2016 NW Hydro Forum
PFMA California State Water Project

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Overview

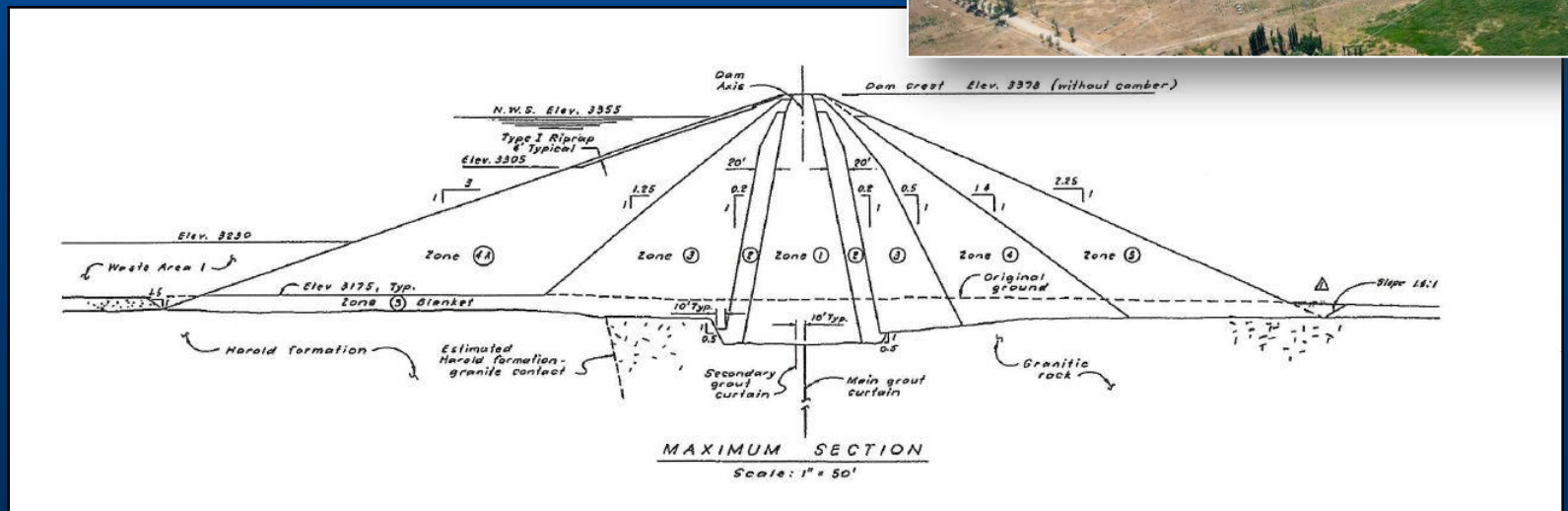
- Southern Field Division Dams Evaluated (FERC P 2426)
- Previous PFMAs
- 2014 and 2015 PFMAs
- Concluding Remarks and Owners Perspective

