Assessing the Impact of Chloride Deicer Application in the Siskiyou Pass, Southern Oregon

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Prepared in cooperation with the Oregon Department of Transportation

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Outline

- ❑ Background
- ❑ SELDM
- ❑ Methodology
- ❑ Results
- ❑ Conclusion

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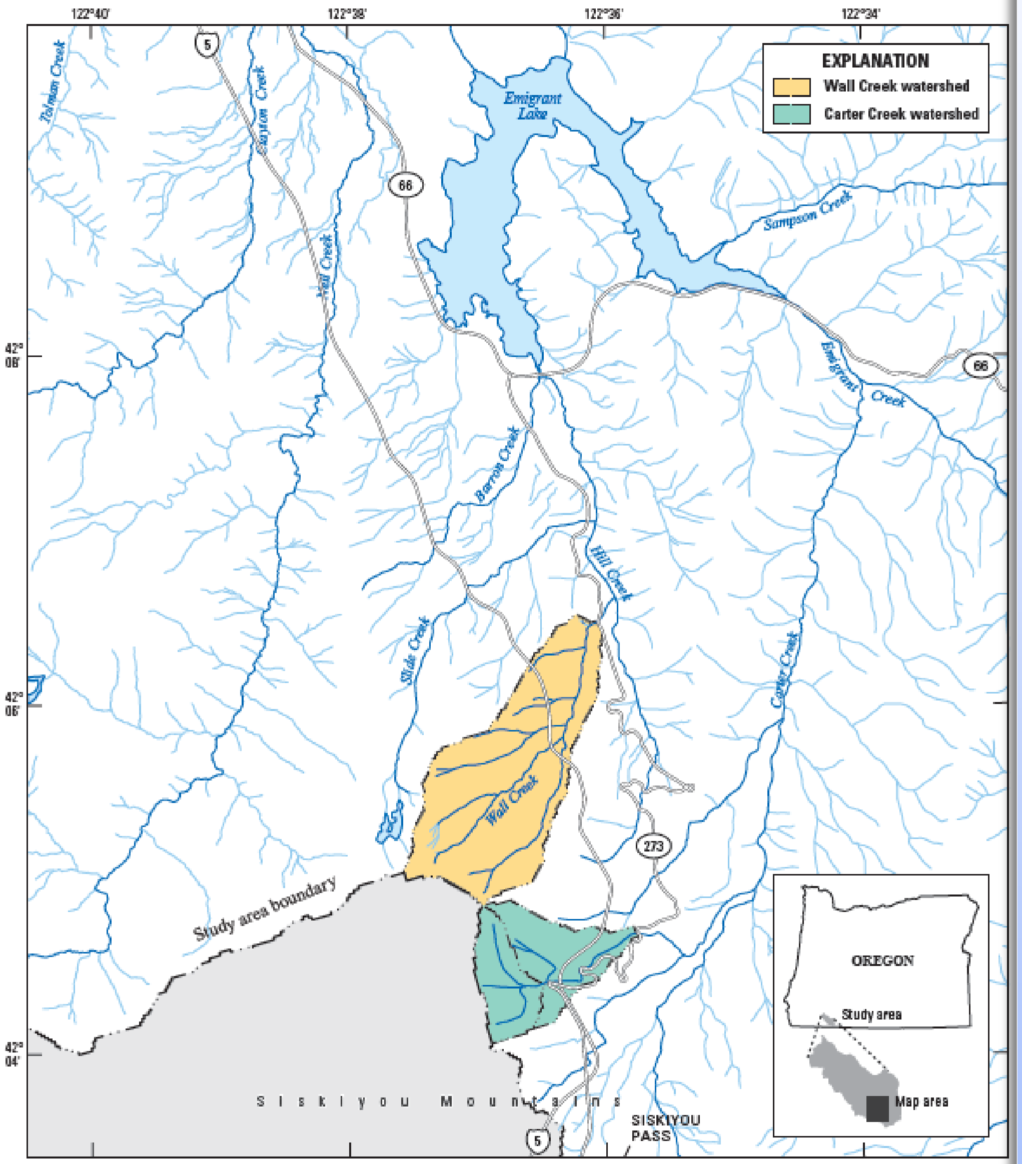
Background

- Chloride deicer applied in Siskiyou Pass
- Effects on surface water runoff and in groundwater?

Oregon Department of Transportation - Oregon DOT Siskiyou Summit Uploaded by Smallman12q https://en.wikipedia.org/wiki/Siskiyou_Summit#/media/File:Oregon_DOT_Siskiyou_Summit_(2928843767).jpg



Base modified from U.S. Geological Survey digital data, various dates and scales; Albers Equal-Area Conic projection, standard parallels 29°30' N. and 45°30' N., central meridian 96°00' W., rotated 16.2°; North American Datum of 1983

Figure 1. Carter and Wall Creek study area in the Siskiyou Pass, southern Oregon.

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Background

- ❑ Small creeks
- ❑ Large Highway (Interstate-5)

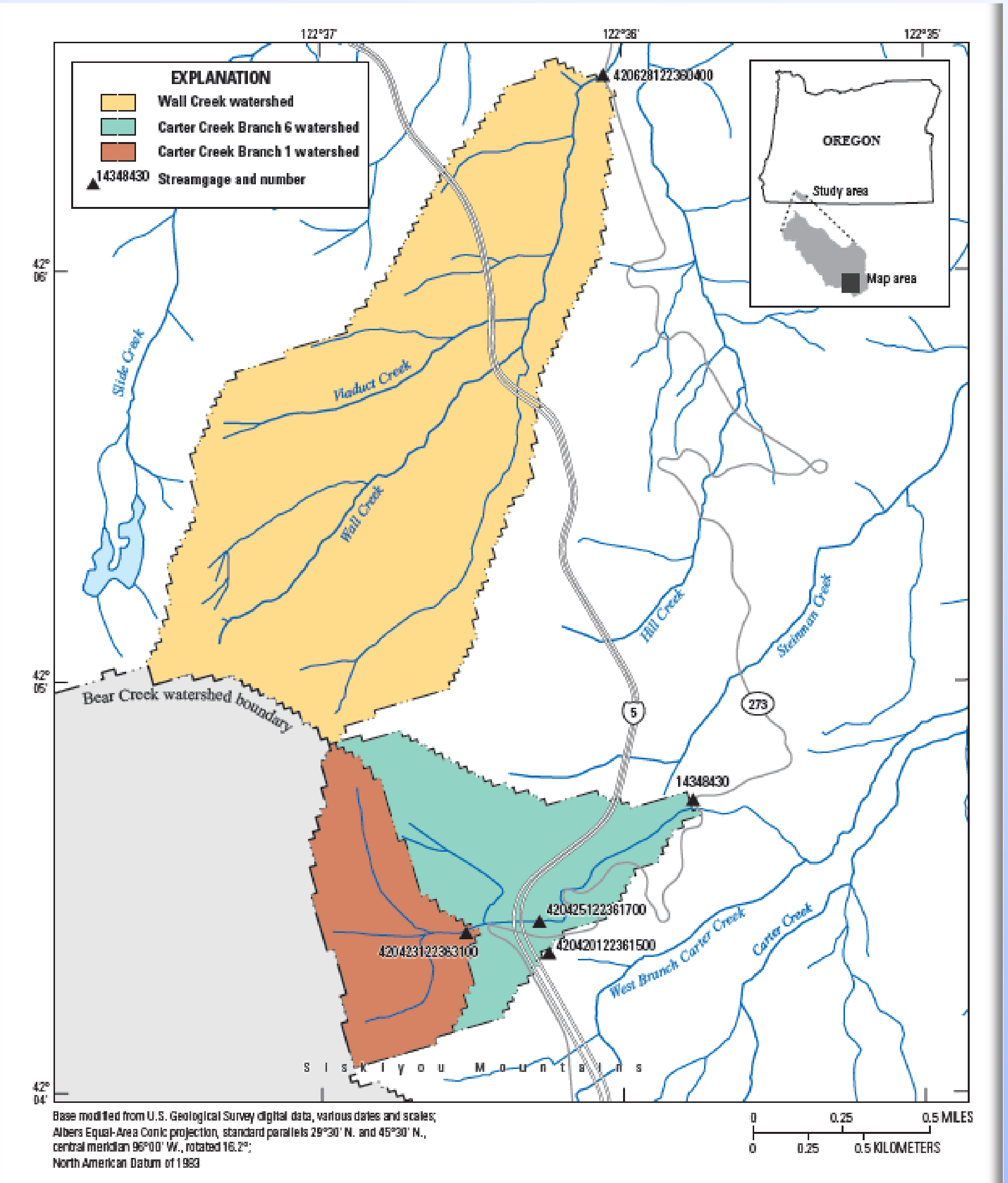

Figure 2. Carter Creek study areas adjacent to Interstate Route 5 in the Siskiyou Pass, southern Oregon.

