NEVADA DEPARTMENT OF TRANSPORTATION
CLEAR CREEK EROSION ASSESSMENT

FINAL REPORT

Prepared for:

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EXECUTIVE SUMMARY

The purpose of this project was to locate and identify erosion and sedimentation areas within the watershed, determine the causes of the erosion and sedimentation, and develop mitigation alternatives and construction cost estimates to eliminate these erosion and sedimentation areas. In addition, an evaluation of the Clear Creek stream corridor for environmental and general geomorphic conditions was included. This evaluation included sampling of biota and aquatic species as well as development of information regarding geomorphic channel characteristics.

Study information was collected by several methods. Previous watershed studies were reviewed. Questionnaires were distributed to stakeholders to further develop background information on the watershed and identify issues and concerns relevant to the study. Field interviews were also conducted with key individuals to provide insight into the natural and manmade processes occurring in the watershed. Field investigations were performed to gather information on the watershed condition.

Collected watershed information was used to conduct hydrologic, hydraulic, erosion and sedimentation, and environmental analyses for the watershed. Once all relevant information was gathered and all analyses performed, the erosion and sedimentation areas were prioritized based on the impact to the overall watershed, main stream corridor, US 50, and other identified areas.

Once the prioritization of erosion and sedimentation areas was complete, mitigation alternatives were developed and order of magnitude construction cost estimates were calculated for each alternative. Multiple alternatives were developed and employed several different methods of mitigation as applicable to each area.

The environmental analysis completed for the Clear Creek main channel was inconclusive. Because detailed historic stream data do not exist for the Clear Creek drainage, a comparison of historical conditions to the existing stream is not possible. The use of bioassessment sampling for determining whether a water body has been affected by a particular disturbance requires comparing data to a reference condition or historical data. The reference site is typically a similar stream with minimal disturbance. The Nevada Division of Environmental Protection (NDEP) is currently identifying a reference stream; therefore, a basis for comparison does not currently exist.

Without historical data or a reference stream, it is difficult to establish impacts of sediment loading and land use modifications to Clear Creek. While it is evident that sediment loading is occurring, it is difficult to establish impacts to the aquatic biota.

The erosion and sedimentation analysis completed for the watershed determined that human influence in the watershed has accelerated erosion in many areas, but to what extent is unclear. In 1978 John Bailey Fisher completed a thesis that concluded that the total average sediment load was 2,200 grams per minute. This thesis provides a baseline of sediment transport data for the Clear Creek main channel; however, the only way to positively determine whether the sediment load in Clear Creek has increased or decreased in the past 25 years would be to complete another study using sediment collecting methods similar to those used by Fisher.

Based on the inventory of drainage structures and drainage corridors in the watershed, approximately 10 percent of these areas are experiencing a relatively high rate of erosion, approximately 15 percent of these areas are experiencing a relatively moderate rate of erosion, and 75 percent of these areas are experiencing low or minimal erosion.

Several general mitigation alternatives were developed for each type of erosion in the watershed, and order of magnitude construction costs were developed for these general alternatives. In addition, areas with high or moderate erosion were evaluated to determine which have the highest impact on the Clear Creek main channel, existing infrastructure such as US 50, and those drainage corridors that are causing substantial damage to the surrounding landscape. For these high priority areas, site-specific alternatives were selected, and order of magnitude construction cost estimates were developed. A recommended set of mitigation components was then selected for each high priority area. The cost of the recommended alternatives for the high priority areas is $2,598,430. It was determined that many of the high priority mitigation sites will be difficult to access and would require demolition of existing vegetation to complete the mitigation construction if conventional construction methods, such as those employing heavy machinery, were used. Therefore, many of the recommended alternatives are intended to be constructed by manual laborers to minimize impacts. These types of alternatives may be less effective in controlling erosion than conventional methods, but they should limit the impact of construction. Care should be taken, however, during the design phase when evaluating the construction conditions for these types of alternatives to determine whether those conditions provide for a favorable environment to complete an effective and relatively inexpensive installation using manual laborers. Construction conditions should also be closely evaluated when designing conventional alternatives and construction methods. The Consultant suggests meeting with several contractors in the field before and during the design phase to obtain information on construction methods and costs in difficult areas.

High priority mitigation sites were grouped into four construction projects, with the first construction project taking advantage of mitigation sites located on public lands that should not require the acquisition of right-of-way. Maintenance for the mitigation alternatives, once constructed, is anticipated to be minimal except after major runoff events because high flow velocities and volumes can likely damage many of the alternatives, but should significantly limit erosion.

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CHAPTER 1 – INTRODUCTION AND PURPOSE

1.1 Introduction

The Nevada Department of Transportation (NDOT) retained PBS&J (Consultant) to complete an erosion assessment for the Clear Creek watershed. The NDOT provided funding for this project; however, the Consultant reported directly to the Clear Creek Steering Committee, which is comprised of the following agencies:

- Nevada Department of Transportation
- Carson Water Subconservancy District
- United States Forest Service
- The Washoe Tribe of Nevada and California
- Carson City
- Douglas County
- Natural Resource Conservation Service

The Clear Creek watershed is located west and south of Carson City between Spooner Summit and the Clear Creek confluence with the Carson River. The total watershed area is approximately 19 square miles. The watershed includes portions of Carson City and Douglas County. The study area is shown on **Figure 1-1**. A description of the study area is as follows:

Township 15 North, Range 18 East:
Portions of Sections 25 and 36
Township 15 North, Range 19 East:
Sections 28, 29, 31, 32, 33, and 34 and portions of Sections 19, 20, 21, 22, 26, 27, 30, 35, and 36
Township 15 North, Range 20 East:
Portions of Sections 31, 32, and 33
Township 14 North, Range 19 East:
Portions of Sections 1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 17, and 18
Township 14 North, Range 20 East:
Portions of Sections 4, 5, 6, 7, 8, 9, and 10

A project contact/distribution list is provided in **Table 1-1**.

1.2 Project Purpose and Description

The purpose of this project was to locate and identify erosion and sedimentation areas within the watershed, determine the causes of the erosion and sedimentation, and develop mitigation alternatives and construction cost estimates to eliminate these erosion and sedimentation areas. In addition, an evaluation of the Clear

Creek stream corridor for environmental and general geomorphic conditions was included. This evaluation included sampling of biota and aquatic species and as well as development of information regarding geomorphic channel characteristics.

Study information was collected by several methods. Previous watershed studies were reviewed. Questionnaires were distributed to stakeholders to further develop background information on the watershed and identify issues and concerns relevant to the study. Field interviews were also conducted with key individuals to provide insight into the natural and manmade processes occurring in the watershed. Field investigations were performed to gather information on watershed condition.

As watershed information was gathered, it was used to conduct hydrologic, hydraulic, erosion and sedimentation, and environmental analyses. Once all relevant information was gathered and all analyses performed, erosion and sedimentation areas were prioritized based on the impact to the overall watershed, main stream corridor, US 50, and other identified areas.

Once the prioritization of erosion and sedimentation areas was complete, mitigation alternatives were developed and order of magnitude construction cost estimates were calculated for each alternative. Multiple alternatives were developed and employed different mitigation measures, as applicable to each area.

FIGURE 1-1. VICINITY MAP

TABLE 1-1 CONTACT/DISTRIBUTION LIST

CHAPTER 2 – DATA COLLECTION

2.1 Studies and Electronic Data

The Steering Committee provided many previous Clear Creek watershed studies to the Consultant. The Consultant collected electronic data for the watershed, a summary of which is provided in **Table 2-1**.

Previous studies and electronic information were used to develop this study. Much of the information is not directly applicable to this study; however, it does provide an historical overview of the watershed. A few previous studies do provide relevant information directly applicable to the information developed for the current study. The most notable of these is the April 1978 thesis by John Bailey Fisher, "Flume Development for a Study of Bedload and Suspended Sediment in Clear Creek Drainage, Eastern Sierra Nevada." This thesis, which provides baseline data for the sediment loading in the Clear Creek main channel, is discussed below.

In 1978 Fisher estimated that for the period March 1975 to September 1977, total average sediment load for Clear Creek was 2,200 grams per minute. The sediment load was estimated using an in-channel flume to collect sediment samples. During periods of normal stream flow, bed load averaged about four times the quantity of the suspended load; this is attributed to the low concentrations of clay and silt in the basin soils. During high flows, total sediment load increases, as does the suspended load, due to higher flow velocities and accelerated erosion.

