6. Restoration and Management Recommendations

Up to this point, the Upper Carson River Stream Corridor Assessment has focused on identifying natural geomorphic or ecosystem function in the watershed, and identifying how human disturbance has changed functional processes. This chapter provides management and restoration recommendations intended to address human disturbance.

In developing recommendations, the assessment team has focused on the restoration of geomorphic and ecosystem processes (Spence et al. 1996). Since most natural stream channel projects will be driven by wildlife and habitat issues, an ecosystem approach should be incorporated into these projects. Important components of an ecosystem approach for stream projects should include (from Spence et al. 1996):

- recognition of the complexity and interconnectedness of ecological systems;
- recognition that ecosystems are constantly changing; and,
- acknowledgement that ecosystem processes operate at multiple temporal and spatial scales.

A process-based approach to stream restoration relies on restoring the geomorphic processes related to channel and floodplain formation (an example is removal of an eroding road embankment to restore natural processes of sediment supply). Much emphasis has been given to restoring and protecting watershed processes in the last few years. It is often argued that this approach is less costly and more effective than direct channel manipulation (Beschta et al. 1994). Certainly, addressing the root cause of channel instability is more likely to be successful than treating symptoms within the channel itself.

Process-based approaches to restoration are commonly used in upper portions of watersheds and focus on reducing the supply of sediment to the channel and reducing the erosive force of peak flows. Direct restoration of the effects of past land use practices is common; familiar practices include removal of roads, management of storm discharge from disturbed surfaces, and stabilization of sediment-producing areas. Management practices also protect watershed processes, such as restriction of land use activities in areas of high erosion. Some management practices even protect processes based on episodic disturbance, such as harvest restrictions that protect the recruitment of large trees to the channel from upland sources through land slides or debris flow.

Protection, restoration and enhancement of watershed processes in the floodplain and riparian areas are also common. Management practices include the restriction of land use activities that reduce channel and floodplain stability or reduce the recruitment of woody debris to the channel, such as logging or road regulations. Direct restoration activities include removal of riparian roads and planting of trees to improve future recruitment of woody debris.

In some cases, the assessment team has also recommended modification of the channel or adjacent floodplain. While these projects may restore site-specific habitat values (increase riparian vegetation density, for example), the focus of these recommended projects is to restore functional geomorphic processes.

As mentioned previously, dynamism is inherent in natural, functional streams (Spence et al. 1996). Restoration projects must therefore consider the role of change in both geomorphic and ecosystem process, and should be designed to allow dynamism to occur. In a geomorphic sense, a stream in equilibrium is considered to be both stable (cross-sectional geometry is constant) and graded -- the slope is just sufficient to transport all the material supplied to the stream (Gordon et al. 1992). Although much of the research in channel design has focused on establishing equilibrium conditions, few natural channels exhibit the same equilibrium conditions at all times in all locations. Within a single watershed, large-scale geologic and geomorphic processes create spatial discontinuity and variability in both the supply and transport of sediment. Moreover, temporal variability in equilibrium conditions at a single location is common in natural systems; sediment may be stored at a location during low flows or flood peaks, only to be scoured by subsequent higher flows or flood peaks.

There is substantial evidence that ecosystems are adapted to the considerable dynamism inherent in natural channels. For example, salmonid fishes often spawn in gravel near pool tail-outs, a location regularly scoured and filled during floods. Also, many plants adapted to riparian environments require bare soil for establishment, a condition common in regularly disturbed stream channels. A channel in a single perfect equilibrium at all times in all locations (e.g. a concrete flume or a highly rip-rapped channel) will not provide the habitat required by the plants and animals in an ecosystem which has evolved in response to inherent natural levels of disturbance. While single-purpose objectives (reduction of fine sediment, reduction of flood hazard) might be met by enforcing perfect equilibrium on a channel at specific locations, restoration of functional aquatic ecosystems must recognize the inherent natural temporal and spatial variability in sediment transport and channel morphology.

Therefore, the assessment team does not recommend highly-engineered, "hard" solutions to stream bank stability for the Carson watershed meadows, such as rip-rap or rock groins. These structures do not allow for regular adjustment of plan form and channel cross section common in alluvial channels. Also, given the available sediment in the system and general dynamism, the use of harder structures such as revetment in discrete locations is likely to generate erosion in other areas. While hard structures may have limited application in discrete locations for limited objectives, their widespread use will not promote geomorphic or ecosystem function.

Also, the assessment team does not recommend complete channel reconstruction in any given location. Complete channel reconstruction would not only be very expensive, it would be very risky given the dynamism inherent in these watersheds. Rain-on-snow floods occur regularly, and would place enormous stress on newly constructed channels. Also, low summer flows will make it very difficult to re-vegetate newly constructed floodplain. As a result, channel reconstruction is not likely to be successful.

The assessment team does recommend some active channel restoration measures in selected reaches. The recommended techniques are relatively low intensity, and will allow the channel to adjust to changing sediment supply or hydraulic conditions over time. Also, these treatments are designed to reinforce natural trends in channel recovery. Although removing the cause of channel disturbance should be the first priority of watershed programs, active restoration may be called for in some circumstances, when natural recovery is slow or cannot proceed because channel geomorphic conditions are so altered.

The assessment team also recommends that each of the following projects have a strong adaptive management component with clearly defined objectives, a detailed monitoring plan, and a strategy for implementing monitoring results.

Based on the preceding considerations, the assessment team developed the following management and restoration alternatives and recommendations. The Alpine Watershed Group has adopted these management and restoration recommendations as priorities to be accomplished over the next five years. Continued input from watershed stakeholders through the Alpine Watershed Group will be necessary as projects are implemented over time. Each project discussed in this chapter is assigned to one of the following categories: roads, stream restoration, floodplain enhancement, water quality, and grazing management. Reach-specific measures, or projects, are considered in the section, organized by the same reaches used for the study.

6.1 Roads

Roads are the primary facility for gaining access to land resources and are often a primary factor in land disturbance. Roads are designed to efficiently convey runoff and eroded sediment particles, from the road surface to the down slope hillside or local flow path, often though a network of inside ditches and cross-culverts. They can contribute to negative impacts by disrupting of soils and by modifying drainage and hydrology. Roads tend to concentrate runoff that is difficult to disperse in steep terrain. Road crossings over waterways introduce sediment by placement of fill, disruption of local channel profile stability, and introduction of culverts.

Given the rural nature of Alpine County and the focus on recreation, rather than past resource extraction activities such as timber harvests and mining, roads occur at fairly low densities throughout the watershed (see Table 2.1). Regardless, road conditions need to be continually monitored and maintained to reduce the potential for excessive erosion and sediment delivery to stream channels that could impair aquatic habitat. The current assessment identified several issues pertaining to roads:

- limited use dirt roads throughout the assessment area are providing sediment to streams through erosion of crossings, embankment, ditches or the road surface itself;
- winter maintenance along area highways supplies sediment, and possible salt, to streams; and,
- erosion of shoulders on maintained roads may supply sediment to streams.

