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## HOW TO PLANT WILLOWS AND COTTONWOODS FOR RIPARIAN RESTORATION

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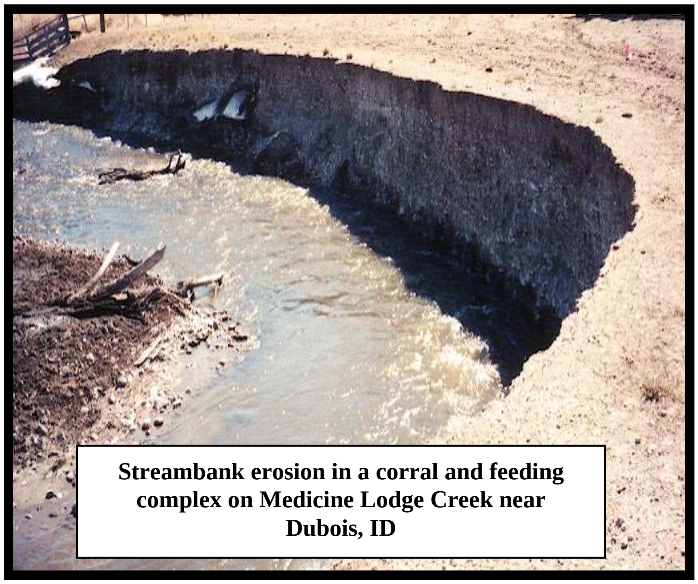
## Introduction

Many riparian areas in the West need rehabilitation. Natural climatic events and abuses in the past have caused the destruction of vegetation and accelerated streambank and stream bottom erosion (Kauffman and Krueger 1984; Skovlin 1984; Platts 1981; Thomas and others 1979). Emphasis on water quality, aesthetics, wildlife, and fisheries has prompted interest in methods for revegetating eroding stream channels (Carlson 1992; Carlson et al. 1991).



**Streambank erosion in a corral and feeding complex on Medicine Lodge Creek near Dubois, ID**

There is increased interest in rehabilitating riparian zones with willows and cottonwoods. The Interagency Riparian/Wetland Plant Development Project, USDA Natural Resources Conservation Service (NRCS), Plant Materials Center (PMC), Aberdeen, Idaho and others are researching harvesting, storage, planting techniques and cultural practices for successful establishment of willows, cottonwoods and other riparian woody vegetation to better meet the needs of riparian rehabilitation.

## Guiding Principles of Stable Stream Channels

Riparian vegetation is a critical part of any stream system. Riparian plants provide a huge web of roots that hold the soil together. They also provide significant roughness from their above ground biomass. Determining where to plant them is often one of the hardest decisions to make. Before starting to restore a stream channel, 3 principles need to be understood (Natural Channel Designs, 2006). They are:

1. **Elevations should rise away from the central channel.**

The central channel flow line must be the lowest point across the riparian area and the channel banks, floodplains, and terraces should slope upward continuously away from the channel. The banks will be most stable if they can be stepped as they rise away from the channel. All flat areas should slope toward the river. If they are level or slope away from the river they will tend to divert overbank flows away from the main channel and could contribute to greater erosion. Banks on the outside of meanders are expected to rise more rapidly than those on the inside, but should still be stepped when possible.

2. **Transitions should be gradual to reduce the potential for erosion.**

In order to minimize the risk of lateral bank erosion, water should flow smoothly through the stream corridor. While meander is a natural part of stream processes, tight turns can create excessive pressure to weak stream banks and increase erosion. Meanders should be gradual and within the dimensions described in specific recommendations. Floodplains and terraces should not be suddenly narrowed by buildings or other structures. Such constrictions force increases in velocity and water elevations that can increase erosion.

3. **Roughness should increase away from the central channel.**
Roughness is resistance to flow contributed by vegetation, rough surfaces, or structures. Increasing roughness away from the central channel tends to center high flows and slows velocities against the more erosive stream banks and terraces. For example, the central channel should be relatively free of vegetation and other obstructions. The areas immediately adjacent to the channel (floodplains) should support dense thickets of shrubby vegetation (i.e., willows, etc) that bend with the flows (Figure 1). Areas further away from the channel (terraces) support stiffer woody vegetation (cottonwoods, Peachleaf willow, etc) that further slows flows. It should be noted that roughness implies a slowing of the flow not necessarily stopping the flow. Structures that completely stop or redirect flow across the floodplain/terrace should be avoided.

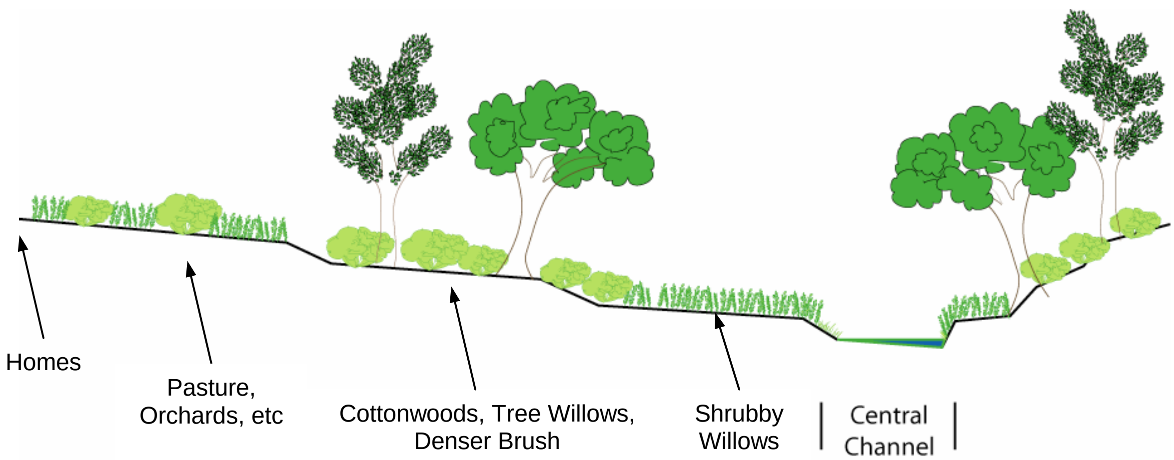



**Figure 1: Roughness - Vegetation provides increasing roughness to keep high velocities in central channel (Natural Channel Design, 2006)**

This Technical Note addresses principle 3 - the addition of roughness to the channel. It should be noted that planting vegetation in a riparian zone without giving serious consideration to where different species of plants should go can cause more problems than those you are trying to fix. For more information on where to plant riparian vegetation, see *Riparian Planting Zones in the Intermountain West* by Hoag et. al. 2001.

