Understanding dispersive soils

Bruce Carey

July 2014

Understanding dispersive soils

Part A

Part B Case studies

May 2014

Introduction

This digital book is an introduction to dispersive soils and their management. It mostly relates to Queensland but the principles would be applicable to other areas. It will be of interest to students, Landcare groups, consultants, commercial organisations, agency employees, and the wider community.

Dispersive soils are very common in Queensland. Dispersion is most commonly linked to sodicity - a natural feature of our soils affecting up to 45% of the state. Soil dispersion has implications for agriculture, construction, mining and water quality. Management of dispersive soils varies with soil type, climate, land use and available expertise and budgets.

Part A provides general information about dispersive soils while Part B contains case studies.

About the author

Bruce Carey began his career as a soil conservation extension officer with the Queensland Department of Primary Industries in 1971. He carried out this role in Millmerran, Goondiwindi, Emerald and Toowoomba before moving to Brisbane in 1988. He maintained his links to soil conservation while working in several Queensland government agencies until his retirement in 2012.

He has a special interest in documenting the knowledge gained about soil conservation in Queensland. He is the author of the publication *Soil conservation measures – A design manual for Qld* and has written numerous fact sheets related to sustainable land management.

Bruce Carey
B. App. Sc. (Rural Technology, Gatton College)
bcarey@tpg.com.au

Acknowledgment

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Thanks also to the Queensland Department of Science, Information Technology, Innovation and the Arts (DSITIA) for providing many of the images used in this publication.

Some tips on using this digital book

- This book is a 28MB PDF file with 240 pages and almost 200 photos and diagrams. It is not intended to be read in one session!
- There are hyperlinks to help you navigate your way around
- The book contains a number of links to websites. It is best to download the PDF file it to the hard drive on your computer. Otherwise the PDF file may close each time you click on a web link
- It is best to view this book in full screen mode (View > full screen mode).
- This book can be referenced as follows . Carey Bruce 2014, *Understanding dispersive soils*, viewed (insert date #####)Landcare Queensland website,

http://landcare.org.au/resources-links/achieving-soil-conservation-in-queensland/

Dispersive soils

- are very erodible

- cause tunnel erosion
- make water turbid
- affect productivity

Dispersive soils are like snakes.
Leave them alone and they won't hurt you,
but they can cause concern when you disturb them.

Some clay types are vulnerable to soil dispersion , which is the breakdown of soil aggregates in the presence of water into very small particles.

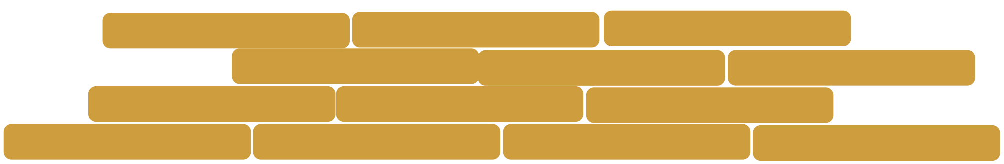
Dispersive soils are highly erodible and cause turbidity in water.

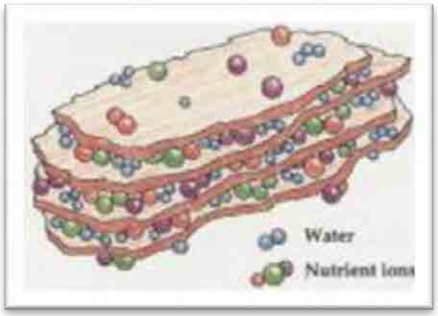
Soil dispersion is associated with soil sodicity. It most commonly occurs in subsoils but may also occur in topsoil. Around 45% of Queensland has soils with sodic properties.

Why do soils disperse?

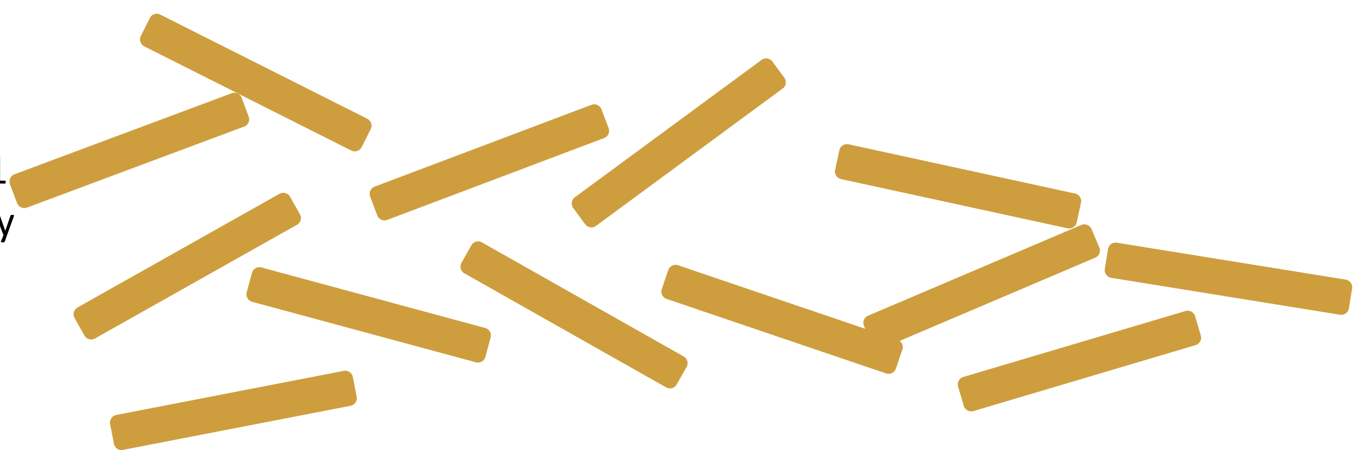
Clay soils are amazing. One teaspoon of a cracking clay soil has the surface area of a football field.

The clay component of soils is made of platelets which are stacked together (flocculated) to form aggregates. The diagram below illustrates a highly simplified version of what clay platelets look like in reality.

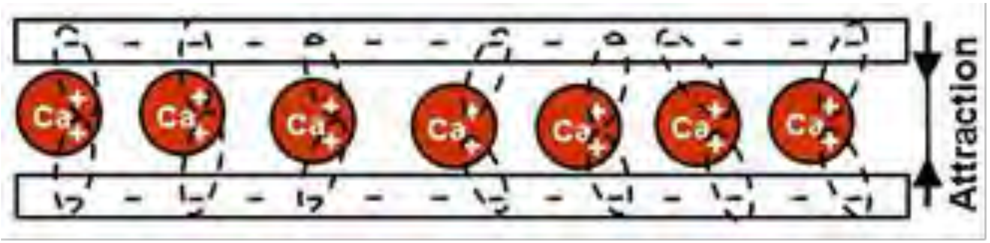




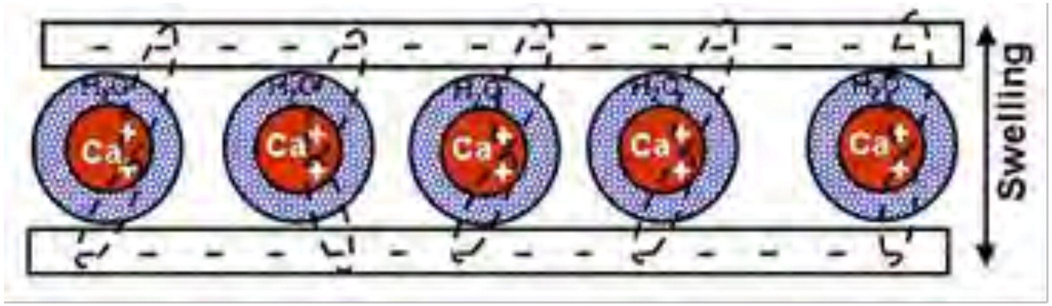
Dispersion occurs when the linkages holding the clay platelets are broken. Clay platelets are microscopic with an average size of 0.001 mm (1 micron). In water they cause turbidity by remaining in suspension.



The susceptibility of a soil to dispersion is related to the relative amounts of sodium and calcium ions between the clay platelets.

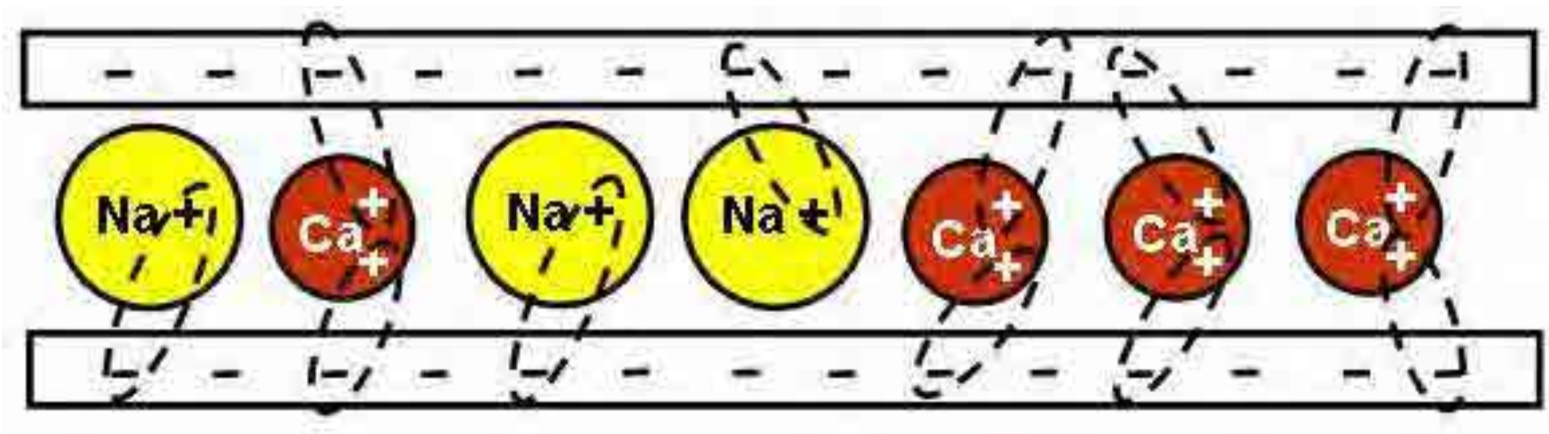


If the layer between clay platelets is dominated by calcium, then dispersion will not occur. Calcium ions are relatively small with two positive charges which attach to negative particles on the clay surface binding them together.

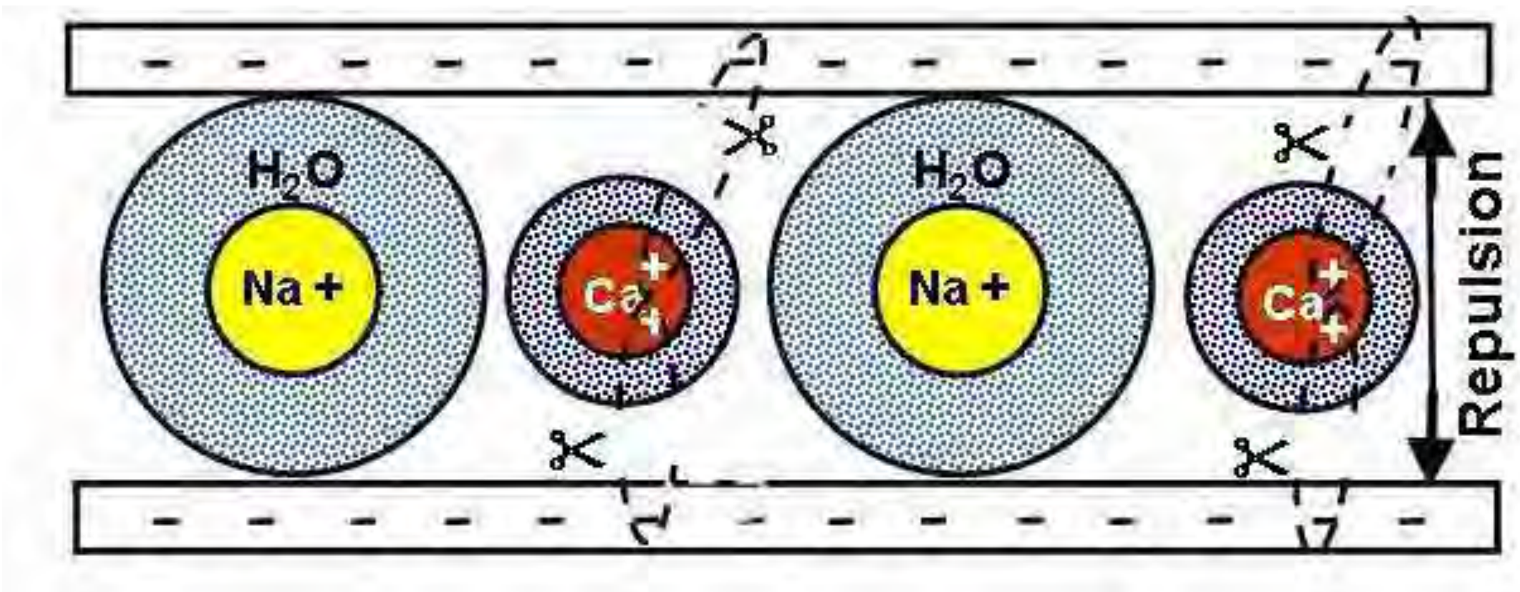


When this soil becomes wet, the calcium ions are hydrated. They become larger in size and some expansion and swelling of the soil occurs. However, the expansion is not great enough to disrupt the electrostatic binding.

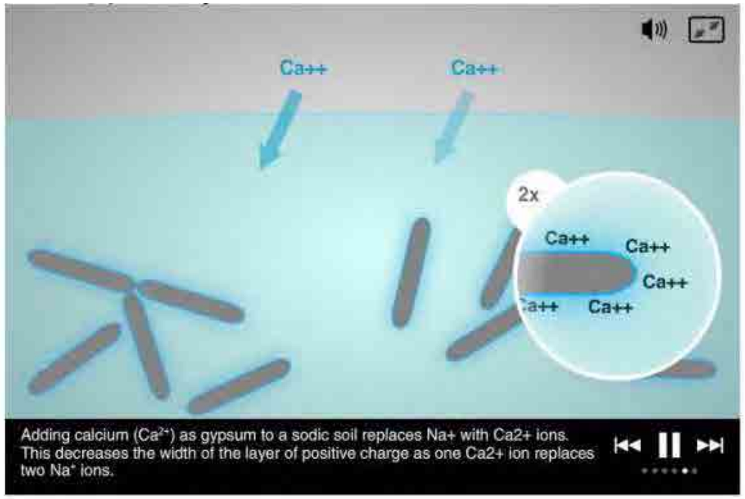
These clay platelets are separated by both calcium and sodium ions. Calcium has two positive charges allowing it to bind to two platelets but the mono-valent sodium, with only one charge can only attach itself to one platelet.



When a soil becomes wet, the hydrated sodium ion is much larger than the hydrated calcium ion. This increases the space between the clay platelets leading to the breaking of the electrostatic bonds resulting in separation (dispersion) of the clay particles.



Soil dispersion is associated with sodic soils. A soil is considered to be sodic when the sodium on the cation exchange surfaces between clay platelets reaches a level where it leads to dispersion.



The web site Victoria On-line has an animation showing how soils disperse.
http://vro.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soilhealth_soil_structure_dispersion

Some clay types are more vulnerable to dispersion than others.

The cation exchange capacity (CEC) of a soil is a measure of the negative charge on clay particles. This determines how many positively charged ions and water a clay soil can store. Fertile soils have clay soils with a high CEC.

Clay soils with layers that occupy a large surface area will have a high CEC and will be dispersive if enough sodium is present.

- a gram of smectite (shrink/swell clay) has a surface area of about 800 m^2 and a CEC of 60-100 (cmol (+)/kg)
- a gram of kaolinite (a rigid clay) only has a surface area of about 10 to 20 m^2 and a CEC of 10 - 30(cmol (+)/kg) .

The role of magnesium and potassium in dispersion

There is evidence that the presence of magnesium and potassium in sufficient quantities can cause dispersion, but this requires further research.

Magnesium ions have a double positive charge, but they are less effective at maintaining flocculation than calcium ions because they are much larger in size. Thus the clay platelets are forced further apart than with hydrated calcium ions.

Potassium ions only have a single positive charge and are larger in size than the calcium ion.

Salinity and sodicity

Soil salinity and sodicity are often confused. Salinity is the presence of a range of salts in a soil such as sodium chloride, magnesium and calcium sulfates, and bicarbonates. Sodicity is the presence of a sufficient amount of sodium ions on the cation exchange surfaces of clay platelets to cause soil dispersion.

Soils may be both sodic and saline. Where sodicity restricts leaching in drier climates, sodic soils tend to be saline, especially at depth. In wetter climates, salinity is less likely to be an issue because the salts are leached out of the soil profile.

Even good quality irrigation water contains some salts (the ‘minerals’ in mineral water are actually salts). If these salts are not leached out of the soil profile, they can accumulate and the soil will eventually become saline. The rate of leaching depends on the climate and the soil type. The drier the climate, the less leaching.

If irrigation water has sodic qualities, then the soil will become sodic, if there is insufficient leaching to remove the sodic salts from the profile.

Salinity and soil dispersion

Salinity and sodicity have opposite effects on soil dispersion. If the water in the soil solution is saline, then a sodic soil is not likely to disperse. The high concentration of ions in saline water tends to compress clay platelets together and overcome the forces provided by enlarged and hydrated sodium ions.

When rain falls on saline subsoils that have been exposed as a result of construction activities, the salt can be leached out of the soil making the soil dispersive.

If the rate of infiltration of rainfall into the soil was to increase, as a result of a change in land use from native vegetation to cropping, leaching of salts may also lead to dispersion. The same effect may arise from the use of good quality irrigation water, in excess of plant requirements, that flushes salts down the profile. A low level of salts in irrigation water can be desirable as it will reduce the amount of dispersion, surface sealing and crusting when this water is applied to soils with a sodic surface.

Freshwater streams become turbid when they contain eroded, dispersed soils in suspension. When these streams flow into saline coastal waters, they flocculate and the water becomes clear when the newly formed aggregates sink to the bottom. A similar process occurs when turbid inland creeks flow into the saline waters of Lake Eyre.

Can other soil textures besides clays be ‘dispersive’?

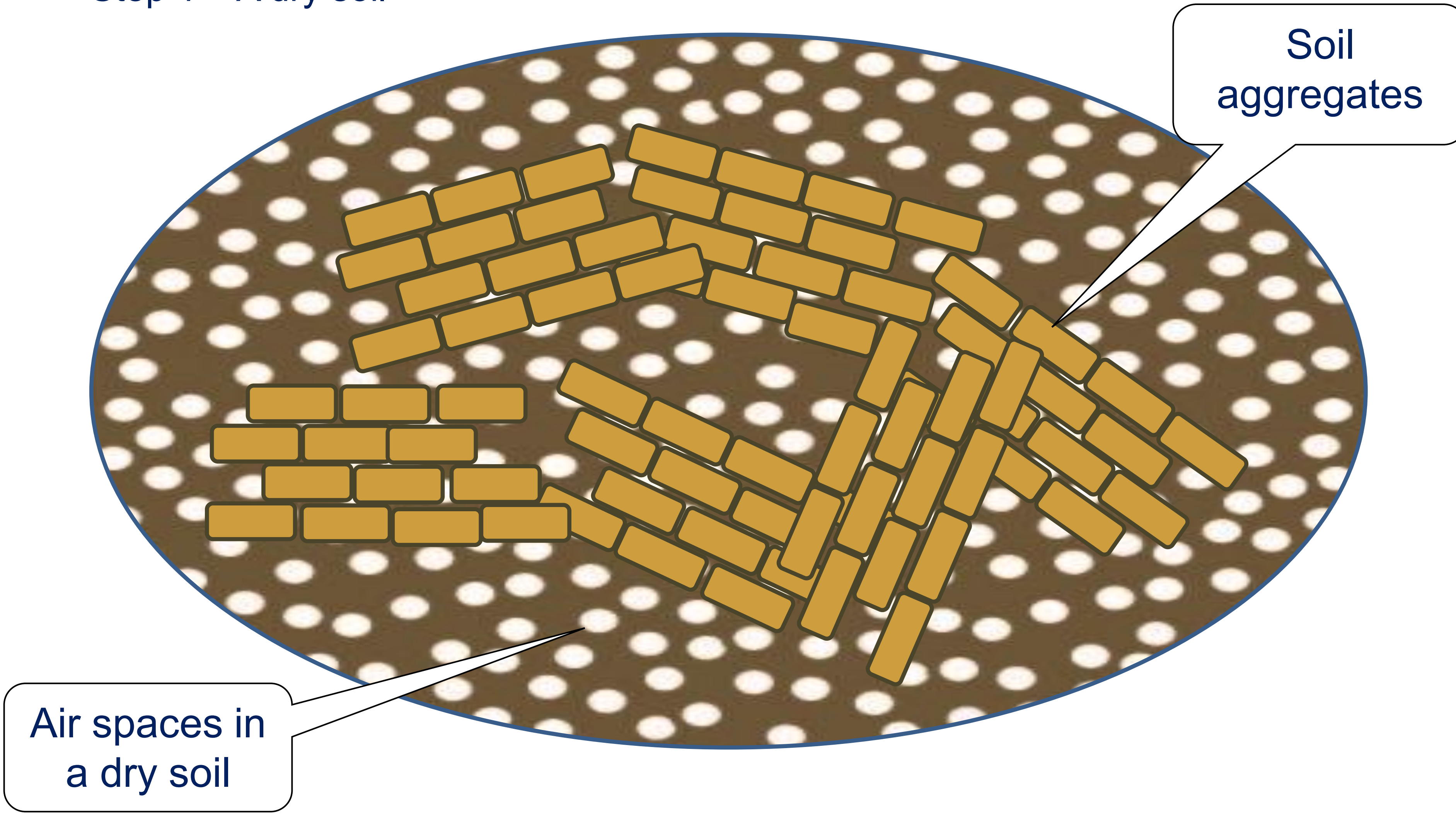
- Strictly speaking the term ‘dispersion’ applies to the manner in which clay platelets are separated as a result of the expansion of the sodium ions between clay platelets. Under this definition only soils that contain some dispersive clay would be ‘dispersive‘.
- While soils with a lot of silt and fine sand are not dispersive, they can act in a similar manner to dispersive soils. Unlike clay particles, these materials carry few electric charges resulting in weak, inter-particle bonds and little cohesion. These soils can liquefy under wet conditions and are easily moved by surface or sub-surface water movement.
- Particles removed in this process would cause turbidity in flowing streams but because fine sand and silt particles are larger than dispersed clay particles, they would more readily settle out in still water.

What is soil slaking and how does it compare to soil dispersion?

- Slaking is the breakdown of soil aggregates into small sub-aggregates when wet rapidly.
- Some soils slake but don’t disperse. Slaking occurs in a range of soil textures and is linked to the desirable process of self-mulching, which occurs in many cracking clay soils (Vertosols). Self-mulching produces a loose surface layer of granular aggregates.
- Some soils are vulnerable to both slaking and dispersion. Slaking is a partner in crime with dispersion. It creates smaller soil aggregates that are more vulnerable to dispersion

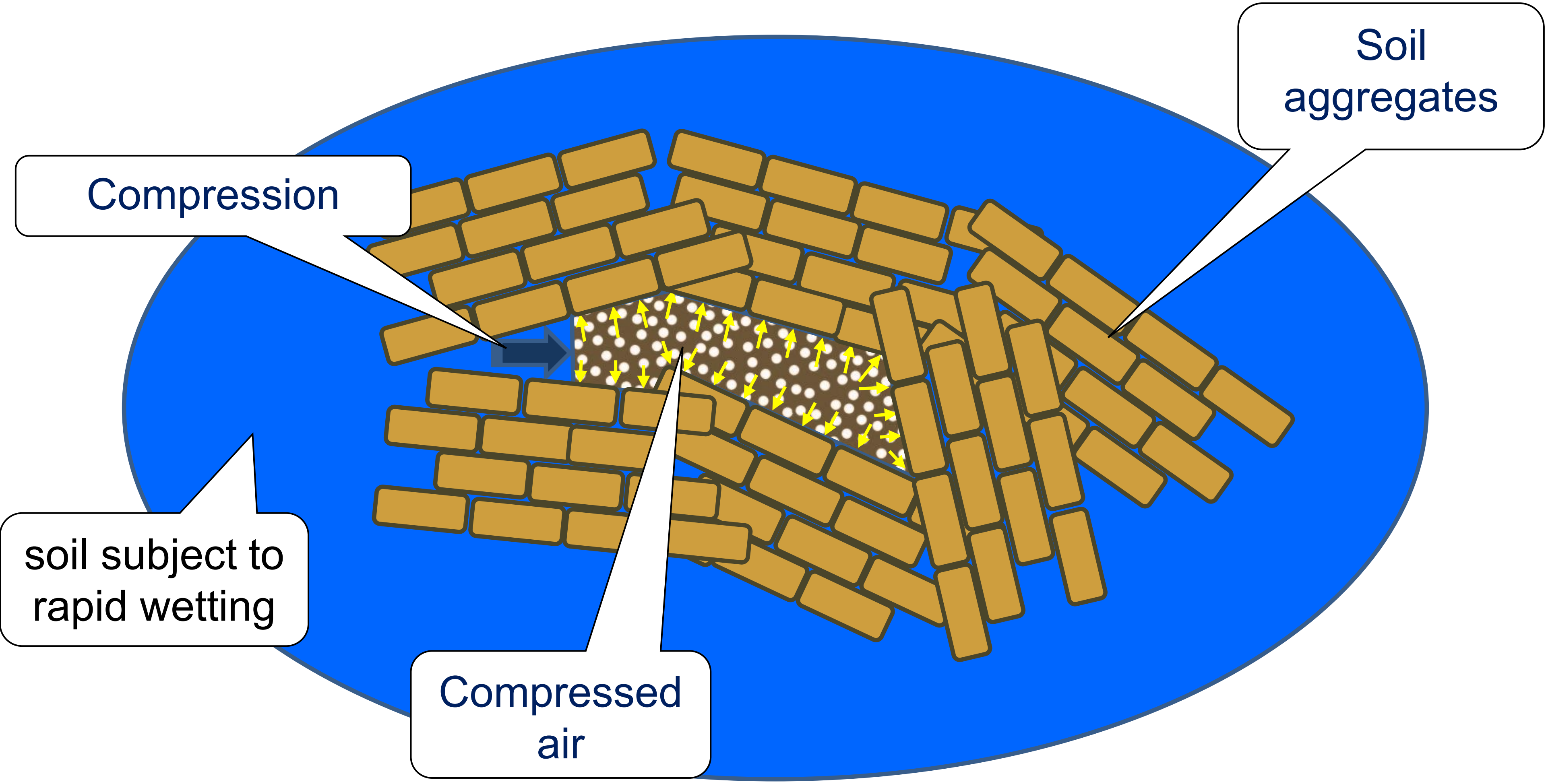
How soils slake

Step 1 – A dry soil



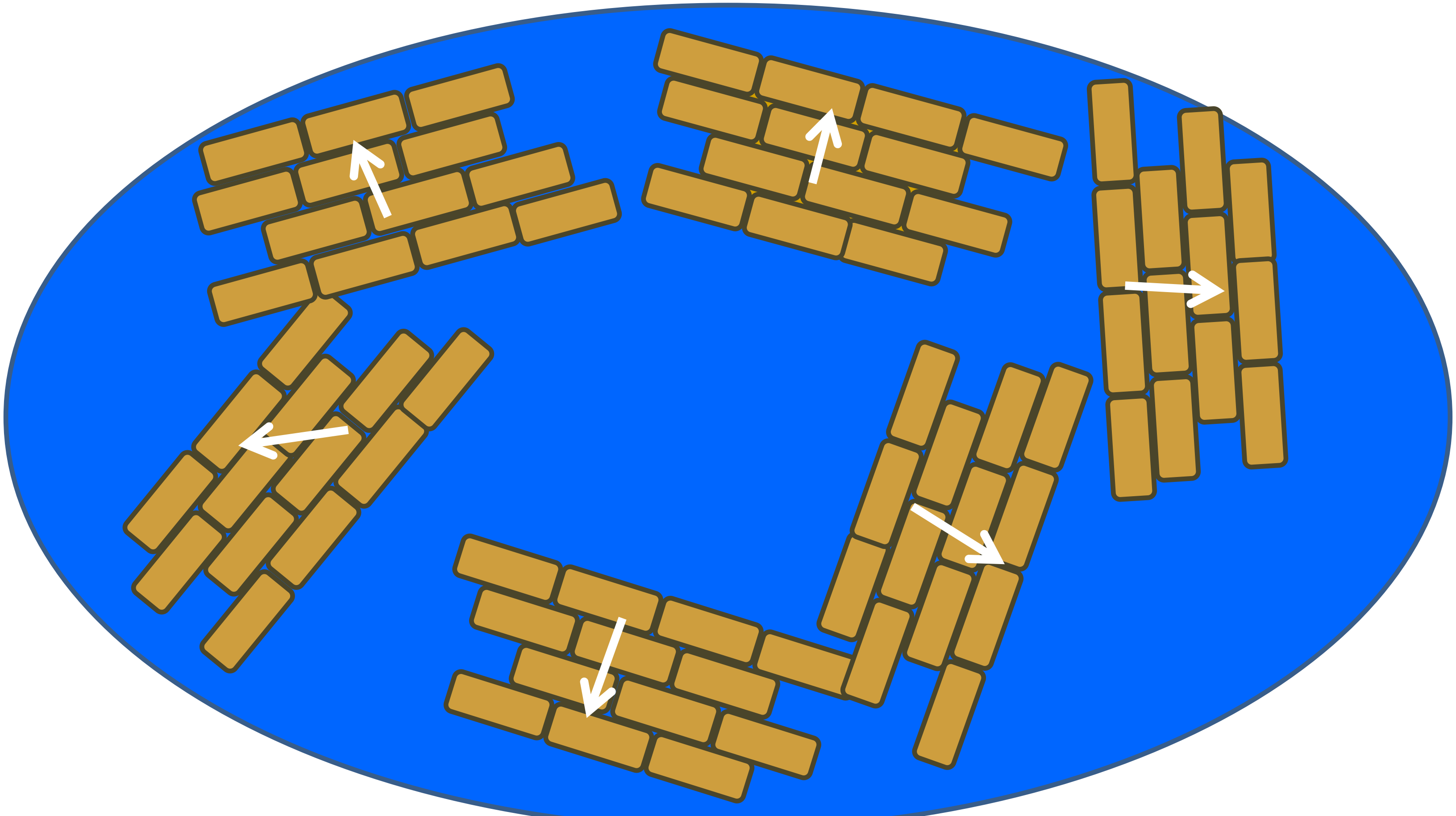
How soils slake

Step 2 – Rapid wetting compresses the air in the pores of the soil.



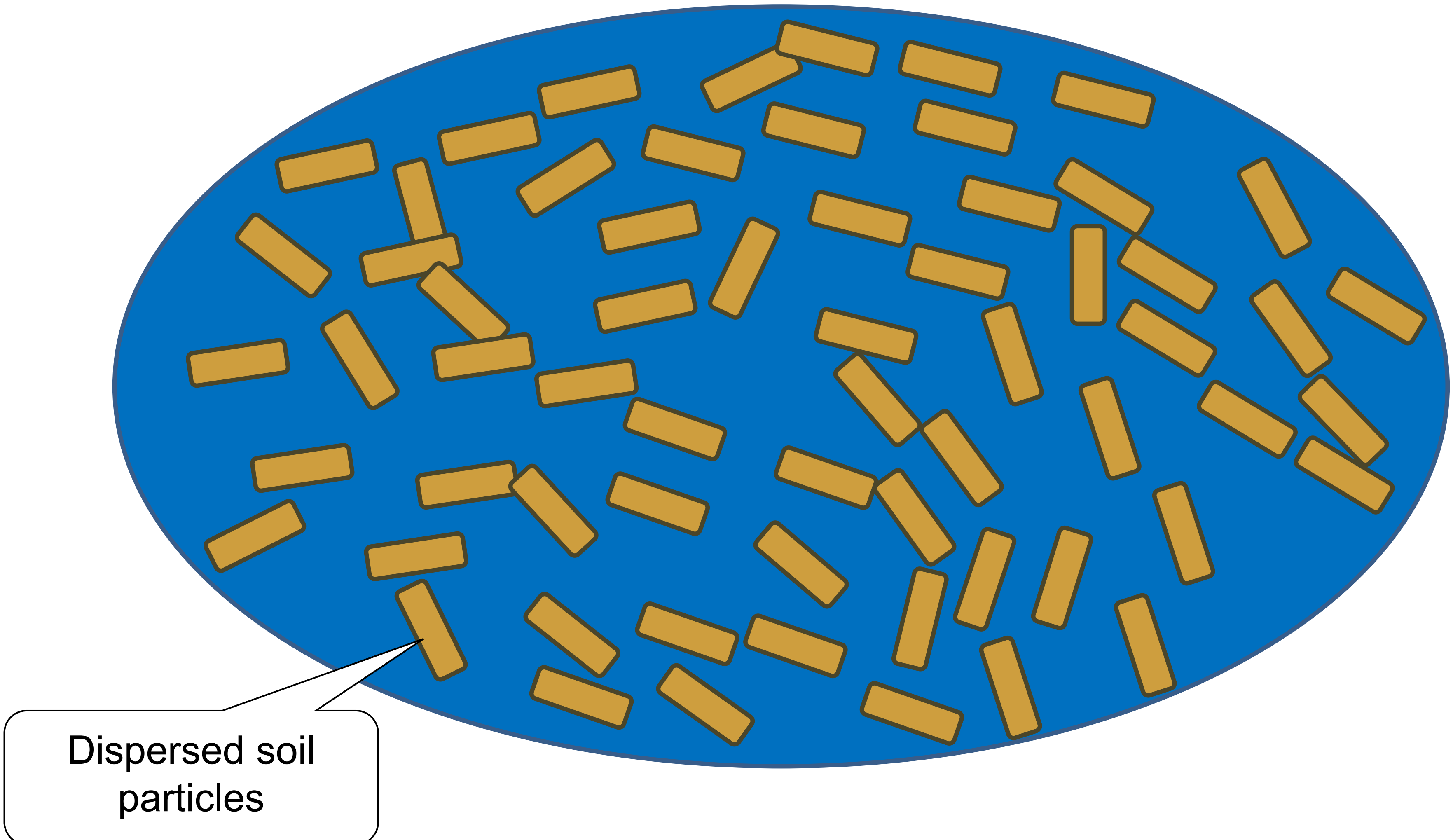
How soils slake

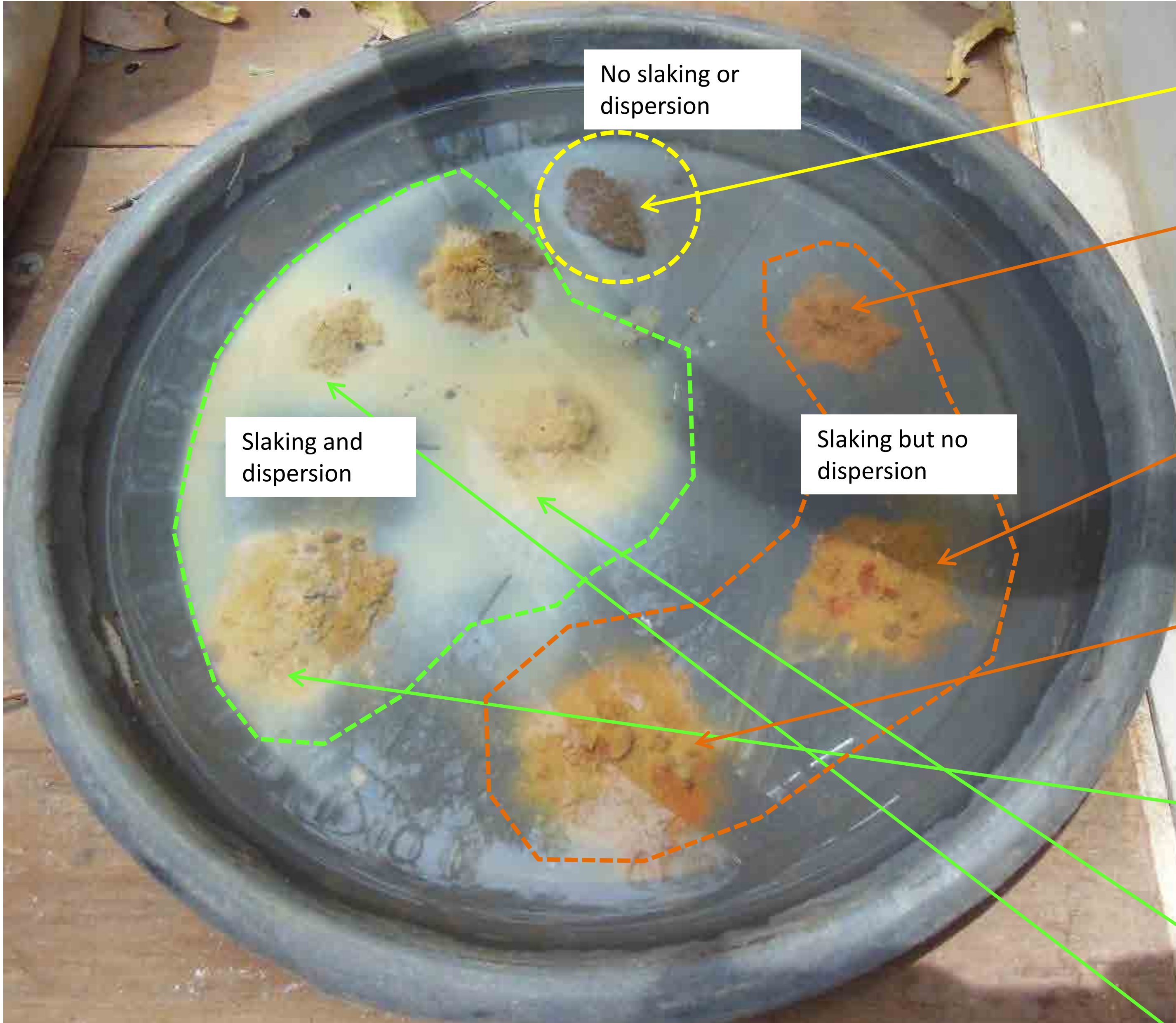
Step 3 – Soil aggregates separated by the explosive force of compressed air



Slaking and dispersion work closely together

- Slaking accelerates dispersion by giving water much faster access to the small aggregates that result from slaking.
- Most dispersive soils will also slake but many soils that slake are not dispersive.





The susceptibility of this brown chromosol to dispersion and slaking varies in different parts of the soil profile (Source: Peter Zund, DSITIA)

What are reactive soils?

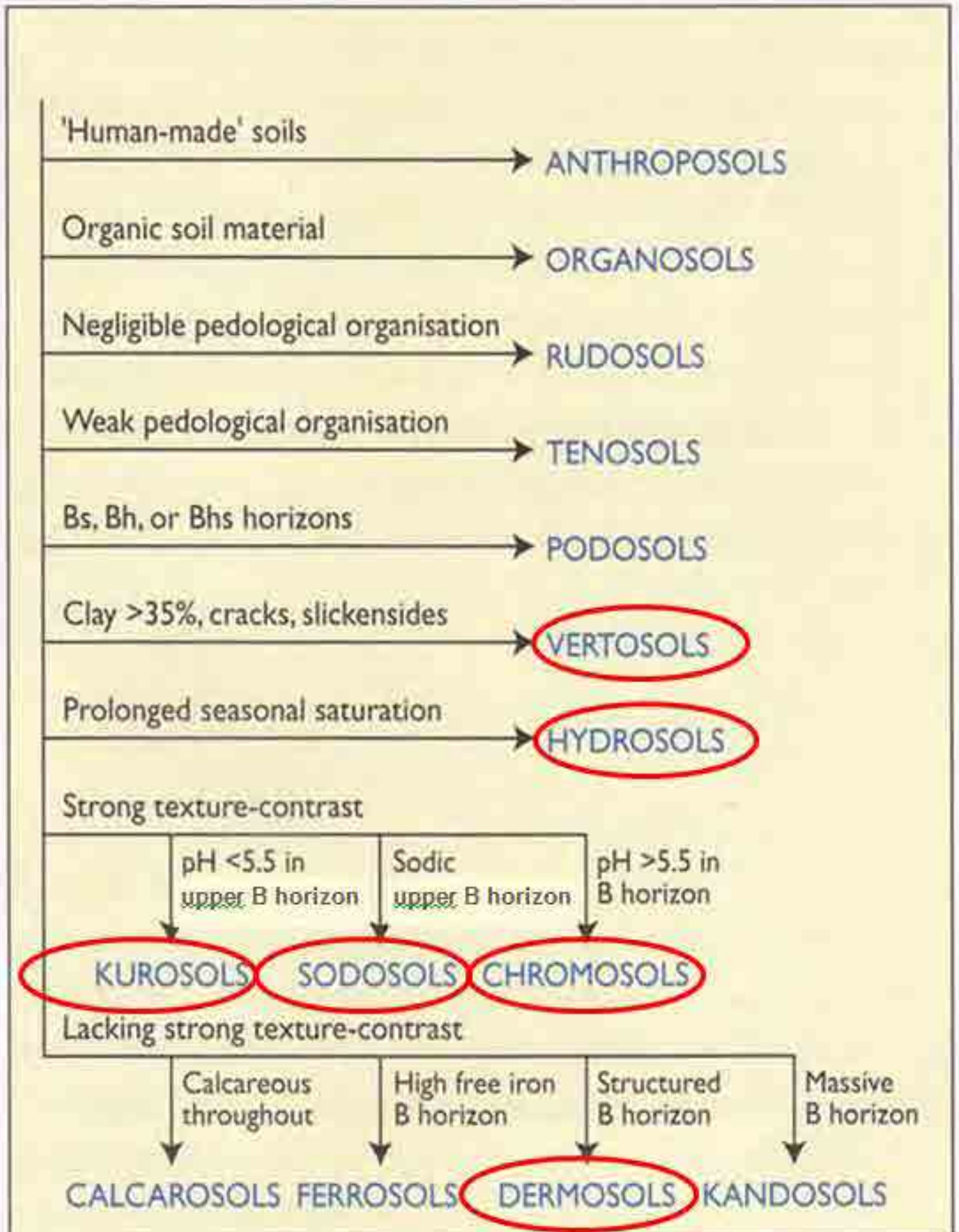
- Soil reactivity is a term used in the construction industry and is not related to dispersion, although some reactive soils are also dispersive.
- Reactive soils contain clay types that shrink and expand depending on soil moisture levels. This movement can damage buildings and the plumbing systems attached to them as well as roads.
- Reactive soils can also be described as being expansive, cohesive or plastic. They have sufficient clay to enable them to be rolled into a thread or moulded into a shape when the soil is moist. They gain considerable strength as they dry out.
- Damage to infrastructure on reactive soils may occur in prolonged droughts, wet seasons or when water pipes around a building are leaking. Large trees close to buildings can cause shrinkage by removing soil moisture.
- Vertosols (cracking clays) are good examples of a reactive soil. They are used extensively for grain growing in Queensland because of their high fertility and moisture holding capacity. Because they are reactive, they create problems for building and road construction.
- The soil on a building block can have variable responses to shrinking or swelling depending on the amount of cut and fill required to level the block. Geotechnical engineers carry out soil tests to determine the reactivity of a soil prior to construction as part of the building planning/approval process. Building regulations specify practices to minimise the adverse impacts of reactive soils.

