R655. Natural Resources, Water Rights.
R655-11. Requirements for the Design, Construction and Abandonment of Dams.
R655-11-1. Authority and Applicability.

The following rule is established under the authority of Title 73, Chapter 5a. The procedures constitute minimum design requirements for dams. Additional procedures may be required to comply with any other governing statute, federal law, federal regulation, or local ordinance. These rules apply to any dam constructed in the state with the exception of those specifically exempted by Section 73-5a-102 and those dams not requiring plans as outlined in Section 73-5a-202.

R655-11-2. Purpose and Scope.

A. The following minimum design requirements will serve as a guide to the owner's engineer. It should be noted that these are minimum requirements for general conditions and may be changed when dealing with a specific structure. Designs below the minimum requirements must be approved in writing by the State Engineer prior to final design submittal of the project. The design requirements are quite rigid, allowing little latitude in the utilization of new materials and unproven construction methods. The burden to show adequate protection of public interests with the use of new materials or unproven methods rests with the owner's engineer.

B. The following minimum design requirements apply to all proposed dams where applicable. Since the vast majority of dams in the state are earthfill or rockfill dams, the focus of the design criteria is on these dams. Specific structural design criteria for concrete dams is not given. The State Engineer, upon approval in writing, will accept structural design criteria for concrete dams developed by other dam regulatory or dam design agencies, providing it reflects state-of-the-art criteria for the design of concrete dams and does not conflict with the following rules.

R655-11-3. Definitions.

Definitions are as outlined in R655-10-4.

R655-11-4. Hydrologic Design.

In order to arrive at an Inflow Design Hydrograph or Inflow Design Flood (IDF) more representative of actual conditions in Utah, the State Engineer has commissioned, or has been involved in, numerous studies to supplement the National Oceanic and Atmospheric Administration's (NOAA) Report entitled "Hydrometeorological Report No. 49 (HMR49) - "Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages". The results of most of these studies are used to better identify soil conditions, discharge coefficients, and unit hydrograph parameters. The results of two of the studies are used directly to refine the calculation of the design rainfall values. Both studies were completed by Donald Jensen of the Utah Climate Center and are entitled, "2002 Update for Probable Maximum Precipitation, Utah 72 Hour Estimates to 5,000 sq. mi. - March 2003" (USUL) and "Probable Maximum Precipitation Estimates for Short Duration, Small Area Storms in Utah - October 1995 "(USUS). All of HMR49, Table 1, page 4 of USUL, and Table 15, pages 74-75 of USUS are hereby incorporated by reference. All High Hazard and Moderate Hazard dams in Utah must use the precipitation values obtained from the use of all three publications. To avoid confusion, precipitation values obtained from HMR49 exclusively will be referred to as the Probable Maximum Precipitation (PMP), while those obtained from using HMR49 in conjunction with USUL or USUS, will be referred to as the Spillway Evaluation Precipitation (SEP). The resulting hydrographs generated will be referred to as the Probable Maximum Flood (PMF) and the Spillway Evaluation Flood (SEF) respectively.

R655-11-4A. Inflow Design Hydrograph Determination.

A) In Utah, the IDF for all High and Moderate Hazard Dams will be the more critical SEF. It will be necessary to calculate both the 72 hour, general SEF using HMR49 with USUL as well as the 6 hour local SEF using HMR49 with USUS. These precipitation values need not exceed values calculated using HMR49 exclusively. Both of these hydrographs must be routed through the reservoir to determine which one represents the most extreme event.

B) Once the critical SEF has been determined, it must be compared to a flood generated by the 100 year, 6 hour (for local storms), or 100 yr, 24 hour (for general storms) precipitation applied on a saturated watershed. If the routed 100 year event, including appropriate allowances for freeboard, is more critical than the SEF it must be used as the minimum IDF. This 100 year flood should also be used as the IDF for all Low Hazard Dams.

R655-11-4B. Freeboard Requirements.

