# Section 3.0 - Development of the Watershed Restoration Plan (Proposed Actions)

## 3.1 Overall Strategy for Restoration Planning

This section defines the underlying principles of the Alamosa River watershed restoration strategy. This strategy was developed in cooperation with the Trustee Council and stakeholders and was discussed in a public meeting on September 15, 2004.

### 3.1.1 Watershed Restoration Vision

The restoration strategy is based on the adopted Master Plan goals and objectives listed in **Section 1.2**, but it must consider constraints that limit the final outcome of the project. Constraints affecting the potential for improvement in the watershed include:

- Available money for restoration.
- Natural environmental conditions limiting quality of resources or habitat.
- Physical constraints due to access, elevation, space to construct projects, climate, and existing infrastructure.
- Human factors including water rights, irrigation use, and natural resource development.

Given the existing watershed conditions and the constraints described in **Section 2**, restoration of the Alamosa River watershed to conditions that existed prior to significant human habitation is not practical. Instead, the overall restoration strategy is to identify and pursue the opportunities for recovering those lost natural values and enhancing those existing features that have the highest potential for success and that have the most favorable ratio of likely benefits to likely costs. Based on this strategy of balancing an idealistic view with pragmatic analysis, a "watershed restoration vision" was developed by the project team, Trustees, and stakeholders as a picture of what the watershed could look like after the Master Plan is implemented. The watershed vision is summarized below according to resource category.

***We envision a naturally functioning channel system***

- Streambanks are stabilized in eroding areas upstream of Terrace Reservoir
- Sediment load from the upper watershed is reduced
- High banks between Terrace Reservoir and Gunbarrel Road are stabilized
- Channel restoration between Gunbarrel Road and County Road 10 is completed and extended upstream of Gunbarrel Road and downstream of County Road 10 to County Road 13
- Sediment is effectively managed downstream to the end of the river

***We envision a balance between competing human and environmental uses of water***

- Perennial streamflow is present from Terrace Reservoir to County Road 10
- Ground water levels can support riparian vegetation and well uses

***We envision water quality that supports beneficial uses in the watershed***

- Water quality meets applicable water quality standards
- Water quality can support reproducing fish populations below Wightman Fork

***We envision Terrace Reservoir utilized reliably to its fullest capacity***

- The storage restriction is removed and the outlet works function reliably
- Terrace Reservoir is operated and maintained with minimal downstream impacts
- The water quality of released water does not impair downstream watershed uses

***We envision a sustainable fishery on the Alamosa River and quality terrestrial and avian habitat***

- There is a reproducing cold water fishery between Wightman Fork and Terrace Reservoir
- There is a reproducing cold water fishery in Terrace Reservoir
- There is a stocked cold water fishery between Terrace Reservoir and Gunbarrel Rd
- Fishery conditions upstream of Wightman Fork are preserved
- Quality terrestrial and avian habitat in the watershed is maintained

***We envision restoration of riparian habitat in the watershed***

- Multi–story vegetative habitat downstream of Terrace Reservoir is enhanced
- Noxious weeds are controlled throughout the watershed
- A sustainable cottonwood/willow habitat community is established below Terrace Reservoir
- Habitat upstream of Terrace Reservoir is improved in locally degraded areas

***We envision an efficient use of agricultural water from the Alamosa River***

- Diversions are sustainable and efficient
- Water quality is acceptable for agriculture

***We envision recreational opportunities in the watershed that benefit the public***

- The watershed is seen as a beneficial regional recreation resource
- Recreation benefits the regional economy
- Expanded opportunities for fishing and camping are available
- Expanded public access to the Alamosa River at designated locations is available between Jasper and Gunbarrel Road

### 3.1.2 Restoration Project Planning Process

The watershed restoration strategy is to implement the best combination of projects to make the watershed restoration vision described above a reality. The best combination of projects is referred to as the preferred alternative. The Master Plan uses the following process to choose the preferred alternative:

- **Brainstorming** – A broad list of individual projects is assembled including all ideas submitted by the project team and local and agency stakeholders. All potential projects are included ignoring constraints.
- **Screening** – Eliminate projects with fatal flaws in the areas of technical feasibility, permitting, cost, legal issues, and public acceptance.
- **Project Development** – Further develop project details for the projects that passed the screening process.
- **Project Evaluation** – Evaluate projects according to their performance when measured against several multi–disciplinary criteria (see **Section 3.3**). Each Project is given a score and the best projects are identified.

- **Alternatives** – In **Section 4** of the Master Plan, the best projects are assembled into watershed–wide alternatives that are different combinations of individual projects, each geared toward obtaining the watershed vision. Up to 3 alternatives are developed for each of 3 funding levels ($5 million, $10 million, and $15 million).
- **Alternative Impact Evaluation** – Both positive and negative impacts of the alternatives are evaluated.
- **Choose Preferred Alternative** – A preferred alternative is chosen for each funding level based on impact evaluation and public comment.

## 3.2 Evaluation of Natural Resources Impacts

An overall evaluation of the Alamosa River watershed stream segments and subwatersheds is included in **Section 2** using evaluation criteria developed for each of the main resource categories. The condition of each stream segment is rated on a qualitative good/fair/poor scale according to each criterion.

This subsection uses the evaluation completed in **Section 2** and summarizes those reaches with the most natural resources impacts due to human activities. Segment impacts from natural causes such as mineralized soils are not included. The segments most impacted by human activities in each category are summarized in **Table 3-1**. The impacted segments are depicted in **Figure 3–1**. Each reach except reaches 11, 12, T1, and W4 is impacted in some way. The most heavily impacted segments are key locations for potential improvement projects. These stream segments will be the top priorities for restoration projects.

**Table 3-1. Segments Most Impacted by Human Activities**

| Impact | Most Impacted Reaches / Subwatersheds |
|---|---|
| Channel instability | 1, 2, 3 |
| Lack of channel capacity | 1, 2 |
| Altered surface water flow regime | 1, 2, 3, 4 |
| Poor surface water quality (instream) | 5, 6, 7, 8, 9, 10, W1, W2, W3 |
| Ground water uses impacted | 1, 2, 3 |
| Sediment in channel | 1, 4 |
| Impacted riparian habitat | 1, 2, 3, 6, 7, 8, 9, 10, W1, W2, W3 |
| Impacted aquatic life | 2, 3, 4, 5, 6, 7, 8, 9, 10 |
| Impacted agricultural resources | 1, 2, 3 |
| Impacted recreational uses | 5, 6, 7, 8, 9, 10, W1, W2, W3 |

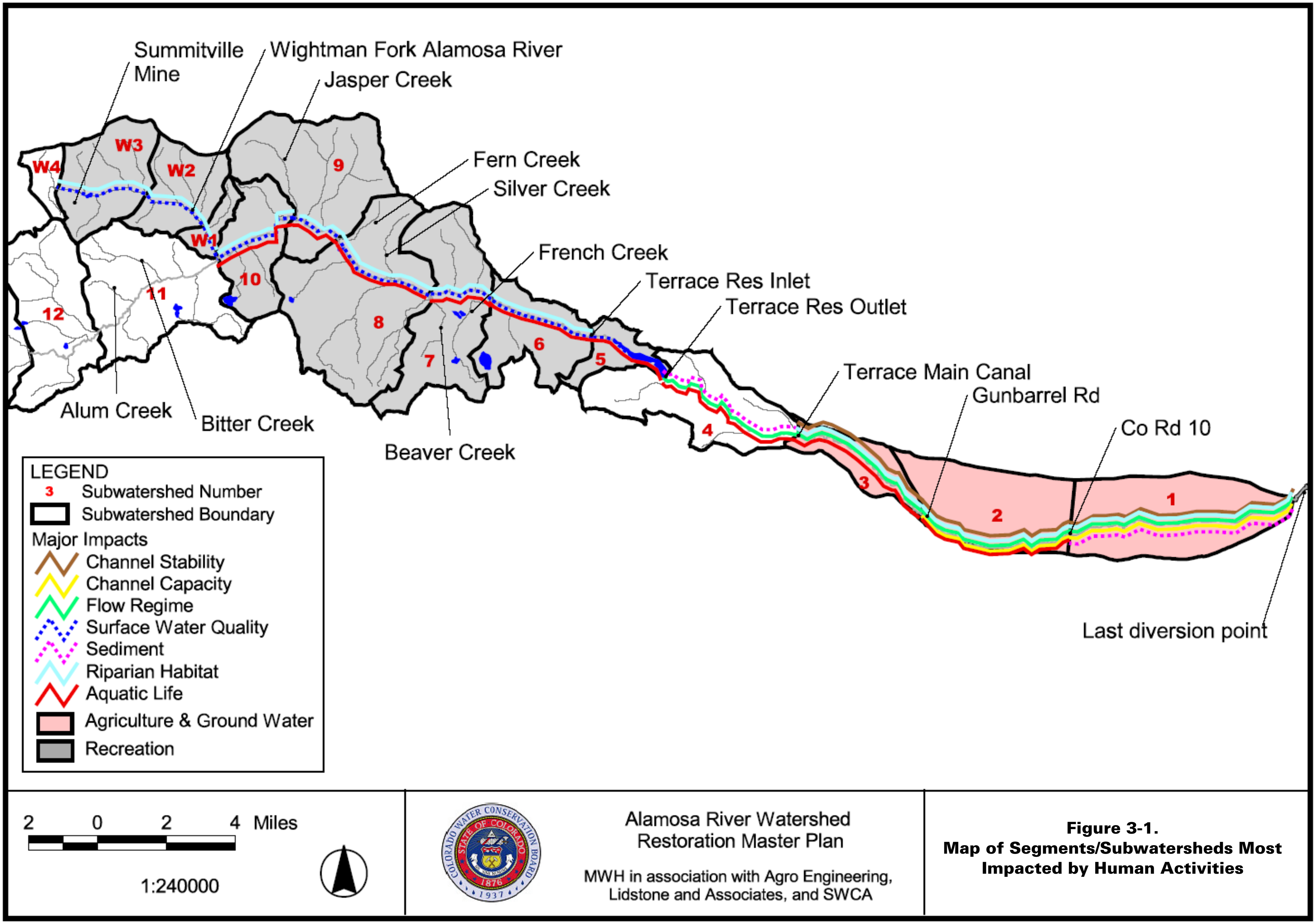



**Figure 3-1.**
**Map of Segments/Subwatersheds Most Impacted by Human Activities**

## 3.3 Process of Analyzing Potential Restoration Projects

### 3.3.1 Universe of Projects

In the brainstorming process, as many potential restoration projects as possible were collected from various sources. The brainstorming process was as open–minded as possible. Projects that were traditional, non–traditional, and unorthodox were all accepted. Projects submitted by different sources were evaluated equally. At least one project was developed for each issue identified in **Section 2**. Projects were geared toward attaining the watershed restoration vision described in **Section 3.1**. The initial list of potential projects encompassing the universe of imaginable projects is shown in **Tables 3–2** to **3–5**, organized geographically.

The tables also indicate if projects were considered for further review or if they were found to have a fatal flaw in the screening process. Fatal flaws were considered in the general categories of technical feasibility, permitting, cost, legality, and public acceptance. Fatal flaws were identified by the project team based on experience, judgement, and the team's understanding of the Alamosa River watershed. The fatal flaws for those projects that were screened out are shown in **Table 3-6**. Some projects were also eliminated or combined with others due to duplication and overlap. Those projects continuing for further review are discussed in more detail in the section indicated in the table.

**Table 3-2. Universe of All Potential Improvement Projects Upstream of Terrace Reservoir**

| Project | Resource Category Where Discussed (Section) | Further Review |
|---|---|---|
| High altitude reservoir to store water for instream flow rights | Water quantity (3.5.3) | yes |
| New main stem reservoir upstream of Terrace Reservoir to store water, capture sediment and improve downstream water quality. | Water quality (3.9.4) | yes |
| Sediment traps, detention ponds, or wetlands near the bottom of Alum, Burnt, Iron or Bitter Creeks to reduce sediment load to the main stem and to trap certain pollutants. | Sediment management (3.8.3)<br>Water quality (3.9.3) | yes |
| Active water quality improvement systems such as lime injection to raise pH, precipitate metals, and improve water quality in main stem. | Water quality (3.9.3) | yes |
| Passive water quality improvement such as wetlands or limestone systems in tributaries to improve water quality in main stem. | Water quality (3.9.2) | yes |
| Lake on Alamosa main stem below confluence with Wightman Fork to reduce fine sediments and improve water quality (with or without lime injection). | Water quality (3.9.4) | yes |
| Treatment of mine drainage from small mines other than Summitville such as the Pass–Me–By Mine. | Water quality (3.9.1) | yes |
| Pipeline to gather low pH tributaries or other sources to one location for water quality improvement | Water quality (3.9.5) | yes |
| Pipeline/ditch from low pH tributaries to area of alkaline soils in lower watershed | Water quality (3.9.6) | yes |
| Summer season land application of selected flows to facilitate metals removal via percolation through soils | Water quality (3.9.7) | yes |
| Facilitate freezing of acidic drainages and tributaries during the winter low–flow period to reduce loading | Water quality (3.9.8) | yes |
| Stream restoration to reduce sediment production, improve aquatic habitat and improve recreational experience (upstream as far as Wightman Fork) | Channels (3.4.1) | yes |
| Manage maintenance of existing roads and construction of new roads to minimize impacts on sediment production and wildlife habitat. | Sediment Management (3.8.2) | yes |
| Noxious weed inventory and control if necessary | Riparian habitat (3.10.1) | yes |
| Revegetate disturbed areas in the upper watershed that should support native vegetation. | N/A | no |

**Table 3-2. Universe of All Potential Improvement Projects Upstream of Terrace Reservoir**

| Project | Resource Category Where Discussed (Section) | Further Review |
|---|---|---|
| Fish stocking, Wightman Fork to Terrace Reservoir | Biological resources (3.11.1) | yes |
| Construction of fish barriers to protect native cutthroat trout populations | Biological resources (3.11.2) | yes |
| Public relations campaign to publicize recreation opportunities. | Studies & Administrative (3.14.1) | Yes |
| Stream buffer | Riparian habitat (3.10.4) | Yes |

**Table 3-3. Universe of All Potential Improvement Projects in Terrace Reservoir Subwatershed**

| Project | Resource Category Where Discussed | Further Review |
|---|---|---|
| Increase capacity of Terrace Reservoir by raising the dam. | Terrace Reservoir (3.7.2) | yes |
| Increase capacity of Terrace Reservoir by removing accumulated sediment. Prevents resuspension and downstream migration of contaminated sediments during high flow events. | Terrace Reservoir (3.7.3) | yes |
| Increase capacity of spillway at Terrace Reservoir to remove 2,200 ac–ft filling restriction; rehabilitate existing spillway or construct new spillway. | Terrace Reservoir (3.7.1) | yes |
| Add hydropower at Terrace Reservoir | Terrace Reservoir (3.7.5) | yes |
| Site specific study of Probable Maximum Flood at Terrace Reservoir to produce a lower probable maximum flood (PMF) and thereby reduce the scope and cost of spillway improvements needed to eliminate the filling restriction. | Studies & Administrative (3.14.2) | yes |
| Improvements to Terrace Reservoir outlet works to reduce the frequency of maintenance and associated reservoir drawdown; repair existing structure or replace with new structure. | Terrace Reservoir (3.7.3) | yes |
| Multi–level outlet works on Terrace Reservoir to improve function and downstream water quality | Terrace Reservoir (3.7.3) | yes |
| Terrace Reservoir water exchange. Acquire appropriate water rights, store in Terrace Reservoir, then have Terrace release throughout winter. | Water quantity (3.5.2) | yes |
| Terrace Reservoir dewatering management plan to prevent huge amounts of sediment from being released during maintenance activities. | Terrace Reservoir (3.14.5) | yes |
| Fish stocking program for Terrace Reservoir. | Biological resources (3.11) | yes |
| Increase elevation of minimum pool (combined with reservoir enlargement) to provide additional fishery and recreation benefits. | N/A | no |
| Improve public access to Terrace Reservoir, i.e. parking area, trail | Recreation (3.13.1) | yes |
| Sediment quality sampling in Terrace Reservoir to understand implication of sediment management/releases/dredging | Studies & Administrative (3.14.6) | Yes |

**Table 3-4. Universe of All Potential Improvement Projects Downstream of Terrace Reservoir**

| Project | Resource Category Where Discussed | Further Review |
|---|---|---|
| New reservoir immediately downstream of Terrace Reservoir; provides regulation storage and serves as a sediment trap for material washed out of Terrace Reservoir during maintenance drawdowns. | Water quantity (3.5.3) | yes |
| Off channel water recharge on the alluvial fan north of the Alamosa River. Either to capture high flows or to store purchased water right. | Water quantity (0) | yes |
| New reservoir in lower watershed on main stem near Gomez Cemetery. Provides conservation storage, sediment storage and flood benefits. | N/A | no |
| Purchase appropriate water rights to provide year–round minimum instream flow of approximately 10 cfs below Terrace Reservoir. | Water quantity (3.5.1) | yes |
| File new junior water right application | Water quantity (3.5.1) | yes |
| Provide alternate water sources to Terrace Irrigation Company shareholders (e.g., ground water, other basins) so minimum instream flows can be supplied by Terrace Reservoir. | N/A | no |
| Provide enough water to fulfill all appropriated water rights by importing water | N/A | no |
| Create a reserve fund to be used by irrigators for sediment management on fields and at headgates on an as needed basis. | N/A | no |
| Headgate consolidations to reduce the number of hard points in the river. | Agriculture (3.12.1) | yes |
| Add lime to irrigation reservoirs and fields for buffering effect. | N/A | no |
| Stream restoration projects from Gunbarrel Rd to County Rd 10 (in–progress Alamosa River Restoration Project). | Channels (3.4.1) | yes |
| Stream restoration projects upstream of Gunbarrel Road to reduce sediment impacts in lower watershed and provide other benefits. | Channels (3.4.1) | yes |
| Setback levees at Capulin to prevent flood damage. | Channels (3.4.3) | yes |
| Bypass channels or restored oxbows to increase flood carrying capacity in vicinity of Capulin. | N/A | no |
| Improve accuracy of flood maps and develop flood maps in unmapped areas | N/A | no |
| Capulin Flood Hazard Mitigation Plan | Channels (3.14.4) | yes |
| Modification of land use regulations to prevent future development in flood–prone areas. | Channels (3.4.3) | yes |
| Local diversion structure improvements | Agriculture (3.12.2) | yes |
| Noxious weed management | Riparian habitat (3.10.1) | yes |
| Grazing management in the riparian corridor | Riparian habitat (3.10.3) | yes |
| Obtain conservation easements from willing sellers to protect and enhance habitat | Biological resources (3.11.3) | yes |
| Native riparian vegetation planting, after instream flow is established. | Riparian habitat (3.10.2) | yes |
| Additional groundwater data collection to better understand well impacts and surface–ground water interactions (quantity and quality) | Studies & Administrative (3.14.2) | yes |
| Develop agreements with selected irrigation ditch owners to take floodwaters and distribute to fields or designed recharge areas. | N/A | no |
| Increase floodplain storage through channel restoration projects to recharge the groundwater aquifer. | N/A | no |
| Improve ditch and on–farm irrigation efficiencies (e.g., ditch lining) and transfer saved water to instream flow right. | N/A | no |
| Artificial recharge of groundwater basin | Water quantity (0) | yes |
| Replace metal irrigation system structures with other materials more resistant to low pH water (e.g., concrete, plastic–coated steel). | Agriculture (3.12.2) | yes |
| Stocking to establish instream fishery, if minimum instream flow is developed and meanders are established (above Gunbarrel Road) | Biological resources (3.11.1) | yes |
| Create sediment traps near Highway 285 or other sediment management activities downstream of County Road 10 | Sediment management (3.8.1) | Yes |
| Ice Jam Flooding Study | Studies & Administrative (3.14.3) | Yes |

**Table 3-5. Universe of All Potential Improvement Projects Covering the Entire Watershed**

| Project | Resource Category Where Discussed | Further Review |
|---|---|---|
| Funding for citizen organization to help implement and monitor Master Plan | Studies & Administrative (3.14.1) | yes |
| Support Summitville Mine cleanup operations. | Studies & Administrative (3.14.1) | yes |
| Public education program to increase visibility of Alamosa River as an important community resource in San Luis Valley. | Studies & Administrative (3.14.1) | yes |
| Acquisition of equivalent resource in an adjoining basin to provide habitat and recreation opportunities | Riparian habitat (3.10.5) | yes |
| Purchase land downstream of Wightman Fork for recreation and habitat | Riparian habitat (3.10.6) | |
| Monitoring plan, including baseline monitoring of fish, wildlife, channel geometry, water quality and vegetation, to determine effectiveness of projects. | Studies & Administrative (3.14.1) | Yes |
| Legal defense fund | N/A | No |
| Conservation easements | Biological Resources (3.11.3) | Yes |
| Dead tree management | Channels (3.4.2) | Yes |
| Access across private lands in designated locations to the Alamosa River for fisherman | Recreation (3.13.2) | yes |

**Table 3-6. Projects Eliminated in Initial Screening**

| Project | Reason Eliminated |
|---|---|
| Revegetate disturbed areas in the upper watershed that should support native vegetation. | Altered areas that are currently unvegetated are probably too steep and acidic to successfully revegetate |
| Increase elevation of minimum pool (combined with reservoir enlargement) to provide additional fishery and recreation benefits. | A put and take fishery would not require a larger minimum pool (current minimum pool is 1,500 acre–feet) |
| New reservoir in lower watershed on main stem near Gomez Cemetery. Provides conservation storage, sediment storage and flood benefits. | Better reservoir locations exist; not publicly accepted |
| Provide alternate water sources to Terrace Irrigation Company shareholders (e.g., ground water, other basins) so minimum instream flows can be supplied by Terrace Reservoir. | Water in other basins is more expensive and is overappropriated |
| Provide enough water to fulfill all appropriated water rights by importing water | Not feasible; no water available; not permittable |
| Create a reserve fund to be used by irrigators for sediment management on fields and at headgates on an as needed basis. | Sediment management plan upstream should provide source control |
| Add lime to irrigation reservoirs and fields for buffering effect. | May not be necessary and may probably already being done in cases where necessary |
| Bypass channels or restored oxbows to increase flood carrying capacity in vicinity of Capulin. | Not included in current river restoration plan near Capulin |
| Improve accuracy of flood maps and develop flood maps in unmapped areas | Limited flooding impact in areas other than Capulin, which is already mapped |
| Develop agreements with selected irrigation ditch owners to take floodwaters and distribute to fields or designed recharge areas. | Most diversion structures and canals already take all of the water they can |
| Increase floodplain storage through channel restoration projects to recharge the groundwater aquifer. | Will be associated with proposed channel restoration projects, not a stand alone project |
| Improve ditch and on–farm irrigation efficiencies (e.g., ditch lining) and transfer saved water to instream flow right. | Improving efficiency would reduce ground water recharge and is not legally feasible |
| Legal defense fund | This is not an appropriate public project because the nature of future legal battles is not known and there is not a source of money for this type of project. |

The projects that were not eliminated in the screening process are described in **Sections 3.4** to **3.14** according to resource category. The top projects were then scored and ranked against each other using a numerical process developed for the Master Plan. The numerical process is described below.

### 3.3.2 Project Evaluation Criteria

The Trustees developed screening and ranking criteria to be used for NRD–funded projects. The NRD criteria are comprehensive and are the basis for ranking potential Master Plan restoration projects. However, the Master Plan is not limited to NRD–funded projects, so the NRD criteria have been modified to eliminate the elements tied to NRD funding. Furthermore, local stakeholders requested the ability to rank projects using additional criteria related to public acceptance and benefit.

The Master Plan project evaluation ranking criteria are summarized in **Table 3-7**. The table describes the scoring methodology for each criterion. Each project is given a score between 1 and 5 for each criterion in **Section 3.15**. The criteria were assigned different weights according to relative importance, as determined by the stakeholders and Trustees at a public meeting on September 28, 2004 in Alamosa. Each potential project was given a total score that is the sum of all of the weighted criteria scores. This score, along with subjective measures, was used to determine the most preferable projects included in comprehensive watershed restoration alternatives. Additional information on alternatives development is included in **Section 4**.

Actual scores for each criterion were suggested by the consultant team and then circulated to the public and Trustees for review and comment. The Board of the Alamosa River Foundation determined the scores in the three public categories. The Foundation Board determined appropriate project scores by reviewing a survey that was mailed to over 200 stakeholders with 60 responses. Each of the five Board members informally spoke to their respective organizations and neighbors to gather feedback on the proposed projects. Feedback was gathered from representatives of Terrace Irrigation Company, Riverkeepers, and water users among others.

Project life cycle cost and potential for funding are considered important but are not included as part of the project evaluation criteria. Project costs and scores are discussed in **Section 3.15**.

