

ROADS and SALINITY



**LOCAL GOVERNMENT
SALINITY INITIATIVE**



Department of
Infrastructure, Planning and Natural Resources

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First published 2003
Department of Infrastructure, Planning and Natural Resources
22-33 Bridge Street
Sydney NSW 2000

Roads and Salinity
ISBN:0 73475377 2
Designed and printed by ClickMedia, Penrith
Photographs: various sources



NSW Agriculture

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Introduction

This booklet is largely a literature review of existing information on the inter-relationship between roads and salinity. It has been developed for use by those involved in the design, construction and management of road infrastructure as well as those involved in salinity management generally. A section on basic road construction is included to provide salinity managers with an understanding of some engineering terms as well as a feel for the complexity of issues facing the road engineer. Further booklets in the Local Government Salinity Initiative series contain additional information on urban salinity identification, investigation, impact on building materials etc.

Salt and Water

Salinity is essentially an issue related to salt and water. It is not always associated with a shallow or rising groundwater table, nor is it always solely attributable to the removal of native vegetation or over-irrigation. It is a complex issue involving water and salt cycles above and below the ground. These processes vary significantly from site to site as well as over time.

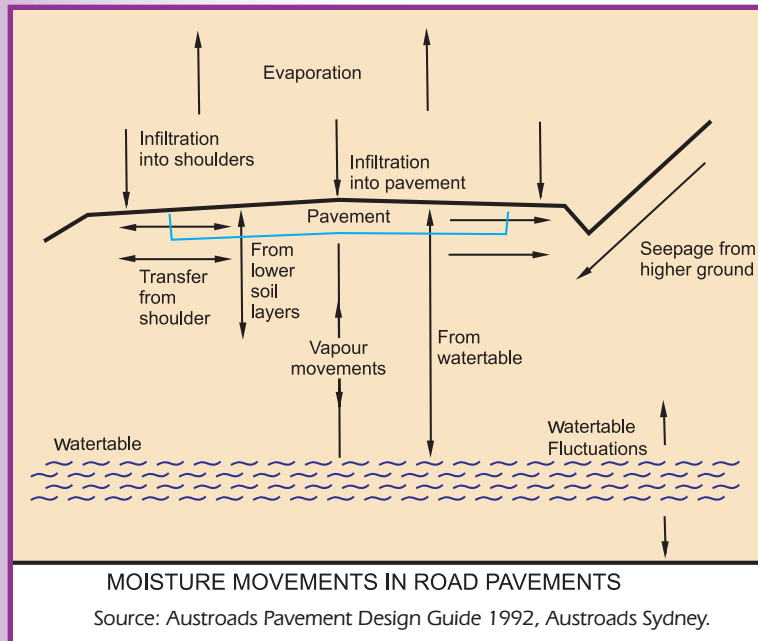
The water or moisture content of roads is one of the main causes of road failure throughout the world. An increase in moisture

content, beyond that which it is designed for, can weaken and/or deform the road, significantly affecting its performance. Moisture can move into a road from a variety of sources as shown in the diagram below.

As salts generally dissolve readily in water, all of the sources of water shown in the diagram will have some salt content and may also mobilise salts present on the site in the soil, aggregate and road additives. If evaporation occurs salts are further concentrated in the remaining water and/or the salts may become solids again in the form of crystals. The type of salts and the conditions under which they crystallise will determine the size and shape of the crystal formed. This in turn helps determine the amount of pressure exerted on the surrounding material as the salt makes space for itself within the road fabric.

Roads and Watertables

The table below outlines the length of road at risk from high watertables in the Murray Darling Basin of NSW. Based on the current trend of rising watertables in the Murray Darling Basin estimates are also given for 2020 and 2050. These predictions highlight the importance of understanding the inter-relationships between roads and salinity and the consideration of salinity in the design, maintenance and refurbishment of road infrastructure.



	2000	2020	2050
Length of Road at Risk (including highways, major and minor roads).	940 km	2 588 km	4 850 km

Predicted increase in the length of road at risk, in the Murray Darling Basin section of NSW
(Source Australian Dryland Salinity Assessment 2000, The National Land and Water Resources Audit, Land and Water Australia.
On behalf of the Commonwealth of Australia).

Basic Road Construction

Roads (or more technically “pavements”) are made up of layers. These vary in composition, thickness and strength. The thickness of layers depends on expected traffic volume, percentage of heavy vehicles and quality of construction material used at the site. The aim is to cushion traffic impact by building up strength in stages.

Sprayed seal	4-6mm
Base	100-400mm
Sub-base	100-400mm
Sub-grade	200-600mm

Typical thickness of layers of a sealed road

The subgrade may be the natural ground, or, at a site where the road has been built up, the upper layer of an embankment. The suitability of this material for road building largely depends on its strength, which varies with soil type, density and moisture content.

Another factor is compaction during construction to increase strength and decrease the amount of moisture present.



Road construction in layers

The strength of the subgrade can be defined by testing for the material’s California Bearing Ratio (CBR) and stiffness can be further derived from this. The desired strength depends on the predicted traffic loading. If the subgrade cannot meet these requirements, subsequent layers must be designed to compensate or a working platform of concrete or rock may need to be installed above the subgrade before further layers are built.

The sub-base and base are usually made of crushed rock imported to the site or the old pavement reworked where a road has deteriorated because of age. The cost of obtaining new material and transporting it to the site is an important component of the selection process. The material used for the sub-base is generally of a poorer quality to minimise costs and the design may specify

such things as the thickness or compaction of the layers, and additives including lime, cement and blast furnace slag to modify the properties of some of the materials used.

The surface of the pavement is often the ‘sprayed seal’. This is usually bitumen (tar-like hydrocarbons derived from petroleum that are applied heated), combined with aggregate (rock pieces of a common size). It is not a structural layer, but acts as a waterproofing and wearing layer for the pavement. The thickness of the sprayed seal varies with the size of aggregate used but is generally 4-6mm thick. During application of the sprayed seal, the moisture content of the base must be carefully managed. If it is too wet or too dry when the sprayed seal is applied, bonding of the seal to the pavement will not occur. Once the bitumen sets, the aggregate is left sitting approximately one third above the surface. This provides traction for vehicles on the road and reduces the speed of water movement across the surface.

A surface layer on the other hand provides structural, waterproofing and wearing support. Typical heavy duty pavements are surfaced with either asphalt, concrete, reinforced concrete or a combination such as asphaltic concrete. Asphalt is aggregate mixed with a binder such as bitumen or a polymer modified additive and mineral filler, for example hydrated lime, flyash or cement, to add strength. Heavy duty pavements are roads such as freeways and motorways, where there are high traffic loads. They are extremely strong pavements and often have a specified surface, which reduces traffic noise.

Unsealed roads consist of fewer layers than sealed roads. Depending on traffic volume and subgrade quality, unsealed roads may consist of only a sub-grade layer. Where a base is constructed it is initially quite thin. Over time, as material is imported to the site to undertake repairs, the thickness of some sections will gradually increase.

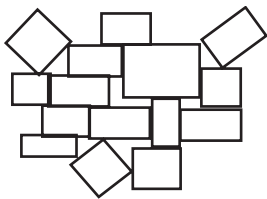
Bridges and drainage structures such as culverts, are other structures that may be associated with pavements and roads. These are generally made of reinforced concrete (concrete with embedded metal bars, mesh or wire to increase strength). These structures and bridges may impact on salinity as well as be impacted by salinity. This is covered in more detail in other booklets of the Local Government Salinity Initiative Series.

Good Road Building Materials

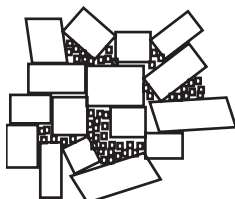
There are a number of characteristics that make a material suitable for road construction. These include:

- Appropriate **distribution of particle size** in the material to ensure that each individual particle receives its maximum load and that density, and thus strength and stiffness, is greatest. This is commonly achieved by grading material according to Fuller's Principle, which selects a mix of particle sizes to ensure that all voids are filled with successively smaller particles. An excess of fine material results in uneven load distribution and increased moisture sensitivity.

