekend role in our eagerness for "improvement," there is more to America which "God has gladly given," a part that was "here long before we arrived, and will be…long after we depart… beautiful, and changing, always changing" (Johnson 1966).

In this document there is a general discussion regarding riparian function, historical site conditions, and active methods for preserving or enhancing private landscapes, with a case study demonstrating how the Lady Bird Johnson Wildflower Center and the Texas Parks and Wildlife Department would advocate for private property owners to deal with storm water and riparian restoration on their properties. This example also provides a complete design drawing set with commonly found conditions along the Blanco and other rivers such as upland, residential, canopy, riparian buffers, and river access points. This design is intended to give landowners options for dealing with rainwater runoff, plantings for areas adjacent to Hill Country rivers, and design suggestions so that landowners may successfully blend "natural" and "formal" areas. Every landowner won't necessarily be able to implement all of the strategies, but they can look at each component (upland, residential, canopy, riparian buffer, river access) and choose those that make the most sense given their property type. Viewing each property as part of a larger riparian system strengthens the impact of the suggested strategies, and more importantly, contributes to the overall health overall health of Hill Country rivers.

government permits


Photo Credit - Steven Schwartzman

A permit is required for construction or fill activities performed within the channel (below the Ordinary High Water Mark). The purpose and scale of the activity will determine which type of 404 permit is required. The USACE administers this process, and more information can be found at:

http://www.swf.usace.army.mil/Missions/Regulatory/Permitting/

The term ordinary high water mark means that line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas (Army Corps of Engineers 2005).

Please call the county or local government before any digging takes place to ensure that the location of all infrastructure is known (e.g. phone, water, gas, sewage, telephone, electrical).

Restoration projects may or may not require permits, but it is best to inquire to avoid penalties such as fines or having to return the site to its prior condition. Submitting thorough sets of plans that clearly illustrate your restoration intent as well as all necessary design/construction drawings will help ensure that your project is permitted in a timely manner, ideally within 45 days.


Photo Credit - Steven Schwartzman

government permits

If you do wish to undertake restoration efforts on your land, contact the Army Corps of Engineers Regulatory Division in Fort Worth, TX at (817) – 886 – 1731 to discuss your project to help determine if permits are necessary. Helpful documents to assemble for your conversation:

- Project location: state, county, city or closest town
- Restoration intentions: i.e. repairing flood damage, habitat improvement, site grading, etc.
- Maps documenting existing conditions: soil maps, drainage maps, plats, topographical surveys, etc.
- Design plans: It will be helpful to demonstrate any physical changes to your property through design drawing sets. The more information you have, the better the chances that ACE will either waive permitting or process necessary permits as quickly as possible. If you don't plan on making major changes requiring drawings by a landscape architect, try and visually demonstrate your restoration efforts as best you can.

US Army Corps of Engineers 404 Permit

Depending upon the size and location of your proposed work, you may be required to provide an application or preconstruction notification (PCN) for USACE review and prior to authorization of your project. For riparian restoration one of the following 404 permits may apply, however it is possible that a separate permit not listed below may be required. Contacting the USACE is essential to determining the appropriate course of action.

- Nationwide Permit (NWP 13 Bank Stabilization – Bank stabilization activities necessary for erosion prevention.
- NWP 18 Minor Discharges – For activities that discharge less than 25 cubic yards of fill material.
- NWP 19 Minor Dredging – For the dredging of no more than 25 cubic yards below the plane of the OHWM.
- NWP 45 Repair of Uplands Damaged by Discrete Events – Authorizes bank stabilization to protect restored uplands damaged by storm, flood, or other discrete events.
- Individual Permit – For larger projects or those that do not meet the criteria of a NWP.

Contact the USACE Fort Worth District –
Regulatory Division: 817-886-1731
http://www.swf.usace.army.mil/Missions/Regulatory/Permitting.aspx

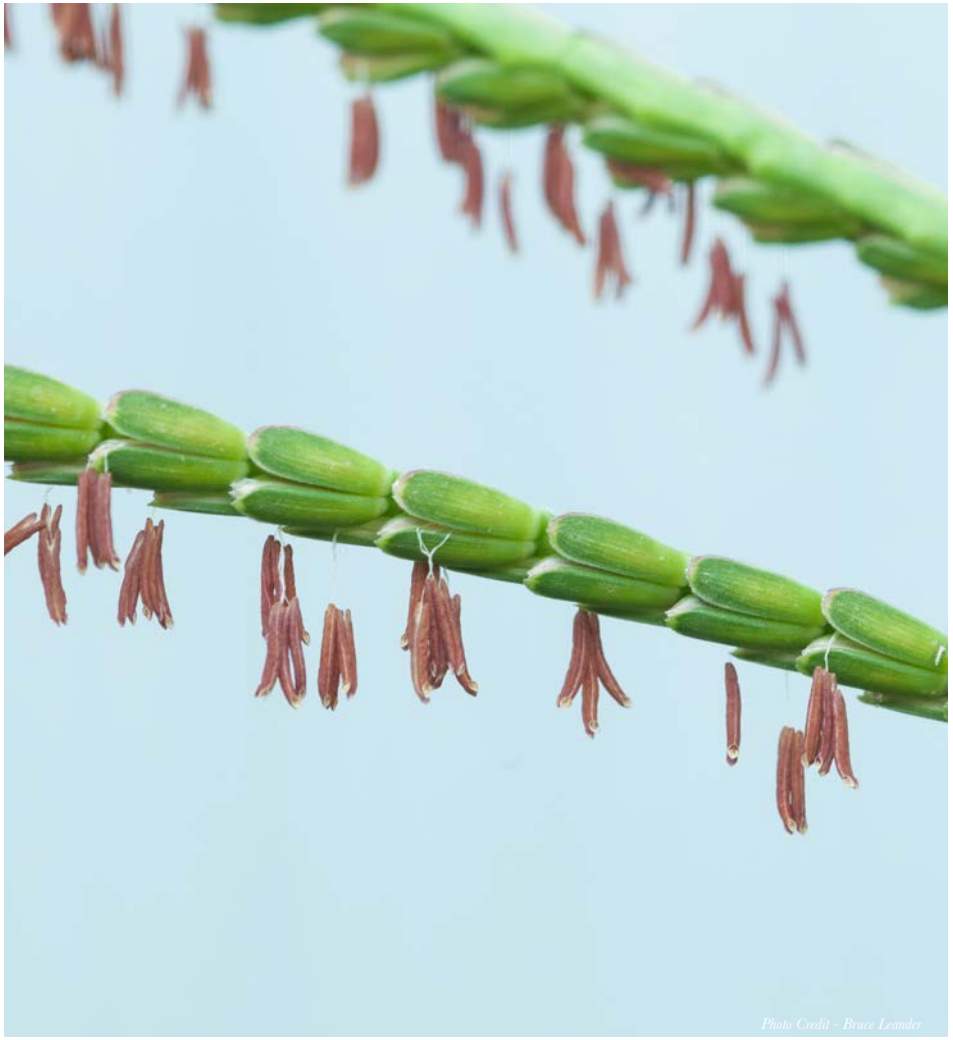
TPWD Sand and Gravel Permit

A permit from the Texas Parks and Wildlife Department is required to "disturb or take" streambed materials from streambeds under the State's jurisdiction. This includes all creeks and rivers 30 feet or wider, regardless of bed ownership. Plant installation should not require a permit if non-mechanized equipment is used.

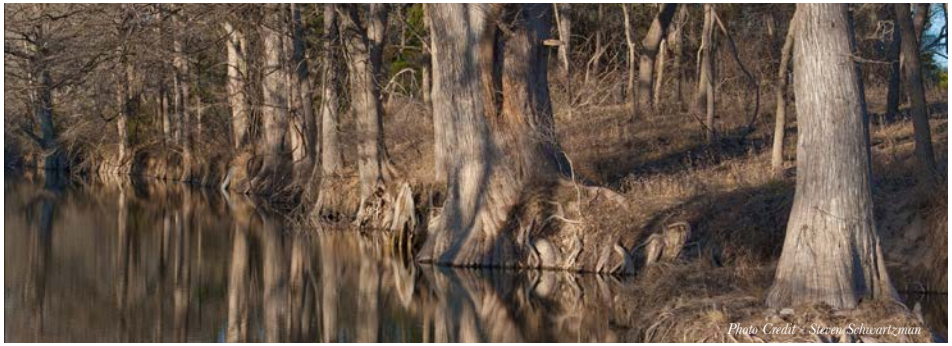
Contact the TPWD Watershed Conservation Program: 512-389-4583.
http://tpwd.texas.gov/faq/landwater/sand_gravel/

Floodplain Regulations

The County Floodplain Administrator may regulate construction or other activities occurring in the floodplain as determined by the Federal Emergency Management Agency's Flood Insurance Rate Maps. Contact the county to receive a permit or exemption.



central texas riparian ecosystems



Twenty percent of bottomland forest ecosystems have been lost in the southern states since 1950 (Kellison and Young 1997 as cited in Holcomb 2004); and by 1986, over one-half million acres have been inundated by reservoirs in Texas (McMahan 1986 as cited in Holcomb 2004). The diversity of plant and animal species found in functioning bottomland forests is unparalleled among other ecosystem types throughout the lower 48 United States (Kellison and Young 1997 as cited in Holcomb 2004). It is important to understand that this species richness and diversity resulted from the convergence of wetland and upland associations. In fact, the U.S. Army Corps of Engineers (COE), the Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), and the Soil Conservation Service (SCS) have expanded their wetland definition criteria to include bottomland hardwood forests (Kellison and Young 1997 as cited in Holcomb 2004).

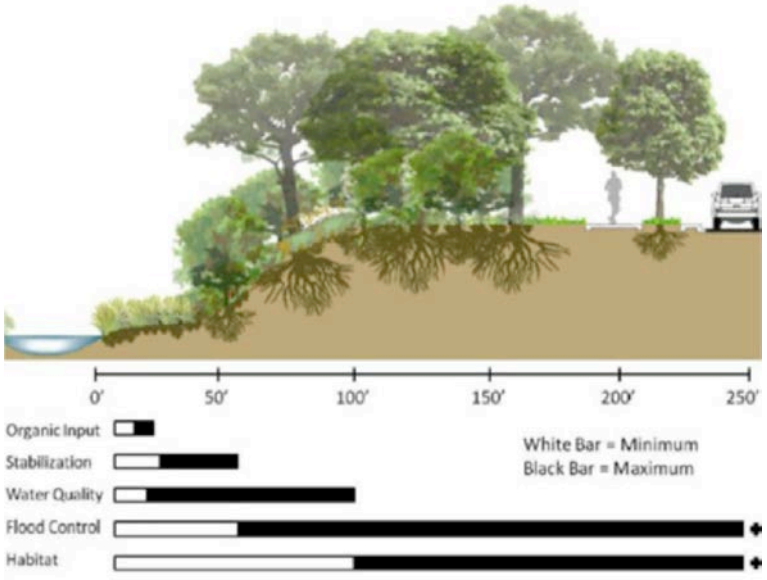


Figure 1 – COA riparian corridor - City of Austin, Watershed Protection Department. Riparian Zone Restoration.

Figure 1. This image above shows the various buffer widths associated with riparian zone function. Organic inputs into the stream are important sources of nutrients and habitat (width 15-25 ft). Stream stabilization is maintained by riparian vegetation (width 30-60 ft). Water quality is the ability of the vegetation to intercept runoff, retain sediments, remove pollutants, and promote groundwater recharge (width 20-100 ft). Flood control is the ability for the floodplain to intercept water and reduce peak flows (width 60- 500 ft). Riparian habitat is the ability of the buffer to support diverse vegetation and provide food and shelter for riparian and aquatic wildlife (width 100-1500 ft).

The health of Texas' rivers, streams, and creeks are important contributors to the overall environmental and human health of urban areas. Many of these ecosystems are threatened by non-point pollution, invasive plant growth, degraded/paved watersheds, and the channelization of streams, thus impacting or eliminating beneficial ecosystem services (Allan et al. 1997, Strayer et al. 2003, Townsend et al. 2003).

Riparian areas perform essential hydrological and biological functions, including flood control, surface water storage, ground water supply recharge, and biological diversity (Dickson 1989, Gregory 1991, Williams et al. 1997). Vegetation in riparian corridors act as a filter trapping sediment, organics, excess nutrients, and pollutants from parking lots, roads, residences, and commercial lot surface runoff, improving water quality (Lowrance et al. 1984, Henley et al. 2000).

Riparian areas are complex ecosystems that contain vital habitat for numerous species. The vegetation not only prevents erosion, but also provides food (Halls 1973), cover (Burk et al. 1990, Halls 1973), and breeding habitat for bird, amphibian, mammal (Dickson and Huntley 1987), fish, and reptile species (Rudolph and Dickson 1990, Brode and Bury 1984). Trees (snags), branches, and leaves falling from riparian edges into the water provide habitat for aquatic organisms (Maser and Sedell 1994) and help build soil by slowing water flows. Removal of this cover results in a reduction in biodiversity and landscape performance.

Opportunities to restore ecological function

There are many opportunities to improve ecological function of Hill Country rivers in addition to creating stunning landscape designs. To restore ecosystem function is not simply to replace plants but to use restoration principles to restore processes that allow natural systems to repair themselves and remain relatively stable. In practice, the assessment and repair of natural processes begins with the soil. Healthy soil, and the healthy plant communities it can support, comprise the foundation for functional ecosystems.

While the land owners may not be restoring property areas to historical climax conditions, restoration principles, which are informed by historical plant communities, still apply and allow a hybrid condition to exist that will foster greater ecological integrity than present conditions. As an overall strategy, it is often beneficial for restoration efforts to occur incrementally so that the challenges of climate (drought, excessive rain, freezes, etc.) do not overwhelm a significant investment or effort. This incremental approach will allow for fine tuning the restoration methods to what works best on site. Initial efforts should begin in high priority areas.

central texas riparian ecosystems

It is important for land owners to understand that the creation of sustained, successful landscapes will only occur if their designs are based on measures of function rather than measures of structure (Grayson et al. 1998). Structure, or patterns of an ecosystem, describes the various physical and biological parts of that ecosystem, whereas function includes the interactions of organisms with one another and with their physical environment (Grayson et al. 1998). Many projects are designed with the assumption that if the structure (i.e. spatial characteristics) looks right, the system will also function correctly, but many restoration/habitat projects that have been deemed a success, in terms of realized project goals, were ultimately not successful because the measures of function were insufficient or absent (Grayson et al. 1998). It is unlikely that everyone's yard can be returned to historical climax community conditions, but their design strategies can implement such achievable goals by defining major design goals during site assessments. For example, the project could aim to increase plant species diversity and richness or reduce erosion (Grayson et al. 1998).

Wetlands

Texas wetlands are some of the state's most endangered ecosystems and are characterized by permanent/semi-permanent water, oxygen poor soils, and obligate plant species adapted living in wet environments (TP WD 2003). Central Texas wetlands included flooded woodlands, river's edges, spring fed pools and seeps. The common feature of functioning wetland ecosystems is the variability of terrain and water depth.

Common wetland species for the site would have been water knotweed (*Polygonum amphibium*), buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), marsh purslane (*Ludwigia palustris*), water pennywort

Photo Credit - Bruce Leander

(*Hydrocotyle ranunculoides*), cattail (*Typha domingensis*), bushy bluestem (*Andropogon glomeratus*), scouringrush horsetail (*Equisetum hyemale*), crimsoneyed rosemallow (*Hibiscus moscheutos*), zigzag iris (*Iris brevicaulis*), Virginia iris (*Iris virginica*), cardinal flower (*Lobelia cardinalis*), bigfoot water clover (*Marsilea macropoda*), nimblewill (*Muhlenbergia schreberi*), American white waterlily (*Nymphaea odorata*), lanceleaf arrowhead (*Sagittaria lancifolia*), and common elderberry (*Sambucus nigra ssp. Canadensis*).

Riparian Edges

Riparian vegetation is a major source of energy and nutrients for stream communities. Overhanging riparian vegetation keeps the streams cool, which is especially important for increasing plant species diversity. The target community for riparian areas frequently consists of a properly functioning gallery forest, dominated by bottomland hardwood species with an herbaceous layer beneath that is composed of species that will enhance bank stability. Historically, the riparian areas along perennial and frequently flowing intermittent streams on the Edwards Plateau consisted of this community type, while intermittent streams and streams in drier areas, like the recharge zone of the Edwards Aquifer, tend to be more reminiscent of the surrounding upland. Gallery forests support the goals of enhanced water quality along stream channels by enhancing bank stability, removing nutrients, pollutants, and sediment, and slow water runoff velocity.

Riparian Plant Community Considerations

For riparian restoration, a healthy, diverse native plant community adjacent to receiving water bodies and riparian zones helps control erosion, filters sediment and pollutants carried in stormwater, supports the health of aquatic ecosystems, and provides flood control and habitat. The root system of the vegetated area is crucial for achieving this health status. Increased native diversity can be encouraged through selective removal of invasive species and seeding of native woody and herbaceous species. Primary goals guiding species selection in riparian areas are enhanced bank stability and water quality. Many species found in central and southwest Texas have been given draft stability ratings based on their contribution to bank stability (Nelle 2009). Stability ratings range from 1 to 10, with 1 approximating the bare ground and 10 anchored rock. Ideally, riparian areas will be dominated by plants with stability ratings between 6 and 9. Stability ratings of 7 or higher are considered to be the minimum for acceptable bank stability. However, combinations of species, particularly woody species in association with grasses or sedges, can provide higher stabilities than reflected in individual species ratings (Nelle 2009).

central texas riparian ecosystems

In addition to stability ratings, USFWS wetland indicator status should be considered. Riparian areas should contain a mix of obligate wetland, facultative wetland, and facultative species, dependent on water availability. It is important that all riparian areas contain some species from the facultative groups to provide stability as water availability fluctuates.

Establishment of these species can be done passively or actively. Passive establishment is the regeneration of an existing vegetated buffer through the succession of native plants and natural seed dispersal. This is facilitated through elimination of invasive species and selective vegetation thinning. Active establishment is a technique used with little or no existing riparian buffer. This technique involves the creation of a site specific plan detailing the species and location of proposed vegetation. In some cases a combination of the two approaches is ideal, but this decision should be based on a per site basis. An active approach is recommended in areas of extreme erosion.

The active approach requires several steps for effective buffer improvements and establishment. Re-establishing the riparian zone should take place after erosion control measures have been established in the area draining to the river. First, it is important to remove invasive species from the riparian zone, keeping soil disturbance to a minimum to reduce vegetation loss and erosion. Erosion control techniques should be implemented adjacent to the riparian buffer, especially in any nearby construction areas, to aid in erosion control adjacent to the river. It is then important to establish different vegetation planting zones: an inner, middle, and outer zone.

The shallow wetland can contain unmanaged vegetation while the drainage and upland areas can contain managed vegetation. When establishing these zones, it is best to plant herbaceous seeding/plantings first before woody species. For tree establishment, it is recommended to plant a mix of balled and burlapped trees and saplings. In general, 30% of the riparian area to be reforested should be planted with 3" caliper trees at 6-7' intervals and 60% of the area with saplings at 15' intervals. These densities and amounts are flexible dependent upon restoration goals. All vegetation will require temporary irrigation after establishment, and the riparian zone will need to be monitored regularly for signs of erosion, sedimentation, debris, native plant establishment or invasive species. Irrigation and monitoring requirements should be detailed in restoration and maintenance plans.

A final consideration is the determination of the riparian buffer width. As mentioned in the site assessment, the current buffer varies with regard to both width and ecological health. When possible, the riparian buffer area shall be as large in size as possible, or a minimum width of 20 feet on either side of the water body. A wider buffer is more effective at filtering and reducing pollutant levels, specifically nitrogen (Mayer et al, 2005). Having a larger buffer zone will also allow for improved bank conditions.

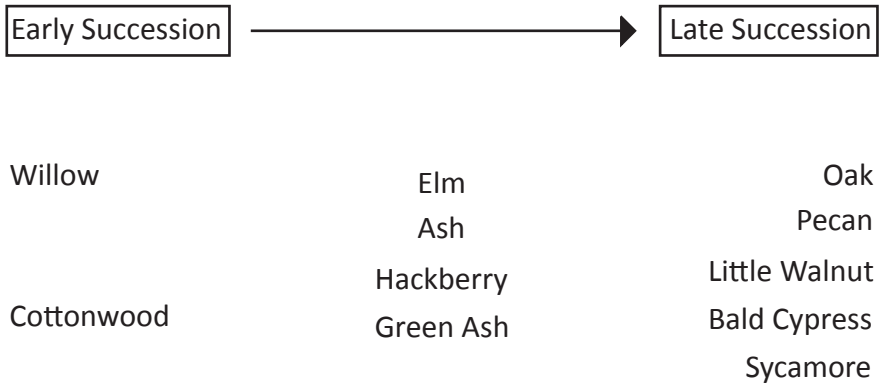
Riparian trees and canopy conditions

Central Texas has recorded some of the most intense rainfall in the world with some singular events depositing over 40" (Guadalupe- Blanco River Authority 2011), however, this region also experiences extended periods of drought. This climatic dichotomy results in a unique topographical system that includes floodplain and terraces formed from older floodplains (Wharton et al., 1982 as cited in Holcomb 2004). Forests in the floodplain are subject to flooding and the accompanying sediment deposition (Hodges, 1997 as cited in Holcomb 2004). The profile of these areas is characterized by a series of small ridges, flats, and sloughs, which influence water retention, sediment deposition, and soil texture (Hodges, 1997 as cited in Holcomb 2004). Species composition also varies with the topography as you move from mid river to upland (Holcomb 2004). Typical riparian species include pecan, little walnut, willow, bald cypress, and sycamore on the riverbanks; less water tolerant species (e.g. elm, hackberry, and plateau live oak) growing on the ridges; facultative wetland species (e.g. bald cypress, American sycamore, cottonwood) in the sloughs; and mixtures of both types, as well as facultative upland species (e.g. green ash) on the flats (Hodges, 1997 as cited in Holcomb 2004). Three types of dominant overstory plant communities can characterize the limestone-dominated Central Texas/Edwards Plateau region: bald cypress and sycamore; pecan and hackberry; and hackberry and elm. (Wagner 2003).

central texas riparian ecosystems

Source: Holcomb 2004. Example of canopy tree species development over time

Large portions of the landscape originally would have consisted of canopy communities of elm, live oak, hackberry, and pecan trees (USDA Soil Survey 1974). This community would likely include Bottomland



Range Site and Blackland Prairie species and also Edwards Plateau flora. These species are considered upland associations and although they are not directly affected by the hydrological conditions, they did act as important sources of organic matter for wetlands and helped create microclimates for habitat, and therefore should be considered part of the riparian system (Gregory et al. 1991). The grassland species also played an important role in controlling sheet flow runoff into receiving waterways during intense rain events and helped mitigate floods. Grass and broadleaf plants in these areas can include species such as purpletop (*Tridens flavus*), sideoats grama (*Bouteloua curtipendula*), Virginia wildrye (*Elymus virginicus*), Canada wildrye (*Elymus canadensis*), Eastern gamagrass (*Tripsacum dactyloides*), inland sea oats (*Chasmanthium latifolium*), wild onion (*Allium canadense*), Drummond's wild onion (*Allium drummondii*), black-eyed Susan (*Rudbeckia hirta*), pigeonberry (*Rivina humilis*), tropical sage (*Salvia coccinea*), purple coneflower (*Echinacea purpurea*), heart-leaf skullcap (S*cutellaria ovata ssp. Bracteata*), and shrubs like Turk's cap (*Malvaviscus arboreus var. drummondii*), American beautyberry (C*allicarpa Americana*), common buttonbush (*Cephalanthus occidentalis*), Mexican buckeye (*Ungnadia speciosa*), and evergreen sumac (*Rhus virens*).

Uplands

Historically the upland consisted of savanna with 20 -25% tree coverage which translates into 2 – 3 trees per acre. Many properties include closed canopy conditions with turf understory. Removing mature, large shade trees is likely undesirable, however, these areas can be dramatically improved with the removal of invasive species, soil amendment, placement of appropriate plant communities, increase of successional plantings, inclusion of micro-topography, and limb reduction.

Photo Credit - Steven Schwartzman

central texas riparian ecosystems

Tallgrasses and wildflowers for sunny spots

Much of the soil adjacent to the Hill Country rivers ranges from of clay loam, silty clay, cobbly clay, and stony clay to loose sand and sediment, cemented sediment, and bare bedrock. These soil conditions will determine the appropriate plant compositions for properties located along the river. Grasses and wildflowers help anchor the soil during high flow events due to their extensive fibrous root systems and their ability to lie down and shield underlying soils during high flow flood events. In eroded areas soil depth, content, and compaction will be a limiting factors for the potential of site recovery. Replanting efforts will likely require multiple seeding sessions as well as planting plugs of key species that usually don't appear until ecosystems have reached a stable mature state (USDA Soil Survey 1974).

Vegetation, especially on areas within the 100 year floodplain, should predominantly consist of tall, warm-season perennial bunchgrasses with lesser amounts of midgrasses. This tallgrass prairie was historically dominated by big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), switchgrass (P*anicum virgatum*), Eastern gamagrass (*Tripsacum dactyloides*), and little bluestem (*Schizachyrium scoparium*). Midgrasses such as sideoats grama (*Bouteloua curtipendula*), Virginia wildrye (*Elymus virginicus*), Canada wildrye (*Elymus canadensis*), cedar sedge (*Carex planostachys*), Texas

Photo Credit - Bruce Leander

wintergrass (*Nassella leucotricha*), Texas cupgrass (*Erichloa sericea*), fall witchgrass (*Digitaria cognate*), green sprangletop (*Leptochloa dubia*), hairy grama (*Bouteloua hirsuta*), dropseeds (*Sporobolus spp.*) and a wide variety of forbs such as Engelmann's daisy (*Engelmannia peristenia*), Maximilian sunflower (*Helianthus maximiliani*), narrow-leaf coneflower (*Echinacea angustifolia*), pink evening primrose (*Oenothera speciosa*), rattlesnake master (*Eryngium yuccifolium*), prairie clover (*Dalea spp.*), dotted gayfeather (*Liatris punctata*), wild foxglove (*Penstemon cobae*), Hill Country penstemon (*Penstemon triflorus*), and snow on the prairie (*Euphorbia bicolor*) add to the diverse native plant community (USDA Soil Survey 1974).

River access and residential areas can utilize native short and mid grasses to recreate turf conditions. Generally the more species planted within these areas the less weeds landowners will have to contend with as the density created by a diverse species mix helps prevent opportunistic invasive plant establishment. Some of the species that can be planted in "turf" areas can consist of species such as side oats grama (*Bouteloua curtipendula*), curly mesquite (*Hilaria belangeri*), buffalograss (*Bouteloua dactyloides*), hairy grama (*Bouteloua hirsute*), blue grama (*Bouteloua gracilis*), Texas grama (*Bouteloua rigidiseta*), purple threeawn (*Aristida purpurea*). These areas can also contain wildflowers such as purple coneflower (*Echinacea purpurea*), mealy blue sage (*Salvia farinacea*), bluebonnet (*Lupinus texensis*), blue-eyed grass (*Sisyrinchium angustifolium*), Hill Country rain lilly (*Cooperia pedunculata*), crow poison (*Nothoscordum bivalve*), and pink evening primrose (*Oenothera speciosa*).

LID

Beyond providing a healthy buffer to enhance water quality and reduce erosion, properties should be evaluated for opportunities to restore and improve hydrological function. As much of the upland areas contribute and drain to the river, slowing surface flow from locations such as parking lots, turf areas, and buildings through dispersed vegetated systems, add to greater health of the river. Low Impact Development (LID) or Green Infrastructure is a comprehensive hydrological approach to site planning, design, and pollution prevention strategies that create a more economically sustainable and ecologically functional landscape. As such, the LID approach provides many benefits to a community's water resources and overall quality of life. It is a comprehensive approach to land development or re-development to manage stormwater runoff. The LID methodology works with nature to manage stormwater as close to its source as possible, treating runoff as a resource rather than a waste product. Using LID techniques can help:

central texas riparian ecosystems

- Emphasize conservation and the use of on-site features to protect water quality
- Create functional and appealing site drainage
- Keep water on the site and allow infiltration into soils
- Recharge groundwater and the aquifer (where appropriate)

Rain gardens (bioretention)

Rain gardens (or bioretention) function as a soil and plant-based filtration device that removes pollutants through a variety of physical land biological processes. These depressed areas allow water to be retained in a basin shaped landscape area with plants and soil where the water is allowed to pass through the plant roots and the soil column. These facilities normally consist of a basin or ponding area, organic or mulch layer, and plants. Constructed rain gardens provide stormwater treatment that enhances the quality of downstream water bodies by infiltrating runoff, or when designed with liner or underdrain, temporarily storing runoff and releasing it over a period of days to the receiving water. The vegetation within the constructed rain gardens can provide shade and wind breaks and help absorb noise. Rain gardens are easily integrated into site landscaping and their design and can be formal or informal in character.

Swales

Swales are vegetated channels that convey stormwater and remove pollutants by sedimentation and infiltration through soil. Unlike rain gardens that capture, retain, and infiltrate stormwater, swales are primarily stormwater conveyance systems. They can provide sufficient control under light to moderate runoff conditions, but their ability to control large storms is limited. Therefore, they are most applicable in low to moderate sloped areas or along roadsides as an alternative to ditches and curb and gutter drainage. Swales can be more aesthetically pleasing than concrete or rock-lined drainage systems and are generally less expensive to construct and maintain. With this technology, it is important that the swale maintain 100% cover with grasses to be effective.

Design Considerations

Before implementing any LID techniques on site, it will important to determine the volume of the annual runoff to be managed. This may be specified in existing local regulations. Or, it is possible to analyze historical rainfall data in the region to determine the relationship between the water quality volume and the amount of the annual runoff to be treated. It will also be important to conduct a thorough analysis of the following, at a minimum:

- Soil type and whether modifications are needed

- The storage needed to capture and treat the runoff (based on local conditions)
- The sensitivity of the receiving body
- Future maintenance
- Installation techniques
- The ability to infiltrate the runoff (or if they will be filtration features)
- The desired performance goals of the LID feature

Restoring landscapes

The restoration techniques mentioned in this booklet are designed to guide landowners in the process of repairing damaged land or converting resource intensive landscapes to areas that are both beautiful and best suited to protect property during high flow flood events. The species listed in this document evolved in disturbance driven ecosystems that included wildfire and flood, and are best adapted to contribute towards the recovery of the floodplain. Landowners should note that the transition of property from a degraded state dominated by invasive plant growth or severe erosion will be challenging and resemble more of a trajectory rather than a singular intervention. Emphasis should be placed on the positive impacts from the restoration process rather than an end product. Minor disturbances in healthy functioning ecosystems usually self heal and return to a stable functioning state within a relatively small amount of time, however, such healthy systems are rare within or near urban and suburban areas because significant alterations to natural processes such as the water's movement through the landscape (hydrology), nutrient cycling (capture and utilization of soil nutrients), and soil health and organic matter production, have resulted in an inability of the land to reset itself (Whisenant 2005). Additionally, major disturbance events, such as the Memorial Day flood, complicate restoration efforts because they require large-scale intervention on both upland and riparian components, and force us to redefine how we choose to interact with our environment.

During restoration efforts it is very likely that the best laid plans will face

central texas riparian ecosystems

setbacks and that multiple efforts will be required to achieve what might be deemed a success, but know that ecosystems are dynamic entities consisting of a complicated network of interconnected biotic (living) and abiotic (physical) components. The Lady Bird Johnson Wildflower Center's restoration experts always face challenges when trying to revive abused or degraded land, and just by simply deciding to slow water and keep it on site, incorporating native plantings in a system based approach (not relegating plants to flower beds), and allowing tallgrass communities to thrive on parts of their property, homeowners will make a major difference and help mitigate damage from flood events. This is not to say that a restoration strategy will completely prevent flood damage, but by embracing these measures landowners will be able to enjoy a more diverse, healthy, and functional Texas landscape and contribute towards an overall improvement of the river's condition.

This booklet also provides landowners with a demonstration of what these efforts can result in when implemented on an actual property located on the Blanco River that experienced severe damage from the floods. We have divided the property into four parts: an upland component, residential area, canopy dominated area, and riparian buffer. The goal is that all properties might not possess all of these components, but by applying similar strategies property owners can design their landscape so that it embraces both nature and beauty; with the hopes that we may move beyond the argument that natural areas look unkempt leaving homeowners only with the option of St. Augustine lawns if they desire a well designed yard. We need to look beyond landscape design that results in entire swaths of neighborhoods that look exactly the same whether you are in Wimberley, Texas or Portland, Maine. Let's make Texas, Texas.

The following recommended restoration measures are based on the Lady Bird Johnson Wildflower Center's years of experience in ecological restoration and hopefully will provide landowners with a framework and number of actions that will enable people to better understand the landscape and processes that helped form the unique and beautiful ecosystem that is Texas Hill Country. This endeavor can, if applied on a large scale, cumulatively result in a net positive change that will benefit both people and the environment, and make a beneficial, demonstrable impact on the Texas landscape, or as Mrs. Johnson called it, "our heart's home."

Photo Credit - Steven Schwartzman

site assessment

Introduction

The first step of any restoration effort is a pre-design assessment of existing site conditions. It is tempting to skip this step in order to get started with design and installation, but an accurate pre-design assessment will maximize the opportunities for beneficial site performance.

