Best Practices for Conduits through Embankment Dams

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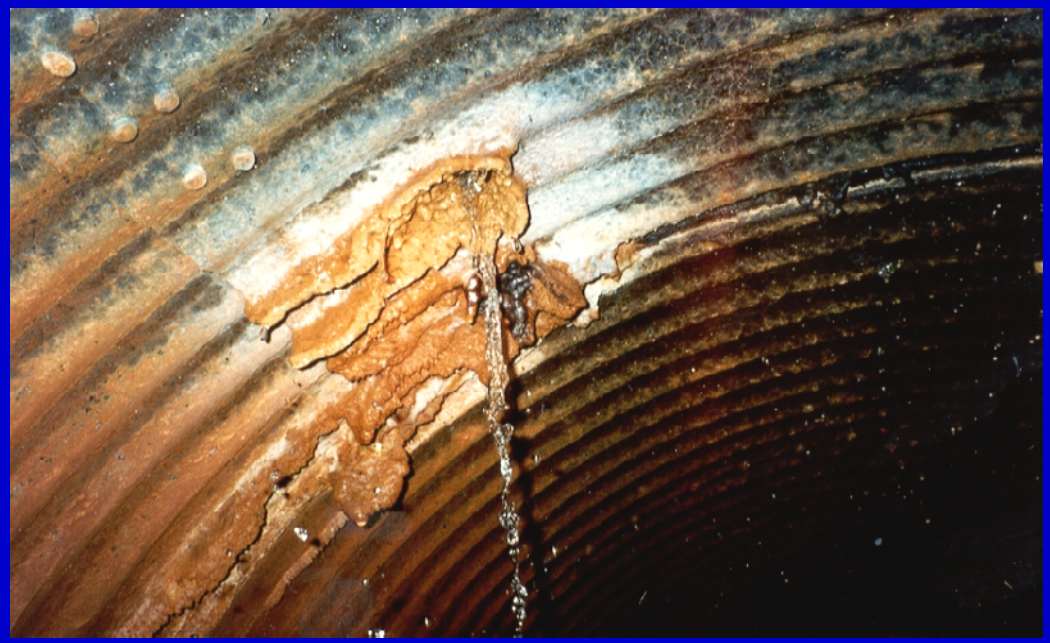
Condition assessment

- Tens of thousands of conduits through embankment dams in the United Sates are aging and deteriorating



Condition assessment

These conduits pose an increasingly greater risk resulting in dam failure with each passing year

Background

- In 1998, a Federal Emergency Management Agency (FEMA) dam safety workshop was held in Blacksburg, VA to discuss internal erosion associated with conduits through embankment dams

Background

- A research initiative was recommended to develop a guidance document for use by dam engineering professionals to address this growing problem

Conduit Guidance Document

Goals:

- Recommend best practices
- Provide detailed experience
- References
- Case histories

Committee members

Association of State Dam Safety Officials (ASDSO)

Bureau of Reclamation (BOR)

Federal Energy Regulatory Commission (FERC)

Natural Resource Conservation Service (NRCS)

U.S. Army Corps of Engineers (USACE)

Acknowledgments

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Topics addressed

- Design and construction
- Problem identification and evaluation
- Inspection
- Maintenance
- Renovation, replacement, repair, and abandonment

General

Conduits are a discontinuity within an embankment dam and can cause:

- Differential settlement of the adjacent earthfill
- Differing compaction around the conduit compared to the rest of the embankment

Discontinuities

Discontinuities can lead to the formation of cracks and other consequences within the embankment dam such as:

- Internal erosion
- Backward erosion piping

Internal erosion and backward erosion piping

- Internal erosion - A general term used to describe all the various erosional processes where water moves internally through an embankment dam

- Backward erosion piping - Characterized by the formation of an open tunnel that initiates at a downstream seepage exit point and progresses back upstream toward the reservoir

Dam failure modes

Internal erosion and backward erosion piping can progress into a number of different modes of dam failure

Dam failure modes

How do conduits contribute to the failure of an embankment dam?

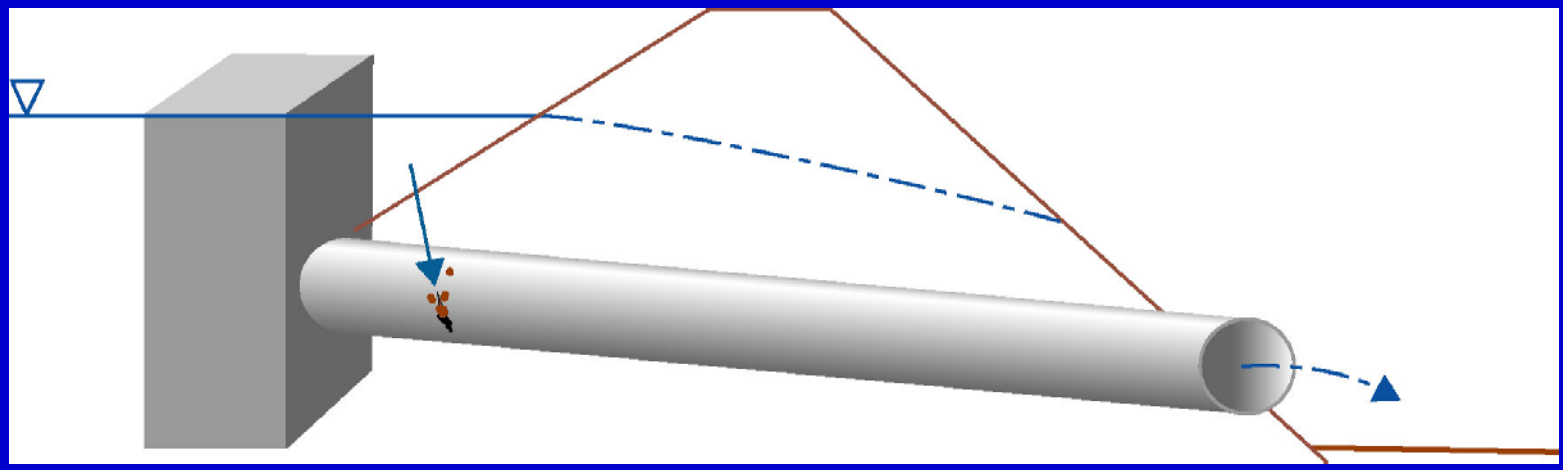
- These failure modes assume no filter protection is provided
- The susceptibility of the embankment to erosion will affect how these failure modes develop

