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Holistic Approach to the Design, Evaluation, and Monitoring of Surface Barrier System

Z.F. ZHANG *, M.D. FRESHLEY, D.M. WELLMAN, M.D. WHITE, AND M.J. TRUEX

Pacific Northwest National Laboratory

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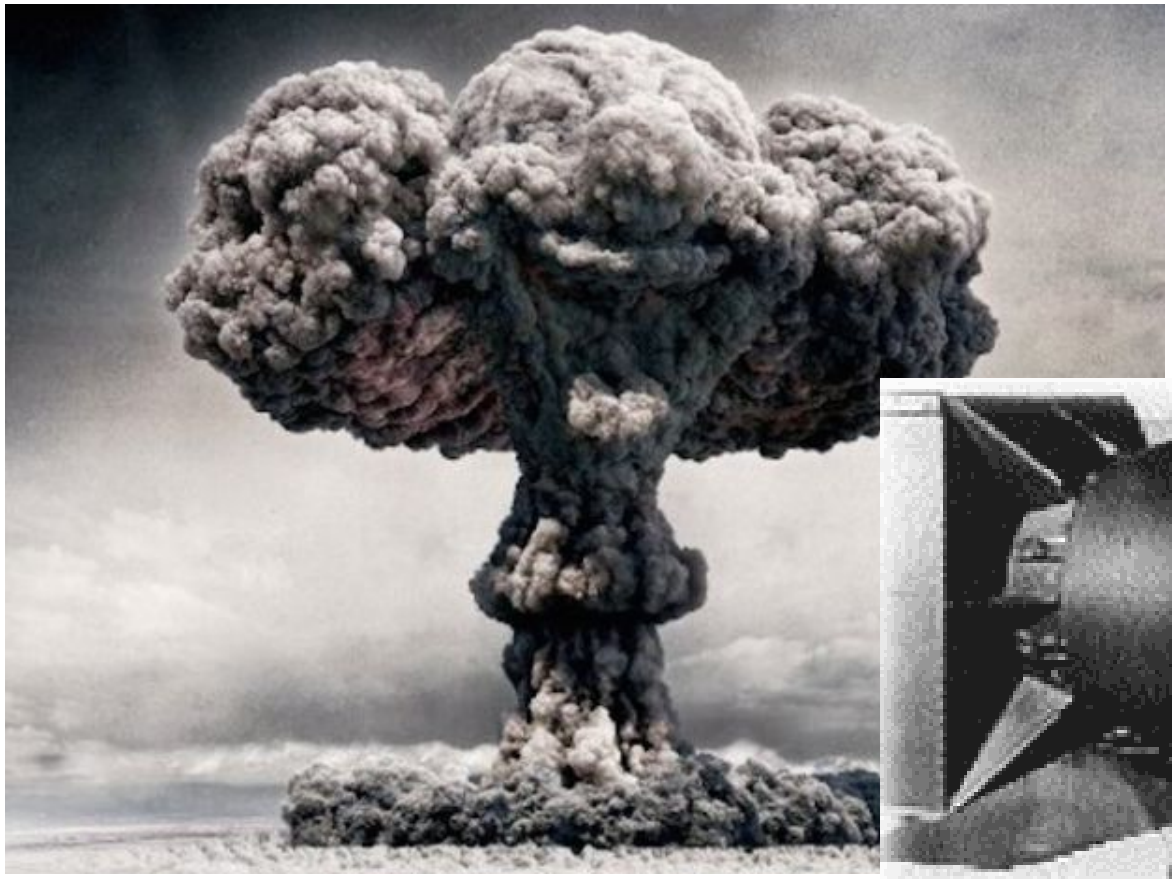
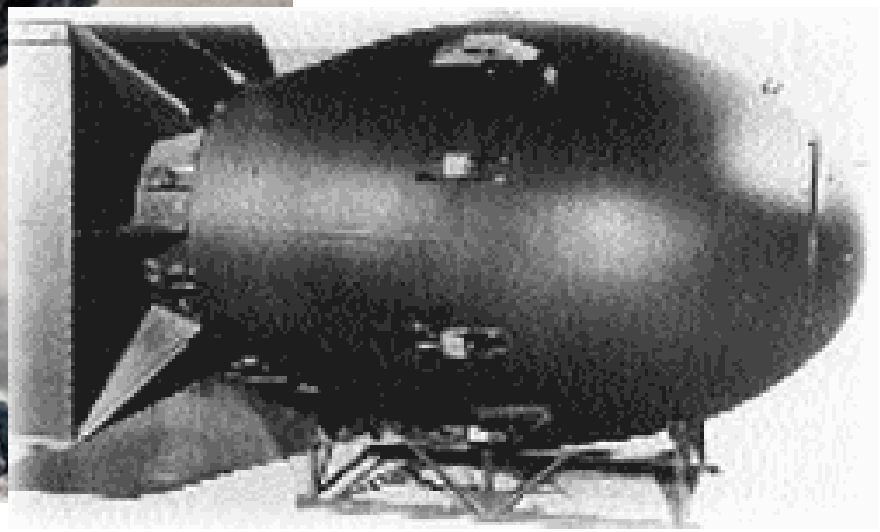
The Fat Man





"Fat Man"

Background - Surface mining

- Alters the vegetation, soils, bedrock, and landforms
- Changes the surface hydrology, groundwater, and flow paths

- Changes ecology of the site

Surface Mining - Problems

- **Surface**
  - Loss of vegetation
  - Loss of soil
  - Erosion
  - Runoff
  - Stream pollution
- **Subsurface**
  - Acid drainage
  - Groundwater contamination

Mine Land Reclamation with Surface Barriers

- **Surface Barrier (Cover, Cap)**
  - is an engineered surface structure
  - covers the exposed rocks
  - isolates rockpile/tailing
  - reduces erosion
  - provides a medium for vegetation growth
  - reduces drainage

- **Targets of concern: waste, environment, and barrier**

Surface Barrier Use on Mine Land

Soil covers for tailings impoundments, waste rock piles, backfilled pits and heap leach pads (Rykaart et al. 2006)

Continent	Country	Number of Cases
North America	Canada	40
	United States	85
South America	Brazil	4
	Chile	2
Africa	South Africa	13
Europe	Sweden	6
	United Kingdom	2
	Germany	18
	France, Czechoslovakia	1 each
	Greece, Norway, Spain	1 each
Australia	Australia	18
Asia	Indonesia	5
	China	1
Total		200

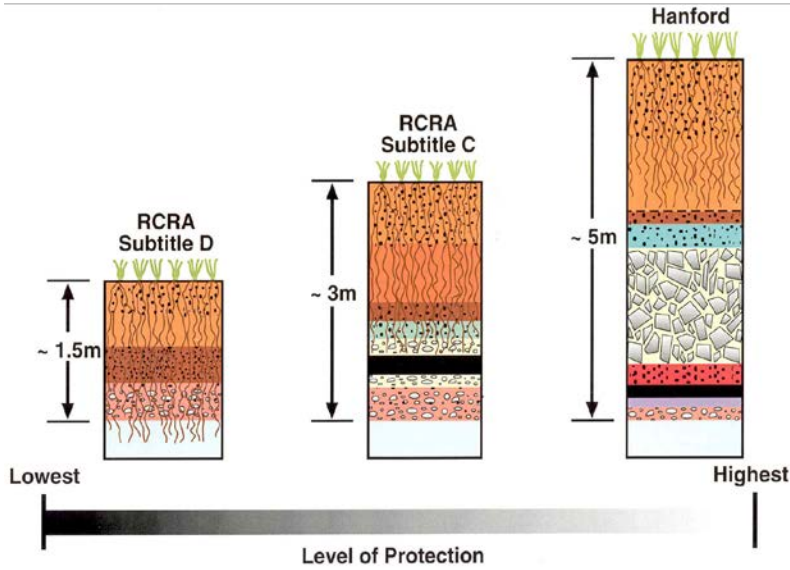
Objectives

- **Introduce a holistic approach considering**
  - **the actions (DEM)**
    - **Design**
    - **Evaluation**
    - **Monitoring**
  - **the targets (WEB)**
    - **Waste site**
    - **Environment**
    - **Barrier**

- **Demonstrate application of the DEM-WEB holistic approach at the Prototype Hanford Barrier**

Surface Barrier – DEM Actions and Challenges

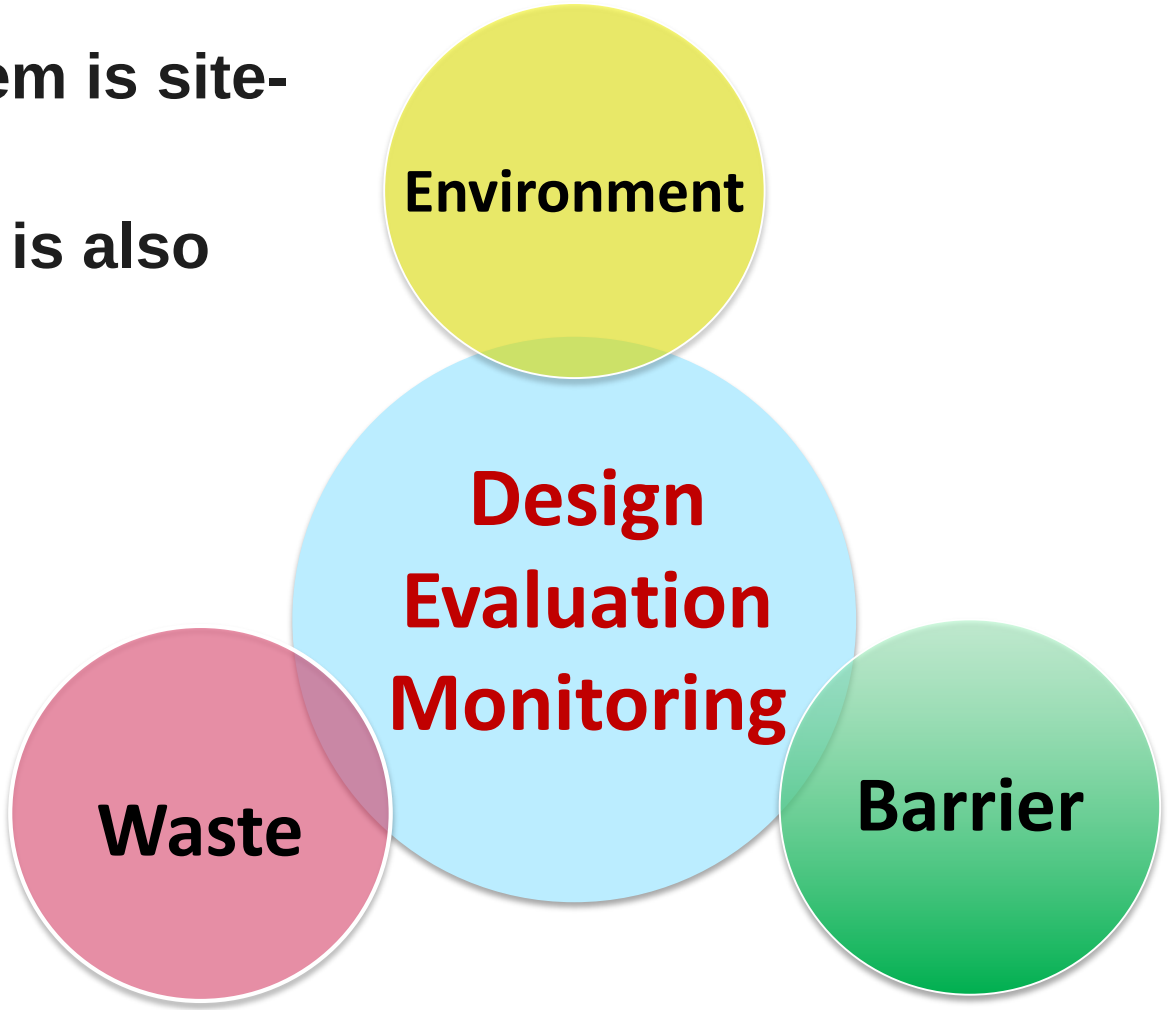
- **Design (D)**
  - types – What types of barrier to use?
  - life – 10s, 100s, or 1000s of years?
  - function – waste isolation? infiltration reduction?
- **Evaluation (E)**
  - performance evaluation
  - impact evaluation
- **Monitoring (M)**
  - What and how?



