Saskatchewan Ministry of the Economy

Uranium Mining Supply Chain Requirement Guide

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1. EXECUTUVE SUMMARY

Mining and milling operations in Saskatchewan have produced uranium continuously since 1953. This guide provides a description of the activities throughout the expected 50 plus year life of a current typical Saskatchewan uranium mining project, and presents order-of-magnitude estimates of the expenditures for supplies and services in each and every stage of the project. These expenditures total more than $10 billion.

Saskatchewan uranium mining operators have the following priorities for sourcing supplies and services, ranked from higher to lower:

- Northern Saskatchewan
- Saskatchewan
- Canada
- Others

Note that Northern Saskatchewan provides mainly services.

Expenditure estimates are made for a model project that includes one of an underground or an open pit mine, a mill, and the site hosting these production plants and the ancillary support facilities. The model project will produce 12,000,000 lb U_3O_8 annually as yellowcake from ore grading 4% U_3O_8.

This guide discusses eight stages in the model project life cycle:

- Exploration
- Regulatory licences, permits and approvals
- Engineering, procurement and construction management
- Mine and surface facilities construction
- Commissioning and ramp-up
- Operations and maintenance
- Closure and reclamation
- Long term site monitoring

We estimate a typical duration for each stage, but this duration is a guide only as the actual duration of each stage has varied between projects.

2. INTRODUCTION

Mining and milling operations in Saskatchewan have produced uranium continuously since 1953, with a new mine/mill development approximately every 12 years on average. Over that period, Saskatchewan has been one of the world's premier uranium producers, yielding approximately 786 million lb. of U_3O_8.

During the anticipated 50 plus year life of a typical Saskatchewan uranium mining project, in excess of $10 billion will be spent on goods and services to develop, construct, operate, maintain and eventually decommission the facilities, including the reclamation of all disturbed lands.

This guide provides information on the quantity, value and scheduling of supplies and services purchased by typical Saskatchewan uranium mining project owners and/or operators to discover, develop, operate, maintain, decommission and close out projects.

The intended readers and users of this guide are current supply and service providers to the industry, potential supply and service providers, and the Government of Saskatchewan to help guide its programs and support for the industry.

This guide attempts to give a balanced understanding of supplies and services purchased during both the capital-intensive engineering design and construction stage, and the operations, maintenance and decommissioning stage. Spending in the earlier stage is relatively rapid, but total value of purchases is greater through the latter stage.

This document has been prepared by AMEC Americas Limited (AMEC) for Government of Saskatchewan. This document has been prepared as a general planning guideline intended to establish an understanding of sector specific supply chain costs. This document is not intended to serve as a basis for facility or application specific design, cost forecasting, defining regulatory requirements, or for investment purposes. This document may only be used by its intended readers in the context and for the express purpose for which it has been prepared. Any other use or reliance on this document by any user is at that party's sole risk and responsibility.

3. HISTORY OF URANIUM MINING AND MILLING IN SASKATCHEWAN

Mining and milling operations in Saskatchewan have produced uranium continuously since 1953, with a new mine/mill development approximately every 12 years on average. Over that period Saskatchewan has been one of the world's premier uranium producers, yielding approximately 786 million lb. of U_3O_8. Refer to Table 3:1.

Table 3:1 General data for Saskatchewan uranium mills

Mill	Production Start-up (year)	Total Lifetime Production at end 2012 (M lb. U_3O_8)	Current Licensed Annual Production Capacity (M lb. U_3O_8)	Current Status as of March 2014
Beaverlodge	1953	47	N/A	Shut down in 1982
Rabbit Lake	1975	186	16.9	Operating
Cluff Lake	1980	62	N/A	Shut down in 2002
Key Lake	1983	441	18.7	Operating
McClean Lake	1999	50	12 (preparing for 24)	Preparing to process Cigar Lake ore

The earliest mines and mills were in the Beaverlodge camp near Uranium City. Although there were approximately ten smaller operations, Eldorado Nuclear's Beaverlodge operation was by far the largest and longest operating, accounted for 95% of the uranium produced from this region. The large Beaverlodge alkaline leach mill, with oxygen oxidant and uranium precipitation with sodium hydroxide, processed ore from the Ace-Fay-Verna East underground mine and the Verna open pit.

Eldorado Nuclear

Figure 3:1 Beaverlodge site
(front mill, mid Ace-Fay-Verna east head frame, rear landing strip)

Uranium milling in Saskatchewan's Athabasca Basin began at Rabbit Lake in 1975. The Rabbit Lake mill processed ore from four open pit mines, Rabbit Lake, A-zone, B-zone and D-zone. Currently the mill is fed by the Eagle Point underground mine. The initial milling process at Rabbit Lake was atmospheric acid leaching with sodium chlorate oxidant, solid/liquid separation in a counter current decantation (CCD) circuit, ammonia solvent extraction (SX) stripping and uranium precipitation with ammonia. In 1982, Rabbit Lake changed to a totally ammonia-free process that uses strong acid (400 g/L H_2SO_4) solvent extraction stripping and uranium precipitation with hydrogen peroxide. Simultaneous with these mill process alterations, Rabbit Lake designed, installed and commissioned the world's first pervious surround in-pit tailings management facility (TMF.) Raise water, essentially water drained and squeezed from the consolidating tailings, is collected and returned to the mill for reuse or treatment. In the Athabasca Basin, the in-pit TMF is considered the state of the art for tailings management.

Rabbit Lake was also the first mill to process a dirty ore. Dirty ore and clean ore have become part of the Athabasca Basin lexicon, where "dirty" means having a substantial arsenic content and "clean" means essentially arsenic-free.

Cameco

Figure 3:2 Rabbit Lake mill site, in-pit TMF upper right corner

Cameco

Figure 3:3 Rabbit Lake open pit mine

The wide range of ore grades mined in the Athabasca Basin is shown in Table 3:2. In its early years (Phase I), the Cluff Lake mill processed a gravity concentrate of D open pit mine ore grading on average 45% U with a very high ratio of U to contaminants. This high grade circuit included acid leaching with sodium chlorate oxidant and direct uranium precipitation using magnesia. Next, during 1983 and 1984, Cluff Lake processed the gravity concentrate residue, which graded 2% to 3% U and required the installation of a salt strip solvent extraction circuit. Stored leach residue from the initial very high grade ore assayed 58 g/t gold. This residue was treated in 1987 and 1988 for gold recovery using a cyanide leach with carbon-in-pulp gold absorption, with subsequent uranium recovery. In Phase II from 1984 to 2002, the Cluff Lake mill processed lower grade ores (0.3 to 1% U) from a four open pit mines (Claude, N Open Pit, DJ North, and DJ Extension) and four underground mines (OP, DP, N Underground, and DJ.) The Phase II milling process included atmospheric acid leaching with sodium chlorate oxidant, CCD solid/liquid separation, SX with sodium chloride stripping, and magnesia uranium precipitation.

Table 3:2 Saskatchewan mill feed grade ranges

Mill	Highest (% U_3O_8)	Lowest (% U_3O_8)
Beaverlodge	0.37	0.18
Rabbit Lake	5.6	0.3
Cluff Lake	*53	0.4
Key Lake	**6	2.5
McClean Lake	***1.5	0.5

***** Gravity concentrate from 8% grade D ore body
****** Diluted down from ~16% (McArthur River Mine)
******* Expected to rise to ~18% (Cigar Lake Mine)

AREVA

Figure 3:4 Cluff Lake mill site

The Key Lake mill was designed to deal with dirty (averaging 1.5% arsenic) and relatively high uranium grade (up to 3.0% U_3O_8) ores from the Gaertner and Deilmann open pit mines. The initial process used high pressure acid leaching in autoclaves with oxygen oxidant, CCD solid/liquid separation, ammonia SX stripping and uranium precipitation with ammonia.
In the fall of 1994, explosions began occurring in the Key Lake leach autoclaves. The cause was quickly traced to high levels of hydrogen in the vapour head atop the leaching slurry. Detailed investigation using deuterium-doped acid showed the hydrogen did not come from the acid. It was soon found that the ore itself was generating hydrogen gas. Tests with ores from other Athabasca Basin uranium mills showed that all of them generated hydrogen during an acid leach. Key Lake has moved away from autoclave leaching, and currently uses pachucas and mechanically agitated tanks, still with oxygen oxidant. Processing relatively high molybdenum (Mo) grade ore required an Mo removal process to avoid refinery penalties. Key Lake invented a process to treat the SX loaded strip solution in a four-stage SX process with LIX 63. In 2000, the Key Lake mill started processing ore from the McArthur River underground mine. The mined ore, averaging approximately 16% U_3O_8, is shipped from the mine to the mill as a slurry. At Key Lake ground waste rock slurry is used to dilute the mill feed ore grade to approximately 4 to 6% U_3O_8.

Cameco

Figure 3:5 Key Lake mill site, Deilmann in-pit TMF in rear

AREVA

Figure 3:6 McClean Lake site, JEB in-pit TMF on left, McClean Lake mill on right

The McClean Lake mill was designed for feed grades as high as 30% U, in anticipation of processing Cigar Lake ore, which averages approximately 18% U_3O_8. The mill has previously processed ore from the JEB open pit mine and the Sue C, A, E and B open pit mines. The Cigar Lake underground mine began delivering ore to the McClean Lake mill in March 2014. The McClean Lake process includes atmospheric acid leaching with hydrogen peroxide oxidant, CCD solid/liquid separation, ammonia SX stripping and uranium precipitation with ammonia.

Table 3:3 Summary of Saskatchewan uranium mill processes

Mill	Comminution	Leach	Solid/Liquid Separation	Impurity Removal	Product Precipitation
Beaverlodge	SAG + Ball	Alkaline, O_2 oxidant	Drum Filter	None	NaOH, Dry
Rabbit Lake	SAG + Ball	Acid, $NaCLO_3$ oxidant	CCD	SX, H_2SO_4 strip	H_2O_2, Dry
Cluff Lake	Crush + Ball	Acid, $NaClO_3$ oxidant	CCD	SX, NaCl strip	MgO, Dry
Key Lake	SAG + Ball	Acid, O_2 oxidant	CCD	SX, NH_3 strip	NH_3, Calcine
McClean Lake	SAG + Ball	Acid, H_2O_2 oxidant	CCD	SX, NH_3 strip	NH_3, Calcine

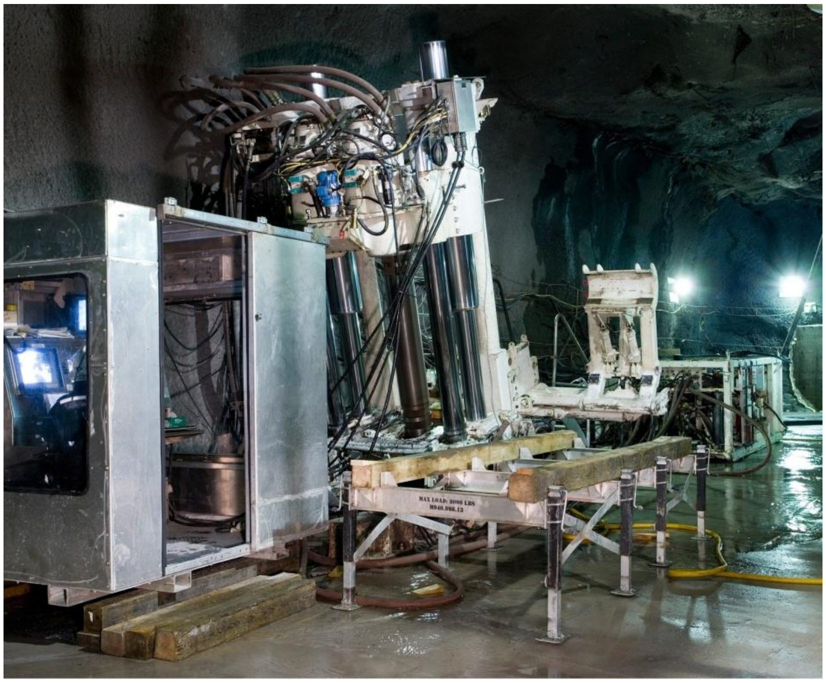
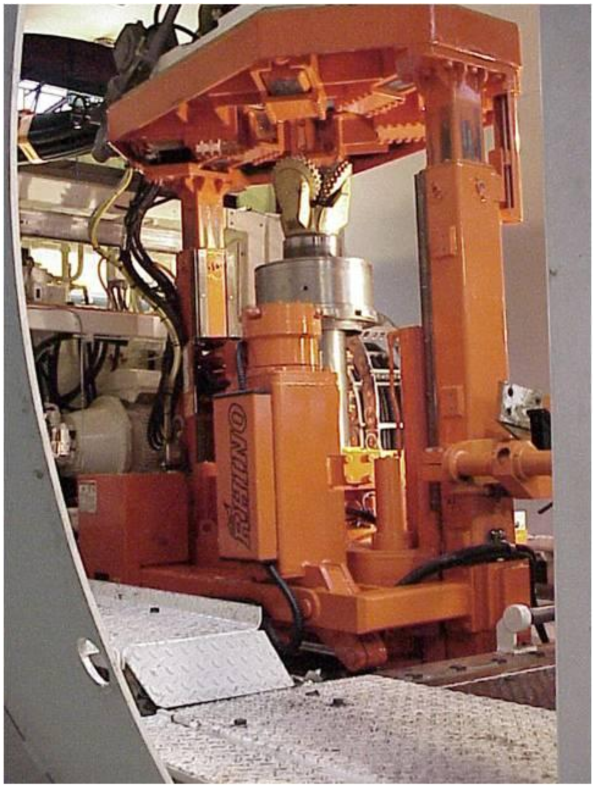

Cameco

Figure 3:7 Raise boring mining machine, McArthur River



Cameco

Figure 3:8 Jet boring mining machine, Cigar Lake

Notable developments and innovations in the Saskatchewan uranium mines and mills include:

- Developing a large, successful alkaline leach mill, at Beaverlodge.
- Strong acid stripping and uranium peroxide precipitation, at Rabbit Lake.
- The first pervious surround in-pit TMF, at Rabbit Lake.
- Processing dirty (that is, high arsenic) ores, at Rabbit Lake, Key Lake and McClean Lake.
- Successfully sequestering arsenic in mill tailings as basic ferric arsenate, at Key Lake, McClean Lake and Rabbit Lake.
- Processing very high grade ore (up to 53% U_3O_8), at Cluff Lake.
- Gold recovery from uranium leach residue, at Cluff Lake.
- Management of hydrogen generated from the ore during an acid leach, at Key Lake.
- Invention of a process to remove molybdenum from SX pregnant strip solution using a four-stage SX process with LIX 63, at Key Lake.
- Crystallizing ammonium sulphate, a fertilizer by-product, to control ammonia in effluent, at Key Lake and McClean Lake.

- Installation and use of monitoring ponds to assure on specification effluent prior to discharge, at Key Lake, McClean Lake, McArthur River and Cigar Lake.
- Ground freezing for underground mine water control, at McArthur River and Cigar Lake.
- Raise bore remote mining of high grade ore, at McArthur River.
- Jet boring remote mining of high grade ore, at Cigar Lake.
- Underground ore grinding followed by hoisting and transport of high grade ore as a slurry, at McArthur River and Cigar Lake.

Table 3:4 Summary of Saskatchewan uranium mine types

Site	Mine	Mine Type
Beaverlodge	Ace-Fay-Verna east	Underground
Beaverlodge	Verna	Open pit
Rabbit Lake	Rabbit Lake	Open pit
Rabbit Lake	A-zone	Open pit
Rabbit Lake	B-zone	Open pit
Rabbit Lake	D-zone	Open pit
Cluff Lake	D	Open Pit
Cluff Lake	Claude	Open pit
Cluff Lake	N open pit	Open pit
Cluff Lake	DJ north	Open pit
Cluff Lake	DJ extension	Open pit
Cluff Lake	OP	Underground
Cluff Lake	DP	Underground
Cluff Lake	N underground	Underground
Cluff Lake	DJ	Underground
Key Lake	Gaertner	Open pit
Key Lake	Deilmann	Open pit
McArthur River	McArthur River	Underground
McClean Lake	JEB	Open pit
McClean Lake	Sue C	Open pit
McClean Lake	Sue A	Open pit
McClean Lake	Sue E	Open pit
McClean Lake	Sue B	Open pit
Cigar Lake	Cigar Lake	Underground

4. MINES AND MILL MODELS

The wide ranges of ore grade and production rate experienced by Saskatchewan uranium mines and mills are described above in Section 3. For this guide, AMEC has selected models that are representative of the current industry. There are two mine models and one mill model.

