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Objectives and Design Solutions of a 1000-year Evapotranspiration-Capillary Surface Barrier System

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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)
  - covers the exposed rocks
  - isolates rockpile/tailing
  - reduces erosion
  - provides a medium for vegetation growth
  - reduces drainage

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

Barrier Design Challenges

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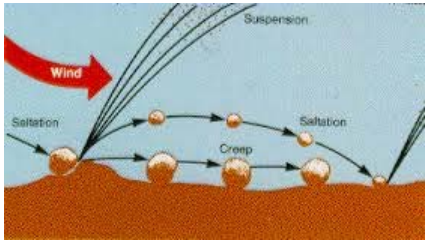
Regulatory requirements

Recharge Control

Wind Erosion



Water Erosion

Animal Intrusion

Plant Intrusion

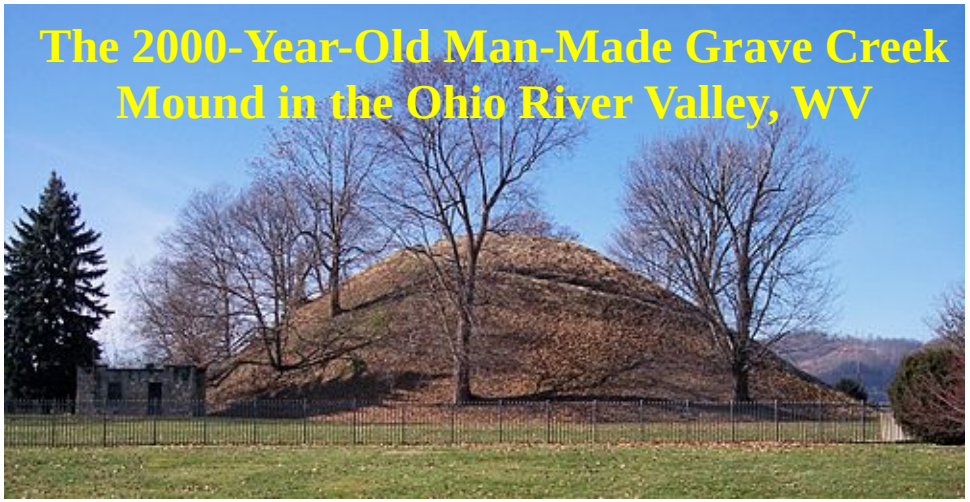
Human Intrusion

Waste isolation

Maintenance

Objectives

- Introduce performance objectives and the design solutions for a long-term (1000 yr) surface barrier
- Evaluate the performance of the surface barrier after a demonstration of 20 years



