



U.S. DEPARTMENT OF  
**ENERGY**

OFFICE OF  
**ENVIRONMENTAL  
MANAGEMENT**

# **U.S. UNIVERSITY-LED INTEGRATED RESEARCH PROJECT**

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## **ADVANCED CAPABILITIES OF NUCLEARIZED ROBOTICS FOR INTEGRATED MAPPING (IRP-EM-1)**

**WEBINAR FOLLOW-UP – AUGUST 21, 2015**

- ❖ This IRP seeks a functional prototype of a robotic solution that will:
  - 1) Remotely gain access to and maneuver within a high-hazard, physically challenged, confined, and unstructured space or area within a nuclear facility;
  - 2) Obtain high-resolution color video footage;
  - 3) Perform simultaneous localization and mapping;
  - 4) Perform radiation and radioactivity measurements of alpha and beta particles as well as gamma rays as dictated by the radioisotope(s) expected to be present;
  - 5) Perform appropriate non-destructive, *in situ* measurements of the materials of construction to help determine structural integrity; and
  - 6) Integrate and correlate SLAM and radiation data for analysis, scientific visualization and computer simulation.

- ❖ **Proposals submitted in response to this IRP must:**
  - (1) Indicate the intention for collaboration with at least one other US university/college having established robotics expertise and assets;**
  - (2A) Indicate the intention for collaboration with at least one DOE national laboratory/technology center OR**
  - (2B) Indicate the intention for collaboration with a laboratory/technology center of another federal agency having established robotics expertise and assets;**
  - (3) Demonstrate full functionality of the robotics system to meet the aforementioned technical objective at a field mock-up;**
  - (4) Provide a strategy for advancing the robotic solution to the next phase of EM radioactive test bed demonstration; and**
  - (5) Demonstrate utility at one of EM's nuclear facilities.**

- ❖ **Representative EM nuclear facilities for this application of robotics include, but are not limited to**
  - **Hanford Site PUREX Plant Tunnels (example #1),**
  - **Underground areas of the Waste Isolation Pilot Plant (example #2), and**
  - **Savannah River Site H-Canyon Exhaust Air Tunnel (example #3).**
- ❖ **Spaces are expected to have irregular (uneven, unleveled) floor/bottom surfaces, poor visibility or limited lighting, obstructed egresses, and wetted and even pooled surfaces**
  - **Spaces may be considered to be unstructured**
- ❖ **High levels of radiation and high levels of radioactivity (loose surface/removable and fixed) contamination may exist**

# Example #1: Hanford PUREX Plant



**The Plutonium-Uranium Extraction (PUREX) Plant is located at the Hanford Site in eastern Washington. It operated from 1956 to 1972 and then from 1983 to 1991 for the recovery of uranium, plutonium and neptunium from irradiated reactor fuel via chemical separation.**

