Problem Soils and Water Skis

Sodic Soils and Design / Construction Implications for a Recreational Lake in Central Western Queensland.

Douglas Partners
Geotechnics / Environment / Groundwater

Contents

- What is soil sodicity?
- Why understanding soil sodicity is important.
- How to identify sodic soils.
- Challenges associated with the construction of a recreational lake in Western Queensland.
- A proposed decision tree for assessment and management of sodic soils for engineering

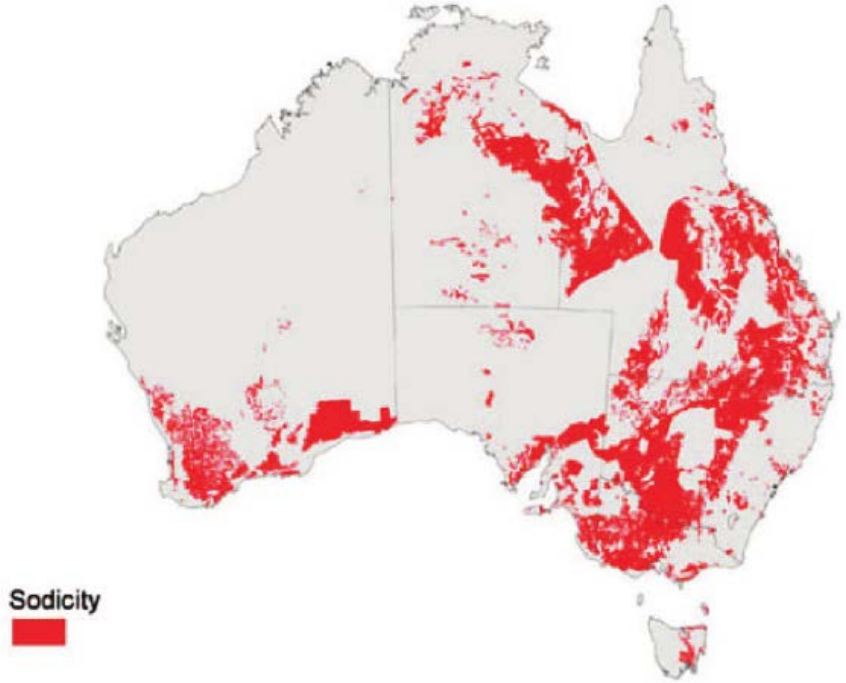
Approx 45% of the Australian landmass is sodic

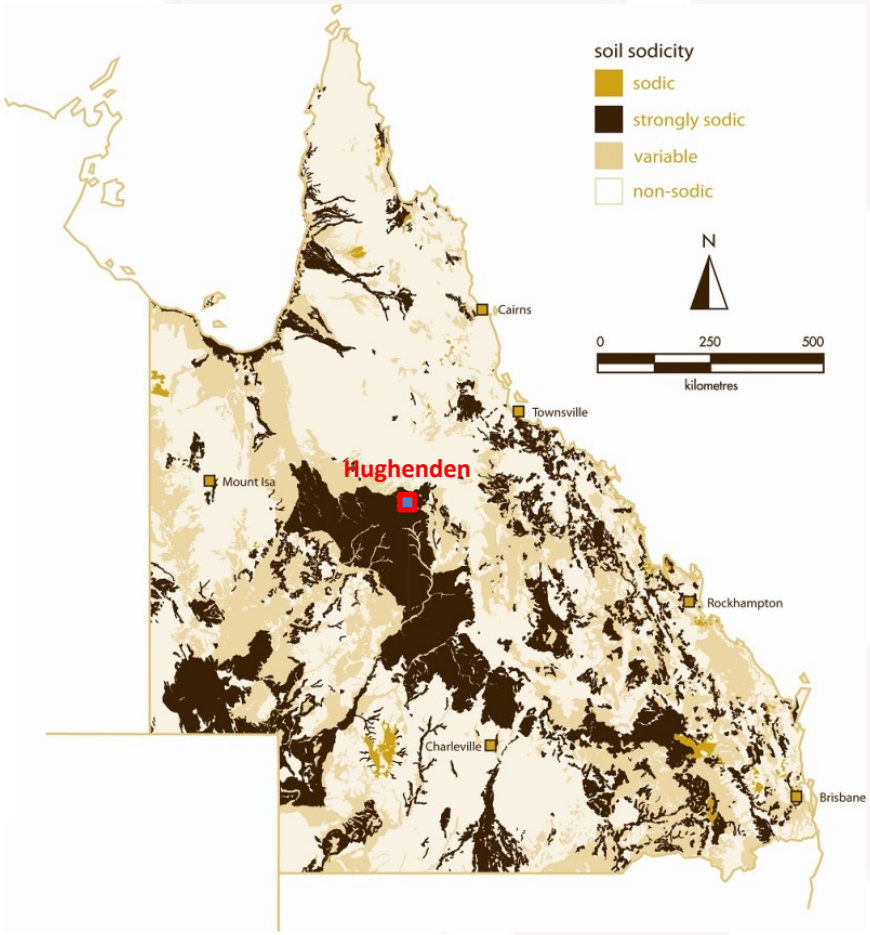
Continent	Area (million hectares)		
	Saline	Sodic	Total
North America	6.2	9.6	15.8
Central America	2.0	-	2.0
South America	69.4	59.6	129.0
Africa	53.5	27.0	80.5
South Asia	83.3	1.8	85.1
North and Central Asia	91.6	120.1	211.7
Southeast Asia	20.0	-	20.0
Europe	7.8	22.9	30.7
Australasia	17.4	340.0	357.4
Total	351.5	581.0	932.2

