BOUNDARY DAM
SPILLWAY NO.1 MODIFICATIONS

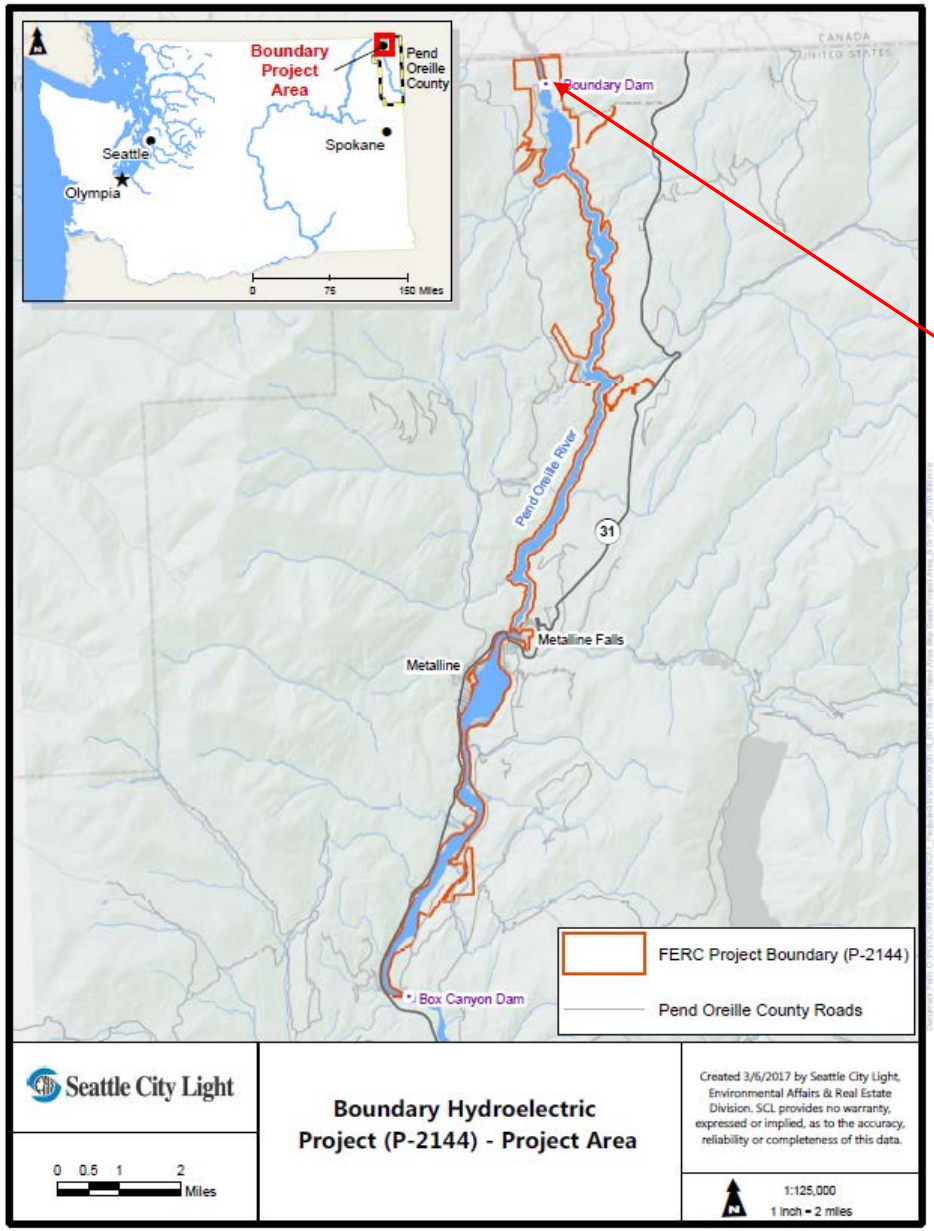
Total Dissolved Gas Abatement Program

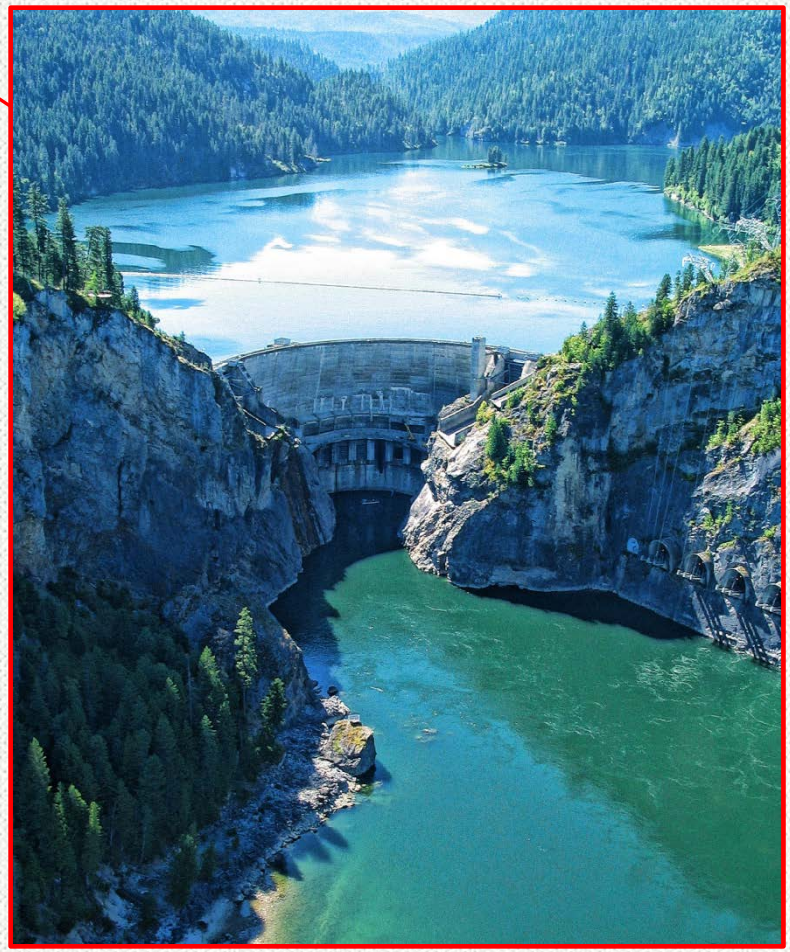
Andrew Bearlin, Sr. Capital Projects Coordinator, Seattle City Light

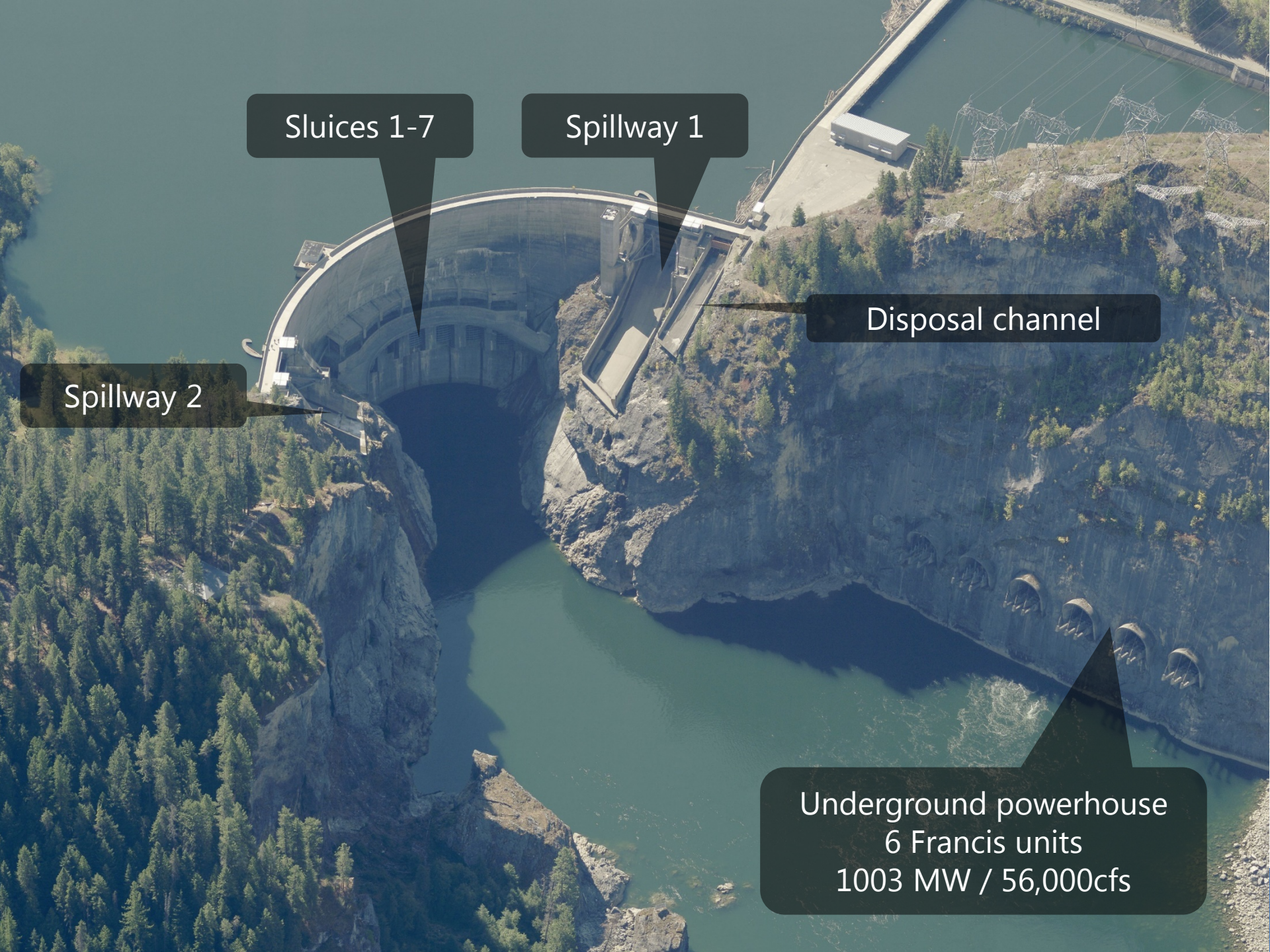
PRESENTATION OUTLINE

- Project Background
- Spillway No.1 Mods
  - Hydraulic Design
  - Geotechnical Design
  - Structural Design
  - Construction sequence

PROJECT LOCATION

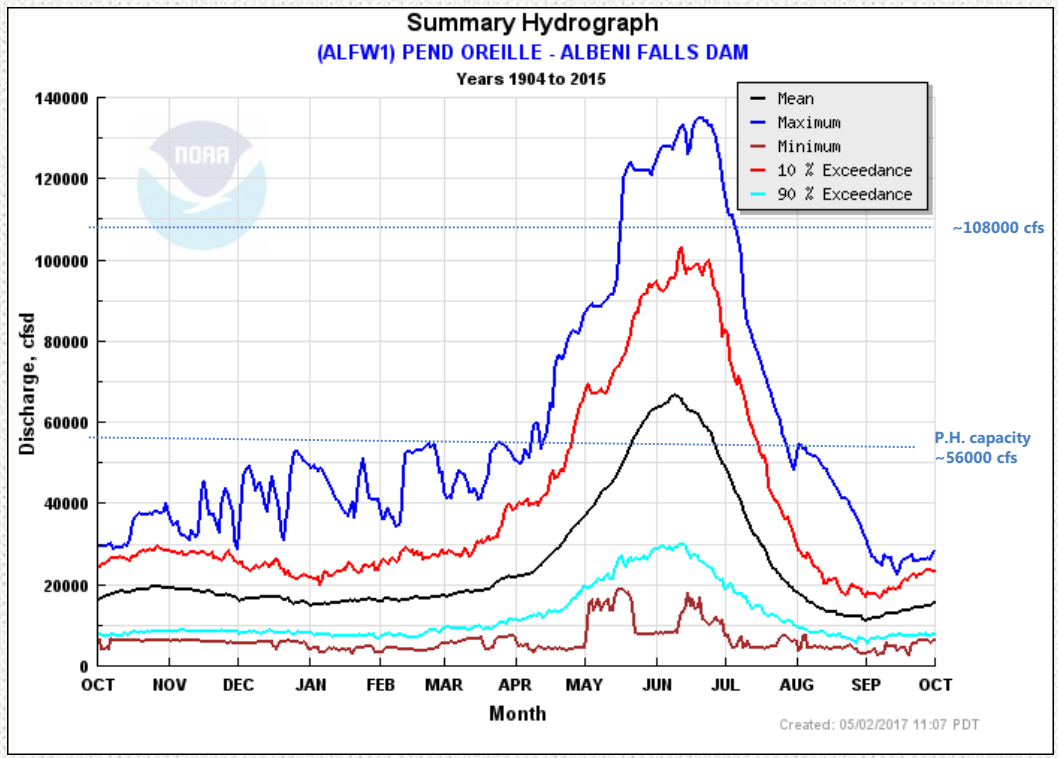





Sluices 1-7
Spillway 1
Disposal channel
Spillway 2
Underground powerhouse
6 Francis units
1003 MW / 56,000cfs