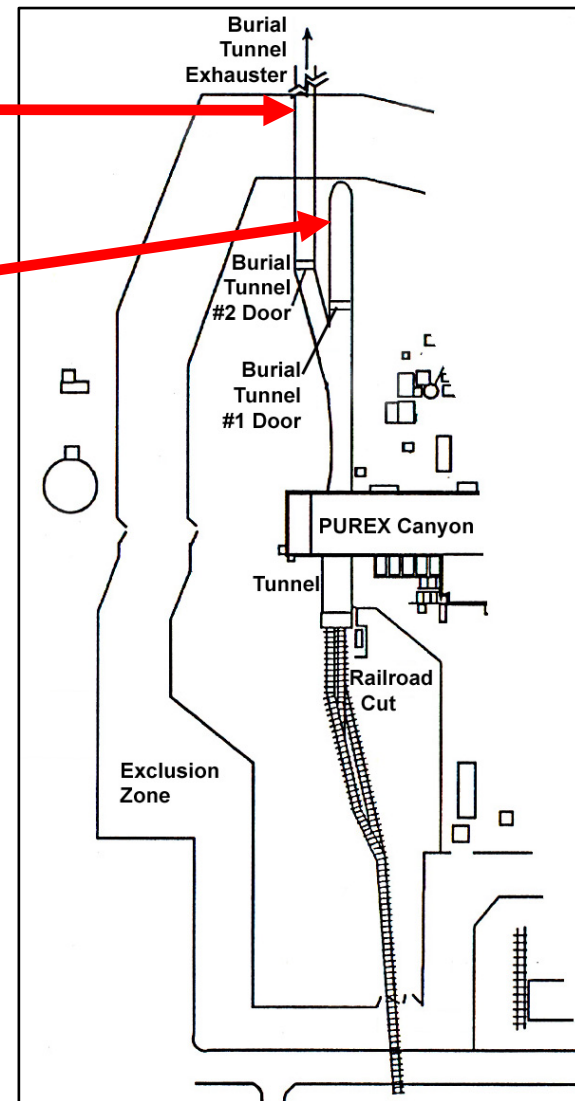
# Hanford PUREX Plant Storage Tunnels



Tunnel #2

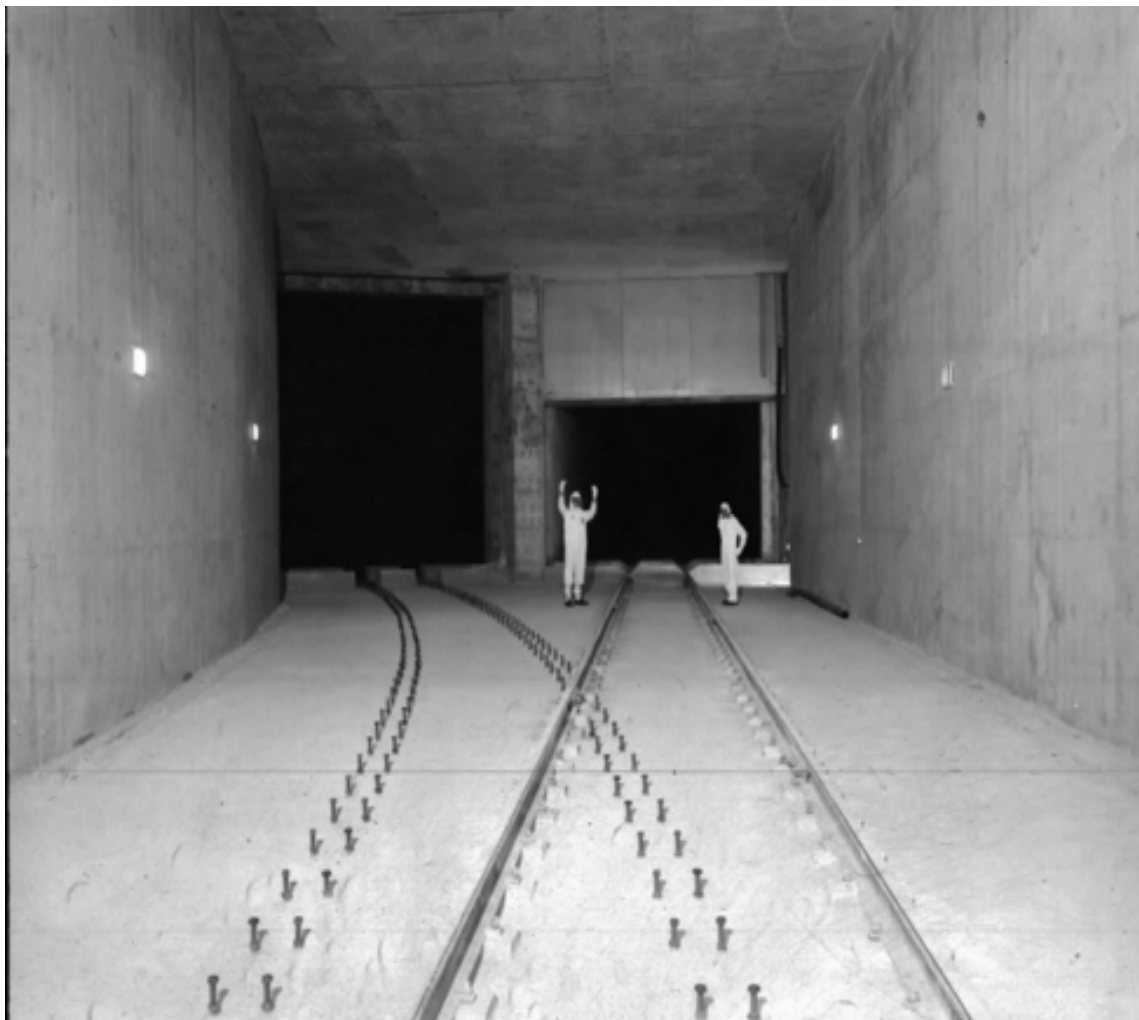
Tunnel #1

- ❖ PUREX Storage Tunnels # 1 & 2 are used for storage of large failed and outworn PUREX process equipment
- ❖ Remote access is needed for initial entry into the sealed tunnels for surveying and characterization



# Hanford PUREX Plant Storage Tunnels

- ❖ The tunnels branch off from the railroad tunnel and extend southward from these the east end of the PUREX Plant
- ❖ There are no electrical utilities, water lines, drains, fire detection or suppression systems, radiation monitoring, or communication systems provided inside the tunnels



## ❖ General construction

- Built in 1956 as part of the original PUREX Plant
- 19 feet wide, 358 feet long, and 22 feet high
- First 100 feet is 3-foot thick re-enforced concrete
- Remaining 258 feet is creosote pressure-treated Douglas fir timber
- Covered by 8 feet of earth fill
- Ventilation shaft is reinforced concrete

## ❖ Storage area

- Eight railcars of highly radioactive failed process equipment occupy and fill the tunnel
- Total volume of equipment is approx. 780 cubic yards
- Storage capacity is approx. 5,400 cubic yards



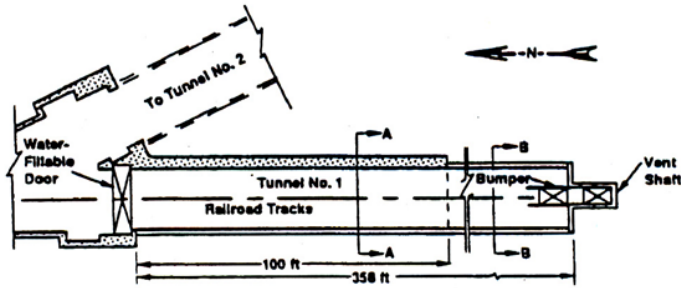
## ❖ General construction

- Added in 1964
- 34 feet wide, 1,688 feet long, and 26 feet high
- Made of steel and reinforced concrete
- Semi-circular shaped roof, supported by internal I-beam wales attached to external, reinforced concrete arches
- Floor, outboard of the railroad ties, slopes upward to a height of approx. 6 feet above the railroad bed
- Covered by 8 feet of earth fill
- Ventilation shaft is reinforced concrete

## ❖ Storage area

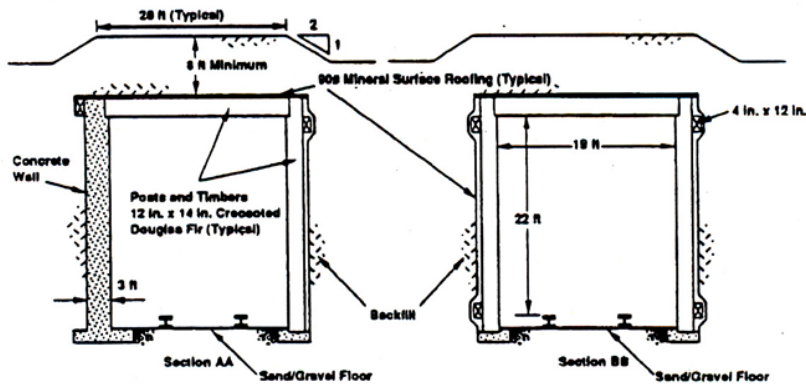
- 28 railcars of highly radioactive failed process equipment occupy and fill the tunnel
- Total volume of equipment is approx. 2,883 cubic yards
- Storage capacity is approx. 26,000 cubic yards