**Table 3-7. Summary of Project Evaluation Criteria**

| Category | Criteria | Score of "1" | Score of "3" | Score of "5" | Weight |
|---|---|---|---|---|---|
| Technical | Likelihood of success (if project is implemented) | Low likelihood of success or no way to measure | Average likelihood of success compared to other projects with similar benefits | High likelihood of success compared to other projects with similar benefits | 2 |
| Technical | Technically feasible (to implement project) | May be technically feasible but must be tested | Likely to be feasible but must be tested in watershed | Proven feasible in similar watersheds | 1 |
| Technical | Protection of implemented project | Project cannot be protected | Project may be protected or partially protected | Project can be protected through land acquisition, easement, or other method | 1 |
| Public | Public acceptance | Significant opposition | Average acceptance | Highly encouraged by public | 3 |
| Public | Addresses issues critical to the public | Does not address critical issues | Moderately addresses critical issues | Significantly addresses critical issues | 3 |
| Public | Public benefit | Limited public benefit | Moderate public benefit | Significant public benefit | 3 |
| Environmental | Public health and safety | Creates public health or safety hazard | Neutral | Solves serious public health or safety problem | 1 |

**Table 3-7. Summary of Project Evaluation Criteria**

| Category | Criteria | Score of "1" | Score of "3" | Score of "5" | Weight |
|---|---|---|---|---|---|
| Environmental | Adverse impacts | Long–term mitigable injuries | Short–term mitigable injuries | No adverse impacts | 1 |
| Environmental | Environmental Permitting / Water Rights | Serious permitting obstacles | Typical permitting requirements | No permitting required | 1 |
| Benefits | Benefits in multiple resource categories | Only benefits 1 resource category | Benefits 3 resource categories | Benefits 5 or more resource categories | 2 |
| Benefits | Time to provide at least 50% of expected benefits[1] | More than 10 years | 4 to 7 years | Less than 2 years | 1 |
| Benefits | Duration of benefits[2] | Less than 10 years | 10 to 20 years | More than 20 years | 1 |
| Benefits | Benefit/Cost | Probable cost greatly exceeds probable benefit | Probable cost equivalent to probable benefits | Probable benefit greatly exceeds probable cost | 1 |
| Benefits | Addresses water quality, riparian and aquatic habitat issues | Does not address water quality, riparian and aquatic habitat issues | Moderately improves water quality, riparian habitat or aquatic habitat | Significantly improves water quality, riparian habitat, or aquatic habitat | 2 |

[1] measured from time of Master Plan acceptance by Trustees
[2] considering regular operation and maintenance

## 3.4 River Channel and Adjacent Corridor

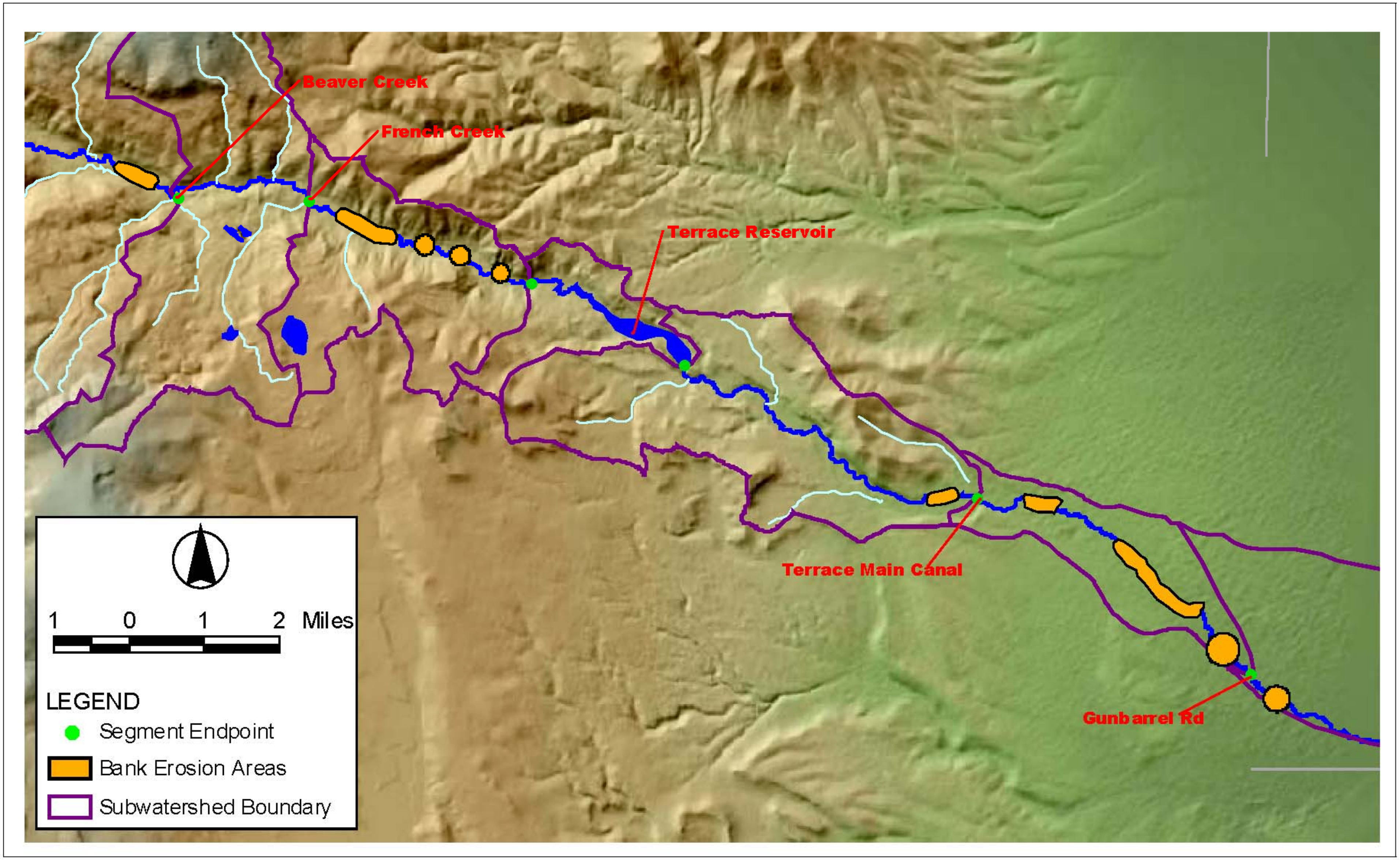
### 3.4.1 Stream Restoration

The stream restoration projects will stabilize the channel, limit the amount of sediment entering the river, promote native vegetation, and enhance migratory bird and fish habitat. The main focus of the proposed stabilization and restoration projects is to limit the amount of sediment entering the river due to human impacts causing stream bank erosion. Mitigating sediment supply will solve other aggradation (deposition) related problems such as channel instability at irrigation diversions, bridges, and in channel reaches without sufficient conveyance. Figure 3–2 shows locations in the watershed where significant bank erosion was observed. The potential stream restoration projects are grouped into the following regional categories.

- Terrace Reservoir to Wightman Fork
- Gunbarrel Road to Gomez Bridge
- County Road 10 to Gunbarrel Road
- County Road 10 to County Road 13

Required stabilization and enhancement measures vary depending on the specific reach. All stream restoration projects will require detailed designs that are location–specific and account for natural processes and appropriate stream type. For example, creation of fish habitat is not a goal below Gunbarrel Road unless the instream flow project is implemented. Conversely, it is important to provide fish habitat in the reach between Terrace Reservoir and Wightman Fork if water quality is improved. The following sections present specific proposed projects for the above mentioned regional categories.

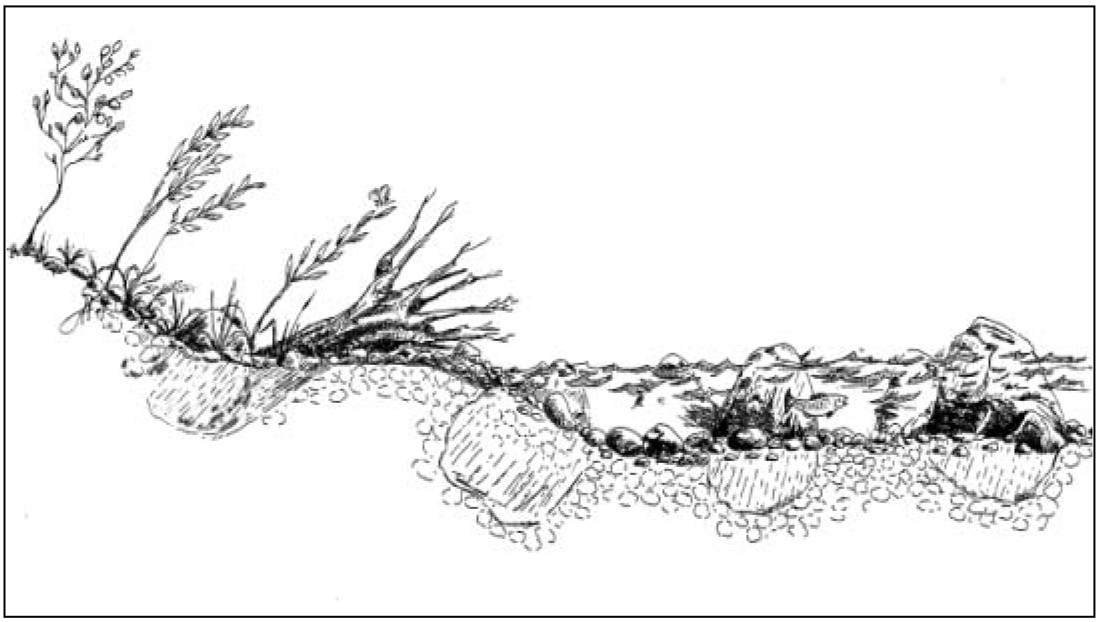
**Figure 3-2. Watershed Areas with Observed Erosion Problems**



### *Terrace Reservoir to Wightman Fork*

The Alamosa River goes through several plan form changes between Terrace Reservoir and Wightman Fork. In Reaches 6 (French Creek to Terrace Reservoir) and 8 (Fern Creek to Beaver Creek) it is an unconfined meandering stream. In these two reaches the river channel is diverse and constantly changing with numerous eroded cutbanks, alternating gravel bars and significant amounts of large woody debris in the channel. The rate and direction of changes must be closely determined prior to final design of channel improvements. The eroded banks in this area are, for the most part, a characteristic of natural Alamosa River processes and may serve some environmental benefits. It is recommended that the stream restoration efforts focus on small areas of the river channel impacted by human influences. By not restricting the channel's natural meandering tendencies in these two reaches the diverse river characteristics will be preserved, benefiting fish, wildlife, and natural biodiversity. Any bank protection projects in the area must be designed to be stable and to blend in with the environment. Fish habitat features could be incorporated into the design to provide areas for fish if the water quality improves. Bank regrading, rock, and vegetation will be required to stabilize eroding banks in specific areas. **Figure 3–3** shows several fish habitat features that will be incorporated into the design when stabilizing banks. The root wads will provide limited bank stabilization benefits and create fish habitat. The randomly placed boulders will create localized scour pools, provide instream cover, and encourage development of small gravel bars.

**Figure 3–3. Fish Habitat Features**



In Reaches 7 (French Creek to Beaver Creek), 9 (Fern Creek to Jasper Creek), and 10 (Jasper Creek to Wightman Fork) the river is confined, with a limited area suitable for stream restoration. These reaches are severely affected by large amounts of sediment entering the river from tributary channels. Therefore, any stream restoration would be futile without first minimizing the sediment load from these tributaries. For this reason, bank and channel stabilization are not being proposed in Reach 7, 9, and 10.

### *Gunbarrel Road to Gomez Bridge*

In the reach from Gunbarrel Road to Gomez Bridge there are steep eroded banks with the potential to introduce significant sediment load to the channel (refer to Figure 3–2 for locations). During periods of high flow, this sediment is transported downstream of Gunbarrel Road where the sediment drops out and clogs the channel.

### *County Road 10 to Gunbarrel Road*

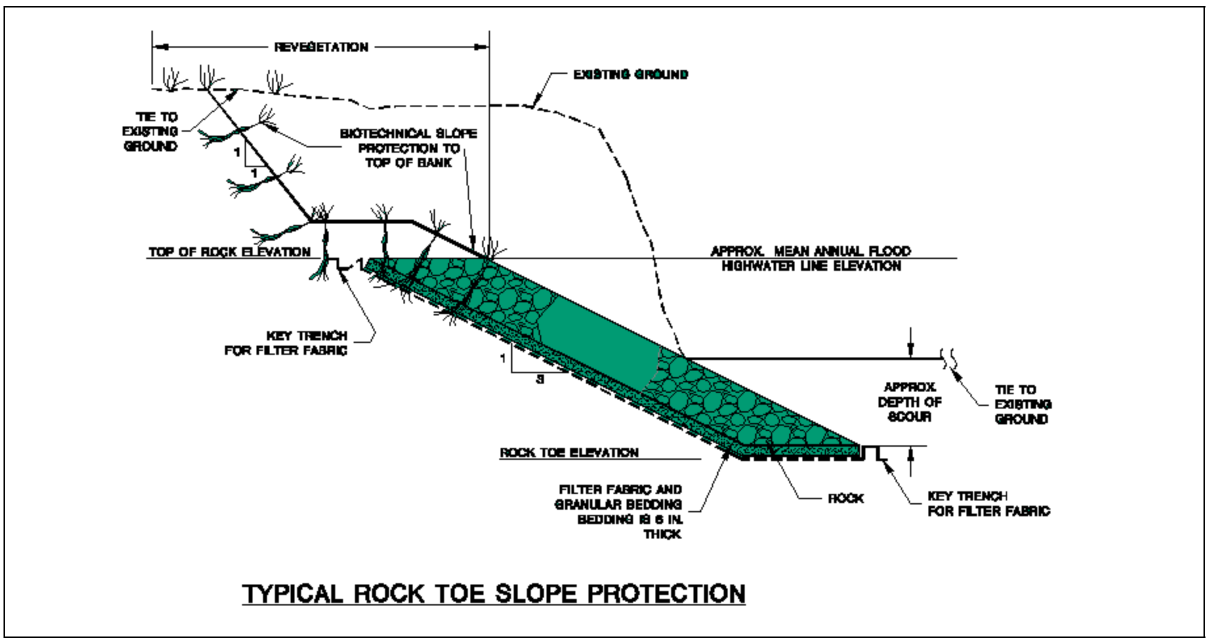
There is currently a stream restoration project underway between County Road 10 and Gunbarrel Road. Black Creek Hydrology developed a design to improve this area and funding was secured through the State of Colorado and other sources. No additional channel improvements or stabilization measures are being proposed in this reach.

### *County Road 13 to County Road 10*

Sediment aggradation is a problem for the reach between County Road 10 and County Road 13. Banks are unstable in isolated locations. The proposed restoration project between County Road 10 and Gunbarrel Road will minimize the amount of sediment entering the channel upstream of this reach. By stabilizing the eroded banks upstream of Gunbarrel Road, less sediment would be transported downstream, which would have a positive impact on the channel from Gunbarrel Road to its end. Also, the sediment deposition locations discussed in **Section 3.8.1** should help stabilize banks in this reach. Therefore, if projects upstream of this reach are implemented, projects in this reach may not be necessary.

Bank regrading, rock, and vegetation will be required to stabilize the eroding banks. **Figure 3–4** is one potential bank stabilization method. The bank is regraded to a stable slope, rock is placed at toe of the bank for stability, and vegetation is established to prevent erosion. Willows, cottonwoods, and native grasses are typically planted to encourage long–term stability and provide wildlife habitat.

**Figure 3–4. Stream Restoration Detail**




Source: Salix Applied Earthcare, 1996

In areas where the river is attacking the outside bank of a channel bend additional measures may be necessary to protect the bank. Bendway weirs or straight vanes consisting of well–graded angular rock are one potential stabilization measure that can be used to stop the bank erosion and encourage areas of diverse aquatic habitat. The structures must be designed on a site–specific basis. If the structures are not designed correctly, they have the potential to change the course of the river in a detrimental fashion. **Figure 3–5** shows the general method of placement for the bendway weirs to arrest the bank erosion.

**Figure 3–5. Bendway Weir Layout**

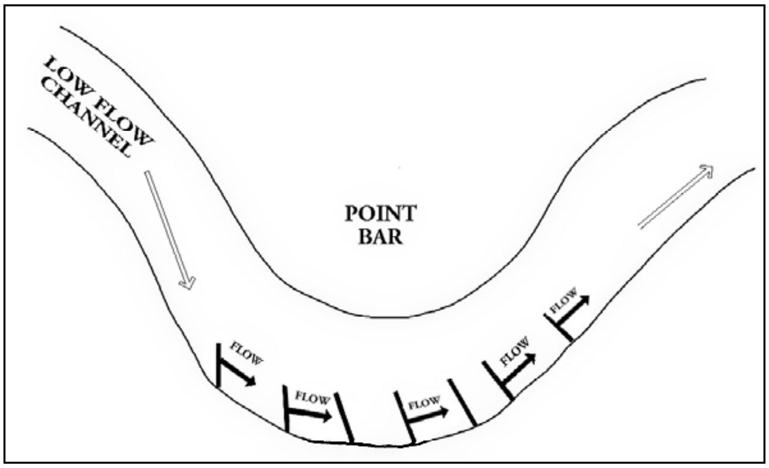



**Table 3-8. Pros and Cons of Stabilizing Banks**

| Pros | Cons |
|---|---|
| • A sediment source entering the river will be eliminated or significantly reduced.<br>• Native vegetation incorporated into the stabilization plan will enhance biodiversity.<br>• Stabilization measures will create channel diversity and potential fish habitat.<br>• Improved function of irrigation diversions. | • Most eroded banks are on private land and landowners may not want to participate in the stream restoration efforts.<br>• In–channel construction will have short–term impacts on water quality.<br>• Without public access, most benefits would accrue to private landowners.<br>• The stabilization of banks will not benefit fish downstream of Terrace Reservoir if instream flow is not provided. |

All of the stream restoration projects will benefit from being combined with revegetation, noxious weed management, and riparian buffer zone projects. In the lower watershed, grazing management and dead tree management projects could help ensure the longevity of the stream restoration efforts. Root wads from the dead tree management project could be used in the construction of stream restoration projects.

### 3.4.2 Dead Tree Management

As banks erode laterally, trees on top of the banks fall into the river. Fallen cottonwoods and their attached root wads can change local flow patterns and can create local vortices or direct the river thalweg towards the nearside bank, quickly causing bank erosion. With time, sediment begins to deposit around the tree and can lead to the creation of islands and a braided channel. This is a natural process, but it may cause additional erosion and sediment loading. In addition, fallen trees may float during high river flows and damage or plug diversion structures or plug bridges causing increased flooding. Dead tree management may have a different emphasis upstream and downstream of Terrace Reservoir.

***Dead Tree Management Upstream of Terrace Reservoir***

There are areas near Jasper where trees have fallen in the river causing water to backup, potentially causing flooding. Specific trees identified as flood risks should be removed from the river.

***Dead Tree Management Downstream of Terrace Reservoir***

Downstream of Terrace Reservoir, there is a stretch of cottonwood trees that are dead and will eventually fall into the river. The trees endangering buildings or posing a flood risk could be removed before they fall into the river. They could be used as material for stream restoration and aquatic habitat projects. Dead trees that are still stable should be left upright for migratory bird habitat. Replacement trees could be planted in some cases.

**Table 3-9. Pros and Cons of Dead Tree Management**

| Pros | Cons |
|---|---|
| • May reduce threat of flooding.<br>• May improve bank stability and reduce sediment load. | • Fallen trees may be on private land. |

### 3.4.3 Flood Control

Flooding is a concern in the lower watershed, especially in the community of Capulin, where structures have been built near the Alamosa River channel. The lower watershed has been mapped using approximate methods to indicate flood–prone areas (see **Section 2.2**). Several potential projects are being proposed to address flooding concerns:

- Modify land use regulations to prevent development in flood–prone areas.
- Build a levee to protect Capulin.
- Capulin Flood Hazard Mitigation Plan (discussed in **Section 3.14**)
- Ice Jam Flooding Study (discussed in **Section 3.14**)

In addition, the stream restoration project between County Road 10 and Gunbarrel Road is expected to reduce flooding in the city of Capulin.

The following sections present specific proposed projects to address flooding problems.

***Modify Land Use Regulations for Flood Control***

The recommended approach for controlling flood damage in developing areas is to avoid building structures in flood–prone areas. While the flooding issue is not completely solved by limiting future structures in flood–prone areas, this is the best way to minimize the creation of greater risk. The first step in modifying land use regulations is to identify flood–prone areas. This has already been done in Capulin by an approximate flood study. The second step is to inform the public and make them aware of the flood–prone areas and the hazards associated with flooding. The third step is to modify the Conejos County land use regulations to limit future development in flood–prone areas. Modifying and enforcing the regulations is crucial to keep people out of harms way and minimize damage. This project is expected to have limited benefits in Capulin due to the lack of anticipated future development.

**Table 3-10. Pros and Cons of Modifying Land Use Regulations.**

| Pros | Cons |
|---|---|
| • Limits development in flood prone areas.<br>• Keeps people out of harms way.<br>• Minimizes flood damage.<br>• Proactive approach to the problem. | • There are already structures in the flood–prone areas that will not be protected by the regulations.<br>• Regulations may impact property values.<br>• Regulations need to be enforced.<br>• Only benefits future development, which may be limited in Capulin. |

***Setback Levees at Capulin for Flood Control***

A typical approach to protecting low areas from frequent flooding is to build levees, which separate the river from the areas that need protection. While building levees is an effective method to protect existing structures from floods and to facilitate future development of the protected area, the levees also have the potential to cause other problems. Levees are designed to address a certain flood or river stage and to provide a certain level of security. When the design event is exceeded, the levees fail, resulting in high flood repair costs. Furthermore, the levees constrict floodwaters, resulting in increased velocities and channel incision through the constricted reach. Downstream of the levee constriction, the sediment generated from channel incision will drop out causing sedimentation problems. Many of these negative effects can be minimized by constructing levees that are setback from the channel as much as possible so that existing developed area is protected but the floodplain is constricted as little as possible.

**Table 3-11. Pros and Cons of Setback Levees.**

| Pros | Cons |
|---|---|
| • Protects structures from flood damage.<br>• Can build houses closer to the river.<br>• Increased developable land. | • May ultimately result in increased flood damage.<br>• Causes channel incision through the restricted reach.<br>• Causes sedimentation problems downstream of the levee. |

## 3.5 Water Quantity Improvement

All of the segments downstream of Terrace Reservoir were given a poor rating for surface water quantity because of the highly altered flow regime produced by operation of Terrace Reservoir and irrigation uses. The segments that are most feasible to improve are 3 (Gunbarrel Road to Terrace Main Canal) and 4 (Terrace Main Canal to Terrace Reservoir Outlet) because they are the least impacted by losses to groundwater and irrigation diversions.

Proposed water quantity projects focus on extending the period of flow in the Alamosa River downstream of Terrace Reservoir. A more dependable flow regime would require flows in the lower Alamosa River, particularly in the winter, such as instream flow, that are not used for irrigation. An instream flow would improve riparian habitat, replenish groundwater, and potentially allow for the development of a fishery.

Establishment of a year–round streamflow in the lower Alamosa River could be problematic due to ice formation problems in the winter months. Historically, when winter releases have been made, ice buildup occurs near the location where live streamflow ends. This can be a flooding risk due to loss of channel capacity. To avoid this problem (and avoid potential liability) it may be necessary to limit instream flows when ice is observed to be forming.

The lack of storage for agricultural water rights not stored in Terrace Reservoir was also a concern raised by some stakeholders.

Four project types are discussed below to improve water quantity conditions on the Alamosa River. The project types and specific project examples are summarized in **Table 3-12**. Each project type and example is discussed below.

**Table 3-12. Water Quantity Project Types and Specific Project Examples**

| Development of Instream Flow | Change Terrace Reservoir Operations | Reservoir Storage | Aquifer Storage |
|---|---|---|---|
| Purchase appropriate priority water rights | Controlled releases from Terrace Reservoir for instream flow with supplemental water source | New reservoir to store instream flow | Aquifer storage for instream flow |
| File a new junior priority water right | Trade of direct flow diversion right for reservoir storage of instream flow | New reservoir to store existing agricultural water rights | |

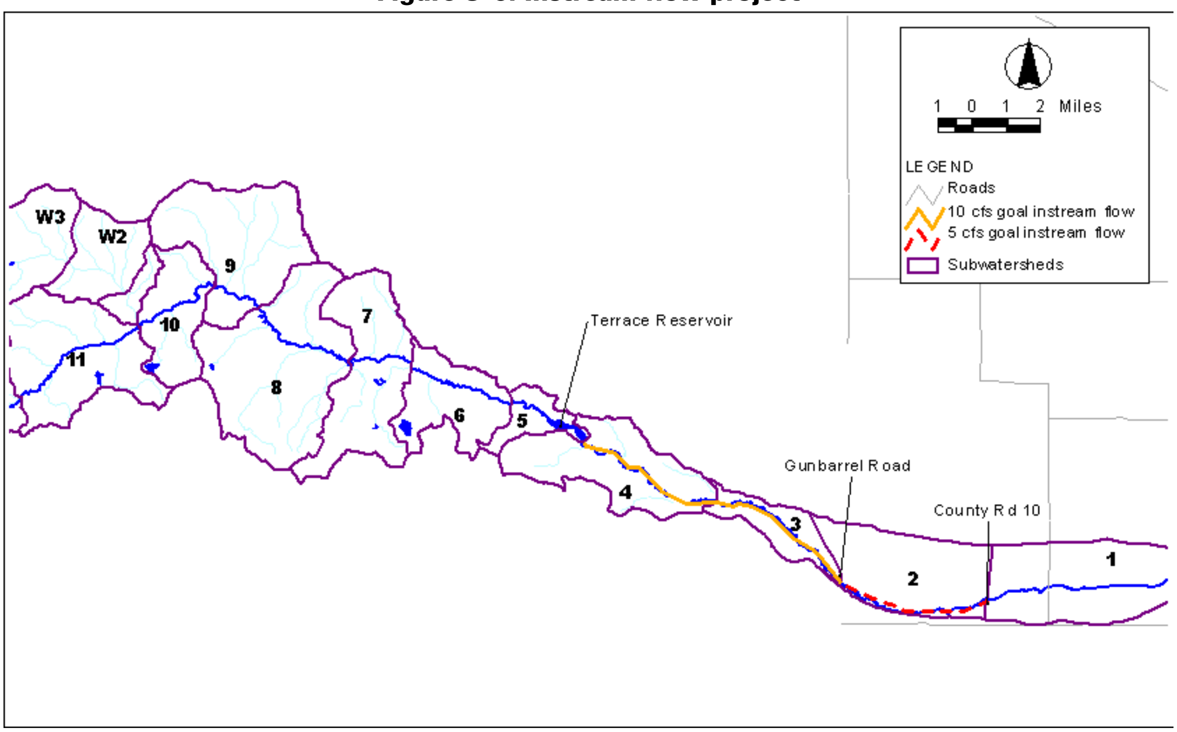
### 3.5.1 Development of Instream Flow

The two options considered to provide instream flow in the lower Alamosa River are to purchase appropriate priority water rights as needed to establish the goal flow or to file a new junior water right. Acquiring a water right to establish a more sustainable instream flow will only be successful if storage is available for that flow. Storage options are discussed in **Sections 3.5.2** through **0**.

***Purchase Appropriate Priority Water Rights***

The minimum flow rate needed to significantly improve water quantity conditions below Terrace Reservoir is not known for certain. It has been assumed that reasonable targets are a 10 cfs minimum flow from Terrace Reservoir to Gunbarrel Road and a 5 cfs minimum flow from Gunbarrel Road to County Road 10 (as shown in **Figure 3–6**). The amount of water that will be lost to groundwater in the reaches below Terrace Reservoir is unknown and is likely to change with time. If a prolonged flow is established, alluvial groundwater levels are likely to rise, reducing the rate of loss from the river. The Division Engineer has been collecting information on the magnitude of Terrace Reservoir releases required to support flows at different points along the river. At least 10 cfs released from Terrace Reservoir is expected to be needed for a prolonged flow to reach Capulin during most of the year (Vandiver, 2002). It is assumed for this project that a minimum of 10 cfs of instream flow released from Terrace Reservoir could improve water quantity conditions in reaches 3 and 4 and potentially reach 2 (see **Figure 3–6**).

**Figure 3–6. Instream flow project**




The large amount of water needed would require acquisition of substantial water rights. A senior priority water right would come into priority and provide yield for sustaining instream flows in virtually every year. A senior right could be combined with other lower priority rights until the goal flow is established. The potential water rights must be investigated by an engineer to determine if they are of adequate type, frequency, and history of usage to make them suitable for conversion to instream flows.

Negotiations by attorneys with the Colorado Water Conservation Board (CWCB) will be required to create an instream flow donation or lease agreement. This is required because the CWCB is the only entity in the state that is legally entitled to hold instream flow water rights. The attorney will also need to work with CWCB to get board approval of the donation/lease. Applications to change the water right to instream flow uses must be formulated by an attorney and approved by the water court. Coordination with CWCB is required because usually the application will be a joint filing with the CWCB.

Acquiring a water right to establish a more sustainable instream flow will only be successful if storage is available for that flow. Seasonal carryover storage would be needed to capture spring and summer runoff for regulated release throughout fall and winter. Assuming storage could fill over 6 months and release over 6 months, about 3,600 acre–feet of storage would be needed. The pros and cons of purchasing an existing senior water right are summarized in **Table 3-13**.

