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Environmental Impacts and Challenges Associated with of Uranium Exploration and Uranium Mill Tailings:

A Slide Presentation Supporting an Invited Statement
before
Quebec Uranium Inquiry Commission
Bureau D'Audiences Publique sur L'Environnment (BAPE)
Quebec City, Quebec, Canada
September 9-10, 2014

Includes:
Part 1 - Uranium Exploration – slides 2 – 16
Slides related to both topics – slides 17 – 21, 65
Part 2 – Uranium Mill Tailings - slides 17 – 64

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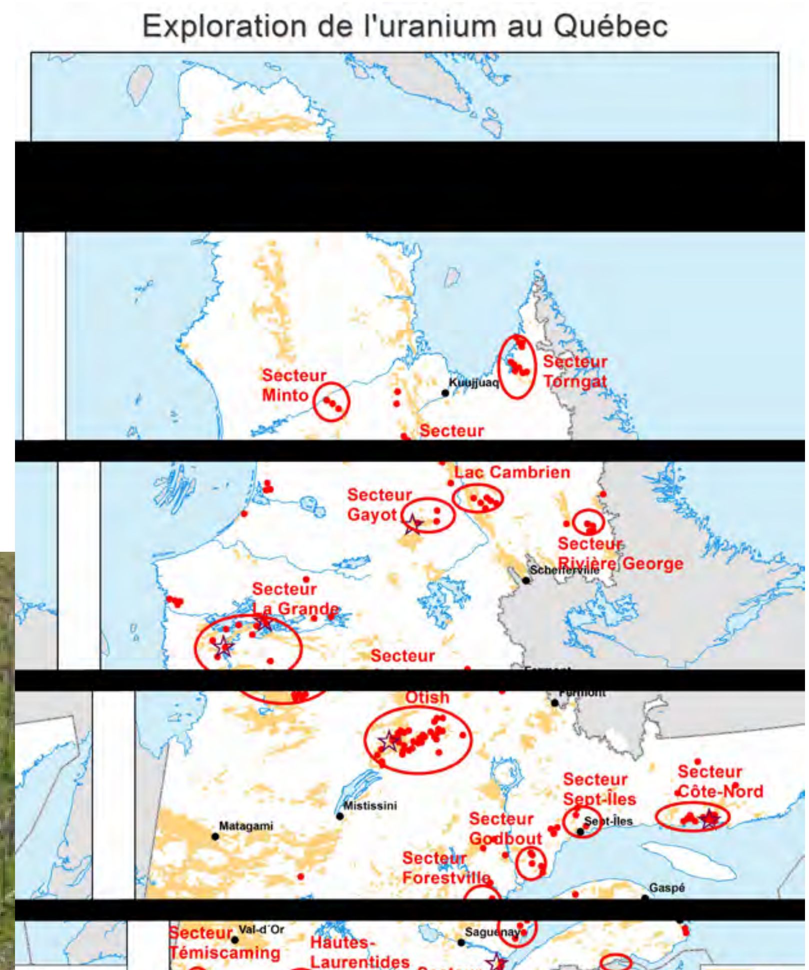
Part 1 – Uranium Exploration

Uranium prospecting brings significant changes to a region, even before drilling begins…
Disturbances such as noise, light, vibrations, smells, and people will change a pristine environment and affect flora and fauna and habitat and lifecycle activities for wildlife, and the availability and quality of subsistence food sources, often before area residents or leaders are informed about proposed activities or before community engagement begins.

http://www.azimut-exploration.com/en-prop-photos.html



http://www.mining.com/study-on-impacts-of-uranium-mining-may-extend-moratorium-indefinitely-report-87731-23280/

Exploration drilling usually follows aerial surveys
Field sampling and trenching. Depending on the site, company and existing requirements, drilling can be a four season operation and spawn mine Camps- mini-villages in areas previously isolated From the sights, sounds and debris of non-traditional societies.

http://magazine.cim.org/en/2014/March-April/special-report/Uranium-exploration-spikes-in-Saskatchewan.aspx

http://resourceclips.com/2014/03/02/athabasca-basin-and-beyond-38/

ww.abenresources.com/i/photos/Justin-Property--2012.jpg

Just looking at selected drilling scenes from company sources….

http://www.uraniumseek.com/news/PeterSpina/1190185231.php

http://www.lapresse.ca/le-soleil/affaires/les-regions/201006/17/01-4290775-uranium-sur-la-cote-nord-uracan-entreprend-sa-grande-seduction.php?utm_categorieinterne=trafficdrivers&utm_contenuinterne=cyberpresse_vous_suggere_4306969_article_POS1

http://www.lapresse.ca/le-soleil/actualites/environnement/201007/29/01-4302383-la-decontamination-des-sols-tarde-au-lac-kachiwiss.php?utm_categorieinterne=trafficdrivers&utm_contenuinterne=cyberpresse_vous_suggere_4304425_article_POS1

…. won't tell the whole story.

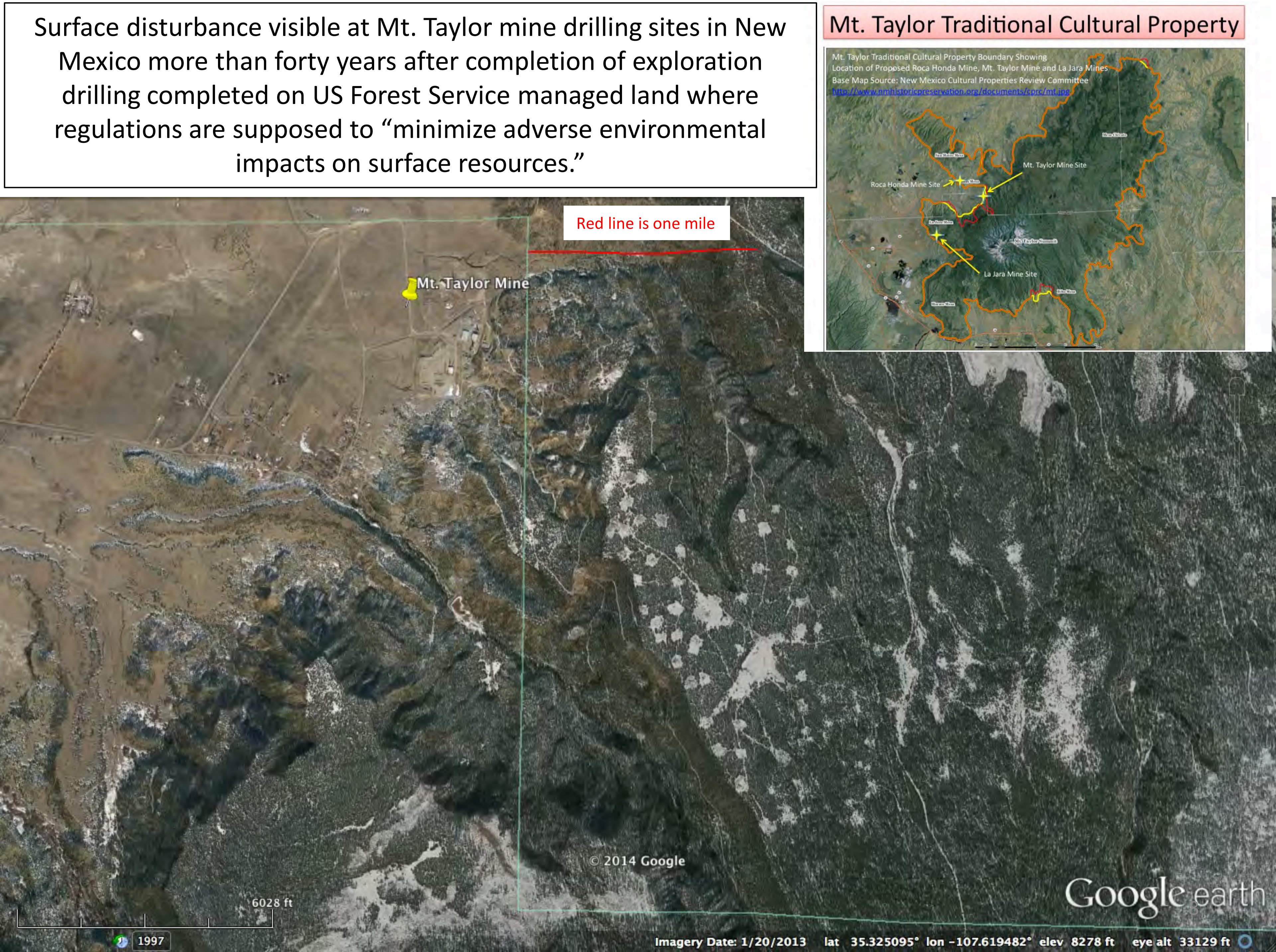
A detailed baseline database, frequent inspections – both-announced and unannounced by professional staff and native land user representatives, photo-documentation, sampling materials on site, reclamation plans with financial guarantee and electronic record keeping are all essential to effective enforcement of legal standards and seeing whether best practices are in use.

Uranium exploration in Quebec – citizen inspections illustrate the failure to use best practices by companies in operations and government in oversight and enforcement.

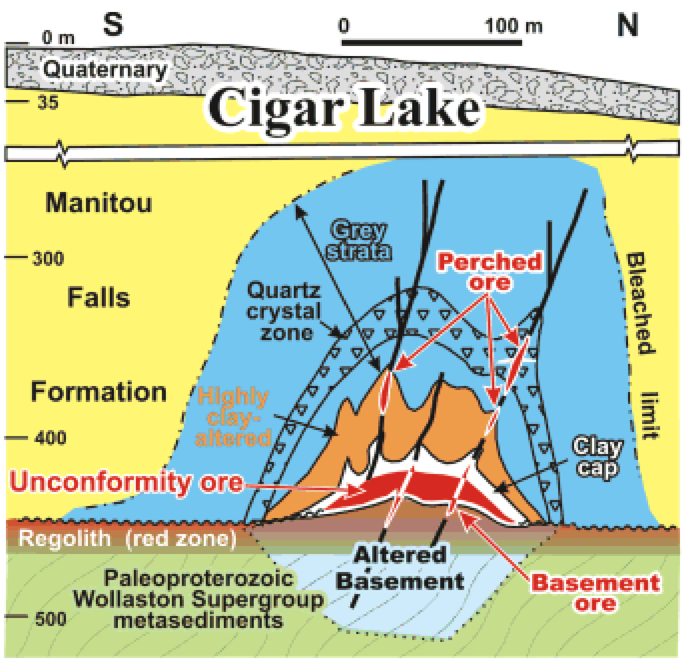
Uranium exploration in Quebec – citizen inspections illustrate the failure lack of best practices by companies in operations and government in oversight and enforcement.

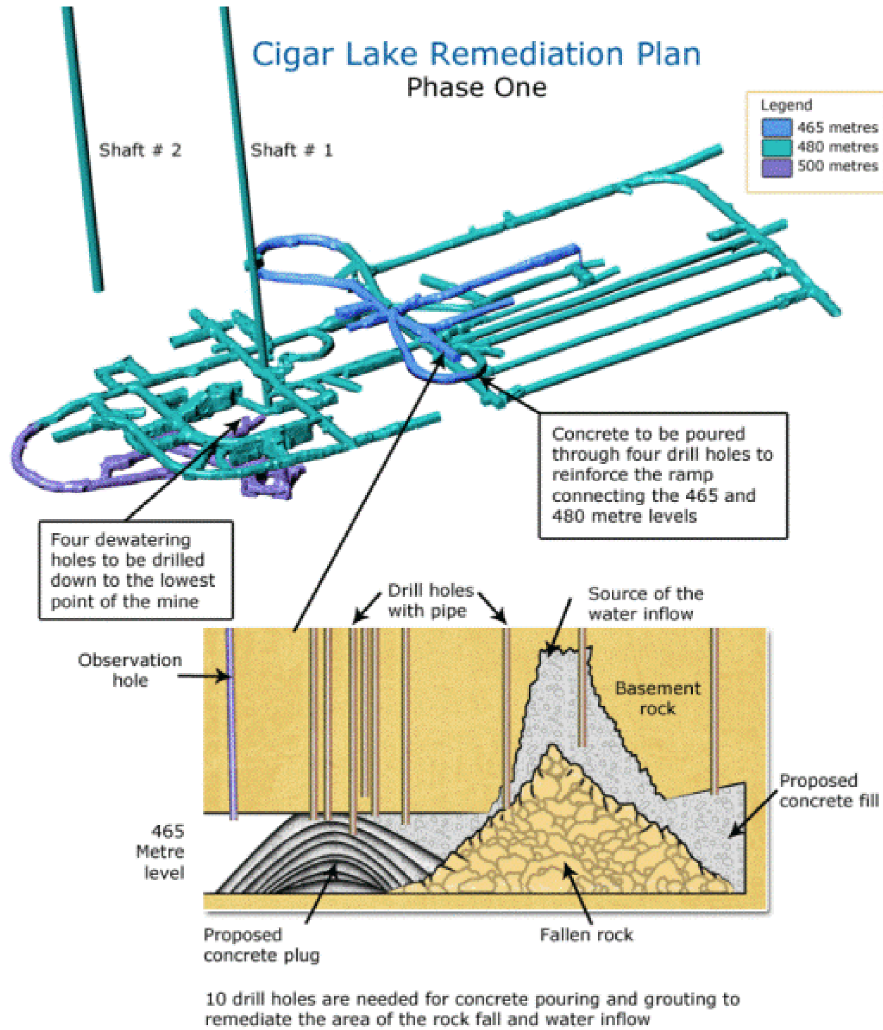
From: SISUR

Surface disturbance visible at Mt. Taylor mine drilling sites in New Mexico more than forty years after completion of exploration drilling completed on US Forest Service managed land where regulations are supposed to "minimize adverse environmental impacts on surface resources."



