DESIGN EXAMPLES—SECTION 5

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5.0 CASE STUDY—SAND CREEK

Bluff Lake Park is a 123-acre park that was created by the City and County of Denver to serve as an educational facility for Denver public school children and also as a gateway to the Sand Creek corridor. The site is located within the former Stapleton Airport operations area and includes the 9-acre Bluff Lake impoundment, 30 acres of wetland areas, abundant shortgrass prairie habitat, a remnant cottonwood gallery, and 3600 feet of Sand Creek, a major South Platte River tributary. The park is both a recreational area (pedestrians, joggers, etc.) and an educational facility where students learn about water quality, wetland, and riverine habitats. Improvements to this reach of Sand Creek include channel stabilization and enhancement of biological function along the corridor.

Historically Sand Creek contained very little or no base flow, with intermittent surface flows occurring in response to precipitation events. Most of the Sand Creek drainage flowed underground as part of the alluvial aquifer. Urbanization of the upstream watershed had impacted the creek, resulting in a flashy hydrograph, increased recurrence of flood flows, and development of a base flow. Erosion and deposition was occurring along the channel bed and banks as the channel tried to conform to the altered hydrology. The bank erosion threatened several structures adjacent to the creek, so bank-hardening treatments had been installed in localized areas as protection. The hardened banks were impeding the channel's natural tendency to meander and exacerbating the erosion problems. The altered flow conditions, the constrictions, and the channel's inclination to restore its wide, shallow, meandering flow pattern (all applied to the channel's highly erodible sandy substrate) were combining to create channel stability problems. These effects had been offset somewhat in the past by an undersized culvert bridge at Havana Road (downstream end of the project reach), which was creating a large backwater area and effectively slowing upstream velocities. The replacement of the culverts with a clear span bridge caused a substantial increase in velocities through the reach. The result was vertical streambanks that were over 12 feet high and channel downcutting up to 4 feet in some areas. Additionally, a large on-site meander was cut off as headcutting occurred through the reach. The unstable bed and banks were

threatening a treated wastewater reuse pipeline crossing and several structures situated along the streambank. The continual erosion had left virtually no streamside vegetation. Additionally, the degrading channel bed was causing an associated drop in the local water table, resulting in adverse impacts to streamside vegetation and related riparian and wetland habitats. Native plants along the corridor, especially the mature cottonwoods, which are an important park feature both for their age and because they provide nesting habitat for species such as Swainson's hawk and the great-horned owl, were showing signs of stress and losing ground to invasive species, including salt cedar tamarisk and Russian olive. Understory grasses and forbs also showed signs of takeover by invaders such as knapweed and leafy spurge.

Aquatic and Wetland Company (AWC) and Camp Dresser and McKee, Inc. (CDM) provided design and construction services for the City and County of Denver for the improvements to the Sand Creek corridor. The option of restoring the historically wide floodplain was not possible due to the adjacent development. Additionally, restoration of a wide floodplain through such high cutbanks would not have been economically feasible due to the large amounts of excavation that would be required. Therefore, the project sought to stabilize the channel bed and banks. All work needed to be compatible with and contribute to the use of the area as a recreational and educational facility. To that end, bioengineering treatments were integrated with more traditional bank stabilization methods, and the additional goals of riparian, wetland, and upland habitat restoration were included. Traditional bank stabilization measures, such as riprap and boulders, were limited to eroded slopes that were too steep for bioengineering treatments and to the critical junction of the channel bank and channel bed. Boulders placed at this junction provide protection to allow sufficient time for vegetation to be established and, eventually, cover the rock. The boulders and vegetation jointly provide protective cover for both vertebrate and macroinvertebrate fauna.

5.1 Design

In addition to the integration of bioengineering techniques and traditional methods to provide the necessary stabilization, an important design concept was to create a meandering low-flow channel within the armored outer banks, or flood channel. A 25- to 40-foot-wide low-flow channel designed to convey a base flow of 20 to 50 cfs was left completely unconstrained to meander at will within the 40- to 140-foot-wide channel (conveying the more frequently

occurring smaller flood flows), in an imitation of the creek's natural condition.

