

Appendix F

Conservation Stormwater Techniques

Grade Controls. Grade controls produce upstream and downstream effects. These effects are complex and interrelated. The design team must understand the interrelated processes of energy management, sedimentation and erosion. Grade controls prevent upstream migration of incision, stabilize banks by reducing bank height and dissipate streamflow energy. Grade control structures are constructed of shot-rock. The rock is sized to resist the highest expected shear stress, which may not be the 100-year flow. The rock should be well-graded, hard and angular and should not contain flat or elongated pieces. Large rock should form the crest and leading and tailing edges at the bank. Grade controls should be tied into banks. While grade controls are often placed in straight sections of the stream, by varying the degree and orientation of super-elevation, they can also be used to guide the flow around bends and manage energy through platform inflection points. The geometry of the grade control should direct the flow towards the center of the stream and reduce the shear stress on the streambanks. This is accomplished by shaping the leading edge in an upstream-facing “V” shape, although this detail is often omitted in small structures with low crest heights. Other energy management design features include setting the crest slope from the banks to the center and the position of the center of the crest relative to the bank abutments. The roughness of the large rocks and long downstream ramp further dissipate energy. The crests and downstream edges of the grade controls are protected with live stakes. As the vegetation becomes established it strengthens the soil while lowering the shear stress at the bank.

The general profile of a raised grade control includes an upstream slope of 5 horizontal to 1 vertical, a relatively flat crest and a downstream slope of 20 horizontal to 1 vertical. The crest width varies with the size of the rock and the ease of construction. The height of the crest is based on many factors, including reach hydraulics, configuration of nearby grade controls, and the health and public safety effects of standing water upstream of the grade control.

Like natural riffles, rock grade controls induce a drop in the water surface at low flows but can be hydraulically transparent at higher flows. The grade control can be flush with the original bottom. The increase in hydraulic roughness dissipates energy at low flows. An embedded grade control strengthens the bed, thereby preventing incision.

The grade controls behave as riffles and can induce scour holes or pools immediately downstream. This combination of pools and riffles is an efficient method of dissipating stream energy. A pool-riffle sequence also provides considerable habitat advantages. Healthy streams contain a broad variety of depths and velocities. Riffles containing coarse bed materials harbor macroinvertebrates while the deeper pools are preferred sites for fish. Finally, streams with a diverse and lively appearance are vastly more attractive than the monotony of a flat, shallow channel.

Grade control structures designed to raise the streambed are constructed of the same materials and with the same design philosophy as incision-stopping grade controls. The primary distinction is that in addition to arresting incision, these structures protect the streambanks by lowering the bank height. The height of the crest is selected based on

the flood hydraulics, the amount that the bed must be raised and the effects of standing water upstream of the grade control.

Live staking at grade controls. Live stakes are added to rock grade controls to provide additional energy dissipation and strengthen streambanks. The stakes are placed at the crest and downstream banks on approximately one-foot centers beginning at about one foot above the average low water line and continuing to the top of the streambank. Because many of the grade controls are located in deeply incised streams, it is especially important to consider the availability of sunlight at these sites when selecting plant species for stake material.

Geogrid reinforced composite revetments. This biotechnical engineering method is used in demanding applications such as artificially steepened slopes. The technique includes lifts of rock, soil, mulch and vegetation shaped by a geogrid spacer and reinforced with layers of geogrid. The slopes are planted with woody vegetation. The plants used in biotechnical designs are integral to the design and are selected primarily for their ability to stabilize the slope and protect the soil from both mass wasting and surficial erosion.

