Acid sulfate soils and their management: a global perspective

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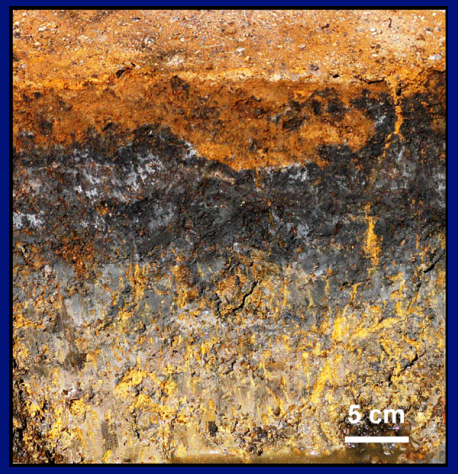
Southern Cross GeoScience,
Southern Cross University, Australia

The soil materials we call *acid sulfate soils* have long been recognised as having important properties and behaviour.

e.g. this group of soil materials has been identified by other names including *argilla vitriolacea* (Linnaeus, 1735), and colloquially as *katteklei* (i.e. *cat clay).*

Such an enduring *ad hoc* classification implies that there has long been utility in grouping these soil materials together.



At the 1st International Symposium on Acid Sulphate Soils held in Wageningen in 1973, Professor Leen Pons defined *acid sulfate soils* broadly:

Image reproduced from:
LEEN PONS Father of the International Acid Sulphate Soil Symposia/Conferences.
D.S. Fanning, 2nd Edition, 2009.

At the 1st International Symposium on Acid Sulphate Soils held in Wageningen in 1973, Professor Leen Pons defined *acid sulfate soils* broadly:

"all materials and soils in which as a result of processes of soil formation, sulfuric acids either will be produced, are being produced, or have been produced in amounts that have a lasting effect on main soil characteristics."

Image reproduced from:
LEEN PONS Father of the International Acid Sulphate Soil Symposia/Conferences.
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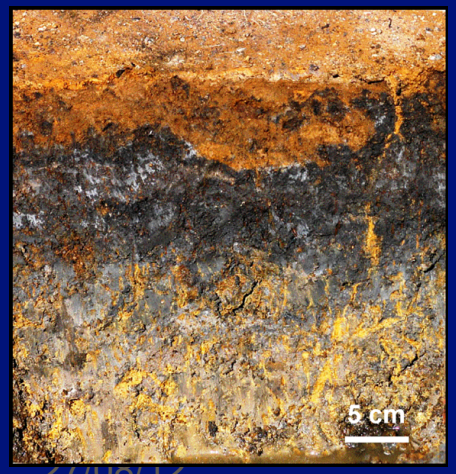
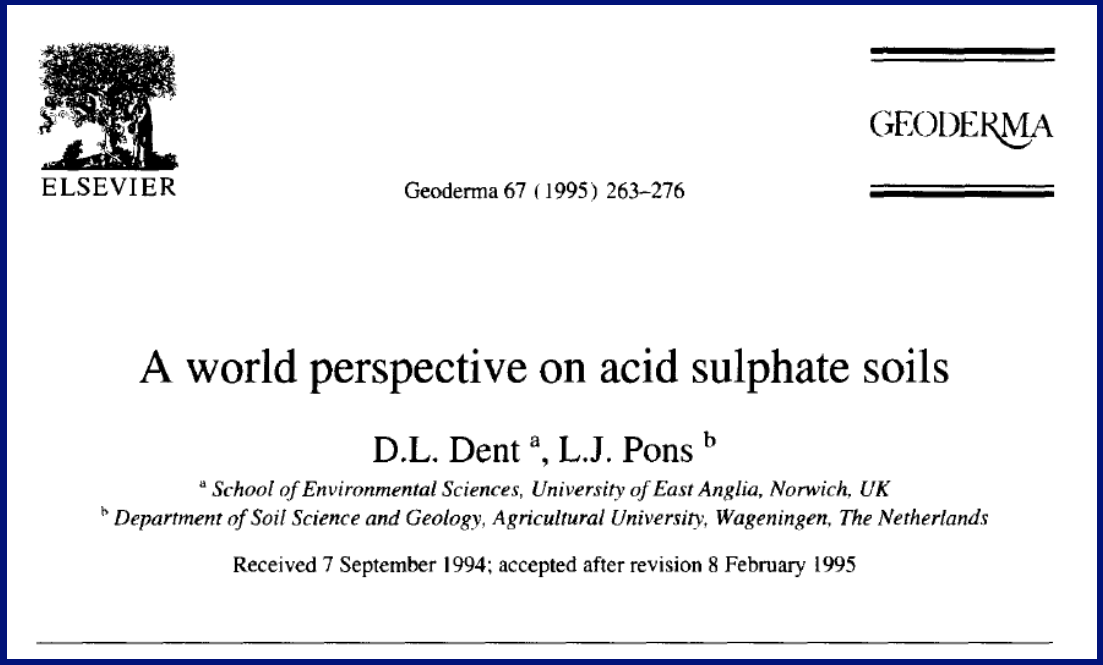
‘Acid sulfate soil’ remains a broad ‘family’ name encompassing a range of soil materials that often have more strict definitions in soil taxonomic systems (e.g.‘sulfuric’, ‘sulfidic’).



We are very fortunate that our understanding of *acid sulfate soil* material has been underpinned by a considerable body of outstanding science conducted by many researchers both prior to 1973 and since.

The last global perspective taken on acid sulfate soils was appropriately undertaken by Dent and Pons in 1995.



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GEODERMA

Geoderma 67 (1995) 263–276

A world perspective on acid sulphate soils

D.L. Dent [a], L.J. Pons [b]

[a] *School of Environmental Sciences, University of East Anglia, Norwich, UK*

[b] *Department of Soil Science and Geology, Agricultural University, Wageningen, The Netherlands*

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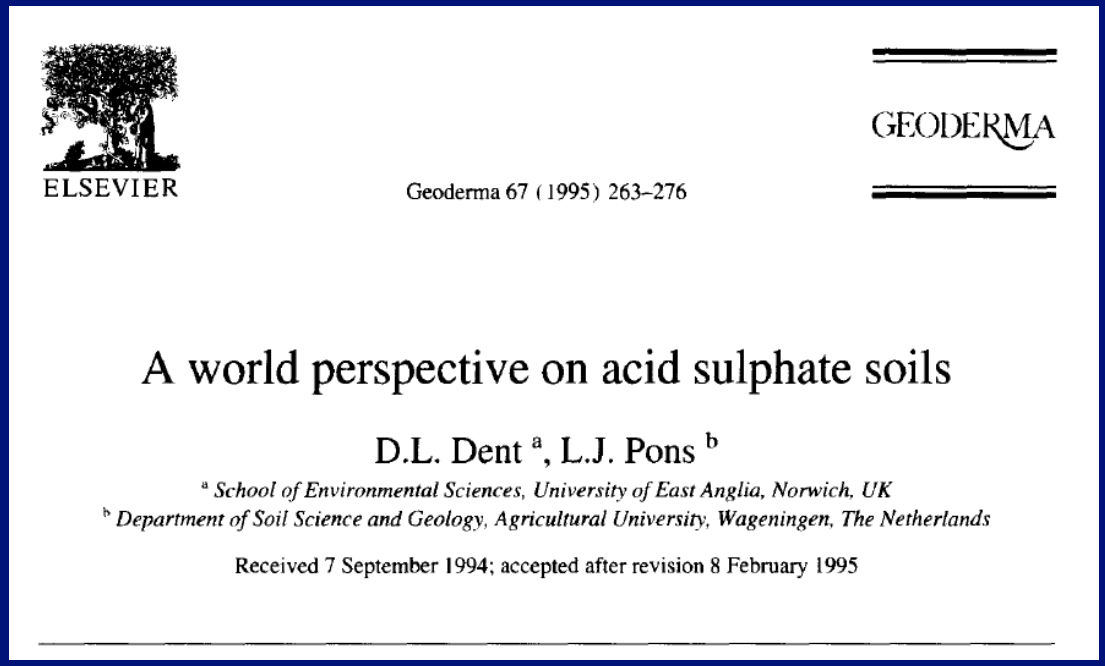

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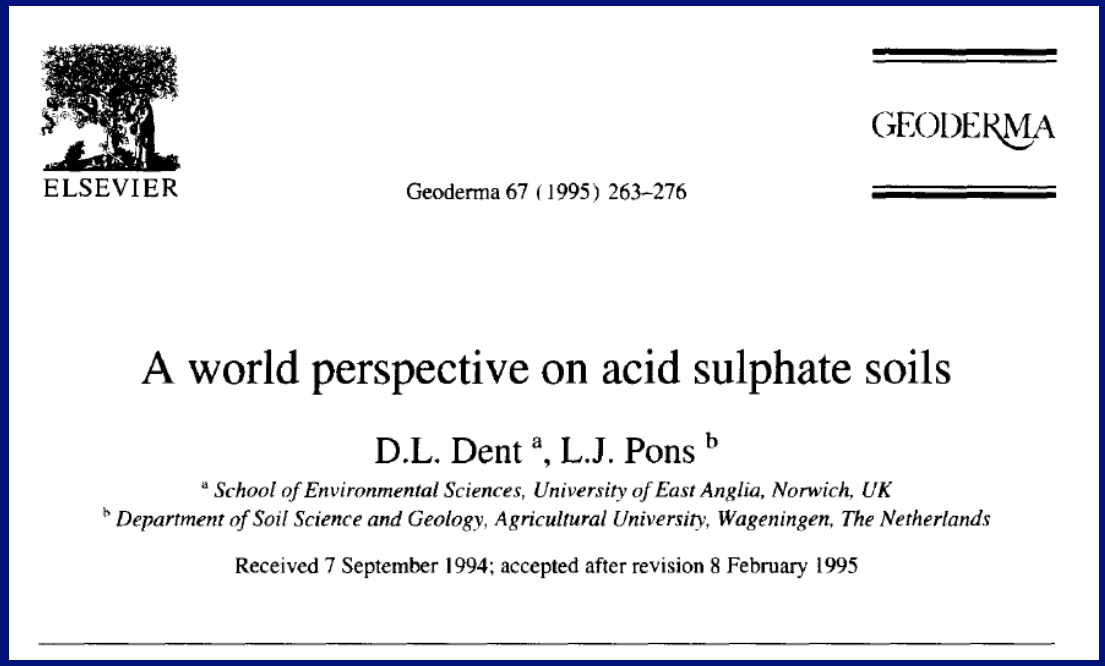

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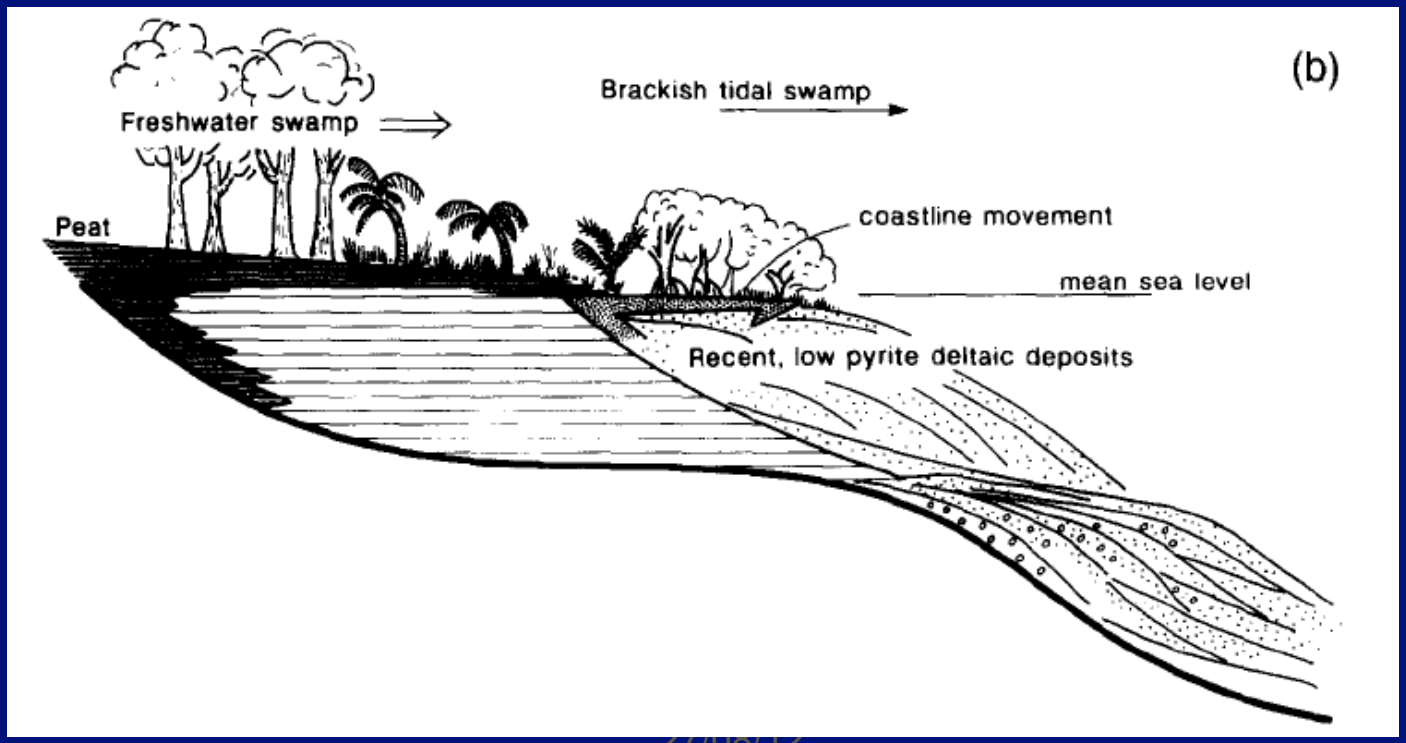
Their perceived 'evil' nature was displayed by "strange colours, bad odour, the sparse and stunted vegetation contrasting with its former luxuriance, and the unusual speed of the transformation"

One of Dent and Pons' (1995) main points was:

A general sequence of sedimentation exists resulting from the accumulation of sulfides and burial of sulfidic material by peat or alluvium of low sulfide content.



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They also addressed the following issues in their perspective:

- metal mobilisation
  - Al^{3+} under acidified oxidised conditions
  - Fe^{2+} under reduced conditions
- H_2S toxicity under reduced conditions

As well as being ‘nasty’, ASS are also the most interesting of soils, spanning the broadest geochemical spectrum possible, from highly oxidised & severely acidic, through to highly reduced & alkaline.

Acid sulfate materials and landscapes are dynamic able to transform rapidly.

