Federal Energy Regulatory Commission
Division of Dam Safety and Inspections

Best Practices in Surveillance and Monitoring Programs

Pre-Workshop Survey Comment

- I'd highly value:
- Examples and explanations of where some kind or frequency of monitoring wasn't sufficient to show a failure early enough to be completely avoided;
- Examples of where the data showed a trending problem, but it was either too subtle or misunderstood to be recognized as early as feasible;
- Examples and explanations of where the data was clear, but not acted on and some problem developed, or a near miss was avoided;

Pre-Workshop Survey Comment

- Examples of when monitoring frequency is not appropriate (too often, not often enough……or correct frequency but collected during a season or time-of-day that obviated a trend);
- Examples of excellent and not-so-good data presentation; and,
- Examples of state of the practice versus old-school/obsolete monitoring and/or data presentation methods.

Challenge

- The challenge is to identify the unexpected performance, evaluate it, then take action in a timely manner to prevent dam failure.
- Understanding performance monitoring data after dam safety incidents is relatively easy compared to identifying the problem in advance.
- Requires creative thinking, critical evaluation and continued pursuit of the understanding of performance data, history and design of the structure.

Meeting the Challenge

- Best Practices:
  - Well-defined PFMs
  - General health monitoring
  - Quality control procedures and training
  - Maintenance of Instruments
  - Timely evaluation of data
  - Evaluating trends and anomalies
  - Graphical presentation of data
  - Preparation for extreme events

Pre-Workshop Survey Comment

- Having a good discussion of perspectives on when an instrument is considered general health. It would be nice to share examples of where different licensees have decided that instruments are general health, and their logic behind that decision.

General Health Monitoring

- Always includes visual monitoring
- Usually includes instruments that are not ties to PFMs. Often this includes deformation surveys, piezometers, and crack gauges
- Should also include review of instruments tied to PFMs to identify unexpected performance

Quality Control

- Starts with training of all involved personnel – integral with Owner's Dam Safety Program
- Verification of readings is essential, which means that the technician must have threshold and action levels with them at that time of measurement
- Appropriate and timely action taken when readings exceed action levels

Quality Control Problems or Anomalous Readings

- Poor quality control can later cause problems because there is no way to tell if an anomalous reading is the result of measurement error or indication of performance
- Anomalous readings must be evaluated to determine if there is development of an identified or unidentified PFM

Reading Verification

- Best if readings are compared with threshold levels at the time of measurement
- Works well for max or min thresholds but more difficult for thresholds that depend on headwater or tailwater levels
- What about action levels related to drain efficiency when the headwater and tailwater fluctuate?

Best Practice

- Assign thresholds and action levels to each instrument – include values in instrument plots
- Train personnel taking readings
- Retake measurements that are not in the expected range
- For readings that exceed action levels: take action in timely manner and document
- Identify and evaluate anomalous readings and trends
- Don’t dismiss readings or trends that you don’t understand

Timely Evaluation of Data

- Disaster was avoided due to intervention at Chilhowee, Morris Shephard, Swinging Bridge, Wanapum, etc. This could be seen as a success for these monitoring programs.
- Review of these incidents indicate that there may have been opportunities for earlier intervention
- Early intervention can lower the likelihood of failure and reduce remediation costs

Timely Evaluation of Data

- Timely evaluation must happen before failure or major safety incident
- Just like with our visual inspections, we must be looking for anything out of place, then determine the cause
- **<u>This is not being done at many FERC regulated dams!</u>**

Best Practice

- Go beyond determining if action values were exceeded to identify and evaluate anomalous readings and trends:
  - Look for visual clues to changes in performance
  - Troubleshoot instruments
  - Create various plots and perform data analysis
  - Review project history and construction records

Graphical Presentation of Data

- Best practice varies by project
- Look at data in multiple ways to gain an understanding of the meaning and look for trends
- Use time series plots and cross sections
- Plots meaningful with regard to PFMs
- Vary period and scale in time series plots to evaluate the data
- Include threshold values and action levels in all plots
- Piezometers related to stability or piping should be plotted in cross sections

Action Level Best Practice

- Action value in this case would be based on drain efficiency calculated after reading is taken
- How do you verify readings are in the expected range at the time of the measurement?
  - Develop spreadsheet to calculate expected range and transcribe to data collection sheet prior to taking measurements
  - Create table for DSSMP with expected ranges for various headwater-tailwater conditions

12.10 Reports Last 12 Months

Incident Type	Number
Gate Chain or Wire Breakage	4
Failure to Open Gate	4
Sinkhole	3
New or Cloudy Seepage	2
Valve Failure (Powerhouse and Low-level Outlet)	2
Conveyance Failure (Penstock and Canal Flume)	2
Powerhouse Mis-operation	1
Rubber Bladder Failure	1
Total:	19

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Gate Category(1 or 2)[1/]	Date of Most Recent Detailed Inspection [2/]	Gate No.	Motor No.	Date of Opening		Purpose of Gate Discharge [4/]	Height of Opening (ft)	Line-to-Line Voltage [5/, 6/]	Phase Current [5/, 6/]		Rated Horsepower [5/]
				Current Year's Annual Test	Last Full Opening[3/]				Startup	Running	

[1/] Category 1 – Failure has significant dam safety or operational consequences.
Category 2 – Failure has minimal or no consequences.

[2/] A close-up detailed inspection is required for all Category 1 Tainter gates every ten years.

[3/] A full open gate test must be performed at least once every five years for Category 1 gates and at least once every ten years for Category 2 gates. If the current opening was a full opening, this column should include the date of the current opening rather than the date of the previous full opening.

[4/] Examples are annual tests, full open tests, flood passage, and maintenance.

[5/] The item is required for Tainter gates only.

[6/] The voltage and current must be the values measured while the gate motors are under load and operating the gates rather than the rated values.

Planning for Extreme Events

- Many existing DSSMPs have a general statement about increased monitoring during floods or following seismic events
- Floods and significant seismic events are a busy time for operations staff and **“general plans”** can lead to missed opportunities
- Detailed site-specific plans should be developed and incorporated into the DSSMP to monitor identified PFMs and confirm design or record analysis assumptions

Flood

Reservoir Level (ft)	Visual Inspection Frequency	Piezometer Readings Frequency	Drain Flow Measurement Frequency
Up to 500	Weekly	Monthly	Monthly
500-505	Daily	Weekly	Weekly
505-515	Hourly	Daily	Daily
> 515	Continuous	Daily	Daily

- **Scour surveys competed following flow events greater than 100K cfs**

Seismic

- General Guidance
  - Visual inspection, seepage measurements and piezometer readings following any seismic event felt at the site
  - Visible damage, changes in leakage, seepage or piezometer readings may indicate the need for deformation surveys and review of PFMs to determine need for increased monitoring or intervention

Conclusions

- Our challenge is timely intervention of developing failure modes.
- Meeting this challenge requires creative thinking, critical evaluation and continued pursuit of the understanding of performance data, history and design of the structure.

Questions?