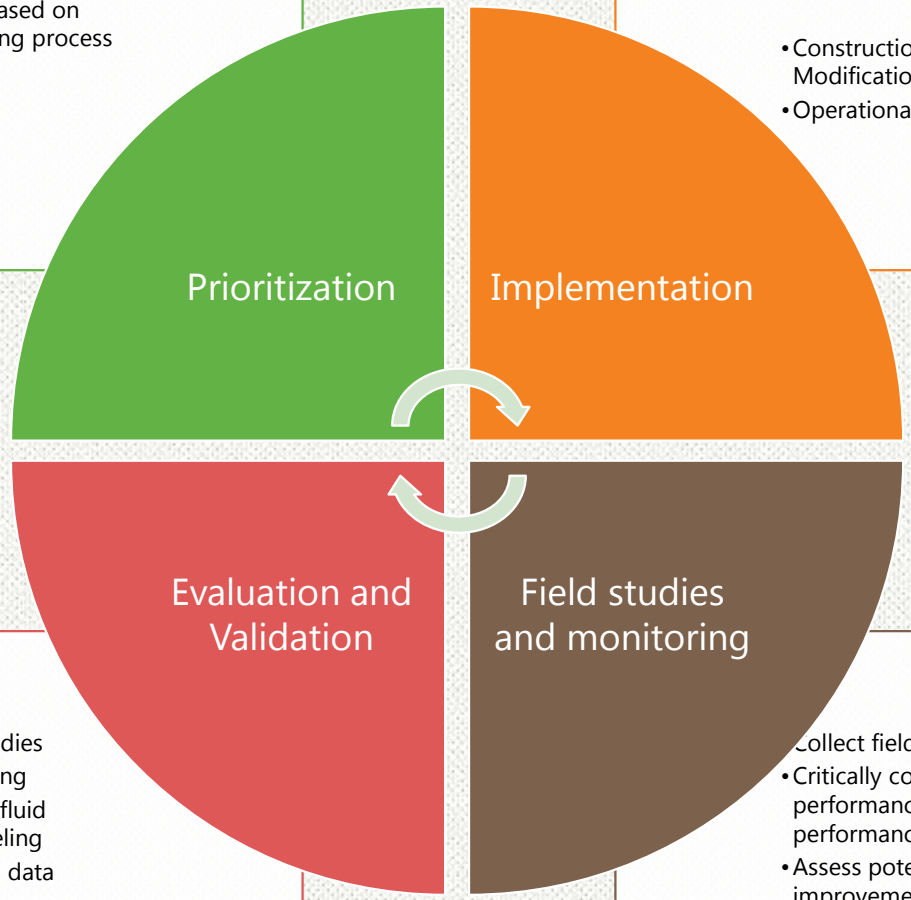
TDG BACKGROUND

- New License issued 2013
- 401 Water Quality Certification Requirements
  - The Project shall not cause any exceedance of TDG water quality criteria of 110% TDG saturation
  - The standard is waived for flows exceeding the 7Q10 event: approximately 108,300 cfs.



PROGRAM LIFE CYCLE

2007 – 2009
Expert panel workshop



- Ranked order of development based on studies – ongoing process

- Construction and Modification
- Operational configurations

- Engineering studies
- Physical modeling
- Computational fluid dynamics modeling
- Analysis of field data

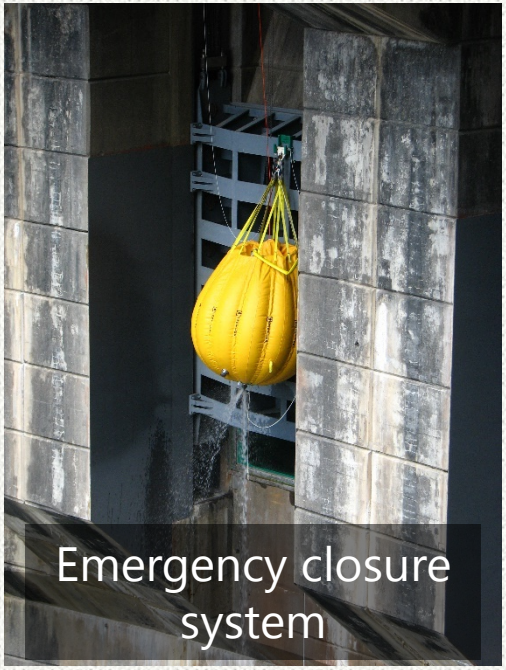
- Collect field TDG data
- Critically compare actual performance to predicted performance
- Assess potential improvements

PREVIOUS WORK

- 2011: Sluice gate work

Added seal plates

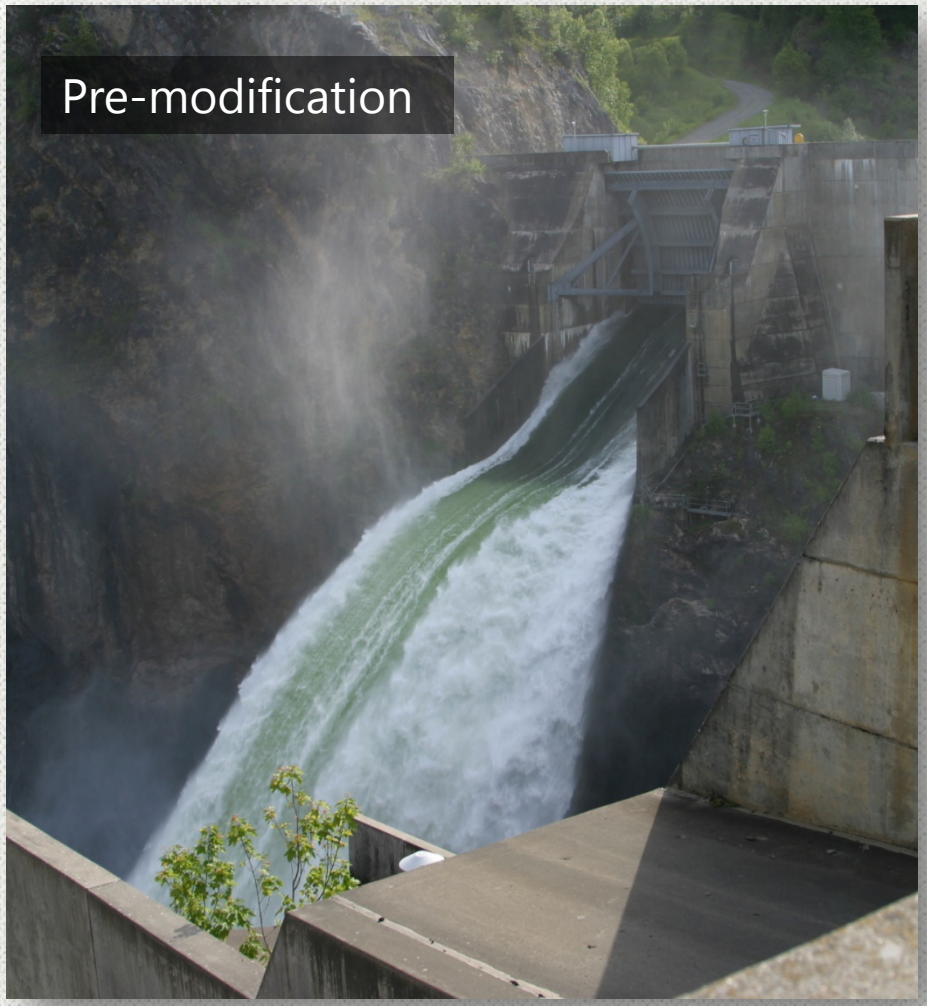
Gate slot deflectors



Emergency closure system

PREVIOUS WORK

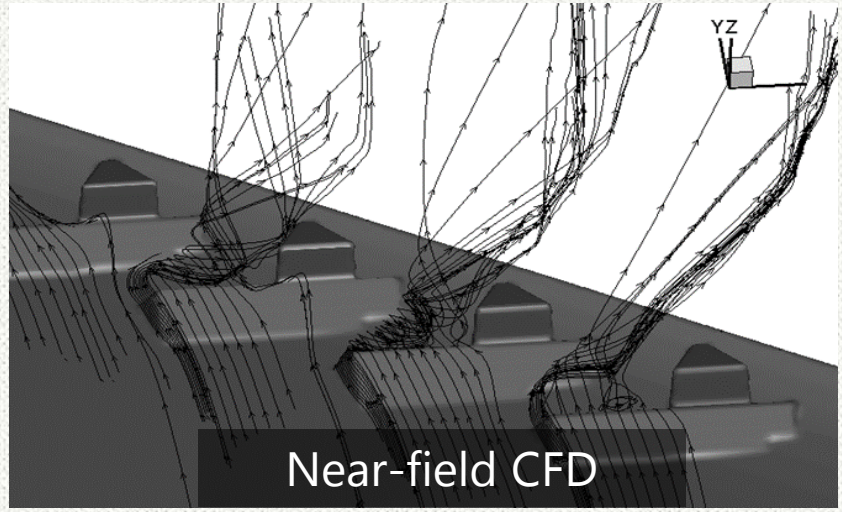
- 2014: Spillway No. 2



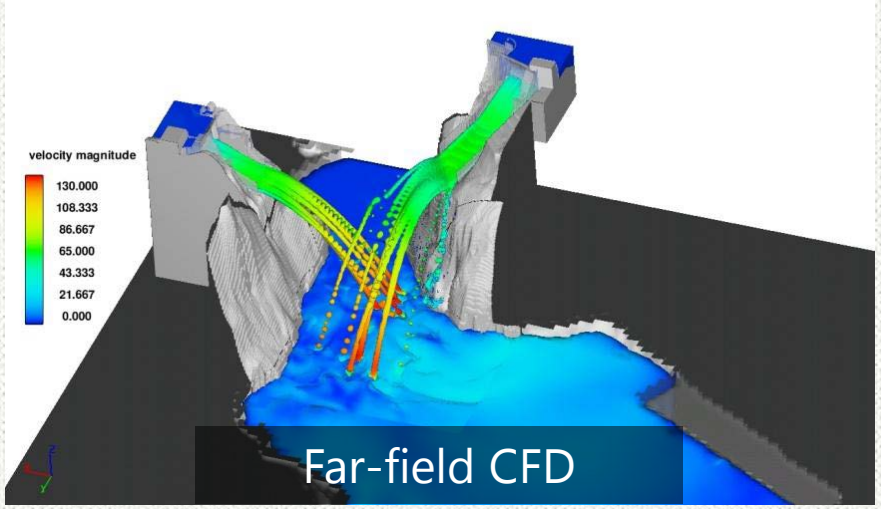
Post-modification

Seattle City Light

DESIGN TOOLBOX

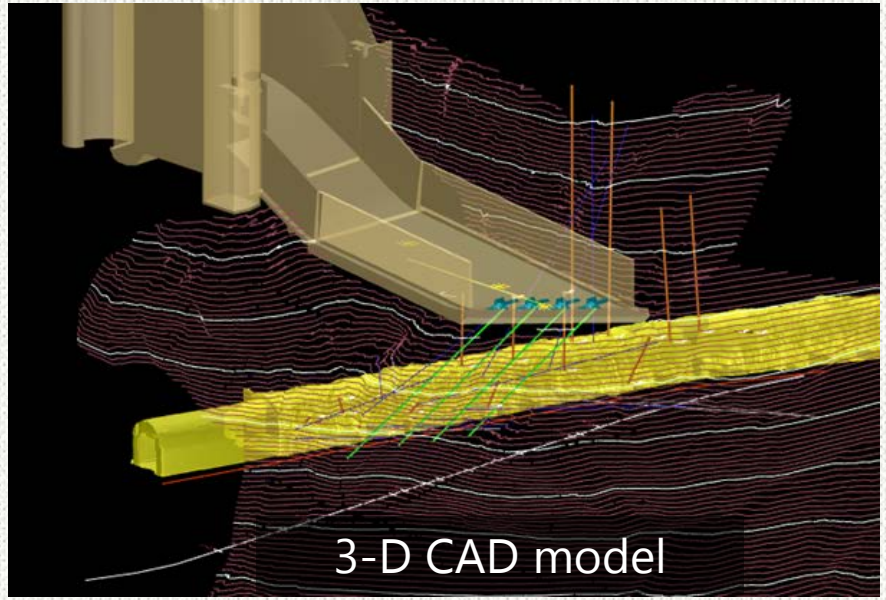


Near-field CFD



Far-field CFD

1:25 physical model

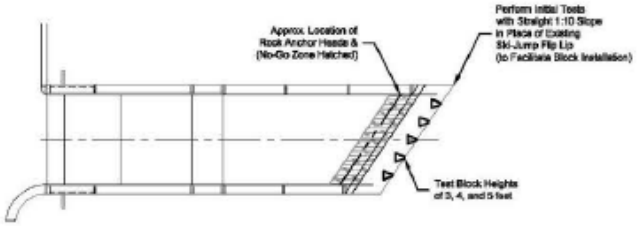


3-D CAD model

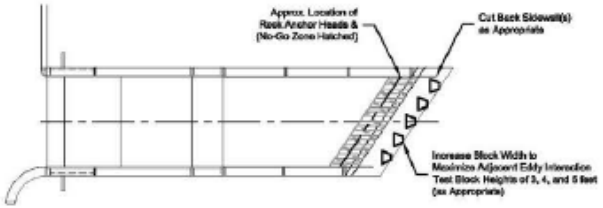
2015/16 SPILLWAY 1 MODIFICATIONS

- Preliminary concept:
  - Roughness elements to dissipate energy
- Objectives & constraints:
  - Minimize Plunge depth
  - Maximize geotechnical stability
  - Minimize erosion risk
  - Minimize cavitation risk
  - Minimize operational constraints
  - Maximize constructability

