STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER RESOURCES

OFFICE OF THE STATE ENGINEER
DAM SAFETY BRANCH

PROJECT REVIEW GUIDE

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COLORADO
Division of Water Resources
Department of Natural Resources
Dam Safety Branch

1313 Sherman Street, Room 821, Denver, CO 80203 P 303.866.3581 F 303.866.3589 www.water.state.co.us

PURPOSE OF THE DAM SAFETY PROJECT REVIEW GUIDE

This document is provided by the Colorado Division of Water Resources (DWR) Dam Safety Branch (DSB) as a technical guide for the engineering community involved with the design and construction of dams under the Colorado Revised Statutes (CRS) and the Rules and Regulations for Dam Safety and Dam Construction (Rules). This Project Review Guide is not intended to instruct engineers on how to design and construct dams. Engineers working on dams in Colorado are expected to be familiar with the current state of the practice in dam design. The guide was developed to aid dam designers in providing all the required information at all stages of the project, while avoiding the unnecessary effort and expense of preparing and submitting voluminous, sometimes inconsequential output.

Review and Approval of a Project Design

Involvement of the DSB as early as possible in the design process will greatly simplify the design review and expedite approval of the design. The dam owner should discuss the general project requirements with the DSB prior to beginning development of the project design. At the beginning of the design development, the owner's engineer should arrange a project scoping meeting with the DSB to discuss the project objectives, proposed repairs or modifications to the dam, and preliminary design concepts.

After the project is determined to be appropriate and feasible and the preliminary concepts have been agreed upon, the engineer should begin preparation of the design documents. The construction file number (C-number) will be assigned to the project during this stage of the design. The engineer and owner should keep the DSB informed of the status of the project, including the several studies (hazard classification, hydrology, and geotechnical) that will require review. Some or all of these studies will need to be completed and approved by the DSB before the dam design to provide a basis for selection of the project design criteria.

The owner and engineer are encouraged to discuss the project status and design development with the DSB at intermediate completion stages. Discussions may be considered informal during this phase of the project and may include phone calls, emails, and/or meetings, as appropriate for the project and agreeable to the DSB. The intent of the intermediate stage discussions is to avoid development and submittal of design criteria or design elements that will not be acceptable. The discussions should largely prevent the submittal and rejection of designs that lack adequate engineering support, include unacceptable concepts, or require major fundamental corrections.

When the engineering design is essentially complete and the design criteria are adequately supported and documented (generally at about the 90% completion stage), the engineer should submit an application package with the design report, drawings, and specifications in their current state of completion. Submittal of the application and design documents before the documents are ready for a thorough review will likely result in multiple cycles of review and resubmittal. Incomplete or inadequate design submittals will be rejected and returned to the engineer.

The 180-day DSB review period permitted by state statute will begin on the date the application for review is accepted. Time required for the engineer to respond to DSB review comments will not be included in the 180-day review period.

Following are the steps for efficient completion and acceptance of a design project. This recommended procedure is intended to minimize the number of submittals and returns required before the project is approved, to facilitate coordination of the submittal schedule for timely review, and to minimize the length of the review period.

1. When the design is submitted for review and the application package is accepted as complete, the DSB will review the design documents and provide comments to the engineer including:
    - Review copy of the Design Report (including separate reports)
    - Review copy of the drawings
    - Review copy of the specifications
    - A letter with review comments to guide the engineer in progressing toward acceptance of the design
2. The Engineer should make the noted corrections to the design documents, provide any required additional information, and review the corrected documents with the DSB before resubmitting them.
3. The DSB will make any further recommendations and request submittal of the final documents for approval.
4. The Engineer will make the final corrections and submit the final documents for approval.
5. The DSB will check the final documents and stamp them as approved for construction.
6. The DSB will notify the engineer and the owner that the design has been approved and will return the approved design drawings and specifications to the engineer.

Project Review Guide Structure

The Project Review Guide is divided into three parts plus an appendix.

PART I - ADMINISTRATIVE REQUIREMENTS: Lists the required documents, description of the documents, and fees associated with filing an application to build, repair, or modify a jurisdictional* dam in Colorado.

PART II - DESIGN AND TECHNICAL CRITERIA: Outlines, clarifies, and supplements the technical requirements of the Rules and provides more detailed discussions of the several submittal components listed in Part I.

PART III – CONSTRUCTION OF JURISDICTIONAL DAMS: Provides information concerning expectations for monitoring, documenting, and reporting the construction of any work on a jurisdictional dam.

APPENDIX – PLANS AND SPECIFICATIONS CHECKLIST and REFERENCES

Parts I, II, and III of the Project Review Guide are each organized into tabular format for convenient reference.

- The left column (Requirements) is a detailed list of documents, processes, and activities normally associated with the design and construction of a dam. Particular effort has been made to develop a thorough list and to reflect the requirements and intent of the Rules. However, the list of requirements should not be considered all-inclusive. The requirements for any given dam project must be discussed with the Dam Safety Branch on a case-by-case basis.
- The center column (Comments) provides further explanation and clarification of the Rules. This information is intended to assist the designer in understanding the purpose and intent of the requirements.
- The right column (Rules and References) is a list of the Rules that govern the particular requirements listed in the left column. Selected technical references are also listed, but the list is not intended to exclude other references that may be

appropriate. Dam designers are expected to be familiar with and to adhere to the current state of the practice in dam design and construction.

The Plans and Specifications Checklist in the appendix is provided as a general guide to the preparation of a complete design to be submitted for review by the Dam Safety Branch. It should be recognized that a given project may require additional items not included in the checklist, and all items listed will not be applicable to every project.

Other Considerations

Under the provisions of Rule 19, individual design requirements or Rules may be waived on a case-by-case basis for good cause shown. The request for a waiver must be prepared and submitted by a registered engineer experienced in dam design and construction, and must clearly demonstrate with supporting analyses that waiving the requirement or Rule will not adversely affect the performance of the dam or pose a danger to the public. The State Engineer has the final authority for accepting or rejecting a waiver request.

No guidance document can address all possible design considerations, nor can it be expected to foresee future changes to laws, rules, and standards of practice. Similarly, no guide can be a substitute for sound engineering judgment or experience. Therefore, this guide is subject to change as improved design and construction techniques and procedures become known.

Permits from other local and federal agencies may be required prior to the start of construction of the project. The appropriate agencies should be contacted for every project to determine which permits are required.

Suggestions and comments for additions and changes are welcome at any time. Please write or call the following:

Colorado Division of Water Resources
Dam Safety Branch
1313 Sherman Street Room 821
Denver, Colorado 80203
303-866-3581

*All dams in the State of Colorado are under the jurisdiction of the State Engineer, except those defined under Rule 17 as “Exempt Structures”. The term “non-jurisdictional” does not exclude a dam from the regulatory authority of the State Engineer. Rule 4.2.5.1 defines a “Jurisdictional Size Dam”, and Rule 4.2.5.2 defines a “Non-Jurisdictional Size Dam”. CRS 37-87-105 requires plans and specifications for construction or repair of dams defined in Rule 4.2.5.1, but the statute does not require plans and specifications for dams defined in Rule 4.2.5.2. Rule 11.3.2 requires submittal of engineered plans and specifications for construction on all High and Significant Hazard non-jurisdictional size dams. The State Engineer has the final authority in determining when a dam construction project requires plans and specifications.

Part I - ADMINISTRATIVE REQUIREMENTS

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
I-A. Submittal for Review	The various reports (items 4, 5, and 6 below) may be submitted separately or in a single Design Report (item 7). Reports submitted separately must be sealed separately by the PE who prepared the report. The specifications must be a separate bound document unless otherwise permitted by the Dam Safety Branch. Additional copies of reports, drawings, and specifications may be requested by the DSB as required. Reports, drawings, and specifications may be submitted in digital format as approved by the DSB. The submittal needs of each project should be discussed with the DSB prior to submitting the design for review. Incomplete submittals will not be accepted.	Rule 5.4
1. Application Form	1 each.	Rule 5.1
2. Construction Plans	1 set of 24"x36" prints and 1 set as PDF files (half size drawings are also accepted). The drawings must provide sufficient detail to permit the contractor to correctly build the project from the approved plans.	Rule 5.2
3. Construction Specifications	1 printed set and 1 set as PDF files. The construction specifications must agree with and support the construction drawings in scope and detail. The DSB will review and comment only on technical construction specifications, not on other contract documents bound with the specifications.	Rule 5.3
4. Hazard Classification Report	1 printed report and 1 report as PDF files – This report should be completed prior to completion of the final design so the project design criteria can be selected appropriately for the dam's hazard classification.	Rule 5.4.1
5. Hydrology Report	1 printed report and 1 report as PDF files – may be submitted prior to the full design package.	Rule 5.4.2
6. Geotechnical Report	1 printed report and 1 report as PDF files – may be submitted prior to the full design package.	Rule 5.4.3

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
7. Design Report	1 printed report and 1 report as PDF files. The Design Report should provide a thorough description of the project design criteria, engineering support for selection of the design criteria, and the methods used to design the various components of the dam, as described in Part II of this Project Review Guide. The report can include reports of other investigations or assessments, such as Risk Analysis or Potential Failure Mode and Consequences Analysis. The Design Report should include an Executive Summary or Basis of Design section to concisely describe the project requirements and how the design meets those requirements. The final Design Report must include the plan for stream and surface water diversion. The final Design Report should reflect the design criteria selected for final design purposes as a permanent record of the design. If design criteria are revised during the review process, a revised Design Report will be required.	Rules 5.4.4, 5.4.5 Rules 5.4.4.13, 5.10.2
8. Instrumentation and Monitoring Plan	1 printed plan and 1 plan as PDF files.	Rules 5.5, 10.3, 15.3
9. Detailed Cost Estimate	Provide the Engineer's Construction Cost Estimate in the Design Report or as a separate document.	Rule 5.6
10. Filing Fee	1 check payable to Colorado Division of Water Resources. Credit Card payments via Visa, Mastercard, and Discover are also accepted.	Rule 5.7
I-B. Supplemental Filing		
1. Corrected documents according to DSB design review memo	The DSB will provide comments and discuss design deficiencies in a design review letter to the design engineer. The letter will describe necessary corrections to the design and actions required for approval of the project. The design review process is typically iterative, and the submittal may require more than one review.	
2. Revised cost estimate	When the estimated cost of the project increases during the design review process, the required filing fee may also increase.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
I-C. Filing for Construction Approval	Once a design is found acceptable for construction, the design engineer will be notified to submit the final documents consisting of the items listed below. The final documents for design and construction shall include sufficient detail for the contractor to construct the project as designed. The approval will have high priority after the final documents have been received.	
1. Final project design reports	1 each, printed and digital.	
2. Final mylar cover sheet drawing	One 24”x36” mylar sheet, sealed and signed in accordance with the current requirements of the Colorado State Board of Licensure for Architects, Professional Engineers and Professional Land Surveyors. The mylar cover sheet to the construction drawings will be stamped by the State Engineer and returned to the design engineer for safekeeping during the construction phase. The approved mylar cover sheet (unaltered) will become the first sheet of the mylar as-constructed drawing set submitted following construction. Because the mylar cover sheet contains the State Engineer’s signature, it is important that this drawing not be altered. Information subject to change, such as the Drawings Index, reservoir capacity, or spillway and outlet discharge rating curves, should not be shown on the cover sheet.	Rule 5.2.2
3. Paper (blueline or blackline) drawings	Complete sets, bound, signed, and sealed in accordance with the current requirements of the Colorado State Board of Licensure for Architects, Professional Engineers and Professional Land Surveyors. Submittal requirements may vary between projects and should be discussed with the DSB prior to submitting the drawings for approval. Copies of sealed original drawings are acceptable.	DORA
4. Specifications	One set for each set of drawings, each specification set bound separately, signed, and sealed in accordance with the current requirements of the Colorado State Board of Licensure for Architects, Professional Engineers and Professional Land Surveyors. Submittal requirements may vary between projects and should be discussed with the DSB prior to submitting the specifications for approval. Copies of sealed original specifications are acceptable.	DORA

