CHERRY CREEK
Dam Safety Modification Study

Steve Butler Soils B

CENWO

April 2014

US Army Corps of Engineers
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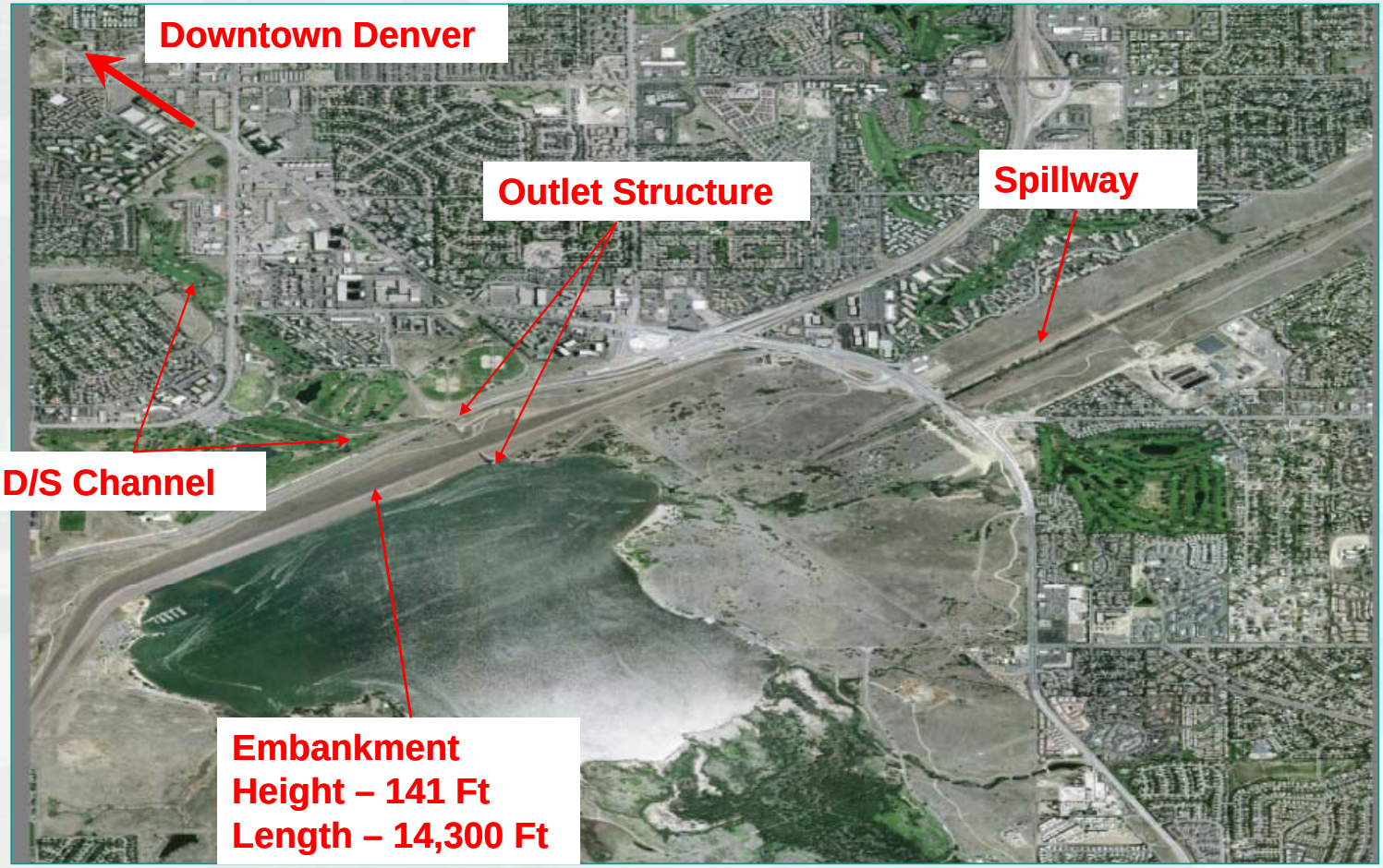
CHERRY CREEK



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Outline

- **Risk Informed Dam Safety Process**
  - Risk = Potential for Failure * Consequences
  - Consequences
  - Potential Failure Modes
- **Interim Risk Reduction Measures**
- **Dam Safety Mod Study**
  - Risk Assessments for Current and Future Conditions
  - Risk Reduction Measures Identification
  - Alternatives Development

Risk Informed Dam Safety Process

- Screening Portfolio Risk Assessment Process
  - ► Screened in 2005
  - ► Assigned DSAC II in 2008
- Interim Risk Reduction Measures Plan
  - ► Original plan approved in 2008
  - ► Plan updated in 2012 and is currently undergoing review
- Issue Evaluation Study - 2009 to 2011
  - ► HQ approved project for DSMS in 2011
  - ► Approval was based primarily on overtopping
- Dam Safety Modification Study
  - ► Began in 2012 with several hydrologic studies
  - ► Risk Assessment began in 2013

