UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
PENNSYLVANIA POWER & LIGHT COMPANY	)	
and	)	Docket Nos. 50-387
	)	50-388
ALLEGHENY ELECTRIC COOPERATIVE INC.	)	
(Susquehanna Steam Electric Station, Units 1 and 2)	)	

AFFIDAVIT OF JOHN M. VALLANCE IN SUPPORT OF SUMMARY DISPOSITION OF CONTENTION 3

City of Washington)
: ss.
District of Columbia)

John M. Vallance, being duly sworn according to law, deposes and says:

1. I am a member of the firm of Pickard, Lowe and Garrick, Inc., which is a consultant to electric power utilities in economic and technical matters, and give this affidavit in support of Applicants' Motion for Summary Disposition of Contention 3. I have personal knowledge of the matters set forth herein and believe them to be true and correct. A summary of my professional qualifications and experience is attached as Exhibit "A" hereto.

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2. Contention 3 alleges that "known and assured" reserves of uranium are insufficient to supply the lifetime fuel required for Susquehanna 1 and 2; that all estimated reserves of uranium will have been consumed prior to the end of the thirty year life of those units; that higher fuel prices will result from the depletion of the uranium reserves; and that "much uranium for the facility will have to be imported." As will be shown below, all of these allegations are incorrect and in fact there will be an adequate supply of domestic uranium at moderate prices to provide fuel for the Susquehanna units throughout their lifetime.

The Uranium Industry

3. The domestic natural uranium supply industry originally evolved to fulfill the needs of the U.S. government for the supply of uranium for defense purposes. The government procurement program was successful, and due to its requirements being fulfilled, the government stopped purchasing natural uranium in 1971. Until the mid-1960's, U.S. law did not permit private ownership of enriched uranium and therefore there was essentially no private market for natural uranium. At that time, the Atomic Energy Act was amended to permit private ownership of enriched uranium and a timetable was also set for the transition to private ownership of enriched uranium which had previously been leased from the government. Since then, the domestic market for natural uranium has gradually evolved,

although 1978 was the first year in which annual production exceeded the levels experienced in the industry during the government purchasing era around 1960.

4. Because the government's demand for natural uranium dropped off faster than the commercial power demand grew in the late 1960's and early 70's, an oversupply of uranium production capacity existed and the utility industry found it could then purchase uranium on a competitive-bid basis at very low prices. This oversupply capability caused low prices to prevail until 1973. At that time, two significant events occurred: (1) the OPEC oil embargo; and (2) the government changed its contracting practices for enriching services. The latter had the effect of locking utility customers into fixed schedules for supplying natural uranium feed to the government for enriching. The former caused many fuel buyers to try to contract for fuel supplies further into the future. The end result was that the uranium supply industry became overwhelmed with proposal requests exhibiting serious interest on the part of purchasers to buy uranium well into the future. The uranium producers were not prepared for such an onslaught of buyer activity and rapidly became "sold out." The producers then had to rely on ongoing expansion programs before they could enter into new supply commitments. The price of uranium increased rapidly from about \$6 to \$7/lb U_3O_8 in 1973 to \$41/lb in 1976, then reached a peak of \$43/lb in 1978. In 1979, the price began a rapid decline. The price

as of January 1981 was $25/lb. It appears that due to the excessive delays that have taken place in reactor construction schedules, there will be an oversupply capability for at least several years. In addition, the outlook for further future growth of nuclear power has diminished and the estimated future uranium demand will be reduced accordingly, as compared with the outlook at previous points in time.

Occurrence of Uranium

5. In the United States, the most common uranium minerals are uraninite (uranium oxide) and coffinite (uranium silicate) (Reference 1).[1] These minerals were deposited through the circulation of uranium-bearing ground waters in permeable sandstone beds in which organic material or other reducing agents were present, resulting in the precipitation of the uranium over an extended period of time, thus producing ore deposits. The uranium in the ground water is believed to have been derived from the weathering of overlying volcanics containing minute amounts of the element. Most of the uranium deposits discovered so far in the United States are in sandstones.

6. The known U.S. reserves of uranium are in deposits ranging from a few hundred tons of ore to several millions of tons, mostly in the West. About 90% of the reserves are in some 200 deposits which range in size from

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1 References are listed at the end of this affidavit.

500,000 tons of ore to 5 million tons or more (Reference 3). Uranium ore is milled to produce an ore concentrate. The uranium content of ore concentrate is normally expressed in terms of its equivalent U_3O_8 content. Natural uranium is usually purchased by utility companies in the form of ore concentrate, or sometimes in the form of uranium hexafluoride (UF_6), a more refined product.

Uranium Resources

7. The average abundance of uranium in the earth's crust is estimated at 1.7 to 4 grams/metric ton (Reference 2). On this basis, the U.S. portion of the earth's crust is estimated to contain 2.6 trillion tons of U_3O_8 (Reference 2). However, we can consider only those deposits of uranium which have a sufficient combination of concentration and accessibility to permit economic recovery. Such deposits are referred to as "resources." The United States Department of Energy ("DOE") prepares and publishes estimates of uranium resources annually.

8. Estimates of uranium resources are generally structured into two major categories: (1) reserves, and (2) potential resources. Reserve estimates are based on a relatively large number of measurements and therefore are reasonably accurate. Potential resources, on the other hand, are based on less complete and in some cases, very incomplete data, and therefore are less certain. Reserves for individual

deposits are calculated from measurements and interpretation of drill-hole logs made available to DOE by uranium companies. Using established engineering, geologic and economic techniques, DOE makes estimates of the amount of uranium that can be produced from a deposit at various levels of forward cost.

9. Potential resources are uranium deposits which have not yet been sufficiently delineated to qualify as reserves. The potential resources are subdivided into three classes: probable, possible, and speculative; listed in the order of decreasing reliability. "Probable" potential resources are those believed to exist as extensions to known deposits or to occur in new deposits in areas known to be mineralized. "Possible" potential resources are those believed to exist in formations which have been productive elsewhere under similar geologic conditions. "Speculative" potential resources are the least reliable class and are allocated to areas that have been identified as having some geologic features believed favorable for uranium deposition but which in the past have not been productive. By their nature, the estimates of potential resources are less certain than those of reserves. However, DOE tends to be conservative in its resource estimates, so use of their data is reasonable.

10. Since the amount of uranium that is available depends on its recovery cost, DOE reports source data in several "forward cost" categories. The forward cost concept takes into account the factors which will affect the cost of mining each individual deposit and permits estimates to be made

of the quantity of reserves and potential resources that will be minable at various cost levels. Forward cost does not represent a projected price. It includes capital and operating costs yet to be incurred. It excludes past expenditures and taxes and return on investment.

11. Table 1[2] provides data on the uranium reserves and resources estimated by DOE as of January 1, 1981. The reserve and resource estimates for the higher forward cost categories, particularly above $50/lb, are conservatively low because the industry has only recently begun looking for higher cost deposits and most of the quantities now estimated in these higher cost categories have been found incidental to looking for lower cost material. In addition to the amounts shown in Table 1, sufficient data exist to indicate that at least 5 million tons of U_3O_8 are available from shale deposits at under $100/lb forward cost (Reference 5). It is doubtful that we will ever need to use such low grade material, but it is there if needed and effectively puts a ceiling on projections of uranium prices.

Uranium Exploration

12. Ore bodies containing large amounts of uranium can occur in physically small dimensions, be discontinuous from other bodies, and hence, can be difficult to find. An ore body

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2 Tables and figures are supplied at the end of this Affidavit.

containing a lifetime supply of uranium for a reactor could occur under a land area covering a few hundred acres. Such discrete deposits are not uncommon.

13. Uranium sometimes occurs along with other primary minerals with the other minerals governing the rate at which the uranium in such deposits is available for recovery. Examples are uranium by-product from gold production in South Africa and uranium by-product from phosphate mining in the U.S., mainly Florida.

14. Almost all of the uranium resources found so far in the U.S. are in sandstone deposits. Elsewhere in the world, large deposits exist in other geologic settings, such as quartz pebble conglomerates in Canada and South Africa and the metamorphosed sediments in Australia.

15. In 1980, additions to reserves in the up to \$100/lb forward cost category amounted to 104,000 tons U_3O_8 (Table 2). Reserves removed from this cost category due principally to the effect of cost inflation, amounted to 167,000 tons U_3O_8. Therefore, the net reduction to the \$100/lb reserve category was 63,000 tons U_3O_8. Production was 25,000 tons.

16. Drilling for uranium in 1980 was down from the four prior years, presumably due to a softer market. In 1980, drilling was 23.2 million feet. Table 3 gives drilling data for 1971-80.

17. Figure 1 gives a picture of the extent of annual drilling for uranium since 1950.

Uranium Production and Production Capacity - Past and Current

18. Uranium ore is crushed and treated chemically at a uranium mill to yield ore concentrate (generally referred to as U_3O_8 or yellowcake). Annual concentrate production capacity is determined by the availability of ore from the mines and by mill capacity. As uranium requirements increase new mines are opened. This may take several years depending on the size of the mine and other factors. Underground mines require the sinking of several large shafts. Open pit mines require the stripping of relatively large amounts of overburden. The industry attempts not to over-build production capacity and therefore monitors projected uranium requirements carefully. In spite of this, current production capability substantially exceeds current demand.

19. The instantaneous production capacity of conventional uranium mills as of January 1, 1980 was about 49,000 tons ore/day. For an ore grade of 0.11% and including non-conventional production, the January 1, 1980 production capability was about 21,000 tons U_3O_8/year. Actual production in 1979 was 18,730 tons U_3O_8 (Reference 3) and in 1980 was 21,850 tons. Table 4 lists U.S. uranium production capacity as of 1/1/80. Concentrate production in the U.S. annually since 1956 is shown in Figure 2.

Effect of Enriching Operations on Natural Uranium Demand

20. U-235 is the only naturally occurring fissile

isotope. Uranium, as mined from the earth's crust, normally contains 0.711% U-235, the balance being almost all U-238. This mixture of U-235 and U-238, in the above proportions, is referred to as natural uranium. Light water reactors such as in the Susquehanna units utilize slightly enriched uranium as the fuel. That is, uranium in which the U-235 concentration is higher than normally occurs in nature.