# Cross-Sectional Views of PUREX Tunnels

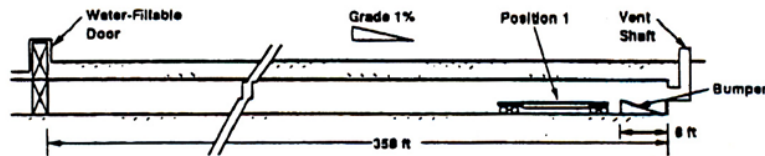


Tunnel No. 1 - Plan View

## Tunnel #1



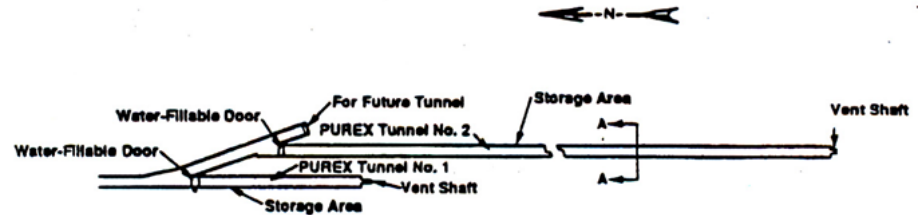
PUREX Tunnel No. 1 - Section Views



PUREX Tunnel No. 1 - Elevation View

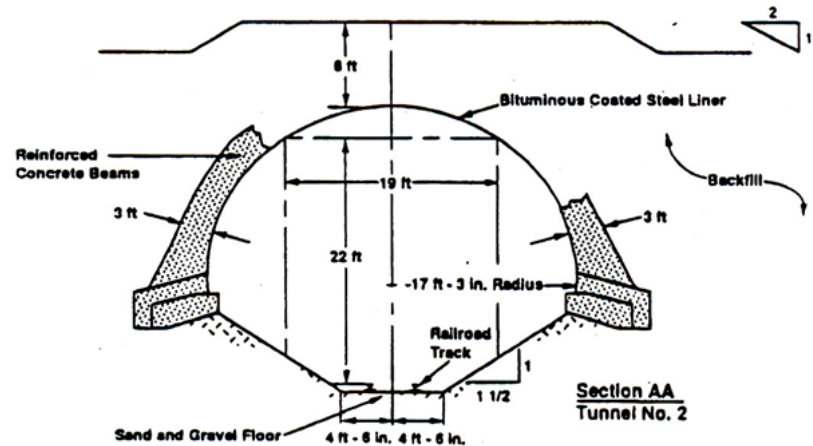
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The PUREX Storage Tunnel Number 1