6.1.1 Detailed Road Assessment

It is recommended that a detailed assessment of road conditions be prepared that identifies potential sources of sediment along roadways located in the watershed. In the following discussion a generalized approach is provided. That approach is based on a prioritization of the watershed into discreet survey areas. The prioritization considered the sub-watershed boundary map (see Figure 2.2), estimated road densities within each sub-watershed based on readily available GIS data (see Table 2.1), and the erosion potential of the sub-watershed where the roads occur (see Figure 2.5). The following discreet survey areas, in order of importance, arose from this analysis:

- ***Watersheds 4, 5, 6 and 9***: Blue and Burnside Lakes Roads.
- ***Watershed 29, 30, 31, and 32***: Silver Hill and Morningstar Roads and associated jeep trails.
- ***Watersheds 15, 14, 24, 20, and 19***: Jeep trails, residential roads, and other small spur roads that occur along the Grover Hot Springs Road.
- ***Watershed 34***: Jeep trails off of Wolf Creek Road.
- ***Watersheds 25, 26, and 33***: Jeep trails off of Highway 89/4.

Erosion sources should be mapped along roads occurring within these areas, including abandoned tracks or skid trails. High-resolution aerial photo-based maps should be used that focus on the discrete assessment area. All known roads or jeep trails should be included in the mapping product. Identified erosion sources should be mapped with GPS. The following features should be identified and mapped.

Point Sources of Erosion - The assessment should identify point sources of erosion that appear to be providing chronic sources of sediment to local waterways. Locations could include unarmored ditches, severe road cuts, perched culverts, or failing road fill. Each feature should be flagged in the field with colored flagging with clear labeling identifying the date, time, survey team, and site number. Data should also be collected in a field notebook identifying the site number, description of the feature, GPS way-point number, if available, and the severity of erosion at the site. It also helps to give the site an erosion severity ranking from one to five with five being reserved for the worst sites that require immediate attention. The severity ranking is valuable for future site prioritization.

Culvert Condition - Since culverts concentrate flow and are often not equipped with energy dissipaters, each culvert should be carefully assessed. At the upstream end of the culvert, identify evidence to determine if the culvert is undersized. Indicators include upstream sedimentation, partially clogged culvert, debris line (similar to a soap line in the bath tub) indicating that water is being impounded behind the culvert, or gully formation across the roadbed, suggesting the culvert occasionally backs up and spills over the road. On the downstream end of the culvert, look for gully formation, evidence of down cutting, and perched culvert conditions. Also, note the level of energy dissipation.

Ditch Relief - Where roads are sloped inward towards the hill slope, water concentrates in a ditch that eventually meets a culvert that conveys the water under the road. During the road assessment, determine whether or not the spacing between cross-culverts is sufficient. Is the inside ditch being overwhelmed and concentrating too much flow? Should additional cross-culverts be installed? When returning from the field, assemble all of the information into an assessment database that could be used by road maintenance crews or others to establish priorities and obtain funding to repair problematic sites identified during the survey. When a recommended action is accomplished, move onto the next area. Be as consistent as possible with your approach within each survey area so that a comprehensive list of priorities could be developed at the end of the assessment.

Road Removal – The road assessment should consider whether some limited use roads can be eliminated. Many roads throughout the watershed receive very little use. Removing them entirely may be the best solution to addressing potential sedimentation issues. Prioritization of removal could be based on sediment-related problems (from assessment), and estimated use. High priority roads would have relatively high sediment delivery potential but low public use.

Maintenance - Regular roadway maintenance, including adequate flow through culverts and along ditches, helps ensure that sedimentation of adjacent waterways is kept to a minimum. With the large number of roads in the watershed, however, adequate maintenance is not always possible. Ways to improve road maintenance, including increased cooperation among various agencies, should be explored.

The road assessment should provide both restoration and management recommendations. Those recommendations should be directed specifically at limiting the amount of sediment or other materials supplied from road surfaces to adjacent stream channels and floodplains. General topics addressed by those recommendations should include:

- explore opportunities to reduce the amount of abrasives or salt used in winter sanding operations on paved roads near streams;
- remove excess abrasives from paved road shoulders each spring;
- explore opportunities to make paved road shoulders more resistant to erosion;
- assess problems associated with limited use roads throughout the watershed;
- explore opportunities for abandoning some limited use roads; and,
- improve cooperation between agencies and increase maintenance efforts along retained limited use roads. Many of the identified problem areas can be addressed by relatively low-cost stabilization techniques such as rock-lining of gullies in embankment, placement of water bars to disperse direct flow from road surfaces, and contouring of road surfaces and ditches to avoid concentration of flow.

Costs associated with the development of a road assessment were developed based on the following project assumptions:

- survey teams would consist of volunteers supported and directed by members of the Alpine Watershed Group or other stakeholder agencies; and,

- there would be a cost associated with base map production and compilation of collected data into a comprehensive road assessment project that should be coordinated at the Alpine County or Alpine Watershed Group level.

The estimated cost to prepare the assessment would be approximately $10,000 - $20,000.

6.1.2 Conduct a Demonstration Project

It is recommended that a demonstration project be developed that would implement and assess various techniques to stabilize limited service dirt roads. This project should focus on relatively low-cost techniques such as those bulleted above. A photo-based monitoring program should be developed along with the project to assess the success of different techniques. Several issues with roads were noted within the upper Charity Valley sediment survey in this assessment, and the demonstration project could be applied to this area. Costs associated with the installation of road improvements were developed based on the following project assumptions:

- erosion from road cuts, shoulders, and inside ditches would be stabilized through appropriate hard and bio-technical techniques;
- culverts would be upgraded to reduce potential for fill failure and gully formation downstream; and,
- water bars and/or additional cross-culverts would be added, where appropriate

The estimated cost would be approximately $20,000 to $40,000 per mile (where upgrades are necessary).

6.2 Stream Restoration

The assessment team recommends some active channel restoration measures in selected reaches. The recommended approach is to employ relatively low intensity techniques that will allow channels to adjust to changing sediment supply or hydraulic conditions over time. The treatments are intended to reinforce natural trends in channel recovery. The following activities are recommended.

6.2.1 Conduct Bio-technical Stream Bank Restoration

The assessment team recommends bio-technical stabilization of stream banks, including willow wattling, brush mattressing (Figure 6.1), brush layering or revetment (Figure 6.2), and placement of fascines (Figure 6.3), and brush packing (Figure 6.4). These restoration practices could be implemented in the form of a demonstration project in a limited area. Several different techniques should be used within the demonstration project area to assess success. A monitoring program based on photo points should be included, along with vegetation transects and other techniques to evaluate project success. Specific locations identified as part of this assessment that should be considered are listed below.

