FY 2018 Congressional Report Requirement:

WIPP Roof Bolting: Not later than 60 days after the enactment of this Act, the Department shall provide to the Committees on Appropriations of both Houses of Congress a plan for maintaining the underground with clear performance metrics for roof bolting and other ground control rehabilitation activities, including estimates of the funding requirements to fully support the plan. Metrics should distinguish activities needed to close out existing panels with those needed for maintenance of active waste disposal pathways, secondary areas, and new mining activities

What is WIPP?

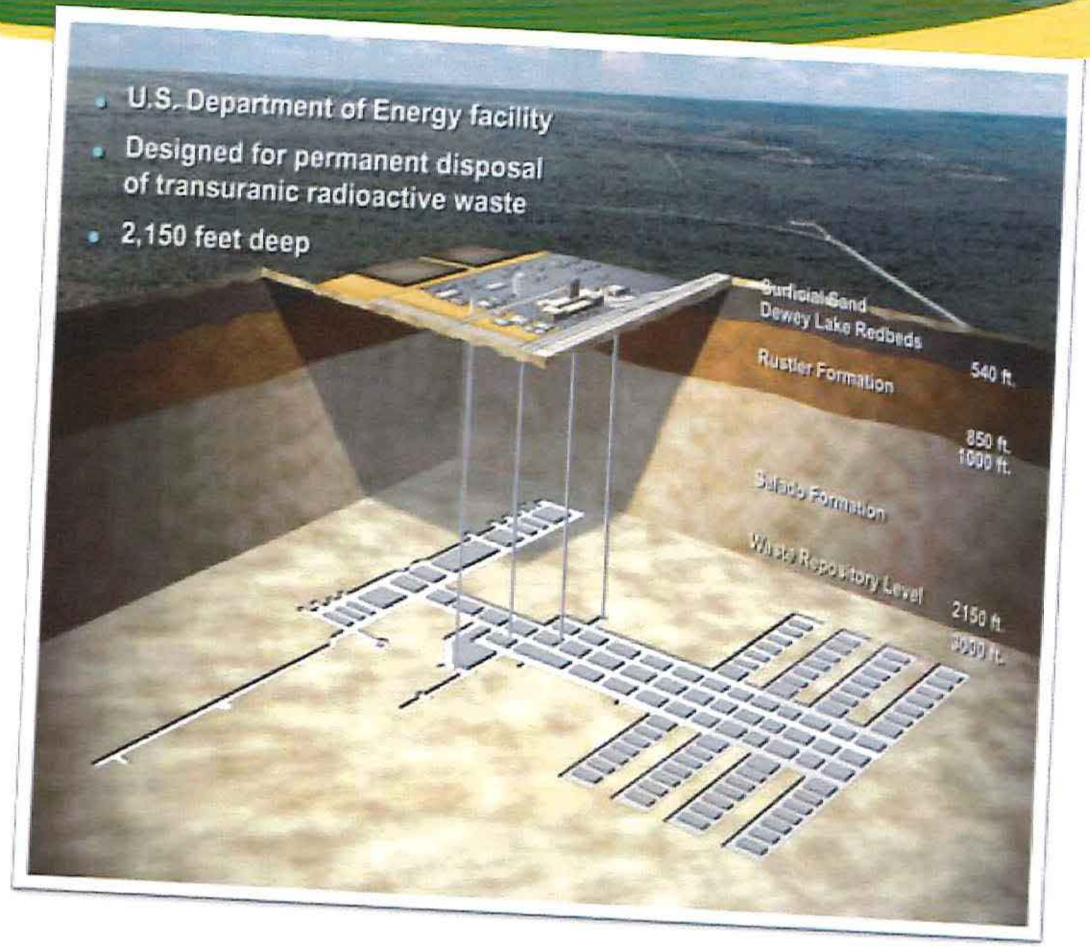
WIPP is a Department of Energy owned deep geological salt mine. It is the Nation's repository for defense related Transuranic waste.

The mine is 2150 feet underground in a salt formation known as the Salado formation.

The Salado Formation is an ancient deposit of layered halite (rock salt) over 2000 feet thick. The formation is located under much of southeastern New Mexico and extends into West Texas.

WIPP is in the middle of the formation at depth and is mined at a single horizon (one level).

The mine is accessed and ventilated via 4 shafts from surface. The waste is transported to WIPP where it is loaded onto a hoist and lowered into the mine. At that point it is transported underground and emplaced in rooms mined out in the salt formation.



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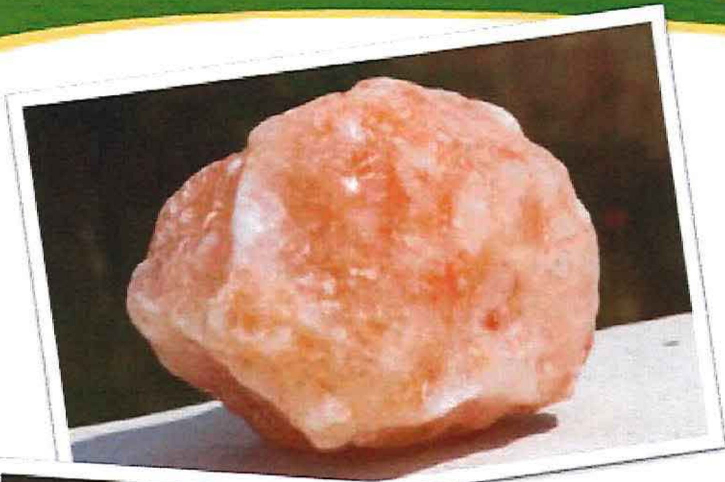
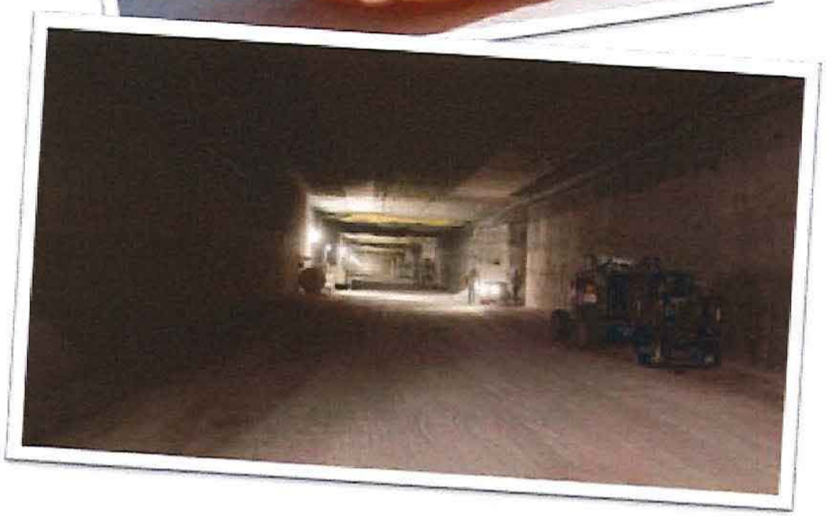
Why use a salt mine to dispose of nuclear waste?





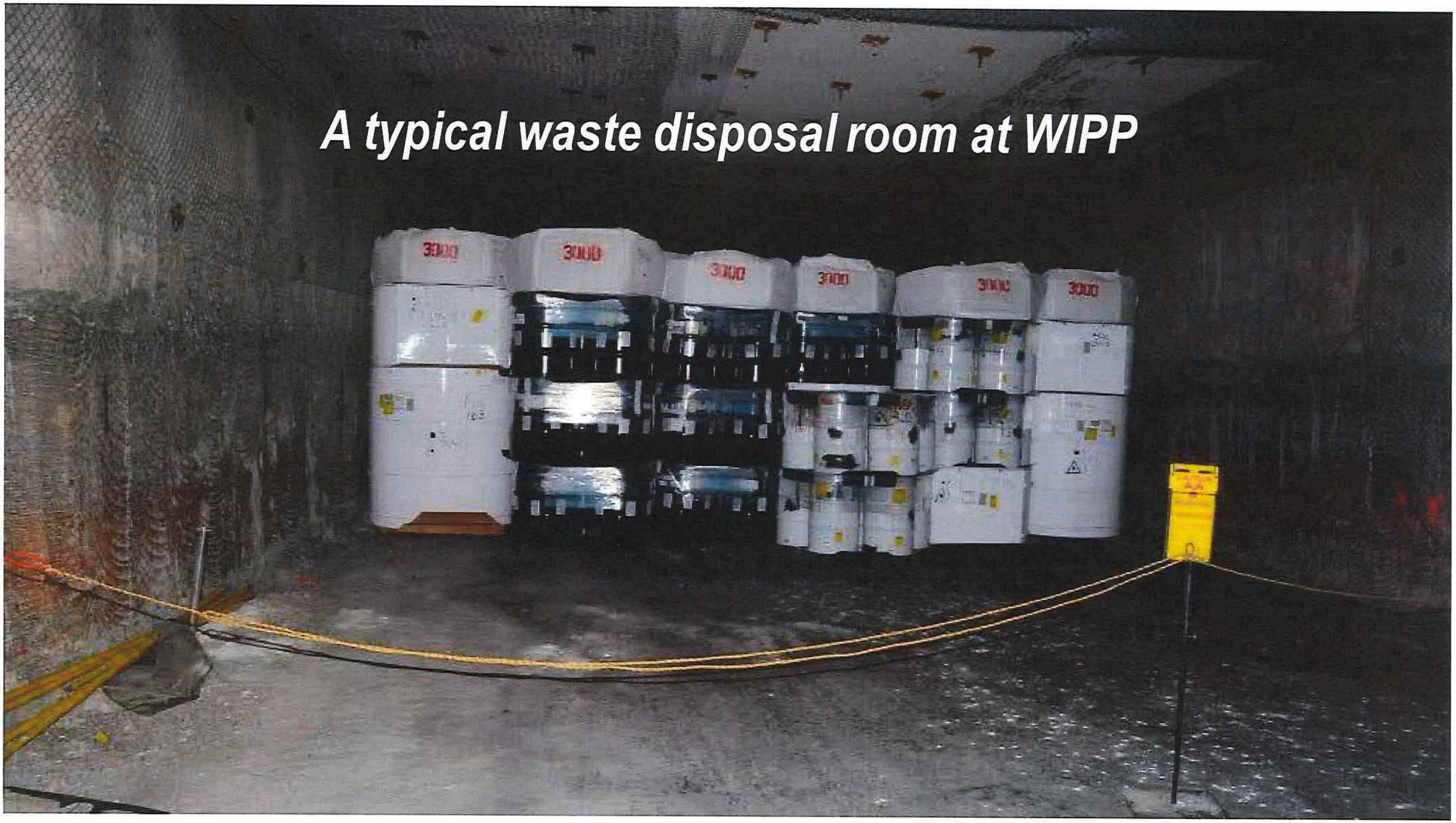
Rock salt (Halite) has favorable characteristics which the DOE uses to its advantage .

Salt is essentially a plastic medium. When you mine an opening in rock salt, the forces at depth in the WIPP mine will cause the salt for all intents and purposes to flow (very slowly) to fill in that space.

In a salt formation underground, the weight of the earth above the mined opening applies pressure to the salt in all directions. This is known as lithostatic pressure and is the reason for the salt matrix reclosing any openings created.

