DRAFT STREAM CROSSING GUIDELINES

North Carolina Division of Parks and Recreation

Natural Resources Program

October 21, 2013

NOTE: This document is for reference purposes only and has not been officially approved by DPR or any other agency.

BACKGROUND

Streams and rivers are critical to sustaining the ecological integrity and diversity of aquatic life. The interconnected nature of stream systems within the terrestrial landscape can make them even more susceptible to degradation. The degradation of larger streams, rivers, and estuaries by development is well documented in the public eye. However small headwater streams are ecologically important, typically comprise between 75-85% of total stream length in a watershed, and are more sensitive to the adverse impacts of development activities, yet are often not protected in the same manner as larger waterbodies. A National Academy of Sciences 1996 report stated that headwaters should be protected in the same manner that all other waters are protected. Many fish need access to wide, un-fragmented linear distances along a stream network through their changing life stages to access appropriate breeding habitats, adjust to seasonally wet/dry conditions, and sustain their populations through seasonal temperature extremes. Therefore long, undisturbed, non-fragmented distances along a small stream network are extremely important for maintaining the ecological integrity of aquatic ecosystems and providing critical habitat for aquatic species such as small fish, salamanders, crayfish, and mussels that do not typically inhabit larger waterways.

The most common type of direct interface with streams within the State Park System are associated with roads and trails. Many of these roads, trails, and subsequent stream crossings were constructed before the property was acquired by the State, were installed historically prior to a higher level of environmental awareness or regulation, or have been informally established over time by park visitors.

Proper planning, design, construction, and maintenance can result in stream crossings that are sustainable ecologically, structurally, and recreationally. These guidelines were developed to provide recommendations for designing stream crossings for existing and future trail and road development that offer a higher level of ecological, hydrological, and structural function. However, these guidelines are also intended to provide general guidance rather than excessive constraints due to the variability of aquatic habitats across the state, project costs, operational considerations, and other factors. This document, along with other appropriate references and/or guidelines, should be referenced when considering work to upgrade or install a stream crossing. This document can also be incorporated into an adaptive management approach to water resource management. The table below outlines some primary benefits of implementing sustainable stream crossings.

ECOLOGICAL	STRUCTURAL	RECREATIONAL
Aquatic passage of aquatic organisms improved or maintained.	More stable trail surface and stream channel.	Visitor safety and accessibility improved or maintained.
Stream hydrology improved or maintained.	Maintenance efforts and costs reduced.	Visitor experience enhanced through not impacting resources.
Habitat fragmentation minimized.	Reduced in-stream erosion and sedimentation	Environmental education enhanced through demonstration of best management practices and low-impact development.

SITE ASSESSMENT

- Onsite determination of jurisdictional streams will be conducted by Natural Resources Program (NRP) staff, or by qualified professionals with experience in making these determinations.
- Amount: Avoid and/or minimize the number of stream crossings where possible.
- Location: Cross stream perpendicular to existing banks to reduce the amount of channel disturbance. Cross where stream channel is most stable: at a riffle, bedrock outcrop, or straight narrow section. Avoid steep banks, stream meanders, or areas of active channel erosion if possible.
- Approaches: should not exceed 8% grade. Bridges are recommended for steep approaches; avoid hardened crossings.
- Sizing: mimic nature by sizing crossing to mimic natural channel dimensions. Do not change width, depth, or gradient (slope) of the stream channel.

PLANNING/DESIGN

- Provide grade reversals or other diversions on approaches to streams to minimize stormwater and sediment from entering streams and degrading water quality.
- Stream crossing projects may require federal and state permitting. Project managers should consult the DPR Environmental Review Coordinator and/or NRP staff during project development to ensure regulatory compliance.
- Match the proportion of the crossing structure with the existing dimensions of the stream channel while considering the stream's capacity for high water flow events.

TYPES OF STRUCTURES

The following preference ranking table of stream crossing structures should be carefully considered during project development. Structures are listed in order of preference, with a description of when best to use each structure.

PREFERENCE	STRUCTURE	BEST USES
1	None	Ideal if crossing location has bedrock/large stones, is very narrow/can be safely crossed, and has gently sloped banks and approaches.
2	Bridge/ Open-Arched Structure	Preferred structure by NRP. Ideal for streams with wide/entrenched channels, steep approaches, perennial flow, or rare/sensitive aquatic species.
3	Hardened Crossing	Ideal for ephemeral or low-velocity streams with shallow banks.
4	Culvert	Ideal for replacement of existing culverts that are not functioning properly. Least preferred option, but generally less expensive than a bridge and safer than hardened crossing in high flow areas.

The guidelines or recommendations listed below are associated with the most common types of structures used as stream crossings within State Parks, but is not a complete list of specifications, considerations, or practices that can be implemented as a suitable stream crossing. Typical crossing designs have been created for the structures listed above and are included as an Attachment to this document.

I. Bridges/Open-Arched Structure

- Bridges are the preferred structure for crossing a stream by the NRP. A 16-foot pedestrian bridge design used Raven Rock State Park that was recently approved by the State Construction Office: 1.) cost less than $1,500 for materials that can be purchased at a local hardware store (equivalent to the cost of materials for a hardened crossing), 2.) could be constructed by Park staff in one day, and 3.) could support passage of a ½-ton truck. Additionally, properly designed, constructed, and maintained

bridges generally do not require Section 404/401 permitting ($240 application fee) and do not adversely impact stream channels.

