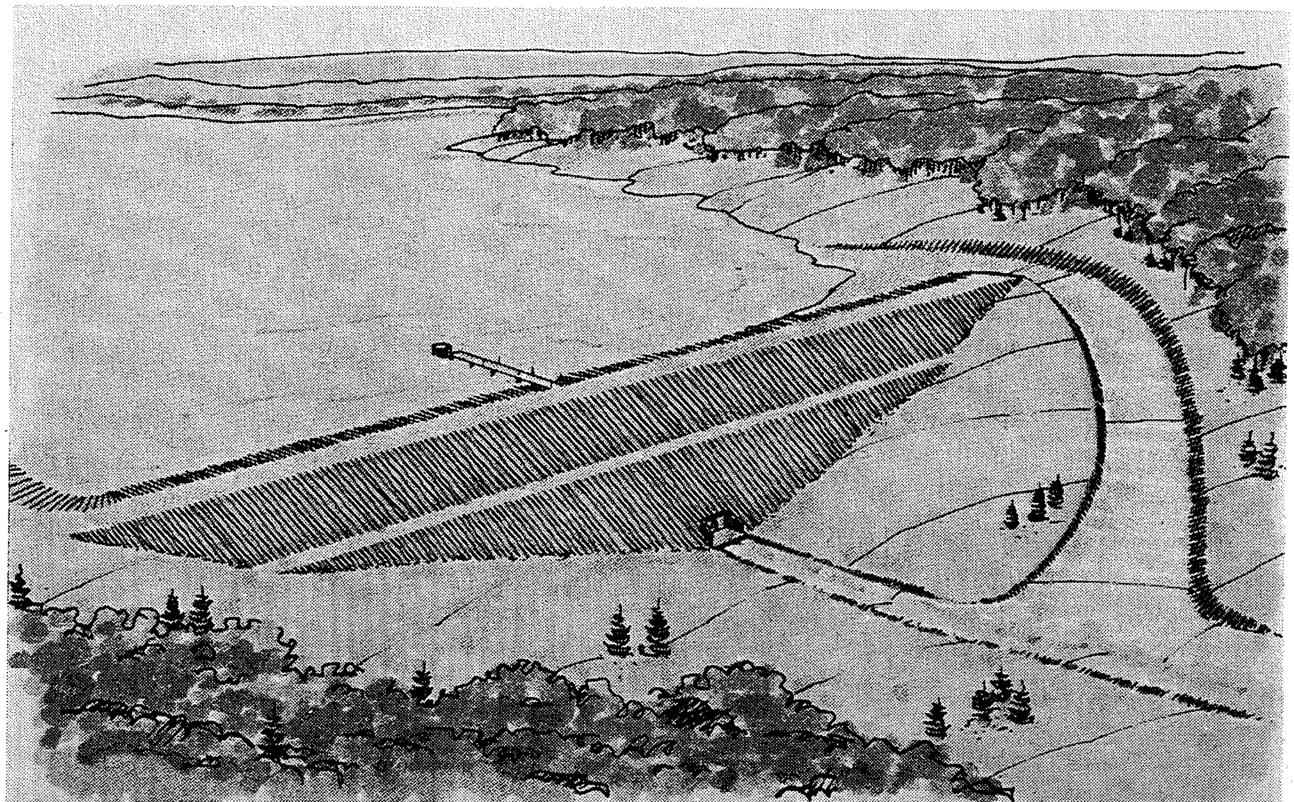

# Dam Safety Guidelines

## Part IV:
## *Dam Design and Construction*

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

July 1993
92-55D

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## 3.3.B CONDUIT SEEPAGE CONTROL - FILTER-DRAIN DIAPHRAGMS

### 3.3.B.1 OBJECTIVE:

Provide a reliable, low cost, easily constructed, measure to address seepage and piping concerns along conduits.

### 3.3.B.2 REQUIREMENT:

All low level, outlet conduits embedded within the soil phase of the embankment or foundation shall be provided with filter-drain diaphragms.