After completing a stream survey, Fisher divided the creek into different stream reaches that are potential sediment sources to the creek. The segment of Clear Creek near Discharge Point 10 (see **Figure 5-1 East** of this report) is indicated to " …contribute a large percentage of the bed load because of the concentration of water by the pavement of the highways." Today much of this sediment appears to be captured by Sediment Basin 159 (see **Figure 5-1 East**), which may have been constructed after Fisher completed his analysis. Generally, Fisher's other findings appear to be consistent with the current watershed condition and the field investigation completed by the Consultant. This includes the meadows area where Fisher indicates that "…exposed roots, ground slumping and active gullies with ten to fifteen feet high banks are common" and "…is a major source area for sediments." Fisher also indicated "…there is a potential for erosion because of steep slopes, fragile vegetation and deeply weathered granitic rock, but there is little evidence of erosion in the basin." Fisher goes on to say that "…a combination of high infiltration and probable lack of intense thunderstorms reduces the chance of erosion." These statements may indicate that at the time Fisher completed his study, the major erosion areas downstream of US 50 may not have been present.

TABLE 2-1 DATA COLLECTION SUMMARY

Further, recent flood events that have occurred in the watershed are likely the primary reason the erosion areas within the watershed are so deeply incised. Fisher's thesis provides a baseline of sediment transport data for the Clear Creek main channel; however, the only way to determine whether the sediment load in Clear Creek has increased or decreased in the past 25 years would be to complete another study using sediment collecting methods similar to those used by Fisher.

2.2 Stakeholder Interviews and Questionnaires

Stakeholder questionnaires were distributed March 4, 2002. The questionnaires were meant to collect additional watershed information, identify additional issues or concerns, and identify locations of features within the watershed that the Consultant may need to investigate during the field investigations. Five completed questionnaires were received from the following entities/landowners:

- NDOT
- Carson Water Subconservancy District
- Carson City
- United States Forest Service
- Michael and Sharon Arnold

The responses were used to complete the field investigation and develop a comprehensive understanding of the sedimentation and erosion issues concerning the watershed. In addition to reviewing the questionnaires, the Consultant attended several meetings of the Clear Creek Watershed Council and made presentations. During the field investigation, information was also gathered from private landowners and others who have an understanding of, or experience with, erosion and sedimentation areas in the watershed. Copies of the completed questionnaires are in **Appendix A**.

2.3 Field Investigations

The field investigations included locating and evaluating all identifiable erosion and sedimentation areas within the Clear Creek watershed as well as creating an inventory of all drainage structures. More than 1,000 field photographs were taken, and approximately 30 miles of drainage corridors were visually inspected. The field investigations occurred on the following dates:

Field Investigation 1
November 19 and 20, 2001

Field Investigation 2
April 15, 16, 17, and 18, 2002
May 6, 7, 8, 9, and 10, 2002
June 18 and 19, 2002

Field Investigation 3
June 3, 4, and 5, 2002

Field Investigation 1 concentrated on the 7 miles of US 50 within the Clear Creek watershed between Spooner Summit and US 395. The Consultant walked this entire reach of US 50 locating and evaluating all associated drainage facilities and erosion and sedimentation areas adjacent to the highway.

Field Investigation 2 concentrated on locating and evaluating all other erosion and sedimentation areas not identified during the previous field investigation. This investigation focused on the area south, or downstream, of US 50 between the highway and the main channel of Clear Creek (including the main channel). The main channel of Clear Creek was also investigated east, or downstream, of US 395 to the confluence with the Carson River.

Field Investigation 3 gathered information on water quality, habitat, biota, and aquatic species for the main Clear Creek channel and areas immediately adjacent to the channel.

Field Investigations 1, 2, and 3 are discussed in the sections below. Data collected and developed during all three field investigations are further discussed in **Chapters 4, 5, and 6** of this report.

2.3.1 Field Investigation 1

Information collected during Field Investigation 1 for the drainage facilities along US 50 consisted of the US 50 plan station number in meters, the size and type of facility, potential depth of water at cross culvert inlets before overtopping for calculation of hydraulic capacity, estimation of percent clogging due to existing sediment deposition, and evaluation of any erosion areas adjacent to the roadway due to culvert discharge or slope erosion caused by surface water overtopping the roadway.

Each erosion area was categorized based on visual inspection as low, moderate, or high erosion. Factors considered were apparent width and depth of the erosion ditch, density of vegetation, presence of flowing water, type of soil material (loose or bedrock), apparent slope of downstream area, apparent vertical distance between the bottom of the culvert outlet and the soil below the culvert; overall stability, existing and potential future erosion potential; proximity of erosion to the roadway, and potential for damage to the roadway through undermining.

After Field Investigation 1, data were evaluated and erosion areas geographically located using Geographic Information System (GIS) and electronic data (such as aerial photos). Each erosion area identified was assigned a number, which not only represents an area of existing or potential future erosion, but also a discharge point from the road.

2.3.2 Field Investigation 2

The Consultant built on the information gathered during Field Investigation 1 by walking the drainage corridors between US 50 and the main channel of Clear Creek. This activity was performed to evaluate the condition of the drainage corridors and to determine whether sediment from the US 50 erosion areas and downstream drainage corridors is reaching the main channel of Clear Creek. Information was also gathered on other drainage facilities such as culverts and sediment basins. Drainage corridors were rated similarly to those developed during Field Investigation 1. Each drainage corridor received an erosion rating of low, moderate, or high; this information was then entered into the GIS database and geographically located. Other erosion and sedimentation areas such as sediment plumes, landslides, hillside erosion, retention basins, detention basins, headcuts, and other drainage culverts/facilities were also identified and located. After evaluating the drainage corridors and locating their discharge points to the main channel of Clear Creek, a qualitative estimate was made of the amount of sediment reaching the main channel relative to each individual discharge point or drainage corridor. This qualitative estimate was made to determine which drainage corridors are likely discharging the most sediment to the Clear Creek main channel.

Other erosion and sedimentation areas in the watershed were also identified and evaluated during Field Investigation 2. Also investigated were the main channel of Clear Creek and adjacent areas including the “Meadows” in the vicinity of the Clear Creek Ranch, the headcut on the Washoe Tribe Stewart property east of US 395, and the reach located within the prison property near the confluence with the Carson River. Kings Canyon Road was driven to determine impacts from the road and to view the watershed.

The Consultant viewed the headcut on the Washoe Tribe property east of US 395 in October 2001 and again in June 2002. The overall headcut height appears to have remained constant during this period (approximately 5 to 6 feet); however, it appears to have migrated upstream approximately 100 to 200 feet. Instead of the headcut being one near-vertical drop at a single location, as it was in October 2001, it now appears to consist of three smaller (1- to 2-foot), separate near-vertical drops spread over a distance of approximately 100 feet. The head cut appears to be migrating upstream at a fairly rapid rate. Although the fact that it has been spread over approximately 100 feet instead of one location may indicate that the channel slope is beginning to stabilize and possibly reach a state of equilibrium. However, further migration upstream is likely, and has the potential to continue all the way up to US 395.

During Field Investigation 2, the Consultant collected four sediment samples in 1- to 2-gallon bags. The samples were taken to a testing laboratory where a sieve analysis was performed. A description of the sediment samples taken is discussed below.

Sample 1, taken at the base of a rock outcrop adjacent to Old Clear Creek Road below US 50 culvert 114, is a representation of decomposed granite immediately after it has been detached from a bedrock outcrop.

Sample 2, taken within the floodplain of Clear Creek from sediment deposited approximately 40 feet from the Clear Creek main channel below US 50 culvert 103, is a representation of decomposed granite after it has been transported from the original source to a location adjacent to the Clear Creek main channel.

Sample 3, taken from sediment deposited in the Clear Creek main channel below US 50 culvert 103, is a representation of the material being transported in the Clear Creek main channel.

Sample 4, taken from sediment deposited in the Clear Creek main channel at Fuji Park, is a representation of the material being transported in the Clear Creek main channel.

Sieve analysis data from the four sediment samples are included in **Appendix B**. Generally, the grain sizes decrease from Sample 1 to Sample 4, seeming to indicate that larger grain sizes may be settling out before reaching the Clear Creek main channel. It could also indicate that they are being buried with smaller sediments and perhaps not being actively transported during low flow conditions because the sediment samples collected in the main channel were taken at the top of the sediment deposition layers. During the field investigation, the Consultant noticed (through visual inspection of the main channel) that small sand grains were actively being transported along the bottom of the channel from areas upstream of the "Meadows" all the way down to the sediment basin on the prison property.

