DAM SAFETY

POLICY MEMORANDUM #15

TO: Dam Owners, Operators, and Engineers

FROM: Stormwater, Dam Safety, and Flood Management Program
Water and Science Administration

DATE: June 1, 2023

SUBJECT: Best Practices for Dam and Small Pond Construction

Policy Statement

It is the policy of the Maryland Department of the Environment (the Department) that proper construction methods and oversight are critical to ensure the long-term performance and safety of dams and their appurtenant works. This policy memorandum provides examples of recommended construction and inspection practices based on the Departments experience and local and national best practices. It is not intended to be comprehensive of all construction methods and practices. Dam owners and engineers should incorporate the recommendations contained in this document into project specifications. Construction inspectors should review this document to ensure familiarity with construction inspection best practices.

Additional Information

Questions about this policy or other items relating to ponds and dams can be directed to the Chief of the Dam Safety Permits Division at 410-537-3552.

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Role of the Engineer in Charge

Even the best designed dam can fail if not properly constructed, therefore it is imperative that a senior member of the design team with experience in both dam design and construction regularly inspects the construction activities to ensure that the plans and specifications are being followed, to review conditions for potential changes from the design assumptions, and to confirm that the design intent is consistent with the construction. This senior-level, qualified professional engineer is referred to as the Engineer-in-Charge (EIC). The designation of an EIC is required when a permit to construct, repair or alter a dam is sought from the Dam Safety Division, and is strongly encouraged for all projects.

Dams are complex structures that require design contributions from multiple engineering disciplines, including structural, geotechnical, hydrology and hydraulics. Accordingly, the EIC may represent the discipline that played the largest role in the design process, or may lead a team representing various disciplines.

This policy memorandum is intended to provide general recommendations for best practices for the contractor, the EIC, their qualified representative, and third-party inspection/testing firms that are tasked with inspecting the construction of the dam. The policy includes examples of what documents may be needed to perform adequate inspections and details of what record-keeping and documentation should be performed.

Dam owners should work closely with the EIC during construction to ensure their active participation in reviewing submittals, attendance at construction progress meetings, and review of material delivery tickets or test results. Where inspection or testing is performed by a third-party firm, the documentation of the inspection should be submitted to the owner and EIC in a timely manner. The EIC should review the submissions promptly and inform the owner of necessary corrections or changes as needed.

Where construction at a dam requires a permit from the Departments Dam Safety Division, the EIC must submit their qualifications and a signed affidavit attesting to their experience prior to the issuance of a permit.

Approved Plans and Specifications

Recommended Practices

- Any deviation from the approved plans for any reason must be approved by the EIC and the permitting/approval authority before proceeding with those deviations from the approved plans.

Examples of Documentation to Review

- Obtain and become familiar with the approved drawings (full-size set), as well as the project specifications, permits, approval letters and similar documents prior to the start of construction.

Reporting and Record Keeping

- N/A

Construction Stakeout / Surveys

Recommended Practices

- To ensure that the work is constructed in accordance with the plans and specifications, the contractor should ensure that a licensed surveyor accurately locates all structures and alignments horizontally and vertically.
- All alignments should be marked with a maximum spacing of no more than 100 feet using stakes, nails or other durable materials. Closer increments may be necessary for certain elements of the construction.
- During the course of the work, the licensed surveyor may need to maintain or remark alignments (e.g., as embankment fill is placed) to ensure that the EIC, their representative, or third-party testing firms can accurately record the station and elevation of important work items (e.g., compaction tests, filters) within +/- 1-foot horizontal accuracy and +/-0.25-foot vertical accuracy.
- An as-built survey of the completed surface and subsurface is required and must include but is not limited to: horizontal dimensions, grading limits, elevations, slopes, types/length/height of features not able to be surveyed after project completion. Documentation of this survey including red-line plans, notes, dimensions, etc. must be provided upon completion of the project.

Examples of Documentation to Review

- N/A

Reporting and Record Keeping

- N/A

Clearing and Grubbing

Recommended Practices

- In the area of a dam embankment, all embedded stumps, roots, and debris must be completely removed on the embankment or beneath the embankment subgrade. Depressions made below the subgrade or embankment surfaces by removal of stumps must be refilled with materials suitable for dam embankment construction, and compacted per requirements in these specifications. Refer to the Dam Safety Policy Memorandum 1: Maintenance and Repair: Trees and Woody Vegetation.

- Inspect the limits of clearing within 15 feet of the dam's embankment or appurtenant structures and within 25 feet of the spillway structures.

Examples of Documentation to Review

- N/A

Reporting and Record Keeping

- Field Reports should document the extents of the area that was cleared and grubbed, the location, depth, and description of any large obstructions (e.g., root balls) or soft/wet areas, and should describe the treatment of obstructions/unsuitable areas. Include photographic documentation.