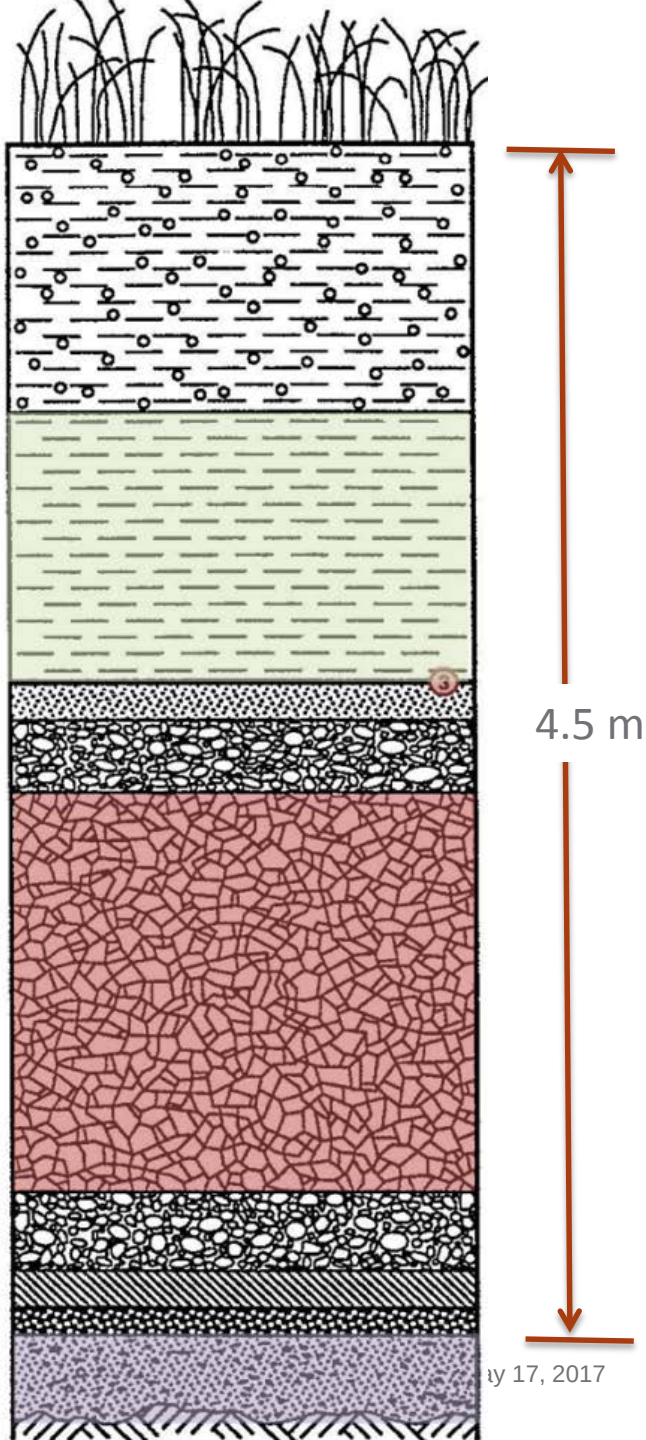
Performance Objectives of a Surface Barrier over a Nuclear Waste Site

	Objectives
Regulatory Requirements:	#1 Meet or exceed RCRA criteria
Functionality Requirements:	#2 Function in a semiarid to subhumid climate
	#3 Limit drainage to less than 0.5 mm yr^{-1}
Longevity Requirements:	#4 Limit runoff
	#5 Minimize erosion
	#6 Minimize biotic intrusion
	#7 Have a design life of 1000 years
	#8 Be maintenance free

Objectives and Solutions - 1

- **Objective #1: Meet or exceed RCRA criteria**
  - **thickness > 0.91 m;**
  - **design life: 30 years;**
  - **conductivity: <32 mm/yr**

- **Design Solution**
  - **thickness of 4.5 m;**
  - **design life of 1000 year;**
  - **drainage rate < 0.5 mm/yr**
  - **containing a coated asphalt concrete (AC)**



