CHAPTER 14

DAM SAFETY
PERFORMANCE MONITORING PROGRAM

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SUMMARY OF CHANGES

REVISION	CHANGE	DATE
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14.1 INTRODUCTION

The guidelines presented in this chapter provide recommended procedures and criteria to develop a Dam Safety Performance Monitoring Program based upon "failure mode thinking" to assist in reviewing and evaluating the safety and performance of water retaining project works regulated by FERC. The procedure includes:

- Development of a Supporting Technical Information Document (STI);
- A Potential Failure Mode Analysis (PFMA); and
- Development of a Surveillance and Monitoring Plan (SMP).

The Supporting Technical Information is prepared by the licensee with assistance as required by the Independent Consultant. A draft of the STI should be prepared prior to the PFMA session and provided to the Core Team to assist them in becoming familiar with the dam. Guidance on preparing the STI is provided in Section 14.2.

The Potential Failure Mode Analysis is conducted jointly by the licensee, Independent Consultant (IC) and FERC staff. Guidance on conducting a PFMA is provided in Section 14.3.

Based upon the results of the PFMA, the SMP is developed. The SMP defines the appropriate monitoring for the water retaining project works based upon the PFMA. An integral part of the SMP is the integration of the licensee's operation, maintenance and inspection programs. Guidance on preparing a Surveillance and Monitoring Plan is provided in Section 14.4

In addition, the Part 12D Independent Consultant's inspection and report and the FERC's inspection program will also be focused using the PFMA and the SMP.

The integration of a Potential Failure Mode Analysis with a Surveillance and Monitoring Plan and the Supporting Technical Information document, results in a more efficient and effective dam safety program. The added value to dam safety includes:

- Uncovering data and information that corrects, clarifies, or supplements the understanding of potential failure modes and scenarios;
- Archiving the key technical information supporting the evaluation of the dam;
- Identifying the most significant potential failure modes;
- Identifying risk reduction opportunities;
- Focusing surveillance, instrumentation, monitoring and inspection programs to provide information on the potential failure modes that present the greatest risk to the safety of the dam; and
- Developing operating procedures to assure that there are no weak links that could lead to mis-operation failures.

Although the traditional emphasis of Part 12D inspections has been on project dams, 18 CFR 12.32 specifically states that all project works with the exception of transmission and transformation facilities and generating equipment are to be included in the inspection by the independent consultant. In addition, certain other water retaining structures such as canals, flumes, tunnels and penstocks may impact public safety if they were to fail. Accordingly, these types of project works may also warrant consideration during the PFMA session. In this document dam and project works may be used interchangeably to designate those licensed project works that could impact public safety in the event of a failure.

The following definitions are provided to assure that all readers have a common understanding of the terms commonly used in this Chapter.

Dam Safety Performance Monitoring Program

The Program developed under this Chapter of FERC’s "Engineering Guidelines for the Evaluation of Hydropower Projects” incorporating a Supporting Technical Information document, a Potential Failure Modes Analysis and a Surveillance and Monitoring Plan to improve the ability of Owners, Consultants and the FERC to manage the risk associated with Commission regulated hydro projects.

Supporting Technical Information (STI)

A document prepared to capture the information necessary to have a complete and thorough understanding of the dam and the analyses completed that support the findings regarding the safety of the structure(s).

Potential Failure Mode (PFM)

The chain of events leading to unsatisfactory performance of the dam or a portion thereof. The dam does not have to completely fail in the sense of a complete release of the impounded water. Failure Modes that result in unintended releases of water, such as the Folsom Dam radial gate failure, are also considered.

Potential Failure Mode Analysis (PFMA)

The process utilized to determine the Potential Failure Modes pertinent to the dam under investigation.

Major Findings and Understandings (MFU)

The most significant items learned by the participants in the PFMA session regarding such items as the construction, performance, and safety of the dam.

PFMA Report

The document prepared to capture the information developed during the PFMA.

Surveillance and Monitoring Plan (SMP)

The SMP is a written monitoring plan that is prepared following the completion of the PFMA that addresses the site-specific potential failure modes that are identified in the PFMA report. It should address all Category I and appropriate Category II and Category III failure modes and be designed to minimize the risk associated with these potential failure modes by providing early warning if the failure modes become active or worsen.

14.2 SUPPORTING TECHNICAL INFORMATION

14.2.1 Purpose

The purpose of the Supporting Technical Information document (STI) is to summarize those project elements and details that do not change significantly between quinquennial FERC Part 12D Independent Consultant Safety Inspection Reports. The Licensee is responsible for compiling the "Supporting Technical Information" (STI) document and will create and maintain this document for use by themselves, the Part 12D Consultant and the FERC.

The STI should include sufficient information to understand the design and current engineering analyses for the project such as:

- A complete copy of the Potential Failure Mode Analysis report
- A detailed description of the project and project works
- A summary of the construction history of the project
- Summaries of Standard Operating Procedures
- A description of geologic conditions affecting the project works
- A summary of hydrologic and hydraulic information
- Summaries of instrumentation and surveillance for the project and collected data
- Summaries of stability and stress analyses for the project works
- Pertinent correspondence from the FERC and state dam safety organizations related to dam safety

The STI should use tables, figures, and drawings in preference to text and should not include complete copies of the original documents except for the "Potential Failure Mode Analysis" study report. Only key paragraphs of the original reports should be included in this document for clarity.

The STI is a "living" document, in that as new data or analyses become available they are appended to the initial STI and outdated material is removed. The document should be bound in a three ring binder to facilitate updating the STI as necessary.

The Licensee should coordinate this document with the Part 12D inspection report outline to be sure the Independent Consultant will have all the information necessary for review of the project. The initial STI should be provided to the IC and three hard copies and two digital copies shall be submitted to the FERC. Updates to this document shall be provided to the current FERC Part 12D IC for review, to the FERC and to other document holders. Document holders should be requested to insert the updated pages in the STI, and add the revision to the revision notice log in the front of the STI.

Except for the initial submittal of an STI document, if no significant changes have been made to the STI since the prior Part 12D Inspection report, either a digital copy of the most current STI in *.pdf, *.jpg, *.tif, or other acceptable formats (check with the FERC for acceptability of alternative formats prior to submittal) or a hard copy of the STI shall be included with the Part 12D report.

Licensees should include complete copies of the reference documents referred to in the STI, or, in some instances, all documents reviewed in the PFMA session, in CD or DVD format with the STI document.

The complete STI should be reviewed and reprinted at least every 15 years and hard copies submitted with the Part 12D report.

The initial STI should be provided to the Independent Consultant and three hard copies and two digital copies shall be submitted to the FERC. As new information is obtained, or modifications are made to the project, the licensee will update this document as required. Updates to this document shall be provided to the current FERC Part 12D Independent Consultant for review, to the FERC and to other document holders. Document holders should be requested to insert the updated pages in the STI, and add the revision to the revision notice log in the front of the STI.

14.3 POTENTIAL FAILURE MODE ANALYSIS

14.3.1 Introduction

The FERC in association with Dam Owners and the Independent Consultants who perform the Part 12D Dam Safety Evaluations have developed these procedures for use within the Part 12D examination process. Specifically, they combine plans to improve and focus the Surveillance and Monitoring Plans for FERC regulated dams, and also provide a fundamental enhancement to the inspection process by focusing on site-specific factors of greatest importance at each project. The Potential Failure Mode Analysis, as outlined below, will serve as the focal point and linking feature within the Part 12D Inspection.

A Potential Failure Modes Analysis is a dam and project safety evaluation tool to be used in the context of the Part 12D program of dam and project works safety evaluation. Traditional dam and project works safety evaluations have tended to focus on a limited number of “standards based” concerns such as hydraulic capacity of spillways and stability of structures under a set of pre-defined load conditions. PFMAs are intended to broaden the scope of the safety evaluations to include potential failure scenarios that may have been overlooked in past investigations. A Potential Failure Mode Analysis is an exercise to identify all potential failure modes under static loading, normal operating water level, flood and earthquake conditions including all external loading conditions for water retaining structures and to assess those potential failure modes of enough significance to warrant continued awareness and attention to visual observation, monitoring and remediation as appropriate.

A Potential Failure Mode Analysis is to be conducted for all FERC regulated dams that are required to undergo Independent Consultant safety inspections as defined in 18 CFR Part 12, Subpart D unless granted an exemption. Once completed, this initial PFMA will only need to be reviewed and updated as necessary during subsequent Part 12D inspections.

A supplementary PFMA should also be conducted after failure of a structure or prior to major modifications or remedial work on a structure. The purpose of the supplementary PFMA is to explore the reasons for the failure or evaluate the recommended modification/remediation plan prior to construction. Before a supplementary PFMA can be conducted for major modifications or remedial actions, the design must have progressed to the point of a recommended alternative. Relatively detailed plans and preliminary specifications for the recommended alternative should be available for the supplementary PFMA. A PFMA type analysis may be useful for the design team to evaluate alternatives, but such evaluation would not be part of a supplementary PFMA.

This section provides guidance and examples and supporting materials to enable a Potential Failure Mode Analysis to be carried out, as follows:

- A brief description of a Potential Failure Mode Analysis;
- A listing of the key goals and outcomes anticipated from a PFMA;
- Guidance for the conduct of a PFMA is given in two ways:
    - A brief statement of the expectations and requirements for a PFMA

    - Detailed, step by step guidance for the conduct and documentation of a PFMA.

- A description of the intended application of the results of the PFMA as a support document for conducting the FERC Part 12D Dam Safety Examination with specific emphasis on the development of the Surveillance and Monitoring Plan for the project;
- A description of the process for "updating of the PFMA" by future Part 12D Independent Consultants, the licensee or the FERC; and
- Appendices containing supporting materials and example products from a PFMA.

14.3.2 Description

A Potential Failure Mode Analysis is an informal examination of "potential" failure modes for an existing dam or other project work(s) by a team of persons who are qualified either by experience or education to evaluate a particular structure. It is based on a review of existing data and information, first hand input from field and operational personnel, a site inspection, completed engineering analyses, identification of potential failure modes, failure causes and failure development and an understanding of the consequences of failure. The PFMA is intended to provide enhanced understanding and insight on the risk exposure associated with the dam. This is accomplished by including and going beyond the traditional means for assessing the safety of project works and by intentionally seeking input from the diverse team of individuals who have information on the performance and operation of the dam. A PFMA includes and uses all of the available data and information from standard engineering analyses of an existing dam. A PFMA should be viewed as a supplement to the traditional process in which a dam's safety is judged based on its ability to pass standards-based criteria for stability and other conditions.

Utilizing an intensive team inquiry process beginning from a basis of no preconceived notions, the potential failure mode examination process has the ability to:

- Enhance the dam safety inspection process by helping to focus on the most critical areas of concern unique to the dam under consideration;
- Identify operational related potential failure modes;
- Identify structural related potential failure modes (e.g. piping) not covered by the commonly used analytical methods (e.g. slope stability, seismic analysis);
- Enhance and focus the visual surveillance and/or instrumented monitoring program
- Identify shortcomings or oversights in data, information or analyses necessary to evaluate dam safety and each potential failure mode;
- Help identify the most effective dam safety risk reduction measures; and
- Document the results of the study for guidance on future dam safety inspections. By updating the documentation (as a living document), the benefit of increased understanding and insight lives on.

14.3.3 Key Goals and Typical Outcomes

The primary product and the main focus of a Potential Failure Mode Analysis is identifying and obtaining a clear understanding of each dam's – site specific - potential failure modes. At the outset of the PFMA the Facilitator should discuss with the entire team that the product of the exercise is not a decision document but rather an informational, resource document, developed from the combined input of the team, that is intended for use and reference for many years.

The potential failure mode "identification" is intended to go beyond a simple generic statement of the potential problem (e.g. operations, piping, slope instability, foundation, overtopping, liquefaction, etc.). The potential failure mode identification, examination and description provides background information on the loadings, structural conditions, circumstances and events at each site that identify why this potential failure mode is being considered for this site. Also the significance of the potential failure modes for the site in terms of the need for awareness, monitoring and surveillance, analyses and investigation or for making operational changes, structural repairs or modifications is discussed. Example descriptions of potential failure modes that have come from prior potential failure mode analyses are provided in Appendix A for a potential operational type potential failure mode and for a potential piping type failure.

The Potential Failure Mode Analysis (PFMA) process is not a substitute for, but rather a guide to help focus, periodic, comprehensive, dam safety inspections. Both activities require and benefit from a comprehensive review and discussion of **all** available information (historic records and photos, engineering analyses, previous inspection reports, etc.). Hence, the detailed reviews commonly done prior to a periodic inspection, especially if an Independent Consultant is not familiar with a project, are still necessary. Linking the accomplishments of the PFMA and periodic inspections is efficient and effective because it allows others, not often in the direct safety evaluation loop, to participate and contribute importantly to the outcome.

Although potential failure mode identification is the focus product from the PFMA process, there are other outcomes that result from carrying out a PFMA in the manner described in this guidance document.

- The process of searching out all the information about the dam for the specific purpose of identifying potential failure modes (plus the involvement of a diverse group of people in the PFMA process), typically results in uncovering data and information that most personnel currently involved in the dam's safety evaluation had not been aware of. Frequently this information plays an important role in identifying a potential failure mode.
- The most significant potential failure modes and failure scenarios will be identified and documented for use and consideration by future Independent Consultants and inspection teams.
- Certain problems, issues and concerns that have been associated with the dam may be found to be of lesser significance than previously perceived from the standpoint of consequence, remoteness or physical possibility.

- Enhancements to the monitoring and visual inspection programs are recognized and readily developed. Monitoring efforts can become more focused on the important issues.
- A wide range of persons (from the dam tender to the owner's dam safety program manager), become aware of the dam's most significant vulnerabilities and the relationship of the surveillance and monitoring programs to these vulnerabilities.
- Gaps in data, information or analyses that prevent characterizing the significance of a potential failure mode are recognized and identified for consideration / action by the owner.
- Risk reduction opportunities applicable to the Surveillance and Monitoring Plan, operations, structure response or emergency preparedness are recognized and identified for consideration by the owner.
- Provides the opportunity to easily and effectively educate all who are concerned with the dam (dam tender, owner, regulator, periodic reviewers, inspectors, designers and others) about:
  1. The potential failure modes for this dam;
  2. How monitoring, including use of specific instrumentation and visual surveillance is used to look for specific symptoms, behaviors or evidence that might warn of a developing failure for the identified potential failure modes;
  3. How "general health" monitoring (e.g., crest monitoring, piezometers) is used as basic data to help watch for conditions that were not identified as potential failure modes;
  4. How operations (i.e., regulated, normal, unusual) of this dam and others upstream may influence dam safety; and
  5. Emergency actions that may be more commonly encountered.

14.3.4 Conduct of the "Initial" Potential Failure Mode Analysis

Specific steps and actions for carrying out a PFMA for a dam are enumerated below and these steps are recommended, as a minimum, for a PFMA to be comprehensive, consistent, and complete. However, in completing these specific steps it is very important that the principles of the process be understood and followed in order for the full value of the process to be achieved. These principles include:

- Diligence in searching for <u>all</u> the background information;
- An open – investigative attitude toward identifying and understanding potential failure modes and failure scenarios;
- Dedication of the assigned persons to the reviewing / reading of all the background information on the dam prior to the PFMA session;

- Diversity in input to the process – field personnel, operations personnel, technical personnel, management personnel and others all contribute to the pool of information. There is no monopoly on good ideas and key information;
- Documentation is the key to capturing the insight and ideas resulting from the process; and
- Willingness of all parties to set aside their normal hats and focus on what the data, information, and experience / knowledge of individuals can teach us about the dam.

Overall Guidance – Potential Failure Mode Analysis Expectations / Requirements

1. Collect all data, studies and information on the investigation, design, construction, analysis, performance and operation of the project. All studies and investigation reports existing that relate to the ongoing safety of the dam must be included and reviewed and evaluated. A listing should be made of the data available for review and considered in the Potential Failure Mode Analysis and the reference list included in the PFMA report documentation.
2. Visit the project site with an eye out for potential failure modes, structural and geologic conditions, review operations, and interview owners/operators for their input on potential failure modes.

   A Core Team, experienced in dam safety evaluation (familiar with dam failure mechanisms), is to review all the background information for general understanding and with these specific questions in mind:

   - How could this dam fail? (Site-specific consideration of loadings, structure condition, and project operations)
   - What happens if the dam fails?
   - Are the identified potential failure modes recognized and being appropriately monitored by visual surveillance or instrumental monitoring?
   - What actions (immediate or long term) can be taken to reduce dam failure likelihood or to mitigate failure consequences? These actions could include any of the following: data collection, analysis or investigations, operational changes, communication enhancement, monitoring enhancement and structural remediation measures.
3. Brainstorm potential failure modes and failure scenarios with the group of persons most familiar with design, analysis, performance, and operation of the dam. Record the identified potential failure modes, the reasons why each potential failure mode is favorable / less likely and adverse / more likely to occur and identify any possible actions related to each that could help reduce risk (i.e. monitoring enhancement, investigation, analysis, and/or remediation).
4. Specifically identify possible Surveillance and Monitoring enhancements and/or risk reduction measures for each potential failure mode for consideration by the owner and the Independent Consultant in the Part 12D inspection and report.

5. Document the analysis, including immediately recording the major findings and understandings from the brainstorming session.

Procedural Guidance – Potential Failure Mode Analysis Step by Step Guidance

Step 1 Designation of the Potential Failure Mode Analysis Participants (Licensee with input from IC and FERC)

Step 2 Collection of Background Data on the Dam for Review by the Core Team (Licensee with input from the Independent Consultant)

Step 3 Site review including interviews with key owner personnel at the Project. (Core Team)

Step 4 Comprehensive review of all of the Background Data on the Dam by the Core Team

Step 5 Conduct of the PFMA Session (The licensee is responsible for the facilities, the Facilitator for assuring the process is followed, and the Core Team for performing the PFMA)

Step 6 Consideration of Surveillance and Monitoring opportunities and/or Risk Reduction measures for Identified Potential Failure Modes - (Note that the Surveillance and Monitoring Plan for Identified Potential Failure Modes is provided to the owner by the Independent Consultant in the Part 12D report)

Step 7 Documentation of the PFMA and Surveillance and Monitoring and/or Risk Reduction opportunities (Independent Consultant)

The time frame for completing the documentation of the PFMA session is provided in the Table below.

Action Item	**Time Frame**
1) Independent Consultant (IC) Transcribes the Major Findings and Understandings and sends them to the Facilitator and the core team for comments.	Within 14 days of the PFMA Session
2) The Facilitator and core team send their comments on the MF&U to the IC.	Within 21 days of the PFMA Session
3) IC prepares the draft PFMA report and sends it to the Facilitator for peer review.	Within 30 days of the PFMA session.
4) Facilitator completes Peer Review of draft PFMA Report.	Within 2 weeks of receipt of the draft report.
5) IC considers Facilitator's comments and suggestions, makes any necessary revisions to the draft PFMA report and sends the revised report to each participant of the PFMA.	Within 60 days of the PFMA session.
6) Participants of the PFMA review the draft PFMA report and send comments to IC.	Within 2 weeks of receipt of the draft report.
7) IC considers all comments received from the participants of the PFMA, makes any necessary revisions to the PFMA report and finalizes the PFMA report.	Within 90 days of the PFMA session

The following sections describe each step in detail:

Step 1 – Designation of the Potential Failure Mode Analysis Team Participants

The potential failure mode analysis participants (team members) consist of all those who will participate in the brainstorming session in which potential failure modes are identified, defined, discussed and categorized. Fundamentally these are persons who have past experience with the design, construction, analyses, performance and operation of the dam or who will obtain knowledge of the project through reading all the background material. A dam-experienced engineering geologist should be a part of the team and should be included in the site visit. The primary advantage of having a variety of people participate in the potential failure mode identification process (<u>and it is a very significant advantage</u>) is that more ideas and more questions are put forward; more knowledge and information is available; and a greater diversity of opinion is input to the process.

Some of the team members have specific roles and responsibilities and need to have the requisite experience and capability to fulfill these roles. The roles and requirements of the team members are given below:

Team Leader - The dam owner would designate one of the participants as the team leader, responsible for coordination activities – including collection of the background information.

Core Team - At least four participants are designated as the "Core Team" members. They are called the Core Team because they are specifically assigned the responsibility to read / review all of the background material.

The Core Team will generally consist (as a minimum) of the following four persons:

- The Independent Consultant(s) who will do the current Part 12D inspection and prepare the Potential Failure Mode Analysis Report.
- A Technical Representative(s) of the Owners Staff (i.e., engineer, field operations person) may or may not be the team leader – see note below.
- The FERC inspector for the dam.
- The Facilitator of the Potential Failure Mode Analysis session who will facilitate the session and Peer Review the Potential Failure Mode Analysis Report on behalf of the owner and all the participants.
- It is strongly recommended that an engineering geologist and a geotechnical engineer be included in the Core Team. Experience has shown that this expertise has proven valuable during the PFMA sessions and the people filling these roles should have the benefit of reading the background material.

Note: The Team Leader may or may not be assigned by the owner as one of the designated Core Team "readers of the material". This is because the coordination / logistic activities may keep the Team Leader from being able to meet the reading and review requirements. If the owner and team leader consider that this may be the case another representative of the owner should be designated to participate in the Core Team review of all the background material.

The following criteria should be considered when selecting the Core Team members:

General Criteria -

- The Core Team members should have knowledge and experience related to dam safety evaluations. It is especially helpful to have persons who have interest and knowledge related to dam failures and who have an inquisitive / investigative personality (they think like coroners or detectives).
- The Facilitator should, in general, be new with respect to examining the dam's operation and history. This is considered an advantageous situation with respect to providing a fresh and vigorous look at the structure.

  Dam owner representatives who have the knowledge, skill and interest and who gain the requisite experience to serve as Facilitators are encouraged to do so via an exchange program with other dam owners. It is considered inappropriate for dam owners to facilitate the PFMA on their own structures.

- The Independent Consultant may or may not be new to the facility, but like the Facilitator must have extensive experience in dams and an open mind relative to identification of potential failure modes. In accordance with current regulations the Independent Consultant must still meet FERC requirements and be approved by FERC.
- The Independent Consultant and the Facilitator should not be from the same organization / firm.
- Persons who had experience with the original design and/or construction of the project can provide invaluable insights and data. Wherever possible, they should be recruited for the PFMA field and data review and the PFMA session. Alternatively, they can be available by phone to answer questions raised during the session.
- In states where the State Dam Safety organization has sufficient resources, the dam safety inspector responsible for the subject project can provide valuable data, information and insights into the project and should be invited.

Facilitator Requirements - The Potential Failure Mode Analysis (PFMA) Facilitator should be a civil, geotechnical engineer or engineering geologist with a broad background and experience in dam safety engineering and experience in performing a PFMA similar to that described in this guidance. A recommended qualification for the Facilitator is that the proposed Facilitator for a project should have been involved in an actual PFMA of the nature described in these guidelines either as a Core Team member of a PFMA or actually facilitating a PFMA. This ensures that the person leading the PFMA process knows not only how the process is carried out, but also is aware of what can be accomplished. This is especially critical if the other Core Team members have not been through a PFMA which may often be the case. As an alternative to actual experience participating or facilitating a PFMA, the proposed Facilitator should have attended an FERC sponsored Dam Safety Performance Monitoring Program Training Workshop. FERC will periodically provide training opportunities to help develop Facilitators.

It is important to understand that if the Facilitator, working with the assembled PFMA team, does not accomplish the goals of the PFMA, which is identifying and obtaining a clear understanding of each dam's site-specific potential failure modes, the PFMA may be required to be supplemented or redone entirely.

Additional PFMA Participants – In addition to the Core Team members, the PFMA sessions should include the key operating staff of the project who will be able to clarify operating rules and procedures and also will learn about the failure modes developed in the process. Also, if not a designated Core Team member, a dam experienced engineering geologist should participate in the PFMA and should review all geological background material, make appropriate observations during the field review and participate in discussions of foundation related PFMs.

In formulating the team it is important to include those individuals with intimate knowledge of the project operations and structures, especially the senior dam tenders and those responsible for collecting monitoring data. The benefits from conducting this exercise include not only bringing focus to the most likely modes of failure based on engineering judgment but also includes increasing the general awareness of dam safety issues by sharing knowledge at all levels. Experience has shown that it is very helpful and valuable to include senior (experienced) field personnel in the actual PFMA session because all information has not been written down and in certain cases assumptions in written reports differ from what is actually done or known in practice. The field personnel also can verify data and information discussed in the session.

Supplemental Resources - In addition to the team participants there are other people who have specific technical knowledge or experience that may be useful to the team. These people would be notified and asked to be available or on call on the day of the PFMA session. This would include such persons as those involved with the construction of the facility, seismotectonic specialists, hydrologists, structural engineers, electrical engineers, mechanical engineers, geotechnical engineers, field personnel, inspectors, instrumentation personnel, emergency preparedness personnel, etc. If there has been a major change to the project (anchoring program) or if there is a complex instrumentation program (unique instrument), it is useful to have the responsible engineer/operator make a short presentation during the workshop so that all participants have a common understanding of the issue.

Step 2 - Collection of the Background Data on the Dam

1. Preparation / Input by the Dam Owner's Team Leader and FERC

   The Team Leader, working in conjunction with the Facilitator, FERC inspector, Independent Consultant, project staff, and geologist, collects and gathers for review, all background information on the project. This data and information is collected in a centralized location for reading by the Core Team members and would also need to be available during the PFMA Session. The general rule is: **collect all information on the project.** If there is a question about the need to bring / collect certain material, the Facilitator and owner should discuss this in advance.

   The types of material which should be collected (if available) include but are not limited to the items listed below.

   - Any FERC or state agency construction inspection reports (these have been found to be extremely useful, particularly if the original construction predates the Federal Power Act)
   - Current or most recent dam safety engineering analyses, including stability and stress analyses
   - The most recent monitoring and instrumentation data along with the historic records of monitoring data. Large scale, easily readable, plots of monitoring data over the life of the dam have proven extremely valuable and should be available

at the PFMA session. The licensee or consultant should also provide verification that the instrumentation is properly functioning.

- The most recent surveys for each of the project structures (i.e. horizontal and vertical survey data). This should preferably be the survey that was conducted as part of the current Part 12D inspection. A detailed survey of the crest of all structures including principal and emergency spillway crest elevations to confirm the freeboard assumed in the discussions. Elevations of natural grounds that could result in overflows around the structures should be considered. Also, the datum of the project relative to surrounding grounds should be stated (i.e., conversion of project records to NGVD)
- Current hydrologic studies and the associated flood routings and any hazard / consequence analyses
- The current Emergency Action Plan
- The most up-to-date aerial photographs of the downstream areas that could potentially be impacted by failure of the project structures.
- Original and subsequent modification construction design reports, as-builts, photographs
- Boring logs
- The most recent underwater inspection report. This should preferably be the underwater inspection that was conducted as part of the current Part 12D inspection.
- Recent and historic meteorological and pertinent river records from project or nearby dam or gage records (http://waterdata.usgs.gov/nwis).
- Operation records(particularly historic) of primary and secondary (e.g. fuse plugs) spillway discharge rating curves, mechanism and response times for opening (i.e., stanchion gates, bulkheads, flashboards, gates) and problems (i.e., ice, debris).
- The most recent seismic loading parameters that have been prepared for the site and print records of recent seismic activity (http://earthquake.usgs.gov/).
- Any incident reports

(Note: Basic demographic, seismic, meteorological and/or stream flow data should be reviewed to ensure that previous findings or assumptions related to potential failure mode hazards or consequences are up to date. Hence, recent data and information should be brought to the session or generated at the session as necessary. This will ensure that the PFMA report is an accurate representation of the likely potential failure modes and consequences based on the best information that was available on the date the exercise was conducted.)

A listing of the data available for review and considered in the Potential Failure Mode Analysis should be prepared for use by the Core Team in reviewing the materials and included in the PFMA report documentation.

The owner should establish a means to retain / archive all the information collected for the PFMA.

2. An advance review package on the dam would be prepared for all participants – this package would consist of material already prepared that provides an overview of the dam and its performance. The purpose of an advance package is twofold: to give the Facilitator familiarity with the dam prior to the site review and to refresh knowledge of the dam and stimulate "potential failure mode thinking" by all participants prior to the PFMA session. The previous Part 12D Inspection report, the most recent FERC Operation Report and the draft STI would provide a good "advance package document" to give to the Facilitator and the Core Team (and any other proposed participants) for familiarization with the project prior to the site review. The advance review package should be sent to site review participants prior to their travel to the site.
3. Core Team members are to review all of the above information searching for site specific conditions or situations that would lead to uncontrolled release of the reservoir or other incidents, conditions or situations that would have an adverse impact. This review of materials is scheduled to occur following the site visit and discussion with project personnel.
4. A questionnaire on potential failure mode identification and surveillance and monitoring is to be sent by the Team Leader to all PFMA participants and support personnel (Appendix B provides an example questionnaire along with a draft note to be sent explaining the request for information). Note that prior to the PFMA session, team participants, other than the Core Team members, are only required to complete this questionnaire, review their own files (re-acquaint themselves relative to the work within their area of expertise), and bring their historic knowledge and documents of the project to the session. Only the Core Team members are responsible for reading all the historical and technical documents related to the project.

Step 3 - Site Review of the Dam and Project

Typically the PFMA team (Core Team, including the geologist if present and the owner's personnel) are first assembled at the time of the site review. This is a good occasion for the Facilitator to review the basic concept of the PFMA process and the objectives of the site review and ask if there are any questions (on the order of 5 to 10 minutes). These guidelines layout what is to be accomplished in the PFMA and although the Core Team has likely read them, the licensees operating staff probably is unfamiliar with the process. Therefore, a quick review of the process to make sure everyone is on board is a good idea. Likewise when the Core Team gathers to do the reading, a quick discussion of the plan and objectives of the reading by the Facilitator is appropriate.

1. The detailed Part 12D Inspection of the project will be performed and the accompanying report prepared by the Independent Consultant following the Potential Failure Mode Analysis. However prior to the initial PFMA session, a review of the site, "thinking" potential failure modes, is carried out with the owner's personnel and

the Core Team. The basic purposes of this site review are (1) to let those participating on the PFMA team, who have not seen the site, see it; (2) to have the team "think / see" potential failure modes in the field; and (3) to discuss the site and operations with site personnel in their own environment. Owner's may find it valuable to include all or most of the employees that they plan to have participate in the PFMA also participate in the site review.

2. Typically the site review performed in association with the Potential Failure Mode Analysis should be scheduled just before the Core Team members review the background materials. Such a schedule takes greatest advantage of the interaction between potential failure mode analysis and site visitation.
3. The site review should include the opportunity to discuss the Project with field maintenance personnel and plant operators, including but not limited to those who will be team participants.
4. The comprehensive review of background data and information on the dam by the Core Team is scheduled to occur following the above site visit and discussion with project personnel. Experience has shown that it is much more efficient and effective to review the bulk of the background materials after a physical review of the site.

Step 4 – Comprehensive Review of the Background Material

Prior to the Core Team beginning its review of the background material, the Facilitator should review the basic concept of the PFMA process and the objectives of the material review and ask if there are any questions.

The Core Team and the geologist gather and review the data on the dam. The review of the material should take place at a convenient location considering the location of the site, data, and where the PFMA session will take place. The background material should preferably be in the same as room as the PFMA session in order to facilitate finding reference material during the PFMA session.

Assemble in a group setting for efficiency in sharing the collected data and to provide a "captive" condition to ensure that the material is reviewed by all the Core Team members. Also being together allows for collaboration on items that may need clarification by the entire core group. The team geologist should ensure that the relevant geologic data is available for Core Team review and the geologist should also review this material personally. *(Note: Allow one day for the review plus afternoon/evening of the site review and evening before PFMA as necessary. This review is essential to an effective PFMA.*)

Step 5 - Conduct the Potential Failure Mode Analysis Session

A brief description of the Potential Failure Mode Analysis Session is given below – a more comprehensive example of a typical session is given in Appendix C. It is important for the Facilitator to involve all participants in the discussions and give everyone an opportunity to provide their knowledge, understanding and views on the potential failure modes, consequences and possible risk reduction actions / measures.

Just as discussed for the site review and the reading session, the Facilitator, at the outset of the PFMA session, should give some introductory remarks about the PFMA session, (goals, objectives, process), should provide everyone a handout on the Potential Failure Mode Categories (it is best to discuss this however at the point the first potential failure mode is to be categorized), and should discuss with the entire team that the product of the exercise is not a decision document but rather an informational, resource document, developed from the combined input of the team, that is intended for use and reference for many years. (This is one important reason that the process works so efficiently and effectively)

1. Consider the possibilities for failure, loading by loading condition (static reservoir, hydrologic, seismic, ice, debris impact and any other loading relevant to the site) for each component of the project (main dam, spillway, gates, dikes, outlet works, power plant, etc.). Consider how an uncontrolled release of the reservoir or a dam breach could occur. Also consider total system operation aspects (communication and response [i.e., personnel, remote telemetry], facility access, weather conditions, equipment) with respect to the possibility of their contribution to development of a potential failure mode/failure scenario.

2. Team participants are asked to suggest or propose "candidate" potential failure modes that they have considered during the site visit, review of the background material or when completing the advance questionnaire. The ideas, suggestions and comments brought up during the potential failure mode discussion session vary and can take several paths.

   If a candidate potential failure mode is suggested, it is discussed until a clear characterization of the potential failure mode and failure scenario is developed. Once a candidate potential failure mode is fully developed by the team and the team decides that the failure mode is a reasonable and credible potential failure mode, it is carried forward to the "discovery phase" (see Step 3 below) which is the identification by the team of the factors that indicate how and why the potential failure mode is either likely or not likely to develop and what other adverse or positive aspects exists relative to the potential failure mode.

   Sometimes this preliminary or developmental discussion of the initial suggestion may lead to two or more separate or related potential failure modes, which are then developed separately.

   Sometimes an item or issue brought up relates to dam safety, surveillance and monitoring or is of general concern but is recognized by all as something that does not or would not result in failure of the dam or other water retaining structure at the project and is thus not a candidate potential failure mode. However, such items still need to be included in the documentation to illustrate that they were identified, considered and were left to be addressed (potential identification of action) by the Part 12D consultant and or the owner. Such items are referred to as "Additional Monitoring or Performance Related Items Discussed" and are to be included in the report in a section under that heading.

   In other cases, a PFMA team member may suggest a "candidate" potential failure mode which the PFMA team, after preliminary discussion, believes is not a credible or viable potential failure mode or is considered to not be physically possible. If as a result of this preliminary discussion clear reasons are identified for discounting the viability of the potential failure mode (**based on information currently available)** and there is team consensus on this finding, then the candidate mode along with the fundamental reason(s) for its lack of viability or credibility is documented as "Category IV" (see Table 1 below) and sub-steps 3-5 below are skipped. The Facilitator should move to full consideration of the Potential Failure Mode (sub-steps 3-5) if there is not clear consensus among the PFMA team on the candidate mode's lack of credibility.

One exception to the general rule of not carrying forward a candidate potential failure mode that has, by consensus been judged as not viable, is when the preliminary discussion establishes that the mode is not credible but the owner (or regulator or IC) wants the mode to be fully developed and presented (e.g. – it has been a topic of discussion for a long time and the fact that it is judged to not be a credible potential failure mode [Category IV] deserves more complete documentation. Of course it is possible that after full discussion it could move to a different category.

In the context of the FERC's Part 12D Independent Consultant's Safety Inspection, Potential Failure Modes related to acts of terrorism are not considered. However, the PFMA process may be applicable in assisting a licensee in evaluating the vulnerability and risk associated with acts of terrorism.

3. Once a candidate potential failure mode has been characterized / described such that there is a common understanding of the potential failure mode, (See Appendix A – Part 1 for example potential failure mode descriptions.) The potential failure mode description is noted on a flip chart by the Facilitator and should be recorded in detail by the Independent Consultant at that time; then the potential failure mode and failure sequence is discussed. The nature of the breach (or other failure condition) is defined and the potential consequences of failure are discussed. The failure mode should be developed so that each step in the failure mechanism from the loading condition to the final failure condition is sufficiently defined so that the Surveillance and Monitoring Plan can be developed to detect a developing failure as soon in the process as possible. All the data, information, factors and conditions that suggest the ways that the potential failure mode is more likely or less likely to occur (adverse factors and positive factors) are noted. (See Appendix A – Part 2 for an example) Also during this discussion possible risk reduction actions that may be taken are suggested:

    - Means for monitoring/inspecting for the development of potential failure modes.
    - Opportunities for risk reduction.
    - Possible investigations or analyses.

    All of this information is noted (in brief) on a flip chart to facilitate documenting the suggestions. Although some PFMAs have successfully utilized a computer with projector to record the PFM information, the computer should not be considered a complete substitute for the use of flip charts. The flip charts are essential for keeping track and summarizing the PFMA discussions. The use of a computer can assist in recording and organizing the details which makes it possible for the IC to efficiently complete the PFMA report. When a computer is used to record the session, a person other than a Core Team member should take the notes to assure the Core Team members can actively participate in the discussions. The note taker should be an experienced dam engineer.

The consequences of failure and the circumstances surrounding a failure (advance warning, detection possibilities, impact of the failure, etc.) should be discussed for each potential failure mode during the discussion of the potential failure mode since these factors play a role in assessing the significance of the potential failure mode. However, experience has shown that it is necessary, valuable and instructive to specifically raise the topic of "consequences" as part of the PFMA and brainstorm site-specific factors and potential failure mode consequence related factors (in the event they have been overlooked during the technical discussion of the potential failure mode)

4. When each site-specific potential failure mode is identified, the nature of the breach / uncontrolled release that may occur is discussed and the range of failure scenarios and consequences that may result are identified. The emergency action plan response to potential failure scenarios is examined and any concerns with the plan are identified.

5. After a potential failure mode has been identified, described and discussed, each potential failure mode is classified / categorized according to the classification system given in Table 1. After all potential failure modes have been discussed the classifications made are reviewed and discussed. Note that if team members do not reach consensus on the category, dual categorization is permissible (e.g. I/II or III/II), requiring only that the reasoning behind each category used be provided After all potential failure modes have been discussed, the classifications made are reviewed and discussed. The Part 12D Independent Consultant may later recommend resolution or modification of the classification as part of the Part 12D Report.

   It is important to note that the categorization of potential failure modes is not related to a possible need for additional surveillance, monitoring, maintenance or remediation. The categorization is intended to give the licensee, the Independent Consultant and the FERC inspector a relative sense of the importance of the Potential Failure Modes, to assist in designing the Surveillance and Monitoring Plan, and to provide focus to inspections of the dam.

Table 1 - Categories of Identified Potential Failure Modes

Category I -	*<u>Highlighted Potential Failure Modes</u> - 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 conditions and events leading to failure seemed reasonable and credible) are highlighted.*
Category II -	*<u>Potential Failure Modes Considered but not Highlighted</u> - 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 all 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.
Category III -	*More <u>Information or Analyses are needed in order to classify</u> these potential failure modes 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.*
Category IV -	*<u>Potential Failure Mode Ruled Out</u> Potential failure modes may be ruled out because the physical possibility does not 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.*

Category I Potential Failure Modes are those considered most credible and most important to be brought to the attention of the dam owner, dam operators, and personnel performing the monitoring and routine and periodic inspections. Because of the importance of monitoring the performance of the dam, surveillance, monitoring or instrumentation enhancement or other risk mitigation measures should be considered (See Step 6 below).

Category II Potential Failure Modes are also considered credible, in that they are physically possible, but are not highlighted for one or more reasons such as no direct or indirect evidence of any indication of problem development, the loading required to initiate the potential adverse response is not as likely as Category I, or the magnitude of consequences is not as significant as Category I.

Category III Potential Failure Modes are those where more information or analyses are needed in order to be classified.

Category IV Potential Failure Modes are those that have been ruled out as a result of finding specific information that shows that the subject PFM is not physically possible or initial brief consideration by the Core Team shows that it is not a credible failure mode.

In general, Potential Failure Modes that have been fully developed and agreed to as reasonable and credible PFMs, i.e. they constitute a physically possible mode of failure, should be categorized as either Category I or Category II. However, there may be some Potential Failure Modes where the physical impossibility of the failure mode is only discovered after full development of the PFM description and discussion of the likely/not likely factors. These PFMs may be assigned to Category IV.

Categories I and II are provided to allow the use of judgment by the team and to provide an easy differentiation of relative importance for the owner. The differentiation between Category I and II should be based on the need to "Highlight" the PFM for the benefit of the licensee's operating and technical staff and for development of the Monitoring and Surveillance Plan. Generally, Potential Failure Modes that, if activated, would result in high downstream consequences, should be classified Category I. Similarly, dams that require operation or maintenance actions to maintain adequate factors of safety (i.e. such as assuring that drains are functioning to relieve uplift, tendons maintain sufficient pre-stress, gates must be operated to prevent overtopping, etc.) should be classified as Category I to make sure that the licensee's O&M program is designed to assure that operating and technical staff are aware of the critical nature of these facilities. The magnitude of consequences is a factor that should used to differentiate between Categories I and II.