- Designs for bridge structures or other long, open span structures should be prepared or reviewed by a Professional Engineer to assure structural integrity and suitable engineering load rating considerations.
- Consider current and future potential for lateral and vertical adjustment of stream channel. Posts and pilings should be located a safe distance away from the top of bank to reduce the potential of
- adverse impacts from streambank erosion, bank failure, and pile maintenance.
- Bridge structures on roads should be designed long enough to traverse the floodplain to maintain existing hydrology and not constrict the flow of water into one narrow area. If roadway fill is placed in the floodplain, culverts should be incorporated into the causeway to attenuate flood flows.
- Bridge structures on roads should be designed to span the waterway, keeping bridge pilings out of the water. This will minimize direct impacts as well as reduce future debris maintenance.
- Bridgemats should be used as temporary crossings for forestry or prescribed fire operations. See http://ncforestservice.gov/water_quality/bridgemats.htm.

II. Hardened Crossings/Armored Fords

- Minimize changing the width, depth, or gradient (slope) of the stream channel. Size the crossing to mimic existing channel dimensions upstream and downstream of proposed crossing.
- Material: Use rock or gravel size that most closely matches existing stream bed substrate. Do not use artificial fill material such as concrete, asphalt, or scrap metal.
- Crossing must be designed and installed at the existing grade of the stream bed so that low water flow is not blocked and passage of aquatic organisms through the crossing is not hindered.

III. Culverts

- For proper culvert sizing, consult with DPR Engineer or 'Permanent Culvert Sizing Table for Forestry' found in 'Stream Crossings' section of NCFS's *North Carolina Forestry Best Management Practices Manual*. Old culverts are often undersized based on their upstream drainage arearesulting in erosion,maintenance, and aquatic habitat fragmentation issues.
- Culverts should be designed and constructed to handle the more extreme flow of storm events, while ensuring the passage of aquatic organisms during low flow conditions.
- Section 404/401 permitting requires that culverts > 48 inches in diameter be buried at least one foot below the streambed where possible. Culverts <48 inches in diameter should be buried to a depth equal to/greater than 20% of their diameter. Both the inlet and outlet of the culvert bottom should be buried. Avoid "waterfall" drops on the outlet of culverts.
- Sometimes burying the bottom of the culvert is not feasible due to bedrock; in this case the culvert can be set on bedrock without the need to chisel or blast the bedrock. The bedrock will act as the grade control for stability, however usually this does result in the loss of bed material remaining in the culvert. If bedrock is present, investigate the use of a bottomless-arch culvert.
- Consider another crossing option if culvert needs to be longer than 40 linear feet.. However, if a culvert must be used and sufficient slope exists, install alternating or notched baffles in the baseflow pipe in a manner that mimics the existing stream pattern. This should enhance aquatic life passage by: 1) depositing sediments in the pipe, 2) maintaining channel depth and flow regimes, and 3) providing resting places for fish and other aquatic organisms.
- Culverts or pipes should be situated along the existing channel alignment whenever possible to avoid channel realignment. Widening the stream channel must be avoided. Stream channel widening at the inlet or outlet end of structures typically decreases water velocity causing sediment deposition that requires increased maintenance and disrupts aquatic life passage.

- Plastic pipes should be corrugated (not smooth or slick) on the inside to ensure the passage of aquatic organisms and allow for the establishment of natural streambed materials on the bottom of the pipe.
- Avoid the use of flat concrete aprons between wing-walls and the use of riprap in the streambed if possible.
- If multiple pipes/boxes are required, pipes other than the baseflow pipe should be placed on or near stream bankfull or floodplain bench elevation. This may be accomplished by utilizing sills on the upstream and downstream ends to restrict or divert flow to the base flow barrel(s). The proper use of a sill at the outlet will insure the culvert holds bed load eventually leading to a stable stream with a natural bed. Additionally, at least one pipe/box should be designed to remain dry during normal flows to allow for terrestrial wildlife passage within the riparian corridor.

- Perched or unstable culvert outlets can be retrofitted with a rock cross vein or series of cross veins to stabilize and raise the grade to the pipe. Make sure structures are large enough to remain stable during flood flows. Prior to installing any cross vein structure, consult with a hydrologist and/or professional that is knowledgeable of natural stream restoration techniques.

REFERENCES

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ATTACHMENTS

- Stream Crossing Photo Log
- Stream Crossings: Trails From A Rivers Point of View. National Park Service document. Available at: http://www.nps.gov/ncrc/programs/rtca/whatwedo/recent_innovations/wwd_ri_stream.html
- Maine Stream Crossings: New Designs To Restore Stream Continuity. Maine Forest Service document. Available at: http://www.maine.gov/doc/mfs/fpm/water/docs/stream_crossing_2008/MaineStreamCrossingsPoster.pdf
- DPR Pedestrian Bridge Design
- DPR Service Road Hardened Crossing Design
- DPR Culvert Design

Stream Crossing Examples

Photo 1: IDEAL - Hardened crossing in low gradient stream with natural substrate allowing for un-impeded stream flow.

Photo 2: NOT IDEAL: - Hardened stream crossing with gravel in stream bed that is impeding stream flow and creating check-dam effect.

Photo 3: IDEAL – Culvert buried below stream bed with natural substrate; stable earthen material around culvert with minimal erosion.