Cigar Lake - Modern Uranium Mine with a Major Problem –
Nine-year mine closure due to unforeseen and extensive mine flooding problem





July 16, 2014 - Canadian uranium miner Cameco Corp said on Wednesday that some ore from its Cigar Lake, Saskatchewan, mine would not be milled until early 2015, instead of before the end of 2014, due to problems with a mining process that involves freezing the ore and the ground around it.

As a result, Cameco said it will lower its 2014 uranium target for milling Cigar Lake ore, which is currently 2 million to 3 million pounds.

Cameco, the world's third-biggest uranium producer, first expected to open Cigar Lake in 2007, but two floods pushed the launch of the mine well behind schedule. The mine finally began production in March 2014.

"UPDATE 1-Uranium output at Cameco Cigar Lake mine delayed by freezing problem", - http://ca.reuters.com/article/companyNews/idCAL2N0PR11G20140716

October 23 2006 - Cameco Corp. said its Cigar Lake underground uranium project in northern Saskatchewan is expected to flood completely after a rockfall yesterday.

Cameco said the fall occurred Sunday afternoon in an underground area that had been dry and a "significant" amount of water started flowing in.

"Cameco's Cigar Lake mine inundated; stock falls" Last Updated: Monday, October 23, 2006 http://www.cbc.ca/money/story/2006/10/23/cameco.html

Nov 6, 2007 - Cameco doesn't have a "fixed" deadline for the overhaul of its flooded Cigar Lake mine, the uranium miner's chief operating officer said in documents made available on Tuesday.

At a hearing last week before the Canadian Nuclear Safety Commission (CNSC), which is considering extending Cameco's construction license to rehabilitate the mine, COO Tim Gitzel said Cameco, the world's largest uranium producer, would not take shortcuts in the overhaul process.

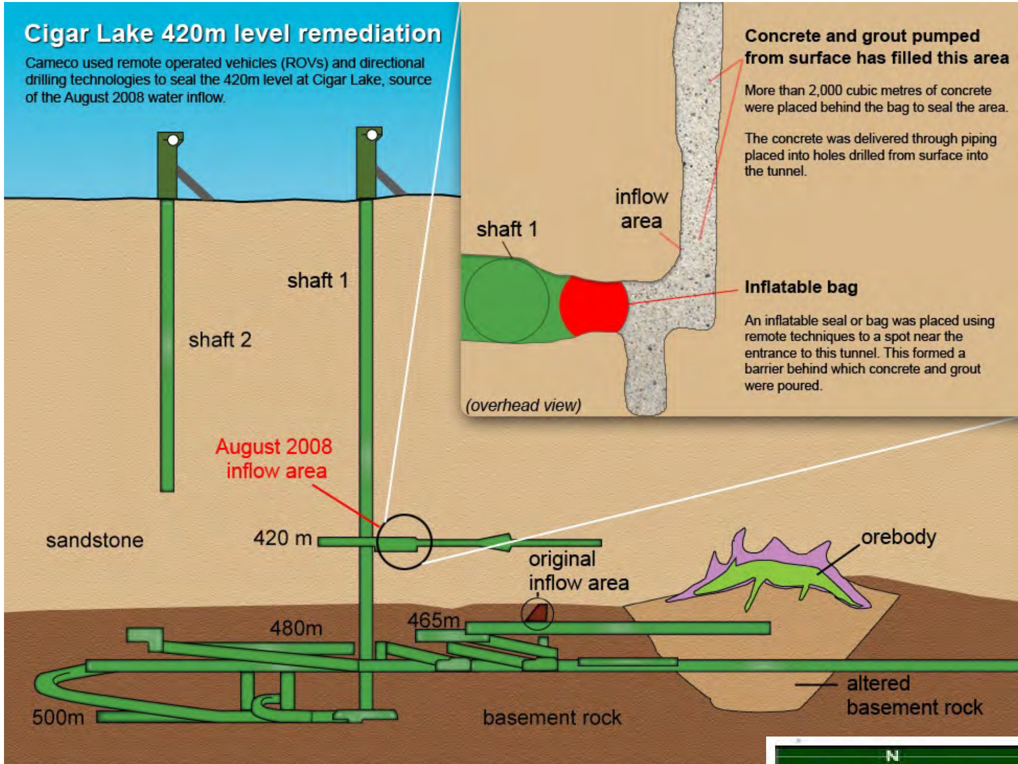
"No set deadline for Cigar Lake repairs-Cameco COO" | Reuters Wed Nov 7, 2007http://energynet.newsvine.com/_news/2007/11/07/1080920-no-set-deadline-for-cigar-lake-repairs-cameco-coo-reuters

Updated Preliminary Assessment of the Matoush Project Central Quebec, Canada for Strateco Resources by Scott Wilson Roscoe Postles Associates, April 2010
http://www.stratecoinc.com/data/pdf/Scoping%20Study/ScopingStudyPart1April122010_1-56.pdf

"The Matoush Project site is located at the top of a watershed, and the underground mine is entirely located within fairly permeable sandstone. Groundwater which will likely be the largest contributor to the mine effluent, and average yearly stream flows within a radius of a few kilometres around the site are likely to be less than the mine effluent average discharge rate. Considering the physical limitations of natural streams to take up additional flow without generating uncontrolled erosion and the potential sensitivity of aquatic species, it is unlikely that the mine effluent discharge point will be close to the mine site. There will likely be a trade-off between water treatment cost, water segregation cost, and distance of effluent relative to the mine facilities.

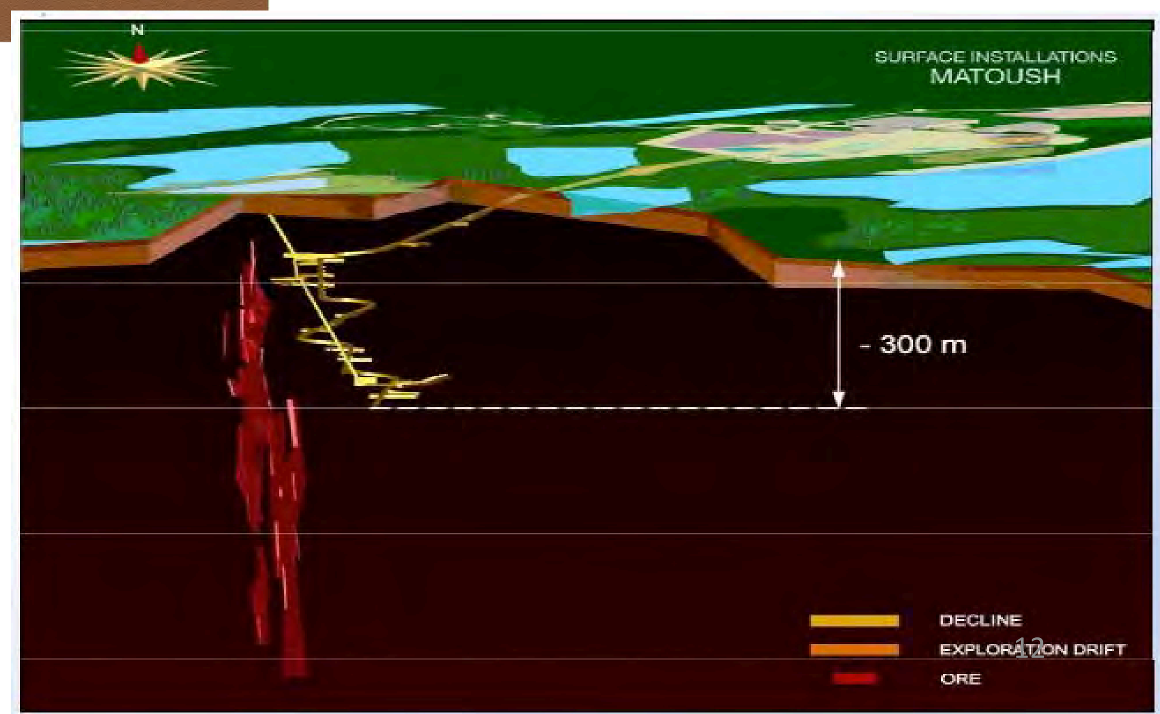
"Hydraulic conductivity of sandstone facies ACF4 (400 m thick), the basal conglomerate (28 m thick), the basement regolith (4 m thick) and the Archean granitic basement has not been assessed. Some of these geological features may provide conditions for permeable zones. Assessment of deep hydraulic conductivity and deep groundwater chemistry should be assessed in the future in order to evaluate potential mine water inflows and mine seepage water quality.

"Mine water seepage in deep uranium mines within or at the contact with sandstones is known to pose major challenges to mining operations in Saskatchewan. Detailed mine seepage estimations should be carried out and use of mitigation measures should be assessed in order to reduce the operational risks, if any, and reduce the volumes of water that could potentially require treatment.



Cigar Lake Underground Mine Cross-Section

Matoush Project Underground Mine Development Ramp Cross-Section



Matoush “Data”

HIGH QUALITY AND UNIQUE DEPOSIT

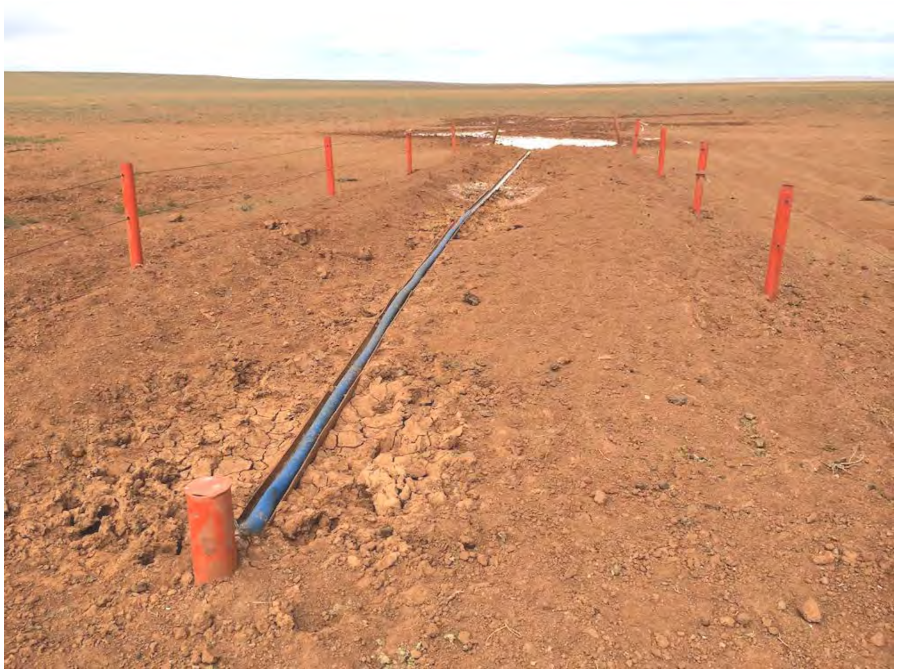
Deposit characteristics	Operating Uranium Mines in Canada	Matoush Project
Acid-generating sulphide minerals	Various levels	traces
Thorium-232 minerals	Various levels	none
Toxic elements		
arsenic	Various levels	traces
selenium	Various levels	traces
Elements		
copper	Various levels	traces
nickel	Various levels	traces
molybdenum	Various levels	traces

Source: Expected environmental Conditions for a Potential Uranium Mine at the Matoush Project Site, SENES Consultants Limited

Uncontrolled flow from released from artesian wells created for use in aquifer tests at uranium exploration site has resulted in significant drop in flow at a natural spring that is sole water source for a county in southeast Mongolia.
Pre-drilling environmental assessment identifying water sources and hydrologic conditions may have been able to prevent this damage

Ongon Soum, Sukhbaatar Aimag, Mongolia

Water waste and unknown groundwater conditions….



