DEPARTMENT OF PLANNING, INDUSTRY AND ENVIRONMENT

MAY 2021

PUBLIC

# SNOWY MOUNTAINS SPECIAL ACTIVATION PRECINCT – SALT IMPACT MANAGEMENT PLAN

KOSCIUSZKO NATIONAL PARK

Question today
*Imagine tomorrow*
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# Snowy Mountains Special Activation Precinct – Salt Impact Management Plan
# Kosciuszko National Park

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| E | 07/05/2021 | Final Salt Impact Management Plan |

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# GLOSSARY AND ABBREVIATIONS

| | |
|---|---|
| 2-Lane Kilometre | A one-kilometre length of a two-lane road. |
| Anti-Icing | Activities to prevent ice from forming. Anti-icers (typically liquids) are applied prior to snowfall to prevent snow and ice from bonding to the pavement. |
| AVL | Automatic Vehicle Location (usually using GPS technology) |
| Benchmarking | Calculating and on-road verification of the amount of material required per pass on each beat. |
| Black Ice | A transparent coating of ice found on a road or other paved surface. |
| Blended Sand | Winter sand mixed with chemicals (usually salt at between 3% to 10% salt to sand). |
| Brine | Water based solution often containing 23% salt (but can also be other chemicals). |
| CaCl2 | Calcium Chloride |
| Calibration | Mechanically assuring that the material spread rate is correct to the controller settings. |
| Combo-Unit | A vehicle that can both plough and spread materials simultaneously. |
| Data Logger | Part of the truck mounted computer that records settings, durations and locations. |
| De-Icing | The process of removing ice from a surface. When a de-icing solution such as salt is applied to a surface a brine solution is created. Brine is water saturated or nearly saturated with salt and has a lower freezing point than water. The brine loosens the ice or snow from the pavement. |
| DLA | Direct Liquid Application of materials for anti-icing (typically) or de-icing. |
| Electronic Spreader Controls | A truck mounted computer that matches the travel speed to the set application rate. Same as a Ground Speed Controller. |
| Engineered Liquid | A proprietary chemical used as a brine or pre-treatment. |
| GPS | Global Positioning System |
| Ground Speed Controller | See Electronic Spreader Controls |
| HWY | Highway |
| IRT | Infra-Red Thermometers used to measure road temperature. |
| Lane Kilometre | A one-kilometre length of a one lane road. |
| Liquid Anti-Icing | Activities using a brine-only approach to anti-icing. Also called DLA. |
| Liquids | A solution of any de-icing chemical. |
| LOS | Level of Service |
| Pre-Treated Salt | Salt pre-treated with another chemical, typically magnesium chloride. |
| Material Application Rates | The rate at which materials are spread. Rates vary with weather, pavement temperature etc., and the addition of other chemicals. |
| MgCl2 | Magnesium Chloride |

| | |
|---|---|
| NaCl | Sodium Chloride (Road Salt) |
| OGRA | Ontario Good Roads Association |
| Oil/Grit Separator (OGS) | A trap in the sewer line designed to catch foreign materials before they enter the main sewer line. |
| On Board Pre-Wetting | Spraying liquids onto dry salt or sand on the truck at the discharge point. |
| Ploughing | Activities that push snow off a surface usually to the left side of the truck. |
| Pre-Treated | Sand or salt containing a liquid chemical additive to increase its effectiveness. |
| Pre-Wetting | Spraying liquids onto dry salt or sand on the truck at the discharge point. |
| Road Salt | Sodium Chloride |
| ROW | Right of Way |
| RWIS | Road Weather Information System is a weather station located along a highway that provides local pavement and meteorological data. |
| Salt Storage Facility | A designated area for the storage of road salt or salt/sand mixtures transported to the site in bulk. |
| Secondary Containment | Protective barrier to hold liquid materials if the primary tank is punctured. |
| SIMP | Salt Impacts Management Plan |
| Snow Removal | Loading snow windrows off a road or parking lot. |
| Snow Storage Site | Area where snow is stored and melted. |
| Spread Only Unit | A vehicle that only spreads materials and cannot plough. |
| Spreading | Placing winter materials onto the road surface. |
| Susceptible Area | Susceptible Area is a road section where a steep hill, sharp curve or other area is prone to drifting snow and/or slippery conditions (i.e. structures). |
| SVA | Salt Vulnerable Area |
| TAC | Transportation Association of Canada |
| TfNSW | Transport for New South Wales |
| VAMS | Value Added Meteorological Service. A weather service that provides a site-specific forecast tailored to an agency's needs that includes but is not limited to atmospheric temperature, relative humidity and/or dew point, wind speed and direction, and precipitation. |
| Winter Event | Winter Event is a weather condition affecting roads such as snowfall, wind-blown snow, sleet, freezing rain, frost or ice, to which a winter event response is required. |
| Winter Patrol | Winter Patrol is the field observation of weather and road conditions. |

# 1 INTRODUCTION

Road salts (primarily sodium chloride) are the preferred de-icing/anti-icing chemicals for maintaining winter safety because of their cost, effectiveness, and ease of handling. The amount of salt we use is a function of the level of service policies and budgets, the transportation system, snow fighting strategies and techniques and weather conditions. Excessive use of salt can have impacts to both the natural and built environments.

## 1.1 PURPOSE AND SCOPE

This Salt Impact Management Plan (SIMP) is intended to provide opportunities for improvement in the management of salt on highways and roads controlled by Transport for New South Wales (TfNSW) and high traffic areas within the Kosciuszko National Park (KNP) and ski resort management units.

This SIMP includes the following:

- identification of the legislative framework in which road salt applications are managed in NSW
- a summary of known and suspected impacts from road salt within the KNP
- a discussion of best practices from Canada and other jurisdictions and identification of opportunities for improvement.

# 2 OVERVIEW OF THE ROLE OF ROAD SALT IN WINTER MAINTENANCE

The maintenance of safe travel conditions during the winter depends upon achieving enough traction on travel surfaces to prevent slipping during vehicle operation and walking. Slippery conditions result from moisture being deposited on the pavement from fog, rain, freezing rain/fog, sleet, snowfall etc. when the pavement temperatures are below freezing. These slippery conditions result from a loss of friction on the surface.

Winter maintenance actions are directed at maintaining or restoring the desired level of friction within the desired timeframe. Improved friction can be achieved by improving bare pavement conditions or applying an abrasive to a slippery surface.

As precipitation accumulates on the pavement (and if as snow, is compacted by traffic), it typically forms an ice bond with cold pavement making it difficult to remove mechanically. Anticipating these situations, the main purpose of applying road salt is to prevent ice bonding. Road salt interacts with the moisture on the pavement to create brine which in turn prevents or breaks the bond, thus permitting the snow and ice to be broken up and ploughed. This is termed de-icing and is illustrated in Figure 2.1.

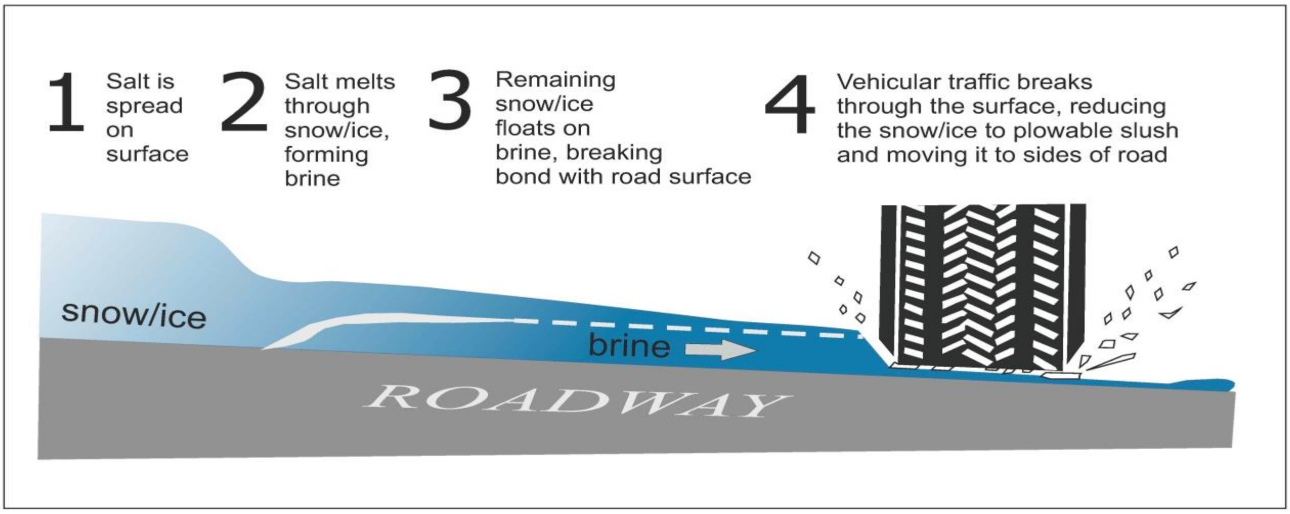



Figure 2.1 De-Icing process (TAC, 2013)

Where bare pavement is the desired end condition, the trend is to apply salt before or at the beginning of a storm to prevent the formation of the ice/pavement bond. This preventative approach, called anti-icing, is typically done with brine (liquid road salt) and requires less road salt than the amount required to de-ice pavement once the ice pack has formed.

Each winter event is unique. Proper information on existing and pending weather and pavement conditions and the professionalism of the snow fighting supervisors and operators is required to determine the approach (including if anti-icing and de-icing is needed) when to apply materials, the amount to apply, and when to re-apply if needed.

# 3 LEGISLATIVE CONTEXT

## 3.1 SALT USE

While various states in Australia and areas within the purview of TfNSW apply salt for various winter maintenance and safety purposes, formal legislation and regulation are limited and have been found only within water protection legislation including the National Water Quality Management Strategy (NWQMS), the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG), the Australian Drinking Water Guidelines (NHMRC), and the Basin Plan.

### *3.1.1 THE NATIONAL WATER QUALITY MANAGEMENT STRATEGY*

The NWQMS aims to protect Australia's water resources by improving water quality while supporting the businesses, industry, environment and communities that depend on water for their continued development. The main policy objective of the NWQMS is to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development.

The NWQMS includes water quality guidelines that define desirable ranges and maximum levels for certain parameters that can be allowed (based on scientific evidence and judgement) for specific uses of waters or for protection of specific values. They are generally set at a low level of contamination to offer long-term protection of environmental values. The NWQMS water quality guidelines include the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Department of Agriculture, Water and the Environment 2018, ANZG 2018) and the Australian Drinking Water Guidelines (NHMRC 2011). According to the NWQMS, water quality indicators and management recognise establish metrics, indicators, and plans around community values including the health of aquatic ecosystems, cultural and spiritual values of the water, drinking water, industrial water, primary industries, and recreational water and aesthetics.

### *3.1.2 THE AUSTRALIAN DRINKING WATER GUIDELINES*

The Australian Drinking Water Guidelines set guidelines values for the health and aesthetics of water. For chloride concentrations, the guidelines note that there is insufficient data to set a guideline value based on health considerations, and that the aesthetic guidelines are 250 mg/L.

### *3.1.3 AUSTRALIA AND NEW ZEALAND GUIDELINES FOR FRESH AND MARINE WATER QUALITY*

The Australian and New Zealand Guidelines for Fresh and Marine Water quality (ANZG 2018) have been prepared as part of the NWQMS. The guideline provides a process for developing water quality objectives required to sustain current or likely future environmental values for natural and semi-natural water resources. These guidelines are an updated version of the previous guidelines known as the ANZECC 2000 guidelines.

Table 3.1 shows the default guideline values for salinity (electrical conductivity) for South-East Australia from the ANZG 2018. The water quality guideline values are considered to be a low risk for of unacceptable effects occurring. Default guideline values for Victorian alpine stream ecosystems were used as this ecosystem type compares most closely to the sites in this study. Default guideline values for NSW upland ecosystems were used when a Victorian alpine ecosystem guideline value was not given. Further details regarding the application of guideline values for impact assessment and monitoring are provided in the Snowy Mountains SAP Flooding and Water Quality Technical Study (WSP, 2021).

Table 3.1 ANZG 2018 guideline water quality trigger values for physical and chemical stressors for slightly disturbed ecosystems in upland rivers and freshwater lakes and reservoirs in south-east NSW

| PARAMETER | VALUE | |
|---|---|---|
| | Upland Rivers* | Freshwater lakes and reservoirs |
| Salinity (µS/cm) | 30 – 350 | 20 – 30 |

*Upland rivers are defined as those >150 m altitude

### 3.1.4 BASIN PLAN

The 2012 Basin Plan was prepared to reverse past over-allocation of water and to provide certainty for how water is used in the future for the Murray-Darling Basin river system. While there are no specific targets mentioned for the park, any water which ends in the Murrumbidgee River via the Snowy Hydro scheme would be subject to the guidelines of the Basin Plan. The NSW end-of-valley targets are listed below in Table 3.2.

Table 3.2 Salinity (electrical conductivity) End-of-Valley targets for NSW

| WATER QUALITY ZONE | MONITORING LOCATION AND NUMBER | SALT LOAD PER YEAR (T/YR) | END OF VALLEY TARGETS (ABSOLUTE VALUE) | |
|---|---|---|---|---|
| | | | Median (50%ile) | Peak |
| Murrumbidgee | 410130, Murrumbidgee River D/S Balranald Weir | 169,000 | 162 | 258 |

## 3.2 NSW FISHERIES MANAGEMENT ACT 1994

Fish habitats in NSW are protected via the *Fisheries Management Act* (FM Act) 1994. The purpose of the act is to regulate activities that can impact on fish habitats. Specifically, the FM act, aims to:

- conserve fish stocks and key fish habitats
- conserve threatened species, populations and ecological communities of fish and marine vegetation, and
- promote ecologically sustainable development, including the conservation of biological diversity, and, consistently with those objects promote viable commercial fishing and aquaculture industries, and
- promote quality recreational fishing opportunities, and
- appropriately share fisheries resources between the users of those resources, and
- provide social and economic benefits for the wider community of New South Wales.

In accordance with the FM act, endangered ecological communities face a very high risk of extinction in the near future as determined by the Fisheries Scientific committee. An ecological community is eligible for listing as endangered if it has undergone a very large reduction in ecological function, geographic distribution, or genetic diversity, and is affected by a threatening process.

The aquatic ecological community of the Snow river Catchment has been listed as an endangered ecological community under the FM act, which includes all native fish and aquatic invertebrates within all rivers, creeks, and streams of the Snowy river catchment. Both the Snowy and Thredbo rivers are located within this catchment.

## 3.3 NSW BIODIVERSITY CONSERVATION ACT 2016

The *Biodiversity Conservation Act 2016* (BC Act) came into effect on the 25 August 2017. This Act repealed the *Threatened Species and Conservation Act 1995* (TSC Act), *Native Vegetation Act 2003* and parts of the *National Parks and Wildlife Act 1974*. All threatened entities previously listed under the TSC Act have now been listed under the schedules of the BC Act.

Threatened ecological communities (TECs) associated with waterways and wetlands in KNP in areas adjacent to key roadways which may be affected by salt runoff includes:

- Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands, and Australian Alps bioregions.

No further assessment of TECs has been undertaken for this review.

## 3.4 ENVIRONMENTAL PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999

The *Environmental Protection and Biodiversity Conservation Act* (EPBC Act) 1999 provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities – defined as matters of national environmental significance (MNES).

No wetlands of international importance occur near areas of salt use adjacent to Kosciuszko Road and Alpine way.

One EPBC listed Threatened Ecological community (Alpine Sphagnum Bogs and Associated Fens) is known to occur near Perisher, Charlote Pass and Guthega. Road maintenance

## 3.5 ROAD MAINTENANCE

The winter maintenance of roads inclusion snow and ice clearing in NSW is the responsibility of the NSW Transport for New South Wales (TfNSW) and are subject to the Memorandum of Understanding between the National Parks and Wildlife Services and the former NSW Road Transport Authority (Shenton, 2018). This is a formal but non-legally binding document outlines road management responsibilities and protocols.

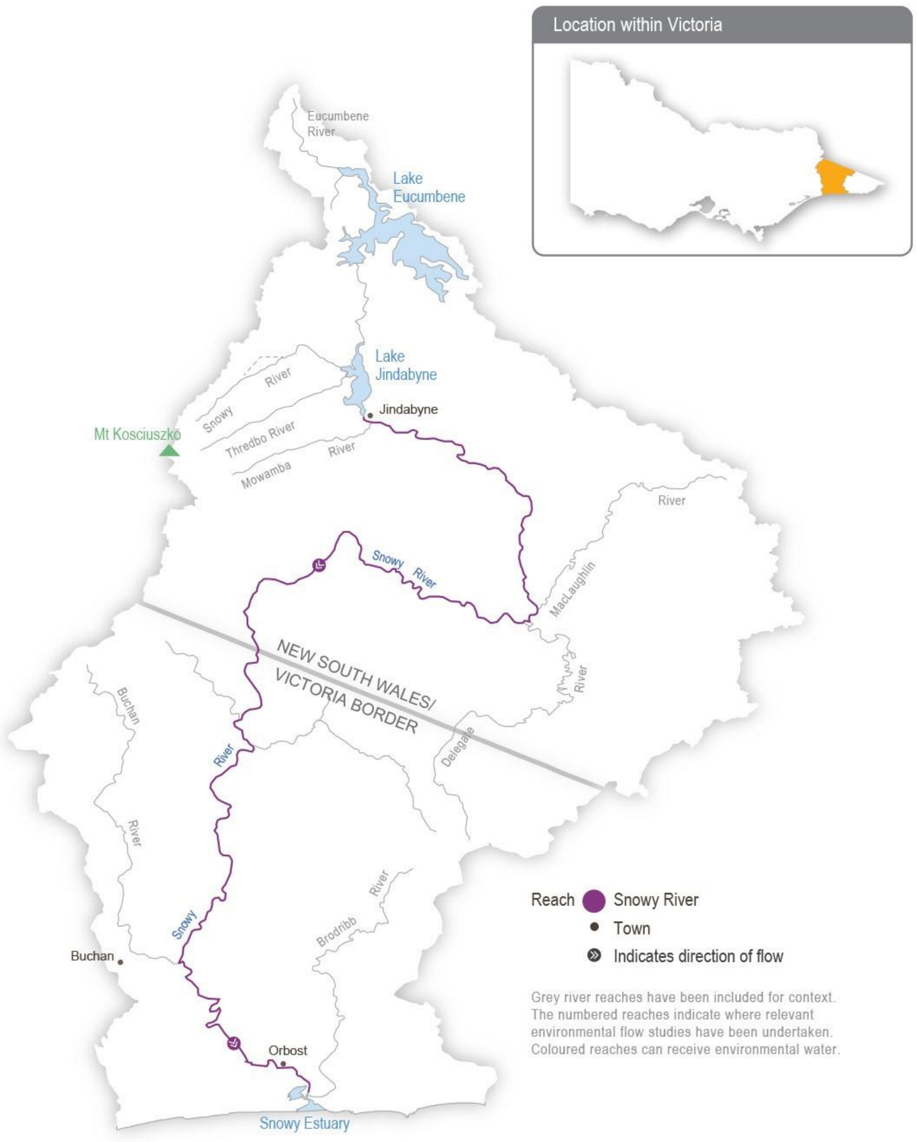
# 4 EXISTING CONDITIONS

## 4.1 WATERWAY CATCHMENTS

The regular use of salt for road and ski resort snow clearance (Perisher, Thredbo and Charlotte pass) is mainly confined to the upper catchments of the Snowy River.

The Snowy River is one of the largest snowmelt rivers in Australia. It flows east off the slopes of Mount Kosciuszko and then into Victoria and into Bass Strait. There are four major dams and multiple diversion weirs in the upper Snowy River Catchment that divert water to the Murrumbidgee and River Murray valleys.

Figure 4.1 shows the Snowy River catchment both upstream and downstream of Lake Jindabyne and several of its tributaries, including major tributaries in KNP. The waterways with the greatest potential to receive salt laden inflows are the tributaries of the upper Snowy river, (upstream of lake Jindabyne) and the Thredbo River.




*Source:* https://www.vewh.vic.gov.au/rivers-and-wetlands/gippsland-region/snowy-river

Figure 4.1 Snowy River catchment

## 4.2 SUMMARY OF CURRENT ROAD MAINTENANCE

Transport for NSW (TfNSW) is responsible for winter maintenance (snow and ice management) on the main highways including in the Kosciuszko National Park, with the ski resorts managing snow and ice within resort areas.

The following information is based on emails from TfNSW and the following documentation:

- Perisher: Plant and Labour Hire Summary Sheets for:
  - July 2017
  - August 2017
  - October 2017
  - June 2018
  - July 2018
  - August 2018
- salt use data for 2015
- snow clearing map 2015.

Typically, the winter season lasts from the June long weekend to the October long weekend. The following average amounts of road salt are used per season:

- Snowy Mountain and Monaro Highways: 30 tonnes
- Kosciuszko Road: 250 tonnes
- Alpine Way: 120 tonnes.

TfNSW's crews manage and deliver all winter maintenance on Snowy Mountain and Monaro Highways. Contractors for TfNSW provide winter maintenance services for the Kosciusko Road and Alpine Way. Schmidt Stratos salt spreaders are used on the Snowy Mountain Highway, Kosciusko Road and Alpine Way. These spreaders have pre-wet capabilities. TfNSW is currently evaluating Winterlogic system on their spreaders for dispensing salt, recording data, usage, GPS locations and quantities. Salt is only applied on the areas that required de-icing. While the road salt application rate is varied to address road and weather conditions, the average rate is estimated to be 20 $g/m^2$ overall with the following breakdown:

- 10–20 $g/m^2$ for Snowy Mountain and Monaro Highways
- 20–30 $g/m^2$ for Kosciusko Road and Alpine Way.

Trucks have road pavement temperature detectors. Wetted salting ($CaCl_2$/NaCl) has been shown to be more effective than dry salting (Wil Allen, N.D.). Wetted salting (CaCl2) was introduced by NSW National Parks and Wildlife Service (NPWS) is the mid-1990s on a trial basis pending the outcome of an environmental study. The resulting "Wetted Salt Spreading on Kosciuszko Road; end of season (1996) report" (NPWS 1997, unpublished report) showed that over three winters this method did perform better than dry salting in most of the circumstances presented on Kosciuszko Road. The environmental impacts were found to be insignificant in most circumstances. Following its adoption by NPWS after 1997, TfNSW continued the practice of using wetted salt as a primarily method for chemical de-icing. More recently, specific locations that channel and trap salt runoff were examined, with significant salt related issues reported (UC, 2005). The improvement of these sites by NPWS, Perisher and TfNSW is ongoing.

In the ski resort areas, three types of icy road conditions, typically of short duration (NPWS, 2020):

1. blizzard conditions deliver a thick snow cover on roads
2. cold and frosty conditions in which icy roads are responsive to salt treatment but specific high points and shaded locations resist salting and blading, and
3. snow ploughs crush then compact snow into black ice resulting in dangerous, low-friction conditions which do not respond well to salt application.

## 4.3 SUMMARY OF CURRENT ALPINE RESORT SALT USE

Thredbo has a one tonne capacity 'wet salt' spreader mounted on Canter truck which began operations in 2010 (with records of use since 2015). In addition to use on the main roads, salt use has also been noted on 2 kilometres of pedestrian pathways, around 1,800 parking spaces and aisles, around ski lodges, ski lodge driveways, ski runs (for racing), and ski terrain parks.

Wetted salting ($CaCl_2$) was introduced by NPWS is the mid-1990s on a trial basis pending the outcome of an environmental study. The resulting "*Wetted Salt Spreading on Kosciuszko Road; end of season (1996) report*" (NPWS 1997, unpublished report) showed that over three winters this method did perform better than dry salting in most of the circumstances presented on Kosciuszko Road. The environmental impacts were found to be insignificant in most circumstances. Following the adoption of wetted salting by NPWS, TfNSW continued the practice of using wetted salt as a primarily method for chemical de-icing. More recently, specific locations that channel and trap salt runoff were examined, with significant salt related issues reported (UC, 2005). The improvement of these sites by NPWS, Perisher and TfNSW is ongoing.

Bulk salt and brine have been used on the road networks and car park aisles spread using the truck mounted wet salter. Pedestrian pathways and base station paved areas used 25 kg bags which are spread by hand. Salt has also been proposed as an adaptive measure for snowmaking. Road salt is currently used in four locations, shown below in Table 4.1.

Table 4.1 Application rates for roads in Kosciuszko National Park

| LOCATION | APPLICATION RATE* (G/$m^2$) | LANE WIDTH ASSUMED (m) | APPLICATION RATE (kg/2LN-km) |
|---|---|---|---|
| Snowy Mountain Highway | 10-20 | 4 | 40 to 80 |
| Kosciusko Road | 20-30 | 3 | 60 to 90 |
| Alpine Way | 20-30 | 3 | 60 to 90 |
| Average every day during the snow season | 20g/$m^2$ | 3 | 60 to 90 |

*assumed pre-wet rates

Table 4.2 below provides a summary of Thredbo alpine resort snow clearing log history (2009–2019).

Table 4.2 Thredbo alpine resort snow clearing log history 2009-2019

| DATE | CLEARING | SNOW DEPTH | GRIT | SALT | BULK SALT | BRINE | BAG SALT |
|---|---|---|---|---|---|---|---|
| | Events | (maximum event for season) | Events | Events | Weight (kg) | Volume | Weight (kg) |
| 2019 | 13 | 40 cm+ | 0 | 11 | 7250 | 3875 | 6000 |
| 2018 | 16 | 25+ | 6 | 13 | 8500 | 4250 | 7000 |
| 2017 | 19 | 20 cm+ | 3 | 16 | 13250 | 6500 | 10000 |
| 2016 | 17 | 40 cm | 6 | 14 | 9500 | 4750 | 8000 |
| 2015 | 16 | 15 cm | 5 | 14 | 5500 | 2500 | 4000 |
| 2014 | 14 | 50 cm | 13 | 18 | – | – | – |
| 2013 | 8 | 20 cm | 7 | 7 | – | – | – |
| 2012 | 10 | 20 cm | 0 | 7 | – | – | – |
| 2011 | 9 | 20 cm | 0 | 3 | – | – | – |
| 2010 | 14 | 25 cm | 11 | 9 | – | – | – |
| 2009 | 12 | 30 cm | 7 | - | – | – | – |

## 4.4 WEATHER AND CLIMATE

As an alpine region with complex terrain, temperature in this area vary with altitude, and precipitation is strongly influenced by local microclimates and micro cells of weather. Winter temperatures can abruptly drop to -10ºC, but this is usually of short duration. During the winter season, heavy snow can obstruct the roads, and strong winds can knock over trees to block paths and trails. The weather data presented in Table 4.3 is from the Charlotte Pass (1755m) and Thredbo village (1380m) weather stations, and represent the most accurate weather information related road salt management due to both location and elevation (Australian Government, 2020).