Facilities Evaluated

- Cedar Springs Dam
- Devil Canyon Second Afterbay
- Pyramid Dam
- Quail Dam

Cedar Springs Dam

- Built in 1971
- 250ft Tall
- 75K Acre-ft

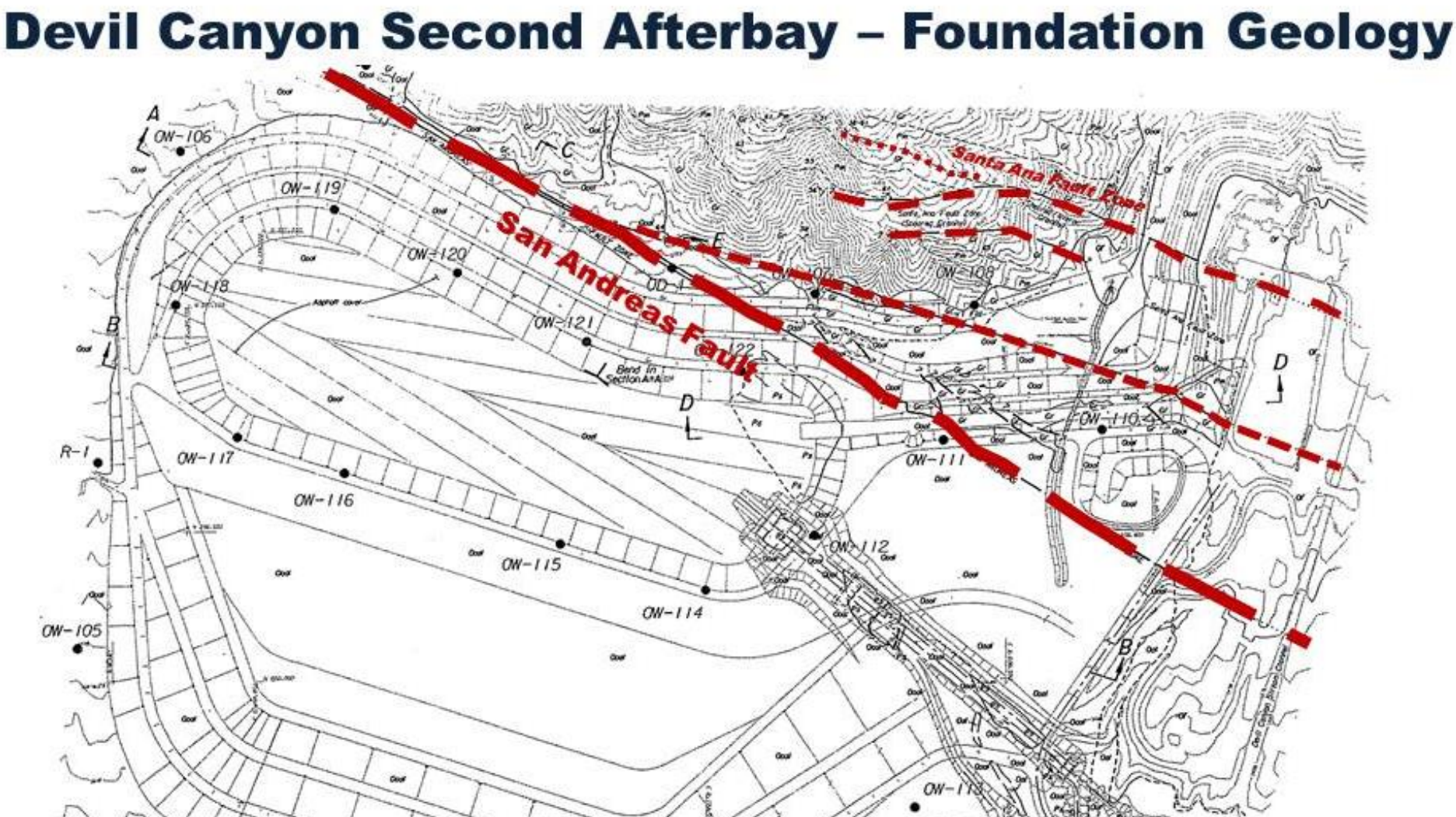


Mapped Faults at Cedar Springs

Devil Canyon Second Afterbay

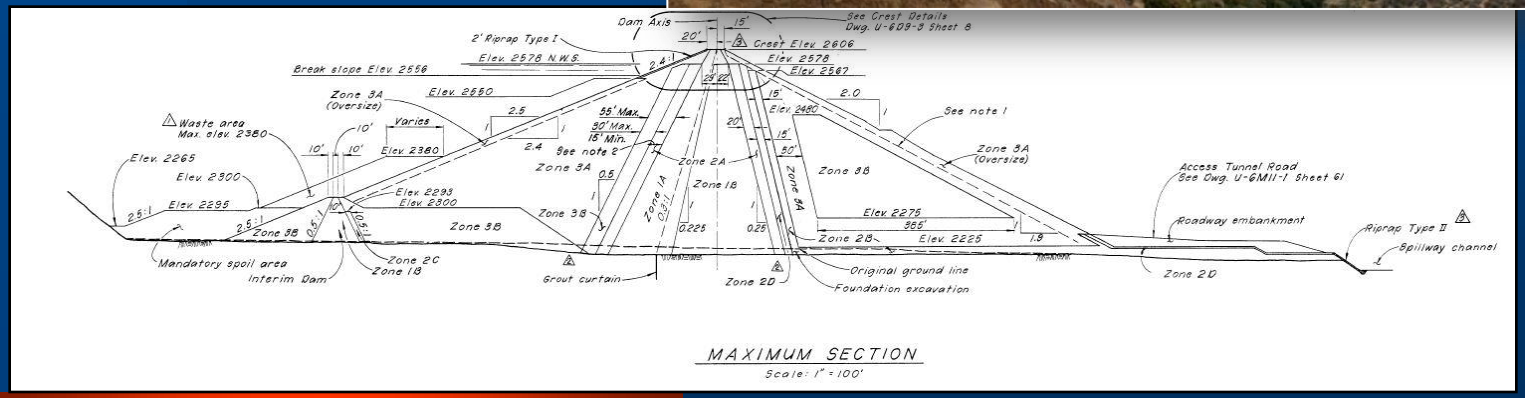
- Built in 1995
- 88-ft Tall
- 960 Acre-ft

