Battelle

The Business of Innovation

Long-term Cover Design and Performance Assessment- A Hanford Case Study

11th Annual British Columbia ML/ARD Workshop

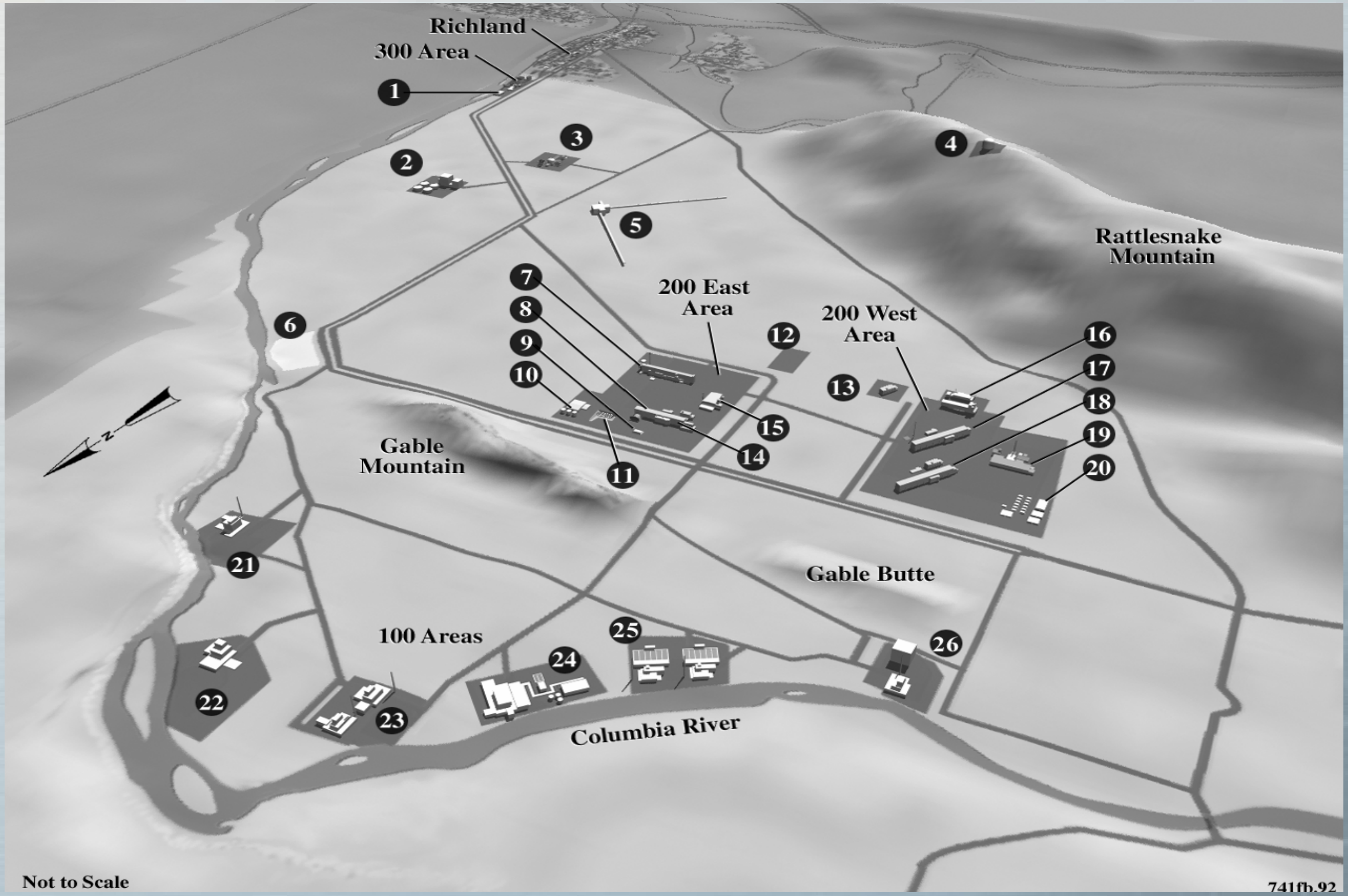
December 1-2, 2004

Andy Ward

Hydrology Technical Group

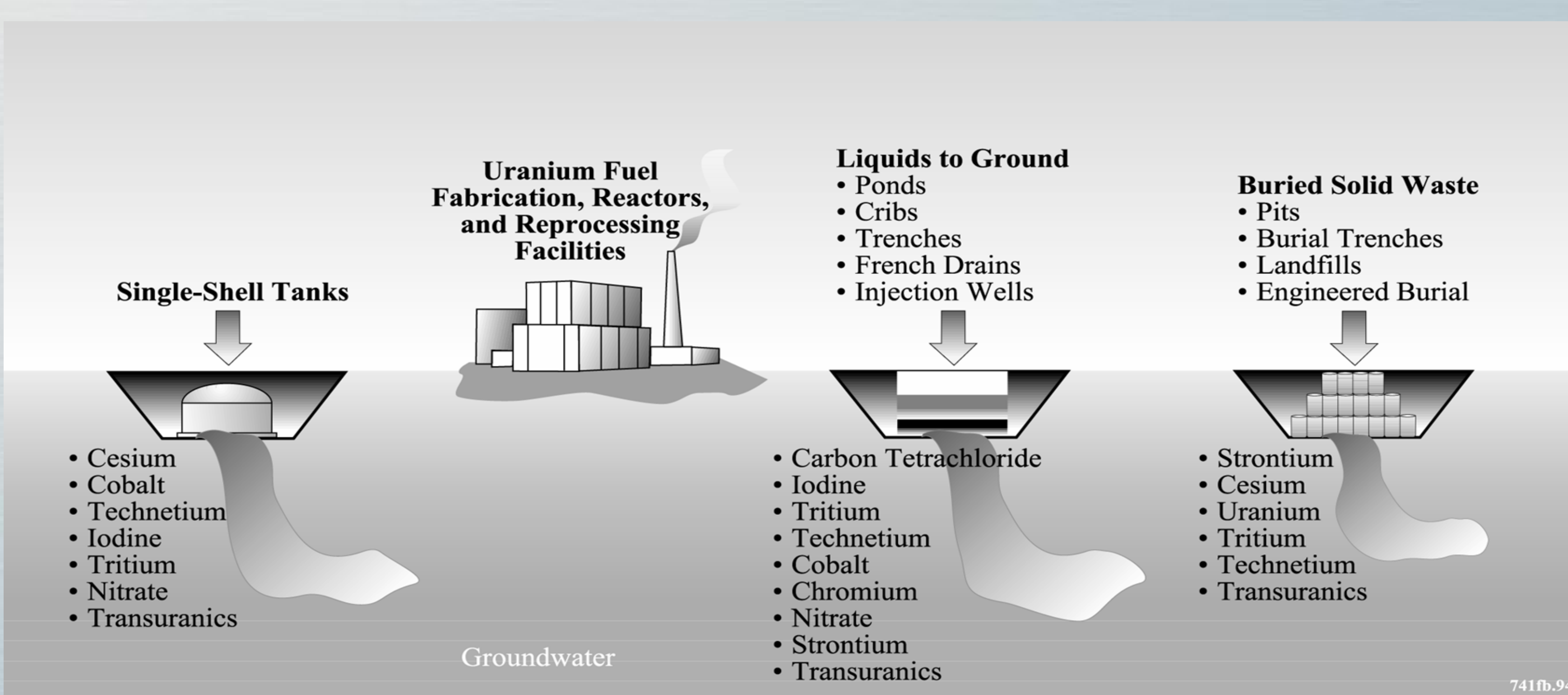
Pacific Northwest National Laboratory Richland, WA

Hanford Site Facilities



Battelle
The Business of Innovation

Contaminants in Soil and Groundwater



Surface Barrier Needs

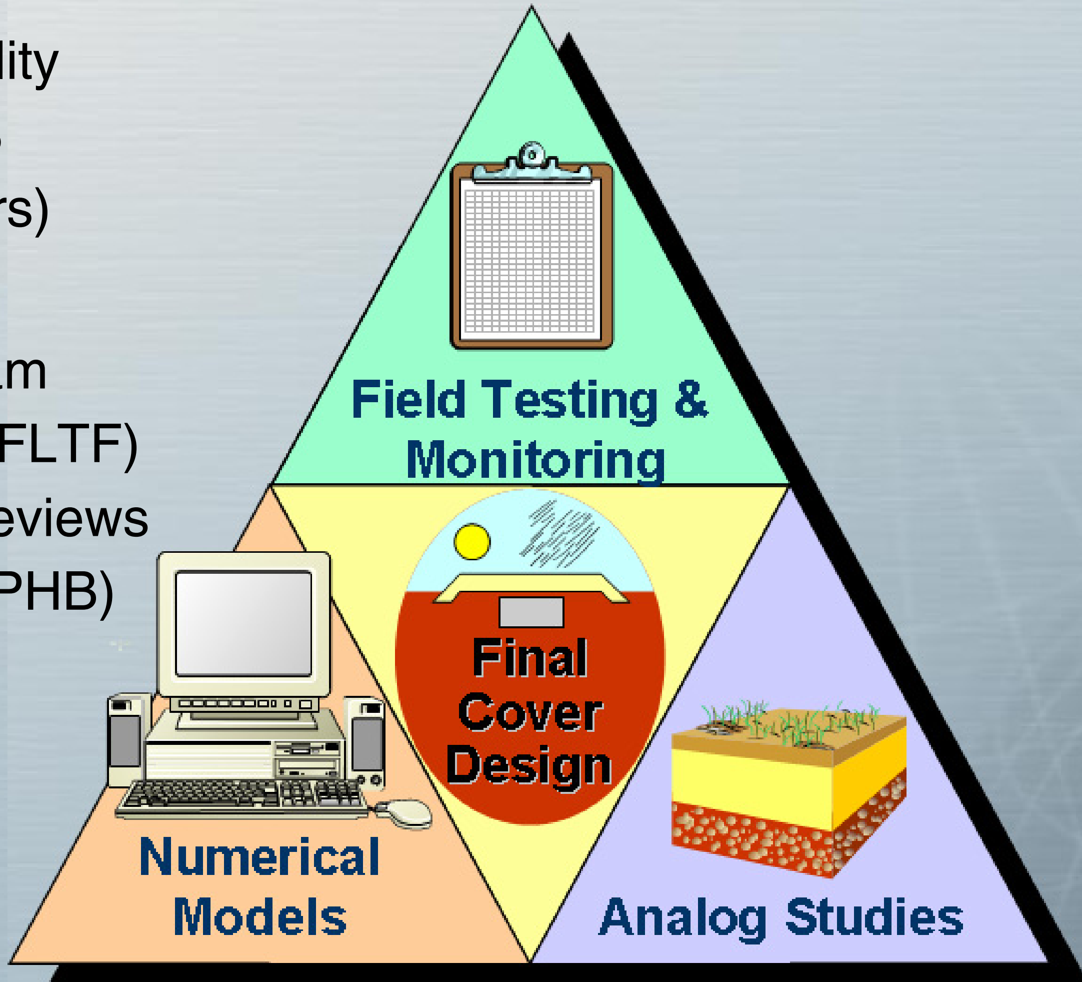
- Surface barriers are needed for closure at most DOE sites
- At Hanford alone, over 1600 liquid and solid waste sites, including 12 tank farms
- Some 200 sites ($\cong$1000 Ac) require engineered covers for long-term isolation of subsurface contaminants
- Yet, much uncertainty about field-scale performance
  - long-term data to demonstrate performance
  - robust, long-lived monitoring technologies
  - design optimization (e.g., models, storage, stability, side slopes)
- Uncertainties in performance *and stewardship* can impact long-term post-closure care of covers