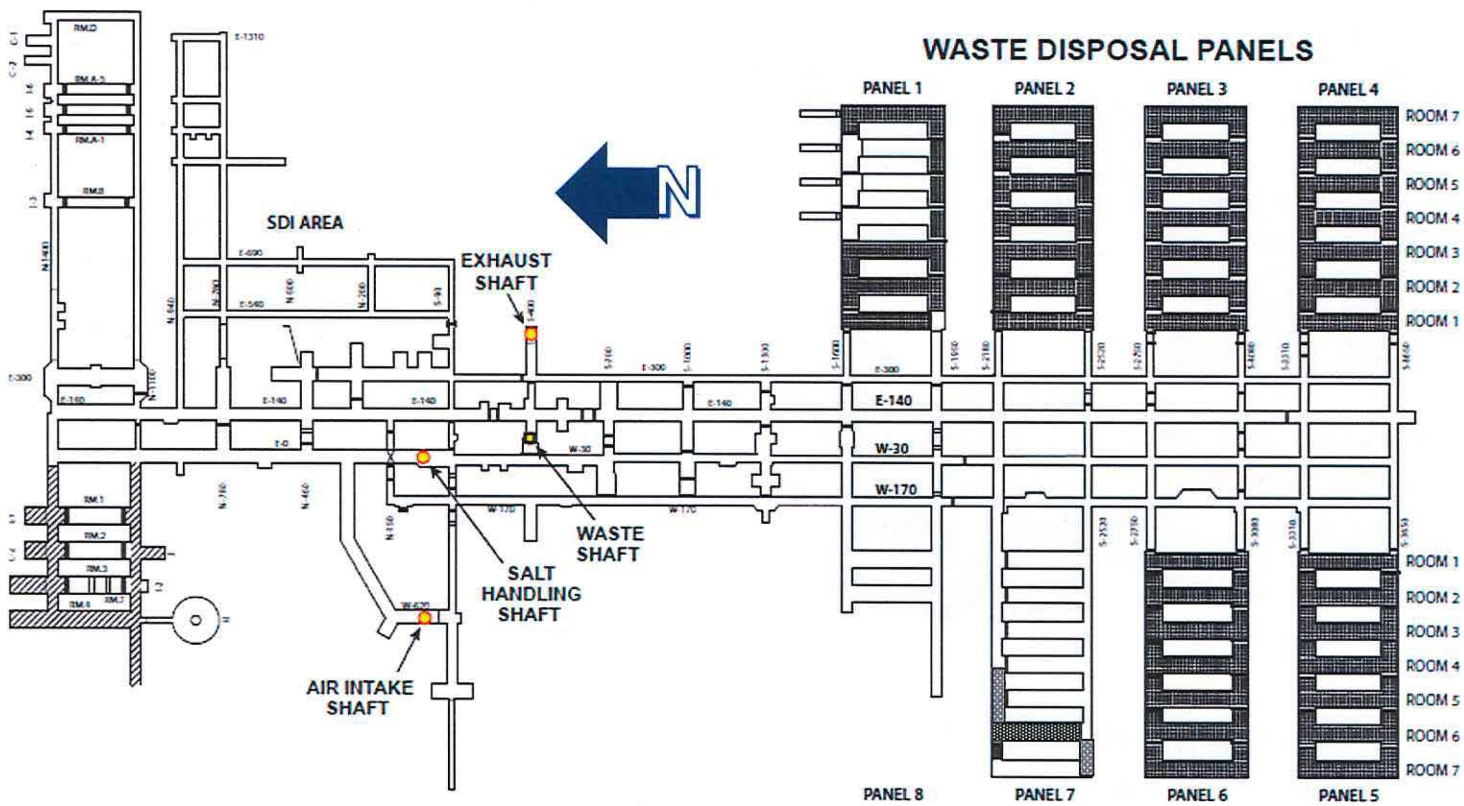
In the WIPP underground, nuclear waste emplaced in rooms mined into the salt will eventually be encapsulated by the salt and entombed in the salt matrix.

The challenge is to keep the spaces open and safe while working in them. Some of the WIPP tunnels "known as drifts" have been kept open for 30 years and may need to remain open for an additional 30 years.


A typical waste disposal room at WIPP

WIPP Underground Map and Quick Facts

- 4 main North-South tunnels or "drifts"
- 1 mile in length N to S
- ½ mile in width E to W
- 12 miles of tunnels (drifts)
- Waste emplaced in 7 Panels
- 1 Waste Panel under construction
- 4 shafts
- 3 Hoists
- 7 available exhaust ventilation fans
- Up to 114,000 cfm (currently)
- Up to 130 workers in the mine



Ground Control

Every opening in the WIPP mine is continually experiencing the forces from lithostatic pressure.

Salt, in addition to acting as a plastic medium may fracture or be brittle near opening surfaces

The forces of lithostatic pressure can act upon the bedded layers of salt to cause cracks and spalling which can free chunks from the matrix and pose hazards to the workforce in the WIPP mine. Salt rock weighs 135 pounds per cubic foot.

The lithostatic force acting on the salt is equal to approximately 1 psi for every foot of ground above the opening or approximately 2150 psig acting on all exposed surfaces.

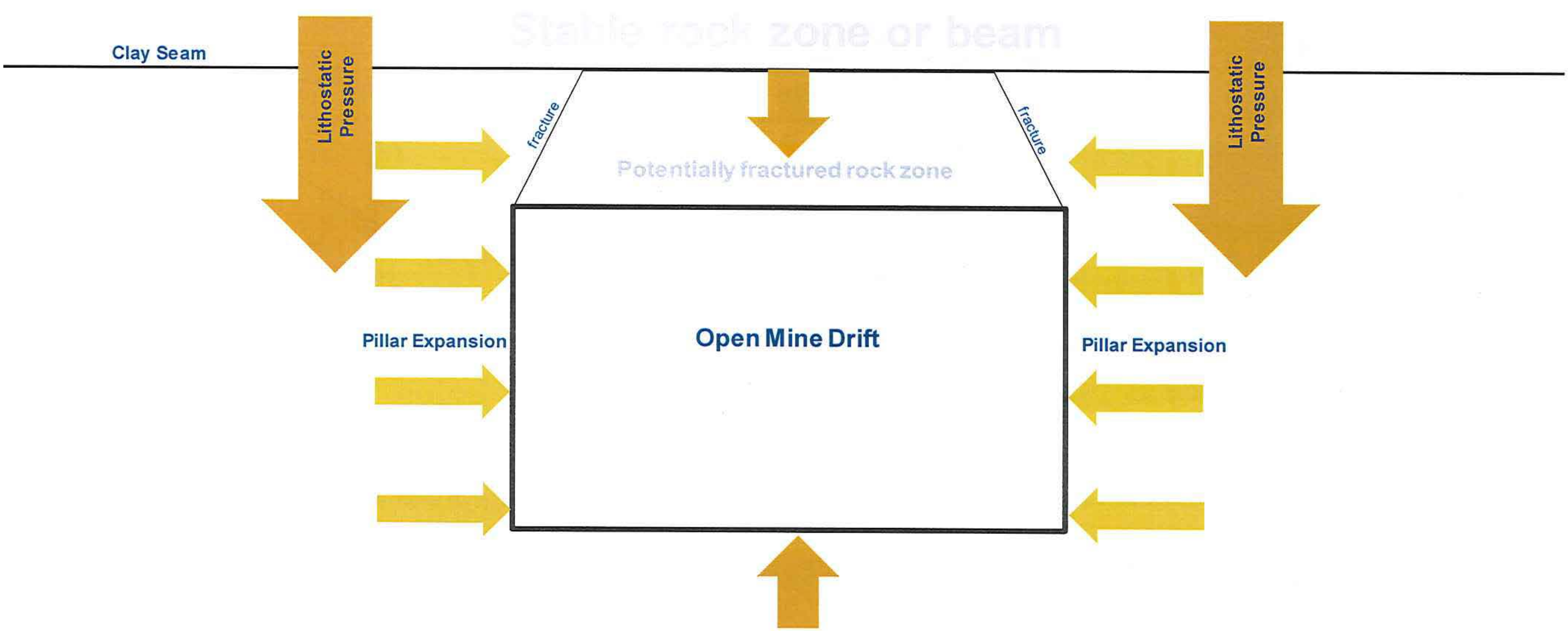
As a result the roof (called the back), walls (called the ribs), and the floor will converge and close the opening over time.

Unless controlled by bolting, the back and ribs will slowly creep until becoming unstable and then fall into the opening. The floor will "heave" or buckle upward.

Because of the risk caused by the movement of the salt, WIPP employs a "Ground Control" program to maintain the mine openings in a safe condition for our workers.

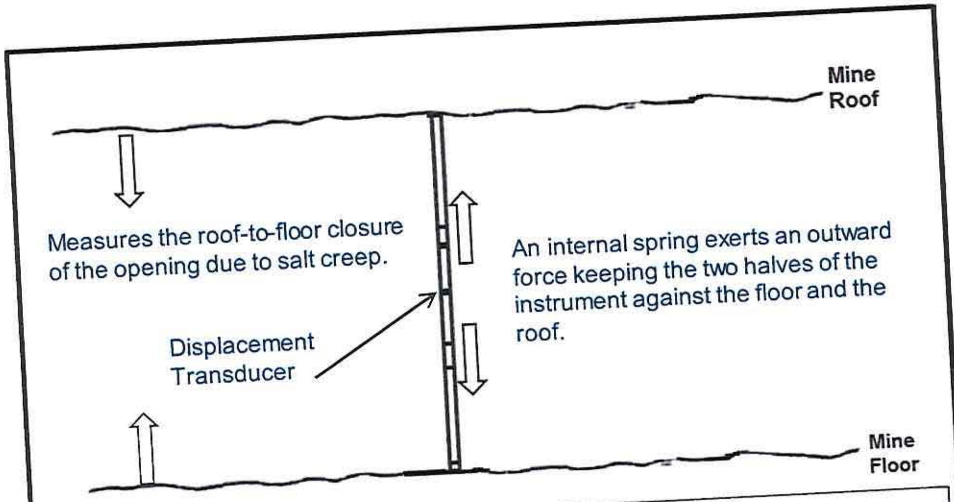
A diesel powered roof bolter

What Happens To Mine Openings



Ground Control Metrics – Pogo Sticks

The following slides show examples of some of the tools and instruments used by the NWP Geotechnical group to measure convergence rates in the mine. It should be noted, however, the vast majority of convergence data is manually collected with calibrated measuring tapes.



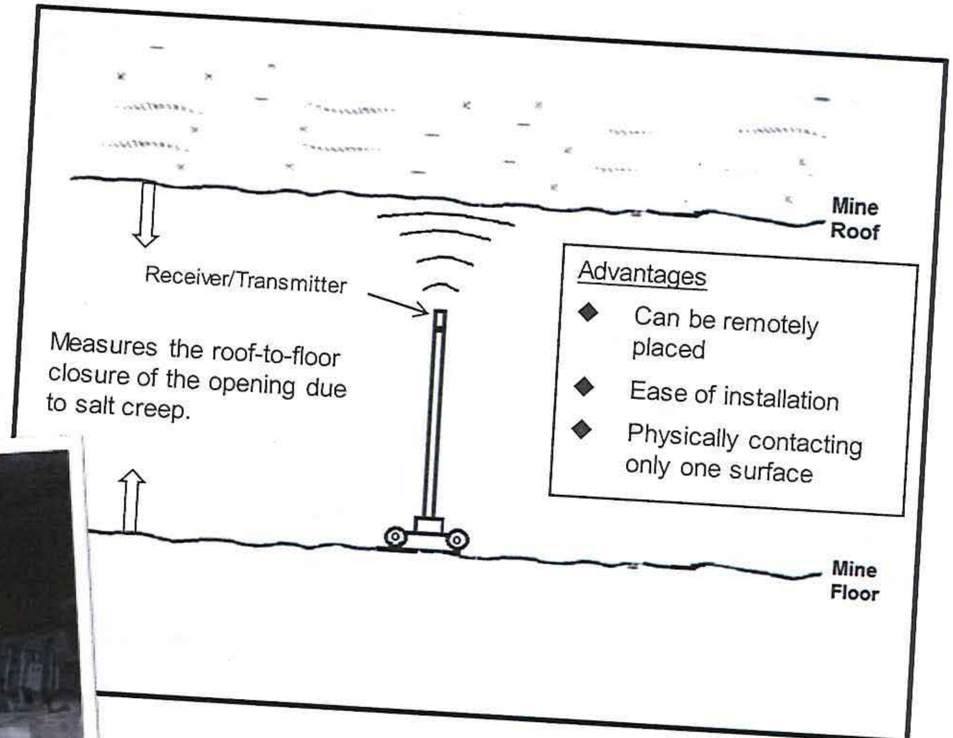
Methodology

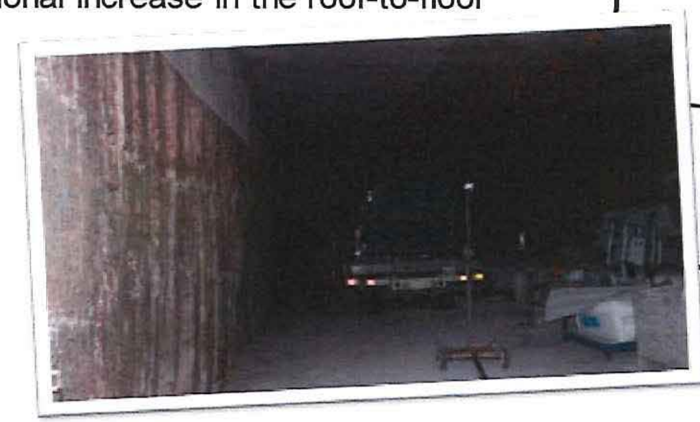
- As salt creep compresses the two halves of the instrument the displacement transducer compresses an equal amount and outputs a voltage proportional to the displacement
- Instrument output varies linearly with the roof-to-floor convergence