21. Natural uranium can be enriched in its U-235 concentration in isotope separation plants. Currently, the U.S. Government owns and operates several plants where enriching of uranium is done for both domestic and foreign customers, at prices established by the government. The government is expanding the capacity of these plants, which incidentally were originally built for national defense purposes, and is also planning to build new plants.

22. The need for the U-235 isotope in the reactor fuel (typically, the uranium is enriched to 2.5 to 3% in its U-235 content), together with the way the enriching plant is operated, determines the requirement for natural uranium. The enriching plant can be operated to strip varying amounts of the U-235 isotope from the uranium being fed to the plant. Thus, the plant can "work hard" and remove a large portion of the U-235 from the natural uranium feed, or it can be operated to remove only a small portion. The measurement unit of the enriching work done is called a separative work unit (a SWU).

23. The enriching plant can be considered to operate with (1) a feed stream of natural uranium, (2) a product stream

of enriched uranium, and (3), a depleted uranium tailings stream containing the unrecovered U-235 (the U-235 concentration in this stream is referred to as the "tails assay"). There is a trade-off between the amount of separative work and the amount of natural uranium needed to produce a given quantity of enriched uranium. More SWU's and less natural uranium can do the job, or alternatively, fewer SWU's and more natural uranium. Of course, the more SWU's expended, the lower the resulting tails assay (i.e., more recovery of the U-235 in the feed).

24. Data on specific quantitative relationships between SWU's, feed, and tails assay are given below. These are set forth parametrically for various discrete tails assay values.

To Produce 1 Kg U at 3% U-235

Tails Assay	Separative Work	Natural Uranium Feed
%U-235	Kg SW	Kg Nat. U
0.1	6.0	4.7
0.2	4.3	5.5
0.3	3.4	6.6
0.4	2.8	8.4
0.5	2.4	11.8

25. Thus, it can be seen that considerable changes in the relative amounts of natural uranium feed and separative

work can be effected to compensate for shortages or surpluses in either of them. Depending on the cost of each of these components, there is a unique tails assay value that results in minimum product cost. We call that value the "optimum tails assay." Currently, and in the foreseeable future, the optimum tails assay is expected to fall in the range of 0.20 to 0.30%. The higher the natural uranium price, the lower the optimum tails assay. The standard tails assay used by DOE for enriching transactions is 0.2%, although DOE offers a selection to the user in the range of 0.16 to 0.30%. A tails assay of 0.2% is used herein for calculations of natural uranium demand.

Demand For Uranium

26. There are two important non-reactor type uncertainties affecting the amount of natural uranium needed for a given reactor. These are (1) the enriching plant tails assay discussed above, and (2) whether or not recycle of recovered fuel is allowed. Reprocessing of spent fuel, followed by recycle of the recovered uranium and plutonium, serves to reduce the natural uranium demand of a reactor by about one-third.

PP&L Reactors

27. Each of the Susquehanna reactors, over a 30-year life, and assuming a lifetime average capacity factor of 70%, an enriching tails assay of 0.2% and disposal of spent fuel

(rather than recycle), will have a need for about 6100 tons of U_3O_8 to provide the enriched uranium needed. This equates to 5.8 tons of U_3O_8/MW (electric).

Domestic Reactors

28. Currently, there are about 161,000 MW (electric) ("MWe") of uranium fueled steam electric plants (comprising 165 units) in operation, being built or committed for construction in the U.S., some of which will not enter service until the 1990's and some of which may yet be cancelled or further delayed.

29. The status of domestic reactor projects as of the end of 1980 is summarized as follows:

Nuclear Power Plants; Operating, Under Construction and Planned

Status	Number Of Units (No.)	(Cum.)	Gigawatts (No.)	(Cum.)
In Commercial Operation	67	67	51.4	51.4
Under Construction (including plants awaiting operating license)	77	144	85.1	136.5
Have C.P. but Const. not started	8	152	8.4	144.9
CP Application Pending	11	163	13.5	158.4
Indefinite Schedule	2	165	2.2	160.7

30. Using the Susquehanna reactor parameters, the lifetime requirement of 161,000 MWe (30 year, 70% capacity factor, enriching tails assay = 0.2%) is about 935,000 tons U_3O_8 for a non-recycle mode of operation. About 175,000 tons of this requirement has already been delivered to U.S. utility companies and another 192,000 tons is under contract to be delivered, leaving 568,000 tons yet to be placed under contract and 760,000 to be delivered (Ref. 3). Thus, the outstanding needs of all domestic reactors currently in operation, under construction and on order can be met from current uranium reserves, which are 787,000 tons at $50/lb or less. See Table 1.

31. The future growth rate of uranium fueled steam electric plants is uncertain and this of course creates major uncertainties in natural uranium demand and the planning of production capacity expansion programs. During the past two years, a number of previous nuclear plant orders have been cancelled and no new orders have been placed.

32. Based on current perceptions, it appears reasonable for planning purposes to assume the growth of nuclear fueled steam electric plants will lie within the range of 150 to 200 GWe (1 GWe = 1000 MWe) of operable plant capacity by year 2000. For perspective, plants currently operable, under construction or planned amount to 161 GWe. Figure 3 shows the nuclear power growth projections used herein for purposes of developing an estimate of a credible range in

natural uranium demand over the lifetime of the Susquehanna reactors. The "high case" closely follows current announced completion dates for reactors not yet operable, plus some new reactors not presently planned coming into service in the latter 1990's. The "low case" characterizes a condition of substantial additional plant slippages and terminations, with no new plants beyond those already planned. As of 2013 (when the operating licenses of the Susquehanna units will expire), the projected low case nuclear capacity is 150 GWe and the high case is 330 GWe. The most likely growth scenario lies between the high and the low cases.

Industry Uranium Demand

33. As used in this affidavit, "demand" refers to delivery of U_3O_8 to a converter, in order to subsequently deliver UF_6 to the enriching plants on schedules consistent with the stated power growth curve. The relationships between demand and required domestic production are discussed later.

34. Tables 5 and 6 provide detailed data on annual uranium demand for the assumed growth rates. The amount of uranium needed for initial cores, which is proportional to growth rate is shown; and the amount for reloads, which is proportional to total installed power and capacity factor is also given. Fuel performance of all the reactors is assumed to be the same as the Susquehanna Units and plant capacity factor is assumed to average 70% over the life of the reactors. The

enriching plant tails assay is assumed to be 0.2% throughout the period.

35. For the period 1980 to 2000, the average annual rate of increase in uranium demand for the high case is 5.4% and for the low case is 3.6%. These are rather modest production expansion rates and can easily be achieved by the industry, which is capable of expanding production at considerably higher rates.

36. Figure 4 provides a visual comparison of the cumulative uranium demand over time and the current estimates of domestic uranium reserves and resources and provides a rather vivid picture of the adequacy of the resource base. As shown by the figure, the domestic resource base is considerably larger than the cumulative uranium demand through the period covered. The demand curve in Figure 4 is the demand through the stated point in time. The high demand case shows a cumulative demand through 2013 (when the operating licenses of the Susquehanna units will expire) of 1,280,000 tons of U_3O_8, which (taking into account that 175,000 tons have already been delivered) is only slightly larger than current proven domestic reserves, and well below the estimates of potential uranium resources. For the low demand case, the cumulative demand is 802,000 tons, minus 175,000 already delivered--well within current domestic reserves. For a most likely intermediate case, the cumulative demand would also lie well within current proven domestic reserves.

37. Another way to look at the supply-demand situation is to compare the lifetime requirement of a given amount of nuclear power capacity with the resource base. Using this approach, together with a reactor lifetime uranium requirement as listed above for the Susquehanna Units (5.8 tons/MWe), gives a lifetime requirement for the high case year 2000 capacity (200 GWe) of 1,160,000 tons U_3O_8 and 870,000 tons for the low case (150 GWe). These amounts are also only a small fraction of the domestic resource base. Also, for this lifetime demand comparison, it should be noted that of the total requirements of the above reactors, approximately 175,000 tons of U_3O_8 has already been delivered.

38. Thus, it appears there is no reason for concern about the adequacy of domestic natural uranium for the projected U.S. nuclear power capacity. It appears likely there will also be substantial quantities of uranium potentially available from other countries for import into the U.S., which further assures a plentiful supply.

39. If it ever appeared that there is a serious concern about the continued adequacy of uranium to sustain the existing and planned nuclear power plants for their normal lifetimes, a self-regulating corrective action would take place; namely, new reactors would no longer be planned and those in the planning stage would be terminated. This natural feedback mechanism assures that the total nuclear power capacity constructed will not outstrip the available uranium supply.

Supply of Uranium From Non - U.S. Sources

40. Foreign resources are usually categorized as "reasonably assured" and "estimated additional." For the most part these are equivalent to the DOE definitions of "reserves" and "probable" resources respectively. Estimates of resources in non-communist countries are given in Tables 7 and 8.

41. These resources are more than sufficient to meet the projected cumulative foreign demand through year 2000 even without plutonium recycle. Because much of the world has not yet been adequately explored for uranium, it is reasonable to expect the foreign reserve picture to improve dramatically as exploration proceeds. Resources do not seem to be a limiting factor to nuclear power expansion over the expected lifetime of the Susquehanna units.

42. Because the U.S. resources of uranium appear to be adequate to meet domestic demand, there is no need for the U.S. to become dependent on the supply of foreign uranium. Whether the U.S. will in fact rely on importing a portion of its uranium requirements will probably depend largely on whether or not it is economically advantageous to do so. However, until 1984, there are limitations imposed by the U.S. government on the amount of foreign origin natural uranium that may be used as feed for the production of enriched uranium for domestic use. The permissible amounts are: 40% in 1981, 60% in 1982, 80% in 1983 and 100% in 1984 and after.

Current Uranium Supply Status of PP&L

43. As of the end of 1980, PP&L nad 1704 tons of U_3O_8 (or equivalent) either in process or in inventory as follows:

Status	Tons U_3O_8
At Conversion Facility	382
At DOE Enriching Facility	801
At Fuel Fabrication Facility	607
TOTAL	1790

In addition, as of the end of 1980, the following amounts of U_3O_8 are under contract to be delivered to PP&L:

Supplier	Tons U_3O_8
General Atomic Company	1266
United Nuclear Company	150
Mobil Oil Company	1380
TOTAL	2796

44. These 4586 tons of uranium, either on hand or under contract, should be adequate to supply the initial core and 9 reloads for Susquehanna Unit 1 and the initial core and 8 reloads for Unit 2. Therefore, PP&L has in hand or under contract sufficient uranium to satisfy the needs of the Susquehanna units through about 1993. PP&L also has additional uranium under contract, but its delivery is not firm. If this

additional uranium were delivered, it would extend coverage of the needs of the Susquehanna units through about 1996-1997. Given the estimates of the availability of uranium in the future, it is expected that PP&L will have no difficulty obtaining contracts for the supply of the additional uranium needed in the 1990's and later.