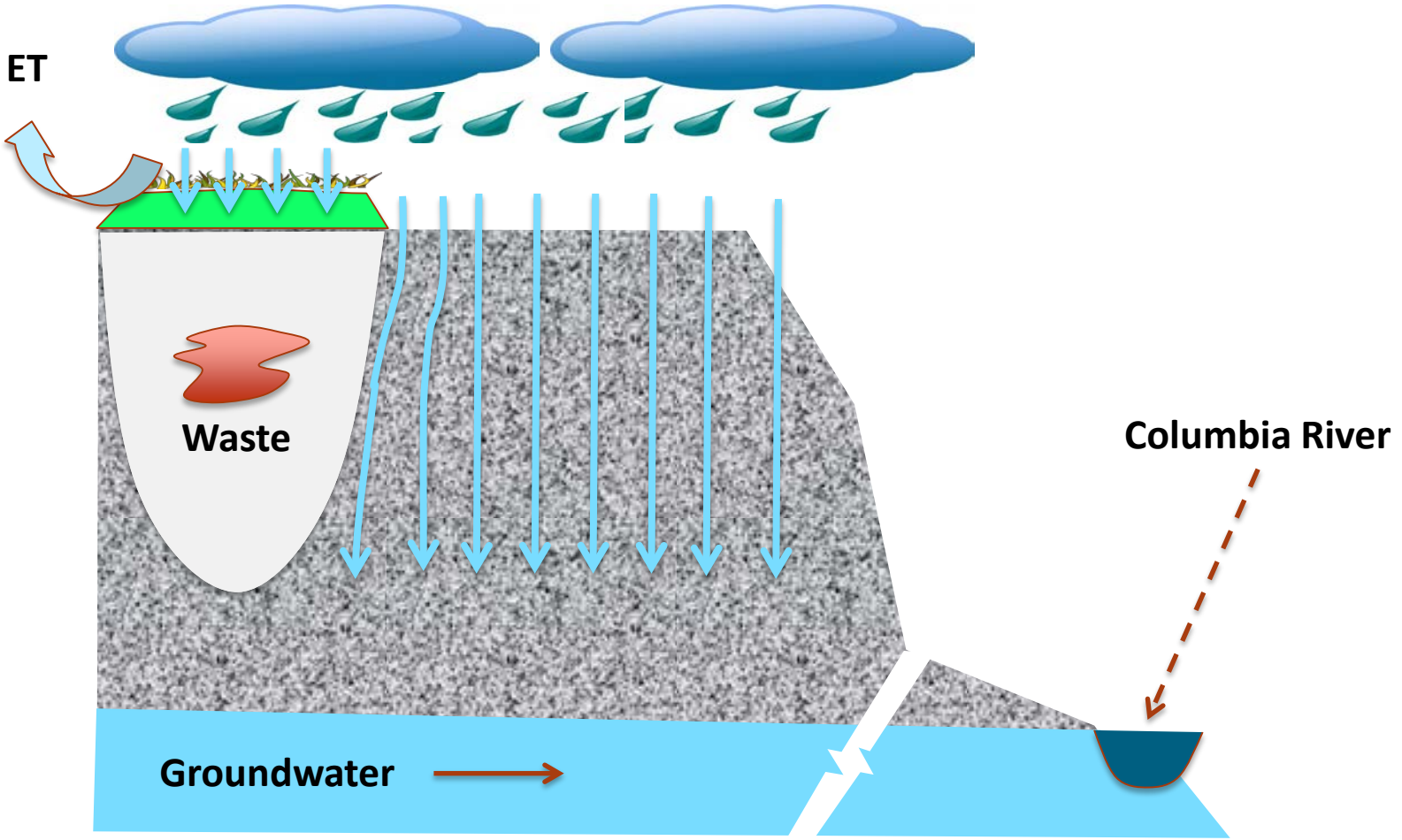
The DEM-WEB Holistic Approach

Holistic Approach – DEM-WEB

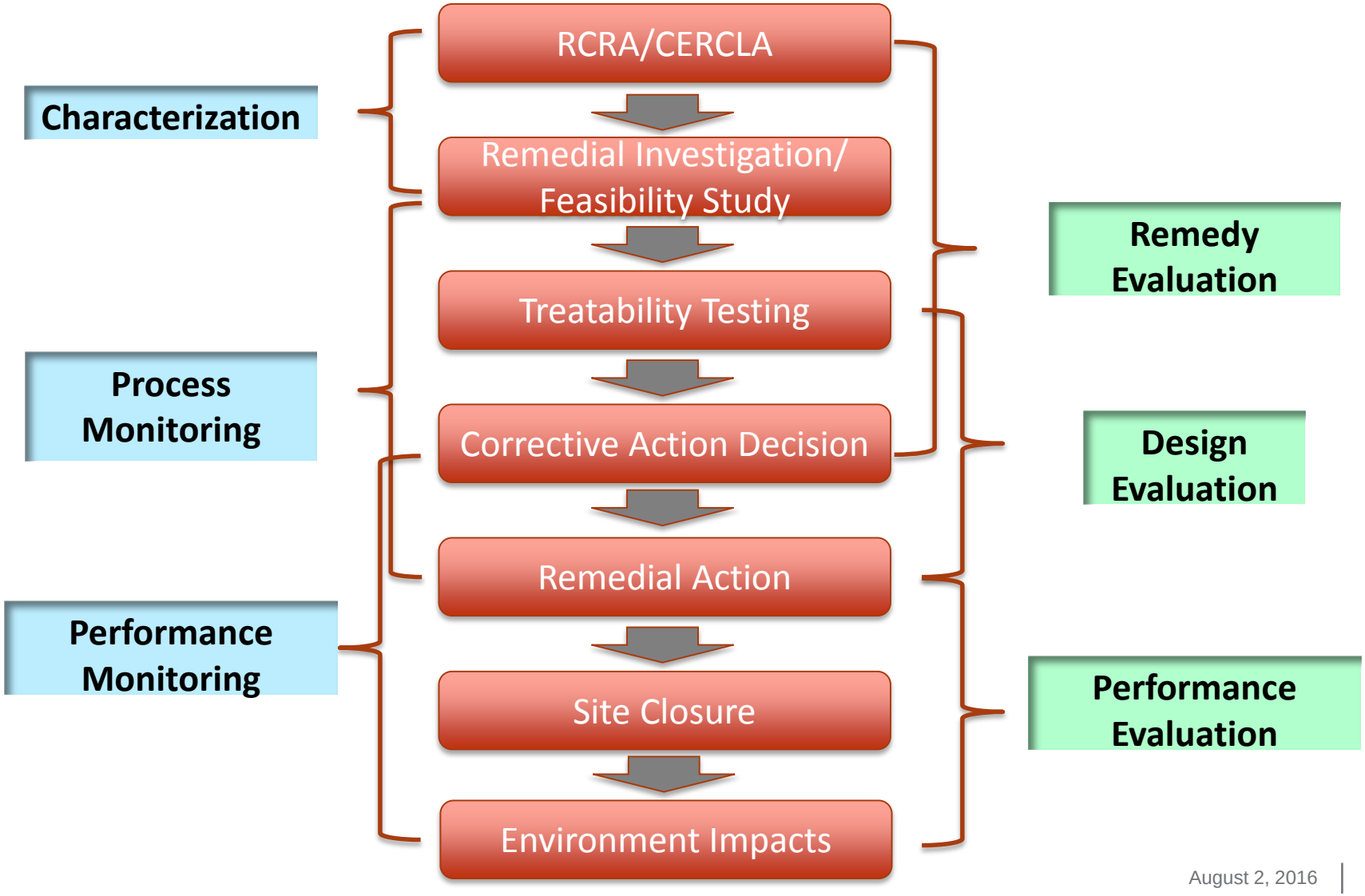
- Each WEB system is site-specific
- Hence, the DEM is also site-specific



