13.0 DROP INLET SPILLWAYS

13.1 General

The drop inlet spillway is commonly used for providing flood protection for earth dams which have smaller reservoirs and/or smaller basins. Generally, the spillway is designed to pass floods up to a chosen SDF under a specific amount of surcharge above the reservoir FSL. The drop inlet spillway by itself or in conjunction with an auxiliary spillway is designed to pass more extreme flood events up to and including the IDF without overtopping the dam.

Guidelines for establishing the IDF are usually based on the consequences of failure of the dam as discussed in CDA (1999).

For “low” and “very low” consequence dams, the following may be considered in the selection of an appropriate IDF:

- For “low” consequence dams, the IDF should normally have an AEP of 1/100 for projects deemed to be at the lower end of the consequence range, increasing up to 1/1000 for those judged to be at the upper end of the range.

- For “very low” consequence dams, the 1/100 AEP should normally be used.

- Both of the above cases are subject to: a) possible adoption of a smaller flood subject to an economic risk analysis with consideration of environmental and social impacts as per Note (d) of Table 6-1 of CDA (1999); and b) adoption of a larger flood where economics so suggest.

For smaller projects constructed by the Province, where auxiliary spillways have been provided, the SDFs have been commonly in the range of 1/15 to 1/50 AEP. Selection of the SDF should include consideration of the following:

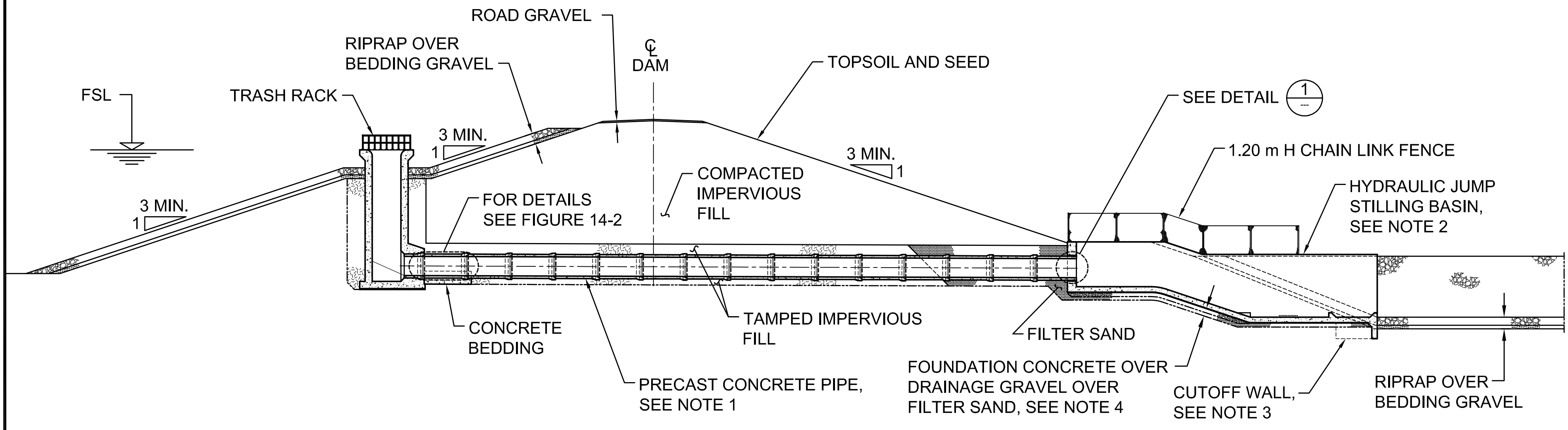
- Magnitude of the IDF and the capacity and reliability of the auxiliary spillway.

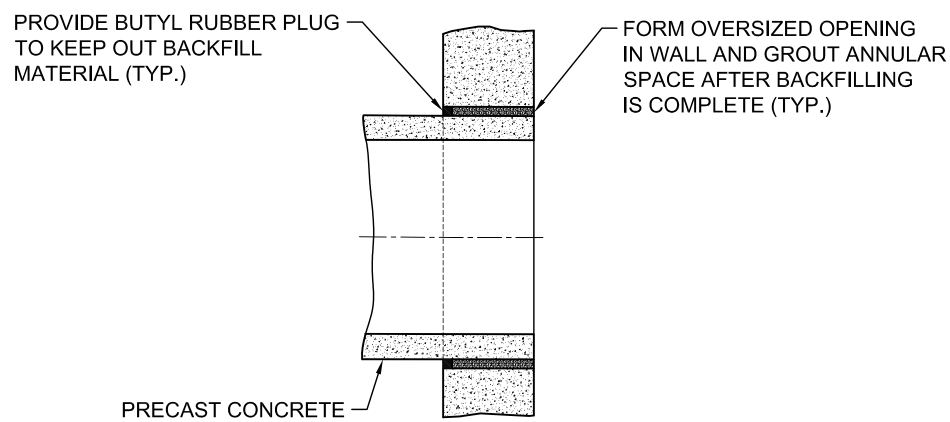
- Environmental and social considerations, particularly those associated with operation of the auxiliary spillway.