**Table 3-13. Pros and Cons of Purchasing Appropriate Priority Water Rights**

| Pros | Cons |
|---|---|
| • Improves riparian habitat.<br>• Replenishes groundwater.<br>• Could allow for fishery development.<br>• Provides water to stream reach being restored.<br>• Requires less storage than junior right. | • Potential for speculation in water rights sale.<br>• Limited number of senior rights available.<br>• Would require storage and controlled release to provide prolonged flows.<br>• Requires water rights change through water court.<br>• Potential impacts of drying up agriculture and changing return flow patterns. |

### *File a New Junior Priority Water Right*

This project consists of filing a new junior water right to capture currently unused Alamosa River streamflows. A water right with a larger flow will be needed to create a prolonged flow because this right will not come into priority very often. **Section 2.3.6** indicates that runoff is capable of supplying all current water rights only 1 percent of the time. Although some rights are not normally exercised, it is evident that a junior water right would generate very little yield on an average annual basis. In addition, since this flow does not come into priority frequently, a large amount of storage would be needed to store a peak flow that can slowly be released over a number of years. Even assuming a junior right would come into priority once in 10 years, the right would have to yield 36,000 acre–feet in years it is in priority and a similar amount of storage would be required.

The pros and cons of filing for a new junior water right are summarized in **Table 3-13**.

**Table 3-14. Pros and Cons of Filing a New Junior Water Right**

| Pros | Cons |
|---|---|
| • Improves riparian habitat.<br>• Replenishes alluvial groundwater.<br>• Could allow for fishery development.<br>• Does not affect current water rights holders. | • Junior rights will produce yield in very few years.<br>• Would require large storage capacity to capture flows when they come into priority (high cost).<br>• Division Engineer may consider this a violation of Rio Grande Compact.<br>• Requires adjudication through water court. |

### 3.5.2 Change in Terrace Reservoir Operations for Instream Flow Storage

Instream flow could be provided for the lower Alamosa River if Terrace Reservoir made controlled releases during periods when the gates are currently closed to store irrigation water. These controlled releases could have negative impacts on Terrace Reservoir shareholders if hydrologic conditions are such that the reservoir does not completely fill. As shown in **Section 2.3**, Terrace Reservoir has only filled once every 5 to 6 years since 1975. Therefore, annual controlled releases from Terrace Reservoir are only feasible if there is a backup source of water for Terrace Reservoir shareholders. Two options were identified to change Terrace Reservoir operations to provide instream flow.

***Controlled Releases from Terrace Reservoir with Supplemental Water Source***

This project is another option to provide instream flow at times when the river is currently dry. Instream flow could be provided for the lower Alamosa River if Terrace Reservoir made controlled releases during periods when the gates are currently closed to store irrigation water. The releases would free extra storage space for high runoff flows in the spring. A release of 10 cfs for 3 months is approximately 2,000 acre–feet. This volume would be captured and used to fulfill the Terrace Irrigation Company water right if it was not released.

In some years, Terrace Reservoir would still fill and Terrace shareholders would not be impacted. However, in years when hydrologic conditions cause Terrace Reservoir not to fill, shareholders would be impacted. Thus, a supplemental source of water is needed to offset the impacts of instream releases. Since most of the water released for instream flow is lost to groundwater, it may be possible for Terrace to pump this amount of groundwater to fulfill their water right. Surface supplies from adjacent basins could also be investigated.

This project is expected to be difficult to implement. There are some complicated water law issues to be resolved, and the cost of supplying a supplemental water source would be substantial. The Division Engineer is not likely to support this project due to the complicated accounting that would be necessary as well as issues related to the Rio Grande Compact.

**Table 3-15. Pros and Cons of Controlled Releases from Terrace Reservoir with Ground Water Backup**

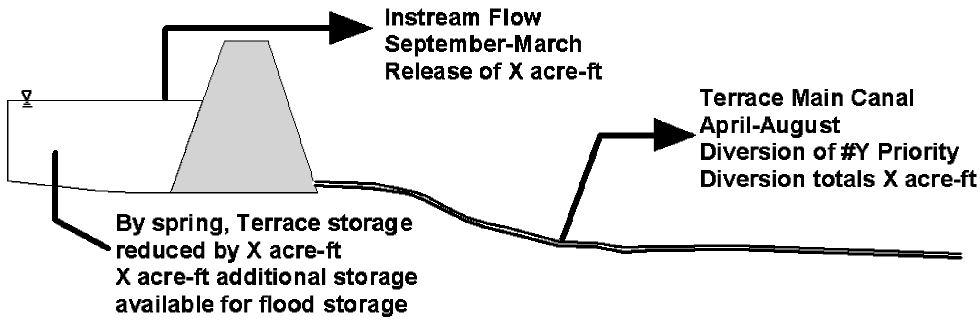
| Pros | Cons |
|---|---|
| • Improves riparian habitat.<br>• Replenishes alluvial groundwater.<br>• Could allow for fishery development. | • Terrace Reservoir rarely fills when the gates are closed during the winter. Therefore, backup water would be needed most years.<br>• Division engineer may not agree to this scenario.<br>• May require change in water right.<br>• Could increase ground water deficit.<br>• Little data is available regarding local groundwater levels and percolation rates. |

***Trade of Direct Flow Diversion Right for Reservoir Storage***

Storage of the acquired water rights would be needed to capture spring and summer runoff for release throughout fall and winter. Assuming storage could fill over 6 months and release over 6 months, about 3,600 acre–feet of storage would be needed. There are two identified methods for utilizing storage space in Terrace Reservoir without construction of new storage facilities.

**Method 1 – Direct Trade:**
Potentially, Terrace Irrigation Company could use the acquired water right as it is available in the spring and summer for irrigation purposes. The amount diverted would vary based on the water year. Then, an equal amount could be released from water stored under Terrace Irrigation Company's storage right during late fall, early spring, and perhaps winter months as a trade. **Figure 3–7** shows a simple schematic of a potential trade of use. This release would probably start after the Capulin Ditch went out of priority in late summer and stop when the first ditch calls for water in the spring.

**Figure 3–7. Schematic of Trade of Direct Flow Right for Storage for Instream Flow**




By spring, the release out of Terrace Reservoir would reduce the storage volume in Terrace Reservoir by the total amount diverted the previous season through the Terrace Main Canal. This additional space could then be used to capture high spring flows. Therefore, the storage available for Terrace Irrigation Company to capture high flows would not be reduced. However, the Terrace Irrigation Company would probably be forced to divert more water early in the irrigation season while the acquired water right was in priority and reduce stored water that would be available late in the irrigation season. With the trade, reservoir storage in the fall would have to be maintained at the level of the conservation pool plus the amount diverted through the Terrace Main Canal using the transferred senior priority so that the release of the instream right would not lower the storage of Terrace Reservoir below the level of the conservation pool.

This project would require Terrace Irrigation Company to agree to the trade, and reservoir improvements may be needed as an exchange for the trade. It would also require approval from the Division Engineer and potentially a water right change. However, this method would allow for more instream flow water in more years than Method 2.

**Method 2 – Conversion to Storage Right:**
The acquired water right would be changed from a direct flow right to a storage right in Terrace Reservoir in water court. The instream flow would be stored in the reservoir in the same manner as water stored for agricultural purposes. The instream flow, however, would not be released until it is needed when irrigation ceases in the fall. The right to store water in Terrace could potentially be paid for through reservoir improvements.

A management plan could be signed with Terrace Reservoir that would ensure that all instream flow storage will be released prior to complete filling of Terrace Reservoir in high water years so that storage availability for irrigation water is not reduced in Terrace Reservoir. Available storage will be exceeded in high water years in which the reservoir is filled, and the amount of the instream water right coming into the reservoir outpaces the release of water stored by Terrace Irrigation Company for irrigation. Examination of storage in Terrace Reservoir between 1991 and 2002 showed that with the current filling restrictions in Terrace Reservoir at 13,000 acre–feet, instream flow could only be stored completely in

Terrace Reservoir about half of the years. If the filling restriction was removed, the entire amount could be stored approximately 90 percent of the time.

**Table 3-16. Pros and Cons of Trade of Direct Flow Diversion Right for Reservoir Storage**

| Pros | Cons |
|---|---|
| • Makes use of Terrace Reservoir for benefit of in–basin interests.<br>• Improves efficiency of Terrace Reservoir storage volume.<br>• Provides storage without making physical improvements to existing or new facilities. | • Requires approval by, and cooperation of, Terrace Irrigation Company.<br>• Requires approval of Division Engineer and water right change..<br>• Negative impacts of retiring historically irrigated land from production.<br>• Change in return flow patterns.<br>• May require water court decision to change to a storage right. |

### 3.5.3 New Reservoirs

A new reservoir in itself would not improve water quantity conditions in the watershed, but it would be combined with one of the water right acquisition options to provide year–round streamflow. Alternatively, a new reservoir could be used to store existing agricultural water rights in the basin.

New reservoirs could be constructed at different locations in the watershed. Potential locations that have been identified are discussed below. The volume of water needed to provide a 10 cfs instream flow for 6 months of the year is 3,600 acre–feet. Assuming a reservoir area of 200 acres, the total volume of storage needed accounting for evaporation is about 4,300 acre–feet. This size is the basis for all estimates.

Any new reservoir will require considerable effort for implementation. The following factors make construction of new reservoirs difficult:

- Potentially serious environmental impacts and permitting requirements
- Considerable engineering analysis and design required
- The Division Engineer may not permit additional storage due to the Rio Grande Compact
- High cost relative to other restoration projects

All reservoirs are likely to have water quality benefits by allowing for sedimentation and associated removal of selected pollutants. If additional water quality measures are included in the design, such as incorporation of limestone amendment, pH could potentially be increased for further water quality benefits.

An investigation of potential reservoir sites was performed based on review of USGS topographic maps and aerial photography. The minimum required reservoir capacity was 4,000 acre–feet. **Table 3-17** summarizes the potential reservoir sites that were identified. **Figure 3–8** shows the approximate location and size of the identified potential reservoirs (each shown in a different color). Many of the sites could provide significantly more than 4,000 acre–feet of storage. Enlargement of Terrace Reservoir as an alternative for creating additional storage in the watershed is discussed in **Section 3.7**.

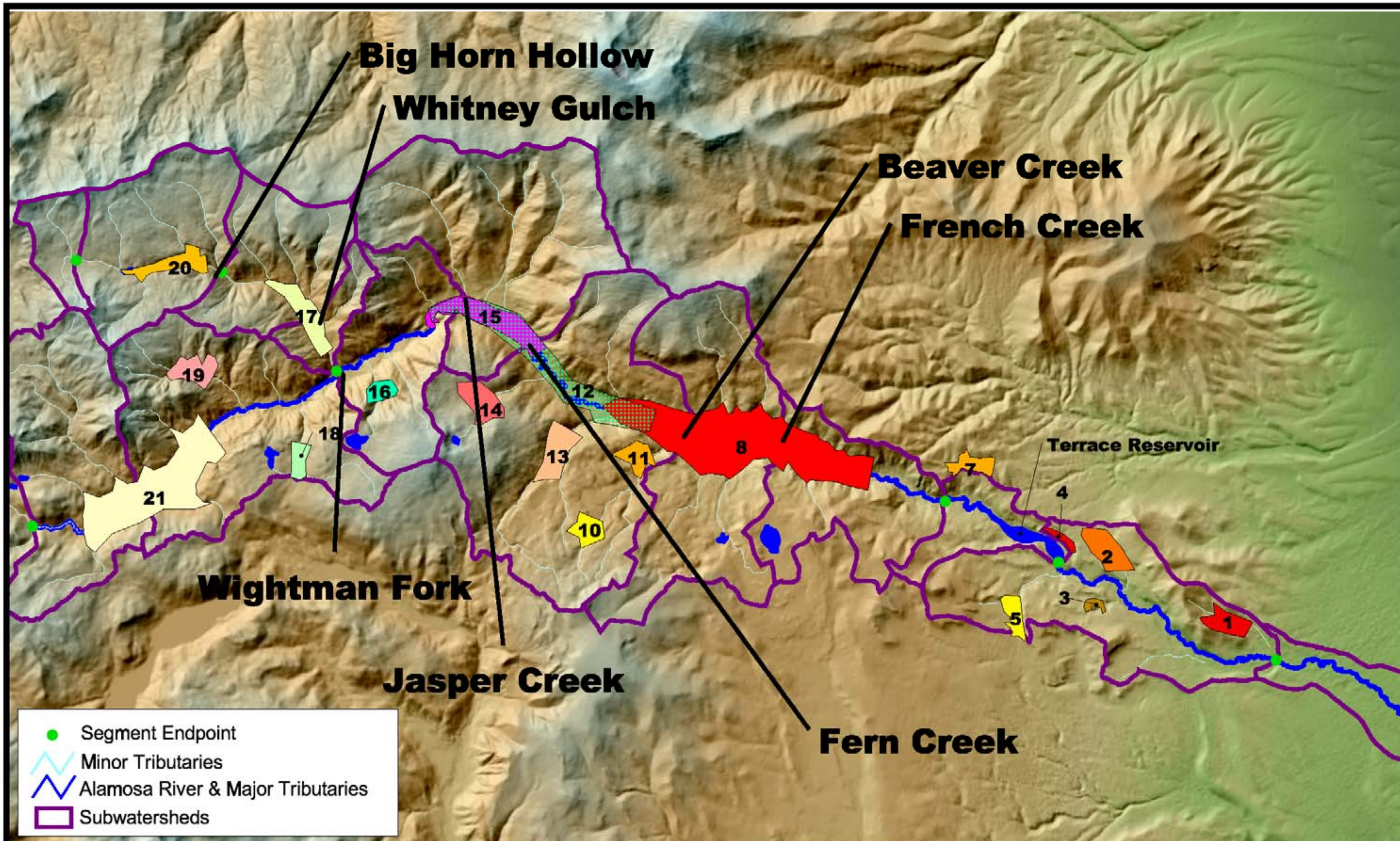
**Table 3-17. Potential Reservoir Sites**

| Site Number | Watercourse | Segment | Feasible Dam Type | Max Dam Height (ft) |
|---|---|---|---|---|
| 1 | Unnamed Tributary | 4 | RF, CFR, RCC | 450 |
| 2 | Unnamed Tributary | 4 | E, RF, CFR, RCC | 50 |
| 3 | Unnamed Tributary | 4 | RF, CFR | 200 |
| 4 | Unnamed Tributary | 4 | RF, CFR, RCC | 80 |
| 5 | Unnamed Tributary | 4 | RF, CFR | 240 |
| 7 | Pump back from Alamosa River | North of 5 | RF, CFR | 280 |
| 8 | Alamosa River | 6 | RF, CFR, RCC | 800+ |
| 9 | Alamosa River | 6 | RF, CFR, RCC | 800+ |
| 10 | Rhodes Gulch | 8 | RF, CFR, RCC | 240 |
| 11 | Rhodes Gulch | 8 | RF, CFR, RCC | 320 |
| 12 | Alamosa River | 8 | RF, CFR, RCC | 240 |
| 13 | California Gulch | 8 | RF, CFR, RCC | 520 |
| 14 | Castleman Gulch | 8 | RF, CFR, RCC | 560 |
| 15 | Alamosa River | 8 | RF, CFR, RCC | 120 to 1200+ |
| 15a | Alamosa River | 8 | RF, CFR, RCC | 120 to 1200+ |
| 16 | Unnamed Tributary | 10 | RF, CFR, RCC | 600 |
| 17 | Wightman Fork | W | RF, CFR, RCC | 480 to 800 |
| 17a | Wightman Fork | W | RF, CFR, RCC | 480 to 800 |
| 17b | Wightman Fork | W | RF, CFR, RCC | 480 to 800 |
| 18 | Unnamed Tributary | 11 | RF, CFR, RCC | 480 to 800 |
| 19 | Bitter Creek | 11 | RF, CFR, RCC | 240 |
| 20 | Wightman Fork | W | RF, CFR, RCC | 560 |
| 21 | Alamosa River | 11 | RF, CFR, RCC | 640 |

Notes: RF = Rockfill, CFR = Concrete Faced Rockfill, RCC = Roller Compacted Concrete, E = Embankment
Site 6 was eliminated
Sites with a, and b are different dam configurations in the same location

**Table 3-18. Pros and Cons of Building New Reservoirs**

| Pros | Cons |
|---|---|
| • Additional storage available.<br>• Water quality and sediment control benefits.<br>• Potential recreation benefits for upper watershed. | • On federal land, reservoir construction would require NEPA documents.<br>• Storage could only be used for purchased water rights. New water rights or storage of flood water would not be permitted by the Division Engineer.<br>• High cost. |




1 0 1 2 3 Miles

1:160000

Alamosa River Watershed
Restoration Master Plan

MWH in association with Agro Engineering,
Lidstone and Associates, and SWCA

**Figure 3-8.**
**Potential Reservoir Sites**

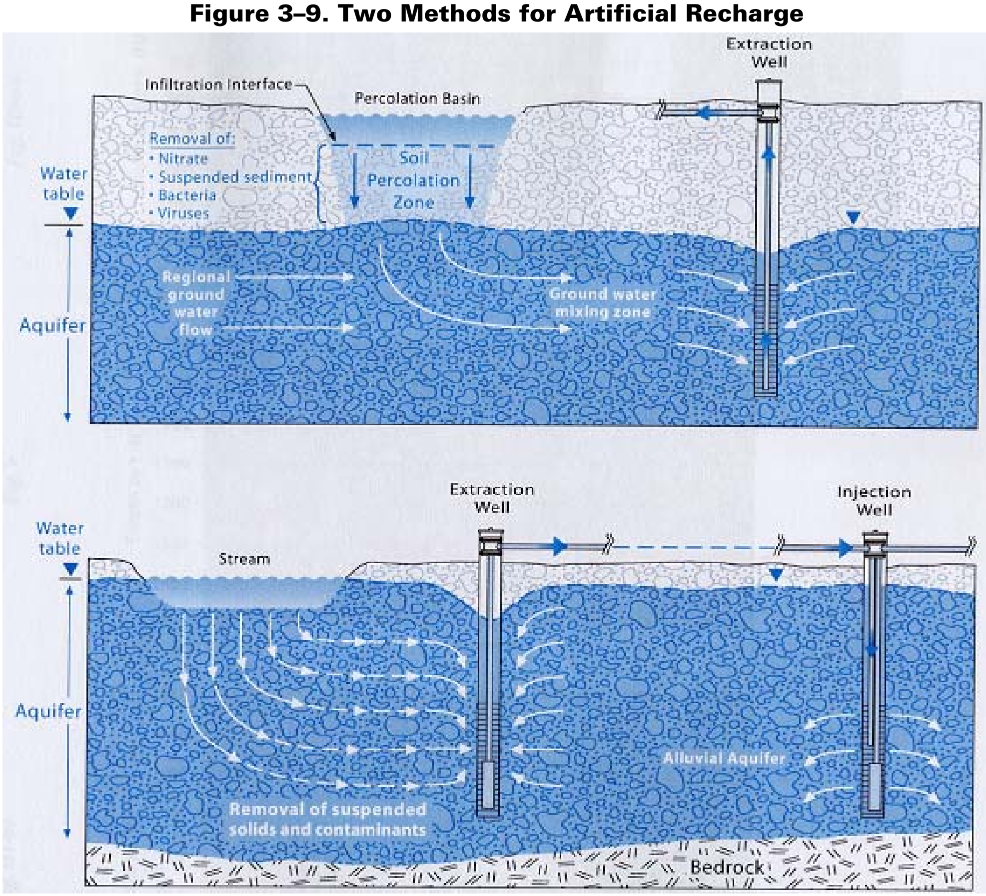
### 3.5.4 Aquifer Storage for Instream Flow

Artificial recharge, or aquifer storage and recovery (ASR) is an option for water storage that would essentially use the groundwater basin as a reservoir for instream flow. Like a new surface reservoir project, this alternative would only be useful when combined with a water rights acquisition project. Water could either be injected into the groundwater basin, or applied to the surface for recharge. A wellfield would be required to recover the stored water and delivery to the Alamosa River. **Figure 3–9** shows two methods for artificial recharge, land application and injection.

Seasonal groundwater storage is currently used in the San Luis Valley during the spring and winter through infiltration pits at the corners of irrigated sections and leaky ditches. The most likely location for aquifer storage in the watershed is on the upper portion of the alluvial fan near the foot of the mountains north of the Alamosa River channel where grain size is larger and transmissivities are greater. A groundwater augmentation plan may allow the entire historical water right, not just the consumptive use, to be transferred recharged to the groundwater, as long as the headgate location is not changed. Probably only the consumptive use could be pumped back out to be put into the stream, but, recharging the groundwater could be beneficial to water levels in the River.

This project is expected to be difficult to implement. A feasibility study would be necessary to determine the rate at which water can be injected and extracted from the aquifer. In addition, it would be difficult to control the use of the recharged groundwater by others.

**Figure 3–9. Two Methods for Artificial Recharge**




Source: CGS, 2004. Note: soils may also remove metals although not listed in figure.

**Table 3-19. Pros and Cons of Aquifer Storage**

| Pros | Cons |
|---|---|
| • No evaporation losses if injection is used.<br>• Fewer environmental considerations than surface water storage.<br>• Relatively short implementation time required compared to surface water storage.<br>• Increased groundwater level. | • Requires drilling new wells.<br>• Would require feasibility assessment.<br>• May be more difficult to control the use of groundwater than water stored on the surface.<br>• Must find location allowing proper groundwater administration. |

### 3.5.5 Water Quantity Projects Eliminated from Further Consideration

The only project eliminated from further consideration is filing for a new junior water right. There is not enough yield on an average annual basis and too much storage space would be required to capture rare, large storm events. In addition, the Division Engineer is not permitting new water development in the already over–appropriated basin.

## 3.6 Ground Water Improvement

The confined and unconfined ground water aquifers in the Alamosa River watershed are important resources for agricultural and domestic land use, as well as to support riparian vegetation. Currently, there are limited data available pertaining to the relationship between surface and ground water in this portion of the San Luis Valley. As such, there is a poor understanding of the interactions between the river and the ground water aquifers. In addition, there is an insufficient amount of monitoring wells in the vicinity of the study area. While it is believed that the recent drought and the removal of instream flows have resulted in a lowering of the ground water table, the lack of available data makes it difficult to quantify this effect. Also, some residents are concerned that channel bed degradation may have a local effect on the shallow ground water table. The only groundwater improvement project proposed is a ground water monitoring plan.

Due to the importance of this resource and its extensive use within the watershed, it is recommended that a ground water monitoring plan be initiated. Such a plan can be expanded as financial resources become available. More discussion of a groundwater monitoring plan is included in **Section 3.14**.

## 3.7 Terrace Reservoir Improvements

This section describes several potential improvements to Terrace Reservoir that address the issues identified in **Section 2.6**.

A major problem with Terrace Reservoir is its undersized spillway, which has resulted in a filling restriction, effectively reducing the reservoir capacity. The filling restriction ordered by the State Engineer is in place because the existing spillway is unable to pass the required probable maximum flood (PMF) design flood. Upgrading the existing spillway could provide approximately 2,200 acre–feet of currently unusable storage. Many of the potential improvement projects to Terrace Reservoir focus on lifting this filling restriction.

The following types of improvements to Terrace Reservoir are discussed below:

- Increase spillway capacity
- Raise crest of dam
- Sediment removal to increase capacity
- Improve outlet works

- Hydropower generation
- Site specific PMF Study (discussed in **Section 3.14**)
- Dewatering management plan (discussed in **Section 3.14**)

If any of these projects are paid for with public funds, they should be combined with benefits to the public. Benefits for the public could include increased access to Terrace Reservoir for recreation purposes. Also, if publicly funded projects increase the storage available at Terrace Reservoir, some of that storage could be used for public good, such as storing water designated for instream flows.

### 3.7.1 Increase Spillway Capacity

Several options exist to increase the spillway capacity of Terrace Reservoir to remove the State Engineer imposed filling restrictions and therefore increase the storage capacity of the reservoir. Descriptions of these options are presented below. The viability of these options may be contingent upon the State Engineer allowing an increase in storage at Terrace Reservoir. This may depend on interpretation of water rights requirements in the Rio Grande compact as discussed in **Section 2.3**.

The easiest and most economical way to increase the water storage at Terrace Reservoir is to rehabilitate the existing spillway to remove the existing State Engineer's Office filling restriction on the reservoir. The only option considered in the 1981 dam assessment study to rehabilitate the existing spillway was to increase the spillway capacity by constructing an emergency fuse plug spillway south of the existing chute spillway (Davis, 1981). This is a viable option but the existing spillway will still require extensive rehabilitation of the concrete so it can safely operate. Other options exist that were not considered in the 1981 study for the rehabilitation of the spillway at Terrace Reservoir.

Since the 1981 study, the state of practice in the design of spillways has advanced with the advent of several new innovations in dam and spillway rehabilitation. Several alternatives that should be considered for the rehabilitation of the spillway at Terrace Reservoir in addition to a fuse plug emergency spillway and their associated pros and cons are summarized in **Table 3-20**.