### 3.3.B.3 ENGINEERING CONCERNS:

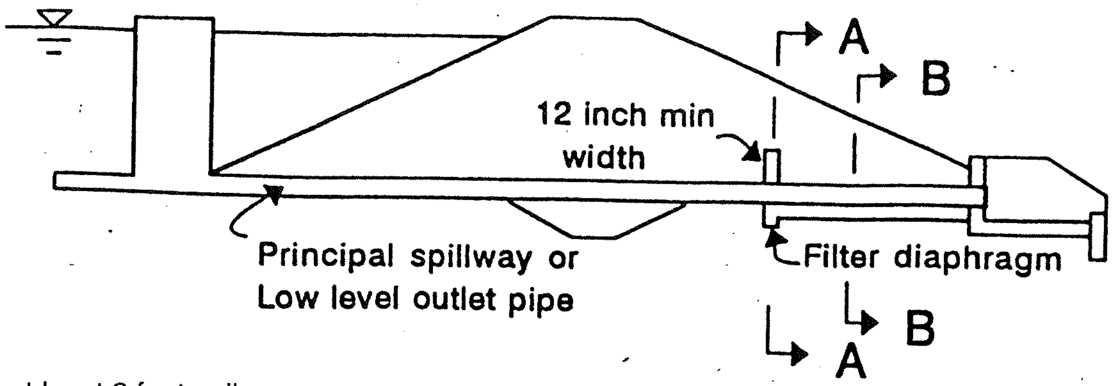
Seepage along conduits pose two principal problems. The first class of problems arise from wetting of the soils. The seepage saturates a portion of the embankment around the pipe, increasing forces tending to cause movement while reducing the resistance of the soils to such movement. Typically, this seepage produces only shallow surficial slides in the immediate area of the pipe outfall. The seepage is more of a nuisance than a significant threat to the integrity of the dam. The water frequently ponds around the pipe outfall, where it fosters the growth of a thick vegetative zone. This vegetation inhibits inspection and attracts burrowing animals. Infrequently, the volume of seepage can precipitate deeper slides that require prompt attention to prevent further sliding or "piping" that could conceivably breach the impoundment.

The second class of problems is associated with seepage eroding soils supporting the pipe. The loss of subgrade support for the pipe can cause joints to open or damage seals between pipe sections. This concern underlies the DSS requirement that conduits be encased in concrete when the dam height exceeds 15 feet. This policy effectively minimizes this problem as a threat to dam integrity.

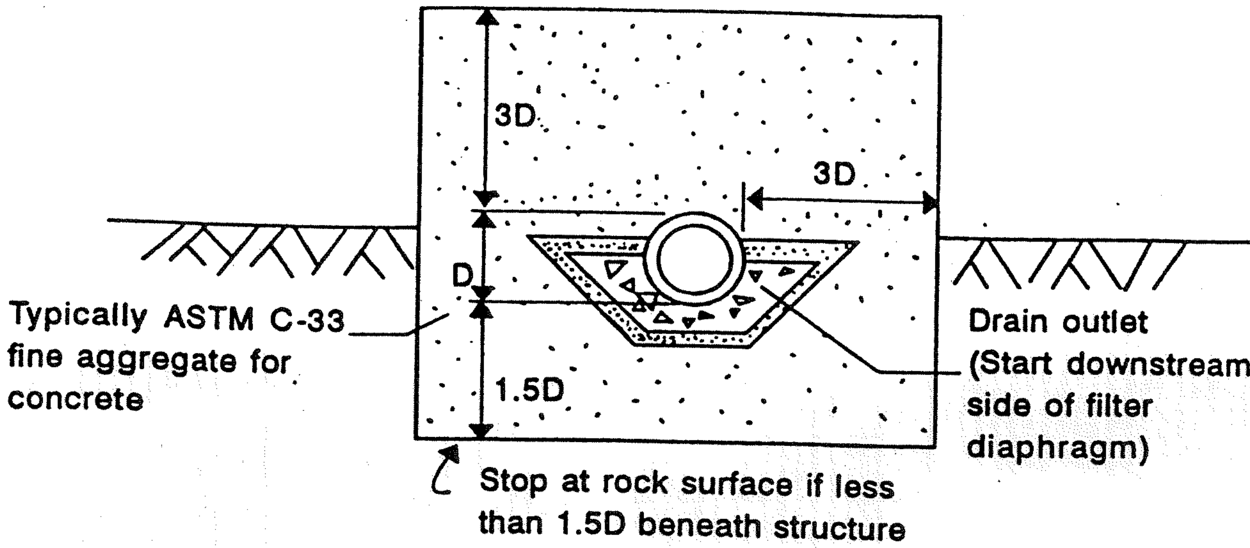
### 3.3.B.4 DESIGN APPROACH:

