ROAD OPERATION AND MAINTENANCE PRACTICES EFFECTIVENESS TESTING

TECHNICAL DOCUMENT

FINAL: NOVEMBER 2015

2NDNATURE
ecosystem science + design

Road Operation and Maintenance Practices Effectiveness Testing

Technical Document
Final November 2015

Road Operation and Maintenance Practices Effectiveness Testing was a 2 year collaborative effort between the Tahoe jurisdictions, project team, and funders. Special thanks to the road operations and maintenance crews from each participating jurisdiction for their continuous efforts in protecting Lake Tahoe clarity and their work in data collection and sharing to make this study possible.

Prepared for:

NEVADA DIVISION OF ENVIRONMENTAL PROTECTION

NEVADA DIVISION OF STATE LANDS

US Army Corps of Engineers® Sacramento District

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NCE

Nevada Tahoe Conservation District

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Any questions regarding the user guidance or associated process to conduct RO&M effectiveness study within a jurisdiction should be directed to 2NDNATURE (info@2ndnaturellc.com).

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1 Executive Summary

The Road Operation and Maintenance (RO&M) Practices Effectiveness Testing was undertaken to develop standardized guidance for Tahoe jurisdictions to document and test the effectiveness of specific RO&M practices that could be implemented to achieve credit awards through the Lake Clarity Crediting Program LRWQCB and NDEP; 2015a). The effort involved extensive and continued cooperation and collaboration with jurisdictional stormwater managers and road maintenance personnel, regulators, and field personnel conducting Road RAM observations. The specific objectives of the study were to: 1. improve our understanding of the factors influencing road condition; 2. inform jurisdictions as to expected road condition scores from the implementation of a suite of RO&M practices; 3. improve communication and coordination within and between jurisdictions; and 4. develop a simple and repeatable methodology for consistent future RO&M practices effectiveness testing.

Benefits

There are a number benefits of this effort:

- The RO&M practices effectiveness study raised awareness and increased understanding of the value of RO&M programs around the Tahoe Basin. PLRM v1.0 modeling suggests water quality minded RO&M practices are highly cost effective means to achieve and sustain significant pollutant load reductions from urban catchments (2NDNATURE & nhc 2011). This effort served as a first step to validate the feasibility and cost-benefit of RO&M practices based on field testing data. Real world validation is critical to increase the ability to secure and maintain funding support for RO&M practices and equipment that grant programs commonly restrict from funding.

- The high level of engagement and participation throughout this effort by road maintenance personnel and stormwater managers from multiple jurisdictions fostered critical thought, collaborative discussion, information sharing and technology transfer to advance the use of best practices to reduce fine sediment generation and transport from paved roadways. It is hoped that continued communication of experiences and institutional knowledge will facilitate innovation and continuous improvement, resulting in the implementation of the most efficient and effective RO&M practices across jurisdictions.

- Based on the lessons learned from this effort, the Road Operations and Maintenance Practices Effectiveness Testing User Guidance (2NDNATURE and NCE 2015) provides a standardized data collection, management, and analysis framework to guide and inform effective RO&M management decisions into the future. The feasible and defensible experimental design instructs jurisdictions to select test networks and segments to consistently determine and compare expected road condition scores and associated costs for a suite of RO&M practices. Scalable cost estimates are valuable for the purposes of fiscal planning and advocating for RO&M funding support.

- Using an 84 year climatic data set (1932- 2015), the project team developed a Tahoe winter severity index (WSI) and defined 5 WSI types. While a more robust methodology could be developed to include the timing of the freezing conditions relative to the precipitation, this approach using readily available air temperature and precipitation data provides a simple yet reasonable mechanism to interpret effectiveness testing results in the context of relative winter weather conditions.

Challenges

A number of challenges were experienced:

- Due to the mild and very mild winter severity index of WY14 and WY15 respectively, there is low certainty that expected road condition scores for the RO&M practices evaluated will be achievable in severe winters. Mild winters likely lead to higher than average annual RAM scores and lower RO&M costs compared to a severe winter due to the relatively lower abrasive application and recovery needs. The applicability of the results presented herein to inform PLRMv2 expected road condition scores can be improved by the continuation of the consistent testing over more severe winter conditions.

- There were a number of challenges associated with consistent documentation of the abrasive applications and sweeping practices conducted within a road network. The primary barriers included existing jurisdictional data management systems that did not align spatially with the road networks selected by the jurisdictions. Accommodations were made to communicate and coordinate with each jurisdiction to make the desired data collection and information sharing as simple as possible given existing practices. The same challenges existed for the data and information required to estimate comparable annual costs for each RO&M practice implemented. There remains a level of uncertainty in the summary of road practices implemented and associated costs due to inconsistent information available to the project team.

Key Findings

A number of conclusions are applicable to future RO&M testing and management efforts:

- Consideration of the climatic context is critical when applying study results to inform average annual road condition scores. Measured road practices and condition scores were collected during 2 mild winters; consequently, results from this effort only represent conditions and costs from a narrow climatic condition range. Average annual RAM scores presented in Figure 11 are not based on a representative range of climatic conditions that occur in the Tahoe Basin. Average RAM scores reported herein are higher than the scores that should be input as expected RAM scores into PLRM v2 for the given RO&M practice. It is strongly recommended jurisdictions continue effectiveness testing efforts through both average and severe winter years to ensure RO&M practices are feasible to implement and the road condition scores modeled in PLRM v2 are achievable long-term.

- The two most important controllable factors for improved road condition are: the amount of material put down and the residence time of the material applied (defined as the duration between applications and subsequent sweeping). Municipalities that applied <3 cu-yards of abrasive per center mile or had an average residence time of <5 days consistently had relatively higher observed road condition scores and more cost effective practices to achieve road condition scores (<$1K/RAM/CM/WY). Minimizing abrasive applications and residence times is a critical strategy to effectively reduce FSP generation and transport from paved roads. Longer residence times may result in the accumulation of a caked layer on road surfaces, which requires additional sweeping efforts to dislodge and recover and may contribute to FSP dispersion and further pulverization throughout the road network.

- Jurisdictions that put forth a large effort to sweep and recover material as soon as possible following a storm, but had poorly performing, inefficient road sweepers, did not show the same improvement in road condition scores as those jurisdictions with highly functional equipment. Road maintenance personnel must have access to sweepers that are well maintained, function efficiently and effectively recover applied abrasive material.

- Water-quality minded road operations remain an important, cost-effective strategy for jurisdictions to meet their TMDL load reduction milestones. Based on the cost information and data compiled for this effort, the estimated average annual RO&M costs range from $550,000-$1.6 million to maintain all jurisdiction roads at the observed road conditions for an average water year and winter severity. These annual RO&M estimates remain more cost effective than the implementation and maintenance of water quality improvement projects (WQIPs) or private parcel BMPs and generally support the conclusions of the Placer County Stormwater TMDL Strategy (2NDNATURE and NHC, 2011).

2 Introduction

The Lake Tahoe Total Maximum Daily Load (TMDL) documents an estimated 72% of the < 16-micron sediment (fine sediment particles (FSP)) load to Lake Tahoe originates from the urban upland source category (i.e., urban stormwater). The urban stormwater source was also determined to be the greatest opportunity to achieve load reductions of FSP and associated phosphorus pollutant to Lake Tahoe. Consequently, the TMDL implementation plan focuses on load reductions stemming from this source. Moreover, the TMDL and subsequent land use specific research (2NDNATURE 2010, 2NDNATURE and NHC 2012) suggests impervious roadways have the greatest FSP loading potential per unit area and the greatest opportunity to achieve cost-effective load reductions (2NDNATURE and nhc 2011).

The Lake Clarity Crediting Program (Crediting Program), developed and administered jointly by the Lahontan Water Board (LRWQCB) and Nevada Division of Environmental Protection (NDEP), is an innovative program in which Lake Tahoe urban stormwater jurisdictions (i.e., local governments and state transportation agencies) will participate during implementation of the Lake TMDL (LRWQCB and NDEP 2010). The Crediting Program is the framework that connects the stormwater management and regulatory community to the goal of restoring Lake Tahoe clarity. It defines a standardized process, protocols and tools that facilitate comprehensive and consistent quantification, tracking and reporting of load reduction actions. Participation will provide incentives to urban jurisdictions to implement priority actions on the ground, while increasing the transparency and accountability for the expenditures of public funds on these actions.

Pollutant Load Reduction Model (PLRM) is the standard load reduction estimation tool used for the Crediting Program to estimate the FSP loads and the expected load reductions associated with water quality improvement actions on an urban catchment scale (nhc et al. 2009). These load reduction estimates include expected load reductions associated with improved road maintenance and operation strategies. PLRM outputs are used to develop catchment credit schedules that specify the load reduction actions that the respective urban jurisdiction will implement and for which the regulators will hold them accountable.

PLRM users estimate the effectiveness of road maintenance practices on a 0-5 scale as defined by the Road Rapid Assessment Methodology (Road RAM; 2NDNATURE et al. 2010). Road RAM is the condition assessment tool used for the Crediting Program to verify that municipal road maintenance actions have resulted in the expected average annual road condition as modelled in PLRM. This comparison is critical for the regulators to determine if the full credit award is justified. Since Road RAM is the common unit of measure of road condition in the Tahoe Basin, it can be used to inform PLRM inputs by using Road RAM to measure the effectiveness of specific roadway operations and maintenance actions and strategies to protect downslope water quality.

Lake Tahoe urban jurisdictions are currently in the process of registering the actions and to meet load reduction targets and milestones specified in permits and agreements. The TMDL implementation strategy completed for Placer County indicates roadway operations, specifically roadway sweeping, as the most cost effective means to achieve pollutant load reductions (2NDNATURE & nhc; 2011). However, water quality-minded road operation strategies are continuing to be understood and applied as jurisdictions continue to seek out simple, cost-effective practices to improve road conditions while maintaining winter driver safety. Innovative strategies that show promise have been considered but have yet to be implemented due to lingering questions regarding implementation feasibility, cost-effectiveness, and a lack of implementation guidance.

There is a strong need to identify and document road operation and maintenance strategies that are feasible for jurisdictions to implement and consistently minimize the amount of potential FSP delivered to the stormwater systems from roads. To date, the link between the jurisdictions' RO&M strategies and the expected load reductions has been identified as a priority data gap as the jurisdictions develop their TMDL implementation strategies. The Road Operations and Maintenance Practices Effectiveness Testing Study was developed as a means to fill this gap.

2.1 Tahoe Stormwater Tools

The Crediting Program has created a functional relationship between PLRM road inputs and Road RAM observations to estimate credit awards and verify that road conditions year after year align with the expected road condition modelled in PLRM. The Credit Accounting Platform (CAP) is a web-based data management platform that simplifies the tracking of credit schedules and annual awards for the jurisdictions and regulators.

Figure 1 outlines the functional relationships between the Tahoe Tools: PLRM, CAP, and Road RAM; and how this road operations and maintenance study is intended to inform PLRM inputs. This study was designed to assist jurisdictions and provide guidance on how to design and implement a RO&M practices effectiveness study to obtain measured RAM scores and inform the expected road condition scores to be input into PLRMv2. PLRM uses the expected scores input by the user to quantify the expected pollutant loading from RO&M practices. Pollutant load reductions resulting from RO&M practices are used to define the Credit Schedule, including the number of potential annual credits, for the Road Operations Registration. Throughout each year, jurisdictions are required to conduct Road RAM assessments at a selection of road segments to verify the expected road condition scores input in PLRM. At the end of each water year, the RAM scores are averaged and compared to the expected condition score to determine if the annual credit award to the jurisdiction is valid. In other words, were road conditions during the year at or above the registered condition score as used in PLRM?

2.2 Project Goals

RO&M Practices Effectiveness Testing was undertaken to develop standardized guidance for Tahoe jurisdictions to document and test the effectiveness of specific RO&M practices that could be implemented to achieve credit awards through the Lake Clarity Crediting Program. Nevada Division of Environmental Protection (NDEP), Nevada Division of State Lands (NDSL), and the US Army Corps of Engineers jointly funded the RO&M Practices Effectiveness Study. The project team of 2NDNATURE, NTCD, and NCE were contracted in August of 2013 and data collection was conducted for two full water years (WY14 and WY15). The implementation of this effort required extensive and continued cooperation and collaboration between several entities, including the jurisdictional stormwater managers, road maintenance personnel, regulators, and Road RAM personnel. Without their cooperation, this effort would not have been possible.

The project team established a number of goals to involve all stakeholders and guide the study to provide valuable management information to jurisdictions.

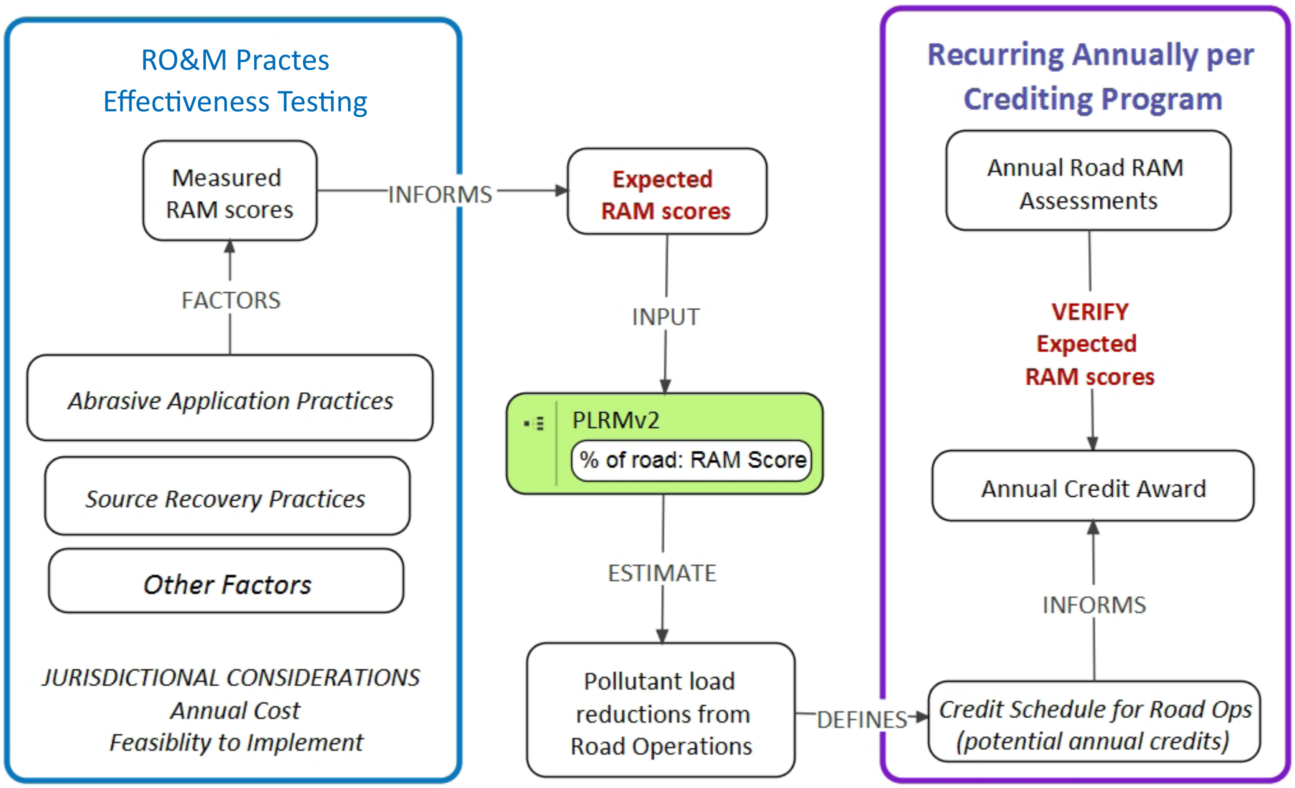
1. Improve communications and coordination between stormwater managers and road operations personnel within each jurisdiction.

2. Improve our collective understanding of the factors influencing road condition (i.e., amount of FSP on roadway) over time and the role road operations may have on maintaining road conditions to minimize FSP generation and transport from roads.

3. Improve the capabilities of municipalities to determine what reasonable PLRM road condition score inputs are based on actual RO&M practices that will be implemented over time on specific road classes/networks.

4. Develop and provide a feasible and defensible experimental design and associated guidance for jurisdiction to compare road practices, road O&M costs and Road RAM results into the future to directly inform PLRM v2 expected road condition scores.

Relationship between RO&M Practices Effectiveness Testing and Crediting Program



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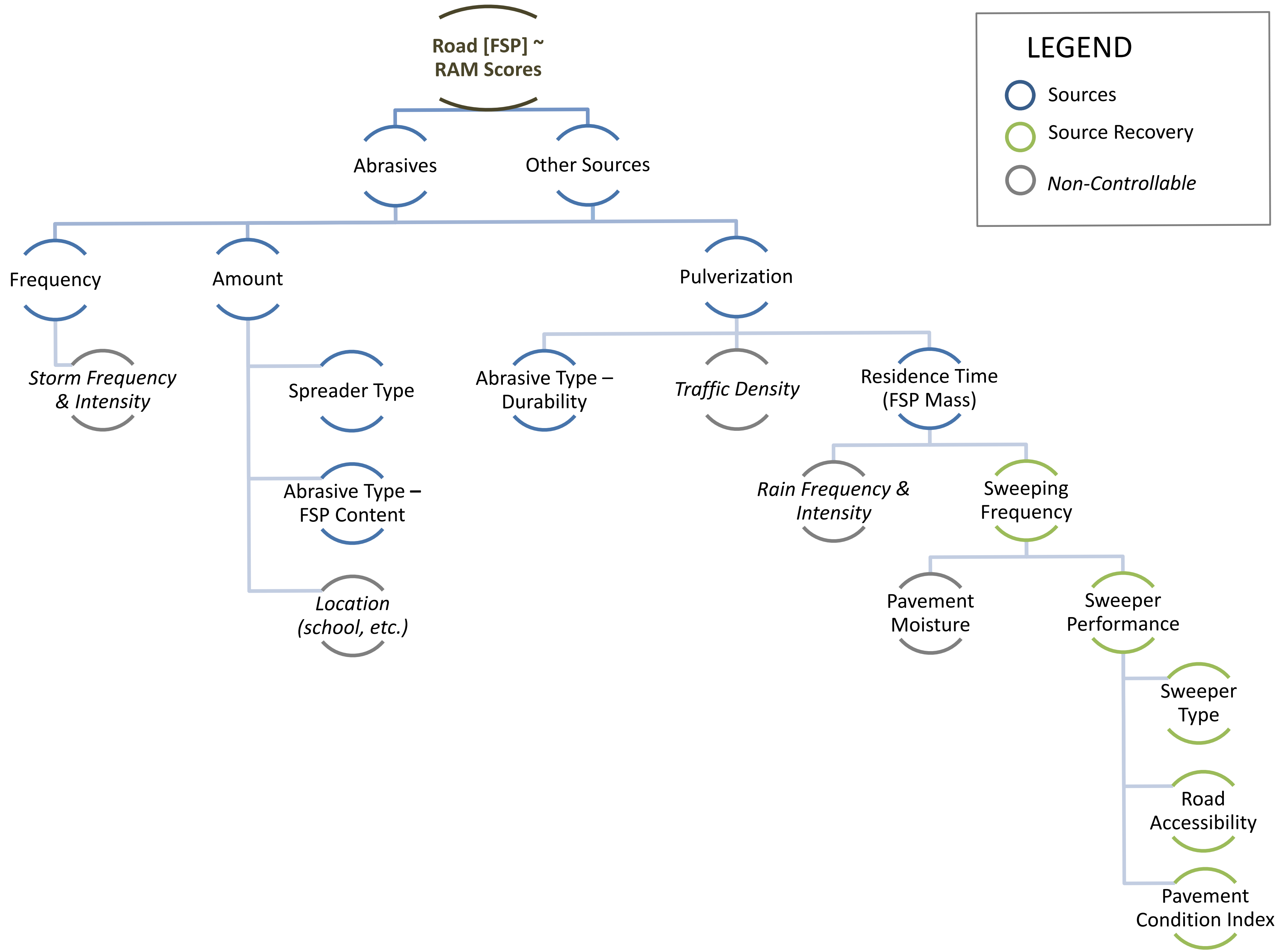
RELATIONSHIP OF STUDY TO CREDITING PROGRAM

FIGURE 1

3 Road Condition Defined

Road RAM scores are a relative estimate of fine sediment particles (FSP) concentration of a road segment at the time of evaluation, expressed using a 0-5 scale. The technical details underlying the assessment protocols and score generation are detailed in the Tahoe Road RAM technical document (2NDNATURE et al. 2010). The road condition, or RAM score on any road at any point in time is driven by a number of interacting factors. Figure 2 summarizes the factors that can influence road condition of a specific road at a specific time. There are uncontrollable (weather-driven; grey circles) and controllable factors (blue and green circles). In combination, all of these factors have a variable influence on the actual Road RAM score over time and across roads. The best road condition (i.e., RAM scores > 3.5) will result if the collective sources of FSP to a road (blue circles) are minimized and the source recovery actions (green circles) are as effective as necessary to remove any FSP sources prior to the next runoff event. The storm frequency and temperature patterns inherently influence the relative condition of the roadways, as road maintenance crews are required to manage winter road conditions and protect driver safety. However, once winter freezing conditions subside, road conditions can be greatly improved and maintained by effective and well timed sweeping practices. Other sources of sediment to the roads such as road cuts, unpaved road shoulders, unpaved driveways, and construction sites can be a chronic source of additional particulate material to the road surfaces. The other sources vary seasonally and spatially. Another critical factor in maximizing RO&M strategies is the maintenance of pavement condition. Cracked and degraded pavement can be additional source of material to the road surface further pulverized by traffic. Perhaps more critical to road condition is that sweepers can't effectively extract FSP from cracked pavement, reducing the effectiveness of sweeping actions. However, subsequent storm events and associated runoff effectively mine these cracks and transport the accumulated FSP into the stormwater system (2NDNATURE et al. 2010).

The experimental design carried out over the course of the study aimed to highlight factors that were within control of the jurisdiction and could be improved or modified by the jurisdiction to improve overall road condition (Figure 2). RO&M strategies that minimize both the magnitude of material delivered to the impervious road surface and the residence time of that material on the road surfaces, and maintain pavement condition will increase the average annual road conditions.



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FACTORS AFFECTING ROAD CONDITION

FIGURE 2

4 Methods

4.1 Experimental Design

Testing RO&M effectiveness on roadways required participating jurisdictions to establish and follow an experimental design for the duration of the study. The RO&M study covered 2 water years and data collection spanned 16 months, commencing in December 2013 and concluding at the end of April 2015. Experimental design steps involved the selection of a subset of roads where defined road practices were implemented and road condition was periodically measured. Each section below provides a description of the experimental design components with a summary of what was instituted for WY14 and WY15 testing by each jurisdiction. Throughout the RO&M study a number of lessons were learned, driving the development of the User Guidance (2NDNATURE 2015). These findings are summarized in Chapter 3.3.

4.1.1 ROAD PRACTICES AND DOCUMENTATION

Jurisdictions were tasked with designating a road network and then defining road practices to implement within the selected road network. Detailed records of road practice actions (sweeping, abrasives application) were reported to the project team.

