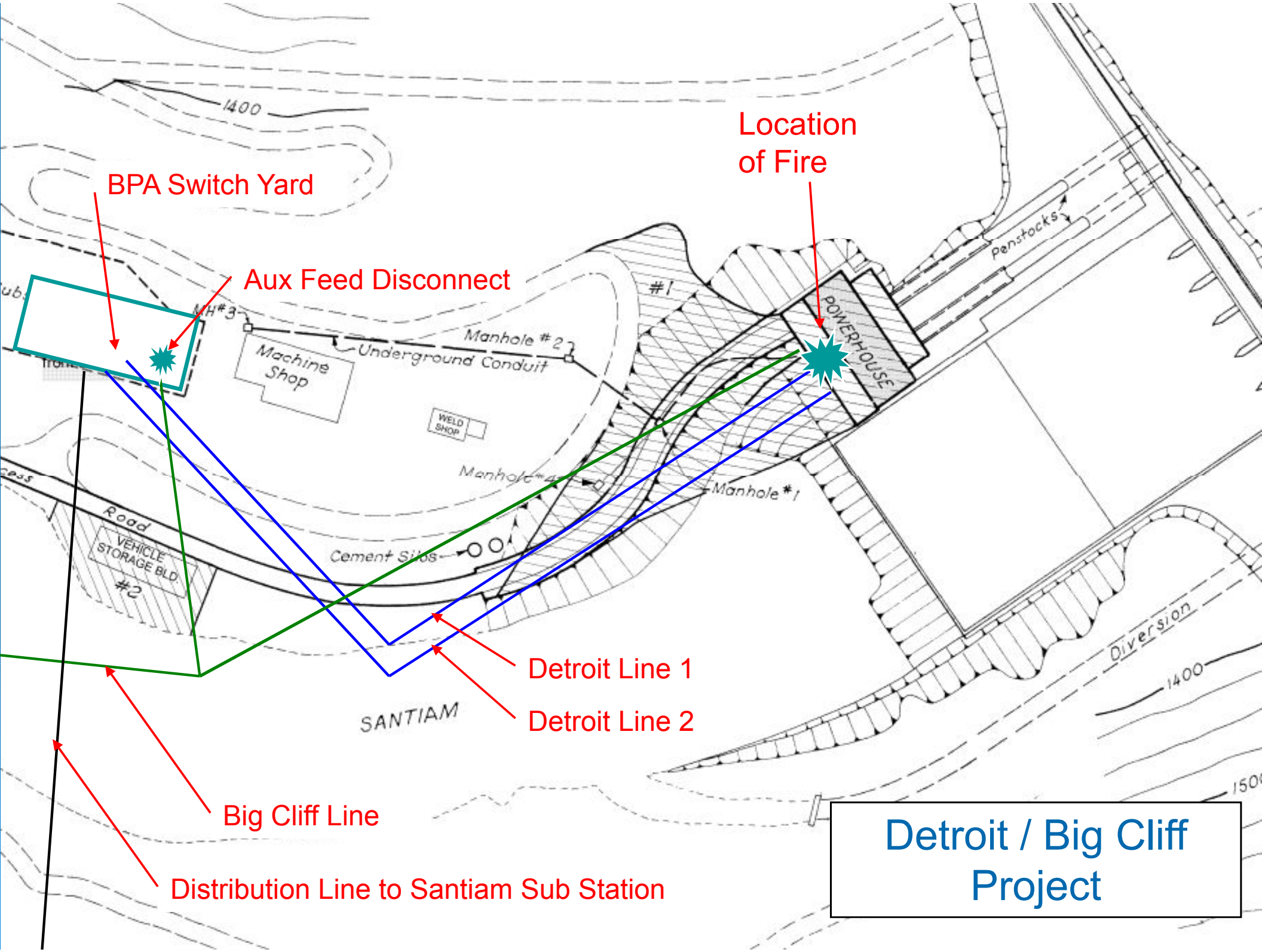
Detroit Dam
Electrical Failure and Fire

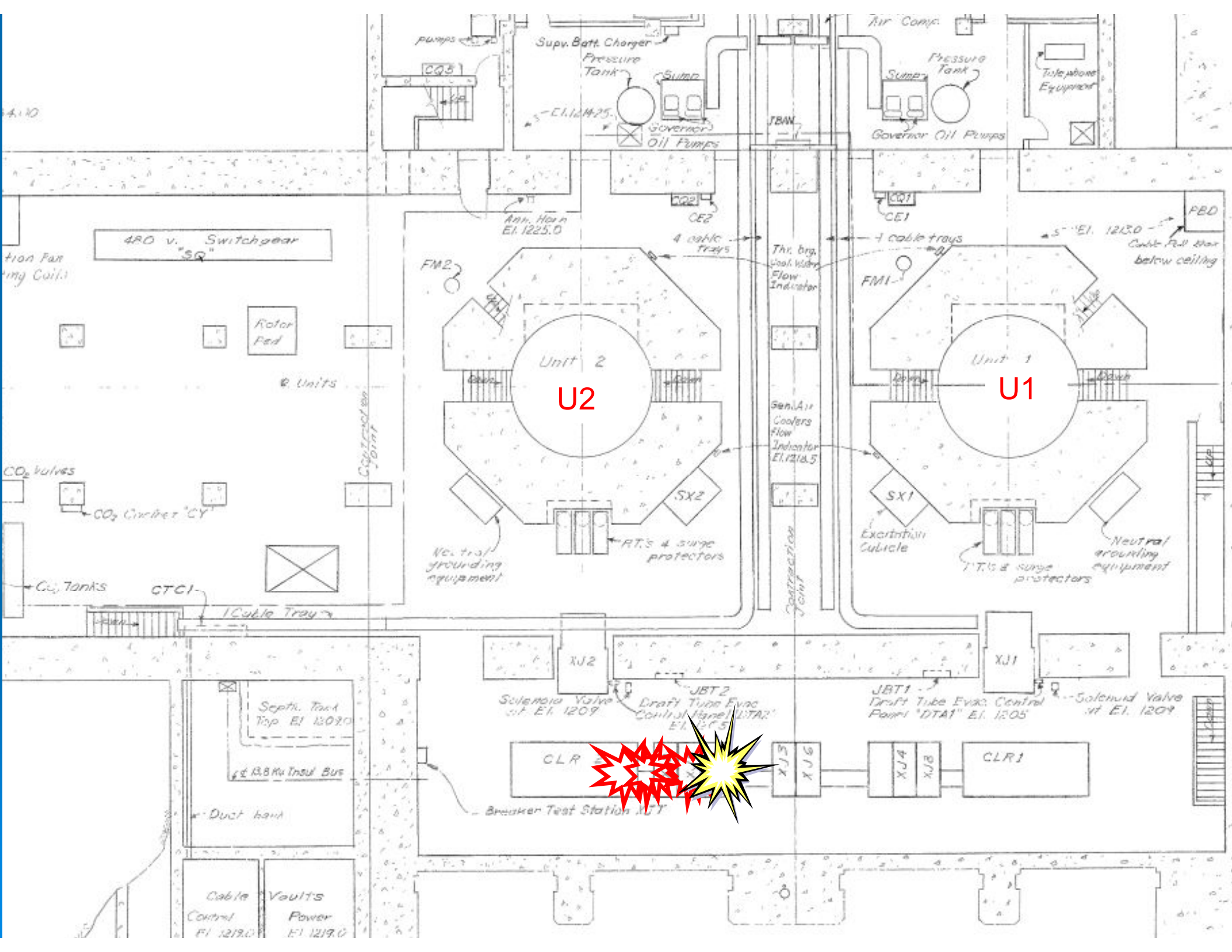
Some Protective System Lessons Learned – NW Hydro Operators Regional Forum May 22, 2008