Category II should be reserved for those Potential Failure Modes that are physically possible but do not need to be highlighted to the owner for various reasons. Category II PFMs would not result in a downstream hazard; have a low probability of occurrence; or there is an existing monitoring or maintenance program that makes the probability of occurrence remote. For instance, failure of a gate where the water release would stay in bank and there is not a significant recreation use of the river downstream of the dam, could be classified Category II. Similarly, a dam that has high calculated factors of safety, i.e. the probability of failure is remote, and or the downstream consequences are small, may also be classified as Category II.

Category III Potential Failure Modes are those where there is insufficient information to make a determination as to classification. Generally, a Category III PFM will require additional investigations and/or analyses in order to determine an appropriate classification. When the additional information/analyses required to resolve a Category III PFMA are completed, that potential failure mode should be re-categorized.

Attention to monitoring and surveillance relates to Category II and III potential failure modes just as it does for Category I modes.

As noted above, in some instances a candidate potential failure mode can be dismissed as a potential failure mode without fully carrying out numbers 3 through 5 above. In such cases the PFM will be classified as Category IV. Category IV can also include PFMs with fully developed descriptions if the physical impossibility of the PFM is only discovered after a full discussion. The PFMA report will include a brief description of the postulated PFM and identify why the team did not discuss it in further detail. Category IV should only include PFMs that have been dismissed as physically impossible. Low consequences and/or low probability of occurrence alone are not sufficient reason to classify a Potential Failure Mode Category IV.

Sometimes an item or issue brought up relates to dam safety, surveillance and monitoring or is of general concern but is recognized by all as something that does not or would not result in failure of the dam or other water retaining structure at the project and is thus not a candidate potential failure mode. However, such items still need to be included in the documentation to illustrate that they were identified, considered and were left to be addressed (potential identification of action) by the Part 12D consultant and or the owner. Such items are referred to as "Additional Monitoring or Performance Related Items Discussed" and are to be included in the report in a section under that heading.

6. In the Part 12D report, all Potential Failure Modes, irrespective of Category, should be reviewed and assessed by the Independent Consultant. In the Part 12D report the IC may make recommendations to move a Potential Failure Mode from one Category to another. If such a recommendation is made, the IC should provide the proposed category and the reasoning supporting the recommendation.

   It is important to note that the Potential Failure Modes are placed into categories by judgment. The basic purpose is to help the dam owner's personnel and the current and future inspectors dealing with the dam to understand what the evaluation team considered were the most significant potential failure modes, so that they can consider / prioritize for action a smaller number of items rather than the total array of potential failure modes considered. The breakdown may also help with prioritization of actions to be taken. It is quite common in the PFMA for a monitoring or visual inspection action to be identified for a Category II potential failure mode that is easy to implement.

Step 6 – Evaluation of Surveillance and Monitoring Requirements

As a part of the Part 12D report the Independent Consultant will be required to assess the Surveillance and Monitoring Plan for the dam / project. A SMP is required for each Category I Potential Failure Mode. Surveillance and Monitoring Plans will also be included for selected Category II and III Potential Failure Modes which the Independent Consultant believes are warranted. In the Part 12D report the Independent Consultant must explain why surveillance and/or monitoring is not warranted for any specific Category II or III potential failure modes. In addition any requirements for "General Health Monitoring" independent of an identified potential failure mode will be defined. The plan presented should consider the items enumerated below. To facilitate development of Surveillance and Monitoring Plans, the PFMA team should include comment and discussion on these items as appropriate for each potential failure mode identified.

1. The type and frequency of inspections (visual surveillance requirements) should be evaluated to address the identified potential failure modes. This item may include the recommendation of developing customized checklists for the dam. (*The nature and content of the checklist, if recommended, is developed by the Independent Consultant in consultation with the owner. The checklist should identify specific visual clues that may indicate a suspected potential failure mode has activated, and the checklist should provide instructions as to what step(s) should be taken once a clue is observed).*
2. The current instrumentation and visual surveillance program should be critiqued. It should be determined if the existing instrumentation is operating properly and that the readings can be relied upon. In some cases, instruments may be obsolete and serve no purpose in monitoring for the development of a potential failure mode. In other cases additional instrumentation or visual surveillance may be needed to monitor for a potential failure mode development
3. Reporting requirements should be reviewed. Action limits may need to be established for some of the instruments and procedures developed for reporting variations in instrumentation readings. As a minimum, annual engineering review, evaluation and reporting of the instrumentation data is required.
4. In some cases additional analyses or investigations may be required to fully evaluate a potential failure mode prior to establishing a SMP for it. The PFMA team should identify what information is needed. The Part 12D Independent Consultant would recommend what information is needed and how to obtain this information.
5. If enhancements to the monitoring or visual surveillance are identified by the PFMA/Part 12D process then priorities for improvement in the SMP should be discussed, and appropriate recommendations and schedules provided, in the Findings and Recommendations Section of the Part 12D Report.

Step 7 - Documentation of the Potential Failure Mode Analysis

1. For the knowledge gained, information obtained and results achieved in the Potential Failure Mode Analysis to be effectively used for the current Part 12D and for future dam safety Part12D inspections the documentation of the work must:
    - Be done promptly;
    - Be definitive in describing the identified potential failure modes;
    - Be complete in recording factors considered relative to the viability of each potential failure mode considered;
    - Discuss possible risk reduction actions identified relative to each credible potential failure mode (e.g., surveillance and/or monitoring, investigations, remediation activities); and

- Clearly relay the major findings and understandings achieved as a result of the process.

It was specifically noted during the review of pilot study draft reports that greater attention needs to be paid to fully stating the sequence of conditions and events that constitute the potential failure mode and failure scenario. (See Appendix A for an example potential failure mode description)

The time frame for completing each of the steps described below is provided in Section 14.3.4 “Procedural Guidance”.

2. At the end of the PFMA session, the Facilitator should ask the participants to reflect on what they learned during the PFMA process. After a few minutes the Facilitator should ask the participants to state what were the Major Findings and Understandings (MFU) they gained during the PFMA session. Typically this is done by going around the room and asking each participant to provide a MFU and then starting again with the first person until all participants have had the opportunity to express their findings. MFUs may relate directly to a Potential Failure Mode or may reflect a more general understanding about the dam or the PFMA process.

   If any MFU describes a serious dam safety issue, this should be immediately brought to the attention of the FERC-D2SI Regional Office.

   The Independent Consultant writes up the “Major Findings and Understandings” immediately after the session. The items noted during the session are typically abbreviated and should accurately reflect what the individual participants stated as their major finding or understanding gained during the session. Where the MFU relates to a PFM, a brief discussion (3 to 5 sentences) relating the MFU to the PFM should be prepared by the Independent Consultant and included with the MFU. The write up of the major findings and understandings is then sent to the Facilitator and the other Core Team members for review. Appendix E provides an example of a write up of major findings and understandings resulting from a potential failure mode analysis.

3. The Independent Consultant prepares the draft Potential Failure Mode Analysis Report, describing each potential failure mode considered and referencing key adverse/likely and positive/not likely factors, identifying any suggested visual surveillance or instrumental monitoring, describing consequences of potential failure and site-specific conditions or factors related to consequences and noting any potential actions identified (information inquiries, investigations, analyses or risk reduction opportunities). The failure mode should be presented pictorially whenever possible. The write up should include a brief statement as to the adequacy of the project documentation and overall quality of the data that formed the basis of the PFMA. If prepared technical presentations of new material, not contained in the record documents, were made by consultants during the course of the PFMA their presentation should be documented in, or appended to the PFMA report.

   The draft report is then sent by the Independent Consultant to each participant of the PFMA session for review and comment.

Appendix D provides an example outline for the documentation of the analysis. This outline is designed to take advantage of the information collected on flip charts during the potential failure mode analysis session in order to make the documentation process simple, fast and effective.

4. All reference material available and used by the team in the Potential Failure Mode Analysis is recorded and key items of data and information (that led to important findings or conclusions – see discussion under point 5 below) are included in an appendix to the PFMA report for ready reference. Photos of past conditions or photos of current conditions, elucidating key information about a potential failure mode, are highly recommended for inclusion in the body or appendix of the PFMA report. The PFMA appendix should be concise and not duplicate parts of the STI or Part 12D report.

5. Preparation of a listing of the documents gathered by the owner for review, in advance of the review, has been found to serve as a valuable tool for the reviewers to use to assure that they have seen all the materials collected and should be included in the PFMA report.

6. The PFMA report will then become Section 1 in the Supporting Technical Information (STI) document and the findings of the PFMA report will be discussed and summarized in the Part 12D report. In some instances, due to the size of the PFMA report or the STI document, the PFMA may be bound as a separate volume in which case Section 1 of the STI should include a statement that the PFMA report is bound separately and provide a copy of the cover of the PFMA report showing the title and date of the report. It is not the intent of the PFMA appendix to include the reports and documents that comprise the "background material" that was read and used in the discussions. However, often a key paragraph, photograph, test results or other documentation is found in a document that elucidates whether or not a potential failure mode is more or less likely and it is valuable to include that specific information in the PFMA appendix. (e.g. photographs may show planar joints, or gunite treatment of the foundation, or shear keys; statements might be made by the consulting review board about the condition of the filter material, tests results might provide definitive information that counters what has been stated in opinions / observations in construction reports; erosion or the lack of it may have been documented following a flood). These specific pages, photos, quotations or data that provide direct support to the "likely" or "not likely" aspects of a potential failure mode should be reproduced and included in the appendix to the PFMA report.

7. The report should state whether the findings are a consensus of the team. If not a consensus, the differences of opinion and reasons therefore should be documented in the report findings. If no consensus is reached, the Part 12D consultant is still required to make a definitive assignment of all identified failure modes.

8. The Report should include a section on Additional Monitoring or Performance Related Items Discussed. Issues or items that are brought up during the PFMA session that relate to dam safety and performance monitoring or are of general concern but are recognized by all as something that does not or would not result in failure of the dam or other water retaining structure at the project are included here.

There are a variety of these types of items that get raised and for completeness they need to be included in the documentation to illustrate that they were identified, considered and were left to be addressed (potential identification of action) by the Part 12D consultant and or the owner.

9. The report should include an assessment of the overall adequacy, completeness and relevance of background data that was furnished for the Potential Failure Mode Analysis, identify any discrepancies, inaccuracies, or deficiencies in the records, and determine if adequate information was provided to conduct the PFMA. The report should document any potential shortcomings in the PFMA due to lack of sufficient data for consideration of specific potential failure modes.
10. When a PFMA is being conducted not in association with a Part 12D report (for example, in support of a major remediation or maintenance), the report preparation should follow the same time frame or schedule described above. Following Core Team review and coordination of the draft report, the final PFMA report should be submitted within 60 days of the PFMA session. At the next Part 12D inspection, the Independent Consultant should include a review of this supplemental PFMA report in Section 3.0 of the Part 12D Report (see Appendix H).

Appendix G provides the PFMA process in a task by task table format for dam owners as a supplement to the above discussion format for their convenience if desired.

14.3.5 Use of the Potential Failure Mode Analysis report as a support document to the conduct of the FERC Part 12D Dam Safety Inspection

Appropriate sections of the Part 12D report should provide commentary and/or information that relates to and addresses the potential failure modes identified in the PFMA. Appendix H includes the Part 12D Report outline and provides guidance on what is to be included in each section. The manner in which that is intended to be accomplished is outlined in general terms below:

Field Inspection – The Part 12, Subpart D Independent Consultant should make observations of project features independent of the PFMA. It is important that the consultant keeps an open mind during the Part 12D Dam Safety inspection and be alert for any unusual conditions that may not have been identified in the PFMA. The purpose of the Part 12D inspection is not to only inspect for those conditions that may develop as described in the PFMA but to document the actual condition of the project structures.

1. Part 12D Inspection Report – The inspection report includes the following with respect to Potential Failure Modes:
    a. Findings and Recommendations – A brief summary of the Independent Consultant's findings during the inspection and the recommended actions that could be taken with regard to information inquiry, investigations, analyses, or structural or non-structural actions in terms of the identified potential failure modes. Recommendations may pertain to changes in operations or maintenance required in order to maintain the status quo as well as recommendations to improve project safety.

b. Discussion of the Potential Failure Modes Analysis Report - The Independent Consultant's commentary on the Potential Failure Modes identified in the Potential Failure Mode Analysis report. This section of the Part 12D report is provided to allow the Independent Consultant the discretion to increase emphasis on or to de-emphasize any of the "team findings" presented in the Potential Failure Mode Analysis report. It also allows for incorporation of any new information, results of analyses, or other findings that come to light during the Independent Consultant's inspection and report.

c. Surveillance and Monitoring Plan - Each potential failure mode identified shall be reviewed to determine whether visual surveillance or instrument monitoring is adequate to detect the onset of the potential failure mode or the onset of conditions which may contribute to or "allow" development of the potential failure mode. Any relevant comments relating historic and current performance indicators to identified potential failure modes are provided. The Independent Consultant should address whether the instrumentation at the dam is functioning properly.

d. Field Inspection - A discussion of the field observations relative to each of the identified potential failure modes as well as the Independent Consultant's own assessment on the significance of the identified potential failure modes and on whether any other potential failure modes exist, or conditions may have changed that would impact previous conclusions regarding potential failure modes.

e. Operation and Maintenance Program – A discussion of the Independent Consultant's observations of the Licensee's O&M program relative to identified Potential Failure Modes.

14.3.6 Updating the Potential Failure Mode Analysis

The comprehensive "initial" Potential Failure Mode Analysis and the resulting section in the STI appended to the Part12D report described above is intended to be performed only once for each project (or at extended intervals (e.g. - 15-20 years), but it should be regarded as a living document to be appended as conditions at the site change or as new information is obtained at any time following the initial PFMA or discovered during subsequent Part 12, Subpart D inspections.

If the initial Potential Failure Modes Analysis is successfully performed, then that report will serve as a key document and foundation for the Independent Consultant inspection in subsequent Part 12D inspections. (Availability of this document should make the Independent Consultant's work easier, more focused and effective and less costly) If as a result of the detailed inspection, the Independent Consultant finds new or varying information or has a professional opinion that necessitates revision of the findings of the original PFMA, the Independent Consultant would provide the licensee with a fully developed PFMA description as a supplement to the PFMA report. The licensee would then provide copies to all holders of the STI document with a request to append the supplement to the PFMA report as discussed in Appendix I. The licensee's cover letter transmitting the revision to the PFMA report should discuss the reason for the revision including who developed the supplemental PFMA and its potential impact on Project safety. That "updated" PFMA would then be the foundation for the next Part 12D Independent Consultant inspection report 5 years later.

It is also possible that new information would come to light in the interim between the Part 12D inspections. In this case, the owner and FERC would prepare a supplemental PFMA description and provide it to the Licensee for distribution to the STI holders as described above. In this way, the Potential Failure Mode Analysis report as maintained in Section 1 of the STI is a living document that will document the progression and variety of analyses and professional opinions that went into the current updated / appended PFMA report findings.

It is important to retain the original PFMA report as prepared so that the findings, discussions and thought processes of the original Potential Failure Mode Analysis session are retained for future evaluations.

14.3.7 Conduct of a "Supplementary" Potential Failure Mode Analysis

A supplementary Potential Failure Mode Analysis should be conducted for projects that fall under Part 12 Subpart D of the Commission's regulations when major modifications are to be constructed. The "Supplementary" PFMA is conducted using the same procedures outlined above for the "Initial" Potential Failure Mode Analysis. Supporting documentation is needed for the proposed modification. The design for the proposed modification should be at least to the 50% level to enable the PFMA team to critically evaluate the modification for potential failure modes and to determine if construction of the recommended alternative may adversely impact other structures, resulting in new failure modes not considered in the "Initial" PFMA. Conceptual designs would not be adequate for this evaluation as they may undergo significant modifications during the design process, which might trigger the requirement for additional PFMAs.

At a minimum, the supplementary PFMA session should include a Core Team similar to that described above for an initial PFMA. If a Board of Consultants has been convened for the project, the PFMA may be held as part of a Board meeting to obtain the insights and thoughts of the Board.

14.4 SURVEILLANCE AND MONITORING PLAN

Monitoring the performance of the dam / project to assure that possible dam failures are avoided or adequate warning time of potential or impending failures is an essential part of a dam safety program.

These guidelines:

- Provide a discussion of the various performance monitoring principles and methods used to aid in evaluation of a structure; and
- Present performance monitoring procedures and principles for a number of common adverse responses or conditions that typically are indicators or contributors to potential failure modes. These basic principles and procedures provide general guidance that is then made specific for an individual dam for the potential failure modes identified as part of the PFMA process.

As part of the Part 12D report the Independent Consultant shall assess, or develop if a SMP does not already exist, the Surveillance and Monitoring Plan for the dam / project. The SMP must include each Category I Potential Failure Mode, unless the Category I Potential Failure Mode is recommended to be addressed through dam safety modifications. The Plan should show details of the types of instrumentation required, their locations and frequency of measurements, and action limits for each instrument. The SMP must also include each Category II Potential Failure Mode unless the Independent Consultant discusses the reasons that he/she considers a specific SMP to be not warranted for any such potential failure mode. The IC may recommend monitoring of the Category III failure modes as part of the SMP in-lieu of further studies if in his judgment studies to further define the failure mode are unnecessary. In addition, any requirements for "General Health Monitoring" independent of an identified potential failure mode should be identified. Chapter IX of the Engineering Guidelines provides guidance on the level of instrumentation necessary for monitoring the general health of a dam. Recommendations made by the consultant with respect to the SMP are actionable items, similar to the other recommendations contained within the Part 12D report, and should be included in the final recommendations section of the Part 12D report.

The adverse responses and conditions and the companion monitoring procedures and principles described in this guideline should not be considered as complete, as each dam will have its own characteristics. ALL combinations of failure, and particularly operating conditions that may present more complex potential failure modes and failure scenarios, must be developed and the appropriate means for monitoring these unique or complex modes established.

14.4.1 Principles and Methods of Performance Monitoring

This section describes fundamental principles and methods used to aid in the evaluation of the performance of a dam. Performance is assessed through evaluation of observations and instrument data relative to the expected observations and data based on design assumptions and the findings from the PFMA.

1. Visual observation

Visual observation is an important surveillance activity. Many dams were constructed without the benefit of instrumentation and thus visual observation offers a first impression/opportunity to evaluate integrity, movement and loads. Visual observation at regular intervals by trained personnel will often detect unusual conditions, such as increased seepage, cloudy seepage, or movements and is the dam owner's primary defense against serious problems. However, visual observations are judgmental rather than quantifiable. Instrumentation may be needed to provide information to enhance our ability to analyze the condition of the structures.

Inspections/observations of remote projects which may not be accessible in winter conditions and may be covered by snow and ice must be specially programmed. The Surveillance and Monitoring Plan must be developed with consideration of such winter conditions and persons performing inspections / observations must be specially briefed on the requirements. The necessity for winter inspections/observations should consider the criticality of a particular potential failure mode.

2. Instrumentation systems

The types of instruments used for investigating a certain behavior are generally outlined in Chapter IX of the Engineering Guidelines. Each instrument should be reviewed for its location/depth, suitability to provide the desired information and confidence that the instrument is providing valid readings. The overall number and types of instrumentation should be reviewed to determine if they are sufficient to assess the total structure. The critical sections of the structure should be defined and the location of instruments relative to the critical section reviewed. The frequency/regularity of reading and timing of readings should be reviewed. The occurrence of taking the reading should be logically related to the date, corresponding reservoir levels, climatic conditions (i.e., rain, winter) and operations (i.e., lag times of drawdown) as appropriate.

The personnel taking the readings should be queried for the procedures used to acquire the readings and their awareness of certain threshold/action levels. The procedure for processing the raw data should be reviewed for correctness and timeliness. If data are not being processed and evaluated in a timely and correct manner, personnel involved in the instrumentation and monitoring program should be reminded, and further trained if necessary, in the importance of each phase of the program and the potential impacts with respect to dam safety. The type of presentation graphs should be reviewed for the data included and the use of proper scales and format to improve the ability to interpret data (refer to Chapter IX). Often great clutter is apparent because graphs are presented monochromatically using only minute symbols to differentiate the lines. Project plan drawings should be prepared that clearly show the locations of all instruments at the development site should. Sections through the structure should be prepared to show information such as the sensing zone of piezometers. Details of the instrument installation should also be available.

3. Comparison of instrument readings to predicted and required action levels

Threshold and Action limits should be developed and the criteria used to develop them should be documented. A Threshold value is the value used in the analysis or design, or is established from the historic record. An Action Level is the instrument reading that triggers increased surveillance or an emergency action. Threshold and Action limits should be established based on the specific circumstances. In some cases, they can be based on theoretical or analytical studies (e.g. uplift pressure readings above which stability guidelines are no longer met). In other cases, they may need to be developed based on measured behavior (e.g. seepage from an embankment dam). Sometimes they may be used to identify unusual readings, readings outside the limits of the instrument's historic range, or readings which, in the judgment of the responsible engineer, demand evaluation. Both magnitude and rate of change limits may need to be established. If trends or inter-relationships between data are not clear, it may be appropriate to take more frequent measurements or collect additional complementary data.

All data should be compared with design assumptions. For example, measured phreatic levels and uplift pressures should be compared against those used in stability analyses. If data are available for unusual load cases, such as rapid drawdown and floods, they should be compared with assumed pressures.

More than one phreatic surface may exist where there are impervious strata in the foundation or embankment. Piezometric data should be evaluated with geologic and construction data to identify multiple phreatic surfaces. If the phreatic surface for any strata is above the ground surface, the stability of the dam should be evaluated using the elevated phreatic surface.

All data will follow trends, such as decreasing or increasing with time or depth, seasonal fluctuation, direct variation with reservoir or tailwater level, direct variation with temperature, or a combination of such trends. The trends are usually evident in the plotted data. Statistical analysis of data may be useful in evaluating trends that are obscured by scatter. However, such analyses are no substitute for judgment based on experience and common sense. Data inconsistent with established trends should be investigated. Readings deviating from established trends should be verified by more frequent readings. Erroneous readings should be so noted on the original data sheets and should be removed from summary tables and plots.

If no unusual behavior or evidence of problems is detected, the data should be filed for future reference. If data deviates from expected behavior or design assumptions, action should be taken. The action to be taken depends on the nature of the problem, and should be determined on a case-by-case basis. Possible actions include:

- performing detailed visual inspection;
- repeating measurements to confirm behavior;
- verify that instruments and reading devices are working properly;
- reevaluating stability using new data;
- changing frequency of measurements;

- installing additional instrumentation;
- special investigations;
- designing and constructing remedial measures;
- operating the reservoir at a lower level; and
- emergency lowering of the reservoir.

Guidance on methods for establishing Threshold and Action parameters is presented for the various types of instrumentation described. The Independent Consultant in consultation with the licensee should establish Threshold and Action parameters.

4. Consider a way to flag instruments that are trending in an adverse manner and what additional focus should be placed on those instruments

Instruments that do not appear to be functioning properly should be further investigated. For example, data should be checked against redundant data to determine whether or not trends and magnitudes are the same. Calibration of the instruments should be checked (this is paramount). Often, tests can be devised to evaluate proper functioning. It is important to plot all the data on record so as to be sure to detect slow trending data.

5. Additions/deletions/duration (how long an instrument should be read)

Instrumentation, in addition to the minimum recommended, should be required wherever there is a concern regarding a condition that may affect dam safety or other critical water retaining structures. Typical reasons to require additional instrumentation are: to check design assumptions; to provide data to evaluate specific problems such as continuing movement, excessive cracking, or increased seepage; to provide data to support design of remedial modifications; and to provide data to evaluate effectiveness of remedial work. Note that continually progressive conditions may require immediate action rather than belated installation of extra instruments.

Instruments should be reviewed for their life expectancy. Readings from advanced age instruments should also be evaluated with respect to whether the instrument readings can be trusted. A failed instrument should be removed to avoid obtaining erroneous data later.

6. Redundancy

There is no such thing as a redundant instrument. All instruments should have real value, if not they should be eliminated. The only redundancy would be to use different instruments to measure the same feature.

7. Summary

Instrumentation and visual surveillance provide the means for helping to develop the understanding or verify the performance of a dam.

The purpose of instrumentation and monitoring is to help quantify behavior and provide data to evaluate whether the dam is performing as expected and to provide a warning of developing or changing conditions that could endanger the safety of the dam. This information and data are used to maintain and improve dam safety.

If there is a discrepancy between the measured and expected behavior of the dam, it may indicate that the dam is not performing satisfactorily and that failure is developing or occurring or it may be that the data or observations do not adequately represent the behavior of the dam, or that conditions exist that were not accounted for in the expected behavior. In either case it is often useful to perform field investigations and install additional instrumentation to evaluate the behavior. Note again that rational judgment must be used to take action rather than do further investigation. If what is going on is serious enough you could put in more instruments just to see the dam fail or confirm failure of the dam.

14.4.2 Surveillance and Monitoring Procedures and Guidelines

From these guidelines, necessary surveillance and monitoring techniques and devices and threshold parameters to be employed at a specific dam can be developed. The existing surveillance and monitoring systems in place at that specific dam can then be reviewed by the licensee, the Independent Consultant and the FERC Inspector together and supplemental surveillance and monitoring systems agreed upon as appropriate. Additional information on the details of surveillance and monitoring instrumentation is presented in Chapter IX, Instrumentation, of the Engineering Guidelines.

This section has been designed to acquaint you with some of the adverse responses of dams and the associated surveillance and monitoring systems and suggested methods to develop threshold parameters. Many dams will share the commonality of a potential failure mode but the SMP must be customized for each structure. Some of the types of dams are:

- Concrete Arch Dams (including multiple arches)
- Concrete Gravity Dams (including cyclopean and RCC)
- Masonry Dams
- Earthfill Dams (homogenous dams, zoned dams, asphalt core or faced dams, and concrete or membrane faced dams.)
- Rockfill Dams (earth core dams, asphalt core or faced dams, and concrete or membrane faced dams.)
- Concrete Slab and Buttress Dams
- Timber Crib Dams
- Rubber Dams

Some typical adverse responses and conditions related to potential failure modes and scenarios are:

- Abutment and/or Foundation Movement
- Abutment and/or Foundation Seepage
- Structure Movements and Stresses

- Overtopping of Dam and Washout of Abutments or Foundations
- Deterioration of Concrete
- Operations Procedures
- Equipment (e.g. gates) testing and/or maintenance

1. **Surveillance** and **Monitoring Guidelines for Abutment or Foundation Movement**

   a. Visual Observation

   The first line of defense for monitoring almost all potential failure modes is visual observation. While visual observation of gross movement of a dam or foundation would indicate that a very serious condition is occurring or developing, more subtle indications of movement can be observed. Cracking, new areas of leakage through the dam or foundation, and displaced foundation material, are all visual clues of possible movement. Visual observation is beneficial in that it may readily identify changed conditions and it has the advantage of complete coverage (as opposed to instruments that only monitor point locations). For concrete dams, pins can be established at the crest or in galleries along contraction joints to determine whether differential movement is indicated or has taken place. These pins can readily be observed during routine site visitations and after significant loading events as well as during regular inspections rather than depending only on annual surveys for an indication of movement.

   b. Precise Movement Surveys – Horizontal and Vertical

   Precision surveys of permanent monuments on the dam and adjacent foundation is a periodic monitoring requirement. Typically, movement monuments are placed at several points along the crest of the dam where they are line-of-site visible from benchmarks established some distance away from the dam abutments. Monuments may need to be located at foundation contact locations where abutment instability is a potential failure mode. Periodic measurements of the location of such monuments provide data for detecting movements of the dam or adjacent foundation. To avoid seasonal influences on the readings, it is helpful to take the readings at the same time each year.

   c. Movement Monitoring Devices (Inclinometers, Deformeters, Tiltmeters, Pendulums, Extensometers, optical surveys)

   Devices for more frequent monitoring of small movements of structures and foundations include inclinometers (generally used to define planes of movement in soil), extensometers (measure change in distance between two fixed points), tiltmeters (measures vertical or horizontal angular changes) and embedded cross-arm settlement devices for internal embankment movement. These devices are used to take frequent readings, generally quarterly, monthly or weekly, to obtain information on specific small movements, generally related to ongoing investigations or to establish movement history with regard to changing reservoir or foundation water levels, changes in temperature, or in regard to special concerns triggered by other observations.

d. Establishing Threshold and Action Parameters for Movements

Once a series of movements over some period of time has been developed, and confirmed by stress analysis as being appropriate, threshold and action parameters can be established that would require further investigation or action. Before initiating action however, measurements falling outside of a threshold parameter should be carefully checked and confirmed.

Other threshold parameters can be defined relative to assumed parameters used in the stability analyses.

2. Surveillance and Monitoring Guidelines for Dam Structure, Abutment and Foundation Seepage

Seepage through a dam or through the foundations or abutments of dams is a normal condition. However, increases in historically observed amounts of seepage, in the elevation of the phreatic surface in the dam, or abutments, in the uplift/seepage pressures beneath the dam or the appearance of transported material in the seeping water may be symptoms of a developing potential seepage related problems. The appearance of transported material in the seeping water of an embankment or soil foundation may indicate piping or seepage erosion which could lead to a failure.

a. Visual Observation and Leakage Weirs

The visual observation of new seepage or an increase in volume of seepage requires action be taken to quantify the problem and to watch for the presence of material being transported in the seepage. For example, if a rapid increase in the seepage rate is observed, it may be a strong indication of a developing failure situation and emergency action must be taken. Visual observations of depressions or sinkholes in an embankment or upstream abutments or foundations are strong indications of piping occurrence.

To accurately monitor any seepage, it must be collected and passed through a weir for periodic measurement. A weir is a superior way for monitoring for the possibility of material movement for several reasons. It provides a continuous means for settling and trapping particles that may be piping or eroding as a result of the seepage flow. Episodic material discharge has been observed in several instances, thus a periodic check of seepage flow for material may not reveal whether the seep is actually moving material. Weirs also allow the material collected over a period of time to be measured and weighed. If weirs are used in an area where fines may be blown or eroded into the weir, a cover is necessary. Also the weir should be routinely cleaned after each periodic measurement so the amount of new material between collections can be accurately assessed.

Flumes allow for accurate measurement of seepage rate but do not provide a means for collecting material. Regardless of the method used to measure the seepage rate (weir, flume or bucket and stop watch), a sample of the seepage water should be collected and allowed to settle out, at least overnight, to check for the presence of any suspended material (fines) being transported (piping or seepage erosion). Drainage pipes within a downstream embankment provide a convenient method for collecting and measuring seepage. Care must be taken that such pipes are properly filtered to prevent piping and if not it is even more important that the flow from the drain pipe(s) be routed through a weir to allow capture of any material being moved.

When new wet areas are observed on the downstream face of an earthfill dam, a determination needs to be made as to whether this water is emanating from a perched, more pervious zone in the embankment lying above a less pervious layer, or is indicative of a high phreatic surface. Wet areas and points of seepage exit should be marked on the dam face by large stakes so that any change with time / season can readily be assessed. Monitoring of vegetation (big roots can initiate piping) and rodent holes is critical. The determination of the nature of such seepage can usually only be confirmed by the installation of piezometers. The flow rate of such seeps should be monitored by weirs and checks made on transported material in the flow.

Although increases in seepage are generally considered to be more of an indicator of a potential problem, decreases in seepage (particularly in a concrete dam foundation but also within embankment dam foundations or drainage elements) may indicate that flow paths / drains are being blocked within or near their exit from the dam or foundation resulting in an increase in pressures. Thus when seepage decreases occur, checks should be made on piezometer or uplift gauges (if this instrumentation is present) and on the cleanliness of the drain elements.

The onset of significant increases in seepage may correlate with reservoir elevation reaching particular levels or recent heavy rainfall and this possibility should be reviewed at sites with significant seepage.

b. Piezometers and Observation Wells

A great benefit to understanding the potential for failure mode development related to seepage from a dam /foundation system is to develop an understanding of the relative pore pressures and direction of flow within and through the dam. If the pressures in the foundation (below the core of an embankment dam) exceed those in the dam then the direction of flow indicated is from the foundation into the dam and the possibility of piping of material from the dam to the foundation is remote. Conversely if the direction of flow indicated is from the dam base into the foundation then the physical possibility of piping from the dam through the foundation is indicated. The best way to determine this flow regime is to review the piezometric, observation well and seepage data.

Whenever there is concern for stability that may be sensitive to the phreatic surface or seepage forces in the abutment, foundation or embankment (such as in a rockfill dam with a wide central core), periodic measurement of water levels must be made. The measurement of seepage forces in abutments and foundations and particularly in a dam embankment is usually made by piezometers sealed to determine the water pressure in specific strata or zones. The phreatic surface in the abutments or foundation can be measured by observation wells, usually open tube pipes with long sensing zones and with only the top of the tube sealed to prevent surface water infiltration. If stratification exists in the abutment, consideration for different piezometers sealed in the various soil horizons should be given.

One of the key and often overlooked steps in interpretation of piezometer and open well instrumentation is failure to correlate the water level with the bottom elevation of the well/piezometer tip. In many cases, they turn out to be the same elevation and the unit is dry.

c. Monitoring for Movement of Material (Piping)

Whenever seepage is observed emanating from / through the dam, foundation or abutments, periodic checks on movement of material should be made. A sample of the seepage water should be collected and allowed to settle out, at least overnight, to check for transported material (piping). Crest settlement surveys are an important source of early warning of piping failures, particularly in earth and rock-fill dams. Specific inspections to look for depressions or sinkholes, particularly in upstream areas, should be made frequently.

Increases in phreatic surface or seepage pressures in the foundation or abutments may also indicate that movement of material is occurring.

Where the foundation materials may be susceptible to solution from water of certain chemical properties, frequent checks on groundwater and reservoir water chemistry and on the chemical composition of seepage water should be made. Evidence of solution of foundation materials or strata such as gypsum layers requires prompt intervention.

d. Establishing Threshold Parameters for Seepage

Seepage through a concrete dam is usually monitored by observation and mapping (see Visual Observation). If seepage appears to be spreading or increasing in volume, then an investigation and action to reduce the seepage may be necessary. It is generally difficult to accurately determine the effects of through seepage on concrete dams.

Seepage through an embankment dam is usually monitored by observation, timed flows discharging from drainage pipes and weirs or other flow measurement devices. If seepage flow is increasing, then an investigation and evaluation of the situation is necessary to determine if remedial action is required. Once a history of variation in seepage flow has been established with respect to season and reservoir level, then corresponding threshold parameter levels can be established that will trigger the need for further investigation and remedial action.

The location of the phreatic surface in the embankment or the seepage pressures at specific strata can be determined by piezometers. Seepage through the abutments or foundation is similarly monitored. A steadily rising phreatic surface or increasing seepage forces should trigger a prompt review and, if necessary, remedial action.

Periodically, the measured phreatic surface or seepage pressures must be reviewed against those surfaces or pressures that were used for the most recent stability analyses. If the actual phreatic surfaces or seepage pressures exceed those used in the stability analyses, then a special engineering review must be initiated and remedial action may be required.

Seepage through abutments or foundation however can usually be collected and measured by weirs or other flow measurement devices. Once a history of variation in seepage flow has been established with respect to season and reservoir level, then threshold parameter data related to seasons and reservoir levels can be established that will trigger further investigation and remedial action.

3. Surveillance and Monitoring Guidelines for Structure Movements and Stresses – Static and Seismic Loading

When possible distress of the dam structure itself is suspected as a result of observation of cracking, new leakage, movement monument measurements, or updated stress analyses, more detailed measurements of dam structural performance are required. Slab and buttress dam designs have typically been designed for in plane loading only. They are often inadequately reinforced and are incapable of resisting cross canyon earthquake accelerations.

It is difficult to determine stresses directly on an existing dam unless stress or strain meters or load cells were installed during the initial construction. Therefore, most performance monitoring is aimed at determining strains under varied loadings to calibrate stress analyses.

a. Precise movement surveys (surface) – horizontal and vertical.

Additional surface monuments can be quickly installed and more frequent measurements made to obtain additional data.

b. Plumb lines

Plumb-lines are very difficult to install on existing concrete structures. They also require vertical alignment that cannot be achieved in double-curvature arch dams unless galleries have been specifically placed to accommodate installation.

c. Tilt meters

Measurements by tilt-meter are also useful. Tiltmeters can be installed on existing concrete structures and readings can be obtained quickly after installation. Tiltmeters are sometimes used instead of plumb-lines because they are easier to install and require little maintenance. Tilt Meters can be used to calibrate FEM models and to back calculate foundation moduli if the reservoir can be raised or lowered a significant amount.

d. Load cells

For direct measurement of loads in the dam, load cells must be installed during construction. While they can provide meaningful data, if they are not in the area of highest stress, they have limited usefulness. If post-tensioned anchors are used to improve stability, either in part of the dam (such as abutment blocks) or in the foundation, some anchors should have load cells installed to monitor their loss of tension so that retensioning can be performed as necessary.

e. Strain Gages

Stain gages can provide valuable direct stress data if installed during construction. However, they are subject to the same limitations as load cells.

f. Seismographs

Seismographs provide a valuable research tool when they are mounted on dams and triggered by significant earthquakes. They can provide response data for improving seismic stress models of the structure or for deformation models of an embankment. However, they are not useful for monitoring performance of dams but can confirm the response of the dam to an earthquake, e.g. crest amplification of shaking.

g. Additional piezometers can be installed and more frequent measurement made to obtain additional data.

4. Surveillance and Monitoring Guidelines for Erosion of Abutments or Foundations

Surveillance and monitoring of embankment dams relative to washout is pertinent only with respect to ensuring the condition and levelness of the crest. Low spots, rutting or "built in" unevenness in the crest can exacerbate the potential for overtopping failure of an embankment dam. Spillway capacity must be adequate to prevent this potential failure mode. In the case of embankment dams, the rule is to prevent overtopping, because it can lead to catastrophic failure.

a. Observation and Measurement of Deterioration of Abutments, Foundations, and/or Spillway Outfall/Energy Dissipater Areas

In order to monitor the deterioration of dam abutments, foundations, and/or spillway outfall/energy dissipater areas to assess the potential for washout failure, it is necessary to have data on the potential for flow over the abutments, including volume and frequency relationships, and specific data on large flows that would impact the foundation.

The foundation, abutments, and spillway outfall areas should be surveyed and a profile of the foundation impact area of overflows, abutments and/or spillway outfall/energy dissipater areas made. Because survey markers in such situations will probably be lost in flow situations, the survey should be at precise station points along the abutments within the flow zone and on the downstream foundation offset from the crest of the dam. Such surveys should be repeated after major flows have occurred and the changes in the profile plotted and reviewed and the erosion potential quantitatively estimated. Utilizing the flow volume and frequency relationships, an assessment of potential failure due to washout can then be made.

b. Periodic Assessment of Geologic Conditions and Deterioration

In addition to the survey and assessment above, close geologic inspection of the foundation, abutments and/or spillway outfall/energy dissipater areas should be made including mapping of joints that could permit loss of foundation or abutment rock material. Such inspections should be repeated after major flows and the potential for washout failure made.

5. Surveillance and Monitoring Guidelines for Leakage through Dam Joints or Cracks, Along Penetrations, Conduits and Structures

a. Periodic Visual Mapping of Leaks/Wet Areas on Downstream Dam Face

Using a downstream profile map of the dam, showing any visible vertical joints and horizontal joint or lift lines, make a periodic map of all cracks, leakage locations and seepage areas. The mapping should be supplemented by detailed photographs. If there are significant leakage locations or areas, such maps and photographs should be made at least semi-annually, at coolest and warmest times of the year, and regularly compared. Particular care must be taken to note areas of increasing leakage flow or extension of cracks.

b. Measurement of Seepage Quantity by Weirs, Flow Meters or Other Devices

Where it is difficult to determine if the quantity of dam seepage is increasing, various devices are available to measure flow. Unfortunately, they may be physically difficult to install on the vertical or overhanging face of an arch dam. They would generally only be utilized in cases of significant concern.

6. Surveillance and Monitoring Guidelines for Deterioration of Concrete

Concrete in dams sometimes deteriorates. Usually such deterioration is due to poor quality concrete having been used for construction. On older dams, alkali aggregate reaction is not uncommon. For dams at high elevations and in northern areas, freeze-thaw deterioration is a concern.

Concrete deterioration is more critical in Ambersen slab and buttress type dams where design stresses in the water retaining slabs and reinforced concrete beams are about 50% of the ultimate capacity utilized under normal loading. Concrete deterioration not only reduces the cross-section properties but also exposes the reinforcing allowing it to corrode and reduce cross-section.

a. Periodic Visual Inspection and Mapping of Deteriorated Areas.

Make a periodic map of all areas of deterioration whether caused by freeze thaw, alkali-aggregate reaction, or other mechanisms. The map should show any visible vertical joints, horizontal joints, lift lines, any loss of masonry elements or mortar from the joints. The mapping should be supplemented by detailed photographs. If there are significant deteriorated locations or areas, such maps and photographs should be made at least semi-annually.

b. Periodic Measurement of Deteriorated Areas

Measurements should be periodically made to assess the changes in the structure. In the case of alkali-aggregate reaction, periodic surveys of dam crest elevation should be made to ascertain the amount of swelling of the concrete. Also, cores of the expanded concrete should be taken at intervals and tested for compression and tension (if subject to tensile stresses.) The strength data obtained from the tests should be compared with the results of a stress analysis, to determine the adequacy of the structure.

