Teck Coal Environmental Office
Bag Service 2000, 421 Pine Avenue
Sparwood, B.C. Canada V0B 2G0
+1 250 425 3331 Tel
www.teck.com

Technical Report Overview

Report: Calcite Monitoring Program 2017 Report

Overview: This report presents the 2017 results of the calcite monitoring program required under Permit 107517. This report summarizes the degree and extent of calcite formation in specific stream reaches within the Elk Valley watershed.

This report was prepared for Teck by Lotic Environmental Ltd.

For More Information

If you have questions regarding this report, please:
- Phone toll-free to 1.855.806.6854
- Email **feedbackteckcoal@teck.com**

Future studies will be made available at **teck.com/elkvalley**

Teck Coal Ltd.
2017 Calcite Monitoring Annual Report

Elk Valley

May 2018

Prepared by

Lotic Environmental Ltd.
2193 Mazur Road
Cranbrook BC
V1C 6V9

Suggested citation

Smithson, J., Robinson, M.D. and K. Baranowska. 2018. Teck Coal Ltd – Elk Valley 2017 Calcite Monitoring Program Annual Report and Program Assessment. Prepared for Teck Coal Ltd. by Lotic Environmental Ltd. 27 pp + appendices.

On behalf of Lotic Environmental,

Mike Robinson MSc, RPBio
Senior Aquatic Ecologist
mike.robinson@lotic.co

Acknowledgements

We would like to thank Kevin Atherton, Lee Wilm, and Andy Wight for their involvement in this program and in particular with reviewing the initial work plans, field work, and final site selection. We would also like to thank Dr. Carl Schwarz (Department of Statistics & Actuarial Science – Simon Fraser University) for input to the statistical assessments in this report.

Table of Contents

Executive Summary VI
1 Introduction 1
1.1 Program Objectives 2
1.2 Linkage to Adaptive Management 3
2 Methods 3
2.1 Study area 3
2.2 Stream segments 5
2.3 Updates for the 2017 Program 7
2.4 Additional sampling 8
2.5 Field surveys 8
2.6 Data analysis 8
2.6.1 2017 Calcite Index and general distribution 8
2.6.2 Rate of change in calcite deposition 9
2.6.3 Inter-program comparisons 11
2.6.4 Data quality assurance 11
3 Results 12
3.1 2017 Calcite Index and general distribution 12
3.2 Rate of change in calcite deposition 14
3.2.1 Mann-Kendall 14
3.2.2 Block design 16
3.2.3 ANOVA (Tukey's HSD post-hoc) 17
3.2.4 Contrast – each year against all previous years 18
3.2.5 Contrast – each year against all years 20
3.2.6 Other Observations 20
3.2.7 Inter-program comparisons 21
3.3 Data quality assurance 23
4 Discussion 24
5 Future Monitoring 28
6 Literature Cited 31
7 Appendices 32

List of Figures

Figure 1. Elk River watershed study area map. 4
Figure 2. Percent distribution of exposed stream kilometers among *CI* bins by stream category and year (each year sum to 100% for the stream category). 13
Figure 3. Percent distribution of reference stream kilometers among *CI* bins by stream category and year (each year sum to 100% for the stream category). 13
Figure 4. Mean reach *CI* from 2013 – 2017 from the Mann-Kendall test. 15
Figure 5. Mann-Kendall box-plot of Block design. 16
Figure 6. Bar graphs showing results of significant one-way ANOVA tests. Same letters on graphs denotes no significant differences in mean *CI* among years, with reach. 18
Figure 7. Correlation table of *CI* values for reaches sampled during multiple programs. 22
Figure 8. *CI* values from FORD9 for regional and other calcite sampling programs. 23

List of Tables

Table 1. Permit 107517 annual reporting requirements. 2
Table 2. Summary of the segments created and the corresponding reaches. 5
Table 3. Stream calcite distribution (km) estimates for the four stream categories, by *CI* ranges for 2017...12
Table 4. Reaches with significant changes in *CI* from 2013 – 2017 using Mann-Kendall...........14
Table 5. P-values of contrast analysis of each year's mean compared to all previous years, by reach (Red cells = significantly higher year. Green cells = significantly lower year)..................19
Table 6. P-values of contrast analysis of each year's mean compared to the mean of the mean of all previous years, by reach (Red cells = significantly higher year. Green cells = significantly lower year). 20
Table 7. Key differences between Teck calcite monitoring programs methodologies. 21
Table 8. Comparison of statistical analyses, significant results and interpretation. 27
Table 9. Recommended sampling sites for the 2018 Sampling Program..................................28

List of Appendices

Appendix 1. Summary of reach-level results by program year
Appendix 2. 2017 Elk Valley calcite monitoring results by stream reach
Appendix 3. Calcite distribution maps
Appendix 4. Mann-Kendall results
Appendix 5. ANOVA results for reaches with significant effect of year and significant year-year pairings identified from Tukey's HSD.