4.1 Base Data

The selected base data are:

Ore grade	4% U_3O_8
Annual ore feed to mill	143,000 tonnes
Annual production from the mill	12,000,000 lb. U_3O_8 as yellowcake

4.2 Underground Mine Model

The selected underground mine model is:

Mine access	Shaft
Mining	Raise boring and blasthole stoping
Ore transfer to mill on surface	Hoist ore as rock and truck to mill
Ground water control	Freeze wall
Backfill	Cemented rockfill (crf)

Other potential underground mine options not selected for this model are:

Mine access	Ramp from surface
Mining method	Jet boring
Mining method	Box hole boring
Ore transfer to mill on surface	Hydraulic hoisting and pump to mill
Ground water control	Bulk freezing

4.3 Open Pit Mine Model

The selected open pit mine model is:

Mine area preparation	Remove overburden and drain swamp
Mine access	Pit wall ramp road
Mining	Truck and excavator
Ore transfer to mill on surface	Truck
Ground water control	Perimeter dewatering wells

Other potential open pit mine options not selected for this model are:

Mine area preparation	Dike and dewater a lake
Ground water control	No dewatering wells

4.4 Mill Model

The selected mill model is:

Ore comminution	SAG mill and ball mill
Ore leaching	Acid (sulphuric acid)
Leach oxidant	Sodium chlorate
Post leach solid liquid separation	Counter current decantation
Uranium purification	Solvent extraction, strong acid strip
Yellowcake precipitant	Hydrogen peroxide
Yellowcake preparation for drumming	Drying
TMF type	In pit
TMF construction	Purpose built

Other potential mill options not selected for this model are:

Ore comminution	Crusher, rod mill and ball mill
Ore leaching	Alkaline (sodium carbonate/bicarbonate)
Leach oxidant	Oxygen
Leach oxidant	Hydrogen peroxide
Post leach solid liquid separation	Belt filtration
Uranium purification	Solvent extraction, ammonia strip
Uranium purification	Resin-in-pulp (after acid leaching)
Yellowcake precipitant	Ammonia
Yellowcake preparation for drumming	Calcining
Toll milling	Ore processed in a mill owned and operated by another firm on another site
Underground milling	For high grade ore
TMF construction	Previously mined out open pit

Based on these selected models, this guide provides detailed descriptions of and cost estimates for the supplies and services required during the entire lifetime of Saskatchewan uranium projects.

NOTE: The other potential options tabulated above are for information only. Detailed descriptions and cost estimates are not provided for the other potential options.

5. URANIUM FACILITY LIFE CYCLE STAGES

Figure 5:1 provides a high level look at a typical Saskatchewan uranium mining project life cycle for a conventional mine and milling facility designed to produce 12 million pounds annually of U_3O_8 in yellowcake form. The duration of a project may vary substantially, particularly at the front end during the exploration and regulatory approval stages and at the conclusion of the operations phase when the site must be decommissioned and monitored for long term environmental compliance. During the anticipated 50 plus year life of a typical project, in excess of $10 billion will be spent on goods and services to develop, construct, operate, maintain and eventually decommission the facilities including the reclamation of all disturbed lands.

A brief description of the major lifecycle stages selected for this guide follows:

- **Exploration**: This initial stage includes a variety of exploration techniques with the objective of discovering a potentially economic uranium deposit. Typically, airborne geophysical exploration methods are used to identify promising targets for follow up ground surveys and diamond core drilling. Following identification of a potential mineral resource, the next phase is to assess its size and scope in terms of tonnes and ore grade. Additional diamond drilling is usually required to provide information for modeling the orebody.

- **Regulatory Licences/Permits/Approvals**: This stage of the project encompasses studies, reports and assessments to obtain the information necessary for the preparation of the submissions required to obtain the various construction and operating approvals required from provincial and federal regulatory authorities.

- **Engineering/Procurement/Construction Management (EPCM):** While the environmental assessment stage is in progress, engineering studies are undertaken to assess the feasibility of the project. Normally, engineering progresses through a series of stage gates to arrive at accurate capital and operating costs. Toward the middle of engineering, procurement activities are initiated to obtain the equipment and services needed to construct the necessary infrastructure for the project. Construction management services, typically provided by the engineering company designing the facilities, are required for the duration of the construction stage.

- **Mine/Surface Facilities Construction**: Typically construction activities are initiated around the middle of the EPCM stage. A construction period of about three years is anticipated for a uranium mine/mill of this size.

- **<u>Commissioning/Ramp-up</u>**: Commissioning of the new facilities is initiated towards the end of construction, followed by a period in which capacity is ramped up to achieve production targets in terms of ore tonnes, ore grade and U_3O_8 production.

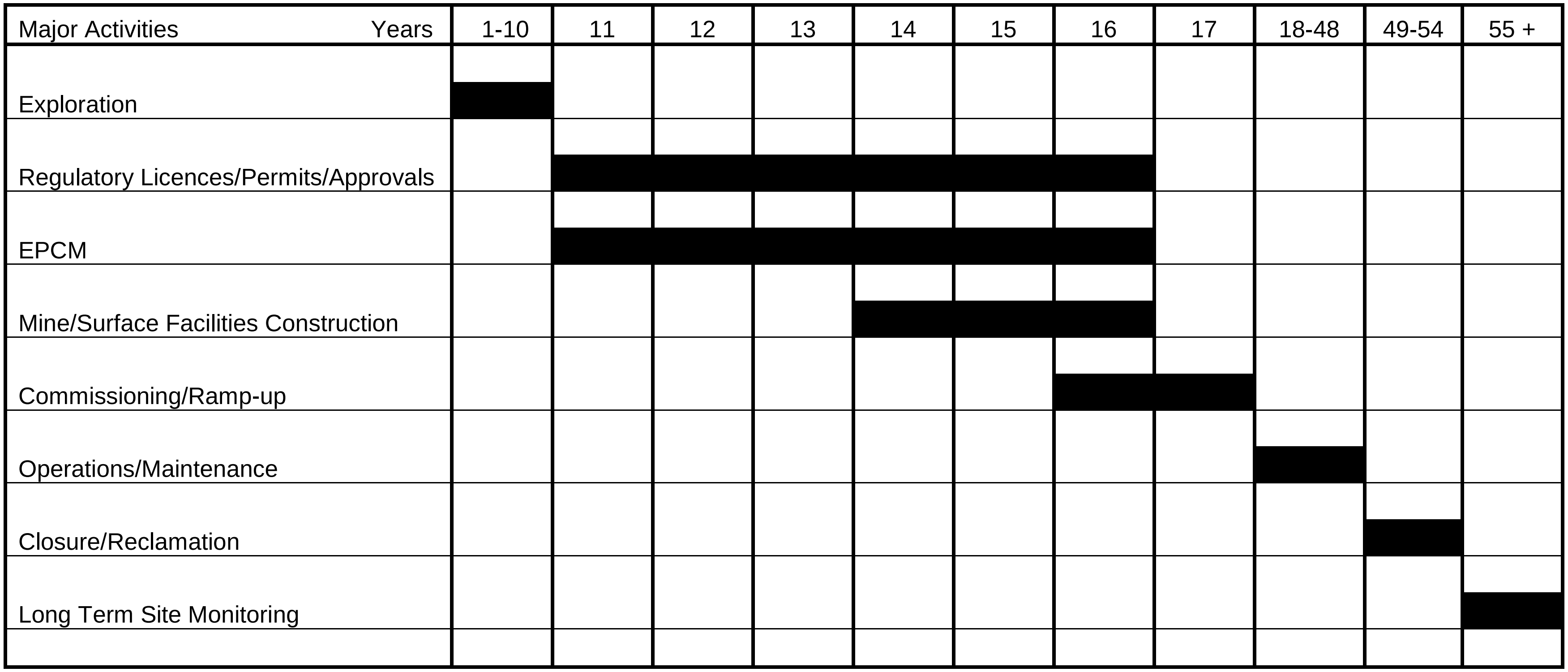


Figure 5:1 Typical Saskatchewan uranium mine project life cycle

- **Operations/Maintenance**: A lengthy period of regular operations and maintenance will normally occur once the new facilities meet their production targets. The expected operating life of a new uranium mining project depends on the size of the ore body and the selected capacity of the production facilities. A twenty year design life is typical. However, with good maintenance, lifetimes of forty years or more are achievable.

- **Closure/Reclamation**: An approved closure and site reclamation plan must be implemented once the original ore body has been exhausted and it has been determined that there is little or no potential for the discovery of new uranium ore sources in the vicinity of the existing mill site.

- **Long Term Site Monitoring**: Once the site has been successfully reclaimed, a lengthy period of environmental monitoring must occur before the property can be returned to the Crown.

The lifecycle stages are developed in the following sections of this report in terms of the value of goods and services that are necessary for the successful execution of the model project. In addition, operating cost estimates are provided encompassing the goods and services currently required for the total Saskatchewan uranium industry as it exists at the time this guide was prepared.

6. EXPLORATION

Most of the uranium deposits in Saskatchewan are associated with the Athabasca Basin, an approximately 100,000 square kilometer sandstone basin that occupies much of the northernmost one-quarter of the province (Figure 6:1). The style of uranium deposits is known as unconformity-type deposits, where uranium is constrained to faults in the Archean basement rocks near the contact with the overlying sandstone of the Athabasca Basin. At its deepest parts, the Athabasca Basin can be as much as 1.5 kilometers from the surface. The uranium deposits have some of the highest grades in the world, but are relatively small in size making them difficult to find. These factors make uranium exploration in Saskatchewan a very challenging endeavor. In addition, much of the Athabasca Basin remains remote wilderness with limited road access.

Exploration projects make use of all geoscience disciplines, including geophysics, geochemistry, surface and subsurface geological mapping and sampling. This work is supported by various logistical and analytical services. A typical greenfields exploration project will include the following stages:

- Area selection
- Target identification
- Drill testing and resource evaluation

Details of the type of services involved in these exploration stages, and associated expenditure estimates are provided in the following sections. The services and related cost estimates are for the discovery and resource identification development of a uranium deposit that will support a mine grade of 4% U_3O_8 with a production of 12 million pounds U_3O_8 per annum. The cost estimates are for each stage. The duration of each stage varies according to the effort expended (that is, the rate of diamond drilling.)

6.1 Area Selection

The first stage of exploration involves identifying the location of faults that are favourable for containing deposits of uranium. These faults would ideally contain graphite, a naturally occurring concentration of carbon that promotes the accumulation of uranium in the geological environment. The faults tend to be located along the edges of rock bodies and the graphite is electrically conductive. In addition, circulating geothermal water carrying uranium in solution within the faults causes changes in the rocks that are important to detect.

Various geophysical techniques are applied in order to identify those areas that have conditions favourable for uranium deposition and accumulation. Magnetic and various electro-magnetic geophysical surveys are undertaken to identify potential graphitic faults and rock body contacts. Gravity surveys are used to detect changes in rock properties and identify areas where rocks have been changed by geothermal activity. Radiometric surveys are used to try and detect concentrations of uranium directly. Many of these geophysical surveys are conducted by air using fixed wing aircraft or helicopters to overcome the problem of limited road networks.

It is usually during the area selection stage that new mineral claims are staked or existing mineral claims may be reduced or increased using the Government of Saskatchewan's Mineral Administration Registry System (MARS).

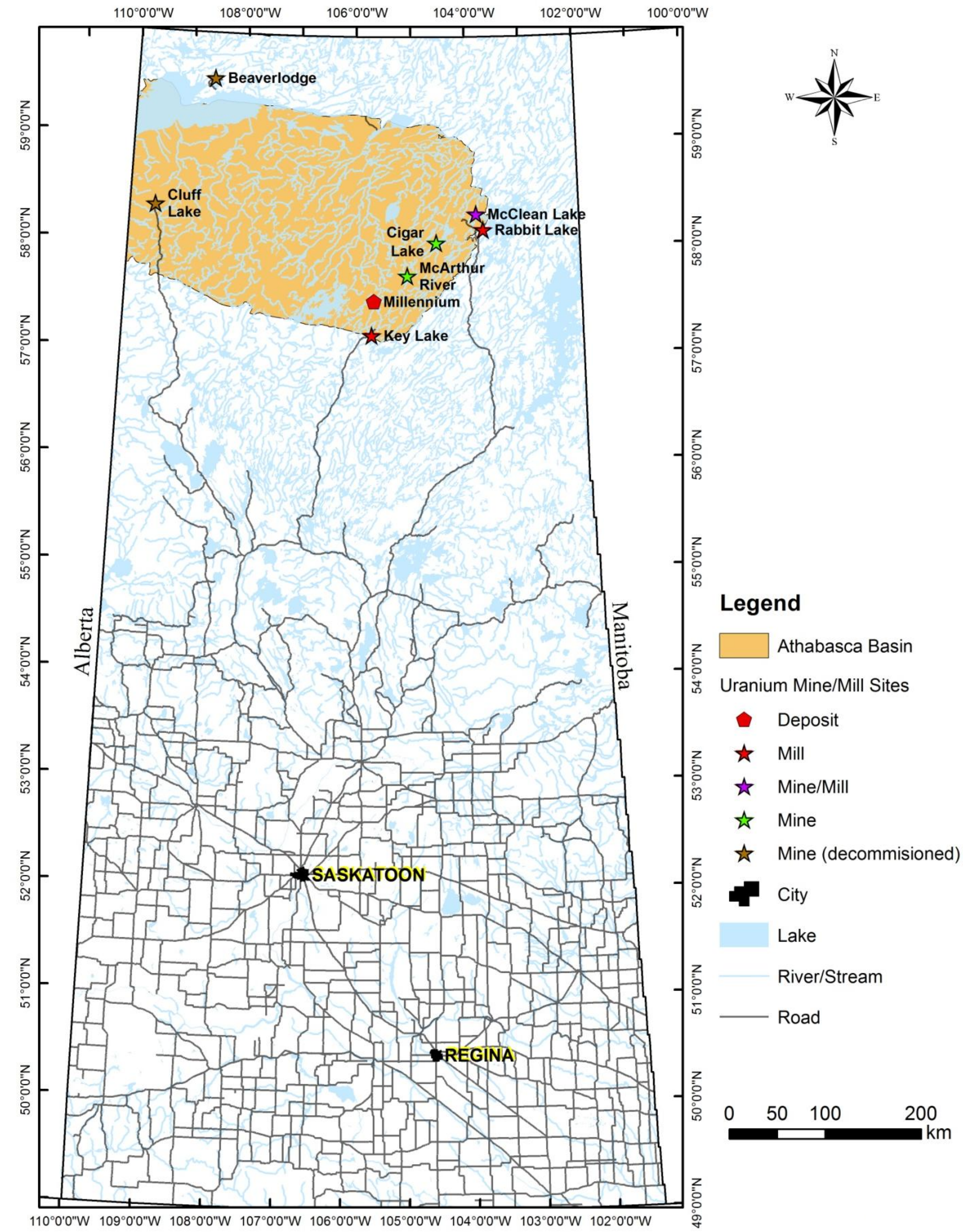


Figure 6:1 Athabasca Basin location map

After favourable areas are identified from aerial surveys, more detailed ground surveys using these same geophysical techniques are usually conducted to gain further detail. Also, rock boulders, soil, lake, stream and vegetation geochemistry surveys are usually undertaken to sample uranium levels and changes in ground and rock chemistry in the vicinity of positive geophysical signals. These analysis techniques are used complimentary to each other to identify potential targets for uranium deposits. Table 6:1 identifies services and estimated expenditures associated with the area selection stage.

Table 6:1 Estimated expenditures related to the area selection stage

Service	Average Rate	Estimated Cost	Industry Cost*
Airborne magnetic/ electromagnetic/resistivity	$150 per km	$1,500,000	$6,000,000
Airborne radiometric	$500 per km	$5,000,000	$20,000,000
Professional consulting	$225 per hour	$225,000	$900,000
Logistical services	$100 per hour	$216,000	$864,000
* Assumption for 4 similar projects running concurrently			

Figure 6:2 Airborne magnetic survey aircraft

6.2 Target Identification

This stage involves further refinement of the results obtained in the area selection stage. More focused and detailed geophysical and geochemical ground surveys will be undertaken. Geophysical ground surveys usually require some preparation work such as surveying and establishing a network of cut-lines through the ground vegetation. Temporary camps of various sizes may be established to accommodate the work crews. Consultants may be employed for specialized analysis of geological results. Table 6:2 identifies services and estimated expenditures associated with the target identification stage.

Table 6:2 Estimated expenditures related to the target identification stage

Service	Average Rate	Estimated Cost	Industry Cost*
Ground geophysics	$150 per km	$375,000	$1,500,000
Ground geochemistry	$100 per km	$250,000	$1,000,000
Professional consulting	$225 per hour	$50,000	$200,000
Technical consulting	$150 per hour	$50,000	$200,000
Analytical services	$110 per sample	$11,000	$44,000
Logistical services	$100 per hour	$110,000	$440,000
* Assumption for 4 similar projects running concurrently			

Figure 6:3 Ground gravity survey

6.3 Drill Testing and Resource Evaluation

Once specific targets are identified, the next stage is to drill test them to recover rock cores for direct identification and sampling. The services of a drill contractor are obtained along with the required logistical services. These can include camp and catering services, various equipment and truck rentals etc. The services of geochemistry and other geotechnical analytical laboratories are engaged. After drilling has confirmed the presence of a potential uranium deposit, the exploration work focuses on quantifying the amount of U_3O_8 in the ground. Included is more geotechnical work to understand the geological conditions associated with the potential deposit. Drill testing is ongoing to collect enough information suitable for mine design planning, determination of economic resource extraction and determining the mine life. Table 6:3 identifies services and estimated expenditures associated with the drill testing and resource evaluation stage.

Table 6:3 Estimated expenditures related to the drill testing and resource evaluation stage

Service	Average Rate	Estimated Cost	Industry Cost*
Drilling services	$200 per m	$25,000,000	$100,000,000
Borehole geophysics	$50 per m	$6,700,000	$26,800,000
Analytical services	$15,000 per hole	$1,500,000	$6,000,000
Logistical services	$60,000 per year	$600,000	$2,400,000
* Assumption for 4 similar projects running concurrently			

AMEC has shown industry cost for 4 similar projects running concurrently because we see this as a reasonable representation of an industry average. The number of concurrent projects at any one time varies widely, depending on market conditions and expectations.

