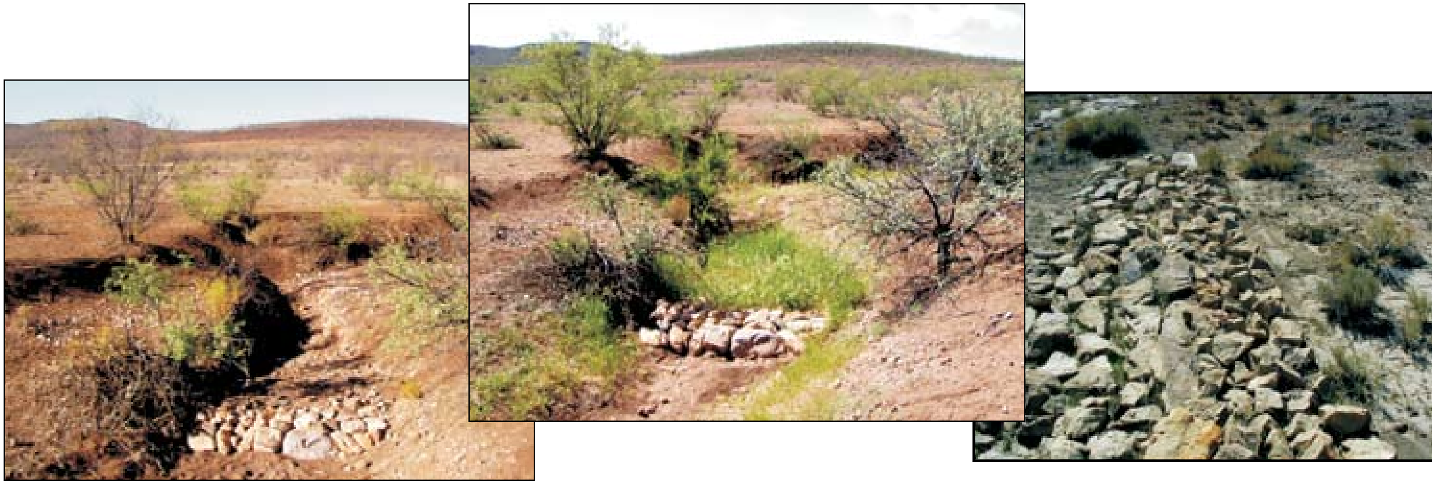
An Introduction to Erosion Control

by Bill Zeedyk and Jan-Willem Jansens



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Contents

This document describes erosion control techniques, such as those used for several demonstration sites in the Galisteo watershed as part of the Galisteo Watershed Restoration Project –phase 2 (2002-2005). This project was sponsored by the New Mexico Environment Department with financial support under Clean Water Act Section 319(h) administered by the US Environmental Protection Agency. The project protected surface water quality in New Mexico waters by reducing nonpoint source pollution of the waters of the Galisteo Creek.

Introduction to Erosion Control is an illustrated field guide for the general promotion of erosion control techniques. It is designed to be used by a broad audience that includes project managers, government officials, participants of educational workshops and field tours, along with contractors and volunteers (during installation of structures). This field guide is not to be used or interpreted as a design manual.

Three-thousand five-hundred copies were printed in the first edition, three-thousand in the second.

Cover Photos:
Front: [left] One-rock dam, Red Windmill Draw, Malpai Ranch; [middle] The same dam, a little while later; [right] Large one-rock dam, Torreon Chapter, 2002. (Photos courtesy of Van Clothier and Earth Works Institute.)
Back Photo: Log and fabric step falls installed on San Pablo Creek near Cuba. (Photo courtesy of Mike Chavez.)

I. Introduction to Erosion Control

Why this Field Guide?

The soil, the upper part of the earth's "skin," is a living environment. The top soil layer, typically 4 inches or less in our desert climate, includes billions of microorganisms per cubic foot. The top soil also includes plant roots, fungi, worms, and insects. One part of this living tissue grows into living organisms such as plants, mushrooms, and small animals, while the other part helps break down dead organic material into components that serve as nutrients (minerals and "vitamins") for the regeneration of new life. To function well as a spawning bed for life, all soil needs is sun, air, water, and plant residue.

This field guide is intended to inform those of us who depend on the soil and its life-giving properties. In this guide, we will discuss ways to regenerate soil so that it holds more water, supports more vegetation, and reduces soil erosion. In the end, soil conservation will reduce "non-point source pollution" in our surface watercourses. We will focus on affordable and replicable techniques based on natural processes and advocate the use of low-cost and locally available, natural materials.

Restoring the "Sponge"

The soil plays a crucial role in the regeneration of life on earth. Therefore, it is of utmost importance that the soil structure, composed of mineral particles, decomposing organic matter (humus), and microorganisms, is of optimal quality to help regenerate life.

One of the most important factors in the soil's structure is its capacity, like a sponge, to absorb water and hold it in its pores. Degraded soils have lost their sponge capacity. Soil conservation and restoration in our desert climate must focus on restoring the sponge effect.

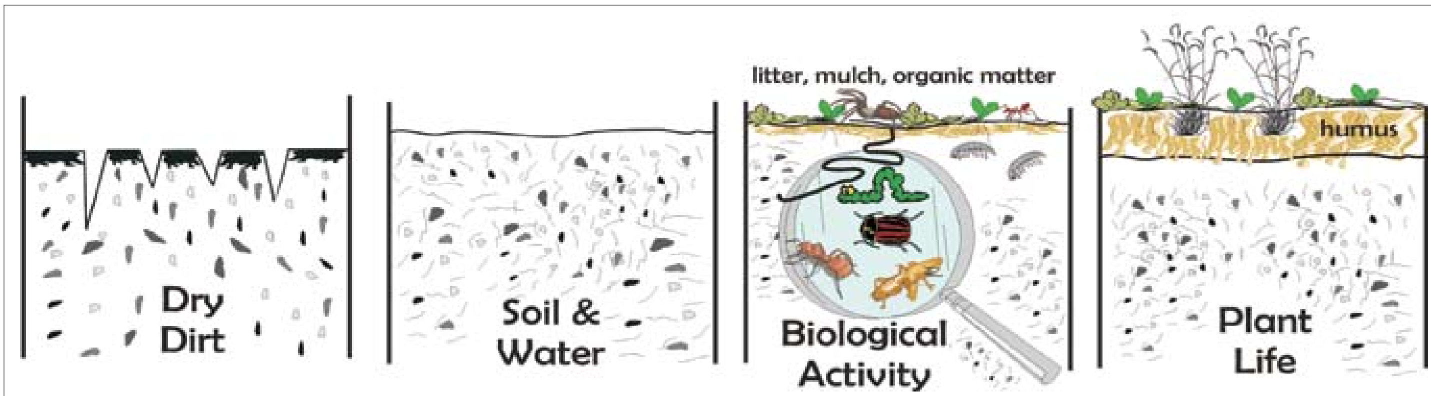
In many landscapes in the West, soils have been seriously degraded by the impact of uncontrolled land uses, such as unmanaged grazing, mining, construction, pollution, and excavation. In many cases, these activities have led to a hardening or removal of the top layer of the soil. As a result, it is difficult for rain or snow melt to infiltrate the soil. Instead, precipitation runs over the land surface in large quantities. Poor infiltration depletes the soil's ability to absorb water and sustain plant growth.

If we want to bring back life to degraded land, it is important to help the soil retain more water. One way we can do that is to direct water to sites where infiltration occurs or is enhanced. Once water is slowed down or retained, it is given more time to soak into the soil. In that process, the soil's crusty structure softens and allows more water to soak in and cling to soil particles. In addition, it enlivens microorganisms, such as mycelium (fungi), that help transport water from the pores in the soil to plant roots. The roots "wake up" and become more able to absorb the water to strengthen the above-ground plant parts. In sum, water harvesting reinvigorates existing plant life.

