www.csiro.au

Monitoring of acid sulfate soil environments in the Lower Lakes and adjacent tributaries

Dr Andrew Baker
Research Scientist
24th August 2011

Australian Government

Government of South Australia

CSIRO

Talk Outline

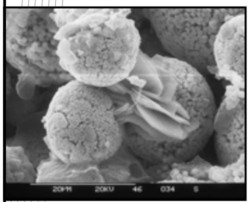
- What are acid sulfate soils (ASS) ?
- ASS monitoring projects in the Lower Lakes
    - Monitoring of reflooded ASS in Currency Creek and Finniss River
    - Community monitoring of ASS in the Lower Lakes region
    - Changes in ASS and organic carbon following revegetation and liming at Waltowa and Browns Beach (Lake Albert)
    - Overarching CSIRO monitoring of 57 ASS sites in the Lower Lakes region
- Monitoring results and discussion
- Conclusions
- Future work

CSIRO

Definitions of acid sulfate soils*

Soils and sediments containing detectable sulfide minerals, principally pyrite (FeS_2) or monosulfides (FeS) or impacted by their oxidation products

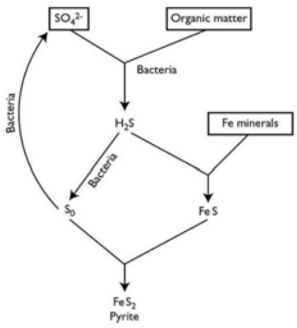
- Soil "materials" in ASS classification are:
  - **Sulfidic** soils are those that contain detectable sulfide

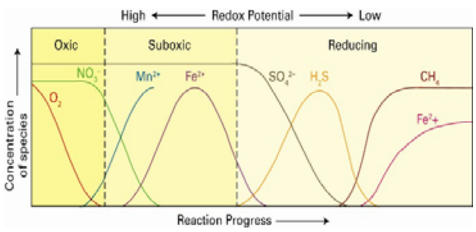


    - **Hyposulfidic** soil is sulfidic soil material that is not capable of severe acidification (pH < 4) as a result of oxidation of contained sulfides
    - **Hypersulfidic** soil is sulfidic soil material that is capable of severe acidification (pH < 4) as a result of oxidation of contained sulfides
  - **Sulfuric** soil has a pH less than 4 (1:1 by weight in water, or in a minimum of water to permit measurement)
  - **Monosulfidic** soil material contains ≥ 0.01% acid volatile sulfide

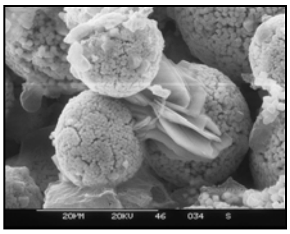
* Sullivan, L.A., Fitzpatrick, R.W., Bush, R.T., Burton, E.D., Shand, P. and Ward, N.J. 2009 Modifications to the classification of acid sulfate soil materials. Southern Cross GeoScience Technical Report No. 309.

Formation of pyrite in ASS





Forms in reducing environments



Pyrite framboids

Large surface area to volume

↓

very reactive

Soil acidification by pyrite oxidation

- Complex series of reaction steps during drying
- Overall reaction:

pyrite + oxygen + water ➲ iron (aq) + sulfuric acid (aq)

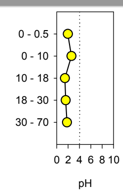
FeS_2 + ${}^{15}/_{4}O_2$ + ${}^{7}/_{2}H_20$ ➲ $Fe(OH)_3$ + $2SO_4^{2-}$ + $4H^+$

each mole of pyrite ➲ 2 moles sulfuric acid

i.e. <u>this produces a lot of acidity</u>

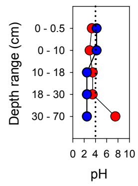
Methodologies used to test for acidification potential

1. Peroxide testing



2. Soil incubation/ageing

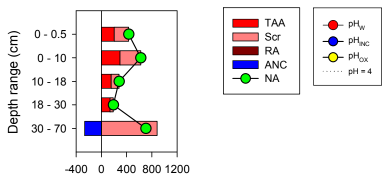
"Let the soil speak for itself"



