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Environmental Impact of Acid Sulfate Soils near Cairns, Qld

Executive Summary of Research Undertaken by CSIRO Land and Water to March 1999

W. S. Hicks, G. M. Bowman and R. W. Fitzpatrick

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Technical Report 15/99, March 1999

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Background to the Problem

Acid sulfate soils (ASS) originate as estuarine deposits that contain abundant fine particles of the mineral iron pyrite (FeS_2). ASS are environmentally unfriendly soils if disturbed or drained. They are widely distributed around the eastern, northern and northwestern Australian coastline. ASS underlie coastal estuaries, embayments and floodplains on or near which the majority of the Australian population and urban development is located. They also underlie significant fish-nursery areas and coastal agricultural industries such as sugar cane, dairying and tea tree oil.

Left undisturbed ASS are benign, but disturbance exposes sulfur-containing compounds in the soil to air, resulting in the formation of damaging levels of sulfuric acid. Further deleterious effects come from the action of the acid on the soil, producing high concentrations of toxic metals – especially aluminium and iron – which end up in waterways. Nationally, there is an estimated 30,000 km^2 of ASS.

Acid runoff from these areas causes adverse impacts to the environment, coastal development, fishing and agricultural industries. Costs to local and regional communities are:

1. Poor water quality with attendant loss of amenity, damage to estuarine environments and reduction of wetland biodiversity.
2. Rehabilitation of disturbed areas to improve water quality and minimise impacts.
3. Loss of fisheries and agricultural production.
4. Maintenance of community infrastructure, particularly concrete, steel, and other materials affected by acid corrosion.

Major environmental impacts include fish and oyster kills, fish disease, destruction of fish nursery habitat, and loss of aquatic biodiversity.

Economic impacts are broad and substantial. Coastal development, driven by the high value of waterfront investment, and associated infrastructure worth over $10 billion, is threatened by ASS impacts. Costs of treating and rehabilitating ASS associated with urban development and infrastructure projects total many millions of dollars. As a consequence, many projects have stalled and some have been abandoned. Millions of dollars worth of infrastructure corroded by acid water has had to be replaced. Millions of dollars of oysters, prawns and fish have been destroyed, nursery areas have been decimated, and land has been degraded by poor ASS management. Acid drainage and poor water quality also pose considerable threats to coastal tourism and communities that rely on good quality estuarine water to attract visitors.

Example of a Prime Study Site in North Queensland

Production, export, and fate of leachate from Australian ASS are poorly understood. In 1995, CSIRO undertook research into the formation and degradation processes operating in Australian ASS to:

- obtain better information,
- relate the processes to environmental controls and
- provide more accurate environmental hazard assessment.

East Trinity, a site adjacent to Cairns City and within the Great Barrier Reef Marine Park, provided a unique site for research into tropical Australian ASS. Acid sulfate soils at East Trinity result from the drainage of mangrove swamps, back swamps and salt flats for sugar cane production some 20 years ago. At East Trinity, undrained soils were present in their original condition immediately adjacent to their drained counterpart, creating an ideal opportunity to measure changes. Severe and ongoing environmental hazards posed by this site were identified from data collected for our research.

Key Findings

Our research indicates that:

- The land at East Trinity is severely degraded and is a continuing environmental hazard
- Sophisticated ASS management and a site remediation plan is needed to reduce the environmental impact
- Pyrite is continuing to oxidise and produce toxic leachate
- Acid was produced at 110 times the rate estimated for temperate Australia
- 72 000 tonnes of sulfuric acid equivalent has been released since 1976
- Substantial reservoir of oxidisable pyrite remains
- Severe acidification of about 110 ha of land has occurred
- Calculations of carbon lost from the acid-affected soils indicate that Australia's greenhouse gas (carbon) emissions due to land use change have been underestimated
- Water discharged into Trinity Inlet contains dissolved aluminium between 120 and 6000 times the Australia and New Zealand Environment and Conservation Council (ANZECC) guidelines
- Discharge into Trinity Inlet of dissolved iron and zinc in excess of ANZECC guidelines
- Flushing into Trinity Inlet of iron precipitates enriched in arsenic and zinc
- Possible contamination of flora and fauna on the site by arsenic and zinc released from soil minerals by acidification. A concern is that feral pigs, feeding in the drained swamp, may ingest sufficient levels of arsenic to create a human health problem when hunted and consumed for food by indigenous Australians in the area.