In addition, if the moisture is retained long enough and if it is replenished effectively, dormant seeds in the soil may germinate. The renewed and reinvigorated plant life intercepts and slows down precipitation as it runs off along plant leaves and stems to soak into the soil. Plants also slow air movement and cast some shade on the ground, reducing evaporation, so that more water in the soil is available to plants. Plant stems and roots hold together the soil, dead plant matter adds to the organic components of the soil and stimulates the proliferation of microorganisms, and plant roots again support other microorganisms. In this way, plant life helps develop soil structure and biological activity (Figure 1).

This biological process also helps retain and catch soil particles, thus reducing soil loss due to erosive forces and reducing pollution of waterways with dirt (a major form of non-point source pollution in the Southwest). The result of "sponge" restoration is the resurgence of native plant growth and the reduction of unchecked runoff and erosion. With this, the native ecosystem

Figure 1. Restoring the soil's "sponge" capacity restores the watershed.



receives an indispensable boost to its capacity to begin a new cycle of plant succession. Typically, plant diversity will increase, meaning the number of perennial plants, the percentage of ground cover, and with all this the resilience of the plant community to sudden, catastrophic impacts (fire, pests, flooding, drought). In addition, plant communities help create habitat for an increasing number of insects, arachnids, reptiles, birds, and mammals. Eventually, the landscape may become productive again for managed human use, such as a garden, farm, or pasture.

II. Landscape Degradation Processes

How do landscapes lose their water-storing capacity?

Slopes: Sheet, Rill, and Wind Erosion

When the topsoil is disturbed, its plant cover destroyed, and its structure broken, microorganism life decreases, water is readily drained, and a crust forms on the soil hampering infiltration of water. As a result, seeds and microorganisms wash or blow away. Technically, soil erosion occurs when there is insufficient cover to protect the soil's surface from raindrop impact or the shear stress of flowing water. Erosion worsens with increasing slope angle, slope length, and fragility of the soil.

These weakened soil conditions then increase the impact of raindrop splash, wind, and storm water runoff. Soil loss (erosion) in the form of sheet flow, rills (small erosional rivulets), and gullies will follow.

Gully on San Pablo Creek.

Eventually, the water table drops as a result of the draining of the soil. When water rapidly runs through clay soils, mineral compounds, such as salts, are leached out (deflocculation). The clay loses its structure and is blown or washed away. Too much air in the clay hampers plant growth and increases underground water drainage, causing tunnel erosion (piping). Eventually the soil collapses, which is the beginning of gully erosion.

Gullies and Badlands

Gullies occur when rills converge in a concentrated flow of surface runoff. As the soil surface steepens, the velocity of the surface flow increases and the energy of erosive forces increases exponentially.

Runoff causes an abrasive force on the soil. Where the grade steepens or where the soil hardness changes abruptly, runoff will scour more and create a headcut. Headcuts travel upstream disturbing more soils, and gutting entire hillsides and pastures. Headcuts increase rapid runoff as a result of increased drainage patterns. The end is what is called "badlands": a landscape with a multitude of gullies and headcuts, flat areas consisting of rock and gravel, and devoid of vegetation. The regeneration capacity of soils in badlands is minimal due to poor soil structure, very low water holding capacity, lack of seeds, and absence of microbial life.

Gully near Santa Rosa.

III. General Soil Healing Techniques

Soils can be healed through water harvesting and soil improvement techniques.

A. Water Harvesting

In our dry, Southwestern landscapes, effective rainfall for plant growth is scarce and often further limited due to unintended water losses. Therefore, it is important to harvest as much precipitation as possible and make it infiltrate the soil. Water that is stored in the soil evaporates slowly and flows gradually downhill to the main watercourses and wetlands of the area, providing valuable flow to springs and seeps, which maintain riparian habitat. Water harvesting on slopes can be achieved best by placing barriers on contours, technically forming a small terrace. Regionally appropriate, low-cost harvesting techniques include:

- Structures that retain or divert stormwater runoff, such as rolling dips, diversion drains, swales and berms, and micro-catchments. These structures are designed to hold the water back and water should not flow over them. They are, therefore, high enough to retain or divert the water flow.
- Structures that slow the flow of water to give it more time to infiltrate, such as one-rock dams, rock lines on contour, straw wattles, and strawbale dams. These structures are designed to be overtopped by water flows and are therefore rather low.
- Mulching: the spreading of a protective layer on top of the soil to protect and enrich the soil. Organic mulch protects the soil against wind erosion and evaporation, and adds organic matter while decomposing. Mulch also provides a more cohesive structure

to the soil, which helps keep soil particles together. Mulching can be combined with other techniques, such as enriching the soil with compost.

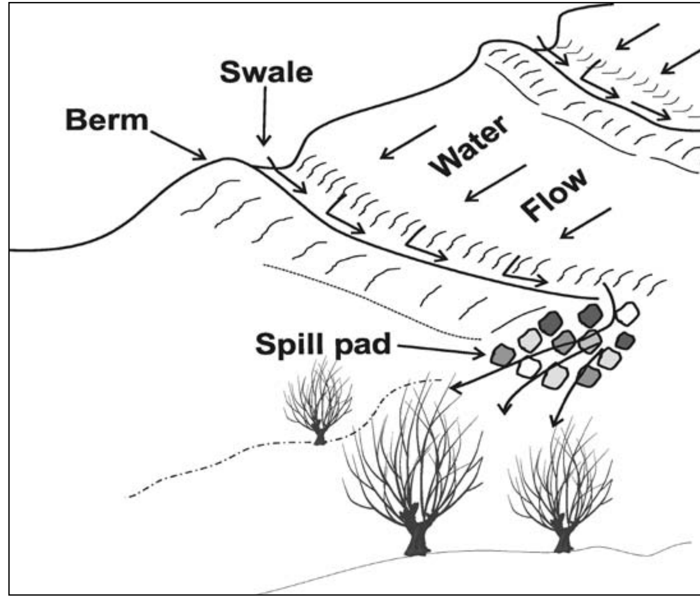
1. Retention and Diversion Structures

Rolling dips are shallow depressions with gently rolling humps on the down grade side, diagonally placed across roads and trails, to divert runoff from the road surface to a side drain or slope. The dip and hump are wide rather than deep in order to cause the least hinderance to traffic. Dips and humps should stretch the length of the average car using the road. Humps are best made in a triangular shape with the apex of the triangle pointing toward the outslope of the roadway.

Diversion drains are trenches (swales) with an earthen wall on the downhill side (berms) that are laid at a grade of 0.5 to 1% on the slope to divert flows to a stable drainage path (rock surface, riprap spill path, stabilized gully, or grassed waterway) (Figure 2). The mouths of diversion drains are armored with rock to prevent headcut erosion. Diversion drains should not be filled with plantings or lined with mulch as this will lead to the deposition of sediment that obstructs water flow and causes water to breach the wall and create unwanted erosion.

Swales and Berms are shallow trenches following the contour of a hillside. The excavated dirt is piled in a linear mound on the downslope side of the trench, creating the berm. Swales

Figure 2. Diversion drains.



capture runoff and make it soak in the soil. Swales and berms work best on well-drained, sandy and loamy soils in conjunction with other soil conservation and water harvesting techniques. On clayey soils infiltration is too slow, which may cause swales to overflow and breach, which exacerbates the erosion we intend to stem. Swales and berms are labor intensive to install and need annual inspection and maintenance, which make them less desirable in extensively used, large areas, such as rangelands.

Micro-catchments (also called boomerangs) are half-moon or V-shaped mounds with shallow depressions behind them. These depressions can make excellent planting areas for trees, shrubs, or grasses.

2. Water Slowing Structures

One-rock dams are so named because they are only one rock tall. The dam should be built with several rows of rock across from the upstream to the downstream edge. The dam should not be taller than 1/3 bankfull depth of the planned channel (Figure 3 and Figure 6, page 11).