Background- Purpose and Scope

1. Evaluate background levels of chloride, magnesium, and sodium in streamflows for the region.
2. Model how often we expect to exceed water-quality standards.
3. Model the effect of Best-Management Practices (BMPs) on mitigating effects of chloride deicers.
4. Collect data to analyze how much of chloride downstream of highway is from NaCl and MgCl2.
5. Determine which locally collected data were most useful for modeling efforts.
6. Evaluate the expected percentage of deicer chlorides applied to roadways that will reach receiving waters.

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SELDM- Stochastic Empirical Loading Dilution Model

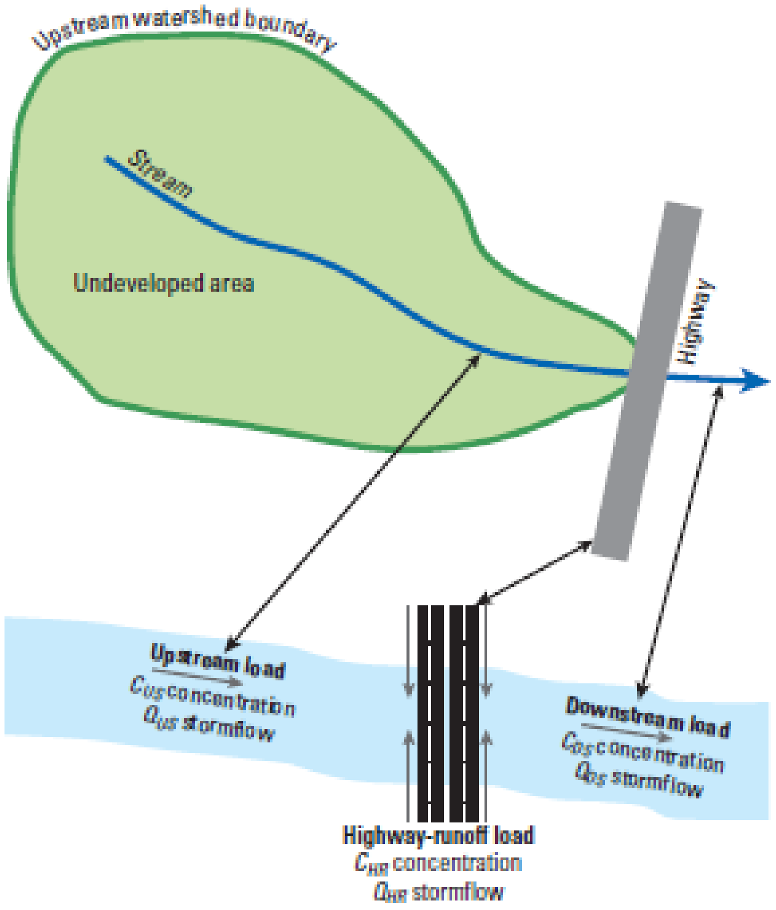

Figure 11. Schematic of SELDM Simulation Scenario 1—Natural Conditions. (CDS, concentration of downstream load; CHR, concentration of highway-runoff load; CUS, concentration of upstream load; QDS, stormflow downstream load; QHR, stormflow of highway-runoff load; QUS, stormflow of upstream load)

Stonewall, A.J., Granato, G.E., and Glover-Cutter, K.M., 2019, Assessing potential effects of highway and urban runoff on receiving streams in total maximum daily load watersheds in Oregon using the Stochastic Empirical Loading and Dilution Model: U.S. Geological Survey Scientific Investigations Report 2019–5053, 116 p., https://doi.org/10.3133/sir20195053.

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Stochastic Empirical Loading Dilution Model (SELDM)

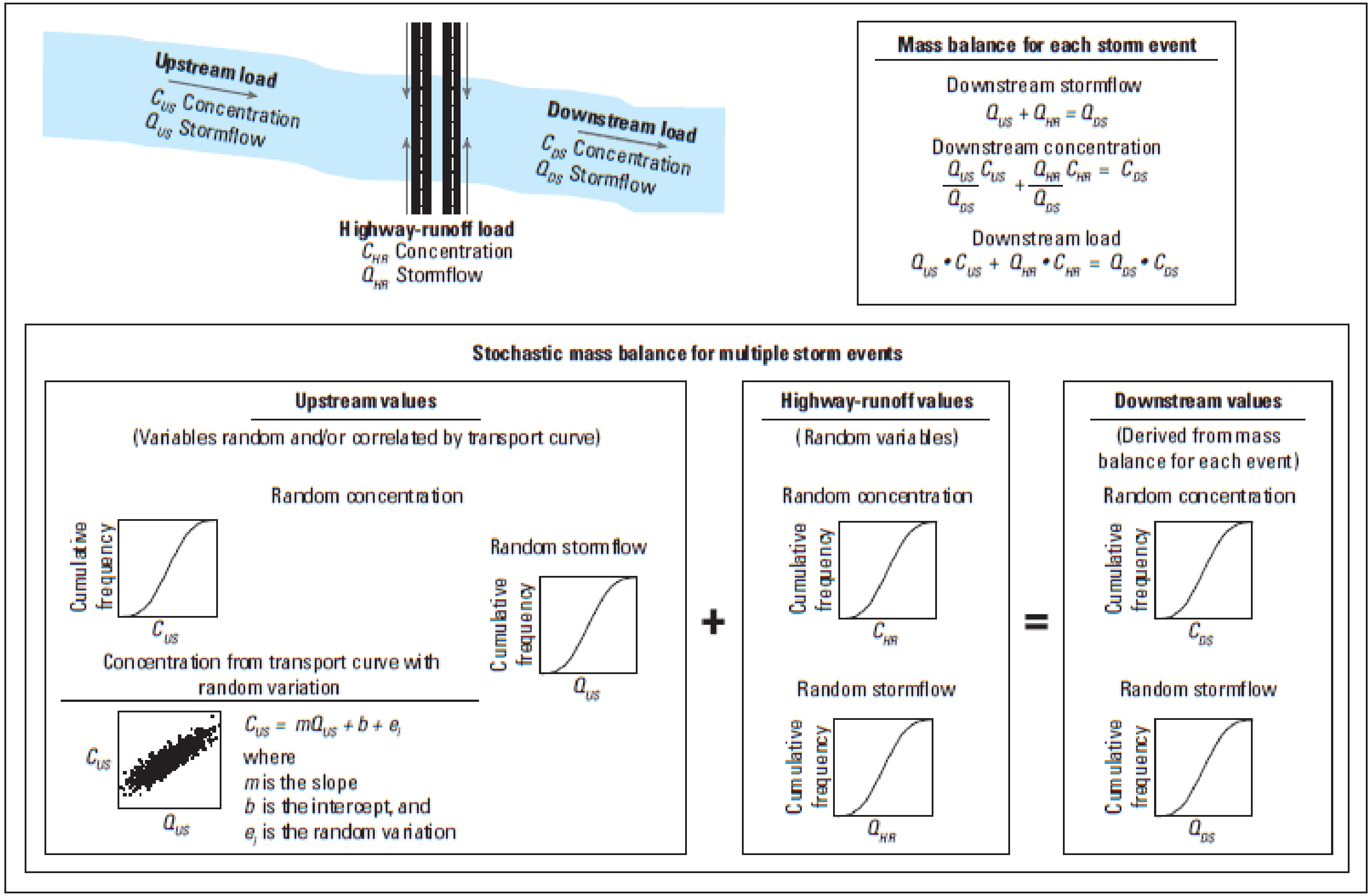

Figure 5. Components of the Stochastic Empirical Loading and Dilution Model.

Stonewall, A.J., Granato, G.E., and Glover-Cutter, K.M., 2019, Assessing potential effects of highway and urban runoff on receiving streams in total maximum daily load watersheds in Oregon using the Stochastic Empirical Loading and Dilution Model: U.S. Geological Survey Scientific Investigations Report 2019–5053, 116 p., https://doi.org/10.3133/sir20195053.

Stochastic Empirical Loading Dilution Model (SELDM)

Model inputs

Highway site characteristics:
- Drainage area
- Drainage length
- Slope
- Imperviousness
- Basin Development

Upstream basin characteristics:
- Drainage area
- Drainage length
- Slope
- Imperviousness
- Basin Development
- Hydrograph recession parameters

Precipitation :
- Storm event volume statistics
- Storm event duration statistics
- Inter-event timing statistics
- Number of events statistics
- Total annual precipitation statistics

Streamflow statistics:
- Too many to list here
- Examples include mean, standard deviation, skewness and median of the retransformed Log10 arithmetic statistics for nonzero daily-mean streamflow values.

Volumetric runoff statistics:
- Imperviousness or average, standard deviation and skewness of runoff events for highway site.
- Imperviousness or average, standard deviation and skewness of runoff events for upstream basin.