Definitions

- Degree – The amount of calcite deposition estimated by the level of concretion.
- Exposed – Stream locations with mine-influenced water. Areas downstream of mining.
- Extent – The spatial coverage of calcite deposition which can be expressed as an area covered at a specific location or linear coverage over a stream profile.
- Habitat unit – A distinct channel unit possessing homogeneous geomorphological characteristics (e.g., riffle, pool, glide, cascade). Also referred to as channel unit or mesohabitat.
- Reach – A relatively homogeneous section of stream in terms of channel morphology, riparian cover and flow (RISC 2001).
- Reference – An area without upstream mining activity.
- Sampling unit – A single unit used to describe a larger entity. For example, a site could be considered the sampling unit for estimating the average calcite coverage over an entire reach.
- Segment - Combines adjacent reaches that have similar calcite indexes identified from previous sampling and have the same exposure to mining.
- Site – A location within a reach where observations of calcite deposition were made. These are replicate observations (sample units) within the treatment unit (reach).

Executive Summary

Teck Coal Ltd. (Teck) conducts an annual Calcite Monitoring Program (the Program) in part to satisfy monitoring and reporting requirements of the Environmental Management Act Permit 107517 (the Permit) (Teck 2014), but also to inform management actions to address calcite formation as per objectives of the Permit. Sampling in 2017 followed the updates made to the Program for 2016 – 2018, which was submitted to the British Columbia (BC) Ministry of Environment and Climate Change Strategy (ENV) and the Environmental Monitoring Committee (EMC) as required by Section 12.2 by the Environmental Management Act Permit 107517 (Robinson and Atherton 2016). Updates revised the Program for 2016-2017 to provide efficiencies while maintaining a high standard of spatial and temporal monitoring (Robinson and Atherton 2016).

Sampling completed in 2017 was the second year following the updates to the Program after 2013-2015. Sampling was again based on “stream segments” that used an indicator reach to estimate Calcite Index (*CI*) over a larger area. This redistributed effort in terms of the number of sites per reach from reaches where *CI* variability was low to areas where *CI* variability was higher.

Sampling effort beyond the standard protocol was added to three areas. In 2016 and 2017, additional sampling was added to support the understanding of calcite management in Greenhills Creek and to provide more detailed monitoring downstream of new mining activity in Dry Creek (Line Creek Operations). In 2017, Michel Creek – Reach 2 was added back into the Program to establish a baseline value prior to the operation of the Elkview Saturated Rock Fill (SRF) full-scale trial. In 2016, Michel Creek – Reach 2 was included in a segment with Reach 1, where Reach 1 was the indicator reach. The third area was Sparwood Ridge. Three watercourses draining from Sparwood Ridge into Michel Creek – Reach 2 were added to the Program in 2017.

Revisions were made to data analysis methods in 2017. Linear trends were assessed using Mann-Kendall analysis instead of linear regression as previously completed. The Mann-Kendall analysis is a non-parametric test that does not require the assumption that data need to be normally distributed. Linear trends were assessed on data by reach and also by reach type in the Block design recommended by the EMC, which is a joint committee of stakeholders (e.g., Teck, Ktunaxa Nation Council, ENV, Ministry of Energy and Mines, Interior Health Authority, and Independent Scientist) which provides technical advice and reviews submissions. ANOVA analysis used in previous years was conducted as previously done with Tukey’s HSD *post-hoc* analysis. Contrast analysis was also incorporated following feedback received from the EMC. Contrast analyses are essentially a customizable *post-hoc* analysis that follows an ANOVA. For this Program we ran two contrast models. One tested for significant differences between *CI* of a year and all years prior. The second tested for significant differences between *CI* of a year and all years (excluding the year of interest).