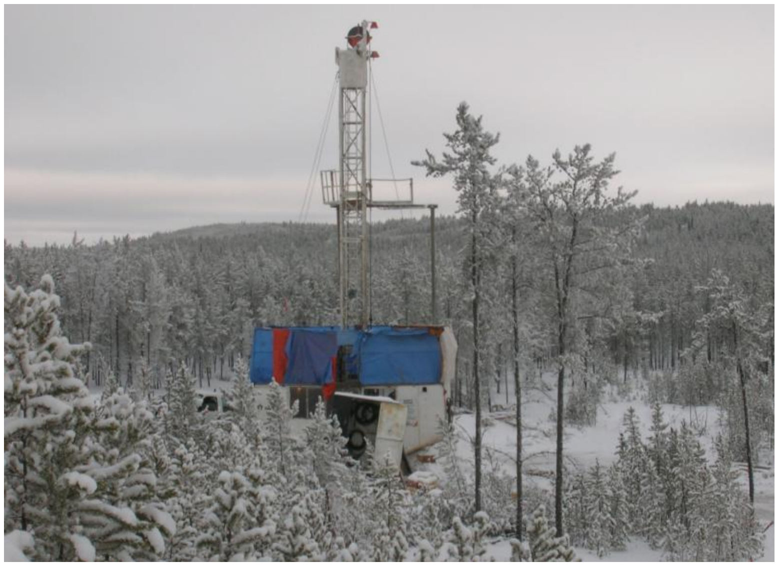


Figure 6:4 Diamond drilling rig at the Cameco Millennium deposit

Denison

Figure 6:5 Athabasca Basin uranium exploration diamond drill core

6.4 Exploration Service Provider Information

Further information on service providers to the Saskatchewan uranium exploration industry can be found on InfoMine (http://www.infomine.com), and the Northern Miner Suppliers Buyers Guide (http://www.northernminer.com/esource/).

7. REGULATORY LICENCES, PERMITS AND APPROVALS

7.1 Approval Processes

Uranium mine and mill facilities in Saskatchewan are regulated both federally and provincially through comprehensive acts and associated regulations. All phases of uranium mine and mill operations, from exploration through construction, operation, closure and abandonment require specific approvals and, with the exception of early phase exploration activities, must also be supported by comprehensive environmental assessments. Licences issues under federal jurisdiction must be supported by environmental assessments completed to meet the requirements of the *Canadian Environment Assessment Act*, whereas permits issued under provincial jurisdiction must be supported by assessments that meet the requirements of the *Saskatchewan Environmental Assessment Act*. Figure 7:1 demonstrates the federal licensing and assessment process. Figure 7:2 demonstrates the provincial environmental assessment process, which in turn supports provincial permitting efforts.

The requirements of the federal and provincial assessment processes are coordinated under the *Canada-Saskatchewan Agreement on Environmental Assessment Cooperation* in order to reduce duplication of effort, while still meeting the specific requirements of both jurisdictions.

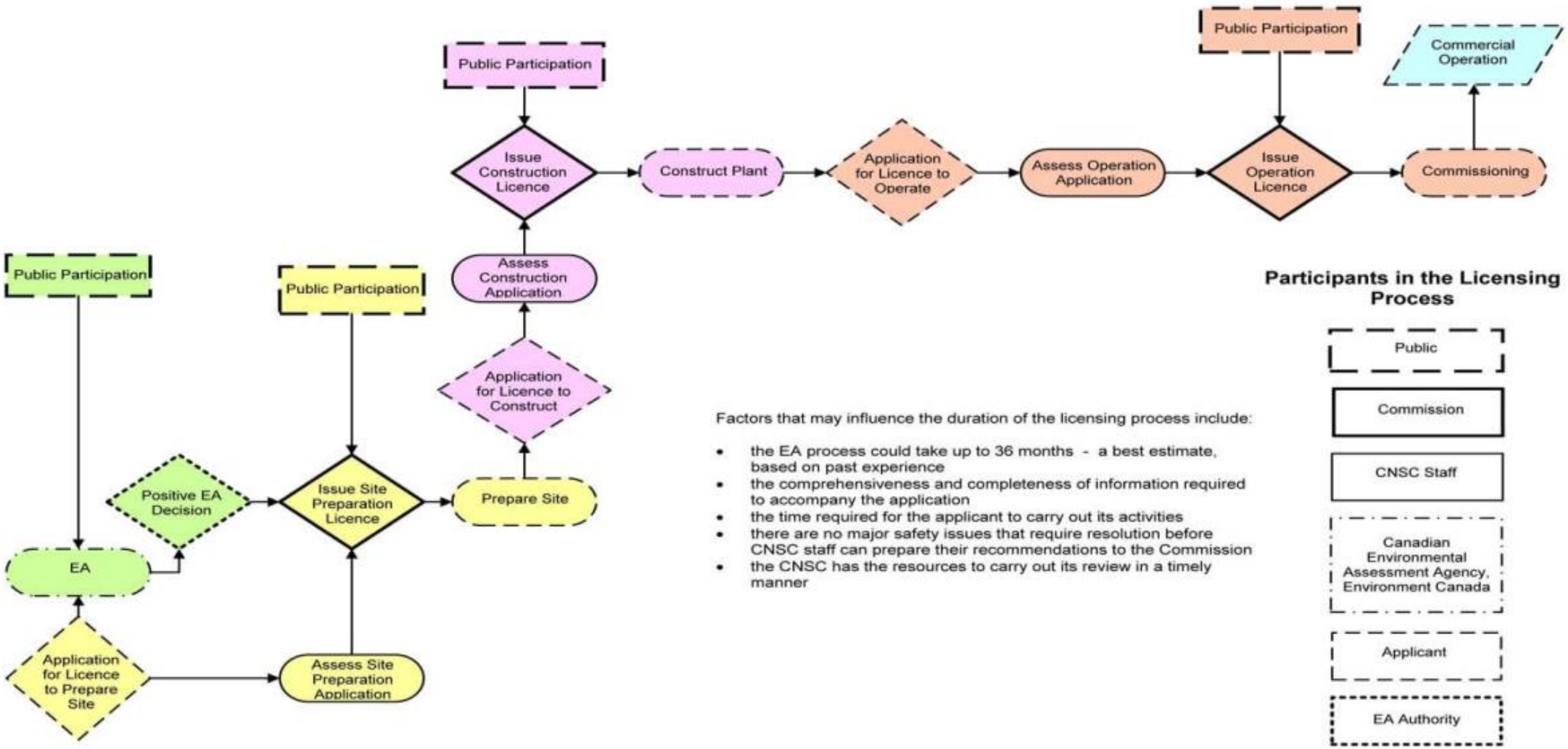


Figure 7:1 Federal licensing and assessment process

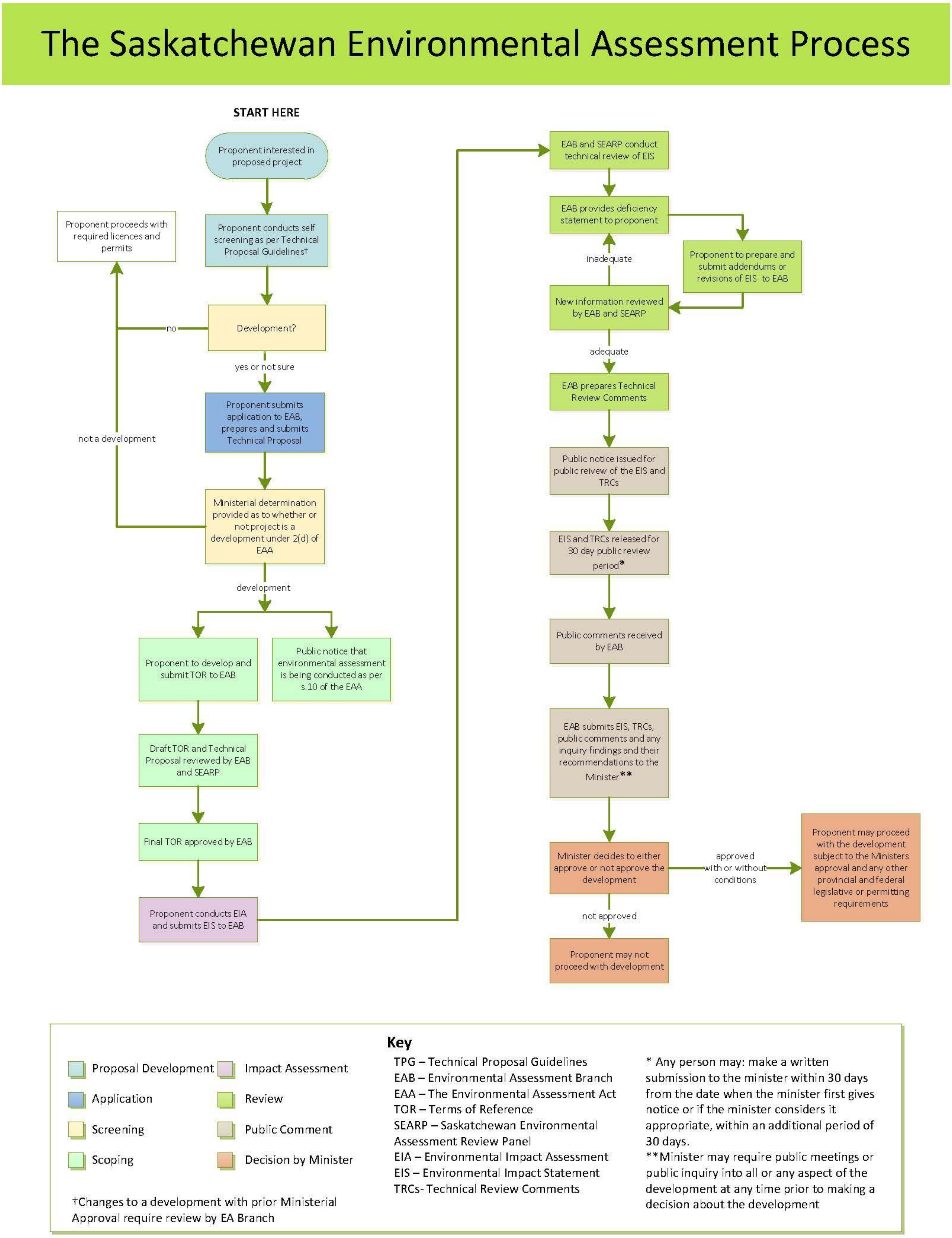


Figure 7:2 Provincial assessment process

7.2 Licences and Permits Required

7.2.1 Federal Regulation

Table 7:1 identifies federal regulatory agencies that are or could be involved in regulating uranium mine and mill facilities depending upon the environmental, socioeconomic and other project-specific regulatory and statutory circumstances of each particular facility.

Table 7:1 Federal regulatory agencies

Canadian Nuclear Safety Commission
Canadian Environmental Assessment Agency
Environment Canada
Fisheries and Oceans Canada
Health Canada
Human Resources Development Canada
Indian And Northern Affairs Canada
Major Projects Management Office
National Energy Board
Natural Resources Canada
Transport Canada

The role of the Major Projects Management Office (MPMO) is to provide overarching project management and accountability for major resource projects in the federal regulatory review process. The objectives of the MPMO are to promote certainty and predictability in the regulatory system, avoid regulatory duplication and unnecessary delays in the review of major resource projects.

The lead federal regulator for the uranium industry is the Canadian Nuclear Safety Commission (CNSC.) The CNSC issues licences for uranium mine and mill facilities under the Nuclear Safety Control Act (NSCA). The NSCA provides general regulations with respect to licence applications and renewals, as well as Uranium Mine and Mill Regulations that are specific to these types of facilities. Guidance can also include information on best practices and domestic and international standards including standards published by the Canadian Standards Association (CSA).

As noted above, these licences, issued for all phases of a mine and mill through site preparation to closure, must be supported by environmental assessment(s) under the Canadian Environmental Assessment Act (CEAA).

7.2.2 Provincial Regulation

The Saskatchewan uranium industry is regulated at the provincial level by the Saskatchewan Ministry of the Environment under a number of acts, including the Environmental Management and Protection Act, the Clean Air Act, the Fisheries Act and through the issuance of surface leases and construction and operating permits, all with the primary intent of protecting the environment through the assessment and regulation of pollutant control facilities.

Saskatchewan's Environmental Assessment Act (SEAA) is administered directly by the Saskatchewan Environmental Assessment Branch. Saskatchewan is in the process of adopting a new, results-based model for environmental regulation that is intended to improve protection of the environment, while promoting innovative new tools in environmental management, including the Saskatchewan Environmental Code.

7.3 Types and Values of Services

The primary licensing/permitting phases of a uranium facility are:

1. Mine and Surface Facilities Construction (Section 9 of this guide).
2. Commissioning and Ramp-Up (Section 10 of this guide), followed by Operations and Maintenance (Section 11 of this guide).
3. Closure and Reclamation (Section 12 of this guide), followed by Long Term Site Monitoring (Section 13 of this guide).

Each of these phases must be supported by a formal environmental assessment.

7.3.1 Mine and Surface Facilities Construction

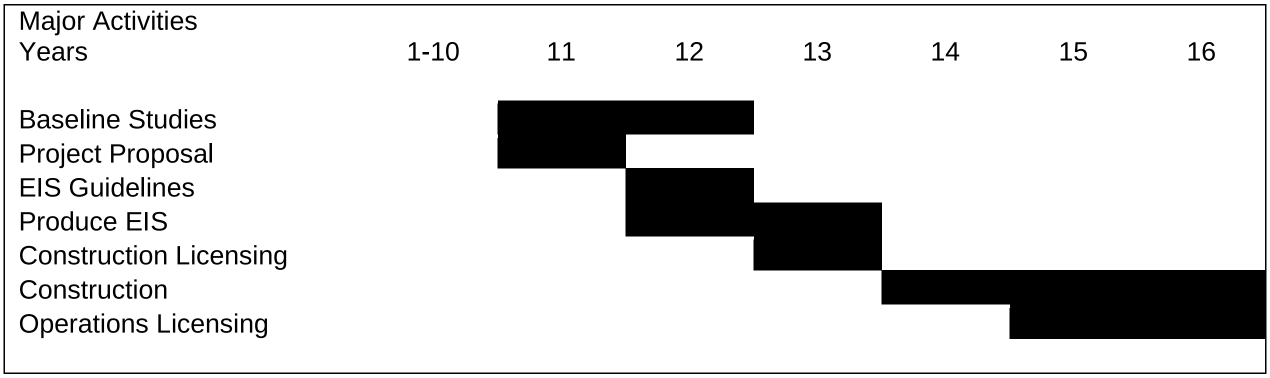


Figure 7:3 Project licensing schedule – construction into operation

Figure 7:3 provides a high level summary of key activities and typical timelines for activities leading to and executing through the mine and surface facilities construction.

Typically the first two phases, as well as a conceptual decommissioning plan for the third phase will be assessed during the first Environmental Impact Statement (EIS) in the first main environmental assessment for the facility.

Throughout this approximate 10 year period there are a number of services required, both direct and indirect, to support the development of these facilities.

Table 7:2 provides a summary of the direct services. Although an indication of costs is provided, actual costs are very site specific. Circumstances where there are sensitive environmental conditions, or where extensive monitoring and or mitigation are required, could substantially increase any of these costs, as well as the regulatory effort required.
Note that in some cases, a well established client may provide these services with internal resources.

Table 7:2 Mine and surface facilities construction project licensing service requirements

Service Description	Amount ($ millions)
Baseline environmental studies	2 - 3
Stakeholder management consulting	0.5 - 0.75
Environmental impact specialist services	3 - 5
Radiation management specialist services	0.5
Geotechnical services	1
Legal services - environmental	1

7.3.2 Commissioning and Operation

The commissioning and operating phase license permits the processing of radioactive ore and management of wastes and byproducts created in the production of uranium yellowcake concentrate. Licensing support services for this phase are driven by requirements and commitments documented in the EIS and in the licensing documents for the facility. Most routine environmental and operational monitoring activities will be undertaken by client staff. Periodic EIS validation program monitoring will present opportunities for environmental and socioeconomic service companies.

Periodic renewals of permits will continue throughout operations.

Table 7:3 provides a summary of the direct services. Although an indication of costs is provided, actual costs are very site specific.

Table 7:3 Commissioning and operations project licensing service requirements

Service Description	Amount ($ millions)
Environmental special monitoring/studies	2 - 3
Stakeholder management consulting	0.5 - 0.75
Environmental impact specialist services	0.2 - 0.3
Radiation management specialist services	0.1
Geotechnical services	1
Legal services	1

8. ENGINEERING, PROCUREMENT, and CONSTRUCTION MANAGEMENT (EPCM)

EPCM costs typically make up 15 to 20 percent of a project's total capital cost. For a given project, EPCM may be carried out by a single general engineering firm or alternatively the activities may be divided between several specialist firms and possibly the owner. The early engineering stages are normally carried out in conjunction with the environmental studies.