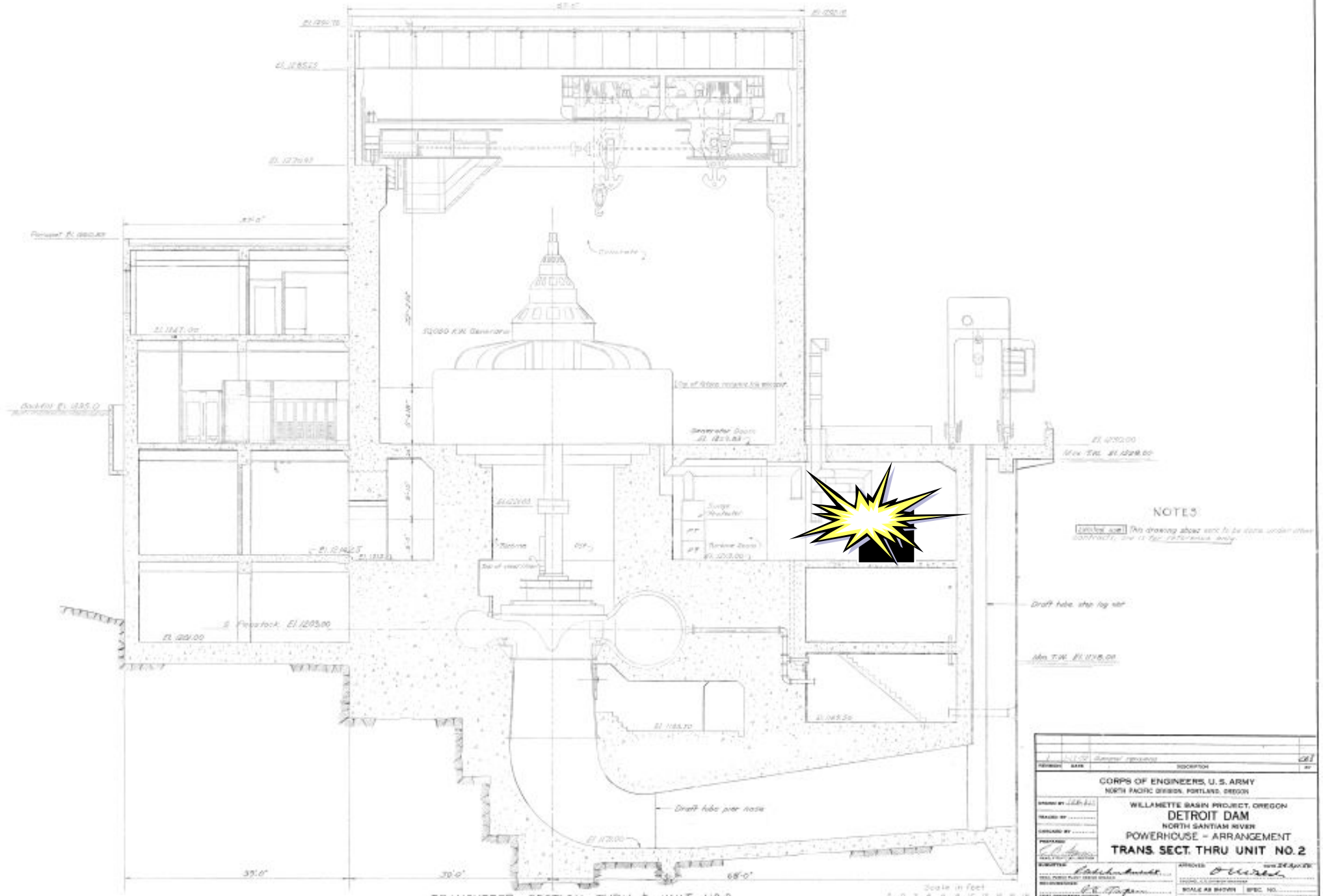
US Army Corps of Engineers

Portland District

Detroit Dam


Location of Fire
BPA Switch Yard
Aux Feed Disconnect
Detroit Line 1
Detroit Line 2
Big Cliff Line
Distribution Line to Santiam Sub Station
Detroit / Big Cliff Project
1400
MH#3
Manhole #2
Underground Conduit
Machine Shop
WELD SHOP
#1
POWERHOUSE
Penstocks
Manhole #4
Manhole #1
Road
VEHICLE STORAGE BLD #2
Cement Silos
SANTIAM
Diversion
1400


Air Comp.
Supv. Batt. Charger
Pressure Tank
Sump
Governor Oil Pumps
Telephone Equipment
JBAN
CQ3
CQ2
CQ1
CE2
CE1
Ann. Horn El. 1225.0
480 v. Switchgear "SQ"
4 cable trays
Thr. brg. Cool. Water Flow Indicator
FM2
FM1
PBD
Rotor Pad
Unit 2
U2
Unit 1
U1
Gen. Air Coolers Flow Indicator El. 1218.5
SX2
SX1
Neutral grounding equipment
RT's & surge protectors
Excitation Cubicle
CO2 valves
CO2 Tanks
CTC1
1 Cable Tray
Contraction Joint
XJ2
XJ1
JBT 2
JBT 1
Draft Tube Evac. Control Point "DTA1" El. 1205
Solenoid Valve at El. 1209
CLR
CLR 1
XJ3
XJ6
XJ4
XJ5
Breaker Test Station
Septic Tank Top El. 1209.0
Duct bank
Cable Vaults Control El. 1219.0
Power El. 1219.0



TRANSVERSE SECTION THRU ℄ UNIT NO.2

NOTES

Caution note: This drawing shows work to be done under other contracts, and is for reference only.