Photo 4: NOT IDEAL – Culvert perched above stream bed and impeding aquatic passage upstream. Large scour pool indicates culvert undersized.

Rivers, Trails, and Conservation Assistance Program

National Park Service
U.S. Department of the Interior

Stream Crossings

Trails...from a River's Point of View

There's more to me than you might know
- I am a river.
- I am dynamic, ever-changing.
- I am pleasing to the eye and to the ear.
- I cut through the earth.
- I meander across the landscape.
- I carry water, sediment, and debris.
- I adjust my shape to maintain balance among runoff, sediment, and slope.
- I provide critical habitat for unique and diverse communities of aquatic and terrestrial organisms.
- I am home to many species of fish, mollusks, insects, amphibians, mammals, reptiles, and birds.
- I provide transport routes to their areas of food, shelter, reproduction, and colonization.
- I change and evolve over time in predictable patterns.
- I tend toward stability unless disturbed.

Trails can harm me or be my welcome companions; poorly designed, constructed, or maintained trail crossings can:
- Deliver polluted runoff and sediment to my channel.
- Divert, capture, or block my flow.
- Cause my channel to become unstable and disrupt transport of water, sediment, and debris.
- Impede or bar passage of fish, macroinvertebrates, and other aquatic organisms.
- Fragment habitat by creating impassable water depths, flow velocities, or jump heights.
- Impair or prevent access to food resources, refuge from unfavorable conditions, reproductive success, and new areas for colonization.
- Diminish biological diversity and species abundance.

I prefer solitude
- It's best to keep your distance - avoid interacting with me ; trails can be too close for comfort.
- Travel parallel to my course, rather than perpendicular to it.
- Select a path that's higher, flatter, and drier.
- Leave a healthy fringe of vegetation -- riparian buffer -- between me and a trail.

But, if you must come near or cross me…
- Minimize the number of crossings.
- Cross where my channel is most stable - at a riffle or where my banks are solid rock.
- Use a bridge instead of a ford or culvert.
- Span as much of my active floodplain as possible, preferably at least twice my bankfull width.
- Use an armored ford instead of a culvert.
- If you must use a ford or culvert - minimize the width of the ford or length of the culvert.
- Mimic nature; don't change width, depth, or gradient.
- For culverts, use a natural bottom; don't change the substrate.
- For fords, armor the crossing if the natural substrate consists of clay, silt, sand, or gravel; use stones large enough to withstand scour during flood events.

- Size culverts to handle the largest expected flows and to allow a flood fringe to develop inside.
- Design the approach, to descend into and climb out of the crossing, at an 8% grade maximum.
- Provide grade reversals on both approaches to prevent water and sediment from entering the stream.
- Get runoff from the trail into the soil - use outslopes, dips, and waterbars. Avoid outside berms.
- Plan and design for possible failure of the crossing.
- Integrate other restoration activities into the design and construction of new or rebuilt crossings.

If you can do all this, we can peacefully coexist…but, there will be times when I will flood you…it's natural!

For more information:
www.nps.gov/ncrc/programs/rtca/whatwedo/wwd_innovations.html

For more stream crossing resources:
www.nps.gov/ncrc/portals/rivers/projpg/stream.htm

MAINE
stream crossings

new designs to restore stream continuity

Stream continuity is critical to all creatures that depend on streams, including invertebrates, fish, amphibians, reptiles, and mammals. The design and condition of stream crossings determine whether a stream behaves naturally and whether wildlife can migrate freely. Through the effects of dams and poorly designed stream crossings, we have fragmented streams and hindered wildlife dispersal throughout our watersheds. In many cases, even crossings that were once effective are now barriers because of erosion or mechanical breakdown. Safe and stable stream crossings can accommodate wildlife and protect stream health while reducing expensive erosion and structural damage. By adhering to the standards in the *Maine Department of Transportation Fish Passage Policy and Design Guide*, town officials, highway departments, and private landowners can help protect and restore stream continuity in Maine.

KEY FEATURES OF WELL-DESIGNED CROSSINGS
(fish friendly)

- Large sizes suitable to handling flood flows and debris
- Bridges and open-arch designs considered optimum under most conditions
- Crossings are wide and high relative to their length
- Greater than 1.2x stream width maintains dry banks for wildlife passage
- Water depth and velocity match conditions upstream and downstream
- Natural substrates create good conditions for stream wildlife
- Long life span with significant cost savings over time

EFFECTIVE CROSSINGS INCLUDE...
- Bridges and open-bottom arches
- Culverts that span and are sunk into the streambed

STREAM CROSSING PROBLEMS

UNDERSIZED CROSSINGS restrict natural stream flow, causing several problems, including scouring and erosion, high flow velocity, clogging, and ponding. Crossings should be large enough to retain natural substrates and to pass fish, wildlife, floods, and debris.

SHALLOW CROSSINGS have water depths too low for many organisms to move through them and may lack appropriate bed material. Crossings should have an open bottom or should be sunk into the streambed to allow for natural substrate and water depths.

PERCHED CROSSINGS are above the level of the stream bottom at the downstream end. Perching can result from either improper installation or from years of downstream bed erosion. Crossings should be open-bottomed or sunk in the bed to prevent perching.

SLIPLINING is NOT the answer!

Sliplining, inserting a smooth plastic liner to an older culvert, may save money in the short run, but it nearly always decreases fish passage. Liners raise crossing elevations and increase flow velocities, removing crossing bed material and increasing downstream scour.