*Adapted and compiled from Dregne and Chou (199

Douglas Partners
Geotechnics / Environment / Groundwater

Distribution of Sodic Soils





Douglas Partners
Geotechnics / Environment / Groundwater

Visual Signs of Sodic Soils

- Salt tolerant plants (eg salt bush / samphire etc)
- Scalding / bare earth, worming on exposed soil surfaces
- Gully erosion – including tunnels
- Ponded water after rains being ‘milky’
- Slow infiltration
- Very soft/ boggy when wet or very hard when dry

Why do some soils disperse? (Dave Millard 2018)

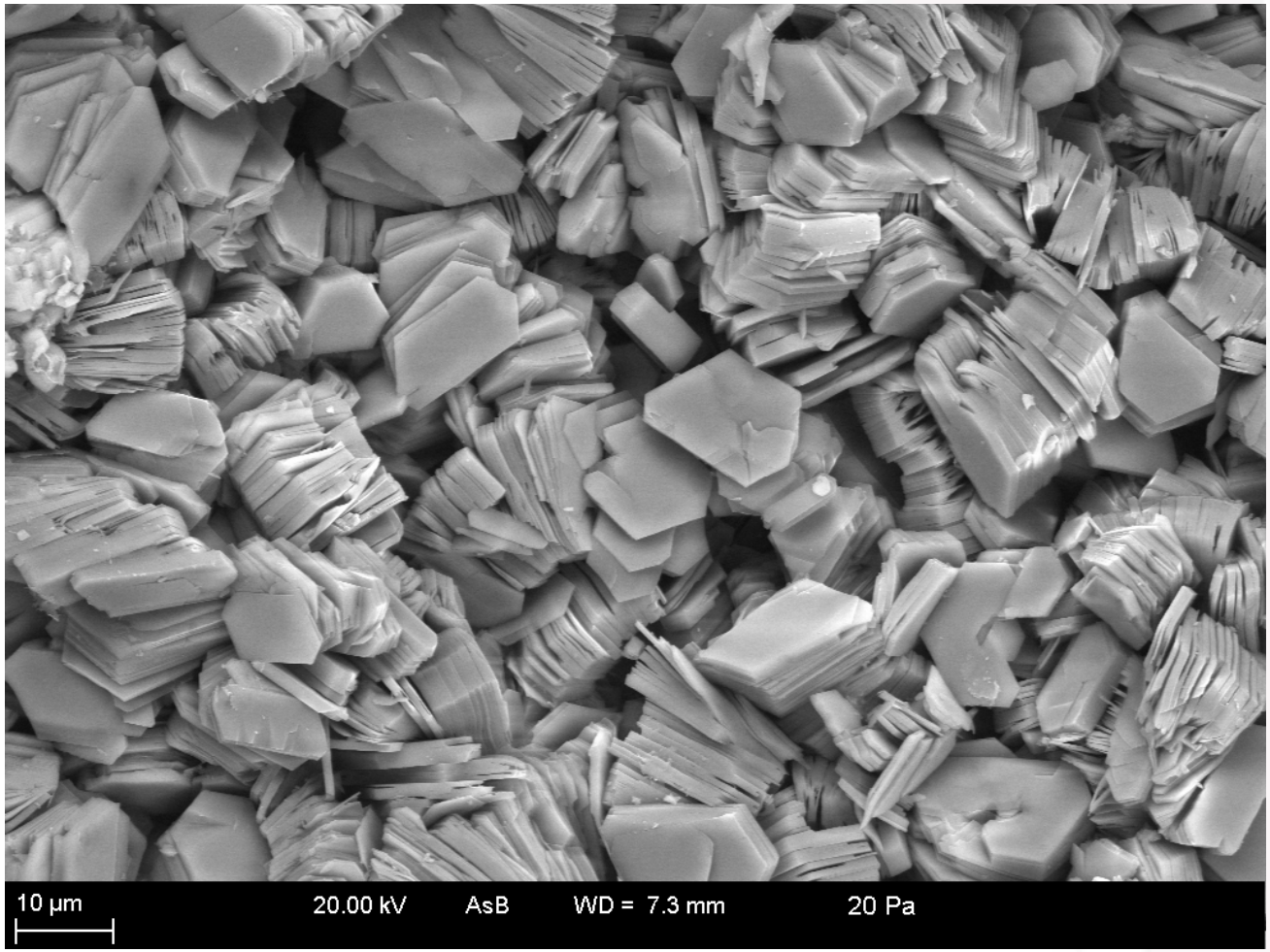
- Clay is a crystalline mineral with a complex chemical formula.

