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# Finding a Site to Store Spent Fuel in the Pacific Basin

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# Finding a site to store spent fuel in the Pacific Basin

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**How can one decide on a site to store spent LWR fuel, after the Presidential embargo on reprocessing? In this article, Palmyra Island is identified as the best site for the nations bordering the Pacific to store spent fuel. The quantitative methods used to reach this decision are outlined.**

Recent US policy statements [1,2,3] have identified the need for a spent nuclear fuel store. The location of this centre poses severe political and geological siting problems. The results of improper management of nuclear waste are international in consequence and hence control may best be handled on a multinational basis, even though some member nations may possess no nuclear facilities. Logically, a multinational nuclear community will be established along geographic lines as has taken place in Europe (Euratom). A future example would be the Pacific Basin region (Pacatom). This region is composed of Australia, with large uranium resources; Japan, Taiwan, China, South Korea, Canada, Mexico, and the United States, with dependence on nuclear facilities; and many countries that have no immediate plans for nuclear developments.

The great diversity in size, form of government, and economic level makes this area an excellent candidate for analysis. In order to identify a safe and acceptable location, the analysis must consider all pertinent parameters. The first item is the political environment that affects waste production and isolation. Certainly, the US policy of non-proliferation will be dominant in the area and consequently it is unlikely that a reprocessing facility would appear in the Pacific region in the next 20 years, if current US policy continues unchanged. This policy means that the waste facility will be orientated principally toward recoverable storage of spent fuel rather than high level waste disposal. The non-proliferation and safety constraints require that the method of transport and storage meets guidelines. This study will focus on developing a formal method of analysis for evaluating and comparing candidate waste storage sites.

The political stability of the site is crucial, and would require a politically stable country in the region; at present Australia, Canada, Japan and the United States are the most stable countries likely to meet this criterion. They are also the most advanced technologically, and therefore have a technical community suitable for management of a spent fuel storage site. However, Australia has refused to accept wastes from other countries, and this rejection would be expected to extend to spent fuel. Japan has domestic political problems which make it difficult to site nuclear reactors and other essential nuclear facilities.

President Carter's policy on non-proliferation of nuclear weapons is an important motivating force behind the establishment of a waste storage centre, and hence, the territorial burden would probably be placed on the United States. The political problems of any State within the USA accepting wastes are increasing in severity, even in the case of domestic wastes; the problems associated with accepting wastes from other countries could be insurmountable. Therefore, US territories that are not part of continental USA, Hawaii or

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**Table 1. Undisputed US Territory in the Pacific**

| Islands | Area (sq. miles) | Population | Status |
|---|---|---|---|
| American Samoa | 76 | 20 051 | Organized unincorporated and territory |
| Swains Island | 1 | 125 | " |
| Guam | 209 | 67 044 | " |
| Midway Islands | 2 | 2 356 | Unincorporated territory |
| Wake Island | 3 | 1 097 | " |
| Johnston Island Sand | 1 | 156 | " |
| Palmyra Island | 4 | 0 | " |
| Kingman Reef | (1) | 0 | " |
| Howland, Baker, Jarvis | 3 | 0 | " |

**Table 2. Primary site requirements**

- Uninhabited, not too close to any large populated islands, and not belonging to a State of the USA
- Should not be near territories used for nuclear testing or any Trust Territories which do not belong to the USA
- Should have undisputed US territorial ownership
- Should not be of great resource or military value
- Area of at least half a square mile (160 acres)
- Should have a natural harbour or a reef or other projections which would make it suitable for creating a harbour
- Air accessibility
- Near geometrical centre of spent fuel generation sites
- Fresh water supply
- Geological and climatological stability

Alaska are the only possibilities left.

Young and Leslie [4] have proposed Canada, the USA, Mexico, Japan, South Korea and Taiwan as a likely consortium to be in need of a spent fuel storage facility at the Second Pacific Basin Conference.

