Intermediate-Depth Borehole Disposal

KHNP Training Program

Module 12 Interim Storage of Spend Fuel

13 December, 2007

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Sandia National Laboratories

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Agenda

- Background:
  - Why proceed with disposal?
  - What is safe disposal?
  - Fundamentals of U.S. Radioactive Waste Disposal
- LILW Characteristics and Disposal Options
- Intermediate-Depth Borehole Disposal
  - U.S. GCD Experience
  - International Experience
  - U.S. GTCC Option
- Advantages of Borehole Disposal

What is Intermediate-Depth Borehole Disposal?

Disposal of radioactive wastes in augered shafts or boreholes at depths of 30 to 300 m.

Background:
Why Proceed With Disposal?

- The people that created and benefited from radioactive materials should safely dispose of the radioactive materials

- The burden of radioactive waste disposal should not be passed to generations that did not create or benefit from the radioactive materials

- Critical part of countries infrastructure for peaceful uses of radioactive materials

Background: Why Proceed With Disposal?

- **Long-term storage of unwanted radioactive materials is not considered sustainable, and in many cases long-term storage may represent a high-risk situation (IAEA Tech Report 436, 2005)**
  - **Many remain hazardous 100's to 1,000's of years and individual and government control can not be guaranteed**
  - **Safety and Security hazard**

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Background:
Current Hazard Sealed Radioactive Sources

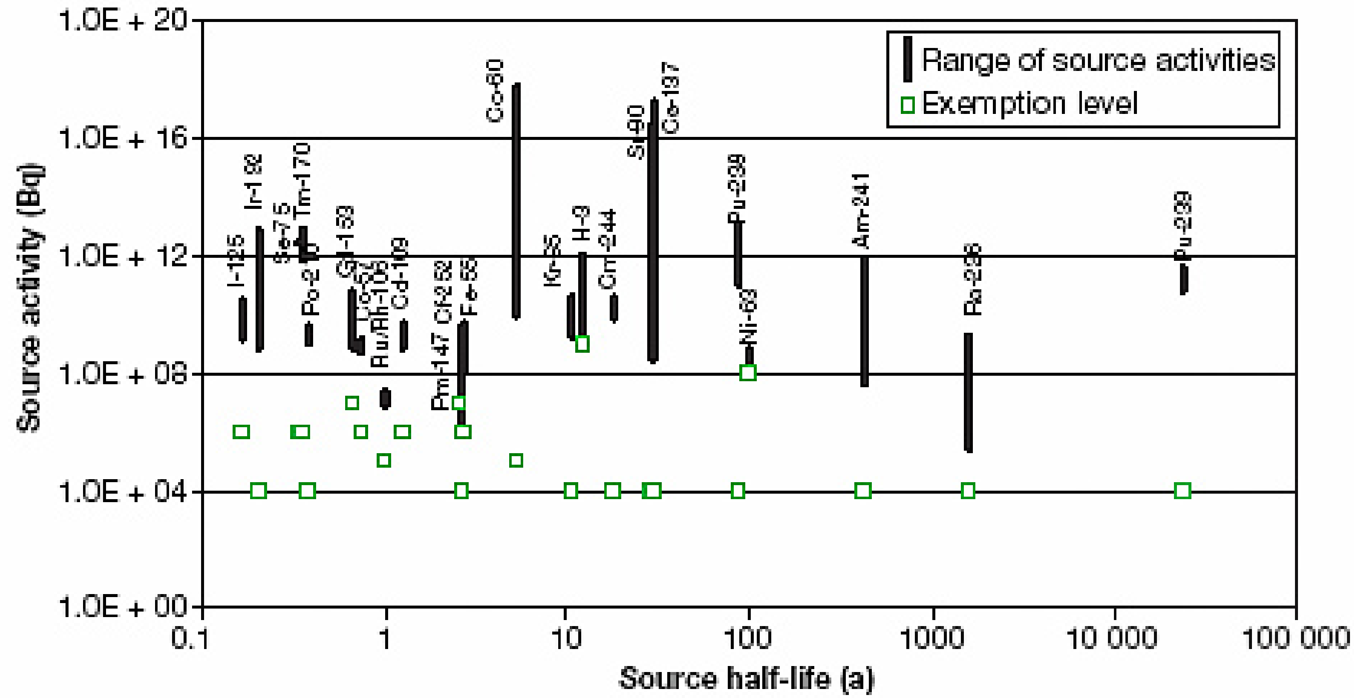

FIG. 1. Ranges of source activities for various radionuclides.

