APPENDIX D

DAM RISK INVENTORY ASSESSMENT

Table of Contents

Section **Page**

LIST OF EXHIBITS

LIST OF TABLES

LIST OF FIGURES

D.1.0 DAM RISK INVENTORY ASSESSMENT

Since Storm 2006, the City of El Paso has performed a number of investigations and studies to address dam safety. These studies have included:

- Inspection of twenty-two dams to assess flood damage and current conditions (URS Corporation (URS), December 2006);
- Hydrologic and hydraulic analyses of selected dams per Texas Commission on Environmental Quality (TCEQ) 2007 Guidelines (URS, February 2008);
- Concept designs and cost estimates for improvement of selected dams estimated to require upgrades per TCEQ Guidelines (URS, July 2008); and
- Preparation of an Emergency Action Plan (EAP) for twenty-seven El Paso dams (URS, June 2008).

The above studies focused on current dam condition and hydraulic adequacy. The purpose of the dam risk assessment undertaken for the Stormwater Master Plan (SMP) was to address other modes of failure (e.g. piping failure) not considered previously, and to rank dam safety needs in terms of risk for prioritizing associated capital improvements. This assessment analyzed twenty-four dams in the Central, Northeast and Northwest watersheds as shown in Exhibit D-1.

D.1.1 Methodology

In 2004, the Federal Emergency Management Agency (FEMA) and American Society of State Dam Safety Officials (ASDSO), with the help of URS, developed a risk-based dam safety prioritization system for assessing an inventory of dams. The City of El Paso dams were evaluated using this system. This system is a simplified version of what is used by the United States Bureau of Reclamation (USBR). Risk, for the purposes of this section, is defined as the product of probability of failure and consequences of failure. The probability of failure for a given failure mode was estimated using the data available from previous studies (URS, December 2006, February 2008, June 2008, and July 2008), information in the City of El Paso, and TCEQ files that were available at the time of the analysis.

In terms of consequence of failure, an important part of the prioritization process is a new simplified “lives consequence assessment” methodology developed by Wayne Graham of USBR based on dam failure hydrologic information typically available to state regulators. This process was used in the development of the Life Loss Potential (LLP) for the El Paso Dams. The LLP methodology was verified against a number of case histories with comprehensive dam break/inundation modeling.

The prioritization process:

- builds on the successful elements of various dam safety ranking systems currently in use;
- simplifies potential failure modes analysis and dam risk assessment processes;
- is based on accepted international standards; and
- is flexible and quantitative.

The process covers the most important failure modes for a wide variety of dam types and explicitly quantifies risks posed by different failure modes. This allows the likelihood of each failure mode and its consequences to be computed and graphed, and then the failure mode risk and overall dam risk quantified and compared against risk tolerability criteria.

Information for the dams was compiled by reviewing As-Built drawings, Drainage On-Call Services Work Order 1 and Work Order 3 data and reports, Dam Safety Inspection Reports, FEMA Countywide Flood Insurance Study (FIS), Texas Department of Transportation (TxDOT) 2004 Topography, City of El Paso 2006 Orthophotography, and photographs. Table 2 summarizes the information that was collected and calculated for the evaluation process. There are gaps in the data that limited this analysis which are reflected in Table 2. Fields in Table 2 with the comment “unknown” denote information that was not available at the time of this analysis. Some of the failure modes included in the prioritization process were not used for this analysis due to the lack of relevant data for those modes.

Risk was only analyzed for failure modes where there was sufficient information to warrant an analysis. The failure modes evaluated for the Earthfill/Earth Rockfill/El Paso Dams included:

- Threshold Failure Flood (failure due to flood overtopping);
- Piping Potential (failure due to internal erosion of the dam due to piping of fine material);
- Normal Stability (failure precipitated by a slope failure of the embankment);
- Emergency Spillway Erosion (failure due to headcutting erosion in the spillway during spillway flows that would affect the integrity of the dam);
- Principal Spillway/Outlet Conduit (failure of the dam due to a failing conduit system); and
- Piping along Conduit (failure of the dam due to piping of fines through the dam along the outside of a conduit).

Failure modes not analyzed:

- For Earthfill Dam: Earthquake (insufficient information on the seismic design criteria for the structures); and
- For Outlet Works: Tower stability (failure mode is for earthquake loading and there was no information in the files on the design of the towers related to seismic criteria).

Most of the City of El Paso is in Seismic Zone 1, with some outlying areas in Zone 2. High Hazard Class dams in Zone 2 require special investigation (United States Department of Agriculture [USDA] Natural Resources Conservation Service [NRCS}, July 2005). A more current National Seismic Hazard Map released by the United States Geological Survey (USGS) in May 2008 shows the earthquake peak horizontal acceleration (PHA) that as a 10 percent (%) chance of being exceeded in 50 years has a value between 4 and 5% g for El Paso (USGS NRCS, May 2008).

Some of the failure modes can only occur with a substantial sustained head of water impounded. A factor was applied to the probability of failure to account for the fact that the reservoirs are dry most of the year and only impound water for short periods after rain events.

The normal stability, piping and the outlet works/conduit failure modes were multiplied by the estimated annual exceedance probability that a flood event will fill a reservoir to the auxiliary spillway. This is still a very conservative analysis since the reservoirs are designed to fully drain in a matter of days.

The risk categorization of each dam was established by taking the calculated risk level and ranking its position consecutively relative to recognized risk criteria. Each dam was ranked by total risk and by individual failure mode risk. Risk categories parallel those used by the USBR and reflect different levels of risk used in this evaluation. The risk categories used for the El Paso dams are:

- Priority A - Annualized risk greater than 10^{-2} (1 in 100);
- Priority B - Annualized risk between 10^{-3} and 10^{-2}; and
- Priority C - Annualized risk less than 10^{-3} (or 1 in 1,000).

These risk values are not analogous to an annual probability, such as the 0.01 annual exceedance probability associated with a flood with a 100-year return period, for two basic reasons:

1) Risk is a multiple of an estimated probability of event (in this case dam failure) occurrence times a numerical value for potential consequences; the 100-year flood only reflects an estimated probability of event (in this case a flood of an estimated magnitude); damage associated with the flood is not considered in the value;

2) The 100-year flood is statistically derived from storm or flow data collected at local gauges, and as such typical statistical parameters such as confidence limits can be used to define the accuracy of the return period estimate. For the dam risk analysis both the estimated probability of event (dam failure) and the estimated consequences are consensus-based values derived from nationwide dam engineering professionals; and their purpose is to provide a profession-wide basis for identification of structures that have issues to be considered for action. There is no statistical means to estimate confidence limits or other accuracy indicators on the values selected.

Figure D-1 presents an example of risk worksheets for an earthfill dam. Figure D-2 presents an example risk profile of the various failure modes for an earthfill dam.

D.1.2 Dam Analysis Results

The El Paso Dam Total Risk Profile is presented in Figure D-3a. Figure D-3a ranks the total annualized lives risk of each of the dams relative to the different priority classifications. According to Figure D-3a, 17 of the 24 El Paso dams are Priority A classification. Of the remaining dams, 4 dams are Priority B, 1 dam is Priority C, and 2 dams are below Priority C. Over 70% of the dams that were analyzed received an overall Priority A classification, prompting further review of the results. Table D-1 shows those 17 dams listed by watershed, their contributing failure mode(s) with Priority A and B classification noted, as well as the LLP values for each dam. The most useful means to review the assessment results is to focus on two aggregations of the failure modes -- overtopping (i.e. risk due to hydraulic inadequacy) and piping/conduit -- and to review those results separately.

Figure D-4 shows the risk by piping and conduit failure modes and expresses the probability of failure of the 24 dams based on those two failure modes. According to Figure D-4, analyzing only piping and conduit failure modes, 10 of the 24 El Paso dams receive Priority A classification. Of the remaining dams, 11 dams are Priority B and 3 dams are below Priority C. An analysis of this risk demonstrates that the consequence of failure (e.g. lives at risk) rather than probability of failure drives the high risk ranking in almost all cases, as shown in Figure D-5. In other words, the density of population downstream of the dam is so high that even a low risk of failure results in the failure mode receiving priority attention.

Figures D-6 and D-7 present the results of the risk analysis for the flood failure mode. This analysis shows that when considering flood failure mode alone, only 5 of the 24 El Paso dams receive Priority A classification, 1 dam is Priority B, 2 dams are Priority C, and the remaining 12 dams are below Priority C. This clearly demonstrates that the risk of dam failure due to overtopping of the dam is not a major concern for the majority of the dams. The five Priority A dams for flood failure mode are Van Buren Dam, Dam 7, Dam 4, Dam 3, and Dam 2. The return period for the storms estimated to cause

overtopping of these Priority A dams are each substantially less frequent than the 1000-year flood; i.e. the risk of overtopping is substantially less than the risk of flooding associated with each project identified in Section 6.0. As with piping failure, a review of the analysis shows that the consequences rather than the probability of failure are the driving force behind the high risk values as shown in Figure D-7. The elevated estimated risk of these dams is created by the large populations located immediately downstream. These dams are all in the Central Watershed.

Figures D-8, D-9, and D-10 show the risk for each dam by each specific failure mode for the Central, Northeast and Northwest watersheds respectively.

D.1.3 Recommendations

The dam safety-related projects recommended for inclusion in the Capital Improvement Program (CIP) derive from three sources: the risk analysis (discussed above), previous dam inspection, and previous study of hydraulic adequacy per TCEQ rules.

D.1.3.1 Recommended Projects per Dam Risk Analysis Study

It should be noted that the seismic-related failure modes were not analyzed due to lack of information in the files regarding seismic design basis of the embankments or the outlet works. Based on El Paso's seismic region, it is very likely that many dams could be classified as high risk (above Priority A line) due to seismically inadequate design based on current standards. Notwithstanding the seismic failure modes, the following recommendations are based on the above-described dam risk analyses, in order of priority in terms of dam safety risk.

Upgrade of Dam 9. The existing corrugated metal pipe (CMP) principal spillway would be replaced by a reinforced concrete pipe (RCP) principal spillway. An upgrade to modern construction with concrete cylinder pipe and filter protection to prevent piping along the conduit would lower the probability of failure and resulting total risk several orders of magnitude.

Upgrade of Van Buren Dam. The concept design for this project is provided in *Concept Designs And Cost Estimates For Improvement Of Selected Dams Estimated To Require Upgrades Per TCEQ Guidelines* (URS, July 2008), and consists of the following major components:

- Install roller compacted concrete (RCC) stepped spillway;
- Install parapet wall (maximum height ~5 feet) around the top of embankment;
- Plug one of the two 72-inch CMP outflow pipes;
- Excavate area in southwest corner of reservoir; and

- Install stilling basins and line outflow channel to protect against erosion and reduce velocities downstream.

Upgrade of Keystone Dam. Construct a toe drain system to mitigate seepage per previous URS Technical Memos (URS, February 2008). This project will lower the probability of failure due to seepage-induced piping in the embankment. Inspections by TCEQ (TCEQ, September 2006) and URS (URS, February 2008) each noted the presence of ongoing seepage through Keystone Dam.