Performance Criteria

- function in a semiarid to subhumid climate
- function for ≥ 1000 yrs
- limit recharge to ≤ 0.5 mm/yr
- limit runoff
- minimize erosion
- Minimize biotic intrusion
- Maintenance free
- Free of institutional control
- Meet or exceed RCRA performance criteria

Surface Barrier Development at Hanford

- 1982-1985
  - Engineered barrier test facility
  - Hanford defense waste EIS
  - Site-specific data (lysimeters)
- 1986-1994
  - Barrier development program
  - Field lysimeter test facility (FLTF)
  - Peer & value engineering reviews
  - Prototype Hanford barrier (PHB)
- 1994-Present
  - Focused feasibility study
  - FLTF (> 16 yrs of data)
  - PHB (> 10 yrs of data)

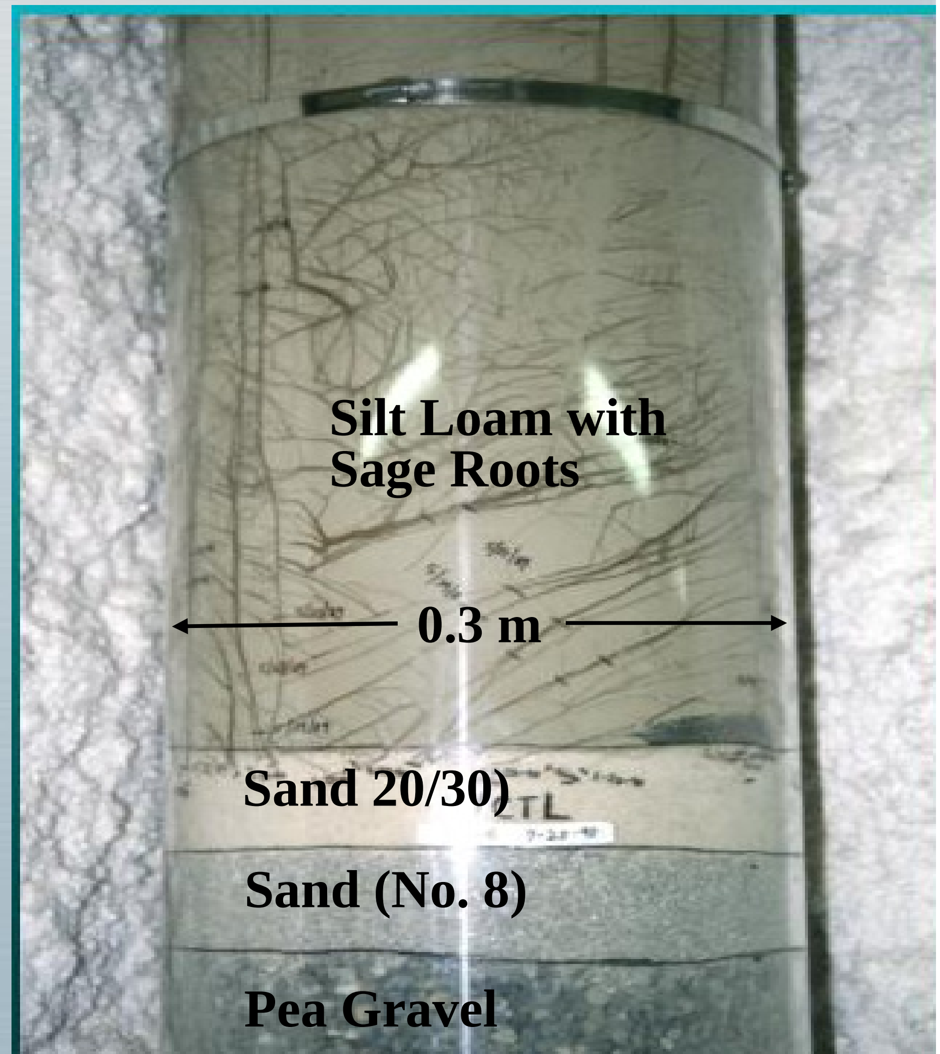


Field Lysimeter Test Facility
(FLTF; ca. 1988)

Battelle
The Business of Innovation

Vegetated Multilayered with Capillary Break (Lysimeter C6)

- 1.5 m silt loam above capillary break, which is above basalt riprap
- Elevated precipitation
  - 3 yr @ 2x
  - 13 yr @ 3x)
- Result? ***Zero Drainage***



Battelle
The Business of Innovation

Results of FLTF Tests

Description	Veg. Trtmt.	Reps	Avg. Drainage (mm/yr) Ambient Precipitation	Avg. Drainage (mm/yr) Enhanced Precipitation*
Gravel Mulch	No plants	1	**89.1**	**332.0**
Pitrun Sand	Shrub-steppe	1	**21.3**	**69.0**
Riprap Side Slope	No plants	1	**53.9**	**269.0**
Sandy Gravel Side Slope	No plants	1	**109.0**	**365.0**
Hanford Barrier: Eroded, then Dune Sand Deposition	Shrub-steppe	2	**0.0, 0.0**	**58.5, 123**
Modified RCRA Subtitle C Barrier	Shrub-steppe	1	**0.0**	**0.0**

*Enhanced Precipitation = 32 cm/yr for 3 years, then 48 cm/yr

Application to Field-scale Design

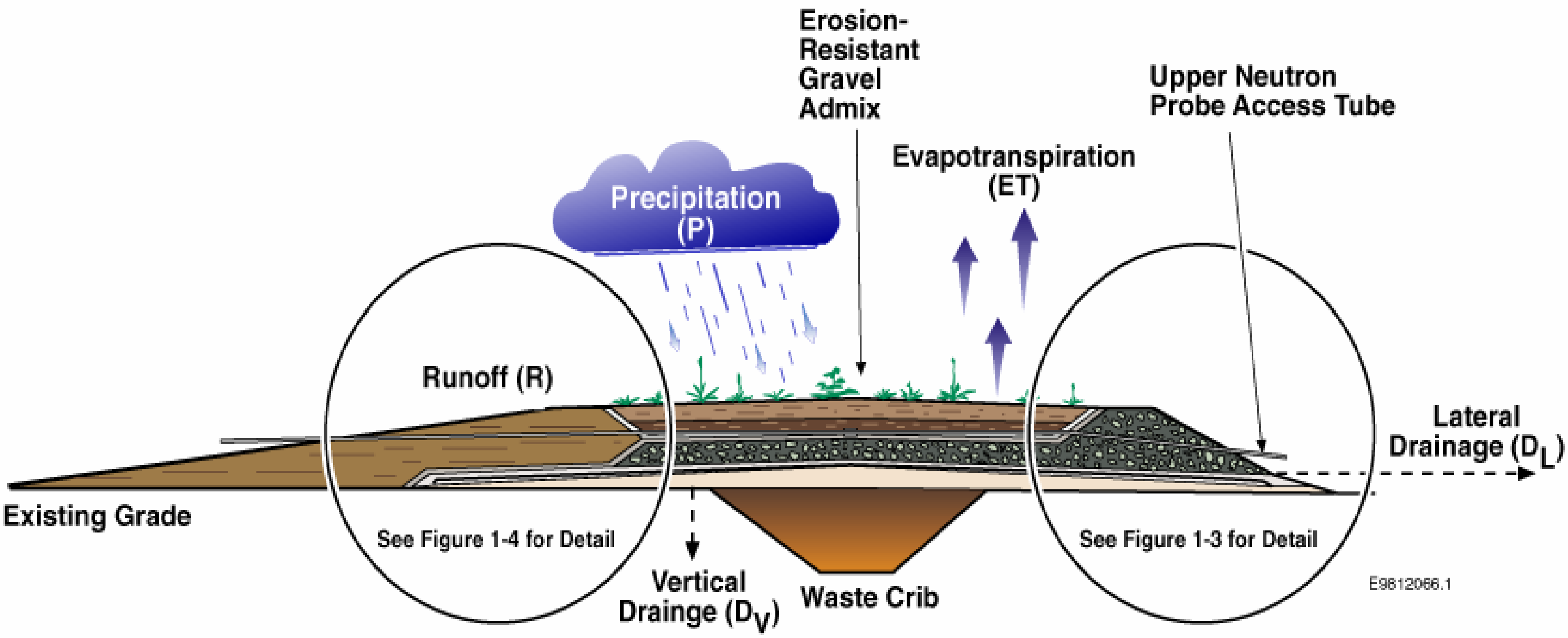
- Multidimensional design problem
  - raised sloped surfaces
- Protective side slopes
  - no standard practice
  - no design standard
- Barrier dimensions
  - subsurface heterogeneity
  - strong anisotropy→ underflow
- Limitations in design tools
  - not all are physically based
  - semi-empirical climate coupling
  - mass and energy not coupled
  - not suited to sparse canopies typical of arid environments

