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Uranium in Canada 1980 Assessment of Supply and Requirements

Report EP 81-3

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Figures

Tables

Contents

Foreword

This is the seventh in a series of reports that has been published annually since the Uranium Resource Appraisal Group (URAG) was established within the Department of Energy, Mines and Resources (EMR) in late 1974. A brief historic review of EMR's uranium resource assessment activities can be found in Appendix 1.

A review of priorities within EMR has led to a decision to publish this report biennially (i.e., the next report, to be based on URAG's 1982 assessment will be published in September 1983). Some of the data regularly acquired in the course of URAG's on-going assessment may continue to be made available on an annual basis.

Summary

A Uranium Resource Appraisal Group (URAG) was established within the Department of Energy, Mines and Resources (EMR) in September 1974 to audit annually Canada's uranium resources for the purpose of implementing the federal government's uranium policy. URAG completed its seventh annual assessment in mid-1981, using two price ranges: (a) up to $135/kg U and (b) from $135 to $200/kg U (Canadian dollars). Results are shown below for the three resource categories used for the purpose of allocating reserves to be set aside by Canadian producers to meet domestic requirements; the figures represent the totals for both price ranges, that is, for estimated resources mineable at a uranium price of $200/kg U or less:

	Tonnes U* contained in mineable ore
Measured	73 000
Indicated	185 000
Inferred	315 000

The total of these three categories is less than that in the 1979 assessment by 14 000 tonnes U. Resource estimates in the indicated and inferred categories are, by definition, less reliable than those for the measured category; for allocation purposes, weighting factors of 1.0, 0.8 and 0.7 are applied to each producer's tonnage in the measured, indicated and inferred categories respectively. Individual mill recovery factors are also applied to arrive at each producer's recoverable **adjusted reserve.**

Of the total recoverable **adjusted reserve** summed for all Canadian uranium producers marketing uranium, about 18 per cent will be needed to provide the 30-year fuelling requirements of 62 000 tonnes U for the 15 111 megawatts (MWe) of nuclear power capacity now operating in Canada or committed for operation by 1991. No additional capacity is planned for this period. Moreover, to conform to federal policy, domestic utilities are required to have contracted for their forward 15-year fuelling requirements which, for the capacity noted above, amount to 31 000 tonnes U.

* 1 tonne U (1 metric ton of elemental uranium) is equivalent to 1.2999 short tons U_3O_8.

In 1980, Canada had seven uranium operations which in total produced concentrates containing some 7 145 tonnes U; these "primary" uranium producers employed 6 068 people at their mining and milling operations. Based on currently envisaged production centres, Canada's projected annual primary uranium production capability could grow from 8 400 tonnes U in 1981 to some 15 000 tonnes in the mid 1980s.

This report also contains estimates of prognosticated resources associated with known uranium deposits, and estimates of speculative resources thought to exist in virgin areas or in areas where only uranium occurrences are known. Prognosticated resources mineable at uranium prices of $200/kg U or less are estimated to contain 445 000 tonnes U, about the same as was reported in 1979. Speculative resources in areas assessed during 1980 are thought to contain between 1.2 to 1.4 million tonnes U, mineable at prices of $200/kg U or less.

Uranium exploration expenditures in Canada in 1980 were an estimated $128 million, almost equivalent to the $130 million reported for 1979. Exploration drilling and surface development drilling in 1980 was reported to be 503 300 metres, more than 70 per cent of which was in Saskatchewan.

Part A. Ten-Year Perspective

I. Supply

a) Supply Sources

Measured, Indicated and Inferred Tonnages

The terminology and definitions employed by EMR, and their relationship to the internationally used terms and definitions established by the Nuclear Energy Agency (NEA) of OECD and the International Atomic Energy Agency (IAEA), are outlined in Appendix 3. The methodology employed in previous assessments continues to apply to this report.[1]

For policy purposes, i.e., for assigning domestic allocations among producers, only uranium resources in the measured, indicated and inferred categories are considered by EMR; estimates of 1980 resources in these three categories are presented in Table 1. These resources are associated with identified deposits in areas shown in Figure 1. This assessment of Canada's uranium resources was conducted by the subcommittees of URAG commencing in December 1980. The assessment was done using two price ranges; the lower price range was limited by the uranium market price estimated in Canadian dollars at $135/kg U in December 1980, when most of the data for the assessment were gathered, while the higher range spanned the $135 - $200/kg U interval. All quantities are reported in metric tons (tonnes) of elemental uranium (U), consistent with international practice. Prices are given in dollars/kg U*.

* 1 tonne U (1 metric ton of elemental uranium) is equivalent to 1.2999 short tons U_3O_8; $1/lb U_3O_8 = $2.6/kg U.

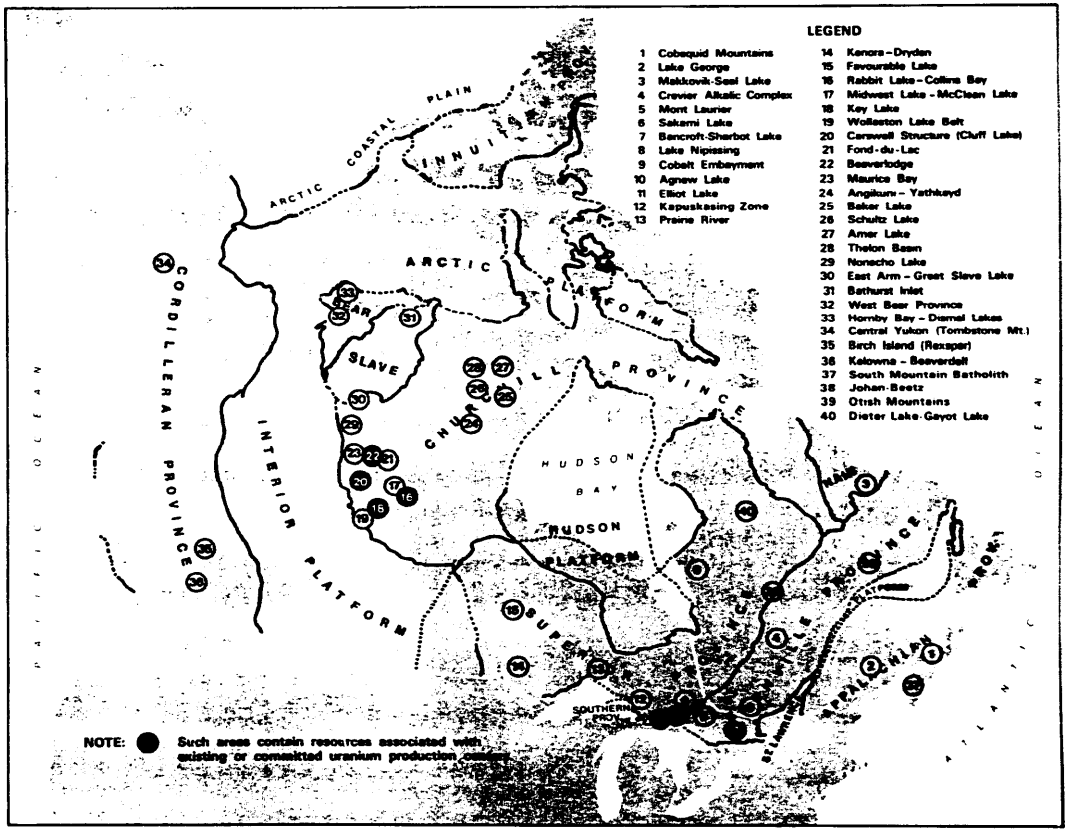

Figure 1. Areas in Canada with uranium resources associated with identified deposits.

TABLE 1

1980 Estimates of Canada's Mineable Uranium Resources

Mineable at uranium prices	Uranium contained in mineable ore* (thousands of tonnes U)					
	Measured		Indicated		Inferred	
Up to $135/kg U**	67	73***	163	157	214	230
$135 to $200/kg U**	6	4	22	25	101	90
Total	73	77	185	182	315	320

* Uranium recoverable from such ore will be less, because of milling losses (see text).

** The dollar figures refer to the market price of a quantity of uranium concentrate containing 1 kg of elemental uranium. The prices were used in determining the cut-off grade at each deposit, taking into account mining methods and milling losses.

*** Shaded figures are from the 1979 assessment using price ranges of up to $130/kg U and $130 to $200/kg U.

The price of $135/kg U was an average weighted price for the year under contracts, including spot sales, made by Canadian producers for deliveries in 1980, and under earlier contracts that had provision for price renegotiation. It is important to clarify that the prices reflected in this average determination would have been negotiated, in most cases, prior to the major decline in prices that occurred during 1980.

In addition to the 1980 estimates, Table 1 shows the 1979 estimates of Canada's mineable uranium resources. The comparison indicates a 5 per cent decrease in the measured category, a slight increase in the indicated category and a decrease in the inferred category of about 4 per cent. The total of the three resource categories is less than that in the 1979 assessment by 14 000 tonnes U, representing a net decrease of about 2 per cent. If 1980 production and average processing recoveries are considered however, the reduction over the period amounted to only 6 400 tonnes U, or a decrease of just over 1 per cent. Changes in the distribution of resources among individual categories resulted from the technical-economic re-evaluation of some segments of the Beaverlodge deposits, the continued evaluation of the Midwest Lake deposit, and the re-assessment of the Key Lake deposits, all in northern Saskatchewan.

It is pertinent to note that almost 95 per cent of the total resources in the three categories combined is tributary to the production centres listed in Table 3.

The resource estimates are expressed in terms of quantities of uranium contained in mineable ore. In underground operations, mineable ore is generally 75 per cent to 85 per cent of the ore-in-place; as a rule, higher mining recoveries are achievable in open-pit operations.

For categorization by price level (i.e. level of economic exploitability), cut-off grades are chosen which cover all costs of production after due consideration of processing losses (normally about 5 per cent to 10 per cent), plus any required forward capital costs. The difference between the cut-off grade and the average grade of the resources for each individual deposit is then examined to determine if the difference is sufficient to carry such items as taxes and royalties, head-office overhead, forward exploration and development costs, and an acceptable rate of return on invested capital (i.e. costs associated with the use of capital). If the difference betweer the chosen cut-off grade and the average grade is judged sufficient, the tonnage is taken to be mineable at a price below the stated limit. In most cases, cut-off grades chosen for individual deposits were those used in the 1979 assessment. In view of more recent downward price trends, however, upward adjustments in cut-off grades may be appropriate and a detailed study of the relationship of costs, prices and cut-off grades is planned toward this end.