Early Warning System Development. Ten dams have estimated risk above the Priority A line and no recommended capital improvements. In this circumstance (low, but apparent probability of failure coupled with high consequences of failure), the recommendation is for installation of early warning systems/procedures to address the elevated risk. A project is recommended for the CIP to design and implement early warning procedures.

D.1.3.2 Recommended Project per Previous Dam Inspection

Upgrade of Pershing Dam. The Storm 2006, coupled with the 2008 URS inspection of Pershing Dam, helped to identify the lack of flood pool between the elevation of the principal spillway and auxiliary spillway. URS developed a concept design to address this issue (URS, July 2008). Since the lack of flood pool results in relatively high frequency flooding, this project should be allocated a relatively high priority within the CIP.

D.1.3.3 Recommended Projects per Previous Study of Hydraulic Adequacy per TCEQ Rules

A previous study (URS, February 2008) by URS of a selected series of El Paso dams identified Dam 4, Dam 5, Dam 10, Keltner Dam, and Van Buren Dam as not meeting TCEQ standards for hydraulic adequacy. Concept designs to meet TCEQ standards and to provide additional benefits (e.g. expand the flood pool) were developed as a follow-on (URS, July 2008) for these structures.

Since the development of these designs, TCEQ issued proposed revised dam safety rules (TCEQ, 2008) which revised the definition of a regulated dam. This new definition is expected to become law in 2009. In the previous definition, a dam was a structure over 6 feet in height (with no volume stored criterion); in the revised definition, dams of relatively tall height (up to 70 feet tall) but very small storage (15 acre-feet or less) are excluded from Texas Dam Safety Regulation. Based upon the new definition Dam 4, Dam 5, Dam 10, and Keltner Dam are each excluded from Texas Dam Safety Regulation; only Van Buren Dam is regulated by TCEQ.

All five of these improvements are recommended for inclusion in the CIP. It is recommended that improvement of Van Buren Dam receive significantly higher priority than improvement of the other structures, which will no longer considered regulated.

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D.2.0 REFERENCES

City of El Paso, 2006. Orthophotography.

Federal Emergency Management Agency (FEMA). Flood Insurance Study (FIS) Volumes 1-3. http://www.ci.el-paso.tx.us/development_services/flood_zone_maps.asp.

Texas Commission on Environmental Quality (TCEQ), 2008. Texas Administrative Code Title 30 Part 1 Chapter 299 (Dams and Reservoirs). http://www.tceq.state.tx.us/compliance/field_ops/dam_safety/damsafetyprog.html.

TCEQ, September 2006. TCEQ Dam Safety, Field Operations, Dam Evaluation Report "Keystone Dam." September 27.

Texas Department of Transportation (TxDOT), 2004. Topography. El Paso Office.

United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), July 2005. Earth Dams and Reservoirs Technical Release-60

United States Geological Survey (USGS), May 2008. National Seismic Hazard Maps.

URS Corporation (URS), July 2008. Capital Improvements Report, Drainage On-Call Services Task 4 of Work Order 3. Concept Designs and Cost Estimates for Improvement of Selected Dams Estimated to Require Upgrades per TCEQ Guidelines.

URS, June 2008. Emergency Action Plan (EAP), City of El Paso, High Hazard Dams.

URS, February 2008. Dam Analysis Report, Drainage On-Call Services Task 3 of Work Order 3.

URS, 2008. Electronic Data - Appendix E, Dam Analysis Report, Drainage On-Call Services, Task 3 of Work Order 3.

URS, 2007a. Electronic Data-Appendix G, Drainage System Evaluation and Audit Report, Drainage On-Call Services, Work Order 1.

URS, 2007b. Electronic Data-Appendix I, Drainage System Evaluation and Audit Report, Drainage On-Call Services, Work Order 1.

URS, December 2006. Drainage System Evaluation and Audit Report, Drainage On-Call Services Work Order 1.

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EXHIBIT

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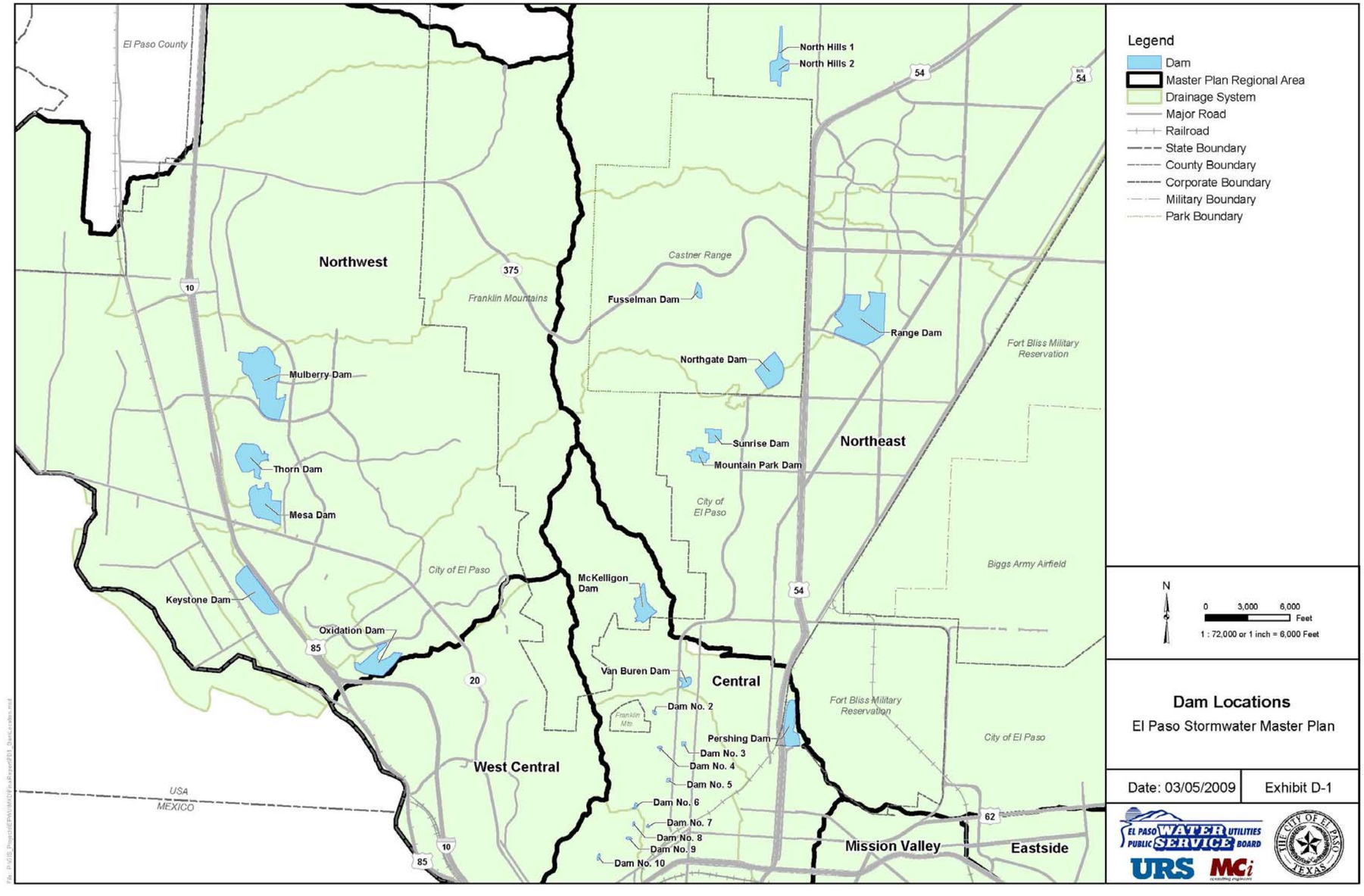
Exhibit D-1. Dam Locations - El Paso Stormwater Master Plan



TABLES

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Table D-1. Dams Categorized as Priority A - Contributing Factors

DAM	TOTAL RISK VALUE	LLP	FLOOD	CONDUIT	PIPING	UNLINED CHANNEL	NORMAL STABILITY
CENTRAL WATERSHED							
Dam 9	3.60E-01	119	*B*	**A**			
Van Buren Dam	2.70E-01	371	**A**	**A**			
Dam 7	2.20E-01	30	**A**	*B*			
Dam 4	8.00E-02	20	**A**	*B*			
McKelligon Dam	4.90E-02	24,300		**A**	**A**		
Dam 2	3.40E-02	239	**A**	**A**			
Dam 3	2.00E-02	45	**A**	*B*			
Pershing Dam	1.40E-02	4,780		*B*	*B*		
NORTHEAST WATERSHED							
North Hills 2 Dam	1.40E-01	6,160		**A**	*B*		
North Gate Dam	3.20E-02	8,080		*B*	*B*	*B*	*B*
Range Dam	2.20E-02	5,400		*B*	*B*	*B*	*B*
Sunrise Dam	1.20E-02	2,960		*B*	*B*	*B*	*B*
Mountain Park Dam	1.20E-02	3,860		*B*	*B*	*B*	
NORTHWEST WATERSHED							
Keystone Dam	1.06E-01	304			**A**		*B*
Mulberry Dam	3.60E-02	8,860		*B*	*B*	*B*	*B*
Mesa Dam	3.10E-02	7,710		*B*	*B*	*B*	*B*
Keystone Dam	1.06E-01	7,710		*B*	*B*	*B*	*B*
Thorn Drive Dam	1.20E-02	2,930		*B*	*B*	*B*	*B*

The Total Risk Values should not be considered as an indication of the actual likelihood of a fatality from dam failure. These numbers serve only to provide a relative risk ranking across the El Paso dam inventory.