2.3.3 Field Investigation 3

Field Investigation 3 helped to develop the stream category evaluation where the main channel of Clear Creek is subdivided in reaches, with each reach having similar characteristics. These characteristics include slope, sedimentation, erosion, water quality, habitat, biota, and aquatic species. The biologist who conducted Field Investigation 3 investigated the different reaches of the main channel and completed a pedestrian survey and grab samples of invertebrates from the stream and observed the channel and riparian conditions. Data were also obtained from similar field investigations completed by the Carson Valley Conservation District. The information gathered during Field Investigation 3 is discussed further in **Chapter 4** of this report.

2.3.4 Field Data Inventory

Data collected during the field investigations were organized, tabulated, and geographically located. This information should be useful to stakeholders attempting to improve the watershed condition in the future. A geographic representation of the data collected during Field Investigations 1 and 2 is shown on **Figures 5-1 East** and **5-1 West**. A geographic representation of the data collected during Field Investigation 3 is shown on **Figure 4-1**. A **Field Picture Inventory** was created for the watershed using more than 1,000 photographs taken during the field investigation. This inventory is contained in **Appendix J** on the **Field Picture Inventory CD**. The CD contains free software (ArcReader) that the user loads onto a computer. The software then displays a map of the watershed with aerial photo background and the information contained on **Figures 5-1 East** and **5-1 West**. The map contains points hyper-linked to the field photo database. To view a picture for a specific location, the user clicks on the associated point and the field photo(s) for that point are automatically displayed. A description of each drainage system in the watershed is also included on the **Field Picture Inventory CD**. The drainage systems are identified by the discharge point numbers (see Section 5.4) and one of the seven Clear Creek main channel subreaches (see **Chapter 4**).

Appendix C contains an inventory of all drainage facilities identified during the field investigation. The inventory includes the erosion component number, erosion component type, NDOT US 50 plan station number (if applicable), erosion rating (low, moderate, or high—if applicable), a description of the erosion component, and any significant field notes. The erosion component is any identifiable feature of the watershed that may have an impact on or is related to erosion and sedimentation in the watershed. The 11 types of erosion components are defined below.

Type 1: US 50 Cross Culvert
Collects runoff from natural areas on the upstream side of the road and conveys it to the downstream side of the road.

Type 2: US 50 Drop Inlet Culvert
Drop inlets connected to a culvert, which collect runoff from the roadway surface only and discharge through the culvert to the downstream side of the road.

Type 3: US 50 Cross Culverts with Drop Inlets
Combination of Types 1 and 2, cross culvert with drop inlets directly or indirectly connected to the cross culvert. Indirect connection is a drop inlet that discharges to the upstream side of the road with the flow traveling overland to a cross culvert inlet.

Type 4: US 50 Slope Erosion
Pavement surface flow overtopping the edge of pavement and draining down the adjacent roadway slope causing erosion.

Type 5: Other Drainage Culvert/Facility
Primarily cross culverts for other roads in the watershed other than US 50.

Type 6: Headcut
Vertical or near-vertical drops in the flow line elevation of a drainage corridor/channel. The drops are primarily 1 to 6 feet and generally have a tendency to migrate upstream and increase sediment yield.

Type 7: Sediment Basin
Excavated depressions in the soil that collect runoff from upstream drainage corridors but have some kind of outlet to discharge the water they collect. These tend to collect sediment from the upstream watershed due to a reduction in flow velocity as the incoming flow enters the standing water in the sediment basin.

Type 8: Retention Basin
Same as a sediment basin except it has no outlet to discharge the incoming water. An outlet pipe may have existed at one time, but it has likely been covered by sediment. Water entering these structures will likely soak into the ground or exceed the top of the basin and sheet flow downstream.

Type 9: Sediment Plume
An area with significant previous sediment deposition.

Type 10: Hillside Erosion
A steep hillside with little vegetation cover to anchoring surface soil.

Type 11: Landslide
A steep hillside where surface soil several feet deep has broken away from the hillside and collapsed at the toe of the slope.

Each erosion component is identified by a number (0 to 245), which is shown on **Figures 5-1 East** and **5-1 West**. Other erosion components (such as drainage corridors and bank erosion along the Clear Creek main channel) are also shown on **Figure 5-1**, but were not given numbers because they are linear components.

CHAPTER 3 – HYDROLOGIC AND HYDRAULIC ANALYSIS

3.1 General

To aid in the erosion and sedimentation analysis, hydrologic and hydraulic data (such as soils information, rainfall, land use, and subbasin delineations) were developed for the watershed. This information is provided in **Appendix J** on the **Electronic Data CD**.

A rational formula method (RFM) analysis was performed to analyze runoff from the US 50 pavement for the 25-year frequency flood event and to estimate the amount of runoff reaching the drop inlets in US 50. The HEC-12 computer program was then used to estimate the capacity of each drop inlet and the total flow to the associated culvert.

An inlet capacity analysis was performed for all US 50 cross culverts, which collect runoff from tributary areas upstream of US 50 and convey the runoff through the road fill to the downstream side of the road. The capacities of these culverts were estimated using Federal Highway Administration (FHWA) inlet control nomographs.

Stream flow gauge data was collected from a United States Geological Survey (USGS) stream gauge located on the Clear Creek main channel approximately 1.5 miles upstream of U.S. 395. The USGS gauge number is 10310500. The tributary area to the gauge is approximately 15 square miles. Stream flow data is limited to average daily flow and annual peak flow. Published data for the gauge is available from 3/1/1948 to 9/30/1962 and from 1/18/1989 to 9/30/2000. The maximum recorded peak flow from the gauge is 266 cubic feet per second (cfs) and was recorded on 1/2/1997. The average daily flow and the annual peak flow for the published period is included on the **Electronic Data CD** in **Appendix J**.

Hydrologic and hydraulic information collected and developed is discussed in the sections below.

3.2 Hydrologic Data

3.2.1 Watershed and Subbasin Delineations

Using available topography and information gathered during Field Investigation 1, the watershed and subbasin delineations were created in GIS. The main channel of Clear Creek bisects the watershed and drains from west to east. Areas tributary to the main channel generally drain from north to south, perpendicular to the main channel.

3.2.2 Rainfall

Rainfall depths were developed from the November 1993 National Oceanic and Atmospheric Administration (NOAA) Precipitation–Frequency Atlas of the Western United States, Volume VII–Nevada. The NOAA Atlas provides rainfall depths for different frequency flood events through state maps that show isopluvial lines representing a constant depth of precipitation (similar to the contours on a topographic map). The range of rainfall depths for the watershed is shown in **Table 3-1**.

TABLE 3-1. RAINFALL DEPTHS

Frequency Flood Event (24-hour)	Rainfall Depth (Inches)
2-year	1.42 to 2.45
25-year	2.42 to 3.43
100-year	3.71 to 5.20

3.2.3 Soils

The soils data are based on the Natural Resource Conservation Service (NRCS) Soil Surveys for the Carson City, Douglas County, and Tahoe Basin Area dated 1979, 1984, and 1974, respectively. Soil types and delineations were taken from the Soil Survey Geographic Data Base (SSURGO), which is an electronic version of the hard copy NRCS Soil Surveys. SSURGO database information was supplemented with, and checked against, the hard copy soil surveys.

Each soil type is classified by hydrologic soil group, which is the relationship between soil type and the amount of runoff that can be expected from a given area. The hydrologic soil group can be A, B, C, or D. For a given area, the runoff potential increases as the soil type changes from A to D, with D soil producing the most runoff.

3.2.4 Land Use

Table 3-2 summarizes the eight land use categories developed for the watershed. Each land use was defined by a specified percentage of the six different ground cover types. Land use and ground cover types are based on aerial photos and observations made during Field Investigation 1. Areas within the upper portion of the watershed near the Clear Creek Camp are assumed to be completely undeveloped even though there may be some minor development in the area. These developments were estimated to make up less than 5 percent of the area, and were assumed to be insignificant in terms of runoff potential.