This inland sediment cycles seasonally between being monosulfidic during reducing regimes to sulfuric during oxidising regimes

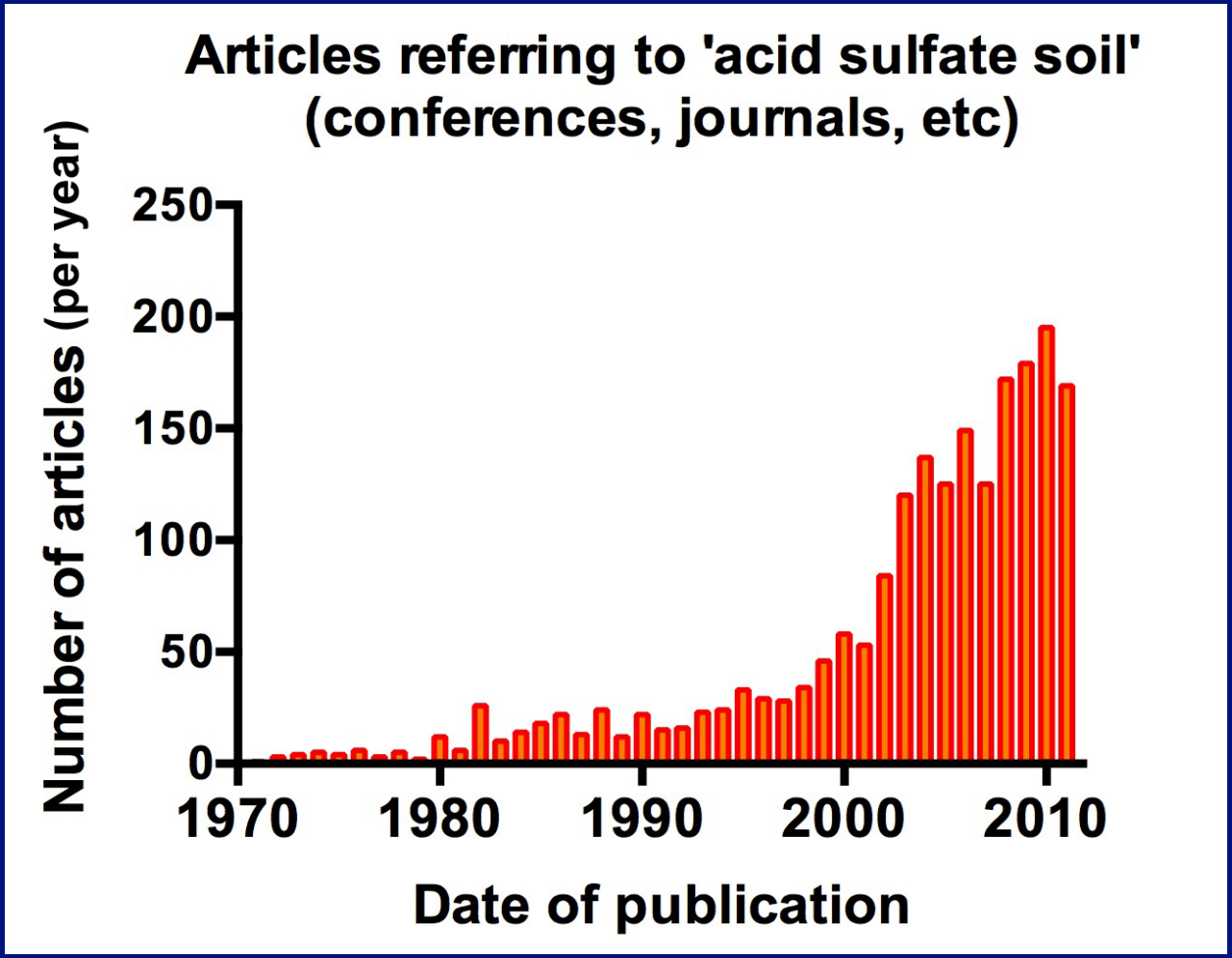
ASS are also a most important type of soil, often occupying land under high developmental pressure, or supporting large populations, or impacting detrimentally on critical environments if mismanaged.

Hong Kong harbour

Mekong, Vietnam

Fish kill

Since 1995 the volume of the literature on acid sulfate soils has continued to expand considerably (using Google Scholar® search).



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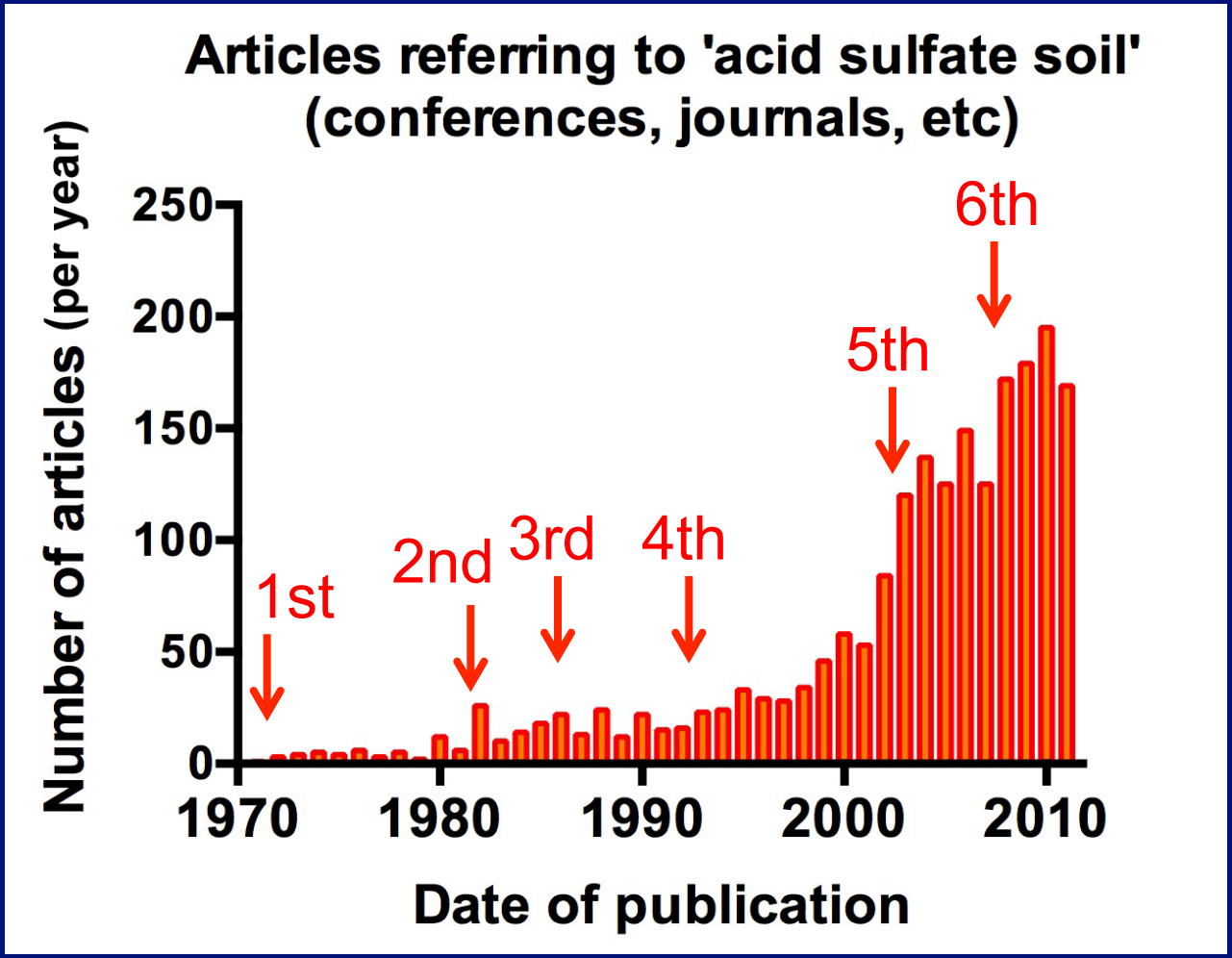

The international conferences have played an important role in stimulating research in acid sulfate soil.

Clearly, building from a sound base, our knowledge of the processes and environmental consequences associated with acid sulfate soil materials has been considerably enhanced further over the last 15 years.

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I want to chart here some of this further progress in our journey to understand and manage these soils to provide a perspective on where acid sulfate soil science and management has progressed.

The specific areas I will outline here are developments in:

* mapping and our understanding of the distribution of ASS
* analytical techniques
* ASS mineralogy
* regulatory approaches
* management practices
* classification

Areas affected by tidal or other marine influences

Type locations of acid sulfate soil materials

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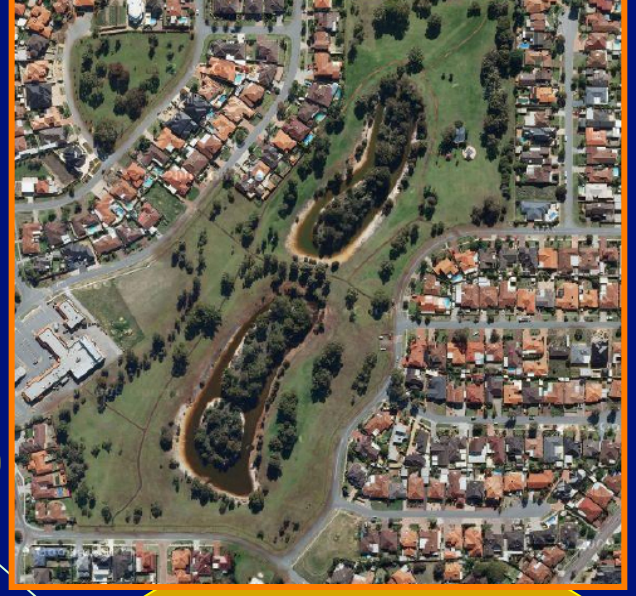


Type locations of acid sulfate soil materials

Upland coastal plains affected by aeolian marine salt deposition

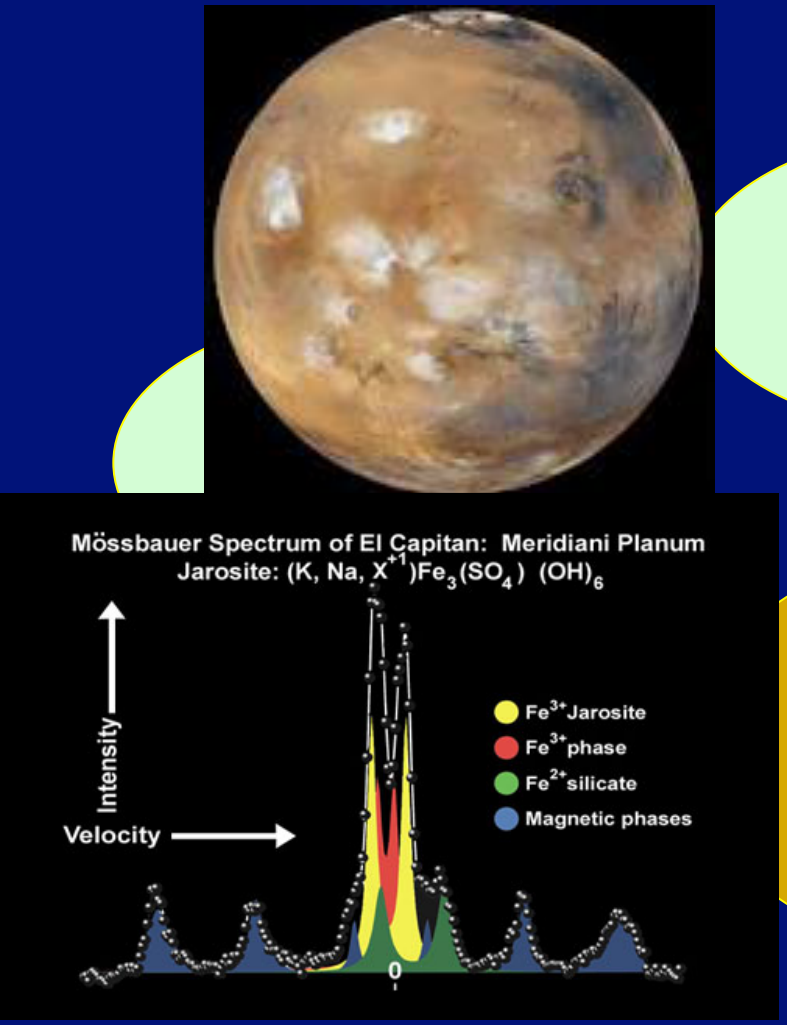
Areas affected by tidal or other marine influences

Subaqeous locations in waterways

Exposed sulfidic regolith

Inland areas affected by salinity

Dredged material from waterways



Mars

Areas affected by tidal or other marine influences

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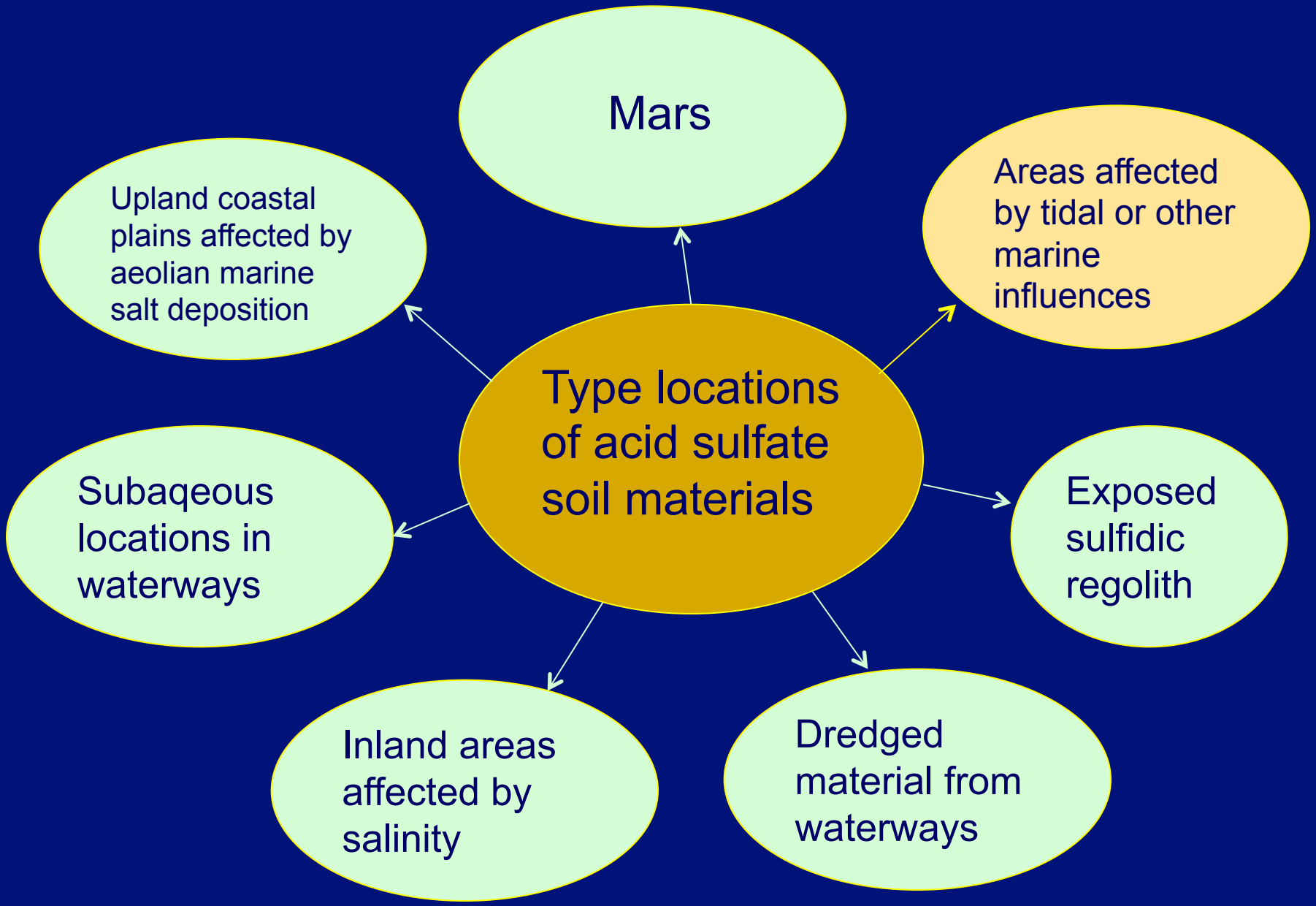
Inland areas affected by salinity

