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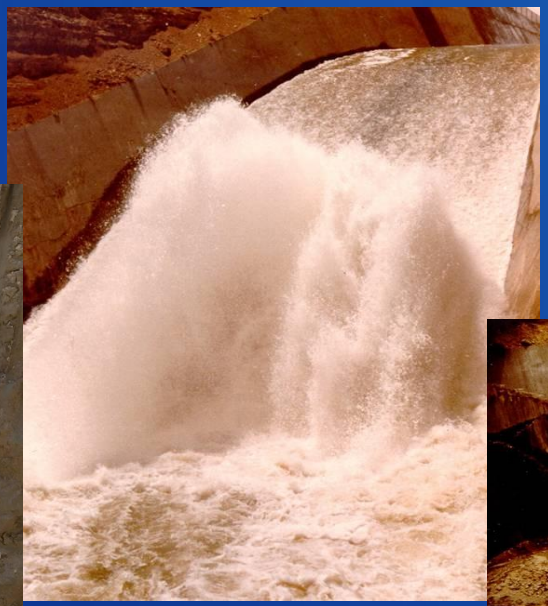
Managing Water in the West

High Velocity Flows Over Spillway Chutes

U.S. Department of the Interior
Bureau of Reclamation

Reclamation Experiences

- **Failures or near failures**
  - **Big Sandy Dam, Wyoming**
  - **Dickinson Dam, North Dakota**
  - **Hyrum Dam, Utah**



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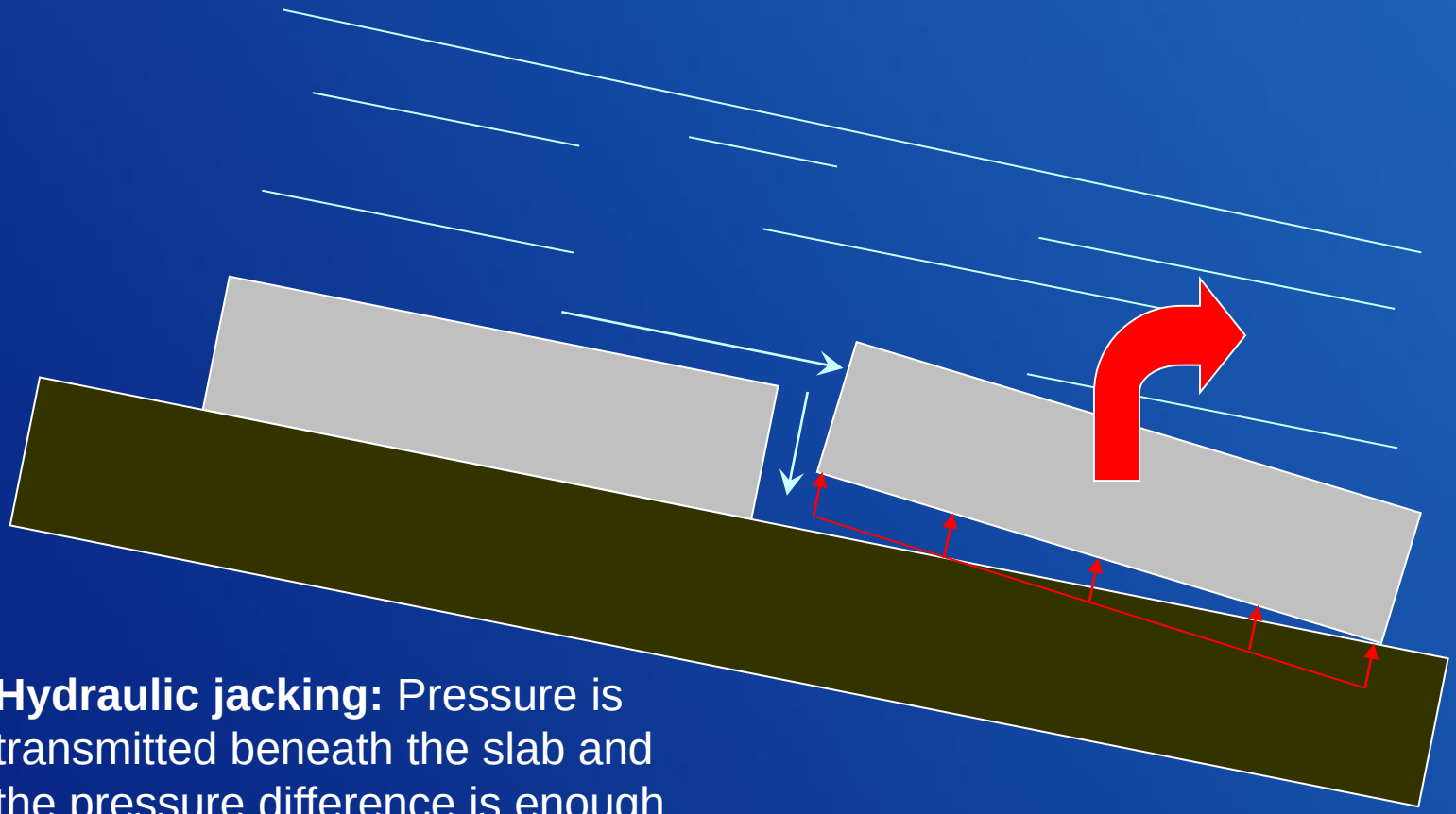
Uplift due to stagnation pressure in spillways