Uranium Prices - Historic Trends

45. Production of uranium in substantial quantities began in the later 1940's. The Atomic Energy Commission purchased large quantities from U.S. producers during the period 1948 to 1971. In the late 1960's, the private uranium market began to evolve.

46. Figure 5 is a plot of uranium price from 1948 to 1980. In order to provide perspective regarding the trends in real price, these price data have been converted to constant January 1981 dollars. The procedure used is to multiply the old price by the ratio of the Producer Price Index for Industrial Commodities at the desired current date (January 1981 is used) to its value at the old point in time. This removes the effect of inflation on the price, in that the resulting price is in real dollars relative to the price of all industrial commodities.

47. On a constant January 1981 dollar basis, the price peaked at \$42.50/lb U_3O_8 in 1953, then gradually declined to about \$14/lb in the early 1970's. In the early 1970's the

price continued declining and the market was depressed. However, in 1973, the OPEC oil price increases and the change by AEC from requirements to fixed commitment enriching contracts apparently were major contributors to causing uranium buyers to attempt to line up their supply well into the future and this flurry of market activity caused a very substantial upward movement in the price of uranium, increasing from about $15/lb in 1973 to $63/lb in 1976. Since then, the real price has declined at a very substantial rate. As of January 1981, the market price was about $25/lb U_3O_8.

48. In Figure 5, data published by the DOE were used as the basis for the prices paid by AEC over the period 1948 to 1971, and the "Exchange Value"[3] published by NUEXCO was used to characterize the market price for industry purchases over the period 1968 to 1981. In both of these sets of data, the adjustment by the Industrial Commodity price ratio was made to the reported data, in order to place it in constant dollars.

49. Figure 6 is a plot of the uranium market price since 1971. The lower curve, labeled "Then-Current Dollars" is the price reported by NUEXCO as the exchange value as of the end of the month, and gives a reasonable representation of the market price in then-current dollars. The upper curve, labeled "Constant January 1981 Dollars" is the adjusted price, which

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3 Exchange Value is NUEXCO's judgment of the price at which transactions for significant quantities of natural uranium concentrates could be concluded.

has removed from it the effect of the inflation that has been occurring so as to provide better perspective in real price trends.

50. As can be seen from Figure 6, the decrease in price began in 1976, when the then-current price began to increase less rapidly than the rate of inflation. Since then, the rate of decrease steadily accelerated and the market price as of early 1981 was $25/lb.

Future Market Price

51. The possible behavior of the future uranium market was investigated using the EUREKA[4] uranium market model. Many computer runs were made so as to try to reasonably bracket the range in uncertainty in some of the more important input variables such as:

- the uranium demand trajectory.
- short term mine and mill expansion plans.
- the ultimate amount of uranium resources.
- the extent to which uranium is imported.

52. Some of these input variables are difficult to project and are themselves affected by the future market. Therefore, it is not possible for anyone to make an exact

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4 The EUREKA uranium market model is an elaborate computer program simulation of the uranium supply industry, created by Pickard, Lowe & Garrick and Colorado Nuclear Corporation. A brief description of the model is contained in Appendix A.

projection of the market. The results obtained for individual cases are best used in evaluating possible price trends and the likely effects of various potential actions by buyers and sellers on the market. The price trend shown in Figure 7 reflects a judgment of the composite results of the cases considered, and represents my projection of the trend in uranium prices in the future.

53. The projected uranium prices given herein are in \$/lb U_3O_8, in January 1981 dollars. The price given for year N represents the estimated price for long term supply contracts entered into in year N, with the deliveries being made at that price during the period N + 2 to N + 10 years. As shown in Figure 7, I project the following prices: \$35/lb in 1985, \$39/lb in 1990, \$55/lb in 1995 and \$65/lb in 2000, and continuing to rise at a gradual rate of about \$1.5/lb per year after 2000, for an estimated price of about \$85/lb in 2013.

Effect of Uranium Demand on Price

54. Figure 8 shows the uranium prices projected by EUREKA for high and low demand cases and for a mid-case, which is the average of the high and low cases. The high and low cases used for these projections are very similar to those detailed in Tables 5 and 6.

55. The price trajectory of the three cases is about the same, although the lower the demand, the larger the oscillations about the mean of the trajectory. This general

lack of sensitivity to demand is attributed to the fact that the demand is relatively low, even in the "high" case, and these demand levels can easily be met by the industry. The demand estimated for the high case is 1,260,000 tons U_3O_8 over the period 1980-2013; the Susquehanna Units comprising about 1% of the total.

Effect of Short Term Mine and Mill Expansion Plans

56. Producers can defer uranium production expansion programs when there is a surplus of production capacity and depressed prices. This can cause a later deficiency in production capability and can therefore affect the future price.

57. In our analysis of the market, if the market price is below the price needed for a given facility being constructed or being expanded to be profitable, the completion of such additional production capacity is assumed to be deferred. Similarly, production from existing facilities is curtailed if the market price is not sufficient to permit continued operation at a profit.

58. Thus, if there were a severe curtailment of production expansion programs in the future, the short-term price might become higher, which in turn would cause an increase in production capacity and result in lower prices in the longer term.

Effect of Ultimate Resource Base

59. While domestic uranium resources appear large relative to demand, the EUREKA program was used to ascertain if there is any likely sensitivity between the calculated price and the assumed ultimate resource level. The reference assumption is that the total domestic resources of uranium are 4.3 million tons. Alternate cases were considered where the ultimate resource level was set at 3 and 2 million tons.

60. With the EUREKA program, when the availability of sufficient resources limits the development of new reserves and production, the model predicts a steeply rising non-reversing price trend. For the cases described herein, (and indeed for any cases which can be reasonably anticipated during the lifetime of the Susquehanna units) this condition was not encountered and there was little effect of the varying assumptions on the calculated prices.

61. However, for the lower resource base cases, the model predicts increased import levels, which are discussed below.

Import of Uranium

62. In the mid and long term, it is assumed that there are no governmental limitations on the amount of uranium that can be imported. The EUREKA model is basically a domestic market model and the affect of imports is studied by the use of

the "trigger price" concept. The trigger price is the price at which uranium for import is assumed to be readily available (with some limitations on the rate of growth). Thus, if EUREKA calculates a market price that exceeds the specified trigger price, a portion of the forward demand will be absorbed by imports.

63. The extent to which uranium will be imported depends on the supply/demand balance in the foreign sector and on the price that foreign producers put on the material. It appears there will be an excess of foreign production capacity and much of the production will be at costs lower than U.S. production. This will encourage foreign producers to decrease prices to the degree necessary to enable them to achieve sales targets in the U.S. This may well act as a restraining force on the extent to which new higher-cost domestic production capacity is brought into service.

64. Imports could comprise a substantial portion of domestic uranium demand in the long term. Utility policies which place a preference on ordering from domestic suppliers, and which assign specific cost or intangible adjustments to assurance of supply considerations in evaluating foreign versus domestic suppliers may be needed in order to prevent a serious loss by the domestic producers of a large share of the expanding domestic market. If such policies were implemented, they would place a limit on uranium imports. Nevertheless, the anticipated excess of foreign uranium production capacity will

help to assure the continued availability of uranium in the U.S. at reasonable prices.

John M. Vallance

DISTRICT OF COLUMBIA) SS

Sworn to and subscribed before me
this 28th day of July , 1981.

Notary Public - Maureene A. Quick

My Commission expires: April 30, 1986

References

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(5) DOE, Results of Low-Grade Uranium Studies, F.E. McGinley, Oct 1979

(6) DOE Press Release 81-79, dated May 13, 1981

(7) DOE, An Assessment Report on Uranium in the United States of America, GJO-111(80), dated October, 1980

(8) DOE Press Release 81-48, dated March 30, 1981

(9) DOE Press Release 81-90, dated June 4, 1981

Table 1

U.S. Uranium Resources as of January 1, 1981*

Forward Cost Category, $/lb	Estimated Recoverable Ore, 10^3 tons U_3O_8					
	Reserves**	Potential				Total
		Probable	Possible	Speculative	Total	
Up to 30	470	885	346	311	1542	2012
Up to 50	787	1426	641	482	2549	3336
Up to 100	1034	2080	1005	696	3781	4815

* The reserves are as of January 1, 1981. The potential resources are as of October 1, 1980.

** In addition to these quantities, it is estimated that 140,000 tons U_3O_8 can be produced through year 2010 as a by-product of phosphate and copper production.

Source: References 6 & 7.

Table 2

Changes in Uranium Ore Reserves

During 1980

	$30	$50	$100
1/1/80 Reserve	645,000	936,000	1,122,000
New Properties	1,000	13,000	20,000
Reevaluation - Additions	21,000	48,000	84,000
Reevaluation - Subtractions	(175,000)	(186,000)	(167,000)
Depletion - Production	(22,000)	(24,000)	(25,000)
1/1/81 Reserve	470,000	787,000	1,034,000

Source: Reference 6.

Table 3

HISTORICAL DRILLING DATA

Year	Number of Holes	Average Depth (Feet)	Total Footage (Millions)
1971	38,900	400	15.5
1972	36,600	420	15.4
1973	34,300	480	16.4
1974	39,700	550	22.0
1975	55,900	460	25.5
1976	67,600	510	34.2
1977	106,000	430	45.6
1978	104,400	450	47.0
1979	90,600	450	40.8
1980	58,100	465	28.2

Source: Reference 8 & 9.