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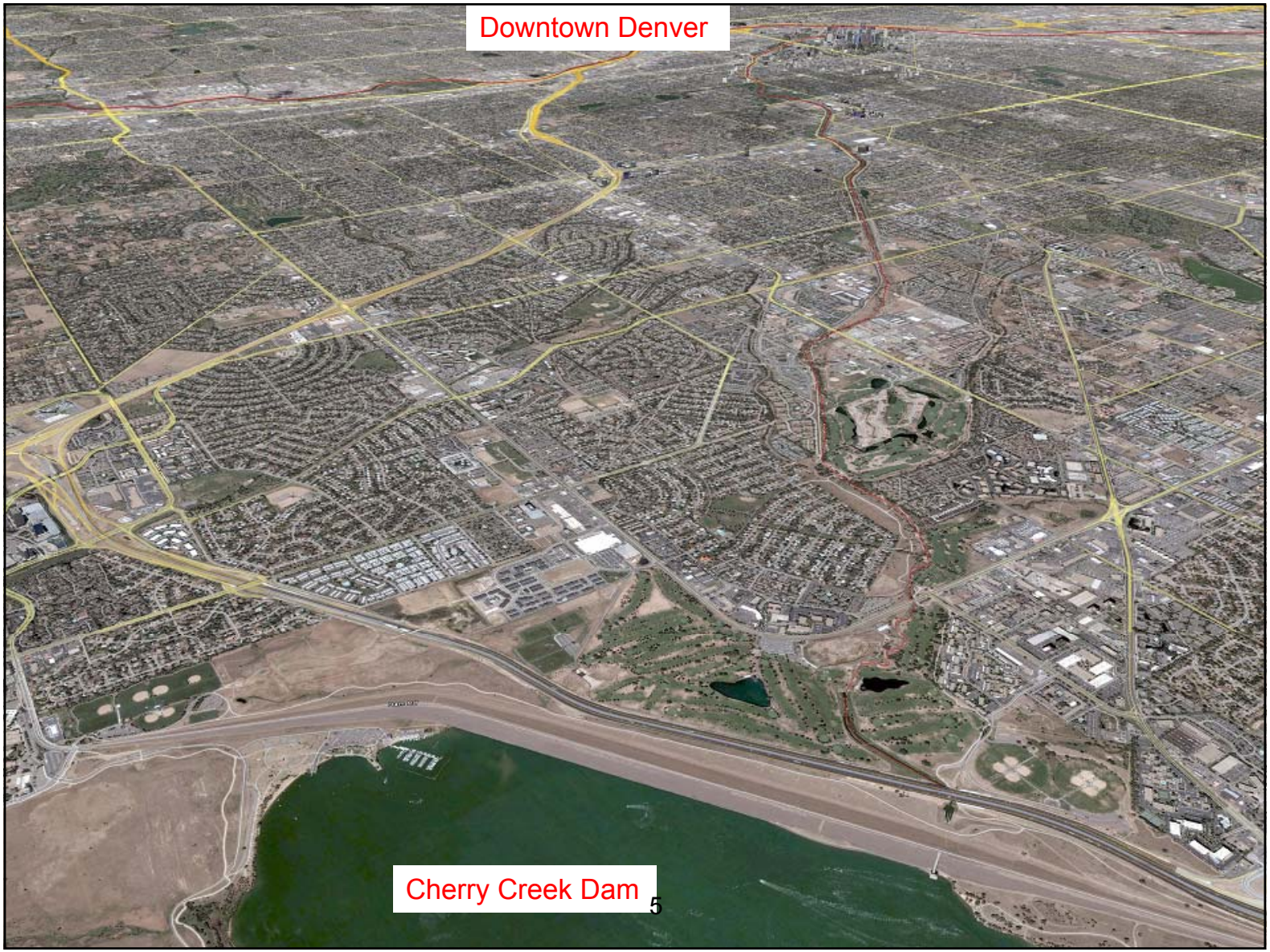
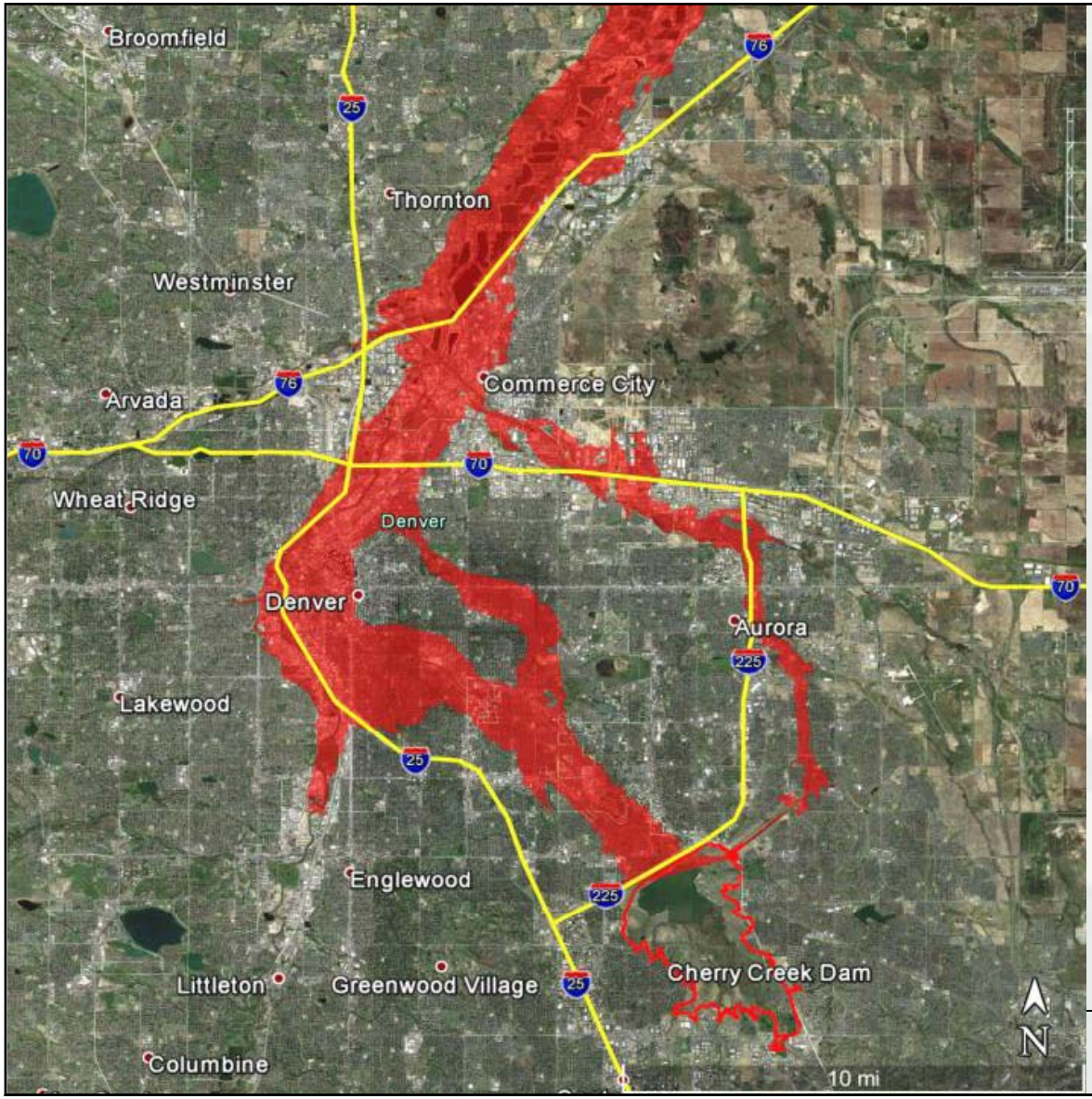