Hydraulic jacking: Pressure is transmitted beneath the slab and the pressure difference is enough to lift (or jack) the slab out of place

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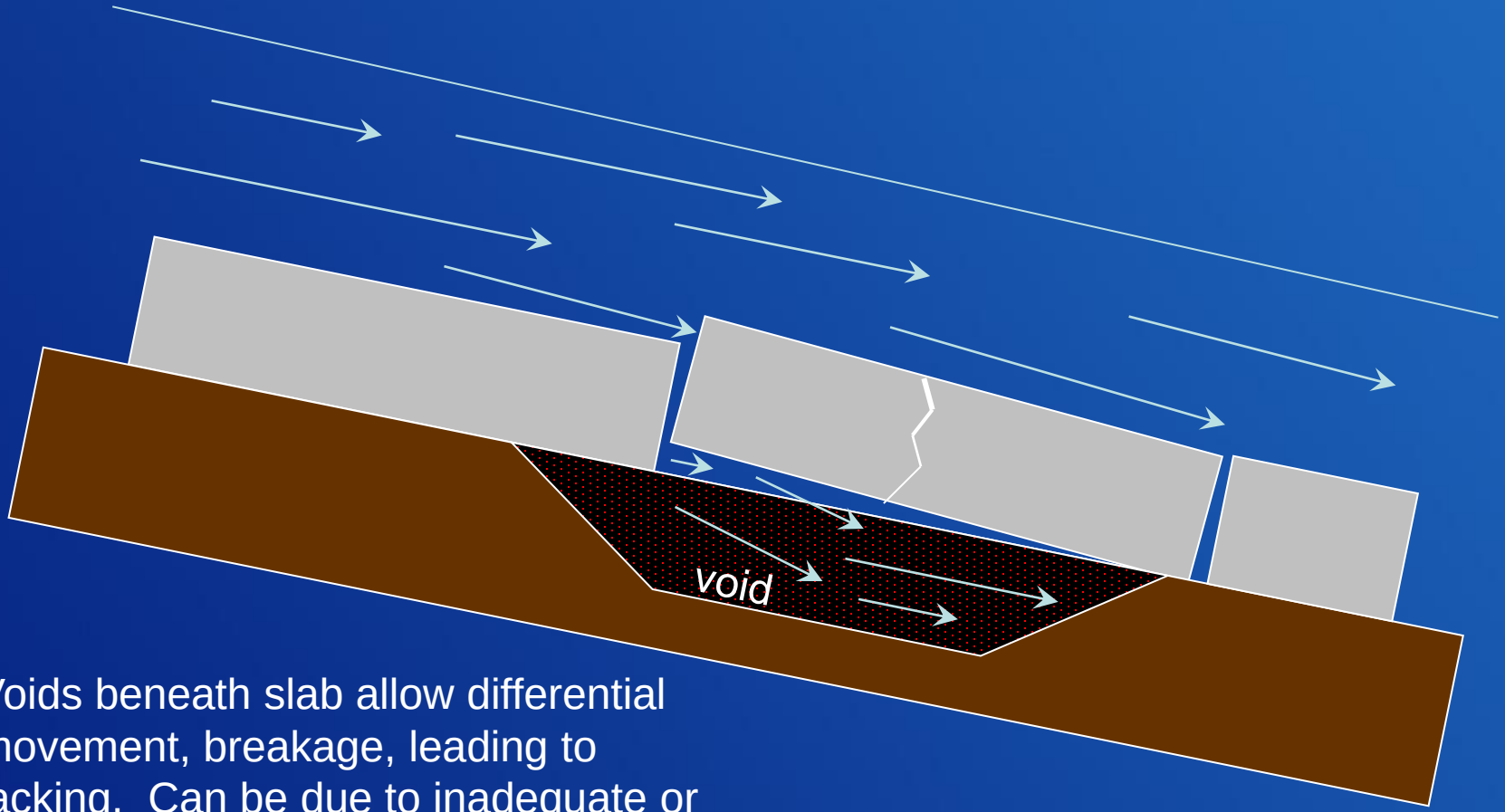
Structural collapse due to erosion of foundation materials



Voids beneath slab allow differential movement, breakage, leading to jacking. Can be due to inadequate or old or damaged underdrain system.