Subgrade Preparation – Soil Foundations

Recommended Practices

- Subgrade for conduit and structures must be inspected and approved by the EIC, their representative, or a third-party testing firm. For structure foundations, the bearing capacity of the subgrade should be confirmed using a dynamic cone penetration (DCP) test per ASTM D6951 (or other method as approved) to ensure it equals or exceeds the design bearing capacity assumption.
- Old stream channels and pockets of sand or gravel should be excavated and backfilled with compacted fill.
- Upon reaching the foundation subgrade elevation of the dam, the site should be proof-rolled under direction of the EIC or the representative of a third-party testing firm. Any soft or excessively wet areas should be undercut and backfilled with compacted soil, flowable fill or concrete. The use of thick "bridge lifts" in areas with poor subgrade conditions is not acceptable.

Examples of Documentation to Review

- Project Geotechnical Reports or Memoranda

Reporting and Record Keeping

- The EIC, their representative, or a third-party testing firm should issue written reports concerning subgrade preparation noting the following:
    - Date of inspection.
    - Subgrade preparation intent (e.g. for structure, for conduit, etc.).
    - Approximate location (base line station, offset, and bottom elevation) of the subgrade preparation.
    - Area of the subgrade preparation.
    - Visual observations of the subgrade including ground surface condition, any cleaning, deleterious material removal, and/or surface preparation completed, measured bearing capacity, etc.
    - Modifications to the subgrade made by the contractor as a result of findings (e.g. "recompact", "pour mudmat" (with details of thickness and material used), etc.).
    - Photos of the subgrade.

- Written reports should be submitted to the project team, and where required, the Dam Safety Division, on a regular basis, typically no less than once per week.

Subgrade Preparation – Rock Foundations

Recommended Practices

- Rock foundations should be carefully prepared and cleaned once excavation of the overburden is complete. Loose rock, overhangs and sharp transitions should be removed. Cracks, joints and discontinuities in the rock should be cleaned then filled by placing dental concrete or slush grout. Dental concrete is used to fill irregularities in the foundation surface due to joints, bedding, sheared zones, overhangs, or excavated surfaces following a thorough removal of all soft and loose material and cleaning. Slush Grout is a neat cement grout or a sand-cement slurry that is applied to cracks in the foundation. Slush grout should be used to fill only narrow surface cracks.
- Rock surfaces should be cleaned by air-water cutting, water jetting, wire brush scrubbing, or other suitable methods determined necessary to obtain an acceptable surface. No dental concrete or slush grout should be applied until rock surfaces have been inspected and approved by the EIC or their representative. Rock surfaces must be maintained free of standing or running water during the placement of surface treatment material.
- Dental concrete should have a minimum 28-day strength of 3,000 p.s.i.
- Slush grout aggregate should have a maximum particle size no larger than one-third of the smallest crack width.
- Aggregates should conform to the requirements of ASTM C33.
- Hot weather and cold weather concreting accommodations must be made in accordance with ACI 305 and ACI 306 respectively.
- Concrete must be conveyed by methods that prevent segregation of the aggregates, loss of mortar, or both. Concrete must not be allowed to free-fall more than four (4) feet unless suitable equipment is used to prevent segregation.
- Dental concrete shall be placed a minimum of six (6) inches in thickness. Feathering at the ends of slabs is not permitted – a beveled edge with minimum thickness of six (6) inches shall be provided at the top of the fillet when placing dental concrete against vertical or near-vertical surfaces. Edges of slabs shall be sloped no flatter than 45 degrees. When formed, dental concrete shall not be placed at slopes greater than 0.5 horizontal to 1 vertical.
- Concrete shall be filled against any specified remaining rock surfaces that exceed the slope limitations and shall be shaped so that no part of the finished surface exceeds these limitations. The upper surface of overhangs shall be cleaned thoroughly and shaped to allow air to escape during concrete placement to ensure a strong bond between the rock and the concrete.
- Slush grout can be applied by brooming over the surfaces containing closely-spaced cracks or by troweling, pouring, rodding, or funneling into individual cracks.
- Material placed in cracks, fissures, and solution channels must be consolidated by vibration, spading, or tamping as necessary to assure complete filling of the void.
- Proper concrete curing practices are required. Embankment fill should not be placed over the dental concrete or slush grout for at least 72 hours to ensure the material is set and sufficient strength has been gained.

Examples of Documentation to Review

- Mix Design: Contractor should submit mix designs for all dental concrete and slush grout to the EIC and obtain approval of said mix designs prior to their use. The mix design submittal should include:

    - Date of Mix Design Analysis
    - Design proportions of component materials by weight per unit of material
    - Design unit weights of component materials
    - Specific gravity of component materials
    - Absolute volume of component materials
    - Theoretical unit weight of material
    - Design strength of material
    - Slump of material
    - Water to Cement Ratio of Material
    - Air Content of Material
    - Sources/Suppliers of each of the component materials
    - Specification sheets for all component materials
    - Certification of the mix design by an accredited laboratory

Reporting and Record Keeping

- All rock subgrade preparation must be documented thoroughly and transmitted to the project team on a regular basis. The subgrade preparation documentation should include, at a minimum the following:

    - Date of Inspection
    - Weather
    - Surface Treatments Applied
    - Type of treatment
    - Station, Offset, and Elevation of treatment
    - Approximate area of treatment
    - Photos of treatment

    The dental concrete and slush grout should be sampled for quality control purposes as described in the “Concrete” section of this policy.