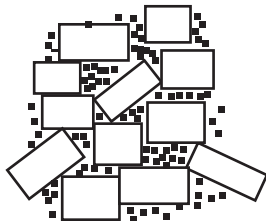
Distribution



Too many big and medium particles. Not enough fine particles to fill gaps



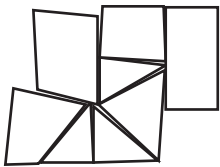
Range of sizes fill all the gaps



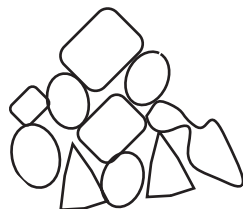
Too many big and fine particles. Not enough medium particles

- **Particle shape** affects the interlocking of particles and thus the load-carrying capacity of the material. It relates to the ratio of length to thickness (flakiness) and length to width (elongation). The optimum particle shape is angular with sharp edges, as opposed to rounded.

Particle Shape



Angular particles with sharp edges = strong mechanical interlock



Rounded particles = weak mechanical interlock

- **Permeability** is the ability for moisture to move through the spaces or cracks between pores in material. Where permeability is low, movement of moisture is restricted and thus a build-up of pressure can occur quickly. This pore pressure can lead to cracking of the seal, allowing

further moisture to enter and break down the pavement structure.

- **Plasticity** refers to the stage at which a soil's moisture content allows it to be remoulded. Plasticity depends on the amount and type of clay, and the amount of organic matter, in the soil. The "plastic limit" is the moisture content (by weight) above which a soil becomes plastic. Clay soils have a much higher plastic limit than sandy soils as they can hold more moisture before they reach this moulding point. The "plasticity index", on the other hand, is the range of moisture content at which a soil remains plastic before becoming a liquid. A soil that has a low plasticity index is more susceptible to changes in moisture content because the soil moves from a solid to a liquid with little change in moisture content.
- The **hardness of the source rock** is important as it affects the rate of material breakdown over time. Breakdown can result in the generation of finer particles. This in turn impacts on density, making the material weaker and more susceptible to moisture. The breakdown of the material also results in a volume change which can lead to deformation of the road surface.
- Finally, the **stiffness of the material** used in the base is important for the lifespan of the seal. Movement of the seal as traffic passes across it is determined by how stiff the base is. If material in the base is not stiff and held firmly in place, passing traffic will compact the base slightly. This will strain the seal that is covering the base, causing fatigue to occur sooner.



An urban road showing damage

Construction of Layers

Pavement construction involves the compaction of material in each of the layers described above. This ensures most air and moisture have been removed from the material and that particles are arranged to fit closely together like a jigsaw puzzle. This is described as mechanical interlock. Effective compaction increases the density of the material evenly throughout the pavement layer, thus increasing strength, reducing permeability and reducing the chance of deformation.

Each layer is compacted individually using the appropriate equipment. Water is added to the material to ensure it is able to be “worked” or moulded during compaction. The amount of water used depends on the density and moisture content of the material being used, the depth of the layer being compacted and the desired density.

Stabilisation or Modification of Layers

Stabilisation of thick pavement layers or modification of thin layers involves the incorporation of additives (cement-based, foamed bitumen, organic or polymer-based), into the material. When mixed into the material the additive coats individual particles. In some cases such as foamed bitumen, only fine particles are coated. This coating waterproofs these particles and binds them more tightly to one another, reducing the material’s permeability, and in the case of stabilisation, also increasing the material’s stiffness. Depending on the quantity of additives used, material is regarded as modified, lightly bound or heavily bound (in order of increasing additive dosages).

Stabilisation or modification can be used to overcome deficiencies in the strength



A rural road with “deformation”



A rural road showing damage

or permeability of construction material or the sub-grade. It may also be used to extend the life of an existing road (in-situ stabilisation). When material is altered, the tighter bonds between particles cause shrinkage. In existing pavements this can lead to shrinkage cracking. An altered layer also becomes more sensitive to vehicle overloads and localised deficiencies in thickness or stiffness. This can lead to fatigue cracking of the layer, again potentially causing cracking and degradation of the seal.

Stabilisation can occur at depths of up to 400mm, commonly called Deep Lift Stabilisation, or it can be applied to individual layers. Dual Layer Stabilisation occurs when two layers are stabilised with different additives.

Costing Salinity Damage to Roads

Salinity can cause costly damage to road infrastructure. However, it is difficult to accurately cost the impact of salinity on roads as it is difficult to separate salinity damage from damage caused by other factors, such as poor construction or increased traffic loading.

Costs can be incurred at a number of different stages, including

- construction (through the use of different materials, methods or design),
- ongoing repair and maintenance
- reduced lifespan.

Construction

Estimates of the increase in construction costs for roads in areas subject to high watertables for dryland areas (where agriculture depends on rainfall) are not available. However, information from irrigation areas indicates that costs are significantly higher than for equivalent roads in dryland areas*. Increased construction costs may result from the use of higher grade materials (such as concrete with a greater strength to reduce permeability), establishing thicker layers of material, installing better roadside drainage or raising the height of the road above the natural surface.



A roadside drain with visible salt crystals

Repair and Maintenance

Accelerated damage to roads in areas subject to high saline watertables means that the level of repair must increase in order to maintain them. The severity of damage and amount of repair necessary, will vary depending on the degree of waterlogging and salinity experienced at the site, as well as the age and construction method of the road. The additional costs incurred as a result of the increased repair work have been estimated in



A road in an irrigation area showing damage

Additional Repair and Maintenance Expenditure

Road Class	Severe Impacts (\$/km/yr)	Moderate Impacts (\$/km/yr)	Slight Impacts (\$/km/yr)	Very Slight Impacts (\$/km/yr)
National and state Highway	\$31,185	\$3,600	\$1,200	\$800
Main Sealed Road	\$17,325	\$1,600	\$450	\$200
Minor Sealed Road	\$1200	\$700	\$300	\$100
Unsealed Road	\$800	\$500	\$200	\$75
Urban Roads *	\$2,400	\$1,500	\$375	\$150

Additional repair and maintenance expenditure by road class and severity of damage

Source: Wilson, S.M. 1999, Dryland Salinity – What are the impacts and how do you value them?. An Ivey ATP and Wilson Land Management Services Report prepared for the Murray Darling Basin Commission and the National Dryland Salinity Program, Canberra

* extrapolated data

* MDBC, 1994, A study into the benefits of roads and other infrastructure of providing drainage in the irrigation areas of the Murray Darling Basin", Drainage Program, Technical Report no. 1, Canberra as cited in Wilson, S.M. 2001 Dryland Salinity – What are the impacts and costs to non-agricultural stakeholders?: Lachlan Region, A Wilson Land Management Services report prepared for the Murray Darling Basin Commission and the National Dryland Salinity Program, Canberra.

Reduced Lifespan

The average expected lifespan of sealed roads is 20 years; 40 years for heavy duty pavements. Salinity can shorten these expected lifespans by accelerating the rate of deterioration. The reduction in road lifespan will vary depending on the severity of damage, the original construction method and the repair and maintenance program.



An urban driveway with groundwater seepage

Estimates suggest that low damage levels can reduce road lifespan by 10%. Severe damage can reduce road lifespan by up to 50% (reductions averaged for both sealed and unsealed roads). The cost of shortening the lifespan (by one third) of approximately 1700km of sealed, Unsealed and urban roads funded by local government in the Lachlan Catchment, was estimated at \$1.4 million per annum (Wilson, 1999*).



A rural road showing damage

Treating Salinity Damage in Irrigation Areas

The Berriquin Irrigation District located in southern NSW has developed a Land and Water Management Plan to address the future management of the area and tackle local issues such as salinity. Over time inefficient irrigation practices in this area have allowed too much water to enter the groundwater system, causing the watertable to rise.

Approximately eighty kilometres of the Riverina Highway shows severe damage. Traffic volumes are around 800-1000 AADT with an estimated 10-15% heavy vehicles. The surrounding land use practices, surplus irrigation water runoff into table drains and flooding of gravel and borrow pits adjacent to the highway, have provided opportunity for water to move into the pavement. The pavement damage has led to increases in maintenance and restoration costs of around \$630 000 annually, compared to other roads within the region.

