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DISCUSSION OF A PROCEDURE FOR GEOTHERMAL PROPERTY APPRAISAL

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ABSTRACT

This paper discusses a procedure for estimating the value of a hot water geothermal property. The procedure involves two methods: a so-called conservative method and a so-called optimistic method. The methods share a common set of assumptions (e.g. that current unit price of the hot water is the same) but each also involves some different and debatable assumptions (e.g. that price of geothermal hot water will-or will not-increase substantially in the future). The methods lend themselves to graphical display: value for the conservative method is shown as a function of discount rate with no anticipated price increases; value for the optimistic rate is shown as a function of liklihood that development will occur under circumstances wherein discounting is completely offset by price increases. Together, these methods define a range of values that might reasonably be assigned to a property.

SUMMARY

Estimates of the monetary fair market value of a hot water geothermal property are of interest in connection with leasing of federal and state geothermal acreage and in buying and selling privately owned, undeveloped geothermal property. These estimates are also of interest in comparing one property with another regardless of absolute monetary value. This paper explains a procedure involving two different methods for estimating the value of a property. One method leads to a suite of so-called "conservative" estimates; the other, to more "optimistic" estimates. Two methods have been developed because it is impossible to address and appreciate the significance of so many assumptions (e.g. future prices of energy) in just a single method. Together the two methods provide perspective on a reasonable range of values. However, we have concluded that it is impossible to avoid subjectivity in assigning a single value or even a narrow range of values to an undeveloped property.

The conservative procedure assumes 1) that the physical characteristics of the resource, i.e. its size, representative depth and temperature, etc. are known; 2) that price and cost estimates proposed as applicable to hot water resources are valid (see Howard, 1980a, 1980b), and 3) that the resource will be exploited to support at least one project the energy demand of which is dictated by the representative temperature of the resource. These assumptions permit calculation of present value profit ("PVP") for the single project that is supposed to occur. PVP is shown as a function of discount rate for future income, and provides one generally conservative suite of estimates for the monetary fair market value of the property.

Still other considerations should, however, be taken into account in trying to fairly appraise the value of a geothermal property. These considerations include: 1) allowance for escalation of the price of energy with time;

2) assignment of value of the useful, cost-competitive resource not exploited by the anticipated initial project; and 3) evaluation of the liklihood that the property will actually be developed in view of practical geographic and demographic constraints. We propose a) that escalating prices are such that, to a first approximation, one can reasonably neglect discounting future income to present time, b) that the initially unused portion of the property has <u>no</u> fair market value (but does have a royalty value) and c) that evaluation of the liklihood of development is subjective for each property and should be recognized as such. In view of these considerations, as well as the assumptions involved in the "conservative" estimate, a suite of present value profits can be calculated as a function of a "liklihood" factor f. The factor f $(0 \leq f \leq 1)$ is an expression of opinion that escalation of prices will offset the effect of discounting future income and also that development will occur. The entire suite of values provides another measure of the monetary fair market value of the property. Unless the factor f is quite small (say less than 1/6) these estimates lead to higher values for the property than the conservative estimate and thus we have termed these estimates "optimistic".

Conservative and optimistic estimates may differ substantially because they emphasize different assumptions. However, the two estimates converge as the discount rate decreases and as the value of the liklihood factor, f, increases. Our opinion, however, is that serious buyers and financiers will favor the conservative estimates with discount rates greater than 12% but that sellers will favor optimistic estimates using a liklihood factor of 0.5 or greater.

Our procedure is illustrated with an example involving the federal geothermal resources in the Boise Barracks Military Reservation. Calculations of value are listed in Table 5. This property was eventually sold by the Bureau of Land Management for $20K. This figure contrasts with our conservative estimate of zero and an optimistic estimate of $195K when the "liklihood factor" is set at 0.5.

INTRODUCTION

Purpose and Scope

This paper describes and illustrates a procedure for estimating the value of a hot water geothermal resource. Within the geothermal community, the question of the value of an undeveloped property arises quite commonly. This question is a key question in connection with leasing of federal and state acreages. It could be an important question in settling an estate or in selling privately owned, undeveloped geothermal property. It is a question that could arise as developers review a suite of properties to determine which is most desirable to develop or which should be dropped. Conceivably also, although not presently known to be used for collateral, an undeveloped geothermal property may have such a role in the future.

This paper also provides a rational basis for concluding that all or part of a geothermal resource is a reserve, according to the U.S. Geological Survey definition of the term "reserve."

The value of an undeveloped geothermal property can be measured, in principle, in a variety of ways. As we explain in more detail below, however, we have chosen to strive to determine the "monetary fair market value of an undeveloped hydrothermal resource. By "monetary fair market value," we mean the price which an undeveloped hydrothermal resource might be expected to bring if offered for sale in a fair market (cf. Hughes, 1967, p. 61). Although an exact definition can be given for this concept, the actual estimation of this price is difficult to carry out and subject to a series of assumptions.

The procedure described in the paper is directed at hot water geothermal resources, and certain underlying assumptions (e.g. sales price of a pound of geothermal fluid) have been derived from review of only hot water resources. Nevertheless, the reasoning underlying our analyses could be used to appraise vapor dominated resources.

Our analysis assumes that the geology of the resource is fully known. Procedures that take into account uncertainty associated with all of the parameters that describe the resource (or, for that matter, the price and cost of geothermal energy) are beyond the scope of this paper. However, extensions of the procedure could be made that would include consideration of uncertainties and probabilities (cf. Nathenson, 1978).

Our procedure is a procedure for appraising property for which no specific development plans are announced. It may be termed "property appraisal." Our procedure should not be confused with the procedure one would follow in deciding upon the financial merit of a specific plan for development of a specific property. Such a procedure may be termed "project evaluation." It is a key part of an advanced phase of geothermal resource development and is the procedure used, for example, by the U.S. Department of Energy, Geothermal Loan Guarantee Staff, in order to determine if a loan to support specific development will be guaranteed. "Property appraisal" procedures contrast with "project evaluation" procedures, most notably because project evaluation includes specific information about many of the key parameters, e.g. exact schedule for development, that one must assume in property appraisal.

Definitions

The meaning of the terms "resource" "reserve" and "value" are discussed below. We follow here the definitions of resource and reserve as explained by Muffler and Cataldi (1978) as later restricted by Muffler and Guffanti (1979).