Water-quality statistics:
- Can be random, dependent or a transport curve
- For upstream and highway runoff (no transport curve option for highway)
- Too many to list here

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Stochastic Empirical Loading Dilution Model (SELDM)

Model inputs

Level 1 analysis:
- ❑ National /regional data
- ❑ High variance
- ❑ Fast and easy
- ❑ First-order evaluation

Level 2 analysis:
- ❑ Regional/local data
- ❑ Data analysis/manipulation
- ❑ Medium variance
- ❑ No new data collection
- ❑ Second-order evaluation
- ❑ Most common SELDM analysis

Level 3 analysis:
- ❑ Local data and/or data collected specifically for model
- ❑ Low variance
- ❑ Takes time and funding
- ❑ Typically best results

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Stochas ELDM)

Level 1 ana
- Use of r
  precipit

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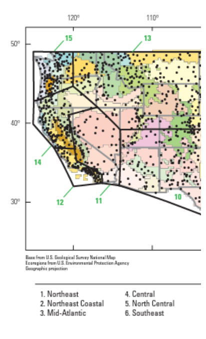

Figure 6. The spatial distribution of 2,610 hourly-precipitation d
Palhegyi, and others, 1989) and the U.S. Environmental Protection
in the conterminous United States. Ecoregions are identified on t

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Methods

SELDM scenario	Location	SELDM input series: Highway site	Upstream basin characteristics	Precipitation statistics	Streamflow statistics	Volumetric runoff coefficient statistics-highway	Volumetric runoff coefficient statistics-upstream	Chloride: Water quality-Highway random	Chloride: Water quality-Upstream random	Scenario goal
1	Carter Creek Branch 1	Level-1	Level-1	Level-1	Level-1	Level-1	Level-1	Level-2	Level-2	Evaluate accuracy of planning level simulations
2	Carter Creek Branch 1	Level-1	Level-1	Level-2	Level-2	Level-1	Level-1	Level-2	Level-2	Evaluate accuracy of level 2 analysis
3	Carter Creek Branch 1	Level-3	Level-3	Level-2	Level-2	Level-3	Level-3	Level-2	Level-2	Evaluate value of Level-3 highway information
4	Carter Creek Branch 1	Level-1	Level-1	Level-1	Level-2	Level-1	Level-1	Level-2	Level-2	Evaluate value of regional precipitation data
5	Carter Creek Branch 1	Level-1	Level-1	Level-3	Level-2	Level-1	Level-1	Level-2	Level-2	Evaluate value of local precipitation data
6	Carter Creek Branch 1	Level-1	Level-1	Level-2	Level-1	Level-1	Level-1	Level-2	Level-2	Evaluate value of regional streamflow data
7	Carter Creek Branch 1	Level-1	Level-1	Level-2	Level-3	Level-1	Level-1	Level-2	Level-2	Evaluate value of local streamflow data
8	Carter Creek Branch 1	Level-1	Level-1	Level-2	Level-2	Level-1	Level-1	Level-2	Level-2	Evaluate value of regional stream concentrations of Cl
9	Carter Creek Branch 1	Level-1	Level-1	Level-2	Level-2	Level-1	Level-1	Level-2	Level-3	Evaluate value of local stream concentrations of Cl
10	Carter Creek Branch 1	Level-1	Level-1	Level-2	Level-2	Level-1	Level-1	Level-3	Level-2	Evaluate value of local highway runoff concentrations of Cl
11	Carter Creek Branch 1	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Best estimate based on all local data available
12	Carter Creek Branch 1	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Evaluate effect of BMP
13	Wall Creek	Level-1	Level-1	Level-1	Level-1	Level-1	Level-1	Level-2	Level-2	Evaluate accuracy of planning level simulations
14	Wall Creek	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Best estimate based on all local data available
15	Carter Creek Branch 6	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Level-3	Best estimate based on all local data available

Level 1 Analysis

Level 2 Analysis

Level 3 Analysis

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Methods

Wall Creek- specific conductance

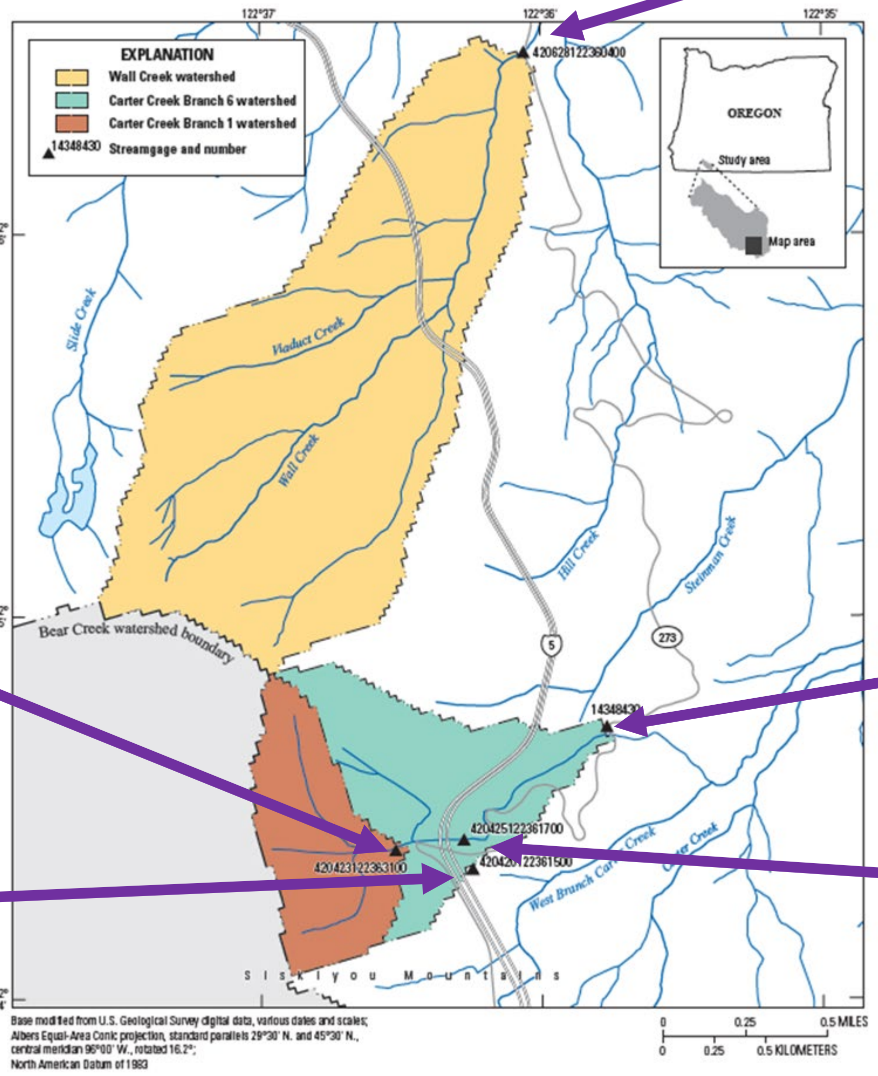

Figure 2. Carter Creek study areas adjacent to Interstate Route 5 in the Siskiyou Pass, southern Oregon.