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Table D-2a. El Paso Water Utilities Dam Summary Table

DAM NAME	PMF Passed	Peak Breach Discharge (cfs)	10-Year Inflow (cfs)	EARTHQUAKE		FLOOD		PIPING		NORMAL STABILITY	
				Source/Comment	Value	Source/Comment	Value	Source/Comment	Value	Source/Comment	Value
C-Dam 10	No	3396.0	119.5	unknown	-	TFF	2.05E-05	unknown	-	unknown	-
C-Dam 2 (Ft. Blvd.)	No	39621.0	196.2	unknown	-	TFF	5.50E-05	unknown	-	unknown	-
C-Dam 3 (Louisiana)	No	13159.0	272.0	unknown	-	TFF	4.24E-04	unknown	-	unknown	-
C-Dam 4 (Memphis Lower)	No	3602.0	227.0	unknown	-	TFF	3.94E-03	unknown	-	unknown	-
C-Dam 5 (Kentucky Lower)	No	4091.0	191.7	unknown	-	TFF	1.80E-06	unknown	-	unknown	-
C-Dam 5 (Upper)				unknown							
C-Dam 6 (San Diego)	Yes	5435.0	156.5	unknown	-	TFF	1.00E-09	unknown	-	unknown	-
C-Dam 7 (Tremont)	No	16701.0	60.5	unknown	-	TFF	7.14E-03	unknown	-	unknown	-
C-Dam 8	No	4762.0	69.6	unknown	-	TFF	5.50E-05	unknown	-	unknown	-
C-Dam 9	No	18920.0	56.2	unknown	-	TFF	5.50E-05	unknown	-	unknown	-
C-McKelligon	Yes	1528912.0	1171.4	unknown	-	TFF	1.00E-09		5.00E-04	unknown	-
C-Pershing	Yes	60114.0	2256.5	unknown	-	TFF	1.00E-09	none	2.00E-05	unknown	-
C-Van Buren	No	23820.0	1233.6	unknown	-	TFF	5.88E-04	none	2.00E-05	unknown	-
NE-Fusselman	Yes	122910.0	1366.1	unknown	-	TFF	1.00E-09	Well compacted, no erosion observed	1.00E-04	unknown	-
NE-Mountain Park	Yes	54503.0	503.6	unknown	-	TFF	1.00E-09	none	2.00E-05	unknown	-
NE-North Gate	Yes	126450.0	1013.1	unknown	-	TFF	1.00E-09	some minor erosion	1.00E-04		1.00E-05
NE-North Hills 1	Yes	35137.0	922.3	unknown	-	TFF	1.00E-09	blanket drain, partial cutoff, impervious core	1.00E-04	unknown	-
NE-North Hills 2	Yes	67668.0	1153.4	unknown	-	TFF	1.00E-09	blanket drain, partial cutoff, impervious core	1.00E-04	unknown	-
NE-Range	Yes	120210.0	1033.0	unknown	-	TFF	1.00E-09	none	1.00E-04		1.00E-05
NE-Sunrise	Yes	34991.0	352.2	unknown	-	TFF	1.00E-09	none	1.00E-04		1.00E-05
NW-Keystone	Yes	88138.0	2577.3	unknown	-	TFF	1.00E-09	Clear seepage at toe of downstream slope of the embankment	2.00E-05	Clear seepage at toe of downstream slope of the embankment	5.00E-03
NW-Mesa	Yes	101653.0	1804.2	unknown	-	TFF	1.00E-09	none	1.00E-05		1.00E-05
NW-Mulberry	Yes	131824.0	1916.7	unknown	-	TFF	1.00E-09	some minor erosion	1.00E-05		1.00E-05
NW-Oxidation	Yes	173972.0	3371.5	unknown	-	TFF	1.00E-09	none	2.00E-05	unknown	-
NW-Thorn Drive	Yes	70880.0	1641.3	unknown	-	TFF	1.00E-09	none	1.00E-05		1.00E-05

Sources:
W.O. 3, Task 3, Table 15 (URS, February 2008)
W.O. 3, Task 5 Dam Height Comparison (URS, June 2008)
W.O. 3, Task 5, Draft EAP CoEP High Hazard Dams (URS, June 2008)
Plans/USACE Phase 1 or Design Memo
URS or CoEP Inspection Reports
URS, February 2008
Estimated (info not available)
Does not pass PMF

EARTHFILL DAM

CoEP - City of El Paso.
cfs - Cubic feet per second.
PMF - Probable maximum flood.
TFF - Threshold failure flood.
USACE - U.S. Army Corp of Engineers.

Table D-2b. El Paso Water Utilities Dam Summary Table

DAM NAME	ABUTMENT OUTFLANKING Source/Comment	Value	LINED CHUTE AND DISSIPATOR Source/Comment	Value	UNLINED CHANNEL Source/Comment	Value	TOWER STABILITY Source/Comment	Value	CONDUIT Source/Comment	Value	GATES Source/Comment	Value	VALVES Source/Comment	Value	FLOOD LOADING Probability
C-Dam 10	TFF	-	none	-	none	-	unknown	-	36" RCP	5.00E-03	none	-	none	-	7.41E-04
C-Dam 2 (Ft. Blvd.)	TFF	-	unknown	-	unknown	-	unknown	-	12" CI	3.00E-02	none	-	none	-	2.86E-03
C-Dam 3 (Louisiana)	TFF	-	unknown	-	unknown	-	unknown	-	36" RCP	5.00E-03	none	-	none	-	5.22E-03
C-Dam 4 (Memphis Lower)	TFF	-	none	-	unknown	-	unknown	-	unknown size/metal	3.00E-02	none	-	none	-	2.35E-03
C-Dam 5 (Kentucky Lower)	TFF	-	unknown	-	unknown	-	unknown	-	60" CMP	3.00E-02	none	-	none	-	1.36E-04
C-Dam 5 (Upper)	TFF	-					unknown	-	2' x 3.5' masonry						0.00E+00
C-Dam 6 (San Diego)	TFF	-	none	-	none	-	unknown	-	unknown		none	-	none	-	1.71E-04
C-Dam 7 (Tremont)	TFF	-	unknown	-	unknown	-	unknown	-	42" RCP	5.00E-03	none	-	none	-	7.14E-03
C-Dam 8	TFF	-	none	-	none	-	unknown	-	unk. size/CMP	3.00E-02	none	-	none	-	1.67E-02
C-Dam 9	TFF	-	none	-	none	-	unknown	-	30" CMP	3.00E-02	none	-	none	-	1.00E-01
C-McKelligon	TFF	-	none		A.S. in rock	1.00E-06	unknown	-	36" CIPC	1.00E-04	none	-	none	-	9.13E-04
C-Pershing	TFF	-	concrete spillway with dissipators	1.00E-05	none	-	unknown	-	15' x 16' CIPC Box	2.00E-04	none	-	none	-	3.20E-03
C-Van Buren	TFF	-	none	-	No A.S.	-	unknown	-	Double 72" CMP	3.00E-02	none	-	none	-	4.16E-03
NE-Fusselman	TFF	-	none	-	Earthen A.S. w/conc. Control section	1.00E-04	unknown	-	24" CIPC	1.00E-04	none	-	none	-	2.71E-03
NE-Mountain Park	TFF	-	none	-	A.S. in weathered rock, concrete control section	1.00E-05	unknown	-	36" CIPC	1.00E-04	none	-	none	-	7.00E-04
NE-North Gate	TFF	-	none	-	A.S. in weathered rock, concrete control section	1.00E-05	unknown	-	36" CIPC	1.00E-04	none	-	none	-	1.80E-04
NE-North Hills 1	TFF	-	none	-	Concrete embankment overflow	1.00E-06	unknown	-	30" RCP	5.00E-03	none	-	none	-	3.53E-03
NE-North Hills 2	TFF	-	none	-	Concrete embankment overflow	1.00E-06	unknown	-	30" RCP	5.00E-03	none	-	none	-	4.17E-03
NE-Range	TFF	-	none	-	Earthen A.S. w/conc. Control section	1.00E-04	unknown	-	36" CIPC	1.00E-04		-		-	2.40E-03
NE-Sunrise	TFF	-	none	-	Earthen A.S. w/conc. Control section	1.00E-04	unknown	-	36" CIPC	1.00E-04	none	-	none	-	1.92E-03
NW-Keystone	TFF	-	none	-	Earthen A.S. w/conc. Control section	1.00E-04	unknown	-	96" CIPC	1.00E-04	none	-	none	-	1.36E-03
NW-Mesa	TFF	-	none	-	Earthen A.S. w/conc. Control section	1.00E-04	unknown	-	36" CIPC	1.00E-04	none	-	none	-	1.38E-03
NW-Mulberry	TFF	-	none	-	Earthen A.S. w/conc. Control section	1.00E-04	unknown	-	36" CIPC	1.00E-04	none	-	none	-	1.73E-03
NW-Oxidation	TFF	-	none	-	some erosion	2.00E-04	unknown	-	unk. size/RCP	5.00E-03	none	-	none	-	2.68E-03
NW-Thorn Drive	TFF	-	stilling basin	none	Earthen A.S. w/conc. Control section	1.00E-04	unknown	-	36" CIPC	1.00E-04	none	-	none	-	1.56E-03
Sources:	**UNGATED SPILLWAY**						**OUTLET WORKS**								**Probability Factor**

W.O. 3, Task 3, Table 15 (URS, February 2008)
W.O. 3, Task 5 Dam Height Comparison (URS, June 2008)
W.O. 3, Task 5, Draft EAP CoEP High Hazard Dams (URS, June 2008)
Plans/USACE Phase 1 or Design Memo
URS or CoEP Inspection Reports
Estimated (info not available)
Does not pass PMF

A.S. - Auxiliary Spillway.
CI - Cast iron.
CIPC - Cast-in-place concrete.

FIGURES

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Figure D-1a. Example Failure Modes Evaluation and Risk Worksheet - Earthfill Dam

OBSERVATIONS	FAILURE MODES			
	Earthquake [2] ▲	Flood [1] ○	Piping ■	Normal Stability ◇
Significant deformation and transverse cracking Concentrated seepage with turbidity Large slumps Large trees in spillway and embankment	Not designed for EQ loading in high hazard area Soils liquefy FS<1.0* in EQ/AEP 10[-4]	TFF <10[-4]	Observed piping of embankment or foundation Erodible / poorly compacted / dry and brittle core* and No or inadequate filter Unprotected seepage exit low discharge capacity No or ineffective cutoff	FS < 1.0* Slopes steeper than 1H:1V Uncompacted Rockfill Poor Foundation
Observed deformation and cracking steep abutments and slope changes Clear seepage or wet areas Trees on slope or at downstream toe	Loose soils present in fdn or embankment Soils liquefy or FS<1.0* under Operating Basis Earthquake (OBE)	TFF <10[-4]		FS < 1.1* Slopes steeper than 1.3H:1V Uncompacted Rockfill High phreatic surface
Limited Cracking Embankment Vegetation Cleared Animal Burrows		TFF < 10-3	Well compacted clay core performing well No observed piping Nonerodible soils Uncertain Filter Compatibility Dirty rockfill Partial Cutoff Uncertain Foundation	FS < 1.2* Slopes steeper than 1.5H:1V Poor Quality Rockfill Weak Foundation
Performed adequately for at least 50 years	Marginal soils FS>1.0* under OBE FS<1.0* for Maximum Design Earthquake (MDE)	TFF <10[-4]		FS <1.3 Adequate Rockfill Weak Foundation
Embankment condition adequate, confirmed by regular inspection	Dense foundation or compacted embankment soils FS>1.1 under MDE	TFF <10[-5]	No known cracks Modern, fully penetrating filter Regular monitoring Full Cutoff	FS >1.3 Regular monitoring Compacted Rockfill
	FS>1.3 under MDE	TFF > PMPDF or Probable Maximum Flood	Wide filter and blanket drain Extensive monitoring	FS >1.5 High Strength Compacted Rockfill Strong Foundation Regular monitoring
Failure Mode F		5.88E-04	2.00E-05	
Flood Loading Prob.	1.00E+00	1.00E+00	4.16E-03	4.16E-03
Total Prob of Failure	1.00E-06	5.88E-04	1.00E-06	1.00E-06
Life Loss Potential		371.0	371.0	

Notes: (* or unknown)
1. TFF - threshold failure flood flood which overtops sufficient to cause breach
2. Skip earthquake failure mode if in low seismicity area where MDE pga < 0.1g