IAEA Technical Report no. 436, 2005

Background:
Future Hazard Sealed Radioactive Sources

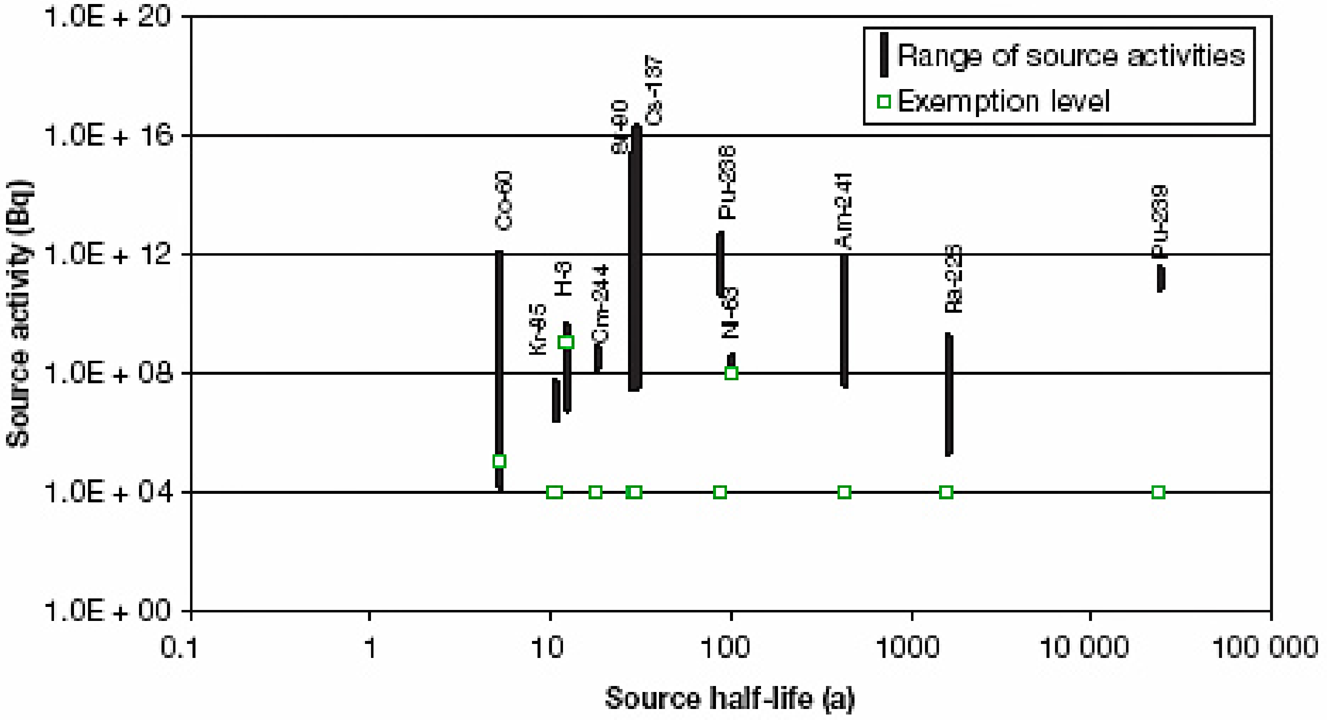

FIG. 2. The effect of 100 years of decay on the ranges of source activities.

IAEA Technical Report no. 436, 2005

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What is Safe Disposal?

- Permanent isolation of radioactive wastes from humans and the environment
  - Keep people from accidentally contacting wastes
  - Keep wastes from migrating to people

What is Safe Disposal?

- Permanent isolation of radioactive wastes from humans and the environment
  - Keep people from accidentally contacting wastes
    - Inadvertent human intrusion
  - Keep wastes from migrating to people
    - Burrowing animals, roots
    - Vapor phase
    - Surface water / sediment transport
    - Groundwater

Options for Safe Disposal Depend on the Characteristics of the LILW

- **Very low activity**
- **Low activity, high volume** (mine/mill tailings, contaminated soils)
- **Low activity, low volume** (medical wastes, NPP operating wastes, most sealed radioactive sources)
- **High activity, low volume** (some sealed radioactive sources, activated metals from NPP decommissioning)
- **High activity, large volumes (SNF)**

Example: Sealed Radioactive Sources

- **Globally, 15% to 25% unwanted**
- **SRS nuclides may be long lived and/or high activity**
  - Sr-90
  - Cs-137
  - Pu-238
  - Am-241
  - Ra-226

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U.S. NRC LLW Classification (10 CFR Part 61.55)

NRC Category	Description	Disposal Method
Class A	**Least hazardous – short & long-lived waste that will not endanger inadvertent human intruder beyond 100 years**	**Near-Surface**
Class B	**More hazardous – short-lived wastes that will not endanger inadvertent intruder beyond 100 years**	**Near-Surface with 300 year waste stability**
Class C	**More hazardous – short and long-lived wastes that will not endanger inadvertent intruder beyond 500 years**	**Near-Surface with 300 year waste stability, and greater depth or 500 year intruder barrier**
Greater-Than-Class C	**Most hazardous of LLW - dangerous to intruder beyond 500 years. Must be disposed in geologic repository unless alternate method proposed by DOE and approved by NRC.**	**Geologic repository unless alternate method approved by NRC.**

