

RECLAMATION

Managing Water in the West

Design, Estimating and Construction Review

Truckee Canal Issue Evaluation

**Newlands Project, Nevada
Mid-Pacific Region**



Truckee Canal Headworks and Derby Diversion Dam



**U.S. Department of the Interior
Bureau of Reclamation
Technical Resources
Design, Estimating and Construction Office
Denver, Colorado**

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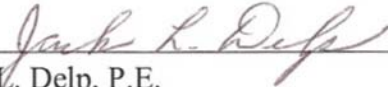
**Design, Estimating and Construction Review
Truckee Canal Issue Evaluation**

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2/26/08
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Truckee Canal Risk Assessment

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I. Introduction

The purpose of a Design, Estimating and Construction Review (DEC Review) is to assure Reclamation's executive level managers that major products related to design, cost estimating, and construction are technically sound and appropriate for their intended use. The benefits to Reclamation include increases in quality, accuracy, credibility, and transparency to customers and the general public. These reviews are conducted with a broad corporate perspective in mind to identify issues, impacts, and/or ramifications of a corporate nature that may not be evident from the technical or local perspective.

On January 5, 2008, a breach occurred in the Truckee Canal (Canal), a Newlands Project facility owned by Reclamation and operated and maintained by the Truckee-Carson Irrigation District (TCID). Soon thereafter, a Risk Assessment Team was formed to evaluate the potential risks of placing the Canal back into service. Karl Wirkus, Deputy Commissioner, Operations; in concurrence with Mike Finnegan, Acting Mid-Pacific Regional Director, and David Gore, Mid-Pacific Regional Engineer; requested a DEC Review on the findings and recommendations of the Risk Assessment Team (January 24, 2008 e-mail).

The DEC Review Team (DEC Team) consisted of the following members:

- Perry Hensley, P.E., Senior Advisor, DEC/DSO
- Jack Delp, P.E., Consultant, Reclamation Retiree

II. Background

Description of Incident

At approximately 4:00 a.m. on January 5, 2008, a small section of the Canal failed, diverting a substantial amount of water into the City of Fernley (Fernley), Nevada. Five hundred and ninety (590) homes were flooded, about 138 with moderate to severe damage. No fatalities occurred.

Description of Project

The Canal is part of Reclamation's Newlands Project. Its purpose is to take water that is diverted from the Truckee River at Derby Diversion Dam and transport it into Lahontan Reservoir, providing some agricultural irrigation along the way.

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To meet the intervening irrigation demands, check structures, turnouts and smaller canals have been built. The Gilpin Wasteway (about 2 miles upstream of Fernley) was also constructed to divert water back into the Truckee River, should the need arise. The Carson River also flows into Lahontan Reservoir and helps fill it.

The Canal was designed and constructed by Reclamation in 1903. It is approximately 31 miles in length, beginning at Derby Dam Head Works and ending at the Lahontan Inlet Structure. The January 5, 2008, breach occurred at approximately Milepost 13.6. This approximate location was based on a references system created subsequent to the Canal breach with limited data; thus all references to stationing and mileposts should be considered approximate.

In 1926, operation and maintenance of the Canal was contracted to the TCID. Since then, Reclamation's oversight role has been to determine the amount of water that may be diverted into the Canal, monitor TCID's maintenance activities, and provide dam safety-related services for Lahontan Dam.

The decision to approve the diversion of water from the Truckee River in the Canal is made by Reclamation. Once Reclamation makes an approval, it is up to TCID to monitor flows in the Truckee River and make day-to-day decisions on the amount of flows to divert at Derby Dam – including making actual diversions.

Truckee Canal Risk Assessment Team

At the request of the Mid-Pacific Regional Engineer, the Technical Service Center (TSC) provided emergency response assistance to repair of the breach. During a meeting held on January 23, 2008, in Reno, Nevada, the Regional Engineer asked that a Truckee Canal Risk Assessment Team be formed to look at the data collected on both the Canal failure and repair and to evaluate the potential risks of placing the Canal back into service. Specifically, the Risk Assessment Team was to formulate answers to the following questions:

1. In order to resume operations of the Canal what other repairs need to be done immediately?
2. What are the criteria, standards, risks, and engineering judgments that will go into assessing the ability of the Canal to pass a range of flows, ranging from zero to full capacity with some acceptable risk?
3. From Item 2, what operational restrictions should be imposed, and ensure that the basis of these restrictions are fully reasonable and justified?

4. What are the short- and long-term recommendations for needed actions to reinitiate operations of the Canal?
5. What procedures should be recommended and followed in resuming flows in the Canal?

The Risk Assessment Team was formed as requested and met February 18 through 22, 2008, to address these questions. The urgency associated with the Canal situation, necessitated the initiation of the DEC Team review before the Risk Assessment Team efforts were fully completed. Due to the expedited nature of the DEC Review, the DEC Team was only provided a preliminary draft of the Truckee Canal Issue Evaluation Technical Report of Findings (ROF) prepared by the Risk Assessment Team, just prior to their closeout briefing on February 22, 2008. The DEC Team also attended that closeout briefing for the ROF and held discussions with Risk Assessment Team members on the morning of the briefing.

III. Supplemental Information and Field Review

Prior to the scheduled DEC Review, the DEC Team members were provided with an information package for review. The package included:

- Volume I – Reports, Memorandums, Correspondence, and Photos (1993 to Present)
- Volume II – Review of Operation and Maintenance (RO&M) (1993 to Present)
- Volume III – Geologic Investigations, Muskrat Burrow Investigations, and Hydrologic Analysis
- Volume IV – Miscellaneous Reports and Analysis
- Volume V – Photogrammetric Horizontal Alignment, Photogrammetric Sections, and Hydraulic Sections

These materials were supplemented by a draft copy of the Forensic Evaluation Report for the recent Canal failure, original specifications, additional hydraulic analysis of the Canal, and other materials listed in the Reference section of this report.