Dredged material from waterways

Greater attention paid recently to ASS in these other locations

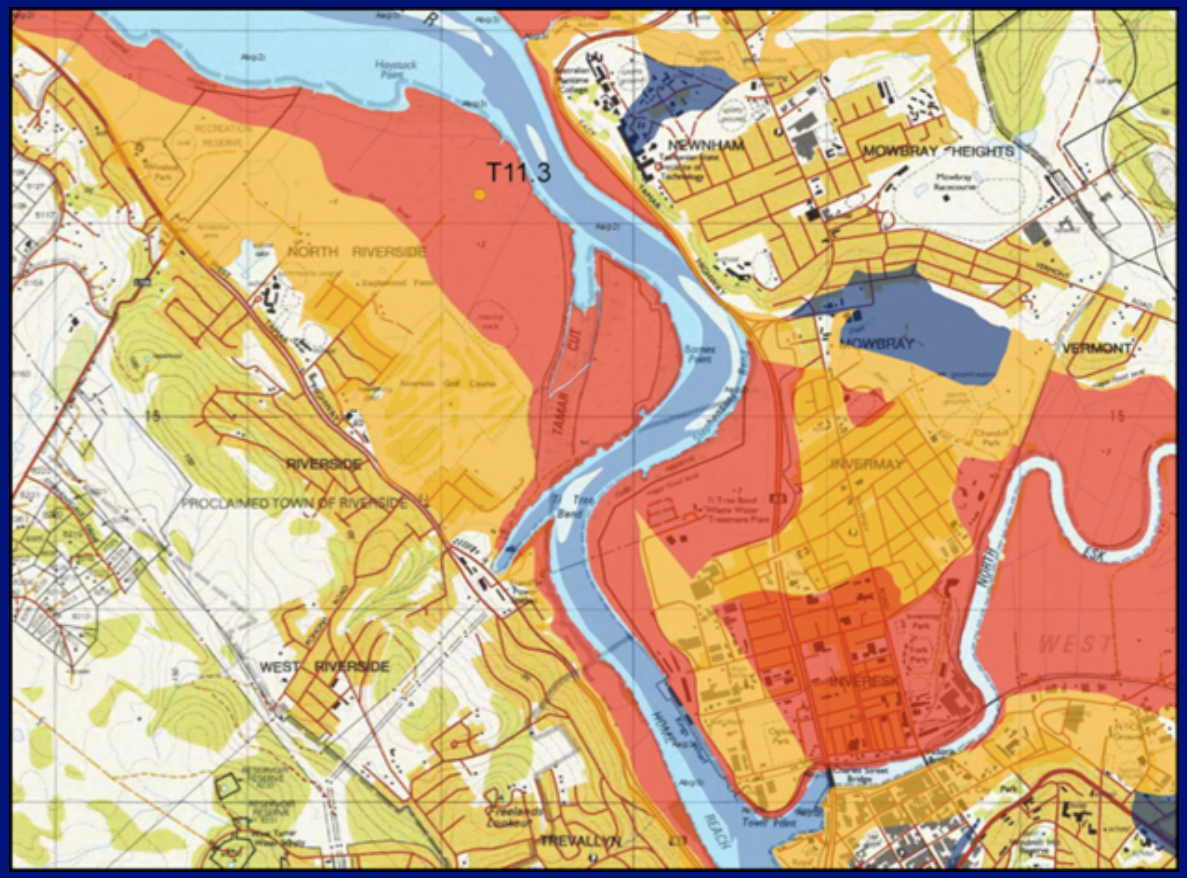


Dent and Pons' regarded ASS soil survey data as "relatively patchy".

ASS soil survey data is “relatively patchy” (Dent and Pons,1995).

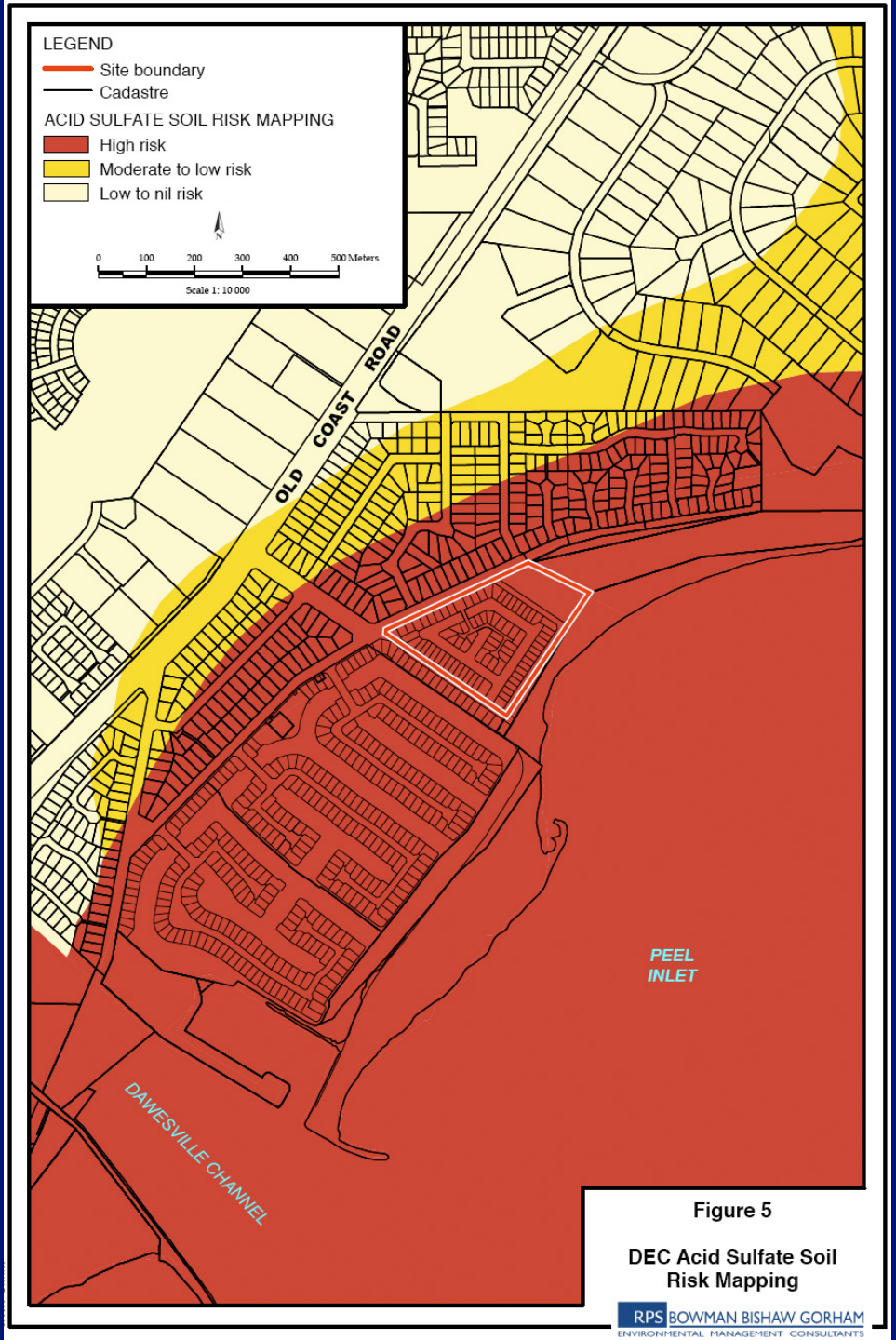
One of the reasons for ‘patchiness’ of ASS maps is that ASS surveying can be a challenging occupation.

Innovations in GIS and advanced DEM and our understanding of ASS distribution, have both allowed the development of detailed ASS risk maps.



ASS risk map of northern Tasmania: Launceston
(red colours - high probability, yellow - low probability)

Detailed ASS risk maps are very useful as a land-use planning instruments and in triggering requirements for detailed investigations when new developments are proposed.



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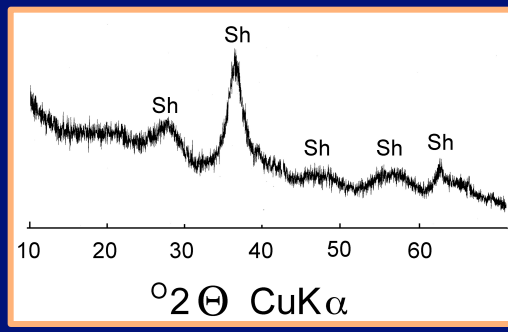
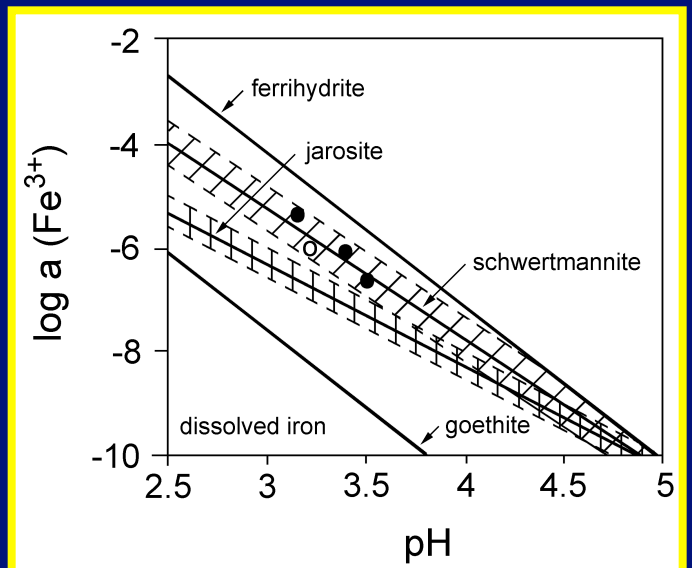
* using isotope methods for the examination of geochemical and hydrological processes

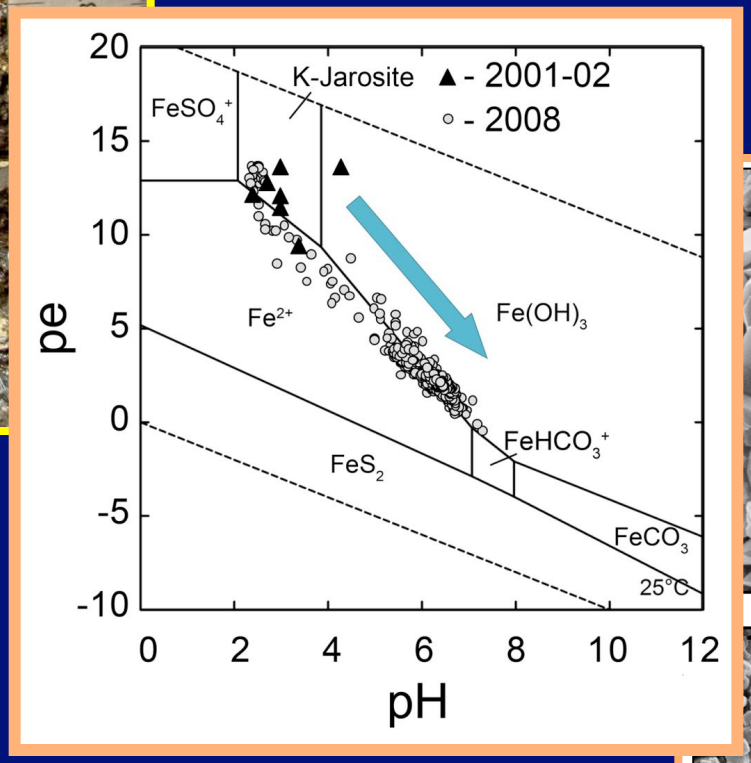
In the last decade we have also further enhanced our understanding of the mineralogy including:

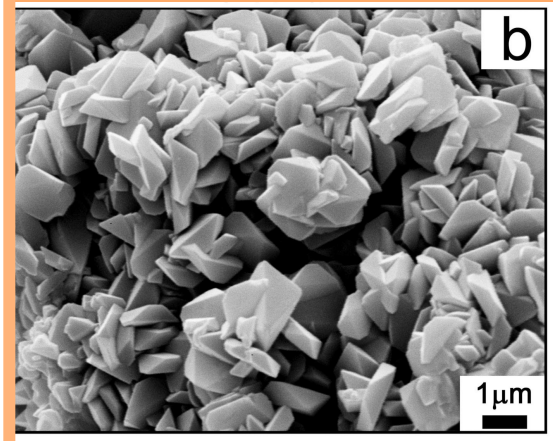
* the existence, distribution and behaviour of schwertmannite in acidified ASS landscapes

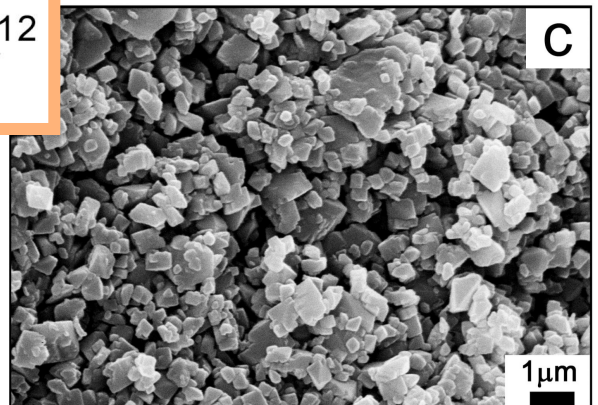




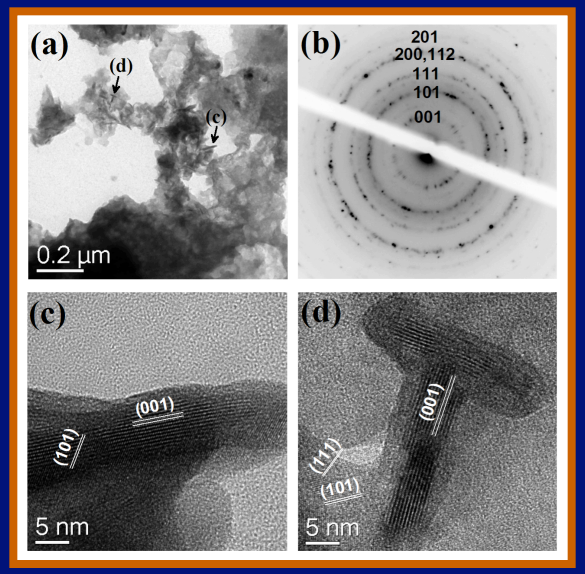
* The geochemistry of jarosite

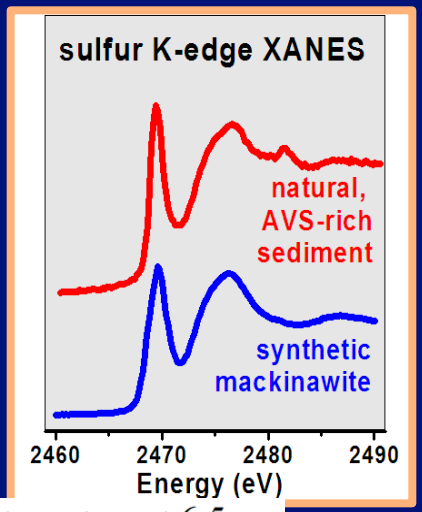


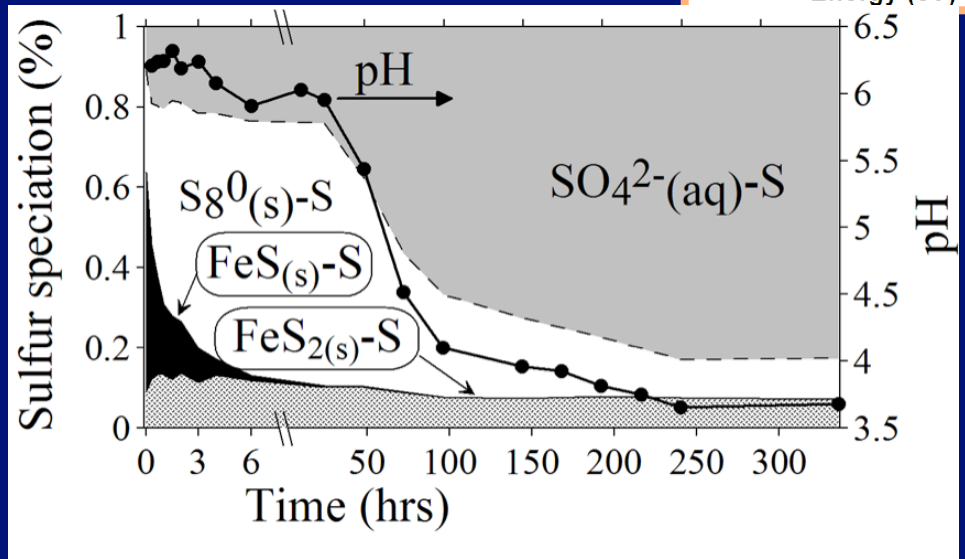




* The distribution, nature, and behaviour of monosulfides in sulfidic ASS materials.







