Appendix F.
Cost Guidance Assumptions

BUREAU OF BUSINESS & ECONOMIC RESEARCH

The following assumptions guided our impact analysis. They were verified by experts versed in the technical aspects of uranium mine remediation.

Section I: Characteristics and Challenges

The project presented several challenges:

Information

- Data was inconsistent and difficult to locate, despite contacts at agencies and companies who have done this work.
- Many documents don't exist online, or possibly at all, because of the age and number of mining records.
- Information about methods in mining and ore production is impossible to find for many defense-related operations
- The most comprehensive and easily accessible collection of information is McLemore's database
- The distribution of authority and responsibility creates a loss of information due to lack of interagency communication. Agency authority has also changed over time, as have regulations governing the access to information and requirements of each agency to get public feedback.
- There are hundreds to thousands of sites – including some anomalies – this presents a huge task for any agency responsible for locating, monitoring, or investigating sites.
- Because information was unclear or nonexistent, it's difficult to come up with an exact number of mines that have been cleaned up, or how many are left.

Site Characteristics

- Geological similarities aside, geographical and hydrological differences can cause major fluctuations in cost.
- Sites that were left prior to the new regulations could be partially cleaned up or not at all, and this changes costs.
- Additional actions performed on these sites can significantly increase the levels and area of contamination.
    - Processed ore storage from a nearby mill
    - Ore left with the usual protore/waste
    - Exploratory drilling
    - Changes in mining methods over time
    - Erosion and other extreme weather events
- Different mining methods change the amount of work needed for clean up

Organization of the information included in the investigative or cost documents was necessary to understand the variables. First, we outlined terms that we would use in our own documentation:

- Site: refers to a geographic area delineated by operational, ownership, or lease history.
- Project: refers to the entirety of the work to be done to a specific area – this can be one mine or multiple, depending on how they are related and costs are estimated. For some larger projects this

is important as there are multiple mines spread out geographically, and therefore the work is divided differently.

- Project Type refers to the mining methods used, which changes the nature of the work.
- Option refers to what is often called an alternative in the EE/CAs. An option is the type of remediation work that will be done. There are usually three – an administrative control alternative, onsite disposal, and offsite disposal. These are important to separate because they change cost significantly.
- Job refers to a type of work being done, which can include labor, materials, and equipment. This could be "road improvement."
- Action refers to the specific action being done within a job – "scrape road"
- Input is the thing being used to complete the action – this can be labor, equipment, materials, or travel.
- Type refers to the type of input – to scrape the road we need equipment, and the type would be a scraper.

By splitting into these categories we could seek out similarities in what was needed for every type of work. Additionally, we defined what are universal costs – things that are always included (but not a fixed price). Then to be more specific, we broke down the work needed for each type of mine. Most of the mines in New Mexico are surface mines, followed by underground, then combination (surface & underground), and rarely, in-situ leach operations.

Universal Costs/Needs

1. RSE/POLREP (Site Investigation)
    a. Each site requires an initial site investigation, usually determined by regulatory agency. This is not always present in cost documentation; the company performing work will do the investigation as part of the EE/CA preparation.
2. Mobilization/Demobilization
    a. 10% of total capital costs
    b. Cost usually associated with the transport of heavy equipment
3. Access Improvement
    a. Establishment or improvement of roads for easy access.
4. Resource Surveys
    a. Cultural and/or archaeological surveys are necessary before work begins
5. Fencing
6. Project Management
    a. Project managers, lead engineers, site supervisors, etc.
7. Administrative and Planning Costs