Failure modes associated with conduits

Failure Mode 1: Seepage into a non-pressurized conduit

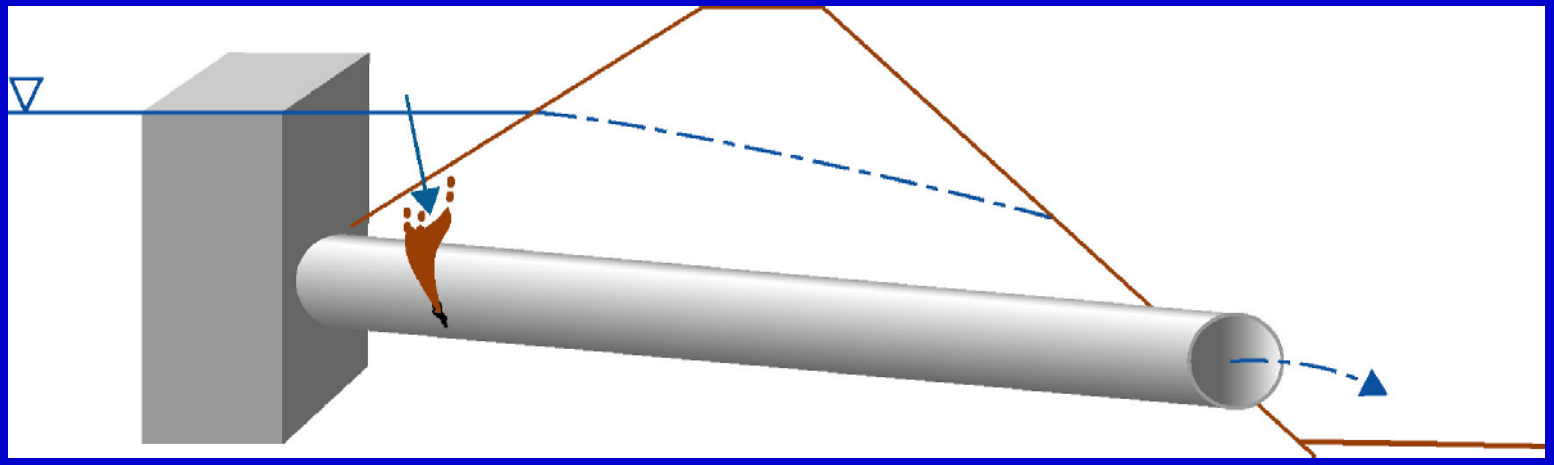
Failure Mode No. 1 - Seepage into a non-pressurized conduit

1. Seepage develops through the dam.



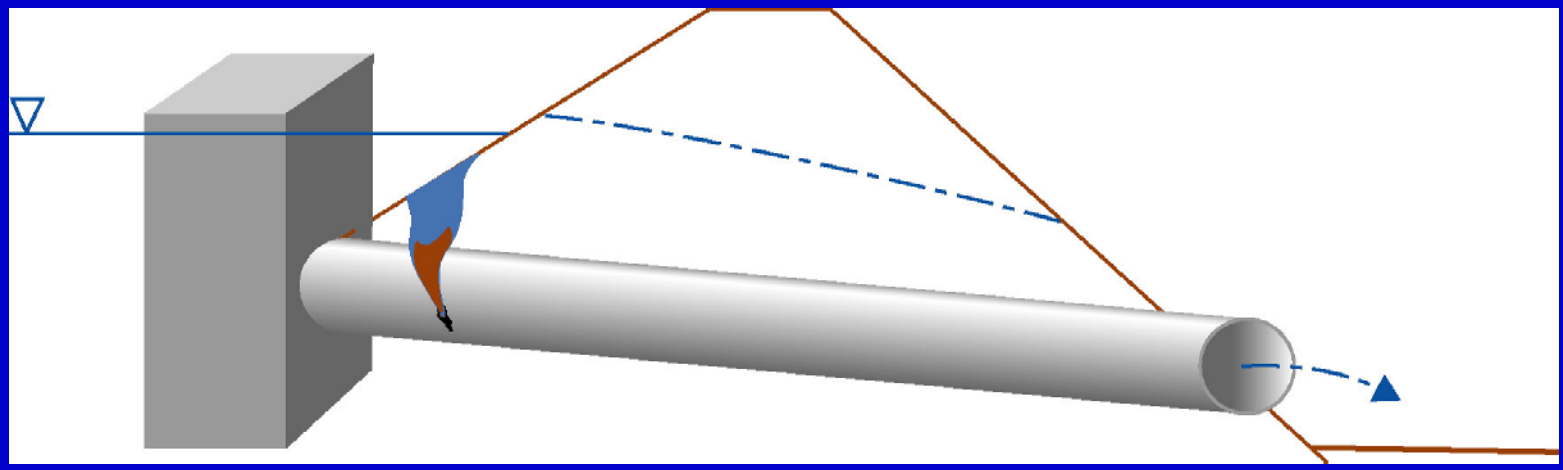
Failure Mode No. 1 - Seepage into a non-pressurized conduit

2. Seepage enters the non-pressurized conduit through a defect.



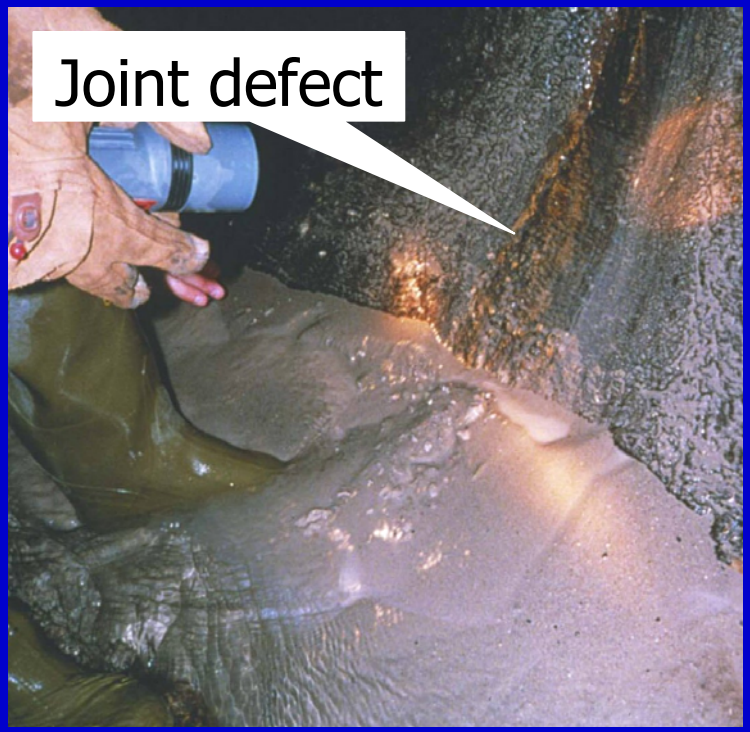
Failure Mode No. 1 - Seepage into a non-pressurized conduit

3. Embankment materials are eroded into the conduit. This can lead to the development of a sinkhole or breach of the dam.