- WF8-Lower Hope Valley: Although grazing impacts have been removed from this reach for over a decade, stream banks are still relatively unstable. Slow recovery of riparian vegetation is partly due to the high elevation and short growing season. Continuing channel instability may also reflect adjustment to upstream perturbations. There is evidence that natural recovery is occurring; restoration practices designed to work with and augment natural recovery are likely to substantially speed restoration of geomorphic and ecosystem function.
- WF10-Upper Hope Valley: Like Reach WF8, no direct impacts are currently active in this reach, but stream bank instability remains high and recovery is slow. Bio-technical stream bank stabilization is recommended along this reach.
- WF14 & 15-Failth Valley: Bio-technical stream bank stabilization is a potential alternative for restoration of this reach. However, incision is relatively advanced in the channel downstream of the beaver dam, and bank stabilization alone may not address reestablishing the historic relationship between the channel and the floodplain.
- MC2-Markleeville/Hot Springs Creek Near Markleeville: In the upstream portions of this reach (upstream of Markleeville), stream bank stability is low. Implementation of a bio-technical bank stabilization project is recommended.

Bio-technical stabilization involves the introduction of willow wattling, brush matting, etc. The cost estimate for this type of project is based on the following assumptions:

- one meander wavelength will be treated, but larger areas may experience an economy of scale;
- volunteer workgroups will be used during implementation with oversight from trained professionals; and,
- plant material will be obtained from local cuttings of primarily willow species.

The estimated cost, per site, including planning, design, and implementation would be approximately $8,000 to $10,000. If brush layering or other more intensive techniques requiring earthwork are used, an additional $5,000 to $7,000 should be added to the cost. A 3-5 year monitoring plan should be developed and implemented by trained restoration ecologists. This monitoring plan should include the potential for periodic hand watering of plant material within the project site. The estimated cost to develop and implement the monitoring plan would be approximately $15,000 to $20,000.

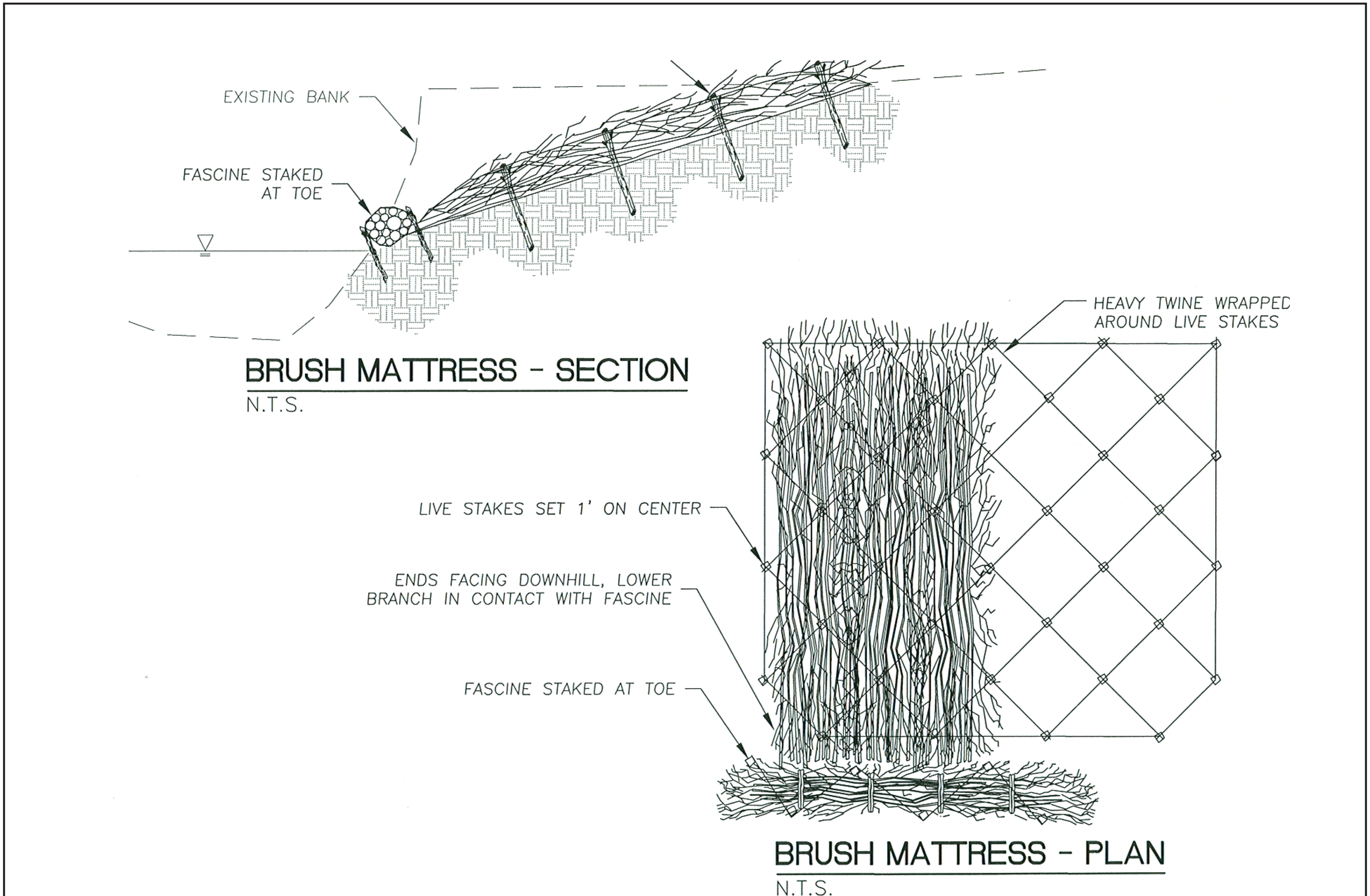

Figure 6.1. Brush mattress as bioengineered treatment for bank stabilization.