Since 1995, regulatory approaches used to appropriately manage ASS have also advanced substantially.

However, the enthusiasm of regulators and the vigour of such regulation is variable across the globe, across countries, and across jurisdictions within countries ranging from slight to strong.

At one end of this spectrum is Western Australia: where ASS often fall under their Contaminated Sites Act.

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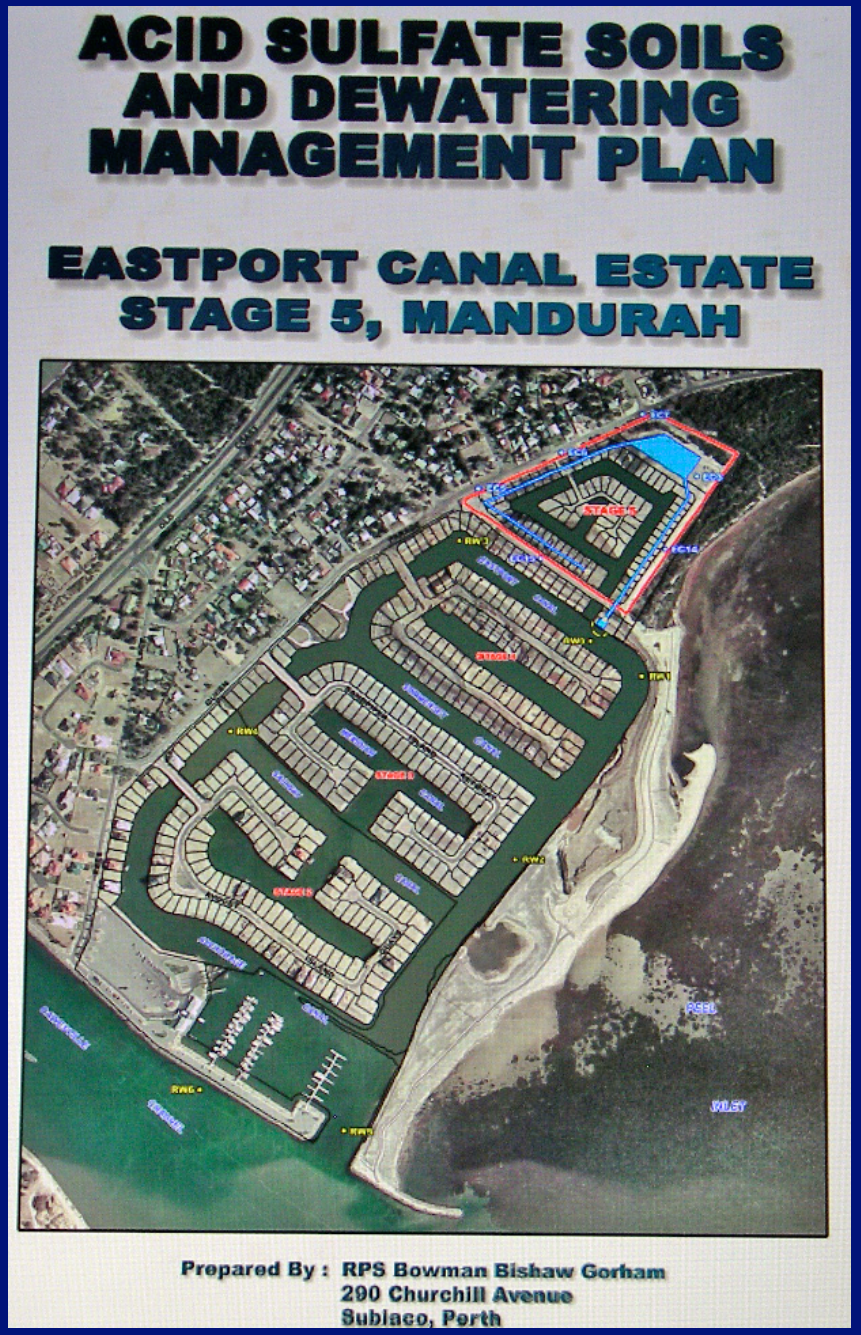
Development approval for projects in WA is based on a comprehensive Acid Sulfate Soil Management Plan (roughly equivalent to a Contaminated Site Assessment and Management Plan).



Such Acid Sulfate Soil Management Plans include:

- detailed assessment of the site characteristics

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- detailed contingency plans
- detailed reporting plans, and
- detailed close-out reports (by independent consultants)

For example, here is a typical receiving water monitoring & response flowchart for a development site on ASS

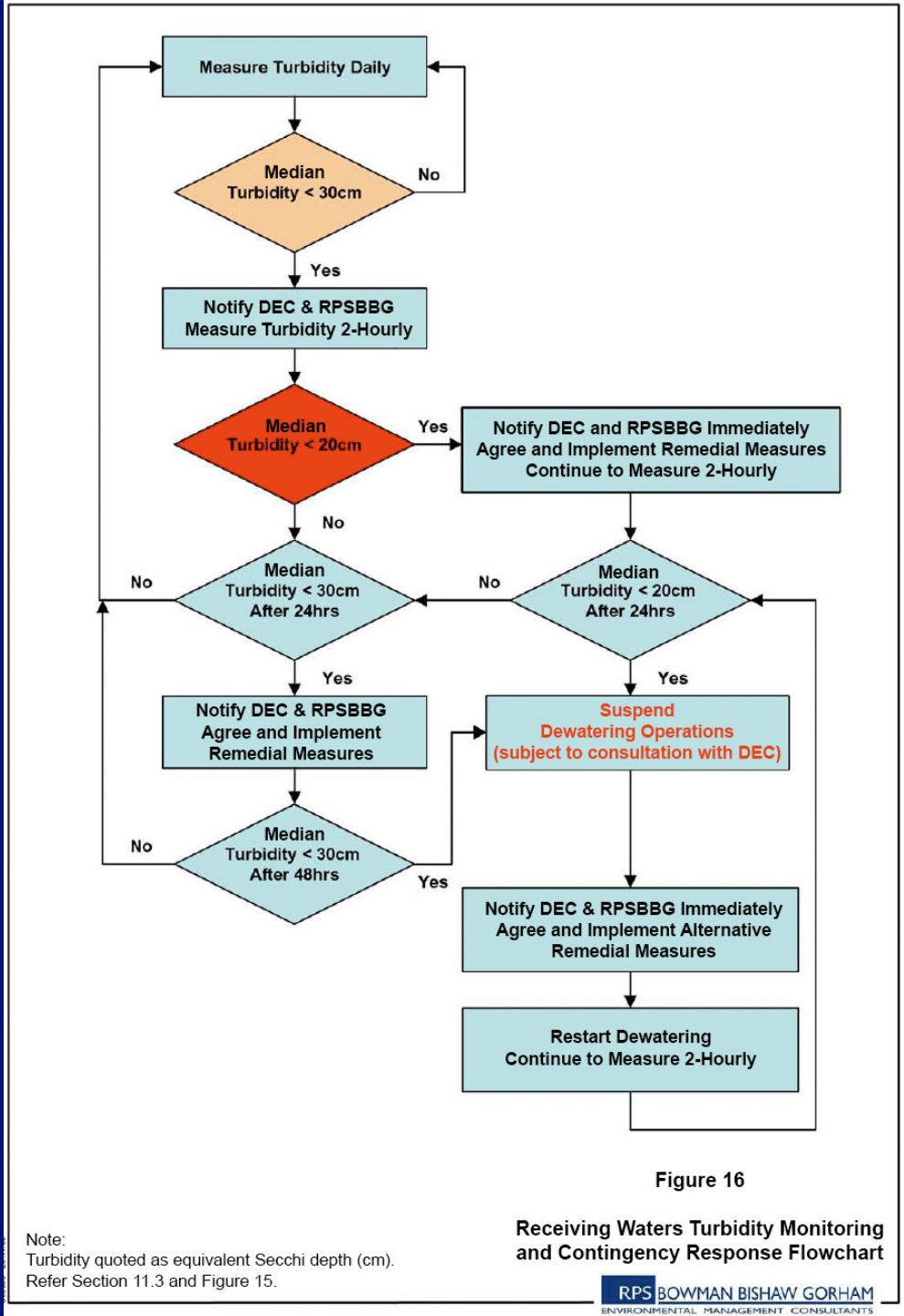

Figure 16

Receiving Waters Turbidity Monitoring and Contingency Response Flowchart

Note:
Turbidity quoted as equivalent Secchi depth (cm).
Refer Section 11.3 and Figure 15.

RPS BOWMAN BISHAW GORHAM
ENVIRONMENTAL MANAGEMENT CONSULTANTS

In the past 15 years the range of management practices to minimise disturbance and impact of ASS has developed further.

There will be many other innovative management approaches that will be discussed during the conference.

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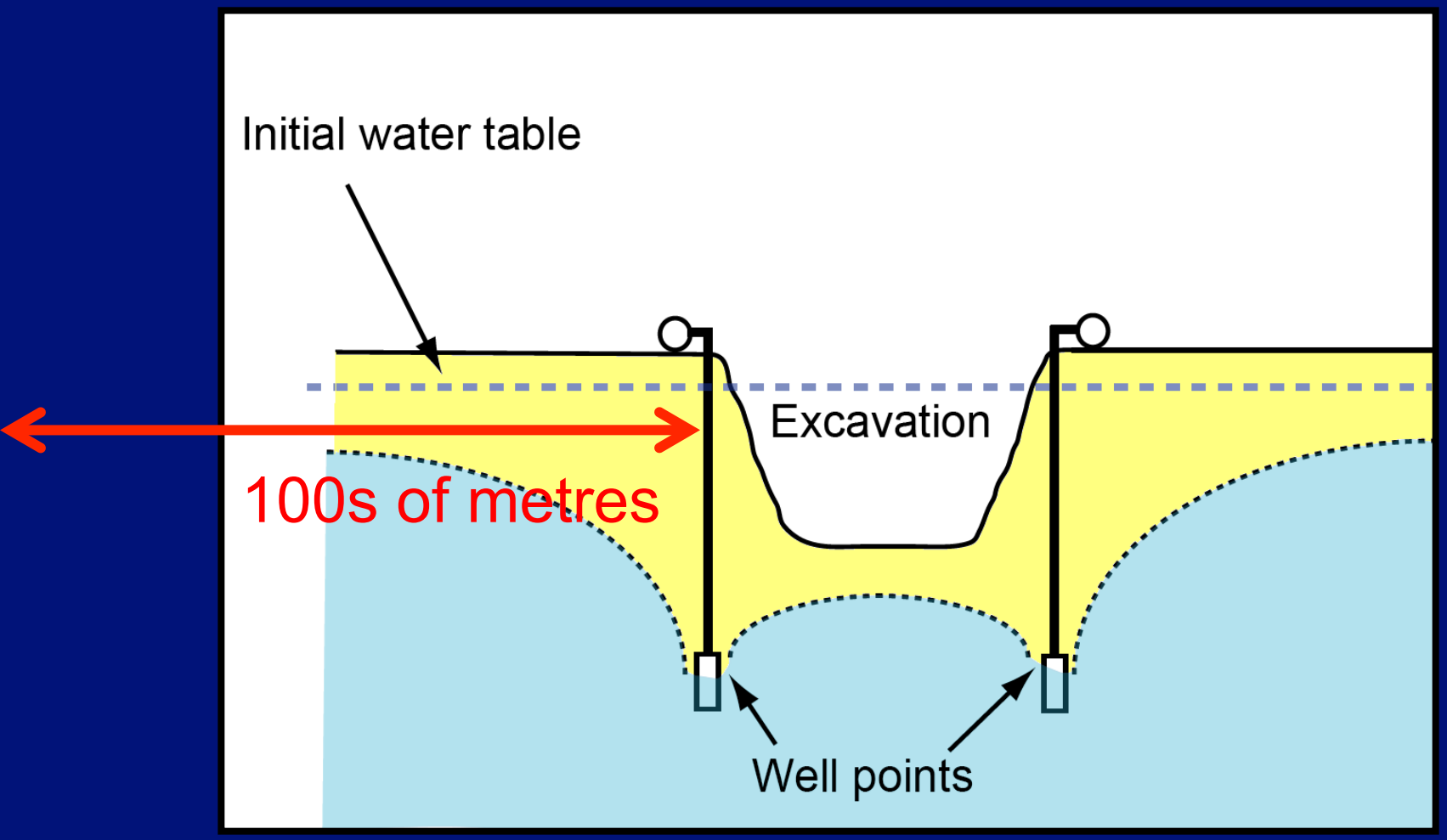
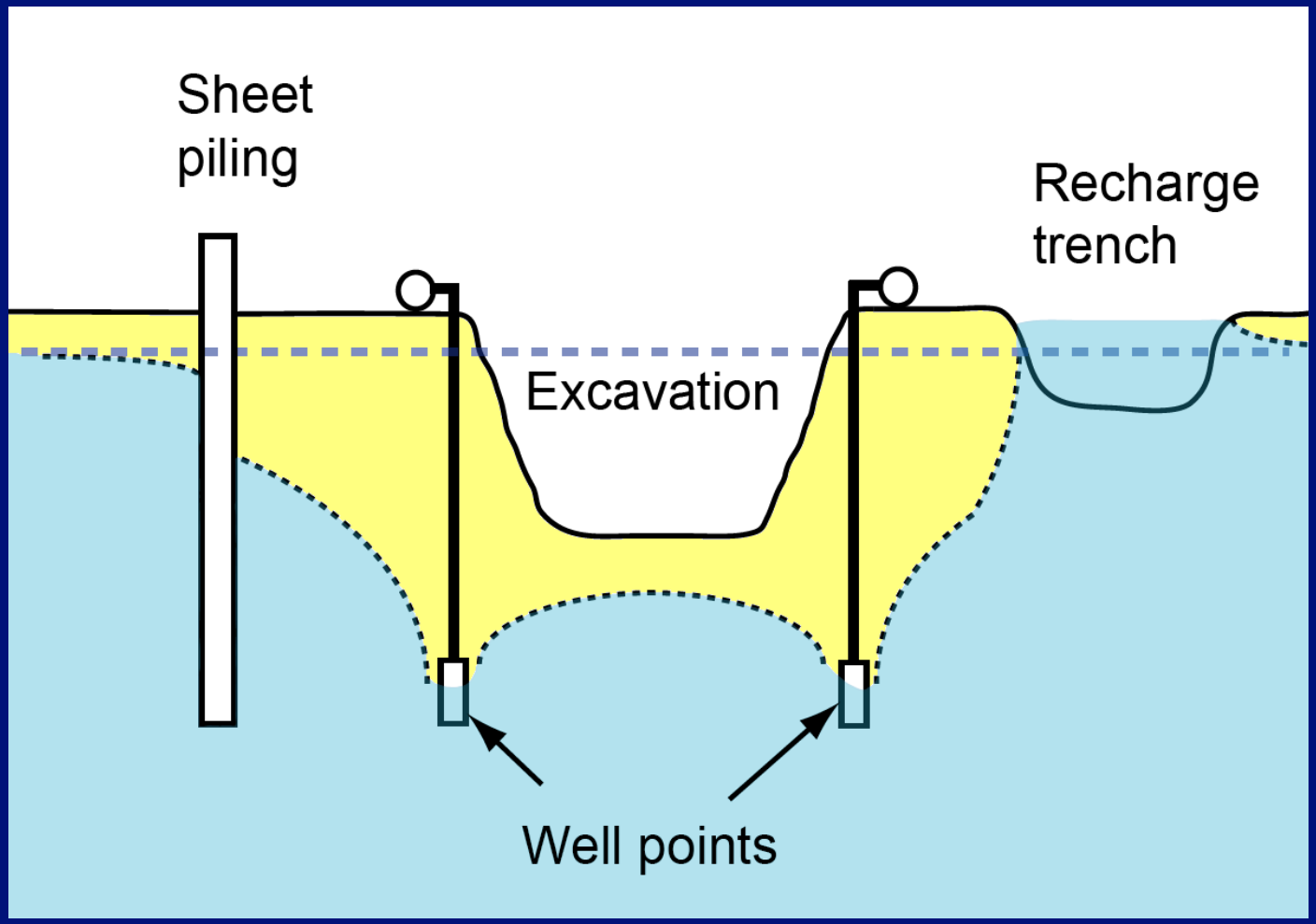
I want to briefly outline just two areas:
1) dewatering, and
2) dandscape scale rehabilitation

Dewatering to allow excavation for infrastructure can cause long-term off-site acidification legacies.



