

# RISK AND RESOURCE ASSESSMENT

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## Abstract

*The process of field proving is a balance between on the one hand expenditure of money and time, and depletion of the reservoir by discharge, and on the other increasing certainty gained about the size of the resource and size of a power station built to exploit it. Underlying this process are the techniques used to assess the resource, and to reach a considered opinion about its size.*

*Improvements in resource assessment in recent years are primarily a consequence of the accumulated experience of the global geothermal industry; rather than any radical change in approach or technique. Use of simulations has helped impose consistency on reservoir assessments, and provide assurance against gross errors.*

## 1 INTRODUCTION

Most geothermal development around the world now occurs under a process controlled by financial processes. The step at which one obtains commitment to development is a major one, and one where the resource assessment is paramount. Typically one party is a steamfield developer who has undertaken exploration activities including drilling. Another party will construct a power station, and bank will be providing project finance to this station, and associated steamfield development. The details vary with the actual project, and sometimes one party may be doing both steamfield and power station. In all cases the crucial step is getting the bank to commit to the finance.

Getting the financial closure requires assurance that the project is viable. The nature of a geothermal resource is not understood by people outside the industry, and the track record of some projects indicates that there are real risks that the size has not been correctly estimated. The problem projects are mainly American, but so are the financing organisations. So the resource risk dominates this transaction.

Figure 1 shows an estimate at one time of the size of a particular resource, Mahanagdong. The details are not important for the present discussion. The result is typical. At the state of knowledge of the reservoir, there is a broad spread of uncertainty about the resource size. The distribution would normally be similar to figure 1 - probably log-normal in most cases, or roughly a triangular distribution.

Given such uncertainty, an economic optimisation must be done in a manner that explicitly recognises the presence of uncertainty. Figure 2 shows

Mahanagdong field size distribution

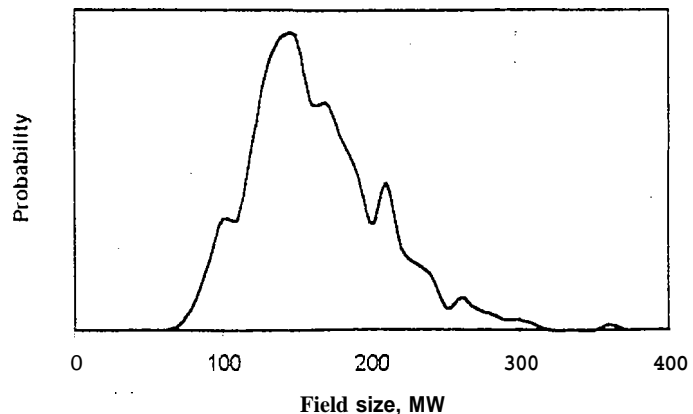
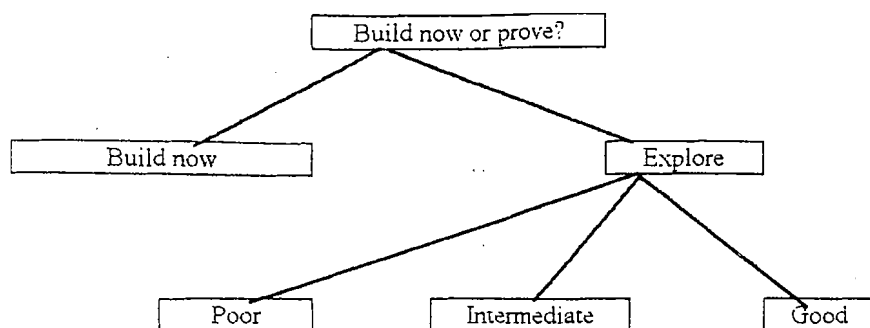


Figure 1 Probability distribution of resource capacity of Mahanagdong. From Bayrante et al. (1992).



**Figure 2 Decision tree**

a typical decision tree. at the point of a decision to further prove the field or commit not. Such optimisation usually indicates that a first stage station should be built at a size in the lower quartile of the distribution. ie near but somewhat above the lower limit. and below the mode or median of the distribution. (Grant & Mahon, 1995. Grant, 1996). In most cases: this size is smaller than the field will ultimately be proven to support. If the

desire is to increase the capacity to which it is reasonable to commit, it is more important to move the lower limit of the distribution upwards than the upper limit, since the optimal size lies near the lower limit. So resource proving is more about eliminating risk of catastrophe than exploring the upper limit of what is possible. In figure 2, it would be more valuable to eliminate the "poor" outcome than to make the "good" outcome even better.

## 2. PROVING CRITERIA

So what criteria are used for proving? They are a mixture of defined steps and judgement.

### 2.1 Defined steps

Defined steps are reasonably widely accepted:

- exploration and delineation drilling to define area and depth of reservoir
- downhole measurements to define reservoir temperature
- well testing for permeability
- some element of extended discharge or interference to make some measure of permeability over a wider area
- reservoir simulation with match to natural state; and march to drawdown, if any
- \* allow a decent buffer between injection and production (this may require discounting some of the potentially productive resource)
- tracer testing for potential injection returns

### 2.2 Judgement

The role of judgement is more difficult, but extremely important. Reservoir simulations are now widely accepted as producing reasonable results, and no-one would reasonably contemplate a resource assessment without one. A decade ago simulations were not so well accepted, nor were their results as good. If one examines the descriptions of simulations now, and a decade ago. they are very similar. The numerical codes have changed little - only in presentation, not in process. What has changed is the weight of collective experience. This guides the conscious and unconscious choices made in formulating conceptual models. A similar effect of experience is present in resource assessment in general.