Understanding dispersive soils
Part A contents ⮌

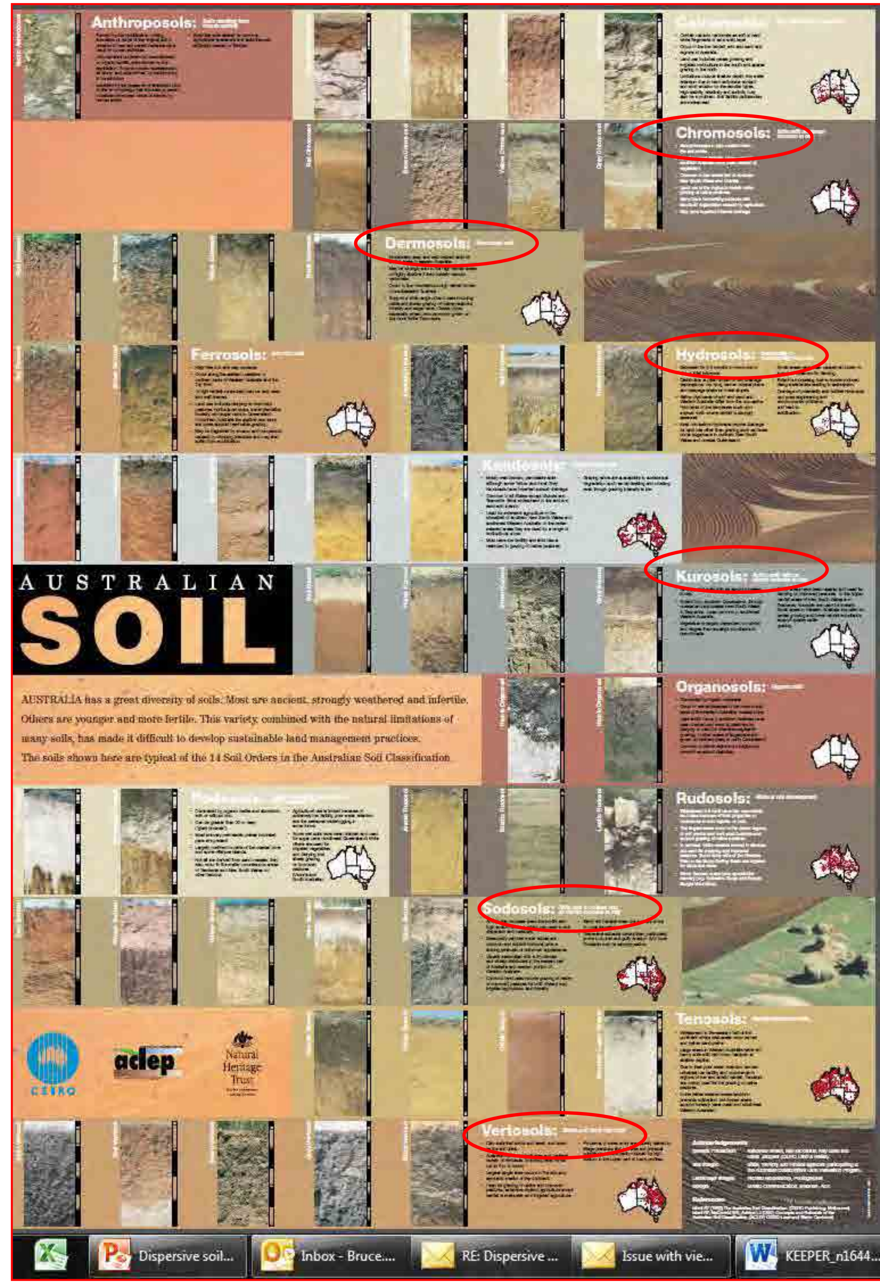
Identification of dispersive soils

Dispersion is most commonly linked with Sodosols. These are texture contrast soils which have an abrupt change in texture from the topsoil to the subsoil and are also referred to as duplex soils.

The soil in this photo has a light textured, sandy or loamy topsoil with an abrupt change to a dispersive clay subsoil.

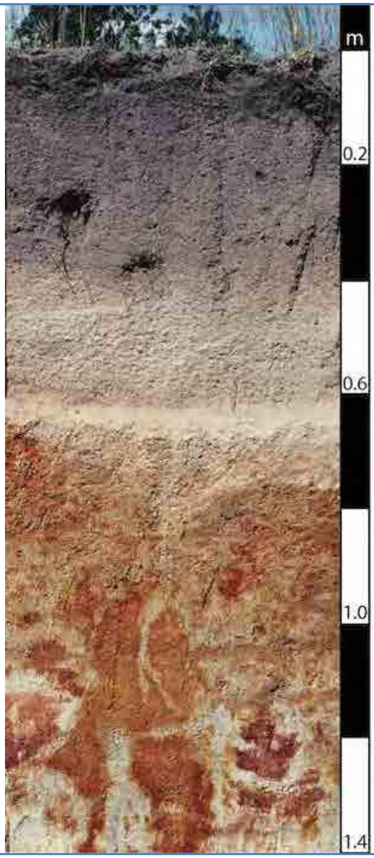


Soil orders that might contain dispersive soils



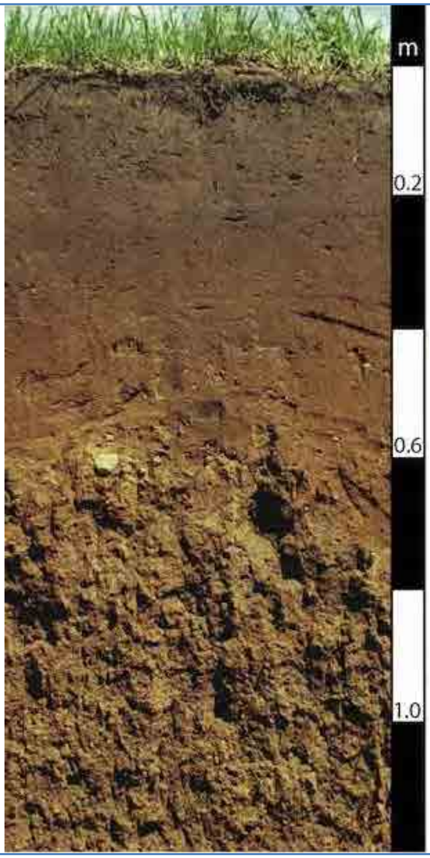
Soil profile type	Distinguishing characteristics	Soil Order	Susceptibility to soil dispersion
Strong texture-contrast (between A and B horizons)	pH < 5.5 in upper B horizon	Kurosol	• surface soil is generally not sodic, • Subsoils may be sodic, but dispersion is not common due to the high acidity (and usually high aluminium). • lower part of subsoil may be dispersive
	Sodic (ESP ≥ 6) in upper B horizon	Sodosol	• surface soil is generally not sodic, but may be erodible especially if loose sand, poorly structured or cleared of vegetation. • upper part of subsoil (B horizon) is sodic and usually dispersive
		Chromosol	• surface soil is generally not sodic, but may be erodible especially if loose sand, poorly structured or cleared of vegetation. • upper part of subsoil (B horizon) is not sodic and therefore not usually dispersive. • lower part of subsoil may be sodic and dispersive.
Lacks strong texture-contrast	Clay soil throughout, with strong cracking (i.e. cracking clay soils)	Vertosol	• may be sodic in both surface soil and subsoil. • dispersion will be influenced by amount of soil salinity • those formed on sedimentary rocks and alluvium from mixed sources are more likely to be sodic and dispersive. • those formed on basalt or alluvium derived from basalt are generally not sodic or dispersive
	Gradational texture profile (clay content increase gradually with depth)	Kandosols	• surface soil is generally not sodic, but may be erodible especially if loose sand, poorly structured or cleared of vegetation. • not commonly sodic and dispersive • potentially sodic and dispersive in the deeper subsoil.
	Structured B horizons; usually gradational texture profile; may be clay soils but without cracking.	Dermosol	• subsoil may be sodic and dispersive • surface soil may also be sodic and dispersive at the surface, but only if it is a clay loam to clay texture.
Wet soils	Prolonged seasonal saturation	Hydrosol	• formed from a range of parent materials, but are confined to poorly drained areas e.g. drainage depressions, low lying coastal plains • may be sodic and dispersive, but do not usually constitute an erosion hazard due to their low lying landscape position.

Provided by Ben Harms



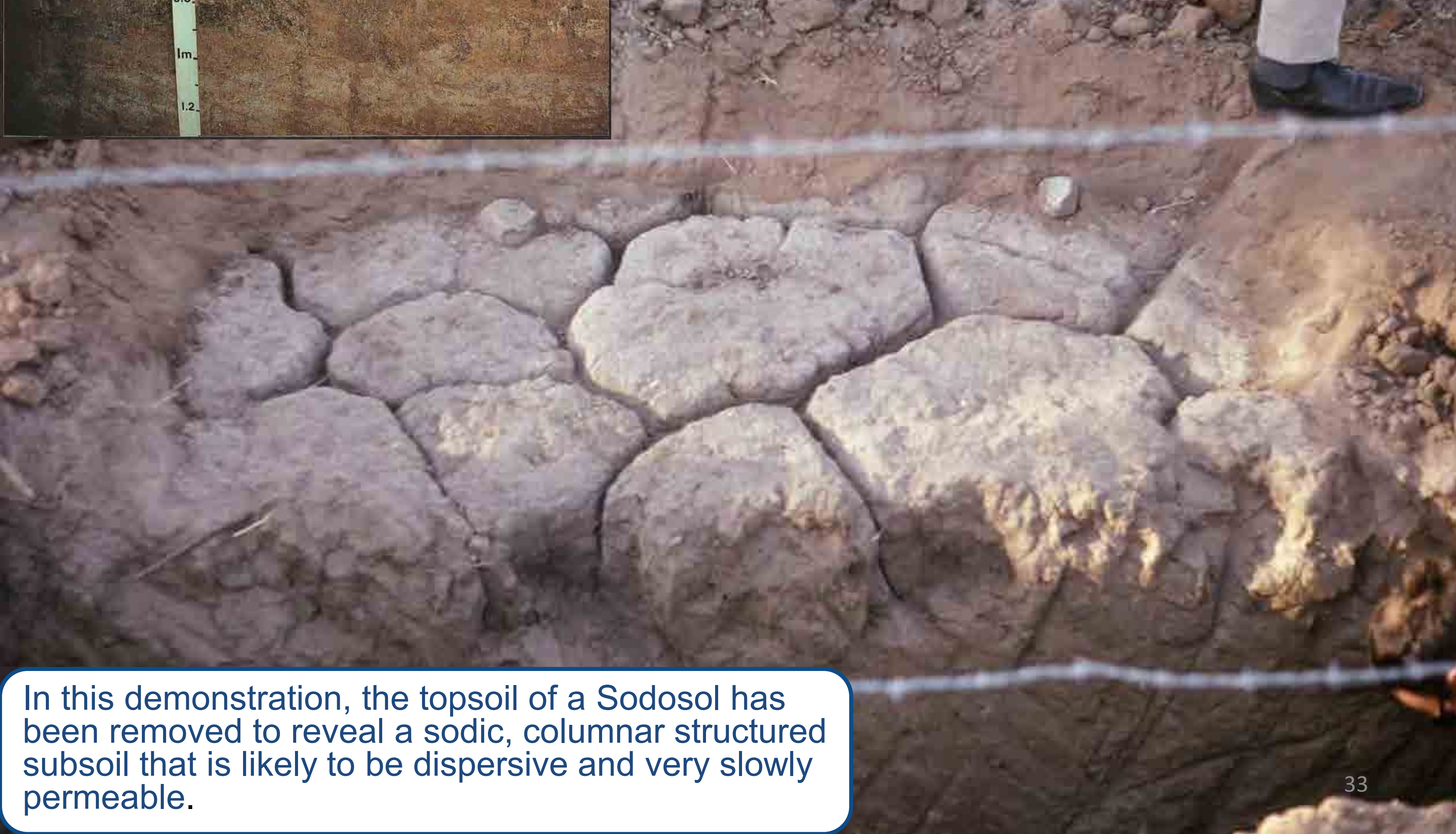
Kurosol

Sodosol

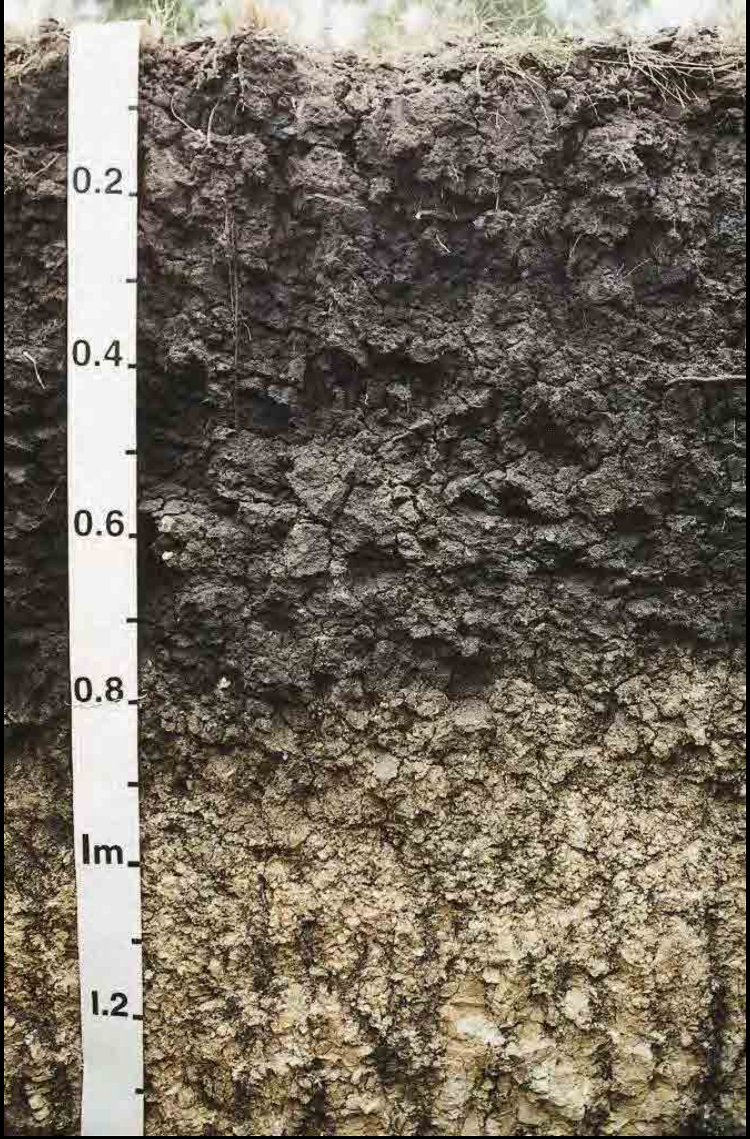


Chromosol

Examples of texture contrast (duplex) soils. The non-dispersive top soil changes abruptly to a dispersive subsoil. Dispersive soils come in many colours. They can be brown, black, grey, yellow or reddish. They sometimes have a bleached A2 horizon.



In this demonstration, the topsoil of a Sodosol has been removed to reveal a sodic, columnar structured subsoil that is likely to be dispersive and very slowly permeable.



Some Vertosols (cracking clays) can be dispersive in both topsoil and subsoil. Many good cropping soils that once supported brigalow vegetation are in this category.

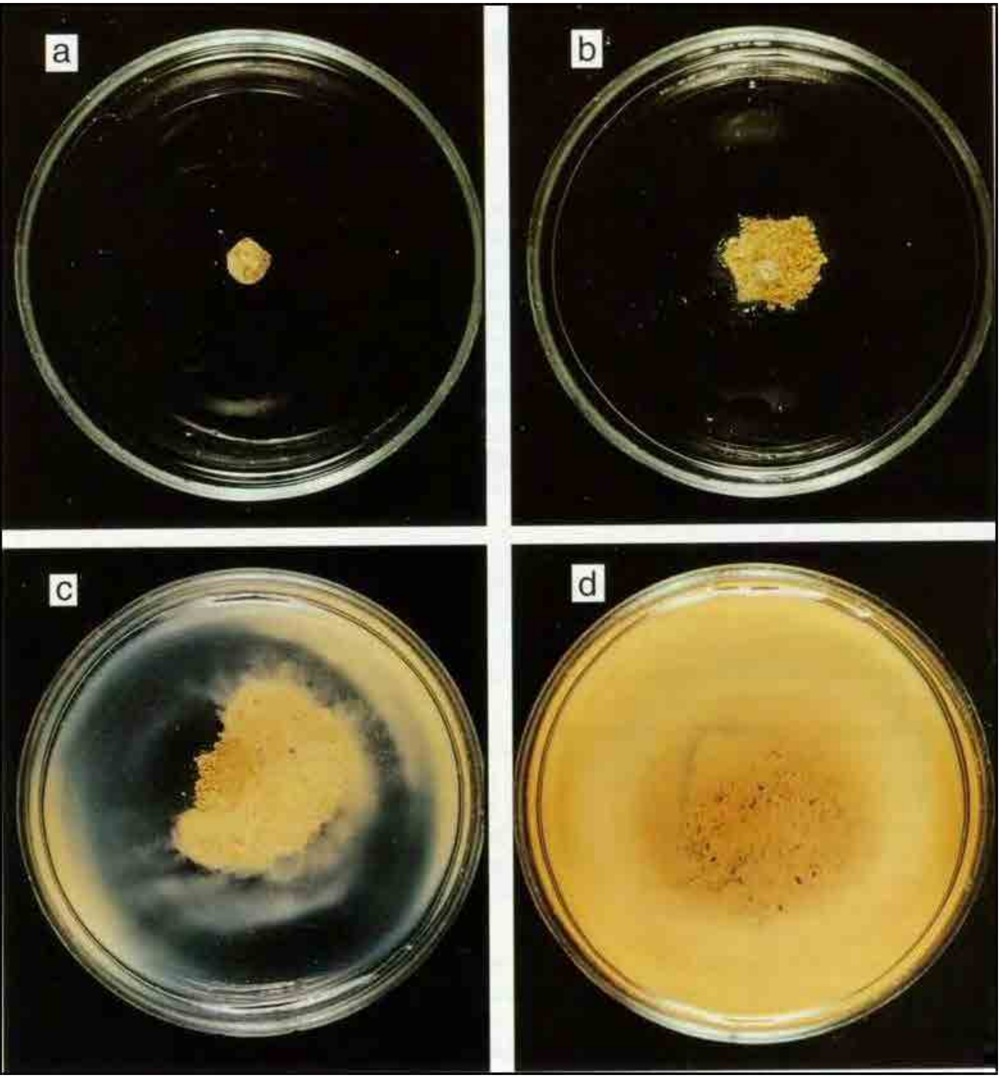
Field indicators for the presence of dispersive soils

Field indicators for the presence of dispersive soils include:

- the Emerson aggregate soil immersion test
- bleached A2 horizon
- columnar structure
- vegetation associations (e.g.bull oak, cypress pine, poplar box, Brigalow).
- poor crop growth
- soil structural problems
- gully and tunnel erosion
- turbid water ponding on the soil surface.

Soil pH of 8.5 is often an indicator of sodic soils. However some acid soils in coastal areas can be sodic and dispersive.
The potential for dispersion to occur will depend on soil salinity, clay content, organic matter, and sesquioxide content.

The Emerson Aggregate Immersion test



In the Emerson Aggregate Immersion test, a small aggregate of soil is observed after it is placed in de-ionised or rain water.

a - No dispersion or slaking

b - The aggregates of a slaking soil can completely collapse when placed in water but there will be little turbidity with the water remaining clear.

c and d - If the soil is dispersive, the clod appears to 'dissolve' and is surrounded by a milky ring or halo.

Source: CSIRO Division of Soils

Laboratory tests – Exchangeable sodium percentage (ESP)

In a laboratory, sodicity is measured by the exchangeable sodium percentage (ESP). Sodic soils may also be dispersive, depending on the soil salinity. ESP provides an indication of soil dispersion. It requires the determination of the cation exchange capacity (CEC) of a soil which is a measure of the negative charge on clay particles.

This value varies with different clay types. The ESP is the proportion of the CEC that is due to sodium in the clay, compared to other cations such as calcium, magnesium and potassium. It is expressed as a percentage and is calculated as follows
ESP = 100 Na+ / CEC (CEC is expressed in the units cmol/kg):

Exchangeable cations	Cmol per kg	Percentage of the total cations
Potassium (K^+)	0.7	2.4
Calcium (Ca^+)	4.6	15.9
Magnesium (Mg^+)	14.7	50.7
Sodium (Na^+)	9	31.0
Total base CEC	29.0	100

In this example, the ESP would be calculated as being 100 * 9/29 = 31.

Interpreting ESP to determine susceptibility to dispersion

Soils are considered sodic when the amount of sodium reaches a level which impacts on soil structure. This value varies with different soils. Typically sodic soils are those with an ESP from 6–14, strongly sodic soils are those with an ESP of 15 or more.

However sodic soils may not always disperse. For example, sandy soils will have a low CEC because of their small amount of clay. However they could have a high ESP because sodium could be well represented in the relatively few cations that are present. Sandy soils are not dispersive but they can act like dispersive soils because they carry few electric charges resulting in weak, inter-particle bonds and little cohesion. Such soils can liquefy under wet conditions and are easily moved by surface or sub-surface water movement.

Saline sodic soils may with a high ESP will not be dispersive because salts in the soil solution can suppress dispersion. If the salt content is lowered by leaching from rainfall or irrigation, the soil could become dispersive. This is why de-ionised water or rain water is used in the immersion test. If saline water is used, dispersion is not likely to occur.

Organic matter levels also need to be taken into account as high levels can help to overcome the effect of sodium in causing dispersion.

Determining the dispersion percentage in a laboratory

One method of determining the dispersion percentage is to determine the ratio of soil material less than 5 microns (0.005mm) after shaking in water compared with the total soil material less than 5 microns as determined by particle size analysis.

Another method is the pinhole laboratory test. It is a direct measurement of dispersion. The assessment involves the passing of water through a one mm diameter hole drilled into a soil sample. For dispersive clays, the water flowing through the sample carries a cloudy coloured suspension of colloids, whereas water running through non-dispersive soils is clear.

This publication contains more information about the pinhole test *Identification and management of dispersive mine spoils* 2004 (C Vacher, R Loch and S Raine), Australian centre for Mining Environmental Research
http://eprints.usq.edu.au/1311/1/Dispersive_spoils_report_final_June2004b.pdf

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Where are our dispersive soils?

Conditions leading to the formation of dispersive soils

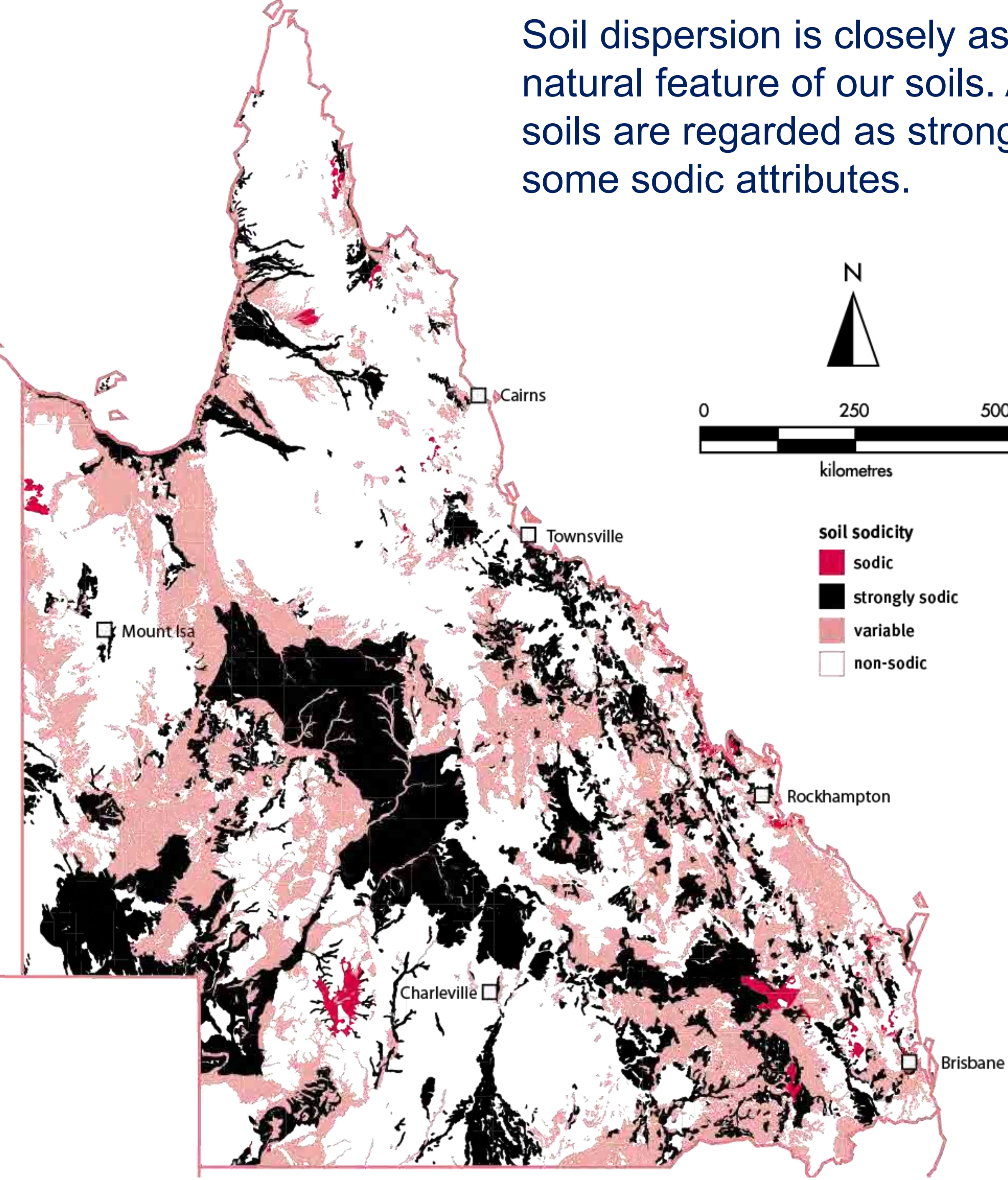
Dispersive soils can form where soil parent material is high in sodium minerals that weather to form clay. Sedimentary parent materials of marine origin are a common source of sodium. All rainfall contains some dissolved salts such as sodium chloride; even in areas distant from the coast. Sodium is a soluble and mobile ion which accumulates in the lower parts of landscapes via lateral movement of groundwater.

Irrigation water containing a high proportion of sodium can lead to sodicity and problems associated with soil dispersion.

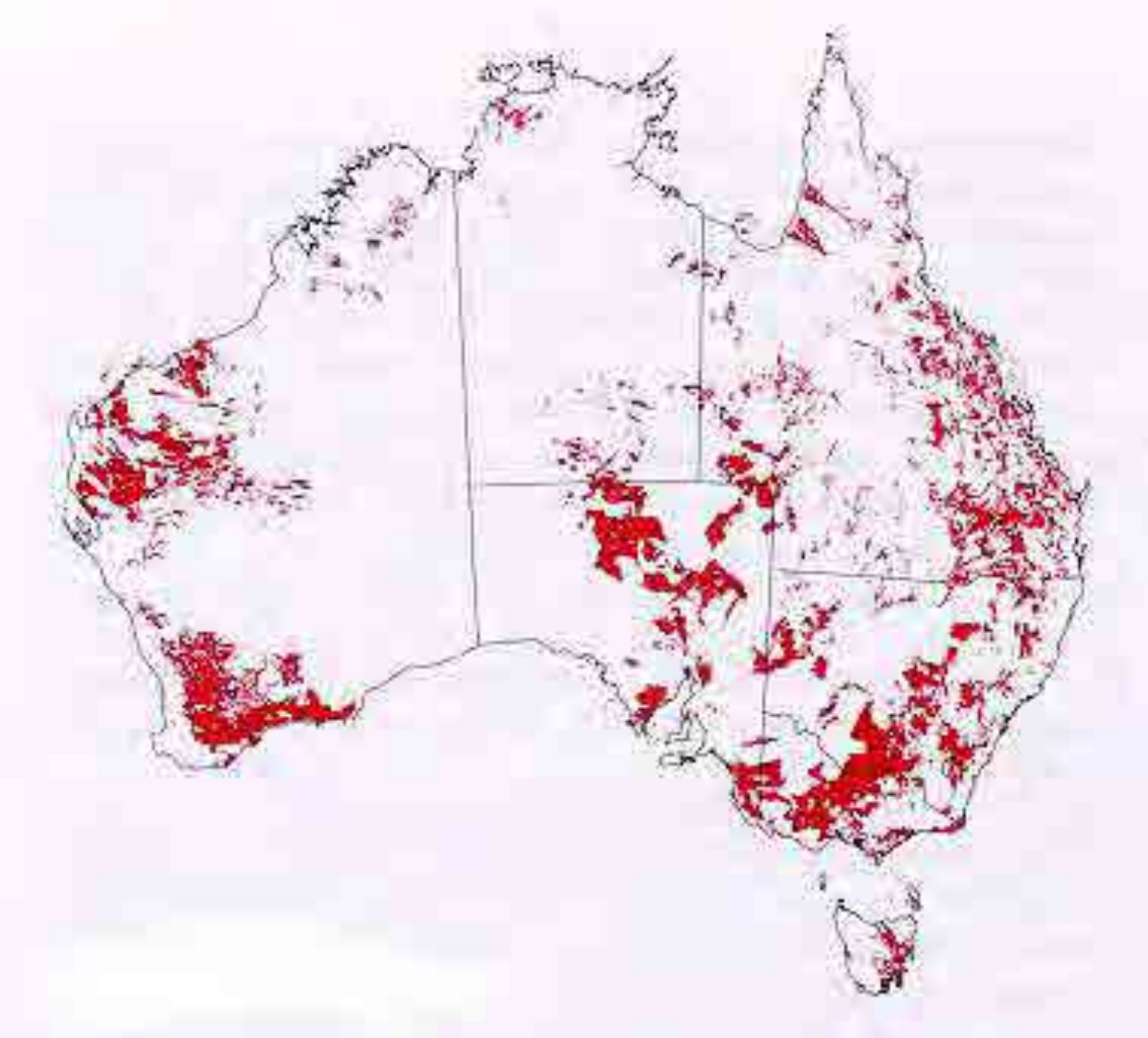
Salinity is an undesirable soil property but a certain level of salts prevents soils from dispersing. When the electrical conductivity of a soil is reduced by the leaching of salts out of the soil profile, it can become dispersive. Salts can be removed when:

- rain falls on saline subsoils that have been exposed as a result of construction activities
- the rate of infiltration of rainfall into the soil increases as a result of a change in land use from vegetation to clearing
- good quality irrigation water, in excess of plant requirements, is applied.

Soil dispersion is closely associated with sodicity which is a natural feature of our soils. Around 25% of Queensland soils are regarded as strongly sodic and another 20% have some sodic attributes.



Source: *Queensland salinity management handbook* (map originally sourced from CSIRO)



Distribution of Sodosols in Australia

(Source: *Concepts and rationale of the Australian Soil Classification*, Isbell et al. 1998)

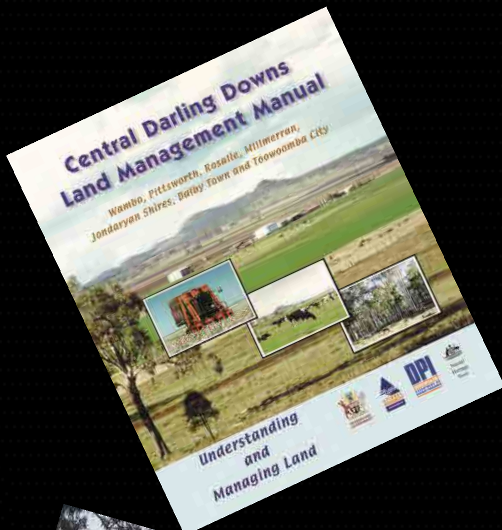
Where are dispersive soils in Queensland? – sources of information

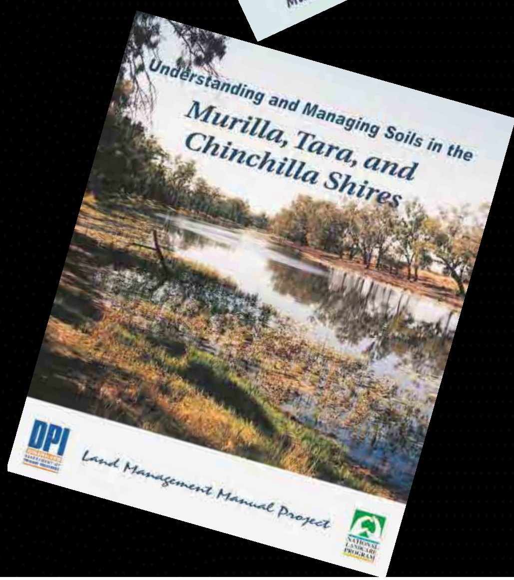
- Land management field manuals – refer to the next slide

- See the *Soil management* section on the Queensland government website http://www.qld.gov.au/environment/land/soil/
- *Soils information for Queensland*. A presentation to an ASSSI training workshop in 2009. It includes information on what soils data is available and how to access soils reports, maps and digital spatial data

http://www.soilscienceaustralia.com.au/images/stories/qld/refresher/ASSSI_QLD_training_course_2009_brisbane.pdf

Land Management Field Manuals provide useful information to assist with identifying dispersive soils





LEYBURN

Common soil in LRAs: 4a, 9a

Associated soil in LRAs: 3a, 11a, 12a and 14a.

Brief description

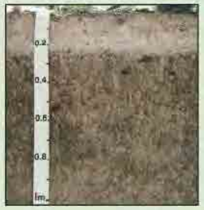
Leyburn is a deep (100-150 cm) texture contrast soil with a shallow, hardsetting surface, underlain by a bleached A2 and a yellowish brown to brown clay subsoil (includes the soils *Gully* and *Wilkie*).

Landform and distribution

- flat plains and very gently sloping (<1%) valley floors of mixed sandstone and traprock alluvium.

Vegetation

- poplar box grassy woodland with wilga; or
- poplar box, gum topped box open forest.
- mostly cleared.
- Regional Ecosystem 11.3.2/11.3.26



Example soil profile description

Depth (cm)	Description
0-5	dark yellowish brown; fine sandy clay loam; massive; clear to:
5-20	brown; bleached when dry; clay loam; massive; abrupt to:
20-60	yellowish brown; medium clay; moderate coarse angular blocky or prismatic structure; gradual to:
60-110	brown; medium clay; weak to moderate coarse prismatic structure.

Australian Soil Classification: Eutrophic, Subnatric, Brown Sodosol

General soil features

- texture contrast soil with a sharp change between the surface and the subsoil.
- *surface soil*: hardsetting, loamy sand to clay loams underlain by a bleached A2 to 10-40 cm. Occasional gravel. Slightly acid to neutral (pH 6.0-7.0).
- *subsoil*: yellowish brown and brown, coarse blocky or columnar structured impermeable clays. Neutral to strongly alkaline (pH 7.0-8.5). Strongly sodic from 50 cm and highly saline from 50-90cm.
- PAWC is low (50 mm).
- responds to N, P and Cu.

LEYBURN

Land use limitations

- moderately fertile soil with low PAWC and shallow effective rooting depth due to sodic and saline subsoils.
- surface structure deteriorates with cultivation and forms a hard surface crust after heavy rain.
- workability difficult due to hardsetting surface soil.
- susceptible to wind and water erosion if surface soil is unprotected.
- subsoils have a high bulk density.
- seasonal waterlogging due to impermeable subsoils.
- very abrasive on tines and other cultivation equipment if worked dry.
- sodic and relatively impermeable subsoils susceptible to gullying if exposed.

Land use suitability

This soil is suited to grazing native and sown pastures only.

- suitable sown pasture species include: Katambora Rhodes grass, creeping bluegrass, purple pigeon grass, buffel grass, premier digit grass, medics and subclovers.
- key native grasses include: Queensland and pitted bluegrass.

Best management practices

Cropping

- not recommended.

Vegetation

- conservation status of remnant vegetation is *of concern* (11.3.2)
- conservation status of remnant vegetation is currently *not of concern* (11.3.26).
- planning guidelines and restrictions apply to clearing and land development.

Grazing

- restrict grazing to retain pasture cover (above 30% basal cover) to ensure more desirable species are not grazed out and to prevent scalds forming.
- strategically locate watering points to avoid areas of overgrazing, use centrally located watering points (1 watering point / 200ha) - scalding may become a problem where there are insufficient or badly located watering points.
- recommend species suited for crusting soils and low to moderate fertility levels.
- strategic grazing and spelling is required to allow seed to set and pastures to bulk up.
- fertilising with phosphorus and sulphur will improve pasture production.
- adjust stocking rates to suit seasonal conditions.
- stocking rates *native pasture* 1 AE/3.0-3.5 ha
  sown pasture 1 AE/2.5 ha

Land Management Field Manuals were produced for most cropping districts in Queensland in the 1980s and 1990s. They are all listed in the section on 'Further Information' and can be downloaded from the EHP (Queensland Department of Environment and Heritage Protection) Library Catalogue

An example of the broad scale mapping in a land management field manual that provide an indication of where dispersive soils might be found

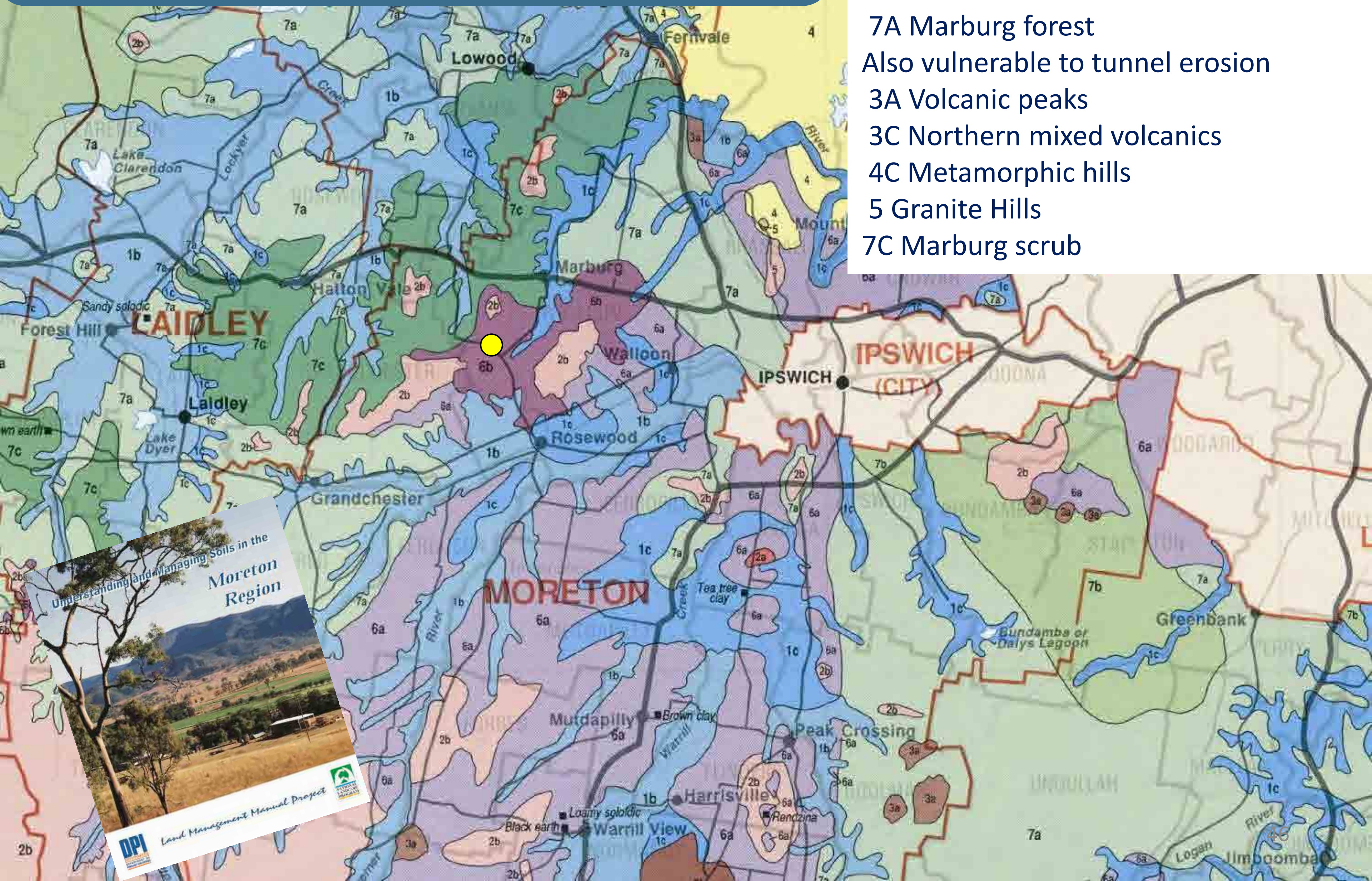
Most vulnerable to tunnel erosion

- 1C Mixed alluvials
- 6A Forest walloons
- 6B Scrub walloons
- 7A Marburg forest

Also vulnerable to tunnel erosion

- 3A Volcanic peaks
- 3C Northern mixed volcanics
- 4C Metamorphic hills
- 5 Granite Hills

7C Marburg scrub



What **impacts** do dispersive soils have?

