MAINTAINING THE URANIUM RESOURCE ASSESSMENT DATA SYSTEM AND ASSESSING THE 1992 U.S. URANIUM POTENTIAL RESOURCES

Final Report

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By

**W.I. Finch, W.D. Grundy,
C.T. Pierson, and J.O. Kork**

U.S. Geological Survey

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EXECUTIVE SUMMARY

For 1992, estimates of U.S. undiscovered uranium resources were generated using revised economic index values (current to December 1992) in the Uranium Resources Assessment Data (URAD) System's cost model. The endowments associated with the Estimated Additional Resources (EAR) and Speculative Resources (SR) values for all regions are unchanged from the 1991 values. Although higher 1992 indexes resulted in increased costs, the mean values for the \$30-, \$50-, and \$100-per pound U_3O_8 forward-cost EAR category resources for 1992 show no significant changes when compared to the values in 1991. The mean values for the \$30-, \$50-, and \$100-per pound U_3O_8 forward-cost SR forward-cost category show decreases of 4, 3, and 1 percent, in the three categories respectively.

Under the Memorandum of Understanding (MOU) between the Energy Information Administration (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 URAD System that is maintained for the EIA by the USGS. Endowment estimates were added for the solution-collapse breccia pipe uranium deposits in the Grand Canyon region in 1989 and for young surficial uranium deposits in the Flodelle Creek area in Washington in 1991. Estimates of uranium endowment for roll-front uranium deposits in northwestern Nebraska and adjacent states are nearly completed and will be added in 1994. Assessment of undiscovered uranium endowment in new areas by the USGS will be discontinued in FY 1995 due to phasing out of the uranium resources program in FY 1994.

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 system¹. The conversion to dBase IV was made because this system is more widely used and more flexible than the earlier system, dBase XL, 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 1992 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) URAD 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).

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

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

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 (DOE), 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; Finch and others, 1990). 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 1992 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 - The contractor shall be responsible for the following ongoing work items relating to system management, maintenance, and computations:

- a. Manage and maintain the full 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 installing, accessing, and running the URAD System on the EIA computer system.
- 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 1992 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 1992 uranium resources data from the MAPPER files output also shall be provided by the contractor.
- g. Provide compilations on computer diskette of final uranium Estimated Additional Resources (EAR) and Speculative Resources (SR) assessment for the \$15, \$30, \$50, and \$100 per pound U_3O_8 cost categories for 1992. 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, 1993
2. Report of 1992 EAR and SR for various cost categories	June 15, 1993
3. Installation of 1992 URAD data base programs on the EIA computer system	July 1, 1993
4. Draft Final Report	November 30, 1993
5. Final report on URAD System maintenance and 1992 potential resources assessment	December 31, 1993

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:

U.S. 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 1992 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	MSI 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
1992	117.4	358.2	943.1

1992 Cost Escalators

$$\begin{aligned}\text{CEP}_{80} &= 358.2/261.2 = 1.37136294 \\ \text{MSI}_{80} &= 943.1/659.6 = 1.42980594 \\ \text{MSI}_{82} &= 943.1/745.6 = 1.26488734 \\ \text{WPI}_{80} &= 117.4/88.0 = 1.33409091 \\ \text{WPI}_{81} &= 117.4/97.4 = 1.20533881 \\ \text{WPI}_{82} &= 117.4/100.0 = 1.17400000\end{aligned}$$

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

²Producer Price Index (Industrial Commodities), Bureau of Labor Statistics, April 1993.

³Chemical Engineering Plant Cost Index, Chemical Engineering, April 1993.

⁴Marshall & Swift Equipment Cost Index, Chemical Engineering, April, 1993.

Year	Average Price ⁵
1992	\$7.85

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 1992 URANIUM RESOURCE ESTIMATES

Using the URAD data records and the PC-based dBL database management system, the updated 1992 economic indicators discussed in Section 2.1 were entered, and the 1992 EAR and SR for the various cost categories were submitted to EIA on June 7, 1993. The following sections are slightly modified after those published in the Uranium Industry Annual 1992 (EIA, 1993).

3.1 Support from the U.S. Geological Survey

In accordance with a MOU signed in 1984 between the EIA and the USGS, 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 U₃O₈. 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 URAD System. In this manner, the USGS has continued the assessment of Nation's Uranium endowment begun during the DOE's uranium resource appraisal program, the National Uranium Resources Evaluation (NURE) Program, 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 USGS uranium program is being phased out in FY-1994, and the USGS will discontinue assessing uranium endowment in FY-1995.

