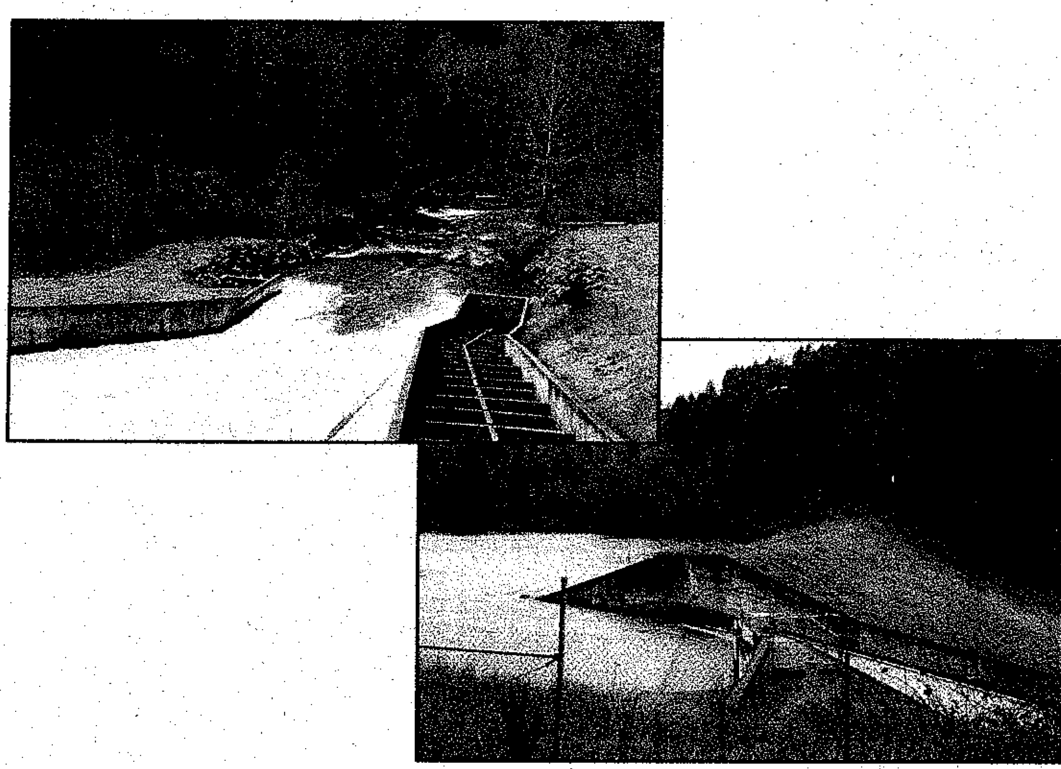
Silver Creek Dam
Early Warning System
Preliminary Design Report

Prepared for:
City of Silverton, Oregon



Monitoring Systems Group

For More Information Contact:

Barry Myers, P.E.
barrym@squier.com

503-635-4419 voice
503-635-1430 fax

SQUIER ASSOCIATES

4260 Galewood Street
Lake Oswego, Oregon 97035

April 2002
201608

City of Silverton, Oregon
306 S. Water Street
Silverton, Oregon

Silver Creek Dam
Early Warning System
Preliminary Design Report

April 25, 2002

Gregory C. Dutson
Systems Integration Specialist

REGISTERED PROFESSIONAL ENGINEER
19728PE
OREGON
MAY 5, 1998
BARRY K. MYERS
EXPIRES: 12/31/02

Barry K. Myers, P.E.
Project Manager

201608

Squier Associates, Inc.
4260 Galewood Street
Lake Oswego, Oregon 97035
Phone: (503) 635-4419
Fax: (503) 635-1430

TABLE OF CONTENTS

TABLE OF CONTENTS *(Continued)*

List of Tables

List of Figures

List of Appendices

Section 1

INTRODUCTION

1.0 INTRODUCTION

1.1 Project Background

The Silver Creek Dam is located approximately two miles southeast and upstream from downtown Silverton, Oregon (see Figure 1, Vicinity Map). The dam and reservoir is owned and operated by the City of Silverton and was constructed in the late 1970's to provide raw water storage and recreational uses for the City. The crest length of the dam is 680 feet, and it has a maximum height of 65 feet. A 120-foot wide rectangular reinforced concrete chute spillway is located on the right abutment. The regulating outlet is a 42-inch inside diameter cast-in-place concrete pipe which is located on rock near the maximum embankment cross section. The dam is constructed as a zoned earth embankment dam with a 3H:1V upstream slope, a 2H:1V downstream slope and a central core.

Soon after the first filling, horizontal drains were installed from the downstream toe area and a buttress was added to the lower portion of the slope to remediate higher than expected seepage on the downstream face. Embankment piezometers were also added to monitor the long-term seepage performance of the dam. As we understand the results of the monitoring performed to date, they have not shown any degrading trends in the seepage performance of the dam.

A Phase I Inspection Report was prepared in June 1981 by the Oregon Water Resources Department in cooperation with the US Army Corps of Engineers, as part of the National Dam Safety Program. The purpose of the inspection and report was to identify any conditions that could threaten public safety. The inspection included general assessments and recommendations pertaining to the condition and future use of the dam. The report indicates that the existing upstream and downstream slopes yield acceptable factors of safety and that the abutments and foundation were performing adequately. Silver Creek Dam was classified as a high hazard dam based on the potential for loss of life and substantial property damage that could result from failure of the dam.

Subsequent to the March 25, 1993 Scotts Mills Earthquake, a Seismic Stability Analysis was performed by Cornforth Consultants, July 21, 1999 using revised earthquake criteria. The analysis concluded that the embankment has adequate factors of safety against sliding. The analysis evaluated three loading conditions including steady-state, rapid drawdown, and seismic. The conclusions of the study indicated a minimal threat of dam failure due to seismic loading.

In addition to the Seismic Stability Analysis, a Dam Break Analysis was performed by Philip Williams & Associates, January 18, 2000 based on two dam failure scenarios: piping and over-topping. As part of this analysis, inundation models were created based on the two failure modes concluding that a failure of the dam would be catastrophic to the City of Silverton. The study cited that if a dam failure occurs, a flood wave would travel down the Silver Creek channel reaching the downtown area of the City within 15 minutes of the breach with flood wave heights in excess of 10 feet in some areas. The study also concluded that minimal time from breach to flooding of the downtown area necessitates the installation of an early warning system to allow advance notice for the inhabitants to evacuate the flood inundation area.

In order to address this concern, the City of Silverton desires to identify and implement improvements that can be made to allow for early warning of an imminent failure condition with sufficient time to evacuate all persons within the downstream inundated area.