Impacts of dispersive soils

- They are very susceptible to most forms of soil erosion, including raindrop impact, gully, tunnel, and streambank erosion. Wind erosion can also occur after a bare soil surface has been ‘flattened’ by raindrop impact.
- They are vulnerable to serious erosion damage in infrastructure like roads, tracks, dams, pipelines, cables and power line corridors.
- They have natural features which limit agricultural productivity (refer to the next slide).
- They are responsible for most of the turbidity in water.

For more information on the impacts of dispersive soils, check *Part B – Case studies.*

Impacts of dispersive soils – affects on agricultural land

Dispersion can have significant impacts on soil productivity:

- As well as their susceptibility to soil erosion, dispersive soils are prone to hard setting of the soil surface.
- They can have low fertility and poor soil structure.
- Dispersed clay particles act as a filler and binder in soil. This increases the size and density of aggregates leading to cloddy seedbeds.
- Dispersed clay is also easily mobilised by water and can block soil pores. It can lead to hard setting of surface soils including the formation of scalds in grazing lands.
- Hard setting leads to reduced water entry and movement, increasing runoff and erosion, and the crusting of seedbeds in cropping land.
- Waterlogging can also result. With less leaching, salts can accumulate in the soil over time leading to the development of salinity.

However some dispersive soils, such as those in the Brigalow Belt, do not have all of the above restrictions and can be quite suitable for cropping.

Impacts of dispersive soils – affects on infrastructure

These case studies in *Understanding dispersive soils Part B – Case studies* contain information about the impact of dispersive soils on a range of infrastructure projects

- mining
- roads and tracks
- batter stabilisation
- buildings
- dams
- trenches for pipes and cables.

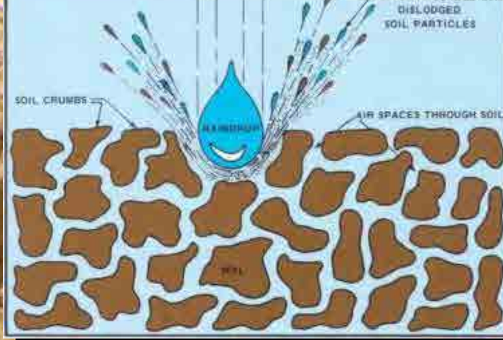
What impacts do dispersive soils have? ⮌

Erosion and dispersive soils

- Raindrop or sheet erosion
- Gully erosion
- Tunnel erosion
- Stream bank

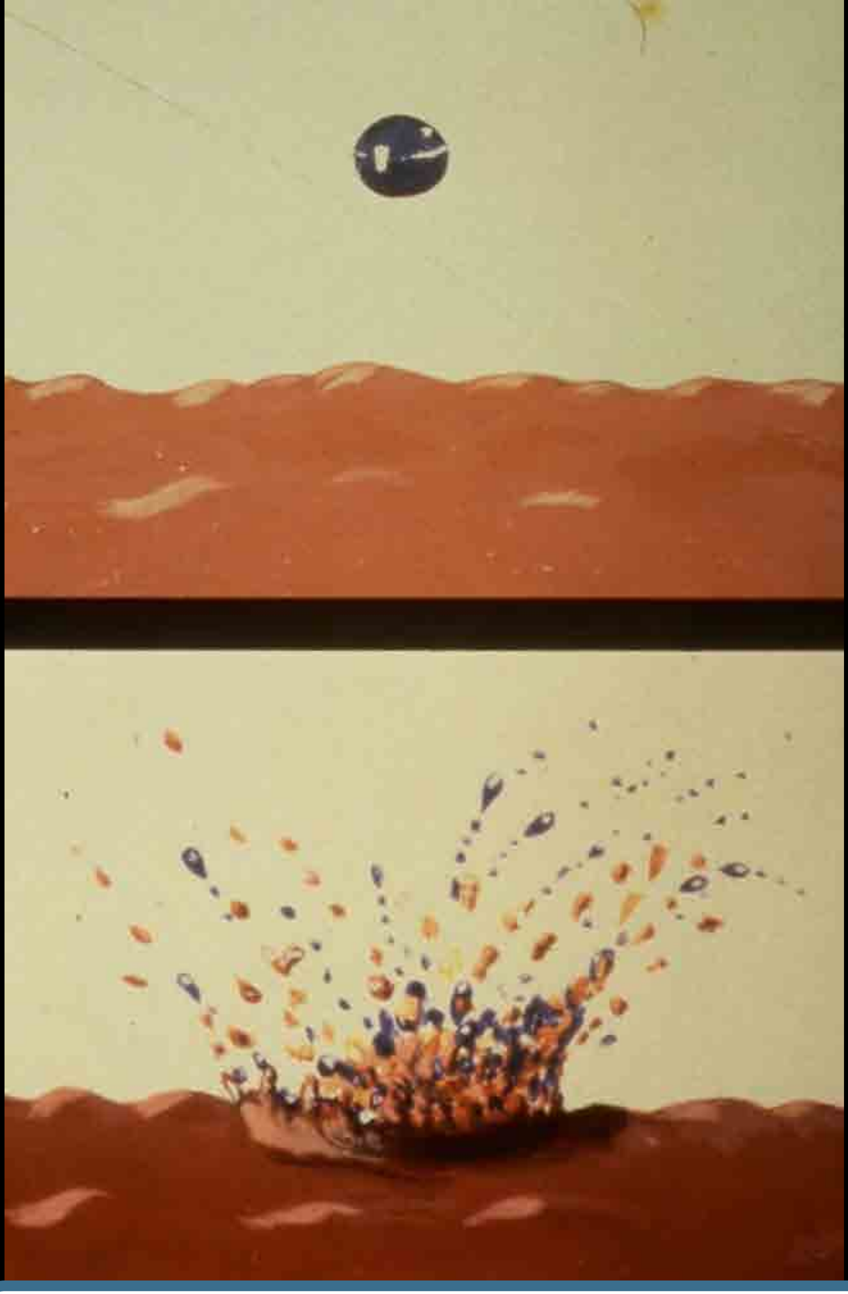
Erosion and dispersive soils ⮌

Raindrop impact and dispersive soils



Disturbed, dispersive soils are especially vulnerable to erosion by raindrop impact. They usually have no surface protection (except for the odd stone as shown above) and rain leaches salt out of the soil making it more dispersive.

Erosion of dispersive subsoils in the Burdekin Catchment
Source: ASSSI

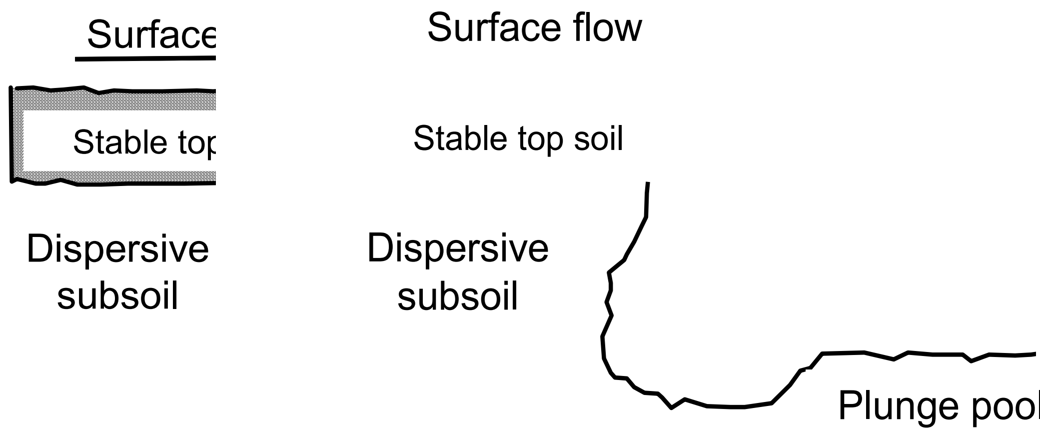


Bombs away!

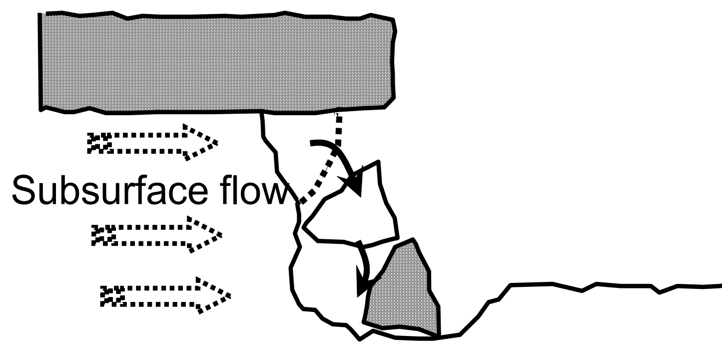
Erosion and dispersive soils ⮌

Gully erosion and dispersive soils

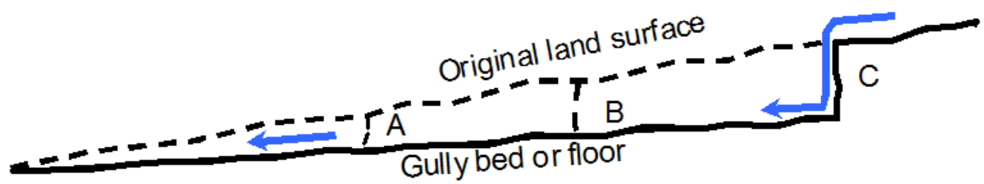
Gully head extension in dispersive soils



Expansion by surface runoff



Expansion by sub-surface flows

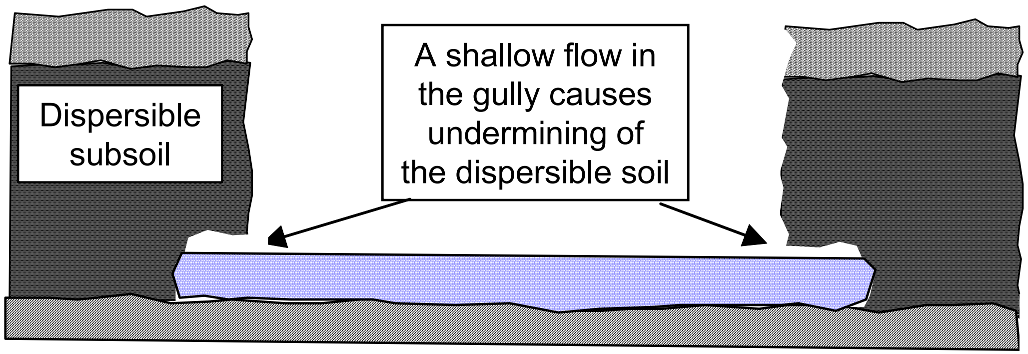


A gully head retreating up a drainage line. As the head advances, the height of the head and gully walls will increase while the slope in the gully bed will be less than the original land surface.

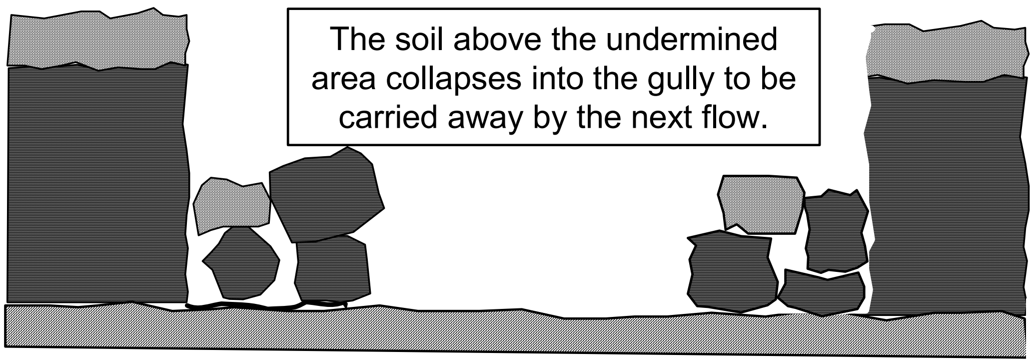
A gully advancing in a ‘steps’ and ‘stairs’ pattern in a dispersive soil

Sidewall expansion of gully heads in dispersive soils

Gully wall expansion by undercutting



Shallow flows are a common cause of significant gully expansion in dispersive soils by undercutting and slumping.



Undercutting of the toe slope on the side of a gully in the Bremer Catchment.

Most gullies have far more capacity than they need to accommodate the runoff they receive (including the Grand Canyon in the USA).

Dispersible soils produce ‘U-shaped’ gullies with vertical sides

Ivory Ck (SEQ Catchments photo)

Gully erosion in dispersive soils

Mornish, west of Rockhampton

The Deebing Ck area, close to the Bremer river

North Queensland
Photo: Isha Shegboer

Gully erosion in dispersive soils

Near Wuruma Dam, 40km south west of Monto

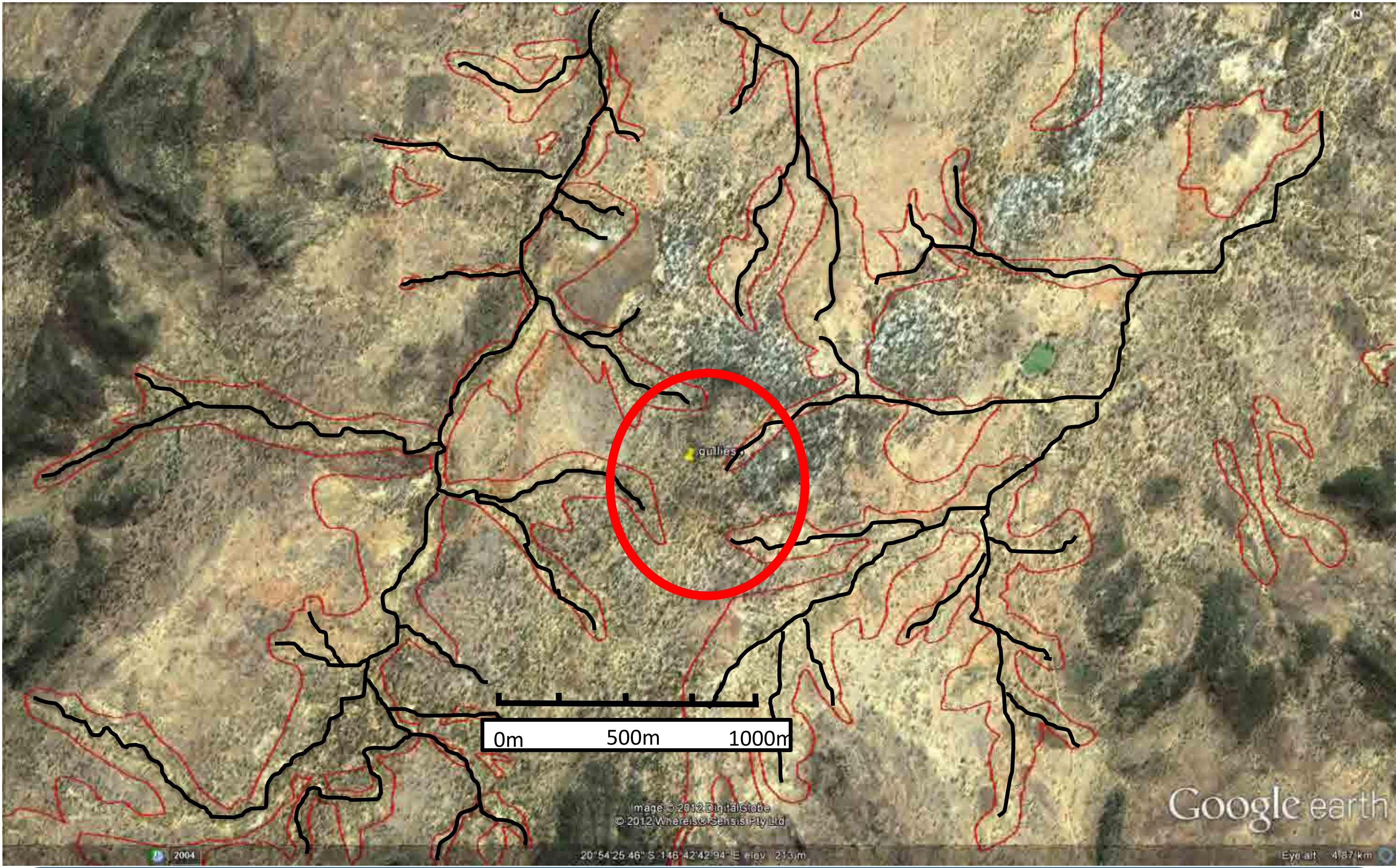
Innamincka on the South Australian–Queensland border is surrounded by actively growing gullies in highly dispersive soils . It has a desert climate with an annual rainfall of only 210 mm.

The Innamincka cemetery threatened by gullies

Soil loss from raindrop impact in the floor of a gully in the Knapps Ck area, Beaudesert

Gully erosion resulting from a failed diversion bank on a dispersive soil near Meandarra (150 km west of Dalby)

A communications cable exposed by erosion of dispersive soil in the Lockyer Valley



Extensive gullying in dispersive soils in the Burdekin catchment. Note how the gully heads in the circled area have almost retreated to the tops of their catchment. This indicates that there are a number of factors affecting gully expansion besides the manner in which the area above the gully head is managed.

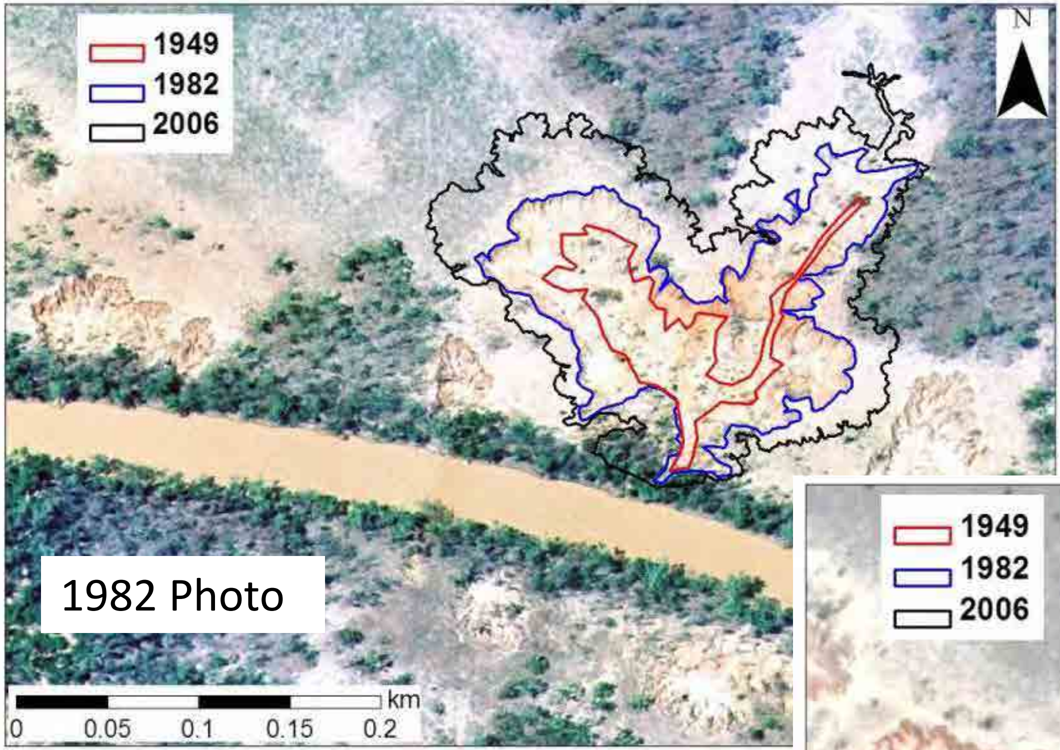

Two advancing gully heads about to meet up in the Burdekin catchment
PHOTO: Bob Shepherd
DAFF Charters Towers

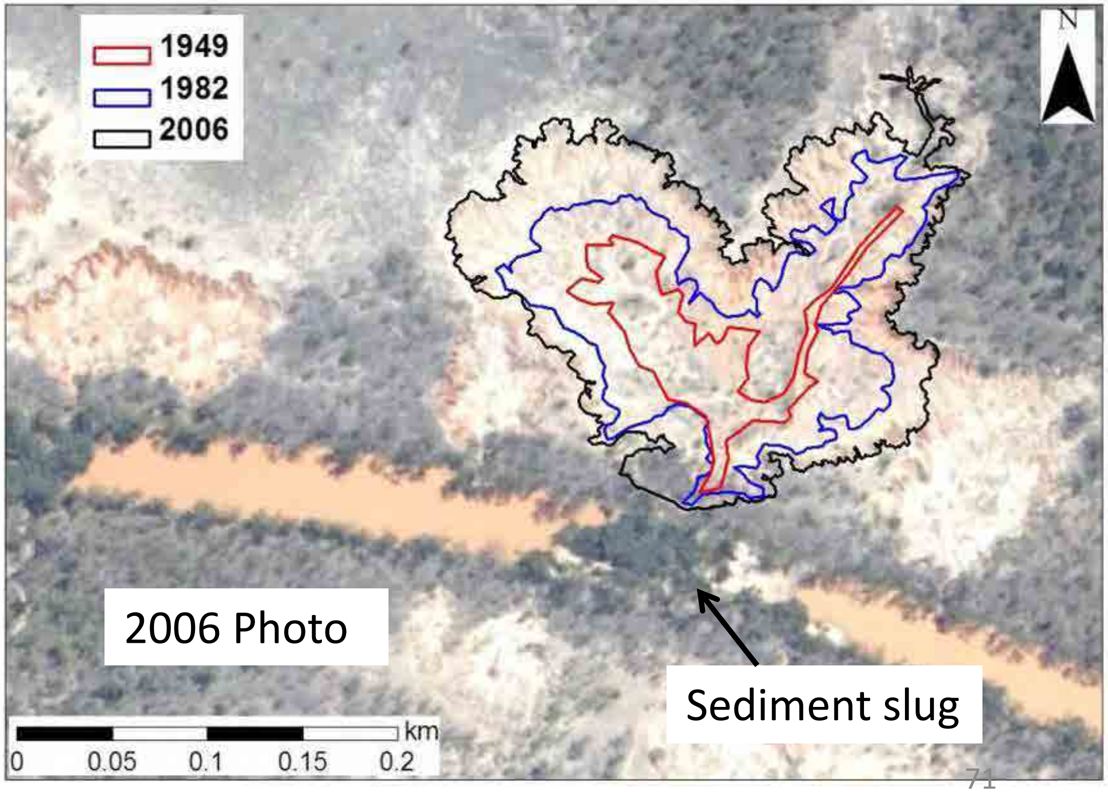
Alluvial gully erosion into dispersive floodplain soils

Source: Dr. Jeff Shellberg, Australian Rivers Institute

- occurs along floodplains of creeks and rivers where soils are dispersive clays or silt
- the gullies erode perpendicular into adjacent floodplains
- initiated when rainfall/runoff from floodplains enters an incised stream
- stock pads, vehicle tracks, and diversion banks can initiate the gully
- the gully can be as wide as it is long due to lack of confinement
- a highly connected source of sediment to rivers and high sediment yields
- a complex suite of erosional drivers and resistors

Alluvial Gully Growth Over Time





Source: Dr. Jeff Shellberg, Australian Rivers Institute, Griffith University

Alluvial gully erosion can consume large areas of floodplain landscape and riparian zones across northern Australia

Source: Dr. Jeff Shellberg, Australian Rivers Institute, Griffith University

Sources of information on alluvial gully erosion

Shellberg, J.G., Brooks, A.P., 2013. Alluvial Gully Prevention and Rehabilitation Options for Reducing Sediment Loads in the Normanby Catchment and Northern Australia. Griffith University, Australian Rivers Institute, Final Report for the Australian Government's Caring for our Country - Reef Rescue Initiative, 312pp. http://www.capeyorkwaterquality.info

Brooks, A.P., Shellberg, J.G., Spencer, J. and Knight, J., 2009. *Alluvial gully erosion: an example from the Mitchell fluvial megafan, Queensland, Australia*. Earth Surface Processes and Landforms, 34: 1951-1969, + 2010. Erratum. Earth Surface Processes and Landforms, 35: 242–245.

Shellberg, J.G., Brooks, A.P., Spencer, J. and Ward, D., 2012. *The hydrogeomorphic influences on alluvial gully erosion along the Mitchell River fluvial megafan, northern Australia. Hydrological Processes.* DOI: 10.1002/hyp.9240.

Current Queensland Government fact sheet on gully erosion (L81)

http://www.nrm.qld.gov.au/factsheets/pdf/land/l81.pdf

Other sources of information on gully erosion

- Gully erosion control – check the case study in Part B
- Catchments and Creeks web site
  http://www.catchmentsandcreeks.com.au/

[Erosion and dispersive soils ⮌]

Tunnel erosion and dispersive soils

Tunnel erosion in the Samford district west of Brisbane

A large sinkhole in the Bundaberg district

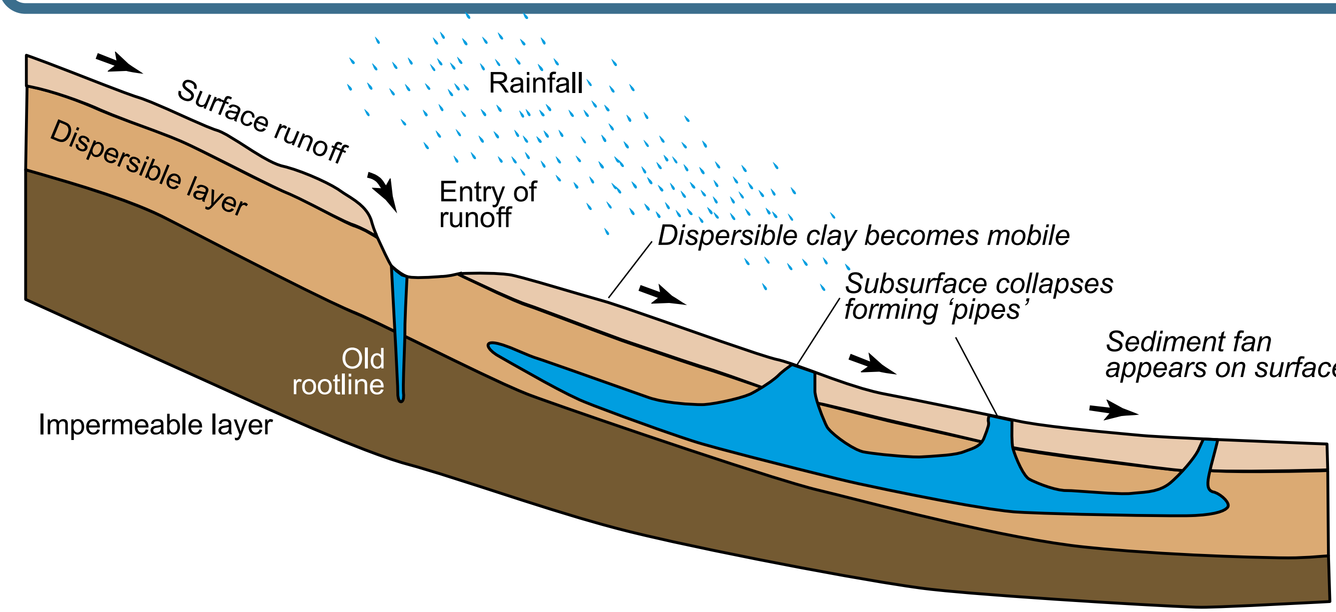
…and you thought you had a bad day!

A photo from somewhere in Southern Australia

Factors contributing to tunnel erosion

- A soil that is easily detached and transported by water flow through the soil. This could be a dispersive clay or a soil with high levels of silt and fine sand
- A head of water to provide a potential for water flow through the soil (any structure that ponds water)
- A system of cracks or pores that provide a relatively rapid flow path through the body of the soil
- Tunnelling can occur in paddocks, in and around gullies or whenever dispersive soils are used for construction purposes – roads, dams, mine rehabilitation.

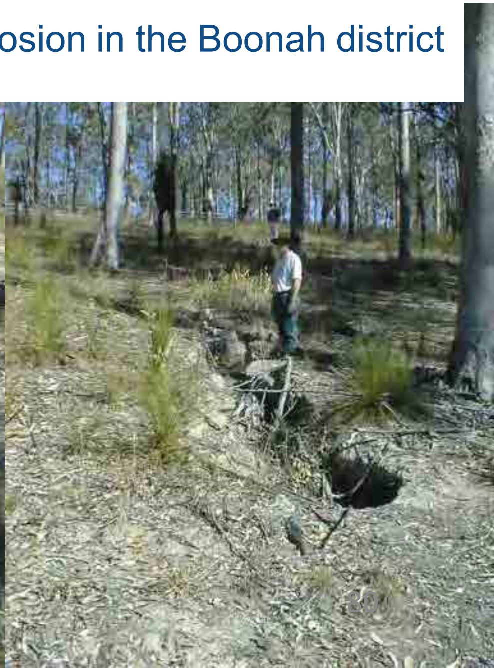
Tunnel development on a hillslope



Tunnel erosion in the Lockyer Valley

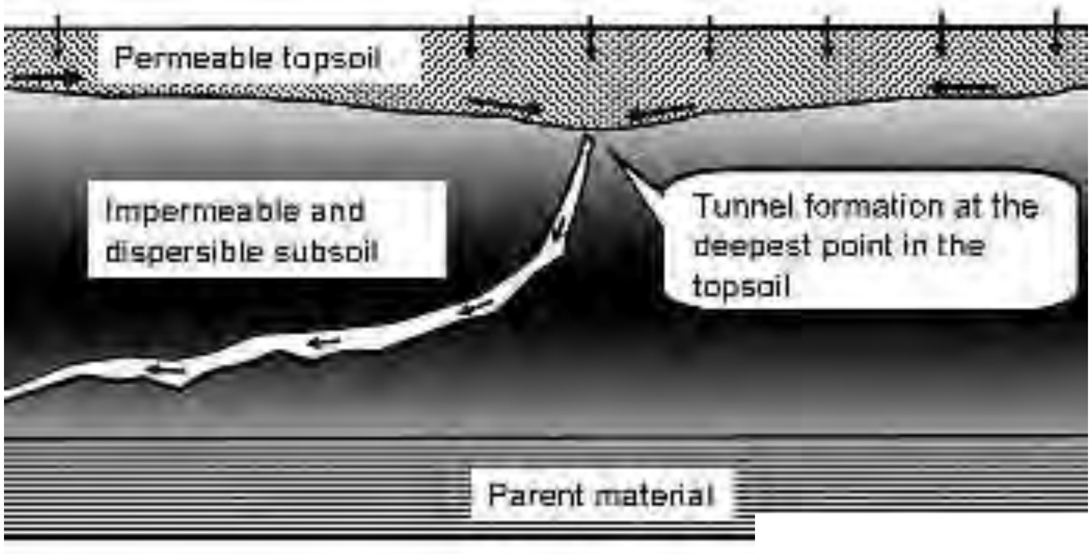
Photo: SEQ Catchments

Tunnel development leading to gully erosion in the Boonah district



Surface water flowing into a sinkhole created by tunnel erosion

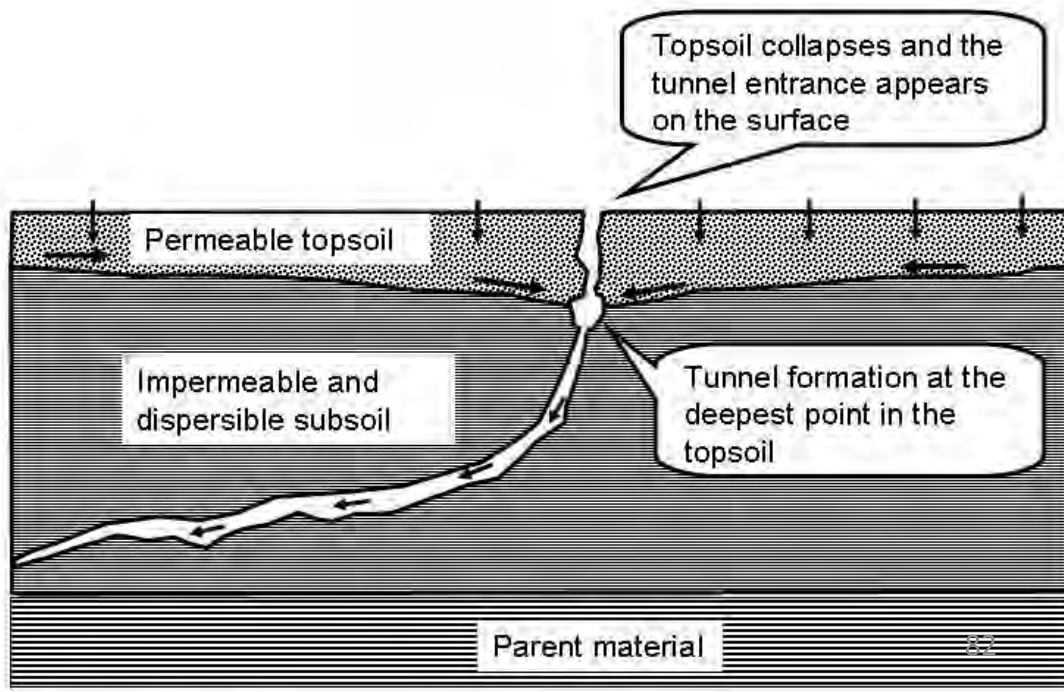
Tunnel development on a flat landscape – a theory



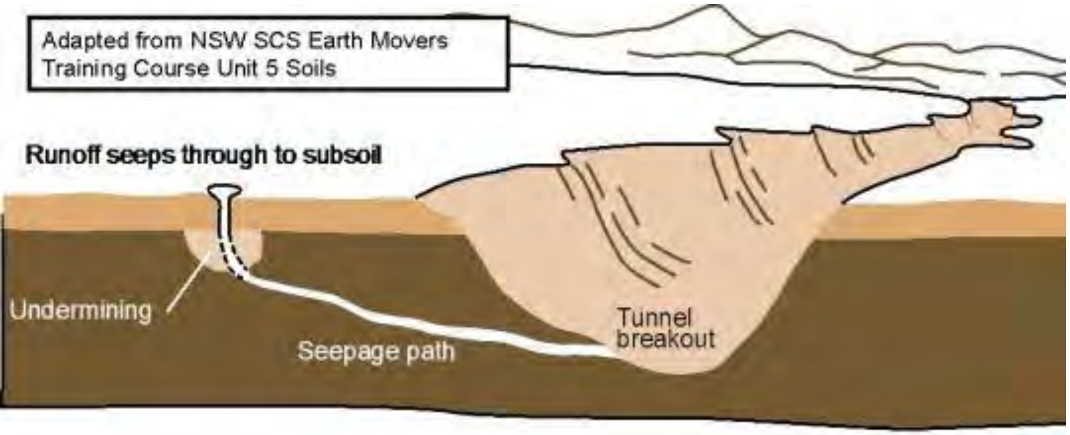
Seepage in topsoil creating a tunnel in the subsoil of a relatively flat landscape. The exit point for the flow could be an adjacent incised gully or even an underground cave.

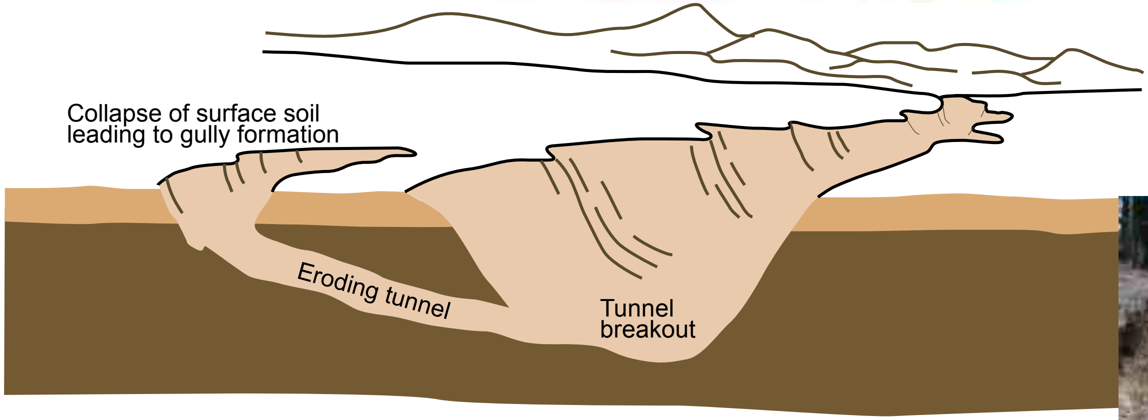
The tunnel is connected to the surface when the topsoil gives way.

A tunnel opening (sinkhole) observed in the Chinchilla district had an opening of 1.2 metre diameter and a depth of 10 metres. There was no evidence of any outlet for the tunnel.

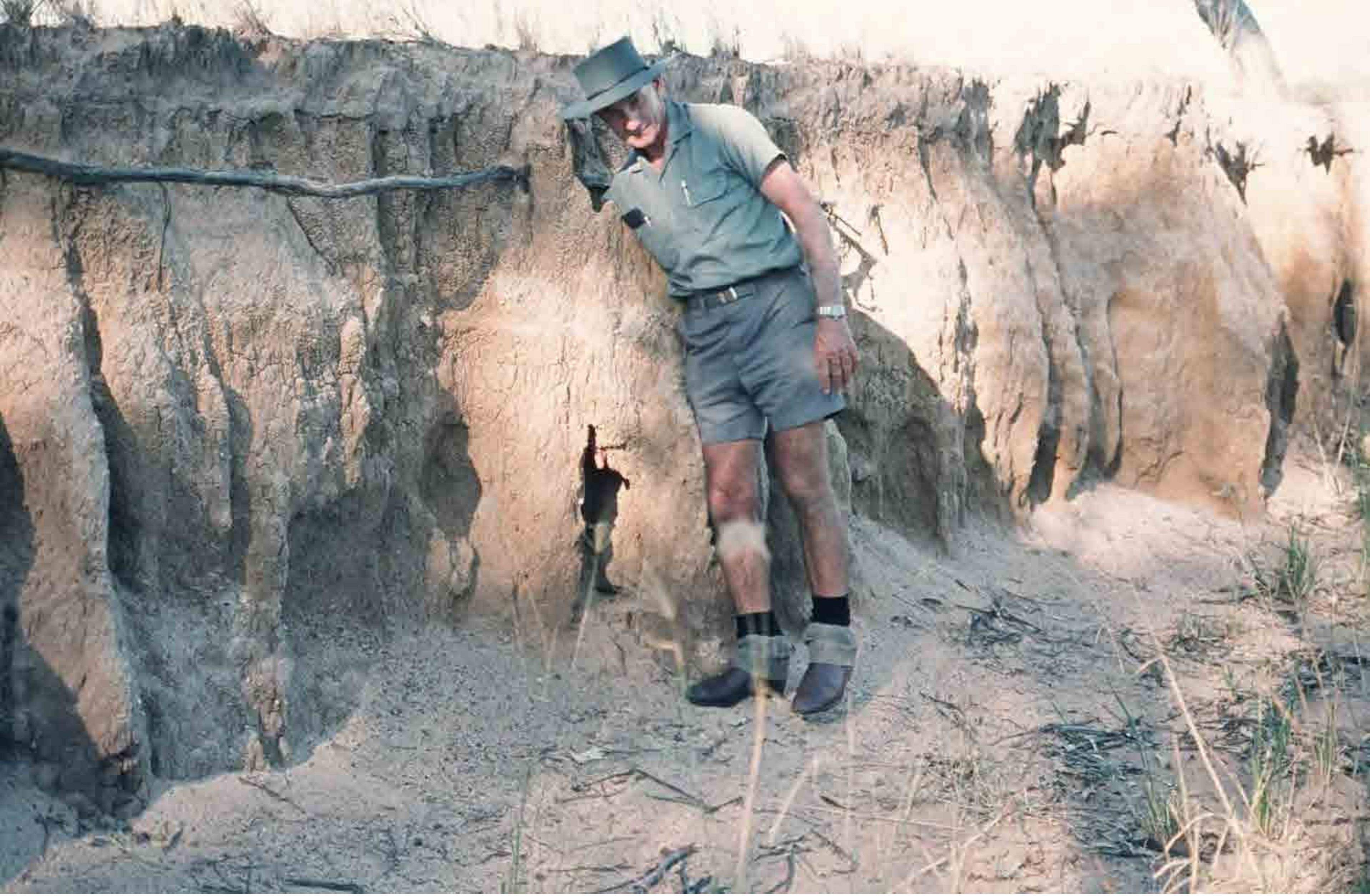


Tunnel erosion can greatly increase the rate of expansion of a gully





Tunnel erosion on the sides of a gully in the Bremer catchment



Tunnel erosion contributes to gully erosion

Case studies in *Understanding dispersive soils Part B* related to tunnel erosion

- Streambank erosion
- Agriculture
- Mining
- Roads and tracks
- Batter stabilisation
- Buildings
- Dams
- Trenches for pipes and cables

Other sources of information about tunnel erosion

- *Natural Resource Assets and Sustainable Land Use in the Black Snake Creek Catchment.* SEQ Catchments. 2008
- *Dispersive soils and their management – Technical Reference Manual* available on line from the website of the Tasmanian Department of Primary Industries, Parks, Water and Environment at www.dpiw.tas.gov.au
- *Australian Sodic Soils* – distribution, properties and management editors R Naidu, ME Sumner and P Rengasamy. CSIRO Publishing, 1995.