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Collapse into a Void

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Problems Often Begin at Joints

Applicable Studies on Uplift

- Previous studies of steep canal wasteways (Johnson 1976) only went up to velocities of 15 ft/s
  - Extrapolation was needed to cover most dam spillways
- No information on flow rates through open joints
- Reclamation's Dam Safety Office funded research to extend the collect more experimental data and make it more generalized for use in risk assessments
- Studies performed 2006-2007 by Warren Frizell, Joe Kubitschek

2007 Research Study

- A sectional model in a high-speed water tunnel was used to measure uplift pressure and discharge into open-offset joints
- Joints were perpendicular to the flow (worst case scenario) and spanned the full width of the (narrow) test section
- Three details tested
  - sharp-edged, chamfered, and radius-edged
- Offset heights of ⅛-, ¼-, ½-, and ¾-inch, with horizontal gaps of ⅛-, ¼-, and ½-inch
  (3, 6, 13, 19 mm)

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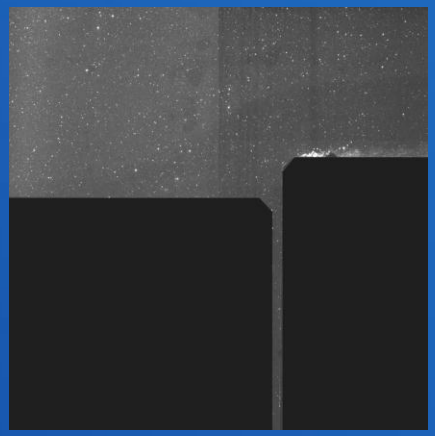
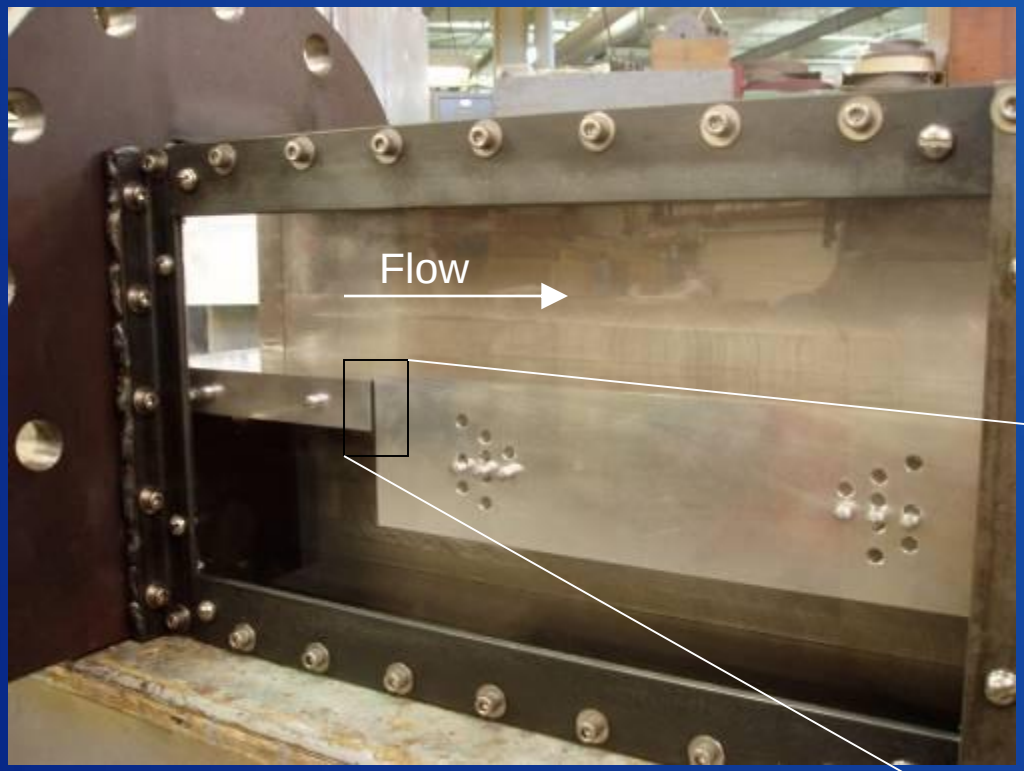
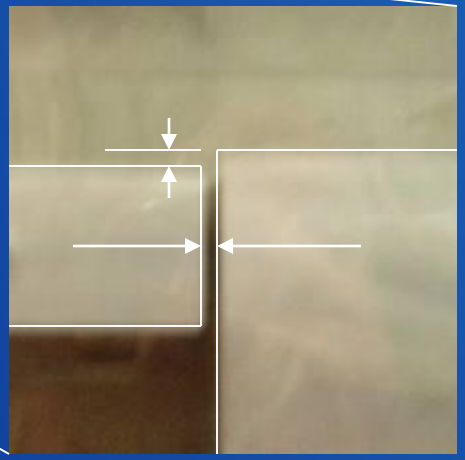
Model Test Section