Ground Control Metrics – Ultrasonic Convergence

Methodology

- The instrument transmits sound energy to the mine roof
- The sound energy is reflected back to the instrument
- The round-trip travel time for the sound energy is measured by the instrument
- The distance between the receiver/transmitter and the mine roof (roof-to-floor closure) is calculated by the instrument using the measured round-trip travel time and the speed of sound in air
- A decrease in the round-trip travel time of the sound energy corresponds to a proportional increase in the roof-to-floor closure





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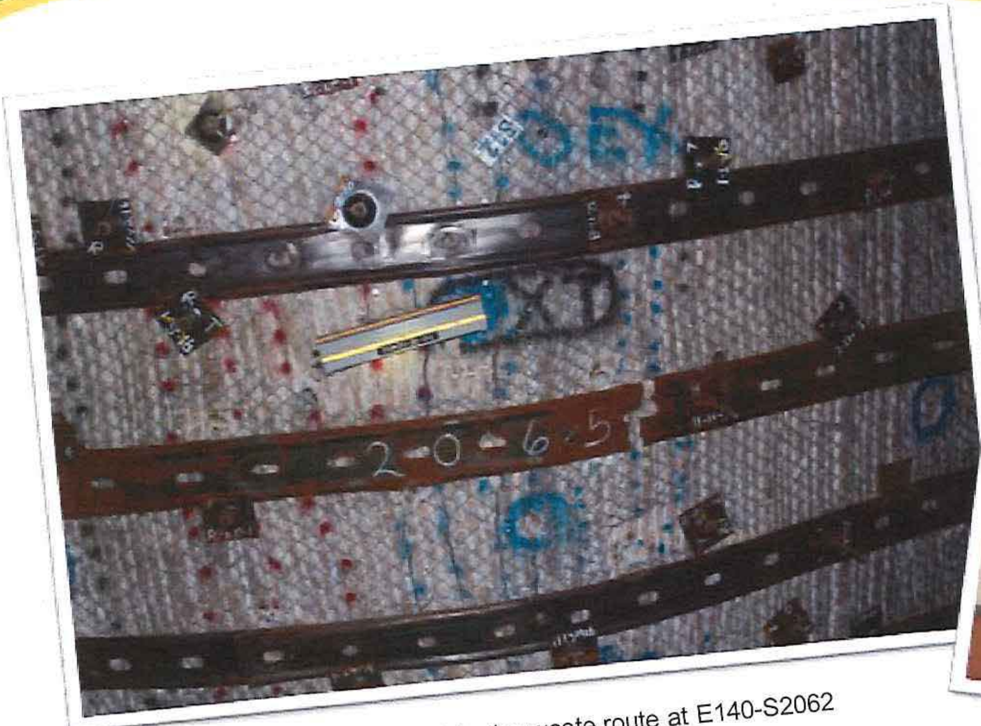
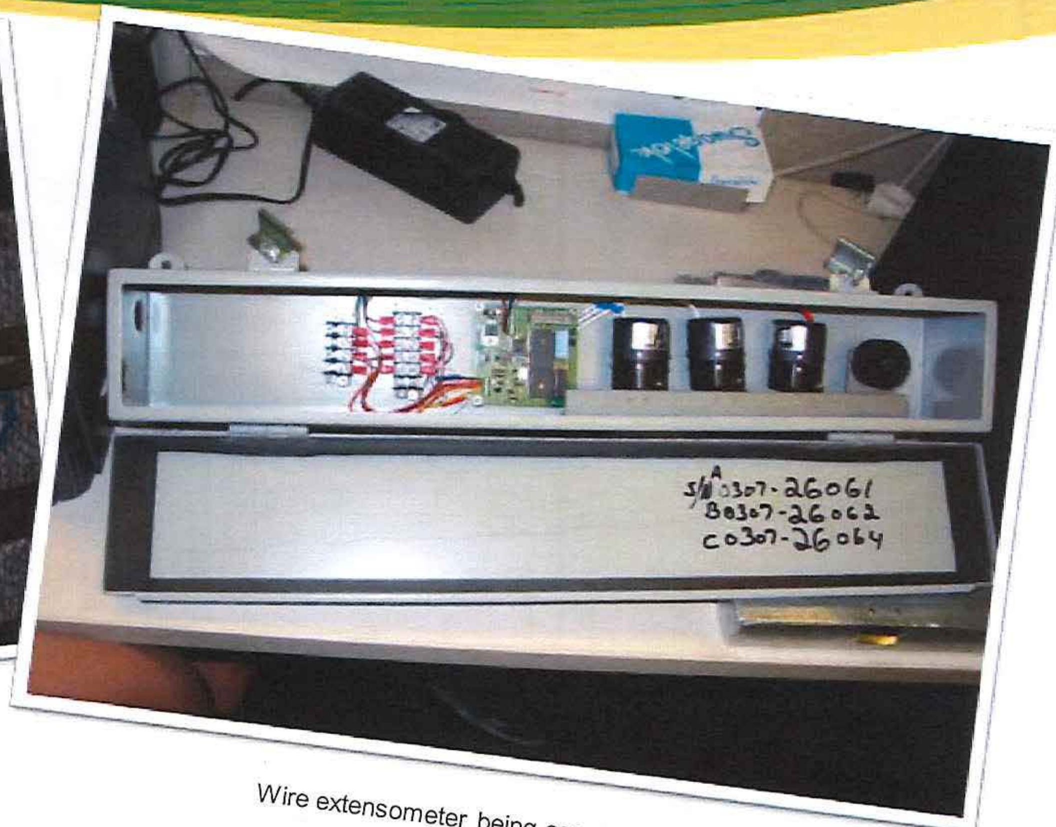
Ground Control Metrics - Extensometers



Wire extensometer installed in the waste route at E140-S2062



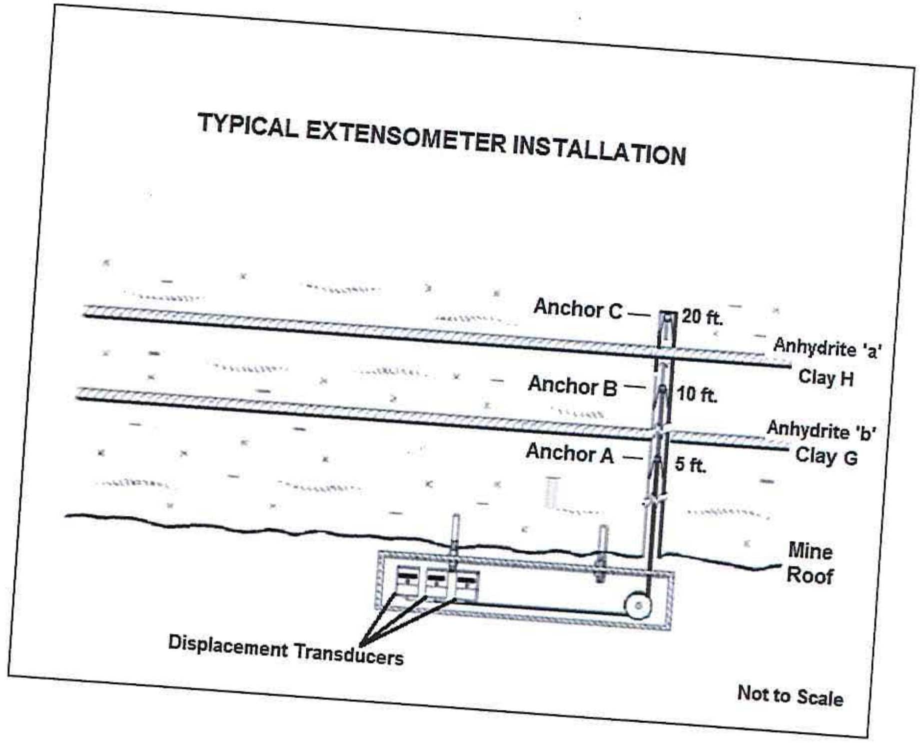
Wire extensometer being assembled

Ground Control Metrics - Extensometers

- Extensometers are used to measure the expansion of the roof beam (roof sag) as referenced from three fixed locations within the roof beam (referred to as anchors A, B and C in the above sketch)
- Each anchor is attached to a displacement transducer within the body of the extensometer—the extensometer body is attached to the mine roof
- The roof beam deflects downward as a result of lateral forces acting on the ends of the roof beam
- Eventually the beam deflection results in separations developing at the clay seams and fractures developing within the roof beam

A particular anchor will only record separations within the roof beam that occur between the anchor and the mine face.

- For example, any separation that occurs below anchor A will be recorded by all three anchors
- A separation that occurs between anchors A & B will be recorded by only anchors B & C
- A separation that occurs between anchors B & C will be recorded by only anchor C



Ground Control Metrics

Alcove west of W-170 and S-400

The data indicates the back and the floor have converged nearly a yard in 29 years.

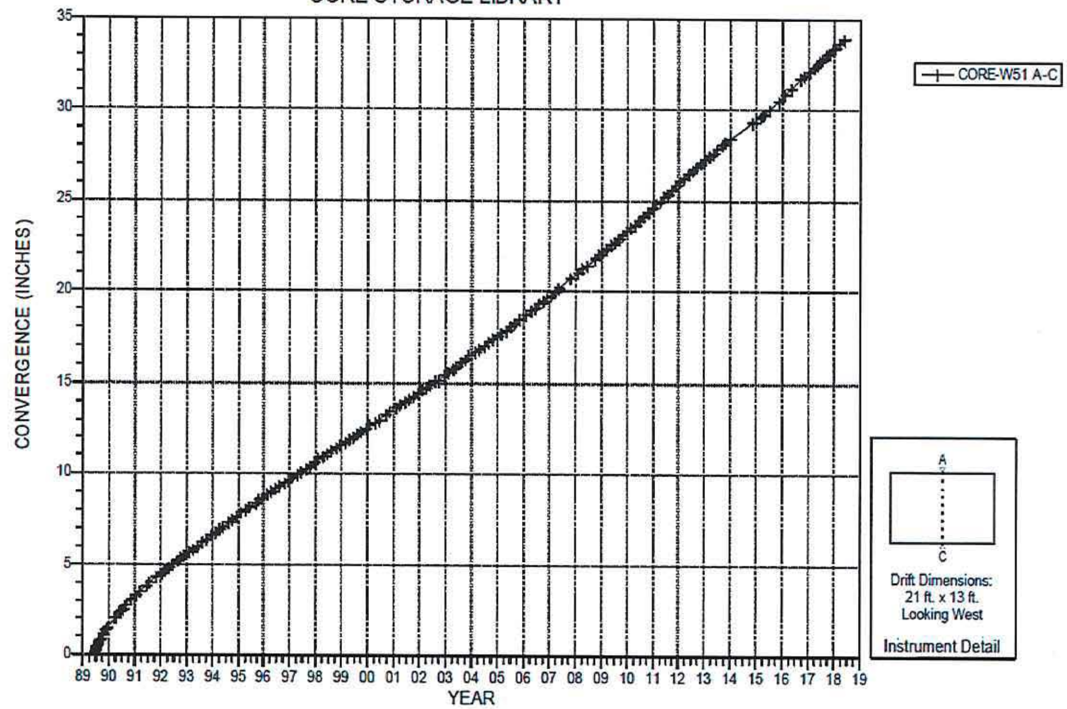
Averaged over that period this is a convergence rate of 1.2 in/yr

This is a very stable area and expectedly so as it is in area around the escape hoists where WIPP controls the extraction ratio of salt to less than 15%.

Typically convergence rates in the mine can be anywhere from 2 in/yr to 7 in/yr without concern.

Convergence rates showing acceleration may indicate developing instability and require monitoring by Geotechnical professionals and may require ground control actions.

Areas accelerating can be bolted to control the rate or could be prohibited access.



