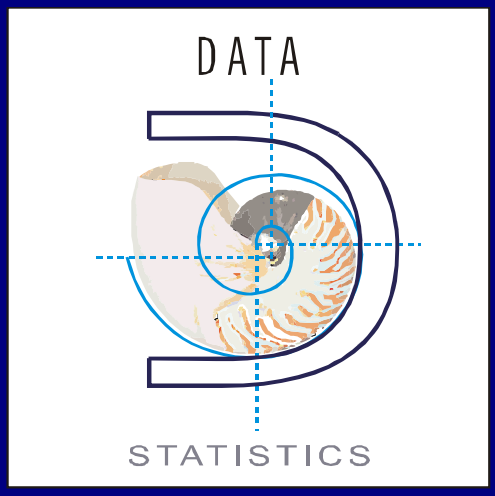

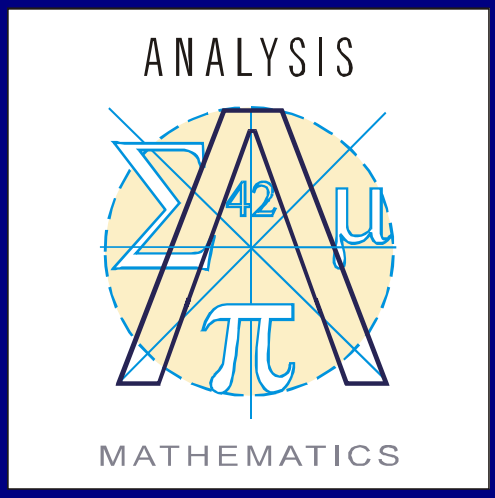

S T R A T E G I C
I N F O R M A T I O N
C O N S U L T A N T S

Proposed Mundaring Water Treatment Plant – Rating of Sites

September 2007

Project: WATER/60

DATA ANALYSIS AUSTRALIA PTY LTD

Proposed Mundaring Water Treatment Plant – Rating of Sites

September 2007

Client: Water Corporation

Project: WATER/60

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1. Introduction

Mundaring Weir is the primary source of drinking water to about 100,000 people in the Hills suburbs of Perth, east of Hardey Road Glen Forrest, and those served by the Goldfields and Agricultural Water Supply Pipeline. Disinfection facilities have existed at Mundaring Weir for many years but as yet the water is not filtered. A water treatment plant is needed to introduce the filtration process for all water from Mundaring Weir to provide the best possible drinking water to the 100,000 people dependent on this source.

The Water Corporation conducted a series of public meetings and community forums in 2007, run by an independent facilitator, Colin Penter of Matrix Consulting. At the community forums, site options for the water treatment plant were examined and participants in the forum were given the opportunity to rate the sites based on a number of criteria. Data Analysis Australia was commissioned by the Water Corporation to undertake an independent analysis of these ratings to identify the site(s) preferred by the community for the water treatment plant.

2. Background

Participants at the community forums had filled in two forms to indicate preferences for where the Water Treatment plant should be located and criteria for why it should be located there. Data Analysis Australia analysed this information and compiled a report for the Water Corporation (Water/55 – Analysis of Water Treatment Plant Data). The Water Corporation used this information to select four sites as viable and popular options for where the Water Treatment plant will be built. They were:

- Site One
    - Site One is below Mundaring Weir on Mundaring Weir Road, south of the Helena River. This site is located in Reserve 5342 and includes Reserve 39644, which is vested in the Water Corporation for the purpose of Water Supply - Mundaring Weir, and is zoned "Parks and Recreation" in the Metropolitan Region Scheme (MRS). A complication is that if Site One is selected, the chlorine store and the drying beds will need to be located elsewhere, at one of the other three sites.
- Pine Plantation
    - This site is located to the north-east of Mundaring Weir, alongside an airstrip managed by Department of Environment and Conservation (DEC). The site lies off Allen Road, to the east of Mundaring Weir Road. This site is within State Forest and is zoned Water Catchments and State Forest in the MRS.