Erosion and dispersive soils ⮌

Streambank erosion and dispersive soils

Dispersive soils are vulnerable to streambank erosion

Source: Grant Witheridge, Catchments and Creeks

Sinkhole adjacent to the creek has since collapsed to form part of the creek

Sinkhole outlet into the creek

Sinkhole outlet into the creek

Examining the outlet

A sinkhole causing expansion of streambank erosion in a dispersive soil in the Boonah district

Other sources of information on streambank erosion

- Abernethy Bruce and Rutherfurd Ian (1999). *Guidelines for stabilising streambanks with riparian vegetation,* Technical Report 99/10.
- Carey Bruce (2014) Draft chapter on *Stream stability* for the Queensland Government publication *Soil Conservation Guidelines for Queensland. Burnett Mary Regional Management Group* *http://www.bmrg.org.au/files/4013/9650/8415/Chapter_13_stream_stability_BMRG.pdf*
- Catchments and Creeks web site http://www.catchmentsandcreeks.com.au/
- Kapitzke, I.R., R.G. Pearson, S.G. Smithers, M.R. Crees, L.B. Sands, S.D. Skull and A.J. Johnston, 1998. *Stream Stabilisation for Rehabilitation in North-East Queensland*. Land and Water Resources Research and Development Corporation, Occasional Paper 05/98, Canberra
- Lovett, S and Price P (Eds) 1999 *Riparian Land Management Technical Guidelines Volume 1*, Principles of Sound Management, Land and Water Resources Research and Development Corporation, Canberra.
- Price, P. & Lovett, S. (eds) 1999, *Riparian Land Management Technical Guidelines, Volume 2:* On-ground Management Tools and Techniques, Land and Water Resources Research and Development Corporation, Canberra.
- Price, P. and Lovett, S. 2002, *Streambank stability*, Fact Sheet 2, Land & Water Australia, Canberra.
- Rutherfurd ID, Jerie K, Marsh N (2000) *A rehabilitation manual for Australian Streams Volume 1,* Cooperative Research Centre for Catchment Hydrology, Land and Water Resources Research and Development Corporation.
- Rutherfurd ID, Jerie K, Marsh N (2000) *A rehabilitation manual for Australian Streams Volume 2*, Cooperative Research Centre for Catchment Hydrology, Land and Water Resources Research and Development Corporation

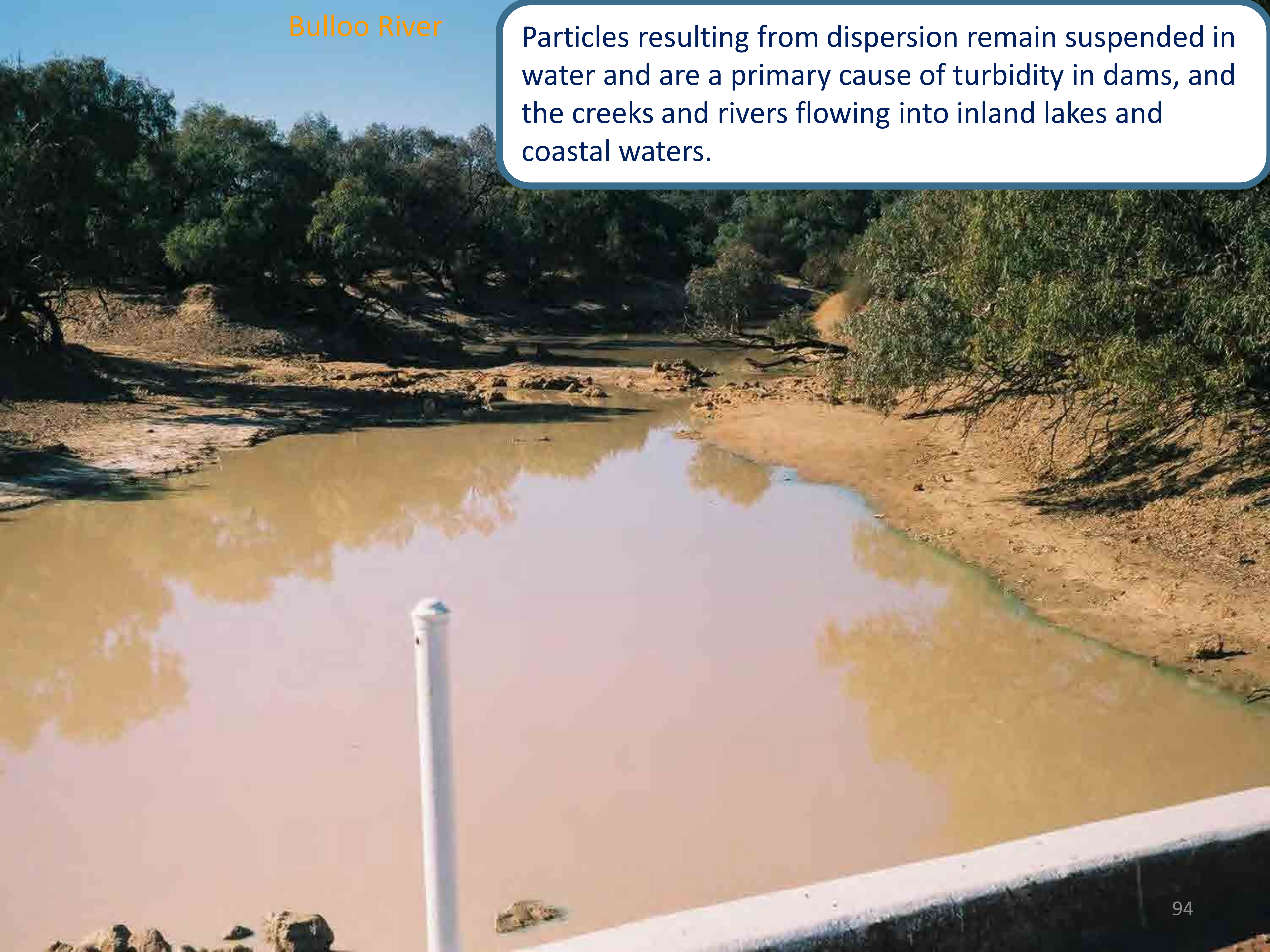
What impacts do dispersive soils have? ⮌

Dispersive soils and **water quality**

The impacts of dispersive soils on water quality.

	Diameter	Average Diameter
clay	< 0.002 mm	0.001 mm
silt	0.002 – 0.02 mm	0.01 mm
sand	0.2 – 2.0 mm	1 mm

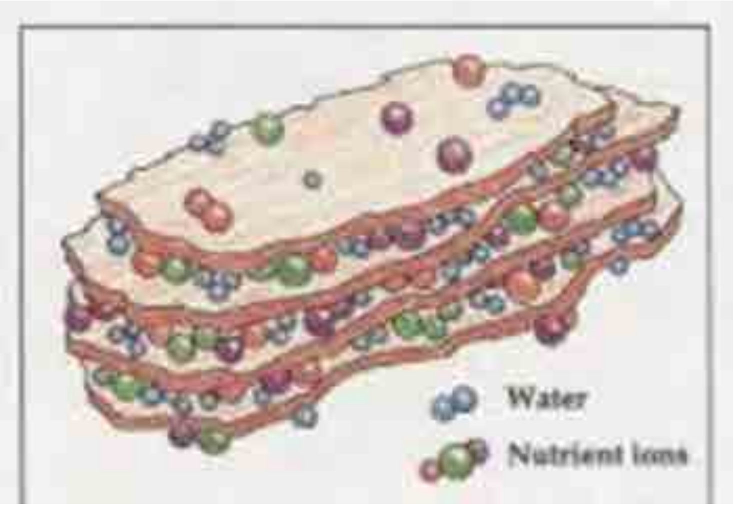
This slide shows the relative size of the mineral particles that make up soils. Sand and silt are relatively large and readily settle out in water. Aggregates of clay will also settle out but when they are dispersed into microscopic sized, individual clay particles, they remain suspended in water causing turbidity.



Bulloo River

Particles resulting from dispersion remain suspended in water and are a primary cause of turbidity in dams, and the creeks and rivers flowing into inland lakes and coastal waters.

As well as causing turbidity in water, clay particles carry nutrients and pesticides that may be attached to them.



Runoff from gullies in dispersive soils will be turbid

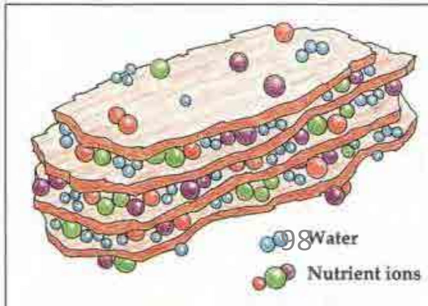
Turbid runoff from gully erosion in a dispersive soil.

Dispersive soils and water quality

Dispersed clay particles are so small that they remain suspended in still water. This explains why water in some dams, creeks and rivers is always turbid with a muddy or milky appearance.

Clay particles reduce light penetration into streams affecting the the growth of aquatic plants. Water quality will not improve until the clay particles are flocculated resulting in the formation of larger particles which can then settle.

Nutrients and pesticides and nutrients can be attached to the clay particles



Clear spring-fed water in a sandy river bed at the headwaters of the Nogoa river at Salvator Rosa National Park.

Turbid water from the erosion of dispersive clay soils in an upper tributary of the Dawson (Fitzroy catchment).

When turbid streams flow into sea water or saline lakes, the suspended sediments flocculate and the water becomes clear as the newly formed aggregates sink to the bottom smothering aquatic habitats and benthic ecosystems.

The flocculation is caused by the high concentration of ions in saline water which compresses clay platelets together. This overcomes the repulsive forces where the hydrated and enlarged sodium ions cause clay aggregates to break up into microscopic particles.

For small stream flows, flocculation and settlement of sediments will occur in the stream estuary but they will be moved further out into the sea during a flood.

In major floods, flocculation and settlement will occur on the edge of the freshwater flood plume as it spreads out into the salty sea water. A similar process occurs when turbid inland creeks flow into the saline waters of Lake Eyre.

Clearing turbid water for domestic or commercial use

- Water made turbid from sodic dispersed clay is undesirable for most household and commercial purposes. When used for irrigation, the fine clay particles in the water can clog up irrigation equipment, especially where fine nozzles are used as in trickle or drip irrigation
- Turbid water can be treated with filtration systems or with flocculants.
- Flocculants, replace the adsorbed sodium on clay particles. This results in the flocculation of fine clay particles causing them to settle out. Automated ‘clarifiers’ are available for domestic or commercial use.
- Flocculants include finely ground gypsum (calcium sulfate) and alum.
- For domestic supplies, large quantities of flocculant would be required to treat the water in a dam; hence it is preferable to treat turbid water in storage tanks. Tanks should have two outlets, one near the base to drain off the sludge deposited in the bottom, and a higher one to take off the clear water. The tank should be made of a non-corrosive material as alum can lead to acidity. The addition of lime may be necessary to overcome this acidification.
- Flocculant application rates depend on the amount of turbidity and should be obtained from the supplier of the product. The correct dosage can also be found by trial and error, by treating a small sample of the water.

As soil becomes more acidic, aluminium in the soil becomes more soluble. The aluminiinium ion is a good flocculator because it has three positive charges that combine with negatively charged clay particles to cause flocculation and settlement.

Water bodies adjacent to acid soils can be crystal clear or jade coloured. Aluminium toxicity can kill fish and other biota. Biodiversity in such water bodies will be very low.

Irrigation and dispersive soils

Dispersion may be induced by sodium salts in irrigation water. Groundwater is likely to have higher levels of salts than surface water. The amount and type of salts in groundwater depends on the type of rock strata it was stored in.

The level of sodium in water is measured by the sodium adsorption ratio (SAR). The SAR level can be reduced by adding calcium salts such as gypsum to the water. Dissolved gypsum will also help to prevent dispersion by increasing the electrolyte content of the water.

As gypsum is sparingly soluble, it needs to be very fine to dissolve in water. Different sources of gypsum have differing degrees of fineness. Agitators in the mixing tank will assist.

Water from the Great Artesian Basin and that extracted from coal seams can have high levels of salts including sodium salts. This water requires treatment before it is suitable for irrigation. The treatment can involve the lowering of the salt level by osmosis and the reduction in sodium ions by treatment with gypsum.

Instead of applying gypsum to the irrigation water another option may be to apply regular amounts of gypsum to the soil.

A natural feature of Great Artesian Basin water is that it usually has high sodium levels. It has limited value for irrigation because it makes soils go sodic.

Hot artesian pools at Mitchell, west of Roma in Queensland

We need to know about the balance of mineral ions in a water supply

- mineral ions in water are a source of nutrients for our health
- but too many mineral ions will make water and soil saline
- too many sodium ions cause sodicity. Calcium ions need to be added to make it suitable for irrigation
- too many calcium and magnesium ions will make domestic water ‘hard’ and it needs to be treated with sodium-based compounds known as ‘water softeners’. (

Before the construction of Wivenhoe dam in 1984, many Brisbane households had water softeners to reduce the hardness in the water supply. The hardness came from the high proportion of base flow from streams like the Stanley River which flowed into Somerset Dam. Baseflow originates from mountain aquifers and has high levels of natural minerals.

Most of the storage in Wivenhoe dam originates from flood flows resulting from prolonged rainfall events. These produce high rates of surface run-off yielding water with low levels of mineral salts.

Understanding dispersive soils
Part A contents ⮌

Management of dispersive soils

Management of dispersive soils when used for agriculture

Grazing

- Soils with dispersive properties can be suitable for grazing provided stocking rates are carefully managed.
- Areas prone to gully erosion need special care
- The use of chemical amendments or fertilisers in extensive grazing lands is not economically viable and they are not used in Queensland.

Cropping

- Dispersion limits the suitability of soils for cropping. Dispersive topsoils can seal readily causing low rates of seed germination and establishment.
- Dispersive subsoils can be dense with low rates of permeability and poor subsoil drainage.
- Soils with a good depth of non-dispersive topsoil can be suitable for cropping
- Depending on the soil pH, amendments such as gypsum, lime and dolomite can be used to improve the quality of dispersive soils

For more information check the case study on agriculture

Management of dispersive soils when used for infrastructure projects

- Dispersive soils are especially vulnerable to most forms of soil erosion, including sheet, rill, gully, tunnel and wind.
- Of most concern is the very high erodibility of the subsoils.
- This has implications for a wide range of infrastructure projects including the construction of dams, trenches and roads.
- Many outback soils have dispersive subsoils. Despite the low average annual rainfall, these soils can be seriously eroded whenever they are disturbed. The low rainfall compounds the problem by increasing the difficulties of establishing vegetation.

Management of dispersive soils – options for infrastructure projects

Wherever possible, the disturbance of dispersive soils should be avoided. If this is not possible, the following management options should be considered:

- keep topsoil separate from subsoil when excavating
- chemical amendments (such as gypsum)
- compaction
- runoff management
- revegetation.

Topsoil and stockpile management

- Any projects involving excavation of dispersive subsoils should allow for the stockpiling of non-dispersive topsoil to spread over the disturbed area at the completion of the project. This should be followed by the planting of grasses and other species to provide good ground cover.
- Where excess dispersive soils remain after a project they may need to be permanently stockpiled.
- Such stockpiles need appropriate management to ensure that they don’t become an erosion hazard.
- Note that saline – sodic soils may become dispersive if the salt is leached out of the stockpiled soil

Chemical amendments - 1

Gypsum (calcium sulfate) is the most commonly used ameliorant for managing alkaline dispersive soils in Queensland. It acts in three ways to alleviate sodicity and dispersion:

- The calcium in gypsum displaces the sodium on the exchange surface of clay platelets. This causes the clay platelets to flocculate or bind together.
- Gypsum is sparingly soluble and will increase the electrolyte concentration of the soil solution. The electrolyte concentration in the soil solution reduces the size of the hydration shell around the sodium ions and thus the platelets are not able to separate enough to overcome the electrostatic forces between the clay plates.
- As gypsum improves soil structure, the quality of the soil improves. Greater plant growth produces more plant residue and higher levels of organic matter and soil carbon. This leads to greater microbial activity and, as a consequence, the production of organic polysaccharides (‘glues’), which further improves soil structure and stability.

.

Gypsum (calcium sulfate) is used to alleviate dispersion in alkaline dispersive soils by replacing sodium ions in the soil with calcium.
If a clay soil is not dispersive, gypsum will have no effect in improving the soil structure.

As well as being a soil conditioner, gypsum can be a fertiliser by providing both sulfur and calcium for plant growth.

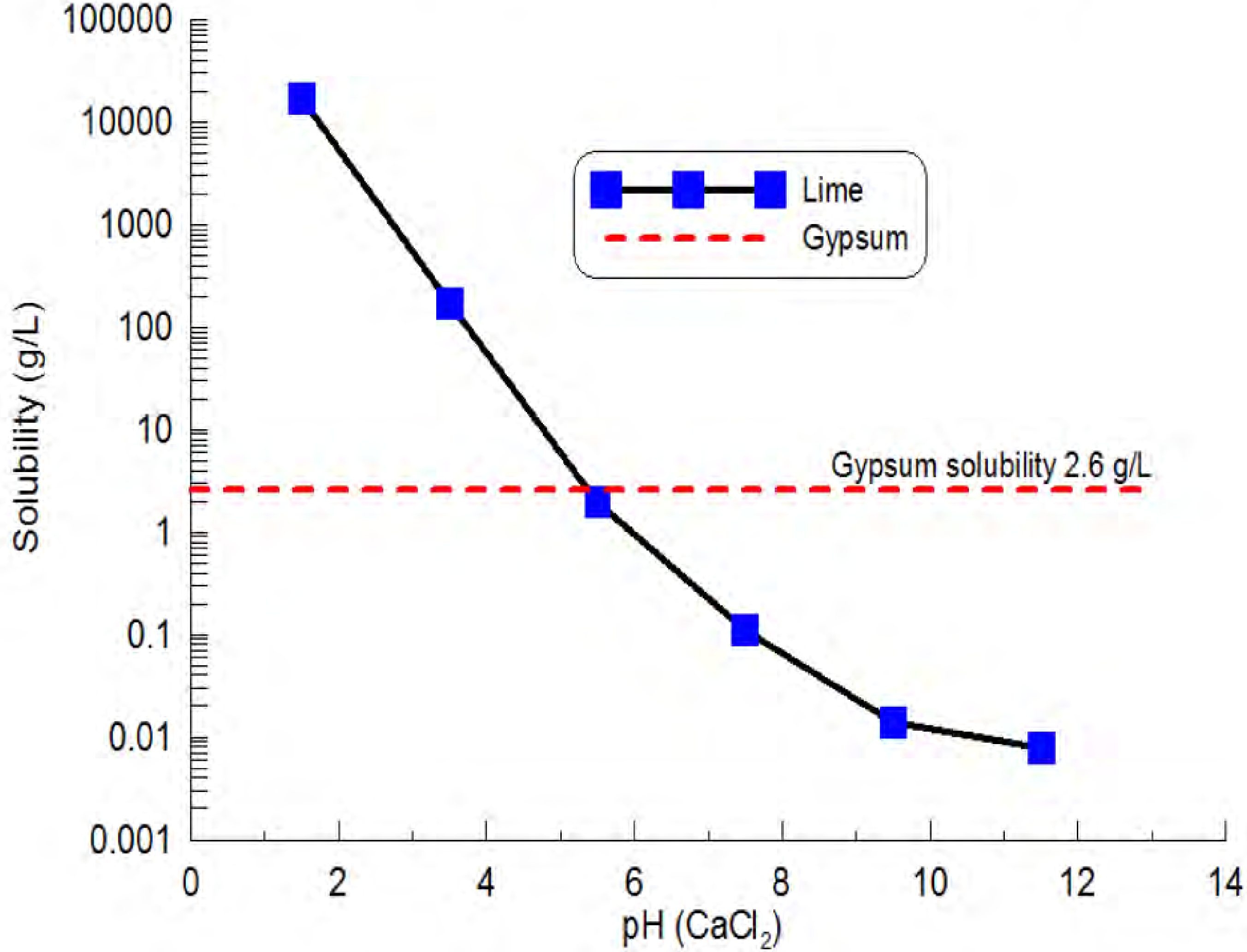
For more information on the use of gypsum check the Agriculture case study.

Agricultural lime (calcium carbonate) is insoluble in alkaline conditions and would be unsuitable for controlling dispersion in this situation. If an acid soil was dispersive, lime could be used to increase the pH. It would have some benefit in reducing dispersion because it becomes more soluble under acid conditions. In acid dispersive soils a lime/gypsum mix could also be used.

Chemical amendments - 2

- As the mode of action of a flocculating agent depends on its dissolution, its solubility and particle size is important. Gypsum produced as a byproduct of the production of phosphorus fertiliser has a finer particle size than natural gypsum which is mined from dune deposits adjacent to evaporative basins.
- The soil pH will affect the type of amendment to be used. Most sodic soils in Queensland are neutral to alkaline and gypsum is recommended in this situation. Lime is insoluble in alkaline soils with pH > 8.5 but becomes more soluble as pH decreases below this value. In dispersive soils with pH below 7, lime or dolomite are recommended to increase the pH as well as overcoming some dispersion. If used in conjunction with gypsum there should be a greater reduction in the amount of soil dispersion. Hydrated lime can also alleviate dispersion. However, it is quite alkaline and corrosive and should only be used carefully and sparingly on acid soils as an amendment.

Gypsum & Lime solubility



Estimates of lime/gypsum requirements requires a calculation of how much sodium has to be replaced by calcium. This depends on:

- Clay content
- Soil CEC
- Soil ESP
- Depth to be treated
- Soil bulk density
- Factor for purity/effectiveness.

Lime can turn a dispersive soil into a cracking clay soil

The regular addition of lime to mark out the boundaries of this baseball field at Minnippi Parklands, Tingalpa, Brisbane has modified this dispersive soil. Flocculation of the clay particles helps to promote cracking of the soil along the line.

Photo: Ray Kelly

Chemical amendments - 3

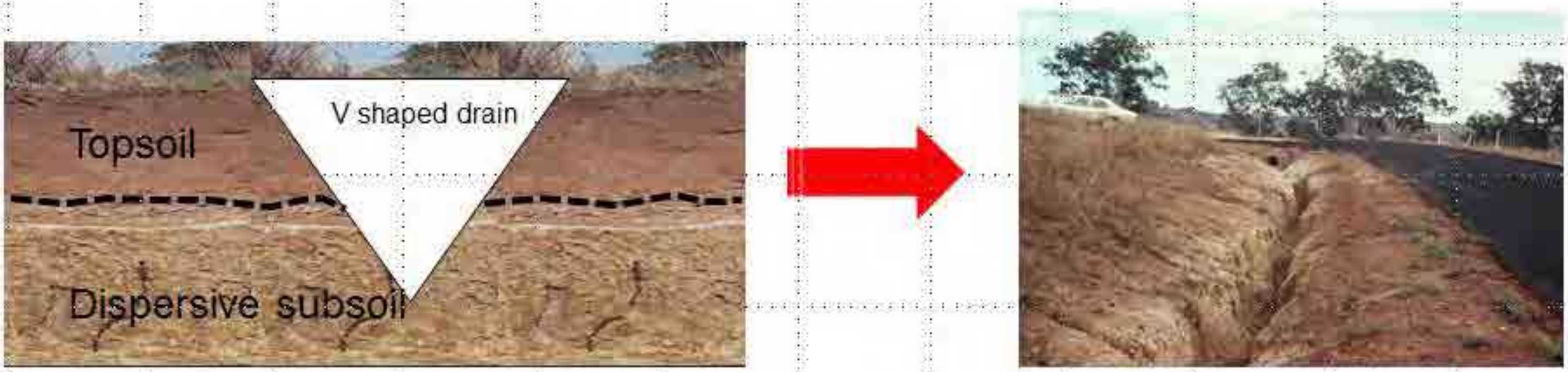
- Another flocculating agent is alum (aluminium sulfate) which is used to clear turbid water and has been used to prevent dam failure and protect embankments from erosion in southern states (Hardie 2009).
- Alum is highly acidic (pH 4-5), and alum treated soils would need to be capped with topsoil in order to establish vegetation. Alum is corrosive and care should be taken with its use.

Compaction

- When excavated, dispersive soils form strong, tough, impermeable clods when they dry out.
- When water enters the soil, it will pass through air voids between the clods and small ‘pipes’ can form which quickly develop into tunnels leading to the failure of structures such as dams.
- This process can be avoided by using specialist compaction equipment during the construction process.
- Specialist equipment such as a sheepsfoot roller is required to achieve adequate compaction. Bulldozer tracks provide insufficient compaction unless the soil is moist and is compacted in thin layers by multiple passes of the equipment.
- Dispersive soils should be compacted in layers at the optimum moisture content. This may require the application of water. Moist soils have some plasticity which allows for compaction to occur.
- Compaction should be avoided on the non-dispersive topsoils that are spread over dispersive soils as it will discourage the growth of plants.

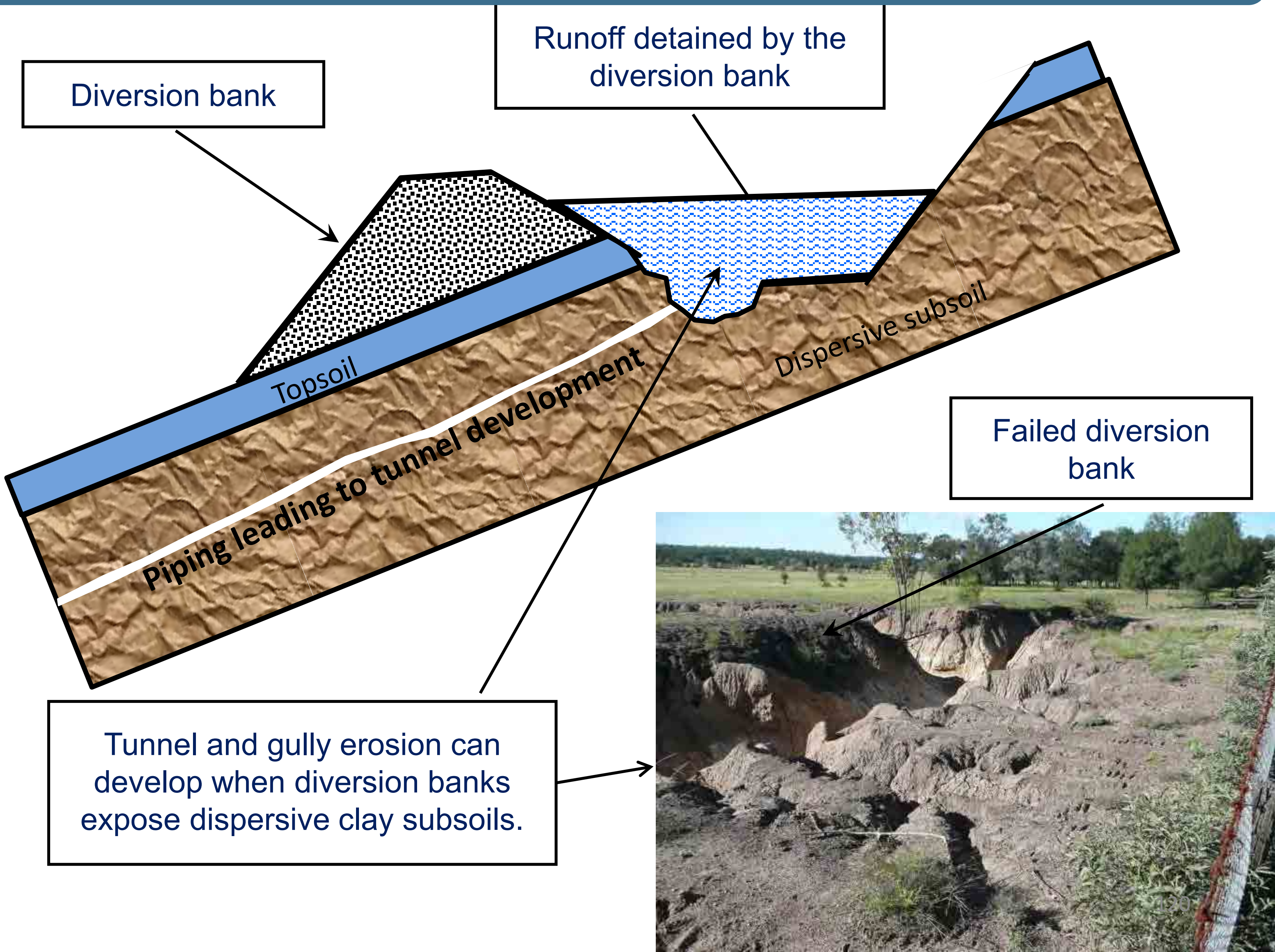
Runoff management

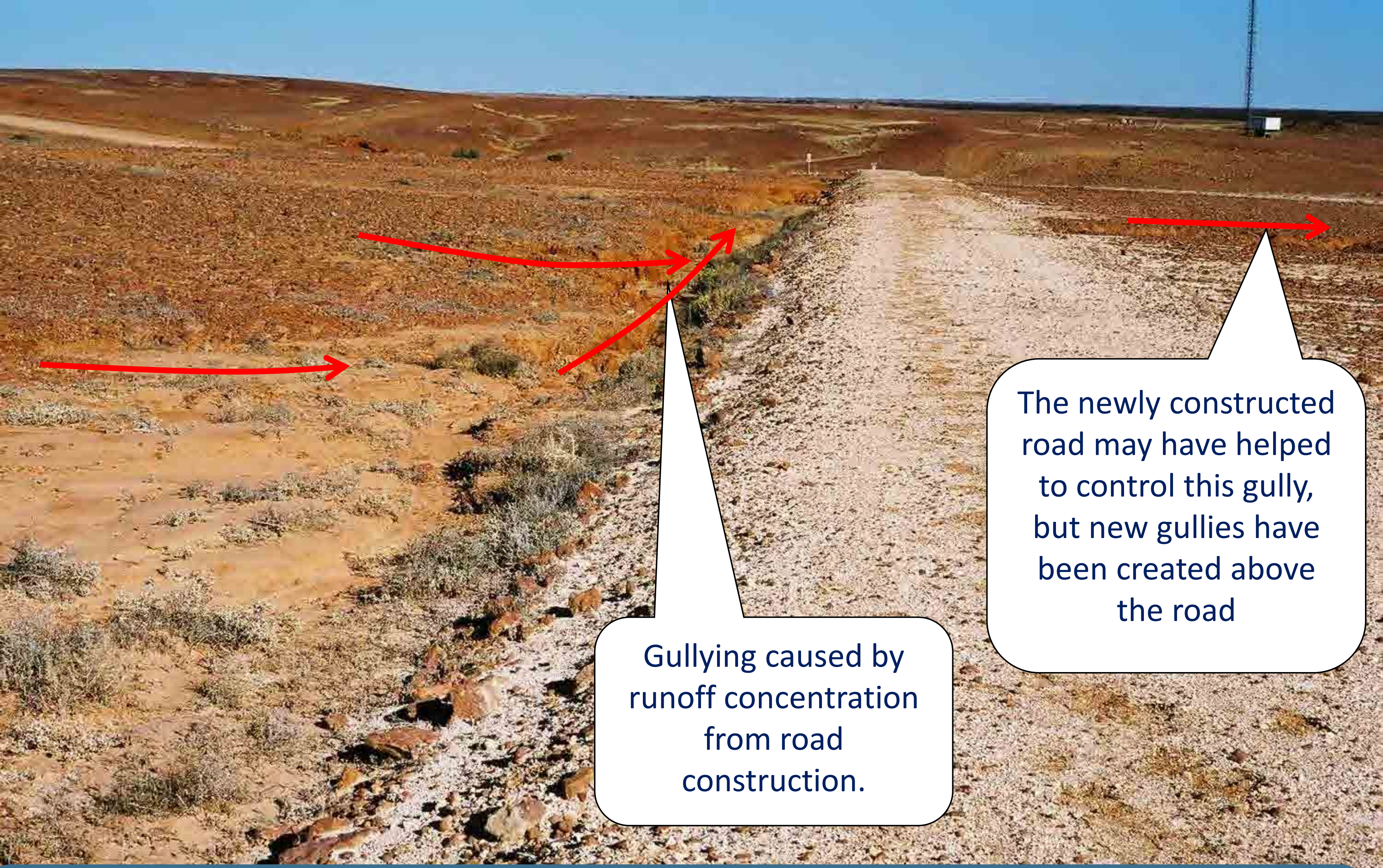
- Where projects involve dispersive soils, runoff needs to be managed to avoid erosion.
- Banks, drains, waterways and road table drains need to be carefully constructed to avoid the exposure of dispersive soils in the channel (for more information, check the case study on roads)



V shaped road table drains constructed into dispersive subsoils are a high erosion risk

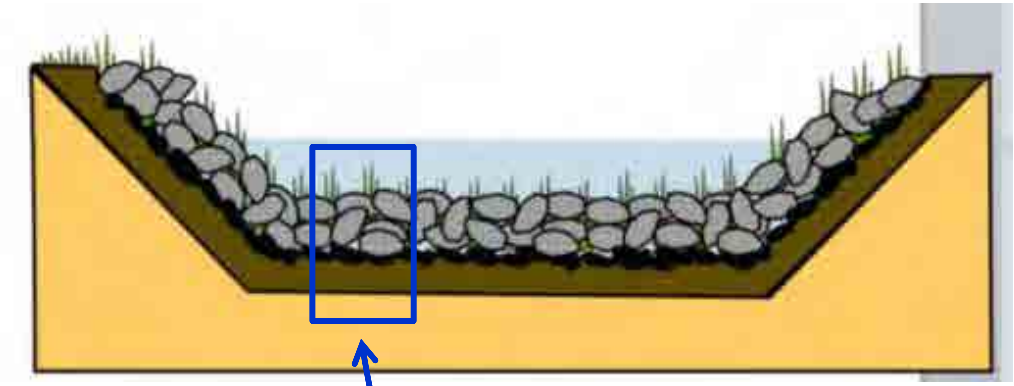
Banks with a channel constructed into dispersive soils can be a high erosion risk



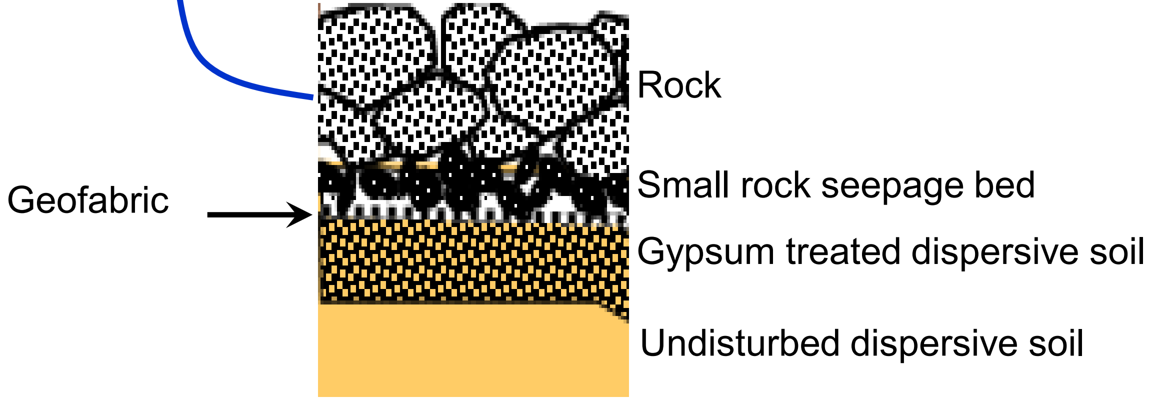


Innamincka on the South Australian – Queensland border. In this low rainfall, desert environment with highly dispersive soils and minimal cover, erosion occurs whenever runoff is concentrated.

Poorly placed rock always results in failure. A common problem is that the structure has no capacity to accommodate run-off. When run-off does occur, the rocks just divert run-off.



A rock chute constructed in dispersive soils. The chute has plenty of capacity to accommodate run-off.

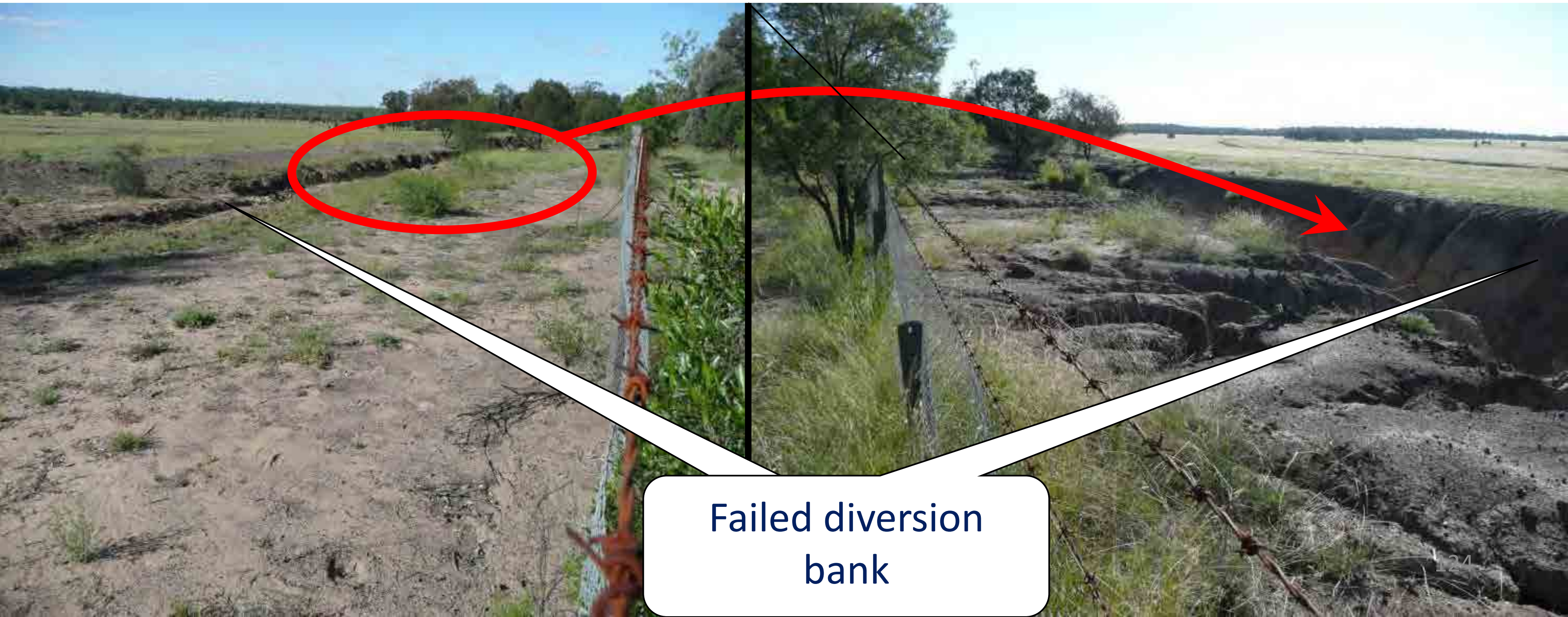


Revegetation

- Revegetation with species that provide protection from erosion is essential for projects involving dispersive soils.
- Many soils with dispersive properties have an infertile layer of light textured soil overlying a dispersive clay. This creates challenges for revegetation even when a topsoil capping is applied to disturbed subsoils. Key fertility limitations that need to be managed include organic matter, nutrient availability and pH.

How could this site be reclaimed?

1. Remove the failed diversion bank and stockpile any available topsoil
2. Deep rip the affected area after applying high rates of gypsum (as per a laboratory test)
3. Fill in the gully by dozing in layers of soil following additional ripping and gypsum application
4. Compact each layer of soil using specialised machinery such as a sheepsfoot roller. If the soil is too dry to compact, water will need to be applied.
5. Spread topsoil treated with gypsum over the treated area and add fertiliser (and a compost blanket if the budget allows)
6. Plant ground cover species suitable to the local area
7. If the pasture below the area is well managed, it would not be necessary to reinstate the diversion bank (there is always a risk of failure when banks are built in areas with dispersive soils).



Additional **sources of information** about dispersive soils

Additional information – Web pages from Queensland

- *Soil management* section on the Queensland government web pages
  http://www.qld.gov.au/environment/land/soil

- *Soils information for Queensland*. A presentation to an ASSSI training workshop in 2009. It includes information on what soils data is available and how to access soils reports, maps and digital spatial data

http://www.soilscienceaustralia.com.au/images/stories/qld/refresher/ASSSI_QLD_training_course_2009_brisbane.pdf

- *What is a sodic soil? Identification and management options for construction sites and disturbed lands*. Steven Raine USQ and Rob Loch, Landloch

http://www.usq.edu.au/users/raine/index_files/Raine&Loch_WhatIsASodicSoil_2003.pdf

- *Identification and management of dispersive mine spoils* 2004 (C Vacher, R Loch and S Raine), Australian Centre for Mining Environmental Research

http://eprints.usq.edu.au/1311/1/Dispersive_spoils_report_final_June2004b.pdf

- *Salinity management handbook* (Department of Environment and Resource Management 2011)

http://www.qld.gov.au/environment/land/soil/salinity/management/

- Catchments and Creeks web site

http://www.catchmentsandcreeks.com.au/

Additional information – Web pages from other states

- *Victoria on line* has descriptions and animated videos of the dispersion and slaking process http://vro.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soilhealth_soil_structure_dispersion

- *Identifying dispersive soils* (WA Department of Agriculture farm note)

http://www.agric.wa.gov.au/objtwr/imported_assets/content/lwe/land/fn_dispersive_soils.pdf

- *Managing dispersive soils* (WA Department of Agriculture farm note)

http://www.agric.wa.gov.au/objtwr/imported_assets/content/lwe/land/fn_managing_dispersive_soils.pdf

- *Dispersive soils and their management – Technical Reference Manual, Tasmanian Department of Primary Industries, Parks, Water and* Environment

http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/SWEN-7SU6SX/$FILE/DPIW_DSM_Manual_April2009.pdf

- *Management of dispersive soils in urban areas*. Marcus Hardie, Tasmanian Institute of Agricultural Research, University of Tasmania, DPIW Tasmania, CSIRO

http://www.stormplastics.com.au/files/SodicSoilsByMarcus.pdf

Additional information - Books

- *Australian Sodic Soils – distribution, properties and management* editors R Naidu, ME Sumner and P Rengasamy. CSIRO Publishing, 1995.
- *Soils – Their properties and management*. Edited by PEV Charman and BW Murphy, third edition 2007. NSW Government, Department of Natural Resources
- *Diagnosis and management of Sodic Soils under Sugarcane*, Edited by PN Nelson, CRC Sugar Technical Publication 2001
- *Soil erosion hazard – an assessment methodology* Lorimer M (2010) produced by DERM. – (download from thefrom the EHP (Queensland Department of Environment and Heritage Protection) Library Catalogue (do a web search for EHP library catalogue)
- *Dispersive soils and their management – Technical Reference Manual* -Hardie M 2009 available on line from the website of the Tasmanian Department of Primary Industries, Parks, Water and Environment at www.dpiw.tas.gov.au
- *SOILpak for cotton growers* A guide to best practice soil management for the Australian cotton industry, Third edition, NSW Agriculture, 1998 (available on-line) also chapter D4 slaking and dispersion in the vegetable soil pak
- *Introductory erosion and sediment control guidelines for Queensland Councils*, Local Government Association of Qld – available on line
- *Interpreting soil test results- what do all the numbers mean? Pam* Hazelton and Brian Murphy –CSIRO publishing 2007.