Lead to loss of flow at the sole water source for people and their livestock in Ongon Soum, Sukhbaatar Aimag, Mongolia

TOOLS FOR USE IN DEVELOPING QUEBEC APPROACH:

New Mexico Mining Act of 1993
http://www.emnrd.state.nm.us/MMD/MARP/documents/MiningAct.PDF

New Mexico Mining Act Regulations
http://www.nmcpr.state.nm.us/nmac/_title19/T19C010.htm

“At 2010 rates of consumption, identified resources are sufficient for over 100 years of supply for the global nuclear power fleet.” (P. 9)

Table 1.26. World uranium production capability to 2035

(in tonnes U/year, from RAR and inferred resources recoverable at costs up to USD 130/kgU, except as noted)

Country	2011		2015		2020		2025		2030		2035	
	A-II	B-II	A-II	B-II	A-II	B-II	A-II	B-II	A-II	B-II	A-II	B-II
Argentina	120	120*	150	150*	150	250	500*	500*	500*	500*	500*	500*
Australia	9 700	9 700	10 100	16 600	10 100	24 200	10 100	27 900	9 800	27 600	9 800	27 600
Brazil	340	340	1 600	1 600	2 000	2 000	2 000	2 000	2 000*	2 000*	2 000*	2 000*
Canada	16 430	16 430	17 730	17 730	17 730	19 000	17 730	19 000	17 730	19 000	17 730	19 000
China*	1 500	1 600	1 800	2 000	1 800	2 000	1 800	2 000	1 800	2 000	1 800	2 000*
Czech Republic	500	500	50	50	50	50	50	50	50	50	30	30
Finland**	0	0	0	350	0	350	0	350	0	350	0	350
India*	295	980	980	980	980	1 200	1 000	1 600	1 000	2 000	1 000	2 000
Iran, Islamic Rep. of	70	70	90	90	100*	100*	100*	100*	100*	100*	100*	100*
Jordan*	0	0	0	0	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Kazakhstan	22 000	22 000	24 000	25 000	24 000	25 000	14 000	15 000	12 000	13 000	5 000	6 000
Malawi*	0	1 000	1 270	1 270	1 425	2 525	0	0	0	0	0	0
Mongolia*	0	0	0	500	150	1 000	150	1 000	150	1 000	150	1 000
Namibia*	5 350	5 350	7 600	13 400	9 450	19 250	5 450	15 250	1 600	11 400	1 600	10 050
Niger*	5 400	5 400	5 500	10 500	5 500	10 500	5 500	10 500	2 500	7 500	2 500	7 500
Pakistan*[(a)]	70	70	70	110	140	150	140	140	140	650	140	650
Romania*[(a)]	230	230	230	230	350	475	350	475	350	630	350	630
Russian Federation	3 360	3 360	4 480	4 790	5 840	6 610	6 410	7 270	2 620	11 240	5 450	10 450
South Africa*	1 050	1 050	1 588	2 360	2 686	3 460	2 795	3 565	1 386	2 155	1 381	2 150
Ukraine*	1 500	1 500	2 700	2 700	2 700	2 700	5 200	5 200	5 200	5 200	5 200	5 200
United States[(b)]	2 040*	2 040*	3 400	6 100	3 800	6 600	3 700	6 500	3 100	5 600	3 100*	5 600*
Uzbekistan	3 350	3 350	4 150	4 150	4 500	4 500	5 000	5 000	5 000*	5 000*	5 000*	5 000*
Total	**73 305**	**75 090**	**87 488**	**110 310**	**95 451**	**133 570**	**83 975**	**125 050**	**69 026**	**118 625**	**64 831**	**109 460**

A-II = Production capability of existing and committed centres supported by RAR and inferred resources recoverable at <USD 130/kgU.

B-II = Production capability of existing, committed, planned and prospective centres supported by RAR and inferred resources recoverable at <USD 130/kgU.

* Secretariat estimate.

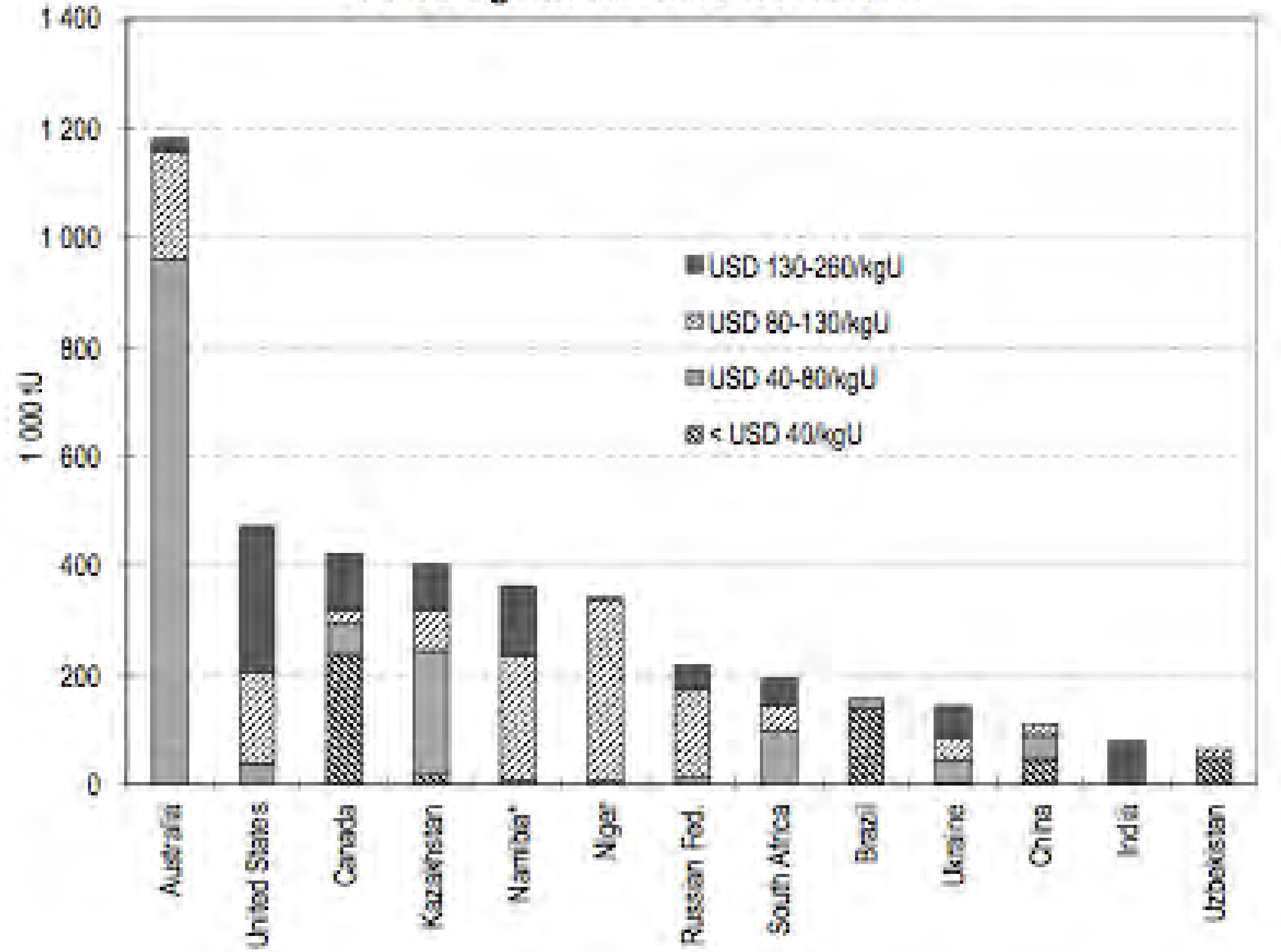
** By-product of nickle production.

(a) Projections are based on reported plans to meet domestic requirements through the discovery of additional resources.

(b) Data from previous Red Book.

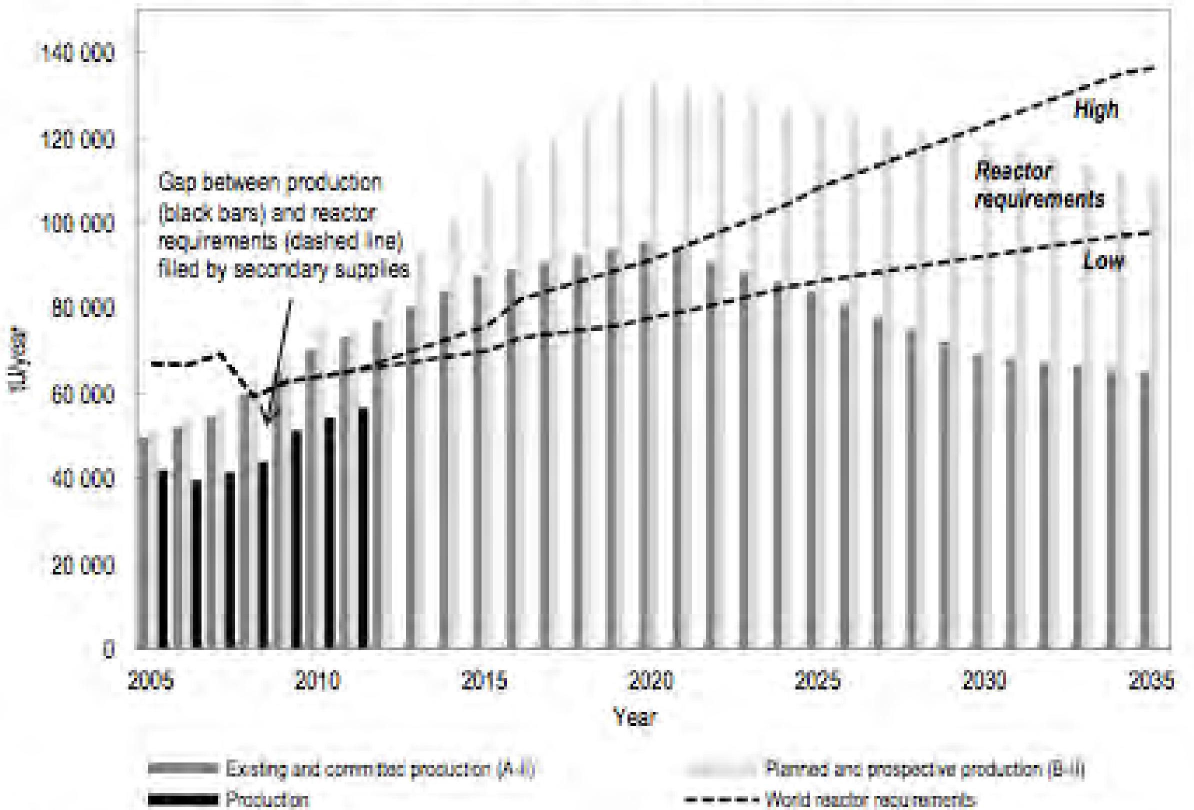
From: Uranium Red Book 2011

Figure 1.2. Distribution of reasonably assured resources (RAR) among countries with a significant share of resources



From: Uranium Red Book 2011

Figure 2.11. Projected annual world uranium production capability to 2035 compared with projected world reactor requirements*



Source: Tables 2.2 and 2.4.

* Includes all existing, committed, planned and prospective production centres supported by RAR and inferred resources recoverable at a cost of <USD 130/kgU.