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
I-D. Construction Phase Filing	After the project is approved for construction, the following documents must be submitted. Submittal details should be discussed with the DSB for each individual project. Some project documents may be uploaded during construction to a central shared website for review by the several parties. The details and procedures for utilizing such shared viewing sites for posting required submittals for DSB review must be clearly established with the DSB prior to beginning the project.	
1. Construction Observation Plan	1 plan, may be submitted in digital format as approved by the DSB.	Rules 9.1.1, 9.1.2, 9.2.2
2. Construction Progress Reports	1 copy of each periodic construction progress report, may be submitted in digital format as approved by the DSB.	Rules 9.1.6, 9.2.3
3. Construction Change Orders	1 copy of each Change Order Request, signed and sealed by the Project Engineer, may be submitted in digital format as approved by the DSB.	Rules 9.1.8, 9.2.4
I-E. Project Completion Filing	After the project construction is completed, the following documents must be submitted. Submittal details should be discussed with the DSB for each individual project.	
1. Engineer's Certification of Completion	1 letter, signed and sealed by the Project Engineer.	Rule 10.2.1
2. As-Constructed Drawings	1 full-size (24"x36") set of reproducible mylars and 1 set of full-size paper drawings, each set signed and sealed by the Project Engineer in accordance with the requirements of the Colorado State Board of Licensure for Architects, Professional Engineers and Professional Land Surveyors.	Rule 10.2.2
3. Final Construction Report	1 copy, typically in a 3-ring binder, signed and sealed by the Project Engineer in accordance with the requirements of the Colorado State Board of Licensure for Architects, Professional Engineers and Professional Land Surveyors.	Rule 10.2.3
4. Monitoring Plans	1 copy of each of the following reports, may be submitted in digital format as approved by the DSB: – Record of Monuments and Instrumentation – First Fill and Monitoring Plan – 5-year Monitoring Plan – Long-term Instrumentation Monitoring Plan	Rules 10.2.4, 10.2.5, 10.2.6, 10.3

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
5. Emergency Action Plan (High and Significant Hazard dams, only)	2 complete EAPs, typically in 3-ring binders, and 1 PDF copy. Additional EAPs should be prepared for the dam owner, dam operations staff, and local and state emergency response agencies.	Rules 10.4, 10.5, 16 (DWR, 2010a)
6. Construction Cost Information	Final payment information for the completed project. To the greatest extent practicable, payment information should be itemized for all project components and engineering costs itemized for design and construction services.	

Part II - DESIGN AND TECHNICAL CRITERIA

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
II-A. Hazard Classification Report	Guidelines for evaluating the potential consequences of failure and assigning the appropriate hazard classification for dam projects in Colorado are described in the Dam Safety Branch document "Guidelines for Hazard Classification" (November 2010, or latest revision). These Guidelines will be used by the Dam Safety Branch to check Hazard Classification Reports submitted for approval. The Hazard Classification Report must be signed and sealed by a professional engineer registered to practice in the State of Colorado. The Hazard Classification Report should be submitted to and approved by the DSB prior to commencing with other design work to ensure design criteria for the dam are appropriate for the hazard classification.	Rule 5.4.1 (DWR , 2010b)
1. General description of dam/reservoir and downstream inundation limits	The description should include the location of the dam and floodplain and a summary discussion of the floodplain land uses that will affect the hazard classification.	
2. Detailed description of breach hydrograph estimation process	Procedures and models recommended for breach analysis of dam projects in Colorado are described in the Dam Safety Branch document "Guidelines for Dam Breach Analysis" (February 2010, or latest revision). These Guidelines will be used by the Dam Safety Branch to check dam breach studies submitted for approval. Spreadsheets and other computational aids included in the Guidelines are available on the DSB website.	Rule 5.4.1.3 (DWR, 2010c)
3. Description of baseline conditions assumed for breach analysis	Baseline conditions include the starting water surface elevation, impounded volume in the reservoir, and the assumed failure mode. Also, any inflow into the reservoir included in the model shall be justified and documented. For normally dry flood control dams, justify any principal spillway flows and downstream tributary inflows assumed for the base flood condition.	
4. Detailed description of routing breach hydrograph downstream of dam	Procedures used to route the breach hydrograph downstream to estimate the hydraulic conditions at critical locations shall be satisfactorily documented. Examples of required information include: Names of all computer programs; hydrologic or hydraulic routing; 1-dimensional or 2-dimensional modeling; steady or fully dynamic unsteady flow analysis.	(USACE, 2010a)
5. Tabulation of dam break and channel discharge parameters	Include any sensitivity analyses performed on the breach analysis and channel routing parameters.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
6. Dam failure inundation maps showing hydraulics at critical locations	The map should include the location and alignment of the cross-sections used in the analysis, water surface elevation, and average velocity in feet per second at each cross-section.	Rules 5.4.1.1, 5.4.1.2, 16.1.5
7. Appropriate annotated cross-sections	Critical sections should illustrate any improved or habitable structures impacted by the dam failure flood wave and show the lowest habitable floor elevation.	Rule 5.4.1.2
8. Modeling parameters	Hydraulic or hydrologic modeling parameters used in the breach hydrograph routing model shall be documented. Examples include roughness coefficients, loss coefficients, and hydrologic routing parameters.	Rule 5.4.1.3
9. Conclusions and statement of recommended hazard classification	The recommended hazard classification for the dam shall be clearly stated.	Rule 5.4.1
10. Digital Submittal	Include a CD with all spreadsheets, computer models, mapping (including GIS shapefiles), and all other files used to support the recommended hazard classification.	
II-B. Hydrology Study	Guidelines for evaluating the Inflow Design Flood (IDF) or a dam project in Colorado are described in the Dam Safety Branch document "Hydrologic Basin Response Parameter Estimation Guidelines" (2008, or latest revision). These Guidelines will be used by the Dam Safety Branch to check the IDF submitted for approval. The Hydrology Report must be signed and sealed by a professional engineer registered to practice in the State of Colorado. The Hydrology Report may be submitted to and approved by the DSB prior to commencing with other design work to ensure design criteria for the dam are appropriate for the hazard classification.	Rule 5.4.2 DWR, 2008
1. Topographic map of dam and tributary basin		Rule 5.4.2.1.1
a) Location of the dam by quarter section, section, township, range, and principal meridian		

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
b) Location of dam by bearing and distance from quarter section or as determined by GPS based on NAD83 datum expressed as UTM coordinates		
c) Drainage area (square miles)		
d) Name of primary watercourse		
e) Watercourse used to develop unit hydrograph		
f) Slope of Watercourse used to develop Unit Hydrograph		
g) Basin centroid and length of watercourse from point of concentration to point perpendicular to basin centroid		
h) Elevation of dam crest based on NAVD 83		
2. Report Components		
a) Basin Description including topography, geology, vegetative cover, identification of natural watercourse, and elevation of the Dam Crest based on NAVD 88		Rule 5.4.2.1.2

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
b) Provide source data and calculations used to develop rainfall data and storm distribution – In many cases it may be necessary to develop flood hydrographs for Probable Maximum Precipitation, Extreme Storm Precipitation, and a frequency based storm for comparison	Depending on Hazard Class and Dam Size, design rainfall may be based on the appropriate Hydrometeorological Report, the currently accepted NOAA Precipitation Frequency Atlas for Colorado, or a Site Specific Hydrometeorologic Analysis. Note: Rule 5.9.1.3 permits determination of the Extreme Storm Precipitation using the Extreme Precipitation Analysis Tool (EPAT). However, several errors have been identified in the current EPAT program, and the tool should not be used to estimate design precipitation until all issues have been addressed and an updated version of the program has been released.	Rules 5.9.1.1 thru 5.9.1.6 (NOAA, 1973) (NOAA, 1978) (NOAA, 1984) (NOAA, 1988) (NOAA, 2013)
c) Summary of method used to develop unit hydrograph and basis for selection of parameters	Procedures for selecting basin response parameters and developing the runoff from excess precipitation are presented in the Dam Safety Branch document “Hydrologic Basin Response Parameter Estimation Guidelines” (May 2008). These Guidelines will be used by the Dam Safety Branch to check hydrology studies submitted for approval. Spreadsheets and other computational aids included in the Guidelines for calculating basin runoff are available on the DSB website.	(DWR, 2008) (USACE, 2010b)
(1) For Dimensionless Unit Hydrographs and S-Graphs, identify all variables and provide a basis for the selection of all parameters used to develop the unit hydrograph	Variables/Parameters include: Area (A), Length of longest flow path (L), Length to point opposite basin Centroid (L_{ca}), Average Slope (S), Lumped flow resistance parameter (K_n), Lag Time (Lag)	
(2) For Clark Unit Hydrograph, identify all variables and provide a basis for the selection of all parameters used to develop the unit hydrograph	Variables/Parameters include: Area (A), Length of longest flow path (L), Length to point opposite basin Centroid (L_{ca}), Average Slope (S), Time of Concentration (T_c), Effective Impervious Area (RTIMP), Storage Coefficient (R), Provide basis for selected Time-Area Relation	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
d) Detailed description of rainfall losses including basis for selection of parameters – include soils data to support selected parameters	A spreadsheet template for calculating rainfall losses based on detailed soil surveys obtained through the NRCS Soil Data Mart is available on the DSB website. SSURGO soil survey data should be used where available. Unpublished soil surveys for National Forest lands should be obtained directly from the soil scientist in each National Forest.	
(1) For Green and Ampt method, provide a basis for the selection of all parameters shown at right, and provide supporting calculations used to develop rainfall losses	Surface Retention Loss (IA), Hydraulic conductivity at natural saturation for bare ground and adjusted for vegetation (XKSAT), Wetting front capillary suction (PSIF), Volumetric soil moisture deficit (DTHETA), Effective Impervious Area (RTIMP).	
(2) For Initial and Uniform Loss method, provide a basis for the selection of all parameters shown at right, and provide supporting calculations used to develop rainfall losses	• Initial Loss (STRTL = IA+II) • Uniform Loss Rate (CNSTL = XKSAT) • Effective Impervious Area (RTIMP).	
e) Spillway Discharge Rating Table	Discharge in cfs for every foot above spillway crest to dam crest. Include equations used to determine the discharge rates.	Rule 5.4.2.1.4
f) Reservoir Area Capacity Table	Reservoir area in acres and storage capacity in acre-feet for every foot above outlet invert elevation to dam crest. Include dead storage below outlet invert as appropriate.	Rule 5.4.2.1.5
g) Provide a summary of the study results including the flood hydrographs and tabular data showing peak discharges and total runoff volumes for all storms modeled	The HEC-DSS program available for download from the USACE Hydrologic Engineering Center (HEC) website provides a convenient tool for presenting results from HEC-HMS models.	Rule 5.4.2.1.3 (USACE, 2009)