1.2 Purpose of the System Design Report

The purpose of this design report is to define the scope and general architecture of the proposed monitoring and early warning system so that the City can establish a budget and time schedule to implement the improvements. It presents the proposed design and cost estimate for the system, and outlines a preliminary evacuation plan. The following items are included within this report:

- Discussion of the performance objectives for the improved monitoring and warning system. These objectives define the basis for the improvements that are recommended and the expectations regarding the ability to detect and respond to a safety concern with the dam.

- Review of the existing monitoring program. A review of the existing dam safety-monitoring program is presented.

- Recommended design for the long term monitoring and warning system. A preferred system configuration is presented, based on the results of the alternatives evaluation.

- Preliminary design of an evacuation plan. Preliminary design of an evacuation plan is provided along with recommendations for further enhancements and Emergency Action Plan coordination issues.

- Recommended process for implementing the improvements. The design report includes a recommended process for implementing the system.

- Estimate of costs for implementation. A cost estimate has been developed for implementing the recommended improvements.

1.3 Monitoring and Early Warning System Objectives

The following is our understanding of the City's objectives for the improved monitoring and notification systems, and the preliminary evacuation plan.

Based on our review of the Dam Break Analysis Report, the warning time appears to be less than 15 minutes for some downstream inhabitants. Given this short warning time the only feasible approach is to detect a developing condition and initiate the notification/evacuation based on a "failure is imminent" condition.

Therefore, the performance criteria and design of the monitoring system is focused on detecting an imminent failure condition. For an internal erosion/piping failure, the precursor events include changes in the seepage performance of the embankment. For a flooding condition failure, the events of concern include large inflows into the reservoir and a rapidly rising reservoir level. To that end, the objective of the monitoring system is to detect and notify City personnel that these events are occurring.

The design also includes determining the decision process for evaluating if a "failure is imminent" condition exists. Having the proper information available to make decisions is critical to balance the risk of false alarming verses not providing adequate time for notification and evacuation.

The objective of the notification system is to provide comprehensive evacuation notification to the downstream inhabitants within the flood inundation area once the decision to evacuate has been made. The evacuation plan provides a preliminary concept of how the population of the inundation area could be divided into evacuation zones. The purpose of the zoning is to efficiently route the population out of the inundation area during an evacuation to avoid traffic problems and confusion or panic.

Section 2

EXISTING MONITORING PROGRAM

2.0 REVIEW OF EXISTING DAM SAFETY MONITORING PROGRAM

The existing dam safety monitoring program consists of collecting and evaluating water level readings on an annual basis from piezometers installed in the embankment and the right abutment. Flow measurements are also collected from the horizontal drains and the 4-inch diameter perforated pipe drains along the toe of the drainage berm. During this annual inspection visual observations of flow from the downstream contact along the left abutment are also made. The results of the measurements and observations are documented in a memorandum that is sent to the Oregon Department of Water Resources (OWRD), Dam Safety Division.

2.1 Piezometers

The water levels in piezometers #2U/S, #2D/S, #3, #4, #5, #6, #9, and #10 are currently read on an annual basis. Water level readings are obtained by manually sounding the standpipe using an electronic probe. The probe is lowered into the standpipe until an audible signal indicates that the probe has been submerged in water. The depth to the water from the top of the standpipe is then recorded. The elevation of the water level is calculated by subtracting the depth to water from the elevation of the top of the standpipe.

2.2 Flow Measurements from Drains

Flow measurements are collected from horizontal drains #1 through #9, and from the 4-inch diameter perforated drain pipes that run along the toe of the drainage berm. Measurements are taken using the timed bucket method. The amount of time that it takes to fill up a bucket of known volume is recorded and used to calculate the flow rate.

2.3 Survey Points

Four settlement monuments are located on the crest of the dam at Stations 0+73.65, 1+56.10, 3+56.15, and 4+93.45. The settlement monuments consist of a 1-inch diameter steel rod set in concrete. Survey monuments consisting of a bronze disc set in concrete are located on the left and right abutments at Station 0+02.59 and 8+23.35, respectively. This network of survey points is used to monitor for settlement and horizontal offset of the dam crest. The last time that the points were surveyed appears to have been in April 1993.

2.4 Reservoir Level

The reservoir level is recorded during the inspection for comparison with the instrumentation data and seepage observations. This is accomplished using a staff gauge that is located on the spillway training wall.

2.5 Visual Observations

Visual observations are made of the general condition of the dam during the inspections. Specific observations have also been documented regarding seepage that is occurring along the downstream contact of the left abutment. These observations have included estimates of the flow rate, the extent of the seepage area, and the clarity of the flow.

2.6 Data Evaluation/Management

The instrument readings are reduced and presented as time history plots using a Quattro Pro® spreadsheet. The results are compared to reservoir level changes and evaluated regarding increasing or decreasing trends in the seepage performance of the dam. The instrument plots and visual observations are then documented in the memorandum that is sent to the OWRD, Dam Safety Division.

Section 3

EVALUATION OF FAILURE MODES

3.0 EVALUATION OF FAILURE MODES

In order to provide early warning of an imminent failure condition, the potential modes of failure, and more importantly the events that lead to the failure, must be understood. The key to identifying an imminent failure condition is to monitor for and detect the developing conditions that would lead to failure of the dam. Therefore, the purpose of evaluating the possible failure modes for this project is to gain a better understanding of the events that could lead to failure so that the detection portion of the early warning system can be focused on monitoring for the occurrence of these events.

3.1 Failure Modes

A number of different failure modes were considered that could lead to an uncontrolled release of the reservoir. Of these modes, the three that appeared to be most likely and worthy of further evaluation included: 1) a seepage failure under normal operating conditions, 2) failure following an earthquake event, and 3) failure under a high reservoir level condition that results from large inflows/flooding. The following is a discussion of the three failure modes.

3.2 Seepage

The mode that was conceived for a potential seepage failure of the dam under normal operating conditions includes: 1) an increase in seepage through the embankment core; then 2) this increase results in an unstable condition developing within the embankment or on the downstream face; then 3) the unstable condition leads to a breach failure of the dam. To further understand this failure mode an event tree was developed. The event tree is an organization of the different possible chain of events, or scenarios, that could occur leading to the mode of failure. The event tree developed for the seepage failure mode is presented as Figure A-1 in Appendix A.