Figure 2.8. Cumulative uranium production and requirements*
(1945-2011)

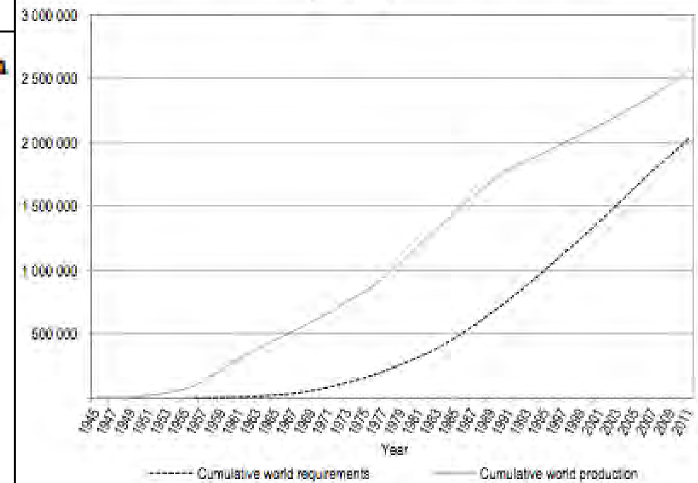
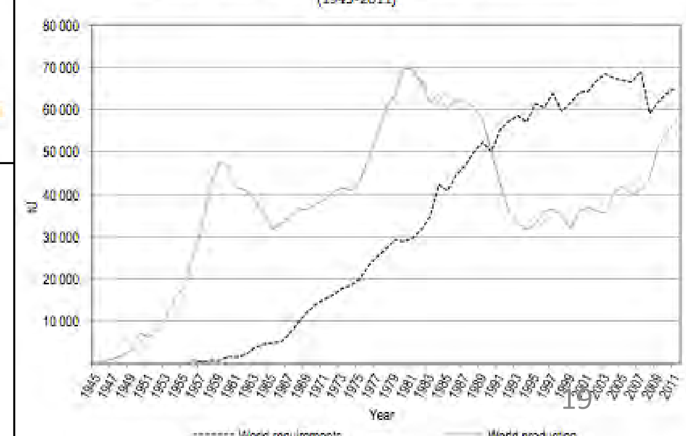
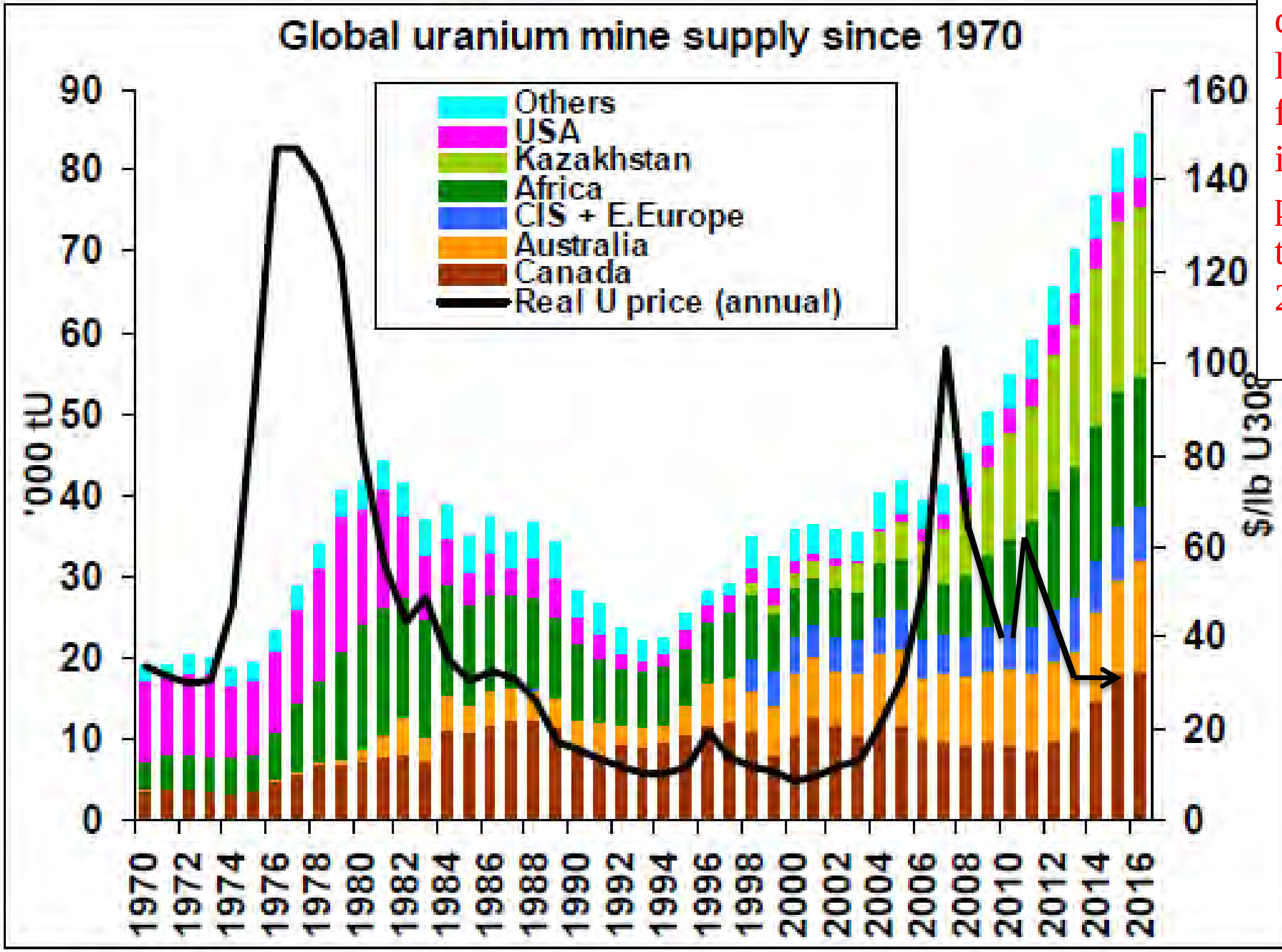


Figure 2.7. Annual uranium production and requirements*
(1945-2011)



From: Uranium Red Book 2011

Mine supply: strong growth assumed



Source: WNA, Macquarie Research, September 2008

Black line shows "Real U Price" that shows the value of old prices in current dollars and demonstrates that the lower uranium prices from the 1970s are equal in value to much higher prices in current dollars than more recent, post-2000, uranium prices

August 22, 2014 Uranium Spot Market Price (www.uxc.com) - $31.00

Updated through August 22, 2014 spot market price from "The Global Uranium Outlook 2008/9"- 2008 World Nuclear Association Symposium at - http://www.world-nuclear.org/sym/2008/presentations/laytonpresentation.pdf

What are the Potential Health Effects from Exposure to Uranium?[1]

- Uranium is a heavy metal and acts similar to lead (another heavy metal) in the body.
- Accordingly, for natural uranium, national and international human exposure standards are based on the possible **chemical toxicity** of uranium (e.g., effect on kidney—nephrotoxicity), not on radiation and possible "cancer effects" (radiotoxicity)

[1]Sources: (1) U.S. Nuclear Regulatory Commission. Standards for protection against radiation. 10 CFR Part 20; 1992. (2) International Commission on Radiological Protection. Limits for intakes of radionuclides by workers. ICRP Publication 30, Part 1.1979. (3) Agency for Toxic Substances and Disease Registry. Toxicological profile for uranium. Department of Health and Human Services, Public Health Service; 1999. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp150.html.

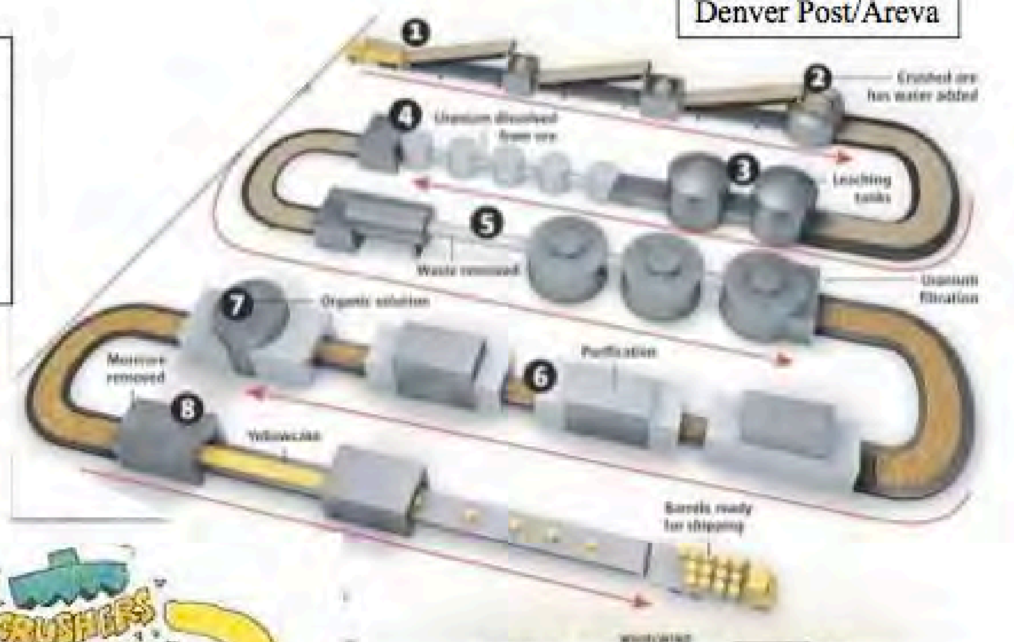
Brown, 2009 NRC/NMA Symposium

Part 2 – Uranium Mill Tailings

Uranium Mining and Milling and Uranium Fuel Cycle Graphics –

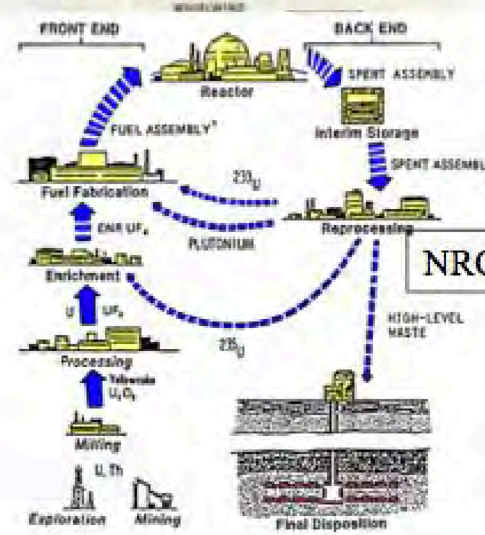
Volume of Mine and Mill Waste vs. Uranium Product Ignored

Denver Post/Areva



CAMECO

NRC



The amount of hazardous constituents in uranium tailings and other wastes and the risks they present varies for each specific waste facility, location and technology

Risks at specific sites usually include:

- Environmental exposures to uranium and its radioactive decay products – radium, thorium, radon and other isotopes among others

- Environmental exposures to heavy metals associated with uranium ore – often including arsenic, cadmium, zinc, copper, selenium, among others

- Acid drainage from waste rock and tailings – due to sulfide content of ore and/or sulfuric acid milling process

Environmental exposures can include releases to air, surface water and groundwater

Long Term Stabilization of Uranium Mill Tailings, IAEA-TECDOC-1403, p. 54

http://www-pub.iaea.org/MTCD/publications/PDF/te_1403_web.pdf

Tailings Disposal Options : Above Ground

Advantages

- Can operate simultaneously with mining
- May be cheap to establish if tailings used in construction
- Valley fill sites may have low construction costs
- Whole tailings can be contained
- Tailings pond can also function as evaporative pan to assist in mine water management
- Most widely used
- Tailings easily accessed for reworking if required

Disadvantages

- Authorities may regard this type as only temporary storage & tailings may need to be relocated e.g. below ground level at end of mine life
- May require construction of associated structures to minimise risk of environmental impact in the case of failure, or to collect/treat seepage etc
- Seepage control essential
- Expensive if built as water containment structure
- Post close-out settlement may take a long time and lengthen period before operator can be released of responsibility
- May need long term maintenance
- Long term risk of tailings spill, increasing as structure weathers and erodes
- Increases land area impacted by mining
- Airborne and waterborne dispersal of contaminants possible following erosion etc

Tailings Disposal Options - Below Ground: In Pit

Advantages
- Very long term containment possible
- Unlikely to ever require maintenance
- Whole tailings can be contained
- Pit preparation costs unlikely to be as high as above ground options
- Airborne dispersal of contaminants effectively impossible
- Structural failure of containment virtually impossible

Disadvantages
- May need pervious-surround work to minimise ground water contamination risk
- Construction cost of impermeable containment could be high if suitable pit not available
- Not normally possible to operate simultaneously with mining at the same location
- Requires a suitable pit to be available pre-mining, or for all ore to extracted prior to milling (e.g. Nabarlek, Northern Territory, Australia)
- May involve double-handing of tailings if no pit available at commencement
- Re-claiming of tailings if required for further treatment will be difficult owing to depth

Tailings Disposal Option -
Below Ground: Underground Mine Workings

Advantages

- Very long term containment possible
- Unlikely to ever require maintenance
- Can possibly incorporate whole tailings
- Can be operated simultaneously with mining
- Airborne dispersal of contaminants effectively impossible
- Structural failure of containment virtually impossible

Disadvantages

- Slimes may need to be contained separately
- Need suitable groundwater conditions
- Mine waste water management system needs to be able to cope with evaporation requirements
- Tailings not available for reprocessing

Tailings Disposal Option - Below Ground:
Purpose-built Containment
(underground void or surface pit)

Advantages

- Very long term containment possible
- Unlikely to ever require maintenance
- Whole tailings can be contained
- Can be operated simultaneously with mining
- Airborne dispersal of contaminants effectively impossible
- Structural failure of containment virtually impossible
- Site can be selected in low-permeability country rock
- Benign rock available for unrestricted use in construction

Disadvantages

- Construction required before milling commences
- Mine waste water management system needs to be able to cope with evaporation requirements
- Suitable site may be remote from mill and increase slurry/paste transport and infrastructure costs
- Paste stabilization normally necessary for underground and optional/preferable for pit.