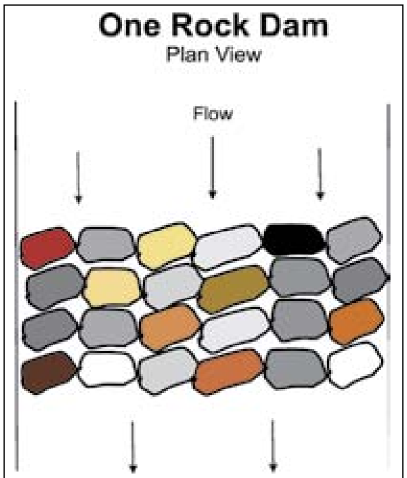


Figure 3.

Stones should be selected, sized, and placed so that the completed structure ends up relatively level from bank to bank and flat from the upstream edge to the downstream edge. This can be accomplished by placing larger rocks in the deepest part of the channel, smaller ones to either side (Figure 6, page 11). Do not stack rocks on top of one another to get the needed height. The stacked rocks will be swept away by flood flows. Placing greatly oversized rocks in the structure will generate turbulence that could undermine it. Rocks should be sized proportionately to the 1/3 bankfull depth of the channel, 20-40 pound rocks for a channel one foot deep, 60-80 pounds for streams one and a half feet deep. Flood flows will pack smaller-sized bedload particles between the rocks, gradually strengthening the structure over time as a new riffle begins to develop at the site (see photo on page 11).


Rock line at Torreon Chapter, 2002.

Rock lines and/or log lines on contours are simple structures that slow sheet flow on a slope. By placing rock, logs, or branches on the contours of the hillside, stormwater runoff is slowed down and sediment trapped behind the structures. Over time, the barriers and sediment will help water to infiltrate more easily, while leaving dirt in place. The materials blend in the landscape. The structures are easy to install and easy to maintain. They work best on gentle slopes of 10% or less.

Straw wattles are sausage-like devices made from straw held together in a biodegradable mesh with a diameter of 6-12 inches. Placed on the contour and pegged down with steel pins or wooden pegs, they slow runoff and help water infiltrate. Over time they disintegrate and add a mulch cover to the slope. Straw wattles became popular in the 1990s in restoration projects on burnt forest areas. They work best on short, gentle slopes of 10% or less.

Straw wattles at the Lippard property, Galisteo watershed, 2001.

Straw bales can be very effective as temporary sediment and runoff catchment devices. They are effective in clayey and loamy soils with sheet flow that moves a significant amount of sediment and in shallow gullies with low flows. They are particularly useful in locations where there is an absence of rock and brush and where you need more mulch and organic matter in the soil. Straw bale dams should not be used in sandy areas where saturated sand may wash away beneath or next to the strawbales. They should also not be used in deep gullies with high flows where the shear stress of the water will easily break through the straw bale (see pages 13-14).

3. Mulch for Soil Cover

Covering the soil with live or dead material reduces evaporation, runoff, and erosion. A soil cover of inert material such as wood chips, straw, or pebbles is called "mulch."

Mulch can also be applied in the form of pre-fabricated blankets or mats of fibrous materials, called "erosion cloth." For our dry Southwestern landscapes, it is advisable to select relatively light and thin erosion cloth in order to allow plants to grow through it. Mulching may benefit the soil by:

- slowing erosion
- helping jump-start the regeneration of plants
- moderating soil temperatures
- controlling weeds
- eliminating soil crusting, allowing water, air, and nutrients to penetrate better
- reducing evaporation

Organic mulches have additional benefits, because: (1) they provide nutrients to the soil when they break down, and can decrease soil nitrogen levels during decomposition; (2) they keep soil temperatures lower; and (3) they can increase the population of certain soil organisms and insects.

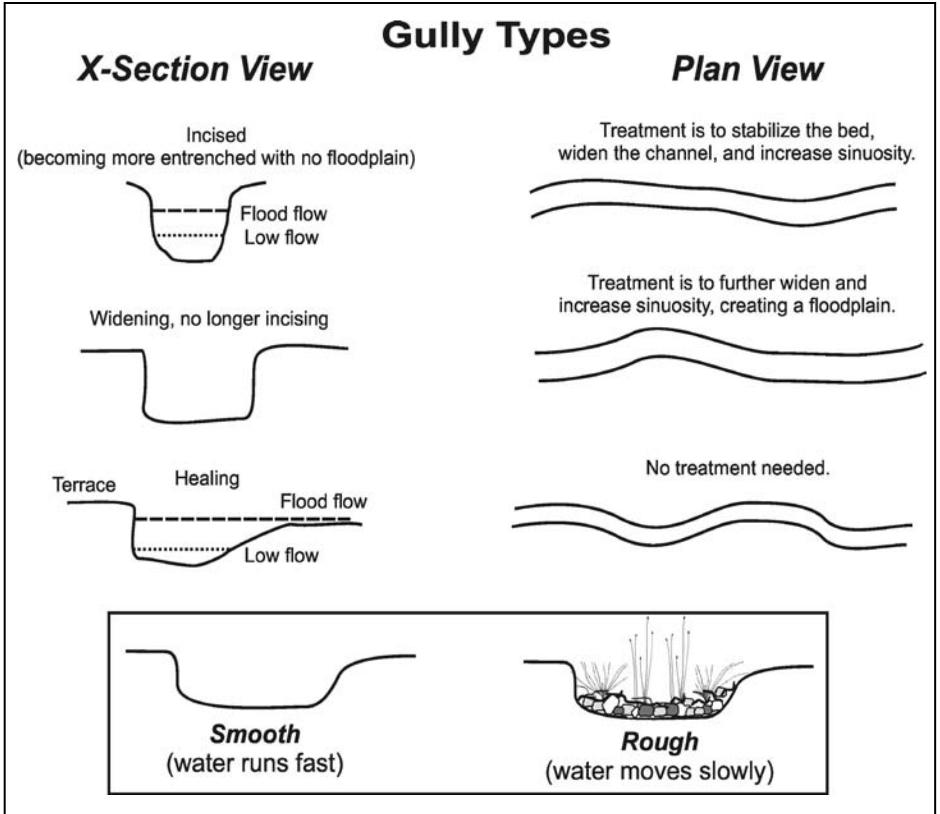
B. Soil Conservation

Besides the techniques described above to capture and conserve storm water and runoff from snow and other forms of precipitation, we need to conserve and improve the soil. Soil conservation and improvement techniques include those that improve soil structure and texture, and soil fertility. We can improve soil structure and texture by applying organic matter (manure, compost, or mulch) or clay, sand, or lime, and by breaking the crust and loosening the top layer of the soil. The latter can be accomplished by raking, tilling, or imprinting the soil or by the hoof impact of animals. Over time, planting vegetation will also improve soil structure and texture. We can improve soil fertility by applying minerals and nutrients in the form of artificial fertilizer or manure, or by the manure produced by direct grazing. In some cases, we have to kick-start biological activity of the soil by inoculating the soil with fungi spores (mycelium) and trace minerals, such as magnesium and manganese, and by spreading seed or planting seedlings of shrubs and trees. In some cases, it may be beneficial to introduce animal life through managed grazing or the introduction of rodents, insects, or birds. The fauna will increase the breakdown of organic matter, availability of minerals and microbes in the soil, dispersal of seed, and the pollination of plants (see also the companion publication, ***Rangeland Health and Planned Grazing Field Guide***, July, 2004). Last but not least, we will conserve soils by altering our land use patterns in such a way that the impact we have on the soil is reduced. Fencing out trespassers, especially off-road vehicles and horses, redesigning roads and trails to spread runoff, and managing the impact of wildlife and domestic animals are crucial to the protection of the fragile soils in the Southwest.

IV. Healing Techniques for Gullies and Headcuts

In a gully, surface runoff is concentrated and acceler-

Figure 4.



ated and surface protection is reduced. Any disturbance can generate a migrating headcut (Figure 4 and Figure 5, page 10). Disturbance exposes the less cohesive subsurface soils to the erosive force of running water, thus increasing the headcutting.

Healing Principles:

- Disperse surface flow, prevent concentration, increase infiltration and percolation.
- Reduce channel slope to reduce runoff velocities to reduce available energy.
- Widen channel bottom to lessen erosion force.
- Increase channel roughness.
- Retain soil moisture to improve environment for colonization and growth of plants.