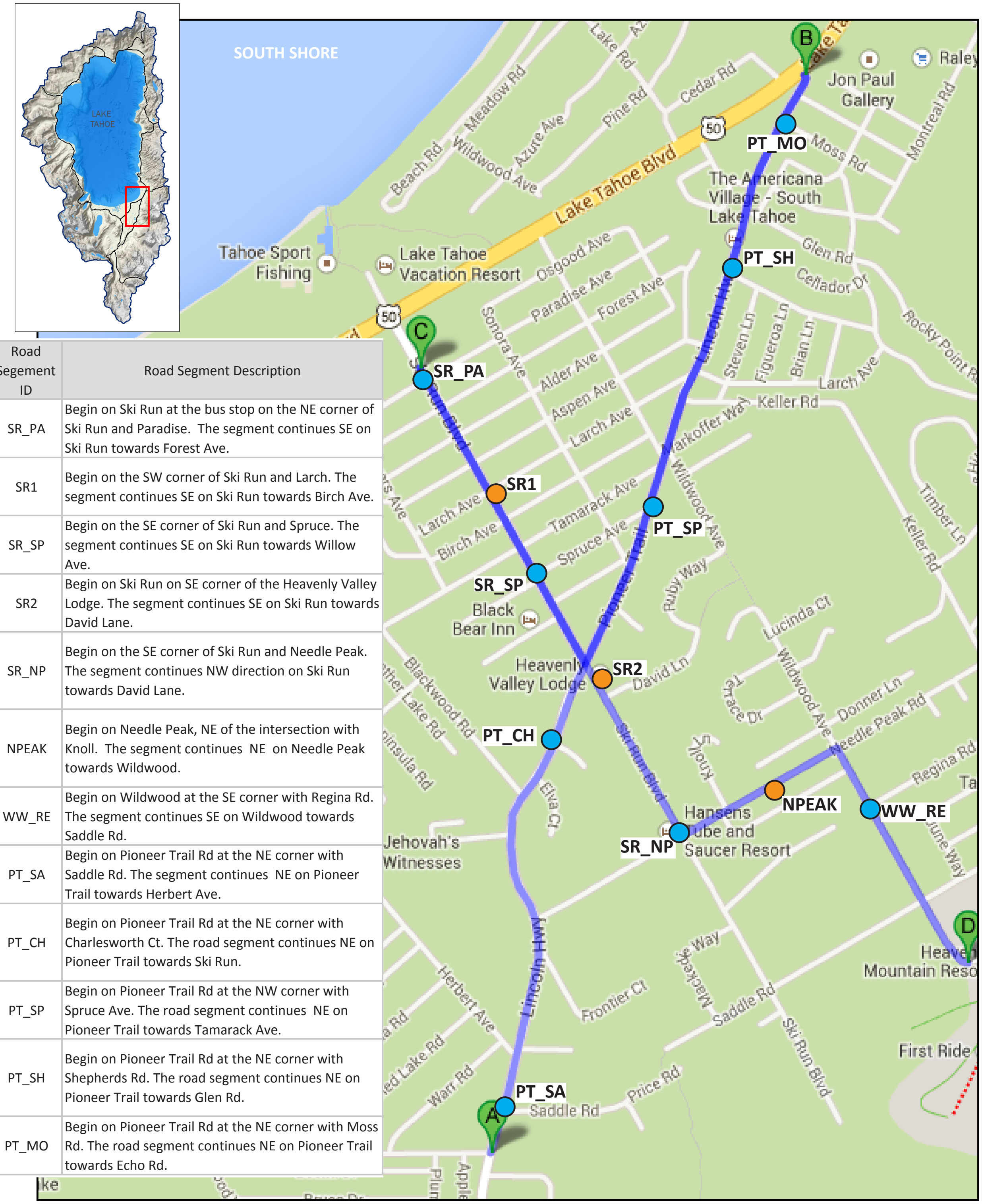
Road Network Selection

A road network is the subset of a jurisdiction's roads selected as the test area where the defined road practices are implemented, tracked and assessed. Criteria for selecting a road network included a minimum of 1.5 center lane miles with consistent traffic density (high, moderate, or low), where similar road maintenance practices could be easily and consistently performed. Road supervisors and stormwater managers collaborated to select road networks at their jurisdiction that would serve as the test area for the 2 year study. Many jurisdictions selected a road network that existed within current sweeping routes or maintenance zones to simplify recording and tracking road operations. Figures 3-8 display road networks selected by all 6 participating jurisdiction.

Select and Define Road Practices to Test

The purpose behind selecting road practices for testing is to provide stormwater managers with a valid measure of RAM scores generated by specific road practices to inform PLRM inputs and the associated load reduction estimates. Jurisdictions could opt to test "business as usual" road practices or could select experimental road practices that aimed to minimize cost and maximize water quality benefits. While jurisdictions were encouraged to collaborate in order to test a collective suite of practices that represented a range of existing to advanced operation techniques, the coordination of such an endeavor proved to be too complicated. In general, the participating jurisdictions chose to evaluate typical road practices with the equipment and techniques they had available.

CSLT Road Network



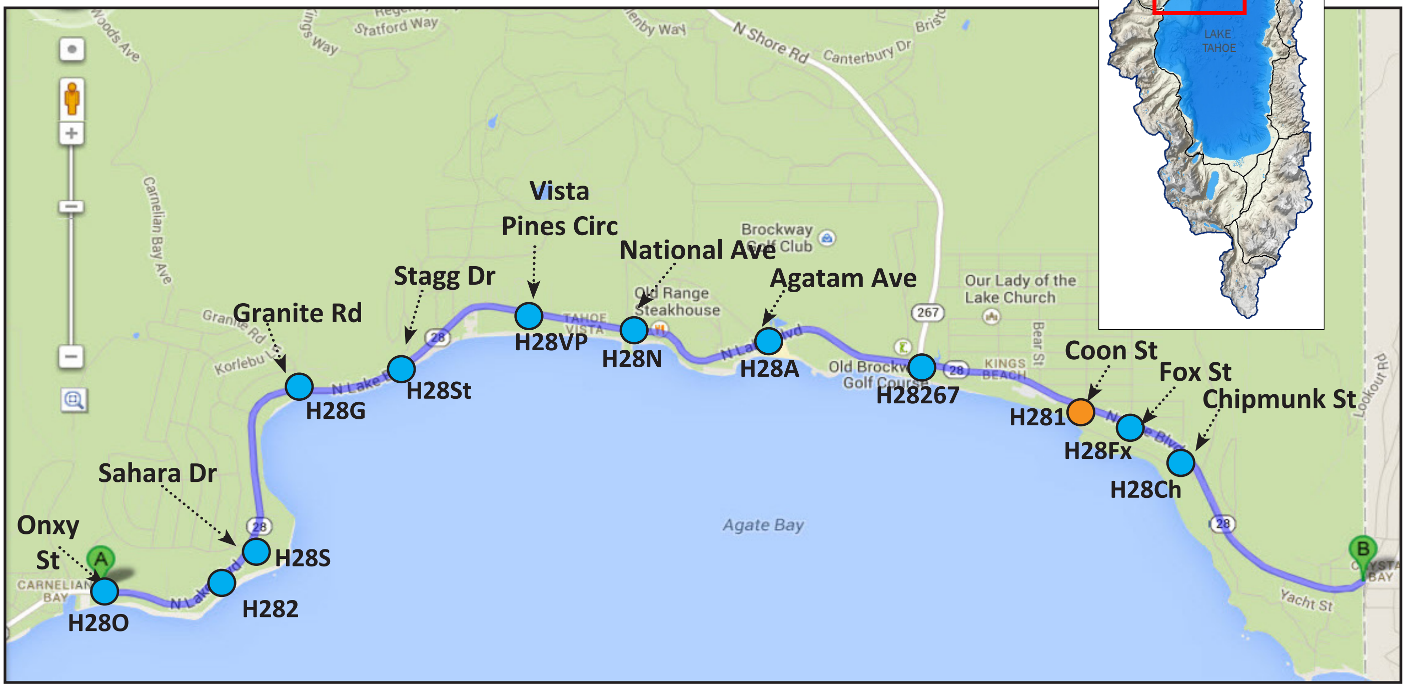
Road Segement ID	Road Segment Description
SR_PA	Begin on Ski Run at the bus stop on the NE corner of Ski Run and Paradise. The segment continues SE on Ski Run towards Forest Ave.
SR1	Begin on the SW corner of Ski Run and Larch. The segment continues SE on Ski Run towards Birch Ave.
SR_SP	Begin on the SE corner of Ski Run and Spruce. The segment continues SE on Ski Run towards Willow Ave.
SR2	Begin on Ski Run on SE corner of the Heavenly Valley Lodge. The segment continues SE on Ski Run towards David Lane.
SR_NP	Begin on the SE corner of Ski Run and Needle Peak. The segment continues NW direction on Ski Run towards David Lane.
NPEAK	Begin on Needle Peak, NE of the intersection with Knoll. The segment continues NE on Needle Peak towards Wildwood.
WW_RE	Begin on Wildwood at the SE corner with Regina Rd. The segment continues SE on Wildwood towards Saddle Rd.
PT_SA	Begin on Pioneer Trail Rd at the NE corner with Saddle Rd. The segment continues NE on Pioneer Trail towards Herbert Ave.
PT_CH	Begin on Pioneer Trail Rd at the NE corner with Charlesworth Ct. The road segment continues NE on Pioneer Trail towards Ski Run.
PT_SP	Begin on Pioneer Trail Rd at the NW corner with Spruce Ave. The road segment continues NE on Pioneer Trail towards Tamarack Ave.
PT_SH	Begin on Pioneer Trail Rd at the NE corner with Shepherds Rd. The road segment continues NE on Pioneer Trail towards Glen Rd.
PT_MO	Begin on Pioneer Trail Rd at the NE corner with Moss Rd. The road segment continues NE on Pioneer Trail towards Echo Rd.

Test Road Network: Pioneer Trail at Walkup Road to Hwy 50 and Ski Run (from Hwy 50), to Needle Peak, and east on Wildwood to Heavenly Resort. **Total Distance:** ~3.1 miles

LEGEND

Road RAM Segments
- **Pre-existing Segment** (orange)
- **Proposed Segment** (blue)

Caltrans Road Network



Test Road Network: Highway 28 from Onyx St near Canelian Bay to Stateline.
Total Distance: 5.0 miles

Road Segment ID	Road Segment Description
H28O	Begin on Hwy 28 on the eastern intersection with Onyx St. The road segment continues east towards Stateline.
H282	Begin on Hwy 28 near house # 5394 N. Lake Tahoe. The road segment continues east towards Stateline.
H28S	Begin on Hwy 28 oat the intersection with Sahara Dr. The road segment continues east towards Stateline.
H28G	Begin on Hwy 28 at the intersection with Granite Rd. The road segment continues east towards Stateline.
H28St	Begin on Hwy 28 at the intersection with Stagg Dr. The road segment continues east towards Stateline.
H28VP	Begin on Hwy 28 at the intersection with Vista Pines. The road segment continues east towards Stateline.
H28N	Begin on Hwy 28 at the intersection with National Ave. The road segment continues east towards Stateline.
H28A	Begin on Hwy 28 at the intersection with Agatam Ave. The road segment continues east towards Stateline.
H28267	Begin on Hwy 28 at the intersection with Hwy 267. The road segment continues east towards Stateline.
H281	Begin on Hwy 28 between Bear and Coon Streets in King Beach. The road segment continues east towards Stateline.
H28Fx	Begin on Hwy 28 at the intersection with Fox St. The road segment continues east towards Stateline.
H28Ch	Begin on Hwy 28 at the intersection with Chipmunk St. The road segment continues east towards Stateline.

LEGEND

Road RAM Segments
- **Pre-existing Segment**
- **Proposed Segment**

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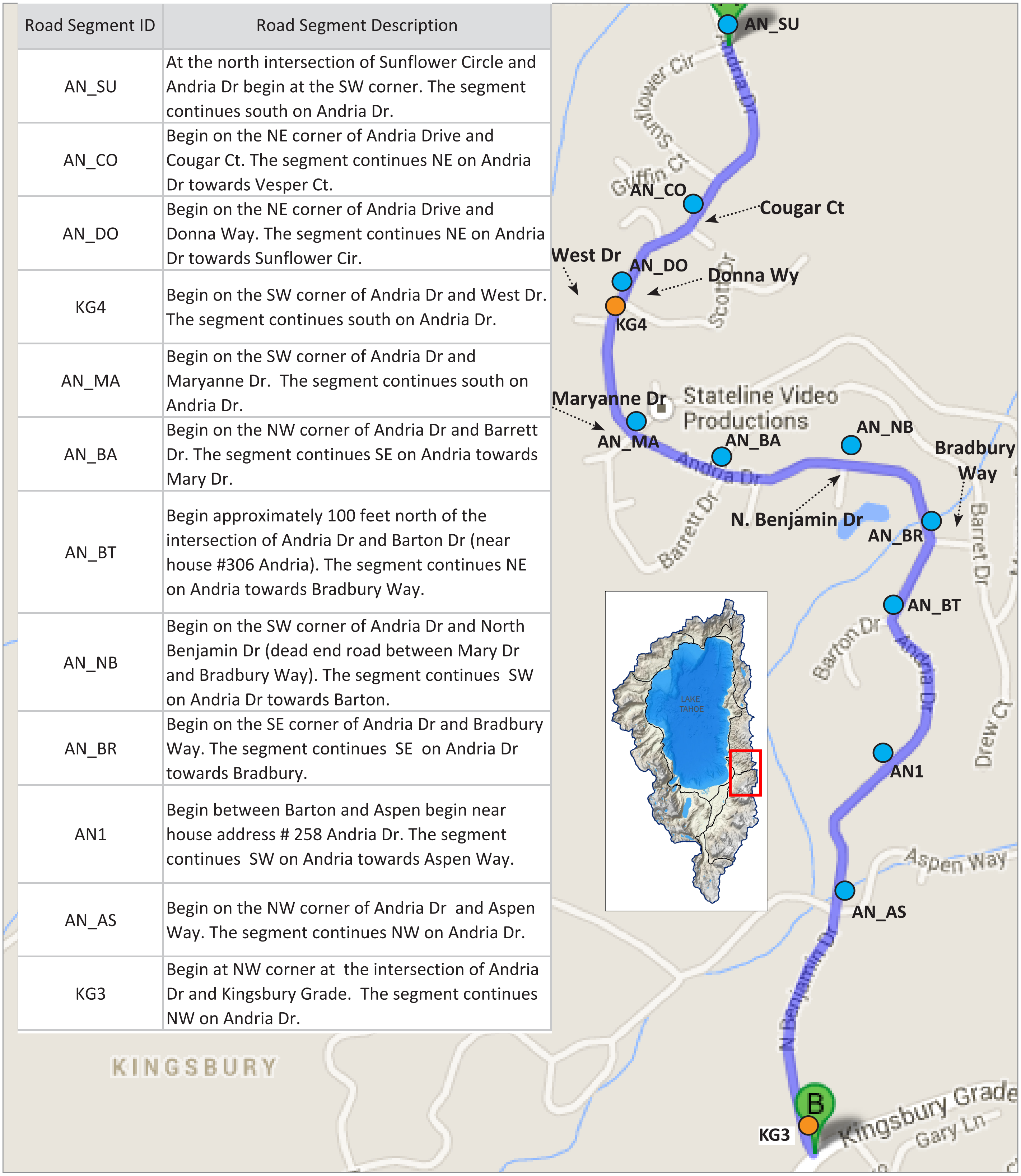
CALTRANS ROAD NETWORK & SEGMENTS FOR TESTING

FIGURE 4

KGID Road Network

Road Segment ID	Road Segment Description
AN_SU	At the north intersection of Sunflower Circle and Andria Dr begin at the SW corner. The segment continues south on Andria Dr.
AN_CO	Begin on the NE corner of Andria Drive and Cougar Ct. The segment continues NE on Andria Dr towards Vesper Ct.
AN_DO	Begin on the NE corner of Andria Drive and Donna Way. The segment continues NE on Andria Dr towards Sunflower Cir.
KG4	Begin on the SW corner of Andria Dr and West Dr. The segment continues south on Andria Dr.
AN_MA	Begin on the SW corner of Andria Dr and Maryanne Dr. The segment continues south on Andria Dr.
AN_BA	Begin on the NW corner of Andria Dr and Barrett Dr. The segment continues SE on Andria towards Mary Dr.
AN_BT	Begin approximately 100 feet north of the intersection of Andria Dr and Barton Dr (near house #306 Andria). The segment continues NE on Andria towards Bradbury Way.
AN_NB	Begin on the SW corner of Andria Dr and North Benjamin Dr (dead end road between Mary Dr and Bradbury Way). The segment continues SW on Andria Dr towards Barton.
AN_BR	Begin on the SE corner of Andria Dr and Bradbury Way. The segment continues SE on Andria Dr towards Bradbury.
AN1	Begin between Barton and Aspen begin near house address # 258 Andria Dr. The segment continues SW on Andria towards Aspen Way.
AN_AS	Begin on the NW corner of Andria Dr and Aspen Way. The segment continues NW on Andria Dr.
KG3	Begin at NW corner at the intersection of Andria Dr and Kingsbury Grade. The segment continues NW on Andria Dr.



Test Road Network: North Benjamin Drive to Andria Drive to the North intersection with Sunflower Circle.

Total Distance: 1.6 miles

LEGEND
Road RAM Segments
Pre-existing Segment (orange)
Proposed Segment (blue)

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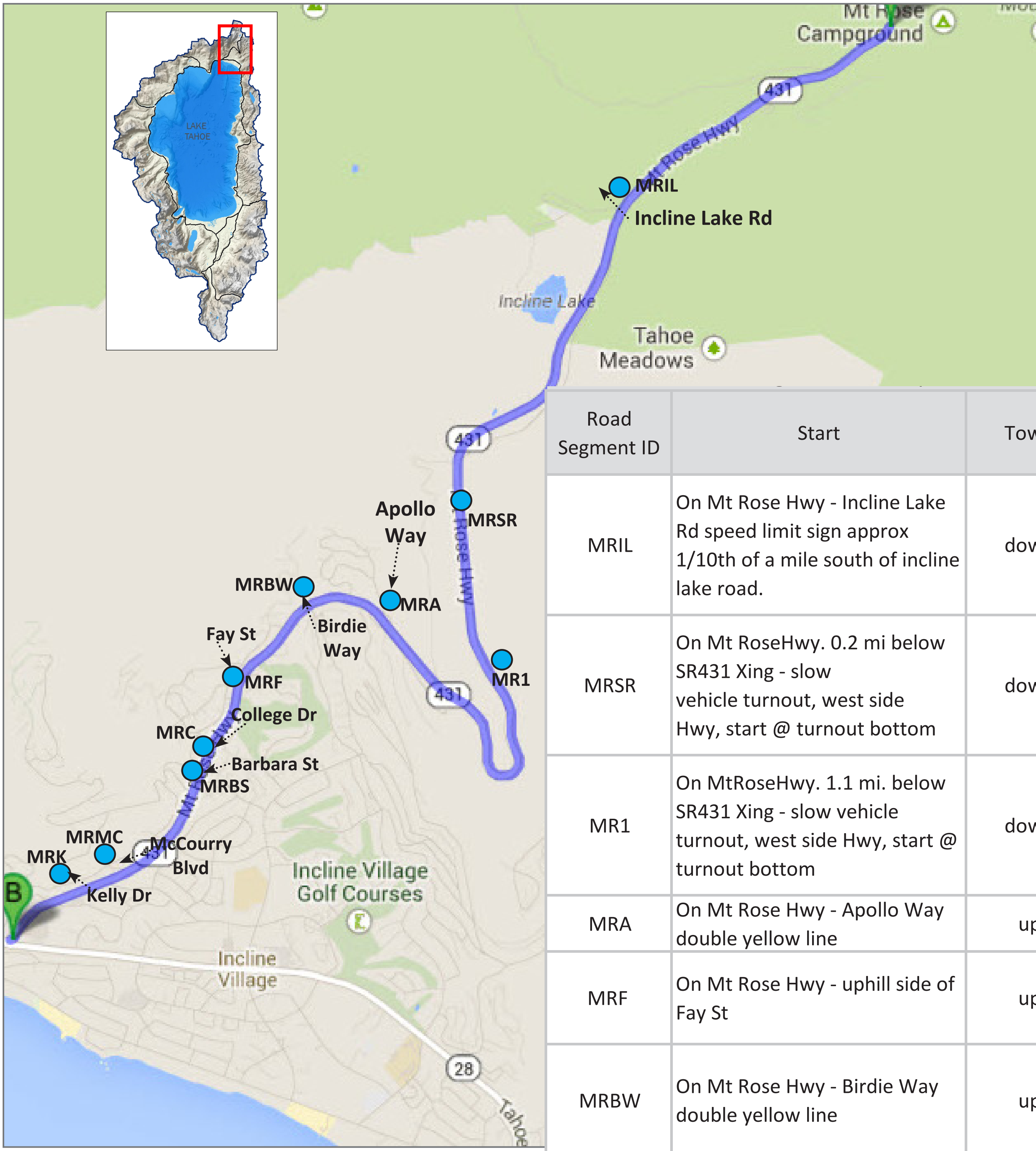
KGID: ROAD NETWORK & SEGMENTS FOR TESTING

FIGURE 5

NDOT Road Network



Road Segment ID	Start	Towards
MRIL	On Mt Rose Hwy - Incline Lake Rd speed limit sign approx 1/10th of a mile south of incline lake road.	downhill
MRSR	On Mt RoseHwy. 0.2 mi below SR431 Xing - slow vehicle turnout, west side Hwy, start @ turnout bottom	downhill
MR1	On MtRoseHwy. 1.1 mi. below SR431 Xing - slow vehicle turnout, west side Hwy, start @ turnout bottom	downhill
MRA	On Mt Rose Hwy - Apollo Way double yellow line	uphill
MRF	On Mt Rose Hwy - uphill side of Fay St	uphill
MRBW	On Mt Rose Hwy - Birdie Way double yellow line	uphill
MRC	On Mt Rose Hwy - College Dr double yellow line	uphill
MRBS	On Mt Rose Hwy - Barbara St double yellow line	downhill
MRMC	On Mt Rose Hwy - McCourry Blvd double yellow line	uphill
MRK	On Mt Rose Hwy - Kelly Dr double yellow line	uphill

Test Road Network: Mt Rose Summit Parking Lot (Hwy 431) to Tahoe Blvd (Hwy 28)
Total Distance: 8 miles

LEGEND

Road RAM Segments
- Pre-existing Segment
- Proposed Segment

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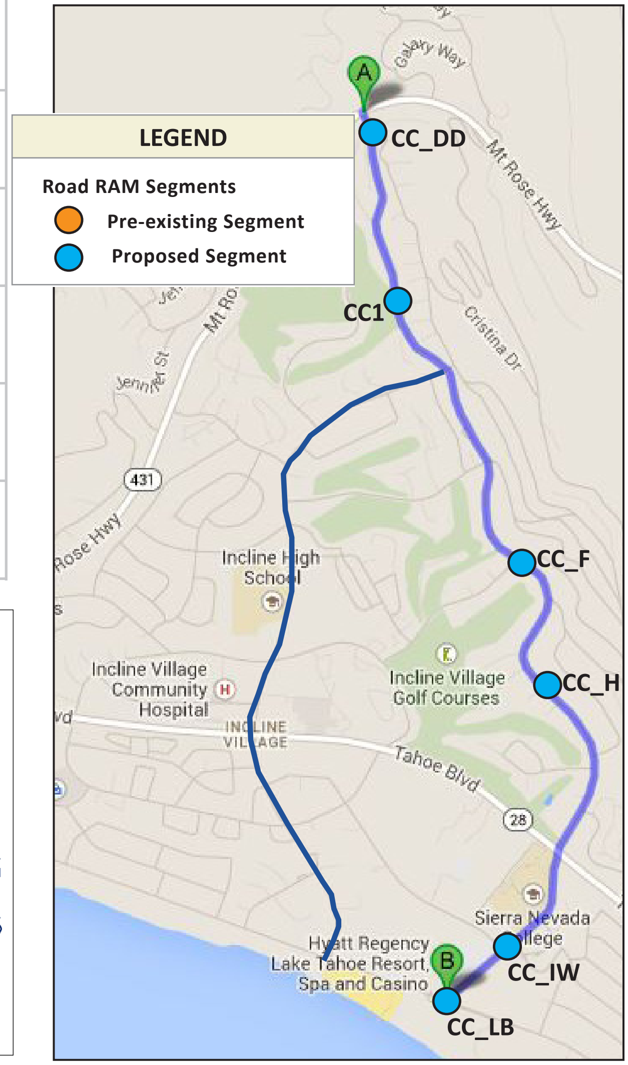
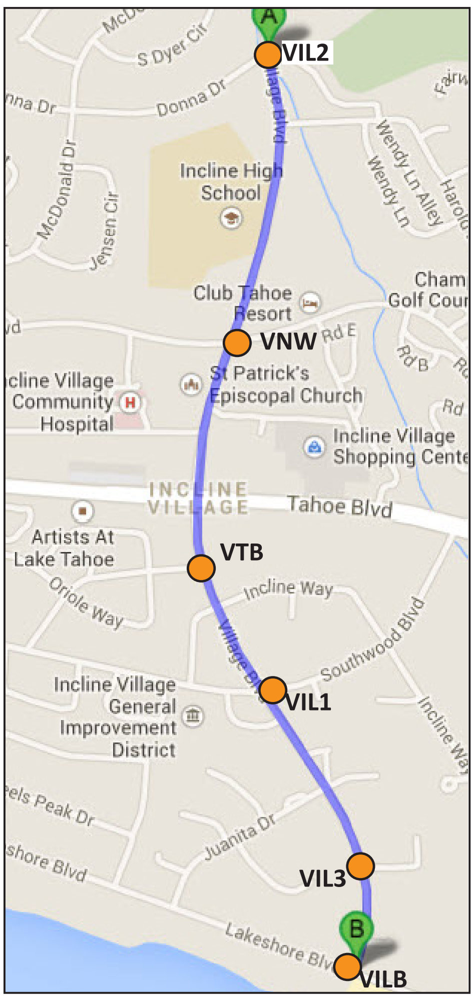
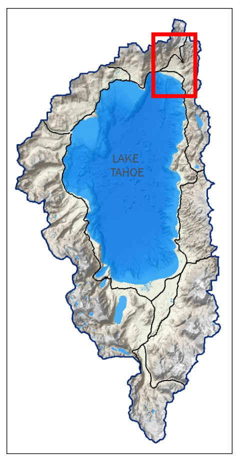
Washoe Road Network

Road Segment ID	Road Segment Description
CC_DD	Begin on Country Club Dr at SE corner with Dana Dr. The road segment continues south on Country Club towards Village Dr.
CC1	Begin approximately 1/4 mile south of Divot Dr on Country Club Drive. The road segment continues south on Country Club towards Village Dr.
CC_H	Begin on Country Club Dr at SW corner with Hook Ct. The road segment continues south east on Country Club towards Tahoe Blvd.
CC_F	Begin on Country Club Dr at NW corner with Fairway Blvd. The road segment continues north west on Country Club towards Village Blvd.
CC_IW	Begin on Country Club Dr at NW corner with Incline Way. The road segment continues north east on Country Club towards Tahoe Blvd.
CC_LB	Begin on County Club Dr at the NW corner with Lakeshore Blvd. The road segment continues north east on Country Club towards Tahoe Blvd.