chamfered edge



100-mm square conduit approaching joint



Flow velocities 3-17 m/s (10-55 ft/s)

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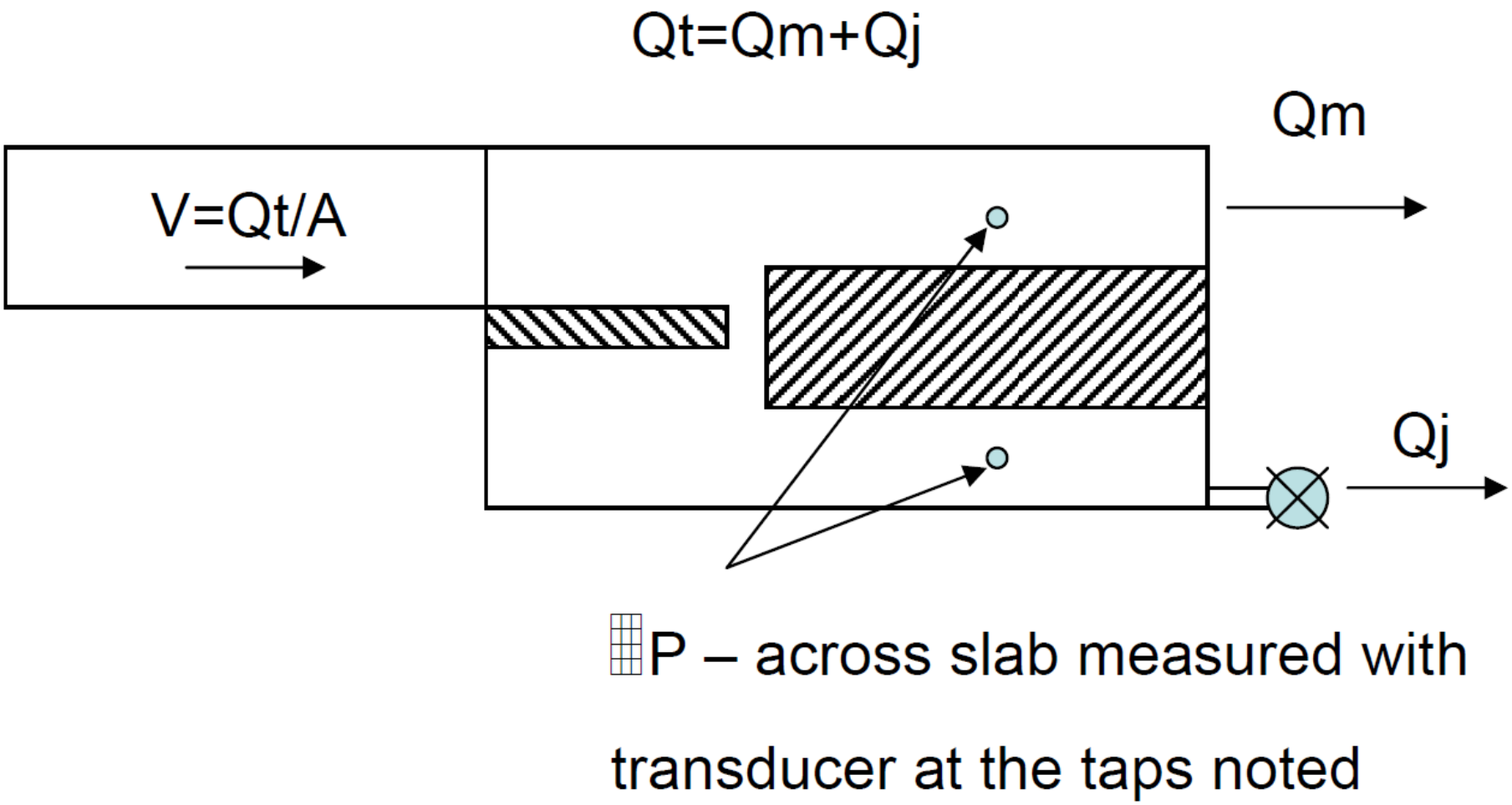
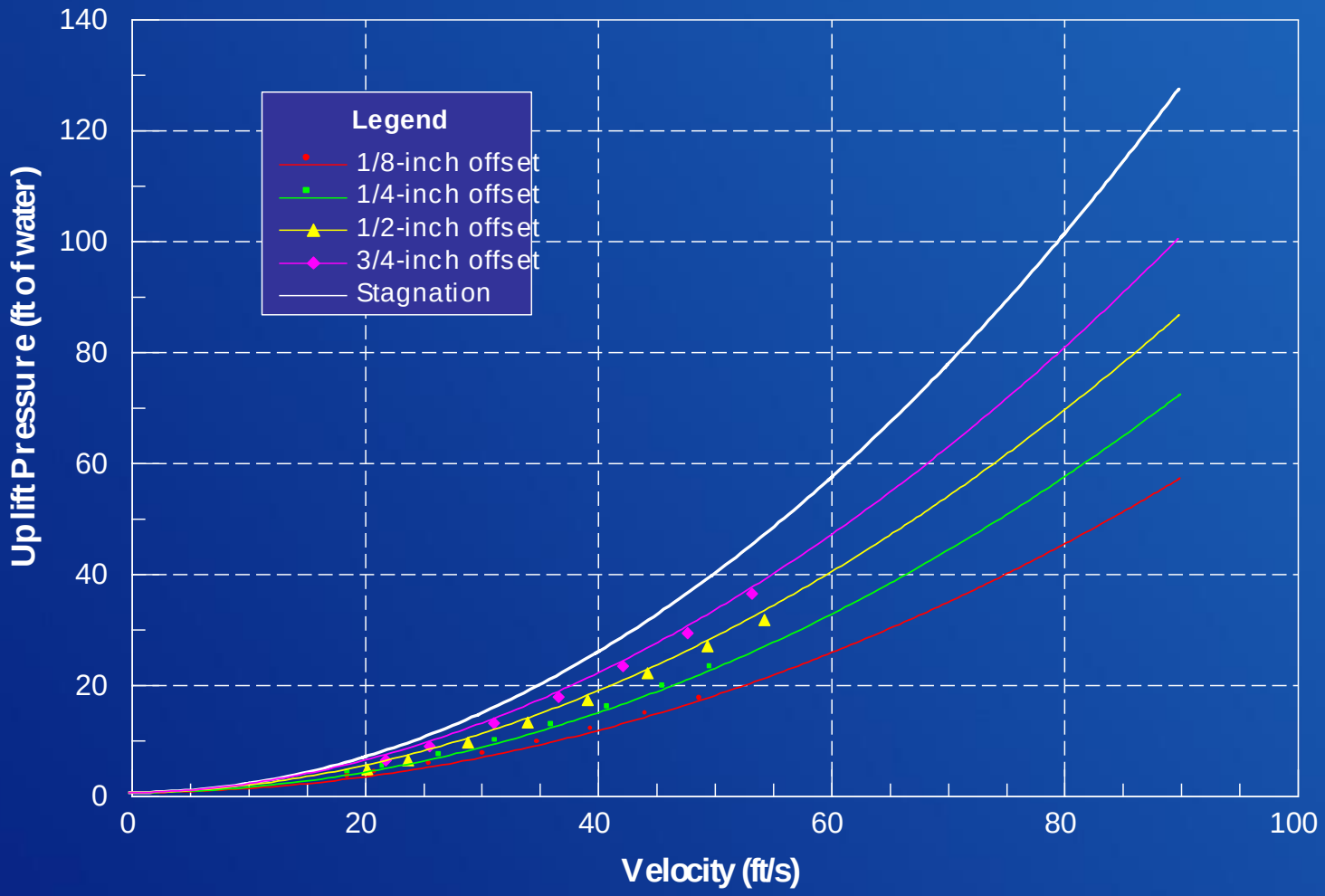


Figure 7.—Side-view schematic of test section showing location of uplift pressure taps.