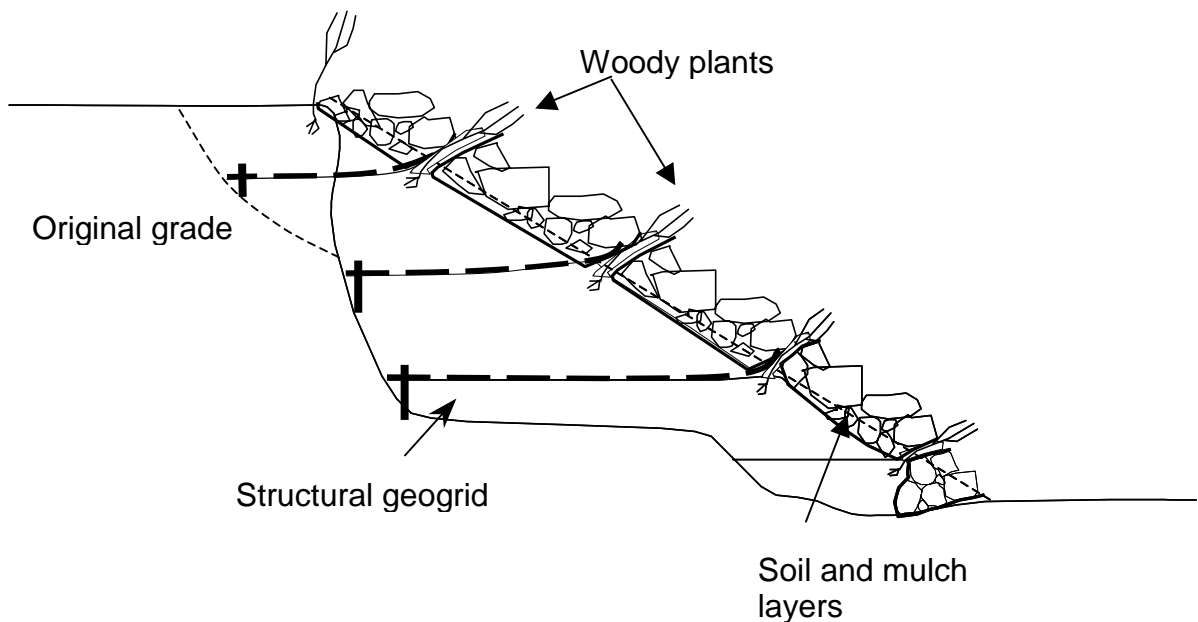


Figure 23. Reinforced Composite Revetment

Selection of plant materials for composite revetments. A composite revetment is a bioengineering technique suitable for high slope, high stress applications. The plant palette, or group of plants selected, for this technique should be capable of withstanding a high flow event soon after installation and should carry elements of a more mature slope as well. The palette should include plants with rapid establishment rates, a

combination of shallow and deep-rooted species and plants representing a range of mature sizes and growth habits. Other important selection parameters include habitat and aesthetic values, size at maturity, and spread potential. Composite revetments may be constructed using cuttings, live stakes or bare root stock, although bare root stock provides the longest seasonal planting window and widest variety of plant species.

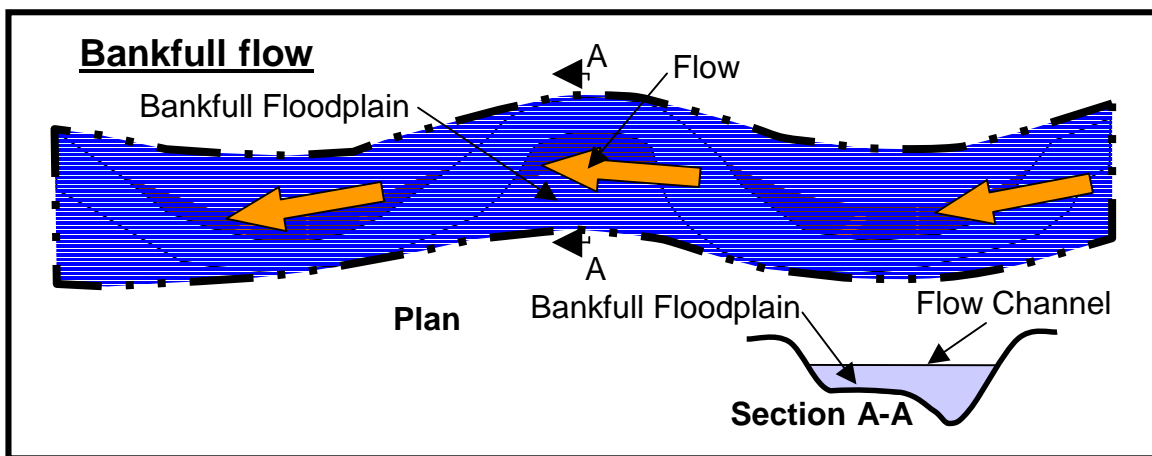
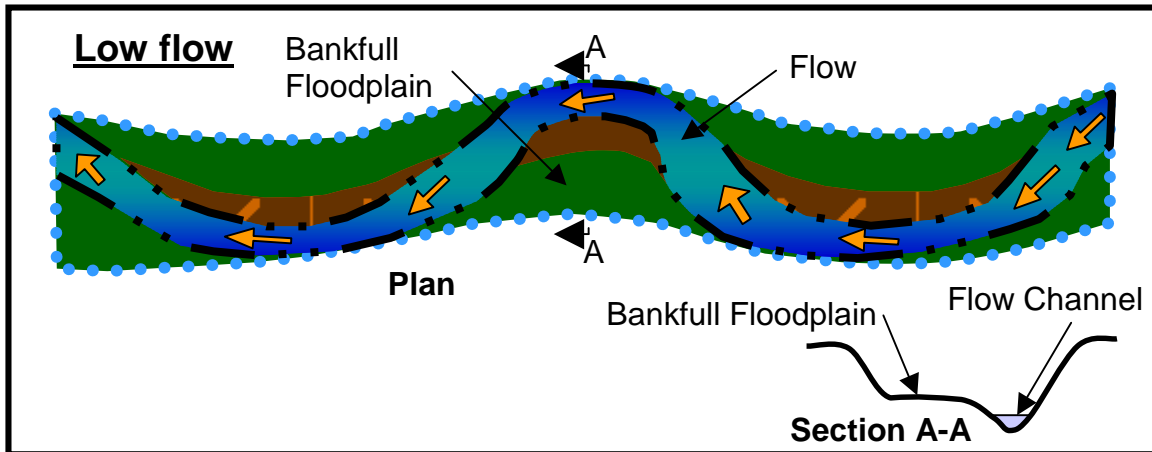
Shaping, protecting and replanting of slopes. Newly constructed slopes should be protected with coir erosion blanket. Care should be taken during installation to prevent tenting of the blanket. The blanket should be placed in such a manner that it is not in tension on the slope. It may be necessary to establish the new toe of the slope with coir logs. The coir logs should be planted with inundation-tolerant herbaceous species.