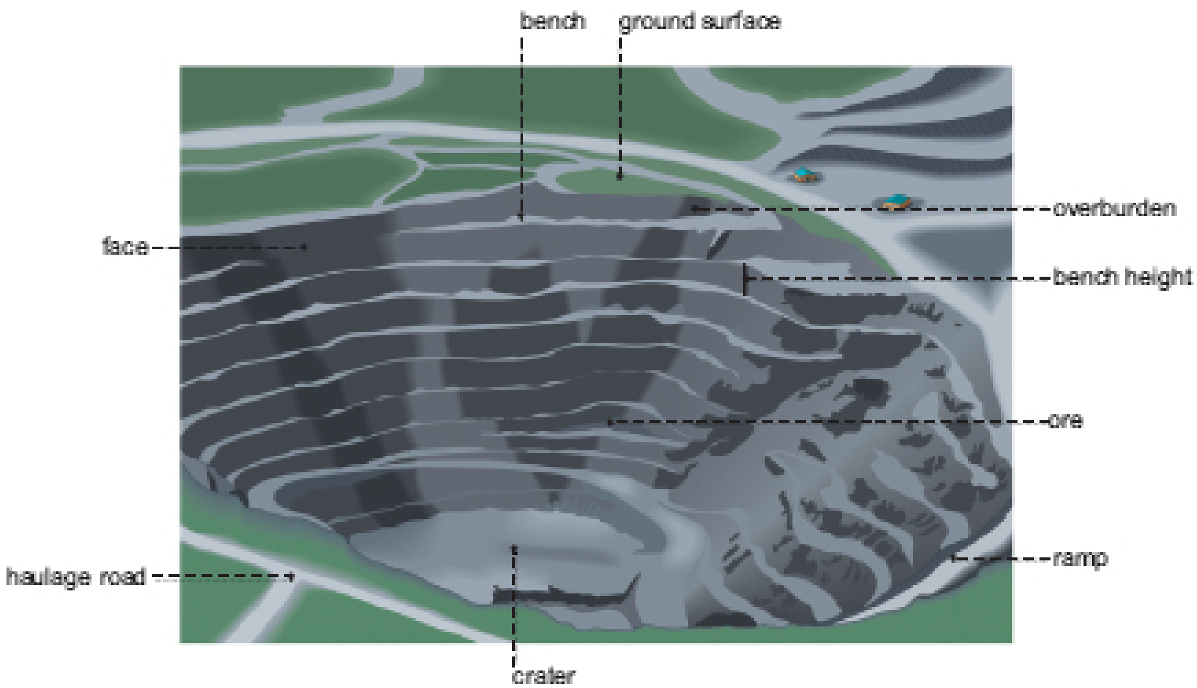
    a. Administrative/Office employee work, report preparation, lab analysis

8. Future Costs

    a. Annual site inspections, monitoring, fence or other feature maintenance

Specific Costs: Surface Mines

Most surface mines are open pit mines, characterized by their large footprint and amount of waste. The open pit mines use conventional techniques and equipment during mining. The style is used for ore bodies closer to the surface and higher grade. The features include the pit itself, overburden and other waste, storage areas for ore, and water/erosion control measures. There may also be additional monitoring equipment used during mining.



Source: QA International, "The Visual Dictionary"

1. Onsite Disposal Option

    a. Waste consolidation & transport to repository

    b. Repository excavation/establishment

    c. Borrow area excavation

    d. Removal area cover/cap

    e. Repository cover/cap

    f. Surface water diversion features

    g. Confirmation sampling and reporting

h. Site restoration (revegetation, fixing disturbances caused by work)