- Economic factors, including capital and maintenance costs for the auxiliary spillway.

13.2 General Arrangement

The drop inlet spillway structure typically consists of a free overflow crest section, a vertical shaft, a horizontal conduit, and a terminal structure. The spillway structure is normally constructed of reinforced concrete. A typical arrangement of a drop inlet spillway is shown on Figure 13-1.





1 DETAIL
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NOTES:

1. USE CAST-IN-PLACE CONCRETE CONDUITS WHERE REQUIRED (I.E. DUE TO LOADS, FOUNDATION CONDITIONS, FLOW CAPACITY).

2. STILLING BASIN SHOWN IS DESIGNED TO RESIST THE FULL UPLIFT PRESSURE DUE TO THE HYDRAULIC JUMP (I.E. DOES NOT RELY ON DRAINS). DEPENDING ON HYDRAULIC CONDITIONS, OTHER TYPES OF TERMINAL STRUCTURES MAY BE CONSIDERED.

3. EXTEND THE CUTOFF WALL BACK SOME LENGTH ALONG THE HEEL OF THE WALL FOOTING WHERE TOE EROSION AND POTENTIAL UNDER CUTTING BENEATH THE SLAB IS A CONCERN.

4. EXTEND FILTER SAND/DRAINAGE GRAVEL OUT PAST THE SLAB AND PROPERLY TIE-IN WITH DRAINAGE MATERIALS ADJACENT TO THE WALLS AND THE BEDDING GRAVEL.

5. WHERE FLOATING ICE OR OTHER LARGE DEBRIS COULD BLOCK THE TRASHRACK. PROVIDE A TRASH BARRIER (e.g. VERTICAL PILES) ON THE BERM AHEAD OF THE TRASH RACK.

ALBERTA TRANSPORTATION CIVIL PROJECTS BRANCH **ALBERTA ENVIRONMENT** WATER MANAGEMENT OPERATIONS	**WATER CONTROL STRUCTURES - SELECTED DESIGN GUIDELINES** **GENERAL ARRANGEMENT OF A DROP INLET SPILLWAY** DATE: November 2004 · CAD FILE: 99008A13-1.dwg · FIGURE No.: 13-1

Possible performance problems with this type of structure include plugging with trash or ice.

Where required, the drop inlet spillway structure could also be:

- Designed to provide temporary diversion during construction of the dam embankment, by extending the conduit upstream. The upstream conduit is later plugged with concrete.

- Combined with the low level outlet into a single drop inlet spillway/low level outlet structure. This can be accomplished by extending the conduit upstream and providing an intake structure, replacing the drop inlet with a gatewell with an internal weir wall which serves as the free overflow crest, and incorporating a slide gate to control low level outlet releases. The general arrangement of the combined drop inlet spillway/low level outlet structure at the Severn Creek Dam is shown on Figure 13-2.

13.3 Location and Layout

The location and layout of the structure will primarily be influenced by foundation conditions, the dam embankment design cross section, construction diversion considerations, potential ice loading, and trash accumulation concerns.

The structure should be sited on the most competent portion of the dam foundation so that the least amount of differential vertical and horizontal movements (foundation settlement and spread) over the length of the structure will occur. In addition, the intake should preferably be placed where the prevailing wind will not cause trash or ice to drift towards it.

Ideally, the invert of the conduit at the terminal structure should be established well above the normal downstream water level to facilitate access for inspection and maintenance.

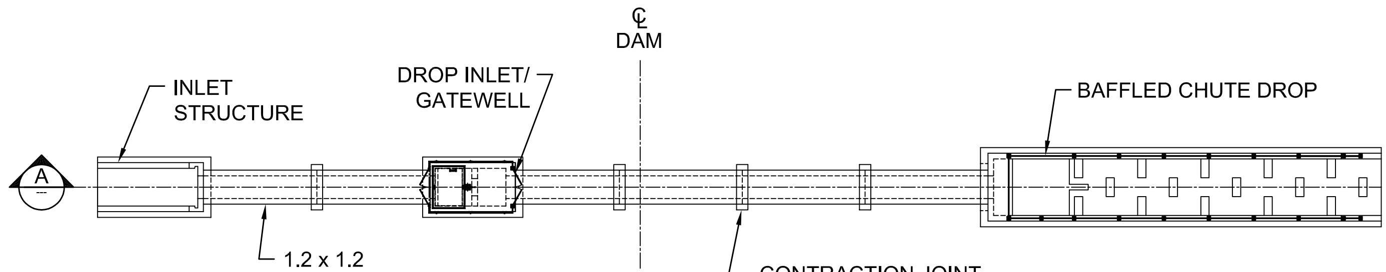
13.4 Seepage and Drainage Measures

Seepage control is normally provided by the impervious backfill placed around the structure as part of the impervious core of the dam embankment. Seepage collars around the conduits, that are cast monolithically or built integrally with the conduit, should not be used since they can produce stress concentrations and cause shearing of the conduit. If seepage collars or similar measures are required, provisions for preventing the development of stress concentrations should be incorporated.