Devil Canyon Second Afterbay



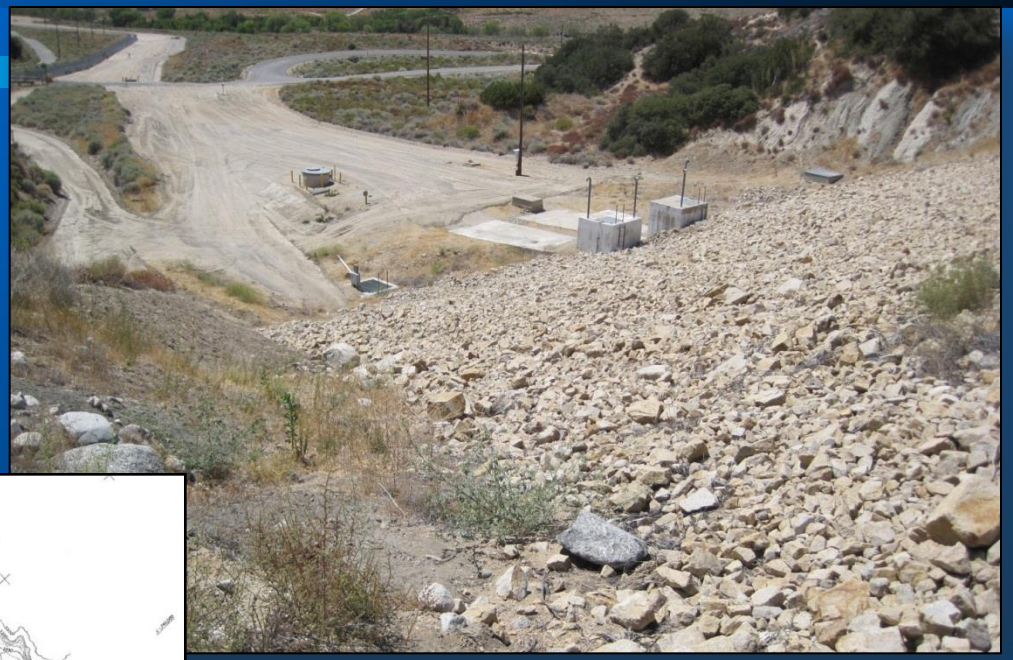
Pyramid Dam

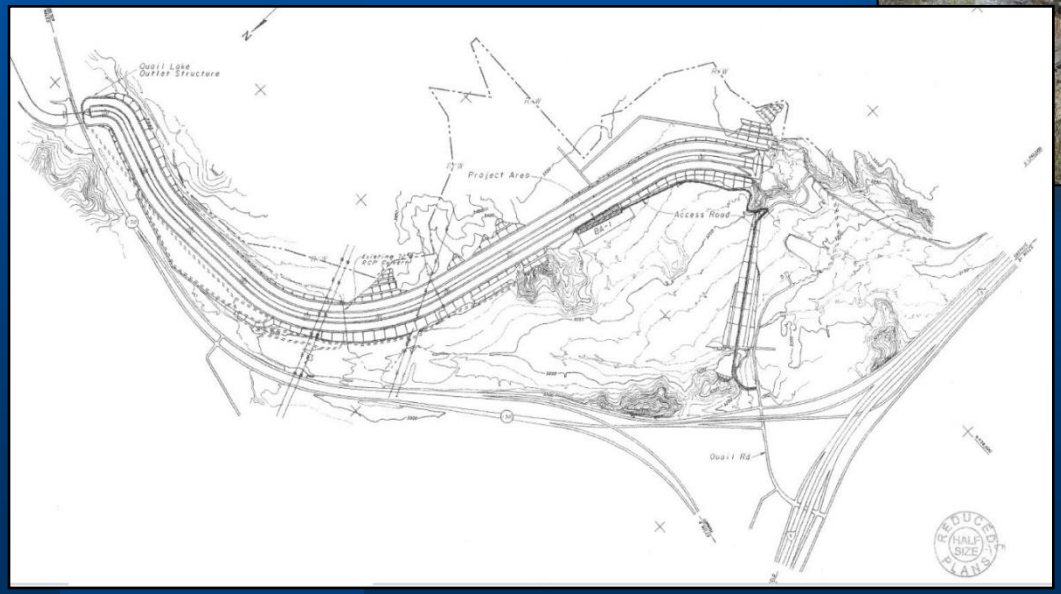
- Built in 1973
- 400ft Tall
- 170K Acre-ft