In the case of freeze thaw or other deterioration mechanisms, the depth of deterioration should be periodically determined. If the area is quite localized, the depth can be determined by probing and measurements from the surface of unaffected areas. One technique is to install reference markers set in the deeper undisturbed concrete and periodically measure the distance from the end of the marker to the sound concrete.

7. Operations Procedures Common to all Dams

Mis-operation of a dam, either through equipment malfunction or human error, is often a viable potential failure mode. This section identifies some adverse conditions and associated defensive measures.

a. Human error

This includes all the site specific scenarios of mis-operation or failure to act. For example, if gate operation is required to pass a flood, but nobody raises the gates, the dam could fail.

Defensive measures could include additional specific training of personnel and emergency procedures exercises that are tailored to specific identified potential failure modes.

b. Equipment malfunction

Power failure - Anytime electrical equipment such as gate hoists, sensors, communications, etc. is required for the safe operation of the dam, power failure can lead to a dam failure.

Defensive measures could include having standby power available at the site, and having manual overrides on critical equipment

Sensor/Telemetry malfunction - If the site is remotely operated, a sensor error or telemetry failure can lead to mis-operation or failure to operate.

Defensive measures may include performing regular telemetry testing, having redundant sensors for critical instrumentation, and having redundant communication systems.

c. Access failure

If personnel must be dispatched to a site to operate it in an emergency, they have to be able to get there. Large flood events are typically accompanied by severe weather that may make roads impassible and helicopter travel impossible.

Defensive measures may include having identified alternative routes to access the site or stationing personnel at the site prior to failure of access roads.

14.5 INSPECTION PROCESS AND COORDINATION

14.5.1 Scope and Purpose

To define the roles, responsibilities and coordination of the Licensee, Independent Consultant and FERC and to develop a process flowchart which links together all of the inspection, analysis, evaluation and emergency action planning elements of the FERC's dam safety program using a potential failure mode analysis approach.

14.5.2 Description and Interrelationship of Dam Safety Program Elements Using a Potential Failure Mode Analysis Approach

1. <u>Periodic routine inspections / observations</u> – These inspections are typically performed by the licensee or a consultant retained by the licensee. People performing the routine inspections or observations should be provided with background information on the potential failure modes identified for the site along with a surveillance and monitoring plan for each potential failure mode. The licensee is responsible for performing these inspections and for coordinating with the FERC resolution of any issues discovered during the inspections. After a discussion with FERC, a decision will be made whether any action such as analysis, repairs or monitoring needs to be implemented.

2. <u>Licensee operation and maintenance inspection and training programs</u> - Those persons performing the inspections or observations should be provided with background information on the potential failure modes identified for the site along with the surveillance and monitoring plan for each potential failure mode. The licensee is responsible for ensuring that its personnel are properly trained and remain current in the knowledge of proper operation and maintenance of the project. The FERC inspector and Independent Consultant should review these programs during their inspections to assure they meet the needs of the Surveillance and Monitoring Plan.

3. <u>FERC operation inspection</u> - FERC will schedule with the licensee in advance and perform this inspection. After the inspection FERC will discuss with Licensee any concerns found during the inspection. The discussion will also include various items relating to the project, such as the operation and maintenance of the project, any instrumentation and monitoring currently at the project and the emergency action plan that is in place at the project site.

   If during the FERC operation inspection a new potential failure mode is identified, the FERC will provide this information to the licensee in the Operation Inspection follow-up letter. If the potential failure mode needs to be evaluated prior to the next Part 12D inspection, a schedule will be established to accomplish this. If it is determined that evaluation of the potential failure mode may be delayed until the next Part 12D Inspection, the FERC will include the request in its one year reminder letter to the licensee.

   FERC will document this inspection and provide a copy to the licensee.

4. Joint Part12D and FERC Operation Inspection - Every 5 years a joint inspection will be made by the Independent Consultant and FERC with proper coordination and support of the licensee.

   The FERC Operation Inspection will be done at the same time that the Part 12D Inspection is done.

   The Consultant will be provided the current Potential Failure Mode Analysis (initial plus any updates) and the Surveillance and Monitoring Plan. The Part 12D inspection will begin with a meeting between the necessary licensee representatives, the Independent Consultant, and the FERC inspector to review the project history including any past or current deficiencies, completed remediation, special investigations previously completed, instrumentation, etc. The group will discuss the development of the potential failure modes and the surveillance and monitoring plan.

   The FERC's operation inspection and the consultant's Part 12D inspection, though conducted concurrently, will be documented independently. It is intended that the inspections allow opportunities for discussions of any problem areas and other important items that might come up.

   Upon completion of the inspections, the group will meet to discuss any additional thoughts concerning potential failure modes that need to be developed.

   Any newly identified potential failure modes will be described by the Independent Consultant and included in Section 4 of the Part 12D report.

5. FERC Construction and Special Inspections - FERC will be responsible for performing and documentation of these inspections on as needed bases with proper coordination with the Licensee.

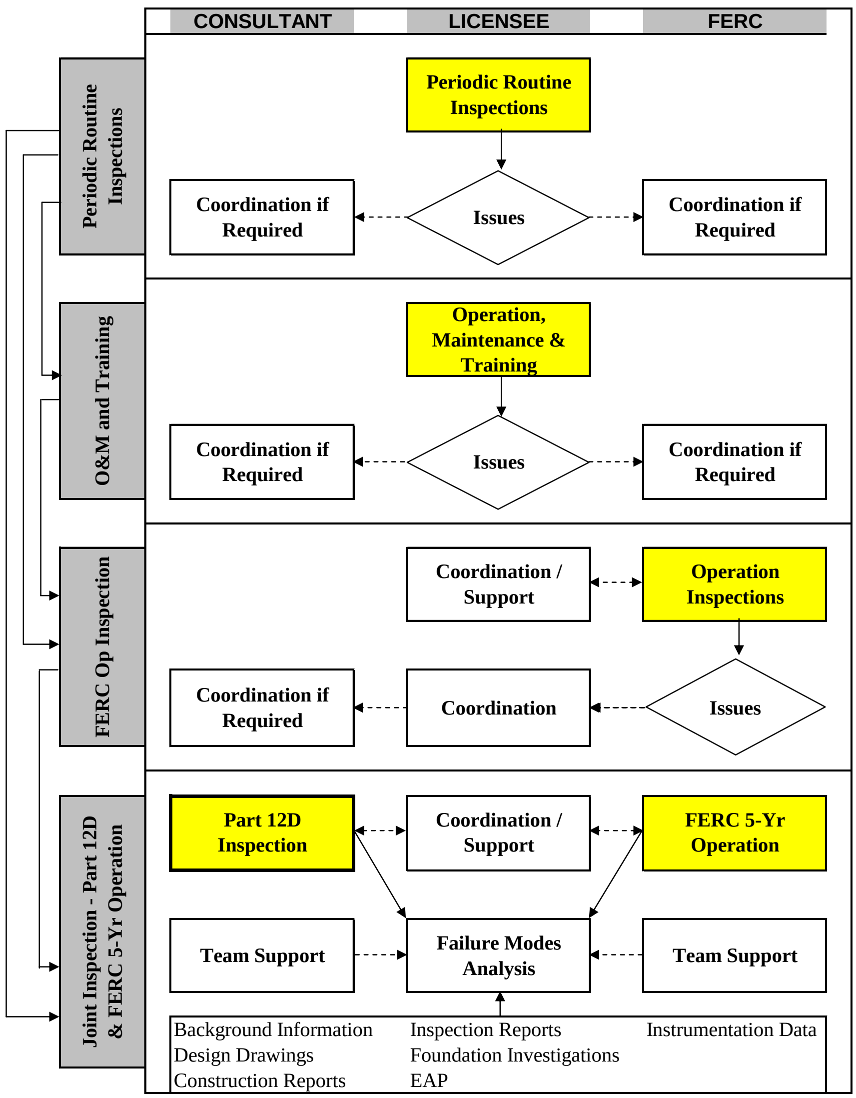
6. Licensee Initiated and FERC Directed Analyses and Evaluations - If during the operation or inspection of the project a concern or issue is raised that requires additional studies it is the responsibility of the party identifying the concern or issue to initiate a discussion with all parties involved. The Independent Consultant and should review/comment on the scope/results of the additional studies. The FERC will also review/comment on the scope and results of the studies. If policies change as to the design guidelines, FERC may direct further analyses and evaluation to determine if a deficiency exists.

7. Recommended Action

Surveillance and Monitoring - If during the operation or inspection of the project a concern or issue is raised that is determined to require surveillance and/or monitoring to determine if the dam's performance is at risk, it will be the responsibility of the Licensee to install, monitor, and evaluate monitoring instrumentation with the coordination of the Independent Consultant and FERC. The Surveillance and Monitoring Plan should be updated when new instrumentation is installed or other changes are made to the existing SMP.

Modification - If during the operation or inspection of the project a concern or issue is raised that is determined to require a dam safety modification, it will be the responsibility of the Licensee to design and make the necessary modifications with the coordination of the Independent Consultant and FERC.

14.5.3 Process flowchart



14.6 EMERGENCY PREPAREDNESS

The Independent Consultant should consider the various potential failure modes determined and review pre-planned procedures for dealing with potential emergencies. If any pre-planned measures need to be put in place, the Independent Consultant will make the necessary recommendations. These measures include necessary equipment, materials, etc.

APPENDICIES

Appendix A
Example Potential Failure Mode Descriptions

Operational Related Potential Failure Mode

The design flood was routed through Dam A by the hydrologic engineering consulting firm using the traditional means and assumptions and the capacities for the facilities provided by the owner. The dam was found to pass a sizeable portion of the probable maximum flood using the Main Spillway gates and the emergency spillways. Thus there was concern for the hydrologic deficiency but not great concern. However, examination at the site for potential failure modes revealed a significant potential for an Overtopping Failure mode due to the following factors:

- The emergency spillway bays were fronted by arch rings designed to be blasted away if the emergency spillway was needed. Discussions with the owner revealed that use of the emergency spillway in such a manner was highly improbable. This was due to the potential liability from such an action (a sizeable town is located just a mile or so downstream) and also due to the physical arrangement of the dynamite ports on the top of the spillway bays (it was likely that these would be underwater by the time a decision to use them was made). Further there were no plans or procedures in place to do the blasting.
- The first location for overtopping of the structure was immediately above the transformer yard. Overflow at this location would have resulted in loss of capability to pass flow through the turbines and while this flow was not relied on in the routing, the early shut off would have exacerbated the overtopping situation.
- Drawings were located for the secondary emergency spillway, which was referred to as a "fuse plug" spillway but this fuse plug actually had to be excavated by a dozer before it was functional. Operators at the site did not know the location of the spillway limits and had no procedures or equipment to initiate this spillway.
- Design crest elevations indicated that the concrete structures would be overtopped prior to the embankment structures. However, examination of survey data, settlement records and settlement projections (along with the physical location of the monuments relative to the crests) revealed that the low point for the project was currently an earthen saddle dam.

Piping Related Potential Failure Mode

The following potential failure mode was highlighted because the specific conditions at Dike 1 and 2 are such that this potential failure mode is physically possible and is one of the most significant potential failure modes definable at this site. Failure of the Dikes poses a high hazard, and diligence in monitoring for development of this potential failure mode is warranted.

Potential Failure Mode 1 - Dikes 1 and 2 - Seepage Erosion and Piping

During site investigation the foundation of these dikes was found to contain joints much more open than anticipated, based on pre-construction investigations. These joints provide a potential path for subsurface erosion of the Zone 1 material leading to an unprotected exit downstream of the dam. Although grouting was performed following construction (during the first filling of the reservoir) and the seepage levels were reduced, the fundamental potential failure mode remains). The presence of 4 to 5 ft^3/s of seepage, which occurred during first filling, from a dike of moderate height and length attests to the possibility of open joints in the foundation capable of carrying adequate flow to result in erosion, and transport of eroded material downstream. The specific potential failure mode paths and the factors relative to the likelihood for the development of this potential failure mode are as follows:

Potential failure mode paths - there are two primary potential paths for seepage erosion/piping to take place through the foundation jointing and two of lesser likelihood. These are:

- Flow through the dike embankment across the Zone 1/ foundation interface. This could result in the Zone 1 materials eroding and being carried through the open joints to an unprotected exit downstream. (Failure would result if backward erosion (piping) through the Zone 1 materials reached the reservoir source. An ever increasing flow potential could then progressively enlarge the flow channel downstream of the point of erosion initiation in the core to an extent large enough to carry continually increasing flows).
- Flow under the foundation attacking the base of the Zone 1 material and removing it by seepage erosion through the foundation jointing

The other two potential flow paths leading to a seepage erosion/piping failure are (1) piping of the Zone 1 through the foundation alluvium and (2) seepage erosion of the foundation alluvium exiting through the open joints in the rock. These are considered to be of significantly lesser likelihood

Part 2 - Example Record of Likely and Not Likely Factors Identified for a Specific Potential Failure Mode

After each potential failure mode is identified and clearly stated and recorded the team brainstorms and discusses what conditions make this potential failure mode more adverse / more likely and what conditions about this potential failure mode are positive making it less likely or less significant. An example of the factors identified for the potential failure mode previously described above is presented below.

Factors increasing the likelihood of this potential failure mode developing include:

- the observation of very open joints in the foundation (greater than 2" wide)
- surface treatment was not provided to exposed bedrock

- grouting procedures used likely resulted in some of the most open joints remaining open due to the presence of the reservoir produced seepage flows during the grouting (this is most likely in the higher head, lower elevation portion of the dikes)
- grouting near the surface was likely not very effective, considering the method used
- large seepage flows are occurring, which can dilute and potentially mask observation of particles being carried by the flows. If an attack begins, large flows can erode large amounts of material relatively quietly.

Factors indicating less likelihood of this potential failure mode developing include:

- There has been no observation of any material being carried by seepage flows at these dikes.
- The Zone 1 appears to be clayey, very impervious, and not easily erodible.
- The placement of the Zone 1 cutoff-wall well upstream of the dike centerline creates a closer source for the reservoir's water, but a large portion of the dike would remain if an erosion path developed at the base of the cutoff.
- The lack of water in the toe drains is a likely indicator that the dikes have not saturated and that the foundation rock behaves as a drain keeping water away from or at low pressures at the dam/foundation contact.
- Seepage flows started downstream of the dikes prior to the water reaching the upstream toe of the dikes. This indicates the pervious nature of the foundation and the likelihood that a large portion of the seepage water passes beneath the dikes (relatively independent of it).

Appendix B
Example Potential Failure Mode Identification Cover Letter and Questionnaire

POTENTIAL FAILURE MODE IDENTIFICATION

__________ Dam will undergo a Potential Failure Mode Analysis (PFMA) as part of the FERC's Part 12D Independent Consultant Safety Inspection. The PFMA process provides for the identification of potential failure modes along with the potential effects and consequences with input from all people with data and information relevant to the design and performance of the dam. Your input is requested. This memo tells you all about how it will work and what your role is.

*** Individual Input to Potential Failure Mode Analysis ***

<u>How is this special effort going to work?</u>
The idea is to produce the potential failure mode analysis efficiently without sacrificing the specific knowledge, information and opinions of people who have worked on the dams in the past or are working on them at present. The information and knowledge you have will be collected in three ways as enumerated below. Please note that the potential failure modes developed as part of this concentrated effort will be based on available data and information. We do not expect you to do any additional studies. However, you may suggest what additional study may be valuable as part of a PFMA for this dam.

<u>How will we get your input?</u>

1. Through a questionnaire completed individually and designed specifically to obtain the information needed to help develop the potential failure mode analysis;
2. Through Core Team review of all work that has been prepared for the dam; and
3. Through a round table discussion with available team members following completion of 1 and 2 above.

The concentrated effort will allow efficiency in preparation and consistency in the product.

Please complete each portion of the attached questionnaire for which you feel you can make a contribution. Feel free to review any relevant portion of your past work on the project to refresh your memory prior to completing the questionnaire. When you have completed the questionnaire send the completed document to ________________________.

Thanks for your help.

POTENTIAL FAILURE MODE QUESTIONNAIRE

for

______________________ Dam

Name ____

Team Members Experience / Role _____________________________________

Phone ________________

Date Due _______

Part 1 - Potential failure modes

"Failure" is considered to be something which causes unsatisfactory performance of the dam (or a portion thereof).

I. What potential failure modes do you think are of specific concern at this project? Please provide a specific description of the potential failure mode, including location of the area of concern.

Potential failure mode 1.

Potential failure mode 2.

Potential failure mode 3.

Part 2 – Surveillance and Monitoring

For each potential failure mode identified in Part 1:

II A. Please describe as specifically as possible what may be observed, monitored or measured to verify that performance is okay relative to the potential failure mode, or that conditions that are conducive to initiation of the potential failure mode have become present or that "activation" of the potential failure mode appears to be taking place. Please suggest how that may be observed or monitored.

II B. Is the monitoring or observation you suggested currently in use at the dam?

III. If you have visited the site either as part of an official inspection or a general site visit, please identify any conditions that are noteworthy from the standpoint of performance of the dam.

Appendix C
A Typical Potential Failure Mode Analysis Session

Step by Step Description of a Typical Work Session

- Identifying Key Technical Back up Information Needed
- Typical Sequence of Brainstorming Activities
- Key information to document during the process

The intent of this appendix is to describe what is done in a typical PFMA session so participants will know what to expect and so that all the right information and data will be on hand and the people needed are there or on call.

Owner / organization prerequisite work: - Gather all background materials for review prior to the session and have available at the session

Required individual advanced preparation activities:

1. Core Team members have read all background materials.
2. All participants have read a general background package (inspection report and / or standards based engineering dam safety report) to become familiar with or to recall the project elements and issues.
3. All participants have completed / considered questionnaire on identification of potential failure modes prior to the workshop.
4. Inspector or instrumentation group has instrumentation and surveillance data updated and ready for review by Core Team prior to meeting and are available to demonstrate reading procedures during the site visit as appropriate.
5. Project leader has references available in meeting room – this includes:
   - all engineering reports and key feature drawings (large scale);
   - construction photos and construction / design history data;
   - flood frequency data and routings and earthquake loading data;
   - data on consequences and emergency preparedness; and
   - inspection reports and instrumentation and surveillance data.

Begin Session

I. Adequacy of Project Documentation - Discuss adequacy of documentation provided for the exercise and determine if any deficiencies exist for specific potential failure modes. Determine if sufficient information exists to adequately perform the Potential Failure Modes Analysis for the project. Document your findings regarding adequacy or deficiencies in project documentation.

II. Potential Failure Mode Identification

A. Go loading by loading and feature by feature.

B. Have drawings or sketches of features.

C. Typically start with flood loading since it is the easiest for all to understand and sets out the reservoir loading conditions.

Flood loading:

- Go over all the key data; size and frequency of floods analyzed, routing data.
- Show crest elevations of key features and amount of overtopping / freeboard for each flood routed. Discuss slope protection, crest condition, discharge locations.
- Examine potential effects / potential failure modes / adverse conditions for dam structures and spillways / outlets. *Note: go over each structure to see if any potential failure mode is evident.*
- Candidate (suggested) potential failure modes are called for and means / steps to failure are discussed. A decision is made whether or not to further consider the candidate potential failure mode.
- If a suggested potential failure mode is considered, the potential failure mode is clearly described. Then, the reasons why the candidate potential failure mode is more or less likely to develop (adverse and positive factors) are listed on a flip chart and/or a computer based table. Based on this discussion, the team classifies the potential failure mode (Category I, highlighted; Category II, considered but not highlighted; etc.).
- Breach formation character and rate of failure are discussed. Consequences of a flood related failure and of operational spillway discharges are discussed.
- Failure scenarios (exposure conditions and warning aspects; detection, decision to warn, dissemination of warning, evacuation, etc) are discussed. The anticipated response is reviewed with field / site personnel. In reality, this exercise is looking for potential failure modes in the preparedness arena.
- Opportunities to achieve risk reduction, structural or non–structural and ways to improve detection via instrumentation or surveillance are identified and listed.
- Data / information needs are discussed and identified.

Reservoir loading / Static load:

Repeat above process. Key changes or additions or points of emphasis in examining this loading are noted below:

- Discuss annual and historic pattern of reservoir loading.
- Discuss performance history of each feature.
- Discuss any instrumentation clues to potential failure mode.
- Discuss Geologic / foundation rock and soils relationship to structures. Examine for potential failure modes. For concrete dams, discern whether or not a foundation analysis based on adequate engineering geologic studies has been completed.

- Trace (from a projection) on a white board a sketch of the cross section of each structure to be evaluated in turn. Sketch each potential failure mode as suggested to enable brainstorming / developing / understanding. Plans and / or profiles are sometimes needed as well.
- Evaluate failure scenarios for each significant potential failure mode. These scenarios do not have the same warning associated with flood or earthquake loadings.
- A list of the reasons why these potential failure modes are more likely or less likely to occur are discussed and recorded. This discussion is very important in evaluating the significance / category of potential failure modes suggested.
- Based on this discussion the team classifies the potential failure mode (Category I, highlighted; Category II, considered but not highlighted; etc.)

Earthquake loading

Repeat above process. Key changes or additions or points of emphasis in examining this loading are noted below: Note, dynamic loading follows static loading because some of the potential failure modes are similar and the degree to which the additional seismic loading may impact static condition can be examined.

- Go over all key magnitude and frequency data for site (historic and tectonic study data) and site attenuation or amplification data to get sense of the loading likelihood.
- Review any dynamic analyses.
- Examine what it takes for failure to occur; i.e. does damage result in failure.
- Compare structures at site to case histories of earthquake related failure.

Consider any other loading relevant to site:

Ice, avalanche, landslide, etc. – Repeat process used for other loadings

Make final team categorization
Significant Potential Failure Modes (Highlighted) in each loading category and Summarize / Rank.
Potential Failure Modes considered but not highlighted.
Potential Failure Modes considered but lacking key data or information to allow categorization. Identify data needs.
Potential Failure Modes ruled out.

IV. Review possible risk reduction / instrumentation / surveillance opportunities identified for all potential failure modes considered

Place the identified potential risk reduction opportunities into two categories:

1. Possible alternative mitigation actions to investigate, and
2. Actions to be considered by the Independent Consultant for implementation by the owner.

V. Identify and Record Major Findings and Understandings

The major findings and understandings achieved as a result of the session (give team members a few minutes to think about these before listing) along with the description of each potential failure mode considered should be written up and distributed to participants of the PFMA session.

VI. Documentation of PFMA Session

The Major Findings and Understandings achieved during the session and the PFMA report should be documented as discussed in Section 14.3.4 Step 6. The overall schedule for preparation of the MFU and PFMA reports is summarized in Section 14.3.4 Conduct of the Initial Potential Failure Mode Analysis in the main text.

Appendix D
General Format for
Potential Failure Mode Analysis Reports

For further guidance and example see a typical report developed from this outline. An electronic copy of an example report was developed for the training classes and may be obtained from the FERC.

I. Introduction and Background

Purpose / description of study

II. Brief Description of Dam and other Key features of project

III. Major Findings and Understandings from study

IV. Potential Failure Modes Identified

The presentation of potential failure modes should be grouped by category.

I Highlighted

II Considered but not highlighted

III Information needed to allow classification

IV Ruled out / Not physically possible

For each Category I, II, III or IV potential failure mode identified there needs to be:

- A Detailed Description of the Potential Failure Mode and potential adverse consequence (scenario developed by the team [**including a sketch where applicable**] and a discussion of the potential adverse consequences of the formulated scenario.) For some Category IV PFMs there may not be a detailed description if the PFM was ruled out by the Team prior to fully developing the PFM.
- A listing of factors that indicate the PFM is more likely or less likely to occur.
- The PFM category selected by the team for each potential failure mode.
- A description of the rationale used for selecting that category (i.e. – the factors with the greatest weight

The Potential Risk Reduction actions identified during the discussion of each potential failure mode should also be documented in the report. These may include items such as:

- Surveillance and monitoring enhancements
- Risk Reduction measures to evaluate
- Investigations / analyses needed
- Data and information needed to collect / prepare for decisions on prioritization of dam safety actions

- Information needed to resolve Category III PFMs

V. Additional Monitoring or Performance Related Items Discussed

This section should include issue or items that are brought up during the PFMA session that relate to dam safety and performance monitoring or are of general concern but are that do not or would not result in failure of the dam or other water retaining structure at the project. They need to be included in the documentation to illustrate that they were identified, considered and were left to be addressed (potential identification of action) by the Part 12D consultant and or the owner.

VI. Summary and Conclusions

This section should include a review of the number of potential failure modes identified within each category, any study specific comments related to the potential modes of failure, and a summary of potential actions identified in the PFMA with respect to Surveillance and Monitoring.

Appendix to Report

Key supporting data and information and references, Figures, Sketches, Photos made during field review showing key elements of dam and auxiliary features should be included along with any photos that show conditions leading to potential failure modes.

Note 1: The report of the PFMA session, although it will reside and be appended in the STID, should be prepared as a standalone document.

Note 2: Use of tables to present Potential Failure Modes information

Tables may be an effective way to present the information related to each potential failure mode identified. However, it may not be possible to fully describe the potential failure mode in a table format. It is important to remember that the description of the potential failure mode must provide a complete understanding of the intent of the team to reviewers 5 to 25 years in the future. Thus, if tables are to be used then extra care must be taken by complete description in Section IV text to ensure that future reviewers obtain a full understanding of the teams meaning and intent. Tables may be used as a means to summarize or supplement a more complete written description of potential failure modes. A possible table format is provided below.

PFM Description	Adverse Factors	Positive Factors	Risk Reduction Actions	Cat

Appendix E
Major Findings and Understandings - Example Write Up

Given below is an example write up of the Major Findings and Understandings gained from a Potential Failure Mode Analysis for a project consisting of a Main Concrete Dam incorporating a Power Station and Two Auxiliary Embankment Dams. Although this was an actual study and presents the actual findings, the names of the dams and the river in the example are not the real names.

- Currently in the event of a very large flood on the Blue River, approaching the PMF, overtopping failure of Auxiliary Dam 1 is the main point of vulnerability at the project. This is because the crest of Auxiliary Dam 1 it is at a lower elevation than is the crest of Auxiliary Dam 2. In the event of Auxiliary Dam 1 failure, peak discharges downstream would nearly triple (from about 1900 m^3/s at failure to 5700 m^3/s at breach) and the consequences of failure of Auxiliary Dam 1 would be high (life loss potential and large economic losses). On the other hand if Auxiliary Dam 2 were to be established at a lower elevation than Auxiliary Dam 1 and thus allowed to fail from overtopping the effects and consequences of overtopping failure would be significantly less. Auxiliary Dam 2 failure peak discharges downstream are estimated to only be slightly larger than flows resulting from the PMF (from about 2100 m^3/s at PMF to 2400 m^3/s at breach). Several measures to achieve overtopping failure risk reduction are identified in the report and the best alternative should be selected after an appropriate risk management evaluation. However, the Potential Failure Mode Analysis team emphatically concluded that it is essential that as long as the potential for overtopping failure of the earthfill dams exists, Auxiliary Dam 2 should be established at a lower elevation than Auxiliary Dam 1.

- Dam failure as a result of piping is a physically possibility at Auxiliary Dam 1 as the result of one or more potential flow paths. Although there is no unequivocal physical evidence that piping has occurred or will occur in the future, the nature and relationship of the materials in the dam and foundation, the water level and piezometric observations, and the performance of the structure (observation of surface seepage and a depression at the toe) allow for this possibility. Further the surveillance and instrumentation have not been extensive enough to rule out the possibility that piping episodes (turbid water or particle transport) have occurred, and even if they had been transport of material could occur subsurface and thus not be amenable to observation. The consequences of a “sunny day” piping failure of Auxiliary Dam 1 would be high with a greater life loss potential due to the possible lack of advance warning. From the standpoint of the Potential Failure Mode Analysis Team, awareness of this potential piping condition is a key finding of the study as this potential failure mode is the most significant structural vulnerability found at the project. Several risk reduction measures, both structural and non-structural were identified and should be considered in the risk management evaluation of the project.

- A potential foundation failure mode identified for the Main Dam was the only PFM of significance identified for this structure. Although, this foundation potential failure mode is considered physically possible it is highly probable that a foundation stability analysis would show that the factor of safety against failure is quite high and thus risk reduction measures would not be required. Thus, the Potential Failure Mode Analysis team considers that analysis rather than consideration of remedial work is the appropriate initial course of action relative to this potential failure mode.
- The Potential Failure Mode Analysis team considered that failure of the Main Dam by overtopping was not a realistic potential failure mode and should not be highlighted. However, the main dam would be the first structure to be overtopped during a major flood condition, well before either of the earthfill dams. This would occur for the PMF but also for floods significantly less than the PMF. It was determined in the Potential Failure Mode Analysis that overtopping of the main dam would result in significant damage to the power facility and that much if not all of this damage is preventable. For example the cable trays are at crest level on the downstream side of the dam and would be destroyed with mild overtopping. Also water flowing over the top of the dam would currently spill directly on the power plant and likely knock that plant out of service and cause considerable damage. This flow could be directed away from the plant area. Thus, main dam overtopping, while not a potential failure mode, would be a significant incident for the Owner and the Potential Failure Mode Analysis team considers that risk reduction measures to reduce the impact of the overtopping of the main dam should be evaluated.

Appendix F
Estimated Time Requirements
(PFMA items only – not subsequent Part 12D activities)

The typical time requirements for the major activities in the set up and completion of an initial PFMA are as follows:

Task 1 - Advance preparation

Facilitator: Consult with and provide information/guidance to owner – ½ day

Owner: Assemble materials, notify participants / send out advance packet of material, setup facility and make arrangements - (The time required for this step can vary widely depending on how well the owner's files are organized. Most owners start this task up to a year in advance of the PFMA session to assure they have adequate time to discover all the pertinent information.)

IC: Preparation – 2-3 days

Task 2 ----Visit site, review materials, carry out PFMA session

Owners Core Team representative: Travel to and visit site with Core Team – review materials and participate in session – 3 days

IC, Facilitator, FERC representative: As above - 3 days each

Task 3 – Documentation of study

IC: Prepare draft of Major Findings and Understandings, distribute for review and comment. Prepare draft of PFMA report distribute for review and comment and finalize - 5 days

Core Team Members: Review and comment on Major Findings and Understandings and PFMA reports - 1 ½ days

Appendix G
Dam Safety Performance Monitoring Program Process

Task	Description	Responsibility
1	**Data Assembly:** Assemble all available background data for the dam and appurtenant works for the project. These data should include investigation, design, and construction reports, construction photos (and all other project photos), construction and as built drawings, geologic reports, construction inspection reports by the owner / designer and those by state and federal agencies for the original construction. Similar data for any project enlargements or modifications for enhanced operation or to improve project safety must also be assembled. Data assembled should also include seismic studies, the most recent flood studies, stability and/or stress analyses, lab test results on rock, soil and concrete, summaries of instrumentation monitoring data and visual inspection reports, periodic dam safety reports including all Part 12D reports, Emergency Action Plans, photographs of key elements and features showing present condition and any remedial work. A summary of key project history by dates including original planning, design and construction as well as all modifications, studies relating to project safety from project inception to the present should be developed.	**Owner with assistance from IC**
2	**Prepare Draft STI Document:** The STI should include sufficient information to understand the design and current engineering analyses for the project The STI should use tables, figures, and drawings in preference to text and should not include complete copies of the original documents except for the "Potential Failure Mode Analysis" study report. Only key paragraphs of the original reports should be included in the text of the STI document for clarity. Licensees should include complete copies of the reference documents referred to in the STI, or, in some instances, all documents reviewed in the PFMA session, in CD or DVD format with the STI document	**Owner with assistance from IC**
3	**Prepare summary informational packet:** Send out a summary informational packet to the Core Team to familiarize them with the project before their site review and to familiarize all other participants before they come to the PFMA session. The summary information packet should included documents describing the dam / project (e.g. the most recent Part 12D Report, FERC operation report, Draft STI).	**Owner with assistance from IC**

4	**<u>Send out Potential Failure Modes Analysis Questionnaire:</u>** Prepare and send a questionnaire to the PFMA session participants (not just the Core Team) requesting their thoughts prior to the PFMA session and to get them all "thinking potential failure modes" and gathering relevant materials and information that may be helpful to the session. A suggested letter format is included in Appendix B.	**Owner**
5	**<u>Determine PFMA Session Participants:</u>** Establish "Core Team" to carry out PFMA - Experienced PFMA Facilitator, Independent Consultant (IC), Owners representative/PFMA Coordinator, FERC Inspector and dam experienced Engineering Geologist where applicable. Also determine who the individuals will be that will support / attend the PFMA, dam engineering geologist, mechanical and electrical specialists (if needed for gate/valve issues), consulting engineering staff, operating staff responsible for surveillance and maintenance of each specific dam, project manager, etc.	**Owner, FERC, IC, Facilitator**
6	**<u>PFMA Field Review:</u>** Physically inspect all aspects of the dam structures and appurtenances (that relate to dam safety). Try to observe / discuss potential circumstances / conditions that could lead to a potential failure (structural or operational). Discuss operations with plant operators / site personnel. The PFMA field inspection is to familiarize the Core Team with the project features and conditions so that they can effectively carry out the PFMA. It is not a substitution for the Part 12D field inspection by the IC, which is to determine the condition of all safety aspects of the dam and power facilities. *(Note: Allow approximately one-half day per dam. May be more depending on the complexity of the project.)*	**Core Team Geologist, Operating Staff, Specialists**
7	**<u>PFMA Data Review:</u>** Review data on the dam. This should be at convenient location considering location of site/data/PFMA. Assemble in a group setting for efficiency in sharing the collected data and to provide a "captive" condition to ensure that the material is reviewed by all the Core Team members. Also being together allows for collaboration on items that may need clarification for the entire core group. The team geologist should ensure that the relevant geologic data is available for Core Team review and the geologist should also review this material personally. *(Note: Allow one day for the review plus evening of site review and evening before PFMA as necessary. Large projects may require additional time. A thorough review is essential to an effective PFMA.)*	**Core Team**

8	**<u>Facilitated Potential Failure Mode Analysis:</u>** Discussion led by Facilitator of candidate potential failure modes (PFMs) for Flood, Earthquake, Normal Operating and other pertinent conditions for each of the structures. Develop (describe events and conditions from initiation to breach or other adverse outcome) each Potential Failure Mode considered realistic and credible by the PFMA team then brainstorm and list all the adverse factors that make the potential failure mode more likely to occur and then all the positive factors that make the potential failure mode less likely to occur. Discuss consequences of each PFM (and / or at end of PFMA discuss consequences and response to potential failure). After discussion of each PFM, categorize the potential failure mode (see Table 1 PFMA Guidance Document). Review the categorizations at the conclusion of the PFMA. During each PFM discussion, identify possible risk reduction actions including; monitoring, surveillance, investigations, analyses, remediation (structural or non-structural) and operational procedures & maintenance programs. Surveillance and Monitoring Plans (SMPs) can vary from periodic visual inspections, to continuous recording instrumentation and may include monitoring of weather forecasts and monitoring of earthquake activity. List Action Items or steps to be taken to resolve difficulties with Classifications of PFMs or Actions to be considered to immediately reduce significant risks identified for specific PFMs. After discussion of each PFM, categorize the potential failure mode (see Table 1 PFMA Guidance Document). Review the categorizations at the conclusion of the PFMA. To complete the PFMA, solicit individual input on the Major Findings and Understandings (MFU) reached during the PFMA process (all the key things learned or more fully understood during the workshop). All the input should be on flip charts (hand written) and should also be fully recorded electronically (laptop) or by copious notes. Ensure that all participants have their input/concerns listed. Photograph hand written charts. End PFMA meeting.	**Core Team, Geologist, Operating Staff, Specialists as needed**
9	**<u>Draft MFU:</u>** IC prepares the Major Findings and Understandings (MFU) of the PFMA, sends MFU to Core Team and Geologist. *(Note: Owner may distribute to staff for further*	**IC and Core Team**

	input). All review and comment /send email to IC. IC modifies MFU to include comments as appropriate.	
10	**<u>Draft PFMA Report</u>**: IC prepares draft PFMA report using FERC report outline and sends draft PFMA report to Core Team and Geologist. All review and email comments to IC. IC modifies PFMA report to include comments (some discussion between IC and others is usually needed to achieve final agreement) as appropriate. The final report must specify the SMP for all Category 1 and 2 PFMs.	**Core Team, Geologist**
11	**<u>Finalize PFMA Report</u>**: IC prepares final PFMA report. Owner forwards final report to FERC with copies to Core Team. Review and comments on the MFU and PMFA drafts typically average about one day for the Facilitator and ½ day or less for each Core Team member and the geologist.	**IC, Owner**
12	**<u>STID Review</u>**: **F**ollowing completion of the PFMA report, the STID should again be reviewed by the Owner and IC and any omissions or additional data revealed in the PFMA data review and sessions included as appropriate. The IC will provide comment on the final STID as part of the Part 12 D report.	**Owner, IC**
13	**<u>Part 12 D Field Inspection</u>**: Should be conducted by the IC in conjunction with the FERC Inspector and the Owner's staff. The field inspection should be conducted as soon after completion of the PFMA session as reasonable, so that the field conditions relating to issues discussed in the PFMA session can be inspected meaningfully.	**IC, Owner, FERC**
14	**<u>O&M Documentation</u>**: Summarize PFMA identified O&M issues and procedures and assess relative to highlighted failure modes. Document O&M for App E (if required as necessary).	**IC and Owner**
15	**<u>Draft Part 12 D report</u>**: To be prepared in accordance with FERC guidelines and outline. The Part 12 D report must specifically discuss and comment on or recommend SMPs for each Category 1 and 2 PFMs. Submit draft report to Owner for review/comment.	**IC, Owner**
16	**<u>Finalize Part 12 D Report</u>**: Responding to Owners comments, IC prepares and certifies final Part 12 D report and delivers to Owner.	**IC, Owner**
17	**<u>Part 12 D Report Submission</u>**: Owner submits Part 12 D report to FERC along with STID, including STID.	**Owner**

Appendix H
Part 12D Safety Inspection Report Outline

Table of Contents

The Table of Contents must show the initial page numbers for each section. If any subsection is not applicable, include the subsection with a statement of "Not Applicable" and an explanation of the reason(s) why.

For licensed projects that include multiple independent dam and powerhouse developments, separate Part 12D reports should be published for each development.

1.0 Findings and Recommendations

2.0 Project Description

3.0 Discussion of Potential Failure Mode Analysis Report

4.0 Surveillance and Monitoring with Respect to Potential Failure Modes

5.0 Field Inspection

6.0 Operation and Maintenance Programs Relative to Potential Failure Modes

7.0 Assessment of Supporting Technical Information Document

List of Tables (with location)

List of Figures (with location)

List of References

<u>**Appendices for Part 12D Inspection Report**</u>

A. FERC Letter Requiring Part 12D Inspection

B. FERC Letter Approving Part 12D Consultant - Include date of current report outline provided by FERC. Use report outline provided with FERC letter, not latest revision.

C. Project Figures

Only provide general overview drawings necessary to understand the project and items discussed in the report. If figures are placed in Section 2, provide a statement that figures may be found in Section 2. Optionally, if the STI is bound with the Part 12D report provide a statement that figures may be found in the STI document; duplicate drawings from the STI do not need to be included in the Part 12D report proper.

Detailed drawings should be included in the Supporting Technical Information document.

D. Instrumentation Monitoring Data Plots

List each figure and drawing included in the report. Optionally, instrumentation plots may be placed in Section 4 of the report and a statement included in Appendix D that the plots may be found in Section 4.

E. Inspection Photographs

Optionally, some or all of the photographs may be included in the appropriate sections of the report. If photographs are included within the report, provide a list of the photographs and the corresponding page number in Appendix E.

F. Inspection Checklists and/or Field Notes (Optional)

G. Operation and Maintenance Documentation (If required)

1.0 Findings and Recommendations

This Section includes a summary of the Part 12D Independent Consultant's findings and assessments and the Part 12D Independent Consultant's conclusions and recommendations.

1.1 Findings

1.1.1 Summary assessment of the PFMA report

1.1.2 Summary assessment of the Surveillance and Monitoring Plan

1.1.3 Summary of Field Inspection Findings

1.1.4 Summary of O&M status

1.1.5 Summary Assessment of "Supporting Technical Information" document

Note: Specifically identify any new calculations prepared subsequent to the previous Part 12D Report.

1.2 Conclusions

The conclusions of the Independent Consultant regarding the condition and suitability for continued safe and reliable operation of the project and specific conclusions regarding the information in each Section of this Part 12D report.

1.2.1 Conclusions regarding the suitability of the Project for continued safe and reliable operation.

1.2.2 Conclusions regarding the Project Description

1.2.3 Conclusions regarding the Potential Failure Modes Analysis Report

1.2.4 Conclusions regarding the Surveillance and Monitoring Plan

1.2.5 Conclusions regarding the Field Inspection

1.2.6 Conclusions regarding the Operations and Maintenance Programs

1.2.7 Conclusions regarding the Supporting Technical Information

1.3 Recommendations

The recommendations of the Independent Consultant to improve or maintain the condition and suitability for continued safe and reliable operation of the project and specific recommendations regarding the information in each Section of this Part 12D report.

