MAINTAINING THE URANIUM RESOURCES DATA SYSTEM AND ASSESSING THE 1991 U.S. URANIUM POTENTIAL RESOURCES

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By

R.B. McCammon,* W.I. Finch,** W.D. Grundy,**
and C.T. Pierson**

U.S. Geological Survey

Reston, Virginia* and Denver, Colorado**

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EXECUTIVE SUMMARY

Under the Memorandum of Understanding (MOU) between the EIA, U.S. Department of Energy, and the U.S. Geological Survey (USGS), U.S. Department of the Interior, the USGS develops estimates of uranium endowment for selected geological environments in the United States. New estimates of endowment are used to update the Uranium Resources Assessment Data (URAD) System which, beginning in 1990, is maintained for EIA by the USGS.

For 1991, estimates of U.S. undiscovered resources were generated using revised economic index values (current to December 1991) in the URAD system's cost model. The higher 1991 indexes which resulted in increased costs were offset by the removal of the cut-off grade threshold value used in the URAD system's cost model and, together with the new assessment of the Flodelle Creek area in Washington, resulted in slightly higher estimates of the quantities of EAR and SR for 1991 for most regions when compared to 1990. The endowments associated with the EAR values for all regions are unchanged from the 1990 values. The endowments associated with the SR values for all regions except for the Northern Rockies are unchanged from the 1990 values. For the Northern Rockies, the SR value increased to 3,940 million pounds U_3O_8 from 3,860 million pounds in 1990. For 1991, the mean values for the \$30-, \$50-, and \$100-per pound U_3O_8 forward-cost EAR category resources show no change when compared to the values in 1990. The mean values for the \$30-, \$50-, and \$100-per pound U_3O_8 forward-cost SR forward-cost category show increases of 8, 5, and 3 percent, respectively.

Improvements to the URAD system included automating the procedures necessary to generate the assessment reports. Data retrieval from the URAD system can now be performed using the dBase IV version 1.5 data base management system. The conversion to dBase IV was made because this system is more widely used and

more flexible than the earlier system, dBSL, and is somewhat faster. Additions to the URAD system include the capability of generating graphs of the EAR, SR, and the endowment, respectively.

1.0 INTRODUCTION

1.1 Purpose

The purpose of this report is: (1) to describe the work carried out to maintain and update the Uranium Resource Assessment Data (URAD) System, (2) to assess the 1991 U.S. uranium potential resources in various cost categories, and (3) to describe the progress that has been made to automate the generation of the assessment reports and their subsequent transmittal by diskette.

1.2 Background on the URAD System

The Energy Information Administration's (EIA) Uranium Resource Assessment Data System contains information on potential resources (undiscovered) of uranium in the United States. The unique mathematical procedures in this system were developed prior to 1983 by Oak Ridge National Laboratory (ORNL) personnel, principally Mr. C.E. Ford and Dr. A.R. McLaren, under the sponsorship of the Grand Junction Area Office of the U.S. Department of Energy (Ford and McLaren, 1980). The URAD System was developed originally on a DEC-10¹ computer. During 1989-1990, the System was converted to operate on IBM-compatible microcomputers by personnel of the Resource Modeling and Technology Economics Group, Energy Division, ORNL, principally Dr. G.L. Chen and Mr. Sujit Das, and by subcontractors, Mr. R. Perubhatla and Mr. R.A. Whitaker, from Coe College and University of Tennessee, respectively (Das and Lee, 1991; Chen and others, 1990; Das and others, 1988).

¹Use of trade names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

The URAD System is used to store subjective geological data on uranium resources for 706 resource areas in the United States. Probabilistic numerical procedures are utilized to compute estimates of resource quantities from these geological data. Estimates are produced for areas that have geological characteristics favorable for the occurrence of uranium deposits. The estimates are classified into categories of Estimated Additional Resources (EAR) and Speculative Resources (SR) and into Forward Cost Categories of \$30, \$50, and \$100 per pound U₃O₈. Although the URAD System is analytically detailed and rigorous, extensive checking, verification, and in some cases revising of URAD output by a knowledgeable geologist is required to assure the quality and reliability of the output data for publication.

Under a Memorandum of Understanding (MOU) between the EIA, U.S. Department of Energy, and the U.S. Geological Survey (USGS), U.S. Department of the Interior, the USGS develops estimates of uranium endowment for selected geological environments in the United States (Finch and McCammon, 1987). The new endowment data are used to update the URAD System files.

Tabulations of U.S. potential resources data are used in the EIA publication Uranium Industry Annual (UIA) and in the EIA's submission for the biennial report Uranium Resources, Production, and Demand, which is published jointly by the Organization for Economic Co-operation and Development (OECD) Nuclear Energy Agency and the International Atomic Energy Agency. The data are also used in preparing the EIA's annual report, Domestic Uranium Mining and Milling Industry, Viability Assessment.