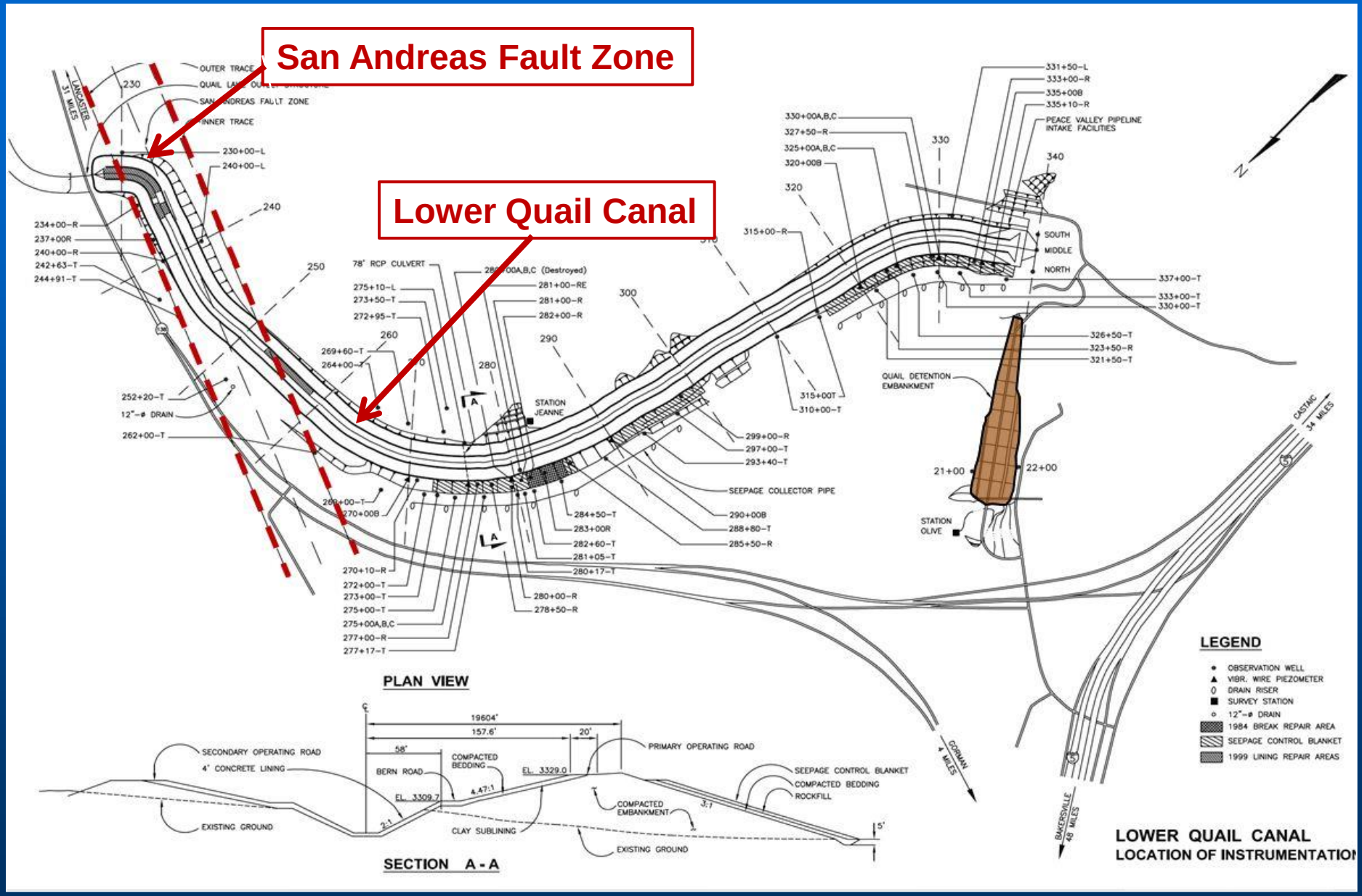


Quail Dam

- Built in 1983
- 50ft Tall
- 1150 Acre-ft






San Andreas Fault Zone
Lower Quail Canal
OUTER TRACE
INNER TRACE
LANCASTER 31 MILES
230
240
250
260
270
280
290
300
310
320
330
340
230+00-L
240+00-L
234+00-R
237+00R
240+00-R
242+63-T
244+91-T
78" RCP CULVERT
275+10-L
273+50-T
272+95-T
269+60-T
264+00-T
252+20-T
12"-ø DRAIN
262+00-T
281+00-RE
281+00-R
282+00-R
STATION JEANNE
299+00-R
297+00-T
293+40-T
SEEPAGE COLLECTOR PIPE
290+00B
288+80-T
285+50-R
284+50-T
283+00R
282+60-T
281+05-T
280+17-T
280+00-R
278+50-R
270+10-R
272+00-T
273+00-T
275+00-T
275+00A,B,C
277+00-R
277+17-T
269+00-T
270+00B
315+00-R
315+00T
310+00-T
331+50-L
333+00-R
335+00B
335+10-R
330+00A,B,C
327+50-R
325+00A,B,C
320+00B
PEACE VALLEY PIPELINE INTAKE FACILITIES
SOUTH
MIDDLE
NORTH
337+00-T
333+00-T
330+00-T
326+50-T
323+50-R
321+50-T
QUAIL DETENTION EMBANKMENT
21+00
22+00
STATION OLIVE
CASTAIC 34 MILES
CORNAN 4 MILES
BAKERSFIELD 48 MILES
N
LEGEND
OBSERVATION WELL
VIBR. WIRE PIEZOMETER
DRAIN RISER
SURVEY STATION
12"-ø DRAIN
1984 BREAK REPAIR AREA
SEEPAGE CONTROL BLANKET
1999 LINING REPAIR AREAS
PLAN VIEW
19604"
157.6'
20'
58"
SECONDARY OPERATING ROAD
4" CONCRETE LINING
BERM ROAD
COMPACTED BEDDING
EL. 3329.0
EL. 3309.7
4.47:1
PRIMARY OPERATING ROAD
SEEPAGE CONTROL BLANKET
COMPACTED BEDDING
ROCKFILL
COMPACTED EMBANKMENT
3:1
2:1
EXISTING GROUND
CLAY SUBLINING
5'
EXISTING GROUND
SECTION A - A
LOWER QUAIL CANAL
LOCATION OF INSTRUMENTATION