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Boundary of Greater-Than-Class C LLW (10 CFR Part 61.55)

Nuclide (half-life)	>Concentration
Long-lived Radionuclides	
	(curies/m^3)
Carbon-14 (5,730yrs)	8
Carbon-14 in activated metal (5,730 yrs)	80
Nickel-59 in activated metal (75,000 yrs)	220
Niobium-94 in activated metal (20,000 yrs)	0.2
Technetium-99 (214,000 yrs)	3
Iodine-129 (16,000,000 yrs)	0.08
	(nanocuries/gram)
Alpha-emitting transuranics (half-life greater than 5 yrs)	100
Plutonium-241 (14 yrs)	3,500
Curium-242 (162.8 days)	20,000
Short-lived Radionuclides	
	(curies/m^3)
Nickel-63 (100 yrs)	700
Nickel-63 in activated metal (100 yrs)	7,000
Strontium-90 (29 yrs)	7,000
Cesium-137 (30 yrs)	4,600

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Options for Safe Disposal Depend on the Waste Characteristics

- Range of LILW Characteristics → Range of Disposal Options
  - Unlimited Release (below exemption level)
  - Decay in Storage
  - Shallow Land Burial
  - Intermediate-Depth Burial
  - Deep Geologic Repository

Disposal Options

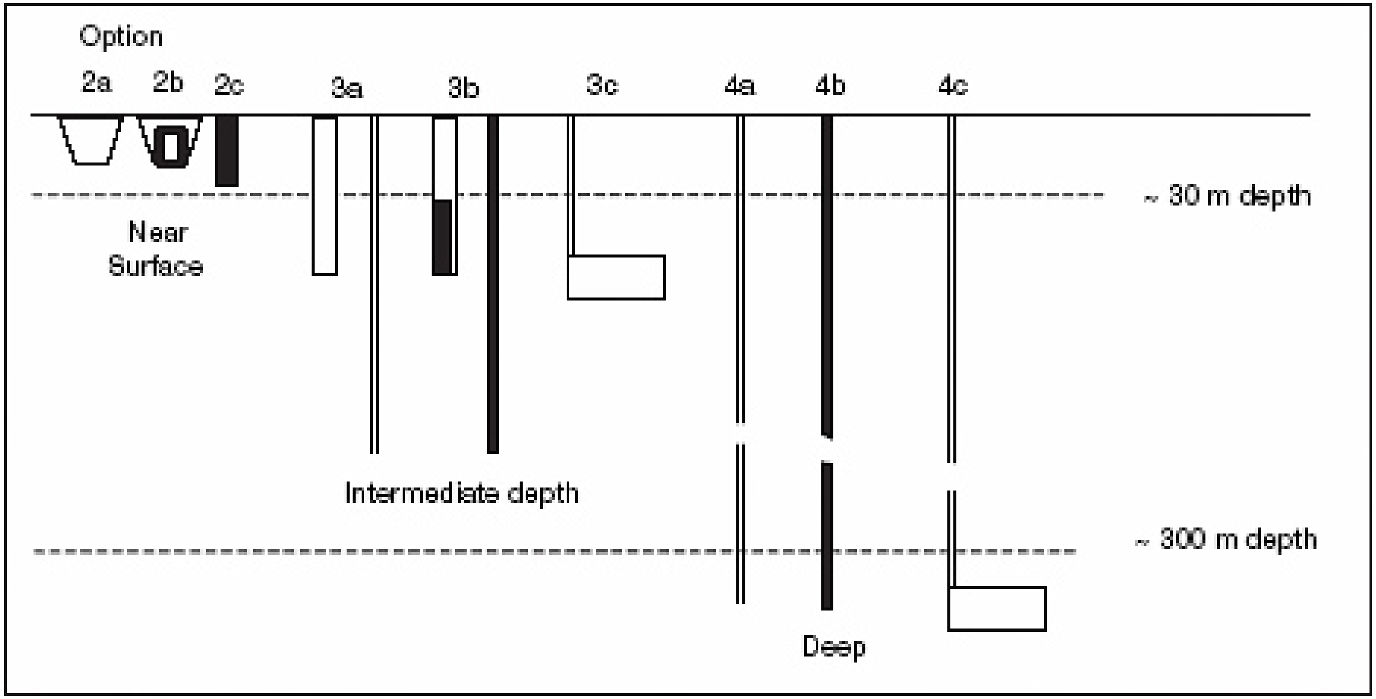

FIG. 6. Conceptual options suitable for the disposal of disused radioactive sources. Option 1 (decay and disposal as exempt waste) is not shown.