TABLE 3-2. LAND USE CATEGORIES

Land Use Index Number	Land Use Description	Mountain Desert Fair Condition (%)	Desert Fair Condition (%)	Agricultural Land Good Condition (%)	Grass Landscaped Fair Condition (%)	Desert Landscaped (%)	Impervious (%)
1	Undeveloped Mountain	100	0	0	0	0	0
2	Undeveloped Desert	0	100	0	0	0	0
3	Agricultural	0	0	100	0	0	0
4	Parks	0	10	0	80	0	10
5	Desert Rural Residential	0	55	0	5	25	15
6	Urban Residential	0	10	0	20	30	40
7	Commercial	0	5	0	5	5	85
8	Public Facility	0	30	0	10	20	40

3.3 Rational Formula Method Analysis

The RFM was used to develop peak 25-year frequency flood event flow rates for each drop inlet along US 50. These flow rates were then used to calculate the total 25-year flow collected by the drop inlet culverts. The NDOT roadway plans for US 50 and the data collected during Field Investigation 1 were used to delineate areas tributary to each drop inlet. It is assumed that only runoff from the US 50 pavement is tributary to the drop inlets. All other runoff reaching US 50 is assumed to be collected by the cross culverts.

The RFM requires the area of each subbasin (acres), the 25-year frequency flood event rainfall intensity (inches/hour), and a runoff coefficient to estimate peak flow rates. Subbasin areas were calculated from the NDOT plans. Rainfall intensity is based on the NOAA Atlas. The rainfall intensity used for this analysis is 3.38 inches per hour. The runoff coefficient is based on standard values for pavement. A runoff coefficient of 0.905 was used for this analysis. A detailed description of the methodology and calculations completed is in **Appendix D**.

3.4 US 50 Cross Culvert and Drop Inlet Culvert Analysis

The peak 25-year flows reaching each drop inlet were developed from the RFM discussed in the previous section. Collection capacity of each drop inlet was then estimated using the HEC-12 computer program. HEC-12 uses the type of drop inlet and associated appurtenant information (longitudinal and cross sectional slope of the roadway surface and peak flow draining to the drop inlet) to estimate the amount of flow collected by the drop inlet and the amount of flow bypassing the inlet. If a drop inlet culvert collects flow from more than one drop inlet, these flows are added to obtain the total flow to the individual culvert. A detailed description of the analysis performed and calculations made for the drop inlets and associated culverts is in **Appendix E**.

Cross culverts under US 50 were analyzed using FHWA inlet control nomographs to determine expected culvert capacities. The capacity of the cross culverts is dependent on culvert size and expected headwater depth. A maximum headwater depth of twice the culvert diameter (up to a maximum of 10 feet) was used unless field conditions at the culvert inlet did not allow ponding to these depths. In this case, the headwater depth was estimated in the field. All cross culverts were assumed to be fully maintained with no debris or sediment blockage of the inlet or outlet. The inlet control nomographs used to calculate the cross culvert capacities are in **Appendix F**.

Table 3-3 summarizes the cross culvert capacities and the estimated drop inlet culvert flow rates for the 25-year frequency flood event.

TABLE 3-3. CULVERT CAPACITY SUMMARY

CHAPTER 4 – ENVIRONMENTAL ANALYSIS

4.1 General

In conjunction with the environmental analysis, a stream category evaluation was completed for the Clear Creek main channel, which was subdivided into seven reaches. Each reach has similar characteristics. **Figure 4-1** is a map of the watershed with aerial photo and the limits of each reach. The map also shows sample sites used during Field Investigation 3. **Figure 4-1** also displays an elevation profile along the main channel and some of the information contained on **Figures 5-1 East** and **5-1 West** (see **Chapter 5**).

4.2 Introduction

Field Investigation 3 was completed June 3, 4, and 5, 2002. Field Investigation 3 established an environmental baseline of the riparian vegetation and assessed the general condition of accessible reaches of Clear Creek. The investigation included a pedestrian survey and grab samples of invertebrates from the stream and visual observations of the channel and riparian conditions. These observations and the invertebrate data gathered by the Carson Valley Conservation District are included in this discussion.

Field investigation 3 inspected all accessible reaches of the Clear Creek channel between US 395 and Spooner Summit. Seven areas were then identified for a detailed characterization based on riparian plant communities, flow regime, and channel substrate. These seven areas were chosen to conduct a preliminary baseline assessment of the Clear Creek biota. Each representative area was characterized for dominant associated land use, riparian vegetation, stream channel substrate, turbidity, and sedimentation. Additionally, the reach of Clear Creek from US 395 to the confluence with the Carson River was visually inspected. Due to the extent of urban modification to the surrounding land use and the changes to the natural channel of Clear Creek in this area, no analysis beyond these observations was made.

Factors affecting biological characteristics of a stream include surrounding land use, topography, and elevation. Land use along the stream channel is changing as residential and commercial development occurs. Natural topography breaks are generally associated with elevation along Clear Creek, with changes in slope and grade occurring as the stream progresses from Spooner Summit to US 395.

Land use adjacent to streams can profoundly affect the biological integrity of the aquatic ecosystem. Changes in the riparian zone can cause modified temperature regimes and nutrient loading and an alteration of the aquatic biota. Changes in tree canopy density, riparian species composition, sedimentation, nutrient loading, and land management practices can alter the energy dynamics of the stream.

4.3 Results

Riparian vegetation along Clear Creek from Spooner Summit to US 395 includes mature coniferous forest, sagebrush scrub, and grassland/savannah-dominated communities, which are a function of topography, elevation, and land use. From the headwaters near Spooner Summit to the confluence with the Carson River, the Clear Creek watershed traverses several ecoregions including montane, pygmy conifer, and sagebrush. These ecoregions are determined predominately by elevations; however, vegetation clearing and land use practices have influenced the vegetation communities.

Reach 1 and Upstream

Upstream from US 50 (upstream of Reach 1), the Clear Creek channel is moderately incised but includes a narrow riparian zone dominated by quaking aspen (*Populus tremuloides*), white pine, mountain dogwood, bitter cherry (*Prunus emarginata*), and greenleaf manzanita (*Arctostaphylos patula*). Land use in this area includes managed forest and recreational activities. The stream channel has a mature overstory with dense understory. Firewood cutting and timber management practices have removed much of the dead and decaying plant materials and reduced coarse particulate organic matter (CPOM) introduction into the stream in this area.

The stream channel from Clear Creek Ranch upstream to US 50 (Reach 1) is deeply incised with a steep gradient. The riparian zone adjacent to Clear Creek is a narrow strip of mature vegetation consisting of quaking aspen and white fir (*Abies concolor*). The understory consists of creek dogwood, mountain alder (*Alnus incana* ssp. *tenuifolia*), and bitter cherry. Ponderosa pine and Jeffery pine occur upslope of the stream and provide a dense canopy over the channel. The channel sediments are composed of coarse and fine grain gravels. The abundance of leaf litter and fallen trees provides large amounts of organic matter to the stream.

The slope of the stream through Reach 1 is approximately 8.7 percent.

Reach 2

Reach 2 of Clear Creek near the vicinity of the Clear Creek Ranch is characterized by increased residential development and associated vegetation modifications. This area includes a proposed residential subdivision development and associated golf course on the upland south side of Clear Creek. The tree canopy is open with a limited overstory of Jeffrey pine (*Pinus jeffreyi*), Pacific ponderosa pine (*Pinus* *ponderosa* var. *ponderosa*), and Washoe pine (*Pinus washoensis*). The understory is dominated by a variety of native and introduced grasses in a savannah community. The channel sediments are large cobble, and coarse and fine grain gravels and flat topography provide for a slower flow; however, bank erosion is increasing sedimentation. The reduction in the tree canopy has allowed increased periphyton growth on the bottom sediments. A large amount of channel meander provides for a series of riffle-pool complexes.

The slope of the stream through Reach 2 is approximately 2.6 percent.

Reach 3

The downstream end of Reach 3 begins approximately 4,000 feet upstream from the USGS gauging station. Adjacent and riparian vegetation transitions to a yellow pine-aspen assemblage of predominately quaking aspen. Low topographic relief results in slower water velocities and a wider channel. This area is undergoing low-density residential land use development north of Clear Creek, resulting in a thinning tree canopy and a reduction in woody vegetation. The channel sediments are similar to those in Reach 2.

The slope of the stream through Reach 3 is approximately 3.1 percent.

Reach 4

Reach 4 is immediately upstream from the tribal lands adjacent to Fuji Park and is marked by an increase in topographic relief and stream flow velocity. Riparian vegetation is a mid-successional, closed canopy dominated by mountain alder, coyote willow, greenleaf manzanita, and western cottonwood. The narrow stream channel is heavily shaded from the dense overstory, and the channel sediments are dominated by large granite boulders and gravel.

The slope of the stream through Reach 4 is approximately 6.6 percent. Although flow velocities are relatively high, there appears to be little erosion; this can be attributed to the presence of many boulders and dense vegetation within and adjacent to the stream.