**Table 3-20. Terrace Reservoir Spillway Rehabilitation Alternatives**

| Alternative | Description | Pros | Cons |
|---|---|---|---|
| 1) Concrete labyrinth chute spillway at location of the existing spillway sized to pass PMF | This alternative would consist of constructing a new chute spillway at the location of the existing spillway in the left abutment with a concrete labyrinth control crest. The labyrinth crest is a series of trapezoidal walls (resembling the teeth of a gear) located within the total spillway width that passes water through more efficiently than a straight spillway. | • Typically low to moderate cost because a labyrinth chute will not require as wide of a channel as a straight spillway.<br>• Constructed at the location of the existing spillway.<br>• Spillway footprint similar in size to the existing spillway structure, reducing construction cost.<br>• Spillway width to pass PMF is very efficient compared to other alternatives. | • Will require downstream channel improvements to carry higher discharge<br>• May require a greater quantity of excavation than the other alternatives |
| 2) Roller compacted concrete (RCC) chute spillway at the location of the existing spillway sized to pass the PMF. | This alternative would consist of constructing a RCC chute spillway at the location of the existing spillway in the left abutment. The control crest would likely be a conventional concrete ogee crest (straight spillway). The chute would be constructed with stepped RCC and the spillway training walls could either be constructed with RCC or conventional concrete. | • Typically low to moderate cost.<br>• Constructed at the location of the existing spillway. | • Will require a much larger footprint than the existing spillway – approximately 300 foot crest length<br>• Will require significant excavation into the abutment to accommodate the structure.<br>• Will require downstream channel improvements to pass higher discharge |

**Table 3-20. Terrace Reservoir Spillway Rehabilitation Alternatives**

| Alternative | Description | Pros | Cons |
|---|---|---|---|
| 3) Concrete chute service spillway on left abutment to pass the 100–year storm and an RCC overtopping emergency spillway over the body of the dam to pass the PMF | This alternative would consist of reconstructing the chute spillway on the left abutment to pass the 100–year storm. The main body of the dam would be armored to allow the remainder of the PMF storm to pass over the dam without damaging the embankment. | • Moderate cost because RCC chutes are typically the most economical way to construct a spillway. | • Will require a service spillway to pass the 100–year storm<br>• More risk in passing the PMF over the dam rather than the left abutment.<br>• Will require downstream channel improvements for service spillway |
| 4) Raise the dam to store PMF and construct a new principal spillway to pass the 100–year storm. | This alternative would consist of raising the crest elevation of the dam to store the PMF and constructing a principal service spillway to pass the 100–year storm. The service spillway could either be a chute spillway constructed on the left abutment or a drop inlet spillway that passes flows through a modified outlet. | • Additional storage can be obtained for increased yield and more operational flexibility.<br>• Minimal spillway requirements. | • Because the Drainage basin is 116 square miles in area, the dam raise to contain the PMF could be substantial.<br>• Typically moderate to high cost.<br>• The internal stability of the existing embankment may not allow for the dam to be raised<br>• Will require a service spillway to pass the 100–year storm<br>• Will require downstream channel improvements for service spillway<br>• Division Engineer may not allow additional storage capacity due to Rio Grande Compact issues. |
| 5) Construct a new drop inlet service spillway to pass the 100–year storm and construct a fuse plug emergency spillway at the location of the existing spillway to pass the PMF. | This alternative would consist of constructing a new drop inlet service spillway to pass the 100–year storm event and the construction of a fuse plug emergency spillway along the left abutment to pass the PMF. A fuse plug spillway consists of a soil plug or dike across a spillway section which prevents the spillway from being used until the water in the reservoir reaches a distinct design or emergency level, after which the soil plug washes out to the bottom of the spillway and the spillway operates at full capacity. After the emergency condition has passed and the reservoir level is lowered the soil plug may then be rebuilt. | • If spillway is operated as a combined spillway / outlet works the drop inlet configuration allows for the release of water at various levels within the reservoir, allowing for adjustments or blending of the water from different depths.<br>• If spillway is operated as a combined spillway / outlet works the drop inlet configuration reduces the sediment load being released down stream of the reservoir.<br>• Fuse plugs can be designed/separated with walls that will allow the crests of each fuse plug segment to be at a different elevation, thus each segment will be activated at a different water elevations. This will reduce the need to rebuild the entire fuse plug when storms less than the PMF occur. | • Typically moderate to high cost.<br>• Will require the modification and possibly enlargement of the outlet tunnel to pass the 100–year storm<br>• May require an energy dissipator at the outlet of the tunnel<br>• Fuse plugs must be rebuilt when they operate |
| 6) Concrete chute service spillway to pass the 100–year storm and a fuse plug emergency spillway at the location of the existing spillway to pass the PMF. | This alternative would consist of constructing a concrete chute service spillway to pass the 100–year storm event and the construction of a fuse plug emergency spillway along the left abutment to pass the remainder of the PMF. | • Typically low to moderate cost.<br>• Fuse plugs can be designed/ separated with walls that will allow the crests of each fuse plug segment to be at a different elevation thus each segment will be activated at a different water elevations. This will reduce the need to rebuild the entire fuse plug when storms less than the PMF occur. | • Will require downstream channel improvements<br>• Will require a much larger footprint than the existing spillway (approximately 40 feet wide for the 100–year spillway and 300 feet wide for the emergency spillway). |

**Table 3-20. Terrace Reservoir Spillway Rehabilitation Alternatives**

| Alternative | Description | Pros | Cons |
|---|---|---|---|
| 7) New drop inlet service spillway to pass the 100–year storm and a fuse gate emergency spillway at the location of the existing spillway to pass the PMF. | This alternative would consist of constructing a new drop inlet service spillway to pass the 100–year storm event and the construction of a fuse gate emergency spillway along the left abutment to pass the PMF. Fuse gates are concrete and steel structures that are placed on a concrete foundation. The gates are designed to tip or "float" off their foundation as a result of hydrostatic uplift forces, and wash downstream opening up a larger channel within the emergency spillway to evacuate the flood event, without causing major damage downstream. | • If spillway is operated as a combined spillway / outlet works the drop inlet configuration allows for the release of water at various levels within the reservoir allowing for adjustments or blending of the water being released.<br>• If spillway is operated as a combined spillway / outlet works the drop inlet configuration reduces the sediment load being released downstream of the reservoir.<br>• Fuse gates are often perceived more reliable than fuse plugs<br>• Fuse gates can be designed to operate at different water elevations.<br>• After a fuse gate operates it can be reused / reset with minor economic costs | • Will require the modification and possibly enlargement of the outlet tunnel to pass the 100–year storm<br>• May require an energy dissipator at the outlet of the tunnel<br>• Typically moderate to high cost.<br>• Fuse gates have higher capital costs than fuse plugs but they are less expensive to put back into service. |
| 8) Chute spillway with fuse gate control at the location of the existing spillway to act as the service spillway as well as the emergency PMF spillway. | A chute spillway fitted with fuse gate control can be constructed at the location of the existing spillway. The spillway can be designed such that it effectively operates as a service spillway designed for the 100–year event when the fuse gates are deployed and as a PMF spillway when the fuse gates operate and wash away. The required width of the spillway will be greater than the existing drop inlet but additional storage can be obtained without modifying the dam. Fuse gates typically range from 3 feet in height to as much as 21 feet in height. | • Added storage in the reservoir can economically be obtained without impacting the embankment<br>• Additional freeboard can easily be added to the embankment by constructing concrete parapet walls on the crest of the dam to meet freeboard requirements for the added storage.<br>• Fuse gates can be designed to operate at different water elevations.<br>• After a fuse gate operates it can be reused / reset with minor economic costs. | • Will require downstream channel improvements<br>• Could require a greater quantity of excavation than the other alternatives<br>• Typically moderate to high cost but the potential for increased storage with minor to no impact to the embankment will offset this. |
| 9) New RCC dam at the location of the existing Terrace dam | This alternative entails the removal of the existing dam at Terrace Reservoir and constructing a new RCC gravity dam in its place. | • This may be an economic alternative when all of the dam safety issues are examined.<br>• Overtopping spillway can be located on the body of the dam.<br>• A taller dam can be constructed at the site that can provide added storage for the facility, which could make this option economically attractive<br>• A multi–level intake can be implemented into the design that would allow for the controlled release of differing qualities of water.<br>• The existing outlet tunnel can be used as a construction diversion and either be abandoned after construction or be integrated into the outlet design.<br>• Portions of the existing embankment structure may prove suitable for use as RCC aggregate.<br>• A small hydropower plant could be included in the project to generate income for the project.<br>• If a saddle dam is required the existing embankment could be used for borrow material. | • Higher costs than repairing the existing spillway.<br>• Requires the removal of the existing embankment.<br>• Would require a saddle dam be constructed in the left abutment if additional storage is desired.<br>• Division Engineer may not allow more storage capacity than existing reservoir due to Rio Grande Compact Issues. |

Note: left and right are referred to facing the downstream direction

Because of these new innovations an updated spillway rehabilitation/reconstruction alternatives study is recommended to determine the optimal spillway system for Terrace Reservoir. This study would develop conceptual layouts and cost estimates for each option such that the most cost–effective option can be selected.

### 3.7.2 Raise Crest of Dam

Additional water storage can also be obtained by raising the crest elevation of Terrace Reservoir dam. By adding additional freeboard to the dam, the required spillway size could be reduced by providing added flood storage and increasing the head of water acting on the spillway, increasing its capacity.

The dam is an embankment structure that utilized early 20$^{th}$ century puddle core dam construction techniques. Historically structures of this type often are internally unstable, especially under seismic loading conditions. In order to increase the crest elevation, the internal stability of the dam structure must be considered. To date no known record of an internal stability assessment exists for Terrace Reservoir utilizing the principles of modern day soil mechanics and seismic and geotechnical engineering.

Several options to increase the crest elevation Terrace Reservoir dam are:

- An upstream raise to the embankment;
- A downstream raise to the embankment;
- A reinforced earth raise to the embankment; and
- The construction of a concrete parapet wall on the embankment crest.

With all of these options an extensive rehabilitation of the existing spillway will be required. If raising the crest of the dam is a preferred option, an optimization study is recommended to identify the most economically feasible method to increase the crest elevation of the embankment structure. All options for raising the dam will have the constraint of obtaining approval from the Division Engineer. Each option will require a geotechnical assessment to verify that the puddle core embankment is internally stable and could support the additional weight of new construction and the increased hydraulic load. Each option is described below.

***Upstream Embankment Raise***

The geometry of the existing embankment is such that an upstream raise to Terrace Reservoir could be feasible. An upstream raise would add material on the upstream side of the dam from the base to the crest in order to raise the dam height. The original embankment was reported to have been designed to be approximately 227 feet in height with a reservoir capacity of 27,000 acre–feet, compared to the constructed height of 124 feet and 15,200 acre–feet capacity.

**Table 3-21. Pros and Cons of Upstream Embankment Raise**

| Pros | Cons |
|---|---|
| • Increased storage capacity. | • Available storage volume is reduced during construction. |

***Downstream Embankment Raise***

A downstream raise of the embankment could also be feasible. In this case, material would be added on the downstream side of the dam from the base to the crest to raise the dam height.

**Table 3-22. Pros and Cons of Downstream Embankment Raise**

| Pros | Cons |
|---|---|
| • Increased storage capacity.<br>• Existing dam remains in service during most of construction period. | • Because of the geometry of the site and the location of the downstream embankment toe relative to the outlet tunnel, a downstream raise would require extensive modifications to the outlet works. |

### *Reinforced Earth Embankment Raise/Wall*

The crest elevation of several embankment dams in Colorado has been increased to provide additional freeboard to pass the PMF event by constructing a vertical to near vertical embankment raise using reinforced earth. This method would use a geofabric and earth in a method similar to create a wall similar to some highway retaining walls. This method can also be used to provide limited additional storage. Because of the crest width of Terrace Reservoir dam, this embankment raising option could be feasible to increase the crest elevation of the dam.

**Table 3-23. Pros and Cons of Downstream Embankment Raise**

| Pros | Cons |
|---|---|
| • Increased storage capacity due to removal of filling restriction.<br>• Existing dam remains in service during construction. | • None identified |

### *Concrete Parapet Walls*

Concrete parapet walls are commonly used to provide additional freeboard to embankment dams. Parapet walls are easy to construct and often relatively inexpensive to construct for embankments with short crest lengths. Concrete parapet walls can readily supply an additional 3 to 6 feet (and have been constructed as high as 10 feet) of freeboard to an embankment dam. They are basically a concrete retaining wall constructed on top of the dam crest. The geometry and geology at the Terrace Reservoir site is such that a parapet wall can be installed to provide additional freeboard to the reservoir to pass the PMF storm and possibly increase the normal pool elevation.

**Table 3-24. Pros and Cons of Concrete Parapet Walls**

| Pros | Cons |
|---|---|
| • Provides additional freeboard to pass PMF and therefore additional storage space.<br>• Easy to construct.<br>• Relatively inexpensive to construct.<br>• Existing dam remains in service during construction. | • None identified |

## 3.7.3 Sediment Removal to Increase Capacity

At least 10 to 20 feet of sediment are believed to be accumulated at the bottom of Terrace Reservoir. Removal of this sediment could provide 250 to 500 acre–feet of additional storage in Terrace Reservoir.

This project increases the storage of Terrace Reservoir without construction of any major structures, but there are several considerations. The sediments are likely to be contaminated and may be difficult to dispose of. The reservoir could either be drained and the sediment removed manually, or sediment could be removed through a dredge. If the reservoir is drained, there will be a risk of sediment migrating downstream and impacting downstream uses.

Table 3-25. Pros and Cons of Sediment Removal in Terrace Reservoir

| Pros | Cons |
|---|---|
| • Increased storage capacity in Terrace Reservoir. | • Sediments may be contaminated. |

### 3.7.4 Improvements to Outlet Works

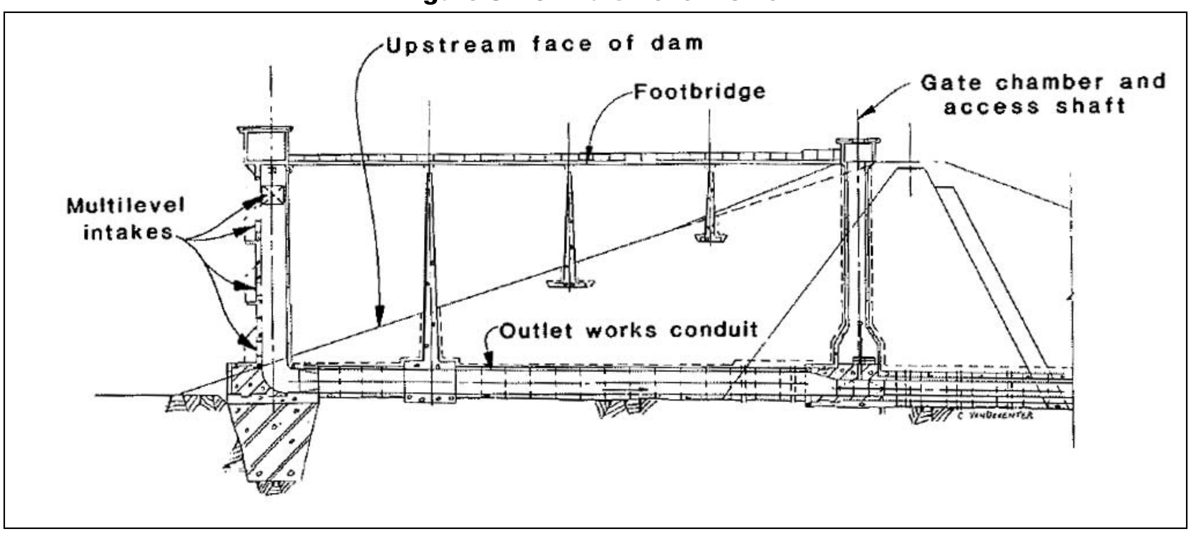
The Terrace Reservoir outlet works have an extensive history of damage and maintenance and repair problems. A mechanical engineer should review the existing facility and determine possible modifications to the mechanical systems of the outlet to allow for its continued safe and economical long–term operation.

***Replacement of Current Inlet with Gated, Multi–Level Tower***

A multi–level tower would allow reservoir operators to select the depth of water for releases from the reservoir. Having various options for the depth of the reservoir outlet is important because the reservoir stratifies during the summer creating layers of different water qualities. A new tower would also add a level of redundancy to outlet works that have historically been difficult to operate or unreliable. The tower gates could be used to control the flow of water leaving the reservoir, removing the reliance on the existing outlet works that have had so many problems in the past. A tower could also reduce unwanted releases of sediment, particularly when gates at higher elevations are used to release water.

A tower could be built on top of the existing outlet structure. The existing 48–inch double disc gates would essentially become emergency guard gates in the system or could possibly be removed. Gates could be located approximately every 25 feet from the bottom of the reservoir. **Figure 3–10** shows an example of a multi–level tower.

Figure 3–10. Multi–level Tower




Source: Bureau of Reclamation, 1987

**Table 3-26. Pros and Cons of Installing Gated, Multi–Level Tower**

| Pros | Cons |
|---|---|
| • Reduce sediment quantity exiting reservoir.<br>• Reduced damage to Howell–Bunger valve.<br>• Reduce reliance on 48–inch double disk gates.<br>• Improved water quality regulation of downstream Alamosa River. | • High cost.<br>• Increased operational responsibility for TIC. |

### 3.7.5 Power Generation at Terrace Reservoir

Installing power generation equipment at Terrace Reservoir could help to offset costs of improvement projects and operations.

A cursory assessment as to the economic feasibility of hydropower generation at Terrace Reservoir indicated, using conservative assumptions regarding the cost of the hydropower unit and a present worth of 5%, that a hydropower project at Terrace Reservoir would break even at a power purchase price of about $0.045 per kilowatt–hour. This brief study indicated that hydropower may be viable for the Terrace Reservoir project. Typically, the price of power ranges from 3 to 5 cents per kilowatt–hour. The actual price at the site would depend on what could be negotiated into a contract based on the market. A feasibility level study is needed to refine the potential benefits and costs. The study would refine the cost of the project by obtaining turbine/generator quotes from vendors and by developing cost estimates of preliminary project layouts. A power marketing study is also needed to show the potential value of the power. The current trend towards "green power" would make the project more attractive. It is possible that trends in the market toward "green power" will make this project more economical in the future.

**Table 3-27** summarizes the pros and cons of power generation at Terrace Reservoir.

**Table 3-27. Pros and Cons of Power Generation at Terrace Reservoir**

| Pros | Cons |
|---|---|
| • Additional source of revenue. | • Large capital cost.<br>• Return on investment depends on the cost of power, which fluctuates.<br>• May require operating the reservoir in a manner that is not as efficient for water resources. |

## 3.8 Sediment Management

Sediment production and deposition is a concern for much of the Alamosa River between Highway 285 and the Iron Creek confluence. Sediment production due to bank erosion is addressed in the stream restoration section. However, bank erosion is only one aspect of the sediment problem and further measures are necessary to adequately address this issue. The potential sediment management projects include the following:

- Create sediment deposition locations in the lower watershed
- Manage maintenance of roads in the watershed
- Control upper watershed tributaries' influx of sediment to the Alamosa River with sediment traps at tributary confluences

### 3.8.1 Lower Watershed Sediment Deposition Locations

The main concern between Highway 285 and Gunbarrel Road is sediment deposition. Deposition is not a problem between Gunbarrel Road and Terrace Reservoir. No sediment deposition projects are being proposed between County Road 10 and Gunbarrel Road due to the stream restoration project currently underway. After this stream restoration project is completed, most of the sediment entering the reach will most likely be conveyed downstream of County Road 10 due to improved sediment conveyance. Thus, the downstream channel will experience stability problems due to the increased sediment load entering the reach between Highway 285 and County Road 10. The channel straightening that took place downstream of County Road 10 will affect sediment deposition, since natural sediment storage locations such as alternating gravel bars have been eliminated.

Creation of sediment storage and deposition sites is recommended between Highway 285 and County Road 10 to provide for the existing and anticipated sediment load. **Figure 3–11** shows an artificial cutoff channel. This feature creates a location off of the main channel for excess sediment to drop out, thus promoting channel stability. The artificial channel is created by excavating material parallel to the main river channel and connecting the upstream end of the cutoff channel to the river.

**Figure 3–11. Artificial Cutoff Channel**

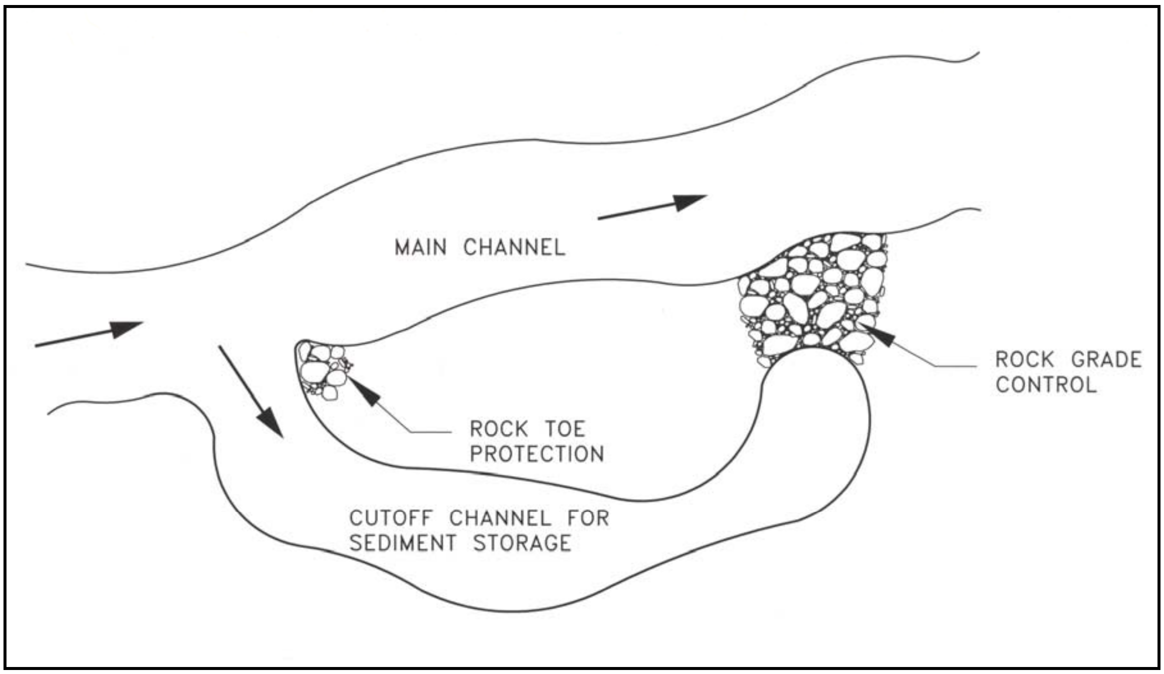



**Table 3-28. Pros and Cons of Sediment Deposition Areas in Lower Watershed.**

| Pros | Cons |
|---|---|
| • Provides a place for sediment to drop out.<br>• Promotes channel stability. | • Much of the channel is adjacent to private land and landowners may not want to participate.<br>• Sediment traps will require regular maintenance. |

### 3.8.2 Road Management in Upper Watershed

There are numerous roads in the steep terrain of the upper watershed. These roads have the potential to produce increased sediment loads. Minimizing these disturbances will decrease sediment loadings. As such, best management practices should be incorporated to minimize the amount of sediment generated in the upper watershed. This option may require closure of certain roads to reduce sediment generation.

**Table 3-29. Pros and Cons of a Road Management Plan**

| Pros | Cons |
|---|---|
| • Minimizes sediment generated from roads.<br>• Closing roads is a low cost solution. | • Road management may not be cost effective given the limited amount of sediment resulting from roads in the watershed.<br>• Road closures will limit access. |

### 3.8.3 Sediment Traps at Upper Tributary Confluences

There are four tributaries in the upper watershed that contribute significant sediment loads to the Alamosa River. The sediment loading and resulting debris fan from these tributaries encroaches upon the Alamosa River channel, limiting the river's movement. Iron, Alum, Bitter, and Burnt Creeks are the main contributors of sediment to the river. These sediment loads are the direct result of large unvegetated areas caused by naturally occurring highly acidic soil that will not support vegetation.

Eliminating the sediment loading by stabilizing the erosive watersheds is the long–term, minimum–maintenance solution. However, the large areas of steep terrain that will not readily support vegetation make this option cost prohibitive. Alternatively, another solution may be to minimize sediment entering the Alamosa River by creating sediment traps at the tributary confluences. There are several sediment trap methods that can be used to minimize sediment loading, but any option that traps sediment will require regular maintenance. Due to the large amount of sediment generated by these tributaries it is recommended that a pilot project be conducted on one of the tributaries to determine the best manner to control the sediment influx. Such a project could include the construction of rock check dams, sediment diversion structures, or off channel sediment storage structures. After an acceptable alternative is chosen, the sediment control measure can be pilot tested, and, if found successful, implemented in the other tributaries.

**Table 3-30. Pros and Cons of Sediment Traps at Tributary Confluences**

| Pros | Cons |
|---|---|
| • A sediment source entering the river will be eliminated.<br>• The Alamosa River channel is expected to be more stable due to the reduced sediment load.<br>• The amount of sediment being transported by the Alamosa River to Terrace Reservoir will decrease.<br>• Water quality in the river channel will be improved. | • Regular maintenance will be required for any alternative that reduces sediment entering the Alamosa River.<br>• A location for disposal of removed material will be required.<br>• The steep gradient, poorly vegetated watersheds present a serious design challenge. |

***Alum Creek Sediment Trap and Improved Water Quality Pilot Project***

During high flows, Alum Creek carries a tremendous bedload of sediments derived from hydrothermally altered rocks to the Alamosa River. These rocks typically contain sulfide–rich accessory minerals, which when oxidized contribute metal loading as well as low pH runoff and acidic conditions in adjacent water bodies, including the Alamosa River. Following spring runoff, a large fan of materials is deposited at the terminus of the creek, and these sediments are then progressively eroded and carried downstream by the Alamosa River. The sediment also contains a high proportion of clays, which are easily suspended and directly impact water turbidity. **Figure 3–12** shows a photo of the sediment fan looking upstream as it was being eroded during summer of 2004. Alum Creek typically has a much higher level of suspended solids than other tributaries. The high load of iron from Alum Creek can also be noted in the photo (seen as the reddish brown staining on the rocks).

**Figure 3–12. Photo of Alum Creek Sediment Fan Being Eroded by Alamosa River**

The steep slope and unstable soils make sediment traps difficult to install directly in the Alum Creek channel. Much of the surrounding terrain is also very steep and suitable off–channel areas are limited. However, a flat floodplain area is located just upstream of the Alum Creek confluence. An oblique aerial photo shows the plan view of the existing Alum Creek fan and the available area upstream of Alum Creek (to the left of the Alum Creek confluence in **Figure 3–13**).

Water quality improvements would consist of regrading the fan area (including high bank shown in **Figure 3–12**), stabilizing the adjacent Alamosa River bank with limestone rock, constructing limestone rock check dams within the Alum Creek channel to trap a portion of the annual bedload, and directing the lower portion of Alum Creek a flow–through pond. **Figure 3–14** shows a photo of the area that could be potentially used for a sediment settling pond. Although a settling pond would impact the riparian vegetation, the impact could be mitigated by replanting and transplanting willows in areas outside the berm and adjacent to the settling pond.

**Figure 3–13. Aerial Photo of Alum Creek Confluence**

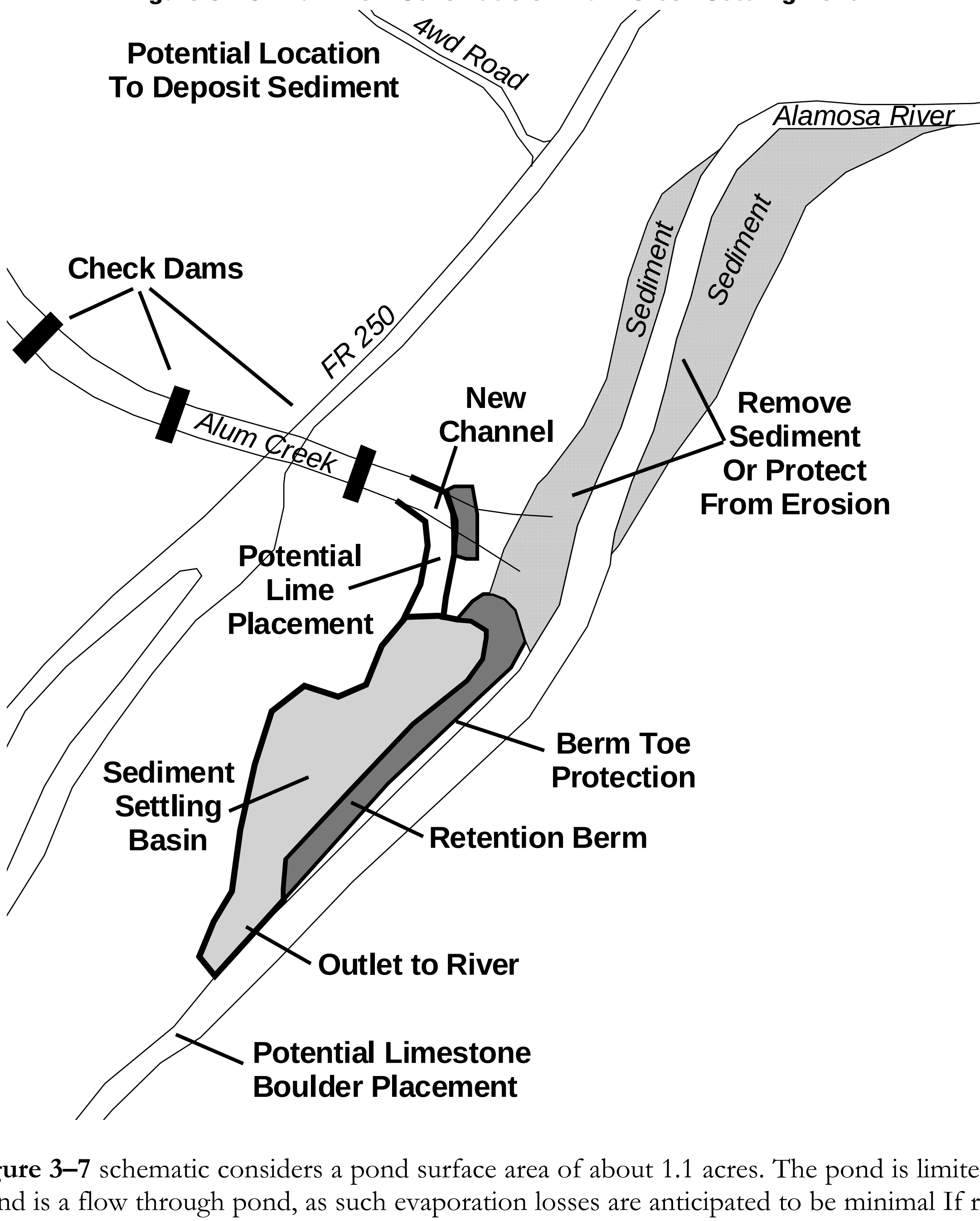
**Figure 3–14. Photo of Potential Area for Settling Pond Upstream of Alum Creek Confluence**

Note: Photo courtesy of Alan Miller

**Figure 3–15** shows a plan view schematic of a potential sediment settling pond and sediment check dams near the confluence of Alum Creek and the Alamosa River. Deposited sediment would need to be excavated from the check dams and pond area on an annual basis. Excavated sediments could potentially be placed in a concealed meadow (**Figure 3–13**) that is located a short distance to the east (upper right side of photo) of Alum Creek. The disposal site would require thorough investigation to assure that the material is placed above the seasonal high ground water table and is isolated from other surface water sources. As material is disposed at this location, agricultural lime should be blended with the sediments and each cell should be topsoiled and reseeded in the fall of each year. The site design should ensure that the dredged material is placed and configured in a geomorphically stable fashion.