IAEA Technical Report no. 436, 2005

Options for Safe Disposal
Very Short Half-Life (< 100 days)

- **Permanent isolation of radioactive wastes from humans and the environment**
  - **Keep people from accidentally contacting wastes**
    - **Inadvertent human intrusion**
  - **Keep wastes from migrating to people**
    - **Burrowing animals, roots**
    - **Vapor phase**
    - **Groundwater**

Decay in Storage

Options for Safe Disposal
Short Half-Life (5 yrs) and/or Very Low Activity

- Permanent isolation of radioactive wastes from humans and the environment
  - Keep people from accidentally contacting wastes
    - Inadvertent human intrusion
  - Keep wastes from migrating to people
    - Burrowing animals, roots
    - Vapor phase
    - Groundwater

} **Shallow Land Burial, with Active Maintenance**

Options for Safe Disposal
Longer Half-Life and Higher Activities

- **Permanent isolation of radioactive wastes from humans and the environment**
  - **Keep people from accidentally contacting wastes**
    - **Inadvertent human intrusion**
  - **Keep wastes from migrating to people**
    - **Burrowing animals, roots**
    - **Vapor phase**

Intermediate Depth Burial or Deep Geologic Repository

- **Groundwater**

Very dry site or very long travel times or engineered barriers

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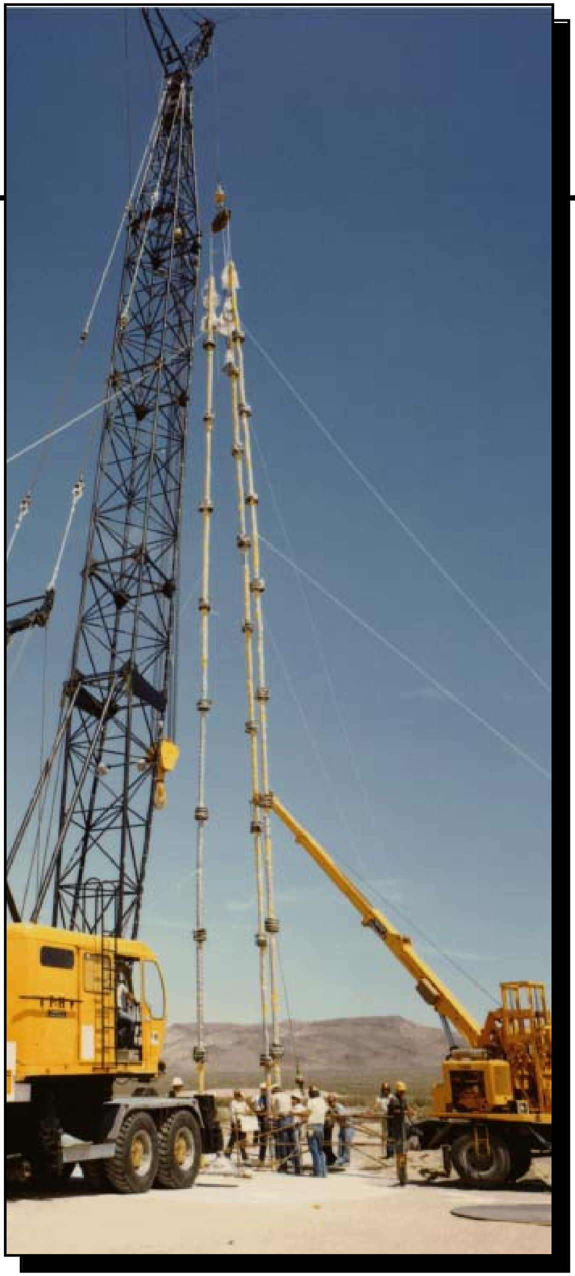
Intermediate-Depth Borehole Disposal

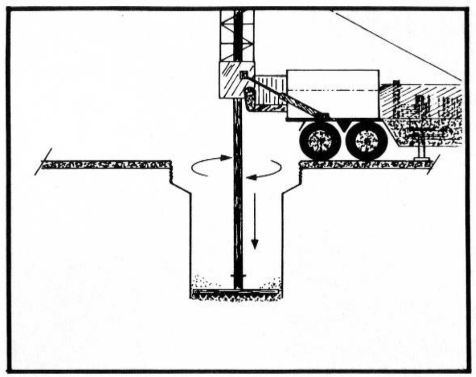
- Disposal at depths of 30 to 300 m
- Can also excavate & backfill trench or tunnel into mountain
- Boreholes least expensive for small volumes and have some advantages
- Boreholes 0.3 to 4 m in diameter

How deep is 30 m?