Table 4

U.S. URANIUM PRODUCTION MILLS
Operating as of 1/1/80

Conventional Mills	Plant Location	Nominal Capacity (Tons Ore/Day)	Nominal Capacity (Tons U_3O_8/Year)
ANACONDA Copper Company	Grants, New Mexico	6,000	
Atlas Minerals Corporation	Moab, Utah	1,400	
Bear Creek Uranium Company	Powder River Basin, Wyoming	2,000	
Chevron Resources Company	Hobson, Texas	2,500	
Conoco-Pioneer Nuclear	Falls City, Texas	3,400	
Cotter Corporation	Canon City, Colorado	1,200	
Dawn Mining Company	Ford, Washington	450	
Exxon Minerals Company, USA	Powder River Basin, Wyoming	3,200	
Federal-American Partners	Gas Hills, Wyoming	950	
Kerr-McGee Nuclear Corporation	Grants, New Mexico	7,000	
Pathfinder Mines Corporation	Gas Hills, Wyoming	2,500	
Pathfinder Mines Corporation	Shirley Basin, Wyoming	1,800	
Petrotomics Company	Shirley Basin, Wyoming	1,500	
Rio Algom Corporation	La Sal, Utah	750	
Sohio-Reserve	Cebolleta, New Mexico	1,600	
Union Carbide Corporation	Uravan, Colorado	1,300	
Union Carbide Corporation	Natrona County, Wyoming	1,400	
United Nuclear Corporation	Church Rock, New Mexico	3,000	
United Nuclear—Homestake Partners	Grants, New Mexico	3,400	
Western Nuclear, Inc.	Jeffrey City, Wyoming	1,700	
Western Nuclear, Inc.	Wellpinit, Washington	2,000	
	Total	49,050	19,000-21,000
Solution Mining Operations	**Plant Location**		
Everest Mineral Corporation	Hobson, Texas		
IEC Corporation	Three Rivers, Texas		
Mobil Oil Corporation	Bruni, Texas		
Union Carbide Corporation	Palangana, Texas		
United States Steel Corporation	George West, Texas		
U.S. Steel-Niagara Mohawk	George West, Texas		
Uranium Resources, Inc.	Bruni, Texas		
Wyoming Mineral Corporation	Bruni, Texas		
Wyoming Mineral Corporation	Three Rivers, Texas		
Wyoming Mineral Corporation	Irigaray, Wyoming		
	Total		1,200-1,600
Phosphoric Acid Byproduct	**Plant Location**		
Freeport Uranium Recovery Corporation	Uncle Sam, Louisiana		
Gardinier, Inc.	Tampa, Florida		
Uranium Recovery Corporation	Mulberry, Florida		
Wyoming Mineral Corporation	Pierce, Florida		
	Total		500-700
Heap Leaching:			
Dumps, Tailings, or Copper Dumps	**Plant Location**		
Durita Development Corporation	Naturita, Colorado		
Solution Engineering, Inc.	Falls City, Texas		
Union Carbide Corporation	Maybell, Colorado		
Wyoming Mineral Corporation	Bingham Canyon, Utah		
	Total		100-300
	Grand Total	49,050	20,800-23,600

Source: Reference 3.

Table 5

Projected Industry Natural Uranium Demand
High Case, Using Susquehanna Reactor Characteristics

		Thousands of Tons U_3O_8			
YEAR	GW	I.C.'S	RELOADS	TOTAL	CUM TOT
1980	55.0	4.8	9.6	14.4	14.4
1981	66.0	8.4	11.5	19.9	34.3
1982	74.0	6.6	12.9	19.5	53.8
1983	88.0	4.8	15.4	20.2	74.0
1984	99.0	7.8	17.3	25.1	99.1
1985	107.0	2.4	18.7	21.1	120.2
1986	120.0	3.6	21.0	24.6	144.7
1987	124.0	4.2	21.7	25.9	170.6
1988	130.0	3.0	22.7	25.7	196.3
1989	137.0	2.4	23.9	26.3	222.7
1990	142.0	2.4	24.8	27.2	249.9
1991	146.0	3.0	25.5	28.5	278.4
1992	150.0	3.0	26.2	29.2	307.6
1993	155.0	3.0	27.1	30.1	337.7
1994	160.0	3.6	28.0	31.6	369.3
1995	165.0	3.6	28.8	32.4	401.7
1996	171.0	3.6	29.9	33.5	435.2
1997	177.0	4.8	30.9	35.7	470.9
1998	183.0	5.4	32.0	37.4	508.3
1999	191.0	6.0	33.4	39.4	547.7
2000	200.0	6.0	35.0	41.0	588.7
2001	210.0	6.0	36.7	42.7	631.4
2002	220.0	6.0	38.5	44.5	675.8
2003	230.0	6.0	40.2	46.2	722.1
2004	240.0	6.0	42.0	48.0	770.0
2005	250.0	6.0	43.7	49.7	819.7
2006	260.0	6.0	45.5	51.5	871.2
2007	270.0	6.0	47.2	53.2	924.4
2008	280.0	6.0	49.0	55.0	979.4
2009	290.0	6.0	50.7	56.7	1036.1
2010	300.0	6.0	52.5	58.5	1094.6
2011	310.0	6.0	54.2	60.2	1154.8
2012	320.0	6.0	56.0	62.0	1216.7
2013	330.0	6.0	57.7	63.7	1280.5
2014	340.0	6.0	59.5	65.5	1345.9
2015	350.0	6.0	61.2	67.2	1413.1

GW = gigawatts (electric) of installed nuclear capacity at year end.
I.C.'S = uranium required for initial cores.
Reloads = uranium required for periodic refuelings.

Table 6

Projected Industry Natural Uranium Demand
Low Case, Using Susquehanna Reactor Characteristics

YEAR	GW	I.C.'S	RELOADS	TOTAL	CUM TOT
		Thousands of Tons U_3O_8			
1980	54.0	3.6	9.4	13.0	13.0
1981	58.0	3.6	10.1	13.7	26.7
1982	64.0	4.2	11.2	15.4	42.1
1983	70.0	4.8	12.2	17.0	59.1
1984	77.0	4.2	13.4	17.6	76.8
1985	85.0	3.6	14.8	18.4	95.2
1986	92.0	4.2	16.1	20.3	115.5
1987	98.0	3.6	17.1	20.7	136.2
1988	[illegible]	3.6	18.3	21.9	158.1
1989	111.0	3.0	19.4	22.4	180.5
1990	117.0	3.0	20.4	23.4	203.9
1991	122.0	3.0	21.3	24.3	228.3
1992	127.0	3.0	22.2	25.2	253.4
1993	132.0	1.8	23.1	24.9	278.3
1994	137.0	1.8	23.9	25.7	304.1
1995	140.0	1.8	24.5	26.3	330.3
1996	14[illegible]	1.2	25.0	26.2	356.5
1997	146.0	.6	25.5	26.1	382.6
1998	148.0	.6	25.9	26.5	409.1
1999	149.0	.0	26.0	26.0	435.1
2000	150.0	.0	26.2	26.2	461.3
2001	150.0	.0	26.2	26.2	487.6
2002	150.0	.0	26.2	26.2	513.8
2003	150.0	.0	26.2	26.2	540.0
2004	150.0	.0	26.2	26.2	566.2
2005	150.0	.0	26.2	26.2	592.4
2006	150.0	.0	26.2	26.2	618.6
2007	150.0	.0	26.2	26.2	644.8
2008	150.0	.0	26.2	26.2	671.1
2009	150.0	.0	26.2	26.2	697.3
2010	150.0	.0	26.2	26.2	723.5
2011	150.0	.0	26.2	26.2	749.7
2012	150.0	.0	26.2	26.2	775.9
2013	150.0	.0	26.2	26.2	802.1
2014	150.0	.0	26.2	26.2	828.4
2015	150.0	.0	26.2	26.2	854.5

GW = gigawatts (electric) of installed nuclear capacity at year end.

I.C.'s = uranium required for initial cores.

Reloads = uranium required for periodic refuelings.

Table 7

REASONABLY ASSURED RESOURCES
(1,000 tonnes U)
Data available 1st January, 1979

COST RANGE	<$80/kg U RESERVES	$80-130/kg U	TOTAL AT < $130/kg U
Algeria	28	0	28
Argentina	23	5.1	28.1
Australia	290	9	299
Austria[2]	1.8	0	1.8
Bolivia	-	0	0
Botswana	0	0.4	0.4
Brazil	74.2	0	74.2
Canada[1]	215	20	235
Central African Republic	18	0	18
Chile	0	0	0
Denmark	0	27	27
Egypt	0	0	0
Finland	0	2.7	2.7
France	39.6	15.7	55.3
Gabon[2]	37	0	37
Germany, Federal Republic of	4	0.5	4.5
India	29.8	0	29.8
Italy	0	1.2	1.2
Japan	7.7	0	7.7
Korea, Republic of[4]	0	4.4	4.4
Madagascar[2]	0	0	0
Mexico[3]	6	0	6
Namibia	117	16	133
Niger[2]	160	0	160
Philippines[2]	0.3	0	0.3
Portugal	6.7	1.5	8.2
Somalia[3]	0	6.6	6.6
South Africa	247	144	391
Spain	9.8	0	9.8
Sweden[5]	0	301	301
Turkey	2.4	1.5	3.9
United Kingdom	0	0	0
United States of America	531	177	708
Yugoslavia	4.5	2	6.5
Zaïre[2]	1.8	0	1.8
Total (rounded)	1,850	740	2,590

\- Less than 100 tonnes U.

1. The material reported as reserves is mineable at prices up to $ CAN 125/kg U and other Reasonable Assured Resources are mineable at prices between $ CAN 125 and $ CAN 175/kg U.
2. Source of data: Uranium Resources, Production and Demand, Paris, 1977.
3. Data refer to resources "in-situ", rather than recoverable.
4. Reported as 13,000,000 tonnes of ore with an average grade of 0.[illegible]% U_3O_8.
5. No uranium production allowed in a deposit of 300,000 tonnes U due to a veto by the local authorities for environmental reasons.

Source: Reference 4.