Objectives and Solution - 2

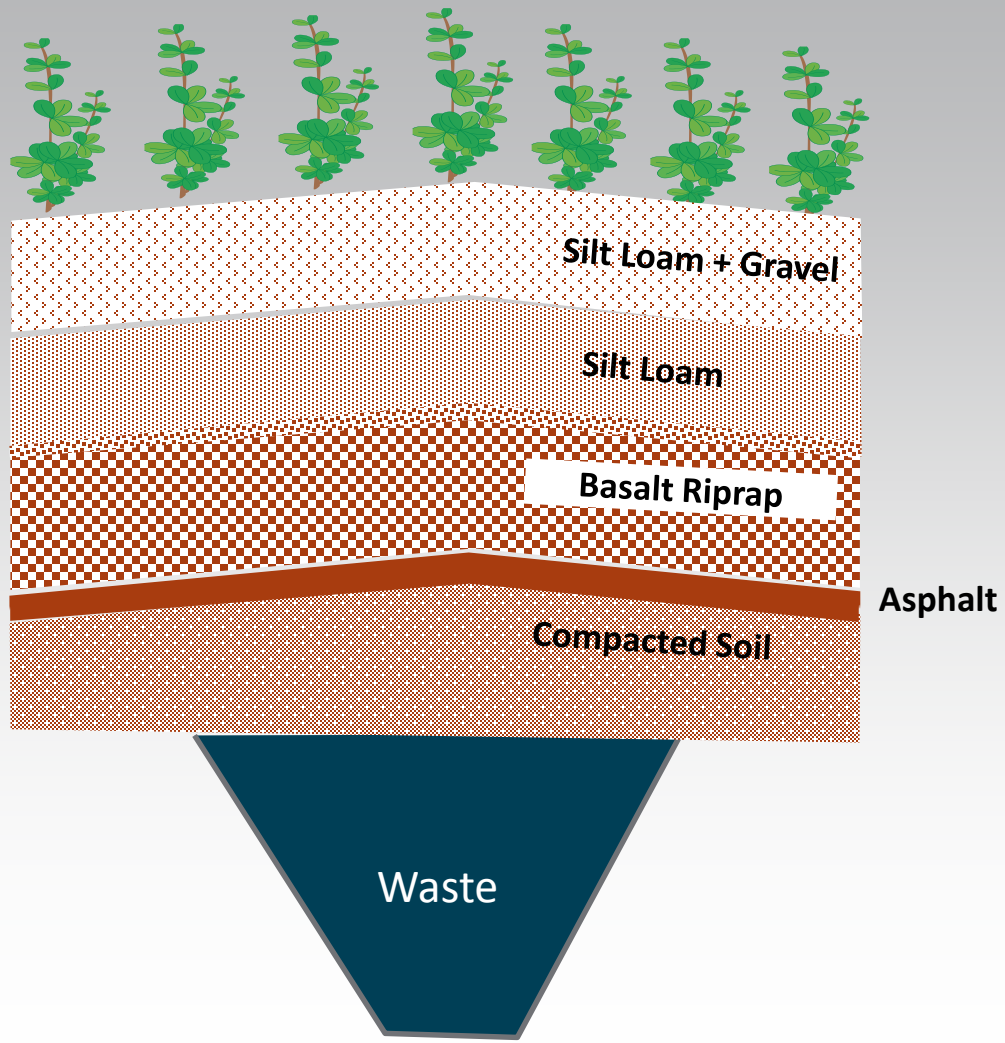
- **Objective #2:**
  - **Function in a semiarid to subhumid climate**
- **Design Solution:**
  - **Use a ETC barrier with 2-m-thick silt loam**
  - **The compacted clay barrier may not work**

$$AI = P/PET$$

Classification	Aridity Index
Hyperarid	AI < 0.05
Arid	0.05 < AI < 0.20
Semi-arid	0.20 < AI < 0.50
Dry subhumid	0.50 < AI < 0.65

Objectives and Solution - 3

- Objective #3:
  - Minimize drainage rate to <0.5 mm/yr
- Design solution
  - 2-m thick ET barrier
  - Capillary break
  - 2% slope of barrier surface



Objectives and Solution - 4

- Objective #4: Limit runoff
- Design solutions
  - Use soil with sufficient large permeability

Objectives and Solution - 5

- Objective #5: Minimize erosion
- Design solution
  - 15% gravel mix
  - vegetation