Downtown Denver
Cherry Creek Dam



Inundation Maps

Probable Maximum Flood (PMF)

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Loss of Life and Damage Estimates

Simulation/Elevation	LOL (Day)	LOL (Night)	Total Aggregate Damages ($ Billions)
Overtopping			
5648.8 NAVD88 (PMF) No Fail	28	11	$5.0B
5648.8 NAVD88 (PMF) Fail	2400	1500	$ 17.0B

Failure Modes Investigated

- Internal erosion through the alluvium where the impervious cut off is incomplete and does not reach the top of bedrock. (IE5)
- Internal erosion due to poorly compacted layers along the conduit (IE1)
- Overtopping, followed by erosion and breach of the embankment due to a Probable Max Flood (PMF) event (HE1)

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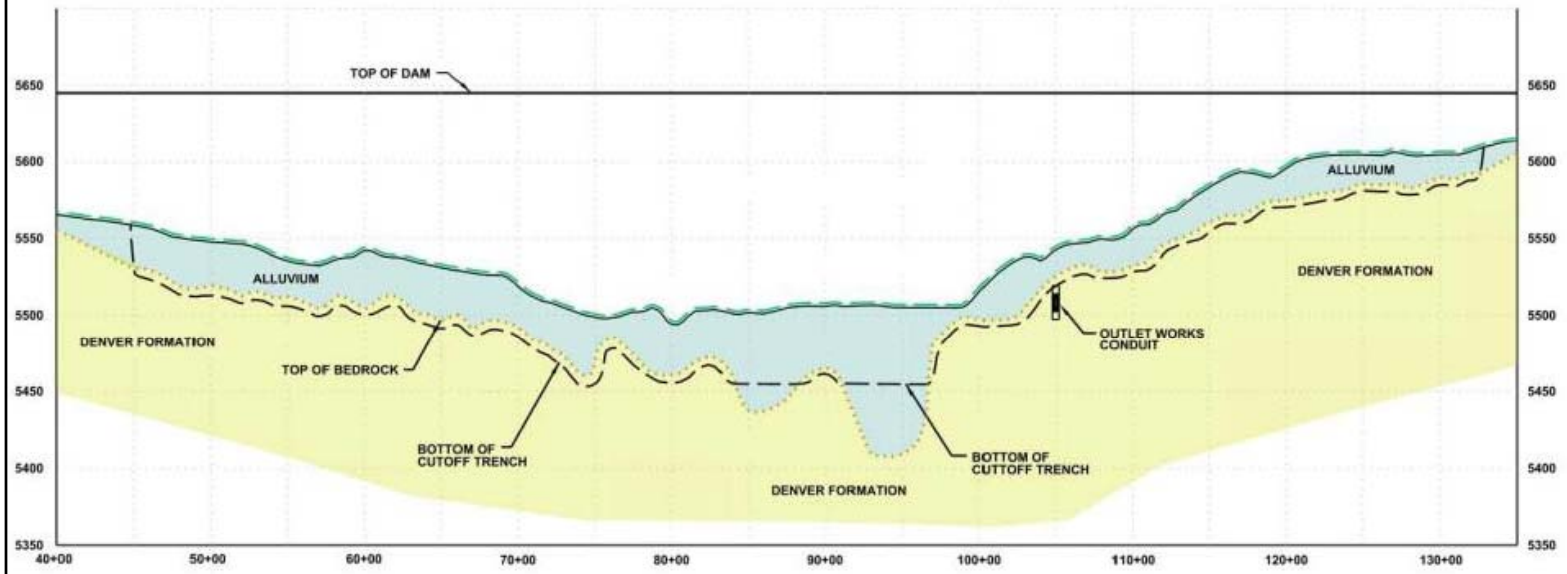
Internal Erosion Through the Foundation IE5