Detailed Findings

A. Soil

Extent of Severely Acidified Soils

The Queensland Department of Primary Industries (QDPI) has mapped the extent of the severely acid soils at the southern end of the East Trinity site. These cover about 110 ha and correspond to the bunded area around Firewood and Magazine Creeks. This survey measured acidity of around 5 kg of sulfuric acid per cubic metre to about 0.8 m depth and reserves of potential acidity exceeding 50 kg of sulfuric acid per m^3 to about 1.8 m depth, extending in 600m from the bund. The remaining potential acidity is estimated to be 600 tonnes of sulfuric acid per hectare, approximately one-third of the pre-drainage potential acidity.

Subsidence

Drainage has resulted in subsidence and compaction. Prior to drainage the surface was at 0.9 m AHD and is now some 1.3m lower at –0.4 m AHD. These level changes mean pre-drainage hydrological conditions cannot be restored, complicating rehabilitation.

Production of Acid

Prior to drainage, the soil stored potential acidity to the equivalent of 1270 tonnes of sulfuric acid per hectare. Drainage and oxidation of pyrite has resulted in this being reduced to 620 tonnes of sulfuric acid per hectare, releasing the equivalent of 650 t sulfuric acid per hectare into the environment. Total acid production is estimated at 72 000 t sulfuric acid, at an average annual rate of 3800 t. This is equivalent to 34 000 kg sulfuric acid / ha / y, some 110 times previous estimates of maximum production of 300 kg sulfuric acid / ha / y.

Consequently, the soil on the site is severely acidified, with an average soil pH of 3.4 at 0.5m. Soil water pH’s are commonly 3.2. Surface water pH’s average 3.4 in drainage channels and Magazine Creek and 4.4 in Firewood Creek.

Carbon Loss

In their undisturbed state, these soils are natural accumulators of carbon. In the southern corner of this site, carbon has accumulated in a peat layer extending from about 0.2 to 0.8 m below ground level. In this layer, carbon content exceeds 15%. Results show that 45% (0.07 million tonnes) of the carbon has been lost as a result of oxidation and the acid dissolution of carbonates. Both these processes result in the emission of the greenhouse gas, carbon dioxide. Australia’s greenhouse gas emissions due to land use change have been estimated at 16Mt p.a. of carbon. The average annual emission rate from East Trinity is 33 t/ha. The total area of ASS in Australia has been estimated at 30 000 km^2. Estimates of the area affected by drainage are unavailable, but if we assume 10%, ASS in Australia have contributed up to 10Mt of carbon per year for the past 20 years.

B. Surface Water

Firewood Creek

Water samples were taken inside the bund adjacent to the discharge point from January 1997 until the April 1998. The samples contained aluminium, iron and zinc in concentrations that, during the wet season often exceeded ANZECC guidelines. Average concentrations in micrograms per Litre for water discharging into Trinity Inlet from Firewood Creek are as follows (with the best available ANZECC guideline value in parenthesis):

Aluminium	4200	(5)
Iron	3800	(500)
Zinc	178	(50)

Magazine Creek

Magazine Ck was sampled from the October 1997 to April 1998. Concentrations of aluminium, iron and zinc exceeded ANZECC guidelines for the entire period. Average results in micrograms per litre were:

Aluminium	10 000	(5)
Iron	15 000	(500)
Zinc	273	(50)

Precipitates

The S-W corner of the bunded area is covered extensive iron precipitates, which extend to about 0.6m below the surface. These precipitates adsorb arsenic and zinc and constitute a highly mobile reservoir of these elements. Measurements indicate that these precipitates contain arsenic at about 300 to 700 mg/kg and zinc from 100 to 500 mg/kg. During the wet season when water levels inside the bund are high, the iron precipitates flush into Trinity Inlet when the tide gates are open. Natural processes in the sediments of the inlet will reduce the iron in the particulate material from its ferric to ferrous state, releasing the adsorbed elements into the surrounding pore waters. The problem is that toxic elements can be taken up by benthic and bottom-feeding organisms.

Conclusions

The East Trinity site is severely degraded. It contains actual and potential ASS which will require sophisticated management to reduce environmental impacts. Water discharging from the site into Trinity Inlet contains aluminium, iron and zinc in excess of ANZECC guidelines. Arsenic and zinc are being transported offsite on iron precipitates where they will become bioavailable and will enter the food chain of animals within the Great Barrier Reef Marine Park. It is likely that already there have been effects on flora and fauna both within and outside the site from elements such as aluminium, arsenic, iron, manganese and silicon.

Experience of CSIRO scientists at the site indicates that remediation by conventional acid neutralisation or simple reflooding would be impractical. Moreover, this approach is likely to be uneconomic and environmentally hazardous.