Courtesy of WA DEC

Techniques to constrain dewatering effects include use of sheet piling or recharge trenches



Courtesy of WA DEC

Dry Excavation Sheet Piling

Recharge trench constructed around the perimeter of the dewatered excavation

Recharge trenches minimise groundwater dewatering

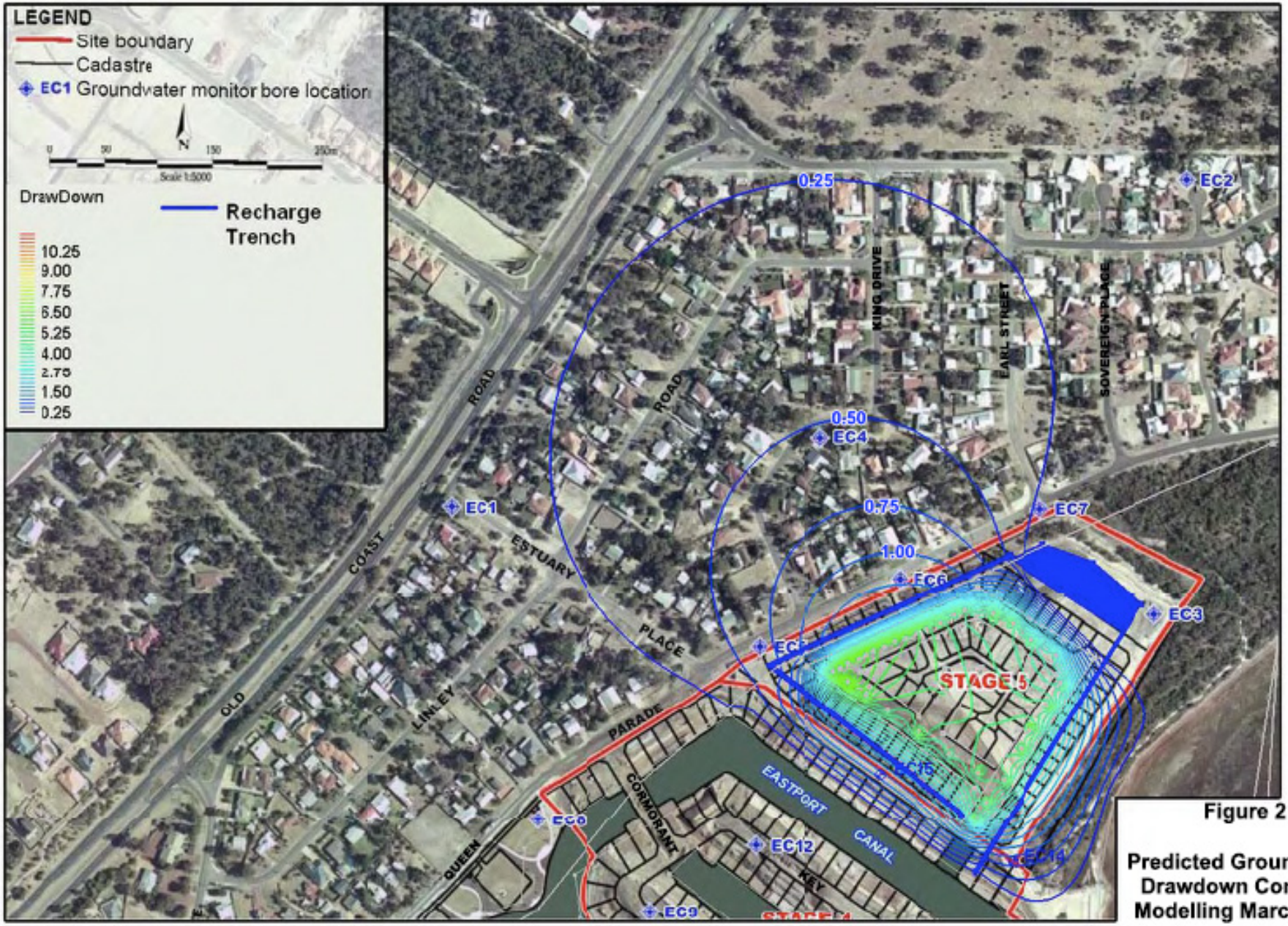


Figure 2

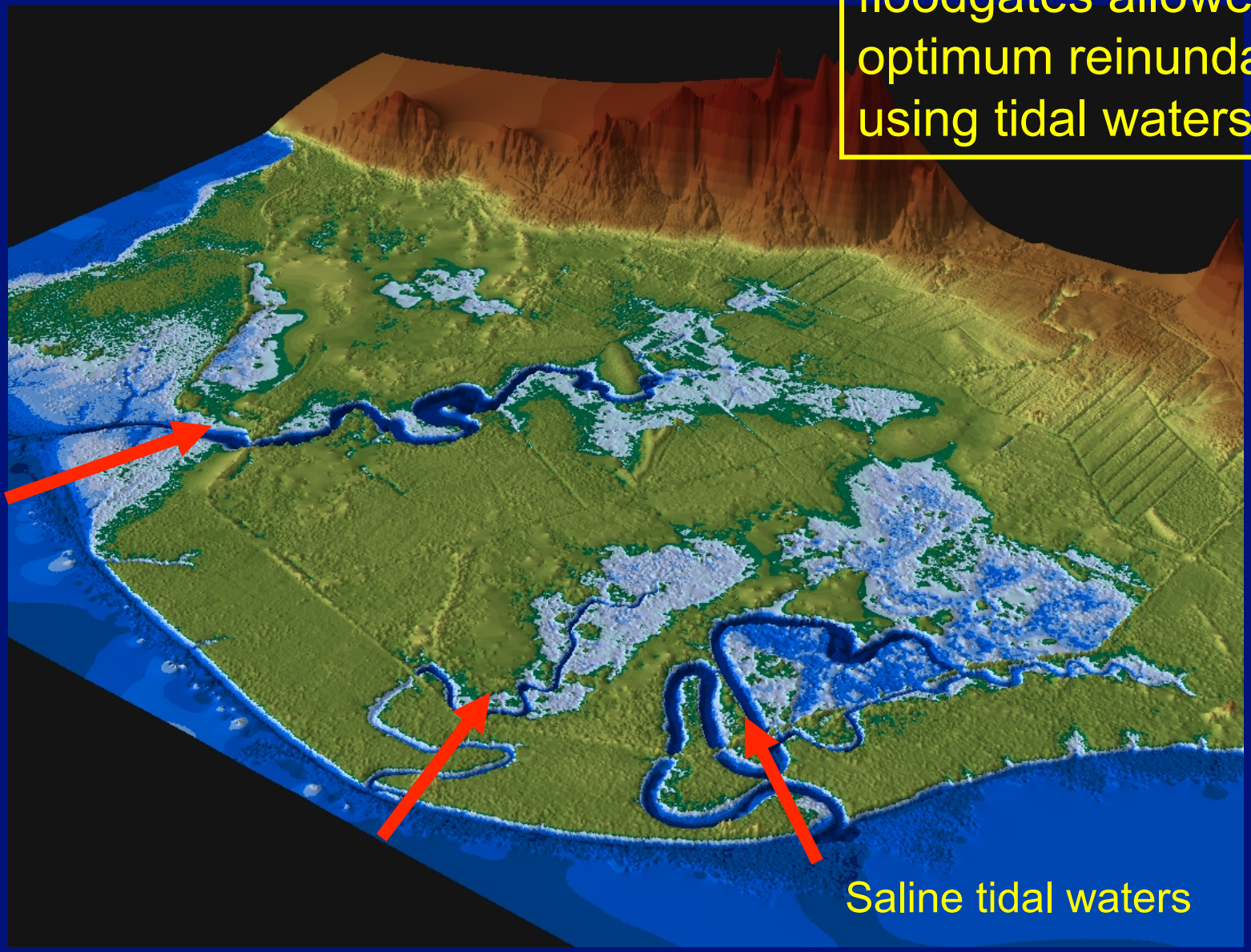
Predicted Groundwater Drawdown Contours Modelling March 2008

RPS

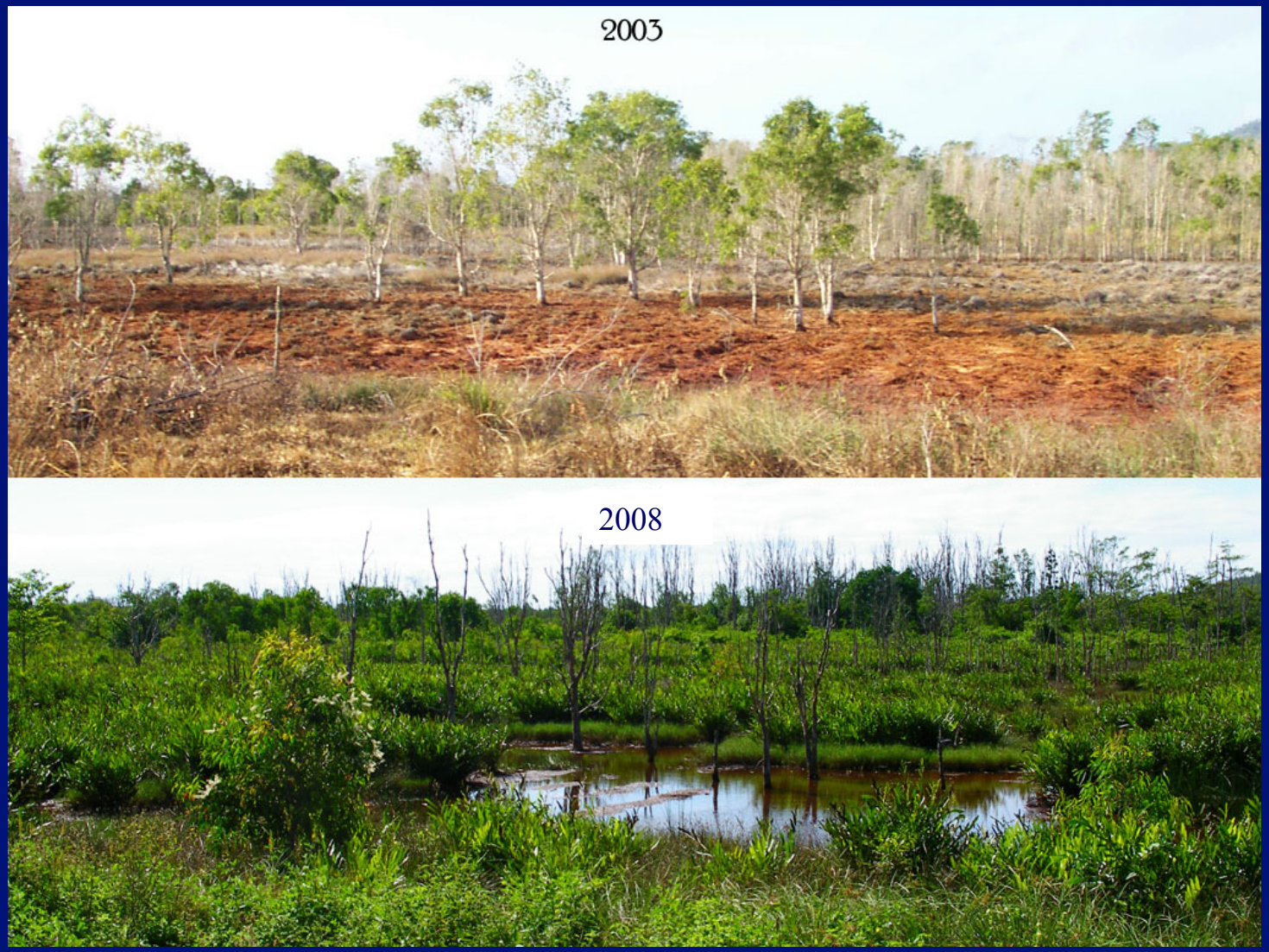
Landscape scale remediation of acidified ASS

Landscape scale remediation of acidified ASS

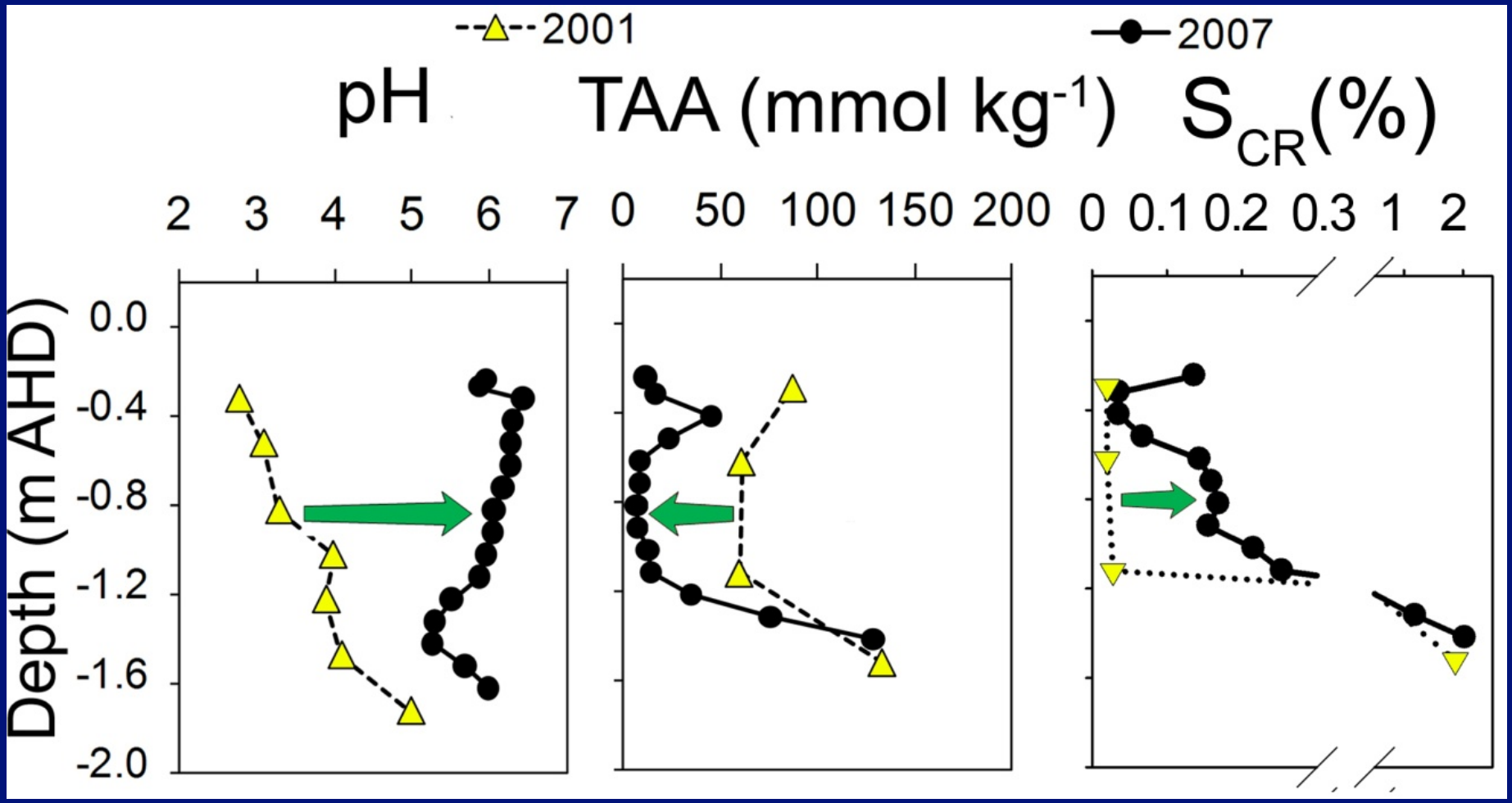
Controlled opening of floodgates allowed optimum reinundation using tidal waters