1.3.1 Recommendations regarding the suitability of the Project for continued safe and reliable operation.

1.2.2 Recommendations regarding the Project Description

1.3.3 Recommendations regarding the Potential Failure Modes Analysis Report

1.3.4 Recommendations regarding the Surveillance and Monitoring Plan

1.3.5 Recommendations regarding the Field Inspection

1.3.6 Recommendations regarding the Operations and Maintenance Programs

1.3.7 Recommendations regarding the Supporting

1.4 Certification

Note: By signing this document, the Part 12D Independent Consultant is stating that the entire report has been developed by and under the direction of the undersigned. The Part 12D Independent Consultant shall make a clear statement that he/she generally concurs with the assumptions, methods of analyses, and results of all studies documented in the report.

The Part 12D Independent Consultant is thus taking responsibility for the Part 12D report contents as a Professional Engineer.

1.4.1 List of all field inspection participants

1.4.2 Reference to FERC Order 122 dated March 1, 1981 and paragraph 12.37 (c) (7).

1.4.3 Signature(s) of Part 12D Independent Consultant(s) and PE Stamp

See Appendix A: **FERC Letter Requiring Part 12D Inspection**

See Appendix B: **FERC Letter Approving Part 12D Consultant** - (Include date of current report outline provided by FERC)

2.0 Project Description

2.1 Brief Project Description

For each major element and ancillary structure, provide a brief description of the type of structure, general dimensions, etc. The detailed project description will be in the "Supporting Technical Information" document.

For multi-project or development licenses, include a brief outline of how this site fits with the other projects.

Include a short paragraph with very brief project history. When constructed, when modified, any incidents.

2.2 Hazard Potential Classification.

Based on views from the dam, other project works inspected and discussion with the licensee, document any changes in upstream or downstream conditions that might affect the Hazard Potential Classification. Review with the licensee the methods and assumptions used to develop the IDF. If the IDF is less than the PMF, the IC should confirm that the IDF is still valid based on an assessment of the downstream conditions as noted above.

2.3 Summary of Standard Operating Procedures

2.3.1 Purpose of Project (Run of river, storage, flow augmentation, flood surcharge storage, control reserve, pumped storage, etc.)

2.3.2 Reservoir rule curves by season (include seasonal reservoir level operating levels and restrictions of reservoir level due to safety concerns, if any)

2.3.3 Standard gate operation procedures (lead and following gates, emergency power systems, etc.)

2.4 Modifications Conducted for Project Safety

Document any modifications to project works since the last Part 12D inspection that have been done to improve project safety. (i.e.: spillway gates reinforced, seepage drain, berm added, crest raised, post-tensioned anchors installed, foundation drains or relief wells cleaned, etc.). In the next Part 12D Safety Inspection Report, these items will become part of Section 2.1. This information should be fully described in the updated "Supporting Technical Information" document submitted with the Part 12D report.

Do not include routine maintenance such as unit overhaul, gate painting, etc. Note, that generators, transformers, and transmission facilities are excluded from the Part 12D program under 18CFR subsection 12.35.

2.5 Flood History

2.5.1 Flood of Record, PMF, IDF

2.5.2 Zero freeboard spillway capacity

2.5.3 Peak spillway discharge during last five year period

2.5.4 Peak reservoir elevation during last five year period

See Appendix C: **Project Figures** (Note: If the STI is bound with this report, do not duplicate figures)

3.0 Discussion of Potential Failure Mode Analysis Report

Do not include security issues in the Part 12D report. For licensed projects that include multiple independent dam and powerhouse developments, separate PFMA studies and reports should be made for each development.

3.1 General

Identify the Core Team members, and their affiliations, who developed the comprehensive Potential Failure Modes Analysis (PFMA) or its update. Note that the process was in accordance with FERC "Engineering Guideline for the Evaluation of Hydropower Projects," Chapter 14.

3.2 Assessment of Potential Failure Mode Analysis Report

Assess the viable potential failure modes identified in the PFMA report. These would generally be Category 1 through Category 3 PFMs. Provide an assessment of the reasonableness and completeness of the failure mode scenario and whether the PFMs identified have a real possibility of occurrence. Potential Failure modes should be listed in order of importance. Each PFM assessment should include:

- A description that includes the sequence of conditions and events that would lead to the potential failure mode;
- An assessment of the risk reduction opportunities for each PFM; and
- An assessment of the Surveillance and Monitoring Plan for each PFM.

For example, the report would be formatted as follows.

3.2.1 PFM 1. (i.e. Internal erosion, piping)

3.2.1.1 Description of PFM (may be taken from PFMA report)

3.2.1.2 Assessment of Risk Reduction Opportunities

3.2.1.3 Assessment of Surveillance and Monitoring Plan

3.2.2 PFM 2. (i.e. Seismic induced deformation)

3.2.2.1 Description of PFM (may be taken from PFMA report)

3.2.2.2 Assessment of Risk Reduction Opportunities

3.2.2.3 Assessment of Surveillance and Monitoring Plan

Etc.

3.3 Are there new potential failure modes that have been identified and addressed in this report or that should be assessed? If so, include the appropriate Description of the PFM, Assessment of mitigation actions and Assessment of the SMP as discussed above.

See "Supporting Technical Information" document: **Potential Failure Mode Analysis Study Report** (Update as appropriate)

4.0 Surveillance and Monitoring with Respect to Potential Failure Modes

Note: Review and assessment of Surveillance and Monitoring Plans must always be done from the point of view of potential failure modes. Although the primary assessment is with respect to the potential failure modes identified in the PFMA study, the Independent Consultant must determine if there are potential failure modes not previously addressed or not adequately considered.

For the purposes of this section, a Threshold Level is the value used in the analysis or design, or is established from the historic record. An Action Level is the instrument reading that triggers increased surveillance or an emergency action.

4.1 Operator's Surveillance Program

Daily/weekly operator's inspections and reports.

4.2 Active Instrumentation: Include a schematic figure showing location of instrumentation (not detailed or cross section).

This will vary by project. Discuss only the instruments actually at the project. Is instrumentation in accordance with Chapter IX of the FERC "Engineering Guidelines for the Evaluation of Hydropower Projects?" Is the instrumentation functioning properly? Etc.

- Piezometers
- Weirs
- Settlement/alignment monuments
- Crack gages
- Upstream river and/or rain gage stations
- Headwater/tailwater (alarm systems)
- etc.

4.3 Threshold and Action levels

For each instrument, or group of instruments as appropriate, provide a table of Threshold and Action levels as defined above.

4.4 Reading procedures/frequency

For each instrument, or group of instruments as appropriate, discuss:

- Data acquisition procedures (manual/automated)

- Data evaluation procedures (process; is data evaluated in a timely manner by a qualified engineer; are readings compared to Threshold and Action levels defined for each instrument)
- Spurious readings (are spurious readings confirmed or explanations provided)

4.5 Assessment of Instrumentation Data and Surveillance and Monitoring Plans Relative to Potential Failure Modes. Include newly identified potential failure modes

5.0 Field Inspection

5.1 Field Inspection Observations

For each element of the project (i.e.: spillway, earthfill embankment, gravity section, intake, powerhouse, conveyance system, etc.), observe and report visual observations of the following issues as appropriate. Include photographs to document significant project features and observations. If an inspection checklist is used, include a copy of the checklist Appendix F. A site specific inspection checklist should be formatted to include specific visual surveillance items identified in the PFMA.

The intent of this section is to highlight changed conditions for the report reviewer, not to document unimportant or minor details.

The report should be in text format by structure or element addressed individually. For each structure or element of the project, the Part 12D Independent Consultant should consider the following items as appropriate:

- Settlement
- Movement – including abutments (cracks or other signs of distress or change)
- Erosion
- Seepage/Leakage
- Cracking
- Deterioration
- Spillway gate Operation/Standby Power (At a minimum, the Part 12D Independent Consultant needs to review the licensee’s annual certificates of spillway gate operation and interview project operating staff to assure that emergency backup systems work and that operating personnel know how to use them. At least one spillway gate should be operated at least one foot during the Part 12D inspection using the standby generator.)
- Outlet/Sluice Gate Operation
- Water conveyance systems (canals / flumes / penstocks / tunnels / surge chambers, emergency bypass or closure systems, etc.)
- Foundation Drain/Relief Well Operation

- Evidence of high artesian or uplift pressures (structures / foundations / abutments)
- Observations of sediment transport (piping evidence)
- Observations of seeps, wet areas, springs, green grass
- Other Pertinent Observations
- Reservoir Rim Stability

5.2 Status of Response(s) to Recommendation(s) in Last Part 12D Report.

5.3 Field Observations with Respect to Potential Failure Modes

Document field observations pertinent to each potential failure mode noted in Section 3

5.4 Adequacy/Operation of Public Alert Systems

Note: Are upstream spillway warning buoys, and downstream sirens and lights operable?

See Appendix E: **Inspection Photographs** (Optionally, some or all of the photographs may be included in the appropriate sections of the report. If photographs are included within the report, provide in Appendix E a list of the photographs and the corresponding page number)

See Appendix F: **Inspection Check List** (optional)

6.0 Operation and Maintenance Programs Relative to Potential Failure Modes

Do not include security issues in the Part 12D inspection report. If observations of significant O&M issues are made, include in report for possible new potential failure mode analysis.

6.1 Summary of PFMA identified O&M issues (from PFMA report)

6.2 Operation and Maintenance Procedures

6.2.1 Communication/Response

Address adequacy and reliability of remote monitoring, communication and control systems (Operations / Instrumentation / Telemetry – Do the systems provide adequate reliability and redundancy? Can a specific spillway gate, valve or other project component be operated remotely on demand?)

6.2.2 Electrical/Mechanical Systems

- Spillway Gate Motors (line/line voltage, amperage draw, motor name plate rating information)

- Standby and Redundant Power Sources
- Manual/Remote/Automatic Operation of Gates and Valves
- Gate Operation Sequence
- Icing protection (heaters/bubblers/reservoir level restriction)

6.2.3 Human Factors

- Adequate Staff for Emergency Response (Multiple Sites)
- Reliable Access Routes (winter/storm conditions)
- Training
- Electricians/Mechanics/Laborers
- Adequate Time to Respond
- Call Out Systems (time for crew to reach site after call out)

6.3 Assessment of O&M Procedures Relative to Potential Failure Modes

See Appendix G: **Operation and Maintenance Documentation**

7.0 Assessment of Supporting Technical Information Document

The purpose of this section of the Part 12D Report is for the Part 12D Independent Consultant (IC) to assess the contents of the “Supporting Technical Information” (STI) document compiled by the licensee and determine both its completeness and appropriateness to the current standard of the practice of dam safety. The STI document should be considered an executive summary that includes general, yet critical summary information needed to fully understand the design, construction, operation, and performance of the project. It should also contain sufficient information to summarize and confirm the underlying assumptions and the conclusions of the analyses of record supporting the assessment of the safety of the Project.

For each section of the STI, the Independent Consultant shall make a clear statement regarding their assessment of the completeness and appropriateness of the section of the STI. In sections where appropriate, they must state that they have reviewed the pertinent analyses and evaluations along with the underlying assumptions and that they have concluded that the assumptions and methods of analysis or evaluation were appropriate for the structure, were applied correctly and are appropriate given current guidelines and the state of dam safety practice. The IC must perform sufficient review and/or independent analysis and document their rationale to support their statement. This must include a brief summary of the parameters, methodologies, and results that document their decision.

Listed below are items to consider when summarizing each section of the STI. This is not intended to be an all-inclusive listing since each project is unique and requires careful review and consideration when reviewing for dam safety. In addition, this section of the Part 12D report is not intended to repeat the STI verbatim, but to summarize key components used by the IC to make their assessment and conclusions regarding the completeness of the STI.

7.1 Potential Failure Modes Analysis Study Report (Include a statement referring to Section 3 for a detailed discussion of the Potential Failure Modes Analysis)

- Adequacy of the summary of current PFMA Report
- Changes in PFMA during current review, including any new PFMs
- Any changes in category for any PFM

7.2 Description of Project

- Summarizes major components of the project, including all those listed in the project Order
- Review description for accuracy and completeness (elevations, capacities, etc.)

7.3 Construction History

- Summarized procedures/methods used for construction
- Includes construction difficulties that could influence long-term performance of the project.
- Summarize any design changes in the project during construction and any modifications since originally constructed
- Construction photographs

7.4 Standard Operating Procedures

- Summary of key operating procedures for dam safety
- Include procedures/sequence for passing flows (gate/powerhouse/flashboard/fuseplug, etc. operation)
- Does the SOP include all the necessary requirements to safety operate the project?
- Discuss any changes that have been made in the operation of any component of the project that is different than originally designed and if there is any impact resulting from the change.

7.5 Geology and Seismicity

- Geology
    - Adequacy of the summary of regional and local geologic conditions
    - Geologic conditions that could impact dam safety performance
    - Any geologic conditions that are important for monitoring the project
- Seismicity
    - Summary of seismic analysis, including key parameters
    - Date of recent analysis and applicability to current studies
    - Design PGA and recurrence interval (if available)

7.6 Hydrology and Hydraulics

- Hydrology
    - Summary of IDF/PMF, including key assumptions and rainfall/runoff parameters used.
    - Applicability of flood to current methods, HMR, etc
    - Specifically identify the studies of record
- Hydraulics
    - Summary of key issues and assumptions, including review of rating curve for spillway.
    - Summarize routing of IDF/PMF through spillway(s), peak reservoir elevation, and residual freeboard.

7.7 Surveillance and Monitoring Program

This section should have an introductory summary of the analysis of record: the actual analyses should be included or attached as an Appendix. Other prior analyses can be included in the Appendix if they are thought to be of significance.

- Status of current DSSMP and DSSMR
- Applicability of program to PFMs
- Determine if any changes to program are required and recommend those changes.
- Discuss the appropriateness of current threshold and action levels

7.8 Stability and Stress Analyses of Project Structures

- Summary of methods, procedures, critical elements, assumptions, input/design parameters, etc… for each structure analyzed
- Resulting factors of safety and comparison to FERC guidelines
- List of all analysis of records and any supplemental studies currently in process or completed

7.9 Spillway Gates

- Category of gates and appropriate requirements
- Date and brief conclusion of most recent detailed gate inspection
- Date and brief conclusion of most recent test operation.

7.10 Pertinent Correspondence Related to Safety of Project Works

- Completeness of documents required to be included in the STI.

7.11 Status of Studies in Process and Outstanding Issues

- Summarize any ongoing analyses, studies, etc.

7.12 References

- Completeness of the list of references and the attached electronic files, if applicable

7.13 Conclusions

- Overall assessment of the condition of the STI

General Statements

The following example statements are offered as general guidance for use by the IC when making definitive statement regarding each section of the STI, **in addition** to the discussion indicated above. The Positive statements are examples of when the STI is acceptable. The Negative statements are examples where the STI does not meet minimum requirements and must be improved upon. There are intended only as examples to be used for the section indicated. *Copying these examples verbatim into the IC's assessment of each section of the STI may result in the rejection of the Part 12 D report; the assessment should be specifically customized for the project under review.*

7.1 PFMA Review

Positive

The PFMA was reviewed for completeness during a PFMA review conducted in conjunction with the Part 12 inspection. I/we reviewed the following items (itemize here) and as a result, consider the PFMs to be, fully developed and appropriately separated by load case and location, well documented, and complete relative to the project information.

Negative

I/we reviewed the following items (itemize here). PFM Number XX was not fully developed and a recommended revision is included in the recommendation section of this report. After review and concurrence by FERC, the revised PFM should be adopted. The other PFMs are considered to be well written, well documented, and complete relative to the project information.

7.2 Project Description

Positive

The description of the project is correct and adequately summarizes the major components of the project and provides a good executive review level discussion about the project.

Negative

The project description is inadequate. It is recommended that the description of the project included in the STI be enhanced to include a more detailed description of the spillway gate operators, as noted in the recommendation section of this report

7.3 Construction History

Positive

The construction history is adequately described, including all significant construction issues documented during the construction which include the following key points that could potentially impact the operation and performance of the project features. All available construction photographs are included on the accompanying CD and were reviewed to ensure there are no other previously unidentified defects from the original construction or later modifications.

Negative

The construction history is generally adequately described. However, the construction history did not include the modifications made to the project in 1999, which included (describe the modifications). A recommended revision is included in the recommendation section of this report.

7.4 Standard Operating Procedures

Positive

The Standard Operating Procedures are adequately summarized in the STI and include (list here) that are of specific interest regarding the continued safe operation of the project. The SOP includes all the necessary requirements to safety operate the project.

Negative

The SOP does not account for changes in gate operation to accommodate flow releases required for environmental purposes in 2004. It is recommended that the SOP be rewritten to account for this change.

7.5 Geology and Seismology

Positive

The geology and seismology of the project are adequately summarized and highlight specific issues that could impact the operation and performance of the project and include (summarize here). Our/my review of the seismicity indicates that site seismicity was developed using the most current data and approach available. The assumptions, methods, and use of the data and its application to this project meet the current guidelines and the state of dam safety practice.

Negative

The Geology section of the STI is adequate with the following exceptions:

- The geology does not contain a description of the problematic areas encountered in the foundation during construction. Nor does the geology summarize the actual geology of the site, but only includes a broad regional summary of the area.

- The seismology section of the STI is inadequate. The most current seismic hazard evaluation is not adequately summarized and the design Peak Ground Acceleration is not listed.

- The Geology and Seismology sections of the STI must be enhanced in accordance with the recommendations contained elsewhere in this report.

7.6 Hydrology and Hydraulics

Positive

The hydrology of the project is adequately described in the STI. My/our assessment of the hydrology included a review/analysis of (list studies/reports here). The key assumptions and parameters include (summarize here) and are considered appropriate to the current methodologies, data, and state of dam safety practice for evaluating the hydrologic safety of a dam. The PMF inflow of xxxx cfs is appropriate for this project.

The hydraulics of the project are adequately described in the STI. The spillway and tailwater rating curve(s) are correct and adequately represents the current spillway hydraulics. The project spillway(s)/outlets can pass the PMF/IDF with xx feet of freeboard on the dam. This freeboard is adequate for predicted wind and wave run-up at the dam.

Negative
I/we do not concur with the PMF analysis of record for this project. The PMF was based on PMP developed using HMR43, which was superseded by HMR57 in 1994. It is recommended that the PMF analysis be updated using the updated PMP values from HMR57.

The hydraulics of the project are not properly described in the STI. The rating curve used for the spillway is incorrect and needs to be recalculated.

7.7 Surveillance and Monitoring Program

Positive

The Surveillance and Monitoring Program is adequately described in the STI. My/our review of the DSSMP indicate the most critical elements of the monitoring include (summarize here) and contain appropriate threshold and action levels for each instrument. During the PFMA review, the need for additional surveillance for the project with respect to both identified PFMs and general health was discussed. It is my opinion that existing monitoring program is adequate and no changes are recommended at this time.

Negative

My/our review indicated that several key elements of the project instrumentation are missing (list here). Thus the SMP is inadequate and needs to be revised.

7.8 The Stability and Stress Analyses of Project Structures

Positive

I have reviewed the pertinent analyses and evaluations along with the underlying assumptions and that have concluded that the assumptions and methods of analysis or evaluation were appropriate for the structure, were applied correctly and are appropriate given current guidelines and the state of dam safety practice. I also performed an independent check of the stability calculations and my results agree with the analysis of record. The following project structures are thus found to be safe for continued operation:

- Main embankment
- West diversion dam
- Integral power house
- (List all)

Negative

The STI is inadequate with regards to a summary of the stability and stress analyses for the project structures. The design assumptions are missing for the (xxxx) structural analysis. In addition, the resulting factors of safety on the recently submitted stability analysis do not meet the FERC minimum guidelines and must be reviewed with regards to dam safety concerns.

7.9 The Spillway Gates

Positive

I have reviewed the pertinent inspection reports and stability and stress analyses (if applicable) and have determined that the spillway gates are safe for continued operation.

Negative

I have reviewed the pertinent inspection reports and stability and stress analysis for the spillway gates. The analyses do not properly account for the bent strut on Gate No. 1 that I observed during my field inspection. Thus, before I can determine if the spillway gates are safe for continued operation, the stress analyses need to be redone to account for this issue with Gate No. 1.

7.10 The Pertinent Correspondence Related to Safety of Project Works

Positive

The Pertinent Correspondence Related to Safety of Project Works is complete and adequate in accordance with the requirements of FERC. This correspondence includes the following items of specific note that are most important regarding the continued safety of the project:

1.
2.

Negative

The Pertinent Correspondence Related to Safety of Project Works is incomplete with regards to the requirements of the FERC. The following documents are missing and my/our recommendation is included to obtain and include the following documents in the STID:

- Past three years of the FERC Annual Dam Safety Inspection Reports
- Etc… (detail all accordingly)

7.11 Status of Studies in Process and Outstanding Issues

The Status of Studies in Process and Outstanding Issues include the following:

- List specifics and summarize the issue

OR

There are no outstanding studies in process or outstanding issues with the project that are in process or need to be initiated resulting from my/our conclusions of this Part 12D review and inspection.

7.12 References

Positive:

The References included in the STI and associated electronic files enclosed with the STI are complete and accurate and are formatted for easy reference.

Negative:

The references in the STI are incomplete and inadequately contain all the information contained in the STI. It is recommended that all studies and reports listed below be transferred to a disk and included in the end of the STI.

7.13 The Conclusions

Positive

The overall STI document is complete, well organized, and adequately addresses all of the requirements of FERC, but more importantly provides a complete executive summary document that is useful to all those associated with this project.

Negative

The STI document is inadequate. Rather than summaries of the necessary information, the document contains random copies of studies, project information, and incomplete information that does not allow the user to obtain a general overview of the entire project. Specifically, Sections (list sections) are particularly poor in content and must be completed in accordance with our recommendations.

7.14 APPENDICES TO THE PART 12D SAFETY INSPECTION REPORT OUTLINE

List of Tables (with location)

List of Figures (with location)

List of References

A. FERC Letter Requiring Part 12D Inspection

Note: May include specific FERC concerns to be addressed by Part 12D Independent Consultant.

B. FERC Letter Approving Consultant

Note: Include date of report outline provided by FERC.

C. Project Figures

This Appendix should include the following figures as appropriate. All Figures should be consecutively numbered. Figures should be general without excessive detail so as to be clearly legible. Figures should include documentation of significant changes since last Part 12D report. If STI document to be directly bound in this report, do not duplicate the figures. FERC Exhibit and relicensing drawings can be used.

- Location map with project facilities located including conveyance systems and access routes from main roads and nearest town
- Plans of project facilities
- Typical sections and profiles of key project features (dams, spillways, powerhouses, intakes, emergency/fuse plug spillways, chute profiles, etc.)
- Profiles and typical sections of water conveyance systems (canals, tunnels, penstocks, flumes, surge chambers, etc)
- Satellite or aerial photo of project and downstream area
- Spillway and tailwater rating curves

D. Instrumentation Monitoring Data Plots

Note: Plans and cross-sections with locations of each instrument, including design phreatic surface or uplift pressure profile, and tabulated data for each instrument are included in the "Supporting Technical Information" document only. See Chapter IX, Instrumentation and Monitoring, of the FERC Engineering Guidelines for the Evaluation of Hydropower Projects for additional information. Only time versus reading graphs are included here as NEW information. Tables of data should be provided on a CD bound into the Part 12D report

If data plots are included in Section 4 of the Part 12D report, a statement should be provided here directing the reader to Section 4 for the information.

- Time versus Reading data plots

- Plot all data to date, not just last five years (alternative is to plot last 15 years and note historic range for each unit)
- Do not put too many instruments on one plot
- Try to put all instruments from one section or profile on the same plot
- Mark tip elevation, unscreened length, ground elevation and top of piezometer elevation for each piezometer on the data plot. This information can be provided in a Table to enhance legibility of the graph.
- Use symbols and/or different line types for each unit, not just colors (colors do not reproduce in black and white and some people are color blind - Note that yellow and blue do not reproduce on Xerox machines)
- Include headwater and tailwater levels on each plot
- Force all time scales to show full year cycles from January through December
- For multiple plots for the same project, force vertical and horizontal scales on all plots of the same type to have the same scale or total range so plots can be directly overlaid
- Mark threshold values
- Show monthly precipitation on one sheet
- Mark action levels requiring emergency response

E. Inspection Photographs

F. Inspection Checklist (optional)

G. Operation and Maintenance Documentation (if required)

Appendix I
Guidelines for Supporting Technical Information

The "Supporting Technical Information" document must include a revision sheet and contain the following sections:

Section	Title
	Table of Contents
1.	**Potential Failure Mode Analysis Study Report**
2.	**Description of Project Structures**
3.	**Construction History**
4.	**Standard Operation Procedures**
5.	**Geology and Seismicity**
6.	**Hydrology / Hydraulics**
7.	**Surveillance and Monitoring Plan**
8.	**Stability / Stress Analysis of Project Structures**
9.	**Spillway Gates**
10.	**Pertinent Correspondence Related to Safety of Project Works**
11.	**References**

The information to be included in each section is described below. If an item is not pertinent to the Project, include the item in the report and state that the item is Not Applicable (i.e. Section 9 "Spillway Gates" if the dam has an uncontrolled spillway).

SUPPORTING TECHNICAL INFORMATION

Revision Log
Table of Contents

1.0 Potential Failure Mode Analysis Study Report

Include a complete copy of the latest "Potential Failure Modes Analysis Report" with all attachments. All updates shall be included in this Section of the STI.

2.0 Description of Project Works and Project Drawings

This is a detailed description of the project and project works that is part of the Part 12D Independent Consultant review. In general, this information will come directly from existing sources such as prior Part 12D Inspection Reports, licensing or relicensing documents or company brochures. The detailed descriptions would include the following elements as appropriate:

- General project description including project name and owner
- Project location including nearest town(s), river system, etc.
- Purpose of Project
- Main dam and any auxiliary dams
- Spillway(s) including stilling basins
- Non-overflow water retaining structures such as powerhouses
- Intakes
- Conveyance systems (penstocks, tunnels, surge chambers, flumes, canals, inverted siphons, including control, regulating, and pressure relief devices, etc.)
- Powerhouse(s)
- Low level outlets including minimum flow devices

The following drawings shall be included

- USGS Quad map or other location map with project facilities located including conveyance system alignment
- Plan of licensed project facilities and project boundaries
- Typical sections and profiles of key project works (dams, spillways, powerhouses, intakes, canals, tunnels, penstocks, flumes, surge chambers, inverted siphons, etc.)
- Satellite or aerial photo of project and downstream area if available

3.0 Construction History

In general, this information will be copied directly from existing sources such as prior Part 12D reports, construction reports or company brochures. Include a summary of the project construction history based on the following sources of information:

- Design reports and pertinent memoranda from licensing and permitting documents
- Laboratory investigations and construction testing reports
- Field and lab geotechnical investigations
- Construction reports and photographs
- Specification documents
- Reports of major modifications conducted for dam safety since last Part 12D inspection
- Construction chronology that includes all a summary of original construction and all significant work completed related to project safety. Do not include routine maintenance items such as gate painting, unit overhauls, etc.

4.0 Standard Operation Procedures

Include summaries of the standard operating procedures for the project. This section should include: seasonal minimum flow requirements, lead and follow gate sequence, reservoir level restrictions by season, etc.

4.1 Dam Operations

- Schedule of Inspections (include routine operations by operating staff, inspections by engineering staff, and special inspections as appropriate)
- Inspection checklist(s)
- Procedures for assuring satisfactory operating condition of critical systems including; SCADA systems, spillway gate operators, spillway gates, and low level outlet works

4.2 Reservoir Operations

4.2.1 Normal Operations

- Typical filling schedule
- Inflow forecasting procedure
- Ramping rate requirements (reservoir and releases)
- Downstream minimum flow requirement schedule

4.2.2 Flood Operations

- Criteria for starting gate operations
- Method of gate operation (local or remote)

- Gate operating sequence (both spillway and low level outlets as applicable). Are gates operated such that all gates are opened a similar amount? Are some gates opened fully before others are operated? etc.

5.0 Geology and Seismicity

In general, this section should be copied from existing reports and company brochures. Include summaries of applicable information in the following sections:

5.1 Geology

5.1.1 Regional geology

5.1.2 Site geology and local foundation conditions including geologic maps, cross-sections and profiles under the dam(s) and pertinent project works.

5.1.3 Potential landslides, loose rock formations or adverse bedding orientations that could affect project works

5.1.4 Potential sinkhole, karst, solutioning, basalt flow issues, etc. that could impact project works

5.1.5 Potential weak seams such as bentonite or soluble gypsum layers

5.1.6 Geologic artesian sources (geothermal, high abutments, etc.). Do not include artesian pressures due to normal dam seepage.

5.2 Seismicity

5.2.1 Map of fault traces that effect project. Differentiate between those traces that have been confirmed by trenching or other means and those that are inferred from other means.

5.2.2 Table of fault, distances, depths, magnitude at fault, PGA at site, etc. including local (floating or random crustal) earthquake.

5.2.3 Site MCE and DBE development

5.2.4 Time history of adopted earthquakes

5.2.5 Response spectrum used in analyses

5.2.6 Historic earthquake centers map

The USGS website (http://earthquake.usgs.gov) includes information on seismicity and may be a useful reference.

6.0 Hydrology and Hydraulics

Provide supporting information to document the development of the Probable Maximum Flood (PMF) and the routing of the PMF through the reservoir and project spillways. In general, this information will come directly from existing sources such as prior Part 12D Inspection Reports or company reports. The following information that should be included as applicable:

6.1 Hydrology

6.1.1 Hydrometeorology report used

6.1.2 Probable Maximum Precipitation for general and local storms

6.1.3 Drainage basin description including drainage area

6.1.4 Antecedent conditions

6.1.5 Loss rates

6.1.6 Basin and sub-basin precipitation/runoff models

6.1.7 Unit Hydrograph

6.1.8 Reservoir inflow and outflow hydrographs for the PMF event

6.1.9 Floods of record including highest flood flows and reservoir elevations

6.2 Hydraulics – Dams

6.2.1 Project discharge-rating curves (For multiple gate spillways, outlet structures, powerhouse units, and emergency/fuse plug spillways, include the contribution of each component as well as the total capacity. Include the equations used to develop the curves including overtopping and orifice flow where appropriate).

6.2.2 Tailwater rating curve (Compare to dam break studies)

6.2.3 Normal and IDF freeboard without wave action

6.2.4 Zero freeboard flood capacity (without wave allowance)

6.2.5 Inflow Design Flood (based on dam break) The pertinent information from dam break analyses necessary to support the determination of the IDF should be included

6.2.6 Reservoir Probable Maximum and Inflow Design Flood outflow hydrographs and corresponding reservoir levels

6.2.7 Freeboard for general and thunderstorm events

6.2.8 Stilling basin or plunge pool design flood flow

6.2.9 Operating rule curve (if storage reservoir) including license restrictions on storage levels by season

6.3 Hydraulics – Water Conveyance Systems

6.3.1 Hydraulic capacity of water conveyance system(s)

6.3.2 Normal operating freeboard

6.3.3 Spillway discharge rating curve(s)

6.3.4 Summary of transient analysis

7.0 Surveillance and Monitoring Plan

This section is to include drawings and/or sketches showing the location of each active instrument. Include cross-sections of project structures showing instrument tip elevation, ground elevation and readout point location. See Chapter IX, Instrumentation and Monitoring, of the FERC Engineering Guidelines for the Evaluation of Hydropower Projects for additional discussion.

Note: time versus reading graphs for each instrument will be included only in the Part 12D Inspection Report, not in the STI.

7.1 Plans, sections, and details of active or useful reference instrumentation

If a unit has been abandoned or replaced, but the historic data is still being used for safety evaluations, include the appropriate information for the record

7.2 Reading frequency for each instrument (reading procedures should not be included in this document)

7.3 Procedures for resolving spurious readings

7.4 Tabulated Data for each instrument (may be included on CD in Excel format)

7.5 Type of instrument (pneumatic/vibrating wire piezometer, Parshall flume, gape gage, inclinometer, etc)

7.6 Predicted value for each instrument (threshold values are values used in design or analysis of project structures)

7.7 Historic range of readings for each instrument

7.8 Threshold and Action level for each instrument

8.0 Stability and Stress Analyses of Project Structures

Because every dam and hydroelectric project is unique, it is not possible to list here all the various items that are required to adequately detail stability or stress assessments of the project water retaining structures. It will be the responsibility of the Licensee to include all information necessary for the reader to understand the assumptions, methods of analysis, and load cases assessed for each project structure. Stability and stress analyses for each structure shall be summarized graphically for ease of understanding.

The following types of information should be provided:

8.1 General

8.1.1 Listing of credible load cases analyzed (including water levels for dam, canal and flume analyses or pressure for penstock and flowline analyses)

8.1.2 Statement of the method of analysis used and the computer program adopted.

8.1.3 Properties of materials based on site specific tests or assumptions (state which). Include representative test data and summary sheets.

8.2 For each gravity structure and load case:

8.2.1 Graphic free body diagram (cross-section) of each structure showing:

- the assumed self weight of the cross section
- all applicable loads including, as appropriate:
- assumed uplift pressure distribution
- silt loads
- headwater and tailwater loads
- point loads

- ice load

8.2.2 Key elevations
8.2.3 Key lateral dimensions
8.2.4 Piezometer and drain locations
8.2.5 Foundation shear strength parameters
8.2.6 Minimum cohesion to meet stability criteria
8.2.7 Negative crest pressures
8.2.8 Concrete unconfined and splitting tensile strength test results
8.2.9 AAR potential or evidence
8.2.10 Failure planes investigated, etc.

8.3 For each embankment structure and load case:

8.3.1 Graphic cross-section showing

- embankment zoning
- phreatic surface by load case
- critical failure surfaces
- key elevations
- key lateral dimensions
- slopes
- headwater and tailwater elevations
- relief wells, drainage layers, cutoff trenches, slurry walls, etc

8.3.2 Potential for uncontrolled seepage at toe
8.3.3 Summary of liquefaction analyses
8.3.4 Summary of deformation analyses
8.3.5 Procedures used to determine soil types and properties, etc.

- Soil Classification
- Atterberg limits
- etc.

8.3.6 Procedures used to determine soil strengths

- Triaxial Tests (type and loadings)
- Standard Penetration Tests
- Cone Penetration Tests
- Becker Hammer Tests
- etc.

8.4 For each arch dam load case:

8.4.1 Finite element mesh
8.4.2 Stress contours
8.4.3 Vector diagrams

8.4.4 Thrust block stability and joint sterionets

8.4.5 Pulsating load potential, etc.

8.5 For each water conveyance system that has a highlighted PFM

8.5.1 Stress and stability analyses

8.6 Summary table of factors of safety for each structure and load case, with required value.

For embankment structures and overburden foundations, the material strengths used in the stability analyses should be properly identified i.e. effective stress or total stress. The methods used to determine/estimate pore pressures, such as flow nets or field measurements, should also be described.

For gravity structures, it is useful to provide a spreadsheet of the key numbers from the analysis.

9.0 Spillway Gates

For each spillway gate type, include the following information:

9.1 Table of material properties (steel type, trunnion bearing type and friction properties, etc).

9.2 A summary of the stress analysis computations

9.2.1 Graphic of gate model used for stress analysis

9.2.2 Table of critical stresses in each member for each load condition.

9.3 Trunnion, wheel, or other lubrication procedures, schedule, etc.

9.4 Summary of gate hoist motor load tests to date (motor name plate rating, line-line voltage, amperage draw, reservoir level, and initial draw if available)

9.5 Spillway gate detailed inspection report

10.0 Pertinent Correspondence Related to Safety of Project Works

Include the most recent FERC Annual Operation Inspection Report. Include any major correspondence from FERC or State Dam Safety Agencies related to outstanding dam safety issues for the project.

11.0 References

List of references available for review of dam safety issues and that were used to assemble this document.

Attachments

1) Example of Detail Expected in Supporting Technical Information Document
2) Example of Summary of Embankment Stability Analysis
3) Example of Summary of Structural Stability Analysis
4) Example of Summary of Hydrologic and Hydraulic Information
5) Example of Summary of Instrumentation and Surveillance Information
6) Example of Document Control Log Sheets

Attachment 1
Example of Detail Expected in Supporting Technical Information Document

BASIC DATA AND ANALYSES

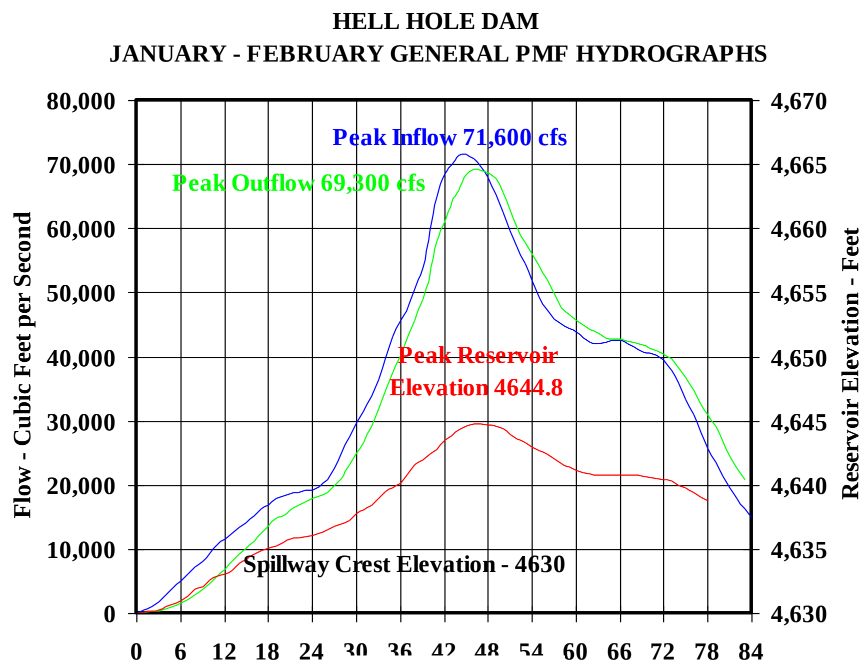
Spillway Adequacy

A. Previous Studies

The original design flood study for Big Hole Dam was presented in "A Study of the Maximum Probable Floods for the Middle Fork of the Big River Project", dated October 1961 and revised in August 1962 by ABC. The design flood developed by that flood study, when routed through the reservoir and spillway, resulted in a peak discharge of 58,800 cfs at reservoir water surface Elevation 4,643.2, leaving a freeboard of 6.8 feet to the nominal dam crest.

In February 1965, ABC updated the flood study by deriving a probable maximum flood based on U.S. Weather Service Hydrometeorological Report No. 36 and U.S. Corps of Engineers reductions. This 1965 study resulted in a maximum water surface Elevation 4,646.7, leaving a freeboard of 3.3 feet to the nominal dam crest elevation.

In 1973, T. J. Corwin reviewed the flood studies, made some independent



Big Hole Dam

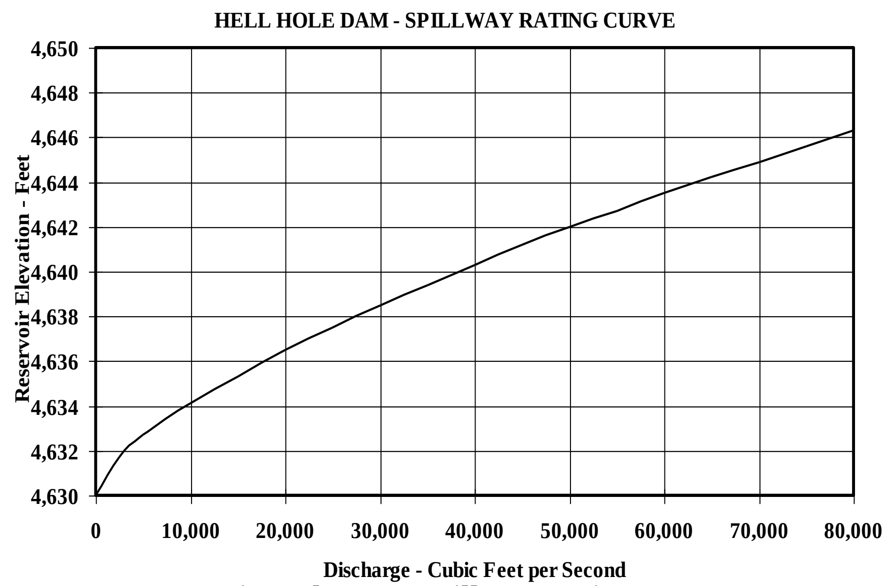
Figure 1

evaluations, and concluded that the maximum inflow flood would be 66,000 cfs. When routed through the reservoir and spillway, the peak discharge would be 55,000 cfs with a maximum reservoir water surface Elevation 4,644, leaving 6.0 feet of freeboard.