Cut-off Trench



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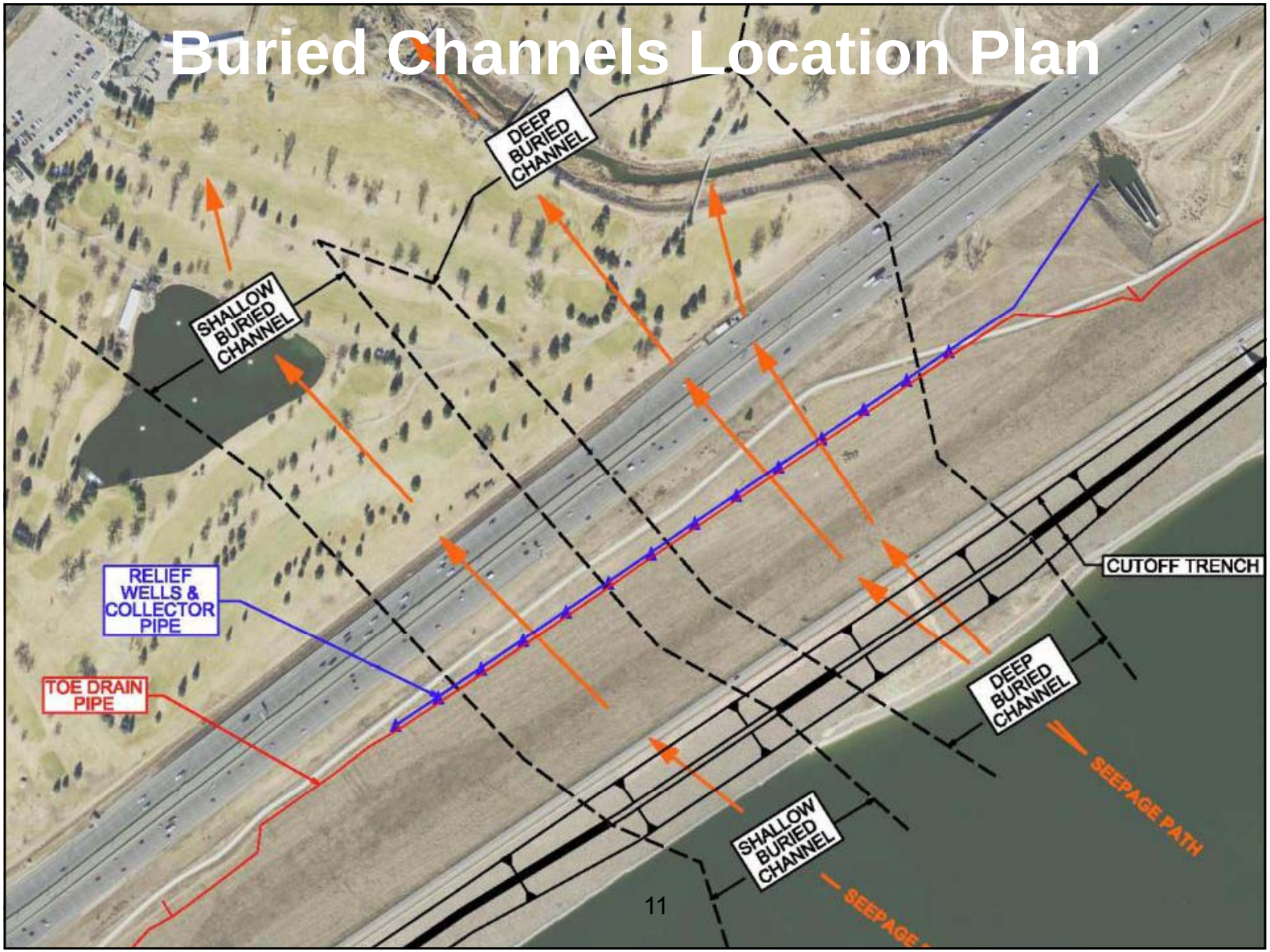
Buried Channels Location Plan



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Internal Erosion Along the Conduit, IE1