Example – Radioactive Nuclear Waste Containment at Hanford



Holistic Approach – Phases



Prototype Hanford Barrier - Design

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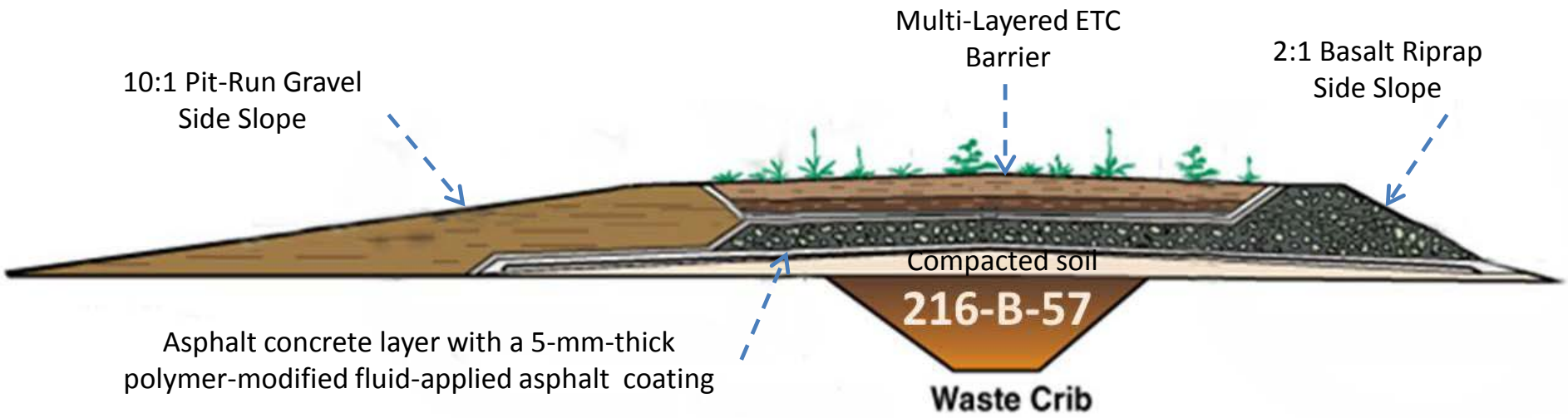
- **Performance Criteria**
  - **Function in a semiarid to sub-humid climate.**
  - **Have a design life of 1000 years.**
  - **Limit drainage to less than 0.5 mm yr^{-1}.**
  - **Limit runoff.**
  - **Be maintenance free.**
  - **Minimize erosion.**
  - **Meet or exceed RCRA performance criteria.**

It will take 10,000 years for contaminants to reach GW



Prototype Hanford Barrier – Design (2)

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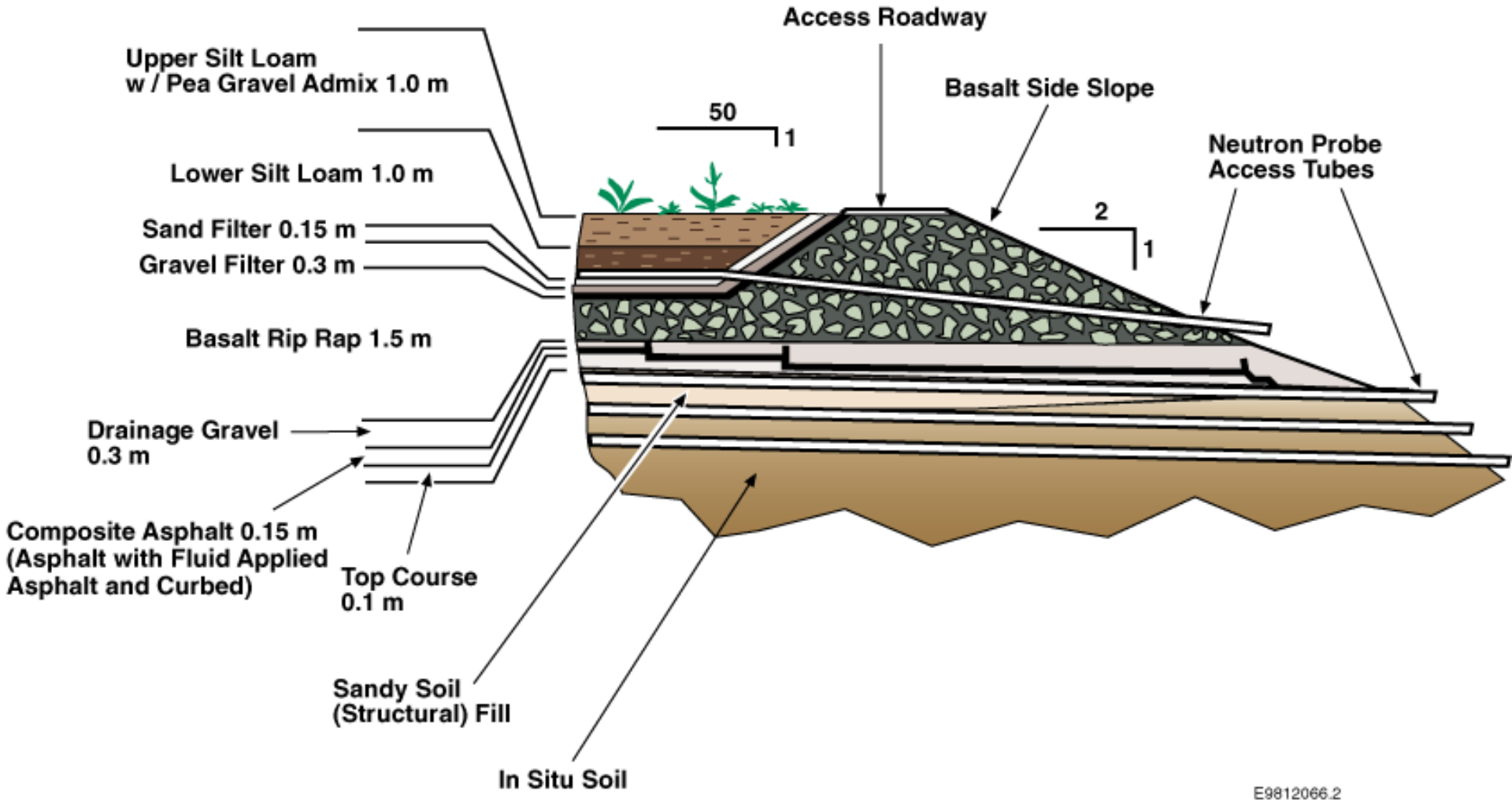
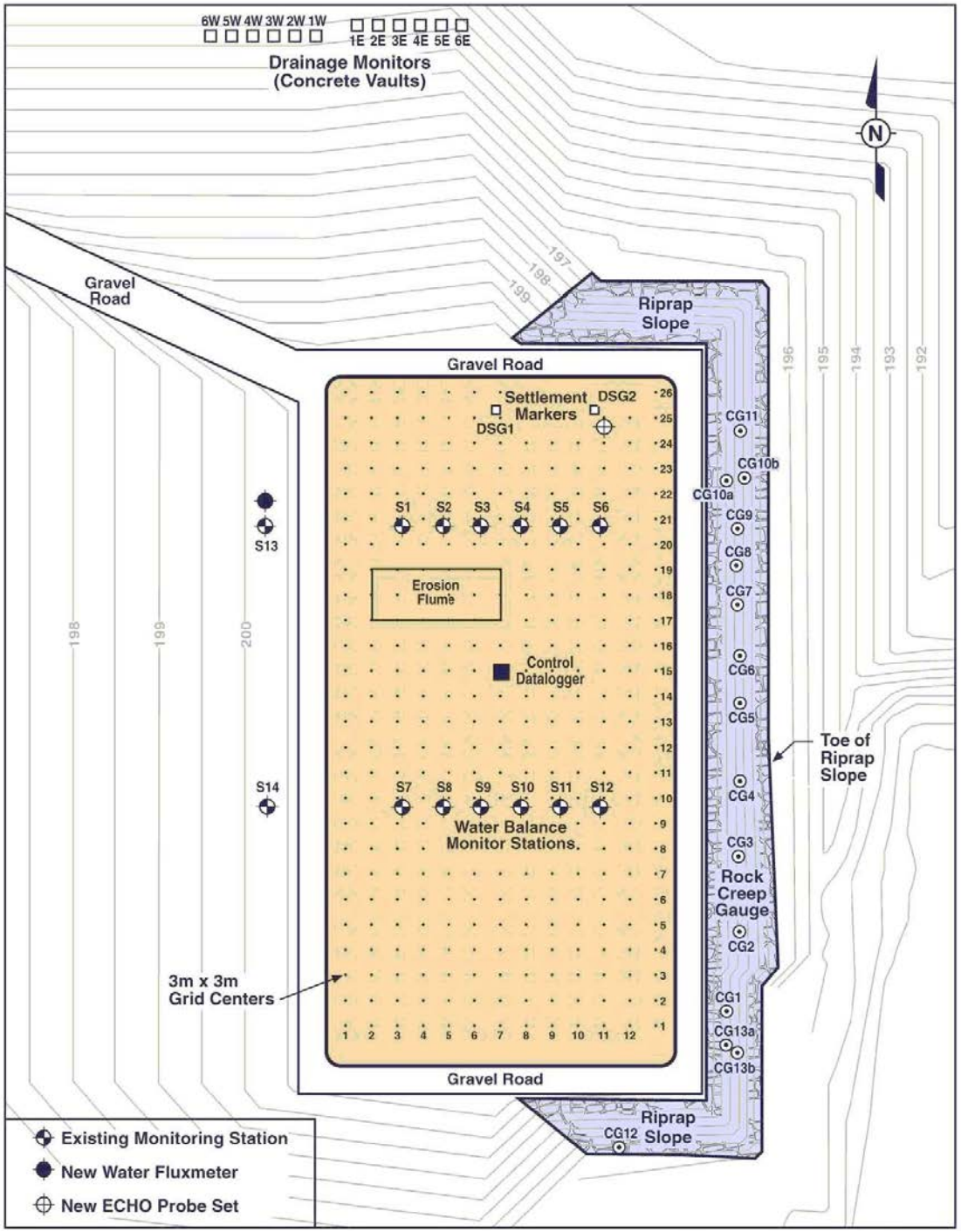


Prototype Hanford Barrier – Monitoring

- Barrier monitoring
  - 14 Water balance stations
  - 14 Lateral neutron probe
  - 1 runoff plot
  - 12 monitoring plots
- Waste Zone monitoring
  - Non-intrusive geophysical methods
- Environment monitoring
  - Groundwater quality monitoring wells



Prototype Hanford Barrier - Evaluation

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- **Performance Evaluation**
  - **Past/present: monitoring data**
  - **Future:**
    - **Data extrapolation**
    - **Controlled tests**
    - **Computer simulation**
- **Environment impact evaluation**
  - **Past: Groundwater monitoring data**
  - **Future: computer simulation**

