Environmental Research &
Information Consortium Pty Ltd
(ABN) ACN (81) 055 194 771
Ph 02 4842 8182
Ph 02 6161 3716
Fax 02 4842 8183
info@eric.com.au
www.eric.com.au

COMMENTS ON THE 2005 VERSION OF:

Technical Report on Salinity Mapping Methods in the Australian Context
by Brian Spies and Peter Woodgate

Brian Tunstall
Aug 2005

Comments here mainly address issues that adversely impact the ERIC capability hence this document is not a full review of the Spies and Woodgate Report (the Report). Extracts from the Report are in *italics*.

General and technical comments on the version of the Report released in 2004 are contained in another document. Specific comments on the DIPNR Review referred to in the Report are provided in another document as access to this Review is restricted. These comments are based on notes without current access to the DIPNR review. All documents developed by ERIC are available on www.eric.com.au.

Use of an Invalid Model

The mechanisms of irrigation and dryland salinity are still identified as being the same, the so-called rising groundwater model, and this is meant to account for all occurrences of dryland salinity. However, the June 2004 the House of Representatives Standing Committee on Science and Innovation report entitled Science overcoming salinity: Coordinating and extending the science to address the nation's salinity problem[1] identifies that the rising groundwater model is not general. The Parliamentary committee had access to a near final draft of the 2004 Spies and Woodgate Report in coming to this conclusion.

With many, and likely most occurrences of dryland salinity the rising groundwater model does not apply regardless of which representation is used[2]. For example, the photograph on Page 67 of the Report used to illustrate the occurrence of adverse salinity identifies impacts that arise from surficial lateral seepage rather than a groundwater system[3]. Occurrence of such seepage depends on climatic conditions and hence it is highly transient. Such seepage occurs in natural systems but the slumping illustrated in the photograph seldom does because the soil is bound by tree roots.

The clearest evidence of the lack of general applicability of the rising groundwater model is presented by Paulin[4]. The work and observations by Whittington in the Western Australian wheat belt reported by Paulin demonstrate two critical points. A

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[1] available on http://www.aph.gov.au/house/committee/scin/salinity/report.htm

[2] Some have water failing to drain while others have water moving vertically upwards but with two different mechanisms.

[3] If soil water is regarded as groundwater, as in the Australian Dryland Salinity Assessment 2000, the results arise through definition hence associated discussion is pointless.

[4] Paulin, S. (2002). Why salt? Harry Whittington, OAM and WISALTS: Community Science in Action. Indian Ocean Books, Perth. 63 pp.

network of piezometers demonstrated that the saline seepage could not have derived from a rising groundwater table as there was no groundwater system remotely close to the seepage. Also, the adverse salinity was reversed by increasing rather than decreasing groundwater recharge on the slopes. The ability to reverse the adverse impacts to the point of returning a stream to something like its original condition is good evidence that the measures implemented by Whittington addressed the cause of the dryland salinity which was soil structural degradation.

The Whittington results were officially reviewed and dismissed because they did not accord with the scientific doctrine of the rising groundwater model. However, application of the scientific method identifies that the results clearly negate the occurrence of any form of the rising groundwater model in his situation. Any exception negates a model as being general. These consideraions are addressed in the paper What Model for Dryland Salinity? available on www.eric.com.au.

An indirect but still clear exposition of the general invalidity of the rising groundwater model is given in a submission by Land and Water Australia to the House of Representatives Standing Committee on Science and Innovation enquiry on dryland salinity. One of the Committee's main findings was that dryland salinity was more complex than they originally thought. That is, dryland salinity could not be addressed solely by application of the rising groundwater model.

Discussion in the 2005 Report on the occurrence of dryland salinity retains the comment that *dryland salinity is a problem associated with increased water supply in salty landscapes*. The additional water is said to be associated with land use change when any water balance identifies that the landscape cannot receive additional water in such a manner. The change is to the partitioning of water and not the amount in the landscape. The Report also contains the comment that the geological processes for irrigated and dryland salinity are similar (Page 14). It is difficult to make any sense of this comment unless geology is equated with hydrology, which is irrational as they are very different. Moreover, while the physical processes underlying irrigated and dryland salinity are the same the hydrologies of irrigated and dryland systems are not.

The general inapplicability of the model for dryland salinity underpinning analyses in the Report and the lack of understanding of the processes involved in dryland salinity invalidate much if not most of what has been concluded.

Use of an Assumed Status to Denigrate Others

The highly derogatory comment that *claims by some vendors have no basis in science* has been removed but arguments used to justify that comment remain. As before, unpublished and unreviewed material that cannot be obtained by anyone other than those involved in producing the Report is used to denigrate results, methods and skills. Apart from representing a gross breach of scientific protocol and community standards this makes a mockery of a suggestion by Woodgate that industry material was not considered because it was not peer reviewed or published.

Applying the scientific method readily negates the above derogatory statement. The associated comments that remain, while not as derogatory, still seek to damage industry and they are similarly invalid when subject to scientific analysis.

> *Some vendor's claim that their methods directly detect salinity are unsubstantiated (e.g. some radiometric and remote sensing proponents claiming direct detection of salinity). It is good practice for potential users to seek*

independent advice on claims made by vendors.