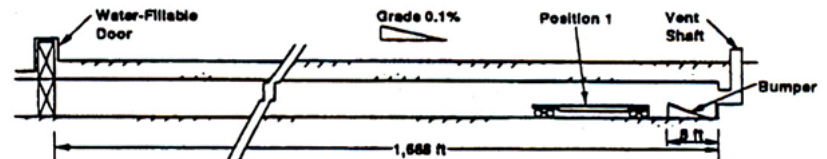


PUREX Tunnels - Plan View

## Tunnel #2



Section AA Tunnel No. 2



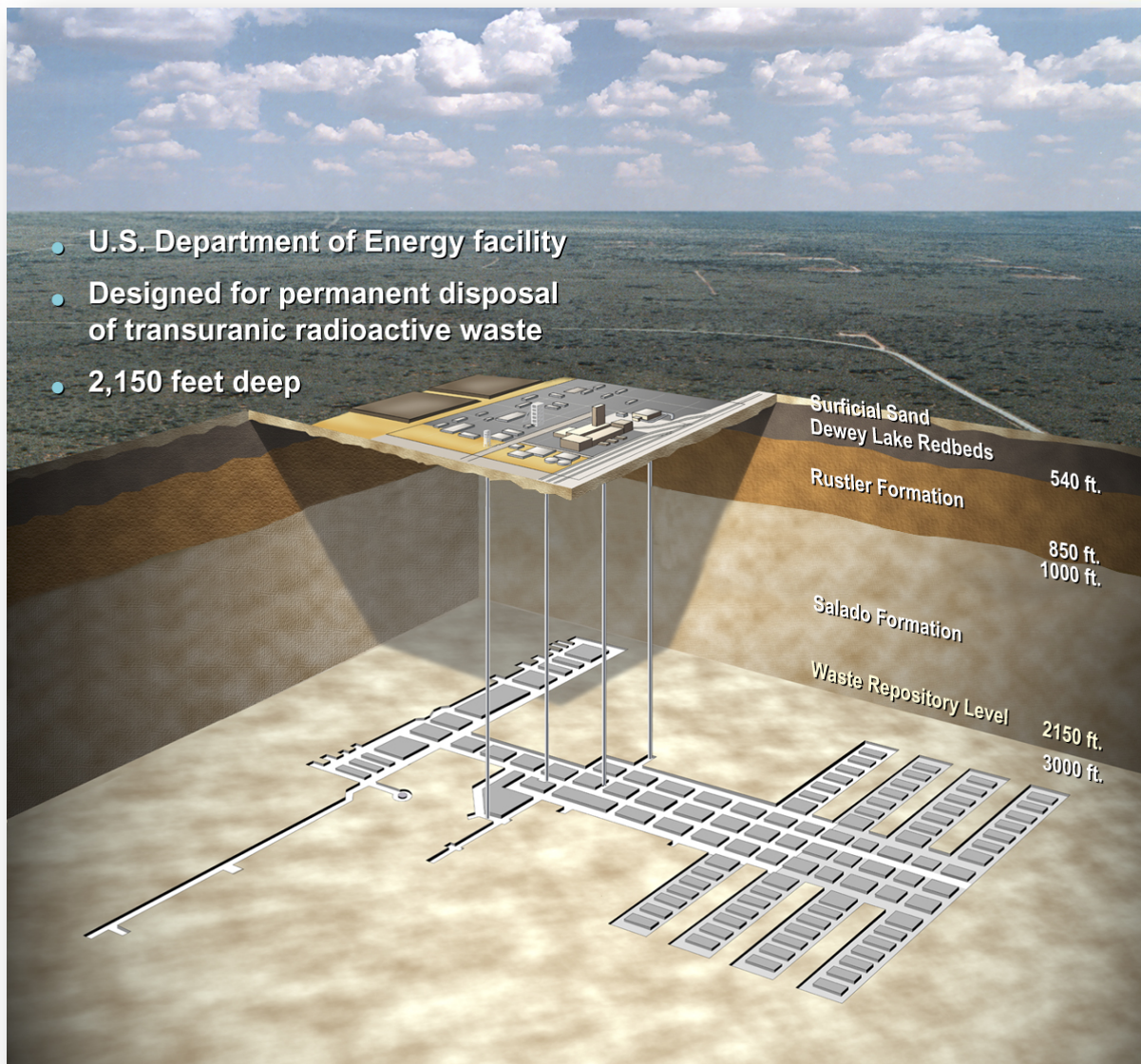
PUREX Tunnel No. 2 - Elevation View

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- ❖ Tunnels are sealed with no access points
  - Possible entry via vent shafts
- ❖ High levels of radiation inside tunnels
  - Signage prohibits/restricts direct entry into tunnels
- ❖ All utilities and ventilation systems are isolated or removed
- ❖ Annual external surveillances and inspections
  - Overall structural deterioration
  - Subsidence
  - Erosion of earth cover
  - Ventilation stack seal/blank
  - Monitor for radioactive contamination migration and changes in radiation levels
- ★ **Remote access is needed for initial entry into the tunnels for surveying and characterization**

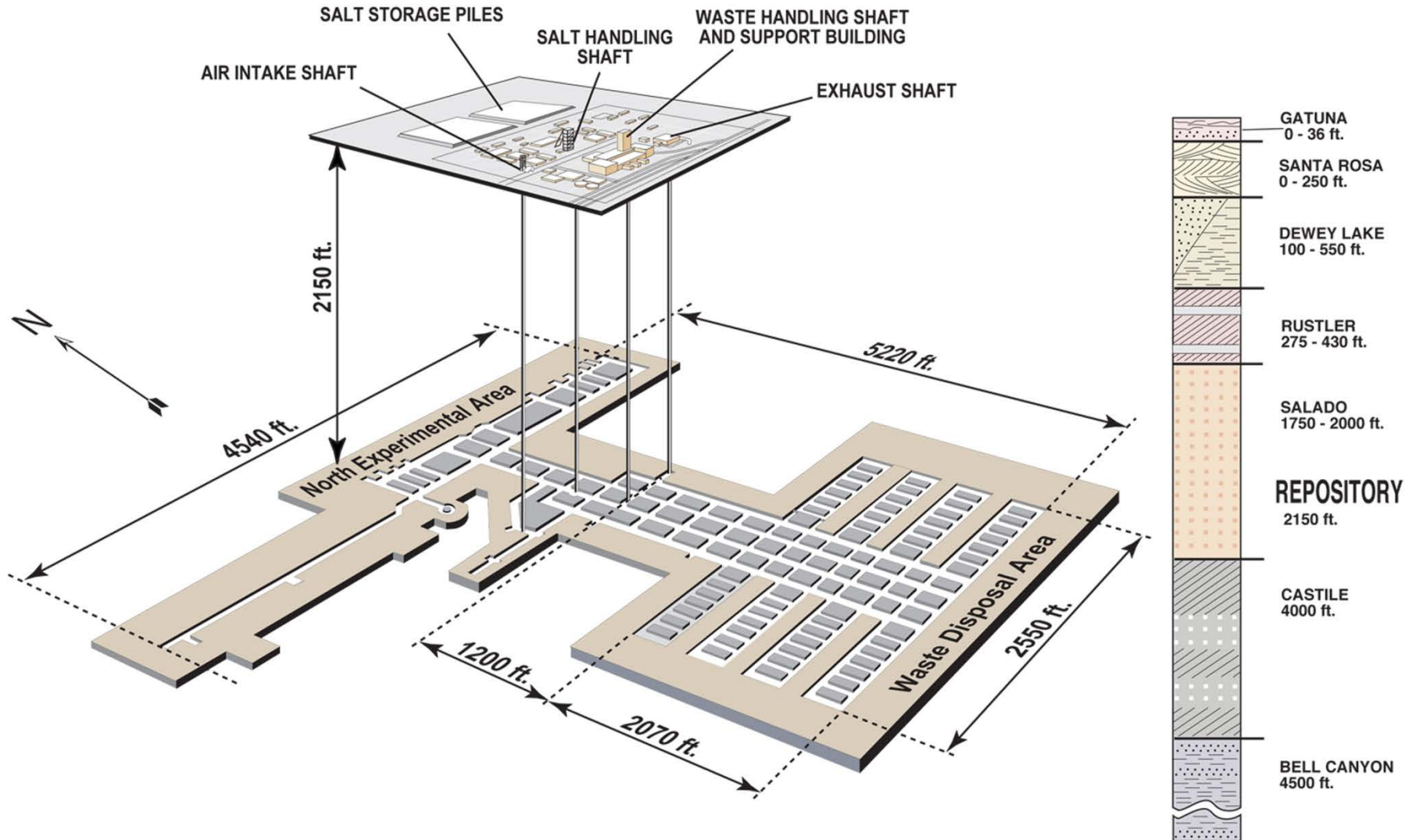
## Example #2: Waste Isolation Pilot Plant

- U.S. Department of Energy facility
- Designed for permanent disposal of transuranic radioactive waste
- 2,150 feet deep



- ❖ Geological repository for the disposal of defense transuranic waste
- ❖ Built in a 250-million-year old, nearly impermeable salt basin
- ❖ Remote access is needed for emergency response, initial re-entry, trouble-shooting, and recovery, particularly when conditions are unknown