For more information on stream crossing surveys in Maine, visit the Maine Forest Service online at:

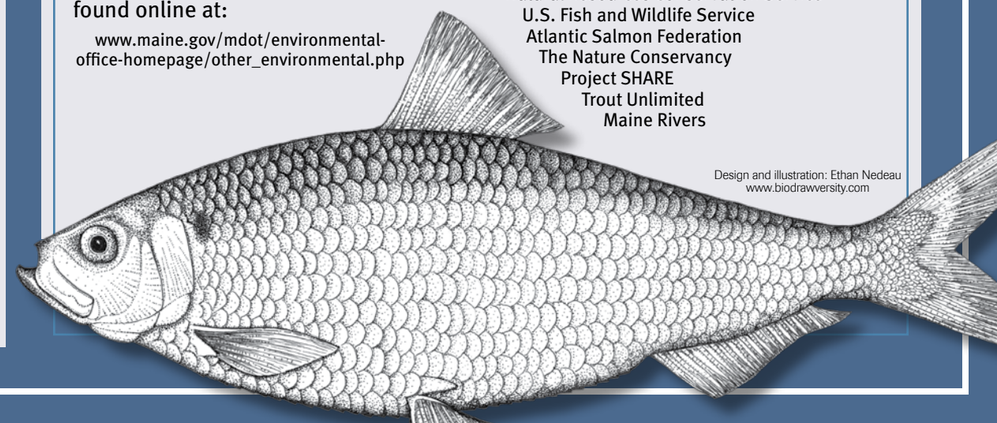
www.maine.gov/doc/mfs/fpm/water/stream_crossing.html

The *Maine Department of Transportation Fish Passage Policy and Design Guide* can be found online at:

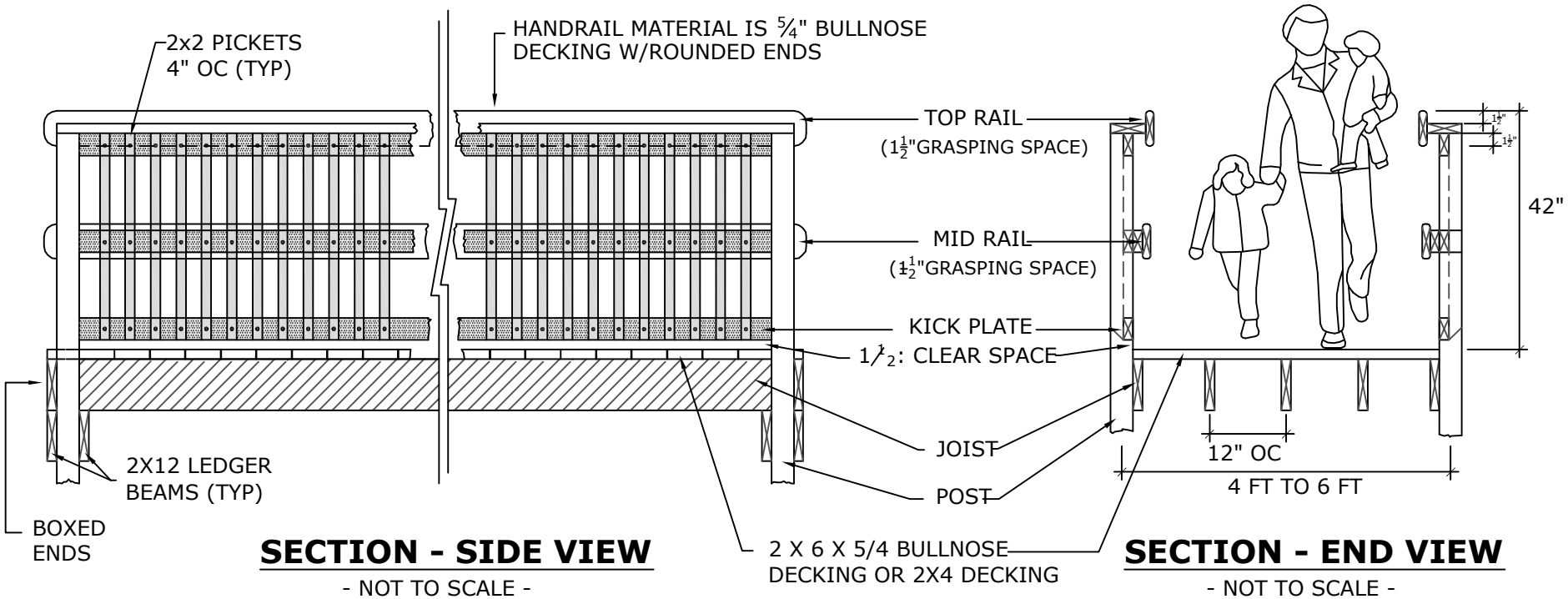
www.maine.gov/mdot/environmental-office-homepage/other_environmental.php

Maine's stream barrier removal efforts are supported by a broad coalition of state and federal agencies and nongovernment organizations:

Maine Forest Service
Maine Department of Marine Resources
Maine Department of Transportation
Maine Department of Inland Fisheries and Wildlife
Maine Department of Environmental Protection
National Oceanic and Atmospheric Administration
University of Southern Maine Aquatic Systems Group
Penobscot Valley Council of Governments
Natural Resources Conservation Service
U.S. Fish and Wildlife Service
Atlantic Salmon Federation
The Nature Conservancy
Project SHARE
Trout Unlimited
Maine Rivers