There are a number of steps that should to be completed prior to any planting. They include a site assessment, an inventory of planting site, and a detailed survey and evaluation of the soils, water, and vegetation. Once you have determined the cause of the erosion and where high priority areas are located on the stream, you should develop a planting plan and determine where and how to plant the vegetation that you will use. This Technical note describes how to select, harvest, treat, and plant riparian woody species.

**Site Assessment**

Before jumping into the water and shoving cuttings in the ground, it is important to understand what is causing the streambank erosion, how extensive it is, and which areas need the most work. A stream assessment should be completed on the stream prior to any restoration or rehabilitation work. The assessment should identify problems on a stream reach basis.   A is defined as a section of stream between two defined points (Fischenich 2000).  A number of assessment protocols are available, such as: Stream Visual Assessment Protocol (SVAP), Proper Functioning Condition (PFC), Rapid Stream Assessment, etc.  The assessment should identify problems such as, water removal, fish barriers, culverts, etc. that affect fish and hydrology by stream reach.  It should also identify eroding areas, the type of erosion, and severity of the erosion.  When the assessment is completed, there should be enough information to identify the reaches of the stream that need some kind of treatment, treatment alternatives that could be used, which reaches are the highest priority, other problems that need to be addressed, and an estimate of the potential success of a planting.  Based on a good site assessment, you should be able to develop a project rehabilitation schedule or plan including a list of treatment alternatives, a cost estimate for each reach, a cost estimate for the entire project area, and a priority list of which reaches should be treated first.

**Site Considerations**

Careful planning before planting is necessary to ensure the solution does not create additional problems.

* Management (prescribed grazing system, livestock exclusion, riparian buffers, etc.) must be in-place to maintain or improve riparian vegetation. Without proper management, planting efforts could be destroyed (Crouse and Kindschy 1984; Van Haveren and Jackson 1986).

* If native willows or cottonwoods are not found in the vicinity, planting them may not be a good option.

* Willow and cottonwood plantings apply only to situations where the rehabilitation time frame is long enough to allow the cuttings to become established and stabilize the site. Hard structures (i.e. rock, concrete, etc.) may be more appropriate under emergency situations.

* Unrooted cuttings can be used on sites that range from flat to near vertical slopes. Risks of wash-out and mortality increase as the slopes become steeper.

A reconnaissance upstream and downstream of the site selected for revegetation may save time and effort. If there are willows and cottonwoods on adjacent sites, check the hydrology, soil and site conditions and compare them to conditions at the revegetation site. Plantings will be most successful on sites similar to the stable vegetated areas. Risk of mortality increases as soil, site, and water column parameters depart from those of the vegetated sites.

**There are reasons for vegetation not growing on the disturbed site.** Some parameters to inventory in addition to management at the revegetation site include: high streamflow velocities, sharp outside curves, vertical to near vertical or undercut banks, hanging streambanks, mixed stratigraphy of cohesive materials over gravel, and evidence of mass soil slumping. When these parameters are present, revegetation can still be considered, but the underlying causes must be addressed. Establishing vegetation is much more difficult under these conditions because the time period required for stabilization increases, the planting schedule must accelerate, and additional soil losses can be expected.

These conditions indicate engineered hard structures or bioengineering techniques not covered in this Technical Note need to be included in the planning considerations.

Some data suggests vegetative protection may be adequate if maximum streamflow velocities do not exceed 8 feet per second. Structural and bioengineering techniques should be considered for velocities greater than 8 feet per second. Woody materials should be considered with velocities less than 8 feet per second. Woody materials in conjunction with herbaceous species should be considered for velocities less than 5 feet per second. Herbaceous materials alone can be used for velocities less than 3 feet per second.

Engineered hard structures or bioengineering techniques may be needed in situations where the toe of the bank is unstable. In these situations, refer to the NRCS Stream Restoration Design Handbook, National Engineering Handbook, Section 654.

**Species Selection**

During the reconnaissance, identify willow, cottonwood and other riparian species, local soil and site conditions and the moisture regime. If species identification is a problem, at least identify the growth form and conditions where the plant is growing (elevation, soils, zone, etc.). Species and/or growth form identification is important so the correct plant species can be matched to the right planting zone at the revegetation site.

Willow species have several different growth forms. Willows come in all sizes, from small shrubs to large trees. There are three basic types of willows: tree-type, shrub-type, and creeping type. Tree-type species at maturity have a large crown, single or multiple stems, and dense basal area. They are usually taller than 20 ft. Shrub-type willows generally have smaller diameter multiple basal stems and rarely get taller than 15-18 ft. Creeping–type willows sucker profusely and are represented by coyote willow (*Salix exigua*).

**Different growth forms of willows along the Snake River near Buhl, ID**

Cottonwood species have narrow to wide crowns and some species sucker (generally only about 10% of a stand will sucker) while others have very shallow root systems.

In general, small to medium size shrub-type willows and rhizomatous or creeping-type willows are used for planting within the channel banks. These can be planted as live poles, vertical bundles or as clumps. Tree-type willows and cottonwoods are normally selected for the upper bank and floodplain areas near the transition zone and can be planted as large poles or clumps.