"Resource base"is all of a given material in the earths crust, whether its existence is known or unknown and regardless of cost considerations" (Muffler and Guffanti, 1979, p. 4, quoting Schurr and Netschert, 1960, and Schanz, 1975). In this case, the "given material" is hot water geothermal energy.

"For hydrothermal connection systems with reservoir temperatures of 90°C or more, the term accessible resource base is restricted to the thermal energy contained in rock and fluid between the specified top and bottom of a reservoir." Muffler and Guffanti (1979, p. 4). Thus, the accessible resource base is physically defined by the top and bottom, as specified, of a reservoir, provided temperature is 90°C or more. "Resource refers to the "useful" accessible resource base, where"useful"indicates that the accessible resource base can be extracted and used (Muffler and Guffanti, 1979, p. 4).

As noted, the top and bottom of the reservoir is to be specified, and we envision that the bottom of the reservoir is the greatest depth of drilling that still allows for the possibility of profitable recovery of geothermal energy. We specify the remaining enclosing surfaces of the resource by an isothermal surface dictated by the minimum temperature requirement for use of the geothermal energy.

A geothermal reserve is "that part of the geothermal resource that is identified and also can be extracted at a cost competitive with other commercial energy sources at present" (Muffler and Guffanti, 1979, p. 4). Thus when we speak of "reserve" we refer to that part of the geothermal resource base

- that is contained in a specified reservoir and
- that can be extracted and used and
- that can be extracted and used at costs competitive with other commercial energy sources at present.

DISCUSSION OF PROCEDURES

Assumptions

In order to carry out our analysis of value we have had to make a series of assumptions regarding:

1. price that one could expect to receive for sale of the geothermal fluid
2. cost to establish the capability to produce the fluid
3. the plan and schedule for bringing the resource on stream.

We also assume complete knowledge of the geology of the resource.

In earlier papers we developed a price equation (Howard, 1980a) as well as a cost equation (Howard, 1980b). We believe that both of these formulations are reasonable but the reader should refer to those papers in order to make his own judgment or perhaps to formulate, in his own opinion, "more satisfactory" equations.

Discussion of the plan for bringing a resource on stream is complex and is considered in a section of its own in this paper (below).

The assumption of complete knowledge of the resource is unreasonable in practice but, for purposes of this paper, is acceptable. We make several other assumptions regarding the resource as follows. We assume that heat contained in the fluid only is recovered and that it is completely recovered. We also assume that any well drilled into the resource will yield an ultimate recovery of in the range of 10^{10} to 10^{11} lbm at a rate of production of 240,000 lbm/hr over a lifteime of at least five years (see Howard, 1980b). We assume that at any time during development enough wells are available to service the instantaneous demand. All of these assumptions are reasonable on average and are reasonable for purposes of illustrating a procedure. However, for practical applications it would be realistic to address the question of uncertainty associated with estimates of these parameters. Such considerations are beyond the scope of this paper (cf. Nathenson, 1978).

In the following sections, we first explain how the presence of a reserve within a resource can be argued for. Then, we explain the method whereby one can estimate the monetary fair market value of the reserve.

Determining the Presence of a Reserve

Procedure.--According to the definition of a reserve, a reserve exists if the geothermal energy can be extracted and used at costs competitive with other energy sources at the present time. The price of hydrothermal geothermal fluid, p, is proposed to depend on its energy content as shown in Figure 1 and is a function of relative specific enthalpy (see Howard, 1980a). Cost of hydrothermal geothermal fluid, c, is proposed to depend on its depth of occurrence and ultimate recoveries per well. Figure 2 shows the cost function. Both functions are given on a mills per pound - mass basis. To a first approximation if

$$p > c$$

for the masses of fluid comprising all or part of a resource that mass can be considered a reserve. We qualified this relationship by the phrase "to a first approximation" because under some conditions the price on a per pound basis may be greater than cost at present but present value of price to be delivered at a later time may be less than cost. We chose to disregard this possibility and accept the position that a reserve exists if at the present time the price of any pound mass is greater than cost. In other words we assume instantaneous production and sale.

Example.--Table 1 lists information regarding a specific resource. This information can be compared with price and cost estimates to determine the part of the resource that is a reserve. The volume under consideration in this example is actually only a part of a still larger resource. The example is bounded by the 310°F isothermal surface, the 7500 foot depth plane, and the vertical sides of the property.

Study of Table 1 shows that, according to definition, volumes between 2500 feet and 6500 are reserves. No reserve exists below 6500 feet because cost exceeds price.

Estimating the Value of a Reserve

Introduction.--The monetary fair market value of a reserve depends not only on its size, average price, and cost per unit mass but also on the plan and schedule for its development. Income to be received at some future time are often discounted in order to compare cumulative income with costs borne at the start of a project. In order to discount future income, however, we need to make some assumptions regarding the way in which a resource is to be developed. Assumptions regarding plan and schedule for development are discussed below.

Assumptions for Development of a Hydrothermal Geothermal Resource.--We assume three different development scenarios for a hydrothermal geothermal resource that depend on the representative temperature of the resource. These scenarios are summarized in Table 2.

If the representative temperature is less than 250°F, we assume that the resource will be used for small scale space heating, (i.e. a greenhouse, church, several houses) calling for an annual load of about 0.5 x 10^9 lbm/yr and a 30 year load of 15 x 10^9 lbm. A single, median productivity well (i.e. 240,000 lbm/hr) can serve the annual load and two wells can serve the 30 year lifetime requirements.

If the representative temperature is in the range of 250°-350°F, we assume that the resource will be used for commercial/industrial heating, such as in sugar refining or wood pulping. This annual load is assumed to be 5 x 10^9 lbm and the 30 year load is 150 x 10^9 lbm. Roughly three median productivity wells can handle the annual load, and fifteen wells are assumed to be capable of handling the 30-year lifetime requirements.

If the representative temperature is greater than 350°F, we assume that the resource will be used for electrical power generation. The annual load is assumed to be in the range of 20 to 100 x 10^9 lbm depending on temperature (see Figure 3) and the 30 year lifetime load is assured to be in the range of 650 to 3000 x 10^9 lbm depending on representative temperature of the resource. Ten to fifty wells of median productivity are required to service the annual load, and 65 to 300 wells are necessary to service 30 year lifetime requirements.