- DEC Land (formerly called the "CALM Land")
  - This site is a 20 hectare site located at the current Department of Conservation and Environment depot to the east of Mundaring Weir Road at Mundaring Weir. The site is located on State Forest and freehold land owned by DEC.
- O'Connor Site
  - The O'Connor site is a 39.7 hectare site located in State Forest at the junction of Mundaring Weir Road and Firewood Road, north of the Weir. It is east of Mundaring Weir Road and north of Firewood Road.

Thus, there were six possible options for where the Treatment Plant will be built namely: Site One and Pine Plantation, Site One and DEC Land, Site One and O'Connor Site, Pine Plantation, DEC Land (formerly "CALM Land") or O'Connor Site. As an input to the decision making process the Water Corporation needed to better understand community preferences between these options. Matrix Consulting and Data Analysis Australia designed the process for collecting information on preferences.

Since the emphasis is on preferences rather than ratings, and since it is just as important to highlight what is least preferred as much as what is most preferred, Data Analysis Australia recommended a "preferential vote" for a questionnaire since this is a format familiar to most of the Australian community. Participants were asked to rank these six options in their order of preference from 1 (most preferred option) to 6 (least preferred option). A copy of the ratings form is given in Appendix A.

Residents who had previously attended at least one of the forums and wished to participate in rating the options were required to register their details with the Water Corporation. The participants were then sent a rating form. The participants could return the form in the post to Data Analysis Australia or submit their rating form to Colin Penter at a community forum held on Thursday, 23 August 2007.

3. Analysis and Results

3.1 Response Rate

In all, 213 people registered their details with the Water Corporation and they were sent a ratings form. Data Analysis Australia received 59 ratings forms back. We received two ratings forms from people who had not previously registered their details with the Water Corporation and we did not allow their ratings forms to be included in this analysis. We also received one form with only a tick mark for the DEC Land option. We included this form in the analysis and ranked the DEC Land option as the participant's first preference

and entered all other sites as fourth preference[1]. Thus, 59 ratings forms were included in this analysis, a response rate of 28%.[2]

3.2 Data

Table 1 gives raw statistics for the most preferred option (i.e. option rated number 1) from the 59 participants. We see that the most preferred option was the Pine Plantation with 19 participants, 32% of the total. The option that received the fewest first preference rankings was Site One combined with the O'Connor Site with only two participants or 3% of the total participants.

	Most Preferred	
Option	**Count**	**Percentage**
Site One and Pine Plantation	12	20.3
Site One and DEC Land	8	13.6
Site One and O'Connor Site	2	3.4
Pine Plantation	19	32.2
DEC Land (formerly "CALM Land")	13	22.0
O'Connor Site	5	8.5
Total	59	100.0

Table 1: The raw statistics of the most preferred option.

Participants were also given the opportunity to enter comments on the ranking form. Many comments were made ranging from being supportive of the process and the information provided through to being highly critical. For our purposes here, the comments appeared to be consistent with the corresponding rankings suggesting that the participants understood what was expected of them in completing the form.

The comments have been forwarded to Matrix Consulting and the Water Corporation in anonymised form.

3.3 Analysis

Although providing useful information, the raw statistics such as the first preferences in Table 1 only gives a partial picture. For example, it does not

[1] A value of 4 represents the average of the ranks 2 to 6.

[2] This is a typical response rate for a self completion survey without active follow-up and reflects the different levels of involvement of participants.

consider whether for some people the Pine Plantation may have also been the *least* preferred option (the option ranked number 6). This highlights the issue of needing a method that utilises the full preference information provided by participants, giving equal weight to what they do want and to what they do not want.

Considering this, Data Analysis Australia decided to analyse the data using a concordance ranking method. This ranking method is similar to single transferable voting but rather than just choosing the "winner", it gives a full overall ranking of the options from the most preferred to the least preferred i.e., rank 1 to rank 6. The formal method of combining these individual rankings as described in Appendix B is based upon maximising the concordance of the common ranking with each of the individual rankings.

The common rankings of the options for where the Water Treatment plant will be built are given below in Table 2. To provide additional guidance on how clearly defined the ranking is, the simple arithmetic average of the ranks for each option is also given. This confirms the reasonableness of the common ranking.

