FAQ: DIFFERENCE BETWEEN SOIL PROPERTY MAPS & THE RADIOMETRIC SALINITY CLASS

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INTRODUCTION

This addresses frequently asked questions relating to these maps. Topics addressed are:

- Similarities and Differences, soil property mapping and the salinity class
- Field Sampling Requirements for Soil Property Mapping
- Production of Soil Property Maps
- Salinity Hazard and Risk, Storages and Flow Pathways
- Depth of Salinity Class Observations
- Nature of the Salinity Class Spectral Signature

SIMILARITIES AND DIFFERENCES: SOIL PROPERTY MAP AND SALINITY CLASS MAP

Summary Descriptions of Methods

Soil Property Map

The soil property mapping is a multi-step process (a methodology) for mapping soil properties. The steps in the process are:

- Development of a map characterising patterns of soil variation.
- Field sampling of soils with stratification based on the reference map.
- Laboratory analysis of soil samples to objectively determine soil properties.
- Statistical analysis and comparison of results with geological and other information to remove artefacts and produce a revised soil map.
- Additional field sampling and laboratory analyses to provide reliable estimates of properties for the mapped classes.
- Production of report containing soil property and thematic maps as required.

The process includes consultation and allows for client participation in the collection of field soil samples.

The map characterising soil variation is usually based on numerical analysis of airborne gamma radiation data (radiometrics) as this provides the best result and is most cost efficient. However, the methodology is applicable where the reference map is derived by other means. The information on soil properties is given as a continuous variable.

Salinity Class Map

This method uses numerical analysis of gamma radiation data to map patterns of soil variation similarly to the soil property mapping. Areas of surficial concentrations of salinity (likely only sodium based salts) are determined from known areas. Regional patterns can be mapped with one field observation or general knowledge of the likely distribution of salinity. The result is presented as a category and does not identify the level of salinity.

Comparison of Methods

Similarities

1. Both methods can use spectral and spatial statistics to map soil related patterns from radiometrics.
2. Both methods provide information on the distribution of high surficial salinity.

Differences

1. Soil property mapping requires extensive field sampling and laboratory analysis for the area of interest. Salinity class results can be produced by extrapolating results from other areas and need not involve field sampling.
2. Soil property mapping provides information on a range of soil properties. It also provides information on the levels of salinity. The salinity class only identifies areas with surficial salinity and does not identify the level of salinity.
3. Soil property maps provide information on the subsoil as well as surface soil properties whereas the salinity class appears to relate to the surface soil.
4. Soil property maps reflect soil profiles developed over hundreds of years. The salinity class results can likely change rapidly (months to a few years) in response to the weather and land use.

Implications

1. The soil property maps provide comprehensive soil property information to address all facets of land use and management. The development of the soil property information is based on detailed field sampling and analysis that comprise the greatest cost component of the soil mapping.
2. The salinity class likely only provides information on areas of surficial accumulation of salt associated with pathways for water movement and can do so with essentially no field sampling. This greatly reduces costs. The likely link between the salinity class and sodium ensures the results have high reliability despite a lack of field sampling.
3. Given a link between the salinity class and cosmogenic sodium the salinity class results will be applicable for monitoring the effects of changes to land use and management.

SAMPLING REQUIREMENTS FOR SOIL PROPERTY MAPPING

The Soil Property Mapping methodology is designed to produce a map where the classes differ significantly at the 95% probability level. However, the percentage variance accounted for is MUCH lower than 95%.

While there is considerable room for improvement the ability to produce soil maps where each mapped category differs significantly is a significant achievement. However, concern is often expressed that the number of soil samples obtained when implementing the methodology is inadequate. These concerns appear to arise from often quoted figures on the number of samples required for different scale map sheets when applying Soil Landscape mapping.

The calculations behind the suggested sample numbers for Soil Landscape mapping are unknown as no reference has been sited. The validity of the estimates therefore cannot be assessed. The approach adopted here is to examine the implications of sampling models applied with Soil Property Mapping. However, it is noted that differences between the Soil Property Maps and Landscape Mapping approaches will inevitably lead to different sampling requirements.

Soil Landscapes contain mixtures of soils described by reference to a pre-existing classification of soil types while Soil Property Map classes are designed to map discrete soils identified by their properties. Soil Property Map classes are described by way of measured soil properties for the area of interest rather than a pre-existing classification. The mapping of mixtures and use of a prior classification of soil types makes it difficult to determine the level of significance of results with Soil Landscape mapping.