All high and moderate hazard dams must have a normal freeboard above the crest of the principal spillway capable of 1) routing the IDF, 2) containing the maximum wave action, 3) containing the combined precipitation and wind event detailed in this paragraph and 4) the normal freeboard will be no less than three feet. Wave action will be determined considering site wind-duration and fetch control characteristics. Wave action includes wave height, maximum runup, and reservoir setup against the embankment slope. Unless otherwise justified by specific data acceptable to the State Engineer, the maximum wave action will be based on a wind velocity (fastest mile) over land of 100 miles per hour. In addition, while routing the 100 year precipitation event through the spillway, sufficient residual freeboard must be available to control wave action from a fetch controlled 50 miles per hour wind. Low hazard dams must have sufficient freeboard to allow the spillway to route the applicable 100 year flood. The State Engineer may reduce the three feet minimum freeboard requirement for low hazard dams based upon a review of the relative increase in risk associated with this reduction.

R655-11-4C. Spillways.

In designing the spillway for a dam to pass the IDF, the State Engineer will consider the use of a principal spillway in conjunction with emergency spillways. The principal spillway must be designed so that no structural damage will occur during passage of the IDF. Emergency spillways, including Fuse Plug Spillways, may be designed so that some damage may be expected during use provided the anticipated damage does not represent a threat to the dam. Sunny day failure modeling of Fuse Plug Spillways may be required to determine if they are creating an additional unacceptable risk. Overtopping of the dam will not be considered as an emergency spillway on earthfill dams, unless it can be demonstrated that the dam is protected from erosion, and the duration of overtopping will not saturate the dam and reduce its stability.

R655-11-4D. Infiltration Rates.

The State Engineer will accept an IDF using SEP values in conjunction with soil moisture conditions representative of historical maximums. If the design engineer is using infiltration rates which represent something less than saturated conditions, information should be submitted to justify the lower soil moisture selection.

R655-11-4E. Flood Routing.

A. In routing the IDF through the reservoir, the initial water surface should reflect conservative estimates which would exist at the time of the flood event. Unless documentation can be provided to the contrary, it should be assumed that all low level outlets are closed during routing of the IDF. For dams receiving inflow from pipelines and supply canals, it should be assumed these additional sources are operating at capacity during the flood event. In the event the spillway is gated or has "stop logs", which are only allowed on existing dams, documentation must be provided to show the gates are automated or operational procedures are in place to insure that the gates can be opened or the stop logs removed in a timely manner.

B. The SEF can be routed so the maximum water surface is at an elevation equal to the lowest point on the crest of the dam with no residual freeboard.

C. In generating the IDF, the basin characteristics used and the parameters used to generate the unit hydrograph should be based on the best information available. Unit hydrographs generated from historical records or calibrated watersheds should be used, where data is available, rather than using synthetic procedures.

R655-11-4F. Incremental Damage Assessment for High and Moderate Hazard Dams.

The State Engineer may, at his discretion, accept an IDF less than the SEF based on the results of an Incremental Damage Assessment (IDA) which shows that failure of the dam would cause insignificant incremental damage to property and no additional threat to human life. The State Engineer may consider the use of early warning systems in evaluating the threat to human life. In requesting the acceptance of an IDF determined from an IDA, documentation must be furnished that the owner of the dam is aware that the design reflects something less than the SEF and they are willing to accept the additional liability. In no case will the State Engineer approve an IDF generated by something less than the applicable 100 year flood event. The resulting selected IDF, based on the IDA, should be reported as a percent of the SEF.

R655-11-4G. Historical Records.

In some cases it may be appropriate to use historical streamflow records to generate a 100 year flood. If these records are used as a basis for the IDF, they should be accompanied by the Synthetic IDF established by using the 100 year precipitation. Following a review of the data, the State Engineer will make a determination of which flood will be used as the IDF.

R655-11-5. Seismic Design.

A. Because each dam site has a unique seismic and geological setting, detailed direction cannot be provided for seismic design which is applicable to all dams. Rather, an order of evaluation is presented beginning with more simplified methods and progressing, as required, to more rigorous procedures. In determining the sophistication of analysis required, the State Engineer may consider factors including consequences of failure, available freeboard, duration of reservoir pool, and site geometry. Regardless of the method of analysis, the final determination of seismic adequacy of a dam will be based on all pertinent factors involved and not strictly on the numerical analysis. The order of progression of the seismic analysis follows:

1. Undertake geological and seismological investigations to determine the potential for earthquakes and associated ground motions at the site, including the source and magnitude of the earthquakes to be considered and the selected motions, including potential fault rupture.