Ranking	Option	Average Ranking
1	Pine Plantation	2.64
2	Site One and Pine Plantation	2.92
3	Site One and DEC Land	3.12
4	DEC Land (formerly "CALM Land")	3.17
5	Site One and O'Connor Site	4.36
6	O'Connor Site	4.80

Table 2. Common rankings of the options, together with the "average rankings".

This formal analysis was further examined to both confirm the validity of the above interpretation and to determine whether there is observable structure in the set of respondents.

Site One raises some important issues – the various versions of Site One secured 27% of the first preferences, placing it ahead of the other single location options. If the primary issue here is the desire to choose Site One, then it might be expected that persons choosing a Site One option for their first preference might also choose Site One for their second preference. The analysis of Table 2 is designed to account for such preferences and if appropriate it will give preference to such combinations since that it will recognise that they were ranked ahead of other locations.

However it is still of some interest to explore the effect of Site One preferences. The relationships between the first and second preferences is illustrated in Table 3 and Figure 1[3]. It can be seen that while a slight majority of second preferences related to Site One first preferences are for another Site One option, this is not overwhelming. It demonstrates that some, but by no means all, of the first preferences for Site One options were primarily based upon a strong preference for Site One itself.

		Second Preferred Option						
		Site One and Pine Plantation	Site One and DEC Land	Site One and O'Connor Site	Pine Plantation	DEC Land	O'Connor Site	**Total**
First Preferred Option	Site One and Pine Plantation	-	8	0	4	0	0	**12**
	Site One and DEC Land	4	-	0	0	3	1	**8**
	Site One and O'Connor Site	1	0	-	1	0	0	**2**
	Pine Plantation	12	1	0	-	6	0	**19**
	DEC Land	0	2	0	6	-	4	**12**
	O'Connor Site	0	0	0	3	2	-	**5**
	Total	**17**	**11**	**0**	**14**	**11**	**5**	**58**

Table 3: Breakdown of the counts for the first preferred option by the second preferred option.

Related to this is the question of whether there is a "statistically significant" difference between the ratings given for the various options. In this context there is no simple model that might give a definitive measure of significance but it is possible to have some guide coming from the rankings. In particular, the question can be asked whether the mean rankings given to the different options differ significantly. This question is complicated by the number of potential pair wise comparisons (15 in all) and the way that they closely relate to each other (the 15 differences are set in only five basic dimensions).

[3] It is noticeable that ratings for only 58 participants were included in this analysis. The reason for this is outlined in section 3.2 where one participant only entered a tick mark for the DEC Land option. We could not decipher the participant's second choice from that information.