Prototype Hanford Barrier - Tests

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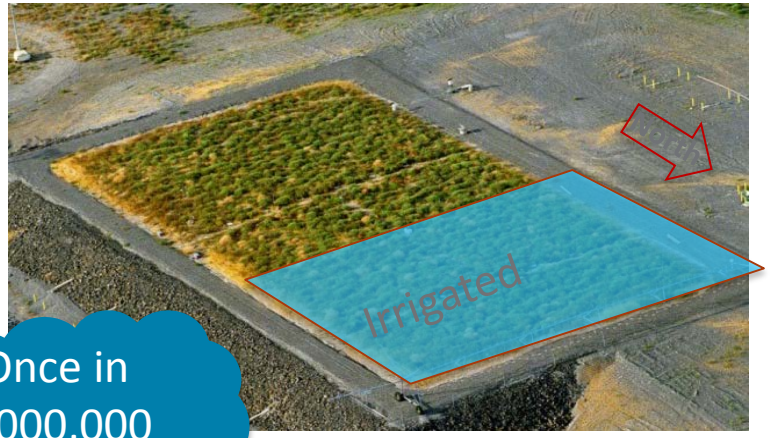
- **Enhanced precipitation test**
  - Nov. 1994 to Oct. 1997
  - Irrigated the north section to about 3x the average precipitation (3x160 = 480 mm/yr)
- **Controlled burn test**
  - The north section was burned in Sept. 2008



Once in 1,000,000 yr

The STOMP Simulator

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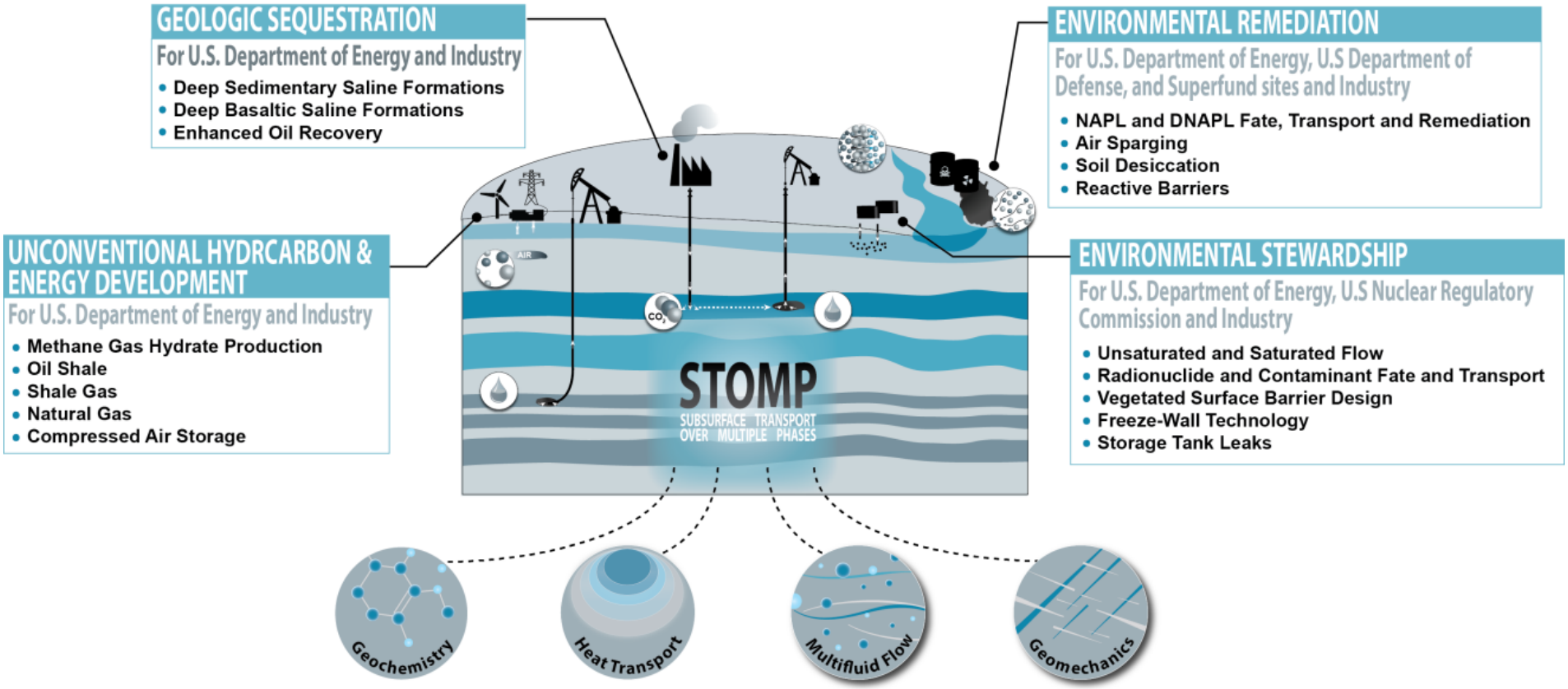
- **PNNL's analytical tool for investigating coupled processes involving**
  - **multifluid flow, heat transport, geochemistry, and geomechanics in the subsurface,**
  - **evaporation at the ground surface and transpiration from plants.**

