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# ENGINEERING GUIDELINES FOR THE EVALUATION OF HYDROPOWER PROJECTS

## CHAPTER 15 – SUPPORTING TECHNICAL INFORMATION DOCUMENT

**DRAFT FOR PUBLIC COMMENT**

FEDERAL ENERGY REGULATORY COMMISSION  
888 First Street NE  
Washington, DC 20426

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| <b>Revision Log</b> |             |                    |
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**ABBREVIATIONS**

|               |   |
|---------------|---|
| CA            | Comprehensive Assessment  |
| CAR           | Comprehensive Assessment Report                                       |
| CFR           | Code of Federal Regulations   |
| Commission    | Federal Energy Regulatory Commission                                  |
| D2SI          | Division of Dam Safety and Inspections                                |
| DSPMP         | Dam Safety Performance Monitoring Program                             |
| DSSMP         | Dam Safety Surveillance and Monitoring Plan                           |
| DSSMR         | Dam Safety Surveillance and Monitoring Report                         |
| EAP           | Emergency Action Plan   |
| FAAP          | FERC After Action Panel   |
| FERC          | Federal Energy Regulatory Commission                                  |
| FERC-RO       | Regional Office (of the FERC, D2SI)                                   |
| FERC-WO       | Washington Office (of the FERC, D2SI)                                 |
| FPC           | Federal Power Commission  |
| Guidelines    | FERC Engineering Guidelines for the Evaluation of Hydropower Projects |
| IC            | Independent Consultant  |
| IC Team       | Independent Consultant Team   |
| IDF           | Inflow Design Flood   |
| IFT           | Independent Forensic Team   |
| Part 12D      | 18 CFR Part 12, Subpart D   |
| PFM           | Potential Failure Mode  |
| PFMA          | Potential Failure Modes Analysis                                      |
| PI            | Periodic Inspection   |
| PIR           | Periodic Inspection Report  |
| PIPR          | Pre-Inspection Preparation Report                                     |
| PMF           | Probable Maximum Flood  |
| PMP           | Probable Maximum Precipitation  |
| Project Works | Features defined as Project Works in the Project License              |
| RA            | Risk Analysis   |
| RAR           | Risk Analysis Report  |
| SSPMP         | Site-Specific Probable Maximum Precipitation                          |
| STID          | Supporting Technical Information Document                             |

Note: all references to "Licensee" in this chapter are also applicable to Exemptees.

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## PREFACE

The information in this chapter was previously contained in Chapter 14, Appendix I of the Commission's Engineering Guidelines. In a significant departure from that guidance, this chapter does not contain any examples of the level of detail expected in the STID. Instead, a more thorough discussion of the required information for each section of the STID is provided in this new guidance.

This chapter substantially increases the guidance provided to licensees for the development of an STID. Several of the enhancements were suggested, or resulted from a discussion of shortcomings, by the Oroville Spillway Independent Forensic Team (Oroville IFT) and/or the FERC After-Action Panel (FAAP). Several pertinent passages from the Oroville IFT Report are shown below (emphasis added):

IFT Report, Page 66:

In support of its Part 12 process, FERC does have specific and detailed requirements for information management. One of those requirements is development of a Supporting Technical Information Document (STID), which is intended to be a 'living document,' updated at an interval of not more than five years, which captures all of the key information needed to properly evaluate a dam and its appurtenances.

The IFT notes that **the STID for Oroville Dam which was updated in 2014 did not include much of the information which would have helped identify the risks at the two spillways, and was therefore incomplete.** Drawings with service spillway chute slab details, as well as numerical flood routings and water surface profile calculations, were among the information which was not included in this STID. Drawings with slab details were included in the 2014 Ninth Part 12D report, however the IFT found no evidence that those details were reviewed.

IFT Report, Page F3-13:

It is significant to note that **neither the 2014 PFMA report nor the 2014 STID include any service spillway chute drawings, either design or as-built.** Further, during interviews, participants in the PFMA did not recall reviewing these drawings.

IFT Report, Page K2-4:

**There does not appear to have been a process to check whether the STID actually contained all information required to properly undertake a design review.** Rather, in the case of the Oroville STID, it contained a limited selection of drawings and documents, none of which in this case detailed local foundation conditions for either spillway nor details of the service spillway chute slab design.

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List of Major Changes

- In general, this chapter provides more detail for what to include in each section of the STID to ensure the summary information is comprehensive. Additional sections have been provided to document information related to appurtenant features, the requirements for documentation of which were not clearly established in previous guidance.
- Section 9 (formerly “Spillway Gates”) has been renamed as “Gates, Valves, and Other Reservoir Control Devices” and expanded accordingly. Documentation must be provided for all types of gates (not just radial spillway gates, as was often the case) as well as valves (e.g., Howell Bungler valves) and other reservoir control devices (e.g., flashboards).
- In each section, the guideline provides a list of the types of references to be provided on the digital reference. Previously, there was no clear guidance on what references were to be provided digitally or how to organize them. **This was identified as an issue by both the IFT and FAAP and the expectations for the provision and maintenance of digital records have been detailed.**

## 15-1 INTRODUCTION

The guidelines presented in this chapter provide details regarding the preparation and maintenance of a Supporting Technical Information Document (STID), which is essential for the review and evaluation of the safety and performance of project works by licensees, consultants, and the FERC.

### 15-1.1 Purpose

The STID serves as a compendium of knowledge and information about a project. The STID consists of two parts; a hard copy and a digital reference. The hard copy portion is a summary of those project elements and details that, except in the event of detailed studies or construction, do not change significantly over time. The digital reference (e.g., a CD, DVD, or other form of electronic media) is a compilation of all available source material and additional supporting information, formatted so that the licensee, the FERC, or consultants can identify and retrieve the information they need. A searchable electronic version of the hard copy material must be included on the digital reference. The Licensee is responsible for compiling the information for the STID and creating and maintaining the document for use by themselves, the Part 12D IC(s), and the FERC.

The STID must include sufficient information to understand the design and current engineering analyses for the project. Section 15-2.1 contains the outline for the STID. A detailed list and description of the recommended information to be included in each section of the STID is provided in Section 15-3.

### 15-1.2 Applicability

All projects subject to 18 CFR Part 12D are required to prepare, submit, and maintain an STID, and to provide physical and digital copies to the D2SI-Regional Engineer [*18 CFR §12.12(d)*]. The FERC recommends, but does not require, that licensees and exemptees prepare an STID for projects not subject to 18 CFR Part 12D. The Regional Engineer may request that the licensee prepare an STID for other projects on a case-by-case basis.



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**15-2 GENERAL REQUIREMENTS**

The STID is a “living” document. When new data or analyses become available and are accepted as part of the project record, they will be appended to the existing STID. This includes updating the summary information in the hard copy STID and adding the reference to the digital reference. Outdated material should be removed from the hard copy and archived on the digital reference.

**15-2.1 Outline of the STID**

The STID comprises two main components: the hard copy and the digital reference containing digital versions of pertinent reference material.

The outline of the hard copy STID is shown below; specific requirements for the content of each section are provided later in this Guideline.

**Table 1: STID Outline**

| <b>Section No.</b> | <b>Section Name</b>  |
|--------------------|--|
| -                  | Title  |
| -                  | Revision Log   |
| -                  | Table of Contents  |
| 1                  | Potential Failure Modes Analysis (PFMA) Report and Risk Analysis (RA) Report |
| 2                  | Description of Project Structures  |
| 3                  | Construction History   |
| 4                  | Standard Operating Procedures  |
| 5                  | Geology, Seismicity, and Geotechnical Data                                   |
| 6                  | Hydrology and Hydraulics   |
| 7                  | Dam Safety Surveillance and Monitoring Plan                                  |
| 8                  | Stability and Stress Analyses of Dams and Water Conveyances                  |
| 9                  | Gates, Valves, and Other Reservoir Control Devices                           |
| 10                 | Pertinent Correspondence Related to the Safety of Project Works              |
| 11                 | References   |

**15-2.2 STID Hard Copy**

The purpose of the STID hard copy is to provide a quick reference to the summary information that is most relevant for day-to-day use. When possible, consider using tables, figures, and drawings in the STID in lieu of text and do not include complete copies of the original source documents (except for the PFMA study report and the

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DSSMP). For all other information, limit text to a summary of factual information from the original reports to provide clarity. Section 15-3 of this Guideline describes the minimum expectations of each section of the STID.