2005 PFMAs

- 2005 – Initial PFMAs – Larry VonThun
- FERC Chapter 14 Engineering Guidelines.
- Cedar Springs – 0 PFMs, 5 OC's
- Devil Canyon – 0 PFMs, 5 OC's
- Pyramid – 0 PFM, 5 OC's
- Quail – 3 PFMs, 7 OC's

2010 PFMA Update

- Performed by DWR personnel and the Part 12 Independent Consultants.
- Review of:
  - 2005 PFMA Workshop Results
  - STID
  - Other documents relating to operation and dam safety;
- Two day workshop.

2010 PFMA Update

- Updated 2005 PFMA Report with revisions called out in the report.
- Modifications to:
  - Major Findings and Understandings,
  - Risk Reduction Measures,
  - Other Considerations.
- No additional PFMs in 2010 update.

2014/2015 PFMA Workshops

- New comprehensive PFMA workshops performed
- Intended to prepare for the upcoming Risk Informed Decision Making guidelines
- Focus on fully developed PFMs
- New PFMA Reports

2014/2015 PFMA Workshops

Cedar Springs Dam – 12 PFMs

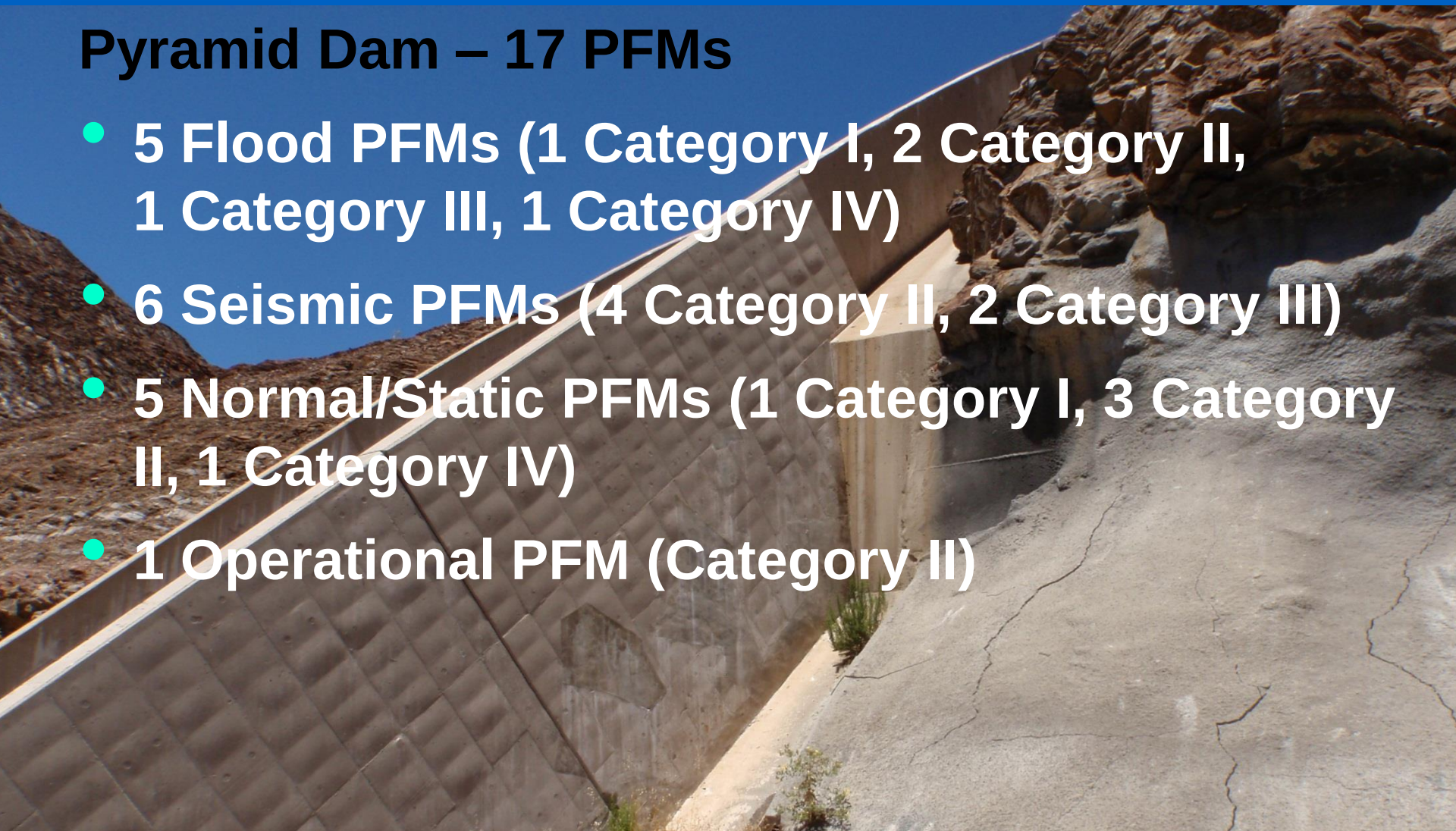
- **Zero Flood PFMs**
- **9 Seismic PFMs (All Category II)**
- **2 Normal/Static PFMs (All Category II)**
- **1 Operational PFM (Category IV)**