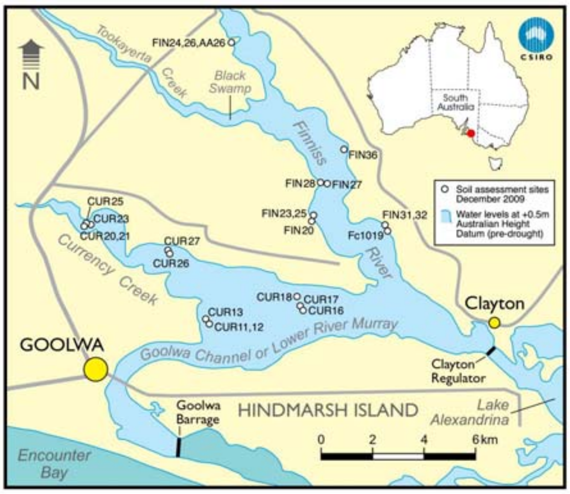
3. Acid-base accounting

Net Acidity = Acidity – Alkalinity

NA = (TAA + S_{CR} + RA) – ANC



Monitoring of reflooded ASS in Currency Creek and Finniss River

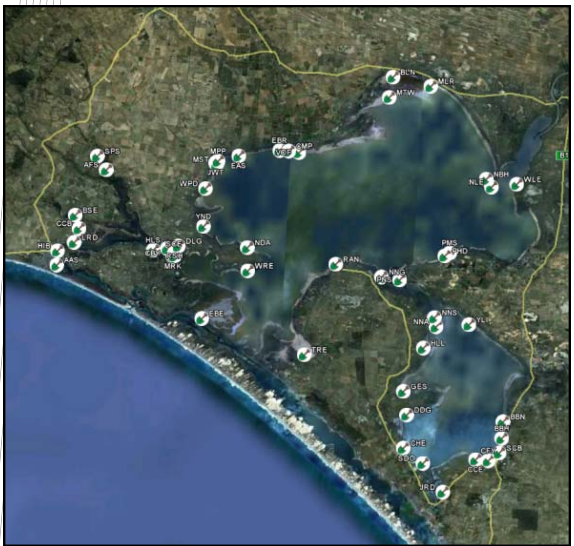


- Construction of the Clayton regulator and pumping from Lake Alexandrina caused water level to increase from -0.70 to +0.5 AHD in November/December 2009
- Surveys carried out in November 2008 (dry) and December 2009 (reflooded)
- 24 study sites
- 160 soil samples:
  - Described/classified
  - Peroxide pH
  - Incubation pH
  - Acid-base accounting

Monitoring of reflooded ASS in Currency Creek and Finniss River

- Drying had resulted in the formation of sulfuric soils by November 2008
- Construction of the Clayton regulator and pumping from Lake Alexandrina caused reflooding of these soils in November/December 2009
- Having been reflooded for only a few weeks, neutralisation of the top few cm had occurred at some sites
- However, underlying soil material remained sulfuric
- 70 of the 80 soil layers resampled had positive net acidities and there had been little or no neutralisation of underlying soil layers

Community ASS monitoring

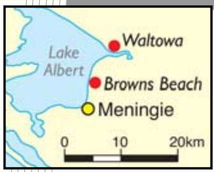


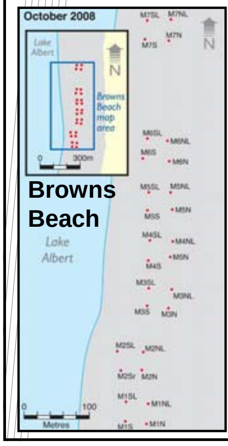
- Monitoring carried out on 4 occasions between July 2009 and June 2010
- Carried out by 85 trained community volunteers
- 51 survey areas
- Soil samples collected at standard depths to a maximum depth of 0.3 m
- Over 1450 soil samples:
  - Described
  - Field pH
  - Incubation pH

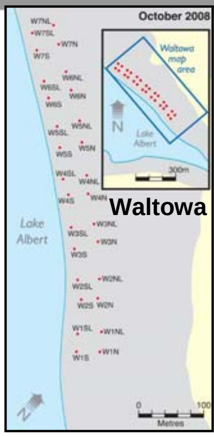
Community ASS monitoring

- Monitoring results indicated that:
  - Drying generally caused hypersulfidic soils to convert to sulfuric soils
  - Sulfuric soils generally remained sulfuric following rewetting (rainfall or re-flooding)
  - At 3 sites, sulfuric soils converted to hypersulfidic soils following rewetting
- Monitoring data was made available via Google Earth
- This project represents a “blueprint” for government-science institution-community monitoring participation
- Monitoring has continued between July 2010 and June 2011 with laboratory analyses supported by CSIRO