Bind the hard copy document in a three-ring binder to facilitate updating the STID, with the following recommendations for printing:

- 8.5x11” pages should be printed on both sides, with each page numbered and dated;
- 11x17” pages should be printed on one side and folded with an engineering (Z) fold, with each page numbered and dated;
- All figures and plots should be printed in color with appropriate legends;
- Tabs should be provided to separate each section of the STID.

Include an indexed, searchable version of the hard copy material on the digital reference.

### 15-2.3 STID Digital Reference

The purpose of the digital reference is to ensure that users of the STID have access to all relevant reference material while limiting the hard copy STID to a single three-ring binder, if possible. **The digital reference must contain legible copies of the source material that was used to develop the hard copy STID.** Include complete copies of the documents referred to in the STID, including design basis reports, project drawings, and additional reference information identified for each section of the STID. In addition to those items, each subsection in Section 15-3 ends with a list of the types of additional materials that should be included on the digital reference, if applicable and available. Also be sure to include all additional documents reviewed in the PFMA session, if they are not already provided elsewhere on the digital reference.

The digital reference must be labeled with the project name and number; the date of the most recent update; and appropriate information security designation (e.g., CUI//CEII). Provide the media in a sleeve or case that is physically connected to the three-ring binder.

Organize the digital reference such that reference material can be located quickly for review in the event of a dam safety emergency. Include individual references as separate files. It is not acceptable to combine separate references into a single file for simplicity. The FERC does not mandate a file structure or organizational system but recommends the use of one or more of the following practices:

- Provide a separate folder to contain references for each section of the STID.
- Include a master table of contents, organized by STID section, which lists the title and date of each reference.
- Combine drawings from a set (e.g., one construction project) into a single file.

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- In the table of contents, include a hyperlink to each reference to simplify access.
- To the extent practicable, ensure all files on the digital reference are word searchable.

Provide the digital copy in searchable PDF format or another acceptable format (check with the FERC for acceptability of alternative formats prior to submittal).

#### **15-2.4 Updating the STID**

An STID requires periodic maintenance in order to remain current and useful. The following information discusses the scope of updates during Comprehensive Assessments (CAs), Periodic Inspections (PIs), and at other times between Part 12D Inspections.

##### Comprehensive Assessments

The scope of a CA includes a comprehensive review and evaluation of the STID. The FERC recommends that the STID be completely reprinted prior to or in conjunction with the CA of the project, to ensure the Part 12D Independent Consultant (IC) is reviewing the most current document. The FERC recommends that the licensee update the STID expeditiously following completion of the IC's review, to address and incorporate the IC's recommendations, such that an updated copy of the STID can be submitted with the Comprehensive Assessment Report (CAR).

Regardless of whether any updates have been made to address the IC's recommendations, hard copies of the STID must be submitted to the FERC within 60 days after submitting the CAR. The FERC may provide additional comments on the STID following completion of their review of the CAR and STID; depending on the situation, the FERC may request that particular sections or the entire document be updated and resubmitted.

##### Periodic Inspections

The scope of a PI does not include an evaluation of the STID; however, it must be current to ensure that the IC can prepare for their inspection. Prior to a PI, the licensee must provide any STID updates to the current Part 12D IC, the FERC, and to other document holders for review prior to the IC's inspection. Include instructions for document holders to insert the updated pages in the hard copy STID. The FERC recommends issuing updates as complete sections instead of individual pages, unless the updates are exceedingly minor. Update the revision notice log in the front of the STID.

If no significant changes have been made to the STID since the preceding CA, provide either a digital copy or a hard copy of the most current STID with the Periodic Inspection Report (PIR).

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Other Updates

As analyses or studies are completed between CAs, after they have been accepted by the FERC, update the corresponding sections of the STID accordingly and provide the updates to the FERC. Again, the FERC recommends issuing updates as complete sections instead of individual pages, unless the updates are exceedingly minor. Update the revision notice log in the front of the STID.

### **15-3 CONTENT OF THE STID**

The following sections describe the expected content expected for each section of the hard copy STID and provide additional guidance for information to include on the digital reference.

**The hard copy STID is to contain factual information; it should be written to avoid statements of opinion** (e.g., “I/we determined that \_\_\_\_\_” or “It is the opinion of the current IC that \_\_\_\_\_”). If the hard copy STID reproduces or paraphrases the opinions of previous consultants or experts, those statements should be introduced accordingly and distinguishable from adjacent text. When such a citation is used in the hard copy, provide a full copy of the document cited on the digital reference.

#### **15-3.1 Potential Failure Modes Analysis (PFMA) Report and Risk Analysis (RA) Report**

In this section, include complete copies of the following reports, inclusive of attachments (with one exception noted):

- The current PFMA report; and
- The current RA report.

If a prior report is attached to the current report as a reference (e.g., a prior PFMA report attached to the current PFMA report), the prior PFMA report does not need to be printed for the hard copy STID. Only include the most recent PFMA report and RA report in the hard copy STID.

Refer to Chapters 17 and 18 of the FERC Engineering Guidelines for the Evaluation of Hydropower Projects for additional information on conducting a PFMA and RA, respectively, and for completing the associated report.

##### **15-3.1.1 Additional Information for the Digital Reference**

On the digital reference, include complete copies of all previous PFMA and RA reports and supplements, including any construction and spillway-specific PFMA reports.

#### **15-3.2 Description of Project Structures**

Provide a detailed description of the project and project works. Ensure that each project feature listed in the project license is discussed, or identify any project features not listed and document the reason for its omission. For projects comprising multiple developments with separate STIDs, only discuss the project features relevant to the particular development.

##### **15-3.2.1 General Project Description**

Provide a general narrative of the project including:

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- Project location, including river/waterway name, county/counties, and nearest towns/cities;
- Licensee name (also provide the dam owner's name when the licensee does not own the dam);
- Project purpose;
- Project hazard potential classification, downstream structures affected by a dam failure, and the population at risk from a dam failure (e.g., a general description of the populated areas that would be affected, or a summary of results from any detailed Population at Risk (PAR) studies); and
- Elevation reference datum(s) for elevations used in the text of the STID. Include conversions, as needed, for other datum references used in documents on the digital reference.

**15-3.2.2 Detailed Description of Project Features**

Include detailed descriptions of each of the following project features:

- Reservoir – include reservoir surface area and storage capacity at normal pool, maximum and minimum operating pools, and flood pool. Include storage capacity at the dam crest if the elevation is different from maximum operating pool level.
- Spillway – include pertinent dimensions of the spillway such as height, crest elevation and width and slopes. Include a description of the type of spillway (uncontrolled weir, gated or ungated, morning glory, etc). Include a description of foundation materials at the spillway.
- Spillway Gates – include gate type, dimensions, and a description of equipment used to lift gates, including all backup power sources.
- Embankments – include description of materials used (soil, rock, etc), original placement method, height, crest width, crest elevation, and upstream and downstream slopes and any slope protection. Describe embankment core walls (materials and dimensions) if applicable. Include a description of foundation materials for all embankments.
- Non-overflow sections – include pertinent dimensions such as height, crest elevation and width and slopes. Include a description of the non-overflow section(s) foundation.
- Intake/powerhouse – include pertinent dimensions for the intake section and the trash rack system. For the powerhouse include structural dimension and construction type, number and type of generating units, and authorized generating capacity. Include a description of the foundation. Also, include a description of the tailrace.

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- Outlet works – include any low-level outlet works, sand gates, etc. Provide dimensions of all outlet works.
- Water Conveyance Features – include pertinent dimensions and construction materials/methods for water conveyance features (penstocks, canals, etc.).
- Provide descriptions of other features associated with the project as necessary.