Site assessments can be conducted at several levels of detail, with the simplest being hand drawn maps of erosion and existing plant communities and the most detailed involving professional surveys of soil, drainage patterns and vegetation. Useful information can be gathered at either end of the spectrum.

This booklet will provide an overview of the elements to consider during a site assessment and will provide resources for multiple levels of site assessment.

Elements to consider

The goal of the site assessment is to identify elements of the site to protect or enhance as well as any problems (erosion, invasive species etc.) that will need to be addressed in the final design. Frequently, the best opportunities for enhancement of the site grow from the site's challenges.

The primary elements to consider during the site assessment are: drainage patterns, impervious cover (buildings, roads etc.), soil type and condition, plant community type, arrangement and composition, channel condition, and bank condition.

Preliminary data gathering

Prior to beginning the on-site assessment, gather the following information.

- EPA level III and IV ecoregion. Ecoregion descriptions will provide you with information on the natural communities that occur in your region and will provide you with some information on species that are appropriate to your area.
  - -http://www.epa.gov/eco-research/ecoregions
  - -http://www.tceq.state.tx.us/assets/public/comm_exec/pubs/as/199.pdf
    - --Wimberley, TX
    - --Level III ecoregion: Edwards Plateau
    - --Level IV ecoregion: Balcones Canyonlands
- 100 year flood plain
  - -https://msc.fema.gov/portal/search

Process

A site assessment is recorded in a series of maps, which can be hand drawn or generated with mapping and design programs such as GIS and CAD. The method is less important than accurately locating important elements spatially which will help to show relationships between them and will often make opportunities stand out. This assessment will focus on the bank and upland areas, not the stream channel itself. The goal is to identify problems and opportunities that the landowner can directly affect, so issues caused by watershed scale processes are not addressed here. Additionally, this is primarily an inventory, not an ecosystem health assessment, though elements of ecosystem health are included.

Topography and flow direction

The first element to consider is topography. Mapping topography is important so that existing drainage patterns can be understood and so interventions can be placed where they will be most effective. A topographic, or contour, map of the property needs to be obtained. Topographic maps show changes in elevation using contour lines. Each line represents an elevation. The interval for the map is how much change in elevation there is between each line. USGS topographic typically have a 10 foot interval, so the land either rises or falls 10 feet between the lines. Surveys done prior to most design work have a 1 foot interval. It is a good idea to have a professional survey done with 1 foot contour lines, but an initial pass can be done with a USGS topographic map.

- USGS quadrangles provide rough contours (10 ft. interval)
  - -The USGS Store https://store.usgs.gov
    - --Download the most recent Road US Topo
    - --Turn on the orthoimage to see aerial imagery
  - -Private companies will create custom topographic maps for your area

Here are some typical patterns seen with contour maps and what they mean to drainage patterns.

The steepness of a slope can be determined by how close the contour lines are to one another. The closer the lines, the steeper the slope.

site assessment

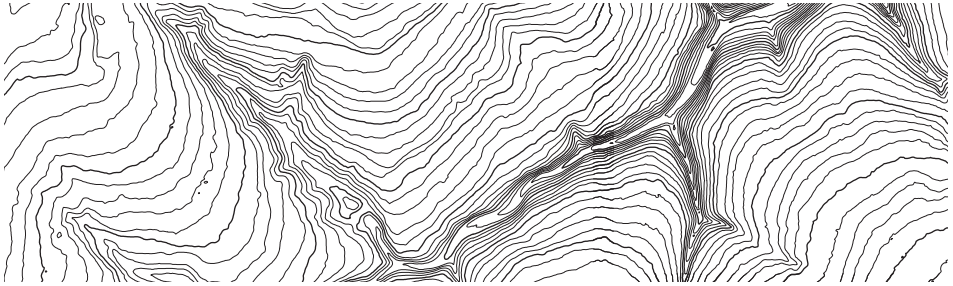


Figure 3.1 Vs or Us are either ridges or valleys. If you are looking at a valley, the point of the V points upstream. Water flow will concentrate in these areas making them more prone to erosion.

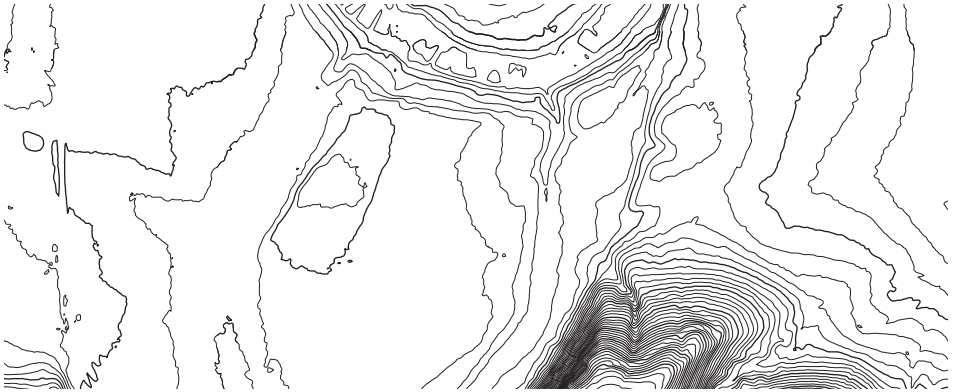


Figure 3.2 Circles are either peaks or depressions. Natural depressions will collect water and create opportunities for elements such as rain gardens.

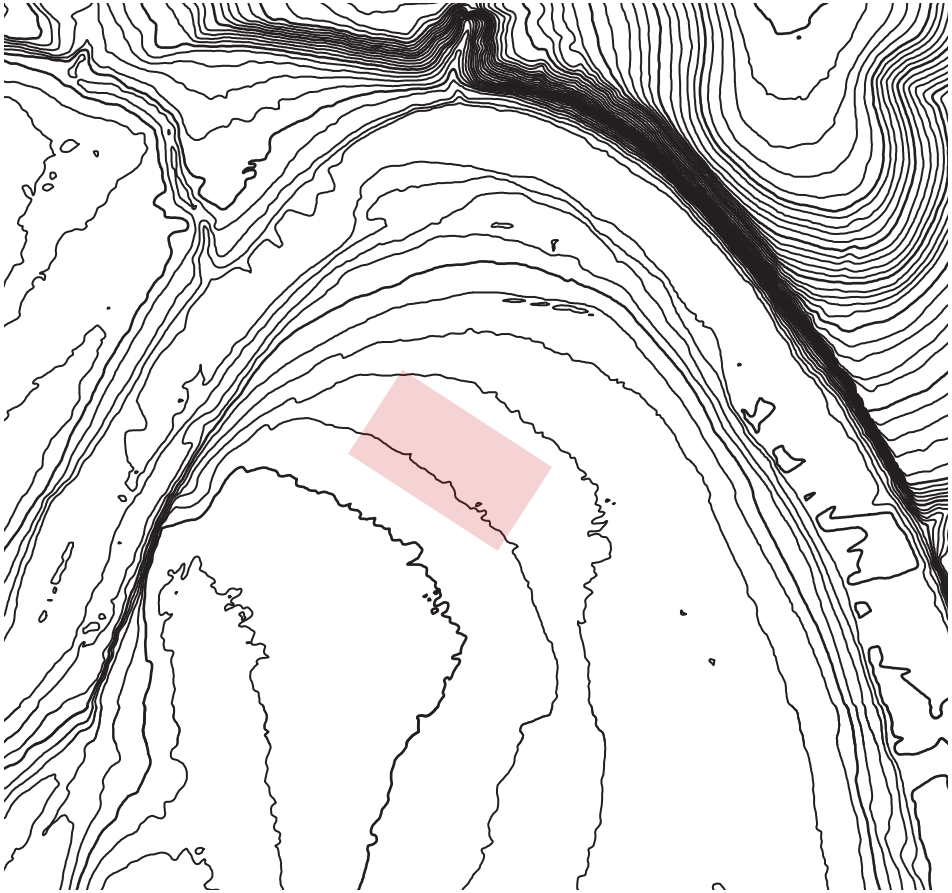


Figure 3.3. Once you have your contour lines, place any existing built elements on the map because these will affect drainage patterns.

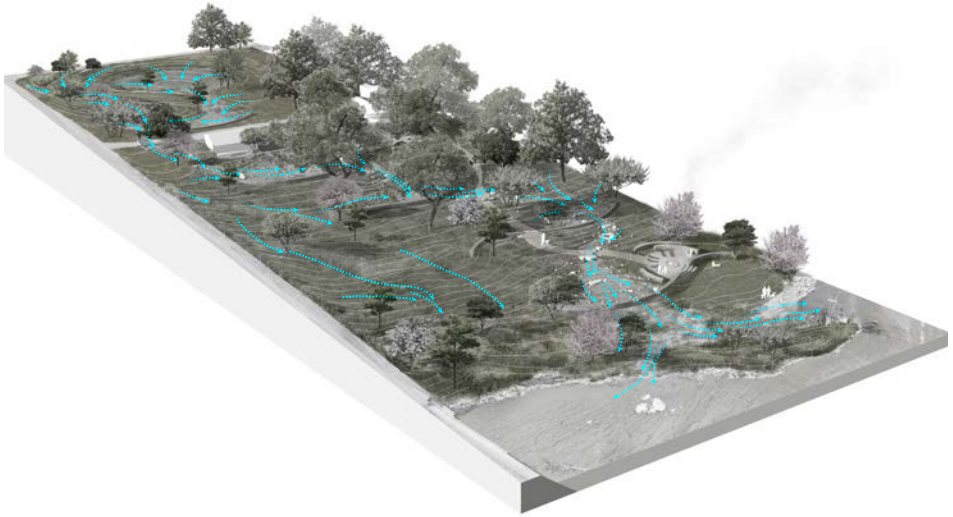


Figure 3.4 Finally, map flow direction and existing signs of erosion and sedimentation. Use your topographic map and site inspection to identify where water causing erosion is coming from.

site assessment

Soils and Plant Cover

Next consider existing soils and plant cover. A custom soil map for your property can be generated using the Web Soil Survey http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm . A tutorial for using the tool exists on the site's home page, and a more detailed tutorial can be found in Appendix A. The soil survey provides a wealth of information about the site. Many properties have more than one soil type and design should take this into account.

When generating your soil report gather the following information at a minimum:

- Soil map
- Ecological site information
- Soil reports
- AOI inventory: component legend, map unit description
- Land classification: hydric soils
- Soil chemical properties
- Soil physical properties: engineering properties, particle size, physical soil properties

In addition to the soil map, it is a good idea to have soil testing done for the site. A soil sample should be taken for each mapped soil type and sent to a soil testing laboratory. Request the following tests: pH, macronutrient (often called routine analysis), organic matter, and texture. This will be important as plant material and other interventions are considered for the site.

Most laboratories will provide instruction for taking soil samples. The Texas A&M laboratory (contact information below) provides instructions on the back of the submittal form.

Texas A&M Agrilife Extension Service,
Soil, Water and Forage Testing Laboratory
http://soiltesting.tamu.edu/
Voice: 979.845.4816
Email: soiltesting@tamu.edu

Plant cover

The soil map can be used as a base map for mapping plant cover. The most basic plant cover mapping involves breaking the plant communities into types: trees/shrubs/herbaceous/bare ground. If you have a topographic survey done, frequently the trees can be included in that as well. Ideally, this mapping will include identification of some of the species. Focus on identifying the dominant, or most common, species in each layer (tree/shrub/herbaceous) and in identifying potential

problem species such as Arundo or elephant ear. Assistance with plant identification is available from a variety of sources.

Consider the overall make-up of the site. How much is devoted to:

- Woody vs herbaceous. Does the area have an overstory (tall trees), midstory (shrubs), and an herbaceous layer (grasses, sedges, wildflowers)?
- How much of the soil is bare? How much is covered with plants or litter (dead leaves, blades of grass, etc.)?
- Within the plant community, how much is devoted to annuals vs perennials?
- Are desirable species present? Examples of desirable species include:
    - Riparian: bald cypress, black willow, buttonbush, cottonwood, sycamore, pecan, little walnut, switchgrass, Eastern gamagrass, sedges, bushy bluestem
    - Transition/upland: oaks, cedar elm, American elm, native bunchgrasses
- Are undesirable species present? Examples of undesirable species include:
    - Riparian: Arundo, elephant ear
    - Upland: Johnsongrass, King Ranch bluestem
- Is there a variety of species present or just one or two?
- Are there multiple ages present? Ages can be approximated with size for woody species. Divide them into knee height, head height, and taller.
- How much standing dead wood is present? <5%, 5-25%, 25-45% or >45%.

The percent cover, or amount of the ground the element shades, can be estimated visually.


Photo Credit - Bruce Leander

site assessment

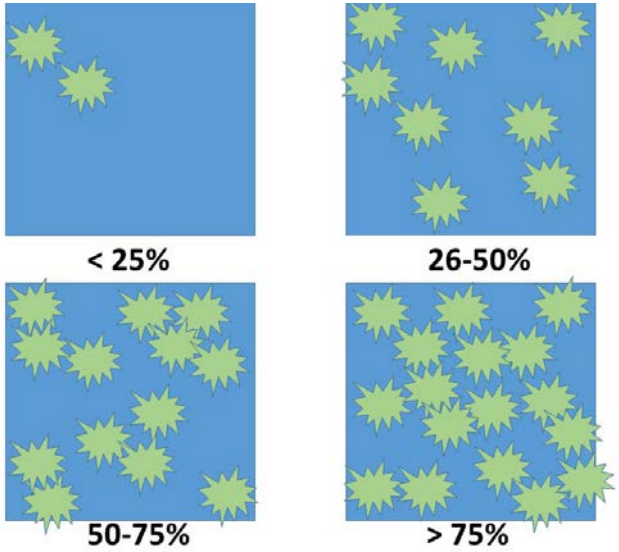


Figure 3.5 percent cover

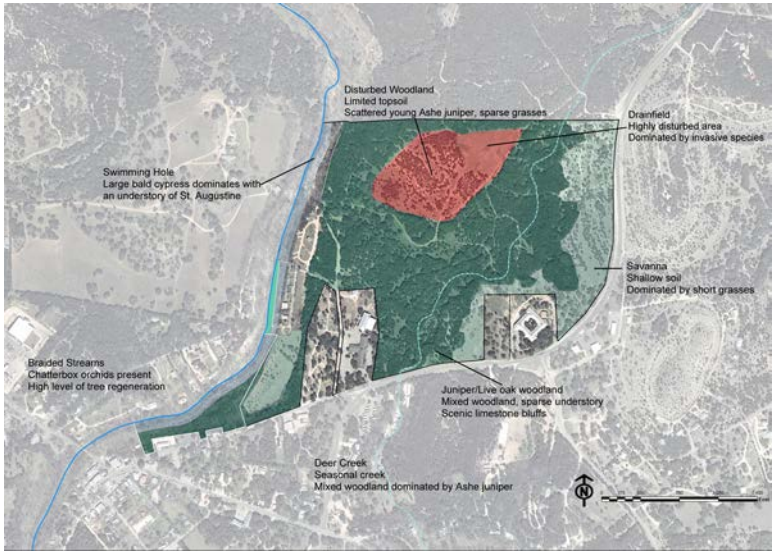


Figure 3.6 Example of plant community map

Channel and Riparian area

All of the elements described above should be addressed in the area adjacent to the waterway, but this area and the channel itself, bring additional considerations.

The presence or absence of large woody debris should be noted. Big woody debris is helpful for riparian health because it slows water, provides a site for sediment to accumulate, and can help provide a safe place for germination. Dense, tall vegetation with stabilizing root mass is important for bank stability. Trees, shrubs, and herbaceous plants like sedges provide good stabilization. Individual species provide different

levels of bank stability. This will be discussed in the Plants and Soils section of this booklet.

Bare areas caused by recent sedimentation is fine and will colonize naturally, but excessive bare ground can be a problem.

See Your Remarkable Riparian for an excellent discussion of riparian plants in the Edwards Plateau and and Rio Grande Plains : http://www.remarkableriparian.org/index.php

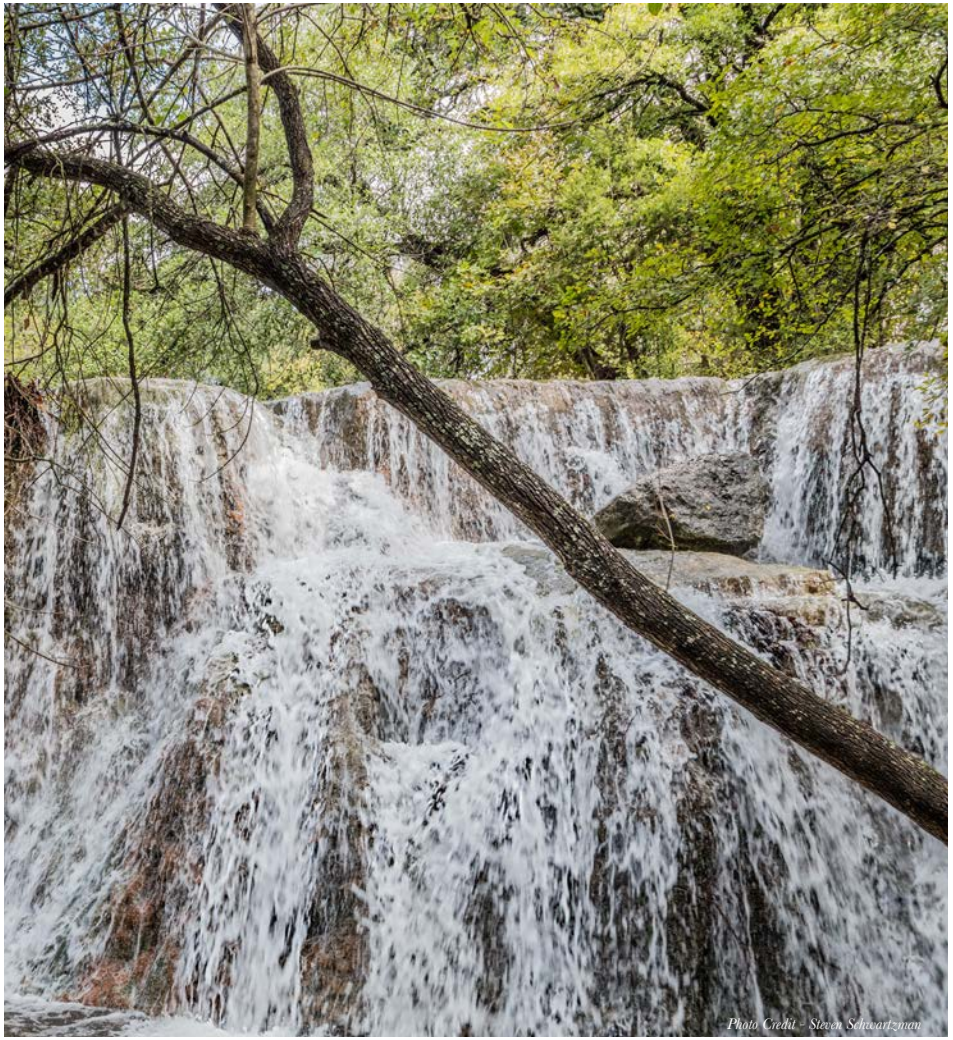


Photo Credit - Steven Schwartzman

uprooted tree depressions

Uprooted trees, minor erosion, and sediment deposition
Many property owners have experienced erosion and damage to their land from uprooted trees, or had large amounts of sediment deposited along parts of the shoreline. Minor erosion events, places where topography was altered, but not dramatically changed, can be re-graded and restored using methods described in this manual. These efforts will likely include: manipulating eroded soils to restore or improve drainage patterns and topography, importing weed free soils, and revegetating areas with native seed and/or plugs.

Some properties have large depressions left on their land from uprooted trees. If these depressions don't threaten infrastructure, lead to further erosion, or prevent access to the river, they present an opportunity for wetland habitat in the form of vernal pools:

Vernal pools are seasonal, depressional wetlands that are covered by shallow water for variable periods from winter to spring, but may be completely dry for most of the summer and fall. These wetlands range in size from small puddles to shallow lakes and are usually found in a gently sloping plain of grassland. Vernal pools are sometimes connected to each other by small drainages known as vernal swales, forming complexes. Beneath vernal pools lies either bedrock or a hard clay layer in the soil that helps keep water in the pool. Climatic changes associated with each season cause dramatic changes in the appearance of vernal pools. The pools collect water during winter and spring rains, changing in volume in response to varying weather patterns. During a single season, pools may fill and dry several times. In years of drought, some pools may not fill at all. In the spring, wildflowers often bloom in brilliant circles of color that follow the receding shoreline of the pools. By early summer, the water has evaporated, and the clay pools appear brown, barren, and cracked. The unique environment of vernal pools provides habitat for numerous rare plants and animals that are able to survive and thrive in these harsh conditions. Many of these plants and animals spend the dry season as seeds, eggs, and then grow and reproduce with the ponds are again filled with water. In addition, birds such as egrets, ducks, and hawks use vernal pools as a seasonal source of food and water (EPA 2014).

These pools will serve as rich amphibian breeding areas that will rely heavily on the pools to complete their breeding cycle. Few species are able to exist in pools that tend to dry up rapidly and many species of amphibians will avoid ponds that are flooded throughout the year; however, pools that tend to stay wet throughout the year can support native fish populations. Whether or not the depressions will hold water will largely depend upon the underlying soils and proximity to the water table. If planned

correctly, vernal pools will not create mosquito habitat as mosquitoes generally have evolved to avoid laying eggs in locations where predators, such as fish, amphibians, and dragonflies live. These unique features can dramatically increase species and habitat diversity along the river and can include plants such as false indigo (*Amorpha fruticosa*), bushy bluestem (*Andropogon glomeratus*), creek sedge (*Carex blanda*), blue mistflower (*Conoclinium coelestinum*), horsetail (*Equisetum hyemale var. affine*), zigzag iris (*Iris brevicaulis*), virginia iris (*Iris virginica*), cardinal flower (*Lobelia cardinalis*), creeping water primrose (*Ludwigia peploides*), clover fern (*Marsilea macropoda*), nimblewill (*Muhlenbergia schreberi*), American white water lily (*Nymphaea odorata*), spring obedient plant (*Physostegia intermedia*), dwarf palmetto (*Sabal minor*), lance-leaf arrowhead (*Sagittaria lancifolia*), buttonbush (*Cephalanthus occidentalis*), osage orange (*Malcura pomifera*), American sycamore (*Platanus occidentalis*), Eastern cottonwood (*Populus deltoides ssp. Deltoides*), Mexican plum (*Prunus Mexicana*), and Burr oak (*Quercus macrocarpa*).

Landowners who have received large amounts of rocky/sandy sediment on their property from flood events should not move any of the sediment or try to manipulate the shoreline. River morphology (the physical shapes of rivers and their changes over time) determines the location of deposition zones and the dynamic nature of rivers means that these large-scale processes cannot be controlled. Management efforts on gravel and sand bars should be confined to seeding if residents wish to alter the bare sediment condition. Native wildflower species such as bluebonnets (*Lupinus texensis*), clammyweed (*Polanisia dodecandra*), huisache daisy (*Amblyolepis setigera*), tropical sage (*Salvia coccinea*), Texas frogfruit (*Phyla nodiflora*), Indian blanket (*Gaillardia pulchella*), zexmenia (*Wedelia acapulcensis var. hispida*), and grasses such as bushy bluestem (*Andropogon glomeratus*), inland sea oats (*Chasmanthium latifolium*), Eastern gammagrass (*Tripsacum dactyloides*), and green sprangletop (*Leptochloa dubia*) are good pioneer species that will help cover up bare spots, add color, texture, habitat value, and initiate organic matter build up.


Photo Credit - Adam Barile

soils and plants

Selecting appropriate plants is important from both an ecological health and a maintenance perspective. Plants should be selected that are suited to the site and that provide the ecological function that is important to the health of the waterway. This discussion will first cover general considerations and then will focus on each zone.

For the purposes of this booklet, the planting zones have been divided into riparian and upland. Soil moisture and frequency of flooding decreases as distance from the waterway's edge increases (Figure 4.1), which affects the plants that can be supported. The ecological function performed by the landscape changes along this gradient as well, with bank stability and organic inputs more important near the water and flood control more important in the uplands (Figure 4.2). Plant species vary in the function they are able to provide to a site and should be selected and arranged accordingly.

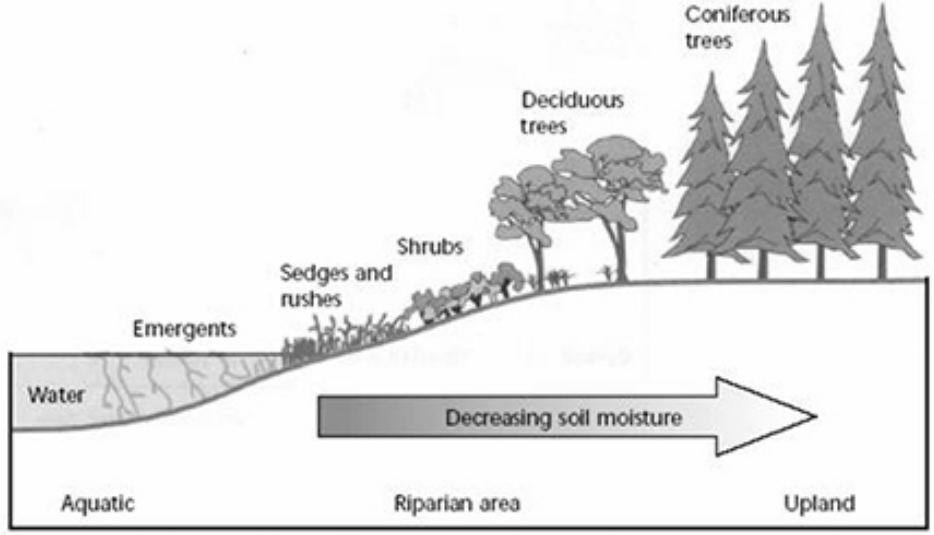
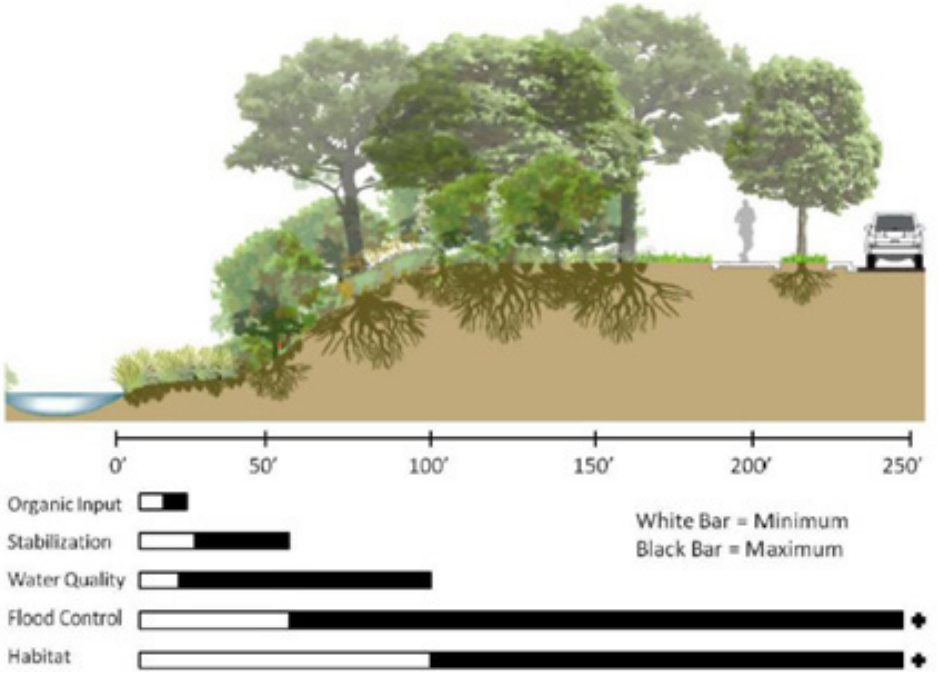


FIGURE 1 *Illustration of the moisture gradient in a typical riparian ecosystem (from Stevens et al. 1995:2).*

https://www.crd.bc.ca/education/our-environment/ecosystems/freshwater/riparian-zones
Figure 4.1. Moisture gradient in a typical riparian ecosystem.



https://www.austintexas.gov/faq/riparian-zone-restoration
Figure 4.2 - Ecological Function - USDA Wetland Indictor Categories

The average moisture in the soil changes on a gradient starting at the water's edge and moving into the uplands, with the wettest soils near the waterway. The USDA has classified plants based on their preferences.

Indicator Code	Indicator Status	Comments
OBL	Obligate Wetland	Almost always occur in very wet locations
FACW:	Facultative Wetland	Usually found in wet locations
FAC:	Facultative	Can be found in wet and non-wet locations
FACU:	Facultative Upland	Usually found in non-wet locations
UPL:	Obligate Upland	Almost never found in wet locations

Stability Ratings

Plants do not contribute equally to bank stability. Many riparian plants have been assigned stability ratings (SR) based on how well they resist the erosive forces of water, with SR 1 equal to bare ground and SR 10 equal to anchored rock. A stability rating of 6-7 is considered the minimum to provide good bank stability. The highest stabilities are provided when woody plants are associated with stabilizing grasses and sedges.

Succession

Early successional, or colonizer, species are the first on the scene following a disturbance. These species create quick cover, grow and reproduce rapidly, and are often short lived. These provide important services in that they cover and protect soil quickly and begin to trap sediment. However, these species are typically weak rooted and do not provide long term stability.

soils and plants

Late successional species are longer lived, slower growing, and slower to establish. Most of the plants that provide the best stability for a bank are in this category.

During restoration and management it is important to have both types of species present, with colonizers encouraged immediately after disturbance, and long term management aimed at encouraging late successional, stabilizer plants.

Types of plant material

Plant material can be added to the site in a variety of forms ranging from seed to containerized plants. The appropriate mix of plant types depends on the plan for the site, the available resources, and the time frame the manager is working under.

Seed is the least expensive option and generally allows for higher diversity added material. It is slower to provide cover and is vulnerable to predation or being washed away. Temporary irrigation during establishment greatly reduces this risk and improves germination rates.

Seeding rates are generally published by seed suppliers. Contact the supplier to find out if they are using USDA range seeding rates or if they have increased the rate. If range seeding rates are being used, it is often prudent to double or triple it for restoration efforts.

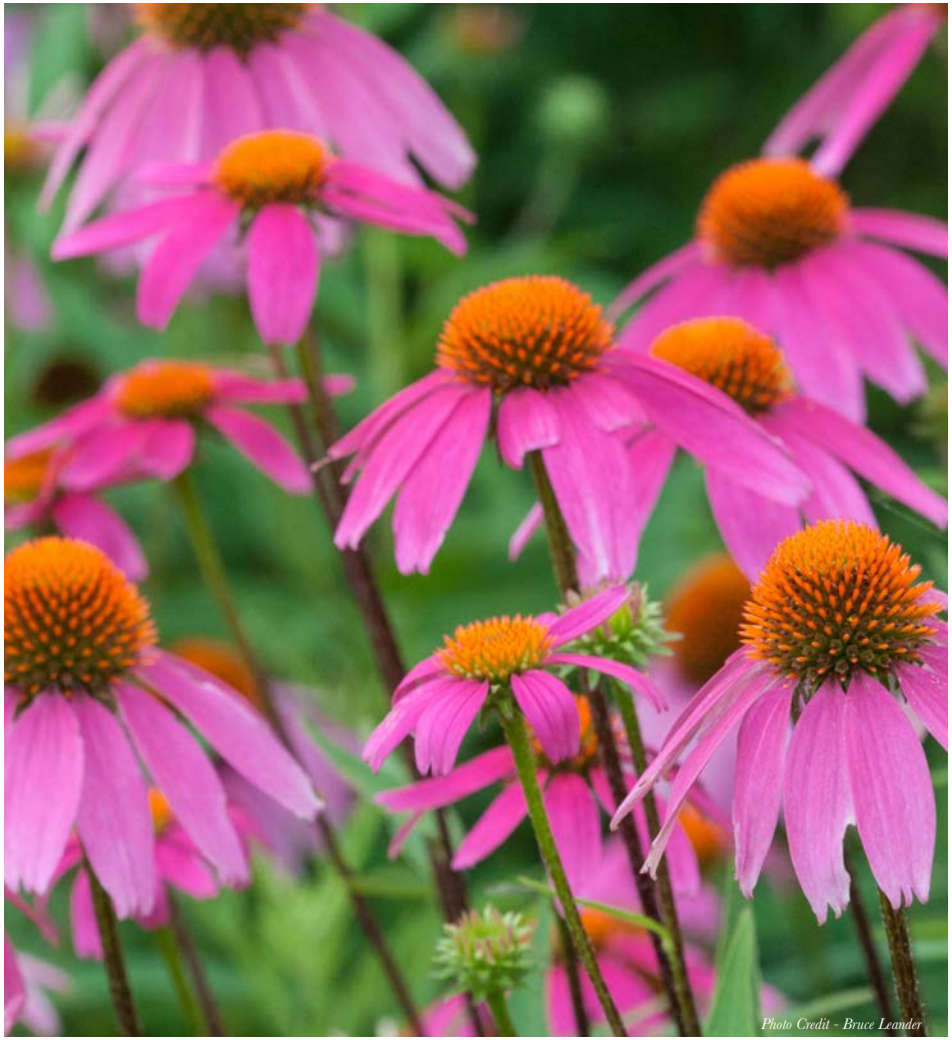
Creating your own seed mix

In order to adjust seeding rates to account for using multiple species, the following calculation can be used: Published seeding rate per acre X percent in mix = adjusted seeding rate.