2. Undertake field and laboratory investigations of the dam and foundation materials to determine their properties and liquefaction potential.

3. Undertake an appropriate analysis for seismic events to predict factors of safety against slope failures, structural deformations, and liquefaction resulting from earthquake shaking or fault rupture.

4. Incorporate defensive design measures based on the analysis and proven practices.

B. In many instances, an adequate seismic analysis can be determined from the geological study and determination of the general properties of the dam and foundation. Other projects may require more detailed investigations and analyses. Decisions as to seismic safety and risk should be made as the analysis progresses and the extent of further investigations required after each step should be determined following consultation with the State Engineer as necessary.

R655-11-5A. Geological and Seismic Study.

A review of the seismic or earthquake history of the region will be performed to establish the relationship of the site to known faults and epicenters. This will be based primarily on review of existing maps and technical literature and should include major earthquakes during historic time, epicenter locations and magnitudes, and the location of any major or regional fault traces. Geologic conditions at or near the dam site that might indicate recent fault or seismic activity should be included. Resulting design earthquakes and associated site ground motion parameters will be selected considering all available evidence including tectonic and seismological history. The ground motion parameters to be selected for the site will consist of those that are needed by the analyses that are appropriately selected for design and may include peak accelerations, velocities, displacements, response spectra, and acceleration time histories. Both the Maximum Credible Earthquake (MCE) and the Operating Basis Earthquake (OBE) will need to be investigated for all projects. The MCE should be evaluated using both deterministic and probabilistic methods.

1. A deterministic analysis from active faults in the region surrounding the dam will be performed to estimate magnitude and ground motion parameters. High and moderate hazard dams will be evaluated using ground motion parameters that are at least equal to mean plus 1 standard deviation predictions (84th percentile). At the discretion of the State Engineer, these values may be reduced to mean (50th percentile) for moderate hazard dams. Low hazard dams will be evaluated using ground motion parameters that are at least equal to mean (50th percentile) predictions. Evaluation of the impacts on the dam from more than one source, including the potential for multi-segment rupture for segmented faults may be necessary.

2. A probabilistic analysis will be performed. The most recent United States Geological Survey (USGS) Interactive Deaggregation tool found on the USGS website, using a 5,000 year return interval, can be used to identify magnitude and ground motion parameters for high and moderate hazard dams. At the discretion of the State Engineer, a 2,500 year return interval can be used for moderate hazard dams. A 1,000 year return interval can be used for low hazard dams. Site specific evaluations may be performed to define ground motions for these events if the methods used and assumptions made are acceptable to the State Engineer. Unless waived by the State Engineer, the minimum earthquake magnitude shall be 6.5.

3. The OBE will be determined by probabilistic methods acceptable to the State Engineer and may include the use of the Deaggregation tool on the USGS website with a 200 year return interval. An OBE evaluation is not necessary for a low hazard dam.

4. Regardless of the assigned hazard rating, the seismic design parameters for flood control dams may be reduced at the discretion of the State Engineer, in consideration of unique operating conditions.

R655-11-5B. Determination of Dam and Foundation Material Properties.

Results of the geological and seismological studies may be sufficient to evaluate seismic safety. However, if it appears the dam cannot safely withstand the earthquake motions or if sufficient information is not available to make an adequate determination, the next step of a phased evaluation program would be a field investigation and laboratory testing program. Field investigation should include a sufficient number of borings and test pits to accurately define the embankment, foundation, and abutment materials types, properties, and extent. Particular care and sufficient field data should be obtained where potentially liquefiable soils are present. In place and laboratory testing should be performed to adequately assess the material properties under the anticipated dynamic conditions.

R655-11-5C. Method of Analysis.

A. Procedures are available for selecting design earthquakes and associated site-specific motions and for assessing the resistance of dams to these earthquake motions. Procedures and techniques for evaluating the effects on dams from estimated earthquake ground motions range from simplified concepts to comprehensive dynamic analyses. When the degree of sophistication of analytical procedures is far advanced, however, uncertainty is produced in the results by imperfect knowledge of input parameters obtained through field exploration and laboratory testing programs.