1.3 Scope of Work

Under the terms of the present agreement, the USGS is responsible for work on the following Subtasks:

Subtask 1: Cost Escalators - Update 1991 economic indicators for the Cost Factor Generator (CFG) in the URAD System. These indicators are:

- a. The Department of Commerce's "Producer Price Index for Industrial Commodities."
- b. The "Marshall and Swift Mining-Milling Equipment Cost Index."
- c. The "Chemical Engineering Plant Cost Index."
- d. The annual spot market price, or "MPRICE" for U_3O_8 concentrate; as determined by the average of Nuexco monthly exchange prices.

Subtask 2: URAD System Maintenance and Computations. This includes:

- a. Manage and maintain the URAD System residing at the USGS computer facility.
- b. Provide support in updating system parameters (i.e., reference information, cost-model data, master-file data, etc.) and the potential resources data in the URAD System as requested by the EIA.
- c. Provide support in updating existing formulas in the Cost Factor Generator and/or adding new subroutines to describe current economic conditions brought about by changes in mining/processing technologies and tax laws.
- d. Provide assistance when requested by the EIA in accessing and running the URAD System concerning uranium potential resources.
- e. When requested, review and analyze new mathematical and statistical methods of resource estimation and other modifications that are being considered for use in updating the URAD System with state-of-the-art resource-estimation procedures. Provide the EIA with expert judgments and findings regarding the suitability of updating the URAD System to incorporate such new procedures. If this task should require a major effort, the contract may be amended to include reimbursable costs

- f. Provide results of URAD-computer potential uranium resources for 1991 from the following standard Tasks (reports); 3, 4, 10, 13, 14, 20, 21, 22, and 23 (Appendix I, "Description of Tasks Available" for description of reports). In addition to these Tasks (reports), a set of cumulative probability distribution graphs showing 1991 uranium resources data from the MAPPER files output also shall be provided by the contractor.
- g. Compile final uranium Estimated Additional Resources (EAR) and Speculative Resources (SR) assessment for the \$30, \$50, and \$100 per pound U_3O_8 cost categories for 1991. In addition, the contractor shall provide a narrative description in support of the assessments and to compare the results to the assessment from the previous year.

1.4 Deliverables and Due Dates

A. Description of Deliverables

	<u>Due Dates</u>
1. Report on updated cost escalation indicators	April 30, 1992
2. Report of 1989 EAR and SR for various cost categories	June 15, 1992
3. Draft Final Report	November 30, 1992
4. Final report on URAD System maintenance and 1989 potential resources assessment	December 31, 1992

B. Reports shall be submitted in accordance with the Reporting Requirements Checklist.

C. The agency shall also deliver one (1) reproducible master of the final technical report to the Office of Scientific and Technical Information at the following address:

Department of Energy
Office of Scientific and Technical Information (OSTI)
Special Assistant for Reproduction and Processing
Post Office Box 62
Oak Ridge, Tennessee 37830

2.0 COST ESCALATORS

2.1 Updated 1991 Economic Indicators

Under Subtask 1 of the Scope of Work outlined in Section 1.3, the 1991 updated cost escalation indices are as follows:

Economic Indicators

Yr.	WPI ²	CEP ³	M&S ⁴
1980	88.0	261.2	659.6
1981	97.4	297.0	721.3
1982	100.0	314.0	745.6
1983	101.1	316.9	760.8
1984	103.3	322.7	780.4
1985	103.7	325.3	789.6
1986	100.0	318.4	797.6
1987	102.6	323.8	813.6
1988	106.3	342.5	852.0
1989	111.6	355.4	895.1
1990	115.8	357.6	915.1
1991	116.5	361.3	930.6

Cost Escalators updated 4/30/92

$$\text{CEP80} = 361.3/261.2 = 1.3832312$$

$$\text{MSI80} = 930.6/659.6 = 1.4108551$$

$$\text{MSI82} = 930.6/745.6 = 1.2481223$$

$$\text{WPI80} = 116.5/88.0 = 1.3238636$$

$$\text{WPI81} = 116.5/97.4 = 1.1960986$$

$$\text{WPI82} = 116.5/100.0 = 1.1650000$$

Annual average spot market price for U₃O₈ concentrate based on exchange value determined as of the last day of the month (\$US/lb U₃O₈).

Yr.	Avg. Price ⁵
1991	8.78

²Producer Price Index (Industrial Commodities), Bureau of Labor Statistics.

³Chemical Engineering Plant Cost Index, Chemical Engineering, April 1992.

⁴Marshall & Swift Equipment Cost Index, Chemical Engineering, April, 1992.

⁵Nuexco Historical Market Data, April, 1992.

2.2 Cost Factor Generator (CFG)

The updated cost escalators are used to generate components of capital and operating costs in the Cost Factor Generator, Version 102 Subroutine in the URAD System. The values are stored in a file named "CFGPI."

