Chapter 5
Special Design Considerations for Rectangular Channels Lined with U-frame Structures

5-1. General

The U-frame structure is basically a U-shaped, open-top concrete section in which the walls and base slab of the structure are monolithic. U-frame structures may sometimes be more economical or functionally desirable than individual retaining walls and separate channel invert slabs.

5-2. Foundation Considerations

U-frame channel structures may be designed for any type of foundation, provided the material strength is sufficient to provide adequate frictional and bearing resistance for structural stability. Pile foundations are sometimes used for localized sections founded on weak foundations.

5-3. Joints in Concrete

a. Base slab section. The base slab of U-frame channel structures are often designed and constructed as continuously reinforced concrete paving. Expansion joints should be provided where the continuity of the structure is interrupted by other structures. Guidance on expansion joints is discussed in paragraph 3-6. Waterstops should be provided in expansion joints and should extend continuously across the base slab. When continuously reinforced concrete paving is not used, vertical contraction joints are provided at the location of wall joints.

b. Wall section. Vertical contraction joints should be provided in walls of U-frame structures. The contraction joint spacing should be approximately 5 to 10 m (20 to 30 ft). However, the joint spacing should be limited to two or three times the wall height. Horizontal construction joints or vertical lift joints should be provided at the base of wall stems and in wall height at intervals of 2.5 to 3 m (8 to 10 ft).

5-4. Drainage Provisions

A drainage system should be provided behind the channel walls and beneath the channel bottom paving to relieve hydrostatic pressures whenever the permanent or fluctuating water table is above the invert of the channel. The design of channel walls and bottom paving should reflect possible increased hydrostatic pressures resulting from some loss of the drainage system effectiveness during the life of the project as discussed in paragraph 2-4*e*.

a. Drainage systems. Open and closed drainage systems are discussed in paragraphs 2-4, 3-3, and 4-5. Refer to Appendix B for a typical analysis of a drainage system for a U-frame structure.

b. Drainage of perched ground water. When ground water levels are below the channel invert and a drainage system is not provided, the designer should develop a pressure relief system for those areas where perched water is encountered during construction of the channel. This drainage system should be defined and included as a requirement of the construction contract.

5-5. Structural Design

a. Loading conditions. The primary loadings on the U-frame structure are weights of the structure and contained water and the geohydraulic pressures resulting from the restraint provided by the structure. The exact nature of the loadings or the physical parameters on which the loadings are based are not precisely known; therefore, the structure should be designed for conservative loadings. An analysis of the structural frame should be performed with the applied loading to determine the reactive foundation pressures and internal loads within the structure for each loading condition.

(1) Case 1, Construction condition (unusual condition). Structure complete with backfill in place; at-rest earth pressure; channel empty; compaction effects and construction surcharge loadings. See Figure 5-1a.

(2) Case 2, Design flood loading (usual condition). Water in channel at the maximum design water level; at-rest earth pressure; backfill saturated to the normal ground water level adjusted to reflect the design effectiveness of the drainage system. See Figure 5-1b.

(3) Case 3, Drawdown loading (usual condition). Channel empty; at-rest soil pressures on walls; hydrostatic pressures reflecting the highest ground water level adjusted to reflect the design effectiveness of the drainage system. See Figure 5-1c.

(4) Case 4, Earthquake loading (unusual condition). Construction complete; water in channel to normal level; active earth pressures; backfill saturated to normal ground water level adjusted to reflect the design effectiveness of the drainage system; seismic loadings. See Figure 5-1d.

(5) Case 5, Other special load cases. Modify all of the previous load cases to include other special loads applied to the U-frame structure. Examples are maintenance vehicles and bridges or other permanent structures which are supported by the U-frame.

b. Stability. The basic stability requirements for the U-frame structure require that the structure be safe against sliding, overturning, bearing failure (excessive differential settlement), and flotation. The criteria for satisfying these stability requirements and the safety factors required for usual and unusual loading conditions are contained in EM 1110-2-2502, Chapter 4, particularly Table 4-1. Resisting loads or foundation pressures on the base of structure are computed to satisfy vertical and rotational equilibrium. The distribution and intensity of base pressures should be determined by using a beam on elastic foundation model, or by use of a pressure pattern which approximates that which would exist beneath a flexible foundation. Excessive differential settlements are avoided by maintaining bearing pressures which are less than the allowable bearing pressure value furnished by the geotechnical engineer. Flotation stability criteria for concrete hydraulic structures is contained in ETL 1110-2-307. Anchors are sometimes necessary to satisfy the safety factor requirements. In rock foundations, anchors often consist of reinforcing bars grouted into drilled holes. The stiffness, strengths, and locations of anchors should be reflected in the structural analysis.

c. Reinforced concrete design.