**15-3.2.3 Drawings**

Provide a list of drawings included in this section as well as a list of the sets of drawings that are included on the digital reference (both lists should be hyperlinked in the searchable PDF of the STID). Include legible hard copies of the following drawings at a minimum:

- USGS Quad map or other location map (e.g., satellite image, drone image) with project facilities located, including the alignment of all water conveyances;
- A plan view of licensed project facilities with the project boundary adjacent to the facilities delineated; and
- Typical sections and profiles of key project works (e.g., dams, spillways, powerhouses, intakes, canals, tunnels, penstocks, flumes, surge chambers, inverted siphons, gates, etc.). Approved Exhibit F drawings may suffice for the hard copy STID.

**15-3.2.4 Additional Information for the Digital Reference**

Include all drawings from the original construction and all subsequent major modifications on the digital reference. As-built drawings, if available, should be provided in addition to the design drawings. Electronically “bind” each set of drawings in a separate PDF file, if possible. If each individual drawing is stored on the media as a separate file, include a master table of contents that lists each sheet number, title, and includes a hyperlinked reference to the associated file.

Drawings related solely to recreational or other facilities that are unrelated to the project works (e.g., Exhibit R drawings) do not need to be included.

**15-3.3 Construction History**

Include a detailed construction timeline beginning with the original site investigation and include the dates for original construction and all major modifications to project works completed to date. Provide general descriptions of the methods of excavation and construction for each project feature; highlighting any unique or contemporaneously non-standard methods or materials. Include representative photographs of critical periods during construction (e.g., foundation preparation) and key project features (e.g., a sheet pile cut-off wall beneath an embankment core, formed shear keys between concrete sections, etc.).

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Base the information in this section on the following sources of information:

- Design reports and pertinent memoranda from licensing and permitting documents;
- Laboratory investigation and construction testing reports;
- Geotechnical investigations;
- Construction reports and photographs;
- Specification documents;
- Reports of major modifications conducted for dam safety;
- Documentation of major maintenance activities; and
- Other available documents.

Include a list of all available design and construction documents that are included on the digital reference. It is not necessary to provide a printed list of the photographs that are included on the digital reference.

#### **15-3.3.1 Additional Information for the Digital Reference**

Include all available design basis reports, construction progress reports, field and laboratory testing reports, specification documents, design basis memoranda, and original calculations (if not included in other sections) on the digital reference.

If feasible, include all available construction photographs from the original construction and all major modifications to project works completed to date. Title each photograph and include a master table of contents file that lists each photograph, a brief description of the photograph contents, and a hyperlinked reference to the photograph. **If the number of available construction photographs makes it impractical to include them all on the digital reference:**

- include a representative sample of the available construction photographs on the digital reference, along with a brief description of and hyperlinked reference to each photograph; and
- provide a list and brief description of the sets of photographs stored by the licensee, such that the FERC and others can identify and request specific files as needed.

#### **15-3.4 Standard Operating Procedures**

Include in this section concise descriptions of the following procedures:



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- Project staffing, including number of hours and days of week when the project is staffed for normal operations, and procedures for response during periods when the project is not staffed
- Normal reservoir operations, including unit operating procedures and SCADA monitored instrumentation and alarms. Include reservoir rule curves for reservoir operations.
- Flood operations, including standard gate operating procedures if there are spillway gates, other gates, or reservoir control valves at the project. Include a gate opening sequence if available. Include project staffing levels for flood operations, if different than normal operations. Include standard protocols used for emergency spillway operation, if applicable.
- Low level outlet and similar control valve operating procedures.
- Winter/cold weather operations.
- Procedures for remote operations of spillway gates and generating units, including staffing of remote operation centers.
- Standard procedures for operating manually-tripped stoplogs or stanchions and other similar devices.
- Routine maintenance procedures, including how maintenance needs are identified and corrections are tracked.
- A list of all written operating procedures applicable to dam safety. The list should include the procedure number, title and revision date.

Do not include routine inspections or instrument reading procedures that are part of the Dam Safety Surveillance and Monitoring Plan (DSSMP), which is covered in Section 15-3.7.

#### **15-3.4.1 Additional Information for the Digital Reference**

Include copies of all written standard operating procedures for the project on the digital reference

#### **15-3.5 Geology, Seismicity, and Geotechnical Data**

##### **15-3.5.1 Geology**

This section of the STID should include sufficient geologic data, analysis, and interpretation regarding geologic and foundation materials, structure, processes, and history to support a full understanding of the site subsurface conditions and foundation behavior. Where more detailed project related geologic information is available in other documents, publications, or reports, a summary of the information should be presented in

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the STID with full citations directing the reader to where the complete information can be found.

#### **15-3.5.1.1 Regional Geology**

Regional geology provides a framework for the site-specific geology. When site-specific geologic data is put in a regional geology context a more complete understanding of the subsurface conditions can be made. Since most geologic information depends on interpretation of subsurface conditions between known data points (i.e. borehole or outcrop locations), understanding the regional geology and geologic history can provide a more accurate and complete understanding of the local geologic and foundation conditions.

This subsection should provide a brief but complete description of the regional geologic and tectonic setting, which may include:

- Physiographic setting;
- Nature and source of available published geologic reports or maps;
- Stratigraphy and lithology of regional formations or geologic map units;
- Geologic structure, including folding, faulting, and discontinuity or fracture characteristics;
- Surface water features and regional drainage patterns;
- Regional groundwater and aquifer conditions;
- Geomorphology and surficial processes; and
- Regional geologic hazard identification and mapping.

#### **15-3.5.1.2 Site Geology and Foundation Conditions**

The adequacy of geologic information for hydroelectric projects depends on accuracy in the description and classification of subsurface materials, documenting how geologic and geotechnical investigations were conducted, and sound geologic interpretation. Materials should be described and classified according to their geologic and physical properties and their engineering behaviors. Interpretation of the unit depositional environments, tectonic and metamorphic histories, and weathering and erosion/scouring susceptibility should also be provided.

- Provide brief but complete descriptions of all geologic rock, soil units, any fill, and structural features mapped or inferred within the project area;
- Provide general soils and rock strength characteristics;
- Provide geologic maps and boring location plans, at readable scales – including plans, foundation maps, photographs of foundation excavations, cross-sections,

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and profiles – that show the foundation conditions under the dam(s) and other pertinent project works. Where available, provide cross sections of the geologic strata with clear labeling or notations;

- Descriptions of geologic discontinuities (e.g., bedding, jointing, foliations, fractures, asperities, etc.);
- Local mapping and/or database listing of adverse geologic or man-made features in the region (e.g., sinkholes, mining activity, etc.)
- Description of any geophysical investigations;
- Description of foundation excavations and preparations;
- Description of foundation treatments; and
- Clearly identify the source(s) of information used to develop geologic interpretations and maps.

#### **15-3.5.1.3 Site Hydrogeology**

Nearly all water-impounding structures (i.e., dams) have significant effects on the local groundwater and aquifer conditions. Conversely, the natural groundwater conditions can impact the performance or seepage conditions of a dam. Therefore, provide documentation of the pre-dam and post-dam site hydrogeology including the following, where available:

- Site-specific, pre-dam groundwater and aquifer conditions, if known;
- Surface water features, streams, and springs;
- General description of water-bearing units (aquifers) and non-water-bearing units (confining units);
- General description of groundwater flow directions and pressure heads;
- Identification of hydrogeologic boundaries; and
- Discussion of aquifer heterogeneities, and porous (soil) vs. conduit (rock fracture) groundwater flow.

#### **15-3.5.1.4 Potential Foundation Weaknesses**

Document the potential for weaknesses in the foundation in the context of potential failure modes (PFMs). The subsequent sections discuss common phenomena that should be specifically addressed even if they do not occur at the project site. Additional sections should be included, as needed, for projects with foundation weaknesses that do not fit into these general categories.

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Slide Potential

Document potential landslides, loose rock formations, or adverse bedding orientations that could affect project works.

Sinkholes, Karst, Solutioning

Document any known or potential sinkholes, karst, solutioning, basalt flow (e.g., lava tubes) issues, or other similar conditions that could affect project works.