3.0 1991 URANIUM RESOURCE ESTIMATES

Using the URAD data records and the PC-based dBXL database management system, the updated 1991 economic indicators discussed in Section 2.1 were entered, and the 1991 EAR and SR for the various cost categories were submitted to EIA on June 15, 1992. The following sections are slightly modified after those published in the Uranium Industry Annual 1991 (EIA, 1992).

3.1 Support from the U.S. Geological Survey

In accordance with a Memorandum of Understanding (MOU) signed in 1984 between the EIA and the U.S. Geological Survey (USGS) of the U.S. Department of the Interior, the USGS provides to the EIA annual estimates of the Nation's uranium endowment. Uranium endowment is the quantity of uranium estimated to occur in rock with a grade of at least 0.01 percent U_3O_8 . Through its ongoing geological programs, the USGS conducts studies of uranium districts and favorable geological environments in selected localities where, because of the availability of new scientific knowledge or industry-developed information relating to uranium resources, opportunities exist for updating the National uranium resource data base, the Uranium Resources Assessment Data (URAD). In this manner, the USGS is continuing the assessment of Nation's Uranium endowment begun the DOE's prior uranium resource appraisal program, National Uranium Resources Evaluation (NURE), which was phased out in 1983. The methodology used by the USGS to develop the U.S. uranium endowment estimates is a modification of the methodology developed during the NURE program by the DOE (Blanchfield, 1980; Finch and McCammon, 1987).

The EIA uses the uranium endowment data to prepare annual estimates of U.S. potential uranium resources, which consist of the portions of the endowment, estimated for each favorable locality, that could be recoverable at selected forward costs of production, based on economic evaluation of anticipated operating and capital costs, cutoff grade, minimum mining grade, and other factors.

3.2 Uranium Endowment by Resource Region

Uranium endowment is the total quantity of estimated resources, irrespective of economic considerations, above 0.01 percent U_3O_8 within geographic areas that have geologic characteristics favorable for uranium deposits. Endowment includes the undiscovered resources (EAR and SR), which are derived by determining economically recoverable portions of the endowment at stipulated maximum forward costs of producing the uranium. The distribution of the mean values of uranium endowment is shown by resource region in Table 1 (Figure 1). The endowments associated with the EAR values for all regions are unchanged from the 1990 values. The endowments associated with the SR values for all regions except for the Northern Rockies are unchanged from the 1990 values. For the Northern Rockies, the SR value increased to 3,940 million pounds U_3O_8 from 3,860 million pounds in 1990.

3.3 Estimated Additional Resources (EAR) and Speculative Resources (SR)

The estimates of EAR and SR presented in this section were developed from a data base of information on uranium deposits and mining economics compiled during the past three decades of Government and industry activities. The data base includes the extensive data on undiscovered uranium resources that were compiled during the NURE program as well as additional data provided by the U.S. Geological Survey. These data are maintained in the Uranium Resources Assessment Data (URAD) system, which is used to generate current estimates of undiscovered resources of uranium at the forward costs of \$30-, \$50-, and \$100-per-pound U_3O_8 .

For 1992, estimates of U.S. undiscovered resources were generated using revised economic index values (current to December 1991) in the URAD system's cost model. The economic indexes are the Wholesale Price Index-Industrial Commodities (WPI), the Marshall and Swift Mining-Milling Equipment Cost Index (MSI), and the Chemical Engineering Plant Cost Index (CEP). The trends of these cost indexes and average annual U_3O_8 spot market prices from 1980 to 1991 are shown in Figure 2. The 1991 spot market price, or "MPRICE", for U_3O_8 concentrate as determined by the average of NUEXCO monthly exchange prices was \$8.78. In 1991, the URAD cost model was revised by raising the threshold value for the average-grade cutoff. This was done in order to more accurately reflect the higher range of average grades encountered in deposits in the breccia-pipe environment in northern Arizona. Revised EAR and SR estimates were generated for 1989, the year when the USGS breccia-pipe evaluations were entered in the URAD data base, and for 1990. The revised values for EAR and SR for 1989 are shown in Table 2. For 1992, the threshold value for the average grade cutoff was removed altogether. This was done in order to reflect more accurately the entire range in grades of the uranium inventory represented by the grade-tonnage curves for each control area. This change resulted in overall increases in the estimates for the total EAR and SR cost categories with progressively smaller increases with progressively higher cost category. The change offset the decreases due to increases in economic indexes. Estimates for years prior to 1990 would also be affected by this change; however, the change in the values would not be significant and therefore have not been made.

Estimates of undiscovered resources shown in Table 2 represent the rounded totals of the expected values of the distributions of estimates in million pounds U_3O_8 for all areas at the end of 1991. For 1991, the mean values for the \$30-, \$50-, and \$100-per pound U_3O_8 forward-cost EAR category resources show no change when compared to the values shown for 1990. The mean values for the \$30-, \$50-, and

\$100-per pound U_3O_8 forward-cost SR forward-cost category show increases of 8, 5, and 3 percent, respectively.