Tributary to Carter Creek- specific conductance

ODOT wareyard- precipitation

Carter Creek- specific conductance, streamflow, automated sampling

I-5 catchment- specific conductance, highway runoff, automated sampling

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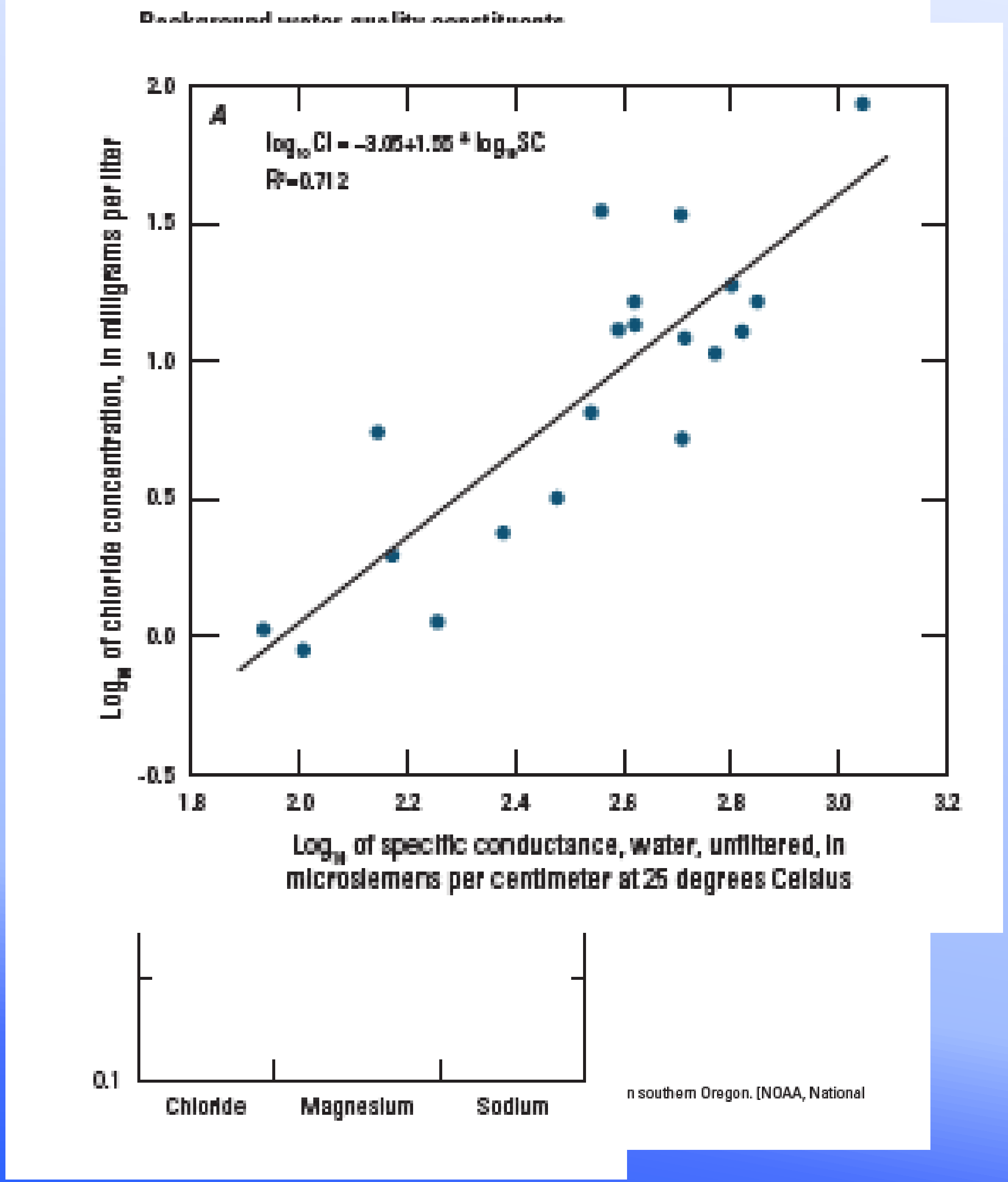
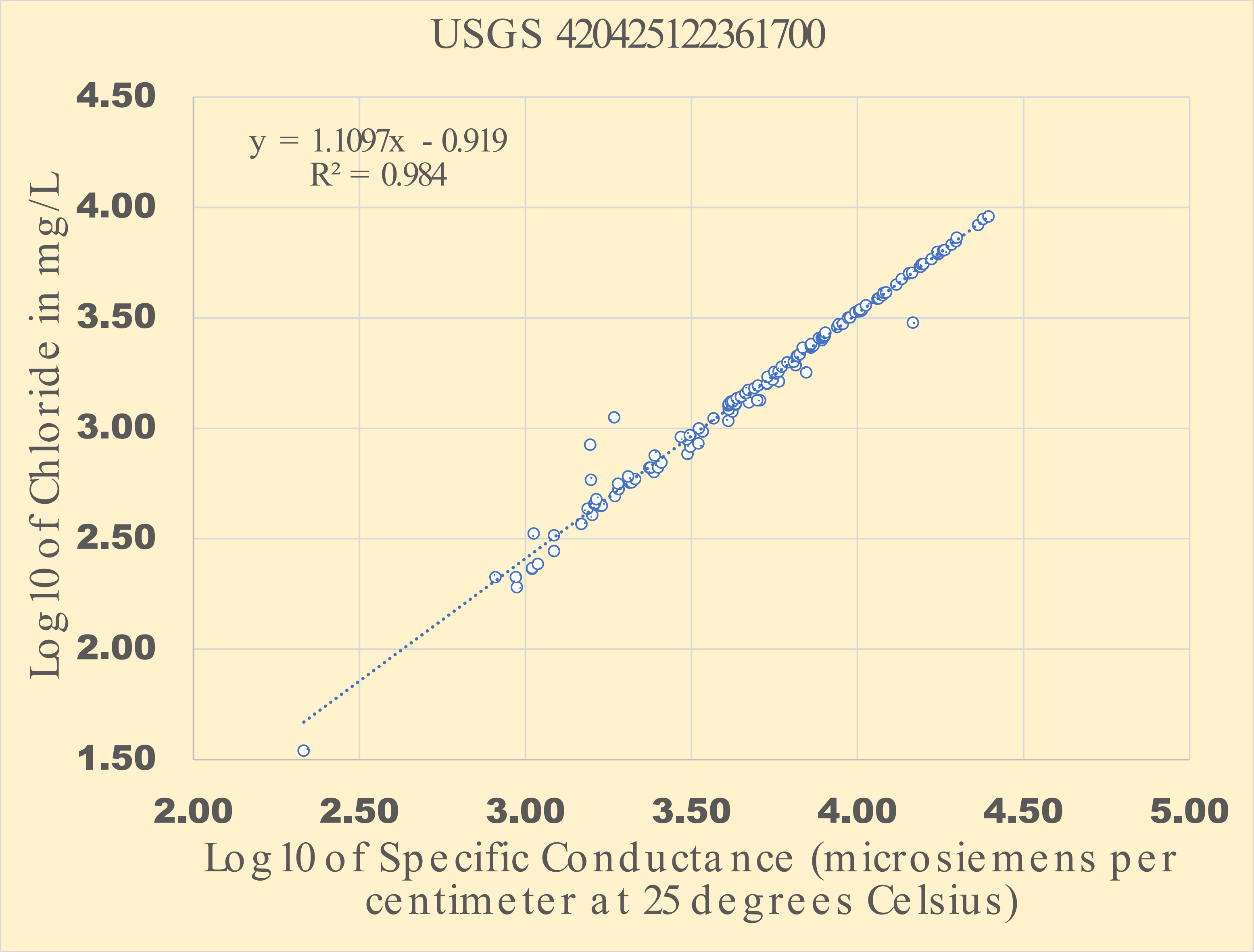
Results



A
$\log_{10}$Cl = –3.05+1.55 * $\log_{10}$SC
R^2=0.712
2.0
1.5
1.0
0.5
0.0
-0.5
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
Log10 of chloride concentration, in milligrams per liter
Log10 of specific conductance, water, unfiltered, in microsiemens per centimeter at 25 degrees Celsius
0.1
Chloride
Magnesium
Sodium
n southern Oregon. [NOAA, National

Results



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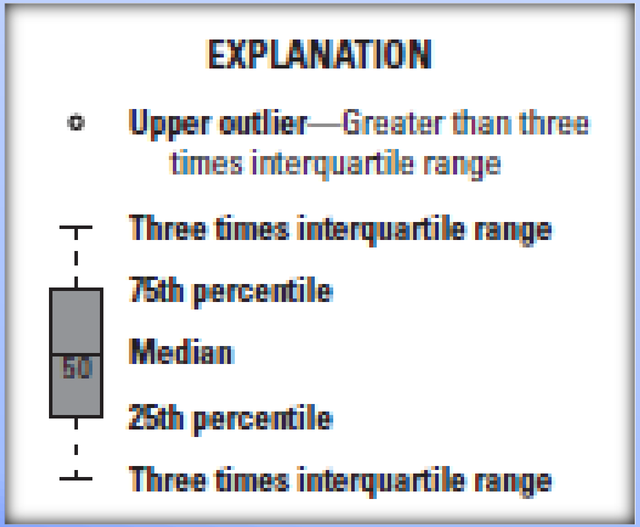
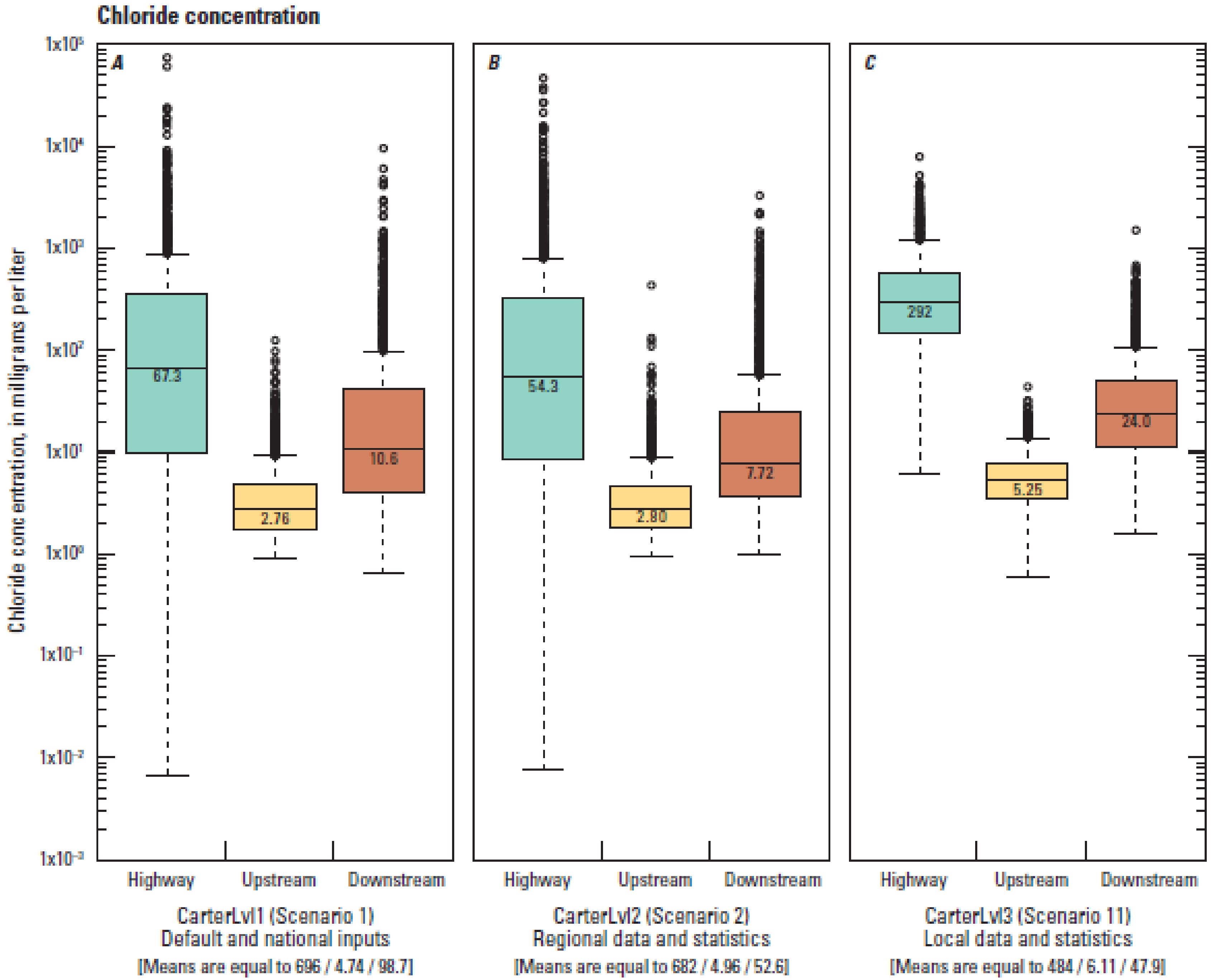
Results