The relevant details and logic are given in the paper Comparison of EM and Radiometrics for Dryland Salinity Mapping available on www.eric.com.au. Basically the ERIC observations cannot be refuted but the suggested experts cannot explain them and have made no apparent attempt to reproduce them. Instead they rely on extrapolating technology to identify that such results either cannot exist or that they arise by chance. The existence of the observations cannot be refuted through theoretical modelling and no evaluation was given of the possibility of the results arising by chance. Even with a basic analysis their arising by chance is much more remote than the expert's estimates of the possibility of measuring a ^{24}Na emission in radiometric surveys[5] that they rely on to deny the ERIC technology.

The issue of independence is addressed further later but in this situation the suggestion is that potential ERIC clients should seek advice from those who gain benefit from implementing and/or promoting competing methods. It is directed at increasing the opportunity for those in statutory (publicly funded) organisations to suppress industry. The benefit is often direct, as where agencies provide services, but it always has a large indirect component. Status and research funding depend strongly on self promotion which is aided by the denigration of alternatives, particularly those deriving from industry. Commercial delivery of services that are technologically superior to their research is an anathema to public scientists as it reduces their status and opportunities for research funding.

The reference to ERIC as simply being proponents of radiometrics and remote sensing is similarly misleading. ERIC does possess a high level of capability in those areas but offers a broad scope of services that have included the use of ground and airborne EM as well spatially detailed soil sampling. Work undertaken includes detailed soil landscape mapping[6] and an objective and integration of radiometric and vegetation information to produce a detailed soils map[7]. While the integrated approach incorporated well defined numerical methods, and was found to be useful by others, it is not recommended by ERIC for baseline mapping because of the lack of independence between the soil and vegetation maps. Any results obtained using such integration contain significant limitations, particularly when the integration subjectively incorporates many layers as advocated in the Report.

ERIC personnel are not bound by any particular method and have used most that have general practical application in addressing land use, including dryland salinity. Moreover, ERIC provides a broad scope of services that include climate analysis, topographic analysis, planning and risk assessment which address a range of applications such as regional development, military land use, viticulture, and forestry. ERIC is therefore well placed to determine which methods best address particular needs of clients noting that cost is always a prime consideration. The same cannot be said of those that claim to be experts in particular fields. As their status

[5] The radiometric signal relates to the material where it originates. A very low estimate of the probability for the occurrence of a distinct signal within a geological formation that is unrelated to the material that comprises the formation is 10:1 against. The probability of this distinct signal occurring in 10 different geological formations is 10^{10}. It is to low to be regarded as even a remote possibility.

[6] Presented in the first of the Singleton series of soil mapping papers on www.eric.com.au

[7] Tunstall, B. R. Marks, A. S. and Reece, Ph. H. (1998). Vegetation and Soil Mapping: Shoalwater Bay Training Area. CSIRO Land and Water, Technical Report 10/98 Under reports on www.clw.csiro

depends on a particular technology they singularly promote that technology and often criticise those that do not use or promote their methods.

Use of Misrepresentation

In an attempt to justify their position the authors have continuously used such misrepresentation. It cannot be determined whether this is deliberate or simply represents a lack of understanding of the subject matter and scientific method. That is, it could be intentional deceit or simply represent a preparedness to comment on something that they are not competent to address.

The miss-representation of the ERIC mapping methods is a key issue. Woodgate has acknowledged that he did not take account of the submissions to his review by NRI[8] and ERIC or the copious associated material that has long been readily available. Woodgate had previously been supplied with a two page list of ERIC reports and papers. Despite this the Report selectively uses information to assert that ERIC methods are scientifically invalid while disregarding results that have been routinely produced. This selective use of information represents scientific deceit.

Personnel from CSIRO Mineral Exploration are similarly selective in making adverse comment while showing they do not understand the basics of either soil mapping or the ERIC SoilSelect method. For example, a deficiency identified in the radiometrics is:

- *since the signal comes from the upper 30 cm, weathering, soil transport and other pedological processes play a large part in responses;*

For this to be a deficiency salinity would have to be independent of *weathering, soil transport and other pedological processes*.

[8] The ERIC technology was being delivered through Natural Resource Intelligence Pty Ltd (NRI) at the time of the submissions.

As salinity depends on these processes the radiometrics can only be a strength in soil and salinity mapping. Putting aside the comment on 30 cm being technically incorrect (at best it is loose or inexact) the remainder identifies why the radiometrics are particularly valuable for soil mapping. The suggested deficiency is why the data have particular value for mapping soils and addressing dryland salinity.

The most significant technical misrepresentation is the suggestion that there must be a necessary relationship between soils and levels of K, U and Th for the radiometrics to be applicable. This assumption is inherent in some mineralogist's attempts to identify mineral composition from the radiometric signature but it does not apply with soil mapping. The authors partly accommodate the issue in their identification of the need to establish empirical relationships but seem to fail to comprehend that establishing such relationships negates any requirement for a necessary relationship.