3.4 Distribution of EAR and SR by Resource Region

Estimates of EAR and SR for the United States are reported for resource regions defined by geologic and physiographic characteristics (Figure 1). The mean values of EAR and SR are summarized by principal resource region and forward-cost category in Table 3. In 1989, Colorado Plateau showed a 135 percent increase in the \$50-per pound U_3O_8 EAR category when compared with the 1988 value³. This marked increase was due to new discoveries and greatly improved knowledge of the distribution of breccia-pipe deposits in the Grand Canyon region of Arizona developed in the past 10 years⁴. In 1990, the Colorado Plateau quantity for \$50-per pound U_3O_8 EAR was slightly lower, which resulted from increased values of economic indexes used in the undiscovered-resource cost model for 1990 as compared with 1989. In 1991, the decreases due to increased economic indexes are offset, in most regions and cost categories, by the increases due to the removal of the grade-cutoff threshold value (compare Table 3 with Table A3). The greatest increases are in the Northern Rockies Resource Region where increases for the EAR and SR \$30-per pound U_3O_8 are 50 percent, the SR \$50-per pound U_3O_8 is 31 percent, and the SR \$100-per pound U_3O_8 is 24 percent. These increases are due to the newly assessed Flodelle Creek area. There are mixed increases ranging from 1 to 12 percent for other regions and a decrease of 3 percent for EAR \$50-per pound U_3O_8 in the Wyoming Basins. The total values for EAR are essentially unchanged whereas the total values for SR have increased from 3 to 7 percent in all categories. The distribution of \$50-per pound U_3O_8 EAR in the 7 regions is shown in Figure 3.

³ Energy Information Administration, 1991, Uranium industry annual, 1990: Energy Information Administration, U.S. Department of Energy, DOE/EIA-0478(90), 133 p.

⁴ W.I. Finch and others, "The 1987 Estimate of Undiscovered Uranium Endowment in Solution-Collapse Breccia-Pipes in the Grand Canyon Region of Northern Arizona and Adjacent Utah," U.S. Geological Survey Circular 1051 (Washington, C.C.: U.S. Government Printing Office, 1990).

3.5 Distribution of EAR and SR by Land Status

The distribution by land status of mean values for \$50-per pound EAR and SR at the end of 1991 is shown in Table 4. Compared with 1990, there is no change in the mean values of EAR. For the SR category, there are slight increases in the mean value for Bureau of Land Management and Forest Service Lands, Indian Lands, State Lands, and Private Fee Lands.

Table 1. Uranium Endowment by Resource Region at the End of 1991
[Million Pounds U₃O₈]

Resource Region	Endowment Associated with Estimated Additional Resources ^a	Endowment Associated with Speculative Resources ^a
Colorado Plateau.....	3,950	2,430
Wyoming Basins.....	1,990	450
Coastal Plain.....	910	410
Northern Rockies	680	3,940
Colorado and Southern Rockies.....	320	360
Great Plains	310	950
Basin and Range.....	1,420	1,080
Central Lowlands	(b)	280
Appalachian Highlands.....	120	1,140
Other Regions ^c	50	120
Total.....	9,750	11,160

^a Values shown are the mean values for the distributions of estimates for each forward-cost category, rounded to the nearest 10 million pounds U₃O₈.

^b No uranium endowment in the Estimated Additional Resources category is estimated for this resource region.

^c Includes endowment associated with Estimated Additional Resources for Pacific Coast region and Alaska and endowment associated with Speculative Resources for Columbia Plateau, Pacific Coast, and Southern Canadian Shield regions and Alaska.

Note: Totals may not equal sum of components because of independent rounding.

Sources: U.S. Department of Energy, Grand Junction Project Office, *Statistical Data of the Uranium Industry* (January 1983). Estimates based on uranium resources data developed under the DOE National Uranium Resource Evaluation (NURE) program, using methodology described in *An Assessment Report on Uranium in the United States of America* (October 1980), and in U.S. Department of Energy, *Uranium Industry Seminar* (October 1980) and under the USGS Uranium Resource Assessment project using in part methodology described in USGS Circular 994 (1987).

Table 2. Estimated Additional Resources (EAR) and Speculative Resources (SR) at the End of the Year, 1974-1991
[Million Pounds U₃O₈]