2014/2015 PFMA Workshops

Devil Canyon Second Afterbay – 5 PFMs

- **Zero Flood PFMs**
- **3 Seismic PFMs (2 Category I, 1 Category II)**
- **1 Normal/Static PFMs (Category II)**
- **1 Operational PFM (Category II)**

2014/2015 PFMA Workshops



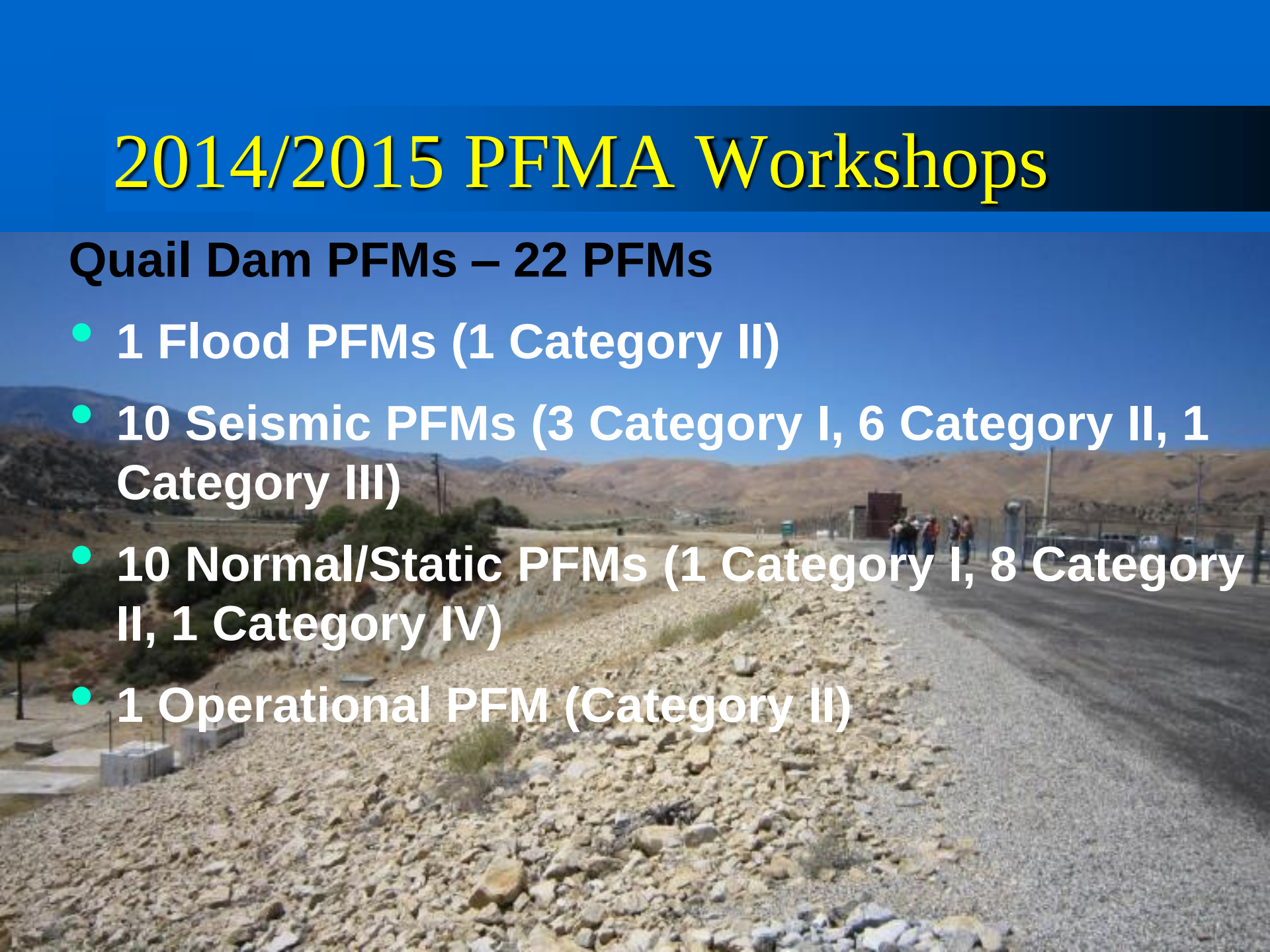
Pyramid Dam – 17 PFMs

- **5 Flood PFMs (1 Category I, 2 Category II, 1 Category III, 1 Category IV)**
- **6 Seismic PFMs (4 Category II, 2 Category III)**
- **5 Normal/Static PFMs (1 Category I, 3 Category II, 1 Category IV)**
- **1 Operational PFM (Category II)**

2014/2015 PFMA Workshops

Quail Dam PFMs – 22 PFMs

- **1 Flood PFMs (1 Category II)**
- **10 Seismic PFMs (3 Category I, 6 Category II, 1 Category III)**
- **10 Normal/Static PFMs (1 Category I, 8 Category II, 1 Category IV)**
- **1 Operational PFM (Category II)**



What Changed?