Mature size and growth form will affect species selection. Large species can partially block or deflect stream currents. If the mature basal size of the selected species will block streamflow near the main channel or on adjacent floodplains, another species with more flexible stems should be considered.

There are many species of willows that occur naturally in different habitats. Upland willow species are found in relatively dry areas not necessarily associated with seeps, bogs, or high water. Scouler willow, a common upland species, is rarely found on wet areas, but more commonly on or near moist areas such as springs or intermittent watercourses. Wetland willows are found growing in standing water or saturated conditions and are adapted to long periods of inundation.

If spreading of planted species is considered a problem, selection might include only male clones. Both willows and cottonwoods have male and female plants. Selecting male plants will reduce spreading from seeds.

More shade will be produced with tall and/or wide canopy species. This may be important for water temperatures and fish habitat. Consider the aspect. Concentrate on tree-type species with wide canopies on the south or east side of stream to achieve the most shade over the widest area.

Stem flexibility is important for species at the waterline to mid-bank on streams with high velocities, debris loads, and ice flows (Parsons 1963; Platts and Rinne 1985). Species with deep or rhizomatous root systems might be better suited to streams with severe ice flows (Platts and Rinne 1985).

**Debris caught on the flexible stems of Booth willow after spring runoff**

Livestock and wildlife can adversely impact the riparian zone. Some plant species such as willow, cottonwood, chokecherry, Skunkbush sumac, golden current, serviceberry, Syringa (mockorange), and silver buffaloberry are fairly palatable. It may be advantageous to plant less palatable species, such as hawthorn, in the bank to overbank zone rather than more palatable species. Other less palatable species include: Woods' rose, Douglas spirea, dogwood, river birch, thinleaf alder, and common snowberry.

Grazing can also reduce regeneration, particularly for those species that reproduce by seed. Species selection of strong suckering or rhizomatous species may be an advantage. Improper grazing management can adversely impact even these species. A grazing management plan is needed whenever riparian areas are grazed, especially after planting. The riparian area should not be grazed for at least 3 years after planting. At the end of 3 years, the area should be assessed for grazing potential and if allowed, be grazed according to a good grazing management plan. Spring grazing is the best because animals have many foraging choices other than the planted woody species. Be careful with fall grazing because woody species are a more desirable foraging choice and there will be no regrowth before the next spring growth period. Overgrazing the woody and herbaceous riparian species will result in less bank and floodplain protection during high runoff events the following spring. The woody riparian species should be used as the key indicator species for when the livestock should be moved out of the riparian zone.

Aesthetics can usually be improved by selecting more than one species to provide differences in size, shape, color, and texture. More than 1 species or clone also increases resistance to pests and diseases, in addition to increasing diversity for wildlife. However, the species planted at the waterline should be a single species so that all the cuttings have similar characteristics for the full length of any one reach so that varying sizes and shapes do not cause the force of water to move behind that planted line.

Most species of willow and cottonwood have good fire tolerance and resprout readily after being burned as long as the fire is not too hot. Many cottonwoods are more susceptible to fire as they mature. Other riparian species such as dogwood and chokecherry also have a high fire tolerance.

There may be times when native species will not meet the landowners' objectives. Introduced species should only be considered in the revegetation plan after careful review of the native sources (more native species are available on the market all the time), landowner objectives, and disease and insect infestations.  Refer to the Idaho Tree Planting Handbook, North Dakota Tree Handbook, and Riparian/Wetland Project Information Series No. 19 for plant characteristics.

**A riparian buffer with different species on Bear Creek, IA**

**Species Distribution or Planting Design**

A planting design should be developed to show where each species is to be planted on the site. The entire problem section should be planted, not just parts of a reach or curve. This will reduce the chance of water eroding behind the planting.

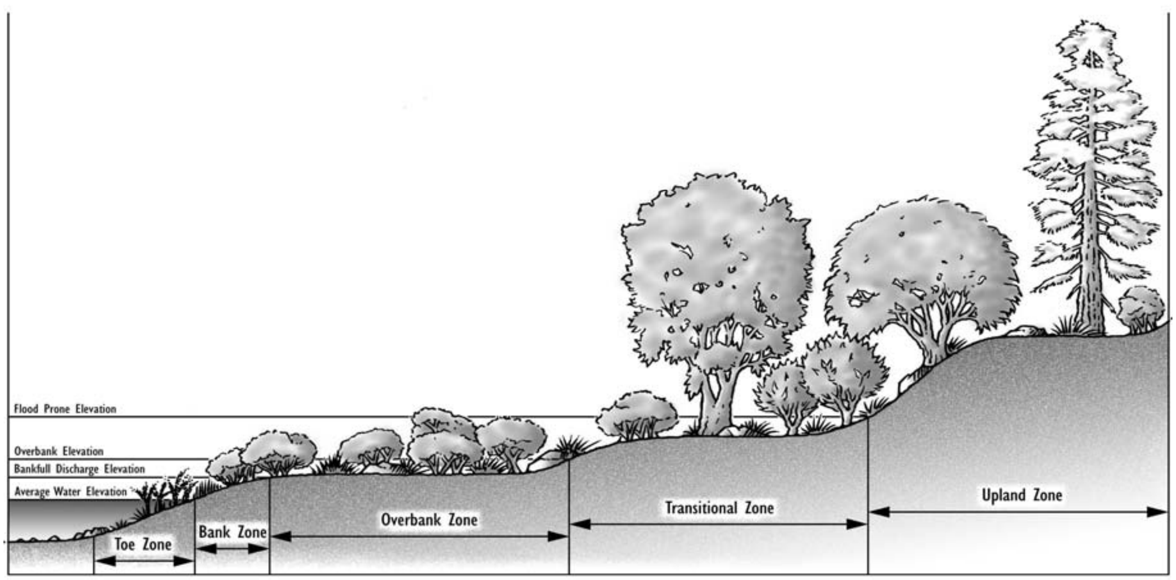



**Figure 2: Riparian Planting Zones can be used to determine where riparian species should be planted in relation to the waterline.  This is a general depiction of a riparian zone.  Not all streams look like this one.  In the real world, some of these zones may be absent. (From Hoag 2001, Hoag and Landis 1999)**

Each species grows in specific ecological zones along the stream channel and flood plain (Carlson et al. 1992). These ecological zones can be equated to planting zones. Riparian planting zones (Hoag 2001) include the toe zone, bank zone, overbank zone, transitional zone and the upland zone (Figure 2).