We further assume that an application in the less-than 250°F temperature range will start to produce a cash flow one year after purchase and will produce a constant cash flow equal to the product of annual load and price per pound mass (dependent on temperature) for 30 years. (Obviously the resource must contain a useful mass greater than the 30 year requirement). For an application in the 250°-350°F range we assume that a constant cash flow will start three years after purchase and will continue for 30 years. For electric power production we assume the start of cash flow to be six years after purchase. We assume that all costs to establish a 30 year capability to produce are borne immediately.

Basis for Assumptions about Development.--Our reasoning in setting up the assumptions that were explained in the previous section are as follows. First it is reasonable to acknowledge that the use of a geothermal resource depends on its temperature. Low temperature resources are not likely to be used for electric power generation because of the inefficiency of conversion associated with lower temperatures. Conversely high temperature resources are capable of generative electricity and such use is expected to yield greater total profit than lower temperature application. The latter assertion is based not only on higher price to be expected from high temperature fluid but more importantly on the total amount of fluid expected to be used. The choice of temperature range in anticipation of a scenario for use is admittedly arbitrary; but, based on a review of possible uses (e.g. Lindal, 1973; Reistad, 1974), we felt that the divisions shown in Table 3 fairly well represented the most logical application for a resource.

Second, the assumptions regarding annual and lifetime loads are based on a selection of anticipated direct use and electric generating programs. These are summarized in Table 3 which lists anticipated annual loads for a variety of uses. The direct use annual loads are based on the Department of Energy-sponsored direct use studies that were reviewed by Bakewell and Herron (1979), and the requirements for electrical power production are based on calculations carried out by Austin (1975) (Figure 3) assuming furthermore that a 50 MW module would be the goal for development.

Information on annual loads as reported by Bakewell and Herron (1979) and loads for 50 MW power plants has been generalized by temperature class to lead to the assumptions presented earlier.

It is worth repeating that we are assuming that the agreed use for a geothermal resource depends on its temperature and furthermore that the amount of use also depends on temperature — with electrical power generation requiring as much as two orders of magnitude more "fuel" than small scale space heating.

The assumptions of development schedule, e.g. power plant producing first cash flow six years from purchase, etc. seem to be reasonable. Space heating low temperature applications are fairly straightforward technically and do not appear to have much environmental impact. Power plant construction is complex and subject to delays over concern for the environment. Six years before start of cash flow may be optimistic.

The assumption of bearing all costs at the start of the project is perhaps unrealistic because wells are almost certainly to be drilled only when needed to service the instantaneous load. However, we felt that discounting the costs of wells to be drilled in the future — and at greater expense (see Chappell et al., 1979) — would be more or less equivalent to taking all costs immediately.

Conservative Estimates of Value

Introduction.—One reasonable estimate of the monetary fair market value of a property can be determined by calculating the present value profit for the initial project one might logically expect the property to support. Such a determination can be made if one accepts the assumptions that:

1) the size and representative temperature and depth to the resource are known;
2) estimates for the average price and cost of the resource are valid (see Howard, 1980a and 1980b);
3) the plan and schedule for development of the first project on the property are those explained in the previous section.

If one accepts these assumptions, it is a straightforward procedure to calculate a present value profit as a function of discount rate for the project as explained below. One may then use these quantities as a measure of the monetary fair market value of the property.

Determination of Present Value Profit.--We calculate the present value profit of the anticipated initial project on the property as follows.

The annual mass use of the resource, Q_A, expressed in pounds-mass, varies with the type of project and, more fundamentally, with the representative temperature of the resource (see Table 2). The price that one might expect to realize from sale of a pound-mass of the resource, p, is a function of relative specific enthalpy given in mills per pound mass (see Figure 1). Annual cash flow, I_A, is the product:

$$I_A = Q_A p$$

We assume a 30 year lifetime for a project and a constant annual income. Thus the value of all income from the 30 year life of the project is, at the start of the project, given by:

$$I' = I_A D'$$

where D' is the discounting factor given by:

$$D' = \frac{(1+i)^{30}-1}{i(1+i)^{30}}$$

The quantity i is the annual interest rate.

Inasmuch as income from the 30 year life of the project will start at various future times depending on the type of project, anticipated 30 year income at the start of the project must itself be discounted to present time. This discount factor is given by:

$$D'' = \frac{i}{(1+i)^m}$$

where, as before, i is interest rate and m is years until start of cash flow.

The present value of future incomes, I", is equal to all income discounted to the start of cash flow, I', and then discounted again to present time.

Algebraically:

$$
\begin{aligned}
I'' &= I'D'' \\
&= I_A D'D'' \\
&= I_A \left\{ \frac{(1+i)^{30}-1}{i(1+i)^{30}} \cdot \frac{1}{(1+i)^m} \right\}
\end{aligned}
$$

The quantity shown in braces is displayed graphically in Figure 4 for various values of m.

Present value profit, PVP, is the difference between present value, I", and present cost, C. We estimate present cost by determining the lifetime mass requirements of the project and multiply by a cost per unit mass, c. **The lifetime requirements are listed in Table 2 and Figure 2 shows costs on a pound-mass basis as a function of representative depth to the reservoir (see Howard, 1980b). Thus:**

$$PVP = I'' - C.$$

Optimistic Estimates of Value

Introduction.--Although an estimate of present value profit, discounted appropriately, of a single most logical project for development of a property, as explained above, provides a basis for estimating value of the property, still another consideration should be addressed in order to fully appreciate the value of an undeveloped geothermal property. Overall, the following considerations lead to a more optimistic higher estimate:

1. escalation of prices and costs over the lifetime of the project
2. assignment of value to that part of the property in excess of the requirements of the initial project
3. factoring in the liklihood that development will actually occur in view of geographic and demographic considerations.

Discussion.--We propose to treat the quesiton of escalation of costs and prices in a simple way because we have no very sound basis for complex treatment. In making our appraisal, we treat all costs as though incurred at the start of the project. Our reasoning is that given in the section on conservative estimates (above).

Escalation of prices for energy has been dramatic in the 1970's and recently they have been on the order of 20-25% (Howard, 1980b). Increases in price on the order of 12% or more per year are in the range of rates of return on investment that appear to be acceptable to resource developers. Comparison of these two variables suggests that increases in prices and the process of discounting future incomes essentially cancel each other. In terms of present value, the result is that the present value of a project is equal to annual income times duration of the project. Income to be received in the last year of the project is just as valuable today as income actually received today.