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
h) Provide a discussion of sensitivity analyses performed on key parameters used to develop the basin lag time and the rainfall losses	At a minimum the sensitivity analysis should consider the published ranges of K_n values for a given watershed and storm type.	
3. Digital Submittal	The hydrology report should include a CD or DVD containing all computer models, spreadsheets, tabulated data, mapping, and other materials used to compute the precipitation and routed runoff for all storms modeled.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
II-C. Site Specific Extreme Precipitation Study	A Site Specific Extreme Precipitation Study may be used where existing precipitation studies are considered to be out-dated or such study may be needed where generalized studies do not accurately account for local climate and terrain due to interpolation, envelopment, etc. Site Specific Extreme Precipitation Studies should follow current standard of practice as defined by approved studies for dam safety regulation or other public safety applications (ex. nuclear power regulation, etc.), published guidance, or peer-reviewed scientific literature. Deviation from standard of practice may be acceptable if justified and approved by the State Engineer.	Rule 5.9.1.6
1. Notice of Scope of Work /Kick-off Meeting	Prior to commencement of a Site Specific Extreme Precipitation Study the dam owner should provide notice to the State Engineer detailing the proposed scope of work. This notice will provide the State Engineer with the opportunity to provide guidance prior to the start of work and to authorize pursuit of the study. Once a consulting meteorologist is selected, it is recommended that the consultant schedule a kick-off meeting with the State Engineer's Office Dam Safety Branch to discuss the scope, State Engineer guidance, and anticipated challenges in the study.	
2. Independent Peer Review	An independent peer review of the Site Specific Extreme Precipitation Study must be performed on behalf of the State Engineer, and must be contractually independent from the consultant performing the study. All peer review comments shall be submitted to the SEO along with responses from the lead meteorologist and with concurrence from the peer reviewer demonstrating that the comments were satisfactorily addressed.	
3. Experience	Site specific extreme precipitation studies for dam safety applications should be performed by a full member of the American Meteorological Society (AMS) or an AMS Certified Consulting Meteorologist with at least 5 years of experience in Probable Maximum Precipitation or Extreme Precipitation Frequency analysis.	
4. Site Specific Probable Maximum Precipitation Guidelines	The following guidelines are provided to define SEO understanding and expectations for a standard-of-practice Site Specific PMP study. Each of the following shall be documented in a summary report and submitted for SEO review.	
a. Literature Review	Review & summarize relevant previous extreme precipitation studies for the study region. The review should include a summary of site specific hydrometeological conditions for the specific basin of interest, including historic floods, historic storms, relevant climate conditions, description of controlling topographic influence, etc. This summary may need to be extended to nearby basins if there is little information available for the basin of interest.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
b. Storm Search	Identify potentially relevant historic extreme storms. Storms are typically screened based on low annual exceedance probability along with the understanding that a more likely event could control PMP for a particular site due to other variables in the PMP analysis.	
c. Storm Analysis	Storm analysis of historic storms must be documented to determine spatial and temporal rainfall patterns, depth-area-duration tables, and relevant climate variables such as inflow moisture trajectory, and dew points. A general description of the meteorological conditions that caused the storm should be provided.	
d. Storm Typing	Storms should be separated by meteorologic type (e.g. convective, frontal, remnant tropical, etc.) and season, as needed, to prevent mixed population PMP estimates.	
e. Transposition Limits	Meteorlogical evaluation should be documented that justifies whether or not each historic storm identified in the storm search is considered to be transpositionable to the basin of interest. Evaluation should be based on the meterological conditions that caused each storm, inflow moisture trajectories, topographic barriers, orographic lift and intensification, etc. A final "short list" of storms shall be documented for determination of PMP at the site.	
f. In-place Maximization	Each storm on the "short list" shall be maximized in-place by scaling the storm based on the maximum moisture supply that could be expected for the location and time of year compared to the observed moisture supply. State of the practice typically uses HYSPLIT, or other inflow trajectory models, and durations relevant to the storm duration to determine moisture supplies.	
g. Storm Transpositioning	Each storm on the "short list" should be transpositioned from its source location to the target location by accounting for differences in available moisture, elevation, and orographics. The NOAA HMR reports used the Storm Separation Method to attempt to account for orographic lift effects; however, this method is generally considered to be complicated and subjective. Current state of the practice uses isopercentile or similar analysis to relate the source and target locations based on underlying precipitation frequency climatology. This method may depend on having accurate precipitation frequency estimates separated by storm type for source and target locations. Snow versus rain precipitation frequency needs to be considered, along with storm freezing level data. In general the use of arbitrary adjustment factors is discouraged; any adjustments applied during storm transpositioning for moisture supply, elevation, or orographics need to be based on data or justified by storm physics relevant to the storm type and site.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
h. Spatial and Temporal Envelopment	Envelopment of spatial and temporal depth-area-duration data may be necessary to ensure that results are not overly sensitive to sample variation based on small storm sample size.	
i. Spatial and Temporal Distribution of PMP	Spatial and temporal patterns of controlling PMP should be provided for each storm type. Document which historic storm(s) control PMP at the site.	
j. Areal Reduction Factors	Development of site specific ARFs should be documented if used to develop spatial site specific storm patterns.	
k. Quality Control	Document quality control measures taken during the study to ensure accuracy of data and analysis. Minimum measures should include QC of original storm data, internal consistency checks of storm depth-area-duration data at each step of PMP analysis process, and manual checks of any automated computations.	
l. Sensitivity/Uncertainty	Evaluation of sources of uncertainty in the PMP analysis process and evaluation of PMP sensitivity should be documented.	
m. Reasonableness checks	Provide comparisons of final Site Specific PMP estimates to precipitation frequency estimates for the basin (areally reduced if applicable) and PMP estimates from past studies. SEO reduction factors (Rule 5.9.1.5) should not be applied to HMR PMP for such comparisons.	
n. Summary table	A summary table should be provided showing all storm-average adjustment factors (in-place maximization, moisture transposition, elevation, etc) for each tranpositionable storm used in the PMP analysis. Provide the equivalent NOAA Atlas 14 annual exceedance probability (AEP) for each storm at its source and at the transposed target location.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
5. Site Specific Extreme Precipitation Frequency Study	Site Specific Extreme Precipitation Frequency Studies may be necessary to facilitate spillway design for Significant Hazard, Minor Size dams or Low/NPH Hazard dams or for Risk-based design or evaluation of dams, as approved by the State Engineer. Such studies shall generally be performed in accordance with industry standards, published guidelines, or peer-reviewed scientific literature. Notice of scope of work, kick-off meeting, experience, and independent peer-review requirements listed above shall apply. The generally accepted procedure uses L-moment regional frequency analysis methods developed by Hosking and Wallis in order to build an equivalent independent record length for homogeneous regions. The analysis should include, but not be limited to, identification of relevant station rain data and quality control of such data, storm typing as needed to minimize mixed-population distributions, L-moment estimation, homogeneous regions and heterogeneity checks, identification of probability distribution(s), precipitation frequency estimates for relevant durations, areal reduction factors, temporal distributions, and estimation of uncertainty.	Rules 5.9.1.2, 5.9.1.6 Wallis et al. 2007 Hosking and Wallis, 1997
II-D. Incremental Damage Analysis (IDA) (optional)	An Incremental Damage Analysis is used to determine spillway size such that no downstream incremental loss of life or significant property damage is expected due to dam failure caused by overtopping. An IDA can sometimes justify a reduction in the required spillway size for High Hazard and Large and Small Size Significant Hazard dams, particularly for smaller dams with larger drainage basins. Washington State Dam Safety Guidelines provide, as a rough measure, that an IDA may be applicable if the ratio of the overtopping dam break peak discharge to the inflow peak discharge is less than about 5. Each situation where an IDA could be useful has its own unique conditions and constraints. The engineering analyses for an IDA must be discussed with the DSB prior to developing a spillway design. All requirements listed above for a Hydrology Study must be included as part of an IDA. The IDA Report shall be included as part of the Hydrology Report submittal.	Rule 5.9.1.7 (FERC, 2004) (Washington, 1993)
1. Preliminary design for all spillways including discharge rating curves	In an IDA study the Inflow Design Flood (IDF) is dependent on the hydraulic characteristics and discharge rating of the spillway(s). Significant changes to the spillway during the design phase may require revision of the IDA study. Minimum freeboard requirements of Rule 5.9.1.8 apply, except that the requirement for 1 foot of residual freeboard above the inflow design flood maximum water surface is not applicable for a dam with a spillway designed by an IDA.	Rule 5.9.1.8