e.g. $(Al_{2-y}Mg^{2+}/_{y})(Si_{4-x}Al_{x})O_{10}(OH)_{2}M^{+}/_{x+y} \cdot nH_{2}O$

- Clay is not simply silt broken down into finer particles.
- Clay particles are formed from aggregations of microscopic platelets stacked together.

Douglas Partners
Geotechnics | Environment | Groundwater

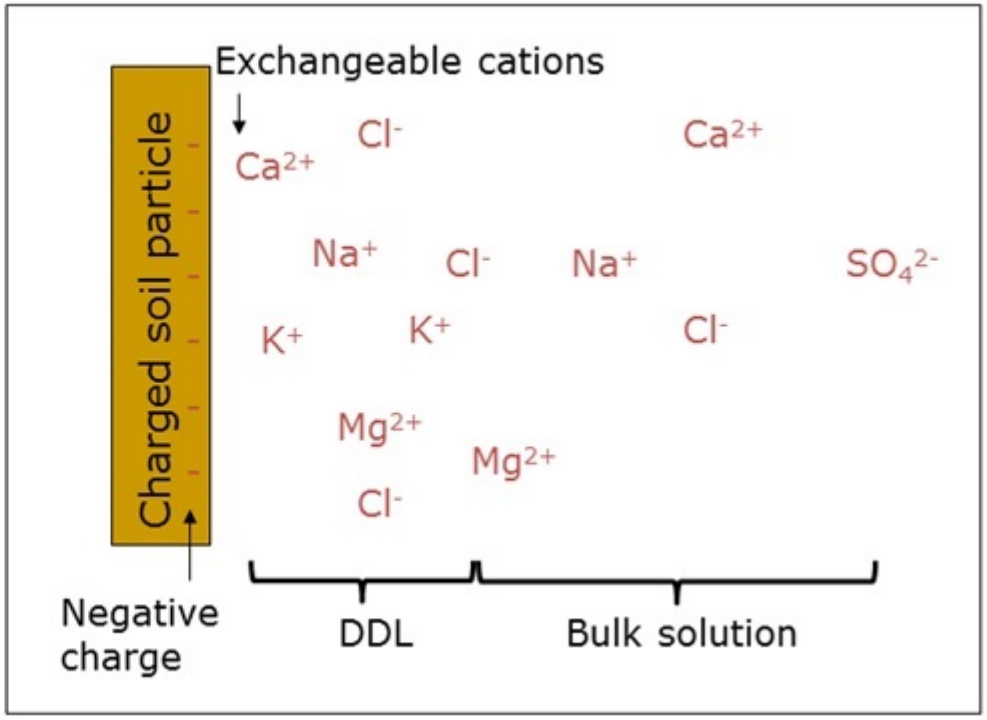
Clay Platelets (DM 2018)