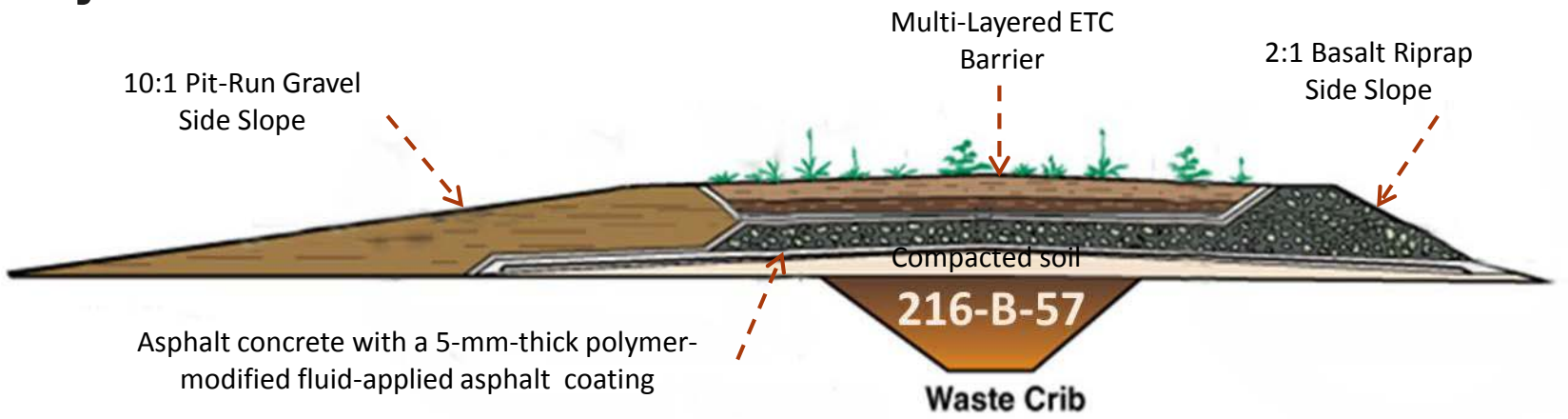
Objectives and Solution - 6

- **Objective #6: Minimize biotic intrusion**

- **Design solutions**
  - **1.5-m riprap layer**
  - **asphalt concrete layer**

Objectives and Solution - 7

- **Objective #7: Have a design life of 1000 years**
- **Objective #8: Be maintenance free**



- **Design solution**
  - **Use natural materials for barrier construction: soil and rock**
  - **Establish a natural ecological system: ETC Barrier**
  - **Include protective side slopes**

Barrier Design: 3D

Functions of Barrier Components

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Silt Loam + Gravel:

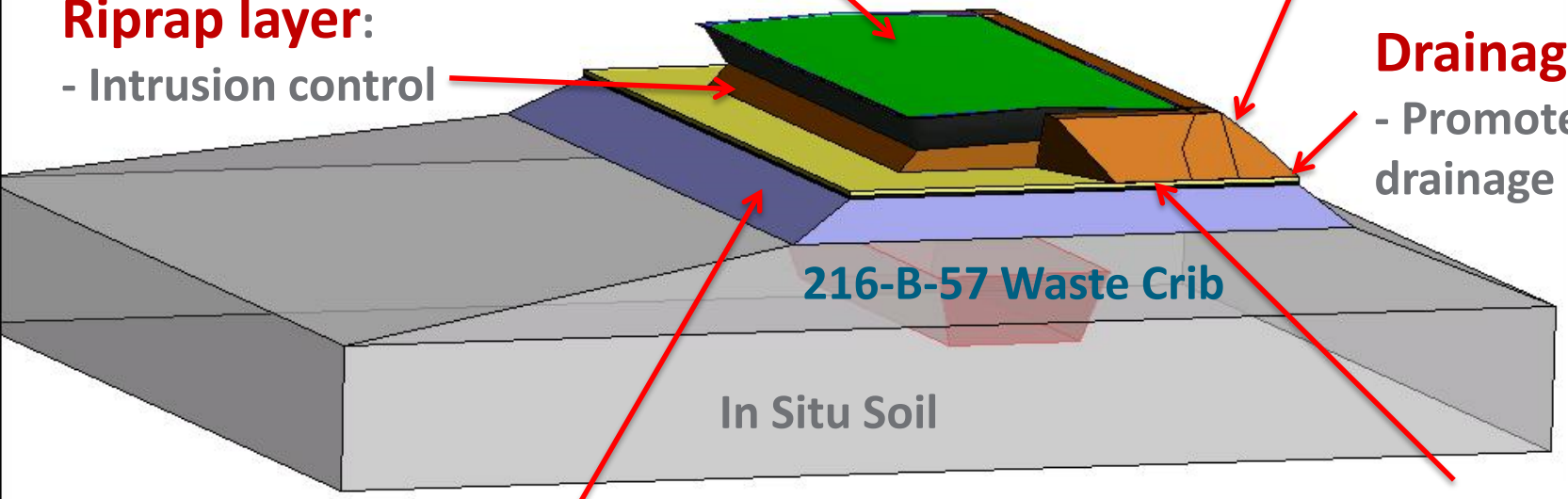
- Vegetation growth
- Precipitation storage and release
- Erosion control