The first response on the event tree is that seepage increases through the embankment. The three categories that were used to describe where the seepage increases could occur include: 1) increased seepage along the abutment contacts; 2) increased seepage through a flaw in the embankment core; and 3) increased seepage along the foundation contact. The tree then branches into possible scenarios for the development of an unstable condition given that an increase in seepage occurs at the different locations. The possible unstable conditions include downstream slope instability, and piping (i.e., migration of soil particles due to seepage) of the core material. If slope instability develops, then the instability can either progress in an upstream direction until a breach failure develops or remain localized with enough embankment left unharmed to prevent a breach failure. If piping of the core material occurs, then the loss of material could lead to the development of a sinkhole on the upstream face or further instability on the downstream slope due to the increasing rate of seepage. The size and location of the sinkhole would determine if the dam is in danger of being breached. The sinkhole could also grow in size as the piping progresses. The affect of the increasing seepage rate on the downstream slope stability would also depend on how the piping progresses. Both scenarios could lead to a breach failure or could remain localized with enough of the embankment left unharmed to prevent a breach failure.

The siren symbols  shown on the event tree indicate the point at which failure would be considered imminent and therefore the evacuation order would be given to the downstream inhabitants. At this point a breach failure still may not occur, but the likelihood of failure would be high.

3.3 Earthquake Loading

For the seismic loading condition, the failure mode that was developed includes: 1) an earthquake occurs producing ground motions at the site that are large enough to cause permanent deformations; then 2) an unstable condition in the embankment develops as a result of the deformations; then 3) the unstable condition progresses leading to a breach failure of the dam.

The resulting event tree for the seismic loading failure mode is presented as Figure A-2 in Appendix A. The first response on the event tree is that an earthquake occurs that results in permanent deformations of either the embankment upstream slope or the downstream slope, or the spillway structure on the right abutment. On the upstream slope, the result of these deformations could include: 1) cracking of the core; 2) increased seepage along the outlet conduit; or 3) a slide mass developing on the upstream slope. If these unstable conditions progress, they could lead to a developing seepage failure or a progressive slumping failure of the upstream face. For the scenario where a slide mass develops on the upstream slope, a freeboard (i.e., the distance between the top of the embankment and the reservoir level) of less than 4.5 feet is significant because the core of the dam only extends to within 4.5 feet of the crest. Therefore, the upper 4.5 feet of the embankment does not contain a seepage control zone. The possible failure scenario resulting from deformations on the downstream slope is progressive slumping that leads to overtopping and a breach failure. If the slide mass develops to a point where half of the downstream slope is incorporated in the movements, then failure of the embankment should be considered likely. The third possible developing condition of concern would be permanent deformation of the spillway structure. If a structural failure occurs, then uncontrolled seepage around or through the structure could lead to progressive erosion and slumping of the downstream slope and eventually a breach failure. The second scenario is that the concrete structure does not fail but the permanent deformation creates a preferential path for uncontrolled seepage. The uncontrolled seepage could then lead to a seepage failure as described in Section 3.2.

3.4 Flooding

The third failure mode that was evaluated includes: 1) large inflows occur from rain fall and snow melt that cause a rise in the reservoir level; then 2) the higher than normal reservoir levels result in the development of an unstable condition; then 3) the unstable condition leads to a breach failure. The event tree that was created to develop a better understanding of this failure mode is also included in Appendix A as Figure A-3. The initial response in the event tree is the level of inflow and the corresponding amount of freeboard that would remain assuming that the reservoir was at a full pool elevation of 424 feet before the flooding event occurred. The relationship between inflow and reservoir level that was used is presented in the Phase 1 Inspection Report, National Dam Safety Program (OWRD, 1981). However, the key parameter for the developing failure mode is the reservoir level and not the inflow. The three flooding scenarios result in reservoir elevations that range between 6 and 3 feet below the crest of the dam. For an inflow greater than 15,000 cubic feet per second (cfs), the amount of freeboard predicted would be less than 3 feet. If the reservoir level continued to rise to within 1 foot of the crest, then overtopping should be considered likely. Erosion caused by the overtopping could then lead to a progressive breach failure. An unstable seepage condition could also develop through the upper 4.5 feet of the embankment that does not include the core for seepage control. A seepage failure condition through the embankment as described in Section 3.2 is also a possibility under these significantly higher than normal reservoir levels.

For inflows between 10,000 cfs and 15,000 cfs (freeboard less than 6 feet), the possibility of overtopping still exists if the spillway becomes blocked by debris. The debris could reduce the capacity of the spillway resulting in a rising reservoir level. This possibility also exists for flooding scenarios with inflows less than 10,000 cfs.

3.5 Alarm Response Plan

The results of the failure modes evaluation were used to identify events that can be monitored to detect a developing condition that could become an imminent failure condition. The specific recommendations for monitoring are included in the recommended system design, as presented in Section 4.0.

The results have also been summarized into a response plan that divides the developing failure modes into three alarm categories and provides specific actions that should be performed to respond to the alarm levels. The Alarm Response Plan is presented as Table 3-1. The purpose of the plan is to provide a framework that can be used by operations personnel to make decisions regarding the condition of the dam and the appropriate level of response during a developing failure mode.

The three alarm levels shown on the Alarm Response Plan (Table 3-1) are directly related to the events presented on the failure mode event trees in Appendix A. The first alarm level "Alert" corresponds to a developing condition of concern, or the initiation of one of the failure modes in the event trees. As the failure mode progresses to the right in the event trees, an unstable condition would develop. This unstable condition corresponds to the "Developing" alarm level. Between the initiation of an unstable condition and failure of the dam is a condition where failure would be considered to be very likely or " imminent." A determination that failure is imminent is made based on an observation of one of the safety conditions listed in Table 3-1 under the "Critical" alarm level. If any of these conditions are observed, then the failure mode has developed to a situation where failure should be considered likely and the evacuation plan should be initiated.

