OVERVIEW

OF

BROOMEHILL '96 and SALTMAP

Prepared for

Water & Rivers Commission

by

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This Report

This Overview is an independent summary of the Broomehill evaluation of some geophysical tools of salinity management in 1996 (*Broomehill '96*). This analysis was carried out under 6-month contracts from the Water and Rivers Commission (WRC) begun in July 1996 and renewed in February 1997. This Overview represents a condensation of a later stage of analysis than given in a 50-page Discussion Paper prepared for WRC and finalised after deliberations at the Broomehill Steering Committee meeting on 24 February 1997 (O'Brien 1997). The emphasis remains deliberately focussed only on Broomehill.

A June 1997 edition of this overview was submitted to the Committee and expert independent referees. This edition was reprinted after a media release and position statement by the Water & Rivers Commission on 9 February 1998, with the position statement agreed to by World Geoscience Corporation Ltd.

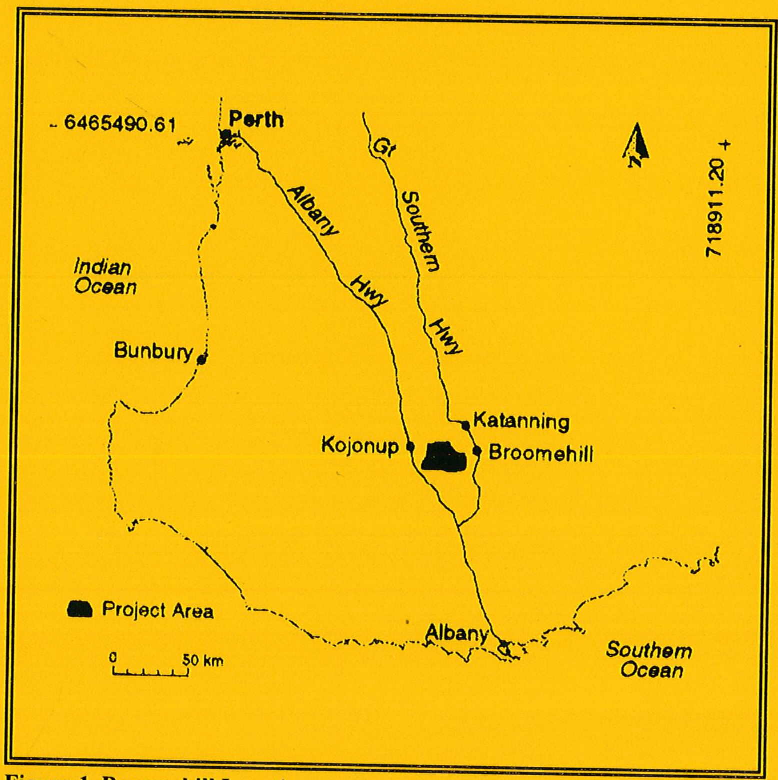

Figure 1 Broomehill Location

Acknowledgements:

All responsibility for views expressed in this discussion paper rests with the consultant. However, thanks are due and appreciation is expressed to the many individuals who assisted so freely and so amicably in development of complex and sometimes robust discussions. Dr Bruce Hamilton initiated and guided the project, skilfully assisted by Robin Smith. Tony Laws and Laz Leonhard from WRC, Dr Richard George and Dr Bob Nulsen from AgWA, John Bartle from CALM, Dr Tim Munday from CRC-AMET, Pat Cunneen, Dr Greg Street and Pru Leeming from WGC, and a number of others were of great assistance throughout. Thanks are given also for the support and helpful comments of referees of the June, 1997 edition.

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1 Introduction

In 1996 the Western Australian Government released its *Salinity Action Plan* (SAP) to respond to increasing damage and threats from salination in dry-land agricultural areas.

A key remedial measure proposed by SAP is to increase local consumption of rainfall by strategical planting. SAP calls for improved information to support planting strategies. It points out that new techniques using geology, geophysics and hydrogeology are emerging "which should greatly improve the accuracy with which perennials can be placed to achieve maximum water use":

> *World Geoscience Corporation (WGC) has developed an integrated airborne geophysical mapping system called 'SALTMAP'*[1]*. While expensive on a Statewide basis, this system may be cost effective for farm-level decisions. It requires urgent evaluation, both as a stand-alone tool and when used in combination with other data sets.* ....(SAP Sect. 4.3.2).