EXPLANATION
Upper outlier—Greater than three times interquartile range
Three times interquartile range
75th percentile
50
Median
25th percentile
Three times interquartile range


Chloride concentration
Chloride concentration, in milligrams per liter
1x10⁵
1x10⁴
1x10³
1x10²
1x10¹
1x10⁰
1x10⁻¹
1x10⁻²
1x10⁻³
A
67.3
2.76
10.6
Highway
Upstream
Downstream
CarterLvl1 (Scenario 1)
Default and national inputs
[Means are equal to 696 / 4.74 / 98.7]
B
54.3
2.80
7.72
Highway
Upstream
Downstream
CarterLvl2 (Scenario 2)
Regional data and statistics
[Means are equal to 682 / 4.96 / 52.6]
C
292
5.25
24.0
Highway
Upstream
Downstream
CarterLvl3 (Scenario 11)
Local data and statistics
[Means are equal to 484 / 6.11 / 47.9]

Results

Table 18. Comparison of Stochastic Empirical Loading and Dilution Model (SELDM) chloride and magnesium outputs from scenarios 1 (CarterLvl1), 2 (CarterLvl2), and 11 (CarterLvl3) for the Siskiyou Pass, southern Oregon.

[mg/L, milligram per liter; ft^3, cubic feet]

SELDM scenario	Scenario abbreviation	Mean of chloride event mean concentrations			Ratio of downstream/ upstream chloride concen- tration	Mean of magnesium event mean concentrations			Ratio of downstream/ upstream magnesium concen- tration
		Highway (mg/L)	Upstream (mg/L)	Down- stream (mg/L)		Highway (mg/L)	Upstream (mg/L)	Down- stream (mg/L)	
1	CarterLvl1	696	4.74	98.7	20.8	57	9.12	17.1	1.9
2	CarterLvl2	682	4.96	52.6	10.6	57	9.12	12.9	1.4
11	CarterLvl3	484	6.11	47.9	7.8	57.1	9.13	13.3	1.5

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Environmental Protection Agency

*"The procedures described in the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably if the **four-day average concentration of dissolved chloride**, when associated with sodium, does not exceed **230 mg/L** more than once every three years on the average and if the **one-hour average concentration** does not exceed **860 mg/L** more than once every three years on the average."*

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From EPA: Ambient Water Criteria for Chloride- 1988
https://www.epa.gov/sites/default/files/2018-08/documents/chloride-aquatic-life-criteria-1988.pdf

How to read probability plots

Each circle represents a modeled (simulated) storm event.

Vertical dashed line shows the exceedance probability needed to achieve USEPA standards.

Y- axis shows the parameter we're interested in. In this case the concentration of chloride.

X- axis shows fraction of events in which a concentration is met or exceeded

If there is a horizontal dotted line, this represents an EPA standard

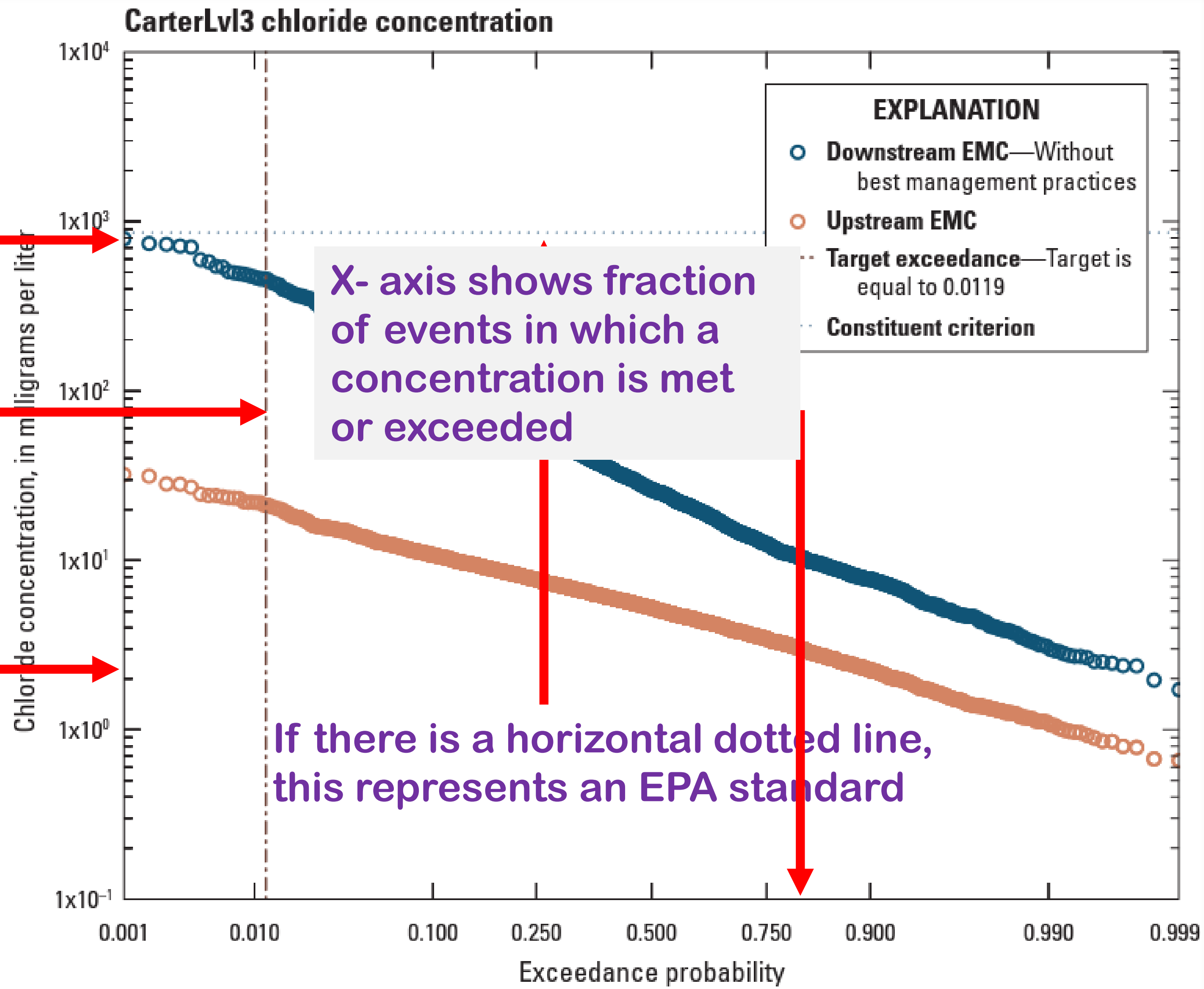

Figure 19. Exceedance probabilities of event mean concentrations of chloride upstream and downstream from the road crossing under scenario 11 (CarterLvl3) at Carter Creek Branch 1 in the Siskiyou Pass, southern Oregon. [EMC, event mean concentration.]