> *We note here some unjustifiable claims regarding radiometrics. Firstly, extrapolations from ground concentrations of K, U and Th to other soil properties (pH, salinity and conductivity) involve correlations that may only be valid locally and have not been generally proven as fundamental properties of soils. Potassium as measured by aerial surveying is not the same as 'available K' as often required for agricultural mapping.*

The initial deficiency in this paragraph is the reference to a proven fundamental property of soils. Empirical correlations establish relationships between the radiometric signal and soil properties such as texture and pH. Within the range of observations these relationships apply without any qualifications other than imposed by the statistical model. It is unclear what a proven fundamental property of a soil is but, if it represents a standard physical or chemical property, then there is no need for the radiometrics to directly reflect any particular soil characteristic for it to be useful in soil and salinity mapping. Indeed, the benefit of radiometrics is that they reflect the complex interaction of minerals and their alteration through soil and landscape processes. Seeking a single relationship, such as with a fundamental soil property, would be counterproductive with soil mapping and this has been the experience with work by Geoscience Australia.

The above comment from the Report is even at odds with another comment from the Report given below which identifies that radiometrics are applicable for extrapolating ground observations as done by ERIC with SoilSelect.

> *Fitness for purpose*
>
> *Radiometrics is readily applicable for soil mapping, with signals emanating from the top 10 to 40 cm of the earth surface, in the upper part of the root zone. A major advantage for soil mapping is that it gives complete ground coverage and so could be used to extrapolate more detailed field measurements of soil properties over wider areas. Radiometrics can also be used as a ground-based method (see Appendix 1.9),*

The second deficiency is the gratuitous comment that *Potassium as measured by aerial surveying is not the same as 'available K' as often required for agricultural mapping.* This form of comment derives from those that have only just encountered soils or who have failed to grasp the fundamentals. Soil potassium can be measured in many ways and each provides different values. Methods used to estimate the amount of potassium available to plants have a theoretical basis in relating to solubility and extractability under different conditions but the value of the different measurement methods is determined by empirical correlations with plant growth. However, there is no single measurement that can accurately identify the amount of Kin soil available to plants as this depends on microbial activity and levels and forms of mineral and organic K as well as K that is solubilised and adsorbed onto soil colloids. There can be no single correct measurement.

I am unaware of any evaluations of plant performance in relation to radiometric measures of K and without such information there is no basis for suggesting that radiometric measures of K are any less useful than other measures of K in addressing its availability to plants. However, the general situation is that for clays the level of ^{40}K indicates the level of weathering and hence is a good indicator of general soil fertility. This is quite apart from the irrelevance of the value of the K measurement for agriculture when the issue being addressed is mapping patterns of soils and salinity.

The gratuitous comments continue with the dot point:

- *interpretation is a skilled task but the apparent simplicity of the data may trap the unwary into inappropriate treatment of the data.*

The authors have demonstrated that they do not have the knowledge or expertise to interpret radiometrics in relation to soils as they do not have the necessary knowledge of soils. However, this comment additionally identifies deficiencies in their understanding of the radiometric data. By comparison with other airborne geophysical measurements, and most measurements in general, the radiometric data are not simple. The scaling of the measure varies with height above the ground, as does its relative sensitivity. The measurement error is not independent of the measured value as normally assumed.

These deficiencies in understanding the basics of the radiometric measurement are reflected in the simplistic assumption that the signal only responds to K, U and Th. It can be shown very simply that the Total Count (TC) band contains information not contained in K, U and Th thus this assumption is wrong. Failure to use the TC band, as is routinely done by CSIRO Mineral Exploration and Geoscience Australia, produces highly degraded results in soil mapping compared with what can be achieved. The failure to use the T C band largely arises from the belief that the requirement is to identify minerals from the concentrations of different elements when this is irrelevant for soil mapping.

The Report still fails to clearly differentiate between the SoilSelect soil property mapping method and the SalinityMap method for mapping salinity and the technical evaluations undertaken on the SalinityMap method that have been used to denigrate it in the Report do follow any scientific method. They simply represent technical extrapolations of existing understanding. This use of technology to attempt to deny the existence of observations is scientifically invalid. Technology can be used to explain how such observations can arise but not to deny their existence.

Biophysical Impacts of Salinity

The Report still contains the assertion that salinity hazard relates only to the level of salt when there is abundant evidence that the composition of salts is equally important[9]. The content of the section on biophysical impacts is given below.

> *The deleterious effect of high concentrations of soluble salts in plant growth are mostly related to the increasing difficulty of extracting water from highly concentrated solutions because of increased osmotic pressure (OP), which is quantitatively related to the EC. of the soil (Chhabra 1996). However Rhoades et al. (2002) argue that the salinity of soil water (the water that is accessible to plants) may be much lower than that estimated from EC. This is because salts will often be present in the saturation-extract that would not be in solution under actual field conditions. Additionally, salts contained within the fine pores of aggregates will contribute to the EC^ value, though it is doubtful that significant amounts of such salts are absorbed by plant roots or affect the availability of most of the water extracted by the plant (which is primarily that present in the larger pores).*

There is evidence that the deleterious effects of salinity on plants relate more to nutrient uptake than the reduced osmotic potential[10]. However, the greatest deficiency is the suggestion that the salinity of water in fine pores will not affect the availability of water in large pores. As the two water sources are directly connected this suggestion is physically unsound.

The current convention is that the soil water potential, which identifies the water availability to plants, is the sum of the component matric, osmotic, and pressure potentials[11]. Combined with the gravitational potential this determines the patterns of water flow in soil. Water moves to eliminate gradients in water potential hence spatial differences in water availability derive from resistances to flow. Resistances can produce large gradients in water content within soil profiles but very local gradients are very small.