B. The extent or scope of studies, investigations, tests and analyses which may be required to adequately determine the seismic safety of a dam will vary from site to site. In general, the following physical factors will indicate a high priority and a greater degree of investigations and analysis:

1. Proximity to known active faults.
2. Indications of low-density materials in the dam or foundation.
3. Zones of high pore pressures or potential liquefaction.
4. Indications of marginal static stability.
5. Lack of adequate construction records for existing dams.

C. Regardless of these factors, however, one of the major considerations will be the "consequences of a failure". High and moderate hazard structures with permanent pools which could result in loss of life or extensive property damage from a failure will, in general, require a greater scope of investigation and analyses.

D. Following are the general analysis requirements, unless otherwise stipulated by the State Engineer, for MCE design earthquakes:

1. Embankments, foundations, and abutments not subject to liquefaction or significant strength loss:

a. For a maximum acceleration of 0.2g or less, or a maximum acceleration of .35g or less if the embankment consists of clay on a clay or bedrock foundation, a pseudo-static coefficient which is at least 50 percent of the maximum peak bedrock acceleration at the site should be used in the stability analysis. The minimum factor of safety in an analysis should be 1.0.

b. For a maximum peak acceleration greater than indicated above, a deformation and settlement analysis should be performed to estimate anticipated total crest movement. The evaluation should consider the potential for excess pore pressure generation and be performed for both the upstream and downstream slopes of the dam. Total crest movement should consider settlement and potential accumulation of movement from both sides. The minimum factor of safety against overtopping should be 2.0.

2. Embankment, foundation, or abutment soils subject to liquefaction or significant strength loss:

a. A liquefaction/strength loss analysis should be completed with enough detail to establish the boundaries of the liquefiable/strength loss soils and the physical characteristics of the soil during and immediately following the design earthquake.

b. A post earthquake stability analysis should be performed to show that the embankment is stable after liquefaction/strength loss occurs with a minimum factor of safety of 1.2. The potential for excess pore pressure generation will be considered.

c. Calculated deformation and settlement of the embankment total crest movement should result in a minimum factor of safety, against overtopping, of 3.0. Analyses will consider liquefaction/strength loss and the potential for excess pore pressure generation.

3. Other more sophisticated analytical procedures may be required at the discretion of the State Engineer, where conditions warrant greater detailed studies.

E. In addition to analysis of deformation and liquefaction, it will be necessary to assess the potential for internal erosion and cracking. Judgment must be used to decide whether or not erosion would tend to be self-healing as a result of filtering.

F. Construction of dams on active faults will not be allowed unless evidence is presented to, and approved by, the State Engineer that the dam can safely withstand the anticipated offset.

G. Evaluation of a dam under OBE conditions should be completed by similar methods to those described for the MCE. Under the OBE loading conditions the dam should experience no significant damage.

R655-11-5D. Design Measures.

Design of new dams should include measures, which provide multiple lines of defense, that enhance their performance under seismic loading. Measures may include:

1. Significantly wide transition and drainage zones in the embankment of material not vulnerable to cracking.
2. Controlled compaction of embankment zones to enhance dynamic performance.
3. Removal or treatment of foundation materials of low strength or density.
4. Enhanced ability to drain reservoir.
5. Flare the embankment core at abutment contacts.
6. Locate the core to minimize saturation of materials.
7. Stabilize slopes around the reservoir rim.

R655-11-5E. Appurtenant Structures.

The effects of seismic loading should also be considered during the design of all appurtenant structures.

R655-11-6. Embankment Requirements.

All embankment designs should meet the following criteria.

R655-11-6A. Factors of Safety.

A. All dams should meet the following criteria for factors of safety under normal loading conditions.

TABLE

Condition	Minimum Factor of Safety
End of Construction Case--upstream and downstream slopes	1.3
Steady State Seepage--upstream and downstream slopes (full pool)	1.5
Instantaneous Drawdown--upstream slope	1.2
OR	
Actual Drawdown--upstream slope	1.5

B. All factors of safety should be generated by methodology acceptable to the State Engineer. In undertaking the analysis, the effects of anisotropy should be considered and a ratio of horizontal to vertical permeability of at least nine should be used in the seepage analysis, unless otherwise justified to the satisfaction of the State Engineer. Ratios of up to 100 should be considered if the material types and construction techniques will cause excessive stratification.