Review of Informational Materials

Volume I information makes reference to Operations and Maintenance (O&M) Contract No. 7-07-20-X0348 between TCID and Reclamation as the document that established the guidelines and principles for the O&M of the Canal, with the

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United States retaining ownership. These materials also included a January 17, 2003, memorandum signed by the Mid-Pacific Regional Director placing restrictions to Canal operations when Canal flows exceed 700 cubic feet per second (ft³/s) for any given 5-day period at a specific Canal location where seepage problems had been identified. Review of the information reveals that there are several specific locations along the Canal where seepage areas have been identified along the outside canal embankments that require close monitoring during high flow conditions.

Volume II provided a history of past TCID's Review of Operation and Maintenance Program (RO&M) inspections of the Canal, including established Field Examination Guidelines dated 1991. Annual RO&M Inspection Reports dated March 9, 2007; February 13-17, 2006; March 9-10, 2005; February 2003; February 2000; November 3-6, 1997; and April 13-15, 1993, were provided. A review of this information gives indications that the TCID Operation and Maintenance Program continually had outstanding Category 2 and 3 corrective work recommendations which were carried over from past inspections. It was also noted the performance of TCID's RO&M Program was given a rating "Fair" in earlier reports and "Good" in later reports, yet the identified corrective work seemed to be repeated.

Volume III documented in detail the geologic conditions of the local area at the January 5, 2008, breach site (approximate Station 714+00), which provided the DEC Team with an understanding of the findings and repairs made at the site prior to the DEC Team's field review of the Canal on February 21, 2008. This material also included a comprehensive report of the muskrat burrow investigations and illustrated the magnitude of damage that the muskrats can do to the canal embankments. A draft *Initial Hydrologic Analysis of the Truckee Canal Breach* provided a good history of the 100-year old Canal. It identified incidents of breaches in the canal embankments at other areas, the estimated Canal flows at different times of a given year, how releases are made to the Canal at Derby Diversion Dam, and the level of flow measurements that exist along the Canal.

Volume IV contained a Special Joint Inspection Team Report of a comprehensive RO&M inspection of the Canal conducted on January 15-17, 2008, and concluded the Canal was in such condition that returning the Canal to previous operation conditions was not recommended without major improvements to the embankments. Conditions of the Canal embankments due to the vegetation growth and numerous visible burrows were identified as a major concern.

Volume IV included a *Preliminary Analysis of Precipitation near Fernley, Nevada*, for January 4-5, 2008; *Current and Historic Procedures and Practices for Truckee Canal Operations*, and a report describing the Canal failure that occurred on January 5, 2008. The Canal operations information acknowledged that flows in the Canal in past practice had flows exceeding 800 ft³/s at times of high flows, that rapid changes in Canal flows were a norm, which include "spike"

conditions (spike condition raising the flows in the canal rapidly as much as 2 feet or more), monthly flow quantities diverted at Derby Diversion Dam to Canal were established by Reclamation and governed by established Operating Criteria and Procedures (OCAP), and Canal operations are the responsibility of TCID.

Review of Draft Forensic Evaluation Report

On February 21, 2008, the Regional Engineer provided the DEC Team with a draft of the *Truckee Canal Embankment Forensic Evaluation Report* (Forensic Report), dated February 15, 2008. The report provided the team with a good understanding of the events that had taken place on January 5, 2008, after TCID had received notice of the canal embankment failure near Milepost 13.6 and the subsequent actions taken to close the breach. The report discussed the estimated flow conditions based on information provided by Reclamation. Discussions of the field investigations performed at the breach site were included which noted the canal embankment adjacent to the breach was approximately 8 feet high and is composed of a homogenous mixture of silt and clay with minor amounts of sand and gravel. Embankment material lift lines were not distinct and there were no horizontal layers of pervious material. The report noted the evidence revealed the outside embankment slope blanketed with sand and vegetative materials derived from years of cleaning the canal prism. Finally, the report reviewed potential modes of failure and concluded that the leading cause for the January 4-5, 2008, breach was piping due to rodent activity when Canal flows were ramped up rapidly.

Field Review

On February 21, 2008, the DEC Team met Mid-Pacific Regional Engineer Dave Gore at Reclamation's Lahontan Basin Area Office in Carson City, Nevada, for a general field review and site visit to the Fernley reach of the Canal. The DEC Team had requested the review to obtain a "hands-on" appreciation of the Canal conditions that were depicted in the numerous photos provided in the review materials.

The first area visited was the site of the January 5, 2008, breach, approximately Station 714+00. The canal embankment at the breach area had been completely reconstructed with rock facing on the embankment slopes on both sides of the operating road. The existing Canal conditions in the area were reviewed and discussed with the Regional Engineer. The group noted the bottom width of the Canal was approximately 30 feet wide, which is considerably wider than the original design sections. Evidence of disturbance in the invert of the Canal due to high velocity flows at time of the breach condition was also noted. The area at Station 714+50 was viewed where muskrat activity had been reported and investigated. Animal burrows were noted in adjacent areas, mostly located at or near the visible high water mark area within the canal prism and upper areas of

the canal embankment outside slope. Along the embankment outside slopes, brush and tree vegetation appeared to have substantial growth and was very noticeable.