Table 8

ESTIMATED ADDITIONAL RESOURCES
(1,000 tonnes U)
Data available 1st January, 1979

COST RANGE	< $80/kg U	$80-130/kg U	TOTAL AT < $130/kg U
Algeria	0	5.5	5.5
Argentina	3.8	5.3	9.1
Australia	47	6	53
Austria [2]	0	0	0
Bolivia [2]	0	0.5	0.5
Botswana	0	0	0
Brazil	90.1	0	90.1
Canada [1]	370	358	728
Central African Republic	0	0	0
Chile	5.1	0	5.1
Denmark	0	16	16
Egypt	0	5	5
Finland	0	0.5	0.5
France	26.2	20	46.2
Gabon [2]	0	0	0
Germany, Federal Republic of	7	0.5	7.5
India	0.9	22.8	23.7
Italy	0	2	2
Japan	0	0	0
Korea, Republic of	0	0	0
Madagascar [2]	0	2	2
Mexico [3]	2.4	0	2.4
Namibia	30	23	53
Niger [2]	53	0	53
Philippines [2]	0	0	0
Portugal	2.5	0	2.5
Somalia [3]	0	3.4	3.4
South Africa	54	85	139
Spain	8.5	0	8.5
Sweden	0	3	3
Turkey	0	0	0
United Kingdom	0	7.4	7.4
United States of America	773	385	1,158
Yugoslavia	5	15.5	20.5
Zaire [2]	1.7	0	1.7
Total (rounded)	1,480	970	2,450

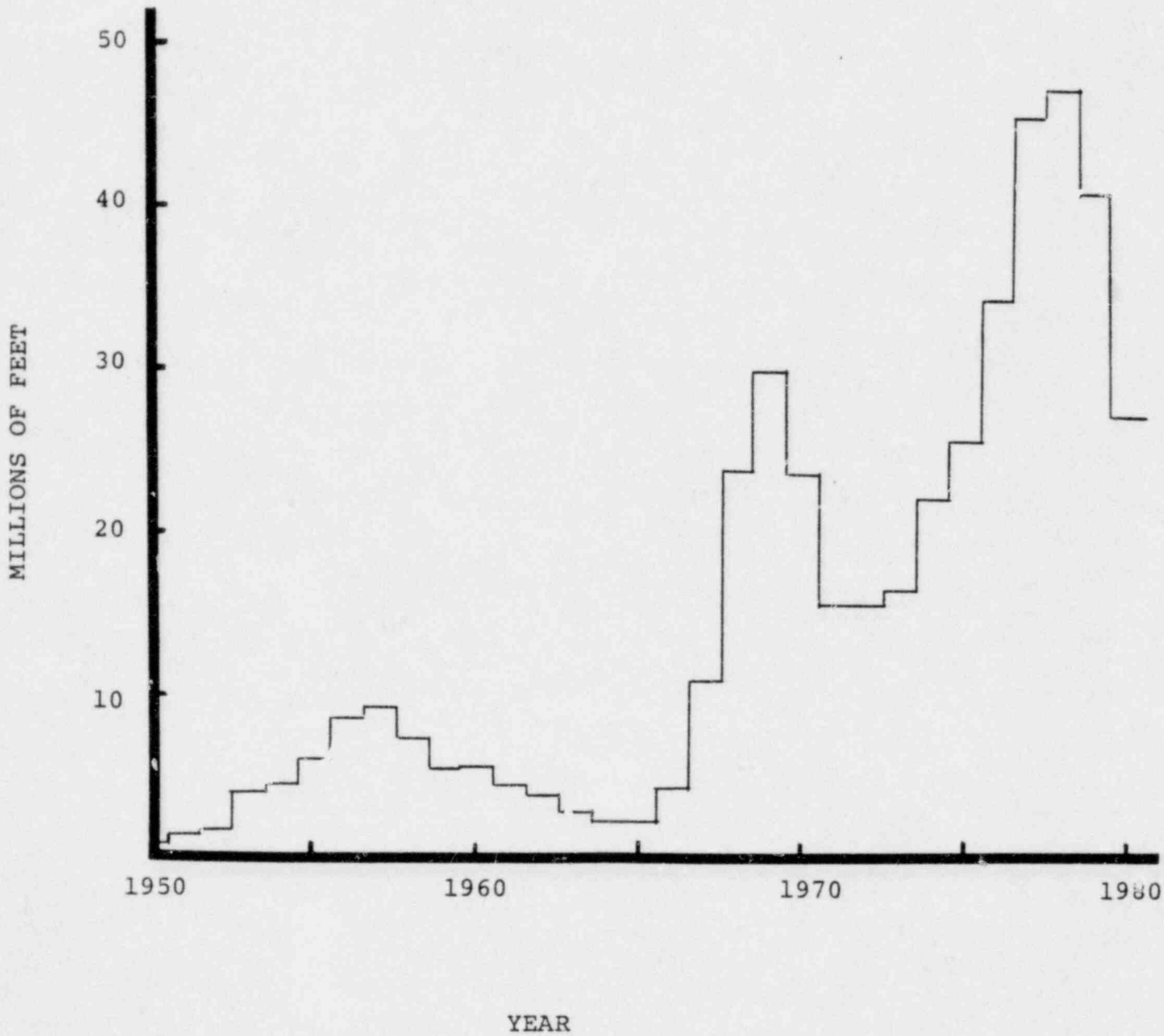
1), 2), 3) - As in footnotes to Table 1.

NB: A number of occurrences of uranium are not well enough defined to be included in Tables 1 and 2 but are described in Part III, the country reports.

Source: Reference 4.