It should be noted that the resources shown in Table 1 as being mineable at prices from $135 to $200/kg U represent estimates restricted mainly to the principal deposits in Canada. Data related to low grade uranium resources in this price range are relatively limited because in the past such material was not recorded. Consequently, estimates of such lower grade material, which would be mineable only within the higher-price range, represent a relatively incomplete appraisal.

It is important to be aware of the distinction between U contained in mineable ore and U recoverable from such ore. While ore processing losses were taken into account in the determination of the cut-off grades, the resource tonnages reported in Table 1 represent quantities of uranium contained in mineable ore, in conformance with the traditional method of reporting metal resources. Most of this uranium can be recovered from the mineable ore, since processing recoveries are normally high; in 1980 the average was 93.2 per cent for existing conventional operations.

Of the total resources in all three categories (measured, indicated and inferred), about 63 per cent is in Ontario and 31 per cent in Saskatchewan. Distributions quoted in the 1979 assessment were 62 and 33 per cent respectively. The redistribution is largely the result of the re-evaluation of certain resource estimates in Saskatchewan.

Over 60 per cent of Canada's uranium resources in the measured, indicated and inferred categories occur in quartz-pebble conglomerates, primarily in the Elliot Lake and Agnew Lake areas of Ontario. Most of the remaining resources in the same three categories occur in vein and unconformity-related type deposits, primarily in northern Saskatchewan.

It is illustrative to note that the sum of the resources in the measured, indicated, and inferred categories has increased, since the first URAG assessment in 1974, by some 168 000 tonnes U; including production of 35 400 tonnes U over the period, total resource additions have exceeded 203 000 tonnes U. During the same period, the federal government reviewed export contracts totalling almost 60 000 tonnes U and found these contracts to be consistent with Canada's uranium export policy (see Table 6). These export quantities represent less than one-third of the total resource additions noted above, illustrating Canada's capability as a secure long-term supplier of uranium.

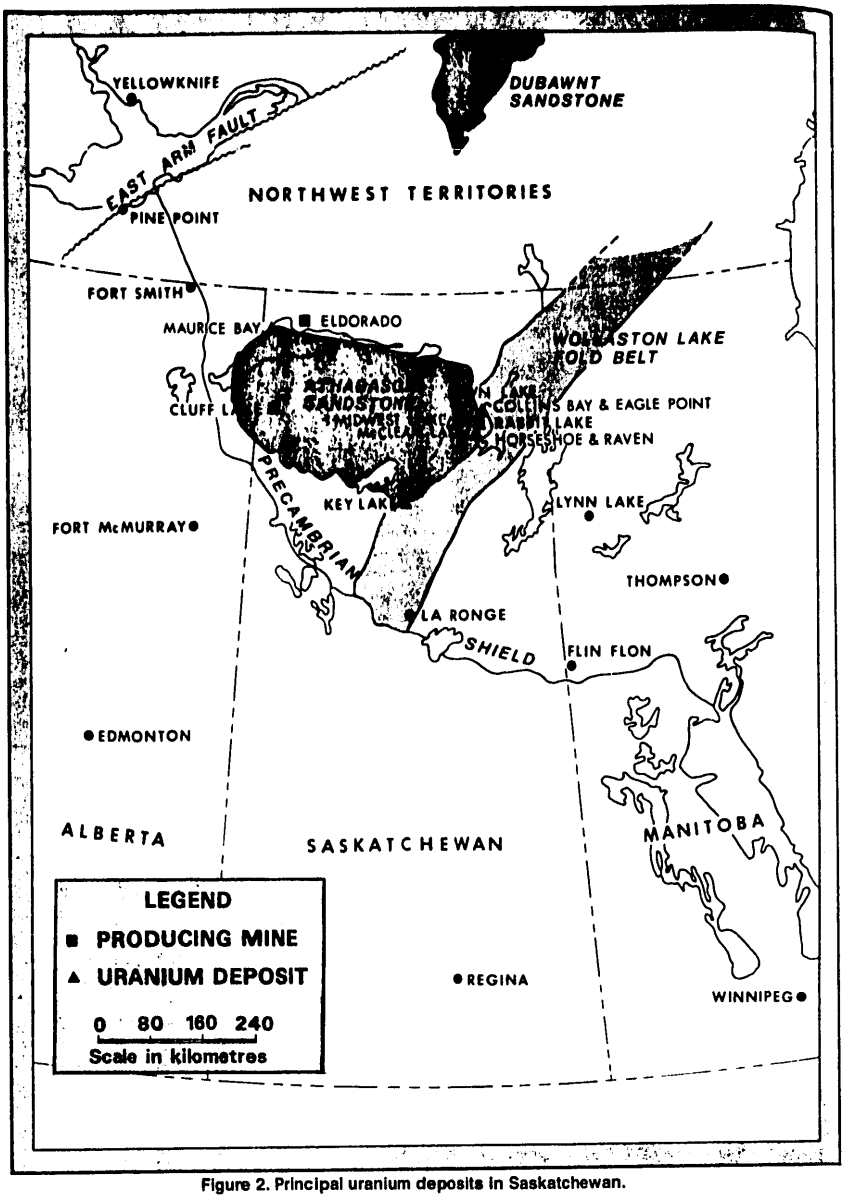

Figure 2. Principal uranium deposits in Saskatchewan.

b) Uranium Availability

Current Operations

In 1980, Canada had seven primary uranium producers: Denison Mines Limited, Rio Algom Limited, Madawaska Mines Limited, Eldorado Nuclear Limited, Cluff Mining (Amok Ltd./Saskatchewan Mining Development Corporation — partnership), Gulf Minerals Canada Limited/Uranerz Canada Limited (Rabbit Lake joint operation) and Agnew Lake Mines Limited. The first four operate underground mines, the fifth and sixth operate open-pits and the seventh uses underground and surface heap-leaching techniques. In addition, ESI Resources Limited began uranium recovery as a byproduct of phosphoric acid production late in the year.[2]

Production from the primary uranium producers amounted to 7 145 tonnes U in 1980, as compared to 6 817 tonnes U in 1979. Shipments of uranium made by these producers from production amounted to an estimated 6 368 tonnes U, valued at $638 million, as compared with final shipments of 6 530 tonnes U in 1979 valued at $616 million. Some 67 per cent of Canada's total uranium shipments in 1980 came from the four producers in Ontario, and the remainder from the three producers in Saskatchewan.

The mill expansion project of Denison Mines Limited at Elliot Lake was set back six months as a result of a multi-million dollar fire in September that destroyed the new acid drum filter area. The mill expansion, which will double the throughput capacity from 6 440 to 13 610 tonnes of ore a day (tpd), is scheduled for completion by mid-1981. Normal production continued at the existing mill which was not damaged by the blaze; uranium output was down by only 1 per cent from 1979. Other phases of the company's expansion program, including underground development work at the Denison mine and reopening of the adjoining Stanrock mine, where dewatering has been completed, will continue until completion in 1982 and 1985, respectively.

Also at Elliot Lake, the bulk of Rio Algom Limited's production continued to come from its 6 350 tpd Quirke mine and mill. As a result of lower recovered ore grades, uranium output decreased by some 8 per cent compared to 1979. Equipment problems encountered during the start-up of the 2 990 tpd Panel mill in late 1979 were overcome and the operation contributed increasingly to production, more than offsetting the Quirke production decline. The rehabilitation of the company's Stanleigh mine and mill, which is being financed by Ontario Hydro, progressed on schedule and within budget. Full production, at a rate of 4 540 tpd is expected in early 1984. From the start of Rio Algom's expansion program in 1975, some $500 million has been invested in the Quirke mine-mill expansion, the rehabilitation of the Panel mine-mill, the rehabilitation of the Stanleigh property, and the associated housing program in Elliot Lake.

At the underground and surface heap-leaching facility of Agnew Lake Mines Limited, 90 km east of Elliot Lake, uranium production increased 13 per cent during the year despite the plan to phase out operations. The company, granted a two-year licence renewal by the Atomic Energy Control Board (AECB), must submit a plan and schedule for decommissioning the leaching and mill tailings area. Mining was discontinued as planned, during the second quarter of 1980; recoveries are from the treatment of mine water and the surface heap-leaching facility. The operation will continue until recoveries decline to a level where further production becomes uneconomic.

Madawaska Mines Limited was able to maintain scheduled production at its 1 360 tpd operation at Bancroft, Ontario. A limited reorganization of the company was approved, whereby Madawaska retained a 51 per cent undivided interest in the assets and liabilities but became wholly-owned by Federal Resources Corporation; Consolidated Canadian Faraday Limited's 49 per cent share interest in the operation was converted to a 49 per cent direct interest.

In Saskatchewan, Eldorado Nuclear Limited's Beaverlodge mill near Uranium City continued to operate below its design capacity. Although a serious forest fire in the area diverted manpower from production, uranium concentrate output was up 9 per cent over 1979. At the Beaverlodge mine, the mechanization program which began last fall resulted in a modest increase in overall productivity.

Despite a forest fire in April that had threatened to delay the operation, mining of Cluff Mining's (Amok Ltd./SMDC) high grade "D" orebody at Cluff Lake, Saskatchewan, began on schedule in June. In the following four months about one-third of the orebody was mined and stockpiled for future processing. Concentrate production started in October at the recently completed mill, where the uranium extraction process relies on direct precipitation of the yellowcake (i.e., purification by ion exchange or solvent extraction is unnecessary). Uranium output during the year was about 11 tonnes U; full capacity is 1 500 tonnes U/year. Development of the "D" orebody, or Phase 1, was completed at close to the $80 million budgeted. An environmental impact study for Phase 2, the development of Cluff Mining's lower-grade Claude and "N" deposits, is in preparation and will be submitted to the Government of Saskatchewan for regulatory approval by early 1982. The reported capital cost of Phase 2 will approach $100 million; project timing will depend upon uranium market conditions.