For example, if combining sideoats grama (Range seeding rate: 7 lbs/acre) and green sprangletop (Range seeding rate: 2 lbs/acre) at 50% each. Here is the calculation:

Species		Seeding rate in mix
Sideoats grama:	7 lbs/acre X 0.5=	3.5 lbs/acre
Green sprangletop:	2 lbs/acre X 0.5=	1 lb/acre

Live stakes/live roots are the least expensive live specimen option. These specimens arrive without soil and must be installed quickly, with the roots kept moist until installation. Installation can be accomplished relatively quickly with minimal soil disruption. Without supplemental irrigation during establishment, these are best suited to riparian areas in which the soil remains moist.



Containerized or balled and burlapped individuals arrive in various sizes with associated soil around the roots. These require watering while in the container, but do not have to be installed as quickly as live stake or bare root specimens. This is the most expensive option, but provides the fastest results. Containerized plantings will require supplemental irrigation during establishment and require larger holes dug for installation. Additionally, unwanted species can sometimes arrive in the soil, so post installation inspections and weeding should be planned on.

Soil

Plants must be matched the soil type that is present. The USDA Natural Resources Conservation Service (NRCS) soil survey provides important information about your property's soil. You can generate a free soil report using the web soil survey

Web Soil Survey: http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

soils and plants

This report will give you an indication of the types of soils present on your property as well as useful ecological information. Gather the following information:

- Physical characteristics
- Chemical characteristics
- Ecological site information: Ecological sites provide you with the types of plant communities that are associated with your soils and can be a useful starting point when considering interventions

The Web Soil Survey homepage provides a brief tutorial for using the system. In addition, Appendix A provides a step by step tutorial on generating you soil report.

In addition to the soil survey, soil testing will provide you with specific information on your soils. Take samples within each soil type on your property and request the following analyses:

- Routine analysis for macronutrients and pH
- Organic matter
- Textural analysis

Having this information in hand will help you select plants that are suited to existing conditions and will help you determine what, if any, soil amendments are necessary. Most labs will provide you with instruction on how to collect a soil sample.

Texas A&M Agrilife Extension Service Soil, Water and Forage Testing Laboratory: http://soiltesting.tamu.edu/

Zones

Plant lists for each zone are found in Appendix C.

Riparian Buffer

This zone is frequently flooded and soil tends to remain wetter than upland areas.

Function: Trap sediment, build and maintain streambank, filter and buffer water, reduce and dissipate stream energy, provide organic matter and shade to in-stream habitat

Vegetative goals: The plant community here should protect and stabilize the bank, slow stream flow allowing for sedimentation, and enhance habitat both in-stream and on the bank. This area should be dominated by woody species with a strong component of stabilizer herbaceous plants. The woody species can be thought of as the skeleton of the bank

as their larger diameter roots help hold the bank in place. Herbaceous stabilizer plants have dense fibrous roots that intertwine with the woody species further enhancing stability. The above ground growth of both woody and herbaceous plants serve to slow water and capture sediment.


Photo Credit - Bruce Leander

Herbaceous plants provide additional protection during flood events because their top growth lays down, protecting the soil and allowing them to remain in place during high flow events.

Plants selected for this area can be obligate wetland (OBL), facultative wetland (FACW), or facultative species (FAC). Obligate wetland plants should be placed near the water's edge where the water table is nearer the surface. Facultative wetland species can be placed at water's edge, or further up the bank where the soil stays reasonably moist. Facultative species can be placed further from the water where the soil is drier. The majority of plants should have stability ratings of 6 or higher.

Immediately after a disturbance, activities that protect soil and slow water movement, such as placing obstructions along contours, will enhance natural recovery processes. Leaving downed wood in place will help the system start to recover. If plant material is added, a focus on colonizer species that will germinate quickly is often employed at this stage, with the goal of increasing the presence of late successional stabilizer plants over time.

soils and plants

Upland

Function: Slow and infiltrate overland flow to mitigate flooding, clean water, provide habitat.

Vegetative goals: The plant community, in combination with the soils, should act like a sponge, absorbing runoff. This community can be more open, with native grasses and wildflowers helping to build the soil and encourage infiltration. Species with deep, fibrous root systems are particularly useful in this respect (Figure 4.3). Species in this area should be primarily facultative and upland species because the soil will remain drier than that in the riparian area.

Figure 4.3. Root Depth and Mass

Riparian Canopy

The division between riparian areas and upland areas is gradual and there is frequently a transitional area that has characteristics of both zones. Facultative plants are the best choice for this area because they can handle wet or dry conditions.

Residential

Residential areas can be placed within either the upland or riparian canopy zones. Plants in this area can be selected to provide the same function as the surrounding area, but arranged in a way that serves human use needs

Low Impact Development (LID)

Features such as rain gardens, filterstrips, and bioswales are elements that can be added to a landscape to enhance the landscape's ability to capture, infiltrate, and clean water. This is particularly important in areas where impervious cover, such as buildings or roads, are present because the LID features can help to mitigate the hydrologic effects of these improvements. Often these features can be designed to be an amenity in their own right. LID features can be incorporated into any of the zones described above.

More information on LID can be found here: http://www.epa.gov/green-infrastructure

Photo Credit - Bruce Leander

site preparation


Photo Credit - Bruce Leander

Preparing the site and soil is the most important step in the success of a project. By clearing existing undesirable plant material and remnant seedbank, the newly planted seedbed will assist in reducing competition for future transplants and seeded species. Management of existing vegetation can be done through mechanical or chemical means, and it is important to seek advice of trained personnel. Additionally, it is important to start at a reasonable scale, allowing proper management of your planting (Shirley 1994, Maywald and Crider).

Any site improvements will most likely consist of some disturbances to the site. Therefore, a preliminary item to consider regarding restoration is how the design will be implemented. Before construction begins it will be crucial to stabilize the site and set up protection measures so that the exposed soil does not runoff into the river. It is anticipated that the installation/construction processes could result in a lot of fine sediment and topsoil being washed into the river. Construction Best Management Practices (water pollution control) should be established and explored to protect these riparian zones.

Site soil measurements of infiltration, composition, and structure can be compared to expected values found in the soil survey to help determine soil health. These measurements can also inform decisions on plant

selection and on appropriate technologies for the site such as rain gardens or bioswales. Because soil restoration is difficult and expensive, effort should be made to identify and protect healthy soil. In some cases, compaction remediation and organic soil amendments may be needed to restore soil health after disturbance. Soil disturbance should be addressed prior to revegetation efforts because damaged soil cannot support healthy plant communities. Healthy, diverse plant communities, that are suited to local conditions, drive ecosystem function. Existing communities can be compared to reference sites with similar conditions and to the ecological sites defined for the projects soils to determine the site's current ecological state and to help determine the appropriate target community for the site. Full shaded areas with bare soil will present a challenge due to the canopy tree's critical root zone. It is recommended that these be lightly roughened and organic matter be incorporated into the soil, but never deeply tilled. If properties have steep slopes, placing brush along contours will enhance natural recovery processes by slowing rainwater runoff, initiating passive soil building, and helping to prevent erosion. Leaving downed wood in place will help the system start to recover and act as a nursery for new trees and germinating vegetation. Large woody debris should not be removed unless it threatens infrastructure in the immediate vicinity, completely blocks access, or contributes to erosion. Large woody debris is typically defined as material greater than 4" diameter and 6' in length. Clean up of this material can be detrimental to river health and is an essential component of river ecosystems. Large woody debris helps stabilize the stream bank and stream channel, promotes new vegetation growth, and provides habitat for fish and other important riparian animal species. If large woody debris has to be moved because there is concrete evidence that it might contribute to erosion or damage infrastructure, landowners should coordinate their efforts, if possible, with Texas Parks and Wildlife Department or other experts to help determine the best method that will result in the least damage to the land. Some debris may be partially removed by cutting or anchored to the ground so that it still provides benefits without causing damage.

The next step will involve the removal of existing invasive species, making any necessary grading changes, preparing the soil for vegetation establishment, and then seeding or plugging the site according to the landscape zones established in the design plan. Even areas without impervious cover will most likely be compacted if heavy equipment is used. Thus, the next step in site restoration is to conduct soil preparation prior to seeding (or plugging) the areas to be revegetated. It may be necessary to roughen the surface through a means such as ripping/roto-tilling to a depth of a few inches (1-4"). This method allows for organic matter to move deeper into the soil, serving to anchor soil amendments

site preparation

and more rapidly establish healthy soil conditions. During this process, organic matter may be added to the soil. Low-nutrient compost is recommended for soil treatment. Ripping and roughening also helps prevent erosion. By increasing soil surface roughness and providing areas for sediment to be captured, runoff volume and erosion is reduced. Soil preparation requires planning and time. If done properly, however, the efforts will reduce time and inputs in the long-term and plant establishment will have a greater chance of success.


Photo Credit - Bruce Leander

Weed And Non-Native Grass Removal

The removal of unwanted vegetation is sometimes necessary before restoring native vegetation. These unwanted plants compete with native restored plants for valuable resources such as soil nutrients, water, light, and space.

There are several approaches that you can use to control weeds. Early weed control during site preparation will also reduce seedling competition for moisture and other limiting resources. Before seeding, weeds can be controlled with manual removal, tillage, or herbicides. Post-establishment control methods may consist of mowing, grazing, hoeing, or the use of selective herbicides. Even with ample preparation some weeds will still emerge and compete with planted species. When restoring areas, establishing a cover crop or quickly establishing natives will assist in recovery (Maywald and Crider, Native Prairie Association of Texas).

Soil Conditions

Limits of Construction

Construction impacts from overall site development decrease the capacity of the soil to support the desired vegetation and retain resources. A well developed and communicated soil management plan should be

created prior to construction to: limit construction disturbance, assist soil restoration efforts, and define soil protection zones. Soil protection zones should be delineated to prevent any construction activities or storage of equipment on those areas (Sustainable Sites Initiative 2014).

Common signs of impacted soils include:

- Ponding of water on soil surface (poor infiltration)
- Surface water runoff
- Bare soils
- Shallow tree rooting
- Stunted vegetation

Soil Erosion

Soil erosion is the most damaging form of degradation, degrading the physical, chemical, and biological properties of a site, and is irreversible. Consequently, erosion reduces water-holding capacity of a soil, plant production, and increases mortality of individual plants and communities. Damaged biotic components capture and retain fewer resources, and assessments should begin with soil surface features and associated hydrologic processes.

Soil surface stability is assessed as the degree and nature of: soil movement, surface rock and litter, pedestaled plants or rocks, flow patterns, and rills and gullies. Live vegetation, litter, mineral soil crust, surface gravel, or microbiotic crust increase the stability of soil surfaces. Interrill erosion, rills, channels, gullies, and pedestaled plants indicate soil loss. The accumulation of eroded material indicates erosion occurred elsewhere (Whisenant 2005).

Repairing Damaged Processes

Addressing soil surface problems can repair hydrologic and nutrient-cycling processes, especially when using adaptive species that improve soil conditions. Adaptive plants grow under existing conditions, initiate autogenic (plant driven) repair, and increase resource retention. Increased resource retention produces more plants. Primary emphasis on soil surface conditions and associated processes should consider soil crusting, erosion, runoff, and infiltration.

Increasing the stability and infiltration rate of the soil surface initiates the repair of damaged soil processes. Management practices that improve soil structure and conserve soil moisture increase a soil's resistance to erosion. Initial soil surface treatments involve: increasing soil roughness and adding aboveground obstructions.

site preparation

Increasing soil roughness focuses on reducing runoff and erosion by retaining precipitation through roughness, vegetative cover, and reducing distance of unobstructed soil. Soil roughness strategies, such as micro-catchments, pits, basins, ripping, and chiseling, affect soil roughness and accompanying infiltration rates.

Surface obstructions promote the retention of water by reducing the amount and velocity of surface and channel flows. Surface obstructions, including organic matter (compost), mulch, and woody debris, improve soil aggregation and provide initial stability to establish vegetation.

These obstructions reduce the flow rates of water and wind, capture and concentrate resources, and increase infiltration rates. All of this leads to an increase in plant establishment and accelerated vegetative development. Onsite sources of logs, felled trees, brush piles, contoured rock rows, or purchased burlap wattles are all examples of surface obstructions that impeded increasing water velocity and improve resource retention (Whisenant 2005).

Soil Compaction

Natural soil forming processes create soil that possesses suitable levels of compaction for ground stability and the growth of plant roots. Soil in undisturbed sites rarely exhibit compaction levels (bulk density) that are beyond the threshold where plants will not grow. Human activity (i.e. mechanical) typically increases the compaction level beyond the threshold, preventing plant root systems to explore the soil profile for needed resources.

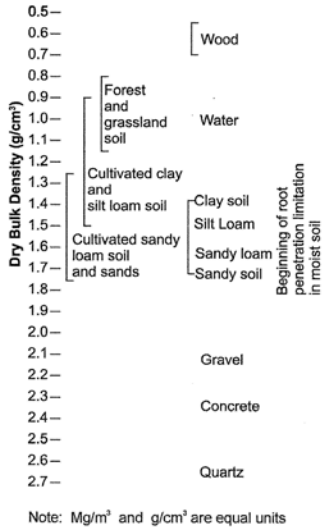
During the process of compaction, organic bonds that bind the soil and provide soil structure are broken. As a result of this activity, pore spaces between soil particles are lost. These pore spaces are essential in the ability of plant root systems to absorb water, nutrients (in solution), and oxygen. The plants have less access to these items, growing fewer roots in the more difficult conditions and stressing the plants.
Soils have different densities at which roots will no longer be able to penetrate the soil, In turn, plants vary in their ability to penetrate dense soils or function in soils with reduced pore spaces. Optimum soil compaction for planting soil should be one-tenth of a gram, per cubic centimeter, below the root limiting value (Figures 5.1). The root limited bulk density for a clay loam is approximately 1.45g/cm3.

Engineers measure compaction as a percent of maximum dry density obtained under optimum moisture content. Proctor density indicates the relationship of Proctor levels to bulk density levels. Compaction levels between 80 and 85 percent dry density will begin to restrict root growth (Urban 2008, USDA-NRCS 2008).

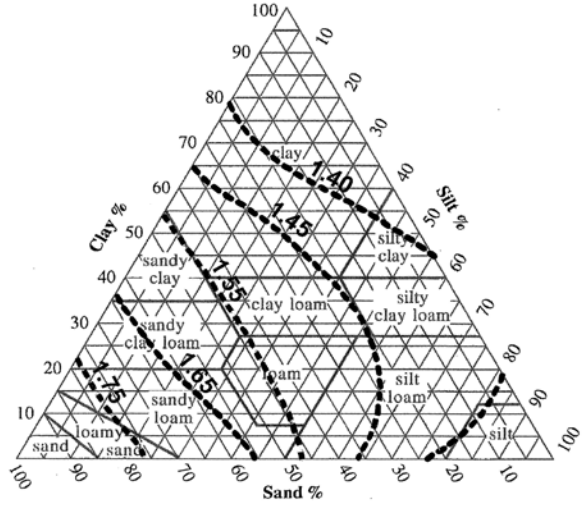
Strategies for improving soil quality:

- Avoid working soil when excessively wet or dry
- Reduce traffic and use controlled traffic patterns
- Avoid using heavy machinery
- Subsoil amendment (aerate, rip, till, disc)
- Add organic amendments

Table 1.2.4. Soil types and bulk density relationships. Note that these tables should not be used to evaluate compaction in soil mixes that include organic amendments or lightweight aggregates.



a. Ranges of soil densities. *(Source: Brady et al. 1999)*

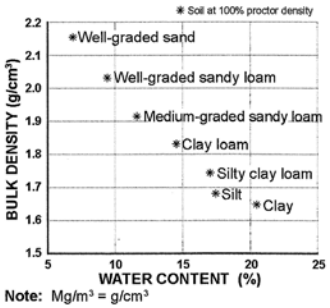


b. Root-limiting soil densities. A reasonable specification for compacting planting soil by bulk density would be between 0.1 g/cm³ and 0.25 g/cm³ below the value predicted as root-limiting with some settlement expected at that range. *(Source: Adapted from Daddow and Warrington 1983)*

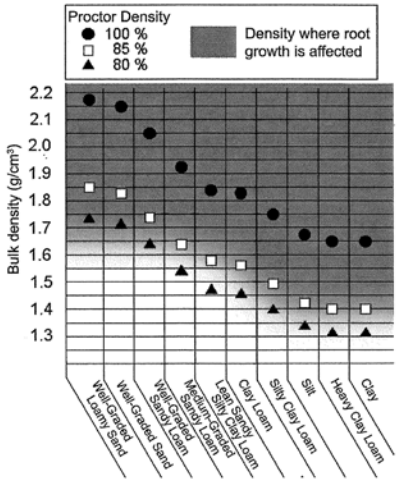
Figure 5.1. Soil Types and Bulk Density relationships (Urban 2008).

site preparation

Table 1.2.3. The relationships of soil types to bulk density and Proctor values.



a. Various soils compacted to 100 percent of maximum dry density (Proctor). Note that as sand content increases, less water is needed to obtain the maximum density and the soil reaches maximum dry density at a higher bulk density. *(Source: Abramson et al. 1995)*



b. Bulk density and levels affecting rooting compared to several Proctor densities. Note that soils to be used for most trees and shrubs should always be compacted to less than 85 percent of maximum dry density. There is limited research comparing bulk density to Proctor value, but a reasonable specification for compacting planting soil would be between 75 and 80 percent, with some settlement expected at that range. Sandier soils can be compacted up to 85 percent, with the exception of well-graded sandy soils. *(Source: Data adapted from Daddow and Warrington 1983, Lichter and Lindsey 1994, and Brady et al. 1999)*

Figure 5.2 Optimum soil compaction for planting soil and rooting. Recommended soil compaction should be less than 80% Proctor Density (Urban 2008).

Soil Amendment

At most projects, the mineral soil resource may need to be modified. Soil damage during the construction process (compaction, grading, and contamination) affects the soil's ped structure, chemical and organic composition. Compaction reduction activities (tilling, disking, ripping) and organic soil amendments may be needed to restore it to a useful state. Soil improvement procedures would be benefitted if good records were created on the extent and depth of soil resources during the site analysis phase (Urban 2008).

Adding organic matter to the soil will introduce an artificial structure to repel the tendency toward re-compaction. As the dense soil is fractured, organic matter is incorporated into the mineral soil creating open pore spaces. The organic matter should be stable, low-nutrient, static piled compost similar to native soils of the region. The addition of composted organic matter is the best method of improving soil texture and drainage. In healthy prairies, organic matter content may exceed 3.5 % - up to 4.8% (Native Prairie Association of Texas).

Compost Recommendations

Composted material for use as organic matter for soil amendment and for seed application should meet ideal ranges and texture recommendations,

and must be tested to ensure that it is a healthy material suitable for application to the project.

Incorporate living compost with a low nitrogen and low phosphorus content into the top 3 inches of your prepared soil. DO NOT use tree bark, wood shavings, or mulch, as grass will not grow in this. Particle Size - 98% of the compost material shall pass a 3/4" screen and 75% through 1/2" screen. Texture and Smell - 95% by volume must be indistinguishable from parent material (i.e. should not be apparently 'woody'). The compost must not smell like urine, manure, sewage, or softwood organic compounds (eg. Turbines or 'piney' smell). There MUST be a dominant, sensible fungal (mushroom) smell similar to hardwood forest soils.

Alkaline Soils

Alkaline soils are common in arid regions where evaporation exceeds precipitation. Calcium and magnesium accumulate in the soil, raising the pH higher than neutral (7). When pH exceeds 8, the solubility and availability of nutrients for plant uptake is limited (US Botanical Garden 2014).

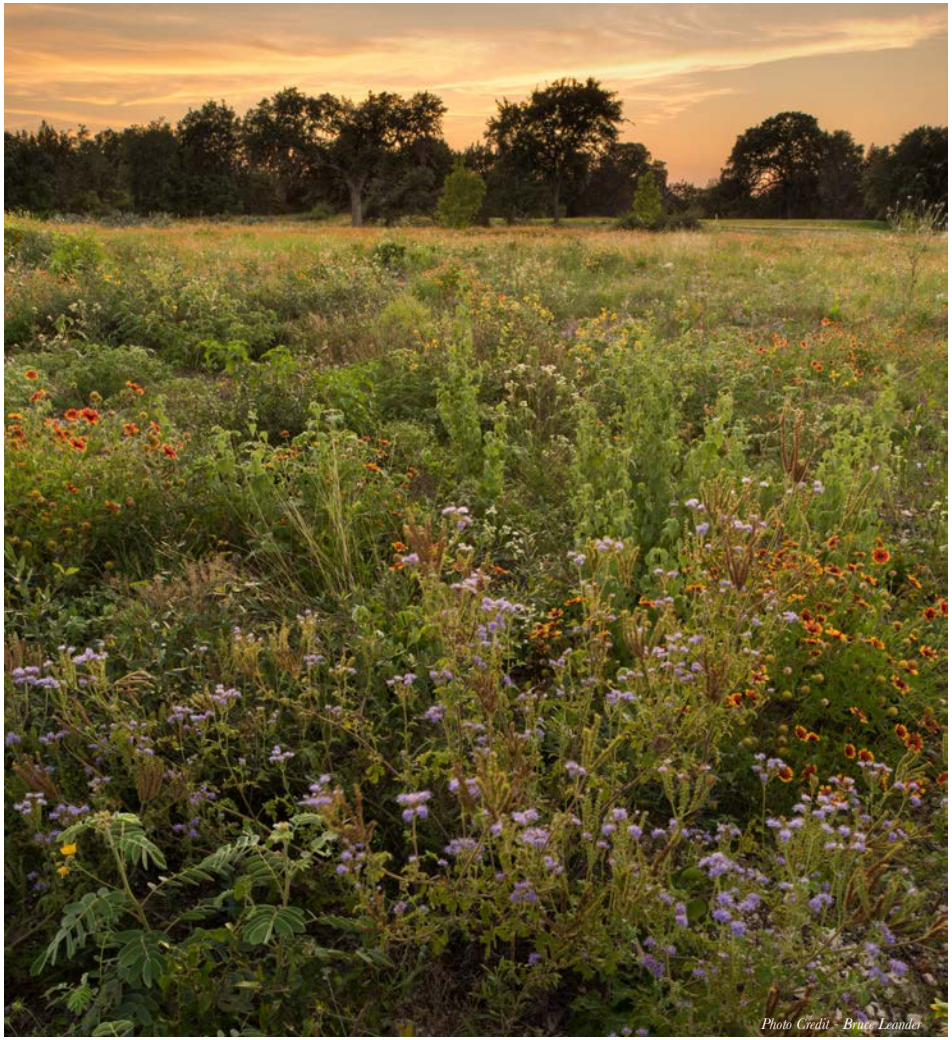


Photo Credit - Bruce Leander

site preparation

Strategies for working with alkaline soils:

- Utilize plants adapted to alkaline soils
- Utilize compost and other organic amendments that can lower soil pH

Shallow Soils

Shallows soils constrict plant roots, tend to be nutrient-deficient, and dry out quickly. Shallow soils consist of a thin layer of soil on top of a dense, clay subsoil or bedrock. Shallow soils can also be caused from construction processes (US Botanical Garden 2014).

Strategies for working with shallow soils:

- Utilize plants adapted to shallow soils (shallow-rooted) and are drought resistant
- Utilize compost or other organic matter and organic amendments
- Cultivate the soil lightly, avoiding large tree roots, and incorporate compost into the soil

Seedbed Preparation

Preparing a seedbed is the most assured method of high establishment rates. Creating a natural appearing, evenly roughened, fertile and friable seedbed to capture and retain water and establish micro-habitat for seed germination and seedling establishment is critical. Within restoration


Photo Credit - Bruce Leander

zones and landscaping areas, ensure ground layer is cleared of leaf litter and other duff prior to seeding. Apply soil amendments prior to tillage operations.

Till soil by contour chisel rip furrowing a minimum of 4 inches deep. Using sufficiently sized machinery, rip soil along natural site contours to a minimum depth of 6 inches. Incorporate soil amendments into the soil profile using a roto-tiller. Do not pulverize the soil. Cultipack or lightly harrow to break up large clods or fill soil voids if necessary. Remove obtrusive and hazardous rocks and debris. Seedbed preparation can require several trips over the ground with equipment suggested, a drag to smooth the seedbed and lastly a roller packer to firm the seedbed just before planting.

installation

After the site has been graded, stabilized, and invasive plants have been treated and/or removed, seeding is the least expensive method for plant establishment. The ideal times to seed are in early spring for grasses and annual wildflowers or mid to late fall for wildflowers in general. It is recommended to seed wildflowers in the fall for optimal germination. It will be important to monitor the areas to be seeded for any invasive species that might have encroached in these areas if there is a large amount of time between site preparation and seeding. It will be important to remove these species before seeding. Using no-till drill is a very effective method for installing seed, especially for large sites. Ask contractors if they have experience planting with no till drills. If you cannot locate a contractor with no till drill experience, or if topography prevents the use of such equipment, seed can be hand broadcast and then raked in by hand or with a tractor-drawn harrow to achieve good soil-seed contact. A majority of the seed can be obtained from a commercial outfit, however it is recommended to additionally add local seed to increase diversity and local genetic stock to ensure that the plants are adapted to that region and add robustness to the mixture. Get in touch with your local Master Naturalist group to see if there are any opportunities for collecting seed from nearby healthy sites. Seeding methods, equipment rentals and types, and exact timing and rates should be further developed in the restoration plan.

There might be areas on the site where establishing vegetation from container plants would be preferred. These areas include fully shaded upland areas or areas with steep slopes. Some of the riparian species are difficult to establish from seed and container plants and may be preferred in these areas as well. Container plants are more expensive than seed, but will establish faster, enhance soil biology, prevent erosion, and provide a more immediate, finished aesthetic.

Immediately after installing the seeds and/or plants, temporary irrigation will be necessary for successful establishment. Irrigation will probably be required for a full growing season; however, specific rates and methods should be established in a site restoration plan. Trees will require higher amounts of watering and longer establishment periods. The formal planting areas surrounding buildings may require more regular irrigation post-establishment than other areas of the site. In this case, an irrigation system can be installed or the areas can be hand watered. Either method could also use rainwater captured from the buildings' rooftops and collected in cisterns. This method would also help promote site educational components including water conservation and stormwater runoff management.

Timing/When To Plant

Depending upon current climatic conditions, ideal planting/sowing windows for each type of plant are listed below.

Spring Planting: March – April

Warm Season Grasses: March – June or Late September – November. If it is excessively hot or if a freeze has occurred, then seeding should be delayed.

Perennial Forbs (wildflowers): Late September through second week of November

Annual Forbs (wildflowers): March - April

Shrubs: Late September – Early November and March – June

Trees: November – February. It is usually better to plant trees when they are dormant during the winter to avoid transplant shock, however they can also be planted, depending on climatic conditions, in fall and early spring.

Photo Credit - Bruce Leander

Seeding Methods

Grass and forb species can be established within a variety of situations using a range of planting techniques. To achieve good vegetative cover, seeds should be placed in contact with the soil surface and where the soil will remain moist during germination and seedling development. Good seed-soil contact is critical.

installation

The following is a list of planting methods, techniques, and guidelines:

Planting Method	Planting Technique	Planting Guidelines
Broadcast	Fertilizer spreader	Mix with disperser, good for large acreage where cattle rotational graze at high stock densities
	Air seeder	Same as above
	Chaffy seed spreader	Good for small acreage, difficult to calibrate
	Hand broadcast	Good for small acreage
	Hydro-seeder	Uses a hay mulch and water as carrier to blow seed on soil surface. Good for soil erosion control
Seedballs		Good for small to medium acreage or where rocky soil precludes the use of seeding equipment.
Seed hay		Good method of obtaining local genotypes / ecotypes
Drilling chaffy seed	Chaffy seed drill	There are several drills on the market designed to meter. Drills can be rented from multiple sources. Good for large acreage.
	Grain drill	Must mix seed with fertilizer. Not good for grain box if used on large acreage
Live plants	Planted by hand	Plants are started from seed, placed in pots, and grown in the green house. This method is very labor intensive, and best suited to small areas.
Bare roots	Planted by hand	Roots are taken from live plants, placed in a prepared seedbed and watered in. Very high survival rate. Well suited mall garden landscapes

Figure 6.1. Tallgrass restoration manual planting methods, techniques, and guidelines (Native Prairie Association of Texas).

It is recommended the following restrictions be met for seeding and establishment, during one of the identified planting windows.

- Sow seed with spreader or no-till drill. Hand broadcast seed in areas that are difficult to access with spreader. Do not broadcast or drop seed when wind velocity exceeds 5 mph.
- Sow seed mixes at rates as indicated by range site rates or seed provider.
- Rake seed lightly into top 1/8 inch of soil, roll lightly, and water with fine spray.
- Make sure seed is integrated into soil surface, but not buried deeper than top 1/8 inch of soil.
- Lightly roll seeded areas with a cultipack roller and irrigate according to irrigation establishment specifications. Do not let seed dry out for a minimum of ten days.
- Protect seeded areas with slopes exceeding 1:4 with erosion-control blankets and 1:6 with erosion-control fiber mesh installed and stapled according to manufacturer's written instructions.
- Plug Planting - Install around 'high energy' areas, spacing plugs approximately 6-12" apart, 2-3" deep

Live Plantings

Seeding is much cheaper than installing plants, but properties might need to employ a planting strategy on areas of steep slopes or if landowners would like to incorporate later successional species that don't often germinate as successfully in newly established native planting areas. By mixing seeding and plantings you can increase the diversity of plantings and provide a short cut to a more mature grassland state. Live plants can be purchased in flats that contain 20 4" container plants or you can purchase larger containers in gallon increments, but the 4" containers are much more economical and allow the landowner to achieve greater coverage. The ideal planting spacing is to install 4" container plants on a 12-18" grid so that the plating area is adequately covered. Seeding and planting on a 12-18" grid will achieve dense coverage in a relatively small amount of time and is great for any areas that have experienced erosion or on slopes were complete cover is absolutely necessary.

When installing live plants the hole should be similar to the size of the planting (e.g. 4", 1 gallon, 3, gallon, etc.). The hole should not be too deep so that the base of the plant is lower than the surrounding ground level. The excavated soil should then be used to fill any air spaces, but the soil should not be over compacted.

Watering

The following irrigation schedule is recommended for establishment, and may need more if sowing goes into summer months (i.e. June onwards):

WEEKS 1-2: 0.5" per day in two events (dawn and dusk – more frequently if hot and windy) to keep top 2" of soil sensibly (i.e. feels wet to touch) moist, but not so much that the soil is consistently saturated – this will cause seedling rot. This effort might require irrigation twice a day, once in the morning and once in the late afternoon.

WEEKS 3-4: 1" at least twice to three times a week to maintain sensible soil moisture in top 1" to 6" of soil. Note: top ½" of can be allowed to periodically dry out.

installation

WEEKS 5-6: 1" at least twice a week to maintain sensible soil moisture in top 1" to 6" of soil. Note: top ½" can be allowed to periodically dry out.

WEEKS 7-16: One 1" event per week to wet at least top 6" of soil.

Irrigation should occur during times when water loss from evaporation is lowest (dawn and/or dusk), but without potentially creating a disease prone environment. Irrigation should not occur after a sufficient rain event or when otherwise unnecessary.

Caveat

These are estimates and soil conditions (night and day air temperatures, wind, recent rain, amount of clay, compaction, and arrangement (cracks)) can alter these amounts, so these conditions should be considered as approximations that may need to be adjusted. Substituting for soil moisture sensors, taking cores and using touch to assess the 'sensible' soil moisture to depth is an excellent way to keep constant track of water requirements. This should be at least daily for the first two weeks and thereafter monitored on a weekly basis until good establishment (50% canopy cover) is achieved.

Long-term irrigation

Once the vegetation is established in four to five months, you may opt to stop irrigating to save water and allow the plants to go 'drought dormant'. Native grasses will go brown and temporarily stop growing but, adapted to drought, will green-up once rain returns. In prolonged drought (say over 4 weeks in summer with no rain) an irrigation event (if allowed) once every month while not triggering "green-up" will keep the dormant plants alive. However, if a significant drought sets in you might need to extend irrigation during the first season of growth.

Subsequent seasons after the first year of establishment can thrive on rainfall alone, but if landowners wish to ensure regular wildflower blooms they can irrigate during the fall and early spring if seasonal rains are delayed or non-existent.

Bare patches

Bare patches can occur from a variety of reasons including inadequate irrigation, lack of available nutrients, and erosion events. If bare areas appear landowners should seed these areas as soon as possible even if outside of proper seeding windows as weeds will likely move in if no actions are taken. Roughen the soil (lightly disturbing, but not tilling) so that the seed is incorporated into the top layer of the soil, but not buried deeper than a ½" and then follow the appropriate irrigation schedule. The following species are great for repairing bare patches:

Grasses - green sprangletop (Leptochloa dubia), sideoats grama (Bouteloua curtipendula), blue grama (Bouteloua gracilis), purple threeawn (Aristida purpurea).

Forbs - Indian blanket (Gaillardia pulchella), pink evening primrose (Oenothera speciosa), lemon mint (Monarda citriodora), Texas star (Lindheimera texana).