Year	Forward-Cost Category in Nominal Dollars ^a									
	\$10 per pound		\$15 per pound		\$30 per pound		\$50 per pound		\$100 per pound	
	EAR	SR	EAR	SR	EAR	SR	EAR	SR	EAR	SR
1974.....	900	1,000	1,400	1,700	2,300	3,500	(b)	(b)	(b)	(b)
1975.....	900	1,100	1,300	1,900	2,100	3,700	(b)	(b)	(b)	(b)
1976.....	600	400	1,200	1,400	2,200	3,200	2,700	3,900	(b)	(b)
1977.....	(b)	(b)	1,100	1,300	2,000	3,100	2,800	4,200	(b)	(b)
1978.....	(b)	(b)	800	600	2,000	2,000	3,000	3,400	(b)	(b)
1979 ^c	(b)	(b)	800	600	2,000	2,000	3,000	3,400	(b)	(b)
1980.....	(b)	(b)	600	300	1,800	1,300	2,900	2,200	4,200	3,400
1981.....	(b)	(b)	(b)	(b)	1,200	900	2,200	1,800	3,500	2,900
1982.....	(b)	(b)	(b)	(b)	1,300	900	2,300	1,800	3,800	3,000
1983.....	(b)	(b)	(b)	(b)	1,300	1,000	2,400	2,000	3,800	3,200
1984.....	(b)	(b)	(b)	(b)	1,300	1,000	2,300	2,000	3,700	3,200
1985.....	(b)	(b)	(b)	(b)	1,300	1,000	2,400	1,900	3,800	3,200
1986.....	(b)	(b)	(b)	(b)	1,300	1,000	2,400	1,900	3,800	3,200
1987.....	(b)	(b)	(b)	(b)	1,300	1,000	2,300	2,000	3,700	3,200
1988.....	(b)	(b)	(b)	(b)	1,300	1,000	2,300	2,000	3,800	3,200
1989.....	(b)	(b)	(b)	(b)	R2,300	R1,400	3,400	R2,300	5,000	3,500
1990.....	(b)	(b)	(b)	(d)	2,200	1,300	3,400	2,200	4,900	3,500
1991.....	(b)	(b)	(b)	(d)	2,200	1,400	3,400	2,300	4,900	3,600

^a Values shown are the mean values for the distributions of estimates for each forward-cost category, rounded to the nearest 100 million pounds U₃O₈. Resource values in forward-cost categories are cumulative: that is, the quantity at each level of forward cost includes all resources at the lower cost in that category.

^b Not estimated for the indicated forward-cost category.

^c No new estimates were released for the end of 1979, since the NURE program was to publish estimates of undiscovered resources by October 1980.

^d Resource values were estimated for the \$15 per pound U₃O₈ forward-cost category, but were not included in the table.

R = Revision.

Sources: 1974-1982—U.S. Department of Energy, Grand Junction Project Office, *Statistical Data of the Uranium Industry* (January 1983). 1983-1991—Estimates based on uranium resources data developed under the DOE National Uranium Resource Evaluation (NURE) program, 1974-1983, using methodology described in *An Assessment Report on Uranium in the United States of America* (October 1980), and in U.S. Department of Energy, *Uranium Industry Seminar* (October 1980) and under the USGS Uranium Resource Assessment project using in part methodology described in USGS Circular 994 (1987).

Table 3. Estimated Additional Resources (EAR) and Speculative Resources (SR) by Resource Region at the End of 1991
[Million Pounds U₃O₈]

Resource Region	Forward-Cost Category in Nominal Dollars ^a					
	\$30 per pound		\$50 per pound		\$100 per pound	
	EAR	SR	EAR	SR	EAR	SR
Colorado Plateau.....	1,370	500	1,940	800	2,570	1,240
Wyoming Basins.....	170	90	350	170	680	260
Coastal Plain.....	380	130	500	180	610	240
Northern Rockies.....	30	120	60	210	170	310
Colorado and Southern Rockies.....	140	90	180	140	220	190
Basin and Range.....	60	110	170	190	410	340
Other Regions ^b	110	350	190	640	270	1,020
Total.....	2,240	1,400	3,390	2,330	4,920	3,580

^a Values shown are the mean values for the distributions of estimates for each forward-cost category, rounded to the nearest 10 million pounds U₃O₈. Resource values in forward-cost categories are cumulative: that is, the quantity at each level of forward cost includes all resources at the lower cost in that category.

^b Includes Appalachian Highlands, Great Plains, Pacific Coast and Sierra Nevada, Central Lowlands, and Columbia Plateau regions and Alaska.

Note: Totals may not equal sum of components because of independent rounding.

Source: Prepared by staff of the U.S. Geological Survey, U.S. Department of the Interior, based on uranium resources data developed under the DOE National Uranium Resource Evaluation (NURE) program and the USGS Uranium Resource Assessment project, using methodology described in *An Assessment Report on Uranium in the United States of America* (October 1980), and in U.S. Department of Energy, *Uranium Industry Seminar* (October 1980).

Table 4. Estimated Additional Resources (EAR) and Speculative Resources (SR) in the \$50-per Pound Forward-Cost Category by Land Status at the End of 1991

Land Status	Estimated Additional Resources ^a		Speculative Resources ^a	
	Million Pounds U ₃ O ₈	Percent of Total EAR	Million Pounds U ₃ O ₈	Percent of Total SR
Public lands				
Bureau of Land Management and Forest Service Lands	980	28.9	490	21.1
Bureau of Reclamation	(b)	(c)	(b)	0.2
Wilderness Areas	20	0.5	20	0.7
National Park Service Lands	110	3.3	10	0.6
Wildlife Refuges	(b)	(c)	(b)	0.2
DOE-Administered	10	0.2	(b)	(c)
Indian Lands	460	13.6	240	10.2
State Lands	200	5.9	170	7.2
Private Fee Lands ^d	1,550	45.9	1,340	57.8
Other (Military Reservations, Waterways, Reclamation Projects, Proposed Withdrawals, etc.)	60	1.8	50	2.2
Total	3,390	100.0	2,330	100.0

^a Values shown are the mean values for the distributions of estimates of EAR and SR, rounded to the nearest 10 million pounds U₃O₈.