A. Gully Treatments

Gully treatments can include grade control structures, induced meandering, water harvesting and revegetation.

This manual will feature hand-made treatments and, for the most part, locally available,

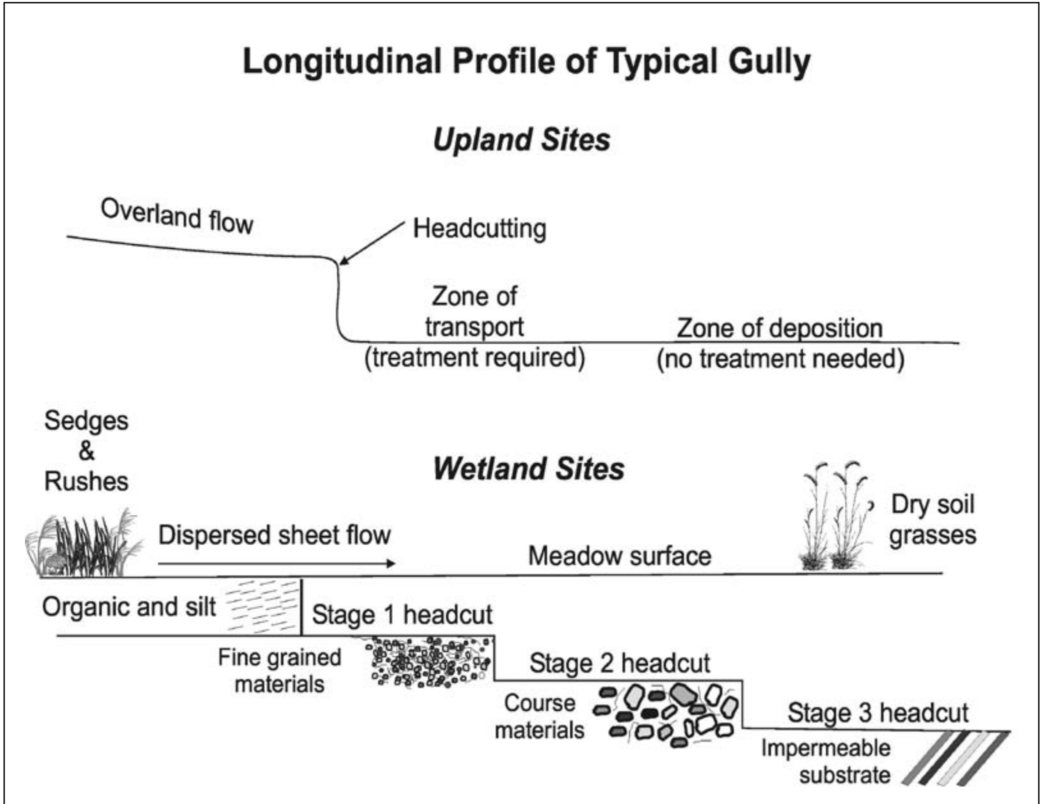


Figure 5.

natural materials such as rocks, logs, trees, brush, and straw bales. Artificial materials are limited to sand bags, erosion fabrics, and wire. Use of wire baskets, concrete, and steel structures will not be addressed.

1. Grade Control

The primary purpose of a grade control structure is to keep a gully from eroding deeper. Properly used, grade control structures are the first step in reversing the erosion process and initiating sediment deposition, water harvesting, nutrient retention, revegetation, and bank stabilization. Grade control structures are especially important in harvesting a bit of water from each storm flow in order to irrigate and nurture newly established plant growth. Vigorous plant growth is critical to increasing channel roughness, trapping sediments, detaining and retaining organic debris, and capturing soil nutrients. Ultimately, it's the new vegetation that stops erosion, not the structure itself.

Grade control structures include one-rock dams, log mats, felled trees, brush dams, wicker weirs, and straw bale dams. In all cases, emphasis is placed on keeping these structures low in profile and compact in form. In contrast, check dams tend to be tall in profile and designed to trap large volumes of sediment and water. Check dams tend to be vulnerable to undercutting and endcutting when too much water is stored behind the dam or once the structure has filled with stored sediments.

One-Rock Dams. A one-rock dam consists of more than one rock! The key to its success is that rocks are placed only one tier deep! They are not stacked. Rocks are placed in several, parallel rows across the gully floor and packed tightly together. A row of rocks should be of equal height and appear relatively flat or level from bank to bank (Figure 6). The elevation of the upstream row can be slightly higher than the downstream row so that the dam slopes gently from the top edge to the bottom edge.

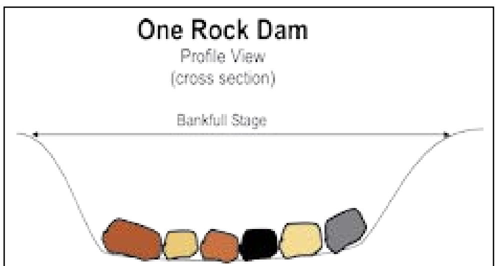


Figure 6.

Dams consisting of 3 to 5 parallel rows of rocks have considerable mass but minimal surface exposure to the force of moving water (Figure 3, page 6). Therefore, advancing flood waters slide across the surface of the dam rather than pushing against it. Because the dam is low in height, the water drops only a few inches and has little power to erode a scour pool that might undercut the structure. Successive floods pack sand, gravel, and organic material between the rocks forming an excellent seed bed for new plants to colonize the site. Moisture accumulates under the rocks to nurture the young plants. Soon the roots of the maturing plants bind the rocks of the dam together for greater resistance to successive flood forces.

One-rock dam at Torreon Chapter, 2002, doing what one-rock dams are supposed to do, hold water and grow grass.

Log Mats. Log mats are fashioned from one tier of small logs wired together and staked in place. Logs are oriented parallel with the current to minimize bed scour rather than perpendicular to the flow. Log mats conserve moisture, detain sediments and shelter young plants.

Wicker-Weirs. Wicker weirs are small dams across a creek or gully built by driving sharpened stakes or pickets into the channel bed and then weaving saplings, tree limbs, or willow cuttings between the stakes perpendicular to the flow (Figure 7). They are designed to control streambed elevation, channel slope, and pool depth while enabling free passage of water.

Brush Dams. Brush dams are built of loosely piled brush or tree branches piled in gully bottom. These can be wired together for strength and increased stability. Keep them loose and low in height in order to stimulate plant growth. Tall, thick brush dams smother new plant growth.

Felled Trees. Felled trees (can be full length) should be placed one layer deep with the top pointing down stream. Their branches become impaled in the gully bottom, holding the trees in place. Green trees will tend to bend and mold to irregularities in the stream bottom and are preferred to dead material.

Straw Bale Dams. Straw bales can be effective if embedded at least 80% of their height in a trench and staked in place. Straw bale dams are especially vulnerable to end cutting and undercutting if flood waters are impounded too deeply. A key advantage of straw bales is the ability to trap seeds and plant propagules from the water flow and to store water, sponge like, for extended periods of time to nurture new plant growth.

Figure 7.