Earthwork

Recommended Practices

- The EIC must be contacted, and work in that area must be stopped, if unsuitable bearing materials or unanticipated subsurface conditions are encountered at required subgrade elevations during excavation.
- Sheeting, shoring, and bracing is not permitted for excavations in dam embankments unless approved by MDE. The embankment must be excavated to safe, stable slopes of two (2) horizontal to one (1) vertical (2H:1V), or flatter using a sawtooth/stair-step style excavation. No vertical trenching should be allowed. All conduits penetrating through the dam's embankment must be installed during construction/re-construction of the embankment. Conduits may not be installed in vertical trenches after the embankment has been constructed.
- Excavation for structures must conform to elevations and dimensions shown on the plans within a tolerance of plus or minus 0.1 foot. Excavations should extend at least 36 inches from the edge of footings, cradles for spillway conduits, and foundations to permit placing and removal of concrete formwork and to provide adequate space to properly compact backfill.
- Make every attempt to avoid disturbing the bottom of excavation. This may require excavation by hand to final grade or use of a smooth-edged bucket.
- Where excavations encounter structures to be abandoned as part of the work, the structure must be removed in its entirety.
- Excavations should not be backfilled prior to the EIC, their representative or the third-party testing firm has approved the subgrade.
- The use of explosives is prohibited unless authorized in writing by MDE.
- Compaction of embankment materials should be performed using smooth drum vibratory rollers on clean sands and gravels only. Use padfoot or sheepsfoot type rollers for all soils with a significant percentage of fines such as clays, silts, and silty/clayey sands. Use hand tampers to compact soil adjacent to structures.
- The adequate compaction and moisture content of all soil materials must be confirmed with soil density testing using a nuclear density gauge (ASTM 6938) or sand cone (ASTM D1556). Test frequency must be a minimum of one (1) per 5,000 square feet but not less than one (1) per lift of material. Cutoff trench compaction must be tested a minimum of one (1) per 50 linear feet of trench but not less than one (1) per lift of material.
- Verification of the in-place moisture content as determined using the nuclear density gauge should occasionally be checked by over-drying a representative sample. This is particularly important in very micaceous soils where natural carbon content in the soil minerals may bias the nuclear density gage readings. At a minimum, an oven-dry moisture content should be compared to gage readings for each new soil used for construction.
- Proper care of material to be used as dam embankment and/or impervious material is necessary, including protection against contamination, moisture and other undesirable effects.

- Coarse-grained materials used for the embankment shell must be classified in accordance with Unified Soil Classification System (USCS) Soil Types GC, GM, SC or SM, and the maximum dry density must be not less than 110 pcf as determined by ASTM D698.
- Fine-grained materials used for the embankment shell must be classified in accordance with USCS Soil Types, CL, or ML and the maximum dry density must be not less than 105 pcf as determined by ASTM D698.
- Materials used for the impervious core, cutoff trench or liner must be classified in accordance with USCS Soil Types GC, SC, CH, or CL and must have a minimum of 30% passing the #200 sieve. The material must have a maximum dry density not less than 105 pcf as determined by ASTM D698.
- All satisfactory soil materials must be free of rock or gravel larger than two (2) inches in any dimension, debris, waste/rubbish, frozen materials, organic, and other objectionable materials. A larger maximum particle dimension may be acceptable in some larger embankments.
- Prior to the first use of a material, the material must be tested by an accredited laboratory and the EIC should approve each material as acceptable for use in construction. Where material tests are provided by the quarry/borrow source, the tests should be performed on the material intended to be used for construction, and should not be older than 30-days from the anticipated date of delivery. A new set of tests is required whenever the material changes, even if from the same source. The material submittal should include the following:

    - Sample ID (note: if multiple submittals are provided from the same borrow site, each submittal must have a unique location ID and this ID must be provided on the delivery ticket so the appropriate Proctor analysis can be used during compaction testing).
    - Particle Size Distribution Report per ASTM D421/D422.
    - Atterberg Limits analysis including values for Liquid Limit, Plastic Limit, Plasticity Index per ASTM D4318 and USCS Classification per ASTM D2487
        - Proctor Analysis per ASTM D698 or AASHTO T-99 noting:
        - Maximum Dry Density (MDD)
        - Optimum Moisture Content (OMC)
        - Natural Moisture Content (NMC)
- All fill material must be inspected by the EIC, their representative, or a third-party testing firm prior to placement for consistency with the approved submittal.
- Fill materials must be placed in horizontal lifts not to exceed four (4) inches (loose thickness) around pipes or structures and eight (8) inches (loose thickness) for embankment and other fills. Lifts should be continuous and horizontal over the entire length of fill.
- Compaction of fill materials must be to 95% of the laboratory maximum dry density as determined by ASTM D-698 or AASHTO method T-99 (Standard Proctor) with moisture content between -2% and +4% of laboratory optimum unless otherwise specified. Standard Proctor results in slightly wetter, more flexible, fill that can better settle without formation of cracks.
- Do not cover any material that freezes after being placed in the embankment until it has

thawed and been recompacted.

