U.S. DEPARTMENT OF ENERGY | OFFICE OF ENVIRONMENTAL MANAGEMENT

Frozen Soil Barrier at Oak Ridge National Laboratory

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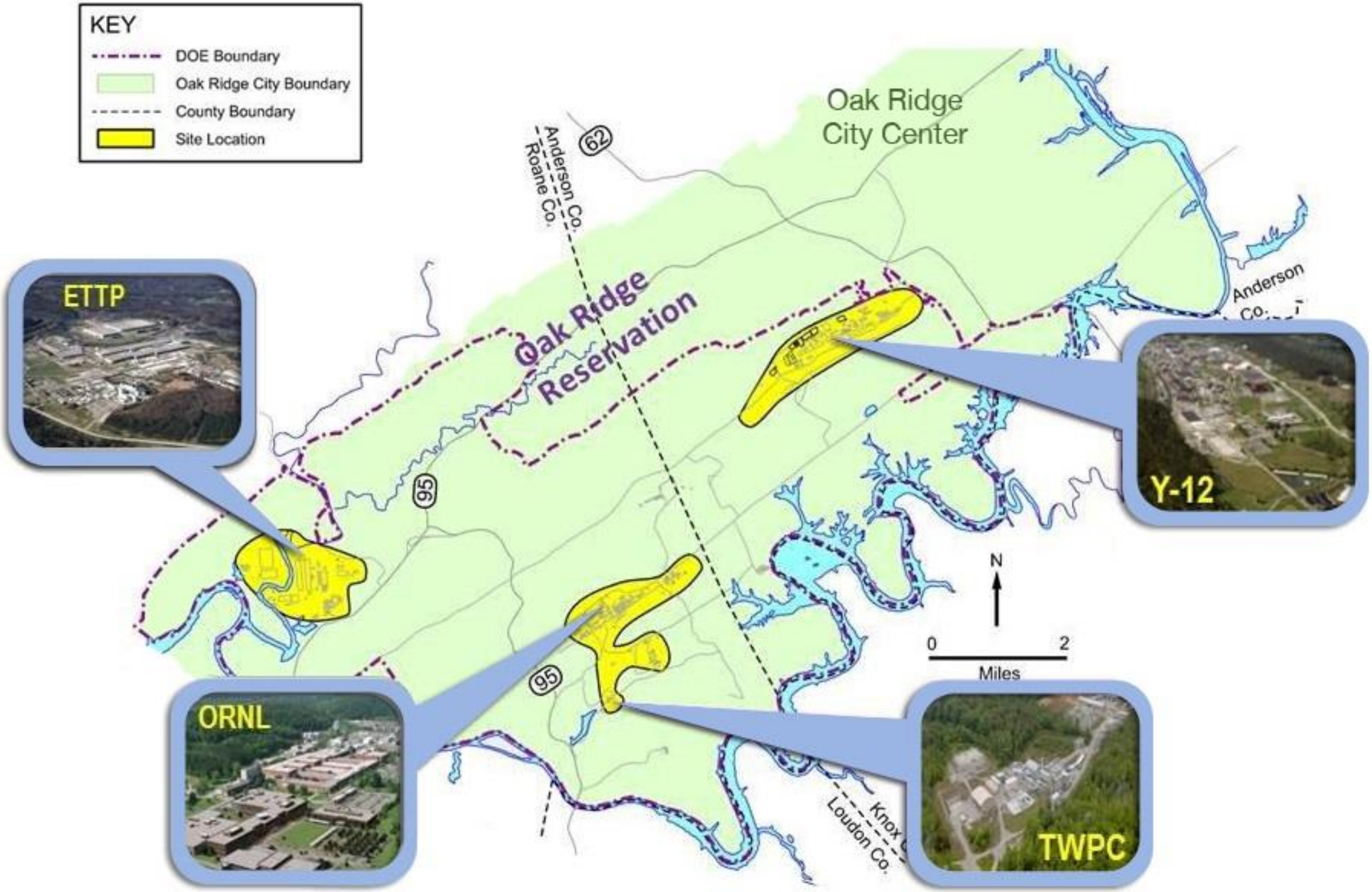
OREM manages several projects within the Oak Ridge Reservation



The Frozen Soil Barrier project began in 1995

- In 1995, I was selected as the procurement lead and project manager to build a frozen soil barrier on the Oak Ridge Reservation.
- The team consisted of Lockheed Martin, ORNL, DOE, EPA, TDEC, and the contractor, Arctic Foundations Inc. from Anchorage, Alaska.
- The decision was made to locate the barrier at the Homogenous Reactor Experiment Pond site, a reactor cooling water retention pond containing strontium 90, cesium 137, and tritium.
- The barrier was constructed in 1996 and operation began in 1997; it operated for six years.
- The integrity of the barrier was verified as a success by the EPA Superfund Innovative Technology Evaluation (SITE) Program and TDEC.