### 2.3 Examples

In general there is little published material that includes a full history of the assessment of a resource, particularly when the assessments are wrong. One published example is Roosevelt Hot Springs. (Faulder 1994. Yearsley 1994). They quote an early assessment of the reservoir fluid volume using a standard petroleum approach.

Their later assessment of the resource, using a simulation match to the subsequent production history and to the original test data, found that this was a severalfold overestimate. The difference derives from a different concept of the reservoir, not from a mistake in the original calculation.

Almost as rare are published examples of assessment history that show an early result was correct. Bödvarsson et al (1993) evaluated the performance of their 1986 simulation model of Nesjavellir, compared to subsequent production. The model performed well. The assessment made in 1986 proved a good guide to field management.

One of the major benefits of a simulation model is the need to specify the model structure and assumptions. This prevents the use of many incorrect reservoir concepts, or of physically impossible processes. In the Roosevelt example, Faulder notes that the reservoir fluid volume originally found needed too large a porosity to fit into the reservoir as then known.

### 3. WHAT PROBLEMS HAVE OCCURRED?

In the early days of field exploration high estimates of possible size are often made. In similar vein national estimates of total geothermal capacity often appear extremely optimistic. Such estimates have a value in helping to get a project moving but raise unrealistic expectations and are often a problem to later plans. Adopting the decision-tree approach from the beginning (GENZL 1987) has advantages. The possibilities of failure are always explicitly considered, and this keeps the expected size of the resource within more reasonable limits, and means that there is at all stages a balanced view of the resource and its possibilities.

Commitment to development needs solid estimates, and this means in particular the need to remove the risk of failure. So what are the risks of failure? What can go wrong? Excluding the special case of The Geysers, problems that have occurred are primarily:

- injection returns - probably the commonest problem of all
- ignoring resource assessment
- no resource assessment

Injection problems, when there are rapid and preferential returns, mean that part of the field is not available for production. Some area must be allocated to injection and a buffer zone around it. In essence part of the resource is lost and the field is effectively scaled down in size. Palinpinon is an example. Simulations are not much help here since homogeneous medium models do not handle thermal returns. In most geothermal fields geological structures are important in the permeability distribution. Only in a minority do they produce a real preferential return problem. To the author's knowledge no geologist has been able to discriminate between the cases beforehand. Tracer testing is the only technique to help.

There are some fields where the resource assessment has simply been ignored, for reasons of national or company politics. There is always internal pressure to increase the size of the reserves. Sometimes a turbine manufacturer offers a larger turbine at an attractive price and the developer decides to take a chance. This chance is particularly tempting since the resource assessment is always qualified as an opinion with the clear possibility of greater reserves. This deliberate choice to increase development size has caused some field problems but they cannot be laid against resource risk, or only to the extent that the known uncertainty in resource assessment provided sufficient ambiguity to allow the increase.

It should also be noted that at current interest rates, a 30-year life is not an optimal choice. A developer will choose more rapid depletion with a larger plant. This is "oversized" against traditional criteria but not a mistake.

There have been a considerable number of small developments in the US Basin & Range. Quite a few are by novices to the geothermal industry, and in some cases there has simply been a bit of drilling followed by the installation of a binary plant, with little more formal assessment. Sometimes this has worked, other times it has not.

For a small project it is probably appropriate to omit the relatively large overhead of a proper resource assessment. These projects should not be considered in the same category as major (>25MW, say) projects.

The Geysers accounts for more overdevelopment than all other cases put together. It appears to be consequence of the divided ownership and control of the resource, which provides strong incentives to overestimate resource size. In theory the stringent US liability practices should provide a counterbalance to this incentive to overestimation but that does not seem to have been effective in this particular case and with the state of knowledge at the time. Developers need to recognise the effects of too much pressure on quality of resource estimates.

#### 4. CONCLUSIONS

The current state of resource assessment, when properly applied, should prevent gross mistakes in development sizing. Experience in geothermal is crucial to a reasonable assessment. Mistakes to avoid are:

- failing to allow sufficient spacing to injectors
- too much pressure to increase reserves assessment
- multiple developers on a single field

#### 5. REFERENCES

- Bayrante, L.F., N.O.Rodis, A.G.Reyes & D.R.Sanchez 1992 "Resource assessment of the Mahanagdong geothermal project, Leyte, Central Philippines" NZ Geothermal Workshop v14, pp171-178
- Bödvarsson, G.S., G.Gislason, E.Gunnlaugsson, O.Sigurdsson, V.Stefansson & B.Steingrimsson, 1993 "Accuracy of reservoir predictions for the Nesjavellir geothermal field, Iceland" Stanford Workshop on geothermal reservoir engineering, v18, pp273-278
- Faulstich, D.D., 1994 "Long-term flow test #1, Roosevelt Hot Springs, Utah" Tran. GRC v18 pp583-598.
- GENZL, 1987 "Indonesia geothermal study and evaluation project" report to NZ Ministry of Foreign Affairs
- Grant, M.A., 1996 "Geothermal resource management" GENZL, Auckland
- Grant, M.A. & T. Mahon, 1995 "A probabilistic approach to field proving and station sizing" Tran. GRC v19 pp493-495
- Yearsley, E., 1994 "Roosevelt Hot Springs reservoir model applied to forecasting remaining field potential!" Tran. GRC v18 pp617-621.