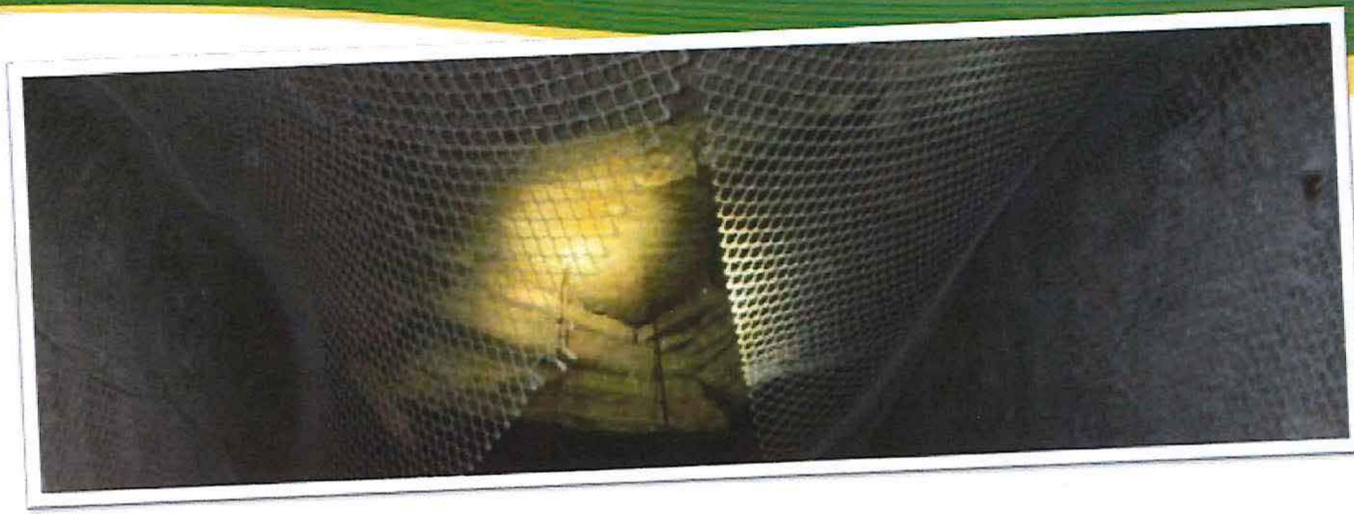
NOTES:
1. Excavation date: May 1989.

Ground Control in a Salt Mine

Tools WIPP uses for Ground control

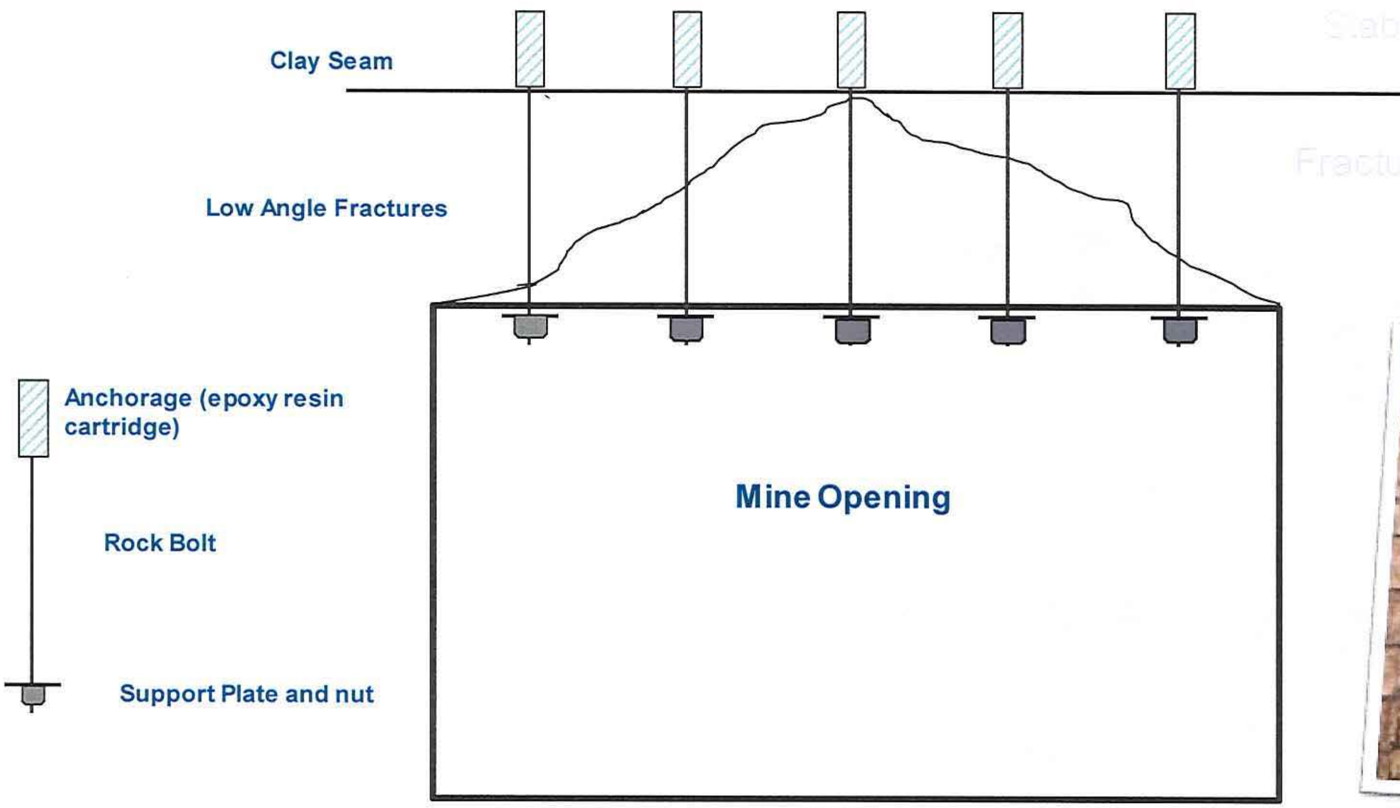
- Rock Bolts – Typically 7/8 inch 5-14 ft. long threaded steel bars
- Chain Link Mesh (extra heavy duty holding 110 lbs./square ft)
- Crib sets (a barrier to prevent propagation of roof falls)
- Scaling – bringing down unstable rock with hand tools or machines

How A Rock Bolt Works



- The bolts pin rock layers (laminations) in the fractured zone together to increase its strength. These are shorter bolts known as mechanical bolts – 2 to 10 feet in length (the picture illustrates the layering in the fractured rock zone)
- Longer bolts anchor the fractured rock zone (roof beam) to stable rock zones above (like nailing drywall to studs). These bolts are anywhere from 5 to 14 feet long.
- Bolts are threaded to allow a metal plate with a hole in the center to be seated up to the salt layer with a large nut. The plate then takes the weight of the rock.

Rock Bolts



Support plate with a lanyard

Low Angle Fracturing

Where the back and the rib meet, the forces in the rock tend to form fractures which propagate at an angle towards the center of the opening.

At WIPP, in the Salado formation, these fractures propagate until they reach the Clay G layer above the underground horizon. This is a layer of clay or sediment which settled over a previously dried layer of salt which had formed when the ancient ocean that once existed in this area of Texas and New Mexico evaporated.

Unless controlled by adding support, the result is a sometimes very large section of the fractured rock zone which is free to fall to the floor unless it is bolted in place.

Depending on the area not supported by bolts, this can be in the thousands of tons.

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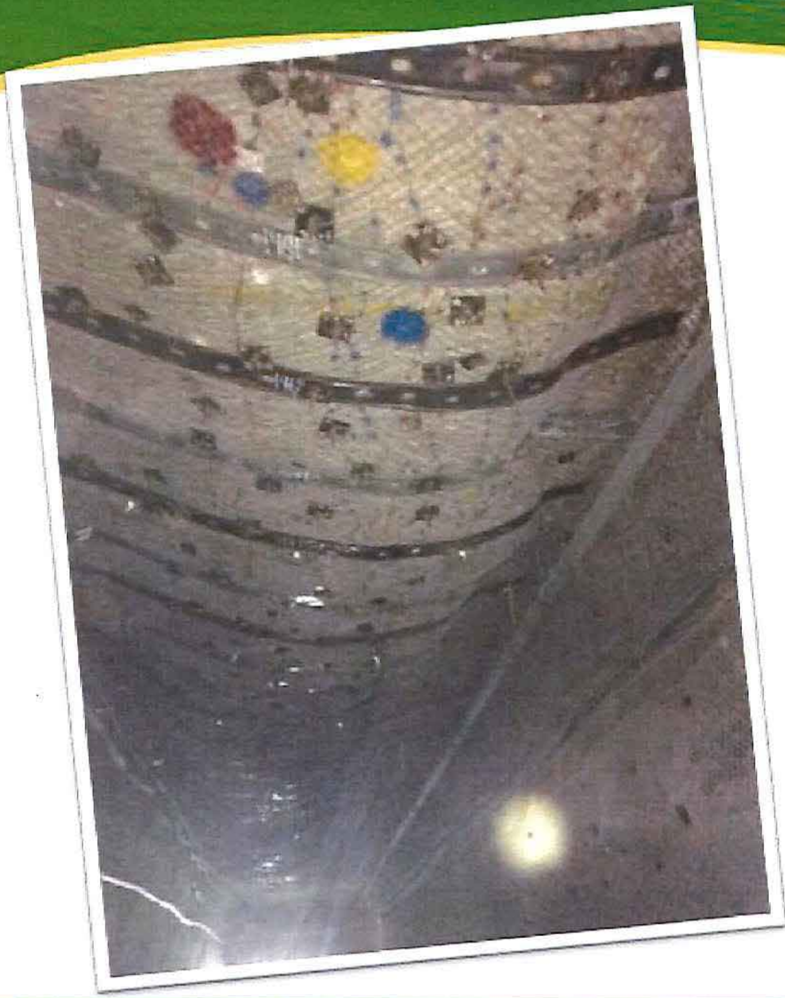
Roof sag or belly

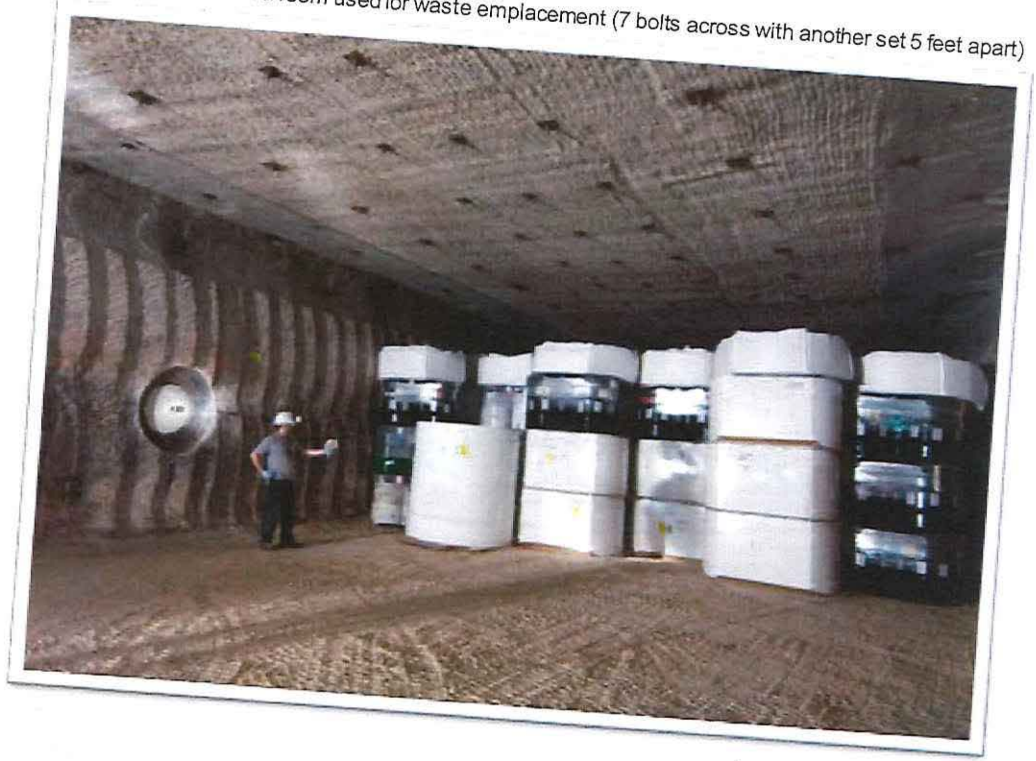


The example to the left illustrates roof sag (sometimes referred to as a belly) caused by pillar expansion and gravity. This roof, which was once flat, has sagged due to the pillars of salt on either end pushing on the roof and individual laminations of salt rock separating in the fractured beam. This drift is safe for access as it has enough unbroken bolts holding the sagging portions to the stable beam above it. WIPP Geotechnical engineers verify the safety of the area by regular measurements.