In 1993, in a joint project with local farmers, WGC flew a SALTMAP survey of Broomehill (Fig.1).

The survey area covered 46,500 hectares with 26 farmer partners. The district was first cleared and settled about 100 years ago, and has mixed farming with grazing of stock and cropping (WGC 1996a). It is classified in the Extreme Hazard zone of SAP.

The Broomehill Steering Committee was instigated in 1996 by the Water & Rivers Commission (WRC) to assist SALTMAP evaluation in the cooperative project *Broomehill '96*. It includes staff from WRC, Agriculture Western Australia (AgWA), WGC, Geological Survey of WA, Dept. of Conservation & Land Management, and others.

The newly-formed WRC contributed field expertise, a $175,000 hydrogeological project analysing 552 regolith samples from 35 bore-holes drilled in 14 transects under WGC flight paths (Leonhard 1998a & b), and this overview consultancy (O'Brien 1997).

AgWA contributed technical field and farm planning expertise (George & Smith 1998).

[1] WGC variously uses the term SALTMAP for a suite of systems or a single airborne electromagnetic (AEM) device. Where possible, this paper favours its meaning as specifying AEM alone.

The group used results of a 1994 seminar at Bunbury. Diagnostic guidelines describe landscape and regolith features that can give rise to salt hazards (the "Bunbury rules", George & Smith 1998).

WGC contributed a report (WGC 1996a) and a data package. They also supplied maps of salt hazards at farm scale using several data sets and WGC interpretation of generic "Bunbury rules". Main attention focussed on output from a single Channel of the SALTMAP (AEM) survey, converted into coloured "salt-hazard" maps of "conductivity."

Broomehill farmers contributed local expertise and historical knowledge in a four-day field trial in November 1996.

***Broomehill '96* was an important benchmark in the Western Australian SAP. It is a useful case study for the Federal plans to test AEM nationally in investigations of its value as a tool in salinity investigations and management. However, because it necessarily followed WGC emphasis on salt hazards, it did not explore any other role for AEM.**

2 Science-based Overview of Governance

Airborne electromagnetic (AEM) devices before SALTMAP have proven their usefulness in geophysical exploration for mineral deposits. Ground-based EM is of value in salinity management. So there is keen interest in whether airborne SALTMAP could be similarly useful but cover more ground. But government agencies faced a major difficulty in 1996.

On the one hand, WGC stated "SALTMAP stands alone as the only cost effective method of detecting [zones of high electrical conductivity which are potential areas of high salt concentration in the near-surface environment]." Further, "SALTMAP is proving invaluable for the mapping of salinity-prone farming land and in the restoration of saline degraded areas."

George & Smith (1998) recorded in field notes:

> *Farmers believe that [airborne] EM offers them something. SALTMAP in Broomehill has raised farmers expectations all over the country.*

One purpose of *Broomehill '96* was to test how well such expectations could be met in the field.

But, on the other hand, the only AEM data provided by WGC for *Broomehill '96* were single Channel 5 analogue maps portraying "conductivity". A vital key to progress was a clear and agreed definition of the meaning and reliability of this "conductivity" in terms of actual regolith[2] properties, particularly those important in management of salinity.

So this consultancy began with a science-based overview of governance of the multidisciplinary project ie management, production of usable data and accountability. In mid-1996 it found two major obstacles to efficient progress, neither caused by technical difficulties or limited resources :

- different cultures of different stakeholders creating communications difficulties
- disproportionate energies being given to airborne electromagnetic (AEM) maps, without clear knowledge of what these maps meant and what regolith characteristics were being mapped.

Efforts were made to reduce those obstacles by:

- extensive discussions
- a draft discussion paper in January 1997 to articulate difficulties and
- subsequent robust discussions.