With respect to the settling pond and diversion channel option, a possible modification could include annual stockpiling of agricultural lime adjacent to and within the diversion channel. The channel dimension could be designed so that the lime would be slowly eroded and mixed into the very low pH water of Alum Creek. The lime would raise pH and encourage precipitation and settling of iron and other metals in the settling pond. This usage of lime is subject to available future funding.

**Figure 3–15. Plan View Schematic of Alum Creek Settling Pond**




The **Figure 3–7** schematic considers a pond surface area of about 1.1 acres. The pond is limited in areal extent and is a flow through pond, as such evaporation losses are anticipated to be minimal If required a small amount of water could be purchased to offset any evaporation losses. This project could conceivably be combined with a project to stabilize and reshape braided channels downstream, and the reduced evaporative losses in those reaches could offset increased evaporation from the settling pond.

This project could also address the sediments that currently choke the area downstream of the Alum Creek confluence. **Figure 3–16** shows a photo of these sediments. The sediments could be excavated and placed in the upland disposal site referenced in the previous paragraphs. Limestone rock bank protection will be used to protect the toe of the regraded fan and channel area as well as to protect the berm of the settling pond during high flows in the Alamosa River.

This project should proceed as a pilot study and a monitoring program should be implemented. The monitoring program should address: (1) the volume of material removed and disposed on an annual basis; (2) the water quality of the Alamosa River upstream and downstream of the project; and (3) geomorphic changes in the mainstem of the Alamosa River.

**Table 3-31** lists pros and cons of a sediment trap, rock check dams, upland disposal site and lime addition project on Alum Creek.

**Figure 3–16. Photo of Sediment Downstream of Alum Creek Confluence**

**Table 3-31. Pros and Cons of Alum Creek Sediment Trap and Lime Addition**

| Pros | Cons |
|---|---|
| • Could remove major source of both fine and coarse sediment, which contribute to the turbidity of the Alamosa River.<br>• Could remove deleterious sediments that contribute to acid conditions and metal loading within the Alamosa River.<br>• Could directly treat the low pH conditions of Alum Creek.<br>• May be more feasible than larger water quality projects. | • Although undetermined at this time, the project may have a limited impact on the overall metal and acid load to the Alamosa River.<br>• Sediment will have to be excavated from settling pond and check dams and disposed at an upland disposal site.<br>• Annual maintenance costs that will be incurred include: removal, transport and haulage of sediment; revegetation and stabilization of a disposal site; and purchase and placement of agricultural lime.<br>• Impacts small area of riparian vegetation. |

## 3.9 Water Quality Improvement

Water quality in the Alamosa River downstream of Wightman Fork has improved significantly in recent years due to remediation efforts at Summitville. However, water quality below Wightman Fork continues to exceed pH, copper, zinc, and aluminum standards, and iron concentrations are high in comparison to toxicological reference values for benthic macroinvertebrates (bottom dwelling animals without backbones) and fish. Suspended sediments are also high in the Alamosa River above Terrace Reservoir and can become extreme after precipitation events. Wightman Fork produces the large majority of copper and zinc in the Alamosa River, while Alum Creek and other sources upstream of Wightman Fork produce the majority of iron and aluminum as well as low pH water during low flow months. Currently, concentrations of copper and zinc between Wightman Fork and Terrace Reservoir appear to be poorest late summer and fall while levels of pH, iron, and aluminum are poorest in fall and winter.

The Alamosa River could probably meet all water quality standards below Wightman Fork if the majority of contaminants could be removed from Wightman Fork and Alum Creek.

In order to restore water quality below Wightman Fork to levels that could support a long–term fishery, water quality improvement mechanisms may be needed to raise pH and remove portions of the copper, iron, aluminum, zinc, and suspended sediment loads. The following projects have been proposed as mechanisms to help restore water quality to instream standards and return a sustainable fishery to the Alamosa River below Wightman Fork. Some of these projects would address problems on Wightman Fork, while others would address problems on tributaries upstream of Wightman Fork.

NRD funds cannot be used for projects at the Summitville site because such projects are covered under the Superfund Program. Due to the limited number of locations between Summitville and Terrace Reservoir to improve water quality, the consultant team also considered projects upstream of Wightman Fork that treat natural sources of water quality impairment. Improving water quality at locations receiving mostly natural contamination was suggested as a replacement for improving water quality at locations impacted by Summitville. Improving water quality, even if from natural sources, will help restore the environment that was potentially injured by hazardous releases from Summitville. This “trading’ approach is often used in water quality and watershed management plans. These “trading” projects qualify for NRD funding, which can be used to “restore, replace, or acquire the equivalent of” natural resources that were damaged from Summitville.

### 3.9.1 Reclamation of Abandoned Mines Other Than Summitville

The Summitville district was the largest and most economically significant mining area in the Alamosa River watershed. However, numerous small mines and prospects dot the upper Alamosa River watershed in the Stunner, Gilmore, and Jasper districts. A total of 219 mine openings and 130 mine dumps were inventoried by the Kirkham et al. (1995) study outside of Summitville. Most openings were small or caved in. Water was draining out of, or standing within, 31 of the inventoried mine openings and from three dumps. Most mine dumps were small. Fourteen dumps were documented with estimated volumes between 1,000 and 10,000 cubic yards. **Section 2.4.3** presents a map of the most significant mines as well as water pH, metal concentrations, and estimates of contaminant loads from 16 mines with the most significant mine drainage. The Kirkham et al. study indicated that the Pass–Me–By Mine produced the highest contaminant loads.

**Section 2.4.9** presented estimates of metal loads currently carried by altered tributaries in the Alamosa River watershed as well as the sum of the loads estimated by Kirkham et al. for historic mines. Kirkham et al. noted that these were maximum load estimates and actual loads may be less. From this table, historic mines appear to contribute approximately 2.3% of the iron, 1.8% of the aluminum, 0.3% of the zinc, and 0.04% of the copper loads to the Alamosa River.

Therefore, loads from historical mining are less significant on a watershed scale than loads from the Summitville site and from natural sources. However, drainage from abandoned mines has significant local impacts on Iron Creek, the upper Alamosa River, and upper Burnt Creek. In addition, mine discharges are relatively contained and concentrated, USFS and BLM have programs to address clean up of abandoned mines on their respective properties. Treatment of inactive mine discharges could be pursued under Clean Water Act or CERCLA authority. **Table 3-32** lists general pros and cons of treatment of drainage from abandoned mines in the Alamosa River watershed other than Summitville.

**Table 3-32. Pros and Cons of Treatment of Mine Drainage from Abandoned Mines**

| Pros | Cons |
|---|---|
| • Could reduce localized impacts to Iron Creek, Burnt Creek, and Upper Alamosa River.<br>• Opportune points of treatment to reduce contaminants to the Alamosa River.<br>• Possible funding through USFS or BLM.<br>• Could pursue under Clean Water Act or CERCLA authority. | • Contaminant loads from abandoned mines are relatively small on a watershed scale.<br>• Most mines are on private land and owners may be uncooperative.<br>• Treatment may require maintenance.<br>• Treatment can be expensive to remove only a small fraction of the total watershed load of metals. |

The following sections list options for reclamation of abandoned mines and treatment of mine drainage. An actual project may include a combination of several different treatment options. For example, reclamation of the Pass–Me–By mine could include an anoxic limestone drain at the collapsed mine portal followed by a sulfate reducing wetland or settling basin as well as capping and diversion of drainage around the mine tailings dump. Selected information for these options was drawn from CDMG (2002).

***Anoxic Limestone Drain***

Anoxic limestone drains are used to raise the pH of acidic drainage when the drainage can be intercepted as it exits a mine portal or seepage area and remains relatively anoxic. Limestone (generally 2 to 6 inch diameter) is buried in a trench, and the acidic drainage filters through the limestone. The alkaline limestone is dissolved and the pH is raised. The anoxic condition prevents precipitation of iron and other metals. If drainage is aerated and not anoxic, iron may precipitate on the limestone and form a coating that will significantly limit its effectiveness. After exiting the limestone drain, the drainage can be aerated and placed in a settling pond where oxidation will cause metals to precipitate and settle. Anoxic limestone drains are generally maintenance free, but their effectiveness may be reduced over time on the order of 20 to 30 years.

***Sulfate Reducing Wetland***

Sulfate reducing wetlands utilize sulfate reducing bacteria to reduce sulfate in mine drainage to sulfides which form relatively insoluble metal sulfide precipitates in an anoxic environment. Incoming water pH should be above 4.5 (CDMG 2002). Drainage usually enters at the top of the wetland and is filtered through a three to six foot layer of organic material such as manure, compost, sawdust, or straw. The organic material provides an energy source for the sulfate reducing bacteria. A sulfate reducing wetland usually resembles an artificial pond behind constructed berms, and measures are taken to discourage plant growth as plants would increase oxygen levels. For this reason, a sulfate reducing wetland does not provide any habitat values. Sulfate reducing wetlands generally operate more efficiently than oxidizing wetlands at high altitudes and in cold climates. However, as sulfate reducing wetlands rely on anoxic conditions and hydrogen sulfide is produced by the bacterial processes, sulfate reducing wetlands usually produce an undesirable strong odor similar to rotten eggs. Although installed sulfate reducing wetlands have shown high treatment efficiencies, odor problems have plagued many installations. Periodic maintenance of a sulfate reducing wetland is required although maintenance requirements are typically less than with an oxidation type wetland. Loads of precipitated metals eventually begin to impact treatment efficiencies, and sulfate reducing wetlands often have an operational life of 20 to 30 years before metal sludge must be removed and the organic substrate material replaced.

***Oxidation Wetland***

An oxidation wetland is similar to the common perception of a wetland. Wetland type plants such as cattails or rushes are planted to keep ponded water oxygenated. Metals are oxidized and precipitate, and are adsorbed on organic substrates and plant materials. Bacterial and algal processes are also important for the treatment functions. The wetland vegetation can have beneficial habitat values for migratory fowl or other animals. However, toxicity effects of accumulating metals may be a concern. Incoming water pH should be at least 6.5 (CDMG 2002). Because oxidation processes depend on plant growth, efficiencies decrease significantly during winter months. Because of this, treatment efficiencies of oxidation wetlands are often limited significantly at high altitudes or during cold months. Periodic maintenance is required to ensure that channelization is not occurring. Loads of precipitated metals will eventually begin to impact treatment efficiencies or may exhibit toxic effects on wetland vegetation. Properly designed wetlands can have an operational life of 20 to 30 years. If toxicity effects are apparent, wetland substrates and vegetation may have to be removed and disposed. If toxicity effects are not apparent, the height of wetland berms can sometimes be increased to continue use of the wetlands without replacement of wetland substrates and vegetation.

***Reclamation of Mine Waste Rock and Mill Tailings Piles***

Several best management practices are available to prevent mine waste rock and mill tailings piles from impacting the water quality in nearby streams. Diversion ditches can be constructed upstream of piles to divert surface flows or shallow groundwater around piles. Piles can be removed from drainages or inundated areas and placed away from water sources. Barriers such as road embankments or walls can be placed between piles and water sources or streams. The erosion of piles can be reduced by regrading piles to a gentle and uniform slope. Regraded piles can also be capped with layers of impermeable fabrics and fine grained soils to inhibit water infiltration and revegetated to control erosion of the cap.

### 3.9.2 Passive Water Quality Improvement on Altered Tributaries

The majority of the contaminant loads are carried to the Alamosa River mainstem by the tributaries in hydrothermally altered areas. Typically, treatment systems for acidic drainage are designed for small flow rates from contaminant sources. However, apart from the Summitville site, the majority of contamination in the Alamosa River watershed is from natural sources that are often diffuse and spatially widespread. Therefore, improving water quality in tributaries could potentially remove much more contamination than isolating and treating small individual sources.

The primary passive treatment devices that would be available for treatment of tributaries would be anoxic limestone drains, sulfate reducing wetlands, and oxidation wetlands, as described in the options for mine reclamation, as well as placement of limestone boulders in "clean" tributaries above metal sources.

Water in tributaries is well aerated, so placement of anoxic limestone drains or limestone filters in stream reaches that have high concentrations of metals do not appear to be viable options. Limestone would probably get coated with iron precipitate and lose its effectiveness. However, limestone boulders could potentially be placed in stream reaches with low iron concentrations just upstream of metal sources. The limestone would slowly dissolve and raise pH in water which would then flow into a lower contaminated reach helping to neutralize acid and transform metals from dissolved to particulate forms. This would allow metals to precipitate out of the stream without coating the limestone boulders. Adequate "clean" stream reaches for this placement are limited, but limestone boulder placement could potentially be effective at several locations.

Oxidation wetlands require an incoming water pH of 6.5 and have limited efficiency at high altitudes and in cold climates. As the water pH of all tributaries is below 6.5 and tributaries are located at relatively high altitudes, oxidation wetlands would probably not be successful. Almost all metals in altered tributaries are in dissolved form, so a settling option such as a lake or reservoir on an altered tributary would also probably not be an effective option. Sulfate reducing wetlands can treat drainage that is above pH 4.5. Wightman Fork and Jasper Creek both have a median pH above 4.5. As mentioned previously, a sulfate reducing wetland does typically produce a bad odor. Jasper Creek is located near the town of Jasper, and there are numerous residences near the creek. Therefore, a sulfate reducing wetland would probably not be appropriate on Jasper Creek. On the other hand, public access to Wightman Fork below the Summitville site is limited, and odors would probably a less significant problem. Therefore, a sulfate reducing wetland may be a viable passive treatment option for Wightman Fork.

***Placement of Limestone Boulders in Clean Tributaries***

Placing limestone in uncontaminated stream reaches would produce alkalinity that could neutralize acid in downstream contaminated reaches while minimizing the coating of the limestone with iron precipitates that would occur if placed in contaminated reaches. Limestone should be large enough so that boulders are not mobilized even at high flows. Minimum boulder size should probably be two foot in diameter or larger, depending on the stream reach. The length of reach for boulder placement will depend on flow rate in the reach, desired design life, and the availability of funding. The effects of limestone on water pH may be limited during high flow, but should increase during periods of low flow. Therefore, limestone boulder placement may be most beneficial in the watershed upstream of Wightman Fork. Upstream of Wightman Fork, water quality is generally poorest during low flow conditions in fall and winter. Below Wightman Fork, water quality is generally poorest in spring and summer months after water begins to flow from the Summitville site.

On the mainstem of the Alamosa River, limestone could be placed just upstream of the confluence with Iron Creek. Iron Creek adds a significant load of iron and lowers the pH of the Alamosa River below the confluence. Unfortunately, access to the site is difficult. Aerial photography indicates that a small logging or mining road off of Forest Road 250 to Stunner pass may get close to the site, but this access may be inadequate. Unfortunately, better access is not available for the next 4 miles upstream. Downstream of Iron Creek, water quality recovers slightly before the confluence with Alum Creek. Limestone could potentially be placed in the Alamosa River just upstream of the confluence with Alum Creek. This placement would be optimum to offset the tremendous load of acidity and metals introduced by Alum Creek, and there is good road access at this location. However, iron from Iron Creek may cause some coating of limestone placed at this location. Limestone placed in the Alamosa River between Alum Creek and Terrace Reservoir would probably become coated in iron precipitate and rapidly loose effectiveness.

Of tributaries on the upper Alamosa River, Iron Creek may be the most favorable for placement of limestone boulders. The upper reaches of Iron Creek are relatively uncontaminated. The Kirkham et al. (1995) study reported that water remained relatively uncontaminated in Iron Creek until a tributary they referred to as tributary "G." Limestone could potentially be placed in Iron Creek just above the confluence with this tributary. However, access is also difficult to this site. The forest road that parallels Iron Creek from the Pass–Me–By mine to Schinzel Flats is located about 0.3 miles away. Better access to Iron Creek is available about 1.5 miles upstream in Schinzel Flats. An uncontaminated tributary to Iron Creek, tributary "J," enters Iron Creek near the same forest road. Access is better to this site that to Iron Creek above tributary "G," but flow is relatively small.

Adequate locations for boulder placements are limited on other contaminated tributaries. The Alum Creek watershed is underlain with pyrite–rich materials, and the majority of flow in Alum Creek originates from springs or groundwater base flow with very low pH and high metals contents. The top of the Alum Creek mainstem was described by Kirkham et al. (1995) as "fairly good water," but access to this point is very difficult, and all remaining tributaries have low pH and high metals. Several upper tributaries to Bitter Creek are relatively uncontaminated, and access could be possible at the very top of the Bitter Creek mainstem and tributaries "E" and "F" (as referred to by the Kirkham et al. study) from a road from the Summitville site to the south and east of Cropsy Mountain. However, flow at these sites is small and amounts of alkalinity that could be introduced to the system would be limited. Limestone could also potentially be placed in several relatively clean tributaries on the north side of Wightman Fork and on Jasper Creek, but limestone treatment would not be as beneficial as placement upstream of Wightman Fork. Limestone could also be placed on the several small uncontaminated creeks that enter the Alamosa River from the south. The most favorable of these creeks may be Globe Creek that enters the Alamosa River just upstream of Alum Creek just below the bridge for Forest Road 250 to Stunner pass. The location of this creek is ideal, but its small flow would probably only produce limited impacts.

A small pilot study could be performed to verify if limestone boulder placement in the Alamosa River above the Alum Creek confluence would be effective. If not effective at that location, use of limestone could also be investigated in the Alamosa mainstem above Iron Creek, in Globe Creek, and at the two specified locations on Iron Creek. Pilot studies should include monitoring of water pH and metals concentrations upstream and downstream of limed reaches and stream confluences.

***Sulfate Reducing Wetland on Wightman Fork***

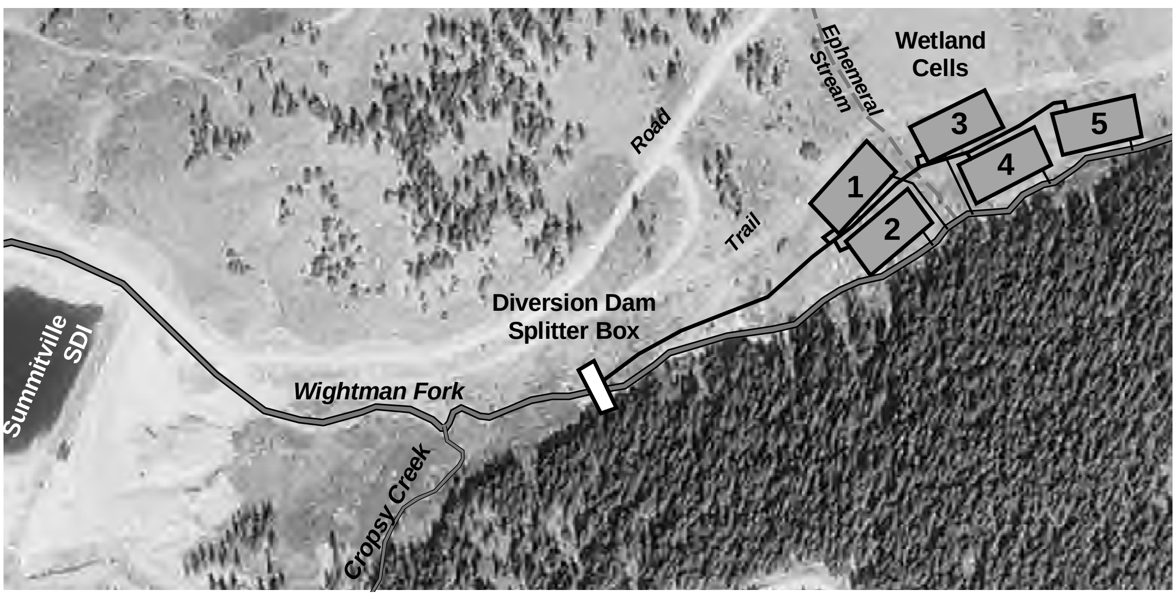
A sulfate reducing wetland could remove dissolved copper and zinc from Wightman Fork upstream of Summitville. Installation of a lake below Wightman Fork (**Section 3.9.4**) could effectively remove aluminum and iron from the upper watershed, but, without lime injection, a reducing wetland may be the most effective option to remove copper and zinc. A series of wetlands below the Summitville site could also potentially buffer limited untreated releases from the Summitville site. As Wightman Fork would be aerated, a thick substrate material may be needed to force anoxic conditions. A sulfate reducing wetland often has a lifetime of approximately 20 to 30 years (CDMG 2002). However, a new treatment plant with improved efficiencies for copper removal may be installed at the Summitville site within this time frame.

The wetlands should probably be installed just below Cropsy Creek in order to limit flow volumes from unaltered areas (see **Appendix F** for Wightman Fork segment map). Channel slopes between Cropsy Creek and Sawmill Creek are approximately 5% and milder than slopes below Sawmill Creek. However, side slopes in the reach (and below Sawmill Creek) are quite steep which severely restricts the potential size of wetland cells. Elevations range between about 11,110 feet at Cropsy Creek to about 10,840 feet at Sawmill Creek. Current median pH just below Cropsy Creek in Wightman Fork is 4.82.

The average yearly flow rates in Wightman Fork below Cropsy Creek is on the order of 7 cfs. However, the streamflow gage that was operational below Cropsy Creek between 1995 and 2000 indicated an average monthly streamflow as high as 60 cfs in 1997 during snowmelt. For years other than 1997, the maximum monthly streamflow during snowmelt was 27 cfs. Currently, concentrations of copper are relatively low during snowmelt in April and May, but increase after the bulk of snowmelt has passed. Flows following the snowmelt period are on the order of about 10 cfs.

A conceptual design is presented for a flow of 10 cfs. However, additional consideration of flow rates would be needed prior to detailed design of wetlands. CDMG (2002) recommends five cubic yards of organic substrate to treat one gallon per minute of mine drainage. Using a substrate thickness of 6 feet to treat a maximum of 10 cfs, this would indicate that 2.3 acres of wetlands would be needed. Five wetland cells would be needed if cells were 100 foot wide by 200 foot long. Wetland cells would have to be oriented down the channel length in order to avoid an extreme amount of earthwork. A flow splitter box could be used to equally split flows to each cell and exclude excess flows during snowmelt. Excess flows and treated effluent would be directed back to the natural channel. **Figure 3–17** shows a conceptual layout of potential sulfate reducing wetland cells below Cropsy Creek on Wightman Fork.
**Table 3-33** lists pros and cons of the potential project.

**Figure 3–17. Conceptual Design of Potential Sulfate Reducing Wetlands on Wightman Fork**




Note: Five 100ft x 200ft cells to treat 10 cfs maximum flow

**Table 3-33. Pros and Cons of Sulfate Reducing Wetlands on Wightman Fork**

| Pros | Cons |
|---|---|
| • May remove significant portions of dissolved copper and zinc in Wightman Fork.<br>• Could potentially reduce concentrations of copper and zinc to water quality standards in Alamosa River mainstem.<br>• Public use of the area is limited and impacts of odors may be limited.<br>• Removed substrate could potentially be disposed of at Summitville site.<br>• Proximity to Summitville site may facilitate management by Summitville contractors. | • Periodic maintenance and management will be required.<br>• Operational life may be limited to 20 to 30 years before substrate will have to be removed and replaced.<br>• Removed substrate may have to be disposed of as a hazardous waste.<br>• May produce significant unpleasant odors. |

### 3.9.3 Active Water Quality Improvement on Altered Tributaries

As mentioned earlier, the majority of the contaminant loads are carried to the Alamosa River mainstem by the tributaries in hydrothermally altered areas. Alum Creek, in particular, produces the largest load of iron and aluminum in the watershed and is probably the largest single source of acidity during winter months. The Alamosa River could probably meet all water quality standards below Wightman Fork if the majority of contaminants could be removed from Wightman Fork and Alum Creek. Unfortunately, tributaries are too aerated to use passive limestone systems such as an anoxic limestone drain or channel placement of limestone. Iron precipitates would probably coat limestone and its effectiveness would diminish. In addition, the pH in tributaries other than Wightman Fork and Jasper Creek are too low to use other passive systems such as sulfate reducing wetlands or oxidations wetlands. Therefore, active systems would probably be the only option for directly treating tributaries other than Wightman Fork and Jasper Creek.

Active systems refer to options that require ongoing operation, maintenance, and management. In the context of mine drainage treatment, active systems also often refer to the addition of a reagent or neutralizing agent to raise pH. Several different agents are available to raise pH including sodium hydroxide and calcium carbonate (lime). Use of sodium hydroxide would increase levels of sodium in the water. High sodium levels can damage plants and crops. Therefore, use of sodium hydroxide is not advisable as it could potentially impact agricultural uses. The addition of lime would raise pH and increase concentrations of calcium. Calcium increases the hardness of water which actually tends to protect aquatic organisms such as fish from the effects of dissolved heavy metals. In addition, calcium is usually considered to be beneficial to agricultural soils. Therefore, the most favorable active system for low pH tributaries would be lime injection. Lime injection can raise water pH to neutral or even alkaline conditions. At high pH, dissolved metals precipitate and settle out of solution.

Typically, mechanical injection is used to inject lime into low pH water. Usually, water is added to finely ground limestone to form a slurry. A mechanical feeder injects the slurry into the low pH water just before a mixing location such as a steep rocky area. Injection into the hydraulic jump of a Parshall Flume would provide mixing as well as a point to measure flow. Flow and incoming pH can be monitored in order to control the amount of lime that is injected. The mechanical feeder and control systems require electrical power; although wind, solar, or hydro–power can potentially be used where electrical supply is not available. This type of system would require periodic replacement of lime in a large hopper or tank as well as ongoing maintenance of the mechanical systems.

Non–mechanical systems can also be used to introduce the lime. An erosional system could potentially be designed so that varying levels of bed shear stress could be used to "erode" appropriate amounts of finely crushed limestone from a channel section given changing flow rates. The crushed limestone would have to be periodically replaced in the channel. Water could also be passed through a large basin into which lime is periodically mixed.