Reaches 5, 6, and 7

Reach 5 crosses tribal lands on both the east and west sides of US 395. Reach 5 also crosses Fuji Park and ends at Bigelow Road at the upstream end of the prison property. Reach 6 includes the improved channelized portion of Clear Creek through the east side of the prison property. Reach 7 crosses the prison property south of the agricultural land and discharges to the Carson River.

Tribal land upstream of Fuji Park is dominated by big sagebrush (*Artemisia tridentata*) scrub with very little tree canopy. Tribal lands were inaccessible during the field investigation; observations were made from the adjacent Old Clear Creek Road. There is an observable but small change in grade and water velocity from the flat Fuji Park reach of the creek.

Riparian vegetation in the vicinity of Fuji Park, west of US 395, consists of mature and mid-successional coyote willow (*Salix exigua*) and western cottonwood (*Populus fremontii*). This area is characterized by a relatively flat topography and a subsequent reduced flow regime, gravel and silt channel sediments, a relatively wide riparian community with associated overbank wetlands, and increased turbidity from sediment loading.

From US 395 to the confluence with the Carson River, the channel and associated riparian vegetation of Clear Creek has been modified through surrounding land use changes, channelization, and vegetation clearing. This reach of Clear Creek is a slow-moving stream. Riparian woody vegetation has been removed through most of this area except within and along Reach 6.

Wetland areas occur within and along the western half of Reach 7. In addition, at the time of the field investigation, the stream corridor of Reach 7 had some evidence of cattle grazing but appeared to be well managed with healthy vegetation that did not appear to be overgrazed. Much of the eastern half of the Reach 7 channel has been fenced off on both sides of the stream to prevent cattle grazing on the channel banks; however, some minor bank erosion was noted.

The Consultant walked the entire length of Reach 7. Other than some minor sediment deposition within the sediment basin at the beginning of Reach 7, there was no indication of sediment deposition. Because this reach is flat (approximately 0.2 percent), it is reasonable to assume that little, if any, sediment is being discharged to the Carson River; otherwise, there should be significant sediment deposition along Reach 7. No water was entering the Carson River from Clear Creek at the time of the field investigation. It is therefore reasonable to assume that the only condition when Clear Creek may be discharging sediment to the Carson River is during a major flood event, but this is unlikely. Even if Clear Creek is discharging sediment to the Carson River, it is probably not a substantial source of sediment considering there appears to be significant bank erosion along the Carson River.

If one accepts the above conclusion, it is also reasonable to assume that the majority of sediment load in Clear Creek, the source of which is primarily in the upper portion of the watershed, is likely being captured along the main channel before reaching the Carson River confluence. Based on the field investigation, it appears that the most likely location for this is through Reach 5 within Fuji Park and the Washoe Tribe property upstream of the park. This is the first reach of the creek that is flat and wide below the steep upper portion of the watershed and appears to have the capacity to capture much of the sediment.

The slope of the stream through Reaches 5, 6, and 7 is 1.0 percent, 0.8 percent, and 0.2 percent, respectively.

The Carson Valley Conservation District has performed some preliminary sampling of invertebrates on Clear Creek between US 50 and US 395. Their results indicate that at the time of sampling (May 2002) mayflies (ephemeropterans) were the dominant benthic macroinvertebrate, followed by beetles (coleopterans), and caddisflies (trichopterans). Mayflies are represented by members of Family Heptageniidae and Family Baetidae, both considered gathering-collectors and scrapers. Dominant beetles include members of the Family Elmidea, also considered to be gathering-collectors and scrapers. Other dominant beetles include members of the Family Hydropsychidae and Family Hydropsychidae, which are considered filtering-collectors.

4.3 Conclusions

Clear Creek can be characterized as a first order stream and classified as a "headwater" under the River Continuum Concept. This concept describes lotic (streams and rivers) systems from source to mouth using both stream order and location along the stream gradient. The concept characterizes streams and rivers for riparian vegetation, benthic macroinvertebrates, and fish communities to describe and predict energy use within the stream.

Headwater streams such as Clear Creek are typically characterized as forested streams with narrow, steep gradient channel with a dense over-canopy of coniferous or deciduous trees. Shredders and collectors are the dominant functional feeding groups in headwater streams. Shredders are characterized by the collection and consumption of CPOM, predominately in the form of needles, leaves, and other plant debris. Collectors can be either filtering collectors, using a filtering apparatus to collect suspended fine particulate organic matter (FPOM), or collector-gathers that consume FPOM through browsing or burrowing.

Shredders and collectors tend to be the dominant functional feeding groups because of the large influx of CPOM from the forest debris and leaf litter and the initial stages of FPOM introduction into the system from the CPOM breakdown. Because first order streams tend to be heavily shaded, significant periphyton development is absent.

Macroinvertebrate data and field observations would suggest Clear Creek is typical of a first order, or headwater, stream. Canopy coverage is predominately dense, preventing light penetration into most of the channel. Some land use modifications and vegetation clearing have opened the canopy and allowed light penetration at various points.

Bottom sediment composition varies from cobbles and large gravels to fine grain materials. Because substrate size and type is an important factor in the biological diversity of both vertebrates and macroinvertebrates, changes can negatively affect existing aquatic biota. Clear Creek appears to have sedimentation occurring, as evident from both channel deposits within the banks of the stream and scoured tributary channels. Sediments being loaded by these tributaries appear to be a medium to small, inorganic gravel (predominately decomposed granite) that is not carried as a suspended solid within the water column for any measurable distance, but is more likely transported as bed load along the channel bottom. Most bed load movement likely occurs during large flood events, with only the smaller gravels and sands being transported during low flow conditions.

Limitations of this biological assessment should be noted. Because detailed historic stream data do not exist for the Clear Creek drainage, a comparison of historical conditions to the existing stream is not possible. The use of bioassessment sampling to determine whether a water body has been affected by a particular disturbance requires comparing data to either a reference condition or historical data. The reference condition is typically a similar stream with minimal disturbance. The identification of a reference stream is currently underway by the NDEP; therefore, a basis for comparison does not exist.

Without historical data or a reference condition, it is difficult to establish impacts of sediment loading and land use modifications to Clear Creek. While it is evident that sediment loading is occurring, it is difficult to establish impacts to the aquatic biota.

FIGURE 4-1. STREAM CATEGORY EVALUATION

CHAPTER 5 – EROSION AND SEDIMENTATION ANALYSIS

The purpose of the erosion and sedimentation analysis was to locate and evaluate the areas within the watershed relative to one another and to identify which areas have the greatest level of impact to the watershed. This chapter discusses the erosion and sedimentation information collected and developed for the watershed and presents the analysis results.

5.1 General Conclusions

The Consultant located and evaluated sources of erosion throughout the watershed. It is the opinion of the Consultant that the sources of erosion presented in this report are reasonably complete. It is likely, however, that some erosion sources were not located because every square foot of the watershed was not visually inspected; such an inspection is beyond the scope of this project. It is believed that these other sources are probably not contributing significant amounts of sediment to the Clear Creek main channel and can for the purposes of this study be overlooked. If one accepts this limitation, it can be assumed that significant erosion sources are identified in this report and an evaluation can be completed to prioritize them based on their individual impact to the watershed and the Clear Creek main channel.

Wind, water, ice, snow, and temperature changes all contribute to the overall degradation of mountains. Even as mountains are created through seismic activity, they are continuously being eroded through environmental conditions. The Clear Creek watershed is no exception. However, the presence and influence of human activity within the watershed is apparent. Clearly, in some areas of the watershed human activity and associated modifications to the environment have accelerated erosion and likely increased the sediment load to the Clear Creek main channel. It then becomes necessary to question how much of the sediment loading is due to natural erosion processes and how much of it has been directly or indirectly caused by humans or human-related activities. It is difficult to determine the causes because detailed historical data on sediment loading of the Clear Creek main channel does not exist.

Sediment loading of the Clear Creek main channel is from two major sources: tributary streams and erosion within or along the banks of the Clear Creek main channel. The total length of all tributary streams is more than the total length of the main channel; therefore, one could assume that the contribution of sediment to the main channel from the tributary streams would also be much higher because there is more channel area to be eroded. Many of these tributary channels convey water only during significant rainfall events, and many channels dump or lose the eroded material in sheet flow areas before reaching the main channel. The main channel has flow year-round, and areas along the channel appear to be actively eroding, even under low flow conditions. Some of these areas along the main channel may appear to be insignificant; however, because they are continuously eroding for months or even years between significant rainfall events, when many of the tributaries transport sediment, they become a more substantial sediment contributor. All sediment eroded from these areas within or along the banks of the main channel is being transported and deposited in the main channel, especially during major flood events when the exposed channel banks are immersed in swiftly flowing water. The three main reaches of bank erosion along the main channel are described below.