Gulf Minerals Canada Limited passed the mid point in the exploitation of the Rabbit Lake open-pit in northern Saskatchewan, which is operated jointly with Uranerz Canada Limited. Gulf is planning to develop its Collins Bay "B" orebody in order to maintain production capacity at the 1 500 tpd Rabbit Lake mill, where uranium output this year fell below the 1979 level by some 5 per cent. Gulf submitted an environmental impact statement to the Saskatchewan government and participated in three public meetings to outline its proposed developments. Mining of the Collins Bay "B" deposit, located some 11 km north of Rabbit Lake, could begin by 1982 although it is not expected that milling would begin before 1983. The presence of metal oxides and arsenides in the "B" ore will necessitate the modification of the Rabbit Lake plant's uranium extraction circuits.

ESI Resources Limited, a wholly-owned subsidiary of Earth Sciences Incorporated of Golden, Colorado, received approval early in 1980 to recover uranium as a byproduct of phosphoric acid production at the Calgary, Alberta, plant of Western Co-operative Fertilizers Limited (WCFL). ESI's recovery plant, the first such operation in Canada, was built adjacent to the fertilizer plant; it was expected that output levels will range between 30 and 60 tonnes U/year. The phosphate rock used by WCFL is imported from the United States and the recovered uranium will be supplied to U.S. customers; for this reason, output is not included in the Canadian total. Commissioning of the facility began in June 1980 and first production was realized by year-end; total output amounted to 2 tonnes U.

As shown in Table 2, the work force at Canada's producing uranium operations as of December 1980 totalled some 6 068 employees. Of this total about 2 557 worked in the mines, both open-pit and underground, and some 831 in the mills, with the balance described as general employees; head-office and construction-related employment is not included. The major changes reflected below are the result of the cessation of mining at Agnew Lake and the start-up of the Cluff Mining operations.

TABLE 2

Work Force Summary — Canadian Uranium Producing Operations (December 31, 1980)

Company Name (mine name)	Total number of employees (mine, mill, general)
Agnew Lake Mines Limited	79
Cluff Mining [Amok Ltd./SMDC]	241
Denison Mines Limited	2 027
Eldorado Nuclear Limited	845
Gulf Minerals Canada Limited/ Uranerz Canada Limited (Rabbit Lake)	320
Madawaska Mines Limited (Faraday)	381
Rio Algom Limited (Panel)	771
(Quirke)	1 404
Total — All producers	6 068

Projected Production Capabilities

In addition to the current operations previously mentioned, there are several deposits in various stages of development that may become sources of uranium within the next 10 years. Production commitments have been made for some of these deposits; for others, feasibility studies are either completed or in progress but no firm commitments have been made.[2] These various production projects are summarized in Table 3.

Key Lake Mining Corporation (KLMC), was formed in 1979 — jointly owned by Saskatchewan Mining Development Corporation (SMDC) (one-half), Uranerz Exploration and Mining Limited (one-third), and Eldor Resources Limited, wholly-owned by Eldorado Nuclear, (one-sixth) — for the purpose of developing and exploiting the Key Lake deposits (Gaertner and Deilmann), 240 km north of La Ronge, Saskatchewan. With the exception of some preparatory site-work, development at the project was deferred for much of 1980, pending the completion of a provincial inquiry established to recommend the conditions under which the project should be permitted to proceed. The summary hearings of the board of inquiry were completed on October 3, 1980 and the recommendations were released early in 1981. Construction of the mill, which would process between 500 and 700 tpd, will hopefully begin in 1981 following the negotiation of a surface lease with the Provincial Government, with first production from the open-pit operation by the summer of 1983; the Gaertner deposit will be exploited first and annual production is planned at a rate of 3 100 tonnes U/year with a possible extension to 4 600 tonnes U/year. Combined reserves of the Gaertner and Deilmann deposits have been reported by KLMC at 73 600 tonnes U. Capital costs for the project are likely to exceed $400 million.

Late in 1979, Canada Wide Mines Ltd., a wholly-owned subsidiary of Esso Resources Canada Limited, took over the management of Esso Minerals Canada's Midwest Lake uranium project, some 24 km west of Rabbit Lake, Saskatchewan (Esso Minerals is a Division of Esso Resources Canada). At the property, owned by Esso Minerals (50 per cent), Numac Oil & Gas Ltd. (25 per cent) and Bow Valley

TABLE 3

Canadian Uranium Ore Processing Plants

Plant	Location	Nominal Daily Capacity (tonnes) of ore)	Annual Production Rate *(1)* (tonnes U)
A. Operating			
Agnew Lake Mines Limited	Agnew Lake, Ont.	n.a. *(2)*	195
Cluff Mining (Amok Ltd/SMDC)	Cluff Lake, Sask.	1 360 *(3)*	11
Denison Mines Limited — Denison Mill	Elliot Lake, Ont.	6 440 *(4)*	1 712
Eldorado Nuclear Limited	Eldorado, Sask	1 630 *(5)*	423 *(6)*
Gulf Minerals Canada Limited	Rabbit Lake, Sask.	1 500 *(7)*	1 960
Madawaska Mines Limited	Bancroft, Ont.	1 360	235
Rio Algom Limited — Quirke Mill	Elliot Lake, Ont.	6 350	1 879
Rio Algom Limited — Panel Mill	Elliot Lake, Ont.	2 990	730
B. Committed			
Key Lake Mining Corporation	Key Lake, Sask.	500-700 *(8)*	3 100-4 600
Rio Algom Limited — Stanleigh Mill	Elliot Lake, Ont.	4 540 *(9)*	–
C. Planned and Possible *(10)*			
Brinco Limited	Makkovik, Nfld.	–	–
Canada Wide Mines Ltd.	Midwest Lake, Sask.	–	–
Consolidated Rexspar Minerals & Chemicals Ltd.	Birch Is., B.C.	–	–
Norcen Energy Resources Limited	Beaverdell, B.C.	–	–
Rio Algom Limited — Milliken Mill	Elliot Lake, Ont.	–	–

n.a. not applicable
– no data available
(1) 1980 production for operating plants; planned rate for others.
(2) Using an underground and surface heap-leaching technique; ceased mining in early 1980 but continued with surface operations.
(3) A two-stage program the first phase of which was completed in 1980.
(4) Increased to 13 610 tpd by mid-1981.
(5) Operated at about half nominal capacity in 1980.
(6) Includes 6 tonnes U from Cenex Limited.
(7) Joint venture with Uranerz Canada Limited; operating in excess of nominal capacity.
(8) Production expected by July 1983.
(9) Rehabilitation to be completed 1983-84.
(10) No firm decisions as to timing and size of operations.

Industries Ltd. (12½ per cent), drilling efforts continued, as work on the environmental impact statement and feasibility studies progressed. Contingent on the availability of markets and early regulatory approval, mine development could begin in 1982, although production is unlikely before 1986. Total capital cost of the project is reported at $500 million.

On February 27, 1980 the Government of British Columbia announced a seven-year moratorium on uranium exploration and mining in the province. This decision caused the suspension of development plans of the Blizzard project, near Beaverdell, a joint venture headed by Norcen Energy Resources Limited, and of the Birch Island project, 130 km north of Kamloops, held by Consolidated Rexspar Minerals & Chemicals Limited. The Royal Commission of Inquiry into Health and Environmental Protection in Uranium Mining, established by the province one year earlier under Dr. David Bates to investigate the health and safety aspects of the uranium industry, was permitted to receive submissions until April 15 although no further hearings were scheduled. The Commission forwarded its final report to the Government of British Columbia on October 31, 1980; it was tabled in the legislature on March 18, 1981. The report recommended that provided that a licensing procedure for uranium exploration was instituted in British Columbia, the moratorium on uranium exploration should be lifted. Despite the recommendations, the B.C. government indicated that the moratorium would not be lifted.

Brinco Limited has deferred the development of its Kitts-Michelin project in eastern Labrador, largely because of the depressed uranium market. In addition, on May 29, 1980 the Government of Newfoundland and Labrador announced that it had accepted the recommendation of the provincially appointed Environmental Assessment Board, that a development licence for the project be withheld until Brinco demonstrated that it could and would safely dispose of the radioactive waste from its proposed mine and mill. It was emphasized that the decision was specific to the Kitts-Michelin project, and that the government was confident that the technological problems could be overcome so that the mining of uranium could proceed in the province.

Two projections of production capability to 1991 are presented in Table 4. The projection shown in Scenario A is considered to be the maximum output attainable based on known deposits associated with all of the production centres noted in Table 3. It assumes an adequate availability of manpower, equipment, capital financing, the existence of base-load contracts, and currently appropriate lead-times. Resources in these deposits in the measured, indicated and inferred categories mineable at a uranium price of $200/kg U or less are incorporated into the projection.

Delays in bringing some of these projects into production because of market conditions would shift the peak production achievable from these deposits into the 1990s. It is pertinent to note that there are certain more recent discoveries that could have some potential for production, which are not considered in this maximum projection because they are not yet fully evaluated and because it is unlikely that they would commence production in the coming decade. The status of such deposits is referred to in the section on Uranium Exploration Activities.

For comparison, Scenario B in Table 4 represents a projection of production capability to 1991 which excludes not only the uncommitted projects of Table 3 but also certain planned, and as yet uncommitted, expansions at operating production centres. Only those resources mineable at a uranium price of $135/kg U or less are considered in the B scenario. The similarity to the A projection indicates that over the next decade the bulk of Canadian production capability can be realized from

resources in the lower price category. The decline in production capability projected in the B scenario in the late 1980s is a reflection of the depletion of certain deposits and of decreasing grades of ore mined from others. Actual achievement of the levels of production under this production capability scenario, however, will be dependent on market developments.

TABLE 4

Estimated Annual Uranium Production Capability From Canadian Deposits Known in 1980

Year	Tonnes U contained in concentrates	
	(A)*	(B)**
1980	7 145 (actual)	7 145
1981	8 400	8 400
1982	9 500	9 500
1983	10 800	10 800
1984	14 800	14 800
1985	14 900	14 700
1986	15 900	14 000
1987	16 800	12 900
1988	16 500	12 300
1989	16 500	11 500
1990	17 000	10 500
1991	18 400	10 200

* Projection based on operating, committed and uncommitted production centres; output from resources currently mineable at a uranium price of $200/kg U or less.