Battelle
The Business *of* Innovation

Flow Anisotropy and Bypass– IDF Site

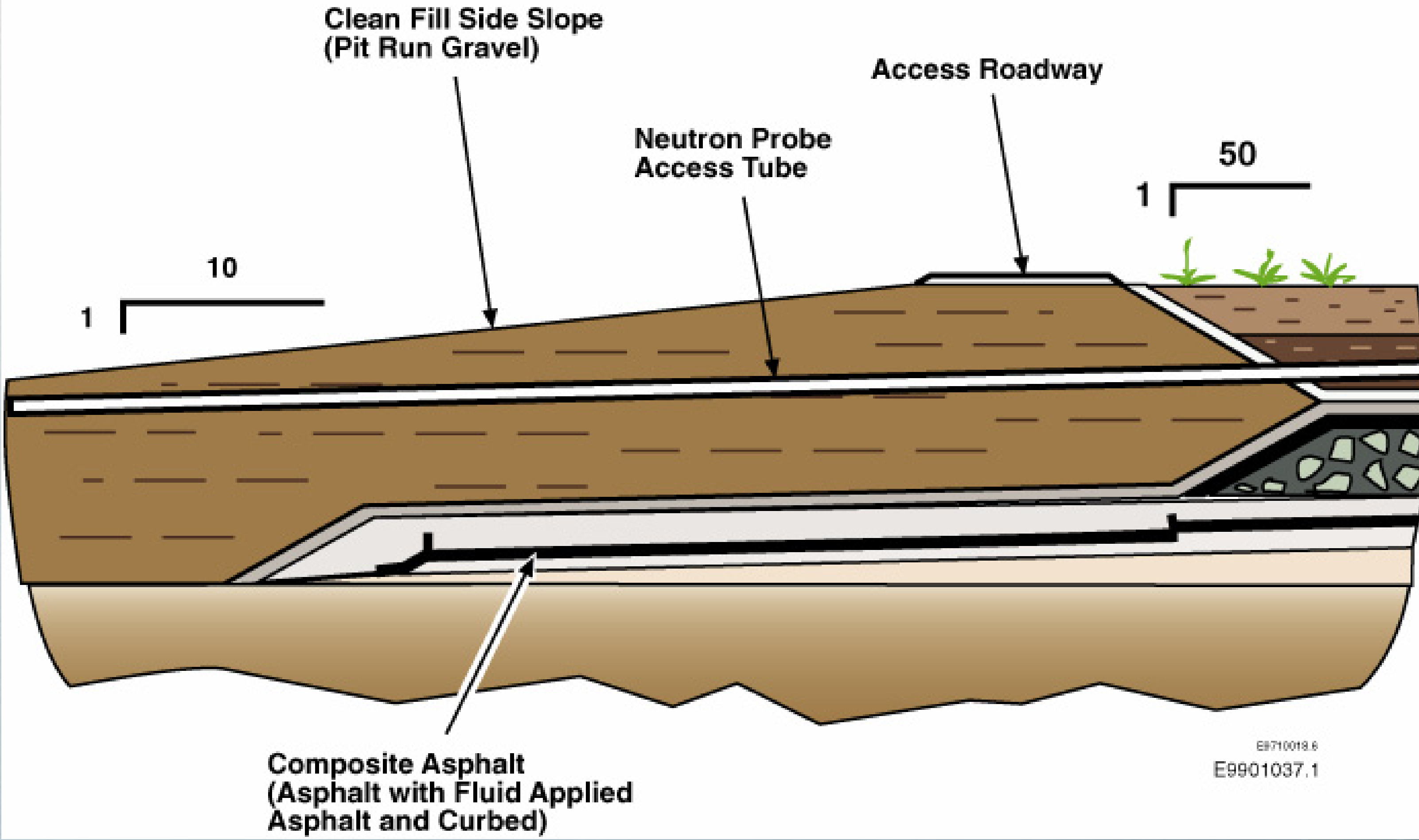
telle
The Business of Innovation

Prototype Hanford Barrier

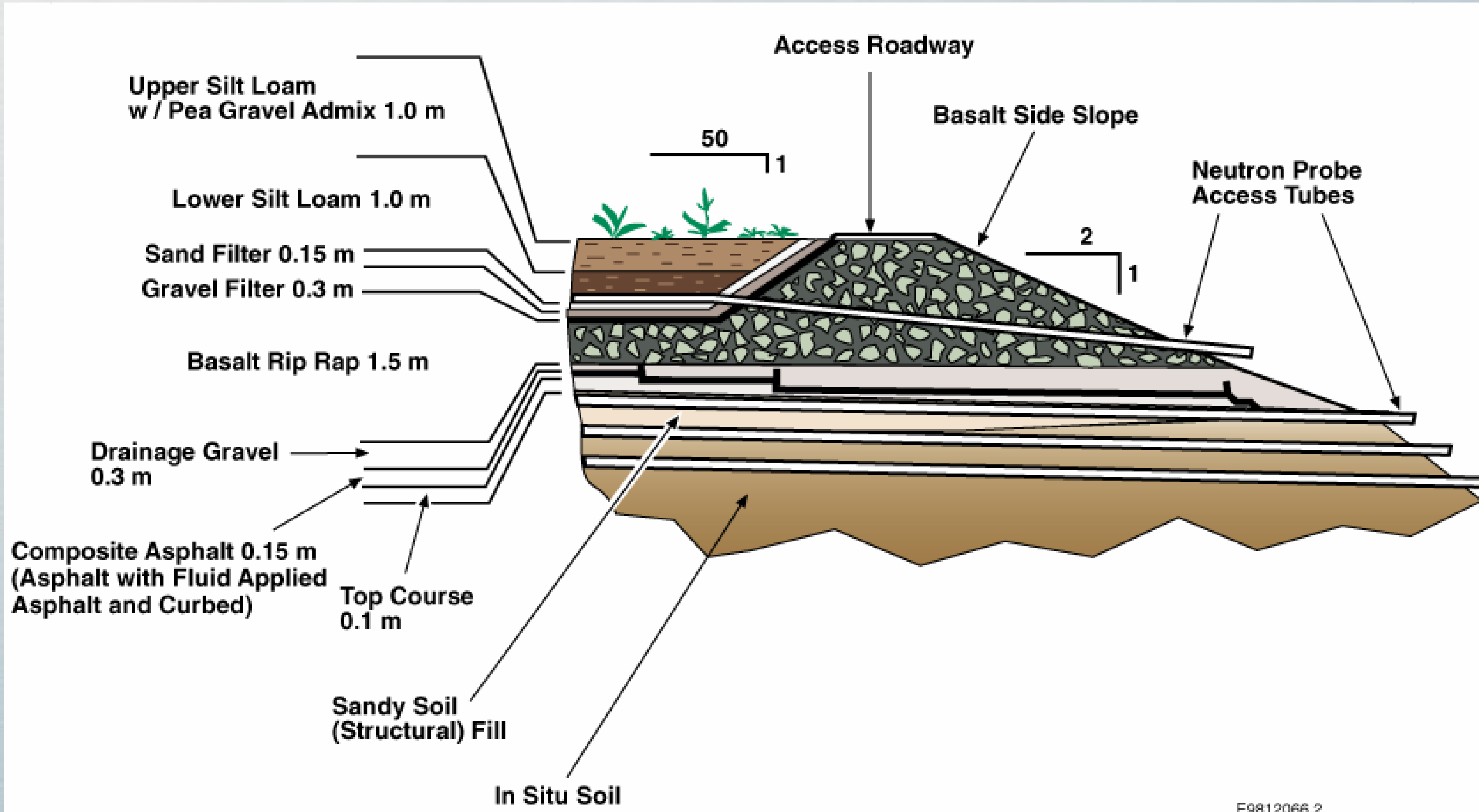


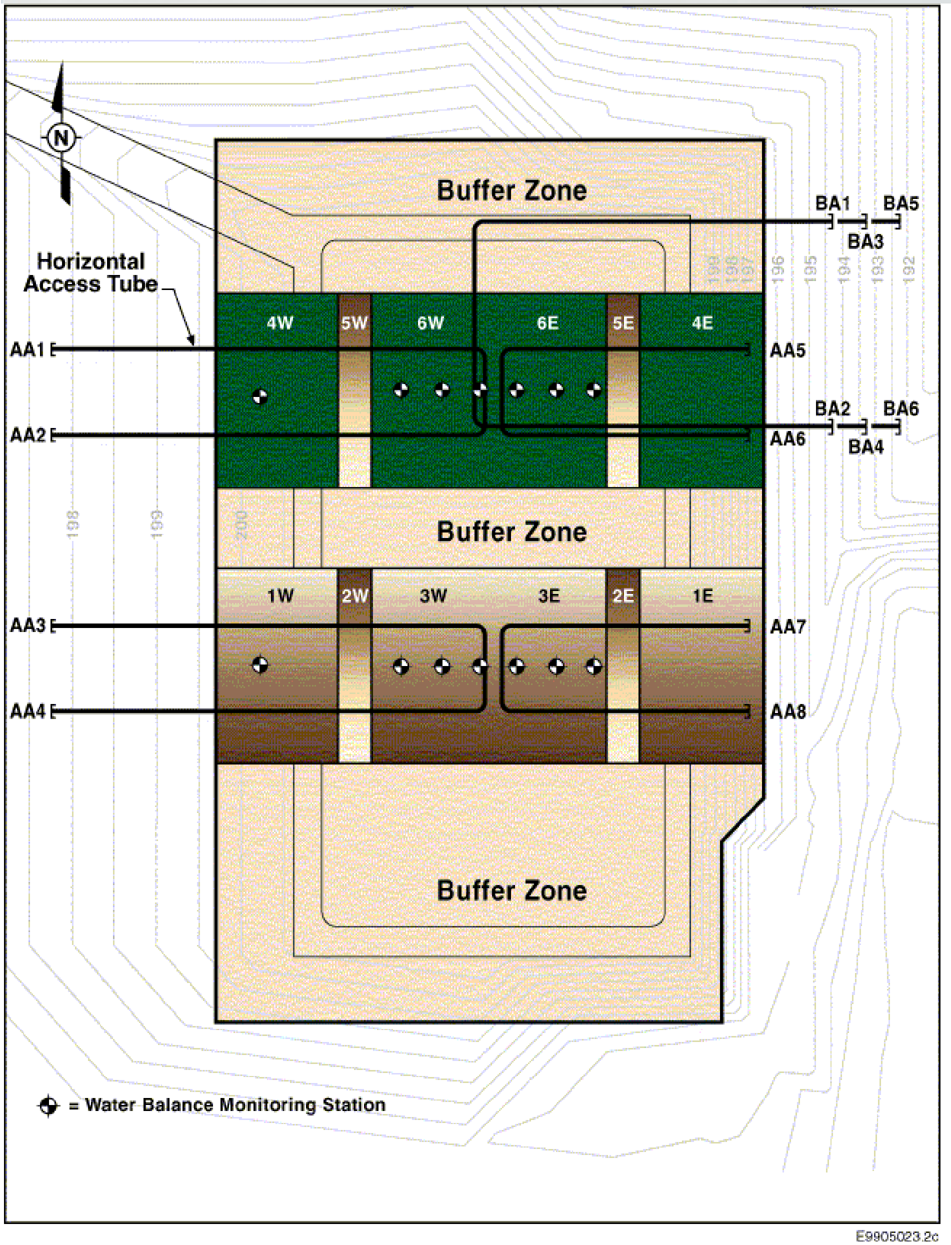
Battelle
The Business *of* Innovation

Pit-run Gravel Side Slope



Riprap Side Slope

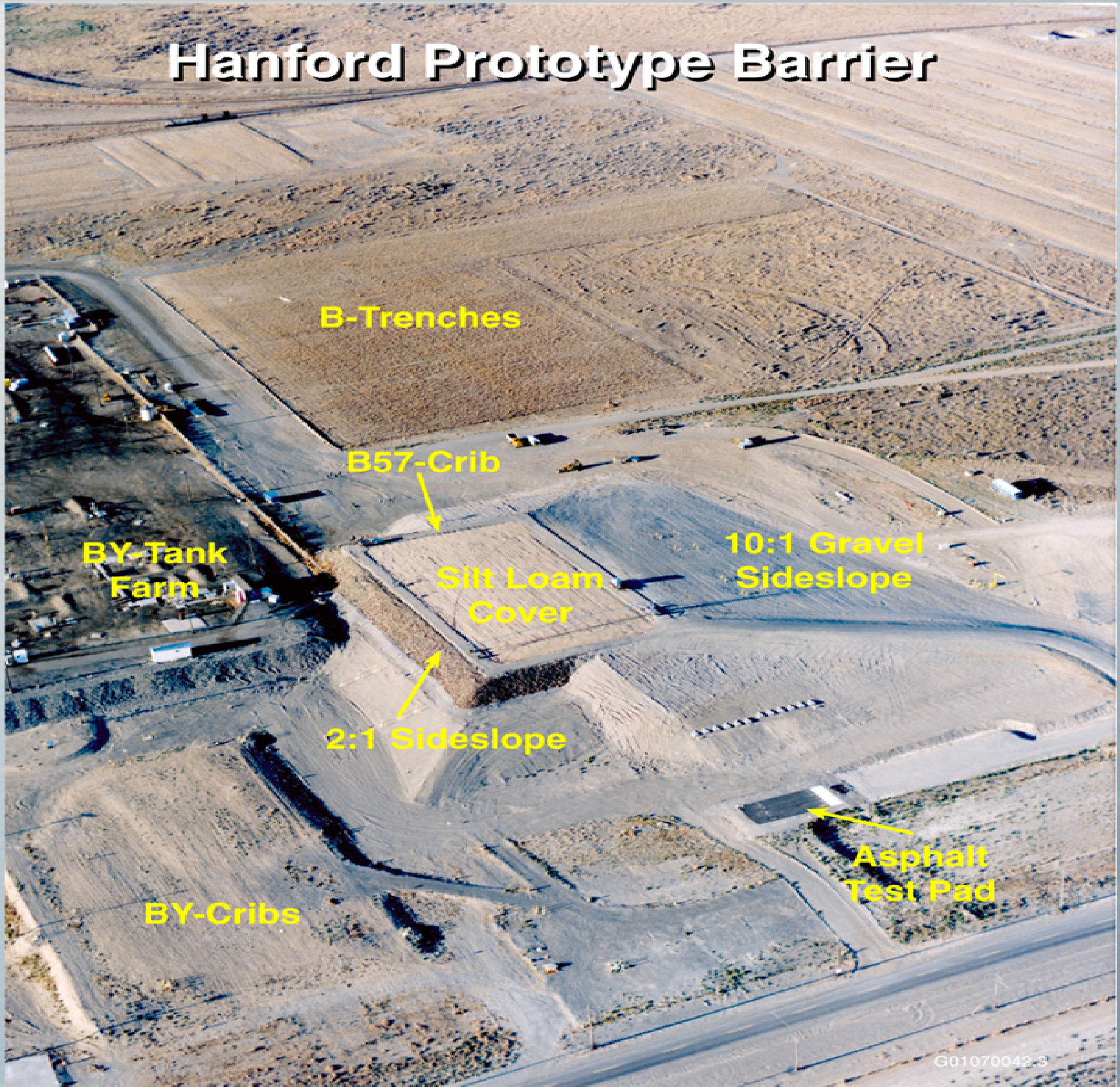




- 8 full-size plots
- 4 transition plots
- 14 monitoring stations
  - vertical access tubes (NP, CP)
  - TDR
  - HDUs, thermocouples
  - Mini-lysimeter for precipitation
- 4 sets of horizontal NP access tubes (at capillary break)
- 3 sets of horizontal NP access tubes 1, 2, 3 m below asphalt layer