The DEC Team then traveled upstream on the south operating road to the Fernley Check Structure, located near Station 695+50. The check structure appeared to be the original construction and the concrete was in poor condition. All the mechanical equipment for raising and lowering the metal slide gates was unpainted and consisted of ring/pinion type gearing with center threads for raising and lowering the gate stems. The ability of actual use and operation of the gates appears questionable. There was no apparent maintenance to the mechanical equipment for an extended period of time. The check structure gates were in down position and there were additional bays of equal width each side of the slide gate openings where boards can be dropped in slots. This method appeared to be the means to control flows. Make-shift wooden triangular sections were visible on each side of the check structure, apparently used for checking flows at the interface point of the structure and concrete canal lining slope. It appears that at any given time flows are checked to a set level to allow canal water surface elevation to be raised to allow deliveries through existing turnouts. A turnout structure was located upstream of the check structure on the north embankment. The mechanical condition of the turnout was similar to the check structure slide gates.

Next, the DEC Team traveled to the section of Canal west of the bridge at Station 684+50 and traveled the north operating road in a westerly direction. This area was reviewed from the operating road level mostly in an upstream direction to approximately Station 550+00. The team's general observation of this section revealed numerous areas where either muskrat or beaver activity was present. Some burrows could easily be associated with noted settlement areas on the operating road and potential connecting burrows were identified on the embankments on the north side of the Canal. The existing turnout structures constructed within the canal prism along this section were found to be in both structurally and mechanically poor condition. The lateral systems that linked to given turnouts were poorly maintained and overgrown with vegetation. The team questioned how water deliveries are made in any type of scheduling manner by TCID. Also, an individual homeowner had constructed a make-shift over-the-bank water pipe, which obviously was used for minor irrigation of yards or lots. The pipe was buried under the operating road at a shallow depth. It appeared the flows were either pumped or siphoned when canal water levels allowed.

On the south side of the Canal the DEC Team observed a notch that was cut in the canal embankment to allow canal flows to enter a small pond area next to a home. A pipe was also buried through the embankment near the notch. There was continuous stretch of vegetation overgrowth with noticeable rodent burrows in the upper section of the Canal. There was no apparent usable operating road. While

the team was at the site, TCID had a track-mounted backhoe with long reaching boom excavating approximately 2 feet of sediment from the Canal bottom and dragging the bucket up the south slope of the canal prism, removing some vegetative overgrowth and covering exposed burrows in the process. On the north operating road, TCID had a motor patrol blading the operating road.

The next area visited extended from one check structure site to another, Station 695+50 to approximately Station 850+00. Both check structures were visited briefly and appeared to be in poor condition. This area's turnout structures were in a similar poor condition as the previous turnout structure. Burrow activity and vegetation overgrowth were noted in an almost continuous stretch along both canal embankments within the prism and along the outside embankment slopes. With the canal prism in dewatered state, the team noted silt deposits in most areas, a wider invert than design specifications, and dried moss along the invert in many areas. At approximate Canal Station 800+00, the Regional Engineer identified the area of the December 1996 Canal breach that occurred on the north embankment. This area is currently being developed with new home construction just below the Canal. The conditions of the canal embankments were similar to the previous areas with visible burrows along the water line and vegetation overgrowth along both canal embankments.

The DEC Team's final site to visit was along Field District Road, at approximately Station 1100+00. The Regional Engineer pointed out the site of the January 1921 canal breach and the location that zone 1 materials were obtained for the backfilling of the January 5, 2008, breach.

At various locations throughout the field visit along the Canal, the DEC Team inspected the rodent burrows more closely to determine the magnitude of the burrow size and depth. At one location, the team walked to the invert of the Canal to inspect what appeared to be a beaver hole near the invert. The hole was found to be open and extended some distance into the north canal embankment.

IV. Findings and Recommendations

The Truckee Canal Issue Evaluation Report of Findings (ROF) represents a pioneering effort in the application of risk assessment to provide needed insight to a major canal safety issue. The Risk Assessment Team is to be commended on their innovative application of risk methodology and qualitative risk descriptors to provide decision makers with a rational basis for making informed operational decisions in a highly visible and politically challenging situation.

The following summarizes the DEC Team's key findings and associated recommendations based on the review of the ROF, available supporting information, site visit, and presentations and discussions with the Risk

Assessment Team. A discussion of the specific ROF recommendations is provided in the “Discussion of Risk Assessment Team Recommendations” section of this report.

DECTCRA – 01

Finding: The qualitative risk descriptors used by the Risk Assessment Team mask the actual contribution of the potential for loss of life in the comparative evaluation of risk from the consequences of operation at different depths of flow in the Canal. This may have contributed to the assignment of “High” risk for failure scenarios that would otherwise, based only on mission or project impacts, have been assigned a lower risk descriptor. Further, the necessary assignment of “High” risk for all failure scenarios with minimal (but non-zero) loss of life potential, is to some extent contrary to Reclamation’s current Public Protection Guidelines for Dam Safety that provide increasing justification for risk reduction based on increasing loss of life potential.

Recommendation: Consider the application of alternative risk descriptors for consequences that allow for variation in the anticipated potential loss of life. Use these alternative descriptors to revise the risk, or alternatively articulate in the risk reduction decision process recognition of the limited potential for loss of life from a canal failure.

DECTCRA – 02

Finding: The qualitative risk descriptors used by the Risk Assessment Team encompassed a broad spectrum of risks, including loss of life, property losses, and the impacts of a failure on the ability of the federal project to make water deliveries. This is a somewhat different approach than traditionally used in the evaluation of dam safety risk. Reclamation’s Dam Safety Program has largely focused on the risk to loss of life and only indirectly accounted for other risks by establishing limits on the probability of dam failure. In the DEC Team’s opinion, the inclusion of the loss of project benefits and property damage into the risk assessment process warrants further consideration. Particularly since the loss of project benefits would nearly always be anticipated to have a major impact on local project beneficiaries. Qualitative descriptors that do not distinguish the relative financial impact may obscure the relative magnitude of the losses and prevent an appropriate comparison of the risk from a broader agency or societal perspective.