B. Methodology to Determine PMF

In 1982, FERC directed Big County Water Agency to provide additional information on flood hydrology for the Middle Fork American River Project. The Agency retained Hydrotech of Bigville to perform that study. Hydrotech's report "Probable Maximum Flood Study for Big Hole, Interbay, and Little Hole Afterbay Dams", dated October 1982, was reviewed and excerpts presented as part of the 1986 Five Year Dam Safety Inspection report.

Excerpts from that report describing the methodology used to determine the PMF for Big Hole Dam follow.



Big Hole Dam Spillway Rating Curve

"The probable maximum floods are based upon a probable maximum storm that could occur during January or February. The storm is estimated using procedures presented in Hydro-meteorological Report No. 36, entitled "Interim Report, Probable maximum Precipitation in California", which was originally issued in October 1961, and was revised in October 1969."

"The probable maximum storm was distributed into hourly precipitatio0n amounts, hourly melting of snowpack was calculated using probable maximum storm temperature and winds, immediate surface runoff losses were subtracted from the hourly precipitation and snowmelt, and the remaining excess amounts of precipitation and snowmelt along with spill from any upstream reservoirs were routed through the basin stream channels to the basin discharge point…"

The Hydrotech report is organized into three sections describing the basin characteristics, the flood analysis, and the probable maximum flood calculation. The Clark Unit Graph method (C. O. Clark, "Storage and the Unit Graph" ASCE Transactions, 1945.)

"Probable maximum flood inflows to Big Hole Reservoir … have been calculated using estimated probable maximum precipitation, snowmelt associated with the probable maximum storm, applying losses based upon losses during historic storms, and routing the sub-basin runoff to the appropriate reservoir." "Each reservoir was assumed to be full at the start of the probable maximum flood."

The flood routing from the Hydrotech study is presented on Figure 1. Peak flood inflow was found to be 71,600 cfs and peak outflow was 69,300 cfs at a maximum reservoir stage of 4,644.8.

It is considered that the Hydrotech flood study was carried out in accordance with previously appropriate standards and procedures. However, in May 1996 and January 1997, large rainfall floods occurred which could affect the unit hydrographs and loss rates used to develop the probable maximum flood (PMF) from the probable maximum precipitation (PMP). In 1999, the National Oceanic and Atmospheric Administration and the Army Corps of Engineers issued

Figure 2

Hydrometeorological Report (HMR) No. 59, which superseded HMR No. 36 on which the precipitation developed in the

Hydrotech 1982 study was based. While the precipitation, loss rates and unit hydrographs used in the Hydrotech study were appropriate and conservative for that time, the precipitation is no longer current data and the loss rates and unit hydrographs should be reviewed as a result of the 1996 and 1997 storms.

The maximum reservoir stage for the routed flood left 5.2 feet of freeboard to the nominal dam crest elevation. That freeboard is judged to be adequate for a dam the height, configuration and material of Big Hole Dam but a new flood study must be prepared for Big Hole Dam and the freeboard adequacy must be reviewed when the results of that study are available.

C. Spillway Rating Curve

The spillway rating curve from the Hydrotech 1982 report is presented on Figure 2. That rating curve has again been reviewed and found to be conservative and appropriate for the spillway at Big Hole Dam.

Structural Stability

A. Previous Studies

The original design analysis was carried out by AB Engineers (ABE) as reported in their 1982 Engineering Data Report. Harlan Miller Tait Associates (HMTA) updated the Stability Analysis for the dam as a supplement, dated April 4, 1984, to the fourth Five Year Dam Safety Inspection Report. In the fifth Five Year Dam Safety Inspection Report (HMTA, 1986), the stability analysis was again updated using additional seismicity data and a more complete analysis.

To comply with FERC criteria, a Simplified Displacement Analysis (SDA) was performed as part of the 1991 Five Year Dam Safety Inspection by HTA. Data and analysis descriptions from those HTA reports are summarized in this Appendix.

B. Method of Analysis

1. Static Analysis

To analyze the static loading conditions, the static stability analysis computer program TSLOPE (by TAGA Engineering Software Services of San Ramon, California) was used.

The Spencer's method program option was selected to determine the factor of safety of a slope using noncircular failure surfaces selected by the investigator. The sliding mass is divided into slices, and all interslice side forces are parallel to each other. Spencer's method satisfies equilibrium conditions for overall moment, individual slice moment, and vertical and horizontal forces.

2. Earthquake Deformation Analysis

For the earthquake deformation analysis, a simplified displacement analysis (SDA) was carried out. The controlling causative fault for the Big Hole Dam site is the undefined “local earthquake” that is capable of an MCE of M=5 at a distance of 5 km that could result in a peak ground acceleration (PGA) at Big Hole Dam of up to 0.19g (Section IV, E. Seismicity) (Sadigh, et.al., 1997). A conservative seismicity of 0.2g was used in the 1991 analysis.

The SDA was performed in three steps:

1. A yield acceleration was determined using static analysis for failure surfaces that would intersect the crest and adversely affect the freeboard.
2. A time-history of accelerations in the dam caused by the controlling earthquake was calculated for the selected yield acceleration surface.
3. The time-history accelerations that exceeded the yield acceleration were used to estimate incremental displacements, which were averaged to calculate the permanent displacement along the failure surface.

TSLOPE was used to determine the yield acceleration for the selected failure surfaces. The yield acceleration is defined as the pseudostatic seismic coefficient necessary to reduce the static factor of safety for the selected failure surface to 1.0, the point of incipient static failure. The Spencer's method program option was selected to determine the factor of safety of a slope using failure surfaces selected by the investigator, as described under Static Analysis, above. Various failure surfaces, which were selected to intersect the crest of the dam and to adversely affect the freeboard, were tried until several surfaces with lower yield accelerations were found.

The program SHAKE, developed at the University of California at Berkeley by Per Schnabel, John Lysmer, and H. Bolton Seed, was used to model the dam's dynamic response to site-modified earthquake records and to estimate the time-history of acceleration on the selected yield acceleration surfaces. SHAKE is used to compute the dynamic response of a one-dimensional system of infinitely long, homogenous, visco-elastic layers subjected to vertically traveling shear waves. The program is based on the continuous solution to the wave-equation (Kanai, 1951) adapted for use with transient motions through the use of the Fast Fourier Transform Algorithm (Cooley and Tukey, 1965). The input to the program is discrete, consisting of acceleration values spaced at a constant time interval. The maximum absolute acceleration value and the time interval between the acceleration values are varied so that the acceleration and predominant period of the record matches those expected at the site. The earthquake records chosen to model the site were the 1954 Taft earthquake and a synthetic motion created by H. B. Seed and I. M. Idriss, both scaled to a PGA of 0.20g. The output from SHAKE is also in discrete format, consisting of acceleration values at constant time intervals that represent the acceleration time-history curve of points within the soil profile chosen by the investigator.

The dynamic response of the dam embankment due to an earthquake with a PGA of 0.20g was computed on the maximum section at several vertical locations in profiles located near the axis of the dam, near mid-slope, and near the embankment toe (see Figures D-3 and D-4) using the program SHAKE. In a trial and error process, the material stiffness parameters were softened at the failure surface until the average acceleration above the failure surface was approximately equal to the yield acceleration. This procedure was required to keep the system in static equilibrium. The acceleration time history at the failure surfaces at the various profiles was then computed, and the maximum value is presented on the Figures. Typically, the Taft motion produced greater accelerations at the failure surfaces.

The program DISPLMT, developed at Arizona State University by William

Houston and Sandra Houston, was used to compute expected permanent displacements in the dam embankment using the acceleration time-history on the selected yield failure surfaces. The program estimates permanent displacements by double integrating accelerations above the yield acceleration produced at the failure surface. The program utilizes the Newmark numerical method to perform the integration, determining the area under the portion of the acceleration time-history curve that exceeds the minimum yield acceleration.

The DISPLMT program calculates the movements along the failure surface using the acceleration time-history generated by SHAKE as the response or input motion. The yield acceleration is assumed constant with respect to time and displacement. The calculated displacement varies from the near-axis, middle, and toe profiles of the embankment slope.

C. Material Properties

ABE data (1962 and 1968) indicate that the foundation was to be on unweathered rock. As-built drawings show the foundation to be hard, massive granitic rock. For the purpose of the stability analysis, it is considered that the foundation is substantially stronger than the embankment.

Materials obtained from the borrow areas and used in the core of the embankment were tested by ABE for their strength characteristics. These tests are summarized in their report (ABE, 1962), and the design parameters adopted are given below. The material strength parameters discussed in that report were judged conservative and appropriate; therefore, those same parameters were used in the 1986 and 1991 analysis and are as follows:

Material Properties Used in Analyses

Parameter	Zone 1	Zone 2 - 7
Moist Unit Weight, γ_m (pcf)	127	124
Saturated Unit Weight, γs (pcf)	130	140.4
Friction Angle, Ø (degrees)	33	40
Cohesion, c (psf)	200	0

D. Phreatic Surface Assumptions and Seepage Pressure Distribution

The phreatic surfaces and hydrostatic forces are based on the water levels shown on the stability analysis drawings (Figures D-3 and D-4). Uniform head loss was used through the core, and it was considered that the transition, drain material, and rockfill are free draining with no head loss in the upstream rockfill and transition. In 1984, FERC questioned the assumption that the upstream rockfill would be free-draining with respect to rapid drawdown stability conditions. An analysis of the permeability of the upstream shell with respect to maximum rate of rapid drawdown was made and presented in the 1986 Five Year Dam Safety Inspection report. The assumption that the upstream rockfill was free-draining with respect to rapid drawdown was affirmed.

E. Stability Conditions, Minimum Criteria, and Calculated Factors of Safety

The stability conditions, minimum criteria, and the calculated factors of safety are presented in the following table. The minimum criteria factors of safety are from: “Engineering and Design Stability of Earth and Rockfill Dams,” EM1110-2-1902, by the Corps of Engineers, April 1, 1970.

For the earthquake deformation analysis, the criterion adopted is that the displacement must not be great enough to lower the crest of the dam below the maximum normal storage elevation in the case of occurrence of the MCE.

Stability analyses were performed for the maximum dam section with the crest at elevation 4660 to allow for the original camber. Pool elevations used in the analysis are elevation 4640, 10 feet above normal maximum operating level, PMF pool elevation 4646, and partial pool elevations 4340, 4465, and 4565.

Analyses were performed for full suites of possible failure surfaces for each of the loading conditions listed above. For each static loading case, we found a surface with a lowest factor of safety and bounded above and below with more stable slip surfaces. To determine the yield accelerations for the earthquake deformation analysis, the same procedure was used. Earthquake time-histories and displacement analyses were performed on only the most critical surfaces (based on the results of the yield acceleration analyses) that, based on their location relative to the crest, adversely affect the freeboard of the dam.

F. Summary of Results - Embankment

The detailed results of the analyses were presented on Figures VII-1 and VII-2 in the HTA 1991 report, and those figures are reproduced as Figures D-3 and D-4 in this Appendix. A Summary of the results is presented in the table following.

An SDA was performed on the downstream failure surface with the lowest yield acceleration (Figure D-3, Case 3, Surface G). The maximum expected displacement was calculated to be 0.01 feet.

On the upstream slope, the failure surface with the lowest yield acceleration (Figure D-4, Case 8, Surface E) was judged to not adversely affect the freeboard of the dam if displacement occurred. Therefore, an SDA was performed on the failure surface with next lowest yield acceleration, Surface D with water at Elevation 4465. The maximum expected displacement was calculated to be 0.01 feet.

The results of these stability and displacement analyses were reviewed as part of this (2001) Inspection. The results indicate that the dam has satisfactory factors of safety for all static loading conditions and that the deformations under earthquake loading are expected to be small and will not reduce the freeboard. The seismicity used for the displacement analysis is judged to be conservative and appropriate.

References

Cooley, J. W., and Tukey, J. W., 1965, “An Algorithm for the Machine Calculation of Complex Fourier Series,” Mathematics of Computation, Vol. 19, No. 90, pp. 297-301.

Harlan Miller Tait Associates, 1984, Stability Investigation, Big Hole Dam.

Harlan Miller Tait Associates, 1986, Five-Year Dam Safety Inspection Report, Big Hole Dam.

Harlan Tait Associates, 1991, Five-Year Dam Safety Inspection Report, Big Hole Dam.

McCreary Koretsky Engineers, 1962, “Big Hole Dam Engineering Data,” dated March, 1962.

McCreary Koretsky Engineers, 1968, “Placer County Water Agency, Middle Fork American River Project, Big Hole Dam, Sections and Details,” dated January, 1968.

Sadigh, K.;Chang; Egan; Makdisi; Youngs (Geomatrix) *Attenuation Relationships for Shallow Crustal Earthquakes Based on California Strong Motion Data.* Seismological Research Letters, Volume 68, Number 1; January/February 1997, Seismological Society of America

Case	Slope/Condition	Min. Criteria F.S.	Min. Computed F.S.
1	Downstream - Pool Elev. 4640, 10 feet above Normal Maximum Operating level	1.5	1.47
2	Downstream/PMF Pool Elev. 4646	1.4	1.47
3	Downstream - Pool Elev. 4640 with Seismic	N. A.	Displacement 0.01 ft. Yield Accel. 0.22
4	Upstream - Pool Elev. 4640	1.5	2.33
5	Upstream - PMF Pool Elev. 4646	1.5	2.34
6	Upstream Pool Elev. 4640 with Seismic	N.A.	Max. Displacement 0.01 ft.- Minimum Yield Accel. 0.30
7	Upstream: Pool Elev. 4340 Pool Elev. 4465 Pool Elev. 4565	1.5	1.98 1.88 2.10
8	Upstream w/ Seismic: Pool El. 4340 Pool Elev. 4465 Pool Elev. 4565	N. A.	Min. Yield Accel's.0.34 0.25 0.24
9*	Upstream/Rapid Drawdown from Normal Maximum Operating Pool to Elev. 4340	1.2	1.95

*Results of Analysis taken from 1986 Five Year Dam Safety Inspection Report (HMTA, 1986).

Attachment 2
Example of Summary of Embankment Stability Analysis

TABLE 5.2.1 - MATERIAL PROPERTIES
Stability Analysis of Embankments
SAMPLE Project

Material Description	γ_{sat} (pcf)	γ_{dry} (pcf)	Φ' (deg.)	c' (tsf)
Lower Reservoir				
Random Fill	147	135	40	0
Compacted Rockfill	144	130	45	0
Filter	141	125	35	0
Clay Core	134	113	25	0
Silt Core	140	—	35	0
Sand/Gravel Foundation	141	125	35	0
Red Silt Foundation	140	—	40	0
Berm Fill	132	110	30	0
Upper Reservoir Dike				
Random Fill	147	135	40	0
Core/Random Fill	147	135	40	0
Filter	141	125	35	0
Sand/Gravel Foundation	141	125	35	0

γ_{sat} = saturated (total) unit weight (pcf)
γ_{dry} = dry unit weight (pcf)
Φ' = effective stress friction angle (degrees)
c' = effective stress cohesion intercept (tsf)

TABLE 5.2.3 - FACTORS OF SAFETY
Lower Reservoir Sta. 12+00
Sample Project

LOWER RESERVOIR DAM EMBANKMENT[1] STA.12+00						
Load Case	Description	Reservoir Elevation (feet)	Factor of Safety			
			Downstream Slope		Upstream Slope	
			Calc.	Req'd	Calc.	Req'd
I	Normal maximum pool with steady seepage	900.5	1.74 2.44[2]	1.5	1.95 2.13[2]	1.5
II	Flood surcharge (PMF)	908.5	1.66	1.4	N/A	N/A
III	Rapid drawdown	860.0	N/A	N/A	1.51	1.1
IVa	Normal maximum pool w/earthquake[3]	900.5	1.25	1.0	N/A	N/A
IVb	Rapid drawdown w/earthquake[3]	860.0	N/A	N/A	1.03	1.0

1. From: Second Safety Inspection Report, Supplement 2, dated February 1988.
2. Based on infinite slope.
3. Pseudo-static earthquake coefficient, a_h = 0.10g.

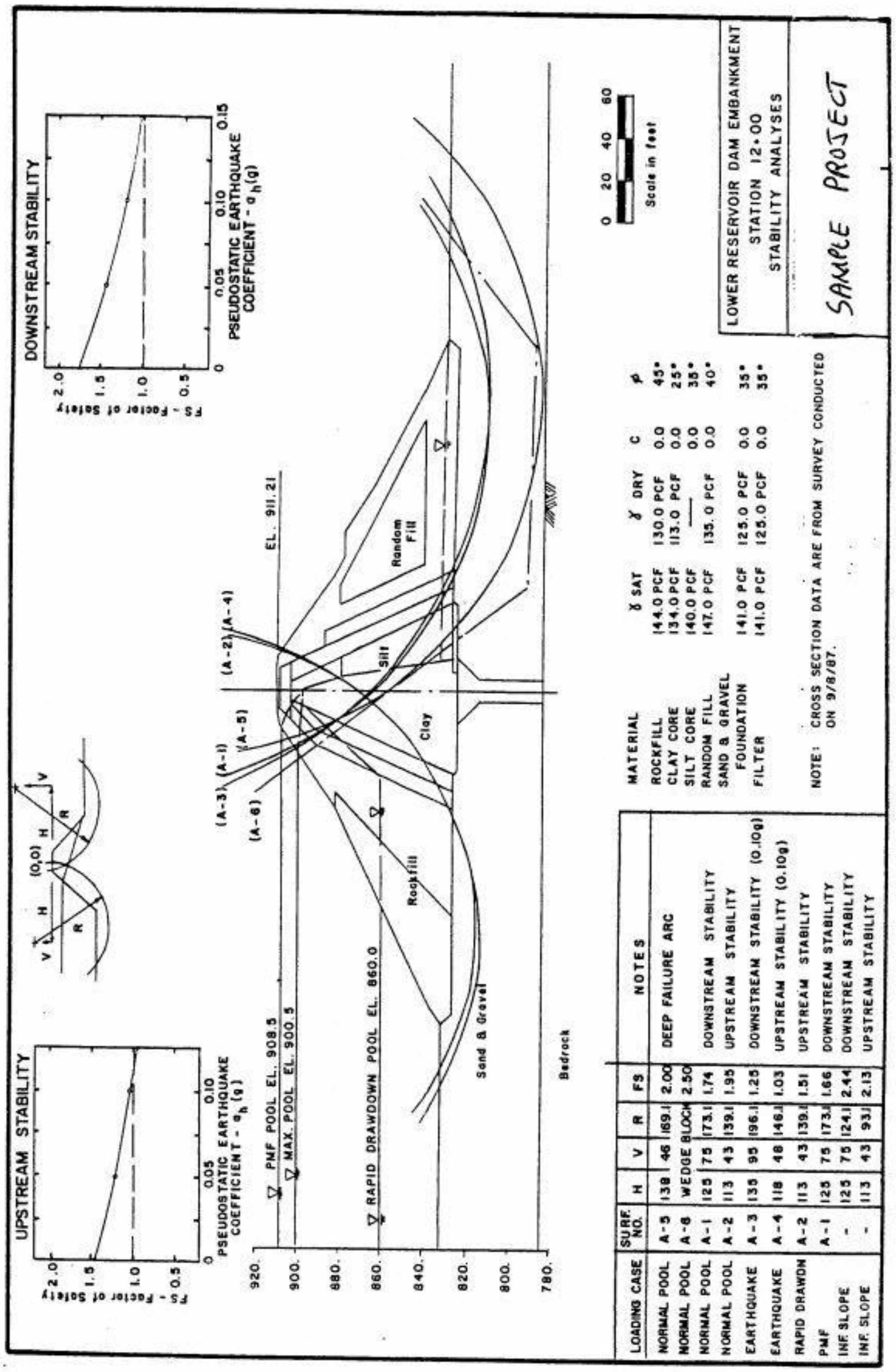

UPSTREAM STABILITY
FS - Factor of Safety
2.0
1.5
1.0
0.5
0
0.05
0.10
PSEUDOSTATIC EARTHQUAKE COEFFICIENT - a_h (g)
V
H
(0,0)
R
DOWNSTREAM STABILITY
FS - Factor of Safety
2.0
1.5
1.0
0.5
0
0.05
0.10
0.15
PSEUDOSTATIC EARTHQUAKE COEFFICIENT - a_h(g)
(A-3)
(A-1)
(A-5)
(A-6)
(A-2)
(A-4)
920.
900.
880.
860.
840.
820.
800.
780.
PMF POOL EL. 908.5
MAX. POOL EL. 900.5
EL. 911.21
RAPID DRAWDOWN POOL EL. 860.0
Rockfill
Clay
Silt
Random Fill
Sand & Gravel
Bedrock
LOADING CASE | SURF. NO. | H | V | R | FS | NOTES
NORMAL POOL | A-5 | 138 | 46 | 169.1 | 2.00 | DEEP FAILURE ARC
NORMAL POOL | A-6 | WEDGE BLOCK | 2.50
NORMAL POOL | A-1 | 125 | 75 | 173.1 | 1.74 | DOWNSTREAM STABILITY
NORMAL POOL | A-2 | 113 | 43 | 139.1 | 1.95 | UPSTREAM STABILITY
EARTHQUAKE | A-3 | 135 | 95 | 196.1 | 1.25 | DOWNSTREAM STABILITY (0.10g)
EARTHQUAKE | A-4 | 118 | 48 | 146.1 | 1.03 | UPSTREAM STABILITY (0.10g)
RAPID DRAWDN | A-2 | 113 | 43 | 139.1 | 1.51 | UPSTREAM STABILITY
PMF | A-1 | 125 | 75 | 173.1 | 1.66 | DOWNSTREAM STABILITY
INF. SLOPE | - | 125 | 75 | 124.1 | 2.44 | DOWNSTREAM STABILITY
INF. SLOPE | - | 113 | 43 | 93.1 | 2.13 | UPSTREAM STABILITY
MATERIAL | γ SAT | γ DRY | C | φ
ROCKFILL | 144.0 PCF | 130.0 PCF | 0.0 | 45°
CLAY CORE | 134.0 PCF | 113.0 PCF | 0.0 | 25°
SILT CORE | 140.0 PCF | — | 0.0 | 35°
RANDOM FILL | 147.0 PCF | 135.0 PCF | 0.0 | 40°
SAND & GRAVEL FOUNDATION | 141.0 PCF | 125.0 PCF | 0.0 | 35°
FILTER | 141.0 PCF | 125.0 PCF | 0.0 | 35°
NOTE: CROSS SECTION DATA ARE FROM SURVEY CONDUCTED ON 9/8/87.
0 20 40 60
Scale in feet
LOWER RESERVOIR DAM EMBANKMENT
STATION 12+00
STABILITY ANALYSES
SAMPLE PROJECT

FIGURE D.5.2.1

TABLE D.5.2.4 - Factors of Safety
Upper Reservoir Sta. 21 + 50
Sample Project

UPPER RESERVOIR DIKE[1] STA. 21+50						
Load Case	Description	Reservoir Elevation (feet)	Factor of Safety			
			Downstream Slope		Upstream Slope	
			Calc.	Req'd	Calc.	Req'd
I	Normal maximum pool with steady seepage	2003	2.31 2.00[2]	1.5	2.97 1.24[2]	1.5
III	Rapid drawdown	1940	N/A	N/A	1.84	1.1
IIIa	Normal maximum pool w/earthquake[3]	2003	1.56	1.0	N/A	N/A
IIIb	Rapid drawdown w/earthquake[3]	1940	N/A	N/A	1.24	1.0

1. From: Second Safety Inspection Report, Supplement 2, dated February 1988.
2. Based on infinite slope.
3. Pseudo-static earthquake coefficient, $a_h = 0.10g$.

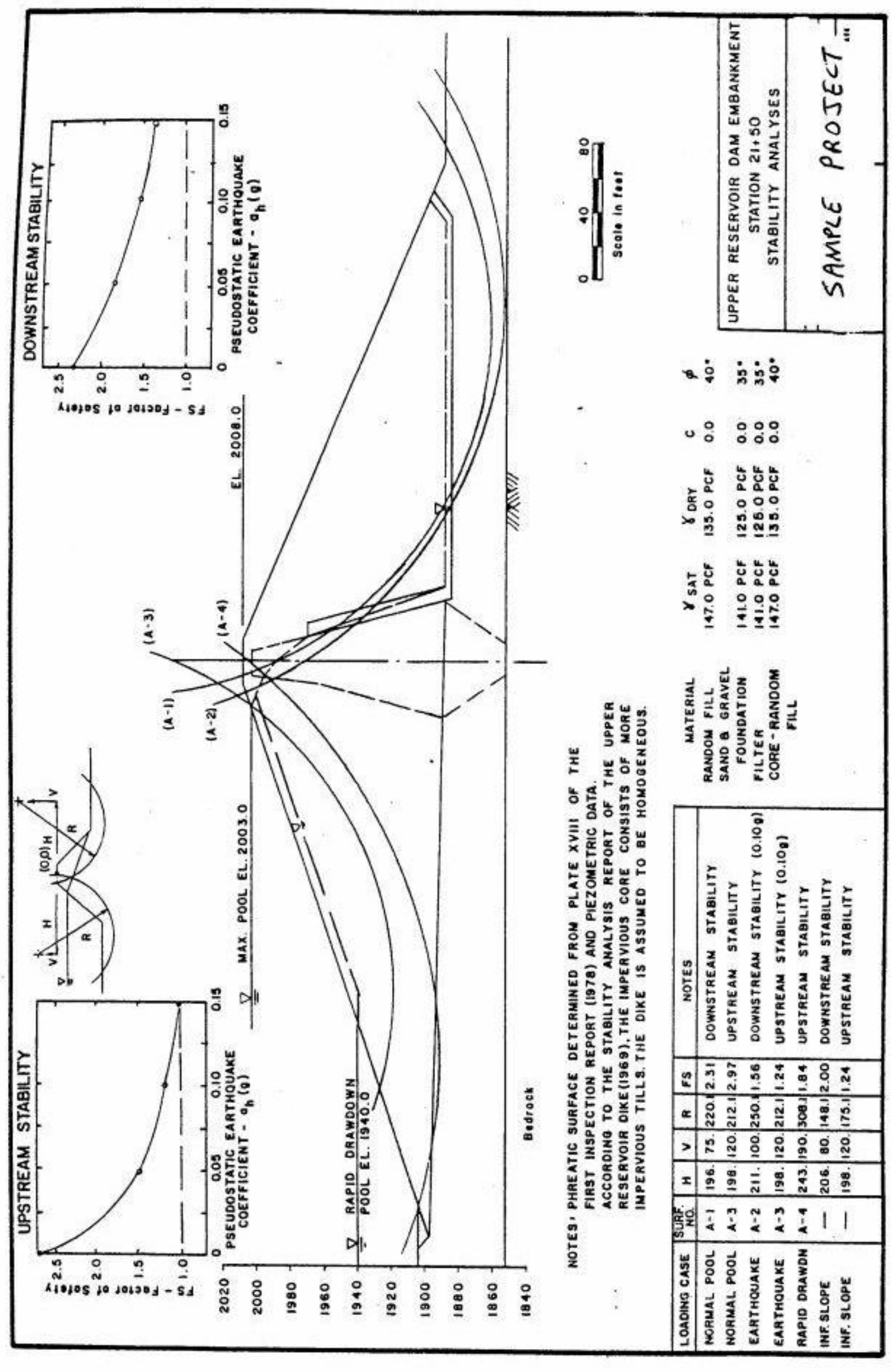

UPSTREAM STABILITY
FS - Factor of Safety
PSEUDOSTATIC EARTHQUAKE COEFFICIENT - a_h (g)
DOWNSTREAM STABILITY
MAX. POOL EL. 2003.0
EL. 2008.0
RAPID DRAWDOWN POOL EL. 1940.0
(A-1)
(A-2)
(A-3)
(A-4)
Bedrock
NOTES: PHREATIC SURFACE DETERMINED FROM PLATE XVIII OF THE FIRST INSPECTION REPORT (1978) AND PIEZOMETRIC DATA. ACCORDING TO THE STABILITY ANALYSIS REPORT OF THE UPPER RESERVOIR DIKE (1969), THE IMPERVIOUS CORE CONSISTS OF MORE IMPERVIOUS TILLS. THE DIKE IS ASSUMED TO BE HOMOGENEOUS.
Scale in feet
LOADING CASE | SURF. NO. | H | V | R | FS | NOTES
NORMAL POOL | A-1 | 196. | 75. | 220.1 | 2.31 | DOWNSTREAM STABILITY
NORMAL POOL | A-3 | 198. | 120. | 212.1 | 2.97 | UPSTREAM STABILITY
EARTHQUAKE | A-2 | 211. | 100. | 250.1 | 1.56 | DOWNSTREAM STABILITY (0.10g)
EARTHQUAKE | A-3 | 198. | 120. | 212.1 | 1.24 | UPSTREAM STABILITY (0.10g)
RAPID DRAWDN | A-4 | 243. | 190. | 308.1 | 1.84 | UPSTREAM STABILITY
INF. SLOPE | — | 206. | 80. | 148.1 | 2.00 | DOWNSTREAM STABILITY
INF. SLOPE | — | 198. | 120. | 175.1 | 1.24 | UPSTREAM STABILITY
MATERIAL | γ SAT | γ DRY | C | φ
RANDOM FILL | 147.0 PCF | 135.0 PCF | 0.0 | 40°
SAND & GRAVEL FOUNDATION | 141.0 PCF | 125.0 PCF | 0.0 | 35°
FILTER | 141.0 PCF | 126.0 PCF | 0.0 | 35°
CORE - RANDOM FILL | 147.0 PCF | 135.0 PCF | 0.0 | 40°
UPPER RESERVOIR DAM EMBANKMENT
STATION 21+50
STABILITY ANALYSES
SAMPLE PROJECT

FIGURE D.5.2.3

Attachment 3
Example of Summary of Structural Stability Analysis

VALUES AND ASSUMPTIONS
STABILITY ANALYSIS
CONCRETE SECTIONS

1. Nomenclature:

   Effective Length = Uncracked Portion of Base

   ΣF_H = Summation of Horizontal Forces - Kips

   ΣF_V = Summation of Vertical Forces - Kips

   ΣM_R = Summation of Resisting Moments - Kip-Ft.

   ΣM_O = Summation of Overturning Moments - Kip-Ft.

   $\frac{M_R}{M_O}$ = Factor of Safety Against Overturning

   $\frac{F_H}{F_V}$ = Coefficient of Sliding

2. Unit Weight of Concrete: 150 lbs./cu. ft.

3. Unit Weight of Water: 62.4 lbs./cu. ft.

4. Uplift Pressure:

   The base pressure was assumed to vary linearly from full head-water pressure at the upstream side to full tailwater pressure at the downstream side taken over 100% of the base area for each case analyzed.

   For analyses which included a reduction in uplift due to foundation drainage, the drains were assumed 50% effective.

   Uplift pressure at drain = TW = 0.5(HW - TW), where HW and TO are the headwater and tailwater pressures, respectively.

   Full headwater pressure over 100% of the area was assumed to extend into the concrete bedrock contact during any case where an assumed crack formed due to the existence of tension stresses in the section foundation. The pressure was assumed to vary linearly from full headwater pressure at the upstream end of the uncracked effective base length to full downstream tailwater pressure at the downstream face.

   Due to the transient or short-term nature of earthquake loading, the uplift is not changed from the pre-earthquake condition due to further propagation of a tensile crack.

   In the event of a tensile crack extending from the heel to the drain', the foundation drains were assumed of greater capacity than the crack. This will result in an uplift pressure distribution equal to that without the crack (full headwater at heel and TW + 0.5(HW-TW) at drain).

5. Lateral Water Pressure:

   Headwater pressures were computed using the full heights of water to headwater elevations over the projected height of the structures. Tailwater pressures were computed using full heights of water Co tailwater elevations for nonoverflow sections and at 60% of full value for cases where deep flow occurs over the ogee spillway, in accordance with U.S. Army Corps of Engineers EM 1110-2-2200 "Gravity Dam Design."

   Tailwater pressures were computed at 100% full value when deep flow occurs over the ogee spillway such that the structure becomes completely submerged, in accordance with data from U.S. Bureau of Reclamation presented in Open Channel Hydraulics by Chow, Ven Te (1959). Figures 14-17 and 14-18.

6. Ice Load:
   5 kips per linear foot at normal water level. If the normal water level is maintained by pin flashboards, water level and ice load are assumed to be at the top of the concrete ogee.

7. Earthquake:

   An acceleration of 0.10 g was applied in a horizontal direction.

   The hydrodynamic force was determined using a method presented in Design of Small Dams, USBR, pages 336-338.

8. Resistance to Sliding:

   Where the ratio of FH/FV is greater than 0.75, the shearing resistance of the foundation to horizontal movement must be investigated using the Shear Friction Formula. The factor of safety against sliding is determined by the Shear Friction Formula as:

$$S_{g\text{-}f} = \frac{f\ V + C\ A}{H}$$

where:

f = Coefficient of the angle of internal friction of foundation material (Tan Φ = 0.75)

ΣV = Summation of vertical forces

c = Unit shearing strength at zero normal load on foundation material (0.192 ksi)

A = Area of potential failure plane (area of base in compression)

ΣH = Summation of horizontal forces

According to U.S. Army Corps of Engineers, Engineering Technical Letter No. 1110-2-256, dated June 24, 1981, which is intended to supersede portions of EM 1110-2-2200 "Gravity Dam Design" criteria, the minimum allowable $S_{s\text{-}f}$ for static loading conditions is 2.0, and for seismic loading conditions, 1.3. Typical values of "f" and "c" were taken from "The Sliding Stability of Dams" by Harald Link in Water Power Magazine, March, April & May, 1969.

9. Bearing Pressure:

   Maximum bearing stress = 20 tsf on bedrock (278 psi).

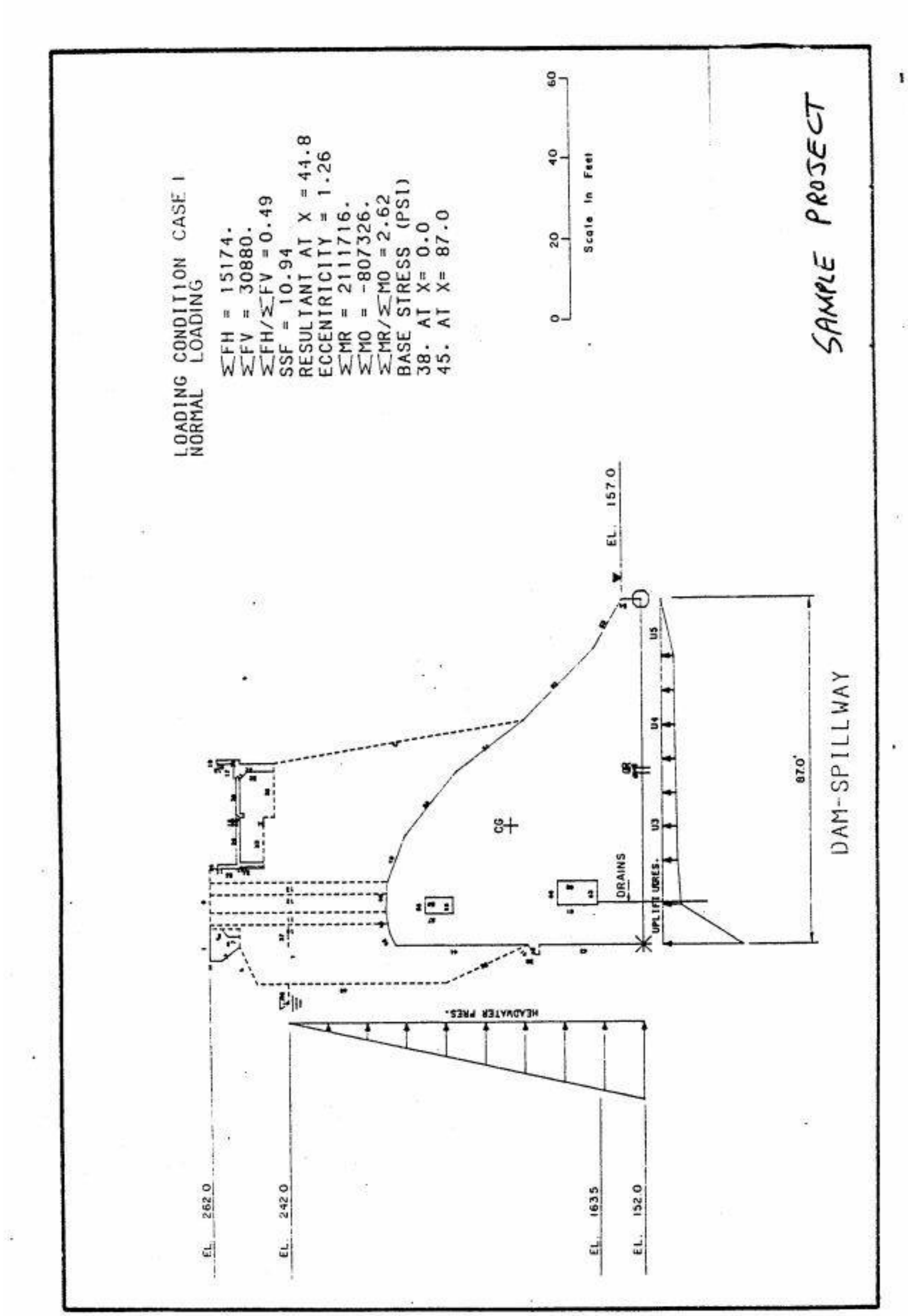
SAMPLE PROJECT
CASES USED IN STABILITY ANALYSIS OF CONCRETE STRUCTURES

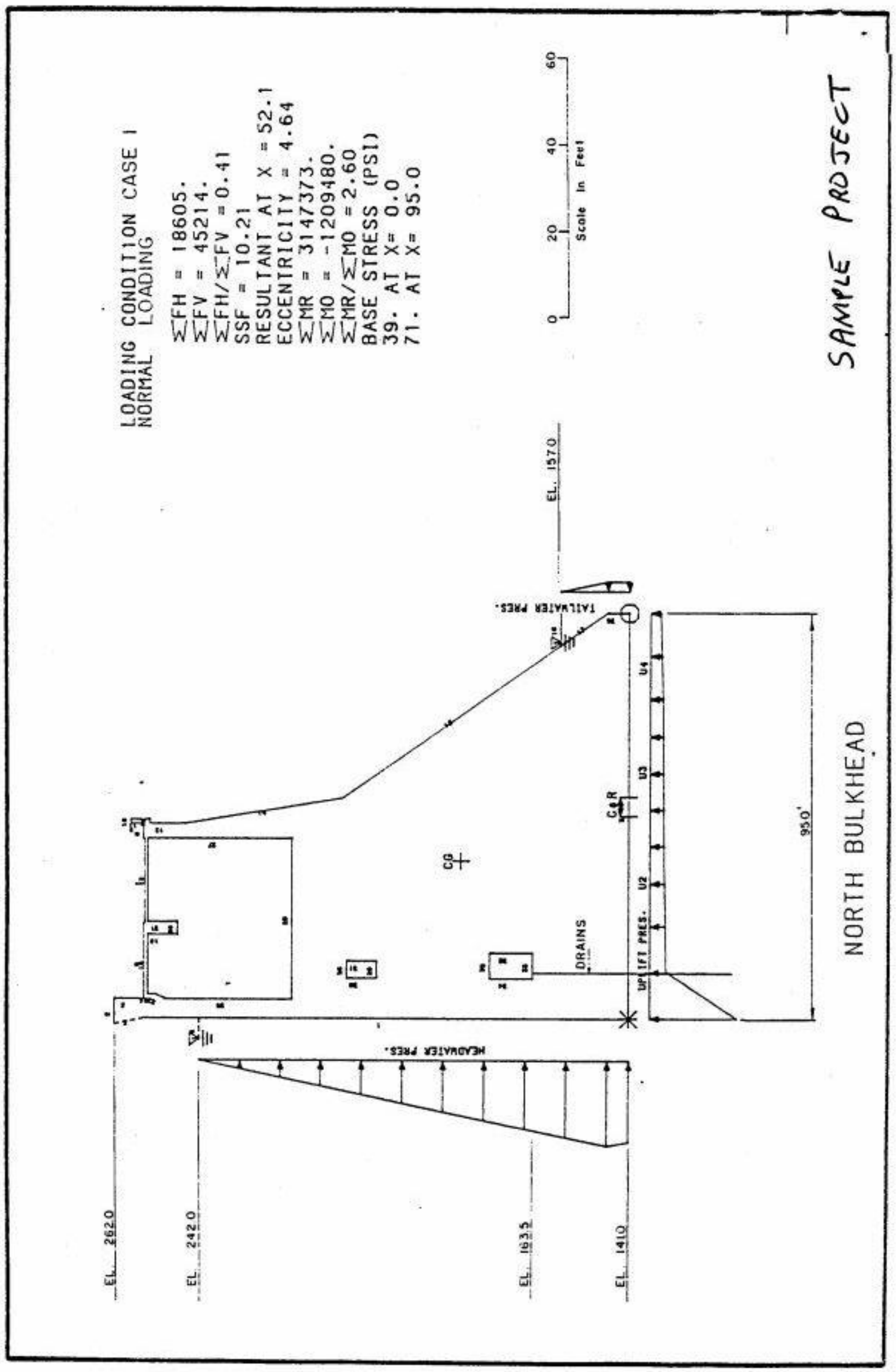
CASE I NORMAL OPERATING WATER LEVELS
H.W.L = 242.0
T.W.L = 157.0