1. The reach through the “Meadows,” Discharge Point 56, approximately 3,000 feet long, with approximately 840 feet of bank erosion.
2. The reach just below the “Meadows” through the Washoe Tribe property, Discharge Point 47, approximately 3,500 feet long, with approximately 930 feet of bank erosion.
3. The reach through the Washoe Tribe Stewart property between US 395 and Center Road, which includes the headcut and the downstream bank erosion, Discharge Points 2 and 1, respectively, approximately 1,100 feet long, with approximately 300 feet of bank erosion and a 5- to 6-foot head cut.

The first two appear to be naturally occurring, and it is unclear whether the third is natural or has been influenced by humans. Past cattle grazing, timber clear cutting, and diversion of stream flows for irrigation can all impact the stability of main channel banks. It is the opinion of the Consultant that the three bank erosion reaches discussed above are the most significant individual sources of sediment in the Clear Creek main channel. Tributary streams may not be contributing as much individually or as continuously as the main channel, but when the sediment from the tributaries is combined, they also become a substantial sediment source. It is interesting to note that the natural wash upstream of US 50 culvert 65 has been classified as moderate, with significant erosion in the wash, and appears not to have been caused by humans. This may indicate that some of the tributary stream erosion is a natural occurrence and may have become apparent only in recent years due to severe flooding, such as the 1997 event. In addition, because substantial timber clear cutting has occurred in the watershed over the past 200 years and the dominant tree species has changed, this may have an impact on the overall stability of soil in the watershed. Changes in soil moisture, ground cover, and vegetation density can all affect erosion potential. In summary, the dynamic interaction between human activity and natural processes is so interconnected with regard to erosion in the watershed that it is impossible to clearly distinguish the level of impact between these two causes, especially without a detailed historic account of the Clear Creek main channel sediment load. The Fisher thesis discussed in Section 2.1 provides good baseline data for the sediment load in the

Clear Creek main channel. If similar field testing and sampling were completed and the results compared to the Fisher baseline data, it would be a significant step toward determining whether the sediment load has increased or decreased over the past 25 years. Regardless, it is the intent and focus of this study to concentrate on what can be done to improve the watershed condition.

5.2 Future Development Impacts

Humans have influenced erosion in the Clear Creek watershed. To what extent, however, is unclear. The negative influence of human activity probably began in the 1800s with timber clear cutting that forever changed the biological diversity of the watershed. This influence has continued with the construction of residential homes, commercial development, recreation, agriculture, and the associated infrastructure improvements necessary to support these watershed modifications. Three primary changes to the environment that impact erosion in the watershed are:

- Clearing and/or damaging the established vegetation cover in the watershed.
- Increasing runoff potential through the construction of impervious surfaces such as rooftops and roads.
- Increasing the destructive energy of runoff through concentrating flows in drainage facilities such as culverts and modification of drainage patterns to areas that historically did not convey substantial runoff.

These three environmental changes must be addressed for future watershed development. Vegetation clearing and/or damage should be kept to a minimum during construction, natural vegetation should be replanted or revived to the fullest extent possible when construction is complete. Activities may include watering disturbed areas after construction is complete to help natural vegetation re-establish itself. Other best management practices should be implemented during construction, such as redistributing pre-construction surface soil to disturbed areas when construction is complete, installing silt fences to limit soil loss from runoff events during construction, implementing emergency action plans for spillage of hazardous materials during construction, minimizing natural vegetation disturbance due to agriculture and recreation, and regularly repairing heavy use areas.

Runoff from developed areas should be detained at the perimeter of developments to capture pollutants and ensure that the flow is returned to its natural drainage corridors at velocities equal to or less than those that existed before development. Sediment basins are excellent for capturing pollutants and sediments, reducing flow velocities, ensuring no increase in runoff volumes, and providing a means for additional soil infiltration to replenish groundwater before releasing flow to its natural drainage corridor. If culverts and storm drains are used, riprap plunge pools (or other similar facilities) should be placed at the outlets to dissipate flow energy. Natural drainage patterns should be followed as much as possible. These steps will not eliminate the impact of future development on erosion; however, if these problems are addressed during the planning and construction phases of development, long-term impacts can be significantly reduced.

5.3 Erosion Component Ratings

Section 2.3.4 described the 11 erosion component types and the drainage corridors and Clear Creek main channel bank erosion areas. Erosion components were evaluated further by assigning each component an erosion rating of high, moderate, or low. The rating is based on visual inspection and evaluation based on several pertinent factors: apparent width and depth of scour (if present), vegetation density, presence of flowing water, type of soil material (loose or bedrock), apparent slope of downstream area, apparent vertical drop of flow line (if present), overall stability, existing and potential future erosion potential, and proximity of erosion to manmade structures. In summary, the erosion rating is a relative estimate of:

- Existing erosion severity
- Future erosion potential
- The risk that the area may cause future damage to existing infrastructure.

For example, if an area is severely scarred by existing erosion that is damaging or destroying existing vegetation or infrastructure, it may be rated “high.” If an area does not have significant existing erosion, but has a high potential for future erosion or to damage existing infrastructure, it may be rated “high.” If a given area has had significant erosion in the past but does not have potential for future erosion (it has eroded down to bedrock), it may only be rated “moderate” or “low.” The erosion rating is represented on **Figures 4-1, 5-1 East** and **5-1 West** as either red, yellow, or green corresponding to high, moderate, and low erosion, respectively.

Table 5-1 summarizes the erosion component types and the associated erosion ratings and frequency of occurrence (or length, as applicable) of each.

TABLE 5-1. EROSION COMPONENT RATING SUMMARY

Facility Type	High Erosion	Moderate Erosion	Low Erosion	Total
Types 1 and 3 – US 50 Culverts	7	7	28	**42**
Type 2 – US 50 Drop Inlets	10	15	50	**75**
Type 4 – US 50 Slope Erosion	6	11	12	**29**
Type 5 – Other Culverts/Facilities	2	9	54	**65**
Type 6 – Headcuts	5	3	0	**8**
Type 10 – Hillside Erosion	1	1	7	**9**
Type 11- Landslides	0	1	0	**1**
Total (Frequency of Occurrence)	**31**	**47**	**151**	**229**
Percent of Total	**13.5**	**20.5**	**65.9**	
Drainage Corridors (Miles)	2.3	4.3	25.3	**31.9**
Main Channel Bank Erosion (Miles)	1.0	0.6	10.2	**11.8**
Total (Miles)	**3.3**	**4.9**	**35.5**	**43.7**
Percent of Total	**7.6**	**11.2**	**81.2**	
Type 7 - Sediment Basins	N/A	N/A	N/A	**7**
Type 8 - Retention Basins	N/A	N/A	N/A	**3**
Type 9 - Sediment Plumes	N/A	N/A	N/A	**8**

5.4 Priority System

After erosion and sedimentation components were identified and assigned an erosion rating, a priority system was developed to determine which areas have the highest sedimentation impact on the Clear Creek main channel. Each erosion and sedimentation component has the potential to contribute sediment to the Clear Creek main channel. To facilitate the priority system development, erosion and sedimentation components were grouped into systems, with each system having a common discharge point to the Clear Creek main channel. These discharge points are numbered (1 to 79) and geographically located on **Figures 5-1 East** and **5-1 West**. The priority system was then used to estimate existing and potential future sediment contribution to the Clear Creek main channel from each system or discharge point. The estimate of sediment contribution to the main channel from each discharge point is qualitative and is intended to be an estimate of sediment yield relative to other discharge points. The sediment contribution estimate was separated into two components—yield and event—which are defined as follows:

<u>Yield (Y)</u>
An estimate of the existing or potential future amount of sediment reaching the main channel of Clear Creek from a given system, which accounts for all erosion components included in the system. Yield has four levels of severity:

Y0: No sediment yield or insignificant sediment yield.

Y1: Sediment yield is low.
Y2: Sediment yield is moderate.
Y3: Sediment yield is high.

<u>Event (E)</u>
An estimate of what surface water runoff event will produce the sediment yield identified above. Event has three levels:

E1: Low flow conditions would include flows corresponding to perennial flow streams, spring-fed streams, and most periods of snowmelt runoff. Generally, all stream flow conditions where no or little rainfall/runoff is contributing to the flow rate. Approximately equal to anything less than a 5-year frequency flood event.