The stratification for field sampling provided by Soil Property Map relates well to patterns of soil properties. The stratification for field sampling provided by Soil Landscape mapping is usually poor due to the map polygons containing a variety of soils and because the polygon boundaries need bear little relationship to the factors determining variations in soils. These considerations alone identify that much fewer samples would be required with the Soil Property Map methodology than with Soil Landscape mapping. The experience with one method is not directly applicable to the other.

Soil Property Map Sampling Model

The simplest model for a Soil Property Map analysis provides around 20 soil classes with five samples per class for at least two horizons. The degrees of freedom in an ANOVA comparing 20 classes is 80 where horizons are analysed separately and 160 where horizons are analysed together. Neither of these situations is limiting.

The most significant aspect of the statistical analysis relates to the assumption that the soils in each radiometric class have similar soil properties (the class contains only one soil ‘type’). If this assumption is valid then triplicate samples for each class can provide good results. Where the assumption is invalid no amount of sampling need produce statistical significance.

The requirement that a class should only contain one soil type can readily be violated when using radiometric patterns to stratify field sampling as the radiometric signal primarily depends on two factors, parent material and weathering. Different combinations of these factors can potentially produce different soils that have similar radiometric signals.

The occurrence of the same radiometric signal for different soils is most common at low signal levels where discrimination is limited by the signal to noise ratio. It is clearly evident in irrigation areas where the application of water greatly reduces the signal.

The Soil Property Mapping methodology incorporates two field samplings to address this issue. The first is primarily designed to identify where classes are ambiguous and where classes can be usefully amalgamated. Ambiguous classes contain a wide range of soil properties and are split, usually by reference to geology. The second sampling and analysis is designed to provide labels for the mapped classes that include statistical measures of significance.

The key with the statistical analysis lies in developing an appropriate stratification for field sampling rather than focusing on obtaining a large number of samples. Four soil horizons can usually be recognised but around 90% of the information is contained in the A2 and B2 samples. There is usually little benefit in analysing the A1 and B1 horizons. However, there may be considerable benefit in analysing the substrate (C or D horizon).

The decision on the sampling regime ultimately depends on cost benefit. Only analysing two horizons halves the soil analytical costs while only slightly reducing the amount of information obtained. Analysing the substrate would likely substantially increase the information obtained but could double the field sampling costs.

Practical Implementation

The issue of cost almost inevitably determines that the second field sampling is limited or non-existent in practical applications. Corrections are always made to the initial map but there is limited information to establish the level of significance. This situation is usually of concern to scientists that are unfamiliar with the area and hence rely on statistics for evaluation of the results. It is of no concern to clients whose local knowledge allows them to readily relate to the mapped results.

Every statistical analysis is constrained by the sampling regime but the significance of this limitation for application can be decreased by involving clients in evaluating the soil mapping results. The best means of avoiding gross errors in regional studies is to use local knowledge.

The experience with Soil Property Mapping results has been that the information provided is much more detailed than previously available to land holders, even with limited field sampling. The greatest need is for education on the means of applying the information to improve business and environmental outcomes. Clients see no benefit on expending funds on determining statistical significance when the money would provide greatest benefits when spent on improving information delivery.

PRODUCTION OF SOIL PROPERTY MAPS

Maps of individual or discrete soil properties can be obtained by:

1. Detailed grid sampling with associated surface fitting.
2. Relating soil properties to mapped soil patterns.

The first approach is generally only applied to small areas subject to high profit land use. The second approach is most commonly used but the mode of map development depends on the nature of the reference soil mapping.

Soil Landscape Mapping

Most soil mapping has been based on Soil Landscapes. This almost inevitably characterises soils using categorical information on soil types that is not ordered in any defined sequence. Variation in soils within the map units can only be addressed by defining the occurrence and relative abundance of different soil types.

The soil types used with Soil Landscape mapping relate to prior classifications and do not directly provide information on the associated soil properties. Much effort has therefore been expended on identifying relationships between soil types and properties. This indirect derivation of soil properties from soil types needed to produce soil property maps introduces considerable uncertainty.

Each Soil Landscape contains a variety of soils thus use of an average of the soil property levels for the different soil types is inappropriate even if weighted according to the dominant soil type present. The most common approach when producing soil property maps is therefore to assign the value associated with the most common soil. This has high unreliability if only because the most common soil may occupy less than 50% of the mapped area.