^b Value is less than 5 million pounds U₃O₈.

^c Value is less than 0.05 percent.

^d Includes railroad lands and patented claims.

Note: Totals may not equal sum of components because of independent rounding.

Source: Prepared by staff of the U.S. Geological Survey, U.S. Department of the Interior, based on uranium resources data developed under the DOE National Uranium Resource Evaluation (NURE) program and the USGS Uranium Resource Assessment project, using methodology described in *An Assessment Report on Uranium in the United States of America* (October 1980), and in U.S. Department of Energy, *Uranium Industry Seminar* (October 1980).

Source: U.S. Department of Energy, *An Assessment Report on Uranium in the United States of America*, GJO-111(80) (Grand Junction, Colorado, October 1980).

Figure 1.—Uranium resource regions of the United States.

Figure 2. Trends of the economic indexes Wholesale Price Index-Industrial Commodities (WPI), the Marshall and Swift Mining-Milling Equipment Cost Index (MSI), and the Chemical Engineering Plant Cost Index (CEP) and of the average annual U₃O₈ spot market prices as determined by the average of NUEXCO monthly exchange prices from 1980-1991.

Figure 3.—Distribution of \$50-pound U₃O₈ EAR by region.

4.0 ADJUSTMENT TO GRADE CUT-OFF THRESHOLD VALUE

4.1 Resource Estimates for Obtained Using the Grade Cut-off Threshold Value of 1.00 Percent U₃O₈

In generating the 1991 resource estimates reported in the main body of this report, the grade cut-off threshold value used in the URAD cost model was removed. As explained in the main body of the report, the reason for removing the grade cut-off threshold value was to reflect more accurately the entire range in grades of the uranium inventory represented by the grade-tonnage curves for each control area. This change resulted in overall increases in the estimates for the total EAR and SR cost categories. In this addendum, the resource estimates for 1991 are presented retaining the grade cut-off threshold of 1.00 percent U₃O₈ that was applied in generating the resource estimates for 1990. The resource estimates that correspond to retaining the grade cut-off threshold of 1.00 percent U₃O₈ are shown in tables 5 through 8.

Table 5. Uranium Endowment by Resource Region at the End of 1991

[Million Pounds U₃O₈]

Resource Region	Endowment Associated with Estimated Additional Resources ^a	Endowment Associated with Speculative Resources ^a
Colorado Plateau.....	3,950	2,430
Wyoming Basins.....	1,990	450
Coastal Plain.....	910	410
Northern Rockies.....	680	3,940
Colorado and Southern Rockies.....	320	360
Great Plains.....	310	950
Basin and Range.....	1,420	1,080
Central Lowlands.....	(b)	280
Appalachian Highlands.....	120	1,140
Other Regions ^c	50	120
Total.....	9,750	11,160

^a Values shown are the mean values for the distributions of estimates for each forward-cost category, rounded to the nearest 10 million pounds U₃O₈.

^b No uranium endowment in the Estimated Additional Resources category is estimated for this resource region.

^c Includes endowment associated with Estimated Additional Resources for Pacific Coast region and Alaska and endowment associated with Speculative Resources for Columbia Plateau, Pacific Coast, and Southern Canadian Shield regions and Alaska.

Note: Totals may not equal sum of components because of independent rounding.

Sources: U.S. Department of Energy, Grand Junction Project Office, *Statistical Data of the Uranium Industry* (January 1983). Estimates based on uranium resources data developed under the DOE National Uranium Resource Evaluation (NURE) program, using methodology described in *An Assessment Report on Uranium in the United States of America* (October 1980), and in U.S. Department of Energy, *Uranium Industry Seminar* (October 1980) and under the USGS Uranium Resource Assessment project using in part methodology described in USGS Circular 994 (1987).