Table 4.3 Weather date for the Winter Season (1976 to 2010)

| STATISTICS | MAY | JUN | JUL | AUG | SEP | OCT |
|---|---|---|---|---|---|---|
| **Charlotte Pass (1755m ASL)** | | | | | | |
| Mean daily maximum temperature (°C) | 7.9 | 3.9 | 2.4 | 3.4 | 5.8 | 9.7 |
| Mean daily minimum temperature (°C) | -1.5 | -3.5 | -5.0 | -4.3 | -2.0 | 0.2 |
| Mean rainfall (mm) | 130.9 | 167.8 | 186.1 | 240.6 | 234.3 | 183.7 |
| Mean number of days of rain ≥ 1 mm per year | 9.8 | 12.1 | 11.9 | 13.2 | 13.4 | 11.3 |
| **Thredbo Village (1380m ASL)** | | | | | | |
| Mean daily maximum temperature (°C) | 10 | 6.6 | 5.5 | 6.6 | 9.9 | 13.5 |
| Mean daily minimum temperature (°C) | -0.5 | -2.4 | -3.6 | -2.5 | -0.4 | 1.8 |
| Mean rainfall (mm) | 152.1 | 159.3 | 166.8 | 192.2 | 202.8 | 180.9 |
| Mean number of days of rain ≥ 1 mm per year | 10.7 | 12.3 | 13.2 | 14.0 | 13.7 | 11.9 |

## 4.5 ENVIRONMENTAL SALINITY

### *4.5.1 BACKGROUND*

Electrical conductivity (EC) is a surrogate for total dissolved salts and was used in the National Water Quality Assessment 2011 as a measure of salinity.

Reduction in the frequency of high flows resulting from river regulation and drought, combined with land clearing, have the potential to increase salinity in freshwater systems. Some systems are naturally saline, particularly where saline groundwater dominates, and geology and soils are high in salt content. Other factors affecting instream conductivity include evaporation and dilution during high flows arising from extensive rainfall. Evaporative losses, particularly in inland lakes, can result in concentration of salts, which is reflected in elevated conductivities. Flood events can flush salts from the landscape into waterways following prolonged drought, which can lead to an initial increase in conductivity, which may be followed by a reduction over time as a result of dilution. It is possible for levels to reach critical thresholds whereby the health of aquatic biota may be compromised.

Salinity is a significant issue in the eastern portion of the Murray Darling drainage division, south-eastern portion of the North-East Coast, eastern portion of the South Australian Gulf and southwest of the South West Coast drainage division.

Conductivity in alpine streams is generally very low, and low salt concentration is an iconic characteristic of KNP’s fresh flowing waters. Any exceedance of conductivity guidelines should be considered a risk to the natural condition of these mountain streams.

### 4.5.2 SNOWY SAP AREA

Monitoring data is taken from the following reports:

- Biological Assessment of the Thredbo River, Institute of Applied Ecology, University of Canberra prepared for Kosciuszko Thredbo Pty Ltd, and
- Kosciuszko National Park, Report Card for Resort Water Quality and River Health Monitoring Program, NSW National Parkes and Wildlife Service.

### 4.5.3 WQ SAMPLE CRITERIA

#### 4.5.3.1 THREDBO

Guideline trigger values for EC for Victorian alpine stream ecosystems were used to assess water quality.

*WATER QUALITY GUIDELINES VALUES*

There are currently no site-specific guideline values for water quality in KNP. Guideline levels for TN, TP, EC, pH, and DO for Victorian alpine stream ecosystems were used for comparison of water quality. Where no guideline level for Victorian alpine stream ecosystems was stated in ANZECC and ARMCANZ guidelines, NSW upland ecosystem guideline for slightly disturbed ecosystems of south-eastern Australia levels were used. Recommended guideline levels for faecal coliform and heterotrophic plate count (HPC) from DeZuane (1990) and ANZECC/ARMCANZ (2000) were used and shown below in Table 4.4. Salt and electric conductivity guidelines for Kosciuszko National Park are shown in Table 4.5.

Table 4.4 Guideline levels for TN, TP, EC, pH, and DO in Victorian alpine stream ecosystems

| | TN (MG $L^{-1}$) | TP (MG $L^{-1}$) | $NH_5$-N (MG $L^{-1}$) | $NO_X$ (MG $L^{-1}$) | DO (% SAT.) | DO (MG $L^{-1}$) | TEMP (°C) | EC (MS CM$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| Guideline level | 0.10* | 0.01* | N/A | 0.015** | 90-110** | N/A | N/A | <30* |

#### 4.5.3.2 KOSCIUSZKO NATIONAL PARK

Table 4.5 Salt guidance levels for Kosciuszko National Park

| RIVER HEALTH CATEGORY | INDEX NAME (UNITS) | SYMBOL | DESCRIPTION | GOOD | MODERATE | POOR |
|---|---|---|---|---|---|---|
| Salt | Electrical Conductivity (EC) (µS/cm) | EC | A measure of electrical conductivity via dissolved solids (usually salts). Alpine water typically has very low EC so elevated levels may indicate STP (sewage treatment plant) discharge or other human sources. High EC may inhibit plant and animal growth and prolonged exposure to elevated salts can lead to decline or change in macroinvertebrates | ≤30* | 30-60 | >60 |

### *4.5.4 EXISTING CONDITION*

#### 4.5.4.1 THREDBO VALLEY – THREDBO RIVER

At the Thredbo River, EC samples were generally in the 'Good' range for all monitoring events from 2016-2019. Moderate EC values were recorded at one site located 80m downstream of the Thredbo Sewage Treatment Plant (STP) in February 2017 and August 2017, and at three sites in August 2018. The sites with moderate values in August 2018 were sites 012, downstream of the Thredbo village but upstream of the STP and at sites 013 and 014, 80 and 350 m downstream of the STP respectively. The highest exceedance was at site 013 which recorded 57 µS/cm.

Sampling locations in and downstream of the Thredbo village are shown on figures in Appendix A.

#### 4.5.4.2 PERISHER VALLEY – SNOWY RIVER

From the years 2016–2018 Sawpit Creek displayed consistently elevated levels of electrical conductivity across all three sites, up and downstream of Ski Rider Motel and downstream of the STP, for all sampling events. The continued impairment of all these sites requires further investigation, however exceedances were recorded for all nutrients, EC and turbidity suggesting that inputs into Sawpit Creek may not be related to the Ski Rider, campground or the STP, but that other catchment characteristics may be responsible. High salt levels in Sawpit Creek may be related to use of salt for de-icing roads and may be temporally and spatially cumulative through the catchment as salt, that has been applied to roads in previous years and washed off with surface runoff, may be accumulating and slowly leaching through the landscape over time.

Moderate measurements were recorded in Pipers Creek and Smiggin Tributary in the 2016- 2018 sampling events as well. All other sampling locations recorded 'good' water quality samples for EC in all 2019 sampling events.

Sampling locations in and downstream of the Perisher valley (downstream to sawpit creek) are show on figures in Appendix A. Note. Only those close to the alpine way and village areas are shown.

# 5 IMPACTS OF SALT USE

## 5.1 ENVIRONMENTAL

This section provides an overview of the impacts of road salt (sodium chloride) on the environment. Ferrocyanide, an anti-caking agent added to road salt, is discussed at the end of this section. Alternative winter roadway treatment chemicals (discussed in Section 6) can have environmental impacts that should be weighed when considering their use.

The impacts of salt on the Australian Alps are unique and relatively unknown due to their relative rarity and lack of urbanised landscape where de-icing has been studied. In this area, the effects of even a small rise in salinity may differ from that observed in other areas due to the evolutionary history of the biota and the natural environment. There is evidence of a very high proportion of salt-sensitive taxa present in the region (Shenton, 2018).

The way road salt reaches the aquatic and terrestrial environments is referred to as a 'pathway'. Figure 5.1 shows the key pathways for road salt entering the environment from use on roads, storage and handling at maintenance yards, and snow storage and disposal sites.

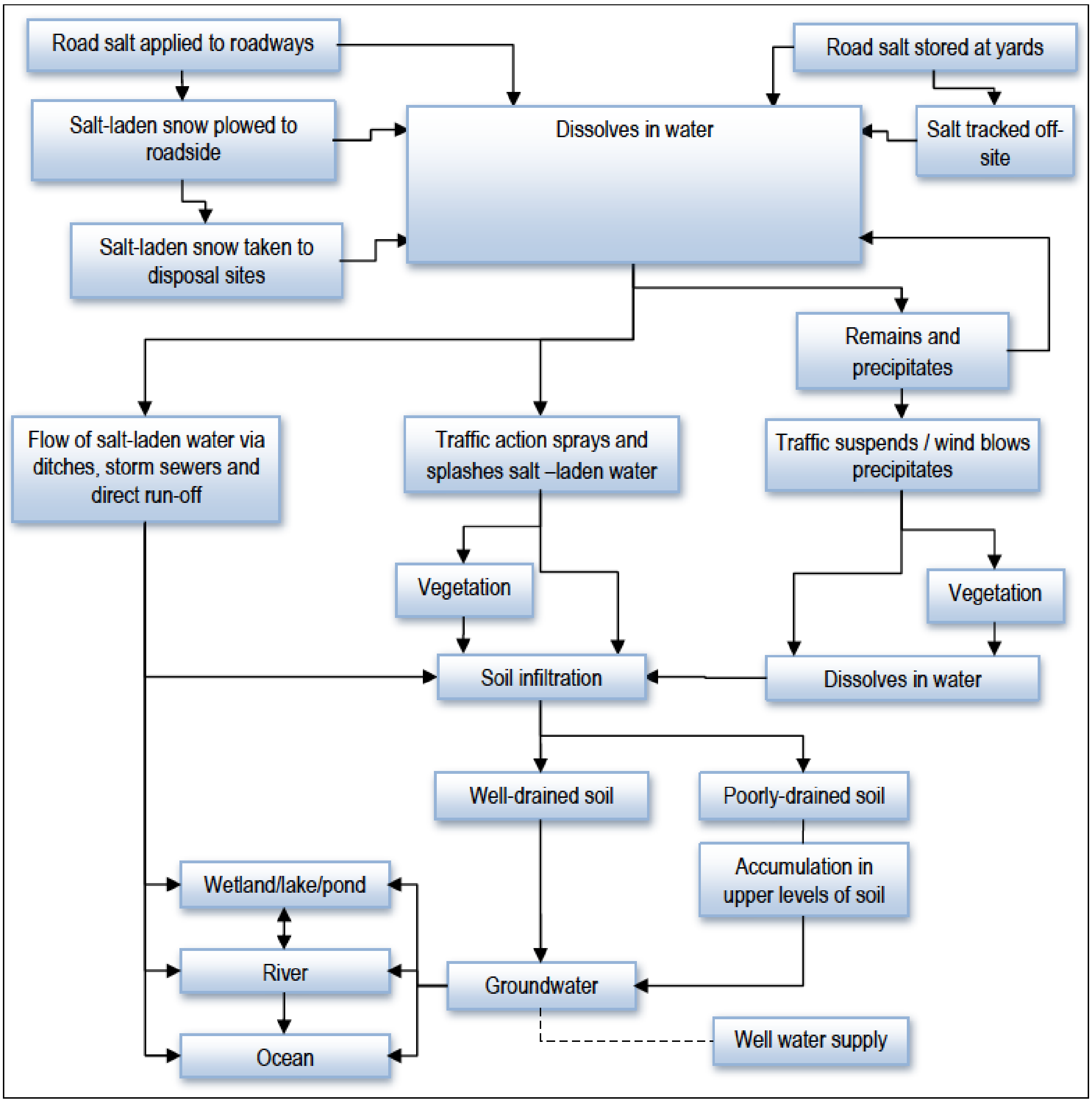



Figure 5.1 Key pathways for Road Salt into the Environment

Sections 5.1.1 to 5.1.6 present a summary of the environmental impacts of de-icing salt taken from TAC (2013), GHD (2018), Shenton (2018), Moulding (2018) and others.

It should be noted, due to the relative absence of need of de-icing in Australia, as compared to the Northern Hemisphere, where a majority of research has taken place, some of the following may be of limited applicability. Wherever possible local data and studies have been mentioned and their results integrated.

### 5.1.1 AQUATIC SYSTEMS

Effects of increased salt loadings presented below are observed in smaller streams, ponds and smaller lakes.

- **Changes in density gradients (ponds and small waterbodies):** High density salt-laden water accumulates in lake bottoms and inhibits the seasonal mixing of the waterbody (meromixis, so that the normal distribution of oxygen and nutrients is interrupted, resulting in decreased oxygenation, nutrients, and temperature in the bottom water and a general disruption of the lake ecosystem. Meromixis has been observed in lakes with concentrations of 600 mg/L of sodium and 105 mg/L of chlorides (Environment Canada, 2004).
- **Contaminant mobility**: Heavy metals including Hg, Cd, Zn, Cu can be released from bottom and suspended sediments into more biologically available forms.
- **Toxicity:** Chloride concentrations that cause acute and chronic effects range greatly for different species. Based on research and US state values, an acute value of between 600 and 850 mg/L and chronic value of between 200 and 500 mg/L depending on hardness (lower for soft water) seem to be a general level for effects to be evident on sensitive aquatic species. Research has shown that chloride concentrations exceeding 100 mg/L can have negative, non-lethal, impacts to certain organisms during sensitive life stages (Findlay and Kelly, 2011).
- **Community:** A decrease in the diversity of benthic macro invertebrate communities, changes in number and biomass of most invertebrate taxa, algal density decrease, bacterial density increase, fungal population decrease.

Watercourses that receive salt-impacted runoff from a dense network of roads and highways have been found to have the greatest impacts. Studies conducted on Kosciuszko Road from 1995–1998 (Allen, N.D.) on the efficacy of road salting techniques found that the dilution of salt was high enough in the area to have little or no water quality outcomes in roadside streams. Potential issues with wetland areas were noted (though monitoring was not undertaken in the Perisher Valley car park).

### 5.1.2 SOIL

- **Soil pH:** Increased pH and soil salinity.
- **Structur**e: Changes in soil structure. Soil solidifies into almost cement-like soil with little or no structure resulting in reduced infiltration, reduced hydraulic conductivity, and surface crusting.
- **Soil Fertility/Vegetation Damage:** Extensive salt infiltration into soils can decrease the fertility of soils and subsequently be detrimental to plant growth.
- **Mobilization of Metals:** Sodium (Na) replaces calcium (Ca), potassium (K), and magnesium (Mg) and heavy metals and/or increases heavy metals bioavailability.

Note, the impacts of salt to soil can be influenced by the soil type as difference soil types have difference electrical conductivity levels. Soils within the sub-alpine areas of Kosciuszko National Park generally have very low natural salinity levels.

### 5.1.3 GROUNDWATER

- **Hardness increases.**
- **Sodium and chloride concentrations increase.**
- **Heavy metals with increased heavy metals bioavailability.**
- **Contamination of surface water** through groundwater recharge (may last decades due to time lag).

### 5.1.4 VEGETATION

- **Toxicity:** The toxicity of elevated concentrations of sodium and chloride ions to many plant taxa is widely recognised. The uptake of sodium and chloride into roadside vegetation can occur through root uptake from the soil or through foliar uptake from the air.
- **Change in Osmotic Pressure:** Dehydration occurs as the water in the roots and crown tissue is drawn into the saline soil solution under high salt concentration.
- **Desiccation:** Salt deposited on foliage and needles can physically damage tissues through the movement of water out of the plant cells and tissue.
- **Cold Hardiness:** Road salt on buds, needles, and smaller and younger tree branches can damage the plant and reduce its cold hardiness and increase the trees' predisposition to cold temperature injury and its tissues to freeze damage.
- **Deficiency Stress:** High levels of sodium chloride in soil can indirectly affect plants by increasing soil pH and reducing the availability of micronutrients.
- **Changes in roadside plant communities:** Shifts to more salt-tolerant species.

The studies conducted on Kosciuszko Road from 1995-1998 (Allen, N.D.) on the efficacy of road salting techniques noted that vegetation very close to roads was affected, but only on years of very high salt use. The quality of the salt was raised as an issue, as were heavy metal in the road verge.

### 5.1.5 TERRESTRIAL WILDLIFE

- **Wildlife:** Wildlife is attracted to the salt on the roadside increasing animal-vehicle collisions.
- **Ingestion of Salt Residue:** Salt tolerance is generally high.
- **Amphibian:** From the limited research, it appears that road salts could have effects on amphibians at environmentally realistic concentrations.
- **Domestic Animals:** Effects are limited

### 5.1.6 AQUATIC WILDLIFE

- **Stream Invertebrates**: There is a decrease in salt-sensitive taxa below salted roads, as determined in a study in the Perisher Region, but there has also been found to be an increase in the relative abundance of salt-tolerant species in these areas (Moulding, 2018, Shenton, 2018). Sensitive stream invertebrates will be stressed by salt pollutants which can have lethal effects.
- **Community Structure and Assemblage**: Increased salinity can change community assemblages and decrease species and taxonomic richness, even at low increases of salinity.
- **Freshwater Fish**: Increased salinity can be toxic to many forms of aquatic life both directly and indirectly through impacts to the food chain. In aquatic environments, it poses a risk to the health of food sources, species growth, reproduction, and species diversity.

It should be noted that low salinity creeks, like that of the Australian alpine area, often have relatively high proportions of taxa that are salt sensitive. The temporal exposure to salinity will also impact aquatic wildlife. Rapid increases in salinity (such as are present during de-icing activities) will have greater sub lethal and lethal effects on macroinvertebrate communities then gradual rises in salinity (Moulding, 2018)

## 5.2 SALT VULNERABLE AREAS

Salt Vulnerable Areas (SVA) are receiving environments that are anticipated to be particularly sensitive to road salt where there may be a risk to "receptors" such as groundwater, drinking water, aquatic life, species at risk or vegetation.

In 2009, Niagara Region in Ontario, Canada undertook an analysis to determine SVA. The analysis used Annex B of Code of Practice for the Environmental Management of Road Salts (Environment and Climate Change Canada, 2004) as a starting point for identifying salt vulnerable areas. The literature review carried out to assess the vulnerability of various land use types to road salt concluded the following factors:

1. Areas draining into bodies of water, such as:
   a. lakes and ponds with low-dilution and long residence times,
   b. watercourses that experience the cumulative effects of a dense network of highways, and
   c. significant wetlands adjacent to roadways, where the addition of road salts has the potential to significantly raise the chloride concentration of the water to the point where it could present a threat of serious or irreversible environmental damage.
2. Areas draining into small, moderately deep lakes where the addition of road salts has the potential to create layers of water of different salinity within the lake that prevent normal vertical mixing of the water (meromictic conditions).
3. Areas where the addition of road salts has the potential to raise the chloride concentration, after mixing, to levels that could harm local fish or fish habitat.
4. Areas adjacent to salt-sensitive native or agricultural vegetation, where the addition of road salts has the potential to cause severe reductions in flowering and fruiting, severe foliar, shoot and root injury, growth reductions, or reductions in germination and seedling establishment caused by elevated soil levels of sodium and chloride or aerial spray of sodium and chloride.
5. Areas where the addition of road salts has the potential to harm the integrity of a life cycle (e.g. spawning grounds, nursery, rearing, food supply and migration areas for birds).
6. Areas where the addition of road salts has the potential to harm a habitat necessary for the survival or recovery of a wildlife species considered Species at Risk under commonwealth or state (such as the Commonwealth *Environment Protection and Biodiversity Conservation Act*, 1999 or the NSW *Biodiversity Conservation Act* 2016).
7. Areas draining into sources of drinking water (surface water or groundwater, including wells), where the addition of road salts has the potential to raise the chloride concentration of the water to the point where it could not be used as a source of drinking water.
8. Areas draining into groundwater recharge zones or that-have an exposed or shallow water table, with medium to high permeability soils, such as medium to coarse sand and gravel, where the addition of road salts has the potential to significantly raise the chloride concentration of the groundwater to the point where it could present a threat of serious or irreversible environmental damage.

Recently, Environment and Climate Change Canada developed the Guide for Management of Salt Vulnerable Areas (GHD, 2018). The Guide assists road authorities in identifying, categorizing, and mapping the impacts of road salts on SVAs. The guide assists users in identifying and tracking potential mitigation measures to minimise the negative impacts of chlorides caused by salt application on roads, parking lots and sidewalks within SVAs. The contents of the guide present a geographical information system (GIS) based methodology that is flexible to the geographical scale (local, municipal, regional), type of environmental receptors and site-specific data availability. The methodology helps to focus the management of road salts by determining priority areas where improved road operations, strategic planning and community education and outreach will be most beneficial to reduce the impacts of road salt application on the environment.

More detailed research is required for salt vulnerable areas within KNP. Current and future salt levels need to be monitored within these and other environments, as well as monitoring of native vegetation, aquatic, and terrestrial biodiversity. It is recommended that TfNSW works closely with NPWS on monitoring and support additional research by Universities in the area.

The general location of SVAs within KPN near the Alpine Resorts and associated infrastructure is included in Appendix A. In reference to the list of SVA considerations above, those within the study area include Alpine bogs and fens, watercourses and riparian lands adjacent and downstream of main roads and alpine village areas. A more detailed assessment of SVA's is required.

## 5.3 MITIGATIVE ACTIONS IN SALT VULNERABLE AREAS

Acting specifically within SVAs can be challenging due to financial limitations, resource capacities (staff, equipment), and finding a balance between providing safe travel conditions, and protecting sensitive areas including meeting legislative requirements. It can be impractical to have dedicated or specialised equipment and/or alternative materials for small areas, and safety is a concern if a level of service changes within an SVA.

To assist, Ontario Good Roads Association and Conservation Ontario (2018) developed a list of "good management practices" for vulnerable areas covered under the Ontario Clean Water Act (CWA, 2006), shown in Table 5.1. while these practices are Canadian Guidelines, they can be applied to an Australian context with similar road and snow conditions. Details of each management practice is discussed in the Section 6.

Table 5.1 Good management practice for Salt Vulnerable areas

| CATEGORY | ROAD SALT GOOD MANAGEMENT PRACTICE |
|---|---|
| Weather Monitoring | Value Added Meteorological Service (VAMS) Subscription to a VAMS provider |
| | Road Weather Information System (RWIS) Consider installing or accessing nearby RWIS stations |
| Equipment | Computerized Spreader Controllers enable spreaders to maintain consistent salt application rates at different ground speeds, to communicate with AVL systems and to generate accurate records of the amount of salt being applied |
| | Pavement temperature sensors on patrol vehicles and plough and spreader equipment |
| | Automatic Vehicle Location (AVL) systems and spreader equipment to track salt usage, monitoring equipment location and operational speeds, and handling community concerns |
| | Carbide Reinforced Plough Blades conform to the roadway and effectively remove snow, resulting in reduced salt usage |
| | Spreader Calibration should be conducted at least twice per season (beginning and midseason) to ensure accurate application rates, as well as after every repair to the truck. |
| | On-board Pre-wetting tanks deliver liquid to salt just before it is applied to roadway to reduces scatter, activates the salt, and enhances its melting capacity to reduced salt use |
| | Direct Liquid Application (DLA) reduces the amount of chlorides required by up to 10 times |
| Personnel | Consider assigning a Winter Maintenance Specialist to administer their Salt management plan |
| | Train in all Operators before the start of the winter season |
| De-icing Materials | No recommendations – just information on alternatives to road salt |

| CATEGORY | ROAD SALT GOOD MANAGEMENT PRACTICE |
|---|---|
| Timing of Application | Anti-icing materials, including Direct Liquid Application, are usually applied prior to the start of a winter event but can also be reapplied during the event |
| Application methods and application rates | Pre-wet salt with liquid before it is applied |
| | Plan plough routes carefully to ensure road sections and intersections are not double salted |
| | Multiple application rates to adjust to conditions |
| Snow storage and disposal sites | A properly planned and designed Snow Management Facility that meets all applicable environmental requirement requirements |
| Snow fences | Consider the use of snow fences to address blowing snow in the open areas of your road network |
| Road Salt Storage Practices | A properly planned and designed salt storage facility that meets best practices |
| Salt management plan | Have a Salt management plan that lays out the 'good practice', gaps and opportunities for improvements |
| | Reviewing and adjusting the Salt management plan (SMP) annually |
| Additional proposed | Reduce the posted speed limit on roads within SVAs. This would allow agencies to lower the level of service and consequently the volume of chemicals entering the environment in these highly vulnerable areas. The designation of a stretch of road for such a strategy should be at least three or four kilometres long. This strategy should be accompanied by a vigorous community awareness campaign and engagement. |
| | Realigning roads to eliminate super elevated curves |
| | Raising roads higher than the adjacent topography |
| | Cut grass and vegetation in the right-of-way short to prevent it from catching blowing snow |

### 5.3.1 MONITORING AND TRACKING SALT LOADING

Another innovative approach could include setting salt loading warning targets for defined areas (such as SVAs) based on defined criteria. Road salt application data tied to GPS data could be used to monitor salt application during the winter season. When salt loading reaches the warning levels, management practices (e.g., no-chloride materials, increased sand use etc.) could be used.

### 5.3.2 STORMWATER MANAGEMENT

Researchers (Nandana, Gharabaghi, Noehammer & Kilgour, 2010) have found that traditional stormwater management practices (such as stormwater ponds) are not protecting groundwater or surface waters from road salt contamination.

Herb, Janke & Stefan (2017) found that all sizes of detention ponds consistently showed relatively low flow rates (from snowmelt events) with high chloride concentrations (up to 12,000 mg/L) in the winter. Chlorides tend to accumulate at the pond bottom, similar to how chloride-rich meltwater accumulates in lakes. In contrast, the export of chloride from detention ponds was found to occur over the entire open water season (roughly April – November), with a relatively steady, low concentration (50–150 mg/L) similar to that observed near the pond surface. This suggests a slow diffusion from or erosion of the saline layer at the pond bottom by inflows and other disturbances (e.g., wind). Chloride residence time in ponds was found to be long, at around 7 months.