Figure 1

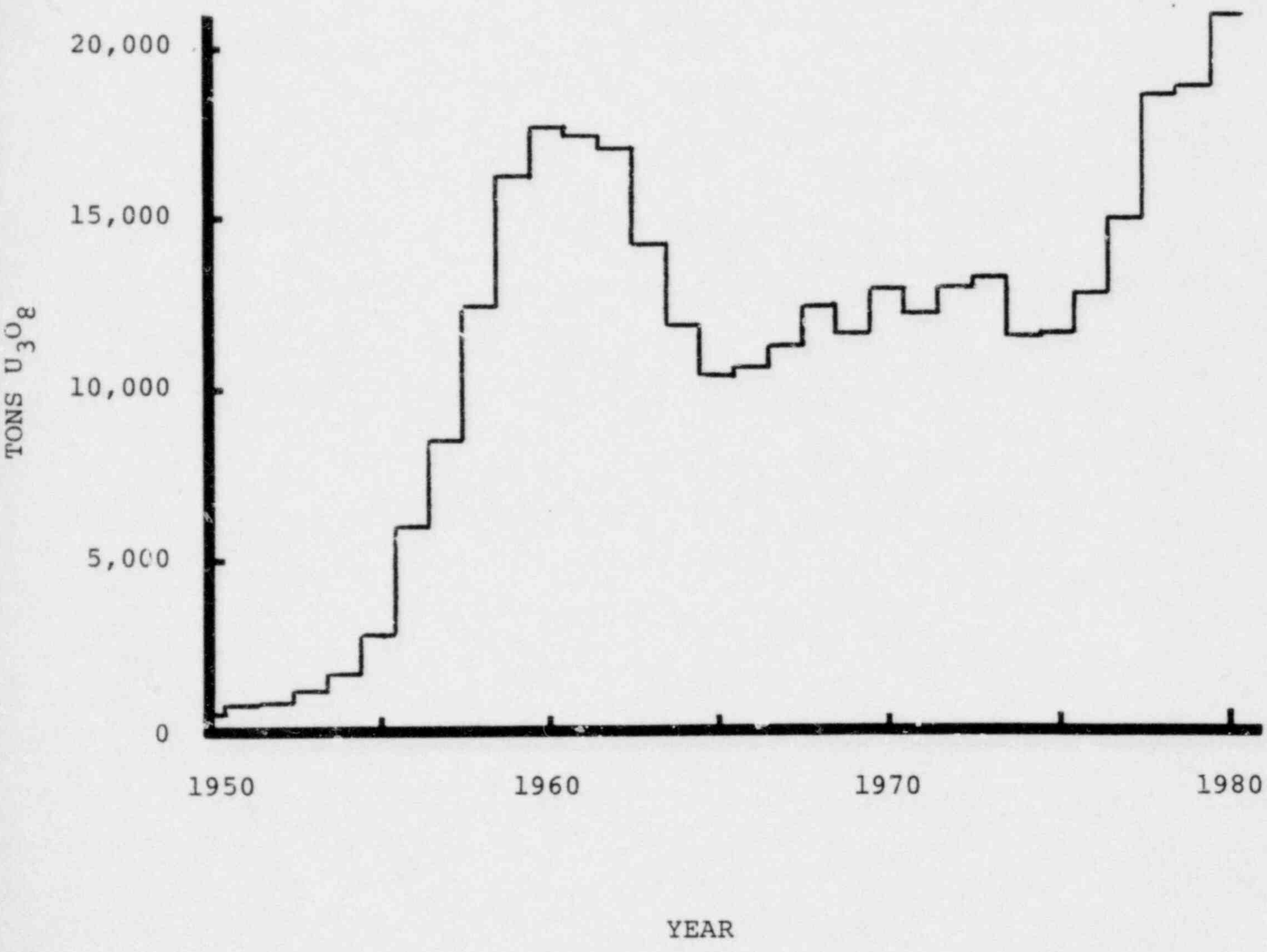
SURFACE DRILLING FOR URANIUM IN THE UNITED STATES
MILLIONS OF FEET BY YEAR



Source: Reference 3 and 8

Figure 2

U.S. CONCENTRATE PRODUCTION
IN TONS CONTAINED U_3O_8 BY YEAR



Source: Reference 3 & 8

Figure 3

Nuclear Power Capacity Projection

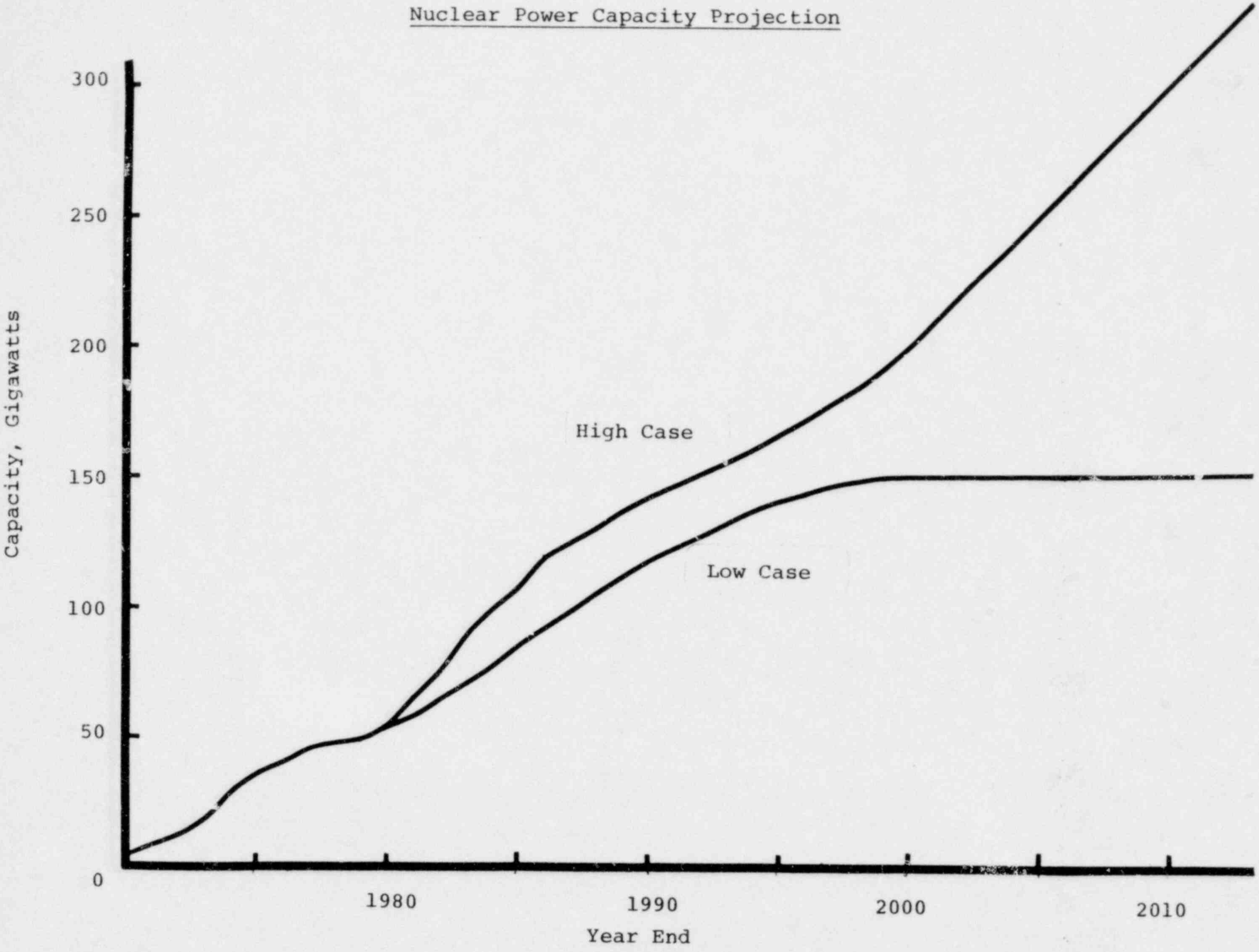


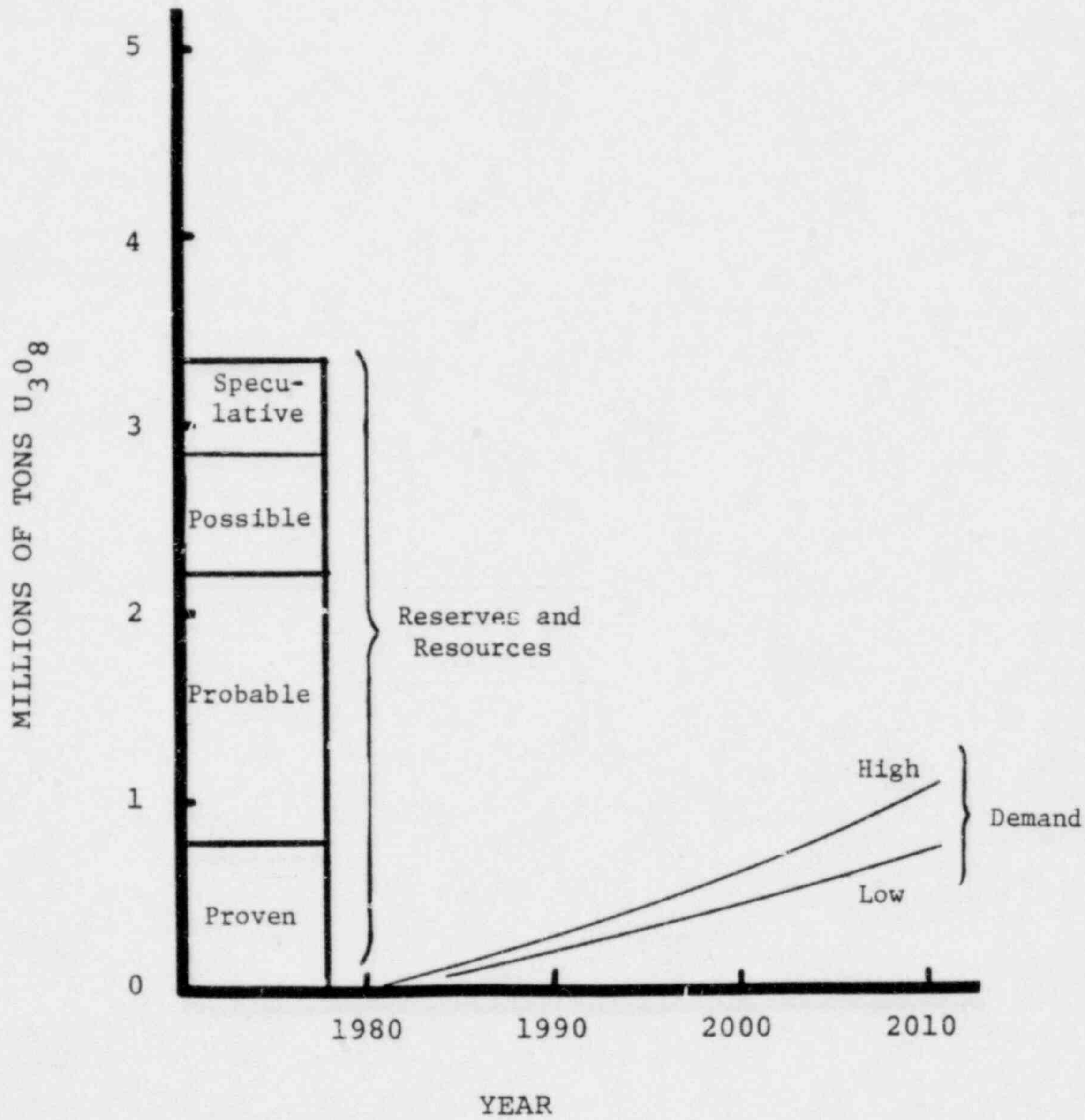
Figure 4

PROJECTED U.S. REQUIREMENT FOR NATURAL URANIUM

AND

U.S. NATURAL URANIUM RESOURCE LEVELS

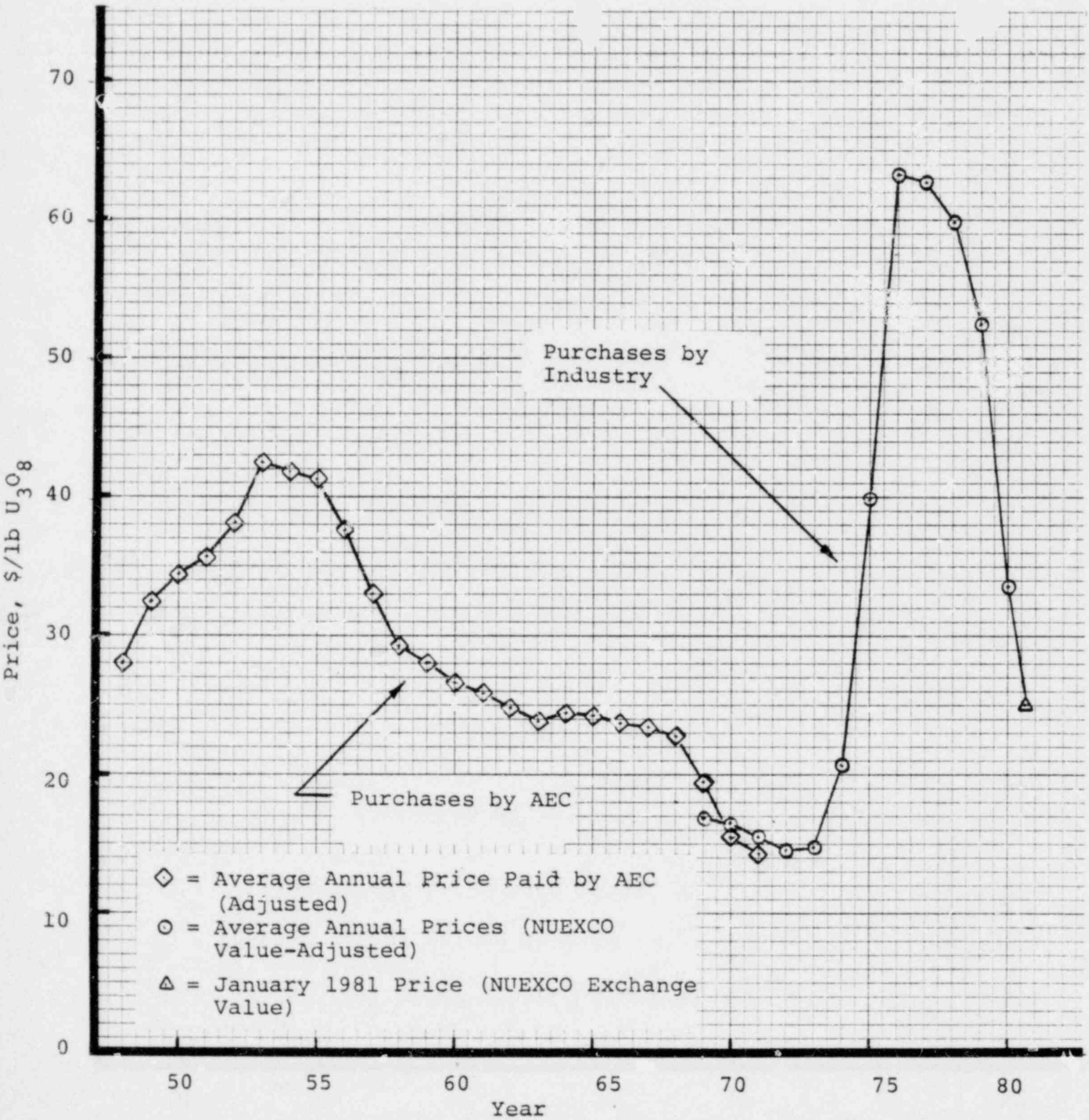
(up to $50/lb Forward Cost)



Source: Requirements - Tables 5 and 6.
Resources - Table 1.