To prevent piping along the outside wall of the conduit, a zone of filter material possibly in conjunction with drainage gravel, is ordinarily provided around the downstream end of the conduit, and properly tied in with the drainage measures provided at the terminal structure.

13.5 Overflow Crest Section and Shaft

The projection of the overflow crest section and shaft above the embankment should be kept to a



PLAN
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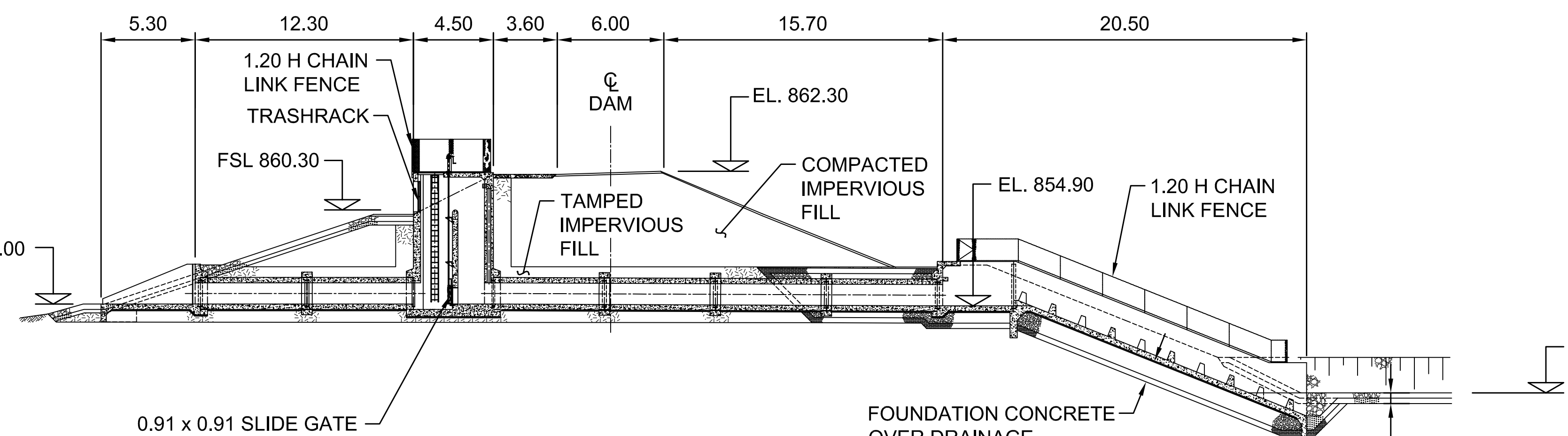

A SECTION
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NOTES:

1. WHERE WINTER OPERATIONS COULD ALLOW FREEZING OF WATER IN THE UPSTREAM SECTION OF THE GATEWELL, PROVIDE AN INSULATED PANEL FOR INSTALLATION BEHIND THE TRASHRACKS.
2. WHERE FLOATING ICE OR OTHER LARGER DEBRIS COULD BLOCK THE TRASHRACK, PROVIDE A TRASH BARRIER (e.g. VERTICAL PILES) ON THE BERM AHEAD OF THE TRASHRACK.
3. ELEVATIONS AND DIMENSIONS ARE IN METRES.

SOURCE. ALBERTA TRANSPORTATION, CIVIL PROJECTS BRANCH, 2000.

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ALBERTA ENVIRONMENT
WATER MANAGEMENT DIVISION

WATER CONTROL STRUCTURES - SELECTED DESIGN GUIDELINES

COMBINED DROP INLET SPILLWAY / LOW LEVEL OUTLET AT SEVERN CREEK DAM

DATE:	CAD FILE:	FIGURE No.:
November 2004	99008A13-2.dwg	13-2

minimum in order to mitigate the potential for damage due to ice. Where hydraulically acceptable, the design of the crest should consider measures such as the inclusion of inclined surfaces to reduce horizontal ice loads.