Before and after tidal water re-inundation



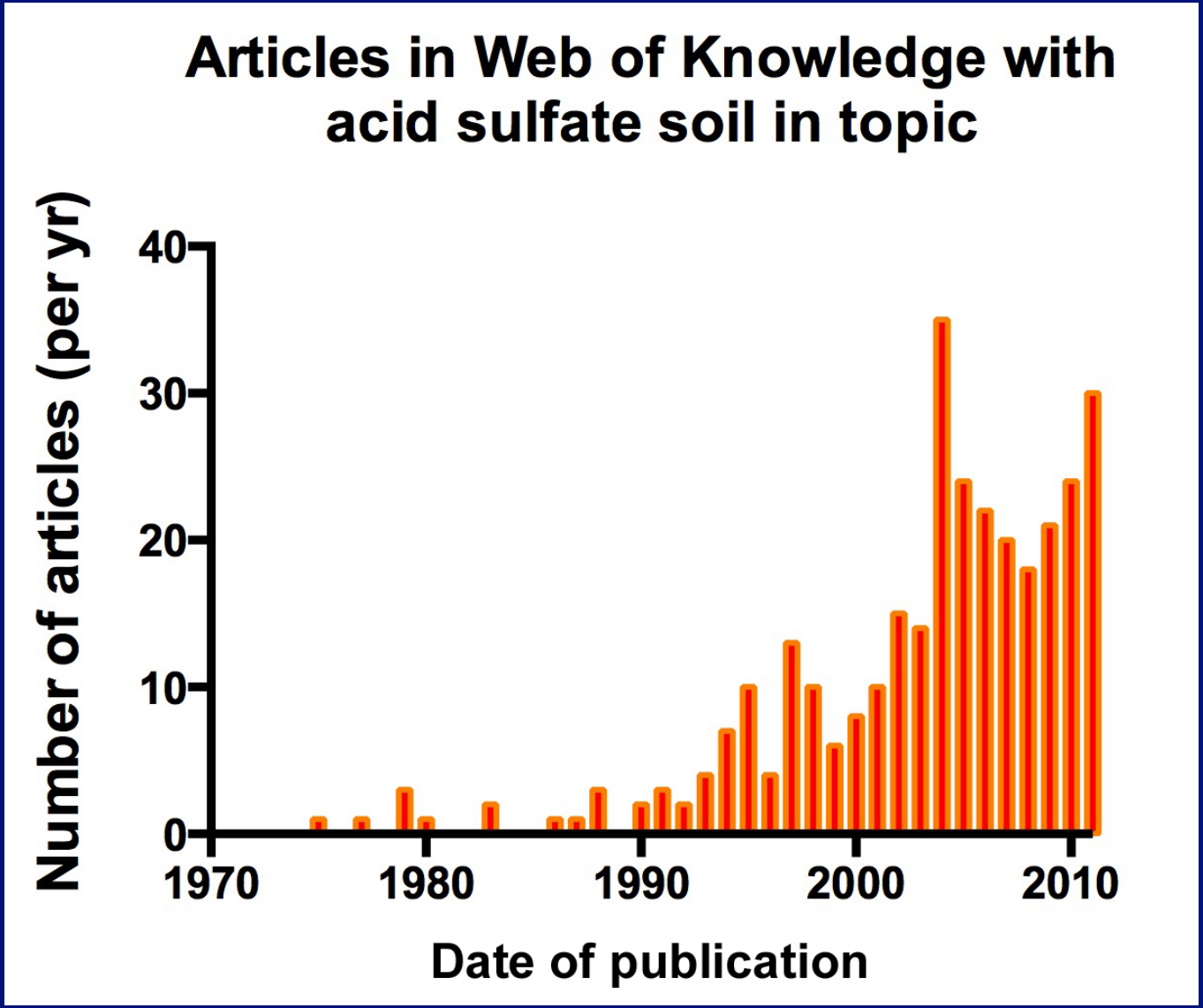
Generation of alkalinity in former sulfuric horizons after controlled re-inundation with tidal waters



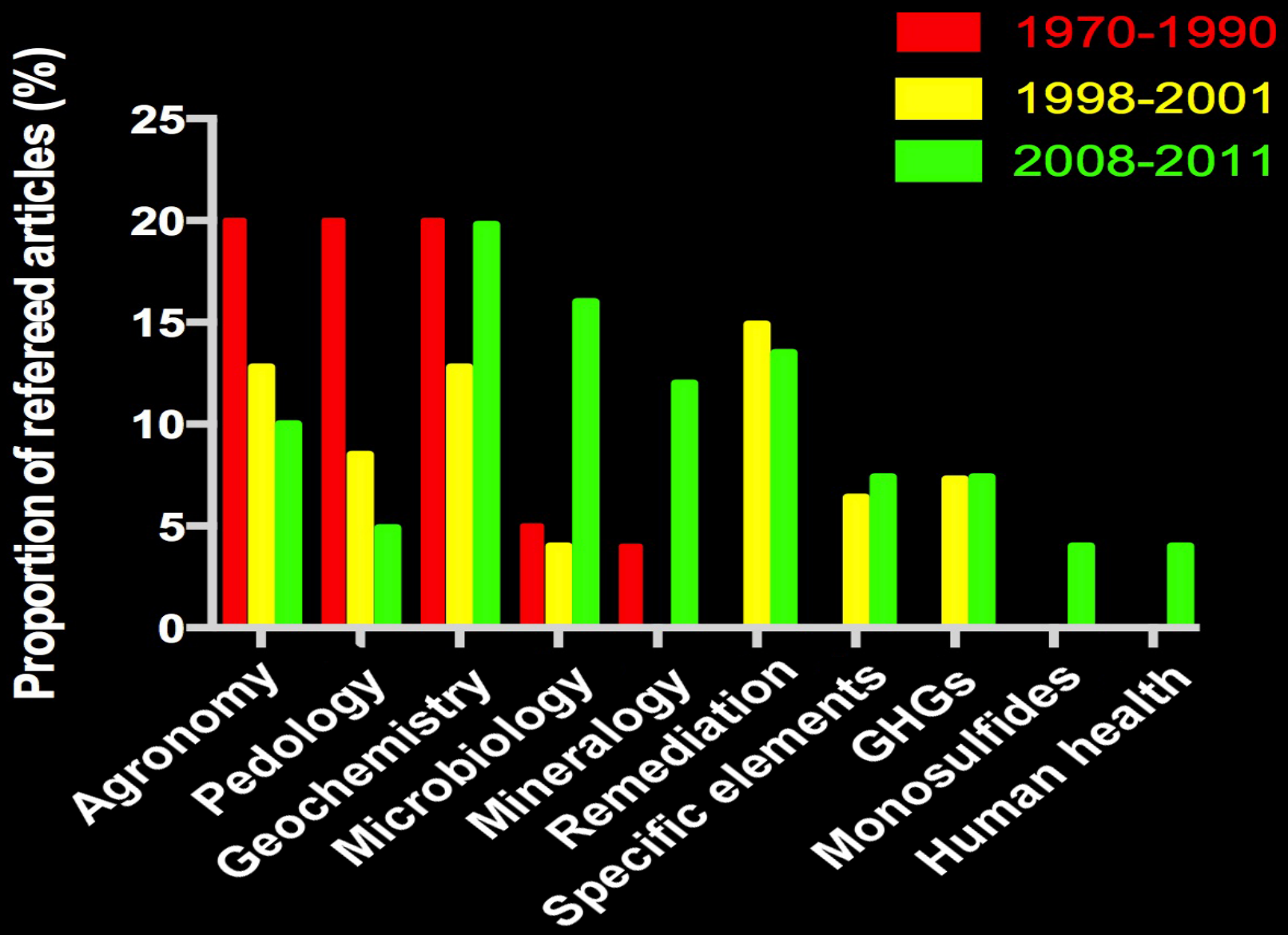
Dent and Pons's (1995) considered that effective systems of management have been developed by farmers but that "the sustainability of these systems is often doubtful due to their detrimental effects on the aquatic ecosystem".

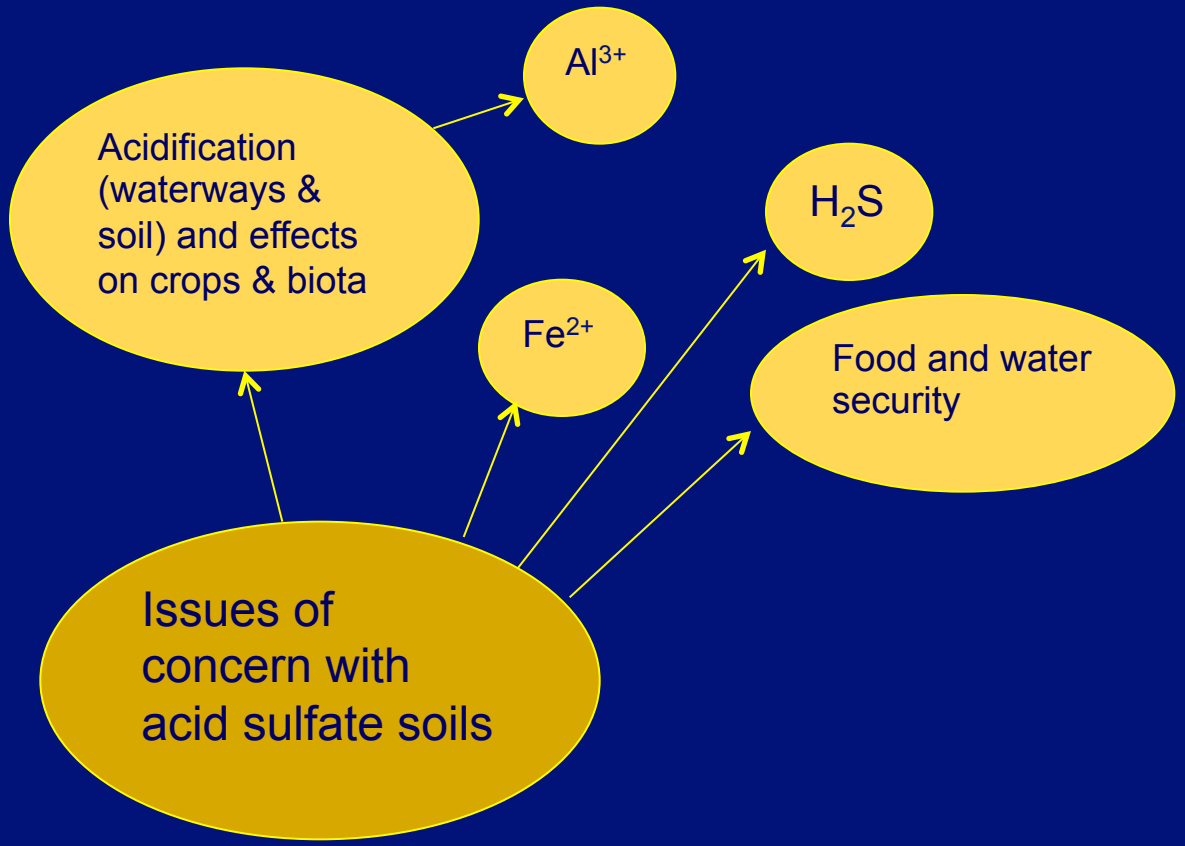
We will hear at this conference some of the considerable progress towards sustainable management of acid sulfate soils that farmers, often working with scientists, have achieved.

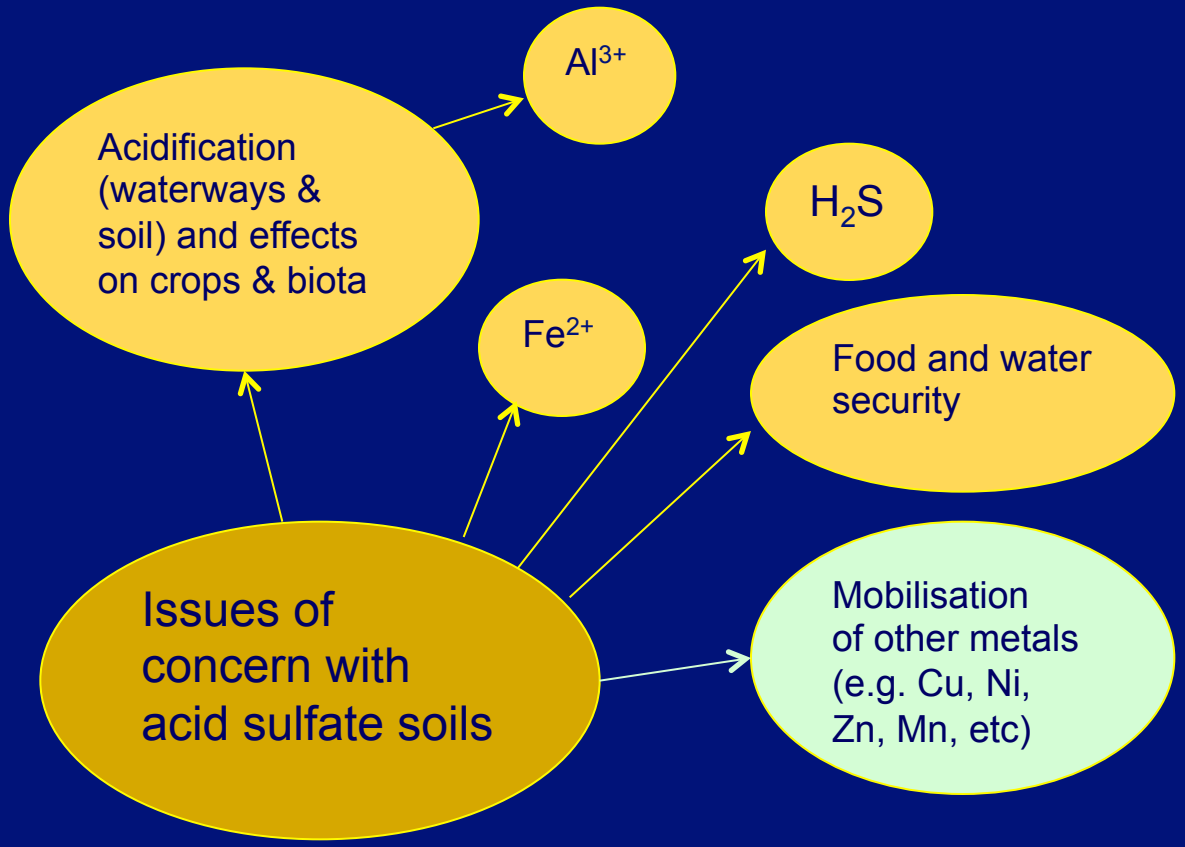
The volume of the peer-refereed literature on ASS has expanded in line with these developments



Publication trends in the main areas of refereed publications (WoK)