Battelle
The Business of Innovation

Prototype Hanford Barrier



Battelle
The Business of Innovation

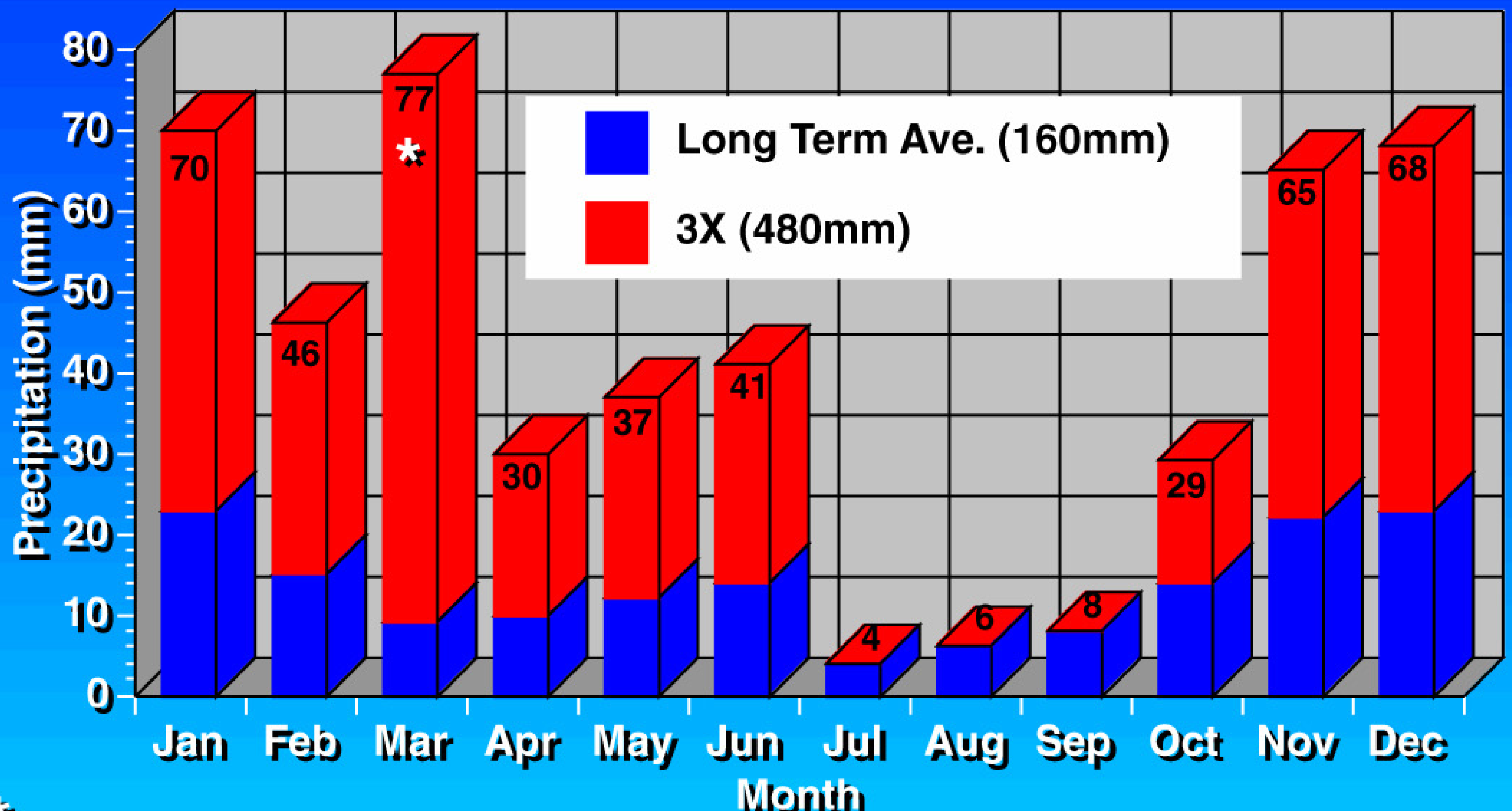
Treatability Test Scope

- Treatability Test Phase I
  - Ease of Construction
  - Cost
  - Asphalt permeability
- Treatability Test Phase II
  - Hydrology (water balance)
  - Erosion (water and wind)
  - Plant growth
  - Biointrusion
  - Barrier stability

Water Balance Tests

- 2 precipitation treatments
  - ambient (160 mm/yr)
  - 3 × ambient (480 mm/yr)
  - Simulated 1000-yr storm (68 mm over 8 hr in late March)
- Testing and Monitoring
  - Precipitation
  - Runoff
  - Water Storage
  - Drainage
  - Evapotranspiration
- Over 10 years of data