Internal Erosion Along the Conduit, IE1

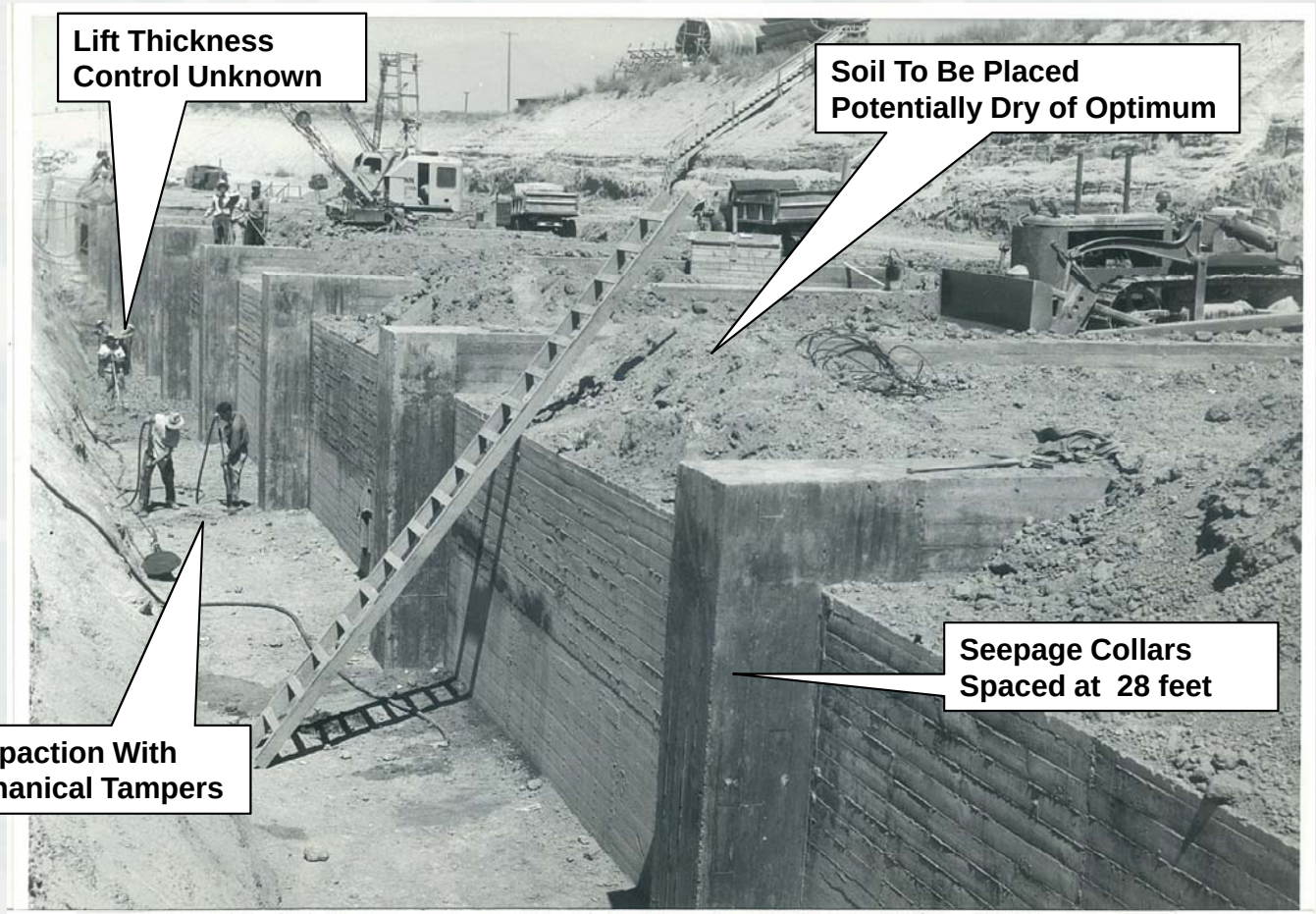

PHOTO NO. 27. Outlet works contract. Looking downstream near Sta. 10+00, showing backfill procedures adjacent to conduit. (20 Aug '48)

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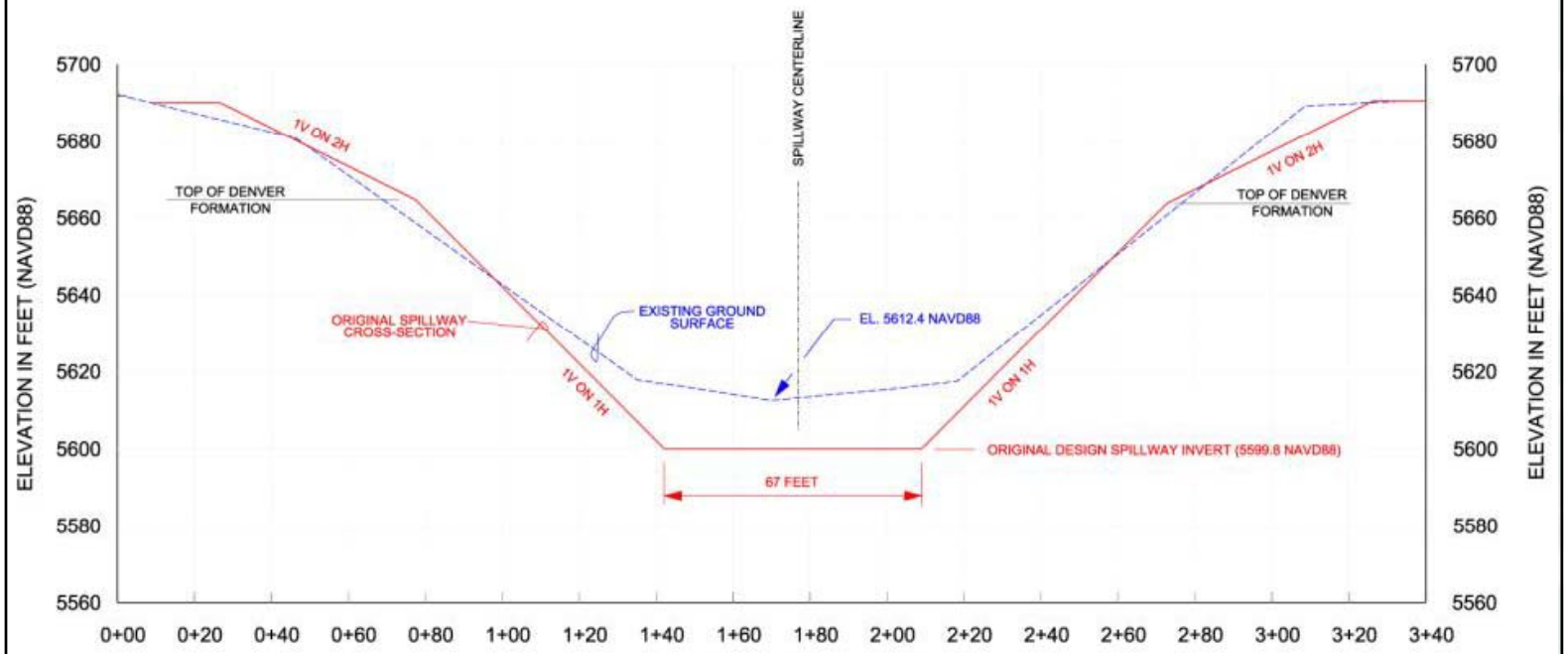
Overtopping, HE1