Denison Mines –Elliot Lake, Ontario
Uranium Mine and Mill

During Operations – tailings disposed in natural lakes

After Decommissioning – tailings covered by lake water

http://www.clra.ca/denison%20mine%20mill.html

Tailings Disposal Options: Deep Lake

Advantages

- Can operate simultaneously with mining
- Cheap to establish
- Whole tailings can be contained
- Very long term containment possible
- Unlikely to ever require maintenance
- Whole tailings can be contained
- Airborne dispersal of contaminants effectively impossible
- Structural failure of containment virtually impossible

Disadvantages

- Authorities may not allow this approach to tailings disposal
- Requires nearby water body not otherwise used for social or economic benefit (i.e. fishery, water supply, recreation)
- Risk of water contamination and tailings redistribution from disturbance by major flood of changed climatic conditions

Moab Tailings Relocation Project showing:
1) 16,000,000 tons Atlas tailings pile before project began 2) tailings removal in progress, and 3) additional tailings removal completed

From: http://www.gjem.energy.gov/moab/
and http://www.moabtailings.org/

Crescent Junction below-grade tailings disposal site – daily cover provided for tailings using material excavated to allow below grade disposal.

From: http://www.gjem.energy.gov/moab/

"Mostly" below-grade tailings disposal design for Pinon Ridge Uranium Mill

"Uranium Tailings Facility Design and Permitting in the Modern Regulatory Environment"http://www.infomine.com/library/publications/docs/Morrison2008.pdf

The Piñon Ridge Project

- Design milling capacity of 500 tons per day, with expansion capacity to 1000 tons per day
- Major mill components:
  - Process plant
  - Tailings cells
  - Evaporation ponds
  - Ore stockpile pads
- Design mill life up to 40 years

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Tailings Cell Design Concepts

- Three tailings cells, constructed in phases
  - Each cell with capacity for 13.4 years at 500 tpd operations
  - Mostly below-grade disposal, with excess cut to be used for closure cover and other site construction
  - 3H:1V internal slopes with intermediate benches
  - 10H:1V external slopes to achieve closure requirements
  - 1% minimum slope at base

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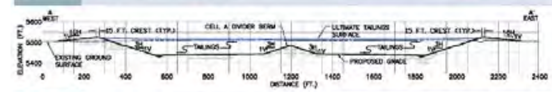
Tailings Cell Design Concepts, cont.



- Tailings Cell A designed as a split cell for contingency purposes
  - For instance, cell A1 could be decommissioned and repaired without disrupting operations
- Tailings Cells B and C are designed as single cells with option for split cell construction

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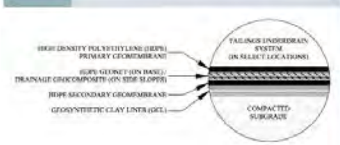
Tailings Cell Liner System Design

- Prescriptive Liner System (40 CFR 264.221) (top to bottom):
  - Primary geomembrane
  - Leak detection layer (drainage gravel or geosynthetic)
  - Secondary geomembrane
  - 3 feet of 10^{-7} cm/sec clay
- Proposed Liner System (top to bottom):
  - 60 mil HDPE primary geomembrane
  - Leak detection system layer with geonet (on base) and drainage geocomposite (on slopes)
  - 60 mil HDPE secondary geomembrane
  - Geosynthetic clay liner (GCL)



Primary Liner Characteristics

- HDPE geomembrane chosen for its long term performance due to:
  - Chemical resistance properties
  - Resistance to UV radiation
  - High tensile strength
  - High stress-crack resistance
- Light-reflective upper surface (i.e., white)
  - Additional UV resistance through UV reflection
  - Minimizes expansion/contraction wrinkles
  - Reduces heat build up and thermal expansion by reflective solar radiation
  - Reduces desiccation effects to subgrade soils
  - Improves visual detection of installation damage
- Conductive liner
  - More reliable quality assurance through spark testing

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Leak Detection System Layer

- Designed per 40 CFR 264.221 to minimize hydraulic head on lower geomembrane liner
  - Leaks through primary liner collected in the LDS layer and routed to a sump
  - Automated submersible pump recovers leak solutions and returns them to the tailings cell
- Leak Detection System (LDS) layer comprised of:
  - HDPE geonet on base of tailings cells
    - High transmissivity
    - Low shear strength in contact with geomembrane, so used only on base of cells
  - Drainage geocomposite on side slopes of cells
    - HDPE geonet laminated on both sides to nonwoven geotextile filtration media
    - Increased interface shear strength for use on side slopes, but decreased transmissivity

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Secondary Composite Liner System

- Designed to maximize the amount of solution recovered by the LDS, and act as a final flow barrier protecting the subgrade
- Design consists of:
  - 60 mil HDPE double-sided textured geomembrane
    - Resistance to chemicals in solution
    - Double-sided texturing to increase frictional resistance
  - Geosynthetic clay liner (GCL)
    - No locally-available sources of clay, and difficult to achieve requirements even by amending local soils with bentonite
    - Compatibility testing with anticipated tailings solution indicate negligible change in GCL permeability
- Analyses (Giroud et al. 1997) show that the proposed secondary liner system with GCL is more stringent than the prescriptive liner system with 3 feet of clay.

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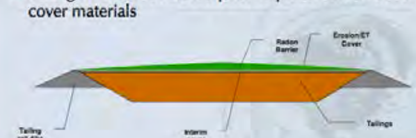
Underdrain System Design

- Underdrain system required to facilitate dewatering of the tailings (6 CCR 1007-1, Part 18, Appendix A, Criterion 5E)
  - Reduce driving head for seepage on the liner system
  - Anticipated tailings gradation is considered amenable to dewatering (i.e., relatively coarse-grained silty sands and sandy silts)
- Design consists of:
  - Perforated HDPE collection pipes at the base of the tailings cell to collect and convey solution to the underdrain sumps
  - Solution collected in underdrain sumps will be returned to the mill circuit through use of automated submersible pumps

Golder Associates

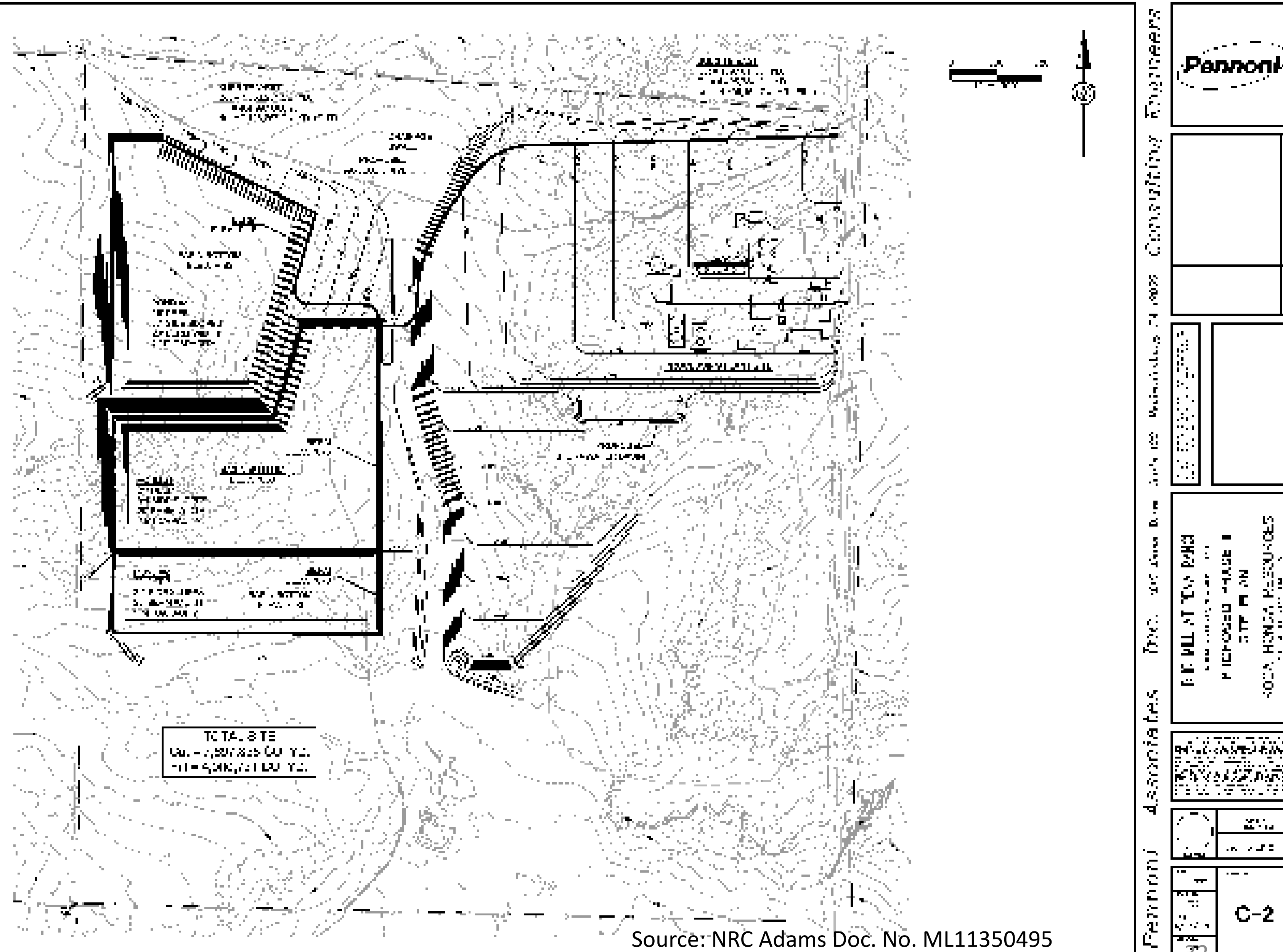
Tailings Closure Considerations

- Minimize post-closure maintenance
- Perimeter external berm side slopes designed at 10H:1V to consider closure
- Cover materials will be placed over tailings in each cell as deposition is complete
- Tailings will be dewatered prior to placement of closure cover materials

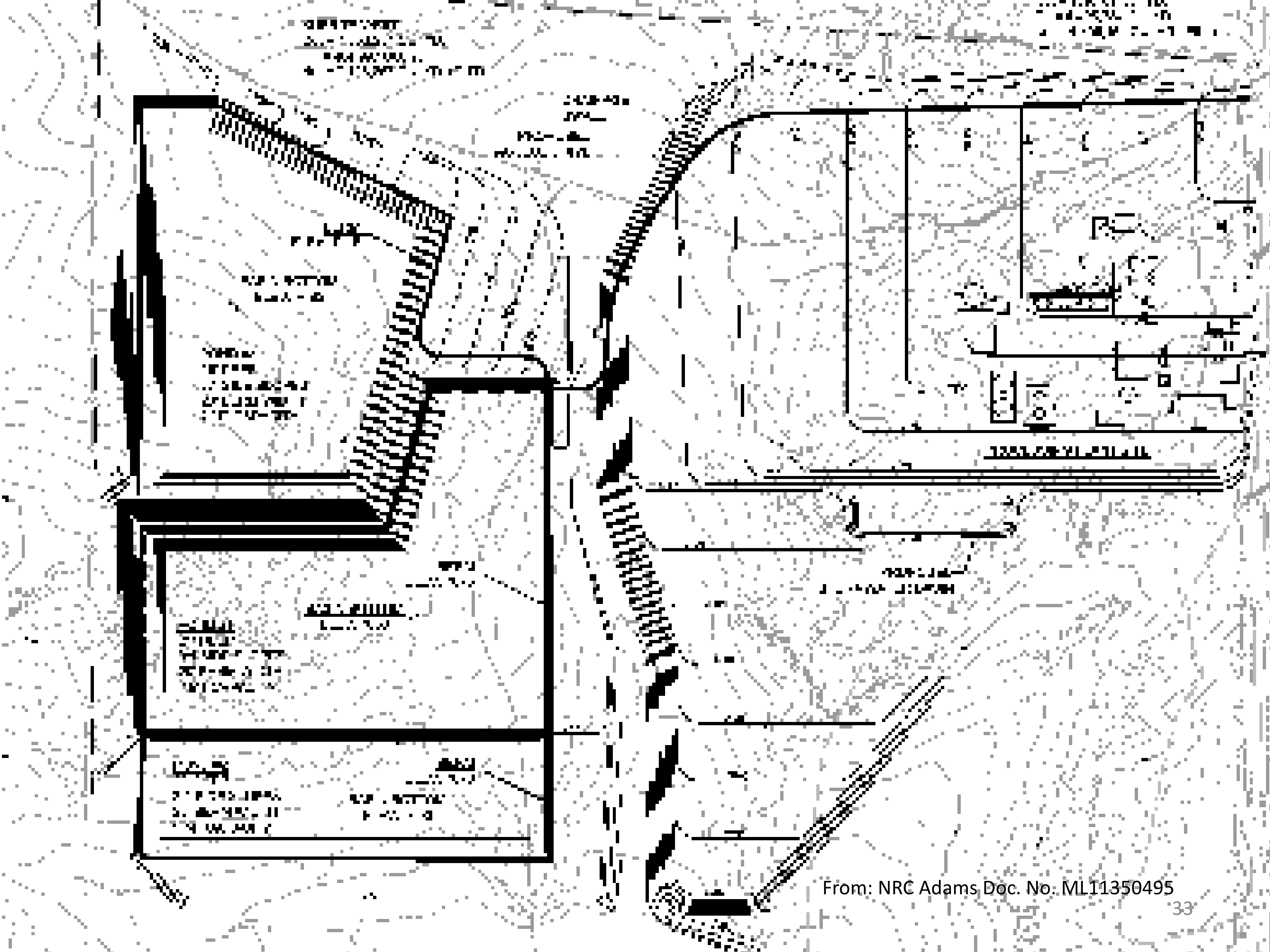


Golder Associates

Design for below-grade uranium mill tailings disposal site for Pena Ranch mill, New Mexico