Al^{3+}
Acidification (waterways & soil) and effects on crops & biota
H_2S
Fe^{2+}
Food and water security
Issues of concern with acid sulfate soils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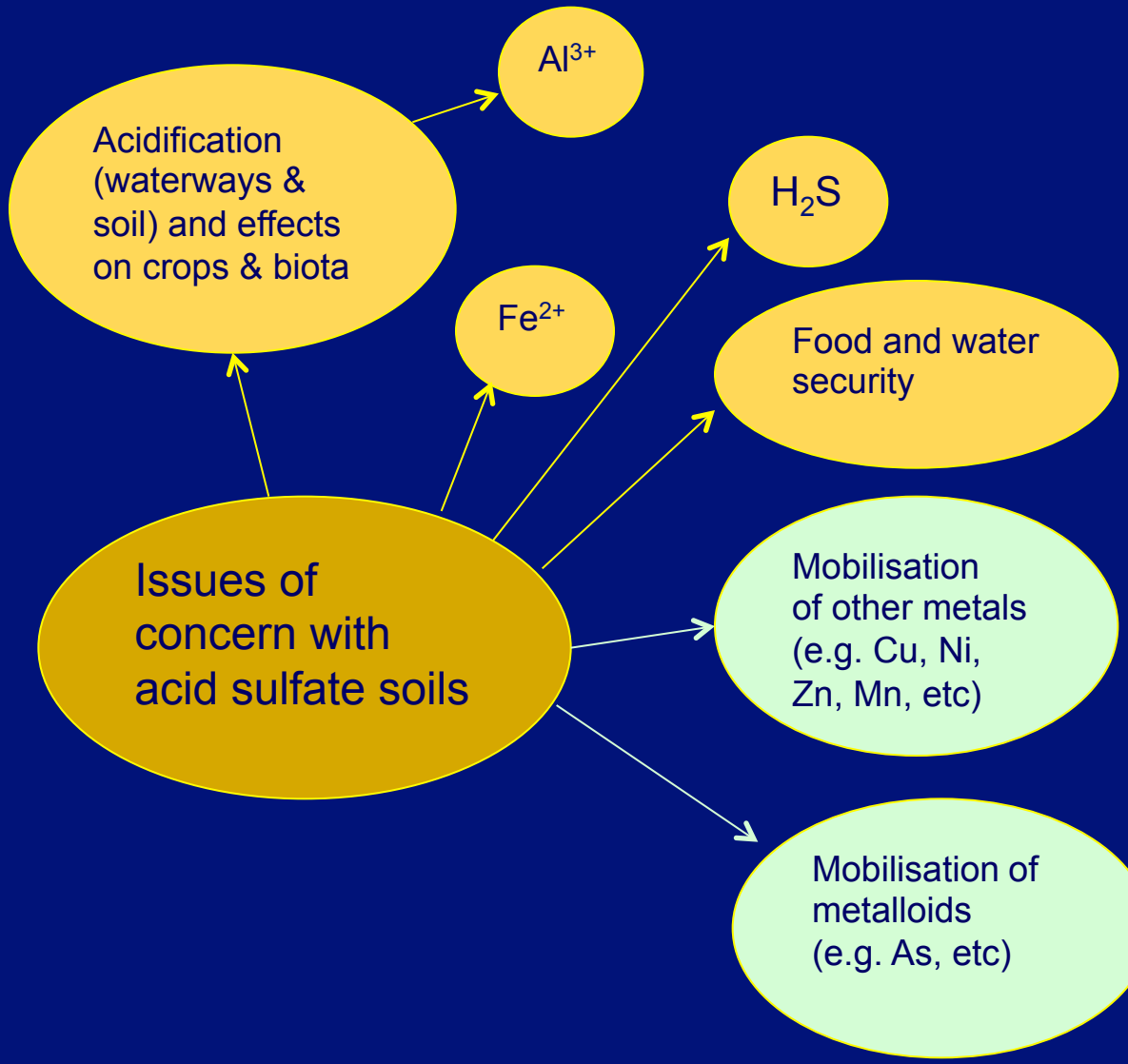
Mobilisation of other metals (e.g. Cu, Ni, Zn, Mn, etc)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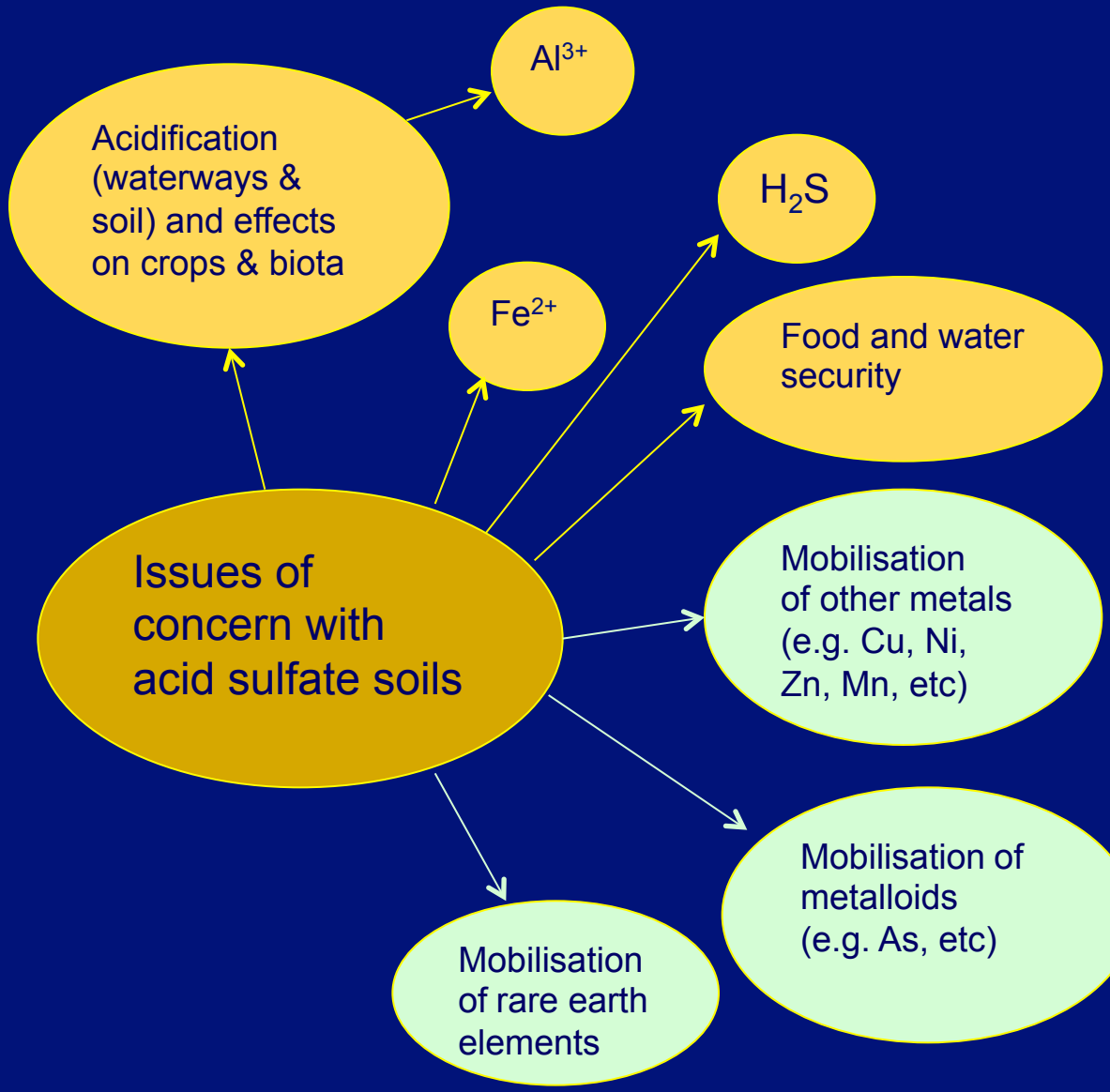
Mobilisation of metalloids (e.g. As, etc)