Shrubby species are normally planted on outside curves of a stream channel as a continuous barrier. Outside curves incur more erosion from streamflow, but have a shorter inundation period. Plant the entire reach with the same mix of species. Shrubby species with flexible stems are planted on the bank zone and the overbank zone or floodplain for diversity and additional stabilization or as a buffer zone.

Plant tree species up the bank from the shrubby species or on top of the bank. The shrubby species provide protection for the tree species when planted in this manner.

The reconnaissance survey will help identify these relationships. See "Spacing" section to help with planting design and to help determine numbers of plants or cuttings needed.

**Type of Planting Stock**

Cuttings, whips, plugs, conetainers, bare-root, potted, clumps, balled and burlap, and paper-sleeved planting stock are all viable alternatives (Carlson et al. 1992; Dirr and Heuser 1987; Platts et al. 1987).

Advantages of nursery stock include: good potential root development, good carbohydrate reserves, few pest or disease problems, readily available for many species, and no labor is needed to collect the stock.

Disadvantages of nursery stock include: more expensive than hardwood cuttings collected near the revegetation site, short root systems can wash out easily, short root system may not reach moist soil during the growing season, and roots of local herbaceous vegetation are in the same zone competing for moisture and nutrients.

**Stem cuttings**

Stem cuttings can be divided into softwood, semi-hardwood (greenwood), and hardwood categories. Hardwood stem cuttings can also be divided into deciduous, narrowleaf evergreen, and broadleaf evergreen (Dirr and Heuser 1987). This Technical Note concentrates on deciduous hardwood cuttings from moderate age stem materials. Deciduous hardwood cuttings of willow and cottonwood species are generally recommended over other types of cuttings because of the high concentration of pre-formed,

dormant root primordia located throughout the length of the stems (Densmore and Zasada 1978; Carlson 1938, 1950; Haissig 1970, 1974).

Pole cuttings (large diameter unrooted stems) of shrub-type willows are recommended for most plantings from water line to mid-bank. Pole cuttings of tree-type willows and cottonwoods are recommended on upper-banks and floodplains where the water table is relatively deep. Pole cuttings provide an effective means to reach saturated soils and establish a high concentration of roots for that portion of the stem within the moist zone.

Pole cuttings have the additional advantage of being relatively inexpensive and easy to harvest and store. They are also easy to plant. High mortality can occasionally occur, but this is somewhat offset by lower cost, ability to rapidly plant large numbers, and ease of replanting the following year.

Generally, whips (less than 3/8 inch diameter) are not recommended because energy reserves in the stem are limited and they are more susceptible to cytospora canker, a fungus that causes twig dieback (Biggs et al. 1983; Briggs 1991).

**Container stock**

Plugs, conetainers, bare-root, potted, balled and burlap and paper-sleeve planting stock are best when used:

*mid-bank to upper-bank or floodplain where long periods of inundation or water erosion are minimized

*where adequate moisture is available -- i.e. natural precipitation or irrigation is adequate for species selected

*where there is no competing vegetation or a 30" diameter area around plant has the competing vegetation scalped off down to mineral soil at planting time

*where plants have a low risk of physically being pulled or eroded out due to shallow rooted systems during establishment

**Source of Cuttings from Commercial Stock**

Willows and cottonwoods have been used extensively for riparian rehabilitation because they are easily established from cuttings. Cuttings can sometimes be obtained from commercial nurseries or more commonly from native stands located near rehabilitation sites. When buying cuttings from commercial sources, released varieties of adapted species should always be specified when available.

PMCs conduct extensive research and testing with native willows and cottonwoods collected from service area states having similar climate, soils, and topography. Once a willow or cottonwood meets the testing criteria, it is released to the public. Commercial nurseries and growers then propagate the species on a much larger scale for sale. The released variety name is the key to getting a plant adapted to conditions similar to where it was tested. All named varieties have documentation that describes growth characteristics, performance, and selection criteria. This ensures they are the same stock as originally tested.

Plugs, conetainers, bare-root, potted, and paper-sleeved nursery stock purchased through nurseries should be established from local materials. This could be from a local ecotype or the same watershed, but should not be from more than 200 miles east or west or 100 miles north or south or more than 2000 feet elevation difference from planting site. Ask the nursery where the stock came from.

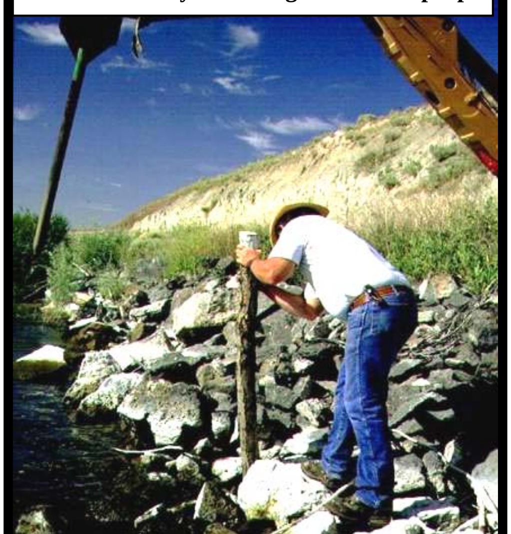
**Source of Cuttings from Native Stands**

Native willow and cottonwood stands located near the rehabilitation site are the most common source of cuttings. Native stands of willow and cottonwood are adapted to local conditions, but may have or have had insect and disease infestations which can stress the plants in the potential "mother" stand. Low water years and long periods of drought may also stress the plants. This stress means that the stem cuttings may not have peak energy reserves. Low energy reserves translate into lower establishment success.