Herb, Janke & Stefan (2017) further found that chloride removal by diversion of saline runoff will be most effective (in terms of mass of chloride removed per volume of water) if implemented at the scale of a roadway, before runoff enters the drainage network. For example, a diversion of 2.5 mm of the most saline runoff at the roadside would remove approximately 80% of surface runoff chloride (requiring diversion of approximately 283 $m^3$ [10,000 cubic feet] of water at the text site). Similarly, withdrawal of saline water from the bottom of a pond was found to be less effective than removal at street- or even watershed-level. However, the authors note that the pond models may be underpredicting salinity stratification, so that further study of pond withdrawals is warranted.

This study suggests that the following:

1 **Seasonal diversion may be effective to remove most chlorides.** The authors concluded that 97% of the chloride in surface runoff could be removed if it is possible to capture all flows during winter (December – March[1]).
2 **Selective withdrawal from stormwater ponds may be an option.** After snowmelt, when the largest chloride loading occurs, the high-chloride water on the bottom of the pond could be pumped, siphoned out or diverted through an outlet structure or underdrain that is only open during this period.

Therefore, alternative stormwater management practices could be considered in SVAs to capture the most impacted runoff and hold/divert/release at less sensitive times.

### *5.3.3 FERROCYANIDE*

Sodium ferrocyanide and ferric ferrocyanide are anti-caking agents applied to road salt to facilitate efficient spread of the salt material (minimise clumping) on roadways during winter salting operations. Ferrocyanide is released in highway runoff water with concentrations of ferrocyanide gradually diluted as the runoff moves through permeable soils and is further diluted upon reaching a watercourse.

In the absence of direct sunlight, the ferrocyanide complex, which is a metal-cyanide (metal-CN) complex, is stable and low in toxicity. Based on the nature of the ferrocyanide ion and the work of several researchers on the environmental effects of ferrocyanide, the current conclusion is that sodium ferrocyanide and the slower dissociating ferric ferrocyanide do not pose a hazard to the environment.

[1] Note: this study was conducted in the Northern Hemisphere whose winter period is opposite Australia.

# 6 ROAD SALT MANAGEMENT OPTIONS AND CONSIDERATIONS

The overall approach to road salt management is typically summarized as four "Rs":

- right material
- right amount
- right place
- right time.

A fifth "R" could be Reducing the amount of snow to be dissolved through prioritizing ploughing.

This section reviews current and leading road salt management practices by looking at:

- salt management plans
- level of service
- weather and conditions information and analysis
- storm response and decision support
- anti-icing and de-icing materials
- equipment
- monitoring and reporting
- material storage and handling
- excess snow removal, storage and disposal
- training
- engagement.

For each of the above, the objective and rational for that objective are provided and following a description of the practices, the opportunity for improvement is provided.

Note, this is not a winter operation guide. The premise underlying identifying the opportunities for improvement is that by following good salt management practices equivalent or better safety and mobility outcomes can be achieved with minimum salt being introduced into the environment. There is no expectation that safety would be sacrificed in the interest of road salt management.

## 6.1 SALT MANAGEMENT PLAN

### *6.1.1 OBJECTIVE*

Develop and maintain a Salt management plan consistent with best practice.

### *6.1.2 RATIONALE*

A Salt management plan (SMP) sets out the plan for ensuring that the management of road salt used in winter maintenance operations is implemented and continuously improved.

A successful SMP is based on the following principles (Transportation Association of Canada, 2013):

- It is activity based, with each activity being assessed at the outset against clearly established standards and/or objectives to determine how they can be carried out with minimal environmental impact.
- Deficiencies in current operations are identified and corrective action established and implemented.
- Required actions are documented in policies and procedures and communicated throughout the organisation – including contractors hired to deliver snow and ice control.

- Activities are recorded, monitored, audited and reported periodically to assess progress and identify areas for further improvement.
- Gaps between actions and desired outcomes are identified and corrective actions are developed and implemented, with necessary modifications being made to policies and procedures and appropriate training.
- This Plan is dynamic. It allows TfNSW to phase in new approaches and technologies in a way that is responsive to fiscal demands and the needs to ensure that roadway safety is not compromised.

It sets out the policy and procedural framework for ensuring that a road authority continuously improves the management of road salt used in winter maintenance operations. The SMP is dynamic – allowing new approaches and technologies to be implemented in a manner that is responsive to fiscal demands and needs, and that works to ensure that safety is not compromised. The typical SMP framework follows an environment management system approach as outlined in Syntheses of Best Practices Road Salt Management – Salt management plans (Transportation Association of Canada, 2013a). This document includes the following principles upon which to base a successful SIMP:

- It is grounded in policy with guiding principles – set and endorsed at the highest level in the organisation.
- It is activity based, with each activity being assessed at the outset against clearly established standards and/or objectives to determine how they can be carried out with minimal environmental impact.
- Deficiencies in current operations are identified and corrective action established and implemented.
- Required actions are documented in policies and procedures and communicated throughout the organisation – including contractors hired to deliver snow and ice control.
- Activities are recorded, monitored, audited and reported periodically to assess progress and identify areas for further improvement.
- Gaps between actions and desired outcomes are identified and corrective actions are developed and implemented, with necessary modifications being made to policies and procedures and appropriate training.
- The cycle begins again and continues an ongoing basis in the spirit of continual improvement.

The approach to salt management follows the standard management approach shown in Figure 6.1.

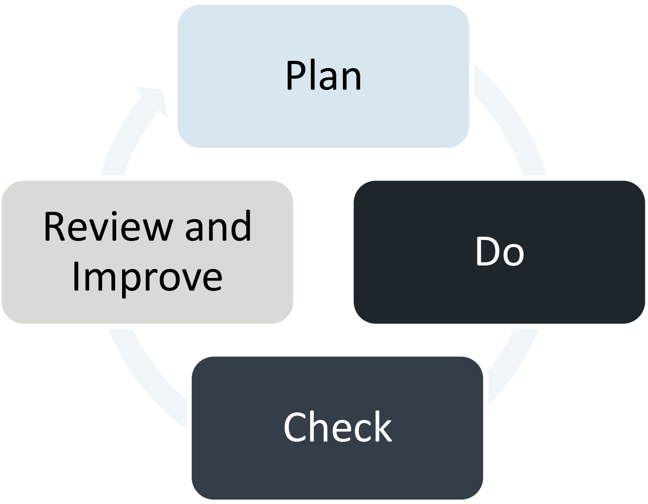



Figure 6.1 Salt management plan approach

**"Plan"** by considering:

- polices, legislative requirements and other guidance
- SVA's
- Level of Service (LOS), which is the winter maintenance performance that is needed for safety.

**"Do"** by:

- monitoring weather and pavement conditions
- responding appropriately to winter storm events to meet the LOS with the right approach that includes the right material, in the right amount, in the right place, at the right time
- having the equipment to implement the response
- training staff
- proper handling and storing road salt.

**"Check"** by:

- monitoring storm response during storm
- review effectiveness after storm events.

**"Review and Improve"** by:

- reviewing effectiveness of salt management at the end of the season
- reviewing and updating operational procedures and the Salt management plan.

The following section is based on the Canadian code of practice and guidelines, however, has relevance to the Australian context and agencies with similar road and snow clearing conditions and needs.

The Code of Practice for the Environmental Management of Road Salts (Environment and Climate Change Canada, 2004) was developed to assist local and state road authorities to better manage the use of road salts in a way that reduces the harm to the environment while maintaining road safety. The Code specifies road managers that use over 500 t/year of salt or who have salt-vulnerable areas in their territory to review their existing winter maintenance operations to improve practices and reduce adverse impacts of salt releases in the environment. For context, from 2015 to 2019 the Thredbo Resort used an average of 15,800 kg of salt per year (not including brine) or 15.5 tons. This would put them below the usage thresholds, however within the SAP Precinct and Snowy SAP boundaries there are vulnerable lands and protection riparian areas (see section 5.2) in addition to other watercourses, waterbodies, bogs, fens, and riparian land and so would require a review of their methods and operations.

In addition to developing and implementing Salt management plans, road managers are asked to voluntarily provide annual reports to the regulatory agency on the progress achieved. A similar practice could be implemented in KNP with road managers being required to create an annual report to provide to NPWS including salt reporting and their management plans.

The following is the recommendation for content of a Salt management plan from the Code of Practice:

- provide a statement recognising the role of a Salt management plan in achieving improved environmental protection without compromising road safety
- provide a commitment or endorsement of the plan at the highest level in the organisation
- identify activities or operations through which road salts may be released to the environment and goals to achieve reduction of the negative environmental impacts of these releases
- assess current practices against recommended best management practices, including those contained in the TAC Syntheses of Best Practices
- contain documentation of all policies and procedures applicable to the Salt management plan
- include communication activities necessary to inform the organisation and the community of the Salt management plan and related policies and procedures

- contain a training program for all personnel when managing or performing winter maintenance activities involving the use of road salts
- provide response procedures to react to uncontrolled releases of road salts that could result in environmental impacts
- ensure monitoring of actions to measure the plan's effectiveness
- include record-keeping
- include a procedure for yearly review of the plan by the organisation with continual improvement of salt management practices and the Salt management plan as better management practices become known and progress is achieved
- establish and implement corrective actions to address deficiencies identified in the operations of the organisation to which the plan applies.

### 6.1.3 OPPORTUNITIES FOR IMPROVEMENT

TfNSW should develop a Salt management plan that is consistent with exiting best practices, such as the Code of Practice for the Environmental Management of Road Salts from Environment and Climate Change Canada (2004), Syntheses of Best Practices Road Salt Management Transportation Association of Canada 1.0 – Salt management plans (Transportation Association of Canada, 2013a), or NZTA's CMA Best Practice Guideline (NZTA, 2012).

Table 6.1 Salt management plan opportunities for improvement for KNP

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Prepare a Salt management plan<br>Review Salt management plan Annually<br>Update Salt management plan regularly (5 years) | Environmental Management of Road Salts from Environment and Climate Change Canada (2004)<br>Syntheses of Best Practices Road Salt Management Transportation Association of Canada 1.0 – Salt management plans (Transportation Association of Canada, 2013a).<br>CMA Best Practice Guidelines (NZTA, 2012)<br>Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Department of Agriculture, Water and the Environment, 2018) | High Effectiveness | No significant barriers | TfNSW should develop a SMP that applies to the contractors and is reviewed and updated regularly |

## 6.2 LEVEL OF SERVICE

### 6.2.1 OBJECTIVE

To ensure that a Level of Service (LOS) policy is set and that any revisions are approved by senior management and communicated to winter maintenance personnel. Level of Service policy is the road authority commitment to what they would do with respect to winter maintenance to attempt to meet community expectations and how they would respond to a winter event considering available resources and local historic experience with normal winter events. The LOS policy must be clear, functional and understandable to operations personnel and the community, and be made clear as to what would and would not be achieved (e.g. there may not be continuous bare pavement conditions throughout a storm).

### 6.2.2 RATIONALE

The prescribed/approved LOS is the foundation for the winter maintenance program and has a significant impact on salt used to achieve the standard. The amount of salt use would depend on the LOS, most directly the winter road condition maintained both during and post storm (which relates to road class) and time to achieve the condition. Road authorities may exceed the prescribed/approved LOS in response to community complaints / desire for higher LOS, particularly in the face of increased traffic.

In some situations, snow covered pavement is the accepted level of service. In these cases, the use of salt is minimal and not required most of the time. It is the case of “white roads”, “white residential areas” and “white parking lots” where abrasives are usually spread instead of salt to improve friction. For roads, salt may be applied to higher risk areas such as in curves, on hills and at intersections when slippery conditions exist. (TAC, 2013)

The LOS is intended to be met by beginning operations preventatively (prior to the winter event), proactively (at the onset of the winter event) and continuous operations that "keep up" with the weather (during the winter event). While LOS could include the time for traffic to return to normal speed or friction coefficient meets a prescribed value, it more typically includes a condition to maintain, winter pavement conditions at a defined time following the conclusion of the winter event and may include includes response times.

### 6.2.3 CONDITIONS TO BE MAINTAINED

The condition to maintain typically applies to snow accumulations such equal to or less than 3 cm of snow accumulations. Icy conditions are typically not specifically defined but the assumption is that is no ice.

### 6.2.4 END CONDITIONS

Typically, the LOS standard is defined as achieving one of the following conditions for snow accumulations:

- **Condition Description Bare and Dry:** Most of the road surface is dry.
- **Bare and Wet:** Most of the road surface is moist.
- **Partially Snow Covered:** Two wheels of a vehicle are on bare surface and the other wheels are likely to be on loose snow.
- **Partially Snow Packed:** Two wheels of a vehicle are on bare surface and the other wheels are likely to be on snow bonded to the road.
- **Partially Ice Covered:** Two wheels of a vehicle are on bare surface and the other wheels are likely to be on ice.
- **Snow Covered:** All wheels of a vehicle are on loose snow.
- **Snow Packed:** All wheels of a vehicle are on snow bonded to the road Ice Covered All wheels of a vehicle are on ice.

### 6.2.5 DEFINED TIME

The time to meet the condition to be maintained following the conclusion of the winter event in hours (e.g., 3 hours). Road Authorities often have several LOS. The LOS for a road can be based on traffic volumes, speed, importance of the corridor for access (e.g. emergency route, bus route, school, economic corridor). The following tables are examples of LOS for snow and ice.

Table 6.2 Level of Service for snow accumulations

| DESIGNATIONS | SNOW DEPTH FOR ACCUMULATION RESPONSE | OBJECTIVE DURING STORM | OBJECTIVE AFTER STORM | TIMEFRAME TO ACHIEVE OBJECTIVE AFTER END OF WINTER EVENT |
|---|---|---|---|---|
| Arterial | ≤ 2.5c | Safe and passable | Bare and wet | 4 hours |
| Collector and Bus Route | ≤ 2.5c | Safe and passable | Bare and Wet | 6 hours |
| Local | ≤ 2.5c | N/A | Partially snow packed | 16 hours |
| Unmaintained | Unmaintained in the Winter | | | |

Table 6.3 Level of Service for ice formations

| DESIGNATIONS | OBJECTIVE DURING AND AFTER STORM | TIMEFRAME TO ACHIEVE OBJECTIVE AFTER END OF WINTER EVENT |
|---|---|---|
| Arterial | Safe and passable | 4 hours |
| Collector and Bus Route | Safe and passable | 6 hours |
| Local | Safe and passable | 16 hours |
| Unmaintained | Unmaintained in the Winter | |

The “highest” LOS, normally for the highest priority roads, has "bare pavement" as the desired outcome. Bare pavement provides the best possible friction for vehicle tires to maintain control. On less travelled roads, a centre-bare or snowpack condition may be appropriate. For centre-bare conditions, less salt is used, whereas for snowpack conditions salt would only be used where there are extreme icy conditions or where mechanical ice-blading does not improve friction.

### 6.2.6 CHAIN TIME

The total time between when chain fitting is required and lifted is a key performance metric on the roads to the ski resorts this (NPWS, 2020). As this is the outcome sought, it should be included as part of the LOS (i.e., defining what a reasonable time is for various snow and ice events.

### 6.2.7 LOS AND SALT MANAGEMENT

The higher the LOS (e.g., lower snow accumulations, shorter defined time (including for chain fitting requirement) and/or bare pavement conditions) the more road salt is needed. The LOS also effects equipment selection, routes, winter event responses, etc.

Winter road salt is the leading cost-effective solution to producing bare pavement for the highest-class standard level of service in winter maintenance. The amount of salt used should be governed by the required level of service with an eye to the economics and the value for money decision on its use. To be efficient, salt must be placed at the right time, in the right place and at the right quantity.

There are three concepts with respect to service levels:

1 the LOS prescribed by the owner
2 the service that is delivered by the maintainer, and
3 the service that the community expects.

An efficient winter maintenance program requires that the service both provided by the snowfighter and that which is expected by the community must be the same as the LOS prescribed by the owner. Where the community expects a higher LOS than that prescribed, there would be pressure to increase the LOS.

There should be a regular review of the service area to ensure that the appropriate standard is established. It is also important to manage community expectations by ensuring that the service provided is the same as the prescribed LOS, and that the community is informed of these intentions.

Road organisations often increase the level of service in response to perceived community support for safer, passable roadways, particularly in the face of increased traffic. If an organisation is truly committed to salt management, it needs to assess these pressures considering safety and service needs as well as the costs of providing winter maintenance service and associated environmental impacts.

In some circumstances, it may be possible to reduce LOS. For example, in urban areas where bare pavement policies are established for local streets, many of these roadways are low volume and flat. A snowpack or "white-road" condition might serve these areas perfectly well, with ploughing to prevent impassable conditions and occasional use of abrasives (sanding) to address slippery conditions when necessary. This level of service standard would use far less salt than a bare pavement policy without significantly compromising mobility or safety. Establishing the LOS is a decision for authorities. An important distinction between North American or European and Australian LOS is considerations of the use of winter tires as standard in vehicles. National Parks in Australia require all non-four-wheel drive/all-wheel drive driving up mountains on snow days to use chains, but the use of winter tires is not prevalent otherwise.

The LOS is based primarily on highway speeds and traffic volumes. TfNSW has already applied a reduced speed limit in this area, with a reduction from 100 km/h in summer to 80 km/hr in winter, and may wish to reduce the LOS required. Additionally, weather information could be used to control variable-message speed limit signs under adverse winter weather conditions. Experiments using this technology are being conducted in Nevada, USA and results to date suggest considerable success Winter Highway Maintenance, A Look Forward TRB A3C09: Committee on Winter Maintenance (Nixon, undated). In Finland, the effects of seasonally changing speed limits from 100 km/h to 80 km/h during winter on selected roads was studied, and all accidents decreased by 14%. Finland continues to have reduced winter speed limits. While not done to reduce salt use, it does suggest that reducing speed limits is viable.

In Quebec Canada, the road authority has the concept of a "winter Ecoroad", which is a road that is subject to an alternative maintenance approach during the winter season, in order to reduce the environmental impacts of de-icing salt on one or more zones sensitive to road salts. Winter Ecoroads: Frame of Reference for the Establishment of a Winter Ecoroad (Quebec, 2013) This maintenance approach priorities ploughing and the use of abrasives at critical points of the network to ensure road safety. However, in some circumstances, the use of road salts remains the recommended method, particularly when the pavement is icy, and at critical locations, such as on slopes, on curves and at stops. The Ecoroad approach is implemented under three principles: primacy of road safety; community support; and reduce the environmental impacts of road salts on sensitive areas. It should be noted that in Quebec, tires specially designed for winter conditions are mandatory.

### 6.2.8 OPPORTUNITIES FOR IMPROVEMENT

Table 6.4 provides a summary of level of service opportunities for KNP.

Table 6.4 Level of Service opportunities for improvement

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| A LOS policy should be specified | Salt Management Guide (TAC, 2013) | The prescribed/approved LOS is the foundation for the winter maintenance program and has a significant impact on salt used to achieve the standard. High Impact | Liability<br>Meeting expectations of community. | Develop a LOS for the KNP |
| The LOS policy should be adhered to as specified. LOS creep can occur where community expectations/ complaints move the LOS higher (e.g., less time) from the stated LOS, requiring more salt use. | Salt Management Guide (TAC, 2013) | TfNSW may exceed the prescribed/approved LOS in response to community complaints/desire for higher LOS, particularly in the face of increased traffic. | Caution, changing of the conditions to be met both during and post storm needs to consider safety, community expectations and should include support of elected policymakers. | Consistently measure service delivered against LOS |

## 6.3 WEATHER AND CONDITIONS INFORMATION AND ANALYSIS

### 6.3.1 OBJECTIVE

To provide timely and accurate information on weather and road conditions (e.g., pavement temperature) to assist in optimal snow and ice control decision-making.

### 6.3.2 RATIONALE

Good snow and ice control decision-making (and thus salt management) depends on consistently accurate and timely weather information. All weather monitoring must be performed at a frequency which enables a winter event response which complies with the minimum standards for highways. Research suggests that most accurate weather sources should be used for winter maintenance within budget limits and other constraints.

To best utilize winter maintenance chemicals, accurate and on time weather information and forecasts are critical (Ye, Strong, Fay, & Shi , 2009). Analysing the benefits of using detailed weather information, researchers found that weather information use had positive effects on winter maintenance costs. Case studies collectively showed that:

- winter maintenance costs decreased with the increase use of weather information or its accuracy.
- accuracy had a greater effect on maintenance costs than frequency.

The benefit–cost analyses showed that the use of weather information could bring more benefits than costs. The benefit–cost ratios for the case studies are 1.8 (Iowa), and 36.7 (Michigan). The Michigan case had the highest benefit–cost ratio due to low costs in weather service. While benefit-cost ratios do not tell the whole story, it is an indicator of reduced cost which is assumed to optimise road salt.

Weather information is important in supporting a variety of winter maintenance operations; however, it is most important to support material use in anti-icing and de-icing. It is expected that the demand for weather information among winter maintenance personnel will increase in the future, especially for current road and weather parameters of interest such as pavement temperature, air temperature, pavement surface condition, precipitation rate, precipitation occurrence, wind speed and direction, and humidity/dew point. This suggests findings have important implications for the type of weather information that would be most beneficial to winter maintenance personnel.

### 6.3.3 WEATHER INFORMATION

Weather information is available free from a variety of sources including the Government of Australia's Bureau of Meteorology (BOM). However, these are general in nature and have limited information. The use of Value-Added Meteorological Service (VAMS) is a best practice for reducing road salt use.

VAMS are site specific forecast from a service provider that is tailored to agency needs that includes, but not limited to: atmospheric temperature, relative humidity and/or dew point, wind speed and direction, and precipitation. As VAMS become more sophisticated, suites of information will become more available to agencies including things like nowcasting. Nowcasting is a detailed description of the current weather obtained by extrapolation for a period of 0 to 6 hours ahead. In this time range it is possible to forecast small features such as individual storms with reasonable accuracy. VAMS services are currently being used routinely by fire management agencies in Australia using BOM resources and could be undertaken for specific locations for TfNSW.

### 6.3.4 LOCAL CONDITION INFORMATION

Public and VAMS weather information is measured about 10 m above the ground providing information on lower atmosphere meteorological conditions. Atmospheric data collected from the Bureau of Meteorology or other service providers typically represent the regional environment and not the road environment. A wealth of local weather and pavement condition information can be collected to provide valuable information for supporting anti-icing and de-icing approaches that help to optimise road salt use.

#### *ENVIRONMENTAL SENSING STATIONS (ESS)*

ESS (also called electronic surveillance) is a broad term for units that measure local environmental data and, for winter maintenance, usually include sensor for weather variables either imbedded into the road surface or installed on the side of the roadway and include a microprocessor, communication device and recording equipment. Several are discussed below:

#### *ROAD WEATHER INFORMATION SYSTEMS (RWIS)*

RWIS are fixed stations, topically in a network, that include various weather and pavement sensors for collecting real-time data on precipitation, pavement temperature, snow coverage, etc. Many transportation agencies, such as Ministry of Transportation Ontario in Canada, have invested in establishing RWIS networks to better support winter maintenance decisions and provide more accurate traveller information. The New Zealand Transport Authority has successfully used thermal mapping and RWIS technology (Metservice New Zealand) in a trial run on the Central Plateau in North Island to focus resources and CMA use. In the case study 4,3000 km of road network was covered by 17 RWIS units and resulted in a 90% accuracy in their treatment decisions and reduced wastage to less than 3% (Vaisala, n.d.).

RWIS stations are costly to install and operate and, therefore, are only be deployed at a limited number of locations. RWIS are intended to work in a variety of meteorological and remote conditions and may feature a variety of data retrieval methods including short-haul telecommunications, telephones (landlines, cellular, voice-synthesizers), radio frequencies, multidrop, and satellite. On site options may also include storage modules and laptop computers.

### *MOBILE WEATHER INFORMATION SYSTEMS (MWIS)*

MWIS (also called Mobile-RWIS, MRWIS or MARWIS) is a system of vehicle-mounted sensors deployed to observe environmental conditions such as pavement conditions (e.g., temperature, friction) and atmospheric conditions (e.g., air temperature), which are transmitted to central locations via Automated Vehicle Location (AVL) and Global Positioning System (GPS) technologies. An important application of MWIS is thermal mapping of road segments (see discussion below).

MWIS technologies are still relatively new to the market, with only a few early-adopting agencies deploying them, primarily in testing situations. Transportation agencies in some United States locations (Iowa, Michigan, and Minnesota) have partnered to deploy and evaluate advanced maintenance vehicles equipped with mobile environmental sensors, including a pavement freeze point sensor and a friction measuring device (FHWA, 2019b). Similarly, Clear Roads funded a comparative analysis of four commercially available MWIS sensors (SRF Consulting Group, Inc., 2019).

### *INTEGRATING MOBILE OBSERVATIONS (IMO)*

IMO involves collecting atmospheric weather, road conditions, and native data from government fleet vehicles' ancillary weather sensors and vehicle-based controllers (and in the future connected vehicles, see below). The data provide maintenance and operations managers with a more detailed view of the weather and road conditions as well as asset locations along the highway network. FHWA (Federal Highway Adminstration , 2020) lists typical IMO benefits including reduction of material use.

For example, Minnesota Department of Transportation (MnDOT) instrumented and deployed 478 heavy duty trucks, 20 light duty trucks, and 5 mowers over three phases of IMO deployment. MnDOT collected data from the vehicle and external sensors using customized software and equipment, then transmitted the data to servers via cellular communications. The data was used by other systems for road weather conditions, end of shift reports, material management, traveller information, and maintenance decision support.

### *ROAD SENSORS*

Embedded pavement sensors can detect various road conditions (such as temperatures, residual salt/chloride, assess the treatment of road surface chemicals, and determine the temperature at which pavement moisture will freeze. While typically part of RWIS, these can be stand-alone units. The drawback with sensors within the road surface is that ploughs can damage or remove them if there is misalignment with the surrounding pavement.

To ensure the appropriate application rate of salt or salt brine on pavement, it is advantageous to have quantitative information about pre-existing/residual salt concentration on the pavement prior to new application of salt or salt brine. This need has been identified as a high priority by several agencies and organisations (Cui, Fey, & Shi, 2015). Salinity sensors have been traditionally employed in road weather information systems (RWIS).