The mapped "conductivity" proved to be a complex response to **several** properties of the local regolith (see S.3), and not simply conductivity.

AEM systems such as QUESTEM and SALTMAP include a suite of Channels corresponding to signals received at different intervals of time after a nominated transmission time. To interpret the vast amount of data, a theoretical model assumes the variation of salt content with depth is uniform over the signal footprint. After correction for instrumental and flight effects, the received signal strength is tested against the predicted theoretical strength, channel by channel. By iterating repeatedly and using the suite of channels, one can find the best inversion fit of conductance and regolith thickness for each model salt profile.

This process is necessarily computationally intensive (see Box). As of February 1997, government agencies had not been supplied with such an inversion of Broomehill data, only channel 5 maps.

All findings from *Broomehill '96* result from only the single channel 5 maps of "conductivity" supplied from 1993 flights. Under the pressure of the aroused expectations, these maps received most attention, were the most costly component of the WGC data package (see Box) and caused the most uncertainty.

Costs of SALTMAP AEM Data

A Salinity Strategy developed by WGC in 1996 advised that Salt Hazard mapping would cost $5 per hectare. It has not been possible to confirm whether this is the cost of single-channel data (as supplied for *Broomehill '96*), or the cost of a computationally-intensive inversion (not supplied).

WGC advised early 1997 computation times on a Sparc 20 for an area the size of the Broomehill evaluation. An "integrated conductivity" for a Channel 5 analogue map took about half an hour. A complete inversion of all Channels of SALTMAP using a simple 3-layer model to produce a plot of regolith thickness and conductance took about 5 weeks computing time.

The overview of governance found that the complexity of technical uncertainties was compounded by cultural differences among stakeholder groups.

For example, there are fundamental cultural differences between use of highly sophisticated methodologies such as AEM to explore for a rare, rich mineral deposit, and its use in salinity mapping. The first searches for anomalies, and can afford to be energy-intensive when it finds one. The second must be routine, reliable, widespread mapping of ubiquitous salinity for low-cost remedial management. In simple terms, the first search might use a costly full inversion but the second search might be able to afford only a low-cost single channel.

One governance issue is choosing the amount of information to do the task responsibly at a cost appropriate to that task. Indeed, a major cultural difficulty is in reaching a clear and agreed articulation of "the task."

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[2] The regolith is the name given to the mantle of soils and weathered material which overlies the basement rock. The variable thicknesses of the regolith, varying salt concentrations, depth of water table and the ease of water movement through the regolith (its hydraulic conductivity) are major controlling forces which influence the extent of salinity hazards.

3 Analytical Overview: SALTMAP & Other Methodologies

AEM has particular *potential* importance as the only airborne tool which can respond to saline fluids, even if they are hidden below the surface. But it is only one tool in a suite of a dozen diagnostic tools and methodologies (Nulsen et al. 1996), such as visual observations and airborne magnetic surveys ("magnetics"), available for management of salinity.

The governance overview (S.2) showed that uncertainties about AEM data and the dominant role assumed for AEM distracted from efficient selection and use of the suite most suitable for Broomehill.

As sketched in Figure 2, visual observations can identify salinity hazards[3] over much of the land. Magnetics might be used to investigate much of the remainder, identifying geological structures such as dykes that block or inhibit water flow, or create areas where salinity might accumulate. Thus a sophisticated methodology such as AEM might not be required to *identify* salt hazards for perhaps 90% of an area.

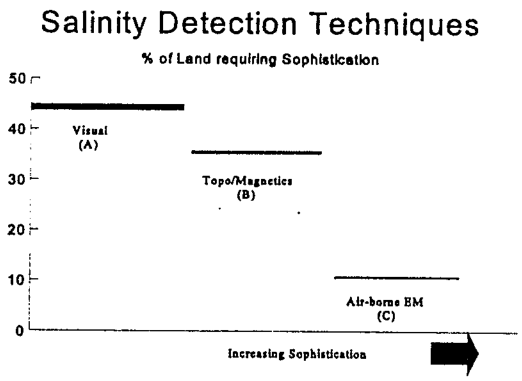

Figure 2 Illustrative sketch of the selective use of methodologies of increasing sophistication (Numbers are hypothetical).