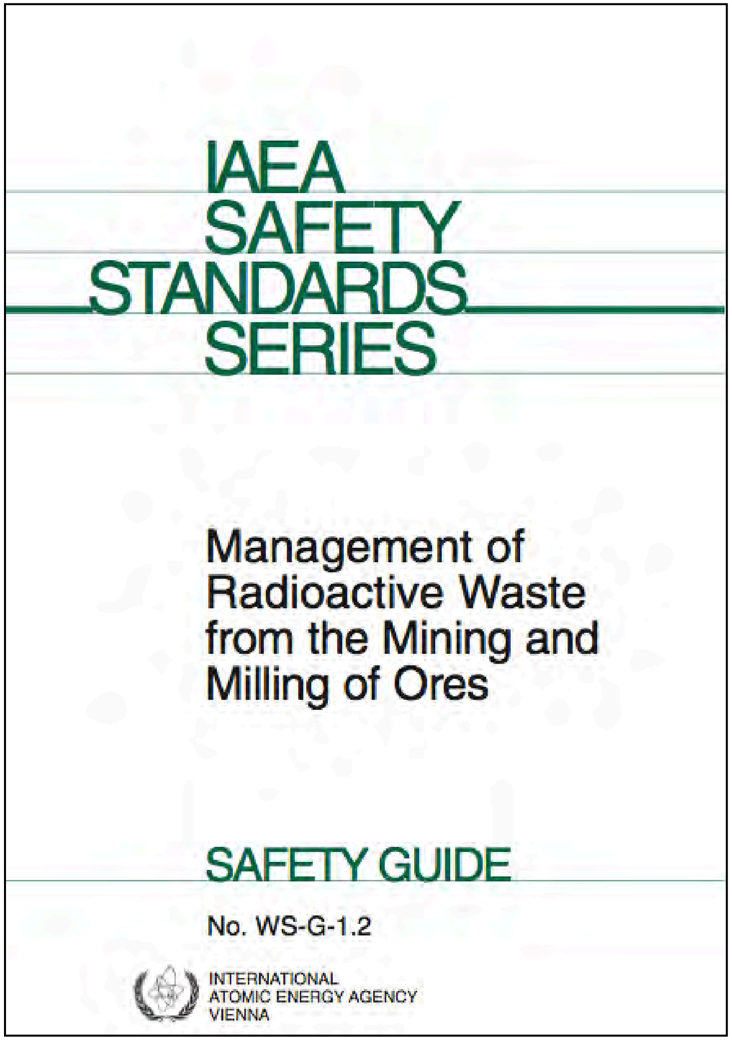


Source: NRC Adams Doc. No. ML11350495



From: NRC Adams Doc. No. ML11350495

INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)
GUIDANCE ON URANIUM MINE AND MILL WASTE MANAGEMENT


IAEA SAFETY STANDARDS SERIES

Management of Radioactive Waste from the Mining and Milling of Ores

SAFETY GUIDE

No. WS-G-1.2

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA

INTRODUCTION – BACKGROUND: The radioactive waste generated in mining and milling activities, especially those involving uranium and thorium (U, Th) ores, differs from that generated at nuclear power plants and most other industrial operations and medical facilities. Waste from mining and milling activities contains only low concentrations of radioactive material but it is generated in large volumes in comparison with waste from other facilities.

The management methods to be employed are therefore different and will usually involve waste disposition on or near the surface, in the vicinity of the mine and/or mill sites. Furthermore, the waste will contain long lived radionuclides, and this has important implications for its management because of the long time periods for which control will be necessary.

Source: "MANAGEMENT OF RADIOACTIVE WASTE FROM THE MINING AND MILLING OF ORES--SAFETY GUIDE," INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2002, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1134_scr.pdf

IAEA GUIDANCE ON URANIUM MINE AND MILL WASTE MANAGEMENT

Radioactive waste arises from all stages of mining and milling processes and includes, in addition to mill tailings, waste rock[1], mineralized waste rock[2] and process water, including leaching solutions. Rainfall and snowmelt runoff and seepage from stockpiles and areas of uranium process plants should also be managed.

The hazards to humans or to the environment posed by mining and milling waste arise not only from its radioactivity but also from the presence of toxic chemicals and other materials in the waste. Achieving a consistent regulatory approach to protect against these different hazards is a challenge for national regulators.

This publication is focused on the management of the radiological hazards associated with the waste, but where there is a particular need for regulators to take account of the non-radiological hazards, this is also indicated.

[1] Waste rock is material that is excavated from a mine and which does not present any significant radiological hazard requiring management to protect human health or the environment. Waste rock may still require management for other reasons, such as to control erosion to prevent the siltation of local surface water bodies.

[2] Mineralized waste rock is material that is excavated from a mine and which has chemical and/or radiological characteristics which necessitate its management to protect human health or the environment.

Source: "MANAGEMENT OF RADIOACTIVE WASTE FROM THE MINING AND MILLING OF ORES--SAFETY GUIDE," INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2002, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1134_scr.pdf

France – Uranium mine and mill reclamation designed and implemented after closure of mine and mill operations is not likely to be permit-able in most uranium mining districts.

IAEA GUIDANCE ON URANIUM MINE AND MILL WASTE MANAGEMENT

RADIOLOGICAL PROTECTION OF THE PUBLIC - Releases of radionuclides from radioactive waste to the environment during mining and milling activities and subsequent waste management activities may result in the radiation exposure of members of the public. Such releases are subject to the criteria that are applicable to releases from any practice in which radioactive material is being handled and, as with occupational protection, national requirements for radiological protection should be consistent with the BSS[1].

However, since mine and mill tailings will continue to present a potential hazard to human health after closure, additional analyses and measures may be needed to provide for the protection of future generations. Such measures should not be left until closure but should be considered and implemented throughout the design, construction and operation of the mining and milling facilities. The protection of the public, from the beginning of operations to post- closure, should be considered in its entirety from the beginning of the design of the facilities. The overall objective and subsidiary criteria developed explicitly for the management of radioactive waste should be consistent with these considerations.

Source: "MANAGEMENT OF RADIOACTIVE WASTE FROM THE MINING AND MILLING OF ORES--SAFETY GUIDE," INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2002, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1134_scr.pdf

Radiological Protection of the Public (continued)

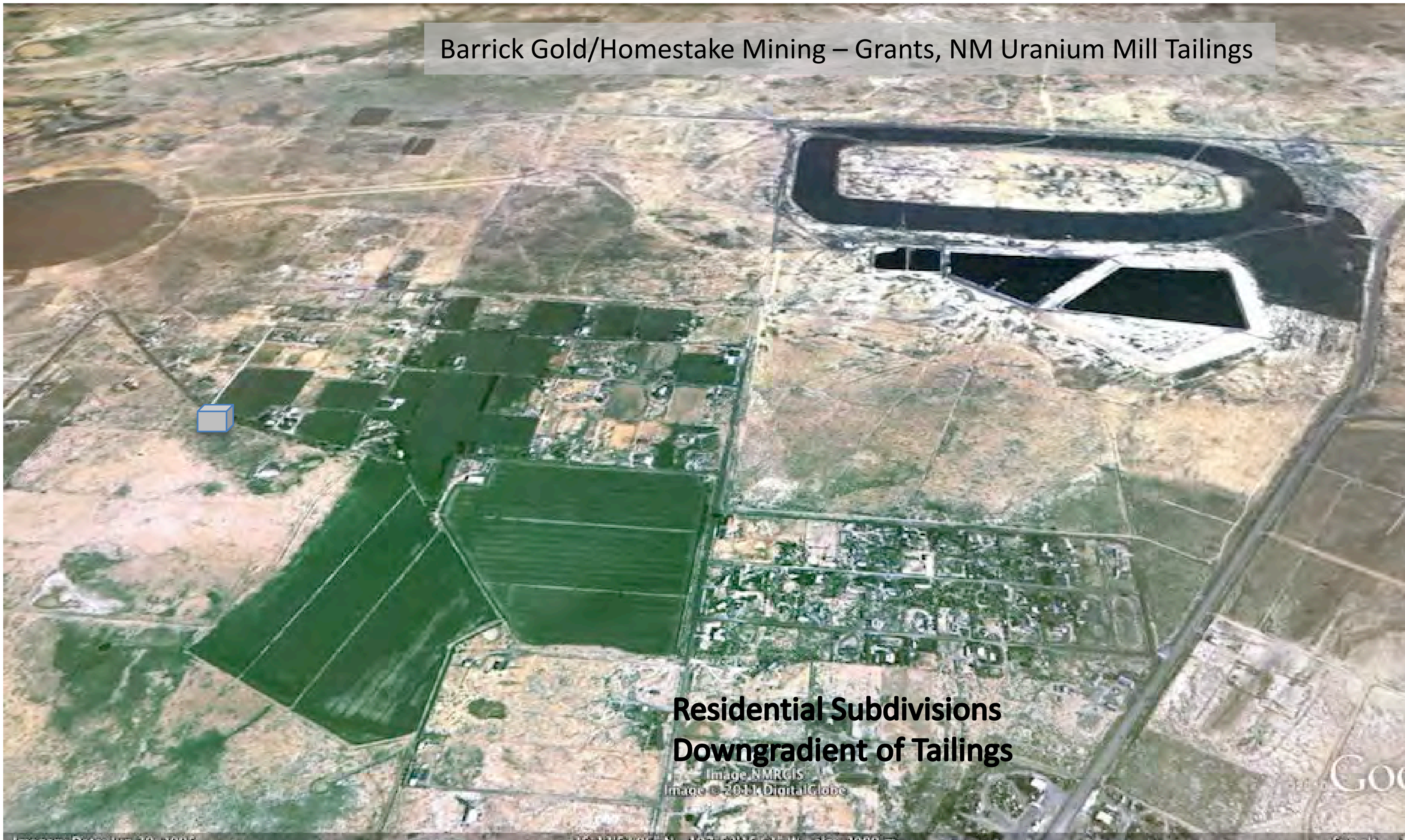
Although mining and milling waste contains only naturally occurring radionuclides, these radionuclides cannot be considered to be in their original states or concentrations, since their physical and chemical forms may have been altered substantially, and exposures may be influenced by the operation of the waste management facilities.

Exposures attributable to such waste should not be regarded as exposure to natural background radiation and exposures of the public attributable to all mining and milling waste should be included in the system of radiation protection for practices as required in the BSS[1].

([1] BSS - International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).)

Source: "MANAGEMENT OF RADIOACTIVE WASTE FROM THE MINING AND MILLING OF ORES--SAFETY GUIDE," INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2002, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1134_scr.pdf

US – Three uranium mill tailings piles remain on the Superfund National Priorities List more than 30 years after groundwater contamination was discovered and more than 20 years after closure – Barrick/Homestake Grants; General Atomics/Cotter – Canon City and General Electric/United Nuclear - Churchrock



IAEA GUIDANCE ON URANIUM MINE AND MILL WASTE MANAGEMENT

NON-RADIOLOGICAL CONSIDERATIONS

Waste from mining and milling activities will also give rise to non-radiological hazards to humans and to the environment. Some of these non-radiological hazards will be similar to those arising from other mining and milling activities. Both radiological and non-radiological hazards should be taken into account in planning the management of this waste.