Bolt breakage and replacement

- WIPP installs patterns of bolts which will conservatively carry the weight of the rock with an added safety factor of at least 30% in most areas of the mine.
- The roof bolt patterns are designed to support the dead-weight load of the rock in the immediate roof (i.e. the roof beam)
- WIPP uses long bolts, called threaded bar, to pin the fractured rock zones to stable zones. These bolts have the strength to hold up to 60,000 lbs. (30 tons) a piece. WIPP only takes credit for 45,000 lbs. (22.5 tons)
- Given the thickness of the rock layer and the square footage exposed after mining, it is possible to calculate how much weight in rock needs to be supported and how many bolts are necessary in the roof to support it from falling.
- WIPP has over 90,000 bolts in the back and ribs of its underground.

Typical bolt pattern a room used for waste emplacement (7 bolts across with another set 5 feet apart)



How bolts break

Bolts will break due to the stress from the movement of the layers of rock in two ways. Sheer stress or tension stress.

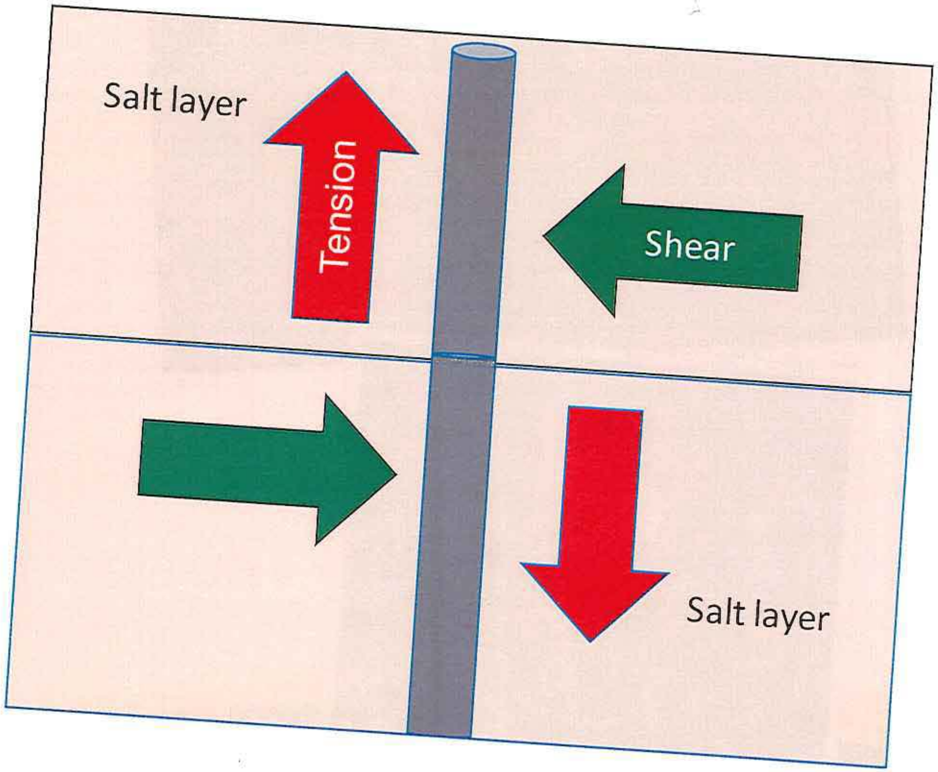
With tension stress, as layers of rock separate, the tension on the bolt, which is anchored at one end in the rock can pull the bolt apart.

With sheer stress, layers of salt rock moving in different directions can sheer the bolts in the rock matrix.

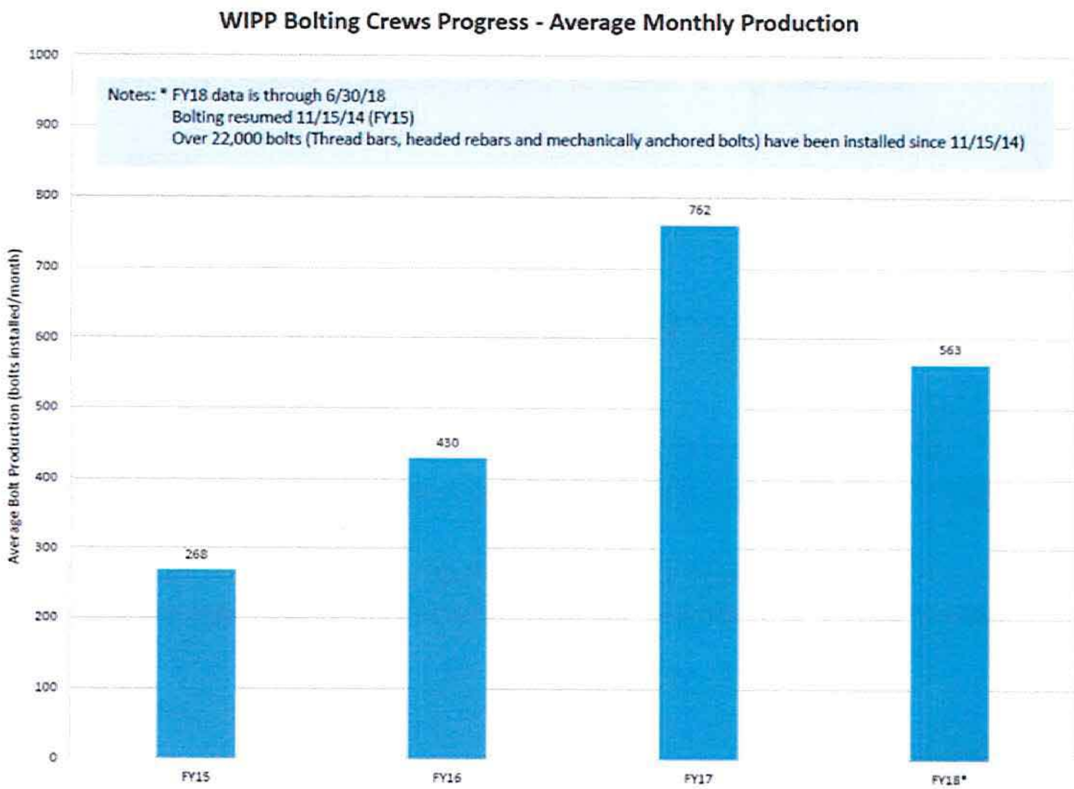
Bolts to break in the WIPP underground at a pace of about 20 to 40 per week.

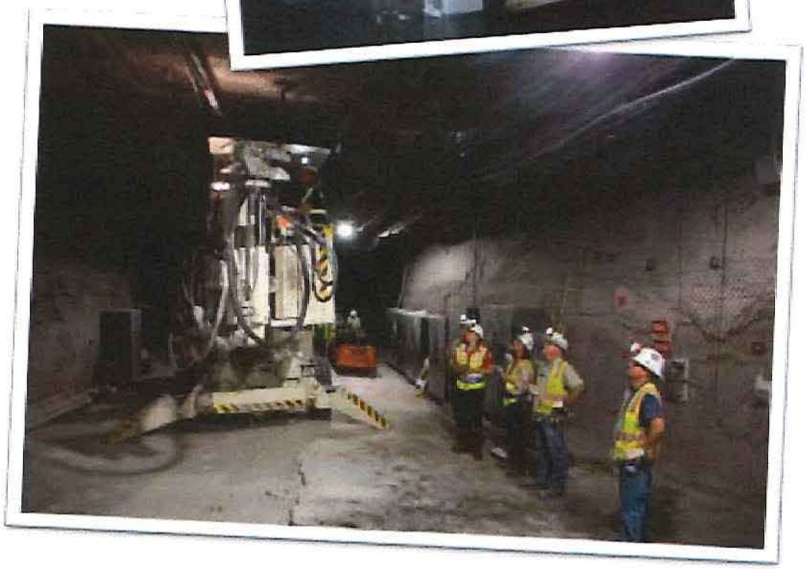
Pattern bolted areas are maintained to have a 1.3 minimum safety factor although they typically have a much higher safety factor.

If any of the areas in the WIPP underground fall below that safety factor, the priority to bolt would be focused on those areas.



Ground Control Metrics





WIPP establishes goals for and tracks the bolts installed on a weekly basis.

Bolting equipment

- WIPP has 5 bolters, 3 of which are traditional units powered by diesel fuel. Two other are hybrids having the ability to bolt in electric mode or via diesel power.
- A bolter has a boom with an operator cab at the end of the boom. They are able to articulate enough to reach the highest back at WIPP (25 feet high)
- Bolting does not occur quickly. For example, to install a threaded bolt, the bolter must be moved into place, outriggers set, the boom articulated into position. A hole must be drilled to proper depth for the length of bolt required, epoxy cartridge put in place, the bolt set into the epoxy, a metal plate put in place around the bolt, a nut screwed onto the threaded end to set the plate against the rock and a lanyard attached to the nut and chain link.
- That is for one bolt and does not take into account having to remove equipment which might be in the way. Power and auxiliary support lines in the overhead sometimes need to be moved or de-energized adding time to bolting operations.
- WIPP loses approximately 40 bolts per week which if not replaced weakens the ground support system.

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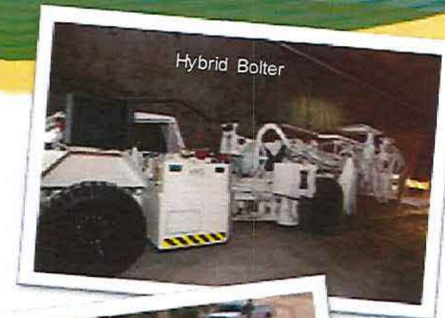
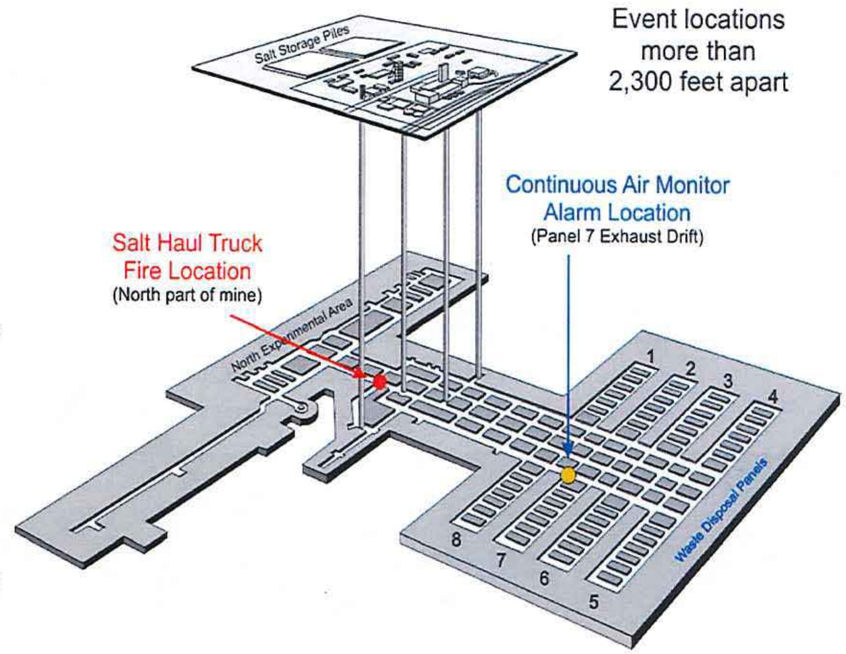
Bolting challenges

- Bolters are diesel powered equipment. To operate safely they require minimum airflow rates according to Title 30 CFR 57 of the Mine Act,. The same is true for all other diesel powered equipment.
- WIPP has been operating at low flow rates since February of 2014 when a contamination event caused the normal unfiltered ventilation from the mine to transfer to a much lower flowrate through HEPA filtration banks.
- Prior to 2014, WIPP could achieve as much as 425,000 cfm of unfiltered flow. Filtration mode is limited 60,000 cfm.
- The amount of airflow in the mine has not been able to support all underground operations at once. WIPP has 200 diesel powered vehicles in the underground supporting ground control, mining and waste emplacement.
- At the limited flowrates of filtration mode, fewer diesel powered activities could be conducted simultaneously leading to competition for air in the WIPP underground.
- In 2016, WIPP installed and started an Interim Ventilation System which raised overall flowrate in the underground to 104,000 cfm. This increased the amount of diesel powered equipment that could operate simultaneously.
- A separate airflow circuit with it's own fan was installed and started in late 2017 to support mining of Panel 8. This was the Supplemental Ventilation System.
- WIPP still struggles with airflow. A new permanent ventilation system is under construction and will provide enough filtered ventilation to allow all operations to occur without competition. It is scheduled to be completed in 2021.