When planning the number of cuttings to harvest, take these stress indicators into account. Always obtain permission to harvest from the landowner, private or public, before starting to cut.

**Timing of Harvest**

Establishment success is significantly increased if cuttings are taken from live, dormant willows or cottonwoods either after leaf fall in late fall, winter, or very early spring before the buds start to break. Densmore and Zasada (1978) found that spring collections survived better than fall collections. However, studies in Idaho have found no such differences (Hoag 1991; Hoag et al. 1991; Hoag et al. 1992). See "Storage" section for procedures when harvesting well before the projected planting date.


**Placing a large diameter willow pole into a hole created by The Stinger in rock riprap**

In some cases, when access to the stream is limited due to regulatory concerns or during fish migration periods (i.e. during salmon migration runs in the spring and the fall), planting may be restricted to non-dormant periods. Rather than do nothing, consider harvesting the cuttings when the plants are in full leaf. When cuttings are harvested during these growth stages, expect the establishment success rate to decrease. Experiments at the Aberdeen Plant Materials Center have shown that when the plants are leafed out and harvested, the establishment success is about 40-50%. If you plan to plant during the active growing season consider planting more cuttings to make up for the lower success rate.

**Cutting Diameter**

Cuttings should generally be 3/4 inch diameter or larger depending upon the species (Briggs and Munda 1992; Hoag 1991; Hoag et al. 1991; Hoag et al. 1992; Fenchel et al. 1988).

Rhizomatous or spreading willow stems will rarely get much bigger than 3/4 inches in diameter. Tree-type willows can be several inches in diameter. Larger diameter cuttings have more energy and stored reserves than smaller diameter cuttings. Highest survival rates are obtained using cuttings 2 to 3 inches in diameter. Cuttings as large as 8 inches in diameter have been tested with excellent success (Carlson et al. 1991; Hoag et al. 1992). However, the larger the cutting diameter, the longer the cutting should be, and the deeper the hole should be to support it. The deciding factor for selecting the cutting diameter is the planting method you will use (see Planting Methods). Larger diameter and longer cuttings will be needed for more severely eroding sites and where the water table is deeper. When planting into rock riprap cuttings should be at least 3- 5 inches in diameter. Cuttings this size will not bend or break when pushed between the rocks in the riprap.

**Cutting Length**

Cutting length is largely determined by the depth to the mid-summer water table and erosive force of stream at the planting site (Briggs and Munda 1992; Fenchel et al. 1988; Hoag 1991; Hoag et al. 1991; Hoag et al. 1992). Plantings can occur at the water line, up the bank, and on top of bank in relatively dry soil, as long as cuttings are long enough to reach into the mid-summer water table. Make sure:

* 6-8 inches of cutting are in the mid-summer water table

* 3-4 buds are above the ground

* No less than 1/2 the total length is in the ground

* If long periods of inundation exceeding 30 days are likely, cuttings should be long enough to extend 6-12 inches above the expected high water level

* If weeds are a problem, the cutting should extend above herbaceous growth in summer to receive adequate light and below the weed root mass to minimize competition (Hoag et al. 1991; Platts et al. 1987)

When planting for bank stabilization, the cutting should extend 2-3 feet above ground so as it leafs out, it can provide immediate bank erosion protection. The cutting should be planted as much as 3-5 feet into the ground (sometimes deeper to ensure they are in the mid- summer water table). If they are not planted this deep, moving water can erode around cutting and rip it out of the ground. Tests have shown that even with established root systems as long as 15-28 feet, the erosive power of a stream can rip a short cutting out of the ground (Hoag 1991; Hoag et al. 1991; Hoag et al. 1992).

**Boyd Simonson standing next to coyote willow cuttings that were 20 ft long**

**Harvesting Cuttings**

Once cutting size and source locations have been determined, the actual cutting process can begin. Lopping shears, pruning shears, a small wood saw, brush cutters, or a chain saw can be used to harvest cuttings. Size of the cuttings will determine what you use to harvest them.

* Ensure all equipment is sharp and make clean cuts.

* Use live wood at least 2 year old or older. However, very old wood should not be used (Briggs and Munda 1992; Fenchel et al. 1988). Chmelar (1974) indicated that larger and older wood is required to propagate species that are difficult to root. The best wood is 2-7 years old with smooth bark which is not split or deeply furrowed.

* Avoid whips and suckers (current year's growth) because they lack the stored energy reserves necessary to consistently sprout when planted especially in dry conditions.

* No more than 1/3 of any individual plant should be removed. In the case of rhizomatous species, no more than 40-50% of the stand should be removed.

* Select branches which will not impair the source willows health and appearance.

* When harvesting from native stands, ensure the stand will not be denuded or destroyed by your cutting activity.

* Consider removing cuttings from inside the crown area rather than the more visually obvious exterior area. Try to spread your harvesting activity throughout the stand.

* Remove the apical bud plus several inches off of the cutting. The apical bud (bud at the tip of the branch) draws too much energy from stored reserves, reducing the chance of survival. Its removal will reroute energy to the side buds including the root buds. The upper part of the

stem also has the flowering parts (Kay and Chadde 1992). By cutting it off, energy is also redirected to the root and branch primordia in the older parts of stem.

* Trim off all side branches so cutting is a single stem.