1	1-57	General revisions
PREPARED	DATE	DESCRIPTION

CORPS OF ENGINEERS, U.S. ARMY
NORTH PACIFIC DIVISION, PORTLAND, OREGON

WILLAMETTE BASIN PROJECT, OREGON
DETROIT DAM
NORTH SANTIAM RIVER
POWERHOUSE - ARRANGEMENT
TRANS. SECT. THRU UNIT NO. 2

DRAWN BY J.E.R. Jr.
TRACED BY
CHECKED BY
PREPARED
SUBMITTED
RECOMMENDED
APPROVED
SCALE AS SHOWN
SPEC. NO.
DEP-2-0-0/8

RASTER# DEP-2-0-0-08_REV-1.tif

Detroit Fire: Context

- Project was undergoing a phased but piece-meal multi-year modernization program:
  - Bridge crane
  - Main Unit Breaker replacement completed in 2004
  - Rewinding Detroit generators
    - Unit 1 was almost complete – but was still out of service
  - SCADA control upgrades
  - 13.8 kV station service breaker replacement project just completed
  - Station service distribution transformer and 480 volt switchgear replacement planned but not yet started

Detroit Fire Immediate Cause Under-rated Surge Arresters 2004

- A contract modification added arresters to temporarily protect several old transformers that would not be replaced until the next phase.
- 12.7kV MCOV proposed and approved.
- 10.2kV MCOV installed (10 sec @13.8kV).

Detroit Fire Causal Analysis
18 June Event Sequence

- Ground fault comes in hard.
- Big Cliff unit trips as designed.
- XJ2, XJ3, XJ5 trip as designed.
- Lights go out.
- Operator gets help.
- Lighting restored.

Detroit Fire Causal Analysis
Start of Fire

- Operator re-closed the circuit breaker energizing the firmly faulted bus.
- 13.8kV ground fault still there.
- Surge Arresters see high voltage.
- Surge Arresters burn.
- Reactor limits fault current
- No relay action since operator did not restart the tripped generator

Detroit Fire Causal Analysis Relay Power Tagged Out, May 07

- Fire burns into XJ5 activating other protective devices – but:
  - A clearance had been taken for the purpose of performing some work on T1 before U1 was returned to service
  - This unknowingly disabled the secondary protective system trip
  - No line lock out relay function.

Detroit Fire Causal Analysis Original Design – 1950's

- Unrealized plans for second yard breaker.
- Yard breaker only tripped by T1 pilot wires or 86L1
- T2 pilot wires do nothing.
- 86L2 must trip 86L1 to trip yard Breaker
- Compromise at the time based on best practices, costs, assumptions.