Fertilizing

If soil tests show that there is no available nitrogen, phosphorus, or potassium (N-P-K) it will be necessary to apply organic fertilizer for a frequency of once every two weeks for the first three months until seedlings are on their way to being firmly established. It is important that you only use low N-P-K value (in the range of 3-3-2) organic fertilizer, as synthetic fertilizers N-P-K ratios are too high and will not feed beneficial microorganisms in the soil. If you apply synthetic fertilizers with high N-P-K values you will get a lot of weedy growth. There are plenty of local manufacturers that produce great organic fertilizers such as Natural Gardener's John's Recipe, Gardenville's Sea Tea, and Hasta-Grow's plant and lawn mixes. These organic fertilizers also often contain other ingredients that benefit soil health such as humic acid and horticultural molasses.

Photo Credit - Bruce Leander

maintenance


Photo Credit - Bruce Leander

Maintenance recommendations

In general, installing and establishing functional landscapes requires more planning and effort than a traditional landscape. However, as time goes on, maintenance requirements will lessen and fewer inputs and resources (such as watering, fertilizers, and mowing) will be needed. Maintenance is a key component to project success and something that should be considered in the predesign and design phases. Once site preparation or any construction activity on the site begins, maintenance begins as well. Landowners should develop key components of a maintenance plan that includes guidelines for installation, establishment, and long term maintenance covering topics such as: invasive species control, soil health, innovative BMPs to mitigate runoff during installation and immediately after, sequencing of site installation, planting and seeding windows, site hygiene (preventing contamination of site with invasive plant seed that might come in on rental and contractor's equipment) and equipment storage (e.g. parking equipment under trees, driving over prepared soils), reseeding, irrigation, and mowing.

Maintenance and ecological success will rely on the maintenance efforts and strategies working collectively to improve the entire site as one riparian system. Therefore, while the site might have a variety of plant communities requiring unique maintenance practices, it should be understood and planned for that activities in one location will have influences on other locations of the site. The primary maintenance focus should be on considering surface flow across the site to the river by improving vegetative habitats. Through improving water quality and quantity and vegetation diversity, other ecosystem services will be increased resulting in a highly performing landscape.

Mowing will replace the natural disturbances of fire and flooding for the upland locations. Understory plantings could be zoned into no mow and mow locations for ease of maintenance. Provided below are general mowing recommendations for tallgrass areas and short grass locations.

These recommendations will need adjustment and refinement based on the ultimate design. Mowing frequencies (and the comprehensive maintenance plan) should respond to things such as climatic conditions, vegetation response, and performance or desired appearance. Maintaining habitats requires adaptive maintenance.

Tallgrass mowing - Tallgrass areas generally do not require mowing on a regular basis and can be maintained by mowing only every three to six years. However, tallgrasses can tolerate annual mowing in winter, when most grasses are dormant, if desired. Mowing at other times of the year may result in loss of that year's seed. Mowing may be undertaken any time after grass seeds have ripened (December), or alternatively may be delayed until very early spring (February) just before the plants begin to green up. Mowing height should be no lower than 6 inches.

Shortgrass mowing - Mow shortgrass prairie areas three times per year, to a height of approximately 3-4 inches. Mow one time in late winter (January - February) to remove dead standing material, after seeds have ripened, and before the spring growing season begins. Mow one time in summer (June - July) to promote spring wildflowers, after wildflowers have dropped their seeds. Mow one time in late summer (September - October) to maintain grass height of approximately 3 inches. To further promote wildflowers in the mixed grass areas, the shortgrass prairie may be mowed more frequently at a height of 3 - 4".

Pruning - Pruning is the removal of plant parts (shoots, branches, roots, flowers, and fruits). Pruning can direct the growth of plants to enhance their performance and function in the landscape. Additionally, pruning can increase the structural strength, trunk quality and aesthetic appeal of trees as a preventative or corrective measure. Since each pruning cut has the potential to change the growth of a tree, causing the tree to allocate resources for wound treatment, no branch should be removed without a


Photo Credit - Bruce Leander

maintenance

reason. When pruning, it is important not to do more harm than good, by removing more foliage and creating more wounding than the tree can defend. The American National Standards institute A300 (ANSI A300) is the industry standard for tree care operations and maintenance. Several guidelines are available for the pruning process: no more than 1/3 of the foliage should be removed from the lower 2/3 of canopy; and, no more than 5% - 25% of the canopy should be removed per annual pruning period.

Plant Stress – Successful germination is only part of establishing permanent vegetation. Many factors can cause stress during plant growth and can include nutrient deficiency and heat stress. Stressed seedlings or plants will often have yellow or purple blades/leaves with dead tips.

If plants begin to exhibit signs of chlorosis (yellow foliage), a treatment of organic nitrogen should be applied to counteract the nutrient deficiency and prevent mortality. Organic nitrogen is recommended for this project due to the close proximity of a waterway. Additionally, organic nitrogen promotes soil health (i.e. microbial activity) and vegetation growth will be promoted. Organic nitrogen possesses lower nutrient levels which aid in the restoration of native soil properties. Immediately before treatment random soil samples should be taken for soil nutrient analysis. Multiple

treatments may be necessary but should only be based upon field observations.

Purple blades/leaves are a result of either heat stress, insufficient water supply, or both. Areas that are planted after preferred establishment windows will most likely suffer from some heat stress. This stress can be extremely detrimental to the development of seedlings and can result in seedling mortality. Young plants have shallow root systems and are unable to source water from lower soil horizons, so the site must be kept consistently moist in order to create a mesic environment.

Invasive Species - Prevention is easier than cure. At a minimum, walk-throughs during the first year should be conducted every two weeks throughout the property to check on desirable species health and identification of unwanted species – this is particularly important during the first 2-3 years of the project establishment. The intent is to spot unwanted species before they flower and become a major problem. Inspection can be reduced to every month for years two and three after establishment, and further reduced to 3 times per year thereafter.

Bare Ground - The upland and riparian buffer should be periodically inspected for new bare ground patches. Determine what is causing the bare spot. Frequently, bare spots are caused by changes in hydrology, so remember to look upslope for anything that may be changing how water is flowing across the site. Keep a rapid revegetation seed mix on hand to address these patches. Grasses such as side-oats grama (*Bouteloua curtipendula*) and green sprangletop (*Leptochloa dubia*) provide quick cover during the spring and fall. Prairie wildrye (*Elymus canadensis*) and Virginia wildrye (*Elymus virginicus*) provide cool season and shade tolerant options.

Photo-monitoring - The establishment of permanent photopoints is recommended. By taking photographs from the same point with the same azimuth, changes in dominant vegetation can be tracked. These points can be marked on the ground with t-posts, rebar stakes, or even trees or fence posts. Once the first photopoint set has been taken, these images can often be used to find the same point the following year. The best results are achieved by taking the photographs at the same times of year (e.g. spring and late summer) at the same time of day (due to the often over-riding effect of shadows). Field notes listing dominant plant species are useful for later examination.

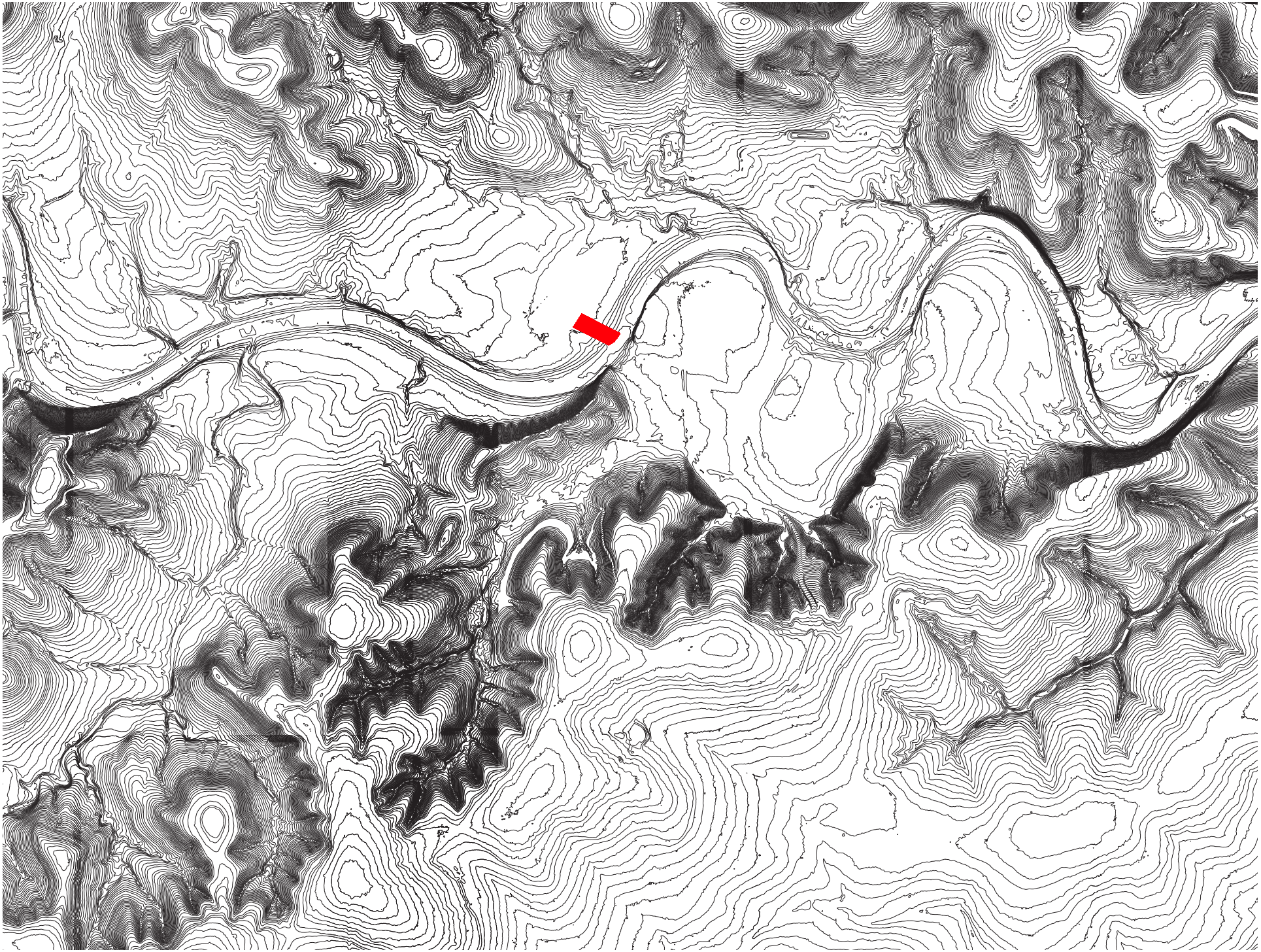


Photo Credit - Adam Barba

intent

Many properties and homes were damaged due to the spring and fall floods of 2015. Record rainfall was the main driver for these events, but development trends of property along the Blanco and other rivers have resulted in landscapes that are impaired in their ability to slow down rainwater and allow it to either infiltrate into the ground or move as sheet flow over the surface of the land before it empties into the river. If we redefine our perception of beauty so that it incorporates more "natural" or "informal" design elements, we can develop creative solutions that truly celebrate our Texas landscape and are based on the cooperation of science and splendor.

The authors hope that residents along Hill Country rivers will adopt some of the measures demonstrated in the following case study. The case study property was chosen because it possesses common conditions – upland (full sun, grass dominated areas), residential (full/part sun or shade, formal landscapes), canopy (part sun or shade, canopy dominated areas with many trees), and riparian buffers (full/part sun to shade, areas immediately adjacent to the river) – that many properties possess. This case study does not suggest that every property should implement a complete redesign, but rather it is our hope that residents will examine some of the suggested strategies and determine actions that are achievable for them. However, the case study that follows also is designed to illustrate what is possible if landowners think about their property as a whole functioning system, and how they can incorporate both "natural" and "formal" components without compromising fundamental elements such as river access, turf, or shortgrass, areas, and social spaces.

Photo Credit - Bruce Leander

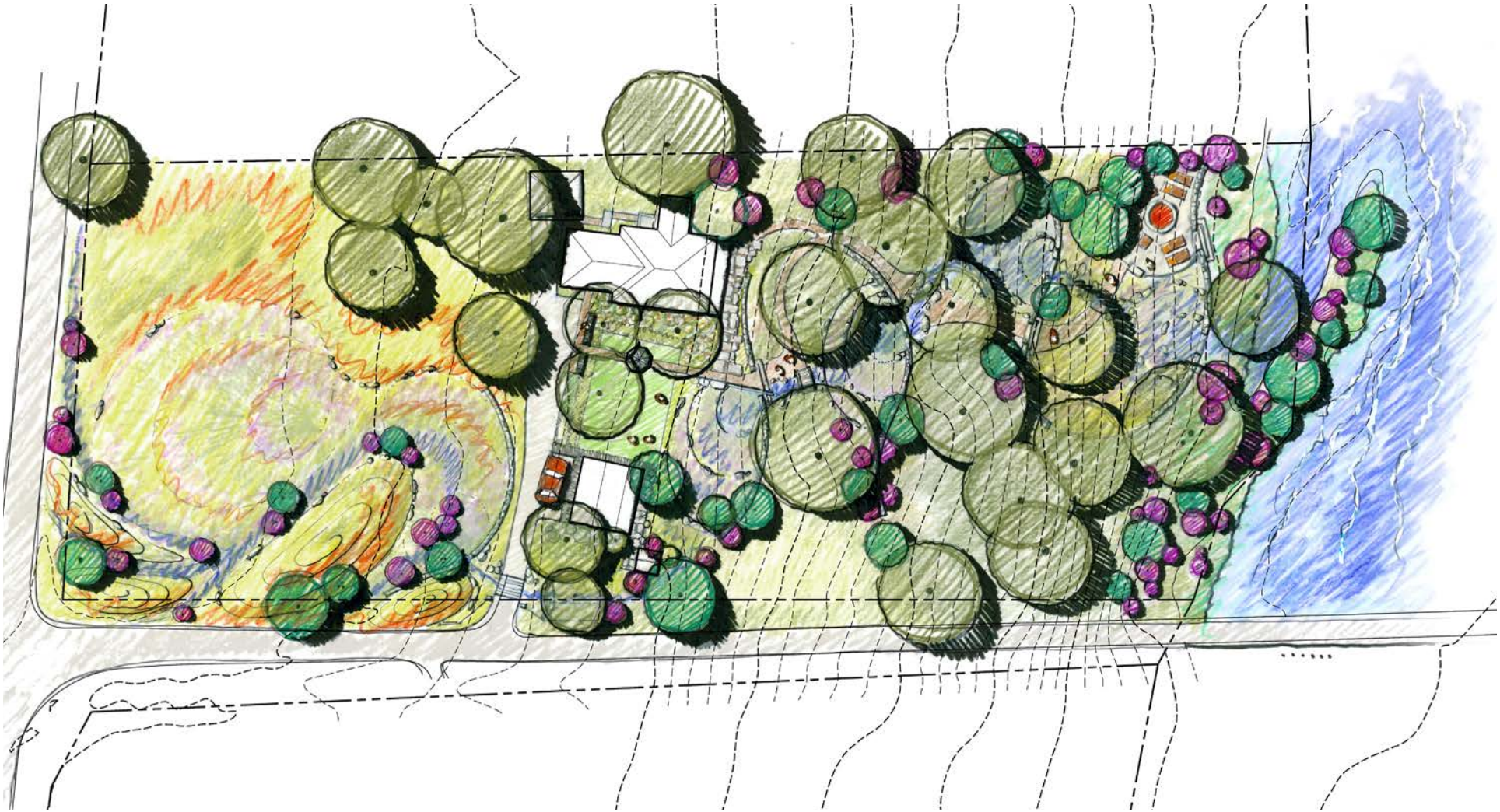
Photo Credit - Adam Barbe

design evolution

The case study design evolved over several iterations and was developed by the Lady Bird Johnson Wildflower Center's team of ecologists, environmental designers, and landscape architects. If landowners are able and wish to implement large scale restoration measures on their property it is extremely important that they work with restoration experts or landscape architects who can help develop ideas and provide owners with the proper set of construction documentation required by the Army Corps of Engineers. If landowners only choose to engage a commercial landscape contractor, they will likely not achieve the desired restoration or receive proper documentation. This is mainly due to the lack of formal training and the contractor industry's focus on aesthetics instead of function. The majority of landscape design work produced today is a collection of plants and design features with little or no overall design "binding them together into a unity greater than themselves" (Eckbo 2002).

Having said that, many of those affected by the flood might not be able to afford large-scale measures or might not have a budget for landscape design at the present time. Landowners can still follow the restoration measures described in the first half of this booklet by simply assessing their landscape and starting invasive plant treatment/removal in order to prepare their site for restoration at a later point in time. Restoration can be phased so that it fits your schedule and budget, but it is important that landowners 1) understand the riparian system they are trying to improve, 2) understand the current state of their land, and 3) develop a restoration plan or design that is cohesive and drives all actions so that the end result is a successfully functioning landscape.

All of your efforts are investments into the land, and good investments yield returns, returns that can be enjoyed by both you and generations hereafter.



site plan

The Jackaroo Ranch case study site was chosen because the property experienced damage during both floods and because the property possesses conditions that are common to many properties along the Blanco and other rivers. The design team divided the property into four zones, Upland Restoration, Residential, Riparian Canopy, and Riparian Buffer. Readers can apply similar restoration tactics to comparable areas of their properties or can focus on a single zone if their property is dominated by that condition.

The main idea is to help slow water on site, celebrating it as a feature rather than pushing it off into adjacent ditches. This goal is achieved by connecting both upland and riparian zones so that they both contribute to controlling rainwater runoff. The design also integrates social spaces into the ecological design aspects by establishing a clear connection to the residence and river access area. A series of low, hand stacked rock walls thread their way through the landscape linking the movements of water and people while simultaneously acting as a stormwater diffuser at 5 key points.

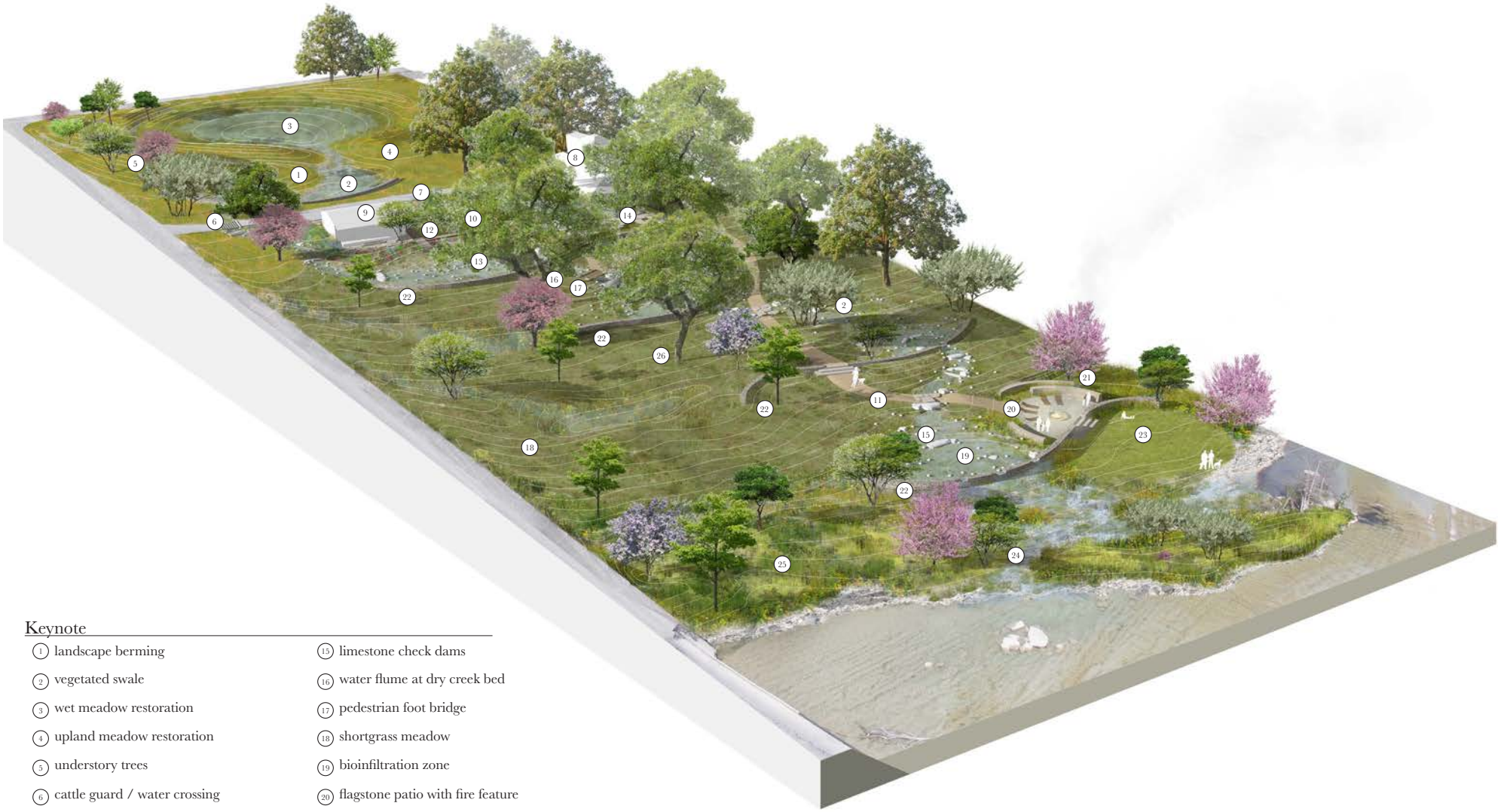
This plan also significantly reduces mowing to perhaps twice a year – late winter and late summer – and replaces the mowed condition with a tallgrass/midgrass plant community forming a substantial network of roots that dramatically helps reduce erosion. The planting scheme also includes the addition of younger existing trees and a number of other diverse understory species that increase habitat potential, provide greater biodiversity, and create a successional community that will continually replace old growth with new.

Keynote

1. landscape berming
2. vegetated swale
3. wet meadow restoration
4. upland meadow restoration
5. understory trees
6. cattle guard / water crossing
7. parking court w/ tube steel stops
8. main house
9. guest house
10. residential lawn
11. aggregate path
12. boardwalk decking
13. residential display garden
14. flagstone paving with planted joints
15. limestone check dams
16. water flume at dry creek bed
17. pedestrian foot bridge
18. shortgrass meadow
19. bioinfiltration zone
20. flagstone patio with fire feature
21. stone seat walls
22. limestone retaining walls
23. waterfront sunbathing lawn
24. riparian outflow
25. riparian buffer restoration
26. existing pecan grove


A
upland restoration
residential


riparian canopy
riparian buffer
A'



Keynote

1. landscape berming
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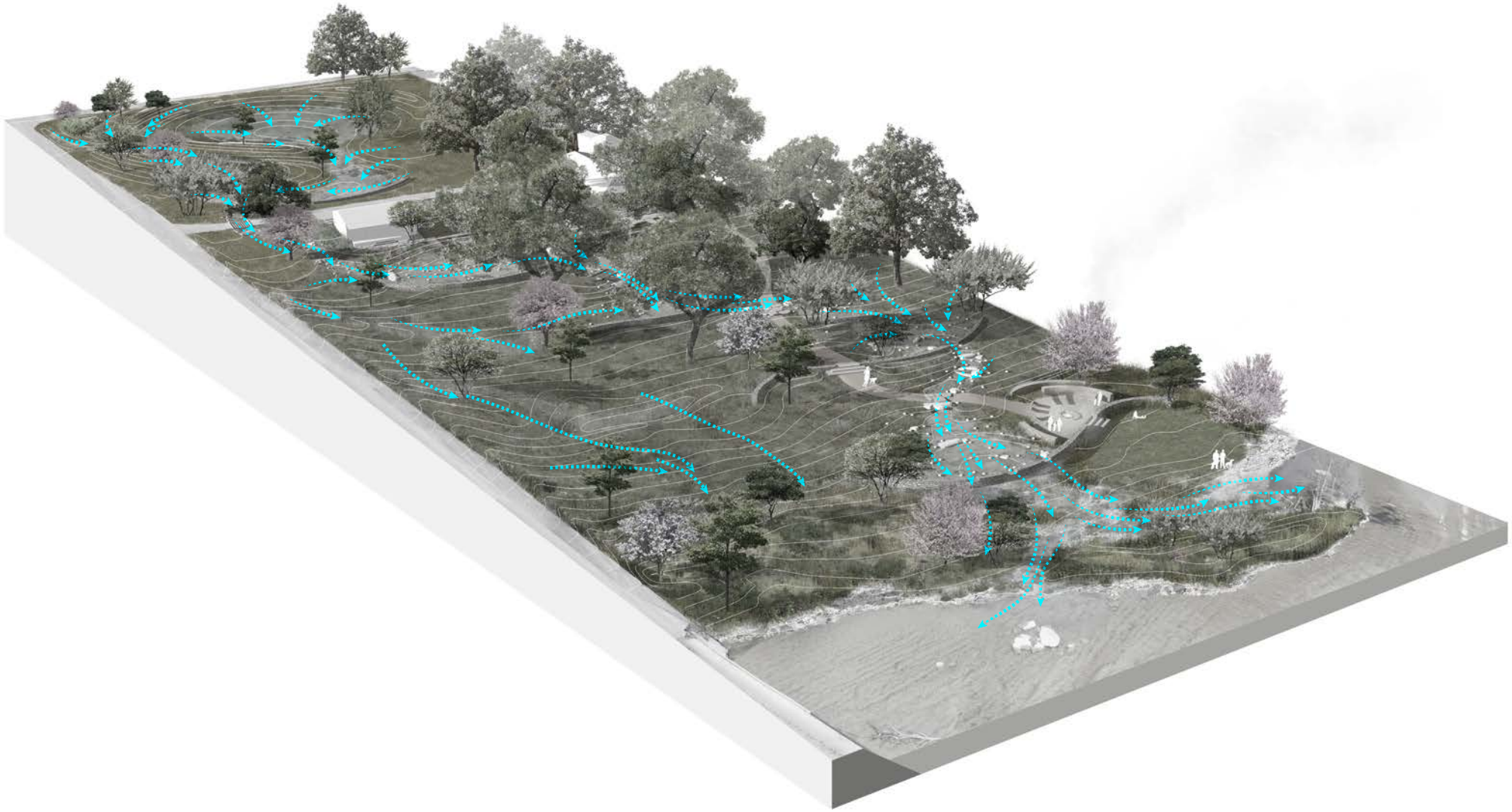



upland
residential
riparian
canopy
riparian

upland restoration

meadow restoration

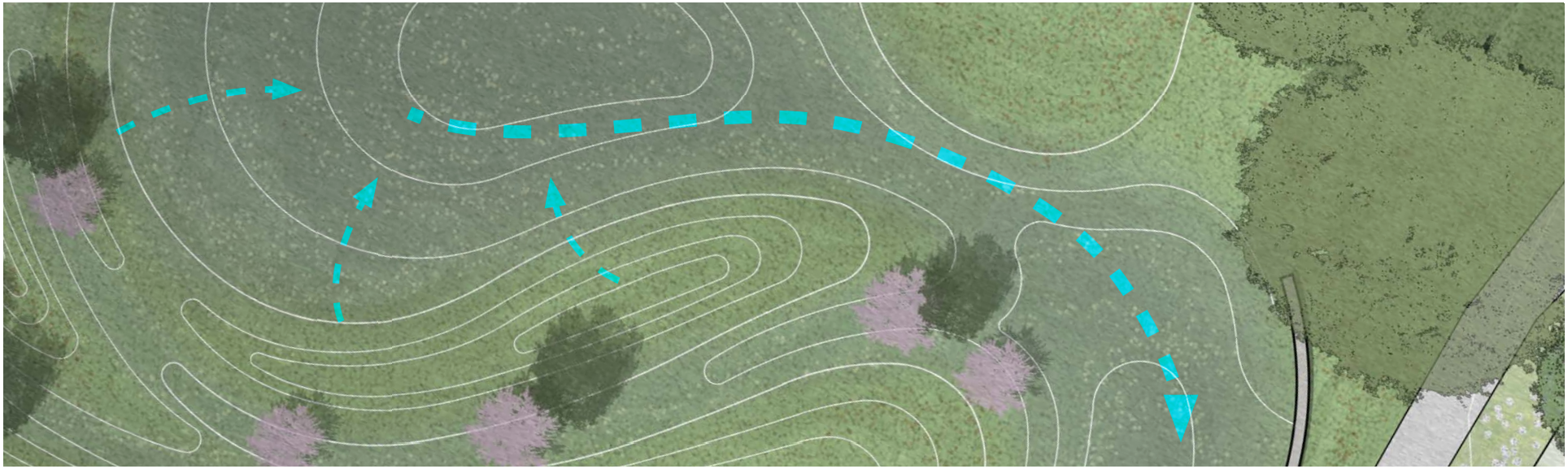
Landscape Architecture by Ten Eyck Landscape Architects
Photo Credit - Adam Barbe

upland restoration

The existing condition is comprised of a mostly flat area, dominated by invasive plant species, such as Bermudagrass (*Cydondon dactylon*) and King Ranch bluestem (*Bothriochloa ischaemum*), that was regularly mowed. Rainwater flowed into roadside ditches that dumped runoff into the Blanco at high rates of velocity.

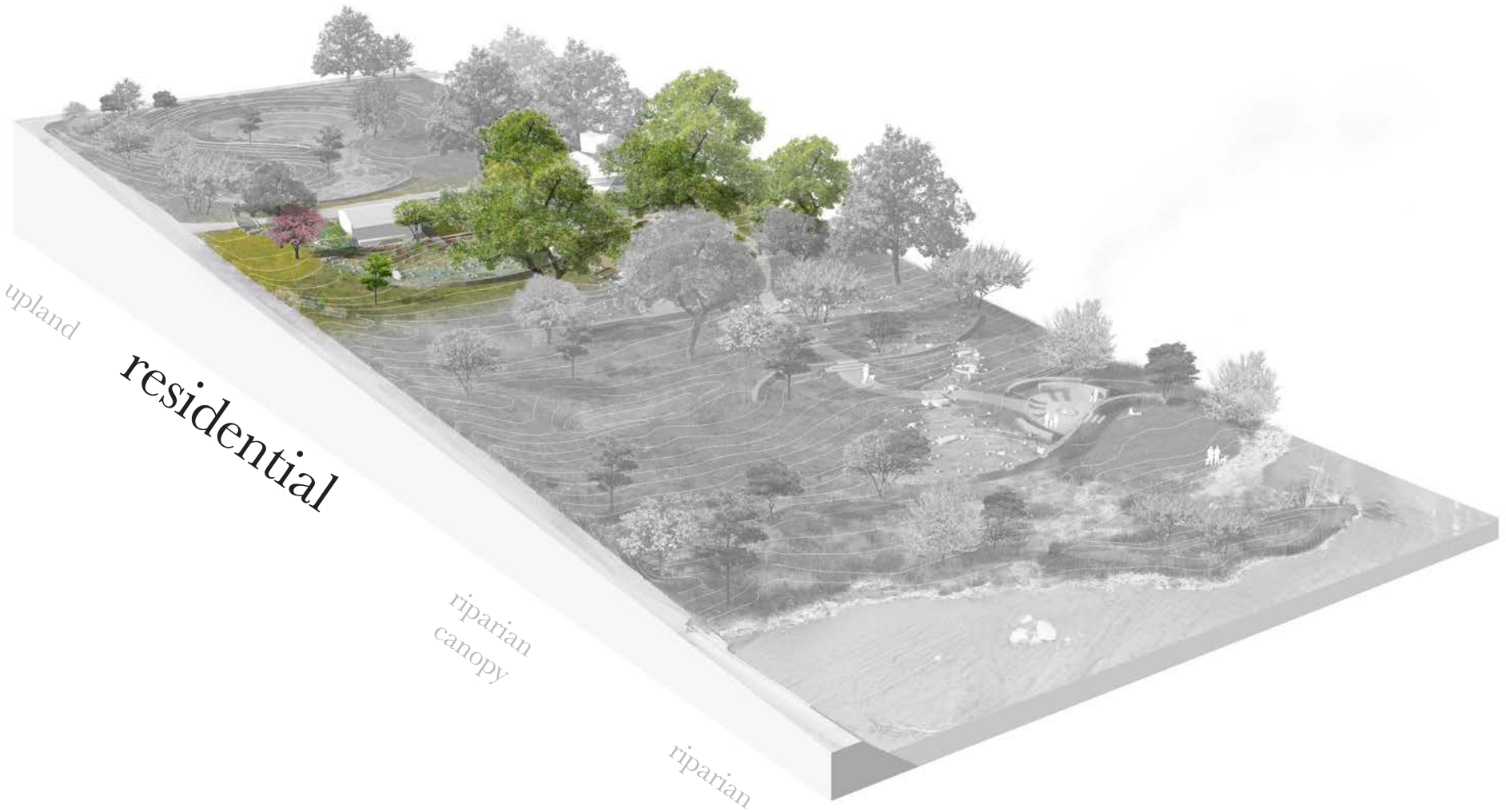
The design strategy pulls water from adjacent ditches and allows it to flow into a rainwater garden depression. Excavation from the rain garden is utilized to form sculptural mounds or "berms" that increases the diversity of soil conditions, allowing the upland to be seeded and planted with a greater diversity of grass and wildflower species. This plant species diversity will become very apparent during the spring and fall when a procession of brilliant bloom patterns slowly shift between pockets dominated by displays of blue, red, orange, pink, purple, and yellow.