In addition to road design and engineering solutions, management of this problem requires work to be undertaken in the broader area, beyond the road pavement. In particular, work on reducing seepage from irrigation channels and changing irrigation practices is being undertaken. A range of design techniques have been used on sections of the Riverina Highway. These include:

- Improvement of surface drainage to alleviate water ponding in table drains.
- Groundwater pumping in selected areas with consideration of reuse options.
- Stabilisation of the sub-base and subgrade.
- Increase in formation heights.
- Use of imported road-making materials and gravel.
- Adoption of pavement designs for future construction work based on an assumed subgrade saturation to the natural ground level.

Source: ARRB Transport Research, 2002. Draft Salinity and Rising Watertables – Attachments.

* Wilson, S.M. 1999, *Dryland Salinity – What are the impacts and how do you value them?*. An Ivey ATP and Wilson Land Management Services Report prepared for the Murray Darling Basin Commission and the National Dryland Salinity Program, Canberra

Salinity Impacts on Roads and Associated Infrastructure

Rising watertables and salinity can have a number of impacts on roads. These impacts can occur simultaneously and result from water getting into the road pavement and the introduction and concentration of salts.

Water

If moisture content reaches the plastic limit of one of the pavement layers, the layer loses stiffness. The weight of passing traffic continually changes the shape of the layer and upper layers are forced to bend and stretch over this weaker moulded layer. This is similar to carpet, where the level of deflection of a carpet under foot is determined by the "sponginess" of the underlay. In this analogy the carpet is the seal and the underlay the base course. A soft (or "spongy") underlay will cause a foot to sink more deeply into the carpet. The greater deflection will result in a higher strain in the carpet, causing fatigue to occur sooner. This fatigue is reflected at the surface by a general break up of material or by the cracking of the seal.

Where expansive clays are present any change in moisture content can lead to volume changes which result in loss of pavement shape and cracking of sealed pavements. The combination of moisture and repetitive load also leads to a build-up of pore pressure within the base that can cause cracking of the seal. The movement of traffic weight across the road "pumps" water and fine material out through these cracks. The loss of these fines leads to a decrease in strength. Additional surface water can enter the pavement through the cracks, further accelerating the degradation.

Watertables at the soil surface or within a couple of metres of the surface, reduce the soil water storage space and thus the soil's ability to absorb rainfall. This increases water runoff and if it occurs across a large enough part of the catchment can make flooding more frequent. As a result there is more surface water contact with road pavements and thus a greater chance of this water entering the pavement and weakening it. The increased water volumes can also overwhelm existing culverts causing erosion and siltation, changing surface drainage and causing waterlogging.

If the watertable beneath the road is at the soil

surface or within two metres of the surface, capillary action can draw moisture into the road pavement just like oil is drawn up a wick. This moisture then migrates upwards through the pore spaces of the material towards the point of evaporation.



An urban road showing damage

Salt

The level of damage that salt will cause to a road depends upon the type and concentration of salt/s present*. The type of salt varies with local climate and geology, however the most common types found include sodium chloride (halite or common table salt), sodium sulphate, sodium carbonate, magnesium sulphate and calcium sulphate (gypsum). The ability of a salt to cause damage depends on its solubility and crystallisation properties. Only water soluble salts can move through a pavement to cause damage. Salt solubility also determines at what point the salt will crystallise. This relates to evaporation which varies throughout the day. This variation means that a salt can crystallise



A roadside salt scald

* Work has been undertaken to identify limits for the salt content of material and water to be used in the construction of pavements. Information can be found in Australian Road Research, 20 (4), December 1990. *Soluble Salt Damage to Thin Bituminous Surfacing of Road and Runways*. Gokhale, Y.C. and Pundhir, N.K.S. 1985 *Effect of Sodium Chloride in Water on Weathering of Road Aggregates* In Indian Highways. pp 15-25

repeatedly, gradually becoming larger due to its tendency to absorb water.

Research has identified that degradation from the introduction and concentration of salts in the road pavement is a two-stage process.



A rural road showing damage

1. Build-up of pressure within the aggregate particles.

Sodium chloride dissolved in water, enters the pore spaces of the aggregate, reacting with the chemical constituents of the mineral aggregate such as compounds of calcium, aluminium, iron and magnesium, forming crystals of different chemical compounds that have larger volumes. The pressure that this crystallisation and increased volume exerts on the aggregate particles causes cracks to develop, allowing more moisture to enter. As moisture levels fluctuate, the change in conditions drives a cycle with the salts crystallising, dissolving and re-crystallising as conditions change.

The pressure from crystallisation and vapour pressure (from the evaporating moisture) builds up beneath the seal and can be sufficient to deform it. Initially deformation may appear as blisters. If the blisters burst, the waterproof layer is broken, allowing the infiltration of surface water and increasing the evaporation rate. This accelerates the crystallisation process, speeding up pavement deterioration.



A highway with blistering of the seal

2. Degradation of aggregate particles

Further growth and expansion of the salt crystals enhances the existing cracks, ultimately causing the particles to break up. The speed at which this deterioration occurs depends on the type and strength of rock, amount and diameter of the aggregate's pores and accessibility to moisture and salt. The increase in fine aggregate from the breakdown of material increases the plasticity of the material and thus reduces its strength. Degradation also alters the shape of the aggregate particles, for example making them more rounded, affecting the mechanical interlock.

The growth of filamentous halite (sodium chloride) crystals or whiskers (also called fibrous halite crystals) has been identified in laboratory tests of spray-sealed pavements. It is not known how frequently these crystals form outside the scenario simulated in the laboratory. However, they are of concern because of the extremely high mechanical strength generated by their crystallisation. Testing found that these whiskers form following the accumulation of weaker cubic halite crystals on the surface of the base before a sprayed seal is applied. Once the seal is applied the reduction in evaporation rate leads to an increased concentration of the salt solution. This is because there remains sufficient evaporation to move saline moisture to the surface, but not enough to allow it to escape quickly. The higher level of supersaturation and confined space between the base and seal provides conditions favourable for whisker growth. As these whiskers grow they exert considerable pressure on the seal, lifting it off the base. Once the blisters crack a dense mat of whiskers may be visible.

Reinforced concrete structures, including bridges and culverts, can be affected by salinity if not designed and constructed for the site conditions. One effect is corrosion of the reinforcement. Chlorides from sources such as surface water, groundwater, the air, admixtures, or the water, aggregate and sand used to make the concrete can reduce the alkalinity of the cement. Corrosion then continues at a rate dependent on the amount of available oxygen, moisture, reactive ions such as chlorides, and remaining alkalinity. As the steel reinforcing rusts, it expands and the concrete section may crack or lose cover material (spalling). This leads to reduced structural integrity.

Treating Salt in Pavements

NSW Roads and Traffic Authority recommended treatments for unsealed pavements containing salt are as follows:

Salt Content of Fines (%)	Preliminary Treatment Method
0 - 1.5*	Apply a prime
1.6 - 2.5**	Apply a primer seal followed as quickly as possible with the final seal
2.6 – 3.0	A sacrificial primed surface swept and followed by a primerseal and final seal may be satisfactory otherwise treat as for 3.0%+
> 3.0	Special investigations will be required and techniques developed. No single method can be sure of success.

* Salt content is determined gravimetrically by drying the saturation extract in a microwave oven.

** For salt content less than 2.5% a primerseal with 10 aggregate and AMC4 primerbinder sprayed at 1.8 L/m² should be satisfactory.

Source: NSW Roads and Traffic Authority, 2002. RTA Sprayed Sealing Guide

heavier trafficked roads or sections are subject to greater pressure and so early blistering will be repeatedly flattened by traffic.



A burst salt blister

- **Staining** – White efflorescence or, if observed after rain, dark brown streaking may be evident on the surface of a sealed or unsealed road affected by salinity. This is a result of the concentration of salts in the upper layer of the road. On sealed roads the staining is caused by the saline discharge released from blisters that have broken open.