E2: Minor to moderate flood events would include rainfall/runoff events that correspond to anything between a 5-year and 25-year frequency flood event.

E3: Severe flood events would include rainfall/runoff events that correspond to anything greater than a 25-year frequency flood event.

The highest (or most severe) rating of a given discharge point would be Y3, E1; the lowest (or least severe) rating would be Y0, E3. To further prioritize each system or discharge point in terms of the contribution of sediment to the Clear Creek main channel, points were assigned to each Y and E rating:

Y0: 0 points
Y1: 2 points
Y2: 4 points
Y3: 6 points

E1: 3 points
E2: 2 points
E3: 1 point

The highest (or most severe) rating of a given discharge point (Y3, E1) would receive a score of 9 points; the lowest (or least severe) rating (Y0, E3) would receive a score of 1 point. This priority rating system is simple but effective for the purpose of this study. **Table 5-2** summarizes the priority system ratings for each discharge point with each discharge point identified by the corresponding number shown on **Figures 5-1 East** and **5-1 West**. The information shown in **Table 5-2** is sorted in descending order based on the total score.

The discharge points with the highest scores in **Table 5-2** were reviewed along with other data collected during the field investigation to determine which erosion areas should be identified as high priority and should be the first areas selected for mitigation. The identification and evaluation of the high priority areas is discussed further in the following section.

5.5 High Priority Areas

If reducing the Clear Creek sediment load is deemed necessary, the erosion sources must first be prioritized to establish which areas are the most critical to develop an effective mitigation plan. The prioritization of these areas is separated into three categories based on what watershed components will be provided the highest benefit from the mitigation of each individual source. These categories are defined as follows:

- Mitigation of areas that will reduce the sediment load to the Clear Creek main channel
- Mitigation of areas that will help protect the integrity of US 50
- Mitigation of areas that have significant local erosion that is compromising the integrity of the natural landscape, but not necessarily contributing a relatively high amount of sediment to the Clear Creek main channel.

Priority Category 1

These areas are identified by the discharge point number provided on **Figures 5-1 East** and **5-1 West,** and **Table 5-2**. These areas are believed to have the highest impact on the sediment load in the Clear Creek main channel. To mitigate these areas and reduce the Clear Creek main channel sediment load, erosion and sedimentation upstream of these discharge points must be reduced.

Discharge Numbers and Descriptions
1, 47, and 56: main channel bank erosion
2, 46, and 53: main channel head cuts
12, 13, 15, 16, 17, and 21: tributary streams Reach 4
24 and 26: tributary streams Reach 3
36 and 38: tributary streams Reach 2
64, 65, 68, 69, 70, 75, and 76: tributary streams Reach 1

TABLE 5-2. PRIORITY SYSTEM RATINGS

Priority Category 2

These areas are identified by the US 50 erosion component number and are areas where a high potential exists for surface water to cause minor damage to the roadway. To mitigate these areas, the integrity of the adjacent roadway shoulder needs reinforcement.

US 50 Erosion Component Numbers and Descriptions
47, 52, 53, 83, 87B, 137, and 138: US 50 slope erosion
93: US 50 drop inlet culvert

Priority Category 3

These areas are identified by the US 50 erosion component number and are areas where the drainage corridors immediately downstream of US 50 have significant local erosion, causing substantial damage to the surrounding landscape and having the potential to impact the integrity of US 50. Mitigation or restoration of these areas would require substantial effort.

US 50 Erosion Component Numbers and Descriptions
24, 62, 67, 69, 84, and 103: US 50 cross culverts
35, 58, 60, 68, 70, and 133: US 50 drop inlets

The areas identified as Priority Category 1, 2, and 3 are shown on **Figures 5-1 East** and **5-1 West**. Priority Categories 1, 2, and 3 are identified on **Figure 5-1** by highlighting the areas included in each category using a different color for each of the three categories. The areas included in Priority Categories 1, 2, and 3 represent severe areas of erosion in the watershed and should be the first areas considered for mitigation. All other areas identified as high or moderate erosion should be next to be considered for mitigation. All other areas identified as low erosion do not appear to require mitigation at this time, but they should be periodically inspected to ensure that conditions have not changed since the completion of this study.

Each of the high priority areas was evaluated to determine what erosion alternatives could be used for mitigation. Mitigation alternatives are discussed further in **Chapter 6**.

FIGURE 5-1. WEST - HIGH PRIORITY AREAS

FIGURE 5-1. EAST - HIGH PRIORITY AREAS

CHAPTER 6 – MITIGATION ALTERNATIVES AND COSTS

6.1 General

This chapter describes conceptual mitigation alternatives and order of magnitude construction cost estimates for erosion and sedimentation areas in the Clear Creek watershed. General mitigation alternatives were developed for the different types of erosion and sedimentation and will provide a database for future users of this document to choose from when selecting an individual alternative for a specific watershed site. The mitigation alternative best suited to a specific location will be determined by the type of erosion and the current environmental conditions of the site. Order of magnitude construction costs for each alternative were also developed.

In addition to general mitigation alternatives, site-specific mitigation alternatives were selected from the list of general alternatives for all of the high priority erosion and sedimentation areas identified in Section 5.5. Several potential mitigation alternatives were identified for each high priority area and order of magnitude construction cost estimates developed for those alternatives. A recommended set of mitigation components was then selected for each high priority area. The high priority areas and associated mitigation components were grouped into recommended construction projects, with each project encompassing several high priority mitigation areas.

The general mitigation alternatives, high priority site-specific mitigation alternatives, construction cost estimates, recommended mitigation components, and recommended construction projects are discussed below.

6.2 General Mitigation Alternatives

This section includes potential mitigation alternatives for areas of erosion in the Clear Creek watershed. These general mitigation alternatives were categorized into five lists based on the type of erosion area being considered. The five types of erosion are:

- Culvert outlets (CO)
- Channels (CH)
- Slopes (SL)
- Clear Creek main channel banks (CC)
- Headcuts (HC)

Each list is further subdivided into Level 1, 2, and 3. Level 1 alternatives are intended to mitigate severe erosion areas; Level 2, less severe; and Level 3, least severe. The three levels generally correspond to the previously identified high, moderate, and low erosion categories. Several alternatives are included for each level and are identified alphabetically (A, B, C, etc.), with the most effective mitigation alternative listed first. The example below explains the identifier given to each alternative.

Identifier name: **CO1A**
Culvert Outlet (CO), Level 1 (1), Alternative A (A)

Order of magnitude construction cost estimates were developed for each general mitigation alternative. In addition, exhibits of many of the alternatives were developed. Many of the exhibits were referenced from other documents; the reference is provided at the top of each exhibit. General mitigation alternative identifiers, descriptions, and associated construction cost estimates are in **Appendix G** along with the exhibits. Section 6.3 describes the development of the construction cost estimates.

6.2 High Priority Mitigation Alternatives

Appendix H has a table that identifies each high priority mitigation area by the discharge point number and the erosion component number. The discharge number (see Section 5.4) is shown on **Figures 5-1 East** and **5-1 West** along the Clear Creek main channel where the drainage system in question discharges to the Clear Creek main channel. The discharge number is displayed on **Figure 5-1** in a rectangular box along with the Yield (Y) and Event (E) rating (see Section 5.4). The **Appendix H** table shows the discharge number in the column titled "System." The erosion component includes culverts, slope erosion, headcuts, sediment plumes, sediment basins, retention basins, hillside erosion, landslides, drainage corridors, and the Clear Creek main channel bank erosion. All of these erosion components (see Subsection 2.3.4) except the drainage corridors and main channel bank erosion are assigned a number, which is displayed on **Figure 5-1**. This numbering system is separate from the discharge number. The **Appendix H** table shows the erosion component number in the column titled "Identifier." The drainage corridors and main channel bank erosion are shown on **Figure 5-1** using arcs (lines) and are red (high erosion), yellow (moderate erosion), or green (low erosion). Property ownership data are also displayed on **Figure 5-1**.

The **Appendix H** table lists the discharge number and each erosion component in the upstream system that requires mitigation. Several mitigation alternatives are listed for each component. The alternatives are categorized as A, B, and C. Alternative A generally proposes to mitigate erosion by extending existing culverts and backfilling the eroded channel or diversion of culvert discharge to a more stable drainage corridor. Alternative B generally proposes to mitigate erosion by installing an energy dissipation structure at the outlet of an existing culvert and then lining the downstream channel by conventional methods such as riprap. Alternative C also proposes installation of an energy dissipation structure at culvert outlets, but uses less conventional methods for lining the downstream channel such as brush fill with check structures. Sediment basins are also incorporated into the mitigation of many erosion areas. Selection of mitigation alternatives was based on field notes, photographs, and the features of each erosion area such as culvert and channel size, approximate slope, severity of existing erosion, vegetation density, presence of flowing water, and accessibility.