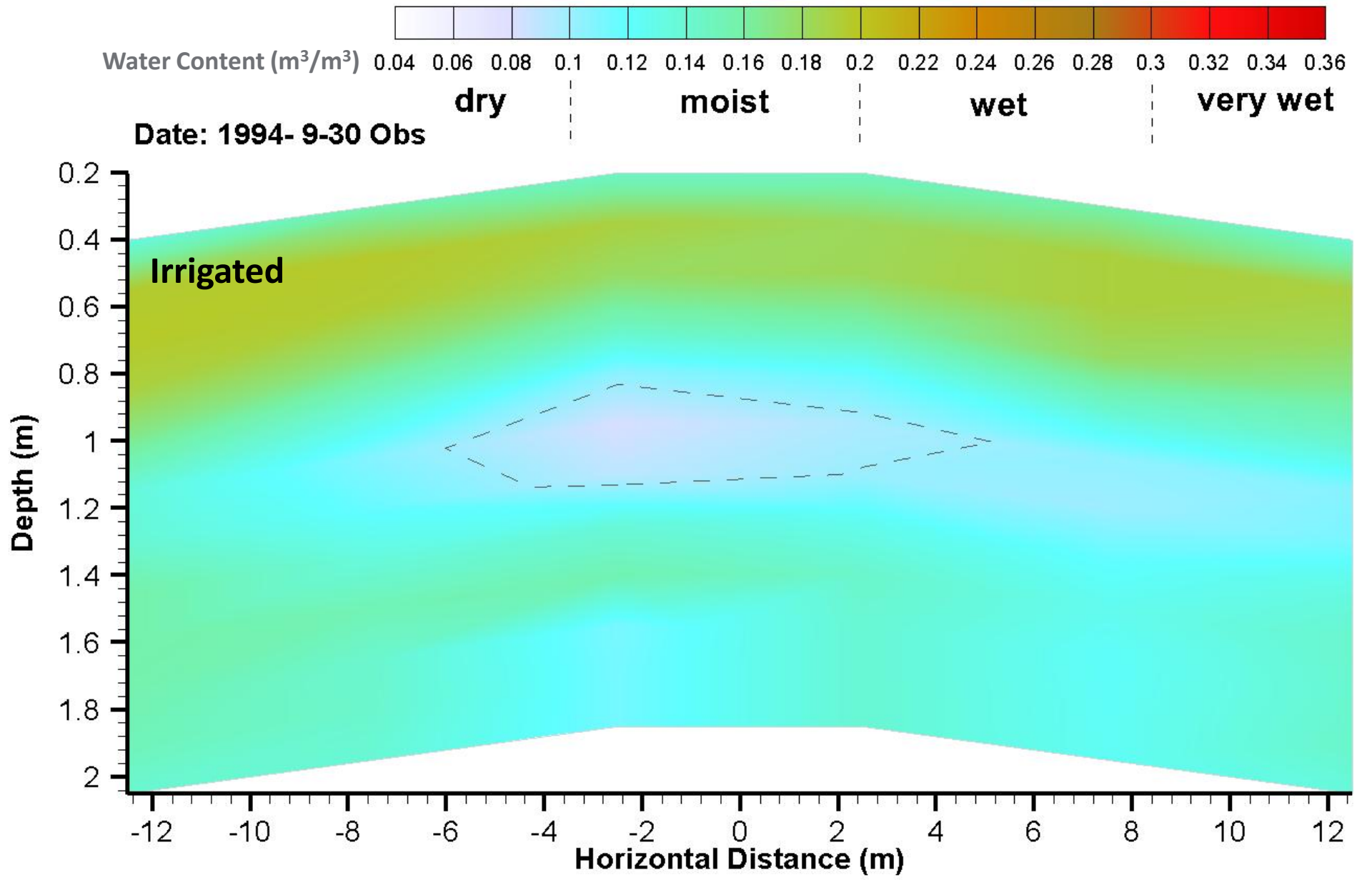


The STOMP Simulator

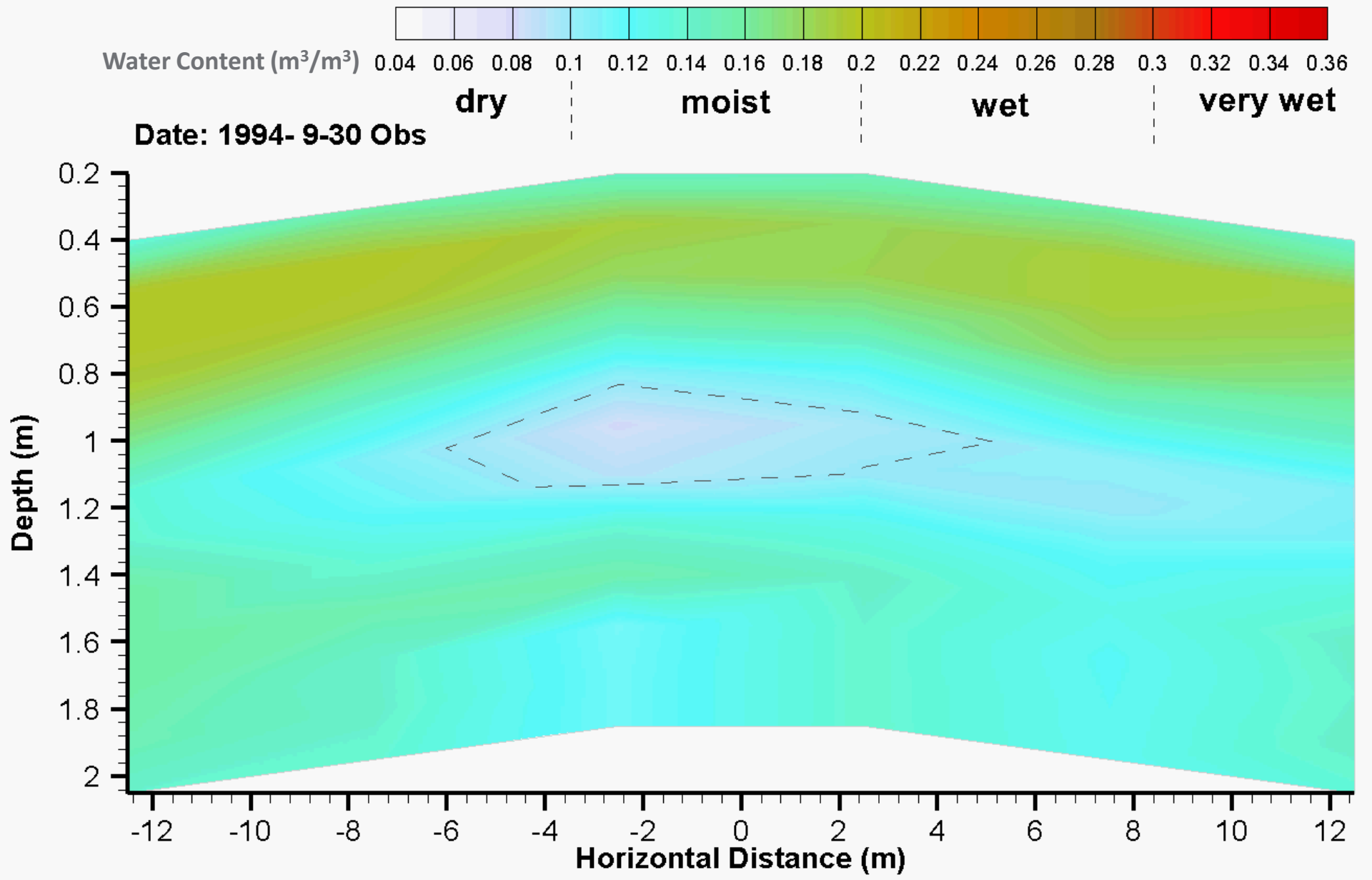
- **Mine closure or abandoned mine remediation**
  - **Investigate remediation options**
  - **Understand the processes of mine drainage for optimal management**
  - **Optimize the design of a surface barrier**
  - **Guide site monitoring**
  - **Predict barrier performance and impacts to the environment**

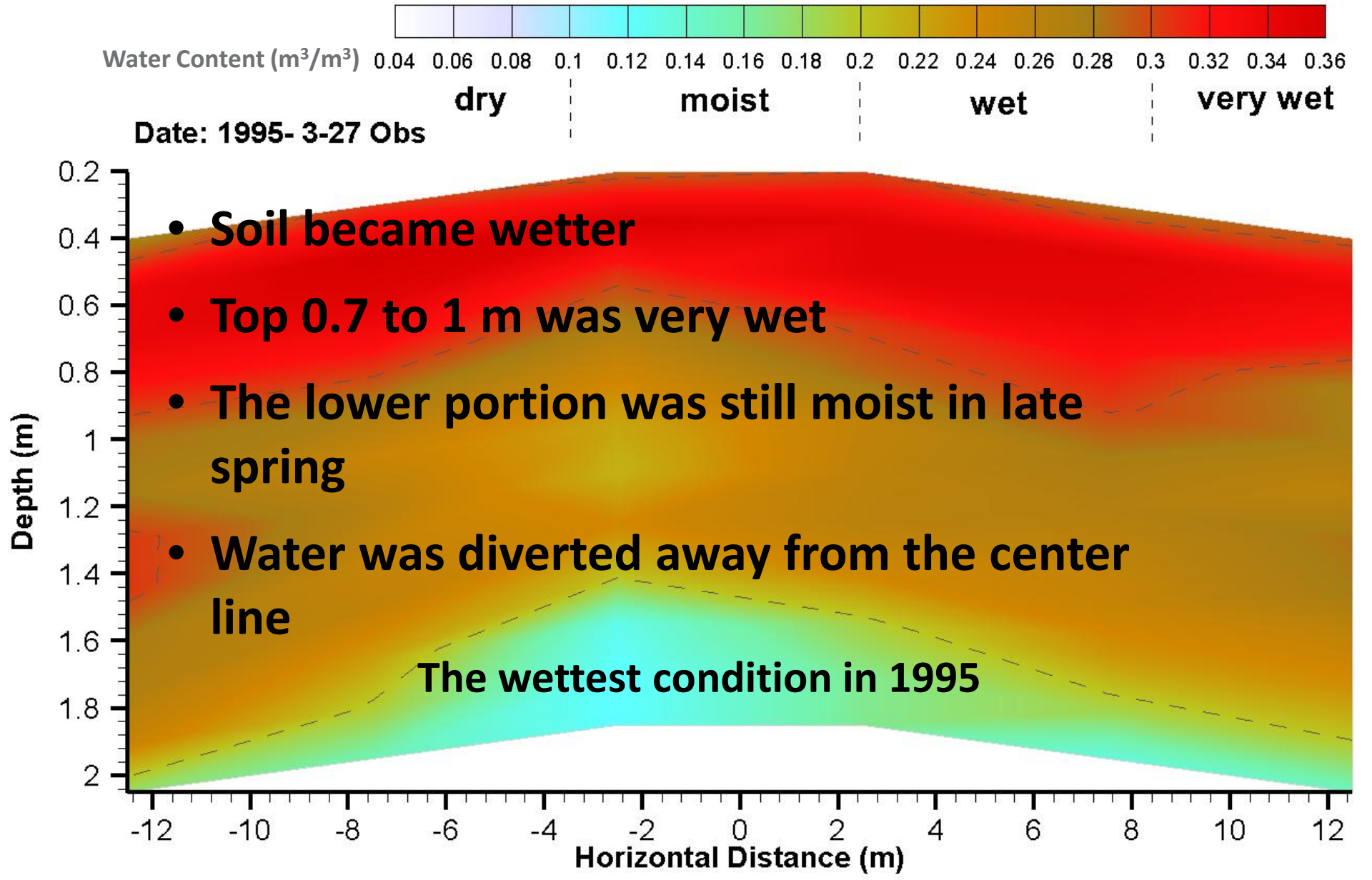
Performance of the Prototype Hanford Barrier

The initial Soil Water Content Distribution (irrigated)



Soil Water Content Dynamics in 9/94-3/95 (irrigated)