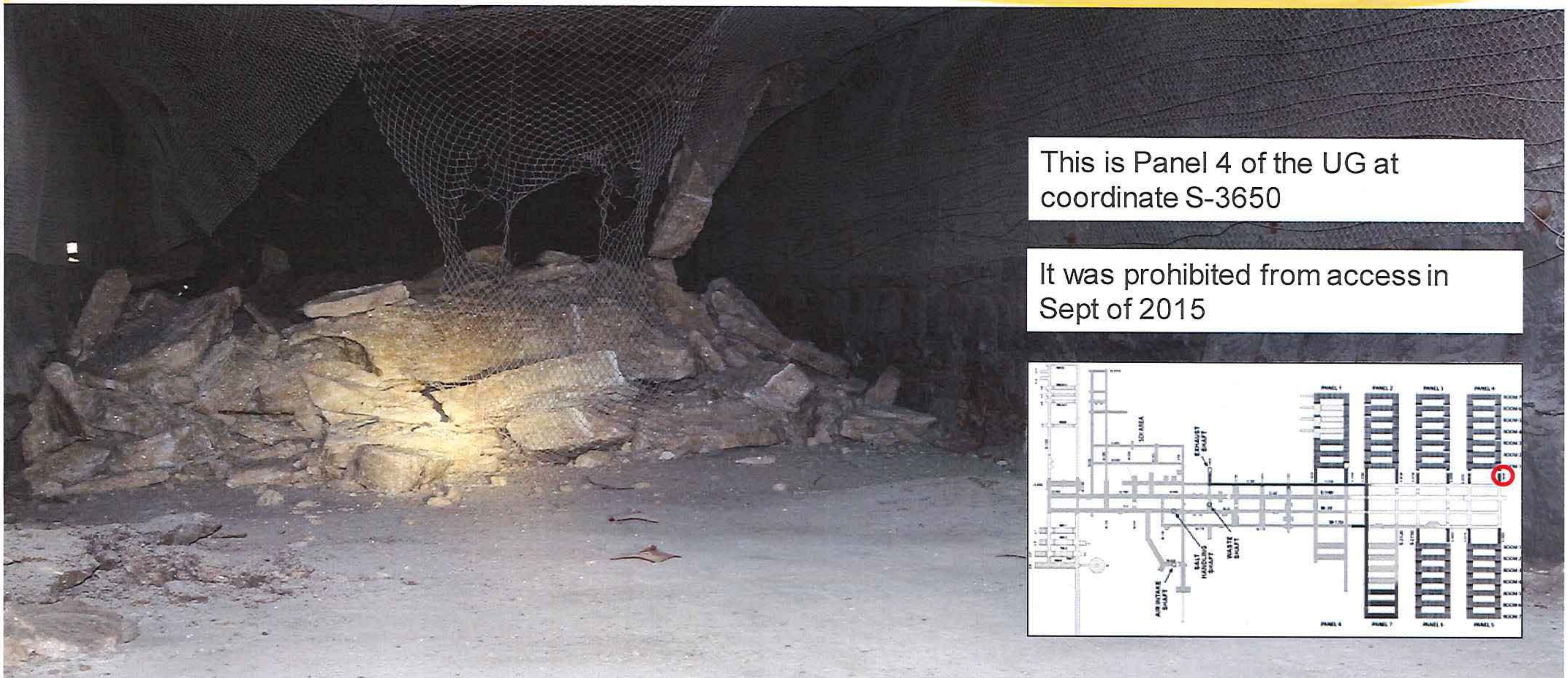


More bolting challenges

- The two events of 2014, the truck fire and the contamination release, caused a disruption in normal ground control activities. For nearly 9 months, WIPP was not able to perform sufficient ground control due to the investigation related to the contamination event.
- Ground control finally resumed, but at a much slower pace. The lower air flowrates rarely allowed more than one bolter to operate at a time until the Interim Ventilation system was installed.
- Many of the areas were now contaminated. The bolting crews had to be trained as Radworkers.
- The crews had to perform their work PPE reducing visibility, manual dexterity and increased heat stress.
- The bolts continued to break and WIPP lost an estimated 1500 to 3000 bolts.
- As a result, portions of the WIPP mine, slated for ground control prior to the events deteriorated and became unsafe resulting in access being prohibited.
- On Sept 27th, 2016, one of those areas experienced a roof fall. Two other falls occurred in the following months.
- In the summer of 2016, a decision was made to withdraw from the far south end of the underground.



Panel 4 Entrance Roof Fall



This is Panel 4 of the UG at coordinate S-3650

It was prohibited from access in Sept of 2015

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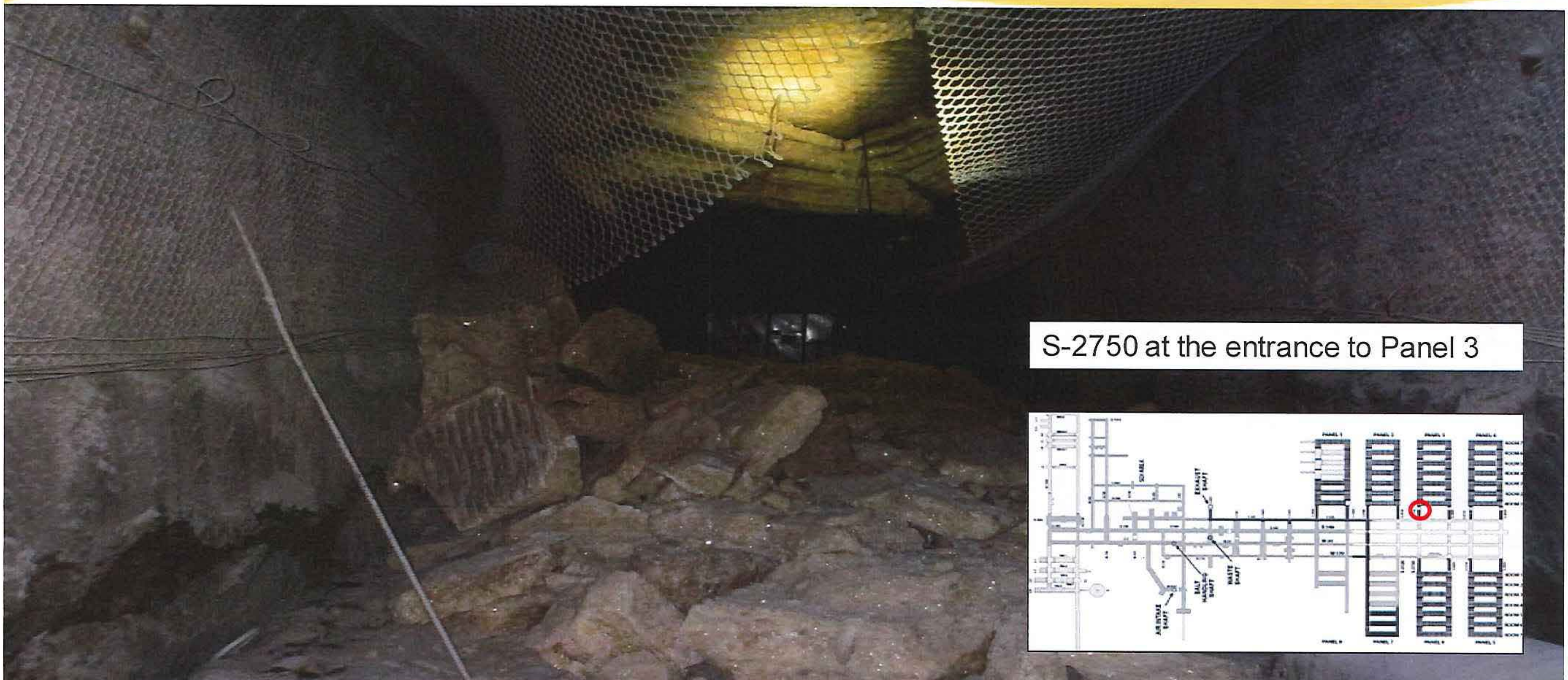
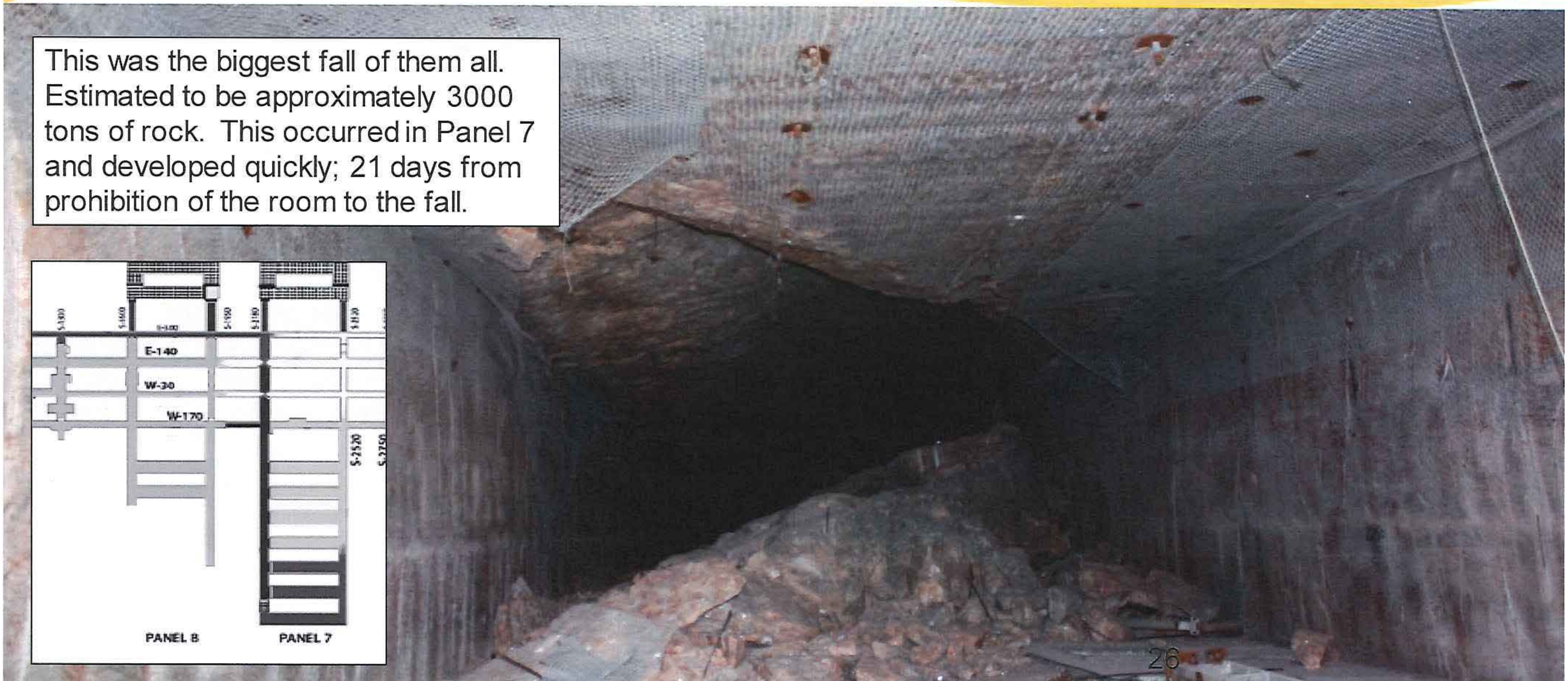
Panel 3 Entrance Roof Fall



S-2750 at the entrance to Panel 3

Panel 7 Room 4

This was the biggest fall of them all. Estimated to be approximately 3000 tons of rock. This occurred in Panel 7 and developed quickly; 21 days from prohibition of the room to the fall.



Lessons Learned - Roof Falls

Unstable ground conditions are the biggest hazard to workers in the WIPP underground.

- The salt never stops moving and requires constant monitoring and upkeep.
- WIPP did not do any ground control (bolting, scaling, installing mesh, etc) for 3 months following the accidents of 2014.
- Bolting started 9 months following the accidents and then at a much reduced pace.
- Prior to 2014, WIPP did not have any unplanned roof falls. There have been 5 since.
- Ultimately, roof falls occur because of a lack of resources necessary to prevent them.
- WIPP withdrew from the south end of the mine due to the lack of air necessary to operate enough bolters to replace the bolts lost from 9 months of inactivity.
- Had WIPP been able to start bolting again with only the 3 month delay, it is still questionable that the south end could have been salvaged.
- In trying to balance the need to support waste emplacement, new mining, and ground control, available resources are split. The lessons from the last four years is that additional resources must be applied to ground control.
- WIPP has since recovered and is approaching the point where it is caught up with all areas of the mine and will be in the maintenance mode of ground control.