Offsetting this are two factors. First, one prefers to understand the *cause(s)* of salinity hazards so that it (they) can be treated by a farm plan. The undeniable attraction of AEM is that it, like magnetics, probes underground and could possibly help measure sub-surface parameters and the *causes* and possibly *severity* of salt hazards. Second, risk management may not be content with treating only 90% of a farm.

However, as the WGC (1996a) report states:

> *The SALTMAP data however does not detect salt scalds.*

Simplistically, SALTMAP's response to salinity in 1993-96 varied from "poor" (say) on the surface to "good" (say) at depth. This has three consequences:

- AEM is not a stand-alone device but must be backed by visual or other tools
- AEM may have little immediate value in areas of advanced surface salinity
- the single-channel AEM methodology has a fundamental uncertainty. AEM signal strength depends on both salt content and the depth where it exists. **If data from a number of channels are available**, one assumes a model profile of salt content versus depth and iteratively tests the "best fit" to all channels. The single-channel maps lack such a capability. They can be ambiguous.

This vitally important conclusion can be reached another way. In the words of WGC (1996a):

> *The conductivity maps from SALTMAP data reflect the variations in salt storage in the regolith, the thickness of the regolith and to a lesser extent the water content and salinity.*

Thus even if the salinity was actually high, AEM might suggest low salinity if the regolith was very thin. Or it might suggest higher salinity where the regolith was thick and salinity only moderate.

A classic scientific problem is solving one equation (e.g. data from a single channel of AEM) when there are two unknowns (regolith thickness and salt content). In some landscapes features may give independent clues to the thickness of the regolith. But without such knowledge, the single channel AEM data could be equivocal. Even with such knowledge, any blindness to near-surface salinity could cause uncertainty unless very early time channels can be used.

Page 19 of WGC (1996a) already contained findings consistent with these analytical expectations.

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[3] There is confusion about the definition of a salt hazard. Some consider it an area where there might be a salt problem in the future, but not at present. Others prefer to include present problem areas. The definition is important in considering a single methodology like visual observations, or AEM. The first mainly sees present problems, while the second can be blind to present problems, in not detecting waterlogging or salinity in the uppermost 1 or 2 metres of the regolith. About 30 per cent of Broomehill land is waterlogged in winter (WGC 1996a).

4 *Broomehill '96* Work and Results

4.1 General

The 1993 Broomehill geophysical data were reviewed by WGC with field visits and reported in September 1996 (WGC, 1996a). That report formed a basis for the evaluation by Government agencies, *Broomehill '96* (O'Brien 1997).

> ***Broomehill '96***
>
> The *Broomehill '96* evaluation had four components:
>
> - analytical overviews of governance and methodologies (O'Brien 1997)
> - desk-top evaluation of WGC 1996a by Government experts facilitated by the consultant (O'Brien 1997)
> - a four-day field evaluation centred on AEM and WGC forecasts of salt hazard sites and guided by the desk-top evaluation (George & Smith 1998)
> - a $175,000 hydrogeological project analysing 552 regolith samples from 35 bore-holes drilled in 14 transects under WGC flight paths (Leonhard 1998 a & b, Munday et al 1997).

4.2 Analytical Overview of Methodologies

The analytical overview is discussed in S.3 above.

4.3 Desk-top Study

On 7 November 1996, after the analytic overview, the consultant facilitated a 2-hour desk-top study of WGC (1996a) in preparation for a 4-day field trial. Agency experts Bob Nulsen and Richard George (AgWA), Tony Laws, Robin Smith and Laz Leonhard (WRC) participated. Findings are given by George and Smith (1998) and O'Brien (1997).

The methodology was guided by Figure 2 leading to Figure 3. The WGC report contains a number of coloured photos of sites identified by WGC SALTMAP as salt hazards. For Broomehill Sheet 22 there were 90 "salt hazards" marked and the report contained May 1996 photos of 50 of these.