Data Collection

- Pressure differential across slab
  - Sealed cavity (outlet valve closed)
  - Vented cavity
- Flow rate through joint
  - Flow rate was being limited by outlet valve (similar to a drainage system limiting flow)
- PIV (Particle Image Velocimetry) also used to map velocity field in and near joint

Stagnation generated uplift for ⅛-inch horizontal gap



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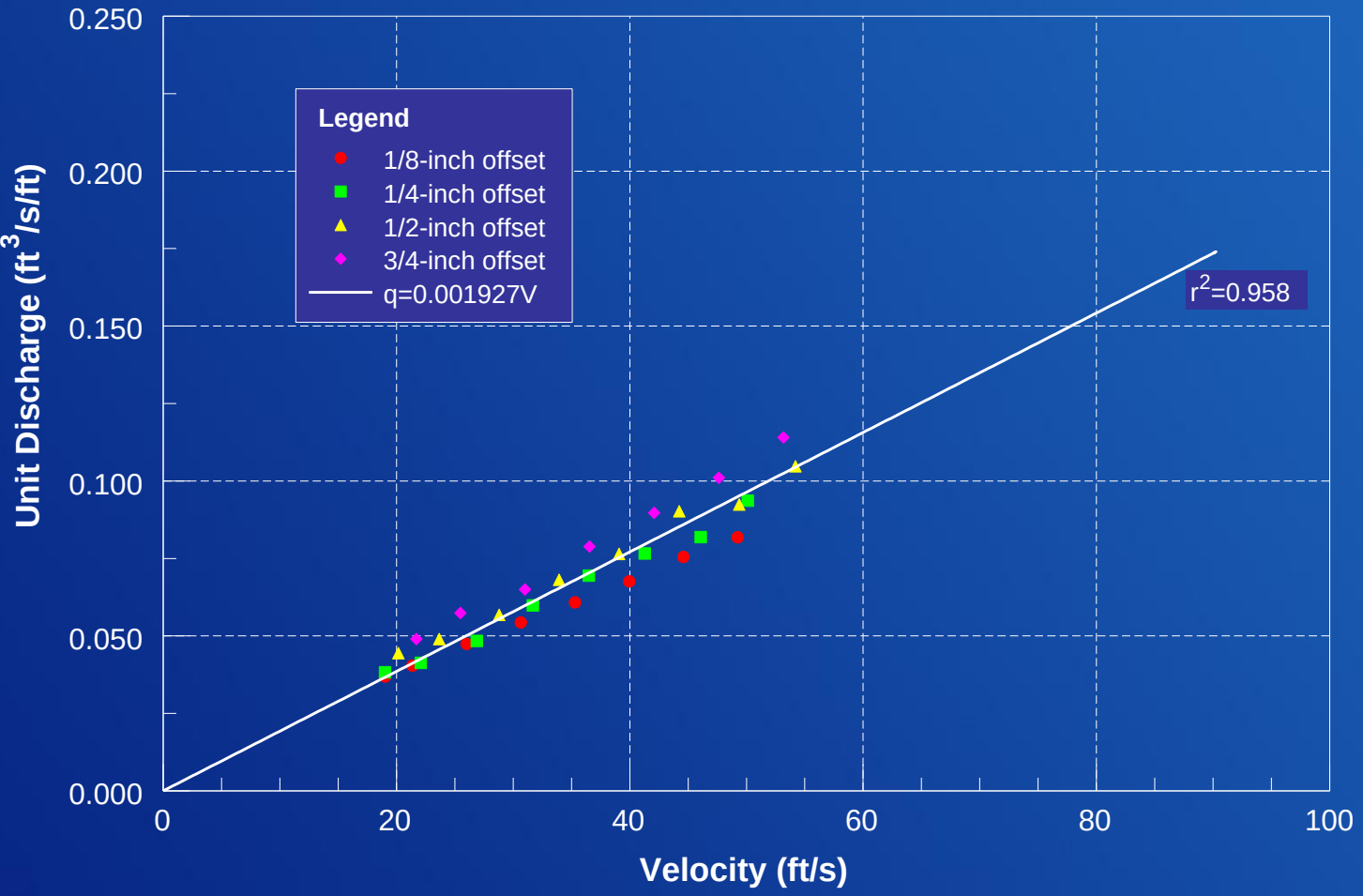
Unit discharge into a ⅛-inch gap (sharp-edged configuration)