The question of assignment of value to that part of the property in excess of that required for the initial project can be handled in several ways. First is to define the property areally (or volumetrically) so that it is insignificantly bigger than that required for the initial project. The second is to expect no present value for the excess but to ask a royalty on production from it, should it ever occur. The consequence of either of these assumptions is practically the same so far as estimating the value of the property is concerned: the excess part is given no value. However, as suggested above, a "deferred value" can be asked for and assigned by obtaining a royalty, should production of the excess ever occur.

The possibility that development will ever occur on a property is impossible to generalize about because it is dependent upon the specific property and on individual judgment. This subjective uncertainty and the uncertainty associated with escalation of prices offsetting discounting of future income may be combined in a single factor, f, that we have called a liklihood factor. We recognize it as a subjective factor and feel that the best way to handle it is to display it clearly as shown in the example of the next section.

Treatment of the considerations introduced in this section of the paper may be summarized as follows:

1) the value of an anticipated initial project on an undeveloped geothermal property is equal to annual income from the project times a 30 year expected project lifetime

$$V = I_A x 30$$

2) the value of the project should be discounted by a factor f

$$0 \leq f \leq 1$$

to reflect the liklihood that development will occur and that no net discounting of future income is necessary

$$V' = Vf = f\ I_A x 30$$

3) the cost of the project c, is calculated the same as in the conservative case

4) the value of the property is then:

$$V'' = V' - C = f\ I_A x 30. - C$$

Comparison of Conservative and Optimistic Estimates

It can be shown that the estimated value of the property is the same according to either method for certain conditions. For

$$i = 0 \quad \text{and} \quad f = 1$$

$$V'' = PVP$$

Furthermore, the two estimates are equal

$$V'' = PVP$$

when

$$f = \frac{D'D''}{30}$$

The quantity D'D" depends on the discounting rate i. For interest rates in the range of 10-20%, namely the range most commonly mentioned as reasonable for discounting, D'D" has a value of about 5. (Fig. 4). Thus roughly

$$V'' > PVP \quad \text{if}$$

$$f \overset{\sim}{\geq} \frac{1}{6}$$

Based on this argument we have termed the method involving the liklihood factor, f, as the optimistic method.

It should be fairly clear from the previous discussion that only a range of values can be reasonably defined by the procedure. Subjectivity cannot be avoided, and perhaps it is unreasonable to propose that it could be avoided. The procedure, however, defines a finite range of values and helps to elucidate the consequences of certain subjectively set prejudices, particularly acceptable discount rates and "hunches" regarding energy prices in the future. We anticipate that sellers will favor the optimistic method; buyers, the conservative method - for obvious reasons. We also propose that the range of values will be practically limited by the conservative method using discount rates close to the prime rate (a low estimate) and by the optimistic method using a liklihood factor of about 0.5. It would be surprising to us if any property were appraised for more than its optimistic value with a liklihood factor of 1.0.

A logical suggestion is that reported sales be compared with the procedure explained in this paper. However, there has not been adequate time for such a comparison (cf. USGS, 1979).

EXAMPLE CALCULATIONS

Introductory Remarks

In this section, we illustrate the procedures explained previously by application to a specific example. Information about the illustrative example is listed in Table 4 and still additional information about the example is given in a report by Isherwood, et al. (1980).

We wish to calculate and display information about the property using both conservative and optimistic methods.

Estimates of Value

Figure 5 shows present value profit for the property as a function of discount rate and liklihood factor. Inspection of the figure shows the following conclusions. For interest rates greater than 8%, value of the property is negative. For an interest rate of 12% value is -$125 K. In contrast, value of the property is estimated to be almost $200 K for a liklihood factor of 0.5.

Study of the report by Isherwood et al. (1980) suggests that ultimate recoveries of more than 10×10^9 lbm per well may be attainable. Initial flow rates per well (pumped) are on the order of 400,000 lbm/hr. The calculations shown in Figure 5 are based on a representative well having an ultimate recovery of 10×10^9, lbm an hourly mass flow of 240,000 lbm and a lifetime of at least 5 years. The wells in the example are reported to have pumped flows of 400,000 lbm/hr. Thus we have recalculated the example using only 60% of costs (i.e. $\frac{240,000}{400,000}$). Recalculation leads to the conclusions shown in Figure 6. For interest rates greater than about 14%, value of the property is negative. For an interest rate of 12% value is $40,000. In contrast, value of the property is approximately $375,000 for a liklihood factor of 0.5.

Discussion of the Range of Values

The range of values estimated for the property are listed in Table 5. These may be compared with the estimated value of $475,000 given by Isherwood et al. (1980) and with the price at which the property was actually paid, namely $20,000 (Isherwood, 1980, personal communication).

Comparison is not intended to evoke criticism of any estimate of value because all have a credible albeit different basis. The rationale whereby the property was finally sold for $20,000 is not known but it is perhaps significant that this price is the price corresponding to calculations based on 60% better than median ultimate recoveries with interest set at slightly less than 13% (12.85%). Such an interest rate corresponds to a reasonable, low current interest rate (1980). Consequently such a valuation is not at all unreasonable. What does continue to be bothersome, however, is the rather wide range of reasonable estimates. Study of the experience in property sales should help to clarify the acceptability by industry of various underlying assumptions of the conservative and optimistic method.

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TABLE 1. DATA ON PROPERTY A*

DEPTH INTERVAL (Feet)	MASS OF FLUID (lbm) X10"	AVERAGE TEMPERA-TURE °F	AVERAGE ENTHALPY PER POUND MASS (Btu/lbm)	AVERAGE RELATIVE SPECIFIC ENTHALPY (Btu/lbm)**	ESTIMATED PRICE PER POUND MASS (Mills/lbm)	**REPRESEN-TATIVE DEPTH (Feet)	ESTIMATED COST PER POUND MASS (Mills/lbm)	DIFFERENCE (Mills/lbm)	COMMENT
2500-3500	7.81	320	264	237	0.171	3000	0.051	0.120	Reserve
3500-4500	7.56	326	270	243	0.174	4000	0.070	0.104	Reserve
4500-5500	11.7	329	273	246	0.176	5000	0.097	0.079	Reserve
5500-6500	17.1	334	278	251	0.180	6000	0.134	0.046	Reserve
6500-7500	16.4	338	282	255	0.182	7000	0.185	-0.003	Not a reserve

*Reservoir originally defined by 310°F surface, 7500 foot depth plane, and lateral boundaries of the property.
**Relative to 27 Btu/lbm reference point.