[9] Addressed in Dryland Salinity Implications of Interactions between Clay, Organic Matter, Salt and Water in Soils available on www.eric.com.au

[10] Plant and site characteristics of advantage with saline soils. Available on www.eric.com.au

[11] Use of the term osmotic pressure is inappropriate for soils. Salts reduce the energy status of water and it takes particular structural arrangements, such plant cells connected to a water supply, to convert this to a pressure.

A non-uniform partitioning of salt within the water can alter the osmotic potential compared with that expected given the usual assumption that the total free energy is the sum of the partial free energies. However, such partitioning serves to reduce the availability of water compared to a uniform system[12]. There is no mechanism by which the osmotic potential can be increased as suggested[13]. An increase can only occur through a loss of salts by leaching or precipitation.

Some of the Technical Errors in Comments on Radiometrics

The comments identify fundamental deficiencies in understanding basic characteristics of airborne gamma radiation data.

A number of caveats apply;

- *the signal is strongly attitude dependent, so classification by slope is required;*

Topographic effects can be complex because of the footprint of the measurement but their significance depends on the purpose. Provided the aircraft can follow the ground they are generally of little consequence for soil mapping. Difficulties mainly arise where steep terrain prevents the aircraft from following the ground. Results for the hills are still generally reliable but those for gullies are not and they cannot be corrected through data processing.

A classification by slope would generally serve little purpose because the aircraft usually flies in alternate directions during a survey to minimise flying time. The combination of an inability to follow the terrain and the measurement footprint means that the errors associated with slope (attitude) vary with the direction of flight and cannot readily be accounted for. For fixed wing aircraft the aircraft attitude differs when gaining rather than loosing altitude, particularly at the low speeds used for measurement. Any adjustment would have to be made on line data rather than image data as inferred.

- *the technique is really only applicable in relatively high energy (erosional) environments, where relief is high;*

This comment is contrary to theory and results. Radiometric mapping in a depositional environment using radiometrics achieved much higher resolution than a traditional soil survey using soil pits on a 100m grid. This example was conducted as a test of the SoilSelect method on a 500ha landholding but there are many other such regional and local examples that the authors have chosen to ignore. The comment above derives from limitations in the capacity of some individuals to analyse radiometric data and in no way reflects what can be achieved.

The image for the entire Mallee region in Fig. 1 represents a compilation of a number of radiometric surveys. The entire region is depositional. The part of the region away from the River Murray derives from beach ridges and aeolian deposits of clay and calcium with alluvial clay deposits adjacent to the river. While erosion is an inescapable occurrence in all landscapes, geologically the area is depositional rather than erosional.

Sands of the Big Desert and Sunset Country are blue (low emissions) while young clays associated with the river are red (high emissions). The subset images show variations in ages of clays around the river and variations in the plains in the SE related to prior strand lines. Areas of highest relief, the sand dunes of the Big Desert, have by far the lowest emissions. Highest emissions arise on flat low lying

[12] Interrelationships Between Salt Content, Water Content and Water Potential in an Expansive Clay Soil Under background papers on www.eric.com.au
[13] The osmotic and matric potentials are negative relative to free water hence a decrease in potential represents a reduction in water availability.

plains. Such data have been used to evaluate commercial mineral sand deposits in the region.

The key points are:

- Radiometrics can be used to map patterns of soils across very large regions.
- Radiometrics are applicable in depositional areas. The signal is not just noise.
- Considerable information can be obtained without the need for field observations.
- The total count band contains a large amount of information.
- There is no necessary relationship between relief and the level of radiometric emissions.

- *the technique has not been shown to work in depositional environments, although variability may represent different soil properties that can be used to define recharge zones;*

This is partially a repeat of the prior point but it is self-contradictory.

If variability represents noise then the data contain no information other than on the level of noise. For some purposes the level of noise can provide useful information but it has no known application in identifying recharge areas. If radiometrics can be used to identify recharge areas then the data identify pattern rather than noise and are therefore applicable in depositional areas. As usual, the level of success depends on analytical skills and the quality of data.

The results in Fig 1 are for raw data for one band and do not identify the resolution that can be achieved with numerical analysis of multi-band data. However, they still clearly illustrate that radiometrics provide very useful information on patterns of soils in depositional environments. These results were available to Woodgate.

- *high rainfall (>650 mm/y) areas are generally leached of salt, even if the environment is right for salt accumulation (e.g. western slopes of the Adelaide Hills);*

The relevance of this comment to salinity observations using radiometrics is obscure. It reflects assumptions concerning landscape effects on salt accumulation and so is irrelevant to the radiometric analysis.

- *the technique is not universally applicable, so rigorous ground-truthing must be carried out;*

This is poorly stated. The soil mapping results depend on empirical correlation and so depend on field observations. The applicability of the results is therefore usually restricted to the area of observation.

