COLORADO
Division of Water Resources
Department of Natural Resources
Dam Safety

State Engineer, Colorado Division of Water Resources
Rules and Regulations for Dam Safety and Dam Construction
Summary of Proposed Revisions

PUBLIC STATEMENT

The State Engineer and his staff have undertaken efforts to review and revise the existing Rules and Regulations for Dam Safety and Dam Construction (2-CCR 402-1), dated January 1, 2007, to ensure they are effective, efficient, and essential for keeping Colorado dams safe. The Dam Safety Program began review of the existing rules and regulations in 2015 and has completed a revised draft in January 2019 that can be found on the Colorado Dam Safety Webpage (http://water.state.co.us/SurfaceWater/DamSafety/Pages/DamSafety.aspx). These draft rules are being provided to encourage dam owners and engineers with an interest in the subject to participate in the stakeholders process.

Publicly announced Stakeholder Meetings will be held later this year in various locations around the state to present proposed revisions to the rules. Additional communication will be provided as those meetings are scheduled. Stakeholders are invited to provide comment via email by contacting Colorado Dam Safety dnr_coloradods@state.co.us

SUMMARY OF REVISIONS

Numerous edits were made during the course of review and revision of the *Rules and Regulations for Dam Safety and Dam Construction (Rules).* The general approach during review and revision was taken from Executive Order 2012-002 Regulatory Efficiency Reviews, which offers the following guidance to whether each rule:

- Is necessary and does not duplicate existing rules;
- Is written in plain language and is easy to understand;
- Has achieved the desired intent and whether more or less regulation is necessary;
- Can be amended to reduce any regulatory burdens while maintaining its benefits; and
- Is implemented in an efficient and effective manner, including the requirements for the issuance of any permits or licenses.

As such, many of the revisions were simply editorial in nature to meet the above guidance. Where significant changes were made from the 2007 Rules, either a new rule was created or the format and wording of the existing rule was edited to make the changes clear and concise.

A comparison document showing all revisions made from the 2007 Rules will be created and submitted to the Secretary of State at formal Rulemaking. For simplicity, the following summarizes substantive proposed revisions (note that all rules mentioned below reflect proposed numbering, unless otherwise stated):

- Editorial revisions ("wordsmithing") in accordance with Executive Order 2012-002.
- Additional definitions added into Rule 4 as needed for clarification of the remaining Rules.
- Deleted rules that were repeated or no longer necessary in accordance with Executive Order 2012-002.

- Reorganization of several Rules to improve the flow of the document, e.g.:
  - Rule 13 (2007) Determination of Safe Storage Level moved to Rule 5 (2019)
  - Rules 5.1 through 5.8 (2007) and Rule 6.1.3 (2007) moved into Rule 6.0 Design Submittal Requirements
  - Rule 5 (2007) and 6 (2007) reorganized and combined into Rule 7 Design Requirements with the following subordinate rules:
    - Rule 7.2 Inflow Design Flood for Spillway Sizing
    - Rule 7.3 Geological and Geotechnical Investigations
    - Rule 7.4 Embankment Dam Design
    - Rule 7.5 Concrete Dam Design Requirements
    - Rule 7.6 Seismic Design Requirements
    - Rule 7.7 Instrumentation and Monitoring Requirements
    - Rule 7.8 Spillway and Outlet Works Design Requirements
    - Rule 7.9 Reservoir and Site Requirements

NEW RULES

Following is a summary of NEW rules proposed for revision of the Rules. For comparison to the 2007 Rules:

- First level rule headings shown below are generally provided for reference only but may be a new number from the 2007 Rules due to other editing and revisions. Note that rule numbers are shown in red and larger font for highlighting purposes only.
- The rules listed below are considered NEW from the 2007 Rules, except where crossed out numbers are shown to provide reference and context for a proposed rule.
- Several proposed rules that appear new in the draft 2019 Rules document but are simply re-written for clarity are not listed below in this summary document.

Rule 1. **Title**

Rule 2. **Authority**

2.2 These Rules do not change the meaning of any statute.

Rule 3. **Scope and Purpose**

Rule 4. **Definitions**

4.2 **Annual Exceedance Probability (AEP)**. The probability of occurrence in any one year.

4.7 ~~4.2.19~~ **Dam Height.**

4.7.2 **Hydraulic Height**. The vertical dimension measured from the lowest point of the upstream toe of the dam to the emergency spillway crest.