8.1 Engineering

Engineering and cost estimating for a capital intensive, long lead time project such as a new green field uranium mine and/or mill will typically progress in stages. Risk adverse mining companies will proceed through most or all of these stages to ensure the economic viability and technical success of their major projects. AMEC uses the following stage gate process adapted from the Association for the Advancement of Cost Engineers (AACE) as summarized below and in Table 8.1.

- Class 5: Assess the preliminary technical and economic viability of the project. The typical duration for an Order of Magnitude study on a large project will be 3 to 6 months.

- Class 4: Determine project configuration through major trade-off studies and develop cost estimates to justify additional project development. Typically, an ore-feasibility study will require 6 to 12 months to complete.

- Class 3: Optimize project configuration, develop engineering to support a cost estimate used as the basis for the project production decision and budgeting. A full feasibility study will usually take 1 to 2 years to complete.

- Class 2: Advance engineering to support the purchase of equipment and construction planning. The basic engineering phase will normally require 1 to 2 years.

- Class 1: Advance engineering towards completion. Detailed engineering follows on from the basic engineering phase and typically will last for an additional 2 to 3 years.

Table 8:1 Study estimate classifications and accuracy

AACE Classification	AMEC Classification	AACE Level of Project Definition	Engineering Complete	AACE Expected Accuracy Range	AMEC
Class 5 Estimate Concept Screening Estimate	Class 5 Estimate Order of Magnitude Study	0% to 2%	0% to 1%	L: -20% to -50% H: +30% to +100%	±30% to ± 50%
Class 4 Estimate Study of Feasibility Estimate	Class 4 Estimate Pre-Feasibility Study	1% to 15%	1% to 5%	L: -15% to -30% H: +20% to +50%	±20% to ± 25%
Class 3 Estimate Budget, Authorization, or Control	Class 3 Estimate Feasibility Study	10% to 40%	10% to 40%	L: -10% to -20% H: +10% to +30%	±10% to ± 15%
Class 2 Estimate Control or Bid/Tender	Class 2 Estimate Basic Engineering	30% to 70%	30% to 70%	L: -5% to -15% H: +5% to +20%	±5% to ± 10%
Class 1 Estimate Check Estimate or Bid/Tender	Class 1 Estimate Detailed Engineering	50% to 100%	50% to 100%	L: -3% to -10% H: +3% to +15%	±5%

8.2 Procurement

Procurement (supply chain management) encompasses the purchase of all the goods and services required to complete the construction of a new uranium mining and/or milling facility. This is split between; procurement of equipment/materials and contracts administration - construction contracts and services. Typically included under supply chain management is the preparation of:

- Specifications
- Work packages
- Modularization requirements
- Bidders lists
- Requests for quotations and proposals
- Contracting strategies
- Vendor and contractor meetings
- Bid analysis and recommendations
- Purchase orders/contract negotiations
- Purchase orders/conformed contracts
- Expediting services
- Supplier quality surveillance
- Shipping and logistics
- Materials management/warehousing

Up-to-date lists of goods and services suppliers to the mining industry are available online and in print. The Infomine website (www.infomine.com), the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) website (www.cim.org), the Canadian Association of Mining Equipment and Services for Export (CAMESE) website (www.camese.org), and the Saskatchewan Industrial and Mining Suppliers Association (SIMSA) website (www.simsa.ca) are reliable sources of this type of information. Most engineering consultancy/project management firms also maintain their own list of suppliers based on recent project experience.

8.3 Construction Management

Managing the construction of a major uranium project requires a team of professionals located at the project site to undertake the following activities:

- Work site health and safety
- Environmental protection related to construction activities
- Planning and scheduling
- Cost control and earned value analysis
- Contractor management
- Materials management
- Quality assurance
- Commissioning (assistance to owners teams)

8.4 Estimated EPCM Costs

The estimated EPCM costs for a project to develop this report's model mines, including all underground and surface facilities are:

Table 8:2 Estimated EPCM costs

Engineering	**Open Pit**	**Underground**
Class 5	$300,000	$300,000
Class 4	$700,000	$700,000
Class 3	$5,000,000	$7,000,000
Class 2	$23,000,000	$30,000,000
Class 1	$52,000,000	$70,000,000
Total engineering	$81,000,000	$108,000,000
Procurement	$62,000,000	$83,000,000
Construction management	$127,000,000	$169,000,000
Total EPCM	$270,000,000	$360,000,000

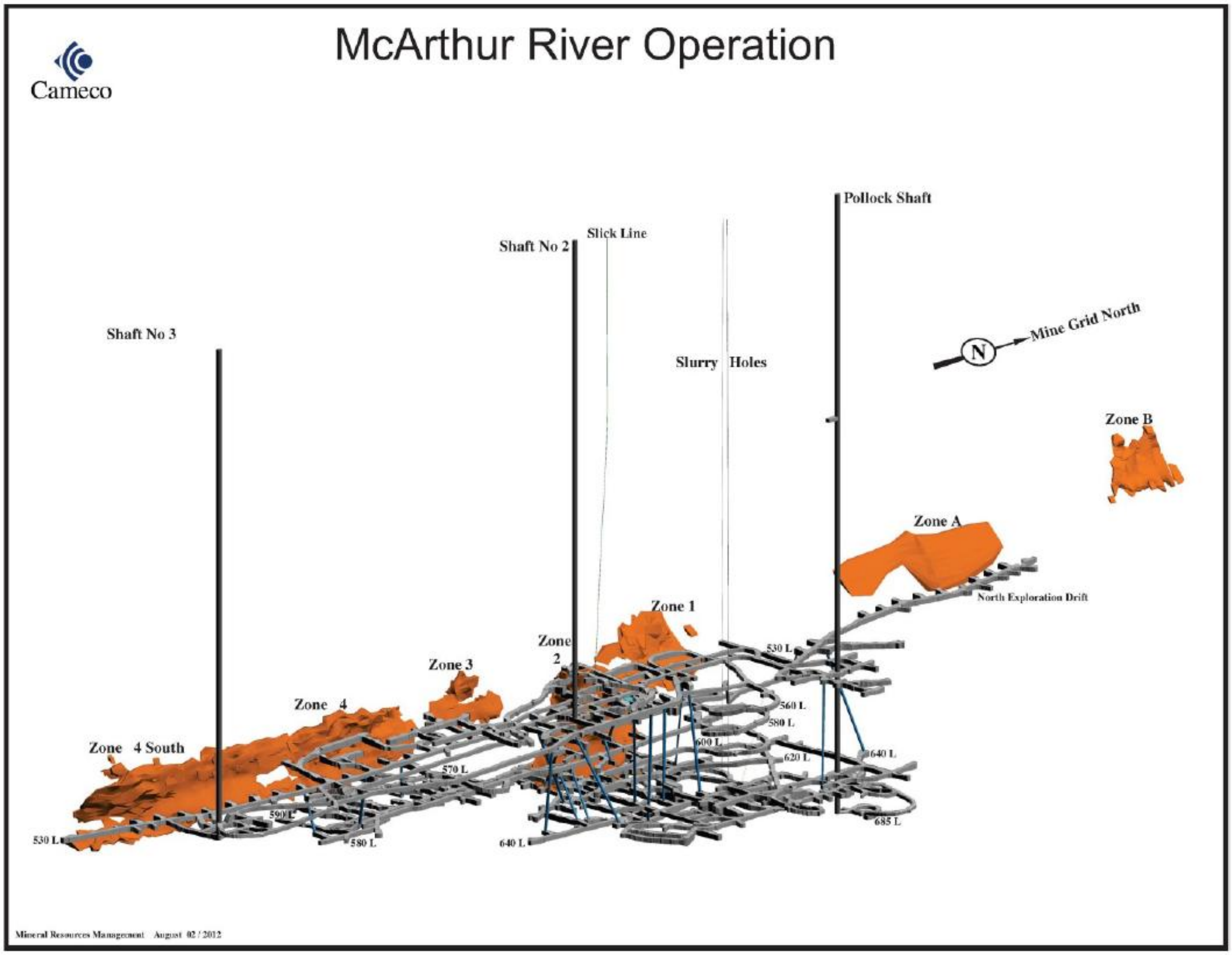
9. MINE AND SURFACE FACILITIES CONSTRUCTION

9.1 Underground Mine

9.1.1 General Description of the Underground Mine Model

The underground mine model assumes a uranium deposit located at a depth of 500 to 600m below surface. Cameco's McArthur River Mine shown in Figure 9:1 is presented as an example of the geometry of the underground mine model. In this figure, surface is located at the top of the vertical shafts used to access the mine, the ore zones are shown in orange, and the mine workings, including levels and ramps, are shown in grey. One significant difference between the McArthur River deposits and the mine model in this report is that the mine model assumes a deposit grade of 4% U_3O_8 while the actual grade at McArthur River Mine is over four times higher than that grade, ranking it as one of the highest grade deposits in the world, along with the Cigar Lake deposit.

The mining methods selected for the model are a combination of raise bore mining and blast hole stoping, similar to that used at McArthur River. Freezing of water bearing rock, in the form of freeze curtains, will be used to prevent water inflows to the workings from the water bearing sandstones overlying the deposits, typical of the Athabasca basin. Progressively, as the ore is mined, the raisebore holes and blasthole stopes will be backfilled with cemented rockfill (similar to lean concrete with coarse aggregate) to maintain the stability of the rock mass.



Cameco

Figure 9:1 3-D View of McArthur River mine showing mineralized zones and mine development

9.1.2 Shafts and Hoisting

Two shafts will provide access to the underground mine; the main shaft for men and materials access, ore and waste removal, and fresh air ventilation supply and the service shaft for return ventilation and emergency egress. Both ore and waste will be hoisted to surface in skips through the main shaft. Each of the two shafts will be circular in cross section, concrete lined over their full depth with a finished inside diameter of 7.5m, and developed to a depth of 650m.

The permanent headframe at the main shaft will be constructed ahead of sinking and used for shaft sinking, while a temporary sinking headframe will be used for the service shaft, with that permanent headframe constructed after sinking. The shafts will be excavated by drill and blast methods.

The working platform for shaft sinking operations will be a custom built steel Galloway platform supported by multiple cables, and controlled by individual temporary winches installed near the shaft collar on surface. The Galloway will be equipped with electric hydraulic drills mounted on drill booms, excavator boom and bucket, submersible pumps, rock grouting pumps and accessories, and staging from which to install shaft concrete lining forms and shaft furnishings. The shaft liner will consist of a 300mm thick monolithic concrete liner with a 7.5m finished inside diameter.

Shaft furnishings will consist of tubular steel (HSS) sets and guides in combination with wide flange (WF) steel sections. Shaft services will be mounted on the shaft walls using conventional rolled channel brackets and inserts to secure all shaft steel and brackets to the shaft walls. Supplies to support the excavation of the shaft will include explosives and detonators, rockbolts (typically 2.4m long continuous thread rebar), resin rockbolt grout, 100mm x 100mm weld wire mesh, grouting materials, drill steel and bits, concrete for shaft lining, plus miscellaneous items.

During sinking operations fresh air will be delivered to the working face through rigid ventilation ducting of between 1.0m and 1.5m in diameter supplied by a temporary axivane fan of approximately 75kW to 115kW located near the collar on surface. During the winter months the ventilation air will be heated to +4°C by a temporary propane fired mine air heater. During the sinking phase, a sinking bucket will be used to transport the blasted waste rock from the shaft and provide access for men and materials to the working areas. Figure 9:2 shows a typical picture of shaft sinking in progress.

Figure 9:2 Shaft sinking in progress

Following excavation, the main shaft will be equipped over its length with cage and skip guides supported on steel sets installed typically every 2.4m vertically, pipes for water and compressed air ranging from 150mm to 305mm diameter, insulated 300mm pipe for brine used for freezing, 13.8kV electrical supply cables, and communications and instrumentation cables. The service shaft will be equipped over its length with cage guides supported on steel sets installed typically every 2.4m vertically, pipes for water and compressed air ranging from 150mm to 305mm, 13.8kV electrical supply cables, and communications and instrumentation cables.

The main shaft headframe will be a standard steel framed structure approximately 50m high and fully clad and insulated constructed over each shaft. It will support the sheave wheels guiding the cables for the shaft conveyances, and house a dumping arrangement for the rock skips. The ore and waste rock will be dumped into separate enclosed and heated concrete bunkers located at ground level for subsequent loading into trucks by front end loader. The headframe will be attached to a collar house and be connected to various adjacent buildings as required to house all the services for the mine. The service shaft headframe will be a standard steel framed structure approximately 32m high and fully clad and insulated, and attached to a collar house. The surface buildings for the shafts will be similar to those at Cameco's Cigar Lake mine shown in Figure 9:3.

Cameco

Figure 9:3 Twin headframes, hoistroom, ventilation fan facilities at Cigar Lake mine

Three hoists will be installed in a main shaft hoisthouse building situated adjacent to the production shaft. Typical specifications for these hoists will be a 2.8m, 1000kW double drum production hoist for skipping ore and waste rock, a 2.8m, 600kW double drum materials handling hoist for a cage for personnel and materials movement, and a 1.7m, 200kW single drum hoist for a small auxiliary cage for personnel, small materials, and secondary egress. A second hoistroom building by the service shaft will contain a 1.7m, 200kW single drum hoist for the service and emergency egress cage. Figure 9:4 shows a typical hoist installation.

Figure 9:4 Typical double drum hoist installation

A loading pocket installation will be constructed in the main shaft for loading ore and waste into skips for hoisting to surface. The loading pocket, located at the lowest level in the mine will be designed such that ore and waste rock will be kept totally separate throughout the loading, hoisting and dumping process. Separate dump points for mined ore and waste will be located on a level above the loading pocket and will be connected to the loading pocket by vertical rock passes. The dump arrangement will consist of a steel 300mm square opening grizzly above each rock pass and a centrally located stationary electric hydraulic rock breaker. Separate skip loading systems for ore and waste will include a loadout conveyor below each rock pass feeding a measuring flask and then flow to the 8t capacity bottom dump skips. One of the two skips will be dedicated exclusively to hoisting ore, while the other to hoisting waste, to ensure that no ore contamination of the waste occurs during the ore transportation process. The cage in the main shaft will have an 8000kg and 30 person capacity while the auxiliary cage in both shafts will have a 2000kg and 10 person capacity.

9.1.3 Development of Drifts and Ramps

From the shafts, horizontal tunnels (drifts) and inclined tunnels (ramps) will be excavated by drill and blast methods to provide access to the deposits and for required infrastructure. Typical drifts and ramps will be 5m high by 5m wide although the actual size will vary throughout the mine to suit specific requirements. To excavate these headings, horizontal blast holes, approximately 4m long (a round), will be drilled by two electric hydraulic drills mounted on a twin boom drill jumbo vehicle (see Figure 9:5), loaded with explosives with the use of a speciality explosive loading truck, then blasted. The blasted rock will be loaded by load-haul-dump (LHD) units and hauled to the grizzly/rockbreaker dump point leading to the shaft loading pocket. If the haul distances for the LHDs are long, over 300m in length, then the blasted rock will be loaded by the LHDs into 30t capacity low profile haulage trucks for transport to the rock dump.

Following clearing of the broken rock from the face, the freshly blasted rock will be supported with the use of a speciality ground support truck capable of drilling holes with an electric hydraulic drill and then placing 1.8m to 2.4m long rockbolts on a set pattern (typical 1.2m x 1.2m). There are several types of rockbolts that may be used depending on the rock support specifications including threaded rebar with resin grout, swellex and split sets. Cable bolts will be used when 3.0m or longer rockbolts are required. As part of the rockbolting procedure 100mm x 100mm weld wire mesh will be installed on the roof and walls and along the full length of the headings and held in place by the rockbolts. If further support is required, then fibre reinforced shotcrete will be sprayed on the roof and walls and over the rockbolts and mesh, to a thickness of 50mm to 150mm depending on the rock support specifications. For the model mine shotcrete will be applied along 50% of the length of all headings. The shotcrete will be placed with a speciality shotcrete jumbo with the shotcrete nozzle located on the end of a hydraulic boom. Shotcrete can be supplied to the jumbo as either wet or dry mix, but for the model mine it has been assumed that all shotcrete will be wet mix prepared on site at the concrete batch plant and delivered underground via a concrete slick line in the shaft. Transmixer trucks of $5m^3$ to $8m^3$ capacity will transport the shotcrete mix from a receiving station at the base of the slick line to the work place.