Table 3-1 Silver Creek Dam Early Warning System Alarm Response Plan

Alarm Level	Safety Condition	Response
Alert	***Developing Condition of Concern*** • Piezometer level exceeds high threshold values • Weir flow exceeds high threshold values • Reservoir level within 8 feet of crest • Earthquake occurs • Network communication error	• Operator on duty notified immediately by cell phone • Operator on duty uses the Network Monitoring Station PC and DamSmart to evaluate the alarm condition • Operator conducts a site visit to observe the conditions that caused the alarm • If the alarm is not the result of an equipment malfunction, then the operator remains on site to monitor for a developing unstable condition
Developing	***Unstable Condition Develops*** • Instability develops on the downstream slope • Instability develops on the upstream slope • Sinkhole develops on the upstream slope • Uncontrolled seepage exiting at the downstream toe or abutment contacts • Structural failure allows uncontrolled seepage around spillway • High reservoir level results in seepage through the upper 4.5 feet of the embankment • Debris in the spillway reduces capacity and causes a sudden rise in reservoir level	• Operator initiates the emergency call out list to issue a "warning" of an unstable condition • Operator continues to monitor the situation from the On-Site Monitoring Station • Engineering evaluation is immediately conducted • Warning condition is removed when the alarm conditions return to a normal level, or actions have been taken to successfully stabilize the situation

Table 3-1 Silver Creek Dam Early Warning System Alarm Response Plan (Continued)

Alarm Level	Safety Condition	Response
Critical	***Imminent Failure Condition*** • Instability incorporates half of the downstream slope • Instability or sinkhole on the upstream slope reduces the freeboard to less than 4.5 feet • Whirlpool develops in the reservoir • Turbid flow is exiting the downstream toe or abutment areas at an increasing rate • Reservoir level rises to within 2 feet of the crest • Erosion/slumping occurs in the upper 4.5 feet of the embankment under high reservoir levels	• Operator activates the notification system from the On-Site Monitoring Station **"Silver Creek Dam Emergency. Evacuate the Area Immediately"** • Evacuation Plan is initiated • All clear notification **"It is Safe to Return. Silver Creek Dam is Secure"** is activated when the condition has been stabilized or the flood wave has passed

Section 4

RECOMMENDED DESIGN

4.0 RECOMMENDED SYSTEM DESIGN

4.1 System Requirements

As discussed in Section 1.3, the early warning system consists of two subsystems that have individual performance objectives but are fully integrated into the overall system. These include the detection system and the notification system.

The primary objective of the detection system is to identify a developing condition of concern in advance of failure to allow time for making a decision regarding when failure of the dam is imminent. The detection system has a secondary purpose of providing information to assist in the decision making process during a developing condition of concern.

The notification system is used to communicate the need to evacuate once the decision that failure is imminent has been made. The objective of the notification system design is to provide notification to all inhabitants in the downstream inundation area within the city limits of Silverton. The following sections describe the recommended design for the detection and notification system.

The design outlined below describes a detection system meeting the requirements as discussed above. Figure 2 shows the preliminary layout of the detection and monitoring components. Figure 3 presents a Dataflow Diagram that illustrates the connectivity of the system.

4.2 Detection System

4.2.1 Recommended Detection System Improvements

The recommended detection system consists of improving the monitoring capability for both existing and new instruments installed at various locations on the dam. The improvements will include:

- Installing a reservoir level monitoring instrument that includes the use of a vibrating wire pressure transducer to monitor the reservoir water level, and detect a rapidly rising/dropping reservoir level condition.
- Outfitting the existing piezometers with vibrating wire pressure transducers to detect changes in the seepage performance of the dam and abutments.

- Installing new weir box instruments to collect and measure seepage at the toe of the dam, the contact with the left abutment, and from the horizontal drains. The weirs will be used to monitor changes in the seepage performance of the dam.
- Installing an On Site Monitoring Station to provide a base station at the dam for on-site monitoring during an alarm condition.
- Installing a new Reservoir Level Site Gauge to provide a back-up point of reference for visual monitoring during a flooding condition.

All of the automated sensors would be connected to Measurement Control Units (MCU) that would collect the data from the sensors and compare the readings to predetermined threshold values. If a threshold value is exceeded and verified by redundant instrument values, then the MCU network will initiate a phone call to the assigned city personnel to alert of a developing condition of concern.

4.2.2 Detection System Components

The following is a more detailed discussion of the individual system components.

Automated Data Acquisition and Alarm Notification

As described above, the MCU's located at the dam will collect the data from the instruments and compare the data to threshold values. MCU1 will also collect and store readings on a daily basis from MCU2 and MCU3 for use in long term performance and trending evaluations. Each MCU will be programmed with logic such that it will independently poll its sensor's and compare the readings to predetermined threshold levels. This architecture strengthens the integrity of the system by reducing the risk of the entire system going down due to an equipment failure of one component.

As shown on Figure 3, various instruments are connected to each MCU. Table 4-1 presents what instruments are used, their purpose, and to which MCU they are connected.

Reservoir Level Monitoring

Because high reservoir levels and ultimately overtopping of the dam is a possible failure mode, an automated sensor will be installed to monitor the reservoir level. This instrument will be located on the upstream face of the dam and will be installed within a PVC pipe buried on the face. The sensor will be located at approximately elevation 400 feet. The instrument will be monitored hourly and compared to the threshold levels as discussed in Section 3.0. If the reservoir level rises to within 8 feet of the crest, then the system will activate the callout procedure to City personnel to indicate a developing condition of concern. The reservoir level monitoring will also be used during an alarm condition to keep track of the reservoir level and rate of rise. During normal operation, daily readings will be stored for use in evaluating the historical performance of the piezometers and weirs.

A manually read site gauge will also be installed to provide a visual confirmation of the reservoir level during a flooding condition. This gauge will be constructed in the vicinity of the right abutment at an elevation of 430 feet so it can be easily observed during a developing unstable condition.

Piezometer Level Monitoring

In order to improve the ability to detect changes in the seepage performance of the dam and right abutment, automated sensors will be added to the existing piezometers. These sensors will be monitored hourly and compared to predetermined threshold levels. If a threshold level is exceeded, the system will activate the callout procedure to City personnel to indicate a developing condition of concern. In addition to the hourly readings, daily readings will be stored for historical evaluation purposes.

Seepage Flow Monitoring

As discussed in Section 3.0 seepage through the dam or at the contact with the abutments could lead to a developing unstable condition. To monitor for this condition, weir boxes will be installed at the locations shown on Figure 2. The weir boxes will measure the flow rates from the horizontal drains and 4-inch diameter toe drains that are currently installed in the dam. Weir W4 will be used to collect and measure seepage from the left abutment contact area. The sources of seepage for each of the weir boxed are also shown on Table 4-1. Flow measurement will be collected hourly and compared to predetermined threshold values. If a threshold level is exceeded, then the system will activate the callout procedure to City personnel to indicate a developing condition of concern. In addition to the hourly readings, daily readings will be stored for historical evaluation purposes.

Data Evaluation/Management

As described earlier, data will be recorded daily for historical evaluation purposes. The purpose of collecting and evaluating this performance data on a regular basis is to identify developing conditions of concern through observation of increasing or decreasing trends in the dam's long-term performance. This regular monitoring is a key part of developing an understanding of how the dam normally performs so that changes in performance can be detected and properly evaluated regarding the on-going safety of the dam. Because of the quantity of data being collected and the long term monitoring objective of the system, we recommend that a database application be integrated with the system. The database application will be installed on a personal computer in the City's office and will be used to manage and evaluate the data. The database will also aid in dam-safety reporting tasks.