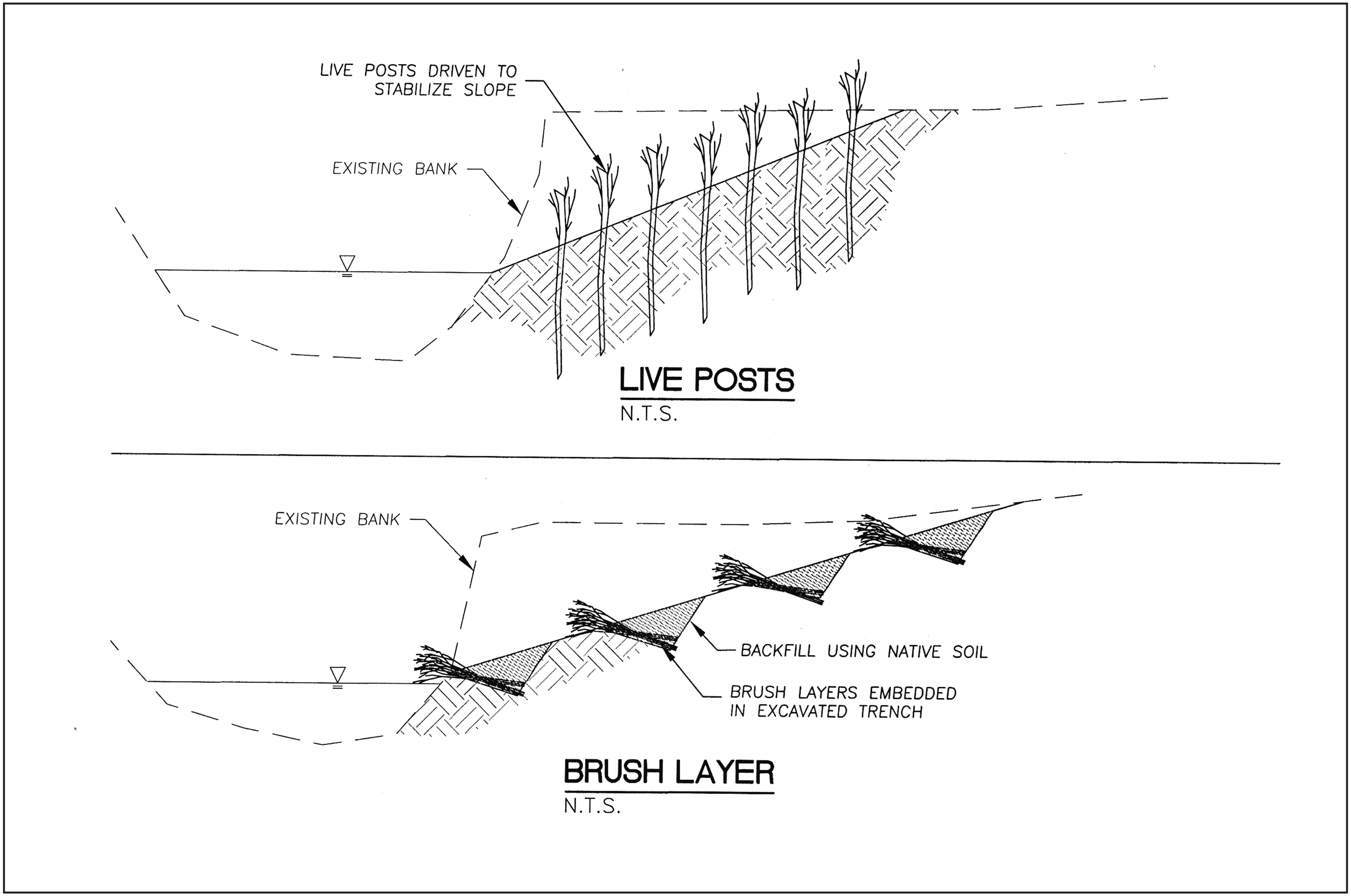

Figure 6.2. Live posts and brush layering as bioengineered treatment for bank stabilization.

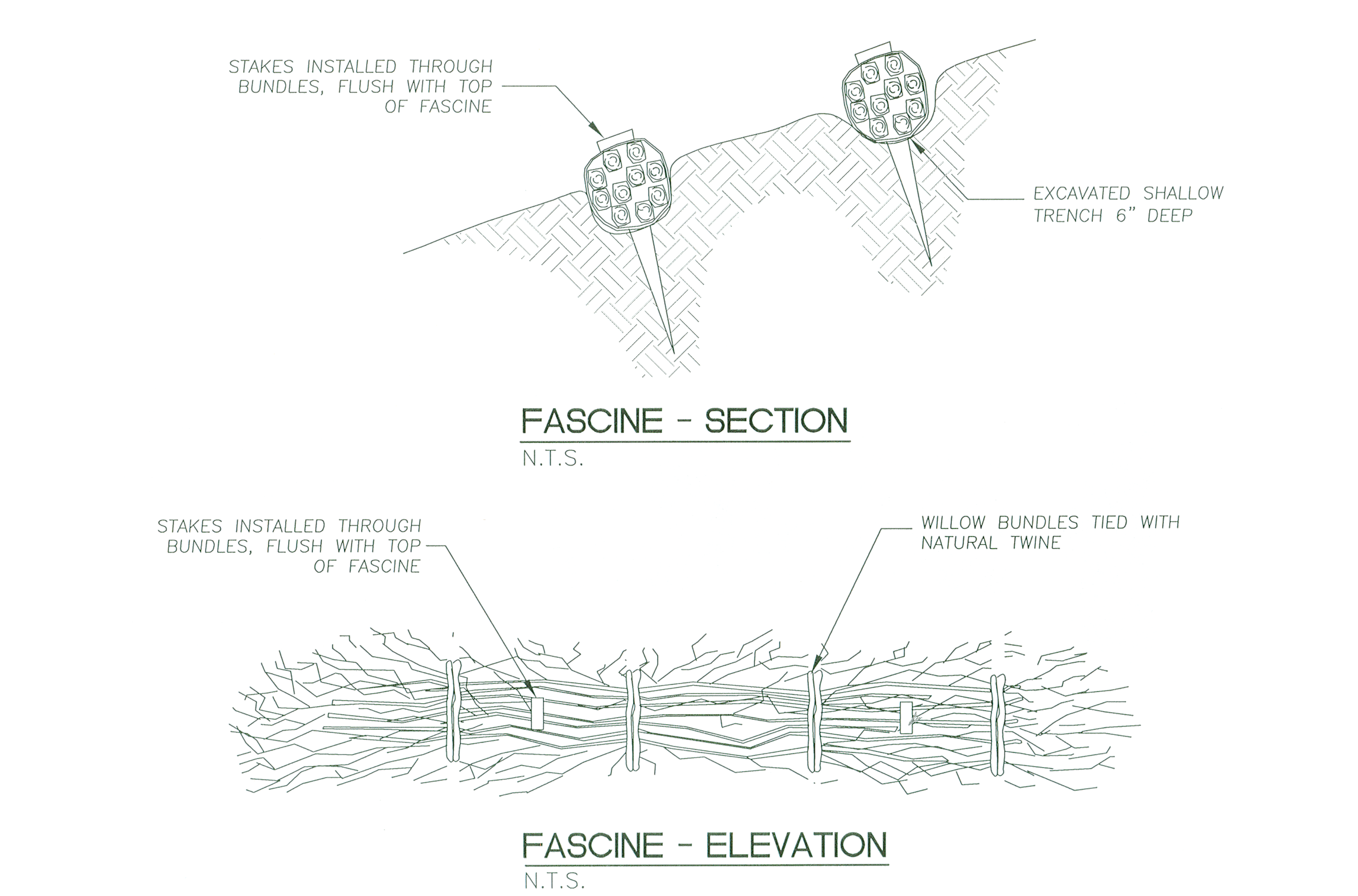

Figure 6.3. Fascine as bioengineered treatment for bank stabilization.