Cameco

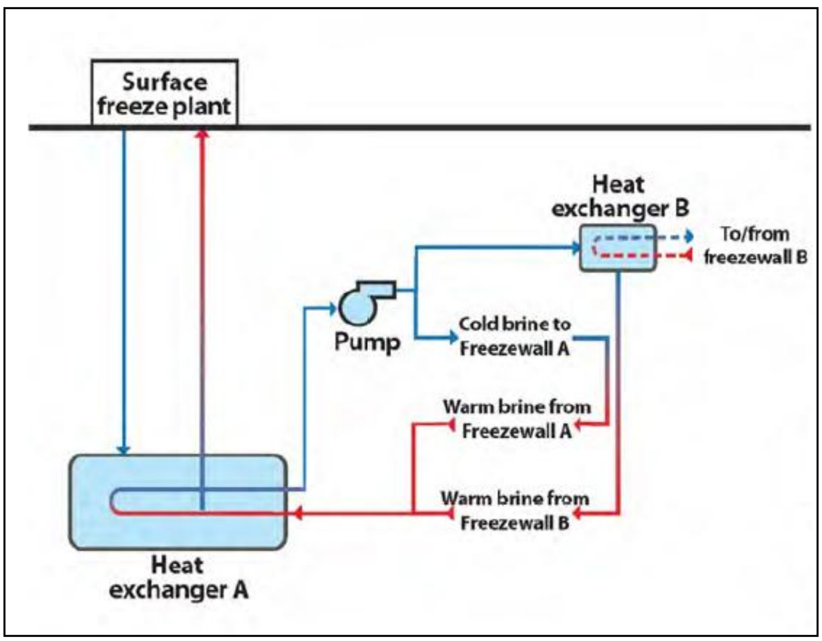
Figure 9:5: **Drill jumbo working in a drift supported with rockbolts and weld wire mesh**

Ventilation air will be delivered to the working faces via either collapsible or rigid ventilation ducting, varying from 1.0m to 1.4m in diameter, and fed by portable axivane fans ranging from 40kW to 115kW depending on the duty requirement. Primary electrical distribution throughout the mine will be at 4.16 or 13.8kV fed from the feeder cable in the shaft through to the working areas via electrical cables progressively installed in the headings as they are advanced. Portable electrical substations will be used to reduce the voltage to 600V, for use by the mine electrical equipment, and these will be installed along the length of the headings at regular intervals as required.

Drifts and ramps will be driven with a grade to promote positive water drainage; sumps will be excavated at low spots and equipped with submersible pumps of 25kW to 75kW to pump water back to a central pump station for pumping up the shaft to surface. Separate steel pipes for fresh water (typ. 100mm diameter), discharge water (typ. 150mm diameter), and compressed air (typ. 200mm diameter) will be installed on the walls of the drifts and ramps throughout the mine.

9.1.4 Ground Freezing System

A ground freezing system will be provided for the creation of the freeze walls to control water inflows into the mining areas. The ground freezing system is shown schematically in Figure 9:6 and will consist of an ammonia refrigeration plant on surface, a surface and underground brine distribution piping system and in-situ freeze pipes. The surface freeze plant building will contain four freezer units each with a capacity of 200t refrigerant. The freezer units will be of the dry ammonia, direct compression and expansion type, each equipped with a low and high stage screw compressor, an evaporative condenser and a brine chiller. A picture of a freeze plant is shown in Figure 9:7. Calcium chloride brine at approximately minus 40°C will be circulated from the freeze plant underground through 300mm diameter insulated pipes installed in the production shaft. The brine piping will be insulated with foam glass insulation and covered with stainless steel cladding. The brine will be received by heat exchangers underground which in turn will cool the secondary brine system circulated through the freeze pipes installed in the freeze holes.



Cameco

Figure 9:6 Freeze system schematic

Cameco

Figure 9:7 Surface freeze plant

9.1.5 Backfill System

For both raise bore and blast hole mining, the mined openings in ore will be backfilled with cemented rockfill (similar to lean concrete with coarse aggregate) to maintain the stability of the rock mass. The backfill system to prepare and distribute the cemented rockfill (CRF) will consist of a cement batch plant on surface, an aggregate crushing and screening facility on surface, a backfill mixing plant underground and mobile equipment underground to distribute the CRF to the working areas within the mine.

The batch plant will produce a slurry consisting of binder and water at approximately 66% solids for delivery underground to the backfill plant. The binder will be a mixture of cement and fly ash in a ratio of approximately 1:1 by weight. The batch plant will consist of storage silos for each of the cement and fly ash, and a delivery and mixing system for the binder and water as well as any additional additives. The slurry will be prepared in batches of 3.5 to 4.0m^3 to match the requirements of the backfill plant underground and will be delivered underground via a 550m long 75mm drill hole lined with 50mm pipe direct to a receiving tank at the batch plant. A second lined drill hole will be provided as a spare. The slurry preparation and delivery system will be completely automated. The batch plant, except for the silos, will be contained in a standalone building.

A portable type crushing and screening plant will provide minus 45mm aggregate for the CRF. Supply of material for the plant will be from a gravel borrow pit or quarry as available and the crushed and screened aggregate will be stored in a covered stockpile near the delivery point to the mine. A heated concrete pad will be provided inside the stockpile building for heating the aggregate during the winter months. The aggregate will be delivered from surface through a 550m long 250mm diameter drill hole direct to a aggregate storage silo adjacent to the underground backfill plant. The drill hole will be fitted with a 180mm inside diameter replaceable abrasion resistant steel liner pipe. A second lined drill hole will be provided as a spare. The aggregate will be loaded into the hole via a front end loader dumping into a hopper and conveyor to the drill hole.

The underground backfill plant will be located in an underground excavation and will operate as a batch system which feeds and measures the aggregate and cement slurry into a mixer in the specified proportions, then feeds the CRF directly into 30t trucks for haulage to the stopes. Capacity of the plant will be 250m^3 of CRF per day. Aggregate will be fed from the underground storage silo by a rock feeder and onto a conveyor and over a belt scale to the mixer. Cement slurry will be pumped by a slurry pump, from the slurry receiving tank, to the mixer with the volume controlled by a magnetic flow meter. The complete backfill system will be automated.

9.1.6 Mining Equipment

The mobile equipment fleet consists of vehicles directly required for development and production and those used more in a support and maintenance role. The development and production equipment has already been discussed in the preceding sections and consists of the following: 4.6m^3 and 6.9m^3 capacity LHDs, two boom electric-hydraulic drill jumbos, 30t capacity trucks, electric ITH freeze hole drill rig, electric ITH blasthole drill rig, rockbolt jumbo, raise borer machine, shotcrete sprayer, shotcrete transmixer, emulsion explosive loading vehicle, and diamond drill rig.

The support and maintenance fleet will consist of the following equipment:

- Scissor lift truck for installation of services and occasional rockbolting.
- Boom truck for moving heavier supplies and maintenance.
- Grader for maintenance of the roadways.
- Fuel/lube truck for fuelling and servicing of certain vehicles such as jumbos.
- Specialized service trucks for mechanical and electrical maintenance.
- Pick-up trucks (or equivalent) modified for underground use as personnel vehicles, supervisors vehicles, and materials delivery.

- Fork lift for materials handling underground around the shaft, warehouse and maintenance shops.
- Backhoe (mini style) for maintenance of ditches on drifts and ramps.

Surface mobile equipment to support the underground mine will include:

- Front end loader (8t capacity) for loading ore and waste at the shaft into trucks and general use.
- Haul trucks (25t capacity) for haulage of ore and waste from the shaft and general requirements.
- Grader for road maintenance and snow clearing.
- Fork lift for materials handling on surface around the shaft, warehouse and maintenance shops.
- Mobile crane (20t capacity) for general site duties.
- Pick-up trucks for personnel and small supplies.

The mobile mining fleet for the underground mine will include both production and support equipment and is listed in the capital cost breakdown in Table 9:04.

9.1.7 Infrastructure Facilities

In addition to the freeze and backfill systems described in Sections 9.1.4 and 9.1.5, there are various infrastructure facilities required to support the mine. These include mine ventilation and heating, mine dewatering, electrical distribution, compressed air, maintenance, refuge stations, fuel distribution, and communications and instrumentation.

Mine Ventilation and Heating

The permanent mine ventilation system on surface will consist of main intake fans and mine air heater at the main shaft and main exhaust fans at the service shaft. Underground there will be one major booster fan plus secondary fans blowing air to working places as required through ventilation ducting.

At the main shaft, three horizontally mounted axial vane intake fans, equipped with 260kW variable frequency drives, and each handling 160m^3/sec of air and fitted with intake bells will blow fresh air through 30MW direct fired propane mine air heaters enclosed in a building, and then fed into the shaft through a sub-surface airway.

The mine air heaters will be used only during the winter to raise the air temperature above 4°C to prevent freezing. In the centre left of Figure 9:3, a row of three intake fans feeding into a mine air heating building can be observed and are typical of this type of fan and heater installation. At the service shaft, three horizontally mounted 560kW axial vane exhaust fans each handling 160m^3/sec and equipped with evases will draw the return air through a sub-surface airway from the shaft.

Underground a horizontally mounted 110kW axial vane fan handling 75m^3/sec will be used as a booster fan. The use of secondary fans for local ventilation is described in Section 9.1.3 and consists of portable axial vane fans ranging from 40kW to 110kW.

Mine Dewatering

The mine dewatering system will be designed to handle both normal inflows and emergency high non-normal inflows. Experience at the existing underground mines has shown that it is essential that the mine have the capacity to handle emergency high non-normal inflows on a short term basis to prevent the risk of flooding the mine.

Mine water will be directed to horizontal settlers prior to pumping. The normal condition dewatering system will consist of two 250m^3/h multi stage centrifugal pump (one plus a spare) operating at 600m static head. The high non-normal condition system (additional 750m^3/h) will consist of three 250m^3/h multi stage centrifugal pumps each operating at 600m static head. Two 250mm pipes will be installed in the shaft to handle the discharge water. For the normal flow rate mode only one discharge pipe would be used, with two pipes for the higher flow rates. The pump system will be automated by level switches starting and stopping the pumps, with manual override.

A number of submersible pumps of 25kW to 75kW will be required for secondary pumping on the levels.

Electrical Distribution

Electrical power will be provided throughout the mine for drill jumbos, fans, pumps, lighting, crushing and conveying and other miscellaneous loads. The power will be distributed to the mine at 13.8kV through two primary feeders, one located in each of the shafts. Both feeders will be supplied from the power station electrical room. A 2000A substation located in the hoist house will be fed from the power house electrical room. From there, power will be distributed to the mine surface facilities including the hoists, collar house, main intake fans, Galloway stage and winches for shaft sinking.

The service shaft hoists and surface fans will be fed from the power station electrical room by overhead lines.

A shaft electrical station, located adjacent to the shaft, will be provided on each underground level and station to house 13.8kV switchgear, 13.8kV/0.6kV transformer for services and an MCC for local services. The shaft electrical station will also provide a location for the network and communication infrastructure hub for the levels, leaky feeder equipment and automation equipment such as PLC panels. Additional electrical substations will be excavated throughout the mine as required and will be equipped with portable substations (mine power centres - MPC) consisting of a 13.8kV/0.6 kV transformer, cascading 13.8kV fused disconnect, and 600V starters with GF/GC.

Communications and Instrumentation

A fibre optic system will tie in the underground workings to the site wide network. All communications, automation, control and monitoring functions will utilize the fibre backbone and Ethernet network for communication.

A fibre optic trunk cable will be installed from the hoist house network room down the shaft to the various mine levels.

An IP phone system will be installed underground, as an extension of the surface phone system. Telephones will be located on the Galloway during shaft sinking, at each of the shaft stations, and the refuge stations. The system will use the Ethernet network for carrier of the voice signal.

A backup Wi-Fi based system will also be installed with repeaters installed as required to provide mine wide coverage.

Refuge Stations

A combination refuge station and lunch room will be excavated and constructed on each of the main levels in the vicinity of the shaft. This will be designed and equipped according to approved mine safety standards. Tables and benches, compressed air line, business network and PC, telephone, potable water, first aid stretcher and kit will be provided. Away from the shaft and in new developing areas of the mine, commercially available fully equipped refuge station units will be used. These can be relocated later to suit a mine wide production phase refuge station location plan.

Maintenance Shop

A maintenance shop facility will be excavated and constructed underground. It will consist of two maintenance bays, equipped with 10t overhead cranes, plus a main service area, tool crib and lunch room/refuge station. The area will be equipped with a fire suppression system including fusible linked fir doors. Nearby a bay will be used for the storage of all lubricants and fluids required to support the equipment fleet. Self contained storage units that include an automatic fire detection and suppression system, and spill containment will be used. The system will use steel totes called bladders in standard 1,000L capacity. The stored products including engine oil, hydraulic oil, transmission fluid, etc. will be pumped from the storage bay to hose reel banks in the shop.

Diesel Fuel Distribution

During mine construction diesel fuel will be transported underground via the cage in the shaft in bulk containers of approximately $4m^3$ capacity. The fuel containers will be delivered to commercially available totally equipped dispensing stations with a capacity of 2,000L. When the mine is in production the fuelling system will be upgraded to “dry line” piping system installed down the shaft and to permanent storage and dispensing stations. The pipe distribution will be completely automated from the storage tanks on surface to the receiving tanks underground. Fire suppression equipment, fuel containment and fire doors are major components of these fuelling stations.

Explosives Storage and Distribution

Emulsion explosives will be used almost exclusively for both development and production blasting. Most of the emulsion will be supplied as a bulk product with a minor amount as packaged explosive. The bulk emulsion will be delivered from surface storage to underground in 1,500kg containers. The containers will be loaded onto the service cage at surface for transport underground then off-loaded onto speciality trucks for transport to their required destination.

Explosive and detonator magazines will be provided underground. Separate explosive magazines will be provided for bulk explosives and packaged explosives. The bulk explosive magazines will be sized to store 20 containers for a total capacity of 30,000kg of emulsion. The packaged explosive magazines are designed to hold just over 1,000 cases of explosive for a capacity of just under 20,000kg. Detonators will be stored in a separate magazine.

While the emulsion transport truck and the containers will be owned by the mine operator, the pumping equipment is highly specialized and can only be leased from an explosive supplier.

Compressed Air Generation and Distribution

Compressed air will be provided for the ITH production drills, shotcrete machines, and small equipment such as hand-held drills, pumps, etc. The required compressor capacity is estimated at 2.8m^3/sec.

Three air-cooled rotary screw compressors powered by 375kW electric motors each having a capacity of 1m^3/s, will provide the compressed air during production. A vertical air receiver will be installed. An electronic control system will regulate, control and monitor the operation of the compressors. Two of these units will be operated during shaft sinking and pre-production development of the ramps and levels, the third is only required once production operations such as ITH drilling start.

The compressors will be housed in one end of the hoist building and separated from it by a firewall. The compressor room will be equipped with an overhead crane and openings will be provided into one side of the building for individual intake and return air ducts.

Compressed air will be distributed from the compressor house to the shaft and headframe via a buried pipe connecting to a 254 mm (10") pipe that will be installed in the shaft. This pipe will be the compressed air main supply line with tees provided at each shaft station to supply air on the individual levels and to the general underground development and production areas. A 152mm (6") pipe will be installed in the ramps and drifts and this pipe network will be interconnected to the shaft pipeline system at each shaft station.

9.1.8 Supplies and Service for Underground Mine Construction

The supplies and services purchased for construction of the model underground mine are tabulated in Table 9:1 following.

Table 9:1 Supplies and services for construction

Description	Material Supply Amount $	Installation Amount $
Shaft pilot holes	$ 2,467,052	$ 2,990,788
Shafts	$ 56,942,535	$ 63,033,814
Headframes	$ 15,360,255	$ 23,692,660
Hoisting plants	$ 16,936,354	$ 11,017,658
Freeze system	$ 27,367,800	$ 6,189,350
Concrete batch plant	$ 2,475,773	$ 2,406,563
Skip loading system	$ 3,118,892	$ 1,336,668
Underground mobile equipment	$ 22,468,716	$ 1,182,564
Electrical distribution	$ 3,630,000	$ 1,170,600
Communications & instrumentation	$ 2,291,520	$ 1,347,472
Lateral development	$ 29,415,000	$ 18,985,300
Dewatering system	$ 5,011,200	$ 3,340,800
Raisebore holes	$ 4,076,800	$ 1,747,200
Diamond drilling underground	$ 2,134,350	$ 2,608,650
Mine ventilation system	$ 3,100,000	$ 600,000
CRF backfill plant	$ 6,100,000	$ 3,900,000
Underground construction	$ 2,500,000	$ 3,000,000
Total Sum	$ 205,396,246	$ 148,550,087

Key quantities and unit prices for the model underground mine are tabulated in Table 9:2 following.

Table 9:2 Key quantities and unit prices for model underground mine

Description	Takeoff Quantity	Unit	Unit Cost $ (Su. and Inst.)
Lateral development	8,000	m	9,000
Diamond drilling - underground	20,000	m	220
Shaft pilot hole drilling surface	3,000	m^3	1,800
Concrete - shaft linings	6,500	m^3	6394
Shaft structural steel	2,600	t	6000
Mobile Equipment			
LHD - 6.9 m3 capacity	4	unit	1,400,000
LHD - 4.6 m3 capacity	2	unit	1,000,000
Two boom electric hydraulic drill jumbo	2	unit	980,000
Haul truck - 30t capacity	3	unit	950,000
ITH drill rig	2	unit	950,000
Rockbolt jumbo	2	unit	1,120,000
Shotcrete sprayer jumbo	2	unit	710,000
Shotcrete transmixer	3	unit	460,000
Explosive loading vehicle	2	unit	490,000
Scissor lift truck	3	unit	440,000
Underground grader	1	unit	444,000
Service trucks - various	5	unit	440,000
Total Cost			**$163,255,000**

9.2 Open Pit Mine

9.2.1 General Description of the Open Pit Model Mine

The open pit mine model assumes a uranium deposit located at a depth of 100 to 200m below surface. The general geology in the Athabasca Basin consists of widespread sandstone rock which overlies the metasediment basement rocks. The uranium deposits can occur in either type of rock and also are frequently found at the “unconformity”, or junction of the sandstone and basement rocks. The Deilmann orebody that was mined (now complete) at Cameco’s Key Lake operation is a close match for the model open pit mine that has been assumed for this Guide. A general geological cross section for the Deilmann ore body is shown in Figure 9:8 where the yellow zone, referred to as the Athabasca Group is the sandstone, the brown zone, called the Paleoproterozic Metasediments are the basement rocks and the uranium orebody (mineralization) is shown in red.