Table 6. Estimated Additional Resources (EAR) and Speculative Resources (SR) at the End of the Year, 1974-1991
[Million Pounds U₃O₈]

Year	Forward-Cost Category in Nominal Dollars ^a									
	\$10 per pound		\$15 per pound		\$30 per pound		\$50 per pound		\$100 per pound	
	EAR	SR	EAR	SR	EAR	SR	EAR	SR	EAR	SR
1974	900	1,000	1,400	1,700	2,300	3,500	(b)	(b)	(b)	(b)
1975	900	1,100	1,300	1,900	2,100	3,700	(b)	(b)	(b)	(b)
1976	600	400	1,200	1,400	2,200	3,200	2,700	3,900	(b)	(b)
1977	(b)	(b)	1,100	1,300	2,000	3,100	2,800	4,200	(b)	(b)
1978	(b)	(b)	800	600	2,000	2,000	3,000	3,400	(b)	(b)
1979 ^c	(b)	(b)	800	600	2,000	2,000	3,000	3,400	(b)	(b)
1980	(b)	(b)	600	300	1,800	1,300	2,900	2,200	4,200	3,400
1981	(b)	(b)	(b)	(b)	1,200	900	2,200	1,800	3,500	2,900
1982	(b)	(b)	(b)	(b)	1,300	900	2,300	1,800	3,800	3,000
1983	(b)	(b)	(b)	(b)	1,300	1,000	2,400	2,000	3,800	3,200
1984	(b)	(b)	(b)	(b)	1,300	1,000	2,300	2,000	3,700	3,200
1985	(b)	(b)	(b)	(b)	1,300	1,000	2,400	1,900	3,800	3,200
1986	(b)	(b)	(b)	(b)	1,300	1,000	2,400	1,900	3,800	3,200
1987	(b)	(b)	(b)	(b)	1,300	1,000	2,300	2,000	3,700	3,200
1988	(b)	(b)	(b)	(b)	1,300	1,000	2,300	2,000	3,800	3,200
1989	(b)	(b)	(b)	(b)	R2,300	R1,400	3,400	R2,300	5,000	3,500
1990	(b)	(b)	(b)	(d)	2,200	1,300	3,400	2,200	4,900	3,500
1991	(b)	(b)	(b)	(d)	2,200	1,300	3,400	2,200	4,900	3,500

^a Values shown are the mean values for the distributions of estimates for each forward-cost category, rounded to the nearest 100 million pounds U₃O₈. Resource values in forward-cost categories are cumulative: that is, the quantity at each level of forward cost includes all resources at the lower cost in that category.

^b Not estimated for the indicated forward-cost category.

^c No new estimates were released for the end of 1979, since the NURE program was to publish estimates of undiscovered resources by October 1980.

^d Resource values were estimated for the \$15 per pound U₃O₈ forward-cost category, but were not included in the table.

R = Revision.

Sources: 1974-1982—U.S. Department of Energy, Grand Junction Project Office, *Statistical Data of the Uranium Industry* (January 1983). 1983-1991—Estimates based on uranium resources data developed under the DOE National Uranium Resource Evaluation (NURE) program, 1974-1983, using methodology described in *An Assessment Report on Uranium in the United States of America* (October 1980), and in U.S. Department of Energy *Uranium Industry Seminar* (October 1980) and under the USGS Uranium Resource Assessment project using in part methodology described in USGS Circular 994 (1987).

Table 7. Estimated Additional Resources (EAR) and Speculative Resources (SR) by Resource Region at the End of 1991
[Million Pounds U₃O₈]

Resource Region	Forward-Cost Category in Nominal Dollars ^a					
	\$30 per pound		\$50 per pound		\$100 per pound	
	EAR	SR	EAR	SR	EAR	SR
Colorado Plateau.....	1,360	490	1,930	790	2,560	1,230
Wyoming Basins	160	90	350	160	680	250
Coastal Plain.....	380	130	500	180	610	230
Northern Rockies.....	20	80	60	170	170	310
Colorado and Southern Rockies.....	140	90	180	140	220	190
Basin and Range.....	60	100	170	180	410	330
Other Regions ^b	110	330	190	620	270	1,010
Total.....	2,230	1,300	3,370	2,240	4,910	3,540

^a Values shown are the mean values for the distributions of estimates for each forward-cost category, rounded to the nearest 10 million pounds U₃O₈. Resource values in forward-cost categories are cumulative: that is, the quantity at each level of forward cost includes all resources at the lower cost in that category.

^b Includes Appalachian Highlands, Great Plains, Pacific Coast and Sierra Nevada, Central Lowlands, and Columbia Plateau regions and Alaska.

Note: Totals may not equal sum of components because of independent rounding.

Source: Prepared by staff of the U.S. Geological Survey, U.S. Department of the Interior, based on uranium resources data developed under the DOE National Uranium Resource Evaluation (NURE) program and the USGS Uranium Resource Assessment project, using methodology described in *An Assessment Report on Uranium in the United States of America* (October 1980), and in U.S. Department of Energy, *Uranium Industry Seminar* (October 1980).