C. The strengths used in the stability analysis should be obtained from tests which best model the situation being analyzed.

D. The analysis of the upstream slope stability for actual drawdown should consider drawdown rates which the low level outlets are capable of generating. Actual residual pore pressures should be used.

E. For low hazard dams the State Engineer may waive the requirements of a stability analysis, including a seismic analysis, if it can be demonstrated that conservative slopes and competent materials are used in the dam, and seismic problems (i.e., liquefiable materials, active faults close to the dam) are not present.

R655-11-6B. Dam Crest Requirements.

A. The crest width of all dams should be, at a minimum, equal to the structural height of the dam divided by five plus five feet. The absolute minimum required shall be 12 feet and the absolute maximum required shall be 25 feet. Wider crest widths may be used at the designer's discretion.

B. All dams shall have a cross slope on the crest of 2% to 3% towards the reservoir.

C. All crests shall be protected with a wearing surface of granular material to prevent vehicular rutting.

D. Dam crests should be cambered to allow for anticipated settlement. The side slopes of the dam may be steepened to accommodate the camber.

E. For dams over 500 feet long which have a crest that dead ends, a turn-around should be provided at the abutment.

F. The impervious portion of the dam under the crest may need to be terminated at the anticipated frost line to prevent desiccation cracking and damage from frost; however, it needs to be carried high enough to prevent seepage over the core by capillary rise.

R655-11-6C. External Erosion Control.

A. All downstream slopes of dams should be protected from erosion by placing armor or seeding with grasses. No planting of any shrubs, trees, or other woody vegetation will be allowed unless it is approved in writing by the State Engineer.

B. All downstream groins of dams receiving runoff from adjacent abutments shall be protected from erosion.

C. All upstream slopes on dams which impound water for significant lengths of time shall be armored. If rock riprap is used it shall be well graded, durable, and sized to withstand wave action. If the material underlying the riprap is fine grained and subject to erosion, a properly designed filter blanket must be installed. Geotextiles may be used in lieu of the filter blanket at the discretion of the State Engineer.

R655-11-6D. Internal Erosion Control.

A. All dams should have design provisions for controlling internal erosion. In zoned dams all adjacent zones must meet filter criteria with the abutting zones and foundation soils. If filter criteria cannot be met, a transition zone must be provided.

B. All filter and drainage zones in a dam must meet criteria acceptable to the State Engineer.

C. In designing filter zones where dispersive clays or broadly-graded materials exist, special considerations may be imposed by the State Engineer.

D. All chimney filter and drainage zones will have a minimum width of three feet per zone unless waived by the State Engineer. Wider zones are encouraged. Chimney drains may be vertical or inclined, but inclined drains may require additional width. In active seismic areas filter widths must be at least twice the predicted lateral deformation resulting from an earthquake.

E. Proper filtering and drainage is essential in all dams where cracking from differential settlement, hydraulic fracturing, or earthquake shaking is possible. Chimney, blanket, and toe drains are considered to be standard design measures. Justification must be provided if these features are not included in the design. Other filter and drainage features may also be appropriate.

R655-11-6E. Internal Drainage.

A. All underdrains and collection pipes shall be constructed using non-corrodible materials capable of withstanding the anticipated loads.

B. Underdrains and collection pipes should be designed to conduct flows several times larger than anticipated. All pipes within the dam which are not easily accessible shall have a minimum diameter of six inches.

C. All internal drain pipes should be enveloped with free draining material, meeting filter requirements with adjacent zones.

D. Where multiple pipes are used to conduct drainage from internal portions of the dam, they should be carried to the downstream toe or gallery separately without intervening connections or manifold systems. If the drain pipes are connected at their termination points, manholes should be provided to facilitate observation and measurement of the separate drain lines.

E. All underdrains and collection pipes should have provisions for measuring discharges in manholes or at their discharge points. If the anticipated discharge is in excess of 10 gallons per minute (gpm), a weir or other suitable measuring device should be provided. If the anticipated flows are less than 10 gpm, provisions should be made so the water can be discharged freely into a vessel 1.5 feet high and one foot in diameter.

F. All exposed underdrain and collection pipes shall have an appropriate rodent screen attached.

G. All underdrains and collection pipes shall be cleaned out and inspected by camera prior to the first filling of the reservoir.