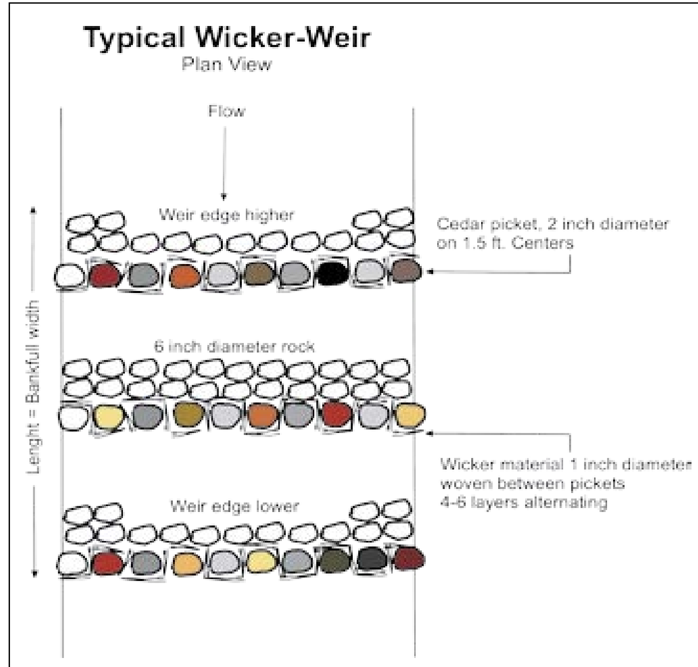
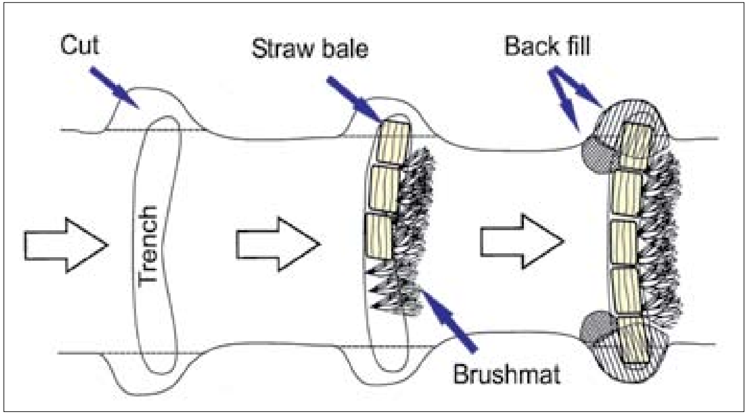


Figure 8.



Straw bale dams are constructed by placing straw bales across the contour of a slope or across a gully channel. To prevent the bales from floating away, it is important to dig a trench as wide as the width of a straw bale and at least 80% of its height or deeper (Figure 8). The trenches should be deeper at the center of the gully. Seen from above, they should form a slight V shape or half moon shape with the point or bottom of the curve pointing upstream. This proper installation will allow the bales to form a lower point at the center of the dam where the water can overtop the bales if necessary and remain concentrated in the center of the channel.

Straw bale dams need to be shaped with a spillway that can accommodate at least a 5-year flood. Make sure that the trenches extend into the banks for several feet (in wide channels, for the length of one entire straw bale), and make sure that the tops of straw bales placed in the banks are as tall as the highest flow you expect once a year in the gully (Figure 9). Place the bales in the trench, leaving the bailing strings attached facing up. This allows the bales to be gently curved in the trench and to absorb moisture faster, while maintaining their integrity. Construct a mat of brush, rock, or preferably another straw bale (partly buried in the ground) at the toe of the spillway to serve as a spill pad. The spill pad must be as wide as a straw bale and

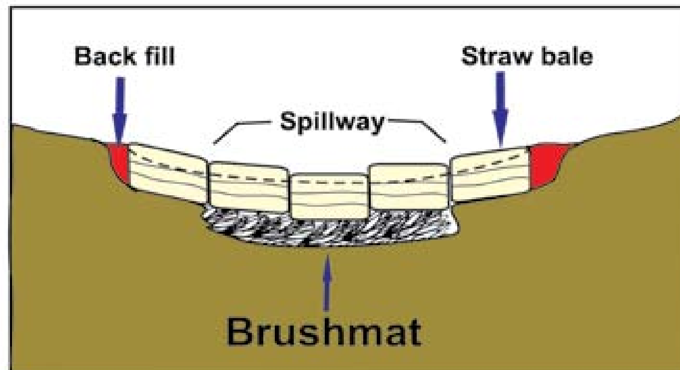


Figure 9.

span the width of the streambed of the gully. The dirt remaining from digging the trenches should be used to backfill holes and openings around the straw bales.

2. Induced Meandering

Induced meandering is an erosion control method which uses instream structures and vegetation manipulation to increase channel sinuosity, bed stability, alluvial bank storage, floodplain development, and channel roughness. For more information, see the companion publication **An Introduction to Induced Meandering: a Method for Restoring Stability to Incised Stream Channels,** June 2003.

Strawbale headcut control on contour, Galisteo watershed, 2001.

3. Water Harvesting Structures

Water harvesting structures are used to pond water temporarily, soak gully banks, increase bank shape, irrigate streambank vegetation, and extend the active growth period for colonizing vegetation. Such structures are especially useful in clayey gullies where infiltration and percolation rates are slow and banks bake hard like adobe in the hot summer sun. Such structures are less important in sandy or gravelly gully systems.

Sand Bag Dams: Sand bag dams are useful in slowing and retaining moisture in small, first-stage gullies incised in former wet meadow and cienega sites. Sand bags are relatively light in weight and easily displaced by high velocity flows and should only be used where low to moderate velocity flows or sheet flows are expected. Placing sandbags at the upstream edge of a rock dam or log mat will provide physical support against strong flows.

Sand Bag Burritos: Sand bags are vulnerable to rapid decay. Burlap bags rot, while woven plastic sandbags decay in ultraviolet light. Wrapping sand bags in a layer of erosion cloth or silt-fencing fabric protects bags from sunlight and extends longevity. The disadvantage is that the fabric will suppress plant growth.

4. Streambank Protection

Streambanks and gully banks erode at variable rates depending on the relative stability afforded by vegetative or mechanical cover. Bank erosion can be caused by stream flow, overland flow, mass wasting or slumping, frost heave, and sloughing with repeated cycles of wetting and drying. Ice flows and debris flows can exacerbate the erosive effects of flooding.

Basically, two types of streambank stabilization methods are available: revegetation and mechanical protection. This booklet addresses only revegetation techniques. Mechanical protection includes rock mattresses, rock baskets, rip-rap, concrete, boulder placement, vanes, deflectors, revetments, and groins. Please consult professional journals and books for details on these techniques.

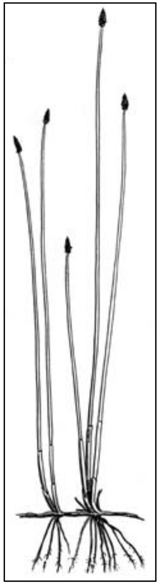
Revegetation Management. Streambank stability can be accomplished by establishing a vigorous stand of vegetation. Native species are preferred. Successful revegetation depends upon effective control of herbivory (grazing or browsing by wildlife and domestic livestock). Control can include total exclusion, seasonal grazing, or species-specific measures such as elk-proof fencing or beaver exclusion. Human uses such as hiking trails may need to be restricted as well as ATV traffic to prevent repeated trampling.

Revegetation success can be enhanced by supplemental irrigation especially through the first growing season after planting. Sprinklers, flood irrigation, drip systems, or even hand watering by bucket can be effective until plants become self-sufficient. Sprinklers are especially effective in stimulating germination and growth of native seeds stored in the natural seed bank or dispersed by the wind.

Cottonwood pole planting on first terrace, Richardson property, Galisteo watershed, 2002.

Herbaceous Species. If soil moisture is favorable, a variety of wetland herbaceous grasslike species can be planted as sod wads, or mats, simply by excavating healthy reproductive materials from established populations and reintroducing them to the new site. Most wet-soil species spread naturally from propagules such as bulbs, tubers, or rhizomes and are adapted to

Sedge (Carex).



uprooting, dispersing by floods. Examples include sedges (Carex), bullrushes (Scirpus), rushes (Juncus), and cattails (Typha). Care should be taken not to spread exotic plants and weeds such as salt cedar, musk thistle, or curly dock incidental to transplantation of desirable species.

Woody Trees, Shrubs, and Vines. Willows can be planted as cuttings, or as rooted stock, or as transplanted wildlings. Willow cuttings are best planted during late winter or spring but can be successfully transplanted in any season if the water table, or its capillary fringe, is within reach of the plant roots, or if transplants are irrigated. Many techniques have been used, ranging from individual stems to standing bundles and wattles. In some studies, success has been achieved when four to six cuttings are bundled and planted together in a single hole, dug to water table depth. After back filling the hole with soil, the bundle should be thoroughly wetted and firmly tamped to remove air pockets that would stifle root development. Cuttings should be pruned to an average above ground height of 2-3 feet in order to reduce water demand in excess of that which newly developing roots can provide.