The government experts viewed the 50 photos[4]. Using Technique A of Figure 2, "Visual", they agreed on whether or not a salt hazard was visible. In 36 cases the answer was Yes (see Figure 3).

The question was then posed whether the remaining 14 salt hazard sites would have been forecast on the basis of magnetic and physiographic features of the area (Technique B of Figure 2). In 13 cases the answer was Yes (see Figure 3).

Only 1 of the photographed salt hazards remained, as a candidate potentially to be located by a more sophisticated technique (Technique C of Figure 2) such as AEM (see Figure 3).

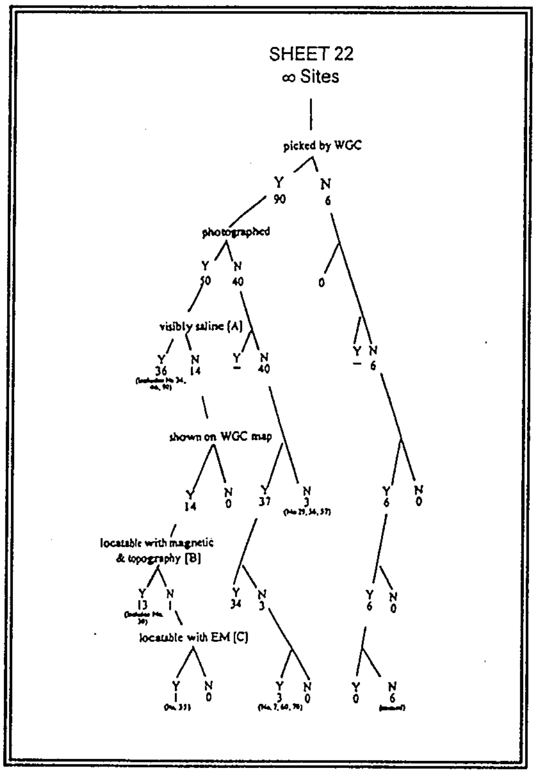

Figure 2 Desk-top decision tree for 50 photographs of sites identified by Saltmap as hazards, 40 sites not photographed and 6 unlisted sites. [Source R. Smith pers.comm].

Similar analysis was made of the 40 sites *not* photographed (middle branch in Figure 3). This found 34 of 37 sites on the WGC map would have been revealed with Technique B alone, without AEM. In summary, only some 5% of the site detection involved AEM.

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[4] Note that since all photos were of areas already deemed salt hazards, the strike rate success of "visual" detection from photos bears no relation to what it might be in alien paddocks. The numbers used in Figure 2 are hypothetical indications of mixing methodologies.

Finally, the top right-hand branch of Figure 3 is an "inverse" check of SALTMAP. It explored Technique B alone. Without photos, government experts searched WGC magnetics and topography information for sites **they** judged likely to be salt hazards which were **not** called salt hazards by WGC. In simple terms, the Government experts matched their interpretations of the Bunbury rules against WGC interpretation of the same data.

Six such sites were quickly located. The number has no statistical or other significance. It simply gave a methodical framework to prove that the field evaluation should also look for salt hazards **not** listed by WGC.

Salinity management is risk management. Too little attention has been given to the failure of a methodology to identify salt hazards. It means at best that trained or expert personnel are required to interpret the data. Otherwise there is a risk that others might interpret data at face value and then plan responses which could be invalid.

4.4 Field Evaluation November 1996

The field evaluation at Broomehill was made by officers of AgWA, WRC and WGC from 12 to 15 November 1996, in consultation with local farmers. A report and field notes (George and Smith 1998) provide details.

There are three separate findings.

First, some 47 sites that had been identified as salt hazards by WGC were found to be indeed salt hazards.

Offsetting that, and pursuant to the right-hand branch of Figure 3, 40 other adjacent sites were easily forecast by government officers as likely salt hazards that had **not** been identified as salt hazards by WGC. On inspection these sites were agreed to be hazards.

No statistical evaluation of these numbers is meaningful (O'Brien 1997).

George and Smith (1998) conclude that about half the salt hazards visited were not identified because WGC neglected salt hazards downslope of relict landscapes. The omissions are attributed to the need to modify the "Bunbury rules" in Broomehill terrain by developing rules to satisfy a more local, hillslope scale.