- Failure of Silver Lake (Michigan)
- Taum Sauk (Missouri)
- The Wanapum Dam (Washington)
- All part of FERC Part 12D Inspection Program

"There are known knowns; there are things we know that we know.

There are known unknowns; that is to say there are things that, we now know we don't know.

But there are also unknown unknowns – there are things we do not know we don't know."

What Changed?

- **Clarification of Categories**
- Refinement of PFM – “Uncontrolled Release”
- Risk Informed Decision Making and PFM Descriptions

Category	Category Description
I	***Highlighted Potential Failure Modes.*** *Those potential failure modes of greatest significance considering need for awareness, potential for occurrence, magnitude of consequence and likelihood of adverse response (physical possibility is evident, fundamental flaw or weakness is identified and/or conditions and events leading to failure seemed reasonable and credible) are highlighted.*
II	***Potential Failure Modes Considered but not Highlighted.*** *These are judged to be of lesser significance and likelihood.* Note that even though these potential failure modes are considered less significant than Category I, they are also described and included with reasons for and against the occurrence of the potential failure mode. The reason for the lesser significance is noted and summarized in the documentation report or notes.
III	***More Information or Analyses are Needed in order to Classify.*** These PFM's to some degree lacked information to allow a confident judgment of significance and thus a dam safety investigative action or analyses can be recommended. Because action is required before resolution the need for this action may also be highlighted.
IV	***Potential Failure Mode Ruled Out*** PFM's may be ruled out because the physical possibility doesn't exist, information came to light which eliminated the concern that had generated the development of the potential failure mode, or the potential failure mode is clearly so remote a possibility as to be non-credible or not reasonable to postulate.

FERC Perspective

- Category 1 and 2 PFMs are not limited to failure modes that need remediation.
- The intent is to highlight PFMs that need to be front and center in an owner's DSSMP.
- These may include things in existing dams that should be remediated but the need to fix something is not the only criteria.
- For example when designing a new embankment dam with filters, drainage and all state-of-the-art features, you can never completely rule out a piping failure because of hidden defects, flaws during construction, etc.

What Changed?

- Clarification of Categories
- **Refinement of PFM – “Uncontrolled Release”**
- Risk Informed Decision Making and PFM Descriptions

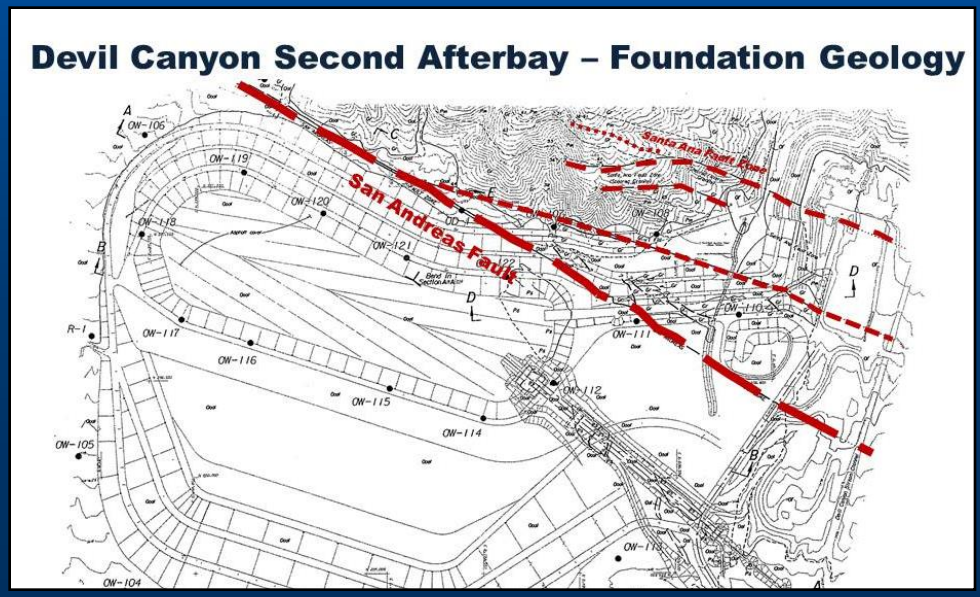
Other Project Features Considered

- Four Embankment Dams
- Section of Canal
- Spillways / Radial Gates
- Lined Tunnels (approx. 11 miles total)
- Pipelines
- Penstocks

Devil Canyon PFM S2 – Earthquake damages Devil Canyon penstock.

- The MCE occurs along the San Andreas Fault.
- Strong seismic shaking damages a Devil Canyon Powerplant penstock.
- An uncontrolled release from the damaged penstock occurs until upstream control can be established.