** Projection based on operating and committed production centres only; certain planned but as yet uncommitted expansions at operating production centres are excluded. Output from resources currently mineable at a uranium price of $135/kg U or less.

II Requirements

a) Domestic Requirements and Assignments

Canadian uranium policy requires that sufficient uranium be reserved for domestic use to enable each nuclear power reactor currently on-stream, or planned to come on-stream within the next 10 years, to operate at an average annual capacity factor of 80 per cent for 30 years from 1981, or from the in-service date of the nuclear unit, whichever is later. Further, domestic utilities are required to demonstrate to the Atomic Energy Control Board that they are maintaining a contracted 15-year forward supply for both operating and committed reactors.

Canadian uranium requirements and domestic assignments are reported here as anticipated in May 1981. The current assessment of domestic allocations for producers and utilities is based on the estimates of installed nuclear generating capacity shown in Table 5. As of May 1981, a total of 15 111 MWe of nuclear power capacity was either already operating or committed for operation by 1991. While the 22 MWe Nuclear Power Demonstration reactor at Rolphton, Ontario is operating, it is basically an experimental and training facility and is therefore not included for

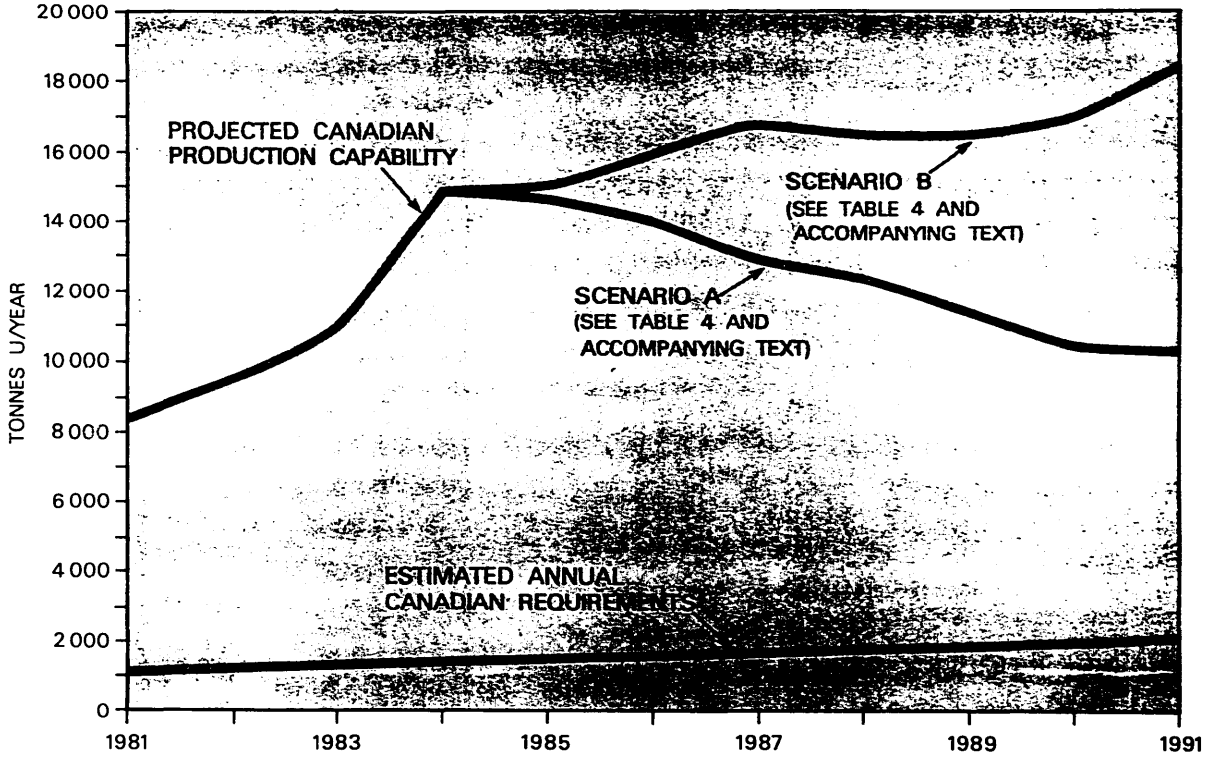

Figure 3. Projected Canadian production capability compared with estimated annual uranium requirements.

long-term uranium allocations. As noted last year, Atomic Energy of Canada Limited's (AECL) 250 MWe Gentilly 1 reactor is also not included. No further nuclear plants are planned to come into service during the 10-year period to 1991.

Uranium requirements for the reactors represented by this 15 111 MWe of capacity were assessed on the basis of the fuel utilization design values for existing or committed stations.

The situation anticipated in 1981 is illustrated in Figure 4. In this figure the uranium which producers are required to allocate for domestic use is represented by the total hatched area under the curve. For the 15 111 MWe projected to be in operation by 1991, this **protected supply** amounts to some 62 000 tonnes U. Of this, utilities will be required to have firm contracts to provide 15-year supplies for those reactors operating or committed for operation. This is represented by the shaded **utility responsibility** area and amounts to 31 000 tonnes U. Annual requirements, including first cores for future reactors, are expected to grow from some 1 100 tonnes U/year in 1981 to between 2 100 and 2 400 tonnes U/year in 1991.

TABLE 5

Nuclear Power Plants in Canada as of May 1981

Operating reactors	Owner	Net output-MWe
Douglas Point	Atomic Energy of Canada Limited	206
Pickering 1 to 4	Ontario Hydro	2 060
Bruce 1 to 4	Ontario Hydro	2 960

Reactors under construction or committed	Owner	Estimated in-service dates	Expected net output-MWe
Gentilly 2	Hydro-Quebec	1982	638
Point Lepreau	New Brunswick Electric Power Commission	1982	635
Pickering 5 to 8	Ontario Hydro	1983-84	2 064
Bruce 5 to 8	Ontario Hydro	1983-87	3 024
Darlington 1 to 4	Ontario Hydro	1988-90	3 524

Total operating or committed for operation by 1991 — 15 111 MWe.

To ascertain each producer's domestic allocation, their measured, indicated and inferred resources mineable at a uranium price of $200/kg U or less are first determined. Weighting factors of 1.0, 0.8 and 0.7 are then applied to each producer's tonnage in the measured, indicated and inferred categories, respectively, in recognition of the lower degree of confidence that is placed (by definition) in the latter two categories. Individual mill recovery factors are also applied. The sum of the weighted tonnages in the three categories adjusted in this manner is termed the recoverable **adjusted reserve**, for the purpose of the domestic allocation procedure. Domestic allocation requirements amount to about 18 per cent of the total recoverable **adjusted reserve** for all Canadian uranium producers marketing uranium.

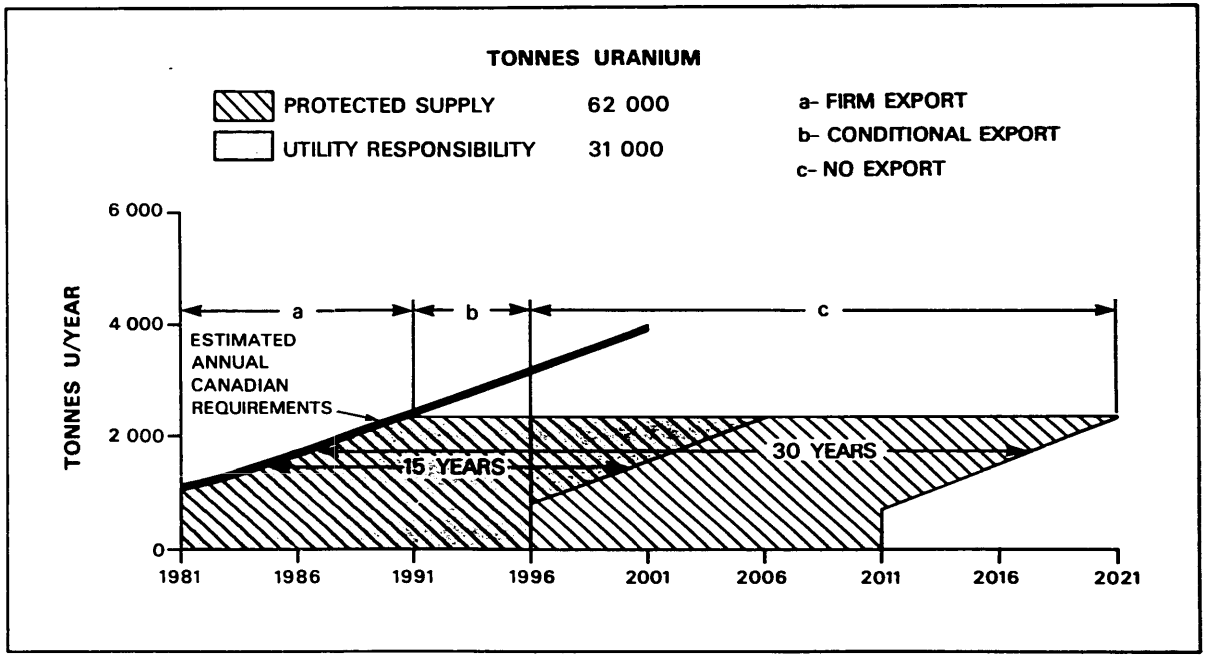

Figure 4. Uranium supply for domestic applications, 1981 situation.

b) Domestic and Export Commitments

From the foregoing section it is clear that the bulk of Canada's domestic needs for the short-term are those required for the Ontario Hydro nuclear power program. Ontario Hydro's two principal uranium supply contracts were approved by the Government of Ontario in February 1978. A contract with Denison Mines Limited calls for the delivery of 48 465 tonnes U over the period 1980 to 2011, while a contract with Rio Algom Limited will provide an additional 27 695 tonnes U over the period 1984 to 2020. These contracts satisfy the bulk of Ontario Hydro's needs to the early part of the next century. Contracts are either in place or are under negotiation relating to most of the remaining domestic requirements to the end of the century.