There is currently more spent fuel being generated on the American side of the Pacific, but in the long run these quantities may become more equitably balanced. Therefore, for ease of transport, a location in the middle of the Pacific would be suitable for the long term. The island siting of a spent fuel store has been considered by the EPA [5] and the Department of Energy[6], and negotiations between the USA and Japan on this issue have been reported recently[7].

The islands considered in the siting analysis are shown in Table 1. Islands offer natural barriers to inhibit accidental intrusions, and the importance of security arrangements for such a facility is obvious. The US island territories in the Pacific are far enough away from all large population centres to make accessibility to unauthorized groups difficult. Only by sea and air transport can one get to or leave these islands. Sea transport is slow enough that interception from US military bases in the Pacific (e.g. Pearl Harbor, Guam) would not be a problem. Even if air transport were used by any "invaders", there probably would be sufficient time for US supersonic fighters to intercept them before any large population centres are reached. Such interceptions would be expected to occur over the oceans.

The parameters shown in Table 2 are considered important in the selection of an internationally acceptable spent fuel storage site in the Pacific Basin.

The rating of the respective islands for the individual parameters can become a very involved process and should ultimately include the formulation of Rating Functions (RF). In this analysis the ratings are based on the authors' knowledge of the Pacific Basin. The philosophy behind this rating, as well as the Weight Vector, will be explained with examples of how Rating Functions could be formulated.

Of primary importance is the population of the island; it would be desirable if the island were totally uninhabited by civilians at the present time. It is considered that the presence of a military population might not only be acceptable, but actually could be desirable in terms of defence of the centre. At the same time, the political stability of the island would probably be the single most important criterion. As such, both "Habitation" and "Undisputed US Territory" are assigned weights of 10 on a weighting scale of 1 to 10. For sociological and regional sensitivity reasons, it is desirable to locate such a site away from Nuclear Test Areas.

Geological and climatological stability is desirable. A minimum size of 100 acres will be needed for the facility and another 100 acres for housing and personnel use. Sea access is a minimum requirement, and air access is strongly recommended. From a transport point of view, the centre should be as close to the geometrical centre of spent fuel generation sites as possible; and these sites are expected to be Canada, USA, Mexico, Japan, and perhaps Taiwan and South Korea.

The presence of natural resources, e.g. oil, phosphates, etc., would be a deterrent to use of the island, as would the island's value as a military base. For purposes of defence, it is important that the selected site be within close range,

**Table 3. Table of ratings and performance indices (PI)**

| | Habitation | Away from nuclear test area | Undisputed US territory | Natural resources & military value | Area | Sea access | Air access | Geometrical location | Fresh water | Geological climatic | PI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight Vector (W) | 10 | 10 | 10 | 5 | 5 | 5 | 2 | 2 | 2 | 5 | |
| American Samoa | 0 | 5 | 5 | 1 | 5 | 5 | 2 | 2 | 2 | 1 | 172 |
| Swain Islands | 0 | 10 | 5 | 5 | 5 | 1 | 1 | 2 | 2 | 1 | 216 |
| Guam | 0 | 5 | 5 | 1 | 5 | 5 | 2 | 2 | 2 | 1 | 172 |
| Midway | 1 | 5 | 5 | 0 | 5 | 5 | 2 | 2 | 1 | 1 | 175 |
| Wake | 1 | 5 | 5 | 0 | 5 | 5 | 2 | 2 | 1 | 1 | 175 |
| Johnston | 1 | 10 | 5 | 0 | 5 | 5 | 2 | 2 | 1 | 1 | 225 |
| Sand | 5 | 10 | 5 | 1 | 5 | 5 | 2 | 2 | 1 | 1 | 270 |
| Kingman | 10 | 10 | 5 | 5 | 0 | 1 | 1 | 2 | 1 | 1 | 293 |
| Palmyra | 10 | 10 | 5 | 5 | 5 | 5 | 2 | 2 | 1 | 1 | 340 |
| Howland | 10 | 10 | 5 | 5 | 5 | 1 | 1 | 2 | 1 | 1 | 318 |
| Baker | 10 | 10 | 5 | 5 | 5 | 1 | 1 | 2 | 1 | 1 | 318 |
| Jarvis | 10 | 10 | 5 | 5 | 5 | 1 | 1 | 2 | 1 | 1 | 318 |