H. All seepage collection systems must include a collection pipe to discharge flows.

I. All internal drains must have a sufficient cover of impermeable material to eliminate the collection of surface waters.

R655-11-7. Outlet Requirements.

All outlet designs should meet the following criteria.

R655-11-7A. Outlet Sizing.

A. All dams shall have a low level outlet capable of draining the reservoir. Exemptions to this requirement may be granted at the discretion of the State Engineer. Normally, exemptions will only be considered for low head, low hazard dams. Any dead storage must be approved by the State Engineer and must be sufficiently low to eliminate any storage hazard. The outlet should be sized to meet the project demands as well as the following criteria.

1. All outlets shall be 24 inches in diameter or larger unless exempted in writing by the State Engineer. Outlets should have valves or capped flanges which can facilitate entry into the pipe by personnel or video equipment.

2. All outlets shall have the capacity to evacuate 90% of the active storage capacity of the reservoir within 30 days neglecting reservoir inflows. The State Engineer may adjust this requirement on large reservoirs if it can be demonstrated that compliance would result in an unreasonably sized outlet or potential releases would exceed the downstream channel carrying capacity.

3. All outlets shall have the capacity to satisfy prior downstream water rights and the owners' release requirements.

R655-11-7B. Outlet Materials.

All outlets will be made of appropriate materials with due regard for loading condition, seismic forces, thermal expansion, resistance to corrosion, and potential abrasion. The use of corrugated metal pipes and other thin-walled steel pipes will not be accepted unless they serve only to provide a form for a poured-in-place concrete conduit or they are specifically accepted in writing by the State Engineer.

R655-11-7C. Outlet Details.

A. All outlets shall have a trash rack to prevent clogging.

B. All outlets connected directly to a downstream pipeline shall have an emergency bypass valve.

C. All outlets shall have a suitable energy dissipater at the discharge end to prevent erosion of the downstream channel.

D. All outlets will be placed on a concrete cradle or encased in concrete unless specifically exempted by the State Engineer in writing. All conduits made of plastic materials will be fully encased. The sequencing and construction methods for secure placement of the conduit to prevent movement during pressure testing and concrete placement must be included in the design documents.

E. All outlets, with the exception of ungated outlets, shall have an operating gate or a guard gate on the upstream end.

F. All outlets shall have seepage control measures to reduce the potential for piping along the conduit. Common methods may include locating the outlet conduit in bedrock and installing a conduit filter drain to intercept seepage. Where possible, the outlet should penetrate the chimney drain so it acts as the conduit filter drain. Where an individual filter drain is used, it must have sufficient lateral extent to also protect against localized embankment cracking as well as seepage along the conduit. The use of cutoff collars is not an approved method.

G. Outlets encased or cradled in concrete should have battered sides to facilitate compaction against the concrete, unless approval is given by the State Engineer to place the conduit in a trench.

H. Every attempt should be made to locate the outlet on bedrock or consolidated materials. In the event this is not possible, consideration should be given to articulating the outlet to allow for settlement.

I. Outlet gates and valves can be either mechanically or hydraulically operated. In either case the hydraulic lines or mechanical stems must be adequately protected from debris, wave action, settlement, and ice damage. Buried stems should be encased in an oil-filled pipe supported on pedestals. No catwalks or similar access structures will be allowed on reservoirs where freezing occurs or significant floating debris is present. All outlets which are operated with motorized equipment must have back-up capability or a manual bypass system capable of being operated in a reasonable amount of time.

J. All outlets shall be properly vented. A vent pipe and air manifold around the perimeter of the conduit immediately downstream of the gate will be required unless waived by the State Engineer. The air supply lines should be conservatively sized for the anticipated flows and protected in the same manner as the outlet control lines or stems.

K. All operators and supporting equipment for outlet controls should be properly protected and secured. Particular attention needs to be given to protection from vandals and unauthorized operation. All outlet controls should be clearly marked as to which way the gates and valves operate so that overloading of a closed gate or valve should not occur.

L. Outlet controls should be accessible when the spillways are in use.

R655-11-8. Spillway Requirements.

A. On all spillway control structures, provisions should be made for aeration of the nappe.

B. All spillways excavated in soils or soft rock should include a check structure to avoid headcutting and lowering of the spillway flowline.