Recommendation: Consider the de-aggregation of the qualitative risk descriptors to portray the risk from loss of life, property damage, and loss of

project benefits separately, so the decision makers can have a clearer understanding of the relative contribution of the risk from various consequences.

DETCRA – 03

Finding: Typically canals have been designed to standards that are reflective of the generally limited potential for catastrophic consequences associated with the inherent limitations on canal breach outflows. While the potential consequences of a canal failure are increased by urban development and other land use changes, the application to canals of performance expectations more closely aligned to dams (with their often much higher breach flow potential) could lead to excessive efforts at canal mitigation that are disproportionate to their actual contribution to societal risk.

Recommendation: Reclamation needs to ensure that the application of risk evaluation to canals is consistently structured to appropriately address the relative risk and be fully reflective of the inherent differences in breach characteristics between canals and dams.

DETCRA – 04

Finding: The Risk Assessment Team's recommendation to reduce the risk of a canal failure by limiting the canal flows to 150 ft³/s appears overly restrictive and that higher canal flows associated with higher levels of risk, may be appropriate, particularly for interim (1 to 5 year) operation of the canal. It is the DEC Team's opinion that there would be significant risk reduction achieved by operating the Canal at a depth below the current concentration of animal burrows located in the upper portion of the embankment near the recent high water level. Based on a conservative review of the average historic rates, it is considered highly likely that there have not been any recorded failures of the Canal at average flows below 400 ft³/s. This flow rate is calculated to provide an unchecked flow depth about 2-3 feet below the water surface at the time of the recent failure. Providing for uncertainties in the historic flow data, a flow depth associated with an unchecked flow of 350 ft³/s may provide an appropriate short-term operational constraint for risk reduction on the Canal.

Recommendation: Consider establishing an unchecked canal flow of 350 ft³/s as the interim (1 to 5 years) operational limit on Canal flows to reduce risk from a canal failure until permanent risk reduction measures can be implemented.

DETCRA – 05

Finding: Consideration of the DEC Team findings presented in DETCRA – 01, 02, and 03 above, may provide an opportunity to develop risk guidance for canals

that allows significantly higher probabilities of failure than would otherwise be appropriate for dams. As such, the long-term risk reduction objectives ultimately established by Reclamation may be significantly lower than those applied in the ROF. This may allow consideration of a broader, and less costly, range of potential structural modifications to obtain the target risk reduction for long-term operation of the Canal than has currently been included in the ROF.

Recommendation: Consider the development of additional structural alternatives to provide long-term risk reduction based on anticipation of lower levels of required probability of failure. Examples include reworking upper portions of the crest, partial lining, shallower cutoff, or other cost effective measures currently excluded by the Risk Assessment Team based on the lower levels of risk reduction provided.

DECTCRA – 06

Finding: The Risk Assessment Team’s recommendation of a partial geomembrane liner on the north canal embankment as a way of providing additional risk reduction is not endorsed by the DEC Team. Although it is desirable to minimize the risk of canal failure, this additional level of short-term risk reduction would far exceed the risk reduction objectives suggested by Reclamation’s Dam Safety Guidelines for dams with a significantly higher potential for loss of life than is presented by operation of the Canal. At best, the DEC Team considers the placement of a temporary partial liner to provide a diminishing risk reduction for the investment. In addition, the installation of such a liner may unnecessarily delay the return of some level of flow to the Canal.

Recommendation: Limit the focus of short-term risk reduction efforts to operational limits on Canal flow, response planning, increased monitoring, and other procedural measures.

DECTCRA – 07

Finding: Over time, the proximity of the Canal to populated areas in the Fernley area has changed the collaborative relationships between local interests, and state, federal, and local agencies. These changes must be considered in TCID’s O&M program. This will require the comprehensive O&M program prepared by TCID, and reviewed and approved by Reclamation, to be proactive with outside interests and consistent with good stewardship of the Canal.

It is of the utmost importance that TCID develop and test a comprehensive Emergency Action Plan (EAP), develop and implement detailed Standard Operating Procedures (SOP) including monitoring requirements, and develop and

implement a comprehensive Maintenance Program that will bring the Canal conditions to current standards within an acceptable timeframe. From the materials provided, the DEC Team was unable to confirm such plans or procedures have been developed or are incorporated in the TCID O&M program.

Recommendation: Take necessary actions to ensure TCID develops and implements a written EAP, SOP, and Maintenance Program for the Canal. The DEC Team suggests the written EAP and SOP programs be current and completed before flows are returned to the Canal.

DECTCRA – 08

Finding: The review of materials assembled for the DEC Review and the physical conditions of existing structures reviewed during the site visit, reveal the service life of the Canal structures has nearly expired. Concrete conditions show extreme levels of deterioration, mechanical equipment has been exposed to the elements with minimum to no protection, and the functionality of the moving components to meet the intent of the original design is questionable.

Recommendation: Perform a comprehensive structures analysis to establish the present conditions of all structures associated with the Canal and have a comprehensive report of findings prepared. Planning for replacement structures is warranted and should be undertaken by Reclamation to maintain the mission of the project.

DECTCRA – 09

Finding: Based on materials provided for review and field observations, the present Canal control features and capabilities appear to be minimal, and nonfunctional in some cases. The potential risks to the public in the Fernley area have changed over the years. The Canal control capabilities are outdated. The response times to an event similar to the January 5, 2008, breach need to be assessed.