The 2017 Program was conducted from October 10 – November 3, 2017. The Program was completed as per the work plan with only minor changes to sites sampled. A total of 85 indicator reaches and 232 sites were surveyed in 2017, which was the same as 2016. Calcite distribution observed in 2017 was relatively consistent with previous observations, with the majority of exposed stream kilometers being classified in the lowest calcite degree category (i.e., 0.00-0.50

CI bin) for both mainstem and tributary categories. The most notable change occurred in the 2.51 – 3.00 bin for the exposed tributaries. In 2017, 15% of the exposed tributary reaches were classified into this highest calcite degree category, while in 2016 this bin made up 5%. Another notable change was that the reference tributaries had stream kilometers classified into a category other than the lowest calcite degree category; 3% of the reference tributaries stream kilometers were classified into the 0.50 – 1.00 CI bin.

Mann-Kendall analysis was run on historical exposure, reference exposure, treated Blocks, and recent exposure. *CI* was found to be significantly predicted by *Year* for the Historical Block ($p<0.01$, tau= 0.10). This is the first time that a Block has had a significant result. The Reference exposure, Treated Block, and Recent exposure were not found to change significantly over time ($p=0.52$, tau= 0.07; $p=0.72$, tau= 0.12, $p=0.37$, tau= 0.16 respectively). The Mann-Kendall analysis was not run on the “future exposure” Block type, as these *CI*-values were constantly 0.00 at all reaches for all years sampled.

ANOVA results showed the *Year* had a significant effect on reach mean *CI* in 18 reaches. This is the same result as 2016. Of these 17 significant reaches, FORD1, FORD12, GATE2, and GODD3 were the only reaches reported to have a significant change using both Mann-Kendall and ANOVA methods. Frequently, the significant ANOVA results appear to be the results of one step-wise increase that generally separated results in 2013-2015 from 2016-2017.

Interpretation of results obtained from ANOVA with Tukey’s, Contrast with previous years only, and Contrast with all years were compared. General agreement among the three methods was found with 8 of 17 reaches with significant *Year* effects on *CI*. ANOVA with Tukey’s appears effective in identifying step-wise changes in the data. Contrast with previous years only was also found to identify step-wise changes. However, it could lead to misinterpretation of results without further investigation of data in subsequent years beyond the initial change. Contrast with prior years only also failed to detect sequential step-wise changes in opposing directions.

Monitoring in 2018 will be completed at all reaches sampled in the 2013 – 2015, as discussed in Robinson and MacDonald (2015). Every reach and site will be sampled so there will be 119 reaches instead of the 85 visited in 2016 and 2017. The purpose of returning to every reach and site in 2018 is to assess the appropriateness of using segments and an indicator reach to represent *CI* over reaches within a segment.

1 Introduction

Teck Coal Ltd. (Teck) continues to monitor the occurrence of calcite deposition downstream of its coal mining operations throughout the Elk Valley to support understanding and evaluation of potential effects of calcite on aquatic biota and habitat. Calcite is a calcium carbonate deposit that precipitates out in freshwater streams, and can cause a hardening of the substrate. Open pit mining has been shown to increase the presence in calcite downstream of operations. Teck has been documenting calcite occurrence in the Elk Valley since 2008 (Berdusco 2009). A formal calcite monitoring program (the Program) was established in 2013 with the objective to monitor the degree and extent of calcite for a three year period (i.e., 2013-2015). In 2015, the Program was re-assessed to determine its effectiveness in monitoring calcite in streams associated with Teck Coal mining operations (Robinson *et al.* 2016). The assessment resulted in an updated Program for 2016 – 2018 (Robinson and Atherton 2016). Sampling in 2017 marked the second year under the updated Program.

As per Section 9.5 of Environmental Management Act Permit 107517 (the Permit), a 2016 – 2018 study design for this Program was submitted to the British Columbia Ministry of Environment and Climate Change Strategy (ENV) on May 31, 2016. The study design was also provided to the Environmental Monitoring Committee (EMC) as required by Section 12.2 of the Permit. The EMC is a joint committee of stakeholders (e.g., Teck, Ktunaxa Nation Council, ENV, Ministry of Energy and Mines, Interior Health Authority, and Independent Scientist) which provides technical advice and reviews submissions. This report is being submitted to fulfill Section 10.7 of the Permit which states:

"*A Calcite Monitoring Annual Report must be submitted to the Director by May 31, of each year following the data collection calendar year.*"

Table 1 outlines the Permit 107517 Section 10.7 annual reporting requirements and which section of this report fulfills each requirement. The Program followed the methods outlined in the Teck Coal Ltd 2016 - 2018 Calcite Monitoring Program (Robinson and Atherton 2016) and the amended approval letter (Calcite 2016 study design approval letter, dated October 19, 2016).