After addition of lime, the water should be directed into a settling pond of sufficient size to allow precipitated metals to drop out. A layer of sludge will form at the bottom of this pond that must be periodically removed. Volumes of sludge are typically high. This sludge is often difficult to dewater, and must be adequately disposed of.

Alum Creek would probably be the best tributary for lime injection. Alum Creek has a very low pH and carries a tremendous load of dissolved metals. Injecting lime in Alum Creek could have a significant beneficial impact on the water quality of the Alamosa River. A channel erosion system or mechanical injection could be used to inject lime directly into the Alum Creek channel and flow could be directed from the channel into a large settling pond. More open space is available at the bottom of Alum Creek (to the south and west) than at most of the other tributaries for facilities and a potential settling pond. However, the area has relatively steep slopes, space is constrained by Forest Road 250, and the area is close to the Stunner campground. Therefore, treated water could be allowed to pass back to the Alamosa River, and precipitated metals could be transported downstream and allowed to settle in a potential lake below Wightman Fork. In either case, facilities would probably have to be designed in an aesthetically pleasing manner due to the proximity to the Stunner campground.

Although Alum Creek is an opportune location for removal of large loads of acid and metals from the Alamosa River, an active system on Alum Creek would face several difficulties. The contamination in Alum Creek is naturally occurring, but improvements could be viewed as an exchange for improvement on Wightman Fork if a project on Wightman Fork is not feasible. However, the system would be quite costly, and a fund would have to be established to fund operation and maintenance of the project for the foreseeable future. The system would have to be designed to operate throughout the winter, or winter access would have to be maintained to the site, as it would be important to treat winter flows. **Table 3-34** lists pros and cons for a lime injection project on Alum Creek.

**Table 3-34. Pros and Cons of Lime Injection System on Alum Creek**

| Pros | Cons |
|---|---|
| • Could remove significant portions of acidity, iron, copper, zinc, aluminum, and other trace metals from Alamosa River.<br>• If combined with sulfate reducing wetland on Wightman Fork, could potentially meet water quality standards and restore fish to entire Alamosa River mainstem.<br>• Could be considered as an exchange for contaminants that can not be removed from Wightman Fork. | • Ongoing operation, maintenance and management needed.<br>• System would have to be maintained for foreseeable future.<br>• Construction and maintenance of system would be expensive. |

### 3.9.4 Lake or Reservoir on Alamosa River below Wightman Fork

A large lake or reservoir constructed on the mainstem of the Alamosa River below Wightman Fork is a viable option to improve water quality conditions on a scale as large as the Alamosa River.

The primary mechanism for water quality improvement in a lake or reservoir is sedimentation. A large lake could potentially remove a large portion of the suspended sediment load. Although suspended sediment data are limited, the largest sources of suspended sediments in the watershed appear to be located above Wightman Fork. Sedimentation could also remove a portion of the load of metals that are in particulate form. Currently, in the Alamosa River between Wightman Fork and Jasper Creek, 98% of the aluminum, 79% of the iron, and 60% of the copper are in particulate or colloidal form rather than dissolved form. The total load of these metals does not change significantly in the upper Alamosa River until Terrace Reservoir, so the particulate or colloidal forms need quiescent conditions in order to settle. Rates of sedimentation of suspended sediments and particulate metals would depend largely on the size and detention time in the lake or reservoir. A large lake or reservoir may also serve, to a limited degree, to buffer highly acidic but small flows from the upper watershed during the winter as well as limited untreated releases from the Summitville site. Removal of sediments, aluminum, iron, and copper and slight improvements to pH would have a significant beneficial effect on the Alamosa River and Terrace Reservoir. However, levels of pH and zinc, and possibly copper, may not be treated to the levels of the water quality standards, particularly in the fall and winter, without an additional mechanism for improving water quality. Lime addition or injection within the lake is an additional active process that could potentially reduce all water quality contaminants to water quality standards.

Lakes and reservoirs constructed on the mainstem of a river typically cause a variety of environmental changes. One of the most significant impacts can be the loss of the riparian corridor due to submersion. In addition, reservoirs and lakes can submerge cultural resources and historical sites. Reservoirs and lakes also modify the water quality of a stream, usually reducing suspended sediments and modifying stream temperature by delaying spring warming and fall cooling. Channel geomorphology upstream and downstream of the reservoir can also be affected. The environmental impacts of any planned lake or reservoir would be thoroughly evaluated through the NEPA process prior to construction.

A list of pros and cons related to a mainstem lake or reservoir below Wightman Fork relative to other water quality improvement projects is presented in **Table 3-35**.

**Table 3-35. Pros and Cons of Lake or Reservoir on Alamosa Mainstem**

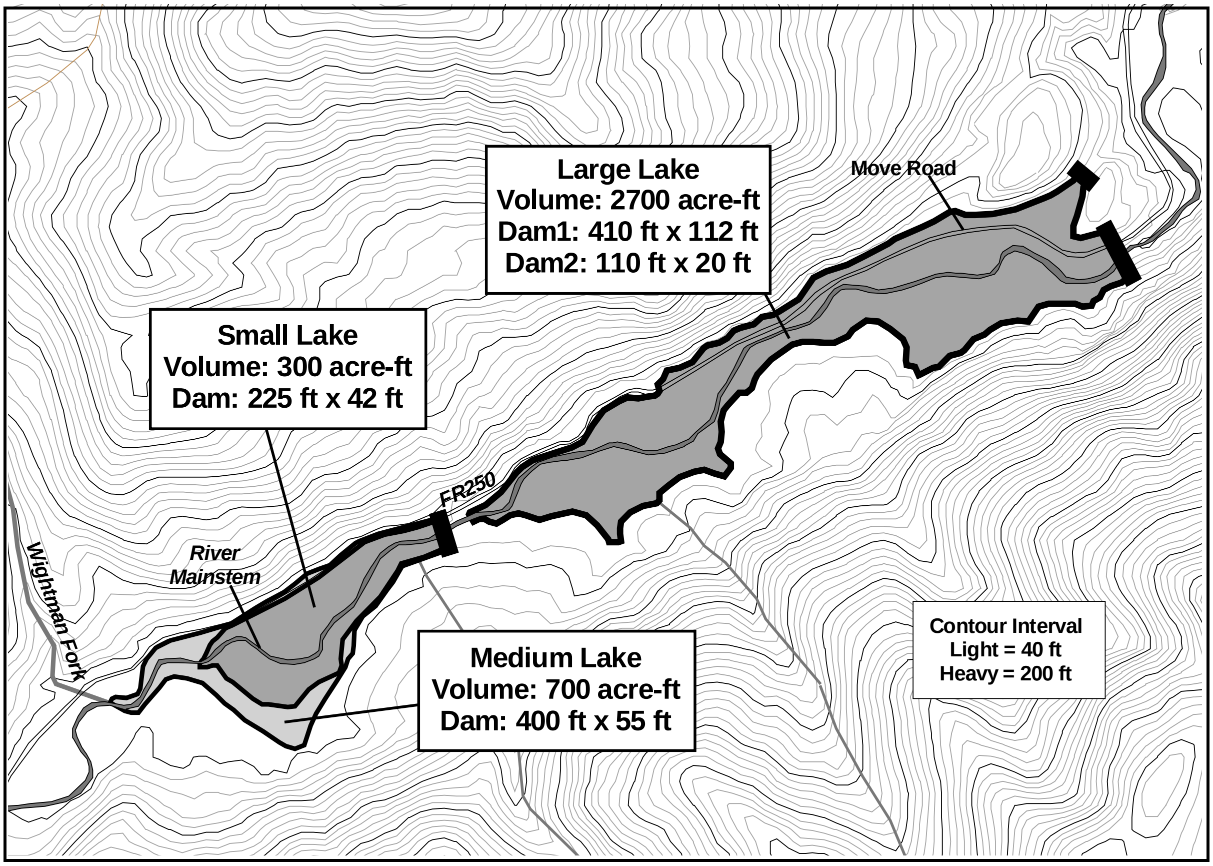
| Pros | Cons |
|---|---|
| • Large scale water quality improvement of entire Alamosa River mainstem with one project.<br>• Removal of suspended sediments and particulate metals (Fe, Al, Cu, Zn).<br>• Buffer low pH winter flows and untreated releases from Summitville site.<br>• Without lime, would require less future operation and maintenance than other potential alternatives.<br>• Lime addition or injection could meet water quality standards for all parameters.<br>• Potential as reservoir to store water for instream flow or flood control needs. | • Relatively expensive.<br>• Limited adjustment of pH or removal of metals without active lime injection or addition.<br>• Lime addition or injection would require future management and funding.<br>• Located on National Forest and would require authorization from Forest Service and compliance with NEPA requirements.<br>• Displace current riparian areas in footprint.<br>• May be difficult to move road. |

There are several function and size options for an impoundment below Wightman Fork. The function options are either a lake with a constant water level, or a reservoir that is also used for water storage. A lake would be more efficient at removing particulate contaminants than a similarly sized reservoir. A reservoir often has a reduced volume of water and a reduced detention time, and sediments may be resuspended due to changing or low water levels. A constant level lake is more aesthetically pleasing than a reservoir with a "bathtub ring" and would not change the natural downstream flow regime in the river. On the other hand, a reservoir could also provide water storage for a potential instream flow right, flood control, or other uses. A reservoir could provide an effective mechanism to improve water quality as long as a minimum pool of sufficient size was maintained. An outlet works that could withdraw water from upper levels in the reservoir would also help maximize water quality improvements.

***Lake below Wightman Fork***

Several options were considered for a constant level lake below Wightman Fork. **Figure 3–18** shows potential locations for a small (300 acre–feet), medium (700 acre–feet), and large lake (2700 acre–feet) on National Forest land just below Wightman Fork. The size of the smallest lake was estimated so that the road would not be inundated. Significant costs could be saved by not having to relocate the road. However, a smaller lake would not remove as much of the contamination and deposited sediments would have to be periodically excavated from the lake (~50 years). The medium size lake would have a greater capacity for sediment deposition. Additional cost would be incurred to relocate the road, but the road could be reconstructed on the milder slopes on the south side of the potential lake. The larger lake configuration, which involves utilizing a location farther downstream than the location for the small lake or the medium lake, would provide longer detention time and may produce greater improvements to water quality, but would be much more expensive and would impact a larger riparian area. It would be very difficult to relocate the road to a suitable location as steep slopes and cliffs would surround the lake. Because of local topography the large lake would require two dams instead of just one. Dams should probably be constructed of roller compacted concrete in order to pass the probable maximum flood over the tops of the dams. The selection between these two dam locations would depend on further study of the stability of materials for dam foundations and the feasibility of moving Forest Road 250.

**Figure 3–18. Conceptual View of Lake and Reservoir Options Below Wightman Fork**




Note: Volumes estimated using cross–sectional analysis of 40 foot USGS contours

Considering the average monthly streamflow below Wightman Fork, overall detention times for the large 2700 ac–ft lake would range from about 5 days in June to 46 days in September and 139 days in January. For the 700 ac–ft lake, detention times would be about 1.3, 12, and 36 days in June, September, and January, respectively. Fortunately, detention times would be highest at the times when incoming water quality is the poorest, and high detention time in fall and winter may help buffer low pH water from the upper Alamosa River above Wightman Fork. Sedimentation theory (Stokes law) indicates that summer and winter detention times are sufficient to remove fine clays assuming ideal conditions.

### *Reservoir below Wightman Fork*

If the primary dam for the larger downstream lake location is raised to 152 feet and the dam across the saddle to the north of the dam is raised to 60 feet, a reservoir extending to the confluence of Wightman Fork with a volume of approximately 7,120 ac–ft could be created. A 2,700 ac–ft pool could be maintained similar to the previously considered large lake which would leave 4,400 ac–ft for water storage. This volume could be used to store an appropriated water right for release in fall or winter months as an instream flow. The addition of an instream flow amount for fall and winter flows in the Alamosa River above Terrace Reservoir would also improve water quality and benefit potential fish populations in this reach. Flood waters could also be stored at times when Terrace Reservoir filled if the

Division Engineer would allow additional storage of flood flows. As in Terrace Reservoir, short circuiting of the reservoir to a bottom outlet during stratified conditions would reduce water quality benefits. An outlet works that could draw water from upper depths could lessen this problem.

Forest Road 250 will have to be moved out of the reservoir footprint. Steep slopes would make road construction very difficult and may be unfeasible. The 152–foot dam may need to be designed to pass the entire probable maximum flood amount. In this case, the main dam could be built of roller compacted concrete and the saddle dam of earth. Alternatively, a spillway could also be incorporated into the dam to the north to pass flood flows over the saddle. The relatively high head of the dam may make hydroelectric generation economically feasible and could also be considered as a potential revenue stream to help pay for the dam or future lime injection or addition.

***Injection or Addition of Lime***

As mentioned earlier, a lake or reservoir would have significant beneficial impacts on water quality. Terrace Reservoir removes large portions of incoming loads of suspended sediments, iron, aluminum, copper, and zinc. However, levels of pH, copper, and iron below Terrace Reservoir exceed water quality standards during some months of the year. Without lime, improvements in water quality in a lake or reservoir below Wightman Fork would be similar, but somewhat less, than improvements currently caused by Terrace Reservoir. In the reach between the Wightman Fork confluence and Terrace Reservoir, acidic water is diluted somewhat and a greater proportion of metals are in particulate rather than dissolved form.

Therefore, active lime injection in a lake or reservoir may be needed to reduce all water quality contaminants to levels of the water quality standard. A slurry of finely crushed lime could be injected into a central location of the lake. The flow rate and water pH could be monitored in order to proportion the amount of injected lime. The injection system could be designed to work automatically without supervision. However, lime would have to be supplied periodically, and ongoing operation and maintenance would be required. A source of funding would be needed for this ongoing operation and maintenance.

It is recommended that limestone be placed in a reservoir or lake during construction. This initially should help raise pH and increase removal of dissolved metals. However, the effectiveness of this limestone will probably decrease after some time. Rather than lime injection, additional lime could be periodically dumped into a lake or reservoir when needed. Water quality improvement would be less efficient than with continual lime injection. However, the option would require less future operation, maintenance, and funding. A funding source would still be needed to purchase lime and transport it to the site.

### 3.9.5 Consolidation of Tributaries for Active Water Quality Improvement

A pipeline or lined ditch could potentially collect and convey drainage from several altered tributaries or other sources to one location for active water quality improvement. As discussed in the **Section 3.9.3**, lime injection would probably be the most appropriate active system. However, the waters could be conveyed to a location more suitable for settling of precipitated metals than near Alum Creek.

A pipeline or lined ditch could collect flow from Alum Creek and Bitter Creek and convey it along Forest Road 250 to Government Park. The system could also collect drainage from the Ferrocrete Mine, Red Mountain Tunnel No. 1, the mine adit referred to as “Adit Under FR250” by Kirkham et al. (1995). A pipeline would be about 1.1 miles between Alum Creek and Bitter Creek and an additional 0.5 miles to Government Park. An additional 1.4 miles of pipeline could convey water from Iron Creek and

"Washout" Creek, although the pipeline would have to be enlarged significantly to convey the larger flow of Iron Creek.

A relatively flat and open area of about 11 acres is available to the northwest of the Alamosa River in Government Park. This would probably be a sufficient size for a mechanical injection facility and a large settling pond. The pros and cons of this option would be similar to those presented in **Table 3-34**. However, additional contamination would be treated, and Government Park would provide a large, more suitable space for facilities. However, an additional "con" could be the potential impacts to the aesthetics of Government Park. Many photos have probably been taken of Government Park with Lookout Mountain in the background as it is a very picturesque setting.

### 3.9.6 Conveyance of Tributaries to Area of Alkaline Soils

The majority of waters and soils in the San Luis Valley outside of the Alamosa River watershed are alkaline. Water from altered tributaries could potentially be collected and conveyed in a ditch or pipeline to more alkaline soils. Altered tributaries are the primary source of acid and metals to the Alamosa River, and removal of this water would have significant beneficial impacts on water quality in the Alamosa River mainstem. The water could be recharged in an area of prairie in alkaline soils well away from any wells. The long flow path would probably improve the quality of the water before it reached areas of wells. A water right would have to be purchased to replace this water or an arrangement established to trade surface water for groundwater.

The average flows of Alum Creek, Bitter Creek, Jasper Creek, and Burnt Creek would be most feasibly conveyed in a ditch or pipeline. Average flows from these creeks sum to approximately 13 cfs. The removal of these creeks would probably significantly improve water pH and concentrations of iron and aluminum. The average flow of Iron Creek is about 10 cfs and would nearly double the conveyance needs. The average flow of Wightman Fork is approximately 23 cfs and would probably not be feasible to convey out of the watershed. Without the inclusion of Wightman Fork, concentrations of copper and zinc would probably remain high in the Alamosa River.

Approximately 31 miles of lined ditch or pipeline would be required to transport tributary flows from Alum Creek to a location in the prairie north of the Terrace Main Canal headgate. This installation would be complicated by several constrained areas with cliffs and steep slopes. Therefore, this option would probably be prohibitively expensive. There would probably be some uncertainty that the alluvial soils could remove all contaminants before the water approached well systems. **Table 3-36** lists pros and cons of a potential pipeline or ditch to convey water from altered tributaries to and area of alkaline soils.

**Table 3-36. Pros and Cons of Conveyance of Tributaries to Area of Alkaline Soils**

| Pros | Cons |
|---|---|
| • Could remove major sources of acidity, iron, and aluminum from Alamosa River.<br>• Less operation and maintenance would be needed than with other systems.<br>• Project would have a longer operational lifetime than other systems. | • Would have to buy replacement water or develop surface water / groundwater trade.<br>• Infeasible to convey water from Wightman Fork; therefore, copper and zinc would probably remain above water quality standards in the Alamosa River.<br>• Could potentially impact groundwater quality.<br>• 31 miles of lined ditch or pipeline would be very expensive. |

### 3.9.7 Summer Land Application of Acidic Flows

Percolation through soils has been shown to reduce metals concentrations in water. Special soils could be brought in from outside the watershed to maximize effectiveness of the land application. The soil could contain the following for improved performance:

Alkaline soils are common in the San Luis Valley and could be brought in from a relatively short distance. The alkaline soils could help neutralize the low pH.
Sands would increase the permeability of the soil mixture and reduce the possibility of clogging. Some sands are coated with iron oxide to increase removal of dissolved metals.
Soils containing organic matter facilitate the complexing of metals to the soil media.
Crushed limestone would help increase the pH of the flow but could become armored with precipitate and would need to be regularly replaced.

Media filtration of water has been used extensively in water and stormwater treatment. Sand filter basins for stormwater treatment are designed to blend into the landscape. They contain layers of media with an underdrain system and gravel bed designed to facilitate flow through the system.

Flows would return to the Alamosa River with improved water quality. Sand filter basins have been shown to remove over 50 percent of total recoverable zinc and total recoverable lead in stormwater (DUDFCD, 1999). Little data is available for removal rates of iron and aluminum.

With a flowrate through the filter of 2 gallons per square foot per day, an area of approximately 10 acres would be needed to treat 1 cfs of flow. The average annual flow from Alum Creek is estimated as 2 cfs, but the flow would be higher during snowmelt in the spring and summer. There is a maximum of about 3 acres of relatively flat land near the Alum Creek confluence that could be used for a water quality project, which will not be able to treat the majority of the flow. Secondly, the high sediment load from the Alum Creek basin is likely to clog any type of filter media.

**Table 3-37. Pros and Cons of Summer Land Application of Acidic Flows**

| Pros | Cons |
|---|---|
| • Significantly improved water quality from the largest source of iron and aluminum in the watershed. | • Would require annual maintenance.<br>• Would need to monitor application site to maintain quality above levels considered hazardous.<br>• Freezing of the media would halt improvement during the winter months when water quality is most critical in the Alamosa River.<br>• Requires large surface area.<br>• Sediment load is likely to clog filter media. |

### 3.9.8 Winter Freezing of Acidic Flows

Metals concentration are usually their highest and pH is its lowest during the winter when flows in the Alamosa River are at a minimum. Freezing acid rock drainage flows during this period of low flow could use the natural climate to delay flows of contaminated water to the Alamosa River mainstem. Water could be frozen in a pre–defined area to impound loading during the low flow period followed by slow release during the spring melt. The spring melt could be treated on site, or allowed to flow to the Alamosa River where dilution would reduce concentrations and potential impacts on aquatic life. Snowmaking and creation of ice are both possibilities, but the lack of power supply in the upper watershed could eliminate the snowmaking option.

Flows in Alum Creek contain high metals concentrations but the flow is relatively small, averaging approximately 2 cfs over the year. Flows in Alum Creek, or from various springs feeding Alum Creek, could potentially be diverted out of their channel and spread in sheet flow to encourage freezing. **Figure 3–19** shows the confluence of Alum Creek with the Alamosa River. The meadow located above the road and the flat area just west of the confluence are two relatively flat areas that could be use to spread or trap flow for freezing. Unfortunately, neither area is large enough to contain a significant portion of the winter flow.

**Figure 3–19. Aerial Photo of Alum Creek Confluence**

This project could potentially be one of the water quality improvement methods investigated as part of the sediment trap pilot study on Alum Creek discussed in **Section 3.8.3**.

**Table 3-38. Pros and Cons of Winter Freezing of Acidic Flows**

| Pros | Cons |
|---|---|
| • Low maintenance method of improving low flow water quality. | • Potential dangers posed by ice flow.<br>• Not enough space available to freeze a significant portion of the flow.<br>• No benefits during spring and summer runoff period. |

### 3.9.9 Water Quality Projects Eliminated From Future Consideration

The following water quality projects are eliminated from future consideration due to significant obstacles:

- Consolidation of tributaries for active water quality improvement was eliminated from further consideration because of its high capital and ongoing costs along with potential degradation of an area outside of the watershed.
- Conveyance of tributaries to area of alkaline soils was eliminated because it would be very expensive and probably not feasible.
- Freezing of acidic flows is eliminated due to space limitations at the tributary confluences that would not allow a significant portion of the flow to be frozen. This project could still be combined on a pilot scale with the sediment trap on Alum Creek project to investigate its performance.
- Summer land application of acidic flows is also eliminated due to lack of flat open space in the tributaries. It could be combined on a pilot scale with the sediment trap on Alum Creek project to investigate its performance.

The following projects are considered for further consideration as the best options of the different types of water quality improvement described above:

- Reclamation of abandoned mines
- Mainstem lake or reservoir below Wightman Fork
- Sulfate reducing wetland on Wightman Fork or other tributaries
- Active systems on tributaries upstream of Wightman Fork

Sediment traps at tributary confluences such as Alum Creek with water quality improvement (discussed as part of Sediment Management Projects in **Section 3.8.3**)

## 3.10 Riparian Habitat

All subwatersheds, except Wightman Fork and Treasure Creek, which have good riparian habitat, were given a fair or poor rating for riparian habitat. Several projects are discussed below to improve riparian habitat in the Alamosa River watershed:

- Noxious weed inventories and management.
- Revegetation of disturbed areas in the watershed that should support vegetation.
- Grazing management in the riparian area in the lower watershed
- Riparian buffer zone
- Establishing conservation, recreation, and access easements on the riparian corridor
- Acquisition of equivalent resource in the San Luis Valley for high quality habitat and recreation
- Purchasing high habitat value land on the Alamosa River downstream of Wightman Fork

### 3.10.1 Noxious Weed Management

Noxious weed management can be conducted in both the upper watershed and lower watershed to improve the condition of riparian habitat.

***Noxious Weed Management in the Upper Watershed***

In the upper watershed, noxious weed management should focus on identification of noxious weed outbreaks, and on prevention of future outbreaks. The extent of weed presence in the upper watershed is unknown at this time. An inventory for weed species should be conducted to determine their presence. A weed control program implemented in the upper watershed would control the proliferation of weeds as outbreaks are identified. Benefits would accrue primarily to wildlife habitat and recreational users. **Figure 3–20** depicts one method of weed management. The pros and cons of noxious weed management in the upper watershed are summarized in **Table 3-29**.

**Figure 3–20. Weed Management**

**Table 3-39. Pros and Cons of Noxious Weed Management in the Upper Watershed**

| Pros | Cons |
|---|---|
| • Would control noxious weeds as outbreaks are identified.<br>• High benefit for minimal cost. | • Long–term maintenance required to be effective. |

### *Noxious Weed Management in the Lower Watershed*

In the lower watershed, the extent of noxious weeds is better known. Currently, there are existing groups attempting to control weeds in the lower watershed. A comprehensive weed management plan in the lower watershed could have funding to existing weed management groups as a component. The weed management plan could also include recommended control measures for targeted areas. In the lower watershed, benefits of weed management would accrue primarily to agricultural landowners. The pros and cons of noxious weed management in the lower watershed are summarized in **Table 3-40**.

**Table 3-40. Pros and Cons of Noxious Weed Management in the Lower Watershed**

| Pros | Cons |
|---|---|
| • Improvement to riparian habitat.<br>• High benefit for minimal cost.<br>• Weed reduction may increase crop yields in fields adjacent to watershed. | • Long–term maintenance required to be effective.<br>• Requires watershed landowners consensus to be most effective. |

## 3.10.2 Revegetation of Disturbed Riparian Areas in the Lower Watershed

After instream flow and any recontouring projects are completed, portions of the lower watershed could be revegetated with native plants. Riparian revegetation should be concentrated on the river from Gunbarrel Road upstream to Terrace Reservoir. The dead cottonwood trees, combined with a lack of understory shrubs and saplings, results in a virtual lack of riparian corridor. Revegetation should focus on creating multistory layers of cottonwoods and willows.

Revegetation projects need to be planned and implemented in conjunction with, or after completion of, other restoration projects, such as stream restoration and grading, water flow establishment, channel restoration, cattle management, and fencing. Cottonwood trees require overbank flooding to flourish, so the reestablishment of trees along the riparian corridor is expected to be more successful after the establishment of instream flow. Any revegetation done without instream flow should be carefully planned with an understanding of the flow regime of the Alamosa River.

The target area for revegetation should be Gunbarrel Road upstream to Terrace and the areas of cottonwood decay. The revegetation could also be conducted in the area of the restoration project between County Road 10 and Gunbarrel Road. Specific activities would include:

- Planting willow bundles
- Planting cottonwood saplings
- Removing or stabilizing dead cottonwood trees
- Mulching
- Seeding native herbaceous vegetation

**Figure 3–21** shows before and after photos of native plant revegetation. The pros and cons of revegetation in the lower watershed are summarized in **Table 3-41**.

**Figure 3–21. Native Plant Revegetation, Before and After**

Source: Sound Native Plants, 2004

**Table 3-41. Pros and Cons of Revegetaton in the Lower Watershed**

| Pros | Cons |
|---|---|
| • Increases available habitat for riparian dependent species.<br>• Provides bank stability and filtering capacity. | • Cannot be implemented until other issues are addressed.<br>• Success is partially dependent on hydrological factors of watershed. |

### 3.10.3 Grazing Management

Grazing in riparian areas can have a significant impact on the overall health of the stream ecosystem. Direct impacts to vegetation include trampling around watering sites and consumption of riparian vegetation, including willows and cottonwood shoots. This can result in a decreased density and diversity of riparian plants in grazed areas. Other impacts include changes to channel morphology and function, and increased surface erosion and subsequent sedimentation in downstream channels.