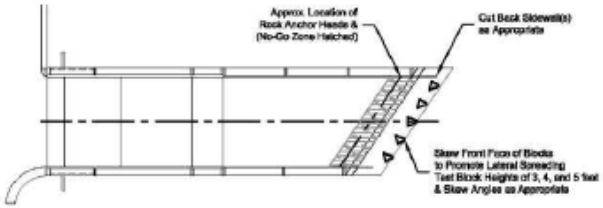
SPILLWAY NO. 1 ALTERNATIVE CONCEPTS



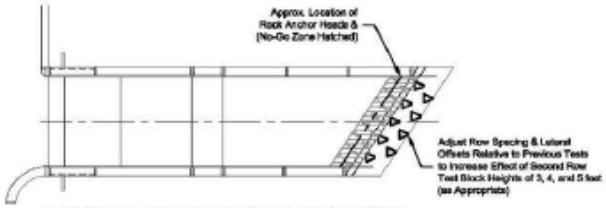
Single Oblique Row - 5 ft Wide Blocks



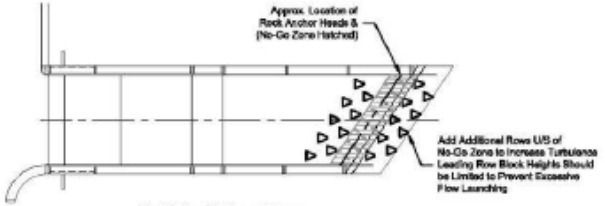
Single Oblique Row - 7.5 ft Wide Blocks



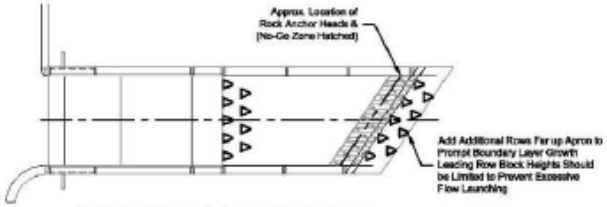
Single Oblique Row - Skewed Faces



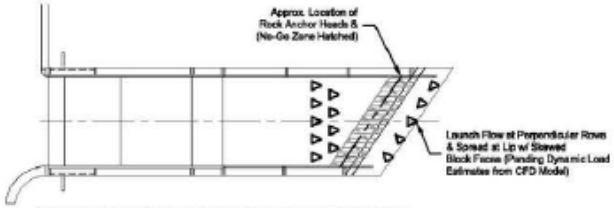
Dual Oblique Row - Tighter Spacing/Lateral Shift



Multiple Oblique Rows



Multiple Oblique & Perpendicular Rows



Combination of Best Performing Concepts to Date

Notes:
1. Model to prototype scale = 1:25

REV:	DESCRIPTION:	DES:	DATE:	CHK:	DATE:
0	For Information	JDW	04/02/14	CEB	04/02/14

SPILLWAY 1 - INITIAL MODIFICATION CONCEPTS - PLAN VIEW
Boundary Dam Physical Model Study
Seattle City Light
Seattle, Washington

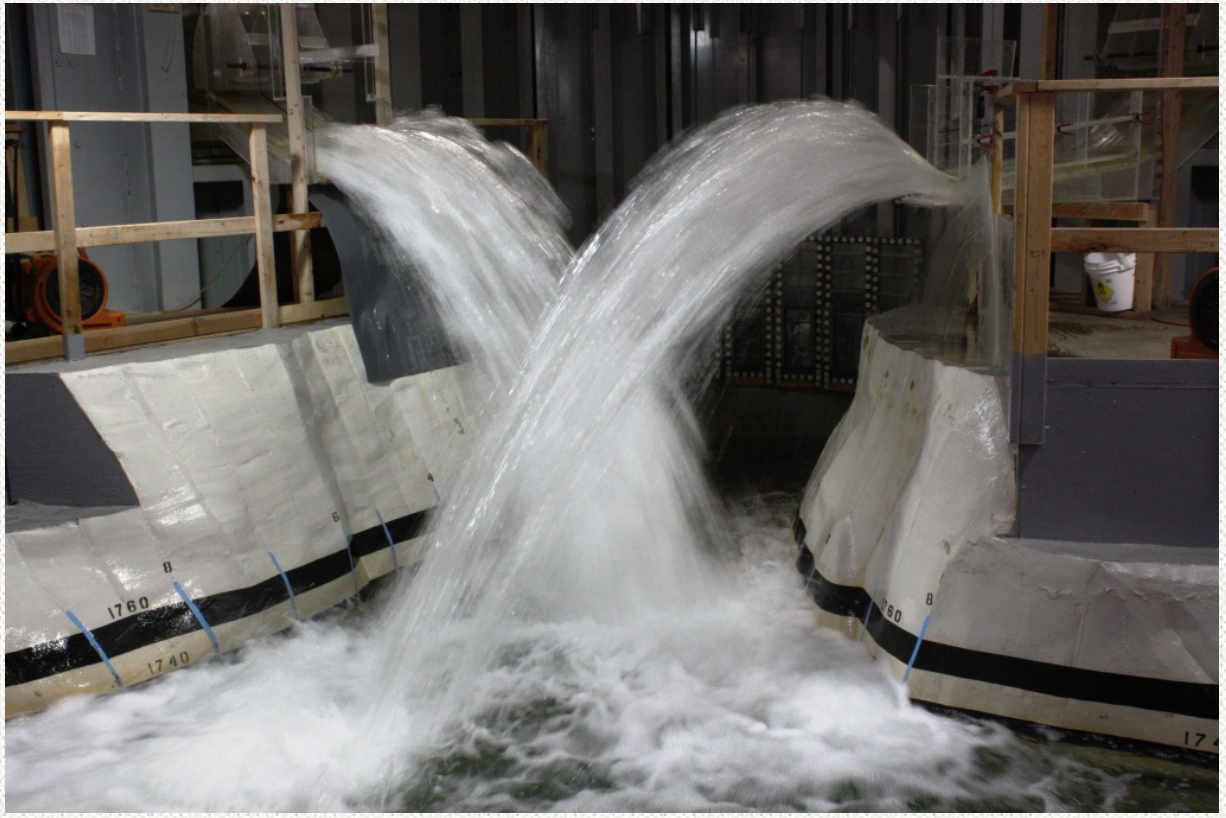
SCALE: 1:30
DATE: 10/08/2014
PROJECT NUMBER: 71203CL001

