PP-76-1

EVALUATING POTENTIAL NUCLEAR POWER PLANT SITES IN THE PACIFIC NORTHWEST USING DECISION ANALYSIS

Ralph L. Keeney

Keshavan Nair

January 1976

Evaluating Potential Nuclear Power Plant Sites in the Pacific Northwest Using Decision Analysis

Ralph L. Keeney [*] and Keshavan Nair[+]

Abstract

This study, authorized by the Washington Public Power Supply System, was made to identify suitable additional future sites for nuclear power generating facilities with a 3000 megawatt capacity in the state of Washington and parts of Oregon and Idaho. A series of screening models was used to identify nine specific sites for evaluation. A decision analysis was conducted to evaluate these candidate sites. Six major objectives concerning human health and safety, environmental effects, socio-economic impacts, and financial considerations were formally utilized over the six attributes measuring the degree to which the objectives were met. Possible impacts at each site were assessed for each attribute by experts knowledgeable about the aspects in question. Evaluation and sensitivity analyses led to the recommendation that site specific studies should be conducted at three sites to select one for proceeding to the formal licensing process.

The Washington Public Power Supply System (WPPSS) is a joint operating agency consisting of 21 publicly owned utilities in the state of Washington. In 1974, WPPSS authorized a study to identify and recommend potential new sites in the Pacific Northwest suitable for thermal electric power generating stations with a nominal capacity of 3000 megawatts electrical that may be required after 1984. The study was to be conducted on the basis of existing information and field reconnaissance; no detailed site specific studies were to be made. The objective of the study was to recommend potential sites that would have a high likelihood for successful licensing and therefore, that

[*] International Institute for Applied Systems Analysis, Laxenburg, Austria

[+] Woodward-Clyde Consultants, San Francisco, California, USA.

would be most suitable for the detailed site specific studies necessary to finally select a single nuclear power plant site. The approach used to conduct this study consisted of two major steps:

- a screening process to identify the candidate sites;
- a decision analysis to evaluate and rank the candidate sites.

Details of the process are described in Nair et al. [4].

This paper focusses on evaluation of the candidate sites. To indicate how those sites were identified, the screening process is first summarized in Section 1. Section 2 describes the objectives and the attributes used to evaluate the candidate sites. The assessment of the utility function is presented in Section 3, and probability assessments describing the possible impacts associated with each site are given in Section 4. Section 5 presents the evaluation of sites using the information developed and the sensitivity analysis. The final section contains our conclusions and recommendations.

1. The Screening Process: Identifying the Alternatives

The study area consisted of approximately 170,000 square miles including the entire state of Washington, the major river basins in Oregon and Idaho which are tributary to rivers in Washington, and the major river basins of the Oregon coast. The study was directed towards finding new sites and therefore all areas within a ten mile radius of the ERDA-Hanford reservation and other site areas for which electric generating facilities have been formally proposed or are under development were excluded. It is clearly impractical to evaluate every possible site in such a large area. Financial and time constraints require that one concentrate on areas where the likelihood of finding candidate sites is high. The purpose of the screening process was to identify such candidate sites.

The first step in the screening process involved establishing the basis for selecting sites. An extensive hierarchy of issues and considerations pertaining to thermal power plant siting was developed. The issues concerned safety, environmental, social, and economic considerations. Criteria defining a required level of achievement on each consideration were established to identify areas for further evaluation. Examples of the specific screening criteria are given in Table 1.

Note that some of the criteria for inclusion result from the rules of regulatory agencies, e.g. distance from a capable fault or location with respect to a protected ecological reserve. Other considerations are functional in nature, e.g. the accessibility to an adequate supply of cooling water. There are also considerations related to cost for which the project team in consultation with representatives of WPPSS established minimum levels of achievement, e.g. distance from railroads, waterways, and rugged terrain. In addition, considerations relating to public opinion and priorities were included. Examples of such considerations are exclusions of areas of scenic beauty or unusual ecological character which have not been designated as legally protected areas.

Once screening criteria were specified, those parts of the study area where a criterion was satisfied were identified and plotted on an appropriate map. Overlay techniques were used to produce composite maps which specified areas meeting all the

TABLE 1. EXAMPLES OF CRITERIA USED IN SCREENING PROCESS

Issue	Consideration	Measure	Criteria for Inclusion
Health and Safety	Radiation exposure	Distance from populated areas	Areas > 3 mi from populated places > 2500 Areas > 1 mi from populated places < 2500
	Flooding	Height above nearest water source	Area must be above primary floodplain
	Surface faulting	Distance from fault	Areas > 5 mi from capable or unclassified faults > 12 miles in length
Environmental Effects	Thermal pollution	Average low flood	Rivers or reservoirs yielding 7-day-average, 10-year-frequency low flow > 50 cfs
	Sensitive or protected environments	Location with respect to ecological areas	Areas outside of designated protected ecological areas
Socioeconomic Effects	Tourism and recreation	Location with respect to designated scenic and recreational areas	Areas outside of designated scenic and recreational areas
System Cost and Reliability	Routine and emergency water supply and source characteristics	Cost of cooling water acquisition	Rivers or reservoirs yielding 7-day-average, ten-year-frequency low flow > 50 cfs
		Cost of pumping water	Areas < 10 mi from water supply Areas < 800 ft above water supply
	Delivery of major plant components	Cost of providing access for major plant components	Areas within 25 mi of navigable waterways

criteria. A field reconnaissance team comprised of experienced engineers, geologists, and environmental scientists visited those areas meeting all the screening criteria. Based on their observations plus published information, these experts identified nine candidate sites for further consideration. The subsequent evaluation of these sites using decision analysis is the main topic of this paper.

Before proceeding, an important remark concerning the screening process is in order. A big assumption is implicitly made when we include or exclude areas merely because they fall just under or over a cut-off level on <u>one</u> criterion. In reality, there is no sharp distinction, and utilizing this approach may disregard potential areas that are fine on several criteria but just barely fail one or two. However, such an approach provides a mechanism of rapidly focussing attention on candidate areas which have higher probabilities of containing acceptable potential sites. We consider the advantages (particularly in terms of time) of applying screening criteria to override the disadvantage of possibly disregarding some candidate areas.

Another point to keep in mind is that screening criteria may change with time; they depend on social, political, technological, and financial conditions. Future siting efforts may need to use different and/or additional criteria as conditions change.

2. <u>Establishing the Objectives and Measures of Effectiveness</u>

To help in identifying those characteristics that would differentiate the appropriateness of locating a nuclear power facility at one site relative to another, detailed descriptions of the sites were developed. The information gathered included the area, location, present use, and ownership of the site; the quality and quantity of water available and location relative to this source; details of the natural factors including geology, topography, flooding potential, and volcanic considerations; population in the vicinity; vegetation and wildlife in the area; fish in the streams; access to various transportation modes for construction and operation of the facility; existence of a local work force and catalog of potential socioeconomic effects of the construction phase, and so on. As a result of this plus information gathered during the screening process, approximately thirty potential objectives with associated attributes for evaluating these particular sites were identified.

It was unlikely that each of these would be significant in the evaluation process. Hence, each one was qualitatively examined (and in some cases, preliminarily quantitatively examined) to determine the reasonableness of keeping it in the evaluation process. Three general concepts were used for this:

(1) The significance of the impact in terms of an attribute in relation to impacts as measured by other attributes. For example, the annualized capital cost of a nuclear power plant is in the range of 200 to 300 million dollars for the candidate sites and the annual revenue loss from adverse effects of plant operation on fish is in the range of 0 to 500 thousand dollars. Under these conditions, the contribution of the latter to the relative preferences of the sites could be neglected.

(2) The site dependent variation of the impact in terms of an attribute. For instance, even though yearly manpower costs for plant operation may be significant, it might be omitted from consideration if these costs are nearly identical for all sites.