Table 1. Permit 107517 annual reporting requirements.

Requirement Number	Description	Report Section Reference
i	A map of monitoring locations	Appendix 3
ii	A summary of background information on that year's program, including discussion of program modifications relative to previous years	2.2 & 2.5
iii	Results of stream selection reassessment – highlight streams added/removed	2.4 & 2.4
iv	Summary of where sampling followed the methodology in the monitoring plan document, and details where sampling deviated from the approved methodology	3.1
v	Statement of results for the period over which sampling was conducted	3.1
vi	Reference to the raw data, provided as appendices	2.6
vii	General discussion of observations, including summary tables of sites with increasing and decreasing deposition indices	3.1, 3.2
viii	Interpretation of location, extent, and any other observations	3.1
ix	A summary of any QA/QC issues during the year	3.3
x	Recommendations for sites to add, sites to remove, modifications to methodology, monitoring frequency adjustments	5

1.1 *Program Objectives*

The objectives of the Teck 2016 - 2018 *Calcite Monitoring Program* (Robinson and Atherton 2016) are:

1. Document the extent and degree of calcite deposition in streams downstream of Teck's coal operations (e.g., streams influenced by mining, calcite treatment, water treatment and in reference streams);
2. Satisfy the requirements for annual calcite monitoring in Environmental Management Act Permit 107517; and,
3. Provide data to support the re-evaluation of Big Question 4 and specific Key Questions in Teck's Adaptive Management Plan as they relate to calcite.

1.2 *Linkage to Adaptive Management*

Consistent with Section 11 of Permit 107517 , Teck has developed an Adaptive Management Plan (AMP) to support implementation of the Elk Valley Water Quality Plan (EVWQP), to achieve water quality and calcite targets, ensure that human health and the environment are protected (and where necessary, restored), and to facilitate continuous improvement of water quality in the Elk Valley. The AMP is structured around a set of six overarching environmental Management Questions that collectively address the environmental management objectives of the AMP and the EVWQP. In addition, the AMP identifies Key Uncertainties underlying each Management Question, which if reduced, either help confirm that Teck's current management actions are appropriate or lead to adjustments that would better satisfy EVWQP objectives.

The AMP was submitted to the Environmental Monitoring Committee and ENV (formerly British Columbia Ministry of Environment [MOE]) Director on July 30, 2016 as required. Study designs for many programs (including the 2016 - 2018 Calcite Monitoring Program) were established before the AMP was submitted. Teck is working to embed elements of the AMP within each program through reviews of monitoring programs at the study design and annual report stages. Gaps identified in reviews of 2017 annual reports will inform future study design updates as required.

As defined in the July 30, 2016 AMP, Management Question 4 ("Is calcite being managed effectively to meet site performance objectives and protect aquatic ecosystem health?") will be re-evaluated through periodic evaluation of monitoring results and treatment effectiveness on a three year timeframe as part of updates to the AMP. This process is defined in the AMP. Calcite monitoring results are also utilized in the prioritization of streams for calcite management and in the periodic review and refinement of calcite SPOs.

Calcite monitoring data collected under this and other programs will also assist in reducing Key Uncertainty 4.1 ("Are calcite SPOs ecologically relevant and protective of fish and aquatic life?"), Key Uncertainty 4.2 ("What are the most effective management methods for calcite?") and Key Uncertainty 4.3 ("Are there interrelationships with calcite and cadmium in surface water that need to be considered when conducting calcite management?"). Progress on reducing these uncertainties will be reported on within annual AMP reports.

2 Methods

2.1 *Study area*

The study area was defined to include each of Teck's five metallurgical coal mining operations in southern British Columbia (Figure 1). Sites are located throughout the Elk Valley to encompass areas downstream of Fording River Operations, Greenhills Operations, Line Creek Operations, Elkview Operations, and Coal Mountain Operations. The downstream study limit was Reach 8 of the Elk River, which extends to Fernie, BC. This study area is consistent with study areas for the 2013 - 2015 calcite monitoring programs.