Canadian producers shipped 6 368 tonnes U in 1980 valued at $638 million. Some 85 per cent of these shipments were destined for the export market, primarily to customers in Japan and Western Europe. As of December 31, 1980, Canadian producers had forward export commitments totalling approximately 48 500 tonnes U, under active contracts that had been reviewed by the federal government and found to be consistent with Canadian uranium export policy. These quantities are to be delivered over the period 1981 to 1993.

The relative importance of Canada's uranium export customers is illustrated in Table 6, which indicates that, during the period September 5, 1974 to December 31, 1980, contracts totalling some 59 000 tonnes U had been reviewed by the federal government and found to be consistent with Canadian uranium export policy. The 59 000-tonne total reflects scheduled deliveries under 50 contracts, only 19 of which remain active. Japan is currently Canada's most important uranium customer, followed by the United States, the United Kingdom and West Germany.

TABLE 6

Uranium Under Export Contracts Reviewed *(1)*
Since September 5, 1974

	(as of December 1980) *(2)*	
Country	Short Tons *(3)* U_3O_8	Tonnes U
Belgium	1 220	938
Finland	2 300	1 769
France	2 000	1 538
Italy	1 800	1 385
Japan	25 358	19 507
South Korea	2 483	1 910
Spain	6 250	4 808
Sweden	1 178	906
Switzerland	200	154
United Kingdom	10 000	7 693
United States	15 640	12 032
West Germany	8 299	6 384
Total	76 728	59 024

(1) Reviewed and found to be consistent with Canadian uranium export policy.
(2) Totals have been adjusted to reflect new contracts and reported changes in quantities and delivery schedules.
(3) Most Canadian uranium export contracts are written in terms of Imperial units.

Part B. Longer-Term Perspective

I. Supply

a) Supply Sources

During 1980, an evaluation covering some 60 uranium-bearing areas in Canada was made of the likelihood of the occurrence of uranium resources in addition to the measured, indicated and inferred tonnages described in Part A of this report. As in the 1979 evaluation, a distinction was made between **prognosticated** and **speculative** resources.

The resources in the prognosticated category, although undiscovered, represent uranium believed to be associated with identified deposits. For this reason, a relatively higher degree of confidence can be placed in them than in estimates of the other category of undiscovered uranium, namely speculative resources. Several efforts have been made since 1976 to clarify the distinction between these two types of undiscovered resources in international terminology. As a result of an IAEA Advisory Group meeting on the Evaluation of Uranium Resources in late 1976[3], the wording of the NEA/IAEA definition for Estimated Additional Resources was modified in 1977. More recently, in connection with an NEA/IAEA study on world uranium potential[4 and 5], the term Speculative Resources was defined and incorporated into NEA/IAEA terminology (see Appendix 3).

Prognosticated Resources

Estimates of Canada's prognosticated resources of uranium are presented in Table 7, together with the 1979 estimates for comparative purposes. While the estimates are the result of an evaluation of all of the important uranium-bearing areas of Canada, estimates of resources existing in additional areas will be made in future assessments along with up-dating of existing estimates according to new results of geological and exploration efforts.

TABLE 7

1980 Estimates of Canada's Prognosticated Resources of Uranium

Mineable at uranium prices	Uranium contained in mineable ore*	
	(thousands of tonnes U)	
Up to $135/kg U	144	143**
$135 to $200/kg U	301	299
Total	445	442

* Uranium recoverable from such ore will be less, due to milling losses (see text).

** Shaded figures are from the 1979 assessment, in which price categories of up to $130/kg U and $130 to $200/kg U were used.

About 38 per cent of Canada's prognosticated resources occur in Ontario, mostly in the Elliot Lake-Blind River, Agnew Lake, and Cobalt Embayment areas, some 33 per cent in Saskatchewan and 18 per cent in the Northwest Territories.

More than half of Canada's prognosticated resources are contained in vein and unconformity-related type deposits, primarily in northern Saskatchewan and the Northwest Territories, illustrating the relative importance of this type of deposit as an exploration objective. A substantial portion of the remaining prognosticated resources is attributable to conglomerate deposits, primarily in the Elliot Lake and Agnew Lake areas of Ontario.

Speculative Resources

The estimates of uranium resources discussed in earlier sections of this report represent an incomplete appraisal of Canada's uranium resources, largely because these estimates are only of resources that are associated with identified deposits (see definitions, Appendix 3). There are many other areas of Canada that are favourable for the occurrence of additional uranium resources, but assessment of this additional potential can only be tentative because:

- Evaluations of the likelihood of occurrences have not been made of all areas that are favourable for uranium mineralization. Moreover, large areas of Canada are covered with glacial overburden and the nature of the underlying bedrock geology can only be assumed.

- There is still much to learn about the formation of various types of uranium deposits.

- The data base, although extensive, is still inadequate for assessing this additional potential.

URAG embarked on its first study of speculative resources in Canada in 1977. The 1980 assessment represents the third revision of this study. Judgments were based on Canada's past production, distribution of known uranium deposits, and on interpretation of selected geological features according to conceptual models simulating formation of selected main types of uranium deposits. Areas favourable for uranium mineralization, some of which were evaluated by the subcommittee, are shown in Figure 5. The speculative resources were estimated using geological criteria derived from known uranium deposits.

Four different approaches were used in the estimation of speculative resources:

- Extrapolation of economic-geological data from relatively well explored (control) areas to less explored areas containing similar geological environments, using a volumetric evaluation method;

- Analogy with a geostatistical analysis of the tonnage-grade distribution patterns of Canada's past production and known uranium deposits;

- A probabilistic study employing a modified Mining Industry Model for Inventorization and Cost Evaluation (MIMIC)[6]; and

- A combined geological and statistical approach using quadrangle cells for estimating speculative resources (applied to part of the Canadian Cordillera).

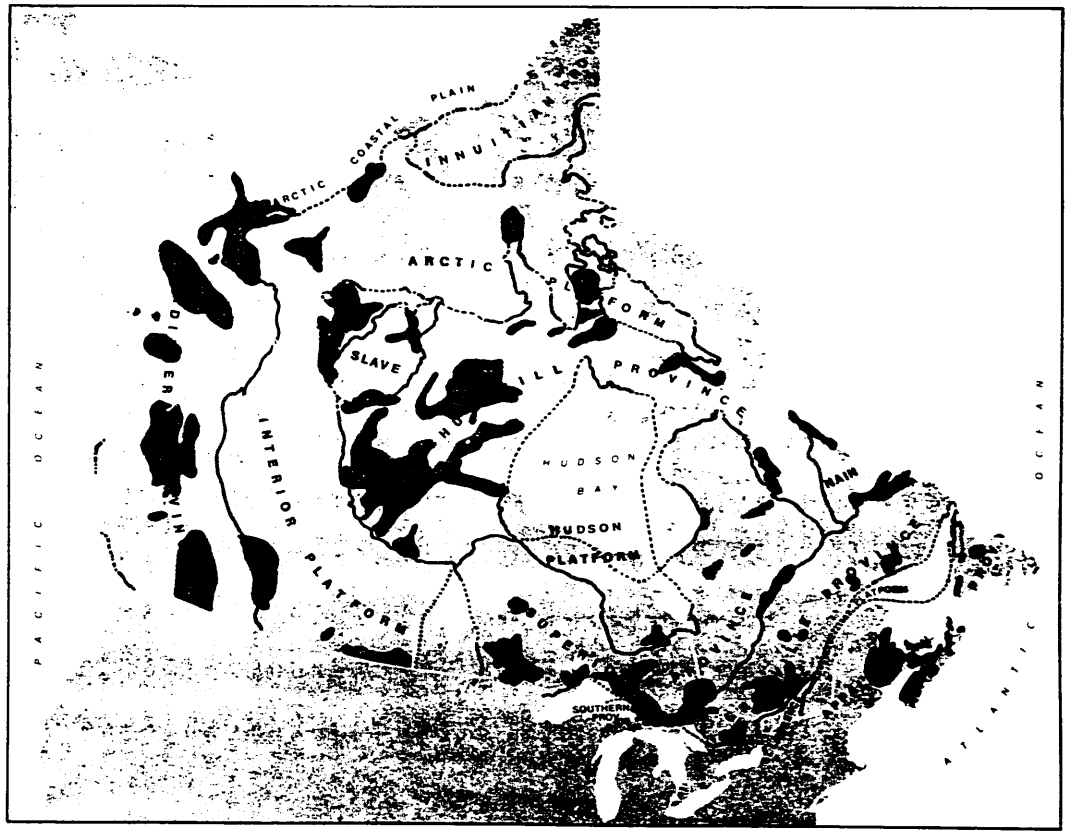

Figure 5. Areas in Canada with speculative resources of uranium or areas favourable for the occurrence of uranium deposits.

It was concluded that speculative resources, additional to resources in the measured, indicated, inferred and prognosticated categories, may amount to approximately 1.2 to 1.4 million tonnes of uranium. These resources would be geologically comparable to resources in known deposits that are judged to be mineable at a price of $200/kg U or less. Further resources might exist in areas that have not yet been assessed.

Some two-thirds of these speculative resources is believed to occur in deposits of vein and unconformity-related type. Areas of particular promise are those along the pre-Athabasca and pre-Martin unconformities in the Athabasca Basin and adjacent areas of Northern Saskatchewan, and beneath the Thelon Basin in the Keewatin District of the Northwest Territories; the pre-Sibley unconformity in the Nipigon area of Ontario is also of interest.

Pegmatitic-type uranium deposits account for about one-fifth of Canada's speculative resources. Environments favourable for this type of uranium deposit can be found in numerous granitic-syenitic terranes of the Canadian Shield and in the Cordillera. Areas of particular interest are in the Grenville Structural Province of Ontario and Quebec.

Perhaps the next most important type of deposit, accounting for some 10 per cent of Canada's speculative resources, is the sandstone-type. Indications of this type of mineralization exist in some of the Phanerozoic basins containing continental sandstones, for example, in the Kelowna-Beaverdell area of the Cordillera, in the Alberta Basin of the Interior Platform, and the Phanerozoic basins of the Maritime provinces.