Example of Failure Mode No. 1

Particles of soil have entered the conduit through a joint defect

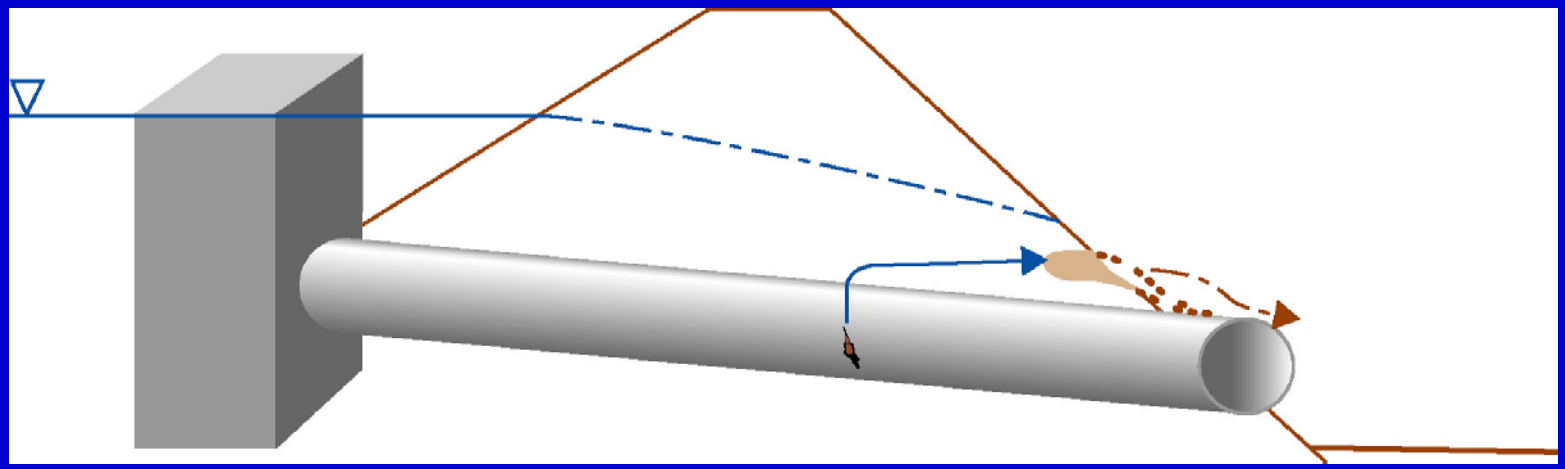


Failure modes associated with conduits

Failure Mode 2: Seepage out of a pressurized conduit

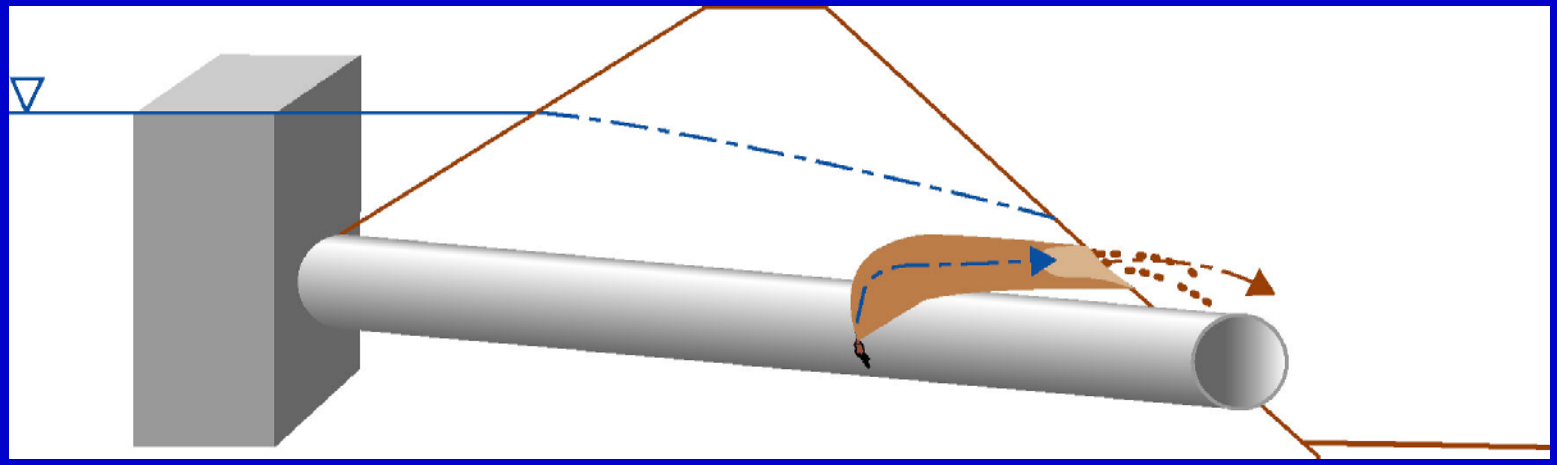
Failure Mode No. 2 - Seepage out of a pressurized conduit