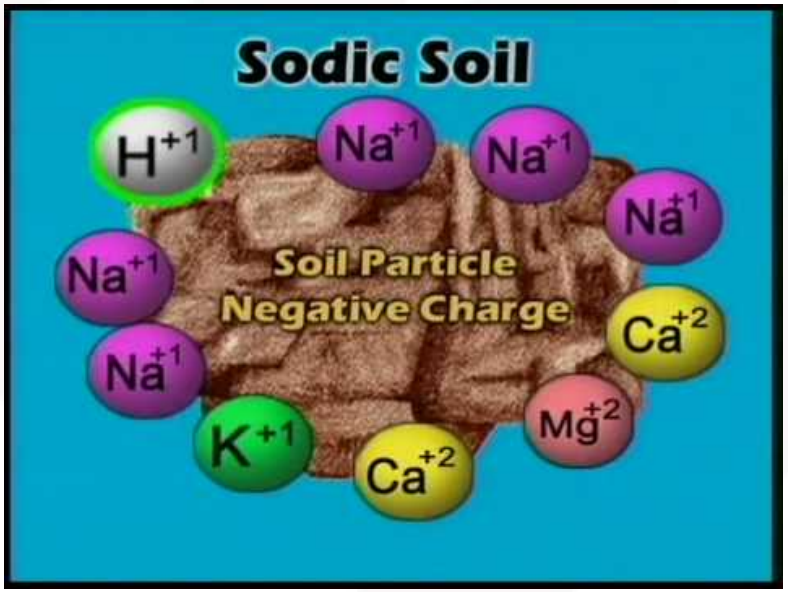


Douglas Partners
Geotechnics | Environment | Groundwater

Soil Sodicity

Sodicity in soil is the presence of a high proportion of sodium ions relative to other cations within the exchange complex.

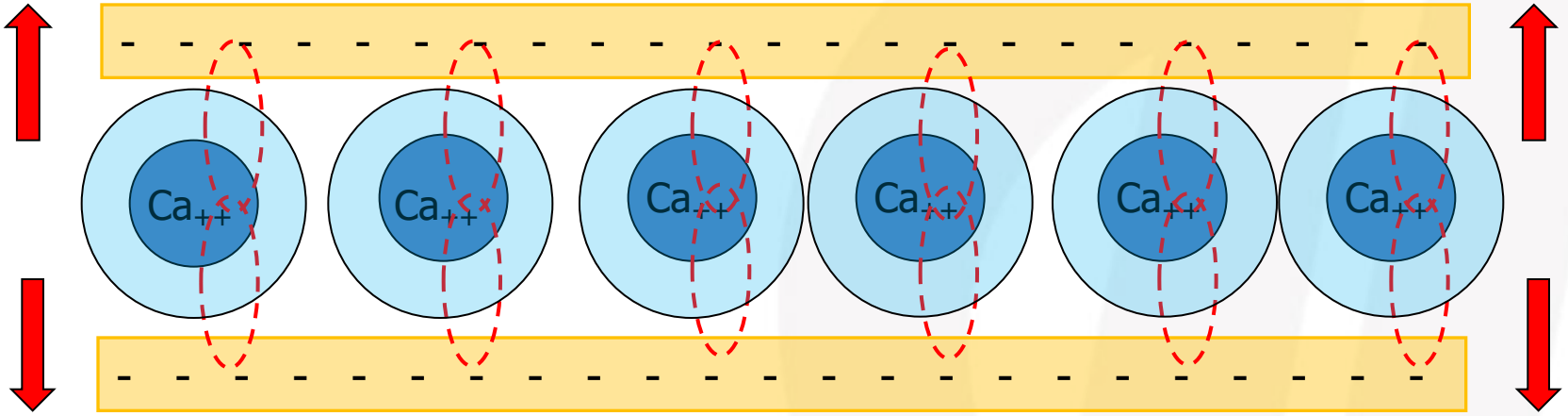




Douglas Partners
Geotechnics / Environment / Groundwater

(DM 2018)

When this soil becomes wet the calcium ions are hydrated and take up a larger volume. This results in swelling of the clay