Photo Credit - Bruce Leander



upland restoration

Rainwater will fill the depression during wetter months and eventually dry out during hotter months. The rain garden is designed to hold around 20,000 gallons of water before overflowing, with overflow cascading down through the lower three zones allowing site users to experience ephemeral flows. The extended presence of water in this area will also attract a large number of native birds, insects, reptiles, and amphibians, and creating important habitat in the upland areas is a helpful element in some permits issued by the Army Corps of Engineers.


upland
residential
riparian
canopy
riparian

residential

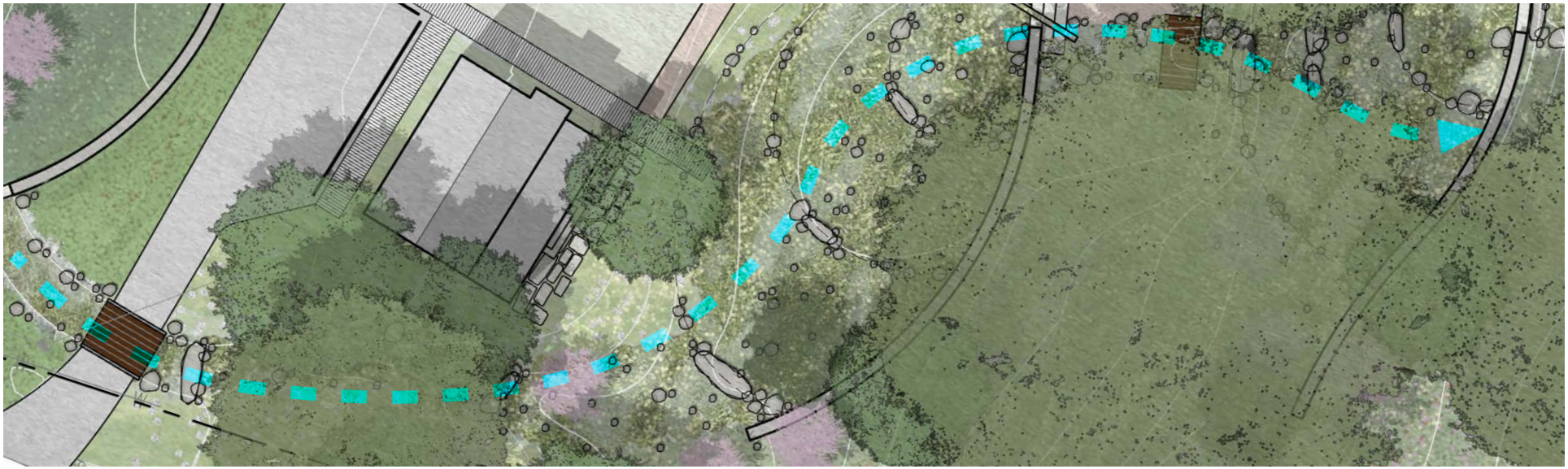
native display garden

Landscape Architecture by Ten Eyck Landscape Architects
Photo Credit - Adam Barbe

residential

Over the last century, loss of native plant communities in central Texas has led to the loss of wildlife habitat, ecological services, and reduced genetic diversity characteristic of balanced ecosystems. This loss has equally had an adverse impact upon people as the loss of central Texas ecosystems has resulted in a disconnection of people to the land. A majority of the problem arises when we replace native plants with nonnative species in residential landscape plantings. The continual use of a limited palette of non-native plants across the U.S. has produced a homogenized landscape that is susceptible to pests and diseases, and overly dependent upon irrigation, fertilizer, and resource intensive maintenance practices. Residential landscapes provide us with the opportunity to understand the complexities of central Texas' ecosystems through the breaking down of diverse plant communities into simplified planting schemes and designs. We can develop and refine our knowledge of gardening by starting at the smaller scale of individual plants, flowerbeds, or yards. Landowners might feel more comfortable starting with a design for the area immediately surrounding their home before attempting a larger restoration project, especially if they don't have experience with gardening. Establishing native plants in your garden usually requires as much effort as non-native species. However, once the plants are established, you will see savings in time, energy, and money.

Photo Credit - Bruce Leander



residential

The design team created a residential area that collects water discharged from the upland restoration zone through a vegetated swale. As the rainwater passes by the guest house, it is allowed to slow, pooling behind a stone retaining wall. As the water pauses, its sediment dissipates and the infiltration rates increase. This area is densely planted with native ornamentals and flowering perennials. The planting design here resembles that of a native botanical garden – dense, lush, and regionally appropriate. The residential zone is designed to encourage social interaction between friends and family. A water-wise lawn has been designed to offer an environment that fosters these interactions. The lawn requires minimal maintenance utilizing a drought tolerant seed species mix.

It is here, in the residential zone, where the pedestrian circulation paths appear orderly and most substantial. The parking court north of the guest house is paved with limestone screenings. The parking stops are constructed of tubular steel stock. Near the main house, limestone paving with planted joints offers a unique outdoor patio space with soft edges. Alongside the guest house a cantilevered boardwalk provides an overlook of the riparian canopy restoration in addition to a unique arrival sequence. Near the first set of stairs a concrete flume captures the overflow from the display rain garden and becomes the headwaters of the dry creek bed that slopes down to the Blanco River.


upland
residential
riparian canopy
riparian

riparian canopy

revegetation & stabilization

Photo Credit - Adam Barbe

riparian canopy

Currently this area is dominated by pecan trees and invasive grasses, such as Bermudagrass (*Cydondon dactylon*) and King Ranch bluestem (*Bothriochloa ischaemum*), with a good deal of bare ground. Shady areas can be a challenge in central Texas because many of the usual turf grass species need full to part sun or are species that require large amounts of irrigation such as St. Augustine. The area has frequently been mowed and the shady condition has resulted in areas of erosion that will eventually become a larger issue if the problem isn't corrected.

This zone connects with the residential zone by extending some hardscape elements into the shady area, thereby increasing the footprint of social areas around the main residential turf area. The design also incorporates some more formal display areas that the landowners can enjoy in more of a traditional garden setting. The upland restoration overflow swale continues through this area and permits further infiltration of rainwater within the critical root zones (CRZ) of existing canopy trees. The CRZ is very sensitive and so construction and plantings in these areas must be mindful to prevent damage that could contribute to the loss of large trees. Because the existing soil is in poor condition, the trees will benefit from lightly loosening of the soil during site preparation and it is likely that some of the trees will require air spading by arborists to treat existing compacted soils. Once the soil has been prepared and treated to

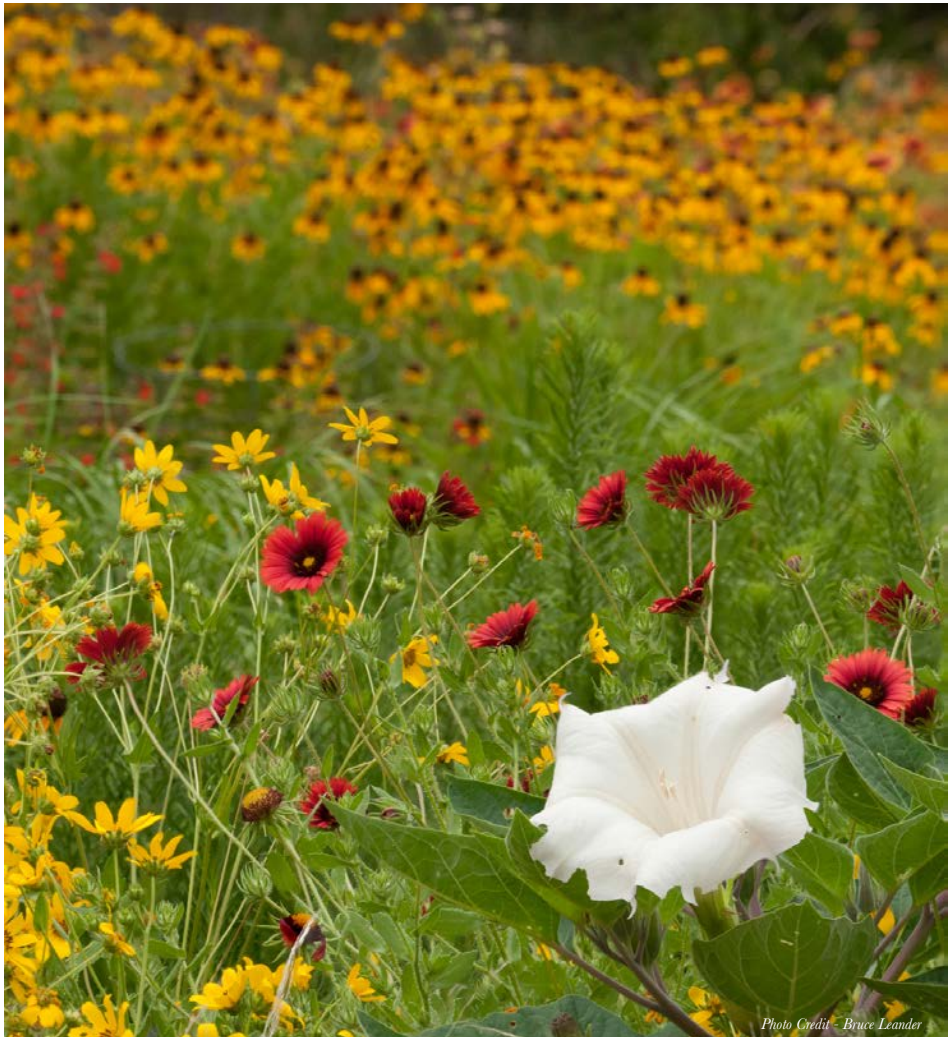


Photo Credit - Bruce Leander

riparian canopy

benefit the existing large trees, the area will be seeded and plugged with shade tolerant midgrass species and wildflowers. This plant community will aid in controlling sheet flow as well as preventing erosion during high flow events of the Blanco River. The team also regraded some of the property next to the road to collect some of the water from the adjacent ditch, in order to help slow runoff into the Blanco River.


upland
residential
riparian canopy
riparian


riparian buffer
edge restoration
Photo Credit - Adam Barbe

riparian buffer

The existing area received a large amount of erosion during the 2015 spring and fall floods. Most of the topsoil was removed and deep ruts of 2-4' formed as the water rushed over the mowed grass condition. Like most of the site, this area contained invasive grass species whose minimal roots systems could not protect the soil surface. There are some tallgrass invasive species such as Johnsongrass (*Sorghum halpense*), but opportunistic native pioneer species such as clammyweed (*Polanisia dodecandra*) have begun to thrive on the disturbed soil condition as well.

The main goals for this area's design were to provide protection against future flood events and allow river access. Due to erosion, most of this zone will require regrading to eliminate ruts and to shape the path from the residential zone down to the river. The area will be seeded and planted with a mix of both tallgrass and midgrass grass and wildflower species as well as a mixture of smaller riparian tree and shrub species. This mixed plant community will provide optimal protection during high flow events as the network of roots will firmly anchor the soil, and the flexibility of the grasses will allow the above ground biomass to bend and cover the ground providing an extra layer of protection. The design team created a destination spot at the terminus of the path that includes a more formal flagstone area with a fire pit and a shortgrass area immediately adjacent to the water's edge. The hardscape elements


Photo Credit - Bruce Leander


741'

riparian buffer

are not anchored by mortar or concrete and are intended to break apart during major flood events so that they don't cause damage to the soil by being ripped out, leading to worse erosion. This area provides plenty of access while preventing the major damage experienced during the recent floods.

appendix a

soil survey tutorial

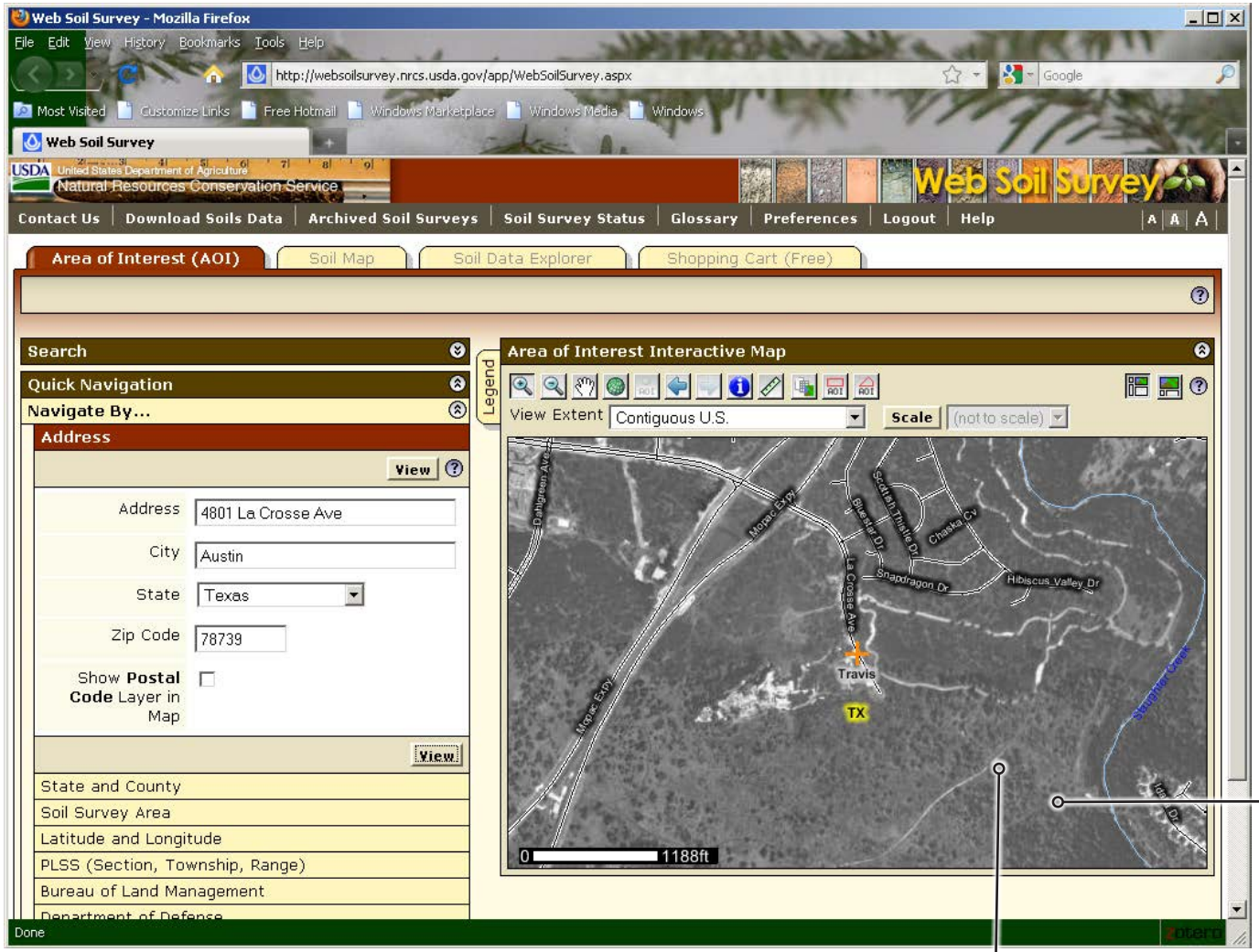
1.

To Begin:

Go to: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Look at the 3 basic steps on this page and then start by clicking the green Start WSS button

2.



Look for this road. It's pretty clearly visible.

The project is just south of this, bounded in the north by another road, that is visible when you zoom in, but hard to see at this point.

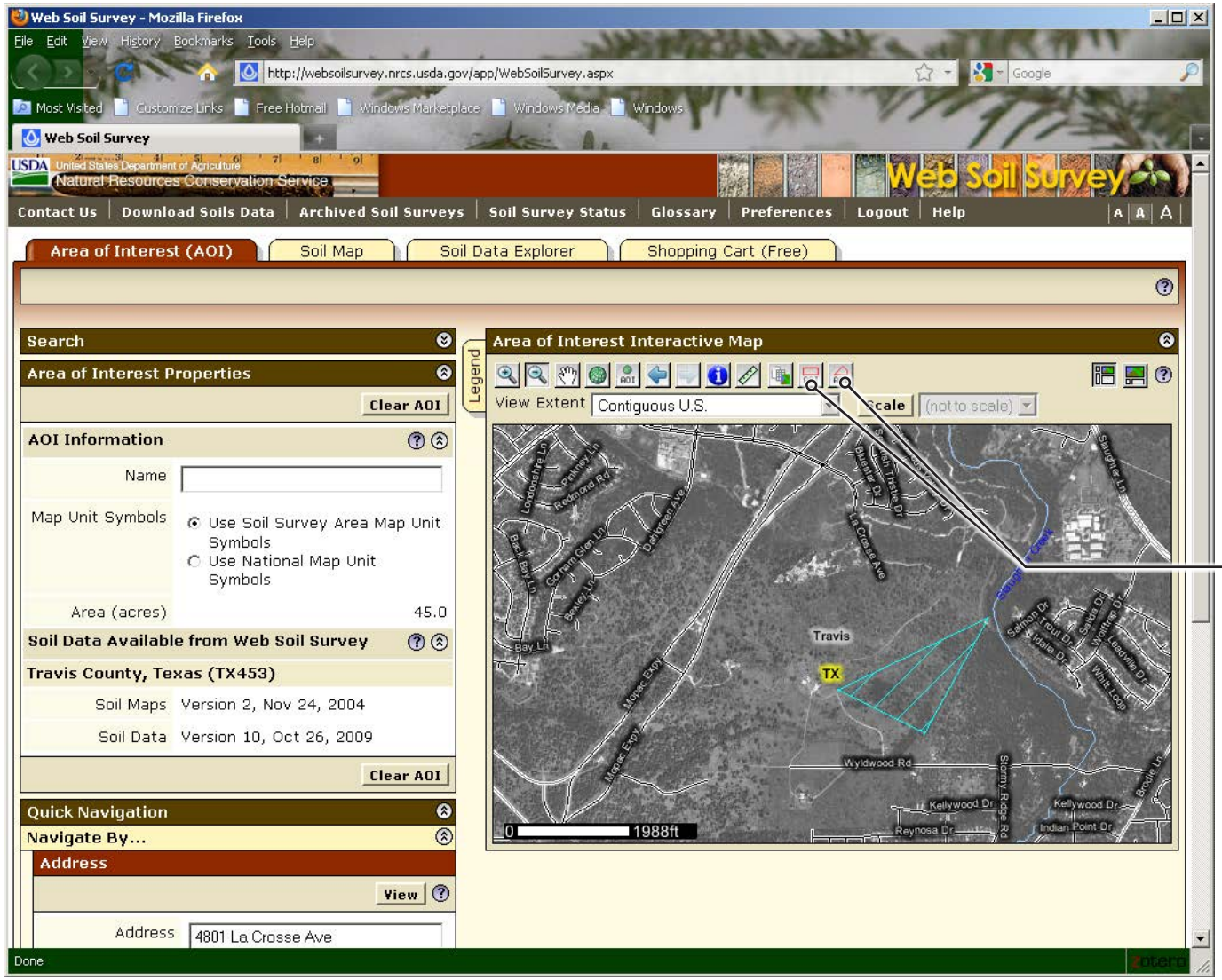
Step 1. Define area of interest.

The first step is to define your area of interest. For this exercise, we will be using an area of the Wildflower Center. You can enter the Wildflower Center's address (4801 La Crosse Avenue, Austin, Texas 78739) and then drag the image to our project location at the southwest corner. Alternately, you can enter latitude and longitude coordinates. Once you are close, you can either attempt to outline just our project, or draw a rectangle that encompasses the area. This is your Area of Interest (AOI).

appendix a

soil survey tutorial

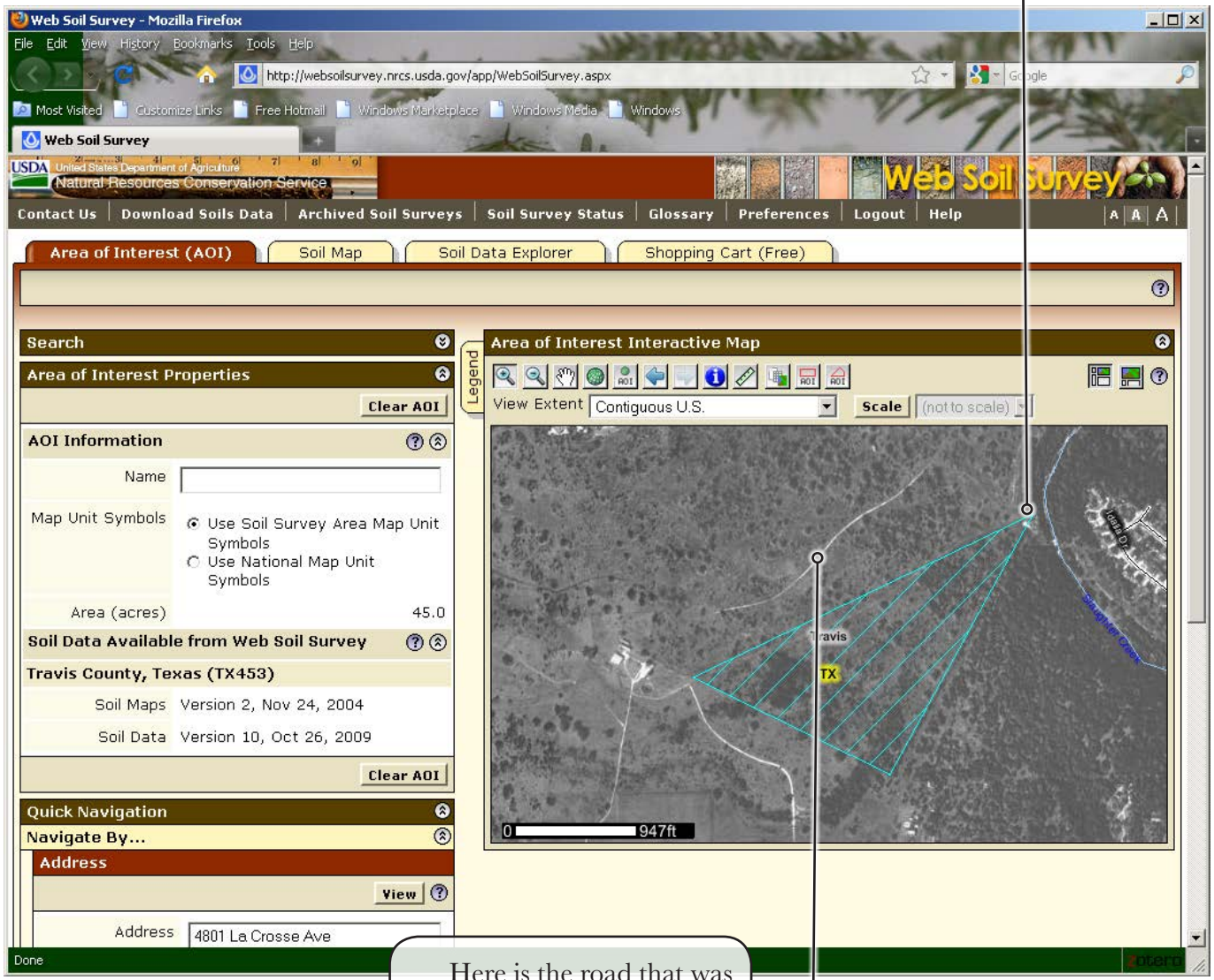
3.



Give your area a name in the Name field- Final Project, Wildflower Center, etc. This will go onto the title page of the final report.

Use one of these keys to define your areas

4.



Step 2. Explore data

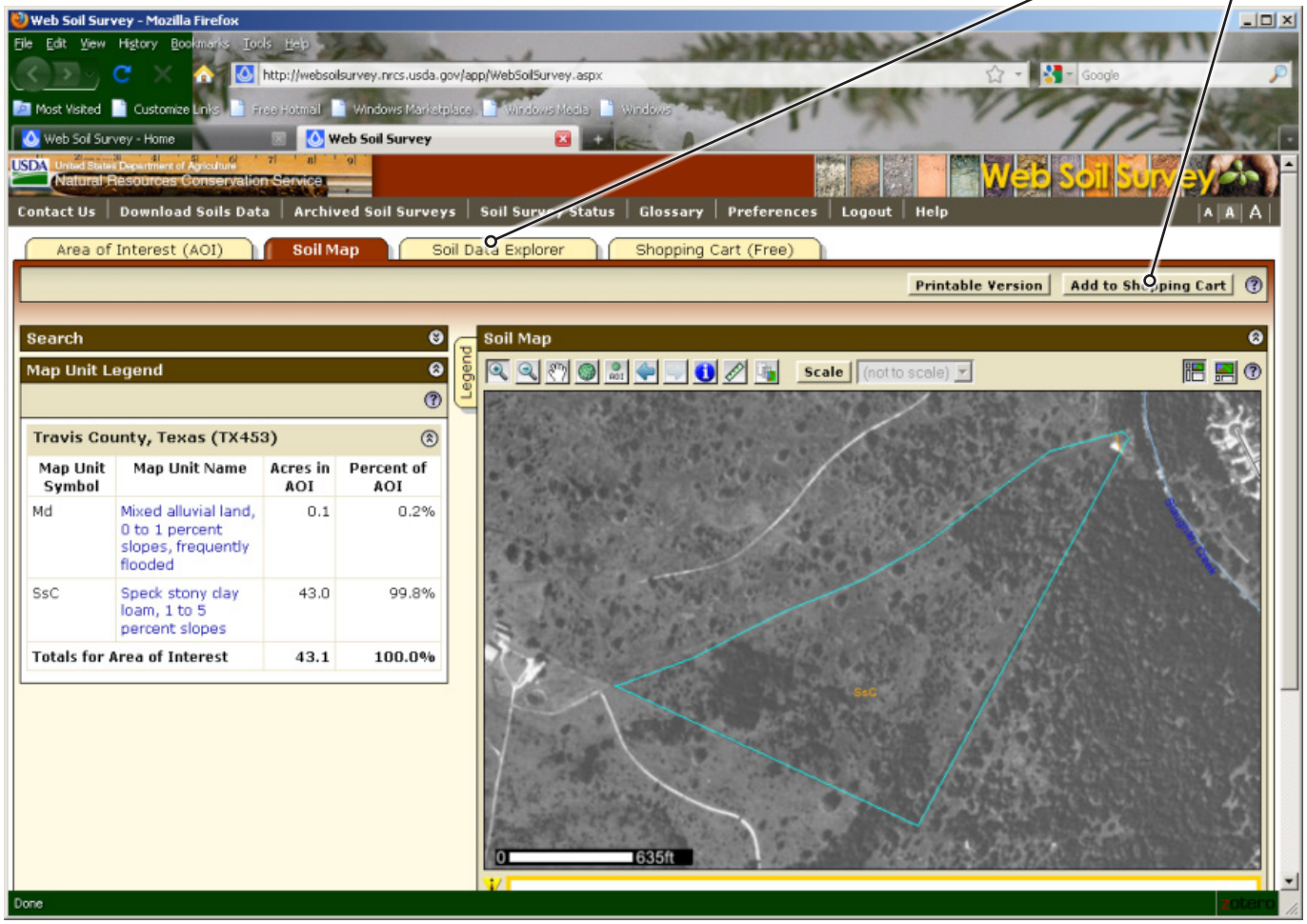
Take note of the 4 tabs: Area of Interest, Soil Map, Soil Data Explorer, & Shopping cart. Use these to navigate the site.

We will want the soil map and several pieces of information available in Soil Data Explorer. As you view each piece of information, you have the option to add it to your shopping cart. The Web Soil Survey will put everything you add to the shopping cart into a single report for you that you can download immediately or later. We will go through each step and conclude with a summary of the information typically needed for restoration projects.

appendix a

soil survey tutorial

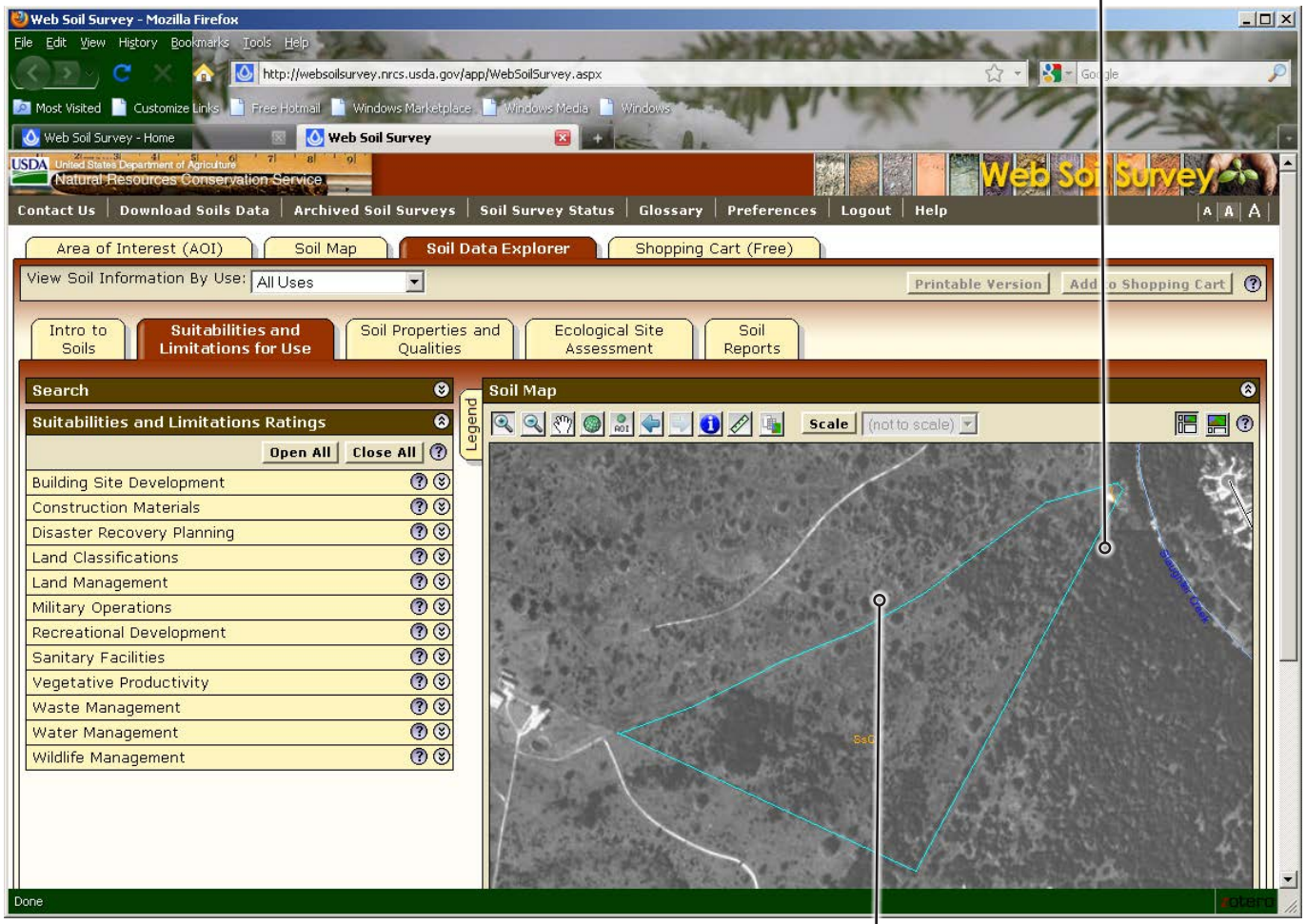
5.



If you are happy with your map, click add to shopping cart and then go to the Soil Data Explorer tab.

It should look something like this. You may or may not have the Md soil layer, depending on how far you extended the north east corner. If you don't have it, you may want to redraw your AOI to get it, because I suspect this is what we have in our drainage.

6.



As you can see, Soil Data Explorer has several sub tabs.

Below, is a summary of what is in each tab and general instructions for getting data, followed by what you will see in each tab, what to click etc.

Intro to Soils: This tab provides a nice introduction to soils.

Suitabilities and Limitations for Use: Pull down any of these that you think would be useful for your project. Building Site Development, Recreational Development, Water Management, and Wildlife management are often worth looking at.

Soil Properties and Qualities: Has detailed information on the physical and chemical properties of your soils. Most of this is summarized in Soil Reports. This section provides more detail than

appendix a
soil survey tutorial
7.

soil reports, so if there is a particular parameter you need more information on, you would get it here. Otherwise, use the soil reports to collect your information.

Ecological Site Assessment: This section and the Soil Reports section are the most useful sections from a restoration point of view. Ecological sites are the updated, and much expanded, versions of the range sites available in paper soil surveys. The focus has shifted from agriculture to ecological function. This is your first step to figuring out what your site is capable of. You should add everything here to your shopping cart.

Soil Reports: This section summarizes the physical and chemical properties of your soils and you should add several of these to your report.

General instructions for adding data to your shopping cart.

1. Expand the topic from the table at the left of the screen.
a. Frequently this will open several sub tables.
2. Click view
3. Click add to cart.