(1) General. Reinforced concrete design should comply with EM 1110-2-2104. For singularly reinforced flexural members the ratio of tension reinforcement provided should be $0.375p_b$.

(2) Minimum reinforcement. Reinforcement for continuously reinforced concrete slabs on soil foundations should comply with Tables 3-1 or 3-2.; except that the area of temperature reinforcement in thicker slabs need not exceed 2,200 mm^2 per meter (1 $in.^2$ per foot). Reinforcement should be placed in two layers, top and bottom of slab, when the slab thickness is 300 mm (12 in.), or greater. For thicker slabs it is common to place 2/3 of the reinforcement in the top face. Minimum temperature and shrinkage reinforcement provisions are discussed in EM 1110-2-2104.

d. Computer programs. Computer programs suitable for the design or analysis of U-frame structures are discussed in Appendix B.

5-6. Special Considerations During Construction

Construction procedures should be given consideration during the design process. Construction difficulties and complexities should be minimized or eliminated. For example, concrete working slabs are sometimes used to protect drainage blankets or to prevent weathering of the foundation materials before the main slab is constructed. When necessary for stability, the contract should include the requirement for the level of backfill behind opposite walls to be limited to a specified differential.

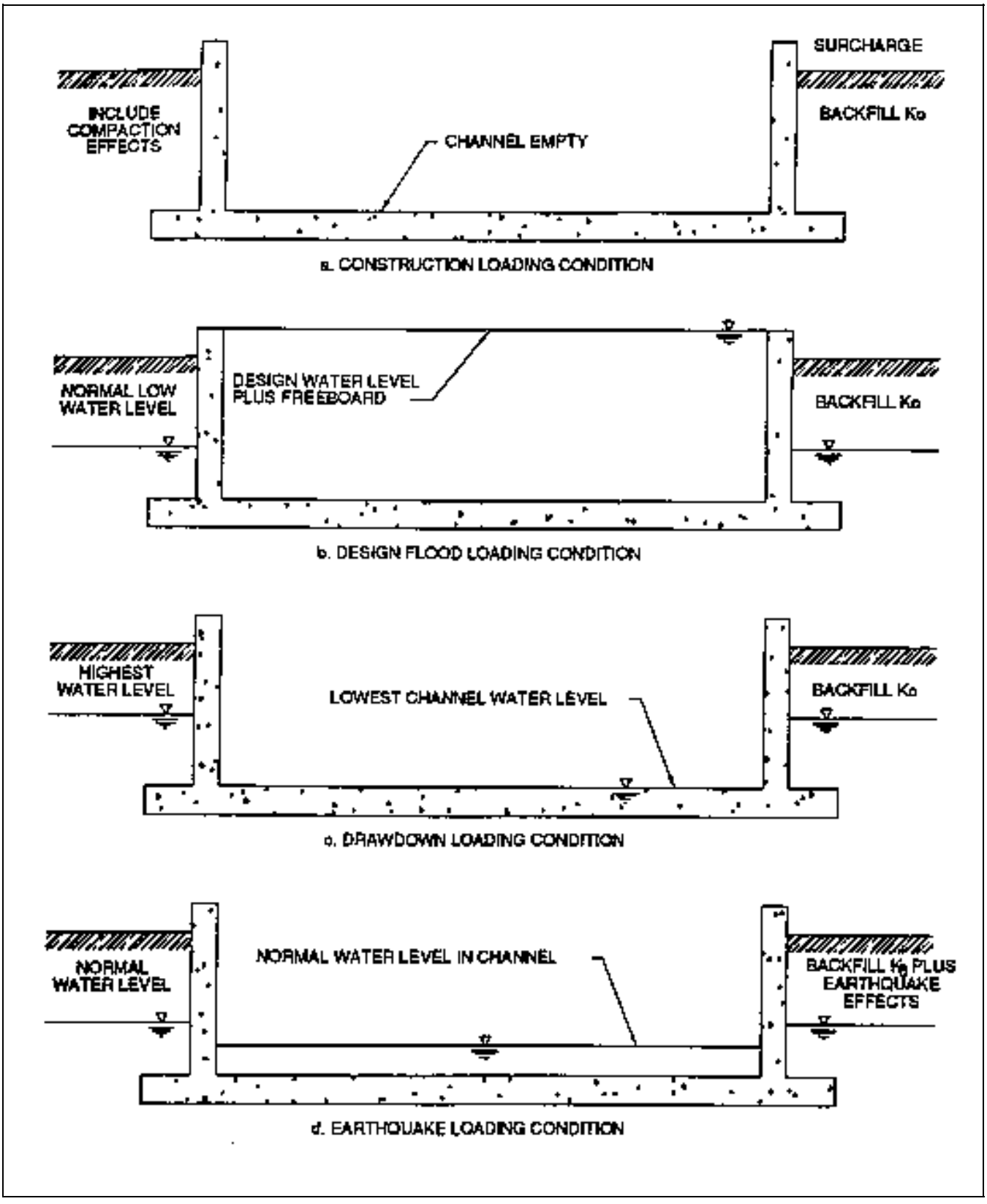
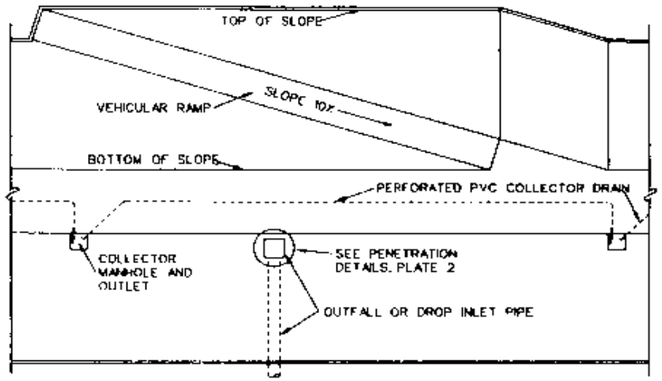
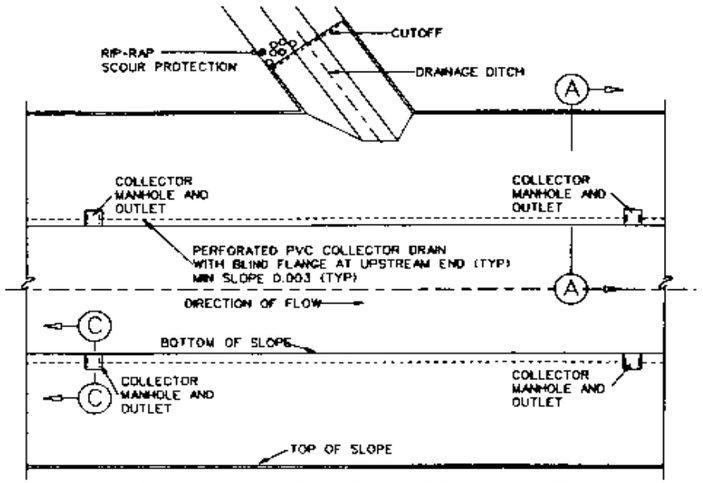