Figure 5

Long Term Historical U_3O_8 Prices, In Constant January 1981 Dollars

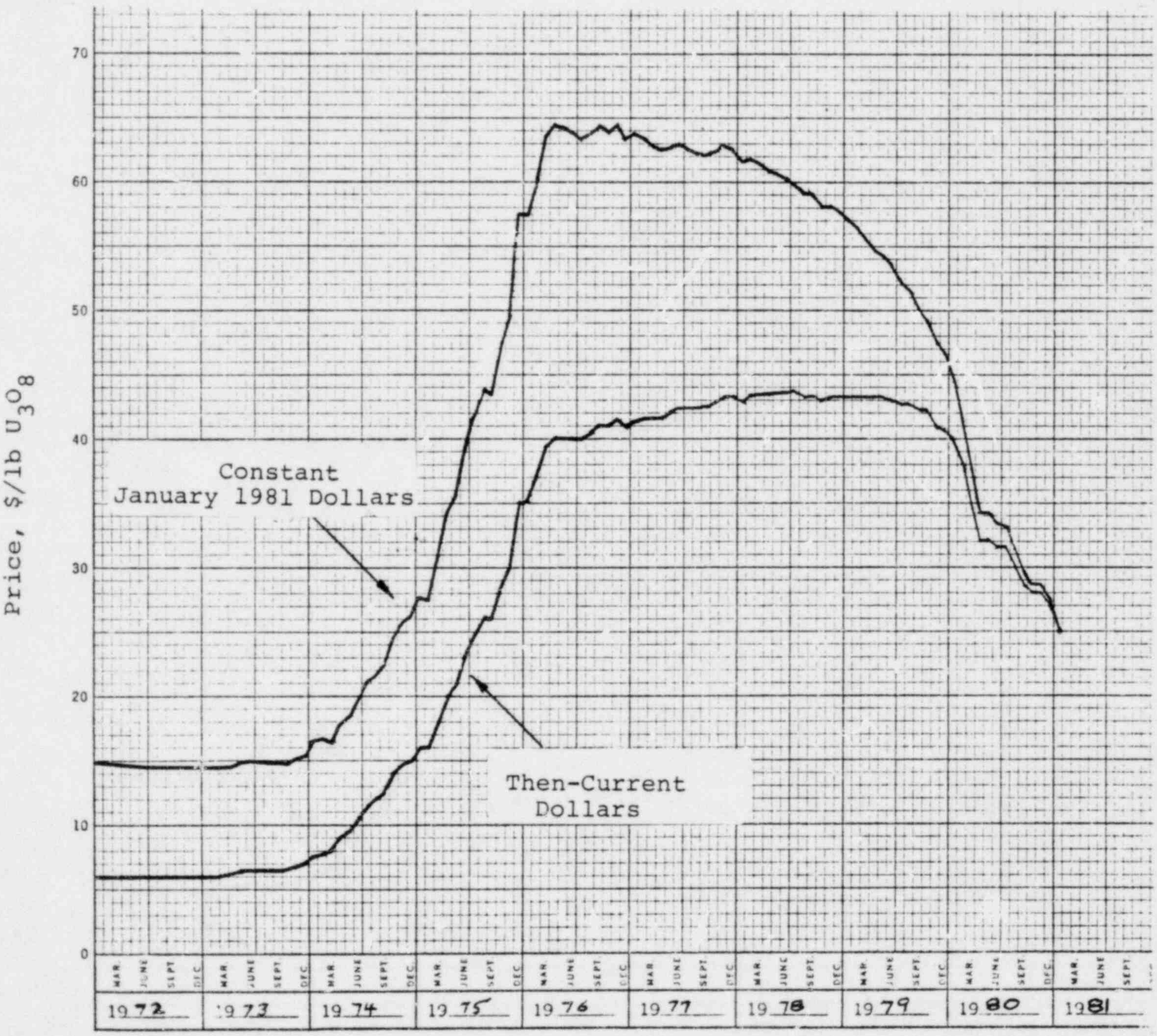


Note: Prices are adjusted to January 1981 dollars using the Producer Price Index for Industrial Commodities.

Figure 6

Historical U_3O_8 Price in Current and Constant Dollars

Monthly Prices Vs Time



(Exchange values reported by NUEXCO, and adjusted herein)

FIGURE 7

Historic and Projected U_3O_8 Price Trend

(in Constant January 1981 Dollars)

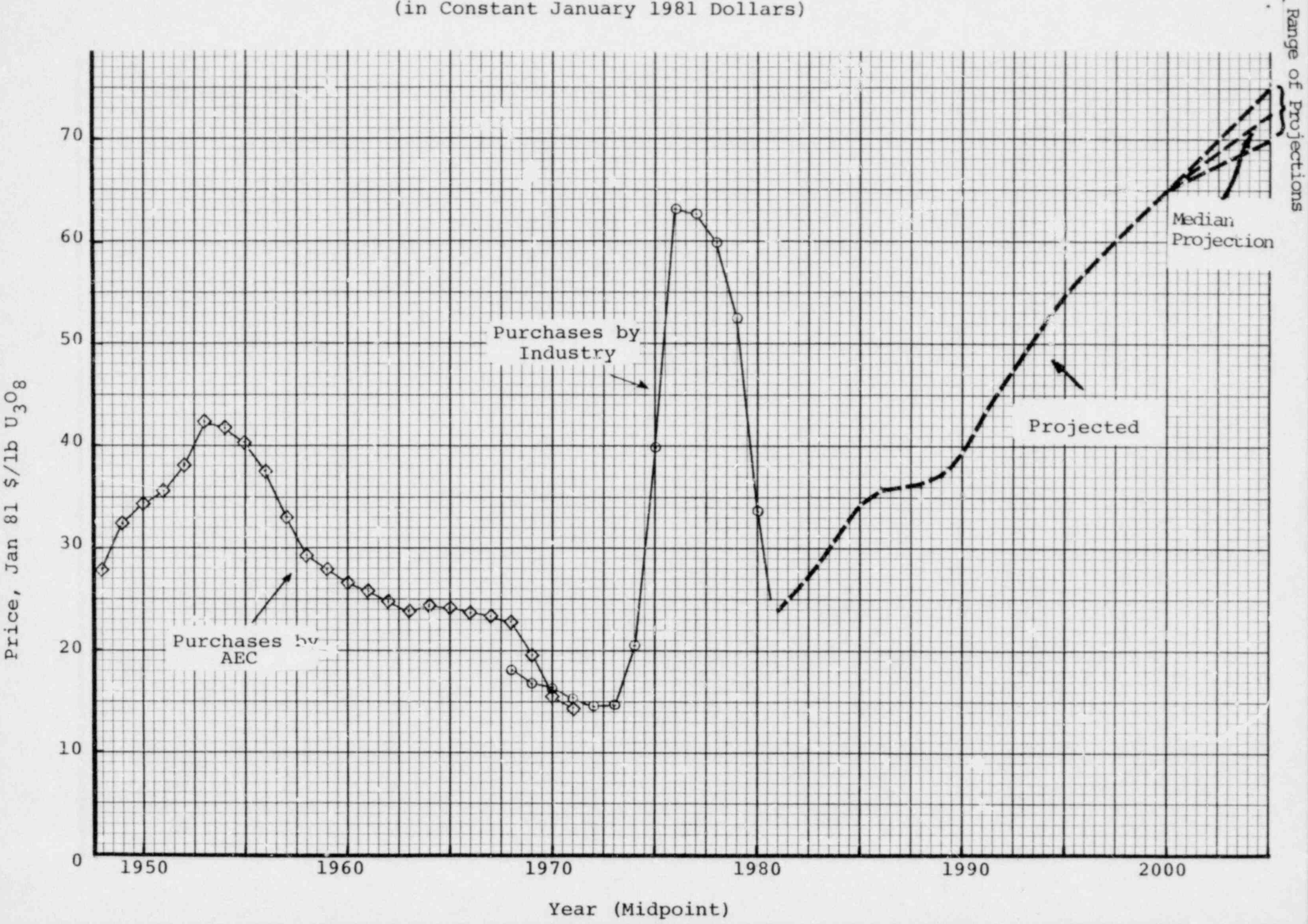
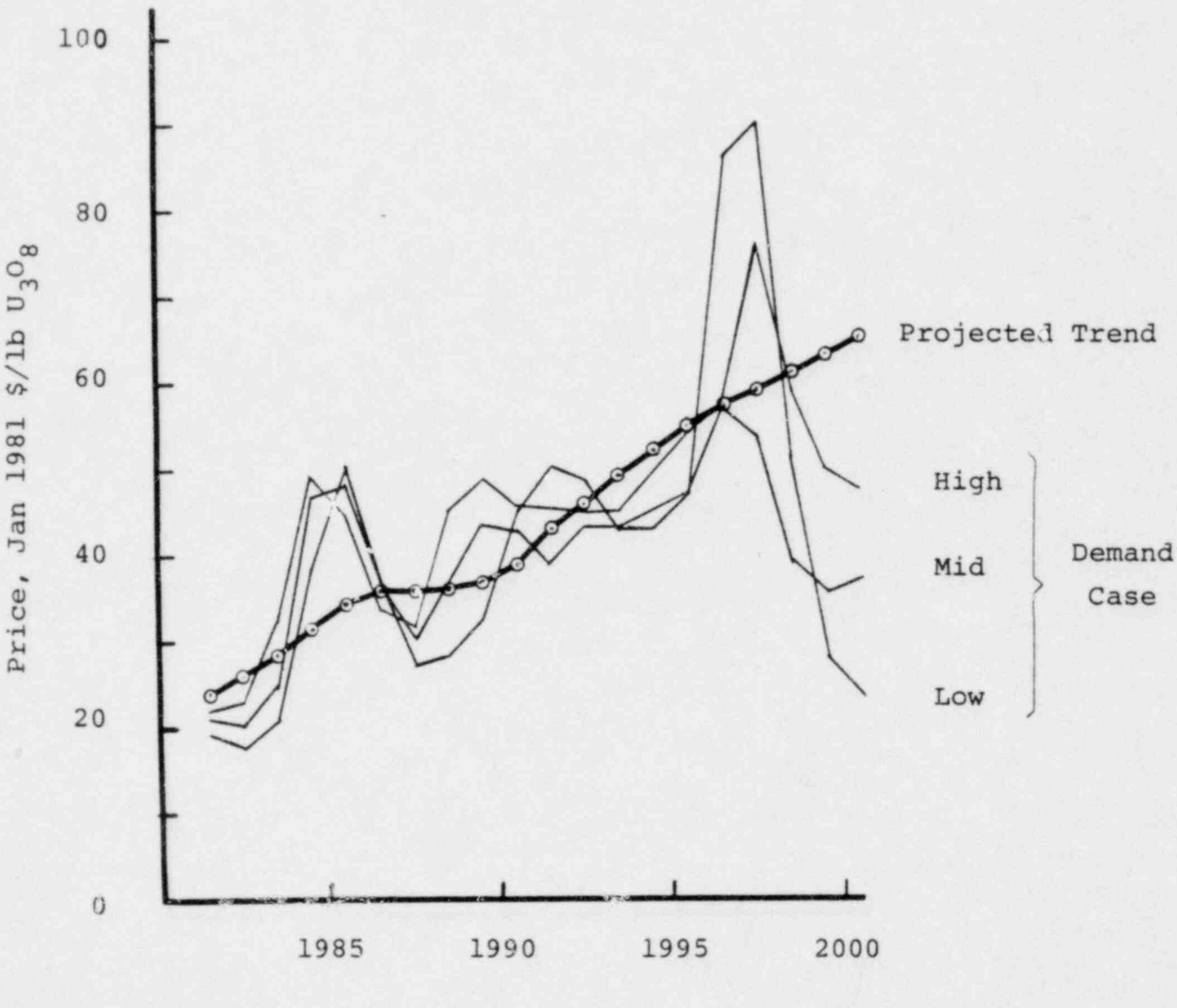