2. Offsite Disposal Option

a. Waste consolidation and loading

b. Removal area cover/cap

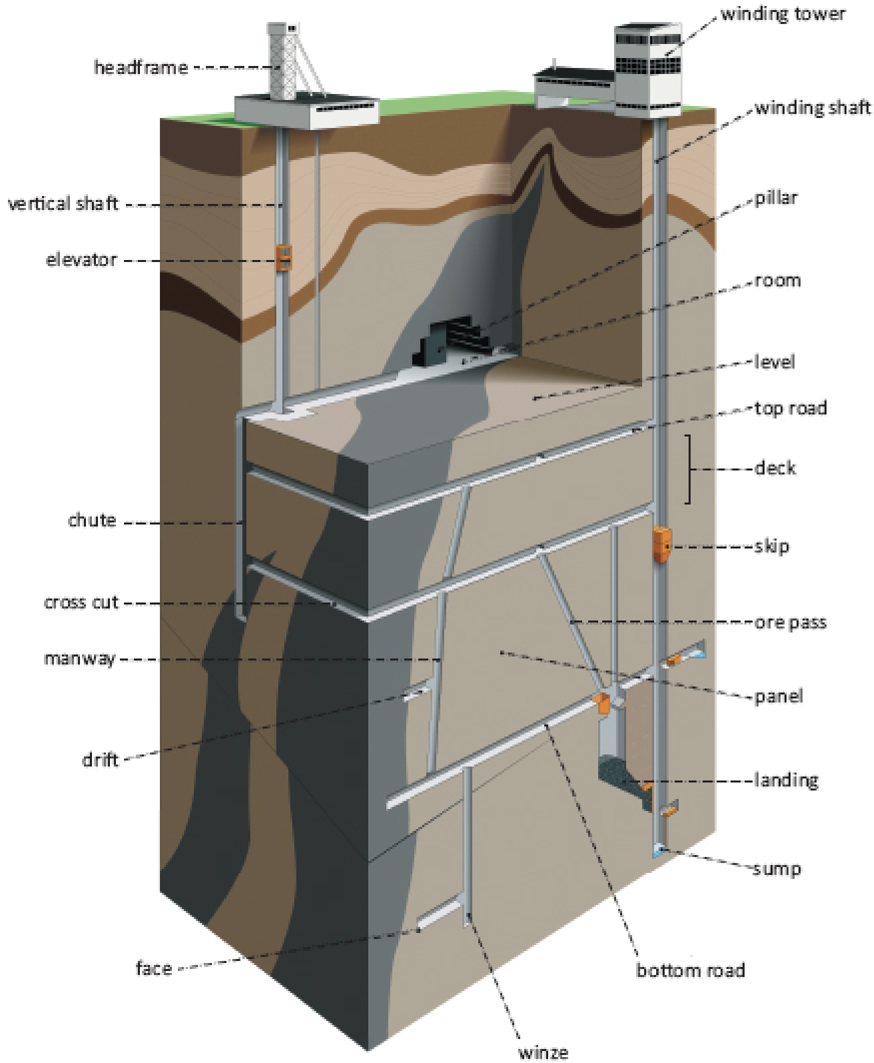
c. Confirmation sampling and reporting

d. Transport and disposal

e. Site restoration

Specific Costs: Underground Mines

Underground mines are used where orebodies are not close enough for open cut/pit mining. Risks are highest in underground mines due to radon gas – ventilation is key. This means that these mines will have at least two openings, one for access and one for ventilation. These can be shafts (vertical) or adits (horizontal), or a combination. The extent of underground development is the biggest cost consideration in closure, especially if no remediation or reclamation has been done previously.



Underground Mine with vertical shaft. Source: QA International "The Visual Dictionary"

1. Onsite Disposal Option
   a. Main shaft/adit closure
   b. Excavate spoils and/or waste
   c. Establish borrow
   d. Establish repository
   e. Fill shafts/adits with borrow
   f. Dispose of wastes in repository
   g. Polyurethane foam