Water & salt crystals in cracks in a carpark

- **Cracking** - The introduction of moisture and growth of salt crystals in the various layers can lead to aggregate fracturing and crumbling. As the crumbled material settles, cracks appear in the surface seal. Cracking can also occur where lower layers become weak and the weight from traffic passing across causes the upper, stronger layers to crack.



Cracking of a road exposed to high levels of moisture

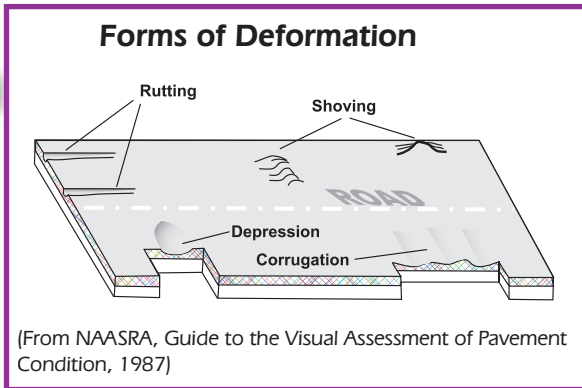
Symptoms of Salinity Damage

Although pavement deterioration can occur as a result of a number of factors some common road defects have been observed in salt affected roads.

- **Deterioration of bitumen seal** (slicking and bleeding) – The seal can be affected in two ways. Firstly bitumen can be stripped from the aggregate due to inundation by saline surface water. Secondly, the base layer can soften as a result of traffic compacting weakened material. This allows the seal aggregate to sink into this layer, reducing traction.
- **Blistering** – As salt crystals form between the seal and the top of the base layer, the pressure from their growth heaves up the seal in a dome shape or blister. The thinner the seal the more likely it is that blisters will form. These blisters may be only slightly raised, where they do not seriously crack the surface, or much larger, resulting in severe star shaped cracks. The blisters may contain light coloured salt deposits or a viscous solution (after rain). If blisters are not repaired they may later form potholes. Observations indicate that blisters are more likely to appear on lightly trafficked roads or sections of roads. This is because

- **Deformation** – Distortion of the surface following compaction, movement of weakened material, or lifting of poorly bonded layers can occur when a road is weakened by moisture. This deformation can include rutting along the wheel path of passing vehicles and roughness caused by shoving and corrugation. Where reactive soils are present the introduction of moisture can lead to a volume change and result in depression of the surface.

- **Potholes** – If left untreated and with continued traffic movement, areas of the road that are already weakened as a result of deformation, blisters, the loss of bitumen or extensive cracking can develop potholes. These can be observed on both sealed and unsealed roads.



An urban road showing damage

Deformations	
Form of Distress	Possible Causes
Rutting	- inadequate pavement thickness - post construction compaction - instability of base or surfacing
Shoving	- inadequate surfacing or base strength - poor bond between layers - lack of edge containment - inadequate pavement thickness
Depression	- settlement of service trench of embankment - isolated consolidation - volume change of subgrade
Corrugation	Instability of AC or base course

Source: NAASRA 'Guide to the Visual Assessment of Pavement Condition' 1987. In 'Pavement Design – pavement performance and deterioration', Road Transport Agency South Australia 1994.

- **Cracking and spalling of reinforced concrete** - Reinforced concrete used in bridges and culverts can crack and crumble away from the steel reinforcing or the concrete itself can succumb to physical and chemical attack by salts.



Exposed reinforcing in a concrete piling



Deformation of a rural road



Repair of deformation in a rural road



Kerb and guttering affected by sulphate salts



A rural stormwater drain showing salinity symptoms

Roadside indicators may identify high watertables and salinity as a potential problem to the road. These indicators include:

- Free water in the table drain when no rain has fallen recently.
- Damp soil or salt crystals in table drains.
- Siltation of culverts.
- Dead or dying trees along the roadside.
- Erosion of gullies or table drains.
- Bare areas in adjacent table drains.
- Rusting of steel fence posts.
- The presence of species that can tolerate higher levels of salt and/or waterlogging in the table drain and along the roadside. These species may include Cumbungi (*Typha* spp), Sea Barley Grass (*Critesion marinum*), Annual Beard Grass (*Polypogon monspeliensis*), Couch (*Cynodon dactylon*), Salt Sandspurrey (*Spergularia marina*), Curly Ryegrass (*Parapholis incurva*) or a variety of *Juncus* or Reed species.

The Impact of Roads on Salinity

Just as salinity impacts on road infrastructure, the construction of roads can impact on salinity processes. In particular, the building of embankments and compaction of layers can interfere with groundwater flow and the construction of deep drains can lead to a mixing of surface water and groundwater. Minimising the impact of roads on salinity is critical to managing salinity in NSW. Work is currently being undertaken to amend sections of one of the industry guidelines, AUS-SPEC, to assist this process. Amendments are proposed for specifications dealing with stormwater drainage, sub-surface drainage, control of erosion and sedimentation and landscaping. These amendments will provide detailed information on design recommendations relating to salinity.



A crop showing salinity symptoms

Roads In Flat Areas

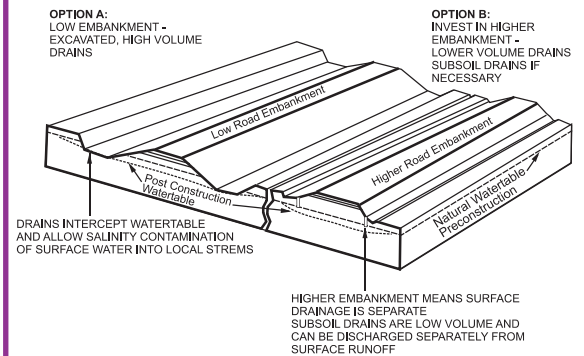
The following diagram illustrates the two main options for road design in flat areas.

Option A is a low embankment with deep drains. The drains are designed to intercept the watertable. If sufficient water is removed, the watertable may be lowered, which in turn could minimise the ingress of moisture into the subgrade of the road. However issues arise with regard to disposal of this salt water and because the drains act as direct entry points for surface water to flow into the watertable, increasing the level of recharge at the site. If the watertable rises, the drains and disposal system may overflow and saline groundwater will flow out into the surrounding landscape. In the long term this will lead to degradation of the surrounding landscape and an increased salinity problem.

Option B, is a higher embankment (or one that is stabilised) that provides

adequate strength to overcome the effects of a subgrade weakened by moisture. The higher embankment also allows for the separation of surface drainage from any sub-surface drainage. In selecting this option, the longer life of the strengthened road structure must be weighed up against road safety and the costs involved in the establishment of the higher embankment.

Road Design in Flat Terrain



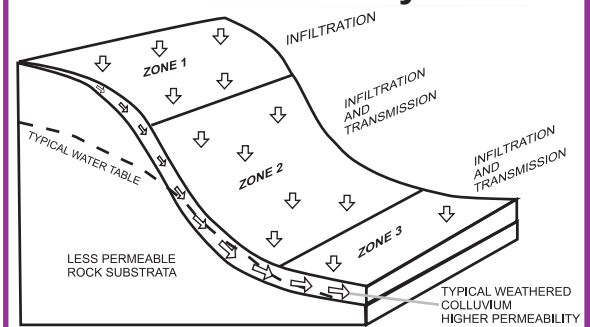
Source: "Practical Measures Within Road Reserves to Avoid Development of Catchment Salinity Problems". Clifton and Porter, 2001.

Roads In Hilly Areas

The diagram below illustrates the different zones of groundwater movement in hilly terrain. This is a simplified diagram that does not take into account any subsurface geological features that may affect groundwater flow (including faults or impermeable material).

The zone in which the most care must be taken with road construction is zone two.

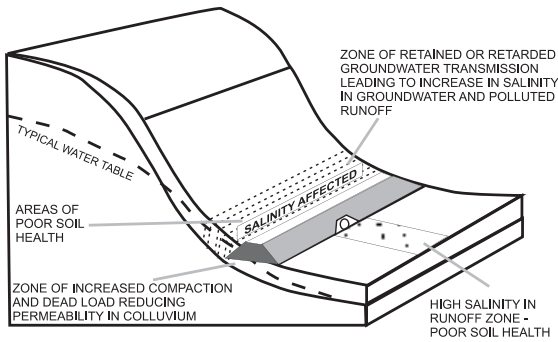
Groundwater Issues in Hilly Terrain



Source: "Practical Measures Within Road Reserves to Avoid Development of Catchment Salinity Problems". Clifton and Porter, 2001.