FIGURE 8

Projected Uranium Price Trend

and

EUREKA Program Results for Three Demand Cases



APPENDIX A

DESCRIPTION OF EUREKA URANIUM MARKET MODEL

Introduction

The EUREKA program is a computer model of the domestic uranium market which simulates the interaction of current and projected demand and supply, projects the extent to which the supply can be changed to meet demand, and forecasts the price associated with achieving this supply level. The program has an extensive library of information on the nature of U.S. resources and on the costs of finding, developing, and producing from these resources. These libraries are kept current and are used in the program to determine when, with a specified rate of return, new resources should and can be developed and put into production to meet projected demand. The program, which basically simulates the decision-making activities of buyers and producers, can accommodate many input assumptions regarding these activities in order to analyze the market effects of a wide range of decision-making factors and related conditions. The program can also be utilized to test pricing sensitivity to various input parameters.

Methodology

In broadest terms, the program attempts to model buyer and supplier decision processes. Of these decision processes, the two most important involve suppliers' decisions concerning: (1) when to put new properties into production, and (2) how much exploration to conduct.

Two main factors influence the first of these decision processes: (1) the short-term economics of starting new production, and (2) the long-term need for such production. The relationship between these two, often opposing considerations is one of the most important and complex decision processes in the model.

Similarly, opposing considerations influence the second of these decision processes, the short-term economics of exploration and the long-term need for such exploration. For example, there may be a considerable need for exploration but little incentive in terms of current prices.

The weighting of factors which influence decisions by the model may be altered. Such factors include, for example, the presumed ability of the suppliers to clearly perceive future demand or the average industry conservatism in making production investments. These subjective conditions are adjusted by a number of variables which range from "conservative" to "speculative" viewpoints and, therefore, has latitude in the decision modeling to reflect the user's perceptions.

Physical and cost bases for decisions are also entered into the model. For example, a value for ultimate level of resources is entered and the program will develop reserves based not only on the exploration efforts, but on adjustable assumptions on the success of finding uranium for various levels of efforts. These assumptions may be further subdivided into finding success versus depth, and so forth. Cost parameters may be varied at successive levels of detail.

The buyer decision factors which may be altered by the user include such items as inventory level, conditions for buying or using that inventory, and average contracting periods.

The model projects the future by building on the "instantaneous" conditions in the calculation or decisions made for a given year based on contemporary conditions. For instance, it allows normal (but again, adjustable) time lags to occur and then implements these decisions. The implementation creates new conditions of supply, demand, costs and reserves. In light of these, a new series of decisions is made. Thus, all previous actions feed into the present and the present feeds into the future.

As the calculations proceed, the prevailing economics and even the projected uranium demand may change. Initially established conditions are not static. For example, cutoff grades, and hence production capability, change with market price; initially predicted demand can be caused to decrease or increase, causing a change in forward planning; buying into inventory may change depending on price and production capacity, etc. All these changes are reflected in their influence on contemporary decisions.

Each year, the short-term supply/demand pressures are the primary driving force as to whether the market price will increase or decrease. There are some additional price adjustments made on the long-term considerations of exploration

needs. As with all other functions that cannot be expressed with established analytical form, the user has some control over how these pressures affect price.

Finally, the output is not just market price. This would be almost useless in the absence of other information. Equally important to these studies are projections of mine and mill capacities, required capital expenditure patterns, exploration activities and results, average prices for forward deliveries, reserve status, and several other factors.

Because the program is one of complex feedback, it cannot easily be described in the order of a calculational sequence. Rather, it is best understood as a series of operations. All through the operations, the forecaster may insert his own judgment.

Data Sources

Source data fall into two broad categories: (1) those pertaining to geology, and (2) those pertaining to costs. The geologic data source is primarily from DOE compilations. However, the program requires more detail on reserve statistics than is actually available, and the DOE data must be combined with certain interdependent assumptions which require additional analyses.

Cost data come from published sources and independent analysis. Mine cost data all fall into this latter category. Essentially, all cost data are user adjustable.

JOHN M. VALLANCE

Summary of Qualifications and Experience

EDUCATION

B.S., Chemical Engineering, Rensselaer Polytechnic Institute, Troy, New York, 1952

Graduate, Oak Ridge School of Reactor Technology (ORSORT), Oak Ridge, Tennessee, 1958

EMPLOYMENT EXPERIENCE

1967 - present Pickard, Lowe and Garrick, Inc., Washington, DC

Consulting in preparation of nuclear fuel bid specifications; evaluation of nuclear fuel supply proposals; negotiation of supply arrangements; administering on-going supply arrangements; preparing nuclear fuel operating plans, supply requirements and procurement strategy; planning and negotiating enriching services arrangements with DOE; preparation of special analytic studies regarding fuel supply; nuclear fuel cost analyses and projections; projections of the component costs of nuclear fuel materials and services; projections of nuclear fuel and reactor performance; risk analyses for nuclear power or other facilities concerning aircraft hit probability; preparation and presentation of testimony at licensing hearings, State Energy Commission hearings or PUC hearings; special studies of the uranium market; probabilistic analyses of supply and demand for nuclear fuel and of fuel costs.

1959 - 1967 U.S. Atomic Energy Commission - Washington Headquarters, Germantown, MD

Engaged in the civilian nuclear power program of the Division of Reactor Development. Participated in planning and evaluating reactor programs and alternate fuel cycles. Active participant in most of the AEC studies on the utilization of nuclear power for peaceful purposes during 1959-1967. Served as an official U.S. Delegate to and presented a paper at the Third International Conference

EXHIBIT A

EMPLOYMENT EXPERIENCE (continued)

on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1964. Delegate to and presentor of a paper at the Inter-American Conference on Economic and Technical Aspects of Nuclear Power Generation in Latin America, Mayaguez, Puerto Rico, 1965; U.S. A.E.C. participant and presenter of paper at the World Power Conference of 1966, Tokyo.

1955 - 1959 U.S. Atomic Energy Commission - Hanford Operations, Richland, Washington

Participated in planning and supervision of the production of special nuclear material and in the reprocessing of irradiated fuel. While employed at Hanford, U.S. AEC sponsored his attendance at the one-year graduate level program of nuclear engineering, the Oak Ridge School of Reactor Technology, which involved six months graduate study at U.C.L.A. and six months further work at Oak Ridge National Laboratory.

1954 - 1955 American Brakeshoe Company - Mahwah, NJ

Engaged in chemical engineering in unit operations for the process development for the manufacture of various friction materials.

1952 - 1954 U.S. Army

Served as a Lieutenant in the Chemical Corps. Primary assignments included Post Chemical Office and Instructor at a Chemical Corps School.

PROFESSIONAL MEMBERSHIPS

American Nuclear Society
Atomic Industrial Forum

JOHN M. VALLANCE

SELECTED PUBLICATIONS

The Effects of Current U.S. Nuclear Energy Policy on Uranium Enriching Operations. Presented at 84th National Meeting of the American Institute of Chemical Engineers, Atlanta, GA, Feb 1978.

The Throwaway Fuel Cycle (Co-author). Presented at AIF Fuel Cycle Meeting held in Atlanta in April 1975.

Nuclear Fuel Capital Requirements, 1973-1990. Presented at AIF Seminar, "Nuclear Power-Financial Considerations," Monterey, California, September 19, 1973.

Uranium Enrichment - A Report of an Ad Hoc Forum Policy Committee, 1972. Principal author of the section of the report on Economic Considerations.

Power Plant Economics. Presented at Southern Interstate Nuclear Board Briefing on Nuclear Power to the Coal Industry, September 1966.

Nuclear Electric Power - Economics of the Conversion of Nuclear Energy to Electricity. Presented at American Chemical Society Fuel and Energy Symposium, April 1965.

Economic and Financial Aspects of Nuclear Power Generation (Co-author). Presented at Inter-American Conference on Economic and Technical Aspects of Nuclear Power Generation in Latin America, Mayaguez, Puerto Rico, February 1965.

Fuel Cycle Economics of Uranium Fueled Thermal Reactors. Presented at 1964 U.N. Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland (paper No. 247).

Civilian Nuclear Power - A Report to the President...1962: Principal contributor, published by USAEC.