**Past Engineering Practice** - A series of metal or concrete collars were placed at intervals around the pipe. Their purpose was to lengthen the seepage path water must follow as it moves along the exterior of the pipe. The "rule of thumb" was to provide a sufficient number of collars to increase the seepage path by 20 to 30% over the actual pipe length.[1] There has been a growing recognition that this approach was only marginally successful at addressing the problem in many cases. The poor performance of collars is believed due in a large measure to the low level of compaction achieved along the pipe. The collars limited the segments of the pipe wherein it was feasible to operate highly efficient, self-propelled compactors up to the sides of the pipe. Much of the compaction had to be accomplished with less effective, hand operated compactors that could get into narrow confined areas.

**Recommended Practice** - The designer should take all reasonable precautions to minimize seepage along conduits. This normally involves foregoing the cutoff collars. Instead, low permeable

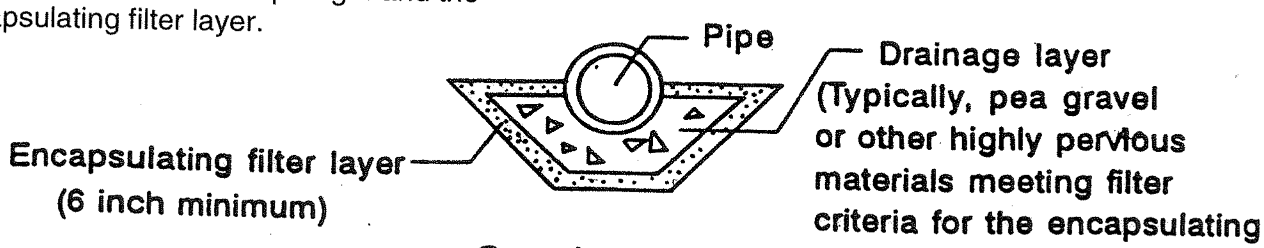



Maintain at least 2 feet soil cover, may limit height above pipe to less than 3 D.




## Section A-A

Use ASTM C-33 or WSDOT 9-03.1(2)B sand for both the filter diaphragm and the encapsulating filter layer.




## Section B-B

Note:
Example shown is for illustrative purposes only. Section view drawings are <u>not to scale</u>. Lead-out drain may be located beneath or along side the outlet pipe. Shapes of lead-out drain pea gravel core and sand filter layer are arbitrary, select for ease of construction.

**Note: Figure prepared with minor modifications from conceptual details in Talbot and Ralston[2].**

bedding and backfill zones are provided along the reach of the pipe passing through the low permeability zone of the dam. Where the pipe will be concrete encased, the sidewalls of the pipe encasement should be battered inward to facilitate operating heavy compaction equipment up against the encasement. Having minimized seepage, the designer then needs to provide a suitable feature to intercept any seepage that bypasses upstream control measures. In our experience this can effectively be accomplished by providing a filter-drain diaphragm.

The filter-drain diaphragm scheme was developed by the Soil Conservation Service (SCS). The principle elements of the SCS scheme are shown in Figure 1. This figure is a derivative of a drawing included in an article by James Talbot and David Ralston[2] of the SCS. The diaphragm consists of a zone of sand and gravel orientated perpendicular to the pipe. The sand and gravel gradition is selected to satisfy filter criteria for the soils immediately upstream. A pervious drain is normally provided beneath the pipe from the downstream side of the diaphragm to the discharge point at the embankment toe. The pervious drain functions to both provide a pipe bedding zone and to carry off any seepage. The pervious drain normally has to be fully encapsulated with a graded filter to minimize the intrusion of fines into the drain.

Where the dam cross-section includes a chimney drain, this feature should functions as a suitable diaphragm. In such cases it is then only necessary to provide a suitable bedding layer and drain for the pipe sections downstream of the chimney drain.

The success of the diaphragm is attributed to number of factors. First, it permits the operation of efficient self-propelled compactors adjacent to the pipe. Second, in the event there is significant seepage along the pipe, the flow generally carries entrained fines plucked from the soil matrix. These fines come to rest on the upstream side of the diaphragm where they form a low permeability "cake". This "cake" then controls the rate of further seepage, dramatically reducing flow volumes.