(3) The likelihood of occurrence of significant impacts as measured by an attribute. If one combines the magnitude of impact with the likelihood of its occurrence, the resulting "weighted" impact can be relatively insignificant. Consider, for example, adverse effects on crops could amount to as much as 9 million dollars per year. However, considering the near zero probabilities of such extreme losses, the "weighted" impact is in thousand of dollars rather than in million of dollars. Such an impact is considered insignificant.

The examination of possible objectives was evolutionary in nature. Preliminary estimates were made of possible impacts and their probabilities. Using this, some objectives were disregarded. Estimates of the remaining impacts were updated on the basis of field visits and a few more objectives discarded. Based on this process, the list of attributes in Table 2 were generated for evaluating candidate sites.

For each of the attributes, a measurement index was established and ranges of possible impact determined. The attributes can be grouped into two classes: those which have an objective scale and those which have a subjective index. An 'objective' scale is one for which the basic measure is quantified. Each point on such a scale is clearly specified.

Table 2. ATTRIBUTES AND RANGES USED IN EVALUATING THE CANDIDATE SITES

Issue	Attribute	Range Worst	Range Best
HEALTH AND SAFETY	X_1: Site Population Factor	0.20	0
ENVIRONMENTAL EFFECTS	X_2: Loss of Salmonids	100% of 100,000 fish	0
	X_3: Biological Impacts at Site	(Subjective scale described in Table 3)	
	X_5: Length of Intertie (to 500 kV system) through environmentally sensitive areas	50 miles	0
SOCIOECONOMIC EFFECTS	X_4: Socioeconomic Impact	(Subjective scale described in Table 4)	
SYSTEM COST	X_6: Annual Differential Cost Between Sites (1985 dollars, 30 year plant life)	$40,000,000	0

For example, attribute X_6 has an objective scale since it is quantitatively defined as costs in terms of dollars. The attributes measured with objective scales were X_1, site population factor, X_2, impact on salmonids, X_5, environmental impact of transmission intertie, and X_6, annual differential site cost. The levels of X_3, biological impact, and X_4, socioeconomic impact, were represented on subjective scales for which a number of specific points were qualitatively defined. A level of impact could occur in the interval between points on the scale; however, only the specific points were clearly defined. The definition of points on the scales was made by describing levels of the various components of the attribute. This will become clearer with what follows.

2.1 Clarifying the Attributes

Attribute X_1, the site population factor, is an index developed by the U.S. Atomic Energy Commission to indicate the relative human radiational hazard associated with a nuclear facility. The site population factor at a location L, denoted SPF(L), is defined by

$$SPF(L) = \frac{\sum_{r=1}^{50} P(r)r^{-2}}{\sum_{r=1}^{50} Q(r)r^{-2}}. \qquad (1)$$

where r is miles from site L, P(r) is the population living between r-1 and r miles of L, and Q(r) is the population that would live between r-1 and r miles of L if there were a uniform density of 1000 people per square mile. The r^{-2} is meant to account for the decrease in radiation exposure hazard as a function of distance. The purpose of the denominator in (1) is to allow one to interpret a SPF = 0.1, for example, as equivalent to a uniform distribution of 100 (i.e. 0.1 times 1000) people per square mile within 50 miles of the site.

Two separate indices were required to adequately measure the salmonid impact. These are the percent of fish lost in a stream and the number of fish in the stream. The reason for this, rather than simply using the number of fish lost is that the geneology of the salmonid in each stream is distinct. Therefore the loss of 2000 fish in a stream of 2000 is a bigger loss than 2000 fish in a stream of 50,000. For the Columbia River (over 350,000 salmonid), only the number lost is important since it is virtually impossible that a large percentage of these fish affected by a specific nuclear power plant and because the fish in the Columbia are endogenous to several different streams which flow into the Columbia.

Because attributes X_3 and X_4 were meant to capture many detailed possible impacts, it was necessary to develop subjective indices for each of them. The subjective index for biological impacts shown in Table 3 was developed by two experienced ecologists on the study team. Three main features captured by this scale are native timber or sagebrush communities, habitants of rare or endangered species, and productive wetlands.

The subjective index for socioeconomic impact, attribute X_4, was constructed by a sociologist/planner associated with the study team. The scale includes the implications on the public debt, social and cultural institutions, municipal

Table 3. SUBJECTIVE SCALE FOR BIOLOGICAL IMPACTS AT THE SITE

SCALE VALUE	LEVEL OF IMPACT
0	Complete loss of 1.0 sq mi of land which is entirely in agricultural use or is entirely urbanized; no loss of any "native" biological communities.
1	Complete loss of 1.0 sq mi of primarily (75%) agricultural habitat with loss of 25% of second-growth; no measurable loss of wetland or endangered species habitat.
2	Complete loss of 1.0 sq mi of land which is 50% farmed and 50% disturbed in some other way (e.g., logged or new second-growth); no measurable loss of wetland or endangered species habitat.
3	Complete loss of 1.0 sq mi of recently disturbed (e.g., logged, plowed) habitat plus disturbance to surrounding previously disturbed habitat within 1.0 mi of site border; or 15% loss of wetlands and/or endangered species.
4	Complete loss of 1.0 sq mi of land which is 50% farmed (or otherwise disturbed) and 50% mature second growth or other community; 15% loss of wetlands and/or endangered species.
5	Complete loss of 1.0 sq mi of land which is primarily (75%) undisturbed mature "desert" community; or 15% loss of wetlands and/or endangered species habitat.
6	Complete loss of 1.0 sq mi of mature second-growth (but not virgin) forest community; or 50% loss of big game and upland game birds; or 50% loss of local wetlands and local endangered species habitat.
7	Complete loss of 1.0 sq mi of mature community or 90% loss of local productive wetlands and local endangered species habitat.
8	Complete loss of 1.0 sq mi of mature, virgin forest and/or local wetlands and/or local endangered species habitat.

Note: This is a qualitative scale of potential short and long-term impacts which could result from the construction and operation of a power plant on a site. The impacts range from "0" for no impact to "8" for maximum impact. Site visits and general reconnaissance showed that the biologically important characteristics (aside from aquatic resources) of the regions are:

- virgin or large, mature second-growth stands of timber or "undisturbed" sagebrush communities.
- known or potential habitat of endangered species.
- wetland areas (though most are small and are comprised of small swamps).

services, and local authority due to the construction and operation of the nuclear facility. The idea of such a scale is to identify a number of impact levels which are clearly articulated. In evaluating any specific site, one states the likelihood the true impact will be between any particular adjacent pair of impact levels defined in Table 4.

The length of the transmission intertie line running through environmentally sensitive areas is measured by attribute X_5 in miles. Attribute X_6 is the annual differential cost between sites in terms of 1985 dollars assuming a 30 year plant life. The discount rate used was 8.4 percent. Costs such as the major plant components are not included in attribute X_6 since these would be the same for all sites. The differential is calculated relative to the lowest cost site for which the 'differential cost' is set at zero.

3. Determining the Preference Structure

The position taken in determining the preference structure was that Woodward-Clyde Consultants would take the role as the decision-maker for WPPSS. Other points of view were considered by conducting sensitivity analyses. It was decided that for each attribute the utility function would be assessed for the most knowledgeable members of the team (i.e. the "experts"). The tradeoff constants would be jointly assessed by key members of the project team on the basis of their perception of the WPPSS point of view.