The slopes are generally planted at a density of at least 1 plant per 9 square feet. There should be species diversity. Plant density should transition from newly planted slopes into naturally vegetated slopes in such a way that the change in hydraulic roughness is not abrupt.

Selection of plant materials for slope protection. The plant palette and plan for slope protection is similar in many respects to that used for composite revetments. In addition to selecting plants that provide both rapid leafy cover and root development, it is important to re-establish a normal riparian forest structure to the extent possible. The inclusion of herbaceous species such as sedges and rushes in the toe zone and native grasses and forbs in the upland zones increases slope stability as well as the aesthetic value of the slope. As the woody species mature, they will eventually displace the grasses.

Meandering. Straightened channels can be meandered if the landform and flows can accommodate the slope of the meandered channel. Three-dimensional channel geometry should be reviewed by a geomorphologist and compared to reference reaches within the watershed.

Two Stage Channel. A two stage channel is characteristic of a stable natural system. Streams construct low flow channels to accommodate flows up to the stream-forming or dominant flow. This stage has a return interval of approximately 1.8 years and represents the flow that, over time, moves the most sediment and exerts the greatest influence on channel geometry. Streams also construct intermediate benches called bankfull floodplains to accommodate larger flows.



There are compelling advantages to incorporating a two-stage channel into a design. First, this is the most stable and maintainable configuration. The design contrasts sharply with conventional over-widened trapezoidal channels. Designing a single-stage channel based on the anticipated maximum flow grossly over widens the channel and ignores the stream's ability to self-form and adjust to intervention. When a stream channel is over-widened, the system's stability is disrupted. Over-widening has the same effect as increasing the stream gradient. This increases the upstream velocity and therefore the erosive power of the stream. The stream immediately begins re-establishing a stable configuration. This normally means that the stream erodes bed or bank material from upstream areas and deposits the material downstream. This results in damage to both upstream and downstream properties.

Further, because the stream begins filling in the channel, the desired flow capacity is not achieved. This results in recurring and expensive maintenance and repair.

Conversely, a two-stage channel with its shape determined by geomorphic parameters does not induce erosion elsewhere in the reach and maintains its conveyance without excessive maintenance. Other advantages include marked improvements in water quality. The low flow channel is relatively deeper than its single-stage counterpart. Deeper water provides better aquatic habitat because it is cooler and contains more

dissolved oxygen. This is especially important in the summer when shallow water becomes too warm to contain concentrations of dissolved oxygen needed by fish. Fine sediment also moves through the system more easily or is deposited on the bankfull floodplain instead of in the channel. At low flows, the channel meanders. At higher flows, the channel is much straighter as is true of most natural channels. So, the two-stage channel design provides both conveyance at high flows and a stable, self-maintaining geometry.

Bankfull Floodplains. Bankfull floodplains are intermediate benches that provide conveyance for flows above the stream forming flow return interval. This configuration lowers the velocity and stream power of higher flows. The elevation of the bankfull floodplain is critical for proper function. If the floodplain is set too high, the dominant or stream forming flow will not reach the floodplain and the flow will be confined to the narrow low-flow channel. There is no natural adjustment process for this short of complete destruction and reconstruction by the stream itself. For detailed design, a geomorphologist should determine the height of the bankfull floodplain.

The tops of the bankfull floodplains should be planted with inundation-tolerant vegetation. The vegetation protects the floodplains primarily by increasing the shear resistance of the soil through root strengthening. In addition, the foliage shifts the high shear areas away from the ground surface. The aesthetic and habitat values of the vegetated bankfull floodplains are dramatically superior to that of a hard-armored trapezoidal channel. The toe of bankfull floodplains can be established with coir logs.