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
2. Base Flood Hydrograph	Provide hydrologic model input for reservoir routing, output summary table showing peak reservoir level, the reservoir inflow hydrograph, the reservoir outflow hydrographs for all spillways, and report the Base Flood as a fraction of the Probable Maximum Flood (PMF). The Base Flood is the minimum fraction of the PMF hydrograph that exceeds the capacity of all spillways and results in overtopping of the dam. In practice this should conservatively be the fraction of the PMF hydrograph that results in zero feet of residual freeboard. In some cases a greater depth of dam overtopping may be used for the Base Flood where engineering analysis demonstrates the proposed overtopping depth would not be expected to cause failure of the dam. Rule 5.9.1.7 states that the Base Flood is to be "routed through the downstream floodway assuming no dam is in place." The DSB has interpreted this Rule to mean that the Base Flood is the reservoir inflow flood prior to reservoir routing, based on the reasoning that by CRS 37-87-104 a dam owner is not liable for passing reservoir inflows, so downstream property owners are not entitled to flood protection provided by the dam. However, it should be noted that a more conservative analysis consistent with Federal guidelines will define the Base Flood as the reservoir outflow hydrograph for all spillways. The PMF hydrograph used to derive the IDA Base Flood should be the controlling Hydrometeorological Report (HMR) General Storm or Local Storm event that results in the highest reservoir stage during reservoir routing.	Rule 5.9.1.9
3. Dam Failure Flood hydrograph	The Dam Failure Flood is the flood resulting from overtopping and failure of the dam during the Base Flood event. The overtopping breach is assumed to occur as a result of the Base Flood and must be initiated in the model at the peak reservoir stage associated with the Base Flood hydrograph. Procedures and models recommended for performing the breach analysis are described in the State of Colorado document "Guidelines for Dam Breach Analysis". Document dam overtopping breach parameters for empirical breach method or input to physically based breach model. Document breach size and failure time used to model the overtopping breach flood.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
4. Floodwave routing for the Base Flood and Dam Failure Flood hydrographs	Provide at a minimum: river cross-sections/floodplain topography, hydraulic conditions at critical cross-sections, roughness coefficients, and dynamic routing parameters. Both the Base Flood and Dam Failure Flood must be routed downstream to a location where there is no threat attributed to the increased flow resulting from the Dam Failure Flood. Ch. 2 FERC Engineering Guidelines may provide guidance in determining the downstream limit of study. Methods and models recommended for floodwave routing are described in the "Guidelines for Dam Breach Analysis". It is expected that the Intermediate or Advanced Level of Analysis (Table 1) will be required to achieve the level of accuracy needed to evaluate downstream incremental impacts.	(FERC, 1993)
5. Downstream Concurrent Inflows	Because dam failure is assumed to occur during flood conditions, it may be acceptable to include downstream concurrent (i.e. tributary) inflows for Base Flood and Dam Breach Flood routing. Ch. 2 FERC Engineering Guidelines may provide guidance for determining concurrent inflows. If a flood study is performed for downstream tributaries, conservative judgment should be used, recognizing that the assumption of large concurrent flooding downstream of the dam may be unconservative from a dam safety standpoint in some situations. The DSB will review assumptions of concurrent flooding on a case-by-case basis considering the magnitude of the proposed Base Flood, type of PMF used to define the Base Flood hydrograph (i.e. General Storm or Local Storm), hydrologic similarity of downstream basins, and other relevant factors.	(FERC, 1993)
6. Downstream Incremental Impacts	The proposed spillway design will be acceptable where it can be shown that the Dam Failure Flood would cause no additional loss of life or additional significant property damage relative to the Base Flood. Rule 5.9.1.7.1 states that no significant damage or loss of life is expected if the increased flow depth is two feet or less and the product of the flood flow velocity in the incremental zone and the depth of flow at critical sections is less than seven. On a case-by-case basis, the DSB may allow the determination of incremental damage to be based on an engineering examination of individual structures and other improvements in the inundation zone, as described in FEMA P-94. This analysis would typically be suited to rural areas. However, the dam owner must be made aware that such IDA findings may change in the future based on new development.	Rule 5.9.1.7 (FEMA P-94, 2013)

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
7. Minimum required spillway capacity	Provide all hydrologic model parameters, input, hydrographs, and model output to demonstrate that the IDA-designed spillway can also convey the 24-hr, 100-YR event which is the minimum IDF allowable by the Rules for all High Hazard, Significant Hazard, and Large and Small Size Low Hazard Dams.	Rules 5.9.1.3.7, 5.9.1.4.8
8. Sensitivity Analysis	IDA results may be sensitive to parameters used in the rainfall-runoff hydrology, spillway hydraulics, dam breach analysis, and downstream floodwave routing, as well as to the accuracy of topography and critical structure elevations. The incremental increase in flood depth predicted by a hydraulic model may be accepted with reasonable certainty; however, the accuracy of the Base Flood profile may be uncertain, unless it has been calibrated to observed floods. Therefore, sensitivity analysis may need to examine a range of Base Flood profiles.	
9. Summary of critical results and conclusions	Minimum IDA Report contents include: – Inundation Map(s) showing both the Base and Dam Failure Flood inundation areas. Hatch the incremental zone. Current aerial photography shall be provided as the base map. – Water surface profiles of the Base and Dam Failure Floods at usable vertical and horizontal scales. – Cross-sections at downstream critical locations showing flood stage, velocity, and discharge for both floods. – Table summarizing results at each downstream critical location: o Downstream Distance o Base Flood: ▪ routed discharge ▪ velocity ▪ water surface elevation ▪ depth relative to critical structure(s) ▪ depth x velocity product o Dam Failure Flood: ▪ routed discharge ▪ velocity ▪ water surface elevation ▪ incremental flow depth ▪ Depth relative to critical structure(s) ▪ Depth x velocity product – Determination of whether incremental impacts are expected.	Rule 5.9.1.7.2

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
	– Additional documentation may be required by the DSB on a case-by-case basis.	
10. Digital Submittal	The combined Hydrology and IDA report shall include a CD or DVD containing all supporting computer models, spreadsheets, tabulated data, mapping, and other materials relevant to supporting the study's conclusions.	
II-E. Geotechnical/Geological	A complete geotechnical and geological investigation must be conducted in sufficient detail to support the structural design for all new, rehabilitated, or enlarged dams. The extent of the required investigation, testing, and evaluation varies with the hazard classification, size, and complexity of the dam; however, it is intended that an adequate level of investigation and analysis is conducted for every dam in accordance with modern standards of engineering practice. The Geotechnical Report submitted for approval must be signed and sealed by a Professional Engineer. All investigations requiring drilling or excavation within 200 feet of existing dams must be reviewed and approved by the DSB prior to the field work. Feasibility level investigations and reports are not sufficient for design purposes.	Rule 5.9.3
1. High and Significant Hazard dams		
a) Geotechnical/geological investigation and analyses		
(1) Geological assessment	Provide a thorough geological assessment of the dam and reservoir site, including evaluation of the regional geologic setting; local and site geology; geologic suitability of the dam foundation and reservoir area; slope stability and seepage potential of the reservoir and abutment areas; seismic history and potential, including areas of industrial drilling that utilize injection methods and other subsurface activities ; and other potential geological hazards posed by the site and proposed construction. Assess the potential for hillsides and rock formations around the reservoir perimeter to become unstable or for existing faults to become mobilized as a consequence of construction of the dam. The effects of reservoir leakage must be thoroughly investigated and the adverse effects mitigated.	Rule 5.10.1.2
(2) Seismicity	The study shall determine and justify the appropriate seismic parameters to be used for design. The seismic assessment shall also address the stability of appurtenant structures to the dam during the design earthquake. Deterministic and probabilistic methods are both acceptable.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
(3) Field investigation	A sufficient number of soil and rock samples must be obtained from the field investigation to provide a statistically meaningful representation of the materials to be evaluated.	
(i) Foundation investigation	The subsurface exploration shall provide information required to characterize the foundation soils, estimate the permeability of foundation soils and rock, evaluate the depth and geologic classification of the bedrock, estimate foundation excavatability, characterize the competency of the foundation under the dam and appurtenant structures, and assess the need for and anticipated extent of any treatment program(s) required to adequately stabilize the foundation and/or control seepage.	Rules 5.4.3.1.2, 5.9.3
(ii) Borrow investigation	Identify the location(s) and availability of enough suitable borrow materials to construct the dam, and evaluate the need to blend or otherwise process borrow materials.	Rule 5.9.2
(4) Laboratory testing	A sufficient number of laboratory tests must be performed for each material included in the dam or foundation to support the selected design criteria. Laboratory tests must include index testing for adequate classification of all soils. The test program should allow direct determination of the drained shear strength and undrained shear strength parameters needed for slope stability and bearing capacity analyses. Simple Direct Shear tests performed at conventional strain rates without pore pressure measurements are not appropriate for determining the drained strength of soils that do not drain quickly. Consolidation/swell tests should be performed on undisturbed and/or remolded samples, as appropriate, of all soils or rock that could affect the stability of the dam or appurtenant structures through settlement or heave. Test conditions should reflect the loading conditions anticipated for the soils. Foundation soils and soils to be used for embankment fill must be tested to evaluate the potential for dispersive behavior and alkali-aggregate reaction with concrete. Foundation rock must be evaluated for intact strength and joint/bedding strength. Permeability tests for foundation, abutment, and embankment materials should be conducted under laboratory conditions that represent the anticipated loading conditions for the materials. Permeability tests should be conducted on both undisturbed and remolded samples, as appropriate for the dam design.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
	A sufficient number of lab tests should be performed to permit accurate characterization of the engineering properties of each material affecting the construction of the dam. Laboratory test results should be tabulated and presented in the Geotechnical Report for easy reference to each test result with respect to the dam element or material zone represented by the test.	
(5) Stability analyses	All dams must be shown to meet the requirements for minimum factor of safety against slope and foundation failure both during construction and under all conditions of reservoir operation. Proper shear strength parameters should be used for the various loading conditions and materials, depending on the rate of loading and the anticipated drainage properties and conditions.	Rule 5.9.4.1
(6) Seepage analyses	Seepage through the embankment, abutments, foundation, and under and around appurtenances shall be analyzed for design of seepage controls to prevent internal erosion, piping, and external sloughing and to provide for adequate stability of the dam. Results of the seepage analyses will form the basis for design of the filters, drain blankets, toe drain, uplift resistance, etc. Geotechnical analyses should include filter compatibility analysis on all material boundaries in the dam and foundation that are subject to seepage flows. Unfiltered seepage or seepage that exits the dam or foundation uncontrolled is not acceptable.	Rule 5.9.4.2 (FERC, 2011)
b) Geotechnical Report	The Geotechnical Report presents the results and conclusions of all field investigations and field and laboratory testing. The report may also include technical analyses performed to develop the project design criteria.	Rules 5.4.3, 5.9.3
2. Low Hazard dams	Requirements for field investigations, laboratory testing, analysis, and reporting for Low Hazard dams are less stringent than the requirements for High and Significant Hazard dams. Results of all investigations, testing, and analyses shall be presented in the Geotechnical Report.	Rule 5.4.3.4
3. NPH dams	Requirements for field investigations, laboratory testing, analysis, and reporting for NPH dams are less stringent than the requirements for Low Hazard dams. Results of all investigations, testing, and analyses shall be presented in the Geotechnical Report.	Rule 5.4.3.5

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
4. Digital Submittal	The geotechnical report should include a CD or DVD containing all tabulated field and lab test results, spreadsheets, computer model results, and other calculations for evaluating the stability and safety of the dam, dam foundation, spillway(s), and appurtenant structures.	
II-E. Dam Design Requirements		Rule 5.9
1. Seismicity	All High and Significant Hazard dams must be analyzed and designed for seismic stability.	Rule 5.9.2.1
2. Embankment dams	Embankment dam designs shall be based on acceptable criteria for slope stability, deformation, seepage control and internal drainage, embankment geometry, material placement and compaction, and riprap or other erosion protection.	Rule 5.9.4
3. Concrete dams	Concrete dam designs shall be based on acceptable criteria for overturning and sliding stability, crest access and geometry, overtopping protection, internal drainage, and control of uplift pressures. RCC dam designs shall include the design provisions for concrete dams plus additional provisions especially pertinent to roller-compacted concrete including mix design testing, crack control, constructability, interior drainage, etc.	Rules 5.9.5.4, 5.9.5.5, 5.9.5.6
II-F. Spillway Design Requirements	The spillway(s) should be capable of passing the IDF to prevent overtopping of the dam and be capable of withstanding the sustained forces of the IDF without causing or experiencing unacceptable damage. Spillway design is a complex process that is of critical importance to the safe operation of a dam. Inadequate spillways are one of the leading causes of dam failure.	Rule 5.9.6.1 (Reclamation, 1987) (USACE, 1989) (Chow, 1959) (Brater, et.al., 1996)
1. General Policies	Spillway structures founded on the embankment are discouraged for new construction, however they will be considered on a case-by-case basis when a spillway cannot be reasonably built elsewhere. Designs that include an embankment overtopping spillway are discouraged for new embankment dams. Pipe or conduit spillways that serve as the only spillway for the dam are not acceptable. If a pipe spillway is considered the only option, a formal waiver request must be submitted. A permitted pipe spillway shall include a trash rack to prevent clogging and shall be accessible for cleaning or be designed as a self-cleaning type structure. Trash racks should be designed to withstand permissible water velocities	 Rule 5.9.6.1.3