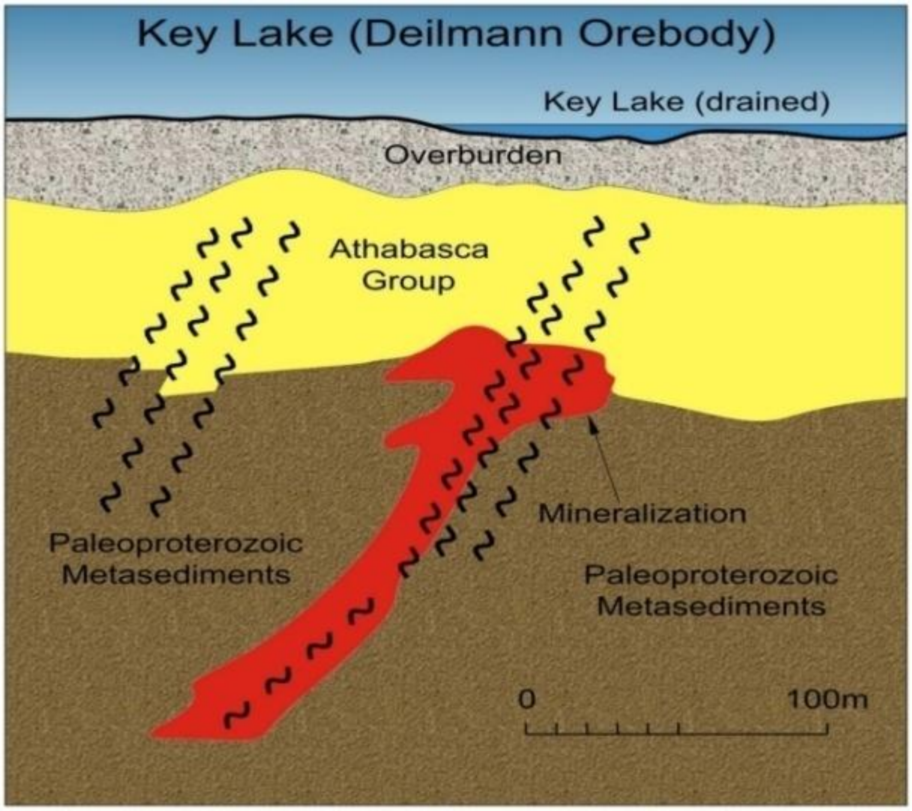


Figure 9:8: Geological cross section of the Deilmann orebody

One of the properties of the sandstone that most impacts mining is that it can be very permeable and exist in a saturated state, like an aquifer. For open pit mining, drainage and control of this ground water is a major design consideration to allow for in-pit mining without disrupting mine operations, and without having to manage constant water inflows.

Open pit mining involves removing the overburden above the deposit and then extracting the ore. The steps in developing an open pit mine are:

- Drainage and or/control of any overlying water bodies. A significant proportion of northern Saskatchewan is covered either by lakes or swamps so there is a high probability that some form of waterbody may be present above the planned open pit. The mine model considers a small water body that can be easily drained. Drainage of the sandstone aquifer and ground water in the upper 50m of the basement rocks requires special measures. The mine model considers a ring of closely spaced dewatering wells installed beyond the mined perimeter of the open pit limits. These wells will be used to draw down the water table, in advance of mining, such that only minimal ground water will enter the pit.

- Removal of overburden above the pit. Typical glacial till 10 to 50m thick is present throughout much of northern Saskatchewan and can be removed directly with excavators and trucks. For the model mine an average overburden thickness of 25m was applied with excavation to a stable slope of 35°.

- Removal of the sandstone and basement rocks above the orebody. These rocks will be drilled and blasted, then loaded into trucks and hauled directly to the permanent waste dumps. The overlying rocks are to be mined to a slope that will be stable over the long term. Experience in the Athabasca Basin has shown that the slopes in the sandstone can vary over quite a range depending on local conditions, from 37° to 52°, with 43° to 45° being typical. The basement rocks are stronger locally but are intersected by faults reducing the overall strength. For the model mine, an overall pit slope of 45° was applied.

- The open pit stripping will be advanced as part of the capital program until sufficient in situ ore in the uppermost part of the deposit is exposed, when production can be sustained at the required rate. For the model mine an initial stripping depth of 80m in sandstone and basement rocks was used (in addition to the 25m of overburden).

- Ongoing stripping will be required during operations to progressively expose more ore on a regular basis. This stripping is an operating cost.

AREVA's JEB open pit mine shown in Figure 9:9 is a typical open pit uranium mine in the Athabasca Basin of northern Saskatchewan.

AREVA

Figure 9:9 AREVA's JEB open pit uranium mine

In Figure 9:9 note the numerous small white structures located on the perimeter road encircling the JEB open pit. These are the locations of the dewatering wells used to control ground water at the JEB pit and are typical of what will be provided for the model mine.

The major components of the model open pit mine are:

- The open pit excavation.
- Mobile equipment mining fleet including production and service equipment.
- Open pit dewatering system including perimeter dewatering wells and in-pit sumps, settling sumps and monitoring ponds for clean water from the dewatering wells, collection ponds and water treatment plant for water collected in-pit sumps.
- Waste dumps for clean and special waste and overburden.
- Infrastructure facilities such as power distribution, maintenance shops, wash bay, explosives and cap storage facility, fuel storage and distribution, truck scanner and scale, and change house facility.

The production rate for the model open pit mine will be 136 kt/year of uranium ore resulting in a rate of 138 t/day, a relatively small rate compared to open pit mines for other commodities. The waste strip ratio will be relatively high compared to non-uranium mines. The initial capital waste strip ratio will be 80:1 but once production starts an average 20:1 waste/ore strip ratio has been used in the model, stripped annually once the capital pre-strip program has been completed.

Prior to start of production a total of 600,000m^3 of overburden and 6,600,000m^3 of waste rock will be mined as part of the project capital. During this capital period a mining rate of 9000m^3/day will be required. Once production starts the annual ore and waste mining rate will reduce to approximately 3000m^3/day.

9.2.2 Open Pit Mobile Equipment Fleet

One of the major capital costs for open pit mining is the purchase of the mobile equipment fleet. The fleet consists of two major parts; (1) production equipment required directly for mining and includes blasthole drills, explosive vehicles, excavators, front end loaders and haulage trucks; and (2) service equipment to support the production fleet and includes dozers, graders, water trucks, maintenance support vehicles, etc. For the model mine the units in the fleet have been selected to meet both the production requirements and the expected operating conditions. One obvious condition is that the winters are long and cold in northern Saskatchewan and the selection must ensure that the equipment design considers cold weather operation for both the equipment and the operators.

The production fleet will consist of the following:

- Blasthole drills – the main drill units will be diesel powered rotary drills, for drilling 16m high benches. Typical hole diameter will be 400mm. These drill rigs are to be equipped with currently best practice monitoring devices, instrumentation and control features. A track drill capable of drilling 100mm to 150mm holes is required for perimeter wall drilling for wall control.

- Explosives – bulk emulsion explosives will be used almost exclusively for blasting. Speciality trucks with the required storage tanks and mixing capabilities will be used for the emulsion transport and loading direct to the blast holes.

- Excavators and front end loaders – the main loading unit will be a diesel hydraulic excavator with a 17m^3 bucket which will match up efficiency with the 90t haulage trucks. Front end loaders will be used for clean up, smaller blasts, and for loading ore if more ore/waste selectivity is required. For this a 9m^3 bucket capacity diesel loader will be used.

- Haulage trucks – the main haulage unit will be a 90t payload capacity fixed body mine truck equipped with the current best practice machine monitoring and instrumentation packages. The ramp in the pit will be at a 10% slope with a width of 12m to allow for safe passage of two 90t capacity mining trucks without the need for turn outs.

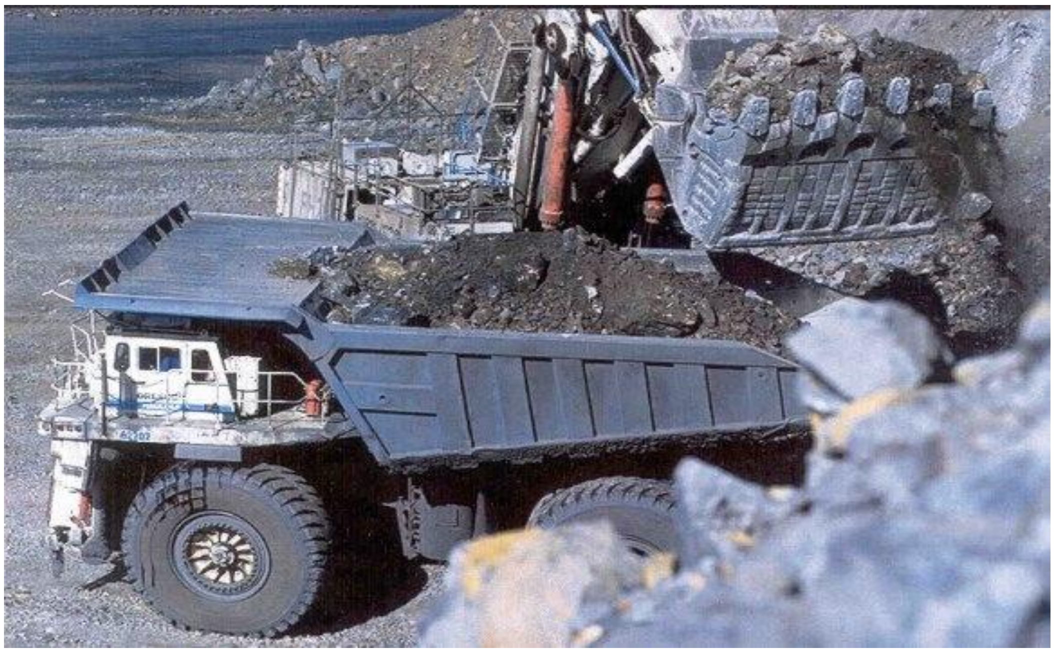


Figure 9:10 Excavator loading a haulage truck

Cameco

Figure 9:11 Rotary blast hole drill

The service fleet will consist of the following:

- Dozers – a large 450kW (typical) tracked dozer is required for pushing rock and clean-up of benches as required. A somewhat smaller more mobile rubber tired wheel dozer will be used to maintain roads and truck loading areas.
- Grader – a road grader in the 30t weight class will be required to maintain the pit haul roads and site roads and for snow clearing in the winter.
- Water truck – a truck with a water tank and spray bar will be used to keep the pit roadways damp to control dust.
- The remainder of the service fleet consist of vehicles used for maintenance, supplies, and personnel transportation. These include: welding truck, service truck, vacuum truck, crane, tire manipulator, flat deck, forklift, busses for crew change, and a small fleet of pickup trucks.

Figure 9:12 Open pit uranium ore mining

9.2.3 Open Pit Dewatering

An effective mine dewatering system is important for the safe and efficient operation of a large open pit mine in the Athabasca Basin. An interceptor perimeter well dewatering system has been included in the model mine to intercept groundwater before it flows into the pit. An in-pit dewatering system will also be provided to collect water falling into the pit from precipitation and minor inflows of ground water through the pit walls.

For the model mine, a steady-state estimate of 625 m^3/h of water captured by the dewatering wells and 125 m^3/h captured by the in-pit dewatering system has been used. The perimeter dewatering system will consist of thirty-three wells 130m deep installed around the perimeter of the pit 50m apart. An additional identical eight wells will be required for monitoring. A drilling contractor will be used to drill the wells, which will be 250mm diameter with steel pipe lining.

A submersible pump will be installed in each dewatering well to pump groundwater to the surface; typical pump specifications will be 125m^3/h at a static head of 120m.

Discharge piping will run from the submersible pump to an enclosed wellhead located on surface. Each wellhead will contain a single header with a manual sampling connection and a flow meter. A three-way valve, located downstream of the manual sampling connection, will direct groundwater flow into one of two pipelines at any one time. The wellhead piping and pipelines will be electrically heat traced and insulated.

Two 200mm diameter HDPE pipelines, insulated and heat traced, will run along the surface to connect to each well. One pipeline will extend 500m to carry clean groundwater to the receiving pond for clean water. The second pipeline will extend 300m to pump contaminated groundwater to the receiving pond that feeds the water treatment plant.

An all weather road will run around the perimeter of the dewatering well circle providing access for vehicles. An overhead distribution power line and communications cable will be installed around the 1,700m loop complete with all the required electrical and communications connections.

The in-pit dewatering system will consist of a series of sumps strategically located around the pit to collect precipitation and water inflows as close to the source as possible. The model mine includes ten submersible sump pumps of which up to six will be operating. The pump specifications will be 125m^3/h at a static head of up to 100 m. Each sump will be provided with 150mm insulated and heat traced HDPE discharge pipe connecting at the pit rim to the contaminated dewatering pipeline. An in-pit power line and communications cable will connect to each of the in-pit sumps.

9.2.4 Open Pit Infrastructure

Infrastructure directly related to open pit operations includes explosive storage and associated facilities, fuel storage, maintenance shops, clean waste and special waste stockpiles, and haul road to the mill.

Fuel Storage and Distribution

Fuel storage and distribution for the open pit mining fleet will be established fairly close to the pit haulage road for efficiency of fuelling. The fuel will be stored in tanks with an appropriate secondary containment system and high speed dispensing pumps. Used oil will also be stored in storage tanks with secondary containment.

Explosives and Detonator Storage Facility

Emulsion explosives will be used almost exclusively for ore and waste and pit perimeter blasting. The emulsion will be supplied as a bulk product with a minor amount as packaged explosive. Ideally, an explosive supplier will establish an emulsion storage and mixing plant at site and further will contract to complete all the blasthole loading on site. A storage capacity of at least 200t of explosives will be required. The emulsion loading truck can be owned by the mine operator but the pumping equipment is highly specialized and can only be leased from an explosive supplier. Detonators will be stored in an approved facility.

Electrical Distribution

From the main site substation power will be distributed to the pit facilities at either 4.16kV or 13.8kV, depending on final design. An overhead line will circle the pit providing power to the dewatering pumps while in-pit lines will be supported by simple structures on the pit floor.

Haulage Road to the Mill and Waste Dumps

Haulage roads will be required to transport ore to the mill and waste to the overburden, clean waste and special waste dumps. The model mine is based on each of the waste roads being 1.5km long and the ore road 2km long. The road width would be 12m which is twice the width of a common 90t haul truck. Pull outs will be provided along the length for safety when multiple vehicles are passing.

9.2.5 Supplies and Services for Model Open Pit Construction

The supplies and services purchased for construction of the model open pit mine are tabulated following in Table 9:3.

Table 9:3 Supplies and services for model open pit construction

Description	Material Supply Amount $	Installation Amount $
Prepare pit site for mining	764,085	1,146,128
Overburden removal	10,090,840	15,136,259
Perimeter dewatering system	17,513,313	9,430,245
Capital period dewatering operation	640,000	160,000
Waste stripping (drill and blast)	32,832,544	26,862,990
In pit dewatering system	620,895	758,872
Maintenance shop	3,600,000	2,400,000
Mine dry	2,400,000	1,600,000
Open pit control office	540,000	360,000
Mobile mine equipment fleet	39,736,000	2,500,000
Technical services	6,440,000	2,760,000
Total	**115,177,677**	**63,114,495**

Table 9:4 Unit costs for model open pit construction

Description	Takeoff Quantity	Unit	Unit Cost $ (Su. and Inst.)
Dewatering well pumps (50-75hp)	33	units	40,000
Submersible sump pumps (150hp)	8	units	100,000
Dewatering well drilling (254mm dia)	15,300	m	500
Clearing and grubbing	21	ha	43,344
Pit excavation - overburden	4,600,000	m^3 (bcm)	5.30
Pit excavation - waste rock - drill & blast	6,600,000	m^3 (bcm)	8.90
Diamond drilling	20,000	m	220.00
Mobile Equipment Fleet			
Fixed body mine haulage truck - 90t	8	units	1,983,000
Hydraulic excavator - 17 m^3 bucket	2	units	3,500,000
Front end loader - 9 m^3 bucket	1	units	1,500,000
Rotary drill rig - 16.5m holes, 400mm dia.	2	units	3,000,000
Track drill - 16.5 m holes, 100-150mm dia.	2	units	1,100,000
Explosive truck - bulk emulsion	1	units	370,000
Blasthole stemming truck	1	units	350,000
Dozer – 450kW typical	1	units	1,757,000
Rubber tired dozer	1	units	820,000
Grader - 30t weight class	1	units	1,000,000
Forklift	2	units	85,000
Crane truck	2	units	140,000
Water truck	2	units	325,000
Service vehicles	15	units	30,000
Total Cost			$136,611,224

9.3 Mill

9.3.1 General Description of the Model Mill

As described in Section 4.4, the model mill will produce 12,000,000 lb. U_3O_8 annually as yellowcake from 143,000 tonnes of ore grading 4% U_3O_8.