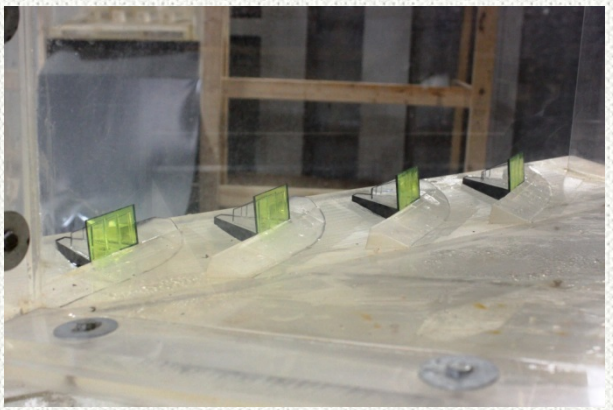
ALDEN
9521 WILLOWS RD NE
REDMOND, WA 98052
(425) 681-7700
WWW.ALDENLAB.COM

FIGURE NUMBER: 14

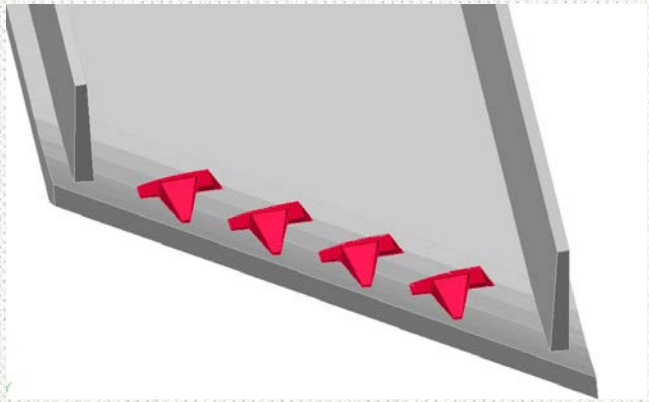
SHEET: SPW1 CONCEPTS

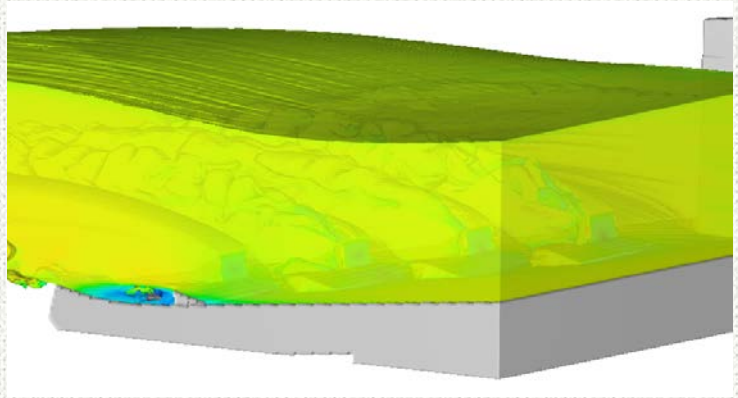
HYDRAULIC DESIGN – PHYSICAL MODEL

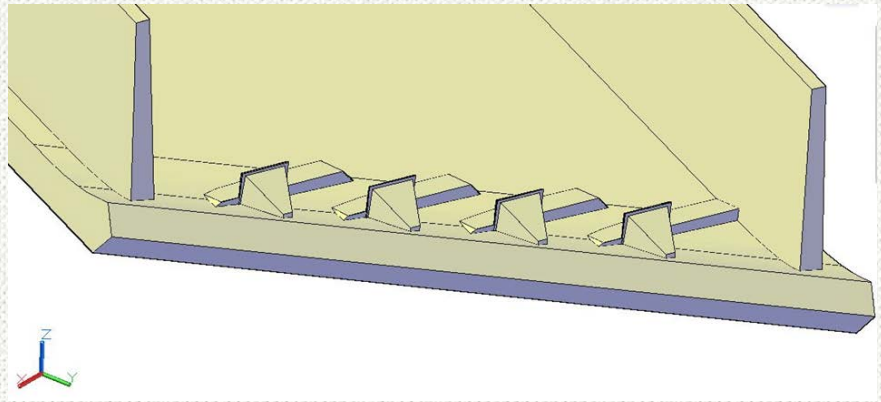


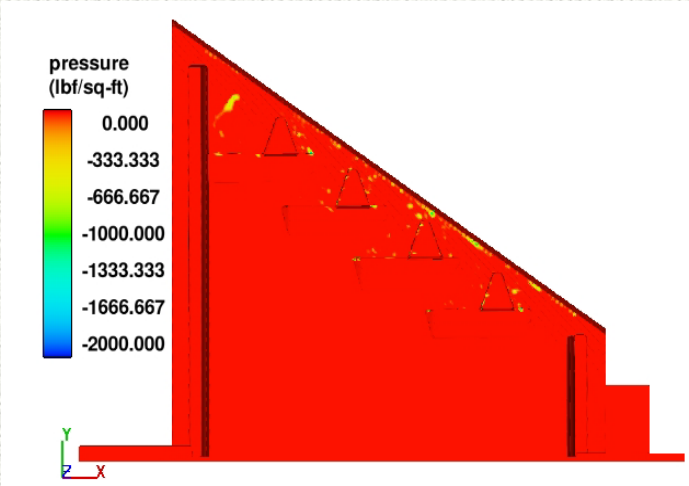


HYDRAULIC DESIGN: NEAR FIELD TESTING

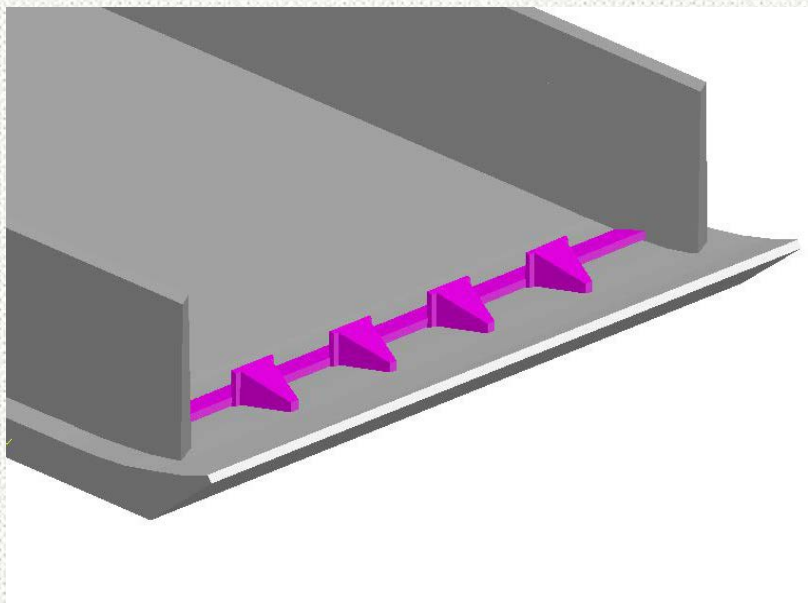




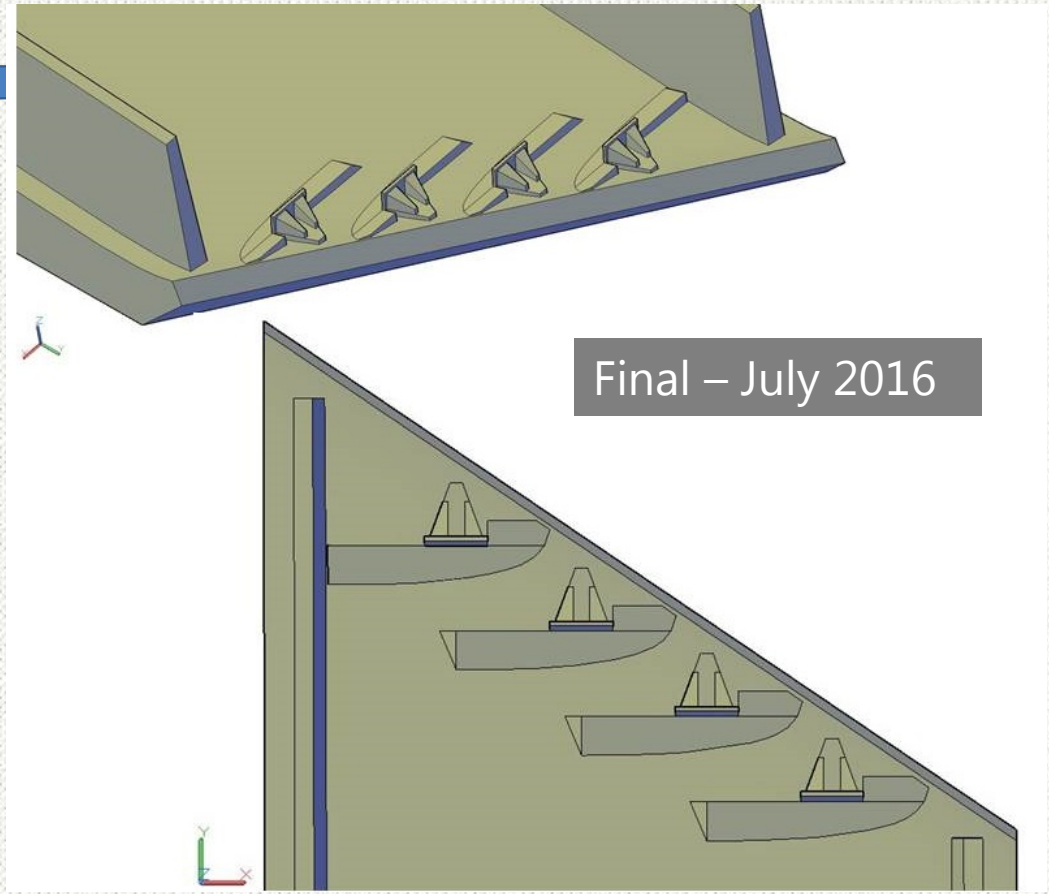