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
	and hydrostatic pressure assuming that the trash rack is 50% clogged with debris.	
2. Design Considerations		Rule 5.9.6.1
a) Control section	Spillway flow control sections should be stable at a fixed location and should not become submerged by downstream conditions during any discharge. For open channel spillways, weir equations are not valid, and the backwater must be taken into account during the spillway capacity and rating curve development. Due to the significant impact that roughness coefficients have on the spillway rating curve development, the analysis must include a sensitivity analysis justifying the chosen roughness coefficient(s).	
b) Control weir	If the spillway flow control section includes a weir, the profile of the weir should be designed to prevent excessive negative pressures and cavitation on the downstream face of the weir. If the design parameters chosen require an aerated nappe, air demand and venting calculating shall be provided.	
c) Fuse Plug and Other Dump-Type Spillways	Fuse plugs, fuse gates, and erodible section or dynamic and/or mechanical dump type spillways may be allowed on a case-by-case basis. Spillway activation must be initiated by the flood and must not require human and/or mechanical/electrical intervention to activate.	
d) Spillway Channel/Chute Protection	The design of the spillway and channel protection shall consider the duration and volume of frequent flows. Earth spillways shall be protected from frequent flow by a service spillway that carries the majority of normal reservoir inflows, or shall be designed to pass frequent flows without sustaining damage. There are various methods that can be utilized to protect the spillway channel from erosion while routing the IDF for the dam. Some special considerations for each are provided below:	
	• All spillway channels not protected by concrete lining or constructed in sound rock shall have at least one concrete erosion control beam across the channel at the control section to establish the spill elevation. Earthen spillways shall include an erosion analysis to demonstrate that the spillway can safely route the IDF without initiating an uncontrolled release of the reservoir. Additional erosion control beams or other erosion control measures may be required based on the results of the erosion analysis.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
	• Spillway chutes designed for supercritical flow shall be designed to either eliminate standing or cross-wave problems or have sufficient freeboard to contain such phenomena. An appropriate energy dissipation structure must be included to control the hydraulic jump at the end of the spillway.	
	• Grass cover in an earthen spillway channel can significantly increase its resistance to erosion. Earthen spillways shall include a revegetation plan that includes soil amendments, and a seed mix design appropriate for the specific climate. If a spillway relies on grass cover for erosion resistance, the construction will not be considered complete until the grass cover has been established for one year.	
	• Riprap protected channels should include a layer of granular filter bedding between the riprap and subgrade to prevent loss of supporting subgrade material during flow events. Geotextile fabrics are discouraged due to durability, constructability, and slope stability issues that they present.	
	• When a hydraulic model is utilized to predict erosive forces created within the spillway and to develop spillway freeboard requirements, the analysis shall consider the effect of the selected roughness coefficient(s) on the necessary erosion protection and freeboard and include a sensitivity analysis justifying the chosen parameters.	
	• The formation of a hydraulic jump within an earthen spillway channel poses a significant erosive threat to the channel. Earthen spillway channels should be designed to prevent supercritical flow and hydraulic jumps. If supercritical flow is unavoidable, adequate energy dissipation must be provided.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
	• For high velocities in concrete channels, special designs are required to mitigate cavitation, control joint deflection, and provide subgrade/backfill protection against hydraulic jacking and removal of underlying soils. Required provisions to mitigate these factors include, but are not limited to, articulated/shingled construction joints with waterstop. Reinforced concrete spillway chutes shall be designed to reduce/eliminate uplift pressure with the use of adequate subgrade/backfill drainage and shall be anchored to the foundation to provide an adequate safety factor against sliding and buoyancy with the use of rock anchors, soil nails, bulb anchors or similar means.	
	• Spillway channel side slopes should be stable during the design event to prevent spillway channel blockage due to a slope failure.	
e) Labyrinth spillways	Due to H/P considerations, labyrinth weir spillways often become concrete dams impounding a significant portion of the reservoir storage. As such, they are subject to the requirements for concrete dams under the Rules. Additional factors that should be taken into consideration for Labyrinth Weir Spillway design include: The receiving watercourse must be evaluated for capacity to ensure that the weir does not become submerged. Extra care should be taken and controls provided in the specifications to ensure that the crest of the labyrinth is properly formed. Because labyrinth weir discharge equations are empirically based, care must be taken to ensure that the weir geometry matches that used in the development of the equation.	Rule 5.9.5 (Lux ,1985) (Tullis, 1995) (Falvey, 2003) (Paxson, 2011)
f) Energy Dissipation	The increased velocities and energy for spillway flows must be dissipated prior to returning the flow to the downstream channel and floodplain. Allowances may be made on a case-by-case basis for reducing the design discharge to some fraction of the IDF spillway discharge. Approval to design the energy dissipation facilities for less than the full IDF discharge will only be granted if the damage to the facilities expected during the IDF flood would not endanger the dam or its appurtenant structures or result in an uncontrolled release of stored water. The approval will be conditional upon the dam owner agreeing that the spillway and energy dissipator will be rebuilt after they are damaged by a flood exceeding the design capacity.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
	The spillway and channel should be located away from the dam and terminate far enough downstream to prevent erosion damage to of the dam or appurtenant structures.	
g) Entrance/Discharge Channel	Booms shall be installed where logs and other debris may block spillway flow or damage spillway structures. Booms or other features should also be considered for public safety and security.	Rule 5.9.6.1.2
h) Blockage	Spillways subject to snow and ice conditions shall be evaluated for blockage during the spring. Placing the spillway on the sunny side of the reservoir or otherwise minimizing snow drift formation in the spillway can help mitigate the problem. Potential for weathering of the approach channel, chute, and energy dissipation system should be considered and appropriate protection provided.	
i) Spillway Right-Of-Way	The dam owner must possess either title or an easement for the spillway channel from the high water line in the reservoir to the natural channel including the stilling basin downstream of the dam.	Rule 5.9.6.1.1
j) Drop Inlet Service Spillways	Drop inlet service spillways may be incorporated into outlet works for the dam. Special considerations for this type of design include ventilation and sizing of the conduit to prevent pressurization and/or surging of flow. The conduit downstream of the spillway entrance must have capacity for both spillway flows and maximum outlet releases without pressurizing the conduit. The flow area should be limited to ensure that the conduit does not pressurize. The bottom of the drop inlet spillway for deep drops should be adequate structurally to resist hydrodynamic forces.	
3. Spillway Design Report	The spillway design should be fully described within a Spillway section of the Design Report.	Rule 5.9.6.1.4
a) Discharge tables	Discharge table(s) showing the discharge for each foot of head between the crest of the spillways and dam. The stage-discharge relationship should be determined at a section in the reservoir with negligible velocity head, i.e. where reservoir surface level is not affected by the water surface drawdown at the spillway approach.	
b) Discharge equations	Equation(s) and model(s) used for determining spillway discharge shall be included.	
c) Discharge rating model	In cases where the spillway discharge may not be described by classic hydraulic equations, a hydraulic model must be used to describe the spillway stage-discharge relationship. A best fit curve equation of the model results can then be developed describing the spillway discharge capacity.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
II-G. Outlet Design Requirements	Outlets serve a critical function to both the normal and emergency operation of a safe dam. An outlet conduit penetrating a dam creates a discontinuity in the dam and/or foundation which can lead to internal erosion and failure of the dam. As such, the proper design, construction, and operation of the outlet are paramount to the safety of the dam. Outlets are costly structures and are often difficult and very expensive to replace or repair. Their design requires careful and deliberate consideration to ensure that they will provide adequate performance over the expected life cycle of the dam. Key items to be considered include the hydraulic capacity to meet drawdown criteria and delivery requirements (with possible consideration given to subsequent sliplining rehabilitation in the future), structural design, foundation design, and design of appurtenant equipment such as gates and valves. The pipe material selected should be durable and capable of withstanding the unique conditions in which it will be installed. The designer should consider all potential failure modes associated with faulty conduits and incorporate preventative measures to arrest the failure mode into the design. All outlet conduits should be pressure tested in-situ to at least 150% of the maximum reservoir head to ensure that they have been properly installed.	Rule 5.9.6.2 (FEMA, 2005) (USACE, 1980)
1. Capacity		
a) Stream diversion during construction	Outlet size and capacity could be controlled by the need to bypass the stream flow during construction. This option should not be overlooked in the design and planning phase.	
b) Minimum Capacity	The Division Engineer has final approval of the required outlet capacity for water administration.	
c) Emergency Drawdown	Emergency release requirements for all High Hazard dams are based on releasing at least the top 5 feet of the reservoir storage in 5 days, beginning at the high water line. Emergency conditions may warrant higher drawdown rates. It is recommended that other Class dams be designed using similar criteria. Outlet design should give consideration to emergency drawdown of the reservoir during normal inflow conditions.	Rules 4.2.15, 5.9.6.2.1
2. Trash Racks	Outlets shall have trash racks unless exempted by the State Engineer for good cause shown.	Rule 5.9.6.2.4

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
a) Maximum Velocity	For trash racks that are not accessible for cleaning, the maximum velocity through the rack should be limited to 2 feet per second. If the rack is accessible for cleaning the velocity may approach 5 feet per second. However, damaging vibrations may become a problem at higher velocities. The design must include provisions for controlling vibrations and preventing damage.	
b) Structural Design	Trash racks shall be structurally designed for a loading condition of 25 percent of the maximum reservoir head applied when the trash rack is 50% clogged.	(USBR, 1987)
3. Guard Gates	Except for ungated outlets on flood control dams, all new dams shall have operating guard gates or bulkhead provisions installed at the upstream end of the conduit. Outlet intakes that are being replaced shall include new upstream guard gate systems.	Rule 5.9.6.2.3
4. Transmission Pipeline Connections	All principal outlets that are tied to transmission pipelines shall have a bypass or blow-off valve that will meet the outlet capacity requirements. Prudent design of the valve will allow for access by video camera for inspection of the interior of the conduit.	Rule 5.9.6.2.2
5. Energy Dissipation	All outlets shall have energy dissipaters, plunge basins, or adequate riprap channel protection to prevent undesirable erosion of or damage to nearby structures. The energy dissipation facilities should be designed to withstand the forces of the discharge from the conduit assuming all gates are fully open and assuming the reservoir is at the peak water surface elevation required to route the IDF.	
6. Air Venting	Air venting of the outlet works should be considered to permit air to enter the conduit on the downstream side of the outlet control structure or gate. Air vents can prevent collapse of the conduit or prevent the formation of low pressures which can lead to cavitation damage.	(Falvey, 1980) (USACE, 1964) (Tullis, 2011)
7. Filter Zones	Outlet conduits in embankment dams shall have provisions for preventing the development of piping along the outside of the conduit. This may include filter diaphragms, filter collars, or installation of a filter envelope along the downstream portion of the outlet pipe. Filter zones around the outlet conduit should include a drain pipe that daylights to the downstream end of the outlet so that seepage intercepted by the filter can be monitored.	(FEMA, 2005)