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Results

Evaluate results for different levels of analysis.

More local data shows less exceedance of water-quality criterion and less overall variability in results.

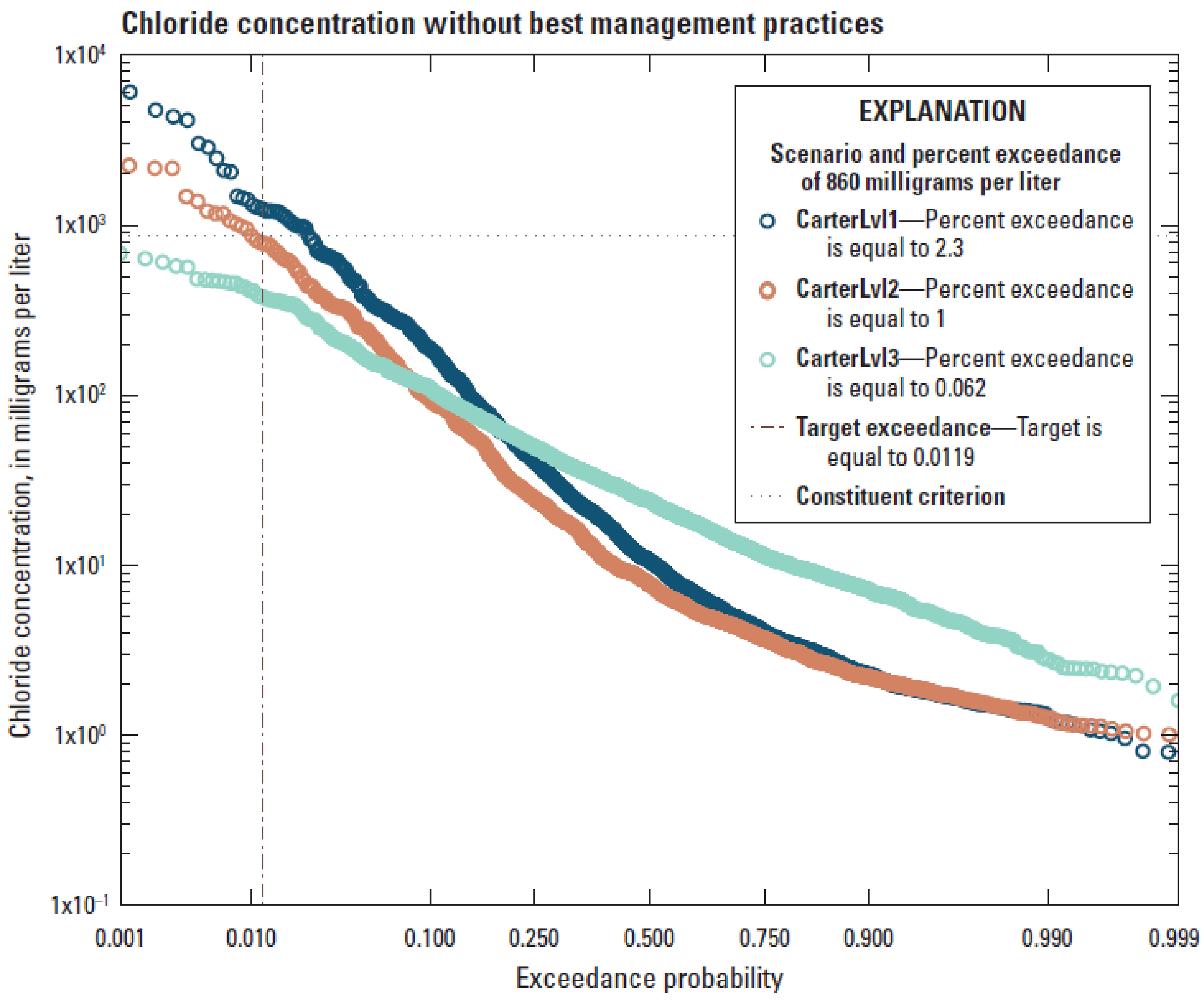

Figure 16. Exceedance probabilities of downstream event mean concentrations of chloride under scenarios 1 (CarterLvl1), 2 (CarterLvl2), and 11 (CarterLvl3) at Carter Creek Branch 1 in the Siskiyou Pass, southern Oregon.

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Results

More slope means a greater amount of variance between storm events.

Adding regional data reduces variance which in turn reduces uncertainty.

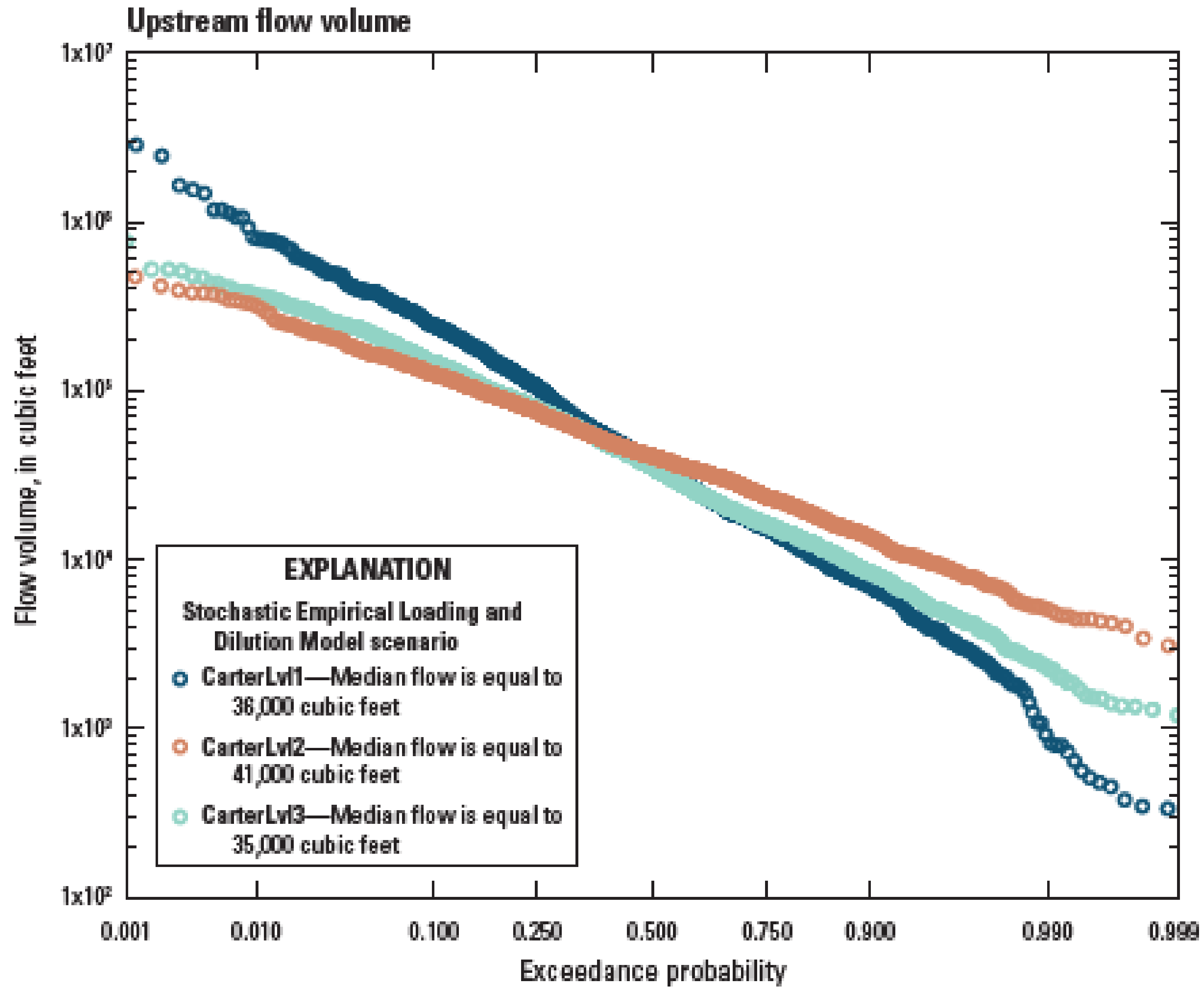

Figure 10. Exceedance probabilities of stormflow volumes under scenarios 1 (CarterLvl1), 2 (CarterLvl2), and 11 (CarterLvl3) at Carter Creek Branch 1 in the Siskiyou Pass, southern Oregon.

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Results

Adding regional data reduces variance which in turn reduces uncertainty.

Annual loading of chloride can be aggregated across multiple events.