Changes in ASS and org-C following revegetation and liming at Waltowa and Browns Beach (Lake Albert)







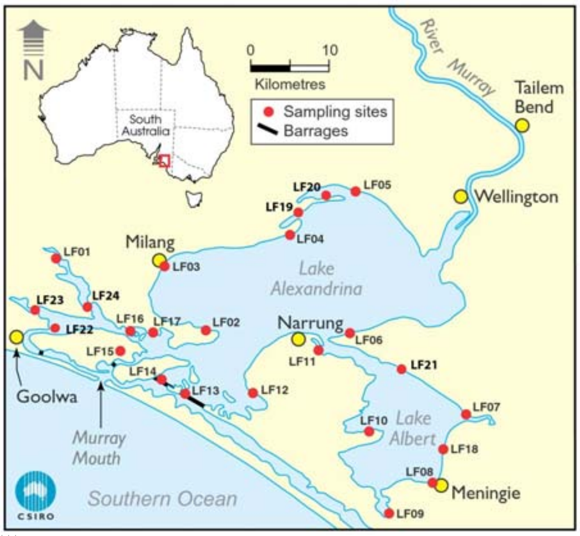
- 56 soil profiles were sampled in October 2008 prior to liming and sowing for revegetation trials
- All profiles were resampled in March 2010 (17 months later)
- Soil samples were:
  - Described/classified
  - Analysed for org-C and N
  - Peroxide pH
  - Incubation pH
  - Acid-base accounting
- During this period, soil profiles were influenced by a number of factors:

(1) Time (2) seiching events (3) wind and water erosion (4) local rainfall (5) applied treatments of ± lime and sowing with a range of plant species.

Changes in ASS and org-C following revegetation and liming at Waltowa and Browns Beach (Lake Albert)

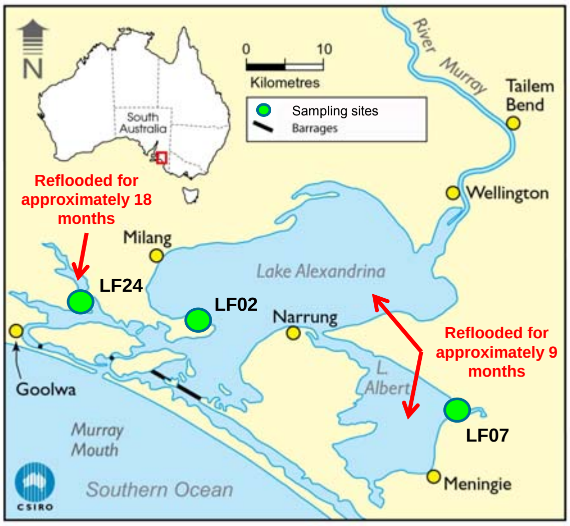
- The depth of the oxidised layer increased and there was an increase in sulfuric material
- A greater proportion of the soils were classified as ‘hyposulfidic’, especially near the waterline, due to loss of reduced sulfur and flushing with rain and alkaline seiche water
- Lime application showed no clearly significant effect, probably due to seiche effects, wind and water erosion.
- At Waltowa (not Browns Beach), revegetation trials resulted in a significant increase in organic carbon:
  - 0–1 cm by a factor of 10
  - 1–10 cm by a factor of 6
- Low C:N ratio (<10) suggested that this increase was related to soil microbial biomass (fungi, bacteria & algae) and not from the plantings
- Good source of labile carbon to re-establish reducing conditions following reflooding