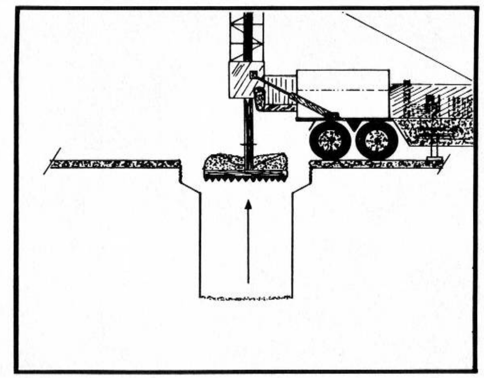
Placing monitoring string in 36 m deep GCD Borehole



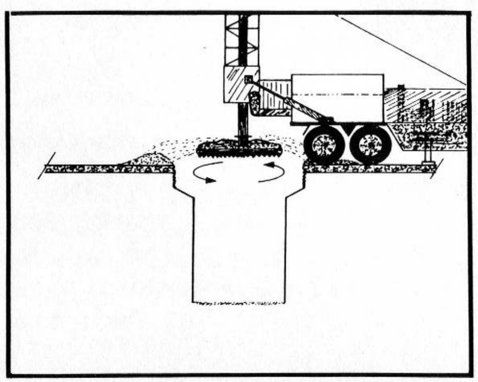
Low Technology Drilling in Weakly Consolidated Materials



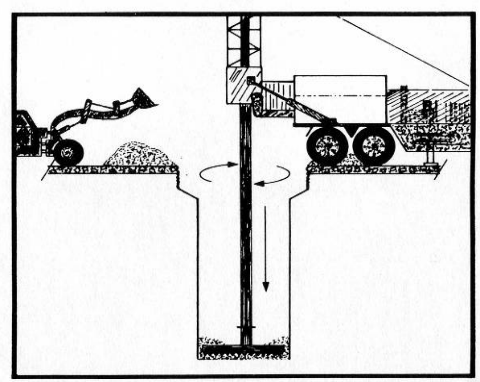
Auger drills into soil



Bit carries soil to surface



Backspinning throws soil off bit



Front-end loader removes soil

Low Technology Drilling in Weakly Consolidated Materials

Drilling in Consolidated Materials

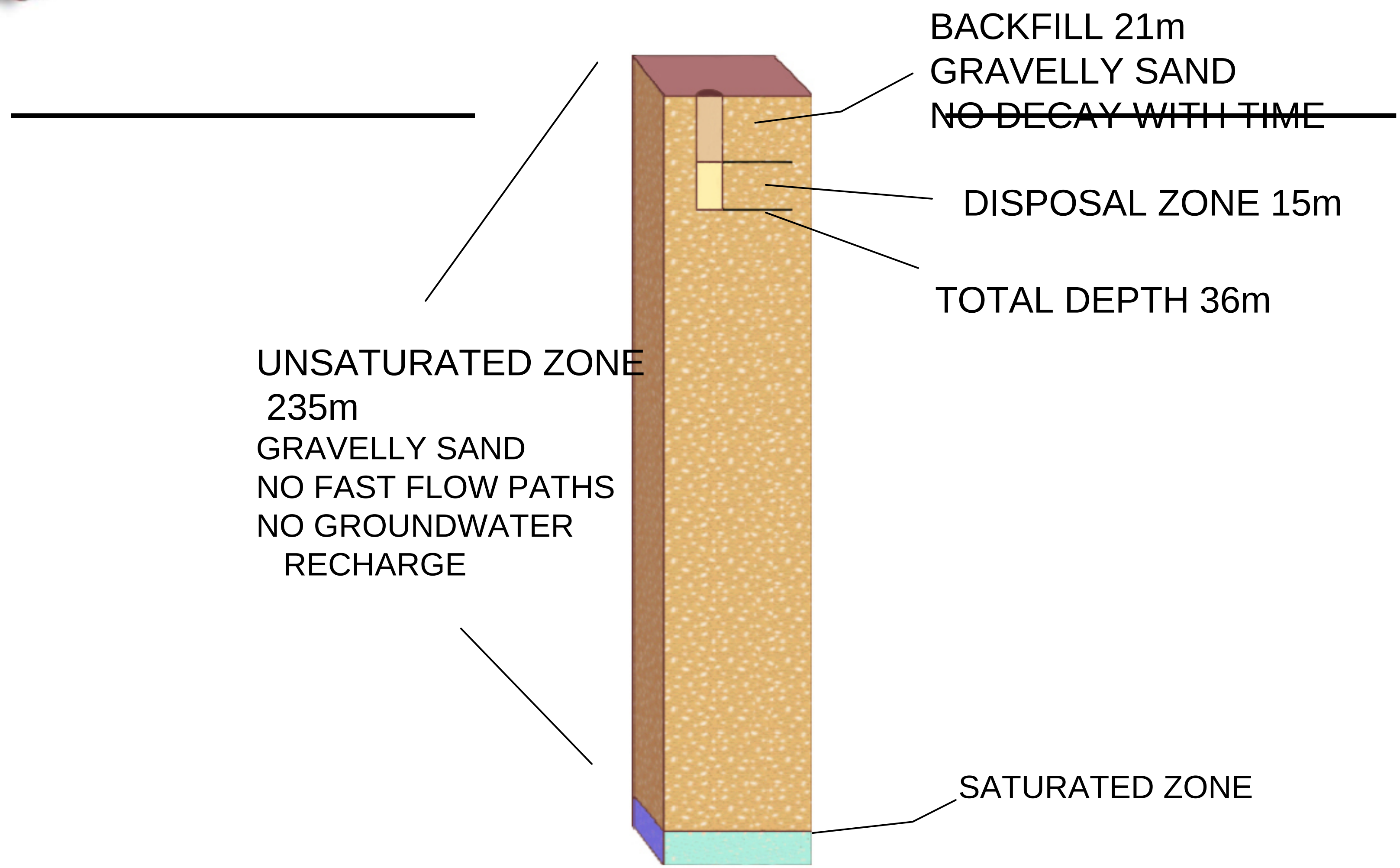
5.5 m Bottom Hole Assembly. Intake Air Shaft 100 m Deep – Kentucky, USA