- When placing and compacting embankment on hillsides or against existing embankments, continuously bench the slopes where the slope is steeper than 4H:1V. Perform the benching operation as the embankment is constructed in layers. Maintain a bench width of at least five (5) feet to ensure adequate width for compaction equipment. Begin each horizontal cut at the intersection of the original ground and the vertical sides of the previous cut. If the material cut from the benches meets embankment requirements, compact this material along with the new embankment material.
- Backfill adjacent to pipes and structures associated with dam must be placed in horizontal layers not to exceed four (4) inches in thickness and compacted by hand tampers. The fill material must fill completely all voids under and adjacent to pipes and structures. The backfill should only be placed once the concrete has achieved at least 80 percent of the specified compressive strength.
- Equipment must not be driven over any part of concrete structure or pipe unless there is compacted fill of 24 inches or more over the structure or pipe.
- Impervious cores must be constructed to the elevation and dimensions noted in the plans. Impervious cutoff trenches must extend to an impervious layer, but must not be less than four (4) feet depth below the embankment fill. The impervious backfill material must be placed in layers not exceeding eight (8) inches for the entire length of the embankment fill. The impervious core material should be placed concurrently with the outer shell of the embankment.

Examples of Documentation to Review

- Project Geotechnical Reports or Memoranda
- Material submittals and lab testing
- US Army Corps of Engineers “General Design and Construction Considerations for Earth and Rock-Fill Dams” EM 1110-2-2300.

Reporting and Record Keeping

- All excavations should be supervised and inspected by the EIC, their representative, or a third-party testing firm. The inspector should issue reports for each excavation on a regular basis (weekly is recommended) to the project team indicating:

    - Date of inspection
    - Excavation intent (e.g. for structure, for conduit, etc.)
    - Approximate location (base line station, offset, and bottom elevation) of the excavation
    - Area of the excavation
    - Visual observations of the excavation including ground surface condition, any cleaning, deleterious material removal, and/or surface preparation completed,
    - Photos of the excavation
    - Sketches of the excavation geometry (horizontal and vertical) noting dimensions, side slopes, and depth

- All filling should be supervised and inspected by the EIC, their representative, or a third-party testing firm. The inspector should issue reports documenting construction on a regular basis (weekly is recommended) to the project team indicating:

    - Verification that the subgrade is acceptable prior to placement of a new lift, including bearing tests as applicable
    - Verification that maximum loose (uncompacted) lift thickness is within accepted ranges
    - Equipment used to compact the lift, and number of passes
    - Description of moisture conditioning performed by the contractor (if any)
    - Compaction Test Results:
        - Test Date
        - Gauge Serial Number
        - Station/Offset Location
        - Elevation
        - Depth of Test (through lift)
        - Wet Density
        - Moisture Count
        - Moisture Content
        - Dry Density
        - Maximum Dry Density (from approved submittal)
        - Optimum Moisture Content (from approved submittal)
        - Percent Compaction Required
        - Percent Compaction Obtained
        - Any relevant remarks (“failure”, “re-test”, etc.) [Note, materials outside of specified moisture content range must be considered as a failed lift, even if the desired percent compaction is achieved]

Internal Drains/Filters

Recommended Practices

- Filters and drains are critical features within the dam, and must be constructed according to specifications. Aggregate size for filters is dependent on the adjacent soils. If a contractor proposes to substitute a different aggregate, the filter must be re-designed.
- Aggregates for filters and drains must be clean and non-calcareous.
- To confirm the filter/drain aggregates meet project specifications, one (1) sieve analysis in accordance with ASTM C136 should be performed for every 500 cubic yards of filter/drain aggregate installed with one (1) test required per "installation" per material. Each drain/filter (e.g., filter diaphragm, chimney drain, toe drain) constitutes a separate "installation".
- Aggregate should be placed in uniform lifts no thicker than eight (8)-inches (measured before compaction).
- Clean sands typically used for filter aggregate cannot be adequately compacted by tamping alone. Accordingly, each lift should be wet thoroughly with potable water prior to compaction. Compaction should occur just after water drops below sand surface.
- Aggregate should be placed to avoid segregation of particle sizes and to ensure continuity and integrity of all zones.
- Care must be taken to prevent contamination of the filter media by adjacent soil lifts, construction debris, or other material. Contaminated areas must be removed and replaced.
- Any damage to the foundation surface or the trench sides or bottom during placement of filter/drain aggregate must be repaired before placement of the sand media continues.
- The upper surface of the filter zone constructed concurrently with adjacent fill zones should be maintained at a minimum elevation of one (1) foot above the upper surface of adjacent fill.
- It is permissible to place up to four (4) feet of dam embankment on top of a lower portion of the filter. The contractor must then excavate down to expose the filter. After removing any unsuitable materials, trench is then filled in eight (8) inch thick layers, flooded and compacted, until the top of adjacent fill is reached.
- Filter diaphragm drain(s) should outlet at the principal spillway outlet and extend a minimum of two (2) inches beyond the end of any support wall.
- Internal drain pipes must be sloped to maintain positive drainage toward the outlet.
- Perforated pipes must be placed with the perforations down and arranged symmetrically about the vertical axis.
- The ends of internal drain pipes must be plugged or fitted with cleanouts as directed in the approved plans.
- Check perforated/slotted pipe to ensure the pipe is the proper schedule and that perforations/slots are appropriately sized and spaced.
- To the extent possible, internal drain pipes should use 22.5 degree elbows or larger radius sweeps to facilitate future video inspection.
- Internal drain pipes should be cleaned and video inspected following backfilling.
- No geotextiles are permitted within dam embankments or drain features unless specifically noted in approved plans.