The process of determining the utility function can be broken into four steps:

Table 4. SUBJECTIVE SCALE FOR SOCIOECONOMIC IMPACTS

SCALE VALUE	LEVEL OF IMPACT
0	Metropolitan region, population 100,000. No significant impact.
1	Semiremote town, population 250. Self-contained company town is built at the site. As many as half of the plant construction force continue to commute from other areas. Some permanent operating personnel continue to commute. Cultural institutions are overloaded, very little change in the social order. Public debt outstrips revenues by less than six months over previous levels.
2	Remote town, population 250. Self-contained company town is built at the site. Most of the work force moves into company town. Most permanent operating personnel begin to assimilate into the community. Cultural institutions are impacted, significant changes take place in the social order. Growth of the tax base due to permanent operating personnel is orderly, but public debt outstrips revenues by more than six months, less than a year, over previous levels.
3	Semiremote city, population 25,000. About half of the plant construction force immigrates and seeks housing in the city. Most of new growth is in mobile homes. All city systems (law enforcement, sewer, water, schools, code enforcement) are taxed to the limit. Outside financial assistance is required. Cultural institutions are impacted, social order is slightly altered. Permanent operating personnel easily assimilate into community, tax base grows significantly, but lags in assessment, planning, and capital improvements construction produce a boom-town atmosphere. Public debt outstrips revenue growth by one to two years.

Table 4. (continued)

4	Remote city, population 25,000. Most workers locate in the city. All city systems are impacted. Land-use patterns are permanently disrupted. Growth outstrips planning activities and regulatory systems. Assessment falls behind. Revenue-debt lag is greater than two years.
5	Semiremote town, population 1,500. Many workers commute from outside areas. Permanent operating personnel and some workers seek housing in the city. New growth is predominantly mobile homes, with much permanent construction as well. New construction in service establishments and expansion of commercial facilities. Town has basic planning and land-use regulatory functions established, but these are overwhelmed by magnitude of growth. Assessment and enforcement lag two years or more; community facilities are impacted. Land-use patterns are permanently disrupted. Cultural institutions are severely impacted; social order is permanently altered. Much growth occurs in unincorporated areas, untaxable by town.
6	Remote town, population 1,500. Most workers try to locate in or near the town. Most growth in unincorporated areas. City systems are impacted; lack of regulation in unincorporated areas impacts rural development patterns, which in turn severely impacts the cultural institutions and social order of the small town. Tax base cannot expand to meet demand for capital improvements.
7	Remote city, population 10,000. Severe impact due to attractiveness to large numbers of plant workers. Basic services and established planning, assessment, and enforcement procedures are sufficient to provide the framework for rapid growth, but insufficient to handle the magnitude of such growth. Massive imbalances in long-term city finances occur, leading to several-year lags in revenues to debts. City size and bonding experience probably do not permit revenue financing, so the "bust" portion of the cycle is virtually inescapable.

(1) determining the general preference structure,

(2) assessing the single-attribute utility functions,

(3) evaluating the scaling constants,

(4) specifying the utility function.

Before illustrating our procedure, let us define x_i to be a specific amount of attribute X_i, $i = 1,2,\ldots,6$, so for instance x_6 may be eight million dollars, a specific amount of the differential cost attribute X_6. We want to determine the utility function $u(x_1,x_2,\ldots,x_6)$ over the six attributes of Table 2.

3.1 Determining the General Preference Structure

The first important step in selecting the form of the utility function involves investigating the reasonableness of preferential independence and utility independence conditions. Provided certain of these conditions are appropriate, the six-attribute utility function is expressible in a simple functional form of the six one-attribute utility functions. Let us illustrate with examples how one checks for such conditions.

Two attributes $\{X_i,X_j\}$ are preferentially independent of the other attributes of the preference order for (x_i,x_j) combinations does not depend on fixed levels of the other attributes. Consider differential cost X_6 and impact on salmonids X_2. We first asked ourselves what level of X_6 would make (x_6, 100% of 100,000 salmon lost) indifferent to (40 million, 0%) given that the other four attributes were at their best levels. The answer obtained was 20 million. We then examined the same question with the other attributes at their worst levels. We still felt an appropriate response for x_6 was 20 million. By considering other pairs of indifferent points, we established that the tradeoffs between $\{X_6, X_2\}$ would be independent of the level of the other attributes. Since the project team had been exposed to concepts of preferential and utility independence, they were in a position to state after an initial series of questions of the above type over the attributes that in general the tradeoffs between any two attributes did not depend on the levels of the other attributes. Thus each pair of attributes was considered preferentially independent of the others.

Attribute X_i is defined to be utility independent of the other attributes if the preference order for lotteries on X_i does not depend on fixed levels of the other attributes. This implies the conditional utility functions over X_i are the same regardless of the levels of the other attributes.

To establish whether X_3 (biological impact) was utility independent of the other attributes, we assessed the conditional utility function for X_3 assuming the other attributes are at fixed levels. We then reassessed the conditional utility function with the other attributes fixed at different levels. The assessment was conducted using the techniques described in the subsequent section. It was decided that the relative preference for lotteries involving uncertainty only in the consequences for X_3 did not depend on the other attributes. Thus, attribute X_3 was utility independent of the other attributes.

The above independence conditions which were deemed appropriate allowed us to use the following in structuring the utility function.

Theorem. Given attributes $\{X_1, X_2, \ldots, X_6\}$, if for some X_j, $\{X_i, X_j\}$ is preferentially independent of the other attributes for all $i \neq j$, and X_j is utility independent of the other attributes, then either

$$u(\underline{x}) = \sum_{i=1}^{6} k_i u_i(x_i) \quad , \tag{2}$$

or

$$1 + ku(\underline{x}) = \prod_{i=1}^{6} [1 + kk_i u_i(x_i)] \quad , \tag{3}$$

where u and the u_i are utility functions scaled from zero to one, the k_i's are scaling constants with $0 < k_i < 1$, and $k > -1$ is a scaling constant.

Equation (2) is the additive utility function and (3) is the multiplicative utility function. More details about these, including suggestions for assessment, are found in Keeney [1]. The result says that the multiattribute utility function can be completely defined knowing the individual attribute utility functions u_i and the value of the scaling constants k_i. For reference, the multiplicative utility function turned out to be the appropriate one for this study as we will later show. Although only one utility independence assumption is necessary to invoke the above theorem, this condition was verified for all the other attributes as a consistency check.

3.2 Assessing the Single-Attribute Utility Functions

The assessment of the utility functions with objective indices--that is u_1, u_2, u_5, and u_6--was done using the standard 50-50 lottery technique discussed in Keeney and Raiffa [2]. For instance, by considering preferences between a series of specified levels of X_6 and a 50-50 lottery yielding either a 0 or 40 million dollar differential cost, each with probability 0.5, it was decided that WPPSS would be indifferent for a specified level of 22 million dollars. Thus, since utility is a measure of preference, the lottery and 22 million must have equal expected utilities. Consistent with (3), we set the origin and scale of u_6 by letting the utility of the worst point 40 (see Table 2) equal to zero and the utility of the best point 0 equal to 1. Equating expected utilities leads us to $u_6(22) = 0.5$, which gives us another point on the utility curve. From this, the exponential utility function in Figure 1H was evaluated. By examining the implications of this utility function for additional choice situations, it was decided that it was appropriate for evaluating the various sites.

For the subjective scales, a modified assessment technique was required. In order to achieve meaningful utility assessments for these attributes, only the defined points on the scales were used. For instance, with biological impact, the biologist member of the team was asked "For what probability p is a biological impact of magnitude 4 (see Table 3) equivalent to a lottery yielding a p chance at level 0 and a (1-p) chance at level 8?" By trying several values of p, we found p = 0.6 as the indifference value. Consistent with (3), we set $u_3(0) = 1$ and $u_3(8) = 0$ from which it followed that $u_3(4) = 0.6$. Questioning continued in this manner until the utility of each of the defined points on the subjective scale was fixed. A number of consistency checks were used which resulted in some changes to the original assessments.