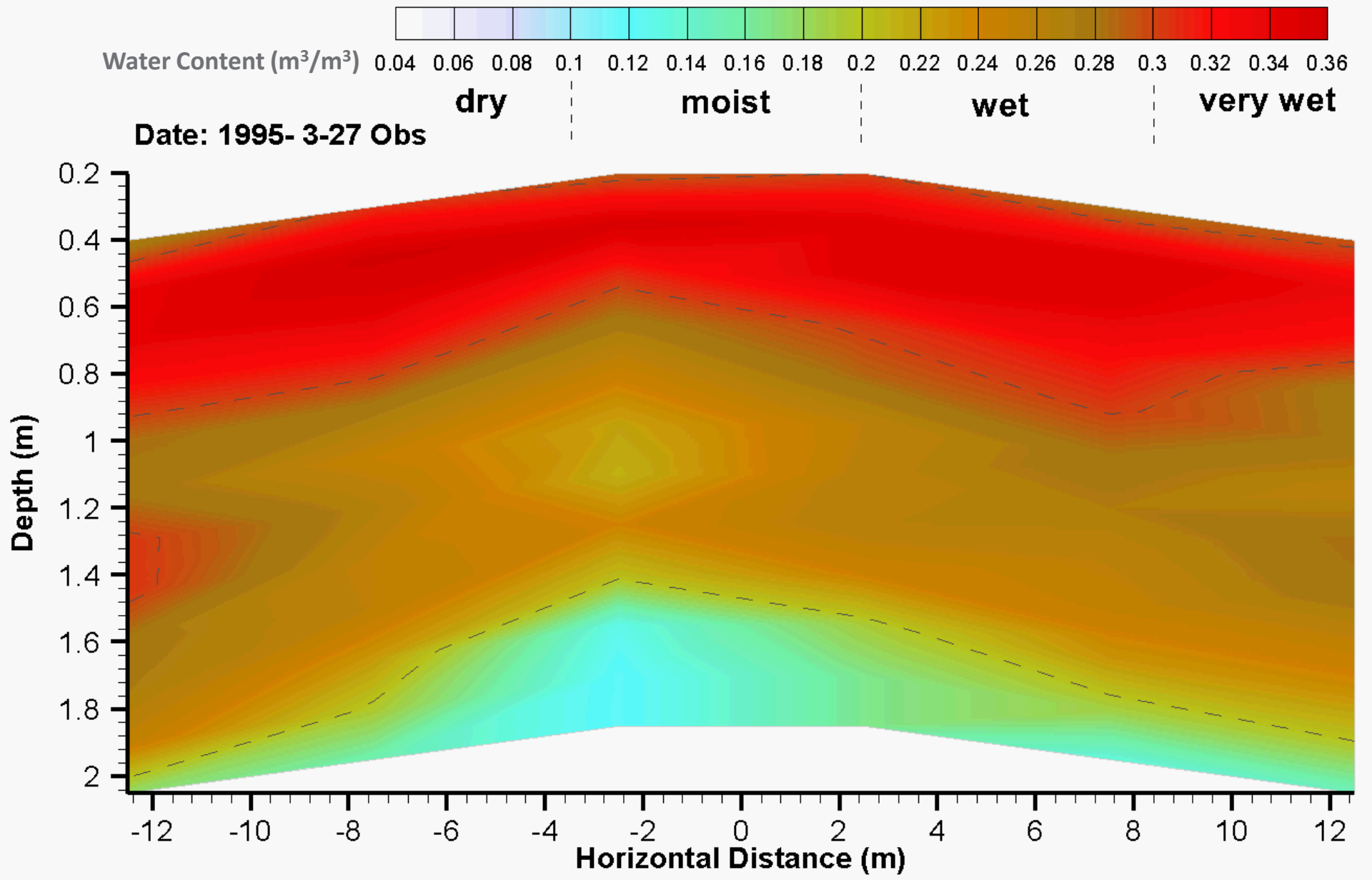


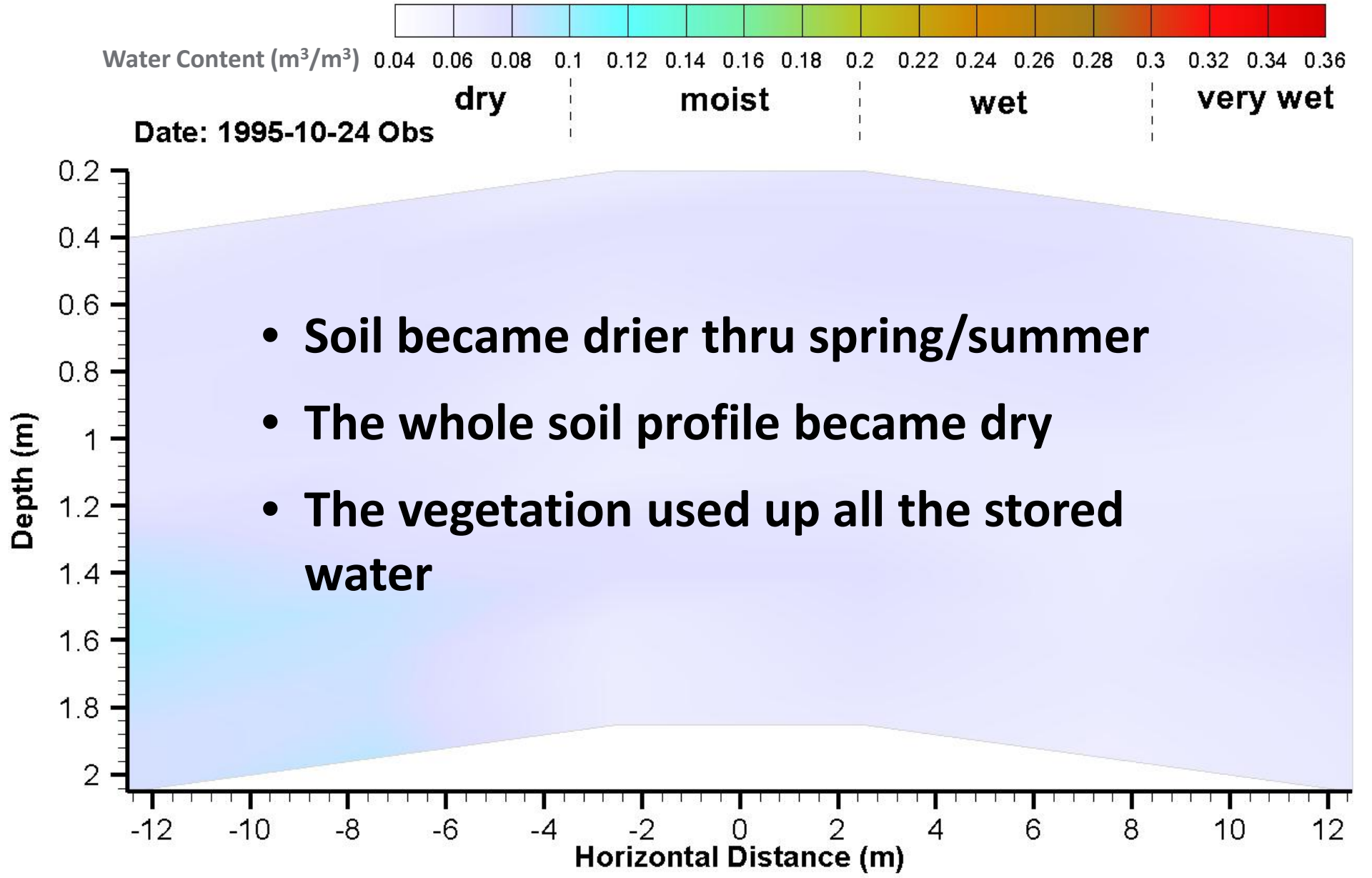


- **Soil became wetter**
- **Top 0.7 to 1 m was very wet**
- **The lower portion was still moist in late spring**
- **Water was diverted away from the center line**

The wettest condition in 1995

Soil Water Content Dynamics in 3/95-10/95 (irrigated)





- **Soil became drier thru spring/summer**
- **The whole soil profile became dry**
- **The vegetation used up all the stored water**

Prototype Hanford Barrier – Past Performance

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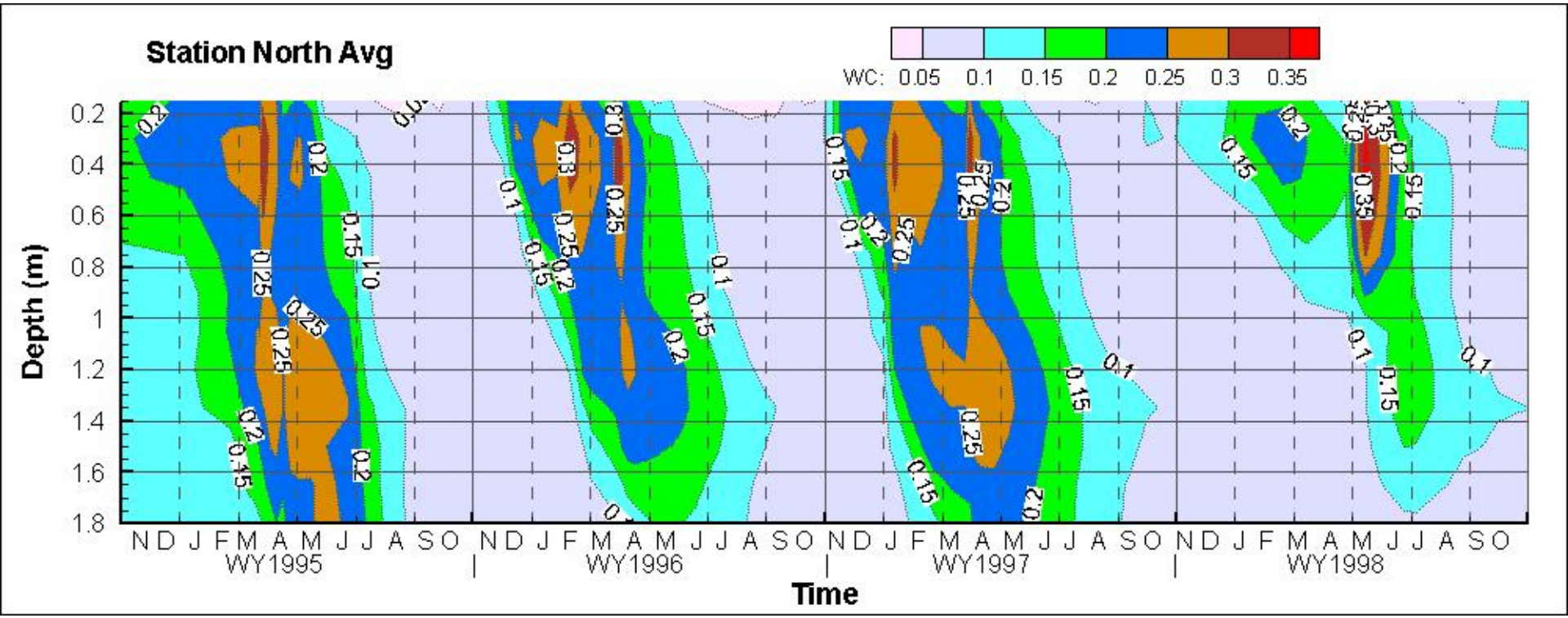
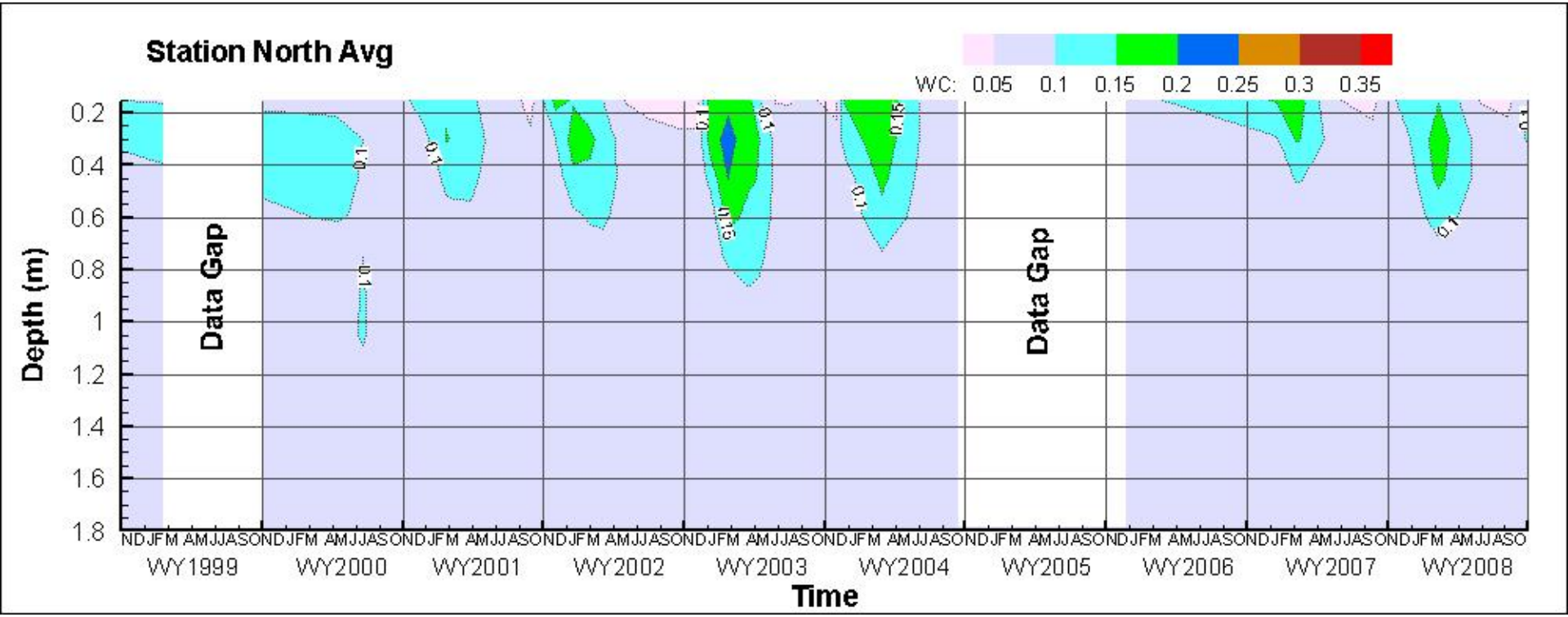
- **Water content in the ETC barrier (3X precipitation)**



Prototype Hanford Barrier

- **Water content in the ETC barrier (no irrigation)**



No irrigation in WY09 and after.