1. Water is forced out of a defect in a pressurized conduit.



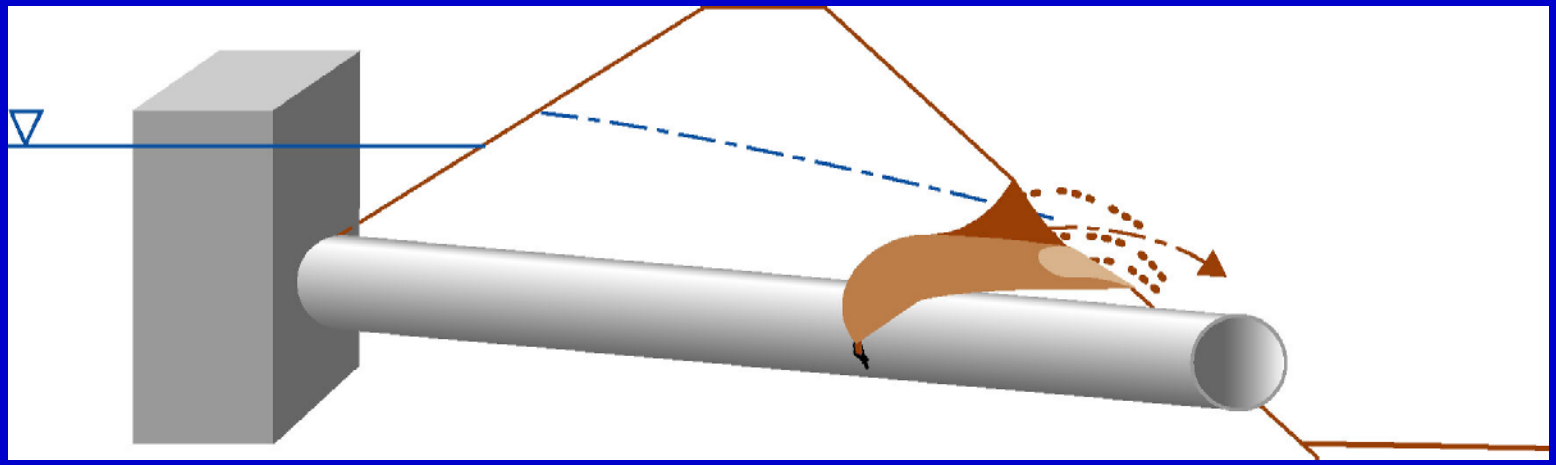
Failure Mode No. 2 - Seepage out of a pressurized conduit

2. Seepage forces carry soil particles to an exit face.



Failure Mode No. 2 - Seepage out of a pressurized conduit

3. Backward erosion piping occurs. This can lead to a breach of the dam.

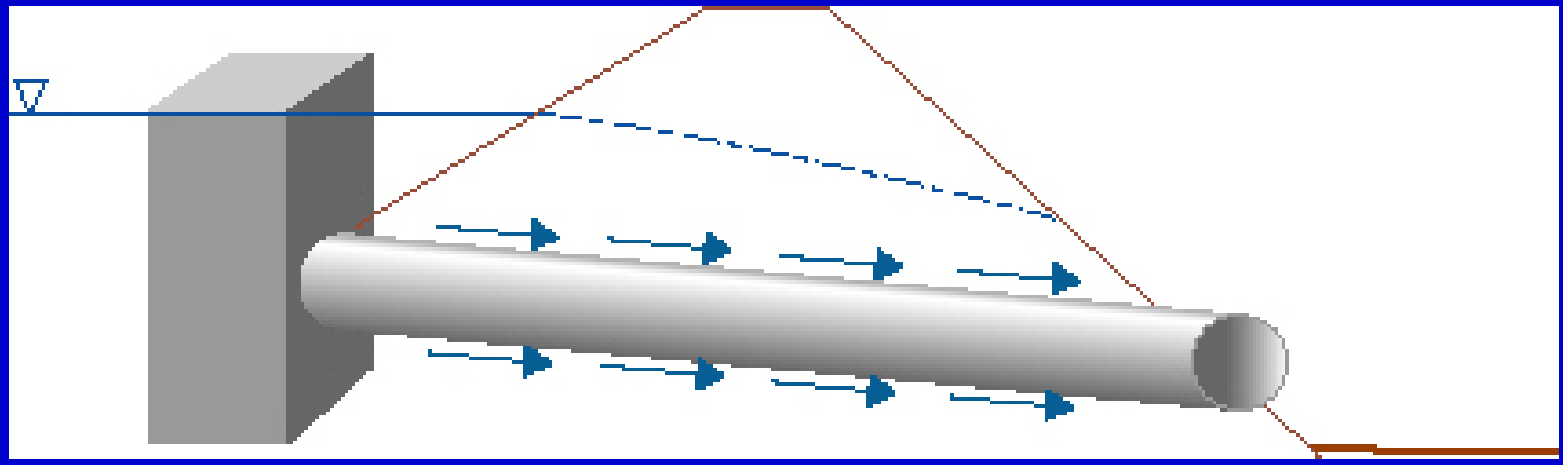


Failure modes associated with conduits

Failure Mode 3: Seepage along the outside of the conduit

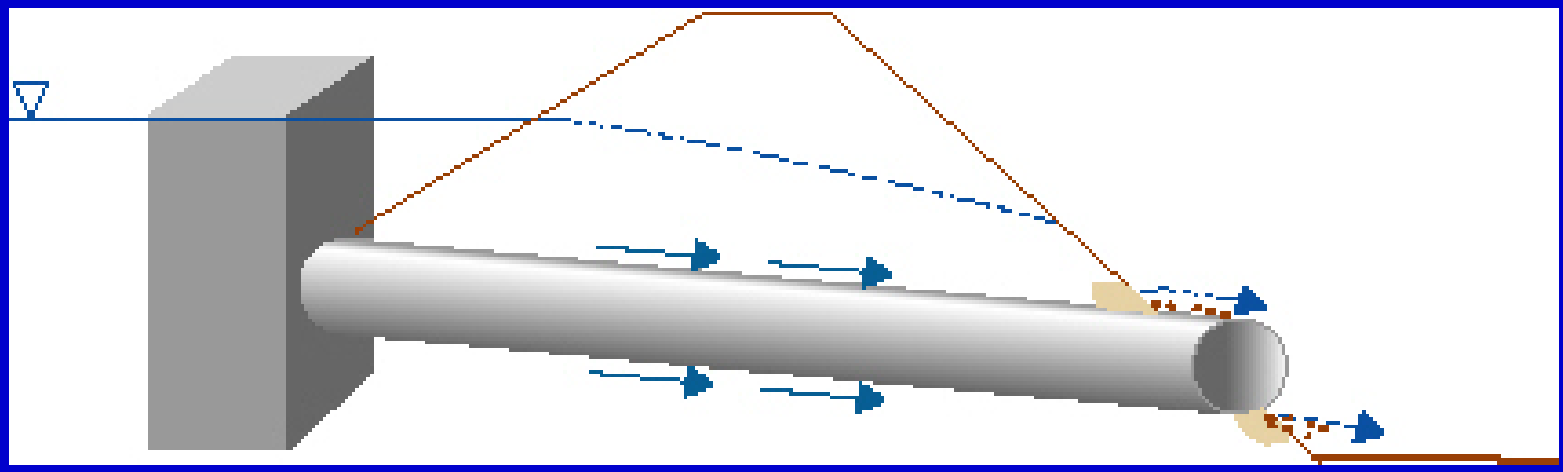
Failure Mode No. 3 - Seepage along the outside of the conduit