Weak or Erodible Materials

Document the existence of any potential weak materials in the foundation or spillway channel/tailrace, or rock types that are often found in conjunction with weak materials; this may include, but is not limited to, the following examples:

- Bentonite or soluble gypsum layers;
- Materials within a fault zone (e.g. gouge, highly fractured rock);
- Weathered shale/claystone layers;
- Highly jointed or fractured rock with low Rock Quality Designation (RQD);
- Clay interbeds; and
- Coal seams.

Artesian Sources

Document artesian sources in the vicinity of the project; for example, geothermal sources or high abutments. Identify whether each is geologic in origin (i.e., they exist in the absence of the project reservoir) or if it is related to the reservoir (e.g., presence or volume of flow varies with pool elevation).

**15-3.5.2 Seismicity**

List the date, author, and summarize the procedures and findings of the most recent seismic study or Seismic Hazard Assessment (SHA). If a site-specific SHA has not been completed for the project, provide the best available information. Refer to Chapter 13 of the Engineering Guidelines for additional information on conducting a site-specific SHA.

Include summary discussion and provide the relevant figures and tables for the following items:

- A map of fault traces that affect the project. Differentiate between those traces that have been confirmed (by trenching or other means) and those that are inferred.
- A table of faults, distances, lengths of rupture, depths, magnitude at fault, and peak ground acceleration (PGA) for the considered sources, including the local

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(floating or random crustal) earthquake. Include the estimated recurrence interval for each, if known.

- A map of historic earthquake centers.
- A table and map showing controlling fault sources.
- Attenuation relationships.
- Seismic ground motions and design spectra used for analysis of project structures.

The USGS website (<http://earthquake.usgs.gov>) may be a useful reference for general information on seismicity, and for the development of several of the required general figures. See Chapter 13 of the Guidelines for more information on the use of this website.

### 15-3.5.3 Geotechnical Data

This section provides a summary of geotechnical data obtained from original design, construction, and subsequent investigations, including drilling logs from the installation of instruments such as piezometers, inclinometers, etc. For embankment and foundation material properties, include a summary discussion and references to supporting documentation on the digital reference.

#### Material Properties

Summarize any laboratory and in-situ testing, including the results and procedures used to determine soil types and properties. For example:

- Laboratory testing: Atterberg limits, grain size distribution, hydraulic conductivity tests, direct shear test, proctor test, unconfined compression test, triaxial tests, etc.
- In situ testing: standard penetration test (SPT), cone penetration test (CPT), dynamic cone penetration test (DPT), Becker Penetration Test (BPT), pressure meter test (PMT), seismic refraction test, downhole method, ground penetrating radar (GPR), rising/falling head hydraulic conductivity test, etc.

Clearly identify whether each material property was derived from in situ testing, laboratory testing, or was assumed from literature values. State the date for any testing

If in situ testing was conducted, note any site conditions that could potentially affect the recorded data (e.g., CPT in gravelly conditions, lack of recovery from split-spoon sampler, use of rope and cathead for SPT testing, uncalibrated manual and automatic hammer for SPTs, questionable accuracy of efficiency corrections for SPT, soil heave or artesian conditions, qualifications of staff on site, etc.). Document any correlation method that was applied to translate one testing method into another to approximate material properties (e.g., BPT data correlated to SPT values).

For any derived soil parameters, document the following information about the data set and methodology:

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- State the number of tests used to derive each strength parameter;
- Include explanation for why any data points were excluded in derivations;
- Note the location of in situ testing (e.g., borings) and whether the location is an accurate representation of the embankment or foundation zone material (show locations on a cross-section or profile); and
- Note the statistical approach to apply the data for deriving material strength parameters (e.g., the mean, the lowest third of the lowest 33 percent, the lowest SPT value, etc.).

If values are selected from literature list the source title and date and provide a discussion of how the literature source was used in lieu of site specific testing and data.

#### **15-3.5.4 Additional Information for the Digital Reference**

Include the following on the digital reference:

- Geologic and geotechnical investigation report(s) from original design and construction;
- Reports from any subsequent geologic and geotechnical investigations;
- Boring and test pit logs and laboratory test data. If the boring is used as a monitoring well or piezometer and the boring log is provided in the DSSMP, do not include it here. If not provided in the DSSMP, include the instrumentation boring logs here; and
- Any seismicity studies and/or seismic hazard analysis reports.

#### **15-3.6 Hydrology and Hydraulics**

This section provides supporting information to document the development of the Probable Maximum Precipitation (PMP), Probable Maximum Flood (PMF), Inflow Design Flood (IDF), and routing of the IDF through the reservoir and project works. Include the following information as applicable. Provide clear citations to the source(s) of information used for development of the PMP.

##### **15-3.6.1 Hydrology**

###### Hydrometeorological Report (HMR) or Site-Specific Report Used

Specify the HMR or site-specific report(s) used to develop the PMP. Reproduce the information below (Probable Maximum Precipitation through Reservoir Inflow and Outflow Hydrographs) from the referenced source(s).

###### Probable Maximum Precipitation (PMP)

Document the PMP depth, area, duration, orientation, and center location for the critical PMP configuration. If applicable, identify any areal reduction factor applied to calculate

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the basin-wide PMP depth. Provide a hyetograph in graphical and tabular format showing the temporal distribution of the critical PMP. Provide a figure depicting the spatial distribution of the critical PMP configuration. Describe the storm type (e.g. tropical, general, local) and seasonality (e.g., all-season, cool season) of the critical PMP.

Provide a brief summary of other PMP configurations that were considered and not determined to be the critical PMP. Include a table showing the 1, 2, 6, 24, 48, and 72 hour PMP depths.

### Drainage Basin

Provide a short description of the drainage basin (topography, soil cover, upstream lakes, and reservoirs). Include a figure that delineates the drainage basin and identifies the project location. If practical, include a separate figure delineating the sub-basins and indicate those sub-basins that are gaged versus ungaged.

### Antecedent Conditions

Document the antecedent conditions for the basin, including storms preceding the PMF, snow depths, soil saturation, base flows in the river and any tributaries, reservoir level, and other relevant information.

### Snowmelt

If snowmelt is a contributor, summarize the snowmelt model used, assumptions, and input data including snowpack water equivalent, wind speed, and temperature.

### Basin and Sub-basin Precipitation/Runoff Models

Identify which hydrologic model(s) was used to transform precipitation to runoff and the routing of the runoff through the dam and the downstream reach. State the model name, developer, and version of the model used for the study of record. If practical, include the model on the digital reference

### Loss Rates

State the loss rate method applied in the PMF hydrologic model and describe how the loss rates were developed (i.e. methodology) and applied to the basin and sub-basins (i.e. basin-averaged or distributed). Summarize the loss rates used for each sub-basin and document the key assumptions.

### Unit Hydrograph

Describe the unit hydrograph method and how the unit hydrograph parameters were selected. Provide a table summarizing the unit hydrograph parameters for each sub-basin. Provide the unit hydrograph in tabular and graphical format.

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Channel Routing Method

Describe the channel routing method and how the routing parameters were selected. Provide a table summarizing the routing parameters for each sub-basin reach.

Calibration and Validation

Summarize the calibration approach and the performance of the loss rates, unit hydrograph, and routing parameters with regard to replicating volume, peak, and timing of historic storm events, if applicable to the development of the hydrologic model. Describe any verification/validation that has been performed.

Reservoir Inflow and Outflow Hydrographs

Provide hydrographs and a table summarizing the total runoff volume from the watershed, total infiltration losses, peak inflow, regulated outflow, headwater elevation, and tailwater elevation for the events listed below. If any of the events do not apply or are not available, state so and document the reason for omitting the event.

- 100-year (1 percent annual chance event);
- Inflow Design Flood (IDF); and
- Probable Maximum Flood (PMF).

Flood Frequency Analysis

Describe the methodology and inputs (e.g., stream gages) used to determine the flood frequency events and identify any stream gages that are affected by upstream regulation. Provide a plot of the flood frequency analysis for the project, including confidence limits (if available). Provide the flood frequency curve and table. Include a summary of the methods used to develop the analysis.