The overflow crest section should be located, sized, or protected such that the types of debris expected do not enter the structure, or can be readily passed through the structure. Safety provisions, in conjunction with or independently of a trashrack, should be considered. A trashrack mounted directly on the crest is generally not preferred largely because of plugging concerns. Alternatively, a trash barrier, such as a series of piles, can be installed some distance offset from the crest. The trash barrier provides a larger flow area than the trashrack mounted on the crest.

For a specific installation, special care is required in identifying all of the conditions and loading combinations that can occur. Some examples of conditions and loading combinations that may apply in the design of a typical overflow crest and shaft section are provided below. The load symbols are defined in Section 4.0, and load factors are discussed in Section 9.0.

Construction Condition:

- D+E+V (surcharge)

Usual Condition

- $D+E+H_{FSL}$ (external)$+U_{FSL}+I_S$
- $D+E+H_{SDF}$ (external and internal)$+U_{SDF}$+Hydrodynamic Load

Unusual Condition

- $D+E+H_{FSL}$ (external)$+U_{FSL}+Q$

Extreme Condition

- $D+E+H_{IDF}$ (external and internal)$+U_{IDF}$+ Hydrodynamic Load
- $D+E+H_{FSL}+Q_{IDF}$

Loading combinations assuming a partially plugged crest condition should also be considered.

13.6 Conduit

The conduits will generally be exposed to similar load types as previously described for the vertical shaft. Consequently, examples of typical loading combinations will be similar to those identified for the vertical shaft; however, additional load cases that may also have to be considered include:

- Assuming a higher and lower lateral earth pressure coefficient.

- Assuming internal hydrostatic pressure acting alone (internal bursting). It is noted that this load case is normally used in the design specifications for precast concrete pipe.

For a particular headwater level, the external hydrostatic pressure is typically based on the phreatic level within the dam, whereas the internal hydrostatic pressure is derived from the hydraulic grade line.

As noted in Section 3.6.2, only cast-in-place reinforced concrete conduits or precast reinforced concrete pipes designed for pressure applications may be used within earth dams.

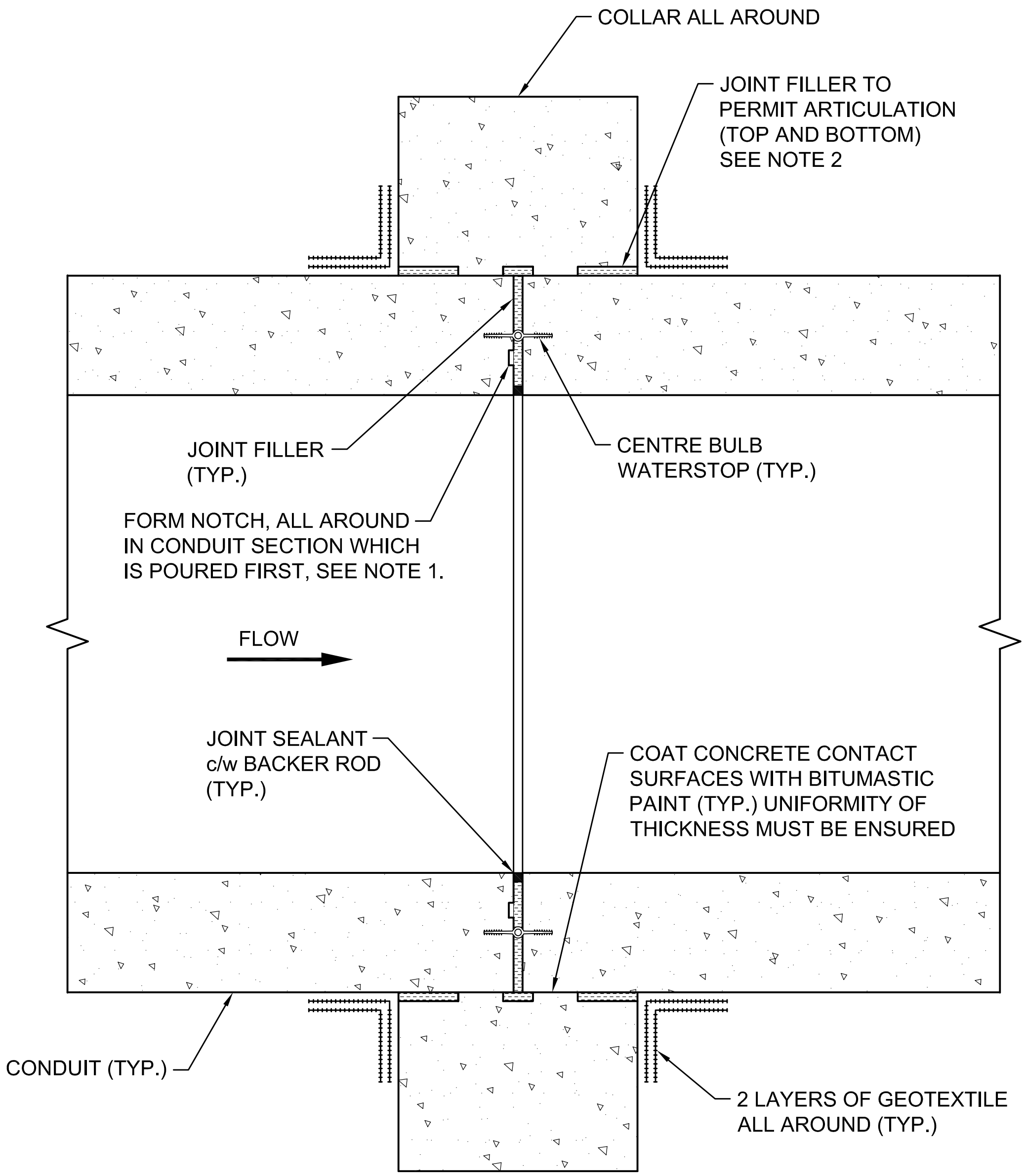
Cast-in-place reinforced concrete conduits are used where the design flow capacity, loading, foundation conditions, and potential deformations warrant a specific design. It is also generally preferred due to its robustness in cases where it is equally or more cost effective than precast concrete pipe.