Examples of Documentation to Review

- Review the filter/drainage aggregate compatibility computations to understand assumptions made in the design process.
- Review the manufacturer's certifications of the filter and drainage aggregate and check to ensure they meet the project specifications.

Reporting and Record Keeping

- All filter and drain construction should be supervised and inspected by the EIC, their representative, or a third-party testing firm. The inspector should issue reports documenting the construction on a regular basis (weekly is recommended) to the project team. The inspection and report should verify that all joints are properly seated, bonded or mechanically attached, and that there is no damage to the installed pipe (prior to backfilling).
- The inspector should confirm the validity of the material delivered to the site both by visual-manual classification of the material and by collecting and reviewing the material ticket for each load of material delivered and confirms that it meets the project specification.

Spillway Conduits

Recommended Practices

- Many pond failures occur along the principal spillway because of the difficulty in compacting soil along a pipe. Exercise care in this process.
- Vertical excavations, including shored excavations, are not acceptable for spillway conduit installation within an embankment or in the foundation. Use of vertical trenches can result in stress differentials within the soil matrix (e.g., arching effects) that can promote settlement, cracking or seepage. Where trenching is necessary to install spillway conduits, excavation side slopes should be two (2) horizontal to one (1) vertical (2H:1V) or flatter.
- The use of gravel or other free-draining bedding material is not acceptable under spillway conduits, risers or outlet structures. Where necessary, a working slab or mud mat (four (4) to six (6) inches thick) of concrete or flowable fill may be used at the bottom excavation. If undercut is necessary due to poor soil conditions, the areas should be backfilled with compacted fill, flowable fill (aka “Controlled Low Strength Material”, per MDOT SHA specifications) or concrete as directed by the design engineer.
- All spillway joints must be watertight to prevent infiltration of embankment soil into the conduit. All joints must be constructed as designed by pipe manufacturer. "Field joints”, where the ends of the pipes are cut off in the field are not acceptable.
- All pipe gaskets must be properly lubricated with the material (vegetable grease or soap) provided or approved by the pipe manufacturer. Use of incorrect lubricant may cause deterioration of gasket material. The gasket should be properly "tensioned". Failure to do this may result in improper joints that are not watertight, or may cause pipe failure.
- All pipe conduits should have a manufacturer’s stamp indicating the size and class of the pipe on each length of pipe conduit installed. Stamps on reinforced concrete pipes should be located on the inside wall of the pipe.
- Reinforced concrete pipe associated with dam embankments and spillways must be watertight and meet ASTM C 361. These pipes must have bell and spigot joints with O-ring rubber gaskets seated in a groove. Alternative joint design (shoulders and “profile gaskets”) should not be installed without prior approval of the design engineer and the owner.
- Corrugated metal pipe (CMP) spillways must meet or exceed the minimum requirements in NRCS MD-378. Check for metal thickness (compare manufacturer’s certification that should accompany pipe shipment with plans), corrugation size, number of re-rolled end corrugations, proper connecting bands, and gasket type. Note that the engineer may specify a heavier gage than MD-378 for increased design life.
- Heavy duty corrugated black polyethylene pipe (HDPE) must meet the requirements of AASHTO M252 Type S for diameters of three inches through 10 inches and AASHTO M294 Type S for diameters of 12 inches through 60 inches. All pipe must have a smooth walled interior.
- DIP Ductile Iron Pipe (DIP) must meet AWWA C150 and C151 and follow special thickness class minimum Class 51 for four (4)-inch through 54-inch diameters. DIP must include restraining joints if located within a dam embankment. DIP fittings must be either ductile iron bell, mechanical, or push-on joint unless noted otherwise on the Contract

Documents. Fittings must meet AWWA C110 or AWWA C153 and AWWA C111. Flanged fittings where noted on the Contract Documents must meet AWWA C110. Bolts, nuts, and studs for flanges must be 304 stainless steel.