It is not known if WGC use of AEM exacerbated this flaw. But it is certain that the flaw was identified when government experts deliberately set AEM aside.

Second, the analytical overview (S.3) suggested that single-channel AEM maps could be ambiguous. This was confirmed in the field. AEM showed low "conductivity" in many sites that were highly saline. This flaw is deemed to be caused by shallow regolith thickness. It is called the "Gunwarrie effect" after a similar problem developed in QUESTEM surveys near Frankland (R. George *pers.comm.*). SALTMAP was developed in part to provide earlier time, ie shallower regolith, data than QUESTEM.

Third, both the analytical overview and desk top studies suggested most salt hazards could be identified without reference to AEM. This was confirmed in the field to be about 95%.

Furthermore, AEM data were used in less than 15% of the field cases for specifying management action.

Even then, expert interpretation was required on whether the Gunwarrie effect was present.

While AEM data, combined with magnetics, did suggest landscape patterns which reflect historic hydrologic processes, few people can interpret the data for farm and catchment planners. Hence even the single-channel AEM is expensive in time and expertise.

The evaluation clearly demonstrated the need to have farmers participate in discussions, providing much-needed historical and local information. As common sense suggests, the suite of sophisticated methodologies is inadequate without local ground truth and local knowledge.

However, the down-side was that the on-site emphasis was often understandably diverted from a rigorous, clinical assessment of SALTMAP by discussions about actual salt management and possible farm plans.

Some technical reasons for inadequate returns from SALTMAP are understood for *Broomehill '96*, but all remain issues for WGC to address.

The field results are broadly consistent with analytical expectations (S.3), desk-top study (S.4.3) and earlier field results of WGC (1996a).

4.5 Bore Holes and Hydrogeological Evaluation

In 1996 WRC drilled 35 bore holes in 14 transects under WGC flight paths, yielding 552 regolith samples (Leonhard 1998a).

Plots of nine bore-hole parameters (such as total salt content, regolith thickness) against "conductivity" as read from maps of AEM Channel 5 found no clear correlations (Leonard 1998b).

The analysis was being extended in mid-1997 using new AEM data from WGC as well as new, supplementary bore-hole data. A complete inversion was being analysed by CRC-AMET (Munday, *pers.comm*). Bore-hole data may provide insight into answering questions about which regolith properties are being measured and reliability and accuracy of the measurements (Munday et al. 1997).

Until then it is not known whether even the inversion SALTMAP AEM can give reliable data on regolith thickness and salt profile. Two cautions are added.

First, the equivocal nature of single-channel data, the Gunwarrie effect, will be a specific issue to be investigated. Large scatter of AEM can be expected because salinity profiles and regolith thickness are not constant over the surveyed area.

Second, there is a fundamental fragility in bore-hole data used to "test" AEM because the bore-hole samples a much smaller horizontal cross-section of the regolith than the "football-stadium" footprint of the AEM.

Both effects will cause significant scatter in correlation attempts even if both bore-hole data and AEM **data** were experimentally precise. While this is generally recognised, the inverse usually is not. Because of its large scale, any individual AEM at any site may not give precise **information** about that site.

This conclusion is relevant locally to any farm plan guided by the AEM data.

It is relevant strategically to the extent that catchment plans, say, are influenced by local detail.

Conversely, the large footprint of AEM may provide data for hydrogeological interpretation of a landscape and regional studies which might otherwise require an impracticable number of bore holes.

Although the two methodologies are often perceived to be competitive they might be complementary. For example, a bore-hole which measures regolith thickness can give guidance on whether a Gunwarrie effect in AEM is likely.