### *NON-INTRUSIVE SENSORS*

#### *INFRARED THERMOMETERS (IRT)*

Pavement temperature is the primary piece of information necessary for determining if frost or ice will form, or snow will accumulate on the pavement and the amount, type and timing of material use. Pavement temperature can fluctuate significantly depending upon the time of day, degree of cloud cover, subsurface conditions (e.g., frost penetration, moisture presence, thermal retention properties, etc.) and type of pavement. It is a best practice that road authorities use infrared thermometers mounted to vehicles to monitor pavement temperature.

*OTHER SENSORS*

There are many emerging non-intrusive road sensor equipment working on a variety of principles including optical/spectroscopic and microwave reflection. Non-intrusive sensors are typically installed 6 to 15 meters above the road and can weather parameters or road conditions such as: water layer thickness, salinity at the surface, presence of snow, ice, or water and determine ice percentages and friction coefficients (FHWA, 2003). Benefits reported over embedded sensors include: easy insulation and repair, reduce downtime, accurate measure of ice crystals prior to road becoming slippery, early frost/ice formation (Clear Roads, 2015). These can be stand-alone units or part of RWIS or MWIS.

### 6.3.5 WEATHER AND CONDITION ANALYSIS

Mobile temperature measurements, or thermal mapping, have been used in applied road climatological studies since the middle of the 1970s. Mobile infra-red (IR) sensors are used to quantitatively describe the thermal behaviour of roadways under various weather conditions. The diagrams produced are generally referred to as thermal fingerprints. As more roads in an area are 'fingerprinted', a two-dimensional thermal map for an entire road network, or part of it, can be produced. Traditionally thermal mapping is used as a method to detect locations which differ in temperature to identify the most suitable locations RWIS stations. More recently, IR thermometry is being used to identify and map sections of the road network prone to ice occurrence or other hazards based on reading from RWIS stations.

Traditionally, thermal mapping has been expensive as five to six surveys are need under varying weather conditions and it is still questionable whether the full range of atmospheric conditions is adequately covered. However, more robust statistical analysis procedures are reducing the number of thermal mapping surveys that are required, lowering costs (Marchetti, Chapman, Khalifa, & Buès, 2014).

#### 6.3.5.1 EXAMPLE OF THERMAL MAPPING AND HAZARDOUS CONDITION PREDICTION

IceCast Traffic Safety Solutions which provides weather hazard warning, monitoring and prediction information in support of timely Winter Service decision making. The information enables customers to optimise the safety of the road user at the most economic cost. About 250 authorities have invested in the IceCast Ice Prediction System. Its combination of sensors, thermal mapping, road weather stations, and site-specific forecasts reduces winter maintenance costs enormously. Each thermal map defines the pattern and size of road surface temperature variation for specific weather conditions. Such information is essential in tackling winter problems.

There are typically four parts to the IceCast system, which follow a sequential order:

1. thermal mapping of the road network
2. installation of surface sensors and weather stations
3. forecasting for selected weather stations and extrapolation using thermal mapping, and
4. route optimization of the road network (Vaisala, undated).

Thermal mapping extended the ability for ice prediction at weather stations (point locations) to the entire road network by identifying patterns of temperature variation across roads using specially equipped survey vehicles under different weather conditions. This was important because, on a typical winter night, temperature differences across a road network can be as high as 10°C due to various factors including altitude, exposure and traffic.

There are two prediction types: 3-hour nowcasting and 24-hour forecasting of surface temperature and surface state. Three-hour forecasts use real-time measurements from each station, whereas 24-hour forecasts are based on a heat-balance model that uses wide-scale inputs of atmospheric weather parameters to produce station specific forecasts. Nowcasting and forecasting techniques are used to predict at what time individual roads will reach a critical state and require treatment. A decision maker can also monitor predicted and observed data and identify when the two data sets deviate. Consequently, given roads within the network can be treated ahead of schedule.

Route optimisation decreasing the number of routes required to treat and allowing for selective treatment of routes.

Vaisala who developed the system notes several benefits of the IceCast Ice Prediction System including:

- identifies dangerous sections that are not apparent when using only weather stations
- identifies the optimum location and number of weather stations
- extends ice prediction from RWIS station locations to an entire road network
- enables selective anti-icing strategies that avoid the unnecessary treatment of warmer network sections, reducing time and costs
- provides quantitative reference data.

### *6.3.6 OPPORTUNITIES FOR IMPROVEMENT*

Table 6.5 provides a summary of weather and condition information opportunities for KNP.

Table 6.5 Weather and Condition information opportunities for improvement

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Use of weather forecasts and Value-Added Meteorological Service (VAMS) to improve decision making and storm response. A subscription to a VAMS provider allows customized weather forecasts four times a day that are specific to your area as well as give you the information you need to adjust the application rates of road salt to meet local pavement and weather conditions. | Salt Management Guide (TAC, 2013), Good Practices for Winter Maintenance in Salt Vulnerable Areas (ORGA, 2018) | Good snow and ice control decision-making (and thus salt management) depends on consistently accurate and timely weather information.<br>Impact: High | Costs for VAMS<br>Location specific availability | Have value added Meteorological Service (VAMS) customized weather forecasts provided for at least 3 times/day. |
| Use of RWIS to improve understanding of pavement temperature forecasts and trends can improve the accuracy of decision-making | Salt Management Guide (TAC, 2013) | | High capital, operational and maintenance costs | Implement a network of RWIS stations, which is expected to be very valuable in the complex topography of the KNP. |
| Vehicle-mounted RWIS systems (mobile weather information systems or MWIS): can include pavement freeze point sensor and a friction measuring device. | Standards and Guidance for Using Mobile Sensor Technology to Assess Winter Road Conditions (May 2019) Surveillance, Monitoring and Prediction (FHWA, 2019) | | Cost for MWIS | Implement a system of MWIS as part or instead of RWIS, which is expected to be very valuable in the complex topography of the KNP. |
| Infrared thermometers (IRT) can be used to determine the current surface temperatures. | Salt Management Guide (TAC, 2013), Good Practices for Winter Maintenance in Salt Vulnerable Areas (ORGA, 2018) | | None | While currently the trucks are set up with road pavement temperature detectors, all ploughs, spreaders, combination units and support vehicles should have infrared thermometers (IRT). |

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| For the IRT, there should be procedures on their operation, recording keeping and calibration, plus training. | Salt Management Guide (TAC, 2013) | | None | Develop procedures for consistent use and documentation supported by training. IRT calibration should be recorded. |
| Thermal Mapping is a technique to generate road-condition forecasts for entire routes based on particular points and mobile sensors. | None | | Costs | Consider doing a road network temperature survey to develop a thermal mapping, which may be very valuable in the complex topography of the KNP. |
| Non-Invasive Sensors: Non-invasive road weather sensor are mounted several meters above the surface and measures surface conditions such as: wetness, ice, snow, or frost, water film heights, ice percentage in water, freeze point temperature. Through these measurements, a friction coefficient on the road can be generated. This produces real-time friction level of the road surface that can be used in decisions to plough and/or apply materials and, if used properly, can prevent over application. | Syntheses of Best Practices Road Salt Management 9.0 – WINTER MAINTENANCE EQUIPMENT AND TECHNOLOGIES (TAC, 2013) | | Costs, data compatibility | Consider non-invasive sensors as part of a MWIS/RWIS system or instead. Localised information is expected to be very valuable in the complex topography of the KNP. |

## 6.4 STORM RESPONSE AND DECISION SUPPORT

### 6.4.1 OBJECTIVE

To implement a consistent and effective snow and ice control in response to a winter event that includes preventative actions to meet the LOS, with the optimised amount of material use. In other words, to provide the right material, in the right amount, at the right time and in the right place.

### 6.4.2 RATIONALE

Snow and ice control decisions that are not clearly supported by procedures (including handling unusual and emergency conditions), leads to a less than optimal use of salt, usually more. At its most complex, these decision support procedures become expert systems. Maintenance Decision Support System (MDSS) is, in its most general terms, an automated tool for providing decision support to winter road maintenance managers. In a broader sense, MDSS is a multi-layered, information system that provides forecasts, predictions, reports on observed weather and road conditions.

Decision Support is a tool to help analyse the various information (weather conditions, pavement temperature, equipment etc.) in order to come to optimal response decisions. Expert Guides can take different forms and have different levels of sophistication. Examples of Expert Guides in common use include: decision trees that document successful experiences that can be repeated or a table with headings such as: temperature range, type of precipitation, road condition, activity (plough, sand, salt), and recommended treatment (beginning, during, end of storm).

There are benefits and issues expressed regarding MDSS programs. A case study of New Hampshire's five previous winters showed that, had MDSS been used, 23% less salt could have provided the same level of service. (2010 Transportation Pooled Fund Study TPF-5(054) Maintenance Decision Support System). Trail stakeholders were interviewed, and they generally had a positive view of the MDSS (Western Transportation Institute and Tiers, Inc. 2010).

#### 6.4.2.1 DECISION SUPPORT TABLES

The most comprehensive is from the Anti-Icing and De-icing Road Salt (Sodium Chloride) Treatment of Road Surfaces by Anticipated Event Type (Blackburn and Associates, 2014) which uses pavement temperature as a key determinant, as shown below in Table 6.6.

Table 6.6 Weight factors for snow and ice control chemicals relative to NaCl= 1 at various temperature bands

| PAVEMENT TEMPERATURE °F | SOLID NaCL LIQUID gal/LM | 23% NaCL LIQUID, gal/LM | SOLID 90-92% $CaCl_2$ LIQUID, lb.LM | SOLID 100% $MgCL_2$, lbs/LM | 32% $CaCL^2$ LIQUID, gal/LM | 27% $MgCL_2$ LIQUID, gal/LM | SOLID 100% Kac, Lb/LM | 50% Kac LIQUID, gal/LM | SOLID 96% CMA, lb/LM | 25% CMA LIQUID, gal/LM |
|---|---|---|---|---|---|---|---|---|---|---|
| 31-32 | 100 | 44 | 110 | 31 | 90 | 32 | 168 | 32 | 170 | 18 |
| 26-30 | 100 | 44 | 110 | 31 | 90 | 32 | 168 | 32 | 170 | 18 |
| 21-35 | 100 | 44 | 110 | 31 | 93 | 33 | 154 | 29 | 160 | 17 |
| 16-20 | 100 | 44 | 107 | 30 | 88 | 32 | 140 | 26 | 150 | 16 |
| 11-15 | 100 | 44 | 103 | 29 | 85 | 30 | 130 | 24 | 150 | 16 |
| 6-10 | 100 | 44 | 103 | 29 | 83 | 29 | 130 | 24 | 140 | 15 |
| Below 5 | | | | | | | | | | |

### 6.4.2.2 MAINTENANCE DECISION SUPPORT SYSTEM (MDSS)

MDSS (a computerised expert system) is an innovation that was started in the early 2000s. Agencies believed that they could provide more effective maintenance, and provide it more efficiently, with the help of an automated Maintenance Decision Support System (MDSS) that could:

- assess current road and weather conditions using observations and reasonable inferences based upon observations
- provide time- and location-specific weather forecasts along transportation routes
- predict how road conditions would change due to forecasted weather and the application of several candidate road maintenance treatments
- notify state agencies of approaching conditions and suggest optimal maintenance treatments that can be achieved with resources available to the transportation agencies; and
- evaluate the reliability of predictions and the effectiveness of applied maintenance treatments for specific road and 170weather conditions for decision support to be improved.

Over the last 15 years an MDSS software package that was developed by the Federal Highway Administration has been used and refined by at least 15 states (FHWA, 2019a). The FHWA MDSS integrates relevant road weather forecasts, coded maintenance rules of practice, and maintenance resource data to provide winter maintenance managers with recommended road treatment strategies.

Based upon user requirements, a team of national laboratories developed the MDSS prototype in 2001. From 2002 to 2007, the prototype underwent five development cycles and three field demonstrations in the US states of Iowa and Colorado. In 2007, 21 state transportation agencies were using or developing MDSS tools. Sixteen states have joined the MDSS Pooled Fund Study led by the South Dakota Department of Transportation (DOT) to develop an enhanced version based on the federal MDSS prototype, while others were in the process of procuring the software or have contracted with private vendors for maintenance decision support capabilities. In 2007, the US Federal Highway Administration (FHWA) conducted benefit/cost analyses of operational MDSS applications being used by the pooled fund states (see case studies below for Maine DOT).

FHWA reports that the MDSS program development process has been an extraordinary success. The American Association of State Highway and Transportation Officials (AASHTO) Technology Implementation Group evaluated and determined that the MDSS project is a market ready. FHWA three value added meteorological services vendors offer MDSS and MDSS-type services in their product lines. However, in both 2015 and 2017, FHWA noted evidence of stagnation of MDSS adoption.

In 2011, the Weather Network (Meteo Media) did a field trial of an MDSS. The following were the reported results (The Weather Network Commercial Services, 2011):

- Chemical usage was reduced, especially in scenarios where road temperatures were at or above 0ºC. In many cases, this appeared to be due to a proactive anti-icing type of suggested strategy. In scenarios where the road was above freezing, gains were more significant; perhaps due to an understandable reliance on below freezing air temperatures by decision-makers.
- MDSS suggested treatments are plausible but not a substitute for the human experience factor.
- MDSS can bring new staff up to speed quicker and fosters consistency between staff members.
- MDSS reinforces weather and RWIS information, understanding and use; and, therefore, gains.

Alberta Transportation (Canada) offered MDSS to their contractors on a trial basis. Four contractors accepted the offer and found MDSS to be useful saving them both overtime and chemical costs. Then on February 7, 2012, Alberta Transportation advertised request for proposal (RFP) to provide all services required to develop and implement a MDSS for winter road maintenance suitable for Alberta’s road and climatic conditions. Outcomes from that are not yet available.

### 6.4.3 OPPORTUNITIES FOR IMPROVEMENT

Schmidt Stratos salt spreaders are used on the Snowy Mountain Highway, Kosciusko Road and Alpine Way and RMD is currently trailing Winterlogic system spreaders for dispensing salt, recording data, usage, GPS locations and quantities. The optional WinterLogic desktop application stores and organizes data from every de-icing operation ever performed to create reports and statistics, planning guidelines and efficiency analyses to optimise fleet performance and maintenance schedules. This cloud-based application extracts information directly from the controller and feeds into a central operating system. The manufacture also has a ThermoLogic dosing system, which adapts the amount of salt to changing road and weather conditions. As the road surface temperature drops, more salt is applied. The state-of-the-art sensor continually monitors the temperature of the road surface and transmits it to the closed loop control system.

Table 6.7 provides a summary of storm response and decision support opportunities for KNP.

Table 6.7 Storm response and decision support opportunities for improvement

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Decision Support is a tool to help analyse the various information (weather conditions, pavement temperature, equipment etc.) in order to come to optimal response decisions. Expert Guides can take different forms and have different levels of sophistication. | Salt Management Guide (TAC, 2013), Maintenance Decision Support System (FHWA, 2019) | Generally speaking, decision support and the more elaborate MDSS programs are effective at reducing salt use as it allows agencies to better customize responses to winter events and optimise material use.<br>Impact: High effectiveness | None | Create a decision support tool with several application rates. This should help with the following conditions:<br>**1** Winter contractors apply salt only for it to be bladed away a short time later by a snow plough. Decision support tool could include plough priority and anti-icing to address this condition.<br>**2** Road salt has not been given enough time to work before another treatment is applied. Decision support tool can include appropriate application rates and materials for this condition. |
| US Federal Highway Administration has been developing a Maintenance Decision Support System (MDSS). | | | Cost to implement and maintain the system, could be significant data acquisition costs and issues | In addition to trailing the Winterlogic system, consider reviewing the ThermoLogic dosing system. Also considering reviewing the FHWA MDSS. |

## 6.5 DE-ICING AND ANTI-ICING MATERIALS

### 6.5.1 *OBJECTIVES*

To provide the right material, right amount, at the right time and in the right place.

### 6.5.2 *RATIONALE*

The types and phases materials should be optimised to support the winter event response decisions in order to meet the LOS in a manner that is responsive to equipment available, fiscal demands and safety.

This section provides a review of the following:

- application approaches: the right time and in the right place
- material types: the right material
- application rates: the right amount.

### 6.5.3 *APPLICATIONS APPROACHES*

There are two general application approaches: de-icing and anti-icing.

#### 6.5.3.1 DE-ICING

De-icing is the application of solid and/or liquid materials after the winter event has started. Solid sodium chloride is applied to the ice and snow on the road to form a brine that breaks the bond that has formed between ice/snow and the pavement allowing it to be removed by ploughing and/or action of vehicles or in the case of ice/frost melt. De-icing as a control measure works in most weather and traffic conditions, and locations.

For example, the New Zealand Transport Agency (NZTA) discontinued the use of de-icing salt in the 1908s as a result of environmental and community concerns. They chose the calcium magnesium acetate (CMA) as their de-icer of choice due to its proven performance as well as minimal environmental impact (Vaisala, n.d.). In combination with thermal mapping and RWIS (Road Weather Information Systems) the NZTA has created a system which monitoring has shown has had no long-term cumulative impact on the environment.

Pre-wetting (also called pre-treatment) is the process of spraying salt with a liquid de-icing agent (such as salt brine) before spreading the solid salt on the road. This can be done at the yard, in the box of the spreader or at the spreader.

#### 6.5.3.2 ANTI-ICING

Anti-icing is a proactive treatment method for snow and ice on roads, which can be initiated before the weather event begins or just as the precipitation begins falling (i.e. “just-in-time” anti-icing). Anti-icing can help to prevent black ice and prevents or weakens the bond that could form between the pavement and ice, ultimately allowing for easier removal of snow and ice using ploughing techniques. Anti-icing can be done with liquid, solid, and pre-wet chemicals.

Anti-icing has the potential to provide the benefit of increased traffic safety at lower road salt use. However, to achieve this benefit the maintenance manager must adopt a systematic approach to snow and ice control and must ensure that the performance of the operations is consistent with the objective of preventing the formation or development of bonded snow and ice. Such an approach requires use of considerable judgment in making decisions, requires that available information sources be utilized methodically, and requires that the operations be anticipatory or prompt in nature.

Anti-icing is well suited to routes with a higher level of service. This is because the vigilance and timeliness of successful anti-icing operations are most compatible with service levels requiring earlier and higher frequency winter maintenance operations. It is also because the preventive nature of anti-icing can support higher service level objectives such as maintaining bare pavement throughout a storm or returning to bare pavement as soon as possible following pack formation. Sufficient evidence has accumulated from years of anti-icing testing to demonstrate the effectiveness of anti-icing practices (FHWA, 1996).

The benefits of anti-icing compared to traditional methods include (NDDOT, undated):

- anti-icing is a pro-active approach to winter road maintenance. It forms a bond-breaker between the pavement surface and the snow and ice layer which melts snow more quickly and reduces the chance that ice will form and bond to the surface. It reduces the amount of time required to restore the roads to a clear, dry state
- reduced use of abrasives on the road results in reduced environmental impacts
- snow and ice control cost savings results in benefits to road agencies and the community
- improved winter roadway conditions result in safer driving conditions for motorists
- lower accident rates – the US state of Colorado experienced an average decrease of 14% in snow- and ice-related crashes.

Direct Liquid Application (DLA) reduces the amount of chlorides required by up to 10 times by preventing formation of the bond between ice/snow and the pavement. DLA is also effective as a pre-treatment for frost events and to prevent black ice from forming. (OGRA, 2018). MN/DOT found that anti-icing is often the most cost-effective and environmentally safe practice in certain winter road maintenance situations (Mn/DOT, 2005).

Guidelines for anti-icing (FHWA, 1996):

- anti-icing is often effective for heavy frosts
- anti-icing works best when combined with accurate road weather information
- early application is particularly important for frost or light freezing drizzle
- liquids are the best as they may be applied days in advance of an event
- pre-treated salts will work at lower applications (lowest possible setting) closer to the expected event.

In the ski resort areas, anti-icing may assist in the following conditions (NPWS, 2020):

1. Blizzard conditions deliver a thick snow cover on roads, winter contractors apply salt only for it to be bladed away a short time later by a snow plough ordered to deal with a rapid build-up of snow. Pre-wetting will prevent ice from compacted snow forming a bound with the pavement, allowing effective ploughing.
2. Snow ploughs crush then compact snow into black ice resulting in dangerous, low-friction conditions which do not respond well to salt application.

### 6.5.3.3 OPPORTUNITIES FOR IMPROVEMENT

Table 6.8 provides a summary of de-icing and anti-icing opportunities for KNP.

Table 6.8 De-icing and anti-icing opportunities for improvement

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Anti-icing is the proactive winter maintenance practice of adding road salt or other chemicals to the road prior to the winter event. It has been shown to improve level of service (LOS); reduce the need for products, abrasives or ploughing; and associated cost savings and safety and mobility benefits. Direct liquid application (DLA) has emerged as the most commonly used proactive winter maintenance practice. | Salt Management Guide (TAC, 2013), Good Practices for Winter Maintenance in Salt Vulnerable Areas (ORGA, 2018), New Zealand Transport Authority (Vaisala, n.d.), others | Generally speaking, anti-icing is an extremely effective practice at reducing application of winter maintenance products relative to other practices, such as de-icing, because lower application rates can be used.<br>DLA has been found to remain on the pavement and effective over a long period of time, and even after a snow event.<br>Impact: High to Moderate | Cost of additional equipment, lack of experience/expertise in using anti-icing approaches, community concern.<br>Freezing rain is a challenging condition to manage, anti-icing materials (usually solid salt) applied preventatively may simply dissolve and wash way if rain persists. | Look to implement and/or expand anti-icing. |

## *6.5.4 MATERIAL TYPES*

Roads and Maritime Services has historically predominantly used a wet salt mix in their snow and clearing operations, sometimes used dry salt during cold conditions (RMS, 2016). Three methods of road de-icing are used in Australia (Moulding, 2018):

1. applicable of dry Sodium Chloride salt (granulate NaCL)
2. application of Calcium Chloride salt brine ($CaCl_2$)
3. application of evaporated sea salts.

Kosciuszko Road and Alpine Way have been noted to use NaCl and $CaCl_2$ through granulate and brine spread from the same truck (Moulding, 2018).

For comparison, from a North American salt management perspective there are two primary types of products wildly available:

- Chloride based:
  - Sodium Chloride (NaCl)
  - Calcium Chloride (CaCl2), and
  - Magnesium Chloride (MgCl2)
- Non-chloride based:
  - Acetates: potassium acetate (KAc), and calcium magnesium acetate (CMA)
  - Liquid agricultural/organic by-products (ABPs / OBPs).

ABPs / OBPs are blended with water and chloride salts to improve their performances in snow and ice control. ABPs/OBPs include: corn syrup, corn steeps, and other corn derivatives; beet juice-sugared or de-sugared; lignin/lignosulfonate; molasses (usually from sugar cane); brewers/distillers by-product; and glycerine.

A survey was distributed to assist in defining snow and ice control material use in North America (Levelton Consultants Limited , 2007). Like the agencies, solid road salt (NaCl) was the most commonly used snow and ice control chemical and was considered a first preference for 57 percent of the respondents. NaCl brine was a first or second choice for 43 percent of the respondents, with several respondents had both salt and salt brine as their first preference. This is primarily a function of cost as shown in Table 6.9.

Table 6.9 Comparative costs of Road Salt Alternatives (TAC, 2013)

| SELECT ALTERNATIVE MATERIALS | COST COMPARED TO ROAD SALT (SODIUM CHLORIDE) |
|---|---|
| Solids | |
| Calcium Chloride | 343% |
| Calcium Chloride + Sodium Chloride + Magnesium Chloride | 143% |
| Calcium Magnesium Acetate (CMA) | 1386% |
| Liquids | |
| Calcium Chloride (29% CaCl2) | 233% |
| Magnesium Chloride (22% MgCl2) | 142% |

Magnesium chloride, used as a liquid, was the next preferred chemical with 14 of the respondents rating it as either their first, second, or third preference (50 percent). Calcium chloride, primarily used as a liquid, was the next most popular, with 12 of the respondents rating it as either their first, second, or third preference (43 percent). For the most part, respondents reported $MgCl_2$ and $CaCl_2$ is used as blended products containing organic materials used as corrosion inhibitors. $MgCl_2$ and $CaCl_2$ is used because of their ability to be effective at temperatures below -9$^{o}$C, where NaCl become less effective. Given the climate within the KNP, this may not be a driving consideration for TfNSW.

Calcium magnesium acetate (CMA), potassium acetate (KA), as well as some proprietary organic products are not as popular as chloride-based products. These chemicals are considerably more expensive on a weight basis than traditional chemicals (Table 4), and larger amounts of these chemicals are needed to achieve lower temperatures than chloride-based products. The higher cost and application rates for KAc and CMA make them impractical chemicals for routine road treatment. CMA was considered to be the most suitable de-icing agent after a 1996 study by Transit New Zealand as it was considered to have the lowest risk of skid resistance compared to other de-icing agents used in Europe and North America, though there were limits regarding application times, magnitude, and duration (Jamieson and Dravitzki, 2006). The New Zealand Transport Agency (NZTA) has produced a CMA Best Practices Guideline (NZTA, 2012). Certain chemical substances such as nitrates and phosphates (for example, urea) and organic substances such as methanol, alcohol, or ethylene glycol present particular hazards to the aquatic environment and should not be used in bulk as de-icers except in special circumstances (MOECC, 2011).

ABPs / OBPs are liquids used alone or more commonly as additives for chloride-based products. ABP are commonly from beets, corn, beer brewing or cheesemaking. ABP appear to significantly lower the freezing point of -23°C of NaCl brine, but do not significantly improve the ice melting capacity at various temperatures. ABP exhibit significant benefits in reducing the corrosivity of NaCl brine but may have other environmental impacts. Issues using ABP includes clogging of spray equipment especially at lower temperatures and bacterial growth.

#### 6.5.4.1 OPPORTUNITIES FOR IMPROVEMENT

Table 6.10 provides a summary of material type opportunities for KNP.