The adjusted utility functions assessed for each individual attribute are shown in Figure 1. Details of the assessment of the utility functions u_2 and u_3 are given in Keeney and Robilliard [3]. The assessment of u_2 was particularly interesting because of the two separate measures -- the numbers and the percentage lost -- required to adequately describe the possible impact on salmonids. Let us define Y as the number of salmonid in a stream in thousands and Z as the percent lost Then attribute X_2 is a composite of Y and Z so we will define $x_2 \equiv (y,z)$. If a stream has less than 100,000 salmonids, a utility function u_2 was found to be

$$u_2(x_2) \equiv u_2(y,z) = u_Z(z) + u_Y(y) - u_Z(z)u_Y(y) \quad , \; y \leqq 100 \quad ,$$

where u_Y and u_Z are illustrated in Figures 1B and 1C. For streams with greater than 300,000 salmonids, an appropriate utility function was

$$u_2(x_2) \equiv u_2(y,z) = 0.568 + 0.432 \; u_Q(q) \quad , \quad y \geqq 300 \quad ,$$

where Q, defined as the number of salmonid lost, is Y times Z, and u_Q is shown in Figure 1D. There are no streams with between 100,000 and 300,000 salmonids in the areas involved in our study so the discontinuity in u_2 between y equal 100 and 300 is not a difficulty.

3.3 Evaluating the Scaling Constants

The scaling constants were assessed by five members of

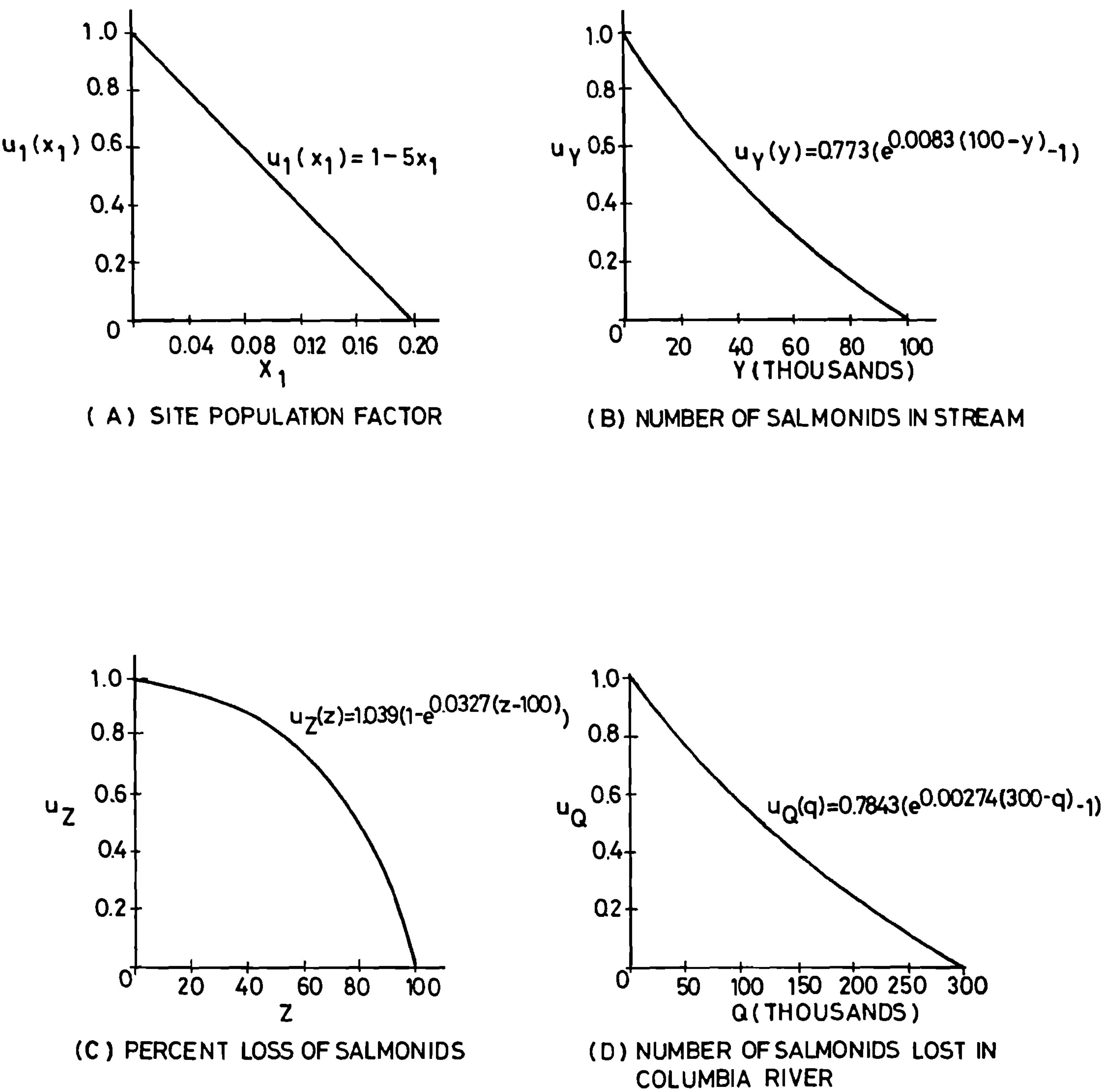
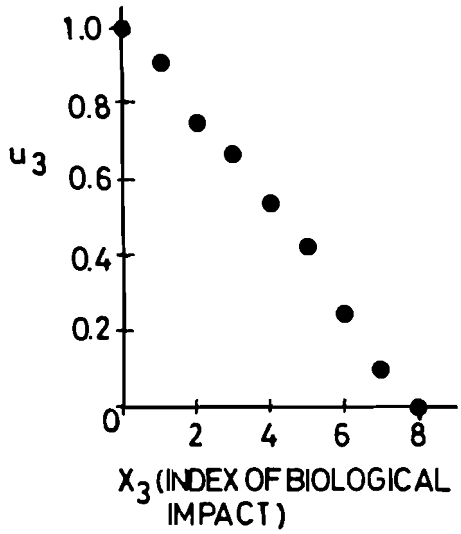
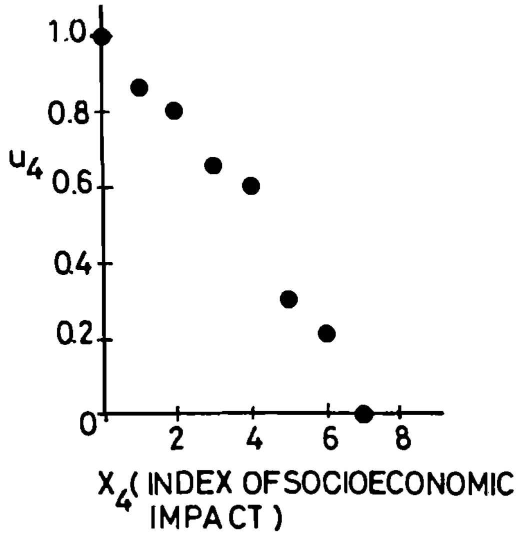


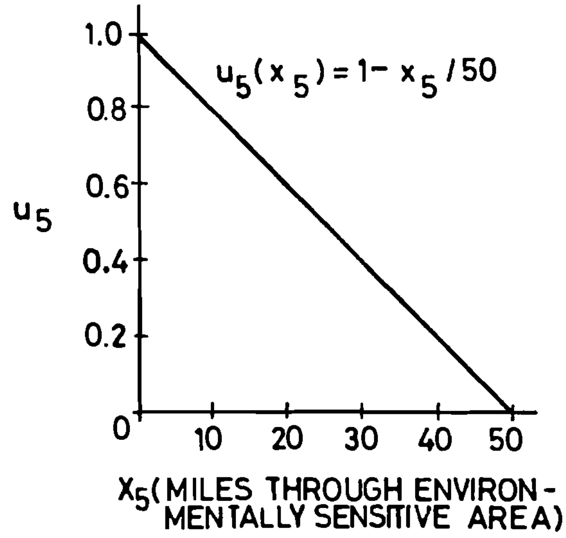
FIGURE 1. THE SINGLE-ATTRIBUTE UTILITY FUNCTIONS.