PMP Uncertainty

Cherry Creek Dam Safety Study Chronology

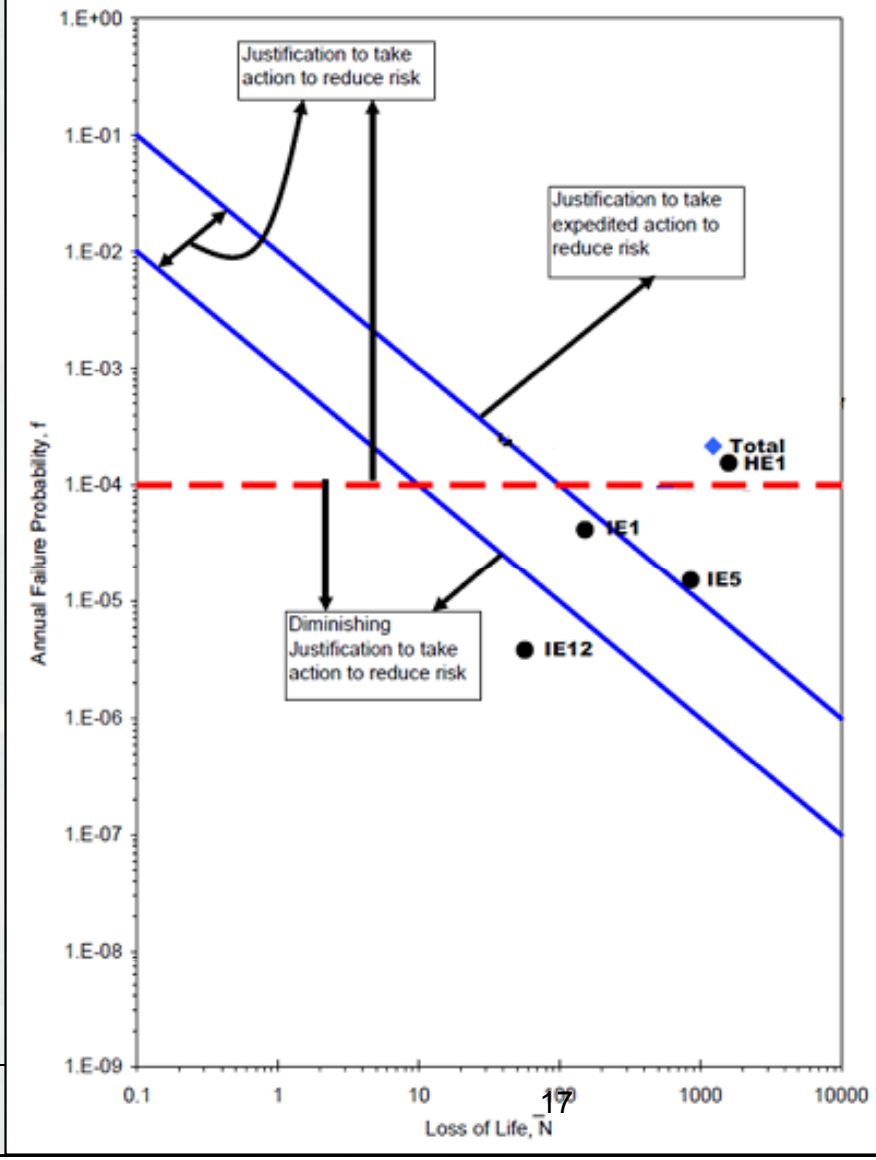
- 1969 – HMR44 Published – Identified Overtopping as an issue
- 1984 – HMR55 Published – Overtop 4.4’
- 1988 – HMR55A Published – Overtop 4.2’
- 1993 – Dam Safety Recon Report Approved
- 1995 – NWS Site Specific PMP – Overtop 2.5’
- 1997 – Scoping Meetings – Tomlinson comments
- 1999 – Congress pulls funding for Dam Safety study
- 2001 – CWCB hires AWA for independent PMP study
- 2003 – AWA PMP Study completed
- 2006 – Corps receives funding to proceed, reviews AWA study
- 2010 – NWS PMP Adopted - Approved by USACE Hydrology Committee and Federal Inter-Agency Extreme Storm Events Work Group

Spillway Cross-Section



CROSS-SECTION AT EXISTING SPILLWAY CREST
(NEAR PIPELINE CROSSING @ SPILLWAY STATION 136+50)

f-N Chart



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INTERIM RISK REDUCTION MEASURES

2014 Interim Risk Reduction Measures (IRRMs)

- Improve Flood Warning System - Ongoing
- Improve Reservoir Regulation System – Ongoing
- Emergency Action Plan (EAP) Update - Ongoing
- Continue Conducting Emergency Exercises – Ongoing
- Update Surveillance Plan – Ongoing
- Evaluate/Rehabilitate the Foundation/Embankment Seepage Collection System – Ongoing
- Perform Gate Repairs - Complete

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Dam Safety Modification Study

Dam Safety Modification Study

- (2012-2013) Hydrologic and Geotechnical Site Characterization Studies
- (2013-2014) Risk Estimate
  - Baseline Conditions
  - Future without Action Conditions
- (2014-2015) Formulate and Evaluate Risk Management Plans
  - NEPA Process
- (2015-2016)Dam Safety Modification Study Report

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Dam Safety Mod Study

Hydrologic Studies

Supplemental Hydrologic Studies

Hydrologic Study	Description
Update PMF with new HMS	PMF estimate was calculated using the most recent HEC-HMS. Slight increase in runoff. Peak discharge also increased slightly. 3.2 feet of overtopping.
Antecedent Flood Study	Antecedent flood is assumed to occur prior to the PMP, partially filling the reservoir. Study recommends reducing the antecedent flood from 50 percent of the PMP to 32 percent of the PMP. HQ must approve this change.
Dam Breach and Consequences	Lidar surveys used to improve inundation mapping. HEC-RAS modeling used to estimate flood inundation for PMF with dam breach and PMF without dam breach
Spillway Erosion	Spillway erosion study performed to determine the length of time that would be required to remove the sediment during a spillway flow and impact on downstream consequences.