Additional information – Soil Science Australia (formerly ASSI) soils training workshops

- Between 1985 and 2010, the Queensland Branch of the Australian Society of Soil Science (ASSSI) ran 12 training courses. Most of these courses contained information about dispersive soils and soil sodicity.
- All of the presentations can be downloaded from the ASSSI web site or enter 'soils training courses queensland' into a web search engine.
- The site includes one pdf file which contains the contents of all of the training courses.

http://www.soilscienceaustralia.com.au/index.php?option=com_content&view=article&catid=3%3Abranches&id=151%3Aqueensland-refresher-courses-and-workshops&Itemid=83

Land Management Field Manuals produced in the 1980s and 1990s contain useful information on dispersive soils. They are available for download from the EHP (Queensland Department of Environment and Heritage Protection) Library Catalogue (do a web search for EHP library catalogue).

- Atherton-Mareeba Land Management Field Manual
- Central Darling Downs Land Management Manual
- Crows Nest Land Management Field Manual
- Dawson-Callide Land Management Field Manual
- Inglewood Shire Land Management Manual
- Roma Land Management Field Manual
- SE Darling Downs Land Management Field Manual
- Understanding and Managing Soils in the Central Highlands
- Understanding and Managing Soils in the Inland Burnett District
- Understanding and Managing Soils in the Moreton Region
- Understanding and Managing Soils in the Murilla, Tara and Chinchilla Shires
- Understanding and Managing Soils in the Stanthorpe-Rosenthal Region
- Waggamba Land Management Field Manual
- Wandoan Land Management Field Manual.

Note that the following manuals are no longer available because more accurate soils information is now available.

- Coastal Burnett Districts Land Management Manual
- Maryborough Districts Land Management Field Manual.

Understanding dispersive soils Part B Case studies

Part A

Part B Case studies

Understanding dispersive soils
Part B contents ⮌

Gully erosion control

A case study on dispersive soils

Measures to control gully erosion

Management options for gully erosion control include:

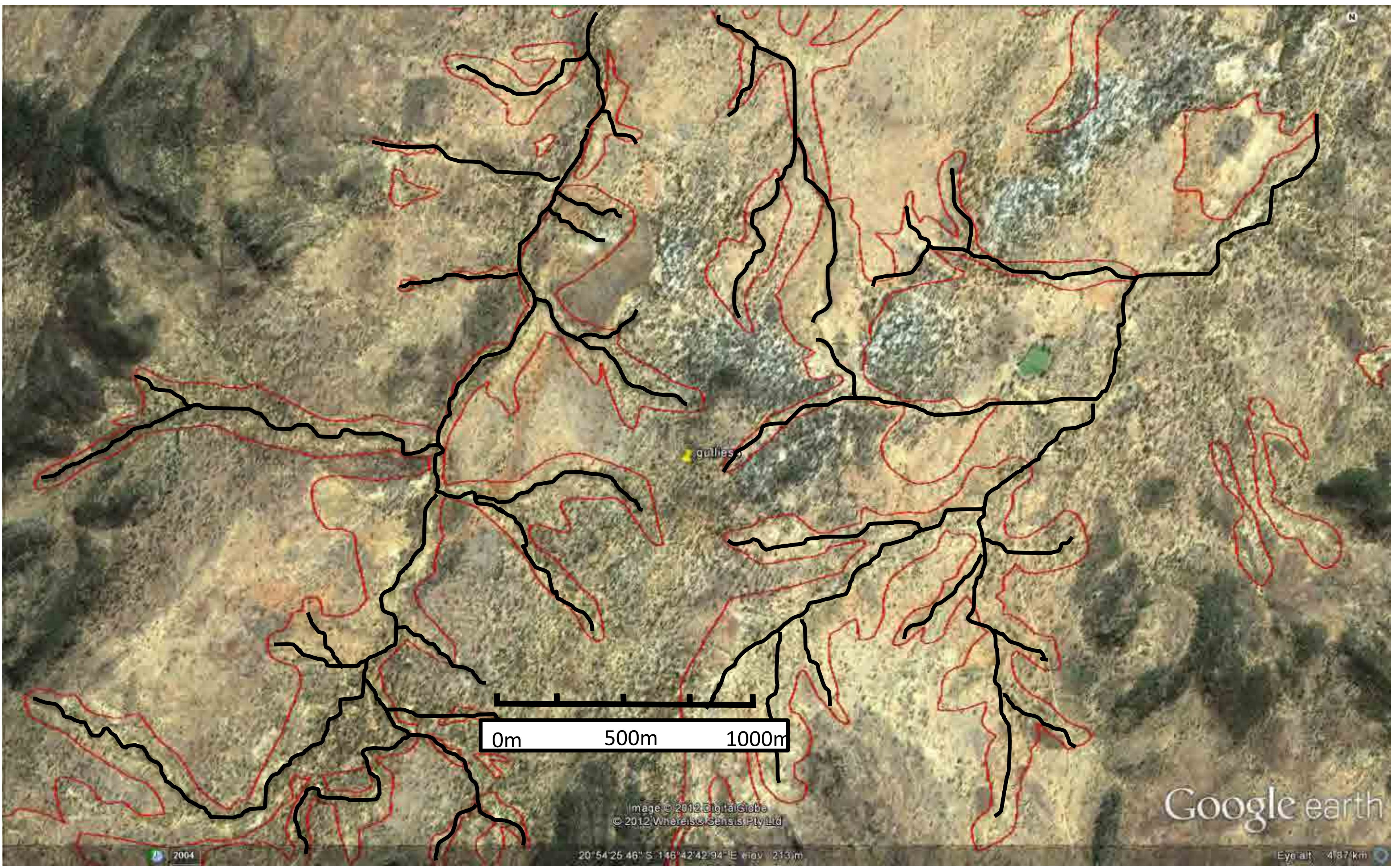
- managing catchments to limit the rate and amount of runoff produced
- fencing off a gully system to encourage revegetation and natural recovery
- filling or reshaping the gully and stabilising the drainage pathway
- stabilising the bed of the gully with a series of low weirs
- stabilising the head of the gully with a chute, flume or drop structure
- reducing the effects of seepage by encouraging greater water use by plants
- diversion of runoff away from the gully.

Structural gully control measures such as flumes and drop structures can be costly, require a high level of expertise and are often subject to failure in dispersive soils. They can be justified in one-off situations where a gully is threatening a structure such as a road or pipeline. However, where extensive gullying is occurring, more passive attempts at gully control can be the only option. They include managing catchments to achieve high levels of cover and fencing off gullied areas to exclude grazing animals and to encourage vegetative growth.

Fencing off individual gullies or removing stock from paddocks with many gullies is often the only practical option for achieving some measure of gully control. Placing fallen tree branches in the gully can assist by restricting stock access and encouraging sedimentation and vegetation growth

A fenced off gully in the Beaudesert district. Some gully head advancement is still occurring, but the gully floor below the head is well grassed and trapping sediment

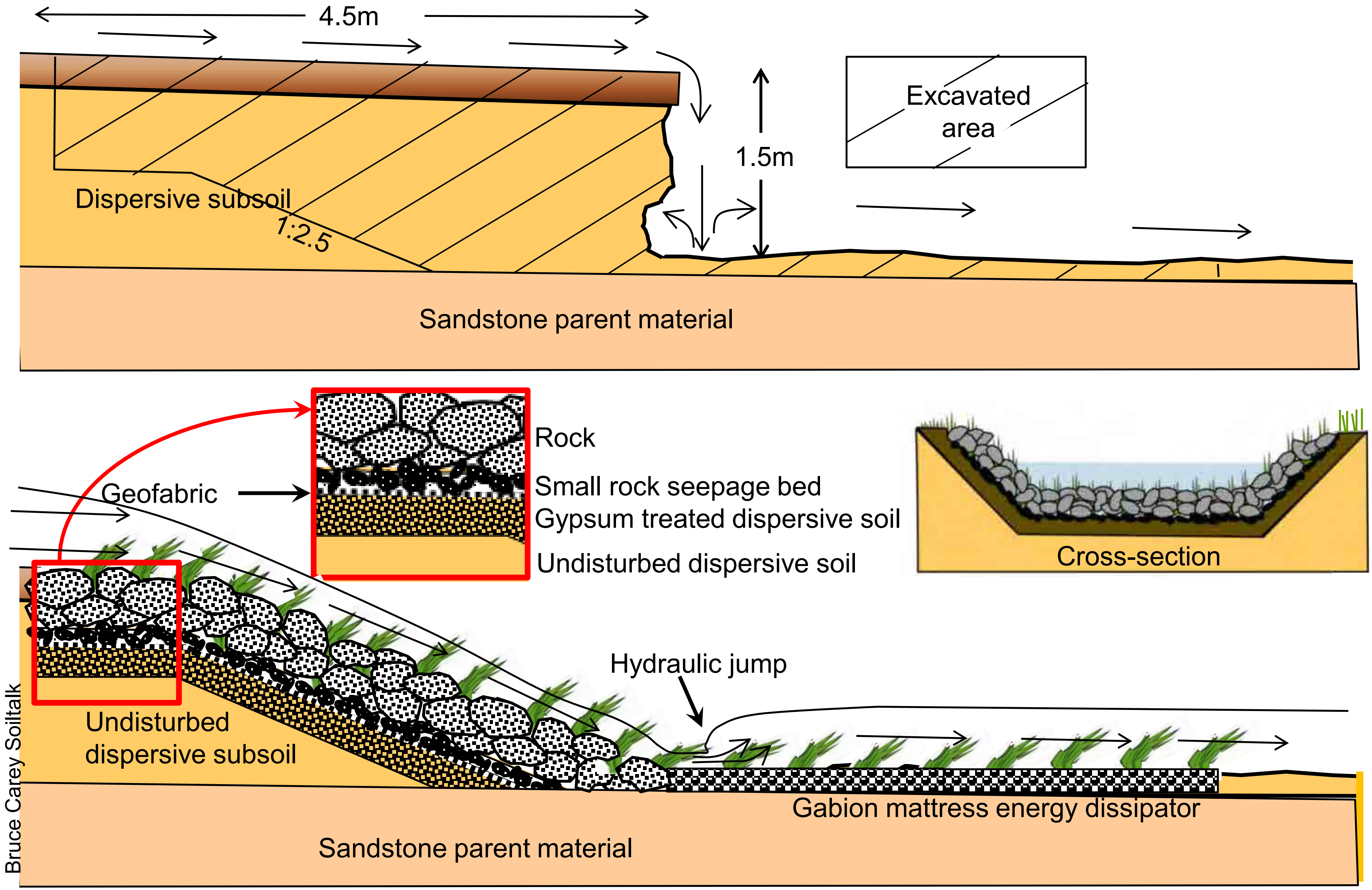
50 metres below the gully head



It is impractical to fence off individual gullies where gully systems occur throughout a landscape. (Burdekin catchment)

Gully head diversion – a relatively easy option but often there is no suitable location to divert the runoff to. The problem is simply transferred from one location to another.

This tree planting program will have limited success in stabilising the gullies adjacent to the creek.



Rock chutes (or flumes) can stabilise eroding gully heads, but they involve significant cost and expertise, and can only be justified where infrastructure such as roads are threatened. They are designed to accommodate the expected rate of run-off from the catchment for a 1 in 10 to 1 in 50 year return period.

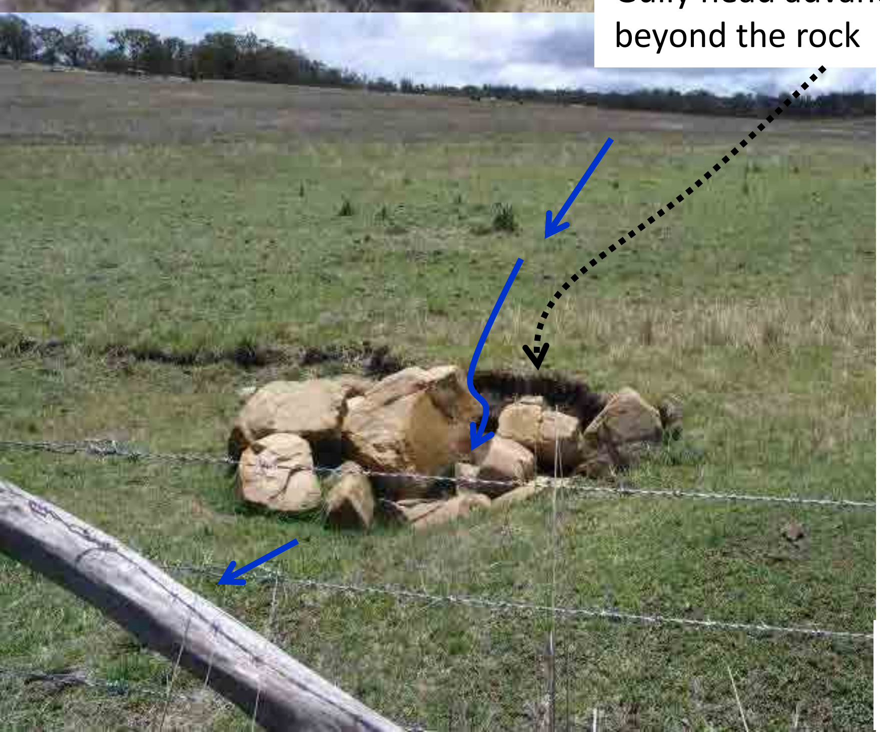
A rock flume for gully erosion control in the Rolleston district of Central Queensland (Photo: NSW Soil Conservation Service) The project was carried out in 2011 as a consultancy by the Soil Conservation Service of NSW to stabilise a gully that had exposed a gas pipeline.

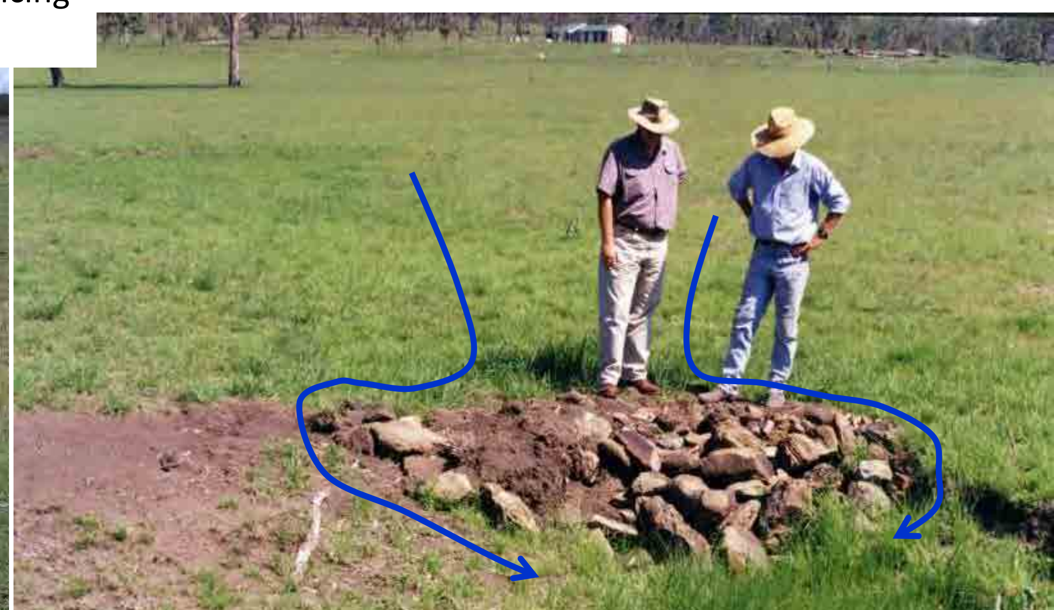
Delivering rock to the site shown in the previous photo
(Source: NSW Soil Conservation Service)

Gypsum is required in large quantities for treating dispersive soils. This photo shows a 50 tonne load being delivered to a gully erosion control project at Rolleston in Central Queensland. (Source: NSW Soil Conservation Service)

Rocks placed randomly at the head of a gully, usually fail as a gully control structure.

Gully head advancing beyond the rock

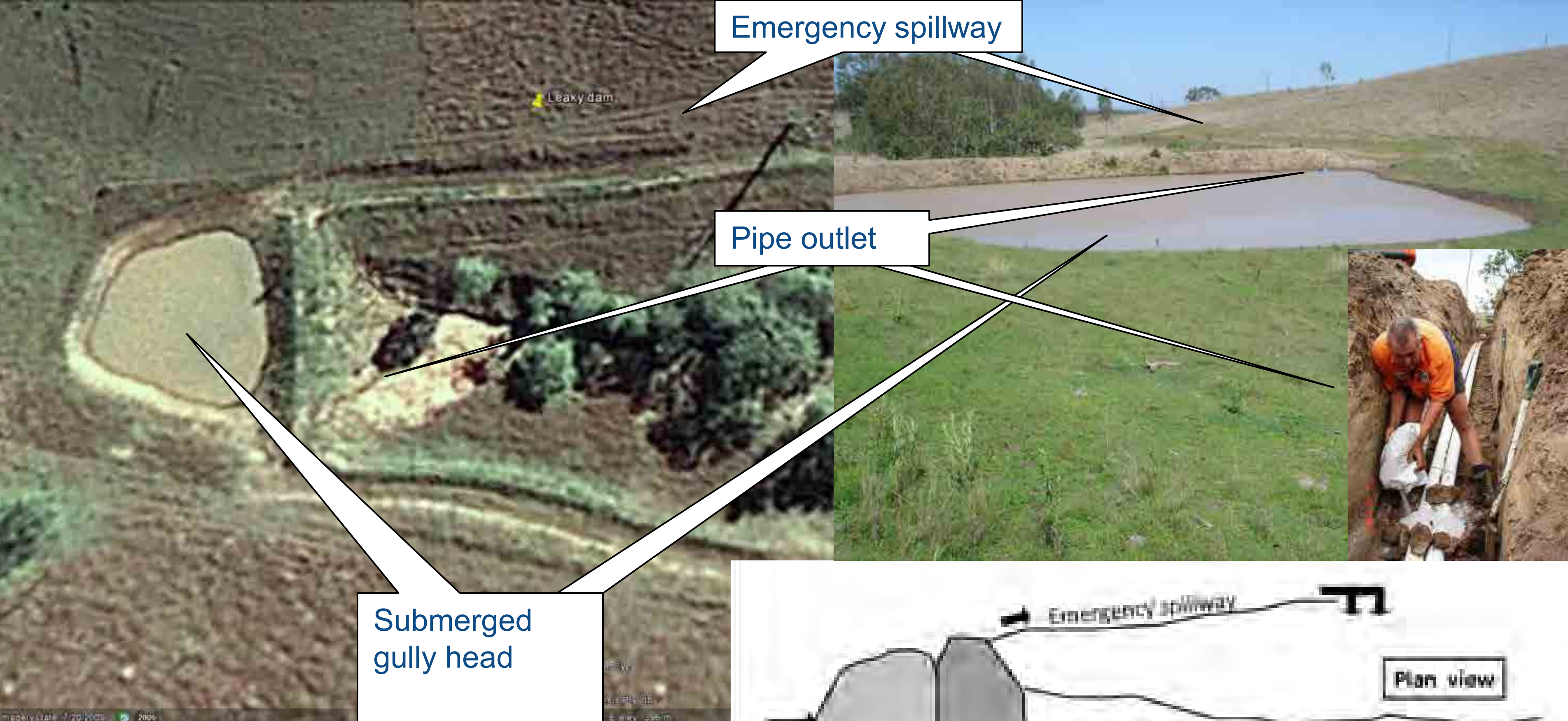


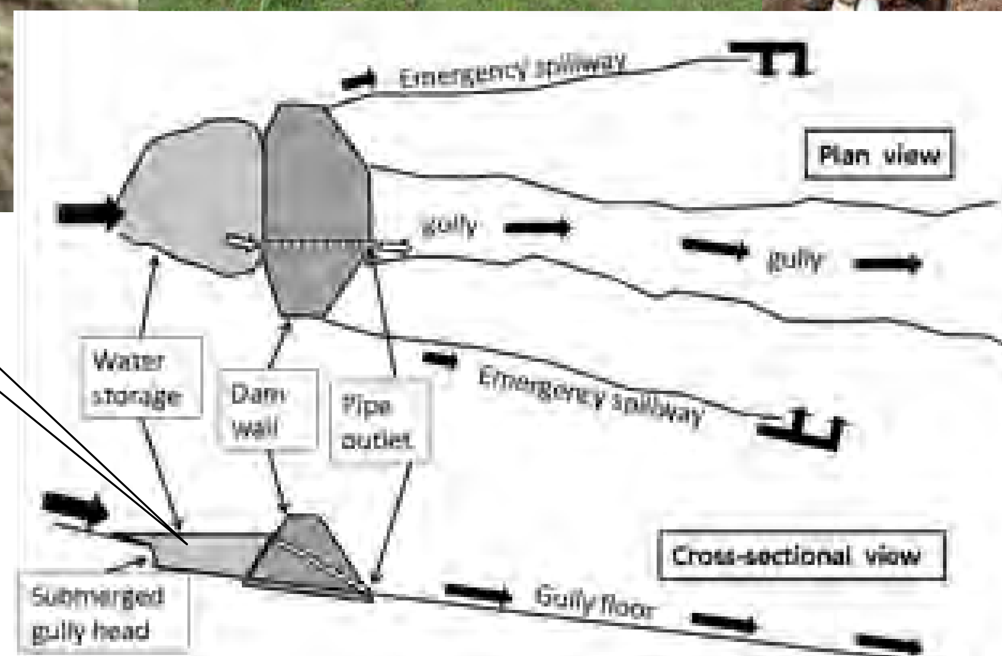


Runoff always follows the least line of resistance. It prefers to run around an obstruction rather than to pass through it

A gully control structure made from concrete filled sandbags under flow conditions in the Miles district (1980s photo)

SEQ Catchments trial project to use a 'leaky dam' for controlling a gully head in dispersive soils in the Wivenhoe dam project





SEQ Catchments project to use a 'leaky dam' for controlling a gully head in dispersive soils

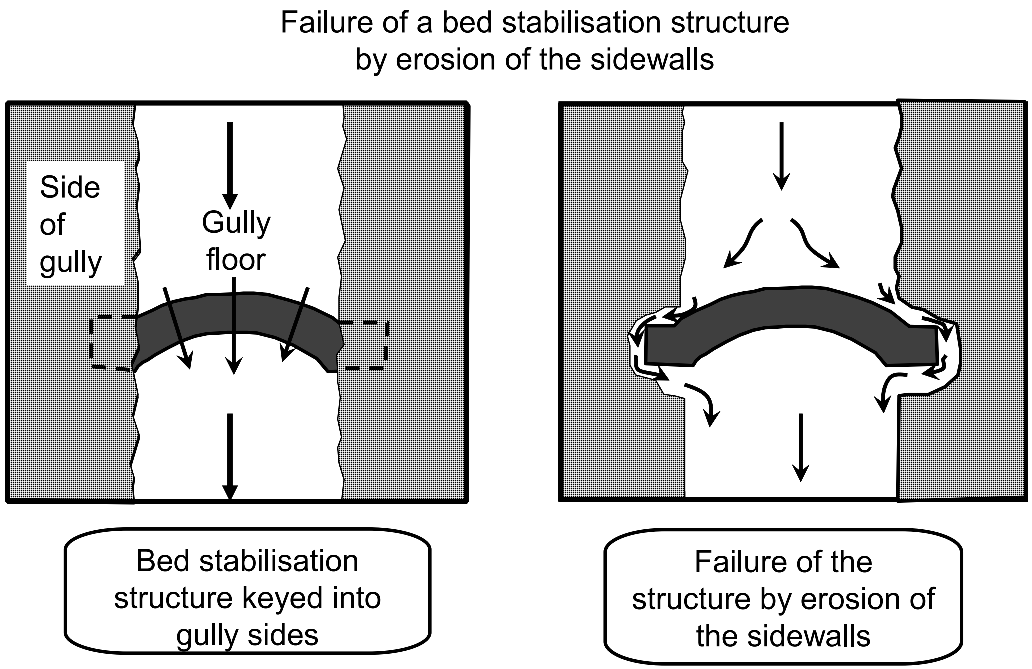
Low weirs in gully floors can be a relatively low cost option to encourage sediment deposition and vegetation growth

Sticks and small branches in wire netting secured to the gully floor by stakes

A weir constructed with recycled truck tyres with one sidewall removed

Dispersive soils present many challenges when building gully control structures. These photos show how a structure failed in the Mareeba district (1970s photos)

Weirs for gully control can fail despite being keyed into the dispersive soils on the gully sides.



Failure of a weir made of sheet steel

Understanding dispersive soils
Part B contents ⮌

Using dispersive soils in agriculture

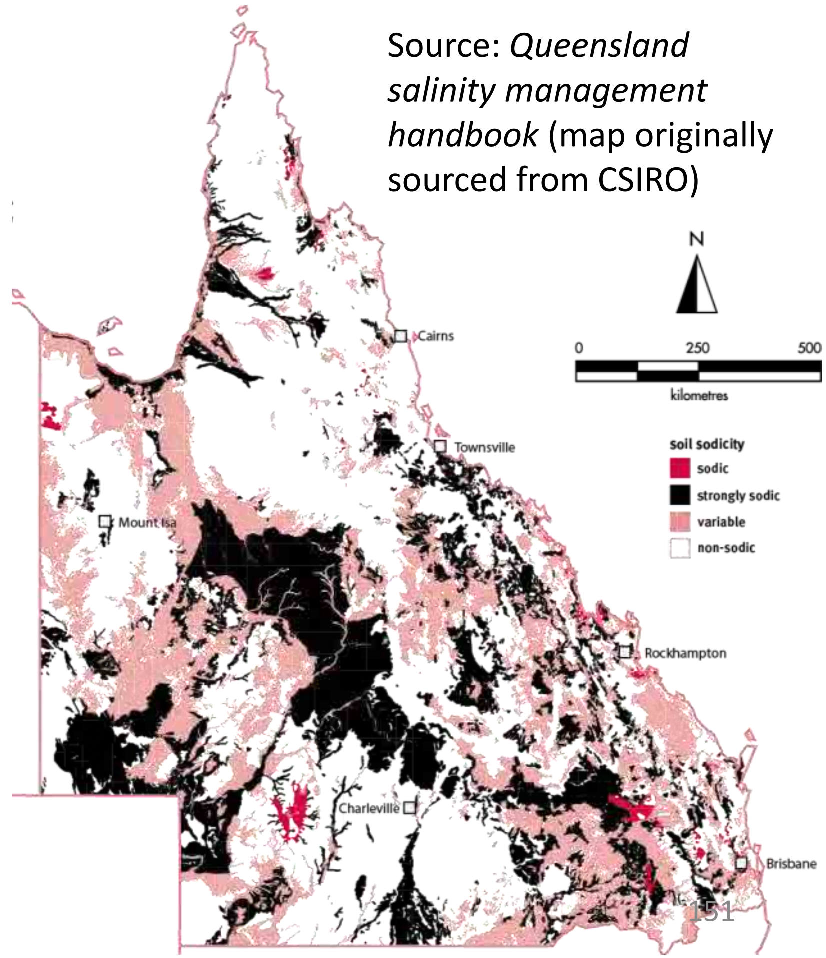
A case study on dispersive soils

Some texts refer to soil sodicity as a common and costly form of land degradation. But it is a natural feature of our soils that affects up to 45% of the total area of Queensland . With careful management, most of these soils are suitable for grazing. Some sodic soils are also suitable for cropping

The use of irrigation water with sodic properties, can lead to sodicity, but only 0.7% of Queensland is irrigated and only a small component of this is affected by sodic irrigation water.

Dispersive soils with thin layers of topsoil have low agricultural value but they support a range of native vegetation ecosystems, including very large trees.

Cypress pine, bull-oak and ironbark forest in the Miles district. Source:Understanding and Managing Soils in the Murilla, Tara and Chinchilla Shires



Source: *Queensland salinity management handbook* (map originally sourced from CSIRO)

Dispersive soils in grazing lands

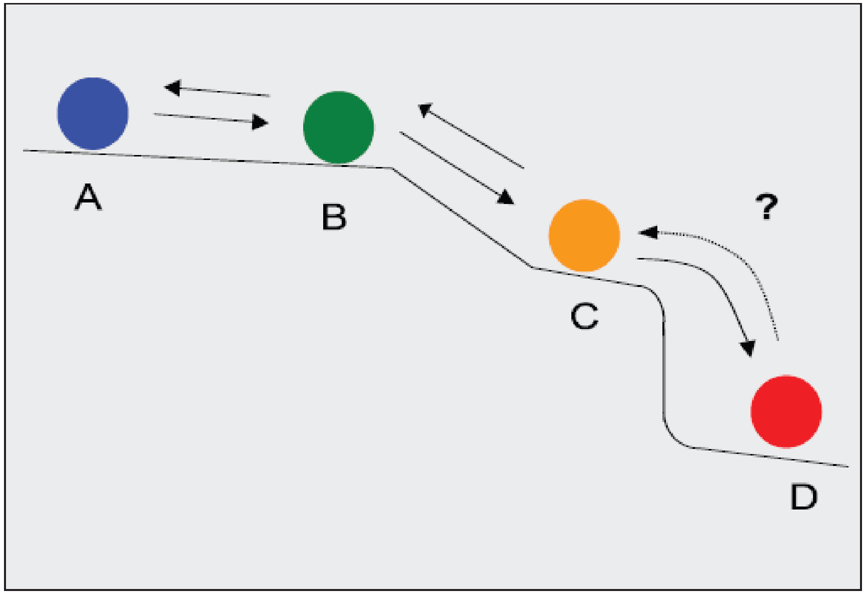
Soils with dispersive properties are used widely for the grazing of native pastures in Queensland. Many are 'texture contrast' or 'duplex' soils with an infertile, light textured topsoil and an abrupt change to a dispersive clay subsoil.

These soils are suitable for grazing provided stocking rates are carefully managed. If ground cover levels are insufficient, they are vulnerable to soil erosion including gully and wind erosion.
Although they are dispersive and have low fertility, there is virtually no use of chemical amendments or fertilisers in extensive grazing lands as these practices are not economically viable.

Dispersive subsoils may show short term benefits from deep ripping but any gains will soon be lost as the soil returns to its original nature.

For more information on grazing management, check the 2011 Queensland Government publication *Managing grazing lands in Queensland*
http://www.dnrm.qld.gov.au/__data/assets/pdf_file/0019/110476/managing-grazing-lands-qld.pdf

Assessing the condition of grazing land



The Rolling Ball concept of land condition

(Adapted from Quirk and McIvor 2003)

UNDERSTANDING THE ABCD FRAMEWORK

The rolling ball concept of land condition is useful for understanding the ABCD land condition framework. The text below has been summarised from the Meat and Livestock Australia EDGE*network*® Grazing Land Management (GLM) Technical Manual (Quirk and McIvor 2003).

Land in A condition is fairly stable. Land trending towards B condition can quickly revert back to A condition with a change in management. Yet, land in B condition is susceptible to a quick decline to C condition. Reversing C condition to B condition may require a more significant change in management. Land in C condition is susceptible to rapidly falling into D condition. D condition will not simply revert back to C condition with a change in management, at least not in time-frames of practical interest. Normally reversing D condition will require major management action (e.g. mechanical or chemical); this is represented by the ball having 'fallen off' a steep gradient.

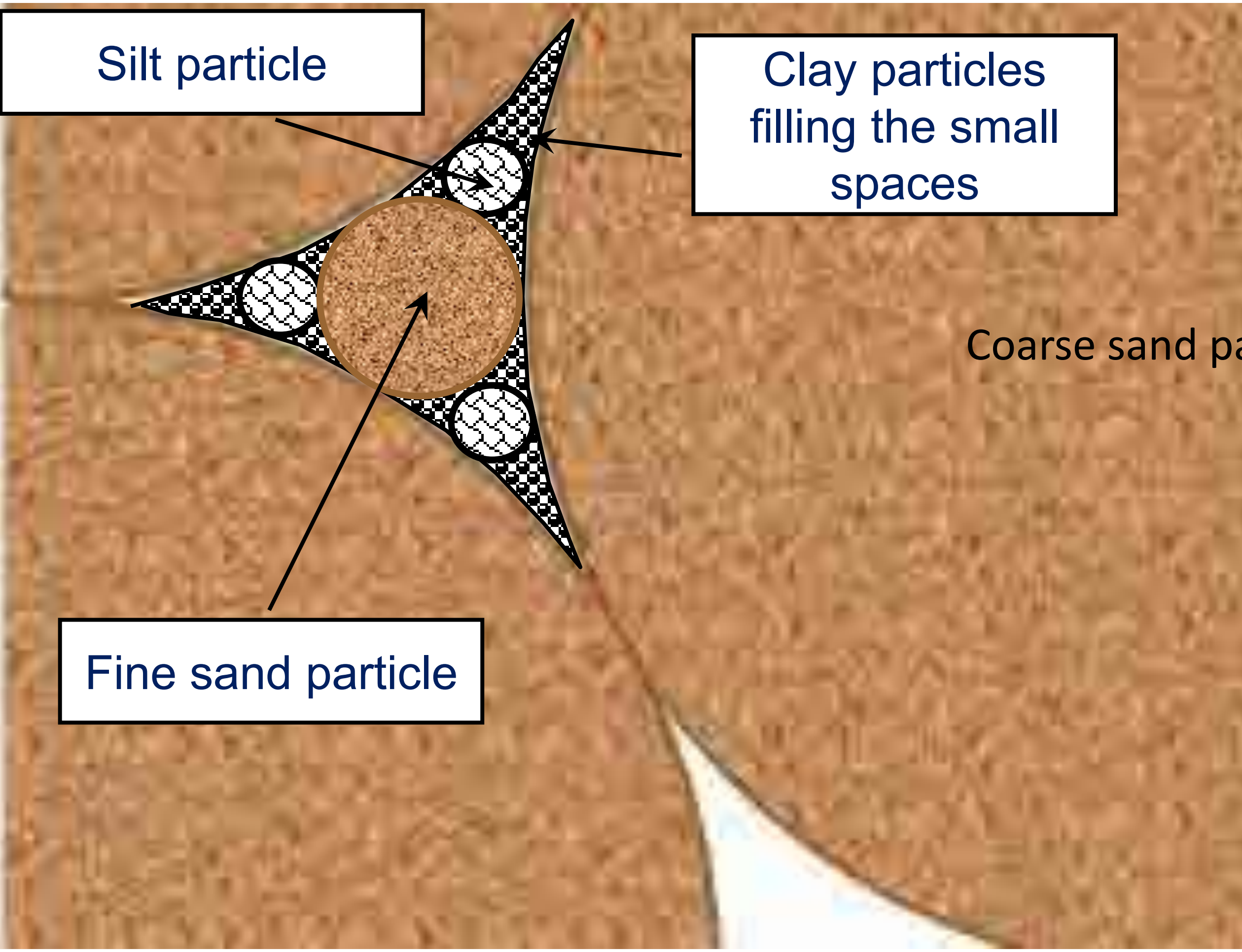
Source: *Land condition photo standards for the Burdekin dry tropics range lands – a guide for practitioners*

Grazing land in condition D, has often lost its topsoil. The exposed subsoils have very low fertility and are very prone to erosion. Even in good condition, this land has very little economic value. It is difficult to justify the high costs associated with the rehabilitation of land in condition D.

A compost blanket might be an option but its costs are prohibitive on land of this value.

Hardsetting

Following slaking and dispersion, individual soil particles of clay, silt and sand can pack down to a high density and then dry to form a hardsetting tightly packed structure.



	Diameter	Average Diameter
clay	< 0.002 mm	0.001 mm
silt	0.002 – 0.02 mm	0.01 mm
sand	0.2 – 2.0 mm	1 mm

Based on Figure E2-3 *SoilPak for Cotton Growers* – Third edition

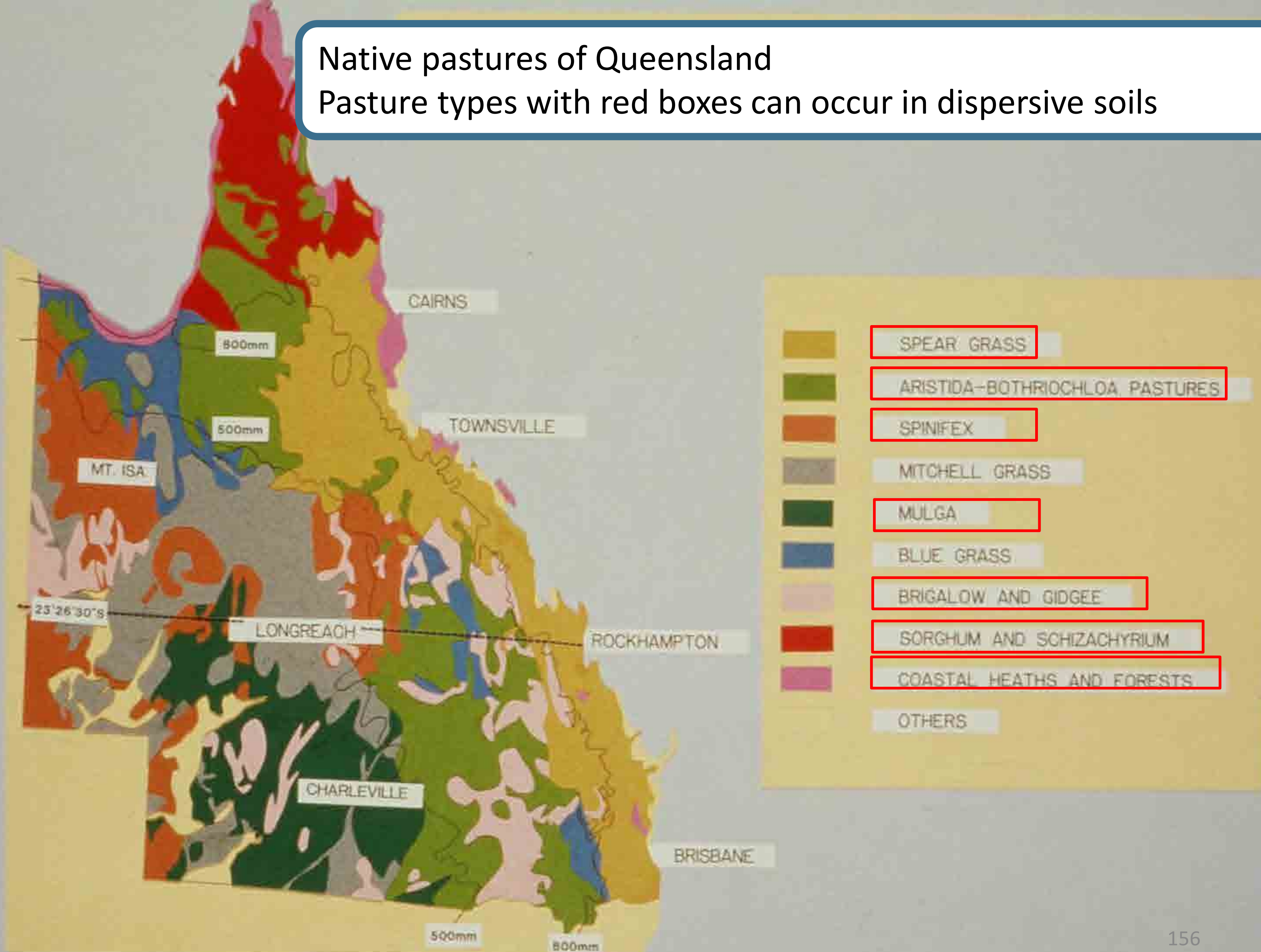
Impacts of slaking – surface sealing on clay pans results in the formation of hard surface crusts on drying, limiting seedling emergence and water infiltration

The hard, bare surface of a clay pan in the Roma – Mitchell area

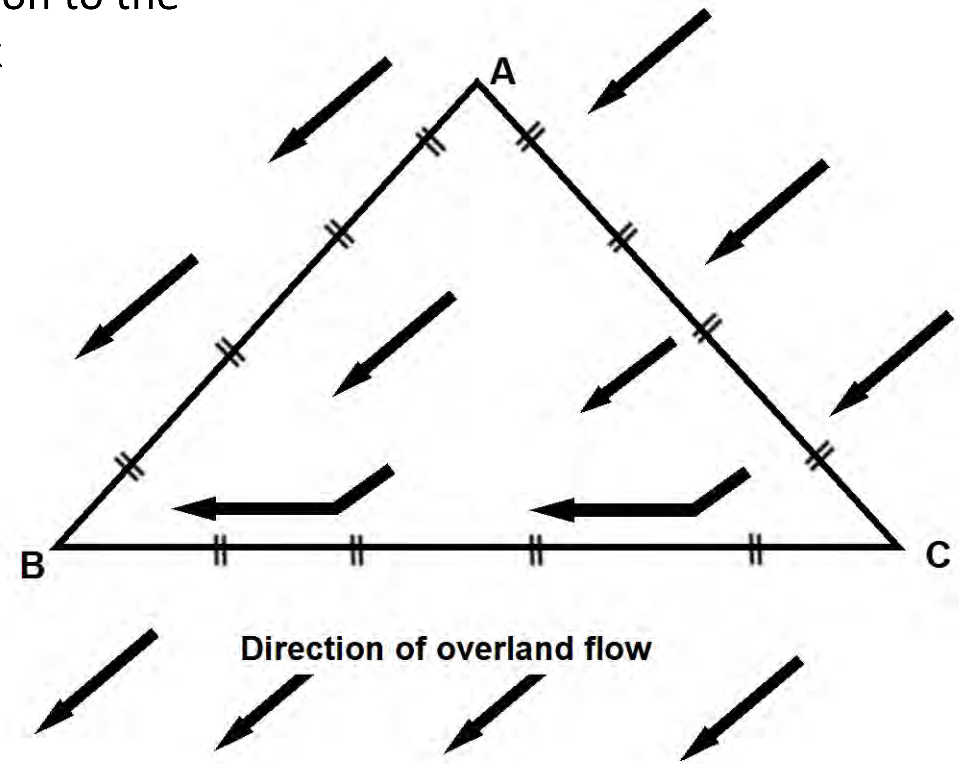
A one cm layer of firmly packed fine sand/silt at the surface, underlain by aero-bar like bubbles.