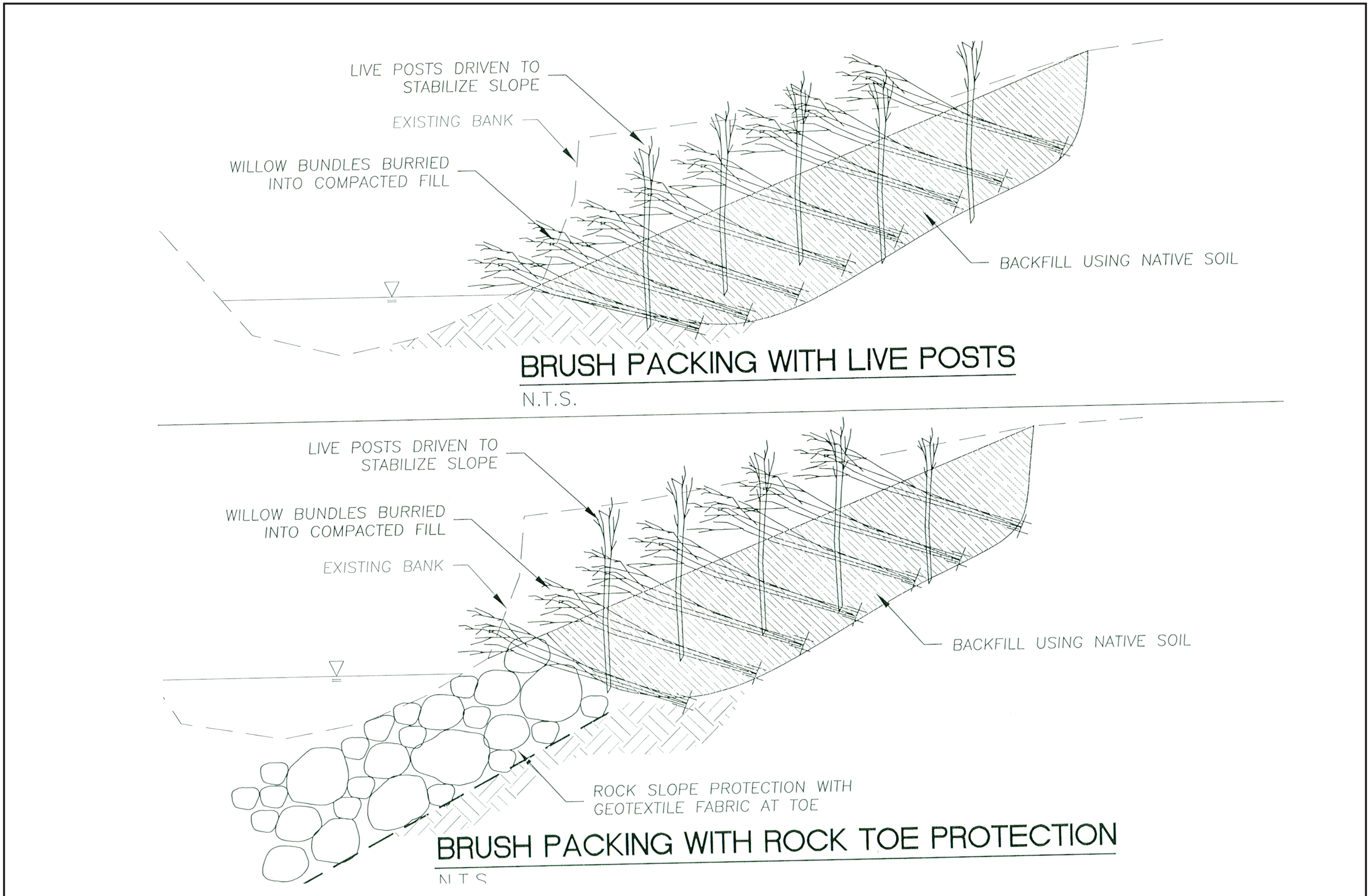

Figure 6.4. Brush packing as bioengineered treatment for bank stabilization.

6.2.2 Stabilize Faith Valley

The Faith Valley reaches (WF14, 15) of the West Fork are highly dynamic and appear to have been substantially disturbed (see Figure 5.10). Restoration of geomorphic function will be most difficult in this reach. The assessment team has identified four alternatives for specific restoration projects. These projects could be implemented singly or in conjunction.

- The beaver dam is currently holding a substantial amount of grade and keeps the groundwater elevation high in the adjacent meadow. Without stabilization, however, it will eventually fail, resulting in extensive erosion and lowering of the groundwater table. This dam could be stabilized to the extent feasible, utilizing biotechnical methods. Estimated costs associated with this project are based on the assumption that geo-technical review would be required to assess design considerations, that temporary dewatering would be required, and that re-vegetation efforts would be limited. The estimated cost, including planning, design, and implementation, would be approximately $70,000 to $100,000. It is important to note that stabilization of the beaver dam may carry with it some level of assumed liability. The issue of assumed liability should be given due consideration during geo-technical review. If it is determined that there is an assumption of liability, then long-term monitoring and regular maintenance would be required as part of this project.
- Long portions of the channel have been cutoff over the past 30-40 years. Reactivating these meanders would increase stream length and bring the channel up in elevation, closer to the surrounding floodplain. However, this project would be substantially more expensive that other alternatives, and would entail more risk. Estimated costs associated with this project are based on the assumption that the existing channel segment would be filled following reactivation of the historic channel, limited geo-technical review of the site will be required to determine appropriate soil compaction criteria, and the design may include biotechnical stabilization at key locations in the newly reactivated channel. The estimated cost, including planning, design, and implementation, would be approximately $160,000 to $220,000. A 3-5 year monitoring plan should be implemented to evaluate benefits of the project. The estimated cost of monitoring would be $30,000 to $50,000.
- The introduction of beaver could be considered. Beaver would likely construct dams in the channel, with effects similar to the existing dam. However, long-term residence of beavers would be necessary to realize positive effects. This would require the presence of an adequate food source. The animals may also require protection. Introducing beaver into the West Fork of the Carson River should be further evaluated to assess potential opportunities, constraints, costs, liability issues, and the potential for success. A study should be commissioned to address the benefits, potential impacts, probability of success, and expected outcome of various introduction scenarios. The proposed study should be prepared under the direction of a technical advisory committee made up of regulatory agencies and interested stakeholders. The resulting report would address potential issues, provide cost estimates for potential reintroduction alternatives, and make recommendations for a preferred alternative. The estimated cost to conduct the feasibility assessment would be approximately $20,000 to $35,000.
- Recreational impacts are fairly extensive in this reach, which should receive high priority for managing recreation to reduce riparian and floodplain impacts.

6.2.3 Selected Placement of Woody Debris

Riparian forests are common along reach MC3 (Hot Springs Creek downstream of Grovers Hot Springs) and woody debris has played an important role in channel function and stability. However, stream bank instability is high. Engineered woody debris jams (which function like natural log jams) have been successfully used to promote bank stabilization (Abbe and Montgomery 1996; Abbe et al. 1997). This technique is based on the natural processes of debris jam formation, and therefore influence local channel processes and reduce stream bank erosion in ways similar to how natural recovery would occur.

Woody debris jams in the channel would cause local aggradation upstream and an increase in groundwater elevations. These conditions would promote the colonization and establishment of vegetation along the existing channel (the active floodplain) and on the surrounding valley flat (the low terrace), particularly in low areas where small increases in groundwater elevations will have dramatic impact. Increased grade stability would allow the system to progress in its evolution toward historic functionality. Larger floods would store and sort sediment both within the channel and on the low terrace, allowing for additional vegetative colonization and establishment. Additional aggradation in the channel would also tend to increase groundwater elevations, further promoting vegetative establishment.