Radiometric Soil Property Maps

Soil description with the Soil Property Mapping methodology discussed here is based on the direct measurement of soil properties as continuous variables. The variation in soils within map units can therefore be described by way of a mean and variance as each map unit is designed to be homogeneous with regard to soil properties. The validity of this approach depends on accommodating assumptions concerning the distribution of observations within classes as identified above under soil sampling.

While Soil Property Map results can be directly presented as discrete soil property maps issues arise as to the reliability that can be assigned to the mapped differences. The relationships between classes can be complex as they depend on the relative variance within classes. Class A can differ significantly from B when B does not differ significantly from A. Moreover, A and B can differ from each other when neither is significantly different from class C. Such situations make it difficult to ensure that all differences in the mapped patterns of soil properties are significant.

The practical solution is to identify discrete classes for properties that ideally represent natural subdivisions in the data. The main consequence is that not all boundaries between mapped categories need be statistically significant. The use of class means in this way is a normal but is seldom applied in soil mapping due to the constraints imposed by the Soil Landscape mapping procedure.

SALINITY HAZARD AND RISK, STORAGES AND FLOW PATHWAYS

Definitions

Hazard and Risk

The definitions used here are that hazard represents a potential for adverse impact while risk evaluates the significance of that potential for a particular purpose. Salinity, frost, and flood risks are categorical in identifying that a potential for adverse impact exists. However they do not identify what the level of damage might be.

Hazard is a binary situation in that exists or does not but the existence of a hazard depends on the nature of the land use. Appropriate grazing on saltbush plains would not present a salinity hazard but conversion to irrigated agriculture would.

Risk evaluates the potential for a hazard to cause damage in particular circumstances. These circumstances must usually be well defined. For example, the frost risk depends on the likely occurrence of frost at particular stages of plant development hence its prediction depends on detailed knowledge of the developmental characteristics of the particular variety of the crop being considered.

The generally recognised elements of risk are:

- The potential magnitude of adverse change (magnitude of impact).
- The likelihood of the change occurring (probability of adverse impact).
- Public perception of the consequences of change (perception of significance).

The likely magnitude and probability of impact can be combined to provide an integrated measure of biophysical risk but public perception is a separate consideration. Situations arise where a low biophysical risk is associated with a publicly perceived high risk, and vice versa.

The biophysical risk can arise through in situ change (intrinsic) or be induced through changes occurring elsewhere (extrinsic). Change can be localised but it can also have the potential to cause adverse change elsewhere. Areas considered **at risk** would usually have low salinity but be susceptible to changes occurring elsewhere. Areas that **constitute a risk** would have high salinity and an explicit potential to cause adverse change elsewhere.

Salt stores can but need not constitute a hazard, and hence level of risk, as most salt stores are immobile and are likely to remain so. A risk only arises where it can be determined that changes to land use will significantly increase the mobilization of salt and that the salt will adversely accumulate elsewhere in the landscape.

Determining which sites are at risk depends on good knowledge of the distribution of salt in the landscape and the likely changes associated with land use. Our current level of knowledge of the structural controls to water and hence salt movement severely limits such predictions. Projections are generally based on simply identifying low parts of the landscape in areas with appreciable salinity when the development of adverse salinity depends additionally on the accumulation of water and barriers to drainage.

Storages and Pathways

Storages represent the amount stored in a given volume and may be given as total amounts or concentrations. Flow pathways represent areas subject to inputs and outputs. Technically a pathway is any area other than where there are no salt outflows as all areas receive some aeolian accession. However, for practical purposes pathways have accessions and outflows associated with water flows.

Most soil represents a salinity pathway but rates of flow differ depending on structural controls. Within profiles most inflow and outflow can be on top of the B horizon while most flow within a horizon can be associated with structures such a cracks and old root channels.

The preferred pathways for surface flows are stream lines and these often become incised. The preferred pathways for subsurface flows are less well defined and can depend on soil profile development and geological structures such as dykes, fractures, fault lines and other unconformities. Subsurface flows can exhibit complex preferential flow patterns due to the diversity of structural controls.

Salinity Hazard Mapping

Salinity hazard mapping is straightforward as it represents an existing situation. Soil Property Mapping results for soil salinity levels and dispersibility can be combined to present a hazard map for agricultural purposes. However, such a map does not identify hazards for issues such as groundwater salinity. The mapped hazard is usually purpose / application specific.

Salinity Risk Mapping

Risk mapping inherently contains uncertainty as risk addresses uncertainty. Also, the risk is more purpose / application specific than for hazard mapping. For example, a risk of high stream salinity can be beneficial to soils while being considered undesirable due to its impact on water supplies and aquatic biota.