# WIPP Facility and Stratigraphic Sequence

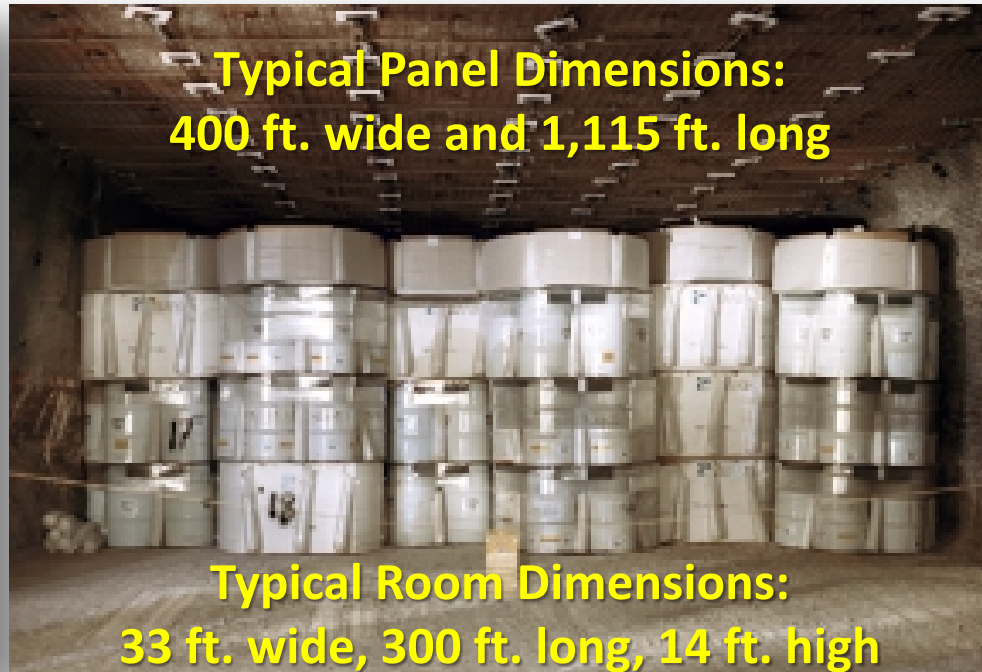


# WIPP Typical Dimensions and Layouts

**Typical Access Drifts:  
40 ft. wide and 14 ft. high**



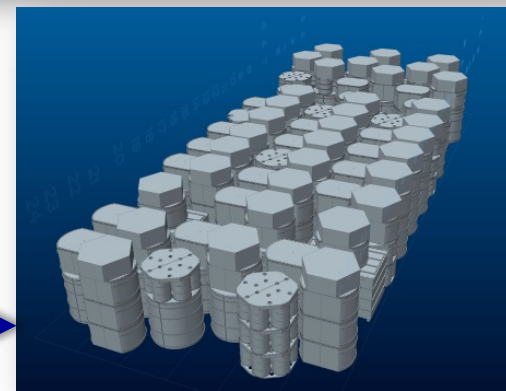
**Typical Panel Dimensions:  
400 ft. wide and 1,115 ft. long**



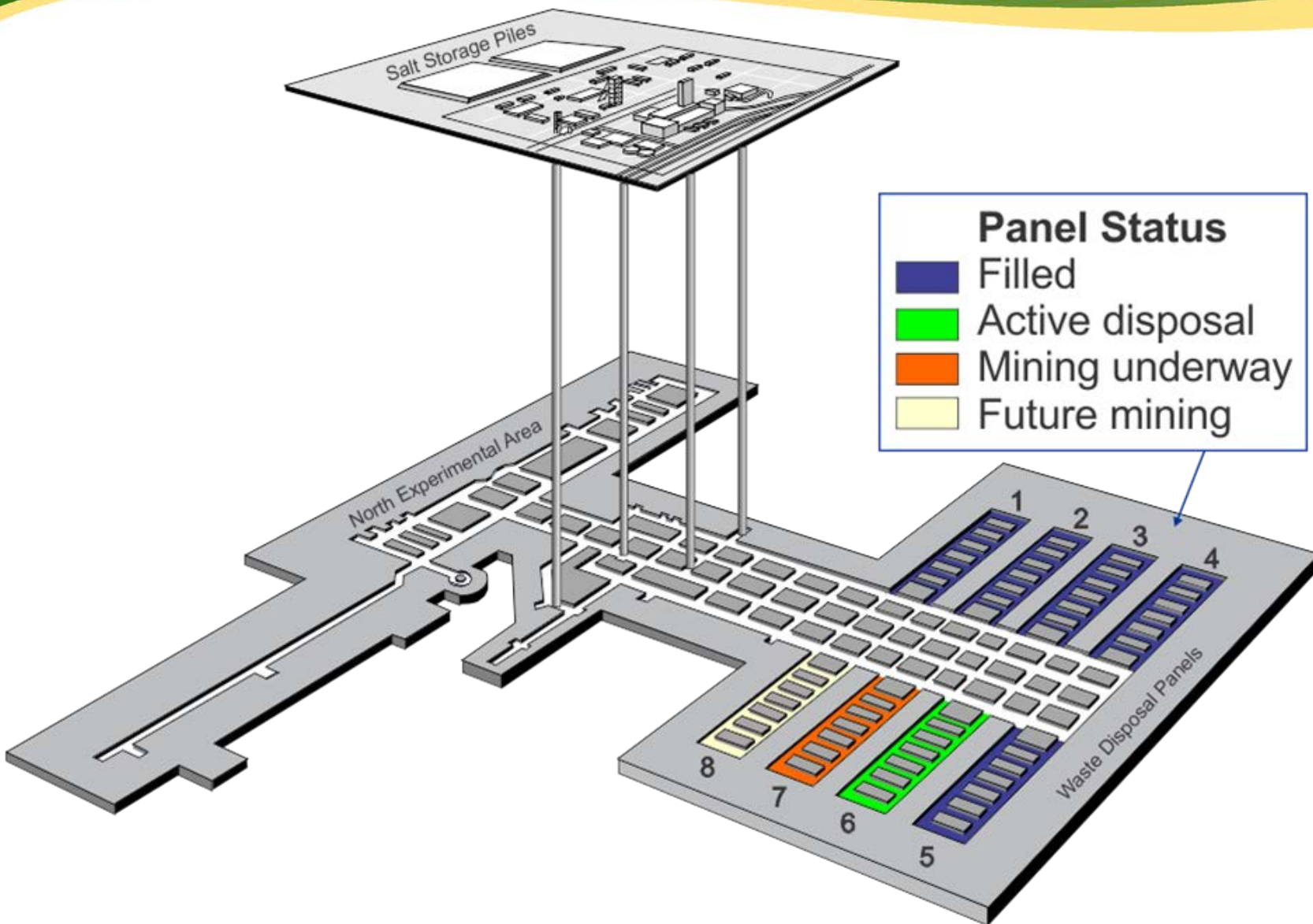
**Typical Room Dimensions:  
33 ft. wide, 300 ft. long, 14 ft. high**