Figure 5-1. Loading conditions - rectangular channels with U-frames



CHANNEL WITH ONE DRAIN LINE
NO SCALE



CHANNEL WITH TWO DRAIN LINES
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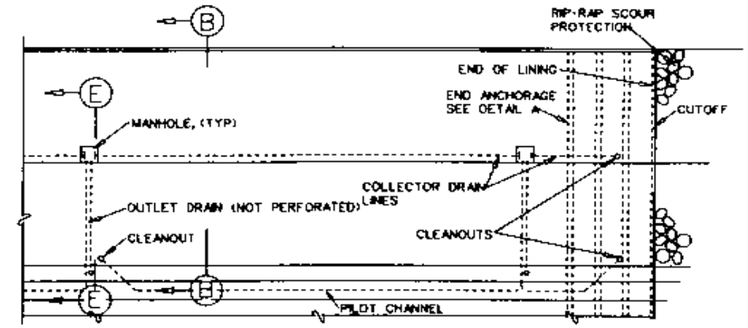
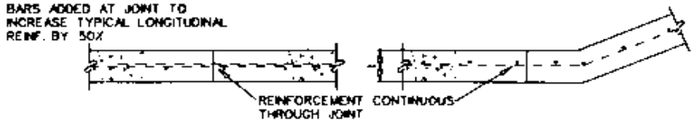
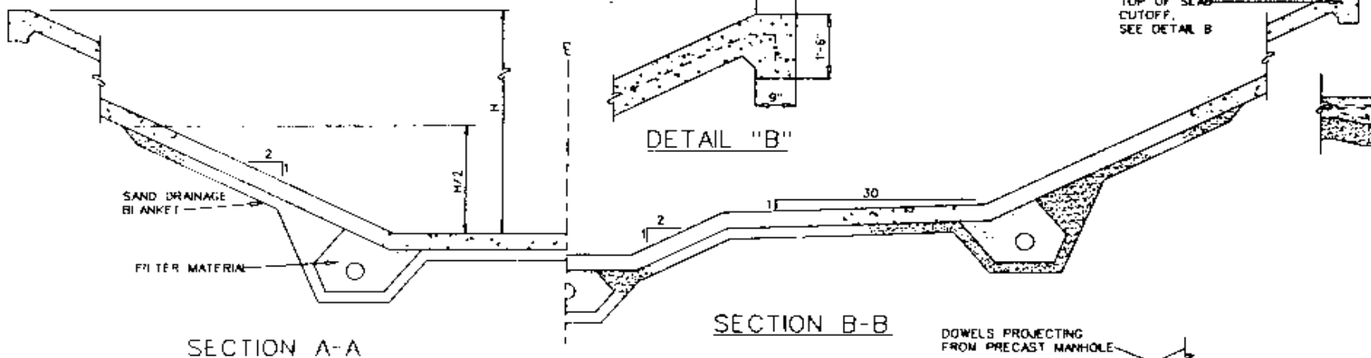