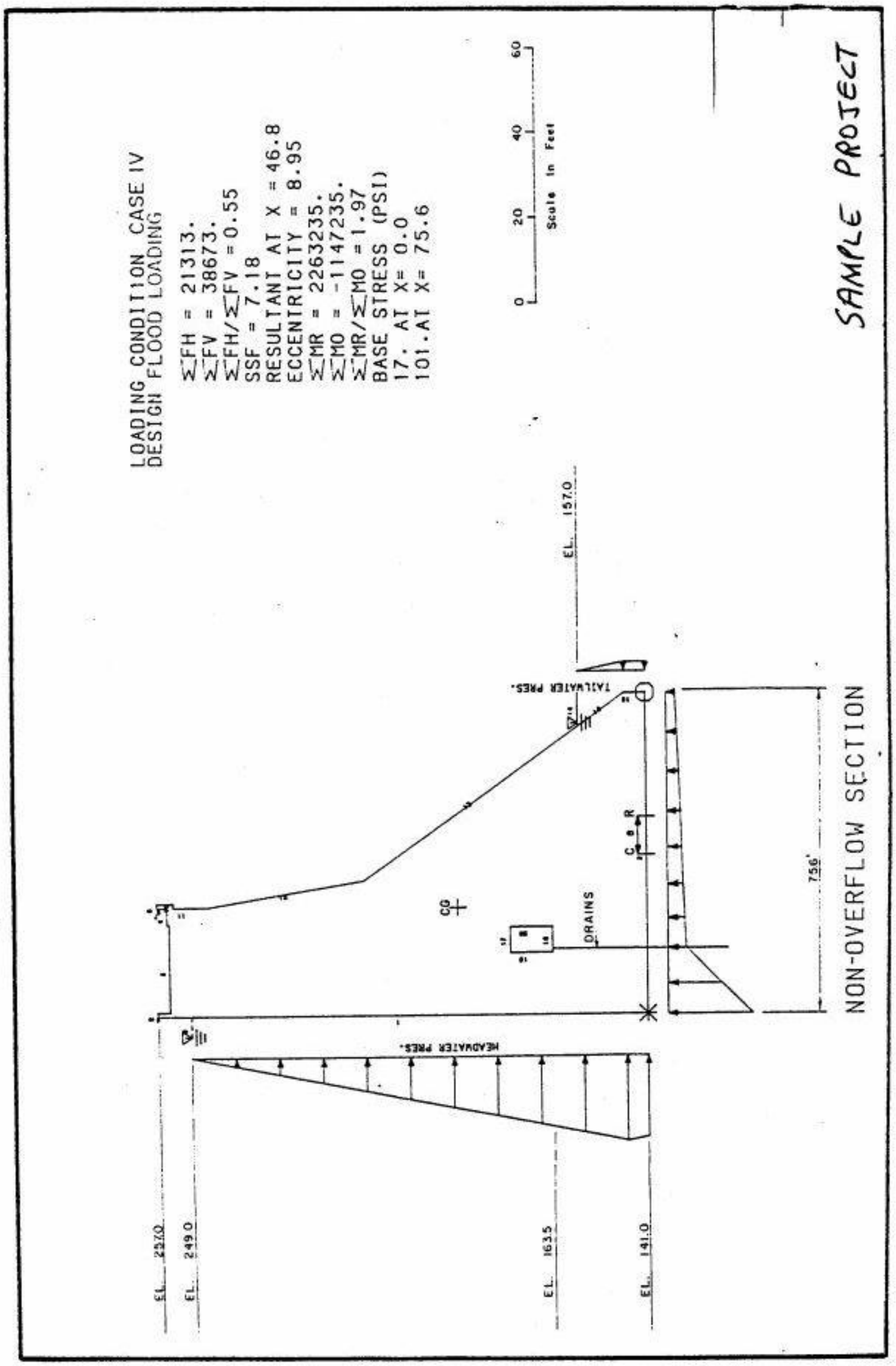
CASE II NORMAL OPERATING LEVELS WITH ICE
H.W.L = 242.0
T.W.L = 157.0
ICE LOADS 5 kips/ft

CASE III NORMAL OPERATING WATER LEVELS WITH EARTHQUAKE
Water Levels same as CASE I
Horizontal acceleration due to earthquake is 0.10g

CASE IV PROJECT DESIGN FLOOD
H.W.L = 249.0
T.W.L = 157.0


LOADING CONDITION CASE I
NORMAL LOADING
ΣFH = 15174.
ΣFV = 30880.
ΣFH/ΣFV = 0.49
SSF = 10.94
RESULTANT AT X = 44.8
ECCENTRICITY = 1.26
ΣMR = 2111716.
ΣMO = -807326.
ΣMR/ΣMO = 2.62
BASE STRESS (PSI)
38. AT X= 0.0
45. AT X= 87.0
0
20
40
60
Scale In Feet
EL. 157.0
EL. 262.0
EL. 242.0
EL. 163.5
EL. 152.0
HEADWATER PRES.
UPLIFT PRES.
DRAINS
CG
U3
U4
U5
87.0'
DAM-SPILLWAY
SAMPLE PROJECT

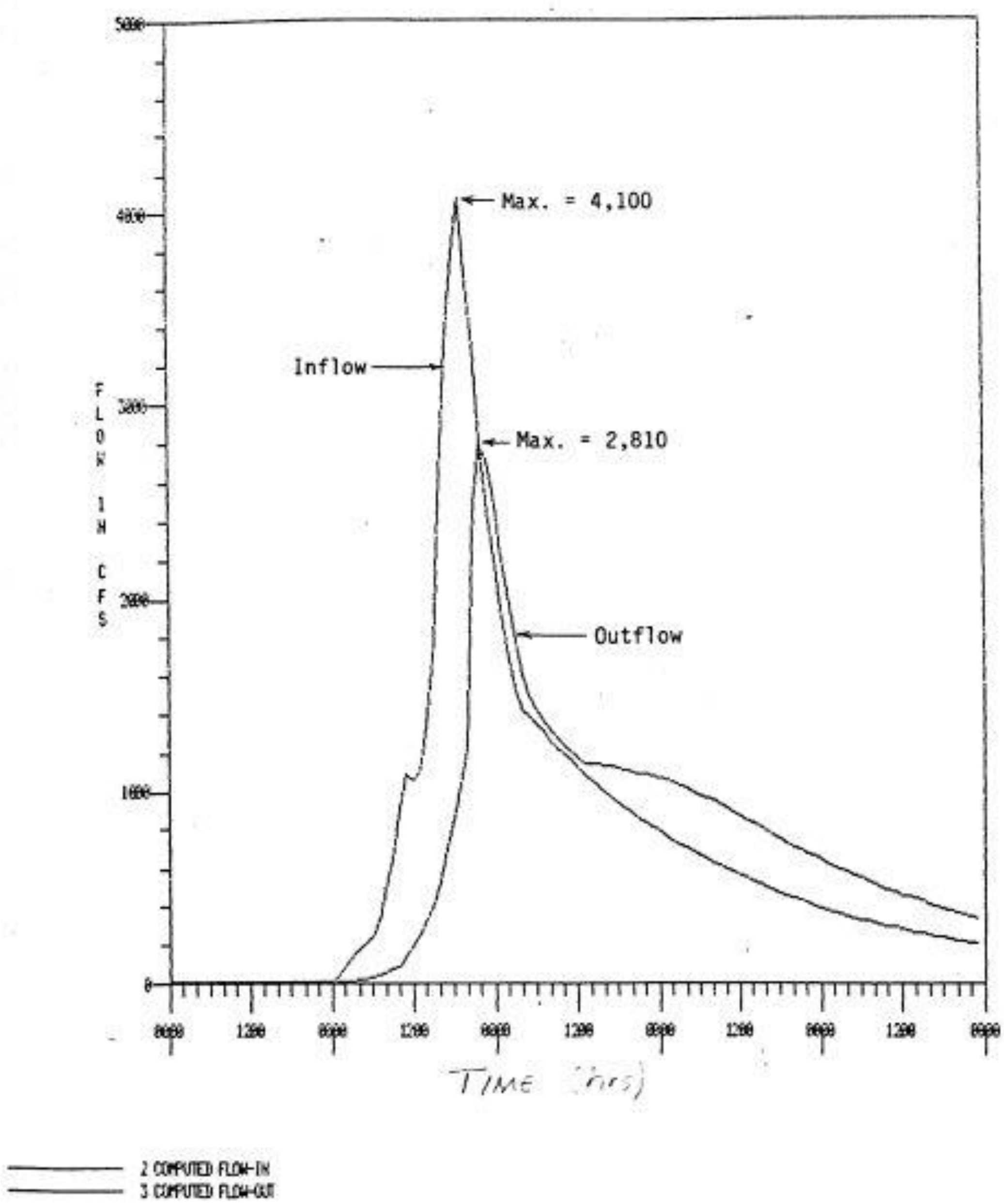

LOADING CONDITION CASE 1
NORMAL LOADING
ΣFH = 18605.
ΣFV = 45214.
ΣFH/ΣFV = 0.41
SSF = 10.21
RESULTANT AT X = 52.1
ECCENTRICITY = 4.64
ΣMR = 3147373.
ΣMO = -1209480.
ΣMR/ΣMO = 2.60
BASE STRESS (PSI)
39. AT X= 0.0
71. AT X= 95.0
0 20 40 60
Scale In Feet
SAMPLE PROJECT
EL. 1570
TAILWATER PRES.
HEADWATER PRES.
UPLIFT PRES.
DRAINS
CG
U2
U3
U4
950'
NORTH BULKHEAD
EL. 2620
EL. 2420
EL. 1635
EL. 1410


LOADING CONDITION CASE IV
DESIGN FLOOD LOADING
ΣFH = 21313.
ΣFV = 38673.
ΣFH/ΣFV = 0.55
SSF = 7.18
RESULTANT AT X = 46.8
ECCENTRICITY = 8.95
ΣMR = 2263235.
ΣMO = -1147235.
ΣMR/ΣMO = 1.97
BASE STRESS (PSI)
17. AT X= 0.0
101. AT X= 75.6
0
20
40
60
Scale In Feet
SAMPLE PROJECT
EL. 157.0
TAILWATER PRES.
CG
DRAINS
75.6'
NON-OVERFLOW SECTION
HEADWATER PRES.
EL. 257.0
EL. 249.0
EL. 163.5
EL. 141.0

SAMPLE PROJECT
STABILITY SUMMARY

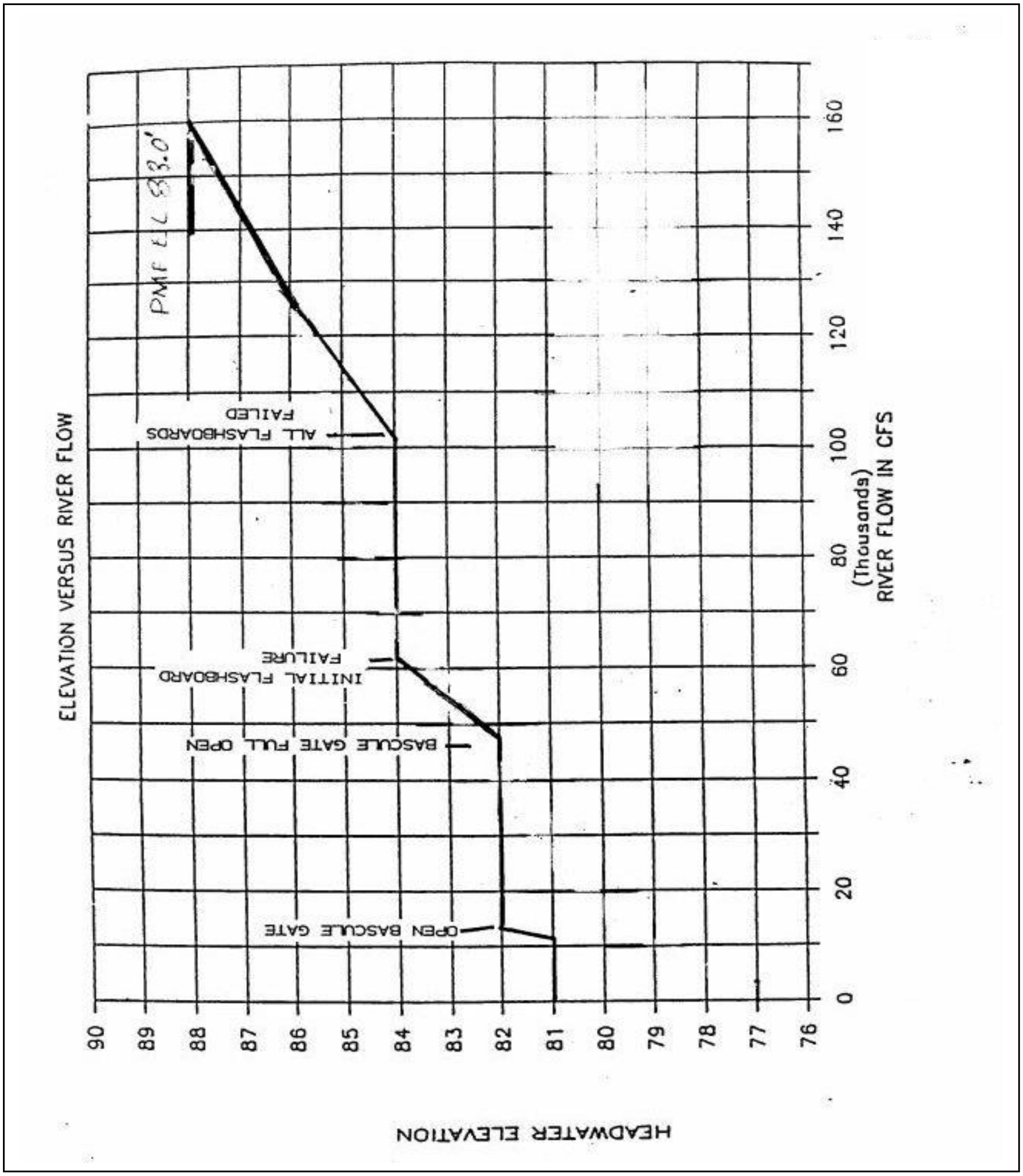
CONDITION	BASE			FH (kips)	FV (kips)	FH / FV	S_{s-f}	Resultant from Downstream	M_R	M_O	M_R / M_O	BASE STRESS (psi)	
	TOT LEN	CRK LEN	EFF LEN									Upstream	Downstream
Spillway													
CASE I	87.0	0.0	87.0	15170	30880	0.49	10.94	42.24	2112000	807300	2.62	37.5	44.7
CASE II	87. 0	0.0	87.0	15170	30880	0.50	10.73	41. 38	2112000	834000	2.53	35.1	47.1
CASE III	87.0	0.0	87.0	20440	30880	0.66	8.12	36.37	2112000	988600	2.14	20. 9	61.3
CASE IV	87.o	0.0	87.0	17610	29870	0.59	9.38	38.12	2122000	987000	2.15	25.3	54.7
North Bulkhead													
CASE I	95.0	0.0	95.0	18600	45210	0.41	10.21	37.86	3147000	1209000	2.60	38.9	71.2
CASE II	95.0	0.0	95.0	18910	45210	0.42	10.04	42.20	3147000	1239000	2.54	36.6	73.5
CASE III	95.0	0.0	95.0	26010	45210	0.58	7.3	36.33	3147000	1505000	2.09	16.2	94.0
CASE IV	95.0	0.0	95.0	21320	43980	0.48	8.86	38.76	3147000	1430000	2.20	25.2	62.1
Non-Overflow Section													
CASE I	75.6	0.0	75.6	18590	37710	0.49	8.20	32.36	2249000	1028000	2.19	32.8	82.6
CASE II	75.6	0.0	75.6	18890	37710	0.50	8.07	31.55	2249000	1058000	2.12	29.1	86.3
CASE III	75.6	1.2	74.4	25100	37710	0.67	5.99	24.80	2249000	1513000	1.71	0.0	117.3
CASE IV	75.6	0.0	75.6	21310	38670	0.55	7.18	28.80	2263000	1147000	1.97	17.0	101.1

Attachment 4
Example of Summary of Hydrologic and Hydraulic Information

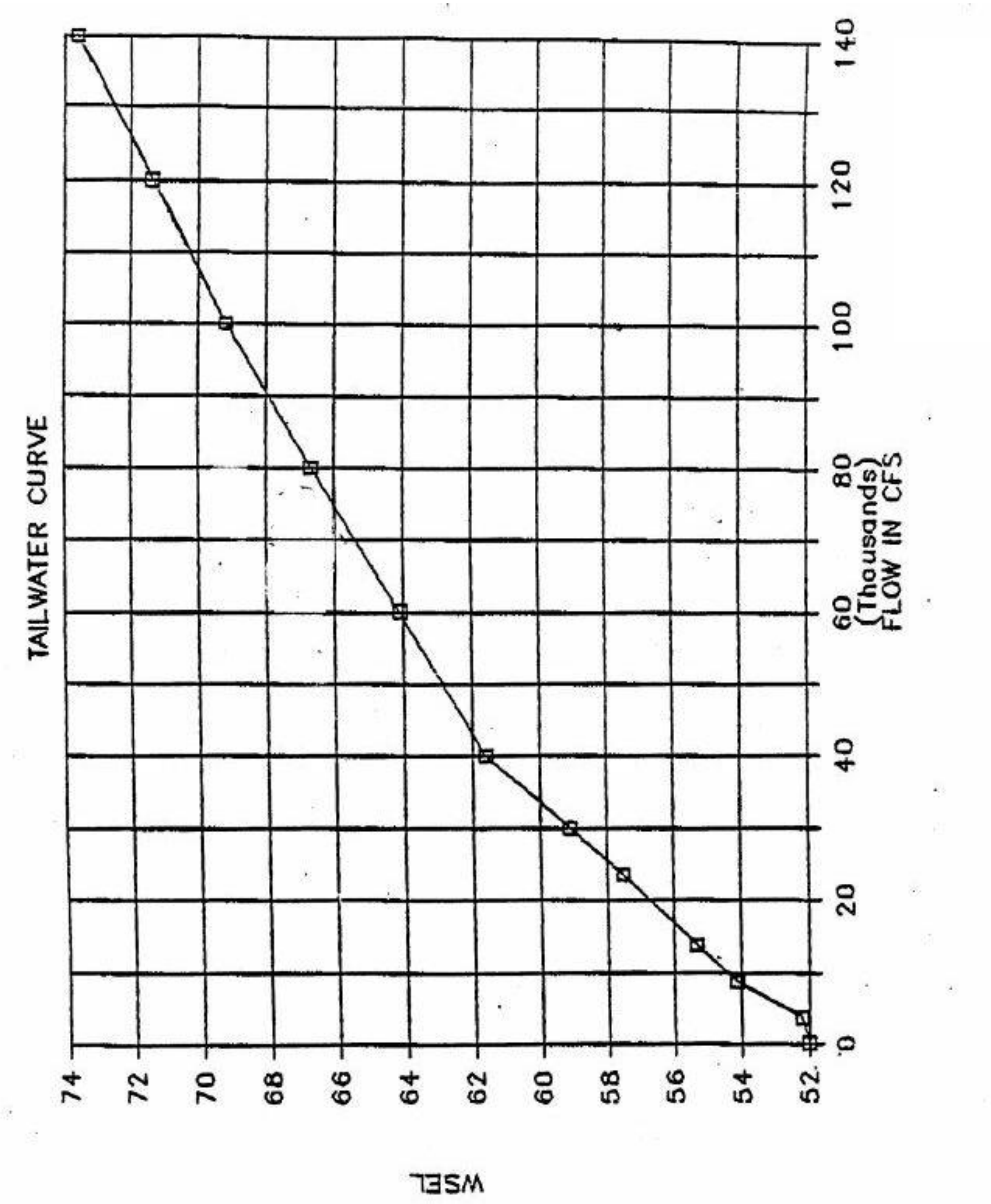


Inflow/Outflow Hydrograph
for General Storm PMF

SAMPLE PROJECT



SAMPLE PROJECT
SPILLWAY RATING CURVE



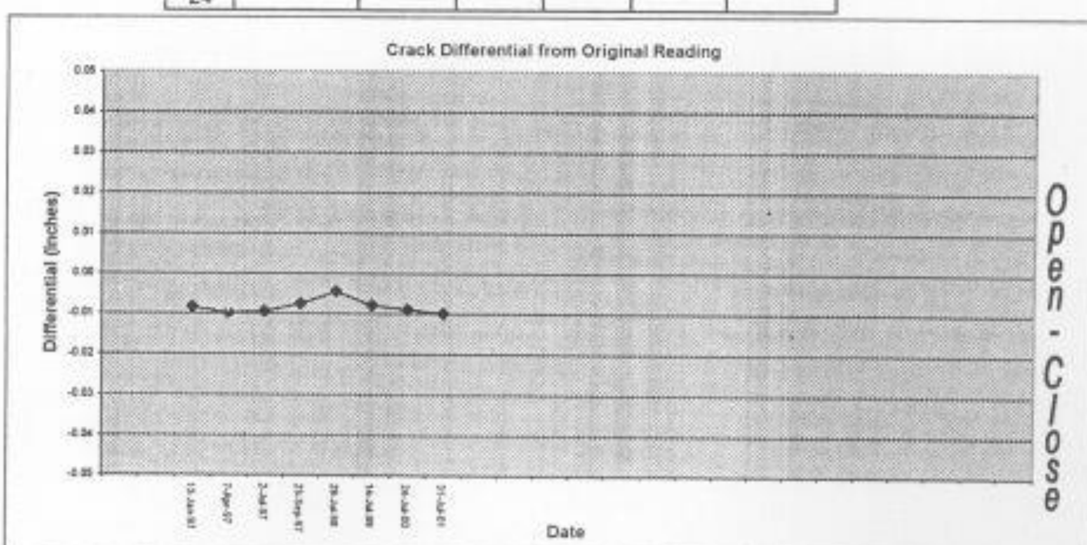
SAMPLE PROJECT
TAILWATER RATING CURVE

Attachment 5
Example of Summary of Instrumentation and Surveillance Information

SAMPLE PROJECT

Crack Measurement Station No. 1
Initial Reading: 5.900
Date: 12-29-81

No.	Date	Reading By	Measurements (Inches)			Diff. From Original Reading
			1	2	Average	
1	13-Jan-97	HTG	5.891	5.892	5.892	-0.008
2	7-Apr-97	HTG	5.890	5.890	5.890	-0.010
3	2-Jul-97	HTG	5.890	5.891	5.891	-0.010
4	23-Sep-97	HTG	5.893	5.892	5.893	-0.008
5	28-Jul-98	HTG	5.896	5.895	5.896	-0.005
6	14-Jul-99	HTG	5.892	5.892	5.892	-0.008
7	24-Jul-00	HTG	5.891	5.891	5.891	-0.009
8	31-Jul-01	HTG	5.890	5.891	5.890	-0.010
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						



SAMPLE PROJECT – . Embankment Seepage Weir

Weir Box Location: . embankment. (Twice annually).

Date	Elevation (ft., USGS)	Weir Box Flow (inches)	Checked by:	Comments
28-Jul-97	491.01	2.50	KWL	Area below toe wet.
4-Aug-97	491.31	2.25	KWL	Area below toe wet.
12-Aug-97	491.45	2.25	KWL	Area below toe wet.
6-Nov-97	485.27	1.00	KWL	Area below toe damp.
20-May-98	491.40	1.75	KWL	
17-Jun-98	491.18	2.00	KWL	
23-Sep-98	487.12	2.00	KWL	
28-Aug-99	490.01	2.00	KWL	
15-Jun-00	490.87	2.00	KWL	
27-Aug-00	490.35	2.50	KWL	
21-May-01	487.83	1.50	KWL	
25-Aug-01	488.24	2.50	KWL	

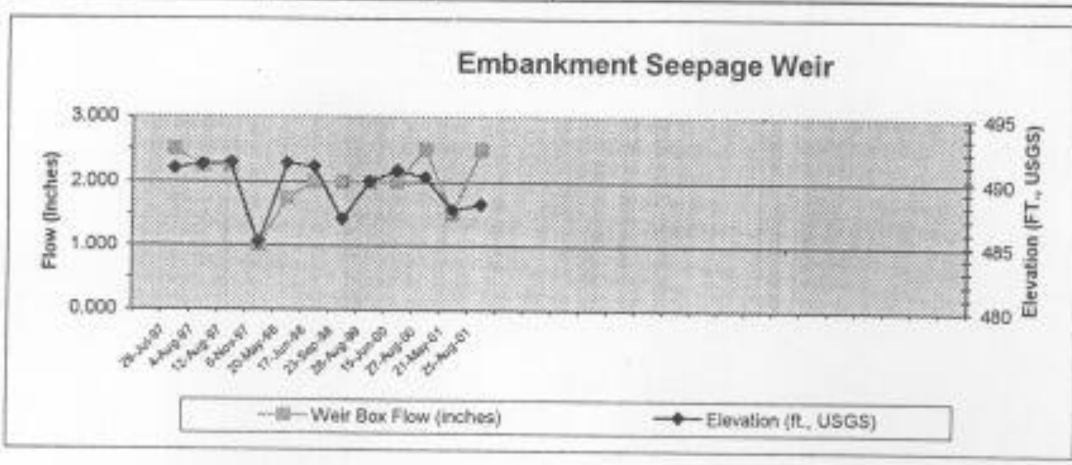
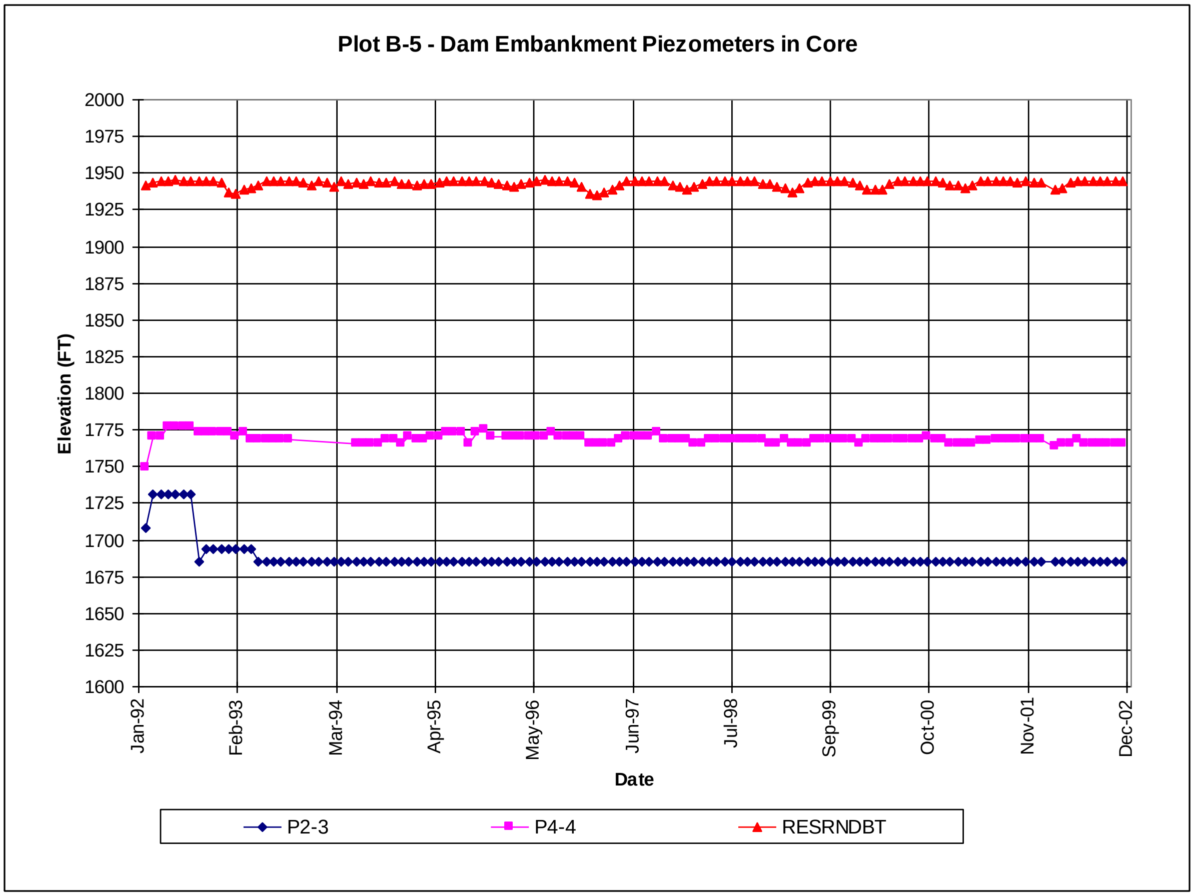


TABLE 1 - PIEZOMETER READINGS

PIEZO	DATE	PRESS (psi)	PIEZO ELEV (ft)	PIEZO	DATE	PRESS (psi)	PIEZO ELEV (ft)
P2-3	1/30/1997	0.0	1685.0	P4-4	8/30/1997	37.0	1770.5
P2-3	2/28/1997	0.0	1685.0	P4-4	9/30/1997	38.0	1772.8
P2-3	3/30/1997	0.0	1685.0	P4-4	10/30/1997	36.0	1768.2
P2-3	4/30/1997	0.0	1685.0	P4-4	11/30/1997	36.0	1768.2
P2-3	5/30/1997	0.0	1685.0	P4-4	12/30/1997	36.0	1768.2
P2-3	6/30/1997	0.0	1685.0	P4-4	1/30/1998	36.0	1768.2
P2-3	7/30/1997	0.0	1685.0	P4-4	2/28/1998	35.0	1765.9
P2-3	8/30/1997	0.0	1685.0	P4-4	3/30/1998	35.0	1765.9
P2-3	9/30/1997	0.0	1685.0	P4-4	4/30/1998	36.0	1768.2
P2-3	10/30/1997	0.0	1685.0	P4-4	5/30/1998	36.0	1768.2
P2-3	11/30/1997	0.0	1685.0	P4-4	6/30/1998	36.0	1768.2
P2-3	12/30/1997	0.0	1685.0	P4-4	7/30/1998	36.0	1768.2
P2-3	1/30/1998	0.0	1685.0	P4-4	8/30/1998	36.0	1768.2
P2-3	2/28/1998	0.0	1685.0	P4-4	9/30/1998	36.0	1768.2
P2-3	3/30/1998	0.0	1685.0	P4-4	10/30/1998	36.0	1768.2
P2-3	4/30/1998	0.0	1685.0	P4-4	11/30/1998	36.0	1768.2
P2-3	5/30/1998	0.0	1685.0	P4-4	12/30/1998	35.0	1765.9
P2-3	6/30/1998	0.0	1685.0	P4-4	1/30/1999	35.0	1765.9
P2-3	7/30/1998	0.0	1685.0	P4-4	2/28/1999	36.0	1768.2
P2-3	8/30/1998	0.0	1685.0	P4-4	3/30/1999	35.0	1765.9
P2-3	9/30/1998	0.0	1685.0	P4-4	4/30/1999	35.0	1765.9
P2-3	10/30/1998	0.0	1685.0	P4-4	5/30/1999	35.0	1765.9
P2-3	11/30/1998	0.0	1685.0	P4-4	6/30/1999	36.0	1768.2
P2-3	12/30/1998	0.0	1685.0	P4-4	7/30/1999	36.0	1768.2
P2-3	1/30/1999	0.0	1685.0	P4-4	8/30/1999	36.0	1768.2
P2-3	2/28/1999	0.0	1685.0	P4-4	9/30/1999	36.0	1768.2
P2-3	3/30/1999	0.0	1685.0	P4-4	10/30/1999	36.0	1768.2
P2-3	4/30/1999	0.0	1685.0	P4-4	11/30/1999	36.0	1768.2
P2-3	5/30/1999	0.0	1685.0	P4-4	12/30/1999	35.0	1765.9
P2-3	6/30/1999	0.0	1685.0	P4-4	1/27/2000	36.0	1768.2
P2-3	7/30/1999	0.0	1685.0	P4-4	2/29/2000	36.0	1768.2
P2-3	8/30/1999	0.0	1685.0	P4-4	3/31/2000	36.0	1768.2
P2-3	9/30/1999	0.0	1685.0	P4-4	4/27/2000	36.0	1768.2
P2-3	10/30/1999	0.0	1685.0	P4-4	5/30/2000	36.0	1768.2
P2-3	11/30/1999	0.0	1685.0	P4-4	6/27/2000	36.0	1768.2
P2-3	12/30/1999	0.0	1685.0	P4-4	7/31/2000	36.0	1768.2
P2-3	1/27/2000	0.0	1685.0	P4-4	8/30/2000	36.0	1768.2
P2-3	2/29/2000	0.0	1685.0	P4-4	9/29/2000	37.0	1770.5
P2-3	3/31/2000	0.0	1685.0	P4-4	10/30/2000	36.0	1768.2
P2-3	4/27/2000	0.0	1685.0	P4-4	11/29/2000	36.0	1768.2
P2-3	5/30/2000	0.0	1685.0	P4-4	12/27/2000	35.0	1765.9
P2-3	6/27/2000	0.0	1685.0	P4-4	2/1/2001	35.0	1765.9
P2-3	7/31/2000	0.0	1685.0	P4-4	2/28/2001	35.0	1765.9



PLOT of PIEZOMETER READINGS

SAMPLE PROJECT

Settlement Point No. 8
Initial Elev: 304.15
Date: 12-31-81

No.	Date	Survey By	All Elevations USGS Reservior Elev.	Settlement Point Elev.	Initial Elev.
1	15-Jan-97	HTG	335.87	304.15	304.15
2	8-Apr-97	HTG	335.83	304.15	304.15
3	2-Jul-97	HTG	335.96	304.16	304.15
4	23-Sep-97	HTG	332.06	304.16	304.15
5	8-Jul-98	HTG	336.01	304.15	304.15
6	14-Jul-99	HTG	336.02	304.15	304.15
7	25-Jul-00	HTG	336.08	304.15	304.15
8	31-Jul-01	HTG	336.06	304.15	304.15
9					304.15
10					304.15
11					304.15
12					304.15
13					304.15
14					304.15
15					304.15
16					304.15
17					304.15
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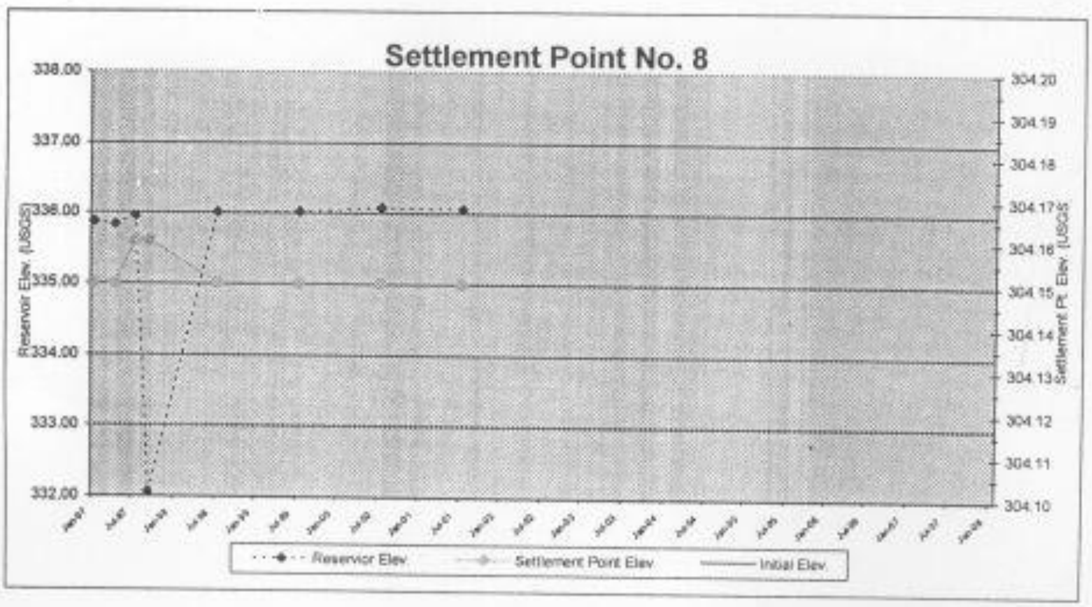
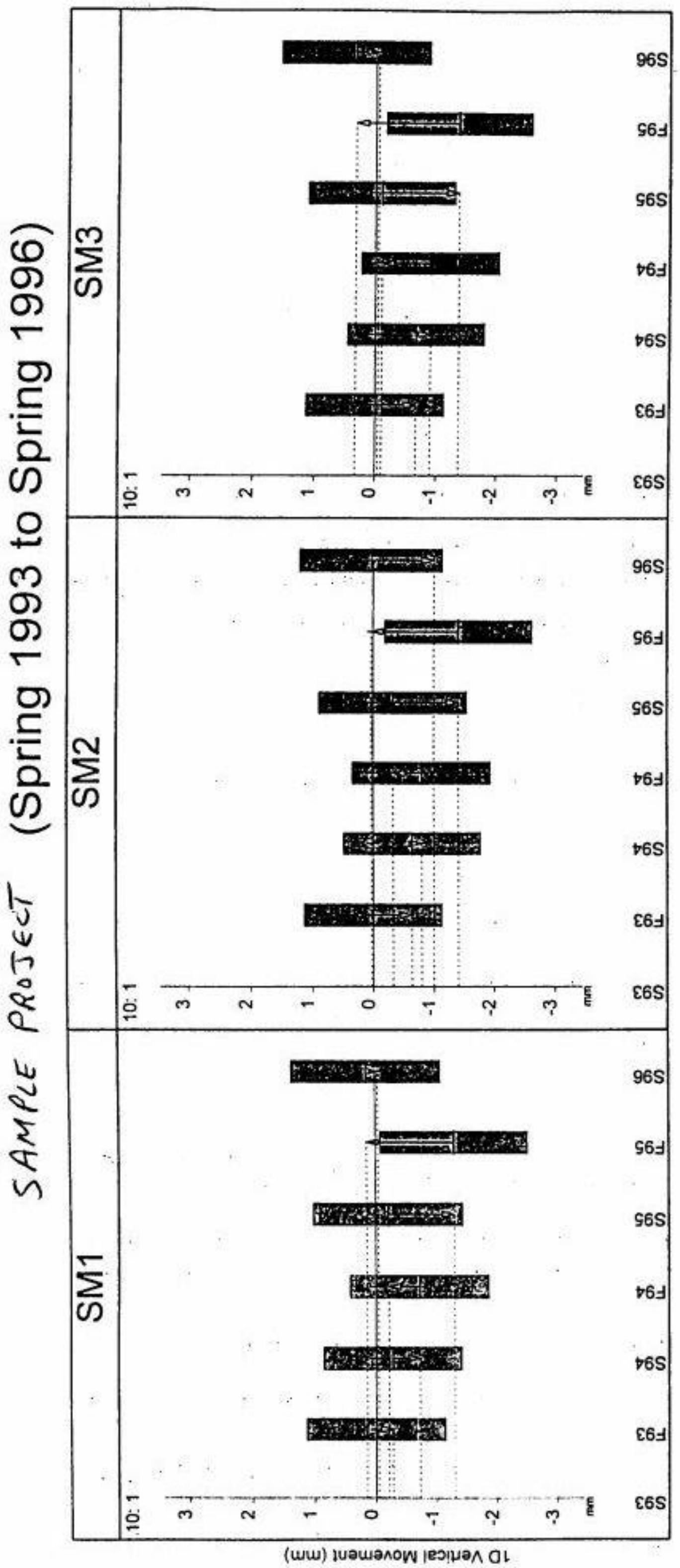
20					304.15
21					304.15
22					304.15
23					304.15
24					304.15



SAMPLE PROJECT

Summary of Vertical Movements (Spring 1993 to Spring 1996)