Table 6.10 Material types opportunities for improvement

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Depending on their composition and how they are used, alternatives to road salt (NaCl) can reduce or replace the use of road salt. | Salt Management Guide (TAC, 2013) | Impact: High effectiveness | Cost: alternatives to sodium chloride (road salt) are more expensive (can be 10s to 100 times more expensive)<br>Alternatives have environmental impacts as well. For example, CMA can contribute to biochemical oxygen demand, and KA has been known to impact asphalt and concrete pavements.<br>Alternatives have different properties that may require alternative equipment for use, different operational / environmental considerations for effectiveness etc.<br>The use of any additional chemicals on National park roads would need to be preceded by a thorough environmental study and endorsement by NPWS. | If TfNSW is interested in evaluating alternatives to road salt, Clear Roads has developed procedures for considering low chloride or no-chloride alternatives. *Determining Effectiveness of De-icing Materials and Procedures* (December 2009), and *Development of Standardized Test Procedures for Evaluating De-icing Chemicals* |

### *6.5.5 APPLICATION APPROACH*

Pre-wetting (also called pre-treatment) is the process of spraying salt with a liquid de-icing agent (such as salt brine) before spreading the solid salt on the road. This can be done at the yard, in the box of the spreader or at the spreader.

Pre-wetting salt decreases the amount of road salt and helps it work more effectively in 2 ways:

1. Pre-wet salt stays on the road instead of bouncing off or being swept off by traffic. This results in up to 30% more salt remaining on the road.
2. Pre-wetting the salt before spreading it onto the road helps to start the he chemical process of de-icing. It begins immediately after it is spread and thus helps clear the road surface of snow/ice earlier than dry salt.

#### 6.5.5.1 OPPORTUNITIES FOR IMPROVEMENT

Table 6.11 provides a summary of application approach opportunities for KNP.

Table 6.11 Application approach opportunities for improvement

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Adopting either increasing pre-wetting capacity or using pre-treated salts. | Performance Indicators and National Targets for Environmental Management of Road Salts (ECCC, 2019)<br>Salt Management Guide (TAC, 2013)<br>Risk Management Measures Catalogue (2019) | Pre-wetting has shown to increase the performance of solid products or abrasives and their longevity on the roadway surface, thereby reducing the amount of materials required. Studies suggest that pre-wetting salt reduce salt loss by up to 30%:<br>Pre-treated material is now offered on the market as a cost-effective alternative that can provide similar results.<br>Impact: High Effectiveness | Costs of additional equipment.<br>Education and training in its use. | All spreaders for all routes should have pre-wet or 100% use of pre-treated materials. Currently, Schmidt Stratos Salt Spreaders are used on Snowy Mtn Hwy, Kosciusko Road and Alpine Way. These spreaders have the ability to pre-wet. |

### *6.5.6 APPLICATION RATES*

For highways in Ontario Canada, the application rates used for the pre-treated salt were 90, 105 or 130 kg/2 lane km depending on weather conditions. Clear Roads Organisation undertook a study titled *Establishing Effective Salt and Anti-icing Application Rates* (Blackburn and Associates, 2014). The study developed application rates based on pavement type, pavement temperature, adjusted dilution potential, and cycle time for a range of chemical types. The influence of weather patterns, storm type or scenarios, and site characteristics are to be treated as classifying elements in the recommended application rate tables. Table 6.12 and Table 6.13 are two extracts from that report for snow, and frost and black ice, respectively.

Table 6.12 Clear roads effective application rates for snow (with pre-wet)

| PAVEMENT TEMPERATURE (°C) AT TIME OF PRECIPITATION | LIGHT SNOW | | | MODERATE SNOW | | | HEAVY SNOW | | |
|---|---|---|---|---|---|---|---|---|---|
| | Anti-icing /2ln-km [g/m$^2$] | | De-icing (/2ln-km) | Anti-icing (/2ln-km) | | De-icing (/2ln-km) | Anti-icing (/2ln-km) | | De-icing (/2ln-km) |
| | Solid | Liquid | Solid | Solid | Liquid | Solid | Solid | Liquid | Solid |
| | Kg | L | Kg | Kg | L | Kg | Kg | L | Kg |
| Over -1.1 | 30.9 | 56.1 | 67.5 | 36.6 | 66.7 | 74.5 | 42.2 | 77.2 | 81.6 |
| -1.1 to -3.3 | 45.0 | 81.9 | 98.4 | 49.2 | 88.9 | 105.5 | 53.4 | 97.1 | 112.5 |
| -3.9 to -6.1 | 56.2 | 101.8 | 119.5 | 59.1 | 107.6 | 126.6 | 61.9 | 112.3 | 133.6 |
| -6.7 to -8.9 | 64.7 | 117.0 | 140.6 | 67.5 | 122.8 | 147.7 | 70.3 | 127.5 | PA |
| -9.4 to -11.7 | 73.1 | NR | PA | 75.9 | NR | PA | 78.7 | NR | PA |
| Below -12.2 | PA | NR | PA | PA | NR | PA | PA | NR | PA |

PA = Plough and Apply Abrasives as needed

NR = Not Recommended

Table 6.13 Clear roads effective application rates for frost and black ice

| PAVEMENT TEMPERATURE (°C) AT TIME OF PRECIPITATION | ANTI-ICING | | DE-ICING | |
|---|---|---|---|---|
| | Dry salt | Salt brine | Dry and prewet | Salt brine |
| | Kg/2ln-km | L/2ln-km | Kg/2ln-km | L/2ln-km |
| Over -1.1 | 28.1 | 51.5 | 63.3 | 114.6 |
| -1.1 to -3.3 | 36.6 | 66.7 | 70.3 | 127.5 |
| -3.9 to -6.1 | 45.0 | 81.9 | 77.3 | 140.4 |
| -6.7 to -8.9 | 53.4 | 97.1 | 84.4 | NR |
| Below -9.4 | AA | NR | AA | NR |

PA = Plough and Apply Abrasives as needed

AA = Apply Abrasives as needed

NR = Not Recommended

Based on information provided, Table 6.14 is the application rates in the park.

Table 6.14 Application rates for roads in Kosciuszko National Park

| LOCATION | APPLICATION RATE* (G/M$^2$) | LANE WIDTH ASSUMED (M) | APPLICATION RATE (KG/2LN-KM) |
|---|---|---|---|
| Snowy Mountain Highway | 10-20 | 4 | 40 to 80 |
| Kosciusko Road | 20-30 | 3 | 60 to 90 |
| Alpine Way | 20-30 | 3 | 60 to 90 |
| Average every day during the snow season | 20g/m$^2$ | 3 | 60 to 90 |

*assumed pre-wet rates.

### 6.5.6.1 OPPORTUNITY FOR IMPROVEMENT

Table 6.15 provides a summary of application rate opportunities for KNP.

Table 6.15 Application rates opportunities for improvement

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Using the right amount of salt (i.e., only the amount needs to effectively meet the LOS / safety goals) is key to reducing the amount of salt introduced into the environment. | Guidelines on Snow Disposal and De-icing Operations in Ontario (MOECC, 2011) | The LOS sets the performance requirements and the application rates should be tuned to meet the LOS based on the winter event without over-achieving. Impact: High Effectiveness | Safety is paramount and drives the desire to apply materials at a rate to overachieve the LOS. | The applications rates used within the park appear generally consistent with leading practices. |

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Having multiple application rates for solids allows better matching of salt application to conditions and thus optimises salt use. | Salt Management Guide (TAC, 2013) | Coupled with decision support tools, multiple application rates can optimise salt use. Impact: Moderate to High depending on rates used | Education and training on using multiple rates, should have a decision support to maximize benefit. | Review application rates based on peers and research (see Clear Roads report). Consider several rates for liquids and solids for anti-icing and de-icing. This is especially useful when using decision support tool / MDSS. More application rates provide the opportunity for a more nuanced response to winter events, and ultimately less road salt being used. |

## 6.6 EQUIPMENT

### *6.6.1 OBJECTIVE*

Select and use equipment that achieves road salt optimization.

### *6.6.2 RATIONAL*

The equipment used how it is calibrated and the information provided back from that equipment has significant impact on optimising salt use.

Leading practices include:

— All spreaders are calibrated at least at the start of each season and when repaired as per manufacturer's instruction including using actual volume testing.

— All spreaders have pre-wetting capacity (if pre-treated road salt not being used).

— Use electronic spreader controls that can be accurately calibrated, regulated to ground speed with reporting capabilities to better track route times and salt application locations, and generate salt-use data.

— Use AVL/GPS technologies with reporting capabilities to better track route times and salt application locations. Automatic Vehicle Location/Global Positioning Systems (AVL/GPS) are, fundamentally, systems for winter maintenance vehicles provide vehicle operational data, including vehicle location, road surface conditions, plough position, material application rates and other related data, such as air and pavement temperature readings, vehicle mounted camera views. Data collected allows for automatic production operational reports and alerts. Communication to a central software management solution is typically via a modern standard wireless data transmission.

As discussed in more detail below, potentials practices could include:

— ploughs and blades
— smart equipment: mobile data collectors and sensors
— using fixed application systems (FAST).

#### 6.6.2.1 PLOUGHS AND BLADES

One of the most important methods for winter road maintenance involves the mechanical removal of snow and ice from roadways using snow ploughs. Snow ploughing is initiated after a specific amount of snow has fallen. Snow ploughs are used to scrape the snow and ice from the roadway to ensure safe driving conditions. Through the use of efficient snow removal, agencies can reduce the amount of de-icing materials used.

The Transportation Association of Canada (TAC, 2013) made the following recommendations on blade types:

- Rubber and polymer/plastic blades to "squeegee" the surface to remove slush in areas where the ambient temperatures usually rise above the freezing point during daylight hours after a storm. In areas with colder temperatures the use of theses blades has not been as successful.
- Special plough blades with sliding segments that move up and down vertically facilitate the thorough clearing of rough or distorted pavement, reducing the amount of snow and ice chemicals required. These blades are well suited for high speed and rural ploughing.
- A new blade design was developed to allow more versatility, and to increase performance, service life, and maintainability. The new design consists of a two-blade system in which a sacrificial blade, made of a flexible cutting edge, is used to cut through snow and ice, and an independently operated blade, which is used to remove excess liquid or slush.

Clear Roads website (https://clearroads.org/equipment-plough-blades/) has resources on different ploughs and blades and current research.

#### 6.6.2.2 SMART EQUIPMENT (CONNECTED SENSORS)

This section provides a review of the following:

- mobile data collector (MDC)
- on-board pavement condition sensors for salinity, friction and freeze-point.

It should be noted that sensors and other devices used on winter maintenance vehicles are often provided by different vendors, each with their own proprietary communication protocols and data formats. It is costly and time-intensive to integrate the different systems into one data stream. Clear Roads in the US has undertaken an initiative to develop a standard protocol and specification that will allow plug-and-play connectivity among vendors who follow the protocol.

##### *MOBILE DATA COLLECTOR (MDC)*

An MDC is a controller in combo units that receives input from the operator, spreader controller, GPS and plough blade sensors. Weather forecasting and chemical application recommendations are then provided back to the controller using a Maintenance Decision Support System (MDSS), which includes local and regional weather radar information. "Having the most current information on road and weather conditions improve the overall efficiency of our operation, thus, reduces the amount of applied materials, and decrease overall costs" (South Dakota DOT, 2017).

The increased availability of real-time mobile observations obtained from vehicles drastically improves the coverage and types of information on roads, and supports the optimization of winter maintenance operations, including material application.

##### *ON-BOARD PAVEMENT CONDITION*

###### *SALINITY*

On-vehicle salinity sensors can be used to monitor the residual salt concentrations on a road surface along entire stretches of roadways, which allows for more accurate application rates. Integrating measurements from salinity sensors with automatic spreader controls, can improve applying the right amount of product in the right place. There are two general methods for on-vehicle salinity sensors, measuring the conductivity of collected tire splash and the refractive index of an aqueous solution atop of the road surface. Preliminary studies suggest that mobile salinity sensors available in Japan, Europe, and prototypes in the US may be viable options for integration into winter maintenance operations.

*FRICTION*

Mobile sensors can collect and transmit data on road surface grip (friction), relative humidity, dew point, layer thicknesses of water/ice/snow, and air and surface temperature. During the 2018-2019 winter season, 20 pilots were completed in nine countries with 6,000 hours of sensor data compiled across all locations. The sensor and its platform relay information on pavement temperature changes, along with the level of friction and moisture present along a roadway and determine salt, liquid materials, ploughing, or a combination of treatments.

Overall, the mobile sensors reliably provided users with real-time road conditions during winter storms that reduce operational costs. The pilot programs indicate the benefit that mobile sensors have in providing real-time feed-back to both the driver and the maintenance facility for improved operational decision-making, including when and where anti-icing and de-icing chemicals are needed.

As part of that pilot project, Colorado Department of Transportation(CDOT) found mobile road condition and friction sensors helped to reduce unnecessary salt usage, leading to significant savings. Between the 2017 and 2018 winter season, CDOT reported a solid material usage reduction of 21% and liquid material reduction of 56% on a small selection of roads, adjusted for winter severity. In this test region, these reductions resulted in $180,000 in material cost savings. CDOT projected that when such mobile sensors are implemented state-wide, it will save over $1 million annually (Colorado Department of Transportation, 2018). According to CDOT, "By mapping site-specific data from the friction sensors, maintenance workers are able to focus in on the areas that need treatment rather than treating whole sections of roadways."

*FREEZING POINT AND ICE-PRESENCE DETECTION SENSORS*

Vehicle-mounted freezing point and ice-presence detection sensors are relatively new. There is little pilot or operational information about the technologies since most of the technologies are currently under development. In the future, they may offer a cost-effective solution for agencies to overcome the practical infeasibility of having a dense network of in pavement sensors.

*AUTOMATED/FIXED MATERIAL APPLICATIONS*

Fixed Automated Spray Technology (FAST) remotely sense the potential of frost or ice formation on pavement considering atmospheric and pavement data from RWIS or an Environmental Sensor System (ESS) and apply anti-icers in a timely manner. A complete FAST system includes a spray subsystem that delivers the anti-icing chemical onto the road surface and a control subsystem that triggers the spraying action (Clear Roads, 2015).

In Micro-FAST systems are similar but de-icing chemicals are applied as a fine, invisible and dense stream at the crown of the road. Micro-FAST strips cover up to 1 km (2 lane) Micro-FAST has been installed in four states: Pennsylvania (2005), Vermont/New Hampshire (2006), Montana (2006) and Alaska (2006).

Ye, Wu, el Ferradi, & Shi (2013) undertook a literature review and agency surveys on the state of the practice of FAST systems. Experience with FAST systems in North America and Europe has revealed a mixed picture. On the one hand, several studies have indicated reductions in mobile operation costs and significant reductions in crash frequency, resulting in favourable benefit-cost ratios. On the other hand, there have been a variety of problems related to activation frequency, system maintenance and training. Installing a FAST system is complex and the challenges are often site-specific. However, the evaluations cited show that FAST systems can be cost-beneficial if their locations are carefully chosen and if the system is supported with reliable environmental sensors. In Ontario Canada, the Ministry of Transportation currently operates eight bridge FAST systems.

While safety has been improved, there is limited data on the material reduction from using the FAST system. The costs of anti-icing/de-icing materials are reported to be less by all road authorities using FASTs, but no specific information is provided. Several road authorities including MTO uses potassium acetate in their systems, which would eliminate chlorides.

### *6.6.3 OPPORTUNITY FOR IMPROVEMENT*

Table 6.16 provides a summary of equipment opportunities for KNP.

Table 6.16 Equipment opportunities for improvement

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Equip all spreaders with electronic spreader controls that can be accurately calibrated, regulated to ground speed with reporting capabilities to better track route times and salt application locations, and generate salt-use data in order to optimise salt | Salt Management Guide (TAC, 2013): Performance Indicators and National Targets for Environmental Management of Road Salts (ECCC, 2019): Guidelines on Snow Disposal and De-icing Operations in Ontario (MOECC, 2011) | Groundspeed oriented electronic controllers on salt spreaders help to ensure that salt is applied at the proper rate regardless of the speed of the truck being used to spread the salt, and that salt stops discharging when the truck is stopped. Adoption and use of this and AVL/GPS technologies are expected to increase and become a core practice for all organisations.<br>Impact: High | Additional costs of equipment. Additional technical expertise needed in both using new equipment and integrating it into maintenance practices | Equip all spreaders with electronic spreader controls Schmidt Stratos Salt Spreaders are used on the Snowy Mtn Hwy, Kosciusko Road and Alpine Way. |
| Use AVL/GPS technologies with reporting capabilities to better track route times and salt application locations. | Salt Management Guide (TAC, 2013) Synthesis on Global Positioning Systems/Automatic Vehicle Location Equipment Used for Winter Maintenance (Potter, Gallagher, & Bayer, 2016) | | | |
| All spreaders are calibrated at least at the start of each season and when repaired as per manufacturer's instruction including using actual volume testing. | Salt Management Guide (TAC, 2013) | Correctly calibrated spreaders are essential for being able to apply the material at the selected application rate, avoiding overapplication.<br>Impact: High | Additional costs for calibration. In-house expertise is needed or get outside expertise must be obtained. | All spreaders should be calibrated preseason, and after a major repair. |

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Other sensors could be added to spreaders, such as:<br>— on-board freezing point and ice-presence<br>— salinity/residual chloride | Vehicle-Based Technologies for Winter Maintenance: The State of the Practice (Xianming, et al., 2006) | Allows for more accurate application rates. Install sensors to provide information to drivers and/or can be integrated to automatic spreader controls to apply the right amount of chemicals in the right place.<br>Impact: Moderate to High | Vehicle based sensors have not been well-established, or widely deployed for field use. While studies suggest that they are generally reliable, implementation issues (such as need to clean the sensor heads regularly) as still under development. | Schmidt Stratos ThermoLogic dosing system monitors road surface temperature and could be evaluated. |
| Mobile Data Collector (MDC) An MDC is a controller in combo units that receives input from the operator, spreader controller, GPS and plough blade sensors. Weather forecasting and chemical application recommendations are then provided back to the controller using a Maintenance Decision Support System (MDSS), which includes local and regional weather radar information. | Vehicle-Based Technologies for Winter Maintenance: The State of the Practice (Xianming, et al., 2006) | Having the most current information on road and weather conditions improve the overall efficiency of our operation, thus, reduces the amount of applied materials, and decrease overall costs.<br>Impact: Moderate | Costs, user acceptance, and need for advanced training have been identified as barriers. Integration is critical for communications, user interface, and hardware/software expandability and compatibility. | Should be considered in combination with MDSS. |
| Consider specialised ploughs and plough blades to improve removal of snow and ice such as flexible cutting edge placed in front that adjusts to the contours of the roadway. | Salt Management Guide (TAC, 2013) | More effective removal of snow and ice reduce the need for de-icing chemicals.<br>Impact: Moderate | Costs, durability, and need for training have been identified as barriers. | Consider evaluating different blades |

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Fixed Automated Spray Technology (FAST) are stand-alone system that automatically sprays an anti-icing chemical onto the road surface. It remotely senses the potential of frost or ice formation on pavement via atmospheric and pavement data from RWIS or an Environmental Sensor System (ESS). | Salt Management Guide (TAC, 2013) | Localized application (such as bridges) but users report a reduction in chemical application at these locations, especially effective if non-chloride anti-icers are used. Can be considered for SVAs. However, all agency reports a positive Benefit/Cost when used in appropriate locations.<br>Impact: Moderate | Costs and reliability (need for maintenance) have been identified as barriers. | Consider evaluating FAST systems for select sensitive watercourses. |

## 6.7 MONITORING AND REPORTING

### 6.7.1 *OBJECTIVE*

To review winter maintenance activities at various times to monitor and gauge the effectiveness of actions to optimise salt use and reduce salt loss and provide direction for continuous improvement.

### 6.7.2 *RATIONALE*

To optimise salt use, monitoring and assessment of salt applications within an event, post-event and post-season should be considered. Many agencies have asked the question: “How do we determine if optimal salt use is being achieved each season, each storm, and each crew-shift?”. Optimal salt use depends on the Level of Service (LOS), the characteristics of the event and the equipment and staffing available. Road authorities and researches have had many approaches to monitoring salt use and comparing use between road authorities, benchmarks, seasons, storms and routes/shifts, as well as overall salt loadings to the environment. Making accurate comparisons is very challenging. Each weather event and season is different because of the numerous variables and antecedent conditions. This is further complicated by differences the types and quality of data collected by road authorities.

This section provides a review of how road authorities and researchers have monitored salt use and comparing use between:

- during an event
- post-event, seasons
- overall salt use and loadings.

### 6.7.3 *DURING AN EVENT*

Because of the demand on resources during events, it is difficult to find the time and resources to undertake salt optimization reviews. However, there are some opportunities:

1. patrolling
2. use sensors to assist in monitoring treatment performance
3. shift summary.

#### 6.7.3.1 PATROLLING

Patrolling is the review of the condition of a road by a municipality. For winter maintenance, the municipality determines representative roads and the intervals by which they are patrolled. Typically, municipalities patrol representative roads daily if weather monitoring indicates that there is a substantial probability of snow accumulation or ice formation. Patrolling provides important but qualitative information on the performance of the operations with respect to meeting the LOS and overall condition of the roads.

The information noted includes:

- Date and Time
- Weather conditions (air temperature, snow, freezing rain, etc.)
- Road Surface / Bicycle Lanes / Sidewalk Condition (temperature, bare & dry, partially ice covered, snow covered drifting black ice etc.)

This information is used to direct actions for winter maintenance.

#### 6.7.3.2 USE SENSORS TO ASSIST IN MONITORING TREATMENT RESULTS

As discussed in previous sections, equipment-mounted, RWIS integrated, or stand-alone sensors can be used to monitor the result of salt application (e.g., residual chloride, road surface traction / friction). With the use of sensors, the amount of salt used can be optimised during some events.

#### 6.7.3.3 SHIFT SUMMARY

The City of Kitchener in Ontario Canada has an innovative approach for drivers' to immediately update supervisors on status at end of shift. They use a mobile survey app (formally called Polldaddy now called CrowdSingal). At the end of shift, drivers complete several questions at the end of shift to update supervisors on status, and includes information on weather information, material use, road conditions. The app aggregates and presents the data, allowing outliers to be identified.

### *6.7.4 REVIEWS DURING A SEASON*

The leading practice is to periodically compare salt usage by route to identify and address any inconsistencies.

As, chain bay requirement time is key performance indicator for winter operations in KNP, the achievement of set levels in the LOS (as discussed in section 6.2) can be review post-event with achievement and salt use (as well as other operational metrics such as resources used and techniques applied).

All agencies have GPS/AVL units and gather the data and compile in a central data source. The Region of Waterloo, Canada, for example, has developed an Excel workbook to automate the GPS/AVL data checking and review. The data review is conducted once a week to look for deviations from the other equipment and patterns to identify units that out of calibrations, drivers who are not adhering to the application rules, etc. Road Authorities (such as Iowa Department of Transportation) have had this same idea and taken it a step further with the development of a "Salt Dashboard".

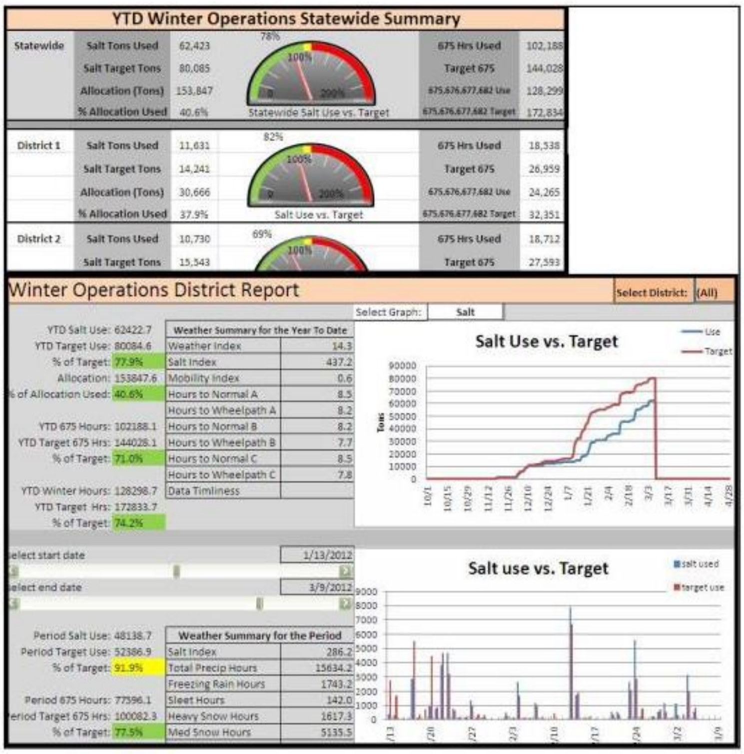
A generic term used for management application, a Salt Dashboard collects and analyses data and provide a "dashboard" of information to managers with respect to salt usage. In the US, the Iowa Department of Transportation (DOT) has been using and refining management dashboards since 2011. Since that time, they have developed five dashboard innovations to assist managers in decision making, one is called salt salt/labour management.

Iowa DOT developed this dashboard tool to better track salt use and to see how salt supply is being utilized for each region (called garage) on an ongoing basis. This has led to measurable reductions in Iowa DOT's state-wide salt use over the years (FHWA, 2019).

Iowa DOT developed decision support tool (see Table 6.7) relating weather observations to a suggested salt application rates based on the different service levels. This tool was used to create a program that estimates an expected salt or labour amount used in a recent storm for each garage based on its responsibility-area characteristics and its local weather information. Iowa DOT has found this to be a good benchmark of comparison for their actual use. These comparisons flow into an online interactive reporting system available to Iowa DOT maintenance supervisors, allowing them to more closely monitor salt use, staff time and "Time to Normal" measurements.

Figure 6.2 shows some components of these dashboards:

- state, district, and garage-level displays
- colour-coded dials indicating actual salt usage versus the targeted usage
- interactive graphs and charts to view area and time-period of choice
- salt purchasing status
- comparisons to estimated 'target' use, based on storm weather information
- comparisons to budget availability
- daily, Pay Period, or Year-to-Date summaries.




*Source: FHWA, 2019*

Figure 6.2 Iowa DOT salt use dashboard

### 6.7.5 SEASONAL REVIEW AND MAKING COMPARISONS

To review salt use seasonally, the following are leading practices:

1. set standard performance metrics
2. develop Winter Severity Index
3. set and implement a procedure to:
   a. retrieve weather and equipment generated data on a year-end basis
   b. analyse weather conditions, and rationale for treatment (storm decision), total salt usage goals, LOS achieve by events, seasons, road authorities, etc.
4. track your material use. (loader/scales) to confirm use
5. year-end reconciliation of materials used for salt, abrasives and liquid to identify losses
6. consider ensuring that the year-end review consists of a total inventory of salt use including sidewalks, driveways, and parking lots.