Shaft Drillers International

Drilling large diameter shafts in hard rock is much more difficult and expensive than drilling in weakly consolidated material

Use of Borehole Technology for Disposal in the United States

- Successfully used at DOE's Nevada Test Site (NTS)
- The Greater-Confinement-Disposal (GCD) boreholes.
  - 3 to 3.6 m in diameter
  - 36 m in depth



GREATER CONFINEMENT DISPOSAL BOREHOLE

Use of Borehole Technology for Disposal in the United States

- GCD operations 1983 - 1989
  - 4 boreholes High Specific Activity LLW, ~ 80 PBq (2,300 KCi)
  - 4 boreholes classified transuranic (TRU) wastes
    - Nuclear Weapons Accident Residue (NWAR)
    - Classified for national security reasons (not WIPP certifiable)

GCD Site Setting at the NTS

- ❖ Thick alluvium (sand), 235 m (~ 800 ft)
- ❖ Arid - 130 mm / year (5 inches / year)
- ❖ No “fast flow paths” through the sand
- ❖ No groundwater recharge
- ❖ Remote location
- ❖ Existing LLW disposal facility

Area 5 of DOE's Nevada Test Site

Transfer of remote-handled reactor fuel cladding

Remote-disposal of reactor fuel cladding in GCD borehole

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- Assisted with site characterization
- Conducted safety assessment for TRU wastes against U.S. EPA 10,000 year probabilistic standard 40 CFR 191

Physical Processes Addressed

- **Unsaturated Zone**
  - Infiltration/Downward Advection (Liquid)
  - Upward Advection (Gas)
  - Upward Advection (Liquid)
  - Thermal Convection
  - Plant Uptake
  - Bioturbation (Animals)
  - Diffusion (Gas, Liquid)
  - Adsorption
  - Chemical Reactions (Precipitation, Complexation)
  - ➔ Preferential Pathways
  - Subsidence
  - Climate Change
- **Surficial Processes**
  - Flooding
  - Erosion
  - Sediment Deposition
  - Fracturing
  - Subsidence
  - Climate Change
- **Source Term/Containment Specific**
  - Gas Production(organics)
  - Radioactive Decay
  - Waste Solubility
  - Reactions (nuclear criticality)
- **Future Disruptive Events**
  - Volcanism
  - Techtonism
  - Changes in Land Use (human)
  - Inadvertent Human Intrusion

How GCD Boreholes Isolate Wastes > 10,000 Years

- **Leach to Groundwater**

- **Vapor Phase**

- **Biological Processes (roots, burrowing)**

- **Inadvertent Human Intrusion**

How GCD Boreholes Isolate Wastes > 10,000 years

• Leach to Groundwater →	Arid climate, no fast flow paths in thick sand, no water recharge
•Vapor Phase →	Travel time through sand backfill >> half-life of radon
• Biological Processes (roots, burrowing) →	Wastes deeper than biologically active zone
• Inadvertent Human Intrusion →	Wastes deeper than almost all normal human activities (foundations, basements, utilities, septic …)

SANDIA REPORT
SAND2001-2977
Unlimited Release
Printed September 2001

Compliance Assessment Document for the Transuranic Wastes in the Greater Confinement Disposal Boreholes at the Nevada Test Site

Volume 2: Performance Assessment
Version 2.0

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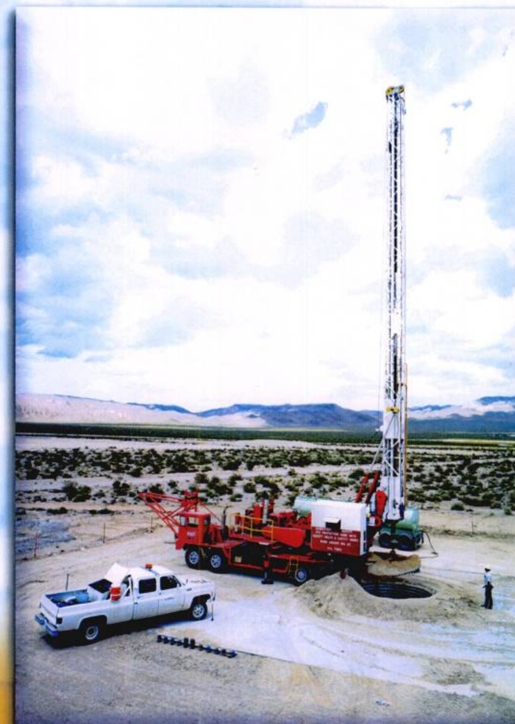

http://infoserve.sandia.gov/sand_doc/2001/012977.pdf (72 Mb)