h. Contour, cover/cap

i. Erosion control

j. Site restoration

2. Offsite Disposal Option

a. Main shaft/adit Closures

b. Excavate spoils and/or waste and load

c. Establish borrow

d. Fill shafts/adits with borrow

e. Polyurethane foam

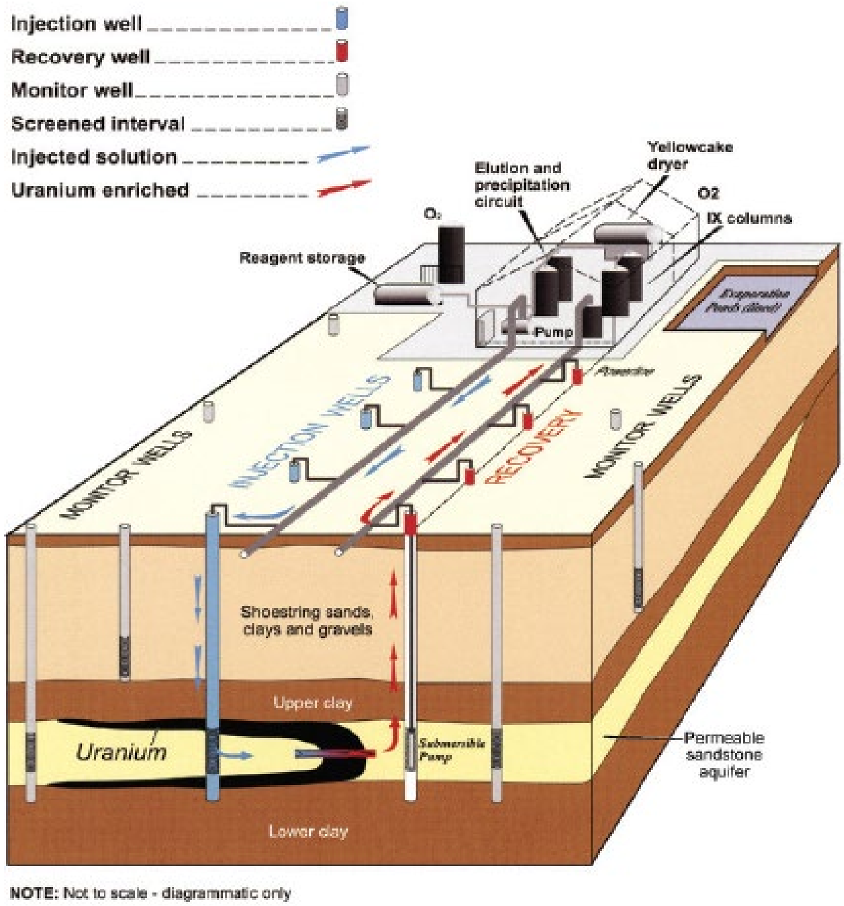
f. Erosion control

g. Transportation & Disposal

h. Site restoration

Specific Costs: In-Situ Leach Operations

In-Situ Leach (ISL)/In-Situ Recovery (ISR) mines are unique in their use of ground water resources to extract low-grade uranium. In New Mexico, there are few of these types of mines. Those that exist are small in scale and usually pilot mines or a few "stope leaching" operations. ISL/ISR mines require the most future monitoring and groundwater treatment.



In-Situ Leach Operation. Source: Heathgate Resources Pty

1. Decommissioning ISL/ISR Facilities

    a. Dismantle and decontaminate recovery plany

    b. Transport and dispose of materials and equipment at designated site

    c. Remove contaminated ground and restore

    d. Clean groundwater in leached zone

    e. Remove well-field equipment

    f. Shred and dispose of piping

    g. Plug holes, fill, resurface

    h. Remove pond residues and dispose at designated site

    i. Fill, contour, and resurface pounds

    j. Extended monitoring of groundwater.

Section II: Methods and References Used in Cost Estimation

Standardized Reclamation Cost Estimator (2006, Updated 2017)

The Standardized Reclamation Cost Estimator (SRCE) model was developed for the state of Nevada by SRK consulting. The project was a joint effort between the Nevada Division of Environmental Protection Bureau of Mining Regulation and Reclamation (NDEP), the Bureau of Land Management (BLM), the Nevada Mining Association (NvMA).

- The SRCE model is an interactive estimator that has the potential to benefit regulatory agencies and bidders working on uranium mine reclamation in New Mexico.
- While the model was used most for coal mine reclamation, its reliance on volumetric data, Caterpillar (CAT) productivity calculations, and CAD and GIS data has proven the model's accuracy for various situations.
- For more complex situations, or itemized cost data, the SRCE model may be manipulated to reflect costs specific to uranium mines and New Mexico.
- For bidding companies or engineers producing bids and cost estimates in general, the SRCE calculator can provide a standardized approach, resulting in an accurately detailed final document. In general, this would help reduce major changes to costs while the work is being performed.
- This model helped us develop our own methods to create a universal format for the different types of cost data.