Issues of concern with acid sulfate soils
Acidification (waterways & soil) and effects on crops & biota
Al^{3+}
Fe^{2+}
H_2S
Food and water security
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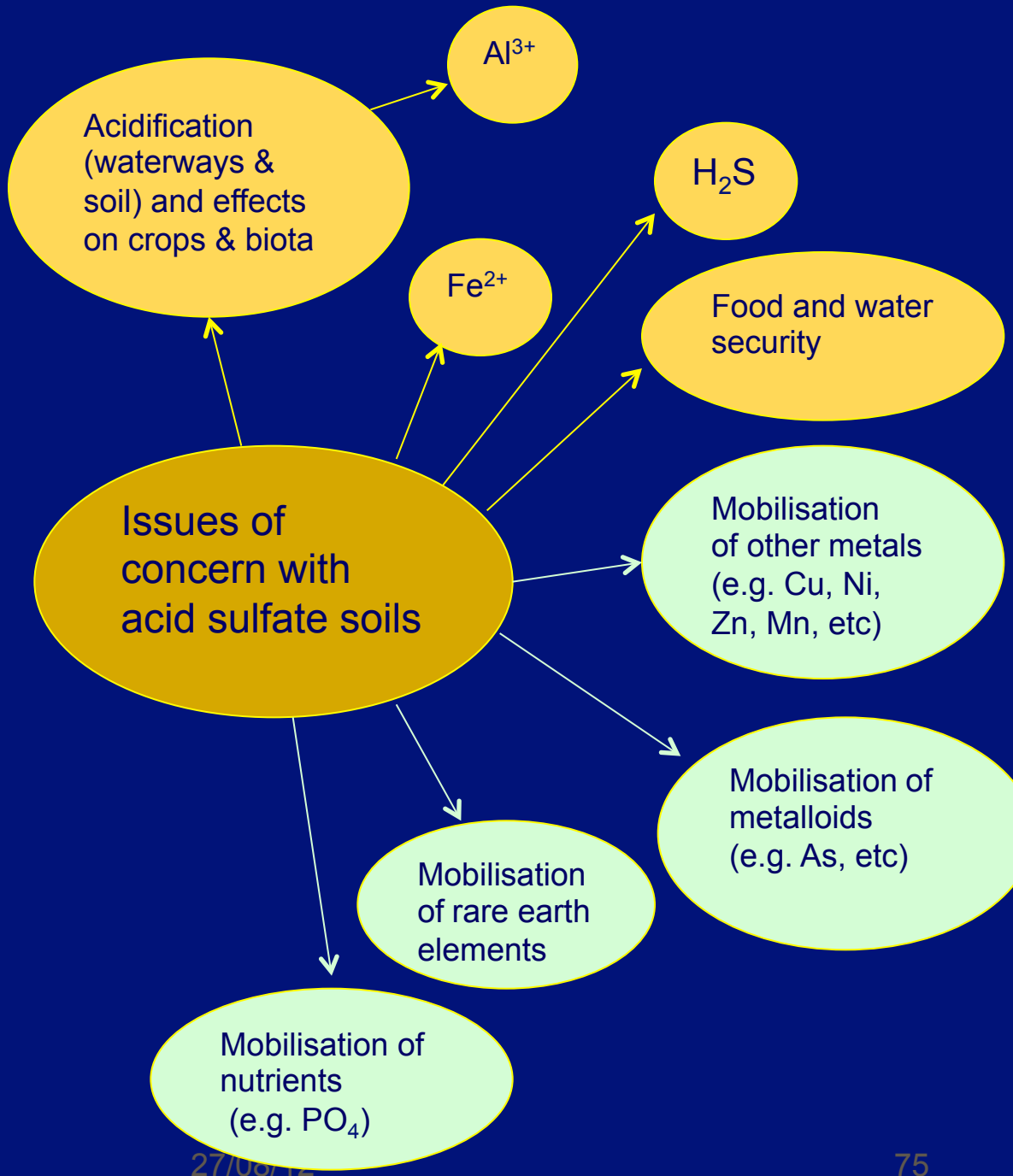
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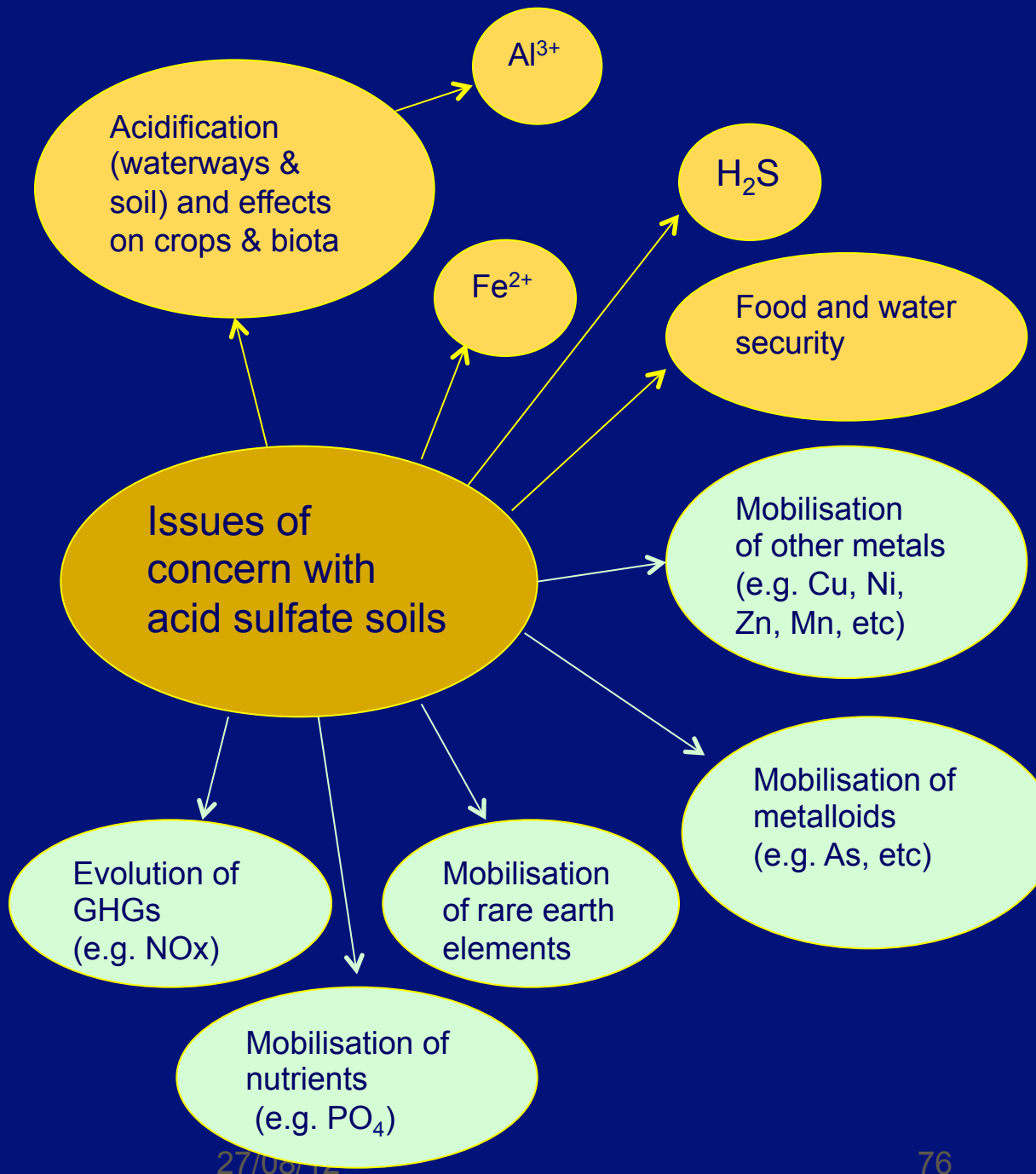
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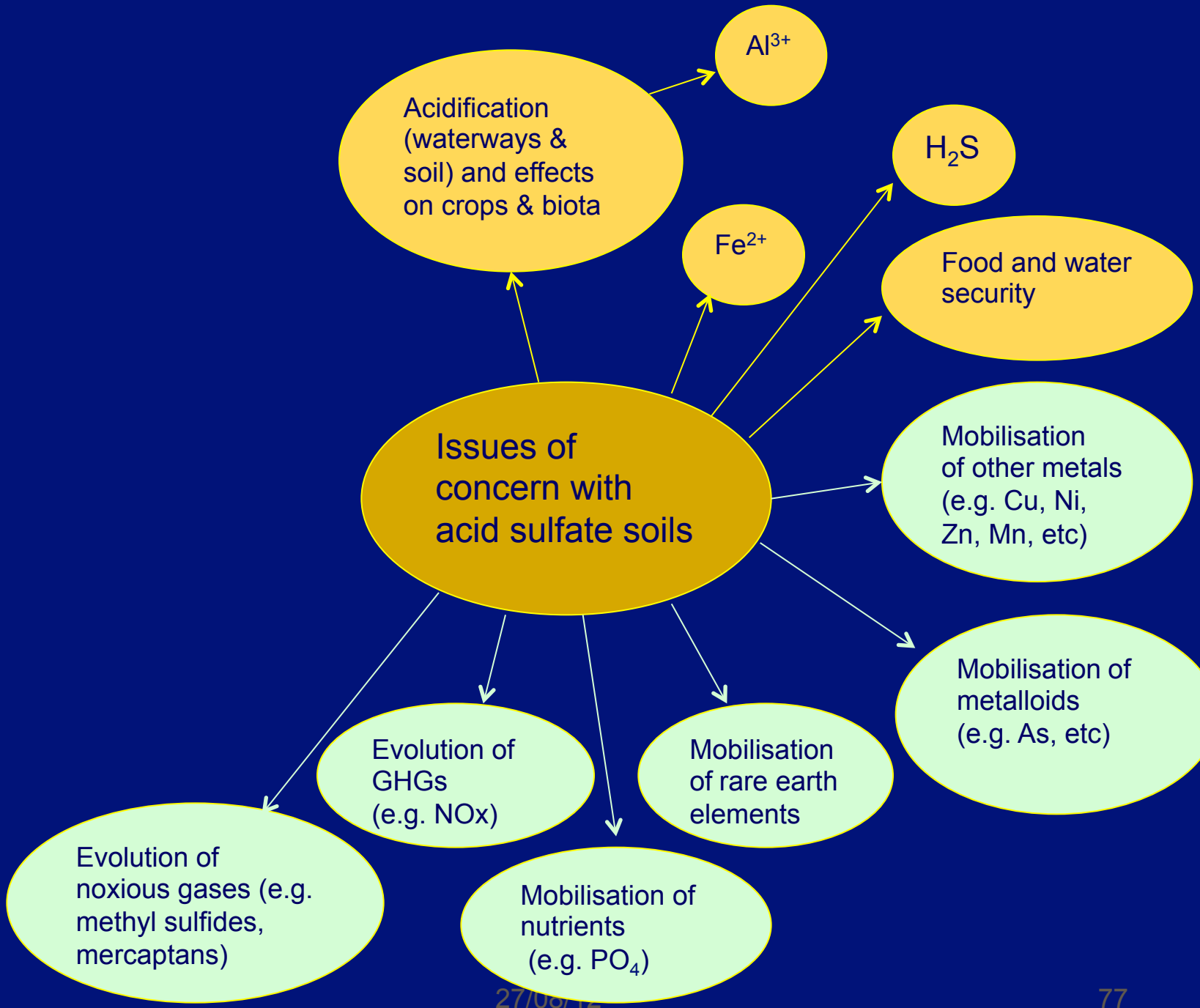
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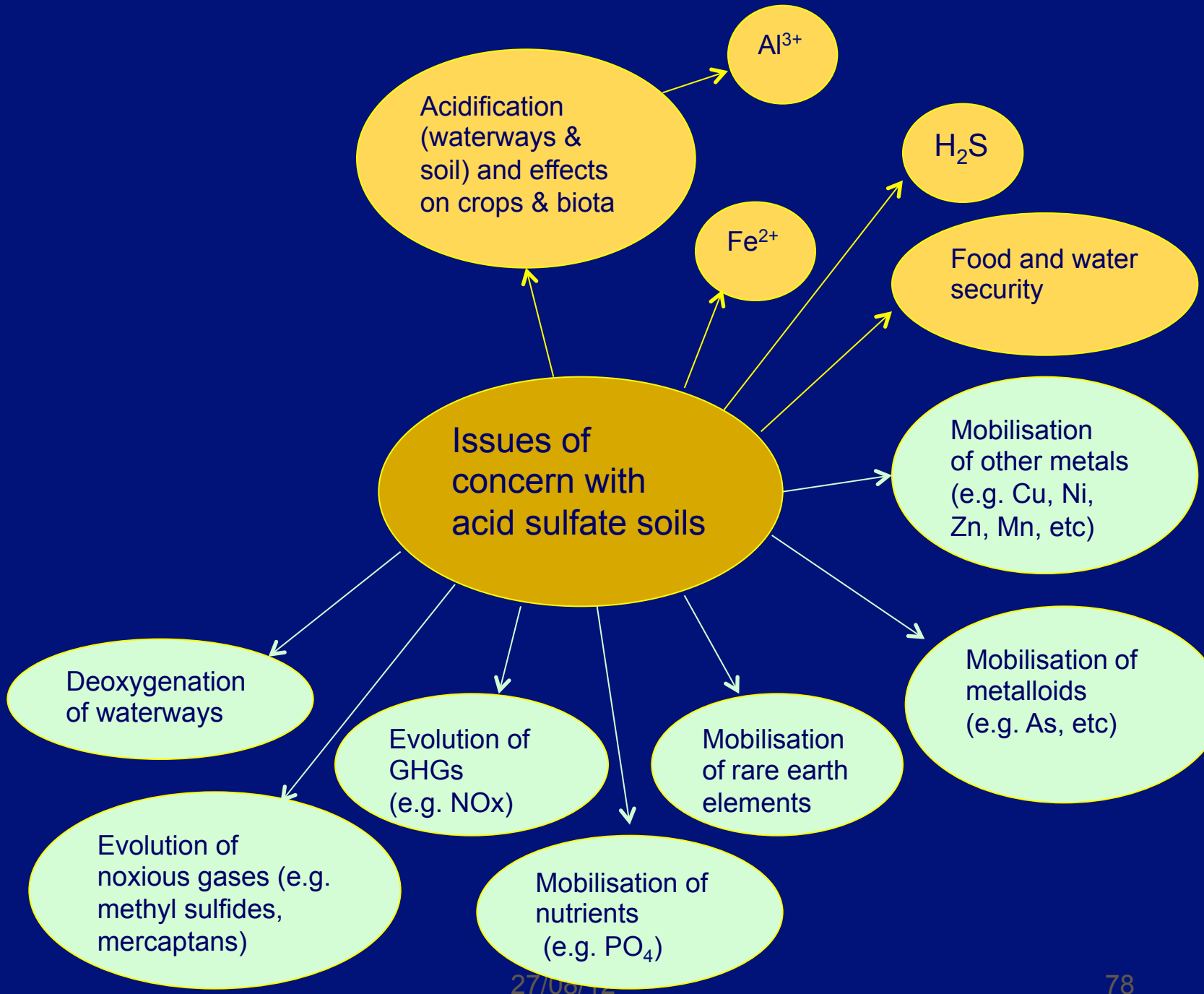
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Issues of concern with acid sulfate soils
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Impacts on human health
Effects of sea level rise
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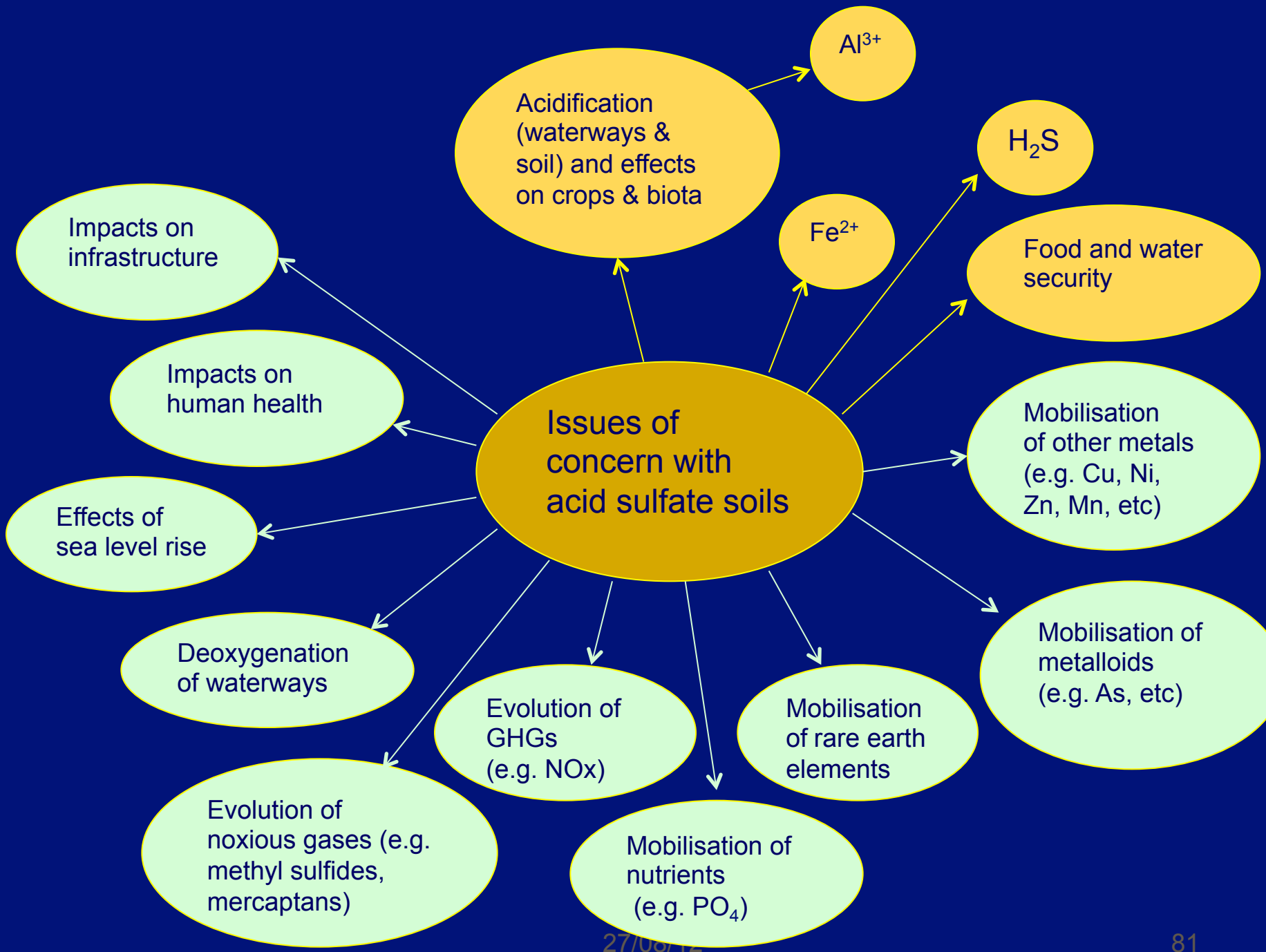
Issues of concern with acid sulfate soils
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Issues of concern with acid sulfate soils
Impacts on the microbial ecology
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By this taxonomic vibrancy criterion, ASS science is healthy.

In conclusion, I believe it is clear by any measure, that globally, our understanding of acid sulfate soils and their impacts have grown substantially in the recent past.

Over this period we have developed:

* a better understanding of its distribution
* better techniques to map and analyse ASS
* better understanding of ASS's behaviour
* better regulatory approaches
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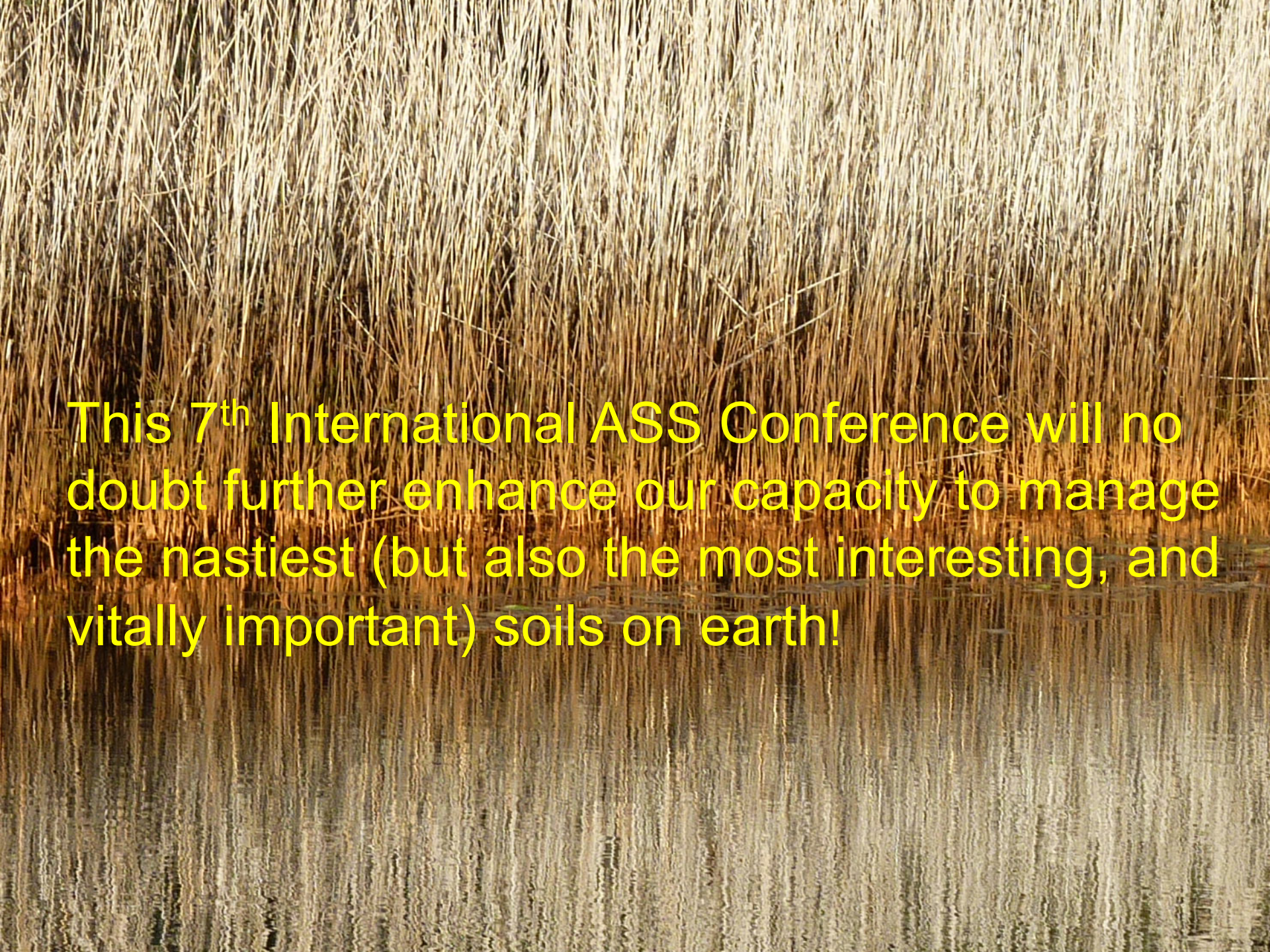
But we still have a long way to go.


This 7th International ASS Conference will no doubt further enhance our capacity to manage the nastiest (but also the most interesting, and vitally important) soils on earth!