References

ANZECC (1992). *National Water Quality Management Strategy – Australian Water Quality Guidelines for Fresh and Marine Waters* Australian and New Zealand Environment and Conservation Council, Canberra.

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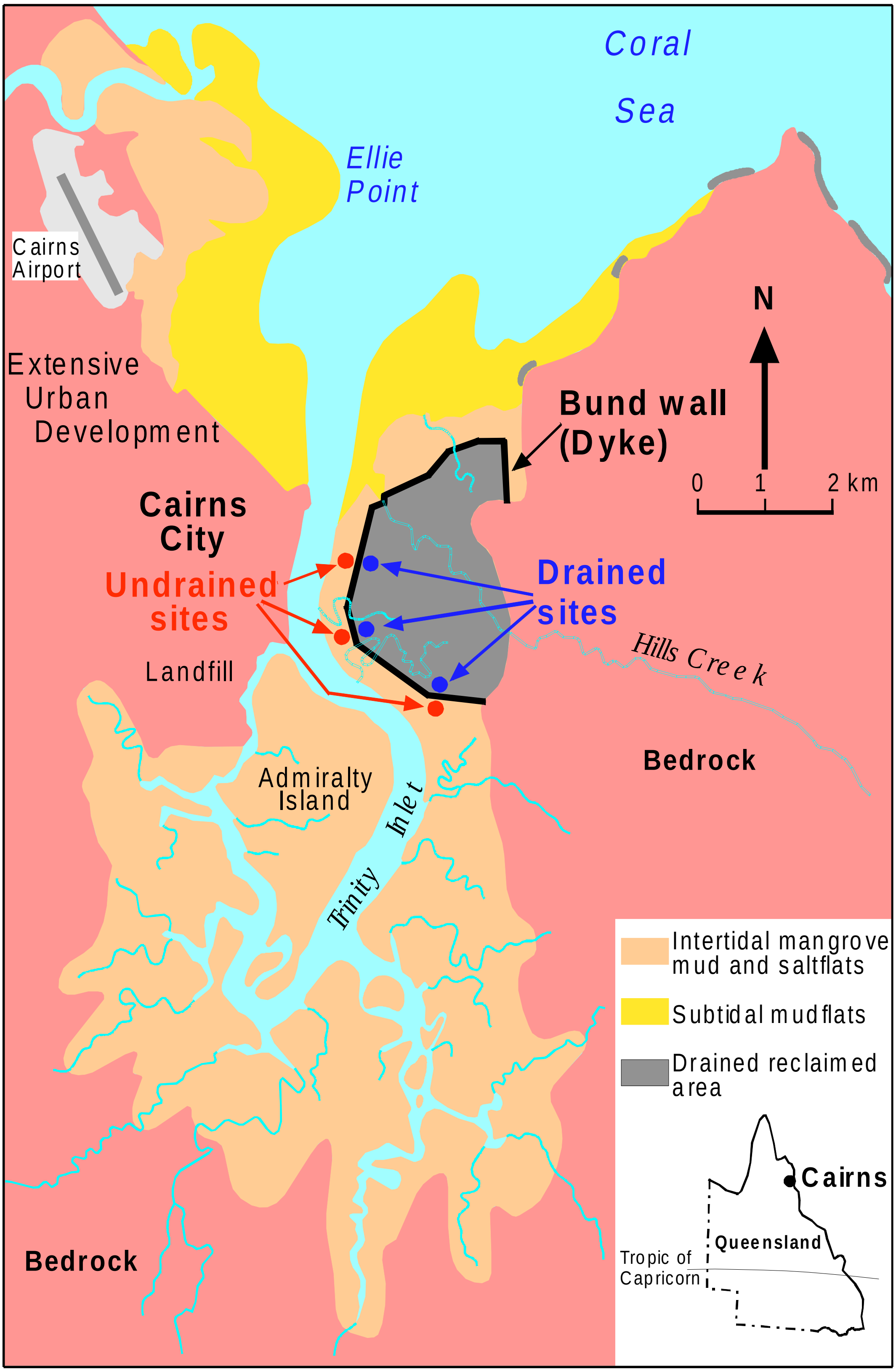

Location of East Trinity Study Site

Southernmost end of site, showing the original condition (top) and drained condition (below). Leachate shown in the bottom picture contains a cocktail of toxic elements.

Firewood Creek at discharge point showing channel to Trinity Inlet (top) and drained sections (left). Note corrosion of steel and iron precipitate.