4.7.3 **Structural Height**. The vertical dimension measured from the lowest point of the excavated foundation to the crest of the dam.

4.12 **Geologist.** An individual possessing specific knowledge of the geological sciences and the principles of engineering analysis and design acquired by professional education or demonstrated experience related to dams, and qualified to apply such knowledge to assure geologic elements affecting the dam are adequately accounted for in design and construction.

4.15 **Hydrologic Hazard**. Potential consequences downstream of a dam caused by floodwaters released by overtopping failure of the dam. Hydrologic hazard establishes design criteria for spillway size.

4.15.1 **Extreme.** Life loss potential of 1 or more.

4.15.2 **High.** Life loss potential of less than 1.

4.15.3 **Significant.** No life loss potential but significant damage is expected to occur.

4.15.4 **Low.** No life loss potential or significant damage is expected to occur.

4.16 **Incremental Consequences**. The difference in impacts that would occur due to failure or misoperation of the dam over those that would have occurred without failure or misoperation of the dam or appurtenances.

4.23 **Potential Failure Mode (PFM).** A physically plausible process for dam failure resulting from an existing inadequacy or defect related to a natural foundation condition, the design or construction of the dam or appurtenant structures, the materials incorporated, the operations and maintenance, or the aging process, which can lead to an uncontrolled release of the reservoir.

4.24 **Potential Failure Modes Analysis (PFMA)**. The process by which the site-specific PFMs are identified, described in detail, and evaluated to determine the likelihood and consequence of occurrence.

4.25 **Probable Maximum Flood (PMF)**. The flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the drainage basin under study.

4.29 **Risk**. The product of (1) the likelihood of a structure being loaded, (2) the likelihood of adverse structural performance, and (3) the magnitude of the resulting consequences.

4.29.1 **Risk Management**. Action implemented to communicate the risks and either accept, avoid, transfer, or control the risks to an acceptable level considering associated costs and benefits of any action taken.

4.29.2 **Risk Analysis**. Qualitative or quantitative procedures that identify potential modes of failure and the conditions and events that must take place for failure to occur.

Rule 5. ~~Rule 13~~ Determination of Safe Storage Level

5.2 **Methods to Determine Safe Storage Level**. The State Engineer will use the following methods to determine the safe storage level.

5.2.2 **Potential Failure Modes Analysis**. Potential Failure Modes Analysis may be performed following identification of a concerning issue during the regular or interim inspection and/or as part of a periodic comprehensive dam safety evaluation.

Rule 6. ~~Rule 5.0~~ Design Submittal Requirements

6.1 An Owner proposing to construct a new jurisdictional dam or alter, modify, repair, or enlarge an existing jurisdictional dam and/or appurtenant structures shall submit an application package in a form acceptable to the State Engineer. Construction activities may not commence until the State Engineer has provided written approval of the design.

6.2 **Pre-Design Meeting**. Prior to design commencement, the Owner and Engineer shall meet with the State Engineer to discuss the scope and objectives of the project. Meeting minutes shall be provided by the Engineer to establish a clear understanding of the project requirements.

6.3 **Application Package**. The application package shall meet the following criteria.

6.3.1 **Format.** The application package shall be submitted in portable digital file (PDF) format unless otherwise requested by the State Engineer. All electronic submissions shall consider the following:

6.3.1.1 **File Size**. Efforts shall be made to minimize digital file size from the earliest stages of document development. Efforts may include use of file compression techniques in each step of the document development.

6.3.1.2 **Appropriate Security Settings**. Security settings shall allow for the required digital review and approval process by the State Engineer.

6.3.1.3 **Appropriate Resolution**. Digital files shall include a resolution appropriate to allow for printing both 22- by 34-inch and 11- by 17-inch (half-size) drawings without losing clarity, quality, or scalability.

6.3.1.4 **Electronic Signatures**. Appropriate engineering stamps and signatures will be required on the final version of the design documents before construction approval will be granted.

6.3.1.5 **File Name**. A table with document name, document description, and document type of all materials in the application package shall be included.

6.3.1.6 **File Transfer**. Digital file transfer methods shall be discussed and arranged in consultation with the State Engineer.

6.3.2 **Content**. The application package shall include the following:

A. Application Form,

B. Engineer's Qualification Statement and Affidavit,

C. Construction Plans,

D. Construction Specifications,

E. Design Report,

F. Inundation Map (High and Significant Hazard dams only),

G. Cost Estimate, and

H. Filing Fee.

6.5 **Engineer's Qualification Statement and Affidavit**. The Engineer shall submit qualifications and a signed affidavit attesting compliance with the requirements as defined in Rule 4.10.