The Frozen Soil Barrier Project Team consisted of members from many organizations

This image depicts a typical brine system surface configuration

The ORNL completed barrier - facing south

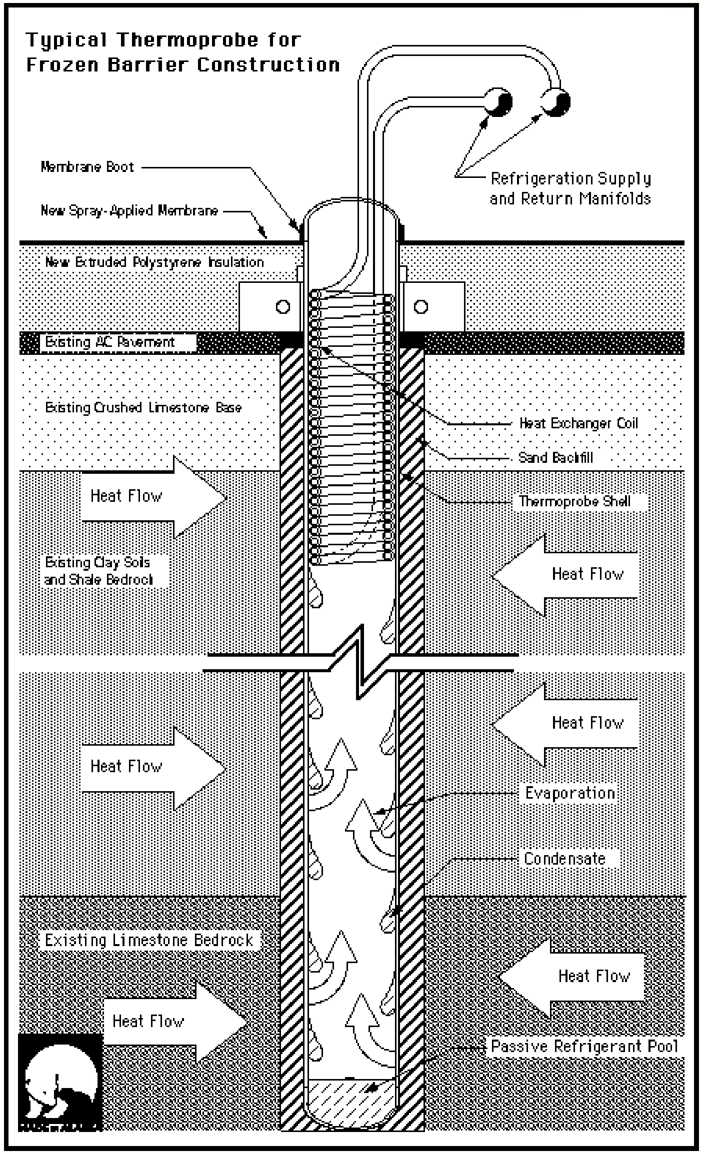
The Frozen Soil Barrier was designed to meet specific criteria

- 25 x 27 x 10 meters deep.
- The 50 Thermoprobes were made of Schedule 40 Stainless steel pipe, installed on two meter centers to a depth of 10 meters.
- Used hybrid themosyphon technology that was originally used to stabilize features in summer when permafrost partially melts.

The Frozen Soil Barrier works by changing the form of carbon dioxide to capture energy

- Liquid and vapor phase carbon dioxide function as the working fluid to move heat against gravity.
- The liquid phase carbon dioxide boils and the vapor rises to the upper portion of the device. At the top, a heat exchanger coil connected to an above-grade refrigeration unit cools and condenses the carbon dioxide vapor back into its liquid phase.
- The liquid flows down the inside walls, drawing heat energy from the soil, vaporizing the liquid and the cycle repeats.