Design and illustration: Ethan Nedeau
www.biodrawversity.com



SECTION - SIDE VIEW

- NOT TO SCALE -

SECTION - END VIEW

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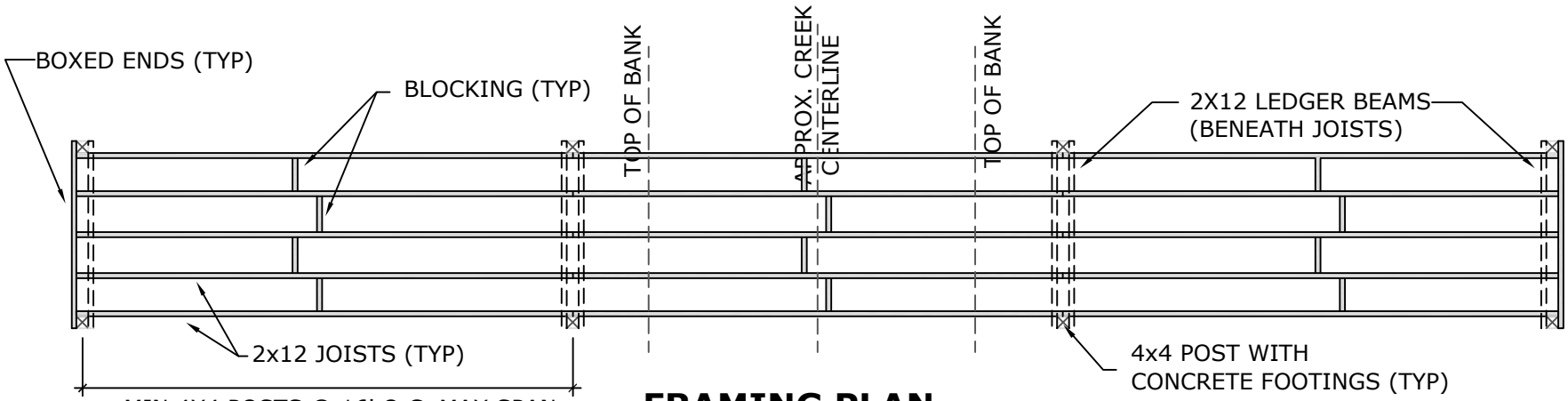

FRAMING PLAN

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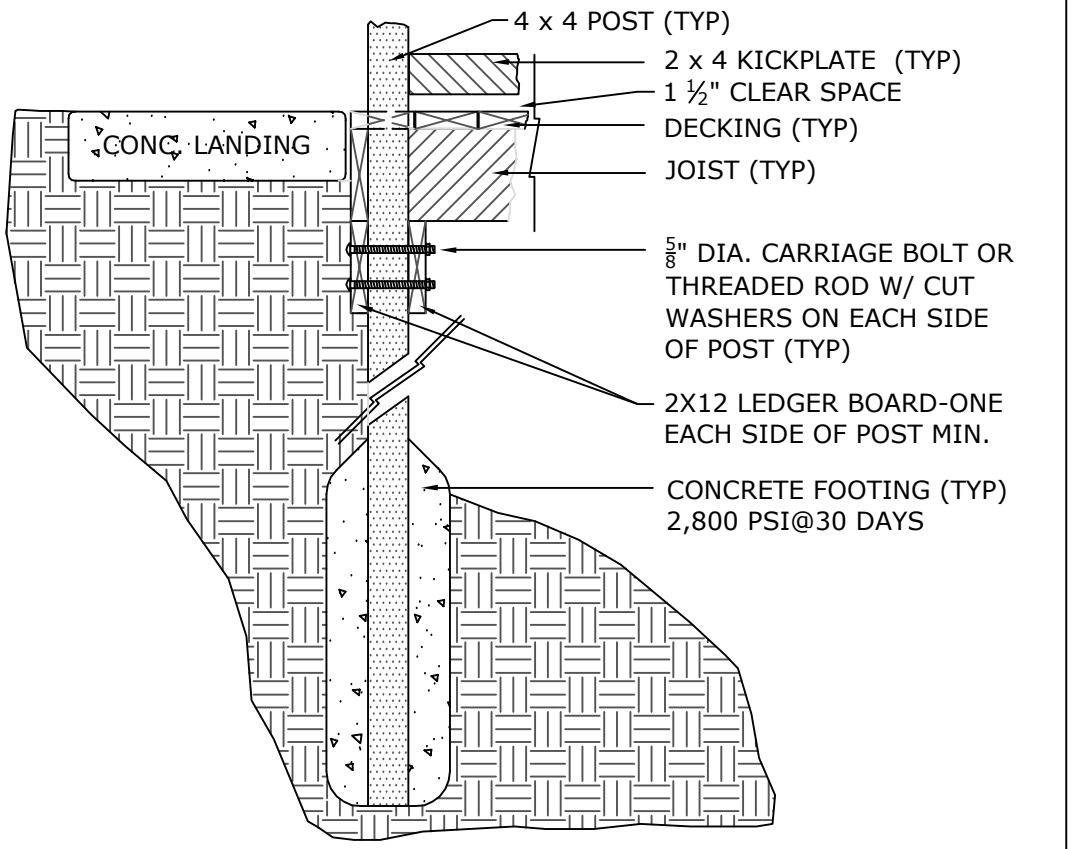
THESE EXHIBITS ARE PROVIDED FOR INFORMATIONAL PURPOSES ONLY AND ARE NOT INTENDED AS COMPLETE PLANS OR APPROVED CONSTRUCTION DOCUMENTS.