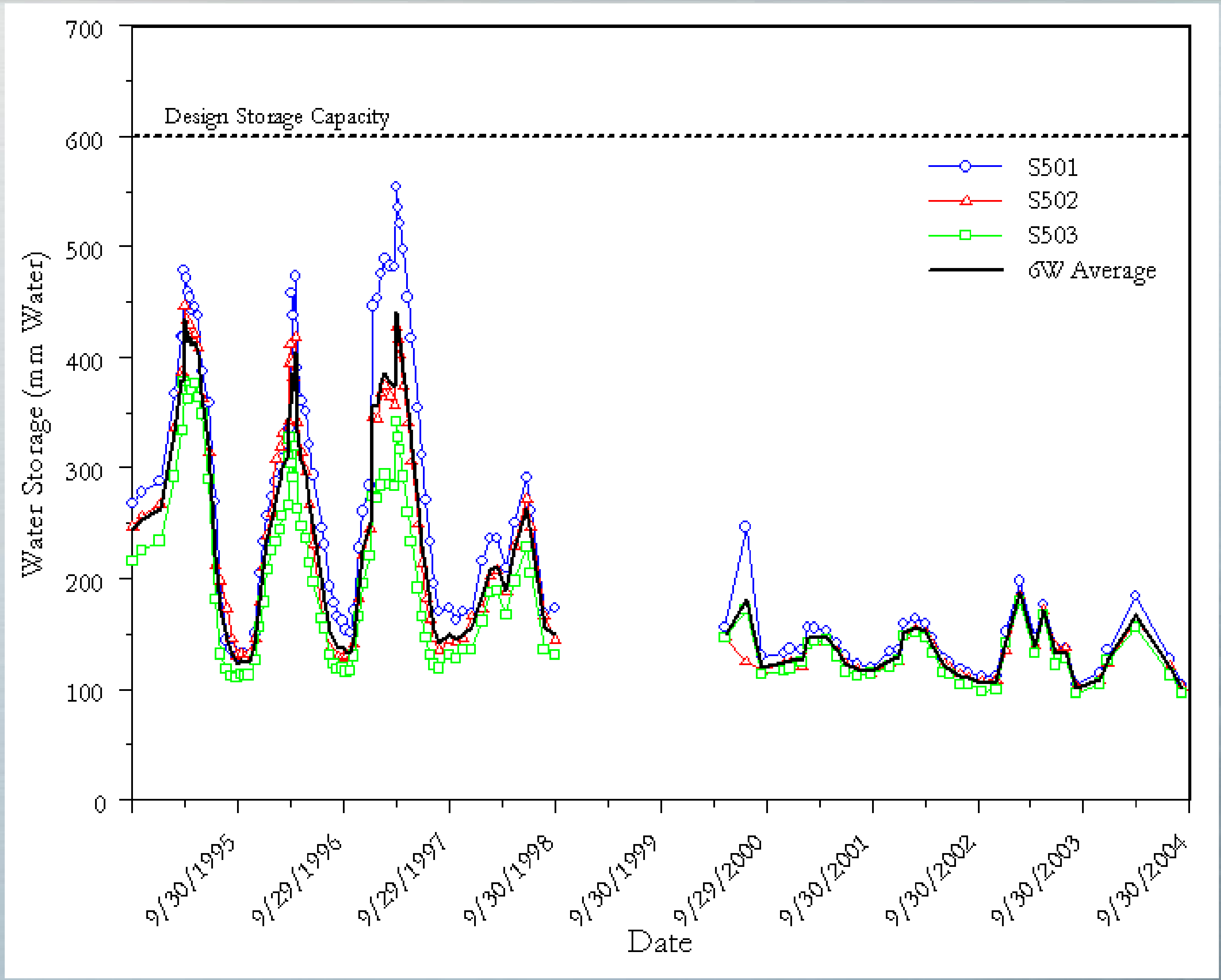
Barrier Water Application



*1000-yr Storm (68 mm in one day)

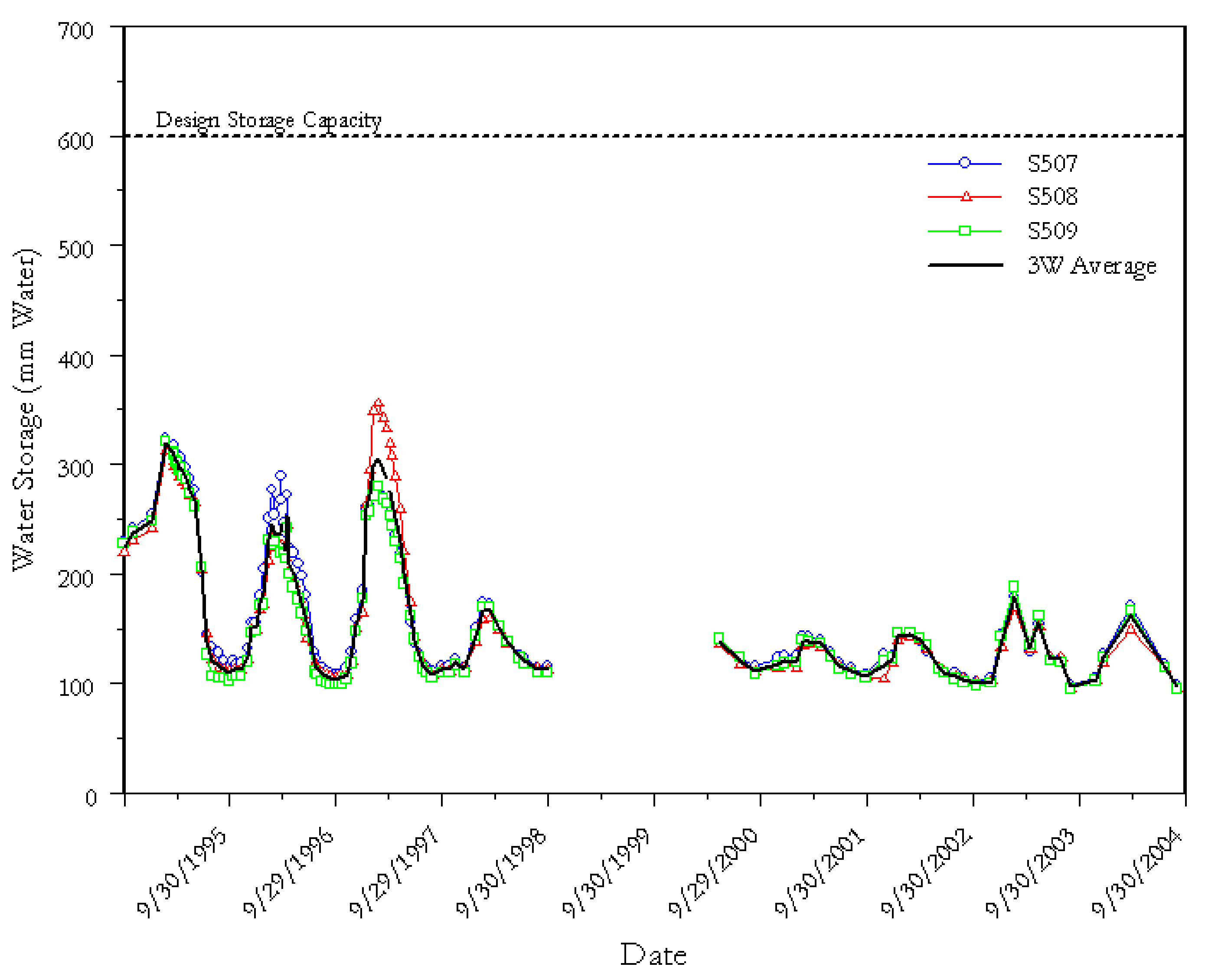
S9504008.1

Water Storage (Irrigated Plot 6W)



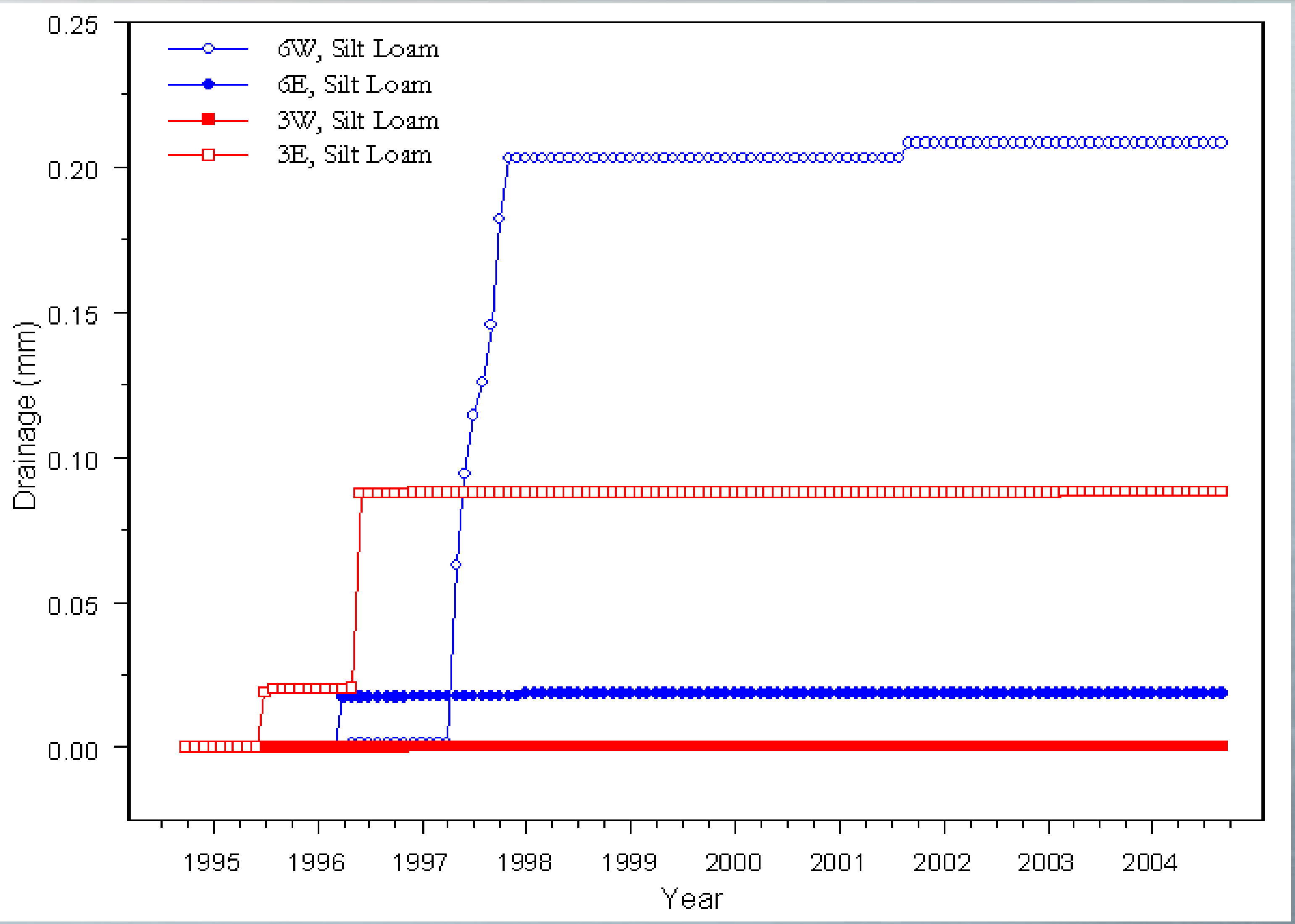
Battelle
The Business of Innovation

Water Storage (Irrigated Plot 3W)