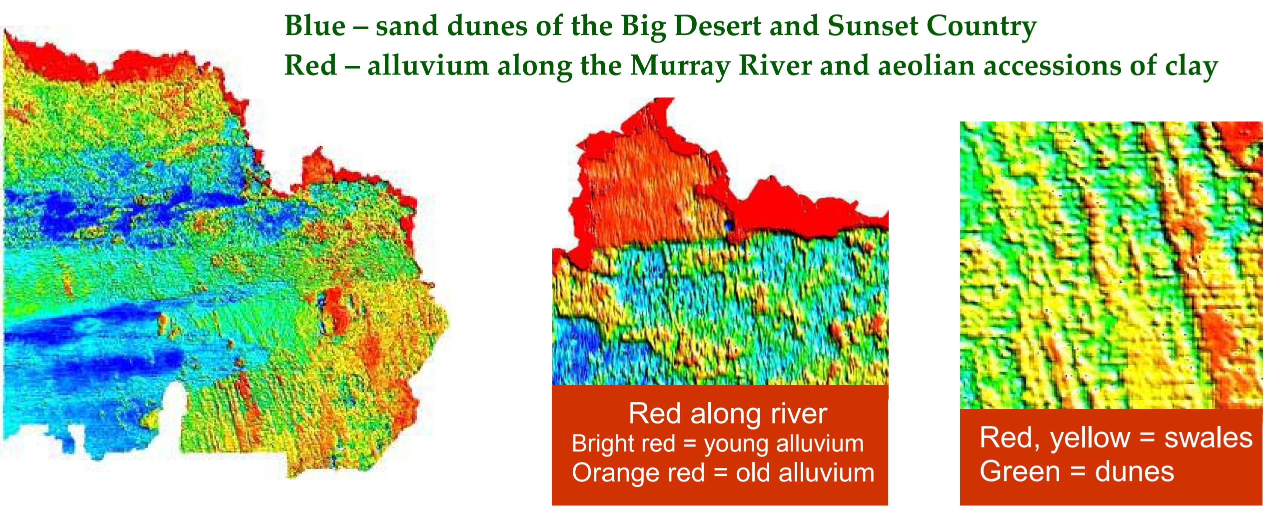

Fig 1. Edge enhanced Total Count for the Mallee region of NW Victoria

However, in areas of simple geology the main soil patterns can be mapped for a very large area without field sampling and results can be extrapolated across surveys, as illustrated in Fig. 1.

Use of EM to map soils or salinity similarly depends on correlation as suggested for radiometrics but this is not made clear in the Report.

- *while the aircraft samples every seven metres across the terrain, the footprint is of the order of 10 to 100 m for each spot so boundaries may not be as well defined as an image may indicate.*

This comment is also poorly stated and it is difficult to see that is has any validity.

The aircraft does not sample but moves during the integration period for the measurement. The distance traveled during each sample is typically around 60m which gives a generally ellipsoidal sampling pattern or footprint for each observation. The proportion of the travel distance sampled varies with the technology but modern electronics allow sampling of the entire length. A more valid explanation given in the Report is:

> *Gamma rays recorded in airborne surveys originate from a thin layer at the earth's surface with an elliptical shape approximately twice the flying height wide and a similar distance plus flying time over which the signal is measured (typically one second). The lower the flying height the better the resolution of the data. At 100 m height, about 80% of recorded gamma rays originate from a region below the aircraft several hundred metres wide.*

The footprint for the measurement by way of size and relative contribution from different parts of the measured area varies with height above the ground. The spatial resolution varies strongly with the height of measurement above the ground and surveys are designed such that this relates to the flight line spacing. The nominal spatial resolution (rule of thumb) is one quarter of the flight line spacing. However, the measurement more closely approximates a point the closer the aircraft gets to the ground and the flying height affects the spatial resolution independently of the flight line spacing. A lower flying height also improves the signal to noise ratio with higher improvement at lower energies. With current data this differential improvement is reflected in a greater amount of information being available from total count at lower flying heights.

The spatial resolution also varies with the effort and expertise in producing the image from the individual observations and the methods used to analyse the image. ERIC achieves much higher spatial resolution that others considered possible (it was initially said that such resolution could not be achieved) because of the use of a spatial statistic in the analysis.

Limitations

Limitations of the method are:

- *high noise since normal rocks and soils have on average 1% K, 2 ppm U and 8 ppm Th which gives a very low gamma-ray emission;*

This perpetuates the myth that information can only be derived from the K, U and Th bands. Also, the level given for K relates to total K and not the radioactive ^{40}K that is measured and so is irrelevant.

With basic analyses the issue is the signal to noise ratio rather than the absolute level. The uranium band generally provides little information because of a low of signal to noise ratio. Total Count has a much higher signal to noise ratio than K, U or Th and is most important for mapping soils.

- *the signal from any one lithology is not unique;*

This is definitively worth stating but it should be accompanied by the comment that lithologies tend to have distinct radiometric signals. That is why radiometrics are used in mineral exploration and is the basis for the desire of some to determine absolute concentrations of K, U and Th. This comment as presented is indicative of the penchant to knock or promote rather than provide objective analysis.

- *since the signal comes from the upper 30 cm, weathering, soil transport and other pedological processes play a large part in responses;*

This is a benefit rather than deficiency when mapping soils. It can be a deficiency with some approaches to mineral exploration but ERIC has used it to advantage to map particular forms of depositional areas for mineral exploration companies.