Input Required
Delete if not applicable

Total probability of failure

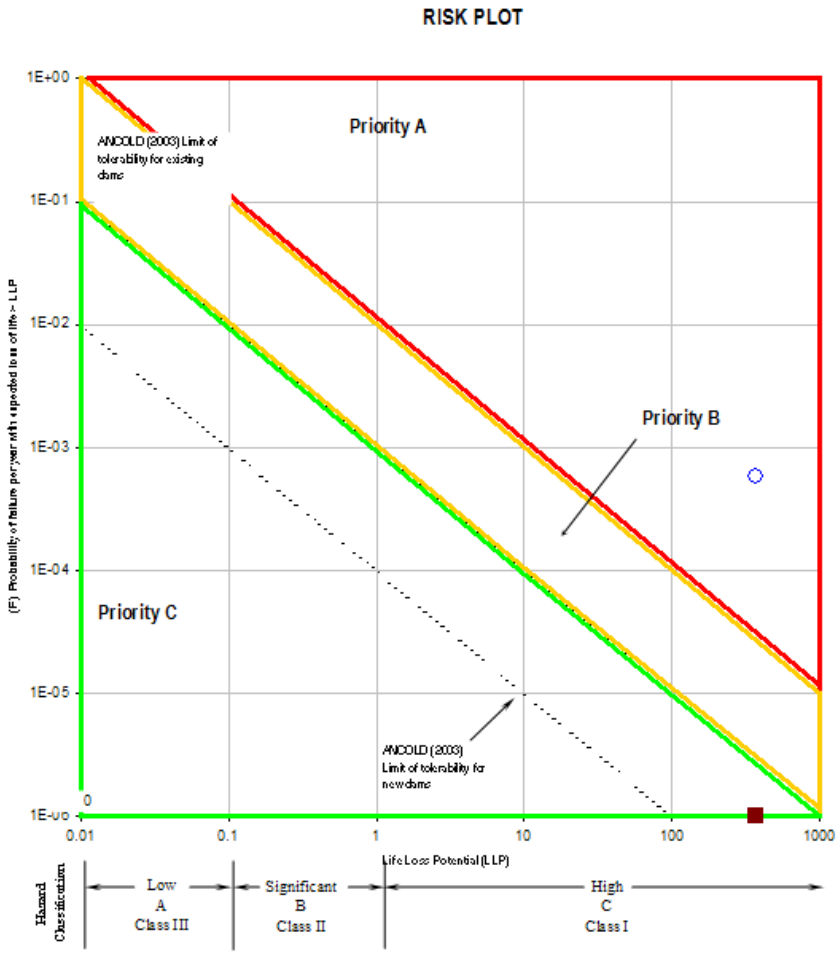

Figure D-1b. Example Failure Modes Evaluation and Risk Worksheet - Ungated Spillway

OBSERVATIONS	FAILURE MODES			
	Training Walls ▲	Abutment Outflanking ○	Lined Chute & Dissipator ■	Unlined Channel ◇
Excessive concrete deterioration[1] Highly erodible foundation Voids observed	Distressed wall, evidence of instability Overtopped by less than 10 yr flood	TFF <10[2]	Open, offset joint (chute) No drains or anchors Inadequate energy dissipation	Excessive erosion whenever spills Control section damaged or ineffective
Excessive Cracking Leakage Moderately erodible foundation Piping observ	Marginal stability, Inadequate backfill drainage Frequent overtopping	TFF <10[4]		
Minor concrete deterioration AAR Observed Low erodibility Frequently operated without incident		TFF < 10-3	Water flowing into joints Deteriorated drains or anchors Dissipator damaged under moderate floods	Moderate erosion Some protection from grass or riprap
	Adequate flood freeboard Not designed for EQ loading in high seismicity zone	TFF <10[4]	Uncertain condition of drains or anchors Minor joint defects Minor dissipator damage	Minor erosion
Concrete condition adequate confirmed by regular inspection and maintenance Waterstops in good condition Nonerodible foundation	Walls stable under normal, Flood and earthquake loading	TFF <10[2]	Joints sealed Drains or anchors work Dissipator works effectively	Rock founded control section No erosion during flow
		TFF > PMP/DF or Probable Maximum Flood		
Failure Mode F				
Flood Loading Prob.	1.00E+00	1.00E+00	4.16E-03	4.16E-03
Total Prob of Failure	1.00E-06	1.00E-06	1.00E-06	1.00E-06
Life Loss Potential				

Notes: (* or unknown)
1. Concrete deterioration consists of cracking, leaks, exposed rebar, and spalling.
2. TFF - Threshold failure flood causes overtopping, cavitation, turbulence or erosion
3. Skip earthquake failure mode in area of low seismicity

Total probability of failure

Input Required
Delete if not applicable

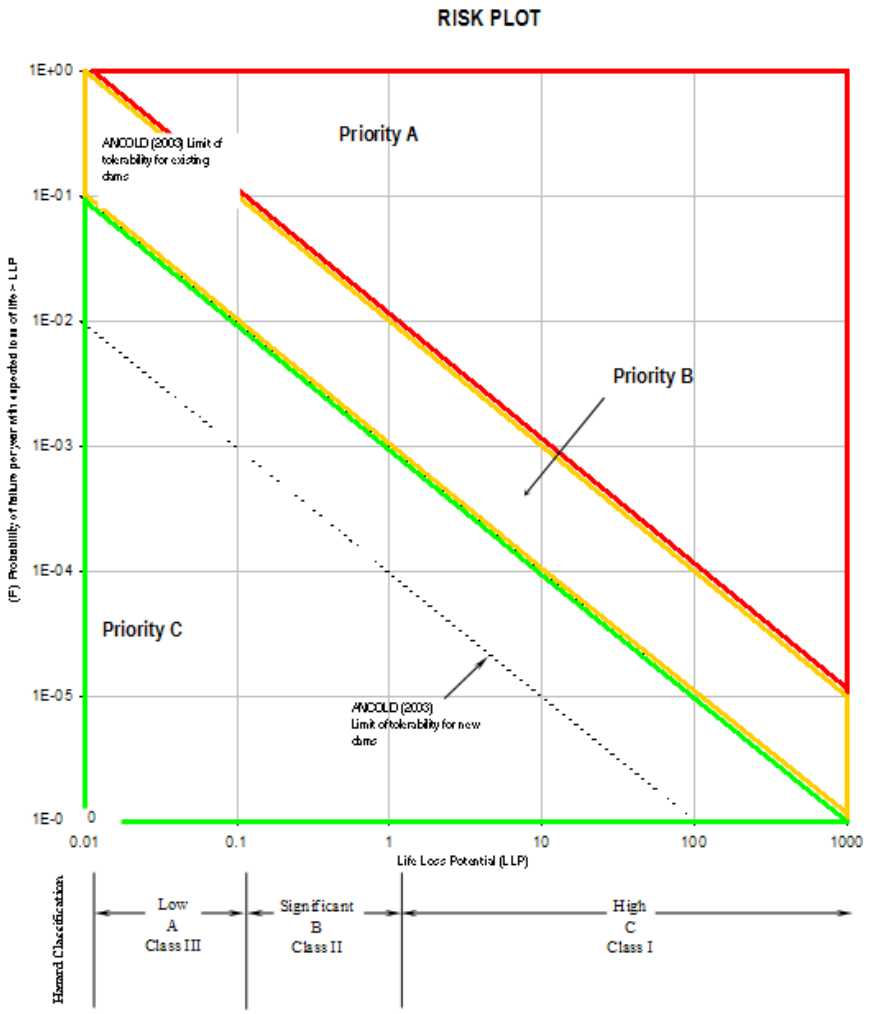

Figure D-1c. Example Failure Modes Evaluation and Risk Worksheet - Outletworks

OBSERVATIONS	FAILURE MODES			
	Tower Stability (EQ) ▲	Conduit ○	Gatee ■	Valvee ◇
Excessive concrete deterioration[1] Lack of Maintenance Excessive corrosion	Not designed for EQ loading in seismically active area FS<1.0* in EQ/AEP 10^-4	Turbid seepage or piping observed along conduit No filter or encasement around pipe with erodible soils CMP used Narrow deep conduit trench Excessive settlement on yielding foundation	Inoperable* Does not close into flow Design inadequate *	Inoperable* No backup Inaccessable Low reliability No training or inexperienced operators
Excessive Cracking Leakage AAR Observed Corrosion	Tower damage during shaking FS<1.0* under Operating Basis Earthquake (OBE)		Uncertain Reliability Maintenance Problems Component damage Inexperienced operators	
Minor concrete deterioration Staining		Seepage collars RCP with leaking joints Tolerable settlement Tolerable corrosion No bends, Accessible Partial Encasement	Operational Backup Available Some training Minor maintenance problems	Operational Backup Available Some training Minor maintenance problems
Concrete condition adequate confirmed by regular inspection	FS>1.0* under OBE/MDE	Filter collar RCP with secure joints Steel cylinder pipe Welded steel pipe Full Encasement Rock Foundation	Operated regularly Multiple backup Reliable Good training No maintenance issues	Operated regularly - Multiple backup - Reliable Good training - No major maintenance issues
	FS>1.3 under Maximum Design Earthquake (MDE)	Annual inspection and testing through full pressure range	Annual full range testing Preventative Maintenance Release redundancy	Annual full pressure testing
	FS>1.5 under MDE			
Failure Mode F		3.00E-02		
Flood Loading Prob.	1.00E+00	4.16E-03	1.00E+00	1.00E+00
Total Prob of Failure	1.00E-06	1.25E-04	1.00E-06	1.00E-06
Life Loss Potential		371.0		

Notes: (* or unknown)
1. Concrete deterioration consists of cracking, leaks, exposed rebar, and spalling.
2. Skip earthquake failure mode in area of low seismicity