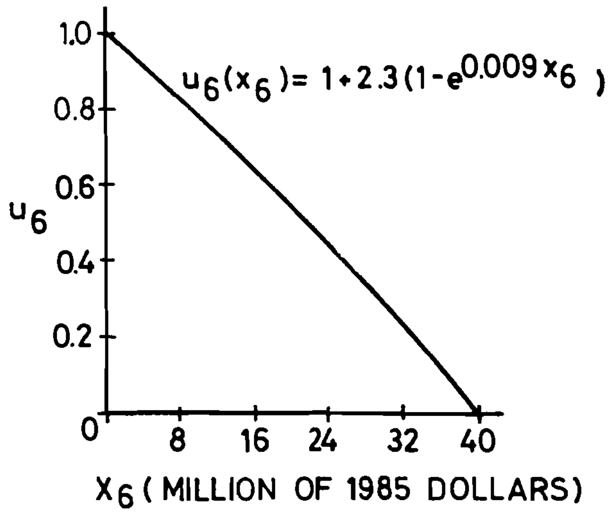
(E) BIOLOGICAL IMPACT AT SITE



(F) SOCIOECONOMIC IMPACT



(G) ENVIRONMENTAL IMPACT OF INTERTIE



(H) DIFFERENTIAL SYSTEM COSTS

FIGURE 1. THE SINGLE-ATTRIBUTE UTILITY FUNCTIONS.

the project team in two steps. The first consists of ranking the ranges of attributes in order of importance and the second involves quantifying the magnitude of each k_i.

To establish the ranking of the k_i's, the first question asked was: "Given that all six attributes are at their worst level as defined in Table 2, which attribute would you most like to have at its best level assuming that the other five attributes remain at their worst levels?" The answer to this question identifies that attribute whose k_i value should be the largest. A similar question was repeated considering only the remaining five attributes and this process was repeated until the complete ranking of the k_i's was determined.

It was the consensus judgment that if all attributes were at their worst levels and only one attribute could be moved to its best level, the single attribute which should be moved was attribute X_6, annual differential site cost. This represents changing annual differential site costs from \$40 million per year for 30 years to \$0 per year. It should be noted that if the worst value of the differential site cost were smaller than \$40 million, some other attribute might have been moved first. Of the remaining five attributes, the site population factor X_1 was most desired at its best rather than worst level.

The remaining order in which the attributes were moved from their worst to their best levels was X_2, X_4, X_5, and X_3. This ordering implies

$$k_6 > k_1 > k_2 > k_4 > k_5 > k_3 \quad . \qquad (4)$$

The next step was to establish the actual values of scaling constants. This was accomplished by assessing specific tradeoffs between attributes. The tradeoffs measure how much one is willing to give up on one attribute to gain a specific amount on another attribute. For example, the tradeoff between attributes X_6 and X_1 was established from the following considerations:

(1) Based on the relative rankings, k_6 is greater than k_2. This implies that if site A has an annual differential site cost of $40 million and a site population factor of 0, and site B has an annual differential site cost of $0 and a site population factor of 0.20, site B should be preferred given that all other attributes are fixed at the same levels for both sites A and B.

(2) Consider a site C with a SPF = 0.2 and unspecified annual differential site cost. At what value of annual differential site cost would you be indifferent in choosing between site C and site A, which has an annual differential site cost of $40 million and a SPF = 0, given again all other attributes are fixed at identical levels for both sites A and C?

The project team's response was that if site C had an annual differential site cost of $5 million, it would be indifferent to site A. This implies that the project team was willing to incur an increase in annual differential site cost from $5 to $40 million in order to move a site from a sparsely populated area (SPF = 0.20) to an uninhabited area (SPF = 0).

This assessed tradeoff is represented pictorially in Figure 2A.

The remaining tradeoffs assessed for other pairs of attributes are also shown in Figure 2.

The implications of these tradeoffs are:

- One is willing to incur an increase in annual differential site cost from $20 to $40 million in order to save all the salmonids in a river of 100,000 salmonids.
- One is willing to incur an increase in annual differential site cost from $31 to $40 million in order to eliminate completely the severe socioeconomic impact of a full boom-bust cycle (i.e. change level 7 on the subjective scale of Table 4 to level 0).
- One is willing to incur an increase in annual differential site cost from $35 to $40 million in order to avoid laying the new transmission intertie lines through 50 miles of environmentally sensitive areas.
- One is willing to incur an increase in annual differential site cost from $39 to $40 million in order to eliminate completely an extreme biological impact over one square mile (i.e. change level 8 on the subjective scale of Table 3 to level 0).

In order to check the consistency of the tradeoffs, several other tradeoffs not involving cost were empirically established. These are shown in the insets of Figure 2. They proved to be very consistent with the original assessments. The implications of these tradeoffs are given below:

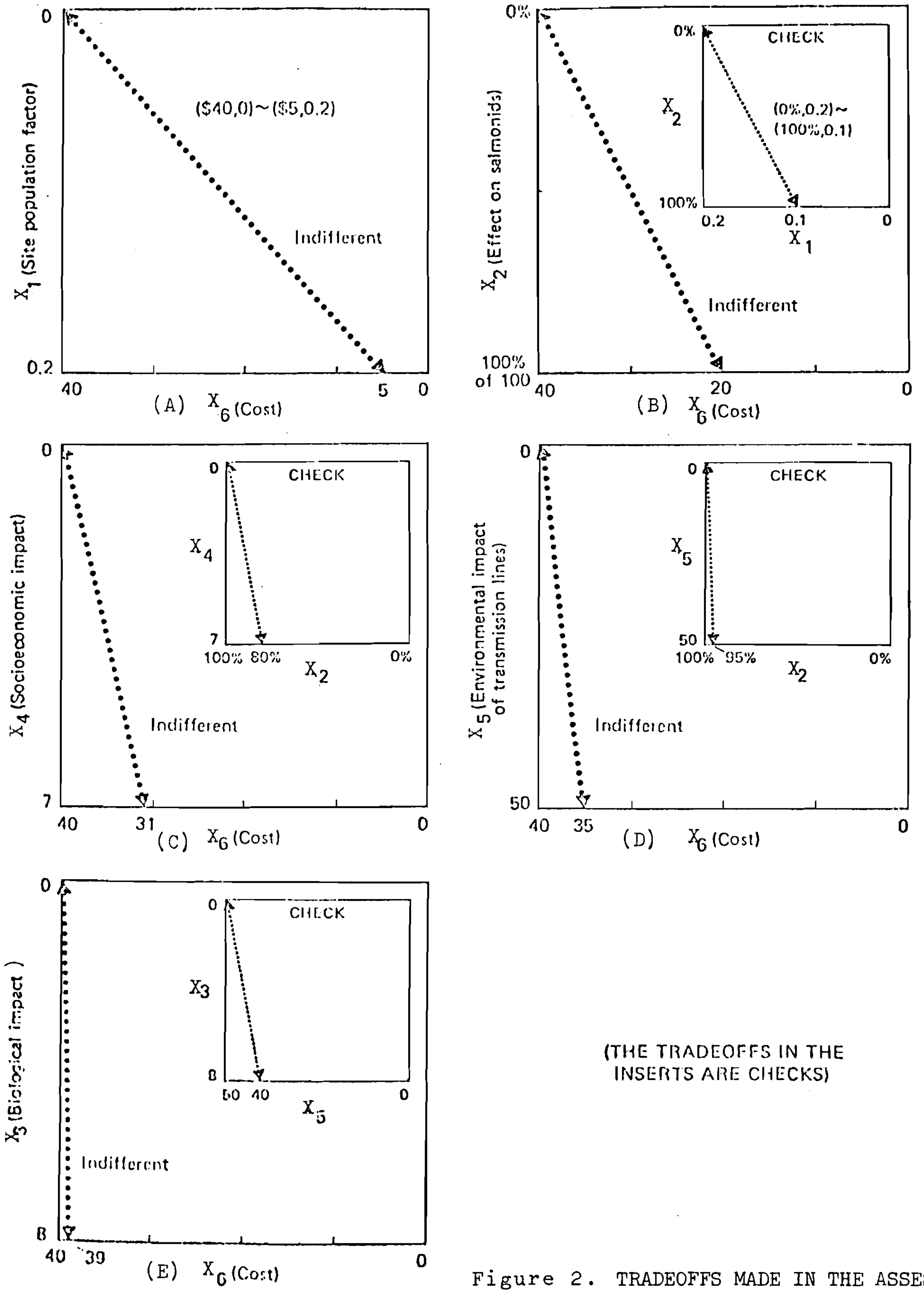


Figure 2. TRADEOFFS MADE IN THE ASSESSMENT OF SCALING CONSTANTS

- One is willing to accept a loss of all salmonids in a river of 100,000 in order to move the site from sparsely populated area (SPF of 0.2) to a less populated area (SPF of 0.1).
- One is willing to accept an extreme socioeconomic impact (7 on the scale) instead of no impact (0 on the scale) in order to save 20% of the salmonids in a river of 100,000 fish.
- One is willing to accept disturbance of 50 miles (instead of 0 miles) of environmentally sensitive area due to new transmission intertie lines in order to save 5% of the salmonids in a river of 100,000 fish.
- One is willing to accept an extreme biological impact over one square mile (8 on the scale) instead of no impact (0 on the scale) in order to reduce the environmentally sensitive area being disturbed due to new transmission intertie lines from 50 to 40 miles.

The next step in the assessment of scaling constants involved determining a probability p such that option A, a consequence with zero differential cost and all other attributes at the worst levels of Table 2, and option B, a lottery yielding either all attributes at their best levels, with probability p, or all at their worst levels, with probability 1-p, are indifferent. After considering several levels of p, the group's response converged to p = 0.4. Such a response implies, for instance,

(a) if there is a choice between a lottery involving 50% chance of getting all the attributes at their best levels and 50% chance of getting them at the worst levels ($p = 0.5$); and a sure outcome of getting best cost level (0 differential cost) and worst levels of all the other attributes, the group would choose the lottery;

(b) if the chances given above now change to 30% of getting all attributes at best levels and 70% of getting all at their worst levels ($p = 0.30$), the group would choose the sure outcome of getting cost best and all others worst.

3.4 Specifying the Utility Function

By definition, when all attributes are at their best levels, $u = 1.0$, and when all attributes are at their worst levels, $u = 0.0$. Therefore, the expected utility of the lottery above is

$$p(1.0) + (1-p)(0.0) = p \quad .$$

Since indifference between the two choices above occurred when $p = 0.40$, the expected utilities must be equal. From (3), the utility of the sure consequence is k_6, so

$$k_6 = p = 0.40 \quad . \tag{5}$$

The assessed tradeoffs between cost and each of the other attributes are used to express all other scaling constants in terms of k_6. Since k_6 is known, the other k_i values can be determined.

Consider the calculation of scaling constant k_1, associated with attribute X_1, the site population factor. By definition, the indifference points of the tradeoff assessments must have equal expected utilities. Thus, from the indifference point of the assessed tradeoff in Figure 2A, we know that

$$u(x_6 = \$40\ , x_1 = 0) = u(x_6 = \$5\ , x_1 = 0.2) \quad , \qquad (6)$$

where we have not bothered to specify levels of the other attributes. However, because of the preferential independence conditions previously verified, we know that (6) is valid for all values of the attributes X_2, X_3, X_4, and X_5. In particular, assume that the other attributes are at their worst levels such that $u_2(x_2) = u_3(x_3) = u_4(x_4) = u_5(x_5) = 0$. Then using (3), the utilities in (6) are equated by

$$1 + kk_1 = 1 + kk_6(.895)$$

which simplifies to

$$k_1 = .895\ k_6 \quad .$$

Since we know that $k_6 = 0.40$,

$$k_1 = .895(0.40) = 0.358 \quad .$$

The remaining tradeoff constants can be calculated in an analogous manner yielding the set

$$k_6 = .400,\ k_1 = .358,\ k_2 = .218,\ k_4 = .104,\ k_5 = .059,\ k_3 = .013 \quad . \qquad (8)$$

The constant k is calculated from (3) given the k_i values. If (3) is evaluated with all attributes at their best values (i.e., all utilities are 1.0.), then k is the solution to

$$1 + k = \prod_{i=1}^{6} (1 + kk_i) \quad , \qquad -1 < k \neq 0 \quad .$$

Using (8), the unknown k is calculated to be

$$k = -0.325 \quad . \tag{9}$$

The multiattribute utility function (3) is completely specified by the k_i's in (8), the k in (9), and the single-attribute utility functions in Figure 1.

4. The Probability Assessments

The consequences associated with site development at each site can be characterized by the levels which the six attributes of Table 2 would assume should a power plant be constructed on that site. To account for the uncertainty associated with estimating the levels of the attributes, probabilistic estimates were made.

4.1 Form of Probability Assessments

The estimation of the possible impacts at each site was accomplished in three forms. Attribute X_1, site population factor, and attribute X_5, length of power transmission intertie passing through environmentally sensitive areas, were assumed to be deterministic, as each was known with a high degree of certainty. For attributes X_3 and X_4, measured by subjective indices, the probabilities that the impact would fall within ranges specified by two adjacent impact levels were assessed. The probabilistic estimates for attributes X_2 and X_6 were quantified by assessing the parameters--the mean and variance--for a normal probability distribution.

Assessing the probabilities over each attribute individually implicitly assumes that probabilistic independence existed between the attributes. After our initial assessments, the project team discussed this assumption in detail. We concluded that it was reasonable to assume that conditional on any alternative, the probabilities associated with the level of any attribute were independent of the level of any other attribute. Thus, for example, the probability of various levels of biological impact was independent of the level of impact on salmonids given a particular site.

4.2 The Assessments for Each Attribute

The probabilistic assessments for each site were based on existing information, site visits, and data developed during the study. Each attribute for each site was assessed by specialists in each of the relevant disciplines. Thus, the assessments represent the professional judgment of individuals based on their expertise and on all information currently available concerning the candidate sites. The resulting data is illustrated in Table 5, where we have labelled sites S1 through S9. Let us briefly mention how this was done for each attribute.