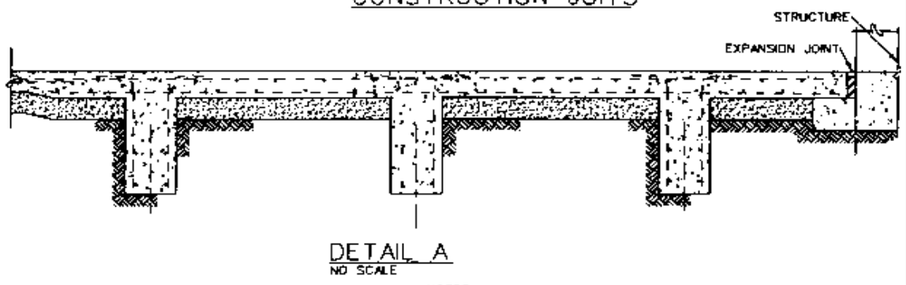
CHANNEL WITH PILOT CHANNEL
NO SCALE



TRANSVERSE LONGITUDINAL

CONSTRUCTION JOITS

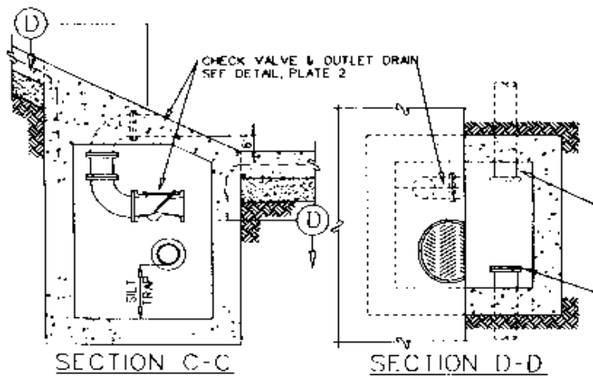




DETAIL A
NO SCALE

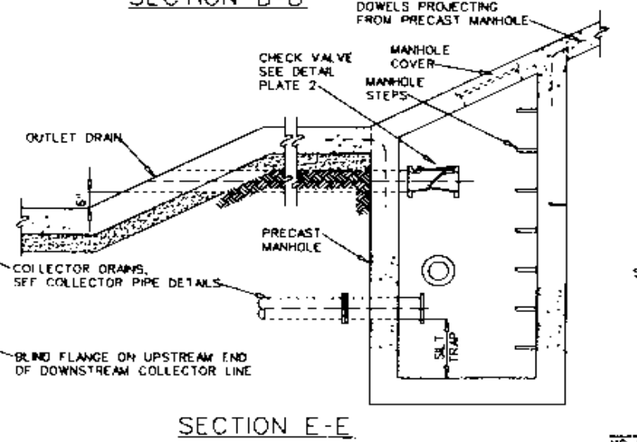
NOTES:

1. FOR OUTLET AND INLET DETAIL SEE PLATE 2
2. FOR DETAILS OF PENETRATIONS IN CONCRETE LINED TRAPEZOIDAL CHANNELS, SEE PLATE 2.
3. POLYETHYLENE FOAM FILLER, "PLASTAZONE" OR APPROVED EQUAL. DO NOTE ANCHOR WITH NAILS OR BONDING AGENT, KEEP IN PLACE WITH FREXH CONCRETE. DO NOT ALLOW FRESH CONCRETE BETWEEN FILLER AND PREVIOUSLY PLACED CONCRETE.
4. CONTINUOUS GALVANIZED PLATE
5. CONTINUOUS GALVANIZED ANGLE WITH HEADED STUDS.
6. LOW DENSITY POLYETHELENE BEARING PLATE ATTACHED TO LOWER SLAB WITH ADHESIVE. COMPACT SOIL TO TOP PLANE OF PLATE.
7. SEE FIGURE 3-6 OF TM 5-825-3 FOR DETAIL OF EXPANSION JOINTS
8. SEE PLATE 2 FOR COLLECTOR PIPE DETAILS

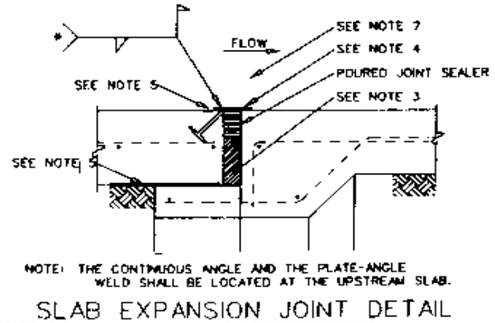


SECTION C-C

SECTION D-D



SECTION E-E



NOTE: THE CONTINUOUS ANGLE AND THE PLATE-ANGLE WELD SHALL BE LOCATED AT THE UPSTREAM SLAB.

SLAB EXPANSION JOINT DETAIL
NO SCALE

EM 1110-2-2007
FLOOD CONTROL CHANNELS CONCRETE LINED TRAPEZOIDAL CHANNELS TYPICAL DETAILS
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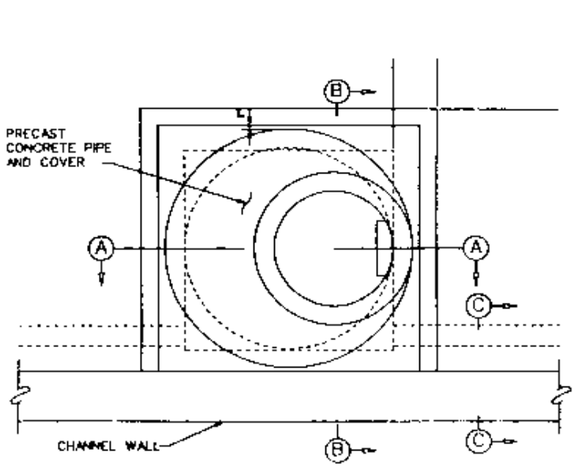
PLATE 1