### *SET PERFORMANCE METRICS*

Metrics for salt optimization can include:

- comparisons to set targets for
  - salt use per event, based on weather information,
  - total salt use per road class, season or agency, year-over-year
  - salt loadings per area (such as SVA), and
  - combinations of the above
- time taken to reach end condition (as specified in LOS policy)
- bare pavement regain time: time between salt application and the point where 80% of the pavement is bare.
- time taken to recover normal traffic speed
- measured friction levels.

### *DEVELOP WINTER SEVERITY INDEX*

To evaluate salt use between seasons, the variability of winter events and maintenance practices needs to be addressed. To account for and normalizes the variables for consistency, a winter severity index (WSI) is used. A WSI (also known as severity index, storm index, or salt index) is used to quantify the relationship between winter weather severity and roadway conditions, safety or road salt use. It can be calculated in many ways, depending upon desired results and available data. The Transportation Association of Canada undertook a study of developing a Winter Severity Indicator models (Suggett, Hadayeghi, Mills, Andrey, & Leach, 2007). This looked at a model to measure the relative impact of winter weather on winter road maintenance operations using historical meteorological and/or Road Weather Information System (RWIS) data. University of Waterloo, in 2017, presented a methodology to create a province wide WSI and describes how a WSI can be developed for road authorities (Matthews, Andrey, Minokhin, & Perchanok, 2017).

Although developed to normalize maintenance activities and not salt use specifically, the following WSI is an example of a WSI that can be used to characterize the winter weather for any given place and time using a single number. Days in the winter maintenance season are assigned a winter severity score, as per Table 6.17. There are five weather components relevant to winter maintenance. Each component has one or more thresholds to classify the day's weather and determine the severity score. For example, a day with daily snowfall accumulations between 1.91 to 4.9 cm, would have a severity score of 1.0. The severity score for a day would be reduced by -45% if the average mean temperature is >-1 °C for the 6-day period centred on the day in question, which is referred to as the "Adjustment factor for warm weather".

Table 6.17 Summary of Weather Severity Scores for the Ontario for Highway Maintenance WSA (after Matthews, Andrey, Minokhin, & Perchanok, 2017)

| WEATHER COMPONENT | CONDITIONS | SEVERITY SCORE* |
|---|---|---|
| 1. Snowfall | Low amount of snow (daily accumulation): (0.2 to 1.9 cm) | 0.5 |
| | Moderate amount of snow: (1.91 to 4.9 cm) | 1.0 |
| | High amount of snow: (> 4.91 cm) | 1.3 |
| 2 Surface ice warning** | Low: < 0.2 cm daily snowfall, and between 25% and 70% of road surface, ice warnings | 0.3 |
| | High: < 0.2 cm daily snowfall, and more than 70% of road surface ice warnings | 0.8 |
| 3 Rainfall with low temperatures | Daily snowfall < 0.2 cm, Conditions for ice warnings not met<br>Daily rainfall ≥ 0.4 mm<br>Min temp < -0.2°C | 0.4 |

| WEATHER COMPONENT | CONDITIONS | SEVERITY SCORE* |
|---|---|---|
| 4 Series of cold days | Daily precipitation < 0.2 mm<br>Conditions for ice warnings not met<br>Conditions for rainfall with low temperatures not met<br>Conditions for blowing snow not met<br>Max temp in previous three days < -12°C | 0.5 |
| 5 Blowing snow | Daily precipitation < 0.2 mm<br>Conditions for ice warnings not met<br>Conditions for rainfall with low temperatures<br>Wind speeds ≥ 15 km/h, Snowfall accumulations of previous three days ≥ 5 cm | 0.5 |
| **Adjustment factor for warm weather*: the severity score is reduced by -45% if the average mean temperature is >-1 °C for the 6-day period centred on the day being scored<br>** The "surface ice warning" component is the total daily count of the five RWIS ice warnings ("Black ice warning", "Ice warning", "Ice watch", "Snow/ice warning", and "Snow/ice watch") as a percentage of all valid surface readings. | | |

*TRACK ACTUAL MATERIAL USE*

Loader-Mounted electronic weighing equipment or truck scale, and liquid meters are all methods to confirm the amount of material loaded. This can be used to confirm amounts spread on the specific route and can help look for overuse, deficiencies, calibration errors etc.

### 6.7.6 OPPORTUNITIES FOR IMPROVEMENT

Table 6.18 provides a summary of monitoring and reporting opportunities for KNP.

Table 6.18 Monitoring and reporting opportunities for improvement

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Set and implement a procedure to retrieve and review weather and equipment generated data on an event and year-end basis | Salt Management Guide (TAC, 2013) | Review of weather, environmental conditions (like surface temperature), and winter maintenance activities, would support and improve snow and ice control decisions, leading to efficient use of salt.<br>Impact: High | Staff resources, trained personnel's availability to undertake analysis. | Establish and implement a data review procedure. |

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Develop standard metrics to measures road salt use | Snow Removal Performance Metrics (Xu, et al., 2017) | Standard performance measures would help all agencies develop and implement a consistent and comparable performance review program. Measures should be developed at the senior management (strategic), at the supervisor (program) and front-line staff (service) levels. Annual measures should be compared to the previous year's results or to some other benchmark set by the municipality.<br>Impact: High to Moderate | Costs to have staff work to develop standard metrics. | As, chain bay requirement time is key performance indicator, the achievement of set levels should be part of a post-event review. A simple index can be created against which the daily performance of the TfNSW winter operations could be measured i.e. when chain bays were lifted, so that performance by icing event (and by season) can be achieved. |
| Develop Weather Severity Index to compare road salt use, season to season. | Snow Removal Performance Metrics (Xu, et al., 2017)<br>Also<br>Suggett, Hadayeghi, Mills, Andrey, & Leach, (2007) | To allow the evaluation of salt use between seasons, the variability of winter events and maintenance practices needs to be addressed by developing a winter severity indexes (WSI).<br>Impact: Moderate | Costs to have staff work to develop standard metrics. | |
| Opportunity: Kitchener innovative use of a mobile app for drivers' to immediately update supervisors on status at end of shift. | | The mobile survey app (formally called Polldaddy now called CrowdSingal) is relatively cheaper and relatively customizable. At the end of shift, drivers complete several questions at the end of shift to update supervisors on status, and includes information on weather information, material use, road conditions. The app aggregates and presents the data, allowing outliers to be identified. | None | |

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Periodically compare salt usage by route to identify and address any inconsistencies | Salt Management Guide (TAC, 2013) | Periodic in season reviews of material use, application rates selected, etc. can deviations from the other equipment and patterns to identify units that out of calibrations, drivers who are not adhering to the application rules, etc.<br>A generic term used for management application, a Salt Dashboard collects and analyses data and provide a "dashboard" of information to managers with respect to salt usage (e.g., Iowa DOT).<br>Impact: High to Moderate | Integrating technologies from various manufacturers into a cohesive, smooth operational system is challenging. Few turnkey options exist and integrating sensor, camera, data collection and GPS presents several technical challenges. | Consider implementation of a salt management dashboard. |
| Set standard performance metrics | Transportation Association of Canada (2003); Cui, Fay, and Shi (2015) | Reviewing key performance indicators allows refinement of salt management practices.<br>Impact: Moderate | None | Review salt management successes, standard metrics (key performance indicators) need to be established for and targets established. These could include salt use per event, total salt use per road class, salt loadings per area (such as SVA), time taken to reach end condition (as specified in LOS policy). |
| Track your material use: (loader / scales) to confirm use | Transportation Association of Canada (2003) | Loader-Mounted electronic weighing equipment or truck scale, and liquid meters are all methods to confirm the amount of material loaded. This can be used to confirm amounts spread on the specific route and can help look for overuse, deficiencies, calibration errors etc.<br>Impact: High to Moderate | Cost of additional equipment. | Recommend installing loader-mounted electronic weighing equipment. Suggest investigating loaders systems whereby amount of material loaded is metered out based on amount needed based on storm response decisions. |

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Only load spreaders with enough salt to complete the route | Transportation Association of Canada (2003) | Only loading the needed salt onto spreaders avoids the temptation to over-salt routes.<br>Impact: High | None | Recommend using weighing equipment to load only enough salt for the route. |
| Conduct a year-end review | Transportation Association of Canada (2003) | Lessons can be learned from a review of winter maintenance operation. Improvements in policy, operations, and even in equipment, can be identified and implemented through a post-season assessment of the practices, procedures and treatments used.<br>Impact: Low to Moderate | None | Undertake post-season review. It is important that all levels of the organisation be involved in these evaluations from senior managers, to front line supervisors, to equipment operators. As part of the post-season assessment, staff would need to compare this year's results using a series of performance measures. |
| Year-end reconciliation of materials used for salt, abrasives and liquid to identify losses | Transportation Association of Canada (2003) | Year-end reconciliations are important as they allow road authorities to determine loss of salt from storage facilities, and inconsistencies between actual total material use and total materials use reported. | None | Undertake year-end material reconciliations. This should include |

## 6.8 MATERIAL STORAGE AND HANDLING

### *6.8.1 OBJECTIVE*

To ensure that salt and the salt in blended abrasives do not dissolve into water (such as rain or stormwater) and leave the site into the environment during delivery and storage.

### *6.8.2 RATIONALE*

If not properly stored, snow and ice control chemicals can be lost to the environment in large quantities because of exposure to precipitation and wind. This loss can be costly due to the actual loss of salt and can lead to environmental damage. Many road organisations have incurred large costs to clean up salt contamination from maintenance yards where materials have been poorly stored and handled.

There can also be direct environmental damage to watercourses, wetlands, and vegetation as a result of salt contaminated drainage from maintenance yards. As well, salt washed off equipment can contaminate the surface water, soil or groundwater.

Leading practices include:

- storing road salt in permanent storage structures that:
  - have a permanent roof
  - have impermeable pads/impervious liners
  - are dyked to prevent the seepage of salt leachate
  - allow all road salt delivery and handling to occur inside
- storing treated (with road salt) abrasives in permanent storage structures that:
  - have a permanent roof
  - have impermeable pads/impervious liners
  - are dyked to prevent the seepage of salt leachate
  - allow blending of abrasives with salt to occur inside
- storing liquid road salt in tanks that:
  - have an impervious bases with spill protection
  - have barriers to prevent vehicle collisions
  - have leak and spill prevention measures, alarm system and automatic valves
- having documented standard operating procedure (good housekeeping), including:
  - recording deliveries and determining end-of-season residuals and conducting a year-end reconciliation to determine any losses
  - having rules (such as weather conditions and delivery times) for delivery of road salt and blending of abrasives to minimise salt loss
  - having a response plan for road and yard spills of de-icing/anti-icing materials that includes running mock emergencies to test response
  - having surface water and groundwater monitoring programs
- properly containing and managing wash water from vehicles (especially spreaders)
- reducing existing salt contamination at the site by:
  - undertaking an assessment of the site (such as electromagnetic survey, well survey, and monitoring wells) to determine salt impacts, and undertake remediation of salt-impacted soils and groundwater as needed
  - decommissioning wells that are no longer needed or are not in use
- new salt storage sites are located outside of and include a separation distance from SVAs
- accurately measure and recording the amount of materials (solids and liquids) loaded to and unloaded from spreaders.

For the latter, loading extra material onto a spreader can lead to overloading or the temptation to over apply the salt. Overloaded trucks also contribute to contamination in the area of the salt storage facilities.

- Loaders with electronic scale control systems. Some of these devices can measure a predetermined load size for the scheduled route (length of route X application rate + a limited contingency amount for bridge decks, intersections, etc.). Models are available that record while the loader in motion so operation is not impeded.
- Weighing the trucks as they enter and leave the maintenance yard is one way of determining the material loaded and the resulting spread rate for the serviced route. This function can be automated with a weigh-in-motion pad that tracks the equipment movement and can serve to reconcile the data from the spreader controller and other documentation.
- Pump meters should be used to measure all brine/liquid.

- Have standard operating procedure for delivery of road salt, abrasive and liquid delivering, and handling be available on site for reference, which includes weather conditions to accept delivery, cleaning up of spilled materials.
- Consider running mock emergencies to test response to spills.
- Consider initiating surface water and groundwater monitoring programs to detect chloride losses. Surrogate parameters (such as conductivity) can be used to reduce monitoring costs.

### *6.8.3 OPPORTUNITIES FOR IMPROVEMENT*

Table 6.19 provides a summary of materials storage and handling opportunities for KNP.

Table 6.19 Materials storage and handling opportunities for improvement.

| LEADING PRACTICE | REFERENCES | RATIONALE AND IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITIES FOR IMPROVEMENT |
|---|---|---|---|---|
| Apply best management practices to design and operation of road maintenance yards. | Risk Management Measures Catalogue (2019);<br>Performance indicators and national targets for environmental management of road salts (ECCC, 2019);<br>Guidelines on Snow Disposal and De-icing Operations in Ontario (MOECC, 2011);<br>Salt Management Guide (TAC, 2013) | Improved operational standards for road maintenance yards can enhance their environment design and operation, and thereby prevent off-site environmental impacts.<br>Impact: High Effectiveness | None | Apply best practices |
| De-icing chemicals or sand/salt stockpiles should always be protected from precipitation or surface runoff. Road salts should always be stored under a permanent roof and on impermeable pads | | Research shows that loss of salt from storage and handling can be a significant source to the environment.<br>Use impervious liners for salt storage facilities to minimise loss of sodium chloride solution to the groundwater system.<br>Impact: High Effectiveness | Cost | |
| Brine tanks should be on impervious bases with spill protection and barriers to prevent vehicle collisions | | Leak and spill prevention measures and equipment include alarm system & automatic valves to prevent brine and and/other chemicals storage tanks from being overfilled and the containment and collection of spills and storm runoff.<br>Impact: High Effectiveness | Costs for leak and spill prevention measures (e.g., secondary containment) and alarms | |
| Use leak and spill prevention measures and equipment: alarm system and automatic valves. | | | | |

| LEADING PRACTICE | REFERENCES | RATIONALE AND IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITIES FOR IMPROVEMENT |
|---|---|---|---|---|
| **Handling and Good Housekeeping** | | | | |
| Solid materials unloaded outside should be brought under cover as soon as possible following delivery, with delivery in favourable weather | As above | Research shows that loss of salt from storage and handling can be a significant source to the environment.<br>Impact: High Effectiveness | None | Apply best practices |
| Good Housekeeping standard operating procedures should be written that include: Material delivery and mixing (abrasives), storage, spreader loading / unloading, liquid storage and handling, vehicle washing, and training. | | | | |
| Record delivery records and end-of-season residuals for salt, sand and liquid to determine any losses and conduct a year-end reconciliation of bulk material use been done for salt, sand and liquid. | | To determine losses, a year-end reconciliation of bulk material use should be done for salt, sand and liquid.<br>Impact High Effectiveness | None | |
| **Spills** | | | | |
| Have response plan for road and yard spills of de-icing / anti-icing materials | As above | Spills can be a significant source of salt to the environment.<br>Impact: Low Effectiveness | None | Apply best practices |
| Run mock emergencies to test response | | Spills can be a significant source of salt to the environment. | | |
| **New Facilities** | | | | |
| Building allows all salt delivery and handling (including blending of abrasives) to occur inside. | As above | Spills from handling of salt are a significant source of salt to the environment.<br>Impact: High Effectiveness | Cost of large structure, land and design. | Apply best practices |
| Setbacks for land application: separation distance from waterways. | | A separation between storage facility and waterways would reduce the risk of contamination reaching source water.<br>Impact: High Effectiveness | | |

| LEADING PRACTICE | REFERENCES | RATIONALE AND IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITIES FOR IMPROVEMENT |
|---|---|---|---|---|
| Runoff Collection and Diversion Systems. | As above | Collection, storage and diversion systems isolate runoff from on-site contaminant sources, preventing pollutants from contaminating storm water runoff and water sources.<br>Impact: High Effectiveness | | Apply best practices |
| Wash water -Vehicles (especially spreaders) should be washed at a location where the wash water can be properly diluted, disposed, or recycled/reused. | | Wash water should be disposed of to sewers (sanitary) and would need to conform to system requirements. Vehicle wash water should not be allowed into the storm water system as they are directly connected to waterways.<br>Impact: Low Effectiveness | | |

### 6.8.4 EXCESS SNOW REMOVAL, STORAGE AND DISPOSAL

For locations where snow storage is not adequate, snow accumulations need to be removed for safety (such as re-establishing sightlines). The most cost effective and easily mobilized snow removal operation is using a loader to fill conventional dump truck with snow, which is hauled away for disposal. Excess snow handing has been evolving from dumping it into water bodies, to dumping it on convenient flat areas to melt, to creating engineered SSDFs. However, it is important to remember that engineered meltwater systems at SSDS direct and typically delay and dilute the chloride released, but do not remove it. Snow melters have also been used to reduce snow accumulations. Mobile melters can be located on-site (e.g., downtown) or at nearby locations (e.g., large parking lot) or more permanent melters are installed at a SSDF.

Snow storage and disposal facilities (SSDF) can contribute chloride to the local area. In 2007, researchers found that a facility in Richmond Hill (Ontario, Canada) had 16 tonnes of chloride pass though it with the highest concentrations of chloride were present in early melt, with 50% of the chloride released within the first 30% of the meltwater (Exall, Rochfort, Marsalek, & Kydd, 2011).

All existing snow disposal sites should be evaluated with respect to groundwater and surface water sensitivity, and the quantity of snow which can be stock-piled based on estimated runoff rates and quality, the dilution capacity of the watercourse to which the melt will discharge, and downstream water uses.

At older SSDFs, existing salt contamination at the site should be assessed (such as electromagnetic survey, well survey, and monitoring wells) to determine salt impacts, and undertake remediation of salt-impacted soils and groundwater as needed. Also, all wells that are no longer needed or are not in use should be decommissioned. A ground and surface water monitoring should become part of routine operations.

### 6.8.5 OPPORTUNITIES FOR IMPROVEMENT

Table 6.20 provides a summary of snow removal, storage and disposal opportunities for KNP.

Table 6.20 Excess snow removal, storage and disposal opportunities for improvement.

| LEADING PRACTICE | REFERENCES | RATIONALE AND IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Direct disposal of snow to watercourses or ice-covered lakes and rivers shall be eliminated wherever possible. | Guidelines on Snow Disposal and De-icing Operations in Ontario (MOECC, 2011) | Avoid direct impacts. No salt use reduction. | None | Fully evaluate all alternatives to direct disposal before considering this option. Disposal on an appropriate land sites is considered in most cases the best solution. |
| The snow storage site should be remote from surface watercourses with very low chance of flooding. | | Avoid direct impacts. No salt use reduction. | Cost of an engineered snow storage and disposal site can be relatively high. | Recommend comprehensive planning for new facilities, which considers appropriate locations and design. |
| The quantity of snow which can be stockpiled at a particular site should be assessed in relation to estimated runoff rates and quality, the dilution capacity of the watercourse to which the melt will discharge, and downstream water uses. | | | | |
| Use of ground water immediately down-gradient of a possible site should be determined as part of the site evaluation process. | | Avoid direct impacts. No salt use reduction. | | Hydrogeologic investigations should be conducted to determine the potential for ground water pollution from contaminants in the snow. Wherever possible, land disposal sites should be located in areas where an impervious stratum will prevent the migration of soluble contaminants to the ground water aquifer of in areas of ground water outflow. |

| LEADING PRACTICE | REFERENCES | RATIONALE AND IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| Sampling and Monitoring Programs (Surface Water and Groundwater). | | These provide evidence of contamination caused by malfunctions, deterioration, etc., Impact: Medium Effectiveness | | Surface water monitoring program should be incorporated into any existing or future water quality monitoring program, it provides evidence of contamination caused by malfunctions, deterioration, operator error, leaks, spills or runoff. |

For additional resources on snow disposal guidelines please consider the following resources:

- *Snow Disposal Guidelines for the Province of Alberta* (1994): //open.alberta.ca/publications/0778513815
- *Environment and Climate Change Canada's Synthesis of Practices Road Salt Use Management: No. 8 Snow Storage and Disposal* (2013): https://www.tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/roadsalt-8.pdf
- *The Ministry of Environment and Climate Change's Guideline for Snow Disposal and De-icing Operations in Ontario*: //www.ontario.ca/page/guidelines-snow-disposal-and-de-icing-operations-ontario
- *Transport Association of Canada's Town of Richmond Hill Snow Storage Facility and Performance Evaluation Study* (2008): http://conf.tac-atc.ca/english/resourcecentre/readingroom/conference/conf2010/docs/a1/richmond.pdf

## 6.9 TRAINING

### 6.9.1 OBJECTIVE

To ensure that all in-house and sub-contracted staff, including council, management, supervisors, patrollers and operators, have appropriate awareness of training in salt management practices.

### 6.9.2 RATIONALE

To achieve effective implementation of a salt management program, those people charged with delivering the snow and ice control program must understand the rationale behind the measures being implemented as well as what is expected of them. This can only come through a thorough education / training program, including annual refreshers.

For salt management improvements, effective training programs must demonstrate the value of new procedures and ensure that personnel are competent in delivering new programs. This can be a significant shift for long-time winter snow and ice control operators. IN the US, the Minnesota Department of Transportation developed a performance-based program for reducing application rates, called "Salt Solutions," that provided operators with tools and systems for making better application rate decisions. Application rates dropped when the entire organisation actively supported the operators in making better decisions and the agency took the time to measure and reward improved performance. (National Academies of Sciences, Engineering, and Medicine, 2009).

### 6.9.3 OPPORTUNITIES FOR IMPROVEMENT

Look to on-line training from North American sources such as Snow Fighters school by OPGRA None.

Table 6.21 provides a summary of training opportunities for KNP.

Table 6.21 Training opportunities for improvement

| LEADING PRACTICE | REFERENCES | RATIONALE AND IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITY FOR IMPROVEMENT |
|---|---|---|---|---|
| The organisation must promote a culture that supports learning.<br>The organisation needs to identify training needs as they relate to the SMP and a training program should be planned, organized and scheduled.<br>Using expert instruction to ensure that the information is factual, topical, current, and relevant. | Syntheses of Best Practices Road Salt Management: 2.0 – TRAINING | Road authorities should have a comprehensive training program that demonstrates the purpose and value of new procedures and ensures that personnel are competent to carry out their duties.<br>Impact: High Effectiveness | Access to trainers, training materials, and costs for staff | TfNSW should provide yearly winter operations training for all staff involved in the delivery of winter services. |
| Confirm that the desired learning transfer has occurred/effectiveness of the training. | | | | It is recommended that TfNSW provide mid-season reviews with winter operations staff to confirm effectiveness of training. |

## 6.10 ENGAGEMENT

### 6.10.1 OBJECTIVE

To communicate effectively with the community and the media about the importance of road salt to maintaining safe roadways during the winter season and about what the agency is doing to improve salt management. To inform the community about the current level of service policy.

### 6.10.2 RATIONALE

An informed community and media are more likely to become effective partners in achieving the goals of the Salt management plan.

Successful salt management for winter road maintenance is about achieving a reduction in salt usage while maintaining the same level of safety for all travellers. It is important that the community is informed and educated on the benefits of salt management and on ways to reduce usage. Additionally, through raised awareness, it is likely that there would be greater acceptance for lowered LOS, where appropriate.

In Canada, the Region of Waterloo's "Curb the Salt" campaign, launched in 2014, focused on educating individuals about what they can do on private properties to reduce salt use while not compromising safety. Actions include avoiding applying excess salt and giving it time to work, as well as using alternatives like sand or non-clumping kitty litter to create traction (Region of Waterloo Water Services).

Region of Waterloo launched a campaign at the end of 2017, with the participation of several regionally- and privately-owned properties, on reducing salt use by closing portions of walkways and stairs (Weidner, 2017). Although not directly related to using less salt on roadways, a campaign like this can foster a shift in community perception and mindset towards responsible salt usage.

In the US, Vermont's Agency of Transportation developed a Snow and Ice Control Plan which prioritized level of service based on roadway classification, traffic volumes and truck traffic (Borst, 2015). The goal was to maintain "safe roads at safe speeds" as opposed to "bare roads" in an effort to maximize the use of limited state resources. Although the level of community engagement in this plan is uncertain, promoting awareness of salt reduction strategies while maintaining safety is key for community acceptance and support.

Several states, including Minnesota, Iowa and Wyoming, have adopted citizen reporting of winter road conditions as part of their strategy to improve winter road maintenance (Fiecke, 2015). The reporters, mainly truckers, either call in road conditions or update the local municipal service system, which improves the timeliness and detail of road condition data. Active community engagement like this would likely increase awareness and support for maximizing the use of resources and maintaining acceptable levels of service required for safe driving.

### 6.10.3 OPPORTUNITIES FOR IMPROVEMENT

Table 6.22 provides a summary of training opportunities for KNP.

Table 6.22 Summary of training opportunities for KNP

| LEADING PRACTICE | REFERENCES | IMPACT ON SALT USE REDUCTION | BARRIERS | OPPORTUNITIES FOR IMPROVEMENT |
|---|---|---|---|---|
| A communication plan for the Winter Maintenance that incudes salt management | Salt Management Guide (TAC, 2013) | An informed government, community and media are more likely to become effective partners in achieving the salt optimization goals, including any changes to LOS.<br>Impact: High | Sensitivity of road authorities in what is communicated and how to the community, including competing messaging and community being overwhelmed | Develop a communication strategy for winter maintenance the includes explaining the purpose of salt management |
| The community should be kept informed about the actions being taken by to manage road salt use and the Agency's winter maintenance program | | | | |

# 7 SALT MANAGEMENT POLICY

For agencies to optimise salt use and reduce salt loss, the senior management must commit to salt management. This typically takes the form of a policy that commits the agency to measurable improvements in its salt management practices. This is provided below.

Transport for New South Wales (TfNSW) and KNP operators commit to providing efficient and effective winter maintenance within the Kosciuszko National Park (KNP) and ski resort management units to ensure the safety of users of the roads in keeping with applicable law and accepted standards while striving to minimise adverse impacts of road salt to the environment.

This commitment would be met by meeting the following practices.

### *SALT MANAGEMENT PLAN*

**1** Develop and implement a Salt management plan that is consistent with exiting best practices, which includes an assessment of potential Salt Vulnerable Areas.