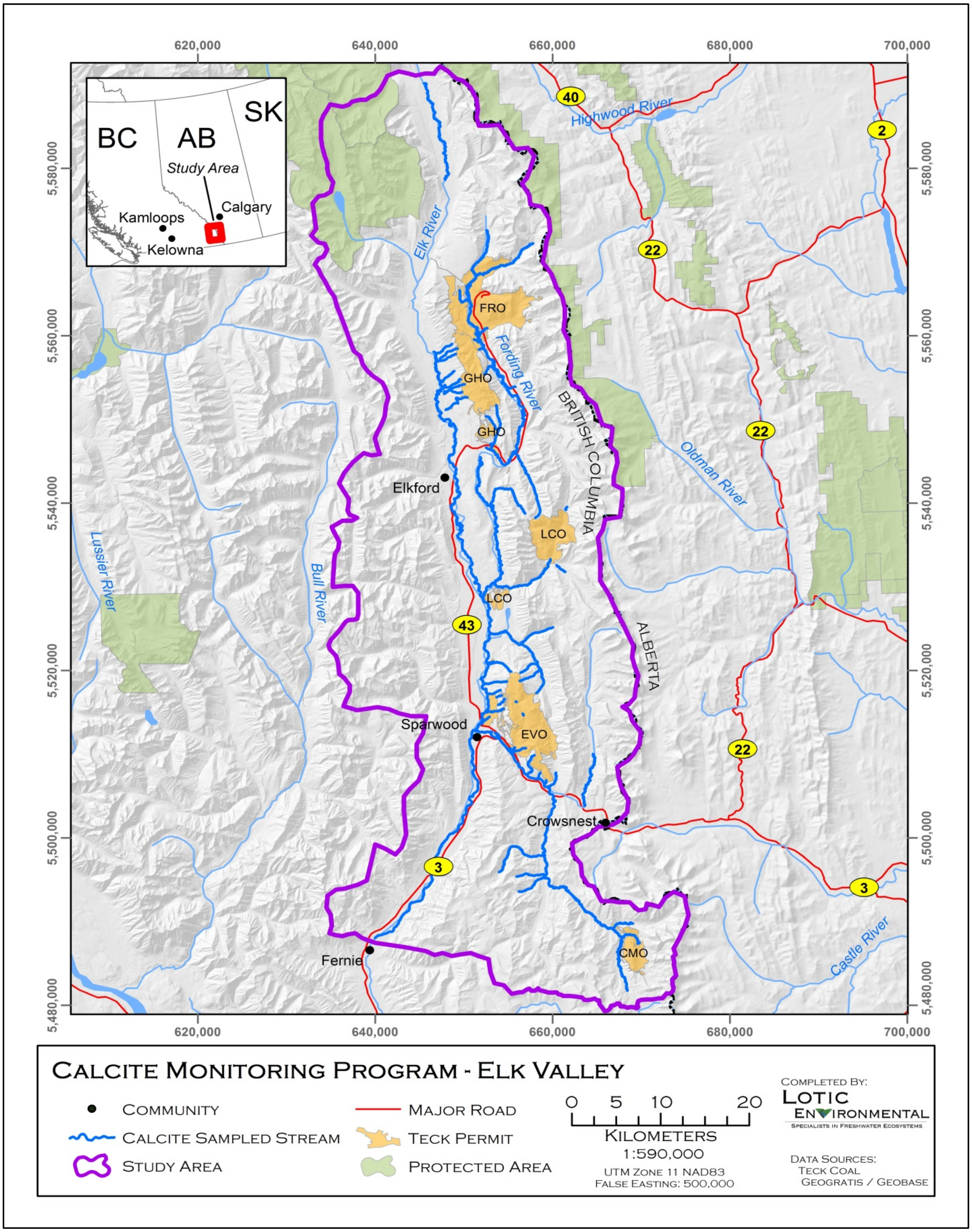


Figure 1. Elk River watershed study area map.

2.2 *Stream segments*

In 2016, stream segments were created by grouping contiguous reaches of similar historic calcite scores and mining exposures. The segments were created to streamline sampling effort and to increase the sampling focus on reaches that have high calcite variability (e.g., *CI* = 1.00 – 2.00). One indicator reach would then be sampled to represent the stream segment, recognizing that calcite presence remains variable throughout the reach and stream segment. The use of stream segments was continued in 2017 (Table 2). Each stream segment was visited at 1-6 sites during the sampling year. The same sites were visited in every year.