Prototype Hanford Barrier - Drainage

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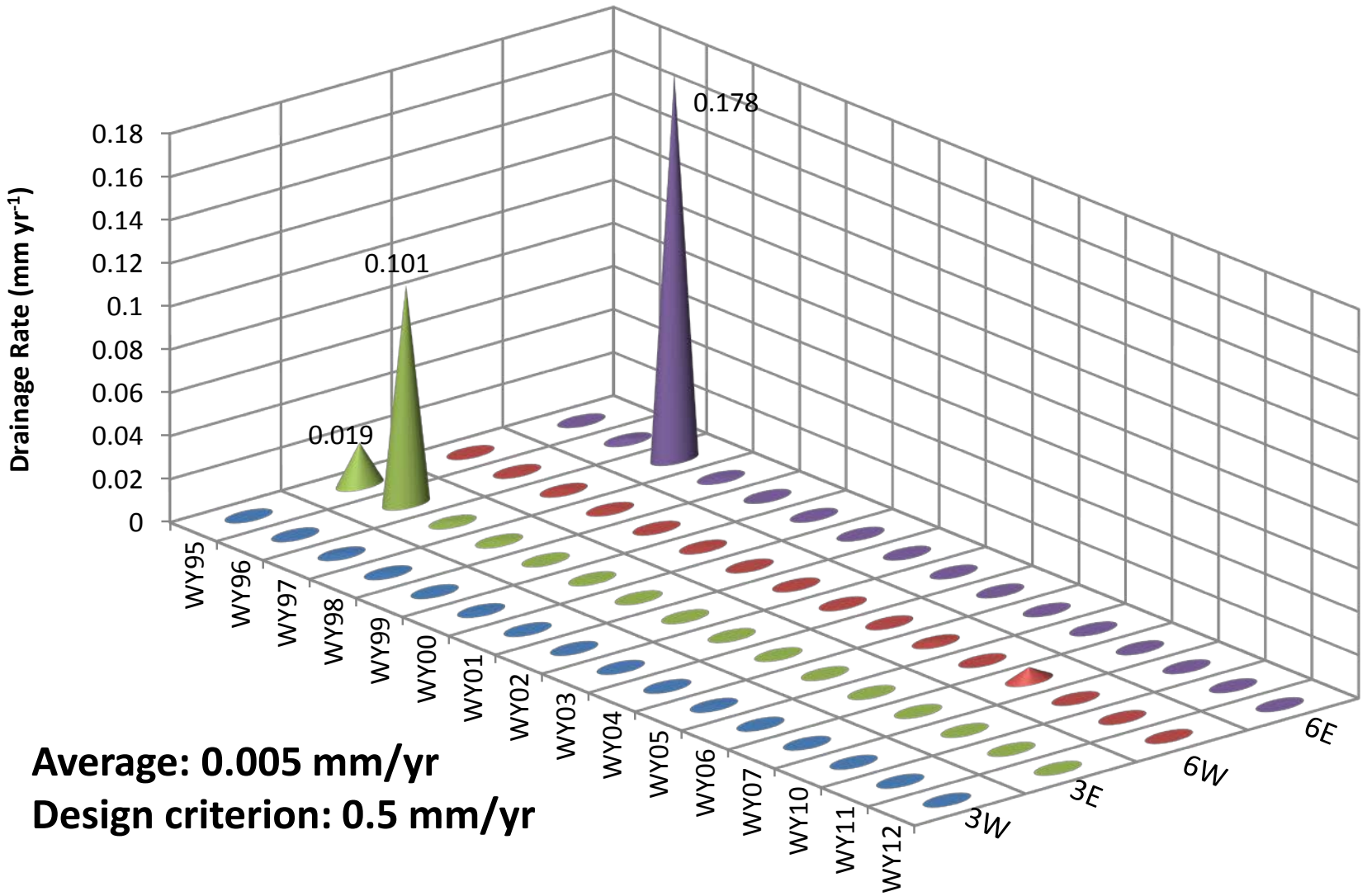

Average: 0.005 mm/yr

Design criterion: 0.5 mm/yr

Prototype Hanford Barrier – Store-and Release Mechanism

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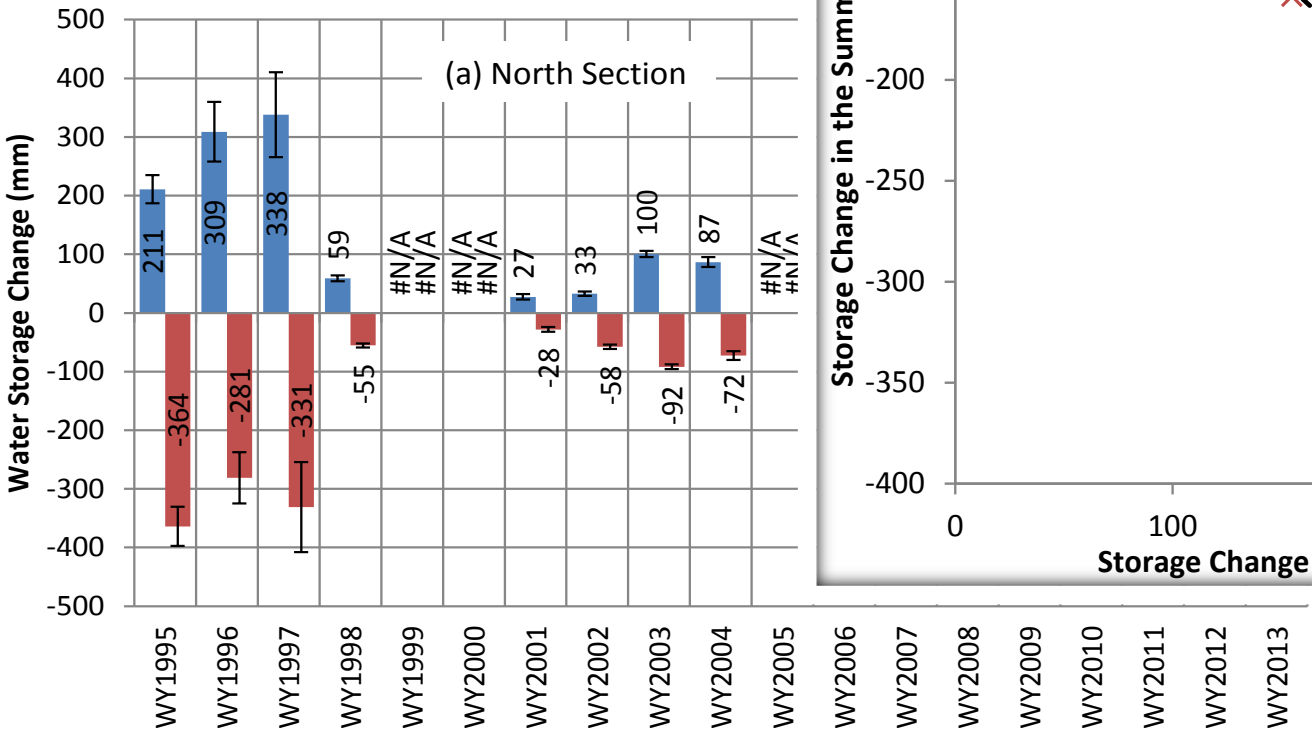
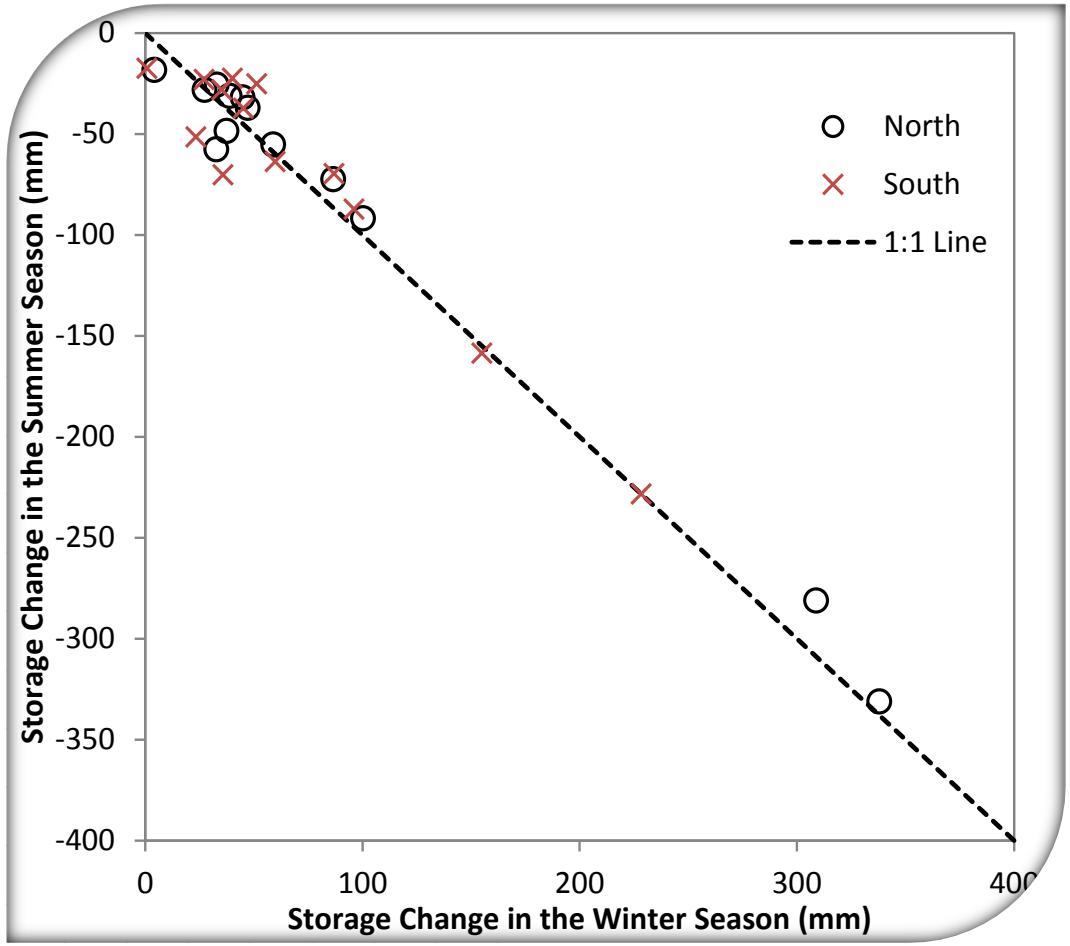
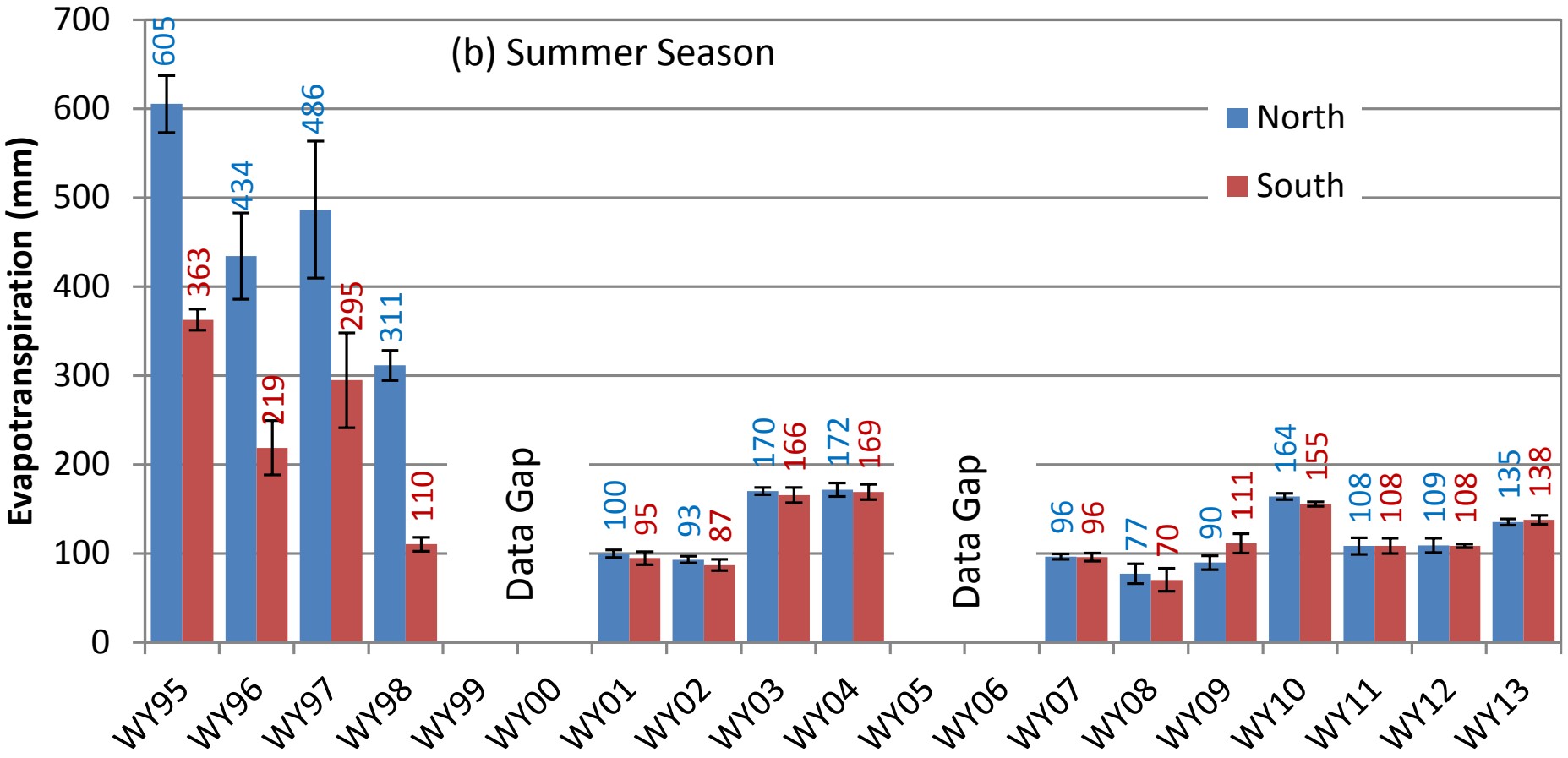
Winter vs. Summer Water Storage Change