* A processing consideration is to cut the top of cutting with a horizontal cut and bottom of cutting with a 45 degree cut. This allows quick recognition of cutting top (see also Sealing Harvested Cuttings).

* Care should be taken to select materials free of splitting, disease, and insect damage.

**Painting Harvested Cuttings**

One of the most important steps in this process is the identification of the **TOP** of the cutting. If cutting is planted upside down, significant mortality can occur. To identify which end is the top of cutting, look at the leaf scar and emerging buds. Buds emerging from leaf scar always point up. In addition, the stem is usually smaller diameter near top of cutting, but this is not always obvious. The leaf scars are the most reliable key.

When the top of cutting has been identified, it can be painted. Dipping the **TOP** 1-2 inches of cutting into a 50:50 percent mix of light colored latex paint and water, does a number of things. Perhaps the best reason for painting the top of cuttings is it helps inexperienced planting crews plant cuttings properly, with the top up! It also helps locate the cuttings more easily for future planting evaluations. It may also prevent excessive transpiration of water from cutting (the literature is mixed on this point, but Aberdeen Plant Materials Center research shows a higher establishment rate can be expected) This technique is inexpensive, easy, and effective.

**Painting the tops of willow cuttings**

**Storage**

The preferred timing for harvesting willow and cottonwood cuttings is when they are dormant. To minimize storage time, harvest cuttings in late winter to early spring and plant immediately when possible. If this is not possible, cuttings can be harvested in late fall or winter and stored in a large cooler at 33-40°F until just before planting. Cuttings can be stored for 3-4 months in a cooler. In Illinois, cuttings are stacked outside and covered with snow until they are planted in the spring (personal communication, D. Roseboom, Illinois State Water Survey, 1993). Whether cuttings are kept in a cooler, root cellar, garage, or shop floor, make sure the storage area is dark, moist, and cool at all times. If cuttings are stored at higher temperatures, a fungicide should be applied to prevent damage caused by pathogens or saprophytes (personal communication, D. Darris, Corvallis PMC, 1993).

**Treatment of Cuttings**

Testing at Aberdeen PMC using fertilization, treatments with rooting hormone, or treatments with a fungicide have not significantly affected the rooting or establishment of willow and cottonwood cuttings (Hoag 1991; Hoag et al. 1991; Hoag et al. 1992; Fenchel et al. 1988; Ogle 1990). Many willows and cottonwoods are very easy to root without special treatment. These treatments increase cost, labor requirements, and time necessary to plant without significantly increasing survival.

**Pre-plant Soaking of Cuttings**

Soaking the cuttings prior to planting will increased survival in addition to root and shoot production. Pre-soaking improves stem water content and early root and shoot initiation (Phipps et al 1983; Schaff et al 2002). Phipps et al (1983) indicated that pre-soaking in water is beneficial under hot, dry conditions that induce high moisture stress. The increased water content from pre-soaking allows the cuttings to cope with planting in dry conditions by delaying desiccation and loss of cell turgor (Schaff et al 2002). Pre-soaking that results in early root and shoot formation can also extend the growing period during the establishment year, which is important when establishing plants in colder climates (Phipps et al 1983). Soaking is important because it initiates root growth processes within the inner layer of bark in willows and cottonwoods.

**Soaking willow poles in a small pond prior to planting**

Prior to planting, all cuttings should be soaked for a minimum of 24 hours (Hoag 1991; Hoag et al. 1991; Hoag et al. 1992). Some research recommends soaking the cuttings for as long as 10-14 days (Briggs and Munda 1992; Fenchel et al. 1988). The main criterion is that cuttings should be removed from water prior to root emergence from the bark. This normally takes 14 days or longer depending upon species (Peterson and Phipps 1976).

The entire cutting should be covered with water. Any part of cutting that is exposed will start sprouting as the soaking date comes closer to bud break. Soaking can be accomplished in a garbage can, irrigation ditch, stream, pond, lake, or other body of water that is deep enough as long as the cuttings are protected from sun and wind exposure during the soaking process. Soaking significantly increases the survival rate of the cuttings (Briggs and Munda 1992; Fenchel et al. 1988; Hoag 1991; Hoag et al. 1991; Hoag et al. 1992; Peterson and Phipps 1976).

**Spacing Considerations**

Plant cuttings about 1-3 feet apart for creeping-types, 3-8 feet apart for shrub-types and about 8-16 feet apart for tree-types. In areas where you expect erosion, plant creeping-types 1-2 feet apart to ensure better protection of the banks. If the holes are large enough, multiple stems can be planted together. Exact spacing between tree-types further up the bank in the transition zone and creeping or shrub-types in the bank or overbank zone should be based on crown characteristics and height. General ideas on spacing can be found in Idaho Plant Materials Technical Note No. 43: *Tree Planting Care and Management* (Stange et al 2002). However, crowding cuttings a little will not stress them because they will not lack for water when planted into the mid-season water table and more dense plantings will provide better protection to the bank.

### When to Plant

Willow and cottonwood cuttings have been successfully planted from early spring to late fall (dormant plantings).

* Preferably, cuttings should be planted in early spring after spring runoff occurs in streams or after high water drops to typical levels on reservoirs, ponds, or lakes.

* Rooted stock should be planted in early spring after frost has left soil. See Idaho Plant Materials Technical Note No. 43 for additional information. Avoid planting cuttings or rooted stock during the heat of summer because of the stress it places on them.

* When planting multiple sites along a stream, sites may need to be planted in different years.

* Consideration should be given to planting outside curves first and allowing time for establishment. Delay planting the inside curve until two or three years later. The inside curve is often not eroding and will begin to heal without planting. In addition, if the inside curve becomes established prior to the outside meander; there is a good chance that the stream current will be pushed into the eroding outside meander. This will increase the stress on the outside meander and make establishing woody riparian species more difficult.