A number of grazing regime options can be considered to improve deteriorated riparian areas in the lower watershed. Any ranch with active grazing in the riparian corridor would be targeted for the Grazing management project. The following options were suggested by Chaney et al. (1990):

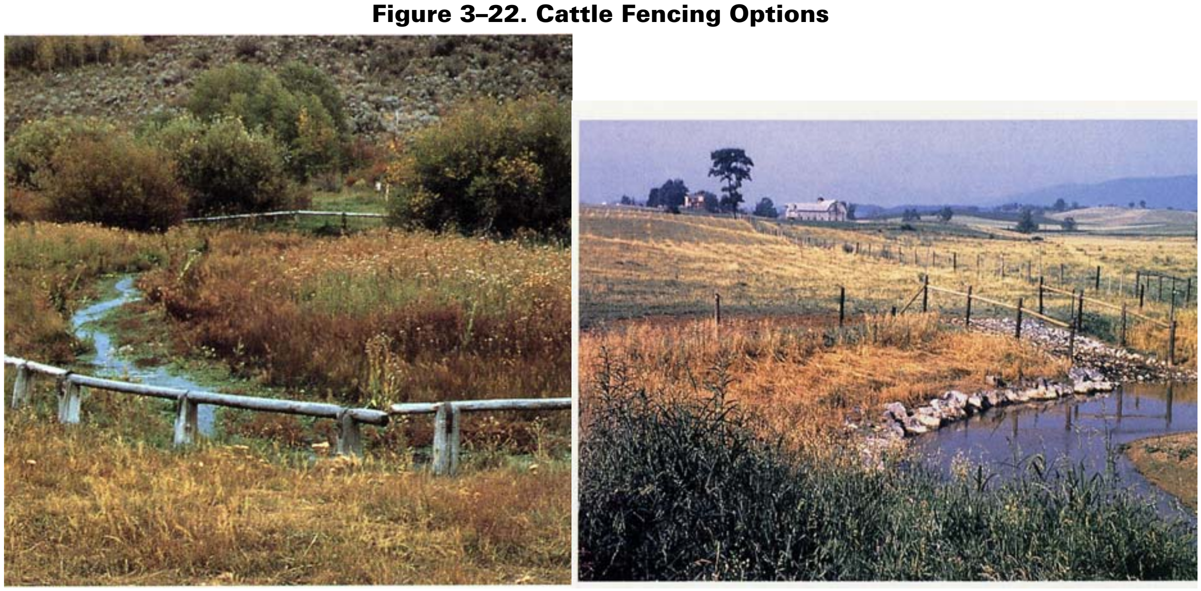
Designate pastures with riparian area as separate units with individual management objectives and strategies. Pastures with riparian area can be integrated with adjacent pastures in a rest rotation, two or three pasture deferred rotation, or a simple deferred grazing plan to provide adequate rest and protection from overuse by livestock.

Use fences or herding to keep livestock out of the riparian corridor until vegetation and streambanks recover. Water gaps can be constructed where water is required
Control the timing of grazing to keep livestock off streambanks when they are most vulnerable to damage. Graze only when riparian soils are dry.
Add more rest to the grazing cycle to increase plant vigor and permit more desirable plant species to compete effectively with undesirable species.
Permanently exclude livestock from riparian areas if the other options are not practical.

A grazing management plan for the Alamosa River watershed could be developed and distributed to ranchers. An incentive program for ranchers could be established for a variety of improvements, such as additional off channel water sources, to help create a healthier riparian zone. Grazing management would also be a requirement for participating in publicly funded stream restoration projects. The Management Plan for the Alamosa River watershed (CCSCD, 1997) includes an inventory or grazing allotments in the Rio Grande National Forest portion of the watershed. Some historical problem grazing areas are listed that may still need improvement. A similar inventory could be conducted to obtain information on current problem areas.

**Figure 3–22** shows two possible options for cattle fencing in the riparian zone. The picture on the right shows fencing with access for stock water. The pros and cons of grazing management are summarized in **Table 3-42**.

**Figure 3–22. Cattle Fencing Options**



Source: USDA et al. 1998

**Table 3-42. Pros and Cons of Grazing Management**

| Pros | Cons |
|---|---|
| • Proper grazing practices should promote a healthier riparian system.<br>• Grazing can provide brush and weed management.<br>• Can provide noxious weed control allowing for native vegetation growth.<br>• Reduces soil compaction and degradation of stream banks.<br>• Improve water quality. | • Grazing must be more intensively managed.<br>• Grazing rotation will need to occur more frequently depending on season and environmental conditions.<br>• Increased costs associated with the construction of fencing and stock tanks. |

### 3.10.4 Riparian Buffer Zone

A riparian buffer is an area located adjacent to a water body that has been set aside for conservation and maintenance to protect stream quality. Activities such as farming and development are limited in the buffer zone. The typical width of a buffer zone is 100 feet on either side of the channel with additional space in wetland areas or areas with significant streambank erosion. Buffers can be created through a combination of ordinances and acquisition of easements, or can be implemented on a voluntary basis. In the Alamosa River where development pressure is minimal, a voluntary stream buffer implemented through education and easements may be the preferred option.

The following practices and activities should be restricted in the buffer area:

- Clearing of existing vegetation
- Soil disturbance by grading, stripping, or other practices
- Filling or dumping
- Drainage by ditching, underdrains, etc.
- Construction of any buildings or related improvements
- Storage or operation of motorized vehicles, except for emergency use

A number of financial incentives for agricultural landowners to establish riparian buffers exist from government and private sector programs such as the Conservation Reserve Program discussed in **Section 5.3.2**.

**Table 3-43. Pros and Cons of Stream/Riparian Buffer**

| Pros | Cons |
|---|---|
| • Provides habitat and corridors for wildlife<br>• Provides shade to moderate water temperature.<br>• Stabilize streambank.<br>• Reduce flood risk to structures.<br>• Improved aesthetics and recreational activities. | • Lost income to landowners who cannot use land in buffer zone.<br>• Political and social obstacles to implementing buffer ordinances. |

### 3.10.5 Acquisition of Equivalent Resource in San Luis Valley

Land may be available in adjoining basins that could be purchased by a land trust or government organization for conservation purposes. This land could be used for recreation activities such as fishing and could be protected to preserve high quality wildlife habitat. Access to the land in an adjoining basin may not be as convenient to residents of the Alamosa River watershed as access to the Alamosa River itself, but regional habitat preservation and recreation benefits may be the same or greater. In particular, benefits in adjacent watersheds may be better if water quality conditions are not degraded by natural and human factors as they are in the Alamosa River. Adjoining basins that may be candidates for land acquisition are Rock Creek, La Jara Creek, Conejos River, and Trinchera Creek.

One particular opportunity is currently available and of interest to the federal Trustees. This project is the BLM acquisition of 420 acres of private lands belonging to Mack Crowther. This acreage is for sale now, and Mr. Crowther is not interested in continuing ownership nor selling an easement. The tract is in Conejos County straddling the Conejos River, in sections 11, 12, 13, and 14 of Township 35 N, Range 10 E, about 6 miles east of the town of La Jara and 12 miles south of Alamosa. It lies just west of McIntire Spring and north of Saddleback Mountain, and contains 1½ miles of riverbank. There are 20 acres of riverbank lowlands, 310 acres of seasonally flooded lowlands, and 80 acres of uplands. Sixty acres are designated habitat for the endangered southwest willow flycatcher. These lands accommodate fishing access to the Conejos River. The acreage includes an 8 cfs water right.

The Crowther tract is very close to the Alamosa River, in the adjacent watershed. Purchasing the 420 acres and 1½ miles of Conejos River frontage would safeguard new acreage and additional riverbank frontage from continuing development pressure, which threatens these natural resources and services, including wildlife habitat and valued fishing access. The land includes riparian and endangered species habitat. This riparian habitat would continue to support resident birds and wildlife, including the endangered southwest willow flycatcher and yellow–billed cuckoo. The 8 cfs water right could allow for creating and maintaining habitat features. This land purchase would preserve fishing areas and increase access on 1½ miles (both sides) of the Conejos River. This is a warm water fishery of interest to local fishermen.

The Conejos acquisition would replace interim losses of services in the Alamosa River watershed. The community has lost riparian ecological services and fishing opportunity for at least several decades. The direct Alamosa restoration efforts alone will not replace the services the public has lost over time. The Conejos River land purchase would provide immediate certainty of preserving existing high quality habitat, while the extent and level of success of the planned Alamosa riparian projects is uncertain. Safeguarding Conejos habitat and fishing opportunity might reduce the area needed for riparian habitat restoration on the Alamosa River, enabling the Trustees, stakeholders, and public to avoid conflicts between projects benefiting habitat and agricultural uses.

The project is consistent with long–term BLM plans for land acquisition and the San Luis Valley Regional Habitat Conservation Plan. The project has widespread support from state, local, and federal agencies, as well as non–governmental organizations, and has received a small amount of grant funds from the USFWS.

The pros and cons of purchasing land in an adjoining basin are described in **Table 3-44**.

**Table 3-44. Pros and Cons of Acquisition of Equivalent Resource**

| Pros | Cons |
|---|---|
| • May be an efficient use of available funds.<br>• Preserves environmental resources that are not injured.<br>• Land is available for purchase and contains documented environmental resources. | • May not be supported by watershed residents who would like to see improvement to the Alamosa River watershed. |

### 3.10.6 Purchase Land Downstream of Wightman Fork for Recreation and Habitat

If there is a willing seller of land with high quality riparian habitat between Wightman Fork and Gunbarrel Road, that land could be acquired for conservation and recreation uses. Purchasing parcels of land that are adjacent to the river but also include upland habitat can provide important connections for species that utilize both the riparian and upland zones. A number of parcels crossing the river can form a ladder configuration providing multiple locations for species to cross the stream as well as providing sediment trapping benefits and providing organic matter for the stream system. An oasis of high quality habitat can also benefit wildlife, particularly migrating birds.

**Table 3-45. Pros and Cons of Purchase Land Downstream of Wightman Fork**

| Pros | Cons |
|---|---|
| • May be an efficient use of available funds.<br>• Provides recreation and habitat improvement in the Alamosa River watershed. | • May not be any willing sellers with high quality habitat. |

## 3.11 Biological Resources

The following projects are discussed below to improve biological resources in the Alamosa River watershed:

- Fish stocking programs throughout the watershed, including Terrace Reservoir.
- Construction of fish barriers to protect native trout.
- Conservation easements

The biological resource projects emphasize aquatic organisms. There is not enough data to support the development of projects for terrestrial species. The monitoring plan proposed in **Section 3.14** could provide data that could lead to terrestrial species related projects.

### 3.11.1 Fish–Stocking Programs Throughout Watershed

Water quality and habitat improvement objectives must be met before a fish–stocking program can be implemented in the watershed. When adverse conditions for establishing a fishery have been removed, stakeholders should work with the Colorado Division of Wildlife to develop a stocking program. Care should be taken when developing this program given that native Rio Grande cutthroat trout currently inhabit several tributary streams in the watershed and any stocking of native or non–native species may have adverse impacts on their populations if proper actions are not taken.

Three potential reaches for fish–stocking identified in the watershed vision are:

- Between Wightman Fork and Terrace Reservoir
- In Terrace Reservoir
- Terrace Reservoir to Gunbarrel Road

Stakeholder comments indicate that the reach below Terrace Reservoir is a lower priority due to the uncertainty of water availability downstream of Terrace Reservoir. The pros and cons of developing fish–stocking programs are summarized in **Table 3-46**.

**Table 3-46. Pros and Cons of Developing Fish–Stocking Programs**

| Pros | Cons |
|---|---|
| • Increases recreational opportunities.<br>• Stocking could restore native fish populations and enhance ecosystem health.<br>• Could benefit local economy by providing additional recreation–related revenues. | • Not possible in all sections of the watershed due to absence of suitable flow or water quality conditions.<br>• May impact native Rio Grande cutthroat trout and other native species if not implemented properly. |

### 3.11.2 Construction of Fish Barriers to Protect Native Trout

Several populations of native Rio Grande cutthroat trout occur in tributary streams in the Alamosa River watershed. Because of possible competitive pressures or hybridization, these populations could be subject to adverse impacts if non–native fish species are stocked in the Alamosa River or in Terrace Reservoir. Additionally, improvements in water quality could allow non–native trout species that are currently in the headwaters of the watershed to move into areas that are currently not habitable, thus creating additional competitive or hybridization concerns to the native cutthroat populations. Where natural barriers, such as waterfalls, do not occur to protect the native trout, fish barriers could be created to protect current and future populations of Rio Grande cutthroat and other native species.

Fish barriers would be most effective on reaches and tributaries with steeper gradients and bedrock or boulder bed material. Physical barriers can be installed in shallow streams less than 30 feet wide. Electronic barriers can be installed in deeper channels to discourage passage. Electronic barriers could use lights, electrical pulses, or sound frequencies to discourage fish from entering the area.

**Figure 3–23** shows a photograph of a physical fish barrier in another watershed. Electronic barriers can also be used in certain circumstances. The pros and cons of constructing fish barriers are summarized in **Table 3-47**.

**Figure 3–23. Fish Barrier**

Source: California Department of Water Resources, 2004

**Table 3-47. Pros and Cons of Building Fish Barriers**

| Pros | Cons |
|---|---|
| • Protects sensitive Rio Grande cutthroat and other native fishes.<br>• Protects reaches of rivers and streams that can be used to restore native aquatic and riparian communities.<br>• Could improve recreational experience for fishermen.<br>• Could enhance sediment retention. | • May not be favorable to all fisherman.<br>• Some cost of construction and maintenance.<br>• Accessibility to certain construction areas could add cost.<br>• Permitting necessary on public land. |

### 3.11.3 Conservation Easements

Conservation easements may be negotiated with willing landowners in the Alamosa River watershed as a tool to protect and enhance the existing quality habitat and areas that are improved through restoration projects such as those in the riparian corridor. Conservation easements are legal agreements between a landowner and a public body or conservation group, in which the parties agree to protect certain natural resource values of the land. Riparian easements are a particular type of conservation easement that applies only to riparian areas, and are dedicated for the purpose of protecting streamside habitats, floodplains, and water quality.

Conservation easements are recorded in the local courthouse, and run with the land as the land is passed to heirs or sold. Each easement is tailored to reflect the conservation values of the property, the individual goals of the landowner, and the goals of the holder of the easement. It is a legal agreement in which the landowner retains ownership and control, but conveys certain specified rights, which are negotiable, to the holder of the easement. The public does not necessarily gain access to the property. The easement holder works with the landowner to develop a management plan to ensure the protection of the riparian zone. Usually this includes maintaining woody vegetation and limiting livestock access and buildings. Several conservation organizations, government agencies, and land trusts will hold conservation easements. The financial costs of entering a piece of property into conservation easement include an appraisal, baseline inventory, stewardship donation to a land trust or entity holding the easement, and legal representation. These costs could be provided by master plan funding.

Willing landowners would need to be identified throughout the lower watershed. The entire lower watershed could benefit from this project and should be included. A land trust such as Trust for Public Land or another agency belonging to the Colorado Coalition of Land Trusts could be involved to assist in conservation easement development.

The pros and cons of establishing conservation easements along the watershed are summarized in **Table 3-48**.

**Table 3-48. Pros and Cons of Establishing Conservation Easements**

| Pros | Cons |
|---|---|
| • Financial benefits for landowners.<br>• Held in perpetuity.<br>• Provides riparian protection. | • Held in perpetuity.<br>• Limits activities for the landowner in the easement area.<br>• Does not provide for public access without a separate access easement. |

## 3.12 Lost Agricultural Uses

Many potential projects that are presented in other sections can benefit agriculture in the Alamosa River watershed. Improvement of water quality will benefit agricultural use of this water. Stream restoration, reduction of channel erosion, reduced sediment loads, and improvement of diversion structures will improve the ability of irrigators to divert water from the Alamosa River. Improvements to Terrace Reservoir will benefit agriculture in the area served by the Terrace Main Canal and could help prevent sediment releases from the reservoir which can potentially impact other water users. Improved ground water levels can help channel conveyance efficiencies, agricultural use, and agricultural wells. Therefore, although these projects are not presented in this section, the benefits of these multi–disciplinary projects for agriculture in the watershed should be recognized. Two potential multi–disciplinary projects are presented here; consolidation of ditch diversion structures and replacement of ditch headgates made of corrosion resistant materials.

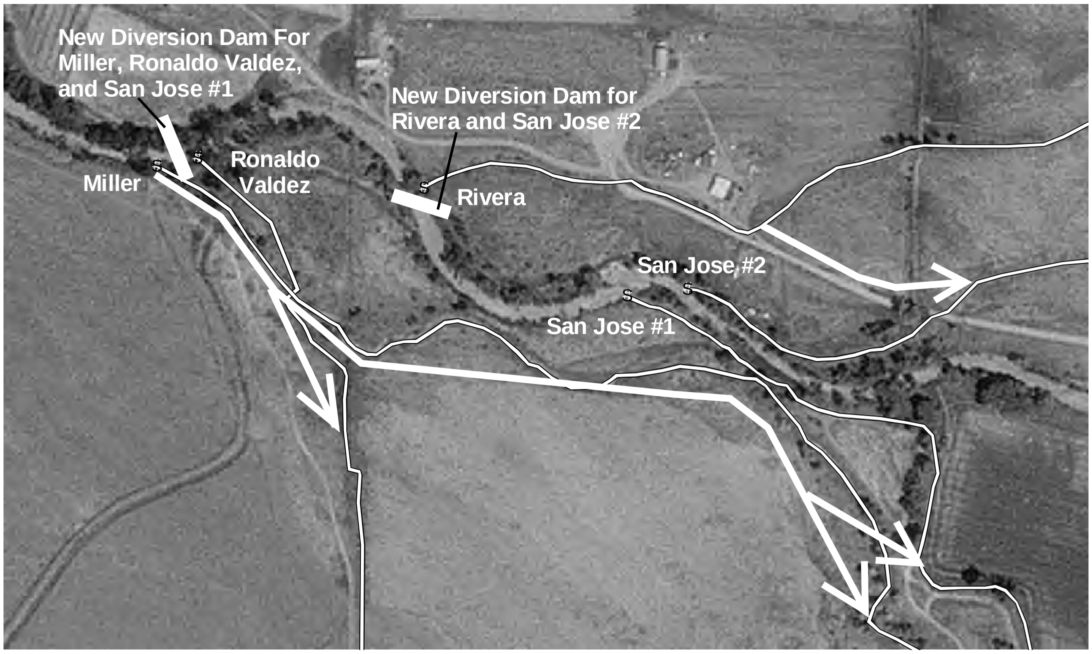
### 3.12.1 Ditch Headgate Consolidation

Many diversion structures on the Alamosa River have been impacted by deteriorated river channel conditions. Downcutting of the channel bed, erosion, sedimentation, and lateral instability have impacted the ability to divert. In turn, ditch diversion structures impact natural river function and migration by creating hardpoints that must be maintained and by abruptly changing sediment carrying capacity. Many diversion dams and headgates are currently in poor condition and need repair or replacement. Therefore, an opportunity exists to consolidate several groups of ditches on the Alamosa River. This would reduce the number of hardpoints that must be maintained, reduce the number of diversion dams that must be maintained, and allow a more naturally functioning river in some areas.

**Figure 3–24** shows a group of ditches that could be consolidated to the northeast of Capulin. Currently, the San Jose #1 and San Jose #2 diversion structures are in poor condition and diversion is difficult into these two ditches. Both ditches could be consolidated with upstream ditches. To the south of the Alamosa River, the Miller, Ronaldo Valdez, and San Jose #1 ditches could be consolidated at one common diversion structure near the current location of the Miller Ditch headgate. To the north of the river, an improved diversion structure at the Rivera Ditch could also be used to feed water to the San Jose #2 ditch. The figure also indicates locations where individual ditch flows could be directed to their respective ditches from a consolidated ditch.

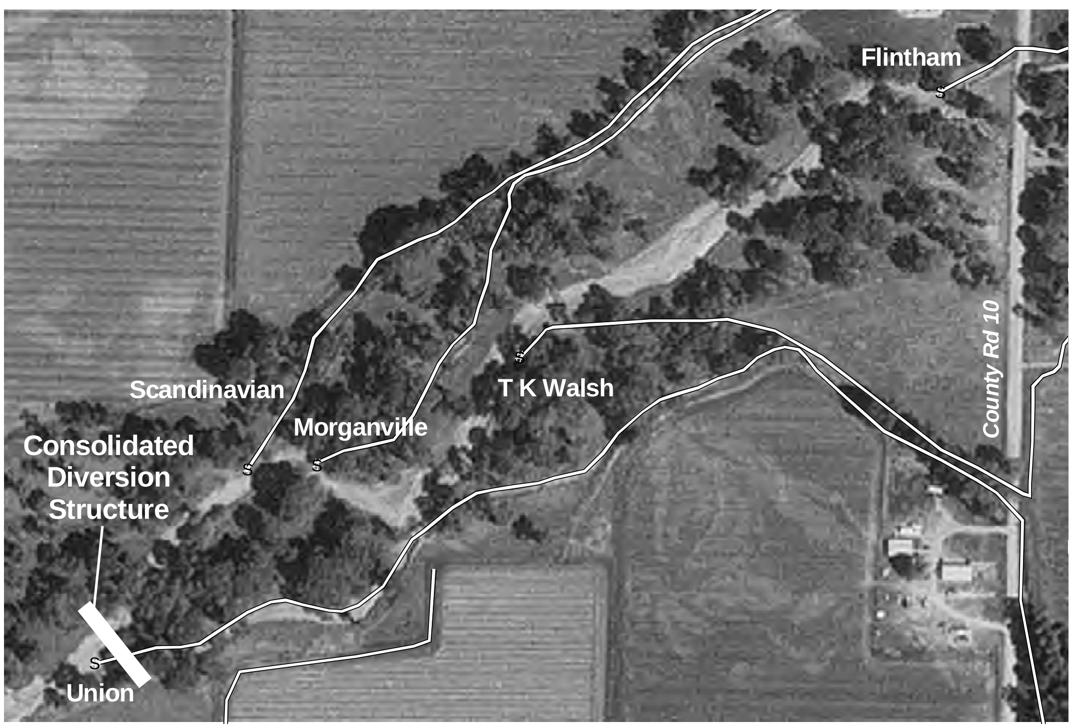
The Union, Scandinavian, Morganville, TK Walsh, and Flintham ditches near County Road 10 could potentially be consolidated to use only one diversion structure at the current location of the Union Ditch headgate. **Figure 3–25** shows the location of these ditches. The river in this stretch is in poor condition, and removal of diversion structure constraints could help restore natural stream function.

**Figure 3–24. Potential Consolidation of Miller, R. Valdez, Rivera, San Jose #1 and #2 Ditches**




Note: Current structures shown white with black, potential consolidated structures show as bold white

**Figure 3–25. Consolidation of Union, Scand., Morganville, TK Walsh and Flintham Ditches**




Note: Current structures shown white with black, potential consolidated structure show as bold white

Ditch companies and owners are often resistant to ditch consolidation. Ditch users may feel that they have less control of a consolidated ditch structure. However, consolidated diversion structures could probably provide more efficient diversion, less maintenance, and reduced costs for individual ditch users. **Table 3-49** presents potential pros and cons of ditch consolidation.

**Table 3-49. Pros and Cons of Ditch Consolidation**

| Pros | Cons |
|---|---|
| • Reduction of hard points on river.<br>• Reduced maintenance costs for individual water users.<br>• Improved water diversion. | • Resistance by ditch companies and water users. |

### 3.12.2 Replacement of Ditch Headgates with Corrosion Resistant Materials

Very low pH water in the Alamosa River following open pit mining at Summitville may have significantly impacted many headgates built of steel. Water quality has been improving downstream of Terrace Reservoir following remediation activities at Summitville. However, several irrigators have reported continued corrosion of some headgates and other irrigation infrastructure. Corroded headgates could potentially be replaced with materials that are more resistant to corrosion or treated to resist corrosion. Concrete can be used to form the wing walls and structure of a headgate. However, the gate itself typically has to be constructed of other materials. Gates can be built of wood. However, wooden gates require periodic maintenance, and metal fasteners such as bolts and screws may corrode. Steel can be treated with epoxy or other corrosion resistant coatings. Joe McCann, the water commissioner for Division 21, noted that coal tar epoxy has been successfully used in several locations and appears to adequately resist corrosion (Joe McCann, oral commun. 2004). The NRCS could potentially assist in replacement or improvement of headgate structures. Other water quality projects could potentially continue improvements to pH levels downstream of Terrace Reservoir and decrease corrosion problems associated with Alamosa River water.

**Table 3-50. Pros and Cons of Replacing Ditch Headgates with Corrosion Resistant Materials**

| Pros | Cons |
|---|---|
| • Could be combined with headgate consolidation.<br>• Increased efficiency for water diversion.<br>• Reduced future maintenance costs.<br>• NRCS may be able to provide financial or technical assistance. | • Expense to irrigators.<br>• Water quality has improved considerably, and continued corrosion may not be a significant problem. |

## 3.13 Lost Recreational Uses

The following projects are proposed to restore recreational uses to the Alamosa River watershed:

Improve public access to Terrace Reservoir.
Improve public access to the main stem of the river in the upper watershed.
Public relations campaign to increase recreational use of the watershed (discussed in **Section 3.14**)

### 3.13.1 Improve Public Access to Terrace Reservoir

Improving public access into Terrace Reservoir should increase recreational utilization of the Reservoir. Improving access will require coordination and agreements with the Terrace Reservoir Irrigation Company. Improvements can include improved and increased parking on FR 250, the establishment of a maintained trail from parking area to the surface water of Terrace Reservoir, a trail around the reservoir for fishermen and hikers, small boat access to the reservoir, picnicking facilities, and lavatory facilities. The pros and cons of improving public access to Terrace Reservoir are presented in **Table 3-51**.

**Table 3-51. Pros and Cons of Improving Public Access to Terrace Reservoir**

| Pros | Cons |
|---|---|
| • Increases potential recreation utilization of Reservoir.<br>• Fee stations could cover maintenance costs of established facilities and provide funding for other access improvements.<br>• Increase recreational utilization of Reservoir will help local businesses that rely on fisherman and tourists. | • Requires use–agreement with Reservoir owners.<br>• Increased liability and safety concerns for Reservoir owners and operators.<br>• Established facilities will require maintenance.<br>• Periodic drawdowns for reservoir maintenance will deter utilization during those periods.<br>• Potential traffic congestion near parking area. |

### 3.13.2 Accessing Main Stem of River Across Private Lands

From Terrace Reservoir through the Jasper community, much of the Alamosa River is encompassed by private land. This private ownership limits fishing opportunities in the area. Once a fishery is restored in the upper watershed, the demand for recreation access to the river likely will increase dramatically. To facilitate fishing access along the entire main stem of the Alamosa River, riparian easements or public use agreements could be negotiated with landowners. Access points from the road to the river would need to be established. To explore the opportunity to implement this project, initial contact should be made with landowners through written correspondence or telephone. Response from this initial contact would guide the expansion of public access opportunities to the river.

If an instream flow is created in the lower watershed, public access to the Alamosa River should also be provided. Public access in the lower watershed should focus on allowing fishing or other recreational uses of the river.

The pros and cons of improving access to the main stem of the river across private lands are presented in **Table 3-52**.

**Table 3-52. Pros and Cons of Improved Access to Main Stem of the River Across Private Lands**

| Pros | Cons |
|---|---|
| • Increase accessibility of main river for fisherman. | • Private landowners may not allow the crossing of their property by the public.<br>• Would require riparian easements or use agreements.<br>• Costs of implementing accessibility agreements may outweigh benefits.<br>• Parked vehicles along forest roads may cause a hazard for thru traffic.<br>• May cause conflicts with local owners and community associations. |

## 3.14 Studies and Administrative Activities

There were several studies and administrative activities suggested as projects that would either improve conditions in the watershed or provide information in critical areas. Each project is described below.