Table 2. Summary of the segments created and the corresponding reaches.

Water feature	Segment Name	Reaches Included	Indicator Reach
Alexander	ALEX_A	ALEX3	ALEX3
Andy Good	ANDY_A	ANDY1	ANDY1
Aqueduct	AQUE_A	AQUE1, AQUE2, AQUE3	AQUE1
Balmer	BALM_A	BALM1	BALM1
Bodie	BODI_A	BODI1	BODI1
	BODI_B	BODI3	BODI3
Cataract	CATA_A	CATA1, CATA3	CATA1
Chauncey	CHAU_A	CHAU1	CHAU1
Clode West Infiltration	CLOW_A	CLOW1	CLOW1
Corbin	CORB_A	CORB1, CORB2	CORB1
Clode Pond Outlet	COUT_A	COUT1	COUT1
CCR Seep	CSEE_A	CSEE1	CSEE1
Dry (EVO)	DRYE_A	DRYE1, DRYE3, DRYE4	DRYE3
Dry (LCO)	DRYL_A	DRYL1	DRYL1
	DRYL_B	DRYL2	DRYL2
	DRYL_C	DRYL3	DRYL3
	DRYL_D	DRYL4	DRYL4
Elk	ELKR_B	ELKR11, ELKR12	ELKR12
	ELKR_D	ELKR15	ELKR15
	ELKR_A	ELKR8	ELKR8
	ELKR_C	ELKR9, ELKR10	ELKR9
Eagle Pond Outlet	EPOU_A	EPOU1	EPOU1
Erickson	ERIC_A	ERIC1, ERIC2, ERIC3, ERIC4	ERIC1
Feltham	FELT_A	FELT1	FELT1
Fennelon	FENN_A	FENN1	FENN1
Fording	FORD_G	FORD12	FORD12
	FORD_A	FORD1	FORD1
	FORD_B	FORD2, FORD 3	FORD2
	FORD_C	FORD4, FORD 5	FORD4
	FORD_D	FORD6	FORD6
	FORD_E	FORD7, FORD 8	FORD7
	FORD_F	FORD9, FORD 10, FORD11	FORD9
Fish Pond	FPON_A	FPON1	FPON1
Gardine	GARD_A	GARD1	GARD1
Gate	GATE_A	GATE2	GATE2
Goddard	GODD_A	GODD1	GODD1
	GODD_B	GODD3	GODD3

Water feature	Segment Name	Reaches Included	Indicator Reach
Grace	GRAC_A	GRAC1, GRAC2, GRAC3	GRAC1
Grassy	GRAS_A	GRAS1	GRAS1
Grave	GRAV_A	GRAV1, GRAV2	GRAV1
	GRAV_B	GRAV3	GRAV3
Greenhills	GREE_A	GREE1	GREE1
	GREE_B	GREE3	GREE3
	GREE_C	GREE4	GREE4
Harmer	HARM_A	HARM1	HARM1
	HARM_B	HARM3, HARM4, HARM5	HARM3
Henretta	HENR_A	HENR1, HENR2, HENR3	HENR1
Kilmarnock	KILM_A	KILM1	KILM1
Leask	LEAS_A	LEAS2	LEAS2
Lindsay	LIND_A	LIND1	LIND1
Line	LINE_A	LINE1, LINE2, LINE3	LINE1
	LINE_B	LINE4	LINE4
	LINE_C	LINE7	LINE7
Lake Mountain	LMOU_A	LMOU1, LMOU3, LMOU4	LMOU1
Michel	MICH_A	MICH1, MICH2	MICH1
	MICH_B	MICH3, MICH4	MICH4
	MICH_C	MICH5	MICH5
Mickelson	MICK_A	MICK1, MICK2	MICK1
Milligan	MILL_A	MILL1, MILL2	MILL2
North Thompson	NTHO_A	NTHO1	NTHO1
North Wolfram	NWOL_A	NWOL1	NWOL1
Otto	OTTO_A	OTTO1, OTTO3	OTTO1
Pengally	PENG_A	PENG1	PENG1
Porter	PORT_A	PORT1	PORT1
	PORT_B	PORT3	PORT3
Qualteri	QUAL_A	QUAL1	QUAL1
Sawmill	SAWM_A	SAWM1	SAWM1
	SAWM_B	SAWM2	SAWM2
Site 18	SITE_18	SITE18	SITE18
Six Mile	SIXM_A	SIXM1	SIXM1
South Line	SLIN_A	SLIN2	SLIN2
South Pit	SPIT_A	SPIT1	SPIT1
	SPIT_B	SPIT2	SPIT2
Smith Pond Outlet	SPOU_A	SPOU1	SPOU1
Spring	SPRI_A	SPRI1	SPRI1
Stream #02	STR02_A	STR02	STR02
Stream #18	STR18_A	STR18	STR18
Swift	SWIF_A	SWIF1, SWIF2	SWIF1
South Wolfram Creek	SWOL_A	SWOL1	SWOL1
Thompson	THOM_A	THOM1, THOM2, THOM3	THOM2
Thresher	THRE_A	THRE1	THRE1
Unnamed South of Sawmill	USOS_A	USOS1	USOS1
Willow Cr North	WILN_A	WILN2	WILN2
Willow Cr South	WILS_A	WILS1	WILS1
Wolf Creek	WOL1_A	WOL1	WOL1
Wolfram	WOLF_A	WOLF2	WOLF2
	WOLF_B	WOLF3	WOLF3