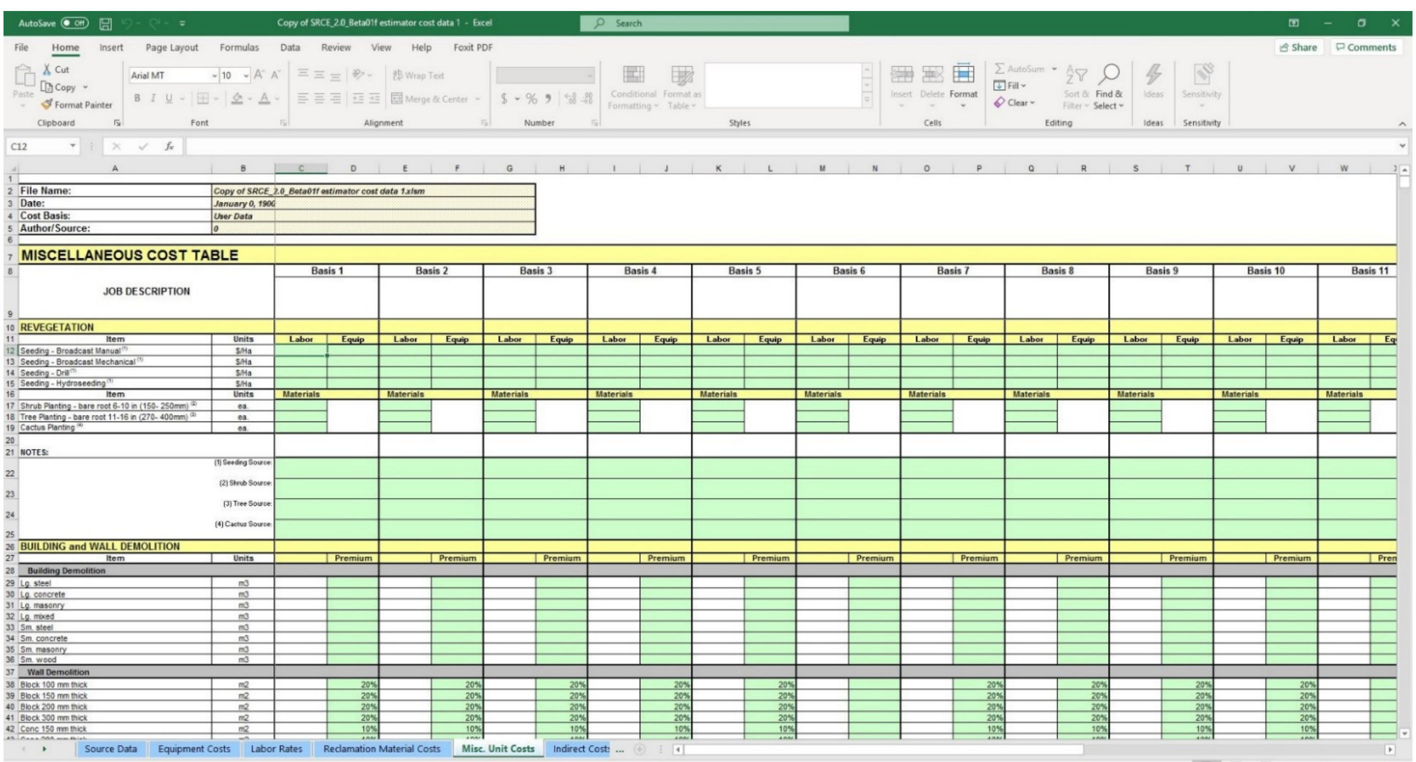


Figure 1. Detail View of SRCE model, blank. Beta 2.0 from NDEP bond site. https://nvbond.org/

"Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico" – Energy, Minerals & Natural Resources Department (EMNRD) Mining & Minerals Division (MMD) & New Mexico Environment Department (NMED) (2016)

The joint guidance document offers information about clean-up requirements by regulatory agency, recommended methodology, and implementation guidance.

- Regulatory authorities and requirements change depending on site location and status. Methodology and implementation, however, are generally the same across sites.
- An outlined, acceptable reclamation methodology provides important guidance for bidders, as well as informs the public about the basic processes that go into reclamation. This type of methodology can be used to help calculate costs as well as timelines.
- We used the outlined reclamation guidance to better understand the process, and outline specific actions and their personnel, material, and equipment needs.

"Financial Assurance Calculation Handbook" – US Department of the Interior, Office of Surface Mining Reclamation and Enforcement (1987)

The handbook was made to provide methodology for MMD employees to calculate reclamation bonds. Although it's older, the methodology itself is still relevant.