TABLE 2. ASSUMPTIONS FOR DEVELOPMENT OF A HOT WATER GEOTHERMAL RESOURCE

CLASS	TEMPERATURE RANGE °F	ANNUAL LOAD $X10^9$ lbm	LIFETIME LOAD (30 YEARS) X 10^9 lbm	INSTANTANEOUS WELL REQUIREMENTS NO.	LIFETIME (30-YEAR) WELL REQUIREMENTS NO.	DELAY TO START OF CASH FLOW-YEARS
LOW	<250°F	0.5	15	1	2	1
MEDIUM	250-350°F	5.0	150	3	15	3
HIGH	350°F	20-100	600-3000	10-50	60-300	6

TABLE 3. TEMPERATURES AND LOADS FOR A SAMPLE OF PROPOSED USES OF GEOTHERMAL HOT WATER.

PROCESS	INLET TEMPERATURE REQUIREMENTS, °F	ANNUAL LOAD x 10^9 lbm		
		CLASS <250°F	250-350°F	>350°F
2 - DIRECT HEAT*	302		4.77	
3 - " "	260		1.42	
4 - " "	340		2.03	
5 - " "	160	1.32		
6 - " "	110	0.45		
7 - " "	300		2.95	
8 - " "	327		11.14	
9 - " "	200		0.36	
10 - " "	200	0.09		
11 - " "	230	0.15		
12 - " "	200	0.17		
13 - " "	300		10.00	
14 - " "	300		10.00	
15 - " "	300		2.27	
16 - " "	300		2.27	
17 - " "	300		3.17	
18 - " "	300		3.17	
19 - " "	340		2.36	
20 - " "	300		5.54	
21 - ELECTRIC GENERATION**	351			96.4
22 - " "	572			21.9
		(Av.= 0.44)	(Av.= 4.4)	(Range - 20-100)

*Bakewell and Herron (1979)

**Austin (1975)

TABLE 4. INFORMATION ABOUT THE ILLUSTRATIVE EXAMPLE

ITEM			COMMENT
$\tilde{T}$,	representative temperature	180°F	Isherwood et al. (1980) Table 1
$\tilde{d}$,	representative depth	1300 ft.	Ibid., p.14, p.22, p.28 and Table 2
R,	total mass of fluid in the reservoir	2.79×10^{11} lbm	Ibid., calculated from their table
I_A,	anticipated annual income from initial project	\$42,470	0.5×10^{9} lbm $\times$ 0.0849 $\frac{\text{mills}}{\text{lbm}}$
C_{30},	anticipated total cost of recovery to service initial project	\$442,564	15×10^{9} lbm $\times$ 0.029504 $\frac{\text{mills}}{\text{lbm}}$
$\dot{q}$,	reported flow rates	800 gpm (∿400,000 lbm/hr)	Ibid., p.30

TABLE 5. VARIOUS ESTIMATED VALUES FOR THE ILLUSTRATIVE EXAMPLE

ESTIMATE $K	METHOD OR SOURCE	COMMENT
+20	Bureau of Land Management	Property sold by federal government to City of Boise, Idaho, at this price
∿+40	Better than median well performance, discounted at 12%	Perhaps the logically most defensible appraisal in view of present interest rates (1950)
0	Median well performance discounted at 8%	
+177	Better than median well discounted at 8%	
+195	Median well performance, liklihood factor set at 0.5	
+372	Better than median well performance, liklihood factor set at 0.5	
+475	USGS Area Geothermal Supervisor's Office	A reasonable, clear and defensible basis for the appraised value is given in Isherwood et al. (1980)