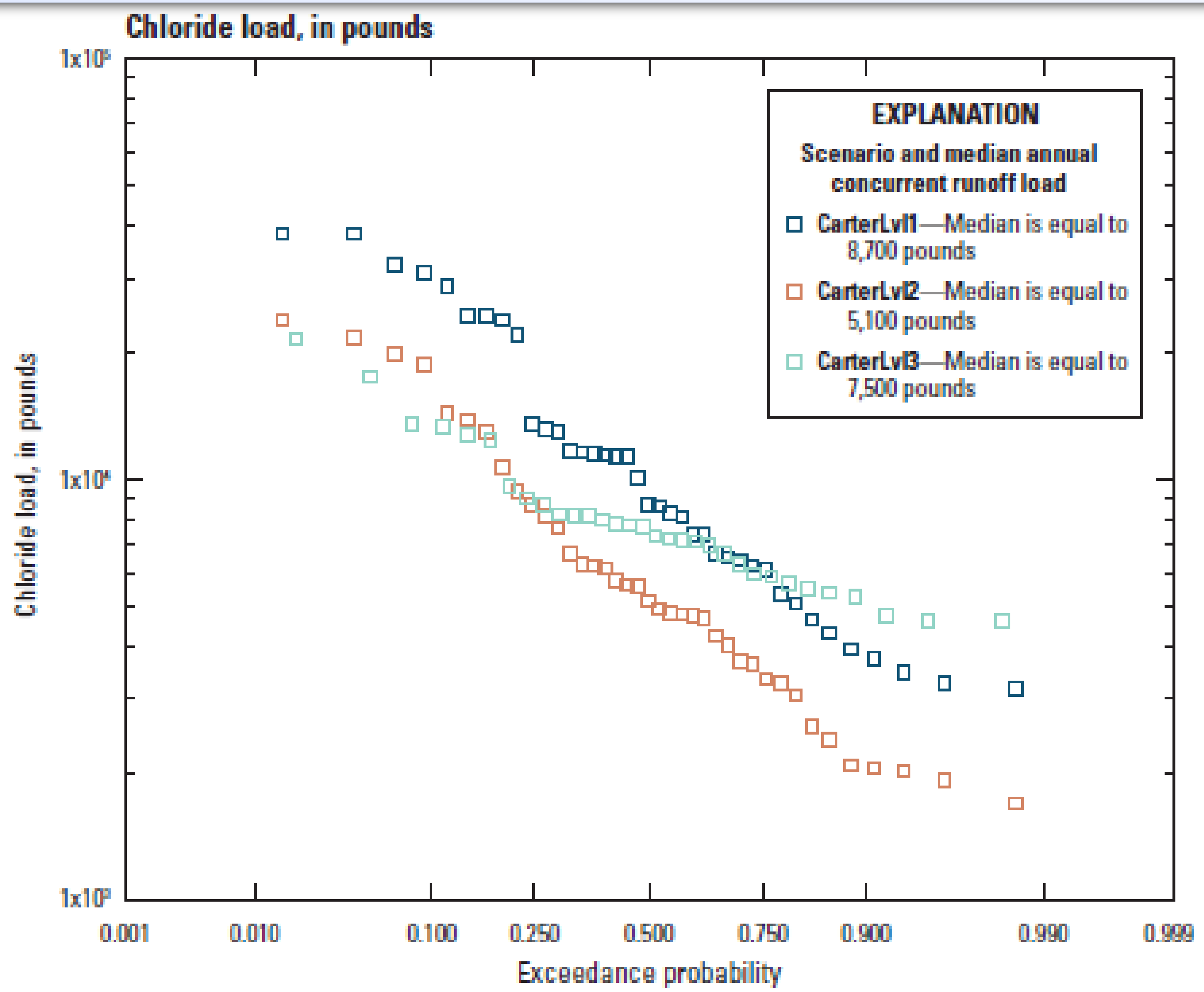

Figure 13. Exceedance probabilities of annual concurrent runoff loads of chloride under scenarios 1 (CarterLvl1), 2 (CarterLvl2), and 11 (CarterLvl3) at Carter Creek Branch 1 in the Siskiyou Pass, southern Oregon.

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Results

- The Oregon Department of Environmental Quality (ODEQ) acute water-quality criterion for chloride is 860 mg/L.
- Depending on how much local data are used, model results show an event-mean concentration (EMC) exceedance level of between <.1 to 2.3%.
- This range is well within expected model error of the EPA criterion exceedance rate of 1.1%.
- As more local data are included in model simulations, the range of EMCs is reduced.

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Results – Metrics of Interest

- Downstream Event-Mean Concentration (EMC)- What type of chloride concentrations are we seeing downstream of the highway?
- Criterion Maximum Concentration (CMC) Exceedances – How frequently are we exceeding water-quality criteria?
- Mean annual concurrent runoff load- How much chloride is being added over the course of a year?

Results

Table 27. Qualitative ratings of effects of the inclusion of local data on various Stochastic Empirical Loading and Dilution Model outputs for Carter Creek Branch 1 in the Siskiyou Pass, southern Oregon.

[EMC, event mean concentration; CMC, criterion maximum concentration]

Local data included	Qualitative effect		
	Downstream EMC	CMC exceedance	Mean annual concurrent runoff load
Precipitation	Low	Low	High
Upstream streamflow	High	Moderate–high	Low
Upstream concentrations	Moderate	Moderate	Low
Highway concentrations	Moderate–high	High	Low
Volumetric runoff	Moderate	Low	Low

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Results

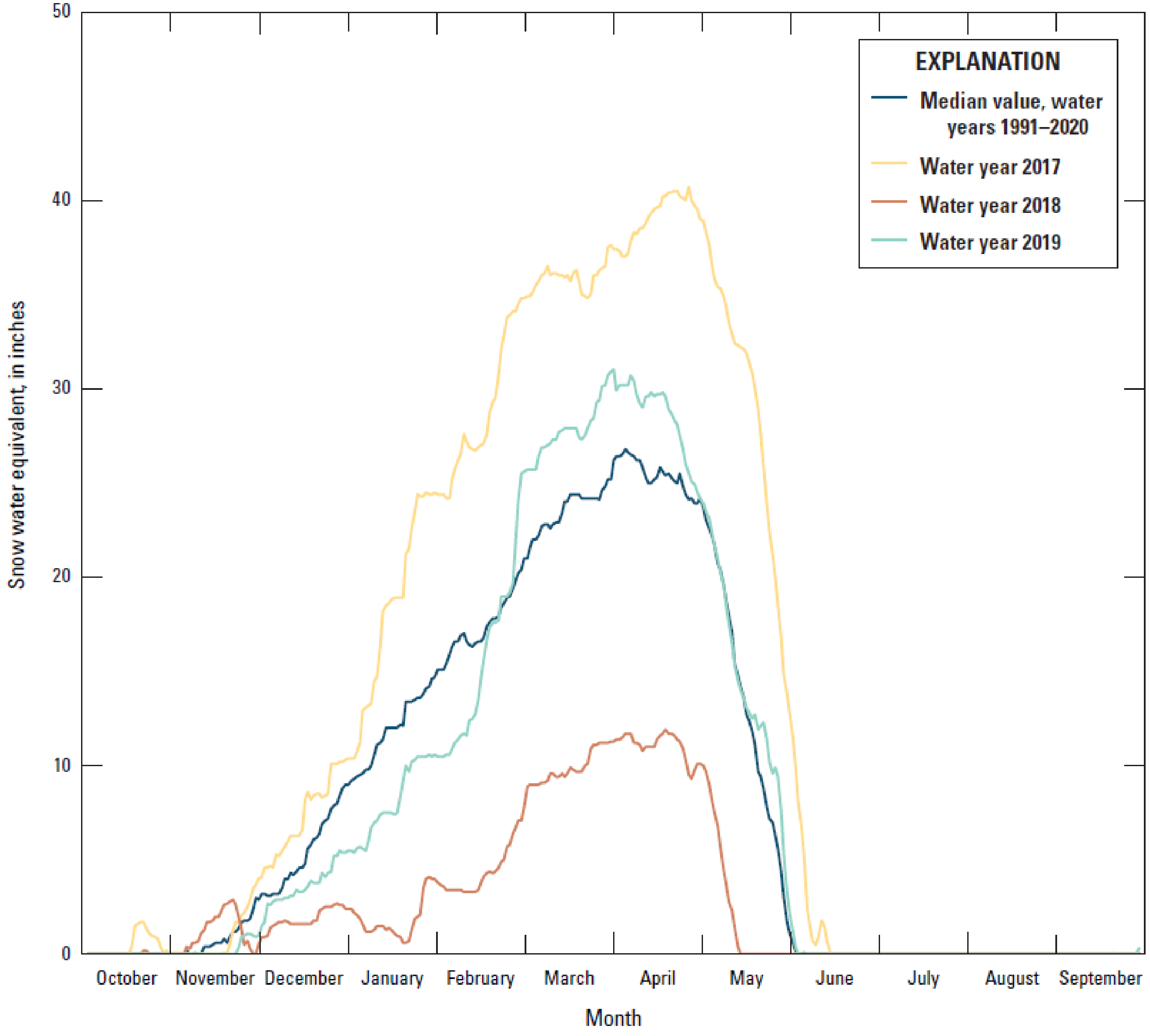

Figure 56. Snow water equivalent values from the Middle Rogue Valley SNOTEL site for water years 2017–19 compared to median value for water years 1991–2020. [Data from the Natural Resources Conservation Service (2022).]