PLAN MANHOLE
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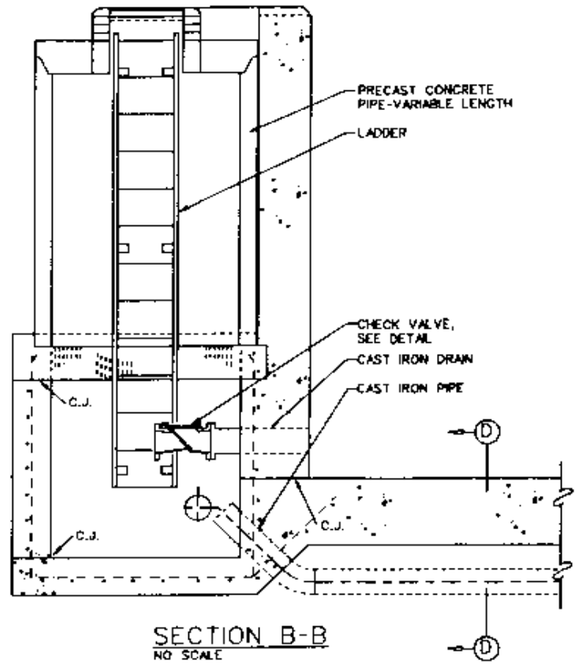

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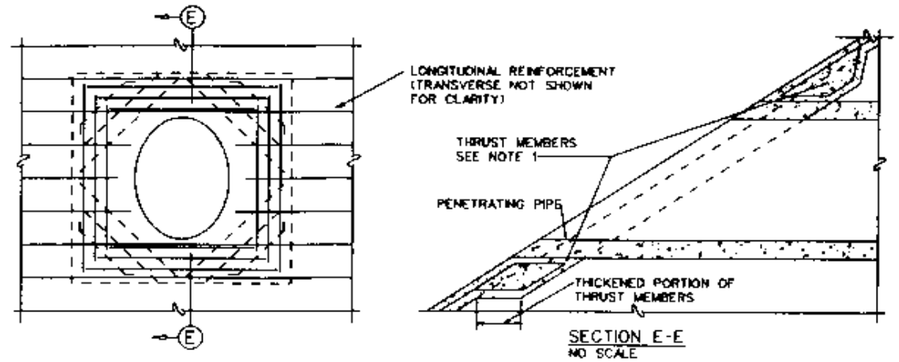

SECTION E-E
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0.6 TO 1.2m (2 TO 4 ft) PENETRATIONS
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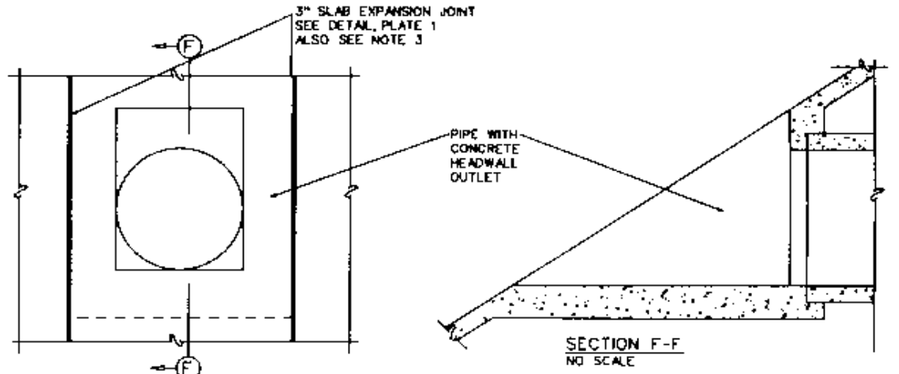
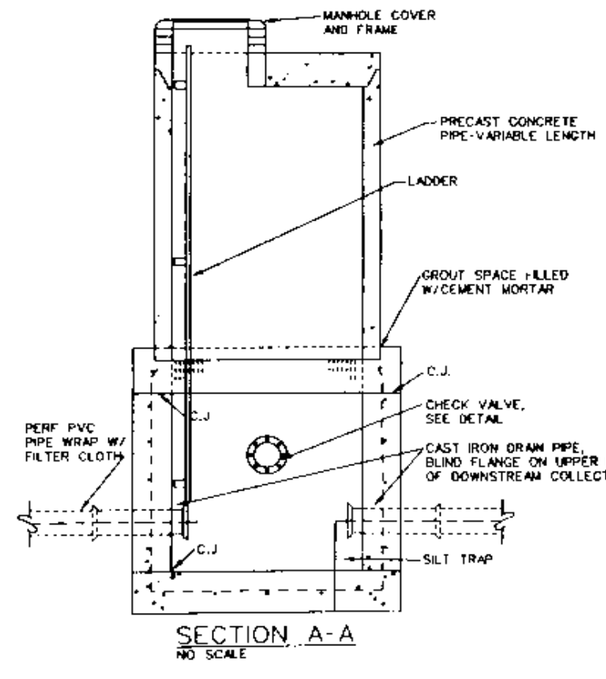