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International Borehole Disposal Project (BOSS)

- **IAEA Borehole Disposal of Sealed Sources (BOSS)**
- **Integrated system to help Member States with limited infrastructure and small inventories sealed sources**
  - **IAEA & Nuclear Energy Corporation of South African pilot project: <u>small diameter boreholes (0.14 to 0.26 m)</u> with depths ranging from 30 to 100 m**
  - **Wastes <u>doubly encapsulated in stainless steel capsules</u> (Engineered Isolation)**
  - **Being considered by several other nations in Africa, Middle East, South East Asia, and Latin America**
  - **Developing "*Generic Post-Closure Safety Assessment for Borehole Disposal Facilities*"**

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IAEA’s BOSS

Photograph of the BOSS Outer Disposal Container (11 cm in diameter) with the Two Sizes of Inner Capsules on the bottom of the Photograph (from IAEA, draft, 2006)

IAEA's BOSS

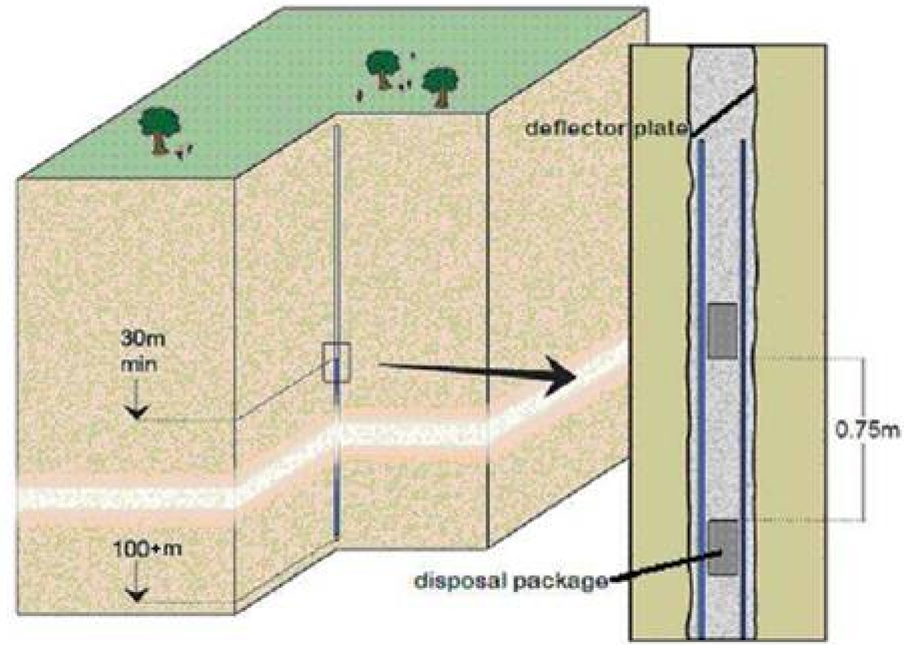

Diagram of the Possible Implementation of the IAEA's BOSS Disposal System (from IAEA, draft, 2006)

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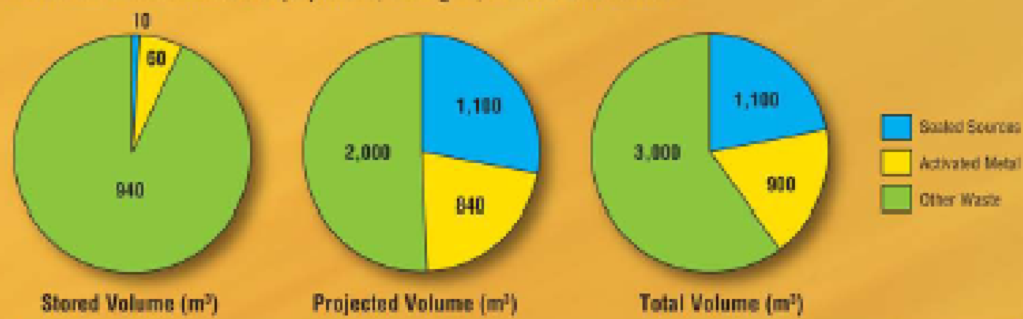
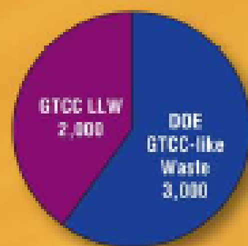
U.S. Currently Considering Intermediate-Depth Disposal for GTCC LLW