Table 5. PROBABILITY ASSESSMENTS OF ATTRIBUTES BY SITE

Attribute		S1	S2	S3	S4	S5	S6	S7	S8	S9
X_1 (CDF)		0.057	0.04	0.025	0.048	0.044	0.023	0.052	0.011	0.015
X_2 (loss of salmonids)	$\bar{x}_2$	8	8	8	15	15	15	15	4.3	3.65
	$\sigma^2_{x_2}$	16	16	16	56.25	56.25	56.25	56.25	4.62	3.33
	y	75	75	75	5.5	17	5	3	430	365
X_3 (biological impact at site)		Range Prob.	Range Prob.	Range Prob.	Range Prob.	Range Prob.	Range Prob.	Range Prob.	Range Prob.	Range Prob.
		1-2 0.9	1-2 0.9	1-2 0.8	2-3 0.2	3-4 0.2	3-4 0.2	1-2 0.3	0-1 0.1	0-1 0.7
		2-3 0.1	2-3 0.1	2-3 0.2	3-4 0.8	4-5 0.5	4-5 0.5	2-3 0.6	1-2 0.5	1-2 0.3
						5-6 0.3	5-6 0.3	3-4 0.1	2-3 0.4	
X_4 (socioeconomic impact)		1-2 0.2	1-2 0.25	1-2 0.3	2-3 0.2	1-2 0.2	2-3 0.1	2-3 0.2	2-3 0.1	1-2 0.05
		2-3 0.65	2-3 0.55	2-3 0.45	3-4 0.5	2-3 0.45	3-4 0.55	3-4 0.5	3-4 0.4	2-3 0.6
		3-4 0.15	3-4 0.1	3-4 0.15	4-5 0.3	3-4 0.2	4-5 0.3	4-5 0.2	4-5 0.4	3-4 0.2
			4-5 0.1	4-5 0.1		4-5 0.15	5-6 0.05	5-6 0.1	5-6 0.1	4-5 0.15
X_5 (length of intertie through sensitive environments, miles)		1	1	7	6	12	1	0	0	0
X_6 (differential cost \$ 10^6/year, 1985 dollars)	$\bar{x}_6$	2.035	0 4.929[c]	1.535 15.343[c]	1.933 7.613[c]	12.347	17.713	4.834	10.936	11.423
	$\sigma^2_{x_6}$	0.259	0 1.518[c]	0.147 14.713[c]	0.234 3.622[c]	9.528	19.609	1.461	7.475	8.155

Note: X_1 and X_5 were treated deterministically, normal distributions were used for X_2 and X_6.

[c] With additional costs associated with elimination of possible liquefaction potential

The Site Population Factor. To calculate the SPF, the number of people residing in concentric rings with centers at the candidate sites was needed. Since people residing close to the candidate sites receive more weight in the SPF calculations, it was considered necessary to obtain more accurate counts in this region. Therefore, using detailed maps, houses within five miles of the candidate sites were counted and an average of three people per house was assumed.

For distances greater than five miles from the sites, maps were used to identify cities. The population of each was obtained from census data. However, the populations of towns and cities are generally given for the corporate area only. The unincorporated population in each county was assumed to reside near the incorporated areas rather than, for instance, uniformly over the county. Therefore the town and city populations were proportionally scaled up to equal the total population for each county. These scaled up estimates for each city were used when calculating SPF.

Special consideration was also necessary when a corporate area fell on a ring boundary. If the population was less than 100,000, it was assumed that all the population resided in the ring closest to the site. This assumption will yield a higher SPF than actually exists. For cities with a population greater than 100,000, it was assumed that the population was evenly distributed within the city. In these cases, the proportion of the area within each ring was used to estimate the population within that ring.

Impact on Salmonids. The assessment of the reduction in the annual spawning escapement of salmonids was based on losses associated with construction of the cooling water intake structure, intake and discharge of cooling water, and storage impoundments for cooling water. The impact on salmonids is dependent on the proportion of the river flow used for cooling water. Since the cooling water requirements remain approximately constant for all candidate sites, the impact is determined by the size and characteristics of the river supplying cooling water. The salmonids which could be entrained are those passing the intake along the edge of the river. To be conservative, it was assumed that the concentration of salmonids along the edges was higher than in the middle. The estimates of losses due to entrainment in Table 5 were made assuming the use of newly developed intake structures designed to minimize or virtually eliminate entrainment (i.e., Raney Well). The effect of construction of the intake structure and storage impounds would primarily result in loss of spawning and juvenile rearing areas.

Biological Impact at Site. The scale for assessing the biological impact at each candidate site was presented in Table 3. The ecologists were asked to assess the probabilities that the impact would fall between adjacent intervals on the scale. To help in thinking about this question, descriptions were developed for each site. A summary description of the existing biological characteristics of two sites is given below to indicate the idea.

S6 The site region consists of varying proportions of mature second-growth, logged areas, and some small agricultural areas. There are a few small swampy areas and nearby wetlands. There is a high likelihood that Columbia white-tailed deer may occupy the site or nearby environs.

S9 This area is primarily agricultural, mostly wheat and potatoes, with small pockets of sagebrush habitat. There are no wetlands or known endangered species habitats.

Socioeconomic Impact. A subjective evaluation was made of the likely socioeconomic effects of a nuclear plant to communities near each site and of the expected magnitude of these effects. The effects included rapid population growth, overloading of municipal service systems, impaction of cultural institutions, alternation of the social order, increased demand for capital improvements, changes in the tax base, impaction of municipal administrative services, alteration of land use patterns, and revenue lags in public financing of capital projects. These considerations are the primary components of what is commonly termed a "boom-bust" cycle. To make subjective probability assessments shown in Table 5 required a series of considerations.

First, for each candidate site, the percentage of the plant construction labor force likely to immigrate was estimated. This was superimposed over the existing characteristics of communities near each of the nine candidate sites. Existing characteristics of communities included: population size, travel time from site to labor supply, age of community, type of public financing for which the community is likely to be eligible (based primarily on size and age), size of the corporate area, role of the community in the region, and generalized land use patterns (used also to subjectively evaluate the tax base.) The major plant-related condition superimposed over the existing community characteristics was the presence or absence of a company town built at the site. No candidate sites were located within corporate limits, and the assumption was made that payments in lieu of taxes would not be made to any municipal corporation.

Environmental Impact of Transmission Intertie. The length of power transmission intertie passing through environmentally sensitive areas (i.e., land which was not clear cut, cultivated, or urbanized) was used as a proxy variable to measure adverse environmental impacts. This length was assessed from field visits to each of the sites. Since the values for this attribute were known with a high degree of certainty, this attribute was was treated as a deterministic variable.

Annual Differential Site Costs. The economic comparison does not include a detailed estimate of the total cost of a plant at each of the candidate sites, but is considered to be a representative evaluation of the differential costs of construction and plant operation associated with each site. Differential costs are measured relative to the least expensive site S2. The comparison was based on current (1975) bid prices which were escalated to a proposed bid date of 1980 (on-line date in 1985) using an 8.4 percent average annual rate of escalation. Allowances for contingencies, interest during construction, and bonding cost were included in the differential costs. The differential capital costs were converted to an annual cost expressed in 1985 dollars using an appropriate factor for cost of bonds and an estimated plant life. This non-escalatable annual cost plus the annual differential costs of operation formed the basis for the economic comparison of the sites. The cost estimates were developed using "standard power plant arrangements" at each of the candidate sites.

Site visits indicated that a potential for liquification of existing foundation materials under earthquake loading existed at sites S2, S3, and S4. Because the likelihood of liquifaction at these sites can not be ascertained without site-specific studies, two cost estimates were made for the sites; one if the elimination of liquefaction potential is not necessary, and one if it is found to be necessary. The method to eliminate the potential for liquefaction used to arrive at cost estimates was to remove the liquefiable foundation materials and replace them with suitable compacted fill. These additional costs were incorporated in the capital costs associated with site grading and are reflected in the annual differential site costs.

The primary cost estimates were average values. The uncertainty in these estimates was represented by a normal probability distribution, and it was assumed that the standard deviation was equal to one-fourth the mean values. Little data was available to justify this assumption so we were particularly careful to check the cost estimates in the sensitivity analysis of the next section.

5. Evaluating Sites and Sensitivity Analysis

Since the cost to eliminate liquefaction potential are significant and since site specific information could eliminate the uncertainty, it was considered appropriate to analyze the problem once including potential liquefaction costs and then excluding them. The results would provide guidance on whether it would be worth obtaining definitive information on liquefaction potential. For example, if the sites that are ranked high without considering liquefaction potential are ranked very low when considering liquefaction potential, then it may be appropriate to obtain site specific information.

A small computer program was developed for evaluating the sites and conducting sensitivity analyses. Because of the utility independence assumptions verified before selecting the utility function (3) and the assumption of probabilistic independence conditional on each alternative, it was appropriate to calculate certainty equivalents attribute by attribute for each of the alternatives. This gave us a six-attribute vector representing the 'equivalent certainty impact' of each site. These were examined for dominance. No strict dominance existed, but there were several cases of 'almost' dominance (e.g. one alternative preferred to another on all but one attribute.)