For the design of cast-in-place concrete conduits, pertinent information can be found in USACE EM 1110-2-2902 (1998) and USBR (1987). Although USACE suggests that the spacing of transverse joints should be limited to 6 m on earth foundations and 9 m on rock foundations, a greater transverse joint spacing can be used in cases where settlement analyses have been conducted to estimate differential settlement and longitudinal movement (spreading), and the joints are designed to accommodate such displacements. The Province has commonly used maximum conduit lengths of 9 m on earth foundations.

At locations along the conduit where large differential settlements are expected, somewhat more closely spaced articulated joints may be used to accommodate such displacements. Typically, articulated joints are similar to expansion joints and include a compressible joint filler material, waterstop, and joint sealant.

For a single-cell conduit, the use of a collar at the articulated joint has normally been used as a means of maintaining alignment at the joint, particularly if large differential movements are expected. A typical articulated joint detail is shown on Figure 13-3. For specific applications, the design and construction of such joints needs to minimize the risk of load concentrations at locations that could cause the concrete to crack into the waterstop. At locations where large differential settlements and longitudinal movements (spreading) are expected, a closure section can be incorporated to allow for much of the movement to occur prior to completing the conduit for its intended use. An example of a closure section is shown on Figures 13-4 and 13-5. For a multiple-cell conduit, a collar may not provide the shear capacity required at the joint, therefore a bell and spigot type arrangement may be required.

For conduits constructed on an earth foundation, longitudinal tensile stresses may be induced in the conduit wall by the longitudinal movement (spreading) of the adjacent earth. These tensile stresses could result in the formation of cracks particularly near the mid-length of a section of conduit. Such cracking has been observed in precast concrete pipe units by the SCS (1970). As well, differential settlement can cause longitudinal flexural stresses within the conduit length. Sufficient longitudinal