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Results

https://desertmtncorp.com/meltdown-liquid/

Table 28. Deicer application rates within the highway catchments of Carter Creek Branch 1, Carter Creek Branch 6, and Wall Creek in the Siskiyou Pass, southern Oregon, water years 2017–18.

[All values are in pounds avoirdupois. Data source: Jon Lazarus, Oregon Department of Transportation, written commun., 2019. Cl, chloride; $MgCl_2$, magnesium chloride; NaCl, sodium chloride; Mg, magnesium; Na, sodium; NA, not applicable]

Water year	Cl from		Total Cl	Mg from		Total Mg	Na from		Total Na
	$MgCl_2$	NaCl		$MgCl_2$	NaCl		$MgCl_2$	NaCl	
Carter Creek Branch 1									
2017	44,400	129,000	173,400	15,300	NA	15,300	NA	112,000	112,000
2018	51,100	32,100	83,200	17,600	NA	17,600	NA	28,000	28,000
Mean values	47,750	80,550	128,300	16,450	NA	16,450	NA	70,000	70,000
Carter Creek Branch 6									
2017	11,500	32,700	44,200	3,960	NA	3,960	NA	28,500	28,500
2018	14,100	8,500	22,600	4,870	NA	4,870	NA	7,400	7,400
Mean values	12,800	20,600	33,400	4,415	NA	4,415	NA	17,950	17,950
Wall Creek									
2017	27,700	64,100	91,800	9,550	NA	9,550	NA	55,800	55,800
2018	37,000	14,900	51,900	12,700	NA	12,700	NA	13,100	13,100
Mean values	32,350	39,500	71,850	11,125	NA	11,125	NA	34,450	34,450

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Conclusions

1. The Stochastic Empirical Loading Dilution Model (SELDM) is a useful tool for evaluating expected criterion maximum concentration (CMC) exceedance rates, downstream event-mean concentrations (EMCs), and annual loading of water-quality constituents.

2. Downstream EMCs of chloride and magnesium rarely exceeded CMCs used in this study.

3. Downstream EMCs for all three water-quality constituents were substantially larger than upstream EMCs, indicating that highway runoff is a dominant driver in downstream EMCs.

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Conclusions (cont.)

4. Level-3 analyses tended to produce much less variability in estimated EMCs than level-1 or level-2 analyses.

5. If a study allows for local data collection, which data are most important to collect depends heavily on the metrics of interest-

For **downstream EMCs**, collection of upstream streamflow as most important.

For **CMC exceedance**, collection of highway runoff chloride concentrations was most important.

For **annual loading**, collecting local precipitation data was most important.

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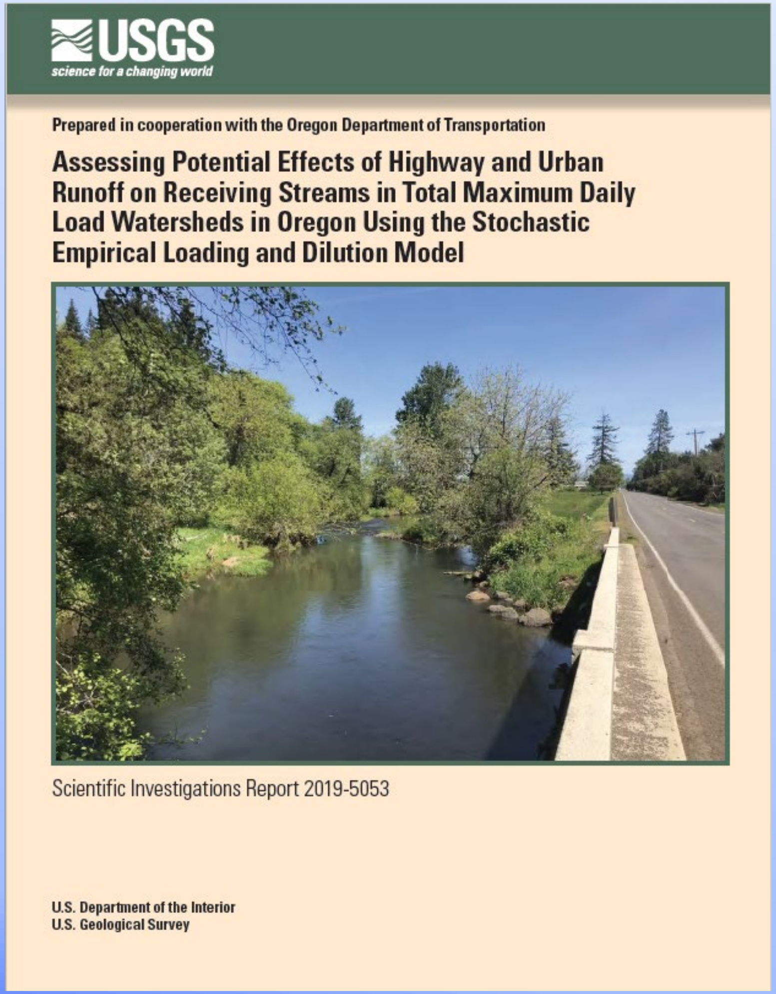
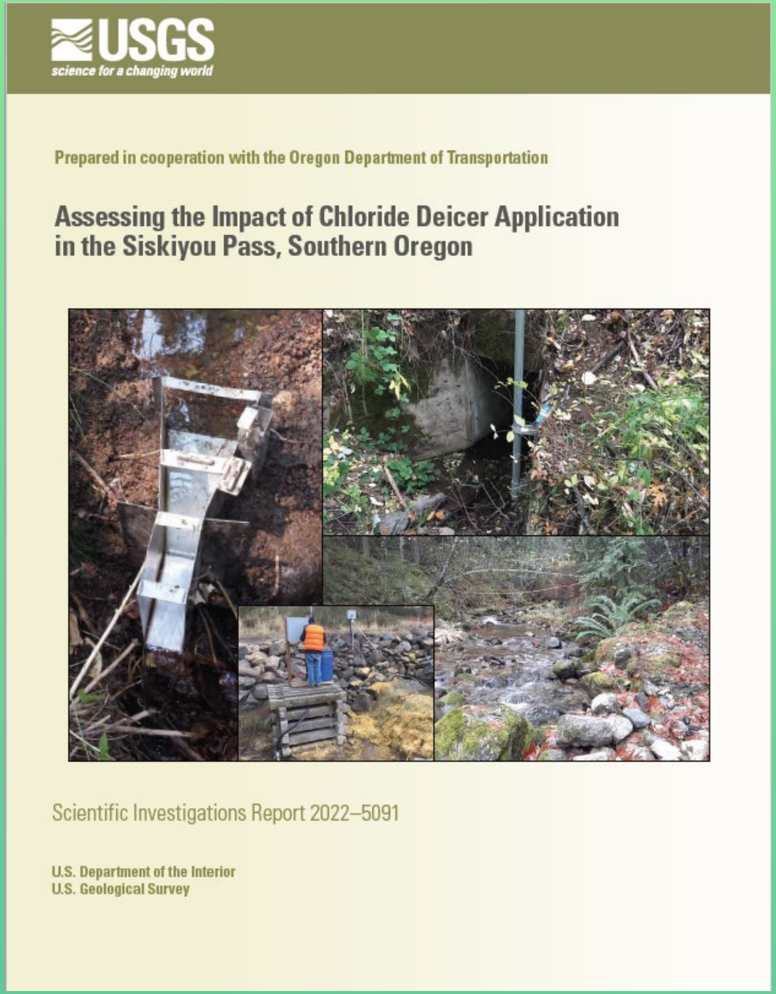
USGS Oregon reports using SELDM





Risley, J.C., and Granato, G.E., 2014, Assessing potential effects of highway runoff on receiving-water quality at selected sites in Oregon with the Stochastic Empirical Loading and Dilution Model (SELDM): U.S. Geological Survey Scientific Investigations Report 2014–5099, 74 p., https://doi.org/10.3133/sir20145099.

Stonewall, A.J., Granato, G.E., and Glover-Cutter, K.M., 2019, Assessing potential effects of highway and urban runoff on receiving streams in total maximum daily load watersheds in Oregon using the Stochastic Empirical Loading and Dilution Model: U.S. Geological Survey Scientific Investigations Report 2019–5053, 116 p., https://doi.org/10.3133/sir20195053.

Stonewall, A.J., Yates, M.C., and Granato, G.E., 2022, Assessing the impact of chloride deicer application in the Siskiyou Pass, southern Oregon: U.S. Geological Survey Scientific Investigations Report 2022–5091, 94 p., https://doi.org/10.3133/sir20225091

Questions?

https://www.alco-chem.com/blog/tips-for-applying-ice-melt-correctly

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