- The handbook uses standardized methodology for estimating costs of earthwork and revegetation for site-specific operations. Earthmoving activities represent the greatest costs in most mining reclamation projects.
- The handbook uses four sources of data for determining costs:
  - The mining reclamation/closeout plans provided by the applicant
  - The Caterpillar Performance Handbook
  - The Dataquest Cost Reference Guide for Construction Equipment
  - RS Means Building Construction Cost Data
- With new legislation, some mines do have closeout plans. However, this is not the case for the majority of the abandoned uranium mines in New Mexico.
- Two data sources remain relevant in estimating reclamation costs today: The Caterpillar Performance Handbook, and the RS Means Construction Cost Data. These two sources are used by bidders for reclamation projects and regulatory agencies alike and are constantly updated.
- Volumetric data to calculate the costs of earthmoving in reclamation can be taken from existing closeout plans or can be calculated during aerial or ground surveying. This data is the most important in determining the overall costs
- These methods use standard engineering cost estimating procedures and include worksheets that can be used to highlight the unique characteristics of different mine sites.

When speaking with project engineers, consulting companies, or agency employees about how to calculate a universal cost, they overwhelmingly agreed this was not possible. Though approaches to estimating costs are very similar, the work itself differs greatly. There are many factors that influence cost, and many characteristics that make each project unique. This presented a challenge, especially as uranium mine cleanup projects seem extremely technical and unpredictable. However, documents like this one provided an important framework for understanding the complexity of this type of work.

The smallest details can make major differences in the type of work done, and it's an engineer's job to know about these details. For us, on the other hand, the large details of these projects – and these projects in New Mexico – were the most important. Most abandoned uranium mines don't have EE/CAs, and not all have site investigations that provide feature or status information – examples of unique scenarios are few compared to a vast number of unreclaimed mines. To approach estimation from a large-scale, area-specific perspective, it is important to understand the mine-specific processes for estimation. Thanks to this document we could identify the "universal" factors influencing cost and apply this to our large-scale model.

The CAT (Caterpillar) Performance Handbook

The CAT handbook is used by agencies and companies alike to estimate costs related to equipment usage.

- Productivity is estimated in the handbook, based on ideal conditions. Productivity is then used to calculate the hours needed to complete the work required.
- Productivity estimates are used to determine periods of equipment usage and rental, as well as operator hours.
- The handbook is updated often so there are differences based on when an EE/CA was done, however, every document we encountered referenced the handbook as the tool used for estimating.
- The handbook is comprehensive and includes every type of heavy equipment used in uranium mine cleanup.
- We used the handbook as guidance to identify the similarities in equipment needs and hours with different sites to create geneon-ral assumptions about the equipment needed and associated hours.

RS Means Construction Cost Data

RS Means is a North American based construction cost data base created and monitored by cost engineers. It is an industry standard to use estimating software and/or cost books for construction related cost estimation. We used the data, provided by Gordian in a free trial, to check the accuracy of our data and the data of our other sources for cost.

Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) from Uranium Mining - - Volume I: Mining & Reclamation Background

TENORM Volume I examines uranium extraction methods over time. In addition, it examines volume and characteristics of uranium mine waste over time. We used this data to calculate ore to waste ratios that were used to check our other final numbers. These ratios will be key in estimating a universal, large-scale remediation estimate. With ratios like these, we're able to predict the potential for work that remediation of New Mexico's mines will create. With further research and testing, the ore to waste ratios, as well as our own earthwork ratios, can be used to produce a generalized cost per ton of waste, depending on mine type.

1. Reclamation and remediation costs at uranium mines could include costs associated with:
   a. Overburden and waste rock piles
   b. Heap-leach piles
   c. Ore storage and loading areas
   d. Underground mines
   e. Open-pit mines
   f. Buildings and infrastructure
   g. ISL/ISR infrastructure
   h. Contaminated soils and groundwater

2. Costs of environmental management following closure of a mine consist of reclamation and monitoring costs. Reclamation may include:
   a. Partial or complete backfilling of pits
   b. Stabilization of waste rock
   c. Appropriate contouring of disturbed land surfaces
   d. And revegetation
   e. Monitoring is generally a future cost most mines

3. Costs of reclamation vary significantly due to differences in ore conditions, mining methods, climate, remediation scope, and objectives. In instances where a facility has been reclaimed due to releases of hazardous substances under CERCLA, costs can be much larger.