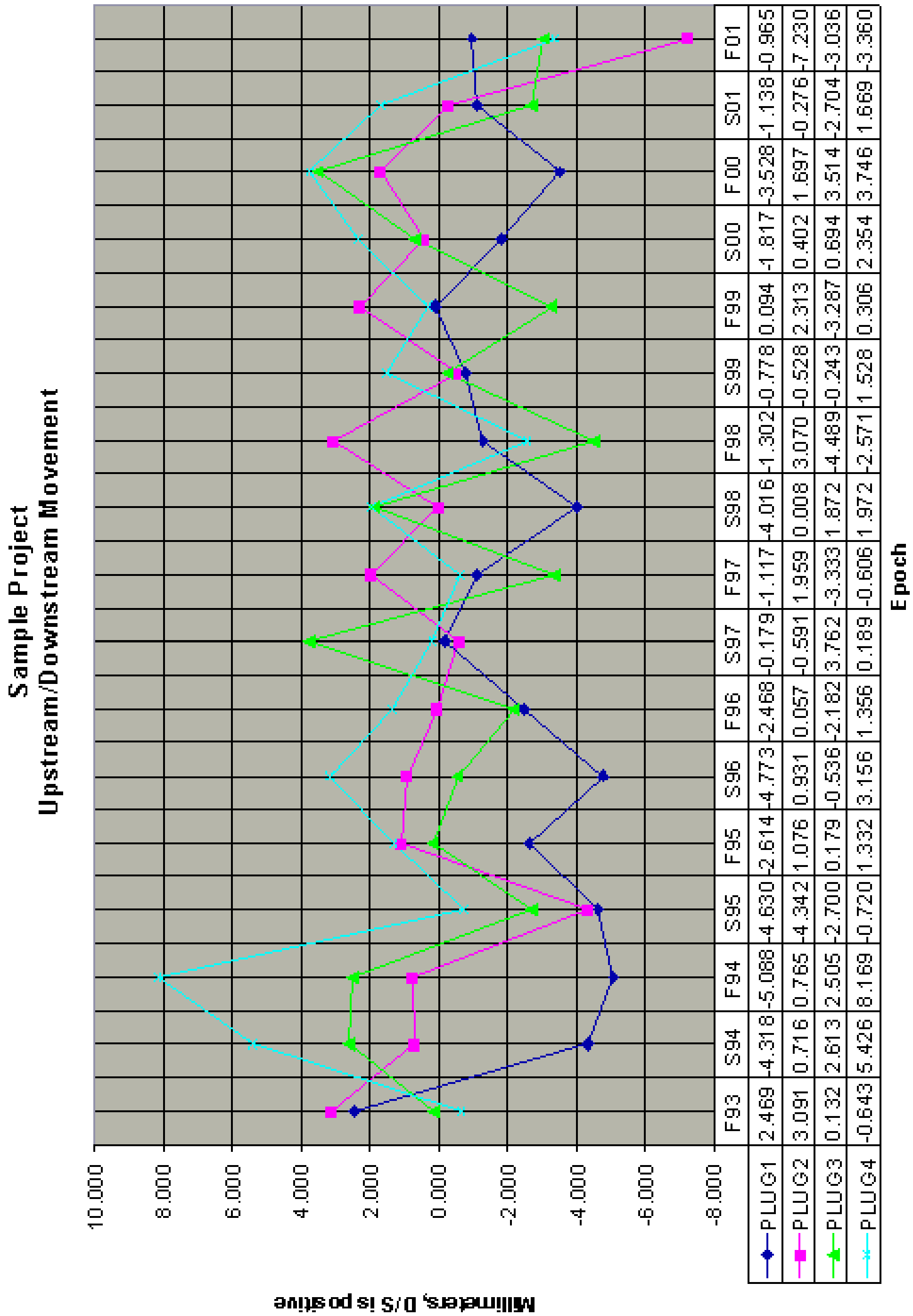
Point	To From	F93 A=> (mm)	95% Conf. Region (mm)	S94 A=> (mm)	95% Conf. Region (mm)	F94 A=^ (mm)	95% Conf. Region (mm)
SM1	S93	-0.278	1.134	-0.426	1.159	-0.212	1.143
	Incremental	-0.278	1.134	-0.444	1.133	0.511	1.142
SM2	S93	-0.641	1.130	-0.502	1.157	-0.330	1.138
	Incremental	-0.641	1.130	-0.159	1.130	0.470	1.138
SM3	S93	-0.672	1.130	-0.609	1.158	-0.105	1.136
	Incremental	-0.672	1.130	-0.234	1.128	0.801	1.135
SM4	S93	-0.94	1.140	-0.946	1.185	-0.364	1.145
	Incremental	-0.94	1.140	-0.359	1.140	0.936	1.145
SM5	S93	-1.388	1.138	-0.853	1.185	-0.399	1.143
	Incremental	-1.388	1.138	-0.183	1.138	0.807	1.143
SM6	S93	-0.887	1.136	-0.548	1.184	-0.278	1.140
	Incremental	-0.887	1.136	-0.014	1.137	0.623	1.141
SM7	S93	-0.893	1.135	-0.119	1.184	-0.196	1.138
	Incremental	-0.893	1.135	0.421	1.135	0.276	1.138
WP1	S93	0.210	0.843	-0.209	0.750	-0.111	0.853
	Incremental	0.210	0.843	-0.790	0.843	0.468	0.853
WP2	S93	0.057	0.845	1.224	1.184	0.390	0.848
	Incremental	0.057	0.845	0.815	0.845	-0.482	0.848
MM6	S93	-0.236	0.777	0.188	0.672	-0.228	0.781
	Incremental	-0.236	0.777	0.023	0.777	-0.015	0.782
MM7	S93	-0.031	0.124	0.022	0.078	-0.051	0.125
	Incremental	-0.031	0.124	-0.048	0.124	0.028	0.125


SAMPLE PROJECT (Spring 1993 to Spring 1996)
SM1
SM2
SM3
S93
F93
S94
F94
S95
F95
S96
1D Vertical Movement (mm)

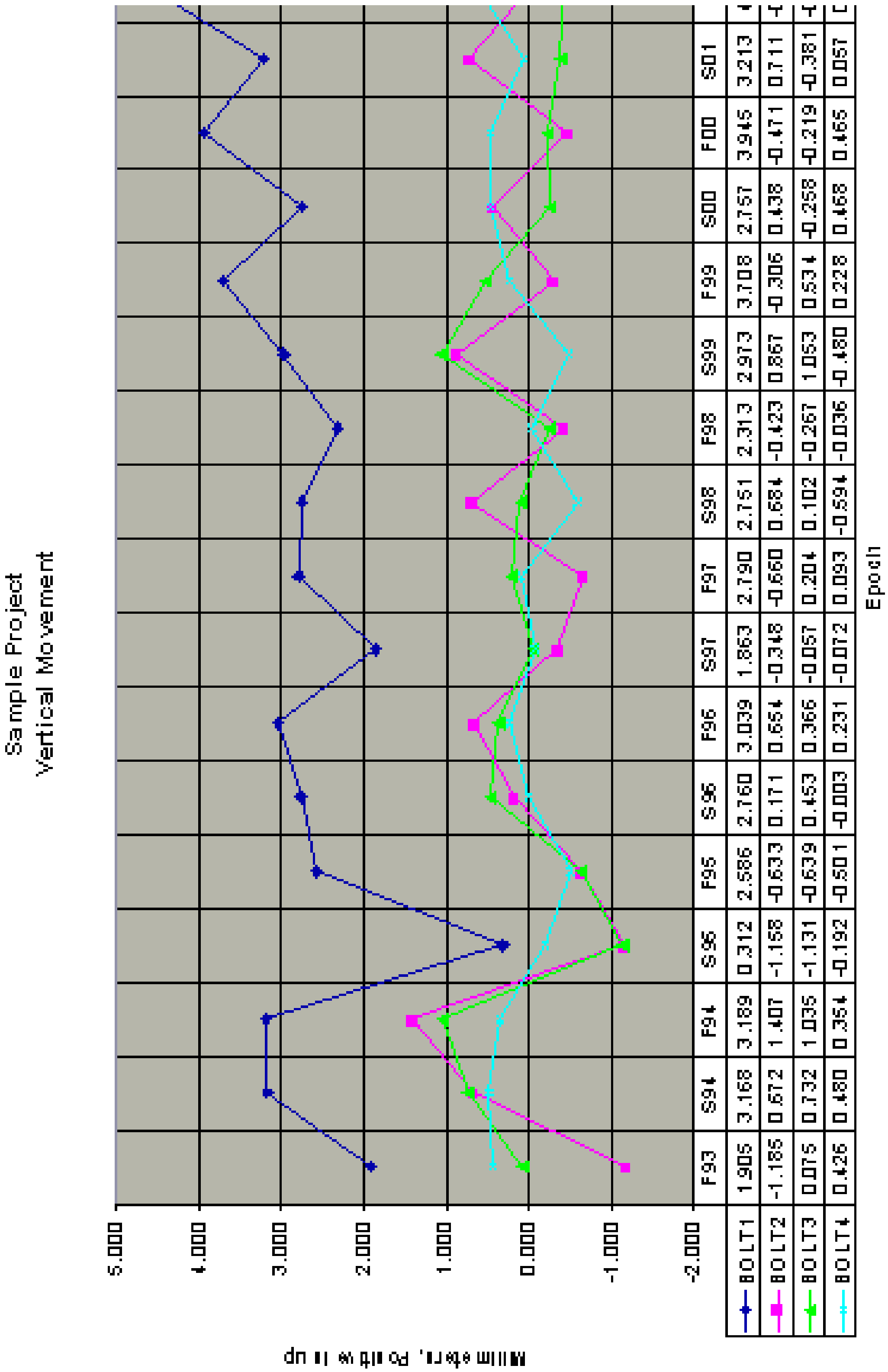
SAMPLE PROJECT

Summary of Horizontal Movements (Spring 1993 to Spring 1996)

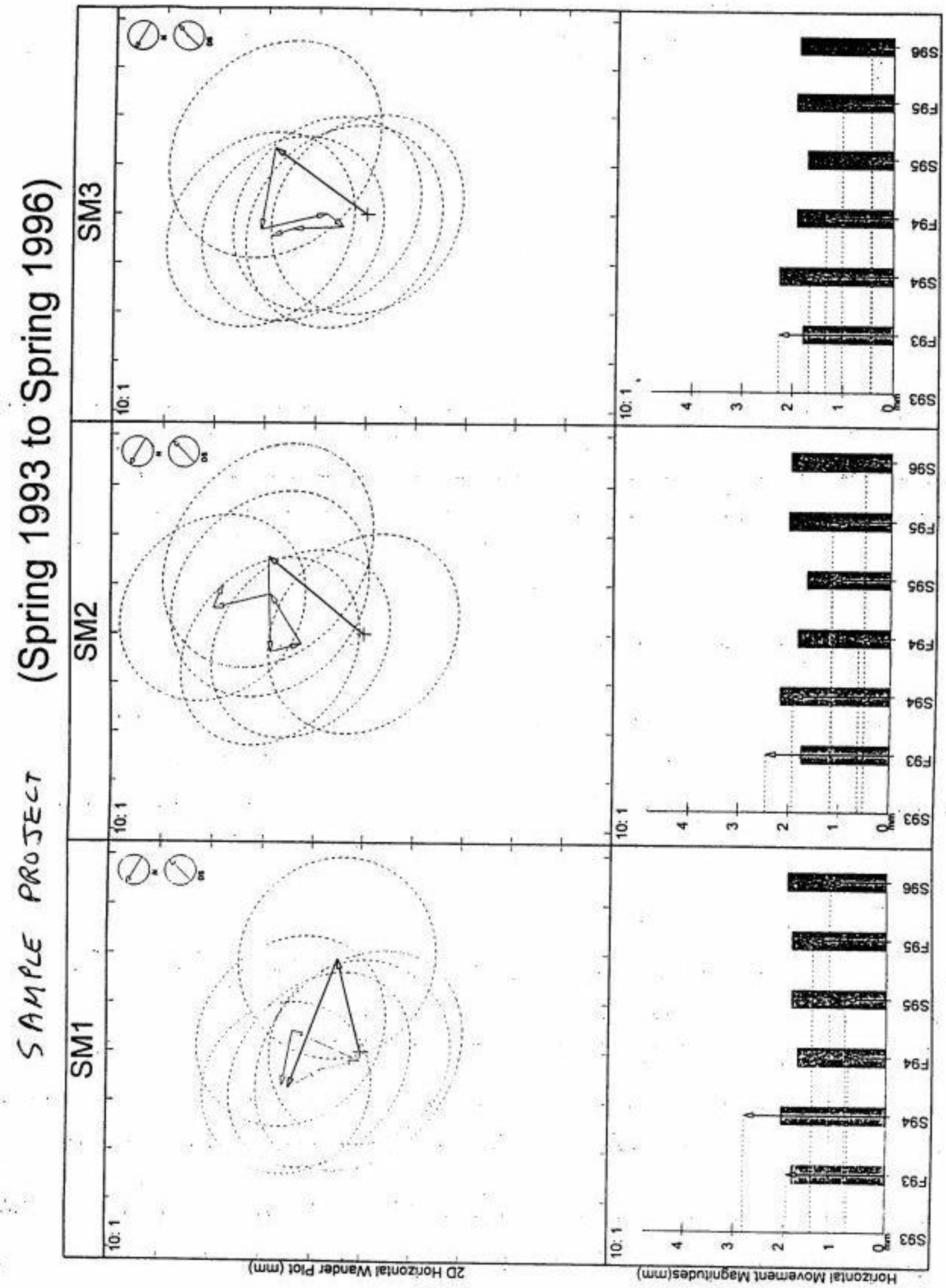
Point	To / From	F93 A=> (mm)	Direction (degrees)	95% Conf. Region (mm)	S94 A=> (mm)	Direction (degrees)	95% Conf. Region (mm)	F94 A=^ (mm)	Direction (degrees)	95% Conf. Region (mm)
SM1	S93	1.955	76	1.85	0.846	329	1.751	0.935	352	1.582
	Incremental	1.955	76	1.85	2.813	290	2.073	0.752	149	1.746
SM2	S93	2.463	39	1.752	1.227	356	1.742	1.389	0	1.606
	Incremental	2.463	39	1.752	1.933	268	2.182	0.627	165	1.833
SM3	S93	2.277	35	1.793	1.593	357	1.782	0.981	13	1.658
	Incremental	2.277	35	1.793	1.677	279	2.264	1.353	165	1.922
SM4	S93	1.797	32	1.802	1.286	12	1.749	1.028	331	1.742
	Incremental	1.797	32	1.802	0.943	280	2.157	1.204	218	1.682
SM5	S93	1.004	36	1.798	0.739	96	1.982	0.776	351	1.723
	Incremental	1.004	36	1.798	0.555	187	2.071	0.904	291	2.11
SM6	S93	1.487	84	1.447	0.935	64	1.376	1.776	356	1.705
	Incremental	1.487	84	1.447	0.947	300	1.868	1.361	314	1.719
SM7	S93	2.942	57	1.779	0.288	124	1.875	2.003	2	1.625
	Incremental	2.942	57	1.779	2.896	235	1.867	1.877	354	1.762
WP1	S93	2.355	56	1.821	0.63	299	1.318	1.089	33	1.197
	Incremental	2.355	56	1.821	2.839	265	1.96	1.268	102	1.375
WP2	S93	3.648	133	1.781	1.946	214	1.645	2.515	277	1.591
	Incremental	3.648	133	1.781	3.953	282	1.848	2.291	320	1.734
MM6	S93	0.557	215	1.308	0.84	299	1.308	0.236	231	1.204
	Incremental	0.557	215	1.308	0.988	312	1.447	0.906	131	1.337
MM7	S93	1.053	289	1.426	0.997	158	1.374	0.708	211	1.115
	Incremental	1.053	289	1.426	1.152	147	1.73	0.312	234	1.29
MM8	S93	0.346	249	0.961	4.087	242	3.494	0.395	262	0.916
	Incremental	0.346	249	0.961	0.605	245	1.052	0.732	52	0.907
MM9	S93	0.18	63	1.458	-0.218	159	0.651	0.357	107	1.511
	Incremental	0.18	63	1.458	1.468	87	1.808	1.315	255	1.498



	F93	S94	F94	S95	F95	S96	F96	S97	F97	S98	F98	S99	F99	S00	F00	S01	F01
PLUG1	2.469	-4.318	-5.088	-4.630	-2.614	-4.773	-2.468	-0.179	-1.117	-4.016	-1.302	-0.778	0.094	-1.817	-3.528	-1.138	-0.965
PLUG2	3.091	0.716	0.765	-4.342	1.076	0.931	0.057	-0.591	1.959	0.008	3.070	-0.528	2.313	0.402	1.697	-0.276	-7.230
PLUG3	0.132	2.613	2.505	-2.700	0.179	-0.536	-2.182	3.762	-3.333	1.872	-4.489	-0.243	-3.287	0.694	3.514	-2.704	-3.036
PLUG4	-0.643	5.426	8.169	-0.720	1.332	3.156	1.356	0.189	-0.606	1.972	-2.571	1.528	0.306	2.354	3.746	1.669	-3.360



	F93	S94	F94	S95	F95	S96	F96	S97	F97	S98	F98	S99	F99	S00	F00	S01
BOLT1	1.905	3.168	3.189	0.312	2.586	2.760	3.039	1.863	2.790	2.751	2.313	2.973	3.708	2.757	3.945	3.213
BOLT2	-1.185	0.672	1.407	-1.158	-0.633	0.171	0.654	-0.348	-0.660	0.684	-0.423	0.867	-0.306	0.438	-0.471	0.711
BOLT3	0.075	0.732	1.035	-1.131	-0.639	0.453	0.366	-0.057	0.204	0.102	-0.267	1.053	0.534	-0.258	-0.219	-0.381
BOLT4	0.426	0.480	0.354	-0.192	-0.501	-0.003	0.231	-0.072	0.093	-0.594	-0.036	-0.480	0.228	0.468	0.465	0.057


SAMPLE PROJECT
(Spring 1993 to Spring 1996)
SM1
SM2
SM3
10: 1
2D Horizontal Wander Plot (mm)
Horizontal Movement Magnitudes(mm)
S93
F93
S94
F94
S95
F95
S96

Attachment 6
Example of Document Control Log Sheets

THIS
SUPPORTING TECHNICAL INFORMATION
IS THE PROPERTY OF

LITTLE POWER COMPANY

111 MAIN STREET
ANYTOWN, USA

(If this STI is lost,
finder please return to
the above address)

ISSUED TO:

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STI NO. ________________________

The person or organization to whom this manual
is issued, is responsible for its safekeeping and
its being kept up to date.

LITTLE POWER COMPANY

Big Power Project: FERC No. XYZ

Supporting Technical Information Change No. ____

Section	Instructions	Summary of Changes
Table of Contents	Remove previously issued Table of Contents (6/18/2002) and replace with Table of Contents dated 1/22/2003 rev. 1	Updates revision numbers and effective dates
Section 1 Failure Modes Analysis	Insert Addenda 1, Failure Mode 7 dated 1/2/2003	Addends Failure Modes Analysis Report to include new Failure Mode 7

SUPPORTING TECHNICAL INFORMATION

REVISION LOG NOTICE

BIG POWER PROJECT

Revised Item	Date Entered	Initials	Date Read	Initials

Appendix J
DAM SAFETY SURVEILLANCE AND MONITORING PLAN OUTLINE

PURPOSE:
The Dam Safety Surveillance and Monitoring Plan Outline (DSSMP) provides the details of how an owner will monitor and evaluate the performance of a dam or project structure. The DSSMP is Section 7 of the Supporting Technical Information Document (STID) contains information that remains relatively unchanged throughout the life of the project unless there is a significant modification or investigation that results in the need for new instrumentation. This information includes details such as types of instruments, definition of action levels and threshold values, reading procedures, surveillance plans and procedures for visual inspection and documentation of data processing and evaluation methods.

The following quote is from Dr. Ralph Peck, 2000. "Monitoring of every dam is mandatory because dams change with age and may develop defects. There is no substitute for systematic and intelligent surveillance". In addition, Dr. John Dunnicliff states concerning data interpretation "Monitoring programs have failed, because the data generated were never used, if there is a clear sense of purpose for a monitoring program, the method of data interpretation will be guided by that sense of purpose. Without purpose there can be not interpretation." Good design, operation, and maintenance does not guarantee freedom from unexpected events that adversely affect the safety of a dam.

A Dam Safety Surveillance and Monitoring Plan should be developed for every project regardless of its size or hazard potential rating. The DSSMP should be appropriate to the complexity of the project. The DSSMP could be as simple as a single page document outlining the basic observations necessary to evaluate the condition of the dam.

The DSSMP includes the requirement to periodically submit a Dam Safety Surveillance and Monitoring Report (DSSMR). The DSSMR is a separate periodic report that presents a careful analysis, evaluation, and interpretation of the dam safety surveillance and monitoring data, and provides findings on the overall performance of the dam. The DSSMR outline is described in Appendix K.

The DSSMP and DSSMR should be submitted in hard copy. Upon request of the Regional Office, an electronic version of the DSSMR will be required. Voluntary electronic submissions are encouraged.

The DSSMP and DSSMR should include a detailed table of contents; all pages including the content of any appendices should be numbered in order for the reviewer(s) to confirm that all materials are included in the documents.

1. Dam Safety Surveillance Program

Include enough information in this section to describe the Licensee's visual inspection program. The visual inspection plan should include as a minimum:

- The major components of the Project included in regular surveillance such as dam, penstock, spillway, etc.
- Identify what typical observations are made; for example: alignment/misalignment of dam structures or appurtenants in place on the structures (fences, guardrails, pavements, signposts, and power lines), leakage/seepage, depressions/ruts, cracks, consistency of crest elevation or slope, spalling/pitting, rust, tight/open joints, buckling, bending, corrosion, clean, recently painted, bulging, etc. Consider documenting both positive as well as negative dam safety observations.
- Identify areas requiring regular or special monitoring or repeatable photographs for historical documentation such as, crack monitoring, rock erosion, or seepage. These areas may be identified from a PFMA or standards based engineering analyses i.e., slope stability, or be site specific features such as deicing mechanisms, etc). Note the actual photos should be reproduced in the DSSMR and a map of the photo locations should be provided in the DSSMP.
- Provide the frequency of the inspections.
- Describe procedures to report unusual observations.
- Describe inspection procedures used during and immediately following significant floods, earthquakes, or other unusual events.
- The training performed to ensure the inspectors complete reliable inspections and understand the relationship between the inspections and the safety of the dam or structure.
- Procedures to integrate inspection findings into maintenance schedules or initiate responses or actions if a moderate or serious condition is found.
- Archival, peer review, and dissemination of information procedures should be documented.

Appendix C of this outline presents an optional form that could be used to aid in the visual assessment of the project structures. An example of any customized blank inspection forms developed for the project shall be included in Appendix C of the DSSMP. Actual inspection forms completed since the last periodic submission can be presented in Appendix A of the DSSMR. Inspection forms that contain relevant important information can be preserved in the DSSMP however, a complete chronology of the actual inspection forms should not be preserved in the DSSMP.

2. Instrumentation Monitoring Program

This section shall include information about the Licensee's current instrumentation program.

Where appropriate, summary tables should be used to provide the desired information. Also, appendices shall include information such as schematics/drawings, blank data collection sheets, and other instrumentation details, if available. Although the licensee may elect to preserve copies of the 'raw' field or processed data forms in the DSSMP or DSSMR, consideration should be given to reduce the bulk by including only those documents containing significant information. The document should explain how electronic data is collected or reported i.e. headwater/tailwater readings, temperature, precipitation, piezometers, etc. The drawings should clearly show the location of the instruments in both plan and section views. The section drawings should show the top, bottom and critical elevations of the instrument including the sensing zone(s).

Examples of instrumentation types include, but are not limited to: piezometers, observation wells, weirs/seepage collection points, load cells, stress/strain gages, settlement/alignment/deformation monuments or instruments, crack gauges, river flow and/or rain gaging stations, headwater and tailwater gages (including electronic, staff and alarm systems), seismic instrumentation, temperature, etc.

2.1 Instrumentation

The following information, as appropriate, should be included in this section. This list is not all-inclusive.

- Tables documenting pertinent details of each instrument should be developed. These tables will be used to help confirm that all instrumentation data has been plotted and evaluated. Include abandoned instruments and note date and reason for abandonment. All pertinent reference information that is known about the instrument such as instrument ID, Boring Number, location, date of installation, elevations (top of casings, tip, ground, etc.) type, brand, model, calibration, date of manufacture, sensing elevation, and location (for piezometers), etc., should be included in the table. Readout instruments should be similarly documented especially with calibrations and calibration dates.
- Note: a specific instrument (instrument ID) may have been referenced in the past using a different designation system than that currently in use; a correlation of the old versus new designation should be provided.
- The purpose/intent of the instrument or visual monitoring program should be documented relative to potential failure modes. If the instrument or visual monitoring program does not apply to a specific potential failure mode, discuss its use to monitor the general health of the dam, or to monitor for the development of undocumented potential failure modes. This information should be brief, preferably summarized in a table, as required for the DSSMR (see Appendix K, Dam Safety Surveillance and Monitoring Report Outline). A more elaborate discussion of PFMs should be covered in section III.
- The physical property measured by each instrument and its location in the dam, such as monitoring pore pressures in the foundation, evaluating phreatic surface through the embankment, or measuring specific areas of seepage or total seepage, as examples. A brief

historical discussion regarding the instrument, including the reason installed or abandoned, method of installation/abandonment, problems, changes in performance, changes in reading schedule, etc. should be included. The actual intent of the instrument versus the terminology used to reference the instrument should be verified and documented (e.g. the difference between “observation well”, “monitoring well”, and “piezometer”).

- Method of data collection (*e.g.*, manual, semi-automated or fully automated). Can automated systems be confirmed by manual readings? How often are automated systems confirmed?
- Where remedial construction has been performed, the inclusion of any new instrumentation or the effect of construction on any existing instrumentation should be discussed. For example: grouting or maintenance drain cleaning may alter weir readings; post tension stabilization may alter the pattern and magnitude of deformations.
- For abandoned instruments, the method of abandonment should be described.
- If drilling logs and/or detailed drawings for instruments are available they should be included in Appendix B. If drilling logs are already placed in another location in the STID, it would be acceptable to simply refer to their location. However, a list of each instrument should be created with a reference to its associated drilling log.
- Photographs of different instrument types used at a project are encouraged.
- Provide a table showing the history of maintenance performed (i.e. falling head tests, control surveys, cleaning/purging of drains and piezometers, etc.) or clearly indicate such historic testing as notes on the time-series plots provided in the DSSMR. An optional Section II.2 can be created to cover this item

2.1.1 Action Levels

Action Levels should be developed to aid in immediate field-verification of instrumentation readings and/or to assist in determining if readings are approaching a level which would cause concern regarding the instability of a structure. It is highly recommended that Action Levels be established for instruments that are used to evaluate and monitor the development of a specific Potential Failure Mode.

The Design Basis Value for the DSSMP/DSSMR is the value used in the design analysis of the project. For instance, if the stability analysis of a concrete gravity dam assumed a particular uplift distribution, the Design Basis for a foundation interface piezometer would be the value corresponding to the design uplift pressure at that piezometer. For an embankment dam the Design Basis for a piezometer in the dam might be the pressure corresponding to the phreatic level at that piezometer.

The Threshold Value is a reading that indicates a significant departure from the normal range of readings and prompts an action. Exceeding the Threshold Value usually does not by itself directly imply a perceived instability of the structure. For example, a high reading of one piezometer in an earth dam may exceed the phreatic surface used in the stability analysis at that location, but other piezometers along the same cross section could indicate the overall phreatic surface is lower than assumed in the design stability calculations. The same logic holds for piezometers used to evaluate the uplift pressure beneath a concrete gravity dam. For these cases a single instrument indicating values above design level does not automatically indicate a process headed towards instability.

In some instances, a Threshold Value may be a lower limit; i.e. a decreasing trend of piezometric level may indicate the opening of a flow path to the downstream side of the dam. Or it may be desirable to maintain a certain piezometric level in order to retain submergence and prevent deterioration of wooden piles. For this reason, the setting of Threshold Values should include a careful consideration of Potential Failure Modes and more than one Threshold Value may be appropriate if development of different PFMs would result in different responses. In either case, deviation of the readings relative to the Threshold level starts the process of a more detailed examination defined by the Action Levels.

Once an instrument reading exceeds the Threshold Value an action is necessary. The range of response will vary greatly according to the severity of the situation. It may be necessary to designate multiple Action Levels that are progressively serious. These should account for:

- a minor departure from the historical record (possibly in order to simply receive an alert from the person reading the instrument thus verifying that measurements are being made);
- a major departure from the historical record (possibly indicating a developing failure mode);
- a departure from historical reaction to other instruments or;
- levels indicating the approach of instability or other forms of failure such as piping.

Depending on the performance and response of the instruments to changing conditions, Action Levels related to magnitude and rate of change limits as well as to address daily, seasonal, or other cyclic relationships may need to be established.

Actions to be taken may include; double checking the reading(s), checking the instrumentation, increased surveillance, review of stability analysis assumptions and/or additional analyses, field investigations, or emergency action.

For those projects where Action Levels are incorporated, the following must be documented: how these were developed; how they are used; actions to be taken for each level; and why they were developed. Where appropriate, a table or drawings should be developed to summarize the Action Levels for each instrument.

2.1.2. Reading Frequency and Procedures

This section should include information on the frequency and procedures used to acquire, confirm the validity, resolve irregular or atypical readings and evaluate data. Considerations for this section should address:

- When are instruments read and how?

- How fast the parameter that is being monitored changing and what is is the basis for the reading frequency?
- Describe any situations such as seasonal limitations that may restrict the ability to acquire data. What procedures are followed to assure dam safety if the dam or instrumentation is inaccessible for a portion of the year?
- How is the raw data confirmed to be valid, etc.? Describe what testing and quality control procedures are in place to ensure the reliability of the data collected.
- Training for personnel in both proper reading of the instrumentation and in how the instrumentation relates to safety of the dam or structure particularly as it pertains to PFM's.

During and immediately following significant flood or earthquake events, instruments should be read, recorded and evaluated along with documentation of the event.

Appendix C presents an optional table **(SCHEDULE FOR DAM SAFETY DAM SAFETY SURVEILLANCE AND MONITORING)** that could be used to list the dam safety surveillance and monitoring methods, frequency or schedule of readings, and other pertinent observation and instrumentation reading information. This table could prove very useful in: a) updating/revising instrument reading frequency or schedules, and b) providing field personnel a one-page reference sheet for instrumentation reading frequencies. In using this table, this section of the report could be structured to refer the reader to the table in Appendix C for specific information regarding the frequency of readings and other monitoring information that may be more subject to change. Therefore, if, or when, these types of monitoring changes occur, then only the table would have to be revised and the updated copy replaced in the Appendix of the DSSMP. Alternately, these types of revisions would be made in the text of the DSSMP and the appropriate page(s) updated and revised.

2.2 Equipment Maintenance Program

A maintenance plan for the instrumentation should be developed and followed. The maintenance program should include an annual visual inspection, cleaning, and calibration check for all instrumentation. Maintenance of abandoned instruments should be considered in the case readings need to be reinstated. The program should also include procedures for checking instrument performance if erratic readings are observed. If automatic data acquisition equipment is used then the maintenance program will need to include visual observations for moisture intrusion and overheated components, replacing desiccant, testing transient protection devices, testing batteries, and testing that the notification capabilities are working properly in order to determine if an action level has been encountered.

3. Potential Failure Modes

A discussion should be provided that addresses the dam safety surveillance and monitoring related to site-specific potential failure modes that are identified in the PFMA report. The DSSMP should address all Category I and appropriate Category II and Category III failure modes and be designed to minimize the risk associated with these potential failure modes by providing early warning if the failure modes become active or worsen.

4. Approach to Review DSSMP and DSSMR

The key to a good instrumentation system at a dam is to have a complete understanding of the design intent, installation details and proper maintenance procedures for the instruments. Instrumentation and surveillance programs coupled with a good monitoring program can be designed with a clear understanding of PFMs so that early warning signs of failure might be detected to provide opportunity to respond and prevent failure. John Dunnicliff's book titled "Geotechnical Instrumentation for Monitoring Field Performance", and the manual from the Center for Energy Advancement through Technological Innovation (CEATI) titled "Dam Safety Performance Monitoring and Data Management-Best Practices" provide excellent road maps for developing and implementing an effective instrumentation monitoring program.

Using these publications as a guide, a good instrumentation system at an FERC project starts with the following steps:

- Review and understanding of the basic information contained within the STID
- Review and confirm that all Potential Failure Modes (PFM) are identified and fully developed
- Identify the instrumentation that aids in evaluating each PFM
- Identify the measurements to be made to assess the performance of the dam
- Assess the effectiveness of the overall monitoring system
- Review the effectiveness of maintenance procedures and data collection system procedures
- Review calibration and testing procedures of instruments
- Review effectiveness of procedures to collect, process and evaluate data and take action on results

This list above is a brief overview of the steps one should take in reviewing an instrumentation program; however, the reader is urged to review the referenced publications for further details.

APPENDICES FOR THE DSSMP

DSSMP Appendix A:

Drawings

Hard copies of drawings, etc. should be provided in a size that allows all details to be easily read without the use of optical magnifiers. If reduced size copies result in unreadable drawings, the drawings, etc. should be provided as full size copies and folded in pocket dividers. Preferably any drawings submitted in an electronic format should be such that details can be enlarged without loss of resolution (AutoCAD or others). Judgment should be applied in assembling drawings, etc, clutter should be avoided; additional figures may be required.

Plan Drawings

Plan drawing(s) of the project structures should clearly show project components and instrument locations (actively being monitored and those having been abandoned/terminated/idled). The drawing(s) should have a graphical bar type scale to facilitate interpretation of enlarged or reduced copies and the title block should include what horizontal or vertical control is being used (i.e. NAD state plane coordinates and zone, NAVD88 datum or NGVD29 datum). Plan drawings should be consistent with the datum used to record the instrument value (for example, survey monuments). Locations of notable seepage or other structure irregularities that are visually monitored should also be shown. If scalable drawings are not yet available, schematic drawings should be provided in the initial DSSMP and efforts to complete scalable drawings for the next DSSMP update should be initiated. Text on the drawings should be readable in the format presented.

Cross-Section Drawings

Representative cross-sections of project structures should be made to show the dam structure/foundation configuration/zonation, instrument locations, and pertinent instrument details. A graphical scale or a vertical axis with elevations and a horizontal axis with distance should be included on the sections. Each drawing should include a title block. Where practical, the phreatic surface used in the stability analyses for embankment dams or the uplift diagram for concrete structures, the slip circles for minimum FERC required factors of safety, Threshold Values and Action Levels should be shown on each cross section. Locations of notable seepage or other structure irregularities that are visually monitored should also be shown if possible.

Aerial Photographs

When available, include aerial photos to help orient the reviewer to the project structures and their relative locations with respect to each other.

DSSMP Appendix B: Instrumentation Details

Provide any instrumentation details in this appendix that may help the reviewer understand the instrumentation and its intended use. For example: soil boring logs and installation details for a piezometer, installation details for an inclinometer, photographs, coordinates and elevations of benchmarks for surveys.

DSSMP Appendix C: Inspection Forms

This appendix shall include the blank inspection forms used to document any formal inspections of project dams or facilities conducted by the Licensee or blank instrumentation collection forms. Inspection forms that contain relevant important information can be preserved in this appendix however, a complete chronology of the actual inspection forms should not be preserved in the DSSMP.

Example of Optional Inspection Form for Embankment Dams

Ongoing Visual Inspection Checklist

Sams Dam

Schedule: Perform **monthly** under normal operating conditions. Perform **immediately** if the reservoir rises above 9332.0 feet (historical maximum) or after an earthquake that is felt at or near the site. If unusual conditions are seen during or after the high reservoir event or earthquake, perform **daily** until conditions stabilize.

Inspector:	___________	Date:	________
Reservoir Elev.:	________feet	Time:	_________
Weather:	___________	Temperature:	_______ºF

A "Yes" response should only be given to question(s) below where observed conditions are different from previously observed conditions. Any observed conditions that have previously been reported and are currently unchanged should receive a "No" response. For any question below answered "Yes," please provide additional information describing the situation as completely as possible under item 7, "Additional Information." Also, take photographs of the situation, and include with this report. A "Yes" response indicates unexpected behavior that needs to be investigated.

1. Crest of Dam:

   a. Any cracks, either transverse or longitudinal? ☐ No ☐ Yes

   b. Any scarps, sinkholes or areas of unusual settlement? ☐ No ☐ Yes

2. Downstream Slope of the Dam:

   a. Any new seepage areas or wet areas? ☐ No ☐ Yes

   b. Any changes in conditions at existing seepage areas or wet areas? ☐ No ☐ Yes

   c. Any materials being transported by seepage flows at existing or new Seepage areas (such as discolored seepage water or sediment deposits)? ☐ No ☐ Yes

   d. Any scarps, sinkholes, sloughs, slides or areas of unusual settlement? ☐ No ☐ Yes

3. Upstream Slope of the Dam:

   a. Any significant erosion due to wave action? ☐ No ☐ Yes

   b. Any scarps, sinkholes, sloughs, slides or areas of unusual settlement? ☐ No ☐ Yes

   c. Any whirlpools in the reservoir? ☐ No ☐ Yes

4. Downstream Toe Area, Abutments and other Areas Downstream:

Note: Extend the inspection to all areas within 50 feet of the toe of the dam and all the way up both abutment groins and to within 50 feet either side of the groins. Inspection for seepage and sediment in the river channel should be performed during low flows and be extended along the river channel for at least 300 feet.

a. Any new seepage areas or wet areas? ☐ No ☐ Yes

b. Any changes in conditions at existing seepage areas or wet areas? ☐ No ☐ Yes

c. Any cracks, sinkholes, sloughs or areas of unusual settlement? ☐ No ☐ Yes

d. Any new seepage areas along the banks of the river channel? ☐ No ☐ Yes

e. Any new sediment deposits along the banks of the river channel? ☐ No ☐ Yes

5. Outlet Works:

a. Any new or enlarged cracks or spalls in the concrete? ☐ No ☐ Yes

b. Any unusual deformations or displacements? ☐ No ☐ Yes

c. Any unusual flow patterns or conditions during releases? ☐ No ☐ Yes

d. Any new seepage into the outlet works conduit? ☐ No ☐ Yes

e. Any sediment accumulation upstream from the weir plate at SM-1? ☐ No ☐ Yes
(Feel the material and determine if it contains sediment. If yes, dry, weigh and determine the volume and report in item 7 below and have a sample of it analyzed for soil content at a laboratory. Once the analysis results are received transmit them to the contact listed below).

6. Spillway:

a. Any new or enlarged cracks or spalls in the concrete? ☐ No ☐ Yes

b. Any unusual deformations or displacements? ☐ No ☐ Yes

c. Any unusual flow patterns or conditions during releases? ☐ No ☐ Yes

7. Additional Information:

NOTE: All descriptions should include specific location information and all other seemingly relevant information. Seepage area descriptions should include: estimated seepage amount and water clarity description (clear/cloudy/muddy, etc.). Crack descriptions should include orientation and dimensions. Descriptions of changes at cracks should include the estimated amount of movement, and movement direction. Deteriorated or spalled concrete descriptions should include degree of deterioration and approximate dimensions of the affected area.

Example Schedule for Dam Safety Surveillance and Monitoring

SCHEDULE FOR DAM SAFETY SURVEILLANCE AND MONITORING

PROJECT NO. P-XXXX DATE ____________________

PROJECT ____________________ VERSION ____________________

DAM ____________________ CONTACT ____________________

State ____________________

MONITORING METHOD	FREQUENCY/ SCHEDULE	COMMENTS
Visual Observations	Daily	During the winter, the scope of inspections can be scaled back to what reasonably can be performed, given the site conditions. 1/ 2/ 3/ 4/
Seepage Monitoring Installations	Weekly	During the winter, obtain readings when this can reasonably be done, based on site conditions. 2/ 3/ 4/ 5/
Mapping of Seepage Areas on a Plan View Drawing	Annually	On approximately July 1.
Piezometers (Porous-Tube and Vibrating-Wire)	Monthly	During the winter, obtain readings when this can reasonably be done, based on site conditions. 2/ 3/ 4/
Internal Vertical Movement (IVM) Devices	On Standby	Obtain readings only if a specific request is received.
Embankment Measurement Points	In 2007	Thereafter, on standby - survey only if a specific request is received. 6/

REFERENCE DRAWINGS: 426-D-2073 Plan View of Instrumentation

NOTES AND REMARKS:

1/ Visual Observations should be performed using the “Dam Safety Observation Checklist." A copy of each completed "Dam Safety Observation Checklist" should be placed in the instrumentation notebook. A copy of pertinent checklists should be included in the DSSMR.

2/ To the extent possible, obtain readings and perform inspections at times when no precipitation or significant snowmelt has occurred in the preceding 72 hours. If this is not possible, precipitation and/or snowmelt within the last 72 hours should be reported (amount and time).

3/ In the event that the reservoir elevation rises above 1235.5 feet, visual inspections and seepage and piezometer readings are to be performed every other day. Should the reservoir elevation rise above 1239.0 feet, visual inspections and seepage and piezometers readings are to be performed daily.

4/ Obtain instrument readings and perform an ongoing visual inspection as soon as possible following significant seismic shaking at the damsite (peak horizontal acceleration in excess of 0.05g) and following a significant flood event (reservoir elevation above 1239.0 feet).

5/ Whenever flow rates are being read, check for indications of sediments being carried by the flows (discolored water, sediment deposits in front of weirs, etc.) and report immediately if noted.

6/ Obtain current top of casing elevation for IVM installations whenever surveys are performed.

Appendix K
DAM SAFETY SURVEILLANCE AND MONITORING REPORT OUTLINE (DSSMR)

The purpose of the DSSMR is to review the instrumentation and monitoring data, as well as other project information to determine if any particular potential failure modes (PFM) are developing, thus providing advance warning and information required for dealing with or remediating against that occurrence. Thus, it is expected that the DSSMR includes adequate and sufficient information demonstrating the detail of instrumentation review, interpretation, and evaluation to properly determine if the dam is performing as intended.