⁵NUEXCO Review, 1992 Annual, 1993.

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 by resource region (Figure 1) is given in Table 1. The distribution of endowment values for all regions are unchanged from the 1991 values.

3.3 Potential Uranium Resources for 1992, EAR and 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 database 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 URAD System, which is used to generate current estimates of undiscovered potential resources of uranium at the forward costs of \$30-, \$50-, and \$100-per-pound U_3O_8 . For 1992, estimates of U.S. undiscovered potential resources were generated using revised economic index values (current to December 1992) in the URAD System's cost model. The economic indexes are the WPI, CEP, and MSI. The trends of these cost indexes and average annual U_3O_8 spot market prices from 1980 to 1992 are shown in Figure 2. The 1992 spot market price, or "MPRICE", for U_3O_8 concentrate as determined by the average of NUEXCO monthly exchange prices was \$7.85. For 1990 estimates, 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, (Energy Information Administration, 1990). The revised values for EAR and SR for 1989 are shown in Table 2. For 1991 estimates, 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 1989 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 1992. For 1992, the mean values for the \$30-, \$50-, and \$100-per pound U_3O_8 forward-cost EAR category resources show no significant changes when compared to the values shown for 1991. The mean values for the \$30-, \$50-, and \$100-per pound U_3O_8 SR category show decreases of 4, 3, and 1 percent, in the three categories respectively.

The probability distribution of the endowment values in EAR, SR, and total EAR + SR at the end of 1992 is shown in Figure 3.

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 value⁶. 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 years⁷. However in 1990, 1991, and 1992 (this report) the Colorado Plateau quantities for \$50-per pound U₃O₈ EAR were slightly lower, which resulted from increased values of economic indexes used in the undiscovered-resource cost model for these years. The addition of the new Flodelle Creek favorable area in the Northern Rockies Resource Region in 1991 resulted in increases for the EAR and SR \$30-per pound U₃O₈ of 50 percent, SR \$50-per pound U₃O₈ 31 percent, and SR \$100-per pound U₃O₈ 24 percent⁸. In 1992, the values of EAR and SR for individual regions in the three forward-cost categories show either mostly slight decreases or some no changes (Table 3) due to increased economic indexes. The total values for EAR show decreases of less than 1 percent and for SR show decreases of 1 to 4 percent in all categories. The distribution of \$50-per pound U₃O₈ EAR in the various regions is shown in Figure 4.

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 1992 is shown in Table 4. Most values are unchanged. A slight decrease in the quantity of EAR and SR over that for 1991 is shown for Bureau of Land Management and Forest Service Lands and Private Fee Lands. A slight decrease is shown in the SR value for State Lands.

⁶Energy Information Administration, 1991, Uranium industry annual, 1990: Energy Information Administration, U.S. Department of Energy, DOE/EIA-0478(90), 133 p.

⁷W.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, D.C.: U.S. Government Printing Office, 1990), 19 p.

⁸Energy Information Administration, 1992, Uranium industry annual 1991: Energy Information Administration, U.S. Department of Energy, DOE/EIA-0487(91), 137 p.

Table 1. Uranium Endowment by Resource Region at the End of 1992

Resource Region	[Million Pounds U ₃ O ₈]	
	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 of EAR and SR, 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: 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), in U.S. Department of Energy, *Uranium Industry Seminar* (October 1980) and under the USGS Uranium Resource Assessment project using the methodology described in *Uranium Resource Assessment by the Geological Survey: Methodology and Plan to Update the National Resource Base*, U.S. Geological Survey Circular 994 (1987).

Table 2. Estimated Additional Resources (EAR) and Speculative Resources (SR) at the End of the Year, 1974-1992

Year	[Million Pounds U ₃ O ₈]									
	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
1992.....	(b)	(b)	(d)	(d)	2,200	1,300	3,400	2,300	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 3. Estimated Additional Resources (EAR) and Speculative Resources (SR) by Resource Region at the End of 1992

[Million Pounds U ₃ O ₈]						
Forward-Cost Category in Nominal Dollars ^a						
Resource Region	\$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	670	250
Coastal Plain.....	370	130	490	180	600	230
Northern Rockies.....	30	110	60	200	170	300
Colorado and Southern Rockies.....	140	90	180	140	220	190
Basin and Range.....	50	100	160	180	400	330
Other Regions ^b	110	340	190	620	270	1,000
Total.....	2,220	1,340	3,360	2,270	4,900	3,530

^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 1992

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	480	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)	0.1
DOE-Administered	10	0.2	(b)	(c)
Indian Lands	460	13.5	230	10.2
State Lands	200	5.9	160	7.2
Private Fee Lands ^d	1,540	45.9	1,310	57.7
Other (Military Reservations, Waterways, Reclamation Projects, Proposed Withdrawals, etc.)	60	1.8	50	2.2
Total	3,360	100.0	2,270	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 U_3O_8 spot market prices as determined by the average of NUEXCO monthly exchange prices from 1980-1992.