- *varying moisture levels affect repeatability;*

The issue of repeatability does not affect soil or salinity surveys that are based on empirical correlation. However, moisture patterns must be considered as water greatly reduces the level of emissions. Radiometric surveys are generally undertaken under dry conditions to maximise the signal hence water is mainly an issue in irrigation areas.

- *naturally occurring airborne radon can degrade surveys;*

Technically degradation is not a limitation unless it is shown to prevent the achievement of a define outcome. The comment addresses process rather than outcomes and as presented has no relevance to the issues being addressed.

- *interpretation is a skilled task but the apparent simplicity of the data may trap the unwary into inappropriate treatment of the data.*

This is addressed above noting that radiometric data are complex compared with most other data used in land survey.

Appendix 1.16 Airborne gamma-ray spectrometry (radiometrics)

------ *A gamma-ray spectrometric survey measures the spatial distribution of the three most common radioactive elements (potassium-K, thorium-Th and uranium-U), in the top 30 - 40 cm of the earth's crust. Radiometric mapping products are valuable in assisting trained practitioners to understand soil, regolith and geomorphological conditions, and are often used in the production of soil maps over large regions. There are no independently verified and proven applications of radiometrics for salinity hazard mapping. Moreover the physics of radiometrics suggests that based on our current understanding there is little likelihood of a technique being found that will do so in the future.*

This technical description of the radiometric measurement is misleading. A more informative description is:

Airborne radiometric survey data obtained for mineral exploration are usually measured over 256 or 512 bands across the gamma radiation spectrum of 0.3 to 3 MeV using a sodium iodide detector. These spectra are typically characterised by a small number of poorly defined emission peaks due to the large number of elements that contribute to the signal and the limited energy resolution of sodium iodide detectors. Peaks identified as corresponding to the elements potassium, uranium and thorium are the only ones considered to be generally capable of providing reasonable discrimination. Consequently, three broad bands or regions of interest are usually selected for analysis that are traditionally assumed to be associated with potassium (^{40}K), Thorium (actually Thallium 208 which is linked to the decay of Thorium), and Uranium (actually Bismuth 214 which is linked to Uranium decay). A Total Count (TC) measure is also provided that includes the entire gamma radiation spectrum from 0.3 to 3 MeV. Traditionally these windows were fixed as below but some current techniques slide the windows to improve the signal to noise ratio.

K band 412: 1.37 – 1.57 MeV
U band 414: 1.66 – 1.86 MeV
Th band 416: 2.41 – 2.81 MeV

TC band 418: 0.03 - 3.00 MeV

That is, uranium and thorium are not directly measured, and the signals in all bands contain contributions from elements other than those used to name the bands. A nominal stripping ratio is applied to bands (removes the proportion of the signal assumed not to derive from the designated element) but this degrades the data without providing benefits other than allowing calculation of an estimated absolute level for the element. Many current methods used in preprocessing the radiometric data for mineral exploration degrade its value for soil mapping.

The comment that *There are no independently verified and proven applications of radiometrics for salinity hazard mapping* has been addressed previously on many occasions by ERIC. The initial issue is that of independence: Independent from what? ERIC results are usually independently evaluated by clients but that does not occur with scientific papers where assessments conducted by authors are rarely repeated by reviewers or other scientists.

Given that the ERIC results have been rejected by those involved with the Report, and as they have shown no evidence that they have implemented the full SoilSelect method, it is not surprising that they conclude there has been no independent assessment. The reality is that they have failed to implement basic requirements in application of the scientific method in claiming something that has been produced cannot be produced while failing to implement the methods used to produce the results.

The Cootamundra Shire results map salinity hazard for the region (Fig. 2) as well as providing detailed information on other soil properties. They are noteworthy as the Shire had previously evaluated all available salinity results and found they did not identify known occurrences of salinity. Deficiencies included the inability of existing models to explain how salinity could intermittently appear and then disappear. Such deficiencies are why ERIC was contracted, because ERIC offered to provide new information. The salinity results developed by ERIC accorded with what they knew about their land and explained many apparently anomalous occurrences of salinity (Fig. 3). The key point for the Shire's General Manager related to why a stretch of road suffered around $50k worth of damage each winter as this provided substantial annual savings which alone provided a large return on investment (Fig. 4).

This work was presented at the National Local Government Salinity Summit, Momama-Echuca, July 2001 by a Shire planner and ERIC[14]. Geoscience Australia presented in the same session and CSIRO personnel at others. Anyone involved in applying geophysical data to salinity mapping has no excuse for not being aware of the results as they were also identified in an article in the spatial industry magazine (Salt of the Earth on www.eric.com.au).

The Shire subsequently made available to ERIC results from an EM survey conducted for a proposed development on a particular landholding. These accorded with the ERIC regional results (Fig. 5). Regional salinity mapping has been done using radiometrics and the results have been independently evaluated.

Deficiencies in Integrating Diverse Information to Produce Outcomes

Salinity mapping is based on measurement hence technical detail in the Report addresses different measurement methods. Most of these assessments are reasonable but some are misleading, as with radiometrics. However, to be of use the measurements require interpretation and to

[14] Application of Radiometrics to Identify Salinity Risks in the Cootamundra Shire Available on www.eric.com.au

address dryland salinity this involves integration. The interpretations span across disciplinary boundaries.