Floods of Record

Document the top five floods of record at the project site, including floods which predate the project works. If the information is available, include the date, inflow, regulated outflow, peak reservoir elevation, tailwater elevation, and flood characteristics (e.g., ice jam, snowmelt, associated weather event) for each event. Summarize whether any project water control features (gates, stoplogs, flashboards, etc.) were operated to pass the flood. Summarize any changes to upstream flow regulation that have occurred since the floods of record. Provide an estimate of the return frequency for each event based on the current flood frequency analysis, or regional flood frequency regression equations, if insufficient streamflow data is available.

**15-3.6.2 Hydraulics – Dams**

This section documents the overall hydraulics of the project.



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Project Discharge Rating Curve

Provide an overall discharge rating curve for the project. For projects with multiple contributors to the discharge capacity (e.g., spillway gates, outlet structures, powerhouse units, fuse plugs, overtopping, etc.), include the contribution of each component as well as the total capacity. List the percentage of total discharge for each component making up the discharge rating curve. Provide the total time to open all gates.

Tailwater Rating Curve

If available, provide a tailwater rating curve in graphical and tabular format. Include all tailwater rating curves developed for the project that are used in the record stability analyses for the project structures. Extend the curve(s) to include the IDF.

Freeboard

Document the available freeboard for each water-retaining structure under normal operating conditions and during the IDF, excluding the effect of wave action. Include a summary of the maximum expected wind-generated setup and wave run-up during normal and IDF conditions.

For embankment dams, state the elevation of the top of the earthen core or core wall, for comparison to the normal and maximum pool elevations. For other types of dams, identify and state the elevation of the lowest point of the crest.

Zero Freeboard Discharge Capacity

State the total discharge capacity of the project assuming zero freeboard (i.e., at the initiation of overtopping), excluding any wave allowance. State the elevation and identify the limiting project structure(s) at zero freeboard. State whether the spillway has capacity to pass the IDF.

Inflow Design Flood (IDF)

State the peak IDF inflow and outflow and provide tabular and graphical hydrographs for both. If the IDF is less than the PMF, provide a citation to the incremental hazard analysis used to establish the IDF. Provide pertinent information summarizing the dam breach analyses as discussed in Section 15-3.6.5.

**15-3.6.3 Hydraulics – Spillways**Hydraulic Capacity

State the total hydraulic capacity of each spillway(s), for normal maximum pool and flood surcharge pool (if applicable). Provide a summary discussion on the overall spillway capacity with regard to downstream structures (e.g., training walls, flood protection measures, channel capacity).

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Discharge Rating Curve(s)

For each gated spillway, provide a discharge rating curve that documents the discharge for a range of gate openings, including the maximum opening height, and pool elevations. (Note that ungated spillway rating curves should be adequately represented on the Project Discharge Rating Curve, as discussed in the preceding section.) Clearly identify the transition between free flow and orifice flow, if applicable. Identify the total time to open all gates. Include a summary of the procedures, assumptions and discharge coefficients used to develop the curve(s). Summarize any hydrodynamic analyses (e.g., computational fluid dynamics models) completed to support stability analyses of the spillway.

Freeboard

Document the minimum available freeboard along the alignment of any spillway chute for the maximum discharge during the PMF. If any portion of the chute walls is expected to overtop during normal or flood conditions:

- Document the maximum flow that can be discharged without overtopping the chute walls; and
- Clearly indicate the areas that are expected to overtop and the expected depth of overtopping for each flow considered.

Scour

Describe the channel material and scour and cavitation protection measures in place (e.g. rock, riprap, armor, baffle blocks, plunge pools, etc.) and their design resistance to scour and cavitation. Provide a brief summary of any scour and/or cavitation analyses and scour protection design that have been performed for the project including the expected scour potential for flows up to the IDF. If applicable, provide a brief summary of the analysis the stilling basin/apron and its adequacy to contain the hydraulic jump.

Describe the velocities and expected shear stresses for flows up to the IDF at the following locations:

- exit of each spillway,
- within the channel of any unlined erodible spillway,
- around any bridge piers that are part of the project, and
- at the toe of non-overflow sections.

Summarize the findings of any quantitative evaluations of scour potential; if none have been completed, describe the scour potential qualitatively.

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**15-3.6.4 Hydraulics – Other Water Conveyance Systems**

List each water conveyance system. As applicable, document the following for each system:

- Total hydraulic capacity;
- Normal operating freeboard of any non-enclosed components of the system (i.e., conveyances with open channel flow, such as flumes and canals);
- Maximum rated discharge capacity of each component of the system (e.g., individual turbine-generator units) under controlled conditions (i.e., functioning as intended without a rupture or other failure) with documentation of the headwater/tailwater elevations where the ability to operate the turbine-generators is lost; and
- Hydraulic considerations related to transient analyses (e.g., physical limitations that affect the minimum closure time for wicket gates, valves, etc.).

**15-3.6.5 Dam Breach Studies**

Summarize pertinent information related to any dam breach analyses, including assumptions such as:

- Description of hydraulic model and version used in the analysis.
- Breach width (bottom, top, and average), shape, bottom of breach elevation, top of breach elevation, side slopes and formation time.
- Breach location(s) considered in the analysis.
- Summarize sensitivity analysis of breach parameters.
- Reservoir water surface and inflow/outflow at breach initiation.
- Reservoir volume for the breach including discussion of the effects of sediment depth, as applicable.
- Downstream lateral inflow from tributaries.
- Manning's "n" values used in routing breach flow downstream.
- Gate operations prior to breach initiation, and a comparison of the assumed operations to standard operating procedures.
- Cascading (domino) failure(s) including downstream dam breach initiation and parameter assumptions.
- Summarize the downstream incremental rise and impacts to downstream structures during the sunny day and IDF conditions. Include reference to the Emergency Action Plan (EAP) document for detailed inundation maps.

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**15-3.6.6 Additional Information for the Digital Reference**

On the digital reference, include:

- The current and any previous PMP and PMF studies, including (if available) all supporting digital hydrologic model input and output files.
- Any documentation related to an incremental hazard analysis to develop an IDF, including dam breach studies.
- Reports on physical or analytical model studies.
- Flood frequency analysis supporting calculations.
- Input and output files for dam breach and computational fluid dynamics (CFD) hydraulic models.
- Other supporting calculations/documentation for the following:
  - Flood frequency analysis.
  - Rating curves.
  - Wave run-up analysis.
  - Scour analyses.

To the extent practical, provide digital versions of other calculations and supporting files, such as: spreadsheets, CAD drawings, ArcGIS shapefiles, and Digital Elevation Model (DEM) files.

**15-3.7 Dam Safety Surveillance and Monitoring Plan (DSSMP)**

Include a complete copy of the current DSSMP, exclusive of its appendices, in Section 7 of the STID. If the DSSMP is voluminous, it is acceptable to provide the DSSMP as separate binder with an appropriate reference to it on a placeholder page in the STID. Refer to Chapter 9 of the Commission's Engineering Guidelines for the Evaluation of Hydropower Projects for details on the content of the DSSMP.

**15-3.7.1 Additional Information for the Digital Reference**

On the digital reference, include the following:

- A searchable PDF copy of the current DSSMP, including all appendices.
- Digital copies of previous DSSMRs (if historical monitoring information is well documented in the current DSSMR, providing the two most recent DSSMRs in digital form would be sufficient. However, if there are discontinuities in historical data reported in the current DSSMR, relevant previous DSSMRs should be provided so that a complete understanding of all historical monitoring activities can be obtained.).

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- Standard Operating Procedures (SOPs) for operating and recording data from instrumentation.
- Historical instrumentation readings data in Excel file or similar format applied in populating instrumentation plots.
- Historical maintenance and/or testing of instrumentation (e.g., piezometer falling head permeability tests).
- Special Inspection Reports (e.g., annual dive inspection reports). If there is no notable difference in the findings of the special inspections, providing the last 3 reports is acceptable. However, if there are notable changes over time, provide the relevant previous reports so that a comprehensive understanding of the changes over time is obtained.
- Any documentation of instrument installation and associated collected data, including boring logs and as-built drawings of observation wells/ piezometers showing the sensing zones and the subsurface stratigraphy.
- Instrumentation assessment reports.