Any excavation or compaction of this zone can lead to interference with lateral groundwater flow, either exposing it at the surface or blocking movement and causing it to build up. The likely effects of constructing a road in zone two, without considering the impact on groundwater flow, are illustrated below.

Salinity Issues for Critical Road Positions



Source: "Practical Measures Within Road Reserves to Avoid Development of Catchment Salinity Problems". Clifton and Porter, 2001.



Numerous blisters in the seal of a rural road

Assessing Roads for Salinity Damage

A number of tools are available to assist in identifying roads with salinity damage or potential for damage. Most of these tools are regularly used by those working with roads, however the application and/or interpretation with respect to salinity may require the assistance of a salinity specialist.

It is unlikely that one tool will be successful in identifying or predicting salinity damage in all scenarios. This is due to inadequacies of these tools, but also because the processes that cause salinity can change considerably over time and space. Where possible, the outputs of a number of tools should be examined together before any assumptions are made.

Site Assessment

A salinity site assessment may be undertaken for new roads and for pre-existing roads undergoing reconstruction or maintenance. Assessment can vary from a simple visual inspection to detailed soil, aggregate, surface and groundwater investigations. Obviously the time and cost of detailed site assessments are easier to justify when high traffic volume roads and/or high construction costs are involved or where more certainty is required for future asset management.

A framework methodology for site assessments is given in the Local Government Salinity Initiative Booklet, "Site Investigations for Urban Salinity". The booklet provides detailed information about four phases of investigation. The first phase involves walking the site looking for visual indicators such as salt tolerant plants and the presence or absence of the symptoms of salinity damage, either in the road pavement, table drain or across the proposed site. It also involves the collection of existing information regarding salinity in the area. In NSW, state and local governments are involved in the identification and treatment of salinity in both rural and urban areas. Staff from the Department of Infrastructure, Planning and Natural Resources (DIPNR) and NSW Agriculture, may be able to provide advice on salinity identification. DIPNR also maintains soil (SALIS) and groundwater (HYDSYS) databases. The Local Government Salinity Initiative Booklet "Broad Scale Resource for Urban Salinity" lists some of these sources of information as well as the advantages, disadvantages and costs associated with these tools.

The information collected in phase one of a site assessment enables a decision to be made as to whether further soil and groundwater testing is required. Phase two involves the collection of these samples, while the third phase involves laboratory analysis of selected soil and water samples and interpretation of results. It is important to compare results with construction standards. It is presently common to class sites as non saline, moderately saline and so forth, however this is based on plant growth type characteristics rather than aggressiveness to concrete and other building materials.

The fourth phase of the site assessment involves selection of appropriate management and evaluation techniques to suit the salt and water processes, proposed construction method, material, traffic conditions, maintenance and construction budget etc.



A rural road showing damage

Aerial Photography

Saline sites in rural areas can often be identified using aerial photography. As well as speeding up the process of identifying currently affected roads, aerial photography can facilitate the identification of future saline sites when the information on existing sites is examined with watertable data. This can then be used to highlight sections of road that are at risk from further damage, by comparing road elevation profiles with the predicted affected area. An example of the application of this technique to the Great Eastern Highway is provided below.

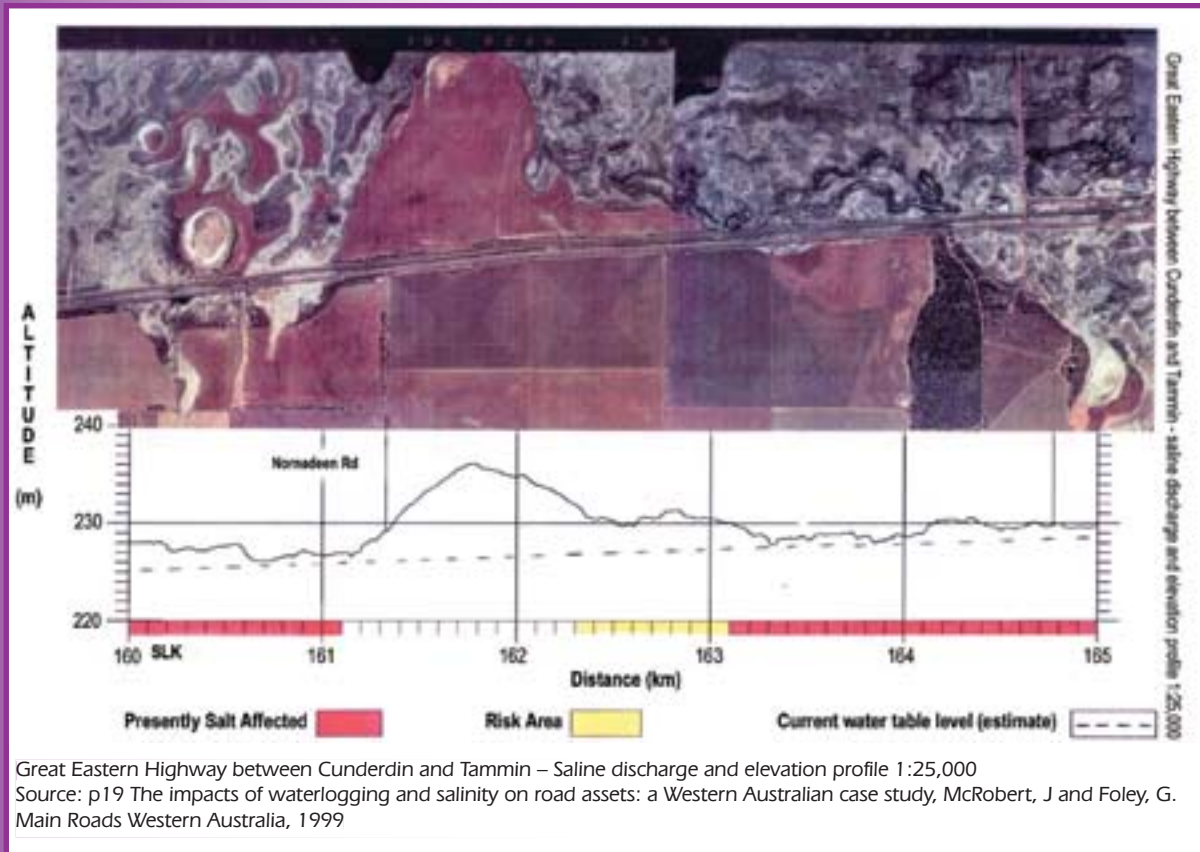
Interpretation of Satellite Imagery

The use of Landsat TM imagery (which highlights vegetation cover and health) combined with Digital Elevation and Water Accumulation Models to identify affected and risk areas is another available technique. Ground-truthing of this result is then undertaken to validate the assumptions made in interpreting the data.

Pavement Condition Data

A number of techniques to identify salinity damage using pavement condition data have been identified in the Western Australian Case Study booklet, "The impacts of waterlogging and salinity on road assets: a Western Australian case study," McRobert, J and Foley, G. Main Roads Western Australia, 1999. These include deflection testing and attempts at correlating road elevation and roughness data.

Deflection testing identifies the current pavement strength and if measured periodically can identify change in strength over time ie. rate of deterioration. It can be undertaken on sites already affected as well as those sites under threat. Existing damage in the form of roughness (as a result of moisture ingress weakening the subgrade) can be assessed using automated data collecting tools such as lasers and accelerometers mounted on a survey vehicle. These tools can also record the elevation (as height above sea level) of each section of road.