2.3 *Updates for the 2017 Program*

The Program was completed as per the work plan with only minor changes to sites sampled:

- At Elkview Operations (EVO), only SPIT1-0 was sampled instead of the six sites sampled in 2016. This SPIT1-0 site coincides with the SPIT1-12.5 from 2016. This site was sampled since it is downstream of the pond. CSEE was removed from the Program since the site had been altered as part of the mine site operations. Only BOD1-25 was sampled for BOD1 as the creek was dry.
- At Greenhills Operations (GHO) THOM1 was replaced by THOM2. THOM1 is a wetland and is lentic habitat. Previous Program revisions resulted in lentic habitat being excluded from calcite monitoring as much of the areas were too deep to effectively sample. However, THOM1 continued to be sampled in the inlet channel to the wetland. THOM2 is considered to be more representative of Thompson Creek and lotic habitat, and will be sampled instead of THOM1 during future monitoring. WOLF2 was removed from the Program due to active construction at WOLF2-75 during the time of sampling.
- Two sites on the Fording River Operations (FRO) were removed from the Program. Those sites are: 1) LMOU1-25 (stream is now confined to a culvert), and 2) SPSE1-50 (a lentic site). The sites FPON1-50 and FPON1-75 were not sampled due to active fish habitat construction in the area at the time of sampling. Both of these sites will be revisited in future sampling events.
- For the regional sites, FORD6-25 was inaccessible due to excessive ice cover over the stream. This site will be revisited in future sampling events.
- Other additional reaches sampled in 2017 included three streams (i.e., Stream #2, Stream #14, and Site 18) located on Sparwood Ridge. Sparwood Ridge is located on the west side of Highway 3 across from the Elkview Operations. Sampling was completed on Sparwood Ridge to fulfill the requirement in bullet 7 of the October 15, 2016 Environmental Site Assessment Letter from ENV. This is the first year of sampling for these streams.

Another update for the Program was the addition of compulsory pebble counts for every site visited, regardless of calcite presence. This was added to ensure a through site visit for all locations.

An update to the data analysis section for 2017 is the use of the Mann-Kendall trend test in place of linear regressions. The Mann-Kendall test is used to determine if there are any trends (positive or negative) in the data over time. It is a non-parametric test that makes fewer distributional assumptions. At recommendation by the EMC, contrast analyses were used as an additional *post hoc* test, to further assess reaches with significant Analysis of Variance (ANOVA) results.

In addition to the initial habitat surveys for new sites, and calcite index, an additional parameter was included in the site assessment. A “flag” has been included for each site where field crews observe or are informed of any activity thought to have the potential of changing stream substrate and *CI*. Flags could include natural events such as flooding or anthropogenic events such as the habitat construction that occurred at Fish Pond Creek in 2017.