### 3.3.B.5 REFERENCES:


1. Bureau of Reclamation, Design of Small Dams, 3d Edition, Department of the Interior, p. 474, 1987.

2. Talbot, J.R. and Ralston, D.C., 1985, Earth Dam Seepage Control, SCS Experience, In R.L. Volpe and W.E. Kelly (ed.), Seepage and Leakage from Dams and Impoundments, Proceedings of a Geotechnical Engineering Division Symposium in Denver, Colorado, May 5, 1985. American Society of Civil Engineers. New York, N.Y., p. 59.

TABLE 3

DESIGN MINIMUMS FOR NON-PRESSURIZED CONDUITS
FOR EARTHEN DAMS WITH LOW DOWNSTREAM HAZARD CLASSIFICATIONS
[Design Step Levels 1 and 2]

| ITEM - ISSUE | REQUIRED MINIMUM/DESIGN PRACTICE |
|---|---|
| Minimum Pipe Size[1] | 12 inch diameter for concrete encased pipe, otherwise 15 inch diameter<br><br>Provisions must be available to pass the normal reservoir inflow during periods of high runoff while still pulling the reservoir down within a span of a few days to weeks for inspection, repairs or emergency purposes. This discharge capacity may be obtained from use of the low level outlet and/or from other permanent or temporary hydraulic systems |
| Pipe Gauge or Wall Thickness | Adequate to account for anticipated construction and service loads, abrasion, long term durability and non-uniform foundation support |
| Pipe Joints | Rubber gasketed joints are required, except for welded pipes<br><br>For corrugated metal pipe, widest available bolted connectors are required |
| Concrete Encasement | Required for pressurized conduits in small dams and for all intermediate and large dams[2] |
| Upstream Control Valve to Regulate Water Releases[3] | Required |
| Atmospheric Vent for Low Level Outlet | Required on all conduits with the exception of pressurized conduits in small dams |
| Filter-Drainage Diaphragm | Required |
| Low Permeability Pipe Bedding Zone | All bedding material upstream of filter-drainage diaphragm must have a permeability less than or equal to that of the surrounding material and must satisfy filter criteria for all adjacent materials |

1 Use straight alignment whenever practicable to facilitate future sleeving of the pipe

2 Pipe cradle scheme considered for non-pressurized pipes in stormwater detention facilities with temporary pools

3 Not required on conduits for drop inlet, culvert spillways or conduits where inflow is regulated by intake structures

TABLE 4

DESIGN MINIMUMS FOR CONDUITS FOR EARTHEN DAMS
WITH HIGH OR SIGNIFICANT DOWNSTREAM HAZARD CLASSIFICATIONS
[Design Step Levels 3 and Greater]

| ITEM - ISSUE | PERMANENT OR SEASONAL POOL | | | TEMPORARY POOL/INTERMITTENT RESERVOIR OPERATION | | |
|---|---|---|---|---|---|---|
| | SMALL DAM | INTERMEDIATE DAM | LARGE DAM | SMALL DAM | INTERMEDIATE DAM | LARGE DAM |
| Minimum Pipe Diameter[1,2,3] | 12" | 12" | 12" | 12" | 12" | 12" |
| Complete Concrete Encasement of Pipe[4] | Required[5] | Required | Required | Required[5] | Required[5] | Required[5] |
| Upstream Shutoff or Control Valve[6] | Required | Required | Required | Required[7] | Required[7] | Required[7] |
| Atmospheric Vent for Low Level Outlet | Required | Required | Required | Required | Required | Required |
| Low Permeability Foundation and Backfill | All earthen materials upstream of filter-drainage diaphragm must have a permeability less than or equal to that of the surrounding material and must satisfy filter criteria for all adjacent materials | | | All earthen materials upstream of filter-drainage diaphragm must have a permeability less than or equal to that of the surrounding material and must satisfy filter criteria for all adjacent materials | | |
| Filter-Drainage Diaphragm | Required | Required[8] | Required[8] | Required | Required[8] | Required[8] |

[1] Use straight alignment whenever practicable to facilitate future sleeving of the pipe

[2] Outlet should be sized to be able to pass the normal reservoir inflow during the high runoff period while still capable of pulling the reservoir down within a span of a few weeks

[3] Pipe gauge or wall thickness adequate to account for abrasion, long term durability and other site-specific concerns

[4] Minimum of 6 inches of reinforced concrete for encasement of pipe section

[5] Pipe cradle in combination with precast reinforced concrete pipe may be used where the design can be justified on the basis of favorable site conditions