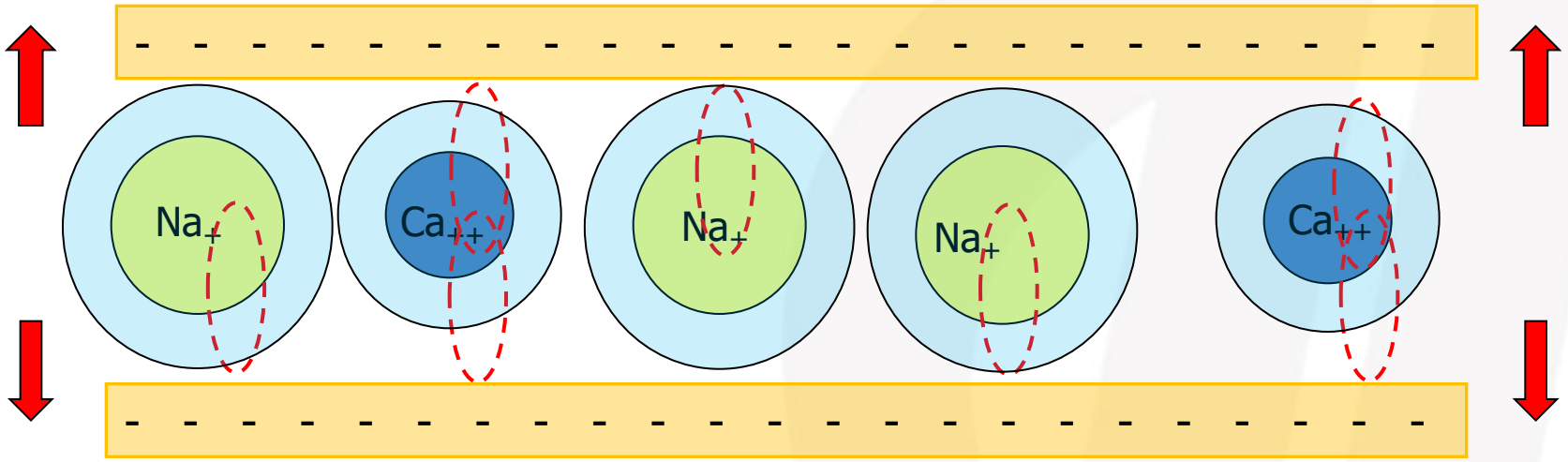


Expansion is not great enough to break the electrostatic bonding.

These types of expansive clays are called SMECTITE clays and include MONTMORILLONITE and BENTONITE.

(DM 2018)

When this soil becomes wet, the hydrated sodium ion is much larger than the hydrated calcium ion. Also important to note that sodium is monovalent and so only sticks to one platelet, where as calcium is divalent



The increased volume between the clay platelets is enough to break the electrostatic attraction between them, after which the sodium rich platelets repel each other.

The result is **DISPERSION** of the clay particles.

Sodium particularly effects clays such as MONTMORILLONITE and ILLITE

Difference Between Slaking and Dispersion

- **Slaking** – rapid wetting compresses the air in the soil pores, which results in separation of soil aggregates by explosive force of compressed air.
- **Dispersion** – electrostatic bonds holding the clay platelets together are broken due to swelling followed by repulsion (eg monovalent sodium ion can only attach to one platelet).

http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/0d08cd6930912d1e4a2567d2002579cb/soilhealth_soil_structure_dispersion

Douglas Partners
Geotechnics | Environment | Groundwater

Is My Soil Sodic?

Initial screening for soil sodicity is as simple as undertaking an Emerson Class test, which assesses the response of air dried soil crumbs to immersion in water.

SLAKES only – structural issues other than sodicity (such as due to low organic matter content, or acidic pH)

DISPERSES - sodic.

Samples that don't disperse, MIGHT still be sodic.

Therefore. Additional testing should always be undertaken.

ESP (%)	
Non-sodic –	ESP <6%
Sodic –	ESP 6-14%
Strongly Sodic -	ESP>14%

Salinity (µS/cm)	
Non-saline –	0-2000
Slightly saline –	2-4000
Moderately saline –	4-8000
Strongly saline –	8-16000
V Strongly saline –	>16000

Additional testing suites should include:
pH, EC (saturated / 1:5 extract), Cl, SO_4

Cation Exchange Capacity & Exchangeable Sodium Percentage

Calculate Total Cationic Concentration = EC (µS/cm) * 100

NOTE: **Saline-sodic soils** do not necessarily disperse under natural conditions.