SECTION F-F
NO SCALE

PENETRATIONS > 1.2m (4ft)
NO SCALE

PENETRATION DETAILS
CONCRETE LINED TRAPEZOIDAL CHANNELS



SECTION A-A
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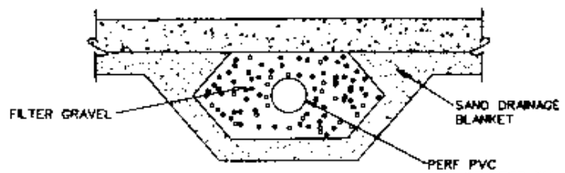

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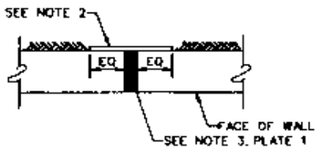
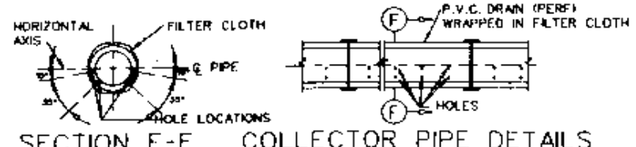
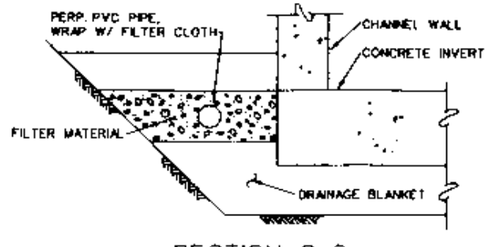


WALL EXP. JT. (F)
NO SCALE



SECTION F-F
NO SCALE

COLLECTOR PIPE DETAILS
NO SCALE



SECTION C-C
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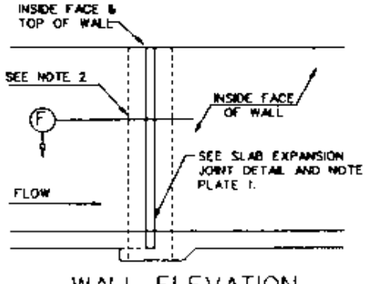
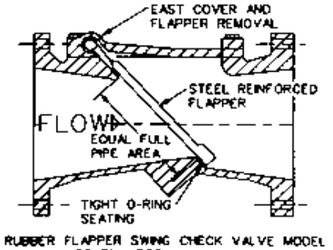


WALL ELEVATION
NO SCALE



RUBBER FLAPPER SWING CHECK VALVE MODEL 106.1 AS MFD. BY APCO VALVE AND PRIMER CORP SCHAUMBURG, IL

OUTLET & INLET VALVE DETAIL
NO SCALE

NOTES:

1. THE AREA OF CONCRETE AND REINFORCEMENT IN THE THICKENED PORTION OF THRUST MEMBERS SHOULD BE ≥ 1.5 TIMES THE AREAS DISCONTINUED BY THE PENETRATION.
2. LOW DENSITY POLYETHELENE PLATE.
3. EXPANSION JOINTS EXTEND ACROSS FULL WIDTH OF CHANNEL PAVING.

EM 1110-2-2007
FLOOD CONTROL CHANNELS
CONCRETE LINED
RECTANGULAR CHANNELS
TYPICAL DETAILS

DEPARTMENT OF THE ARMY
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WASHINGTON, D.C.

PLATE 2