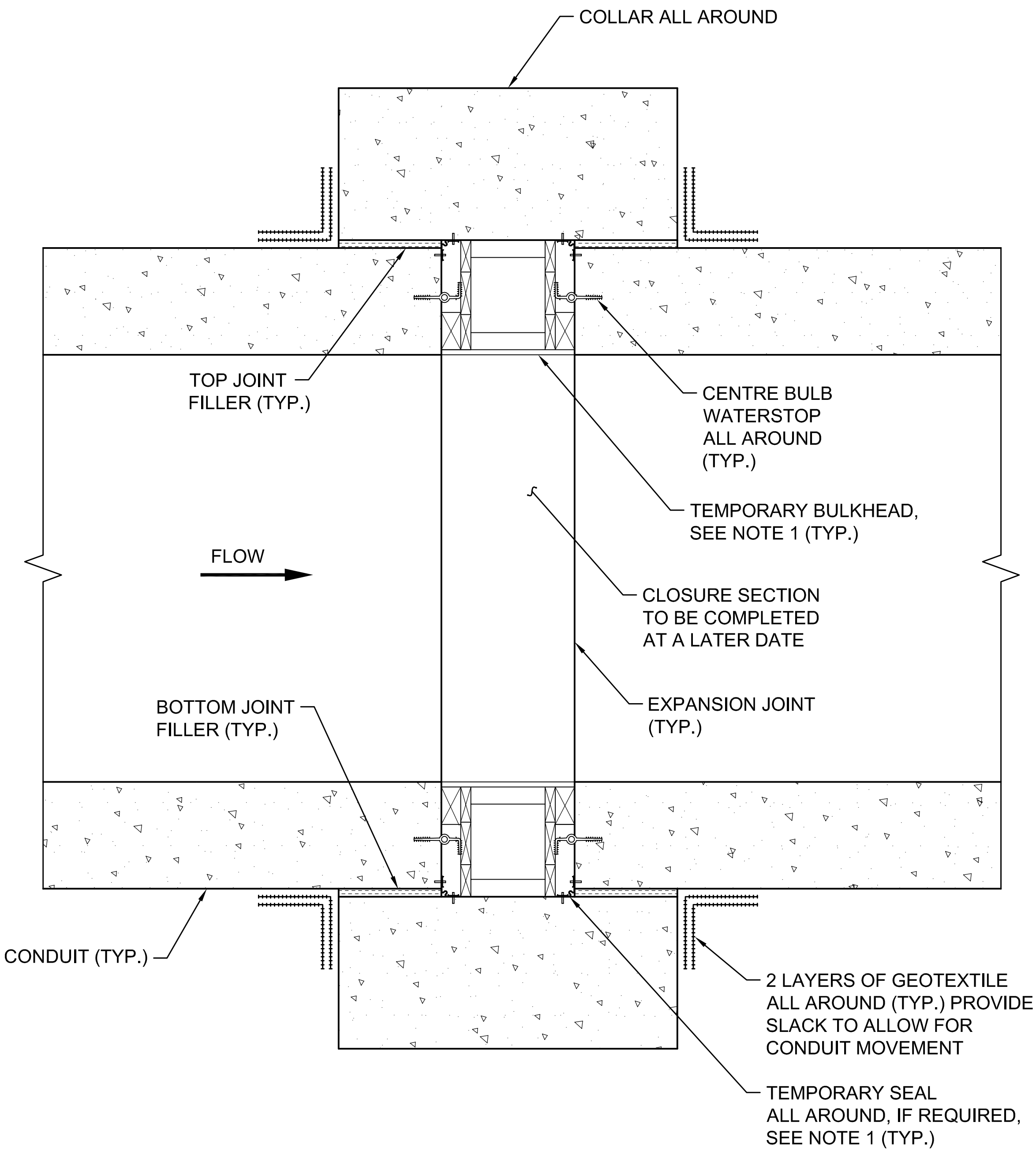
NOTES:

1. PROVIDE NOTCH TO FACILITATE FUTURE SEALING OF JOINT, IF REQUIRED.

2. ENSURE THE CONFIGURATION DOES NOT POSE A RISK OF FAILURE FROM BEARING AREAS INTO THE WATERSTOP, PARTICULARLY FOR THIN CONDUIT SECTIONS.

13-3 Jan 07'2005 - 10:43am Jesse Llorca

ALBERTA TRANSPORTATION CIVIL PROJECTS BRANCH **ALBERTA ENVIRONMENT** WATER MANAGEMENT OPERATIONS	**WATER CONTROL STRUCTURES - SELECTED DESIGN GUIDELINES** **ARTICULATED JOINT FOR A SINGLE-CELL CAST-IN-PLACE CONCRETE CONDUIT** DATE: November 2004 · CAD FILE: 99008A13-3.dwg · FIGURE No.: 13-3