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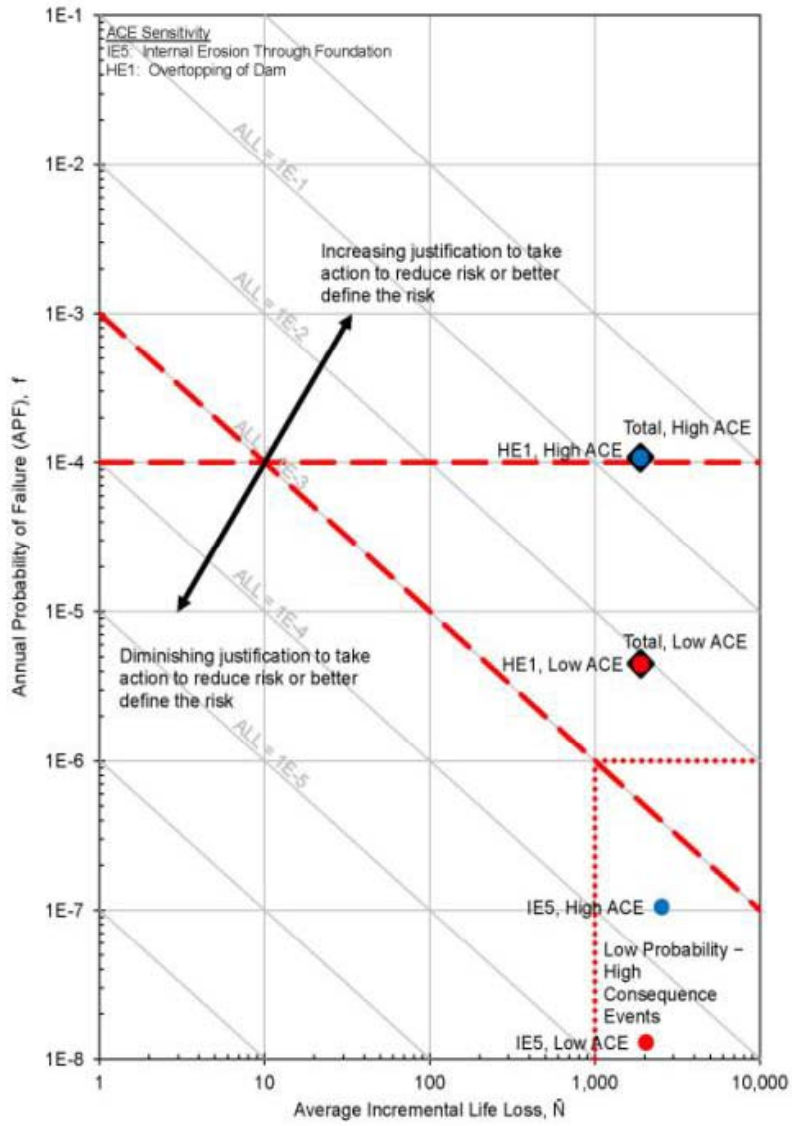
Dam Safety Mod Study

Baseline Risk Assessment

Future Without Action Condition



Baseline Risk Assessment

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Dam Safety Mod Study

Identify Risk Reduction Measures

Potential Risk Reduction Measures for Foundation Seepage (IE5)

- Do Nothing
- Cutoff wall into the foundation
- Downstream filter berm
- Upstream blanket
- Add relief wells

Potential Risk Reduction Measures for Seepage Along Conduit (IE1)

- Do Nothing
- Filter at downstream end of conduit
- Cutoff wall
- Grouting
- Replace conduit

Potential Risk Reduction Measures for Overtopping (HE1)

- Increase upstream storage capacity
- Modify the dam
- Modify the spillway
- Modify outlet works
- Harden downstream dam face
- Dredge reservoir area
- Restrict pool elevation