Recommendation: The present operational controls of the Canal available to TCID should be reviewed in detail. The means for measuring flows, the control of flows, the communications systems, and the ability of TCID to respond to an emergency event should be analyzed and assessed for needed improvements to meet current needs. The assessment should also discuss any modernization and improvements to the current control and security systems that would provide better canal protection and meeting the newly developed EAP commitments.

DECTCRA – 10

Finding: Based on the DEC Team’s site visit to the Canal through the 11.7 mile area near Fernley, the existing canal prism conditions give the impression that the design canal section has changed from the cross sectional area that the original design sections indicate. The team observed that the earth canal prism appears to have areas where the canal section has increased in width and some areas where the section invert appears to be a shallower depth. Based on the original specification design sections there were 11 canal sections for both concrete and earth canal sections with flow design “Q” ranges from 1,189 ft³/s to 1,520 ft³/s and the design flow depths at those flows ranging from a “d” value of 9.0 feet through 22.0 feet. Using 1189 ft³/s as a conservative estimate for the design flow and the flow of 750 ft³/s, which is the anticipated flow on January 5, 2008, the Canal at present is capable of conveying approximately 70 percent of design flows. At the Fernley Check Structure, it was obvious, by the wooden triangular sheets, the TCID in their current operation of the Canal check water elevations over the full width of the structure at this location, which does not appear to have been the intent in original design. Based on discussions with the Regional Engineer and from the DEC Team’s field observations, it appears the normal maintenance practice by TCID is to excavate the canal prism without survey control, which in the long term has contributed to the change in the prism sections from the original design and construction and could have an effect on how the silt deposits are distributed throughout the canal prism because of changing flow velocities at given sections of the Canal.

Recommendation: Considering the existing canal prism sections have experienced changes from O&M activities through the years and the cross sectional area and invert elevation of the Canal is directly related to flow conditions, it is recommended that a complete survey of the Canal earth prism sections be performed to establish the current conditions of the prism. This survey information will provide valuable information for engineering and maintenance decisions by Reclamation and the District in development of the TCID Maintenance Program.

V. Risk Assessment

The Risk Assessment Team adopted a qualitative approach to evaluate the risk associated with the continued operation of the canal. The approach consisted of assigning descriptors of High, Moderate, or Low for both the likelihood of a canal failure and the associated consequences. These descriptors were then used with the risk matrix in Table 1 to assign the overall risk to one of five risk categories.

Table 1. Failure Mode Risk Evaluation Matrix

CONSEQUENCES OF FAILURE	FAILURE MODE LIKELIHOOD		
	LOW Likelihood $\leq 10^{-5}$	MODERATE $10^{-3} \leq \text{Likelihood} \leq 10^{-5}$	HIGH Likelihood $> 10^{-3}$
HIGH Consequence Category	III Low Likelihood High Consequence	II Moderate Likelihood High Consequence	I High Likelihood High Consequence
MODERATE Consequence Category	IV Low Likelihood Moderate Consequence	III Moderate Likelihood Moderate Consequence	II High Likelihood Moderate Consequence
LOW Consequence Category	V Low Likelihood Low Consequence	IV Moderate Likelihood Low Consequence	III High Likelihood Low Consequence

Probability of Failure

Although the descriptors for the probability of failure were intended to be qualitative, the Risk Assessment Team loosely associated numerical ranges for the probability of failure for each of these descriptors, as shown in Table 2.

Table 2. Relative Likelihood of Failure Separating Failure Descriptors

Descriptor	Likelihood of Failure
Low	Likelihood $\leq 10^{-5}$
Moderate	$10^{-3} \leq \text{Likelihood} \leq 10^{-5}$
High	Likelihood $> 10^{-3}$

Through discussions with the Risk Assessment Team, it is understood by the DEC Team that these ranges of probability are generally indicative of the Risk Assessment Team’s estimation of the anticipated recurrence probabilities for canal failure associated with each of the qualitative descriptors.

Consequences

Due to the lack of established guidance for assessing the relative impact associated with the consequences of a canal failure, the Risk Assessment Team adopted definitions for the qualitative descriptors of these consequences based on the National Institute of Standards and Technology, *Federal Information Processing Standards Publication 199* (FIPS 199). Although these definitions provided a reasonable basis for the Risk Assessment Team to evaluate the relative

impacts of a canal failure, the DEC Team has some concern that these definitions may not provide sufficient distinction between low and high potential loss of life scenarios.

The qualitative descriptors used by the Risk Assessment Team may to some extent mask the actual contribution of the potential for loss of life in the comparative evaluation of risk for operation at different depths of flow in the canal. Specifically, the DEC Team is concerned that this may have contributed to the assignment of “High” risk for failure scenarios that would normally be anticipated to have a limited potential for loss of life and would otherwise, based only on mission impacts, have been assigned a lower risk descriptor. The assignment of “High” risk for all scenarios with any loss of life potential, is to some extent contrary to the Reclamation’s current Public Protection Guidelines for Dam Safety that provide increasing justification for risk reduction based on increasing loss of life potential. Further, within Reclamation’s Dam Safety Program, dams with a low potential for loss of life are typically excluded from the program and generally are not considered for specific actions to reduce risk from a dam failure.

The application of risk evaluation to canal safety is a relatively new endeavor for Reclamation and the engineering profession as a whole. As such, the DEC Team is also concerned that the use of “High” risk descriptors, based in large part on the limited potential for loss of life, may lead to an expectation for canal performance that is out of proportion to the actual risk they represent to the public. Typically, Reclamation’s canals have been designed to standards of loading that are reflective of the generally limited potential for catastrophic consequences associated with the inherent limitations on breach outflows. While the potential consequences of canal failures are unarguably increased by urban development and other land use changes, the application of performance standards intended for dams with unlimited breach flow potential should be carefully considered and justified on a case-by-case basis.