Rule 7. ~~5.9~~ Design Requirements

7.1 This Rule applies to design of new dams and alteration, modification, repair, or enlargement of existing dams. In the case of existing dams, only the pertinent sections will apply.

7.2 ~~5.9.1~~ **Inflow Design Flood (IDF) for Spillway Sizing**.

7.2.1 **Prescriptive Method.** Table 7.1 provides rainfall requirements for the Inflow Design Flood (IDF) based on Hydrologic Hazard. The spillway must safely route a flood generated by Critical[1] Rainfall shown in Table 7.1.

Table 7.1: Prescriptive IDF Requirements

Hydrologic Hazard	Critical[1] Rainfall
Extreme	Probable Maximum Precipitation (PMP)
High	0.01% AEP
Significant	0.1% AEP
Low	1% AEP

[1] Critical refers to the controlling storm duration, spatial pattern, temporal distribution and other storm variables that result in the highest maximum reservoir water surface elevation during reservoir routing.

7.2.2 ~~5.9.1.7~~ **Incremental Damage Analysis (IDA) Method.** An IDA may be used to justify an IDF that is smaller than the prescriptive requirement in Table 7.1; however, in no case shall the IDF be less than the flood generated by the Critical[1] 1% AEP Rainfall. An IDA determines incremental consequences caused by an overtopping dam failure flood beyond that caused by the spillway base flood immediately prior to such overtopping failure. Spillway size is acceptable when incremental consequences by overtopping failure are expected to cause no additional life loss and no additional significant property damage when compared to the spillway base flood.

7.2.3 Allowable Rainfall Estimates for developing the IDF.

7.2.3.1 ~~5.9.1.4~~ **Probable Maximum Precipitation (PMP)**. The Probable Maximum Flood (PMF) shall be developed using the most current PMP estimates approved by the State Engineer.

7.2.3.2 ~~5.9.1.2~~ **Precipitation Frequency Estimates**. Frequency-based IDFs shall be developed using the most current precipitation frequency estimates approved by the State Engineer.

7.2.3.3 ~~5.9.1.6~~ **Site-Specific Extreme Precipitation Studies (SSEPS)**. SSEPS may be used to determine the appropriate site-specific extreme storm precipitation (PMP or precipitation frequency estimates) for the determination of the IDF. The SSEPS must be approved by the State Engineer prior to acceptance.

7.2.4 **Atmospheric Moisture Factor.** All rainfall depth estimates calculated by means acceptable to the State Engineer shall be multiplied by a factor of 1.07 prior to calculating runoff to account for expected increases in temperature and associated increases in atmospheric moisture availability over the 50-year period 2020 to 2070.

7.2.5 **Flood Frequency Analysis**. Using systematic records, historical flood information, and paleoflood and botanical information, flood frequency analysis may be used to determine a required frequency flood for spillway sizing purposes. Flood frequency analysis shall follow applicable, current, published guidelines and procedures, such as Guidelines For Determining Flood Flow Frequency (ACWI Bulletin 17C, USGS, 2018).

7.3 Geological and Geotechnical Investigations.

7.3.3 **Subsurface Investigation Plans.** A subsurface investigation plan must be approved by the State Engineer prior to mobilization for all proposed subsurface investigations. The plan shall include the following:

A. Objective(s) of the investigation and descriptions of the specific Potential Failure Modes being addressed in the investigation;

B. Names and qualifications of the investigation team including lead geotechnical or geological engineer, field engineers, and geologists;

C. Figures and description of the existing conditions;

D. Drilling, test pits, and other in-situ testing procedures; and

E. Contingency plans.

7.3.3.1 Drilling methods in all dams and dam foundations shall be chosen to minimize the risk of hydraulic fracturing or otherwise damaging the strata or formations being drilled. Drilling on or within 200 feet of existing dams is prohibited unless approved by the State Engineer.

7.4 Embankment Dam Design.

7.4.1 ~~5.4.4.6, 5.4.3~~ **Foundation and Abutment Design**. The dam foundation and abutments shall be analyzed and design criteria selected to meet the following requirements.

