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EXPLANATION OF DIRECT UTILIZATION POTENTIAL EVALUATION TECHNIQUE FOR THE STATE OF NEVADA GEOTHERMAL ASSESSMENT MAP

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INTRODUCTION

The major problem that must be addressed in any attempt to define the potential for direct utilization of Nevada's geothermal resources is the diversity of the resources in both areal distribution and character. While some resources are closely spaced and can be easily grouped, others cannot be readily associated.

Many geothermal occurrences, for instance, are inaccessible by land vehicles. Temperatures may vary from 20° C to over 200° C, and resources may discharge at the surface or be confined to a reservoir at a depth of 2 km or more. In addition, geothermal fluids range in total dissolved solids (TDS) from 150 ppm (drinking water quality) to over 6000 ppm (saline solution).

The facts that various direct-use applications place differing constraints on the nature of the required resource and that, in many specific geothermal resource areas, detailed data are not yet available, present additional problems to the question of resource assessment. Therefore, any method used to evaluate geothermal potential should be: a) generally applicable, b) sufficiently flexible to allow for future data input or changing priorities in resource requirements, and c) be of limited complexity, yet produce a semiquantitative basis for area to area comparisons.

APPROACH—RATIONALE

To overcome the problems and meet the requirements discussed above, a numerical scheme was developed. The basis of the method is a simple function called the probability function (PF) defined as follows:

$$PF = \Sigma\, Ri\, WFi$$

where Ri = Rank i^{th} parameter ($3^0 - 3^4$)

WFi = Weighting factor of i^{th} parameter (0,1,2)

Several parameters could be viewed as useful for defining potential, a partial list includes: temperature, land vehicle accessibility, rock type, rock age, depth to resource, population centers, geophysical data, fluid chemistry, areal extent, flow rate, permeability, recharge, economics, structure, and environmental considerations. Although the potential function could accommodate any number of parameters, the quantitative data necessary to establish limits for the weighting factors is unavailable in many instances. Such data are presently available for the following parameters: temperature, fluid chemistry, population centers, land vehicle accessibility, depth to resource, and areal extent. These parameters were selected for use with the function.

The direct-use applications selected for evaluation using the scheme are industrial process heat (IPH) and residential/commercial space heating (RSH). Potential for agriculture/aquaculture applications was not evaluated because the nature of the resource required and the method of exploitation are currently in a developmental stage. Having chosen the parameters to be used and the applications to be evaluated, the tasks remaining included establishing an order of importance for both IPH and RSH parameters and defining the limits to be associated with the weighting factor values.

Industrial process heat (IPH) evaluation parameters, in their order of importance are:

Parameter	*Rank*
Temperature	81
Water chemistry	27
Accessibility	9
Population centers	3
Depth to resource	1

where "accessibility" refers to land vehicle access to the resource. Note that the "rank" of the parameters is in terms of decreasing powers of 3. Use of powers of 3 preserves the established order of importance. This will be demonstrated in a later hypothetical application of the scheme. The weighting factors (WFi) associated with these parameters and the limits established for the factors are illustrated in figure 1. A weighting factor of "2" indicates the most desirable range for a parameter, "1" intermediate, and "0" the least desirable range. When judging the value to be assigned to the "water chemistry" weighting factor, consideration was given collectively to pH, TDS, and the presence or lack of corrosives, scaling compounds, or toxins. For example, although a fluid might have a pH between 5 and 6.5 and a total dissolved solids value of 450 ppm, the solids may consist of three hundred ppm dissolved silica which could cause scaling problems and thus the weighting factor used is "0".

The parameters used for the residential/commercial space heating (RSH) potential evaluation are similar, but they assume a different order of importance. Additionally, the weighting factor ranges have been adjusted to values more appropriate to the application. Note that areal extent is now considered because this parameter would be important to the development of a residential area where individual wells are used at each residence (as is the case in Reno, Nev., and Klamath Falls, Oreg.). Accessibility is no longer used because it is assumed to be tacitly accounted for by the presence of a population center. A listing of the residential/commercial space heating (RSH) parameters in their order of importance are:

Parameter	*Rank*
Population centers	81
Depth to resource	27
Temperature	9
Water chemistry	3
Areal extent	1

Ranges and limits used in weighting factor evaluations are given in figure 2. Arrows on the horizontal bars indicate that certain factors (for example TDS) have ranges that extend beyond those used in evaluating the weighting factor. However, once the established limit is exceeded the weighting factor value does not change.