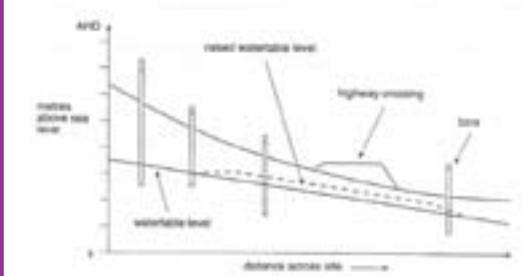
Assessing Roads for their Impact on Salinity

Owing to the impact roads can have on initiating or exacerbating a salinity problem, it is important that at the very least all proposed road developments are assessed for their impact on groundwater salinity. Both surface water and groundwater movement should be examined in order to determine a road's possible impact. This may also be necessary where a road is perceived as contributing to a salinity problem that affects downstream water quality and/or neighbouring infrastructure or productivity.

Surveying of the surface relief and natural drainage patterns can help identify the pattern of surface water movement at a site. Any impediment to water movement, either due to poor surface drainage, the height of the road and/or inadequate culverts, can be identified by comparing the surface contours upslope and the crest height of the road. Areas with considerable lateral groundwater flow (where the groundwater flows close to the surface) are most at risk from road construction impeding this flow. Assessment of lateral flow would assist in determining the likelihood of salinity developing. This information can then be used in road design, in particular the siting of a road, provision of culverts or a drainage blanket. Note that lateral movement is dependant upon the hydrogeological features of a site, and its identification and/or quantification will require the advice of specialists.

The impact of a road on the local watertable can be assessed with the installation of a transect of shallow monitoring bores as depicted in the diagram. If, when comparing the bores above the road with the one below it, the measurement does not indicate a drop in watertable height comparative to the change in elevation, it can be presumed that the road is acting as a barrier to groundwater movement. Over time as groundwater is impeded it will build up behind the road, elevating the watertable in this section.

The impacts of waterlogging and salinity on road assets: A Western Australian Case Study



Bore transect measuring the watertable level under a roadway crossing. (pg 54)

Source: The impacts of waterlogging and salinity on road assets: a Western Australian case study, McRobert, J and Foley, G. Main Roads Western Australia, 1999

Any exposure or release of groundwater during the life of the pavement must be considered for its impact on salinity. Groundwater may be exposed via deep drains or may need to be disposed of following collection and/or extraction. Such exposure may lead to the movement of saline groundwater into the wider environment with subsequent impacts. The extraction and disposal of groundwater requires development approval. For more information contact the Department of Infrastructure, Planning and Natural Resources or the Environment Protection Authority and refer to the Protection of the Environment Operations Act 1997 and Water Management Act 2000.

Is the Road a Problem?

A case study from Western Australia looks at how to determine the role of road infrastructure in a salinity problem and how to identify appropriate steps for remediation. The example relates to the South Coast highway and its obstruction of the natural flow of surface water from farmland.

From a road management perspective, the options to remediate the site included improving surface drainage through the construction of drains, increasing the number and capacity of culverts, or the construction of a floodway. Several site investigations were undertaken and included assessing the effect of the road on the local watertable and calculating the extent of the flooding caused by the road.

Using information collected and with the assistance of an aerial photo, it was concluded that changes to the road would not provide a long term solution because of the ongoing siltation problem due to flooding. Instead, it was identified that options to stabilise the salinity affected country immediately upstream of the road and divert any ponded surface water to farm dams would provide a better long term solution.

Strategies to Prevent or Minimise Salinity Damage

There are a number of strategies that will assist in preventing or minimising salinity damage. However variations in site characteristics mean one strategy is not suitable for all sites. Road design to minimise the effects of salinity often coincides with good general practice and includes:

1. Site assessment for salinity prior to road design and construction.

2. Careful road design with respect to surface water.

In particular, drainage can be designed to ensure it does not excessively concentrate surface runoff and lead to waterlogging of the pavement or additional recharge to the groundwater system. The improvement of shoulder cross falls and table drains reduces any ponding. Increasing the seal width of roads by including the shoulders in the sealing program benefits the management of surface water as well as safety. The increased width adds support to the weaker edge of the road, holding the outer wheel edge more tightly. Surface runoff can also be managed to ensure it does not flow across saline discharge areas, which are both more susceptible both to erosion and sources of high concentrations of salts.

3. Road design to limit ingress of salt and moisture.

The material and water used in construction can be selected to contain minimal, or if possible no salt *. This will reduce the amount of available salt and limit the occurrence of salt-induced road failure in areas where a high saline watertable is not present. Specific design features such as compaction, stabilisation and seal characteristics may limit the surface permeability and thus minimise the amount of saline water being drawn up through the pavement layers by evaporation.

4. Careful location of sedimentation or detention basins.

Sediment basins leak naturally and any concentration of salts may affect the soil structure, increasing leakage.

Bringing Extra Salt to the Site

The use of highly saline base material and sea water or salty bore water for compaction was assessed during investigation of salt attack on the Stuart Highway, RN 100 South Australia in the 1970s and early 1980s.

Investigation identified that road failure was a result of salt crystallisation under the prime or primer seal, leading to blister formation and heaving of the seal as a result of vapour pressure. Examination of the pavement identified that the material used contained greater than 10% of soluble salts by dry mass of aggregate. In addition, the high fines content of the material exacerbated the problem, as it was more susceptible to salt build up and crystallisation.

The following measures were identified from work conducted at this site.

Preventative measures

- Limit salt content of material and water. Material should contain less than 0.25% of soluble salts by dry mass of aggregate. This requirement should extend to a depth of at least 0.5 metres wherever possible.
- Minimise moisture movement by making the surface as impermeable as possible.
- Organise construction such that the seal is applied as soon as possible after the pavement has been compacted.
- Subject the section to traffic or rolling immediately.

Recommended Treatment

Prime	ARS bitumen emulsion @ 1.1L/m ²
Primerseal	Class 170 bitumen @1.0L/m ² 4mm chippings @ 200 m ² /m ³
Double Seal	Class 170 bitumen @ 1.1L/m ² 14 mm chippings @ 95 m ² /m ³ Class 170- bitumen @ 0.9L/m ² Sand @ 200m ² /m ³

Source: Stuart Highway RN 1000 Salt Attack on Sprayed Seals – Interim Report on Problems and Trials conducted to June 1982. R.M. Januszke. Department of Road Transport South Australia. Unpublished

* NSW Roads and Traffic Authority, April 2002. *Interim RTA Sprayed Sealing Guide*.

Treating Salinity Damage

Once salinity has been identified at a site there are a number of options to treat the damage. Unfortunately, although moisture damage can be repaired to a certain degree, once salt has entered the pavement it cannot be removed and will continue to attract other available moisture. Consideration of a particular site's characteristics, such as recharge source, site hydrogeology, and predicted traffic volume, will assist in determining the most appropriate treatment.



Repaired road at a salinity affected site

Intensive Road Maintenance

Intensive road maintenance is a schedule of maintenance that is implemented over a period of years to gradually improve the road. This extends the life of the road and defers major reconstruction costs.

An intensive program of road maintenance will only work on lower volume roads where the rate of pavement distress allows for rehabilitation work to be undertaken over a number of years. In addition, maintenance will disrupt less traffic on lower volume roads. Maintenance work may include drainage works, stabilisation of layers, patching and resealing. In all cases the removal of the affected seal, sweeping and resealing is necessary. It is particularly important when repairing salt blisters that the surface is restored to an even, regular condition and rendered impervious in order to prevent further upward migration of salt.

Reconstruction and Resheeting Program from Loddon Shire – Victoria

The Loddon Shire road network comprises more than 1300 km of sealed roads (main and local) and 3500km of unsealed roads. Some of these roads are located in the lower-lying region of the shire's north east where the watertable is within two metres of the surface in places. Many of the roads in this area also have subgrades comprising expansive clays which can cause cracking of overlying pavement areas.

Many of the road pavements in Loddon Shire have reached the end of their life. An increase in heavy traffic due to deregulation of grain cartage and bulk handling and the arising salinity problem impacted upon design requirements for reconstruction of sealed roads. Reconstruction involved increasing the elevation by approximately 150mm and widening shoulders. In particular it involved:

- Base: 180mm Class 2 Crushed Rock
- Sub-base: 150mm Class 4 Crushed Rock
- Improved Subgrade: 150mm lime stabilised (3% lime)
- Total pavement thickness: 330mm on 150mm improved subgrade

Resheeting under this approach is more costly due to the additional thickness required. However, this is seen as cost effective in areas of a high watertable because of the added strength it provides.