HYDRAULIC DESIGN: NEAR FIELD TESTING



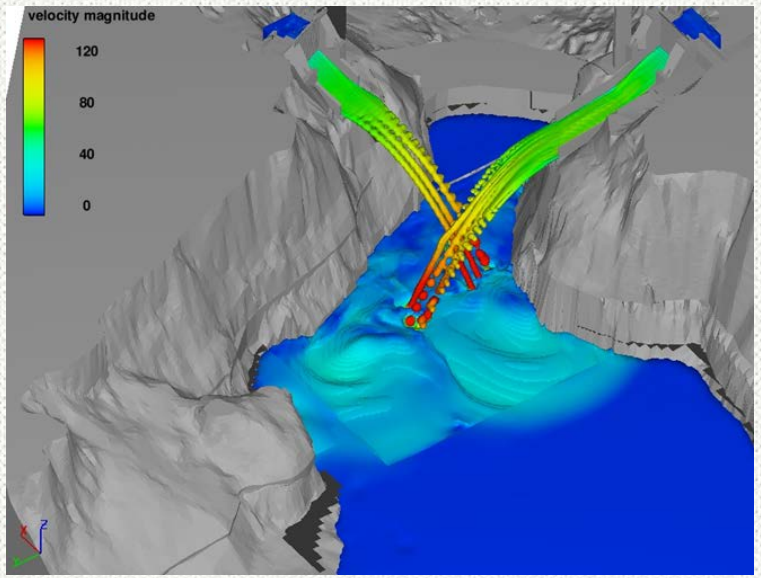
Variant 7B – Dec 2015

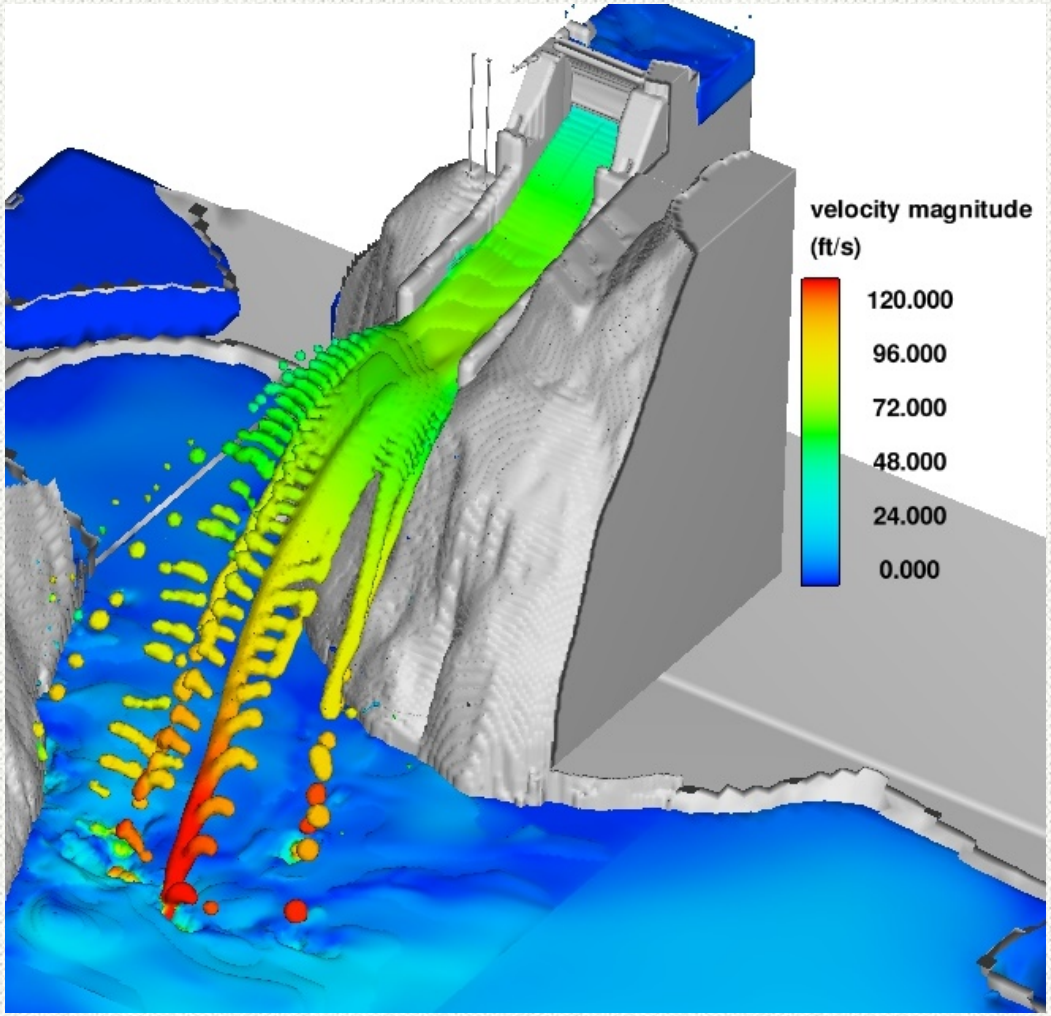


Final – July 2016

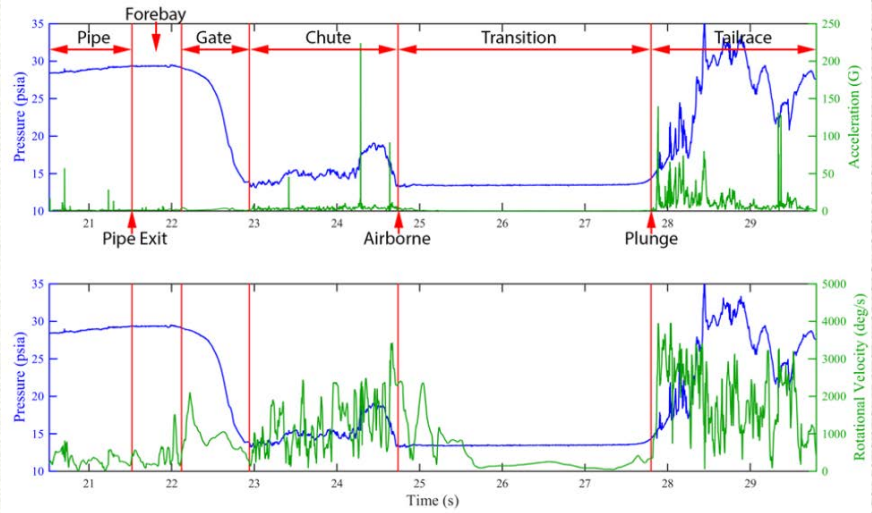
HYDRAULIC DESIGN – FAR FIELD CFD

- TDG performance
- Operational configuration



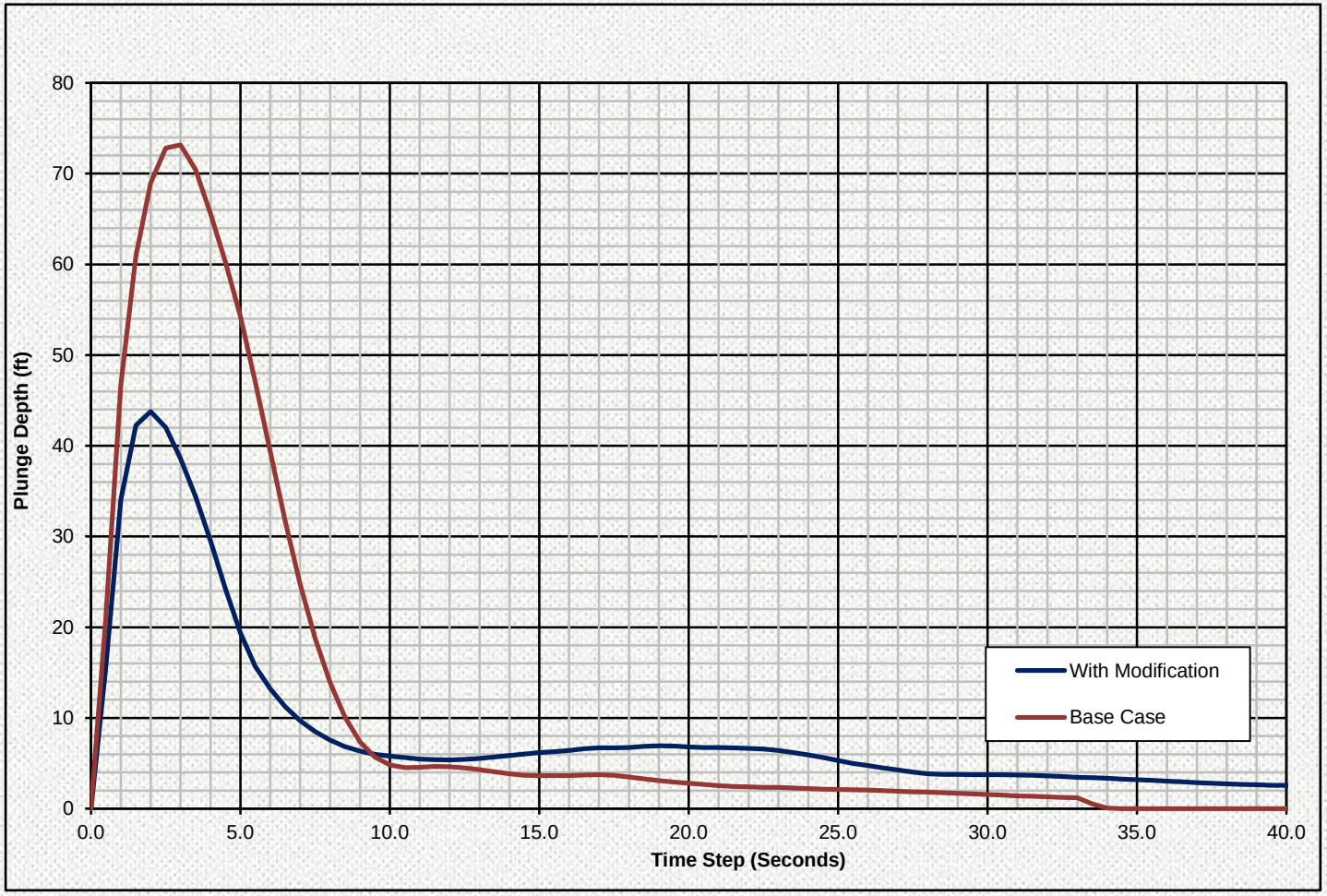


TDG PREDICTION: BUBBLE TRACKING

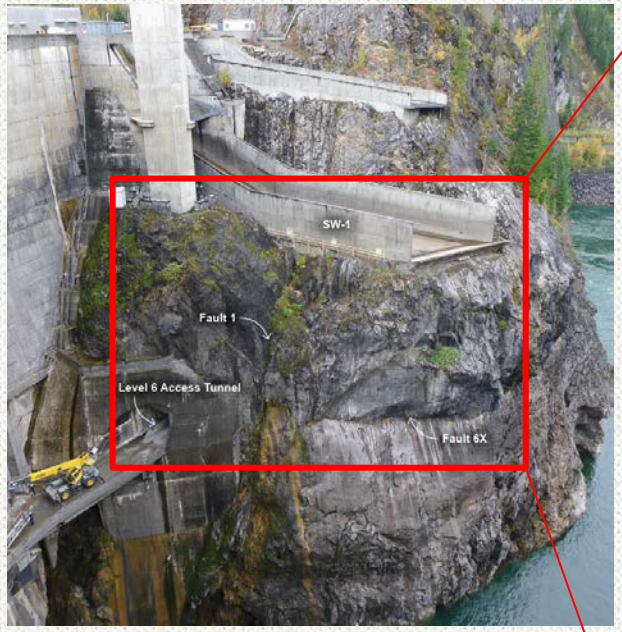


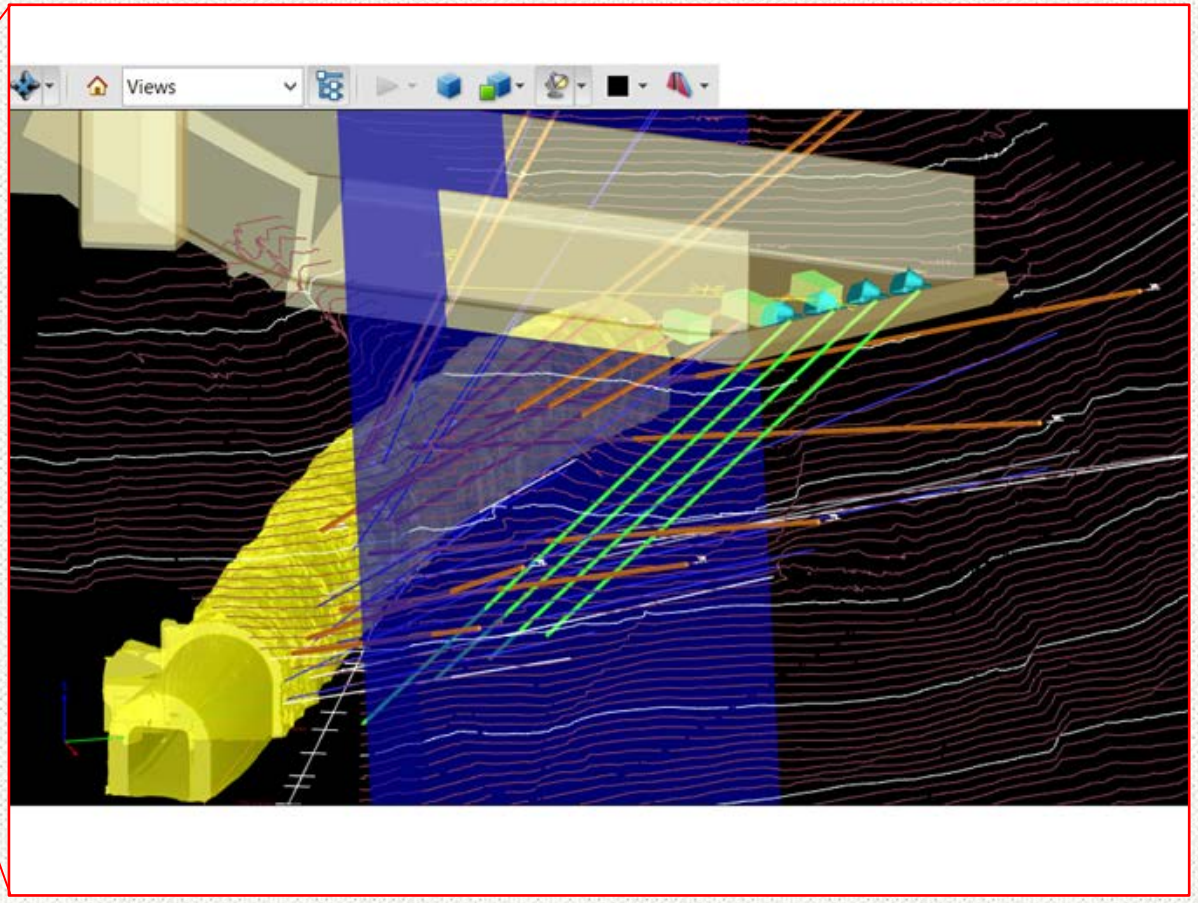
HYDRAULIC DESIGN

Average particle (air bubble) plunge depth (20,000 cfs)