STANDARD FOOTBRIDGE EXHIBIT



POST CONNECTION DETAILING - SIDE VIEW

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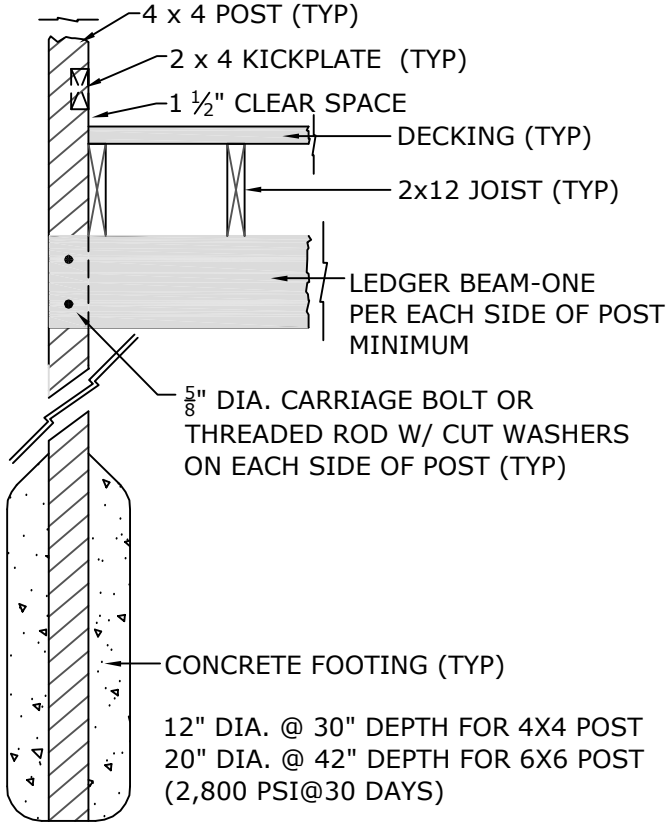

POST CONN. DETAILING - END VIEW

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GENERAL NOTES AND TERMS:

1. ALL LUMBER SHALL BE PRESSURE-TREATED SOUTHERN YELLOW PINE, GRADE #2 OR BETTER. ALL FASTENERS SHALL BE H.D. GALVANIZED OR BETTER. ALL WEATHER OR CERAMIC SCREWS ARE THE PREFERRED FASTENERS. WHERE NAILS ARE UTILIZED, RING-SHANK OR SPIRAL-TYPE ARE PREFFERED.

2 PROTECT MATERIALS AND WORK AREA WHILE UNDER CONSTRUCTION. KEEP LUMBER AND OTHER MATERIALS COVERED AND DRY UNTIL USE. SIGN AND ROPE-OFF THE CONSTRUCTION AREA TO KEEP STAFF AND VISITORS SAFE.

3. ALL RAILINGS SHALL BE FITTED WITH PICKETS OR FENCING MESH SO THAT A 4" DIAMETER SPHERE CANNOT PASS THROUGH. EXTEND RAILING ENDS AT LEAST 4" BEYOND EDGE OF WALKING SURFACE.

STANDARD FOOTBRIDGE EXHIBIT

NOTES:

1. PUMP AROUND NEAR CULVERT INLET OR INSTALL WADDLE NEAR CULVERT OUTLET PRIOR TO CULVERT REMOVAL PER N.C. DIVISION OF WATER QUALITY REQUIREMENTS. REMOVE WADDLE AFTER CONSTRUCTION.