4. The DOE conducted a summary of cleanup costs for 75 production facilities, including mining and milling sites. The costs of reclaiming and remediating the 21 mines that were part of this summary vary widely, by more than two orders of magnitude in terms of cost per ton of ore produced.
   a. The differences can be attributed to acreage of disturbance, but mostly due to the different methods of accounting for cleanup costs.
   b. Some mines performed reclamation during mining, charging the costs against operations. While others had to be separately charged under reclamation costs.
   c. The average cost of cleanup for these 21 mines were:
      i. $3.01/metric ton (MT) of ore mined
      ii. $2,545/kg of uranium produced
      iii. $29,969/hectare of land disturbed
   d. Excluding the most uniquely expensive mine, the Day-Loma mine, the averages drop to:

i. $2.77/MT of ore

ii. $2.34/kg of uranium produced

iii. $27,900/hectare of land disturbed.

5. Standard weight per volume figures used in mine waste calculations are 1.68 tons/y³

a. Large, open pit mines have ratios of waste rock to ore between 8 : 1 to 20 : 1

b. Underground mines range from 1 : 1 to 20 : 1

c. See table below for figures

Total and Average Production and Costs of Reclamation of All Uranium Mines
This table includes mines as well as mill sites.

Number of sites included	21
Metric tons of ore processed	96,900,000
Metric tons of uranium produced	114,803
Average cost of closure, $/MT ore	$3.01
— excluding Day-Loma	$2.77
Lowest cost of closure, $/MT ore	$0.24
Highest cost of closure, $/MT ore	$33.33
Average cost of closure, $/kg U	$2.54
—excluding Day-Loma	$2.34
Lowest cost of closure, $/lb U_3O_8	$0.18
Highest cost of closure, $/lb U_3O_8	$23.74
Average cost of closure, $/ha disturbance	$29,969
—excluding Day-Loma	$27,900
Lowest cost of closure, $/ha disturbance	$2,337
Highest cost of closure, $/ha disturbance	$269,531
Average Closure Cost per Site	**$13,900,000**

Source: U.S. DOE/EIA 2000b.

Utah Abandoned Mine Reclamation Program's "Boilerplate" Construction Contract Specifications

The state of Utah and the U.S. Bureau of Land Management teamed up to address abandoned mines in the state. As part of this the SRCE model was created by an outside firm, and the state of Utah created a construction bid "boilerplate" template. The document contains relevant regulations, types of work, necessary certifications, and is a detailed model for others to follow. It differs from New Mexico's own bid templates because it contains more regulatory information, as well as explains various different scenarios that can change the nature of the work. We used this information to check our own data.

Defense-Related Uranium Mines - Cost and Feasibility Topic Report & Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA

These two documents outline the processes necessary to estimate the costs and feasibility of mine remediation, as well as the regulations guiding them. We used both documents to check our assumptions and data. An example of cost guidance from the cost and feasibility report is included in Appendix C.

Site Investigation Reports, Engineer Evaluation/Cost Analysis, and other Site-Specific Documents and Databases

Our main source of cost data were the cost documents for 12 sites we evaluated. These documents primarily consist of formal EE/CAs, however, there are invoices, bids, and informal cost comparisons used for some sites. The site data we examined included:

1. Barbara J Mine Sites – Engineer's Cost Estimate
2. Cibola Uranium Mines – EE/CA
3. Johnny M Mine – EE/CA
4. King Edward Mines – EE/CA
5. Mt Taylor – Closure Cost Estimate
6. NE Church Rock Mine – EE/CA
7. Red Bluff Mine – EE/CA
8. San Mateo Mine – EE/CA
9. Santa Fe Carson Mines – EE/CA
10. Spencer Mine – Application for Payment
11. St Anthony Mine – Closure Cost Estimate
12. Workman Creek Mines – Invoice

In addition to these documents, which contain cost tables and waste volumetric data (most), we relied on databases with information about the features at different sites, ore production tables, site investigative reports, scholarly articles published about mines, and contacts at various companies and agencies.