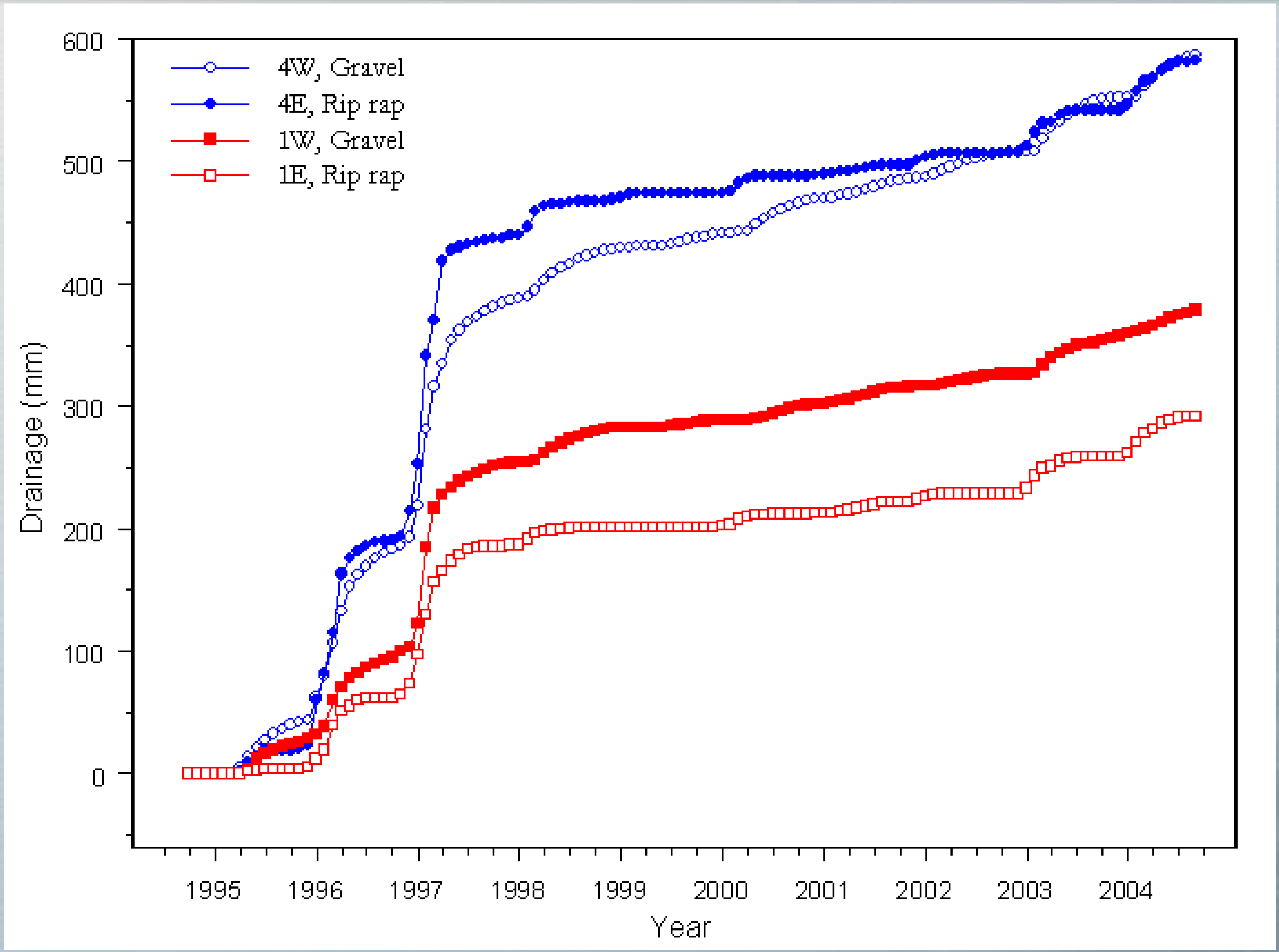
Battelle
The Business of Innovation

Silt-loam Drainage Reaching Asphalt



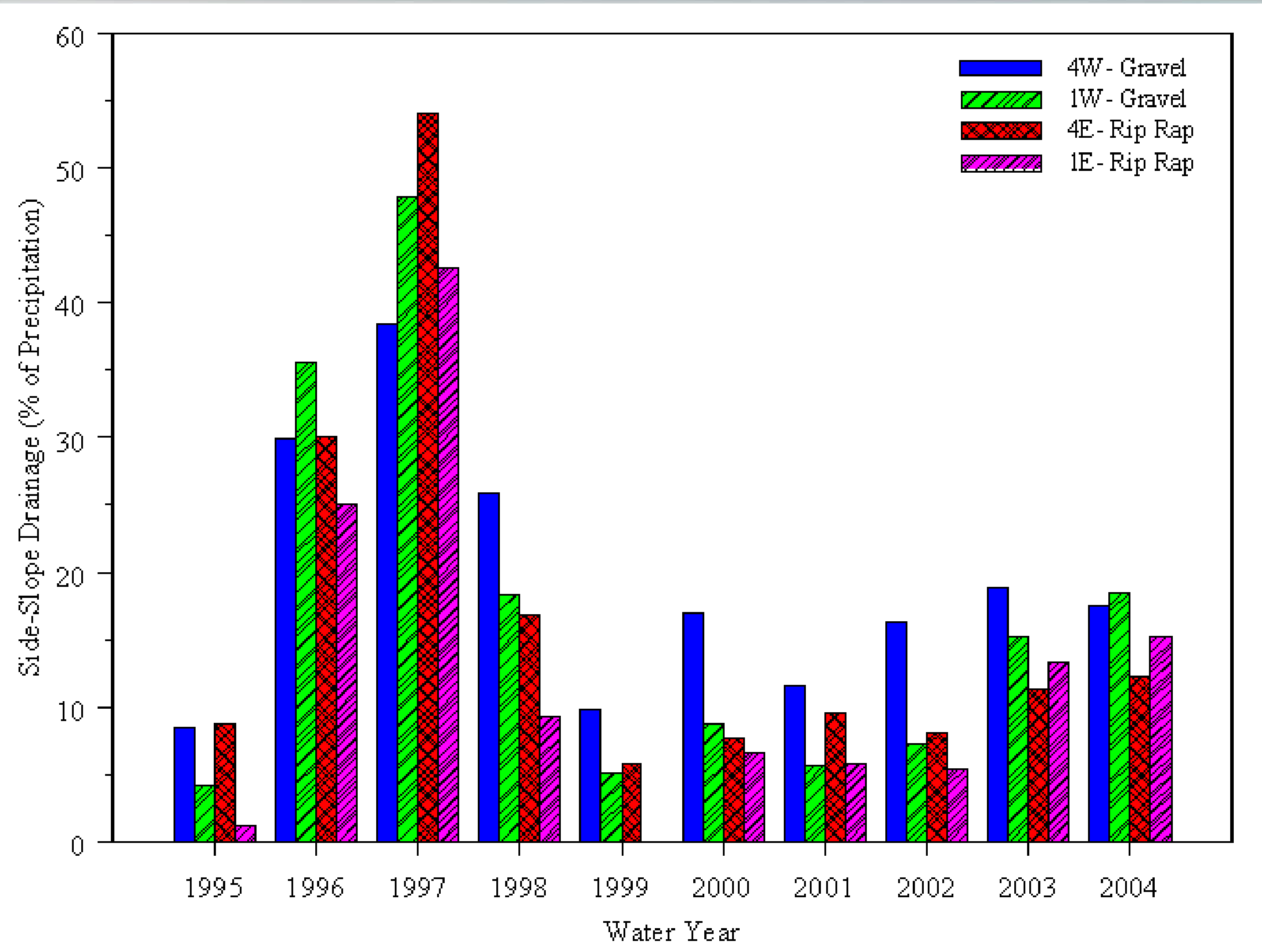
Battelle
The Business of Innovation

Sideslope Drainage Reaching Asphalt



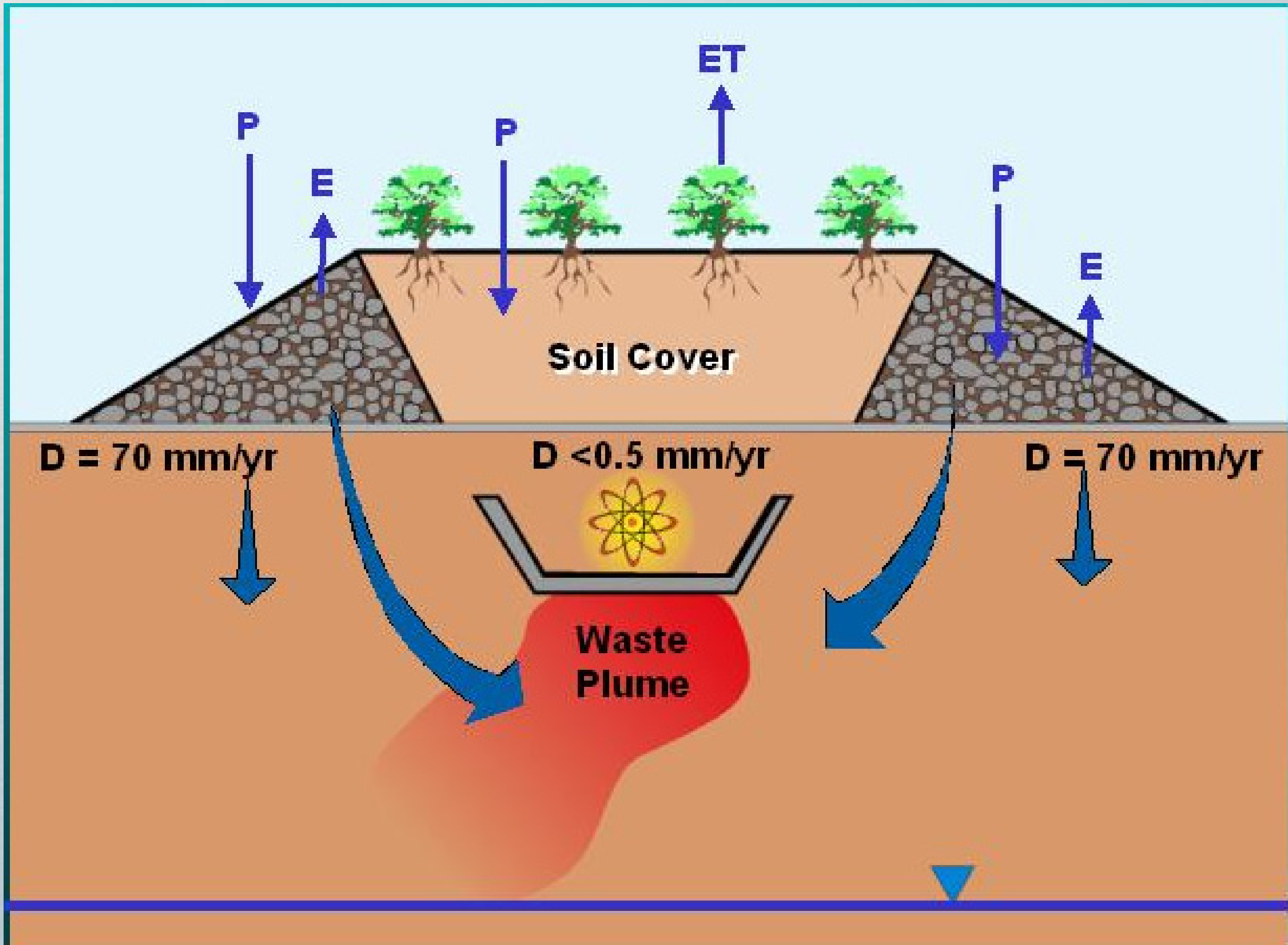
Battelle
The Business of Innovation

Sideslope Drainage as % Precipitation



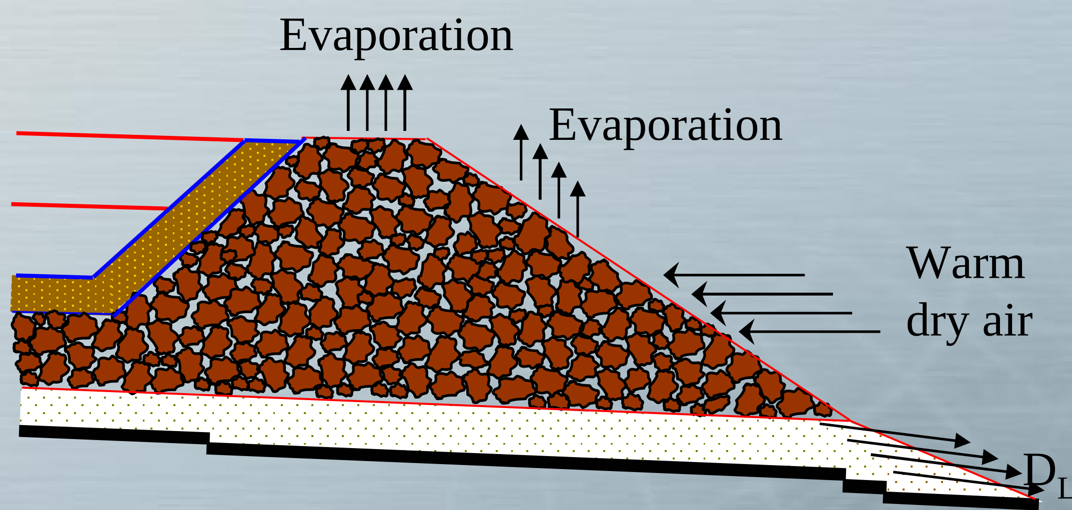
Battelle
The Business of Innovation