VI. Canal Operations

Understanding of Truckee Canal Operations

Purpose

The purpose of the Canal is to convey prearranged monthly quantities of water released at the canal head works located at Derby Diversion Dam to Lahontan Reservoir and meet irrigation demands of the TCID, as defined in the established agreement.

Canal Operations

Diversion of allotted quantities of water from the Truckee River/Derby Diversion Dam is released at the Canal Head Works Structure to the Canal for conveyance to Lahontan Reservoir and/or TCID to meet contract water demands. It appears the release of flows at the head works has no set flow restrictions in to the Canal and there is no means to measure released flows at this location.

The Canal conveyance features include 11 prism sections, three tunnels, concrete-lined and earthen canal sections. The Fernley area consists of earthen canal prism sections. The original design sections have canal flow design capacities ranging from a $Q=1189 \text{ ft}^3/\text{s}$ with bottom width 14.0 feet to $Q=1520 \text{ ft}^3/\text{s}$ bottom width 20.0 feet.

The Canal control structures consist of two spillway structures (Derby and Gilpin Spillways), two flow measurement features (Wadsworth and Hazen), five check structures (depicted on Canal Inspection Maps), and an undisclosed number of turnout structures. The flow measurement features are located at Milepost 7.6 (Wadsworth) and Milepost 27.9 (Hazen) and operate with accuracy in the range of 10 to 15 percent.

The DEC Team has the understanding that during the winter months Reclamation and TCID's main objective is to capture as much flow from the Truckee River as allowed and convey it to the Lahontan Reservoir to meet Carson Irrigation District demands in the following water season. It is understood that TCID's practice is to place the Canal in a "free flow" unchecked condition to allow high flow conditions in the Canal and convey as much water as conditions will accommodate. This includes "spiking" releases from the Canal head works at Derby Diversion Dam. Flow regulation is performed by the two flow measurement feature readings, the two spillway structures, canal flow restrictions within the prism, and releases made at the head work structure. Based on the DEC Team's understanding of the Canal conditions, it is questionable if true flow-through conditions are possible with current check structure conditions and if raising all gates at these structures is indeed practiced. Also, with the existing Canal conditions, it is apparent that original design flows are being considerably impacted and the Canal free board must be encroached upon to convey flows that are approximately 30 percent less than minimum design flow. ($Q=1,189/750 \text{ ft}^3/\text{s}$)

The DEC Team also understands that TCID will make more uniform releases at the head works to meet water orders placed by landowners during the irrigation season. Canal flows are checked up at respective check structures to set elevations to meet the scheduled deliveries. Deliveries may also be continued to Lahontan Reservoir as monthly water releases determined by Reclamation. It is also understood that many landowners adjacent to the Canal obtain water from the Canal through their own "make-shift" pipe systems or by other means.

VII. Discussion of Risk Assessment Team Recommendations

The Risk Assessment Team developed several recommendations in the ROF. These recommendations are discussed by the DEC Team as follows:

Recommendation No. 1

In the 11.7 mile Fernley reach of the Canal, the water surface (operating in either checked or unchecked conditions) should be restricted to a level not to exceed that produced by the unchecked flow at 150 ft³/s. Canal stage increases or decreases should not be allowed to exceed 1-foot per day in any reach of the Canal. There are no direct costs associated implementing this recommendation.

DEC Team Discussion

The Risk Assessment Team established the 150 ft³/s limitation based on the depth of canal flow that would be anticipated to represent a “Moderate” likelihood of canal failure. As shown on Table 1, the Risk Assessment Team generally associates the “Moderate” descriptor with a likelihood or annual occurrence of failure between 1 in 1000 and 1 in 100,000. The recommendation to limit the probability of failure to this level is understood to be driven largely by the “High” descriptor for the consequences of canal failure. This level of risk is considered by the DEC Team to be generally consistent with the risk reduction objectives of Reclamation’s Dam Safety Program, but far exceeds the risk objectives associated with current design loading guidelines for Reclamation canal facilities. As an example, current hydrologic design loadings for new canal structures are generally based on 100-year occurrence probabilities (10 times more likely than the upper limit of the Risk Assessment Team’s “Moderate” descriptor).

As discussed in section V above, the “High” descriptor for consequences is driven in part by the Risk Assessment Team’s evaluation of a limited but non-zero potential for loss of life. Although, there could always be a conceivable scenario developed for loss of life from a canal breach, based on the recent Canal failure, and the lack of a known case of loss of life from a canal failure, it is the DEC Team’s opinion that there is only a limited potential for loss of life associated with a failure of the Canal under current conditions. Further, it is the DEC Team’s position that the Risk Assessment Team’s recommendation to limit the risk of canal failure is overly restrictive and that higher levels of failure probability, consistent with annual occurrence probabilities of 1 in 100 may be more appropriate, particularly for short-term (1 to 5 years) operation of the Canal.

The DEC Team acknowledges that there is a high risk of Canal failure associated with the continued operation of the Canal at depths associated with the 750 ft³/s flow during the recent failure (estimated on the order of 1 in 10 annually or higher based on the number of recorded past failures). However, the DEC Team believes there would be significant risk reduction by operation of the Canal at a depth below the current concentration of animal borrows located in the upper portion of the embankment near the high water level. Based on a conservative review of the average historic flow rates, it is highly likely that there have not been any recorded failures of the Canal at average flows below 400 ft³/s. This flow rate is calculated to provide an unchecked flow depth of 6.1 feet which is estimated to be about 2.3 feet below the water surface at the time of the recent failure. Providing for uncertainties in the historic flow data, the DEC Team considers that a flow depth associated with an unchecked flow of 350 ft³/s may provide a more appropriate short-term operational constraint for risk reduction on the Canal.