### Planting Methods and Planting

**Bobcat with auger attachment, Parker, AZ**


### Cuttings

Backhoes, excavators, tractor-mounted posthole diggers, one- or two-person posthole diggers, soil augers, planting bars, shovels, soil probes, The Stinger, the waterjet stinger, or simply pushing the cutting into moist soil have all been used successfully to plant willow and cottonwood cuttings. When selecting the appropriate planting method, you should keep several things in mind.

* It is essential to have good contact between cutting and soil for roots to sprout. Air pockets around the cutting will kill the roots.

* Additional soil may be needed to ensure good soil to stem contact. Preference should be given to native soil nearby to encourage mycorrhizal formation and/or nodule formation by nitrogen-fixing organisms.

* Mud the cuttings in after they are placed in the hole. Use a bucket and mix soil and water together to get the consistency of cheap syrup. Pour the mix into the hole around the cutting until it reaches the surface. As the water leaches into the surrounding soil, the soil will settle out around the cutting and will ensure good soil to stem contact.

* The planting depth will determine the planting method. Deeper holes will be easier if you use a power auger, The Stinger, the waterjet stinger, or a soil auger.

* Experimentation with planting methods before starting will ensure the right equipment has been selected. This would also be a good time to train the planting crew on use of equipment, safety and planting techniques.

**The Stinger planting tree-type willows on the Snake River near American Falls, ID**

The Stinger is a 3.5 in diameter bar of cold rolled steel that is attached to a backhoe or excavator in place of the bucket. It is used to retrofit rock riprap with willows and cottonwoods.

For more information, see Idaho Plant Materials Technical Note 6: *The Stinger, a tool to plant unrooted hardwood cuttings of willow and cottonwood species for riparian or shoreline erosion control or rehabilitation* (Hoag and Ogle 1994).

**The Waterjet Stinger used for planting willow poles on Fox Creek, Driggs, ID. The pump is riding on a small raft with the suction hose in the water.**

The waterjet stinger is a hydrodrill that uses high pressure water to drill a hole in the streambank. This tool is composed of a high pressure water pump with 2 probes that have stainless steel nozzles that increase the water pressure so it comes out the holes in the nozzle at 80 psi. When the nozzle is placed on the streambank, the water liquefies the soil and cuts a hole as it goes down. The soil is in solution with the water. When the hole is deep enough, the probe is removed and an unrooted willow or cottonwood pole is inserted into the hole. As the water and soil solution settles, the water moves into the soil profile and the soil settles out around the cutting eliminating air pockets that might form around the cuttings resulting in excellent stem to soil contact. Complete information on how to build a waterjet stinger and it's use can be found in Idaho Plant

Materials Technical Note 39: *Waterjet Stinger, A tool to plant dormant unrooted cuttings of willows, cottonwoods, dogwoods, and other species* (Hoag et al 2001).

### Clump Planting

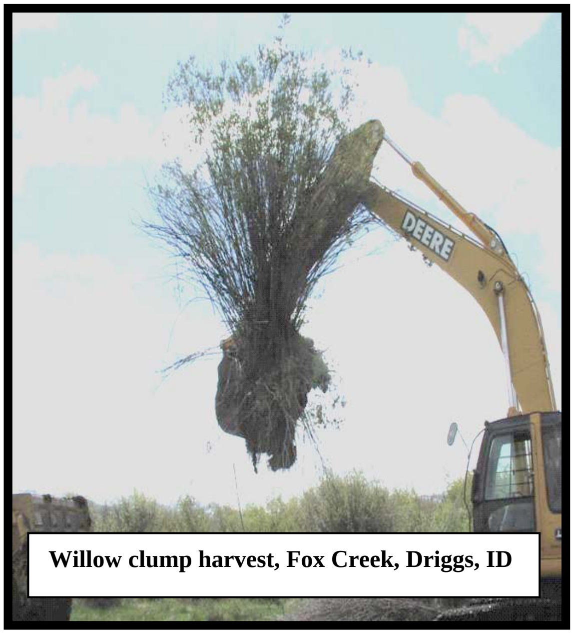
Clump plantings can be used in areas where heavy runoff occurs or where the water column directly impacts vertical banks.  See Idaho Plant Materials Technical Note 42: *Planting Willow Clumps* (Hoag 2003) for more information. These areas are difficult to plant and establish with traditional methods.

* The basic procedure is to locate clumps of willows that are accessible to a backhoe.

* The backhoe digs up a clump of willows, travels back to the planting site, and places the willow clump in a predetermined location by pushing out a hole as it deposits the clump.

* Clumps are then placed close together along the entire problem section of stream to keep water from cutting around the planting. Pulling or pushing soil from the streambank above willow clumps and packing it behind clumps will improve establishment success and assist in bank shaping.

* Sod of rhizomatous grass and grass- like species can be placed behind the willow clumps to speed up recovery time of the mid to upper banks. Some minor bank shaping will improve establishment of the herbaceous material. Grass species can also be seeded by hand.




**Willow clump harvest, Fox Creek, Driggs, ID**

* Planting should be completed following high water flows in the spring to reduce chance of ripping clumps out before the clumps are well rooted and start to spread.

* Temporary protection, such as steel posts with woven wire, sunlight degradable netting, etc., may be necessary to hold willow clumps in place until they are well established which may take 1-3 years. Usually, this is only necessary in areas were high velocities impact the bank.

### Other Planting Stock

See Idaho Plant Materials Technical Note No. 43: *Tree Planting Care and Management* (Stange et al 2002) for information on planting nursery stock.