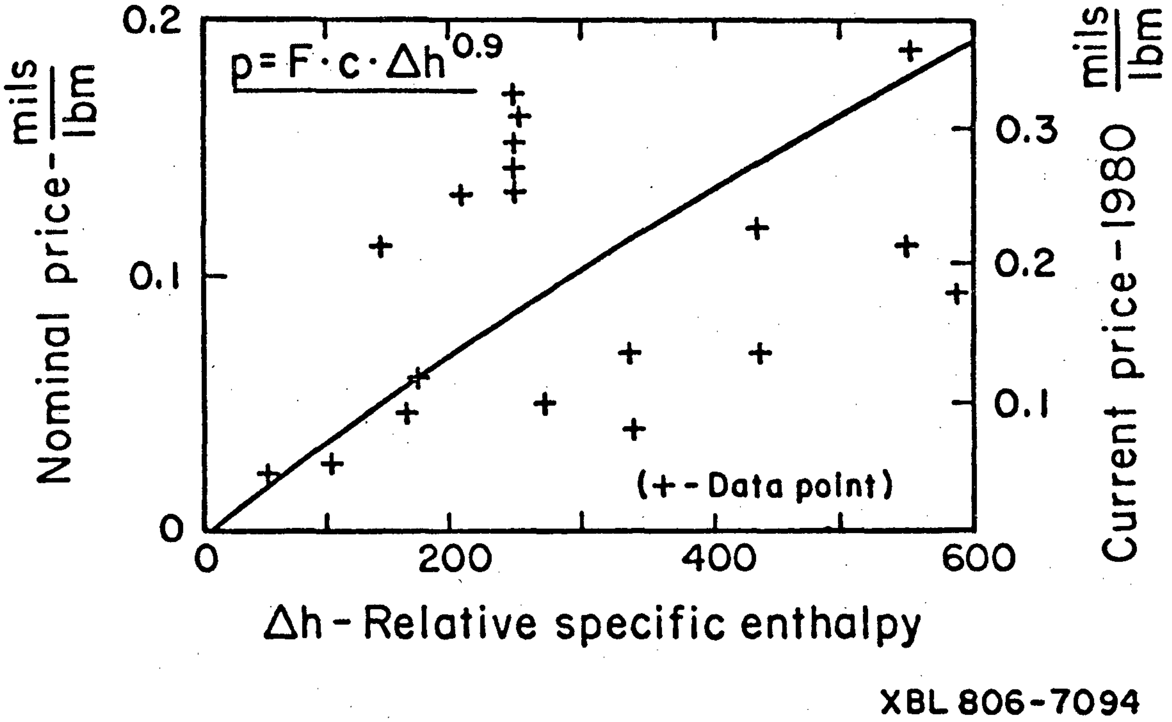
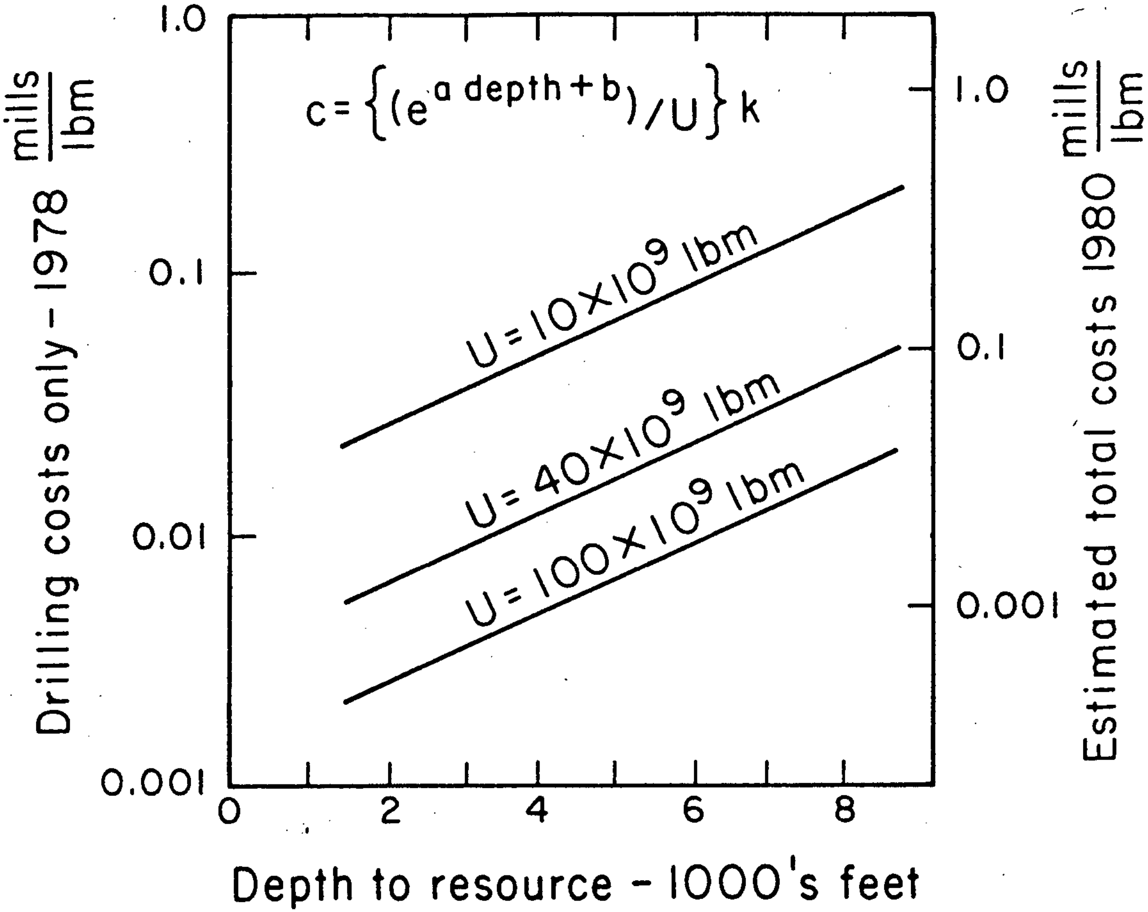
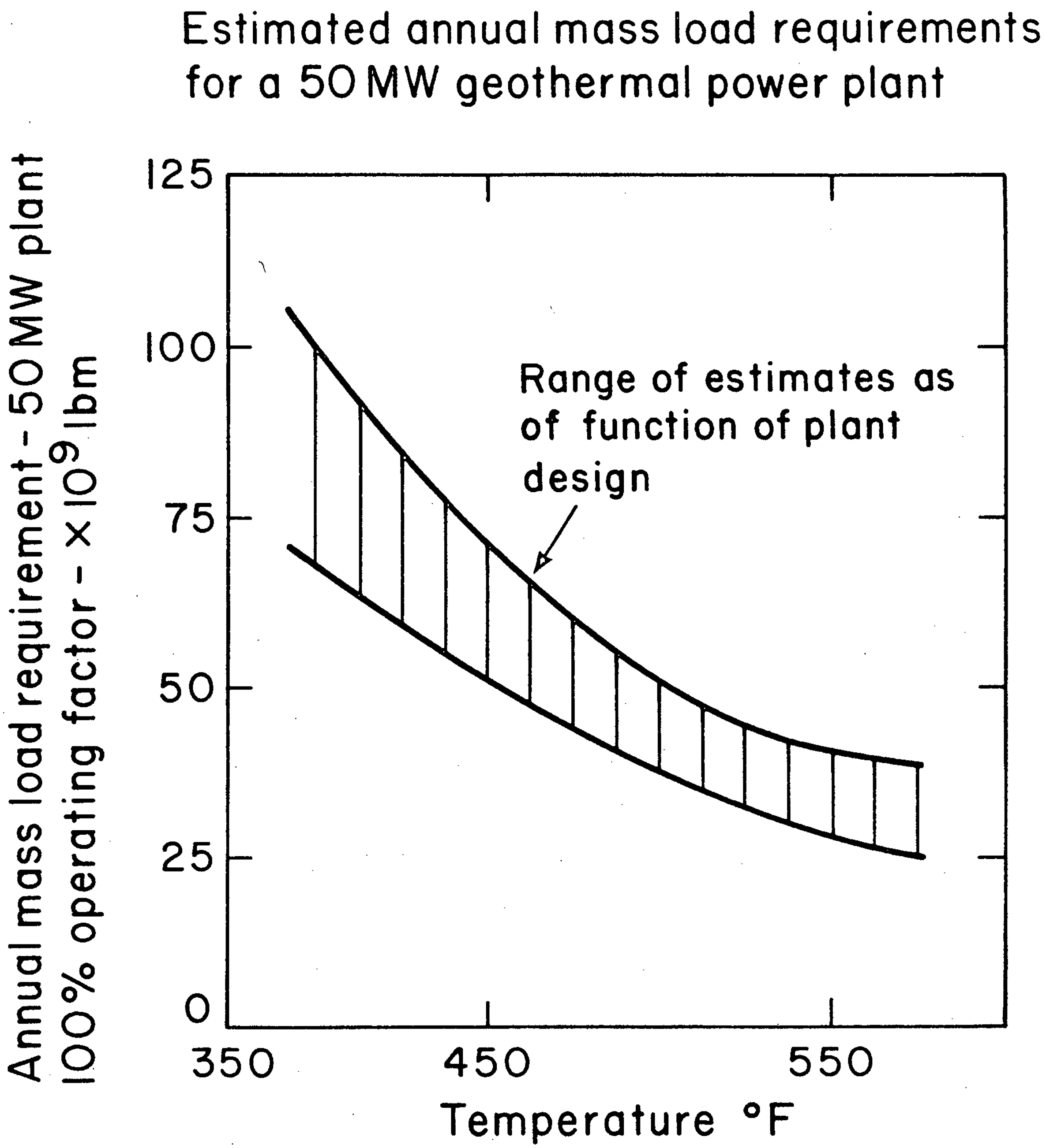


Figure 1. Estimate of price for hot water geothermal energy (XBL 806-7094).