1. Seepage develops along the contact between the conduit and surrounding embankment.



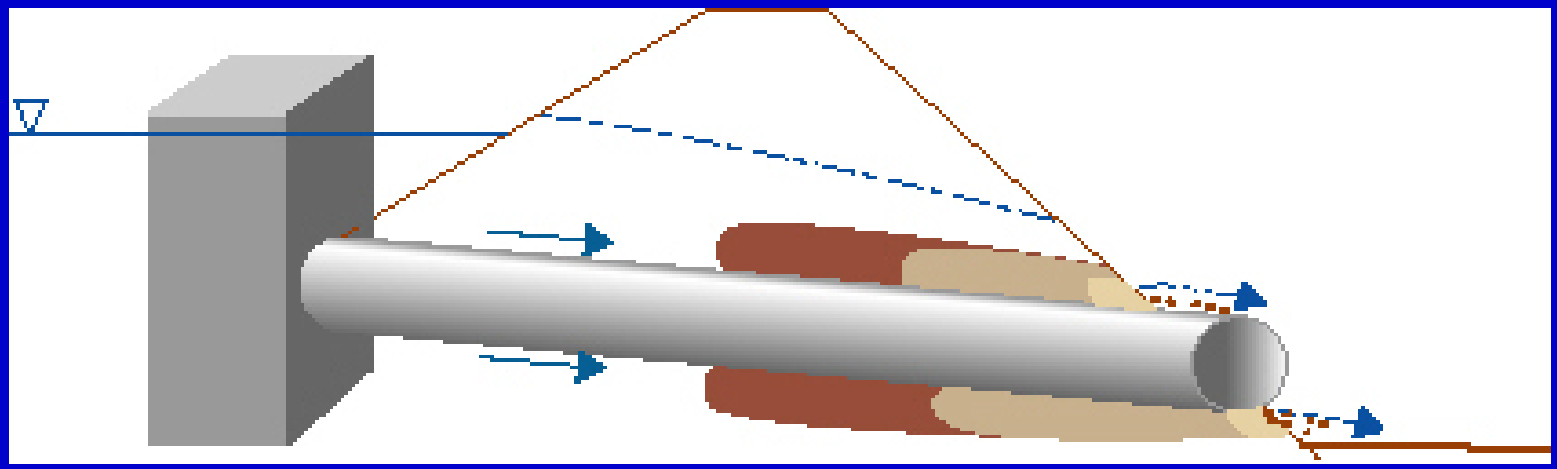
Failure Mode No. 3 - Seepage along the outside of the conduit

2. Seepage erodes soil particles along the flow path.



Failure Mode No. 3 - Seepage along the outside of the conduit

3. Backward erosion piping continues. This can lead to a breach of the dam.

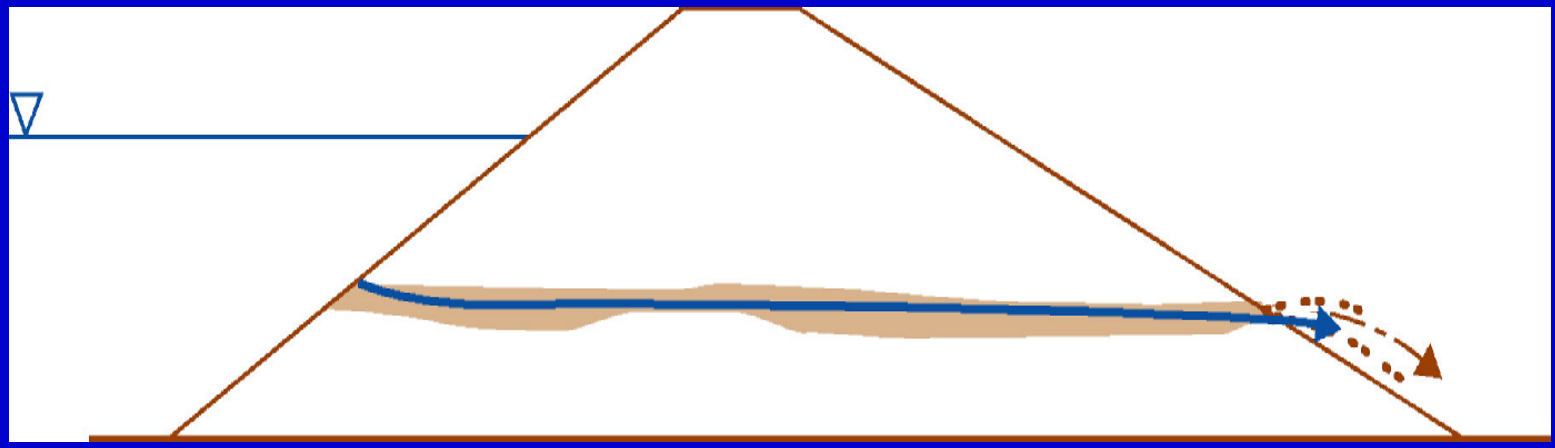


Failure modes associated with conduits

Failure Mode 4: Hydraulic fracture cracks in the earthfill adjacent to the conduit