Testing requirements should also vary depending on project-specific requirements (eg pinhole dispersion for water storage embankments

Douglas Partners
Geotechnics | Environment | Groundwater

Douglas Partners
Geotechnics | Environment | Groundwater

Douglas Partners
Geotechnics | Environment | Groundwater

Douglas Partners
Geotechnics / Environment / Groundwater

Decision Making??

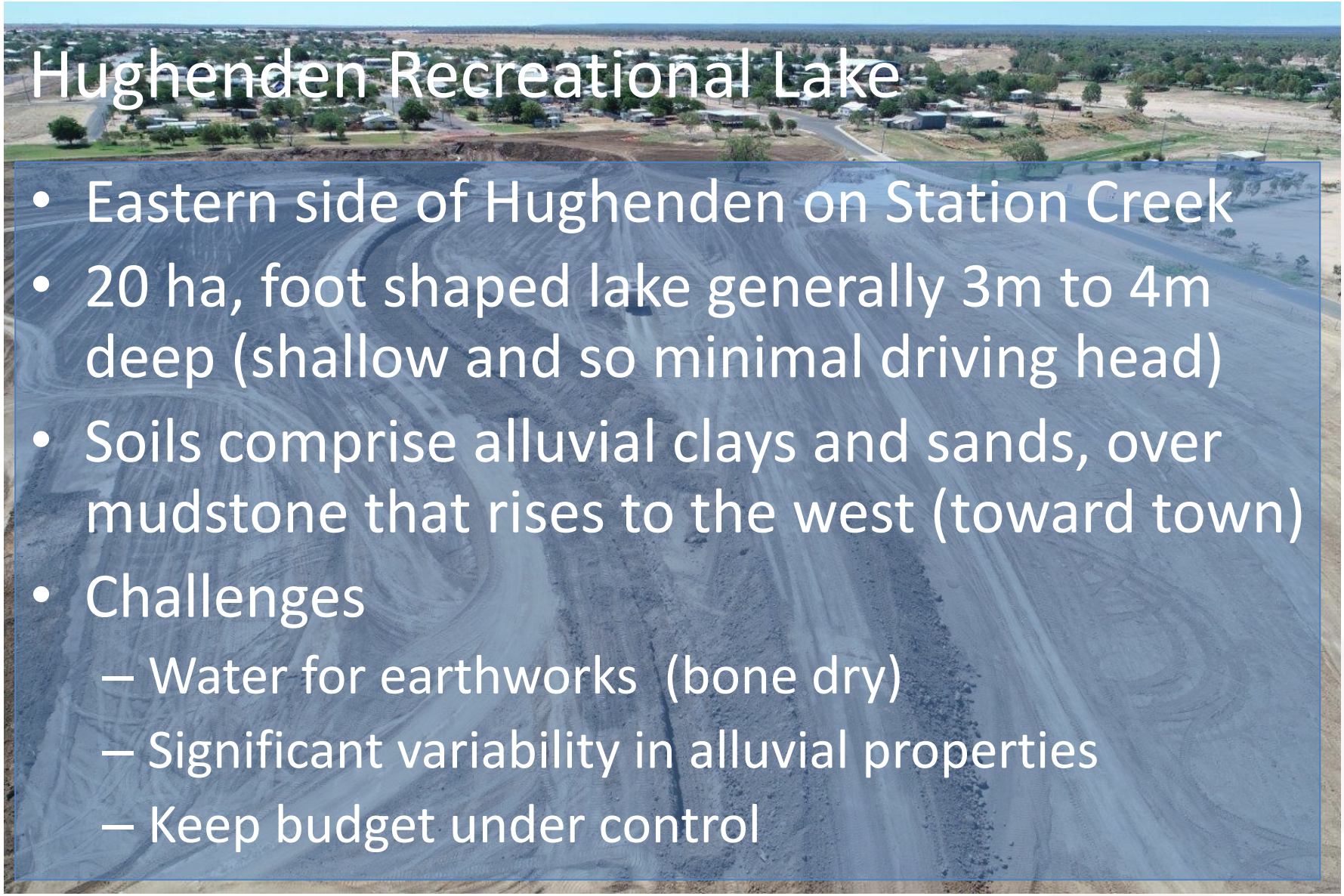
- What are we building/protecting
  - Dam or channel
- What external risks are present
  - Slope
  - Rainfall intensity
  - Vegetative cover
- Are my soils at risk to water erosion
  - Emerson class
  - Pinhole dispersion (esp for dams)
  - Organic matter
  - CEC and ESP
  - pH and EC
  - SO_4
- Clay mineralogy – rigid (eg kaolinite) or swelling (eg illite/montmorillonite)
- Management Options
  - Do nothing
  - Organic matter
  - Gypsum
  - Lime (changes pH as well)