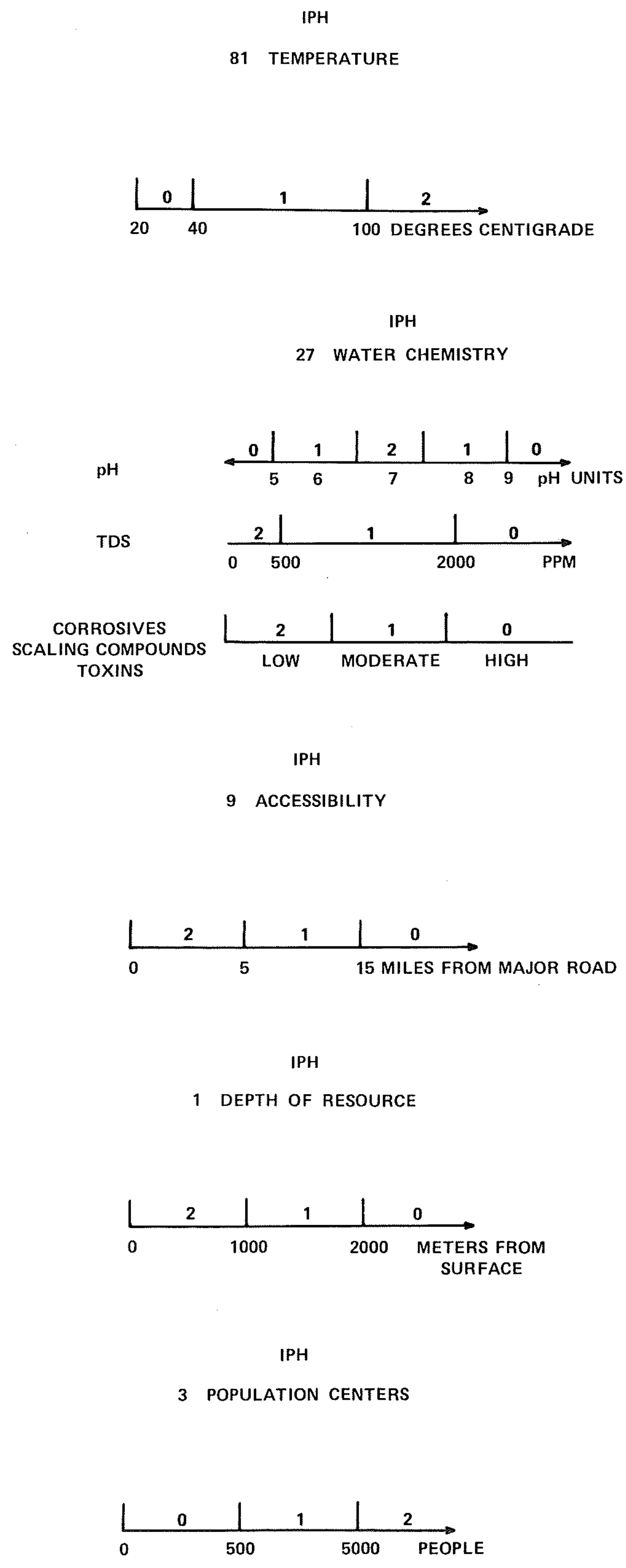

FIGURE 1. Weighting factors and their limits for industrial process heat applications.