Detroit Fire Causal Analysis
Fire Propagation

- XJ5 Burns
- Still No Relay Action

Detroit Fire Causal Analysis
Fire Propagation

- XJ9 Burns
- Still No Relay Action

Detroit Fire Causal Analysis
Energy Source Removed

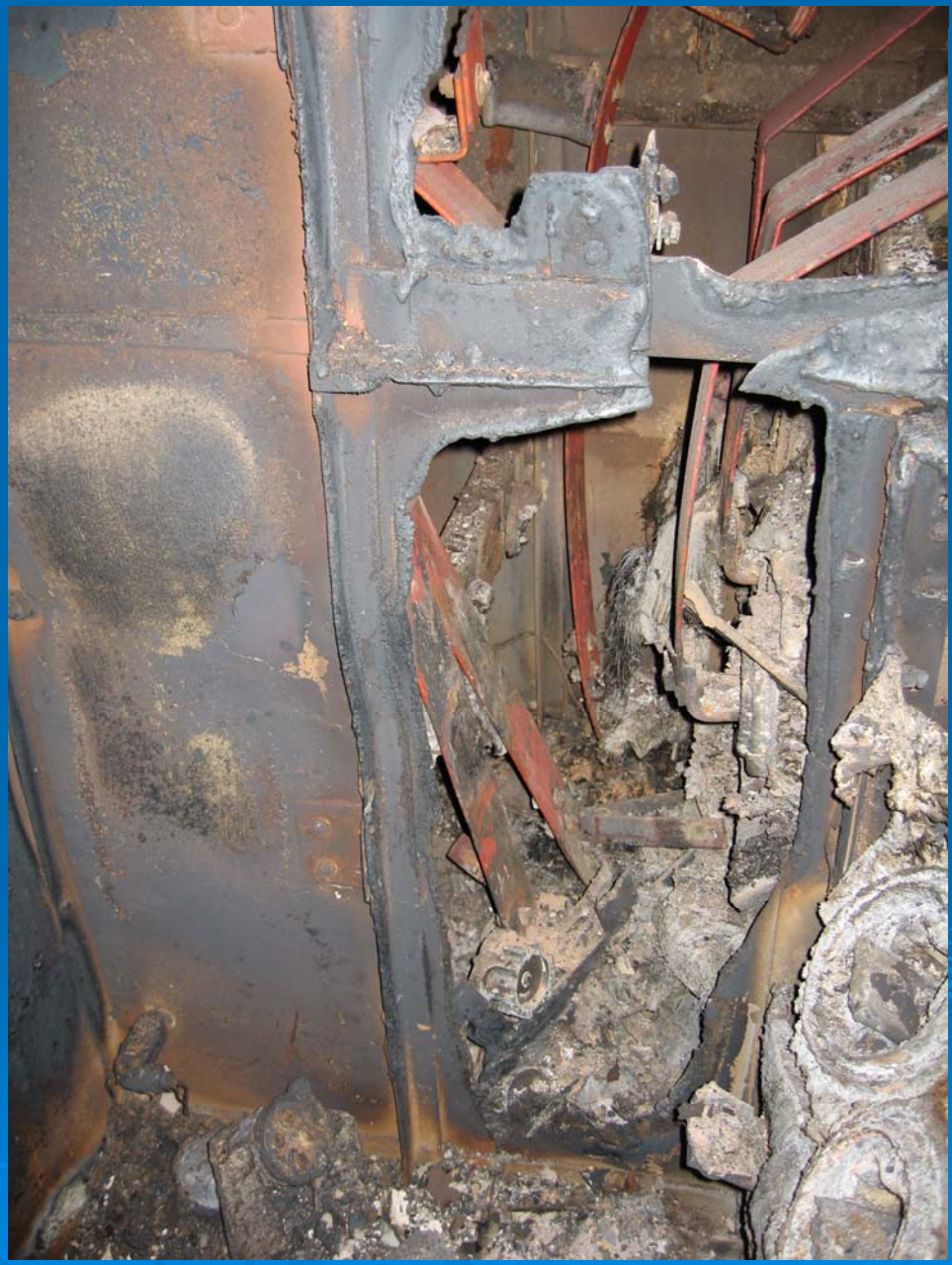
- Bus burns to current limiting reactor.
- Current increases
- BPA over-current relay trips.

Failure Events: Summary

- BPA ground fault
- New under-rated surge arresters burn
- 2 circuit breakers burn
- BCL bus melted
- Fault bypasses reactor
- Substation breaker clears the fault
- Soot and smoke everywhere

Damage Assessment

- XJ5, XJ9 circuit breakers
- Surge arresters & capacitors
- Metering PTs, CTs
- Switchgear enclosures
- Portions of the isolated phase bus work
- Soot everywhere (environmental clean up $2+M)
- Current estimate - $6.5m




99% ISOPROPYL
ALCOHOL


TURBINE BEARING
OIL PRESSURE
EMERGENCY
HEAD GATE CONTROL
OFF
LOWER
LOWER
SCROLL CASE

Electrical System Lessons Learned

- The critical need to keep electrical drawings up to date
- The critical need to carefully evaluate every modification phase in the full context of the protection system operation
- The value of periodically revisiting electrical protection schemes for each project
- The need to revisit clearance procedures to insure they actually do not do more than expected

Other Lessons Learned

- The need to provide more comprehensive operating staff training, especially during time of modernization
- The higher risk of multi-year phased piece-meal modifications to operating electrical distribution systems.
- The lower risk of a holistic system replacement strategy

Things We Are Doing Different

- Redesigning the protective relay systems to automatically isolate problems
  - Reducing the steps an operator needs to take to safely troubleshoot a station service power problem
  - Decreasing the amount of special knowledge needed to operate safely
- Adding new levels of protection that were not cost effective in the past
  - New multipurpose digital devices allow levels of protection not affordable in the past

Things We Are Doing Different

- Carefully coordinating our protective relay settings with BPA
- Implementing a system wide program to revisit protective systems at each project
- Implementing a comprehensive program to update critical project drawings

Things We Are Doing Different

- Improving station service control panel switch labeling
- Improving the event recording part of our SCADA

Questions?