The primary treatment for stabilization of the main channel banks was a double boulder terrace with brush layering. The treatment consisted of two rows of large boulders set on a deep, concrete rubble foundation. The foundation was constructed using recycled runway concrete blocks from the demolition of Stapleton Airport. The minimum cutoff achieved by the boulders and the rubble foundation was 3 feet below the low-flow channel invert. A continuous line of coyote willow (*Salix exigua*) cuttings (brush layering) was then installed behind the lower boulder toe. The provision of vegetation along the immediate channel edge was especially important to restoring biological function because the plants provide leaf litter to the stream system (i.e., base of the food chain), as well as providing overhead cover for fish, and performing shading/cooling functions for the system. A planting terrace with a maximum slope of 3H:1V was created between the rows of boulders. The terraces were planted and seeded with native riparian trees, shrubs, grasses, and forbs. Two unique plant communities were established along the terraces – cottonwood gallery and riparian scrub-shrub. The bank side slopes created by the combination of boulders and terracing were designed with a maximum effective slope of 2.5H:1V, which provided a substantial reduction from existing slopes. In most areas, the effective side slopes that were achieved were flatter than the design maximum. The slope protection in this treatment comes primarily from the two rows of boulders and secondarily from the root structure, which will be created as the vegetation matures.

In some areas, such as low-risk inside bends, hard protection was not needed. A willow log designed specifically for the project was used for toe material, in place of boulders, in these areas. The logs were manually constructed on-site using coir erosion control fabric, native fill material generated by the project, supplemental imported mulch, and willow cuttings. In addition to creating a stabilizing toe for less critical banks, the logs were used to create a check structure to control the minor inflow, consisting of treated wastewater effluent, routed from the neighboring Aurora Wastewater Reuse Plant. The intent of the specialized willow logs was to let the willows in the outer layer of the log produce stabilizing roots and overhead foliage, which will continually increase bank protection as well as riparian habitat. The problem of securing the logs into loose, sandy soil was solved through the use of Duckbill anchors. The Duckbills have anchors that rotate when pulled, locking themselves into place deep in the banks. They perform exceptionally well in sands where typical staking may be ineffective.

Stabilization of the channel bed was accomplished through the installation of two grouted boulder drop

structures with sheetpile cutoffs. The drop heights (4-foot and 8-foot) were set to achieve an average 0.2 % slope for the reach. The drop structures were designed with a step-pool configuration, with a maximum drop of 1.5 feet between each step and a minimum pool depth of 3 feet. These specifications allow for fish passage and provide resting habitat for migrating fauna. The boulder crests were installed in curving alignments and pools were given uneven shapes and sizes to avoid an overly structured look. The larger drop included a planting terrace along its length to restore streamside vegetation and soften the look of the structure. The structure included the wastewater effluent pipeline crossing in its crest. The cascading step-pool design of the grade control structures makes a nice park amenity with its soothing sound and natural aesthetic quality. Additionally, propane testing has indicated that the structure is an excellent passive re-aerator, with the 8-foot drop exhibiting an overall efficiency of 60% and individual step efficiency of close to 19%.

5.2 Criteria

The use of drop structures to reduce the channel slope to 0.2 % follows the recommendations of the District's 1984 Sand Creek Major Drainageway Plan. The channel improvements were designed for general channel stability up to the 10-year flow of 9,000 cfs. The low-flow channel carries the channel's base flow of approximately 20 to 50 cfs. Bioengineering techniques were utilized to the maximum extent possible. Wherever conditions exceeded the expected stabilization potential of available bioengineering methods, vegetative treatments were added to the riprap, boulder, and concrete techniques.

5.3 Construction

AWC and CDM Engineers and Constructors constructed the Sand Creek channel improvements. The 3,600 feet of channel improvements included almost 50,000 cubic yards of cut/fill (largely due to realignment of the lower reach of the creek to avoid the new Colorado Department of Correction Women's Detention Facility), sheetpile installation, structural concrete and grout work, boulder placement, and comprehensive planting and seeding. Timing was the biggest construction challenge. Contract delays caused a late construction start, which pushed construction into the summer thunderstorm season. As a result, construction was interrupted several times by rapidly rising water levels.