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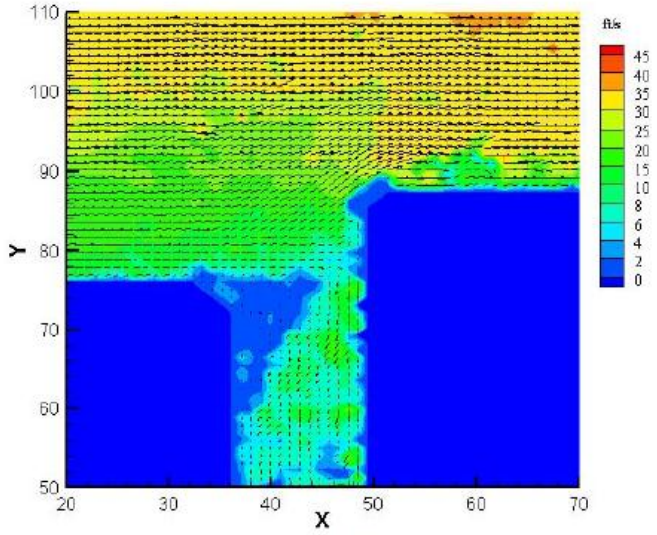
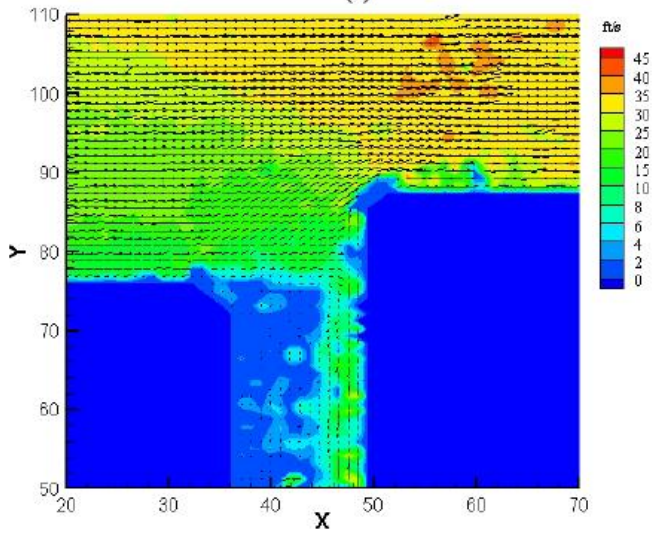
Example PIV

Vented cavity

Sealed cavity



(a)



(b)

Figure 41.—Velocity fields for the ½-inch gap and ½-inch chamfered offset at 30-ft/s free stream velocity test conditions: (a) vented and (b) sealed cavity.

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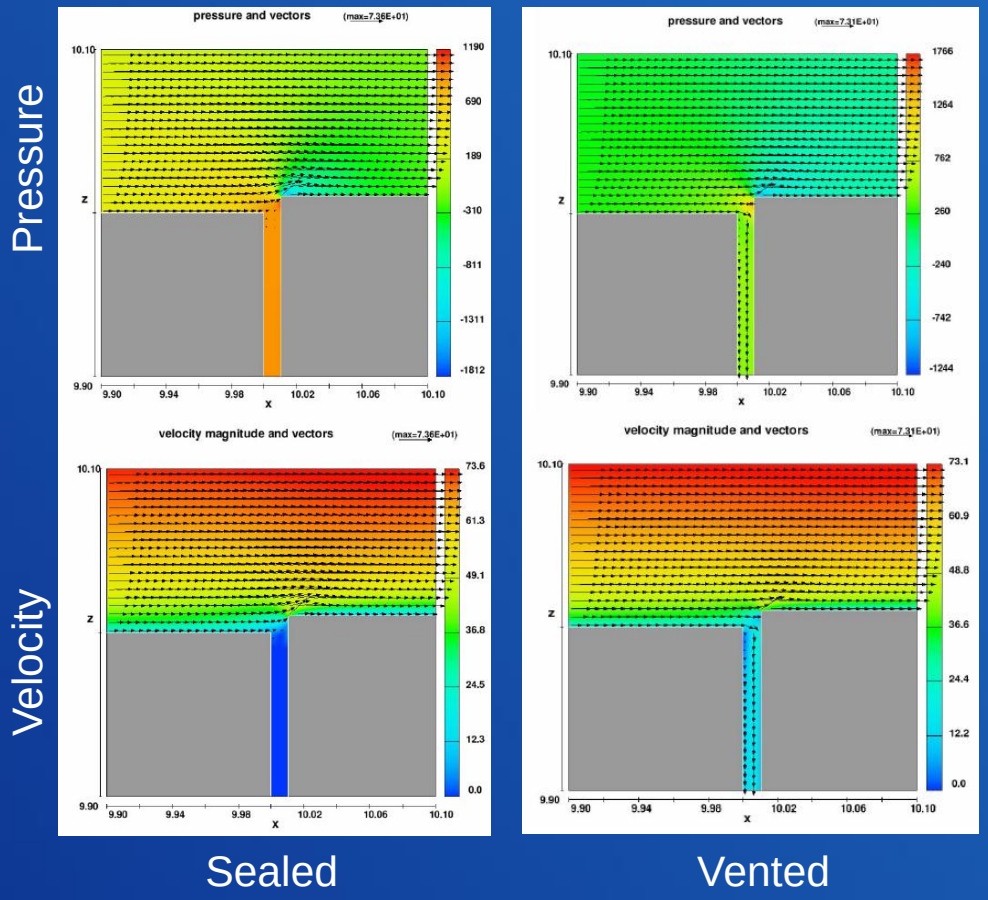
Complementary 2D CFD Modeling