Overarching monitoring of 57 ASS sites

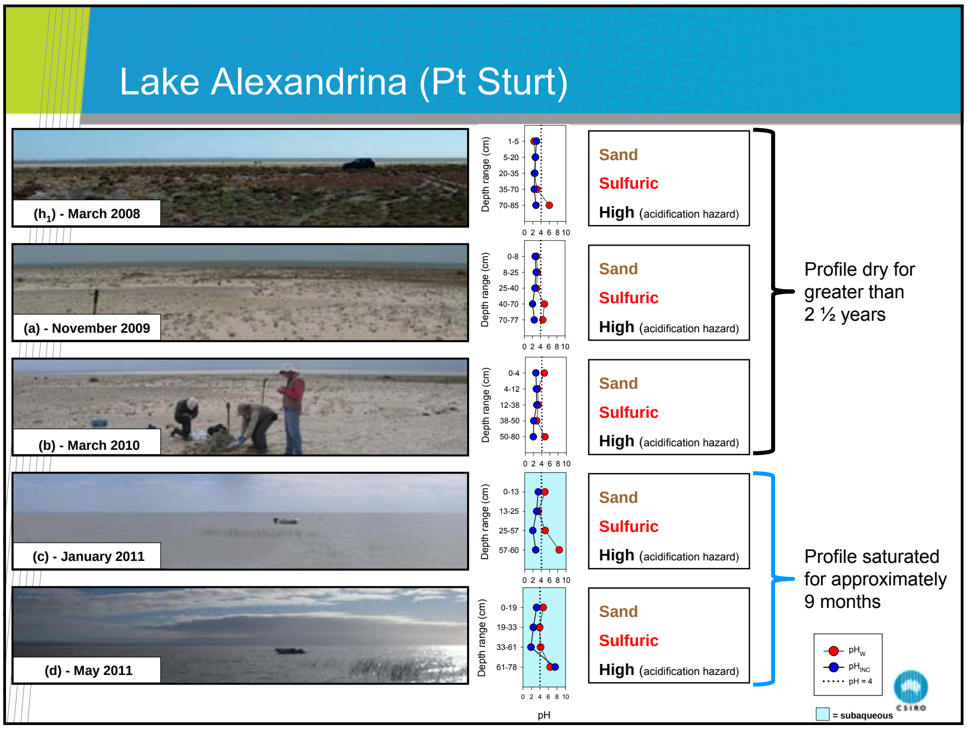


- Includes data collected during other monitoring studies
- 24 transects/study areas
- 57 study sites
- Soil profiles (≈ 1 m deep) collected at each site on 4 or more occasions between March 2008 and June 2011
- Over 1000 soil samples:
  - Described/classified
  - Peroxide pH
  - Incubation pH
  - Acid-base accounting

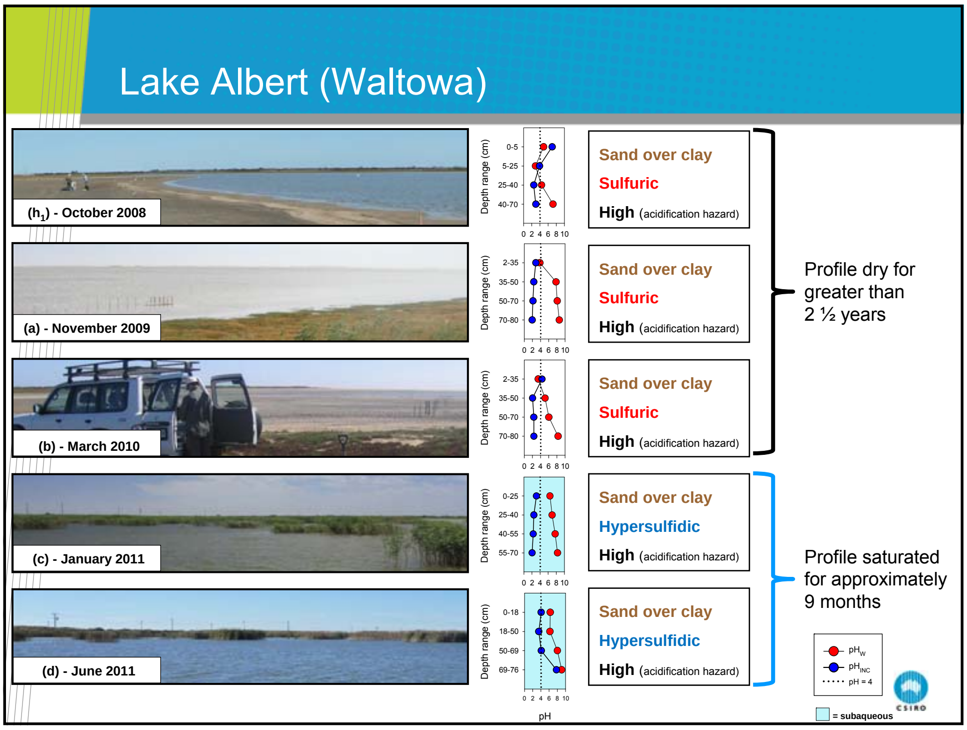
Overarching monitoring of 57 ASS sites



- LF02 - Point Sturt:
  - Sandy profile
  - High acidification hazard
  - Remained sulfuric following inundation (≈ 9 months)
- LF07 - Waltowa:
  - Sand over clay profile
  - High acidification hazard
  - Changed from sulfuric to hypersulfidic following inundation (≈ 9 months)
  - Change restricted to overlying sand
- LF24 – Lower Finniss:
  - Clay profile
  - High acidification hazard
  - Changed from sulfuric to hypersulfidic following inundation (≈ 18 months)
  - Changed throughout profile