Source: ARRB Transport Research, 2002. Draft Salinity and Rising Watertables – Attachments



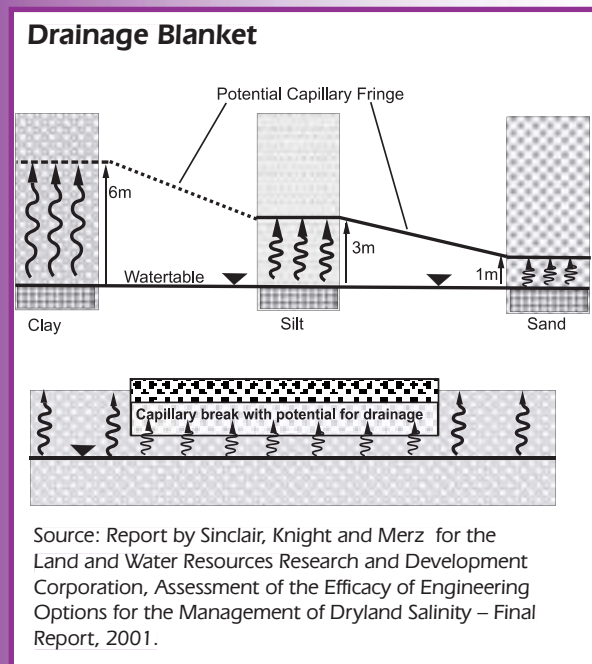
Rural road with salinity symptoms

Major Road Rehabilitation

Rehabilitation techniques lengthen the life of a road affected by salinity, but are short term solutions if the underlying cause of the problem is not also addressed.

Drainage Blanket

All materials contain pores. If these pores are connected the movement of air and moisture through them will be enabled. The material is then said to be permeable. As the pore size gets smaller, the strength of the suction (capillarity) that is drawing the moisture to the surface increases. The introduction of a layer of coarse-grained material with large pores above the subgrade reduces this suction, confining moisture and salts to the lowest layer of the road. This layer is called a drainage blanket or capillary break. The integrity of the drainage blanket is often aided by the presence of a lining of geosynthetic fabric (strong fabric made from polyester or polypropylene).



Raising Road Elevation

A relatively common solution to the problems experienced by low lying roads affected by high watertables has been to raise the height of the road. This involves building up cover over the subgrade, increasing its thickness and incorporating adequate drainage. Consideration of the porosity (pore size) of the fill used in the embankment is critical as it will influence the height required. This is because the bigger the pores, the weaker the suction (capillarity) and thus shorter the distance it can draw moisture towards the surface. For example in Western Australia, sandy soil has been used to build the road up a further one metre. This is above the level that capillary rise can draw moisture towards the surface in a

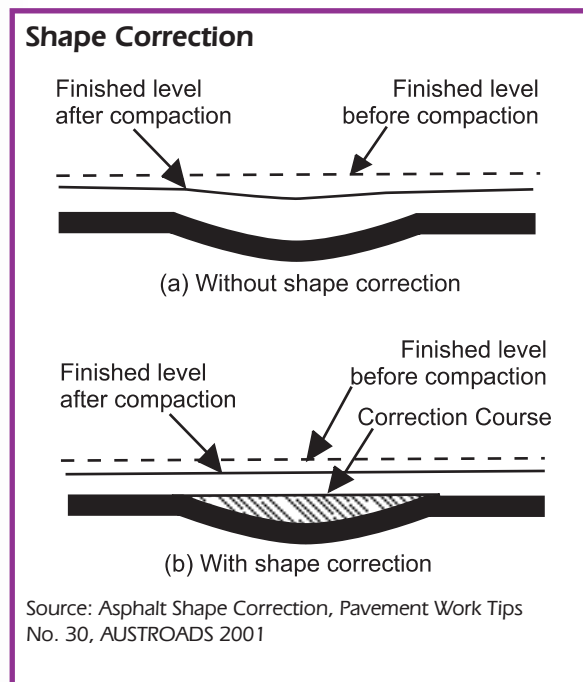
sandy soil. For added security it is suggested that raising the road be combined with the use of a drainage blanket to further minimise capillary action. In urban areas roads cannot be easily raised because height is constrained by kerb and guttering, property access requirements *, noise considerations etc.

Resheeting

After removing the damaged seal, granular resheeting material is applied above the base layer. This can assist in increasing road strength where change in the road level is not required. The permeability of this layer ensures that pore pressure build-up is minimised.

Shape Correction

Areas in which a weakened subgrade has resulted in a change in road shape or increased roughness can be remediated with the application of a hot mixed correction course, which is very stiff. The degraded section may be cut out or the material applied as another layer.



* Groundwater and Salinity: Impact on the Road Network M. Sutherland, RTA NSW

Which Rehabilitation Strategy is Best?

Although the soil and groundwater processes of Western Australia differ to those in New South Wales, the work that has been undertaken there provides useful insight into the problem of roads and salinity.

Extensive road reconstruction has been undertaken on the Great Eastern Highway in Western Australia. This has involved increasing the height of the road to decrease the impact of high watertables. Evaluation of alternative or complementary treatments to this work was undertaken and documented in a report. The project looked at the feasibility of drainage, pumping and revegetation. These options were examined in relation to site characteristics, cost comparisons and likelihood of success.

The case study identified that the selection of a single treatment or combination of treatments depended upon a number of factors. In particular, the evaluation identified that revegetation alone would have only a modest impact on the roadway given the nature of the salinity problem in the area and is more suitable as a proactive solution prior to saturation of the pavement to slow or stop the rate of watertable rise.

Source: The impacts of waterlogging and salinity on road assets: a Western Australian case study, McRobert, J and Foley, G. Main Roads Western Australia, 1999. pg 44-46.

Locally Lower the Watertable

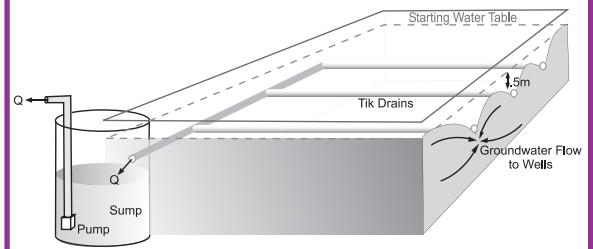
Several techniques are available that may work to lower the watertable locally for a period of time. This can be achieved through drainage via sub-surface or deep longitudinal drains, or through groundwater pumping.

Sub-surface drains (such as tile or mole drains), can be used to lower the watertable in the immediate area to below the depth of earthworks. Tile drains are permeable pipes placed underground that create passages for groundwater. Mole drains are constructed in the soil to create unlined passages for improving internal drainage. However, they are restricted to areas with soils of low permeability (low ability to transmit moisture e.g heavy clay). Water moved through sub-surface drains is collected in a sump or deep drain and removed from the site. Because of its characteristics, a drainage blanket can also work as a sub-surface drain, acting as a path for the movement of moisture.

Groundwater pumping can also lower the

Sub-surface drains concept

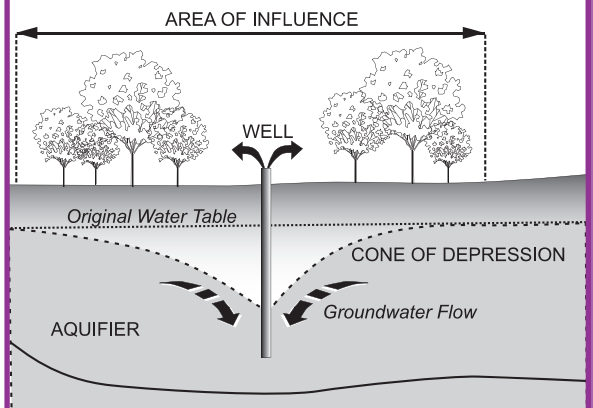
(SKM Engineering Solutions page21)



Source: Report by Sinclair, Knight and Merz for the Land and Water Resources Research and Development Corporation, Assessment of the Efficacy of Engineering Options for the Management of Dryland Salinity – Final Report, 2001.

watertable locally if conditions are right. A “multi-point well system”* is suggested as the most suitable pumping scheme for protecting roads. This system involves the placement of several bores to a depth of 10-20 metres operating through one pump. A nest of observation bores 5-10 metres deep is recommended to monitor the effects of pumping.