Test Road Network: Country Club Dr from Mt Rose Hwy (Hwy 431) to Lakeshore Blvd.
Total Distance: 2.8 miles







Test Road Network: Village Blvd from Country Club Dr to Lakeshore Blvd. **Total Dist:** 1.9 miles

VIL2	Begin on Village Blvd on the SW corner with Donna Drive. The road segment continues south on Village towards Northwood Blvd.
VNW	Begin on Village Blvd on the SW corner with Northwood Blvd. The road segment continues south on Village towards Tahoe Blvd.
VTB	Begin on Village Blvd on the corner with Tanager. The direction of the segment is downhill, towards the Lake.
VIL1	Begin on Village Blvd on the corner with Southwood Blvd. The road segment continues south on Village towards Juanita.
VIL3	Begin approximately 1/4 mile south of Southwood Blvd on the NE corner with the private road. The road segment continues north on Village towards Juanita Dr.
VILB	Begin on Village Blvd on the NW corner with Tahoe Blvd. The road segment continues north on Village towards Juanita.

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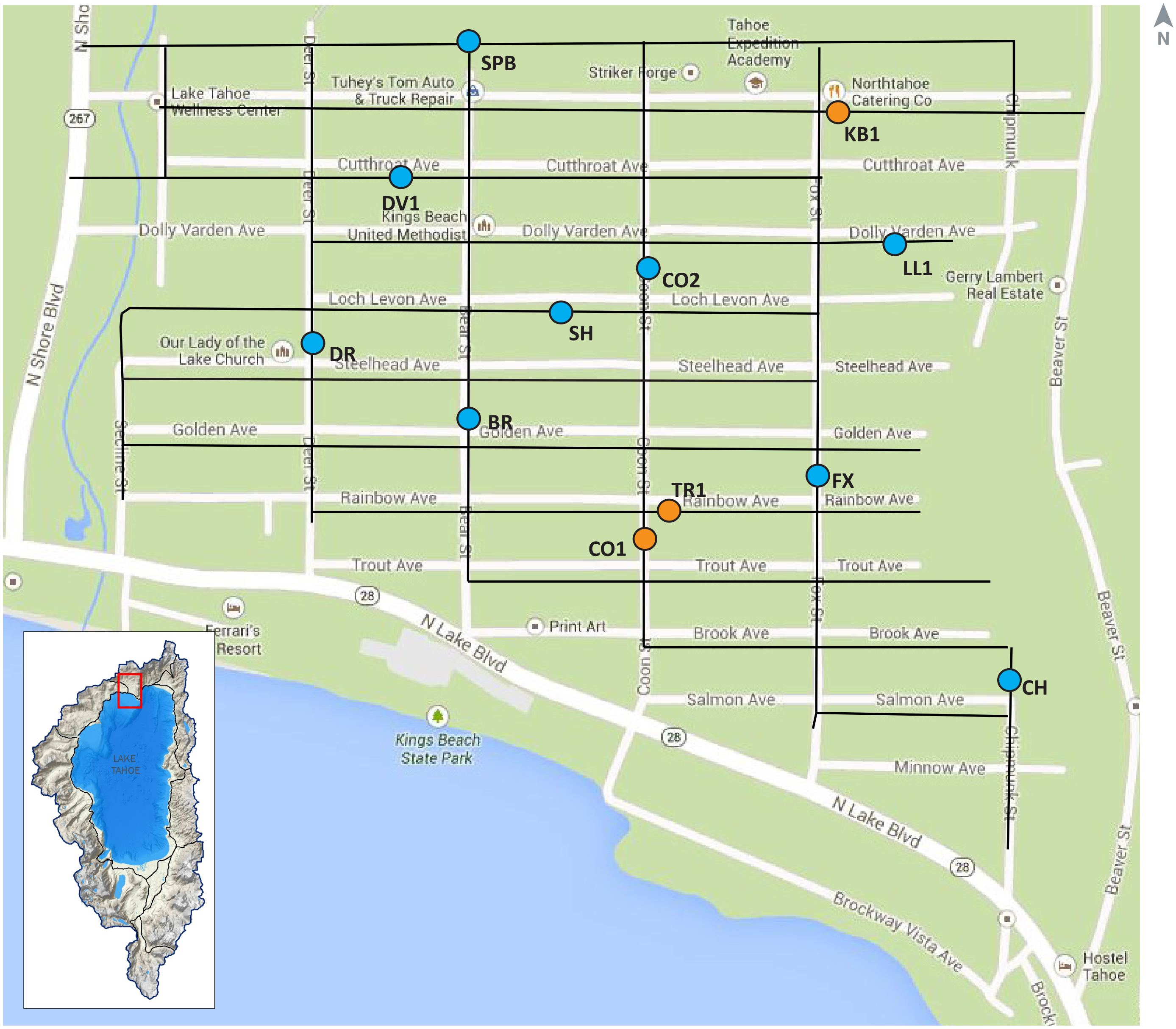
Placer Road Network



Total Road Network: Kings Beach grid. **Total Distance:** ~9.46 miles

LEGEND

Road RAM Segments

- **Pre-existing Segment** (orange)
- **Proposed Segment** (blue)

Road Segment ID	Road Segment Description
BR	On Bear St between Golden and Rainbow Ave.
CH	On Chipmunk St between Salmon and Minnow Ave.
CO1	On Coon St between Brook and Trout.
CO2	On Coon St between Steelhead and Loch Levon.
DR	On Deer St between Golden and Steelhead.
DV1	On Dolly Varden between Bear and Deer St.
FX	On Fox between Rainbow and Trout.
KB1	On Cutthroat Ave, east of the intersection at Fox St.
LL1	On Loch Levon east of Fox St.
SH	On Steelhead Ave between Bear and Coon St.
SPB	On Speckeled at the intersection with Bear St.
TR1	On Trout St east of the intersection with Coon St.

Documenting Road Practices to Test

The documentation of road practices required communication and coordination between the stormwater managers and the road maintenance personnel for each jurisdiction. Table 1 is the collective set of practices and actions that summarize a jurisdiction's road practices conducted on a specific road network. This list was iteratively developed with feedback from the partners. Its purpose is to summarize the road practices with enough detail and consistency that actions implemented on the road influencing condition can be feasibly documented and comparable.

Table 1. Summary of road practices is documented by the following information.

Practice	Description
General Road Operation and Maintenance Information	
Abrasive Type	Type of abrasive applied
% Salt Mixture	Ratio of salt mixed with sand
Spreader Equipment	Equipment used, year purchased
Sweeper Equipment	Equipment used, year purchased
Weather Forecasting Tool	Document what weather source is used
Abrasive Application Strategies	
Application Strategy	Spot sanding versus standard application rate
Sanding Determinants	Document what triggers road operators to sand
Road characteristics used to inform sanding	Identify specific road attributes that influence the amount operators sand: traffic speed, grade, corners, shady areas, weather forecast, stop signs
Pretreatment Strategy	Document any pretreatment strategies utilized and when they are used
Source Recovery Strategy	
Post storm - method used to recover material	Document methods used to recover material following a storm
Post storm - time frame of recovery	Record how soon after a storm crews recover material
Sweep frequency: winter	Document standard sweeper frequency in winter
Sweep frequency: spring	Document standard sweeper frequency in spring
Sweep frequency: summer/fall	Document standard sweeper frequency in summer
Optimization of sweeper accessibility	Identify any practices implemented at the road network to increase sweeper's accessibility to roadway; example parking regulations

Table 2 summarizes the practices and general strategies implemented by each jurisdiction for WY14-WY15 on the designated road networks. Road practices definitions and strategies from participating jurisdictions were collected and documented by interviews and surveys with road operators conducted by Dick Minto (project team).

Daily Road Practice Chronology

In addition to the general approach and equipment used on each test road network, a daily chronological record of the amount of material put down and efforts to pick it up were recorded (Appendix A). Accurate daily road operation records from participating jurisdictions were a critical component for RO&M testing that link the cause and effect between road practices and road condition. The project team provided a Microsoft Excel template to assist groups without a data tracking process to record required daily data for

Summary of Road Practices Implemented by Jurisdiction

Practice	Caltrans	CSLT	KGID	NDOT	Placer	Washoe
General Road Operation and Maintenance Information						
Abrasive Type	Caltrans Spec H	Caltrans Spec H	Washed Concrete Sand	Spec D	Caltrans Spec H	Spec D
% Salt Mixture	None	25%	17%	25%	<1%	25%
Spreader Equipment	Swensen (x7) (1998-2005)	unknown	Contracted out	Flink (x3) (1998 -2000)	Oshkosh (x2) (1986) International- DT 466E (2002)	Epoke - Sirius 3500 (2004) Meyers - (2013)
Sweeper Equipment	Global (x2) (2013) Elgin (rented)	Tymco - DST6 (2008) Athey -M9-D (1998)	Schwarze - A700 (2000)	Tennant - Centurion (2002)	Elgin - Waterless Eagle (2013) Johnston - 4000 (2005)	TYMCO - DST6 (2010 & 2013) Tennant -Sentinel (2014)
Weather Forecasting Tool	7 various weather sites	NOAA	NOAA	RWIS, paid meteorologist computer, local news, NWS	NOAA	Paid meteorologist, NWS, TV, Radio, computer
Abrasive Application Strategies						
Application Strategy	Combination of spot sanding or entire road	Sand maps/Spot sand when possible	Implemented spot sanding (2014)	Sand routes/spot sand intersections and trouble spots when possible.	Sand routes/Spot sand intersections and trouble spots when possible.	Spot sand intersections, steep grades. Aim to minimize application and maintain safe roads
Sanding Determinants	Driver safety	Driver safety	Driver safety	Driver safety	Driver safety	Driver safety
Road characteristics used to inform sanding	Traffic and speed limit Road characteristics (grade, corners, shade) Weather forecast/temperature	Traffic and speed limit Road characteristics (grade, corners, shade) Weather forecast/temperature	Traffic and speed limit Road characteristics (grade, corners, shade) Weather forecast/temperature	Traffic and speed limit Road characteristics (grade, corners, shade) Weather forecast/temperature	Traffic and speed limit Road characteristics (grade, corners, shade) School zones and bus stops Weather forecast/temperature	Traffic and speed limit Road characteristics (grade, corners, shade) Weather forecast/temperature
Pretreatment Strategy	Use salt and brine as feasible	No	No	Use salt and brine as feasible	No	Use salt and brine as feasible
Source Recovery Strategy						
Post storm - method used to recover material	Sweep by area Heaviest sanded first	Sanding routes, heaviest areas sanded first	Sanded roads, heaviest sanded first	Sanded roads, heaviest sanded first	Sanded roads, heaviest sanding first	Sanded roads, heaviest sanding first
Post storm - time frame of recovery	As soon as conditions allow	As soon as conditions allow	Within 1 wk of abrasive application	As soon as weather allows & sweeper available	As soon as weather allows	As soon as weather allows
Sweep frequency: winter	Continuous scheduled sweep events	ASAP after sand event	Continuous sweeping/ASAP after sand event	ASAP after sand event	Continuous sweeping/ASAP after sand event	Continuous sweeping/ASAP after sand event
Sweep frequency: spring	Continuous scheduled sweep events	ASAP after sand event	Continuous sweeping/ASAP after sand event	ASAP after sand event	Continuous sweeping/ASAP after sand event	Continuous sweeping/ASAP after sand event
Sweep frequency: summer/fall	Sweep 1x/month or as needed	Sweep as needed	Sweep as needed	Sweep as needed	Sweep as needed	Sweep 1x/6 weeks
Optimization of sweeper accessibility	No regulations for optimization	No regulations for optimization	No regulations for optimization	No regulations for optimization	No regulations for optimization	No regulations for optimization

testing (Figure 9). Daily chronology data aimed to track the following RO&M information from the specific road network tested to document all relevant road actions performed at the test network:

- Date (m/d/yy)
- Sand - amount of abrasives (sand) applied within road network (cu-yds)
- Salt – amount of salt applied for deicing within network (cu-yds)
- Brine – gallons of brine applied
- Sweeper recovery – amount of abrasives swept in sweeping effort (cu-yds).

At the onset of the study, most jurisdictions already had a RO&M record keeping practice in place and used their established system to submit daily RO&M information. Several municipalities (4 groups) tracked RO&M data for a larger network than the test roads designated for the study. Consequently, RO&M data submitted by these groups was scaled down to represent the test network and these estimations may introduce some sampling error to the values. Road chronology information submitted by the jurisdictions was used to calculate annual road practice metrics (Table 3).

Table 3. Annual Road Practice Metrics calculated. ***Bolded italicized*** metrics indicated metrics selected and utilized for the final data analysis and presentation

Metric	Definition
Total Abrasives Applied	Cumulative volume (cubic yards) of abrasives applied at selected road network over water year.
Total Abrasives Applied per Center Mile	Cumulative volume of abrasives applied per center mile at road network (total abrasive applied/network road length) during water year. Total volume of abrasives applied includes salt mixed with abrasives.
Average Abrasive Residence Time (days)	Average number of days between abrasive application and a sweeping event.
Total # of Sand Events	Cumulative number of instances road crews applied abrasives on road network during water year.
Total Salt Applied	Cumulative volume (cubic yards) of salt applied to road network as pre-treatment during water year.
Total Brine Applied	Cumulative volume (gallons) of brine applied to road network during water year.
Total Brine Applied per Center Mile	Cumulative volume of brine applied per center mile at road network (total brine applied/ network road length) during water year.
Total # of Sweep Events	Cumulative number of instances road crews swept road network during water year.
Total Volume Swept	Cumulative volume of material recovered at road network during water year.
Total Volume Swept per Center Mile	Cumulative volume of material recovered per center mile at road network (total volume swept/network road length) during water year.

4.1.2 ROAD CONDITION MONITORING

Road condition was evaluated periodically at the test networks over the course of RO&M practices effectiveness testing using Road RAM. All observations were made by two RAM personnel for road segment at a given time. Road RAM data collection involved an initial effort to designate and establish safe road segments

Daily Road Operations Chronology

Jursidiction: Road Ops Log					
April-15					
SR431 mile post 0.00 to 8.00					
Day	Salt	Sand	Brine	Sweeper recovery	Notes
	cu-yds	cu-yds	gallons	cu-yds	
1				4.00	
2				4.00	
3	2.00				
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14	6.00		6.00	4.00	
15				8.00	
16					
17	2.00	2.00	300.00	4.00	
18					
19					
20				2.00	
21				2.00	
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
Total	***10.00***	***2.00***	***306.00***	***28.00***	

Example road operation log from WY14-WY15 RO&M testing

DESIGNED BY
2NDNATURE LLC
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DAILY ROAD OPERATION CHRONOLOGY DATA TEMPLATE

FIGURE 9

where road condition was measured, and continuous effort of coordination with the project team and partners to collect RAM observations.

In the first year of the study there was some discussion regarding adjusting Road RAM protocols to focus only on the road right of way that jurisdictions manage. Many jurisdictions have roadways with adjacent continuous impervious area that they do not maintain (e.g., sidewalks) or are difficult to clean with a sweeper (e.g., impervious drainage ditches) and the project team received feedback from municipalities that including continuous impervious surfaces in Road RAM was not justified. However, the fact remains that abrasives and fine sediment material will accumulate in those locations and will be transported downslope during a runoff event. More than likely, the source of sediment in these locations is due to abrasive application on the roads, and therefore jurisdictions should be mindful of how their practices are affecting impervious areas where pollutant recovery is more challenging. After considering all perspectives, the project team conducted Road RAM protocols per the written protocols. The sections below provide more detail of the steps carried out by the project team to collect road condition observations.

Road Segment Selection

Road RAM observations are conducted on road segments, a standardized 10,000 square foot area of the road. For this study, twelve road segments were selected within each road network. The population of 12 road segments increased confidence that the road condition observations would be representative of the network as a whole and provided flexibility in case a road segment became inaccessible for any reason.

Figures 3-8 shows and describes the 12 road segments within each jurisdictions network. Segments were initially designated by the project team from a computer using google street view and were later field verified, and in some cases relocated for the following considerations:

1) Personnel field safety. Road RAM observations are conducted by field personnel outside of the car, taking measurements across the 10,000ft^2 area. Segments were selected on straight, flat sections of road where visibility in either direction was no less than 300ft.
2) Ensure segment is representative of the entire road network. As much as possible, selected segments were characterized by similar pavement condition index (PCI), relatively consistent seasonal contribution from other sources, and similar accessibility for sweeper equipment.

Frequency

Road RAM observations were conducted periodically over the course of the water year with a majority of observations performed in winter and spring. Observations are concentrated in the late winter/spring months, when the stormwater runoff events are more frequent and therefore the bulk of the sediment loading is likely to occur. Observations were scheduled a minimum of 1 week following a snow storm event, to allow road maintenance personnel sufficient time to perform sweeping and ensure road conditions are a result of implemented practices.

The Crediting Program recommends a minimum of 4 observation periods throughout the year to verify the expected road condition scores. Because this research aimed to inform PLRMv2 average annual inputs, the project team conducted more Road RAM evaluations than required by the Crediting Program (Table 4). In total, road networks were evaluated 7 times in WY14 and 5 times in WY15.

Table 4. Seasonal distribution of recommended CAP minimum number of observations and the Road RAM observations periods conducted for this study

Season	CAP Min # of Observations	WY14 # of Observations	WY15 # of Observations
October - January	1	1	2
February – May	2	4	3
June – September	1	2	0
WY Total	**4**	**7**	**5**

Coordination

Prior to each Road RAM observation period the project team coordinated with jurisdictions, RAM field personnel, stakeholders, and traffic control teams, and monitored weather patterns to ensure RAM observations were feasible. All 6 road networks were sampled during each observation period, making coordination between all participating jurisdictional parties a considerable effort. NTCD managed RAM scheduling and contacted jurisdictions a minimum of 1 week ahead of the RAM event. Jurisdictions with high traffic roads (NDOT and Caltrans) and some with moderate traffic roads (Washoe) elected to provide traffic control to ensure Road RAM personnel safety while in the drive lane. RAM field personnel arranged RAM start times with jurisdictions providing traffic control to minimize any waiting time by road traffic personnel.

Observations

During each observation period, 4 of the 12 road segments were randomly selected for Road RAM observations at each network. The random selection of road segments ensured road condition results were representative of the larger network. Observations across all 6 jurisdictions were typically carried out over 2 consecutive days, where NTCD performed RAM observations 1 day at the south shore and 1 at the north shore. Personnel performing Road RAM field observations (primarily by NTCD, with occasional data collection support from 2N and NDEP) followed field protocols provided in detail at www.tahoeroadram.com.

User Precision

User precision between Road RAM field personnel was crucial in demonstrating the differences in road condition were due to differences in road condition and not a result of user error or sampling variability. The project team's primary field personnel (2N and NTCD) prioritized assessing user precision between the two groups and across users. The Road RAM tool targets a user precision of +/-0.5, or half a RAM score. Table 5 displays results from user precision testing for this study, indicating the results are within the accepted precision range.

Table 5. 2N and NTCD Precision Testing Results

Metric	Value
Total # of precision observations	45
Average difference in precision observations	0.3
# observations where difference is 0 (% of total)	3 (7%)
# observations where difference is >0.5 (% of total)	2 (4%)

Qualification of Other Factors

Road RAM observations generate a 0-5 score representing the estimated FSP concentration that would be generated from the road segment should a runoff event occur. The RAM segment score is extrapolated to the road network by averaging the road segment scores. The primary source of FSP on roadways is from abrasive applications and other material source that is then pulverized by vehicular traffic (LRWQB and NDEP 2014). There are a number of other sources of sediment that can be introduced to the road network, as well as a number of factors outside of the jurisdiction's control that can influence the ability of road operators to recover material effectively (see Figure 2). The primary FSP sinks are either effective sweeping or a runoff event (e.g., rain, snowmelt).

Throughout this study, each jurisdiction was faced with these 'other factors' within their test road networks at different times and at differing levels of impact to road condition. In an effort to qualify the influence of other factors on each road network, interviews were conducted with road operators and stormwater managers to document the impact of 4 other factors as defined in Figure 10: (1) other sources of sediment to the road network; (2) sweeper performance and reliability; (3) road accessibility; and (4) pavement condition index (PCI). Road supervisors communicated the relative influence of each factor on its road network by season and the project team translated these to 0-5 annual scores (where 5 is indicative of little to no impact from the 'other factor'). Estimates of the impact of factors and the amount of roadway influenced were not exact and intended to be relative, however, by qualifying each factor, road managers considered what outside factors could be contributing to observed road condition scores over the duration of the study.