Hughenden Recreational Lake

- 20 hectare lake to be used for
  - Watersports
  - Community Events
- Not for fishing
- Not for town water supply
- Not for flood mitigation
- To revitalise the town spirit and provide new focal point for new tourism – lots of local energy (and scrutiny)

Douglas Partners
Geotechnics | Environment | Groundwater

Hughenden Recreational Lake



- Eastern side of Hughenden on Station Creek
- 20 ha, foot shaped lake generally 3m to 4m deep (shallow and so minimal driving head)
- Soils comprise alluvial clays and sands, over mudstone that rises to the west (toward town)
- Challenges
  - Water for earthworks (bone dry)
  - Significant variability in alluvial properties
  - Keep budget under control

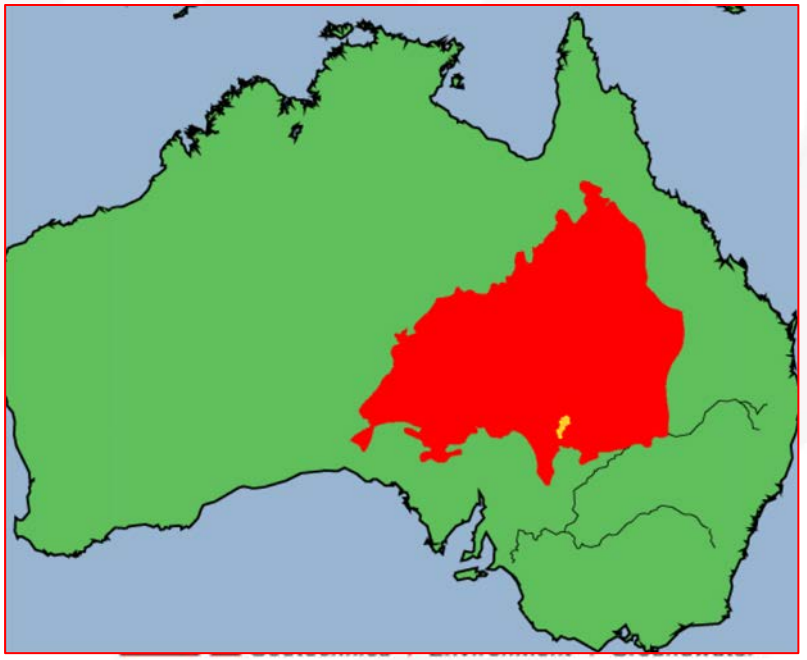
Douglas Partners
Geotechnics | Environment | Groundwater

Hughenden

- Half way between Townsville and Mt Isa
- Population - 1,136 potential water skiiers, but gradual decay due to loss of wool industry (climate related)
- Potentially significant irrigation schemes on the horizon (ie lots more dams)
- Australia's little grand canyon (Porcupine Gorge)
- Part of the Dinosaur Trail – awesome for kids

Dinosaurs and Geology

- Eromanga Basin (Eromanga Sea - Salt)
- ‘Mutt’ the Muttaburrasaurus
- Predominantly marine fossils – including Kronosaurs



Eromanga Geology

- Early Jurassic - Late Cretaceous **basin**. The **Eromanga Basin** encloses the multi-aquifer system of the Great Artesian Basin **(GAB)** and overlies late Palaeozoic and older basins.
- Up to 3000m thick
- Water sources for Hughenden include alluvial aquifers and GAB
- Marine sediments (predominantly mudstone), fossil rich

Problem Soils

- Alluvium properties ranging greatly
- Very low strength mudstone generally exposed on the lake floor, with pockets of crystalline gypsum present
- Most samples highly sodic but all Emerson Class 4 (moderate potential + gypsum presence)
- Shouldn’t strongly sodic soils be highly dispersive??
- Slightly saline soils (which is great for dispersion)

Douglas Partners
Geotechnics | Environment | Groundwater

Remediation Option

- Highly sodic soils – classic option is to add gypsum

Added gypsum (%)	EC (µS/cm)	ESP (%)
0	4200	31.4
2	3500	33
4	4500	27.7
6	4400	25.7