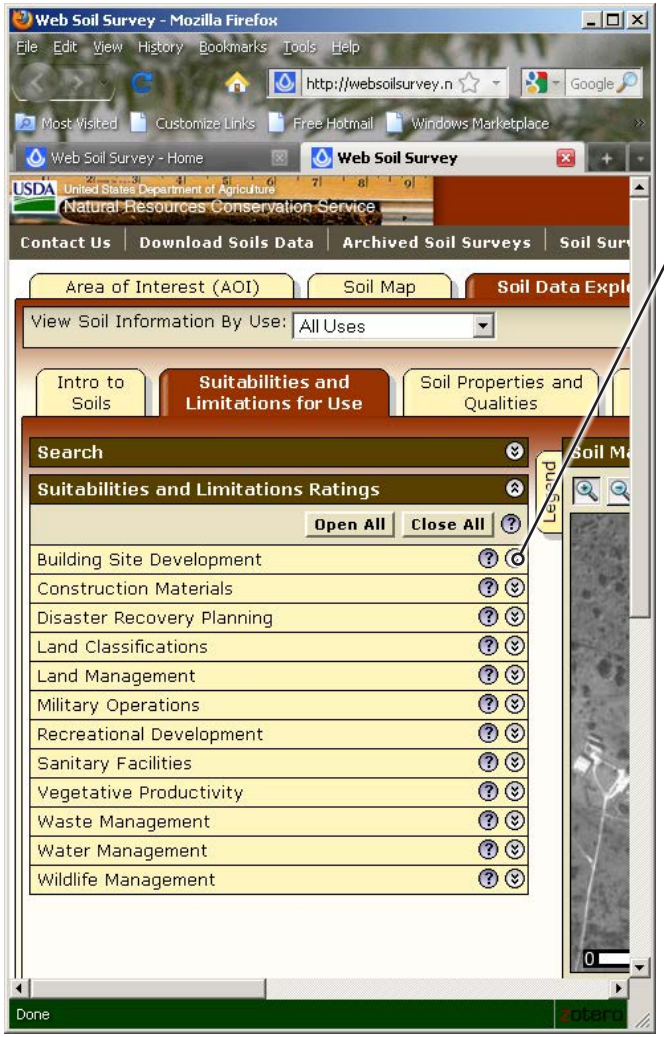
You must do this for every piece of information you want. There is no way to add all.

4. When you have added all the information you want, from all the tabs, checkout. It's free and you will be given download options.

Soil Data Explorer- Suitabilities and limitations for use.
From here you will pick and choose what is most important to your project. Usually going in you have some idea of the types of development that are likely. Much of the information here is summarized in soil reports. You may need to go back to this for more detail after you get further into your design process. Today, add the following to your shopping cart.

You can add as many extras as you like.

8.



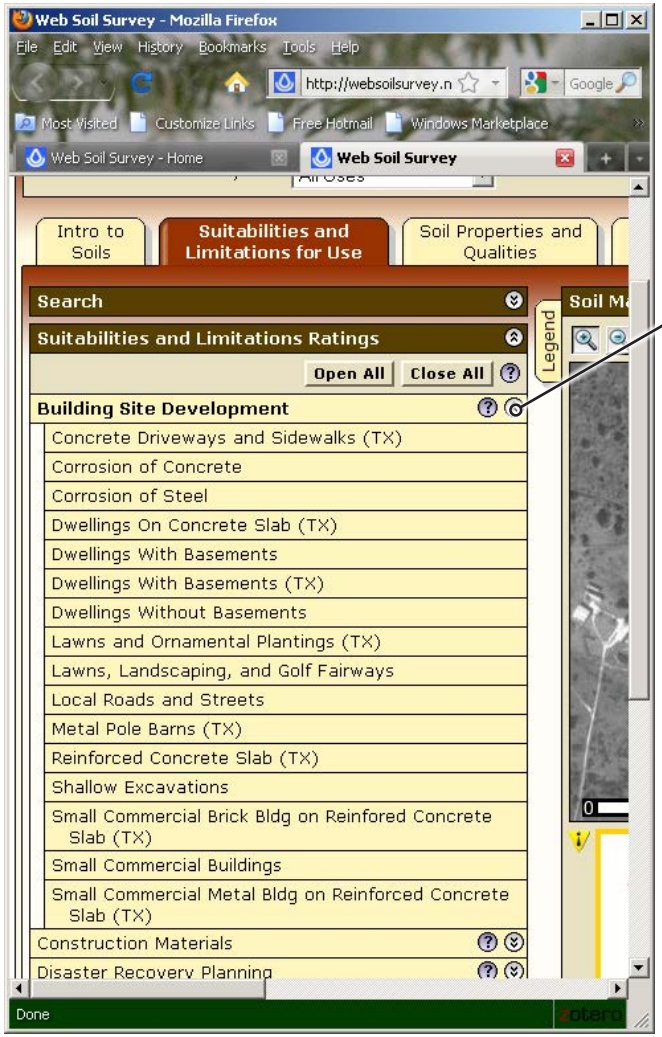
Here is an example of how to add an item.

Expand the subject you are interested in by clicking the arrow. Here I'll do Building Site Development.

appendix a

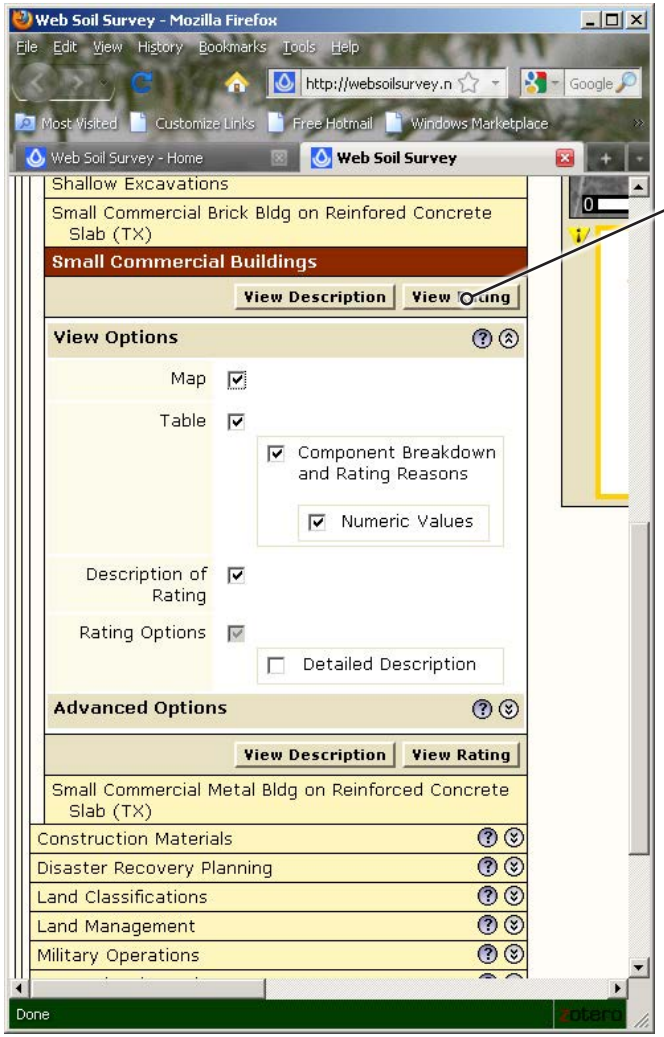
soil survey tutorial

9.



Under building site development, I'm interested in small commercial buildings, so I keep expanding by clicking the arrows

10.



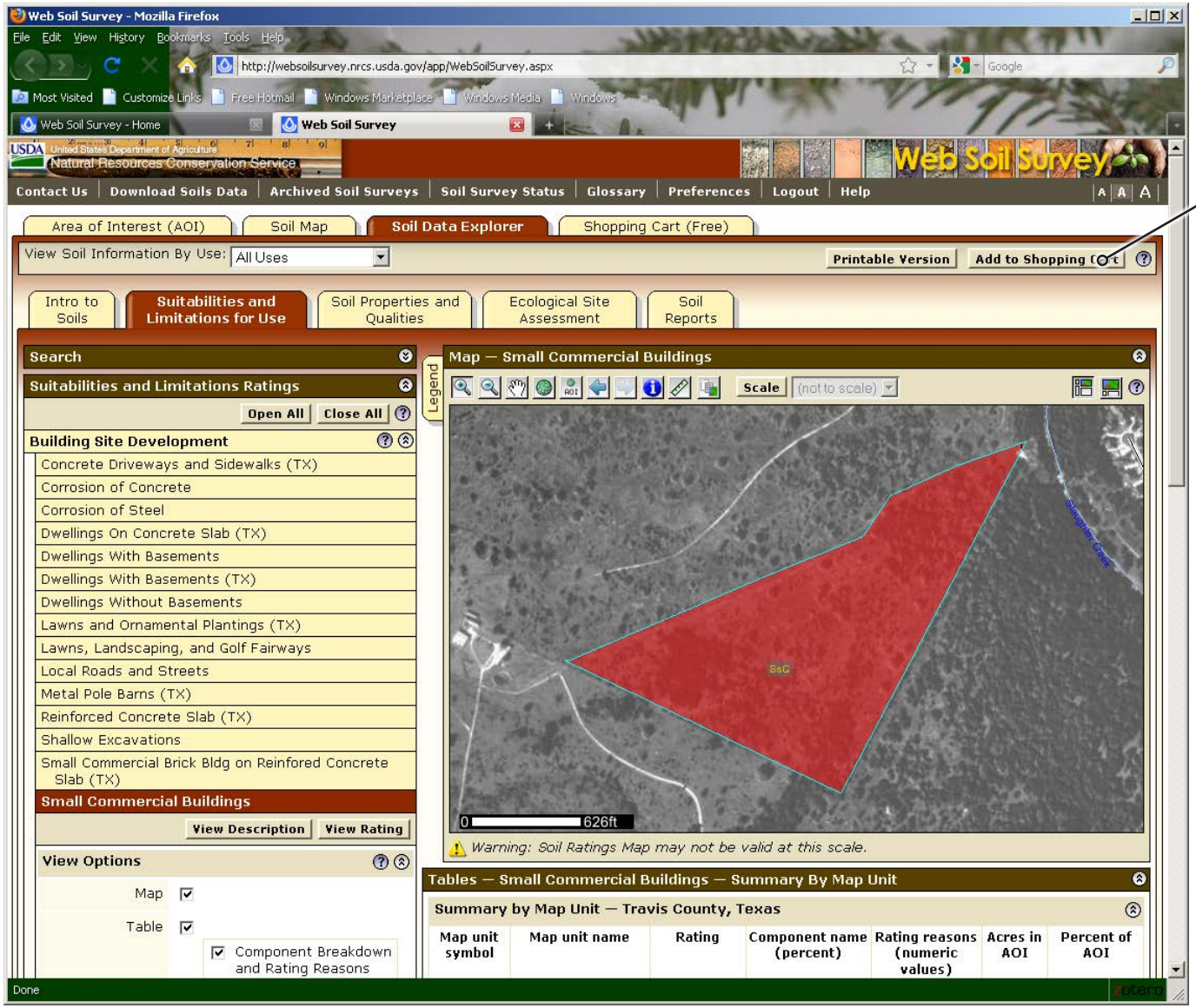
Here, I click View Rating.

This will pull up the information. Once it's up, I can click add to shopping cart. I have to do this with each item I want to go into the report.

appendix a

soil survey tutorial

11.

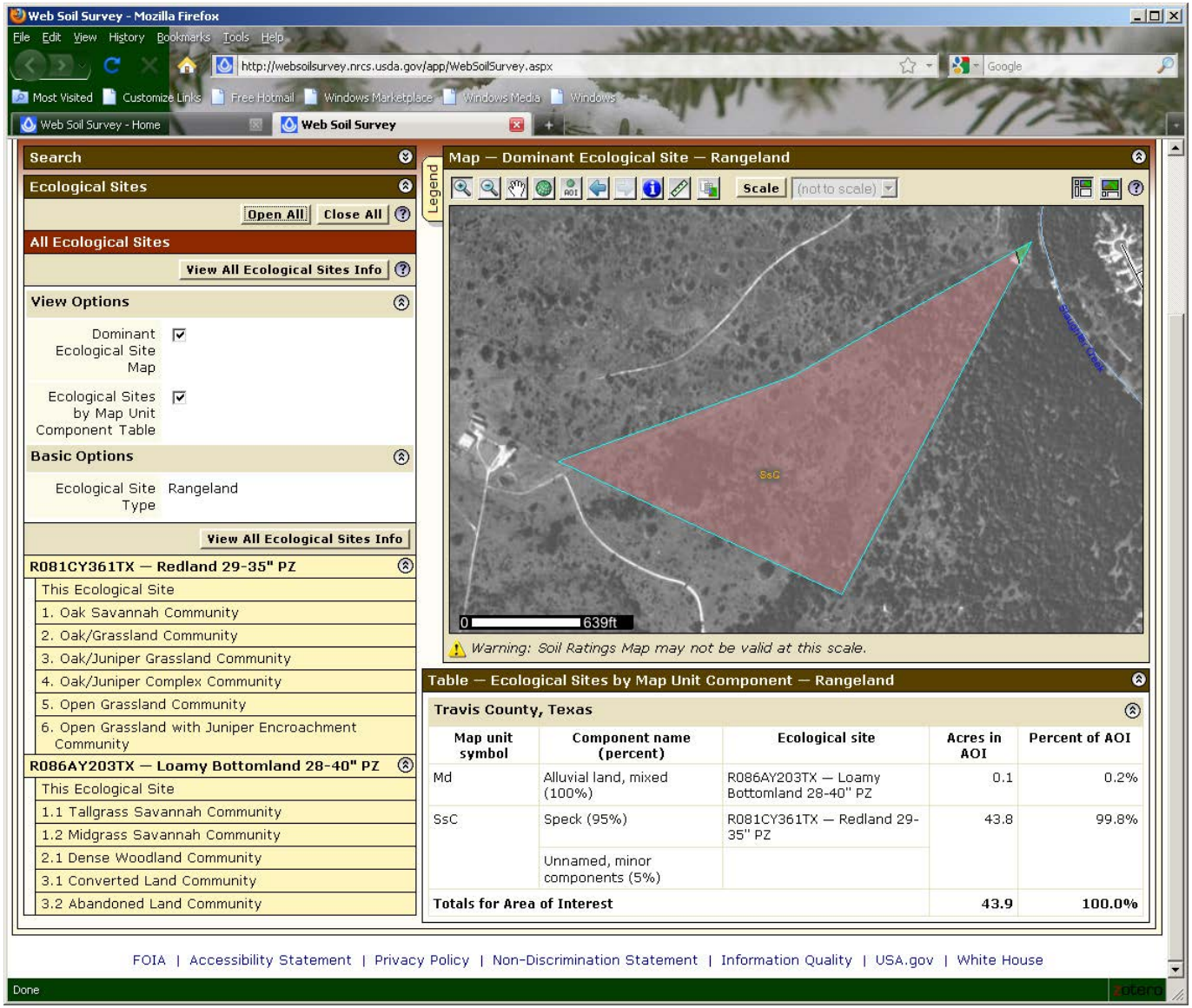


Add to shopping cart here

To summarize, to add an item to your cart:

1. Expand topics with arrows at right
2. Click view rating
3. Click add to cart.

12.



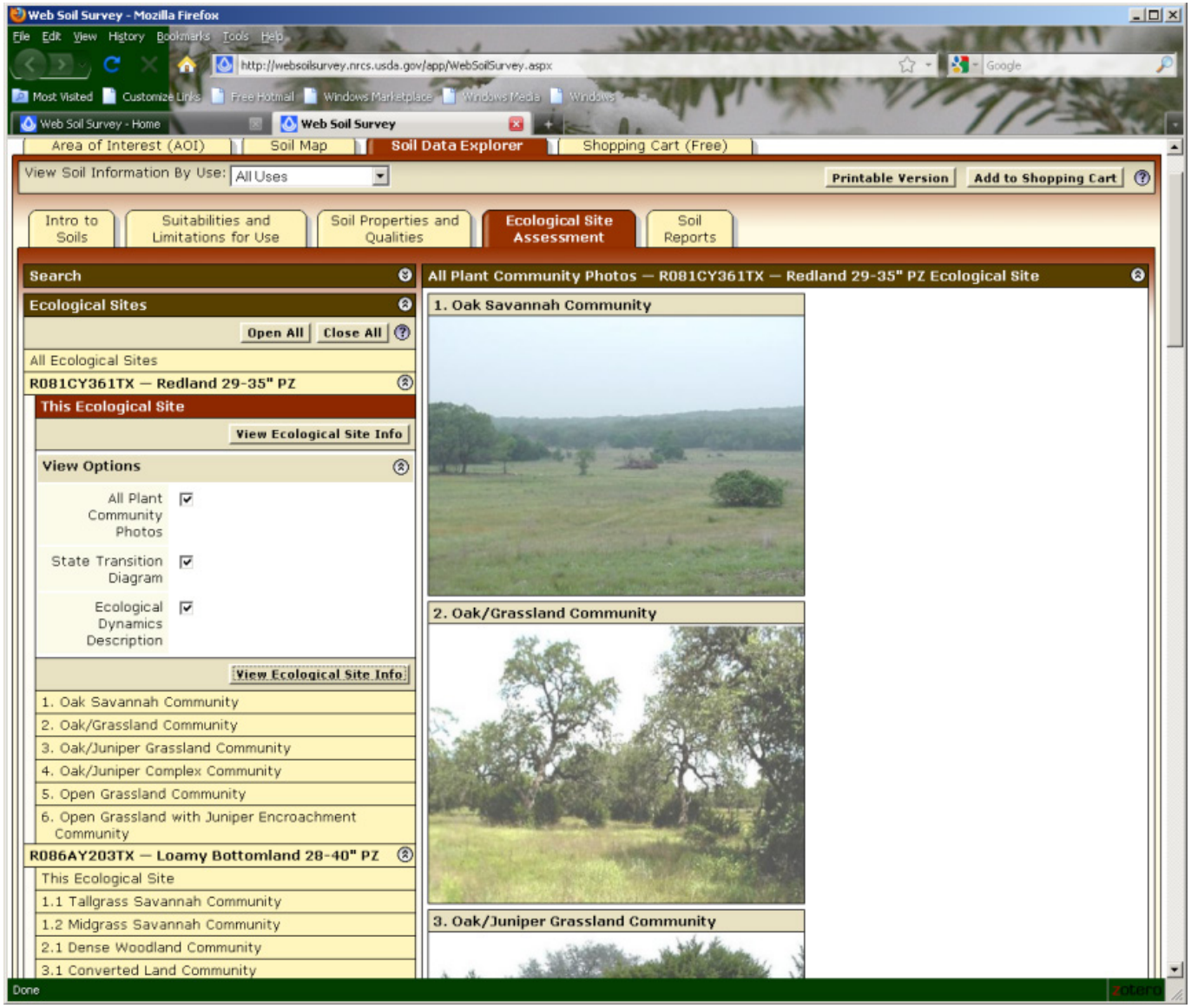
Ecological Site Assessment Tab: Under ecological site assessment, first click open all so you can see both the ecological sites (redland and loamy bottomland) and all the communities within them. You need to expand and add all of these topics.

Here you expand the tree, then click view all ecological sites info, and then click add to shopping cart.

appendix a

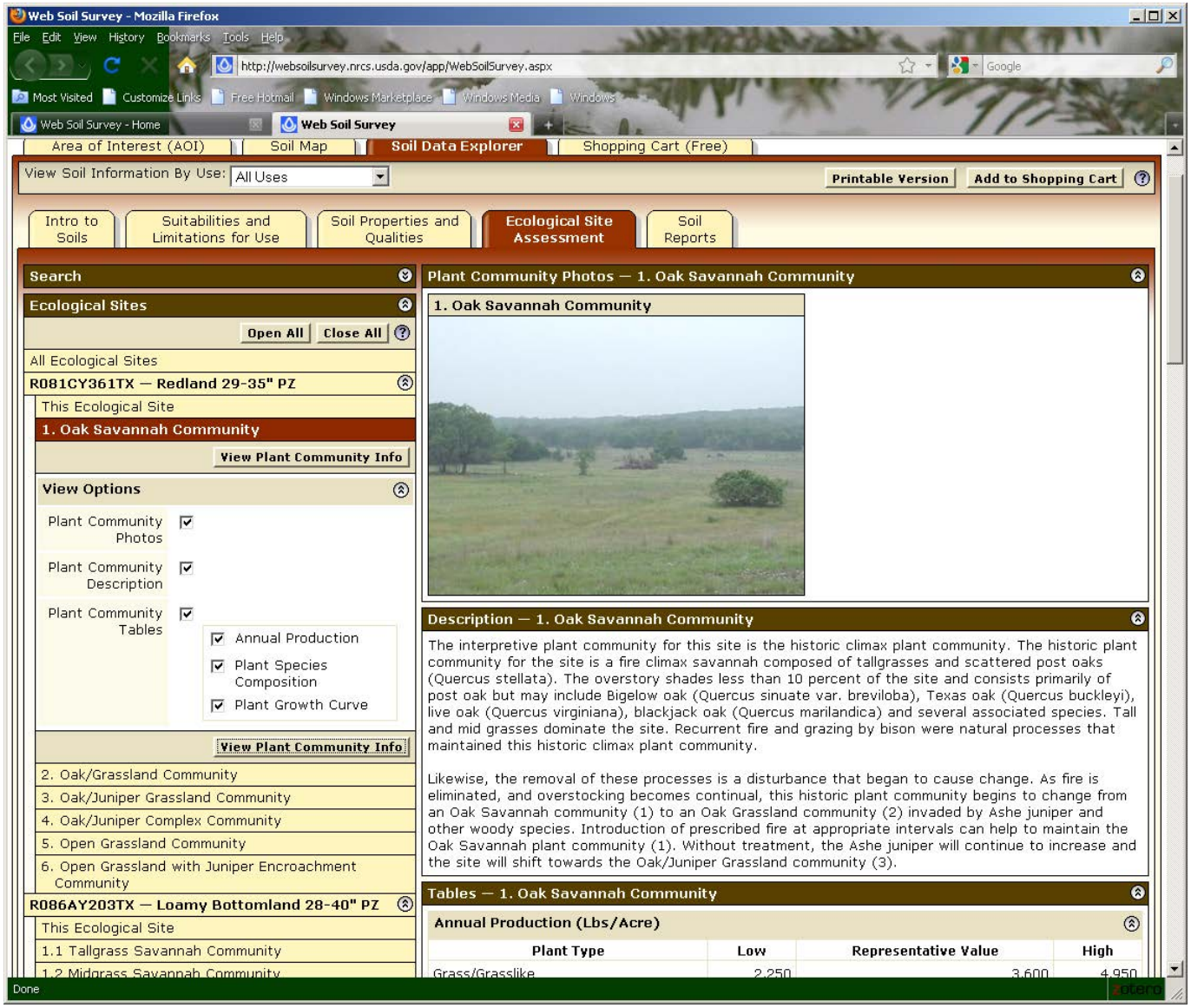
soil survey tutorial

13.



View Ecological Site Info: You want to be sure all 3 boxes are checked. As you move into the individual community descriptions, you can leave off the photos if you want to, but I find them helpful to have associated with their description.

14.



View of an individual community description: Plant community photo is optional since you have it in the ecological site description.

Get everything else.

appendix a
soil survey tutorial
15.

Summary of Information to Retrieve:
This is what to retrieve at a minimum. Add it all to your shopping cart. You can add as much additional information as you want. This takes a bit of time, but it will give you a jump start both on your assessments and on your eventual design.

Once you have added all the information, go to the shopping cart tab and check out.

Area of Interest
Define your area of interest and give it a name

Soil Map
Add your map.

Soil Data Explorer Main Tab
This tab has 5 subtabs below.

Intro to Soils Tab
Lots of useful material in here, and it is worth looking through, but adding any of it to your report is optional.

Suitabilities and Limitations for Use Tab
It is useful to explore this tab. Most of the information can be summarized in the Soil reports tab, so you do not have to add it at this time unless there is a topic you want more detail on.

Soil Properties and Qualities Tab
Similar to Suitabilities and Limitations for use. The information here is summarized in soil reports. This tab provides more detail than what is in soil reports.

Ecological Site Assessment Tab
Everything in here. First, hit open all so that you can see all of the communities as well as the ecosites.

Soil Reports Tab

AOI Inventory
- component legend
- map unit description

Building Site Development
- dwellings and small commercial buildings
- roads & streets

Land Classification
- hydric soils
- prime and other important farmlands
- taxonomic classification – nice but optional

Land Management
- optional

Recreation Development
- these would be nice if you suspect these elements may be in your design

Soil Chemical Properties
- chemical soil properties

Soil Erosion
- rusle2 related attributes

Soil Physical Properties
- engineering properties
- particle size
- physical soil properties

Soil Qualities and Features
- soil features

Vegetative Productivity
- irrigated yield- optional
- rangeland productivity – optional

Water Management – optional, but possibly useful

appendix b
document set

abbreviations

AFF	above finish floor
AC	acres
ADD	addendum
ADJ	adjustable
AGG	aggregate
ALT	alternate
ALUM	aluminum
ANC	anchor, anchorage
ANOD	anodized
APPROX	approximate
ARCH	architect(ural)
AD	area drain
ASPH	asphalt
B&B	balled and burlapped
BM	bench mark
BIT	bituminous
BLK	block
BTM	bottom
BC	bottom of curb
BS	bottom of steps
BW	bottom of wall
BRK	brick
BLDG	building
CAL	caliper
CK	calk(ing) caulk(ing)
CI	cast iron
CIPC	cast-in-place concrete
CB	catch basin
CEM	cement
CL	centerline
CM	centimeter(s)
CHAM	chamfer
CLF	chain-link fence
CIR	circle
CIRC	circumference
CLR	clear(ance)
CONC	concrete
CMU	concrete masonry unit
CONST	construction
CONT	container
CLL	contract limit line
CJ	contraction joint
CMP	corrugated metal pipe
CORR	corrugated
CSK	countersink
CRS	course(s)
CS	cross-slope
CF	cubic foot
CY	cubic yard
DMP	dampproofing
DP	deep, depth
D	degree of curvature
DEMO	demolish, demolition
DEP	depressed
DTL	detail
DIAG	diagonal
DIA	diameter
DBH	diameter breast height
DIM	dimension
DIV	division
DS	downspout
DT	drain tile
DWG	drawing
DF	drinking fountain
EW	each way
E	east
ELEC	electric(al)
EL	elevation
ENCL	enclosure(ure)
ENG	engineer
EQ	equal
EQUIP	equipment
EST	estimate
EXIST	existing
EXP	exposed
EXT	exterior
FIN	finish(ed)
FFE	finished floor elevation
FG	finish grade
FLG	flashing
FLX	flexible
FH	fire hydrant
FL	floor
FT	foot, feet
FTG	footing
FND	foundation
FUT	future
GA	gage, gauge
GALV	galvanized
GV	gas value
GC	general contract(or)
GD	grade, grading
GVL	gravel
G	gutter
HDW	hardware
HWD	hardwood
HDR	header
HD	heavy duty
HT	height
HP	high point
HOR	horizontal
HB	hose bibb
INC	include (d), (ing)
ID	inside diameter
INT	interior
INV	invert
IJ	isolation joint
JT	joint
L	length (of curve)
LA	landscape architect
LT	light
LF	linear feet
LP	low point
MH	manhole
MFR	manufacture(er)
MAT	material
MAX	maximum
MECH	mechanic(al)
MED	medium
MTL	metal
M	meter(s)
MM	millimeter(s)
MIN	minimum
MISC	miscellaneous
MOD	modular
NOM	nominal
N	north
NIC	not in contract
NTS	not to scale
NO	number
OC	on center(s)
OPP	opposite
OH	opposite hand
OD	outside diameter
PTD	paint(ed)
PVG	pave(ing)
PVMT	pavement
PERF	perforate(d)
PL	plate
PWD	plywood
PT	point
PVC	polyvinyl chloride
PSF	pounds per square foot
PSI	pounds per square inch
POB	point of beginning
PCC	point of compound curvature
PC	point of curvature
PI	point of intersection
PRC	point of reverse curvature
PT	point of tangent
PVC	point of vertical curvature
PVI	point of vertical intersection
PVT	point of vertical tangent
PL	property line
R	radius
RL	rail(ing)
RWC	rainwater conductor
REF	reference
REBAR	reinforcement bar
RCP	reinforced concrete pipe
REINF	reinforcing
REV	revision(s), revised
RE	rim elevation
REQ	required
ROW	right-of-way
RIS	riser
RD	road
SAN	sanitary
SCH	schedule
SC	score line
SEC	section
SHT	sheet
SIM	similar
SLV	sleeve
SL	slope
S	south
SP(S)	space(s)
SPEC	specification
SQ	square
SST	stainless steel
STD	standard
STA	station
STL	steel
SD	storm drain
ST	street
STR	structural
T	top
TAN	tangent
TB	top of bridge
TC	top of curb
TEL	telephone
TFF	top of fire feature
TH	thick(ness)
TOL	tolerance
TC	top of curb
TS	top of steps
TSL	top of slab
TW	top of wall
TWF	top of water feature
TRD	tread
TYP	typical
UON	unless otherwise noted
VAR	varies
VFY	verify
VERT	vertical
VC	vertical curve
W	west
WHS	wheel stop
W	width, wide
W/	with
W/O	without
WD	wood
WWM	woven wire mesh
WWF	welded wire fabric

symbols

⊔	align
@	at
'	feet, minutes
"	inches, seconds
°	degrees
℄	centerline
Δ	central/deflection angle
Ø	diameter
#	pound, number

standard environmental notes

ADDITIONAL AREAS NOTES:

1. ALL ASSOCIATED PERMITS AND FEES SHALL BE THE SOLE RESPONSIBILITY OF THE CONTRACTOR.
2. CONTRACTOR MUST INSTALL AND MAINTAIN EROSION/SEDIMENTATION CONTROLS AND TREE PROTECTION FOR ALL SUCH AREAS IN ACCORDANCE WITH THE APPROVED SUBMITTAL OR DIRECTED IN THE FIELD BY THE OWNER'S REPRESENTATIVE.

PRIOR TO CONSTRUCTION:

1. SECURE APPLICABLE PERMITS.
2. NOTIFY OWNER'S REPRESENTATIVE PRIOR TO PLACEMENT OF E/S CONTROLS AND TREE PROTECTION FENCING. ALL PROPOSED PHASING OF CONTROLS MUST BE SUBMITTED TO AND APPROVED BY THE OWNER'S REPRESENTATIVE PRIOR TO THE FIELD PRE-CONSTRUCTION CONFERENCE.
3. PLACE TEMPORARY E/S CONTROLS AND TREE PROTECTION FENCING PRIOR TO BEGINNING ANY EXCAVATION.
4. HOLD ENVIRONMENTAL PRE-CONSTRUCTION CONFERENCE ON SITE WITH THE CONTRACTOR AND OWNER'S REPRESENTATIVE AFTER INSTALLATION OF E/S CONTROLS AND TREE PROTECTION FENCING AND PRIOR TO ANY TRENCHING OPERATIONS.

PROJECT CONSTRUCTION:

1. BEGIN CONSTRUCTION. CONTACT OWNER'S REPRESENTATIVE FOR ADDITIONAL PRE-CONSTRUCTION CONFERENCES FOR EACH PHASE, IF REQUIRED.
2. CONTACT OWNER'S REPRESENTATIVE TO SCHEDULE FIELD INSPECTION PRIOR TO BEGINNING INSTALLATION OF PERMANENT E/S CONTROLS.
3. COMPLETE RESTORATION OF ALL AREAS DISTURBED BY CONSTRUCTION ACTIVITIES FOR THIS PROJECT. (PERMANENT E/S CONTROLS)
4. HOLD ENVIRONMENTAL POST-CONSTRUCTION CONFERENCE ON SITE WITH THE CONTRACTOR, OWNER'S REPRESENTATIVE, AND LANDSCAPE ARCHITECT. ALL PERMANENT E/S CONTROLS MUST BE ACCEPTED BY THE OWNER'S REPRESENTATIVE.
5. FOLLOWING FINAL ACCEPTANCE OF PERMANENT E/S CONTROLS BY THE OWNER'S REPRESENTATIVE, REMOVE TEMPORARY E/S CONTROLS. CLEAN EXISTING STORM DRAINAGE SYSTEMS AS NECESSARY DUE TO CONSTRUCTION OPERATIONS.
6. DRESS-UP AND RESTORE ANY AREAS DISTURBED BY REMOVAL OF TEMPORARY E/S CONTROLS DESCRIBED ABOVE.

general project notes

THE DRAWINGS, SPECIFICATIONS, AND ADDENDA DESCRIBING WORK FOR LANDSCAPE, HARDSCAPE, AND IRRIGATION PORTIONS OF THE PROJECT SHALL BE REFERRED TO AS THE LANDSCAPE CONSTRUCTION DOCUMENTS.