### 15-3.8 Stability, Stress, and Other Analyses of Dams and Water Conveyances

This section provides documentation of the stability, stress, and other analyses of all project structures except gates, valves, and other reservoir control devices (which are to be documented in the subsequent section). The relevant sections for each structure type shall be included for each distinct project feature. For example, if there are multiple gravity sections – such as a spillway, an integral intake/powerhouse, and non-overflow sections on either side – the gravity structure information must be provided for each of those sections.

#### 15-3.8.1 Summary of Results

At the beginning of Section 8 of the STID, include a table that lists each of the water-retaining and water-conveying project features and summarizes the resulting factors of safety, compared to the FERC recommended minimum value (or industry standard, in the absence of FERC guidance) for each load case, or the conclusion, as appropriate for each type of project feature, analysis, and load case. **These summary tables should document the best estimate analyses; findings related to sensitivity analyses of structures (e.g., concrete gravity dams assuming various levels of foundation drain effectiveness) should be documented in the appropriate subsection for each project feature.** Examples for several types of project features are provided below. For some structures, such as arch dams, the summary of results may be more suited to paragraph format to document expected deflections, joint openings, etc.

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**Table 2: Concrete Gravity Stability Results (EXAMPLE)**

| <b>Structure</b>                                | <b>Load Case</b> | <b>% Base in Compression</b>          | <b>Calculated Factor of Safety</b> | <b>FERC Minimum Factor of Safety</b> |
|---|------------------|---------------------------------------|------------------------------------|--------------------------------------|
| Spillway section (concrete-rock interface)      | Normal           | 100%                                  | 1.8                                | 1.5                                  |
|   | Flood (PMF)      | 92%                                   | 1.5                                | 1.3                                  |
|   | Post-EQ          | 100%                                  | 1.8                                | 1.3                                  |
| Spillway section (critical lift joint)          | Normal           | 85%                                   | 1.6                                | 1.5                                  |
|   | Flood (PMF)      | 72%                                   | 1.3                                | 1.3                                  |
|   | Post-EQ          | 78%                                   | 1.4                                | 1.3                                  |
| Right gravity section (concrete-rock interface) | Normal           | <i>Include data similar to above.</i> |                                    |                                      |
|   | Flood (PMF)      |                                       |                                    |                                      |
|   | Post-EQ          |                                       |                                    |                                      |
| Right gravity section (critical lift joint)     | Normal           |                                       |                                    |                                      |
|   | Flood (PMF)      |                                       |                                    |                                      |
|   | Post-EQ          |                                       |                                    |                                      |

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**Table 3: Embankment Slope Stability Results (EXAMPLE)**

| <b>Structure</b>      | <b>Load Case</b>                        | <b>Slope Analyzed</b> | <b>Calculated Factor of Safety</b> | <b>FERC Minimum Factor of Safety</b> |
|-----------------------|---|-----------------------|------------------------------------|--------------------------------------|
| Main embankment       | Steady seepage, maximum normal pool     | Upstream              | 1.8                                | 1.5                                  |
|                       |   | Downstream            | 1.9                                | 1.5                                  |
|                       | Steady seepage, surcharge pool (PMF)    | Upstream              | 1.6                                | 1.4                                  |
|                       |   | Downstream            | 1.7                                | 1.4                                  |
|                       | Rapid drawdown from maximum normal pool | Upstream              | 1.2                                | 1.1                                  |
|                       | Rapid drawdown from spillway crest      | Upstream              | 1.4                                | 1.2                                  |
|                       | Earthquake                              | Upstream              | 1.2                                | 1.0                                  |
|                       |   | Downstream            | 1.3                                | 1.0                                  |
| Saddle dam embankment | Steady seepage, maximum normal pool     | Upstream              | 1.8                                | 1.5                                  |
|                       |   | Downstream            | 1.9                                | 1.5                                  |
|                       | Steady seepage, surcharge pool (PMF)    | Upstream              | 1.6                                | 1.4                                  |
|                       |   | Downstream            | 1.7                                | 1.4                                  |
|                       | Rapid drawdown from maximum normal pool | Upstream              | 1.2                                | 1.1                                  |
|                       | Rapid drawdown from spillway crest      | Upstream              | 1.4                                | 1.2                                  |
|                       | Earthquake                              | Upstream              | 1.2                                | 1.0                                  |
|                       |   | Downstream            | 1.3                                | 1.0                                  |

**15-3.8.2 Analyses of Record**

Provide a summary table documenting the current analysis of record for each project feature. An example table is provided below (Table 4). The intent is to make it easy to identify which analysis of record covers which project feature(s) and loading

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condition(s), and for each report to be easily located on the digital reference. If practical, the version of this table included in the searchable PDF of the STID should contain a hyperlink to the report documenting each analysis of record.

**Table 4: Analyses of Record Summary (EXAMPLE)**

| <b>Project Feature</b> | <b>Load Case(s)</b>    | <b>Report/Consulting Firm Name &amp; Date</b> |
|------------------------|------------------------|---|
| Right gravity section  | Normal, Flood, Seismic | Great Consultants (2008)                      |
| Spillway section       | Normal, Seismic        | Best Dam Consultants (2012)                   |
| Spillway section       | Flood                  | Best Dam Consultants (2017)                   |
| Main embankment dam    | Normal, Flood, Seismic | Best Dam Consultants (2012)                   |
| Main embankment dam    | Filter compatibility   | Soil Sciences (2015)                          |
| Saddle dam embankment  | Normal                 | Best Dam Consultants (2012)                   |
| Saddle dam embankment  | Flood, Seismic         | Saddle Dam Stability Study (2017)             |
| Saddle dam embankment  | Filter compatibility   | Soil Sciences (2015)                          |
| Penstock               | Normal, Transient      | Power Pipe Designs (2002)                     |

### 15-3.8.3 General Information Required for All Sections

In the appropriate section for each project feature, document the following information:

- List the load cases analyzed and any relevant input parameters (e.g., headwater and tailwater elevations; tailwater force ratio; silt loads; seismic acceleration; operating and transient pressures for penstocks; etc.).
- State the method of analysis; if a computer program was used, identify the program and version.
- Document the material properties and clearly indicate whether they are based on site-specific tests or assumed based on literature values. If the former, include representative test data and summary sheets; if the latter, provide a clear citation to the reference and screenshots or quotes, as appropriate. It is acceptable to include a reference to the corresponding information provided in accordance with Section 15-3.5.3, if the relevant information is thoroughly documented there.
- Provide input time-history plots and/or response spectra, as applicable, for any structures evaluated for seismic loading conditions. Describe any steps taken to adjust the seismic loads for application to any computer models (e.g., deconvolution).
- A list of codes, standards and/or other criteria used in the analyses including version and year of release details (e.g., ACI 318-95, ASTM D1557-07, etc.).



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**15-3.8.4 Gravity Structures**

In addition to the information listed in Section 15-3.8.3, document the following, as applicable, in the list of load cases analyzed: gate configurations, spillway discharge (particularly for overflow structures that may experience negative crest pressures), and dewatering conditions (e.g., use of a spillway bulkhead or stoplogs).

Provide a cross-section of each gravity structure and list key elevations, lateral dimensions, and other key physical information (e.g., the locations of piezometers and foundation and/or body drains). If there are any anchors, provide details. Include references to as-built drawings, field surveys, etc. with respect to the assumed key dimensions. Also, provide details of any keying of the dam-foundation interface.

If drains are assumed to be effective at reducing uplift pressures in the analyses, document how drain flows are discharged (e.g., gravity, pumped from a gallery, etc.) and the location of the discharge. Summarize and provide any monitoring data used to support the drain effectiveness used in the analysis. If piezometers are used to justify uplift assumptions, provide a detailed discussion of the justification including any supporting monitoring data.