Table 8. Estimated Additional Resources (EAR) and Speculative Resources (SR) in the \$50-per Pound Forward-Cost Category by Land Status at the End of 1991

Land Status	Estimated Additional Resources ^a		Speculative Resources ^a	
	Million Pounds U ₃ O ₈	Percent of Total EAR	Million Pounds U ₃ O ₈	Percent of Total SR
Public lands				
Bureau of Land Management and Forest Service Lands	970	28.9	460	20.4
Bureau of Reclamation	(b)	(c)	(b)	0.2
Wilderness Areas	20	0.5	20	0.7
National Park Service Lands	110	3.3	10	0.6
Wildlife Refuges	(b)	(c)	(b)	0.1
DOE-Administered	10	0.2	(b)	(c)
Indian Lands	460	13.6	230	10.4
State Lands	200	5.9	160	7.2
Private Fee Lands ^d	1,550	45.9	1,300	58.2
Other (Military Reservations, Waterways, Reclamation Projects, Proposed Withdrawals, etc.)	60	1.8	50	2.2
Total	3,370	100.0	2,240	100.0

^a Values shown are the mean values for the distributions of estimates of EAR and SR, rounded to the nearest 10 million pounds U₃O₈.

^b Value is less than 5 million pounds U₃O₈.

^c Value is less than 0.05 percent.

^d Includes railroad lands and patented claims.

Note: Totals may not equal sum of components because of independent rounding.

Source: Prepared by staff of the U.S. Geological Survey, U.S. Department of the Interior, based on uranium resources data developed under the DOE National Uranium Resource Evaluation (NURE) program and the USGS Uranium Resource Assessment project, using methodology described in *An Assessment Report on Uranium in the United States of America* (October 1980), and in U.S. Department of Energy, *Uranium Industry Seminar* (October 1980).

5.0 RUNNING THE URAD SYSTEM ON USGS COMPUTERS

5.1 Improvements and Additions to the URAD System

Data retrieval from the URAD system can now be performed using the dBase IV version 1.5 data base management system. Only a single line of code must be removed from each of the previously used dBase program files to make them work with dBase IV. The URAD data files do not have to be changed in any way to make the conversion from the dBase system. The conversion to dBase IV was made because this system is more widely used and flexible than dBase, and is somewhat faster.

The ORNL plotting program SUM27 could not be converted for use on the PC because the code made calls to plotting software not available on the PC. Instead, program JAPREP was modified to produce a table of percentiles of the probability distribution of the uranium resources. This table can be readily imported to the Quattro Pro spread sheet program, and plots of the probability distributions of uranium resources can be made using Quattro graphics routines. A graph showing SR, EAR, and total uranium endowment (Figure 4) was produced by invoking a Quattro Pro macro specially written for that purpose.

Program JAPREP was further modified to produce output files for import to Quattro Pro which can be quickly converted into formatted tables suitable for inclusion in the EIA publication *Uranium Industry Annual*. Macros have been written to produce tables B2, B3, and B4 of the from JAPREP output files, and table B5 from program RLSREP output (*Uranium Industry Annual 1991*).

Prior to the above changes, the tables had to be created by hand transcription of various lines of data from the output files, a slow and tedious process.

5.2 Debugging FORTRAN Source Code of URAD Programs

The FORTRAN source code libraries of the URAD system were recompiled using Microsoft's Version 5.1 FORTRAN compiler to detect any problems in these

libraries which had hitherto gone undetected. Several "variable type-size" mismatches were found and these errors were corrected. Limited testing of the corrected versions of the URAD programs has not indicated any change in results from those of the uncorrected versions.

Figure 4.--Probability plot of U.S. potential uranium resources.

6.0 RECOMMENDATIONS

Specific recommendations are made based upon the work that was performed by the USGS under the terms in the current Contract.

6.1 Proposal for Update of Mining and Milling Cost Models

Over the decade of the 1980's, the US and world metal mining industry have changed dramatically as a result of the rationalization of industrial capacity, introduction of new technologies, and the general imposition of much stricter measures to protect the environment. The domestic uranium industry is no exception as most US production has come from mines that probably did not exist at the start of the decade. The USGS incorporates new geologic data to update its assessments of uranium endowment. However, the EIA uranium mining and milling cost models, which were developed and estimated in the early 1980's, are no longer appropriate for calculating the forward cost categories for the resource. These models do not characterize the mining technology used at currently operating mines. Specifically, the mining costs for breccia-pipe uranium extraction, new environmental measures for open-pit mining, and in situ solution mining are not adequately represented in the models. Furthermore, any expansion in production will likely require new milling capacity that will incorporate new technology and that will have to meet new environmental regulations.

Initially, any increase in funding would be used to contract for the development of generalized cost models for mining breccia-pipe type ore deposits. If feasible and within the project budget cost, generalized cost models for the associated milling operations will also developed as part of the mining configuration. Mining and milling costs should be expressed as functions of the grade, geologic factors (depth, rock type), and annual capacity as well as factors relating to the degree of environmental regulations imposed.

6.2 State Tax Equations

The USGS agrees with EIA that there is a need to check on current state tax codes, to add new state severance/royalty tax equations, and to modify the existing equations where necessary. It is recommended that this work be undertaken as part of next year's Contract.

6.3 Automation and Networking

It is proposed that under next year's Contract, further efforts be made to automate the generation of assessment reports that are submitted to the EIA and to explore the opportunities of establishing a computer network for communication between the USGS and the EIA.

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