Thus, without introducing the full power of multiattribute utility, we were in position to specify a reasonable ranking of the sites. In particular, the least preferred sites were easily identifiable. We proceeded to the utility analysis.

5.1 Ranking Results Based on Best Estimates

The expected utility of each site was first calculated using the best estimates of all inputs for both the liquefaction and no liquefaction cases. This resulted in two preferential rankings of alternatives depending on whether or not liquefaction potential exists. Both the rankings and expected utilities indicate how much better one site is than another considering all six attributes. The differences in expected utilities for each site result from changes in all six attributes for the sites. However, it is easier to consider the significance of the difference in expected utility in terms of only one attribute. For ease in interpreting this significance, the differential cost of an 'equivalent' site with attributes X_1 through X_5 at their best levels is shown for each site. This equivalent site is one with the same expected utility as the real site to which it is associated. Note, for instance, that the differences between the sites ranked one and five for both the liquefaction and the no liquefaction cases are equivalent to approximately nine million 1985 dollar per year--a rather substantial amount.

TABLE 6. BEST ESTIMATE RANKING OF NINE CANDIDATE POWER PLANT SITES

Without Liquefaction Potential				With Liquefaction Potential			
Order	Site	Expected Utility	Differential Cost of "Equivalent" Site+	Order	Site	Expected Utility	Differential Cost of Equivalent Site+
1	S3	.921	10.85	1	S1	.894	14.60
2	S2	.920	10.98	2	*S2	.887	15.53
3	S1	.894	14.60	3	S7	.854	19.89
4	S4	.868	18.06	4	S5	.843	21.30
5	S7	.854	19.89	5	*S4	.827	23.35
6	S5	.843	21.30	6	*S3	.822	23.98
7	S9	.812	25.22	7	S9	.812	25.22
8	S8	.811	25.34	8	S8	.811	25.34
9	S6	.808	25.71	9	S6	.808	25.71

*Additional site grading costs associated with correction of possible liquefaction potential included in analysis.

+An equivalent site is one of equal utility with all attributes at their best levels except for costs (in millions of 1985 dollars per year).

5.2 Sensitivity Analysis

The purpose of the sensitivity analyses is to investigate how the ranking of the alternatives changes if the inputs to the decision analysis differ from the best estimate values. Sensitivity analyses were conducted both with and without costs associated with liquefaction potential. For each of these conditions, the sensitivity of the scaling constants in the multiattribute utility function and of certain changes in the possible consequences were examined.

Changes in the Scaling Constants. The best estimate values of the scaling constants k_i, $i = 1,2,\ldots,6$, are given by (8). In the sensitivity analysis, the value of each k_i was increased and then decreased as much as possible without changing the order of these k_i's. For example, k_1 was the second largest k_i value based on the best estimate values. The adjacent values were $k_6 = 0.400$ and $k_3 = 0.218$. Therefore, two sensitivity runs were performed to investigate the influence of k_1 values of 0.399 and 0.219, which represents the range that maintains the same order of the k_i's. The range for k_6 was varied from .358 (i.e. the value of k_1) to .500.

The analysis indicated the rankings of the sites remained essentially unchanged for all the changes in the k_i factors. Specifically, in the case where no liquefaction potential was assumed, there were no changes in the ordering of the best six sites. When liquefaction was assumed, there were a few changes between the sites ranked five and six depending on the specific changes in the k_i's. However, the sites ranked one through four were invariant in this case.

Changes of Selected Consequences. The sensitivity of the rankings in Table 6 to the estimates of the differential costs and salmonid impacts were investigated. Specifically, we separately investigated the implications of each of the following four changes in possible impacts: increases in differential site costs of 20% and 50%, a change in the coefficient of variation* of the normally distributed site costs from 25% to 50%, the unavailability of a scheme to prevent entrainment of salmonids at the cooling water inlets.

For the case including liquefaction potential, there were no changes in the ranking of the six best sites for any of the variations mentioned. Assuming no liquefaction potential, S2 replaced S3 as the best site for 20% and 50% increases in the costs. These were the only changes in the ranking of the best six sites of Table 6. In both cases, there were some changes in the rankings of the worst three sites.

6. Conclusions and Recommendations

The results of the ranking process indicate that six of the nine candidate sites can be identified as being superior to the other three under all reasonable variations of the preference structure and assessed consequences. The six sites are S1, S2, S3, S4, S5, and S7. Considering both the rankings

*An alternative way to state this assumption is that the standard deviation of site costs increases from 25% to 50% of the mean estimated costs.

(i.e., with and without liquefaction), the three sites recommended for detailed site specific evaluation are S2, S1, and S7. If liquefaction potential is studied first and found not to exist at S3 and S4, then the three sites recommended for site specific studies are S2, S3, and S4. In interpreting these recommendations, it should be noted that sites S1, S2, and S3 are located close to each other.

Site specific studies should concentrate on obtaining information to satisfy regulatory agency requirements. The most important of these are the geological, seismological, and geotechnical studies necessary to identify and classify lineaments and landslides. Additional studies to identify potential major environmental, socioeconomic, or cost impacts and to refine some of the cost data utilized in the ranking process should be conducted. Because of the site visits that have already been made, a lower order of efforts is required for these studies.

The sites were identified and ranked on the basis of criteria described in this paper. There are several factors which were not considered in this study but could have a significant bearing on the selection of a specific site. These include political and legal considerations, the necessity for geographic distribution of plants, the future requirements of multiple plants at a site, and the reliability of the transmission grid.

The ranking process was based on the judgments and preferences of the project team. It is recommended that further studies be conducted to include the preferences and judgments of members of WPPSS. It may also be desirable to include explicitly or indirectly the preferences and judgments of the general public.

The preferential ranking of the nine candidate sites is presented in Table 6. However, if the most preferred site is selected for construction, the next best site is not necessarily the second best site in the original ranking. This results because of the influence of the selected site on the desirability of the remaining sites. Procedures could be developed to rank the next best site after selecting one site from the nine considered.

Acknowledgements

Several members of the project team who contributed to the study deserve mention here. Among them are Gail Boyd, Steve James, Gordon Robilliard, Charles Hedges, Ashok Patwardhan, Dennis McCrumb, Don West, Ram Kulkarni, and Wayne Smith, all of Woodward-Clyde Consultants' staff. In addition, the firm of R.W. Beck and Associates provides valuable information on cost and transmission line considerations.

We were particularly fortunate to have a client who was willing to support the use of decision analysis techniques in the ranking process. Both the Public Power Council Siting Committee, Mr. William G. Hulbert, Jr., Chairman, and the WPPSS management, Mr. J.J. Stein, Managing Director, were supportive of our efforts. Mr. David Tillson, Siting Specialist, of

WPPSS, who monitored the contract, was a source of constant encouragement. Without his support this study would not have been possible.

References

[1] Keeney, R.L. "Multiplicative Utility Functions," Operations Research, 22, pp. 22-34, 1974.

[2] Keeney, R.L., and Raiffa, H. Decisions with Multiple Objectives, Wiley, New York, to appear 1976.

[3] Keeney, R.L., and Robilliard, G.A. "Assessing and Evaluating Environmental Impacts at Proposed Nuclear Power Sites," IIASA, Laxenburg, Austria, to appear 1976.

[4] Nair, K., Brogan, G.E., Cluff, L.S., Idriss, I.M., Mao, K.T. "An Approach to Siting Nuclear Power Plants: The Relevance of Earthquakes, Faults, and Decision Analysis," in Siting of Nuclear Facilities, International Atomic Energy Agency, Vienna, Austria, 1975.