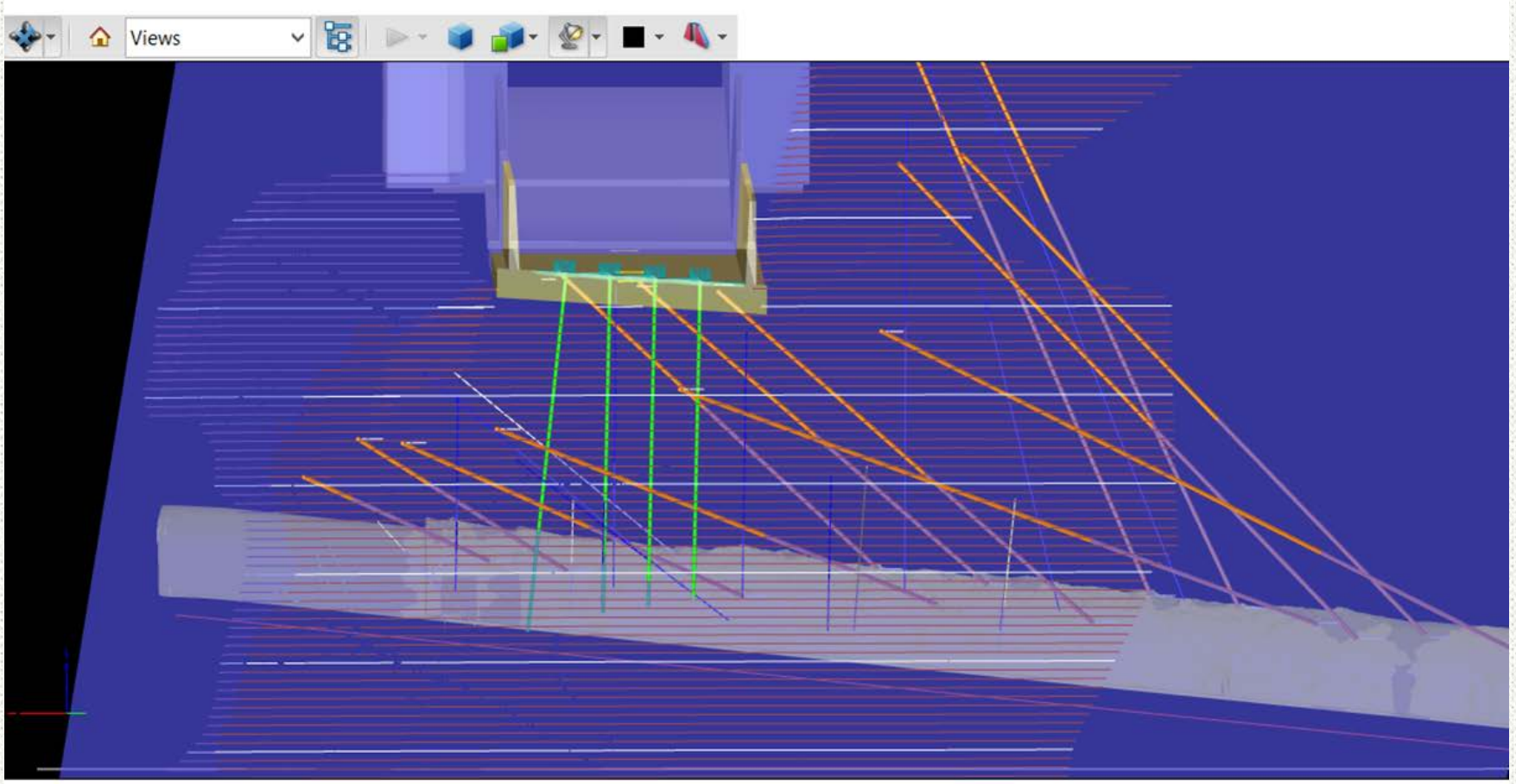


GEOTECHNICAL DESIGN

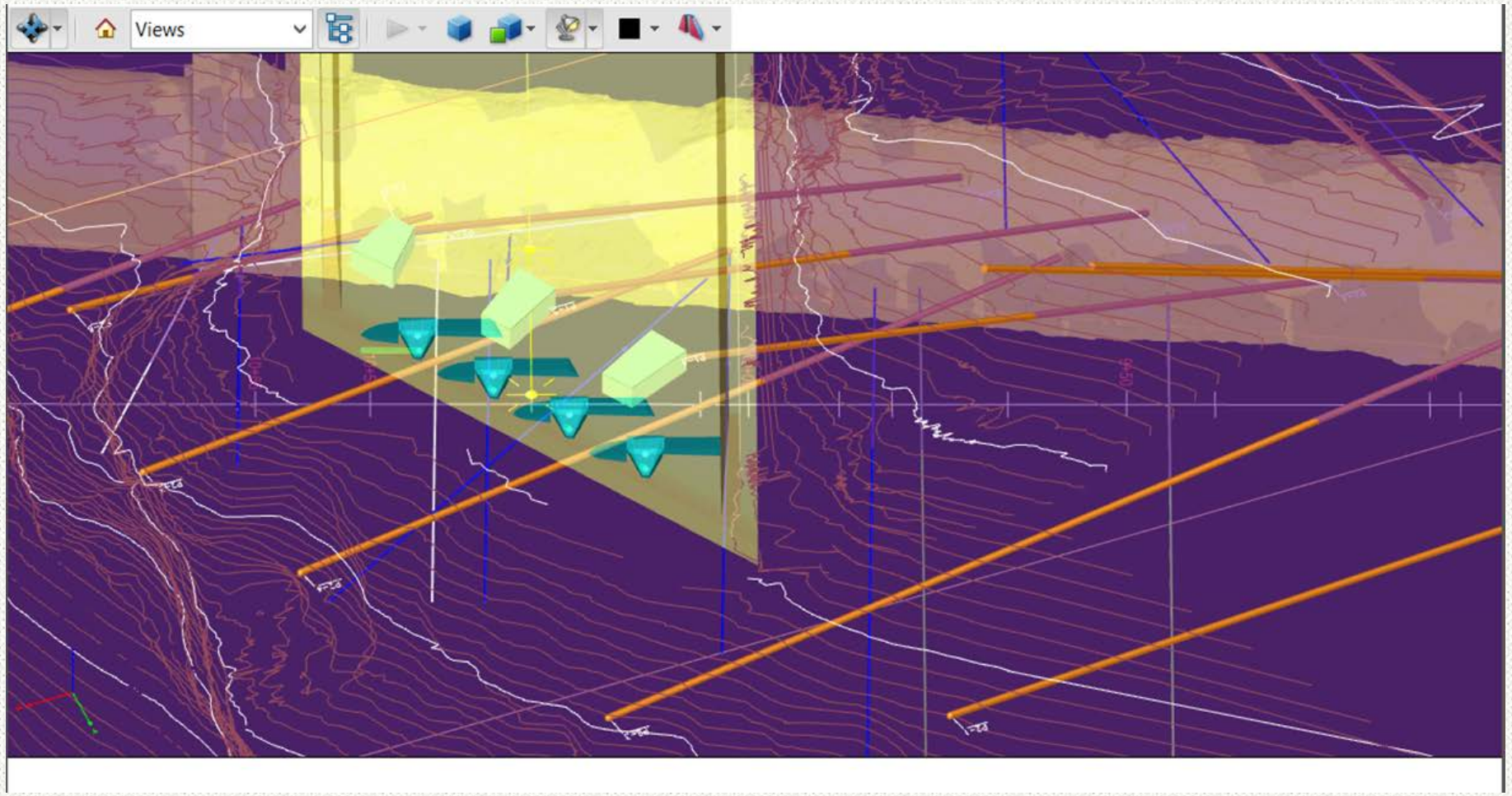




PRE-EXISTING PT ANCHORS



INCLUDING 3 IN THE SPILLWAY ITSELF



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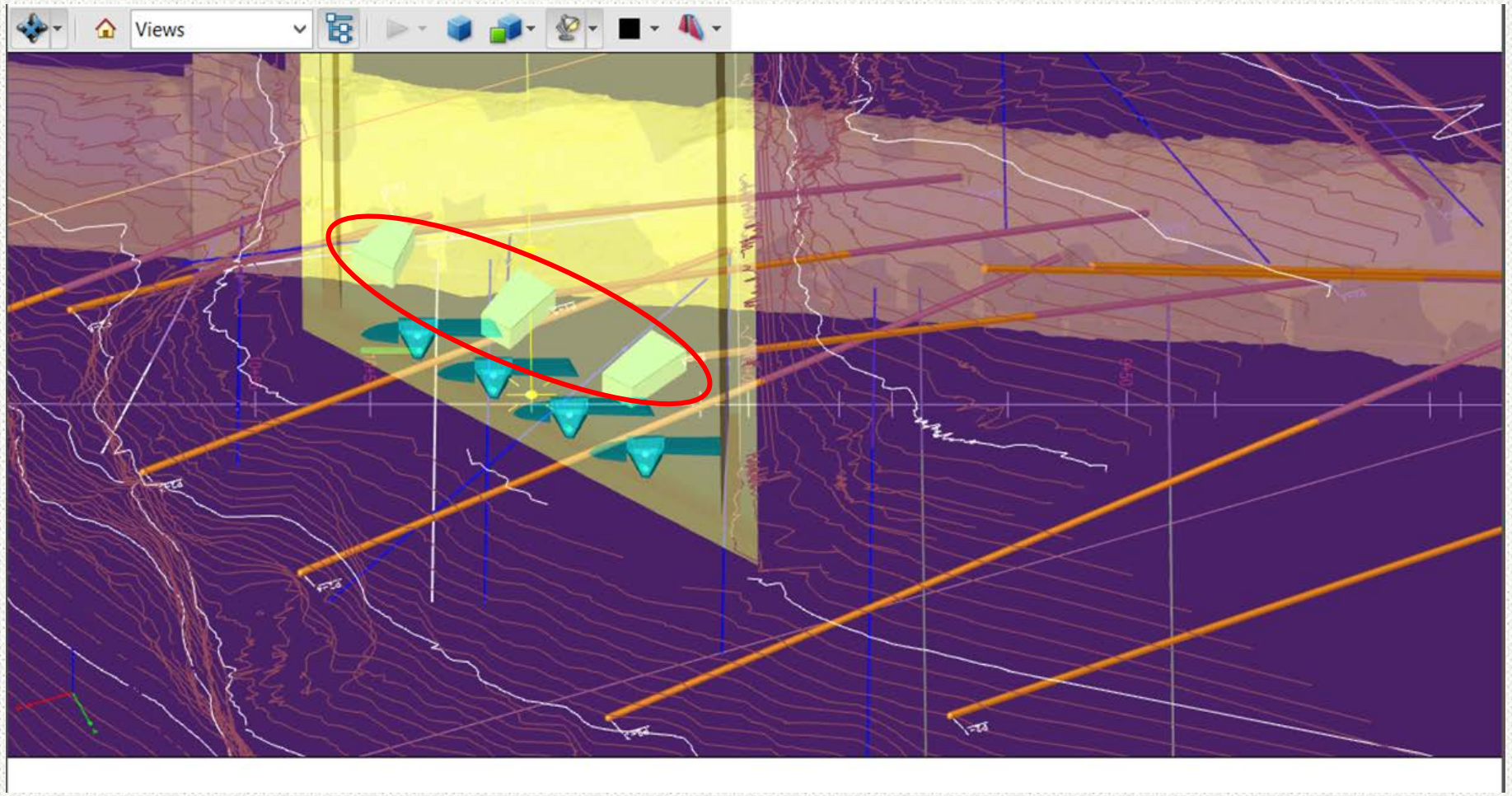
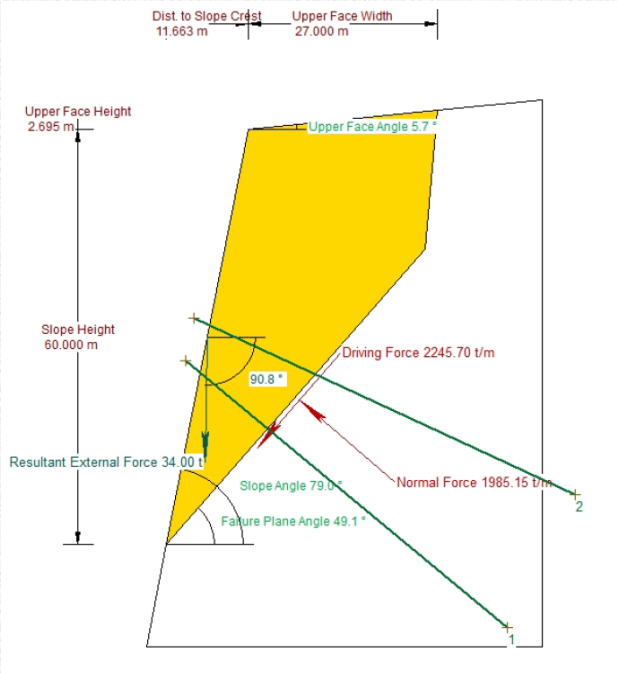
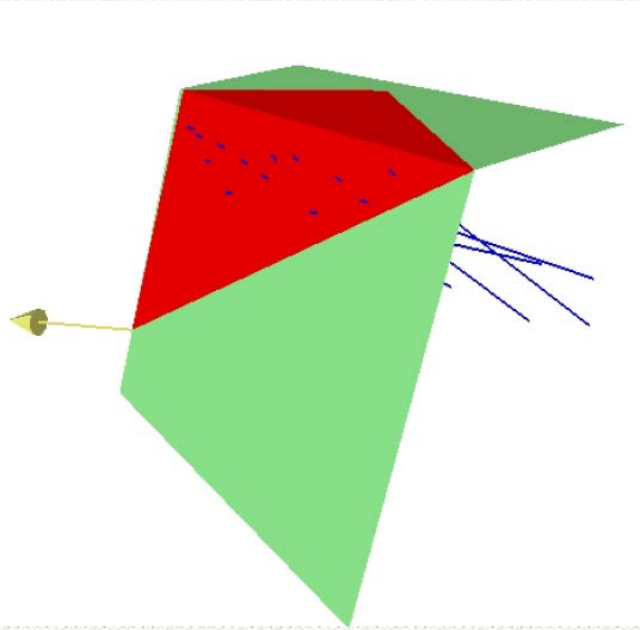


GEOTECHNICAL DESIGN

- 3-D static equilibrium analysis was compared to a 2-D analysis in RocPlane and 3-D analysis using Swedge.
- All 3 models converged within 1%



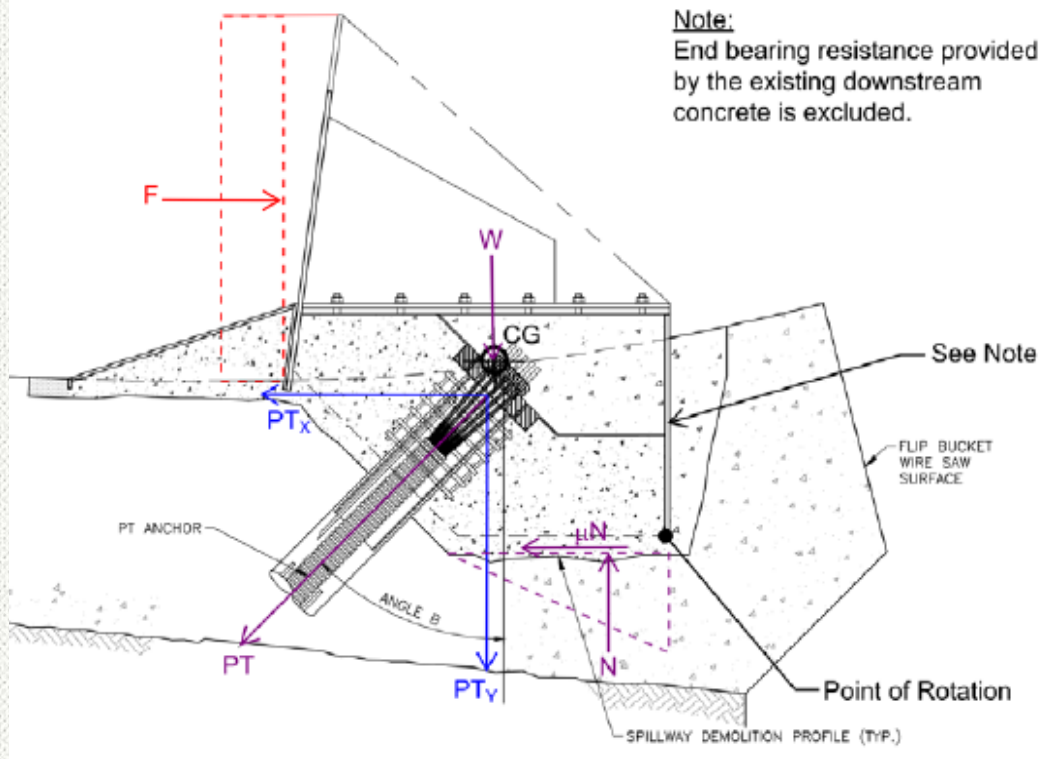
RocPlane Analysis



Swedge Analysis

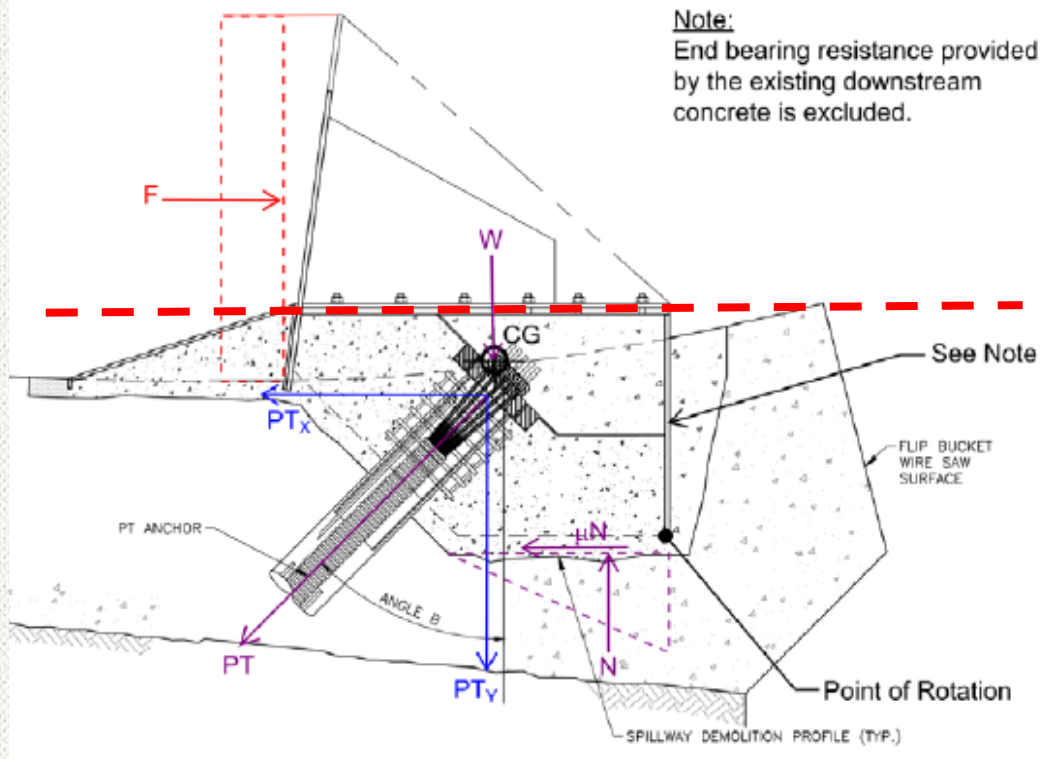
STRUCTURAL DESIGN

- Full stagnation pressure was considered as a conservative hydrodynamic loading for the roughness element design.



STRUCTURAL DESIGN

- Debris loading (impact) was also considered, and a break-away fuse was designed.

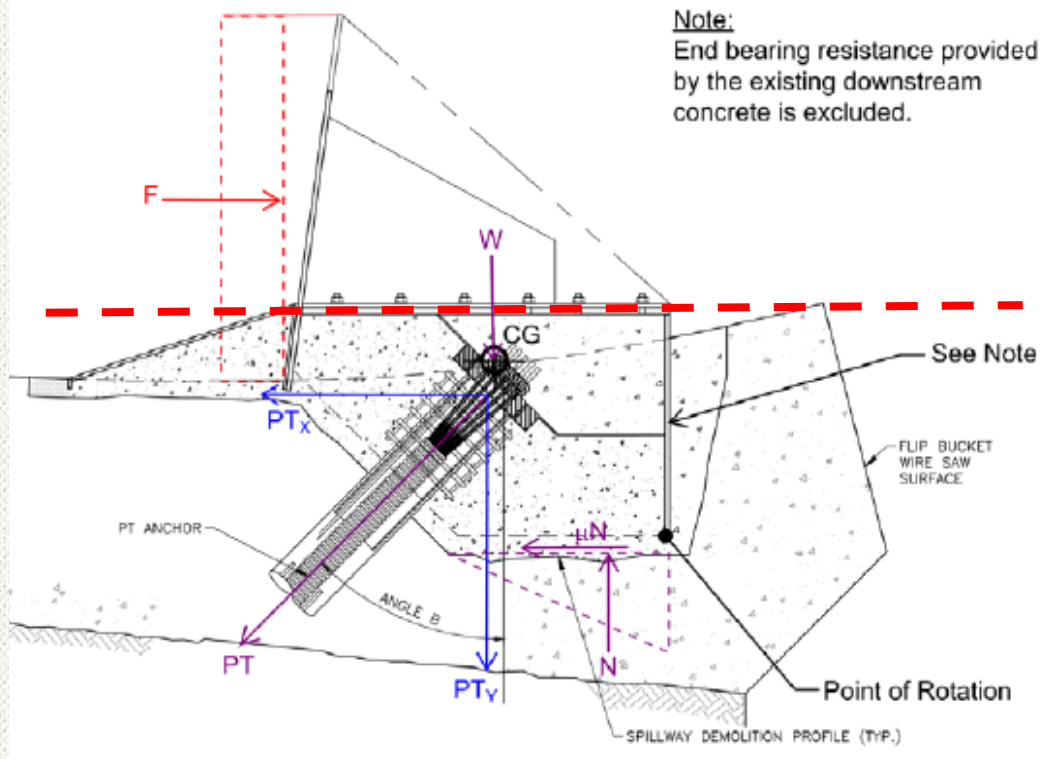


STRUCTURAL DESIGN

Tensile Testing and Failed Specimen

STRUCTURAL DESIGN

- The 20-strand post-tensioned anchors remain elastic under all loadings, even at impact.
- The top section of the roughness element is sacrificial, attached to the embedded base section with "fused" fasteners.