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
8. Gates & Operators		
a) Gate Location	The control structure for the outlet should be located upstream of the impervious zone in the embankment.	
b) Support Structure	Structures designed to operate gates shall be designed with sufficient mass/bulk to resist the forces generated during opening and closing of the gate under full reservoir head in accordance with the gate manufacturer's recommendations.	
c) Hydraulic Systems	Outlet systems that use hydraulic controls shall have backup lines or systems to ensure they will be operable. Hydraulic lines should be installed in buried or concrete-encased conduits to allow easy replacement and minimize potential for damage.	
d) Electrical Systems	For outlet gates and equipment that operate by electricity, accessible standby generators or appropriate manual operators must be available and periodically tested.	
e) Gate Stem Protection	Gate stems subjected to ice action shall be protected from the elements with an oil filled casing pipe with seals and an oil filler cap. Gate stems may be marked for measurement of the reservoir level, but they should be anchored securely to the dam face or slope and protected from damage by ice, waves, or machinery. When possible, the gate stem pipe on an embankment slope should be attached to or encased within a reinforced concrete grade beam. Gate stem operators shall have positive stops to prevent over-stressing and buckling of the gate stem or damage to the gate from improper operation.	
9. Pressurized Outlet Conduits	Pressurized conduits in embankment dams are generally discouraged, but may be allowed on a case-by-case basis. Pressurized conduits may be acceptable if provisions are made to protect the dam from any possible leakage from the conduit. This typically involves sleeving or encasing the pressurized portion of the conduit or placing the conduit in a tunnel through the embankment. Provisions must be made to allow depressurization of the conduit for emergencies or maintenance and for entry to the interior of the conduit for inspection (e.g. upstream guard gate and blind flange man-way downstream). All pressurized conduits must have filter-compatible seepage diaphragms or other acceptable seepage controls to prevent piping along the outside of the conduit.	Rule 5.9.6.2.3

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
a) Shop Test	The specifications should call for shop testing the pipe to 150% of operating pressure prior to delivery to the site per the American Water Works Association standard for the size and type of pipe specified.	
b) In-Situ Test	All conduits, whether they are designed to operate pressurized or not, shall be pressure tested to 150% of the operating pressure once they are in place to ensure that they have been installed correctly. The test may be performed for the entire conduit at once or by testing joints of the conduit after the entire conduit is in place. This test should be performed prior to placement of concrete encasement or backfill around the conduit.	
c) Joint Restraint	Pressurized conduits should avoid bends if possible. If bends are unavoidable, proper joint restraints must be provided.	
10. Conduit Materials	Pipe material shall be durable and structurally capable of withstanding all loadings applied by the embankment and the outlet flows. Many materials such as plastic (HDPE and PVC), cast iron, ductile iron, welded steel, and reinforced concrete (cast-in-place or precast) have been shown in practice to be acceptable for outlet conduits. Selection of the conduit material and construction methods should follow the current state of the practice for the unique conditions of the specific application. Corrugated Metal Pipe (CMP), Vitrified Clay Pipe (VCP), prestressed concrete cylinder pipe, and wood are not acceptable materials for outlet conduits.	
11. Conduit Bedding		
a) Foundation Preparation	Where possible, the outlet conduit should be located on bedrock. If that is not possible, the specifications must provide for the preparation of a firm foundation for the outlet conduit to avoid differential settlement and/or spreading that could lead to damage to the conduit. Placement of granular material to stabilize the subgrade within the outlet trench is not allowed. Removal and replacement of compressible material under the conduit is required, or the conduit and its encasement must be designed to safely accommodate the anticipated differential movement of the foundation.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
b) Backfill Compaction	The design must include special provisions for adequate compaction of the backfill material around the outlet conduit. Special details should be included that address compaction of material in the haunches below the springline of the pipe. Cast-in-place concrete encasement or cradles for the full length of the conduit are encouraged. If the conduit will be concrete encased, the concrete should be able to withstand the loading from the embankment. "Flow-Fill" or "Controlled Low Strength Material" (CLSM) is not allowed for bedding outlet conduits on High or Significant Hazard dams. CLSM may be acceptable on some Low Hazard or NPH dams, as approved by the DSB on a case-by-case basis.	
c) Anti-Seep Collars	Anti-seep collars are not allowed.	(FEMA, 2005)
d) Concrete Encasement	Concrete encasement must include reinforcement designed to withstand the external forces exerted on the outlet conduit by all overburden loads and the internal impact forces exerted by outlet discharges. The encasement section must be designed with battered sides and rounded top to minimize the potential for cracking of the embankment fill. The outlet pipe must be adequately restrained to prevent horizontal or vertical movement during placement of the concrete encasement.	
e) Closure Sections	Installing the outlet conduit within a closure section of the dam should be avoided if at all possible due to the potential for differential settlement and hydraulic fracture of the embankment.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
12. Conduit Rehabilitation		
a) Sliplining	Sliplining products should demonstrate that they have the structural capacity to carry the load of the embankment without any support from the host (carrier) pipe. Key considerations in the design of outlet conduit sliplining projects include verifying the structural capacity of the liner, verifying the discharge capacity of the conduit with reduced diameter, and sealing the annulus between the liner and the carrier pipe. Thorough inspection of the carrier pipe should be performed prior to the design of the sliplining to ensure that the necessary information is available to the designer. Pulling a template through the carrier pipe is recommended to ensure that it will accept the liner pipe without difficulty. The liner pipe size may need to be adjusted to accommodate any defects in the carrier pipe (i.e. joint offsets, deflections, protrusions, etc.) For all outlet sliplining projects, a work plan must be submitted showing that the necessary design considerations have been properly addressed. The work plan must also provide for adequate, qualified field supervision during the sliplining operations, including measures to be taken if the sliplining process is interrupted or is unsuccessful.	
(1) Cured-in-Place Pipe (CIPP)	CIPP lining products should demonstrate that they have the structural capacity to carry the load of the embankment without any support from the host (carrier) pipe. Prior to placement, the carrier pipe must be inspected and cleaned of any defects including roots, rocks and sediment, mineral deposits, concrete, and debris. Any protrusions from the existing pipe should be removed and ground smooth with the interior of the carrier. The carrier pipe should be dewatered. A pre-placement video is required. Hydrophilic water stops are recommended at the upstream and downstream ends of the CIPP liner to prevent the entrance/exit of seepage into the annular space between the carrier/liner. The CIPP pipe must be allowed to cure fully and cool to ambient temperature prior to final trimming of the pipe at the upstream and downstream end. This typically requires waiting 24-48 hours after the pipe has been placed. When installing a CIPP liner, the installation method (air inversion/steam cure vs. water inversion/water cure) should be chosen carefully, depending on project conditions. Consideration should be given to the potential for poor bonding of the CIPP to the host pipe	(ASTM F1216)

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
	because of temperature differentials between the dam interior and the pipe interior. The water inversion/water cure method generally allows for higher equalizing pressure and more controlled cure conditions. A post-placement video inspection is required. Wrinkles that could reduce the hydraulic capacity of the outlet conduit are not allowed. Provisions to repair such wrinkles should be provided in the specifications. Samples cut from the upstream and downstream end of the CIPP liner should be tested to ensure that the liner has achieved the flexural and tensile strength assumed in the design.	
(2) Grouted In Place Pipe Liner	Design considerations for grouted-in-place pipe liners must include at least the following: • A grout volume estimate must be provided so that grout takes can be evaluated. • Bulkheads must be provided to contain the grout within the annulus between the host and liner pipe. • The liner must be provided with physical restraints to center the liner in the conduit and prevent floatation during grouting operations. • Venting must be provided at the top of both ends of the pipe to dissipate pressure buildup within the annulus and allow for removal of bleed water. • Grout Injection Pipes should be located such that the length that the grout must travel is reasonable, given the grout mix design. • To limit the potential for hydrofracture of the embankment, grout pressure should be limited to either a) the external loading capacity of the liner pipe or b) 50% of the overburden pressure, whichever is less. • Grouting procedures should require one continuous placement from one end of the conduit. • The specifications must require the submittal of a grouting plan detailing the contractor's grout mix design, grout mixing and placement equipment, setup, procedures, sequencing, and sealing/bulkheading of the upstream and downstream ends of the conduit to the engineer for approval. The grout mix design must require use of a stable grout to prevent shrinkage or bleed. Written approval of the grouting plan by the DSB is required prior to allowing the contractor to procure the materials for the grouting operation. • A mandatory pre-grouting meeting must be held between the owner, engineer, contractor, and a representative of the Dam Safety. The purpose	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
	of this meeting is to ensure that 1) the approved grouting plan is being followed, 2) the contractor has the necessary equipment and that backup equipment is available, 3) the contractor is planning to order a sufficient quantity of grout, 4) the engineer and/or owner is capable of directing the work of the contractor, and 5) the contractor has contingency plans in place if problems arise during the grouting process. The DSB must be notified at least 7 days prior to the grouting. • Moveable tremie and/or grout injection pipes are not allowed. • To maintain clearance between the liner and the carrier, the OD of the liner should provide adequate clearance to accommodate liner insertion, venting and grouting pipes, deviations in the carrier pipe alignment, and to prevent bridging of the grout. • The designer must address thermal expansion/contraction and stretching of the liner pipe and include provisions for allowing the liner to relax once it is in place and prior to performing grouting operations.	
b) Spray Lining	Emerging technology involving a surface application of a ceramic polymer to the inside of a carrier pipe has not been extensively proven in the field but will be considered on a case-by-case basis.	
c) Cut-and-Cover	Cut-and-cover replacement of outlet conduits should follow the requirements for new conduits. Trench side slopes must be flat enough to allow for effective keying of the backfill into the excavated slopes to minimize the effects of differential settlement and potential for inducing hydraulic fracture.	
d) Seepage Control	Outlet rehabilitations must also include measures such as seepage diaphragms to prevent piping along the outside of the conduit or encasement.	
13. Conduit Abandonment	It is generally desirable to completely remove conduits from embankments when they will no longer be used, because they still represent a discontinuity and potential failure mode for the dam. There are some conditions where removal of the conduit may not be feasible due to the large excavation transverse through the dam. In this case, the recommended approach is to plug the entire conduit with non-shrink grout or concrete. In addition, a filter diaphragm near the downstream end of the conduit is required to intercept any seepage traveling along the outside of the conduit.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
14. Microtunneling and Horizontal Directional Drilling	Directional drilling and microtunneling, sometimes referred to as “pipe jacking” or “boring and jacking”, are generally not allowed, but may be acceptable under certain circumstances in dam abutments. These practices are not allowed through or beneath dams.	Rule 5.10.1.5
15. Tunnel Outlets	Tunnels are considered to be underground facilities and, as such, design and construction of an outlet tunnel excavated in or into the dam foundation must include appropriate geotechnical considerations for underground construction. Tunnels excavated in or into bedrock require the expertise of a qualified professional engineering geologist. Tunnels driven through dam abutments must be designed by an experienced soft-ground tunneling specialist. Outlet conduits located in tunnels should permit ease of access for inspection, maintenance, and repair. Concrete tunnels constructed to carry the outlet conduit beneath the dam must be designed to provide adequate structural support for the dam and must be founded on competent bedrock, as verified by a qualified engineering geologist.	Rule 5.4.3.2
16. Outlet Design Report	The outlet design should be fully described within an Outlet section of the Design Report.	
a) Discharge tables	Discharge table(s) showing the discharge for each foot of head between the outlet intake and the crest of the dam.	
b) Discharge equations	Equation(s) and model(s) used for determining outlet discharge shall be included.	
II-H. Instrumentation Plan	Instrumentation devices are used to monitor the performance of a dam over time. Accordingly, the State Engineer requires a plan for instrumentation and schedules for the periodic measurement, evaluation, and reporting of a dam’s performance. The size and hazard classification of the dam, complexity of the dam and foundation, known problems and concerns, and degree of conservatism used in the design criteria all must be considered in designing the dam instrumentation.	Rule 5.5
1. Design Criteria	Instruments shall be designed to be long lasting or easily replaceable so that little or no correlation adjustment between old and new data is required.	(ASCE, 2000)