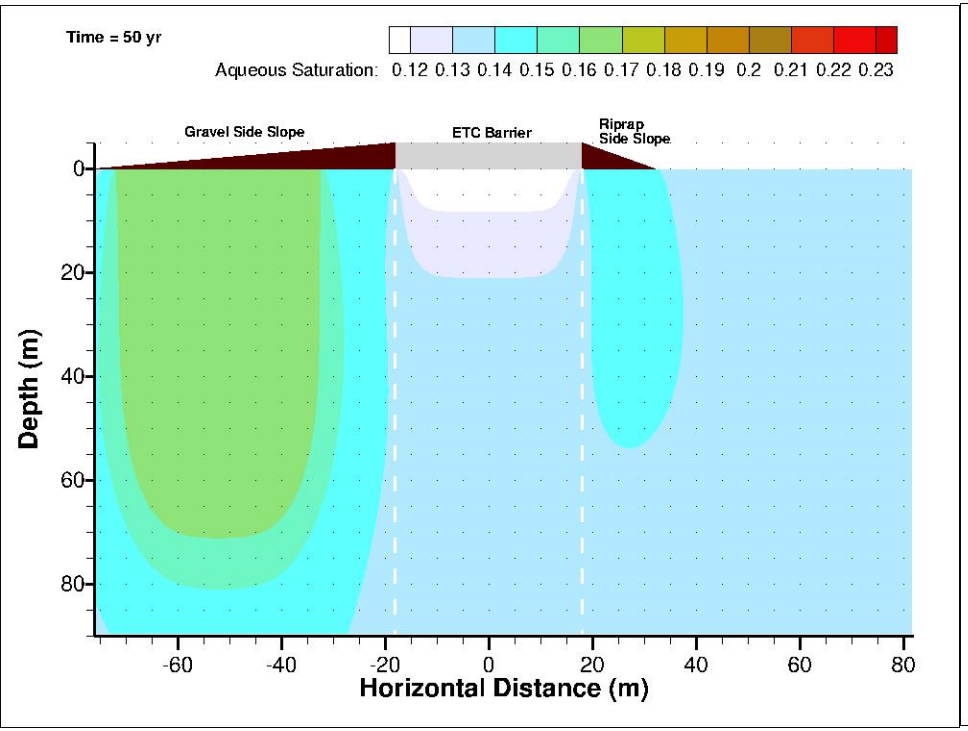
Prototype Hanford Barrier – Summer ET

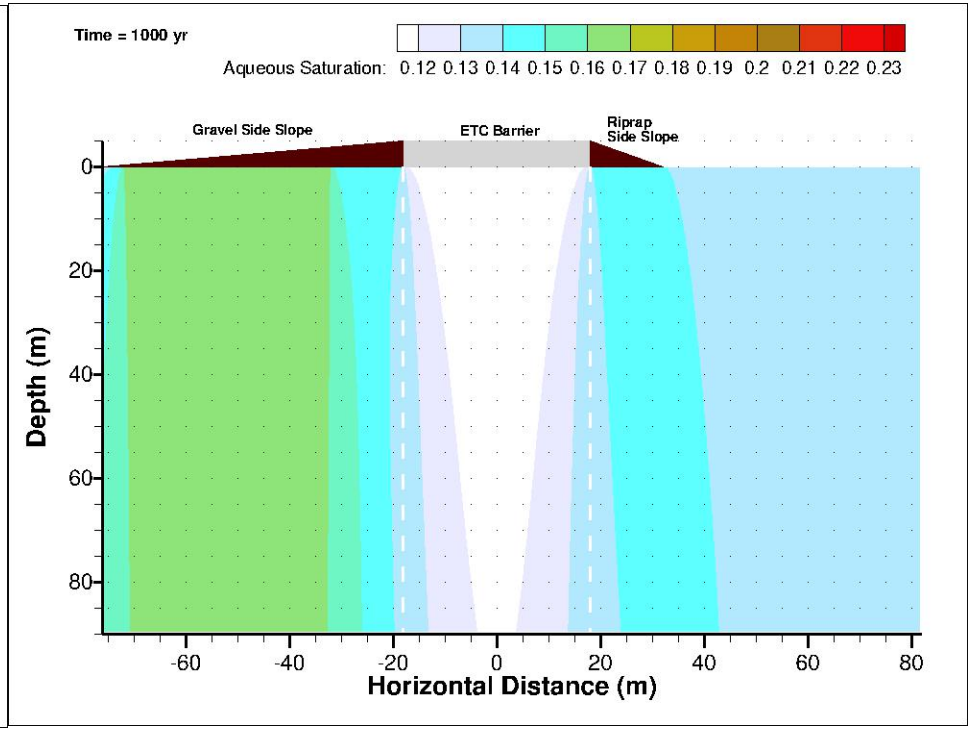


$$ET_s \approx P_a - ET_{w0}$$

Prototype Hanford Barrier – Future Performance

- **Water content distribution at 50 and 1000 years (demonstration)**





Summary

- The holistic approach considers the relationships between all the components of the DEM-WEB systems
- The holistic approach has been demonstrated at the Prototype Hanford Barrier
  - the PHB design is robust and can be adapted to other sites
  - the vadose zone, groundwater, and geophysical monitoring tools are ready for use
  - the STOMP evaluation and prediction tool is well tested for barrier performance evaluation
- The holistic approach can be used for mine land remediation