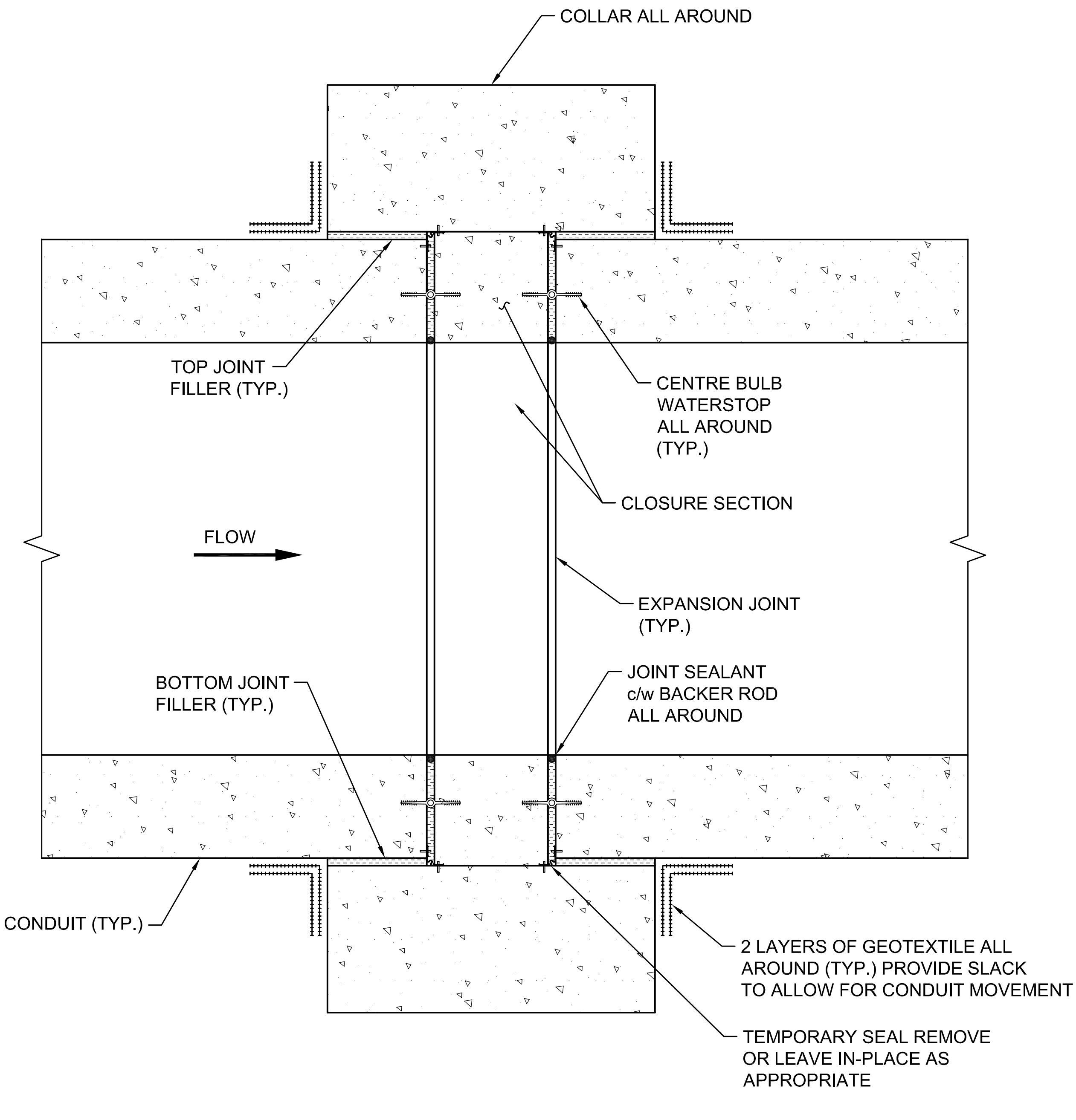


NOTES:

1. IN CASES WHERE WATER MAY BE PASSED THROUGH THE CONDUITS PRIOR TO COMPLETION OF THE CLOSURE SECTION, PROVIDE TEMPORARY BULKHEADS AND SEALS.

2. AT THE SIDES, COAT CONCRETE CONTACT SURFACES BETWEEN THE CONDUIT AND COLLAR WITH BITUMASTIC PAINT.

ALBERTA TRANSPORTATION CIVIL PROJECTS BRANCH **ALBERTA ENVIRONMENT** WATER MANAGEMENT OPERATIONS	**WATER CONTROL STRUCTURES - SELECTED DESIGN GUIDELINES** **CLOSURE SECTION FOR A SINGLE-CELL CAST-IN-PLACE CONCRETE CONDUIT**		
	DATE: November 2004	CAD FILE: 99008A13-4.dwg	FIGURE No.: 13-4



NOTES:

1. COAT CONCRETE CONTACT SURFACES BETWEEN THE CONDUIT SIDE WALLS AND COLLAR WITH BITUMASTIC PAINT.

13-5 Jan 07 2005 - 10:43am Jesse Llorca

ALBERTA TRANSPORTATION CIVIL PROJECTS BRANCH **ALBERTA ENVIRONMENT** WATER MANAGEMENT OPERATIONS	**WATER CONTROL STRUCTURES - SELECTED DESIGN GUIDELINES** **COMPLETED CLOSURE SECTION FOR A SINGLE-CELL CAST-IN-PLACE CONCRETE CONDUIT** DATE: November 2004 — CAD FILE: 99008A13-5.dwg — FIGURE No.: 13-5

reinforcement is required to resist these stresses and limit the resulting crack width. In any case, longitudinal and transverse reinforcement should generally not be less than 0.0028 and 0.0020 times the gross area of the concrete, respectively, with half of the reinforcement provided in each face USACE EM 1110-2-2902 (1998). Additional longitudinal reinforcement may be necessary depending on the length of the monolith and the allowable crack width criteria.