### 3.14.1 Funding for Citizen Group to Help Implement and Monitor the Master Plan

Several citizens groups have formed to promote the health of the watershed and represent the interests of its residents. However, these groups are volunteer organizations. It is recommended that a citizen group be provided with funding for a part–time staff person or persons to assist the Trustee Council in perform the following tasks:

- Act as watershed coordinator to facilitate community meetings.
- Assist in restoration project monitoring activities. Coordinate professionals and volunteers for restoration project monitoring as described in **Section 5.5**.
- Act as a restoration project sponsor/manager to submit proposals to Trustee Council for NRD funding.
- Assist in the implementation of restoration projects listed in the Master Plan but not receiving NRD funding.
- Seek additional funding from other sources for restoration projects to increase the funding available for watershed efforts well beyond the NRD funding.
- Seek additional funds for operating the citizen group to increase the scope and scale of activities they are able to perform.
- Work with the Colorado Tourism Office and other agencies and non–profit groups to promote tourism and recreation in the Alamosa River watershed.
- Conduct a public relations campaign to publicize watershed improvement projects, increased recreational opportunities in the watershed, and success stories.
- Communicate potential work opportunities to local businesses by publicizing requests for proposals (RFPs), contracting, and project management opportunities. Using local project managers and contractors may help maximize cost savings and increase local ownership of the watershed restoration effort.
- Strive to manage and complete projects in the most cost–effective way in order to maximize the goals that can be achieved with available funding.

The most likely citizen group to perform this function is the Alamosa River Foundation, which has been involved with the Master Plan from the beginning. The pros and cons of a funding a citizen group are described in **Table 3-53**.

**Table 3-53. Pros and Cons of Funding for Citizen Group to Help Implement and Monitor the Master Plan**

| Pros | Cons |
|---|---|
| • Increased volunteer involvement and community awareness.<br>• Increased success in project implementation.<br>• Increased tourism and recreation in the watershed. | • Funding for this task will not directly support restoration |

### 3.14.2 Site Specific Probable Maximum Flood (PMF) Study

The potential may exist to reduce the PMF by conducting a site–specific PMF study for the basin. Site specific PMF studies are frequently successful in reducing the amount of flow that structures are required to pass. A lower design flood event will reduce the cost to improve the spillway and remove part or all of the State Engineer's restriction on the reservoir.

**Table 3-54. Pros and Cons of Condcuting a Site Specific PMF Study**

| Pros | Cons |
|---|---|
| • Could reduce filling restriction in Terrace Reservoir without any structural changes.<br>• Likely to reduce cost of spillway improvements.<br>• Low project cost. | • Small chance that PMF could increase and filling restriction would be made more severe. |

### 3.14.3 Ice Jam Flooding Study

The Cold Regions Research and Experiment Lab (CRREL) of the Army Corps of Engineers in Hanover, New Hampshire could be contracted to research problems that may occur if instream flows are established in the winter.

**Table 3-55. Pros and Cons of Ice Jam Flooding Study**

| Pros | Cons |
|---|---|
| • Would provide additional information on flood hazard from ice. | • Is only needed if an instream flow is established. |

### 3.14.4 Capulin Flood Hazard Mitigation Plan

A flood hazard mitigation plan for Capulin would do the following:

- Inventory the number of flood prone structures
- Estimate the potential damage for 10–year and 100–year flows
- Develop structural and non–structural options such as levees, flood proofing, relocation, no actio
- Cost/benefit analysis
- Select preferred option

**Table 3-56. Pros and Cons of Capulin Flood Hazard Mitigation Plan**

| Pros | Cons |
|---|---|
| • Suggests most economical method of flood control. | • The plan would not provide flood control until recommended options are implemented. |

### 3.14.5 Dewatering Management Plan for Terrace Reservoir

The upper Alamosa River watershed naturally produces a high volume of sediment. A large portion of this sediment load is deposited in Terrace Reservoir. During periodic draining of Terrace Reservoir to repair gates, etc., large amounts of sediments are flushed downstream. These sediment releases have had significant downstream impacts. A management plan could be developed to control sediment releases during future draining and maintenance of Terrace Reservoir. This management plan must be developed in coordination with the Terrace Irrigation Company. A dewatering management plan would be a document detailing steps to be taken to dewater Terrace Reservoir in the future. The plan could include monitoring of downstream water quality during draining and steps to follow if water quality problems occur.

When Terrace Reservoir is drained, coffer dams could be temporarily installed in the canyon below the dam as long as they avoided the USGS gage located in the canyon. **Figure 3–26** shows locations for two potential coffer dams. The use of two coffer dams would provide additional removal and protection for sediments. The potential dam locations are on private land, which should make placement easier than if dams were placed on public lands. Access is constrained in the area below the dam. However, equipment could enter the area using the rough road leading to the USGS gage. Two outlets should be incorporated into the coffer dams. One outlet could have a riser pipe to allow filling of the coffer dam and release of water from the top of the basin to maximize sedimentation. A bottom outlet could then aid in dewatering the basin after repairs are completed and the reservoir gates are shut. After the reservoir gates are shut, and sediments in the basins are dewatered for some time, sediments and the coffer dams could be removed using heavy equipment. A fund could be established to help pay for future construction and removal of coffer dams and sediment.

**Figure 3–26. Potential Locations of Coffer Dams Below Terrace Reservoir**

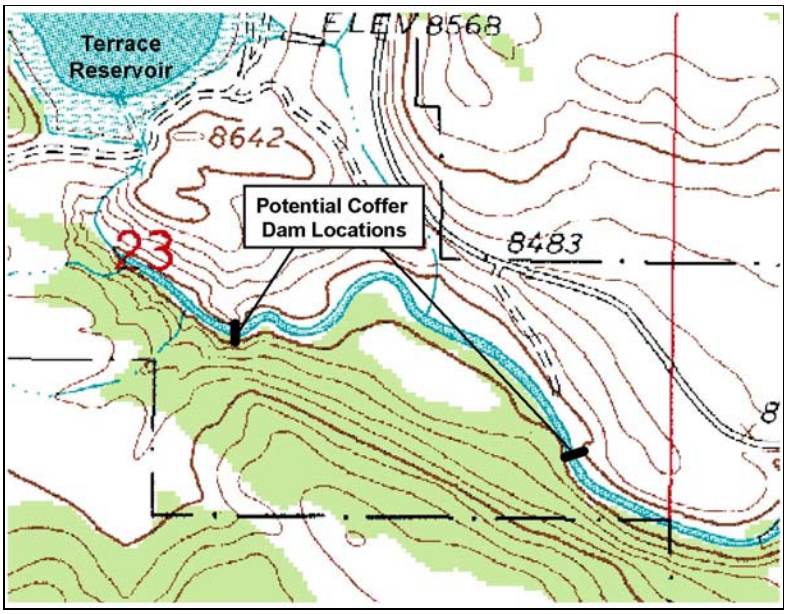



**Table 3-57** discusses the pros and cons of creating a dewatering management plan for Terrace Reservoir.

**Table 3-57. Pros and Cons of a Dewatering Management Plan for Terrace Reservoir**

| Pros | Cons |
|---|---|
| • Reduced risk of future scouring and sediment migration downstream of Terrace Reservoir.<br>• Will eliminate need to obtain emergency funding to cleanup sediments released downstream | • Sediments collected must be deposited somewhere. |

### 3.14.6 Terrace Reservoir Sediment Quality Study

Sediment from the upper watershed has deposited in Terrace Reservoir since its construction in 1912. Ninety years of sediment accumulation has reduced the storage capacity of the reservoir. One potential project described in **Section 3.7** involves removing the sediment from the reservoir to increase storage capacity. Prior to removing the sediment, a sampling study is needed to determine the quality of the material that is likely to be resuspended and transported downstream. Twelve Terrace Reservoir sediment quality samples were collected and analyzed by Rocky Mountain Consultants in 2000. Additional samples should be collected and analyzed in the upstream portion of the reservoir where sediment is likely to be excavated. These additional samples will better define the sediment quality in this area. It is important to determine the sediment quality to develop a plan that properly disposes of the removed material. The pros and cons of a Terrace Reservoir sediment study are summarized in **Table 3-13**.

**Table 3-58. Pros and Cons of Terrace Reservoir Sediment Study**

| Pros | Cons |
|---|---|
| • The sediment analysis will facilitate proper removal of the material. | • May be costly to adequately characterize the sediment.<br>• May be difficult to find a disposal site for the excavated material. |

### 3.14.7 Ground Water Monitoring Plan

A minimal monitoring program could consist of the placement of paired piezometers near existing gaging stations to analyze surface and ground water interactions. In addition, a number of ground water monitoring wells with continuous monitoring devices should be constructed within the study area to gain a better understanding of the current status of ground water as well as to detect any future changes. Test wells addressing aquifer properties could then be instituted to provide critical aquifer parameters for future analytical studies. The ground water study will also be of assistance if a ground water recharge project using flood flows is proposed in the future. The data gathered would also be useful for future plans to manage and stabilize ground water levels.

**Table 3-59. Pros and Cons of Ground Water Study.**

| Pros | Cons |
|---|---|
| • The study would allow interested parties to make informed decisions concerning Alamosa River water.<br>• Will assist local residents by providing valuable information necessary to manage this resource.<br>• Will provide baseline information needed to determine the feasibility of ground water recharge projects.<br>• Can be expanded to address future needs. | • May be costly to adequately determine characteristics of the confined aquifer if implemented all at once.<br>• May initiate additional ground water regulation.<br>• Will require a number of years of data collection before adequate conclusions can be drawn. |

## 3.15 Scoring and Ranking of Projects

**Table 3–60** shows the ranking of the top projects from each of the resource categories described above according to the criteria listed in **Section 3.3**.

## Table 3-60. Weighted Project Scores

| # | | Likelihood of success if implemented | Technically feasible to implement | Protection of implemented project | Public Acceptance | Addresses Issues Critical to Public | Public Benefits | Public health and safety | Adverse impacts | Environmental Permitting / Water Rights | Benefits in multiple resource categories | Time to provide at least 50% of expected benefits | Duration of benefits | Benefit/Cost | Addresses Water Quality, Riparian and Aquatic Habitat Issues | Total | Rank | Page Number of complete description | Estimated Project Life Cycle Cost (50 years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight** | | **2** | **1** | **1** | **3** | **3** | **3** | **1** | **1** | **1** | **2** | **1** | **1** | **1** | **2** | | | | |
| **RIVER CHANNEL/CORRIDOR PROJECTS** | | | | | | | | | | | | | | | | | | | |
| 1 | Stream restoration Terrace Reservoir to Wightman Fork | 4 | 5 | 4 | 3.4 | 3.4 | 3.4 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 3 | **84** | **4** | 3-12 | $1.2M |
| 2 | Stream restoration Gomez Bridge to Gunbarrel Road | 4 | 5 | 3 | 3.6 | 3.6 | 3.6 | 3 | 4 | 3 | 3 | 4 | 4 | 3 | 3 | **81** | **7** | 3-12 | $800k |
| 3 | Funding to complete project between Gunbarrel Road and County Road 10 | 4 | 5 | 3 | 4.2 | 4.2 | 4 | 3 | 4 | 4 | 3 | 5 | 4 | 4 | 3 | **89** | **1** | 3-13 | $120k |
| 4 | Stream restoration County Rd 10 to County Rd 13 | 3 | 3 | 3 | 4.2 | 3.8 | 4 | 3 | 4 | 3 | 3 | 4 | 2 | 2 | 3 | **78** | **10** | 3-13 | $400k |
| 5 | Dead Tree Management Upstream of Terrace Res. | 4 | 5 | 4 | 3 | 2.8 | 2.6 | 5 | 4 | 4 | 2 | 5 | 3 | 4 | 2 | **75** | 14 | 3-14 | $50k |
| 6 | Dead Tree Management Downstream of Terrace Res. | 4 | 5 | 3 | 3.6 | 2.4 | 2.6 | 5 | 4 | 4 | 2 | 5 | 3 | 4 | 2 | **75** | 15 | 3-14 | $50k |
| 7 | Modify land use regulations for flood control | 2 | 5 | 5 | 1.8 | 2 | 2 | 4 | 5 | 5 | 1 | 5 | 5 | 5 | 1 | **64** | 32 | 3-15 | $10k |
| 8 | Setback levees at Capulin for flood control | 3 | 4 | 4 | 1.4 | 1.4 | 1.6 | 5 | 2 | 2 | 1 | 4 | 5 | 3 | 1 | **52** | 42 | 3-15 | $1M |
| **WATER QUANTITY PROJECTS** | | | | | | | | | | | | | | | | | | | |
| 9 | Purchase appropriate water rights for instream flow | 3 | 4 | 5 | 3.2 | 3.4 | 3.4 | 3 | 4 | 3 | 5 | 4 | 5 | 4 | 5 | **88** | **2** | 3-17 | $1–4M |
| 10 | Controlled Releases from Terrace Reservoir with Supplemental Water Source | 2 | 2 | 4 | 2.2 | 2.2 | 2.8 | 3 | 5 | 3 | 5 | 4 | 5 | 3 | 5 | **75** | 16 | 3-19 | $200k |
| 11 | Aquifer storage for instream flow | 2 | 2 | 4 | 2.2 | 2.2 | 2.4 | 3 | 3 | 3 | 5 | 3 | 5 | 2 | 5 | **69** | 23 | 3-23 | $2M |
| 12 | Trade of direct flow diversion right for reservoir storage (no new water source) | 4 | 4 | 4 | 2.6 | 2.6 | 2.8 | 3 | 4 | 3 | 5 | 4 | 5 | 5 | 5 | **84** | **3** | 3-19 | $100k |
| 13 | New reservoir to store instream flow | 5 | 4 | 5 | 2.2 | 1.8 | 2 | 3 | 1 | 1 | 5 | 2 | 5 | 1 | 5 | **70** | 22 | 3-21 | $10M |
| 14 | New reservoir to store existing agriculture water rights | 5 | 4 | 5 | 2.2 | 2 | 2.2 | 3 | 1 | 1 | 5 | 2 | 5 | 1 | 2 | **65** | 29 | 3-21 | $10M |
| **TERRACE RESERVOIR PROJECTS** | | | | | | | | | | | | | | | | | | | |
| 15 | Increase spillway capacity | 4 | 5 | 4 | 3.4 | 3.6 | 3.6 | 4 | 4 | 3 | 3 | 3 | 5 | 4 | 2 | **82** | **6** | 3-26 | $1.5M |
| 16 | Raise crest of dam | 4 | 3 | 4 | 2.6 | 2.6 | 2.8 | 4 | 4 | 3 | 3 | 3 | 5 | 3 | 2 | **71** | 20 | 3-29 | $3M |
| 17 | Sediment removal to increase capacity | 3 | 4 | 3 | 1.6 | 2.2 | 2.2 | 3 | 2 | 2 | 3 | 4 | 3 | 2 | 2 | **57** | 35 | 3-30 | $2M |
| 18 | Improve outlet works (tower) | 4 | 4 | 4 | 2.6 | 2.6 | 2.6 | 3 | 4 | 3 | 3 | 4 | 5 | 2 | 3 | **72** | 19 | 3-31 | $3M |
| 19 | Power generation at Terrace Reservoir | 2 | 4 | 3 | 2.2 | 1.8 | 2 | 3 | 3 | 2 | 1 | 3 | 5 | 3 | 1 | **52** | 43 | 3-32 | $7M |
| **SEDIMENT MANAGEMENT PROJECTS** | | | | | | | | | | | | | | | | | | | |
| 20 | Lower watershed sediment deposition locations | 4 | 4 | 3 | 2.2 | 2.6 | 2.4 | 3 | 4 | 3 | 3 | 4 | 2 | 4 | 3 | **69** | 26 | 3-33 | $200k |
| 21 | Road management in upper watershed | 2 | 3 | 3 | 1.6 | 1.6 | 2 | 3 | 4 | 4 | 3 | 4 | 3 | 2 | 2 | **56** | 38 | 3-33 | $50k |
| 22 | Sediment traps at tributary confluences | 2 | 4 | 3 | 3.2 | 3.6 | 3.4 | 4 | 4 | 3 | 5 | 4 | 2 | 3 | 3 | **78** | 12 | 3-34 | $2M |
| **WATER QUALITY PROJECTS** | | | | | | | | | | | | | | | | | | | |
| 23 | Reclamation of abandoned mines | 4 | 4 | 3 | 1.8 | 2.2 | 2.2 | 5 | 4 | 3 | 4 | 4 | 5 | 2 | 4 | **73** | 18 | 3-39 | $325k – $1.5M |
| 24 | Mainstem lake or reservoir below Wightman Fork | 3 | 4 | 5 | 2 | 2 | 2 | 5 | 2 | 1 | 4 | 2 | 5 | 3 | 5 | **69** | 24 | 3-46 | $3–15M |
| 25 | Sulfate reducing wetland on Wightman Fork or other tributaries | 3 | 3 | 4 | 1.6 | 2 | 2.2 | 5 | 2 | 3 | 4 | 3 | 3 | 3 | 4 | **65** | 28 | 3-43 | $2M |
| 26 | Active water quality improvement on tributaries upstream of Wightman Fork | 3 | 3 | 5 | 1.8 | 2 | 2 | 5 | 4 | 3 | 4 | 3 | 3 | 3 | 4 | **68** | 27 | 3-45 | $1–4M |

## Table 3-60. Weighted Project Scores

| # | | Likelihood of success if implemented | Technically feasible to implement | Protection of implemented project | Public Acceptance | Addresses Issues Critical to Public | Public Benefits | Public health and safety | Adverse impacts | Environmental Permitting / Water Rights | Benefits in multiple resource categories | Time to provide at least 50% of expected benefits | Duration of benefits | Benefit/Cost | Addresses Water Quality, Riparian and Aquatic Habitat Issues | Total | Rank | Page Number of complete description | Estimated Project Life Cycle Cost (50 years) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight** | | **2** | **1** | **1** | **3** | **3** | **3** | **1** | **1** | **1** | **2** | **1** | **1** | **1** | **2** | | | | |
| **RIPARIAN HABITAT PROJECTS** | | | | | | | | | | | | | | | | | | | |
| 27 | Noxious weed management in the upper watershed | 3 | 4 | 3 | 2.8 | 3.6 | 3.6 | 3 | 5 | 5 | 2 | 5 | 3 | 2 | 2 | **74** | 17 | 3-53 | 250k |
| 28 | Noxious weed management in the lower watershed | 3 | 4 | 2 | 3.8 | 4 | 4 | 3 | 5 | 5 | 3 | 5 | 3 | 2 | 2 | **80** | **8** | 3-54 | 250k |
| 29 | Revegetation in the lower watershed | 4 | 4 | 3 | 3 | 3 | 2.8 | 3 | 5 | 5 | 4 | 3 | 5 | 5 | 4 | **83** | **5** | 3-54 | $300k |
| 30 | Grazing management | 4 | 5 | 2 | 3.2 | 2.6 | 3 | 3 | 5 | 5 | 4 | 3 | 5 | 4 | 3 | **80** | **8** | 3-55 | $200k |
| 31 | Riparian buffer zone | 4 | 5 | 2 | 2.6 | 2.8 | 2.6 | 3 | 5 | 5 | 4 | 3 | 5 | 4 | 3 | **78** | **10** | 3-57 | $200k |
| 32 | Acquisition of equivalent resource in San Luis Valley for high quality habitat and recreation | 5 | 5 | 5 | 1.2 | 1 | 1 | 3 | 5 | 5 | 3 | 5 | 5 | 4 | 1 | **65** | 31 | 3-57 | $800k |
| 33 | Purchase land downstream of Wightman Fork for recreation and habitat | 5 | 3 | 5 | 1.2 | 1.2 | 1.2 | 3 | 5 | 5 | 3 | 5 | 5 | 3 | 4 | **69** | 25 | 3-58 | $1–3M |
| **BIO RESOURCES PROJECTS** | | | | | | | | | | | | | | | | | | | |
| 34 | Fish–stocking above Terrace Reservoir | 2 | 5 | 3 | 1.8 | 1.4 | 1.4 | 3 | 4 | 5 | 2 | 4 | 2 | 4 | 1 | **54** | 41 | 3-59 | $50k |
| 35 | Fish–stocking at Terrace Reservoir | 3 | 5 | 3 | 2.4 | 1.8 | 1.6 | 3 | 4 | 5 | 2 | 4 | 2 | 4 | 1 | **59** | 33 | 3-59 | $50k |
| 36 | Fish–stocking below Terrace Reservoir | 2 | 5 | 3 | 2.2 | 2 | 2 | 3 | 4 | 5 | 2 | 4 | 2 | 2 | 1 | **57** | 36 | 3-59 | $50k |
| 37 | Construction of fish barriers | 4 | 5 | 3 | 1.4 | 1 | 1 | 3 | 4 | 3 | 1 | 4 | 4 | 3 | 3 | **55** | 40 | 3-60 | $200k |
| 38 | Establishing conservation easements | 5 | 4 | 5 | 1.8 | 1.6 | 1.6 | 3 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | **76** | 13 | 3-61 | up to $1k/acre |
| **AGRICULTURAL PROJECTS** | | | | | | | | | | | | | | | | | | | |
| 39 | Ditch headgate consolidation | 3 | 4 | 2 | 2.2 | 2.4 | 2.4 | 3 | 4 | 3 | 3 | 4 | 5 | 3 | 2 | **65** | 30 | 3-62 | $200k |
| 40 | Replace headgates with corrosion resistant materials | 4 | 5 | 2 | 3 | 3.4 | 3.4 | 3 | 5 | 5 | 1 | 4 | 3 | 2 | 1 | **70** | 21 | 3-64 | $300k |
| **RECREATION PROJECTS** | | | | | | | | | | | | | | | | | | | |
| 41 | Improve public access to Terrace Reservoir | 3 | 5 | 4 | 1.8 | 1.4 | 1.4 | 3 | 5 | 5 | 1 | 4 | 5 | 4 | 1 | **59** | 34 | 3-64 | $100–200k |
| 42 | Improved access to main stem of the river above Terrace | 4 | 4 | 4 | 1.4 | 1.4 | 1.4 | 3 | 4 | 5 | 1 | 4 | 5 | 3 | 1 | **57** | 37 | 3-65 | $500k |
| 43 | Improved access to main stem of the river below Terrace | 4 | 3 | 4 | 1.4 | 1.4 | 1.4 | 3 | 4 | 5 | 1 | 4 | 5 | 3 | 1 | **56** | 39 | 3-65 | $500k |
| **STUDIES AND ADMINISTRATIVE ACTIVITIES** | | | | | | | | | | | | | | | | | | | |
| 44 | Funding for citizen group to help implement and monitor the Master Plan | 4 | 5 | | | | | 3 | 5 | | | | | 5 | 5 | **36** | **1** | 3-66 | $300k |
| 45 | Site specific PMF study | 3 | 5 | | | | | 3 | 5 | | | | | 4 | 1 | **25** | 4 | 3-67 | $20k |
| 46 | Ice Jam Flooding Study | 3 | 3 | | | | | 4 | 5 | | | | | 2 | 1 | **22** | 7 | 3-67 | $25k |
| 47 | Capulin Flood Hazard Mitigation Plan | 3 | 5 | | | | | 5 | 5 | | | | | 3 | 1 | **26** | **2** | 3-67 | $50k |
| 48 | Dewatering Management Plan | 3 | 3 | | | | | 3 | 5 | | | | | 4 | 2 | **25** | 4 | 3-67 | $25k |
| 49 | Terrace Reservoir sediment quality study | 3 | 4 | | | | | 4 | 5 | | | | | 3 | 2 | **26** | **2** | 3-69 | $75k |
| 50 | Ground water monitoring | 3 | 5 | | | | | 3 | 5 | | | | | 3 | 1 | **24** | 6 | 3-69 | $150k |

Although projects are scored independently, it is important to note that many of the projects should not be implemented alone. For instance, the acquisition of a water right for instream flow is not very useful without a means of storing the flow for controlled releases. Also, projects to improve riparian habitat in the lower watershed should not be implemented without an instream flow because riparian habitat will not flourish without water. **Table 3-61** shows those projects with prerequisites or those that could be logically combined with other projects. Combining projects would maximize the benefits of the individual projects and could reduce the total cost of the projects by using the same equipment and planning resources concurrently.

**Table 3-61. Project Prerequisites and Logical Combinations**

| # | Project Description | Prerequisite or Logical Project Combination |
|---|---|---|
| 1 | Stream restoration Terrace Reservoir to Wightman Fork | Combine with dead tree mgmt, reveg, noxious weeds, riparian buffer zone |
| 2 | Stream restoration Gomez Bridge to Gunbarrel Road | Combine with dead tree mgmt, reveg, noxious weeds, riparian buffer zone |
| 4 | Stream restoration County Rd 10 to County Rd 13 | 9 (benefits occur after instream flow is provided. Combine with dead tree mgmt, reveg, noxious weeds, riparian buffer zone |
| 5 | Dead tree management upstream of Terrace Reservoir | Combine with revegetation, stream restoration, and noxious weed management |
| 6 | Dead tree management downstream of Terrace Reservoir | Combine with revegetation, stream restoration, and noxious weed management |
| 9 | Purchase appropriate water rights for instream flow | 10 ,11 ,12 ,13 ,15 ,16 or 17 (storage facility is needed) |
| 10 | Controlled releases from Terrace Reservoir with supplemental water source | 9 (storage space is only needed if instream flow water rights are obtained) |
| 11 | Aquifer storage for instream flow | 9 (storage space is only needed if instream flow water rights are obtained) |
| 12 | Trade of direct flow diversion right for reservoir storage (no new water source) | 9 (storage space is only needed if instream flow water rights are obtained) |
| 13 | New reservoir to store instream flow | 9 (storage space is only needed if instream flow water rights are obtained) |
| 15 | Increase spillway capacity | 9 and 10 or 12 (projects to improve Terrace Reservoir would only be done in exchange for storage space for instream flow) |
| 16 | Raise crest of dam | 9 and 10 or 12 (projects to improve Terrace Reservoir would only be done in exchange for storage space for instream flow) |
| 17 | Sediment removal to increase capacity | 9 and 10 or 12 (projects to improve Terrace Reservoir would only be done in exchange for storage space for instream flow) |
| 19 | Power generation at Terrace Reservoir | 18 |
| 27 | Noxious weed management in the upper watershed | Combine with revegetation |
| 28 | Noxious weed management in the lower watershed | Combine with revegetation, dead tree management, and grazing management |
| 29 | Revegetation in the lower watershed | 9 (benefits occur after instream flow is provided) |
| 30 | Grazing management | Combine with revegetation |
| 31 | Riparian buffer zone | Combine with revegetation |
| 34 | Fish–stocking above Terrace Reservoir | Water quality improvement is needed to sustain fish populations |
| 36 | Fish–stocking below Terrace Reservoir | 9 (benefits occur after instream flow is provided) |
| 45 | Site specific PMF study | 9 and 10 or 12 (projects to improve Terrace Reservoir would only be done in exchange for storage space for instream flow) |
| 46 | Ice Jam Flooding Study | 9 (only necessary if instream flow is provided) |

It is also important to note that if certain projects are implemented, other projects with the same goals are not necessary. Therefore, unless the benefits of implementing multiple projects with the same goal are additive, only one project of that type should be performed.