A hard, fine, sand/silt layer at the surface, with better structured soil underneath.

Native pastures of Queensland
Pasture types with red boxes can occur in dispersive soils



The orientation of fence lines in relation to the topography can create an erosion risk



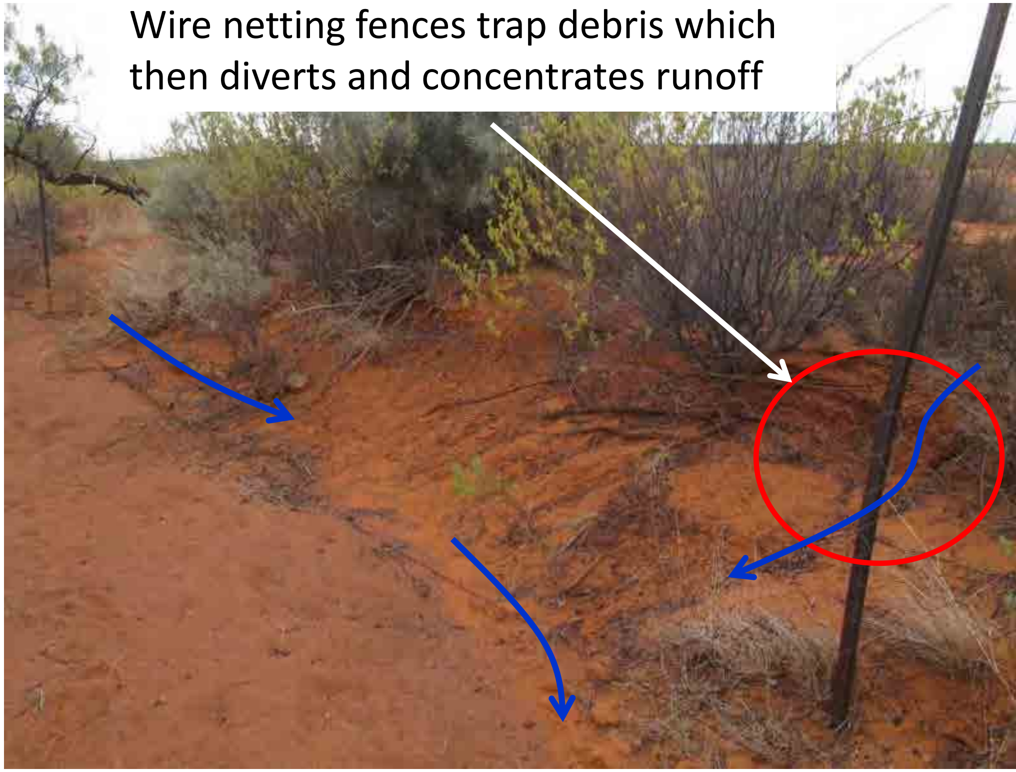
Section A-C is on the contour and, provided there were no obstructions to flow, runoff would flow safely across the fence line.

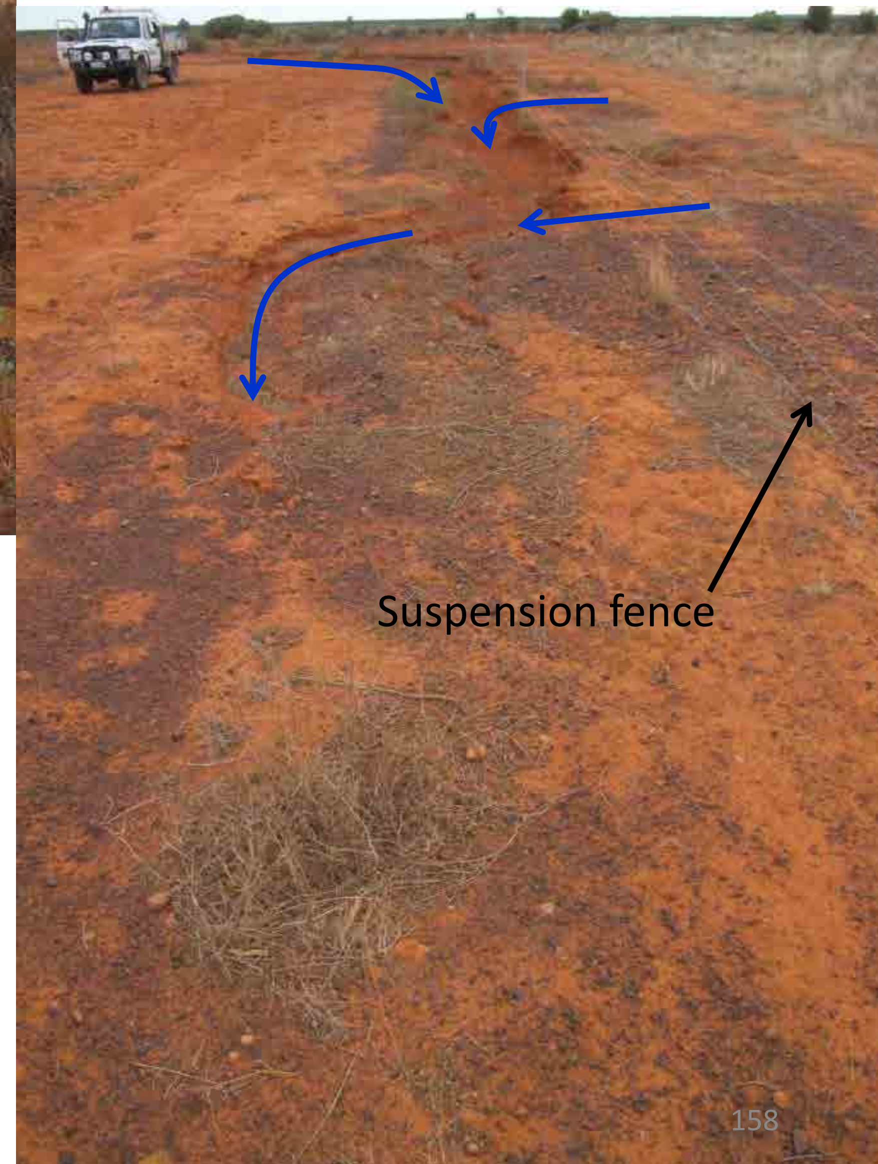
Section A-B is directly up and down the slope, with runoff parallel to the fence. If the slope was steep, any roads or cattle pads along the fence would require whoa-boys or diversion banks to divert runoff from the fence line. Ridge lines run directly up and down slope and are ideal locations for fences.

Section B-C has the greatest potential to intercept and concentrate overland flows. The erosion risk

Wire netting fences have the greatest potential to divert and concentrate runoff

Photos taken at Eromanga, south-west Queensland by Rob Savory



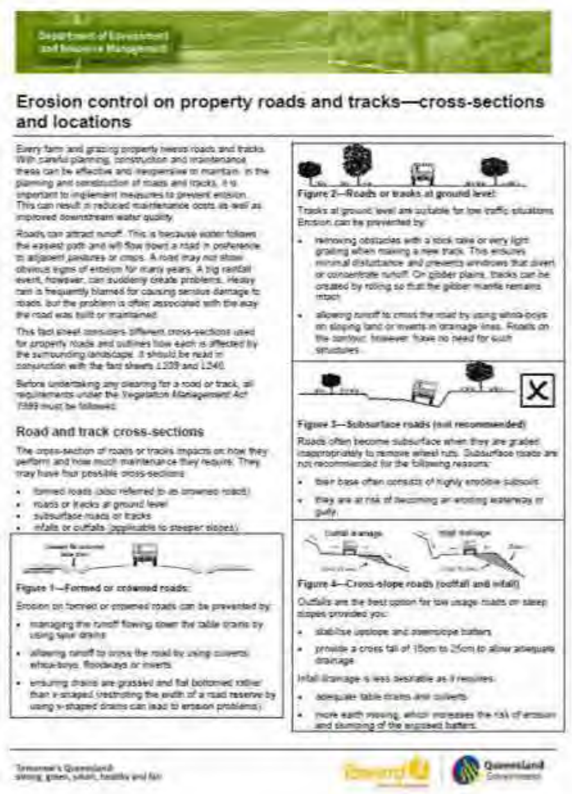


Wire netting fence lines are especially vulnerable to erosion because they readily divert run-off. However, this replacement suspension fence built parallel to the old netting fence is also suffering from erosion damage in these dispersive soils

Tracks and cattle pads, parallel to fences can concentrate runoff and cause serious erosion, especially in dispersive soils

Photo:Jenny Milson DAFF Longreach

Queensland Government fact sheets on erosion control on roads, tracks and fences



Department of Environment and Resource Management

Erosion control on property roads and tracks—cross-sections and locations

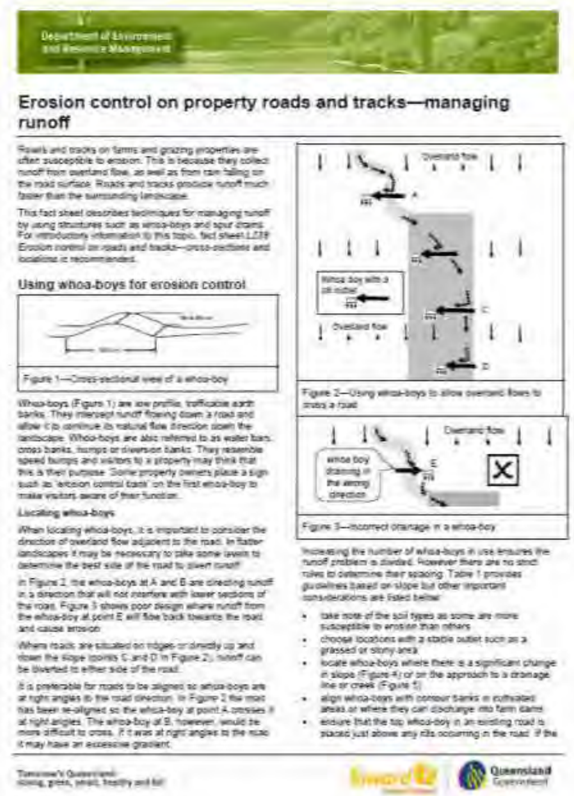
Road and track cross-sections

Figure 1—Formed or crowned roads

Figure 2—Roads or tracks at ground level

Figure 3—Subsurface roads (not recommended)

Figure 4—Cross-slope roads (outfall and infall)



Department of Environment and Resource Management

Erosion control on property roads and tracks—managing runoff

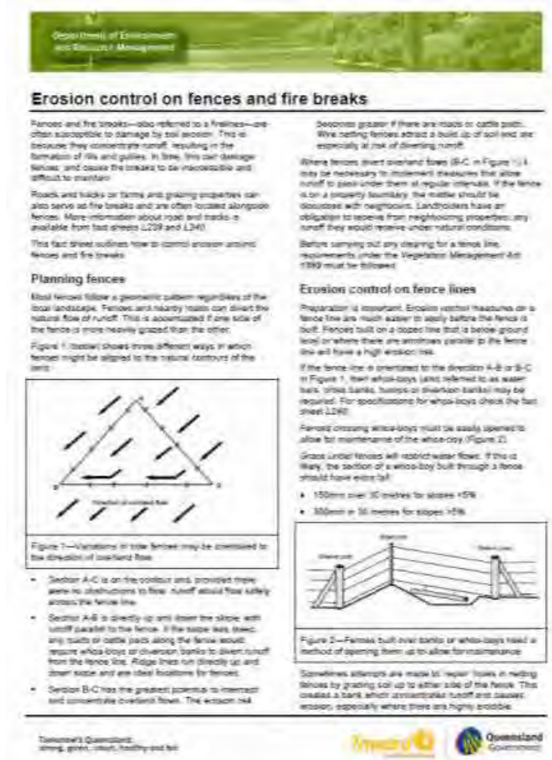
Using whoa-boys for erosion control

Figure 1—Cross-sectional view of a whoa-boy

Locating whoa-boys

Figure 2—Using whoa-boys to allow overland flows to cross a road

Figure 3—Incorrect drainage in a whoa-boy



Department of Environment and Resource Management

Erosion control on fences and fire breaks

Planning fences

Erosion control on fence lines

http://www.derm.qld.gov.au/factsheets/pdf/land/l239.pdf

http://www.derm.qld.gov.au/factsheets/pdf/land/l240.pdf

http://www.derm.qld.gov.au/factsheets/pdf/land/l241.pdf

Use of dispersive soils for cropping

Soils with dispersive properties that are suitable for cropping with appropriate management include:

- duplex soils with a thick layer of light textured topsoil with an abrupt change to a dispersive subsoil (soils with thin layers of topsoil are unsuitable for cropping)
- soils with a clay texture throughout the profile – both their topsoils and subsoils can be dispersive. Examples include some soils in the Brigalow belt.

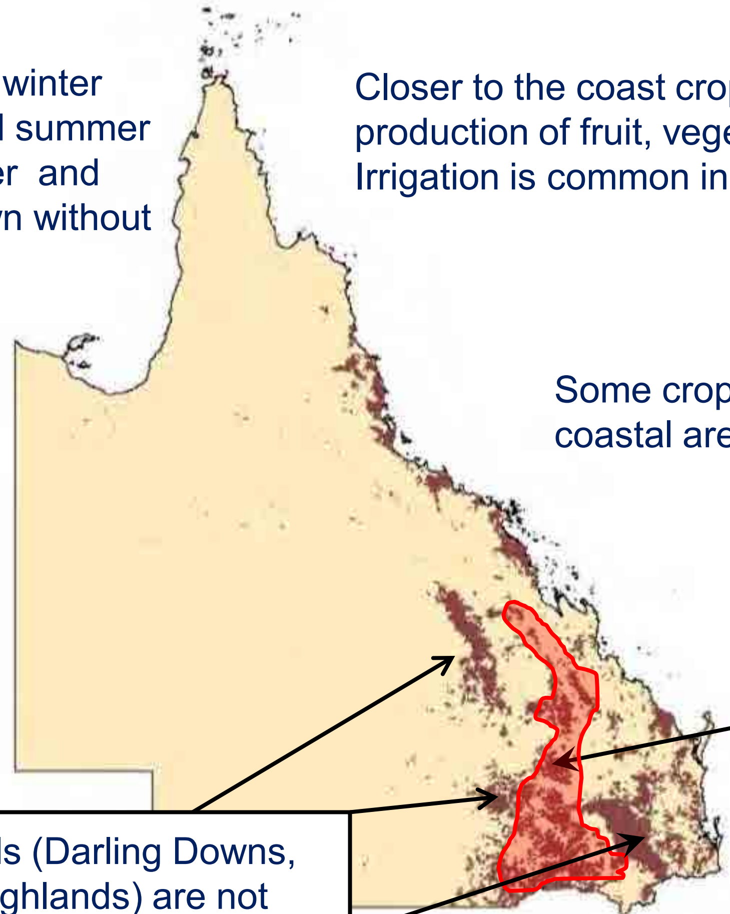
Duplex dispersive soils can have the following limitations for cropping:

- dispersive topsoils can have poor structure. They can seal readily and have low rates of seed germination and establishment.
- subsoils can be dense with low rates of permeability and poor subsoil drainage.
- vulnerable to soil erosion.

Map showing where crops are grown in Queensland (2.5% of the state or around 4.3 million ha)

Inland cropping areas are used for growing winter crops (eg wheat, barley and chickpeas) and summer crops (eg sorghum, maize, cotton, sunflower and mung beans). Most of these crops are grown without irrigation (cotton is usually irrigated).

Closer to the coast cropped land is used for the production of fruit, vegetables and sugar cane. Irrigation is common in these areas



Some cropping soils in coastal areas are dispersive

The grey and brown clay soils of the brigalow belt and some 'Poplar Box' soils on the Darling Downs usually have dispersive properties but they are generally suitable for cropping

The black, 'Open downs' clay soils (Darling Downs, West of Roma and the Central Highlands) are not dispersive and are very suitable for cropping

While cultivated areas in Queensland are at serous risk from erosion by water, most are not at significant risk from wind erosion. However some clay soils, that also contain sand, can be eroded by wind after heavy rainfall. This phenomenon has been observed in the dispersive soils of the Brigalow Belt.

Raindrop impact may 'flatten' a bare soil and leave sand particles on the soil surface. When the soil dries out, the sand particles on the smooth surface can be removed by the strong westerly winds that often follow rainfall events. Roughening the surface by cultivation will reduce the immediate threat. However the best solution is to maintain stubble cover using practices such as zero tillage or reduced tillage. Stubble protects the soil from both water and wind erosion.

1980s photo

Hardsetting

Factors affecting the hardsetting potential of a soil include:

- the particle-size distribution (relative amounts of clay, silt and sand)
- the type of clay minerals in the soil
- the dispersibility of the soil
- the organic matter content
- the presence of cementing or stabilising materials.

Kaolinite and/or illite clay minerals are susceptible to hardsetting. They have minimal swelling when they absorb water. This prevents a hardset soil from repairing itself quickly.

Smectite (montmorillinite) clays swell and shrink allowing the soil to regenerate if hardsetting was to occur.

Source: *Soil pak for cotton growers* – Third edition
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0020/167501/soilpak-cotton-Part-E.pdf

Using gypsum to improve soil structure in dispersive soils used for cropping

Gypsum (calcium sulfate) can be used to reduce the effects of soil dispersion. It acts by displacing sodium with calcium within the clay structure leading to the binding together (flocculation) of the clay particles. Gypsum also reduces dispersion by increasing the electrolyte concentration in the soil solution. Gypsum is sometimes promoted as a ‘clay breaker’. While it can improve the structure of sodic clay soils, it is not likely to improve the structure of non-sodic clays, or soils with small amounts of clay.

When soils respond to gypsum, they have increased surface friability, better seedling emergence and plant growth, less power is needed for tillage, improved infiltration, better drainage and less water logging.

As well as being a soil conditioner, gypsum can be a fertiliser by providing both sulfur and calcium for plant growth. While sulfur deficiencies occur in Queensland cropping soils, calcium is a rarer deficiency that may occur in acid soils of low cation exchange capacity.

As gypsum is only sparingly soluble, its mode of action depends on how fine it is. Fineness varies with the source of gypsum which can be a product of mining or a manufacturing process.

An example of where gypsum is used is on the Cecilvale land type on the Darling Downs. This alkaline grey clay originally grew Poplar Box vegetation and exhibits a number of problems associated with soil dispersion.

Agricultural lime (calcium carbonate) is insoluble in alkaline conditions and would be unsuitable for controlling dispersion in this situation. If an acid soils was dispersive, lime could be used to increase the pH. It would have some benefit in reducing dispersion because it becomes more soluble under acid conditions. In acid dispersive soils a lime/gypsum mix could also be used.

Laboratory tests can determine the theoretical amount of gypsum required to reduce the dispersive properties of a given layer of soil in the profile. The calculated rates are frequently very high and may exceed 10 tonnes/ha. An option is to apply several applications of around 5 tonnes of gypsum per hectare over a period of years. Test strips using various rates of gypsum are also recommended. As gypsum is slowly soluble, its effects may be slow to develop. A rate of 5 t/ha of gypsum would require around 200 mm of rain for dissolution (Landloch)

A dispersive soil with poor structure

A gypsum application of 10 tonnes/ha has alleviated the affects of dispersion and greatly improved soil quality

CSIRO Land and Water information is being migrated to the CSIRO.au website.

View the new website: www.csiro.au/clw

Legacy Links

- Publications
- Technologies and Products

Gypsy

Discounted cash flow analysis for application of gypsum to sodic soils under sugarcane

Gypsy is a computer program designed to help Australian sugarcane growers make decisions on what rates of gypsum to apply to sodic soils. It is intended for use by advisory staff and growers, and should be used together with the CRC Sugar Technical Publications *Diagnosis and Management of Sodic Soils under Sugarcane*, and where necessary, the *Field Guide for Diagnosis of Sodic Soils in the Australian Sugar Industry*.

Download Gypsy Manual	Downloadable Material
Version 1.5 (PDF, 297 KB)	Download Gypsy (2.7 MB)

For further information, contact Paul Nelson (James Cook University and Dept. of Natural Resources & Mines)

Partners

- CRC Sugar
- The Bureau of Sugar Experiment Stations

Irrigation and dispersive soils

As well as being a natural feature of soils, dispersion may be induced by sodium salts in irrigation water. Groundwater is likely to have higher levels of salts than surface water. The amount and type of salts in groundwater depends on the type of strata it was stored in.

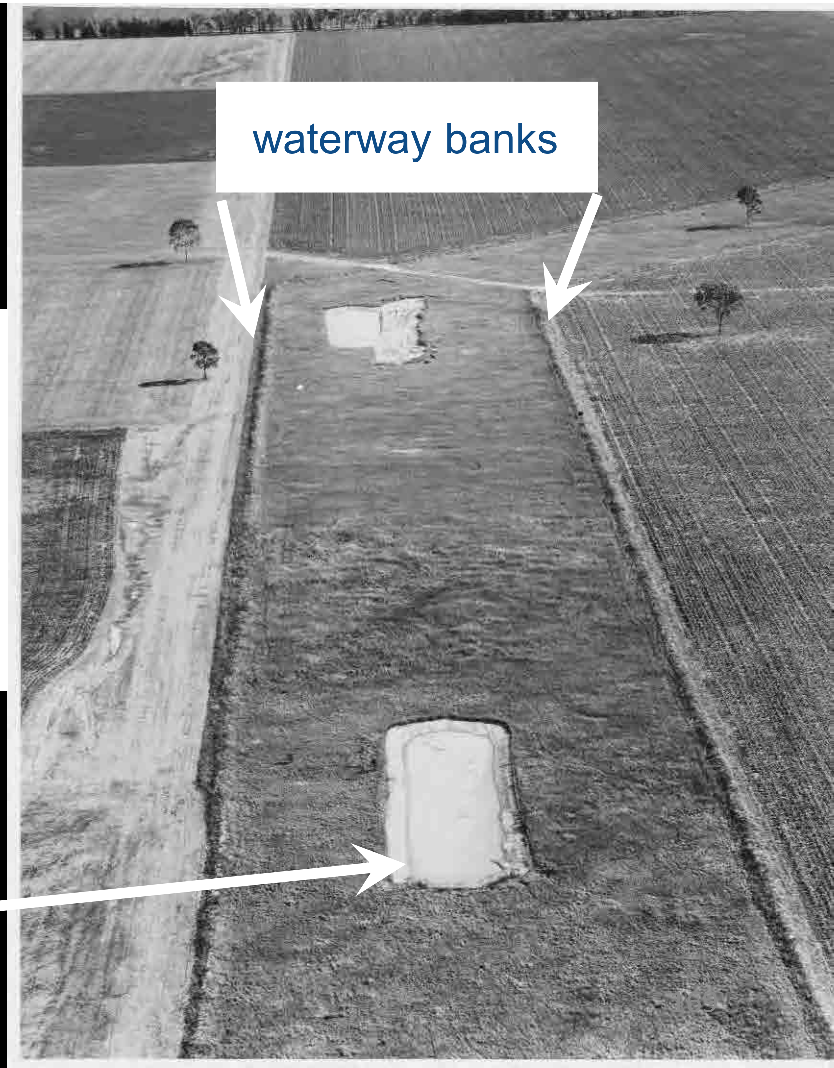
The level of sodium in water is measured by the sodium adsorption ratio (SAR). The SAR level can be reduced by adding calcium salts such as gypsum to the water. Dissolved gypsum will also prevent dispersion by increasing the electrolyte content of the water .As gypsum is sparingly soluble, it needs to be very fine to dissolve. Agitators in the mixing tank will assist.

Water from the Great Artesian Basin and that extracted from coal seams can have high levels of salts including sodium salts. This water requires treatment before it is suitable for irrigation. The treatment can involve the lowering of the salt level by osmosis and the reduction in sodium ions by treatment with gypsum.

Instead of applying gypsum to the irrigation water another option may be to apply regular amounts of gypsum to the soil.

Dispersive subsoils can erode after being exposed by waterway construction

Grassed waterway in the Millmerran district



An alternative method of waterway construction was trialled in the Millmerran district in the 1980s to avoid the need to use topsoil to construct the waterway banks. The banks were built from dispersive soil removed from borrow pits by a scraper. The banks were then covered with topsoil and planted with grass. The grass in the channel of the waterway was not disturbed.

Borrow pit used to extract dispersive soil for use in constructing the banks of the waterway

Tunnel erosion – management on agricultural land

- establish a vegetative cover of both trees and pasture to prevent exposure of bare soil, to increase infiltration and to increase soil water use
- avoid the removal of trees close to existing gullies or cuttings
- deep ripping can be used to break up tunnel systems, where tunnels are shallower than the ripped layer of soil
- consider using amendments such as gypsum.

Deep ripping breaks up tunnel systems to encourage even infiltration of rainfall

Other sources of information on the use of dispersive soils in agriculture

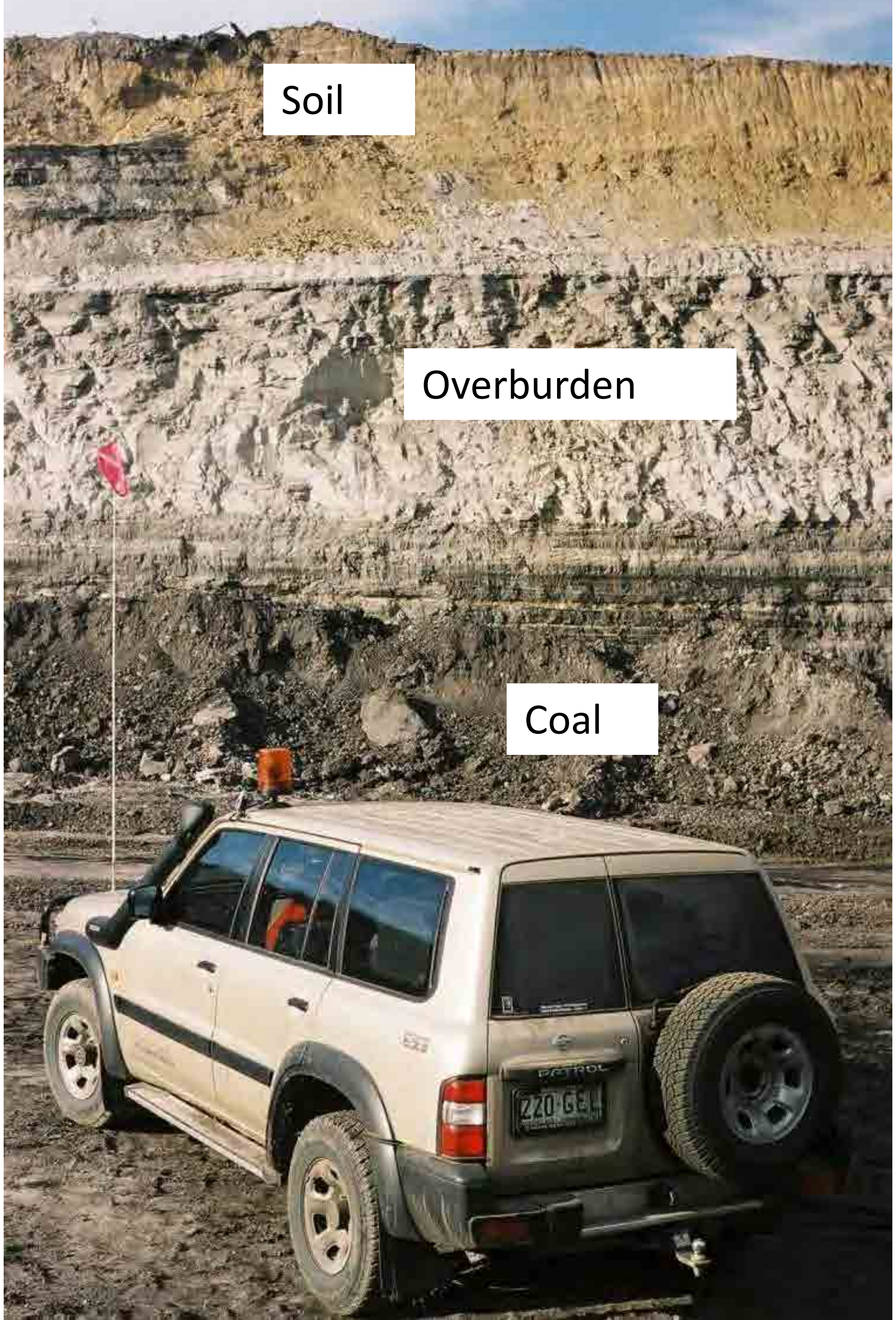
- *Diagnosis and management of Sodic Soils under Sugarcane*, Edited by PN Nelson, CRC Sugar Technical Publication 2001

- *Identifying, understanding and managing hostile subsoils for cropping - A reference manual for neutral-alkaline soils of south-eastern Australia* http://vro.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_mgmt_subsoil

Understanding dispersive soils
Part B contents ⮌

Dispersive soils and **mining**

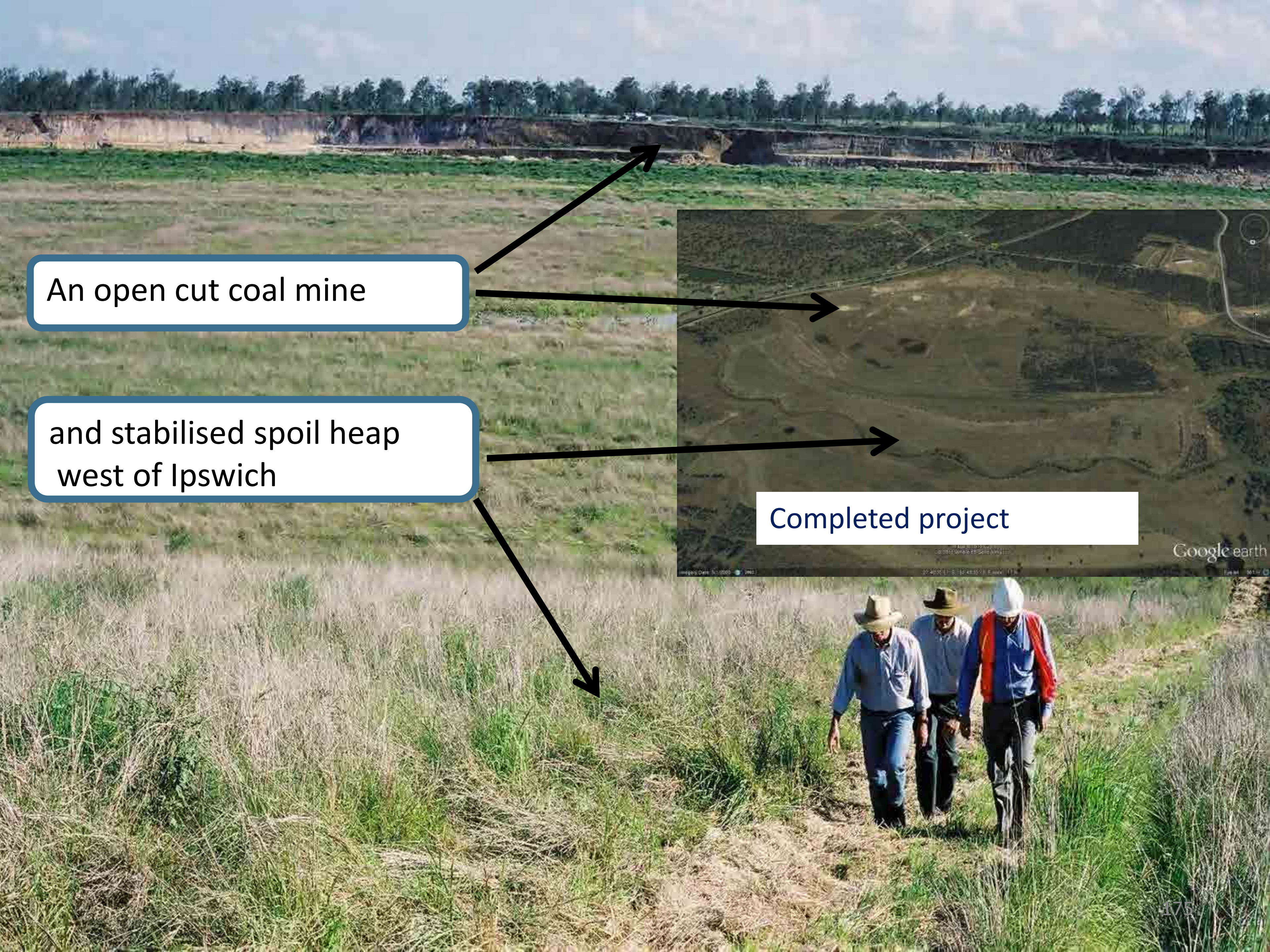
A case study on dispersive soils



Open cut mining

In open-cut mining, topsoil and overburden (spoil) are excavated separately to gain access to the strata containing the required mineral.

Overburden is moved to an adjacent spoil heap (or waste dump) and later shaped into a suitable profile. Topsoil is spread over the spoil, prior to planting vegetation to stabilise the spoil heap.


An open cut coal mine
and stabilised spoil heap
west of Ipswich
Completed project
Google earth

Open cut mining and dispersive soils

Dispersive soils are common in spoil heaps and can lead to high rates of erosion. Tunnel development can go unnoticed until the roof of the tunnels collapse causing gullies to develop.   Runoff management structures such as banks or drains on the batters of steep spoil heaps can fail and discharge concentrated flows onto the slopes below causing further severe erosion. Such erosion systems are unlikely to stabilise and the high rates of erosion can continue indefinitely.

Tunnel and gully erosion in a bank constructed in dispersive soils on a steep-sided spoil dump

Source: Identification and management of dispersive mine spoils 2004 (C Vacher, R Loch and S Raine), Australian centre for Mining Environmental Research

Banks on very steep slopes are not recommended. They have very little capacity and their construction can initiate erosion by increasing the slope leading into the bank. Runoff flowing along the drain will cause erosion and ponding at low points in the drain will lead to tunnel and gully erosion and bank failure.

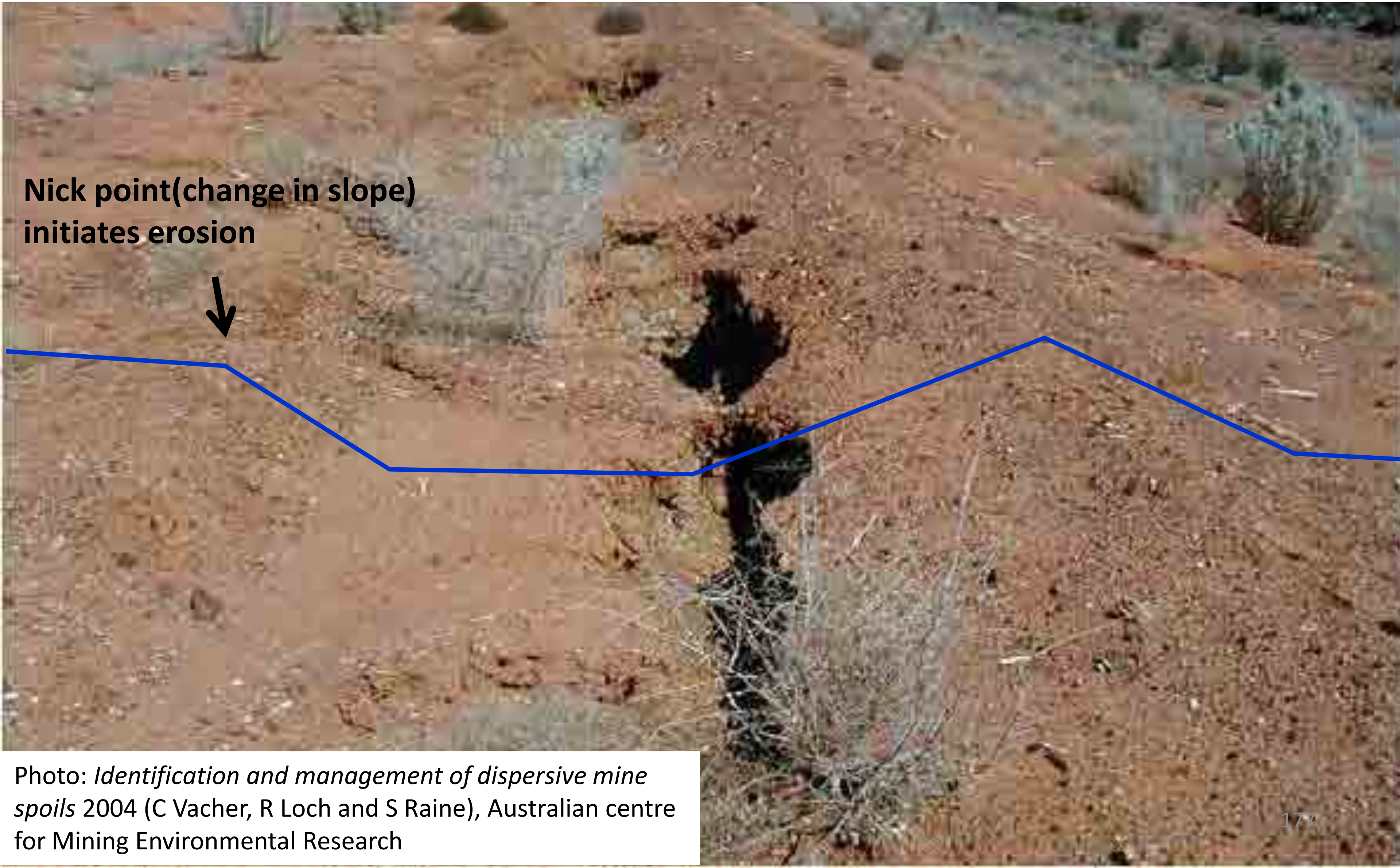
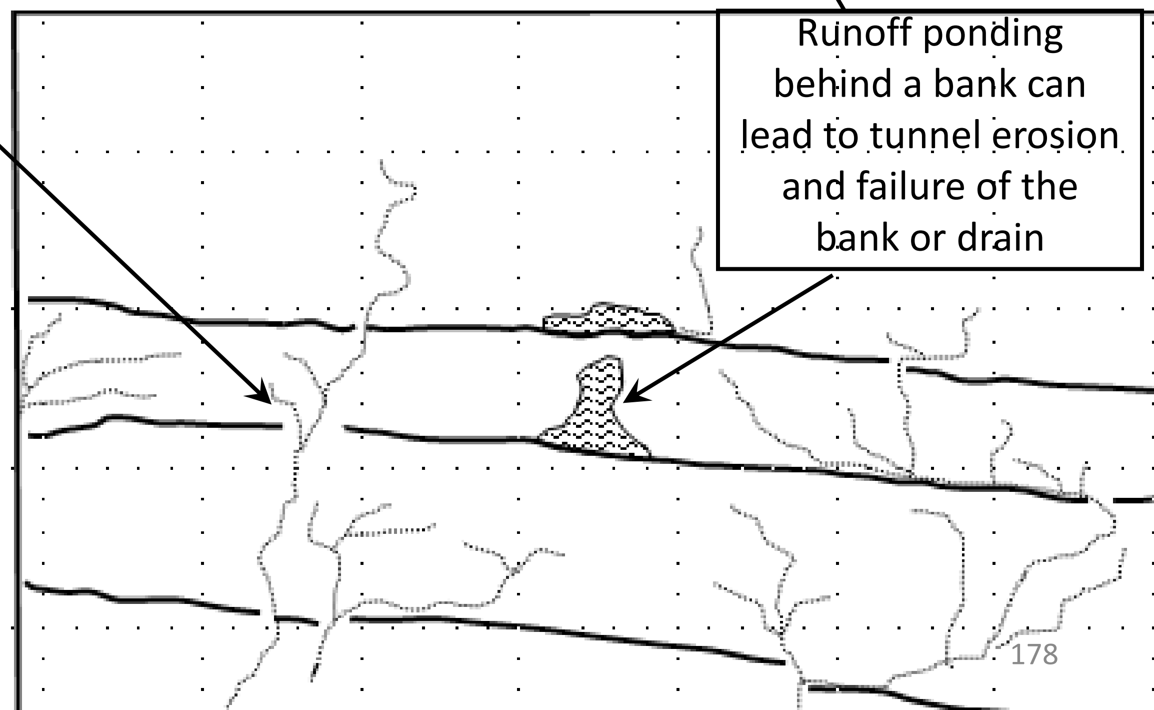


Photo: *Identification and management of dispersive mine spoils* 2004 (C Vacher, R Loch and S Raine), Australian centre for Mining Environmental Research

An un-rehabilitated spoil dump with dispersive soils

Tunnel and gully erosion associated with banks constructed across a steep batter on an un-rehabilitated mine spoil with dispersive soils



Materials in spoil heaps susceptible to tunnelling

- Sodic materials that are non-saline are dispersive and susceptible to tunnel erosion as soon as they are placed on the spoil site. Cracking of the dispersive clay soils can occur as a result of seasonal wet and dry periods as well as by surface water ponding. Cracks can lead to rapid infiltration, super-saturation of a dispersive subsurface layer and tunnel erosion.