On-Site Monitoring Station

In addition to the automated instruments, an On-site Monitoring Station will be constructed on the right abutment above the fish ladder. The On-site Monitoring Station will be used during alarm conditions to monitor the on-going instrument readings and to make visual observations of the dam structure. The structure will be a prefabricated building that will house the MCU1 station. In addition to MCU1, the building will be equipped with floodlights for use in observing the condition of the dam at night and a telephone that can be used to call out as part of the notification callout procedures. A permanently installed generator within the station building will power the floodlights in the event of a power failure. The building will also have a ladder installed to provide access to the roof of the building to provide a better vantage point for observing the dam.

4.3 Notification System

The Notification System is designed to provide evacuation notification to the people inhabiting the flood inundation area as shown on Figure 4. This includes inhabitants with disabilities such as the hearing-impaired and the blind. In addition to the people inhabiting the flood inundation area, certain emergency response personnel must be notified in a timely fashion to assure proper and orderly execution of the emergency response plan.

The boundaries of the flood inundation area are based on the over-topping failure scenario as presented in the Silver Creek Dam Break Analysis Report, (PWA, January 18, 2000). The evacuation notice would be issued as a result of an "imminent dam failure condition" as discussed previously. In order to properly discern a dam failure notification from other types of disasters, the Notification System would also include instructions to the public as to the nature of the evacuation.

4.3.1 Evaluation of System Alternatives

To meet the Notification System requirements, various alternatives were evaluated including:

- Television or Radio Station news broadcasts
- Broadcast notification via audible sirens,
- Direct notification via telephone
- Mobile loudspeakers (public address systems)
- Personal notification (door-to-door)

Each system evaluated has its strengths and weaknesses. The following is a brief discussion of the strengths and weaknesses of each of the notification types evaluated.

TV or Radio Broadcast Notification

This type of notification is based on using television or radio station broadcasts to provide flood notification to the public. In an emergency, special messages would be broadcasted to the public. The strengths and weaknesses for this type of notification are listed below.

Strengths:

- Instant communication to all affected people
- Gives detailed information and can keep people up-to-date
- Generally available (most people have TV's)

Weaknesses:

- Emergency management control is limited (involvement by broadcast stations is voluntary)
- Only applicable to local cable and antenna broadcast stations (satellite or non-local programming would not carry the broadcast)
- Limited usefulness during most times of day or when TV/radio is turned off.
- Limited usefulness for people outside of the house at time of emergency.
- Not a selective broadcast audience so emergency message will carry to all people receiving TV/radio signal.
- Not available during power outages.
- Not able to reach sight or hearing-impaired citizens unless specially equipped with TDD/TDY equipment.

Typically, this type of notification is used for school closures and other types of warning or news information affecting a large population area with notifications that do not require immediate public action. Therefore, using this type of notification for the early warning system is not feasible.

Audible Sirens

As the most commonly used notification system, audible sirens provide immediate notification by broadcasting a tone consisting of a siren wail and a voice message. Audible sirens typically consist of equipment mounted on a utility pole and can include options to broadcast pre-recorded voice messages to provide instructions during an evacuation. Most sirens are powered by AC power with a battery backup system in case of power outages and can be controlled via a direct telephone type connection or individually via radio signal from a central Siren Control Unit. Audible sirens are available in both a directional signal of varying degrees and an omni-directional signal broadcasting in a 360° circle. Both types of sirens come in models that can broadcast varying distances up to approximately 5,000 feet. In order to assure appropriate sound quality, the audible sirens are driven by speaker amplifiers similar to those used in public address systems or large music concerts.

A few of the strengths and weaknesses for this type of notification are listed below.

Strengths:

- Instant communication to all affected people.
- Can give detailed information as to what action to take.
- Easily maintained and City owned.
- Flexible and expandable for future emergency action plans.
- Available during both phone and electric outages.

Weaknesses:

- Limited usefulness for people inside sound dampening facilities/buildings at time of emergency, or for the hearing-impaired.
- Not a selective broadcast audience so emergency message will carry to all people within sound range.

In addition to open-air mounted siren systems, an additional method of siren notification is via sirens or warning lights installed within specials structures or facilities such as police departments, fire stations, hospitals, etc. Buzzers, sirens, and/or warning lights can be installed within the structures or buildings housing these facilities to provide notification to the occupants or special personnel within these facilities.

While siren systems are the most popular notification option, siren systems must be designed properly to minimize notification outside of the intended notification zones and should be used in conjunction with other systems to assure that hearing-impaired people are notified as well.

Notification Via Automated Telephone Service

The use of automated telephone services is another type of notification system available to the City. Automated telephone notification is a service provided by an outside (non-City) service provider that uses a computer to phone the affected population, delivering a warning message or evacuation notice. If the line is busy or does not answer the computer keeps dialing the number. If an answering machine answers the phone then the notification message is recorded.

To initiate this type of notification system, a phone call is placed to the telephone service provider. Once a security authentication is completed, the service provider starts a call-out operation to notify the population of the need to evacuate. Most service providers operate with the ability to place 200 calls simultaneously, with the average callout capacity of approximately 3000 calls in one hour (based on a 20-second notification message). Typically, these service providers charge an initial "setup fee", an annual "subscriber fee", and a per call charge for each number called during the emergency.

A summary of the strengths and weaknesses for this type of notification are listed below.

Strengths:

- Targeted, rapid notification to only those affected or "on the phone call list".
- Can give detailed information as to what action to take.
- Relatively low cost.

Weaknesses:

- Only effective if people have a phone, and it is turned on, it is not in use, and they answer the call.
- Cannot reach people if they are not within reach of the phone (outdoors).
- Not available during telephone outages.
- Not effective for hearing-impaired people unless TDD/TDY equipment is used.

Mobile Loudspeakers

Another type of notification method is the use of loudspeakers mounted in vehicles. Police or fire crews typically carry out this notification method by driving a vehicle with a loudspeaker through the effected area broadcasting a live or recorded message to the public. This method of notification is only effective for small areas and takes the crews away from other more essential tasks such as traffic control and/or emergency rescue responses. Additionally, it risks exposure to the personnel and equipment broadcasting the messages.

A summary of the strengths and weaknesses for the use of mobile loudspeakers are listed below.

Strengths:

- Targeted notification to only those affected.
- High degree of credibility to audience.

Weaknesses:

- Limited information can be delivered.
- Only a limited area can be notified quickly.
- Cannot reach hearing-impaired people.
- Messages can be hard to decipher if people are indoors.