For radioactive contaminants, any chemical toxicity may cause deleterious environmental impacts at concentrations well below those necessary to produce radiological effects. Such concentrations may occur even for releases that comply with criteria established specifically for the radiological protection of humans, especially if the critical group is distant from the source.

These potential impacts should be considered at the planning stage of a mining and milling project and should be periodically reassessed throughout the project’s lifetime. Good mining practice should be followed in a manner consistent with the need for radiological protection, while it is sought to minimize the contaminant source terms, sediment loads and acid generation by means of careful design, construction, operation and closure. Any release of contaminants and sediments to the receiving environment should comply with the criteria prescribed by the appropriate regulatory body.

Source: “MANAGEMENT OF RADIOACTIVE WASTE FROM THE MINING AND MILLING OF ORES--SAFETY GUIDE,” INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2002, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1134_scr.pdf

IAEA GUIDANCE ON URANIUM MINE AND MILL WASTE MANAGEMENT

Various processes should be considered in assessing these impacts. For example, contaminants may be transported to the environment by seepage and surface runoff (dissolved contaminants and suspended sediments) and in mine effluents.

Acid mine drainage is a particular concern with sulphidic ores. Acid generation can lead to a reduction in the pH of adjacent water systems and an increase in the mobilization of contaminants, particularly heavy metals, which may adversely affect surface water ecosystems.

In addition to chemical effects, sediments arising from erosion at waste management facilities may increase turbidity or cause excessive siltation in surface water systems within the catchment area, damaging downstream ecosystems. In addition to chemical effects, sediments arising from erosion at waste management facilities may increase turbidity or cause excessive siltation in surface water systems within the catchment area, damaging downstream ecosystems.

Source: "MANAGEMENT OF RADIOACTIVE WASTE FROM THE MINING AND MILLING OF ORES--SAFETY GUIDE," INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2002, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1134_scr.pdf

General Atomics' Cotter – Canon City, CO Uranium Mill and Tailings

STRATEGY FOR WASTE MANAGEMENT: The principles of radioactive waste management set out in the IAEA Safety Fundamentals apply to the goals of waste management strategies for mining and milling waste.

4.2.The development of a waste management strategy is usually a complex process that has the aim of achieving a reasonable balance between two, often conflicting, goals: maximization of risk reduction and minimization of financial expenditure. The process is one of optimization of protection in which the available alternatives for siting, design and construction, operation, management of waste streams, and closure are evaluated and compared, with account taken of all associated benefits and detriments and any constraints (such as an annual dose constraint) that are required to be imposed. The characteristics of the alternatives (or options) that should be considered include: (a) The radiological and non-radiological impacts on human health and the environment during operation and in the future; (b) The requirements for monitoring, maintenance and control during operation and after closure; (C0 Any restrictions on the future use of property or water resources; (d) The financial costs of the various alternatives and the resources available for implementing the alternatives; (e) The volumes of the various wastes to be managed; (f) The socioeconomic impacts, including matters relating to public acceptance; (g) Good engineering practices.

4.3.The steps taken towards deciding how to manage the waste arising from mining and milling facilities should include: (a) Definition of the criteria for human health and environmental protection; b) Characterization of the waste; (c) Identification and characterization of the site options; (d) Identification and characterization of the waste management options, including engineering controls; (e) Identification and description of options for institutional control; (f) Identification and description of potential failures of institutional and engineering controls; (g) Definition and characterization of the critical group of the population; (H) Estimation of the radiological and other consequences for each combination of options being considered (the 'safety analysis'), including scenarios of potential exposure for each option; (i) Comparison of the estimated doses and risks with appropriate constraints; (j) Optimization of protection so as to arrive at the preferred management option.

Rio Algom/Kerr McGee Underground Uranium Mine - Remediation being planned

GE/UNC - Northeast Churchrock Underground Mine – Remediation being planned

General Electric - United Nuclear Churchrock Uranium Mill and Tailings Pile

IAEA GUIDANCE ON URANIUM MINE AND MILL WASTE MANAGEMENT

4.4.The evaluation criteria and procedures used to select the preferred options and to develop the waste management strategy that will achieve the optimal balance among the above considerations should be clearly defined and presented to the different interested parties in the project, including the public.

4.5.The design of mining and milling facilities will influence the optimization of protection from exposure due to radioactive waste and should therefore be considered with waste management in mind. The mining and milling activities should be designed to reduce, as far as practicable, the amount of waste to be managed. This can be accomplished through the choice of appropriate mining methods and milling processes, and the recycle and reuse of equipment, materials and waste.

4.6. The closure of the waste management facilities should be considered in all phases of the mining and milling operation, that is, during siting, design, construction and operation. Planning for the management of mining and milling waste at closure should not be delayed until the closure stage. For example, taking measures at an early stage to reduce the migration of water-borne and airborne contamination to the surrounding environment will facilitate management of the closure phase.

4.7.The design, construction, operation and closure of facilities for the management of waste from mining and milling should be in accordance with the elements of a quality assurance programme as outlined in Section 7. In particular, facilities should be constructed, operated and closed only according to approved plans and procedures

4.8.Paragraphs 4.9–4.27 outline the important characteristics and desirable features of the options that should be considered in the siting and management of waste from mining and milling, considerations in the design, construction, operation and closure of facilities, and procedures for the release of materials.

OPTIONS FOR WASTE MANAGEMENT TAILINGS:

4.9 Of the different waste streams produced by mining and milling operations, tailings represent the greatest challenge, particularly in terms of long term management, because of the large volumes produced and their content of very long lived radionuclides and heavy metals. The preferred management option for achieving the protection goals will depend on specific conditions at the site, the characteristics of the ore body, the specifics of the mining and milling processes, and the characteristics of the tailings.

4.10. To conform to the principles for managing radioactive waste [3], access to and dispersion in the environment of the hazardous constituents of the tailings should be restricted for long periods into the future. The key issues which should be considered in the design of a tailings management facility include: (a) The stability of the pit, underground mine void, or surface impoundment in relation to natural processes such as earthquakes, floods and erosion. (b) The hydrological, hydrogeological and geochemical characteristics of the site. (c) The chemical and physical characteristics of the tailings in relation to the potential for the generation and transport of contaminants. (d) The volume of material that will be retained on the site as waste. (e) The use of neutralization agents, radium precipitating additives, artificial or natural liners, radon barriers and evaporation circuits, with the reliability, longevity and durability of such agents factored in.

Source: "MANAGEMENT OF RADIOACTIVE WASTE FROM THE MINING AND MILLING OF ORES--SAFETY GUIDE," INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2002, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1134_scr.pdf

Churchrock Uranium District - New Mine Proposed While Remediation Of Old Mines and Mills Continues

http://www.epa.gov/region09/superfund/navajo-nation/images/ne-church-rock-mine-aerial.jpg

4.11. A thorough investigation of these issues should be undertaken at an early stage when considering options for the management of tailings. Details on the application of relevant technologies can be found in other IAEA pubs [18, 19].

4.12. The design of a facility for the management of tailings should incorporate drainage systems to consolidate tailings before closure and to reduce excess pore water pressure. In the case of a surface impoundment or a pit, this could be achieved by the installation of a drainage system prior to or during the emplacement of tailings, or by the use of wicks driven into the tailings after emplacement. The base and cap of the impoundment should be built of a material of low permeability, if possible using material of natural origin.

The addition of a stabilizing agent (such as cement) to the tailings immediately prior to their deposition has the potential to reduce significantly the permeability of the tailings mass, thus retarding the transport of contaminants and binding any pore water. However, in certain cases, a confined, poor quality water covering in a pit may possess excellent characteristics as a radon barrier, thereby obviating the need to perform dewatering to any significant degree.
The decision on which approach to take should be optimized so as to match barrier characteristics with available site conditions. In the case of disposal in underground mines, the increase in structural integrity gained by using concrete with the tailings mass may allow mining to be continued immediately adjacent to the tailings. Prior to adopting this strategy, possible chemical interactions between the stabilizing agent, the tailings and the host rock should be carefully investigated to ensure that the transport of contaminants would not be enhanced at some time in the future…

White Mesa Uranium Mill near Blanding, UT. Owned by Denison Mines. Only uranium mill currently licensed to operate in US.
Operated by processing “alternate feed sources of uranium” rather uranium ore for more than 20 years.

Tailings pond required full reconstruction due to damage to liner exposed to weather during more than 20 years of inactive status. Cost of reconstruction of liner and pond in $50 million range, similar to original price of mill and tailings disposal facilities in 1970s.

The White Mesa Mill is not currently accepting ore for process due to low uranium prices - “During the period ended June 30, 2014, as a result of the drop in the U3O8 spot and long-term prices, a significant deterioration in the Company’s expectation of future uranium prices, and the Company’s expectation to place the White Mesa Mill and all associated mines (collectively referred to as the White Mesa Mill Cash Generating Unit – the “WMM CGU”) on standby once the current planned production at the White Mesa Mill and the Pinenut mine has been completed – August 13, 2103 Press Release – available at http://www.energyfuels.com/investors/press_releases/

Other wastes

4.23 Other solid and liquid wastes that are generated in the mining and milling of ores and which should be managed throughout the lifetime of the mining and milling facilities include sludges, contaminated materials, waste rock, mineralized waste rock, process water, leaching fluids, seepage and runoff.

Of these other wastes, waste rock and mineralized waste rock are generally the more difficult to manage. The management of sludges and contaminated materials should be undertaken in compliance with the requirements and recommendations established in other IAEA safety standards [10, 20]. It should be ensured that all material placed in the disposal facility for tailings waste meets the closure requirements.

4.24. While the radiological hazards associated with waste rock and mineralized waste rock are usually much less significant than those for tailings, non-radiological hazards will remain and should be recognized as often being among the more important matters to be considered in the selection and optimization of management options. There are many possible options for managing waste rock and mineralized waste rock. Whichever management option represents the optimum one will depend on the particular mineralogy, radioactivity and chemical reactivity of these wastes.

Source: "MANAGEMENT OF RADIOACTIVE WASTE FROM THE MINING AND MILLING OF ORES--SAFETY GUIDE," INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2002, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1134_scr.pdf

IAEA GUIDANCE ON URANIUM MINE AND MILL WASTE MANAGEMENT

4.25. Options for managing waste rock and mineralized waste rock include their use as backfill materials in open pits and in underground mines, and for construction purposes at the mine site. The need to cover mineralized waste rock with inert waste rock should be taken into account.

4.26. As with tailings, consideration should be given to the extent to which the various options will help ensure that, when managed on the surface, piles of waste rock and mineralized waste rock are stable and resistant to erosion and rainwater infiltration, and do not result in unacceptable environmental impacts on the water catchment area.

4.27. The main liquid waste will include: process water; leaching fluids; rainfall runoff from the process plant area, waste management area and ore stockpiles; seepage from mill tailings, stockpiles and waste rock disposal areas; and mine water (for example, groundwater which has entered open pits or underground mines). All liquid waste should be managed on the basis of its quality and quantity, with account taken of environmental and human health impacts, rather than on the basis of its sources.

The water management system should be designed to minimize the volume of contaminated water. This could be achieved, for example, by the diversion of clean water away from sources of contamination, the reuse of wastewater in the process circuit and the use of wastewater for dust suppression.

Source: "MANAGEMENT OF RADIOACTIVE WASTE FROM THE MINING AND MILLING OF ORES--SAFETY GUIDE," INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2002, http://www-pub.iaea.org/MTCD/publications/PDF/Pub1134_scr.pdf

Cluff Lake mine undergoing rehabilitation, 2004
http://www.areva.com/activities/liblocal/images/en/activites/mines/detail-activites/reamenagement-sites/section-2-reamenagement-sites.jpg

Cluff Lake mill tailings in 1999
In "VA Uranium Study, US NRC/NAS, p. 150 -
http://www.nap.edu/catalog.php?record_id=13266

Cluff Lake uranium mine and mill complex – Google Earth image

Uranium Mining in Virginia: Scientific, Technical, Environmental, Human Health and Safety, and Regulatory Aspects of Uranium Mining and Processing in Virginia,
US National Research Council/National Academy of Science, 2011
http://www.nap.edu/catalog.php?record_id=13266

Cluff Lake Uranium Mine Decommissioning (p. 148 – 150) "A decommissioning study of Cluff Lake in Saskatchewan, Canada, documents improved outcomes for a relatively modern uranium mining operation (1980-2002) but also reveals some continued environmental problems attributable, at least in part, to acid mine drainage"

"A Canadian Nuclear Safety Commission (CNSC) environmental assessment to guide the decommissioning work was completed in 2003, and actual decommissioning was initiated in 2004. CNSC concluded that the primary environmental effects on completion of the decommissioning would be the migration of contaminants from existing sources (e.g., tailings and waste rock piles) to both groundwater and surface water.