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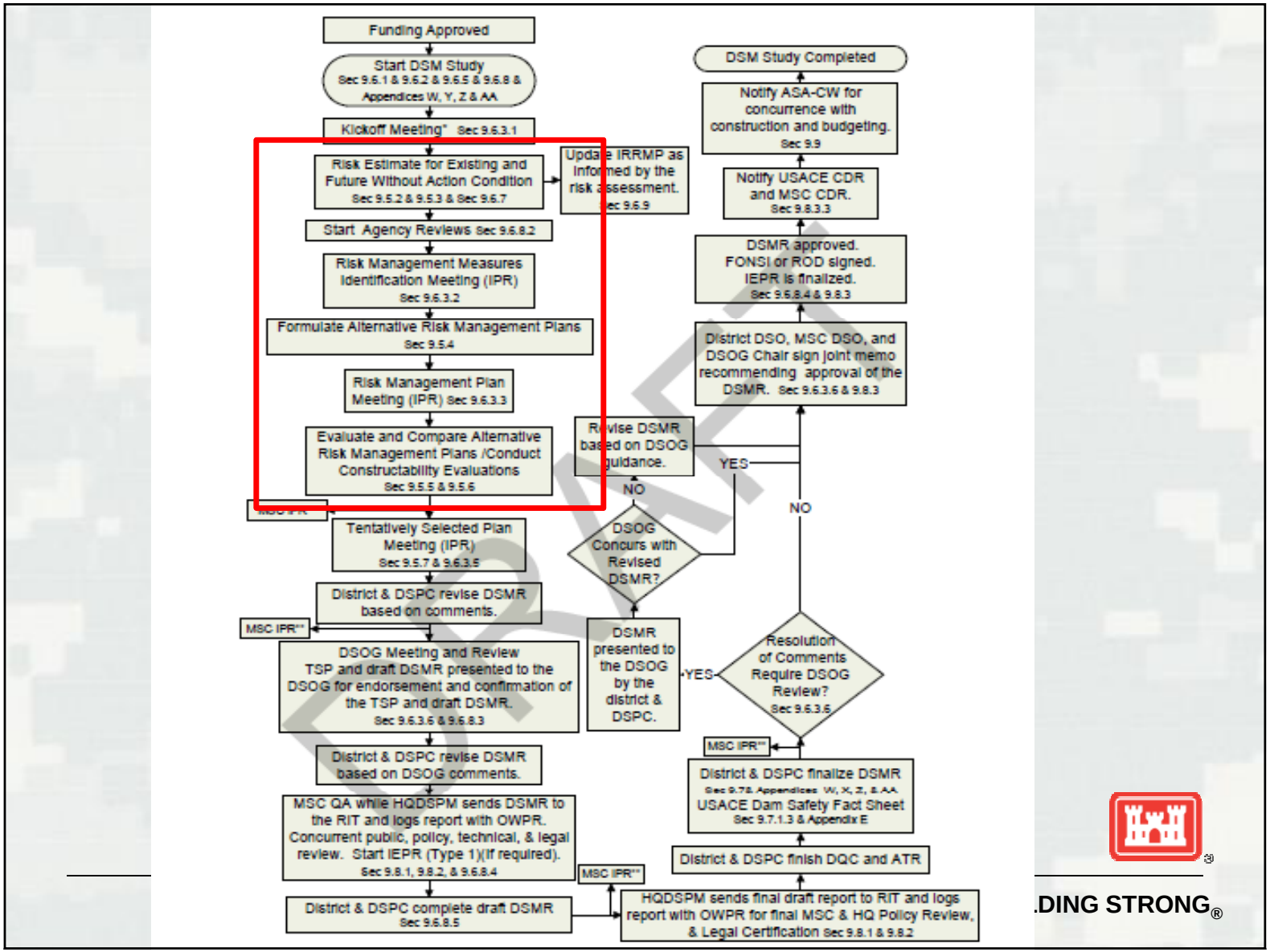
Dam Safety Mod Study

Alternatives Development and Evaluation

Minimum Required Alternatives

- No Action (Future without Action Condition)
- Meet Full Tolerable Risk Guidelines
- Achieve Tolerable Risk for Life Safety
- Remove Structure
- Replace Structure


Funding Approved
Start DSM Study
Sec 9.6.1 & 9.6.2 & 9.6.5 & 9.6.8 & Appendices W, Y, Z & AA
Kickoff Meeting* Sec 9.6.3.1
Risk Estimate for Existing and Future Without Action Condition
Sec 9.5.2 & 9.5.3 & Sec 9.6.7
Update IRRMP as informed by the risk assessment.
Sec 9.6.9
Start Agency Reviews Sec 9.6.8.2
Risk Management Measures Identification Meeting (IPR)
Sec 9.6.3.2
Formulate Alternative Risk Management Plans
Sec 9.5.4
Risk Management Plan Meeting (IPR) Sec 9.6.3.3
Evaluate and Compare Alternative Risk Management Plans /Conduct Constructability Evaluations
Sec 9.5.5 & 9.5.6
Tentatively Selected Plan Meeting (IPR)
Sec 9.5.7 & 9.6.3.5
District & DSPC revise DSMR based on comments.
MSC IPR**
DSOG Meeting and Review TSP and draft DSMR presented to the DSOG for endorsement and confirmation of the TSP and draft DSMR.
Sec 9.6.3.6 & 9.6.8.3
District & DSPC revise DSMR based on DSOG comments.
MSC QA while HQDSPM sends DSMR to the RIT and logs report with OWPR. Concurrent public, policy, technical, & legal review. Start IEPR (Type 1)(if required).
Sec 9.8.1, 9.8.2, & 9.6.8.4
District & DSPC complete draft DSMR
Sec 9.6.8.5
MSC IPR**
HQDSPM sends final draft report to RIT and logs report with OWPR for final MSC & HQ Policy Review, & Legal Certification Sec 9.8.1 & 9.8.2
District & DSPC finish DQC and ATR
District & DSPC finalize DSMR
Sec 9.7& Appendices W, X, Z, & AA
USACE Dam Safety Fact Sheet
Sec 9.7.1.3 & Appendix E
MSC IPR**
Resolution of Comments Require DSOG Review?
Sec 9.6.3.6
YES
NO
DSMR presented to the DSOG by the district & DSPC.
DSOG Concurs with Revised DSMR?
YES
NO
Revise DSMR based on DSOG guidance.
District DSO, MSC DSO, and DSOG Chair sign joint memo recommending approval of the DSMR. Sec 9.6.3.6 & 9.8.3
DSMR approved. FONSI or ROD signed. IEPR is finalized.
Sec 9.6.8.4 & 9.8.3
Notify USACE CDR and MSC CDR.
Sec 9.8.3.3
Notify ASA-CW for concurrence with construction and budgeting.
Sec 9.9
DSM Study Completed
DRAFT

The End