Input Required
Delete if not applicable

Total probability of failure

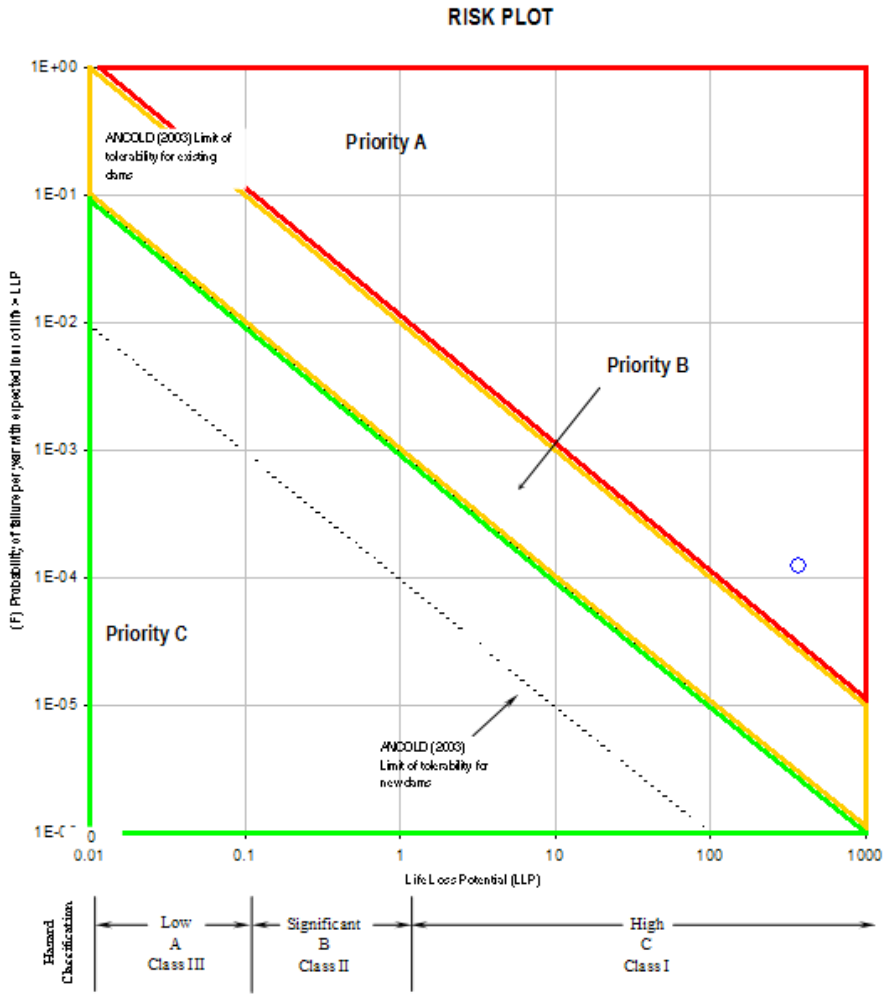

Figure D-2. Example Failure Mode Risk Profile

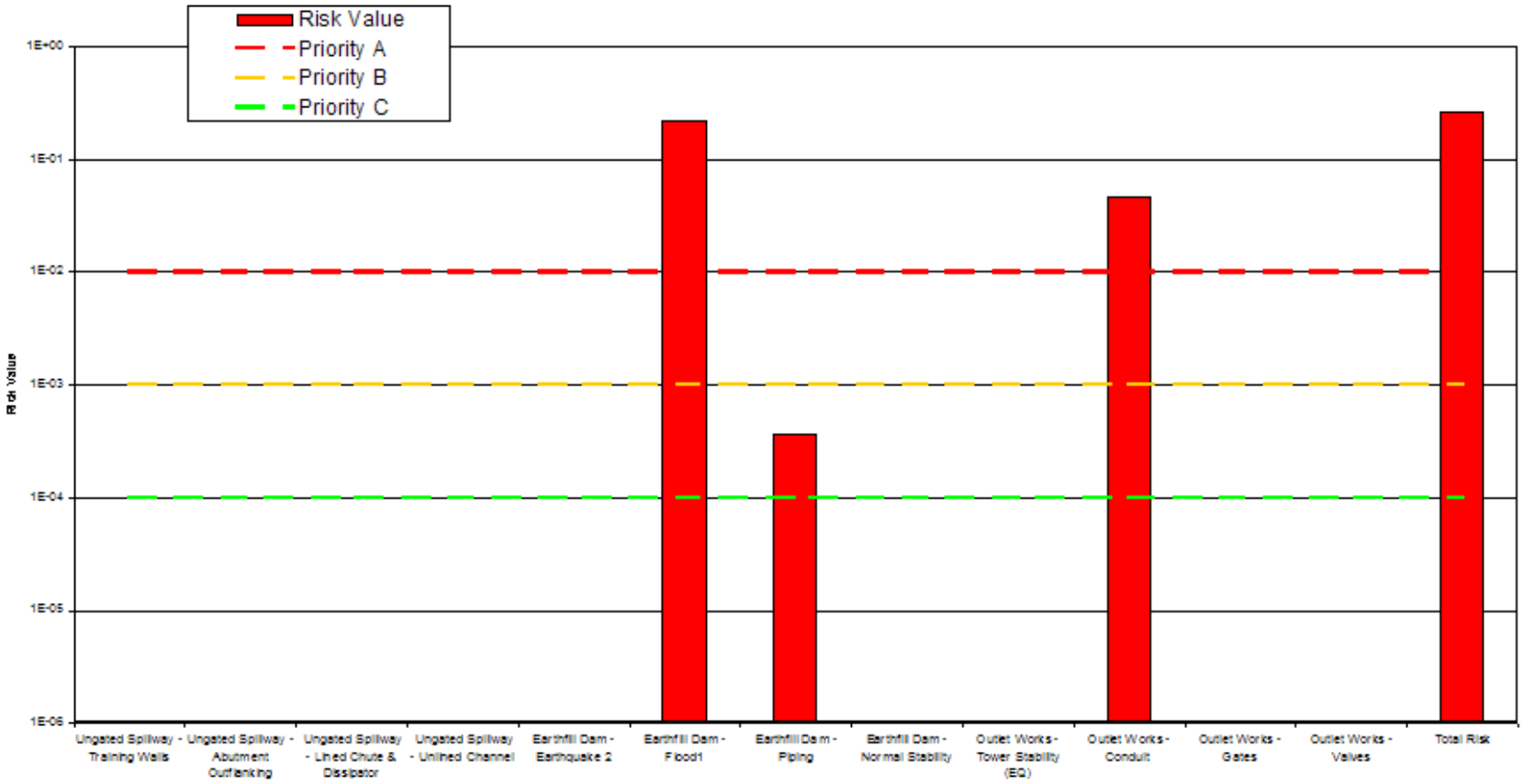

Figure D-3a. El Paso Water Utilities Dam Portfolio Total Risk Profile

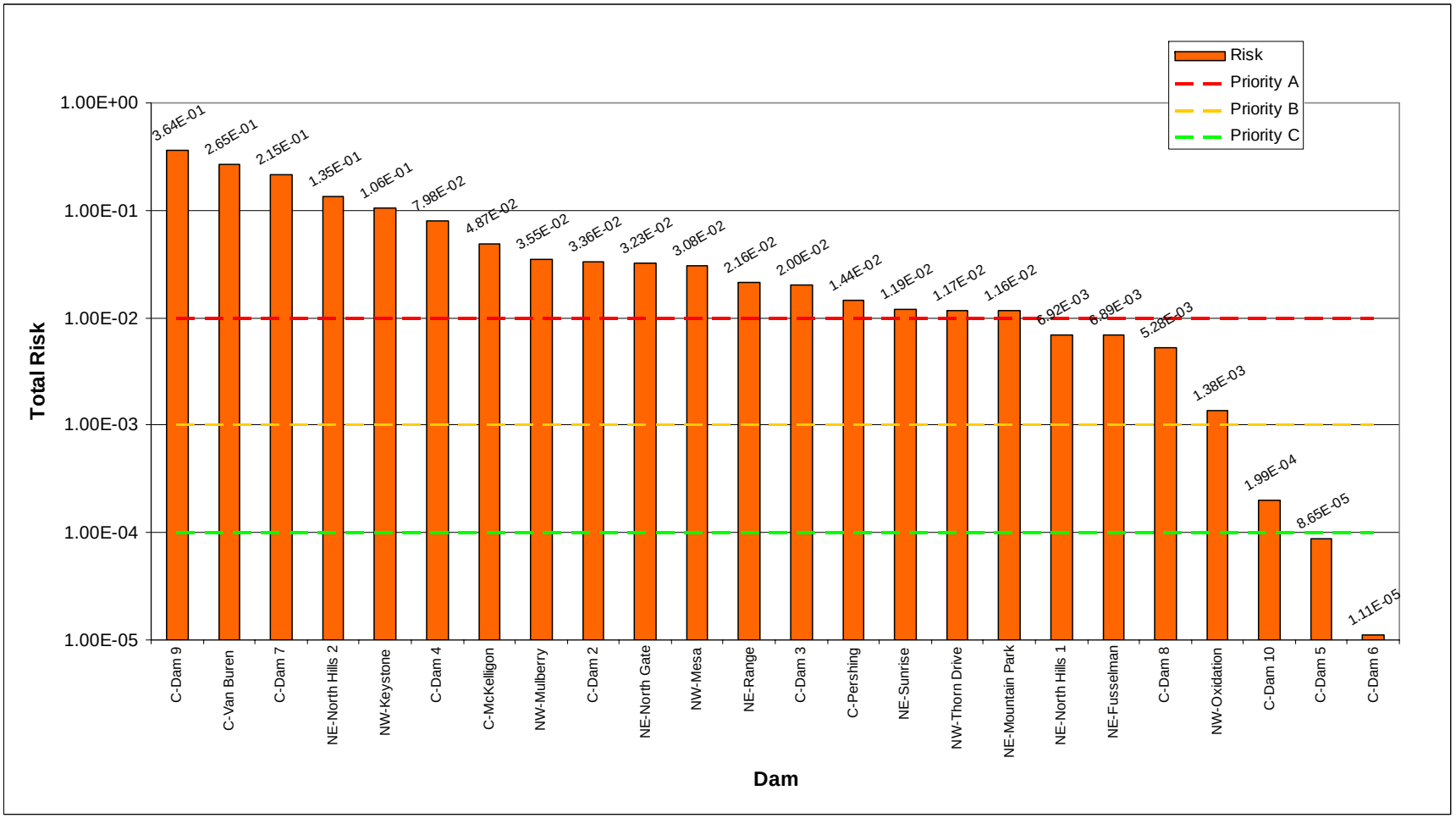

Figure D-3b. El Paso Water Utilities Dam Portfolio Total Risk Profile - Dams in Central Watershed