Some riparian species cannot easily be reestablished as cuttings but should be transplanted from rooted stock or as tublings. These include alders, wild cherry, currants, hackberry, walnut, sycamore and boxelder, for example. Wild roses, however, are easily established as cuttings or as dormant stock.

Cottonwood poles should be planted during late winter or early spring in order to give cuttings time to develop a root system prior to leafing out. Poles should be planted at the level of the first terrace, not within the floodplain, because cottonwood poles are easily damaged during floods.

B. Headcut Treatments

Headcuts are characterized by:

- a waterfall or abrupt change in slope of a streambed
- a fragile, cracked, or crumbling lip of the falls
- a bowl-shaped pool at the base of the falls (plunge pool)
- undercutting
- rapid headward erosion during flood flows
- drying, cracking, and sloughing during the dry season

The higher the falls, the more power available for eroding soil substrates at the base of the cut and the more difficulty in repairing the headcut. Turbulence at the base of the falls undercuts the headwall, which leads to cracking and sloughing. Exposure to sun and air during no-flow periods further dehydrates the soil.

Headcut on the Dry Cimarron, near Folsom, NM.

Healing Principles:

- Lower the height of the falls in order to reduce the force of falling water.
- Widen the lip of the falls to disperse concentrated flow.
- Harden the base of the falls to protect substrates from erosion.
- Conserve soil moisture to enhance plant growth and root densities.

Successful headcut control depends on the successful application of the above principles. These are some techniques that have been shown to be effective:

- Worm Ditches
- Log and Fabric Step Falls
- Straw Bale Falls
- Rock Bowls

Worm Ditch (Bypass Channel). One way to stop a headcut is to starve it for water. Accomplish this by digging a bypass ditch around the headcut (Figure 10, page 18).

A successful bypass will require: (1) a broad valley with sufficient space between the gully and the hill slope for the worm ditch; (2) a well-armored re-entry point downstream of the falls, and (3) wetland soils capable of supporting a dense growth of wetland plants such as sedges.

Select a starting point above the headcut that will collect most of the concentrated runoff. A point 50 to 100 feet upstream should suffice. Select the re-entry point downstream. Measure the straight line distance (the "valley length") between those two points. The constructed worm ditch should have a channel length about two times the valley length and a constant slope of about 1%. Tip: Use a length of rope twice the valley length. On a trial and error basis, lay out the rope in a series of evenly spaced meander

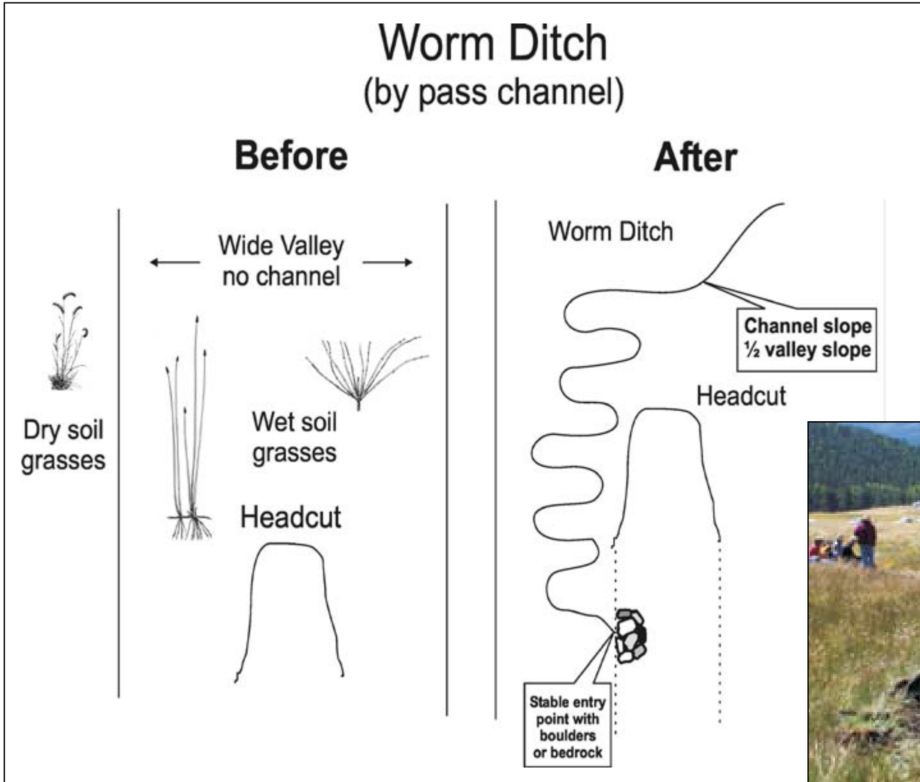


Figure 10 [above]. [Right] Worm ditch near Comanche Creek, Valle Vidal.

loops connecting starting and ending points. This will be the course of the new channel.

Using a sharp spade or shovel, dig a meandering channel next to the rope. Make it 12 to 18 inches wide and 6 to 12 inches deep. Scatter the soil. Do not build a levee along the downstream edge of the ditch except to plug any low spots. Flood flows will follow the channel but some water will spill over to irrigate the wetland plants and heal the cut.

Log and Fabric Step Falls (Headcut Control Structure For Moist Soils). This structure is used to control headcuts advancing through wet soil areas such as wet meadows, spring seeps and cienegas. The erosive action can be stopped if a healthy mat of wet soil plants can become established to hold the headwall in place.

1. Prepare the site by "squaring up" the headwall, sidewalls, and bottom of the channel. Eliminate the scour pool and any irregularities (rocks, roots, or indentations) in the channel bottom, sidewalls, or headwall. Use a shovel, spade, pick, or crowbar to shape the site. Save and stockpile sod clumps of wet soil grasses and sedges for use in the final step.

2. When preparation is finished, cut and drape geotextile fabric across the headwall, sidewalls, and channel bottom. Three pieces work better than one. The first should start about 2 feet above the lip of the headwall, extend down the headwall, and cover the channel bottom for 6-8 feet (the length of the bottom tier of logs). The second should be draped over one side wall and part way across the channel bottom. The third should be draped over the opposite sidewall in a like manner. Temporarily anchor the fabric in place by weighting the ends with rock or sod clumps. Once logs are placed, the extra flap of material will be folded back over the logs.

3. Install logs in the prepared site using as many tiers as necessary to stack them even with the lip of the headwall. (See Figures 11 and 12). Logs within each tier should be of the same diameter; between tiers, they can be of different diameters. Logs in the bottom tier should be the longest; the top tier, the shortest. For example, if three tiers are needed, make the bottom tier 8 feet long, the middle tier 6 feet, and the top tier 4 feet long. It is important to wedge logs tightly against the face of the headwall and sidewalls. When all tiers are in place, fold the extra flap of fabric

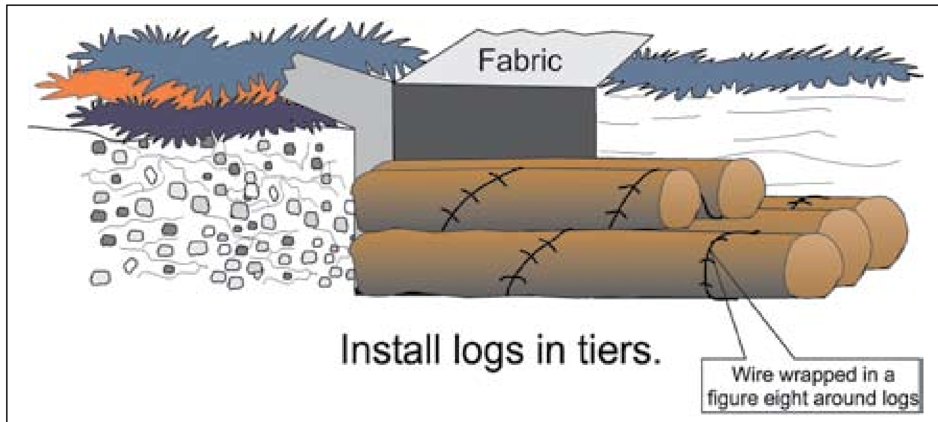


Figure 11.

back over the top logs. Using smooth wire and fencing staples, wire each tier of logs together as you go. (Wire tier one logs before installing tier two, etc.) Tamp soil into any open spaces between fabric, headwall, and sidewalls.