**Interface Parameters**

List the interface strength parameters, including material strengths, base friction angle, effective friction angle, and cohesion value (if applicable) for all failure planes evaluated. Summarize any justification for the failure planes that were selected for analysis. Document any investigations or review performed to validate the assumed parameters. If cohesion is considered to contribute to stability for any load condition, provide detailed documentation of any investigations performed to justify the use of cohesion and document the sensitivity to the amount of cohesion assumed.

Provide brief descriptions of foundation geologic conditions as they relate to gravity structure stability; for example, bedding planes, dip directions, and joints/fractures in rock foundations.

**Free Body Diagrams**

For each gravity structure and load case, provide a free-body diagram (cross-section) of the structure being analyzed. The diagram should include a graphical depiction of the resultant force and its location along the assumed failure plane, as well as all applicable loads, including:

- Self-weight.
- Uplift pressure.
- Silt load.

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- Hydrostatic and hydrodynamic loading, including the effects of flow discharge as applicable (e.g., negative crest pressures, bucket pressures, etc.).
- Ice load.
- Anchor loads.
- Other point or distributed loads, as needed (e.g., gates, permanent machinery, bridges, etc.). For distributed loads (e.g., uplift pressure), show the distribution as well as the resultant and its location.
- For pseudodynamic calculations, include representations of any inertia load; hydrodynamic force distributions; and soil liquefaction.

Finite Element Models

For gravity structures evaluated using a finite element model, include:

- A concise description of the finite element model, including boundary conditions, interface definitions, methods of load application etc.
- Discussion of model verification procedures, including any evaluations of convergence with respect to mesh resolution selection, and results.
- Graphical presentation of the finite element mesh.
- Representative stress contour plots and magnified deflection plots for each load case.

Other Information

- Document the potential for or evidence of alkali-aggregate reactivity (AAR) in the gravity structures.
- Summarize the results of any concrete testing, including unconfined and splitting tensile strength, compressive strength, and shear strength.
- Summarize the results of any thermal studies or performance-based testing.

**15-3.8.5 Embankment Dams**

In addition to the information listed in Section 15-3.8.3, document the following, as applicable, in the list of load cases analyzed:

Computer-Based Analyses

For computer-based analyses of embankment dams, include a summary discussion, with references to supporting documentation on the digital reference, to document the basis for any assumptions related to the following:

- Representative section(s) selected to account for the variations in foundation soil/rock profile, composition of the embankment materials and geometries

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specific to selected sections (upstream and downstream slopes, and slopes of different zones).

- Boundary conditions (e.g. seepage behavior in and out of model, allowed movement during seismic loading, modeling of foundation/bedrock, interfaces, etc.).
- Interfaces with adjoining structures (e.g. concrete training walls, adjacent multiple arch dam, natural rock abutments).
- Internal behavior or composition of embankment materials (e.g. material interfaces, hydraulic conductivity, moisture content, uniformity of gradation of a material zone, uniformity of compaction/density of a material zone, performance parameters of a geotextile or geomembrane).
- Details on the methods applied to model structural components (e.g., tie-back anchors, core walls, cutoff walls, upstream reinforced concrete faces, shotcrete, gunite, etc.).
- The phreatic surface location and how it was derived (e.g., piezometer data, seepage analysis, etc.).

#### Summary of Static and Hydraulic Analyses

For each embankment structure, include a plan view noting the location(s) of analyzed cross-section(s). For each load case, as applicable, include summary discussion and relevant cross-section(s) showing:

- Documentation of the most critical failure planes based on the normal maximum water surface, PMF/IDF loading conditions, and other loading conditions as appropriate.
- Dimensions and location of any core wall/cut-off wall and details regarding the material stratum that provides cut-off from under seepage.
- Summary of the seepage analyses for different loading conditions.
- If overtopping occurs during the PMF/IDF, a summary of the through-flow analyses and/or associated stability and erodibility analyses for overtopping conditions.
- Summary of evaluations of filter compatibility, including clear references to the evaluation criteria (e.g., NRCS, USBR, etc.). Include cross-sections that identify the locations of each zone/material and the applied hydraulic loading being evaluated.
- Discussion of the potential for uncontrolled seepage exiting at the toe or along the abutments based on the seepage analysis results. Include a discussion on vertical and horizontal exit hydraulic gradients at applicable sections of the dam.

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Summary of Liquefaction Analyses

- A summary of seismic records applied and whether the records were scaled or altered. Include the reference and date of the site-specific Seismic Hazard Assessment used for the selection of the critical seismic loads.
- Representative cross-sections, elevations, and profiles documenting the anticipated extent of liquefaction. Include the finite-element-model grid if applicable.
- Plots of the input time-histories.
- A summary of the data that the liquefaction analyses were based on. Include a detailed evaluation of the limitations of the liquefaction screening methodology and in-situ and laboratory testing and their potential impact on the reliability of the liquefaction potential assessment. If the analyses are not based directly on analysis of site-specific embankment and/or foundation materials, a clear statement that this is the case along with a technical justification supporting the adequacy of the assumptions made should be included.
- The magnification on deformation resulting from liquefaction plots.
- A summary of all resulting settlement and how this affects the short-term and long-term performance of the dam (for example, will the initial movement lead to potentially more progressive slides and deformations that may affect the dam's ability to retain pool?).

Summary of Deformation Analyses

- A summary of seismic records applied and whether the records were scaled or altered. Include the reference and date of the site-specific Seismic Hazard Assessment used for the selection of the critical seismic loads.
- Representative cross-sections, elevations, and profiles documenting the anticipated deformation due to seismic loading. Include the finite-element-model grid if applicable.
- Plots of the input time-histories.
- The magnification on deformation result plots.
- A summary of the predicted movement whether the analysis indicates it would be expected to continue (e.g., progressive slumping) or if the remaining section would be expected to retain the reservoir.

**15-3.8.6 Arch Dams**

In addition to the information listed in Section 15-3.8.3, document the following, as applicable:

- Any keying of the dam-foundation interface;

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- Foundation modulus of deformation; and
- Contraction joint details/treatment.

Finite Element Models

For arch dams evaluated using a finite element model, include:

- A concise description of the finite element model, including boundary conditions, interface definitions, methods of load application etc.
- Discussion of model verification procedures, including any evaluations of convergence with respect to mesh resolution selection, and results.
- Graphical presentation of the finite element mesh.
- Representative stress contour plots and magnified deflection plots for each load case.

Other Information

- Document any evaluations of abutment stability, including block stability analyses and overtopping erosion evaluations, to an appropriate level of detail.
- Summarize the results of any thermal studies or performance-based testing.

**15-3.8.7 Buttress Dams**

In addition to the information listed in Section 15-3.8.3, document the following, as applicable:

- Stress analyses of buttresses, slabs, and corbels; and
- The response of the dam when subject to earthquake loads applied in both the stream direction and cross-valley direction.

Finite Element Models

For buttress dams evaluated using a finite element model, include:

- A concise description of the finite element model, including boundary conditions, interface definitions, methods of load application etc.;
- Discussion of model verification procedures, including any evaluations of convergence with respect to mesh resolution selection, and results;
- Graphical presentation of the finite element mesh;
- Representative stress contour plots and magnified deflection plots for each load case.

### Other Information

- Document any evidence of deterioration, cracking, leakage, and offsets between members that could indicate movement.
- Summarize the results of any thermal studies or performance-based testing.

### **15-3.8.8 Spillway Piers**

In addition to the information listed in Section 15-3.8.3, document the following, as applicable:

- Stress analyses of spillway piers.
- A description of the pier reinforcement and the controlling capacity (e.g., unreinforced flexural, reinforced flexural, shear, tension).
- The response of the piers when subject to earthquake loads applied in both the stream direction and cross-valley direction, including any point and distributed loads (e.g., hydrodynamic loads applied directly or translated to the piers through the trunnion anchorage(s), and bridge loads).
- Any observed evidence of deterioration or cracking that may affect the capacity or performance of the spillway piers.

### Finite Element Models

For spillway piers evaluated using a finite element model, include:

- A concise description of the finite element model, including boundary conditions, interface definitions, methods of load application etc.;
- Discussion of model verification procedures, including any evaluations of convergence with respect to mesh resolution selection, and results;
- Graphical presentation of the finite element mesh;
- Representative stress contour plots and magnified deflection plots for each load case.