[6] Not required for conduits on drop inlet spillways and for conduits where the inflow is regulated by intake structures

[7] May not be required for stormwater detention and other flood control projects

[8] The chimney drain zone (*Section 3.2 Embankment Geometry and Zoning*) generally satisfies this requirement

WATER RESOURCES PROGRAM

DAM SAFETY SECTION

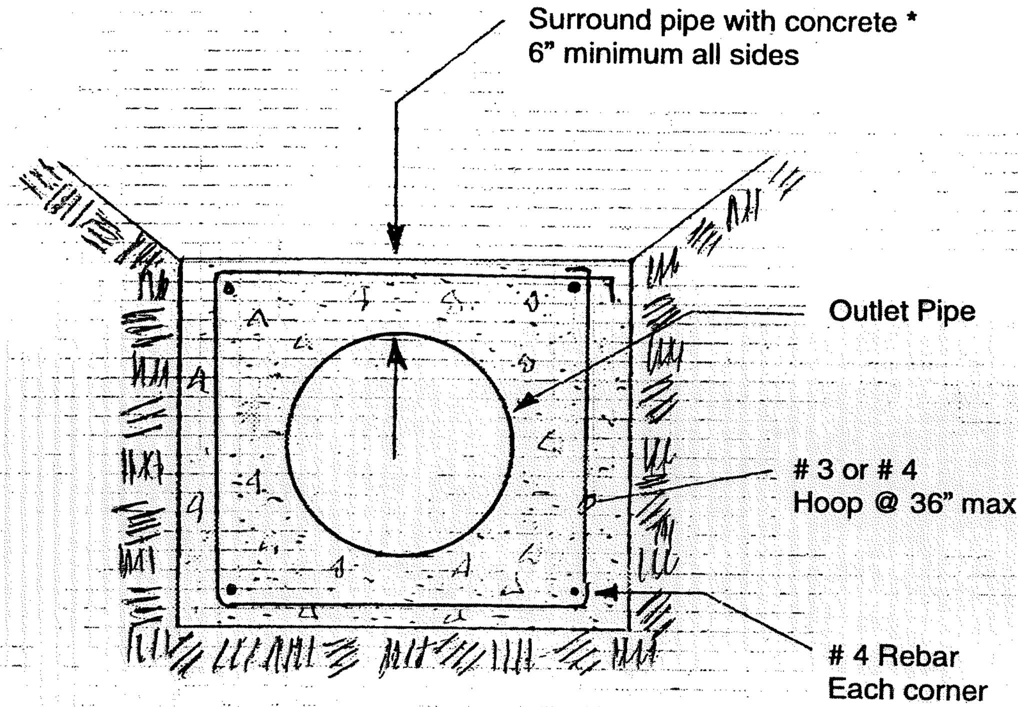
PROJECT ______ FILE ______

SUBJECT ______

INITIALS ______ DATE ______ PAGE ___ OF ___