The issue of the accuracy of absolute values, and even of relative values, of regolith parameters deduced from AEM data, could not be pursued usefully in *Broomehill '96.*

5 Conclusions from *Broomehill '96*

5.1 SALTMAP and Salt Hazards

Focussing on salt hazards there are 13 conclusions about SALTMAP AEM in the form provided for *Broomehill '96*:

- SALTMAP was not a finished product but still in Research and Development (R&D). On 7 February 1997 WGC agreed: "until 1994 SALTMAP was purely a R&D project. Since then it has assumed the status of a Landcare tool and an R&D project (it will always be an R&D project.)" (P.Cunneen, *pers.comm.*)

- Contrary to speculation in the *Salinity Action Plan* (S. 4.3.2) SALTMAP could not be used as a "stand-alone" tool.

- *Broomehill '96* did not confirm SALTMAP as "an invaluable" tool. It was invoked in only of order 10% of the sites.

- No clear and reliable relation was established between single-channel AEM maps of 'conductivity' and properties of the regolith.

- When used in country where the regolith can be thick or thin, single-channel AEM was virtually in a *Catch 22* situation. If the regolith is thin, then it may well cause a salt hazard, called Type 2 by WGC (1996a). Yet paradoxically, at these very locations, where the regolith is thin, the Gunwarrie effect may cause a single-channel AEM map mistakenly to show any high salinity areas as low salinity.

- While *Broomehill '96* revealed some inadequacies of the 1996 SALTMAP AEM, it was not clear how or if some can be removed.

- Any field evaluation of AEM by government agencies should be a clinical, rigorous focus on understanding what the AEM is measuring, to see if rules can be developed for its use, analogous to the "Bunbury rules" for other methodologies. Attempts in 1996 to move directly towards finding a significant role for it in farm planning were fraught with risk and uncertainty.

- *Broomehill '96* could not investigate how many AEM channels will be required, or how they are best to be synergistically mixed, for AEM to become a significant tool in salinity management. Trade-offs between cost, sophistication and value of various suites of AEM channels were unclear.

- An inversion of SALTMAP AEM became available in mid-1997 (T. Munday, *pers.comm.*). A larger suite of AEM data could be used as an R&D component of *Broomehill '97*. Even so, regolith mapping depends on models of salinity profiles and uniformity which may not occur in every real circumstance. Bore-hole data provide basic, limited input but wide scatter is expected.

- The extent to which AEM requires ground-truth support remains uncertain. Even if all uncertainties were removed, Channel 5 was blind to surface salinity. *Broomehill '96* did not confirm or remove concerns that SALTMAP was not only "blind" to the top 1-2 metres of the regolith but perhaps to depths of 5 or 10m.

- *Broomehill '96* did not investigate relative merits of SALTMAP and QUESTEM.

- Strategically the usual assumption that methodologies are time invariant requires close examination. AEM data may have a shelf-life, or vary with season (O'Brien 1997).

- For many such reasons it was premature to establish a library of AEM SALTMAPs (O'Brien 1977).

5.2 Government "Duty of Care"

Government agencies would seem to have several duties of care in such matters as *Broomehill '96*. One consideration remains dominant. The end "owner" of the problem, and the end "pursuer" of the solution, is the land-owner farmer. Where a problem mounts to the point of being of concern to the community, governments may engage in "partnerships" with land owners, as in SAP, or take other steps.

Government investigation of a methodology such as SALTMAP may be interpreted by individual farmers, say, as putting a Government *imprimatur* or stamp of approval on it. We recommend on the basis of *Broomehill '96* that, in response to inquiries, government should adopt a policy of *caveat emptor* to promotion of 1996 SALTMAP.

If expectations raised by SALTMAP are causing delays in SAP (see Sect. 2), remedies should be found.

5.3 Strategic Findings from *Broomehill '96*

The November 1996 field evaluation encouraged confidence in the "Bunbury rules" when locally refined and expertly used, but the emphasis on SALTMAP AEM detracted from a clinical field test and refinement of the rules.

Even if perfected, high-tech capabilities such as AEM may be useful or needed at **this** time in salt-hazard work for only a small percentage of land (5% to 15% at Broomehill). This point is known to participants but not promoted. It has to compete with claims that "SALTMAP stands alone" and "SALTMAP is proving invaluable" (WGC 1996b).

One strategic issue for different locations is the rational balance between urgent coarse treatment of salinity and high-tech detailed scientific evaluation. How much must one know before acting?