4. Working upstream from the lip of headwall, excavate a smooth platform level with the top tier of installed logs and one log-diameter wider on either side of the channel. The platform should extend at least 4 feet upstream from the lip of the headwall. Line the platform with the fabric extending out over the installed logs by 3-4 feet and upstream for 1-1.5 feet.

5. Using logs of equal diameter, install the final tier by wedging and tamping each log firmly in place (Figure 13). The logs should be long enough to extend about 2 feet downstream from the lip of the headwall. Wire this tier together and to the rest of the structure. Tuck the upstream flap of fabric in place along the leading edge (upstream face) of the logs in the final tier (see Figure 14 for cross-section of finished structure).

6. Transplant live green sod clumps of aquatic grasses, sedges, or rushes to the leading edge and sides of the final tier of logs. Completely fill any cracks or holes between the fabric and channel walls with live sod. **This is a key step.** The success of the log structure depends on your successfully establishing a living mat of wet soil grasses and grasslike plants along the upstream edge and sides of the structure.

7. After installation is complete, return to the site periodically (every 2-3 weeks initially, then less frequently) to fill any developing cracks or holes with fresh sod clumps until a healthy mat of vegetation is successfully established and no new cracks or holes develop.

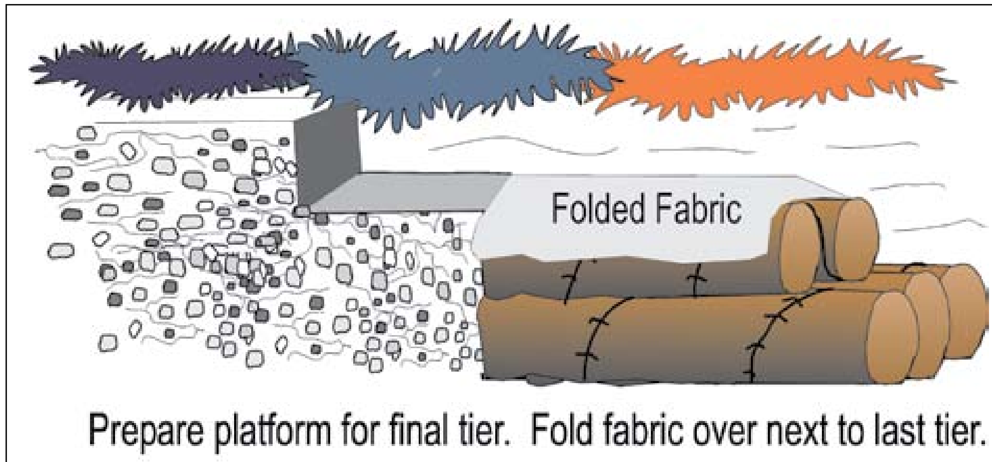
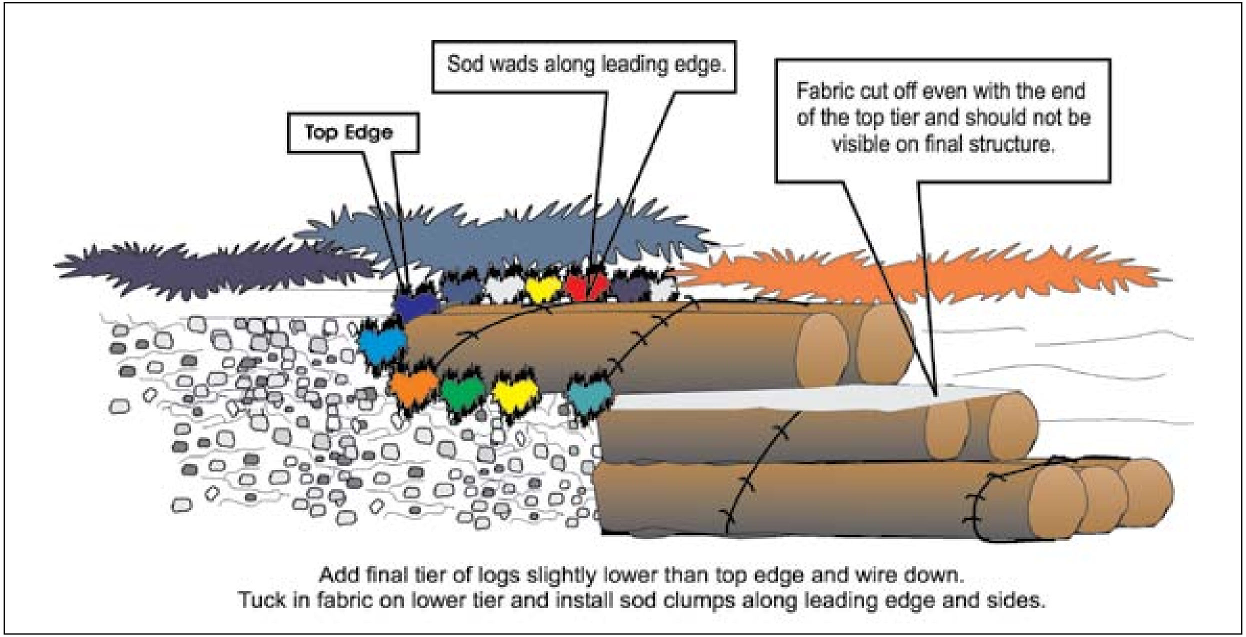


Figure 12.

Figure 13.



Materials Needed

1. Geotextile Fabric (silt fencing fabric in 3 foot widths works well and is convenient to use).

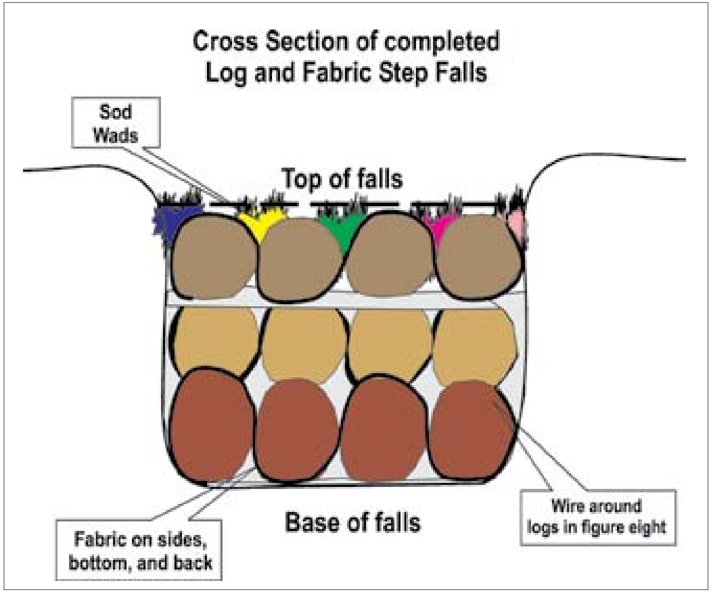
2. Logs: Logs 6 to 10 inches in diameter and varying lengths from 4 to 8 feet long. (For example, bottom tier, 8 feet long, second tier, 6 feet, third tier, 4 feet.) Logs should be straight, trimmed and green, or seasoned, but not rotten. Any protruding knots, limbs, or knobs make stacking very difficult and should be trimmed..

3. Wire: one roll of smooth fencing wire or barbed wire.

4. Fencing staples: 2 inches long, about 2 lbs.

5. Sod clumps: 6" X 6" X 3". Dig locally.

Figure 14.