Four pages of text and figures in the main body of the 2004 Report address the assessment of salinity hazard and risk. Despite this apparently detailed consideration the key table in that Report addressing the applicability of different methods for mapping salinity hazard and risk contained a fundamental error in identifying different levels of hazard. Hazards are categorical in that they exist or they do not, hence they do not have a level. This fundamental error negated most of the conclusions in the 2004 Report and was corrected for the 2005 Report.

This error could reflect deficiencies in the presentation of hazard and risk in the report as, while hazard is implicitly identified as being categorical, this was not explicitly stated. However, it demonstrates the limited ability of those producing the report to integrate the disparate information it contains. If the information in the Report is inadequate for the authors to draw correct conclusions then it would be considered grossly inadequate for those that are meant to use it. If the authors get it wrong from the material presented then it would be reasonable to expect that most people will get it wrong.

This inability to integrate diverse information derives from a failure to apply basic scientific considerations such as the form of variable (e.g. continuous variable or category), independence of observations (the advocated use of information that is not independently derived results in circular arguments) and mutual exclusion between categories. This latter condition is illustrated by the failure to discriminate between soil water and ground water, and the apparent confusion between geology and hydrology.

The mapping capabilities and techniques identified in Table 7 of the 2005 Report represent measured continuous variables (elevation, EM, magnetics, radiometrics), categorical data (land use, infrastructure), general reference information (air photos), and interpreted information (geology, hydrology, soils). This represents an illogical assemblage where interpreted layers such as soils are derived using information from other factors listed, such as elevation. The presentation in the table infers that the factors listed have similar characteristics when they are very dissimilar and must be handled in very different ways.

This confusion continues in Table 8 where for Landscape Map the techniques identified as being used include regolith but this is followed by the comment that regolith is not a technique. This apparent editorial comment is correct but the error remains and is repeated in the table for salinity hazard mapping.

Most presentations in the body of the report breach basic requirements needed for logical analysis. Combined with the logical and technical errors this effectively precludes use of the report for its intended purpose.

Conclusions

Some errors and misrepresentations have been removed from the initial 2004 Report, such as the identification of different levels of hazard and the comment that *claims by some vendors have no basis in science*. However, the Report still contains numerous logical and technical errors and is internally inconsistent. If judged according to fitness for purpose the Report fails because the basic model and many of the components used in its construction are flawed. The report would not run if tested as with a motor vehicle and hence would not have been released.

The apparent inability to comprehend and apply basic scientific principles, such as a single exception negates a model as being general, means that the Report is fundamentally flawed. No amount of promotion of the rising groundwater model in the Report, on the Academy of Science's web site or elsewhere can make the model generally applicable when there are well documented exceptions. It appears that to some the sun will always revolve around the earth where this position is promoted in the Report by failure to apply basic scientific principles, the use of 'information' that is not available to others, misrepresentations, deficient understanding of technologies, ignoring information that does not suit the line being promoted, and only promoting technologies that benefit public agencies. The objectivity expected in a scientific report is not there. While Ray Evans suggested on the Saltlist web site that the time had come to forget Galileo, the Report demonstrates that the situation remains fundamentally unchanged. Those in industry presenting new ideas are pilloried when the new information threatens the beliefs, status and positions of public scientists and administrators. Science then becomes irrelevant as they treat scientific debate as a war wherein truth is always the first causality.

The House of Representatives Standing Committee on Science and Innovation report on dryland salinity identified that the use of EM for salinity mapping had been oversold where this is likely a response to the promotion of EM in the Report. CSIRO Mineral exploration provides commercial services in processing multi-frequency airborne EM and the Bureau of Rural Sciences (BRS) has received considerable funding to investigate its application to salinity, promoting it politically being the 'ultrasound of the earth'. BRS is part of the department that owns the Report, the Department of Agriculture Forestry and Fisheries (DAFF), and that department has joint control in the disbursement of NHT and NAP funds that are used for such purposes[15].

There is no evaluation or test of usefulness of the report for its intended purpose. However, as it misleads those it is meant to inform it can only be defective for purpose. The only purpose it can serve is to justify administrative decisions to channel funds into cost ineffective directions and suppress industry. It should therefore be withdrawn.

Comments in the Report suggesting that results that have been produced cannot be produced contravene the Trade Practices Act as well as the scientific method but those making the claims hide behind the statutory status of organisations. This use of position to suppress industry greatly disadvantages the community that pays for their privilege. The question for the public, and hence politicians, is what can be done to rectify a situation where those being paid to resolve dryland salinity have become a major part of the problem.

Those involved with the Report have been denied any right of reply to the point of suggesting that no further information would be considered. Development evidently stops with the production of the Report. This forces landholders to either continue with practices that historically have been ineffective or to develop alternatives that work. The latter is difficult because the public service has become a government service having the prime focus of promoting its position, thereby blocking the development of alternatives.

The issue for the Academies is the compromise associated with the use of their names to give credibility to scientifically deficient work.

[15] The report is assigned joint ownership to DAFF and DEH but legal ownership is unclear. Through governance and contractual arrangements it could belong to DAFF. The organisation(s) contracting to produce the consultancy report have not been given.

SoilSelect salinity mapping results for the Cootamundra Shire

Mapped using numerical analysis of airborne radiometric data and field soil sampling.