Figure 3.--Probability plots of uranium endowment at the end of 1992.

Figure 4.--Distribution of \$50-pound U₃O₈ EAR by region for 1992.

4.0 MODIFICATION OF THE URAD SYSTEM FOR USGS COMPUTERS

4.1 Improvements and Additions to the URAD System

Data retrieval from the URAD System can now be performed using the dBase IV version 1.5¹ data base management system on a personal computer (PC). Only a single line of code must be removed from each of the previously used dBXL¹ program files to make them work with dBase IV¹. The URAD System data files do not have to be changed in any way to make the conversion from the dBXL¹ system. The conversion to dBase IV was made because this system is more widely used and flexible than dBXL, and is somewhat faster.

The Oak Ridge National Laboratory (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 Pro¹ spread sheet program, and plots of the probability distributions of uranium resources can be made using Quattro Pro graphics routines. A graph showing EAR, SR, and total uranium endowment (Figure 3) 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*. (Energy Information Administration, 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.

4.2 Debugging FORTRAN Source Code of URAD System Programs

The FORTRAN source code libraries of the URAD System were recompiled using Microsoft's Version 5.1¹ FORTRAN compiler to detect any problems in these libraries which had hitherto gone undetected. Several "variable type-size"⁹ mismatches were found and these errors

⁹For example, a variable declared as a character (i.e., text) type in one part of the program might be declared as an integer (numeric) type in one or more subprograms. In some cases, the declared length (size) of a character variable may differ from subprogram to subprogram.

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.

4.3 Installation of Updated URAD System in EIA Computer

The current version of the URAD system was installed on the EIA computer in Washington D.C., in order to run IRAREP, JAPREP, STAREP, and other reports using the DBXL program. The installed system can be easily updated by adding new favorable areas and modifying old ones. A discussion of running the URAD System on USGS personal computers is given in Appendix I.

5.0 RECOMMENDATIONS

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

5.1 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 should also be

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.

5.2 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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APPENDIX I

RUNNING THE URAD SYSTEM ON USGS PERSONAL COMPUTERS

I.1 Files required by the URAD System

As stated in Section 4.0, the URAD System for generating uranium resource reports was modified to run under the DBXL¹ data base management system, rather than the ORACLE¹ data base management system, which was used by ORNL. The change was made to reduce running time, to simplify operation, and to reduce hardware requirements of the URAD System. The contents and formats of the generated output reports were not changed in any way and the logical flow diagram of the system remains the same as that shown in Chen and others (1990)¹⁰.

Personal Computer programs for the URAD System currently implemented on the USGS computer are shown in Table I-1. These are the same twenty report generators that are contained in Chen's original ORNL system. Computer files required to run the USGS computer and their location on a hard disk are shown in Table I-2. These files can be stored in a compressed form on a 3.5 inch, 1.44 megabyte floppy disk for later loading back on to a hard disk.

Directory C:\URAD (see Table I-2) contains both data files and program files. Except for file uradinfo.doc, the data files are required to be present for running the 20 execution modules (extension "exe") in this directory. The two batch files (extension "bat") are required for the automated running of the URAD System. File browse.com can be used to view the output files produced by the URAD System prior to optional printing of these files. Uradinfo.doc contains the information shown in Table I-1 and can be viewed using browse.com.

Directory C:\DBXL (Table I-2), in addition to the DBXL database manager, also contains a data file (uradnew.dbf), a set of DBXL program files (extension "prg"), and an execution module (extension "exe"). Uradnew.dbf is the master data file for the URAD system and is in a file structure compatible with dBASE IV or DBXL database managers. The "prg" files operate on uradnew.dbf in such a way that output files are obtained, which are ordered (i.e., sorted) in the

¹⁰Chen, G.L., Das, S., Perubhatla, R., and Whitaker, R.A., 1990, Uranium Resources Assessment Data (URAD) System, PC-Version 1.1, Briefing and Demonstration: Held U.S. Department of Energy Office, Washington, D.C., January 30, 1990, Oak Ridge National Laboratory, 19 p.

manner required by the “exe” program files in directory C:\URAD. The program file select.exe operates on the output files produced by the “prg” programs to render them into a format that is suitable for reading by the “exe” program files in C:\URAD. The output file created by select.exe is called "select.dat" and is automatically transferred into the directory C:\URAD for use by the “exe” program files.