Category I




Penstocks
Devil Canyon
Second Afterbay
Devil Canyon
Image Landsat
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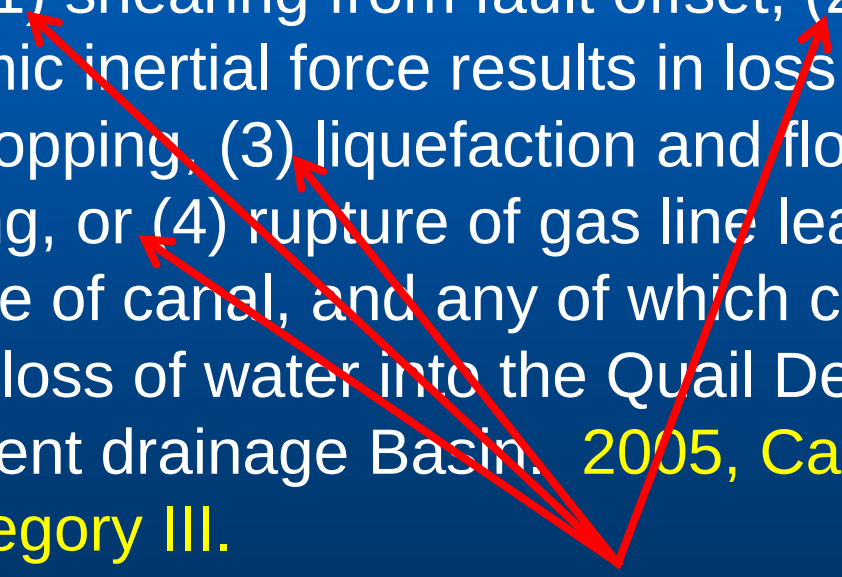
What Changed?

- Clarification of Categories
- Refinement of PFM – “Uncontrolled Release”
- Risk Informed Decision Making and PFM Descriptions

Example: Breaking Up a PFM

- ***2005 Quail PFM 1:*** Seismic loading (shaking or fault offset) results in a failure of Lower Quail Canal Embankment as a result of: (1) shearing from fault offset, (2) sliding instability from seismic inertial force results in loss of freeboard and then overtopping, (3) liquefaction and flow slide and then overtopping, or (4) rupture of gas line leads to an explosion and rupture of canal, and any of which cause a breach of canal and loss of water into the Quail Detention Embankment drainage Basin. 2005, Category II. Update in 2010, Category III.



Three "ORs"

Four PFMs

Example: Breaking Up a PFM

2005 Quail PFM 1 becomes ...

- → ***PFM S1:*** Failure of the Lower Quail Canal Embankment due to fault rupture. Category I.
- → ***PFM S2:*** Failure of the Lower Quail Canal Embankment due to excessive seismic deformation. Category I.
- → ***PFM S3:*** Failure of the Lower Quail Canal Embankment due to seismically-induced rupture of the gas line crossing the canal at Station 288. Category III.
- → ***PFM S4:*** Failure of the Lower Quail Canal Embankment due to liquefaction. Category I.

2005 vs. 2014/2015

Site	2005 # of PFMs	2014/2015 # of PFMs
Cedar Springs Dam	0	12
Devil Canyon 2nd AB	0	5
Pyramid Dam	1	17
Quail Dam	3	22
TOTAL	**4**	**56**

FERC……WTF!

WOW THAT'S FANTASTIC!

Owner……WTF?

WHAT THE …….?

Concluding Remarks

- The cost and duration of the PFMA workshop is driven by the number and collective knowledge of the PFMA participants.
- Participants should familiarize themselves with each dam's design, construction, and historical performance to the level needed prior to the workshop.
- Voting members should be limited to core members only.
- Allowing too many voting participants makes achieving general consensus on a PFM category difficult and time consuming.

Concluding Remarks

- Early clarification and statement of expectations by FERC in advance of a PFMA workshop should streamline the schedule, remove confusion, and limit debate.
- Having co-Facilitators and using multiple note-takers can greatly enhance the ability to capture critical information, expedite the process, and develop a comprehensive document.
- More substantial preliminary effort to develop PFMs ahead of time with a small group will streamline things.

Concluding Remarks

- The development of the risk reduction measures is a brainstorming exercise during which the concepts are minimally vetted and discussed amongst the participants.
- They can become Part 12 recommendations, potentially increasing the cost of Part 12 compliance without fully understanding their practicality or actual risk reduction benefit or cost.

Concluding Remarks

- Carrying the process forward after the PFMA through quantitative risk estimation is a potentially powerful tool.
- Under the best of circumstances the duration of a workshop will still be difficult to predict as it depends on numerous factors, such as:
  - Number of participants and their preparation,
  - PFM brainstorming effort,
  - Dam's complexity,
  - Recorder's speed, and the Facilitator's ability to keep the participants focused and on-task.
- Future PFMAs will include a pre-PFMA conducted by CA DWR only.

Questions?