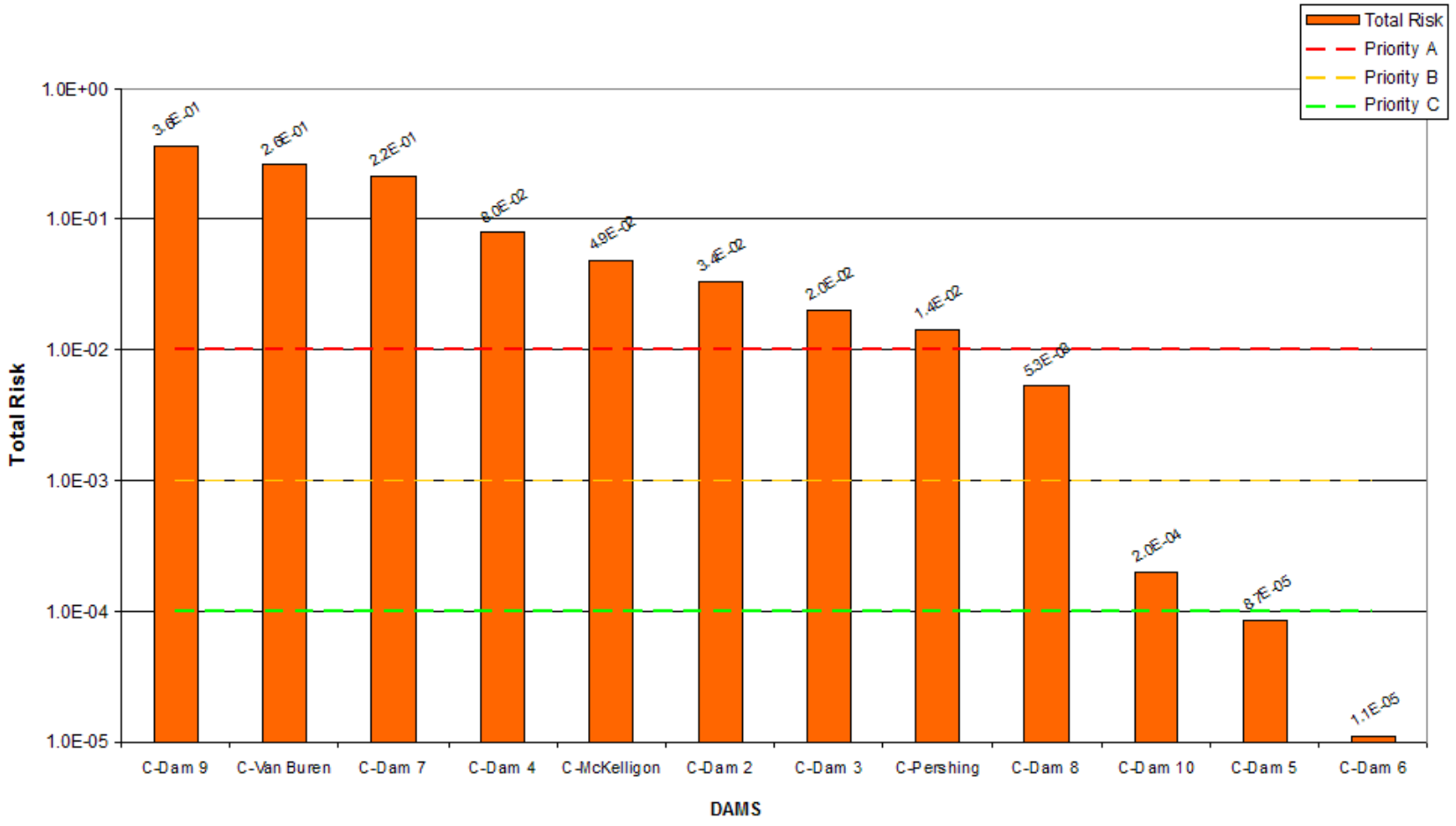

Figure D-3c. El Paso Water Utilities Dam Portfolio Total Risk Profile - Dams in Northeast Watershed

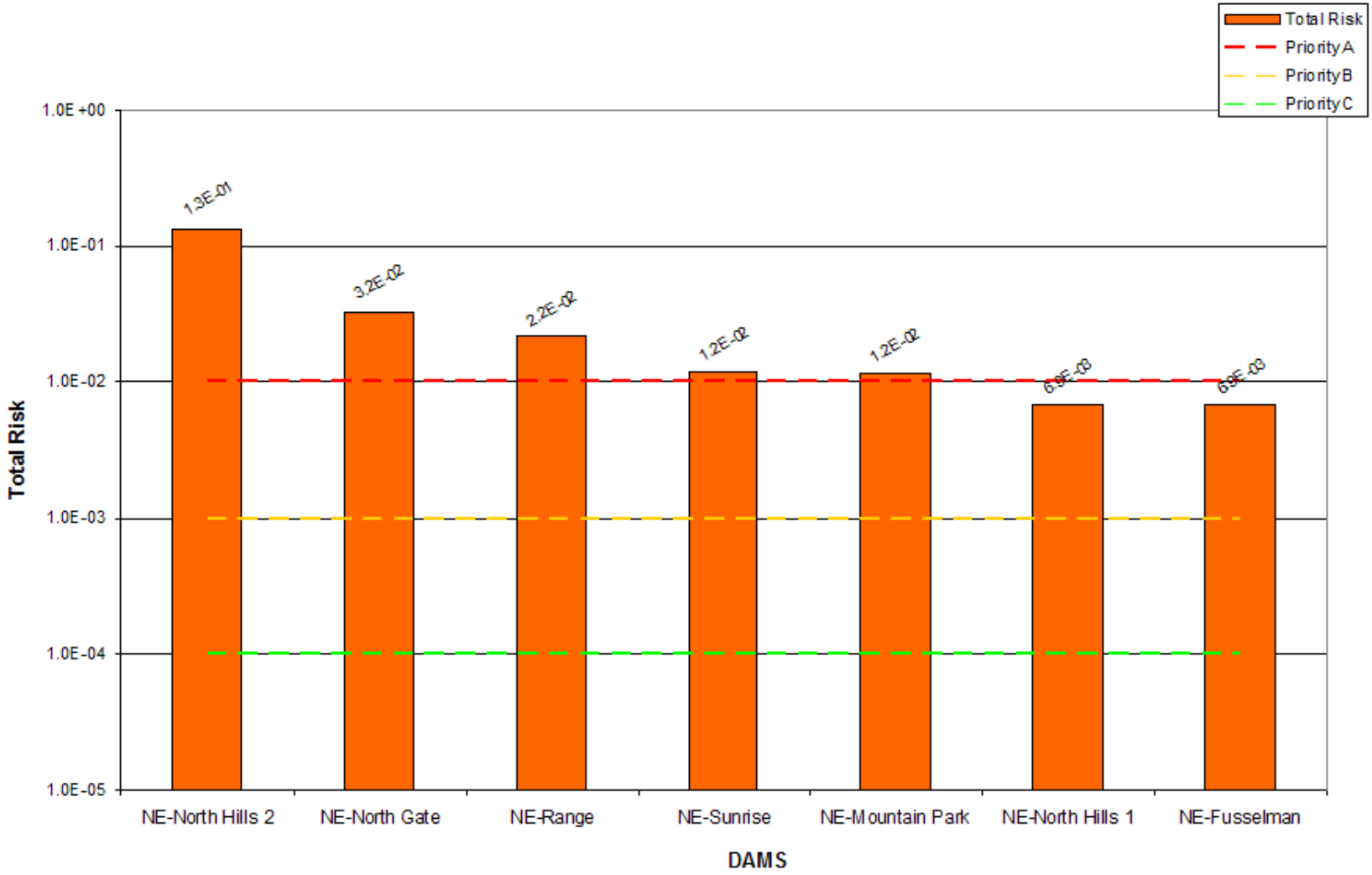

Figure D-3d. El Paso Water Utilities Dam Portfolio Total Risk Profile - Dams in Northwest Watershed

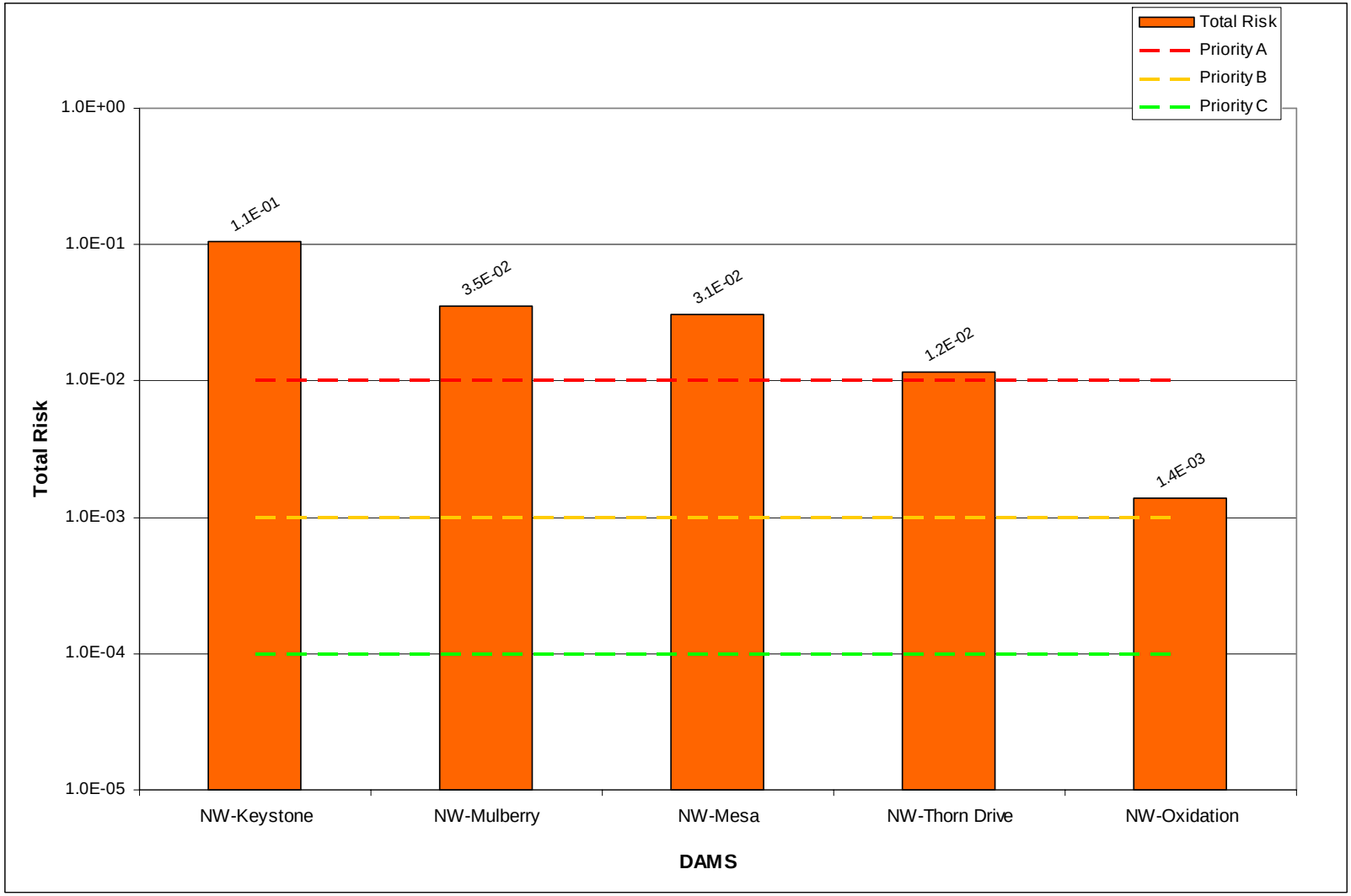

Figure D-4. El Paso Water Utilities Dam Portfolio Risk Profile by Piping and Conduit Failure Modes