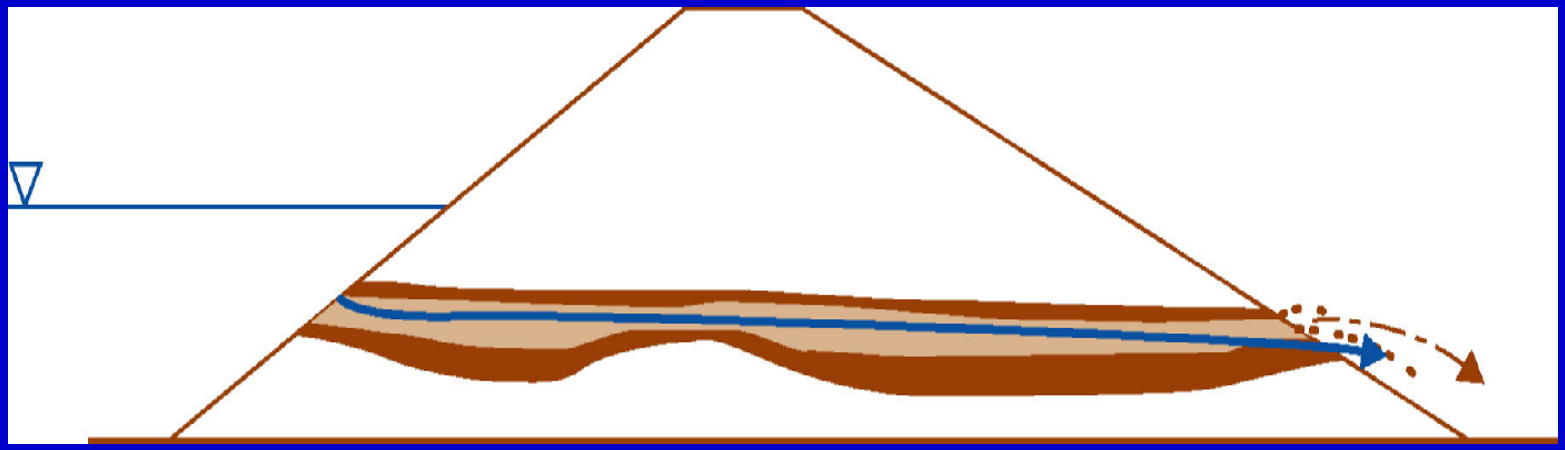
Failure Mode No. 4 - Hydraulic fracture cracks in the earthfill

1. Internal erosion rapidly enlarges a hydraulic fracture crack near the conduit.



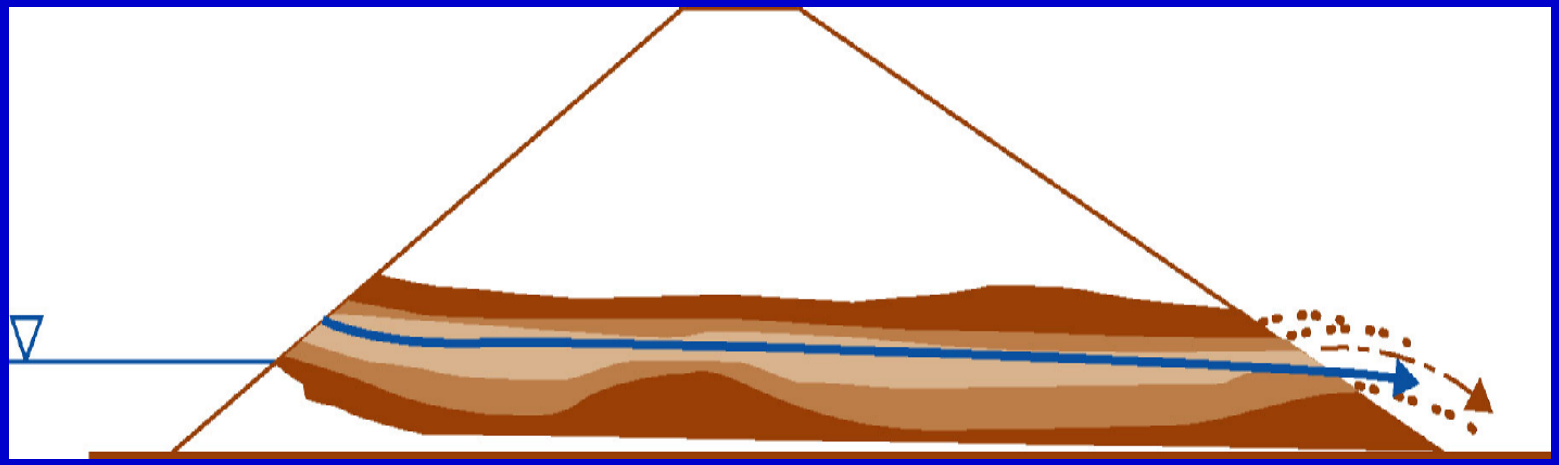
Failure Mode No. 4 - Hydraulic fracture cracks in the earthfill

2. An erosion tunnel develops along the crack.



Failure Mode No. 4 - Hydraulic fracture cracks in the earthfill

3. Continued erosion can lead to a breach of the dam.



Failure Mode No. 4 - Hydraulic fracture cracks in the earthfill

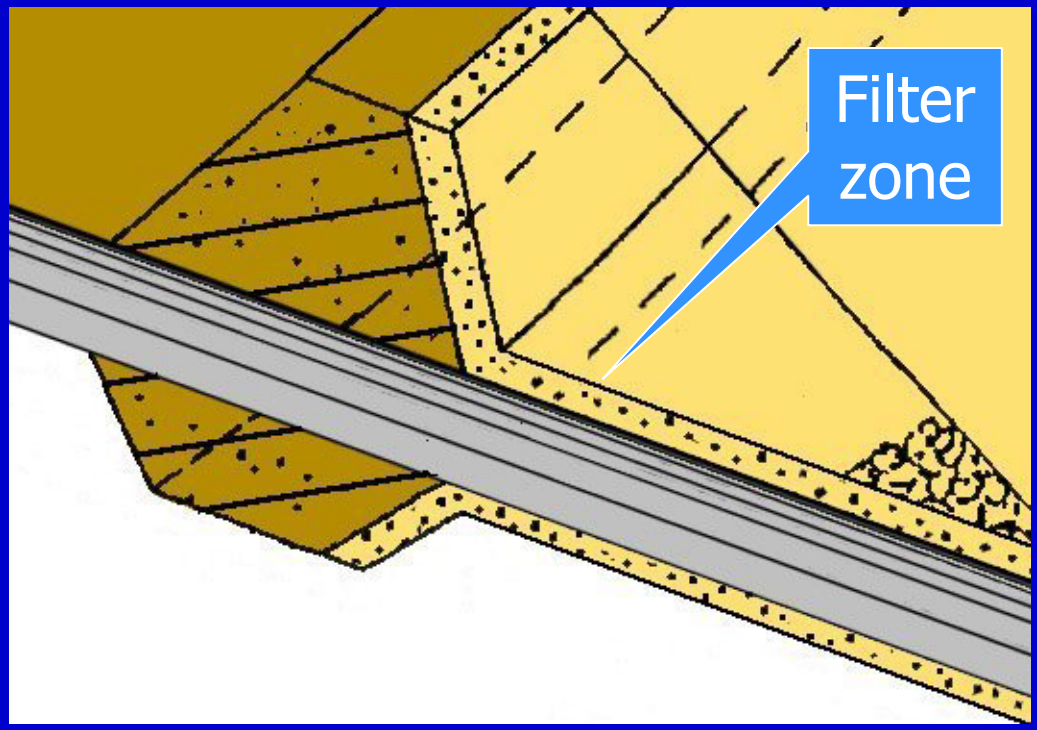
- This dam failed due to internal erosion of hydraulic fracture cracks upon first filling