- Risks exposure to personnel delivering message.
- Uses equipment and personnel that could be used more efficiently elsewhere.

Personal Notification

Lastly, warning each and every citizen personally in the affected area is also a method of notification. With this method, police officers, fire crew, or City personnel would spread out and blanket the entire inundation area, delivering the evacuation notice personally to all occupants. While this method does insure notification to everyone within the inundation zone, it is not feasible to use it as the only notification system because of the limited amount of time available to get the notice to the evacuees. Similar to the use of mobile loudspeakers, this method of notification is only effective for small areas and taking the crews away from other more essential tasks and risking the personnel and equipment going door-to-door.

A summary of the strengths and weaknesses for warning door-to-door are listed below.

Strengths:

- Targeted notification to only those affected.
- High degree of credibility to audience.
- Very strategic notification.
- Can reach all people, including those with disabilities.

Weaknesses:

- Extremely time consuming
- Risks exposure to personnel delivering message.
- Uses equipment and personnel that could be used more efficiently elsewhere.

4.3.2 Recommended Notification System

As discussed in the previous section, there is no single notification method that can completely meet the desired notification system requirements. Therefore, after examining the strengths and weakness of each of the systems described above, we recommend that a combination of methods should be used to provide evacuation notification for the early warning system. The recommended system improvements consist of a siren network and a personal notification component. In addition to notification sirens and personal notification, certain procedures and polices such as notification flow charts, on-going testing, maintenance, and public education, are recommended to assure proper operation of the notification system.

When the evacuation notice is executed, the audible siren network will be used to notify the majority of the population. The notification flow chart will be used as a guide to notify certain City, police, and fire department personnel as part of the emergency response plan. For the appropriate sound quality, the audible sirens are driven by speaker amplifiers similar to those used in public address systems or large music concerts.

A few of the strengths and weaknesses for this type of notification are listed below.

Strengths:

- Instant communication to all affected people.
- Can give detailed information as to what action to take.
- Easily maintained and City owned.
- Flexible and expandable for future emergency action plans.
- Available during both phone and electric outages.

Weaknesses:

- Limited usefulness for people inside sound dampening facilities/buildings at time of emergency, or for the hearing-impaired.
- Not a selective broadcast audience so emergency message will carry to all people within sound range.

In addition to open-air mounted siren systems, an additional method of siren notification is via sirens or warning lights installed within specials structures or facilities such as police departments, fire stations, hospitals, etc. Buzzers, sirens, and/or warning lights can be installed within the structures or buildings housing these facilities to provide notification to the occupants or special personnel within these facilities.

While siren systems are the most popular notification option, siren systems must be designed properly to minimize notification outside of the intended notification zones and should be used in conjunction with other systems to assure that hearing-impaired people are notified as well.

<u>Notification Via Automated Telephone Service</u>

The use of automated telephone services is another type of notification system available to the City. Automated telephone notification is a service provided by an outside (non-City) service provider that uses a computer to phone the affected population, delivering a warning message or evacuation notice. If the line is busy or does not answer the computer keeps dialing the number. If an answering machine answers the phone then the notification message is recorded.

To initiate this type of notification system, a phone call is placed to the telephone service provider. Once a security authentication is completed, the service provider starts a call-out operation to notify the population of the need to evacuate. Most service providers operate with the ability to place 200 calls simultaneously, with the average callout capacity of approximately 3000 calls in one hour (based on a 20-second notification message). Typically, these service providers charge an initial "setup fee", an annual "subscriber fee", and a per call charge for each number called during the emergency.

A summary of the strengths and weaknesses for this type of notification are listed below.

Strengths:

- Targeted, rapid notification to only those affected or "on the phone call list".
- Can give detailed information as to what action to take.
- Relatively low cost.

Weaknesses:

- Only effective if people have a phone, and it is turned on, it is not in use, and they answer the call.
- Cannot reach people if they are not within reach of the phone (outdoors).
- Not available during telephone outages.
- Not effective for hearing-impaired people unless TDD/TDY equipment is used.

Mobile Loudspeakers

Another type of notification method is the use of loudspeakers mounted in vehicles. Police or fire crews typically carry out this notification method by driving a vehicle with a loudspeaker through the effected area broadcasting a live or recorded message to the public. This method of notification is only effective for small areas and takes the crews away from other more essential tasks such as traffic control and/or emergency rescue responses. Additionally, it risks exposure to the personnel and equipment broadcasting the messages.

A summary of the strengths and weaknesses for the use of mobile loudspeakers are listed below.

Strengths:

- Targeted notification to only those affected.
- High degree of credibility to audience.

Weaknesses:

- Limited information can be delivered.
- Only a limited area can be notified quickly.
- Cannot reach hearing-impaired people.
- Messages can be hard to decipher if people are indoors.

population within the inundation zone with disabilities, the personal notification component will be used to assure they receive the evacuation notification and assistance as necessary.

4.3.3 System Components

Audible Sirens

To provide audible notification to the general public, four sirens will be installed at the locations shown on Figure 5. The siren coverage areas are also shown. Each of the audible sirens are controlled by a centrally located Siren Control Unit which uses radio frequency broadcasts to control the sirens located throughout the evacuation zones.

When the evacuation notice is executed, the sirens will broadcast a wail tone followed by a prerecorded voice message "Silver Creek Dam emergency. Evacuate the area immediately". In addition to the warning tone and message, an all clear message "It is safe to return. Silver Creek Dam is secure." will be used to indicate when the flood risk has subsided.

Notification Flow Charts

The details of who will be notified should be evaluated and incorporated into the City's Emergency Action Plan as Notification Flow Charts. The Notification Flow charts will be used as a guide to execute a call out to certain City staff and crew that are expected to respond to the evacuation emergency action plan. Any inter-agency coordination or notification (i.e., interagency coordinators, Marion County, downstream communities, etc.) will also be warned via the Notification Flow Charts. See Section 5.4 for further discussion on the Notification Flow charts.

Personal Notification for the People With Disabilities

Since the audible sirens are used as the primary notification method, another vital component of the Notification System is a system or procedure to provide notification to the population within the flood inundation area that have disabilities. The police department should maintain a list of addresses of households for people with disabilities that will be affected by the flood inundation. This list of households will then be used during an evacuation event so that police and fire personnel will notify those households personally and can provide assistance as necessary. The individual who will be responsible for assuring the households have been notified and evacuated should be identified in the Notification Flow Charts.

Policies and Procedures

Certain policies and procedures should be incorporated into the City's Emergency Action Plan to assure proper execution of an evacuation. These policies and procedures include:

- A Notification Flow Chart
- A comprehensive public education program,
- An on-going public awareness program,
- An on-going interagency and interdepartmental coordination program,
- Regular scheduled maintenance of the notification equipment,
- Regular testing of the notification system and evacuation procedures.