4.1.3 ROAD PRACTICE AND CONDITION DATA MANAGEMENT

The project team set up RO&M networks and segments by participating jurisdictions in Tahoe Road RAM (www.tahoeroadram.com), following the steps outlined within the tool. All observation results were directly entered into the tool for data management and automated spatial extrapolation of the road segment results to the respective test road networks. RAM observations were into Road RAM within 5 days of the observation. Data entered into the tool is saved to the online database. After entering data into Road RAM to generate scores, NTCD shared segment RAM scores with each jurisdiction. Additionally, Road RAM segment scores were managed in a master excel spreadsheet that tracked observation date, road segment name, and score.

Once a month the project team requested the road operation records from each jurisdiction including daily chronology of abrasives, salt and brine applied and the volume swept at the test network. Road operation data shared by jurisdictions were entered into a master spreadsheet that tracked daily road operations from each participating jurisdiction over the course of the study.

Other Factor Metrics Qualification

Other Sources of Sediment to Road

Roads can have significant contribution of sources of sediment other than road abrasives, examples may include tracking from private property, construction, driveways, adjacent erodible surfaces, road degradation, etc. Road managers were asked to estimate the severity/frequency of other sources at the test road network by season. The values in the matrix are % of season and sum to 100%.

Frequent = >75% of season; Occasional = >10% and < 75 % of season; Rare =<10% of the season

Frequency of other sources	**Winter to Spring (Nov 1 2013- May 31 2014)**			**Summer to Fall (Jun 1 2014-Oct 31 2014)**		
	Area of Road Network Influenced					
	> 75%	25-75%	<25%	> 75%	25-75%	<25%
Frequent			**10**			**20**
Occasional						
Rare	**90**			**80**		

Sweeper Performance

Sweeper availability and performance can influence the sweeping effectiveness per unit effort. Jurisdictional road managers were asked how well the sweepers performed in regards to availability, reliability, and performance with respect to removing material from road surfaces. The values in the matrix are % of the season and sum to 100%. *Optimal = sweeper is always available when needed and performs to manufacturers specs. Acceptable = sweeper is available when needed and performs adequately. Unreliable = Sweeper is frequently unavailable, and or performs poorly.*

Frequency	**Winter to Spring (Nov 1 2013- May 31 2014)**			**Summer to Fall (Jun 1 2014-Oct 31 2014)**		
	Sweeper Performance					
	Optimal	Acceptable	Unreliable	Optimal	Acceptable	Unreliable
Rare			**10**			**20**
Occasional		10				
Frequent	**80**			**80**		

Road Accessibility

Barriers in the road way can result in the sweeper not being able to access all paved areas within the network. Road managers were asked to estimate what portion of the road surface was accessible when sweeping. Barriers include anything that obstructs the sweeper from sweeping the road surface (e.g., parked cars, construction, ice, snow berms, snow poles, armored pavement, speed bumps, sidewalks, etc.). The values in the matrix are % of road network and must sum to 100%.

Frequency Barriers Exist	**Winter to Spring (Nov 1 2013- May 31 2014)**			**Summer to Fall (Jun 1 2014-Oct 31 2014)**		
	Area of Road Network Accessible					
	> 75%	25-75%	<25%	> 75%	25-75%	<25%
Frequent		**50**			**50**	
Occasional		**50**			**50**	
Rare						

Interpretation of the table above indicates in the winter - spring season a small amount of road network (<25% or less) is frequently influenced by other sources (10% of the season). The remaining road network is rarely impacted.

Qualifying other factors: road managers indicated what portion of the road network was influenced by season. The project team translated this information to a 0-5 scale (5 indicative of good condition, or little impact from the 'other factor'). Seasonal scores were weighted (winter spring season accounted for 0.6 of score and spring fall represented 0.4 of the average) to report the other factor influence by water year.

4.2 Road Operation and Maintenance Costs

The project team developed a process to estimate comparable costs incurred by jurisdictions to implement defined RO&M practices on test network. The initial intended approach to estimate fully burdened costs for winter storm management and source recovery efforts proved challenging for jurisdictions to extract or estimate given their extreme differences in record keeping practices. Consequently, these initial cost estimates were not consistently generated and therefore not meaningfully comparable across jurisdictions. An alternative approach to estimate more comparable RO&M costs used standard hourly rates for equipment, supplies and operators. This approach was developed to allow simple generation of relative consistent and comparable costs across jurisdictions. Both approaches are reviewed below with the hope that future attempts to track and estimate RO&M costs by jurisdictions may consider developing practice-specific fully-burdened cost estimates.

4.2.1 INTENDED COST ANALYSIS APPROACH

The intended approach to obtain reasonable annual cost estimates requested cost information related to sweeping and abrasive RO&M practices and included capital cost of equipment, annual maintenance costs, and fully burdened operator hourly rates. Below lists the cost information requested from jurisdictions for all pieces of equipment (sweepers and sanders) used within the test network:

- Capital cost of equipment (CC)
- Year equipment purchased
- Lifespan of equipment (years) (LS)
- Annual maintenance cost (MC)
- Total # of hours / year equipment used (T)
- Fully loaded operator hourly rate (Op)

In this approach, the cost information is paired with the daily chronological data recorded by road operators to calculate annual RO&M costs using Equations 1 & 2.

Eq. 1: Fully Burdened Sweeper Hourly Rate $= ((CC_s+MC_s)/T_s) + Op$*, where:*

CC_s *= Sweeper capital cost per year as average over expected lifespan (CC/LS)*
MC_s *= Sweeper annual maintenance cost per year*
T_s*= Hours sweeper used per year*
Op = Operator fully burdened hourly rate

Eq. 2: Fully Burdened Abrasive Application Hourly Rate $= ((CC_a+MC_a)/T_a) + Op$*, where:*

CC_a *= Abrasive applicator capital cost per year as average over expected lifespan (CC/LS)*
MC_a *= Abrasive applicator annual maintenance cost per year*
T_a*= Hours abrasive applicator used per year*
Op = Operator fully burdened hourly rate

Significant time and effort were expended by the project team and jurisdictions to obtain the cost information to complete the intended standardized approach. A number of barriers were experienced:

- Significant inconsistency in cost information management and reporting, including but not limited to:
    - Estimation of annual maintenance cost per piece of equipment is not consistently tracked between jurisdictions.
    - Tracking of sanding equipment capital and maintenance costs are not kept or accessible to several jurisdictions.
    - Management of capital cost records for equipment used is inconsistent between road and stormwater managers for some jurisdictions.
    - Documentation of the annual hours of operation per equipment across jurisdictions is inconsistent
    - Equipment used by each jurisdiction varies over time and at various stages of life cycle. Jurisdictions that manage cost information via depreciation have incomparable estimates to others jurisdictions.

- Winter storm maintenance practices and support records vary significantly relative to storm type, temperature, and timing of response and jurisdictional resources accessible at the time of response. It is too complicated to keep reliable records within a jurisdiction that distinguish hours of operation to plow, brine and/or apply abrasives during a storm, let alone attempt to compare annual winter storm maintenance records between jurisdictions. The approach to estimating the annual capital equipment costs used for winter storm maintenance has proven extremely challenging.

- Annual costs of sweeping practices are tracked by jurisdictions with better consistency than winter road maintenance due to the use of a single piece of equipment, a single operator and standard route maps. However, in many instances jurisdictions have multiple sweepers and time of use of each unit on the test network is not accurately documented and requires estimates in many instances.

4.2.2 ALTERNATIVE COST ANALYSIS APPROACH

In response to the challenges and barriers to obtain the data for the approach above, the project team developed an alternative approach to estimate road maintenance where expenditures and efforts are comparable across jurisdictions. Using available data and input from each jurisdiction, a range of reasonable average rates were developed to be consistently applied to all jurisdictions. For abrasive application, fully burdened rates including equipment and operator costs are based on spreader type (Table 6). In the RO&M study the costs for both the Epoke and conventional style spreader were set at $125/hr to assign an appropriate relative cost to applying sand. In jurisdiction road practice records, the actual time spent applying abrasives is a rough estimate, given the multiple winter maintenance tasks (sanding, plowing, blowing, etc.) that road operation crews are often completing during storm events. Based on conversations between jurisdiction road crews and Dick Minto (project team), a flat rate was applied for all spreaders to minimize error associated with record keeping and keep costs relative and comparable. For sweeping, the fully burdened rate depends on sweeper type and typical annual maintenance costs (Table 7). Sweeper maintenance costs are informed by the annual maintenance costs incurred in the previous water year. Standardized material costs for salt, brine and various type of sand specs used in Tahoe Basin were reported by road operators (Table 8).

Table 6. Fully Burden Rate for Abrasive Application

Abrasive Application Equipment Cost	
Spreader Type	Rate/Hr
Epoke Style	$125
Conventional	$125

Table 7. Fully Burden Rate Sweeping

Sweeping Equipment Hourly Rate			
Sweeper Type	Typical Annual Maintenance Costs		
	High (>$20K/yr)	MOD	Low (<10K/yr)
Vacuum Assist	$225	$200	$175
Regenerative Air	$175	$150	$125
Mechanical Broom	$150	$125	$100

Table 8. Material Applied in Tahoe Basin during test period

Material Cost	
Sand Spec	$/Cu-yd
Salt	$45
Sand D	$15
Sand H	$30
Washoe Concrete Sand	$53
Brine	$0.13/gallon

Estimated winter maintenance and sweeping costs incurred by each jurisdiction were calculated based on the type of equipment used, amount of abrasive and other material applied within the test network, and average time to sand and sweep the test network as reported by each jurisdiction's road operator. Using standard rates of hourly costs of equipment between jurisdictions allowed for consistency across jurisdictions to generate reasonably comparable costs per year per center mile for each collection of practices.

Example Process to Calculate Costs

In WY14 *Jurisdiction A* used a conventional style spreader and regenerative air sweeper with moderate maintenance costs. It took Jurisdiction A 1 hour to sand its network and 4 hours to sweep its 4 mile road network. Jurisdiction A sanded its network on 12 separate occurrences, applying a total of 6 cubic yards of Spec H sand and conducted 16 sweeping events.

How to calculate RO&M cost

1) Select appropriate rate/hr for abrasive application equipment
   a. Conventional - $125/hr
2) Determine the number of hours sander in use
   a. 12 applications at 1 hr each = 12 hrs
3) Calculate cost of abrasive application
   a. ($125/hr x 12hrs) + (6 cu-yds * $30/cu-yd) = $1,680
4) Select appropriate rate/hr for sweeper used in test network
   a. Regenerative air with moderate maintenance costs - $150
5) Determine number of hours sweeper in use
   a. 16 sweep events at 4 hr each = 64 hrs
6) Calculate cost of sweeping
   a. $150/hr x 64 hrs = $9,600
7) Sum cost of abrasive application and sweeping costs
   a. $1,680 + $9,600 =$11,280
8) Divide by network center miles (cm) to normalize costs by center mile

4.2.3 RO&M COST CALCULATOR

A cost calculator was developed by the project team within Microsoft Excel to simplify and standardize the RO&M cost calculation process. For each jurisdiction, the type of equipment used, annual maintenance costs (for sweepers), and type of abrasive applied were selected from dropdown menus. The calculator automatically populates the total cost by water year for winter storm treatment costs and sweeping costs. The calculator has been designed to assist users implementing RO&M practices effectiveness testing in the future by providing a template for road operators to track daily road practice chronology that is linked directly to the cost calculator, streamlining the data collection and analysis process. The road operations testing template can be downloaded from 2NDNATUREs website: http://www.2ndnaturellc.com/client-access/road-ops-files/ or contact 2NDNATURE directly for a copy.

4.3 Data Collection Lessons

The development of the experimental design was an iterative process that required a high level of coordination between the project team, stormwater managers, road managers and other stakeholders. The participation required of various personnel was demanding at times, and a number of lessons have been learned through the development of the data collection process.

- A critical project goal was to ensure a feasible and informative approach to information collection and data management. This proved to be an iterative process with constant vetting and refinement of draft ideas and formats with the jurisdictions, project team and regulators. Based on the feedback and lessons learned, a detailed Road Operations and Maintenance Practices Effectiveness Testing User Guidance has been created by the project team (2NDNATURE and NCE 2015) that contains the recommended experimental design for future RO&M practices effectiveness studies. Given the iterative nature of this preliminary testing effort and associated limited funding to continue the testing, as expected some components were not fully implemented as recommended by all of the partners.

- There was a high level of participation in this study by road maintenance personnel, including attendance in stakeholder meetings. The collaborations and discussions between road and stormwater managers has been critical to creating a better understanding of the role water quality minded road operations could have for their jurisdiction, as well as the clarity of the Lake.

- The standardized costs developed under the alternative cost analysis are based on conversations with the jurisdictions and complicated by the differences in road maintenance tracking and accounting practices by each entity. These estimates can continue to be refined and improved as jurisdictions continue to consider adjustments to their road programs and develop data management systems to better track road maintenance related practices and associated costs.

5 Climatic Context

The severity of the winter will have a direct impact on the road practices conducted within a road network. More mild winters are warmer and have less snow and less frequent freezing conditions, requiring less road operation actions, while more extreme winters will demand more intense actions to maintain driver safety while minimizing potential roadway water quality impacts. Completing the effectiveness testing over a range of winter severities (i.e., an above and below average winter) will improve confidence that the measured Road RAM scores input into PLRM are representative and attainable during more severe winter conditions. Recall that PLRM requires input of a single road condition score that represents the average annual.

The project team developed a simple Tahoe winter severity index (WSI) to provide the climatic context in which road operations are conducted each year, using the Tahoe City gauge operated by the Western Regional Climate Center (WRCC; www.wrcc.dri.edu). The intent is to create a WSI that simply integrates temperature and precipitation in a meaningful way, knowing that the greatest winter road challenges to protect driver safety are large snow events followed by consecutive below freezing days. Using the historic 84-year daily maximum air temperature record (1932-2015), the frequency of cold days (max temp < 33°F) was calculated for each water year winter. This frequency was multiplied by the WY precipitation totals to determine the WSI. The 84 year data set yielded a WSI range from 0.00 to 11.8. A frequency analysis was performed to define 5 WSI types. Table 9 classifies the winter severity and provides a manner to reasonably estimate water year severity for RO&M practices effectiveness testing. Applying these definitions, Table 10 displays the winter severity index categories for WY05-WY15. As noted in Table 10, the two years that were monitored during this study were below average years with respect to winter severity.

Table 9. Winter Severity Index Classification based on Tahoe City gauge (#48758)*

WSI Year Type	WSI Recurrence	Winter Severity Index (WSI)[+]		Annual WSI Exceedance	n
		Lower	Upper		
Very Mild	12	<0.47		>91	7
Mild	4	0.48	1.53	>67	21
Average	3	1.54	2.81	>33	28
Extreme	4	2.82	4.48	>10	20
Very Extreme	10	>4.49		<10	8
Long-Term Average Winter Severity Index = 2.38					
Water Year Record = 1932-2015					

*Tahoe City gauge (#48758) operated by the Western Regional Climate Center; Elevation: 6230 ft; http://www.wrcc.dri.edu/. [+]WSI calculation: Count # of freezing days (max daily air temp <33°F) from Oct 1 – May 31 (243 days). ((# of freezing days / 243) *100) * WY total precipitation = WSI

Table 10. Winter severity index and type for WY05-WY15 based on frequency analysis of the 84-year record at Tahoe City gauge (see Table 9). The water years included in this research are highlighted by type for easier reference.

WY	Winter Severity Index	WY Severity
WY05	1.56	Average
WY06	2.98	Extreme
WY07	1.46	Mild
WY08	1.90	Average
WY09	2.69	Average
WY10	1.08	Mild
WY11	2.96	Extreme
WY12	0.83	Mild
WY13	1.95	Average
WY14	**0.64**	**Mild**
WY15	**0.22**	**Very Mild**

6 Results

Figure 11 contains the overview summary of road condition, road practices, and associated costs for each jurisdiction for WY14 and WY15. The two water years of data are integrated to provide comparable average annual results based on the data obtained. Results with a data interpretation are presented below in Chapter 6 which includes a comparison of the jurisdictions' road practices to road condition results and cost effectiveness given the data obtained.

6.1 Road Practices Summary

Results provided within this document that refer to road operation practices, such as road abrasive application, abrasive application volumes, sweeping events, and swept volumes, are based on information provided by the jurisdictions. Metrics under the header "Road Practices Summary (WY)" present the most valuable metrics related to road condition. Preliminary results were circulated among participating jurisdictions and changes and corrections were encouraged. Record keeping of road practices performed on the specific test networks was a limitation for this study, and as a consequence some final values are likely inaccurate. Notes have been added to Figure 11 with any information where the jurisdictions indicated the value provided was questionable or grossly estimated.

6.2 Cost Summary

Annual costs incurred to implement road practices at the test network were calculated for each jurisdiction and presented in Figure 11 as cost per center mile under the "Cost Summary (WY)" header. Unit costs are presented as winter treatment and sweeping. Unit costs are added to document total annual costs per center mile per water year, termed RO&M in Figure 11.

- Winter treatment costs are an estimate of the fully burdened cost to implement abrasive, salt and brine application (if applicable) on the test road network. Costs include the material supply costs and the hourly sander rate, including operator costs, as described in Chapter 3.2.2. The total number of sand events and the total volume of material applied were the primary drivers of the winter treatment costs.

- Sweeping costs characterize expenditures associated with material recovery and estimate the fully burdened cost to implement sweeping operations at the test road network. Sweeping costs included sweeper equipment, annual maintenance, and labor costs, as discussed in Chapter 3.2.2. Total number of sweep events, sweeper type, and estimated annual maintenance costs were the primary drivers influencing total costs incurred.

6.3 Road Condition Summary

Each observation period measured road condition at 4 road segments at all 6 jurisdiction's road networks, with the exception of Caltrans where two observation periods were missed in April 2014. Twelve Road RAM observation periods occurred over the study's duration, resulting in a total of 280 observations or 48 observations for each network (40 in Caltrans). Figure 12 graphically summarizes Road RAM scores by

Road Operation & Maintenance Practices Effectiveness Testing Results

	Caltrans		CSLT		KGID		NDOT		Placer		Washoe	
Water Year (WY)	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015[1]
Winter Severity Index	Mild	Very Mild	Mild	Very Mild	Mild	Very Mild	Mild	Very Mild	Mild	Very Mild	Mild	Very Mild
Network Road Length (CM)	5		3.1		1.6		8		8.3		4.1	
Road Condition Summary (WY)												
Annual RAM Score	2.5	3.4	3.4	3.8	3.2	3.7	2.6	3.1	2.9	3.7	3.8	4.0
RAM Observations	5	5	7	5	7	5	7	5	7	5	7	5
Road Network Precision	0.4	0.5	0.6	0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5
Road Practices Summary (WY)												
Total Abrasives Applied (cu-yds)	31	18	21	12	19	86	131	182	21	15	8	6
Total Abrasive Applied/ center mile (cu-yds/CM)	6.2	3.6	6.7	3.7	12.0	53.8	16.4	22.8	2.5	1.8	1.8	1.5
Total # of Sand Events	25	17	25	8	4	36	33	34	15	11	18	10
Average Abrasive Residence Time (days)	3	4	5	3	13	11	13	7	8	12	5	19
Total # of Sweep Events	55	52	50	33	37	20	18	41	18	9	12	9
Total Volume Swept (cu-yds)	161	186	192	222	15	68	151	293	133	111	82	9
Total vol swept/center mile (cu-yds/CM)	32	37	62	72	9	43	19	37	16	13	20	2
Cost Summary (WY)												
Winter Treatment ($/CM/WY)	$ 811	$ 816	$ 1,233	$ 265	$ 779	$ 4,647	$ 2,746	$ 3,142	$ 527	$ 385	$ 590	$ 423
Sweeping ($/CM/WY)	$ 11,000	$ 10,400	$ 11,290	$ 3,161	$ 3,438	$ 3,125	$ 5,400	$ 12,300	$ 2,602	$ 1,301	$ 3,951	$ 2,963
RO&M Cost ($/CM/WY)	$ 11,811	$ 11,216	$ 12,524	$ 3,426	$ 4,217	$ 7,772	$ 8,146	$ 15,442	$ 3,130	$ 1,686	$ 4,542	$ 3,387
Cost Effectiveness ($/RAM/CM)	$ 4,811	$ 3,343	$ 3,686	$ 897	$ 1,317	$ 2,098	$ 3,087	$ 4,969	$ 1,079	$ 458	$ 1,197	$ 847
Average Annual Results												
Average Annual RAM Score	2.9		3.6		3.5		2.9		3.3		3.9	
RO&M Average Annual Cost ($/CM/Year)	$ 11,513.49		$ 7,974.90		$ 5,994.49		$ 11,793.75		$ 2,408.03		$ 3,964.31	
Cost Effectiveness ($/RAM/CM)	$ 3,963.34		$ 2,209.88		$ 1,736.09		$ 4,104.85		$ 731.37		$ 1,017.30	

[1] Washoe Road Operation Supervisors indicated sweeping records at its road network were not accuractely tracked at the specific road network through available record keeping software. Washoe officials provided best estimate of the number of sweep events that occurred during WY15 but were not able to provide specific days for some of the sweep events that occurred.

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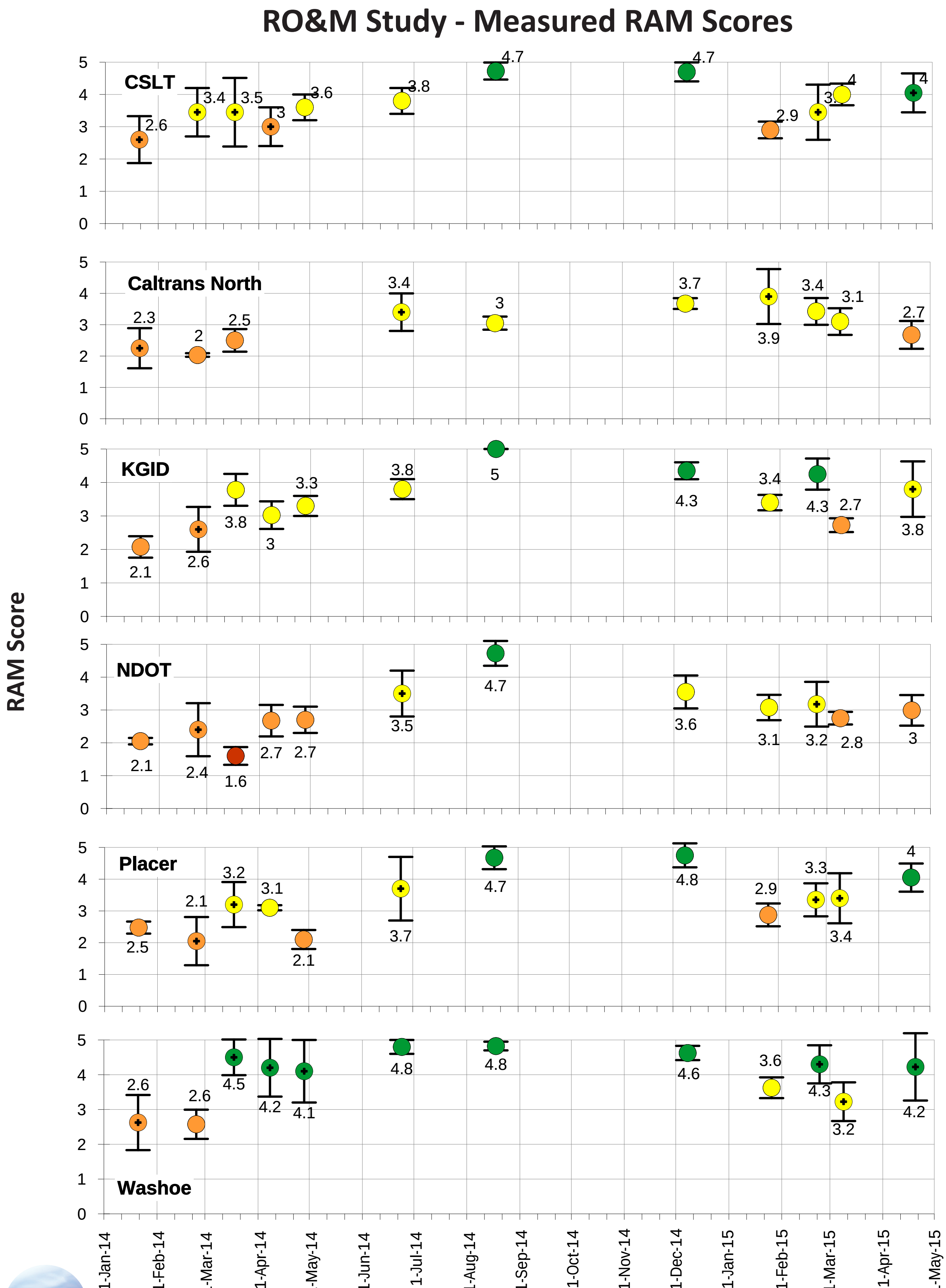

+ located within color circles represent observation periods where the average SD exceeded 0.5

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WY14-WY15 ROAD RAM SCORES

FIGURE 12

jurisdiction over the study period. The colored circles represent the average from the 4 segment scores measured during each period, the whiskers reflect the standard deviation across the 4 sites sampled, and plus sign within the color circles represent instances when the standard deviation exceeded 0.5.