Section III: Key Facts and Assumptions

General Facts & Assumptions

1. Assumption: Elevation variance is not significant enough to include in estimates
   a. According to geographic data, the Uranium ore deposits in Colorado, Utah, Arizona, and New Mexico are located on the Colorado Plateau.

i. Elevation ranges from 500 ft at the bottom of Grand Canyon to 13,000 ft at the tallest peaks. Average elevation is 5,000 ft.

ii. Average elevation of mines has been identified as 5,200 ft for the Colorado Plateau

2. Assumption: Host rock is the same/similar enough to not majorly effect remedial work (see figure A-10).

   a. Geology of the Colorado Plateau is characterized by superimposed layers of sedimentary rock, a result of the erosion of the large mountain ranges surrounding it. Lower layers can be metamorphic, and there are some igneous formations, but most uranium is found within the upper sedimentary layers. Mesozoic Era, primarily Cretaceous and Jurassic eras.

3. Mines in the same areas tend to be of the same type

   a. Mining booms and busts occurred at the same time, and many mine claims were established during the first boom. During this time period deposits were found by surface detection and subsequent exploratory drilling.

   b. Historically, costs of deep underground mining were prohibitive. Many of the oldest mines are large open pit mines. Some were later further developed underground or with in-situ leach facilities as technology changed.

   c. Mine age determines the development – many were first developed as open pits and in sedimentary rocks, the most historically productive areas were in New Mexico.

4. Assumption: The geographical province has relatively shared and predictable precipitation.

   a. Documents recommending mine development, or addressing remedial needs, all cite that the Colorado Plateau receives low precipitation, around 9”-16” annually. High elevation mountains have more precipitation, but generally, this holds true due to the bordering mountains creating a rain shadow.

5. Assumption: Ground water contamination is not a significant factor.

   a. The Colorado Plateau is a semi-arid region with low precipitation, and is characterized by seasonal surface water features.

   b. The Colorado Plateau aquifers have some extractable water, however, the quantity and quality is extremely variable.

   c. Permeable rock aquifers cover 27.5% of the U.S. Colorado River Basin states and 51.5% within the basin boundary. (Foos)

   d. Rural areas depended on seasonal surface water and some underground sources. These sources were presumed to be small because populations were small.

New Mexico Specific Facts & Assumptions

6. New Mexico deposits are primarily in the Grants Uranium District, which is comprised of the two most productive areas: Laguna and Ambrosia Lake. This area is bordered by the San Juan Basin, the Rio Grande trough, the Acoma sag, and Zuni uplift.

a. Between these border landmarks, elevation is fairly consistent accounting for normal faults and minor folds. Generally, the elevation is between 6,000 and 7,000 feet

b. Deposits are listed as existing within 1,000 – 4,000 feet from the surface, most around 1,500 – we will assume an average of 2,000 ft depth based on available data.

7. The Morrison Formation and Todilto Limestone have yielded almost all of the ore.

a. Sandstone & Limestone are the primary host rocks in New Mexico.

b. Limestone host rock is rare, but in the Grants district it accounted for a significant percentage of mines.

c. "Uranium ore deposits in the Grants uranium district are mainly in fluvial sandstones in the Westwater Canyon, Brushy Basin, and Jackpile Sandstone Members of the Upper Jurassic Morrison Formation."(Hilpert)

8. The Grants Uranium District accounts for the largest number of mines in the state of New Mexico

a. The district was also the most productive during the first boom – most deposits were relatively close to the surface and were mined by open pit mining.

b. Open pits in the district were further developed in underground, though this is only a small amount. These have a large footprint and produce a significant amount of waste.

c. Underground, usually room and pillar type mines, are the second most common. These have a smaller surface area footprint and generally produce less waste.

d. In-situ leach operations are rare because it's a fairly new technology and most mine development stopped before it could be used. The numbers for New Mexico are insignificant.

9. Like the rest of the Colorado Plateau, New Mexico has consistent and predictable annual precipitation.

a. 9 – 16" of annual precipitation, many areas around 11", with mountain ranges between 14 – 16".

10. For rural areas, where mining was concentrated, populations relied on a combination of seasonal surface water and deep groundwater.

a. Mines tend to reach below the water table (especially underground). The presence of drinking water quality aquifers is unpredictable, and many sources are naturally contaminated by metals and uranium.

b. Areas of drinking water contamination have largely been identified and remedied due to their effects on people in the area. Some unknown mines and conditions could be a source of contamination.

i. Any water contamination is subject to additional regulations and guidelines for remediation. The costs associated with this type of contamination are much different than with mines not involving drinking water.