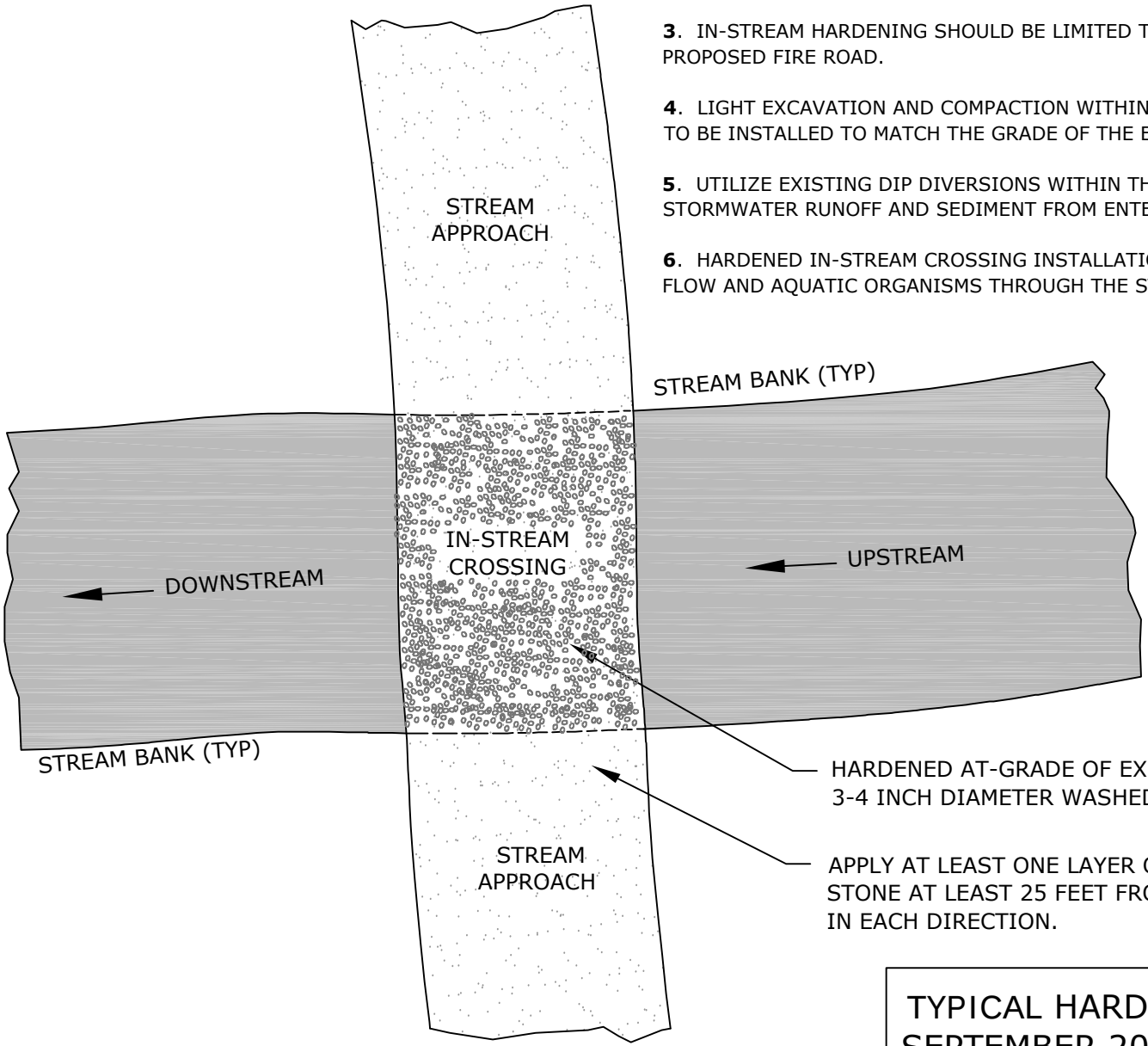
2. **MATERIALS**: 3-4 INCH DIAMETER CLEANED/WASHED STONE FOR THE IN- STREAM CROSSING AND FOR APPROACHES TO THE STREAM.

3. IN-STREAM HARDENING SHOULD BE LIMITED TO THE EXISTING LATERAL FOOTPRINT OF THE PROPOSED FIRE ROAD.

4. LIGHT EXCAVATION AND COMPACTION WITHIN THE STREAM BOTTOM SHOULD ENABLE STONE TO BE INSTALLED TO MATCH THE GRADE OF THE EXISTING STREAM BOTTOM.

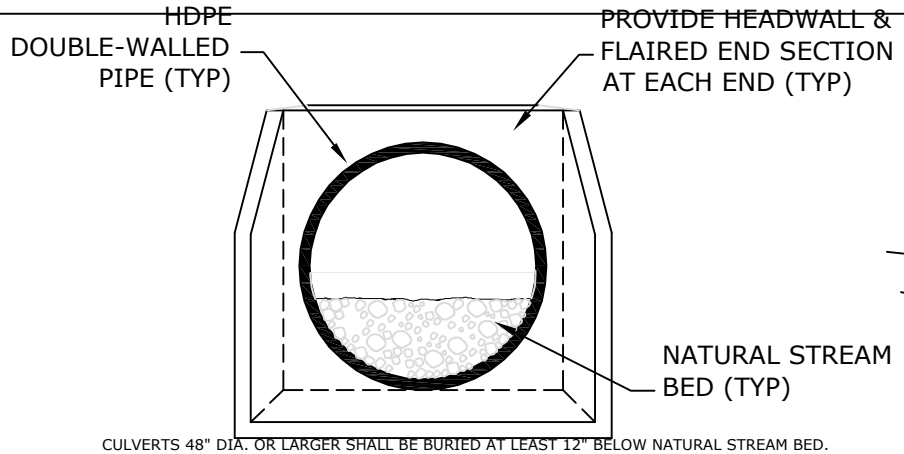
5. UTILIZE EXISTING DIP DIVERSIONS WITHIN THE STREAM APPROACHES TO MINIMIZE STORMWATER RUNOFF AND SEDIMENT FROM ENTERING STREAM.

6. HARDENED IN-STREAM CROSSING INSTALLATION SHOULD ENSURE PASSAGE OF LOW WATER FLOW AND AQUATIC ORGANISMS THROUGH THE STREAM CROSSING.