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Other ground control activities

WIPP performs a variety of other ground control activities including

- Scaling
- Installing chain link mesh
- Installing crib sets
- Barring down ground
- Removing broken bolts
- Replacing plates
- Lanyarding plates
- Mining

Crib sets

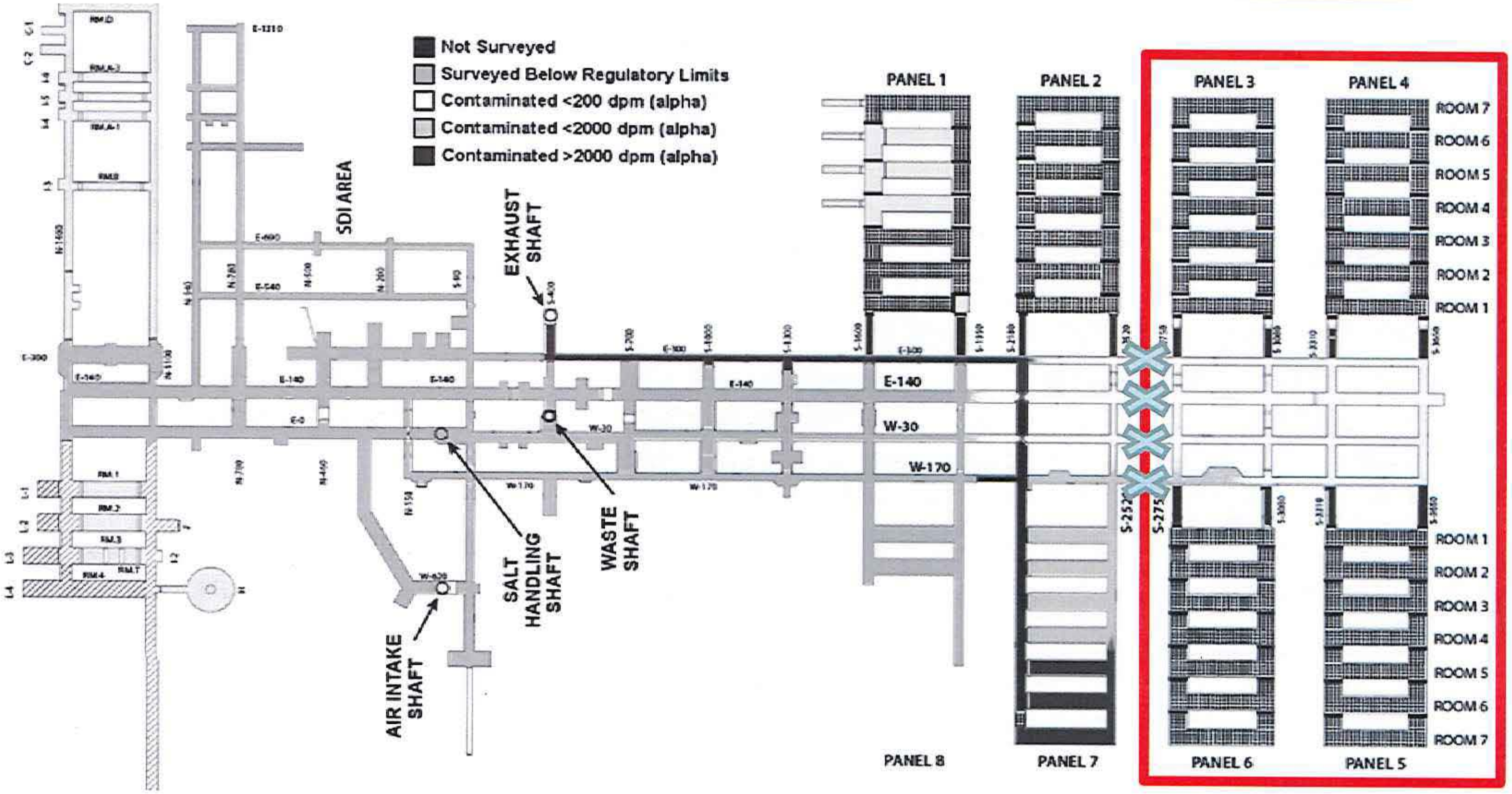
In mines, cribbing was traditionally accomplished with large timbers which would brace the back from falling into the mine opening.

Modern cribs sets are more like Lincoln logs and are much easier to handle and install.

At WIPP, crib sets provide a barrier against propagation of roof falls into areas which will remain occupied.

WIPP installed crib sets in all 4 of its main drifts as a part of withdrawal from the south end of the mine.

South End Withdrawal



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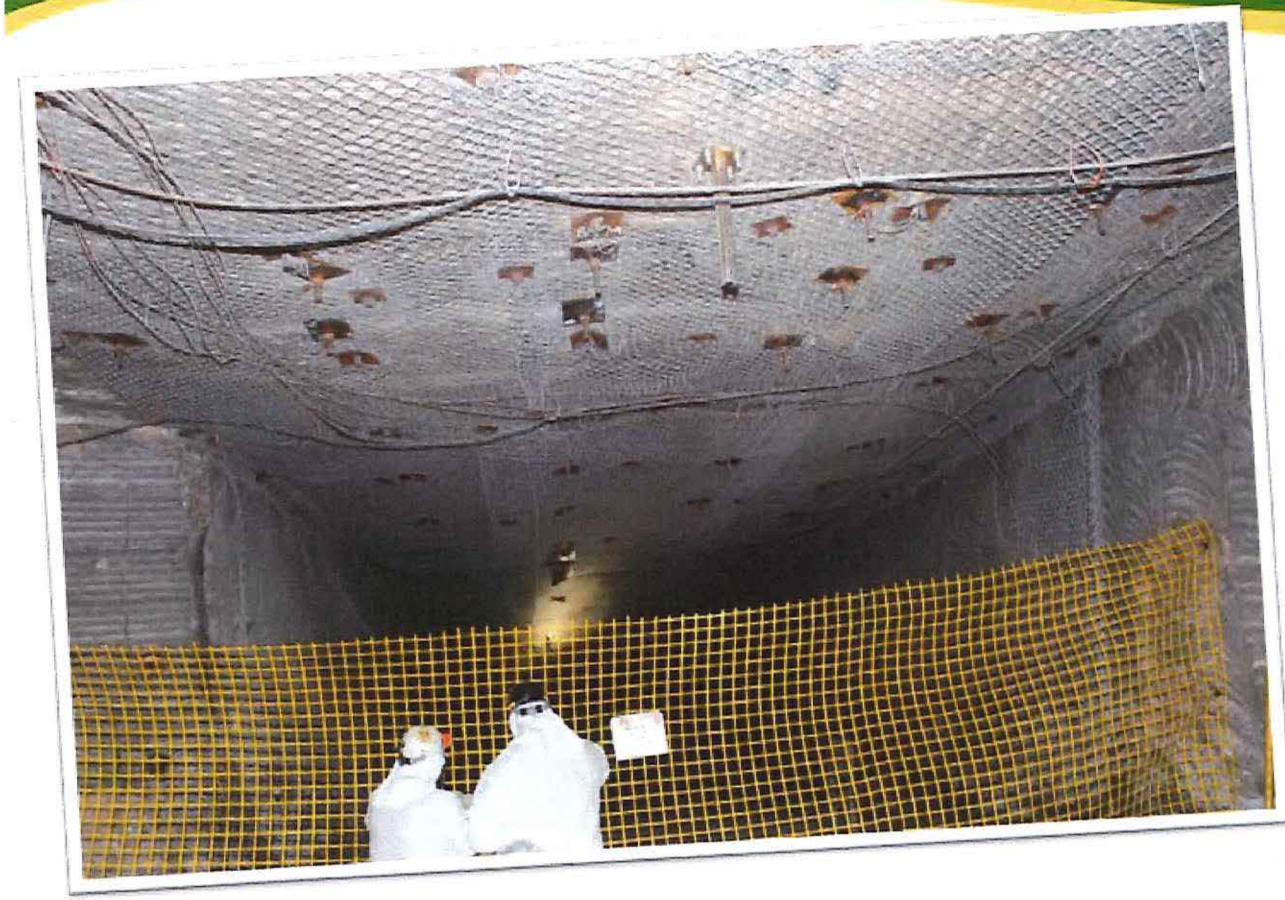
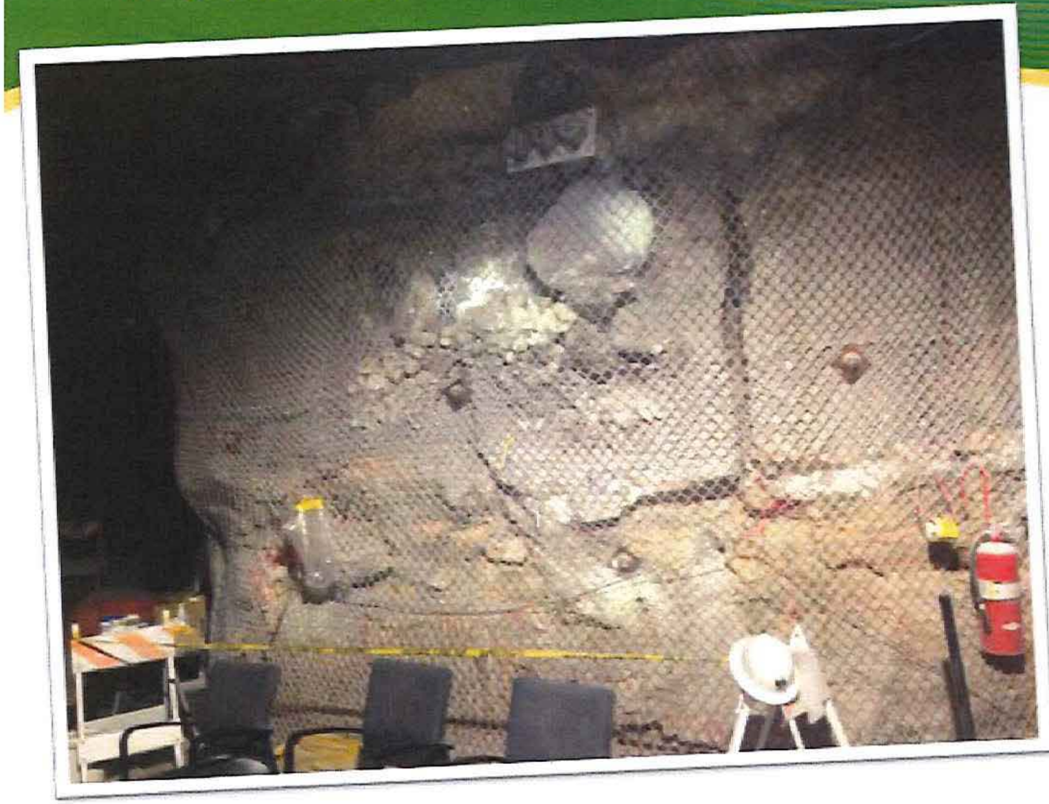
Chain link mesh



Very heavy duty chain link mesh (typically 8 gauge) is installed on the back and the ribs to capture any loose unconsolidated rock that might fall due to fracturing

The mesh used at WIPP, is capable of holding 7700 lbs. per mesh panel (10 ft X 7 ft). That is approximately 110 lbs/square ft.

Chain link mesh



Since rock salt weighs 135 lbs./cubic ft, it does not take a catastrophic roof fall to cause harm to workers in the WIPP underground.