MOBILIZATION

Crane Mobilization into disposal channel

SITE -PREP

CORING PILOT HOLES

HQ3 core drilling

HQ3 Cores

Inclinometer

CONCRETE DEMO

Concrete demo

PERCUSSION HOLE OPENING

FIT-UP & ANCHOR INSTALLATION

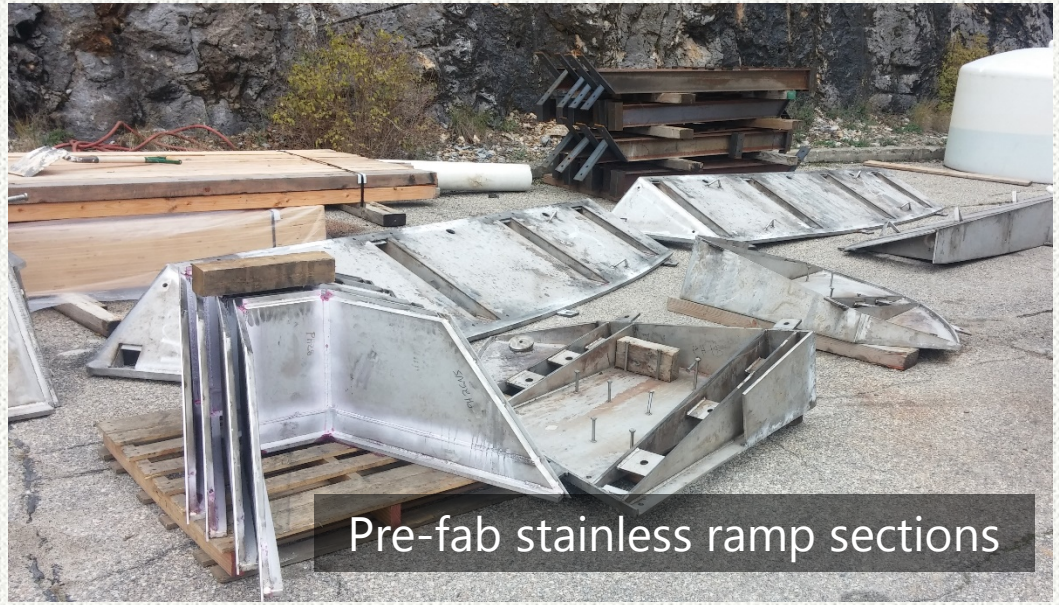
Checking RE lower section fit

Flying in tendons

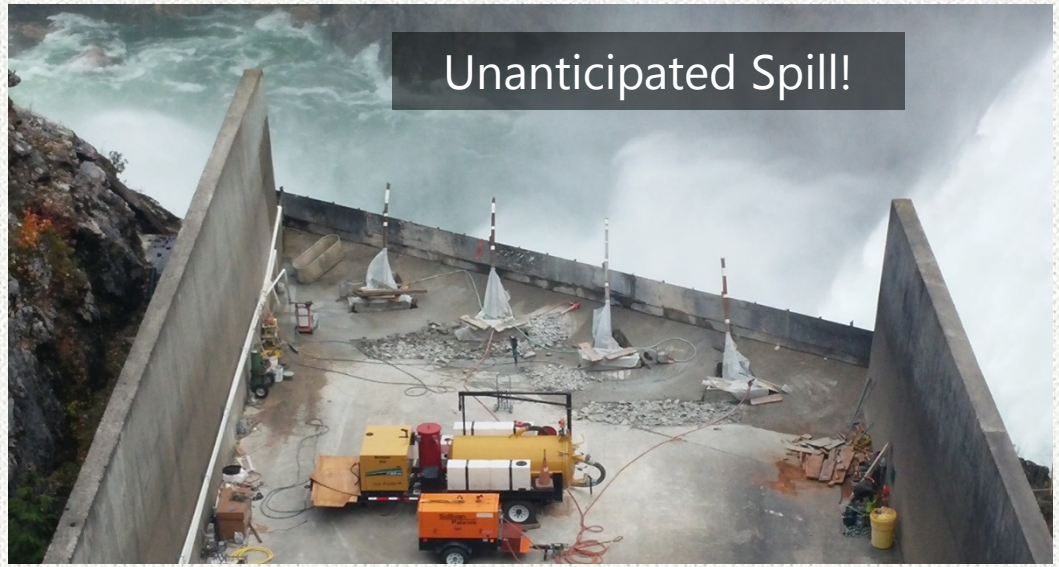
LOWER SECTION ASSEMBLY

Stage 1 concrete

RAMP DEMO & ASSEMBLY



Pre-fab stainless ramp sections



Unanticipated Spill!

ANCHOR STRESSING

Anchor stressing

ANCHOR STRESSING

Anchor stressing

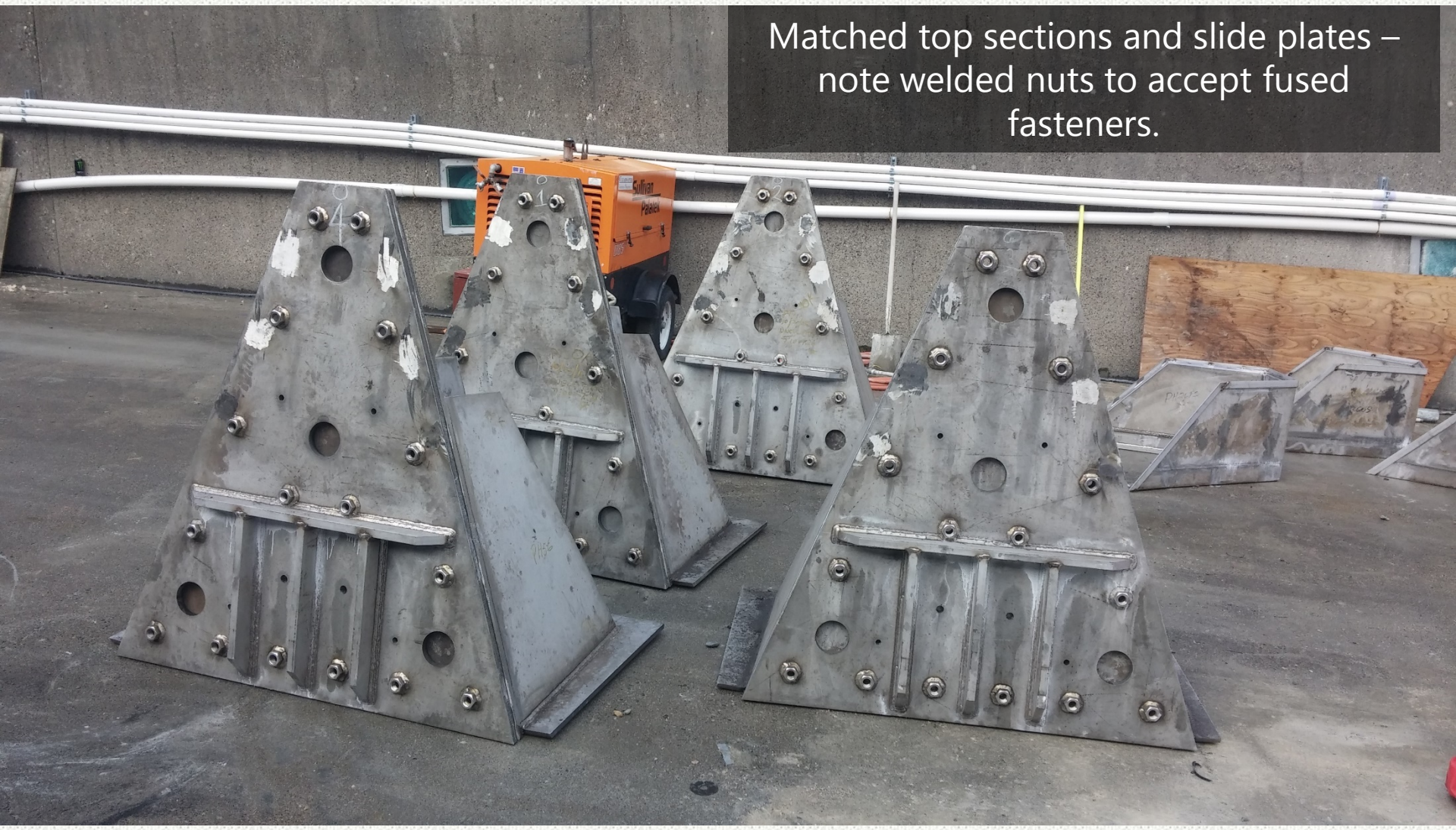
WEATHER PROTECTION

Man-made weather protection

RAMP ASSEMBLY & WELDING

Ramp installation

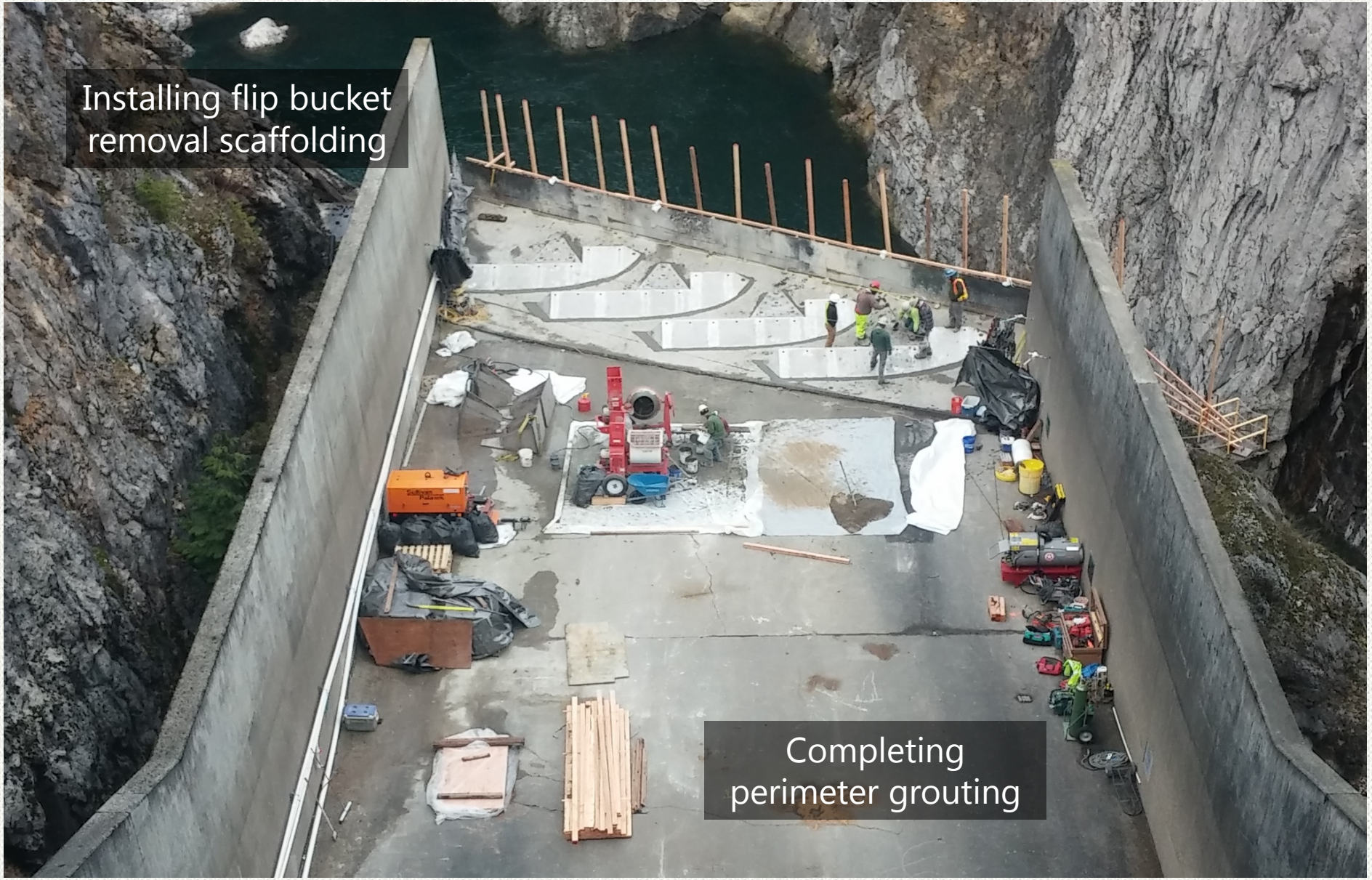
SLIDING PLATE & RE TOP SECTIONS



Matched top sections and slide plates – note welded nuts to accept fused fasteners.