Riprap Side Slope:

- Intrusion control

Riprap layer:

- Intrusion control



Drainage Gravel:

- Promote lateral drainage

Compacted Soil

- Settlement control

Asphalt Concrete

- Drainage interception
- Noxious gas control

2X vertical exaggeration

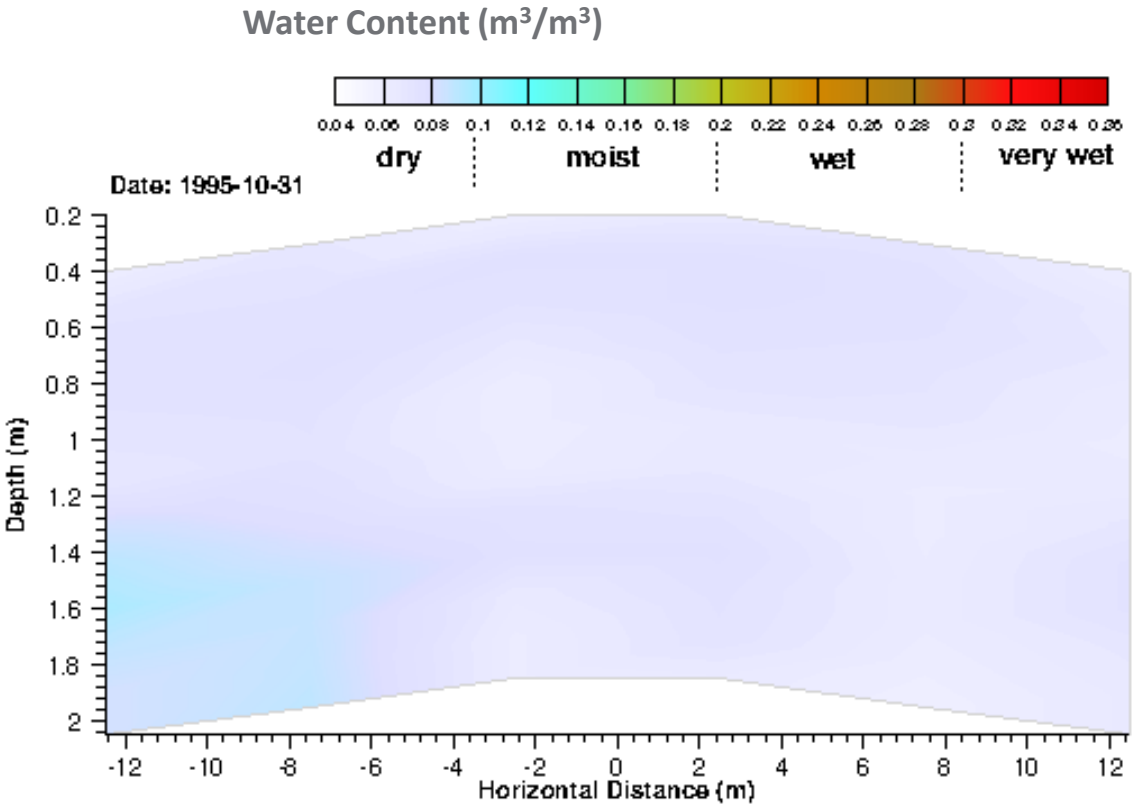
Tests

- **Treatability test**
  - Nov. 1994 to Oct. 1997
  - Irrigated the north section to about 3x the average precipitation (3x160 = 480 mm/yr)