Precast concrete pipes may be used where the foundation conditions would not result in significant longitudinal movement (spreading) and would comfortably limit the potential rotation to within the allowable capacity of the joints. The bell and spigot joints of precast concrete pipes will normally have some deflection (i.e. rotation) capability and therefore some ability to accommodate differential movements. Recommended allowable joint deflections for the pipe should be obtained from the manufacturer. Typically, these allowable values are based on properly installed pipe wherein a uniform joint gap has been obtained and no joint deflection has occurred during installation. Consequently, in determining the amount of deflection that can actually be tolerated, some allowance should be included to account for installation tolerances. At locations where greater differential movements are expected, such as at the pipe to structure interface, somewhat shorter pipe lengths may be used, subject to maintaining adequate joint rotation capacity. In some instances, a standard full-length pipe is cut to produce a short pipe unit; therefore, only one end will have a proper bell and spigot joint. At locations where a series of short pipes are required, the availability and lead-time for casting these special units with complete bell and spigot joints should be confirmed with pipe manufacturers.

For precast concrete pressure pipe, each joint should ordinarily be internally tested using a low pressure joint testing device to verify that the pipes have been properly mated and that the gasket is properly seated.

The inside diameter of the conduit should be large enough to satisfy discharge requirements and permit access for inspection, maintenance and possible repairs. A minimum inside diameter of 1.05 m is considered appropriate since it provides a reasonable balance between access requirements, available joint shear strength as discussed in Section 3.6.2, and sizing of associated structures (i.e. drop inlet and outlet structures). If precast concrete pipe with an inside diameter of 1.2 m or greater is proposed, the reduced shear capacity at the joint should be considered as discussed in Section 3.6.2.

In cases where soft foundation conditions are encountered, the soft materials must be removed and special measures such as overfilling with well-compacted backfill and then re-excavating to the required grade, using fill concrete, providing concrete pipe bedding, or incorporating cast-in-place concrete conduit sections may be required.

For precast concrete pipe, connection details between the pipe and the drop inlet structure, where founded on a competent foundation, are as illustrated on Figures 14-2 and 14-3 between the pipe and gatewell structure of a low level outlet.

Ideally, the invert at the downstream end of the conduit should be set well above the bed of the outlet channel so that it is free draining and free of ice during the winter in order to facilitate access for inspection and maintenance when the structure is not being operated.

13.7 Terminal Structure

13.7.1 General

The terminal structure for a drop inlet spillway normally consists of either a hydraulic jump stilling basin or an impact basin. However, as shown on Figure 13-2, a baffled chute drop has also been used.

13.7.2 Hydraulic Jump Stilling Basin

The hydraulic jump stilling basin is preferred, subject to appropriate tailwater conditions, since it generally requires less maintenance (e.g. trash and debris removal) and allows easier access into the downstream conduit for inspection and maintenance.

Requirements for a typical hydraulic jump stilling basin are described in Section 12.7.1.

13.7.3 Impact Basin

The use of an impact basin is normally limited to a maximum discharge of 11 m^3/s and velocity of about 15 m/s as noted in USBR (1987), and where the properties of the outlet channel are too variable or complex to allow for determining reliable tailwater conditions. An impact basin should not be employed where the potential for trash (e.g. logs) and other waterborne debris to enter the structure and affect its performance or cause impact or abrasion damage exists. In addition, access into the downstream conduit for inspection and maintenance purposes will be made more difficult by the baffle wall.

The design of the impact basin should consider the large hydrodynamic force that will act on the baffle wall, and the turbulence that will occur within the basin. The impact basin should have an adequate sliding factor of safety to resist the impact load on the baffle wall and other lateral pressures. The structure and adjacent materials should also be capable of withstanding the vibration that is inherent with this type of basin. Extending the base slab laterally beyond the sidewalls (to mobilize the weight of the backfill) and providing cross walls will increase the resistance against sliding and reduce vibration.

Adjacent to the impact basin, rock riprap is normally provided on the bed and sideslopes of the outlet channel. The extent of the riprap should consider site specific conditions. USBR (1987) suggests that riprap extend for a minimum distance equivalent to the width of the basin. Guidelines for establishing the size and gradation of riprap are provided in Section 11.1.

13.7.4 Baffled Chute Drop

A baffled chute drop structure is typically used where the water must be lowered from one level to another and the properties of the outlet channel are too variable or complex to allow for determining reliable tailwater conditions. The structure requires relatively low entrance flow velocities, and is normally limited to a maximum unit discharge of 1.7 m^3/s, as noted in USBR (1984). A baffled chute drop should not be used where the potential for trash (e.g. logs and weeds) and other waterborne debris to affect its performance, or cause impact damage, exists.

The design should consider the potential implications of some splash occurring over the walls and the formation of a scour hole in the outlet channel immediately downstream of the structure.

Rock riprap is normally provided to prevent erosion of the banks. The extent of the riprap should consider site specific conditions. Guidelines for establishing the size and gradation of riprap are provided in Section 11.1.