A related question involving AEM is the **net benefit** in its use. The net benefit is the difference between:

(A) its positive value in providing reliable and useful information about the cause of a salinity hazard and

(B) its negative value in its failure to detect surface salinity, its misleading information where there is a Gunwarrie effect, its use in only a few percent of sites, and delays it might cause in salinity management.

Broomehill '96 did not find a net positive benefit in SALTMAP in the form provided.

The potential value adding from AEM itself has been inadequately refined. Those who perceive the AEM as an operational system rather than an R&D system potentially do AEM development a disservice.

State-wide surveys by AEM of all dry-land agricultural areas are not only not necessary for much farm-land salinity work, but could create two new risks.

First, a key component of strategic planning is that even if there were plentiful dollar resources, expert human resources are limited. Use of key personnel in refining sophisticated methodologies of **detection** of salt hazards for only a few percent of sites must be balanced against use of the same personnel in managing less sophisticated methodologies in **field management** of the majority of salt hazards by many stakeholders. One practical criterion to be applied to high-tech methodologies is how well and how reliably they can be taught for use by many.

Second, expectations about AEM raised nationally (see S.2) pose a strategic risk to salinity management. Risk management of salinity requires that such expectations should not delay action on farm plans unless the potential rewards justify such delay. At best, *Broomehill '96* provided no reasons to expect such potential rewards in the near future.

6 Strategic Findings on Future Joint Evaluation of Geophysical Methodologies

O'Brien (1997) provided recommendations to bring the 1996 work to a conclusion as *Broomehill '96.* Dissemination of the results will assist salinity management in Western Australia and nationally.

A set of broad non-technical Guidelines is given for future evaluations like *Broomehill '96* (see Box inside back cover). They are largely commonsense.

The progressive refinement of AEM and other methodologies, and their field testing, must ultimately have a farm plan or catchment objective in mind. But clinically scientific refinements of individual methodologies, and pursuit of cost-effective reliable suites of methodologies best suited to local needs are the way to reach that objective.

A vitally important lesson is that focus on AEM at Broomehill diverted attention from optimising the whole suite of methodologies (Nulsen et al 1996).

A high-profile methodology of any kind can be useful in stimulating interest and community action, but it is also essential to make a reality check periodically on the Emperor's new clothes.

The abundance of rich and varied geophysical information available in computerised data sets too easily obscures the fact that much salinity management can be carried out without it. One does not need to use million dollar magnetic resonance imagery to diagnose and mend a broken arm.

Furthermore, there are competing priorities such as cash flow from the existing farm.

Conversely, one may need the full powers of modern technology and powerful computers to bring some overarching and elegant understanding to complexities of the natural world.

The art and science of governance is to match the tool and the task.

A major strategic and technical challenge which appears largely in default is filtering of land elements through layers of different methodologies to yield reliable and cost-effective land management outcomes (see Nulsen et al. 1996, O'Brien 1997).

This Overview has revealed some of the assumptions and risks in using single-channel 1996 SALTMAP AEM for mapping of salt hazards.

Broomehill '96 contains many other useful lessons. They should not be over-estimated or under-estimated, but simply read as one methodical step in the Salinity Action Plan.

***Broomehill '96* will be most useful as a case study of co-operative ventures if the avoidable flaws it revealed are not repeated. The Guidelines (Box) are a necessary but not sufficient way to avoid such repetition.**

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Guidelines for Future Evaluation of Airborne Geophysical Methodologies

Government agencies, scientific research groups, commercial organisations, community groups and individuals who participate in complex multidisciplinary, multicultural projects like *Broomehill '96* should:

- articulate written, agreed and measurable target objectives and schedule benchmarks
- agree on procedures to resolve conflicts
- agree on deliverables such as data sets and their roles in meeting objectives
- agree in advance on acceptable levels of accuracy and/or uncertainty in data sets
- agree to compete on relative usefulness of each data set to the particular evaluation, *measured against the agreed objective*
- agree on project leader and responsibilities
- develop processes to combine continual improvement in each special discipline with optimising the synergies made available only by multiculturalism.