5.4 Success

Many of Bluff Lake's patrons have praised the Sand Creek Channel Improvements Project for the natural look that was achieved and for the improved habitat along the creek corridor. The project has, to date, met its goals of stabilizing the channel bed and banks

and enhancing biological function, while maintaining compatibility with the District's master plan recommendations and contributing to the use of the park as an education facility. Healthy growth has been observed in the willow brush layering (installed behind the boulder toes, on top of buried rubble as part of all double boulder terrace bank treatments). Combined with pre-existing willow stands located along the creek, the new treatments have created over 5,000 linear feet of solid willow coverage along the water's edge. Individual plant growth was noted at over 3 feet in one growing season in some sections. The planted willows are healthy and robust and appear to be continuing the strong growth pattern as they mature. Great blue herons, hawks, and families of ducks have been observed along the creek and among the willows since the project's completion. This project illustrates that in this reach of Sand Creek, a reach that has been impacted by upstream urbanization, the combination of structural elements with bioengineering techniques can produce an environmentally productive and stable urban stream.

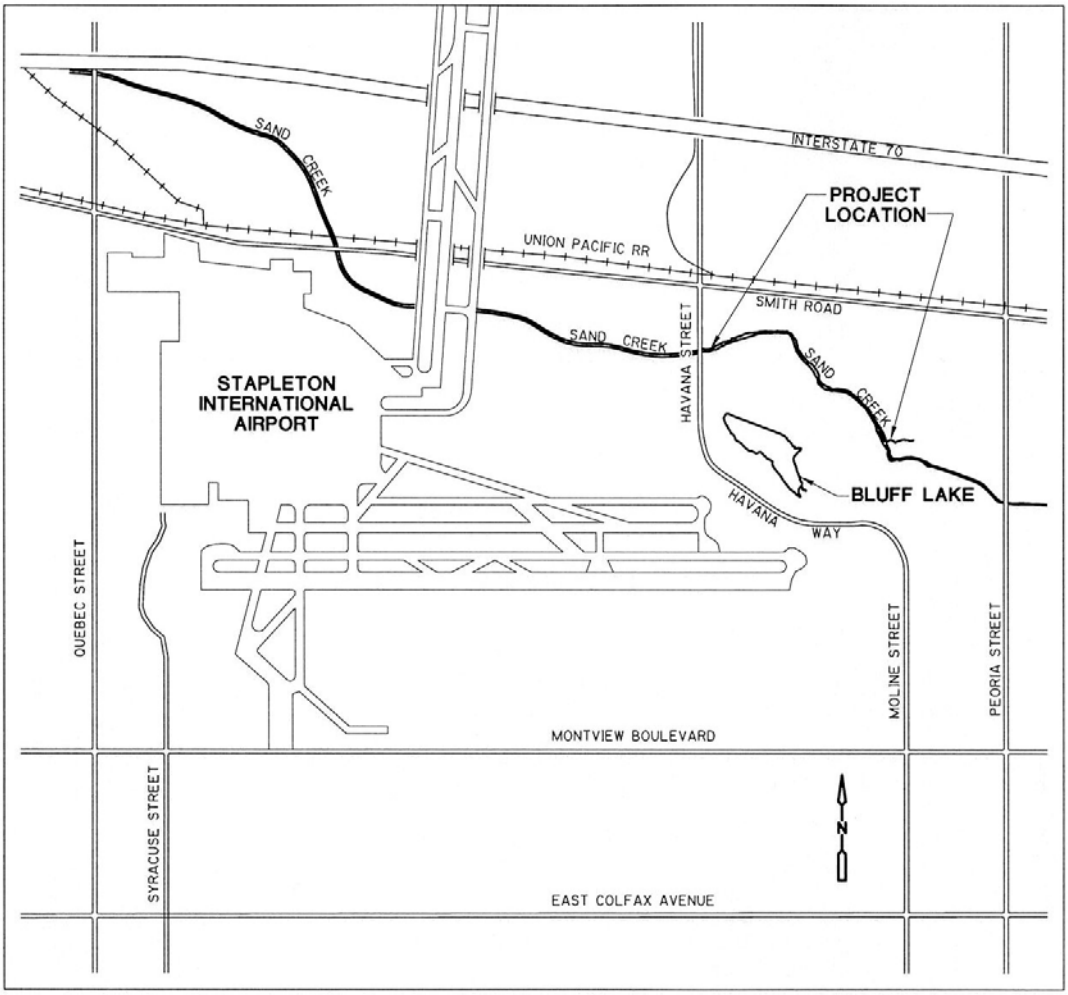

Figure 1—Location Map

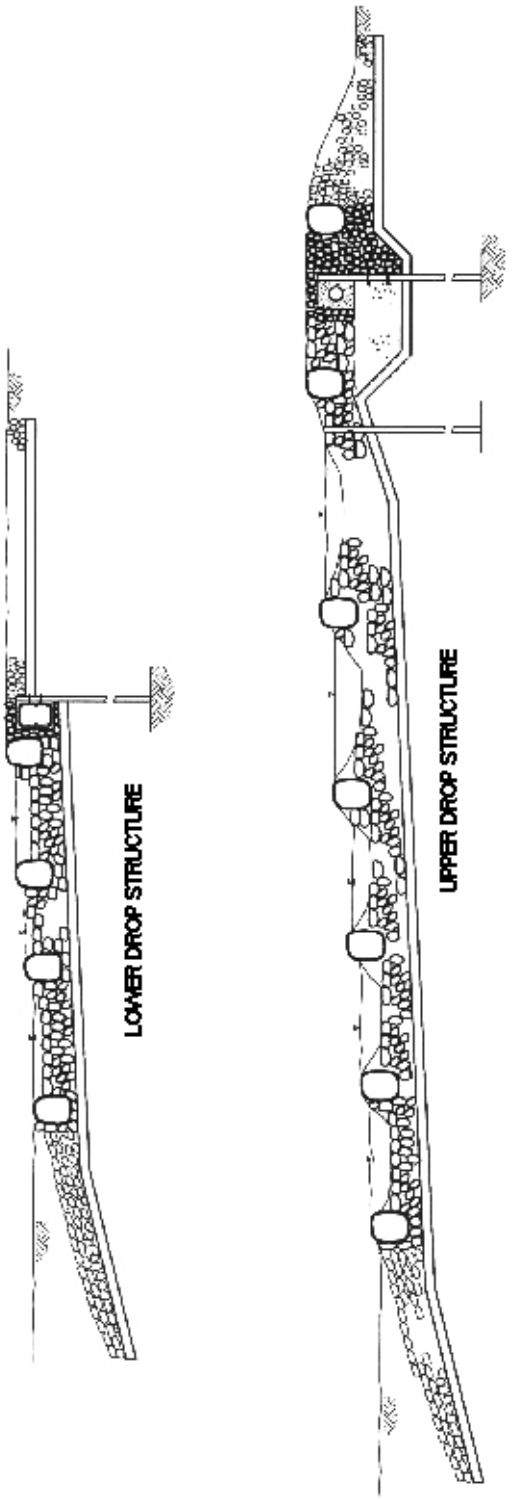

Figure 2—Drop Structures

Sand Creek Channel Improvements at Bluff Lake Park
Denver, Colorado

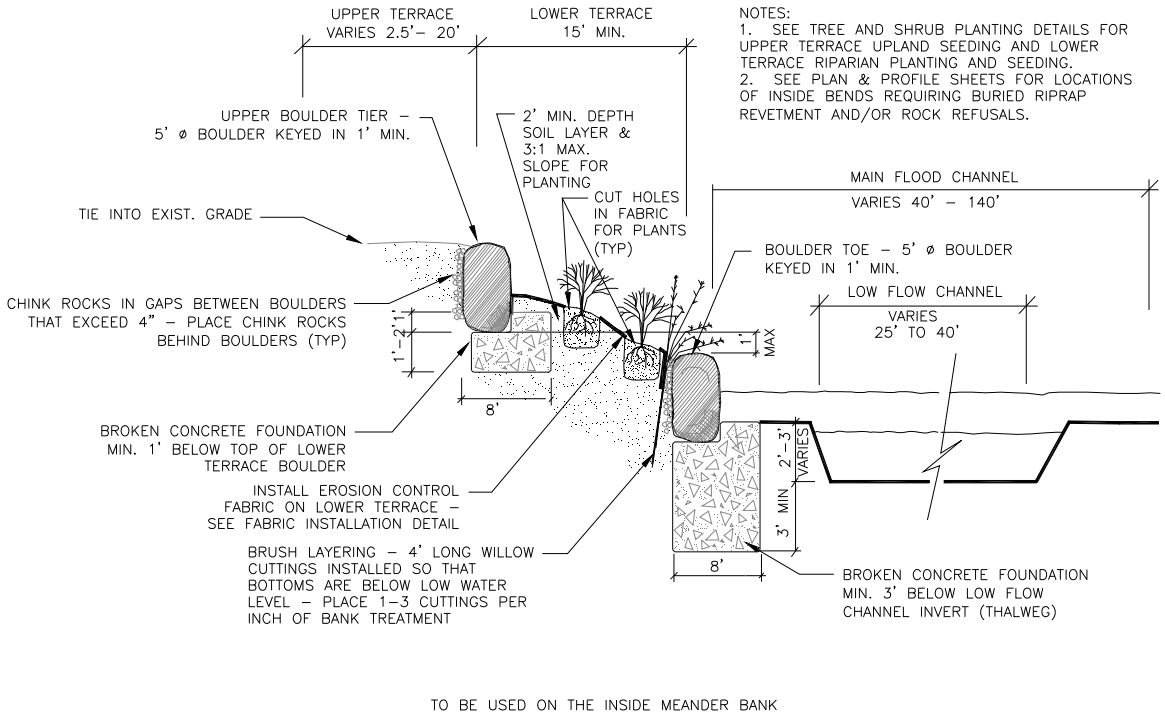

Figure 3—Double Boulder Terrace

Sand Creek Channel Improvements at Bluff Lake Park
Denver, Colorado

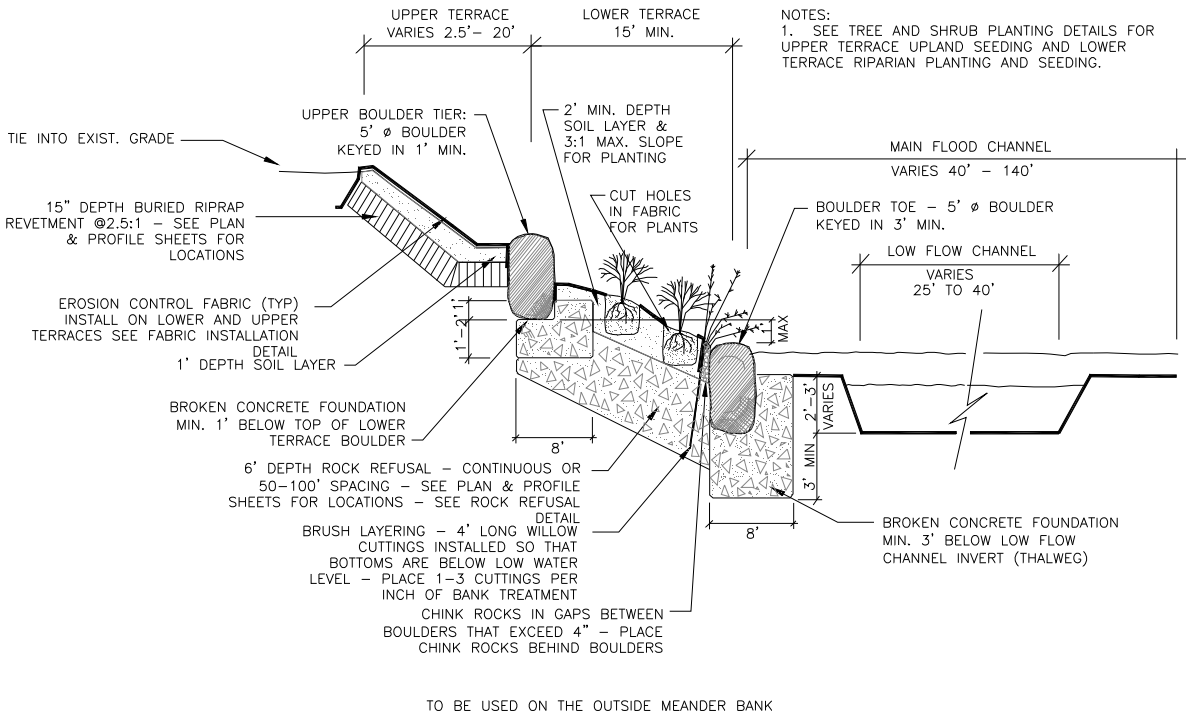