Program file update.prg in the directory C:\DBXL is used to make the yearly cost-factor update of master file uradnew.dbf. The other 20 “prg” files are used in conjunction with their correspondingly named “exe” files in C:\URAD.

I.2 Producing URAD reports

URAD reports from any of the twenty computer programs listed in Table I-1 can be produced either from typing a command from the DOS prompt or by using a mouse to click on icons in Microsoft Windows, version 3.0.

To execute from the DOS prompt, do the following:

1. Make the C:\URAD directory the default directory and
2. Type the following prompt: uradrept taskname, where taskname is any task listed in Table I-1, e.g., agehru, japrep, starep, etc.

To execute from Microsoft Windows, do the following:

1. From the the DOS prompt type the following Windows' prompt win
2. When the Windows Program Manager screen appears, use the mouse to double click on the Urad Reports icon (an example is shown in Figure I-1),
3. When the Urad Reports screen appears, double click on the icon of the selected task (Figure I-2). A DOS screen will then appear which will show the progress of the execution of the selected task,
4. When the selected task is finished, the URAD Reports Windows screen will reappear. If desired, another task can be invoked by double clicking on the appropriate icon, and

5. When finished, click on the button in the left-hand corner of the Urad Reports screen, and then click on the Close button on the drop-down menu. This returns control to the Windows Program Manager.

Output files produced by running the system are all stored in directory C:\URAD. These files will all have the extension "prt" and can be either deleted after printing or viewed on-screen at the discretion of the user. The input file called "select.dat" will also be present in this directory, and it can be safely deleted. Directory C:\DBXL will contain a file called "select.txt", and this also can be deleted as the user wishes.

1.3 Updating (modifying) the master file

The URAD system master file uradnew.dbf must be updated annually to reflect the changes in uranium potential at different forward costs as general economic conditions change. The economic indicators and their mathematical manipulation are described in section 2.0 of this report. The updated escalators for use in the URAD system are called CEP80, MSI80, MSI82, WPI80, WPI81, and WPI82 (see Section 2.1). These escalators are stored in data file "cfgpi" and the file "cfgpi" must be modified annually to allow updating of the master file.

To modify file "cfgpi" do the following:

1. Using a text editor, a word processor, or the DOS copy con command create a six line text file containing the following updated values on each line:

```
line 1.....CEP80
line 2.....MSI80
line 3.....MSI82
line 4.....WPI80
line 5.....WPI81
line 6.....WPI82
```

The file for the end of calendar year 1992 would have the following appearance:

```
1.3714
1.4298
1.2649
1.3341
1.2053
1.1740
```

2. Store the file of new escalators in directory C:\URAD under the name "cfgpi". The file "cfgpi" for the previous year is thereby replaced with the new file.

The URAD system master file can now be updated using the following procedures:

1. From the Microsoft Windows URAD Reports screen double click on the icon for IRAREP,
2. When IRAREP begins execution, at the program prompt type in any four characters for a run identifier,
3. When IRAREP terminates execution, double click on the icon labeled "Update URAD Master File", and
4. When the DBXL program update.prg finishes execution, exit from Microsoft Windows to the DOS prompt.

A new file called "uradupda.dbf" will now exist in directory C:\DBXL. This is the update of the master file "uradnew.dbf". The new file, uradupda.dbf, should be carefully examined using the DBXL data base manager. If no problems are found with the newly created file, back up the original file uradnew.dbf to some other directory or to a floppy disk. Remove uradnew.dbf from directory C:\DBXL and then rename file uradupda.dbf to uradnew.dbf. This completes the update procedures.

After updating is completed, the file select.txt can be deleted from C:\DBXL, and files select.dat and update.dat can be deleted from C:\URAD. A very large file called irarep.prt will remain in C:\URAD. After printing, this file should be deleted or compressed to conserve disk space.

Figure I-1. Windows program manager screen showing the URAD System reports icon.

Figure I-2. Program manager screen showing icons for the URAD computer programs, Index, and Update URAD Master File.