Relative Contributions to Drainage: Sideslopes vs fine-soil

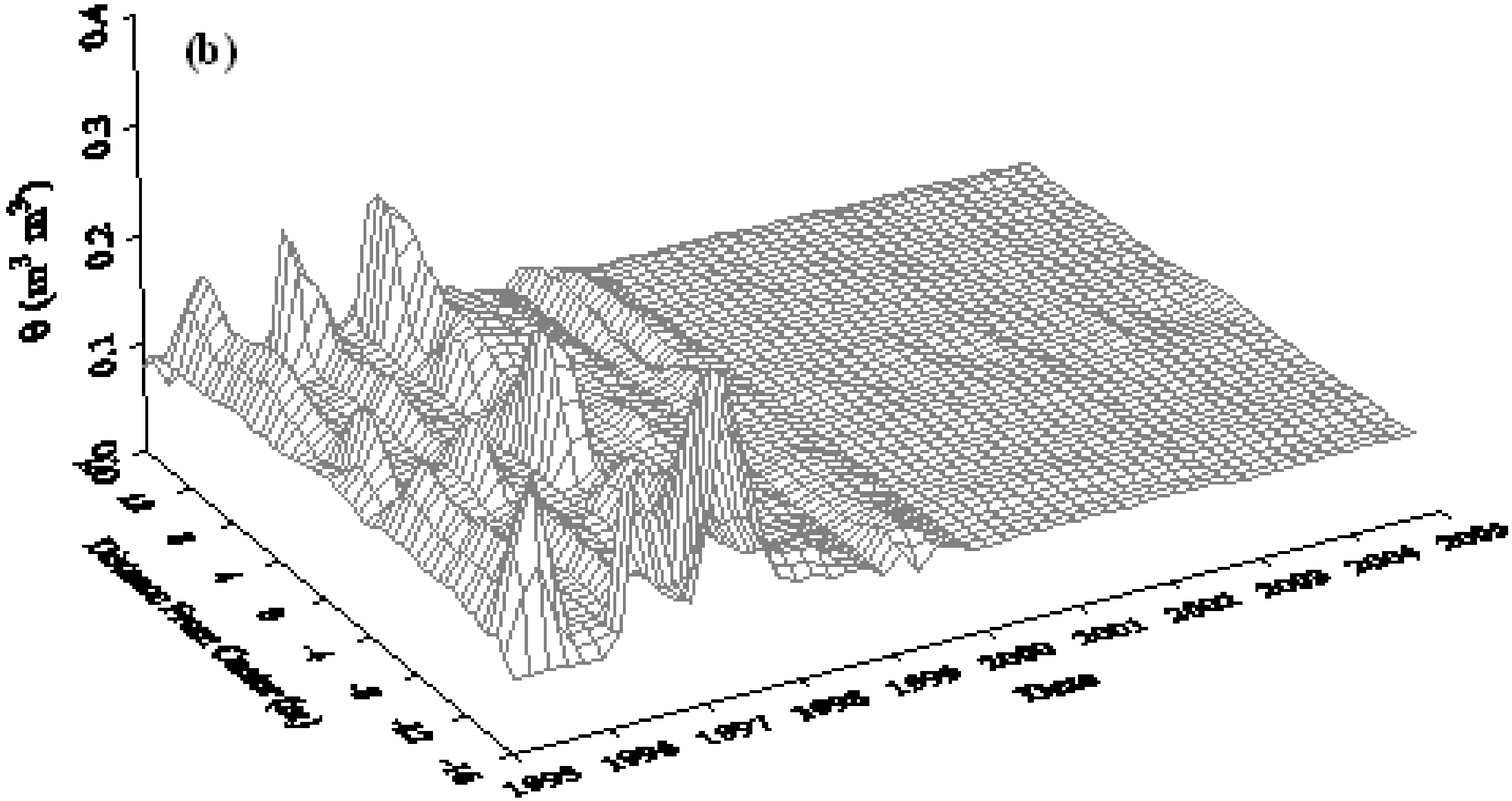


Relative Contributions to Drainage: Riprap vs gravel

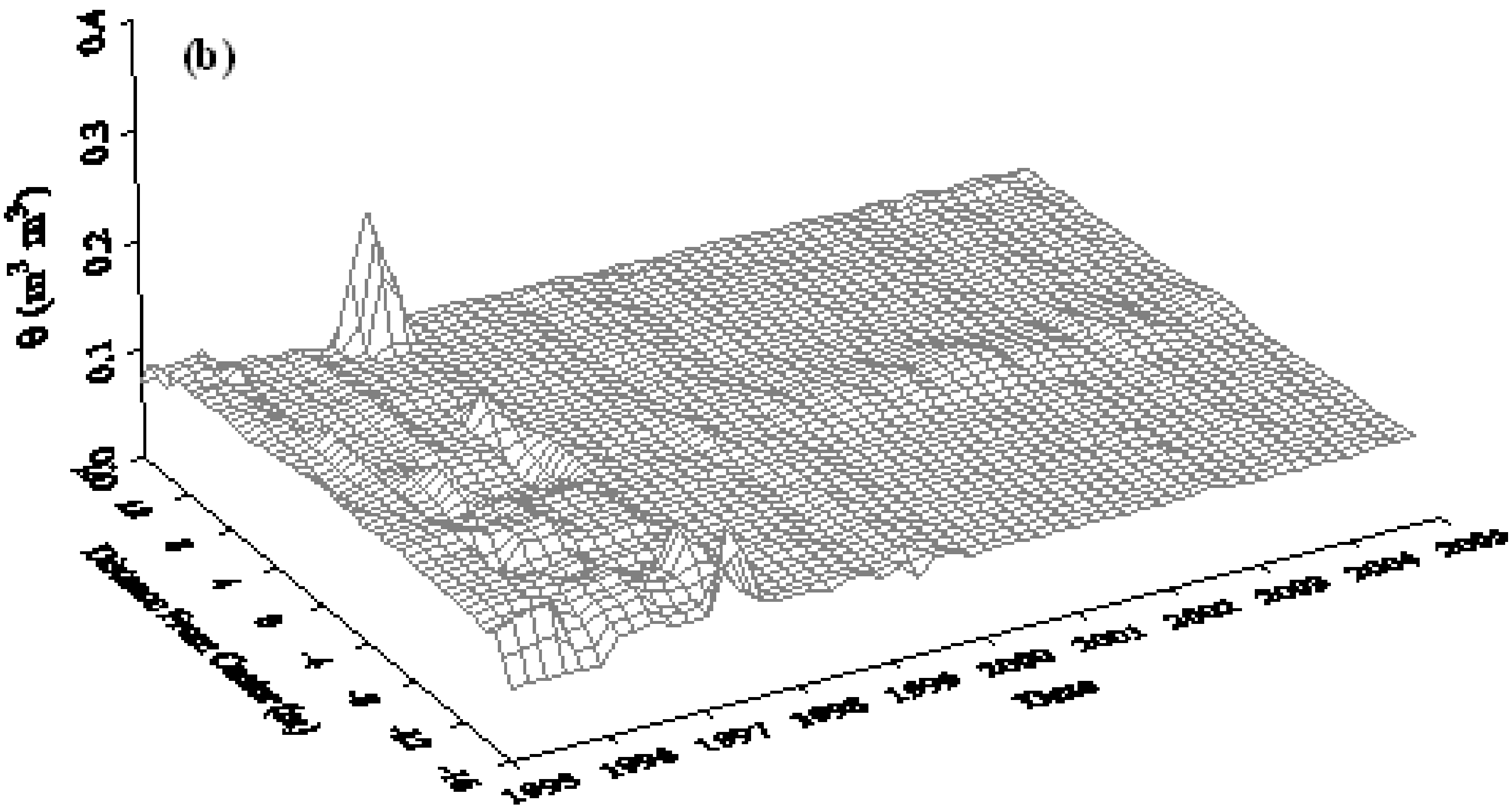
- Advective airflow (air convective embankment)
- STOMP Model
  - Fully coupled
  - bare or vegetated surface
  - time-dependent veg. density
- Solves for aqu. and gas phase flows
  - wind pumping in side slope
  - advective drying
  - reduced temperature
  - reduced recharge