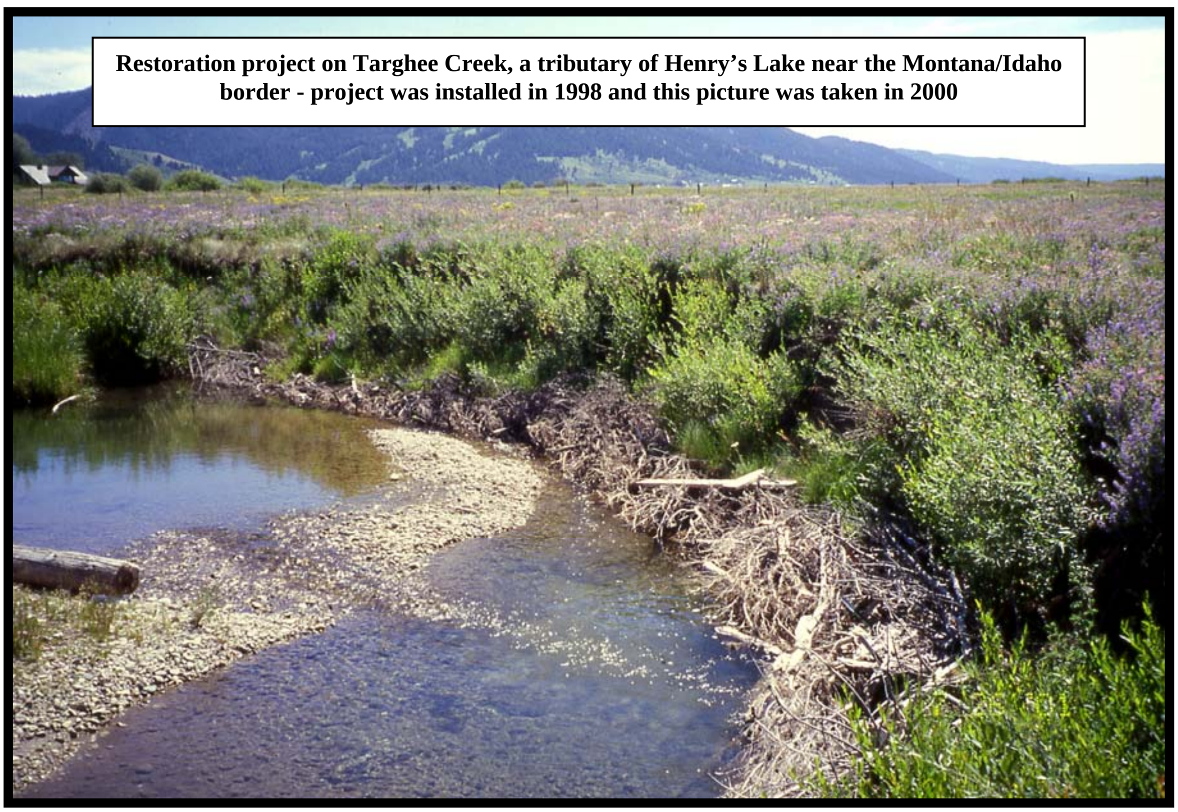
### Permits

The landowner is responsible for all permits prior to any planting. The completed plan should be copied as needed and provided to the landowner for submission to the state Department of Water Resources and/or US Army Corps of Engineers. Each state has specific permitting requirements and the landowner is responsible for locating the appropriate agency. Normally any work done in a stream channel requires notification and approval by these agencies and the issuance of permits before work can begin.

## Management and Maintenance

Preserve or initiate management that will keep, maintain, and improve the planting and other riparian vegetation. Proper management is necessary to maintain healthy, competitive plants that function for the intended objectives. This is as important as the planting itself to ensure long- term rehabilitation of the riparian area. Some maintenance will be needed on site for several years after planting. Vegetation should be evaluated and monitored annually. Some replanting will be needed in succeeding years. If you don't replant the first or second year, your continuous barrier could be jeopardized. Once water gets behind the protected line you have planted, it is extremely difficult to repair the damage.

Monitoring the site is necessary so any in-stream dead organic material (i.e. old logs, dead root masses, branches, etc.) can be removed before stream flow is deflected or gravel bars form. It is much easier to prevent this kind of damage than it is to repair it. As the planting ages and plants start to develop their growth form, some may need to be trimmed or cut to stimulate smaller and denser growth. Trimming should be done in the dormant season so willow growth is not slowed during the growing season. During the establishment period, leave standing dead branches in the clump plantings to reduce stream flow velocities, thus protecting the establishing clumps.



**Restoration project on Targhee Creek, a tributary of Henry's Lake near the Montana/Idaho border - project was installed in 1998 and this picture was taken in 2000**

If livestock use the area, a prescribed grazing plan should be developed. Little to no grazing should occur during the establishment period. This can take 2-5 years depending on growing conditions. Larger planting stock may be more resistant to grazing pressure, but should be monitored closely to avoid serious damage.

Temporary fencing may be necessary to control livestock and wildlife use of the planting during the establishment period. Permanent fencing is an option to prevent grazing by livestock and/or wildlife. Consideration should be given to the creation of "riparian pastures", i.e. grazing units that include riparian zones and floodplains as a majority of the pasture. These riparian pastures increase management flexibility but often require increased maintenance as a result of heavy grazing pressure from both livestock and wildlife. Water gaps to allow livestock access to the stream when necessary should be planned in transition sections between meanders. Off site water may be a better choice in terms of protecting the riparian buffer, increased calf gains, and better overall herd health. These areas have reduced erosion potential, are generally gravelly, and can be planted to a rhizomatous willow that will resprout easily. Access to water gaps can also be protected with gravel or concrete pads if heavy trampling problems arise.

Finally it is critical to protect streambanks and plantings from continuous use during long winter feeding periods. Feed grounds should be located away from streamside areas. If this is not possible, the area should be fenced and water gaps or off-site water provided so direct access to riparian corridor is controlled and potential pollutants can be filtered prior to overland surface waters enter the stream.

**Additional information and more technical papers**

Visit http://www.plant-materials.nrcs.usda.gov/idpmc/riparian.html for additional information on a variety of riparian and wetland plants and planting techniques.

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