C. All spillway channels should have suitable armor to prevent erosion.

D. If the spillway has concrete sidewalls, adequate weepholes should be provided or the walls should be designed with full hydrostatic loads in conjunction with the soil loads.

E. For spillways in remote areas where significant snowfall occurs, efforts should be made to maximize the southern exposure of the spillway to prevent ice blockage. In many cases elimination of tall trees will be required.

F. All construction joints should be provided with adequate water stops.

G. Design provisions should be made so that downstream spillway channel flows cannot encroach on the dam.

H. All spillways draining reservoirs with large amounts of floating debris should include a log boom to avoid plugging the spillway.

I. Spillway designs should provide for energy dissipation so that waters returned to the natural channel will not cause erosion.

J. For spillways with concrete floors, provisions should be made to control uplift pressures.

K. Stop logs or flashboards which restrict the design spillway capacity will not be allowed.

R655-11-9. Other Design Requirements.

A. To facilitate inspection, all dams shall have a zone 25 feet beyond all contacts at the downstream groins and toe of the dam in which all woody vegetation is to be removed.

B. If the dam is located in an area where grazing occurs, then livestock must be restricted from the dam by suitable fencing.

C. Unless the dam crest serves as a public road, a suitable gate or other barrier should be installed to prohibit traffic.

D. Geosynthetics may not be used in a dam as the primary design feature unless specifically approved, in writing, by the State Engineer.

E. The foundation downstream of a dam should be graded to convey seepage waters and runoff away from the dam.

F. All control houses and other structures housing instrumentation and operating devices should be designed to discourage unauthorized entry and damage from vandalism.

G. If burrowing animal activity is anticipated to be excessive, design consideration should be made to prohibit their entry, or place materials as a shell which are not capable of sustaining a rodent hole.

R655-11-10. Instrumentation.

Instrumentation on a dam serves the purposes of comparing actual performance with predicted performance and to observe the long term performance for unexpected changes, indicating a safety problem. Since each dam site and design varies, considerable judgment is needed in developing an instrumentation plan. The State Engineer may require any instrumentation necessary to adequately monitor a dam to insure its safety. Where instrumentation is required threshold values should be established for field personnel. Readings which exceed threshold values will indicate that the design criteria has been exceeded and the stability analysis should be reevaluated. Some minimal instrumentation will be required on dams as outlined in the following paragraphs.

R655-11-10A. Reservoir Staff Gages.

All dams shall have a suitable staff gage to monitor reservoir levels. Staff gages should be designed to be durable and capable of resisting movement, water forces and ice. All gages shall have permanent markings at a minimum of one foot intervals with actual elevations recorded at five foot intervals. The State Engineer may allow the use of other measuring devices if it can be demonstrated that they are reliable and accurate.

R655-11-10B. Survey Markers and Bench Marks.

All moderate and high hazard dams shall have permanent survey markers on the crest of the dam to monitor vertical and horizontal movement. The survey markers should be located to prevent damage from traffic. In conjunction with the survey markers a permanent bench mark shall be installed on each abutment, sufficiently removed from the dam so any effects of the dam movement will not be felt at the bench mark. Reference markers should be established so the bench mark can be reset in the event of damage. Spacing of survey markers should not exceed 200 feet and spacing should be decreased as the height of the dam increases.

R655-11-10C. Piezometers.

A. All high hazard dams as well as moderate hazard dams, at the State Engineer's discretion, shall include piezometers. As a minimum, piezometers should be installed along two cross sections of the dam, one of which should be at or near the maximum section. Each cross section should include piezometers at critical locations in the embankment and foundation. It is preferable to have only one piezometer in each hole; however, more than one piezometer may be installed in each hole if the intervening zone between the piezometer tips can be adequately sealed.

B. All piezometers should have a surface casing projecting beyond the ground with the surface casing adequately sealed. The surface casing should include a locking cap to prevent unauthorized access.

C. All piezometer holes should be logged during drilling and any pertinent information included on the as-constructed plans. As-built locations, designations and elevations of the top, bottom, and porous interval of the piezometers should be shown on the as-constructed plans.

R655-11-10D. Seepage Measurements.