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
2. Gage Rods	Gage rods shall be installed in the proximity of the outlet on all dams. The zero mark of the gage shall be established as the invert elevation of the entrance to the lowest outlet. The gage shall be clearly marked in feet and tenths of feet and extend to within one foot of the dam crest. If the Division Engineer requires, the gage shall be marked in hundredths of a foot. Gage rods shall be correlated with the reservoir storage capacity table and the USGS datum and shall be clearly readable from the dam crest.	Rule 5.5.2 (C.R.S., 37-84-115)
3. Required Instrumentation	Planning for instrumentation requires knowledge of the design and predicted behavior of the dam and an estimate of the precision required for each device to be installed. Special instrumentation or additional requirements will be directed on a case by case basis and would only be required in situations where unusual conditions exist.	
a) High and Significant Hazard Dams		
(1) Monuments	Surface movement monuments must be permanent and be periodically monitored by precise survey instruments. To prevent disturbance by surface impacts, frost action, or vandalism, it is strongly recommended that the upper portion of the monument be encased in a larger steel or concrete pipe. The design engineer shall recommend monument locations based upon dam design, foundation conditions, potential of abutment slide areas and other locations that warrant observation.	Rule 5.5.3.1
(2) Drainage or Seepage measurement	Drainage or seepage measurement weirs shall be permanent and installed to prevent water from flowing around or under the weir. The weirs shall be constructed to meet appropriate standards for measurement devices similar to those defined in the U. S. Bureau of Reclamation Water Measurement Manual. Deviations from standards will require calibration and acceptance by the State Engineer. It is intended that the weir approach basins be designed to allow visual inspection of the water flowing from the source in order to detect whether soil particles are carried in the discharge. When drainage or seepage volumes are too large for accurate measurement in weirs, flumes should be used. Consideration should be given to inspection camera access requirements when sizing pipes for drains and seepage collection.	Rule 5.5.3.2 (Reclamation, 2001)

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
(3) Station Markers	Station markers shall be installed along the crest of the dam away from the vehicle traffic lanes. These markers will allow quick location of a problem area that can be related to construction drawing records on file. This information can play an important role in quickly developing remedial actions to prevent the failure of the dam. In addition, the location of maintenance items can be easily dispatched to a work crew.	Rule 5.5.3.3
(4) Piezometers	Piezometers are devices for measuring the hydrostatic pressure within, beneath, or adjacent to a dam. Vibrating-wire piezometers are read with a meter. Measurement of the water level in an open-well standpipe piezometer is generally performed by an electric water level indicator. The depth to or elevation of the water surface may be made by measuring the pressure head at an isolated point in the foundation or by measuring the integrated or average pressure up through the embankment. Most dams have open standpipe or observation wells that measure the average pressure in the embankment. These well systems are more durable than other types of piezometers, but they respond very slowly to changes in the water level within the impervious section of the dam. The top few feet of each piezometer should be in a strong encasement to prevent damage by equipment or vandals. Piezometers must be sealed at the ground surface to prevent surface water inflow.	Rule 5.5.3.4
b) Low Hazard Dams	Low Hazard dams shall have weirs, flumes or other measuring devices installed, as approved by the State Engineer, to allow monitoring and measurement of seepage through the embankment or foundation.	Rule 5.5.4
II-I. Monitoring Plan	Once the instrumentation is designed a monitoring plan must be developed. It shall include the frequency of monitoring, who is responsible for collecting and reporting measurements, and provide for the plotting and interpretation of the results.	Rule 5.5.1
1. Purpose	Dams and their foundations must be monitored to accomplish the following: 1. To observe the performance of the dam in order to detect abnormal changes early enough to prevent failure; 2. To determine if the dam is performing as designed; and 3. To improve scientific knowledge of dam performance in general.	

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
2. Frequency of Measurements	Once instruments are installed at a dam, they need to be systematically measured according to an established schedule and as soon as possible after unusual events such as earthquakes, heavy flooding, or when unforeseen conditions develop. The schedule should be based on the loading conditions and operation schedule of the reservoir. There are three basic plans that must be developed:	
a) First Filling Plan	The First Fill and Monitoring Plan must be submitted and approved by the DSB prior to storing any water in the reservoir. The objective of the First Filling Plan is to provide a close observation and instrument monitoring schedule while the reservoir level is rising for the first time. The first filling rate should be slow enough to allow the dam to adjust to the new loads and seepage forces. Some dams may require each successive reservoir water level held steady for a week or more before filling to the next increment. Others may be large enough that the filling rate is normally slow. The plan is the responsibility of the design engineer, subject to approval of the State Engineer. Reporting requirements for the first fill monitoring data will be coordinated with the DSB on a case-by-case basis.	Rule 10.2.5
b) First Five-Year Plan	The objectives of an after-construction or first five-year instrumentation monitoring plan include the following: 1) establish baseline historical performance such as dam response time and drain discharge rates as a function of reservoir stage, 2) establish baseline historical performance for piezometer response versus reservoir stage, 3) evaluate post-construction dam and foundation settlement or consolidation rate, and 4) determine if the dam is performing as designed.	Rules 10.3, 15.3.2
c) Long Term Monitoring Plan	The long term plan shall be based on the normal operating schedule of the dam. The time schedule for reading instruments should include the times when the reservoir is at its lowest and at its maximum storage. Embankment movement monuments and inclinometers are to be surveyed once a year for 5 years, then the interval may be changed to every 5 years, provided no significant movement occurs.	Rules 10.2.6, 10.3, 10.4, 15.3
3. Recording and Reporting	The design engineer should develop a system for and train the owner's personnel in the proper measurement of the instruments, including recording and reducing the data into a usable form.	Rule 15.3
a) Accuracy and Consistency	Accurate measurements and recording of instrumentation data cannot be overly emphasized. Suggested forms for recording the data are shown in the DSB Dam Safety Manual.	(DWR, 2002)

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
b) Data Reduction and Plotting	The dam owner taking the reading should immediately reduce and plot the data on the relevant graphs to see if the readings make sense or if there are any anomalies that indicate an emerging problem that should be evaluated by an engineer. This will provide an opportunity to recheck the data for a reading error and to take appropriate action.	
4. Analysis of Data	The data should be reduced and plotted on appropriate graphs and maintained by the owner. These graphs should be reviewed by the owner's engineer for comment annually and sent to the State Engineer.	Rule 15.3.3

PART III - CONSTRUCTION OF JURISDICTIONAL DAMS

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
III-A. Construction Quality		Rule 9
1. Purpose	Ensure construction of a safe and functional dam according to the design engineer's approved criteria, modified as necessary to reflect unanticipated conditions that were not identified during the original site investigation. The Project Engineer is responsible for ensuring and documenting that construction proceeds in accordance with the intent of the approved plans and specifications. The Project Engineer must be a professionally registered engineer experienced in dam design and construction. As indicated below, the role of the Project Engineer depends on the Hazard Classification of the dam.	
2. High and Significant Hazard dams		Rule 9.1
a) Construction Observation Plan (COP)	The COP must be submitted to the DSB no less than 30 days prior to construction. Approval (or conditions for approval) of the COP will be issued within 10 working days of the DSB's receipt of the plan.	Rules 9.1.1, 9.1.2
b) Pre-construction meeting	It is the Project Engineer's responsibility to schedule a pre-construction meeting. The meeting must be held after submittal of the COP and at least 2 weeks prior to commencement of the construction. The meeting will review the respective roles of the DSB, the owner's project engineer, and the contractor during construction to ensure that the responsibilities and authority relationships are clearly established. A tentative list of "milestone" items the State Engineer will want to observe during construction will be provided, including a list of state personnel to contact concerning any matters of construction. The proposed plans for stream diversion and control of the river during construction will be reviewed at this meeting.	Rule 9.1.3
c) Project Engineer's Observation	The Project Engineer provides the authoritative presence on site to interpret the plans and specifications for the contractor. It is the engineer's responsibility to observe the progress and quality of the construction to determine whether the construction is proceeding in accordance with the approved plans and specifications.	Rule 9.1.4

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
d) Construction Records	The Project Engineer maintains a record of the construction, including progress reports, test results, photographs, etc.	Rule 9.1.5
e) Progress Reports	Progress reports shall be submitted at least every 30 days, or more frequently as directed by the State Engineer. Progress reports submitted via email may be acceptable as approved.	Rule 9.1.6
f) Construction Inspection Notice	Generally, at least 5 days notice must be provided for scheduling DSB observation of the critical "milestone" items identified in the pre-construction meeting.	Rule 9.1.7
g) Construction Change Orders	The Project Engineer is responsible for identifying unforeseen site conditions encountered during construction that require deviation from the approved plans and specifications. Construction changes must be approved in writing by the State Engineer prior to implementing the change. Proposed changes during construction must be discussed with the DSB to determine if they are major changes or minor changes under the Rules. Approval of change orders can often be expedited through electronic communications.	Rule 9.1.8
h) Final Construction Inspection	Advise the DSB at least 10 days prior to the project's final inspection.	Rule 9.1.9
i) Construction Completion	Construction will not be considered complete until the State Engineer issues a written statement of acceptance.	Rules 9.1.10, 10.1
3. Low Hazard and NPH dams		Rule 9.2
a) Construction Plan	The project engineer shall notify the DSB of the project construction plan at least 30 days prior to construction.	Rule 9.2.1
b) Construction observation by engineer	The project engineer or authorized technician shall observe the construction to verify that the work is completed according to the approved plans and specifications.	Rule 9.2.2
c) Construction Inspection, Testing, and Reporting	The project engineer will document the construction through inspections and testing of all materials and work to verify compliance with the approved plans and specifications, and will submit required periodic progress reports and the final construction report.	Rule 9.2.3