Table 4-1
Recommended Detection System Instruments for the Silver Creek Dam Early Warning System

Instrument I.D.	Location	Instrument Type	Sensor Type	Purpose	Data Collection Method	Threshold Comparison Frequency	Historical Reading Frequency	Data Management
P-1A&1B	Right abutment	Dual Standpipe Piezometer	Vibrating Wire Transducer	Measure the phreatic surface in the right abutment rock.	ADAS - MCU1	Hourly	Daily	Monitoring System Database
P-2A&2B	Crest of embankment, north end	Dual Standpipe Piezometer	Vibrating Wire Transducer	Measure the phreatic surface in the right abutment rock talus.	ADAS - MCU2	Hourly	Daily	Monitoring System Database
P-3	Crest of embankment, north end	Single Standpipe Piezometer	Vibrating Wire Transducer	Measure the phreatic surface in the right abutment rock talus.	ADAS - MCU2	Hourly	Daily	Monitoring System Database
P-4	Crest of embankment, center	Single Standpipe Piezometer	Vibrating Wire Transducer	Measure the phreatic surface in the embankment.	ADAS - MCU3	Hourly	Daily	Monitoring System Database
P-5	Downstream side of embankment, north end	Single Standpipe Piezometer	Vibrating Wire Transducer	Measure the phreatic surface in the foundation.	ADAS - MCU2	Hourly	Daily	Monitoring System Database
P-6	Downstream side of embankment, center	Single Standpipe Piezometer	Vibrating Wire Transducer	Measure the phreatic surface in the embankment.	ADAS - MCU3	Hourly	Daily	Monitoring System Database
P-9	Upstream side of embankment, north end	Single Standpipe Piezometer	Vibrating Wire Transducer	Measure the phreatic surface in the embankment filter zone.	ADAS - MCU2	Hourly	Daily	Monitoring System Database
P-10	Upstream side of embankment, center	Single Standpipe Piezometer	Vibrating Wire Transducer	Measure the phreatic surface in the embankment.	ADAS - MCU3	Hourly	Daily	Monitoring System Database
W1	Downstream toe, north end	V-notch weir	Vibrating Wire Weir Monitor	Measure total flow from horizontal embankment drains	ADAS - MCU3	Hourly	Daily	Monitoring System Database
W2	Downstream toe, center above outlet	V-notch weir	Vibrating Wire Weir Monitor	Measure flow from embankment toe drain along right side.	ADAS - MCU3	Hourly	Daily	Monitoring System Database
W3	Downstream toe, center north of outlet	V-notch weir	Vibrating Wire Weir Monitor	Measure flow from embankment toe drain along left side.	ADAS - MCU3	Hourly	Daily	Monitoring System Database
W4	Downstream toe, south of outlet pipe	V-notch weir	Vibrating Wire Weir Monitor	Measure flow from seeps occuring along downstream contact of left abutment.	ADAS - MCU3	Hourly	Daily	Monitoring System Database
RL1	Upstream side of embankment, center	Perforated standpipe	Vibrating Wire Transducer	Measure reservoir water level.	ADAS - MCU3	Hourly	Daily	Monitoring System Database
VOB1	Right abutment in vicinity of boat ramp	Painted concrete bollard	N/A	Provide visual confirmation of water level threshold exceedance.	Visual/Manual	Constant during high alert status	N/A	N/A

Section 5

PRELIMINARY EVACUATION PLAN

5.0 PRELIMINARY EVACUATION PLAN

5.1 Overview

A preliminary evacuation plan for the Silver Creek Dam Early Warning System has been formulated and is described below. The evacuation plan divides the inundation area into specific evacuation zones and identifies general routes for the movement of the evacuees out of the inundation areas. For this plan, the assumption has been made that most evacuees will use automobiles as the method of evacuation. Some areas located in remote locations adjacent to Silver Creek might be required to evacuate on foot if floods or other conditions have damaged roads or private driveways to the point where they are impassible by automobile. Evacuation of the facilities located within the inundation zone requiring special attention, such as schools, are also discussed. Coordination of emergency personnel is vital to the success of an evacuation and a brief description of that effort is provided.

5.2 Recommended Evacuation Zones

To facilitate movement of inhabitants within the inundation zone, evacuation zones have been identified as presented on Figure 6. Each zone is identified by a color associated with the area affected by a flood event and arrows indicate the general movement direction to facilitate an evacuation. In most cases, each zone has more than one evacuation route with a road or highway to be used to carry the flow of vehicular traffic.

In order to facilitate vehicular traffic flow during the evacuation, an Evacuation Traffic Control Plan should be created by the City and made part of the evacuation plan. Recommended road closures, vehicle traffic counts, one-way traffic flow, and traffic direction by emergency personnel, barricades, etc. should be considered and planned for.

5.3 Evacuations of Special Facilities/Structures

In addition to evacuation zones, special facilities such as schools or other buildings that have a large number of inhabitants require special coordination to assure that the occupants are evacuated. Both Eugene Field Elementary School and Silverton Union High School are located within the inundation zone. Each of these schools should receive the notification of the "Developing Alarm" condition and should initiate procedures to prepare for evacuation before the evacuation order is given. Further study might indicate that occupants from the Silverton Union High School can evacuate on foot to higher ground outside of the inundation zone to the west. The location of Eugene Field Elementary School precludes this alternative, and busing of the students will most likely be required.

5.4 Coordination of Emergency Response

During an evacuation, the coordination of City, police, fire, and medical personnel is essential. To achieve an orchestrated response and to assure the proper personnel are notified, two notification flow charts should be developed. The notification flow charts should be based on the following alarm conditions:

- Unstable Condition has Developed
- Failure is Imminent or Has Occurred

The flow charts should provide a detailed process of notification for the individual alarm conditions. The notification flow chart should detail the names, titles, and phone numbers of those who are responsible for notification, from the individual observer to the responsible agency representatives. The flow chart should denote the priority or order in which each person on the chart is notified.

The Notification Flow Chart should be distributed to all key supervisory and operational employees. The chart itself should be posted at key locations such as, but not limited to:

- On-site Monitoring Station at the dam;
- City Hall (administrative offices);
- Police Station (dispatch);
- City Shops (maintenance facilities); and
- Fire Stations.

In addition to the notification flow charts, all personnel must be trained on the proper response including where and how they report in and what their responsibilities are during the alarm conditions. Each assignment must be fully understood and coordinated. The agency that will coordinate the evacuation must be identified and an emergency chain of command must be established in advance.