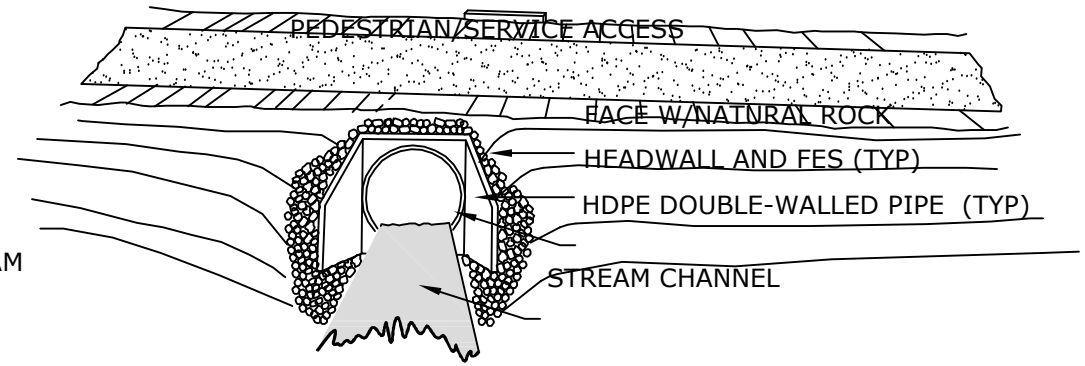
PLAN VIEW - NOT TO SCALE

TYPICAL HARDENED STREAM CROSSING
SEPTEMBER 2013 - NOT TO SCALE

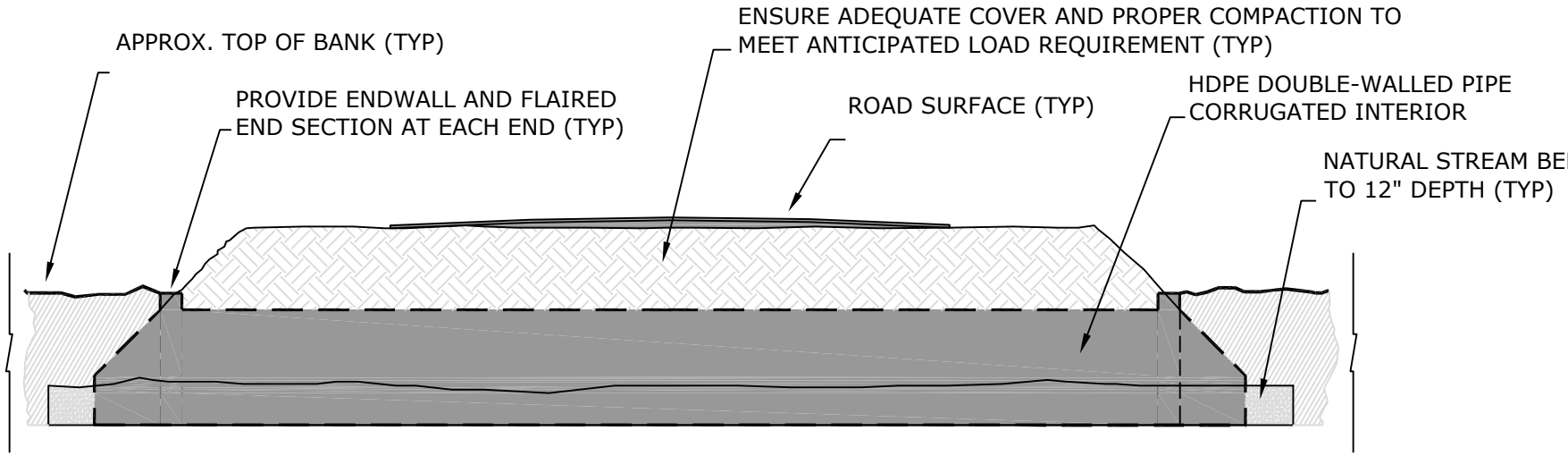


CULVERTS 48" DIA. OR LARGER SHALL BE BURIED AT LEAST 12" BELOW NATURAL STREAM BED.
CULVERTS LESS THAN 48" SHALL HAVE A BURIAL DEPTH EQUAL TO 20% OF PIPE DIAMETER .

EMBEDDED PIPE CULVERT W/ FLAIRED END SECTION
END VEIW - NOT TO SCALE



EMBEDDED PIPE CULVERT W/ FLAIRED END SECTION
SECTION/ELEVATION - NOT TO SCALE



EMBEDDED CIRCULAR PIPE CULVERT
SECTION - NOT TO SCALE

GENERAL NOTE:
1. FOR CULVERT SIZING, CONSULT A PROFESSIONAL ENGINEER OR REFER TO "PERMANENT CULVERT SIZING TABLE FOR FORESTRY" IN THE N.C. FOREST SERVICE BMP MANUAL TO CONSIDER UPSTREAM DRAINAGE AREA AND ENSURE THE PASSAGE OF STORM FLOWS.

2. CULVERT MUST BE DESIGNED AND INSTALLED TO ALLOW PASSAGE OF AQUATIC LIFE DURING LOW FLOWS.

3. RIP RAP SHALL NOT BE PLACED IN THE STREAM BED CHANNEL.

4. A SECTION 404/401 PERMIT WILL GENERALLY BE REQUIRED FOR CULVERT INSTALLATION OR REPLACEMENT UNLESS:
   A. PROPOSED CULVERT HAS THE SAME DIMENSIONS AS EXISTING CULVERT.
   B. NO ADDITIONAL RIPRAP WILL BE ADDED OR ACCUMULATED SEDIMENT REMOVED WITHIN THE STREAM CHANNEL.
   C. CULVERT INSTALLATION IS NOT WITHIN A JURISDICTIONAL STREAM OR WETLAND AREA.

ALL CROSSINGS MUST BE IN COMPLIANCE WITH SECTION 404/401 PERMITTING REQUIREMENTS.

STANDARD CULVERT DESIGN-SERVICE ROAD

OCT. 2013 - NOT TO SCALE - PAGE 1 OF 1