Cone of depression from groundwater pumping



Source: ABC's of Groundwater by Robyn Gill of Centre for Groundwater Studies

* The impacts of waterlogging and salinity on road assets: a Western Australian case study, McRobert, J and Foley, G. Main Roads Western Australia, 1999

Costs involved in the implementation of strategies to locally lower the watertable and their success rate depend on a number of factors. These include:

- **Site Topography**
Sufficient gradient is needed to ensure groundwater collected can be drained to one point.
- **Soil Permeability**
Soils must be permeable enough to transmit water to the drain or well.
- **Aquifer Characteristics**
The aquifer being pumped must be connected to the watertable to effectively lower it. The amount of water that is stored in the aquifer and the speed at which this water moves to the bore will impact upon the costs of water disposal.
- **Disposal Method**
A suitable disposal or reuse method for the water collected is required. The method must ensure minimal environmental impact. Disposal will require consultation with, and generally approval from, the NSW Environment Protection Authority and the Department of Infrastructure, Planning and Natural Resources.

More information on groundwater pumping can be obtained from the report by Sinclair, Knight and Merz for the Land and Water Resources Research and Development Corporation, "Assessment of the Efficacy of Engineering Options for the Management of Dryland Salinity – Final Report" 2001.

Roadside Revegetation

Strategies to address salinity damage may extend into the road corridor and even surrounding land. Trial work undertaken over the last decade has investigated the ability of vegetation, including perennial pastures and salt and/or waterlogging tolerant trees, shrubs and grasses, to lower the watertable beneath the road pavement. A watertable response has not been detected at all sites. This may be due to the rate at which groundwater is moving to the site or limitations to the water use of the vegetation planted. Where a response has occurred it is only expected to last for the short to medium term (up to 20 years)*. This is because trees use less water as they get older and thus will not be able to maintain the drawdown effect. To be successful, roadside plantings may require the cooperation of neighbouring landholders as the narrowness of roadside reserves limits the area that can be revegetated. Works on adjacent properties

such as planting perennial pastures and trees will increase the amount of groundwater being extracted and minimise local recharge.

Characteristics that affect the success of revegetation have been identified in the trial work. These include:

- **Species type**
Water use by vegetation varies with species type and growth stage. For example younger plants generally use more water as they grow more rapidly. The conditions on the site such as depth and salinity of the water table, microclimate, nutrients, weeds and pests will also influence the physiological activity of the plant and thus water use.
- **Planting density**
The appropriate planting density for a site largely depends on the amount of water that needs to be removed. Too great a density can use up all the available water and create drought conditions at the site, affecting plant growth. However, initial over-planting is a precaution against plant loss, spreads insect damage in the early stages of growth, and can be thinned later.
- **Watertable Depth**
Waterlogging can affect plant health and stability. Vegetation is generally most effective where the watertable is deeper than three metres so that rainfall can leach salts out of the root zone of the growing plant.
- **Groundwater Salinity**
The salinity level of the site's groundwater will increase as water, but not salt is used by the plants. The lower the site's original salinity level, the less of an impact this increased concentration will have and thus the greater the chance of the vegetation surviving.
- **Soil type**
A site's soil type impacts upon its leaching potential. For example, the heavier the soil, the longer it takes for water to move through and leach salts away from the root zone. Soils with structural problems either due to sodicity, acidity or compaction will pose problems for plant growth making it more difficult for the plants to cope with wet and/or salty conditions.

* *The impacts of waterlogging and salinity on road assets: a Western Australian case study*, McRobert, J and Foley, G. Main Roads Western Australia, 1999

- **Rainfall**
To have an impact on the watertable, vegetation must at least use an amount of water equal to, or preferably greater than, that provided by rainfall. Rainfall will also affect the leaching rate and will determine the species that can be grown.
- **Aquifer Characteristics**
Several characteristics of the aquifer will impact upon the amount of water the vegetation will need to use to affect the watertable depth. These characteristics include the porosity of the aquifer, hydraulic grades and groundwater storage volumes. A watertable that is the result of a lot of water moving relatively quickly into an area will be harder to manage with vegetation.



Roadside tree planting for groundwater control

Treating Salinity Damage to NSW Highways

Work has been undertaken to treat salinity damage to both the Sturt Highway and Olympic Highway within NSW. This has involved joint research between the Roads and Traffic Authority and various other organisations including the Department of Infrastructure, Planning and Natural Resources, NSW Agriculture and Charles Sturt University.

Rehabilitation of a small catchment upstream of the Sturt Highway at Yarragundry (15 km west of Wagga Wagga) has been undertaken during a five year research project that commenced in 1992. The site exhibited severe salt scalding, salt tolerant vegetation and dead trees above the road embankment with little surface salinity expressed below. The aims of the project were to assess the effectiveness of trees and crops in removing water before it enters the road environment, and to assess the effect of embankments in restricting water flow. Various tools were used to assess the characteristics of the site and observe the impact of the rehabilitation techniques. They included:

- Piezometers on either side of the highway and upstream in the catchment adjacent to saline discharge points.
- Thematic mapping using satellite imagery.
- An Electro Magnetic Induction Survey.
- Attribute mapping by GIS.
- Monitoring of pavement deflection and moisture level.

The project involved the establishment of trees and perennial pastures within the catchment and the identification, and in some cases, fencing out of high recharge and discharge areas. Initial results are not clear due to the impact of drought, and further findings have not yet been published.

Similar work was undertaken on the Olympic Highway at Avoca, north east of Young. At this site revegetation of land adjacent to the road took place in order to address the continuing road failure caused by the high watertable. River Red Gum (*Eucalyptus camaldulensis*) and Swamp Yate (*Eucalyptus occidentalis*) were used together with Tall Wheat Grass. The project also looked at the growth rates and suitability of the timber for milling, the impact of salt tolerant pastures and the quality of these pastures for grazing and silage. Research and findings have not been published.

Sources: Groundwater and Salinity: Impacts on the Road Network, M. Sutherland, RTA NSW
Dryland Salinity Research Project, G Elphick, RTA 1992
Signage at the Olympic Highway Demonstration, "Avoca" Young, NSW.

Concluding Remarks

Salinity has an impact on roads and roads have an impact on salinity processes on the site and within the catchment. Consideration of this two-way process can assist in the design, construction and maintenance of roads to avoid on-site and off-site impacts and to weigh up short term versus long term costs.

The inter-relationship of water and roads has been traditionally considered by road engineers. However, the extra water often associated with salinity hazard areas and the added complications of salt interactions do not appear, to date, to have been extensively researched or deliberately incorporated into road designs and asset management systems.

The limited written material on this subject and the experiences of a few engineers have been collated in this document to assist this evolving process. Some of the management options and strategies may require more dialogue and co operation between road engineers, surrounding landholders and catchment management groups. An added benefit of this process would be a better understanding within the wider community of the complicated decisions necessary to construct and maintain safe, efficient roads in the context of so many competing issues such as salinity, native vegetation conservation and water quality.



Carpark showing damage



Gutter, road and nature strip with salinity damage





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Acknowledgments

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Gavin Jenkins - Civil Engineer, NSW Roads and Traffic Authority, Western Region.

Sian McGhie – Urban Salinity Team Leader, Department of Infrastructure, Planning and Natural Resources, Penrith.

Alistair Lunn – Scientific Officer, NSW Roads and Traffic Authority, Western Region.

David Looney – Scientific Officer, NSW Roads and Traffic Authority, Western Region.

Margaret Sutherland – Improvement Project Manager, NSW Roads and Traffic Authority, Wagga Wagga.

Jencie McRobert – Senior Environmental Research Scientist, ARRB Transport Research, Vermont South.

Elizabeth Madden – Communications Officer, NSW Agriculture, Wagga Wagga.

Nicole Gammie – Salinity Advisory Officer, NSW Agriculture, Condobolin.