Ideally any salinity risk mapping should separately address the three components of risk and should also address different applications. Such mapping has not been implemented due to the limited availability of information. Moreover, there is a desire for a single, simple answer despite the risks inherent in presenting such a map.

The provision of information that improves understanding of salinity processes may provide the best means of addressing risk.

Salt Storages

A number of methods exist for mapping salt storages where EM is prominent. The relevance of EM relates to its response to salinity, albeit confounded by other factors, and the ability to obtain measures across a range of depths. The disadvantages include the costs associated with obtaining EM data and the field measurements needed to determine salt stores. Surficial EM data need only map patterns of clay and/or soil water content.

The main issue in evaluating the significance of salt stores relates to the potential for mobilisation. Most large salt stores are necessarily immobile otherwise they would not exist. The difficulty lies in identifying which salt stores can result in adverse change in response to changes in land use.

Salinity Pathways

Salt movement has often been addressed by assuming flow occurs in a homogeneous porous medium. This approach has been most used where models are driven from measured system outputs and represents a pragmatic approach to limited data availability and the complexity of realistic models.

The acquisition of more detailed salinity data has identified preferential pathways for water and salt. This situation was not unexpected but is seldom addressed due to the difficulties of obtaining information that can be used in models

The difficulty in identifying salinity pathways lies in the inability to directly measure fluxes. Flows must be determined by the balance between inputs and outputs where neither is easy to determine.

Salinity pathways are currently inferred from patterns of salt accession and geomorphology. Salt accumulations associated with unconformities or other permeable situations such as paleo drainage lines are interpreted as being conduits or pathways for salt movement. Salt accumulated in impermeable material such as heavy clay is considered to have low flow.

The limited information on salinity pathways limits our understanding of salinity processes. It is also of particular consequence when addressing salinity risk as this depends on change that can only occur through salt flows.

The salinity areas identified by the Salinity Class represent a mix of surficial salinity pathways and salt accumulations. The salinity pathways represent a hazard in being known but, in being an agent for change, they also determine the risk. High salinity areas fed by these pathways that are not drained are similarly known and therefore represent a hazard. However, as they represent the areas that are most likely to be subject to adverse change they also represent the areas at greatest risk for agriculture.

DEPTH OF SALINITY OBSERVATIONS

Comparison of results from different studies and with different methods invariably invokes scaling issues as differences can arise from differences in scale as well as in the methods and measurements. The scale issue addressed here is the effective depth of the observations.

Around 70% of the radiometric signal arises from the surface 30cm of soil which equates with the A soil horizon. However, it has been found that the properties for the B horizon are equally important as those for the A horizon in differentiating between the radiometric classes. While the B horizon contributes little to the measured signal its properties are important in explaining variations in the radiometric signal.

The significance of the B horizon arises because its development affects conditions in the A horizon. Similarly, deeper structures such as dykes and fractures can affect surface soil conditions and hence the radiometric signal.

As the radiometric signal contains information on subsoils as well as surface soils interpretation of the radiometric patterns requires property measurements for both horizons. The empirical approach used with Soil property Mapping provides independent salinity measurements for the A and B horizons.

The effective depths of results for the Salinity Class are currently uncertain. It appears that surficial salinity along fault lines reflects much deeper conditions. However, it is likely that high salinity identified at the break of slope around hills is a surficial phenomenon. Flows along incised drainage lines appear to reflect deeper expressions while many non-incised flow patterns appear surficial in being perched on the B horizon.

At least 7 different salinity expressions have been observed in Salinity property Map results for one region alone and each requires investigation to determine the cause and understand the implications. All Salinity Class results identify accession sites but some appear to also be flow pathways. This difference is significant as major flow pathways would not be expected to change significantly and hence represent a hazard rather than a risk. Accession areas that are not pathways (not drained) have the potential to change adversely, particularly where fed by a pathway. They therefore represent a risk as well as being an existing hazard.

Deeper salinity expressions will be similarly mapped by the Salinity Class and instruments such as the EM31 where they also have surface expression. However, as the EM31 provides a 'bulk' apparent conductivity to around 6m, the EM results will differ considerably where the Salinity Class reflects surficial expressions only. The differences between EM, the Salinity Class and Soil Property Map results may have considerable benefit they provide opportunities to discriminate between near surface flow pathways and stores.