- **Controlled burn**
  - The north section was burned in Sept. 2008

- **Monitoring: 1994 to 2013**

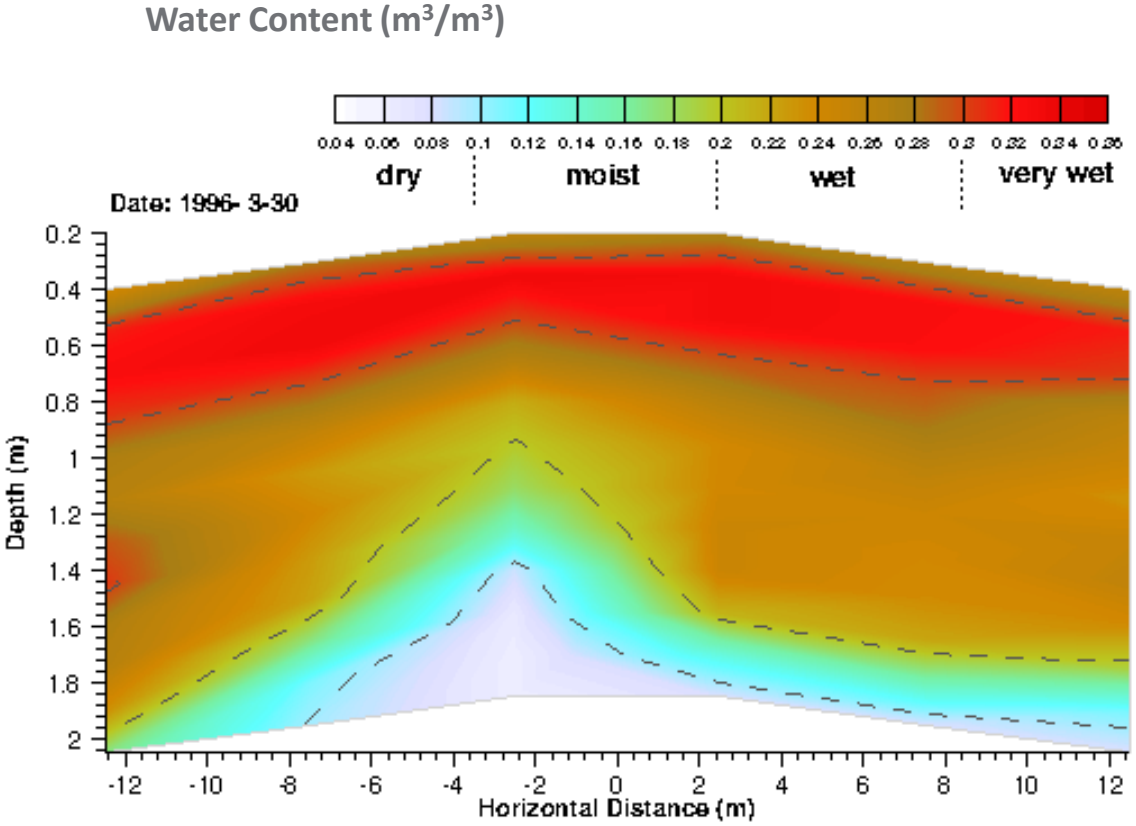
Results: Soil Water Content Dynamics (10/95-3/96, irrigated)



Click to play video

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

Soil Water Content Dynamics (4/96-10/96, irrigated)



- Soil became drier spring/summer
- Entire-soil profile became dry
- ET used up all the stored water

Click to play video

Summary - Design Barriers for Mine Lands

- **Determine barrier objectives**
  - **Regulatory Requirements**
    - Federal
    - State
  - **Functionality Requirements**
    - Climate
    - Maximum drainage rate
    - Runoff control
  - **Longevity Requirements**
    - Design life
    - Erosion control
    - Maintenance
- **Design surface barriers to achieve the objectives**
  - **Type, Complexity**