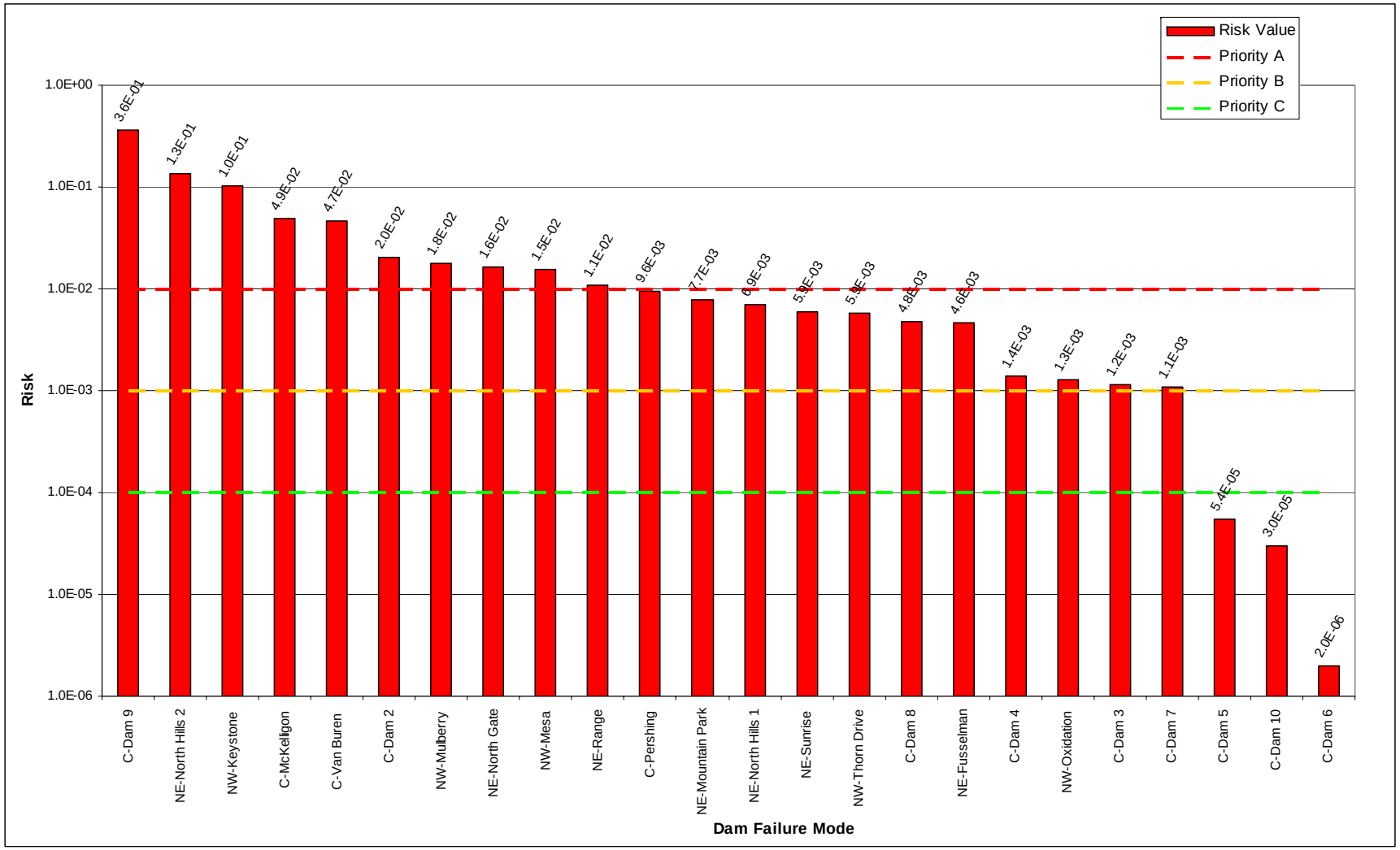

Figure D-5. El Paso Water Utilities Dam Portfolio Risk Profile by Piping and Conduit Failure Modes Relating the Probability of Failure to the Consequences of Failure for Dams in Priority A

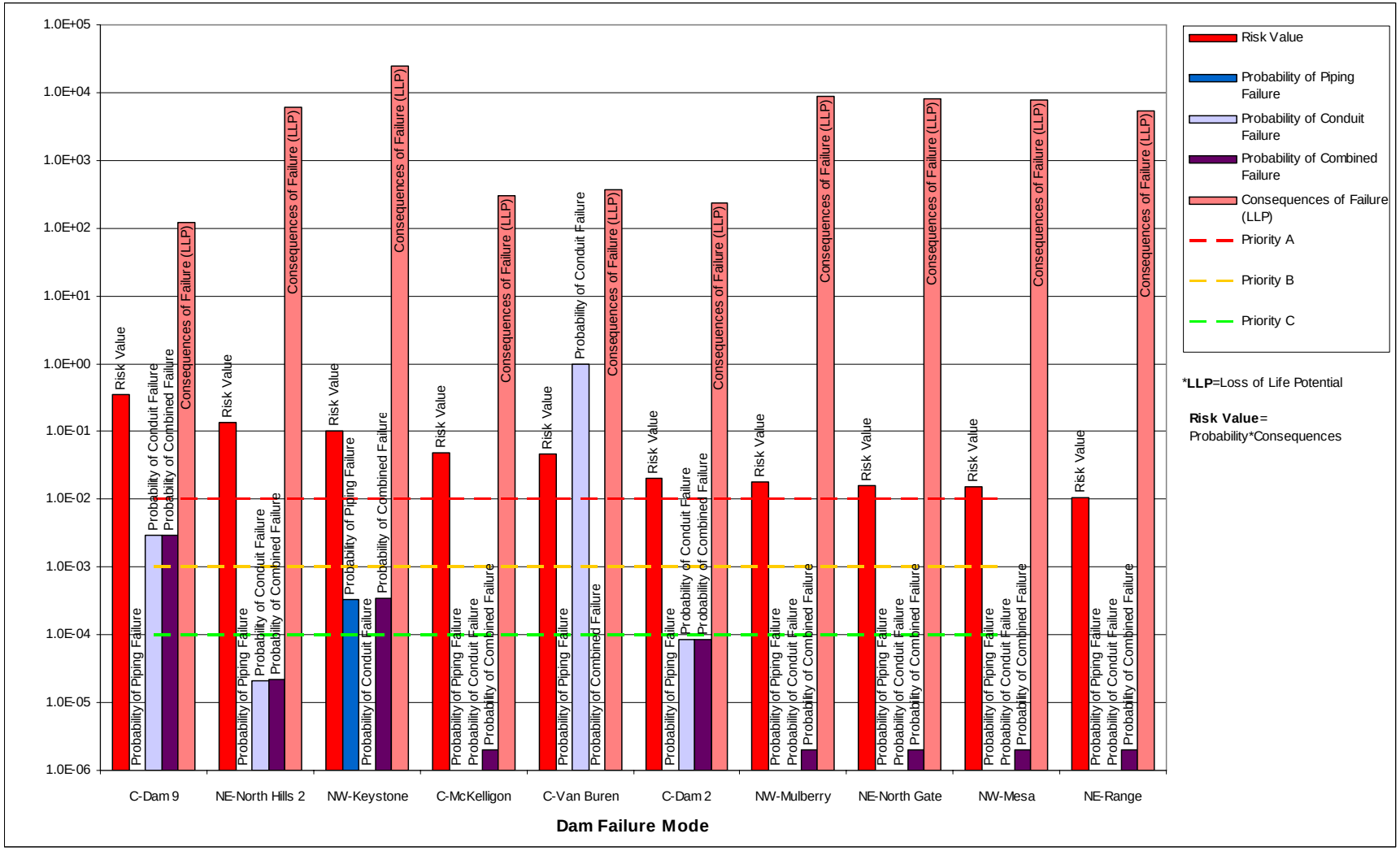

Figure D-6. El Paso Water Utilities Dam Portfolio Risk Profile by Flood Failure Mode

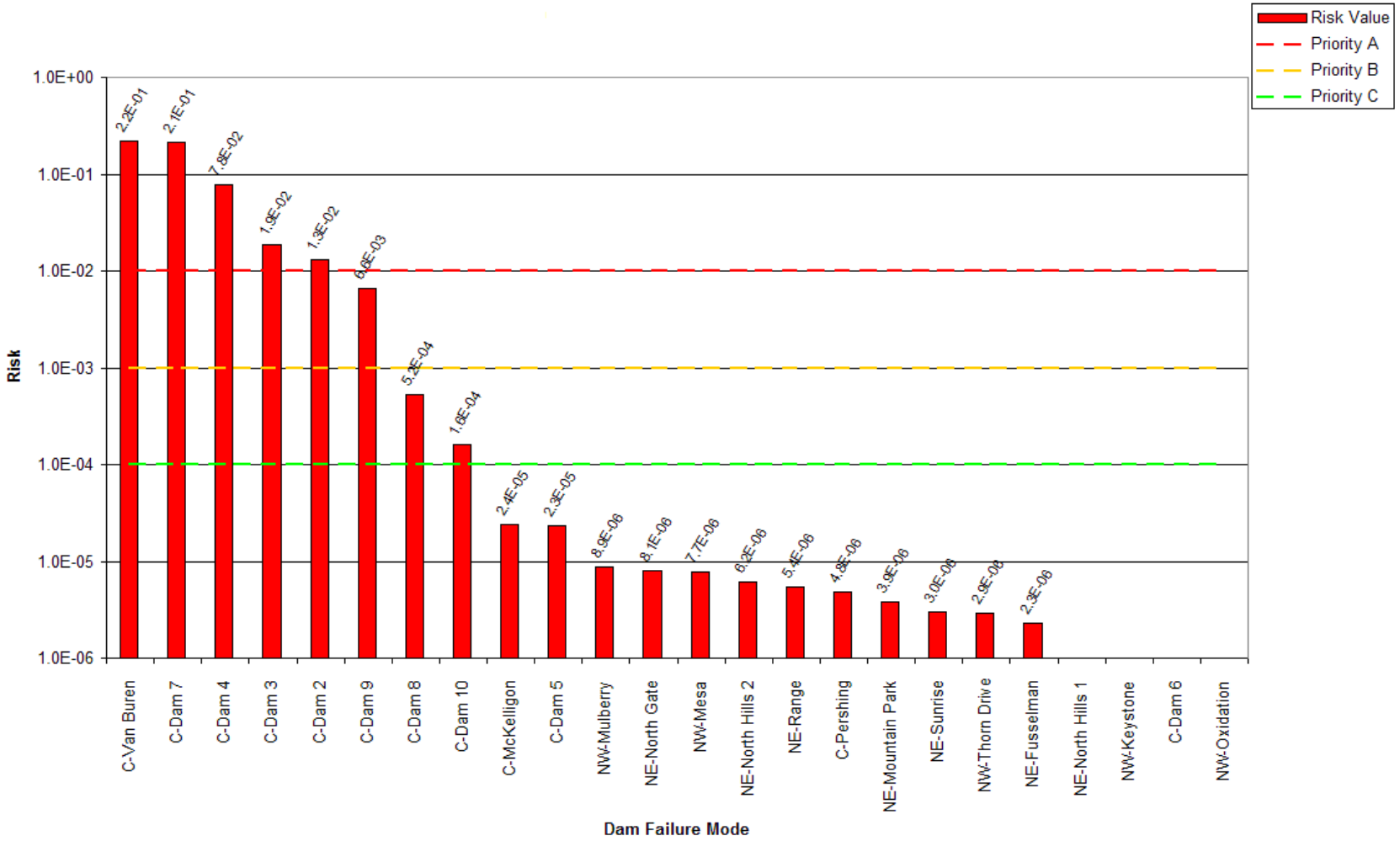

Figure D-7. El Paso Water Utilities Dam Portfolio Risk Profile by Flood Failure Mode Relating the Probability of Failure to the Consequences of Failure for Dams in Priority A