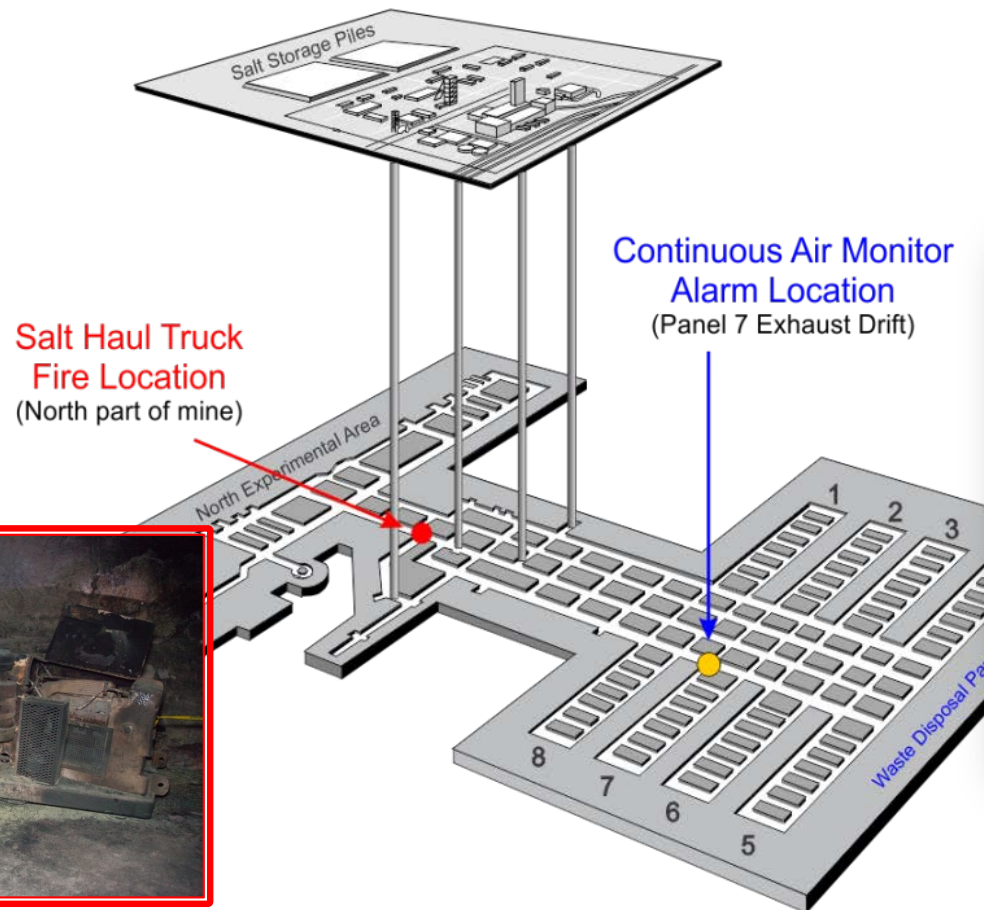
**Typical Placement  
Configurations for  
Contact-Handled TRU  
Waste Containers**



# WIPP Current Configuration Status



Two recent unplanned events highlighted the need for improved operational capabilities such as **remote access for emergency response, initial re-entry, trouble-shooting, and recovery, particularly when conditions are unknown.**





## ❖ February 5, 2014 Truck Fire

- EIMCO Haul Truck 74-U-006B (salt haul truck) caught fire
- Believed to have originated in the truck's engine compartment and involved hydraulic fluid and/or diesel fuel that contacted hot surfaces on the truck, possibly the catalytic converter, and then ignited
- 86 workers in the mine (underground) were safely evacuated
- 13 workers treated for smoke inhalation

## ❖ February 14, 2014 Radiological Incident

- A continuous air monitor detected airborne radiation in the underground
- The ventilation system automatically switched to high-efficiency particulate air filtration mode when airborne radiation was detected
- Release is believed to have originated from a single waste drum within which an exothermic reaction of incompatible materials occurred causing the drum to become over-pressurized, compromising the lid seal, and releasing radioactivity
- No employees were in the underground at the time of the alarm

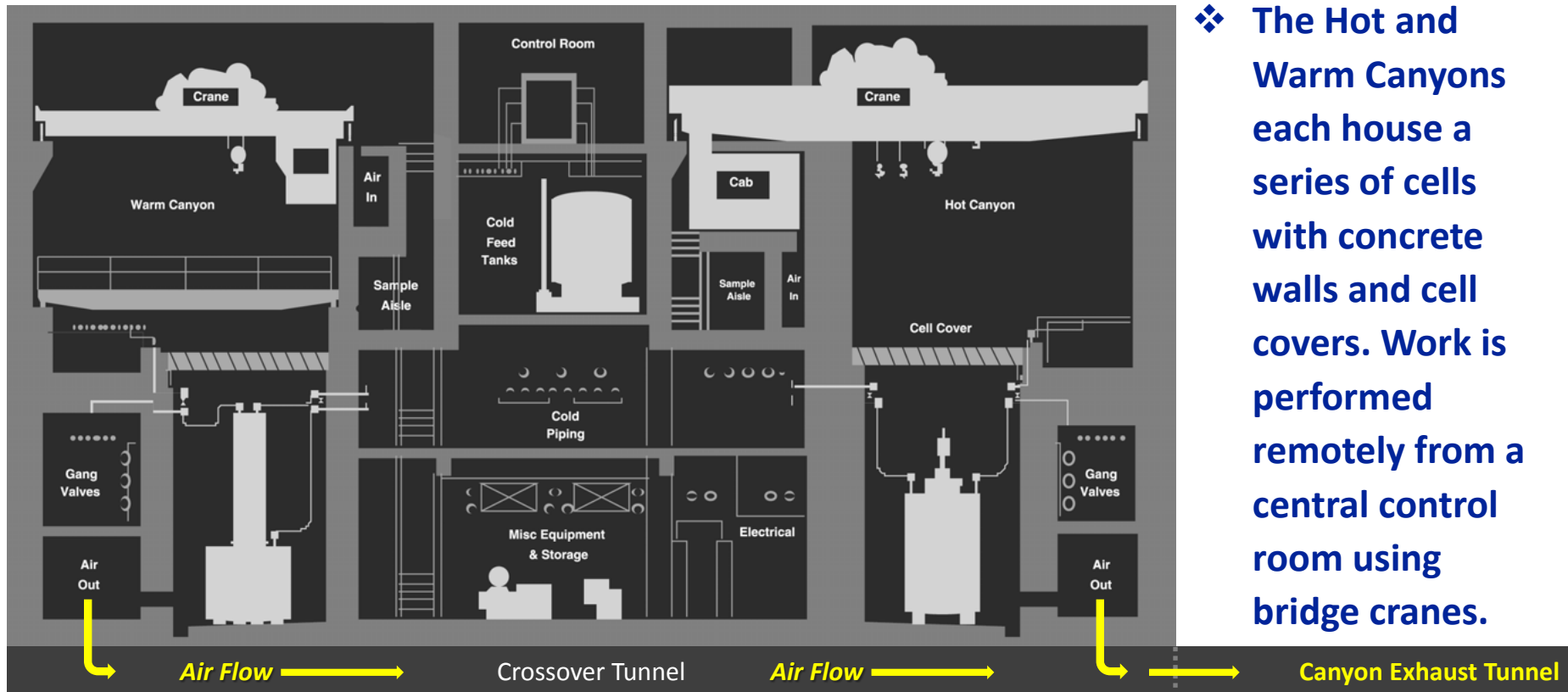
- ❖ **Waste emplacement operations have not resumed pending completion of a series of corrective actions**
  - **Nuclear facility safety document being revised**
  - **Safety management program undergoing revitalization**
  - **Underground restoration continuing**
    - **Re-establish degraded equipment**
    - **Fire protection**
    - **Maintenance and ground control**
    - **Radiological roll-back**
    - **Soot cleaning of electrical panels**
  - **Mine stability being expedited – ground control/bolting**
  - **Panel 6 and Panel 7, Room 7 closed**
  - **Interim ventilation installation in progress**
  - **Supplemental ventilation modifications being planned**