# CONCRETE ENCASEMENT for Outlet Pipe Upstream from Filter Diaphragm

Schematic Detail, Not to Scale



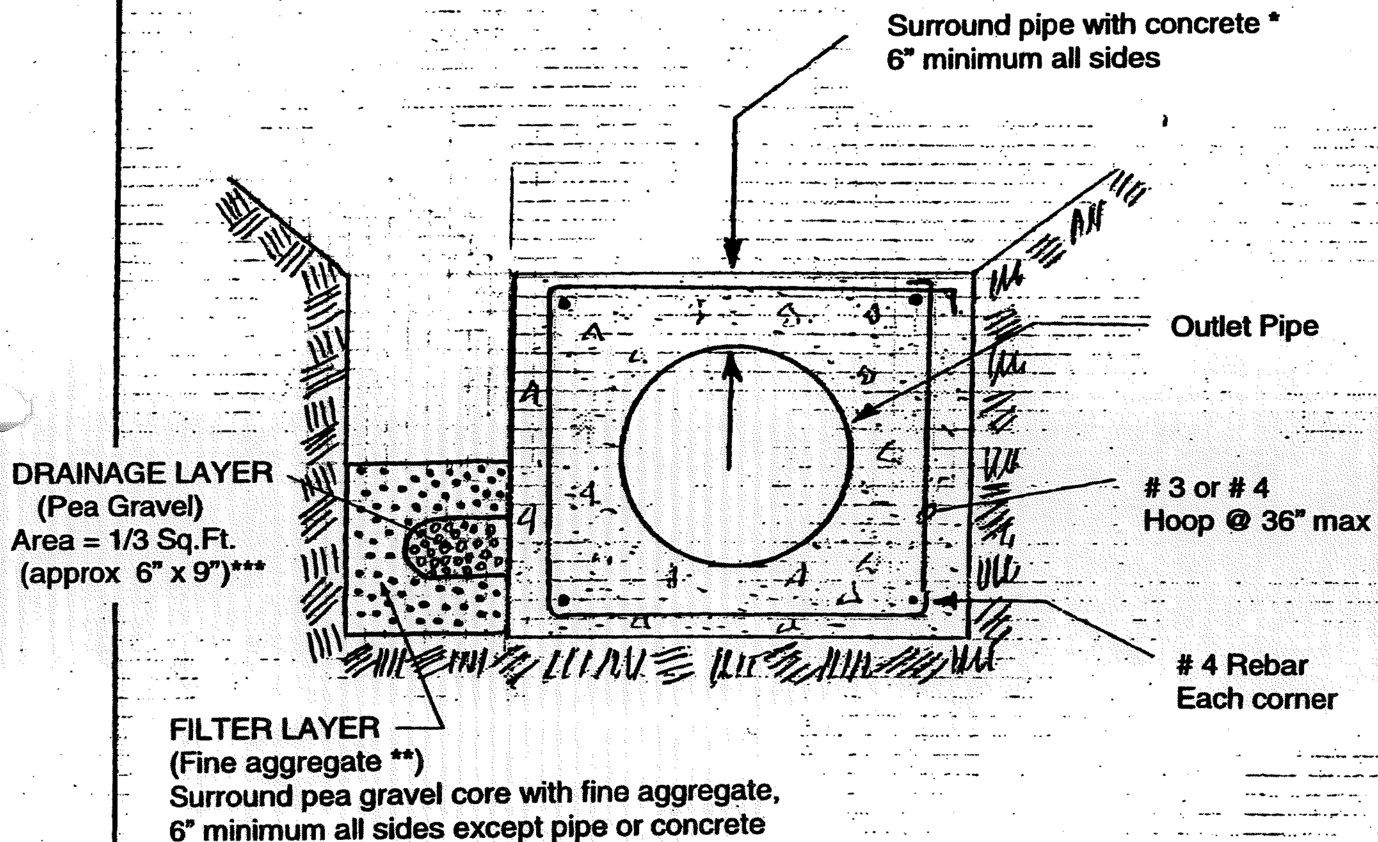

NOTE:

* Concrete: Specify 5 Sack minimum

# CONCRETE ENCASEMENT for Outlet Pipe with LEAD-OUT DRAIN for Filter Diaphragm

Schematic Detail, Not to Scale

(See also Dam Safety Guidelines Part IV, pg. 3-28)




NOTES:

* Concrete: Specify 5 Sack minimum

** Fine Aggregate: ASTM C-33 or WSDOT 9-03.1(2)B Class 1

*** Example is for illustrative purposes only. Shape of pea gravel core cross-section is arbitrary, select for ease of construction.