It is important to note that the placement of woody debris in a stream channel may carry with it some level of assumed liability. The level of liability would vary, presumably based on the size of the material placed and its location relative to other potentially damageable improvements. The issue of assumed liability should be given due consideration during project development.

A cost estimate was developed related to the placement of woody debris in selected locations. Project assumptions included the following:

- the project reach would encompass approximately ½ mile of channel;
- woody material would be placed using a large crane positioned on the bank most accessible from the road; and,
- trees to be used as woody material would be obtained through salvage logging at an estimated cost of $300 per log.

The estimated cost of the project, including planning, design, and implementation would range between $125,000 and $190,000. A 3-5 year monitoring plan should be implemented to evaluate geomorphic and aquatic habitat benefits of the project. The cost of that monitoring plan would be approximately $20,000 to $30,000.

6.3 Floodplain Enhancement

The assessment team does not recommend highly-engineered, "hard" solutions as a means of addressing stream bank stability in Carson watershed meadows. Structures do not allow for regular adjustment of plan form and channel cross section common in alluvial channels. Also, given the available sediment in the system and its general dynamism, the use of harder structures is likely to do nothing more than relocate the problem downstream. Less dramatic measures are recommended below.

6.3.1 Conduct Limited Floodplain Construction

Stream bank instability and stream incision are more pronounced in WF10 (Upper Hope Valley), causing channel behavior to cross a threshold. Natural recovery over time spans less than decades may not be possible. Because the relationship between the channel and the adjacent floodplain has been substantially altered, larger floods are contained within the channel. More erosive force is applied to stream banks and gravel bars and riparian vegetation is unable to stabilize these surfaces. In incised streams, this process is likely to continue until a new floodplain has been created at a lower base level.

This new floodplain surface can also be created by active restoration. The new floodplain allows flood flows to spread out, reducing erosive stress on stream banks and allowing riparian vegetation to become established on both stream banks and bars. A demonstration project to assess this restoration technique should be considered. A preliminary cost estimate was prepared based on the following assumptions

- one meander wavelength will be treated;
- design and implementation will be carried out by trained professionals with a team of volunteers available for revegetation components; and,
- plant material will be obtained from local cuttings of primarily willow species

The estimated cost, per site, including planning, design, and implementation would be approximately $40,000 to $50,000. A 3-5 year monitoring plan should be developed and implemented by trained restoration ecologists. This monitoring plan should include the potential for periodic hand watering of plant material within the project site. The estimated cost to develop and implement the monitoring plan would be approximately $15,000 to $20,000. If monitoring is conducted in conjunction with the Bio-technical Treatment Project, the cost of monitoring could be reduced considerably.

6.3.2 Support Floodplain Restoration in Markleeville

The Forest Service Guard Station occupies historic floodplain just downstream of the Highway 89 crossing in Markleeville Reach MC2). The station is regularly flooded during rain-on-snow floods. The floodplain should be restored in this area. This would require removal of the floodwall, foot bridge, and nearby buildings, thereby improving downstream hydraulic conditions during floods. This project would involve relocation of the existing Guard Station to Turtle Rock Park and restoration of the channel through floodwall removal and floodplain enhancement. The Forest Service has already developed a plan and submitted for funding to relocate the Guard Station. The Alpine Watershed Group and other entities should support the activities proposed by the Forest Service. As appropriate, volunteer groups should be mobilized to assist in revegetation and monitoring efforts.

6.3.3 Support Floodplain Restoration along the East Fork

The road and other infrastructure occupy historic floodplain in locations throughout reaches EF5 through EF9. While moving the road higher in the canyon is not feasible due to high costs, in some isolated locations it may be possible to move the road nearer to the valley wall, thereby restoring floodplain or meanders. Levees constructed to protect the road have had a negative impact on channel and floodplain function. The assessment team recommends that these levees be modified or removed. The reestablishment of riparian vegetation should be incorporated into this project. Recreational impacts are fairly extensive in this reach, which should receive high priority for managing recreation to reduce riparian and floodplain impacts. Suggestions include designation of access for fishing, boating, and camping to allow for recovery and regeneration of riparian vegetation. A cost estimate was developed for this project. Project assumptions included the following:

- the cost estimate has been developed for removal of one levee;
- removal would consist of recontouring of the levee into a geomorphically functional bar (complete removal of the levee would be required at channel inlet and outlet locations);
- additional stabilization of road embankments may be necessary pending the results of the hydraulic modeling. Costs associated with stabilization efforts are not included in this cost estimate; and,
- extensive revegetation of the restored bar and side channel features would be expected.

The estimated cost of the project, including planning, design, and implementation, would be approximately $80,000 to $110,000.

6.4 Water Quality

The improvement of water quality within the Upper Carson River Watershed could be advanced through any one of several activities. General activity categories are described and, as appropriate, specific locations are identified.

6.4.1 West Fork Flow Diversion

Flow diversion in the lower West Fork negatively affects geomorphic and ecosystem processes. Several groups have been working to identify additional sources of water. The work of these groups should be supported, and other efforts to secure more flow for the river should be considered. It is important to note that any action or modification that affects a water diversion would need to be consistent with the Alpine Decree and existing water rights.

6.4.2 Support Efforts to Remediate Effects of Past Mining Activities

Past mining activities have water quality impacts on the watershed today, especially the effects of acid mine drainage (AMD). These effects are known to occur in Leviathan and other creeks in association with the Leviathan Mine (Herbst 2003). Mining impacts have also been documented in Monitor Creek (Millenium Science and Engineering 2003). The potential water quality effects of these activities on the East Fork Carson River have been examined, but no negative impacts have been documented (Herbst 2003; Vinyard and Watts 1992). Some natural mineralization of water occurs in both of these areas, especially the Monitor Creek watershed, and makes identification of potential mine impacts more difficult (Millenium Science and Engineering 2003).

Both of these areas are currently under management by public agencies. The State Water Quality Control Board obtained the Leviathan Mine site in 1985 to facilitate remediation. It was designated a Superfund site in 2000 by the EPA. The State of California has responsibility for meeting EPA Superfund remediation requirements. The Leviathan Unit of the Lahontan Regional Water Quality Control Board implements management at the site, and has several active projects for AMD remediation and site restoration (Lahontan Regional Water Quality Control Board 2003). The Colorado Hill area is almost entirely owned and managed by the U. S. Forest Service. Remediation is currently underway as part of the Interdepartmental Abandoned Mine Lands Watershed Clean-up Initiative (Millenium Science and Engineering 2003).

A cost estimate was developed for a limited water quality monitoring project. Assumptions associated with that prospective project include the following:

- sampling would occur over a five-year period at a total of 6 stations;
- approximately three samples would be collected at each station, three times per year; and,
- sample analysis would be conducted by a certified lab at an estimated cost of $300 per sample.