For each water year, the RAM results by observation periods are averaged by season. These seasonal averages are then seasonally weighted (per distributions in Table 11; LRWQCB and NDEP 2015a) to generate an annual RAM score for each year for each test network. The seasonal weighting is based on the seasonal percent contribution to the total annual FSP loading to the Lake from the TMDL baseline analysis (LRWQCB and NDEP 2008). The most significant loading to Lake Tahoe occurs during the spring due to the risk of remnant winter FSP volumes on the roads being mobilized and transported into the stormwater systems during intense spring rain events. Therefore, road conditions during the spring are more heavily weighted in the final annual RAM score to represent the road condition during these times when pollutant transport from roadways is the greatest threat to lake clarity.

Table 11. Seasonal weight of RAM observations in annual Road RAM scores (LRWQCB and NDEP 2015a)

Season	Weight of Score
October – January	20%
February – May	60%
June – September	20%
WY Total	**100%**

The precision of the observations for a specific road network over a water year is estimated by the average of the standard deviations for each test network for each observation period. RAM standard deviation values provide managers confidence that the measured RAM scores are representative of the larger road network for which the results will be spatially extrapolated. The intent of this study is that road networks are of the same road class and are consistently maintained using the same RO&M practices. A target standard deviation equal to or less than 0.5 suggests that the condition of the road segments within the network are consistent. Spatial extrapolation of the average road segment RAM scores is thus representative of the entire road network. A deviation greater than 0.5 may suggest that road practices are not being consistently implemented across the road network, or there are other factors influencing road condition at those segments such as variable pavement condition or additional sources of material.

For each jurisdiction, the annual RAM score, number of RAM observations, and precision as measured for each road network are provided in Figure 11 under “Road Condition Summary (WY)” heading.

6.3.1 WY14 RAM RESULTS

A total of 7 Road RAM observation periods were conducted in WY14. One observation period was performed in January, while 4 observations were made in the critical spring season between February and May, and the final two observations were made in the summer between June and September. WY14 annual RAM scores were calculated based on the seasonal weighting outlined in Table 11**.** Annual RAM scores & standard deviation from WY14 can be found in Table 12. In most cases, the annual standard deviation is below the desired 0.5 threshold.

Table 12. WY14 Annual RAM Score and Standard Deviation

Jurisdiction	WY14 Annual RAM Score	Standard Deviation
Caltrans	2.5	0.4
CSLT	3.4	0.6
KGID	3.2	0.4
NDOT	2.6	0.4
Placer	2.9	0.5
Washoe	3.8	0.5

6.3.2 WY15 RAM RESULTS

Five RAM observation periods were performed in WY15, with 2 observations between October through January and 3 between February and May. No summer observations were made in 2015 and as result the weighting of RAM scores differed from that outlined in Table 11. In WY15 RAM scores from October through January made up 40% of the annual score, while scores from February through May remained consistent with CAP weighting and were weighted at 60% of the annual score. Annual RAM scores & standard deviation from WY15 can be found in Table 13. In all cases, the annual standard deviation is below the desired 0.5 threshold.

Table 13. WY15 Annual RAM score and Standard Deviation

Jurisdiction	WY15 Annual RAM Score	Standard Deviation
Caltrans	3.4	0.5
CSLT	3.8	0.5
KGID	3.7	0.4
NDOT	3.3	0.4
Placer	3.7	0.5
Washoe	4.0	0.5

6.4 Average Annual Results

The intent of this effort is to improve the capabilities of municipalities to determine what reasonable PLRM road condition score inputs are based on actual implemented RO&M practices. The relative annual comparable cost per implemented practices is also desired. Average Annual Results in Figure 11 summarizes the most informative and comparable metrics from this effort and includes the average annual RAM score, the average annual RO&M cost to implement practices, and the cost per RAM point over the 2 year study. The use and meaning of these 3 values are summarized below.

- The average annual RAM score is the average of the WY14 and WY15 annual scores. As shown in Figure 1, these measured RAM scores can be used to inform managers the expected RAM scores for input into PLRMv2 to estimate the pollutant load reductions expected as a result of road operation practices.

- The RO&M average annual costs per center mile are the average of the two water years for each jurisdiction per the records and information provided to the project team.

- The cost per RAM point value is calculated by dividing the average annual RO&M cost by the average annual RAM score to create a standardized unit by which to compare the costs for the RAM score obtained. The lower the unit cost, the relatively more cost-effective the practices are assumed to be based on the information provided.

7 Data Interpretation

Below is an initial comparative analysis of the 6 road practices tested by 6 jurisdictions during this study, as well as look at the changes in abrasive applications and road conditions over the last decade. A number of factors and challenges influenced the results and conclusions of the RO&M Practices Effectiveness Study. The primary limitations within the study include:

1) The study was conducted during two mild winters based on the WSI. Mild winters likely lead to higher than average annual RAM scores and lower RO&M costs compared to a severe winter due to the relatively lower abrasive application and recovery needs.
2) Tracking, documenting and reporting RO&M practices within the designated road network was challenging. Many jurisdictions tracked RO&M practices with existing data management systems that did not align with the spatial extent of the test road networks, and the submitted data had to be scaled down to reflect the practices within the test network. These adjustments may result in inaccurate estimates.

7.1 Informing PLRM Inputs: Expected RAM Scores

The average annual RAM scores provided for each road network is the average of the WY14 and WY15 road condition observations. As shown in Figure 1, these measured RAM scores at sites with defined road practices inform the expected RAM scores jurisdictions needed for input into PLRM v2. The results of these values are used to estimate pollutant load reductions from road operations for the relevant road class. Due to the unfavorable climatic conditions during the study's data collection (2 mild winters), there is low confidence that the Average Annual RAM scores presented in Figure 11 should be used as PLRM inputs as they likely reflect higher scores than can be achieved over the long term over the range of climatic conditions that occur in Tahoe. Continuation of the effectiveness study through both an average and severe winter would increase confidence and ensure RO&M practices are feasible to implement and the road condition scores modeled in PLRM v2 are achievable long-term.

7.2 Comparisons Across Road Network Results

One of the primary objectives of this study was to develop and provide a feasible and defensible experimental design and associated guidance for jurisdiction to compare road practices, RO&M costs and Road RAM results into the future to directly inform PLRM v2 expected road condition scores. The discussion below greatly informed the development of the associated RO&M Practices Effectiveness Testing User Guidance Document, which summarizes the recommended approach to future RO&M Practices Effectiveness testing efforts based on the lessons learned from this effort (2NDNATURE and NCE 2015).

7.2.1 ROAD PRACTICE TO ROAD CONDITION

The initial intent during the development and implementation of this two year study was for the jurisdictions to collectively define and test a range of different practices that would be comparable and informative to all jurisdictions. This coordination became too challenging and each jurisdiction ultimately tested enhanced standard business-as-usual practices over the 2 years. Below we provide some comparisons based on the data available.

Road condition results are influenced by a multitude of sources and sinks of FSP to the roadway (termed factors), some outside and some within the control of jurisdictions (see Figure 2). In an attempt to compare, on a relative scale, the factors influencing each road network with the observed annual RAM scores, we created Figures 13 and 14. Each provide a relative comparison of the various source and recovery factors in effect at each test road network for WY14 and WY15, respectively. The rationale and methods for the selection and qualification of each of these factors are presented in Chapter 3.1. The selected metrics include comparisons of road practices, as well as the influence of other factors, including other sources of sediment, pavement condition, etc.

In Figures 13 and 14 each factor is qualitatively ranked from light (best for limiting FSP mass on road surface) to dark (worst for limiting FSP mass on road surface) based on the range of values within each factor. For example, high traffic density is shown in black as it is assumed to lead to relatively higher pulverization rates and higher FSP mass, while low traffic density is shown in light grey, as the rate of pulverization is expected to relatively lower than on high traffic roads. The intent of Figure 13 and 14 is to visually compare the relative differences in the practices implemented and evaluate the potential influence other factors may have had on the observed annual Road RAM score. This qualitative comparison does indicate the road networks with the fewest black and dark grey boxes have the highest RAM scores (Washoe, KGID and CSLT) and, conversely, those with more black and dark grey boxes (Caltrans and NDOT) have lower Road RAM scores.

This analysis was then further refined to focus on controllable factors. Based on previous research as well as conversations with road managers, two of the most important controllable factors for road condition (see Figure 2) are: the amount of material put down on the roads and the timing in which it is recovered, where longer durations between applications and subsequent sweeping (termed residence time) will result in a greater accumulation of FSP on the roadway. Our study included 6 jurisdictions with 2 years of data for a total of 12 annual data points. For each test network and water year, four directly comparable metrics are ranked (Table 14): annual RAM score; total annual abrasive volume applied per center mile; average residence time (days); and cost per RAM score (discussed in Chapter 7.2.2). The range of values for each metric define the grey scale. The highest ranking value (i.e., best for limiting FSP mass on road surface) for each metric is assigned a light grey color and the lowest ranking value is marked in dark grey. The median value is used to scale the shades of grey between the minimum and maximum. This coloring scale can be used to inform metric thresholds that are better for road condition (i.e., light grey shades).

In general, when jurisdictions put down less material, higher Road RAM scores are observed. The Washoe WY14 RAM score was among the highest of all the jurisdictions evaluated, and the amount of abrasive applied ranked among the lowest tracked (1.8 cu-yd/CM). When Washoe reduced the amount of abrasives applied in WY15 (1.5 cu-yd/CM), the Road RAM scores also improved. In WY15 Washoe scored the highest annual Road RAM score in the study (4.0). Based on the data presented in Table 14, applying <3 cubic yards per center mile by year appears to be a critical threshold to achieve good road condition (>3.5 annual RAM score).

Jurisdictions that applied larger volumes of abrasives per center mile but minimized the residence time and swept quickly to recover abrasives also had relatively higher RAM scores. The WY15 CSLT annual RAM score was 3.8, the second highest score reported in the study. CSLT applied, on average, 3.7 cubic yards

RO&M - WY14 Summary of Practices

	CSLT	CalT-N	KGID	NDOT	Placer	Washoe
Source Factors						
Abrasive Type	Spec H	Spec H	Washed Conc Sand	Spec D	Spec H	Spec D
Spreader Method	Limited Control	Mod Control	Limited Control	Mod Control	Mod Control	Epoke
Traffic Density*	High	High	Low	High	Low	Mod
Salt Mix with Abr	25%	25%	17%	25%	<1%	25%
Abr applied (cu-yd/ center mi)	7	6	12	16	3	2
Other Sources*	1.8	2.8	4.4	3.1	2	4.5
Recovery Factors						
Road Pavement Condition	3.5	3.9	3.5	4.4	2.5	4.2
Sweeper Freq (W/Sp)	35	48	7	15	17	10
Residence Time	5	3	13	13	8	5
Sweeper Performance	5	1	4.4	2	3	4.8
Sweeper Access	2.2	1.8	5	2.9	2	5
Sweeper Type	Regen	Mech	Regen	Mech	Mech	Vac
RO&M $/Center Mile	>$10K	>$10K	<$5K	$5-10K	<$5K	<$5K
Annual Road RAM Score	3.4	2.5	3.2	2.6	2.9	3.8

* *Source factor outside of jurisdiciton's control*

Dark = worse for FSP on road

Light = better for FSP on road

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RO&M - WY15 Summary of Practices

		CSLT	CalT-N	KGID	NDOT	Placer	Washoe
Source Factors	Abrasive Type	Spec H	Spec H	**Washed Conc Sand**	**Spec D**	Spec H	**Spec D**
	Spreader Method	Limited Control	Mod Control	Limited Control	Mod Control	Mod Control	Epoke
	Traffic Density*	High	High	Low	High	Low	Mod
	Salt Mix with Abr	25%	25%	17%	25%	<1%	25%
	Abr applied (cu-yd/ center mi)	4	4	54	**23**	2	2
	Other Sources*	1.8	2.8	4.4	3.1	2	4.5
Recovery Factors	Road Pavement Condition	3.5	3.9	4.5	4.4	**3.5**	4.2
	Sweeper Freq (W/Sp)	33	52	**19**	38	9	**9** 10
	Residence Time	3	4	**11**	**7**	**12**	**19**
	Sweeper Performance	5	1	4.4	3	3	4.8
	Sweeper Access	2.2	**1.8**	5	2.9	**2**	5
	Sweeper Type	Regen	Mech	Regen	Mech	Mech	Vac
	RO&M $/Center Mile	<$5K	>$10K	$5-10K	>$10K	<$5K	<$5K
	Annual Road RAM Score	3.8	3.4	3.7	3.1	3.7	4.0

** Source factor outside of jurisdiciton's control*

Dark = worse for FSP on road

Light = better for FSP on road

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per center mile on their road network, more than double what Washoe applied, however, the residence time for abrasives on CSLTs network was on average only 3 days (the shortest reported). By recovering material quickly following application, road abrasives were not left on the roads to be pulverized into FSP. Past road research has suggested that long residence times results in the accumulation of caked clay layer on the road surfaces, which requires repeated sweeping efforts and rain events to dislodge and recover (2NDNATURE 2010, 2NDNATURE 2012, NTCD and DRI 2012, Kuhns et al. 2010). Additionally, the longer the pulverized material is on the road surface, the higher the likelihood that vehicle traffic will disperse the FSP throughout the road network, beyond locations where the abrasives are applied (LRWQCB and NDEP 2014). The data presented in Table 14 suggests a residence time of 5 days or less appears to be a critical threshold to achieve good road condition.

Caltrans also demonstrated swift sweeping response times after abrasive application in both WY14 and WY15, 3 and 4 days respectively. However, the observed RAM scores were relatively lower than others despite relatively similar abrasive applications. In qualitative interviews, Caltrans indicated in that sweeper performance was poor throughout the study. Although Caltrans put forth a large effort to recover material quickly, they were working with inefficient sweepers.

Table 14. Road Condition Scores and Key Road Practices Metrics

Annual RAM Score		Abrasive Applied (Cu-Yd/CM/WY)		Residence Time Days Between Abrasive Application and Sweeping		Cost Effectiveness ($/RAM/CM/WY)	
4.0	Washoe WY15	1.5	Washoe WY15	3	Caltrans WY14	$ 458	Placer WY15
3.8	Washoe WY14	1.8	Placer WY15	3	CSLT WY15	$ 847	Washoe WY15
3.8	CSLT WY15	1.8	Washoe WY14	4	Caltrans WY15	$ 897	CSLT WY15
3.7	Placer WY15	2.5	Placer WY14	5	CSLT WY14	$ 1,079	Placer WY14
3.7	KGID WY15	3.6	Caltrans WY15	5	Washoe WY14	$ 1,197	Washoe WY14
3.4	Caltrans WY15	3.7	CSLT WY15	7	NDOT WY15	$ 1,317	KGID WY14
3.4	CSLT WY14	6.2	Caltrans WY14	8	Placer WY14	$ 2,098	KGID WY15
3.2	KGID WY14	6.7	CSLT WY14	11	KGID WY15	$ 3,087	NDOT WY14
3.1	NDOT WY15	12.0	KGID WY14	12	Placer WY15	$ 3,343	Caltrans WY15
2.9	Placer WY14	16.4	NDOT WY14	13	KGID WY14	$ 3,686	CSLT WY14
2.6	NDOT WY14	22.8	NDOT WY15	13	NDOT WY14	$ 4,811	Caltrans WY14
2.5	Caltrans WY14	53.8	KGID WY15	19	*Washoe WY15**	$ 4,969	NDOT WY15

**Washoe was not able to track all the specific days of all sweep events in WY15. Of Washoe County's 9 sweep events in WY15, only 4 had tracked dates and only those 4 sweep events with specific dates were included in the residence time calculations. As a result Washoe's residence time in WY15 is high and most likely not accurate.*

7.2.2 COST EFFECTIVENESS

A desired benefit of these RO&M practices effectiveness efforts is insight on how to optimize the balance between protecting water quality with the cost associated with implementing the road practices. For example, there is a point of diminishing return with increased sweeping frequency, where continuing to sweep a clean road will not result in additional improvements in RAM scores (2NDNATURE 2012, 2NDNATURE and NHC 2014).

The cost data is presented a few different ways for comparative purposes. The unit costs ($/center mile/water year) for winter treatment and sweeping efforts (and the sums "RO&M") are presented under the "Cost Summary" header in Figure 11. In Figures 13 and 14, these RO&M costs are visually compared using a gray scale from least (light gray) to most (dark gray) expensive. To compare relative cost effectiveness from each WY specific or average annual result, the RO&M cost per center mile was divided by the annual RAM score (see Figure 11). The relative WY cost effectiveness is then ranked in Table 14 from low to high. We present a couple of the most interesting points gleaned from these results below.

- Municipalities that applied <3 cu-yards of abrasive per center mile also have more cost effective RO&M practices (Placer and Washoe), due to the high cost associated with equipment, labor and material for abrasive application. When RO&M crews apply less material, whether through focused spot sanding or by applying less volume on the roads, it appears to be a pivotal step in maintaining clean roads and reducing costs incurred by the department.

- In WY14, CSLT spent the third most money for a RAM point ($3,686/RAM point/CM), but with changes to their practices were able to spend 75% less in WY15 ($897/RAM point/CM) while improving annual road RAM scores (3.4 to 3.8). In WY15, CSLT reduced both the amount of abrasives applied and the total number of sweep events, but improved the timing of the sweeping events to reduce residence time as well (see Table 14). While the abrasive application reduction may be due to the mild winter, comparative cost effectiveness improvements were not noted in other jurisdictions.

- Minimizing abrasive applications and residence times is a critical strategy to effectively reduce FSP generation and transport from paved roads. Volumes of abrasives applied and cost reported/RAM point on the lower end of the spectrum (<3 cu-yds/CM and <$1K/CM) may not be repeatable by jurisdictions during more severe winters. However, practices to reduce residence time of abrasives on the roadway can be implemented under any winter severity to effectively treat roads.

7.3 Cost Comparisons to Placer County Stormwater TMDL Strategy

Water-quality minded road operations remain an important, cost-effective strategy for jurisdictions to meet their TMDL load reduction milestones. Cost comparisons completed for the Placer County Stormwater TMDL Strategy (2NDNATURE and NHC, 2011) indicated that per pound of FSP removed, improved road maintenance practices for water quality is the most cost-effective strategy, proving more efficient than the development of water quality improvement projects (WQIPs) or the implementation of private parcel BMPs. Advanced road operations can provide similar load reductions for nearly a tenth the cost of water quality improvement projects.

The cost information and data compiled for this effort are used to provide reasonable estimate of annual RO&M costs to maintain all jurisdiction roads at the observed road condition for an average water year and winter severity (Table 15). Two critical assumptions are applied to the existing data to provide an estimated long-term annual RO&M costs per jurisdictions:

- The costs per center mile and associated road condition scores achieved are applicable to all road miles within the respective jurisdiction. In reality, there will deviations across costs expended and resulting road conditions achieved, but this approach may provide a reasonable jurisdictional scale estimate.
- The annual RO&M costs obtained from this study (Table 15) are reflective of the practices implemented on the select test networks for two dry water years and mild winters. To scale these costs to better represent a reasonable cost year after year (average) given the occurrence of both severe and average winter conditions in the future, we increase the dry year annual costs by a factor of 1.5. As winter severity increases, the RO&M costs required for the jurisdiction to achieve the road condition scores observed in WY14/WY15 will also increase.

Based on these assumptions, the estimated average annual RO&M costs range from $550,000 and $1.6 million (Table 15). While the assumptions and calculation methods shown in Table 15 differ from those applied in the Placer County Stormwater TMDL Strategy (2NDNATURE and NHC 2011), both analyses indicate that the overall costs associated with road maintenance practices are a more water quality improvement solution than typical WQIPs and more accessible to jurisdictional implementation and control than private parcel retrofit efforts (2NDNATURE and NHC (2011)). For context, over the past decade Placer County had or could plan to spend an annualized estimated $8 million per year on WQIP design, implementation and maintenance.

Table 15. Estimated average annual costs to implement RO&M practices on all road miles within a jurisdiction during an average water year.

Jurisdiction	Average Road Condition Score	Dry Year RO&M Annual Cost ($/CM/year)	Total Road Miles (CM)	Estimated Jurisdiction RO&M Average Annual Cost ($/year)
Caltrans	2.9	$11,513	60	$1,050,000
NDOT	2.9	$11,794	40	$750,000
CSLT	3.6	$7,975	130	$1,600,000
KGID	3.5	$5,994	60	$550,000
Placer	3.3	$2,408	140	$550,000
Washoe	3.9	$3,964	90	$550,000

7.4 Qualitative Link: Road Practices and RAM Scores

Based on the findings of this study, as well as previous road-related FSP generation research from 2008 to 2015, 2NDNATURE developed a simple method to estimate the annual condition (annual RAM score) of a road network based on a set of the factors most influential for annual road condition. This approach integrates thousands of data points with best professional judgement to provide an improved approach from PLRMv1 that qualitatively links consistently applied RO&M practices and network pavement condition to expected road condition using the Road RAM 0-5 scale. The approach was developed and refined based on best professional judgement by 2NDNATURE and road maintenance expert Dick Minto, formal lead of Washoe County Road Maintenance Department and currently with NCE.

The assumption is that average annual road condition (annual RAM score) can be reasonably predicted using 8 factors: Abrasive Type, Abrasive Amount, Sweeper Type, Sweeper Frequency, Sweeping Effectiveness, Spatial Applicability, Residence Time, and Average Pavement Condition Index (PCI). The score prediction is a relative addition/subtraction of RAM score units based on the presumed relative influence of each factor (see Table 16 for metric values and associated scoring). A general comparison of the below approach to the 12 observed annual RAM scores obtained during this study (see Figures 13-14) indicated a reasonable dose response of this qualitative approach. This approach provides a reasonable qualitative approach to estimate average Road RAM scores based on a combination of critical practices, but the only way to verify the results is to assess and verify road condition using Road RAM over time.