The results provide paddock level detail with regional coverage. They demonstrate occurrences of dryland salinity that are not associated with so called 'rising groundwater'.

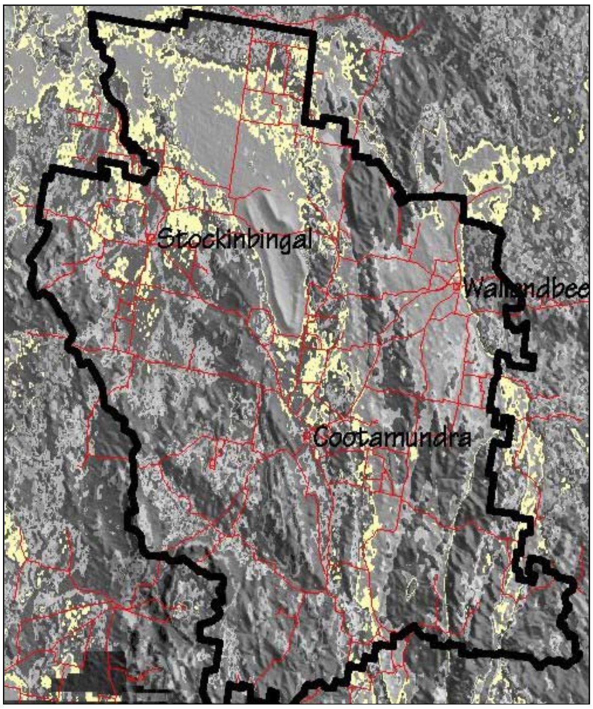

Fig. 2 Areas of high surface soil salinity in the Cootamundra Shire (salinity hazard & salinity pathways)

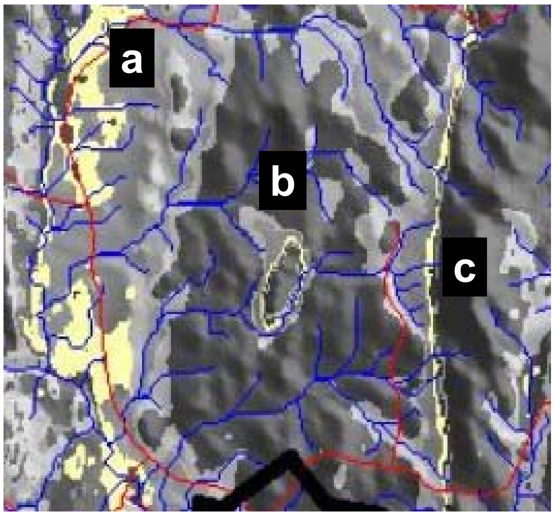

Fig. 3 Some of the patterns of salt flow and accumulation in the Cootamundra Shire.
a Along flats and streams
b Break of slope around hills
c Along fractures and fault lines

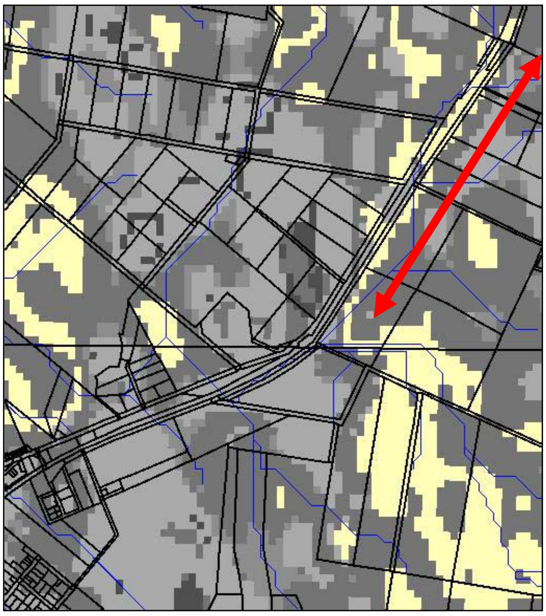

Fig. 4 Section of the Olympic Highway subject to annual repairs (associated with a salinity pathway).

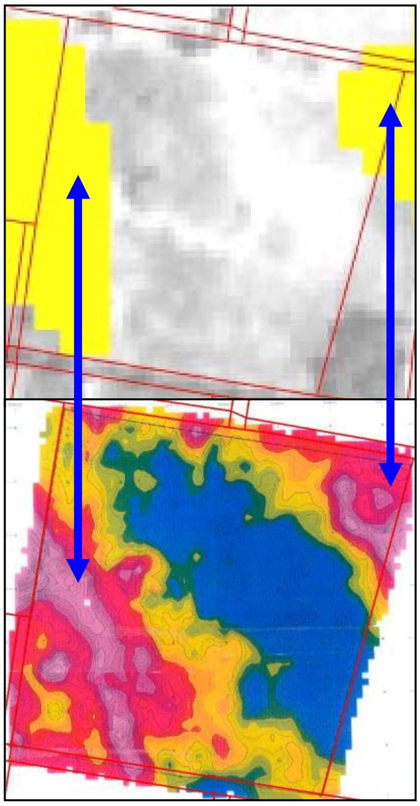

Fig. 5 Comparison of a salinity class (top) and EM31 results (bottom) for an individual landholding.