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
d) Construction Change Orders	The Project Engineer is responsible for identifying unforeseen site conditions encountered during construction that require deviation from the approved plans and specifications. Construction changes must be approved in writing by the DSB prior to implementing the change. Proposed changes during construction must be discussed with the DSB to determine if they are major changes or minor changes under the Rules. Approval of change orders can often be expedited through electronic communications.	Rule 9.2.4
e) Final Construction Inspection	Advise the DSB at least 10 days prior to the project's final inspection.	Rule 9.2.5
f) Construction Completion	The Project Engineer shall notify the DSB of completion of the construction.	Rule 9.2.6
III-B. Acceptance of Construction	Construction will not be considered complete until the State Engineer issues a written statement of acceptance.	Rule 10.1
1. Construction Completion Documents	Construction completion documents shall be submitted within 60 days following the final construction inspection.	Rule 10.2
a) Notification of Project Completion	The Project Engineer shall certify that the project was completed in general accordance with the approved plans and specifications, including approved construction change orders.	Rule 10.2.1
b) As-constructed drawings	As-constructed record drawings shall be on good-quality reproducible mylar or equivalent material and shall indicate the final conditions of the constructed project. As-constructed drawings must be stamped in accordance with the requirements of the Colorado PE licensing regulations.	Rule 10.2.2
c) Final Construction Report	A Final Construction Report must be submitted at the end of construction. The Final Construction Report must include the following minimum information: • Summary of the periodic progress reports • Discussion of problems that arose during the construction and how they were resolved • Description of foundation conditions encountered during construction • Description of borrow areas and borrow materials used in construction • Discussion of all construction procedures and equipment employed • Summary of all construction testing methods and results • Discussion of weather conditions and weather-impacted construction delays • Representative photos depicting the entire construction sequence	Rule 10.2.3

REQUIREMENTS	COMMENTS	RULES AND REFERENCES
2. Record of Monuments and Instrumentation	As appropriate, based on dam hazard classification	Rule 10.2.4
3. First Fill and Monitoring Plan	As appropriate, based on dam hazard classification	Rule 10.2.5
4. Long-term Instrumentation Monitoring Plan	As appropriate, based on dam hazard classification	Rule 10.2.6
5. 5-year Monitoring Plan	As appropriate, based on dam hazard classification	Rule 10.3
6. Temporary Storage	Storage of water is not permitted until the State Engineer has accepted the completed construction in writing. The dam owner may request permission to temporarily store water in the completed project prior to the engineer's submittal of the final project completion documents. Full storage will not be granted until the requirements of Rule 10 and Rule 16 are completely fulfilled.	Rule 10.4
7. Emergency Action Plan	EAP templates and guidelines are available from the DSB.	Rules 10.4, 10.5, 16
8. Construction Cost Information	Final payment information for the completed project. Payment information should be itemized for all project components, and engineering costs should be itemized for design and construction services. The Dam Safety Branch is developing a dam construction cost database, and the final cost information will be utilized anonymously in that database. The database, when fully developed, will be used as a resource for engineers, contractors, and dam owners statewide.	

APPENDIX

Plans and Specifications Checklist

The following checklists are provided as a general guide for preparing a design package for submittal to the Dam Safety Branch. The list is not intended to be all-inclusive, and every item listed is not necessarily pertinent to every project.

I. Plans Check List – note, the Colorado DSB follows the convention of depicting water flowing from left to right and from top to bottom of the drawing sheet. Drawings submitted for review by the DSB should follow this convention as much as reasonably possible.

A. Plan Identification

____ 1. Title Block on each sheet of plans
____ 2. Approval statements placed in lower right hand quadrant of drawing cover sheet. Includes PE number and engineer signature, "As Constructed" statement, and the State Engineer's signature block
____ 3. A consecutive drawing numbering system beginning with "Sheet 1 of ___" on the first (cover) sheet
____ 4. Space for State Engineer's Construction File Number (1/2" X 3") in lower right-hand corner on each sheet
____ 5. The signature block for the responsible engineer shall state: "These plans have been prepared by me or under my direct supervision." A PE stamp alone is not sufficient.

B. Location and Vicinity Maps Showing:

____ 1. Bar Scale and North Arrow
____ 2. Project location
____ 3. Public land grid (PLSS)
____ 4. Drainage area and topography
____ 5. Streams and gaging stations
____ 6. Roads, utilities

C. Plan(s) of Reservoir Area Showing:

____ 1. Bar Scale and North Arrow
____ 2. Topography with M.S.L. elevations with vertical datum
____ 3. Clearing areas and limits
____ 4. Material borrow areas
____ 5. Riprap borrow areas
____ 6. Waste areas
____ 7. Equipment and Material staging and processing areas
____ 8. Centerline of dam showing bearing and coordinates of survey control points
____ 9. Public land grid
____ 10. Geotechnical Investigation drill hole and test pit locations with summary logs
____ 11. Cultural features
____ 12. Roads, utilities, streams, etc
____ 13. NWL and dead storage traverses

____ 14. Land ownership and boundaries
____ 15. Spillway location(s)
____ 16. Excavation Plan
____ 17. Reservoir area and capacity curve and table in acres and acre feet for each foot of elevation to the design crest of the dam

D. Dam and Spillway Plan(s)

____ 1. Scale and north arrow
____ 2. Spillway alignment and centerline stationing
____ 3. Topography with M.S.L. elevations and vertical datum
____ 4. Dam centerline stationing and coordinates of survey control points
____ 5. Section corner tie and bearings
____ 6. Structure locations
____ 7. Riprap placement limit
____ 8. Geotechnical Investigation drill hole and test pit locations with summary logs
____ 9. Locations and limits of blanket drain, toe drain(s) and other filters and drains
____ 10. Locations of instrumentation with details
____ 11. Locations of cross-sections with details

E. Outlet, Maximum, and Typical Cross-Sections of Dam

____ 1. Dam crest width, elevation, slope, and camber
____ 2. High water elevation
____ 3. Normal water elevation
____ 4. Embankment zones
____ 5. Cutoff trench depth and width
____ 6. Grout curtain or other foundation treatment
____ 7. Outlet conduit intake elevation
____ 8. Outlet conduit discharge end elevation
____ 9. Outlet conduit materials
____ 10. Outlet conduit slope, length, diameter, and stationing
____ 11. Location of seepage diaphragm and sand collar
____ 12. Toe drain, drainage blanket, & chimney drain
____ 13. Upstream slope
____ 14. Riprap thickness
____ 15. Bedding thickness
____ 16. Downstream slope
____ 17. Additional necessary sections and details

F. Longitudinal Section (Profile) Through Dam

____ 1. Crest elevation
____ 2. Geotechnical Investigation drill holes and test pit locations
____ 3. Soils logs on profile
____ 4. Cutoff trench
____ 5. Grout curtain or other foundation treatment
____ 6. Dam centerline stationing

____ 7. Dam crest camber

G. Outlet Conduit Details

____ 1. Conduit Diameter
____ 2. Discharge Capacity Curve with equation(s)
____ 3. Conduit Profile with conduit length, slope, elevations, and stationing
____ 4. Air vents or cavitation protection
____ 5. Materials
____ 6. Gage or class
____ 7. Bedding or encasement details
____ 8. Trenching and structural backfill

H. Outlet Intake and Gate Lift Structure Details

____ 1. Materials
____ 2. Gate lift or wheel
____ 3. Trashrack
____ 4. Gate stem and housing
____ 5. Gate stem support
____ 6. Gate type and head rating
____ 7. Stem protection from ice
____ 8. Gate lift mechanism
____ 9. Gate Lift Structure lock
____ 10. Gate stem encasement and details
____ 11. Outlet air vent

I. Outlet Discharge Structure & Channel Details

____ 1. Structure type
____ 2. Construction material(s)
____ 3. Stilling basin, energy dissipater, and downstream channel
____ 4. Erosion protection

J. Spillway Details

____ 1. Size and type
____ 2. Total freeboard
____ 3. Crest or Sill details
____ 4. Residual freeboard
____ 5. Material
____ 6. Channel profile, including approach and discharge sections
____ 7. Channel cross-sections, including approach and discharge areas
____ 8. Riprap or other erosion protection limits and details
____ 9. Concrete construction limits and details, including reinforcement
____ 10. Debris barrier or trashrack details
____ 11. Stilling basin details
____ 12. Discharge capacity table or curve with equation

K. Other

____ 1. Instrumentation locations and completion details
____ 2. Reservoir gage details
____ 3. Logs of drill holes and test pits
____ 4. Cofferdam or diversion facilities details
____ 5. Special construction details (sequence, staging, etc.)

II. Specifications Checklist - It is recommended that one of the standardized specification formats developed by professional organizations such as the American Institute of Architects, the National Institute of Building Sciences, or the Construction Specifications Institute be used. These standardized formats are generally quite thorough and can be easily adapted to different project types to aid the designer in preparing complete, consistent, and adequately detailed specifications.

A. Front Cover

____ 1. Title or Name of Dam (identical to plans)
____ 2. DAMID and C-number
____ 3. Water Division and Water District

B. First page behind Front Cover

____ 1. Title or Name of Dam (identical to plans)
____ 2. DAMID and C-number
____ 3. Water Division and Water District
____ 4. County
____ 5. Design Engineers Seal and Signature
____ 6. State Engineer's approval statement
____ 7. The signature block for the responsible engineer shall state: "These specifications have been prepared by me or under my direct supervision." A PE stamp alone is not sufficient.

C. Other

____ 1. Index (or Table of Contents) is complete and usable
____ 2. The specifications include the following under General Conditions. (It is recommended to include a separate section or chapter of the specifications for the State Engineer requirements listed below.)
____ a. Statement that the plans and specifications cannot be significantly changed without the prior written approval of the State Engineer (Rule 5.3.4)
____ b. Provision that construction shall not be considered complete until the State Engineer has accepted the construction in writing (Rule 5.3.5)
____ c. Statement that the owner's engineer will monitor the quality of construction (Rule 5.3.6)

____ 3. The key contractor submittals are listed with requirements for their submission.

____ 4. The procedures for change orders are clearly stated.

____ 5. All materials are specified, including reference to:

____ a. Quality and type of materials

____ b. Installation/Workmanship

____ c. Applicable industry standards

____ d. Action to be taken for unsatisfactory materials or workmanship

____ e. Required tests and frequency of testing

____ 4. The specifications are in agreement with the plans

Project Review Guide References

1. ASCE (2000), Guidelines for Instrumentation and Measurements for Monitoring Dam Performance, American Society of Civil Engineers Task Committee.
2. ASTM (latest year), Annual Book of Standards, ASTM International, West Conshohoken, PA.
3. AWWA
4. Brater, Earnest; King, Horace; Lindell, James; Wei, C., (Brater, et. al., 1996), Handbook of Hydraulics, 7th ed., McGraw-Hill, New York.
5. C.R.S. (2008), Colorado Revised Statutes, Title 37, Article 87 Reservoirs, Denver.
6. Chow, Ven Te (1959), Open-Channel Hydraulics, McGraw-Hill, New York.
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