- **Abrasive Type**: Certain abrasives are more durable than others, resulting in less pulverized material on the road surface that is both more easily transported in stormwater and more difficult to recover (Caltrans 2010, 2012). Abrasive type is graded on a positive scale (alpine conditions only).
- **Abrasive Amount**: The amount of abrasives (cu-yds) applied per center lane mile can vary depending upon the spreader type, the training of the road operators, and the specific safety concerns of the roads (speed limit, proximity to schools and hospitals, bus routes, etc.). Abrasive amount can have a positive or negative effect on the score (alpine conditions only).
- **Sweeper Type**: Certain sweeper types are more effective at recovering pollutants (NHC et al. 2009, Sutherland and Jelen 1996, Center for Watershed Protection 2008, Blosser et al. 2003, Schilling 2005). The two most common sweeper types are Regenerative Air and Mechanical Broom. Sweeper type is graded on a positive scale.
- **Sweeper Frequency**: Frequent sweeping of roads can help to significantly improve road condition (NHC et al. 2009, 2NDNATURE et al. 2010, 2NDNATURE 2012, 2NDNATURE and NHC 2012, 2NDNATURE and NHC 2014, NTCD and DRI 2011). Sweeper frequency is graded on a positive scale.
- **Sweeping Effectiveness**: Sweeping Effectiveness is evaluated based on the extent of the road (curb to curb) that can be swept and the training of the operator to sweep with an objective to protect water quality. The metric is graded on a negative scale.
- **Sweeping Spatial Applicability**: The spatial applicability of sweeping is evaluated by the percentage of all road miles swept on a categorical scale. If road classes have been properly designated, this value should be 100%. The metric is graded on a negative scale.
- **Residence Time:** The number of days between abrasive application and sweeping are averaged over the water year. The metric is graded on a categorical scale based on results shown in Table 14 (alpine conditions only).
- **Average PCI**: Pavement condition is important because roads with poor pavement condition are likely associated with higher sediment generation due to pavement degradation and trapping of fine sediment that cannot be readily recovered by sweepers of any kind. Relative pavement condition is evaluated on a categorical scale. The metric is graded on a negative scale.

Table 16. Qualitative approach to predict average annual road condition or Road RAM scores based on the combination of the 8 critical factors driving relative condition.

Score Value	Metric Value							
	Abrasive Type	Abrasive Amount (cu-yd/ CM/WY)	Sweeper Type	Sweeper Frequency	Sweeping Effectiveness	Sweeping Spatial Applicability (% road miles)	Residence Time (days)	Average PCI
+3				Weekly				
+2	Spec H	<3	Reg. Air	Monthly				
+1	Spec D	3-10	Mech. Broom				<5	
0	Washed Conc Sand	10-20		> Monthly	High	>75%	5-10	>80
-1		>20			Moderate	25-75%	>10	60-79
-2					Low	<25%		<60

All of the resulting 8 scores are added together to estimate the road condition of the respective road network on a scale from 0-5. This approach used to predict relative road condition can be applied to non-alpine roads using 5 of 8 road condition factors listed above (remove abrasive type, abrasive application, and residence time from estimation).

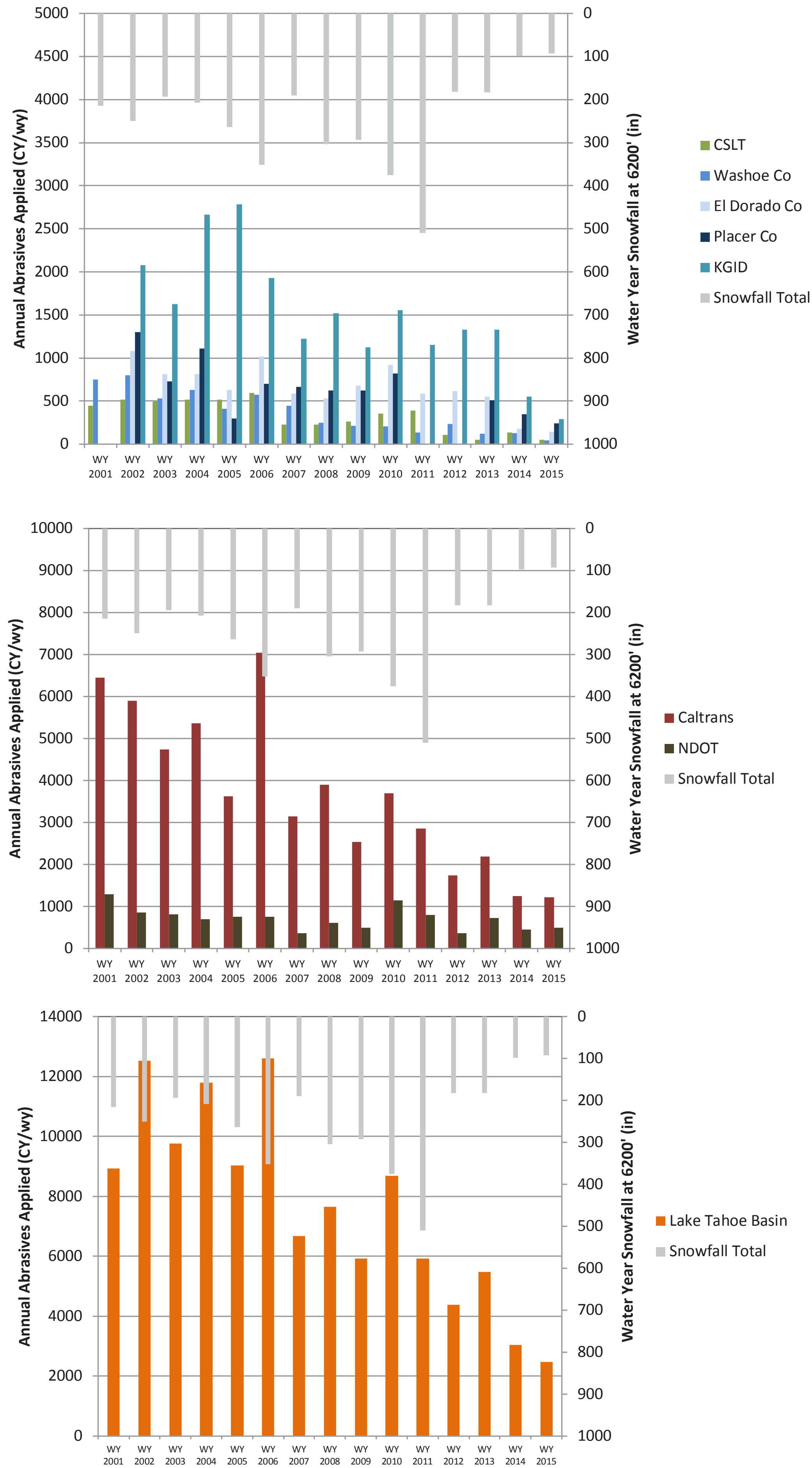
7.5 Trends in Basin Wide Abrasive Applications

A critical take home message from the impervious winter road research conducted over the past decade (2NDNATURE et al. 2010; 2NDNATURE 2010, 2012; 2NDNATURE and NHC 2012, 2014) is that minimizing the volume of abrasives applied is feasible while still protecting winter driver safety. Lower applied volumes not only leads to improved water quality (2NDNATURE 2012, 2NDNATURE and NHC 2012, 2014), but also reduces annual operating costs. These cost reductions are realized from both reduced application costs as well as the reduced subsequent frequency and intensity of sweeping necessary to restore road ways to acceptable conditions. Spot sanding and abrasive controls can focus concentrated sweeping at the abrasive application locations as soon as road conditions allow.

One very positive behavioral shift with respect to Tahoe winter road maintenance is that available records over the past 15 years document a concerted effort by all jurisdictions to reduce the annual application of abrasives (Figure 15). Despite higher snowfall totals, particularly in WY2011, a decreasing trend in abrasive applications can be seen for nearly every single Tahoe jurisdiction. WY14 (98”) and WY15 (93”) are the two lowest totals shown for the period of record. In 2010 (using WY01-WY09 data), the average annual abrasives applied per center mile across all jurisdictions was 14.7 cubic-yards per lane mile. Incorporating the last 5 years of data into the dataset, the current average annual abrasives applied per lane mile across all jurisdictions is now 7.0 cubic-yards, or half of the previous rate. Continued integration and reporting of these annual application values through more severe winters in the future will verify if these trends persist regardless of the recent occurrence of relative mild winters (see Table 10).

7.6 WY2009-WY2015 Road Condition

Over 1,250 Road RAM observations have been collected on Tahoe roads since 2009. While the observations have been made over a range of road segments for a myriad of purposes, we integrated all of the available data by season and by jurisdiction (Figure 16).



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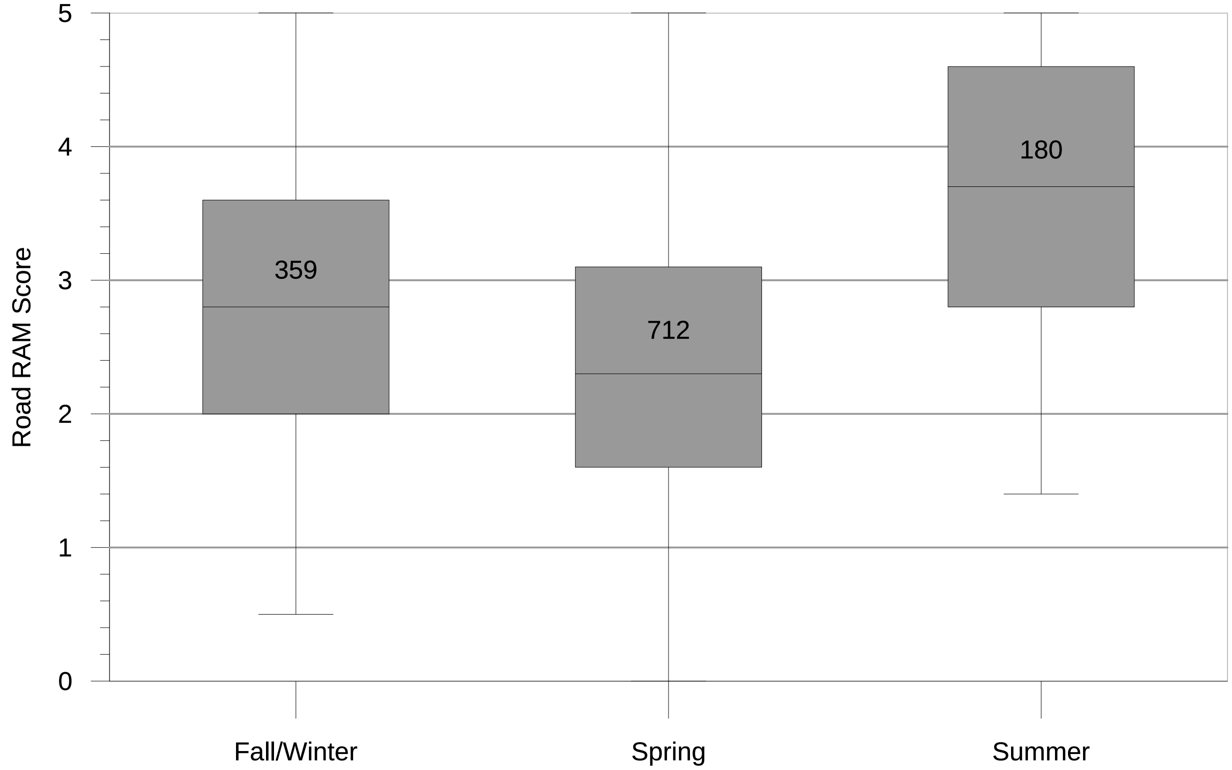
TAHOE BASIN ANNUAL ABRASIVE APPLICATION BY WATER YEAR

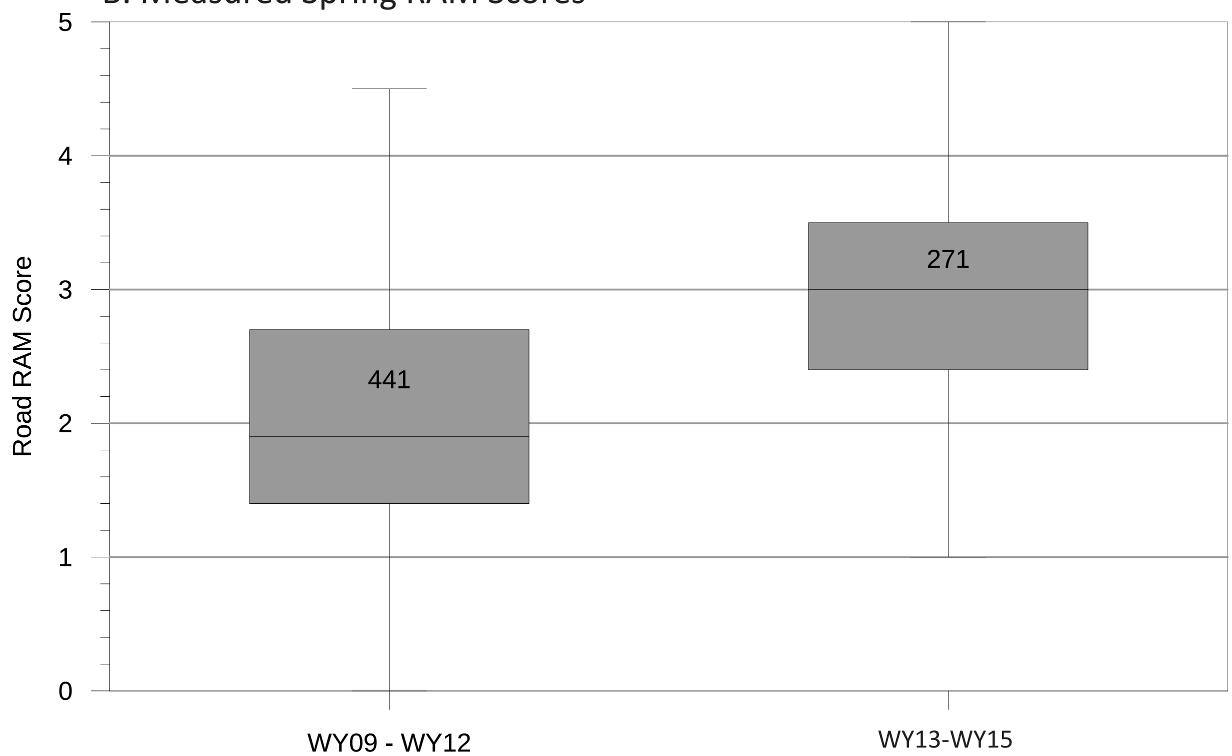
FIGURE 15

A. Measured RAM Scores by CAP Season



Seasonal RAM scores in Plot A are aggregated field data collected from 2009 - 2015. The solid line in the box is the mean value and the number above the line indicates the n value for that season.

B. Measured Spring RAM Scores



Scores displayed in Plot B compare spring RAM scores measured between February through May from WY09 - WY12 to scores measured from WY13-WY15.

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MEASURED RAM SCORES BY SEASON

FIGURE 16

- There are measureable seasonal differences I n RAM scores, as would be expected based on the differences in road practices throughout the year. Road condition in the spring (February-May) is typically the poorest, followed by the fall/winter, with the best conditions in the summer. This seasonal pattern is consistent with many other research efforts conducted on Tahoe roads (2NDNATURE et al. 2010; 2NDNATURE 2010, 2012; 2NDNATURE and NHC 2012, 2014; NTCD and DRI 2011; Kuhns et al. 2010; Zhu et al. 2009).

- Whether a result of a shift towards water quality-minded road operation practices or due to the two consecutive mild winters, winter road conditions have improved over the last 7 years. The spring (February-May) conditions, which are typically the poorest, show a measureable improvement when WY09-WY12 data is compared to WY13-15. WY09-WY12 includes 2 mild, 1 average, and 1 extreme winter, while WY13-WY15 includes 1 very mild, 1 mild, and 1 average winter.

8 Conclusions & Recommendations

Listed below are the objectives established at the onset of the project with a summary of the study's ability to achieve the objectives and address the lessons to inform recommendations for the Tahoe stormwater community to implement and improve the cost-effectiveness of RO&M practices to reduce FSP generation and transport to Lake Tahoe.

IMPROVED UNDERSTANDING OF THE FACTORS INFLUENCING ROAD CONDITION OVER TIME AND THE ROLE ROAD OPERATIONS HAVE ON MAINTAINING ROAD CONDITIONS TO MINIMIZE FSP GENERATION AND TRANSPORT FROM ROADS.

The project team spent substantial time with the jurisdictions considering the relative importance of the road condition factors and developing associated metrics that can be consistently compared across jurisdictions. Several meetings and phone calls were devoted to discussing the limitations, opportunities, and constraints of various data collection and management methods to obtain the desired metrics. Some factors, like abrasive application amount, residence time, and sweeping frequency rely on standardized data management, which was sometimes challenging to obtain. Other factors, such as other sediment sources, sweeper performance and road accessibility, were difficult to quantify and required a qualitative review based on interviews with each jurisdiction to assign categorical values. For pavement condition, locating road networks with consistent PCI across all roads proved difficult. Despite these challenges, the findings of this study continue to suggest that the best approach to reducing FSP volumes on road surfaces is to minimize abrasive application volumes, maintain pavement integrity, and implement a sweeping program with an effective sweeper that minimizes abrasive residence time.

Future studies should build upon the standardized data collection and analysis methods provided in this report to refine the current understanding of the relative importance of these factors. For example, the qualification of other road factors can continue to be improved with more years of data to understand the thresholds for optimal versus unacceptable conditions. While the monitoring approach for this study did not allow us to fully test the impact of pavement condition on individual road segment scores, future design approaches could continue to refine current understanding of the relative impact of pavement condition on Road RAM results. Additionally, study results show both highway departments have the lowest RAM scores despite a substantial effort to sweep and recover material. Highway roads encounter denser traffic with more heavy duty trucks at higher traffic speeds, which in theory deliver an increased force to pulverize road abrasives at a faster rate than on non-highway roads. Future RO&M practices testing could evaluate these variables on highway roads to improve our current understanding of how factors specific to highways roads may influence road condition scores.

IMPROVE THE CAPABILITIES OF MUNICIPALITIES TO DETERMINE WHAT REASONABLE PLRM ROAD CONDITION SCORE INPUTS ARE, BASED ON ACTUAL RO&M PRACTICES THAT WILL BE IMPLEMENTED OVER TIME ON SPECIFIC ROAD CLASSES/NETWORKS.

The Road Operations and Maintenance Practices Effectiveness Testing User Guidance (2NDNATURE and NCE 2015) provides a standardized approach to evaluate RO&M practices and, with reasonable confidence, estimate the average annual road condition expected as a result of implementation. Implementation of the provided experimental design can address the following:

- RO&M practices effectiveness testing is intended to be conducted over a range of winter severity types to provide results that can reasonably inform managers of average annual road condition scores to enter in PLRM. In order to have reasonable road RAM scores for PLRM inputs, the project team recommends that study continues through both, an average and severe winter, to improve the data and results already collected over a mild and very mild winter.

- As collaboration within and between jurisdictions continues, there is a hope that future RO&M practices effectiveness testing will include more innovative practices within a test network. Through resource pooling and cost sharing, jurisdictions could evaluate the effectiveness and cost efficiency of various techniques (e.g., solar powered smart roads, road radiators, etc.) for potential application in the Tahoe Basin.

- The standardized costs developed under the alternative cost analysis are based on conversations with the jurisdictions and complicated by the differences in road maintenance tracking and accounting practices by each entity. These estimates can be refined and improved as jurisdictions continue to consider adjustments to their road programs and develop data management systems to better track road maintenance related practices and associated costs.

- The winter severity index developed for this study provided a simple and reasonable index to rank winter severity over time based on percent of freezing days in the winter and total water year precipitation. However, a more robust metric could be developed to consider the timing of the cold days relative to the precipitation and provide a better comparison of water year results.

IMPROVED COMMUNICATIONS AND COORDINATION BETWEEN STORMWATER MANAGERS AND ROAD OPERATIONS PERSONNEL WITHIN EACH JURISDICTION.

Over the course of the study, road maintenance personnel and stormwater managers regularly attended the stakeholder meetings and ultimately gained a better understanding of the critical role water quality minded road operations could have for their jurisdiction as well as the clarity of the Lake. Road operation personnel have a wealth of institutional knowledge with respect to maintaining clean and safe roads in their respective jurisdiction, while stormwater managers are acutely aware of the TMDL goals and Lake Clarity Crediting Program milestones. This study created an opportunity for jurisdiction personnel to, regularly and frequently, engage with one another and discuss the advantages and disadvantages to various road operation approaches. Additionally, this basin wide study spurred municipalities to share effective road operation information and lessons learned with each other. Overall, the RO&M practices effectiveness study brought awareness and increased value to the RO&M programs currently utilized around Lake Tahoe. Municipalities are encouraged to continue discussions of effective road operations among stormwater managers and road operations personnel both across and within jurisdictions.

Ongoing collaboration between stormwater managers and maintenance personnel is important for the development of new cost effective solutions for maintaining cleaner roads, which can lead to a string of secondary fiscal and water quality benefits. For example, municipalities managing and maintaining cleaner roads will reduce the amount of FSP transported in stormwater runoff, thereby reducing the amount of FSP delivered to stormwater treatment BMPs. Higher volumes of FSP in stormwater runoff can result in the rapid decline of infiltration BMP performance (2NDNATURE and NHC 2013). An effective RO&M

program can reduce the frequency and associated costs of BMP maintenance, which are typically much more resource intensive than RO&M practices.

DEVELOP AND PROVIDE A FEASIBLE AND DEFENSIBLE EXPERIMENTAL DESIGN AND ASSOCIATED GUIDANCE FOR JURISDICTIONS TO COMPARE ROAD PRACTICES, RO&M COSTS AND ROAD RAM RESULTS INTO THE FUTURE TO DIRECTLY INFORM PLRM V2 EXPECTED ROAD CONDITION SCORES.

One of the primary objectives of this study was to create a feasible and defensible experimental design and associated guidance to compare road practices, RO&M costs and Road RAM results to directly inform PLRM v2 expected road condition scores. This proved to be an iterative process with constant vetting and refinement of draft ideas and formats with the jurisdictions, project team and regulators. Based on the feedback and lessons learned from this study, a detailed Road Operations and Maintenance Practices Effectiveness Testing Guidance Document (2NDNATURE and NCE 2015) has been developed that summarizes the recommended approach to future RO&M testing efforts. Key lessons learned include:

- Accurate tracking and recording of road operations performed requires careful consideration. The importance of good record keeping largely influences data analysis and ultimately any conclusions made for management decisions. The project team developed the road chronology template to facilitate proper data collection, management, and analysis through standardized data entry and automated metric calculations.
    - Road operation information should be entered the same day as the activity. The daily road operation chronology should be QAQC'ed on a weekly basis to ensure no data gaps occur, information is entered while it is still recent, and to verify entered data is correct.
    - Qualification of sweeper performance, sweeper accessibility and other sources is scored with each sweep event within the daily chronology template. More frequent entries of 'other factors' influencing road condition can provide additional information with regards to road condition and can provide support and rationale for spurring management decisions such as purchasing a new sweeper or implementing parking restrictions during sweeping to ensure greater access to the roadway.
    - Sanding and sweeping equipment used for road operations is tracked by hours in use within the road network (i.e., # of hours to sand/sweep road network). Tracking equipment by the hour allows for more accurate cost estimation of the activity as a whole.

- Select segments within a road network should have consistent PCI, relatively consistent seasonal contribution from other sources, and similar accessibility for sweeper equipment based on the selected assessment approach to reduce the impact of 'other factors'.