- Polyvinyl Chloride (PVC) plastic pipe must meet the requirements of ASTM D1785. PVC fittings must meet the requirements of ASTM D2466 (Schedule 40) or D2467 (Schedule 80).
- Six-inch hugger bands and "dimple bands" are not acceptable for CMP conduits. Thirteen-inch bands with either o-ring or flat neoprene gaskets are allowed for pipes less than 24-inches in diameter. Larger pipes require 24-inch wide bands with 24-inch wide flat gaskets and four "rod and lug" type connectors. Note that flanged pipe ends with gaskets are also permitted.
- Maximum allowable deflection of CMP conduits is five (5) percent of the pipe diameter. However, with the larger pipe sizes, it may be difficult to get acceptable joints even if deflection is less than this amount. No more than one (1)-inch difference in diameter is allowable between adjacent sections.
- Flat gaskets for CMP must be factory welded or solvent glued into circular ring, with no overlaps or gaps in gasket allowed.
- Pipe manufacturers should properly label and "match mark" their pipe sections. CMP is typically custom fabricated for each job as one long piece and then cut into shipping lengths. By consecutively labeling each piece, the pipe can be re-assembled in the same order as it was manufactured. (Also, have the manufacturer ship the longest sections possible--the fewer joints the better. Avoid use of short sections with anti-seep collars in the middle, as this increases the number of joints.)
- All concrete pipe conduits must be firmly and uniformly bedded in concrete cradles. All other conduits must be firmly and uniformly bedded in earth fill materials, unless otherwise specified on the approved plans. Cradles should be poured to at least the springline of the pipe against undisturbed earth, or they can be formed if there is enough room along on outside of forms for proper compaction. The sides of the formwork should be sloped at 1H:10V to achieve adequate compaction against the concrete.
- Where flowable fill is used for a cradle, the cradle should be poured in two lifts. As the concrete cures it will shrink, so the second lift will help fill voids around the pipe.
- Concrete cradles should be poured in alternating sections (e.g., 1 and 3, then 2 and 4).
- Pipe conduit should be installed from downstream to upstream. Mechanical pipe pullers or come-along devices should be utilized to bring the pipe joins into the “home” position.
- Reinforced concrete pipe installed in a dam embankment and associated with a concrete structure (e.g., riser, endwall) must be installed prior to construction of the structure with the structure then cast around the pipe. The first downstream joint of the pipe should be no less than two (2) feet but no more than four (4) feet from the outside face of the structure wall.
- Ductile iron pipe installed in a dam embankment and associated with a concrete structure must be installed prior to construction of the structure with the structure then cast around the pipe. This installation requires an appropriate water stop to be installed around the pipe to work as a gasket to ensure watertight connection.
- Within 30 days following installation, all spillway conduits should be visually inspected. Any cracks, differential movement, efflorescence, rust stains, spalls, exposed

reinforcement, slabbing, dents, buckling, holes, damaged coating, obstructions, improperly engaged joints, improper gasket placement, excessive joint gaps, misaligned joints, excessive deflection, or undue horizontal or vertical misalignment will be cause for repair or replacement. Video inspect pipes that cannot be physically accessed for inspection.

Examples of Documentation to Review

- Prior to installation of spillway conduits review and become familiar with the following:
    - Manufacturer's certification that pipe meets the appropriate material specification (e.g. AWWA C301, ASTM C361, etc.). This must include the size, material, and specification for each type of pipe used in the project.
    - Mix Design of cementitious bedding materials (e.g. concrete for cradle).
    - Supplier's steel drawing of reinforcement for cradle (if required) indicating all reinforcement to be used including:
        - Bar Size and lengths
        - Bend Types and Dimensions
        - Quantities of all reinforcement materials
    - Become familiar with pipe standards. For example, does the inspector know why reinforced concrete pipe labeled "ASTM C-76, Class V" is not acceptable for pond construction?

Reporting and Record Keeping

- All spillway conduit construction must be supervised and inspected by the EIC, their representative, or a third-party testing firm. The inspector should issue reports documenting the construction on a regular basis (weekly is recommended) to the project team. The inspector must inspect the pipe conduit installation prior to backfill to ensure the conduit installation meets the intended line and grade, that all joints are properly seated, and that there is no damage to the installed pipe.
- Concrete cradles must be installed under supervision of the EIC, their representative, or a third-party testing firm. Reinforcement for cradles must be inspected prior to closing formwork. During construction, the concrete must be tested in accordance with accepted practices as described in the Concrete section of this document.

Riprap

Recommended Practices

- Riprap should be placed on a prepared subgrade that is overlain by an appropriate geotextile (to provide separation between base soils) or a designed aggregate bedding. It is preferred that riprap placed on the upstream slope as wave erosion protection is underlain by an aggregate bedding layer.
- The subgrade must be smooth and firm, free from protruding objects that would damage the geotextile.
- Ensure that the surface elevation of completed riprap installations is flush with adjacent channel bed or bank slope elevations, and does not create an obstacle to the flow.
- The geotextile should be placed on the prepared subgrade without wrinkles or bunching, and adjacent edges should be overlapped (two (2) feet minimum recommended) with the upstream piece on top of the downstream piece. Geotextile that is torn or damaged must be replaced or repaired prior to placement of riprap.
- Any excavation voids existing along the edges of the completed slope and channel protection must be completely backfilled.

Examples of Documentation to Review

- Prior to installation of riprap review and become familiar with the following submittals:
    - Riprap stone including:
        - Gradation
    - Certification that the riprap meets the specified class(es)
    - Aggregate Bedding including:
        - Gradation
        - Certification that the aggregate meets the specified gradations
    - Geotextile Supplier's Material Specification Sheet
        - Material Specification Sheet

Reporting and Record Keeping

- The riprap should be inspected to ensure the installation meets the intended line and grade specified on the plans, that rock is placed at uniform depths and meets the minimum required depth, and that there is no damage to the geotextile if installed. Documentation of such should be included in the periodic reporting to the project team.