9.3.2 Mill Building

The mill building will be a standard steel framed structure, fully clad and insulated. It will occupy an area of approximately 40,000 m^2 and average approximately 15 m high. The building will be sited on a 125,000 m^2 paved mill terrace, which will provide space for vehicle parking. All of the uranium processing equipment, an acid plant and boiler house, reagent receiving and storage facilities, electrical and mechanical service aisles, a central control room, mill offices and dry, and yellowcake product drum storage will be housed in the mill building. HVAC for the building will provide both general area HVAC and special dedicated process HVAC for radon control. The concrete mill floors will be sloped to sumps to allow easy, rapid and complete cleanup of spills.

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Figure 9:13 Exterior view of a typical Saskatchewan uranium mill, Key Lake

Figure 9:14 Interior view from a typical Saskatchewan uranium mill, grinding plant at Rabbit Lake

Figure 9:15 Interior view from a typical Saskatchewan uranium mill, leaching aisle at McClean Lake

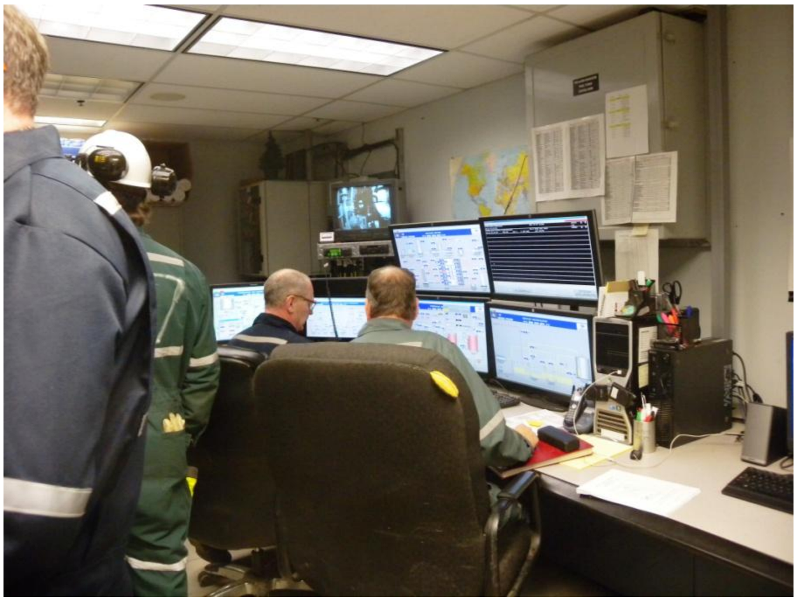


Figure 9:16 Interior view from a typical Saskatchewan uranium mill, acid plant control room at Rabbit Lake

9.3.3 Tailings Management Facility (TMF)

The TMF will be a purpose built in-pit installation. Facilities for water management and recycle of raise water from the TMF to the mill for reuse in the process will be provided.

Cameco

Figure 9:17 A typical Saskatchewan uranium in-pit TMF, at Rabbit Lake
(Note this is not a purpose built in-pit TMF, it uses a mined out pit.)

9.3.4 Supplies and Services for Model Mill Construction

The supplies and services purchased for construction of the model mill are tabulated following.

Table 9:5 Supplies and services for model mill construction

Description	Material Supply Amount $	Installation Amount $
Earthworks services	16,621,969	18,705,873
Supplying backfill	434,355	
Building finishes	4,663,651	8,292,370
Concrete - mill building	21,285,113	27,740,644
Concrete - pads	14,683,410	19,146,675
Doors and windows	438,852	433,122
Structural steel	15,081,750	34,896,446
Interior steel works	2,084,905	6,525,514
HVAC	5,852,065	3,739,368
Tank - CS	338,191	664,020
Tank - SS	92,720	121,941
Tank - FRP	695,732	1,092,452
Tank - steel frp lining	3,559,567	7,991,620
Tank - steel rubber lining	1,486,469	8,598,501
Solution pump <50 hp	259,756	386,146
Solution pump >50 hp, <100 hp	313,635	506,816
Solution pump >100 hp, <200 hp	287,154	201,117
Slurry pump <50 hp	621,645	758,213
Slurry pump >50 hp, <100 hp	90,058	64,358
Slurry pump > 100hp, <100 hp	344,585	241,341
Motor <50 HP	2,579,047	8,894,993
Motor >50 HP, <100 HP	996,324	2,786,256
Motor > 100HP, <200 HP	180,173	392,290
Belt filters	1,206,000	1,206,455
Sand filters	337,333	337,461
Electrical	5,837,408	9,908,876
Instrumentation	7,400,000	6,480,063
Agitator <20 HP	793,730	1,945,598
Process utilities	1,729,430	829,006

Description	Material Supply Amount $	Installation Amount $
Product packaging	418,305	492,606
Acid plant	8,600,000	11,960,455
Sag mill - 300 hp	18,000,000	14,625,000
Ball mill - 200 hp	12,000,000	9,750,000
Ancillary process equipment	11,000,000	8,937,500
Process piping and coating	29,139,767	19,721,790
Dryer	1,997,500	1,998,253
SX - Mixer settlers	8,979,000	8,982,385
TMF-Access road	398,767	1,101,233
TMF-Excavation		48,914,880
TMF-Dewatering wells		2,371,500
TMF-Barge	250,000	277,857
TMF-Lining	3,071,188	16,800,868
TMF-Piping	1,917,137	3,951,134
TMF-Electrical	2,009,158	2,395,901
TMF-Instrumentation	2,200,000	1,943,354
Total	**210,275,850**	**327,112,251**

9.4 General Site

9.4.1 General Site Description

The general site must be prepared to house the mine, the mill, the TMF and all the operation support facilities, including, for example, the residence and its recreational areas, roads, power distribution, water supply and sewage management. The entire site will be graded as required to manage surface runoff from rain and snow melt.

Cameco

Figure 9:18: Aerial view of a typical Saskatchewan uranium operations site, Key Lake

9.4.2 Supplies and Services for General Site Construction

The supplies and services purchased for construction of the general site are tabulated following.

Table 9:6 Supplies and services for general site construction

Description	Material Supply Amount $	Installation Amount $
Site access road	4,776,274	14,805,635
Site preparation	21,930,857	87,723,425
Ponds and pads		42,416,841
Residence and recreation facilities	37,703,410	42,216,619
Backup diesel generators	9,375,750	5,625,140
Communications	752,060	319,505
Electrical substation	8,385,050	4,663,200
Power distribution	4,752,300	923,874
Utilities	1,072,445	938,463
Water supply and distribution	26,844,880	23,492,863
Fencing and security	1,912,328	1,624,790
Sewage system	4,569,379	18,930,383
Propane supply and distribution	2,223,611	1,850,100
Site administration office (includes fire station and ambulance)	3,249,640	3,689,310
Total	**127,547,984**	**249,220,148**

10. COMMISSIONING AND RAMP-UP

As described previously in Section 5, commissioning of the new facilities is initiated towards the end of construction, followed by a period in which capacity is ramped up to achieve production targets in terms of ore tonnes, ore grade and U_3O_8 yellowcake production. Figure 5:1 shows that commissioning and ramp-up typically takes two years. However, the commissioning and ramp-up period may be as short as six months and as long as five years.

Section 8.3 explains that commissioning assistance to the owner's teams is typically the last activity for the construction managers, and so is typically the final work in the scope of the EPCM contractor. The EPCM contractor will appoint a commissioning manager to develop a comprehensive commissioning plan that will include the establishment of a work schedule that takes into account the construction mechanical completion dates. The commissioning plan will also include the schedule for the operation of equipment, and the criteria for system acceptance and handover to the owner operations personnel. The contractor's cost for commissioning is included in the construction management cost; see Section 8.4.

Ramp-up is the period immediately following commissioning in which capacity is ramped up to achieve production targets in terms of ore tonnes, ore grade and U_3O_8 yellowcake production. The ramp-up is carried out by the owner operation personnel. The supplies and services required during ramp-up are identical to those required on a steady basis during operations; see Section 11 following. The amounts of these supplies and services begin small, and increase at a rate commensurate with ramp-up progress. Because the amounts of ramp-up supplies and services are highly variable, not reliably predictable, and relatively small value compared to the life-of-operations supplies and services, the amounts and related costs for ramp-up supplies and services are not estimated in this guide.

11. OPERATIONS AND MAINTENANCE

11.1 Underground Mining

11.1.1 Mining Methods and Freezing

Similar to McArthur River Mine the mining method for the model mine will be the raise bore mining method supplemented with some blast hole stoping. Freezing of water bearing rock, in the form of freeze curtains, has been assumed to prevent water inflows to the workings from the water bearing sandstones overlying the deposits, typical of the Athabasca basin. Progressively, as the ore is mined the voids will be backfilled with cemented rockfill (similar to lean concrete with coarse aggregate) to maintain the stability of the rock mass. The model mine assumes a production mix of 50% from raise bore mining and 50% from blast hole stoping. The two mining methods are illustrated in Figures11:1 and 11:2.

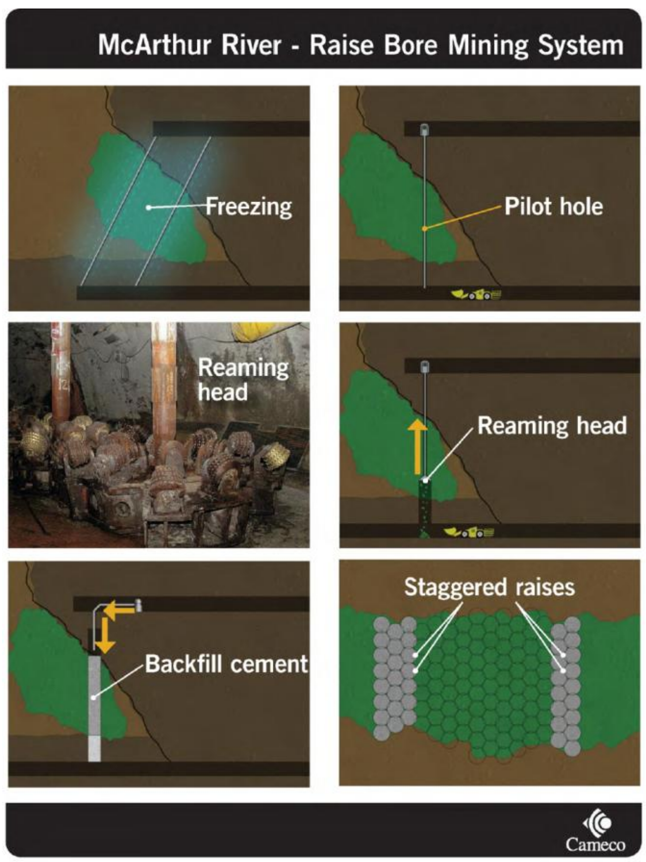
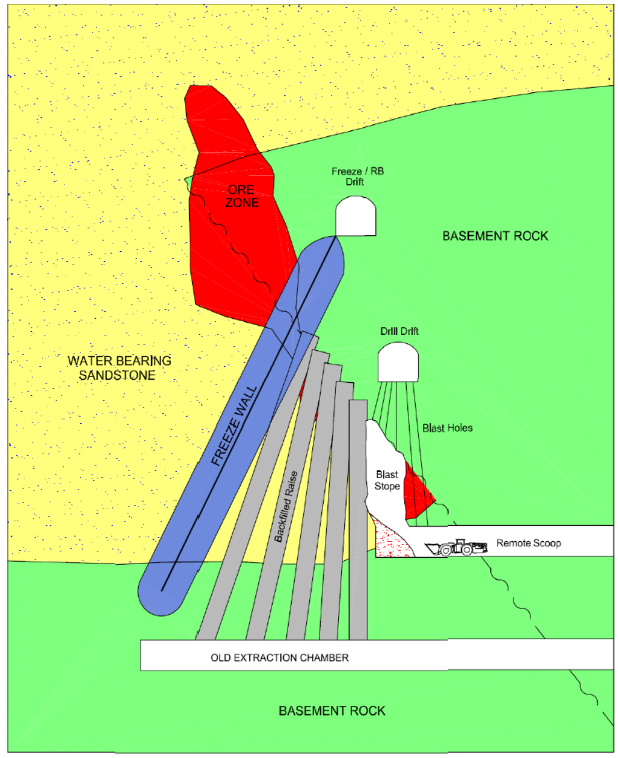


Figure 11:1 Raise bore mining method and mining sequence



Source: Cameco

Figure 11:2 Blasthole stoping mining method – cross section schematic

Prior to drilling each freeze hole in the freeze curtain, a standpipe or casing will be installed in the hole collar to support a preventer system which will be installed to secure the hole in the event that high pressure water is intersected while drilling. The drill rods used to drill the freeze hole will be left in place and used as the freeze pipes. Temperature monitoring holes will also be drilled to measure ground temperatures and indicate the progress of freezing. A specially modified in-the-hole drill rig will be used to drill the freeze and freeze monitoring holes. A picture of a freeze level at McArthur River with connections of the brine system to the freeze holes is shown in Figure 11:3.

Cameco

Figure 11:3 Freeze level

Once the freeze wall has been established, raise bore production mining can commence. The raise bore holes will range from 1.8m to 3.0m in diameter, 30m to 150m in length, and will be drilled with an electric 300kW raise bore machine similar to the one shown in Figure 11:4. A picture of a raise bore reaming head is included in Figure 11:1. Four of these raise bore machines will be required to meet the production requirements. Ore from the bottom of the raise bore holes will be loaded by a remote controlled LHD (approx. 4.6 m^3 tramming capacity) and hauled to the ore dump (see Figure 11:5). These LHDs will be equipped with a remote control operating system including on-board video cameras and will be controlled by operators working in a nearby control room. This remote operation system removes the operator from the environment at the loading point and eliminates associated radiation exposure from the ore.

Cameco

Figure 11:4 Raisebore machine

Cameco

Figure 11:5 Remote controlled LHD located under loading chute at base of production raise bore hole

As with raise bore mining, blasthole stoping can only commence once the freeze wall has been established. Blast holes will be 115 or 150mm diameter collared from a drill drift located above the ore (see Figure 11:2) with lengths ranging between 30 to 80m. Drilling will be done with a mobile in-the-hole (ITH) drill rig with an electric booster compressor raising air pressure to 2100 kPa and a drill rod carrousel (see Figure 11:6). The drill will be configured to employ reverse circulation of drill cuttings to better contain these fine ore particles for radiation control.

Cameco

Figure 11:6 ITH drill rig used for blast hole drilling

Following drilling, the blast holes will be loaded with explosives and the ore blasted. In the case of blast hole stoping, the blasted ore will be drawn from the stope from draw drifts by the same type of remote controlled LHDs as used for raise bore mining. An example of a remote controlled LHD operating in a draw drift is shown in Figure 11:7.

Cameco

Figure 11:7 LHD loading ore from a draw drift below a blasthole stope

During underground mining operations, a program of lateral and vertical development will continue on as during the capital period, but at a lesser rate. For the model mine this will be 1000m advance per year.

The production rate will be 136kt/year of uranium ore resulting in a rate of 138 t/day, a relatively small rate compared to underground mines for other commodities. Mining of ore will be a 50% split between the two mining methods as per the model mine. Freeze walls will be used to isolate all ore mining from potential water sources and therefore, freeze drilling and establishing these freeze walls will be an ongoing mining activity.

Once mined all stopes (mined ore cavities) will be filled with cemented rockfill. Preparation, distribution and placement of this fill will be an ongoing mining activity. Ore and waste will be hauled to the rock dump points, loaded onto skips and hoisted to surface. On surface it is then sent to either the waste dumps or mill ore pad as appropriate.

11.1.2 Supplies and Services for Model Underground Mine Operations and Maintenance

The supplies and services purchased for operation and maintenance of the model underground mine are tabulated following.

Table 11:1 Supplies and services for model underground mine operations and maintenance

Description	Quantity per Year	Unit	Unit Cost $ (Su. and Inst.)
Lateral development	1,000	m	9,000
Diamond drilling - underground	20,000	m	220
Bulk cement	8,000	t	380
Explosives	40,000	kg	2.50
Diesel fuel	800,000	L	1.20
Propane	5,000,000	L	0.80
Electrical consumption	90,000,000	kW/yr	0.15
Annual total cost			$35,000,000

11.2 Open Pit Mining

11.2.1 Open Pit Operations

Operations of the model open pit mine will be almost identical to those during the capital construction period with waste stripping continuing, but with mining of uranium starting and continuing for the life of the mine. The 16m high waste benches will be reduced to 8m high benches in the ore for better geological control. Waste rock will be hauled to either the waste dump or the special waste dump and ore will be hauled direct to the ore pad at the mill. The perimeter well dewatering system will continue to operate through the full life of the mine.

The production rate for the model mine open pit will be 136kt/year of uranium ore, or 138t/day, a relatively small rate compared to open pit mines for other commodities. Conversely, the waste strip ratio will be significantly higher compared to non-uranium mines. The initial capital waste strip ratio will be 80:1 but once production starts an average 20:1 waste/ore strip ratio has been used in the model, stripped annually once the capital pre-strip program has been completed. The annual ore and waste mining rate during operations will be just under 3000m^3/day.

11.2.2 Supplies and Services for Model Open Pit Mine Operations and Maintenance

The supplies and services purchased for operation and maintenance of the model open pit mine are tabulated following.