Defensive measures

Use of antiseep collars was discontinued in the 1980's by most of the major dam building organizations

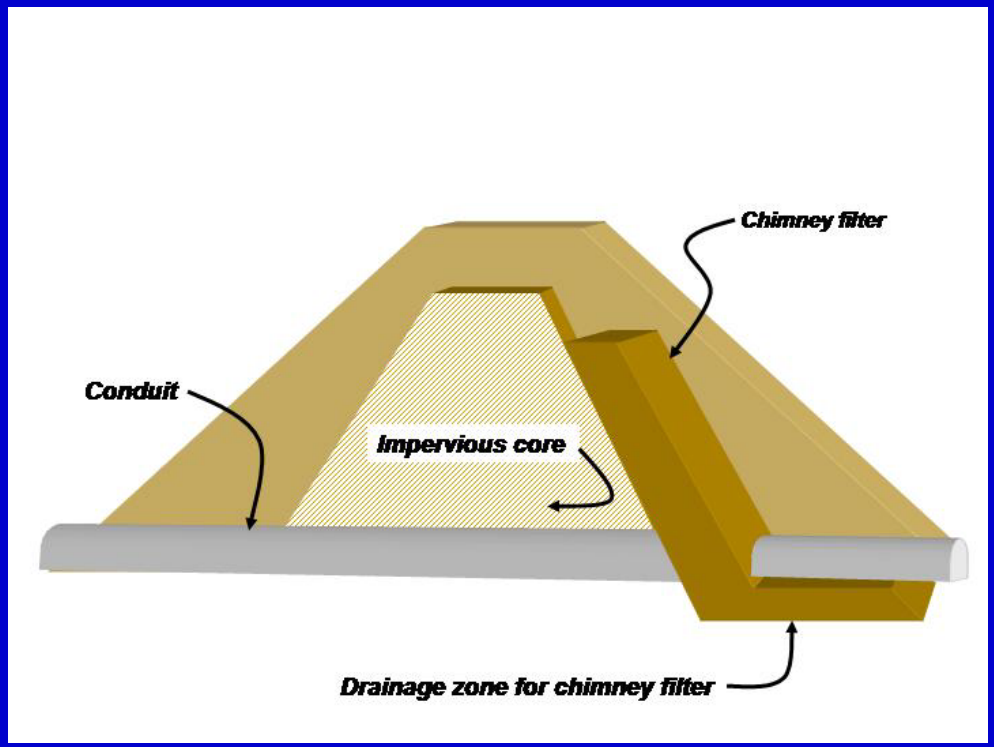
Filter zone surrounding the conduit

A zone of filter material surrounding the conduit is now recommended



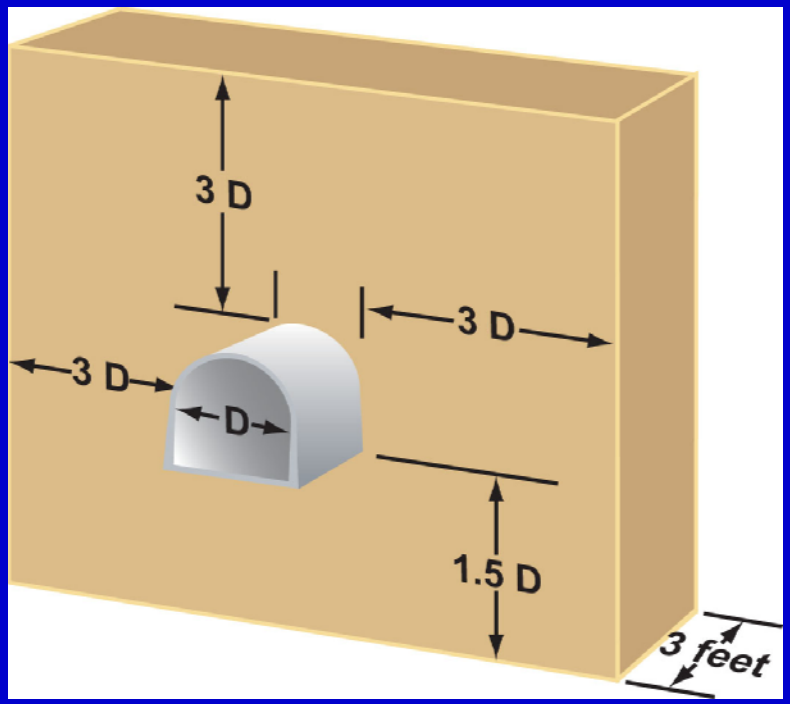
Types of filters used with conduits

- Chimney filter – Used in new construction or extensive renovation



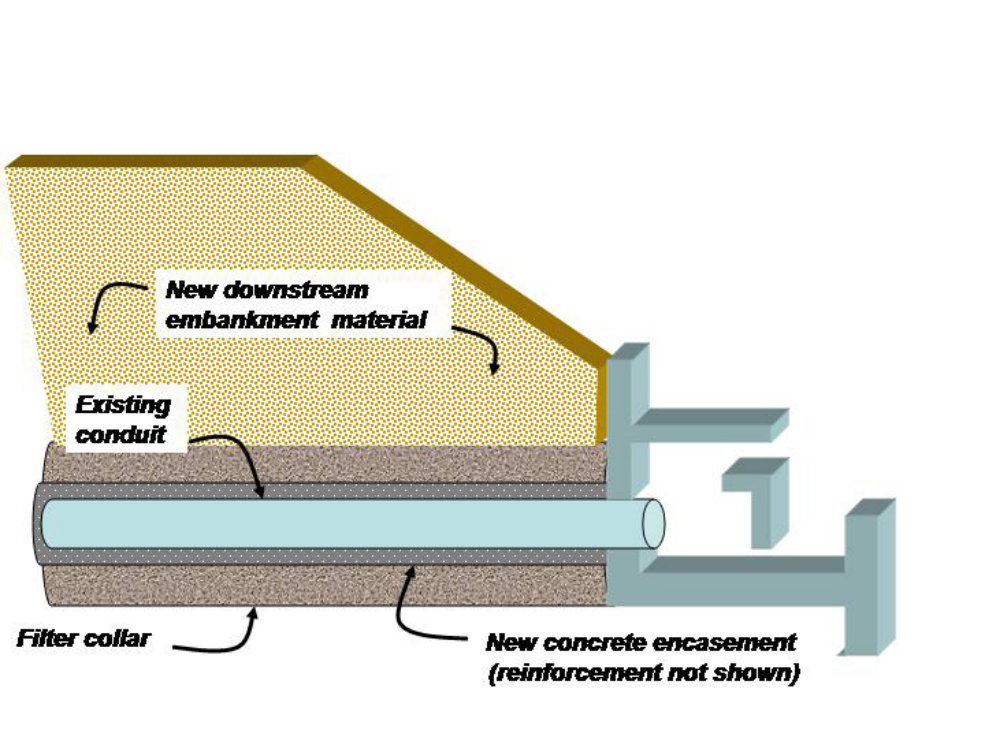
Types of filters used with conduits

Filter diaphragm - Used in new construction or renovation



Types of filters used with conduits

Filter collar – Used in renovation



Conduits

Conduits have been constructed from a variety of materials including:

- Concrete (reinforced cast-in-place, precast)
- Plastic (thermoplastic, thermoset)
- Metal (steel, cast/ductile iron, CMP)

Conduit defects

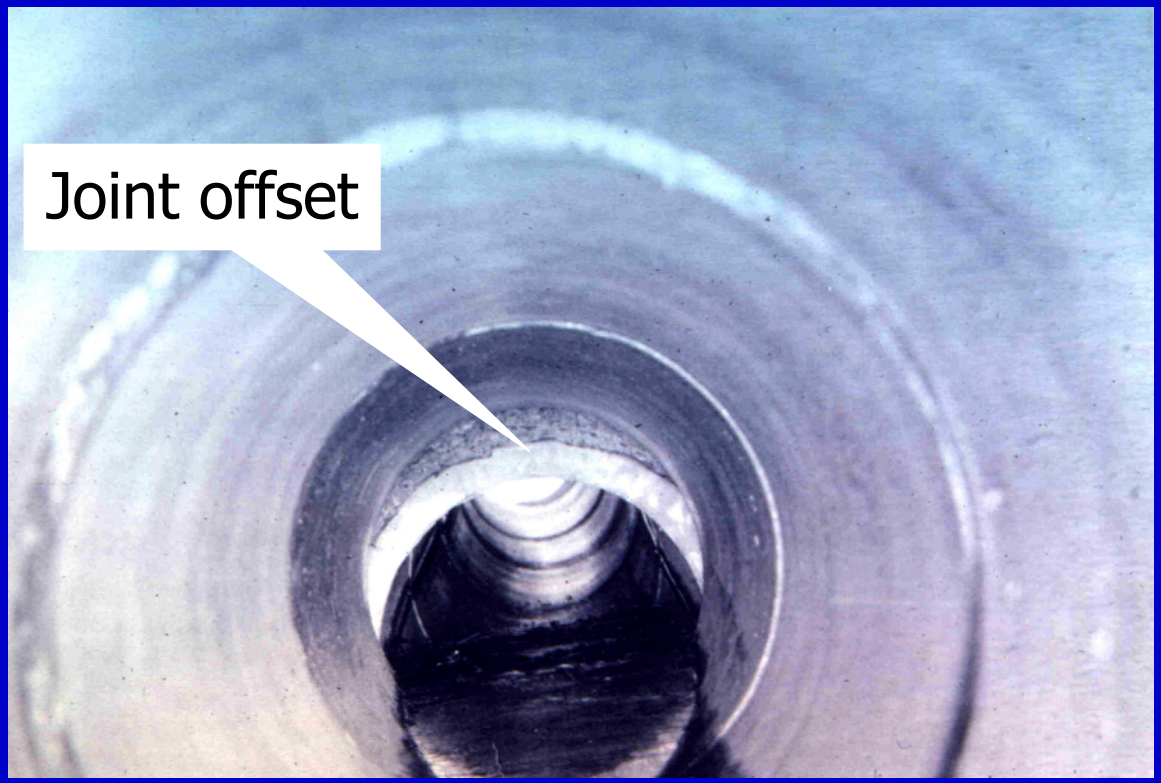
Each conduit material reacts differently within the dam and is subject to a variety of conditions including:

- Deterioration (corrosion, abrasion, aging, cavitation)
- Poor design and construction

Conduit defects - Examples

Corroded CMP

Conduit defects - Examples



Poor design and construction

Common methods of conduit inspection

Man-entry

ROV

Divers

Closed circuit television

Common methods for dealing with problem conduits

- Sliplining
- Remove and replace
- Repair
- Abandonment

Sliplining

High density polyethylene (HDPE) and steel are commonly used

HDPE

Steel

Cured-in-place pipe (CIPP)

Also known as an "elastic sock"

Unloading

Inversion process

Remove and replace

Excavation of the existing conduit

Construction of a new conduit

Repair

Spot repair

Grout injection

Abandonment

Injection of grout into an existing conduit

Outlet works

Best Practices for Conduits through Embankment Dams

The guidance document will be available for free public distribution in the Fall of 2005.

Hard Copy

CD and DVD

Best Practices for Conduits through Embankment Dams

Information on how to obtain a copy of the document will be posted on FEMA's website at www.fema.gov/fima/damsafe/resources

or

Contact Chuck Cooper (Bureau of Reclamation) at ccooper@do.usbr.gov.

Questions