### *LEVEL OF SERVICE (LOS)*

**2** Develop a LOS for the KNP that clear defines what TfNSW would do with respect to winter maintenance. The LOS would include objectives for both during and after the storm event including timeframes and end conditions

**3** Consistently measure service delivered against the LOS to check against over-delivery.

### *WEATHER AND CONDITIONS INFORMATION AND ANALYSIS*

**4** Obtain 3 times per day a value-added Meteorological Service (VAMS) customized weather forecast.

**5** To determine road pavement temperatures, install infrared thermometers (IRT) on all ploughs, spreaders, combination units and support vehicles. IRT units would be calibrated as per manufactures instructions and a calibration record maintained.

**6** Follow developments with respect to Mobile Weather Information Systems (MWIS), Integrating Mobile Observations (IMO), road sensors, and thermal mapping to determine opportunities for use.

### *STORM RESPONSE AND DECISION SUPPORT*

**7** Create and implement a decision support tool with several road salt application rates to consistently analyse the various information (weather conditions, pavement temperature, equipment etc.) to come to optimal response decisions and road salt use.

### *ANTI-ICING AND DE-ICING MATERIALS*

**8** Widely implement anti-icing practices, specifically through the direct application of salt brine.

**9** Have ability to pre-wet road salt with brine before application for all routes, use 100% pre-treated materials, or a combination of the two.

**10** Develop and implement several application rates for liquids and solids for anti-icing and de-icing to better match road salt application to weather and road conditions.

### *EQUIPMENT*

**11** Equip all spreaders with electronic spreader controls and AVL/GPS technologies to ensure that salt is applied at the specified rate.

**12** Calibrate all spreaders pre-season, and after a major repair.

*MONITORING AND REPORTING*

**13** Set and implement a procedure to retrieve and review weather and equipment generated data on an event and year-end basis.

**14** Conduct reviews at the end of each winter event and at the end of the year to improve operations.

*MATERIAL STORAGE AND HANDLING*

**15** Use loader-mounted electronic weighing equipment or truck scale, and liquid meters to confirm the amount of material loaded.

**16** Only load spreaders with enough salt to complete the route.

**17** Store all road salts under a permanent roof and on impermeable pads.

**18** Store all brine tanks on impervious bases with spill and leak protection measures and barriers to prevent vehicle collisions

**19** Bring all road salt unloaded outside under cover as soon as possible following delivery, with delivery restricted to favourable weather.

**20** Develop and implement a Good Housekeeping standard operating procedure that includes material delivery and mixing (abrasives), storage, spreader loading / unloading, liquid storage and handling, vehicle washing, and training.

**21** Record delivery and end-of-season residuals for salt, sand and liquid to determine any losses during a year-end reconciliation of materials.

**22** Have response plan for road and yard spills of de-icing / anti-icing materials.

*TRAINING*

**23** Provide yearly, comprehensive winter operations training for all staff involved in the delivery of winter services.

**24** Provide mid-season reviews with winter operations staff to confirm effectiveness of training.

*ENGAGEMENT*

**25** Develop and implement a community communication strategy for winter maintenance the includes explaining the purpose of road salt management.

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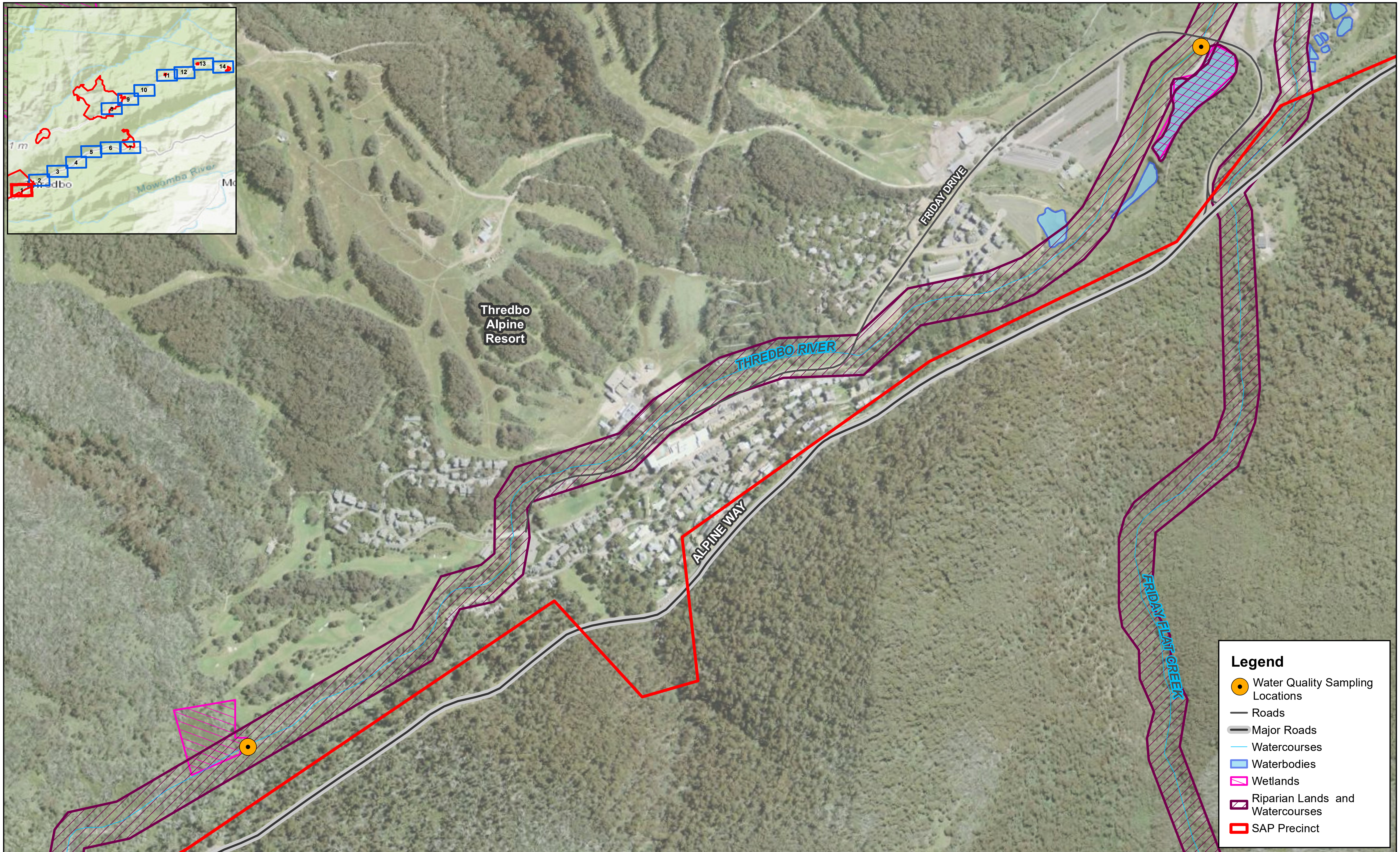
# APPENDIX A

SALT VULNERABLE AREAS

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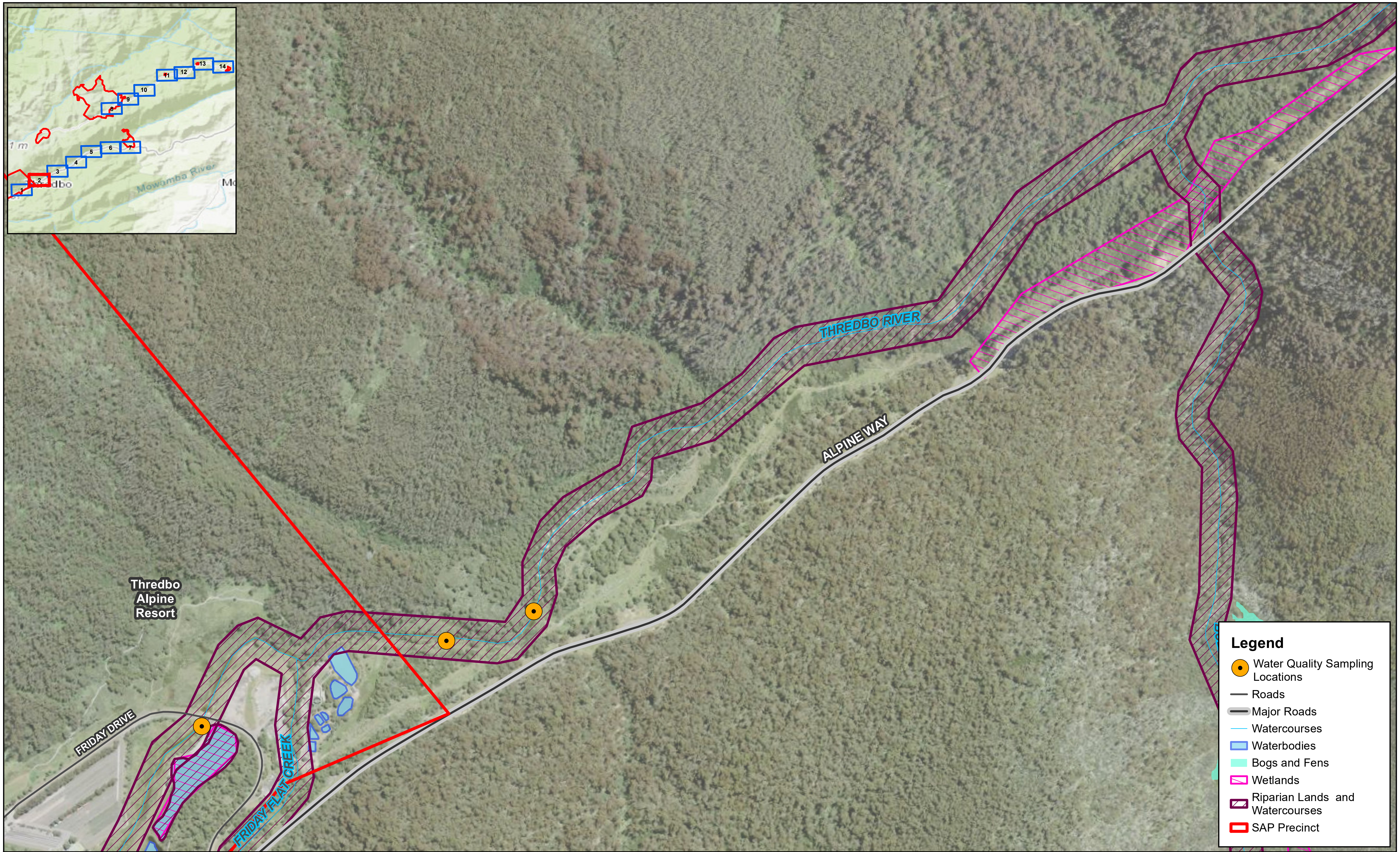


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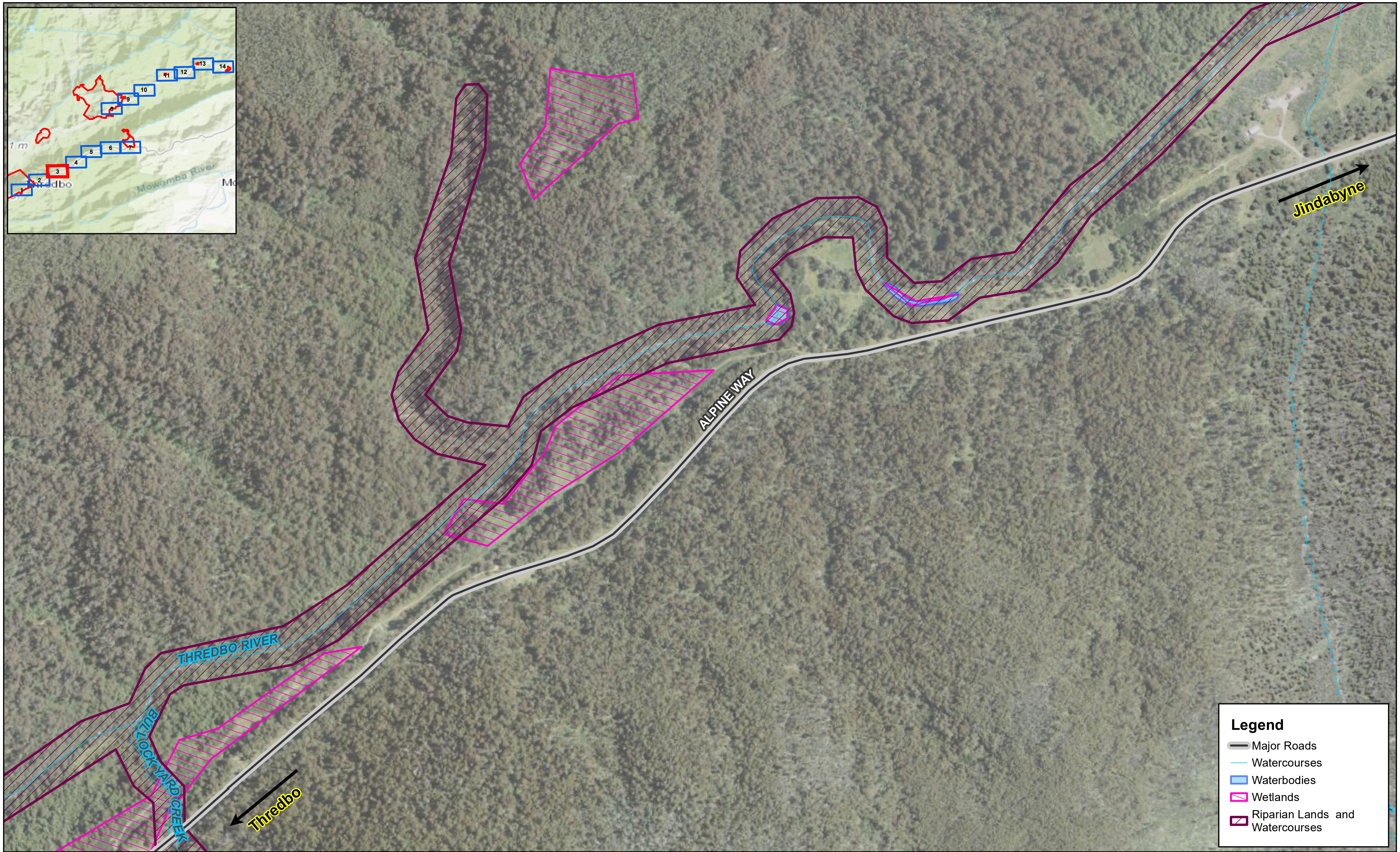


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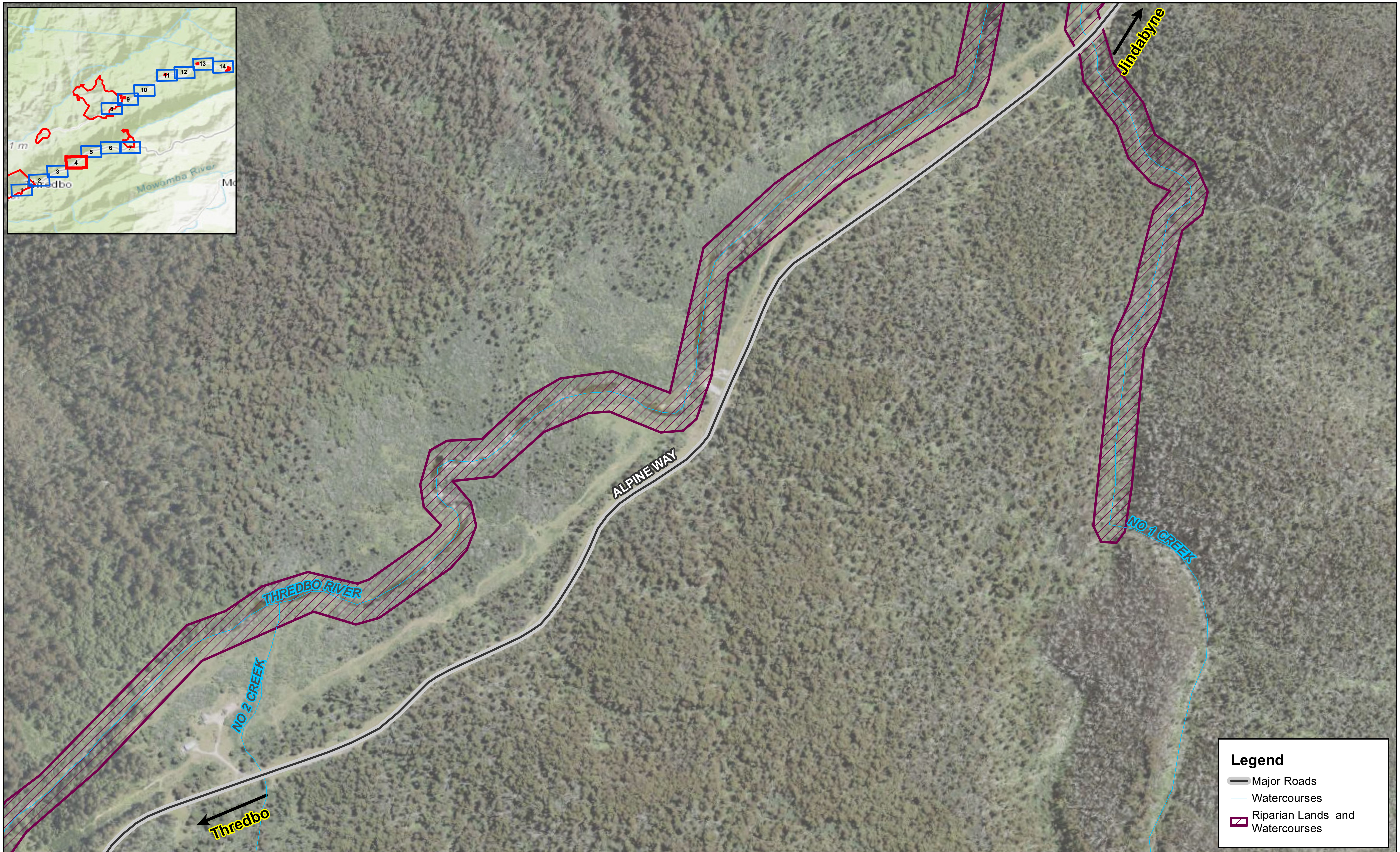


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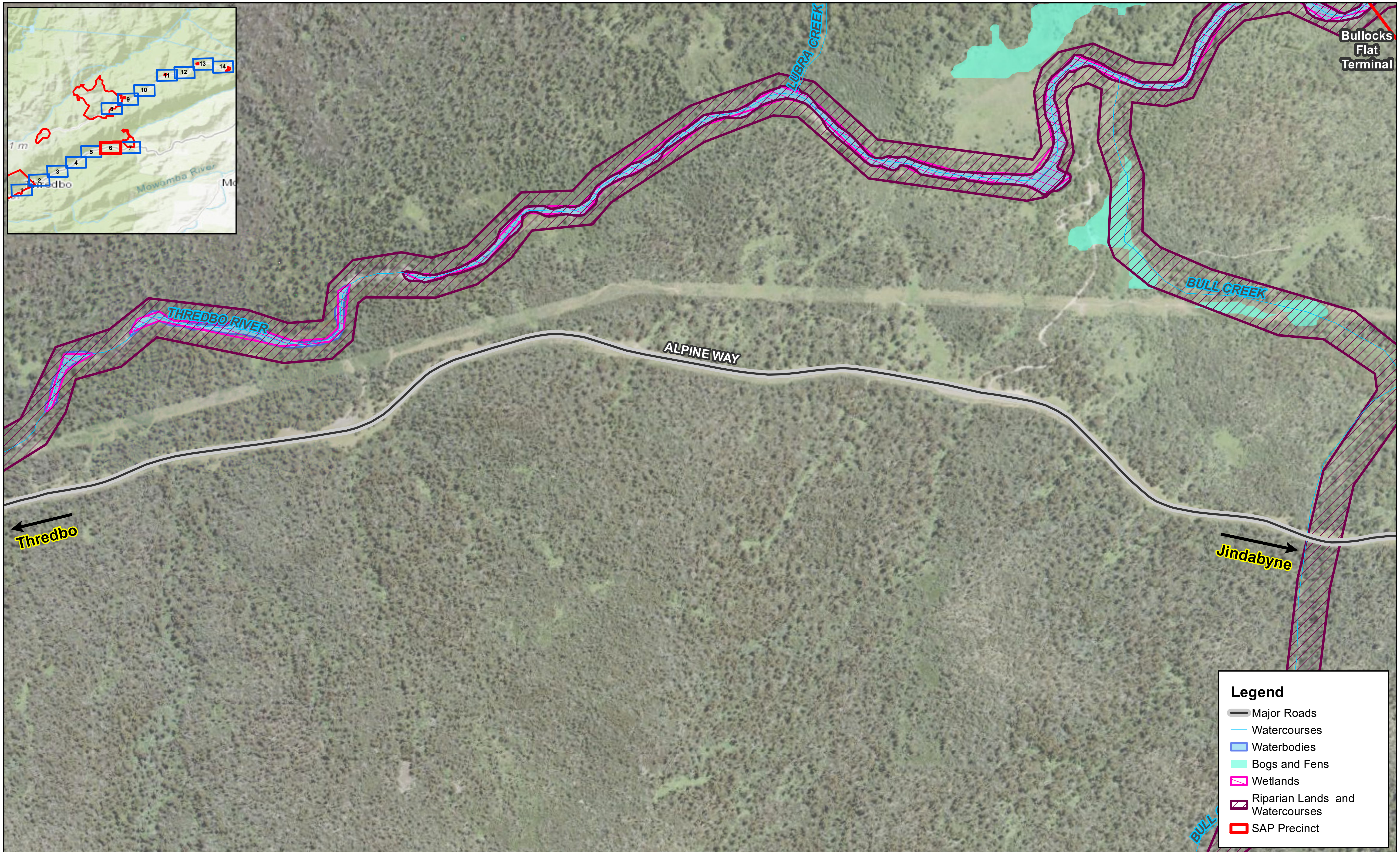


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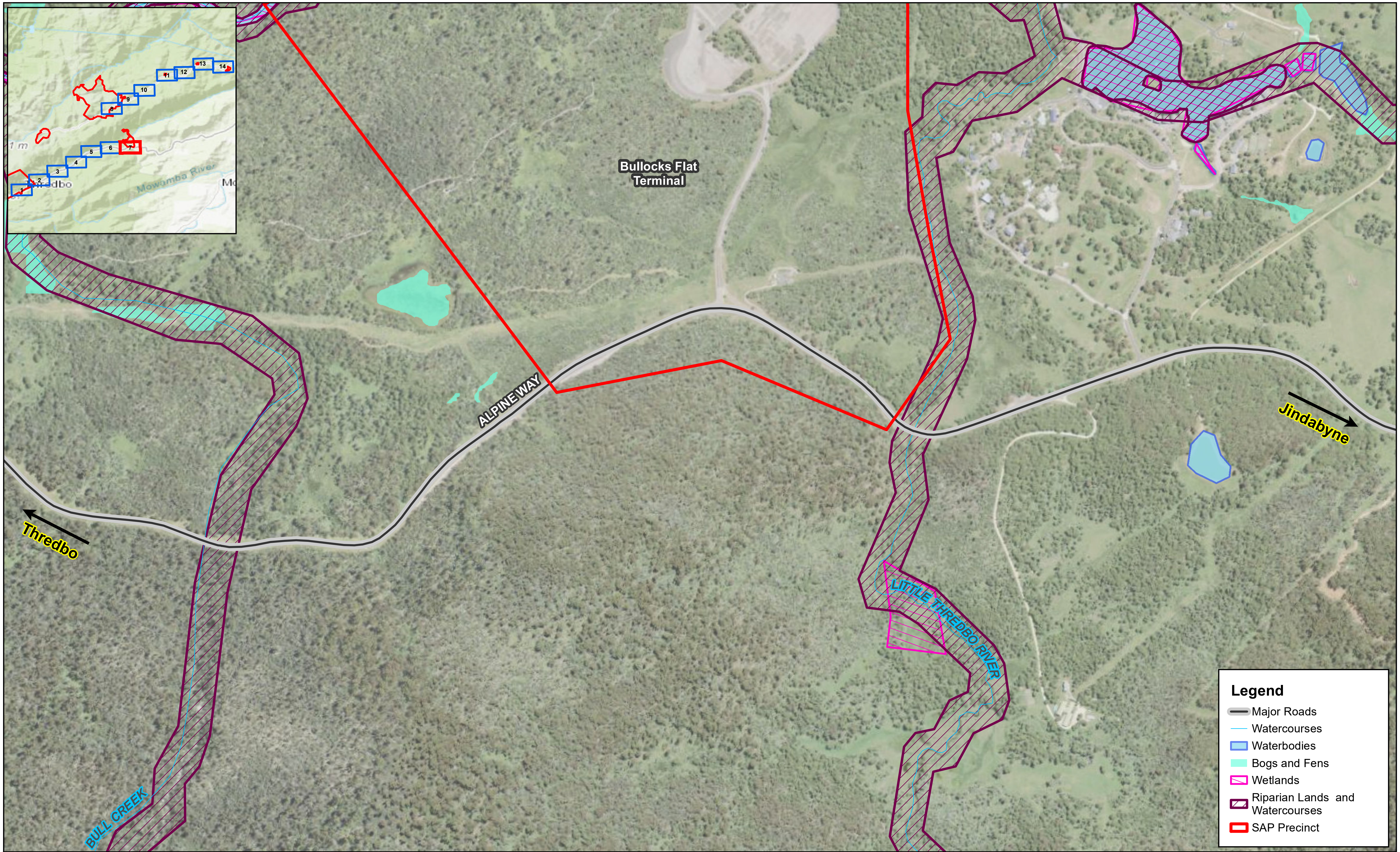