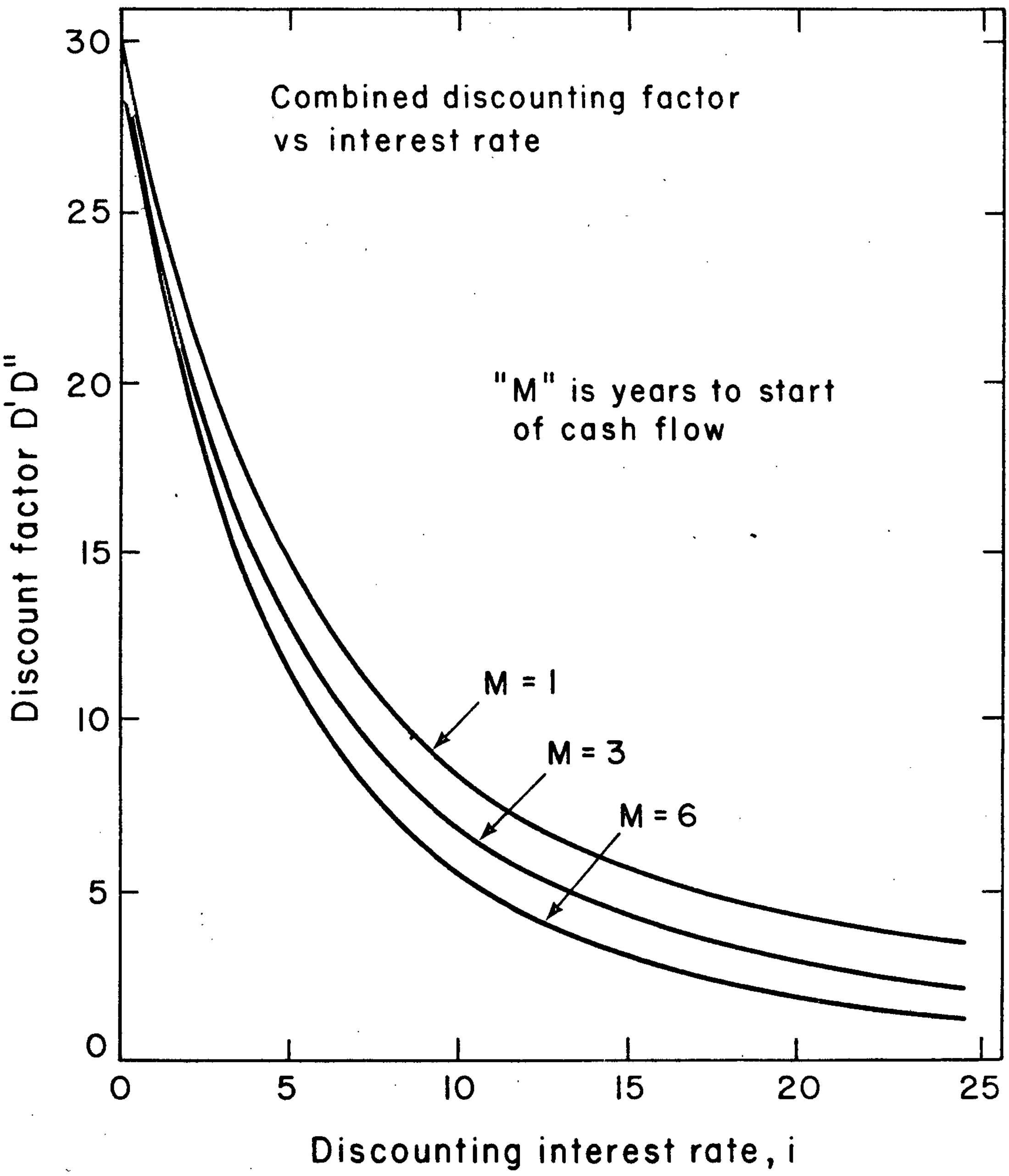
XBL 806-7095

Figure 2. Estimate of cost for hot water geothermal energy (XBL 806-7095).