7.4.1.1 Unsuitable materials shall be removed from the dam foundation and abutments, unless appropriate analyses demonstrate the unsuitable material can be adequately treated so it will not adversely affect the safety and performance of the dam. Unsuitable materials include, but are not limited to liquefiable, dispersive, organic, expansive, and collapsible soils; slaking shales; soluble rock; clay seams in rock; and poor-quality rock.

7.4.1.2 The dam foundation geometry shall be designed to prevent the creation of low stress zones in the embankment that could cause differential settlement and cracking of the dam.

7.4.1.3 The foundation shall be treated as required to prevent deformation or instability of the dam caused by foundation movement as a result of heave, swell, rebound, settlement, or collapse.

7.4.2 ~~5.4.4.8~~ **Embankment Design Requirements**. The dam embankment shall be analyzed and designed to meet the following requirements.

7.4.2.2 **Freeboard Design**. Freeboard for earth and rockfill embankment dams shall be designed in accordance with Freeboard (Design Standard No. 13, Chapter 6, Reclamation, 2012), except as follows:

7.4.2.2.1 The minimum normal freeboard shall be the greater of 3 feet or a 100 mile per hour wind generated setup and runup.

7.4.2.2.2 The minimum residual freeboard shall be the greater of 1 foot or a 10 percent AEP wind generated setup and runup.

7.4.2.3 Embankment Zoning. Shells, cores, filters, and drains for embankment dams shall be designed using industry standards consistent with the current state of the practice.

7.4.2.3.1 All dam embankments shall be protected against internal erosion and piping with suitable filters and drains.

7.4.2.3.2 Shells shall be designed to support the core/impermeable barrier. Transition zones shall be provided as necessary to prevent migration of core material.

7.5 **Concrete Dam Design Requirements**.

7.6 **Seismic Design Requirements.** Seismic stability shall be evaluated for all concrete dams and High and Significant Hazard embankment dams. The level of analysis required shall be commensurate with the known and anticipated site conditions and the level of effort given to developing input parameters. In general, analyses should start at a screening level and progress to more detailed analyses only when necessary. Seismic stability analyses shall be based on the principles provided in Earthquake Analyses and Design of Dams (FEMA-65, Federal Guidelines for Dam Safety, FEMA, 2005), Best Practices Chapter II-3 (Reclamation and U.S. Army Corps of Engineers, 2015), Seismic Analysis and Design (Design Standards No. 13 Chapter 13, Reclamation, 2015), Earthquake Design and Evaluation for Civil Works Projects (Engineering Regulation 1110-2-1806, U.S. Army Corps of Engineers, 2016), or Earthquake Design and Evaluation of Concrete Hydraulic Structures (Engineering Manual 1110-2-6053, U.S. Army Corps of Engineers, 2007).

7.6.1 **Seismic Hazard Analysis**. The seismic hazards, consisting of the design earthquakes and associated ground motions, shall be determined. The seismic hazards shall be justified with due consideration to the hazard classification of the structure, regional and site-specific seismic hazard considerations, and the designated operational function of the dam.

7.6.2 **Dynamic Response Analysis**. Analyses to predict the structural response to seismic loading are required except as described in Rule 7.6.2.1. All seismic analyses shall be evaluated assuming loading and pore pressure conditions expected immediately prior to the earthquake. Acceptable methods for predicting structural response to seismic loading include, but are not limited to, post-earthquake stability, embankment deformation, and probabilistic analyses. Pseudostatic analyses are not an acceptable means of predicting structural response to seismic loading.

7.6.2.1 Dynamic Response Analyses are not required for embankment dams meeting all of the following conditions. The potential for embankment cracking (transverse or longitudinal), damage to appurtenant features (e.g. outlet-works tunnels), and overtopping due to seiche waves as the result of seismic activity are not addressed by these exceptions and shall be considered separately.

A. The dam and foundation materials are not subject to liquefaction and do not include sensitive clays;

B. The dam is reliably compacted to at least 95 percent of the laboratory maximum dry density, or to a relative density greater than 65 percent;

C. The slopes of the dam are 2.5H:1V or flatter, and/or the phreatic line is well below the downstream face of the embankment;

D. The peak ground acceleration (PGA) at the base of the embankment is less than or equal to 0.35g;

E. The static stability factor of safety for all potential failure surfaces involving loss of crest elevation (i.e., slides other than shallow surficial slides) are greater than 1.5 under loading and pore-pressure conditions expected immediately prior to the earthquake;

F. The minimum freeboard is at least 3 to 5 percent of the embankment height and never less than 3 feet; and

G. There are no appurtenant features that would be harmed by small movements of the embankment, or that could create potential for internal erosion or other potential failure modes.