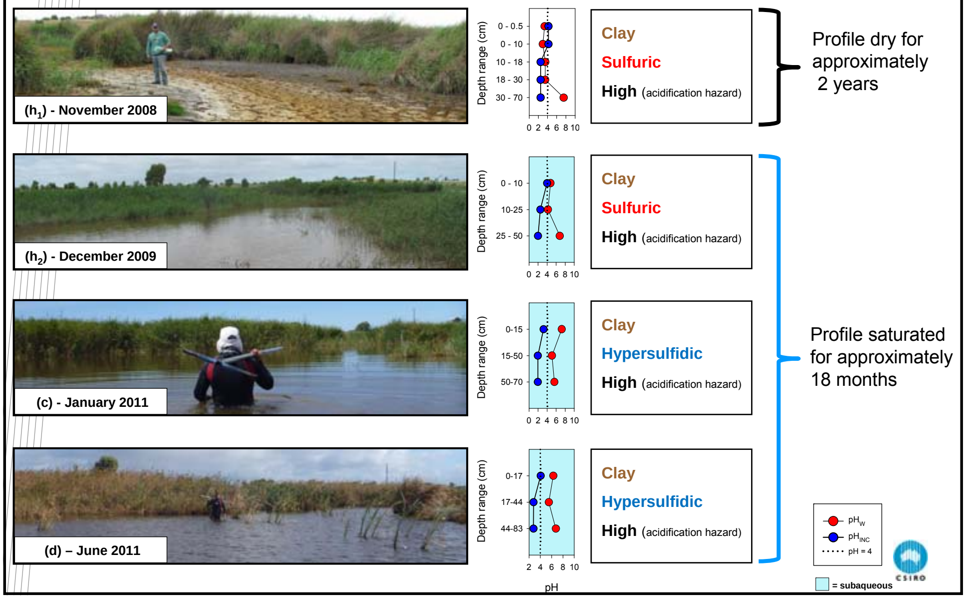


Lake Alexandrina (Pt Sturt)
(h1) - March 2008
(a) - November 2009
(b) - March 2010
(c) - January 2011
(d) - May 2011
Depth range (cm)
pH
Sand
Sulfuric
High (acidification hazard)
Sand
Sulfuric
High (acidification hazard)
Sand
Sulfuric
High (acidification hazard)
Sand
Sulfuric
High (acidification hazard)
Sand
Sulfuric
High (acidification hazard)
Profile dry for greater than 2 ½ years
Profile saturated for approximately 9 months
pHW
pHNC
pH = 4
= subaqueous
CSIRO



Lake Albert (Waltowa)
(h1) - October 2008
(a) - November 2009
(b) - March 2010
(c) - January 2011
(d) - June 2011
Depth range (cm)
pH
Sand over clay
Sulfuric
High (acidification hazard)
Sand over clay
Sulfuric
High (acidification hazard)
Sand over clay
Sulfuric
High (acidification hazard)
Sand over clay
Hypersulfidic
High (acidification hazard)
Sand over clay
Hypersulfidic
High (acidification hazard)
Profile dry for greater than 2 ½ years
Profile saturated for approximately 9 months
pHW
pHNC
pH = 4
= subaqueous
CSIRO

Lower Finniss



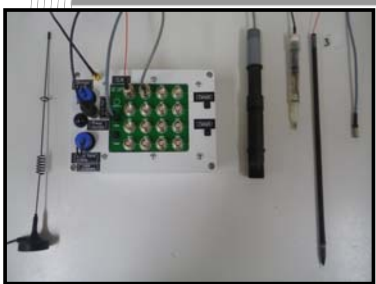
Conclusions

- Drying can cause sulfuric soil conditions to develop around the Lower Lakes
- Following inundation, sulfuric conditions generally prevail for at least 9 months (except in the top few cm)
- Prolonged inundation (> 18 months) results in a change from sulfuric to hypersulfidic soil conditions (only 4 monitoring sites have been inundated this long)
- Planting seems to promote an accumulation of soil microbial biomass that may provide a good source of labile carbon to re-establish reducing conditions

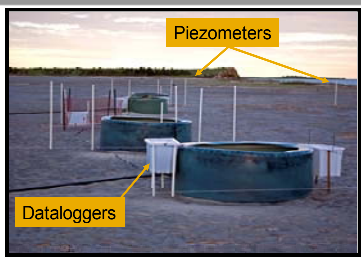
Where do we go from here?