6.3 Mitigation Alternative Construction Costs

Order of magnitude construction costs were developed for all high priority mitigation alternatives and general mitigation alternatives. Cost estimates for general mitigation alternatives and high priority mitigation alternatives are provided in **Appendices G** and **H**, respectively.

Construction cost estimates are based on bid tabulations from previous NDOT construction projects, manufacturer and distributor recommendations, and Consultant research. Accurate construction cost estimates are difficult to develop at this conceptual stage of design analysis. Many assumptions must be made based on a small amount of site-specific data. Also, the inaccessibility of many erosion areas will likely cause construction complications, which are difficult to accurately incorporate into the construction cost. For these reasons, and because construction costs vary widely depending on many factors unrelated to this project, the construction unit costs used for the estimates are based on the higher range of potential values. For example, if the cost of riprap per cubic yard, complete and in place, varies from $20 to $100, a value of $100 was used for the estimates. For some alternatives, construction access and construction methods may not be as difficult. For example, most of the proposed sediment basins should be easy to access and construct; therefore, unit costs used for those basins are more in line with average unit cost values for this type of construction. A contingency factor of 30 percent was added to all construction cost estimates for the high priority areas included in **Appendix H**. This contingency factor should account for design components and issues that may not be included in the current cost estimate due to a lack of site-specific information. A 7 percent mobilization cost and 5 percent traffic control cost has also been added to the construction cost estimates for the high priority areas in **Appendix H**. The 30 percent contingency factor, 7 percent mobilization and 5 percent traffic control cost, was not applied to the general construction cost estimates included in **Appendix G**. Right-of-way acquisition was not incorporated into any of the cost estimates.

The **Appendix H** table includes construction cost estimates for each erosion component mitigation alternative (A, B, and C). Construction cost estimates are then totaled for each set of erosion components proposed for mitigation in a given system and each set of alternatives (A, B, and C).

6.4 High Priority Recommended Alternatives

After the mitigation alternatives and construction cost estimates were completed for the high priority areas, data were evaluated to develop a recommended alternative for each erosion component and system. The evaluation was based on the overall cost of the alternative and how effective each alternative would be in controlling erosion. Another factor considered during the evaluation was what impact the construction could have on the drainage corridor and surrounding area. For example, if it is proposed that a culvert be extended down a slope, and heavy machinery is required for construction, it must be determined what the impact would be on the surrounding environment. It must also be determined whether large trees would need to be removed to facilitate construction or whether the removal of healthy vegetation would be required and what the impact would have on the erosion potential for the area. In some cases, the mitigation could be worse than the existing erosion; in those areas, it could be recommended that a less effective mitigation method be used (i.e., construction without the use of heavy machinery). These are primarily alternatives that use brush fill and small quantities of riprap to mitigate channel erosion. It is assumed that these types of alternatives could be constructed using manual labor instead of heavy machinery.

Cost estimates to construct some of the mitigation alternatives that use laborers instead of professional contractors is based on the assumption that these types of mitigation alternatives can be constructed easily in the conditions of the watershed without causing a significant impact to the health of the surrounding soil and vegetation. It should be noted, however, that rock outcrop and other hard soil conditions could cause the implementation of these alternatives to be difficult. Construction conditions should be carefully evaluated to determine whether those conditions provide for a favorable environment in which to complete an effective and economical installation using manual laborers. Additionally, many of these alternatives require placing vegetation debris in the tributary and main channel streams of the watershed. A potential exists for this debris to be transported in the watershed's channel system during significant runoff events; this could have known or unknown impacts to the watershed. Dead vegetation in the channels can increase the risk of debris flow, clogged roadway culverts, major channel blockages, and damming. It is crucial that all vegetative debris be anchored in the channel soil and underlying layers so that it is not released during significant runoff events.

Recommended alternatives are shown in bold text and highlighted in the **Appendix H** table. The total estimated construction cost of all recommended mitigation alternatives for the high priority areas is $2,598,430.

During the final phase of this project, NDOT provided additional information including two new types of alternatives (developed by Ayres Associates) for the Hoop Creek project for the City of Northglenn, Colorado. One alternative would extend the existing culverts at the outlet. The culvert extension would include baffle rings on the inside of the culvert that encroach on the effective flow area inside the culvert barrel. The baffle rings would help dissipate flow energy so that when the flow exits the culvert, it would have a lower velocity than existed before the extension. This alternative would include a riprap apron at the outlet with boulders at the toe of the apron to help anchor the riprap. The second alternative would use logs and rock to create a stepped weir for steep channels. The channel sides would be lined with logs and anchored with cables and soil anchors. This alternative would place logs (that are spaced at set intervals to create stepped drops in the channel profile) perpendicular to the channel flow. The logs would be anchored with cables and soil anchors with rock placed upstream and downstream of the perpendicular logs. Schematic drawings and specifications for these alternatives are in **Appendix I**.

The two alternatives discussed above could potentially be used in several watershed areas. The culvert extension alternative could be used in areas where alternatives CO1B and CO1C are used. The stepped log alternative could be used in areas where alternatives CH1C, CH1D, and CH1E are used. Construction costs for the culvert extension alternative and the stepped log alternative will be similar to alternatives CO1C and CH1C, respectively.

6.5 Recommended Construction Projects

After the recommended mitigation alternatives were selected, an analysis was completed to group the high priority erosion areas into projects for construction. This analysis was completed considering the available information on the location of public land. Another consideration was what mitigation components in each high priority system would require using heavy machinery and the services of a contractor and what mitigation components could be constructed using manual laborers. Almost all of the recommended mitigation alternatives would require that a contractor install the proposed improvements at the culvert outlets and complete the construction of the proposed sediment basins. Manual laborers could likely complete the construction for most of the drainage corridors or channels between the culvert outlets and the sediment basins. The consultant recommends that a contractor be hired to complete improvements at the culvert outlets and for the sediment basins and that the contractor also haul the required materials for the channel improvements to the construction sites. After this has been completed, manual laborers would use the provided materials to complete the channel improvements. This process should more effectively use available funding.

Four recommended construction projects are listed below. These four projects combined include all the high priority erosion areas. Each project lists the system numbers (discharge point numbers) to be included. Improvements represented by each system number are only those improvements listed in the table in **Appendix H** (recommended alternatives). Project 1 includes all systems located entirely (or almost entirely) on public land based on available property ownership information.

Project 1

Systems 76, 74, 70, 69, 66, 61, 58, 57, 13, and 12

Total estimated cost: $997,986

Project 2

Systems 75, 68, 65, and 64

Total estimated cost: $216, 944

Project 3

Systems 49, 38, 36, 26, 24, 21, 18, 17, 16, 15, 10, 9, and 8

Total estimated cost: $866,984

Project 4

Systems 56, 53, 47, 46, 2, and 1

Total estimated cost: $516,516

6.6 Maintenance

Maintenance of the proposed improvements would generally include checking all structures and channels for damage and/or clogging after major flood events. Vertical and horizontal culvert outlets and all sediment basins should be inspected annually to determine whether removal of sediment and debris is required. The effort required for maintenance is dependent on the occurrence of major flood events. It is anticipated that maintenance efforts could be significant after a major flood event, especially along some of the proposed channel improvements.

Many of the recommended channel improvements cannot withstand high shear stress caused by large volumes of flowing water. Channel improvements should greatly reduce the erosion potential for most flood events, but they will likely sustain damage as well and require maintenance. Maintenance of these channel improvements should not be difficult because many of the improvements can be installed without heavy machinery. The Consultant selected alternatives for many channels that will not completely eliminate erosion, but will significantly reduce it and help stabilize the system. It is anticipated that many of these alternatives will encourage natural vegetation to re-establish in the channels and further stabilize the system. Most proposed channel improvements include components that would survive indefinitely (such as riprap) and include other components (such as brush) that would only survive a short time. These two types of components were combined with the hope that by the time the short-term component deteriorated, natural vegetation would have re-established itself in the system, and over the long term, the system could recover and reach a state of equilibrium. The energy dissipation structures at the culvert outlets (such as vertical risers) would help reduce the erosive force of the water, and the sediment basins at the downstream end of the systems would serve as a backup to prevent sediment from reaching the Clear Creek main channel if the proposed improvements fail or allow minor erosion to occur.

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