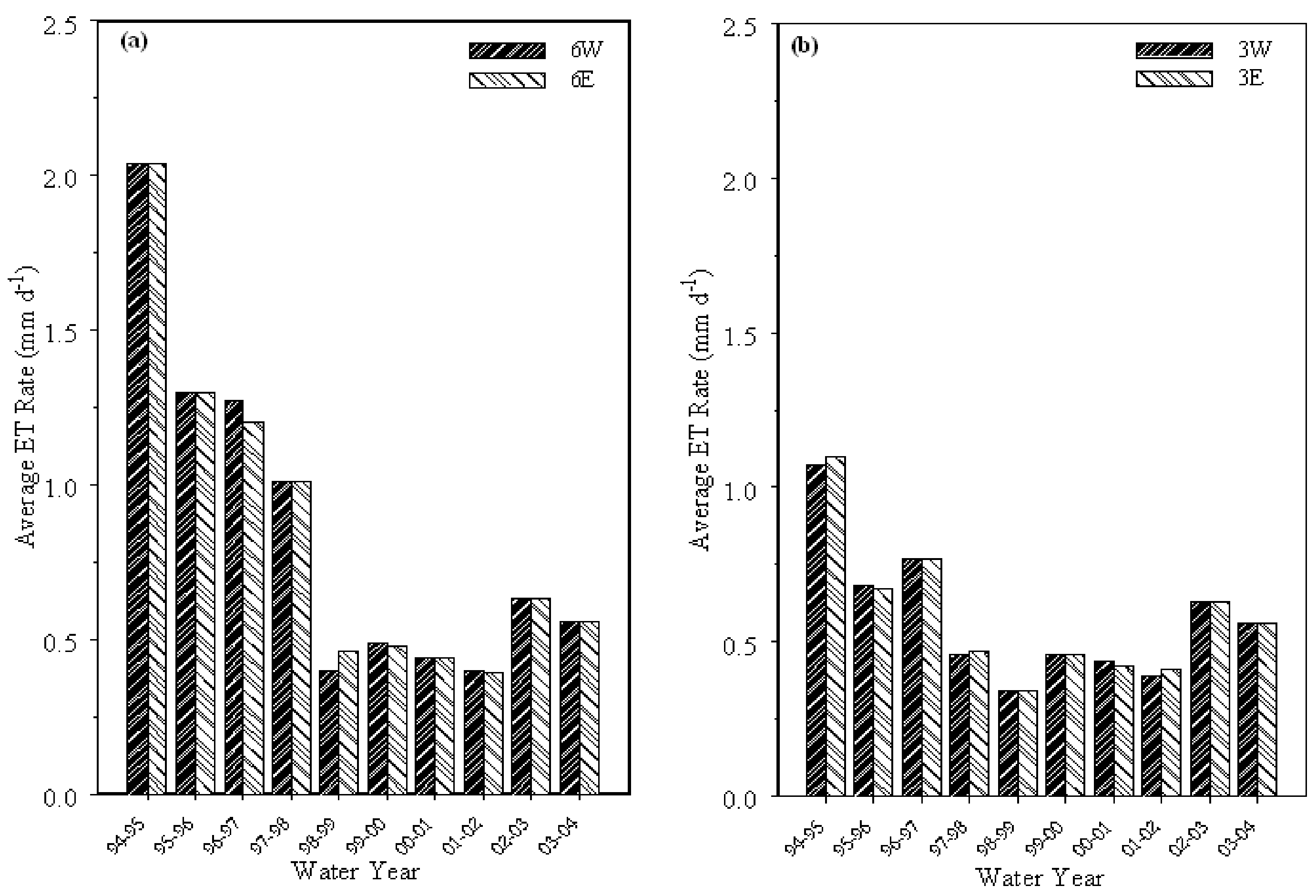
Horizontal Moisture Distribution- Above Capillary Break (Irrigated)



Horizontal Moisture Distribution- Above Capillary Break (Ambient)

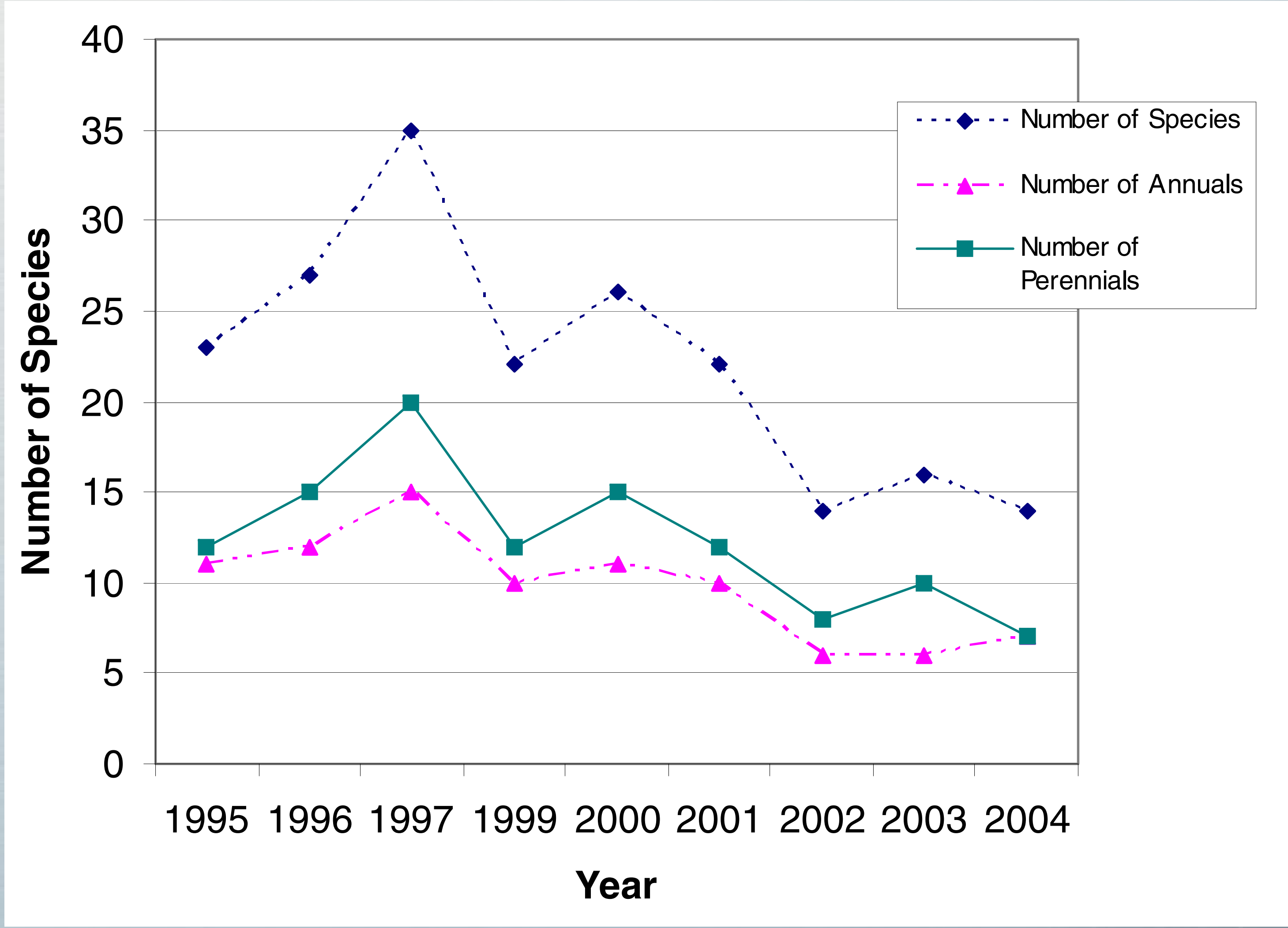


Evapotranspiration



Battelle
The Business *of* Innovation

Number of Plant Species



Battelle
The Business of Innovation

Erosion of Toe Slope

Battelle
The Business of Innovation

Summary of Treatability Test Results

- Prototype Hanford Barrier easily constructed using standard equipment
- Performance objectives met
  – function in a semiarid to subhumid climate
  – no drainage through functional portion
  – evaporation and transpiration effectively recycles water
  – limit runoff and minimize erosion
    - no measurable loss of soil from wind erosion
    - minimal surface water runoff and no water erosion

Summary of Results (continued)

- Performance objectives met (continued)
  - Maintenance free
    - barrier side slopes and surface have remained stable
    - monitoring equipment requires maintenance
  - Minimize biotic intrusion
    - minimal small mammal burrowing activity with no impact on barrier performance
  - Meets RCRA performance criteria

Key Issues

- ***Design*** - Current side slope designs and lateral diversion layers increase deep drainage at the barrier edges.
  - How does this water impact the waste?
  - Can the impact be minimized to acceptable levels?
- ***Performance*** – Type and frequency of measurements needed to satisfy the performance requirements
  - vadose zone monitoring protocols?
  - Remote sensing
- ***Impacts*** - Can predictions of long-term impacts be evaluated acceptably in the short term
  - fire, pests, erosion, climate, eco-succession?
  - Natural analogs
  - Robust models (e.g. STOMP)

Summary

- Capping technology has been tested for 20 years at Hanford (>130 surface barrier publications)
  - http://hanfordbarriers.pnl.gov
- Performance data from lysimeters and the Prototype Hanford Barrier demonstrate the success of specific designs at the Hanford Site
- Armored side slopes and coarse-textured soil surfaces with little vegetation result in significant drainage
- Multiple design options are available for use (i.e., the “graded barriers” approach)
- Final designs can be selected to satisfy site-specific performance requirements using performance data and modeling

Acknowledgements

- Funding for performance monitoring of the prototype Hanford Barrier provided by Fluor Hanford
- This presentation included contributions from Dr. Michael Fayer and Dr. Glendon Gee from the Hydrology Group at the Pacific Northwest National Laboratory
- Pacific Northwest National Laboratory operated by Battelle for the United States Department of Energy under Contract DE-AC05-76RL01830

Battelle
The Business *of* Innovation