- Increase the number of RAM observations beyond the recommendations of the Crediting Program to better understand road condition as it relates to specific road practices.

- Generating fully burdened cost estimates for winter storm management and source recovery efforts that are comparable across jurisdictions is highly challenging, given the differences in record keeping and accounting practices. 2NDNATURE developed an alternative approach using standard hourly rates to provide consistent, comparable results across municipalities. Standard hourly rates for equipment and operator as well as standard rates for materials were pre-populated within a Microsoft Excel cost calculator to simplify the RO&M cost calculation process. The cost calculator is linked to the daily road operation chronology template, streamlining the data analysis process. Hourly fully burdened rates were estimated based on information provided by jurisdictions in spring 2015. Rates should be updated in the calculator as more accurate cost information becomes available.

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Appendix A

Participating jurisdictions daily chronologies submitted of abrasives applied and material recovered;
12/1/2013 - 4/30/2015

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	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
12/1/2013	no			no	no	no			no	no		
12/2/2013	no			no	no	no			no	no		
12/3/2013	7.73			2.25	7	2			4.99	0.52		
12/4/2013	2.10			2.25	no	4	4	600	8.53	0.39		
12/5/2013	0.22			no	no	no			2.67	0.13		
12/6/2013	1.10			no	no	2		200	no	2		
12/7/2013	6.84			2	no	4		150	1.48	0.13		
12/8/2013	0.66			1.75	no	3		700	1.94	no		
12/9/2013	no			0.5	no	no			2.44	no		
12/10/2013	0.11			0.25	no	no			no	no		
12/11/2013	no			no	no	no			1.25	0.2		
12/12/2013	0.11			no	no	no			no	no		
12/13/2013	no			no	no	no			no	no		
12/14/2013	no			no	no	no			no	no		
12/15/2013	0.11			no	no	no			no	no		
12/16/2013	no			no	no	no			no	no		
12/17/2013	no			no	no	no			no	no		
12/18/2013	no			no	no	no			no	no		
12/19/2013	no			1	no	no			no	0.25		
12/20/2013	no			no	no	no			1.22	0.16		
12/21/2013	0.88			no	no	no			no	no		
12/22/2013	no			no	no	no			no	no		
12/23/2013	no			no	no	no			0.8	no		
12/24/2013	no			no	no	no			no	no		
12/25/2013	no			no	no	no			no	no		
12/26/2013	no			no	no	no			no	no		
12/27/2013	no			no	no	no			no	no		
12/28/2013	no			no	no	no			no	no		
12/29/2013	no			no	no	no			no	no		
12/30/2013	no			no	no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
12/31/2013	no			no	no	no			no	no		
1/1/2014	no			no	no	no			no	no		
1/2/2014	no			no	no	no			no	no		
1/3/2014	no			no	no	no			no	no		
1/4/2014	no			no	no	no			no	no		
1/5/2014	no			no	no	no			no	no		
1/6/2014	no			no	no	no			no	no		
1/7/2014	no			no	no	no			no	no		
1/8/2014	no			no	no	no			no	no		
1/9/2014	no			no	no	no			no	no		
1/10/2014	no			no	no	no			no	no		
1/11/2014	2.76			1	no	4		400	no	no		
1/12/2014	no			no	no	3	4	300	no	0.26		
1/13/2014	no			no	no	no			1.18	no		
1/14/2014	no			no	no	no			no	no		
1/15/2014	no			no	no	no			no	no		
1/16/2014	no			no	no	no			no	no		
1/17/2014	no			no	no	no			no	no		
1/18/2014	no			no	no	no			no	no		
1/19/2014	no			no	no	no			no	no		
1/20/2014	no			no	no	no			no	no		
1/21/2014	no			no	no	no			no	no		
1/22/2014	no			no	no	no			no	no		
1/23/2014	no			0.25	no	no			no	no		
1/24/2014	no			no	no	4			no	no		
1/25/2014	no			no	no	no			no	no		
1/26/2014	no			no	no	no			no	no		
1/27/2014	no			no	no	no			no	no		
1/28/2014	no			no	no	no			no	no		
1/29/2014	no			no	no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
1/30/2014	2.32			0.25	no	2			no	0.75		
1/31/2014	0.11			0.25	2.25	2	15	900	1.64	0.26		
2/1/2014	0.22			no	no	no			no	no		
2/2/2014	1.55			no	no	3			no	no		
2/3/2014	2.65			0.25	no	3			0.70	0.65		
2/4/2014	no			no	no	no			no	no		
2/5/2014	no			no	no	2			no	no		
2/6/2014	0.77			0.25	no	no			0.24	0.19		
2/7/2014	3.21			no	no	no			0.10	0.89		
2/8/2014	5.31			0.75	no	8			no	0.33		
2/9/2014	0.22			no	no	no			no	0.39		
2/10/2014	1.00			0.75	no	9			no	no		
2/11/2014	no			no	no	no			no	no		
2/12/2014	no			no	no	no			no	no		
2/13/2014	no			no	no	no			no	no		
2/14/2014	no			no	no	no			no	no		
2/15/2014	0.22			no	no	no			no	0.04		
2/16/2014	0.44			no	no	no			no	no		
2/17/2014	no			no	no	no			no	no		
2/18/2014	no			no	no	no			no	0.04		
2/19/2014	no			0.15	no	2			no	no		
2/20/2014	no			0.75	no	no			no	no		
2/21/2014	no			0.75	no	no			no	no		
2/22/2014	no			no	no	no			no	no		
2/23/2014	no			no	no	no			no	no		
2/24/2014	no			no	no	no			no	no		
2/25/2014	no			no	no	no			no	no		
2/26/2014	no			0.5	no	3			no	no		
2/27/2014	0.33			0.5	no	6			no	no		
2/28/2014	no			1	4	6			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
3/1/2014	no			0.25	no	2		400	2.1	no		
3/2/2014	0.88			no	no	no			no	no		
3/3/2014	no			no	no	2	4	300	no	no		
3/4/2014	no			no	no	no			no	no		
3/5/2014	no			no	no	6			no	no		
3/6/2014	no			no	no	6			no	no		
3/7/2014	no			no	no	no			no	no		
3/8/2014	no			no	no	no			no	no		
3/9/2014	no			no	no	no			no	no		
3/10/2014	no			no	no	3	15	900	no	no		
3/11/2014	no			no	no	no			no	no		
3/12/2014	no			no	no	no			no	no		
3/13/2014	no			no	no	no			no	no		
3/14/2014	no			no	no	no			no	no		
3/15/2014	no			no	no	no			no	no		
3/16/2014	no			no	no	no			no	no		
3/17/2014	no			no	no	no			no	no		
3/18/2014	no			no	no	no			no	no		
3/19/2014	no			no	no	no			no	no		
3/20/2014	no			no	no	no			no	no		
3/21/2014	no			no	no	no			no	no		
3/22/2014	no			no	no	no			no	no		
3/23/2014	no			no	no	no			no	no		
3/24/2014	no			no	no	no			no	no		
3/25/2014	no			no	no	2			no	no		
3/26/2014	no			no	no	no			no	no		
3/27/2014	no			no	no	5			no	no		
3/28/2014	no			no	6	no			no	no		
3/29/2014	no			no	no	2			no	no		
3/30/2014	no			1.5	no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
3/31/2014	no			0.5	no	10			no	no		
4/1/2014	no			1	no	4			no	no		
4/2/2014	no			no	no	no			no	no		
4/3/2014	no			no	no	no			no	no		
4/4/2014	no			no	no	no			no	no		
4/5/2014	no			no	no	no			no	no		
4/6/2014	no			no	no	no			no	no		
4/7/2014	no			no	no	no			no	no		
4/8/2014	no			no	no	no			no	no		
4/9/2014	no			no	no	no			no	no		
4/10/2014	no			no	no	no			no	no		
4/11/2014	no			no	no	no			no	no		
4/12/2014	no			no	no	no			no	no		
4/13/2014	no			no	no	no			no	no		
4/14/2014	no			no	no	no			no	no		
4/15/2014	no			no	no	no			no	no		
4/16/2014	no			no	no	no			no	no		
4/17/2014	no			no	no	no			no	no		
4/18/2014	no			no	no	no			no	no		
4/19/2014	no			no	no	no			no	no		
4/20/2014	no			no	no	no			no	no		
4/21/2014	no			no	no	no			no	no		
4/22/2014	no			no	no	3			no	no		
4/23/2014	no			no	no	no			no	no		
4/24/2014	no			no	no	no			no	no		
4/25/2014	no			no	no	6			no	no		
4/26/2014	no			no	no	6			no	no		
4/27/2014	no			no	no	2			no	no		
4/28/2014	no			no	no	no			no	no		
4/29/2014	no			no	no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
4/30/2014	no			no	no	no			no	no		
5/1/2014	no			no	no	no			no	no		
5/2/2014	no			no	no	no			no	no		
5/3/2014	no			no	no	no			no	no		
5/4/2014	no			no	no	no			no	no		
5/5/2014	no			no	no	no			no	no		
5/6/2014	no			no	no	no			no	no		
5/7/2014	no			no	no	no			no	no		
5/8/2014	no			no	no	no			no	no		
5/9/2014	no			no	no	no			no	no		
5/10/2014	no			no	no	no			no	no		
5/11/2014	no			no	no	no			no	no		
5/12/2014	no			no	no	no			no	no		
5/13/2014	no			no	no	no			no	no		
5/14/2014	no			no	no	no			no	no		
5/15/2014	no			no	no	no			no	no		
5/16/2014	no			no	no	no			no	no		
5/17/2014	no			no	no	no			no	no		
5/18/2014	no			no	no	no			no	no		
5/19/2014	no			no	no	no			no	no		
5/20/2014	no			no	no	no			no	no		
5/21/2014	no			no	no	no			no	no		
5/22/2014	no			no	no	no			no	no		
5/23/2014	no			no	no	no			no	no		
5/24/2014	no			no	no	no			no	no		
5/25/2014	no			no	no	no			no	no		
5/26/2014	no			no	no	no			no	no		
5/27/2014	no			no	no	no			no	no		
5/28/2014	no			no	no	no			no	no		
5/29/2014	no			no	no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
5/30/2014	no			no	no	no			no	no		
5/31/2014	no			no	no	no			no	no		
6/1/2014	no			no	no	no			no	no		
6/2/2014	no			no	no	no			no	no		
6/3/2014	no			no	no	no			no	no		
6/4/2014	no			no	no	no			no	no		
6/5/2014	no			no	no	no			no	no		
6/6/2014	no			no	no	no			no	no		
6/7/2014	no			no	no	no			no	no		
6/8/2014	no			no	no	no			no	no		
6/9/2014	no			no	no	no			no	no		
6/10/2014	no			no	no	no			no	no		
6/11/2014	no			no	no	no			no	no		
6/12/2014	no			no	no	no			no	no		
6/13/2014	no			no	no	no			no	no		
6/14/2014	no			no	no	no			no	no		
6/15/2014	no			no	no	no			no	no		
6/16/2014	no			no	no	no			no	no		
6/17/2014	no			no	no	no			no	no		
6/18/2014	no			no	no	no			no	no		
6/19/2014	no			no	no	no			no	no		
6/20/2014	no			no	no	no			no	no		
6/21/2014	no			no	no	no			no	no		
6/22/2014	no			no	no	no			no	no		
6/23/2014	no			no	no	no			no	no		
6/24/2014	no			no	no	no			no	no		
6/25/2014	no			no	no	no			no	no		
6/26/2014	no			no	no	no			no	no		
6/27/2014	no			no	no	no			no	no		
6/28/2014	no			no	no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
6/29/2014	no			no	no	no			no	no		
6/30/2014	no			no	no	no			no	no		
7/1/2014	no			no	no	no			no	no		
7/2/2014	no			no	no	no			no	no		
7/3/2014	no			no	no	no			no	no		
7/4/2014	no			no	no	no			no	no		
7/5/2014	no			no	no	no			no	no		
7/6/2014	no			no	no	no			no	no		
7/7/2014	no			no	no	no			no	no		
7/8/2014	no			no	no	no			no	no		
7/9/2014	no			no	no	no			no	no		
7/10/2014	no			no	no	no			no	no		
7/11/2014	no			no	no	no			no	no		
7/12/2014	no			no	no	no			no	no		
7/13/2014	no			no	no	no			no	no		
7/14/2014	no			no	no	no			no	no		
7/15/2014	no			no	no	no			no	no		
7/16/2014	no			no	no	no			no	no		
7/17/2014	no			no	no	no			no	no		
7/18/2014	no			no	no	no			no	no		
7/19/2014	no			no	no	no			no	no		
7/20/2014	no			no	no	no			no	no		
7/21/2014	no			no	no	no			no	no		
7/22/2014	no			no	no	no			no	no		
7/23/2014	no			no	no	no			no	no		
7/24/2014	no			no	no	no			no	no		
7/25/2014	no			no	no	no			no	no		
7/26/2014	no			no	no	no			no	no		
7/27/2014	no			no	no	no			no	no		
7/28/2014	no			no	no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
7/29/2014	no			no	no	no			no	no		
7/30/2014	no			no	no	no			no	no		
7/31/2014	no			no	no	no			no	no		
8/1/2014	no			no	no	no			no	no		
8/2/2014	no			no	no	no			no	no		
8/3/2014	no			no	no	no			no	no		
8/4/2014	no			no	no	no			no	no		
8/5/2014	no			no	no	no			no	no		
8/6/2014	no			no	no	no			no	no		
8/7/2014	no			no	no	no			no	no		
8/8/2014	no			no	no	no			no	no		
8/9/2014	no			no	no	no			no	no		
8/10/2014	no			no	no	no			no	no		
8/11/2014	no			no	no	no			no	no		
8/12/2014	no			no	no	no			no	no		
8/13/2014	no			no	no	no			no	no		
8/14/2014	no			no	no	no			no	no		
8/15/2014	no			no	no	no			no	no		
8/16/2014	no			no	no	no			no	no		
8/17/2014	no			no	no	no			no	no		
8/18/2014	no			no	no	no			no	no		
8/19/2014	no			no	no	no			no	no		
8/20/2014	no			no	no	no			no	no		
8/21/2014	no			no	no	no			no	no		
8/22/2014	no			no	no	no			no	no		
8/23/2014	no			no	no	no			no	no		
8/24/2014	no			no	no	no			no	no		
8/25/2014	no			no	no	no			no	no		
8/26/2014	no			no	no	no			no	no		
8/27/2014	no			no	no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
8/28/2014	no			no	no	no			no	no		
8/29/2014	no			no	no	no			no	no		
8/30/2014	no			no	no	no			no	no		
8/31/2014	no			no	no	no			no	no		
9/1/2014	no			no	no	no			no	no		
9/2/2014	no			no	no	no			no	no		
9/3/2014	no			no	no	no			no	no		
9/4/2014	no			no	no	no			no	no		
9/5/2014	no			no	no	no			no	no		
9/6/2014	no			no	no	no			no	no		
9/7/2014	no			no	no	no			no	no		
9/8/2014	no			no	no	no			no	no		
9/9/2014	no			no	no	no			no	no		
9/10/2014	no			no	no	no			no	no		
9/11/2014	no			no	no	no			no	no		
9/12/2014	no			no	no	no			no	no		
9/13/2014	no			no	no	no			no	no		
9/14/2014	no			no	no	no			no	no		
9/15/2014	no			no	no	no			no	no		
9/16/2014	no			no	no	no			no	no		
9/17/2014	no			no	no	no			no	no		
9/18/2014	no			no	no	no			no	no		
9/19/2014	no			no	no	no			no	no		
9/20/2014	no			no	no	no			no	no		
9/21/2014	no			no	no	no			no	no		
9/22/2014	no			no	no	no			no	no		
9/23/2014	no			no	no	no			no	no		
9/24/2014	no			no	no	no			no	no		
9/25/2014	no			no	no	no			no	no		
9/26/2014	no			no	no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
9/27/2014	no			no	no	no			no	no		
9/28/2014	no			no	no	no			no	no		
9/29/2014	no			no	no	no			no	no		
9/30/2014	no			no	no	no			no	no		
10/1/2014	no			no	no	no			no	no		
10/2/2014	no			no	no	no			no			
10/3/2014	no			no	no	no			no			
10/4/2014	no			no	no	no			no			
10/5/2014	no			no	no	no			no			
10/6/2014	no			no	no	no			no			
10/7/2014	no			no	no	no			no			
10/8/2014	no			no	no	no			no			
10/9/2014	no			no	no	no			no			
10/10/2014	no			no	no	no			no			
10/11/2014	no			no	no	no			no			
10/12/2014	no			no	no	no			no			
10/13/2014	no			no	no	no			no			
10/14/2014	no			no	no	no			no			
10/15/2014	no			no	no	no			no			
10/16/2014	no			no	no	no			no			
10/17/2014	no			no	no	no			no			
10/18/2014	no			no	no	no			no			
10/19/2014	no			no	no	no			no			
10/20/2014	no			no	no	no			no			
10/21/2014	no			no	no	4	4	200	no			
10/22/2014	no			no	no	no			no			
10/23/2014	no			no	no	no			no			
10/24/2014	no			no	no	no			no			
10/25/2014	no			no	no	5		300	no			
10/26/2014	no		0.33	no	no	no			no			

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
10/27/2014	no			no	no	no			no			
10/28/2014	no			no	no	no			no			
10/29/2014	no			no	1	6		300	no			
10/30/2014	no			no	no	no			no			
10/31/2014	no			no	no	no			no			
11/1/2014		0.9	265	no	2	no			no			
11/2/2014				no	no	no			no			
11/3/2014				no	no	no			no			
11/4/2014				no	no	no			no			
11/5/2014				no	no	no			no			
11/6/2014				no	no	no			no			
11/7/2014				no	no	no			no			
11/8/2014				no	no	no			no			
11/9/2014				no	no	no			no			
11/10/2014				no	no	no			no			
11/11/2014				no	no	no			no			
11/12/2014				no	no	no			no			
11/13/2014				no	no	3		300	no			
11/14/2014			133	no	no	no			no			
11/15/2014				no	no	no			no			
11/16/2014			44	no	no	no			no			
11/17/2014				no	no	no			no			
11/18/2014				no	no	no			no			
11/19/2014				no	no	6		300	no			
11/20/2014			841	no	no	4	2	300	no			
11/21/2014		0.75		no	no	no			no			
11/22/2014			310	no	no	no			no			
11/23/2014			18	no	no	no			no			
11/24/2014				no	no	no			no			
11/25/2014				no	no	no			no			

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
11/26/2014			531	no	no	no			no			
11/27/2014				no	no	no			no			
11/28/2014			310	no	no	no			no			
11/29/2014	1.2		155	no	no	12		600	no			
11/30/2014	0.6		177	no	no	3		300	no			
12/1/2014				no	no	3	9	300	no	no		
12/2/2014			111	no	1	no			no	no		
12/3/2014				no	1	12		600	no	no		
12/4/2014	0.1			no	1.5	6		600	no	no		
12/5/2014			133	no	no	no			no	no		
12/6/2014				no	no	15		600	no	no		
12/7/2014			88	no	no	no			no	no		
12/8/2014				no	no	no			no	no		
12/9/2014			133	no	no	no			no	no		
12/10/2014			177	no	no	no			no	no		
12/11/2014				no	no	3		300	no	no		
12/12/2014			133	no	1	3		300	no	no		
12/13/2014				no	no	no			no	no		
12/14/2014	1.8	0.3	221	no	no	no			no	no		
12/15/2014	2.2	0.3	1416	no	1	4		300	1.88	0.2	0.2	
12/16/2014		0.7	575	2	5	no	9		1.46	0.2	0.2	
12/17/2014		0.7	354	0.25	no	6		300	1.36	no		
12/18/2014				no	no	no			no	no		
12/19/2014		2.8	1482	no	3	3			no	0.5	0.5	
12/20/2014		0.1	0	0.5	1	no			no	no		
12/21/2014			0	no	no	no			no	no		
12/22/2014			0	no	no	no			no	no		
12/23/2014			199	no	no	no			no	no		114
12/24/2014		2.9	1549	no	1	6		300	no	0.5	0.2	
12/25/2014		5.7	1018	0.33	10	9	8	300	2.02	0.5	0.1	

Date	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
12/26/2014		0	0	0.5	1.5	6	2	300	3.19	no	0.1	
12/27/2014	0.2	0.4	0	no	1.5	no			no	no		
12/28/2014	0.2	0	0	no	no	no			no	no		
12/29/2014		0	0	4	1	no			3.15	no	1	200
12/30/2014		1.1	553	no	no	2			1.36	1	0.2	
12/31/2014			0	2	1	11		300	0.95	no	1	
1/1/2015			0		1	no			no	no		
1/2/2015			0		no	no			1.11	no		
1/3/2015			0		no	no			no	no		
1/4/2015			0		no	no			no	no		
1/5/2015			0		1	no			no	no		
1/6/2015			44		no	no			no	no		
1/7/2015			265		no	no			no	no		
1/8/2015					no	no			no	no		
1/9/2015					no	no			no	no		
1/10/2015					no	no			no	no		
1/11/2015					no	no			no	no		
1/12/2015					no	no			no	no		
1/13/2015					no	no			no	no		
1/14/2015					no	no			no	no		
1/15/2015			88		no	no			no	no		
1/16/2015					no	no			no	no		
1/17/2015					no	no			no	no		
1/18/2015					no	no			no	no		
1/19/2015					no	no			no	no		
1/20/2015					no	no			no	no		
1/21/2015					no	no			no	no		
1/22/2015					no	no			no	no		
1/23/2015					no	no			no	no		
1/24/2015					no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
1/25/2015					7	no			no	no		
1/26/2015					3.5	no			no	no		
1/27/2015			265		1	3	3	300	no	no		
1/28/2015			88		1	no			no	no		
1/29/2015					1	no			no	no		
1/30/2015					no	8	3	300	no	no		
1/31/2015					no	no			no	no		
2/1/2015					no	no			no	no		
2/2/2015					no	no			no	no		
2/3/2015					no	no			no	no		
2/4/2015					no	no			no	no		
2/5/2015					no	no			no	no		
2/6/2015	1.3		708		3	no			no	no		
2/7/2015	1.3				2	no			no	no		
2/8/2015			354		1	no			no	no		
2/9/2015			752		7	no			no	1	1	
2/10/2015			22		no	no			no	no		
2/11/2015			44		no	no			no	no		
2/12/2015						no			no	no		
2/13/2015						no			no	no		
2/14/2015					no	no			no	no		
2/15/2015					no	no			no	no		
2/16/2015					no	no			no	no		
2/17/2015					no	no			no	no		
2/18/2015					no	no			no	no		
2/19/2015					no	3			no	no		
2/20/2015					no	no			no	no		
2/21/2015					no	5		300	no	no		
2/22/2015			531		3	2	2		no	no		
2/23/2015					no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
2/24/2015					no	no			no	no		
2/25/2015					no	no			no	no		
2/26/2015			88		no	no			no	no		
2/27/2015	1.3		1239		no	no			no	no		
2/28/2015	3.5				no	9	6	300	no	1	1	
3/1/2015			1327	2	4.5	no			1.76	1	1	
3/2/2015	0.4				1	3	3		no	no		
3/3/2015					1	3	2		no	no		
3/4/2015					no	no			no	0.25	0.25	
3/5/2015					no	no			no	no		
3/6/2015					no	no			no	no		
3/7/2015					no	no			no	no		
3/8/2015					no	no			no	no		
3/9/2015					no	no			no	no		
3/10/2015					no	no			no	no		
3/11/2015					no	3			no	no		
3/12/2015			675		no	no			no	no		
3/13/2015					no	no			no	no		
3/14/2015					no	no			no	no		
3/15/2015					no	no			4.01	no		
3/16/2015					no	no			no	no		
3/17/2015					no	no			no	no		
3/18/2015					no	no			no	no		
3/19/2015					no	no			no	no		
3/20/2015					no	7	7	300	no	no		
3/21/2015					no	no			no	no		
3/22/2015					no	no			no	no		
3/23/2015	0.4		730		no	no			no	no		
3/24/2015					no	2			no	no		
3/25/2015					no	no			no	no		