7.8 ~~5.9.6~~ **Spillway and Outlet Works Design Requirements**.

7.8.1 ~~5.9.6.1~~ **Spillway Design**. All spillways shall be designed and constructed in a manner acceptable to the State Engineer and meet the following criteria.

7.8.1.1 The starting water surface elevation when routing the IDF shall be the emergency spillway crest.

7.8.1.6 Design of stilling basins for RCC stepped chute spillways shall include assumptions, calculations, and applicable references for estimating energy dissipation and stilling basin entrance velocities.

Rule 8. ~~5.9~~ **Construction Requirements**

8.1.1 ~~5.10.2~~ **Water Diversion Pla**n.

8.1.1.3 A hazard classification evaluation shall be performed by the contractor's engineer based on consequences to the public for any proposed cofferdam. If the water diversion system is found to be High or Significant Hazard, the design shall meet the requirements of Rule 7

Rule 9. ~~**Rule 7.**~~ **Requirements for Removing or Breaching an Existing Dam**

Rule 10. ~~**Rule 11.**~~ **Construction, Modification, Alteration, Repair, and Breach of Non-Jurisdictional Size Dams**

Rule 11. ~~**Rule 12.**~~ **General Maintenance, Ordinary Repairs, and Emergency Actions**

Rule 12. ~~**Rule 14.**~~ **Safety Inspections Performed by the Owner's Engineer**

12.3 **State Engineer Acceptance.** The report will be reviewed by the State Engineer prior to acceptance. If the report and findings are accepted, the State Engineer will provide the Owner with a list of required actions and will notify the Owner of the safe storage level.

Rule 13. ~~Rule 15~~. Owner's Responsibilities

13.1 **Liability.** The sole responsibility for the safety of the dam rests with the Owner and operator, who should take every step necessary to prevent damages caused by leakage or overflow of waters from the reservoir or floods resulting from a failure of the dam. Therefore, it is in the Owner's best interest to operate and maintain the facility in a manner such that the safety of the dam and the general public are not jeopardized.

13.3 **Site Security**. The Owner shall maintain reasonable security measures to prevent intentional misoperation and damage to the facility.

13.4 **Dam Observation and Monitoring Plans**. All dams shall have an observation and monitoring plan that shall include the following minimum requirements:

13.4.1 ~~15.2~~ **Owner Observations**. The Owner is responsible for ensuring frequent observation of the dam, especially at times when the reservoir is full, during heavy rains or flooding, and following an earthquake. The observations shall be conducted in accordance with methods acceptable to the State Engineer. Conditions which threaten the safety of the dam shall be reported to the State Engineer immediately.

13.4.1.1 High and Significant Hazard dams shall be observed at least twice a month when the reservoir water level is greater than half the full storage capacity. High Hazard dams that are seasonally inaccessible shall be provided with remote reservoir level monitoring at a minimum.

13.4.1.2 Low Hazard dams shall be observed at least once every three months.

13.4.1.3 For all dams, routine outlet observations shall include observation of exposed surfaces of the inlet and discharge structures, control valves, gates and vaults; observation of the downstream end of the conduit and adjacent embankment for leakage; and observation of the dam (upstream slope, crest, downstream slope, and natural ground) in the vicinity of the outlet alignment for signs of distress or changed conditions.

Rule 14. ~~Rule 17~~. Exempt Structures

14.4 Dams or other water impounding structures regulated by other State agencies (e.g. COGCC, CDPHE, DRMS, etc.) may be exempt from these Rules to avoid dual regulation. The State Engineer may provide technical consultation as necessary for the permitting of such structures.

Rule 15. ~~Rule 18~~. Restriction of Recreational Facilities within Reservoirs

Rule 16. ~~Rule 19~~. Waiver or Delay of Enforcement of Rules by the State Engineer

Rule 17. ~~Rule 20~~. Appeal of Requirements or Approval

Rule 18. **~~Rule 21~~. Rules by Reference**

Rule 19. **~~Rule 22~~. Severability.**

Rule 20. **~~Rule 23~~. Revision.**

Rule 21. **~~Rule 24~~. Statement of Basis and Purpose Incorporated by Reference**

Rule 22. **~~Rule 25~~. Effective Date**