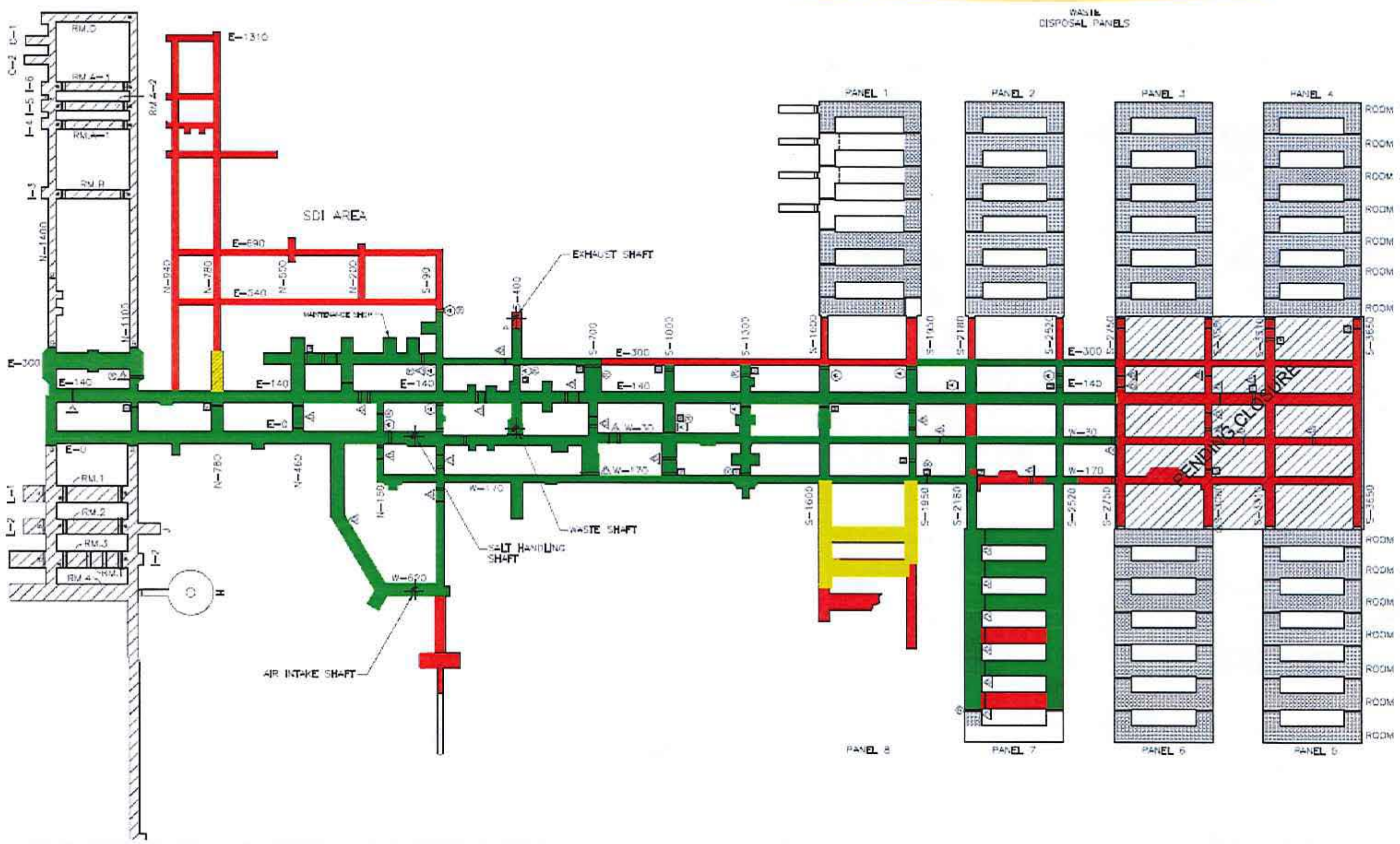
Chain link on the ribs and back captures loose rock and prevents it from falling on workers

Ground Conditions Today

Restricted access

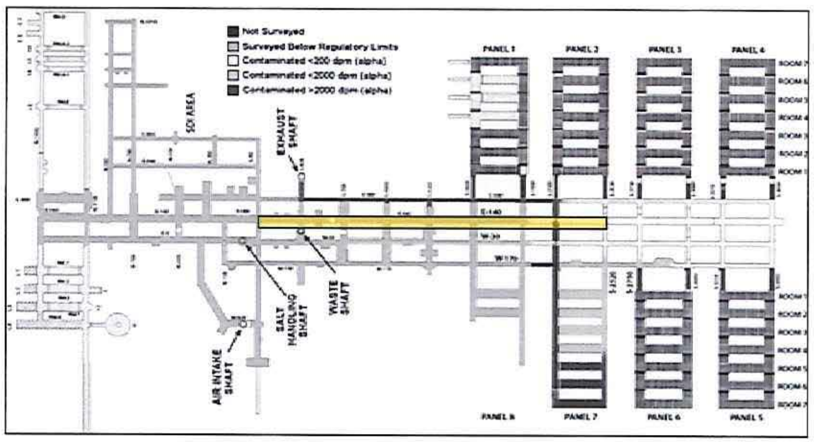
Unrestricted access

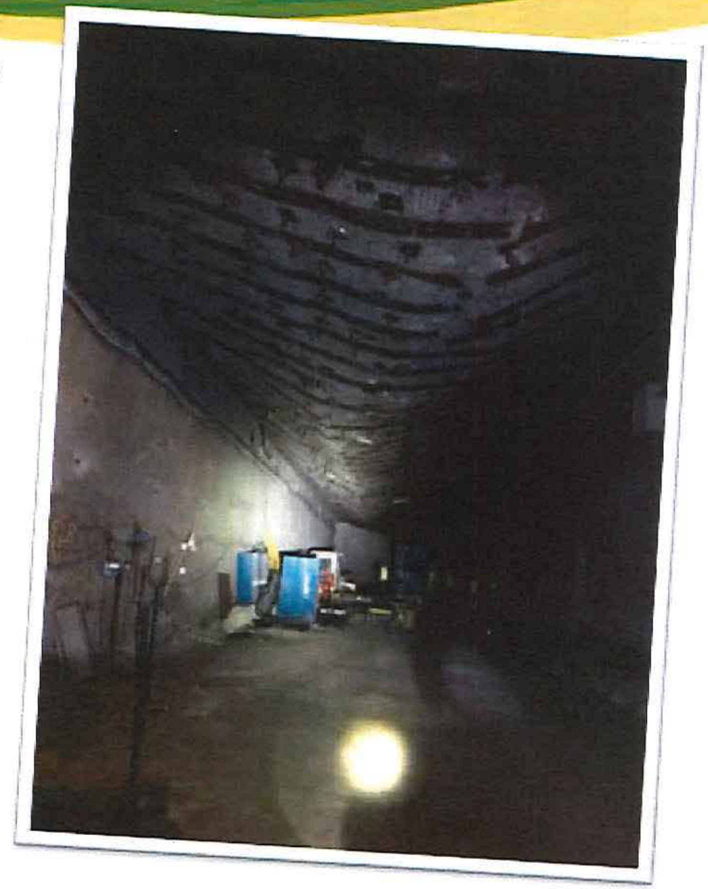
Prohibited access



Future Challenges: E-140

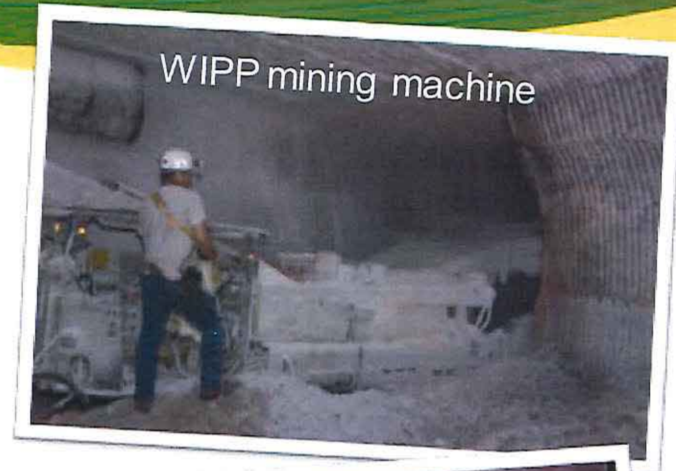
- Multiple reports from independent experts indicate current life expectancy of the current bolt pattern in E-140 to be 3-5 years.
- Due to numerous previous bolt patterns, anchorage zone may be compromised.
- Options for installation of a new generation of ground support all present a time of installation of 2+ years and present the potential for significant operational disruption.
- Abandonment is a possibility with the waste emplacement travel path shifting to W-30.
- The estimated cost of addressing E-140 is $2 to 3 million (rom) with existing methods. Including costs to shift the travel path to W-30 would add an additional $6 million (rom)

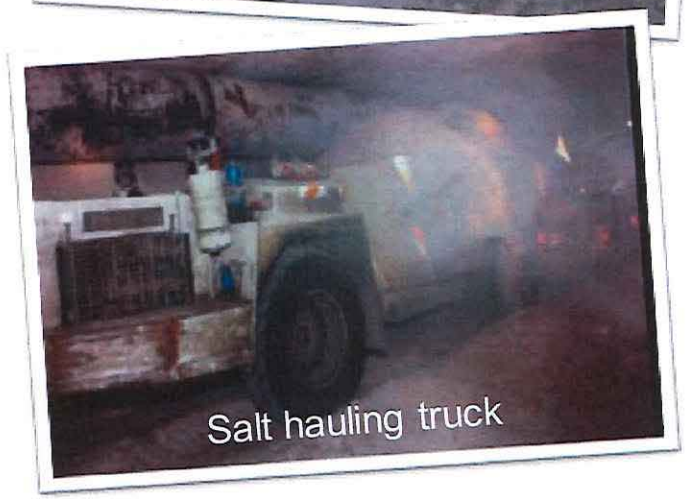




Future Challenges: Panel 8 Mining

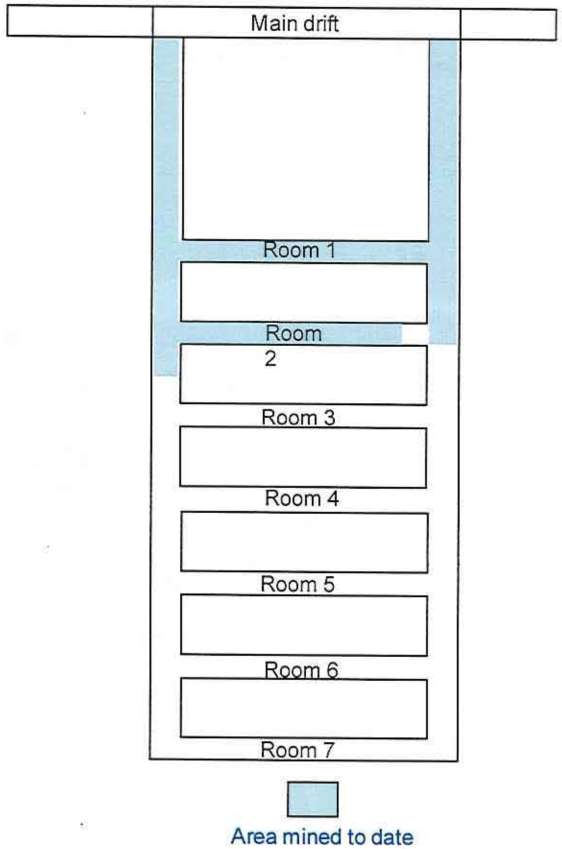
- Mining resumed in Panel 8 in January 2018.
- Due to age of opening, previous back has to be brought down and floor raised.
- Mining has been slower than anticipated.
- 50,000 tons were planned to be mined in FY2018 but forecast is for 35,000-40,000 tons.
- A current choke point is available airflow for salt hauling trucks.
- A recovery plan is being developed.
- Panel 8 is estimated expected to be ready for waste emplacement in 2021.
- The estimated cost of mining and outfitting Panel 8 is $8 to 9 million dollars (rom)


WIPP mining machine


Salt hauling truck

Future Challenges: Panel 8 Mining

- Panel 8 will require nearly 113,000 tons of rock salt to be mined and hauled out of the panel.
- There is little room to store mined salt (called muck) in the underground. Most of the salt must be removed from the mine via the Salt Shaft.
- The mining machines are electric but airflow is required to ventilate the diesel powered salt haul trucks which will carry away the muck.
- WIPP currently only has enough airflow in the Underground to support 2 haul trucks.
- The lower airflow rates have led to buildup of diesel emissions such that area monitors have alarmed requiring work stoppages to allow the air to be cleared by ventilation.
- WIPP has only 1 operational mining machine. Preventative Maintenance or equipment problems causes mining to stop.
- WIPP is working to recover a second machine from another area of the mine potentially purchasing a third refurbished unit from one of the local potash mines.
- Even with more airflow and the ability to run more haul trucks, the salt hoist will eventually limit the amount of salt that can be removed as its salt skip is of finite size and the hoist has speed limitations when hauling.



OFFICE OF ENVIRONMENTAL MANAGEMENT

Future Challenges: New Panels

- Approximately 93,000 cubic meters of waste emplaced at WIPP against a statutory limit of 176,000 cubic meters.
- Once Panels 1-8 are closed, WIPP is projected to have between 115,000 and 120,000 cubic meters of waste emplaced.
- Additional panels will be needed.
  - New designs are being evaluated.
  - Remote handled and contact handled operations may be separated.
- New drifts and panels will take up at least a decade to develop
- Volume of Record changes may require up to 30% additional disposal footprint.
- The estimated cost for new panels is $25 to $30 million