Figure 4—Double Boulder Terrace with Buried Riprap Revetment

Sand Creek Channel Improvements at Bluff Lake Park
Denver, Colorado

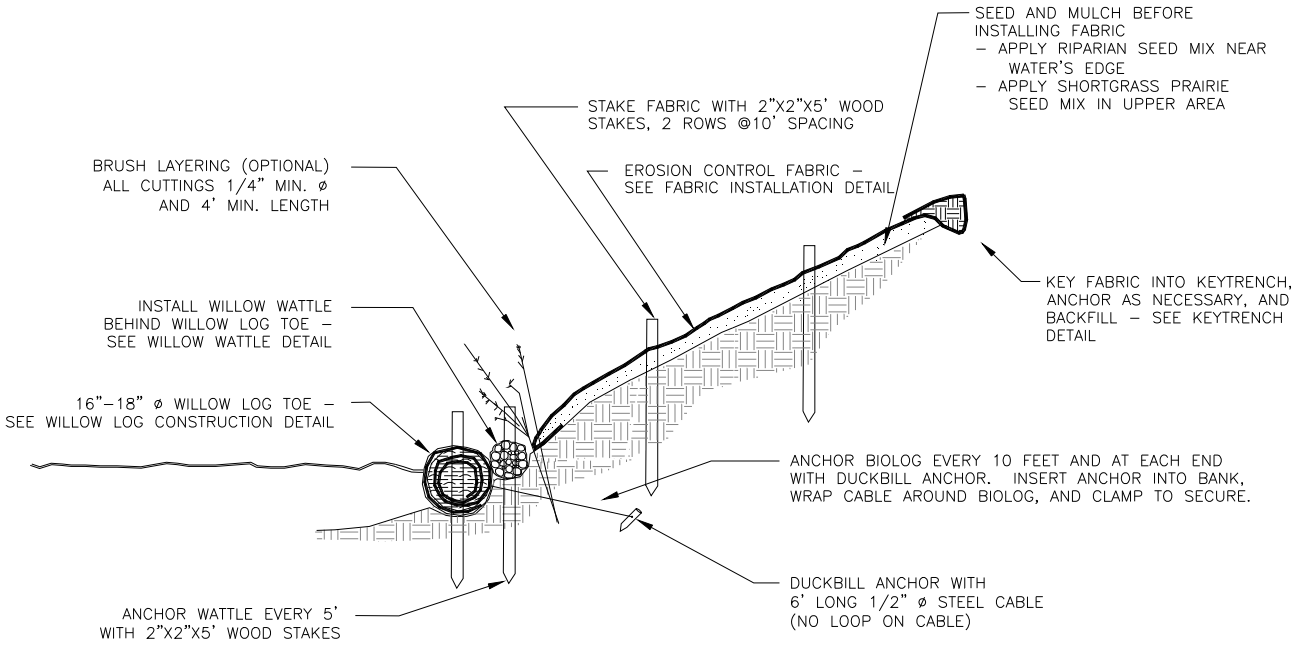

Figure 5—Willow Log Toe with Willow Wattle

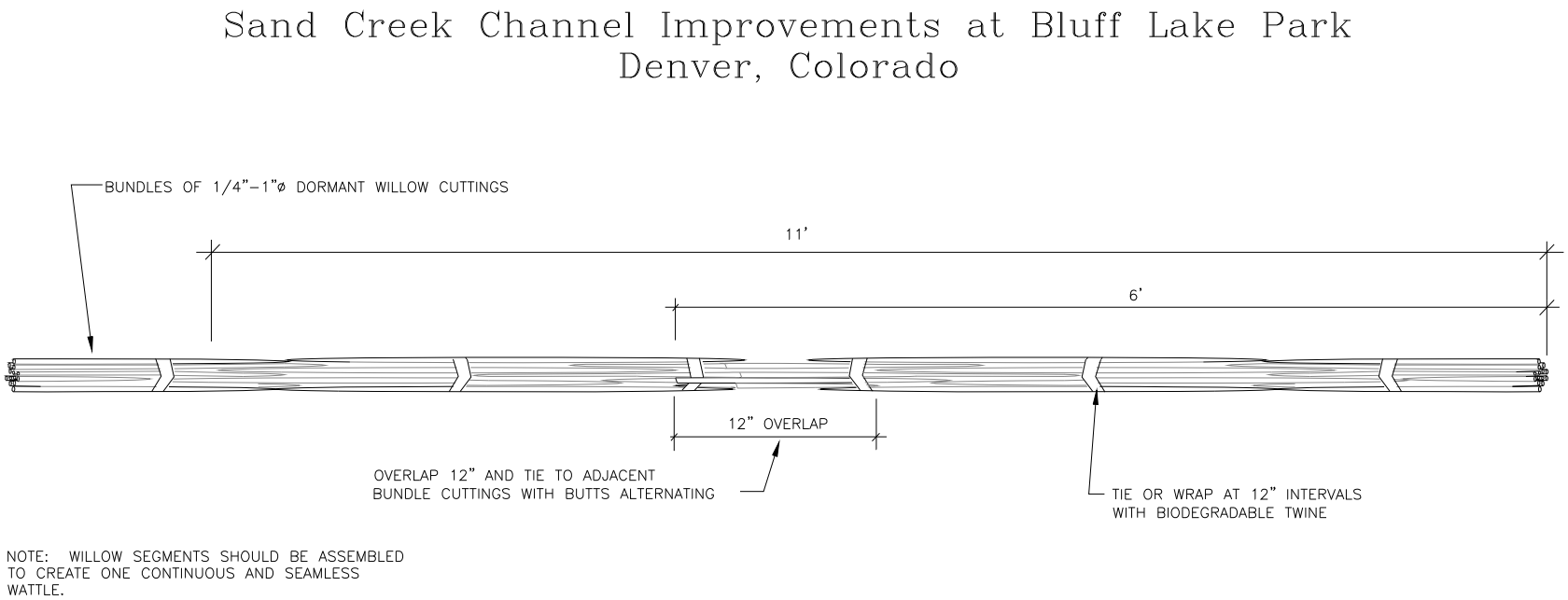

Figure 6—Willow Wattle

Sand Creek Channel Improvements at Bluff Lake Park
Denver, Colorado

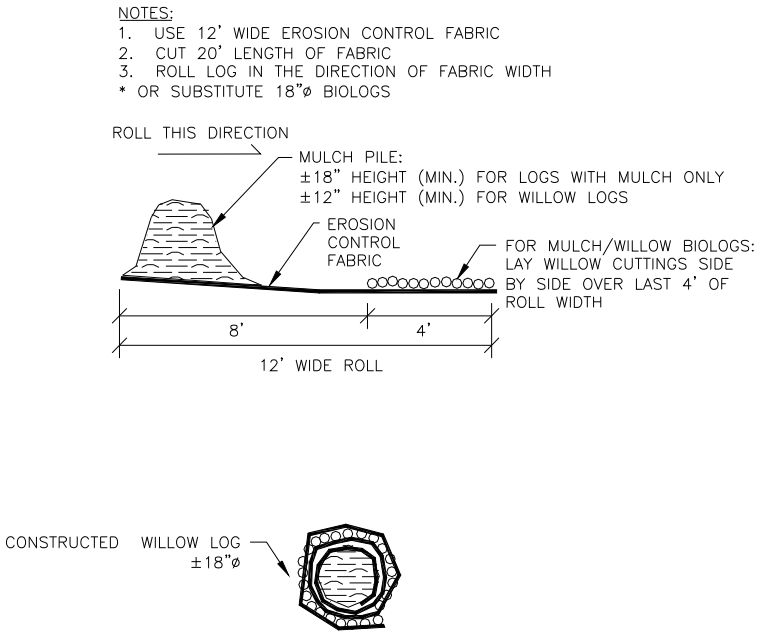

Figure 7—Willow Log Construction