Nature of the Salinity Class Spectral Signature

Context

Spectrographic analysis is based on the assumption that different features have distinct emission / reflectance characteristics and that this signature allows their unique detection. The reliability of this assumption depends on the homogeneity / purity of the feature. Individual molecules have well defined compositions and structures and hence have very distinctive absorption characteristics. This is used to advantage in mapping green vegetation by reference to chlorophyll absorption (the chlorophyll edge).

Most natural features represent complex mixtures of molecules and their signature varies depending on the nature and relative proportions of different molecules. Vegetation, for example, comprises varying proportions of trees shrubs and grass. Moreover, the spectral characteristics of the trees, shrubs and grass can change seasonally. Minerals can similarly vary in composition but have the benefit of no seasonal change. In practice the spectral signature of a given feature can vary considerably.

Particular features can still often be identified by their spectral characteristics despite having variable spectral signatures. This requires the existence of some spectral characteristic(s) that uniquely differentiates them, as with the association between green vegetation and chlorophyll. For salinity the requirement is that salt, primarily sodium chloride, has distinctive emission / absorption characteristics that allow its discrimination from other components of the surface.

The distinctive feature of ^{24}Na is the occurrence of dual emission peaks that fortuitously coincide with bands used for K and Th. The link between these peaks distinguishes the signature from those for K and Th. The emission characteristics of ^{24}Na are highly distinctive.

Past Work

Reflectance

Studies of spectrographic absorption by salt and saline areas in the 1970s determined that NaCl could not be spectrally discriminated with the available survey imaging technology. However, potentially saline areas could be identified by:

- High reflectance of salt scalds
- Anomalous land cover / vegetation

The anomalous land cover is characterised by areas with lower green vegetative cover, higher proportion of bare soil and higher soil moisture content than surrounding areas. Also, the greenness of the vegetation tends to be more constant than elsewhere. Spectrographic detection of salinity was indirect in detecting the effects of salinity on vegetation and soil moisture.

Radioactive Emissions

Neutron bombardment of the stable ^{23}Na produces the radioactive ^{22}Na and ^{24}Na. The signature for ^{24}Na is most distinct in having three peaks at 0.511, 1.368 and 2.754 Me volts. ^{24}Na has a half life around 15 hours and decays to ^{24}Mg. The peaks at 1.368 and 2.754 coincide with the bands used to characterise Th and K respectively in airborne radiometric surveys. .

Studies in North America have used atmospherically generated ^{24}Na to track surface water flows from rainfall. Studies have also used cosmogenic radionuclides produced in near surface rocks to evaluate rates of weathering and erosion.

There are no known studies on soil salinity mapping from radioactive emissions from ^{24}Na. Calculations by others identify that the natural ^{24}Na levels would be undetectable against the background using airborne data acquisition. Also, a ^{24}Na signature evidently cannot be detected in individual ground spectra obtained in saline areas. These calculations and observations have led others to conclude that the signal being detected with the Salinity Class cannot derive from ^{24}Na.

The alternate explanation given for the Salinity Class results is that they derive from a fortuitous correlation between emissions from K, U and Th. This conclusion that they must arise by chance derives from the assumption that K, U and Th or their equivalents account for all of the information in the signal. However, statistical analysis of the Total Count (TC), K, U and Th bands identifies that TC contains information not in the other bands. This additional information mainly arises from lower energy levels as it increases with decrease in the height of data acquisition above the ground.

As the radiometric signal varies strongly with the nature of the material this alternate explanation does not account for the consistent signature across regions having complex geology. It also cannot account for the ability to transfer the signature across surveys. Suggestions that such results arise by chance serve only to admit an inability to provide an alternate explanation to observed results.

Salinity Class Results

The key characteristics of the Salinity Class results are:

- Areas of surficial salinity have a distinct spectral signature.
- The salinity spectral signature is constant across wide regions (is independent of the geology/ parent material).
- The salinity spectral signature can be transferred across different radiometric surveys.

The salinity spectral signature is distinct and stable, and can be detected in areas with complex geology that have a wide range of emission characteristics.

The results demonstrate that Salinity Class results can be transferred across surveys with a high level of reliability when the results for other classes cannot. One or two classes have a distinct spectral signature but the others do not. This ability to transfer the salinity class negates the conclusion that the Salinity Class results arise through a fortuitous correlation between K, U, and Th and salinity.

The conclusion that the results arise through a fortuitous correlation is additionally problematical because no explanation has been given as to how this can arise. It is a bland statement that evidently is expected to be taken as fact.