- Two models
  - Test facility
  - Prototype-scale spillway chute
- Two cavity scenarios
  - Sealed
  - Fully vented (atmospheric pressure). Different from the valved outlet of the model.



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Applying Results

- Significant flows into open joints or cracks are possible, possibly exceeding underdrain capacity.
- Predicted uplift pressures generally a little higher than would have been predicted from the earlier work (Johnson 1976)
- This study aids understanding of effects of gap width, offset height, joint-entrance shape


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Managing Water in the West

Report DSO-07-07

Uplift and Crack Flow Resulting from High Velocity Discharges Over Open Offset Joints

Laboratory Studies

Dam Safety Technology Development Program

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

December 2007

New Project

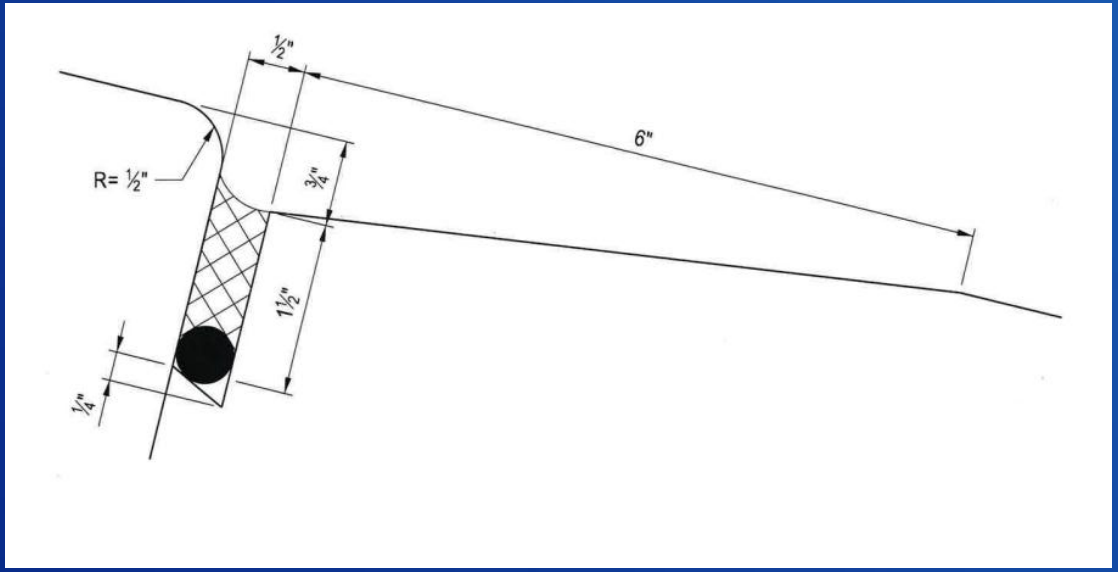
- **Initiated a scoping-level research project for this year**
- **Risk analysis teams have questions about effects of field conditions that differ from the idealized lab tests**

Practical Questions

- **Details – effects of waterstops, keyways, reinforcement?**
- **Openness of joints – open joints rarely seen in field. When joints are filled with debris, does this tend to wash out during operation, remain in place, how does it affect pressure and flow transmission through joint?**
- **How to account for lack of continuity in joint condition?**

More Practical Questions

- What about joints parallel to flow or at other orientations?
- What about spalling at joints instead of offsets?
- Can we optimize a good “modern” joint design?



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Initial Tasks

- Literature review
- Prioritize questions we want to address
- Develop plans for laboratory, analytical, or computational investigations