Although conglomeratic-type uranium deposits account for a large part of Canada's currently identified uranium resources, the potential for additional resources of this type is not believed to be large.[7]

Uranium Reconnaissance Program

In 1975 Canada's Geological Survey embarked on a 10-year, $30 million, Uranium Reconnaissance Program (URP) designed to identify and delineate all areas in Canada which may be favourable for the occurrence of uranium deposits. Principal activities under the program included airborne gamma-ray spectrometry surveys and regional geochemistry surveys. To the end of 1978, over $17 million had been spent on the joint program by the federal and participating provincial governments. Funding for URP was terminated, however, effective March 31, 1979 as part of federal government economy measures, and all outstanding data were publicly released by September 30, 1979. At that time some 25 per cent of Canada had been covered by URP surveys, an area which represented about one-third of the coverage originally intended over the 10-year program.

Certain provinces have since conducted their own regional geochemical surveys — British Columbia in 1979 and 1980, and Ontario in 1979 — following the same national standards as established for URP. The Geological Survey of Canada has continued to acquire a limited amount of airborne gamma-ray spectrometric data in support of geological mapping.

Uranium Exploration Activities

Uranium exploration activity in Canada again surpassed the level established the previous year in terms of drilling effort and very nearly reached the record level of total expenditures established in 1979. Responses to the 1980 Uranium Resource Appraisal Group (URAG) questionnaire were received from 113 companies or joint ventures representing essentially all the major participants active in uranium exploration in Canada. The survey indicates that total expenditures reached $128 million in 1980, distributed among some 377 projects.

Canadian Occidental Petroleum Ltd. and Inco Metals Company continued evaluating their jointly-held McClean Lake deposit, 11 km northwest of Rabbit Lake, Saskatchewan. In May, a year after the original discovery was announced, details of a new mineralized zone were revealed. Drilling along the new McClean South zone, located half a kilometre south of the now-renamed McClean North zone, indicated uranium mineralization over a strike length of some 945 m, at a depth of about 150 m.

Asamera Oil Corporation Ltd. announced the discovery of two new mineralized zones near its original Dawn Lake prospect located in the Keefe Lake-Henday Lake area of northeastern Saskatchewan. Situated between Esso Minerals' Midwest Lake project and Gulf's Rabbit Lake mine, the most recent discovery, Zone 11A, is one of four uranium-bearing zones outlined since 1978. SMDC holds a 50.75 per cent interest in the project, Asamera, the operator, has 25 per cent and the balance is held among seven other private companies.

In June 1980 Gulf Minerals announced the discovery of a new uranium deposit in northeastern Saskatchewan, about 13 km north of the Gulf-Uranerz Rabbit Lake mine. Diamond drilling carried out on the Eagle Point prospect, on ground in part held jointly with SMDC and Noranda Exploration Company, Limited, intersected uranium mineralization over a strike length of about 1 040 m, at depths up to 274 m.

In the Baker Lake area of the Northwest Territories encouraging exploration results have sustained additional drilling efforts by a number of companies. Urangesellschaft Canada Limited is looking for Canadian partners to participate in property development following a successful 1980 drilling program east of the Main Zone of its Lone Gull property in the Sissons Lake area about 80 km west of Baker Lake. Pan Ocean Oil Ltd. continued with a major program in the area between Bissett Lake and Christopher Island in Baker Lake.

Although Saskatchewan remained the centre of activity, exploration programs continued in several other provinces across Canada with the exception of British Columbia, where the announcement of a seven-year moratorium on uranium mining and exploration stopped all such activity. Considerable effort has been expended in the Dieter Lake (Lake Gayot) and Otish Mountains areas of Quebec, the latter area being one of the more attractive exploration targets in the province, where uranium mineralization appears to be related to a major unconformity. Activity in the Wernecke Mountains of the Central Yukon Territory has been of particular interest because of the geological similarities between this area and the Roxby Downs area of South Australia. Also of geological interest has been work in Nova Scotia where uranium mineralization confined to intragranitic fractures appears to resemble some of the uranium deposits of the Hercyian metallogen in Europe. The identification of such geological environments in Canada may lead some exploration companies to develop new exploration strategies.

Table 8 summarizes uranium exploration drilling and surface development drilling activity* by province or territory for 1979 and 1980. As in the past two years, virtually all the surface development drilling in 1980 was associated with recent discoveries in Saskatchewan. Preliminary estimates for 1981 indicate that drilling activity will be in the order of 380 000 metres, or about three-quarters of the effort in 1980.

TABLE 8

Uranium Exploration Drilling and Surface Development Drilling Activity in Canada, by Province or Territory, 1979 and 1980

	1979	1980
	(thousands of metres)	
Saskatchewan	326.6	368.6
Northwest Territories	45.6	55.1
Quebec	19.5	24.1
Nova Scotia	13.9	16.4
Ontario	24.2	11.1
New Brunswick	3.6	9.1
Newfoundland	20.6	8.1
Manitoba	2.3	2.9
Alberta	1.7	1.7
Yukon Territory	5.5	1.0
British Columbia	18.4	0
Unspecified	1.4	5.3
Total	483.3	503.3

A more all-inclusive measure of uranium exploration activity, however, is the level of total exploration expenditures**. Table 9 summarizes the 1979 and 1980 uranium exploration expenditures, by province or territory. Of the $128 million expended in Canada in 1980 (compared with $130 million in 1979), Saskatchewan accounted for 60 per cent of the total (compared with 54 per cent the previous year). The Northwest Territories accounted for 23 per cent of the total, up slightly compared with the previous two years, while Quebec and Nova Scotia ranked third and fourth, with about 5 and 4 per cent of the total, respectively.

* **Exploration drilling** refers to drilling done in search for new uranium deposits or extensions to known uranium deposits and to drilling at the location of a discovery up to the time that the company decides that sufficient ore has been delineated to justify commercial exploitation. **Surface development drilling** refers here to drilling subsequently done to determine more precisely a deposit's size, grade and configuration, and excludes development drilling on producing properties.

** Expenditures on exploration and surface development drilling and all other costs directly associated with uranium exploration activities, excluding land acquisition. Overhead charges not directly associated with such activities are not included.

TABLE 9

Uranium Exploration Expenditures in Canada by Province or Territory, 1979 and 1980

	1979	1980†
	(millions of dollars)	
Saskatchewan	70.5	77.2
Northwest Territories	26.4	29.1
Quebec	7.0	6.4
Nova Scotia	3.8	4.5
Newfoundland	6.8	3.7
Ontario	2.1	1.7
New Brunswick	2.3	1.4
Yukon Territory	2.7	1.3
Manitoba	0.6	1.1
Alberta	1.6	1.0
British Columbia	3.9	0.6
Unspecified	1.8	0.3
Total	129.5	128.0

† Provincial totals rounded.

Figure 6 illustrates the trend in uranium exploration expenditures together with increases in the uranium market price since the early 1970s. By 1976, considerable momentum had been built up in uranium exploration in Canada, primarily in response to the incentive provided by rising uranium prices. Although prices were relatively stable during the late 1970s, the momentum achieved during the mid-1970s together with the major discoveries in Saskatchewan contributed to still further expansion in uranium exploration expenditures. The levelling off of uranium exploration expenditures, caused by the softening in the uranium market, has only recently become apparent.

Of the 113 companies or joint ventures that responded to the URAG survey in 1980, 30 operators spent more than $1 million and together accounted for 90 per cent of the total expenditures. More than one third of this total was accounted for by oil companies or their corporate affiliates while federal and provincial government corporations accounted for 13 per cent of the total.

The 10 most active organizations*, accounting for some 56 per cent of the $128 million total, were, in alphabetical order, Amok Ltd., Asamera Inc., Canadian Occidental Petroleum Ltd., E&B Explorations Ltd., Eldorado Nuclear Limited, Gulf Minerals Canada Limited, Pan Ocean Oil Ltd., Saskatchewan Mining Development Corporation (SMDC), Uranerz Exploration and Mining Limited, and Urangesellschaft Canada Limited. Almost half of the responding operators with expenditures in 1980 were companies whose majority interests were held outside of

* In certain cases, the identified operator company has reported the total expenditures of a joint-venture effort. As such, contributions by other parties not responding to the URAG survey are accounted for in the $128 million total.

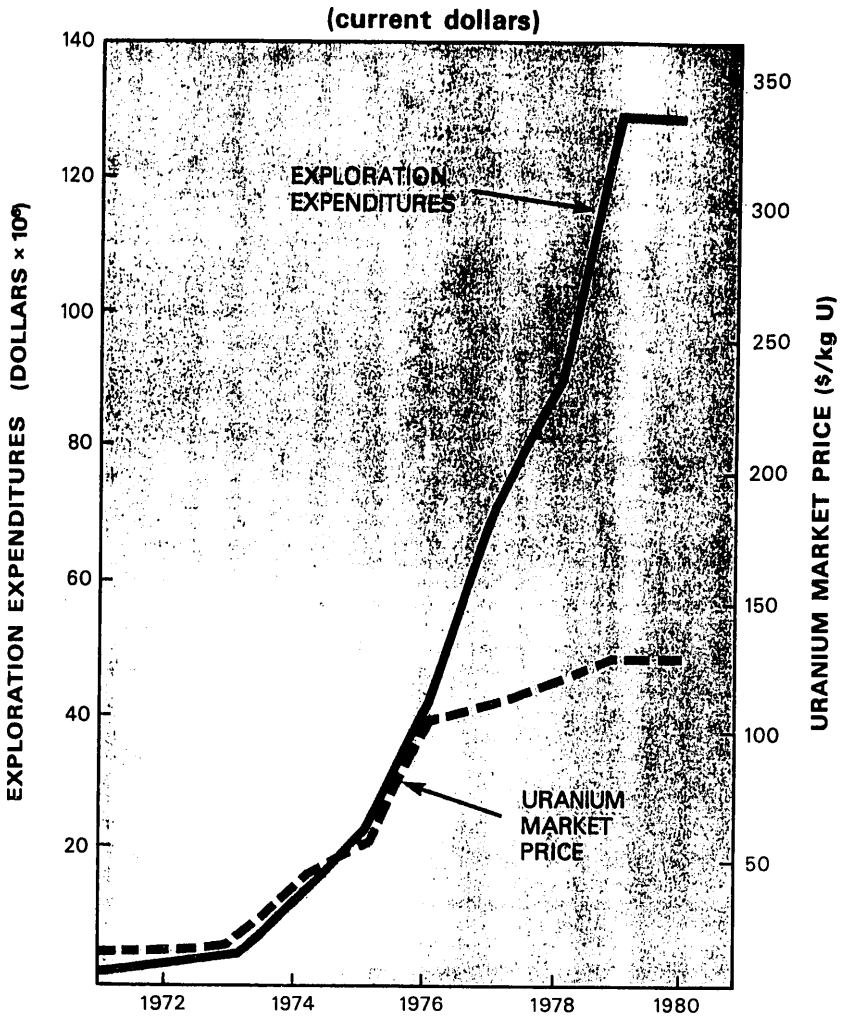

Figure 6. Uranium exploration expenditures in Canada 1971-80 compared with uranium market price.