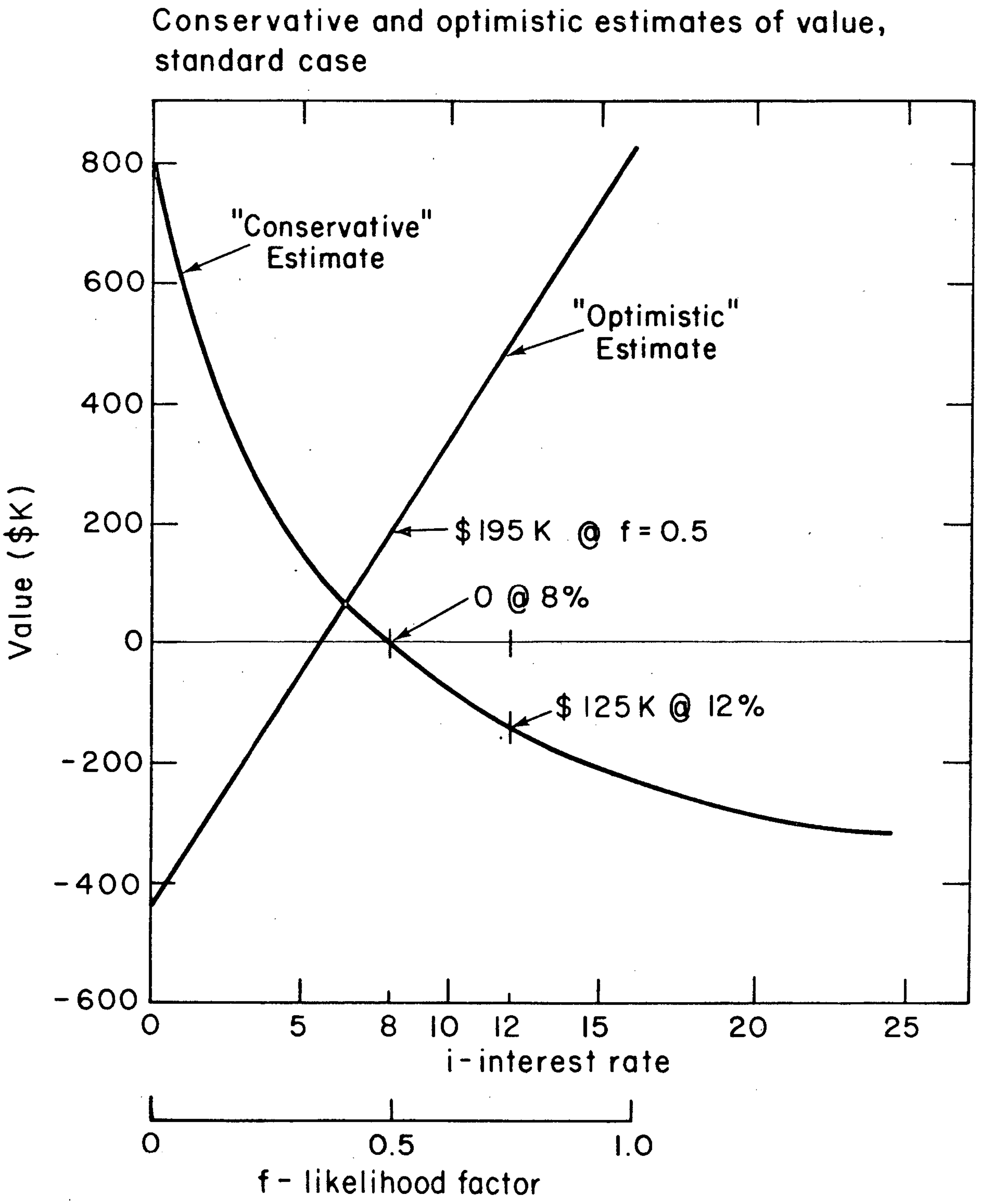
XBL 8010-2206

Figure 3. Hot water mass requirements to yield 1500 MW years of electrical energy as a function of temperature (XBL 8010-2206).



XBL 8010-2207

Figure 4. Combined discounting factor as a function of interest rate, i (XBL 8010-2207).



XBL 8010-2208

Figure 5. Value of the example geothermal property as a function of discount rate, i, and liklihood factor f, standard case (XBL 8010-2208).

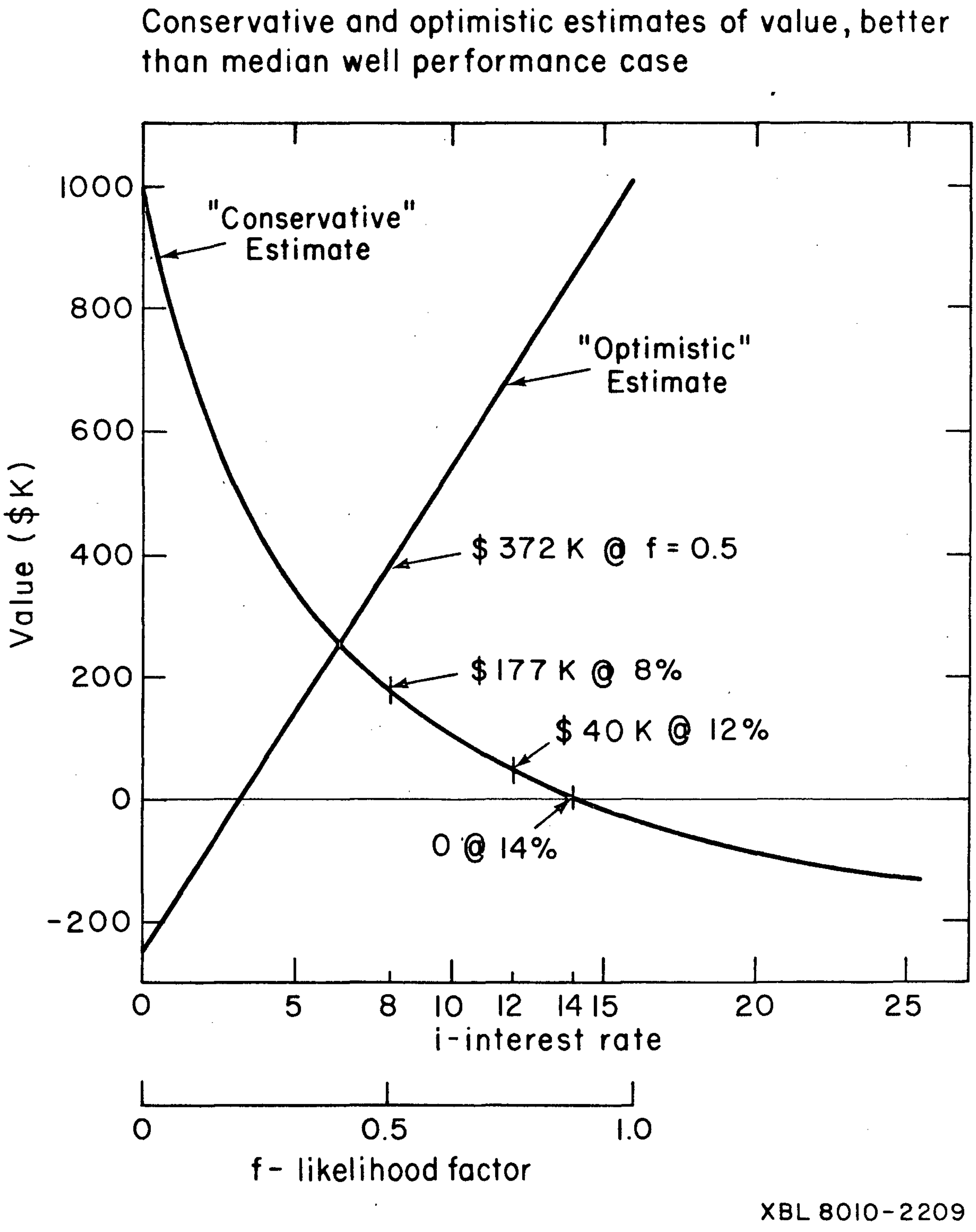


Figure 6. Value of the geothermal property recognizing better than median well performance (XBL 8010-2209).

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