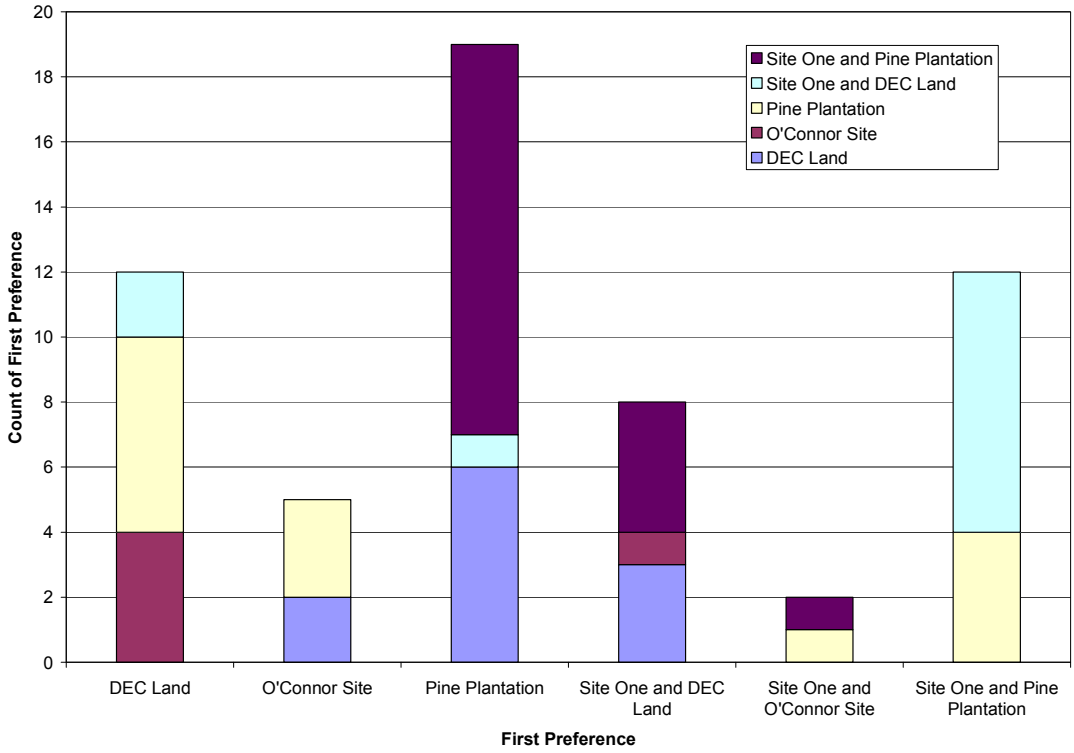

Figure 1: Plot of the breakdown of the counts for the first preferred option (the vertical bars) by the second preferred option (colours within the bars).

Table 4 gives a measure of the significance of each pair wise difference – a t-statistic less than –2 or greater than +2 strongly suggests a real rather than random difference. It can be seen that the large differences all correspond to comparisons between O'Connor and non-O'Connor options.

Hence a reasonable conclusion is that the while the non-O'Connor options are generally preferred over the O'Connor options, the differences between the non-O'Connor options are consistent with the randomness of sampling error.

It is worth noting that the difference between the two O'Connor options is of borderline significance – it appears that the option of siting all the plant at the O'Connor Site is almost definitely the least preferred.

Lastly we considered the issue of structure in the set of respondents. This was done using a simple cluster analysis approach based on each individuals rankings. The clustering showed that the respondents could be roughly divided into three groups. For each of these groups it was then possible to calculate a combined ranking, with the results as shown in Table 5.

Comparison	t - stat
Site One and Pine Plantation & Site One and DEC Land	-0.84
Site One and Pine Plantation & Site One and O'Connor Site	-6.11
Site One and Pine Plantation & Pine Plantation	1.09
Site One and Pine Plantation & DEC Land (formerly "CALM Land")	-0.67
Site One and Pine Plantation & O'Connor Site	-5.01
Site One and DEC Land & Site One and O'Connor Site	-4.87
Site One and DEC Land & Pine Plantation	1.42
Site One and DEC Land & DEC Land (formerly "CALM Land")	-0.21
Site One and DEC Land & O'Connor Site	-4.73
Site One and O'Connor Site & Pine Plantation	6.05
Site One and O'Connor Site & DEC Land (formerly "CALM Land")	3.85
Site One and O'Connor Site & O'Connor Site	-1.96
Pine Plantation & DEC Land (formerly "CALM Land")	-1.50
Pine Plantation & O'Connor Site	-5.99
DEC Land (formerly "CALM Land") & O'Connor Site	-4.99

Table 4: Calculated t-statistics for the pair wise comparisons of options. These t-statistics are an approximate measure of significance and are not independent of each other.

	Groups		
	A	**B**	**C**
Cluster size	12	36	11
1	DEC Land	Pine Plantation	Pine Plantation
2	O'Connor Site	Site One and Pine Plantation	Site One and Pine Plantation
3	Site One and DEC Land	Site One and DEC Land	Site One and O'Connor Site
4	Site One and O'Connor Site	DEC Land	O'Connor Site
5	Site One and Pine Plantation	Site One and O'Connor Site	Site One and DEC Land
6	Pine Plantation	O'Connor Site	DEC Land

Table 5. Results of the cluster analysis, giving the combined within group rankings for each group.

While it is tempting to read too much into such an analysis, one possible interpretation is that the defining characteristics of the group are what they rank last. In particular while there is strong overall support for the Pine

Plantation (with or without Site One), there is a significant minority that rank these last.