Recommendation No. 2

To further lower the estimated risk value rating to **III** (Low Likelihood-High Consequence), a temporary lining system should be added to the north side Canal embankment from the invert to a stage level equal to the unchecked Canal flow of 150 ft³/s, plus some freeboard, through the entire Fernley reach. The temporary lining system is estimated to last approximately 3 years; the length of time estimated to implement a permanent Canal structural fix (see Recommendation No. 6 below). Additionally, known seepage locations should receive a similar temporary lining covering the entire wetted perimeter, plus freeboard, at the 150 ft³/s flow level. The cost assessment rating to implement this lining addition is **LOW**.

DEC Team Discussion

The ROF indicates that the installation of the partial liner would further reduce the likelihood of a canal failure to a “Low” descriptor consistent with an annual occurrence probability of less than 1 in 100,000 for a period of 3 years. Although it is desirable to minimize the risk of canal failure, this level of short-term risk reduction would far exceed even that suggested by Reclamation’s Dam Safety Guidelines for dams with a significantly higher potential for loss of life than is presented by operation of the canal. The DEC Team considers the placement of a temporary partial liner to at best provide a diminishing risk reduction for the investment. Further the installation may unnecessarily delay the return of some level of flow to the Canal.

The potential for placing the partial liner higher up on the north embankment to permit larger canal flows was discussed with the Risk Assessment Team. The Risk Assessment Team expressed concern with depending on the liner to provide significant risk reduction in the higher reaches of the embankment

where there is significantly more animal activity and a higher potential for connectivity of the burrows through the embankment. Further the Risk Assessment Team anticipated that significantly more grading and construction effort would be required to install the liner. The DEC Team generally concurs with the limited benefits of placing the partial liner higher on the north embankment, even in combination with the DEC Team's own Recommendation DECTCRA – 01 to allow operational flows up to 350 ft³/s.

Recommendation No. 3

Truckee-Carson Irrigation District's operations procedures for the Canal should be thoroughly reviewed and revised to provide the necessary and timely response to emergency situations similar to the January 5, 2008, event. In order to adequately address this recommendation, a Standing Operating Procedure (SOP), an Emergency Action Plan (EAP), and a Facility Improvement Plan (FIP) should be prepared by TCID, then reviewed and approved by Reclamation. The cost assessment rating to develop and implement the SOP and the EAP is considered **LOW**. The cost assessment rating to develop and implement the FIP is considered **MODERATE to HIGH**.

DEC Team Discussion

The DEC Team agrees with the Risk Assessment Team's recommendation that a TCID maintenance program is required. The DEC Team believes the program should be comprehensive, well thought out, and resources provided to meet the program objective. The DEC Team believes the RO&M Special Report prepared January 15-17, 2008, provides the necessary information and conditions of the Canal as it presently exists to supplement any current TCID scheduled maintenance activities and allow the development of a comprehensive maintenance program. The development, planning, and implementation of the maintenance program should include an in-depth review of conditions identified in the RO&M Report, engineering solutions to rectify the existing conditions to bring features to current standards, development of resource planning to accomplish the tasks identified, and the necessary oversight and guidance by management to prioritize and schedule the work to bring the Canal back to design operational conditions.

The DEC Team considers the EAP to be a key element of the total TCID O&M program. The DEC Team recommends the Reclamation-approved EAP be in place and functional before the Canal is placed back in service.

The DEC Team also considers the SOP to be a key element of the total TCID O&M program. SOP's, should be developed in writing and implemented before the Canal is placed back in service.

The DEC Team believes TCID oversight and management of the coordination and interface of their maintenance program, EAP, and SOP are critical to the success of the total TCID O&M program.

Recommendation No. 4

In coordination with the SOP and EAP mentioned in Recommendation No. 3, a surveillance program should be developed, exercised, and implemented prior to the reintroduction of any flows into the Canal. This program should interface with the SOP and the EAP; it should delineate staffing requirements, patrolling procedures, and monitoring and recording requirements. The program should present procedures and schedules for cleaning of the downstream Canal embankment slopes to allow for observation and inspection. The surveillance program must be approved by Reclamation prior to implementation. The cost assessment rating to develop and implement the required surveillance program is considered **LOW**.

DEC Team Discussion

The development of the EAP will address concerns expressed by the Risk Assessment Team though the necessary collaboration with the City of Fernley, local agencies, state and federal agencies, and local interest as the EAP is developed. The EAP should address all scenarios of potential canal breaches or impacts in the area and how the event, if it were to occur, would be responded to.

The DEC Team believes a comprehensive TCID SOP and Maintenance Program will address the flow conditions and canal maintenance issues expressed in the Risk Assessment Team's Recommendation no. 5.

The DEC Team also believes the TCID SOP must include a canal surveillance program that will cover the known canal seepage areas, means to systematically inspect Canal embankments during abnormal flow conditions, and for security of the Canal and its related features.

Recommendation No. 5

A comprehensive maintenance plan must be developed. The plan must include components that ensure an aggressive approach to removing vegetation and limiting the animal damage. The plan should include an accountability system in which TCID would show Reclamation schedules for completion milestones, including intermediate status reports. The cost assessment rating to develop and implement the required maintenance program might be considered **MODERATE**.

DEC Team Discussion

The DEC Team supports this Recommendation, but it is the DEC Team's position that without knowing the TCID current Maintenance Program that an in depth review and reassessment of the current maintenance needs for the Canal is warranted.

Recommendation No. 6

Repair the Canal through the Fernley reach with a full structural fix that will address all piping failure modes. The cost assessment rating to develop and implement a full structural fix in the Fernley reach is considered **HIGH**.