Table 11:2 Supplies and services for model open pit mine operations and maintenance

Description	Quantity per Year	Unit	Unit Cost $ (Su. and Inst.)
Diamond drilling	20,000	m	220
Maintenance parts - mobile equipment	4,100,000	$/year	-
Explosives	714,525	kg	2.50
Diesel fuel	6,000,000	L	1.20

11.3 Milling

The uranium milling process extracts uranium from ore to produce a uranium yellowcake product, which is further processed at other sites to produce fuel for nuclear power reactors. Figure 11:8 illustrates the uranium milling process for the model mill.

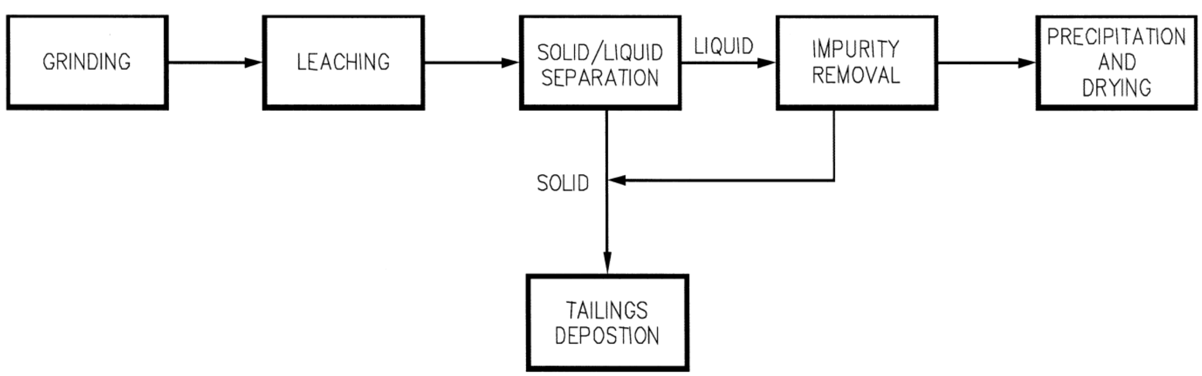


Figure 11:8 Simplified flowsheet of the uranium milling process

11.3.1 Grinding

Grinding breaks down the large rocks that will be delivered from the mine to the ore stockpiles into smaller particles approximately the size of fine sand.

Figure 11:9 Uranium ore stockpiles

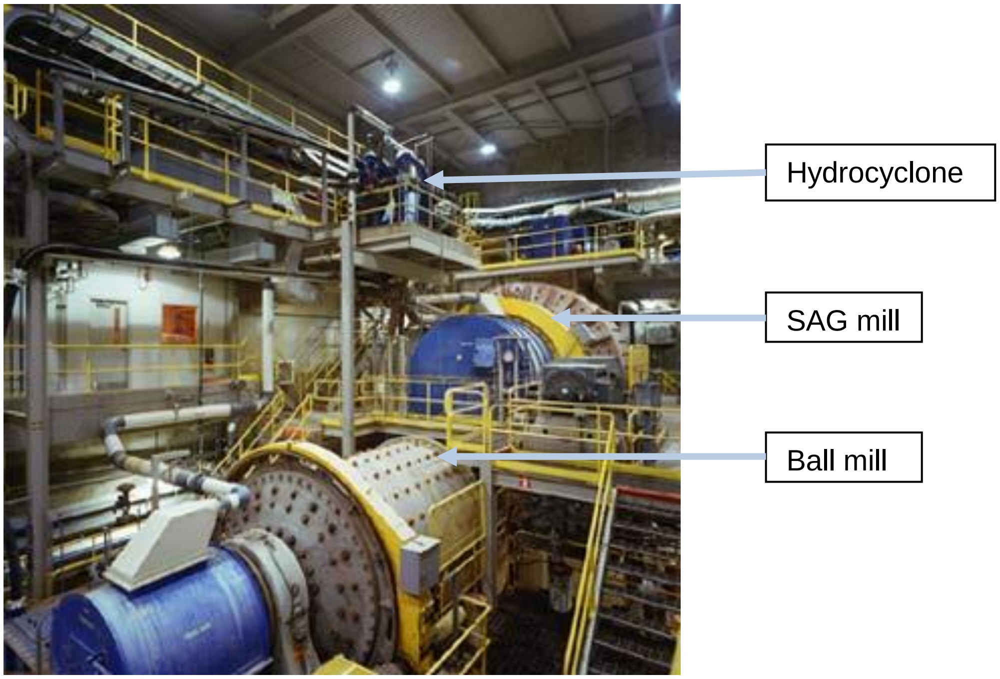


Figure 11:10 SAG mill - ball mill – hydrocyclone grinding circuit for uranium ore

The model mill will use a SAG mill and a ball mill for grinding with hydrocyclones for classification. Classification will assure the ore is ground to the correct size for leaching.

11.3.2 Leaching

Leaching dissolves the uranium from the ground ore. To do this, the ore slurry will be mixed together with the leach reagents (sodium chlorate and sulphuric acid) in atmospheric pressure agitated tanks. Leach temperature is controlled to approximately 50°C.

Figure 11:11 Uranium leach equipment, atmospheric pressure agitated leach tanks

11.3.3 Solid/Liquid Separation

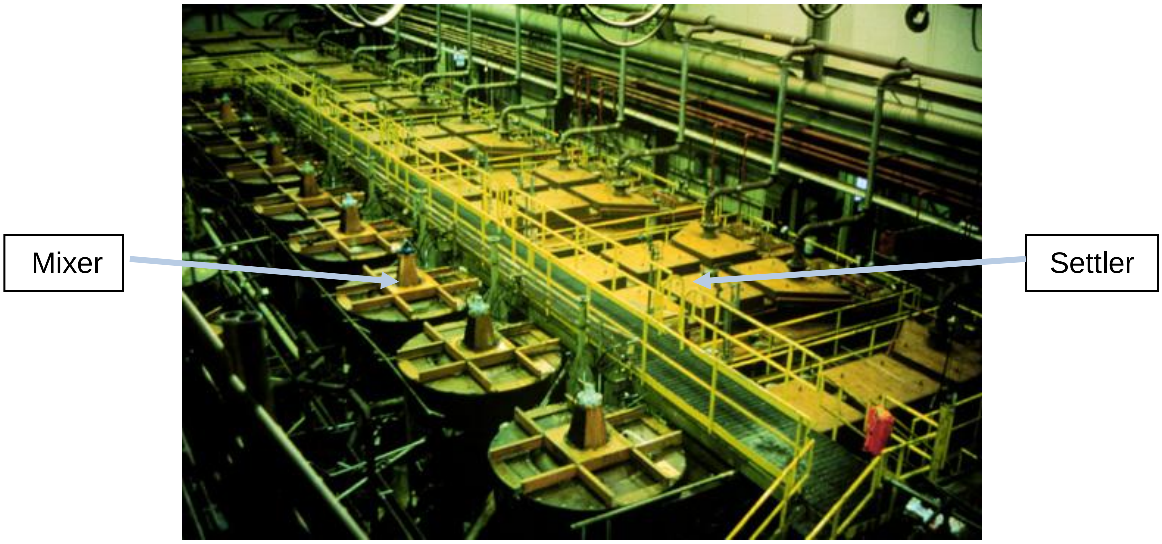
Solid/liquid separation will separate the high value uranium-containing solution from the low value low-uranium-assay solids in the leached slurry. This will be done using a series of thickeners, large tanks in which the solids settle to the bottom and the solution overflows the top. The thickeners will be operated so that the solution and the solids will flow in opposite directions through the series of thickeners. Because of this opposite direction of flows, this operation is called a counter current decantation (CCD) circuit. The solids-free solution will be pumped to impurity removal.

AREVA

Figure 11:12 CCD thickeners for solid/liquid separation

11.3.4 Impurity Removal

Dissolved impurities will be removed, and the solution uranium concentration increased, using a solvent extraction (SX) process. A series of mixer-settlers will be used for this purpose. In the first set of mixer-settlers, the aqueous uranium solution will be mixed with an organic solvent, which will extract the uranium from the aqueous solution; thus the name solvent extraction. The organic solvent will extract practically all of the dissolved uranium and very little of the dissolved impurities, thereby removing the impurities from the uranium production stream. In the second set of mixer-settlers, the uranium-containing organic solvent will be mixed with an aqueous stream which will strip the uranium away from the organic solvent. The now uranium-free organic solvent will be recycled back to the front of the circuit to once again extract uranium. The high purity, high uranium concentration, aqueous strip solution will be pumped to product precipitation and drying.



Cameco

Figure 11:13 Uranium mixer-settlers

11.3.5 Precipitation and Drying

After gypsum precipitation to reduce the sulphate ion concentration in the aqueous strip solution, the solution will be mixed with hydrogen peroxide in atmospheric pressure agitated tanks. This will precipitate the uranium out of the solution and form solid uranium peroxide. This precipitate will be dewatered by belt filtration, then dried and packaged in steel drums. This will be the mill's yellowcake product.

Cameco

Figure 11:14 Uranium yellowcake precipitation tank

Figure 11:15 Uranium yellowcake belt filtration

Figure 11:16 Uranium yellowcake dryer

Figure 11:17 Uranium yellowcake

11.3.6 Tailings Deposition

Tailings slurry will be mixed with barium chloride for radium precipitation, ferric sulphate for precipitation of trace molybdenum and selenium, and hydrated lime for acid neutralization. The neutralized tailings slurry will be pumped into the purpose built in-pit TMF for storage.

Figure 11:18 Uranium tailings neutralization circuit

AREVA

Figure 11:19 Uranium in-pit TMF

(Note this is not a purpose built in-pit TMF, it uses a mined out pit.)

11.3.7 Supplies and Services for Model Mill Operation and Maintenance

The supplies and services purchased for operation and maintenance of the model mill are tabulated following.

Table 11:3 Supplies and services for model mill operation and maintenance

Description	Supply Amount (Annual)		Supply Cost $ (Annual)
Electrical power	51,732,753	kWh	4,138,620
50 mm grinding balls	48,426	kg	84,746
100 mm grinding balls	41,508	kg	70,564
Flocculent	339,495	kg	1,782,351
Sulphur (for H_2SO_4 production)	6,564,389	kg	295,398
Sodium chlorate	968,524	kg	920,098
Kerosene	816,466	kg	1,453,310
Isodecanol	70,760	kg	283,042
Amine	21,772	kg	297,194
Sodium carbonate	54,431	kg	51,710
Sodium hydroxide	1,415,208	kg	1,202,927
Hydrogen peroxide	1,632,932	kg	1,387,992
Propane	7,310,456	L	2,339,346
Drums	16,329		791,972
Barium chloride	42,957	kg	47,253
Ferric sulphate	10,624	kg	818,050
Lime	23,319,869	kg	16,323,909
Maintenance materials	Liners, parts, supplies, etc.		5,000,000
Vehicle fuel/lube	Gas & oil		250,000
Laboratory material	Miscellaneous lab supplies		365,000
	Total		**37,903,481**

11.3.8 Supplies and Services for Uranium Industry Operation and Maintenance

AMEC has extrapolated the model mill data to estimate the supplies and services purchased annually by the entire Saskatchewan uranium industry for operation and maintenance, using the following operational assumptions.

Table 11:4 Supplies and services for uranium industry operation and maintenance

	Key Lake	Rabbit Lake	McClean Lake	Total Saskatchewan
Tonnes leached	163,293	272,155	40,823	476,272
Ore grade % U_3O_8	5.00	1.00	20.00	4.00
Production – lbs. U_3O_8	18,000,000	6,000,000	18,000,000	42,000,000

The extrapolated estimates for supplies and services purchased for operation and maintenance of the entire Saskatchewan uranium industry mill are tabulated following.

Table 11:5 Estimated supplies and services for operation & maintenance of Saskatchewan's uranium industry

Description	Supply Amount (Annual)		Supply Cost $ (Annual)
Power	181,064,635	kWh	14,485,171
50 mm grinding balls	169,492	kg	296,611
100 mm grinding balls	145,279	kg	246,974
Flocculent	1,188,234	kg	6,238,230
Sulphur (for H_2SO_4 production)	22,975,363	kg	1,002,875
Sodium chlorate	3,389,836	kg	3,220,344
Kerosene	2,857,631	kg	5,086,584
Isodecanol	247,661	kg	990,646
Amine	76,204	kg	1,040,178
Sodium carbonate	190,509	kg	180,983
Sodium hydroxide	4,953,228	kg	4,210,244
Hydrogen peroxide	5,715,263	kg	4,857,973
Propane	25,586,597	L	8,187,711
Drums	57,153		2,771,902

Description	Supply Amount (Annual)	Supply Cost $ (Annual)
Barium chloride	150,349 kg	165,384
Ferric sulphate	37,184 kg	2,863,176
Lime	81,619,543 kg	57,133,680
Maintenance materials	Liners, parts, supplies, etc.	15,000,000
Vehicle fuel/lube	Gas & oil	750,000
Laboratory material	Miscellaneous lab supplies	1,095,000
	Total	**129,823,666**

12. CLOSURE AND RECLAMATION

The decommissioning objectives for a Saskatchewan uranium facility are that all structures and disturbed areas be reclaimed to an ecological and radiological condition that is as similar as is reasonably achievable to the surrounding environment with no requirement for long term maintenance. Ultimately, the facility will be abandoned and entered into the province of Saskatchewan institutional control program.

The post operational phase of a uranium facility again needs to be supported by a full scale environmental assessment that considers the means and effects associated with decommissioning the facilities. Closure activities that meet the objective are then implemented. Table 12:1 summarizes the key expenditure areas for these activities.

Table 12:1 Closure and reclamation activities

		Amount $
1	Approvals management	3,463,000
2	Site management	6,280,000
3	Decommissioning management	13,570,000
4	Environmental monitoring	15,599,000
5	TMF decommissioning	81,448,000
6	Ore and waste rock storage areas decommissioning	60,726,000
7	Mill and ancillary facilities decommissioning	
7.1	Mill and mill facilities	12,386,000
7.2	Mine water management	1,057,000
7.3	Utilities and essential services	1,124,000
7.4	Industrial waste, hazardous and radioactive materials	558,000
7.5	Surface ancillary and support facilities	3,568,000
8	Developed site area and general reclamation	3,230,000
	Total	203,009,000

13. LONG TERM SITE MONITORING

The long term environmental monitoring program is intended to measure all relevant parameters of concern that are monitored during operations but at a reduced frequency once the site is decommissioned and effluent releases and emissions have ceased. The final decommissioning environmental monitoring program is subject to regulatory approval. Four distinct phases of environmental monitoring will occur during decommissioning. These phases and approximate timelines are as follows:

- Cessation Period Monitoring (0.5 years)
    - Monitoring during the cessation of operations.

- Decommissioning Period Monitoring (40.5 years)
    - Monitoring during approvals process, care and maintenance, active decommissioning and pump and treat period.

- Transitional Period Monitoring (10 years)
    - Monitoring conducted post active decommissioning to confirm decommissioning criteria is met and the site is in a stable and/or improving condition.

- Institutional Control Monitoring
    - Covers that period of time after transitional monitoring is completed and the site is under institutional control.
    - Includes periodic assessment of and required repairs to or revisions of impacts mitigation structures and systems.

Each of these phases will require some degree of environmental monitoring and associated services directed by the standards of the day. No cost estimate is available for long term site monitoring as there is no experience to use as the basis of the estimate. Long term site monitoring of a current best practice designed and operated mine or mill has not yet occurred.

14. INDEX

This key word index shows the pages of this Guide on which each key word appears.

15. GLOSSARY OF TERMS

AACE	Association for the Advancement of Cost Engineers
AANDC	Aboriginal Affairs and Northern Development Canada
CAMESE	Canadian Association of Mining Equipment and Services for Export
CCD	counter current decantation
CEAA	Canadian Environmental Assessment Agency
cfm	cubic feet per minute
CIM	Canadian Institute of Mining, Metallurgy and Petroleum
CNSC	Canadian Nuclear Safety Commission
CRF	cemented rockfill
CSA	Canadian Standards Association
DFO	Department of Fisheries and Oceans Canada
EC	Environment Canada
EIS	Environmental Impact Statement
EMPA	Environmental Management and Protection Act
EPCM	engineering, procurement, construction management
GF/GC	ground fault/ground check
HC	Health Canada
HDPE	high density polyethylene
hp	horsepower
HSS	hollow structural section
HVAC	heating, ventilation, air conditioning
IP	internet protocol (telephone)
ITH	in the hole (drill)
kg	kilogram
kV	kilovolt
kWh	kilowatt-hour
L	litre
LHD	load-haul-dump
m	metre
m^3	cubic metre
MARS	Mineral Administration Registry System (Government of Saskatchewan)
MCC	motor control centre
mm	millimetre
MPC	mine power centre
MPMO	Major Projects Management Office
NEB	National Energy Board
NRCan	Natural Resources Canada
PC	personal computer
PLC	programmable logic controller

SAG	semi-autogenous grinding
SEAA	Saskatchewan Environmental Assessment Act
SEC	Saskatchewan Environmental Code
SIMSA	Saskatchewan Industrial and Mining Suppliers Association
SMoE	Saskatchewan Ministry of the Environment
SX	solvent extraction
t	tonne
TC	Transport Canada
TMF	tailings management facility
V	volt
WF	wide flange (steel sections)