4. Conclusions

From Table 2, the results of the analysis show that the Pine Plantation was ranked 1 (the most preferred) option. When it was combined with Site One, it was the second most preferred option. The two options involving the DEC land were given a middle ranking, with the option of Site One combined with the DEC land being marginally preferred over the DEC Land by itself.

However the differences in preference for these four options are relatively small – they are consistent with the variability due to sampling and hence care should be taken when assuming that the results apply to the whole population of potential respondents.

In contrast the two options involving the O'Connor Site were the least preferred, with the average rankings clearly separating these options from the rest to a degree that cannot be reasonably ascribed to randomness. The option of the O'Connor site by itself is the least preferred of all.

It was evident in the comments of the returned forms that participants had strong opinions not only about the sites but also the process to which this exercise was run.

A. Appendix: Ratings Form

NAME ..... **Signature** .....

Instructions for completion of Individual rating

- Rate all site options from 1 to 6.
- Place the number 1 in the box for the most preferred site option.
- Place the number 6 in the box for the least preferred site option.
- For the other site options number them 2, 3, 4 and 5 in order of preference.

Site One and Pine Plantation	
Site One and DEC Land	
Site One and O'Connor Site	
Pine Plantation	
DEC Land (formerly "CALM Land")	
O'Connor Site	

COMMENTS

_____

_____

_____

_____

Completed forms can be submitted at the Public Forum to be held on Thursday 23rd August 2007. Completed forms can also be mailed back to

Mundaring Project
Data Analysis Australia
Reply Paid 3258
Broadway NEDLANDS WA 6009

By close of business Friday 31st August 2007

B. Appendix: Concordance Algorithm

It is necessary to introduce some limited notation to accurately describe the concepts that follow. We assume that there are R participants and n items being rated. The ith participant provides a ranking $r_i=(r_{i1},r_{i2},\ldots r_{in})$, giving each item a number indicating how it compares with the others; 1 for the best item possibly through to n for the worse item. To allow for the possibility that some cannot be ranked we may consider some rankings to be missing. These rankings must be compared against a common ranking $\boldsymbol{r}=(\boldsymbol{r}_1,\boldsymbol{r}_2,..,\boldsymbol{r}_n)$.

A basic principle that has been shown in statistical contexts to have effective and useful properties is the concept of concordance. This considers just two rankings and two items at a time. If the two rankings order the two items in the same way, they are said to concur. If they disagree it is called a discordance. The discordance between two rankings is the number of such pairwise discordances.

The aim is to find a common ranking that minimises the total discordance with the individual ratings. That is, the number of instances where $r_{ij}<r_{ik}$ and $\boldsymbol{r}_j>\boldsymbol{r}_k$. This concept of discordance has been used in many statistical constructs such as rank based non-parametric tests and measures of association such as Kendall's τ. (See for example, Kendall and Gibbons, 1990.) It also has the advantage of being mathematically manageable.

The concordance algorithm works by four stages:

- A preliminary ordering of the items is given using the average rankings. Where a participant has not ranked an item, that participant is ignored for the calculation of the average for that item.
- Since it is particularly easy to calculate the effect on the total discordance of transposing two adjacent items, the preliminary ordering is refined using a bubble sort type algorithm until the total discordance cannot be further reduced.
- An exhaustive *branch and bound search* is then applied starting from this ordering, limiting the search to permutations of the first twelve items. (This limitation is the only non-optimal step in the approach - obviously if only twelve or less items are being evaluated the approach is optimal. If it was critical to be certain of the global optimum, this restriction could be relaxed provided sufficient computing resources are made available.) Crucial to this stage is the order in which the orderings or permutations are generated. Standard algorithms (see for example Reingold *et al*, 1977) generate them in an order that does not allow a branch and bound technique. An alternative generation algorithm was used here.

The result from the third stage will in general not be unique - there may be several orderings that score equally in terms of total discordances. Since the usual application only requires choosing the best items - typically the top three - in many cases this is not a problem since the multiple solutions might only diverge after the first ones. However to provide a general solution the fourth stage scores each of the items in each of the solutions and ranks the items using the average score. The output is both the ranks and the scores so that if ambiguities remain they can be readily identified.