DEC Team Discussion

The DEC Team strongly supports this recommendation. The extensive damage from animal burrows to the seepage integrity of the Canal embankments (particularly in the upper portions of the embankments) is well documented in numerous inspection reports and was observed first hand by the DEC Team during the site visit. As further supported by investigations performed since the January 5 failure, it is considered highly likely that either a reduction in seepage path or a direct connection of the animal burrows across the north canal embankment contributed substantively to this latest of nine recorded failures on the Canal. The DEC Team also considers it highly likely that continued operation of the Canal at higher flows, without specific measures to restore the existing damage from animal borrowing, would result in further canal failures. Therefore it is considered essential that modifications be performed to reestablish the seepage integrity of the Canal embankments before the Canal is operated at normal higher level flows. Further, the DEC Team is concerned that continued operation at restricted flow levels may lead to increased animal activity near the newly established maximum water surface, which could over time, further threaten the seepage integrity of the embankments and increase the risk of canal failure at the restricted operational levels.

Recommendation No. 7

Determine the risk of other failure modes not addressed by this report (hydrologic and seismic).

DEC Team Discussion

The DEC Team agrees that assessment of risk from a Canal failure associated with hydrologic and seismic loading conditions may provide useful information for the consideration of permanent modifications needed to safely return the Canal to operations at normal high flows. However, it is the DEC Team's opinion that these risks would not significantly influence the interim operational levels recommended by the DEC Team in this report.

Recommendation No. 8

Determine the risk of those reaches of the Canal that were not evaluated in this report.

DEC Team Discussion

The DEC Team supports this recommendation, but does not consider it necessary to complete further risk assessments prior to making decisions on interim Canal operations.

VIII. Alternatives for Structural Modification

The DEC Team was provided pre-appraisal cost estimates dated February 22, 2008 and February 27, 2008, prepared by the Technical Service Center, Denver, Colorado; with the understanding the estimates were generated for the exclusive purpose to provide a means to compare relative estimated costs for potential options being considered to improve the earth canal sections of the Canal in the 11 mile area that has been developed near the town of Fernley.

The cost information provided to the DEC Team were based on the assumption the Canal had a flow of 800 ft³/s and the reach for consideration was 61,776 feet in length (11.7 miles). The pre-appraisal mark-ups are 5 percent Mobilization, 20 percent Design Contingencies, and 30 percent Construction Contingencies, and 33 percent Non-Contract Costs. The four cost estimates consisted of the following:

- Full Canal Concrete Lining Option – Construction Cost \$44,000,000.
- One-Half Canal Concrete Lining Option – Construction Cost \$29,000,000.
- One Half Canal Riprap Lining Option – Construction Cost \$28,000,000.
- Pipe Option – 198-inch RCP-Single Line – Construction Cost \$390,000,000.

- Fully Penetrating Soil Cement Bentonite Cutoff Wall – Construction Cost \$20,000,000.

The DEC Team understands the pre-appraisal cost estimates were developed from limited in situ and materials investigations and may be subject to significant revision as additional information is provided. Further, it is anticipated that these estimates would be subject to revision and may significantly underestimate the final feasibility cost estimate for any preferred project medications.

The DEC Team believes it would be prudent to develop additional possible options for returning the Canal 11 mile earth section to full-capacity operation based on an anticipation of lower levels of required failure probability. Further, it is suggested that each option be associated with specific levels of risk reduction to assist the decision makers in the selection of the lowest cost option that will provide the desired level of public safety and project reliability.

IX. Conclusion

The Truckee Canal Issue Evaluation represents a pioneering effort in the application of risk assessment to provide needed insight to a major canal safety issue. The Risk Assessment Team's efforts highlighted several complex issues inherent in the nature of canals that have a major impact on the definition of acceptable risk and will require extensive discussion within the profession to reach consensus. However, the DEC Team identified several key aspects of the risk assessment that could have significant impact on the permissible flows for interim operation of the Canal that should be fully represented to the decision makers in their consideration of the Risk Assessment Team's recommendations provided in the ROF. The significant conclusions from the DEC Team review are:

- The Risk Assessment Team used qualitative risk descriptors that do not sufficiently distinguish between failure situations in which the potential for loss of life is low (even considered remote) and those where it is fully anticipated that there would be extensive loss of life.
- The use of risk descriptors that mask the relative contribution of loss of life potential, combined with the lack of current risk guidelines for canals, led the Risk Assessment Team to establish structural performance objectives more closely associated with dams than have traditionally been used for canals.

- The Risk Assessment Team's recommendation to limit interim canal flows to 150 ft³/s is overly conservative given the remote possibility of loss of life as demonstrated by the recent failure and represents a significantly higher standard of performance than is typically required for even new canals.
- Based on recent investigations, past performance, and the Risk Assessment Team's estimation of likelihood of failure, the DEC Team believes that with the present condition of the embankments, limiting interim (1 to 5 years) Canal flows to 350 ft³/s would be a reasonable operational constraint commensurate with the identified risk for Canal failure.
- The DEC Team strongly supports the Risk Assessment Team's recommendation to perform permanent structural modifications to the canal embankments even if the Canal is not returned to full capacity operation.
- The return of the Canal to operation should be conditioned on TCID preparation and implementation of a Reclamation-approved Emergency Action Plan and Standard Operating Procedures.
- The current conditions of the Canal control structures, flow measurement features, and canal prism should be comprehensively documented including detailed surveys of the earth sections of the Canal prior to the return of flows to the Canal.
- A comprehensive program should be developed for the control and eradication of the burrowing conditions that presently exist. The DEC Team believes interim limitations of Canal flows will invite an escalation of the burrowing issue to lower levels in the canal prism unless action is taken immediately.

X. References

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