Most surface waters in the vicinity of the former mine/mill complex received no direct discharge and, therefore, were negligibly or only slightly impacted by previous operations. Island Lake, however, was adversely affected because of its location immediately downstream of the mill effluent treatment systems. Measured mean annual concentrations of total dissolved solids, sulfate, chloride, uranium, and molybdenum in Island Lake in 2002 were two or three orders of magnitude higher than during the baseline (i.e., pre-mining) monitoring period."

Cluff Lake Decommissioning (continued) –

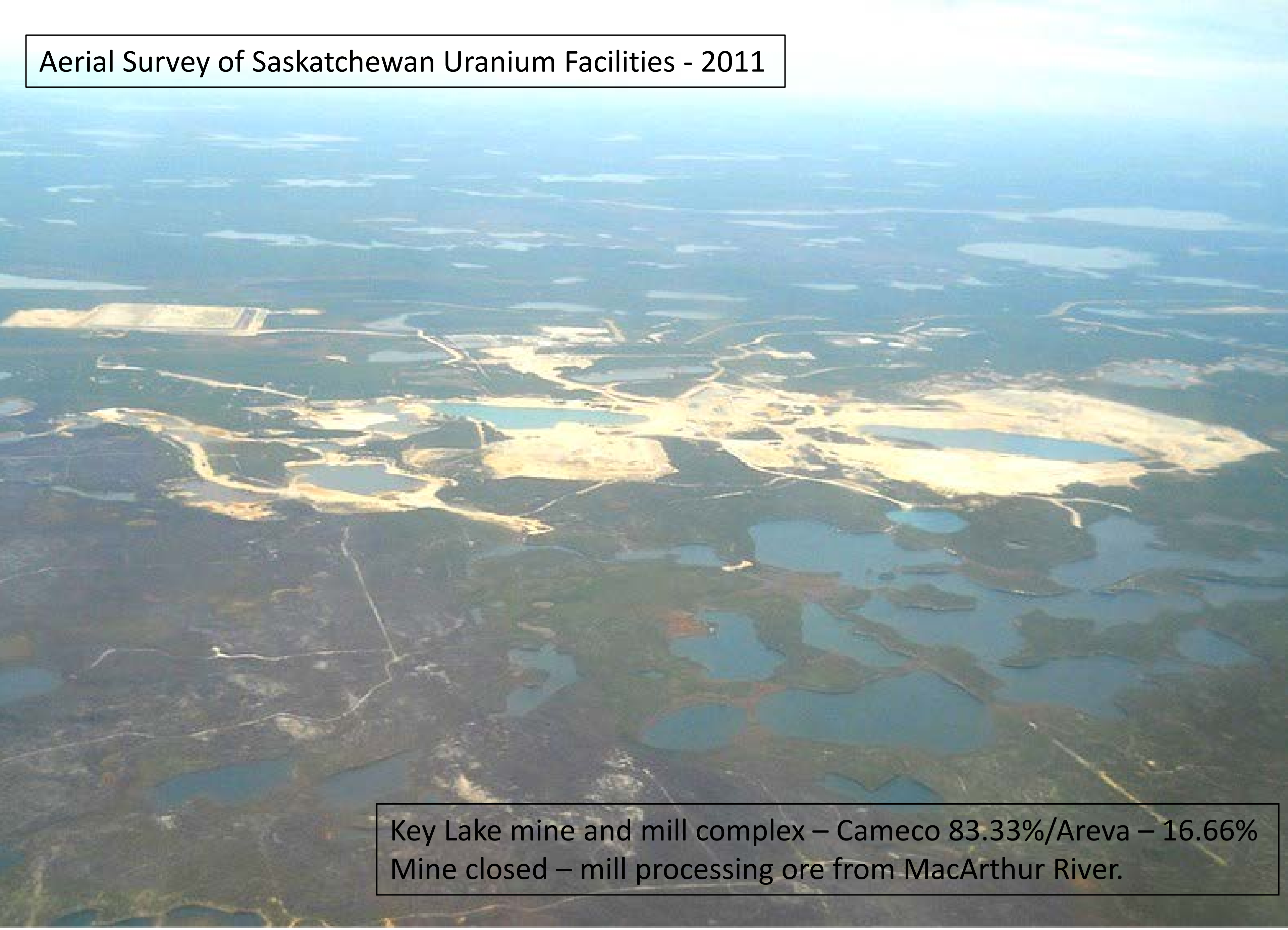
"Acid mine drainage from the Claude waste rock pile caused contamination of the Claude pit, resulting in greatly elevated levels of sulfate, total dissolved solids, uranium, nickel, arsenic, and radium- 226. The relatively poor water quality of the Claude pit necessitated pumping water from the pit to maintain a water level below that of the adjacent lake to prevent transport of contaminants off-site.

Groundwater has been similarly affected by AMD from the Claude waste rock, which has formed a shallow, acidic (pH < 4) groundwater plume with elevated levels of dissolved nickel (> 10 mg/L) and uranium (> 100 mg/L) migrating away from the waste rock pile. Additional potential environmental hazards at the Cluff Lake site include the flooded mine workings and the tailings management area.

The flooded underground mines represent a source of groundwater contamination and, if allowed to overflow, a potential surface water contamination source as well. The tailings management area was constructed as an unlined above-grade facility, using an earthen dam to retain both solid and liquid tailings and enable chemical treatment of the mill effluent prior to discharge into Snake Creek and Island Lake.

The tailings management area represents the principal on-site source of potential long-term environmental effects, although geotechnical evaluations of the earthen dam determined it to be stable, structurally sound, and in compliance with all design specifications. Given its location in a topographic low, constructed surface diversions were employed to isolate the tailing management area from the erosive effects of inflowing surface water."

Aerial Survey of Saskatchewan Uranium Facilities - 2011



Key Lake mine and mill complex – Cameco 83.33%/Areva – 16.66%
Mine closed – mill processing ore from MacArthur River.


Key Lake mine site

McArthur River Mine – 69.8% Cameco/30.2% Areva
Reserves contain 167,000 t U at 15.24% - www.cameco.com
McArthur River ore processed at Key Lake mill.


McArthur River Mine

Cigar Lake Mine – 50% - Cameco; 37% Areva; 7.8% Idemitsu; 5% Tepco

Reserves – 104,650 t U in ore at 17.04% U - www.cameco.com

Mine flooding has delayed start-up; Cameco projects production to late 2104/early 2015

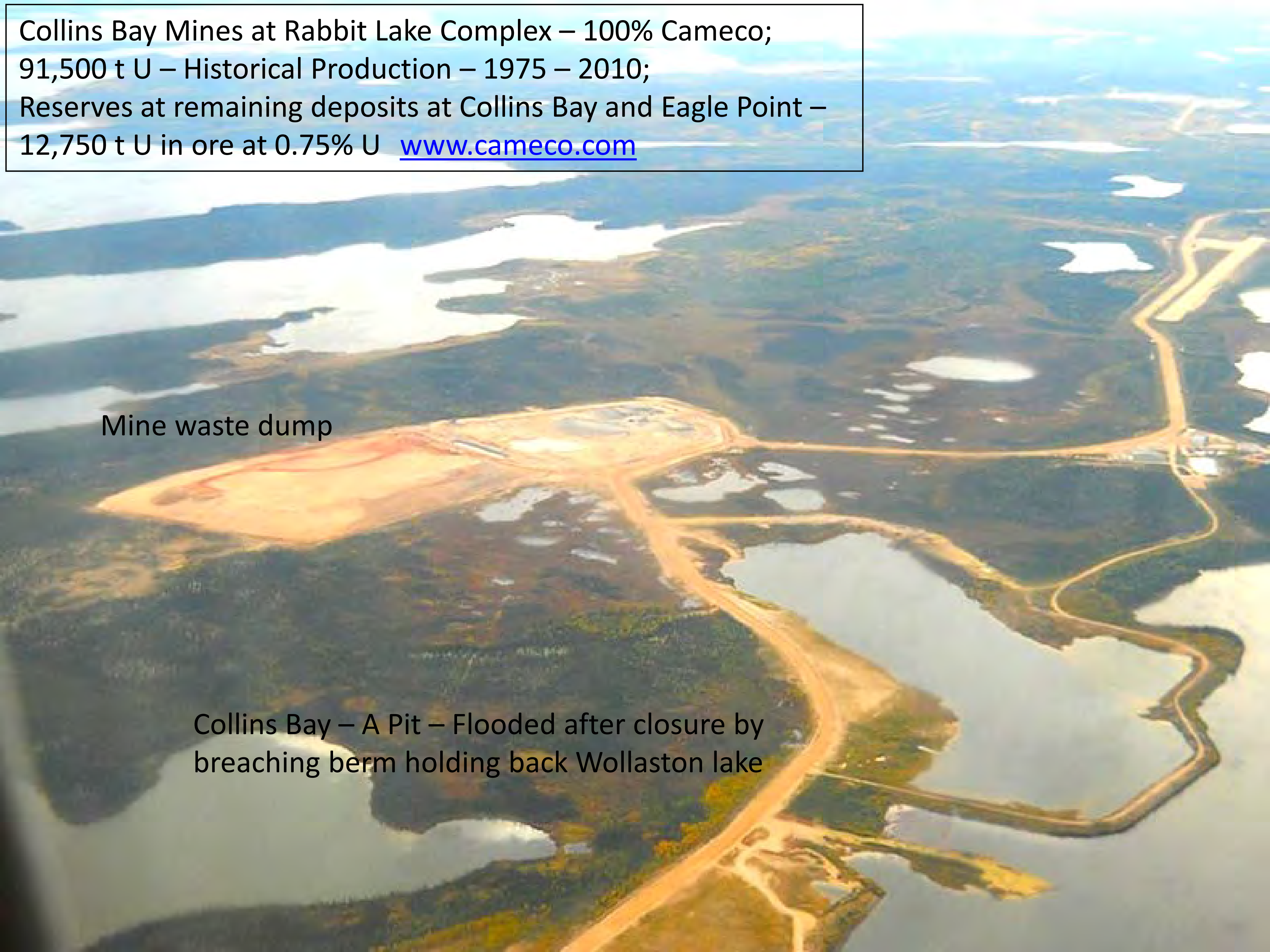
57% of ore to milled at Key Lake; 43% to be milled at McClean Lake

Cigar Lake mine

McClean Lake Complex –Sue Site
70% Areva; 22.5% Denison; 7.5% OURD, Ltd.
23,000 t U produced from Sue Site Mines; Reserves 8,000 t U in ore at 2.2% U; No mines current operating – www.denisonmines.com
McClean Lake mill at JEB Site north of Sue Site


McClean North/Caribou Deposits - Yet to be mined
5,207 t – indicated resources – 2.79% U; 3,556 t – inferred resources – 0.69% U (2007)
Sue B Pit – mined out
Sue C Pit Including
Sue A Pit)– mined out
Sue E Pit – mined out
McClean Lake Mine
– Sue Complex

Collins Bay Mines at Rabbit Lake Complex – 100% Cameco;
91,500 t U – Historical Production – 1975 – 2010;
Reserves at remaining deposits at Collins Bay and Eagle Point – 12,750 t U in ore at 0.75% U www.cameco.com



Mine waste dumps at Collins Bay portion of Rabbit Lake Complex

Ex-Japan PM disavows nuclear power

http://www.echo.net.au/2014/08/ex-japan-pm-disavows-nuclear-power/

It seemed an unlikely pairing: a meeting between the Japanese prime minister who oversaw the response to the Fukushima nuclear disaster and traditional Aboriginal owners of the land at Kakadu that supplied the uranium to Japan's reactors.

Naoto Kan was prime minister of Japan during the Fukushima nuclear crisis that gripped the country following the earthquake and tsunami of March 11, 2011.

On Saturday he travelled to Jabiru in Kakadu National Park, about 260km east of Darwin, to share his experiences with the Mirarr traditional owners of the land partly occupied by the Ranger uranium mine.

He will travel to Perth, Canberra and Brisbane in coming days to highlight concerns about the uranium trade.

Traditional owner and chairwoman of the Gundjeihmi Aboriginal Corporation, Annie Ngalmirama, greets former Japanese prime minister Naoto Kan in Jabiru, Kakadu National Park, on Saturday. AAP Image/supplied, Dominic O'Brien

The nuclear crisis at Fukushima was fuelled by uranium that came from this area; it confirmed the worst fears Aboriginal people had from as early as 1976, that one day there would be a problem, either here or overseas, from the mining in this place,' said Justin O'Brien, CEO of the Gundjeihmi Aboriginal Corporation that represents the Mirarr traditional owners.

'It's important for the former prime minister to see the front-end impacts of the nuclear fuel cycle, how devastating they've been for this community.'

Thank you for your time and attention