## Example #3: Savannah River Site H-Canyon



**H-Canyon is located on the Savannah River Site in Aiken, SC, and is a radio-chemical separation facility built to support the production of nuclear materials. Its main purpose was to reprocess spent uranium fuel and other enriched uranium fuels. H-Canyon began operations in 1955 and remains in operation today. It is an 835-foot long, multilevel facility and is referred to as a canyon because of its long, rectangular shape.**

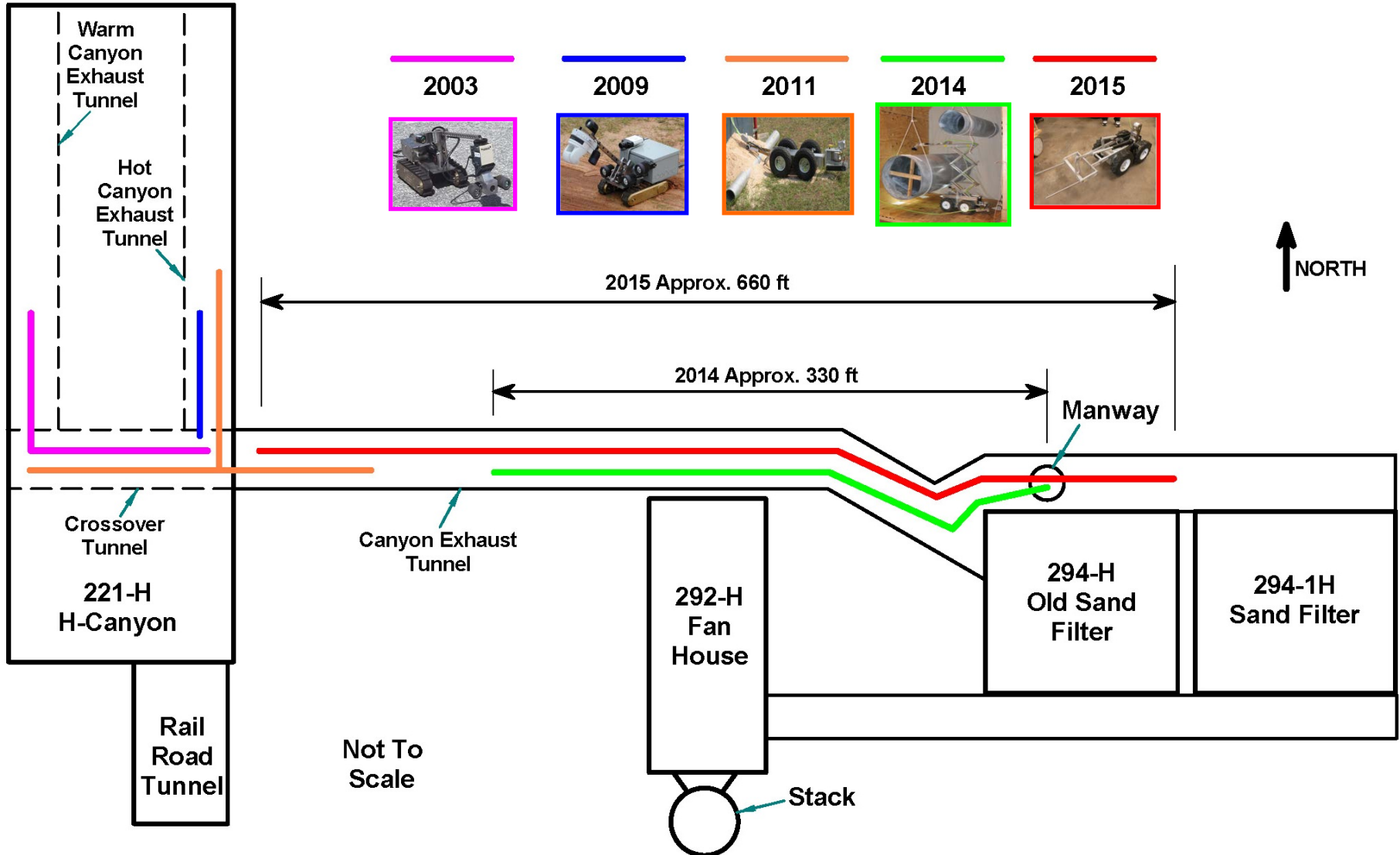
# H-Canyon Cross-Sectional View



❖ The Hot and Warm Canyons each house a series of cells with concrete walls and cell covers. Work is performed remotely from a central control room using bridge cranes.