- Advanced Notice of Intent – May 11, 2005
- Notice of Intent – Spring 07
- Draft EIS – Jan 08
- Final EIS – Oct 08
- Report to Congress on Disposal Alternatives – 0ct 08
- ROD – TBD (following Congressional action on disposal alternatives report)

GTCC LLW and DOE GTCC-like Waste Inventory

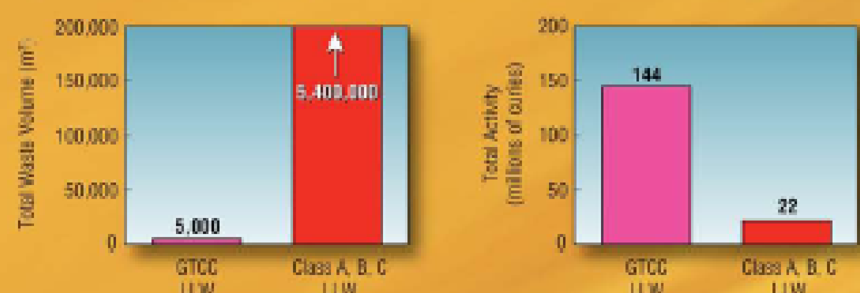
About 20% of the total inventory* is in storage with the remainder projected to be generated by 2062. Inventory consists of three waste categories: sealed sources, activated metal, and other wastes. Other wastes include materials that are not activated metal or sealed sources such as contaminated equipment, sludges, debris and filters.





About 3,000 m³ of the total inventory of 5,000 m³ is DOE GTCC-like waste.

The total volume of GTCC LLW and DOE GTCC-like waste is much smaller than the volume of LLW generated over the same period of time, but contains more activity.



LLW volumes and activities were obtained from the DOE MIMS database, and are projected to 2062.
The GTCC LLW entries are the total for GTCC LLW and DOE GTCC-like waste.

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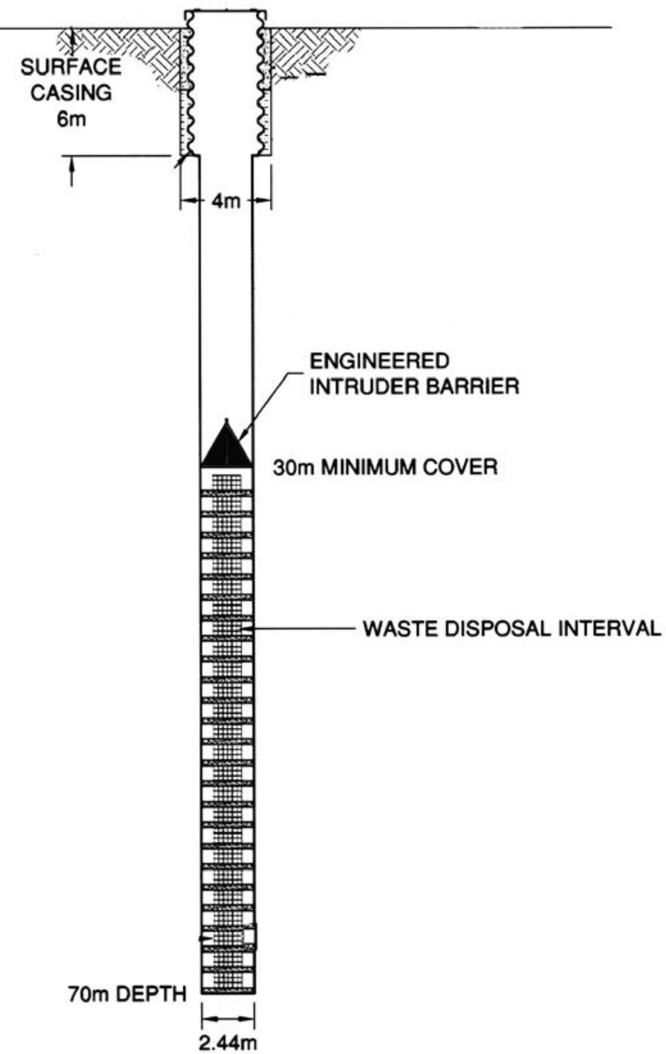
Potential GTCC Disposal Alternatives

- Enhanced near surface
- Intermediate depth borehole
- Geologic repository

Possible Conceptual Design of Intermediate-Depth Borehole Disposal for GTCC LLW



Potential Advantages of Intermediate-Depth Borehole Disposal

- Cost effective means for intermediate depth disposal
- Amenable to intermittent or low-volume operations
- Technology is globally available
- Inadvertent human intrusion is unlikely because of depth of burial
- Inadvertent human intrusion is unlikely because of small footprint
- Can use small intrusion deflector to protect large volume of waste
- Can dispose of unshielded, remote-handled wastes
- Easily co-located with existing or other planned trench disposal facilities
- On the correct setting, can provide geologic isolation of long-lived LILW

Goal: Safe, Permanent Disposal of Unwanted Radioactive Wastes