Tools Needed

1. Shovel (for digging)
2. Pick (for squaring sidewalls)
3. Crowbar (for wedging logs together)
4. Axe (for cutting roots, trimming)
5. Utility knife (for cutting fabric)
6. Claw hammer (for driving staples)
7. Fencing pliers (for cutting wire)
8. Wheel barrow (transport logs, tools, materials)
9. Log carrier (optional – for lifting, carrying logs)

Straw Bale Step Falls. Straw bales can be used to stabilize the face of a headcut and conserve moisture until new plant growth becomes established. Tightly packed bales tied with wire are preferable to loosely tied string bales. Do not use straw bale structures at sites subject to livestock use or grazing (Figure 15).

Before placing bales, shape the face, sides, and base of the gully with shovel, spade or mattock. Excavate a notch at the base of the falls to seat the bales snugly against the face and sides. Be sure to allow plenty of space for the largest expected storm runoff event. Storm flow must be able to pour over the bales, not be forced to go around the bales for lack of channel capacity. Drive stakes or rebar pins through the bales to hold them in place.

Straw bales can be stacked up to 2 bales high and arranged as steps to reduce the force of falling water. It is not necessary to use silt fabric to conserve moisture since the bales themselves store moisture. Large rocks can be placed along the downstream edge of the structure to help anchor the bales.

Rock Bowl. A rock bowl can be used to heal low headcuts up to 2 feet high. Rock bowls harden the base of the cut, stop scour, protect the face of the headcut from drying, sloughing and frost heave; and conserve moisture for enhanced plant growth. The rocks capture sediments, debris, seeds, and plant propagules, and act as rock mulch that protects young plants.

Rock bowls usually require 2 to 4 wheel-barrow loads of soccer to basketball-sized rocks. Line the pool, face, and sides of the headcut with rocks up to the original ground level, but not higher. Next, move down channel from the lip of the cut about 3-4 feet and build a dam about one-half the height of the cut. Make it broad and wide and blend it with the lining to form a bowl shaped depression that will catch water pouring over the lip of the headcut. The face of the bowl should layer gradually down slope to blend smoothly with the bottom of the gully.

Lining the bowl with silt fabric will help catch sediment and detain moisture. If a lining is used, be sure to cover it with rock to secure it in place and hide it from view. Fabric is ugly!

Finally, go down channel and build a one-rock dam about 8-10 feet downstream from the rock bowl. This will help to trap sediment and retain soil moisture for new plant growth (Figure 16).

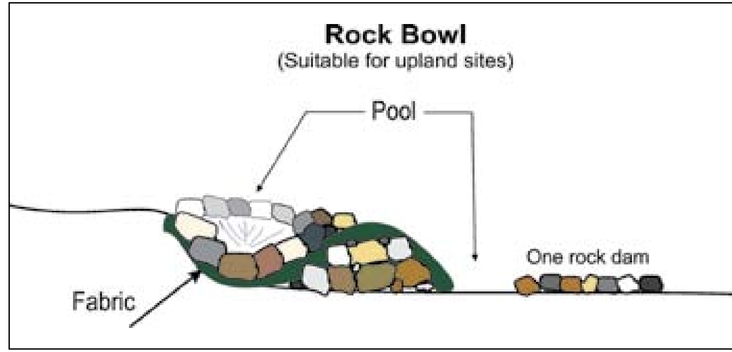
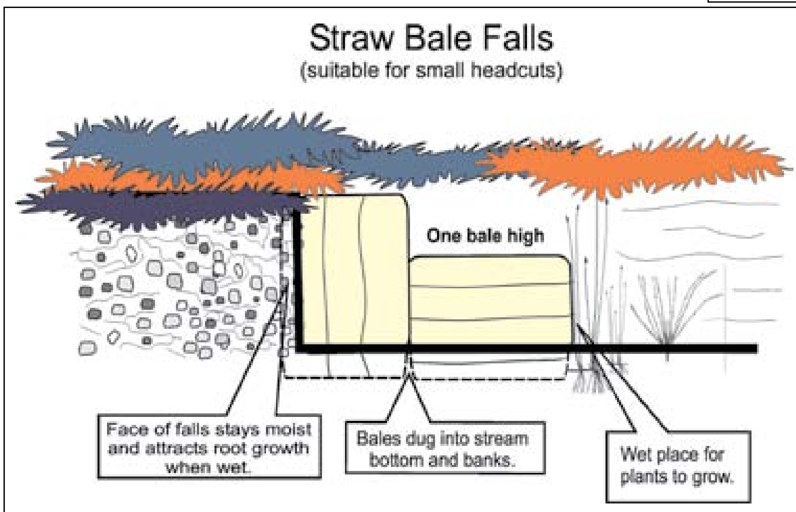
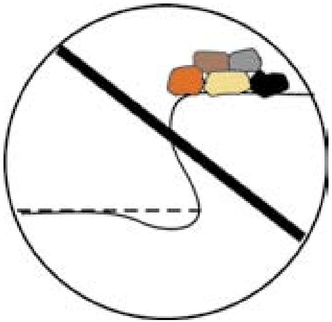


Figure 16.

Figure 15.



V. Not Recommended!



A futile treatment is to pile rock or other materials on the top of the headcut in the belief that doing so will protect the lip from erosion. Since headcuts advance with the progressive undercutting and collapse of the headwall, this treatment will not succeed. In fact, raising the lip only serves to increase the erosive energy of the water falling from a greater height.

Another futile treatment is to pile loose rock at the base of the headwall on the assumption that the rocks will blunt the force of the falling water, stopping the headcut. While this treatment works initially, a space will gradually open along the face of the cut due to drying and crumbling of the soil during dry weather and frost heaving in winter. As the space widens, more and more rocks will be flushed away and the headcut will continue to move upslope.

Piling brush at the face of the cut is sometimes effective, sometimes not, depending on the height of the cut and the nature of the substrate. Brush may trap other debris, thus mulching the site, keeping it moist and encouraging revegetation, but more often than not the cut will continue to move headward.

Dumping trash in a headcut is seldom effective and is never environmentally acceptable for obvious reasons.

When to Use What

TECHNIQUE	PAGE	WHEN TO USE
Brush dams	12	In shallow arroyos and drainages, where rock is in short supply; slopes less than 10%.
Diversion drain	5	At top of slope above a gully, or above series of structures to divert excess runoff from areas you cannot treat.
Felled trees	12	In shallow arroyos and drainages in forest and woodland areas; slopes less than 10%.
Log jumps/mats	12	In wet meadow/stream headcuts.
Log/fabric step falls	19	Use for advancing headcut to establish wet soil plants to hold headwall in place.
Micro-catchments	6	Use where swales are too inconvenient; in particular in combination with trees/shrubs.
Mulch	7	To reduce evaporation, runoff, and erosion.
One-rock dams	6,10	In small rills, gullies, shallow depressions on slopes, to increase, retain channel grade (loamy-clayey soils).
Revegetation	15-16	Stabilize streambanks.
Rock and/or log lines	6	Contoured on steeper slopes.
Rock bowl	22	Heal low (up to 2 feet high) headcuts.
Rolling dips	5	On roads, trails: to drain water to the lower road side.
Sandbag burritos	14	Former wet meadows/cienegas, in headcuts/first stage gullies to keep the bags lasting longer.
Sandbag dams	14	Former wet meadows/cienegas, in headcuts/first stage gullies.
Straw bale dams	12	In shallow arroyos and drainages, where rock and brush is in short supply; best in loamy, clayey soils.
Straw bale falls	22	Stabilize face of headcut and conserve moisture until new plants become established.
Straw bales	7	In loamy/clayey soils; on contours and/or to retain water in shallow gullies and rills.
Straw wattles	7	Over large areas on slopes of 10% or less, when there are no logs or rocks.
Swales and berms	5	In yards, gardens, around homes where maintenance is possible in well draining soils (sandy, loamy).
Wicker weirs	12	In 2-5% grade sandy/cobbly channels.
Worm ditch	17	A bypass channel to starve a headcut for water; use in broad valley with wetland soils.

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