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
3/26/2015					no	no			no	no		
3/27/2015					no	no			no	no		
3/28/2015					no	no			no	no		
3/29/2015					no	no			no	no		
3/30/2015					no	no			no	no		
3/31/2015					no	no			no	no		
4/1/2015					no	no			no			
4/2/2015					1	no			no			
4/3/2015					5	no	2		no			
4/4/2015			265		1	no			no			
4/5/2015	2.2		296		no	no			no			
4/6/2015	0.6		1128		no	no			no			
4/7/2015	3.9		1128		4	no			no			
4/8/2015			796		3.5	no			no			
4/9/2015					no	no			no			
4/10/2015					no	no			no			
4/11/2015					no	no			no			
4/12/2015					no	no			no			
4/13/2015					no	no			no			
4/14/2015			398		no	no			no			
4/15/2015					no	no			no			
4/16/2015					no	no			no			
4/17/2015					no	2	2	300	no			
4/18/2015					no	no			no			
4/19/2015					no	no			no			
4/20/2015					no	no			no			
4/21/2015					no	no			no			
4/22/2015					no	no			no			
4/23/2015					no	no			no			
4/24/2015			400		no	no			no			

	Caltrans North			CSLT	KGID	NDOT			Placer	Washoe		
Date	Abrasives Applied (tons)	Salt Applied (tons)	Brine (gallons)	Abrasives Applied (cu-yds)	Abrasives Applied (cu-yds)	Abrasives Applied (cu yds)	Salt Applied (cu-yds)	Brine (gallons)	Abrasives Applied (tons)	Abrasives Applied (cu-yds)	Salt Applied (cu-yd)	Brine (gallons)
4/25/2015	3		1000		no	no			no			
4/26/2015					no	no			no			
4/27/2015					no	no			no			
4/28/2015					no	no			no			
4/29/2015					no	no			no			
4/30/2015					no	no			no			

	Caltrans North	CSLT	KGID	NDOT	Placer	Washoe
Date	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)
12/1/2013	no	no	no	no	no	no
12/2/2013	no	3	no	no	no	no
12/3/2013	no	no	no	no	no	no
12/4/2013	no	no	no	no	no	no
12/5/2013	no	no	no	no	no	no
12/6/2013	no	no	no	no	4.3	no
12/7/2013	no	no	no	no	no	no
12/8/2013	no	no	no	no	no	no
12/9/2013	no	no	no	no	no	no
12/10/2013	no	no	no	no	no	no
12/11/2013	no	no	no	18	no	no
12/12/2013	1.8	no	2.5	10	no	1.56
12/13/2013	1.8	no	no	no	no	4.44
12/14/2013	1.8	no	no	no	no	no
12/15/2013	2.6	no	no	no	no	no
12/16/2013	2.9	no	no	no	no	4.68
12/17/2013	2.6	no	0.25	no	2.4	2.16
12/18/2013	0.2	3	no	no	no	0.13
12/19/2013	5.3	no	no	no	no	0.39
12/20/2013	4.0	3	no	no	no	0.39
12/21/2013	2.6	no	no	no	no	no
12/22/2013	0.4	no	no	no	no	no
12/23/2013	no	3	0.25	no	7.3	1.82
12/24/2013	no	no	no	no	8.2	2.13
12/25/2013	no	no	no	no	no	no
12/26/2013	no	no	0.25	no	no	1.29
12/27/2013	3.5	3	no	no	no	no
12/28/2013	3.5	no	no	no	no	no
12/29/2013	1.8	no	no	no	no	no
12/30/2013	3.5	no	no	no	no	no
12/31/2013	2.6	no	no	no	no	no
1/1/2014	no	no	no	no	no	no
1/2/2014	no	no	no	no	no	1.32
1/3/2014	no	no	no	6	no	no
1/4/2014	no	no	no	no	no	no
1/5/2014	5.3	no	no	10	no	no
1/6/2014	3.1	no	no	no	1.4	no
1/7/2014	no	3	no	no	14.0	0.91
1/8/2014	no	3	no	no	12.62	1.04
1/9/2014	2.2	3	no	no	no	no
1/10/2014	no	no	no	no	no	0.09
1/11/2014	no	no	no	no	no	no
1/12/2014	no	no	no	no	no	no
1/13/2014	1.3	3	no	no	no	no
1/14/2014	2.6	3	no	6	no	no
1/15/2014	3.1	3	no	no	no	0.65
1/16/2014	no	3	no	no	no	no
1/17/2014	no	3	no	no	no	no
1/18/2014	no	no	no	no	no	no
1/19/2014	no	no	no	no	no	no
1/20/2014	no	no	no	no	no	no
1/21/2014	0.9	no	no	no	no	no
1/22/2014	no	no	no	no	8.24	no

	Caltrans North	CSLT	KGID	NDOT	Placer	Washoe
Date	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)
1/23/2014	no	no	no	no	5.49	1.17
1/24/2014	no	no	no	no	no	no
1/25/2014	no	no	no	no	no	no
1/26/2014	no	no	no	no	no	no
1/27/2014	no	no	no	no	no	no
1/28/2014	5.3	no	no	no	no	0.24
1/29/2014	3.1	no	no	no	no	0.81
1/30/2014	no	no	no	no	no	no
1/31/2014	no	no	2.25	no	no	no
2/1/2014	1.8	no	no	no	no	no
2/2/2014	no	no	no	no	no	no
2/3/2014	no	no	no	no	no	no
2/4/2014	no	no	no	no	no	no
2/5/2014	no	no	no	no	no	1.56
2/6/2014	no	no	no	no	no	no
2/7/2014	no	no	no	no	no	no
2/8/2014	no	no	no	no	no	no
2/9/2014	no	no	no	no	no	no
2/10/2014	2.7	no	no	no	no	no
2/11/2014	7.1	no	no	no	no	no
2/12/2014	3.1	3	no	no	no	0.91
2/13/2014	3.1	3	no	no	no	2.08
2/14/2014	3.1	3	no	no	no	1.17
2/15/2014	no	no	no	no	no	no
2/16/2014	2.7	no	no	no	no	no
2/17/2014	no	no	no	no	no	no
2/18/2014	5.3	no	no	no	1.5	1.95
2/19/2014	5.3	no	no	no	1.7	no
2/20/2014	8.0	6	no	no	no	1.43
2/21/2014	1.3	no	no	no	no	1.3
2/22/2014	no	no	no	no	no	no
2/23/2014	0.9	no	no	no	no	no
2/24/2014	no	6	no	no	no	0.65
2/25/2014	no	no	no	no	no	1.56
2/26/2014	no	no	no	no	no	3.12
2/27/2014	no	no	no	no	no	no
2/28/2014	2.2	no	no	no	no	no
3/1/2014	6.2	no	3.5	no	no	no
3/2/2014	no	no	no	no	no	no
3/3/2014	no	3	no	no	no	0.27
3/4/2014	3.5	no	no	no	13.1	1.17
3/5/2014	1.8	3	no	no	4.2	no
3/6/2014	2.2	6	no	3	no	no
3/7/2014	2.6	6	no	no	no	no
3/8/2014	no	no	no	no	no	no
3/9/2014	0.4	no	no	no	no	no
3/10/2014	1.3	3	no	no	no	no
3/11/2014	no	3	no	no	no	1.56
3/12/2014	no	no	no	no	no	1.95
3/13/2014	no	no	no	no	no	no
3/14/2014	no	6	no	no	no	0.13
3/15/2014	no	no	no	no	no	no
3/16/2014	no	no	no	no	no	no

	Caltrans North	CSLT	KGID	NDOT	Placer	Washoe
Date	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)
3/17/2014	no	3	no	no	10.5	0.91
3/18/2014	no	3	no	12	no	no
3/19/2014	no	no	no	no	no	no
3/20/2014	no	3	no	15	no	no
3/21/2014	no	no	no	10	no	no
3/22/2014	no	no	no	no	no	no
3/23/2014	no	no	no	no	no	no
3/24/2014	no	no	no	no	no	no
3/25/2014	no	no	no	no	no	no
3/26/2014	no	no	no	no	no	no
3/27/2014	no	no	no	no	no	no
3/28/2014	no	9	no	no	no	no
3/29/2014	no	no	no	no	no	no
3/30/2014	no	no	5.75	no	no	no
3/31/2014	no	no	no	no	no	no
4/1/2014	no	no		no	no	no
4/2/2014	no	1		no	no	no
4/3/2014	no	9		no	no	1.3
4/4/2014	no	3		6	11.4	no
4/5/2014	no	no		no	no	no
4/6/2014	no	no		6	no	no
4/7/2014	no	no		no	no	1.3
4/8/2014	no	no		no	no	1.56
4/9/2014	no	4.5		no	no	1.82
4/10/2014	3.52	no		no	no	no
4/11/2014	5.28	no		no	no	no
4/12/2014	no	no		no	no	no
4/13/2014	no	no		no	no	no
4/14/2014	0.88	no		no	no	no
4/15/2014	no	no		no	no	no
4/16/2014	no	no		no	no	no
4/17/2014	no	6		no	no	no
4/18/2014	no	no		no	no	no
4/19/2014	no	no		no	no	no
4/20/2014	no	no		no	no	no
4/21/2014	no	no		no	no	no
4/22/2014	no	no		no	no	no
4/23/2014	no	no		no	no	no
4/24/2014	no	no		6	no	1.08
4/25/2014	no	no		no	no	no
4/26/2014	no	no		no	no	no
4/27/2014	no	no		no	no	no
4/28/2014	no	1.5		no	no	1.17
4/29/2014	no	no		no	no	no
4/30/2014	no	no		no	no	no
5/1/2014	no	no		no	no	0.65
5/2/2014	no	no		no	no	no
5/3/2014	no	no		no	no	no
5/4/2014	no	no		no	no	no
5/5/2014	no	no		no	no	no
5/6/2014	no	no		no	no	1.56
5/7/2014	no	no		no	no	no
5/8/2014	no	no		no	no	no

	Caltrans North	CSLT	KGID	NDOT	Placer	Washoe
Date	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)
5/9/2014	no	no		no	3.85	no
5/10/2014	no	no		no	no	no
5/11/2014	no	no		no	no	no
5/12/2014	no	no		no	22.1	no
5/13/2014	no	no		no	no	no
5/14/2014	no	no		no	no	no
5/15/2014	no	no		6	no	no
5/16/2014	no	no		no	no	no
5/17/2014	no	no		no	no	no
5/18/2014	no	no		no	no	no
5/19/2014	no	no		9	no	no
5/20/2014	no	no		no	no	no
5/21/2014	no	no		no	no	0.39
5/22/2014	no	no		no	no	no
5/23/2014	no	no		no	no	no
5/24/2014	no	no		no	no	no
5/25/2014	no	no		no	no	no
5/26/2014	no	no		no	no	no
5/27/2014	no	no		no	no	no
5/28/2014	no	no		no	no	no
5/29/2014	no	no		6	no	no
5/30/2014	no	no		no	no	no
5/31/2014	no	no		no	no	no
6/1/2014	no	no		no	no	no
6/2/2014	no	no		no	no	no
6/3/2014	no	6		6	no	no
6/4/2014	no	no		no	no	no
6/5/2014	no	3		no	no	0.91
6/6/2014	no	6		no	no	no
6/7/2014	no	no		no	no	no
6/8/2014	no	no		no	no	no
6/9/2014	no	6		no	no	no
6/10/2014	no	6		no	no	no
6/11/2014	no	3		no	no	no
6/12/2014	no	no		no	no	no
6/13/2014	no	1.5		no	no	no
6/14/2014	no	no		no	no	no
6/15/2014	no	no		no	no	no
6/16/2014	no	no		no	no	no
6/17/2014	no	no		no	no	no
6/18/2014	no	no		no	no	no
6/19/2014	no	no		no	no	1.6
6/20/2014	no	no		no	no	no
6/21/2014	no	no		no	no	no
6/22/2014	no	no		no	no	no
6/23/2014	1.32	no		no	no	1.72
6/24/2014	no	no		no	no	1.17
6/25/2014	no	no		no	no	no
6/26/2014	no	no		no	no	no
6/27/2014	no	no		no	no	no
6/28/2014	no	no		no	no	no
6/29/2014	no	no		no	no	no
6/30/2014	no	no		no	no	no

	Caltrans North	CSLT	KGID	NDOT	Placer	Washoe
Date	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)
7/1/2014	no	no		no	no	no
7/2/2014	no	no		no	no	0.39
7/3/2014	no	no		no	no	no
7/4/2014	no	no		no	no	no
7/5/2014	no	no		no	no	no
7/6/2014	3.31	no		no	no	no
7/7/2014	no	no		no	no	1.17
7/8/2014	no	no		no	no	1.17
7/9/2014	no	no		no	no	2.08
7/10/2014	no	no		no	no	no
7/11/2014	no	no		no	no	no
7/12/2014	no	no		no	no	no
7/13/2014	no	no		no	no	no
7/14/2014	no	no		no	no	no
7/15/2014	no	no		no	no	no
7/16/2014	3.53	no		no	no	no
7/17/2014	no	no		no	no	no
7/18/2014	no	no		no	no	no
7/19/2014	no	no		no	no	no
7/20/2014	no	no		no	no	no
7/21/2014	no	no		6	no	no
7/22/2014	no	no		no	no	no
7/23/2014	no	no		no	no	no
7/24/2014	no	no		no	no	0.78
7/25/2014	no	no		no	no	no
7/26/2014	no	no		no	no	no
7/27/2014	no	no		no	no	no
7/28/2014	no	no		no	no	no
7/29/2014	no	no		no	no	0.52
7/30/2014	no	no		no	no	1.69
7/31/2014	no	no		no	no	no
8/1/2014	no	no		no	no	no
8/2/2014	no	no		no	no	no
8/3/2014	no	no		no	no	no
8/4/2014	no	no		no	no	no
8/5/2014	no	no		no	no	no
8/6/2014	no	no		no	no	0.52
8/7/2014	no	no		no	no	0.52
8/8/2014	no	no		no	no	no
8/9/2014	no	no		no	no	no
8/10/2014	no	no		no	no	no
8/11/2014	no	no		no	no	no
8/12/2014	no	no		no	no	no
8/13/2014	no	no		no	no	no
8/14/2014	no	3		no	no	no
8/15/2014	no	no		no	no	no
8/16/2014	no	no		no	no	no
8/17/2014	no	no		no	no	no
8/18/2014	1.77	no		no	no	no
8/19/2014	3.53	2		10	no	no
8/20/2014	no	6		no	no	0.13
8/21/2014	no	1		no	no	no
8/22/2014	no	no		no	no	no

	Caltrans North	CSLT	KGID	NDOT	Placer	Washoe
Date	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)
8/23/2014	no	no		no	no	no
8/24/2014	no	no		no	no	no
8/25/2014	no	no		no	no	no
8/26/2014	no	no		no	no	no
8/27/2014	no	6		no	no	no
8/28/2014	no	2.5		no	no	no
8/29/2014	no	no		no	no	no
8/30/2014	no	no		no	no	no
8/31/2014	no	no		no	no	no
9/1/2014	no	no		no	no	no
9/2/2014	no	4		no	no	no
9/3/2014	no	no		no	no	no
9/4/2014	0.44	no		no	no	0.65
9/5/2014	no	no		no	no	no
9/6/2014	no	no		no	no	no
9/7/2014	no	no		no	no	no
9/8/2014	no	no		no	1.01	no
9/9/2014	no	no		no	no	no
9/10/2014	no	no		no	no	no
9/11/2014	no	no		no	no	no
9/12/2014	no	no		no	no	no
9/13/2014	no	no		no	no	no
9/14/2014	no	no		no	no	no
9/15/2014	no	no		no	no	no
9/16/2014	no	no		no	no	0.78
9/17/2014	5.3	no		no	no	no
9/18/2014	no	no		no	no	no
9/19/2014	no	no		no	no	no
9/20/2014	no	no		no	no	no
9/21/2014	no	no		no	no	no
9/22/2014	no	no		no	no	no
9/23/2014	no	no		no	no	0.46
9/24/2014	no	no		no	no	0.78
9/25/2014	no	no		no	no	0.26
9/26/2014	no	3		no	no	no
9/27/2014	no	no		no	no	no
9/28/2014	no	no		no	no	no
9/29/2014	no	no		no	no	3.52
9/30/2014	no	no		no	no	3.12
10/1/2014	no	no		no	no	
10/2/2014	no	no		no	no	
10/3/2014	no	8		no	no	
10/4/2014	no	no		no	no	
10/5/2014	no	no		no	no	
10/6/2014	no	no	1	no	no	
10/7/2014	no	no		no	no	
10/8/2014	no	no		no	no	
10/9/2014	no	no		no	no	
10/10/2014	no	3		no	no	
10/11/2014	no	no		no	no	
10/12/2014	no	no		no	no	
10/13/2014	no	no		no	no	
10/14/2014	no	no		no	no	

	Caltrans North	CSLT	KGID	NDOT	Placer	Washoe
Date	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)
10/15/2014	no	no		no	no	
10/16/2014	no	no		no	no	
10/17/2014	no	no		no	no	
10/18/2014	no	no		no	no	
10/19/2014	no	no		no	no	
10/20/2014	no	no		no	no	
10/21/2014	no	no		no	no	
10/22/2014	no	no		6	no	
10/23/2014	no	no		9	no	
10/24/2014	no	no		8	no	
10/25/2014	no	no		no	no	
10/26/2014	no	no		no	no	
10/27/2014	no	no		no	no	
10/28/2014	no	no		no	no	
10/29/2014	no	no		no	no	
10/30/2014	no	no		no	no	
10/31/2014	no	no		no	no	
11/1/2014	no	no		no	no	
11/2/2014	no	no		no	no	
11/3/2014	11	12		no	no	
11/4/2014	7	15		no	no	
11/5/2014	4	9		5	no	
11/6/2014	7	16		no	no	
11/7/2014	7	12		no	no	
11/8/2014	no	no		no	no	
11/9/2014	no	no		no	no	
11/10/2014	no	4		9	no	
11/11/2014	no	no		no	no	
11/12/2014	4	no		no	no	
11/13/2014	4	no		no	no	
11/14/2014	1	no		6	no	
11/15/2014		no		no	no	
11/16/2014		no		no	no	
11/17/2014		no		no	no	
11/18/2014		6		no	no	
11/19/2014		no		no	no	
11/20/2014		no		no	no	
11/21/2014		no		no	no	
11/22/2014		no		no	no	
11/23/2014		no		no	no	
11/24/2014		no		no	no	
11/25/2014	2	no		no	no	
11/26/2014		no		no	no	
11/27/2014		no		no	no	
11/28/2014		no		no	no	
11/29/2014		no		no	no	
11/30/2014		no		no	no	
12/1/2014	5	no		no	no	
12/2/2014		no		no	no	
12/3/2014		no		no	no	
12/4/2014		no		no	no	
12/5/2014		no		no	no	
12/6/2014		no		no	no	

	Caltrans North	CSLT	KGID	NDOT	Placer	Washoe
Date	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)
12/7/2014	2	no		no	no	
12/8/2014	1	no	2	15	no	
12/9/2014	2	no	1	3	no	
12/10/2014		no		8	no	
12/11/2014		no		no	no	
12/12/2014	3	no		no	no	
12/13/2014	11	no		no	no	
12/14/2014	5	no		no	no	
12/15/2014		3		no	no	
12/16/2014		no		no	no	
12/17/2014		no		no	no	
12/18/2014		6		3	no	
12/19/2014		no		no	no	
12/20/2014		no		no	no	
12/21/2014		no		no	no	
12/22/2014		no		18	no	
12/23/2014	2	3		3	no	
12/24/2014	4	no		no	no	
12/25/2014		no		no	no	
12/26/2014		no		no	no	
12/27/2014		no		no	no	
12/28/2014		no		no	no	
12/29/2014		9		6	no	
12/30/2014		2		no	no	
12/31/2014		no		no	no	
1/1/2015				no	no	
1/2/2015				no	no	
1/3/2015				no	no	
1/4/2015	3			no	no	
1/5/2015				no	no	
1/6/2015		6		no	no	3
1/7/2015			7	no	11.6	2
1/8/2015	4		7	no	no	
1/9/2015	4		7	no	11.6	
1/10/2015	1			no	no	
1/11/2015	1			no	no	
1/12/2015	0			no	19.2	
1/13/2015	1	6	2	no	no	
1/14/2015	11			no	no	
1/15/2015	4			no	no	
1/16/2015	0	5		no	no	
1/17/2015	0			21	no	
1/18/2015	4			no	no	
1/19/2015				no	no	
1/20/2015		6		no	no	
1/21/2015		6		17	no	
1/22/2015				9	no	
1/23/2015		6		20	no	3
1/24/2015	3			8	no	
1/25/2015				no	no	
1/26/2015	6			no	no	
1/27/2015	1			8	no	
1/28/2015				no	no	

	Caltrans North	CSLT	KGID	NDOT	Placer	Washoe
Date	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)
1/29/2015	1			8	no	
1/30/2015	1			12	no	
1/31/2015				6	no	
2/1/2015						
2/2/2015	1			7		
2/3/2015				3		
2/4/2015						
2/5/2015						
2/6/2015						
2/7/2015						
2/8/2015						
2/9/2015	2					
2/10/2015	15			6		
2/11/2015	9		7	6		
2/12/2015	4		4	3		
2/13/2015			2			
2/14/2015						
2/15/2015						
2/16/2015	2					
2/17/2015	2					
2/18/2015	2					
2/19/2015	2					
2/20/2015						
2/21/2015						
2/22/2015						
2/23/2015		6		3		
2/24/2015		6		3	6.6	1
2/25/2015			2			
2/26/2015		9				
2/27/2015						
2/28/2015						
3/1/2015						
3/2/2015						
3/3/2015	1					
3/4/2015	2	7		6		
3/5/2015	7	6		6		
3/6/2015		9	2			
3/7/2015	3					
3/8/2015						
3/9/2015	3			4		
3/10/2015						
3/11/2015		3				
3/12/2015						
3/13/2015			2		15.8	
3/14/2015						
3/15/2015						
3/16/2015			2		19.8	
3/17/2015			2			
3/18/2015			2			
3/19/2015			2			
3/20/2015				4		
3/21/2015						
3/22/2015						

	Caltrans North	CSLT	KGID	NDOT	Placer	Washoe
Date	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)	Material Recovered (cubic yards)
3/23/2015						
3/24/2015			2			
3/25/2015	0.5	6				
3/26/2015	1	6				
3/27/2015		6				
3/28/2015						
3/29/2015						
3/30/2015						
3/31/2015		6		6		
4/1/2015	2			4		
4/2/2015				4		
4/3/2015						
4/4/2015						
4/5/2015						
4/6/2015						
4/7/2015						
4/8/2015						
4/9/2015						
4/10/2015						
4/11/2015						
4/12/2015						
4/13/2015			7			
4/14/2015			5	4		
4/15/2015				8		
4/16/2015						
4/17/2015		3		4		
4/18/2015						
4/19/2015						
4/20/2015		6		2		
4/21/2015				2		
4/22/2015						
4/23/2015						
4/24/2015					0.093	
4/25/2015						
4/26/2015						
4/27/2015					6.2	
4/28/2015					20.6	
4/29/2015						
4/30/2015		3				