- Sodic materials that are saline will not disperse while the soil remains saline. However, leaching can remove the salt and make the soil dispersive and prone to tunnel and gully formation.

- Soils with fine, non-sodic materials of low cohesion are not dispersive but they act like dispersive soils. Tunnelling can occur as a result of soil liquefaction in materials dominated by silt and fine sand components. Unlike clay particles, these materials carry few electric charges resulting in weak, inter-particle bonds and little cohesion. The weak bonds are readily destroyed by flowing water when the material is wet. Prolonged ponding of water on the surface can lead to liquefaction.

Assessments to determine the risk of tunnelling in spoil stockpiles

- Exchangeable sodium percentage (ESP) to assess sodicity and dispersion potential
- Electrical conductivity (EC) to assess potential for salinity to reduce the risk of dispersion
- Particle size distribution to provide an indication of soil cohesion and liquefaction contributing to tunnel formation/failure
- Clay mineralogy to determine the likelihood of swelling to occur.

Managing spoil heaps with dispersive soils to minimise erosion
Planning

- Strategies to prevent instability on spoil heaps are necessary for successful mine site stabilisation.
- Spoil heaps can contain a range of materials with different rates of infiltration and susceptibility to erosion. Each material should be identified so that it can be appropriately dealt with.
- Prevention is better than cure. Existing erosion and un-collapsed tunnels can make it difficult and dangerous for equipment to access spoil heaps to perform remedial works.

Managing spoil heaps with dispersive soils to minimise erosion

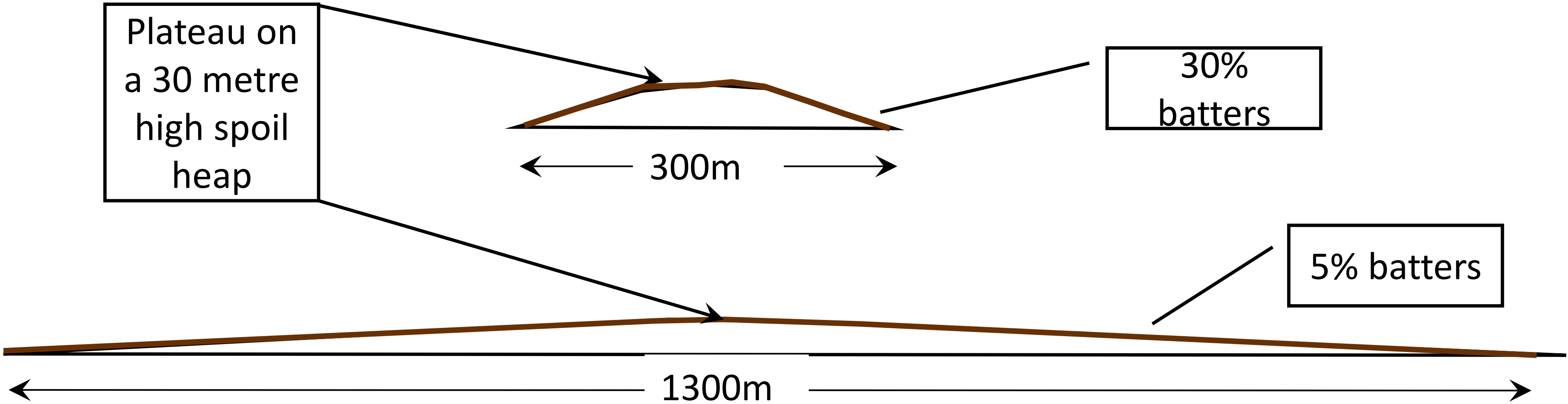
The plateau surface

- Structures or depressions that capture and pond runoff on the plateau surface can lead to
  - tunnel formation and gullying.
  - leaching of salts that can make a stable, saline-sodic soil become non saline and dispersive
  - liquefaction in fine textured, non sodic soils of low cohesion
- The larger the area delivering runoff to a single low point, the greater the potential for the above problems to occur.
- Topsoiling is essential before stabilisation with vegetation

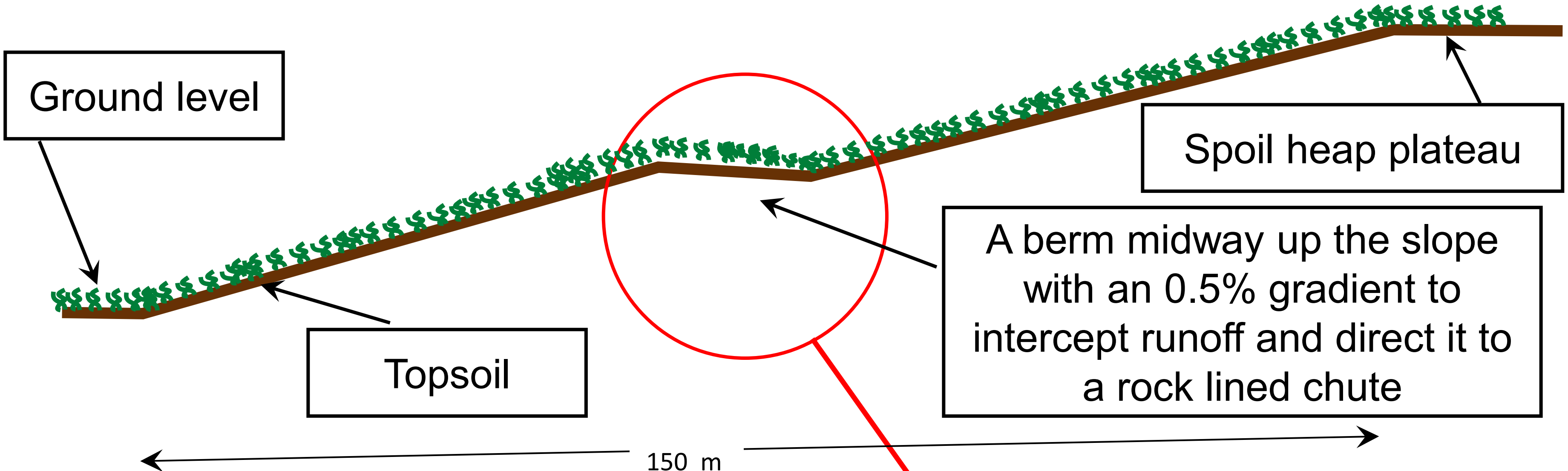
Managing spoil heaps with dispersive soils to minimise erosion

The sides (or batters) of the spoil heap

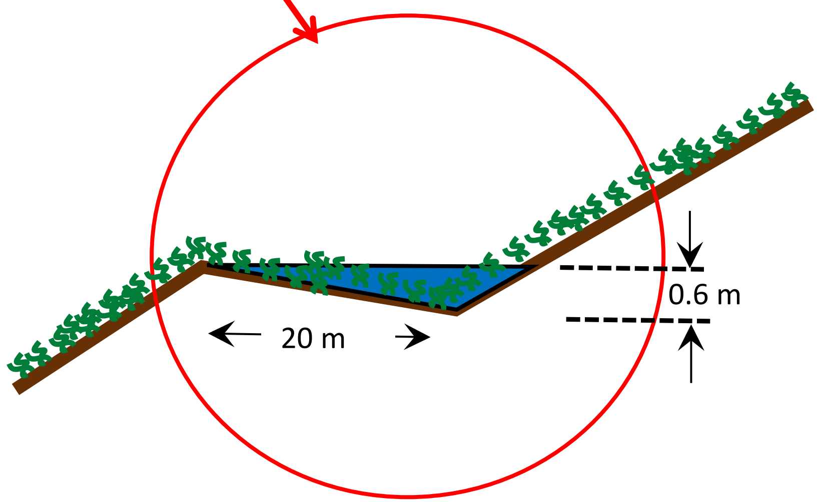
- Prior to rehabilitation, spoil stockpiles can have a natural angle of repose of greater than 40%
- When spoil heaps are reshaped, the lower the batter slope, the less risk of erosion and the heap will occupy a greater area of land. Most rehabilitated spoil slopes are less than 16%.
- Topsoiling is essential before stabilisation with vegetation



A possible alternative to the use of banks and drains could be to incorporate a mid-slope bench or berm on the batter during construction of the spoil heap. This approach has been used in non-dispersive soils and could work for dispersive soils. However any ponding in the drain could lead to tunnel erosion and failure of the drain.



A bench or berm constructed in this manner will have a relatively flat base to carry runoff and will have reasonable capacity.



Managing spoil heaps with dispersive soils to minimise erosion
Topsoiling and vegetating

- Vegetation is essential to stabilise mine spoil and provide protection from erosion.
- As spoil material is usually inhospitable to plant growth, a layer of topsoil needs to be added to the surface of the shaped spoil heap.
- Well vegetated topsoil allows for rain falling on the site to move into the surface layer and be held under tension in s(p)oil pores. High water holding capacity and plant growth in the surface layer will reduce potential deep drainage and leaching of any salts that might be present in deeper layers.
- A topsoil covering will also minimise the chance of cracks developing that may become pathways for water to enter the spoil and lead to tunnel development.
- Laboratory analysis may indicate the need for gypsum to reduce dispersivity of spoil material and improve its ability to support plant growth.

Adding topsoil to the spoil heap
(Source: Xstrata Coal)

A spoil heap after reshaping, topsoiling and vegetating

Some of the information in this case study has been sourced from the following references

- *Identification and management of dispersive mine spoils* 2004 (C Vacher, R Loch and S Raine), Australian centre for Mining Environmental Research

http://eprints.usq.edu.au/1311/1/Dispersive_spoils_report_final_June2004b.pdf

- *Strategies to reduce tunnelling on dispersive mine soil materials* 2004C.A. Vacher, S.R. Raine and R.J. Loch. ISCO 2004 - 13th International Soil Conservation Organisation Conference – Brisbane, July 2004

http://tucson.ars.ag.gov/isco/isco13/PAPERS%20R-Z/VACHER%202.pdf

[Understanding dispersive soils](#)
[Part B contents ⮌](#)

Roads and tracks and dispersive soils

A case study on dispersive soils

Dispersive soils are a common source of erosion on both main roads and property tracks.

Erosion causing severe damage to a road at a gate entry in dispersive soils south of Bogantungan, central Queensland (note the prismatic structure in the exposed subsoil)

Tracks for walking and trail bikes will erode when they concentrate runoff

Roads on dispersive soils are a common source of erosion on rural properties. This leads to untrafficable conditions, high maintenance costs and sediment moving downstream.

Roads attract runoff. Water takes the easiest path and will flow down a road in preference to adjacent pastures or crops. A road may not show obvious signs of erosion for many years until a big rainfall event suddenly creates problems.

Factors affecting the susceptibility of a property road to erosion include :

- The soil type (dispersive soils are most vulnerable)
- The type of road cross-section
- The location of the road in relation to the landscape

Possible road and track cross-sections

[From Queensland Government fact sheet L239 *Erosion control on property roads and tracks—cross-sections and locations*]

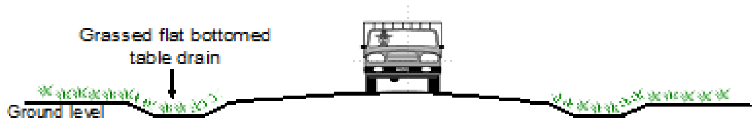


Figure 1—Formed or crowned roads:

Erosion on formed or crowned roads can be prevented by:

- managing the runoff flowing down the table drains by using spur drains
- allowing runoff to cross the road by using culverts, whoa-boys, floodways or inverts
- ensuring drains are grassed and flat bottomed rather than v-shaped (restricting the width of a road reserve by using v-shaped drains can lead to erosion problems).

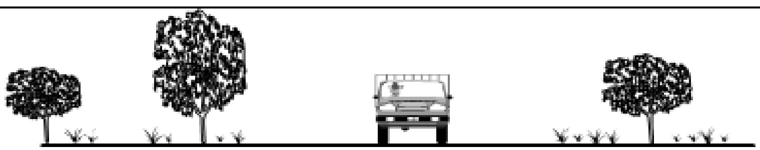


Figure 2—Roads or tracks at ground level:

Tracks at ground level are suitable for low traffic situations. Erosion can be prevented by:

- removing obstacles with a stick rake or very light grading when making a new track. This ensures minimal disturbance and prevents windrows that divert or concentrate runoff. On gibber plains, tracks can be created by rolling so that the gibber mantle remains intact
- allowing runoff to cross the road by using whoa-boys on sloping land or inverts in drainage lines. Roads on the contour, however, have no need for such structures.

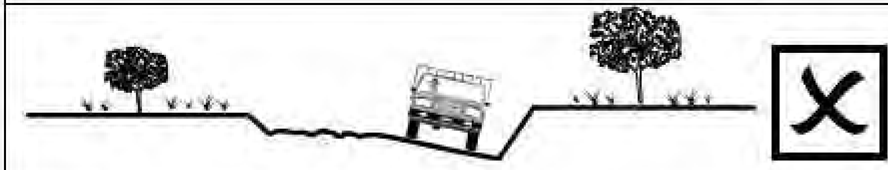


Figure 3—Subsurface roads (not recommended)

Roads often become subsurface when they are graded inappropriately to remove wheel ruts. Subsurface roads are not recommended for the following reasons:

- their base often consists of highly erodible subsoils
- they are at risk of becoming an eroding waterway or gully.

Figure 4—Cross-slope roads (outfall and infall)

Outfalls are the best option for low usage roads on steep slopes provided you:

- stabilise upslope and downslope batters
- provide a cross fall of 15cm to 25cm to allow adequate drainage.

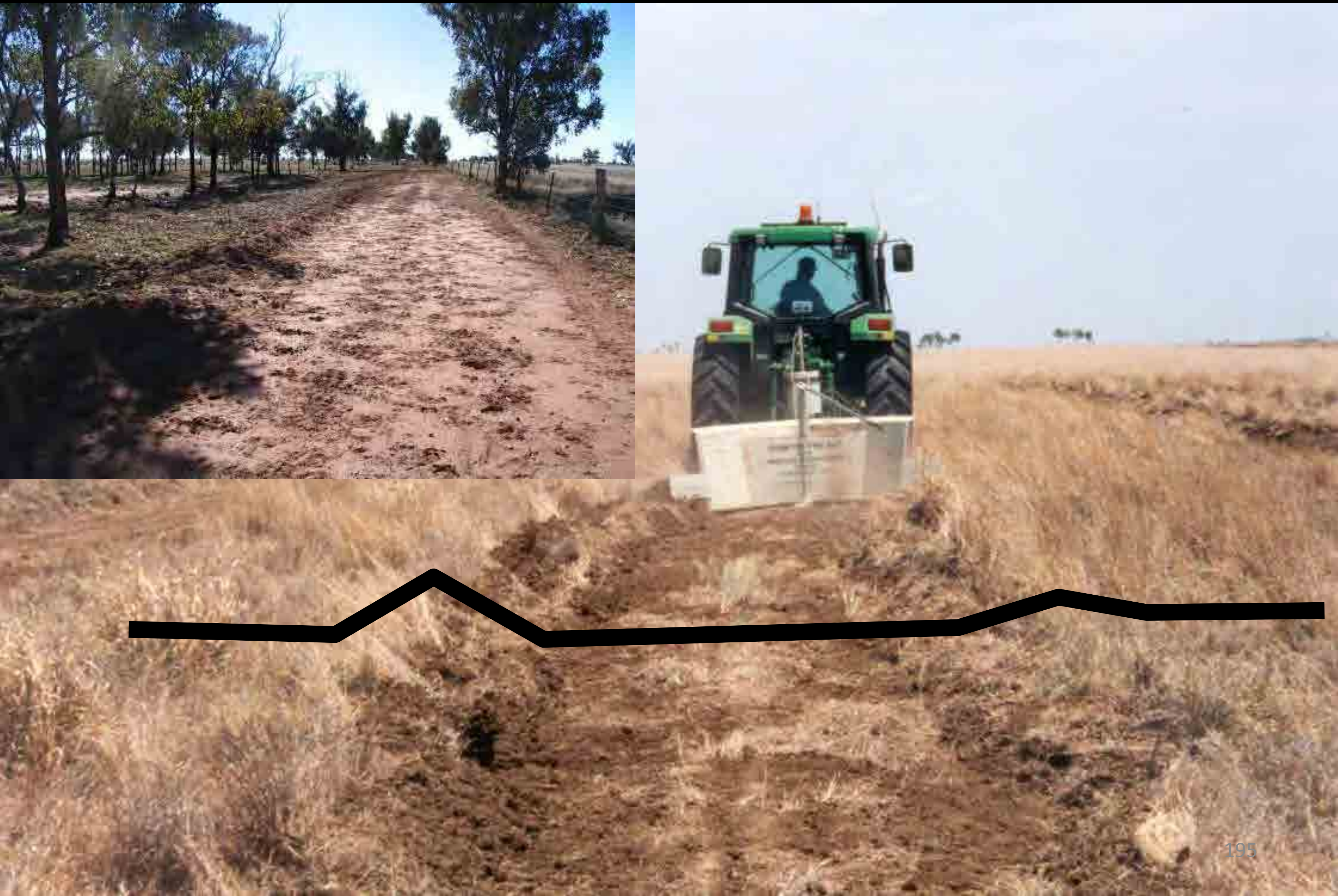
Infall drainage is less desirable as it requires:

- adequate table drains and culverts
- more earth moving, which increases the risk of erosion and slumping of the exposed batters.

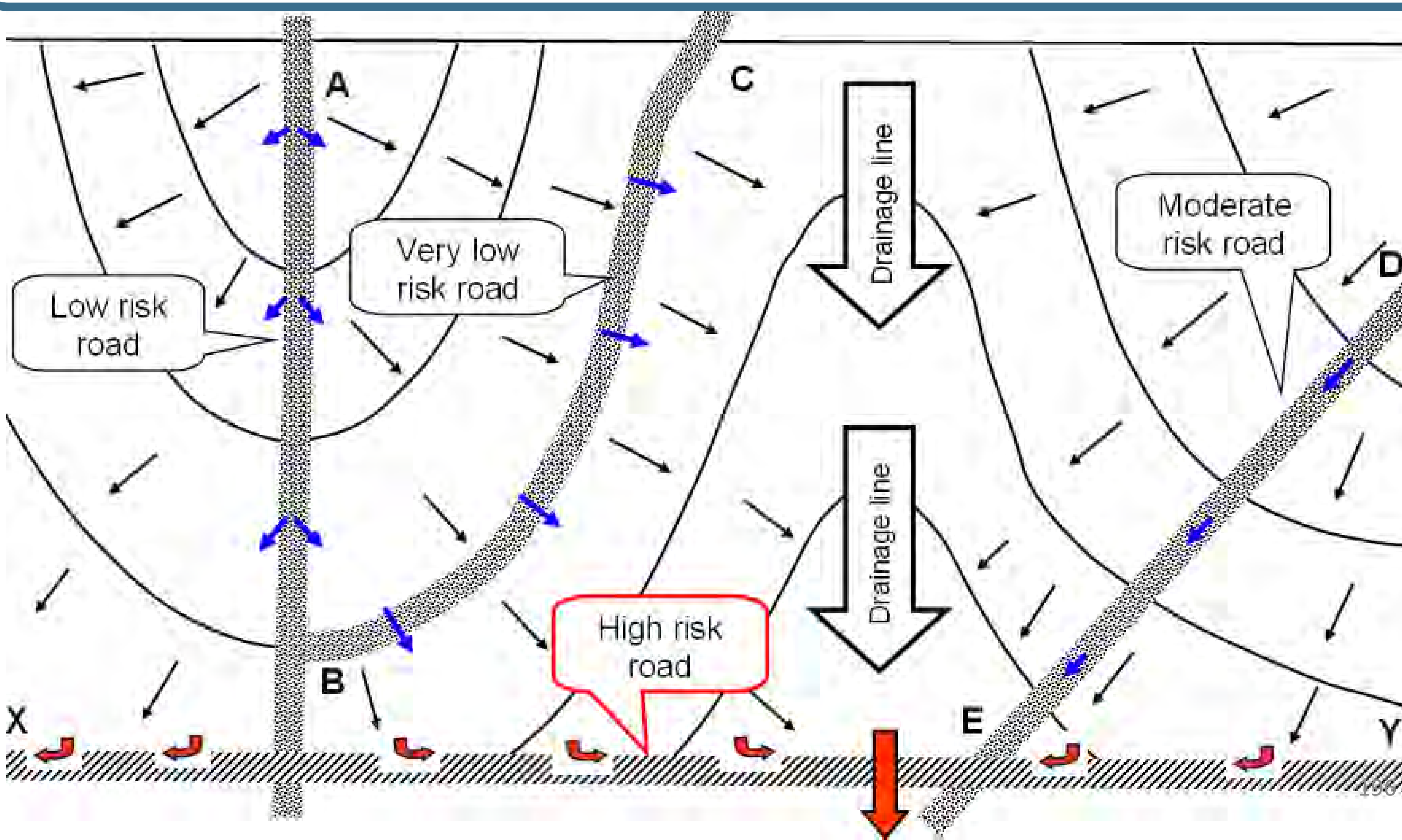
To construct roads and tracks through vegetated land, the topsoil and vegetation is sometimes removed to expose dispersive subsoils

This can be the result

Firebreaks create an erosion risk if they expose dispersive topsoils and if they have no measures to control the runoff that will flow down them

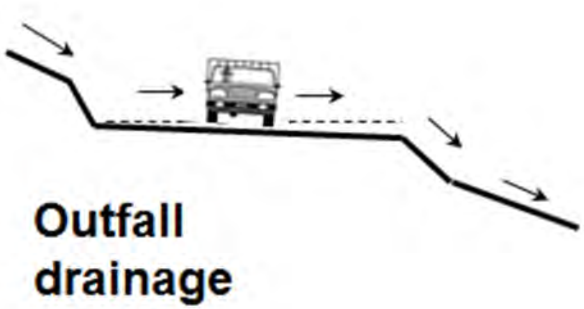


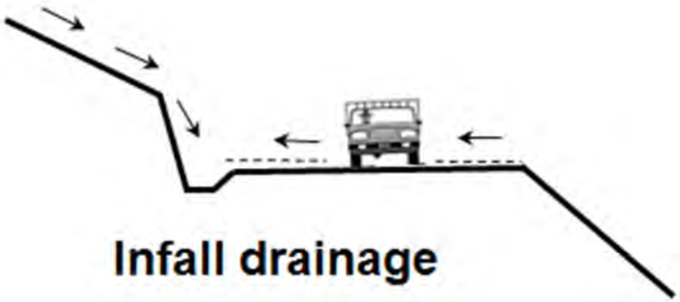
The risk of erosion on a property road depends on how much runoff it collects. Roads running diagonally across the slope (X-Y) collect the most runoff. A road running straight up and down the hill (D-E) will be an erosion risk but it only has to deal with the rain that falls on the road. It collects no overland flow. Roads are best located on a ridge (A-B) or on the contour (B-C).



Tracks on ridges have low erosion risk. They require minimal construction, they collect little runoff which is easy to dispose of and you get a commanding view of the local landscape.

Low speed, infrequently used roads diagonally across steep slopes can be better with ‘outfall’ drainage rather than ‘infall’ drainage

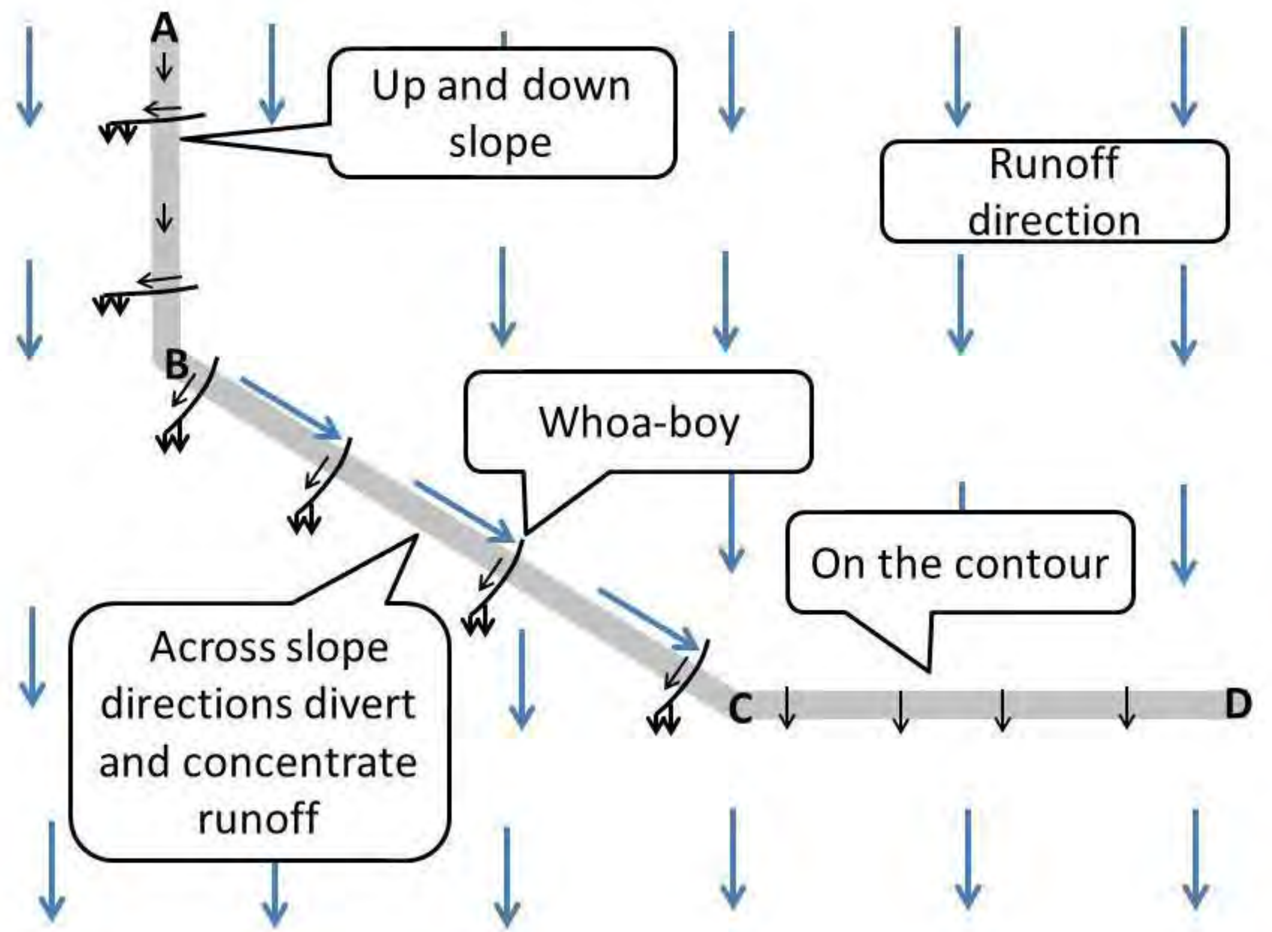




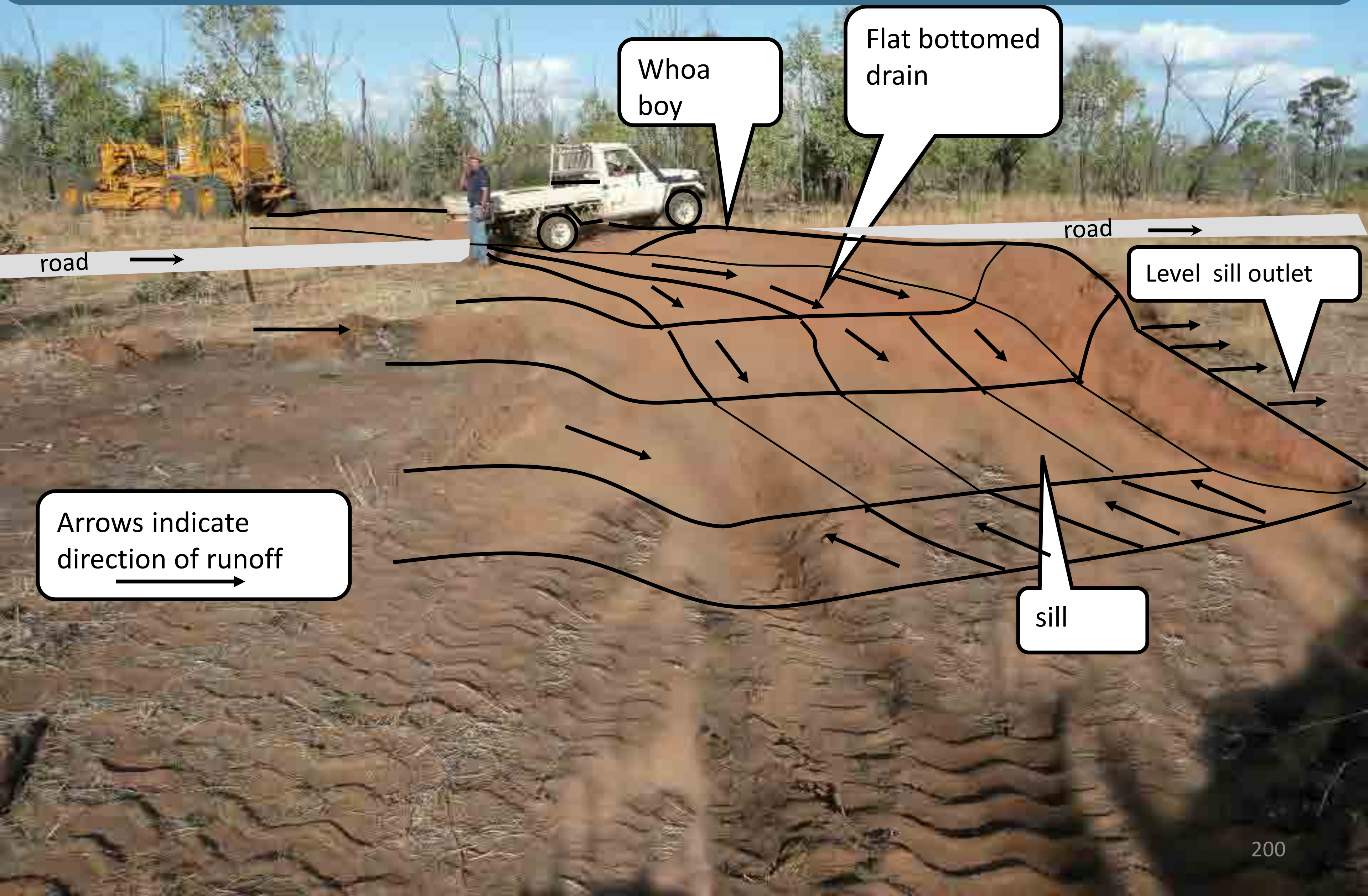
Outfall drainage requires less cut and fill, the batters are not as steep and runoff does not concentrate on the inside of the track

Infall drainage concentrates runoff on the inside of the track

Whoa boys can be used to divert runoff from a property road. Because they look and act like speed bumps, they are not suitable for main roads. Roads on the contour do not require whoa boys

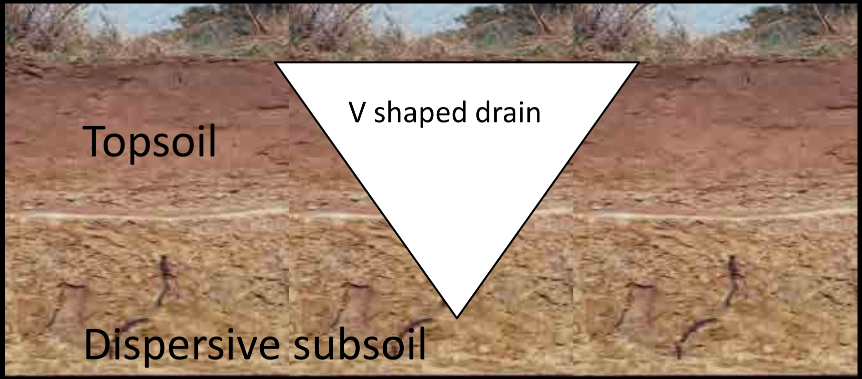


This whoa-boy has a low risk of eroding because it has been constructed with a flat-bottomed channel

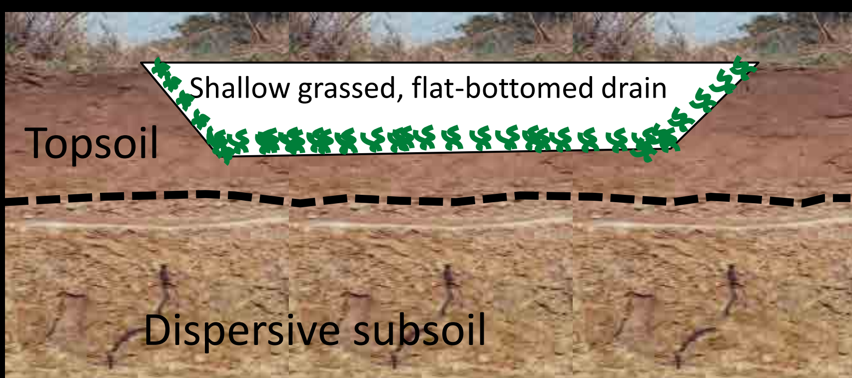


Roads entering steep watercourses with dispersive soils are especially vulnerable to erosion and contribute sediment directly to streams.

On formed or crowned roads, V-shaped table drains are a common source of erosion in dispersive soils



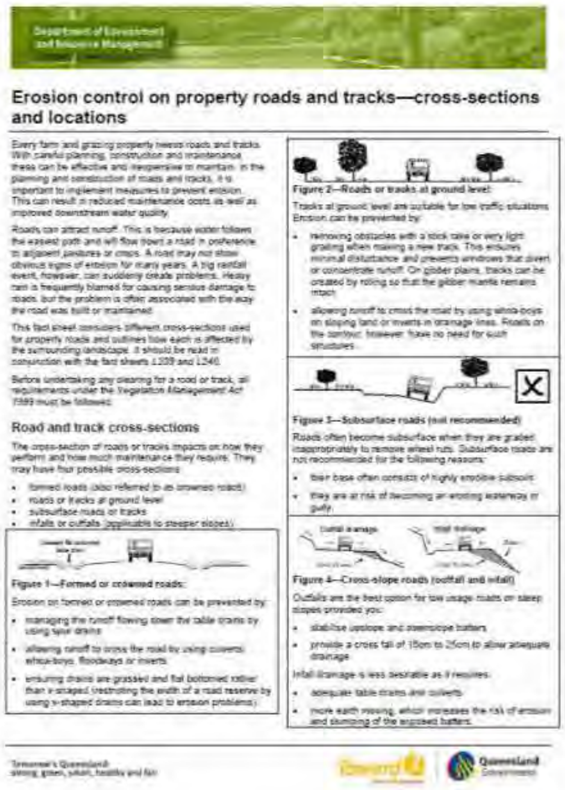
Shallow, flat-bottomed, grassed drains require a wider road corridor, but they have less risk of erosion, and the road has lower maintenance costs.
A 5km long stretch of road with 2 metres extra width to accommodate wider drains would only require one additional hectare of land.



Spur drains used to remove runoff from road table drains

On formed roads, spur drains are used to remove water flowing down table drains. This drain has a blocked outlet causing ponding which could initiate tunnel and gully erosion in this dispersive soil.

Queensland Government fact sheets on erosion control on roads, tracks and fences


Department of Environment and Resource Management

Erosion control on property roads and tracks—cross-sections and locations

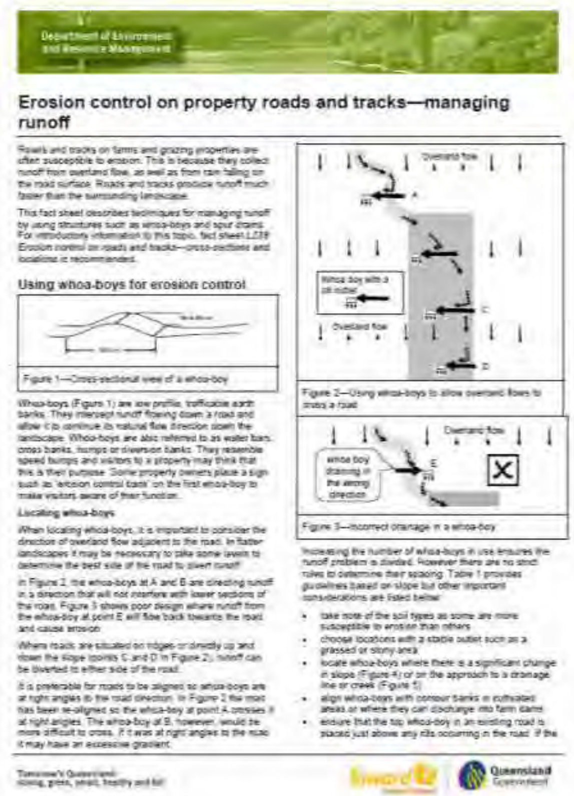
Figure 1—Formed or crowned roads

Figure 2—Roads or tracks at ground level

Figure 3—Subsurface roads (not recommended)

Figure 4—Cross-slope roads (outfall and infall)

http://www.derm.qld.gov.au/factsheets/pdf/land/l239.pdf


Department of Environment and Resource Management

Erosion control on property roads and tracks—managing runoff

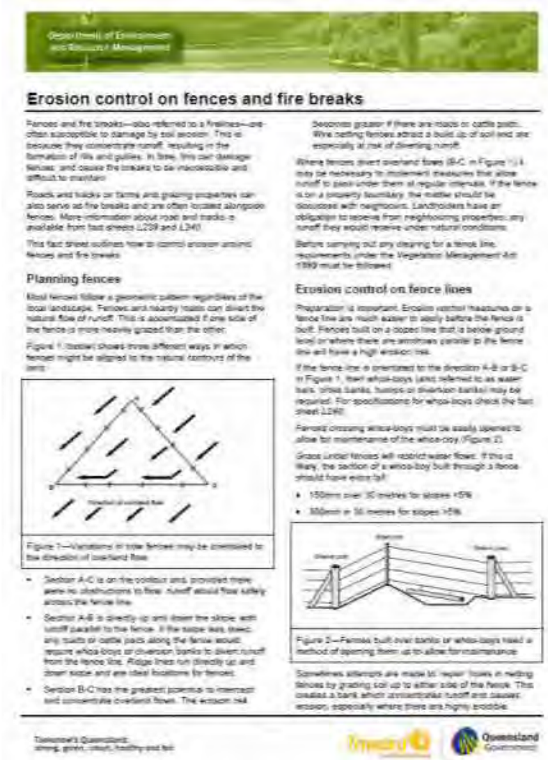
Using whoa-boys for erosion control

Figure 1—Cross-sectional view of a whoa-boy

Figure 2—Using whoa-boys to allow overland flows to cross a road

Figure 3—Incorrect drainage in a whoa-boy

http://www.derm.qld.gov.au/factsheets/pdf/land/l240.pdf


Department of Environment and Resource Management

Erosion control on fences and fire breaks

Planning fences

Erosion control on fence lines

http://www.derm.qld.gov.au/factsheets/pdf/land/l241.pdf

Other sources of information on roads and tracks

- *Roadside Landcare – Guidelines for erosion control on roads and road reserves* by Jim Herbert (Department of Primary Industries) and Peter Evans (Queensland Transport). A report commissioned by the Maranoa Landcare group in 1992. It can be download from the DEHP library catalogue

Understanding dispersive soils
Part B contents ⮌

Stabilising batters on dispersive soils

A case study on dispersive soils

Batters are formed when rail or road cuttings are required to create level surfaces in hilly land.

Erosion on batters of road cuttings with dispersive soils

Erosion on batters of road cuttings with dispersive soils

Creating a ‘stepped’ pattern on a batter slope will provide places to hold topsoil when it is applied prior to planting vegetation

Dispersive soil should be covered by a layer of non-dispersive topsoil before planting vegetation or using hard surfaces such as rock or concrete.

The topsoil layer needs to be between 100 and 300mm thickness depending on the erosion risk.