	Task	Description
1	AGEHRU	Summary of host rock unit codes broken down by geologic age
2	AGEREP	Summary of potential by geologic age
3	AREREP	Summary of potential by class, resource region, exploration area, ore reserve area and locality
4	CAREP	Summary of potential by control areas and class
5	CCREP	Ranking of potential assessments within category and class
6	DEPREP	Summary of potential by deposit type
7	E50REP	Descending ranking of assessments by unconditional mean of \$50/lb endowments
8	ENDREP	Generates descending ranking of unconditional mean of endowments
9	GEOREP	Master list of geographic codes
10	GTREP	Summary of potential resources by geologic type
11	INDEX	List of localities with index to endowment and \$50/lb ranking
12	IRAREP	Produce individual resource assessment reports
13	JAPREP	Produce regional and national uranium resource totals and percentiles
14	LTREP	Summary of potential resources by years-lead-time
15	PDVREP	Conditional means and 25th and 75th percentiles for probable potential
16	REGREP	Summary of potential resources by class and region
17	RLSREP	Summary of potential by class, region, and land-status-type
18	SLSREP	Summary of potential by class, state, and land-status-type
19	STAREP	Summary of potential by state and class
20	YLTREP	Summary of potential resources by years-lead-time

TABLE I-1. List of URAD computer programs on the USGS personal computer

DATA FILES STORED IN DIRECTORY C:\URAD

FILE NAME	BYTES	DATE
CAFILE	7,035	89-09-29
CAFILE1	7,348	90-01-29
CFGPI	67	93-05-10
DEPTYP	2,242	92-04-16
EXAREA	3,250	90-01-09
GEOAGE	1,150	89-09-29
GEOTYP	217	90-11-09
HRUNIT	22,647	89-10-05
LNDTYP	395	89-09-29
LOCLTY	32,983	92-04-01
ORAREA	8,290	90-01-09
PIFIE	4,925	89-09-29
QUADS	18,630	89-09-29
RESREG	587	93-03-02
RESV81	1,445	89-09-29
RESV84	1,445	89-10-13
STATES	672	92-09-29
URADINFO.DOC	1,883	93-08-27
TOTAL BYTES	115,211	

PROGRAM FILES STORED IN DIRECTORY C:\URAD

FILE NAME	BYTES	DATE
UPDATE.BAT	215	93-06-09
URADREPT.BAT	111	90-11-09
BROWSE.COM	960	93-02-09
AGEHRU.EXE	94,337	89-12-13
AGEREP.EXE	36,081	90-01-09
AREREP.EXE	41,169	89-12-19
CAREP.EXE	34,817	90-01-08
CCREP.EXE	37,345	90-01-04
DEPREP.EXE	36,305	90-01-05
E50REP.EXE	93,201	90-07-09
ENDREP.EXE	93,201	90-07-09
GEOREP.EXE	24,465	90-01-09
GTREP.EXE	35,905	89-12-15
INDEX.EXE	33,521	89-12-18
IRAREP.EXE	121,276	92-10-26
JAPREP.EXE	120,630	92-10-26
LTREP.EXE	39,617	90-01-03
PDVREP.EXE	96,833	89-12-05
REGREP.EXE	99,643	93-03-02
RLSREP.EXE	128,070	92-10-26
SLSREP.EXE	66,577	89-11-22
STAREP.EXE	105,803	92-10-29
YLTREP.EXE	34,001	90-01-20
TOTAL BYTES	1,374,083	

DATA FILES STORED IN DIRECTORY C:\URAD

FILE NAME	BYTES	DATE
URADNEW.DBF	717,076	93-05-10

PROGRAM FILES STORED IN DIRECTORY C:\DBXL

FILE NAME	BYTES	DATE
SELECT.EXE	38,707	92-10-21
AGEHRU.PRG	267	90-07-16
AGEREP.PRG	263	90-12-14
AREREP.PRG	267	90-07-16
CAREP.PRG	280	90-09-10
CCREP.PRG	336	90-07-12
DEPREP.PRG	299	90-07-12
E50REP.PRG	309	90-07-12
ENDREP.PRG	311	90-07-12
GEOREP.PRG	267	90-07-16
GTREP.PRG	264	90-07-16
INDEX.PRG	264	90-07-16
IRAREP.PRG	268	91-06-04
JAPREP.PRG	267	90-07-16
LTREP.PRG	292	90-07-12
PDVREP.PRG	267	90-07-16
REGREP.PRG	265	90-07-12
RLSREP.PRG	267	90-07-16
SLSREP.PRG	267	90-07-16
STAREP.PRG	267	90-07-16
UPDATE.PRG	153	93-06-09
YLTREP.PRG	265	90-11-21
TOTAL BYTES	44,412	

Table I-2. Listing and location of files required by URAD System using USGS procedures.

DATE

FILMED

3 / 18 / 94

END