Gabions

Recommended Practices

- Gabion wire baskets must be PVC-coated or galvanized.
- The gabions should be carefully filled with rock by machine or hand methods to ensure alignment, avoid bulges, and provide a compact mass that minimizes voids. Machine placement requires supplementing with hand work to ensure the desired results. Hand placement is preferred.
- Do not drop the stone from a height greater than 36 in.
- Place the stone to provide a minimum of two courses.
- The cells in any row should be filled in stages so that the depth of rock placed in any one cell does not exceed the depth of rock in any adjoining cell by more than 12 inches.
- Along the exposed faces, the outer layer of stone should be carefully placed and arranged by hand to ensure a neat, compact placement with a uniform appearance. The last layer of rock should be uniformly leveled to the top edges of the gabions.
- All geotextiles must be stored under cover per manufacturer's specifications until installation.
- The geotextile should be placed on the prepared subgrade without wrinkles or bunching, and adjacent edges should be overlapped (two (2) feet minimum recommended) with the upstream piece on top of the downstream piece. Geotextile that is torn or damaged must be replaced or repaired prior to placement of riprap.
- Geotextiles must be completely covered with backfill, aggregate, riprap, or other material after installation.

Examples of Documentation to Review

- Gabion stone materials:
  - Gradation (including certification that the stone meets the required specifications)
- Wire Basket Supplier's Material Specification Sheet:
  - Material Specification Sheet must include confirmation that the wire basket wire, ties, and connecting wire meet the minimum tensile strength required in the specifications (typically 60,000 p.s.i.)
  - Fasteners, if substituted for wire ties should be stainless steel interlocking and meet ASTM A313 and maintain closed and locked position when subjected to the minimum specified force (typically 900 pounds).
  - Galvanized coating meets ASTM A123 and galvanization rate meets minimum requirements (typically 0.8 oz./sq. foot minimum).
  - PVC coating meets project specifications (MSMT 508 is an acceptable test method).
- Geotextile Supplier's Material Specification Sheet:
  - Material Specification Sheet must include values for all parameters noted in the specifications.

Reporting and Record Keeping

- Field Reports should document the gabion installation to ensure the installation meets the intended line and grade specified on the plans, that rock is placed as specified, that the wire baskets are properly closed, tied, and fastened, and that there is no damage to the geotextile, wire baskets, or ties.

Concrete

Recommended Practices

- The EIC, their representative, or a third-party testing firm should inspect and reject any concrete structure that is poor in quality for reasons including but not limited to exposed reinforcing steel, misaligned features, poor consolidation of concrete ("honeycombing", "rock pockets", etc.), unacceptable joints, spalls, cracks, damages, or poor workmanship.
- Cast-in-place (CIP) construction should be well timed for pours as longer periods between pours can have detrimental effects on concrete joints leading to leakage in the structure at the joints. Concrete delivery and placement should be scheduled so that each layer is placed while the proceeding one is still plastic to avoid cold joints. Cold joints are generally considered defective work and should be removed.
- Where required, concrete joints should be installed to include water stops to ensure a watertight structure. Commonly used water stops include rubber, PVC, and bentonite. The type and size of the water stops and accommodations for nearby reinforcement is generally provided in the plans. PVC water stops should be at least six (6) inches wide, and must be supported and centered on the joint. PVC water stop can be field spliced by using the electric splicing iron or by using fittings to assure continuity. Swell type bentonite water stops must be placed to ensure a minimum of three (3) inches of concrete cover. Swell type bentonite water stops should only be used in the following cases:
  - Around a conduit penetration through a concrete structure
  - At a joint between existing pre-construction concrete and freshly placed concrete. This application typically occurs during repairs or modifications to an existing concrete structure.
- Concrete material for spillways and control structures must meet the requirements of ACI 350.
- The EIC and/or Structural engineer must review and approve shop drawings for cast-in-place concrete, pipe, precast structures, or other fabricated appurtenances before fabrication or installation.
- Cinder block and masonry riser structures are not allowed.
- Precast box culverts are not approved, as they do not have watertight joints.
- Pre-cast units may not be substituted for cast in-place concrete without prior written authorization of the Owner, the EIC, and approval by MDE, as applicable. NO reduction in wall thickness or reinforcing is allowed when switching from CIP to pre-cast design. Watertight joints between the riser sections and the barrel are required.
- The concrete mix should be designed for protection against alkali-silica reactivity (ASR). Documentation of ASR mitigation must be included with the concrete mix design submittal including test results.
- Field coring of new precast structures is not allowed.
- The base on which concrete is to be poured must be free of water, mud, debris, loose materials, oil, frost, and ice. Gravel must not be used as concrete sub-base in dam embankments.
- Concrete forms must be heavy and secure in place so as not to move during the construction process.

- Concrete must not be dropped from more than four (4) feet above the forms. Concrete must be placed in such a manner that there is no segregation of material or displacement of reinforcement.
- Proper curing of concrete must be accomplished using industry standard practices. Failure to cure concrete appropriately can lead to cracking and should result in rejection and owner-directed removal of the poured concrete.
- Concrete must be thoroughly consolidated during and immediately after depositing by mechanical vibration, internal or external.
- Reinforcing steel and wire fabric must be protected from damage; foreign matter such as dirt, mud, oil and grease; and rust causing conditions. Clean forms and surrounding area before pours as necessary.
- Reinforcement must have adequate cover. Where not otherwise shown, the thickness of concrete over the reinforcement must be as follows:
  - Where concrete is cast against and permanently exposed to earth the cover must not be less than three (3) inches.
  - For all other areas, the concrete the cover must not be less than two (2) inches.