### **15-3.8.9 Spillway Chutes**

Document any stress and stability analyses that have been performed for components of any spillway chute, including slab panels, slab anchors, wall panels, training walls, drains and their capacities, and energy dissipation systems for a range of flows up to the rated capacity. Spillway aprons that limit the potential for foundation erosion at the toe of a gravity structure may require similar documentation. If a scour evaluation of an unlined spillway chute is already documented per the guidance in Section 15-3.6.3, provide a reference to that section here.

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**15-3.8.10 Penstocks and Other Water Conveyances**

For each penstock and other water conveyance that has a credible potential failure mode (urgent or otherwise), document any associated analyses such as the stress and stability analyses, hydraulic analyses (e.g. cavitation and water hammer), etc. Provide a graphical depiction of each water conveyance, identifying each location that was analyzed. Also include free body diagrams for any supporting features that were evaluated (e.g., concrete saddles or thrust blocks).

Clearly state the material properties; original penstock thicknesses, especially if steel; loading conditions, including the valve or gate closure timing for transient loading; section(s) analyzed; evaluation criteria; and results.

**15-3.8.11 Other Structures**

Include summary discussion of analyses related to other types of dams (e.g, timber crib dams, rubber dams, etc.) and appurtenances, such as surge tanks, air vent structures, lock walls, lock gates, power canal walls, etc.

**15-3.8.12 Additional Information for the Digital Reference**

On the digital reference, include:

- The report on the analysis of record for each project feature, including any spreadsheet or hand calculations that may have been completed;
- All previous analysis reports, if available (clearly note which analyses (or portions of the analyses) have been superseded);
- Any previous spillway inspection reports, if available (or provide a reference thereto if they are already included in Section 7 of the STID); and,
- Input files for stress and stability analysis models, if available. Electronic files for all model runs also should be provided when available.

**15-3.9 Gates, Valves, and Other Reservoir Control Devices**

This section includes documentation related to radial spillway gates, other gates, valves and other reservoir control devices. When determining whether a particular feature has to be documented in the STID, it may be helpful to consider whether the discharge provided by the feature is critically important for ensuring safe passage of the IDF/PMF. If it is, the feature must be documented; if not, it may still need to be documented (err on the side of providing too much information rather than not enough).

Provide a plan drawing or aerial image of the project with the location and type of each gate identified, along with any relevant gate numbering. Include a summary table documenting basic information for all spillway gates, other gates, and reservoir control valves. An example table is provided below:

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**Table 5: Gate and Valve Summary (EXAMPLE)**

| <b>Gate/Valve Type</b> | <b>No. of Type of Gate/Valve</b> | <b>Dimensions (WxH or Dia.)</b> | <b>Maximum Discharge (cfs)</b> | <b>Time to Fully Open</b> |
|------------------------|----------------------------------|---------------------------------|--------------------------------|---------------------------|
| Radial                 | 2                                | 30' x 25'                       | 15,000 cfs each                | 30 minutes                |
| Flashboards            | 12                               | 12' x 6'                        | 8,000 cfs total                | 5 minutes                 |
| Howell-Bunger valve    | 1                                | 6' diameter                     | 2,300 cfs                      | 10 minutes                |

In the appropriate subsection for each gate, valve, or other reservoir control device, list the material properties of structural elements and fasteners; state the source of this information (e.g., original specifications, subsequent material testing, etc.). If material properties are unknown, state the most likely material based on the era of construction, literature values, etc., and include a citation.

Include a thorough description of each gate/valve operating system. Describe the physical components of the system (electrical motors including nameplate specifications, gear boxes, couplings, etc.), power sources, and pathways for power, communication and/or control. Document any physical and logical controls that govern and/or indicate gate/valve position, or maintain alignment within operating slots, including limit switches that may prevent over-loading of and damage to gate chains, cables, hoists or operator's bridge. Discuss methods for verifying the operation and percent open of remotely-operated gates. Also include discussion of performance history including any failure incidents and repairs.

### 15-3.9.1 Radial Gates

The following additional information is required for radial gates:

- Document the materials and date of installation of the trunnion, trunnion anchorage, trunnion bearings, and thrust washer (as applicable).
- Describe the trunnion lubrication procedures and lubricant specifications; if none, state that no lubrication is performed.
- Provide a summary of the gate hoist motor load tests to-date (motor name plate rating, line-line voltage, amperage draw, reservoir level, and initial draw if available).
- Summarize the findings and recommendations from the most recent hands-on gate inspection report.



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### Stress Analyses

Include a graphical representation of the gate model used for the stress analysis. State the computer program, version, and the year the analysis was completed. Describe the following:

- Load cases, including the magnitude and method of application of each load;
- Boundary conditions;
- Section properties and connectivity;
- Model verification; and
- Other relevant information, as needed.

Provide a summary of the stress analysis results for each load case, including:

- A table of stresses and/or demand-capacity ratios in each member and connection;
- A graphical representation of the gate with any overstressed members identified; and
- Documentation of any trunnion friction threshold evaluations (i.e., the maximum coefficient of friction that results in acceptable stress results).

If any members or connections are overstressed, provide additional results documenting the stresses and/or demand-capacity ratios with the overstressed members deleted from the model. If the gate anchorage has been evaluated with a stress analysis, provide pertinent information as appropriate; otherwise state that the anchorage was not evaluated.

#### **15-3.9.2 Other Gates**

Document any analyses related to the stability and/or structural adequacy of other gates, such as: sector gates, drum gates, fixed wheel vertical lift gates, slide gates, bear trap gates, inflatable gates (e.g., Obermeyer), etc., and their supporting structures.

Summarize the findings of the most recent hands-on gate inspection, if one has been performed.

#### **15-3.9.3 Reservoir Control Valves**

Document any analyses related to the stability and/or structural adequacy of reservoir control valves.

#### **15-3.9.4 Other Reservoir Control Devices**

Document any analyses related to the stability and/or structural adequacy of other reservoir control devices. For automatic-trip devices (e.g., flashboards, fuse gates, etc.),

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include documentation of the calculations related to the trigger elevation/flow at which the device is designed to activate.

**15-3.9.5 Additional Information for the Digital Reference**

On the digital reference, include:

- Reports on stress and stability analyses of gates and valves;
- Reports on any internal, up-close, or non-destructive examination of gates and valves, including all previous 10-year Gate Inspection Reports;
- Input files for any gate analyses, if available, in a universal (text-based) format (e.g., if the model was performed using SAP2000, include the .S2k files);
- Annual spillway gate certifications including time-history plots of volt/amp readings;
- Manufacturer's specifications and catalog cuts of standard gates, valves and other components, as available; and
- Other relevant information as needed.

**15-3.10 Pertinent Correspondence Related to the Safety of Project Works**

Provide two printed lists of pertinent correspondence:

- All correspondence between the FERC and the licensee related to safety of project works since the previous Part 12D report; and
- Significant correspondence from the entire project history (e.g., completion or FERC acceptance of major studies; mandatory drawdowns; notification of dam safety incidents; etc.).

Other than the two lists, no additional information is required in the hard copy of this section.

**15-3.10.1 Additional Information for the Digital Reference**

On the digital reference, include digital copies of the pertinent correspondence listed in the hard copy. A hyperlinked table of contents is recommended.

**15-3.11 References**

In the hard copy, provide a complete table of contents of the information included on the digital reference. The information should be presented in a manner that enables a user to quickly locate relevant information and subsequently access the file on the digital reference. For projects with large number of drawings and photographs, individual drawing names and photograph descriptions need not be provided in the hard copy, though collections should be listed (e.g., "Original Construction As-Built Drawings –

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Embankment Dam,” “Photos from 2014 Underwater Inspection,” etc.). Refer to the guidance in previous sections of this chapter for details.

**15-3.11.1 Additional Information for the Digital Reference**

On the digital reference, include digital copies of any important reference material that has not already been provided for the preceding sections.

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