The Frozen Soil Barrier uses Thermoprobe technology



The barrier was designed around the site environmental factors

- The HRE Pond was located in Melton Valley, south of the main ORNL complex.
- A tributary stream was receiving radioactive groundwater from the site and flowed into White Oak Lake via White Oak Creek.
- The soil is about 10 meters deep and the top of bedrock contains a permeable, weathered layer that creates a preferential flow path for groundwater.
- Water level data collected at the site from standpipes, piezometers, and wells indicated that groundwater at the site exhibits significant responsiveness to rainfall and storm events.

The barrier was designed around the site environmental factors (continued)

- Geology is the Conasaga Group of interbedded shales, siltstones and limestones, Rogersville Shale and Friendship Formation (formerly the Rutledge Limestone).
- The average depth to groundwater is 2-3 meters below the surface.
- Average rainfall in the area is over 50 inches per year.

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The HRE Pond was chosen as the location for the barrier

The barrier was designed to meet certain project objectives which were:

- To design and install a subsurface frozen soil barrier around a known source of radiological contamination, evaluate the performance of the barrier, and maintain the barrier for an undefined period of time.
- A multi-disciplinary team is needed to perform the work.
- Factors to consider before installing: waste type, topography, overall site hydrology, soil moisture content, subsurface structures, soil types and thermal conductivity
- Configuration of thermoprobes can be either "V" or "U" shaped and spacing can be as close as you need to meet your time table.

Thermoprobe technology uses a two-phase system

- The project used "Hybrid Thermosyphons" which constitute a closed, two-phase system that can be used in active or passive mode.
- Thermoprobes were spaced about 2 meters apart. Fifty thermoprobes, 10 meters in length, were installed and 8 boreholes held temperature monitoring devices.
- R404A was used as the active coolant in the system, the passive refrigerant was carbon dioxide.

The barrier was formed to the planned design

- A 25 x 27 meter box was formed around the pond.
- An insulated cover and sprayed on poly-urea membrane covered the box.
- When the soil reached 0 degrees C, frozen pore water creates the barrier and for this design it was to be a 4 meter thick barrier.

The barrier used a radioactive cuttings containment system with HEPA filter invented at ORNL

Dye was injected into the post-construction site to determine the barrier's integrity

Dye was injected into the center stand pipe

Pre-verification studies were conducted at the site

- Prior to the barrier installation groundwater flow and dye tracer studies were performed by ORNL scientists and EPA SITE scientists.
- Three types of fluorescent dye and helium gas tracers were used to verify connectivity of the pond to the wells, surface water, and springs.
- An electromagnetic geophysical survey was also conducted and detected 3 subsurface anomalies, one of which impacted the project results.
- Groundwater monitoring revealed extreme groundwater level response to storm events inside and outside the impoundment.
- Once the barrier reached its designed thickness, post barrier monitoring was initiated.