Seepage measurements for all drains and collection pipes should be provided, as outlined in R655-11-6E, for all high and moderate hazard dams. Any significant seepage areas which develop must be provided with measuring devices and at the discretion of the State Engineer, must be collected in a filtered drainage system.

R655-11-10E. Strong Motion Instruments.

The State Engineer may require strong-motion instrumentation in seismic zones 2 and 3.

R655-11-11. Abandonment of Dams.

Abandonment of all dams requires approval by the State Engineer.

R655-11-11A. Removal of Dam.

If it is proposed to totally remove a dam, the main concern is to return the stream and reservoir basin to their pre-dam condition. Plans should be submitted showing how the original channel is to be reclaimed, how deposited silts are to be controlled, and what methods will be used to revegetate the reservoir basin and riparian areas.

R655-11-11B. Breaching of Dam.

If a dam is to be breached the following minimum criteria should be met:

1. The flowline of the breach should be excavated down to natural ground or stabilized at the top of the silt level. In most cases grade control and drop structures will be required to avoid mobilization of reservoir silts and debris.

2. The breach should be designed to pass a flood with a return interval of 100 years without backing water up in the historic reservoir more than five feet.

3. Regardless of hydraulic requirements the bottom width of the breach will be one half the structural height of the dam with an absolute minimum of 10 feet. Additional width may be required by the State Engineer in areas where beaver activity occurs.

4. Breach side slopes must be flat enough to hold the slope when saturated, with an absolute minimum of one vertical on one horizontal. In areas where there is significant human travel, the minimum side slopes should be one vertical on two horizontal.

5. The exposed banks and bottom of the breach should be protected with riprap, vegetation, or other suitable means to prevent downcutting and lateral slope erosion.

6. Barriers should be placed on the original dam crest to warn any possible traffic on the crest of the breach.

R655-11-12. Construction.

The State Engineer will monitor construction of approved projects as outlined in the following paragraphs.

R655-11-12A. Informal Construction Inspections.

During the course of constructing, enlarging, repairing, or removing a dam, the State Engineer may make periodic inspections to determine compliance with plans and specifications, as well as to observe field conditions to see if actual conditions are consistent with those used during design. Any problems observed will be pointed out to the resident inspector or engineer for correction or change. All significant problems noted will be outlined in a letter to the owner and the owner's engineer. The engineer must respond in writing to the State Engineer as to what steps were undertaken to correct the problems.

R655-11-12B. Formal Construction Inspections.

In approving plans the State Engineer may require his approval of certain construction operations before the next phase of construction can commence. The owner's engineer or inspector must notify the State Engineer and determine a mutually acceptable time to observe and approve the work prior to continuation of the construction.

R655-11-12C. Construction Reporting Requirements.

Written documentation of all construction activities should be maintained by the owner's engineer. The documentation must be submitted weekly to the State Engineer by the owner's engineer when any work is underway. At a minimum the documentation should include:

1. All materials certifications submitted by suppliers to insure compliance with specifications.
2. Results of all material tests or any other testing undertaken during construction. Any tests not meeting the requirements of the plans must include notations indicating what was done to correct the sub-standard work.
3. All engineers' and inspectors' diaries, field notes, or other written documentation.
4. Photographs to clarify work completed or problems noted.
5. All geological logs of foundation excavations.

R655-11-12D. Change Order Approvals.

All change orders revising the plans that involve technical changes must be approved by the State Engineer. Since the State Engineer is not a party to the construction contract, change orders involving strictly payment to the contractor do not need to be approved by the State Engineer.

R655-11-12E. Final Inspection.

Before any dam can be placed in operation a final inspection of the project must be undertaken by the State Engineer and his written acceptance of the project received. The Emergency Action Plan, Standard Operating Plan, and Initial Filling Plan, if required, must be completed and approved before final acceptance and authorization for filling can be given. During rehabilitation of existing dams, at the discretion of the State Engineer, some reservoir storage may be allowed provided sufficient safety criteria are adopted. Record drawings of the project must be submitted within 60 days of the date of the final inspection. All record drawings submitted must be on a high quality reproducible medium or electronic format acceptable to the State Engineer. Record drawings shall reflect design changes made during construction, geological logs of the foundation excavation, and piezometer borings.

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