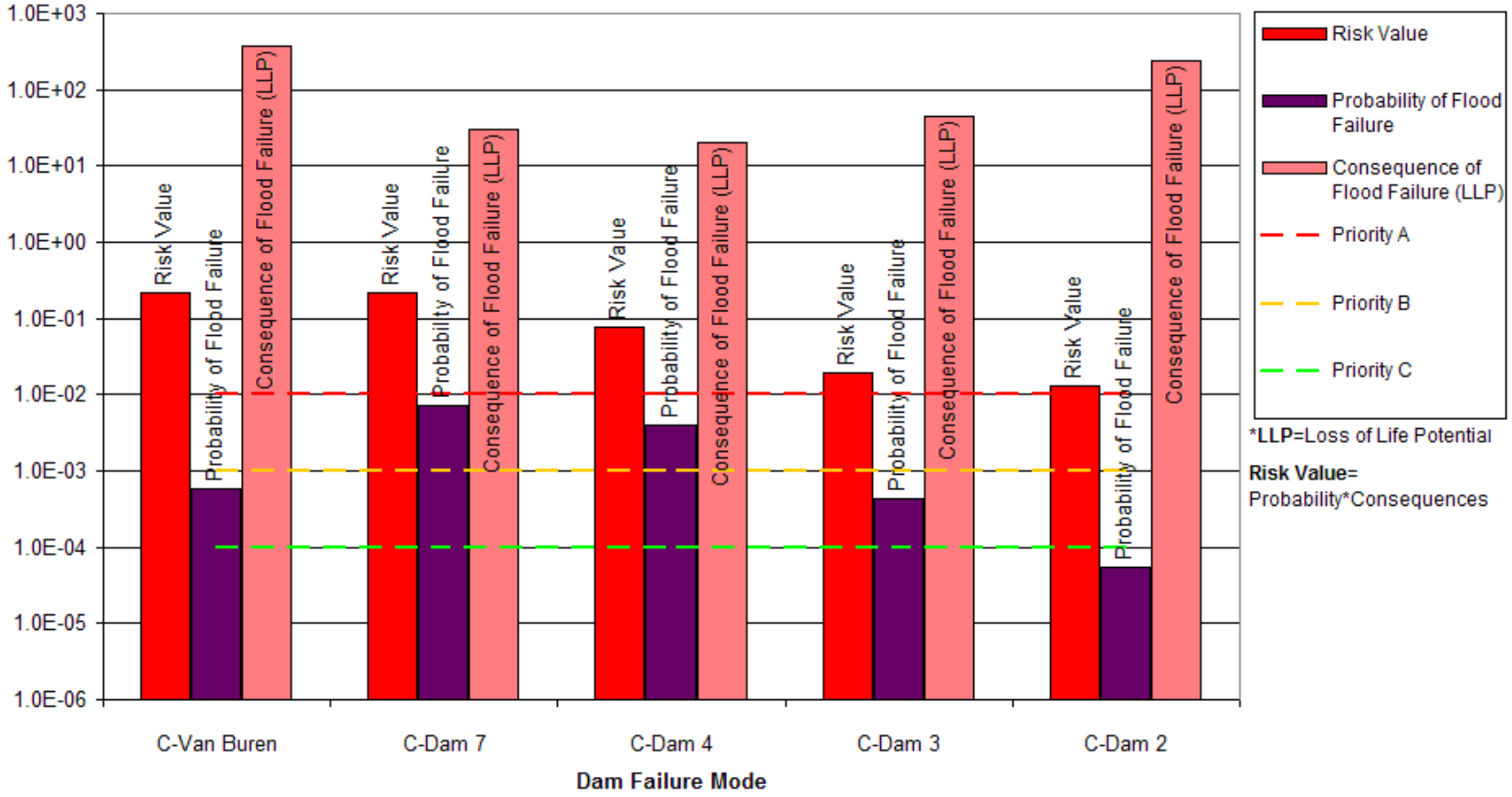

Figure D-8. Dam in the Central Watershed - Risk by Dam Failure Mode

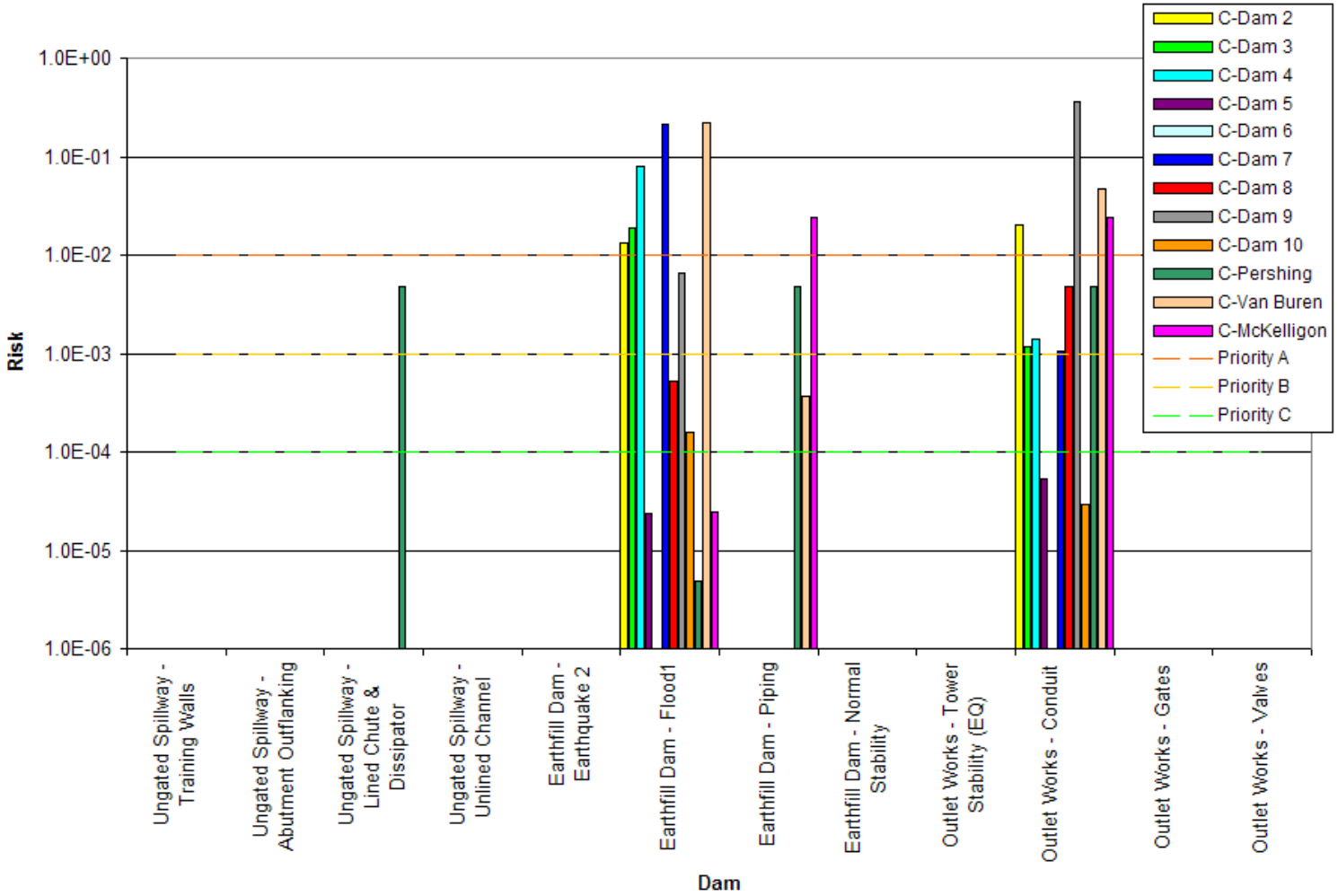

Figure D-9. Dam in the Northeast Watershed - Risk by Dam Failure Mode

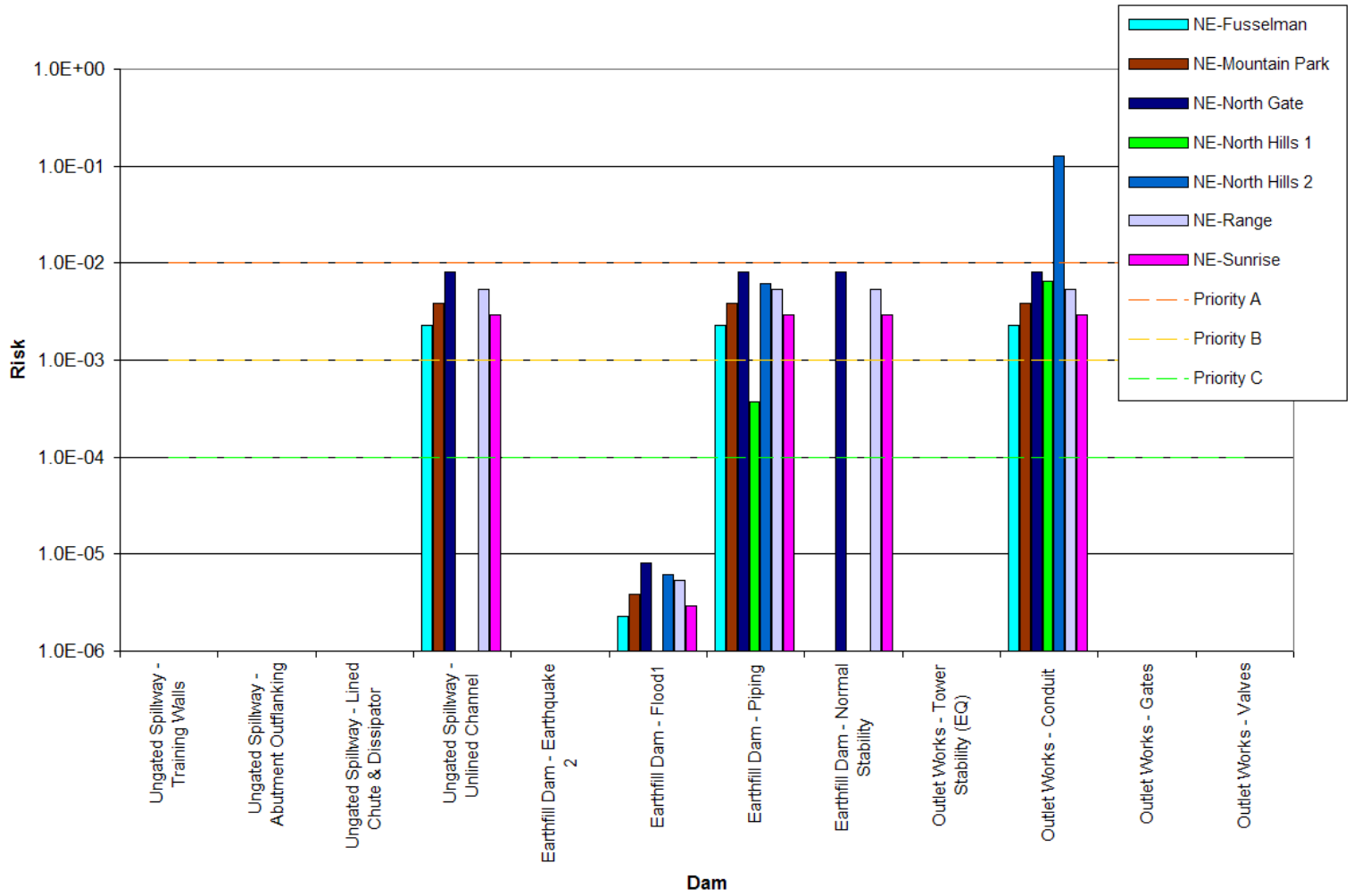

Figure D-10. Dam in the Northwest Watershed - Risk by Dam Failure Mode