ORNL scientists measured groundwater levels

Helium sampling devices were deployed at the site

Helium sampling devices were deployed into the wells

Measurements were taken to capture energy usage

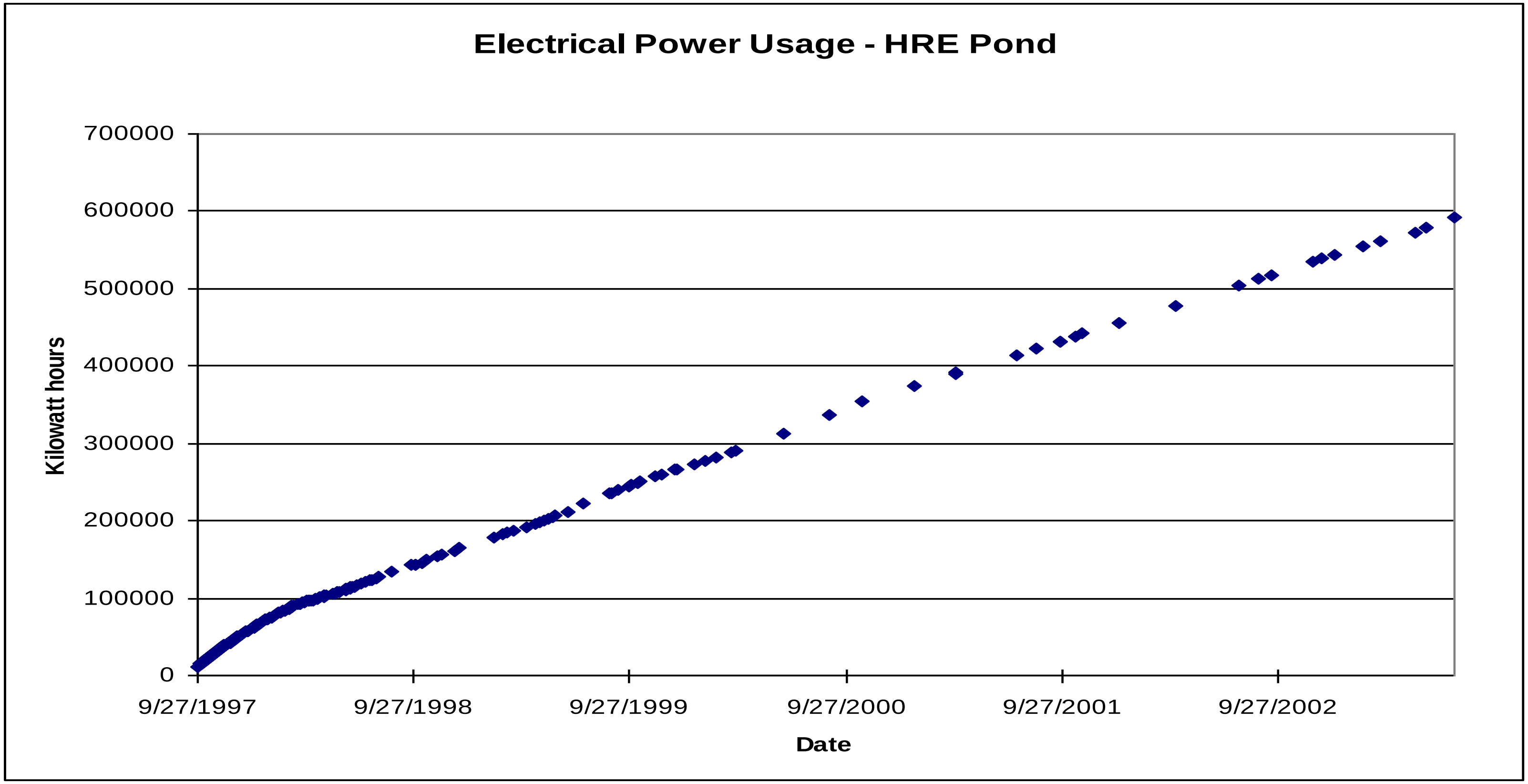
- The barrier was formed within 7 weeks and electrical usage to form the barrier was 33,000 kW hours.
- The barrier walls reached 4 meter thickness within 18 weeks and took 72,000 kW hours.
- The total volume of frozen soil was 36,000 cubic meters and the total amount of material contained inside the barrier was 56,250 cubic meters.

Measurements were taken to capture energy usage

The Frozen Soil Barrier

Total Power Usage

Arctic Foundations, Inc.



Russian Research Center - Kurchatov Institute • Oak Ridge, Tennessee • August 18, 2003

Studies showed the project to be a success

- An 8-day simulated power outage showed no shrinkage of the barrier.
- A dye tracer test conducted outside the barrier after it was complete showed that dye was not detected inside the frozen pond area, and the zone within the frozen barrier behaved as if it were hydraulically isolated from the surrounding area.
- The barrier operated from September 1997 to 2004 and, when excavated months later, the soil was still frozen and the thermoprobes were in pristine condition.

There are factors to consider when building a frozen soil barrier

- Climate and environment should be considered.
- You must have good characterization and understand the hydrology.
- Use a contractor who has experience with this technology.
- Perform a pilot test, in a clean area, to see if it will work at your site.
- Scale the system to meet your needs and time schedule.

The project discovered the following facts

- This barrier is self healing.
- Total cost of our project was $1,809,000.
- Electric power to maintain barrier was 288 kW per day or less than $15 per day. (It could have been solar powered).
- Reduction of 80% of Sr-90 to the creek was measured after the barrier was installed.

Questions?