The estimated cost of the monitoring project, including all travel, sample collection, sample analysis, and data presentation, would be approximately $70,000.

6.4.3 Support Efforts to Minimize Indian Creek Wastewater Export Impacts

Restoration efforts related to the impacts of wastewater export have focused on both Indian Creek Reservoir and Indian Creek itself. Although Indian Creek was outside the scope of this assessment and was not analyzed in detail, it has been highly modified by wastewater management and irrigation diversion. Restoration efforts in this watershed will have substantial ecosystem benefits.

6.5 Land Use Impacts

As discussed at length in Chapter 5, land use impacts have had a pronounced impact on the Upper Carson River watershed over time. Impacts of the greatest intensity clustered mostly during the second half of the nineteenth century. Since that time, most land use activities have declined in intensity, thereby allowing the watershed to improve somewhat. Over the last 50 years, land use impacts have occurred in association with mining (the Leviathan Mine, discussed above in Section 6.4), diminished level of grazing, and recreation.

6.5.1 Grazing Management

The effect of unrestricted grazing in riparian areas has been to reduce stream bank stability. Resulting increases in erosion negatively affected geomorphic and ecosystem function. Furthermore, increased stream dynamism results in the loss of extensive areas of meadow, which represent valuable pasture. Because streams within the watershed are relatively dynamic naturally, reducing the stability of stream banks has served to increase erosion and stream dynamism. As a result, grazing management in riparian areas should focus on maximizing riparian vegetation vigor and density, especially woody shrubs.

Meeting this objective does not necessarily require the exclusion of grazing stock from riparian areas, although restoration of degraded areas in some environments is more rapidly accomplished by exclusion (Bentrup and Hoag 1998; Kattelmann and Embury 1996). Some studies suggest that limited, managed grazing may result in more vigorous riparian vegetation (Leonard et al. 1997). Therefore, the selection of appropriate grazing strategies should focus on:

> "timing, duration and frequency of grazing; distribution of livestock; stocking rates; utilization levels and patterns, and pasture design, including topography and seasonal implications of topography" (Leonard et al. 1997).

Controlling the timing, duration, and frequency of grazing can minimize soil compaction, prevent damage to streambanks, and allow sufficient rest to promote the regeneration of riparian plant species. Fencing the riparian area facilitates grazing management to allow for resting riparian pastures and rotating stock among different areas. Fenced areas should be sized so as to allow for natural stream dynamism (Bentrup and Hoag 1998). Strategies that shift livestock use from riparian to upland areas should also be explored, such as development of water sources, shade, or salting areas in uplands. Other ideas for managing livestock distribution include the designation and hardening of stream crossings, and herd management and husbandry practices that focus on herd mobility through culling, breed type, and livestock age class. Adjusting the stocking rate is of little value unless the herd is managed to utilize more than just the riparian areas, although in some cases temporary reduction in numbers will allow recovery at a specific location. Utilization of pasture and riparian forage can be monitored and animal grazing preferences taken into account to promote utilization of preferred forage. The steepness of slope, wet soils, lack of green forage, and water can be compensated for by selecting the season of use, and by frequently riding and herding the livestock to relieve pressure on key areas. Riparian pasture design incorporates stream position in relation to available and preferred forage, topography, soils, and fencing. Streams used as pasture boundaries often sustain multiple impacts along the fenceline, especially trampling. Exclusion fencing for small seeps or spring areas is effective, but tends to concentrate impacts along the unprotected stream. It is more effective to center the stream within the pasture area, to provide hardened water crossings, and perform other grazing management practices. These grazing practices:

> "…influence the economic feasibility and practicality of the management strategy, which are both essential if commitment to the strategy is to be achieved" (Leonard et al. 1997).

Pastures throughout the assessment area are irrigated by flood techniques. The system of ditches required to get water on pastures may be vulnerable to erosion or capture during large floods. Flood irrigation systems should be designed and operated to minimize the potential for these impacts. Other types of irrigation systems could be considered (sprinklers).

6.5.2 Recreation

Recreation use can have a substantial impact on natural environments. Large and sometimes ecologically sensitive areas are accessed by recreationists who unintentionally trample vegetation, erode soil, and disturb wildlife. Such human-related biophysical changes present a dilemma for land managers charged with providing recreational opportunities and preserving natural environments (Marion 1998). Increasingly, land managers recognize that some degree of resource impairment is an inevitable consequence of recreation use in any form.

By virtue of their numbers, recreationists can pose a real and significant threat to the very resource they so cherish. This is particularly true at locations where effects are concentrated (trails, campsites, river put-in locations, etc.). Specific consequences of visitation to these areas include the trampling and subsequent loss of ground vegetation, shrubs, tree seedlings, and felling of saplings; erosion of surface litter and humus; exposure, erosion, and compaction of mineral soil; and exposure of tree roots and damage to tree trunks. Since the level of use is an inherent determinant of recreational impacts, documenting use levels is an important first step in relating recreational activities to specific types and levels of impact. As the level of recreation increases, so does the need for managers to develop and implement management policies, strategies, and actions that permit the recreational use of areas without compromising their ecological and aesthetic integrity (Hutcheson et al. 1990).

Land and recreation managers have recognized the need for visitor management and resource protection programs to balance visitation with its associated resource impacts. Managers must strive to minimize rather than eliminate impacts, with consideration given to the consequences of their decisions on the quality of visitors' experiences. Managers must consider the individual site and aggregate or area-wide effects of their policies under both short- and long-term perspectives. Visitor impact monitoring programs offer significant benefits and provide an essential element in planning and management decision making. Increased attention to these issues has resulted in the development of a new discipline - recreation ecology. This discipline generally seeks to identify the type and extent of resource impacts and to evaluate relationships between use-related, environmental, and managerial factors.

The assessment team recommends that efforts by Alpine County, the Forest Service, and the Bureau of Land Management to identify and manage impacts of recreation on natural resources be supported. This should include not only recreation that occurs along the banks of the Carson River and its tributaries, but in upland areas as well. Impacts in backwoods areas can lead to increased erosion and sedimentation in area streams. Support could take the form of helping determine existing recreational use levels, develop and distribute educational material, and monitoring of recreation impacts at specific locations.

6.5.3 Forest Structure and Fire

Fire has always been an integral component of low elevation (below 8000 feet) forests along the eastern Sierra front. In many areas, prehistoric forest stand conditions were strongly influenced by regularly occurring, low-intensity surface burning. Although hot, crowning, stand-replacing fires probably occurred in some locations, widespread low-intensity fires were more common, and fire return intervals were much shorter (SNEP 1997). Forests adapted to these conditions were open and dominated by fire-tolerant, fire-adapted species. These ecosystems had fewer small trees and less ground fuel. This scarcity of fuel limited the intensity of wildland fires. Low intensity wildland fires typically did not kill larger fire-tolerant trees but often consumed small encroaching trees, other vegetation, and dead fuels. This fire regime has ecological benefits: nutrients are cycled more efficiently, remaining organic material stabilizes the soil surface, and the soil remains intact (Chang 1997).