Canada; these operators accounted for about half of the total uranium exploration expenditures. Of this "non-Canadian" portion of total expenditures, United States companies accounted for 50 per cent while companies with West German ties accounted for some 30 per cent.

Not all companies that responded to the URAG questionnaire had planned their exploration expenditures for 1981 at the time of the survey. From the responses of those that did submit information, it appears that expenditures for 1981 may be as much as 20 per cent lower than those reported in 1980, no doubt reflecting a loss in incentive resulting from the sharp decline in uranium prices during 1980.

b) Uranium Availability

Uranium availability in the longer term will be dependent on a number of factors, the most important of which will be a continuing and developing market for uranium. Other factors relate to the geological nature of individual deposits, the provision of manpower, equipment and financing, and the economic, political and regulatory climate. Clearly, known uranium deposits, associated with existing, committed and planned production centres, are capable of supporting substantial production levels beyond 1991. Indeed, there are extensions to, and undiscovered resources associated with, these identified deposits (i.e. prognosticated resources), that will extend the life of these production centres beyond the end of the century.

As part of the current NEA/IAEA assessment of world uranium supply, to be published at the end of 1981, a projection was made of the maximum attainable production capability that could be supported on the basis of current world estimates of Reasonably Assured and appropriate portions of Estimated Additional Resources to the year 2025[8]. Of necessity, it was assumed that there would be adequate supplies of manpower, equipment and materials, that there would not be unmanageable financing or regulatory difficulties, and that the market would develop in a regular pattern. A projection for Canada, based on the same assumptions (i.e., an extension of Scenario A described in Part A of this report), indicated that production capability could decline from a peak of about 18 500 tonnes U/year in the early 1990s to some 8 500 tonnes U/year by 2005, without the benefit of new discoveries. After this time, the decline in production capability that could be supported by currently known deposits would be more gradual, illustrating the expected longevity of certain of Canada's uranium producing operations.* In view of the poor short-term market outlook, however, it is likely that the peak level of production indicated in the projection will not be realized until later in the 1990s and thus the long-term availability of uranium from the production centres considered in the projection would be extended accordingly.

If production in excess of such projected levels is to be achieved, it must come from production centres in addition to those described in Part A of this report. Moreover, these production centres would need to be supported largely by new discoveries, the realization of which would involve considerable exploration and development effort on a timely basis. Because of the risk, expense and long lead-times inherent in such activities, it is unrealistic to expect the industry to delineate and develop new discoveries far in advance of firm commitments by utilities. There have been two or three recent discoveries that, upon further evaluation, may prove to be potential new production centres (see section on Uranium Exploration Activities). The potential for additional discoveries in Canada is reflected in the estimates of prognosticated and speculative resources described above.

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* A similar projection was made for the International Nuclear Fuel Cycle Evaluation in 1979[9]. The methodology is described in an EMR publication, Monitoring Canada's Uranium Supply[10].

II. Requirements

The requirements for Canadian uranium in the longer term will depend on the growth in nuclear power capacity in the electricity generating systems of Canada and its trading partners. Projections of installed nuclear power capacity have been revised downward in recent years as a result of lower expected rates of economic growth, and of efforts to introduce energy conservation measures in many countries. It is now expected that Canada's total installed nuclear capacity in the year 2000 will range between 21 000 and 28 000 MWe, requiring from 2 900 to 3 900 tonnes U per year. Clearly, the continued growth in Canada's uranium producing industry will be dependent largely on the export market.

Uncertainty about numerous aspects of the role of nuclear energy in future world energy supply contributes to a wide range of projections of long-term uranium requirements. Studies carried out in connection with the INFCE exercise, the results of which were published in early 1980[9 and 11], indicated that world* requirements could grow from a level of about 30 000 tonnes U per year in 1980 to a level ranging from 130 000 to 160 000 tonnes U per year by the year 2000, and 180 000 to 430 000 tonnes U per year by 2025, assuming a high rate of nuclear power growth and a varying mix of reactor types. Projections that assumed a low rate of nuclear power growth with the same reactor strategies resulted in requirement levels ranging from 95 000 to 110 000 tonnes U per year in 2000 and 90 000 to 190 000 tonnes U per year in 2025.

Subsequent studies, however, have shown that INFCE's projections were optimistic. Based on a paper released by the Uranium Institute in June 1981, it can be seen that the total nuclear power plant capacity committed for 1990 is already about 15 per cent lower than INFCE's low nuclear power growth projection. Based on its current forecast of installed nuclear capacity, the same Uranium Institute paper indicated that the world's uranium requirements would be some 70 000 tonnes U in 1995, about 10 per cent lower than the projection under INFCE's low nuclear power growth scenario.[12] Such reductions in projections of the future market for uranium engender little incentive to the industry to maintain exploration levels required to meet the needs of the post–2000 period.

Whatever the magnitude of future uranium requirements turns out to be, Canada would appear to have the capability to provide for its own needs while maintaining its position as a leading supplier of uranium to world markets. Canadian capabilities can be seen in the world context with reference to the latest published NEA/IAEA assessment of world uranium supply[11]. Canada accounted for some 12 per cent of the world's total **low-cost**** Reasonably Assured Resources of uranium, which totalled 1.85 million tonnes U, ranking fourth, behind Australia, South Africa and the United States. Perhaps more important, in terms of Canada's future capability as a uranium supplier, is its position with respect to Estimated Additional Resources. Of the world total of 2.45 million tonnes U (the sum of the NEA/IAEA's low and **high-cost**** categories) Canada accounted for 30 per cent, ranking second behind the United States.*** The NEA/IAEA's current assessment, to be published at the end of 1981, is not expected to significantly alter this picture.

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* World excludes USSR, Eastern Europe and the People's Republic of China.

** For purposes of international comparison, Canada's low and high **price** categories may be considered equivalent to the NEA/IAEA's low and high **cost** categories, respectively (see Figure A-1, Appendix 3, and accompanying text).

*** URAG's 1978 Assessment of Canada's Uranium Supply and Demand was used for this international assessment.

Canada also continues to rank second, behind the United States, in terms of current world production of uranium, which is estimated to have been in the order of 45 000 tonnes U in 1980. Supported by known major deposits, this position is expected to be held until at least 1985, after which Australia may attain second place if uranium developments in its Northern Territory proceed at the rate projected by the NEA/IAEA. In its December 1979 assessment, the NEA/IAEA estimated that then known resources in the world were capable of supporting production levels of 98 000 tonnes U in 1985 and 119 000 tonnes U in 1990.[11]

Canada should be able to maintain its position as a leading supplier of uranium in the longer term, given appropriate levels of exploration effort on a timely basis. The incentive to expend this effort must by necessity be precipitated by the uranium market, which in turn must be built on the confidence engendered by the continued growth and development of the world's nuclear power programs. As illustrated by current estimates of Canada's speculative resources, there is considerable potential for new uranium discoveries. The realization of even part of this potential should provide the basis for sufficient additional production centres to meet Canada's domestic requirements, and to maintain its position in the export market well into the next century.

Appendix 1

Canadian Uranium Resource Assessments — An Historical Review

On September 5, 1974 the Minister of Energy, Mines and Resources announced a new uranium policy for Canada with two primary objectives:

- To ensure a 30-year reserve of nuclear fuel for all existing and committed reactors in Canada and for those planned to start operation in the following 10-year period;
- To ensure that sufficient uranium production capacity is available for the Canadian domestic nuclear power program to reach its full potential.

In order to implement the policy, the Minister announced the establishment of a Uranium Resource Appraisal Group within EMR, to audit annually Canada's uranium resources. The structure of this Group and the duties of its related subcommittees are described in Appendix 2.

The first assessment of Canada's uranium resources was made in 1958 by the Geological Survey of Canada (GSC) for publication on the occasion of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy at Geneva.[13] The estimates were given by geological type and in terms of short tons of measured, indicated and inferred ore, with average grades. In 1964, for the Third Geneva Conference, a GSC paper further classified Canadian resources as to exploitability at various price levels.[14]

In 1964 the Nuclear Energy Agency (NEA), known at that time as the European Nuclear Energy Agency (ENEA), set up a Working Party on Uranium and Thorium Resources for the purpose of preparing an assessment of the world's uranium and thorium resources. The Canadian delegates to the Working Party adapted the GSC report to the Third Geneva Conference to serve as the Canadian submission to ENEA and this adaptation formed part of an international report published in August 1965.[15] Coverage of these world studies was subsequently widened under the joint auspices of the NEA and the International Atomic Energy Agency (IAEA) and the assessments expanded to examine the status of production and projected demand. Since 1973 the reports have been published on a regular biennial basis.[11, 16 to 21]

URAG was established late in 1974 and completed its first assessment of uranium resources based on data related to the principal deposits of Canada in early 1975. That first report published in August 1975[22], presented estimates of Canada's measured, indicated and inferred resources of uranium. The assessment, with the advantage of more uniform collecting and evaluation criteria, was considered more reliable than earlier ones. The results of a second assessment, begun in September 1975, were published in June 1976.[23] For the first time, estimates were included of prognosticated resources associated with known uranium deposits. A report on a third assessment, initiated in September 1976, which included an evaluation — in some cases only qualitative — of a number of new areas, was published in June 1977.[24] The fourth URAG report, printed in June 1978[25], gave for the first time the results of a survey of uranium exploration activity in Canada. In addition, a number of further areas of Canada were evaluated that were believed to be favourable for the discovery of further resources of uranium; estimates of speculative resources were made for some of these areas. The fifth report, published in June 1979[26], followed the same format.