1. COMPLIANCES
   A. WORK UNDER THESE LANDSCAPE CONSTRUCTION DOCUMENTS SHALL BE IN ACCORDANCE WITH THE LOCAL JURISDICTION UNLESS SPECIFIED OTHERWISE IN THE LANDSCAPE CONSTRUCTION DOCUMENTS. THE CONTRACTOR SHALL BE FAMILIAR WITH THESE STANDARD SPECIFICATIONS, DETAILS, AND SUPPLEMENTS PRIOR TO BIDDING THE WORK COVERED BY THESE PLANS AND SPECIFICATIONS.
   B. WORK UNDER THESE LANDSCAPE CONSTRUCTION DOCUMENTS SHALL CONFORM TO ALL APPLICABLE CODES AND ORDINANCES (FEDERAL, STATE, LOCAL AND HEALTH DEPARTMENTS).
   C. EXISTING TREES TO BE SAVED SHALL BE PROTECTED BY TREE PROTECTIVE FENCING BEFORE CONSTRUCTION BEGINS. NO EQUIPMENT OR MATERIALS SHALL BE STORED, OPERATED OR MAINTAINED WITHIN THE FENCED AREA. FENCES SHALL BE ON THE DRIPLINE AND COMPLETELY SURROUND THE TREE OR CLUSTERS OF TREES. NO CLEANING OF EQUIPMENT TRUCKS WILL BE ALLOWED IN THESE AREAS.
   D. ALL AREAS OF NATIVE VEGETATION BEYOND THE LIMITS OF CONSTRUCTION SHALL BE LEFT UNDISTURBED.
2. CONTRACTOR RESPONSIBILITIES
   A. IT IS THE CONTRACTOR'S RESPONSIBILITY TO INSPECT THE JOB SITE TO BECOME FAMILIAR WITH ALL EXISTING CONDITIONS THAT COULD AFFECT THE INSTALLATION OF ANY WORK SET FORTH IN THESE PLANS PRIOR TO SUBMITTING A BID.
   B. THE CONTRACTOR IS SOLELY RESPONSIBLE FOR OBTAINING AND COMPLYING WITH ANY PERMITS REQUIRED BY THE GOVERNING JURISDICTION TO COMPLETE ANY WORK COVERED BY THE LANDSCAPE CONSTRUCTION DOCUMENTS.
   C. THE CONTRACTOR SHALL REVIEW THIS PROJECT AND PROPOSED CONSTRUCTION SEQUENCE MILESTONE DATES WITH THE LANDSCAPE ARCHITECT PRIOR TO STARTING ANY WORK.
   D. CONTRACTOR SHALL SCHEDULE A PRE-CONSTRUCTION CONFERENCE WITH LANDSCAPE ARCHITECT PRIOR TO COMMENCING WORK.
   E. THE CONTRACTOR IS RESPONSIBLE FOR THE CONSTRUCTION MEANS, METHODS, COORDINATION, & SEQUENCING OF THE WORK.
   F. THE CONTRACTOR IS RESPONSIBLE FOR DAMAGE TO EXISTING WALKS, WALLS, DRIVES, CURBS, UTILITIES, ETC. DAMAGED ELEMENTS SHALL BE REPLACED OR REPAIRED AT CONTRACTOR'S EXPENSE.
   G. THE CONTRACTOR SHALL COORDINATE HIS WORK WITH THAT OF OTHER TRADES ON THE SITE AS NECESSARY TO ENSURE ORDERLY AND EFFICIENT COMPLETION OF ALL WORK.
   H. CONSULT PROJECT SPECIFICATIONS FOR WARRANTY REQUIREMENTS.
3. QUESTIONS, DISCREPANCIES, MODIFICATIONS
   A. SHOULD THE CONTRACTOR HAVE ANY QUESTIONS REGARDING THE LANDSCAPE CONSTRUCTION DOCUMENTS, THE LANDSCAPE ARCHITECT SHALL BE CONTACTED FOR CLARIFICATION BEFORE PROCEEDING FURTHER WITH THE WORK.
   B. ANY DISCREPANCIES BETWEEN THE PLANS AND ANY SITE CONDITIONS SHALL BE REPORTED IN WRITING IMMEDIATELY TO LANDSCAPE ARCHITECT.
   C. NO DESIGN MODIFICATIONS SHALL BE MADE WITHOUT THE WRITTEN APPROVAL OF THE LANDSCAPE ARCHITECT.
4. LOCATE UNDERGROUND UTILITIES PRIOR TO STARTING ANY CONSTRUCTION AND PROTECT FROM DAMAGE DURING CONSTRUCTION. THE CONTRACTOR SHALL CALL THE TEXAS ONE CALL NOTIFICATION SYSTEM (1-800-245-4545) PRIOR TO ANY EXCAVATION. EXISTING UNDERGROUND SERVICES SHALL NOT BE DISTURBED OR REMOVED UNLESS SPECIFICALLY NOTED OTHERWISE ON DRAWINGS OR WITHOUT THE WRITTEN APPROVAL OF LANDSCAPE ARCHITECT. THE CONTRACTOR IS RESPONSIBLE FOR ANY DAMAGE TO UTILITIES AND/OR FACILITIES CAUSED DURING THE CONSTRUCTION OPERATIONS.
5. ANY CONFLICTS OR ADJUSTMENTS, IN LAYOUT INFORMATION SHALL BE GRAPHICALLY PRESENTED TO THE LANDSCAPE ARCHITECT FOR APPROVAL PRIOR TO COMMENCEMENT OF WORK.
6. THE EXISTING QUANTITIES AND EXISTING SITE CONDITIONS SHOWN ON THESE PLANS ARE FOR INFORMATIONAL PURPOSES ONLY. THE CONTRACTOR SHALL VERIFY THE ACTUAL QUANTITIES AND SITE CONDITIONS PRIOR TO BIDDING THE WORK COVERED BY THESE PLANS AND SPECIFICATIONS.
7. ROUGH AND FINE GRADING TO ESTABLISH UNIFORM SMOOTH GRADE IS INCLUDED IN THIS PROJECT.
8. ALL GENERAL SITE GRADING TO WITHIN +/- 0.10 FOOT, INCLUDING ALL BERMS, SWALES AND RETENTION AREAS WILL BE CONSTRUCTED AS PER THE GRADING AND DRAINAGE PLANS. LANDSCAPE AREAS SHALL NOT EXCEED 4:1 MAXIMUM SLOPE (EXCEPT WHERE INDICATED ON GRADING PLANS) AND TURF AREAS SHALL NOT EXCEED 5:1 MAXIMUM SLOPE. THE LANDSCAPE AND IRRIGATION CONTRACTOR SHALL VERIFY AND ACCEPT THESE ROUGH GRADES PRIOR TO STARTING ANY LANDSCAPE AND IRRIGATION WORK. ALL DRAINAGE FLOWS SHALL BE PROTECTED AND MAINTAINED THROUGHOUT LANDSCAPE AND IRRIGATION CONSTRUCTION.
9. QUALITY: WORK & MATERIALS AS PART OF THIS PROJECT SHALL BE OF A GRADE & QUALITY CONSISTENT WITH THE INTENDED USE AS APPROVED BY THE LANDSCAPE ARCHITECT. WORK & MATERIALS NOT IN CONFORMANCE WITH THE LANDSCAPE CONSTRUCTION DOCUMENTS, OR THEIR INTENDED USE, ARE SUBJECT TO REMOVAL AND REPLACEMENT AT THE CONTRACTOR'S EXPENSE.
10. COMPLETE & FUNCTIONING WORK: EQUIPMENT & MATERIALS NOT SPECIFICALLY IDENTIFIED IN THE LANDSCAPE CONSTRUCTION DOCUMENTS --BUT THAT ARE REQUIRED FOR A COMPLETE & FUNCTIONING INSTALLATION-- SHALL BE SUPPLIED AND INSTALLED BY THE CONTRACTOR AS PART OF THIS CONTRACT WORK WITHOUT ADDITIONAL COST TO THE OWNER.
11. CLEAN UP: SITE TO BE KEPT CLEAN AT ALL TIMES. PROVIDE TRASH BINS. AT THE COMPLETION OF THE CONSTRUCTION, THE PROJECT SHALL BE CLEANED OF ANY DEBRIS OR SPOIL RESULTING FROM THE CONSTRUCTION. SITE SHALL BE TURNED OVER TO THE OWNER IN BROOM OR RAKED CLEAN CONDITION.

general construction notes

1. ANY PLANT MATERIAL THAT MUST BE REMOVED DUE TO CONSTRUCTION MUST BE APPROVED BY LANDSCAPE ARCHITECT. NOTIFY OWNER AT LEAST 48 HOURS PRIOR TO REMOVAL AND/OR RELOCATION OF ALL PLANTS.
2. IF ANY EXISTING PLANT MATERIAL THAT IS TO REMAIN IS DAMAGED BY CONTRACTOR, THE CONTRACTOR SHALL REPLACE THE DAMAGED PLANT WITH NEW MATERIAL OF THE SAME SIZE AND VARIETY AT CONTRACTOR'S EXPENSE AND AT NO COST TO THE OWNER.
3. DO NOT DISTURB, COMPACT, OR ADD SOIL WITHIN BRANCH SPREAD OF TREES OR SHRUBS TO REMAIN WITHOUT APPROVAL AND SUPERVISION OF THE LANDSCAPE ARCHITECT.

hardscape construction notes

1. NOTIFY LANDSCAPE ARCHITECT A MINIMUM OF 72 HOURS PRIOR TO COMMENCEMENT OF CONCRETE OPERATIONS. ALLOW LANDSCAPE ARCHITECT TO OBSERVE EXCAVATIONS, FORMWORK, AND REINFORCING PRIOR TO CONCRETE PLACEMENT.
2. PROVIDE ELECTRICAL AND IRRIGATION SLEEVES UNDER PAVING AND THROUGH WALLS TO ALL PLANTING AREAS. NO EXCAVATION UNDER FOOTINGS SHALL BE PERMITTED. ALL SLEEVES TO RUN THROUGH THE STEM WALL BELOW GRADE.
3. CONTRACTOR TO LOCATE ANY EXISTING IRRIGATION SLEEVES THAT NEED TO BE REPLACED FOLLOWING DEMOLITION AND PROPOSE ANY NECESSARY NEW SLEEVE LOCATIONS FOR APPROVAL BY LANDSCAPE ARCHITECT. NEW AND REPLACEMENT SLEEVES TO BE (2) @ 3"Ø SCH. 40 PVC.
4. FOUNDATIONS FOR LANDSCAPE ELEMENTS: EXCAVATIONS SHALL BE NEAT TO LINES OF FOOTINGS. ALL LOOSE MATERIAL SHALL BE REMOVED FROM SURFACE TO RECEIVE CONCRETE. PLACE FOUNDATION CONCRETE ONLY ON CLEAN, FIRM, INSPECTED BEARING MATERIAL. FOOTINGS SHALL BEAR ON UNDISTURBED NATIVE SOIL OR ENGINEERED FILL. REFER TO GEOTECHNICAL REPORT. BEAR FOOTINGS AT DEPTHS INDICATED ON PLANS BUT AT DEPTHS NO SHALLOWER THAN 18" BELOW THE GRADE WITHIN 5 FEET OF THE FOUNDATION.
5. VERIFY HEIGHTS, SLOPES, EDGE THICKNESS, AND TURNDOWNS BEFORE POURING FOOTINGS AND SLABS.
6. CONCRETE FORMWORK FOR EXPOSED CONCRETE SHALL BE INSPECTED BY LANDSCAPE ARCHITECT AND APPROVED PRIOR TO CONCRETE POURS. CURVED FORMWORK SHALL BE CONTINUOUS THROUGHOUT THE CURVE, WITHOUT BREAKS OR FOLDS.
7. CONCRETE FLAT WORK SHALL BE INSTALLED WITH A CONSTANT SLOPE BETWEEN TWO SPOT ELEVATIONS. CHANGES IN SLOPE SHALL BE ACCOMPLISHED IN A GRADUAL MANNER. ALL HARDSCAPE SHALL SLOPE AWAY FROM BUILDINGS AT MINIMUM 1/8:12 (1%) SLOPE [MAXIMUM 1:20 (5%) SLOPE] AND MEET ADA REQUIREMENTS.
8. CONTROL JOINTS IN PAVING SHALL BE SAW CUT (UNLESS SPECIFICALLY NOTED OTHERWISE), STRAIGHT AND TRUE. REFER TO THE DRAWINGS FOR PATTERNS.
9. CONCRETE JOINTING FOR WALLS AND FLAT WORK IS SCHEMATIC IN NATURE AND CONVEYS THE MINIMUM DESIGN INTENT. ADDITIONAL CONTRACTION, CONSTRUCTION AND EXPANSION JOINTS MAY BE REQUIRED. THE CONTRACTOR SHALL REVIEW ALL JOINTS SHOWN ON PLANS AND DESCRIBED IN THE SPECIFICATIONS PRIOR TO CONSTRUCTION. ALL REQUESTS FOR CHANGES TO JOINTING SHALL BE SUBMITTED TO THE LANDSCAPE ARCHITECT FOR REVIEW A MINIMUM OF FIVE (5) WORKING DAYS PRIOR TO CONSTRUCTION. IF ADDITIONAL JOINTS ARE NECESSARY TO ALLEVIATE CRACKING OR FACILITATE CONSTRUCTION, THEY SHALL BE PROVIDED AT NO ADDITIONAL COST. ADDITIONAL JOINTS REQUESTED BY THE OWNER, ENGINEER OR LANDSCAPE ARCHITECT FOR AESTHETIC PURPOSES SHALL BE CONSIDERED ADDITIONAL TO THE BASE CONTRACT.

layout notes

1. CAD FILES WILL BE MADE AVAILABLE TO THE CONTRACTOR TO FACILITATE ACCURATE LAYOUT OF ALL HARDSCAPE ELEMENTS. SOME DIMENSIONS ARE PROVIDED ON THE DRAWINGS TO ALLOW VERIFICATION OF KEY RELATIONSHIPS.
2. THE LANDSCAPE ARCHITECT HAS RELIED UPON THE SURVEY PROVIDED BY THE ARCHITECT FOR LOCATIONS OF ALL EXISTING BUILDINGS, HARDSCAPE ELEMENTS, AND TREES, AS WELL AS GRADES. THIS SURVEY DOES NOT REFLECT CHANGES TO GRADE AND DRAINAGE PATTERNS RESULTING FROM SUBSEQUENT SITE DEVELOPMENT. NO AS-BUILT SURVEY WAS PROVIDED. IN THE EVENT THAT LAYOUT BASED ON THIS SURVEY AND THE CAD FILES PROVIDED DOES NOT MATCH CONDITIONS IN THE FIELD, THE CONTRACTOR SHALL IMMEDIATELY NOTIFY THE LANDSCAPE ARCHITECT AND REQUEST FURTHER DIRECTION TO RECTIFY THE DISCREPANCY. THIS DIRECTIVE INCLUDES, BUT IS NOT LIMITED TO, CONSTRUCTION THAT WOULD IMPACT EXISTING TREES AND ALIGNMENTS WITH EXISTING ELEMENTS THAT ARE IN CONFLICT.
3. CONTRACTOR TO FIELD STAKE ALL HARDSCAPE LAYOUT FOR APPROVAL BY LANDSCAPE ARCHITECT PRIOR TO CONSTRUCTION.
4. CONTRACTOR TO TAG FOR APPROVAL BY LANDSCAPE ARCHITECT ALL VEGETATION PROPOSED TO BE REMOVED TO MAKE WAY FOR NEW CONSTRUCTION.
5. CONTRACTOR TO FIELD STAKE PROPOSED LIMITS OF CONSTRUCTION FOR TREE AND NATURAL AREA PROTECTION FOR APPROVAL BY LANDSCAPE ARCHITECT. (SEE DETAILS FOR TREE AND NATURAL AREA PROTECTION)
6. CONTRACTOR TO FIELD STAKE CENTER LINE OF ALL PATHS FOR APPROVAL BY LANDSCAPE ARCHITECT PRIOR TO SETTING FORMS.
7. CURVES ON ALL PATHS TO HAVE SMOOTH RADII WITH NO SHARP TURNS OR ABRUPT CHANGES.
8. NEW PATHS AND PAVING TO MATCH EXISTING GRADES WHERE TIED IN TO EXISTING SURFACES TO REMAIN. CONTRACTOR SHALL BE RESPONSIBLE TO ENSURE THAT NEW SURFACES SLOPE TO PROVIDE ADEQUATE DRAINAGE AND ALSO MEET ADA REQUIREMENTS FOR MAXIMUM SLOPE AND CROSS-SLOPE. CONTRACTOR SHALL BE RESPONSIBLE TO ENSURE THAT NEW WORK DOES NOT RESULT IN PONDING OR EROSION DUE TO CHANGES IN DRAINAGE PATTERNS. ROUTE DRAINAGE FLOWS AROUND OR UNDER NEW WORK AS REQUIRED. NOTIFY LANDSCAPE ARCHITECT OF CONDITIONS AND CIRCUMSTANCES IN THE FIELD WHERE DRAINAGE ISSUES MAY IMPACT LAYOUT.

blanco river restoration
LANDSCAPE ARCHITECTURAL SUBMITTAL

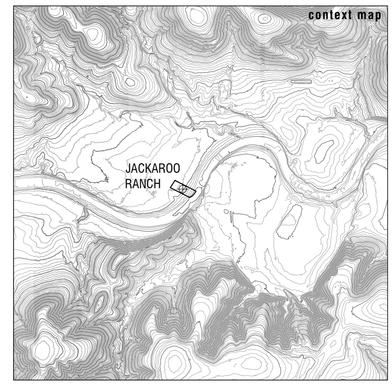
100% FINAL CONCEPT DESIGN

issue history

date:	description:
03.05.2016	site design
-	-
-	-
-	-
-	-

SHEET INDEX

landscape drawings



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date: 03.05.2016
project no: 15004

L000
cover sheet

blanco river restoration
hays county, texas

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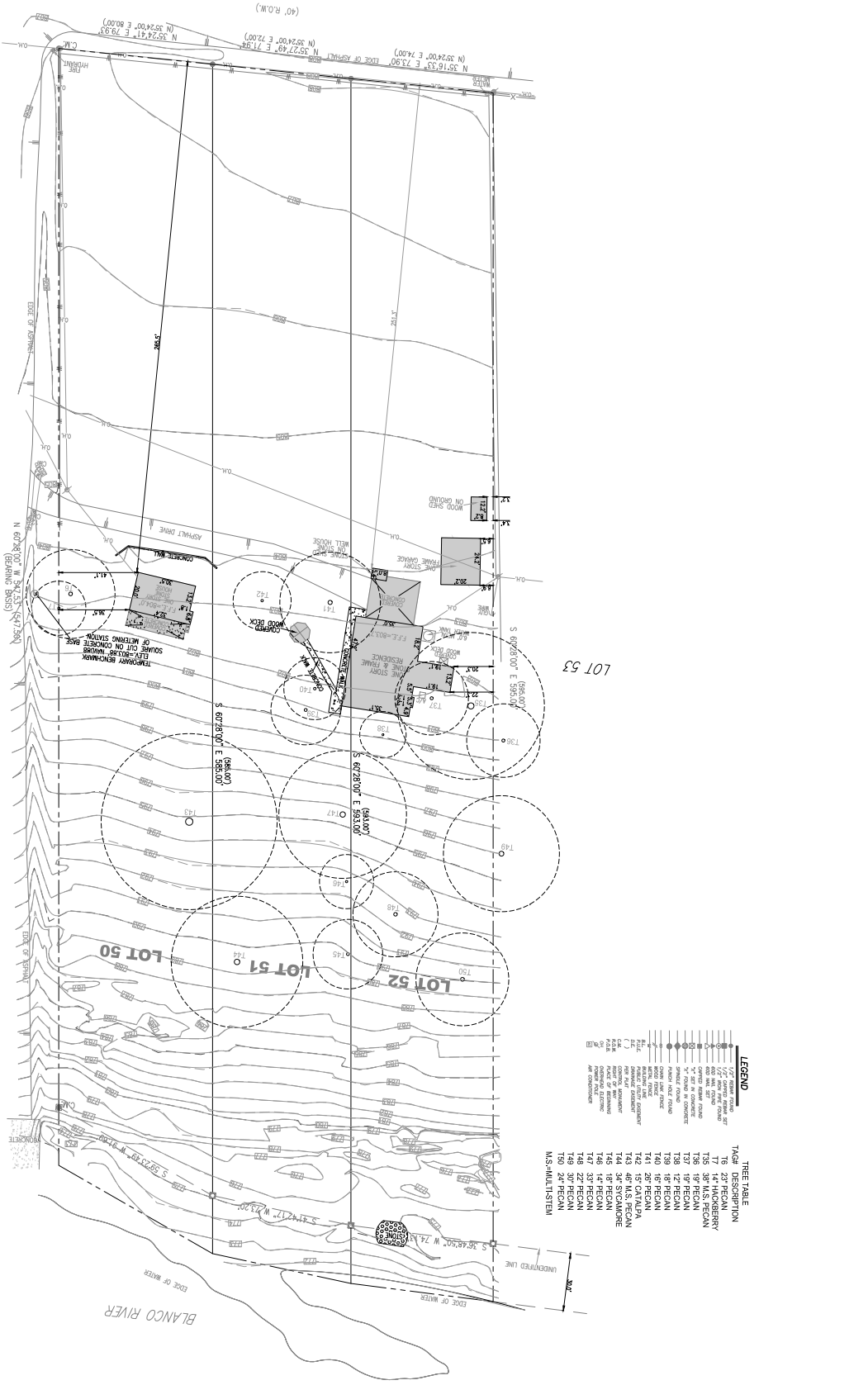

TAG#	TREE TABLE DESCRIPTION
T1	27" PECAN
T35	14" HACKBERRY
T36	38" M.S. PECAN
T37	19" PECAN
T38	19" PECAN
T39	16" PECAN
T40	16" PECAN
T41	28" PECAN
T42	15" CATALPA
T43	46" M.S. PECAN
T44	36" SYCAMORE
T45	14" PECAN
T46	14" PECAN
T47	33" PECAN
T48	22" PECAN
T49	30" PECAN
T50	24" PECAN
M.S.=MULTI-STEM	

LEGEND

1/2" REBAR FOUND
1/2" REBAR W/ CAP SET
1/2" IRON PIPE FOUND
60D NAIL FOUND
60D NAIL SET
MAG NAIL FOUND
"X" SET IN CONCRETE
"X" FOUND IN CONCRETE
PK NAIL FOUND
PUNCH HOLE FOUND
CHAIN LINK FENCE
BARB WIRE FENCE
METAL FENCE
WOOD PICKET FENCE
PUBLIC UTILITY EASEMENT
PER PLAT
PER PLAT EASEMENT
EDGE OF WATER
RIGHT OF WAY
EDGE OF ASPHALT
OVERHEAD ELECTRIC
WATER METER
AIR CONDITIONER

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blanco river restoration
hays county, texas

L100
existing conditions

date: 03.05.2016
project no: 1503.4

issue history

date	description
03.05.2016	site design
-	-
-	-
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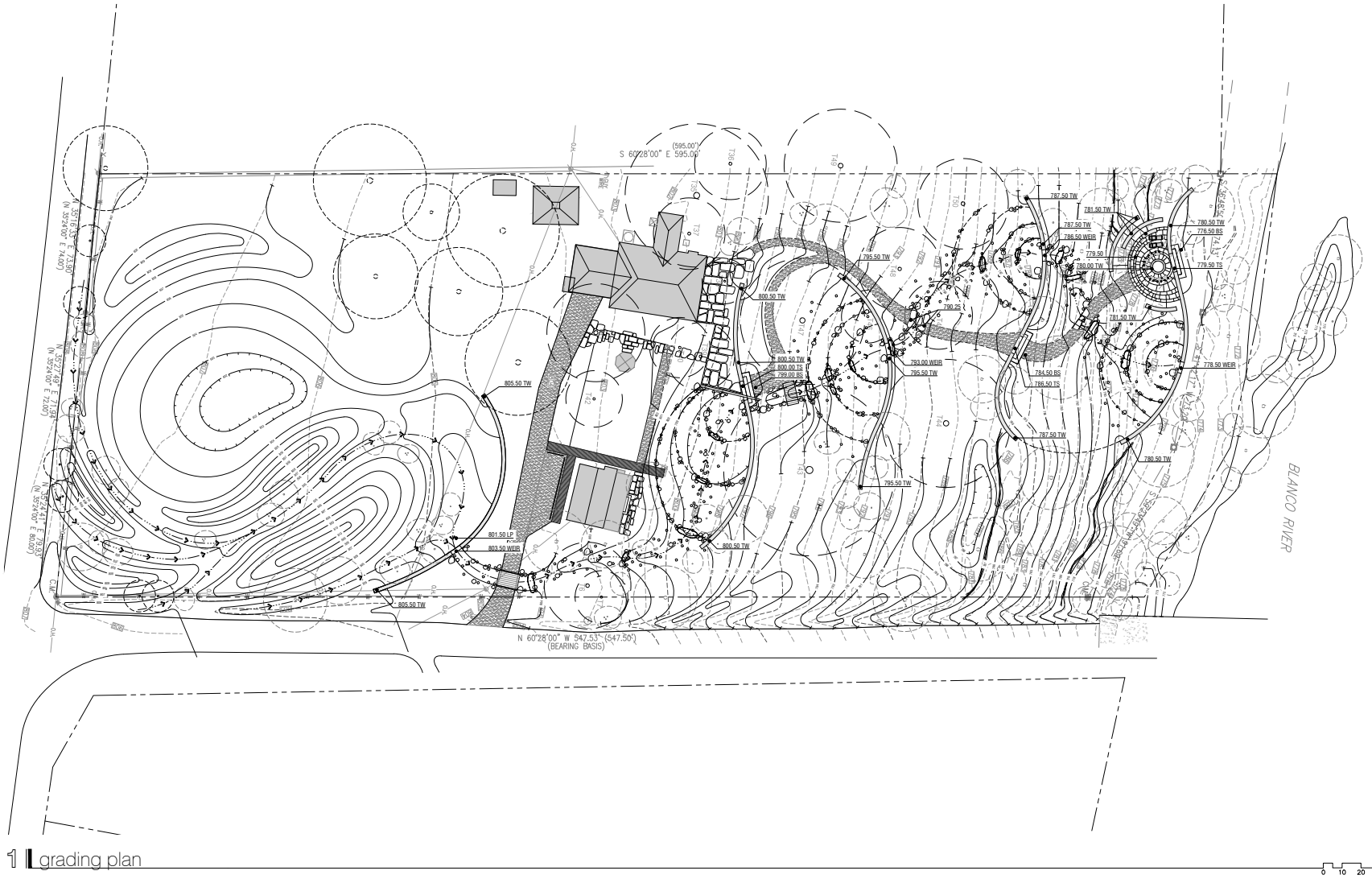
-	-

appendix b
document set



1 grading plan

issue history

LA3 blanco river restoration
COLLABORATIVE WORKSHOP, LLC

L200 grading plan

material/finish schedule

	KEYNOTE #	ITEM	MATERIALS	COLOR	FINISH	CONTACT	REMARKS
1.0		PAVEMENT & MISC. STONE					
	1.1	LIMESTONES SCREENINGS - VEHICULAR PAVEMENT WITH STABILIZER	¼ MINUS LIMSTONE AGGREGATE	NATURAL GRAY		KELLER MATERIALS & STABILIZER SOLUTIONS, 1-800-336-2468	1" OF COMPACTED PAVEMENT TOP DRESSING OVER 12" OF COMPACTED ROAD BASE
	1.2	LIMESTONE SCREENINGS - PEDESTRIAN PATHS WITH STABILIZER	¼" MINUS LIMESTONE AGGREGATE	NATURAL GRAY		KELLER MATERIALS & STABILIZER SOLUTIONS, 1-800-336-2468	1" OF COMPACTED PAVEMENT TOP DRESSING OVER 6" OF COMPACTED ROAD BASE
	1.3	STONE PAVING - MORTAR JOINTS - PEDESTRIAN	LUEDERS LIMESTONE - CUT TO PATTERN, REF. DRAWINGS; 2" TO 2-1/2" THICK; 3/4" MAX JOINT WIDTH; STONE SIZE 1'-6" MIN TO 5'-0" MAX	NATURAL	BUSH-HAMMERED TOP; SAWN SIDES (REFER PLANS)	LOCAL SOURCE	PROVIDE SAMPLE TO LA FOR APPROVAL; PROVIDE ON-SITE MOCKUP FOR LA APPROVAL; GROUT COLOR TO MATCH STONE, FINAL COLOR SELECTION TO BE APPROVED BY LA
	1.4	STONE PAVING - STEPPING STONES @ CREEK CROSSING - PEDESTRIAN	LIMESTONE LEDGE STONE; PLACED AS STEPPING STONES THROUGH CREEK BED; 3" TO 4" THICK; 3/4" MAX JOINT WIDTH; STONE SIZE 1'-6" MIN TO 4'-0" MAX	NATURAL	NATURAL TOP; WORKED EDGES TO FIT (REFER PLANS)	LOCAL SOURCE	PROVIDE SAMPLE TO LA FOR APPROVAL
	1.5	STONE PAVING - PLANTED JOINTS - PEDESTRIAN	OKLAHOMA SUGARLOAF FLAGSTONE; 3" TO 4" THICK; 2" MAX JOINT WIDTH; STONE SIZE 1'-6" MIN TO 5'-0" MAX	NATURAL	NATURAL TOP; MIX OF NATURAL AND SNAP-CUT EDGES (REFER PLANS)	LOCAL SOURCE	PROVIDE SAMPLE TO LA FOR APPROVAL; PROVIDE ON-SITE MOCKUP FOR LA APPROVAL
	1.6	CUT LIMESTONE STEPS	LUEDERS LIMESTONE - CUT TO FIT 4" THICK SLABS WITH 2" RISER FOR 6" TALL STEPS	NATURAL	BUSH-HAMMERED TOP AND SIDES	LOCAL SOURCE	PROVIDE SAMPLE TO LA FOR APPROVAL
	1.7	WOOD DECKING	CEDAR PLANKING	NATURAL	SMOOTH	LOCAL SOURCE	WOODEN BOARDWALK TO CANTILEVER OVER RAIN GARDEN, PIER AND BEAM CONSTRUCTION, TYP.
2.0		SITE WALLS					
	2.1	SEGMENTED LIMESTONE BLOCK SITEWALL	'LEUDERS' MONOLITHIC, LIMESTONE BLOCK; 2'H x 2'W & 2' MIN TO 5' MAX LENGTHS	'LEUDERS'	SPLIT SIDES; VERMEER CUT TOP	SAN JACINTO MATERIALS, 210-736-0924, OR APPROVED EQUAL	PROVIDE SAMPLES ON-SITE FOR LA APPROVAL
	2.2	DRY STACK LIMESTONE RETAINING WALL	LOCAL FIELD STONE	NATURAL	NATURAL	LOCAL SOURCE	CHARACTER TO MATCH THAT OF NEIGHBORING PROPERTY - MONTESINO RANCH
3.0		SITE FEATURES & FURNISHINGS					
	3.1	STONE FIRE PIT @ RIVER'S EDGE	1/2" THICK STEEL; FULLY WELD ALL SEAMS AND CORNERS & GRIND SMOOTH; (2) 96" TROUGH FIRE PIT (96SSHWI-TRGH) BY HEARTH PRODUCTS CONTROLS CO., OR APPROVED EQUAL	NATURAL	MILL FINISH, WEATHERED	HEARTH PRODUCTS CONTROLS CO., 877-433-7001	SUBMIT SHOP DRAWINGS TO LA FOR APPROVAL; PROVIDE SAMPLES ON-SITE FOR LA APPROVAL
	3.2	LEDGESTONE BOULDERS	LEDGESTONE BOULDERS, SIZES PER PLAN	NATURAL	NATURAL	LOCAL SOURCE	PROVIDE SAMPLES ON-SITE FOR LA APPROVAL
	(A)	APPROX SIZE: 1'-6" x 1'-6" x 2'					
	(B)	APPROX SIZE: 2' x 2' x 2'-6"					
	(C)	APPROX SIZE: 3' x 3' x 3'-6"					
	(D)	APPROX SIZE: 4' x 4' x 4'-6"					
	(E)	APPROX SIZE: 5' x 5' x 5'-6"					
	3.3	LEDGESTONE CHECK DAMS	LEDGESTONE SLABS	NATURAL	NATURAL	LOCAL SOURCE	CHECKS DAMS TO SLOW WATER FLOW, USE IN CONJUNCTION WITH BOULDERS
	3.4	C.I.P. BOARDFORM CONCRETE RAINWATER FLUME					
4.0		RAILINGS, FENCING & MISC METALS					
	4.1	STEEL HEADER	1/4" x 4" STEEL	NATURAL STEEL	MILL FINISH	LOCAL SOURCE	PROVIDE SAMPLES ON-SITE FOR LA APPROVAL
	4.2	STEEL WHEEL STOPS	3" DIA. TUBULAR STEEL WHEEL STOPS	NATURAL STEEL	MILL FINISH	LOCAL SOURCE	ANCHOR TO CONCRETE FOOTING
5.0		MISCELLANEOUS					
	5.1	STEEL PEDESTRIAN BRIDGE	HRPO STEEL	NATURAL	12"W x 1-12" H; 11 GA HRPO STEEL TRACTION TREAT PERFORATED PLANK	MC NICHOLS 877-884-4653	SUBMIT SHOP DRAWINGS TO LA FOR APPROVAL; PROVIDE SAMPLES ON-SITE FOR LA APPROVAL
	5.2	TEXAS BLEND RIVER ROCK @ VEGETATED SWALE	3" TO 5" TEXAS BLEND RIVER ROCK	TEXAS BLEND	SMOOTH, WASHED	KELLER MATERIALS OR APPROVED EQUAL	FEATHER OUT EDGES OF ROCK INTO LANDSCAPE; PROVIDE ON-SITE MOCK-UP FOR LA APPROVAL
	5.3	BRUSH-PILE CHECK DAMS	RECYCLE BRUSH DEBRIS			ONSITE DEBRIS	PASSIVE EROSION CONTROL METHOD UTILIZING BUNDLED BRUSH-PILES ARRANGED WITH CONTOURS