- ❖ Potentially contaminated air is pulled from the Hot and Warm Canyons, through air exhaust tunnels and a sand filter prior to being released into the atmosphere.
- ❖ Remote access is needed for more comprehensive inspection, surveying, and characterization of the air tunnels.

# SRS H-Canyon Air Tunnel: Past Inspections



Not To Scale

- ❖ Over the last 60 years of operation, the interior surfaces of the reinforced concrete tunnel have been exposed to 25 to 40 mph air flows of moist, nitric acid-laden air
- ❖ Interior surfaces of the tunnel have eroded away the top 2-inch layer of concrete exposing the inner layer of reinforcing steel



**Exposed Bars Near Western Expansion**

- ❖ Over the last 60 years of operation, degradation of the concrete has resulted in aggregate and debris being deposited on the floor
- ❖ Water has also accumulated on some tunnel floor areas



**Debris created uneven surface**



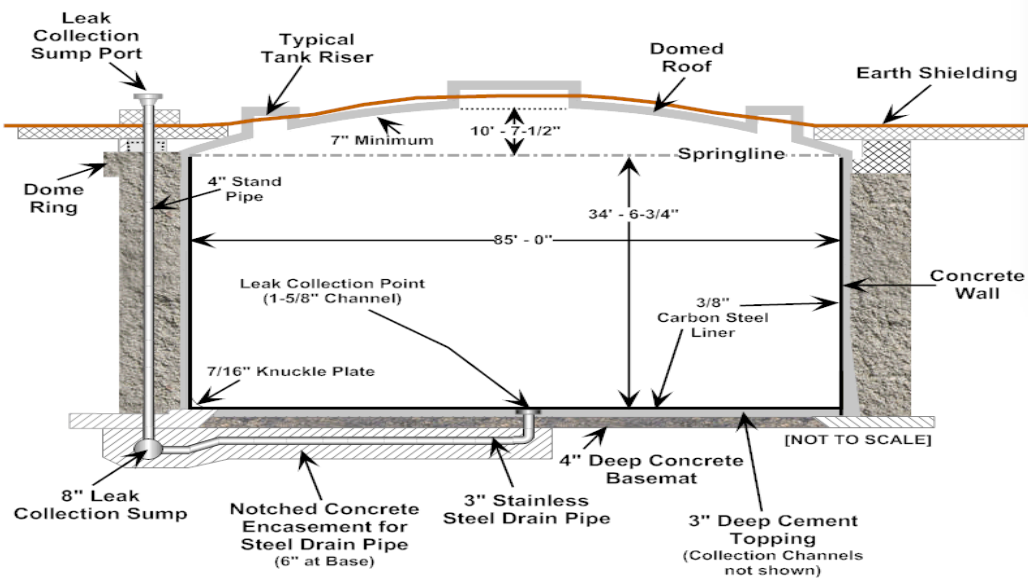
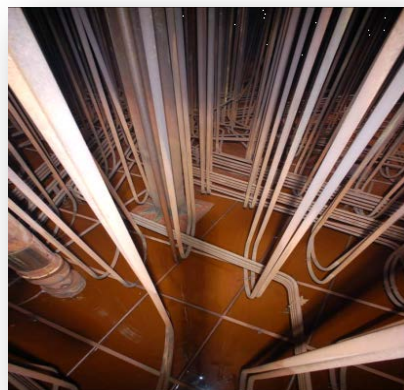
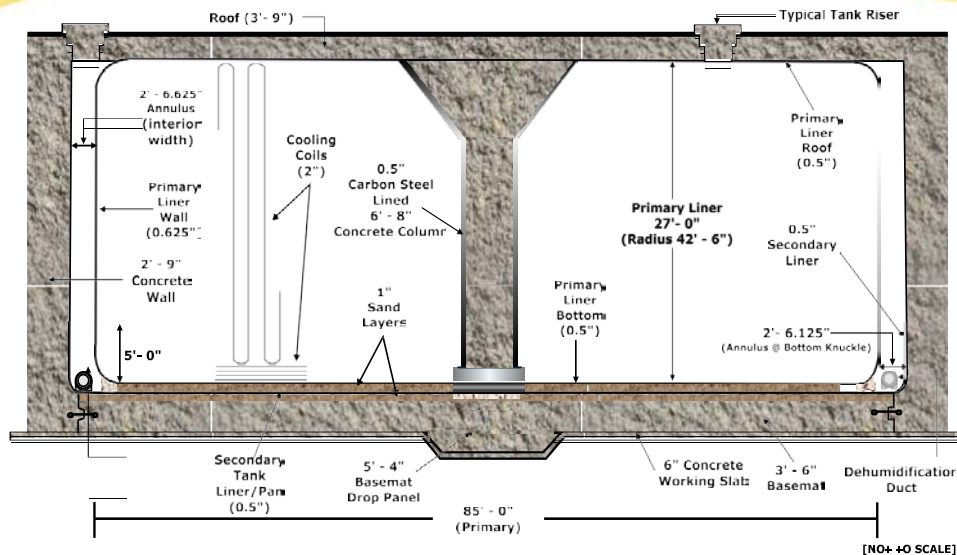
**Standing water**

# SRS H-Canyon Air Tunnel Summary

- ❖ Past visual inspections revealed tunnel degradation
- ❖ Tunnel spaces are expected to have high radiation levels (estimated to be 40 to 250 mrem/hr) and high levels of radioactivity
- ❖ Air flow rates range from 25 to 40 mph of moist, nitric acid-laden vapor
- ❖ Access to the air tunnels is limited
- ❖ Concrete (mud-like) residue on most portions of the tunnel floor as thick as several inches
- ❖ Standing water in some portions
- ❖ **Remote access is needed for more comprehensive inspection, surveying, and characterization of the air tunnels**



# Other Examples: Savannah River Site Underground Radioactive Liquid Waste Tank



❖ Remote access is needed to support surveying, characterization and inspection

# Other Examples: Recent Need at Hanford Underground Radioactive Liquid Waste Tank

❖ Remote access is needed to support investigation and trouble-shooting in DSTs