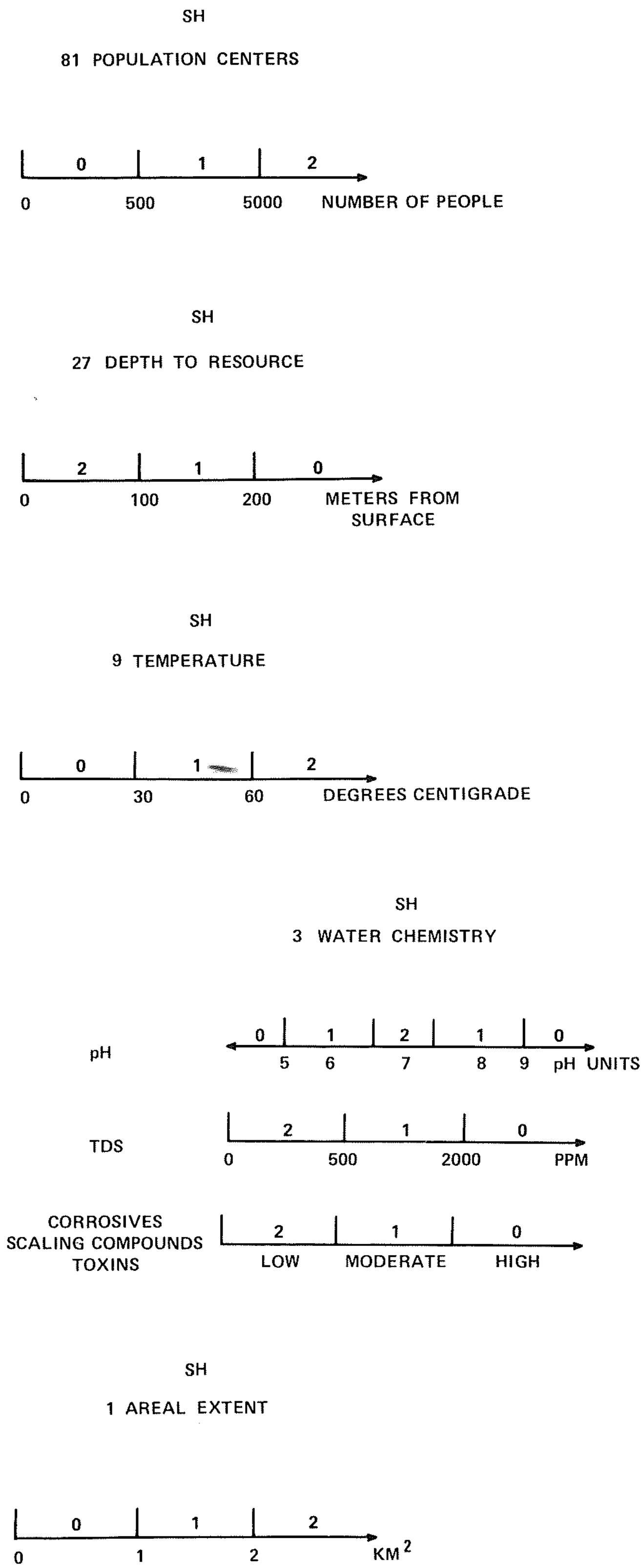

FIGURE 2. Weighting factors and their limits for residential space heating applications.

Numerical values, derived by summing the products of the rank-weighting factor pairs, range from a low of 0 to a high of 242, thus defining the limits of the probability function. This range was divided into three equal parts to obtain the "low", "moderate", and "high" categories of the probability function rating, and are:

Probability function rating	PF value
High	(+) 216–242
	(±) 188–215
	(–) 162–187
Moderate	(+) 136–161
	(±) 109–135
	(–) 81–108
Low	(+) 55–80
	(±) 28–54
	(–) 0–27

Each category is further divided into thirds and this is represented by the "–", "±", and "+" symbols.

The usefulness of powers of 3 in preserving the selected order of parameter importance can be illustrated by a pair of hypothetical industrial process heat examples (table 1). Case A receives a non-zero weighting factor only for the temperature parameter, thus its probability function value is 162 and its probability function rating (PFR) is *High(–)* (table 1a). In case B, all weighting factor values are 2 except temperature, which receives a 1 because it is less than 100° C. Here the probability function value equals 161 and the PFR is *Moderate(+)* (table 1b). Thus, the importance of temperature above all other parameters in the evaluation scheme is demonstrated.

TABLE 1a. Hypothetical IPH example, Case A.

	Weighting factor	Rank	Product
110°C	2	81	162
TDS > 2000 ppm pH > 9 Corrosive	0	27	0
> 15 mi. from major road	0	9	0
< 500 people	0	3	0
> 2000 m	0	1	0
		TOTAL	162

PFR = High(–)

TABLE 1b. Hypothetical IPH example, Case B

	Weighting factor	Rank	Product
60°C	1	81	81
TDS < 500 ppm pH 7.0 No corrosives	2	27	54
< 5 mi. to major road	2	9	18
> 5000 people	2	3	6
< 1000 meters	2	1	2
		TOTAL	161

PFR = Moderate(+)

APPLICATION OF THE SCHEME – AN EXAMPLE –

Application of the scheme to the region surrounding and containing Gabbs, Nev. provides a factual example of the probability function's use in evaluating the potential for direct utilization. Data from the geothermal occurrences in the area indicate an average temperature of 51°C, an average pH of 8.7, an average total dissolved solids of 582 ppm, an average depth to resource of 97 meters, an areal extent greater than 2 km^2, a population greater than 500 but less than 5000, and a distance of less than 8 km (5 mi) from an asphalt highway. Using these data the evaluation scheme applied to Gabbs is as follows:
Probability function ratings are *Moderate(±)* and *Moderate (+)* respectively for industrial process heat and residential space heating applications.

Application	Parameter	Rank	Weighting factor	Product
Industrial Process Heat	Temperature	81	1	81
	Chemistry	27	1	27
	Accessibility	9	2	18
	Population	3	1	3
	Depth to Resource	1	2	2
			TOTAL	131
Residential Space Heat	Population	81	1	81
	Depth to Resource	27	2	54
	Temperature	9	1	9
	Chemistry	3	1	3
	Areal Extent	1	2	2
			TOTAL	149

COMMENTS

As discussed earlier, the evaluation scheme is flexible with respect to the number of parameters it can accommodate; however, modifications are not limited to that aspect of its use. The ordering of parameters and the choice of limits for the weighting factors were based on the characteristics of Nevada and its geothermal resources. This ordering and choice of limits can be changed when using different parameters or a larger or smaller number of parameters to accommodate the data availability, geothermal resource characteristics, or application requirements of non-Nevada resources. It should be emphasized that the scheme is intended to be applied to regions of relatively similar resource characteristics. Geological, hydrological, and other pertinent sources of information should be used when bounding regions for potential evaluation.