**Table 4. Ability of the sites to meet Minimum Acceptability Requirements**

| | Habitation | Away from nuclear test site | Undisputed US territory | Natural resources & military value | Area | Sea access | Air access | Geometrical location | Fresh water | Geological & climatic | $\pi A_i$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| American Samoa | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Swain Islands | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Guam | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Midway | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Wake Island | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Johnston | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Sand | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Kingman | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| Palmyra | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Howland | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Baker | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Jarvis | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

say 1000 miles, of major US bases like Pearl Harbor or Guam. Two thousand miles is considered as the maximum tolerable distance for reasonable defence of the chosen site. The presence of fresh water would be desirable, but if not available, a sea water converter could be installed.

The Table of Ratings with computed Performance Indices is shown in Table 3. The ability of the sites to meet the Minimum Acceptability Requirements, and the computed product of the components of the Acceptability Vector is shown in Table 4. Table 5 lists the SAPI values computed according to the methods outlined (see box).

The preliminary analysis reported here shows Palmyra Island to be the best choice with Howland, Baker and Jarvis Islands being second choice.

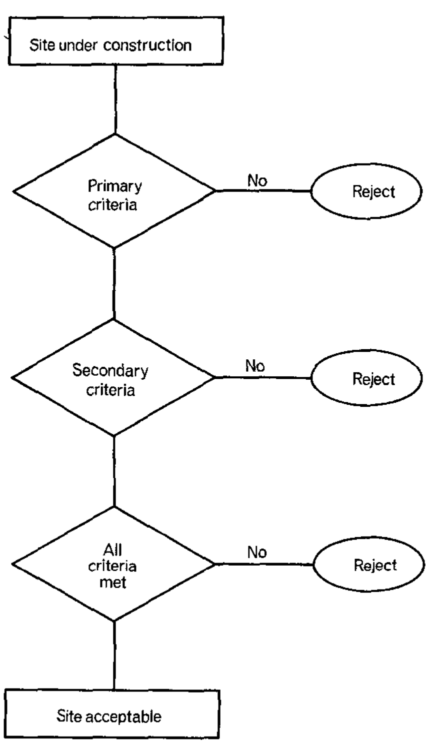
Palmyra Island is approximately 1100 miles south-south-east of Honolulu, and is very close to the Intertropical Convergence Zone. Tropical storms form frequently in the eastern tropical Pacific, many reaching hurricane force, but their tracks are generally northwesterly, thus carrying them toward Hawaii and not near enough to Palmyra to affect the island.[8] The other source area for tropical storms and typhoons lies to the west of the island, and their tracks to the north or northwest actually carry them away from Palmyra. Since Palmyra lies between the two areas of tropical storms

# Decision Analysis Methodology

It is important to realize that the selection of a site for a nuclear facility should be based on formal decision analysis methodologies. Such an approach ensures that all relevant factors are considered and clarifies the basis upon which the decision was made.

One commonly used approach is the Sieve Method according to which candidate sites are examined sequentially against a set of necessary criteria, as shown in Fig 1. While this approach can be extremely useful in narrowing down the number of sites to be considered, it does not give any indication of the relative merit of sites when more than one site is deemed acceptable.

**Fig. 1. The sieve method for decision making.**




In this paper the authors wish to report a decision analysis methodology in which the sites can be tested for acceptability against set criteria, while at the same time permitting the sites to be evaluated relative to one another. The procedure consists of the following steps:

1. Identification of candidate sites $S_1, S_2, \ldots S_n$.
2. Identification of parameters for decision analysis, $P_1, P_2, \ldots P_m$.
3. Identification of the weights each parameter is to have in the decision analysis process. This we shall call the weight vector, **W**, which will be a $(1 \times m)$ matrix.
4. Establishment of an $(m \times n)$ matrix for the purpose of rating the performance of each site for each of the parameters, as shown below. The Rating $R_{ij}$ denotes the rating of site j for parameter i. This rating can be done on either a comparative basis, or absolute basis; in either case the utility function upon which rating is to be based must be clearly defined.