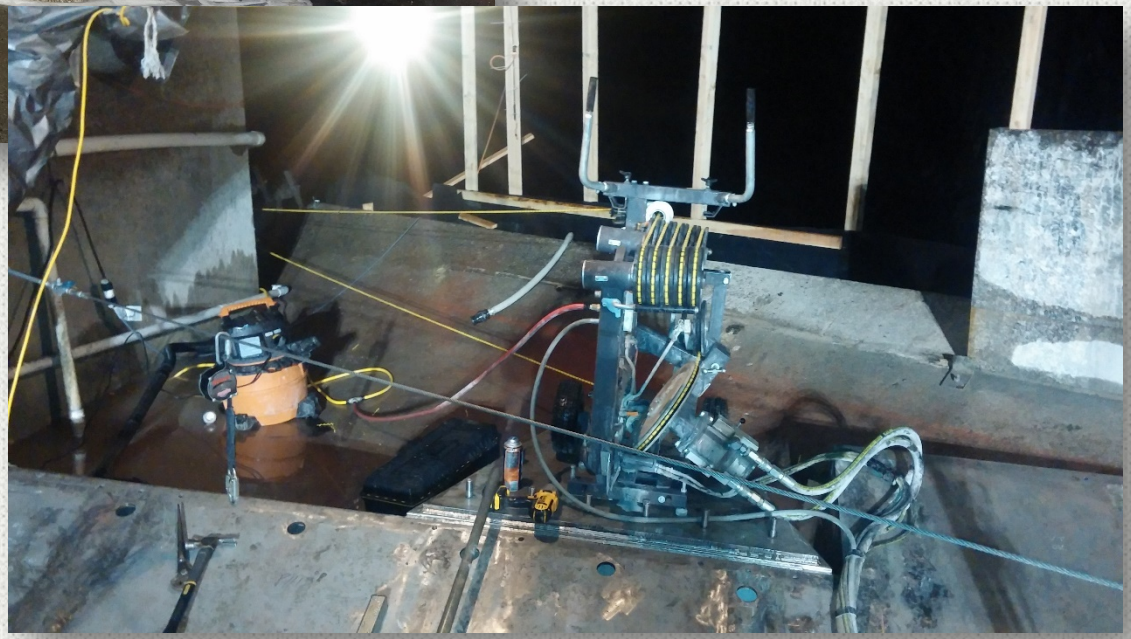
READY FOR GROUT

PREPARING FOR FLIP-LIP DEMO



FLIP-LIP STAGE

NIGHT WORK



Grouting the ramps and setting up the wire saw for flip bucket removal

FLIP-LIP DEMO

FLIP-LIP DEMO

ALMOST DONE

Flip bucket removal complete

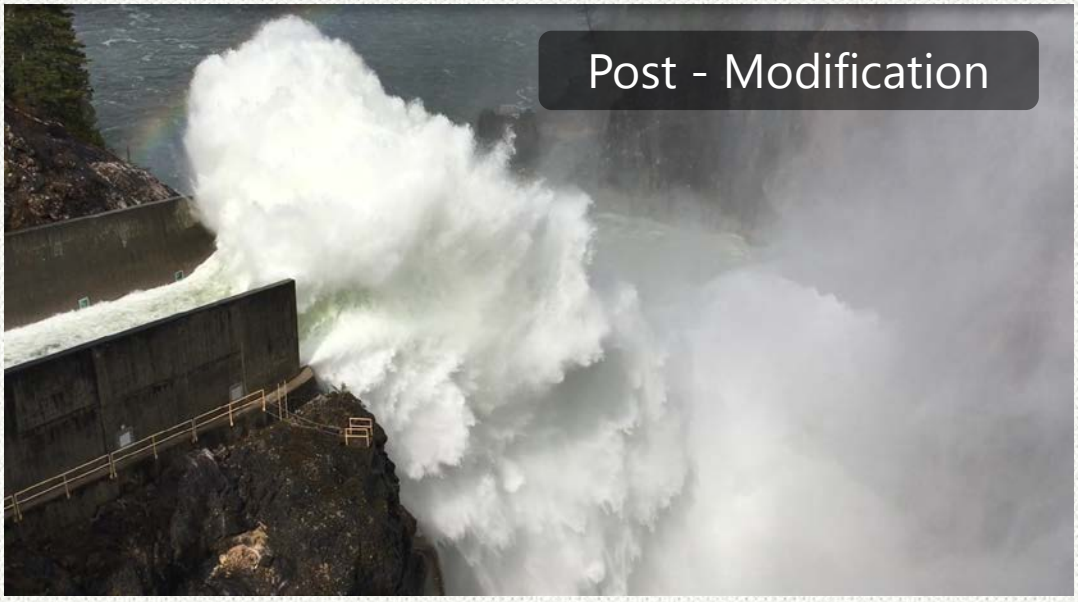
FINAL ASSEMBLY

Torqueing down fused fasteners

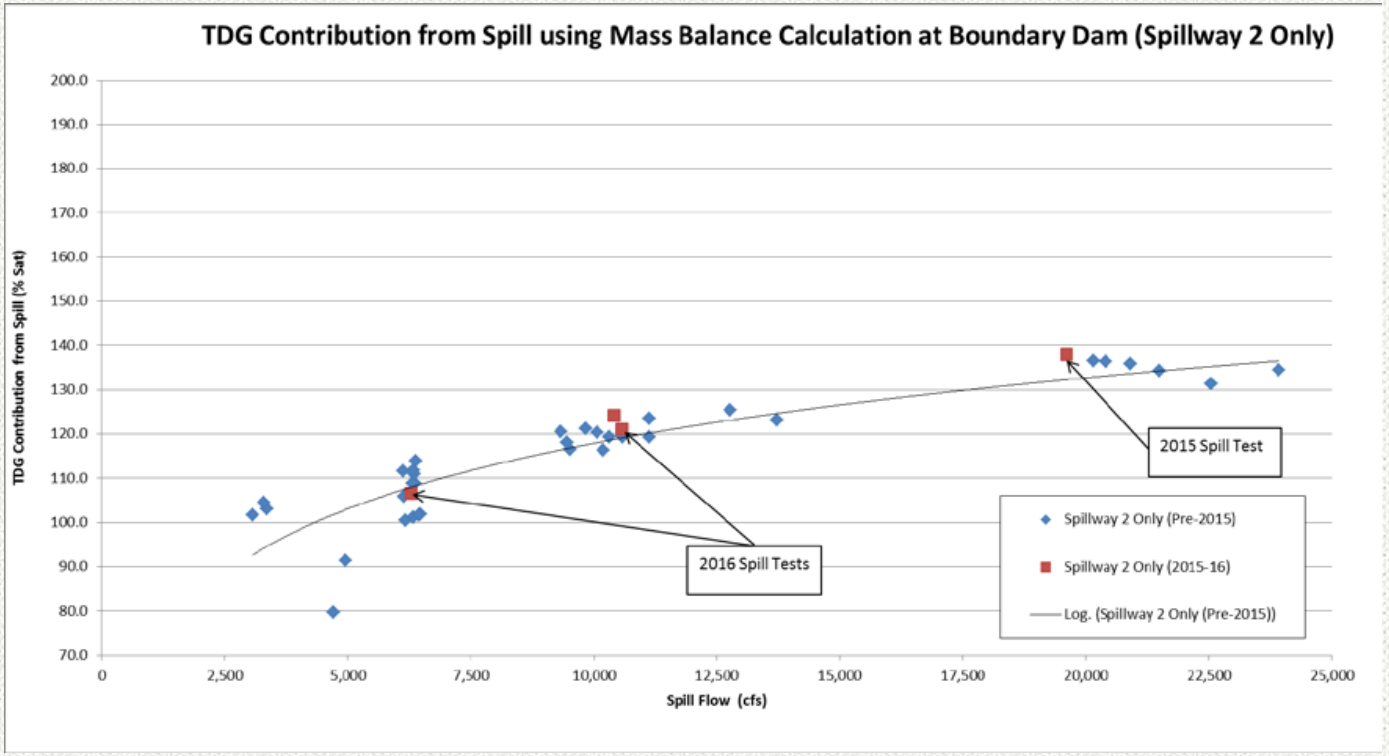
FINISHED!

DE-MOB

Pre - Modification


Post - Modification

RUNNING TO STAND STILL?



Incoming TDG

- Pre 2014 ~ 124%
- 2015 ~ 108%
- 2016 ~ 109%

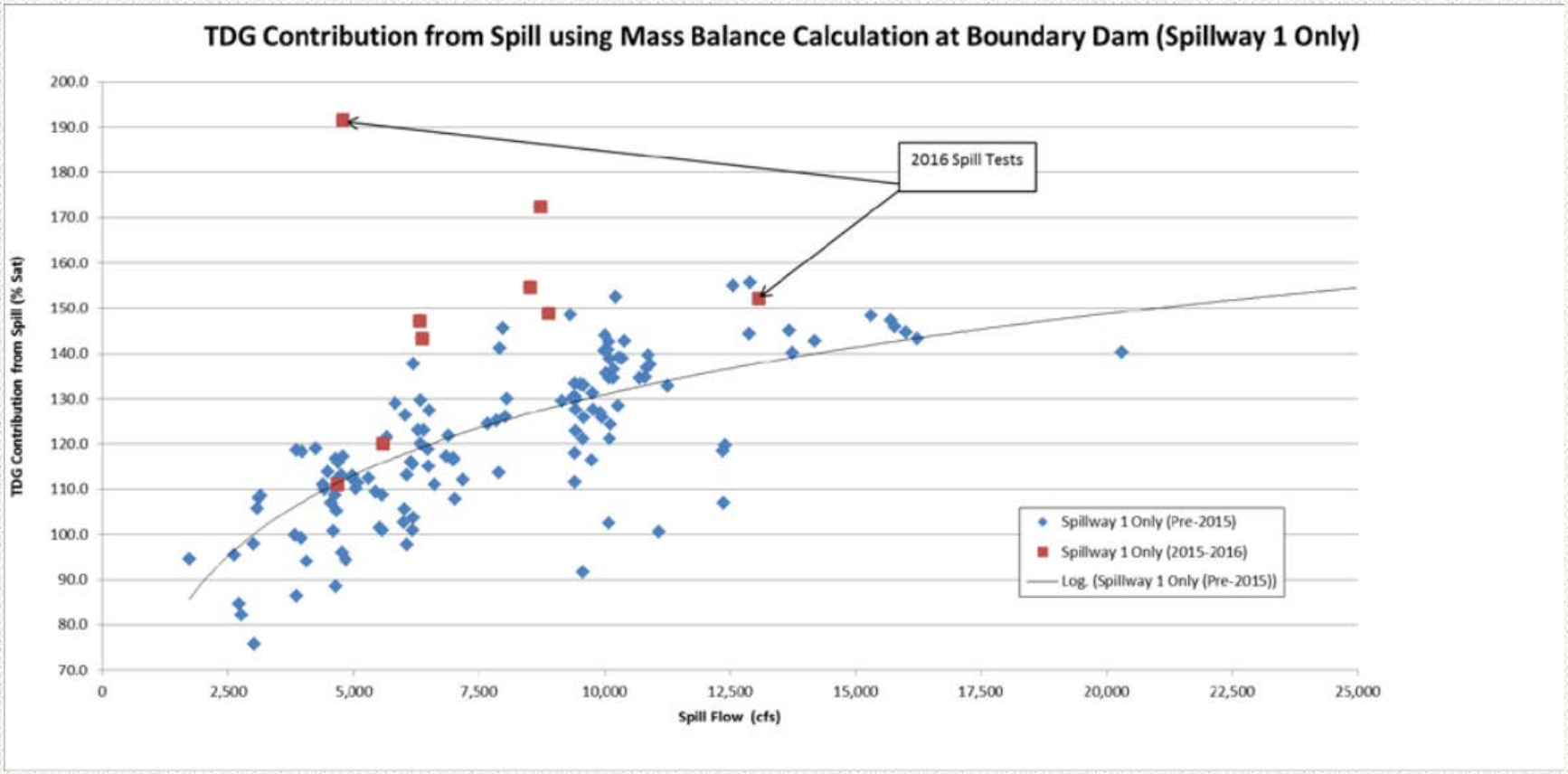
Thanks for your attention!

QUESTIONS?

Acknowledgements:

Construction team:
Clearwater Construction and Management.

Project team (City Light & Consultants):
Dan Kirschbaum, James Lussman, Jim Rutherford, John Werner, Ray Trudgeon, Joe Groeneveld, Nikou Jayaleri, Chick Sweeney, Joe Orlins, Justin Arnold, Keith Moen, Michael Rounds, Shari Dunlop, Kim Pate, Carl Stark; ...and many others.


TDG Contribution from Spill using Mass Balance Calculation at Boundary Dam (Spillway 1 Only)
TDG Contribution from Spill (% Sat)
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
0
2,500
5,000
7,500
10,000
12,500
15,000
17,500
20,000
22,500
25,000
Spill Flow (cfs)
2016 Spill Tests
Spillway 1 Only (Pre-2015)
Spillway 1 Only (2015-2016)
Log. (Spillway 1 Only (Pre-2015))