WATER RESOURCES PROGRAM

DAM SAFETY OFFICE

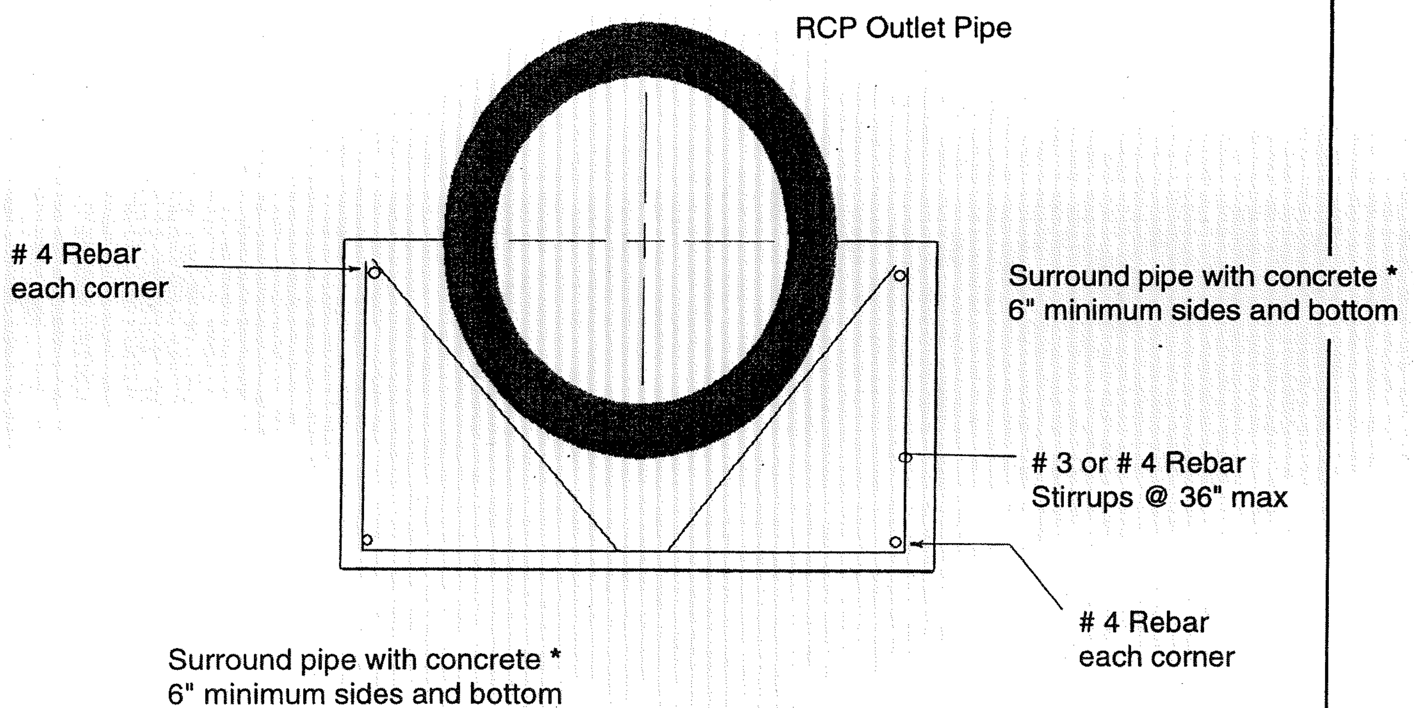
PROJECT ______________ FILE ______

SUBJECT ______________

INITIALS ______ DATE ______ PAGE ___ OF ___

# CONCRETE CRADLE for RCP Outlet Pipe
## Upstream from Filter Diaphragm

Schematic Detail, Not to Scale




NOTE :

* Concrete: Specify 5 Sack minimum

Sample specifications for concrete encasement of conduits

Desired performance of completed work

1. Pipeline acts structurally as a unit. No deflection in pipe, joints or connections due to future differential settlement of overlying embankment material.
2. Interface of pipe and/or concrete with earthen material is not conducive to seepage along the pipeline. Interface with earthen material forms a tight seal on all sides.

Materials

1. Concrete: 5 Sack minimum (5 sacks cement / yard of concrete)
2. Rebar: corners # 4 rebar; hoops # 3 or # 4 rebar @ 36" max

Construction

1. Trench conditions. Pour concrete against firm native soil or compacted embankment material. Remove all loose material from trench. No gravel pipe bedding in trench. (Comment: This provision applies to all concrete structures within the footprint of the dam.) Sides of concrete must be vertical or sloped outward (top to bottom) to allow good compaction of earthen material against these surfaces.

2. Concrete thickness. Surround pipe with concrete 6" minimum thickness all sides. Cover rebar with concrete 2" minimum thickness.

3. Top surface of concrete. Top surface of finished concrete must be relatively smooth to allow good seal of overlying earthen material against the concrete. Eliminate voids or roughness in the concrete and flatten the top surface.

4. Extent of encasement. Encasement must extend to upstream toe and downstream toe of the dam to the point where the thickness of earthen material is less than one foot overlying the top of the finished concrete (or top of pipe for concrete cradle).

Reference: Dam Safety Guidelines, Part IV, Dam Design and Construction, July 1993. See Section 4.1, Low Level Outlet Conduits, pages 4-1 to 4-10. See also Section 3.3.B, Conduit Seepage Control – Filter-Drain Diaphragms, pages 3-27 to 3-30.