**Matrix of Ratings** $(m \times n)$

| | Site 1 | Site 2 | | Site n |
|---|---|---|---|---|
| Parameter 1 | $R_{11}$ | $R_{12}$ | — | $R_{1n}$ |
| Parameter 2 | $R_{21}$ | $R_{22}$ | | $R_{2n}$ |
| \| | \| | | | |
| Parameter m | $R_{m1}$ | $R_{m2}$ | | $R_{mn}$ |

5. The establishment of threshold or acceptable values within which the ratings must fall, e.g.
$$x < R_{ij} < y,$$
$$R_{ij} < z, \text{ or } R_{ij} > m.$$
6. The formation of an acceptability vector **A**, which will be a $(1 \times m)$ matrix. The components of this vector will consist of 1 and 0, respectively indicating that the rating is within acceptable limits or not.
7. The calculation of Performance Indices (PI) for each site based on the formula:
$$PI = \mathbf{W} \cdot \mathbf{R}_j$$
This computed Performance Index is a scalar quantity that gives values with which to compare the candidate sites relative to one another.
8. The ability of the site to meet minimum acceptability requirements (MAR) is determined by computing the product of the components of **A**, i.e.
$$MAR = \prod_{i=1}^{m} A_{ij}$$
MAR can only have values 1 or 0, the former indicating that all minimum acceptability requirements have been met, and the latter indicating that one or more of these requirements have not been met.
9. Finally, the Site Acceptability and Performance Index, (SAPI) is computed thus:
$$SAPI = \prod_{i=1}^{m} A_{ij} (\mathbf{W} \cdot \mathbf{R}_j)$$

Iteration of this calculation for all sites (j = 1 to n) will result in either zero, or non-zero positive values of SAPI. Those sites having a zero SAPI value have not met one or more of the minimum requirements and can thus be excluded from the analysis. The sites with non-zero positive values of SAPI have met all the minimum requirements and the site with the highest SAPI value can be considered the best site for the **W** (weight vector) used in the analysis. This calculation can be reiterated for different **W**'s to reflect the desired weights the analyst chooses to assign to each parameter, as well as for sensitivity analyses.

Table 5. Computed SAPI values

| | PI = Σ W;Ri | π Ai i | SAPI |
|---|---|---|---|
| American Samoa | 172 | 0 | 0 |
| Swain Islands | 216 | 0 | 0 |
| Guam | 172 | 0 | 0 |
| Midway | 175 | 0 | 0 |
| Wake Island | 175 | 0 | 0 |
| Johnston | 225 | 0 | 0 |
| Sand | 270 | 1 | 270 |
| Kingman | 293 | 0 | 0 |
| Palmyra | 340 | 1 | 340 |
| Howland | 318 | 1 | 318 |
| Baker | 318 | 1 | 318 |
| Jarvis | 318 | 1 | 318 |

in the Pacific, it can thus be considered quite safe climatologically. Rainfall is high, with a mean of 163.86in per annum, and a minimum of 121.66in per annum.[9] As such, the rainfall can be used as a source of fresh water. Palmyra is geologically stable, with no seismic activity.

There is a ship channel. Both this channel and the harbour are adequate for tug and barge operations. It could be cheapest to use this form of surface transport from Honolulu. The present airfield runway at 6000ft might be adequate, but it should be cleared and completely resurfaced with a seal coat that would allow the use of jet aircraft that require a paved surface.[10]

The Decision Analysis Methodology reported here permits formal decision analysis using sophisticated techniques while at the same time maintaining the required level of simplicity to make it comprehensible. Inclusion of the weight vector will clarify the relative importance of the parameters in the decision-making process. The next stage of this work is to formulate the Rating Functions for each of the parameters, factor-in the reliability of the available data, and compute SAPI values along with their confidence intervals.

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