<u>Examples of Documentation to Review</u>

- Prior to the beginning of concrete placement review and become familiar with the following submittals:

  - Reinforcing steel shop drawings.
  - Design Mix Certification:
    - Design mixes for each class and type of concrete should be provided, certifying that proposed concrete ingredients and proportions will result in concrete mix meeting specified requirements.
  - Cast in Place Installation Documentation: Proposed methods for controlling concrete temperature and plans for placing concrete considering sun, heat, wind, ambient air temperature or other limitations of facilities that will prevent proper finishing or curing. Become familiar with the provisions of ACI 305R for "Hot Weather Concreting" and/or ACI 306R for "Cold Weather Concreting" as applicable.
  - Concrete Batch tickets: Before unloading at the site, review the delivery ticket from concrete supplier with each batch delivered to the site. The tickets should include the following information:
    - Name of supplier
    - Name of batching plant and location
    - Series number of ticket
    - Date
    - Truck number
    - Specific job designation: contract number and location
    - Volume of concrete in cubic yards
    - Class and type of concrete
    - Time loaded
    - Type and brand of cement
    - Weight of cement and fly ash or ground-iron blast-furnace slag.

        - Maximum size of aggregates
        - Weights of coarse and fine aggregates
        - Maximum amount of water to be added and amount of water added at the site
        - Type and quantity of admixtures – Admixtures containing Calcium Chloride must not be allowed
    - Precast Concrete Certification:
        - Manufacturer's certificates.
        - Any admixtures used.
        - Bonding agent (if any) to connect new to existing concrete.

Reporting and Record Keeping

- Concrete work (including reinforcing steel and waterstops) should be completed under supervision of the EIC, their representative, or a third-party testing agency. The scope of observation and testing should include the following:

    - Prior to any installation of a concrete structure or conveyance piping, the sub-grade must be tested and approved by the EIC, their representative, or a third-party testing firm.
    - Reinforcing must be inspected in the forms and approved before any concrete is placed. Water stops are to be installed and secured in place as specified, and inspected prior to concrete placement. The inspection should include the bar type, bar sizes, bar spacing, clearance to forms, water stop location, type, and dimensions.
    - The EIC, their representative, or a third-party testing firm should be notified at least 48 hours in advance of concrete placement. Form work should be approved for lines and grades prior to placing concrete. Concrete must be poured only in the presence of the EIC, their representative or the third-party testing firm during construction and the concrete should be tested at least once per 50 cubic yards, but not less than once per placement for temperature, air content, slump and compressive strength. The inspector should make test cylinders in accordance with ASTM C31 or AASHTO T23 for all concrete pours. Seven-day (lab cured) and 28-day (lab cured and field cured) tests should be conducted in accordance with ASTM C39 or AASHTO T22. A minimum of eight test cylinders for each day for each 50 cubic yards, for each mix-design is recommended. Six (6) test cylinders should be cured under the laboratory conditions (two (2) for seven (7) days, two (2) for 28 days, two (2) for 56 days) and two (2) cylinders must be cured under field conditions (for 28 days).
    - The inspector should issue reports on a regular basis (weekly is recommended) to the project team indicating:
        - Date/Time of reinforcing steel inspection
        - Structure/Portion of structure inspected (e.g. "EW-1 Footing")
        - Inspected items (reinforcement, water stop)
        - Repair/revision recommendations made to the contractor
        - Date/time of concrete placement
        - Weather conditions
        - Location of placement
        - Concrete supplier

- Estimated quantity of concrete placed
- Concrete slump (ASTM C172/C143)
- Concrete air content (ASTM C172/C173 or C231)
- Concrete temperature (ASTM C172/C1064)
- Number of cylinders made (ASTM C39/ASTM C31)
- Special measures taken by Contractor to protect concrete (e.g. hot weather or cold weather measures)
- Concrete delivery tickets
- Photos of formwork, reinforcing steel, waterstops and concrete placement

Valves

Recommended Practices

- Gate valves and valve extensions must meet the requirements of AWWA C509 or AWWA C515.
- Valve stem extensions must be plumb, supported and installed in such a manner as to allow for proper valve operation.
- Exercise the valve assembly after installation is complete to ensure system operability. Check for binding and difficult operation.
- Ensure stop nuts/set screws are adjusted to prevent over tightening the valve.
- Do not disassemble the valve, frame or other components as shipped from the manufacturer unless expressly approved by the manufacturer.
- Leak test all new valves under full reservoir head in accordance with AWWA C509 or AWWA C515.
- Valves must be installed to allow future replacement.
- Provide valve support concrete block, as necessary, as designed and approved by the EIC.
- Valves and operators should be designed to limit the need for confined space entry protocols.

Examples of Documentation to Review

- Become familiar with the provisions of AWWA C509 and C515.
- Carefully review shop drawings.

Reporting and Record Keeping

- Document the installation of the valve with photographs. Inspection reports should describe the leak test set up, measurements and results.