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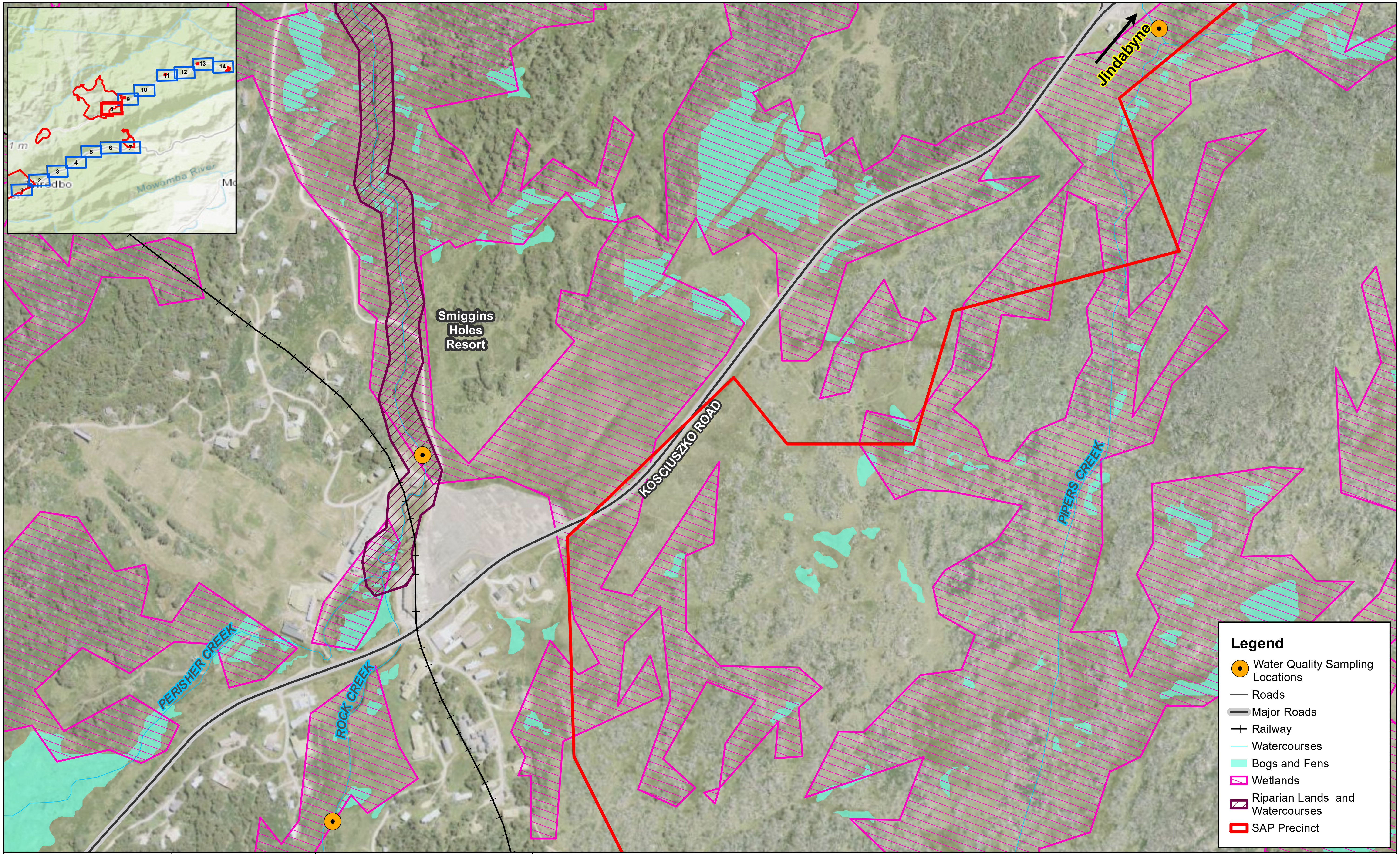


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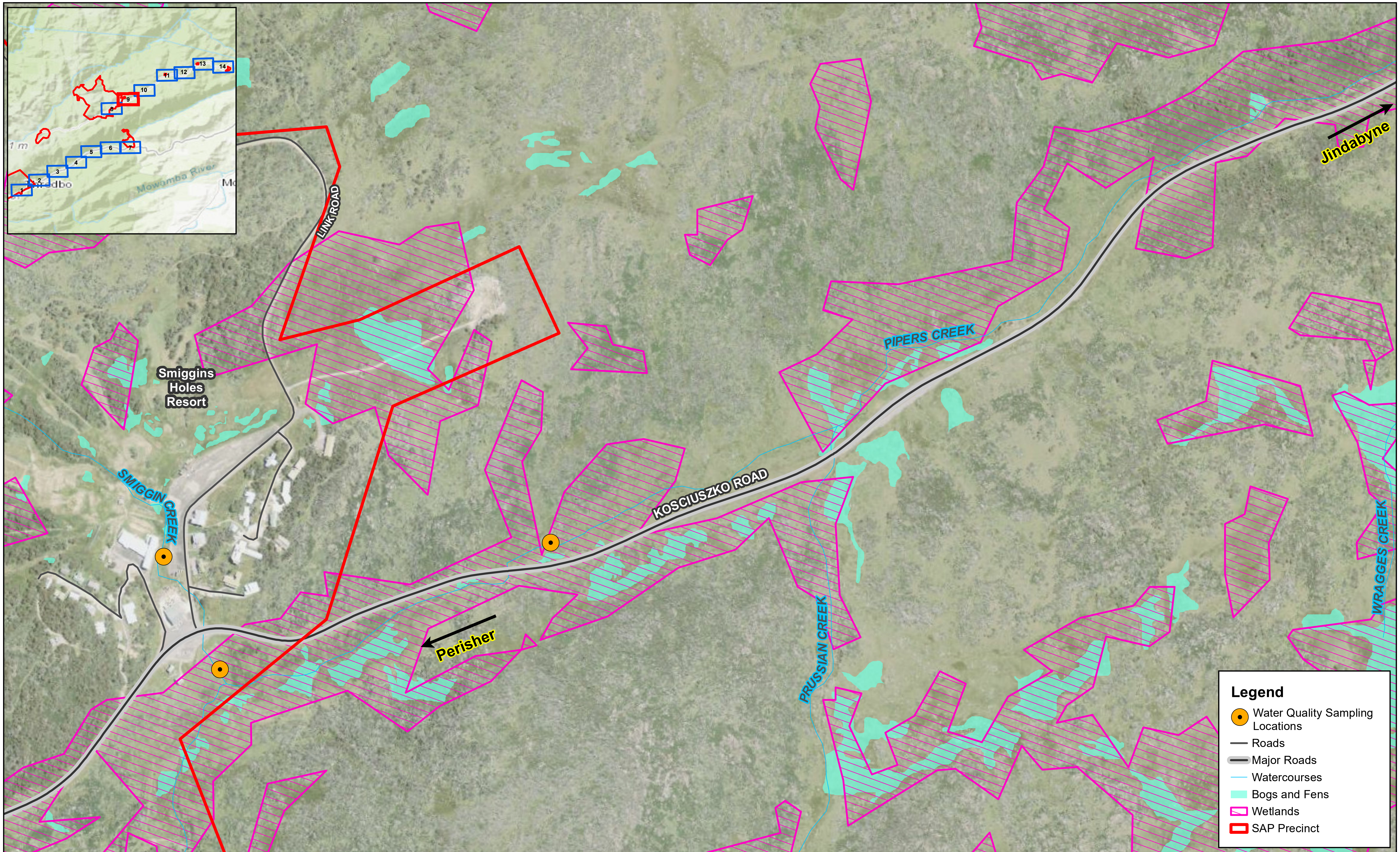
**Salt Impact Management Plan**

Salt Vulnerable Areas - Kosciuszko Road - Perisher

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| Map: PS120074_GIS_029_A5 | Author: David.Naiken |
| Date: 30.03.2021 | Approved by: Morgan.Cardiff |

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Coordinate System: GDA 1994 MGA Zone 55
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**Salt Impact Management Plan**
Salt Vulnerable Areas - Kosciuszko Road - Perisher




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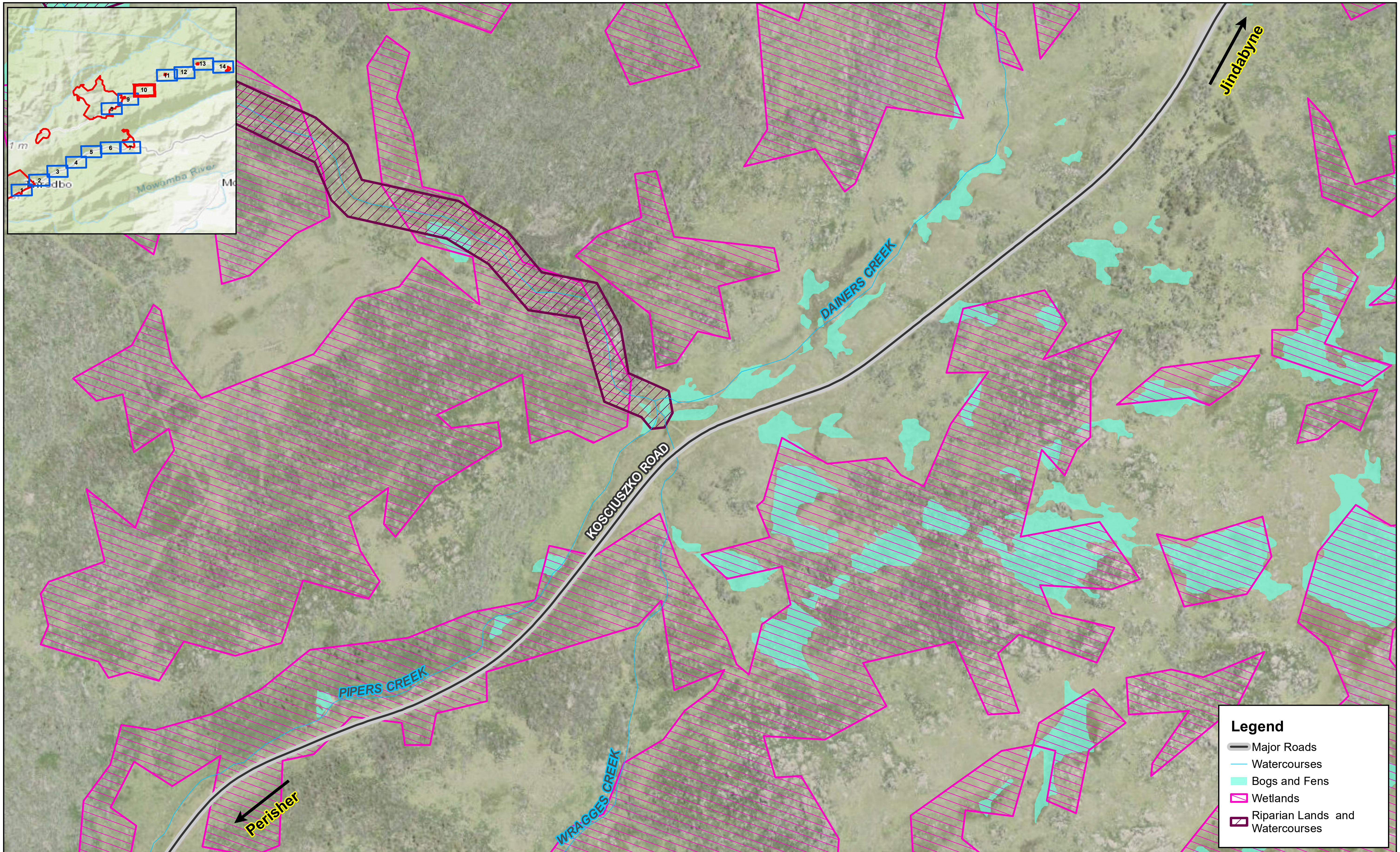


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**Salt Impact Management Plan**
Salt Vulnerable Areas - Kosciuszko Road - Perisher
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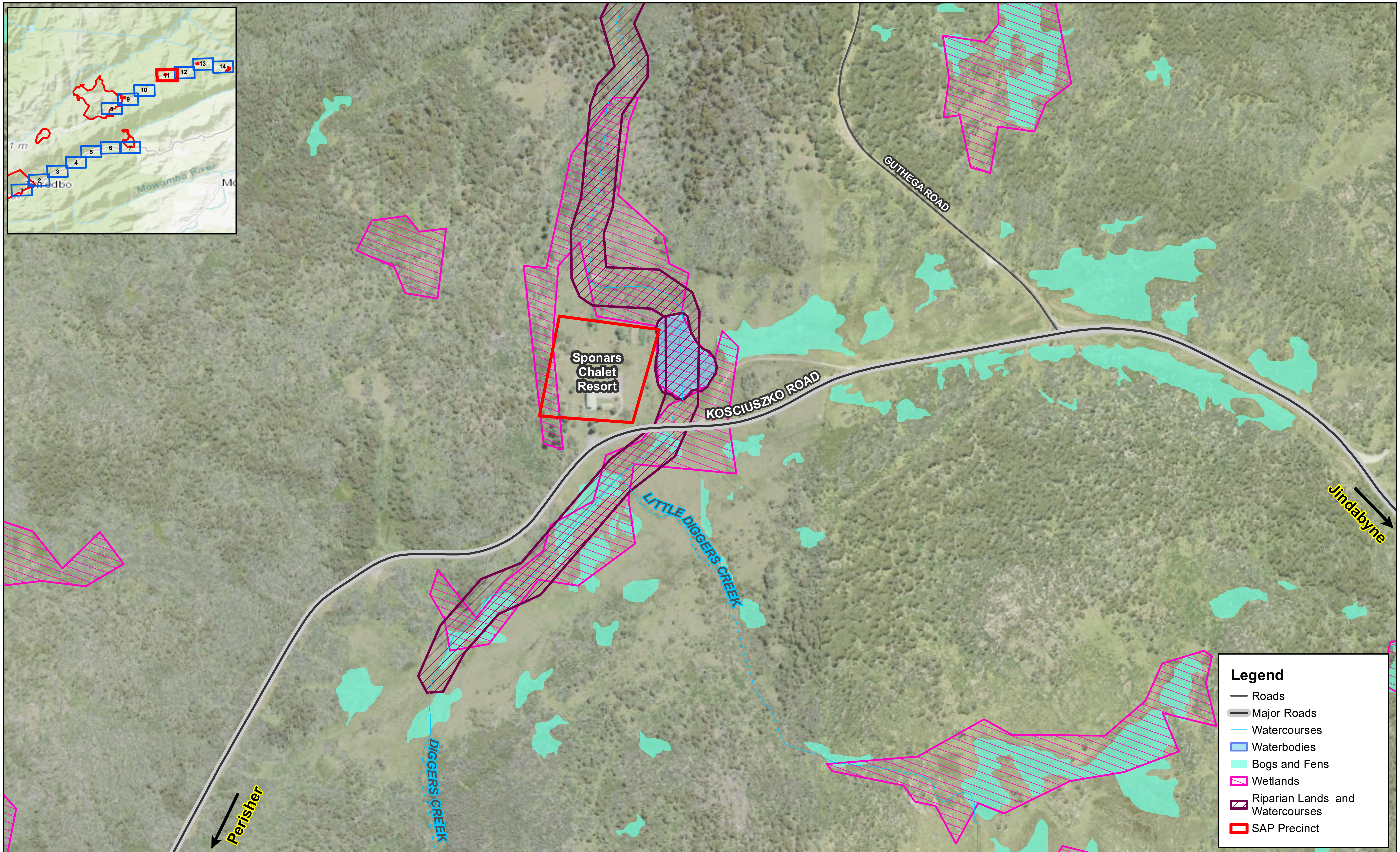


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**Salt Impact Management Plan**
Salt Vulnerable Areas - Kosciuszko Road - Sponars Chalet Resort


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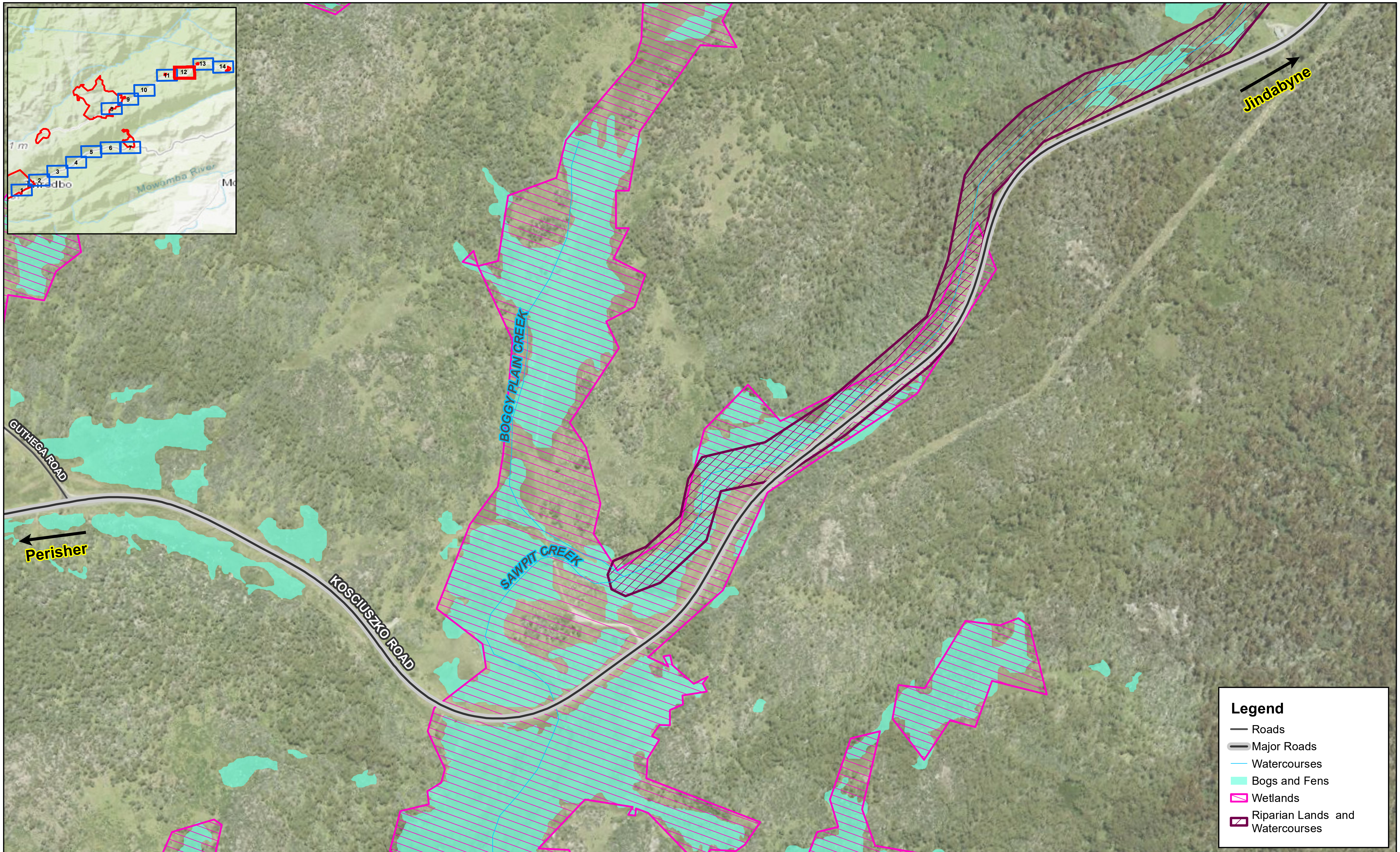


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Salt Vulnerable Areas - Kosciuszko Road




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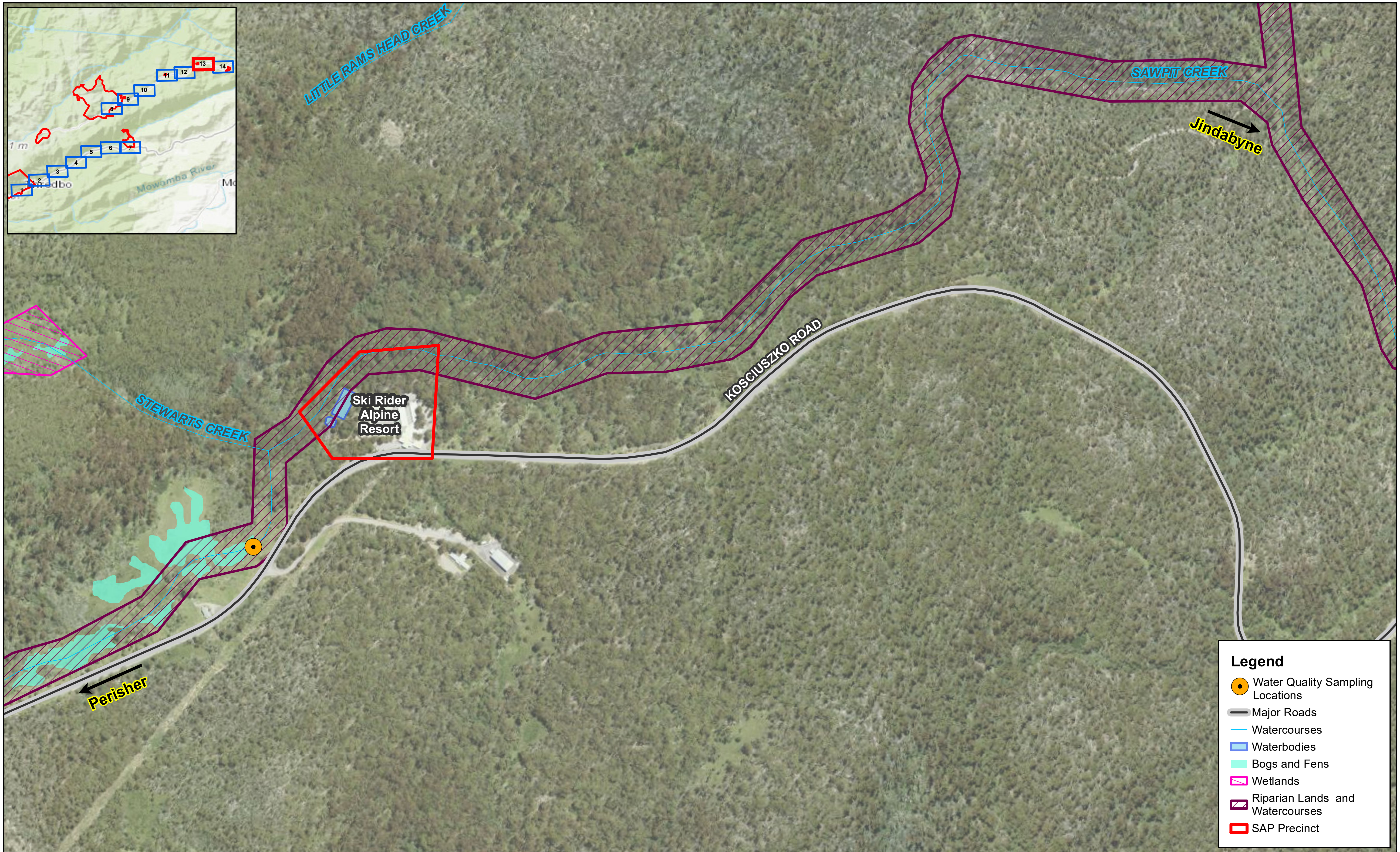


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Salt Vulnerable Areas - Kosciuszko Road - Ski Rider Alpine Resort
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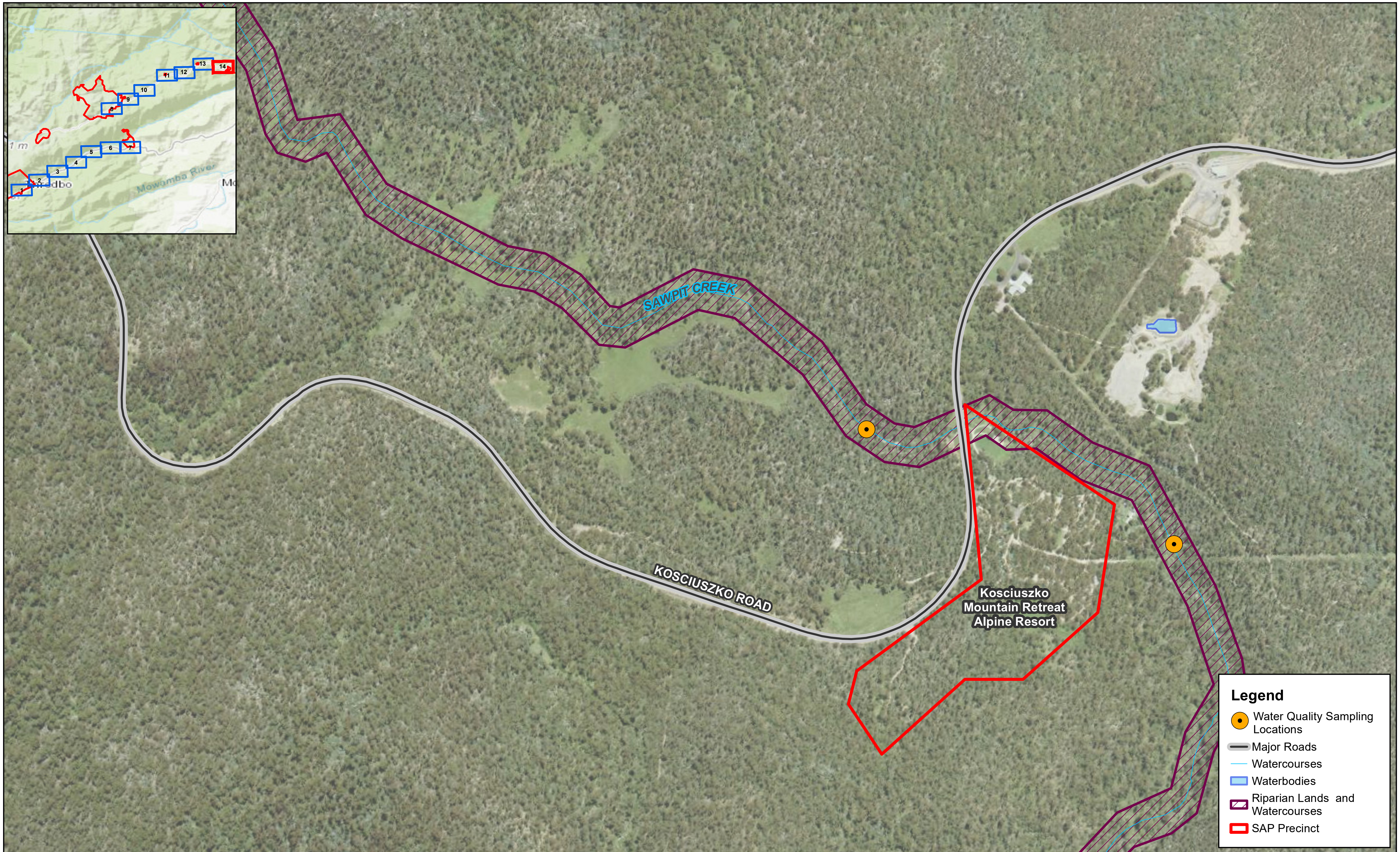


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Salt Vulnerable Areas - Kosciuszko Road - Sawpit Creek
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