issue history

date:	description:
03.05.2016	site design
-	-
-	-
-	-
-	-
-	-

1 | hardscape plan

0 10 20 40

L300 hardscape plan

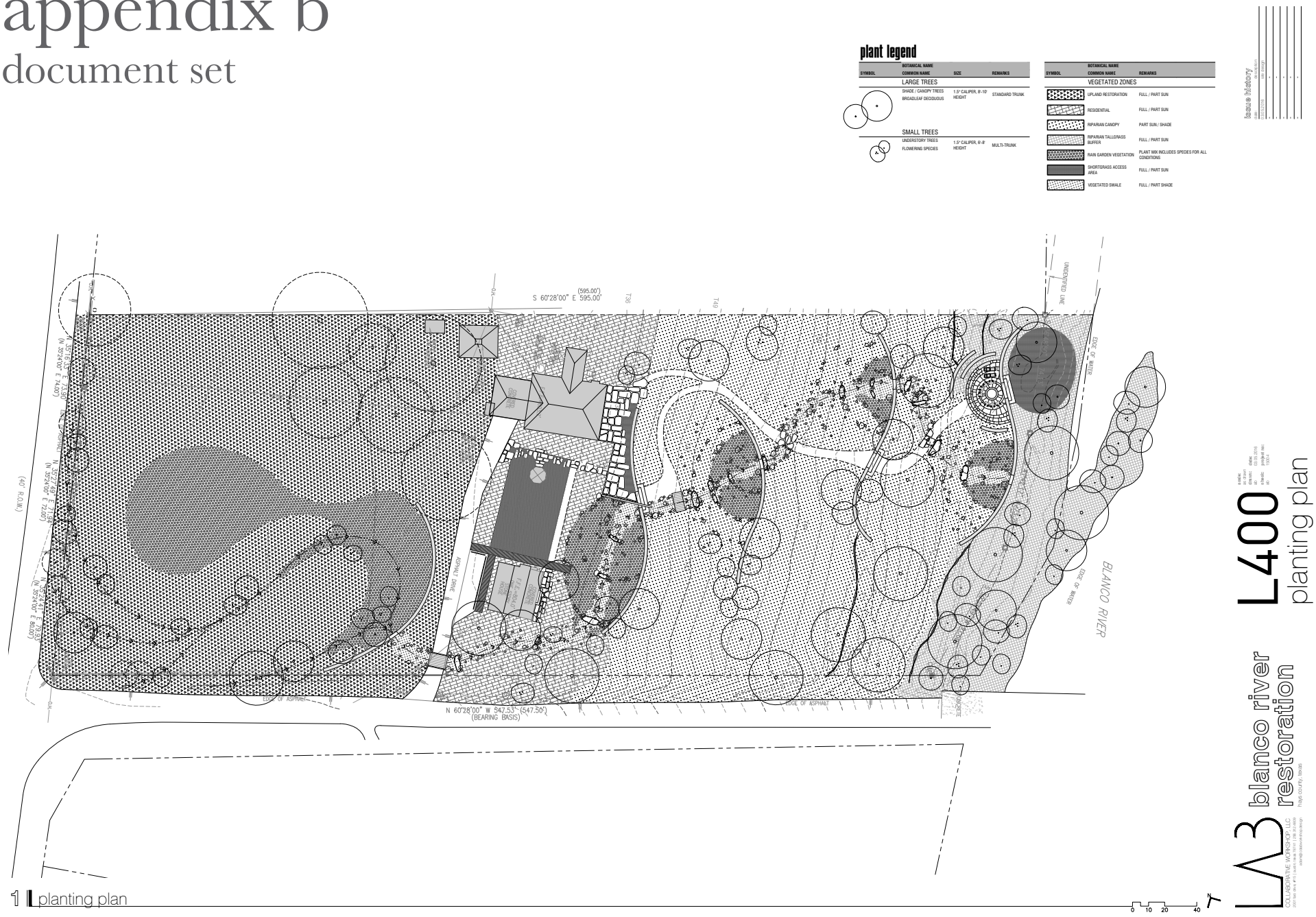
scale: as drawn
date: 03.05.2016
drawn: ab
check: ab
project no: 15004

blanco river restoration

hays county, texas

LA3
COLLABORATIVE WORKSHOP, LLC
2001 faro drive, #15 | austin, texas 78741 | 256.312.4809
adam@colabworkshop.design

appendix b
document set



1 planting plan

appendix b
document set

COLLABORATIVE WORKSHOP, LLC

State of Drawings - Schematic Design
Project Number: 15004
Print Date 3/5/2016

ID #	Item:	unit	qty.	unit cost	total	comments
	TYPCIAL PROJECT START-UP COSTS					
	General Expenses					
	survey / layout	allow.	1	$1,000.00	$1,000.00	*as needed*
	tree protection fencing	allow.	1	$2,500.00	$2,500.00	*wire fencing / wood slats*
				General Expenses Subtotal:	$3,500.00	
				Projected Budget	**$3,500.00**	
	LANDSCAPE RESTORATION					
	Demolition & Site Preparation					
	existing hardscape removal / recycling	allow.	1	$2,000.00	$2,000.00	*haul-off / sorting*
	debris removal / processing	allow.	1	$3,500.00	$3,500.00	*haul-off / sorting*
	fine grading / berming / soil amendments	sf	58,000	$0.20	$11,600.00	*ref. plans and soils report*
				Demolition & Site Preparation Subtotal:	$17,100.00	
	Landscape and Irrigation					
	shade tree - 1.5" cal.	ea.	10	$250.00	$2,500.00	*successional growth*
	understory tree - 1.5" cal.	ea.	25	$150.00	$3,750.00	*successional growth*
	seeded areas (labor costs)	sf	131,347	$0.06	$7,486.78	*$2,500 / acre (labor cost)*
	seeded areas (material costs)	allow.	1	$5,958.00	$5,958.00	
	shrub bed plantings (Mix 60% 5gal, 20% 3gal, 20% 1gal)	ea.	457	$15.00	$6,855.00	*6335sf @ 48" O.C. spacing*
	hardwood mulch @ 3" depth	sf	10,635	$0.30	$3,190.50	
	temporary irrigation system (until establishment)	allow.	1	$10,000.00	$10,000.00	*above ground*
	permanent irrigation for trees	sf	2,730	$1.25	$3,412.50	*bubblers at tree installation*
				Landscape and Irrigation Subtotal:	$43,152.78	
				Projected Budget	**$60,252.78**	

HARDSCAPE ELEMENTS

Pavements						
1.1	limestone screenings - VEH	sf	2,442	$4.00	$9,768.00	*1/4" minus with fines*
1.2	limestone screenings - PED	sf	2,205	$3.00	$6,615.00	*1/4" minus with fines*
1.3	stone paving w/ mortar joints	sf	701	$17.64	$12,365.64	*natural finish, whole pieces*
1.4	stone paving (stepping stones)	ea	10	$150.00	$1,500.00	*natural finish, whole pieces*
1.5	stone paving with planted joints	sf	1,500	$10.00	$15,000.00	*natural finish w/ planting soil*
1.6	cut limestone steps	lf	157	$25.00	$3,925.00	*bush-hammered pieces, mortar set*
1.7	wood decking	sf	209	$20.00	$4,180.00	*cedar planks, treated pine structure*
				Pavements Subtotal:	$53,353.64	
Site Walls						
2.1	segmented limestone block site walls	lf	91	$125.00	$11,312.50	*natural faces, sawn tops & ends; 36" lengths*
2.2	dry stack stone retaining walls	lf	713	$55.00	$39,215.00	*natural stone, local source*
				Site Walls Subtotal:	$50,527.50	
Site Features						
3.1	limestone fire pit	lf	25	$55.00	$1,375.00	*natural stone, local source*
3.2	limestone ledgestone boulders					
a	ledgestone boulders size a	ea	55	$15.00	$825.00	*field stone, local source*
b	ledgestone boulders size b	ea	36	$25.00	$900.00	*field stone, local source*
c	ledgestone boulders size c	ea	24	$40.00	$960.00	*field stone, local source*
d	ledgestone boulders size d	ea	12	$60.00	$720.00	*field stone, local source*
e	ledgestone boulders size e	ea	45	$80.00	$3,600.00	*field stone, local source*
3.3	ledgestone check dams	ea	15	$250.00	$3,750.00	*field stone, local source*
3.4	c.i.p. board form concrete rainwater flume	allow.	1	$5,000.00	$5,000.00	*2x4 forms*
				Site Features Subtotal:	$17,130.00	
Misc. Metals						
4.1	steel header 1/4" x 4"	lf	165	$8.00	$1,320.00	*natural steel, unfinished*
4.2	steel tube wheel stops	lf	42	$25.00	$1,050.00	*natural steel, unfinished*
				Site Walls Subtotal:	$2,370.00	
Miscellaneous						
5.1	steel pedestrian bridge	allow.	1	$3,000.00	$3,000.00	*HRPO finish, steel tread plank*
5.2	Texas blend river rock @ vegetated swale	sf	3,453	$1.50	$5,179.50	*local source*
5.3	brush-pile check dams	lf	240	$7.00	$1,680.00	*from onsite materials*
				Site Walls Subtotal:	$9,859.50	
				Projected Budget	**$133,240.64**	

Projected Budget	**$196,993.42**	
Area Total – Scope Area of Influence	137,982 sf	*3.16 acres*
Total Average Budget per SF – Scope Area of Influence	**$1.43 sf**	

Average Unit Costs 2016

Note: This document represents an opinion of the probable coast of construction based on items defined and similar unit costs within this market. This estimate can provide guidance for your decision making, however it is not intended to be a guarantee of the actual cost of a project. Frequent fluctuations in labor, material costs, and the local bid climate, can substantially alter the construction cost of an individual project. The final determination of construction cost is made through the bidding process with a contractor using a defined design and appropriate documents.

appendix c
plant list - riparian buffer

	Species	Scientific name	Wetland Indicator Status	Stability Rating	Colonizer	Shade tolerant	Habitat value	Ornamental value
Ferns	Maidenhair fern	*Adiantum capillus-veneris*	FACW	5		Yes	Yes	Yes
	Horsetail	*Equisetum laevigatum*	OBL	6		Yes	Yes	Yes
	River fern	*Thlypteris ovata*	FAC	6		Yes	Yes	Yes

	Species	Scientific name	Wetland Indicator Status	Stability Rating	Colonizer	Shade tolerant	Habitat value	Ornamental value
Grass/Grass like	Bushy bluestem	*Andropogon glomeratus*	FACW	5	Yes		Yes	Yes
	Emory sedge	*Carex emoryi*	OBL	9	Yes	Yes	Yes	
	Inland seaoats	*Chasmanthium latifolium*	FAC	5	Yes	Yes	Yes	Yes
	Sawgrass	*Cladium mariscoides*	OBL	9			Yes	
	Flat sedge	*Cyperus* sp.	FACW	5	Yes		Yes	
	Spikerush	*Eleocharis* sp.	OBL	6			Yes	
	Lindheimer muhly	*Muhlenbergia linheimeri*	FAC	7			Yes	Yes
	Switchgrass	*Panicum virgatum*	FAC	8-9			Yes	
	Knotgrass	*Paspalum distichum*	FACW	6	Yes		Yes	
	Rustyseed paspalum	*Paspalum langei*	FAC	5-6		Yes	Yes	
	White top sedge	*Rynchospora colorata*	FACW	6			Yes	
	Eastern gamagrass	*Tripsacum dactyloides*	FAC	9			Yes	

	Species	Scientific name	Wetland Indicator Status	Stability Rating	Colonizer	Shade tolerant	Habitat value	Ornamental value
Trees/Shrubs	Indigobush	*Amorpha fruticosa*	FACW	7			Yes	Yes
	Roosevelt weed	*Baccharis neglecta*	FAC	6	Yes		Yes	
	Brickellbush	*Brickellia sp.*	UPL	4	Yes		Yes	Yes
	Pecan	*Carya illinoinensis*	FAC	6			Yes	Yes
	Sugar hackberry	*Celtis laevigata*	FAC	5-6			Yes	
	Buttonbush	*Cephalanthus occidentalis*	OBL	8		Yes	Yes	
	Desert willow	*Chilopsis linearis*	FACU	6			Yes	Yes
	Roughleaf dogwood	*Cornus drummondii*	FAC	6		Yes	Yes	Yes
	Green ash	*Fraxinus pennsylvanica*	FACW			Yes	Yes	
	Possumhaw	*Ilex decidua*	FACW	6		Yes	Yes	Yes
	Little walnut	*Juglans microcarpa*	FAC	6-7			Yes	
	Black walnut	*Juglans nigra*	FACU	6			Yes	
	Turkscap	*Malvaviscus arboreus*	FAC			Yes	Yes	Yes
	Retama	*Parkinsonia aculeata*	FACW	6			Yes	Yes
	Sycamore	*Platanus occidentalis*	FAC	6			Yes	Yes
	Eastern cottonwood	*Populus deltoides*	FAC	7	Yes		Yes	Yes
	Flame-leaf sumac	*Rhus lanceolata*	FAC			Yes	Yes	Yes
	Arroyo willow	*Salix exigua*	FACW	7			Yes	
	Black willow	*Salix nigra*	FACW	7	Yes		Yes	
	Bald cypress	*Taxodium distichum*	OBL	9			Yes	Yes
	Cedar elm	*Ulmus crassifolia*	FAC	6		Yes	Yes	Yes

appendix c
plant list - riparian buffer

	Species	Scientific name	Wetland Indicator Status	Stability Rating	Colonizer	Shade tolerant	Habitat value	Ornamental value
Forbs	Spiny aster	*Aster spinosa*	FACW	8			Yes	
	Gregs mistflower	*Conoclinium gregii*	FACU				Yes	Yes
	Cardinal flower	*Lobelia cardinalis*	FACW	5		Yes	Yes	Yes
	Water primrose	*Ludwigia sp.*	OBL/FACW	3-4	Yes		Yes	
	Nimblewill	*Muhlenbergia schreberi*	OBL			Yes	Yes	
	Frogfruit	*Phyla nodiflora*	FACW	4	Yes		Yes	Yes
	Drummonds's wild petunia	*Ruellia drummondiana*				Yes	Yes	Yes
	Lindheimer senna	*Senna lindheimeriana*	UPL	6-7	Yes	Yes	Yes	
	Tall goldenrod	*Solidago altissima*	FACW	6-7	Yes		Yes	Yes
	Plateau goldeneye	*Viguiera dentata*	UPL	5			Yes	Yes

	Species	Scientific name	Wetland Indicator Status	Colonizer	Shade tolerant	Habitat value	Ornamental value
Shrubs	American beautyberry	*Callicarpa americana*	FACU		Yes		Yes
	Cenizo	*Leucophyllum candidum*				Yes	Yes
	Agarita	*Mahonia trifoliolata*			Yes	Yes	Yes
	Turks cap	*Malvaviscus arboreus*	UPL		Yes	Yes	Yes
	Pigeonberry	*Rivina humilis*	FAC		Yes	Yes	Yes
	Palmetto	*Sabal minor*	FACW		Yes		Yes
	Tropical sage	*Salvia coccinea*					Yes
	Mealy bluesage	*Salvia farinacea*					Yes
	Heartleaf skullcap	*Scutellaria ovata*	FACU		Yes		Yes

Tallgrasses	Species	Scientific name	Wetland Indicator Status	Colonizer	Shade tolerant	Habitat value	Ornamental value
	Big bluestem	*Andropogon gerardii*	FACU			Yes	
	Silver bluestem	*Bothriochloa laguroides*		Yes		Yes	Yes
	Canada wildrye	*Elymus canadensis*	FACU	Yes	Yes	Yes	
	Prairie wildrye	*Elymus virginicus*	FACU	Yes	Yes	Yes	
	Green sprangletop	*Leptochloa dubia*		Yes		Yes	
	Little bluestem	*Schizachyrium scoparium*	FACU		Yes	Yes	Yes
	Indiangrass	*Sorghastrum nutans*	FACU			Yes	Yes

Shortgrasses	Species	Scientific name	Wetland Indicator Status	Colonizer	Shade tolerant	Habitat value	Ornamental value
	Buffalograss	*Bouteloua dactyloides*	FACU			Yes	Yes
	Blue grama	*Bouteloua gracilis*				Yes	Yes
	Texas grama	*Bouteloua rigidiseta*				Yes	Yes
	Curly mesquite	*Hilaria belangeri*				Yes	Yes

appendix c
plant list - upland/riparian canopy

	Species	Scientific name	Wetland Indicator Status	Colonizer	Shade tolerant	Habitat value	Ornamental value
Shortgrasses	Buffalograss	*Bouteloua dactyloides*	FACU			Yes	Yes
	Blue grama	*Bouteloua gracilis*				Yes	Yes
	Texas grama	*Bouteloua rigidiseta*				Yes	Yes
	Curly mesquite	*Hilaria belangeri*				Yes	Yes

	Species	Scientific name	Wetland Indicator Status	Colonizer	Shade tolerant	Habitat value	Ornamental value
Midgrasses	Purple threeawn	*Aristida purpurea*	UPL			Yes	Yes
	Silver bluestem	*Bothriochloa laguroides*				Yes	
	Sideoats grama	*Bouteloua curtipendula*		Yes		Yes	Yes
	Buffalograss	*Buchloe dactyloides*				Yes	
	Inland seaoats	*Chasmanthium latifolium*	FAC		Yes	Yes	Yes
	Prairie wildrye	*Elymus canedensis*	FACU	Yes		Yes	
	Green sprangletop	*Leptochloa dubia*				Yes	
	Lindheimer's muhly	*Muhlenbergia lindheimeri*	FACW			Yes	Yes
	Texas wintergrass	*Nasella leucotricha*			Yes	Yes	
	Texas bluegrass	*Poa arachnifera*			Yes	Yes	Yes
	Foxtail grass	*Setaria scheelei*			Yes	Yes	Yes

	Species	Scientific name	Wetland Indicator Status	Colonizer	Shade tolerant	Habitat value	Ornamental value
Tallgrasses	Big bluestem	*Andropogon gerardii*	FACU			Yes	
	Silver bluestem	*Bothriochloa laguroides*		Yes		Yes	Yes
	Canada wildrye	*Elymus canadensis*	FACU	Yes	Yes	Yes	
	Prairie wildrye	*Elymus virginicus*	FACU	Yes	Yes	Yes	
	Green sprangletop	*Leptochloa dubia*		Yes		Yes	
	Little bluestem	*Schizachyrium scoparium*	FACU		Yes	Yes	Yes
	Indiangrass	*Sorghastrum nutans*	FACU			Yes	Yes

appendix c

plant list - upland/riparian canopy

	Species	Scientific name	Wetland Indicator Status	Colonizer	Shade tolerant	Habitat value	Ornamental value
Forbs	Horseherb	*Calyptocarpus vialis*	FAC		Yes	Yes	Yes
	Indain paintbrush	*Castilleja indivisa*	FAC			Yes	Yes
	American basketflower	*Centaurea americana*				Yes	Yes
	Partridge pea	*Chamaecrista fasciculata*	FACU	Yes		Yes	
	Goldenwave	*Coreopsis basalis*					Yes
	Plains coreopsis	*Coreopsis tinctoria*	FAC			Yes	Yes
	Scrambled eggs	*Corydalis curvisiliqua*					Yes
	Illinois bundle flower	*Desmanthus illinoensis*	FACU	Yes		Yes	
	Engelmann's daisy	*Engelmannia peristenia*				Yes	Yes
	Eryngo	*Eryngium leavenworthii*				Yes	Yes
	Snow on the mountain	*Euphorbia marginata*	FACU				Yes
	Indian blanket	*Gaillardia pulchella*	UPL	Yes		Yes	Yes
	Maximillian sunflower	*Helianthus maximiliani*	FACU			Yes	Yes
	Standing cypress	*Ipomopsis rubra*		Yes		Yes	Yes
	Texas yellowstar	*Lindheimera texana*				Yes	Yes
	Bluebonnet	*Lupinus texensis*					Yes
	Horsemint	*Monarda citriodora*	UPL			Yes	Yes
	Frogfruit	*Phyla nodiflora*	FAC		Yes	Yes	Yes
	Mexican hat	*Ratibida columnifera*		Yes		Yes	Yes
	Black-eyed Susan	*Rudbeckia hirta*	FACU			Yes	Yes
	Tall goldenrod	*Solidago altissima*	FACU	Yes		Yes	Yes
	Giant spiderwort	*Tradescantia gigantea*			Yes	Yes	Yes
	Pink evening primrose	*Oenothera speciosa*		Yes		Yes	Yes

	Species	Scientific name	Wetland Indicator Status	Colonizer	Shade tolerant	Habitat value	Ornamental value
Shrubs	American beautyberry	*Callicarpa americana*	FACU		Yes		Yes
	Cenizo	*Leucophyllum candidum*				Yes	Yes
	Agarita	*Mahonia trifoliolata*			Yes	Yes	Yes
	Turks cap	*Malvaviscus arboreus*	UPL		Yes	Yes	Yes
	Pigeonberry	*Rivina humilis*	FAC		Yes	Yes	Yes
	Palmetto	*Sabal minor*	FACW		Yes		Yes
	Tropical sage	*Salvia coccinea*					Yes
	Mealy bluesage	*Salvia farinacea*					Yes
	Heartleaf skullcap	*Scutellaria ovata*	FACU		Yes		Yes

	Species	Scientific name	Wetland Indicator Status	Colonizer	Shade tolerant	Habitat value	Ornamental value
Trees	Sugar hackberry	*Celtis laevigata*	FAC	Yes	Yes	Yes	
	Texas ash	*Fraxinus albicans*	FACU		Yes	Yes	Yes
	Sycamore	*Platanus occidentalis*	FAC			Yes	Yes
	Texas red oak	*Quercus buckleyi*			Yes	Yes	Yes
	Bur oak	*Quercus macrocarpa*	FACU			Yes	Yes
	Post oak	*Quercus stellata*	FACU			Yes	Yes
	Live oak	*Quercus virginiana*	FACU			Yes	Yes
	American elm	*Ulmus americana*	FAC			Yes	Yes
	Cedar elm	*Ulmus crassifolia*	FAC	Yes	Yes	Yes	Yes

appendix c

plant list - upland/riparian canopy LID feature

Trees/ Shrubs	Species	Scientific name
	Possumhaw holly	*Ilex decidua*
	Sycamore	*Platanus occidentalis*
	Bald cypress	*Taxodium distichum*

Grasses/Forbs	Species	Scientific name
	Inland sea oats	*Chasmanthium latifolium*
	Bushy bluestem	*Andropogon glomeratus*
	Upland switchgrass	*Panacum virgatum*
	Indiangrass	*Sorghastrum nutans*
	sedges	*Carex spp.*
	Obedient plant	*Physostegia angustifolia*
	Goldenrod	*Solidago altissima*

appendix d
resources

Publications

Design

Bisgrove, Richard. 1992. The Gardens of Gertrude Jekyll. Frances Lincoln Publishers, London, United Kingdom.

Eckbo, Garrett. 2002. Landscape for Living. University of Massachusetts Press, Amherst, Massachesetts.

Oudolf, Piet and Noel Kingsbury. 2013. Planting: A New Perspective. Timber Press, Portland, Oregon.

Rainer, Thomas and Claudia West. 2015. Planting in a Post-Wild World: Designing Plant Communities for Resilient Landscapes. Timber Press, Portland, Oregon.

Plants

Fleenor, Scott and Stephen W. Taber. 2009. Plants of Central Texas Wetlands. Texas Tech University Press, Lubbock, Texas.

Nueces River Authority. 2015. Your Remarkable Riparian: A Field Guide to Riparian Plants Within the Nueces River Basin of Texas. Nueces River Authority.

Wasowski, Sally and Andy Wasowski. 2008. Native Texas Plants: Landscaping Region by Region. Lone Star Books, Lanham, Maryland.

Restoration

Biebighauser, Thomas. 2011. Wetland Restoration and Construction: A Technical Guide. Thomas Biebighauser Publisher, China.

Helzer, C. 2010. The Ecology and Management of Prairies in the Central United States. University of Iowa Press, Iowa City, Iowa.

Maywald, P.D. and D.L. Doan-Crider. Restoration Manual for Native Habitats of South Texas. Caesar Kleberg Wildlife Research Institute. Texas A&M University – Kingsville, Texas.

Whisenant, Steven. Repairing Damaged Wildlands: A Process Orientated, Landscape-Scale Approach. 2005. Cambridge University Press: New York City, New York.

Soils

Urban, James. 2008. Up by Roots: Healthy Soils and Trees in the Built Environment. International Society of Arboriculture. Champaign, Illinois.

Websites

Managing Riparian Habitats For Wildlife – Texas Parks and Wildlife Department
https://tpwd.texas.gov/publications/pwdpubs/media/pwd_br_w7000_0306.pdf

Texas wildscapes: Texas Parks and Wildlife Department
http://tpwd.texas.gov/huntwild/wild/wildlife_diversity/wildscapes/

Native Texas Lawns - Lady Bird Johnson Wildflower Center
http://www.wildflower.org/habiturf/

Recreating a Prairie – Lady Bird Johnson Wildflower Center
http://www.wildflower.org/howto/show.php?id=22

Your Remarkable Riparian – Nueces River Authority
http://www.remarkableriparian.org/index.php

Riparian Zone Restoration – City Of Austin Watershed Protection Department
https://www.austintexas.gov/faq/riparian-zone-restoration

City of Austin Invasive Species Management Plan
https://austintexas.gov/sites/default/files/files/Watershed/invasive/COA-ISMP-Final-7-11-12.pdf

Central Texas Invasive Plants Field Guide – City of Austin
http://www.austintexas.gov/sites/default/files/files/Watershed/invasive/2013_Invasives_guide_small.pdf

USDA plants website
http://plants.usda.gov/java/

Native Plant Information Network
https://www.wildflower.org/plants/
https://www.wildflower.org/collections/collection.php?collection=centex_wetland

Texas invasives
http://texasinvasives.org/

appendix e
references

Allan, J. D. 1995. Stream ecology: structure and function of running waters. Kluwer, Dordrecht, The Netherlands.

Allan, J. D., D. L. Erickson, J. Fay. 1997. The influence of catchment land use on stream integrity across multiple spatial scales. Freshwater Biology 37:149–61.

Army Corps of Engineers. Army Corps of Engineers - Regulatory guidance letters - ordinary high water mark identification [Internet]. 07/2005. Army Corps of Engineers.

Brode, J. M. and R. B. Bury. 1984. The importance of riparian systems to amphibians and reptiles. Pages 30-36 in R. E. Warner and K. M. Hendrix, eds. California riparian system: ecology, conservation, and productive management. Univ. of California Press: Berkeley.

Burk, J. D., G. A. Hurst, D. R. Smith, B. D. Leopold, and J. G. Dickson. 1990. Wild turkey use of streamside management zones in loblolly pine plantations. Proceedings of the National Wild Turkey Symposium 6:84-89.

Cardinale, B. J., J. E. Duffy, A. Gonzalez, D. U. Hooper, C. Perrings, P. Venail, A. Narwani, G. M. Mace, et al. 2012. Biodiversity loss and its impact on humanity. Nature: 486:59–67.
doi: 10.1038/nature11148.

Dickson, J. G. 1989. Streamside zones and wildlife in southern U.S. forests. Pages131-133 in Greswell, R. E., and B. Kershner, eds. Practical approaches to riparian resource management: an educational workshop. U.S. Bureau of Land Management, Billings, Montana.

Dickson, J. G., and J. C. Huntley. 1987. Riparian zones and wildlife in southern forest: the problem and squirrel relationships. Pages 37-39 in J .G. Dickson and O. E. Maughan, eds. Managing southern forests for wildlife and fish. U.S. Forest Service. Gen. Tech. Rep. SO-65.

Eckbo, Garrett. 2002. Landscape for living. University of Massachusetts Press, Amherst, Massachusetts.

Fleenor, S. B., and S. W. Taber. 2009. Plants of Central Texas wetlands. Texas Tech. University Press, Lubbock, TX.

Grayson, J. E., M. G. Chapman, and A. J. Underwood. 1998. The assessment of restoration of habitat in urban wetlands. Centre for Research on Ecological Impacts of Coastal Cities, Marine Ecology, University of Sydney, Sydney, Australia.

Gregory, S. V., F. J. Swanson, W. A. McKee and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. Bioscience 41:540-551.

Griffith, G. E., et al. 2004. Ecoregions of Texas. Environmental Protection Agency, Western Ecology Division.

Halls, L. K. 1973. Managing deer habitat in loblolly-shortleaf pine forest. Journal of Forestry
71:752-757.

Helzer, C. 2010. The ecology and management of prairies in the Central United States. University of Iowa Press, Iowa City, IA.

Henley, W. F., M. A. Patterson, R. J. Neves, and A. D. Lemly. 2000. Effects of sedimentation and turbidity on lotic food webs: a concise review for natural resource managers. Reviews in
Fisheries Science 8 (2):125-139.

Holcomb, S. S. 2004. An examination of the riparian bottomland forest in North Central Texas through ecology, history, field study, and computer simulation (Master's thesis). University of North Texas, Denton, TX.

Johnson, L. B. 1966. Public Papers of the Presidents of the United States: Lyndon B. Johnson, 1965. Volume II, entry 576, pp. 1072-1075. Government Printing Office, Washington, DC.

Jones-Lewey, M. E. S. (2015) Your remarkable riparian: a field guide to riparian plants within the Nueces River Basin of Texas, Nueces River Authority. Uvalde, TX.

Kutac, E. A., and S. C. Caran. 1994. Birds and other wildlife of South Central Texas: a handbook. The University of Texas, Austin, TX.

Leopold, Aldo. 1933. Game management. Charles Scribner's Sons, N.Y. Reprinted in 1986 by University of Wisconsin Press, Madison, WI.

Lowrance, R. T., J. Fail, Jr., O. Hendrickson, Jr., R. Leonard, and L. Asmussen. 1984. Riparian
forest as nutrient filters in agricultural watersheds. Bioscience 34:374-377.

Maser, C., and J. Sedell. 1994. From the forest to the sea: the ecology of wood in streams, rivers, estuaries, and oceans. St. Lucie Press: Delray Beach, FL.

Mayer, P., S. Reynolds and T. Canfield. United States Environmental Protection Agency Office of Research and Development. 2005. Riparian buffer width, vegetative cover, and nitrogen removal effectiveness: a review of current science and regulations. http://www.epa.gov/nrmrl/pubs/600R05118/600R05118.pdf)

Maywald, P. D., and D. L. Doan-Crider. Restoration manual for native habitats of South Texas. Caesar Kleberg Wildlife Research Institute. Texas A&M University, Kingsville, TX.

Messina, M. G., and W. H. Conner, eds. 1998. Southern forested wetlands: ecology and management. Lewis Publishers, Boca Raton, FL.

Native Prairie Association of Texas. Tallgrass restoration manual. (http://texasprairie.org/index.php/manage/restoration_entry/tallgrass_restoration_manual/)

appendix e
references

Nelle, S. 2009. Common plants of riparian areas--Central--Southwest Texas with Wetland Indicator (WI) and proposed stability rating (SR). Natural Resources Conservation Service, San Angelo, TX. Contact: steve.nelle@tx.usda.gov.

Rudolph, D. C., and J. G. Dickson. 1990. Streamside zone width and amphibians and reptiles abundance. Southwestern Naturalist 35:472-476.

Sala, O. E, F. S. Chapin, J. J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L. F.Huenneke, et al. 2000. Global biodiversity scenarios for the year 2100. Science 287:1770–1774. doi: 10.1126/science.287.5459.1770.

Shirley, S. 1994. Restoring the tallgrass prairie. University of Iowa Press, Iowa City, IA.
Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. 1974. Hays County Texas soil survey.

Strayer, D. L., R. E. Beighley, L. C. Thompson, S. Brooks, C. Nilsson, et al. 2003. Effects of land cover on stream ecosystems: roles of empirical models and scaling issues. Ecosystems 6:407–23.

Sustainable Site Initiative. 2014. SITES V2 Reference Guide for sustainable land design and development. The Lady Bird Johnson Wildflower Center at The University of Texas.

Urban, J. 2008. Up by roots: healthy soils and trees in the built environment. International Society of Arboriculture. Champaign, IL.
U.S. Botanical Garden and Lady Bird Johnson Wildflower Center. 2014. Landscape for Life – based on the principals of the Sustainable Site initiative.

Wagner, M. 2003. Managing riparian habitats for wildlife. Texas Parks and Wildlife Department. PWD BR W7000-306.

Wanielista, M. P., N-B. Chang, M. Chopra, Z. Xuan, K. Islam, and Z. Marimon. 2012. Floating wetland systems for nutrient removal in stormwater ponds. Stormwater Management Academy Civil, Environmental, and Construction Engineering Department, University of Central Florida, Orlando, FL.

Whisenant, S. 2005. Repairing damaged wildlands: a process orientated, landscape-scale approach. Cambridge University Press: New York, NY.

Williams, J. E., C. A. Wood, and M. P. Dombeck, eds. 1997. Watershed restoration: principles and practices. American Fisheries Society, Bethesda, MD.

Woodson, D. 2013. Irrigation efficiency. Lecture conducted at the Texas AgriLife Research and Extension, Dallas, TX.