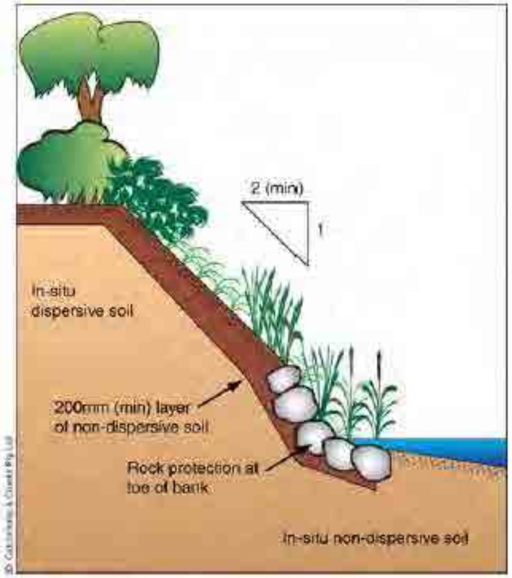


Figure 16 – Revegetation of gully banks containing dispersive soils

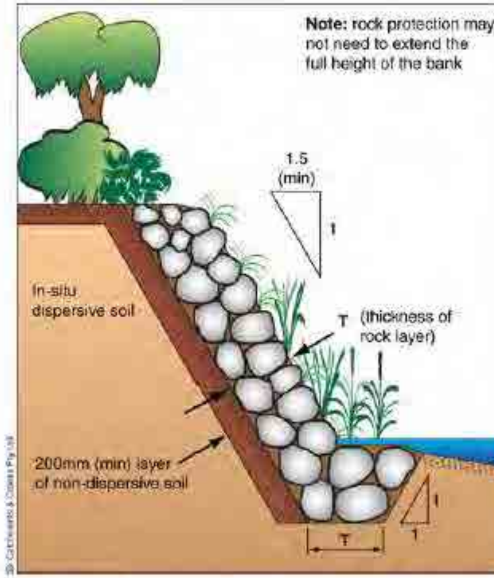


Figure 17 – Rock beaching of gully banks containing dispersive soils

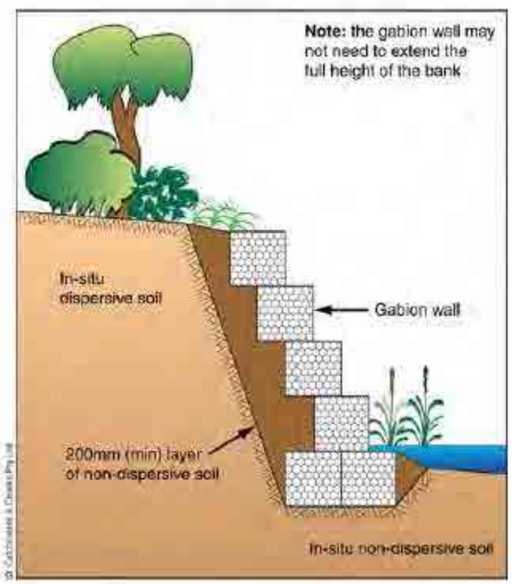


Figure 18 – Gabion stabilisation of gully banks containing dispersive soils

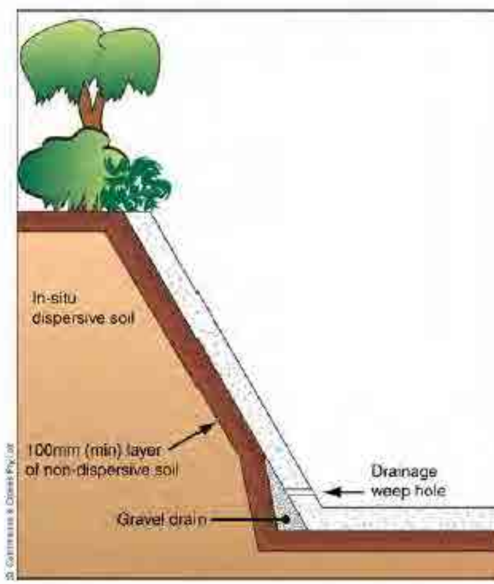


Figure 19 – Placement of hard linings over dispersive soils

Source: *Gully erosion – part 2 Assessment of treatment options*
Grant Witheridge Catchments and Creeks
http://www.catchmentsandcreeks.com.au/docs/Gully2-1.pdf

Dispersive subsoils are an inhospitable medium for plant growth. A compost blanket layer provides a suitable medium for establishing vegetation.

Using rock baskets to stabilise a steep road cutting on dispersive soil

Demonstrating different techniques for stabilising batters at field days

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Building on dispersive soils

A case study on dispersive soils

Tunnel erosion – buildings

In areas with dispersive soils, 'cut and fill' construction for buildings would expose dispersive subsoils. Alternatives to 'cut and fill' construction such as pier and post foundations should be considered. Footings would need be excavated beneath any sodic layers and/or pinned to the basement rock. Post holes should be completely filled and capped with concrete above the soil surface, rather than backfilled with spoil.

Runoff should be prevented from entering post holes by repacking the holes with a mixture of gypsum and soil and a high level of compaction. The holes should be completely filled and capped with concrete above the soil surface.

Surface runoff could be removed by diversion structures provided there was a safe place to dispose of the water. To avoid exposing dispersive sub-soils in channels, diversion banks should be built from the bottom side with a gradient of at least 0.5%. A well grassed channel will prevent erosion from occurring in the channel.

Subsurface water could be intercepted by the use of a sand block or a bentonite filled geofabric. The use of a sand block is described on the next page.

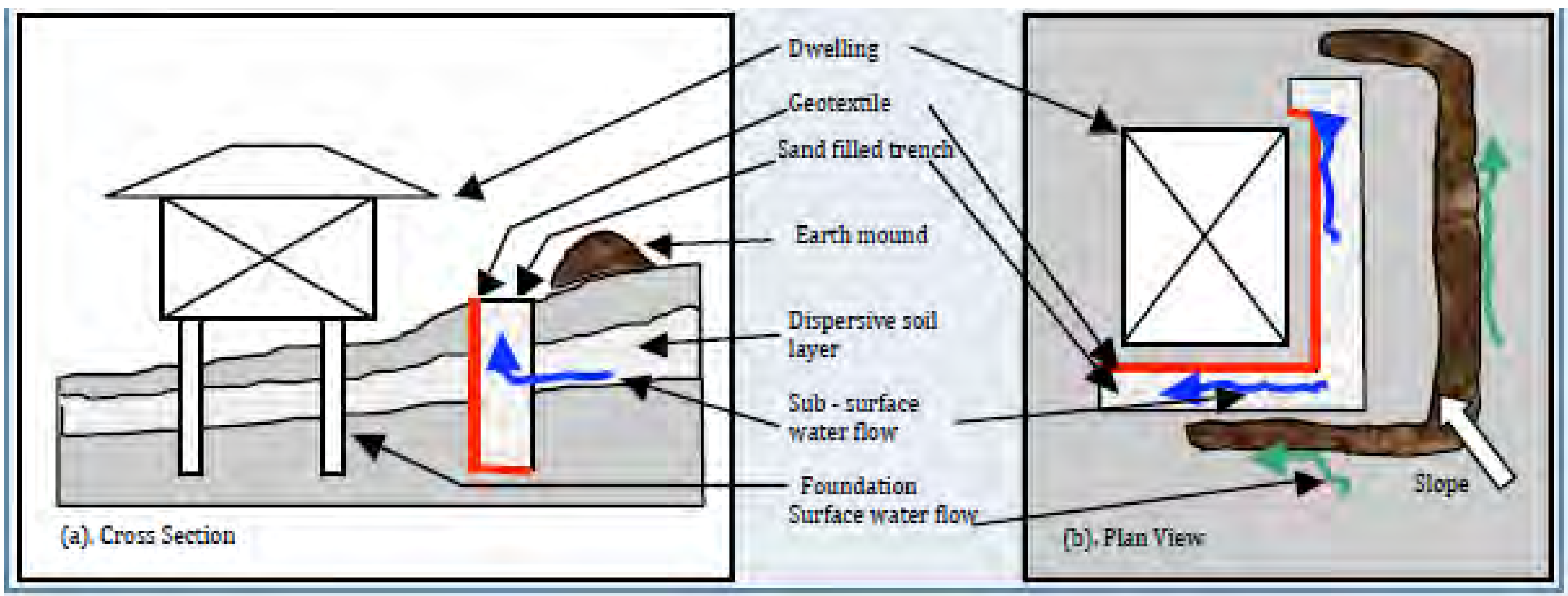
Where soils are dispersive, impermeable surfaces such as concrete would prevent the entry of water into dispersive subsoils. Overwatering of gardens would need to be avoided. Potted plants would be an alternative to conventional gardens.

Proposed technique – a hydrological barrier for buildings

In Tasmania, a hydrological barrier has been proposed for diverting surface and subsurface water away from the footings of buildings on dispersive soils threatened by tunnelling.

The technique would involve a sand and gypsum filled trench installed to the depth of the foundations around the upslope area of the dwelling. The sand/gypsum mixture would trap any dispersed soil moving down developing tunnels while allowing the water to come into contact with the gypsum and rise through the sand and away from the footings.

An earth mound immediately above the sand filled trench would prevent surface runoff entering the trench. The barrier could be installed either during construction or fitted to existing dwellings.



A hydrological barrier to isolate foundations from surface and ground water. Source: Duckett pers coms in *Dispersive soils and their management – Technical Reference Manual*, Tasmanian Department of Primary Industries, Parks, Water and Environment

http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/SWEN-7SU6SX/$FILE/DPIW_DSM_Manual_April2009.pdf

Sinkholes developing in the surrounds of a house on the outskirts of Brisbane.

Examining a sink hole between the house and an eroding gully

Understanding dispersive soils

Part B contents ⮌

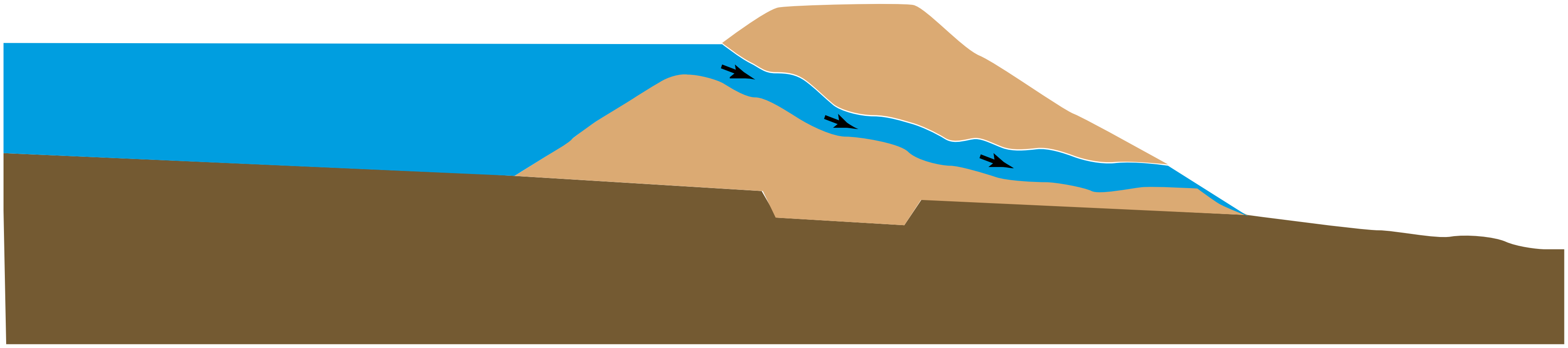
Dispersive soils and **dam construction**

A case study on dispersive soils

Dam construction with dispersive soils.

Dry, dispersive soils form tough clods when they are excavated for use in a dam wall. Such clods are difficult to compact leaving air voids in the bank. When the dam fills, water can quickly seep into the air spaces causing the soil to disperse into tunnels resulting in a breached embankment.

Dams with inadequate levels of freeboard (the difference in height between the spillway (by-wash) and the top of the embankment) are most susceptible to failure by this process.

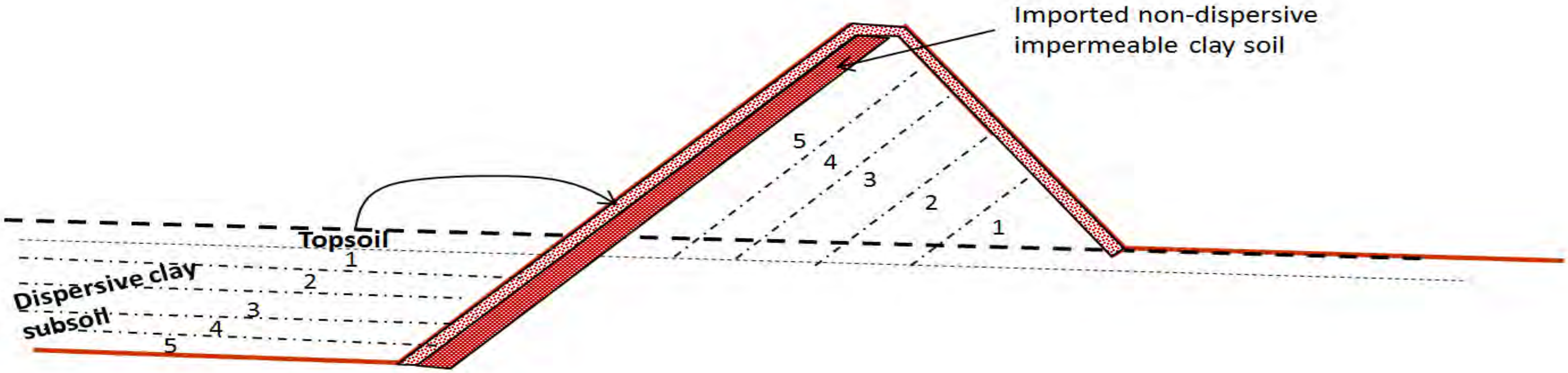


The importance of compaction in dam construction.

Dams can be successfully built from dispersive soils provided they are compacted when the soil is at the correct moisture content. With proper compaction, some degree of dispersion can actually assist in providing a water tight dam.

A sheepsfoot roller is well suited for farm dam construction. Tracks of a bulldozer are designed to distribute weight and are only suitable for compacting thin layers of soil. Many passes of the compaction equipment may be required depending on the moisture content and the thickness of the layers. Under dry conditions it will be necessary to apply water to improve the moisture content. Under these circumstances the addition of gypsum would also be helpful.

The correct moisture content for compaction of clays is when the clay is as wet as can be rolled without clogging a sheepsfoot roller. At this moisture content the clay can be rolled by hand to pencil thickness without it breaking.



Construction of a dam wall with an upstream layer of imported , nondispersive, impermeable clay soil.
The soil is added to the wall in oblique layers. If the layers are horizontal there is a greater chance of tunnels developing within a layer of inadequately compacted dispersive soil .
Topsoil is added to the wall and planted to an erosion resistant grass.

Larger dams can be built with a core of impervious clay material with a pervious layer on either side of the core

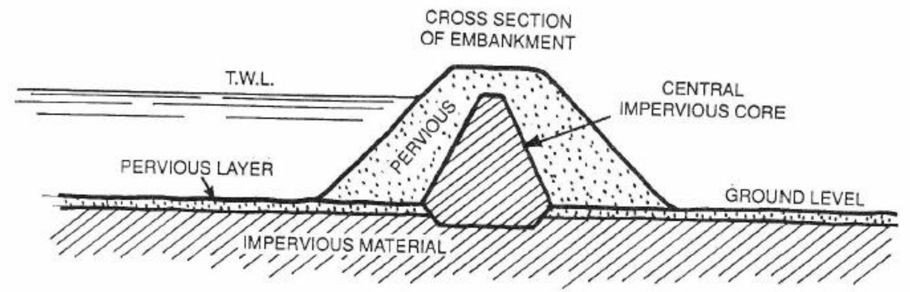


Figure 5: *A zoned embankment with a central impervious core.*

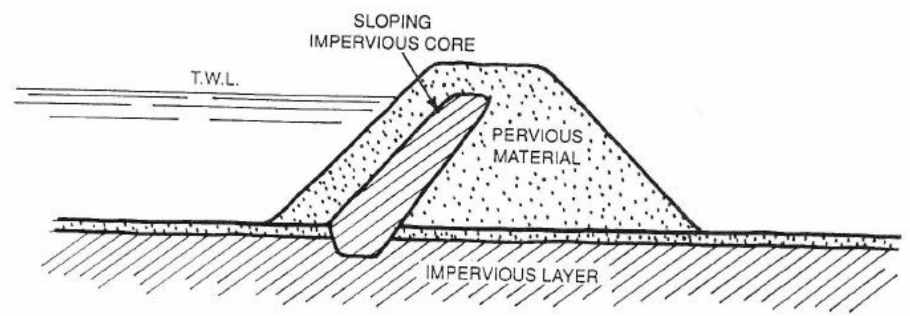


Figure 6: *A sloping impervious core in a zoned embankment.*

New South Wales Soil Conservation Service Earthmovers Training Course, Unit 10, *Construction of Farm Dams*, 1991

If there is insufficient suitable clay for an impervious core, a diaphragm of suitable quality builders plastic can be used to prevent tunnel failure and to seal small farm dams.

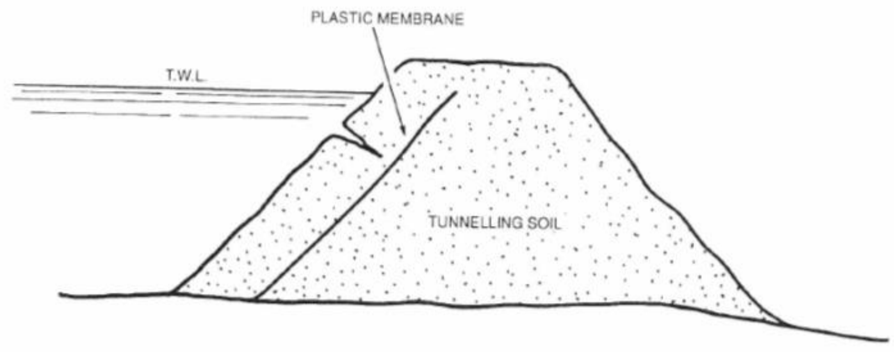


Figure 207: A plastic membrane located in a dam embankment to prevent tunnel failure.

Care should be taken to ensure that all pipes, drains and spillway devices that penetrate the membrane are suitably flashed and sealed to prevent leakage. The membrane needs to be totally covered with a layer of soil (min of 30cm).

The dam should be completed by adding a layer of topsoil and planted to vegetation to prevent erosion of the embankment and to reduce the chances of tunnel erosion developing. The incorporation of gypsum or hydrated lime at 0.5% by weight in the final stages of wall construction could help to prevent the development of tunnelling in the dam wall.

New South Wales Soil Conservation Service Earthmovers Training Course Unit 10 Construction of Farm Dams 1991

Exposed dispersive soils on dam walls are prone to erosion. Dam walls need to be covered by non-dispersive topsoil to promote grass growth.

Long standing dam embankments can fail through piping of dispersive clays when water enters the internal structure through cracks.

Exposed, dispersive subsoils in a bywash create a high risk of erosion and dam failure.
Dam by-washes need to be properly constructed to handle the design runoff and should be constructed on the original soil surface.

A 6 m high overfall in a dam bywash in dispersive soils in south-east Queensland. The concrete floodway is under threat and is the main entry to the property.

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Using dispersive soils for **trenches for pipe and cable installation**

A case study on dispersive soils

Installation of pipes and cables in dispersive soils

Surface runoff can soak into a completed trench or it may intercept subsurface movement of water. Tunnel erosion can develop when water accumulates and flows along the trench. The tunnel system may extend when water escapes the trench at a low point via a crack or decaying tree root and flows to an outlet such as a drainage line, gully or road cutting.

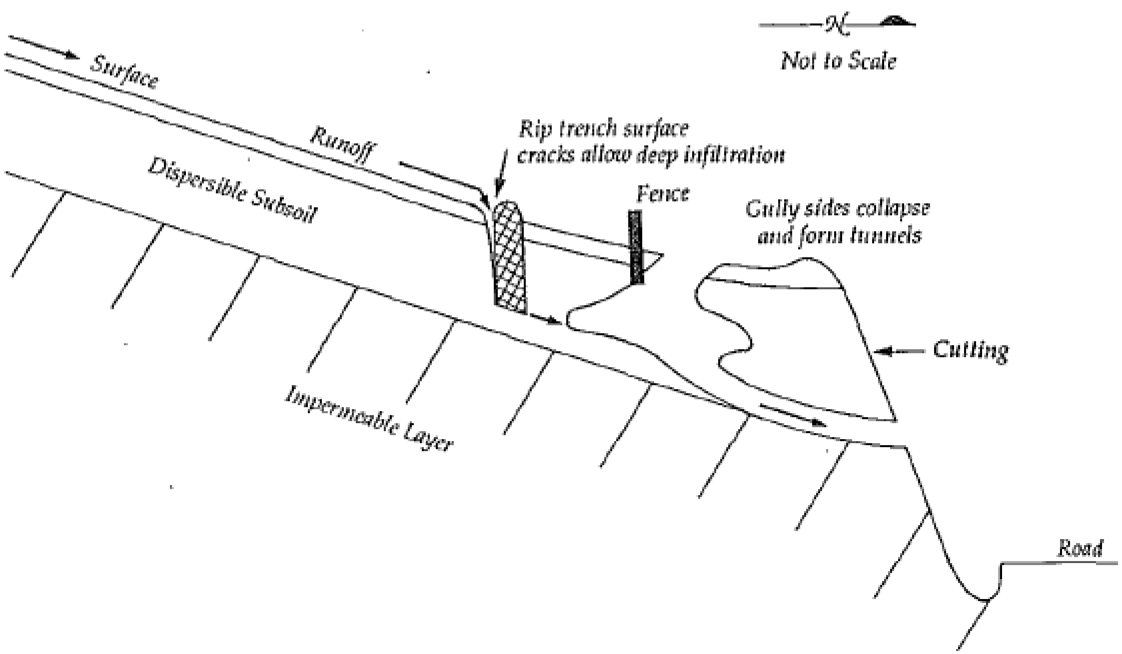


Figure 3. FORMATION OF A TUNNEL - GULLY FROM FENCELINE TO ROAD (MT29 Sheet 5)

Water entering a cable trench has caused tunnel erosion with an outlet onto an adjacent road cutting.

Source: *Report on control of erosion along the Telecom optical fibre cable route Withcott to Helidon* 1990 by M Roberts and B Powell. Published by Queensland Department of Primary Industries and available for download from the DEHP library catalogue.

Management practices to control erosion where trenches for infrastructure are required in dispersive soils

The following practices can lower the risk of tunnel formation in a trench installation:

- topsoil management
- chemical amelioration
- compaction
- sand blocks
- runoff management
- revegetation.

Managing topsoil and stockpiles in trench construction

Trench construction projects involving the excavation of dispersive subsoils should allow for the stockpiling of non-dispersive topsoil to spread back over the disturbed area at the completion of the project.

All of the soil removed to construct a trench to lay a large diameter pipe cannot be returned to the trench. On a one km length of one metre diameter pipe, almost $800m^3$ would be displaced. This material could easily expand to $1200m^3$ after it has been excavated.

Displaced, dispersive material will need to be permanently stockpiled. Management options to stabilise the stockpiles to avoid erosion by raindrop action, tunnelling and gullying would include:

- Stockpiles should not be placed in or near drainage lines.
- Mixing chemical amendments like gypsum into each layer of deposited soils followed by compaction of the layer.
- Avoiding steep batter slopes on the stockpile
- Capping the stockpile with at least 150 to 200 mm of topsoil followed by fertilising and seeding with a mixture of grasses and other suitable ground covers.
- Sediment traps installed down-slope of stockpiles and diversion banks placed upslope would assist in minimising erosion and associated problems.

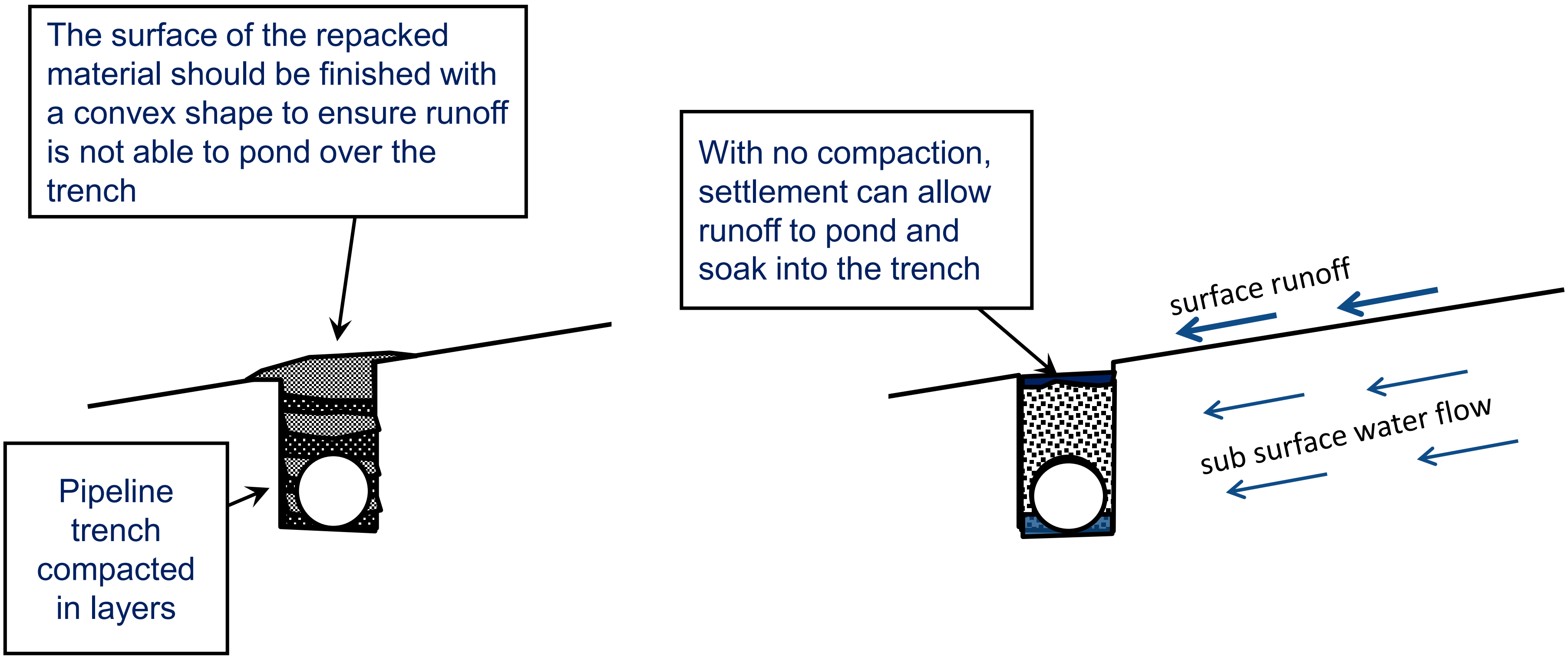
Chemical amelioration in trench construction projects

If soils have a low to moderate risk of dispersion (ESP 6 - 15), dispersive soils excavated from the trench could be treated with gypsum and repacked back into the excavated area. The treated soil should be added to the trench and compacted layer by layer.

The application of gypsum to the soil used to fill the trench would ensure infiltrating water contains sufficient electrolyte to prevent further dispersion.

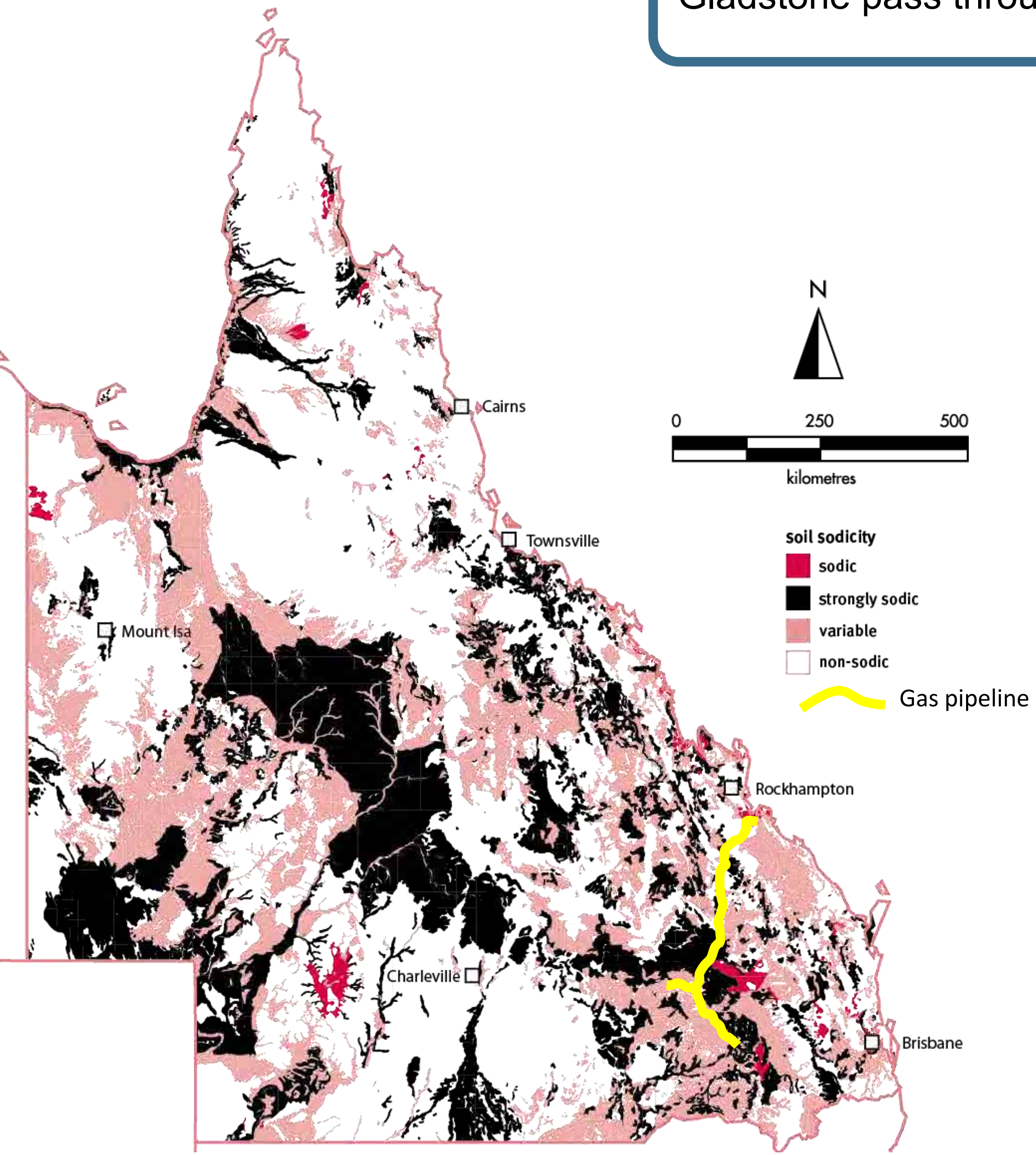
Soil compaction in trench construction

The risk of tunnel development can be reduced by adequate levels of compaction. Soil needs to be compacted in layers at the optimum moisture content with suitable compaction equipment. Driving a bulldozer, excavator or back hoe over a filled trench will not compact the soil in the trench.



Spider ploughs rip a trench and install a cable or pipe in one operation. With no compaction such trenches would be vulnerable to tunnel erosion in dispersive soils.

Gas pipelines from the Western Darling Downs to Gladstone pass through large areas of dispersive soils



Source: *Queensland salinity management handbook* (Originally sourced from CSIRO)

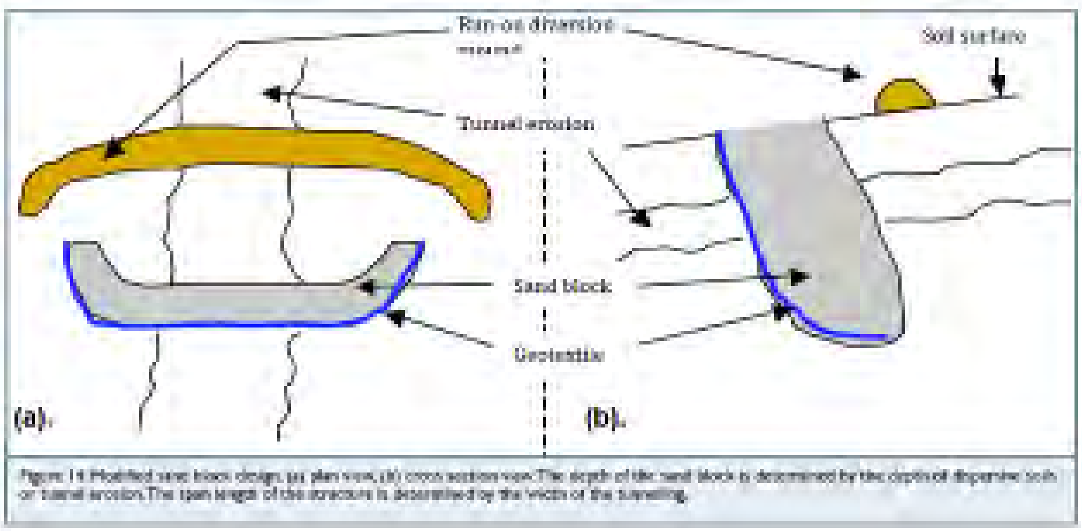
Early signs of tunnel development above a pipeline

Compacting a layer of soil around a pipe in a trench

Source: Concrete Pipe Association

Sand blocks/plugs

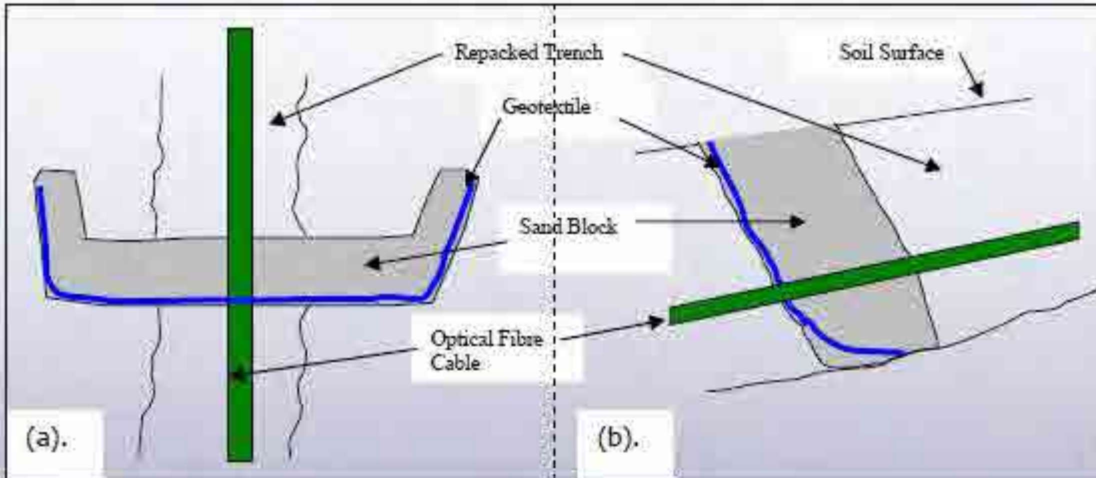
Sand blocks or sand plugs have been used in Tasmania, to prevent the initiation of tunnel erosion along optical fibre cable installations. Sand blocks are plugs of fine sand installed at intervals along a trench. Geotextile on the downslope wall of the plug will prevent the removal of sand and tunnel development. They act as filters to block the flow of dispersed material along the trench. Sand blocks allow seepage flows to rise to the surface through the sand. An earth mound upslope of the structure will prevent surface runoff entering the sand block.



Richley 2000 described a project in Tasmania where sand plugs were installed at intervals of 40 to 75 m along the cable route The plugs were three metres long by 0.5m wide by one metre deep.

Richley 2000 – *Treatment of tunnel erosion in Tasmania.* Journal of the Australian Association of Natural Resource Management.

Use of Sand Blocks



Excavate across trench/tunnel

Geotextile downslope wall

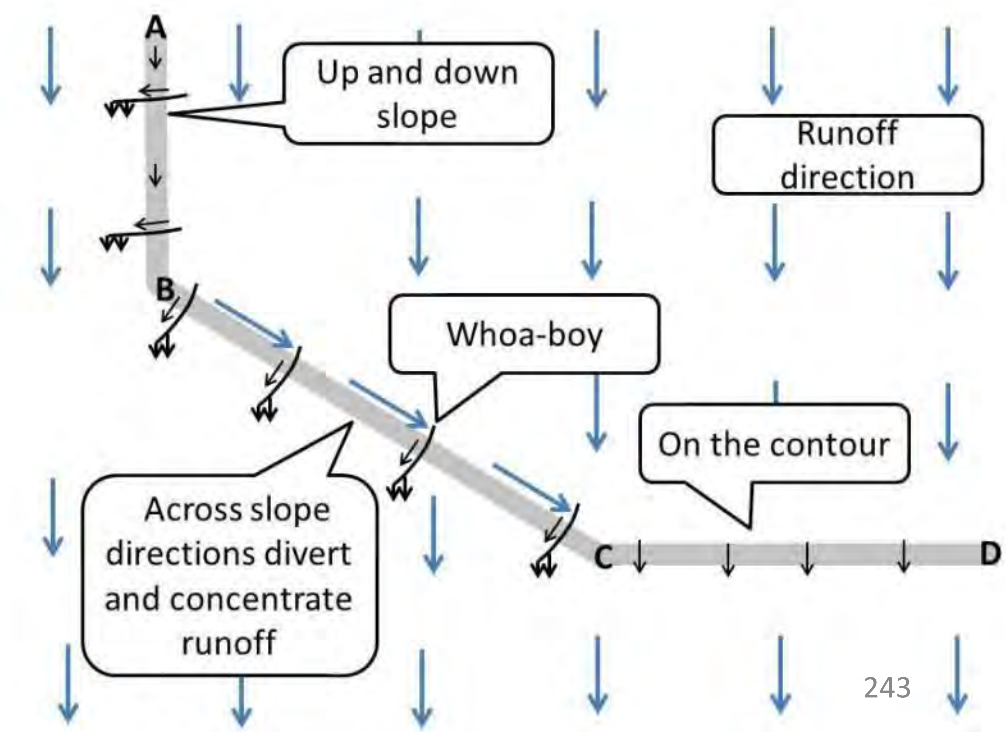
Fill with fine sand and gypsum 5% wt

Leave sand exposed on surface

Trench construction – Runoff management

If water collects and ponds above the trench, tunnelling could occur. Deep ruts left by wheeled vehicles, especially after rain will be a source of erosion and should be levelled out. The mound left over the trench needs to be breached by a series of whoa boys or cross banks to discourage water flowing down the easement. On dispersive soils, any cross banks or other earthworks should be made by carting in topsoil rather than just pushing up a bank and exposing the highly erodible subsoil.

Whoa boys need to be individually surveyed and located in cooperation with the neighbouring landholder. They should discharge on the preferred side, otherwise runoff can flow back onto the drainage easement.

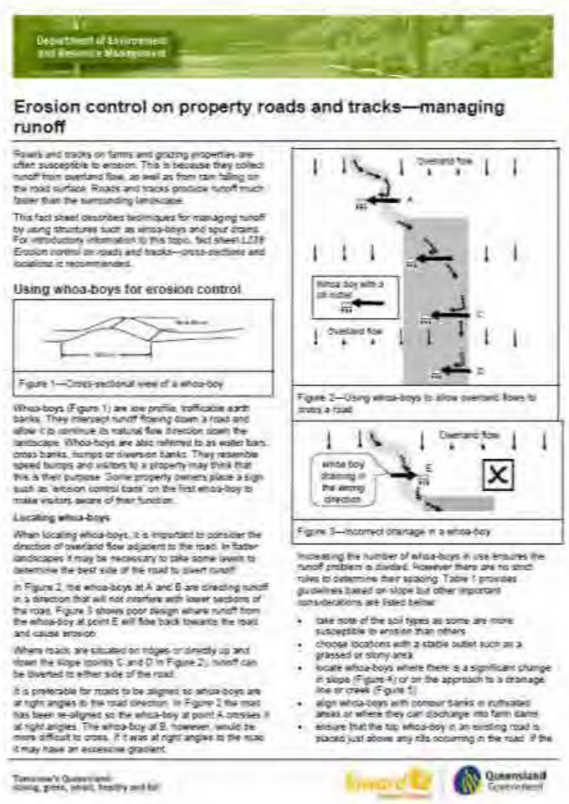


These Queensland government fact sheets contain information useful relevant to erosion control on pipeline easements


Department of Environment and Resource Management

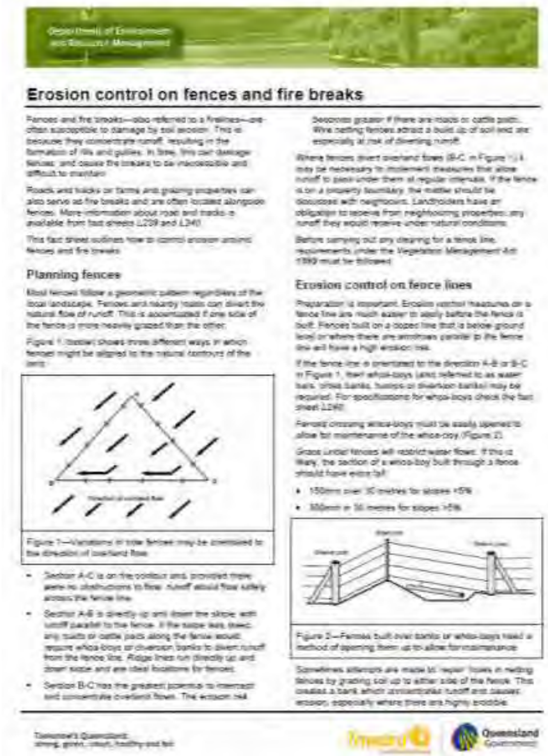
Erosion control on property roads and tracks—cross-sections and locations

http://www.derm.qld.gov.au/factsheets/pdf/land/l239.pdf


Department of Environment and Resource Management

Erosion control on property roads and tracks—managing runoff

http://www.derm.qld.gov.au/factsheets/pdf/land/l240.pdf


Department of Environment and Resource Management

Erosion control on fences and fire breaks

http://www.derm.qld.gov.au/factsheets/pdf/land/l241.pdf

Trench construction - Revegetation

Dispersive subsoils should be covered as soon as possible with at least 150mm to 200mm of non-dispersive topsoil, fertilised and sown with an appropriate mix of grasses and other species to provide good ground cover. Gypsum would be recommended where the soils are dispersive and a compost blanket would greatly assist with vegetation establishment.

Ideally the easement should be fenced to totally exclude stock during the rehabilitation phase. Especially in dry seasons, stock will eat vegetation as soon as it germinates.

Additional information – trench construction

Dispersive soils and their management – Technical Reference Manual -Hardie M 2009 available on line from the website of the Tasmanian Department of Primary Industries, Parks, Water and Environment at www.dpiw.tas.gov.au

http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/SWEN-7SU6SX/$FILE/DPIW_DSM_Manual_April2009.pdf

Code of environmental practice for onshore pipelines The Australian Pipeline Industry

http://www.apia.net.au/wp-content/uploads/2009/10/APIACodeofEnvironmentalPractice.pdf

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Understanding dispersive soils Part B contents ⮌

End