URAG's sixth annual assessment, which was initiated in December 1979, three months later than the previous assessment, brought URAG's activities into phase with company year-end evaluation programs. The results of the 1979 assessment, published in September 1980[27], were presented in a slightly different order, to distinguish the short-term (10-year) supply possibilities from the longer-term possibilities. In addition, more discussion was devoted to the question of availability of uranium from the various supply sources, again from both the short- and long-term perspective. For the first time employment statistics were included to help illustrate the size of Canada's uranium mining industry. Finally, the supply analysis was balanced by brief discussions on domestic and export requirements.

This report presents URAG's seventh annual assessment. It was initiated in December 1980 and follows the format established the previous year.

Appendix 2

Uranium Resource Appraisal Group (URAG)

URAG is an internal committee of EMR Canada composed of senior officials and technical experts in the fields of uranium geology, mining and milling. Activities of URAG are carried out by three inter-related subcommittees:

- **The subcommittee on Reasonably Assured Resources** is responsible for (a) auditing the measured and indicated resources in Canadian uranium deposits mineable under current technological conditions in given price ranges, and (b) assessing the levels of Canadian uranium production that could be supported by these deposits.

- **The subcommittee on Estimated Additional Resources** is responsible for (a) estimating the inferred and prognosticated resources associated with known uranium deposits in Canada, and (b) estimating speculative resources of uranium, beyond the prognosticated category, in regions of Canada which have geological environments favourable for the occurrence of uranium.

- **The subcommittee on Economic Coordination** is responsible for (a) relating known resources to domestic requirements and export commitments, the latter in cooperation with Canadian regulatory agencies, and (b) determining the tonnage of uranium that is to be reserved for reactors in operation or committed by utilities and recommending how this domestic responsibility is to be allocated among individual producers.

Primary responsibility for the work of the subcommittee on Reasonably Assured Resources resides with the Mine Evaluation Group located in the Mining Research Laboratory of EMR's Canada Centre for Mineral and Energy Technology (CANMET). Uranium ore processing expertise is drawn from CANMET's Mineral Sciences Laboratories and uranium production capability projections are prepared with the support of the Resource Evaluation Section of EMR's Mineral Policy Sector. Work associated with the activities of the subcommittee on Estimated Additional Resources is carried out in the Uranium Resource Evaluation Section of the Geological Survey of Canada (GSC), also a Branch of EMR. Finally, the activities of the subcommittee on Economic Coordination are centred in the Uranium and Nuclear Energy Branch of EMR's Energy Sector, which also plays a coordinating role for the overall URAG exercise.

Appendix 3

Definitions of Resources

In its annual assessment of uranium resources, URAG divides its estimates into five separate categories reflecting different levels of confidence in the quantities reported. These categories are further separated into two levels of exploitability related to the current price of uranium.

The following terms and definitions used by URAG are in harmony with those used by EMR for mineral and coal resource assessment:

Ore is a natural mineral-bearing substance that can be recovered by mining and from which one or more commodities can be extracted economically under conditions specified at the time of the appraisal.

Measured ore refers to ore for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, or drillholes, and for which grade is computed from adequate sampling. The sites for inspection, sampling, and measurement are so closely spaced and the geological character is so well defined that the size, shape and mineral content are well established. The tonnage and grade should refer to ore recoverable by mining with due regard for dilution.

Indicated ore refers to ore for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geological evidence. The openings or exposures available for inspection, measurement and sampling are too widely or inappropriately spaced to outline the ore completely or to establish its grade throughout.

Inferred ore refers to ore for which quantitative estimates are based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. Estimates are based on assumed continuity or repetition for which there is geological evidence; this evidence may include comparison with deposits of similar types. Bodies that are completely concealed but for which there is some geological evidence may be included. Estimates of inferred ore should include a statement of the specific limits within which the inferred material may lie. These limits vary depending upon the characteristics and knowledge of the orebodies.

Prognosticated resources refer to estimated tonnages beyond specific limits established for inferred ore. They may include tonnages of portions of identified orebodies or of concealed satellite orebodies, the existence of which can be assumed along well established geological trends associated with known deposits. The attributes of prognosticated resources are, as a rule, derived by extrapolation from identified deposits or by quantification of geological information.

Speculative resources refer to estimated tonnages in deposits thought to exist on the basis of indirect indications and geological extrapolations in virgin areas or in areas where only occurrences are known. These resources would be geologically comparable to resources in known deposits that are judged to be mineable at prices below a given level.

Reserves refer only to those measured and indicated resources that could be mined at the uranium market price as determined at the time of the assessment (equivalent to block 1A of Figure A-1) unless another price is specified.

Resource estimates refer to quantities of **uranium contained in ore mineable at given uranium prices** (i.e. ore recoverable by mining, with due consideration of ore dilution). While milling losses were taken into account in the determination of cut-off grades for ore mineable at given prices (i.e. prices for uranium in concentrate), such losses were not applied to the mineable ores. The recovery of uranium from ores currently being mined is about 93 per cent, but recoveries are likely to be significantly lower as lower grade ores are mined in the future, so that the distinction between mineable resources (U content of ore) and recoverable uranium (U recoverable from ore) will become increasingly important.

For national and international purposes, Canadian resource estimates are often quoted in terms of the international uranium resource definitions employed by the joint NEA/IAEA* working party on uranium resources. The terms **Reasonably Assured Resources (RAR)** and **Estimated Additional Resources (EAR)** and their definitions were first developed in 1964 and have been retained, with minor modification, in periodic NEA/IAEA world uranium supply assessments. It is pertinent to note that, in 1975, the NEA/IAEA changed its resource definitions to refer to **cost** instead of **price**, while Canada has retained the price classification.**

In recognition that assessments covering only RAR and EAR represent an incomplete appraisal of the world's uranium resources, efforts were launched by the NEA/IAEA in late 1975 to review and evaluate what further potential uranium resources are likely to exist, and in what regions exploration should be concentrated to identify them. Phase I of this International Uranium Resources Evaluation Project (IUREP), which was completed in June 1978, led to the establishment of a third category of resources, termed **Speculative Resources.** In the IUREP exercise, Speculative Resource tonnages, in addition to RAR and EAR, were expressed in ranges. The judgements were based on the geological favourability for the existence of as yet undiscoverd uranium deposits exploitable at costs of less than $130/kg U, and were viewed as a qualitative measure of the current state of geological knowledge, with all the inherent uncertainties, and as a guide for establishing priorities for future evaluation efforts.

The NEA/IAEA resource definitions, as published in the working party's most recent world assessment of December 1979, are as shown below. Their relationship to definitions used in EMR's annual assessment of uranium resources is illustrated in Figure A-1.

> "**Reasonably Assured Resources** refers to uranium that occurs in known mineral deposits of such size, grade and configuration that it could be recovered within the given production cost ranges, with currently proven

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* NEA — Nuclear Energy Agency of the Organization for Economic Cooperation and Development.
IAEA — International Atomic Energy Agency.

** For purposes of international comparison Canada's low and high price categories may be considered equivalent to the NEA/IAEA's low and high **cost** categories, respectively, i.e.: The **low** cost/price and the **high** cost/price categories are illustrated by blocks labelled A and B, respectively in Figure A-1.

mining and processing technology. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. Reasonably Assured Resources have a high assurance of existence and in the cost category below $80/kg U (block 1A of Figure A-1) are considered as **reserves** for the purpose of this report."

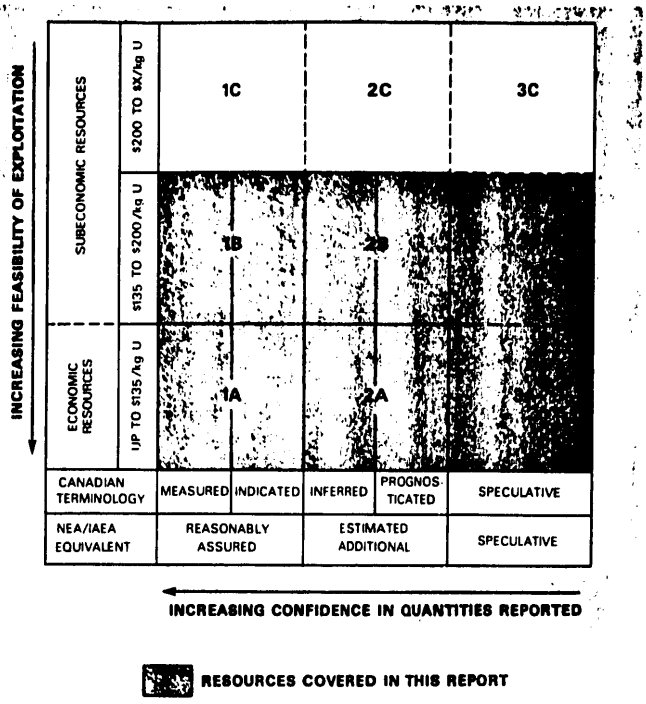

Figure A-1. Classification scheme for recoverable uranium resources (Energy, Mines and Resources Canada).

"**Estimated Additional Resources** refers to uranium in addition to Reasonably Assured Resources that is expected to occur, mostly on the basis of direct geological evidence, in extensions of well-explored deposits, little-explored deposits, and undiscovered deposits believed to exist along a well-defined geological trend with known deposits. Such deposits can be identified, delineated and the uranium subsequently recovered, all within the given cost ranges. Estimates of tonnage and grade are based primarily on knowledge of the deposit characteristics as determined in its best-known parts or in similar deposits. Less reliance can be placed on the estimate in this category than for Reasonably Assured Resources."

"**Speculative Resources** refers to uranium, in addition to Estimated Additional Resources, that is thought to exist mostly on the basis of indirect evidence and geological extrapolations, in deposits discoverable with existing exploration techniques. The location of deposits envisaged in this category could generally be specified only as being somewhere within a given region or geological trend. As the term implies, the existence and size of such resources are highly speculative."

In presenting its definitions, the NEA/IAEA emphasizes that "the distinctions drawn between Reasonably Assured Resources, Estimated Additional Resources and Speculative Resources based on differing degrees of geological evidence, make it essential that each category be regarded as a discrete entity. Therefore, great care should be taken in the use of resources estimates (e.g. not taking the sum of estimates of each of the categories to obtain **total resources**)."

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