Unintended consequences of logging, livestock grazing, and fire control in the assessment area resulted in a change in species composition and forest structure within this type of forest. These changes have likely been most apparent in forests historically dominated by large red fir or Jeffrey pine, were many of the larger trees were harvested in the late nineteeth century. Subsequent fire suppression activities have led to the dominance of these forests by other specieis such as white fir and lodgepole pine, and higher stocking rates of smaller trees (McKelvey et al. 1997). These changes, in turn, predisposed extensive areas to catastrophic, stand replacing wildland fire and forest ecosystem health problems. One of the most striking aspects of our review of historic photos (figures 5.1, 5.2, 5.3, 5.9, and 5.11) was the increase in forest stand density over recent time. Photos were taken from the same place, looking at the same forest, at different periods in time. The photos capture the differences that have developed in species composition and forest structure. Often, today's forests are littered with dead material and choked with small trees that reach into the crowns of the larger, older-age forest above. During drought periods, these forests are predisposed to insect infestations and disease outbreaks. When ignited, small trees and other vegetation (ladder fuels) burn along with the dead material, fueling severe, high intensity wildland fires. At these intensities, wildland fires kill all of the trees – even large ones that, at lower fire intensities, would normally survive.

In these cases, wildland fires damage key ecosystem components. High-intensity fires consume the soil's organic layer and burn off or volatilize nutrients (Chang 1996). The soil's capacity to absorb water is often lost. The fine, powder-like ash that follows a severe wildland fire makes water bead on the surface. These so-called "hydrophobic conditions" result in highly erodable soils. Water can run unimpeded over the surface. Under these circumstances, the soil becomes more susceptible to erosion, washing topsoil off the hillsides, clogging downstream watercourses.

The assessment team recommends that efforts by the Alpine Fire Safe Council, the U.S. Forest Service, the Bureau of Land Management, and Alpine County to address wildfire and forest health issues in the Upper Carson River watershed be supported. Active measures, such as thinning and prescribed fires, may be required to move forest structure toward more historic conditions in areas where logging and fire suppression have resulted in changes in forest structure. The work of agencies or groups that are attempting such measures should be supported. Also, efforts to reduce hazardous fuels must be coupled with efforts to assist private landowners in taking preventative action in their own communities. Creating defensible perimeters around homes, improving building codes, and employing fire resistant landscaping will help reduce fire risk to communities. These and other such actions can help prevent fires from spreading into the wildlands and burning homes. These actions could also result in a reduction in insurance premiums and a reduction in fire suppression costs.

6.6 Monitoring and Adaptive Management

Monitoring is a key element to any long-term watershed restoration effort. Monitoring activities of particular relevance within the context of the Upper Carson River watershed are identified below.

6.6.1 Watershed-wide Baseline Monitoring

Watershed-wide monitoring is important to assess the efficacy of restoration and management efforts, and to determine where restoration should be conducted in the future. Possibly the most valuable information for this assessment has been historic photos of streams, floodplains and riparian areas. Photo documentation is a relatively simple method for monitoring watershed condition over time. Storage and archiving of photos has been simplified through the development of electronic formats. We strongly recommend that the Alpine Watershed Group implement a program of photo documentation throughout the watershed. Permanent photo monitoring locations should be established and photos should be taken at least once a year (preferably at low water). Photos can also be taken during unusual events such as floods.

Currently, water quality monitoring efforts are underway through Alpine County, the Carson Water Subconservancy District, and the Lahontan Regional Water Resources Control Board. Also, the Alpine Water Groups has recently agreed to implement a citizen-based water quality monitoring program. Part of that program will be the establishment of photo monitoring locations and protocols. Current programs have been developed, at least in part, to provide data needed by the Lahontan Regional Water Quality Control Board.

Assessment of water and habitat quality through analysis of aquatic macro-invertebrate populations is a useful tool to identify impacts of land uses. The establishment of reference (or undisturbed) conditions is an important part of such analyses. A large project, funded by the Lahontan Regional Water Quality Control Board., is currently underway to assess macro-invertebrate populations throughout the Lahontan region, and to establish reference conditions. The results of this survey, which will likely be completed at the end of the year, will guide future monitoring needs and may identify specific bio-monitoring projects in which the Alpine Watershed Group can participate. Bio-monitoring may help identify and assess the potential impacts of land uses in riparian areas, such as grazing.

Long-term monitoring of the entire Upper Carson River study area could consist of the elements listed below.

- Sample water quality monitoring points have been established throughout the watershed and should be monitored several times per year, especially during the snowmelt season and first flush in the fall. Much of the monitoring could be conducted through volunteer groups with additional intensive monitoring resulting from analysis of the watershed-wide data set. Aquatic macro-invertebrate sampling should be considered pending the results from Monitor Creek. The estimated cost, including planning, oversight, sample analysis, and database management, would be approximately $20,000 to $40,000 per year.
- Photo points should be established throughout the watershed to identify impacts associated with large flood events. Monitoring could be conducted by volunteer groups with photo points being established by members of the Alpine Watershed Group. The estimated cost, including planning, oversight, and photo collections management, would be approximately $2,000 to $5,000 per year.
- Bank retreat or erosion stakes should be established in Hope, Faith, Charity, and Hot Springs meadows to assess rates of bank erosion. Once established, annual measurements could be taken to allow for refinement of restoration priorities. The estimated cost, including

planning, oversight, materials, and data management, would be approximately $10,000 to $15,000 for first year and $2,000 to $5,000 for each subsequent year.

- Stream flow gages should be established at key locations (approximately 3 sites) on the West Fork to assess summer low flow conditions. Low cost gages could be used for the summer months and then removed during the wet season. The estimated cost, including planning, equipment, training, and monitoring, would be approximately $30,000 to $35,000 for the first year (to establish gages and develop rating curves) and $10,000 to $15,000 for each subsequent year.

6.6.2 Monitor Streambed Degradation at Selected Bridge Locations

Streambed degradation was noted in the vicinity of two bridge locations - the Hope Valley Bridge and the Markleeville Bridge. This condition was noted during hydraulic modeling conducted as part of the detailed analysis and was likely caused by constriction of the channel at each bridge location. The rate of this degradation is not known, but its presence is of concern and should, at a minimum, be monitored. A 3-5 year monitoring plan should be developed and implemented by engineers with specific experience in hydraulic modeling and analysis. The estimated cost to develop and implement the monitoring plan at the two bridges would be approximately $15,000 to $25,000.

Bank stabilization conducted at the Hope Valley Bridge could have an impact on hydraulic characteristics of the channel through the bridge, depending on the magnitude of change and the extent of vegetation removal. Another alternative that could be given consideration is the installation of culverts that would increase the amount of flow that could pass beneath the roadway. Further hydraulic evaluation of these alternatives may be warranted.

Any effort to restore the floodplain downstream of the Markleeville Bridge will likely have an impact on the hydraulic characteristics of the channel through the bridge, and should therefore, be coordinated with a hydraulic analysis at the bridge.