The results of the dam safety surveillance and instrumentation monitoring plan should be evaluated on a real-time basis and not simply accumulated throughout the year only to be evaluated prior to making the annual (periodic) DSSMR submittal.

1. Findings

This section should contain a summary of significant findings, conclusions, actions, changes or recommendations for the subject year or review period. If considered appropriate, bulleted categories may be used to establish priorities for dam safety or maintenance issues such as “serious issues”, “moderate issues” and “minor issues”.

- State if the dam is performing adequately based on the visual inspections and instrumentation evaluations included in the DSSMR or specify any dam safety concerns.
- A statement should be added for each adverse finding to clarify if it is confirmed or not by instruments and/or visual inspection.
- State if the instrumentation and dam safety surveillance monitoring program is appropriate for the critical PFM’s. If not, make recommendations for improvements.
- Maintenance or actions proposed or completed addressing DSSMR concerns.
- Actions requiring future remediation.
- Changes in inspections, in reading procedures and frequencies, or overall instrumentation program. The DSSMP should be updated accordingly.
- Recommendations for additional instruments or to abandon instruments.
- Recommendations to address additional potential failure modes that may be identified as a result of this entire process.
- Have the readings, evaluations etc been timely completed?

2. Field Observations

This section will include a summary of dam safety surveillance and monitoring items detected during inspections performed by plant personnel, staff inspectors or engineers, FERC engineers, state dam safety officials or special inspections such as a diver's inspection, a penstock/tunnel inspection, etc.. Include a summary of significant or notable observations or items requiring maintenance or repair. This may be in tabular form for minor or routine maintenance items. Structural irregularities such as cracks, depressions, and seepage should be shown on plan and section views if possible. Actual field-completed inspection forms or interim reports can be included in Appendix A, however to reduce the bulk of the DSSMR, consideration should be given to include only those documents containing significant observations or minimally a single form documenting typical observations.

3. Instrumentation Evaluation

This section should include an evaluation of active instrumentation supported by sound engineering judgment. Timely compilation and evaluation of the data should be performed to determine if the data supports the satisfactory performance of a structure or that the instrumentation is giving reliable data. Timely evaluation ensures that any adverse trends are recognized and that an appropriate response can be initiated. Unusual observations of data are sometimes due to human error in measurement or compilation that if left unchecked could later raise serious concerns about what actually happened. Periodic evaluation of just how much data is actually needed is also required to monitor the performance of the project structures.

The evaluation should include a statement that the data shown by each instrument or each group of instruments is consistent with reasonable design assumptions or, if not, list the instruments that are inconsistent, why actual performance is not consistent with design assumptions, and the action(s) required to investigate or an explanation to accept the inconsistency. The evaluation of the data should be supported by the documentation included within the DSSMP. If the evaluation concludes the dam is performing satisfactorily or un-satisfactorily, the evaluation should state why and what information led to this conclusion. This may be a reference to a design document, construction documentation, etc.

Water temperature, dam temperature, precipitation, or any other phenomenon that influences the instrument readings should be included in the evaluation of the data. The evaluation can include statistics, if appropriate, from the period covered by this report and compared to relevant historical performance as well as reference to Threshold Values. Also, appendices shall include information such as schematics/drawings, and plots.

The following questions are examples of the items which should be considered in compiling the evaluation:

- How do the readings relate to the design of the project feature?
- How do the readings relate to the Threshold Values and Action Levels?
- How do the readings relate to the design or installation of the instrument?

- Have any calibrations changed? What is the impact on previous readings?
- Are electronic sensors, semi-automated or fully automated systems being confirmed by manual readings?
- Does the instrument still fulfill its intended purpose?
- Does the data support the stability of the structures?
- Is the data supported by the visual observations of the behavior of the structures?
- Is there any trend to the data?
- Are all similar instruments in similar zones responding similarly?
- Can the movement/trend of the readings of an instrument be correlated to any movement/trend of the readings of another type of instrument? (Examples: Is a rise in the water level in a piezometer reflected by an increase in flow at a weir? Are piezometers responding to changes in headwater/tailwater levels?)
- Has enough data been plotted to assess long term trends?
- The use of the terms 'normal', within historical range' and 'no adverse trends' should include an interpretation. Why is it normal? What is the historical range? What is the current reading? Etc.
- Are there any USGS or other off-site instruments that could be used to evaluate the dam performance?

4. DSSMR Changes

This section should document any changes such as updates to the instrumentation, program, and personnel. These changes should be reflected in the DSSMP as appropriate. If there are no changes, so state. List any improvements suggested by the Licensee, FERC, other agencies, or Consultants for the DSSMP or DSSMR.

5. Group and Evaluate Instrumentation to PFM's

This section shall consist of tables and discussion, evaluating the relationship between instrumentation and PFMs, and the general health of the dam. Instrumentation shall be organized into the four groups outlined below. Visual monitoring is also an instrument, and should be included in this evaluation. Before undertaking this evaluation a thorough review and understanding of the STID must be performed. The groups are:

- Instrumentation associated with a PFM. (Identify the instrument and PFM)

- A PFM that has been identified, but not associated with an Instrument

- Instrumentation not associated with a PFM

- PFM not previously identified but discovered when reviewing STID, historical data and evaluation of instrumentation readings. (e.g. PFM and instrumentation identified to address construction issues or unusual historical instrumentation readings)

Example tables showing the four groups are shown on pages 14-K-7 and 14-K-8. Licensees may propose and submit their own tables and format, as long as the information described in these example tables is included. The Results (or Comments) column should summarize the conclusion regarding observations of the annual monitoring efforts for the instrument relative to the PFM, or the general health of the dam.

6. Certification

The DSSMR shall include a signature page indicating who prepared the report (and reviewed the report, if more than one). A professional engineer's stamp is recommended but not required. The qualifications of the reviewer should be included. The certification should identify the date or revision of the DSSMP/DSSMR guidelines that was used to assemble the reports.

7. Chief Dam Safety Engineer (CDSE) Annual Statement for Continued Operation

An additional requirement to the Dam Safety Surveillance Monitoring Reports (DSSMR) begins with the annual report due in 2015. All Licensees and Exemptees to are required to provide an annual statement within their DSSMR from their CDSE, Dam Safety Coordinator or owner that the dam is safe for continued operation.

This statement is to be based on a careful review of all the project information – including Licensee inspections, FERC inspections, Part 12D reports including the Supporting Technical Information Document (STID), and Instrumentation and Monitoring Reports.

The DSSMR should include adequate and sufficient information demonstrating the detail of instrumentation review, interpretation, and evaluation to properly determine if the dam is performing as designed. The CDSE, Dam Safety Coordinator, or Owner shall submit an annual statement upon review of the DSSMR, that the dam is safe for continued operation.

The following wording is suggested for the Annual Statement to be included in each DSSMR:

> "Based on my personal knowledge and meetings and discussions with my engineering staff and/or consultant(s), along with review of the DSSMR, Part 12 Inspection Report, Dam Safety Inspection(s), and Dam Safety Studies, I conclude, that the dam(s) is safe for continued operation.

Or

"Based on my personal knowledge and meetings and discussions with my engineering staff and/or consultant(s), along with review of the DSSMR, Part 12 Inspection Report, Dam Safety Inspection(s), and Dam Safety Studies, I conclude, that the dam(s) is safe for continued operation, with the following issues noted: (*List of outstanding items (instrumentation anomalies, detailed stability analyses, PMP/PMF studies, etc.)*."

If the CDSE or Dam Safety Coordinator cannot make a clear statement that the dam is safe for continued operation, then you must prepare, and submit with the DSSMR a Justification for Continued Operation (JCO) plan and schedule to remediate the dam so that the dam can be considered safe for continued operation. The plan should include interim measures to reduce risk until remediation is complete, and the dam is judged safe for continued operation.

Example Tables to be Included with Annual DSSMR Submittal

EXISTING PFMs WITH INSTRUMENTATION:

PFM – Number/Title(s)	Monitoring Effort	Result
PFM 1 - Sliding failure of the spillway during the PMF (Category I – Highlighted PFM)	PZ-1 (uplift piezometer)	No adverse trends, no thresholds exceeded
	PZ-2 (uplift piezometer)	Rising trend but below thresholds, flushed and readings returned to historic range
	PZ-3 (uplift piezometer)	No adverse trends, no thresholds exceeded
	Deformation Surveys	Adverse trend detected for BM-3 through BM-7, see evaluation on page 16
	Annual dive inspection	No adverse findings related to PFM 1
	Daily operator inspections	No adverse findings related to PFM 1
	Monthly supervisor inspection	No adverse findings related to PFM 1
	Annual engineer inspection	No adverse findings related to PFM 1
PFM 2 - Operational gate failure (Category II – Considered not Highlighted PFM)	Annual dive inspection	No adverse findings related to PFM 2
	Daily operator inspections	No adverse findings related to PFM 2
	Monthly supervisor inspection	No adverse findings related to PFM 2
	Annual engineer inspection	No adverse findings related to PFM 2
	Annual gate testing	Current readings in normal range
	10-year detailed gate inspection	All maintenance actions complete

EXISTING PFMs WITHOUT INSTRUMENTATION:

PFM – Number/Title(s)	Monitoring Effort	Comment
PFM 3 - Failure of low level outlet during normal loading conditions (Category II – Considered not Highlighted PFM)	None identified	Low level outlet is submerged and silted in - could not locate during last dive inspection

Note: Some instruments may be used to monitor development of multiple PFMs and should be listed with each associated failure mode. All instrumentation, including visual monitoring, should be used to monitor the overall condition of the dam and help identify new PFMs. Example Tables to be Included with Annual DSSMR Submittal

NEWLY IDENTIFIED PFMs (Follow Procedure in Chapter 14, Section 14.3.6 for Updating PFM's)

PFM – Number/Title(s)	Monitoring Effort	Result
Sliding of the non-overflow under normal loading conditions (candidate PFM identified during evaluation of deformation survey results)	Deformation Surveys	Differential movement detected and further evaluation of stability is needed
	Daily operator inspections	New cracks found on 9/18
	Monthly supervisor inspection	No adverse findings
	Annual engineer inspection	No adverse findings
Failure of Penstock No. 1 due to corrosion under normal loading (candidate PFM identified during review of STID)	Daily operator inspections	No visual changes to corrosion or leakage detected
	Monthly supervisor inspection	No visual changes to corrosion or leakage detected
	Annual engineer inspection	No visual changes to corrosion or leakage detected
	Ultrasonic thickness measurements	Section loss detected, see evaluation on page 19

INSTRUMENTATION NOT ASSOCIATED WITH A PFM: (General Health of Dam)

Monitoring Effort	Result
PZ-5	No adverse trends, no thresholds exceeded
Surveillance Camera at Weir	No visual changes or seepage with soil fines
Deformation Surveys	No adverse trends, no thresholds exceeded
Daily operator inspections	No adverse findings
Monthly supervisor inspection	No adverse findings
Annual engineer inspection	No adverse findings

APPENDICES FOR THE DSSMR

The figures and other content of the appendices included in the DSSMR should be adequate to support the Evaluations, Findings and Conclusions. Replication of figures and drawings developed for the DSSMP and STID should be limited to those that are needed to illustrate specific points or features of interest with annotations to show specific areas of concern or current levels, etc. to the reader of the DSSMR.

The author of the DSSMR, for clarity, may elect to present select figures within the text of the report; however most figures and drawings should be presented in appendices. Regardless of location, <u>all figures and drawings should be individually listed in the table of contents</u>.

Hard copies of drawings, data, plots, etc. should be provided in a size that allows all details to be easily read without the use of optical magnifiers. If reduced size copies result in unreadable drawings, the drawings, etc. should be provided as full size copies and folded in pocket dividers. Judgment should be applied in assembling drawings, etc, clutter should be avoided; additional figures may be required. The submission of supplemental electronic copies are encouraged.

DSSMR Appendix A: Significant Inspection Forms or Reports

A selection of the latest inspection forms/reports can be included to document visual inspections and instrument readings. These forms shall include enough detail by structure to document site specific conditions as found during the inspection. To reduce the bulk of the DSSMR, consideration should be given to include only those documents containing significant observations or minimally a single form documenting typical observations. Documentation of inspection and readings made as a result of the occurrence of a significant flood or earthquake events should always be included.

DSSMR Appendix B: Supporting Drawings

Plan Drawings
Cross-Section Drawings
Aerial Photos

DSSMR Appendix C: Instrumentation Plots

- This section includes data plots of all pertinent instrumentation. There are four types of plots that can be considered; Time versus Reading Plots, Cross Section Plots, Correlation Plots, or Special Plots. These plots are described below.

Time versus Reading Plots:

- The amount of data shown on each plot and the scales used for the time versus reading plots should be sufficient to show any historical trend. Historical plots of all data should be developed to illustrate long-term trends such as slowly rising pore pressures, or slowly increasing movement of a structure. However, as years of data accumulate, additional plots of the historical data may have value, i.e., from 5 to 15 years of data.
- Data from similar instruments should be logically grouped on the same page. For example, you might want to compare the performance of all core piezometers relative to each other. Other examples include showing all the instruments installed across a cross-section through the dam or along the crest of the structure. It is common to plot data from one instrument in several groupings to evaluate the response to different reference points.
- When the data is being plotted relative to time, an actual time scale should be used. The data should not be plotted on an incident basis where each tick mark along the axis represents one reading. Normally, time is plotted along the abscissa (x-axis).
- All time scales should avail the interpretation of seasonal trends. Showing month and day designations on a long duration time scale is not always practical. This should be an option for short duration scales. Annual designations with semi-annual or quarterly divisions can be used to reveal seasonal trends. Note that some spreadsheet programs can only select 30 days to approximate the months of the year.
- Consistent time scales or horizontal scales should be used so that direct comparison of plots from different instruments can be evaluated.
- Consider forcing vertical scales on all plots of the same type of instrument to have the same scale or total range so plots can be directly overlaid. Engineering judgment should be used in selecting the scale as some instruments may react with large swings whereas others may show only minor variations. The variation of the instruments that only have small reactions may be lost if plotted at the same scale as those with large variations. A secondary axis at another scale may be of use.
- Time-history plots of data should be prepared to provide a graphical representation of the performance. Do not put too much information on a single figure as the data will be more difficult to interpret.
- Tic marks along the axis should be placed at logical intervals so that intermediate divisions can be easily interpreted.
- Use symbols and/or different line types for each instrument in addition to colors. Note that some colors do not reproduce on copying machines nor are easily visible on computer monitors.
- The influence of precipitation on various instruments should be considered although it may be extremely difficult to determine. It may be necessary to plot precipitation daily or some variation on summing or averaging the data over several days or weeks. Often, no correlation can be made.
- Deformation or movement data should be resolved relative to the axis of the dam or structure, not just to the standard east, west, north, and south coordinates.

- For all instruments such as piezometers and weirs or other recordings that may be influenced by reservoir or tailwater levels, plot these levels to show the influence.

Cross Section Plots:

- Create cross-sections plots for critical stability sections or where particular concerns are noted. The sensing zones of the piezometric data must be carefully evaluated to ensure that different phreatic surfaces that may exists in the embankment and foundation are not being incorrectly mixed together and plotted.
- The instruments do not have to be physically in the same plane in order to develop a cross-section plot. Some instruments (piezometers) may be offset from the section and the distance offset should be indicated by distance and direction (left or right) from the section; e.g. 20R could mean 20 feet right. An explanation of the notation should be included below the cross-section.
- Consideration should be given to developing separate cross sections that show data collected on the same day versus all-time historical high/low points.
- Cross section plots should show; a vertical axis with elevations and a horizontal axis with distance; location of the instruments, tip elevations, current instrument reading levels, geologic zonation, assumed phreatic surface or pore pressure distribution (uplift) used in stability analyses. Optionally, Threshold Values, Action Levels, screen zones, unscreened length, etc. can be shown however clutter should be avoided. Some of these could be designated along the vertical axis rather than at the instrument locations. Most of the actual details of this information should already be provided in a table and on cross-sections drawings in the DSSMP.
- Cross section plots are not a substitute for Time Series plots.

Correlation Plots:

Correlation plots may clearly indicate a developing failure mode that can not be easily identified on a time-history plot.

- Use correlation plots where it can enhance the reviewers understanding of repeatable changes in instrumentation due to external factors or site conditions. Examples can include seasonal changes in reservoir levels that are reflected in instruments or seepage; changes in tailwater levels that influence instruments or seepage; precipitation effects upon seepage; etc. These plots may be useful for instant identification of adverse developments following special events as earthquakes.
- Use correlation plots for monitoring of filling or refilling of reservoirs dewatered for repairs.
- Identification of the real stimulus that causes instrument reading variations (example: Is the reservoir causing a foundation piezometer level variation, or is the piezometer level variation caused by pressure in the aquifer fed from a different source?; is the crack movement caused by the reservoir or by temperature?)

- Investigation to determine the level of responsiveness of the instrument (level of piezometer clogging, etc.)
- For impoundments that do not show significant seasonal changes in elevation, correlation plots are not likely to be useful.

Special Plots:

Use special plots where they can show relationships that help in the evaluation of the data collected. Examples can include: x-y 'wander' plots of movement data about survey monuments to show accuracy/repeatability (however, do not include a mass of these plots when there is no significance to the data); cross-sections or plan drawings annotated with sequential lines indicating progressive change such as presentations of the profile of the settlement of the crest or bulging of the slope of an embankment dam (profile plots of settlement data should include IDF/PMF levels to easily show a low spot in the reservoir rim). Inclinometer data is often presented in a sequential format.

DSSMR Other Appendices: As desired

Appendix L
DETAILED RADIAL GATE INSPECTION REPORTS

BACKGROUND AND PURPOSE

The FERC Tainter Gate Initiative (TGI) was implemented in 1998 following the forensic investigation into the failure of a radial spillway gate at Folsom Dam. The purpose of the TGI was to ensure that there would be periodic review of the design assumptions and up-close inspections of radial gates at FERC-regulated projects.

Since the 2001 revision to the initiative, each dam with a **Category 1 radial gate**[1] has been required to submit a detailed **Gate Inspection Report (GIR)** at a ten-year interval. The GIRs submitted have varied in quality, scope, and contents; the purpose of this document is to provide guidance on our minimum expectations for the GIRs.

While this guidance specifically addresses radial gates subject to inspections under the TGI, the FERC recognizes that many dams have other types of gates that could have dam safety, operational, or life safety consequences in the event of failure or misoperation. If the D2SI-Regional Engineer (RE) determines that a gate or set of gates meets the conditions to be classified as a Category 1 gate, and requires detailed "hands-on" inspections, the guidance herein shall apply regardless of the gate type.

RADIAL GATE INSPECTION REPORTS

Submittal Procedures

A GIR should be submitted every ten years, or more frequently if determined to be necessary by the RE. If any conditions are identified during the gate inspection that could reasonably be considered to constitute a dam safety issue, the licensee should immediately report it to the RE in accordance with 18CFR §12.10 (a).

A GIR transmittal letter should be addressed to the RE and should include:

- A summary of the key findings of the GIR;
- A summary of key findings of the previous GIR and any work (e.g., analysis, maintenance, or modifications) performed in the interim;
- A clear statement by the Chief Dam Safety Engineer or Coordinator (CDSE) that they have reviewed the GIR, concur with its findings, or adequate justification and rationale for any 'non-concurrence'; and
- A list of recommendations, as appropriate, for routine maintenance, investigation, or major remediation, as well as the CDSE's plan and schedule for addressing those items.

[1] A Category 1 gate is defined as one for which either of the following is true:
1) A structural failure of the gate, or the gate's inability to open or close, endangers downstream life during normal operations or flood events; or
2) A failure to open or close results in a significant uncontrolled reservoir level rise or drop during normal operations or flood events, affecting upstream life, property, or resources.

The report should be submitted to the appropriate Regional Office per the procedures shown in the FERC Filing Guide (http://www.ferc.gov/docs-filing/forms/fileguide.pdf). The report should be securely bound and each copy should include a DVD containing a searchable electronic version of the report, including appendices. Appendices D and E may be included in electronic format only, if desired.

Outline of the Gate Inspection Report

The GIR should be organized into the following sections:

1. Inspection Scope
2. Review of Existing Documentation
3. Inspection Findings
    3.1. Gate No. 1
    3.2. Gate No. 2
    3.3. Gate No. 3… [etc.]
4. Recommendations
5. Conclusions

Appendices
Appendix A: Inspection Team Resumes
Appendix B: Status of Previous Recommendations
Appendix C: Drawings and Schematics
Appendix D: Inspection Photos (DVD only)
Appendix E: Inspection Field Notes (DVD only)

Contents of the Gate Inspection Report

Inspection Scope

This section should include the following:

- The Scope of Work for the gate inspection;
- The general qualifications and experience of the inspectors, with a reference to their resumes (Appendix A); and
- The name of the lead engineer on the team – each team should include at least one engineer qualified to review and comment on the adequacy of the spillway gate analysis of record; and
- A statement of independence – if the inspection is performed by a party other than the licensee, include a statement declaring that the inspection findings, conclusions, and recommendations were made independent of the licensee and its employees.

Review of Existing Documentation

This section of the report should contain a summary of existing documentation, including gate analyses, licensee procedures, operational history, and prior GIRs. Any other information important to the design, operation, and performance of the gates should be included, including any modifications to the design or operation of the gates. Additional guidance for what to include in this section of the GIR is described below.

Gate Analysis: The inspection team should review the analysis of record and comment on the assumptions (including material properties), methods, and results. If the gate analysis is obsolete, incorrect, or does not exist, the inspection team should immediately contact the CDSE, who should coordinate with the D2SI-Regional Office to establish a schedule for completing a new analysis. This section should include a summary of the load cases, material properties, and other pertinent design basis information.

Structural members and connections should be identified as either critical or non-critical, based on the analysis results. The failure of a critical member would be expected to result in either an uncontrolled release of the reservoir or failure of the gate to operate as designed.

Licensee Procedures: Review and comment on the licensee's procedures for inspection and maintenance (including lubrication, if required) of the gates, hoist equipment, power sources, control systems, and cables that comprise the power and SCADA systems. Attention should be given to discussion of the trunnions, including the manufacturer, installation date, physical properties, and lubrication requirements.

Operational History: Provide a brief list of significant operational issues during the life of the gates. For example, misoperation and racking due to chain binding, or dropping of a gate due to a hoist failure, should be discussed. The annual spillway gate certificates should be reviewed and the team should comment on any apparent trends, unusual amperage readings, and power draw in excess of the rated capacity of the motors.

Prior GIR: Provide an update on recommendations from the prior GIR. Critical recommendations should be discussed in this section; general maintenance items may be mentioned as necessary or simply included in the table in Appendix B.

Inspection Findings

Each radial gate should be discussed individually. The GIR should include clear, definitive statements about the condition of structural members and connecting elements, with an emphasis on those designated as critical based on the review of the analysis. Photos should be provided for significant observations. It is not necessary to include every photo in the body of the GIR, though all photos should be included on the companion DVD.

This section of the report should be presented in an appropriate format (e.g., paragraph, tabular, or diagrams) that clearly conveys the observations. Photos should be used to help explain any conditions noted. The following items should be addressed in the GIR (this is not an exhaustive list):

- Bent, deformed, or missing members or connecting elements;
- Weld defects: identify any instances of cracking, problematic details, or visibly poor weld quality;
- Mechanical fasteners: bolts and rivets should be compared to the information shown on the drawings. Loose fasteners, those visibly cracking or deformed, and those that do not conform to the record drawings, should be identified;
- Corrosion protection: discuss the condition of the coating system and whether there is a need for repair. If there is a cathodic protection system, indicate whether it is well-maintained, functional, and installed correctly;
- Corrosion: provide clear indication of the type of corrosion (e.g., surface, pitting, etc.), the location and percent of the member affected, and whether it may have structural implications;
- Drainage and debris: identify the location of any ponding water and discuss whether drainage should be provided. Accumulation of debris, including excessive animal waste, should be discussed;
- Seal condition and serviceability (including side, bottom, and top seals, as applicable);
- Lifting devices and attachments (including cables, chains, eyebolts, clevises, sheaves, etc.); and
- Mechanical and electrical components of the hoist equipment.

Operation Test: The inspection team should observe each gate moving through its full range of motion, fully closed to fully open and back, and provide observations and comments. If the requirement for a full open test does not coincide with the year of the GIR, it is acceptable for the GIR to include a review and comments on the previous full open testing, provided there is sufficient documentation available from that test for the inspection team to make an informed conclusion regarding the operational condition of the gate (e.g., real-time power draw plots, video with audio, etc.).

Recommendations

The GIR should include recommendations for how any and all identified deficiencies should be addressed. Recommendations should be flagged according to the importance of the issue. For example, categories could be:

- *Critical, dam safety-related*
- *Potential dam safety issue requiring investigation*
- *General maintenance*

Conclusions

The inspection team should provide an overall conclusion regarding the fitness of the gates for continued safe and reliable operation. The discussion should include an assessment of how the overall condition of each gate has changed since the previous GIR.

Appendices for the GIR

Appendix A: Inspection Team Resumes. Include resumes of the inspection team, including the qualified engineer who reviewed the prior gate analysis. That individual should either be a licensed Structural Engineer or have sufficient work experience to demonstrate a comprehensive understanding of issues associated with radial gates.

Appendix B: Status of Previous Recommendations. The status of previous recommendations should be updated in a tabular format. Critical recommendations are to be discussed in detail in the body of the report.

Appendix C: Drawings and Schematics. The drawings and schematics included in this section should convey all required information about the structural members and connecting elements of the gate, anchorage, and hoist equipment. As-built drawings and any drawings depicting significant modifications since original construction are recommended. Drawings should be printed at 11x17 inches and should be clear and legible to the unaided eye.

Appendix D: Inspection Photos (DVD only). If desired, this appendix may be included only electronically and not in hard copy. All inspection photos should be included at full resolution and in folders organized by gate number.

Appendix E: Inspection Field Notes (DVD only). The inspection team field notes should be scanned and included for reference. If desired, this appendix may be included only electronically and not in hard copy.

Previous FERC Letters Regarding Radial Gates

Refer to the following pages.

Original Tainter Gate Initiative (1998)

Federal Energy Regulatory Commission
Chicago Regional Office
230 South Dearborn Street, Room 3130
Chicago, Illinois 60604

February 24, 1998

In reply
refer to: 02161

Mr. Al K. Davis
Vice President of Engineering
Wausau Papers
515 West Davenport Street, P. O. Box 100
Rhinelander, WI 54501

Dear Mr. Davis:

This letter is to inform you that as a result of the findings of the Bureau of Reclamation as to the cause of the 1995 Folsom dam tainter gate failure, the FERC will require a review of the design criteria, inspection, maintenance, and lubrication procedures for all tainter gates (radial gates) at high and significant hazard potential dams. While we are limiting our review to only high and significant hazard potential projects, we recommend that a similar review be conducted for your low hazard projects as well.

The Bureau of Reclamation has released a forensic report on the failure of the tainter gate at Folsom dam in 1995. The failure report entitled "Forensic Report on the Spillway Gate 3 Failure, Folsom Dam" concluded that the cause of the tainter gate failure was as follows:

> Corrosion on the loaded side of the steel trunnion pins increased trunnion friction over time. Trunnion friction, which was not considered in the design of the gate, induced bending moment loads in the gate struts (radial arms), which were resisted principally by the diagonal strut braces. The failure occurred when the strut brace loads caused by the increased trunnion friction exceeded the strut brace connection bolt capacity.

The effort will consist of the following:

A. Conduct a general review of the design of your tainter gates to insure that nothing was overlooked in the design and construction of the gates. Specifically, you should review the design of your tainter gate strut arms to determine if forces and moments due to trunnion friction were considered. If no information is available, this should be stated.

B. Documentation should be developed covering your trunnion lubrication procedures including frequency and type of lubricant used as well as experiences associated with different lubricants. Also, other regular maintenance activities such as painting, seal replacement, etc, shall be covered.

Your findings from items A and B shall be submitted to the Chicago Regional Office within 60 days of receipt of this letter.

C. For all tainter gates, amperage draw and line to line voltage should be measured while lifting the gate under full head. These measurements should be done in conjunction with the annual gate tests currently required and included with the annual gate test certification. You should verify that the values recorded are less than or equal to the motor nameplate values. This information will be reviewed and discussed during the FERC annual operation inspection.

D. The adequacy of your gate design shall be verified by your next Part 12 consultant. As part of your next Part 12 independent consultant's report, your consultant should do the following:

1) Carefully inspect each gate including all structural members and trunnions, and specifically address the findings of this inspection in the Part 12D report.

2) Show that forces and moments due to trunnion friction can be sustained with a temporary over stress allowance of 1.33 on the steel strength. In the absence of a measured value, a friction coefficient of 0.3 shall be assumed with the gate under full hydrostatic pressure. If calculations indicate that the gate can not sustain this load case, remedial measures shall be proposed.

3) Comment on the appropriateness of your lubrication procedures as well as other maintenance activities.

4) Comment on the records of amperage draw and line to line voltage that you will have compiled. Specifically, your consultant shall compare the rated horsepower with these recorded values. This will give an indication of the reserve capacity available in the lifting machinery and allow the opening resistance of a gate to be compared with respect to time and other gates.

For those significant hazard potential projects which are not required to submit a Part 12D, Independent Consultant Inspection Report, you will have to perform an analysis of the design of the tainter gates (items 1-4 above). Before undertaking this activity, please submit a plan of your proposed action to the Regional Office for concurrence.

Thank you for your cooperation in this important dam safety matter. If you have any questions, please do not hesitate to call John Hawk at (312) 353-6168.

Sincerely,

Ronald A.Lesniak, P.E.
Regional Director

Tainter Gate Initiative, Revision 1 (2001)

FEDERAL ENERGY REGULATORY COMMISSION
901 MARKET STREET, SUITE 350
SAN FRANCISCO, CA 94103

FILED
OFFICE OF THE SECRETARY

01 JAN 23 PM 2:39

FEDERAL ENERGY
REGULATORY
COMMISSION

January 18, 2001

In reply refer to:
Project No. 2954-CA

Mr. David H. Johnson
Director, Public Works Department
City of Santa Barbara
P.O. Box 1990
Santa Barbara, CA 93102-1990

Dear Mr. Johnson:

Re: Tainter Gate Initiative Revision 1

Our letter to you, dated March 3, 1998, required inspection, analysis and testing be done on all of your tainter gates. As a result of our ongoing review of this tainter gate initiative, we have recognized the need to focus inspection, testing, and analysis efforts on gates whose failure would have dam safety or operational consequences. To this end, the FERC will now recognize 2 categories of taintergates:

Category 1- Failure or mis-operation (failure to operate) would have dam safety or operational consequences.

1. Structural failure would endanger downstream life and property.

2. Failure to open or close would significantly effect the project's ability to safely pass a flood, endanger upstream life and property, or effect a project purpose or compliance requirement, including important environmental requirements.

Category 2 - Failure would have minimal to no consequences.

The requirements based on gate category are included in the Attachment. Gates will be considered Category 1 unless an justification for Category 2 is made by the licensee. The FERC will base its decisions on the following risk factors :

Consequences of gate failure. Gates can fail in both open and closed position. The upstream and downstream consequences of each failure scenario must be considered.

Redundancy. Gate failure at a site with many small gates may not be as serious as gate failure at a site with a few large gates.

Operator Reliability. If all gates are operated by one traveling hoist, then hoist failure becomes much more critical. (Common cause failure)

Project function. If failure of a gate makes it impossible for the project to function as intended, including fulfilling important environmental requirements, gate failure becomes more critical.

Bulkhead Provisions. If there is another method of stopping flow, the consequences of gate failure may be lessened.

If you have any questions concerning this matter please call Mr. Tilak Dhir at 415-369-3361. Thank you for your cooperation in this important dam safety initiative.

Sincerely,

JAMES GORIS

James Goris, P.E.
Regional Director

Attachment:

FERC TAINTER GATE INITIATIVE REVISION 1

	Proposed —>>	Category 1	Category 2
	Current FERC requirements ↓	1) Structural failure would endanger downstream life and property, 2) Failure to open or close would significantly effect the project's ability to safely pass a flood, endanger upstream life and property, or effect a project purpose or compliance requirement, including important environmental requirements.	Not Category 1.
Close-up Detailed Inspection	NA	10 yrs (every gate)	NA
Visual Inspection	1 yr	1 yr	2 yrs
Ampere Testing	1 yr	1 yr	NA
Full Height Testing	5 yrs	5 yrs	10 yrs
Operation Test	1 yr	1 yr	1 yr
Required Analysis	Static + Dynamic	Static + Dynamic	Static

The FERC will consider all Tainter Gates Category 1 gates unless the owner makes a case for Category 2.

Tainter Gate Initiative, Revision 2 (2002)

FEDERAL ENERGY REGULATORY COMMISSION
Office of Energy Projects
Division of Dam Safety and Inspections
Portland Regional Office
101 S.W. Main Street, Suite #905
Portland, Oregon 97204

JUN 13 2002 P-2899, et al.
JUN 1 3 2002

Re: FERC Tainter Gate Initiative, Revision 2

To Licensees on the Attached List:

By October 13, 2000 letter, we advised of a revision to our tainter gate initiative. As a result of feedback received from licensees and consultants, it is clear that the intended purpose of this revision, which was to focus inspection and analysis efforts on the gates of highest risk, was not achieved. This letter provides clarification and a few additional changes. We will recognize two categories of tainter gates:

Category 1 - Structural failure or mis-operation (failure to operate) of gates would have dam safety or severe operational consequences.

1) Structural failure of a gate or a gate's inability to open or close endangers downstream life and property during normal operations and flood events.

2) Failure to open or close results in a significant uncontrolled reservoir level rise or drop during normal operations or flood events affecting upstream property or resources.

Category 2 - Structural failure or mis-operation would have minimal to no consequences.

1) Gates located at low hazard potential dams.

2) A gate failing in the open or closed position would not impact the dam's ability to safely pass flood flows or affect upstream property or resources.

The requirements for each category are included in the attached table, FERC Tainter Gate Initiative, Revision 2. The requirements of Category 2 have been revised to be more in line with what is currently required at low hazard potential dams. The requirement for structural analysis has been removed, and the frequency of full-height gate tests have been extended to once every 10 years. Annual gate testing requirements are as required by the regulations.

The general requirement for adynamic analysis of Category 1 gates has also been deleted. Earthquake induced tainter gate failures are considered rare. Dynamic analyses will be required on a case-by-case basis for projects with large gates in severe seismic regions where the expected peak ground acceleration is high. Engineering judgment will be required when deciding to require a dynamic analysis. As a guideline, dynamic analysis will be required if peak ground acceleration is over .25g and the gate failure would result in loss of life. It should be understood that this does not relieve the project owner of the necessity of analyzing the gate piers or other gate related structural project features under the appropriate seismic loading.

Gates at high and significant hazard potential dams will be considered Category 1 unless an justification for Category 2 is made by the licensee. The decision will be based on the following risk factors :

Consequences of gate failure. Gates failure can have both upstream and downstream effects. A structural failure or a failure to close can result in the loss of the reservoir and endanger downstream life and property. A failure to open during a flood event can cause the reservoir to rise excessively, threatening the stability of the dam and causing flooding upstream. Of concern is a situation in which a small and frequent flood event is exasperated by a gate which cannot be opened. A gate failure could result in a loss of reservoir and the associated upstream recreational project purposes. The upstream and downstream consequences of each failure scenario must be considered under normal operations and flood flows.

Redundancy. Gate failure at a site with many small gates may not be as serious as gate failure at a site with few large gates.

Operator Reliability. If all gates are operated by one traveling hoist, then hoist failure becomes much more critical. (common cause failure)

Project Function. If failure of a gate makes it impossible for the project to function as intended, gate failure becomes more critical. Consider the impact on a significant reservoir related resource such as major recreation centers.

Bulkhead Provisions. If there is another method of stopping flow, the consequences of gate failure may be lessened. Can a breach flow be quickly stopped with stoplogs or portable cofferdams? Can the gate bay be bulkheaded under flow conditions?

Please review the tainter gates associated with your project(s) and if deemed warranted, provide this office with copies of justification for those tainter gates you feel should be classified as Category 2.

Thank you for your cooperation in this important dam safety initiative. If you have any questions, please call Mr. Edward Perez of this office at (503) 944-6750.

Sincerely,

Harry T. Hall, P.E.
Regional Engineer

Enclosure - FERC Tainter Gate Initiative, Revision 2

FERC TAINTERGATE INITIATIVE
REVISION 2

3/21/02

	Category 1	Category 2
	1) A structural failure of a gate or a gate's inability to open or close endangers downstream life or property during normal operations and flood events. 2) A failure to open or close results in a significant un-controlled reservoir level rise or drop during normal operations or flood events affecting upstream property or resources.	1) Gates located at low hazard potential dams. 2) A gate failing in the open or closed position would not impact the dam's ability to safely pass flood flows or affect upstream property or resources.
Close-up Detailed Inspection	10 yrs	NA
Ampere Testing	1 yr	NA
Full Height Testing	5 yrs	10 yrs
Annual Operation Test	1 yr	1 yr
Required Analysis	Static 1/	NA

1/ As a guide, dynamic analysis will be required if peak ground acceleration is over .25g and the gate failure would result in loss of life. It should be understood that this does not relieve the project owner of the necessity of analyzing the gate piers or other gate related structuralproject features under the appropriate seismic loading.

All tainter gates at high and significant hazard potential sites will be considered Category 1 gates unless the licensee provides justification for reclassification to Category 2.

10-Year Gate Inspection Reminder (2009)

April 28, 2009

RE: Tainter Gate Initiative/Dam Owners Responsibilities

Dear Licensee/Exemptee:

The FERC Tainter Gate Initiative was instituted in February of 1998 in response to the findings of the Bureau of Reclamations forensic investigation of the 1995 Folsom Dam gate failure. Since you are at or approaching the 10 year requirement for a detailed inspection of Category 1 gates, this letter is intended to remind you of the continuing responsibilities that you have under the FERC Tainter Gate Initiative. The table below provides a description of Category 1 and 2 gates and the inspection requirements under each Category of gate.

	Category 1	**Category 2**
	1) A structural failure of a gate or a gate's inability to open or close endangers downstream life during normal operations and flood events. 2) A failure to open or close results in a significant un-controlled reservoir level rise or drop during normal operations or flood events affecting upstream property or resources.	1) Gates located at low hazard potential dams. 2) A gate failing in the open or closed position would not impact the dam's ability to safely pass flood flows or affect upstream property or resources.
Close-up Detailed Inspection	10 yrs	NA
Ampere Testing	1 yr	NA
Full Height Testing	5 yrs	10 yrs
Annual Operation Test	1 yr	1 yr
Required Analysis	Static	NA

A report providing the results of the detailed inspection for your Category 1 gates should be provided with the submittal of your next gate certification due by December 31, 2009. Included with your report should be a plan and schedule to address any deficiencies noted during the inspection. If you are unable to perform the inspection and submit a report of the findings by December 31 you should submit a plan and schedule of when this can be accomplished for our approval.

All tainter gates at high and significant hazard potential dams are considered Category 1 gates by default. The following risk factors are considered to revise the categorization of a gate:

Consequences of gate failure. Gates can fail in both open and closed position. The upstream and downstream consequences of each failure scenario must be considered.

Redundancy. Gate failure at a site with many small gates may not be as serious as gate failure at a site with few large gates.

Operator Reliability. If all gates are operated by one traveling hoist, then hoist failure becomes much more critical. (Common cause failure)

Project function. If failure of a gate makes it impossible for the project to function as intended, gate failure becomes more critical.

Bulkhead Provisions. If there is another method of stopping flow, the consequences of gate failure may be lessened.

Explanation of Requirements:

1) Close up Detailed Inspection. The purpose of this inspection is to detect broken welds and bolts, fatigue cracks, and the initiation of corrosion. Observations from a distance are not sufficient for this purpose. If the inspector is not close enough to touch the gate feature he/she is inspecting, the inspection can not be considered a "Close up Detailed Inspection".

2) Ampere Testing. The purpose of this is to obtain a periodic easily obtainable spot check of operability of the gate machinery.

3) Full Height Testing. This must be performed periodically to insure that the gate can operate through its full intended travel in the event that extreme flood events occur.

4) Annual Operation Test. Every year the operational readiness of each gate must be demonstrated.

5) Analysis. Analysis previously performed in response to the Tainter Gate Initiative need not be re performed. However as with all analyses and studies contained in the STID, it is the responsibility of the Part 12 consultant to review and comment on the accuracy and appropriateness of tainter gate analyses. Gates may require re-analysis if changes have been made to the gates, or if anticipated loading conditions have changed. While static analyses will be sufficient for most gates, large high consequence gates in high seismic areas may require dynamic analysis.

If you have any questions, please call me at 503-552-2741.

Sincerely,

Patrick J. Regan, P.E.
Regional Engineer

Enclosure: Annual Spillway Gate Operating Certificate

Annual Spillway Gate Operation Certificate

A link to download the most recent version of the annual spillway gate operation certificate can be obtained at the following address:
http://www.ferc.gov/industries/hydropower/safety/guidelines/eng-guide.asp