Section 6

SYSTEM IMPLEMENTATION

6.0 SYSTEM IMPLEMENTATION

The next phase of work will involve implementation of the system improvements presented in this report. At this time, we have assumed that the new instrumentation, the Automated Data Acquisition System (ADAS), the data evaluation/management tool, and the notification system would be programmed and installed by a combination of Squier Associates, subcontractors, and City personnel. Therefore, preparation of formal plans and specifications for construction of the proposed improvements will not be required.

6.1 Finalizing The Remaining Implementation Details

The remaining design and installation details that need to be determined in the implementation phase consist of 1) developing threshold levels for the instrumentation, 2) final siting of the siren locations, and 3) finalizing the details of the notification and evacuation procedures. In addition, the City is concerned about vandalism at the dam site. The final installation details will need to consider methods for reducing the exposure of the equipment. A detailed implementation schedule should be prepared that defines when the components will need to be installed and operational.

6.2 Tasks and Responsibilities

In general, the implementation phase will include five main tasks:

1) System construction,
2) System installation,
3) System calibration and testing,
4) Preparing Operations and Maintenance Documentation, and
5) Training Operations and Maintenance on the use and required maintenance of the monitoring and early warning system.

The system construction task will consist of procuring the instrumentation, ADAS, and notification equipment; programming the ADAS; development and programming of the database tool; and performing bench tests of the detection and notification system components. The bench testing is performed in a controlled environment to assure that the system components are working properly and communicating appropriately before they are installed in the field. Installation of the systems would then proceed with 1) installing the new instrumentation,

2) installing the MCU's, 3) installing the data evaluation database tool, 4) installing the notification sirens and 5) performing a complete test of the system operation to demonstrate that it is functioning properly.

Operations and maintenance documentation will be prepared to provide guidance for the operation and maintenance of the detection and notification systems. This would also include documentation on the system configuration. The operations and maintenance documents will serve as the main references for the training task. After the system has been successfully installed and tested, the training task will be performed. The training will involve a discussion of the response procedures for alarm conditions, activation of the notification system and how to operate and maintain the system. The task will also include "hands on" experience for the users in performing the typical operations that will be required for successful operation of the system. This task will be considered complete when the system has been accepted in accordance with the plan as described in the following section.

6.3 Acceptance Criteria Plan

The Acceptance Criteria Plan (ACP) outlines necessary acceptance criteria for successful completion of the implementation phase. The ACP is initially developed by the system developers and then reviewed and commented on by the City of Silverton personnel. The acceptance criteria plan will be used during the system training session for final acceptance of the system.

The system will be deemed successfully complete when the following items are completed to the satisfaction of the City or otherwise resolved with the development team.

1. Demonstrated ability to detect and notify City personnel of an exceedance of threshold levels representing a developing condition of concern at the Dam.

2. Demonstrated ability to transfer historical instrument data from MCU1 to the designated City workstation PC using a telephone modem communication link.

3. Demonstrated the ability to initiate a reading of the instruments from the remote workstation PC and the on-site monitoring station using a laptop PC.

4. Demonstrated the ability to activate the evacuation notification system.

5. Demonstrated the ability to test (silent and/or audible) the evacuation notification system.

6. Demonstrated the ability to load the dam monitoring instrumentation data into the database application and generate the required time history plots for on going dam safety evaluation.

7. The Operations and Maintenance provides the information needed to operate and maintain the system.

8. The user training session objectives have been completed.

Section 7

COST ESTIMATE

7.0 COST ESTIMATE FOR IMPLEMENTATION

We have prepared an estimate of the costs for the implementation phase. These costs are presented in Table 7-1. The cost estimate is based on the design as described in the previous sections and on typical unit costs with some consideration given to constructibility.

The estimate does not include the costs for supplying electricity, lighting, and telephone service to the On-Site Monitoring Station. The estimate also does not include the cost for supplying electricity and/or utility poles (if required) for the locations of the notification sirens.

To allow for uncertainties and unknowns that remain until the design and installation details are finalized in the next phase of work, the cost estimate includes a 20 percent contingency.

The average annual cost for maintenance and service is generally assumed to be 5 percent of the equipment cost. For the estimate provided on Table 7-1, the average annual cost would be approximately $8,000.

Silver Creek Dam Early Warning System

Planning Level Cost Estimate for Implementation

Items	Quantity	Estimated Cost
Supply and Install Monitoring/Detection Equipment		
Measurement Control Units	3	
Pressure Transducers for Piezometers	10	
Reservoir Level Monitor	1	
Horizontal Drain and Toe Drain Weir Boxes	4	
Reservoir Level Site Gauge	1	
On-Site Monitoring Station	1	
		$147,800
Supply and Install Notification System		
Notification Sirens	4	
Control Unit	1	
		$106,100
	Total Installation Cost	$253,900
O&M Manual/System Training (labor)		$16,700
	Subtotal	$270,600
	Contingency for Uncertainty (20%)	$54,200
	TOTAL COST	**$324,800**

Assumptions:

City to provide:

Locations for sirens on existing/new utility poles with 110AC.

Laptop PC and workstation PC in the operations center that meets system software requirements.

On-site generator to power emergency floodlights.

Section 8
LIMITATIONS

8.0 LIMITATIONS

The scope of this report is limited to the preparation of a preliminary design for an improved monitoring and early warning system for the Silver Creek Dam in Silverton, Oregon. The system design is based on our understanding that the city desires to improve the ability to detect a developing condition of concern regarding the safety of the dam, and to provide a system for notifying the downstream inhabitants of the need to evacuate under and imminent failure condition.

This report has been prepared to present the preliminary design and a planning level cost estimate for implementation of the system improvements. The next phase of work includes finalizing the remaining design and installation details, and implementing the design improvements as recommended in this report.

Our description of the project represents our understanding of the significant aspects relevant to the system improvements needed to detect a condition of concern and to provide notification to the inhabitants within the inundation zone.

This report has been prepared for the exclusive use of the City of Silverton for specific application to the Silver Creek Dam in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made.

9.0 REFERENCES

Cornforth Consultants, Inc., "Seismic Stability Analysis - Silver Creek Dam", Prepared for the City of Silverton, July 21, 1999.

Oregon Water Resources Department, "Phase I Inspection Report, National Dam Safety Program, Willamette River Basin - Silver Creek Dam", in cooperation with U.S. Army Corps of Engineers, Portland District, June 1981.

Philip Williams & Associates, Ltd., "Silver Creek Dam Break Analysis - Final Report", Prepared for the City of Silverton, January 18, 2000.