A more logical analysis identifies that applications of the gamma-radiation measurement almost invariably derive from the association between the spectral characteristics and the mineral composition of the material. Different minerals tend to have different spectral characteristics. There is therefore a need to identify how, in an area having different geologies with very different spectral characteristics, there can be a distinct signature that is completely independent of the geology. Any suggestion that this situation can arise by chance across a very large area is grossly inadequate.

The occurrence of a distinct spectral signature (class) that is independent of geology lead to the realization that a distinct spectral signature was being mapped. This is a direct observation that cannot be refuted. It is reinforced by the ability to transfer that signature across surveys.

Given the occurrence of a distinct salinity signature the key issue is how can this arise when all other classes relate strongly to the geology. The most likely explanation relates to the characteristics of the spectral emissions from ^{24}Na and their position relative to the bands recorded in airborne data. This provides the opportunity for the occurrence of a distinct signature embedded in the data. The issue then is how does the analytical procedure allow identification of such a signature against the background variance (background of a highly variable geology, not noise).

Issues

The givens are that ^{24}Na is continuously produced in the atmosphere and the soil. It has a high rate of breakdown and is highly radioactive. It also has a distinct spectral signature.

The uncertainties relate to the detection of ^{24}Na against the background signal. This can readily be done in the laboratory but has been considered impossible with airborne measurements due to the low signal to noise.

The key issue is that a distinct salinity signature is being detected in airborne data when current knowledge indicates that, while such a signature can exist, it should not be capable of detection.

The proposal that a ^{24}Na signature would be undetectable has been used by some to suggest that ^{24}Na should not be identified as a possible cause for the Salinity Class results. This raises issues relating to the scientific method. In effect, a hypothesis has been made that a salinity signature exists related to the occurrence of ^{24}Na. As observations exist of a distinct salinity signature the requirement is to disprove rather than disregard or summarily dismiss the hypothesis.

The issue posed by the field observations is the generation of consistent signal across large regions regardless of geology. Explanations provided include:

1. The signal arises through an association between Na and the emissions of K, U and Th. That is, the signal is not due to ^{24}Na but to a causal link between salinity and the concentrations of radionuclides that derive from radioactive decay.

2. The signal has a distinctive signature that allows its detection against a highly variable background.

Deficiencies in the first explanation relate to the lack of any known mechanism that could link salinity with radioactive decay across a wide range of minerals. Indeed, the proposal runs contrary to known relationships and the use of radiometrics to map patterns of materials.

The second explanation is known to be physically possible as the technique is applied in telephony with CDMA. A distinct signature can be detected in a broad band signal when its level is well below that of the noise. The characteristics of the ^{24}Na signal that could provide such a distinct signature are the linked emissions at two energy levels.

While the second explanation is possible several issues remain. Such signature detection is usually based on knowledge of the characteristics of the signature. Detection requires a 'key'. The Salinity Class analysis is conducted without a key apart from the general knowledge that the K and Th bands are appropriately located.

A second issue relates to band width and noise. A broad band signal is required (detection requires a wide range of observations) and this is provided with regional surveys. A distinct salinity signature could therefore be detected despite it arising against a wide variation in background signals associated with differences in geology. The signature would not be expected to be detected with single point observations.

The analytical method uses spatial as well as spectral statistics to discriminate between classes, hence the spectral variance of classes does not provide a reliable indication of the level of resolution being achieved. The method allows mapping of features one to two pixels wide over distances as great as 100km where this was said to be impossible with airborne gamma radiation data. The discrimination achieved is much greater than has been produced by other analytical methods.

The Salinity Class results indicate that the resolution achieved with the analytical method is much greater than expected or has been achieved by others. However, further research is needed to determine the limits.

Nature of Measurements

EM measurements represent a continuous variable while Salinity Class results represent a category. Salt must apparently be present to be detected as a Salinity Class but the method cannot differentiate between high and low salinity. The lower salinity threshold for the Salinity Class is not known. As the indications are that the results reflect pathways for water movement it is likely that the salinity levels are seldom particularly high.

This difference in the nature of the measurements means that EM and Salinity Class results usually cannot be directly compared. This is reinforced by the differences in the spatial scale of the measurements. Salinity Class results are different from any others previously available and must be appropriately evaluated.

Conclusions

The hypothesis that the Salinity Class results are due to a distinct signature arising from ^{24}Na remains valid until disproved. A rational explanation exists for the hypothesis and there are currently no observations that negate it.

The onus lies in disproof rather than proof and this requires further targeted observations. It requires measurement and analysis and cannot depend on models that simply project prior knowledge and understanding.