- We need a better understanding of the rate of soil neutralisation – is this truly recovery?
- What is the localised Impact on water quality and the Benthos – to what extent has acidification seriously damaged the food web?
- At what rate will these soils re-acidify – it is likely to be fast (immature mineral phases)
- We need to be prepared for when this happens

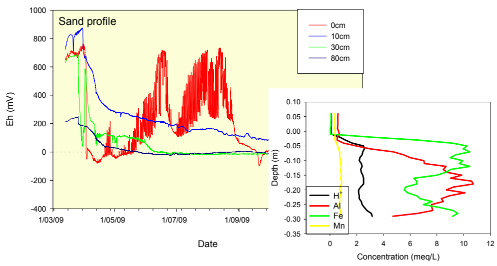
Future work



In situ **Monitoring of field conditions**

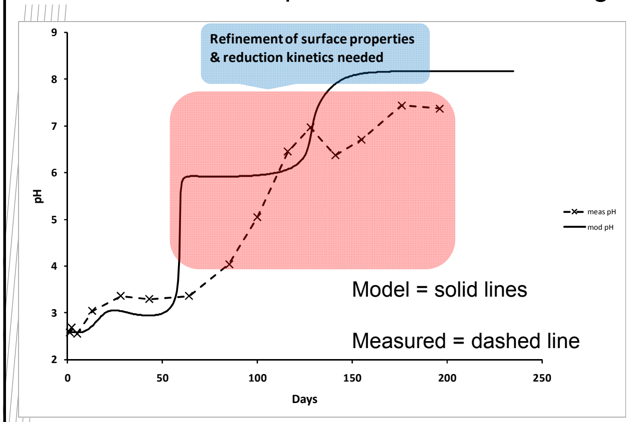


Field and lab experiments



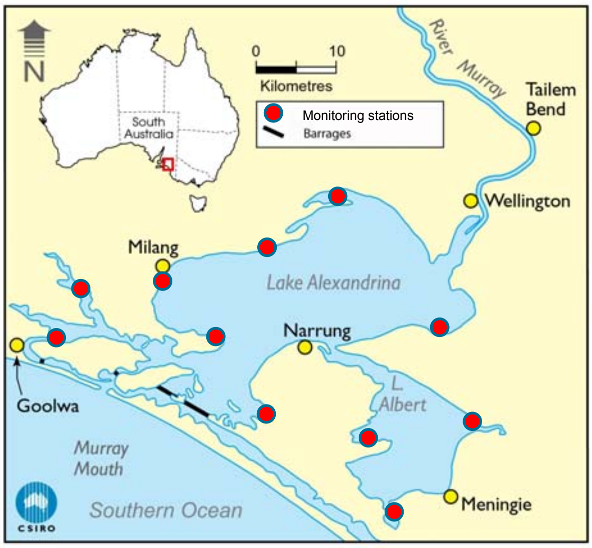
Geochemical models

- Use the data acquired during *in situ field* monitoring and field and laboratory experiments to inform geochemical models - Phreeqc and Hydrus
- Allows us to make predictions about wetting and drying scenarios



- Model of Murray water infiltration through sulfuric sand
- Preliminary model output for porewater composition at 20 cm depth
- Measured values from mesocosm experiment

In situ monitoring of pH and Eh



- Monitoring stations situated in areas of significant ASS risk
- pH, Eh, temperature and photographic data can be displayed on the web live
- Data can be used to inform scientific research (geochemical models)
- Can be used as an early warning system to alert government organisations of imminent soil acidification events

Acknowledgments

- Thanks to the Department of Environment and Natural Resources and CSIRO for co-funding these monitoring projects
- Thanks to the other authors/contributors to these projects: Rob Fitzpatrick, Richard Merry, Warren Hicks, Mark Thomas, Paul Shand, Gerard Grealish and Nathan Creeper
- Thanks for the support, comment and project management provided by Dr Liz Barnett (DENR) and team

www.csiro.au

Thank you

Dr Andrew Baker
Phone: 08 8303 8539
Email: andrew.k.baker@csiro.au
Web: www.csiro.au

CSIRO