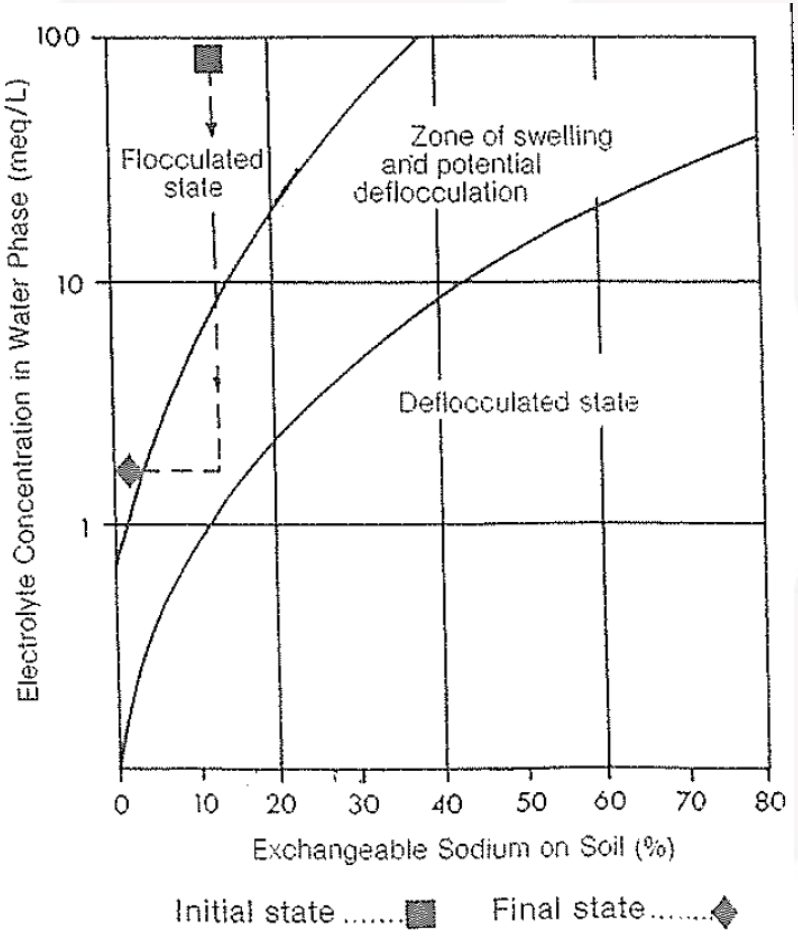
- Exchangeable Ca for this sample was already >60%
- Sulfate levels (SO_4) as high as 12000 mg/kg
- Soils have extremely high exchangeable calcium and sulphate levels ($CaSO_4$ = gypsum)
- Therefore gypsum not feasible

Remediation Options - Floor

- ~~Gypsum~~
- Make it a salt water lake…
- Line the floor – GCL, HDPE – too expensive
- Geo-R-Bond – electrochemical stabiliser
  - 0.045 l/m^2 at $34/l = $300,000 for dam floor excluding earthworks equipment to apply it
- Rip, moisture condition and compact the floor to resist slaking during initial inflows ✓
- Rely on organic matter generation/accumulation to improve structure and reduce slaking potential (when dry) long term

Long Term Concerns

With exposure to fresh water, leaching may cause gradual reduction in EC, therefore potentially leading to longer term dispersion and need for management (eg addition of flocculants, or lining), depending on aesthetic



Douglas Partners
Geotechnics | Environment | Groundwater

Remediation Option – Wall

- Increase dam crest width to approx 50 m
  - To be potentially used as camping/caravan zone with great views (win – win)
- 'Grassroots' facing to inner batters down to below operational level
- Geofabric beneath sand beach zones
- Topsoiling and promote vegetation quickly

Suggestions

- Do suite of Emerson, pH, EC, SO_4, Cl and CEC (incl ESP) – get the full picture (analytical testing cheap)
- For water storage embankments, do pinholes (absolutely necessary)
- If soils are sodic but Emersons are 4 or greater, figure out why – chemistry and salinity. Maybe also ask your lab to run the Emerson for at least 24hrs if you suspect saline-sodic soils (to model water body contact conditions)
- Make sure you consider salinity of the contact water

Questions

Douglas Partners
Geotechnics / Environment / Groundwater