2.4 *Additional sampling*

Sampling effort beyond the standard protocol added to the Program in 2017 included:

1. FORD9 had three additional sites (e.g., FORD9-12.5, FORD9-37.5, FORD9-62.5) sampled this year. These sites were added to the Program to help investigate variability in calcite scores between various other projects.
2. An additional reach was added to Michel Creek (i.e., MICH2 to establish a baseline value prior to the operation of the Elkview Saturated Rock Fill (SRF) full-scale trial, which will discharge into Bodie Creek and Gate Creek (Kevin Atherton pers. comm. 2017). The objective of the SRF is to treat nitrate and/or selenium at a full scale (Kevin Atherton pers. comm. 2017). The effluent from the SRF is likely to have increased levels of calcite saturation (Kevin Atherton pers. comm. 2017).

2.5 *Field surveys*

Field survey methods generally followed those reported in Smithson and Robinson (2017) and Robinson *et al.* (2013) with the exception of the compulsory pebble counts noted in Section 2.3. This year, every site had a pebble count completed regardless of calcite presence or absence. The pebble count was a modified Wolman pebble count (Wolman 1954) to quantify the degree of calcite presence using two metrics to calculate a site-specific Calcite Index (*CI)*:

- Calcite presence: $CI_p = Calcite\ Presence\ Score = \frac{Number\ of\ pebbles\ with\ calcite}{Number\ of\ pebbles\ counted}$
- Calcite concretion: $CI_c = Calcite\ Concretion\ Score = \frac{Sum\ of\ pebble\ concretion\ scores}{Number\ of\ pebbles\ counted}$
- Calcite index: $CI = Calcite\ Index = CI_p + CI_c$

Results were summarized for four stream categories: (1) Fording and Elk mainstems (reference), (2) tributaries (reference), (3) Fording and Elk mainstems (exposed), and (4) tributaries (exposed).

The same *CI* ranges or "bins" used in the previous years to report the distribution of *CI* by stream length were used. Six bins of 0.5 *CI* intervals were used to divide the range of *CI* scores from 0.00 – 3.00 (representing low to high calcite levels). Reach mean *CI* were mapped to depict the spatial distribution of calcite relative to each of the mines.

2.6 *Data analysis*

2.6.1 2017 Calcite Index and general distribution

CI values were calculated for indicator reaches sampled in 2017 and added to the long-term dataset (Appendix 1). Indicator reach values were assigned to the total length of the segment they represented. The 2017 *CI,* CI_p, and CI_c scores for indicator reaches are presented in Appendix 2. Maps of calcite distribution were prepared to provide a spatial reference to the 2017 Program results. Maps show the mean *CI* value for a segment, as calculated at the indicator reach for that segment. Maps are provided in Appendix 3.

2.6.2 Rate of change in calcite deposition

Trends in the rate of change over time were assessed using five variations of three statistical methods. One reason for this was that calcite deposition may change over time either gradually (e.g., linearly) or more dramatically with step-wise changes (e.g., post-flood). Different patterns of temporal change require different assessment methods. In 2017, rate of change analyses were only run on indictor reaches. The five tests ran were:

1. Mann-Kendall – individual reaches
2. Mann-Kendall – Block design
3. One-way Analysis of Variance – Tukey's HSD post-hoc
4. One-way Analysis of Variance – Contrast of each year against all previous years
5. One-way Analysis of Variance – Contrast of each year against all years (pre and post) excluding the year in question.

The Mann-Kendall tests for generally increasing or decreasing trends over time. The Analysis of Variance tests will be used to detect changes that may be more "step-wise" in nature, and if suspected the Tukey's and Contrast assessments will further describe specifically how a year differs from other years sampling within a reach.

Mann-Kendall

A Mann-Kendall test was run on all indicator reaches sampled from 2013 - 2017 to evaluate the relationship of *CI* versus time (*Year*). Temporal trends were statistically assessed using the rank based non-parametric Mann-Kendall test (Hipel and McLeod 2005). The tau coefficient produced by the test indicates the direction of the trend (i.e., positive value indicates an increase in *CI*). The Mann-Kendall tests were performed in R, a language and environment for statistical computing (R Core Team 2017) using the 'trend' package (Pohlert 2017). The repeated measurements on each site within a reach over time were "ignored" given the high variability seen over time and the small number of repeated sites in a reach.

As was decided with linear regression previously used, significance for the Mann-Kendall was conservatively set at an alpha value of $\alpha = 0.10$. Setting $\alpha = 0.10$ relaxes the magnitude of change required to be considered a statistically significant change (Robinson and Atherton 2016). This was considered appropriate given that the data set of five years was relatively short for what would be desired for monitoring environmental change (i.e., >10 years). Results for the Mann-Kendall are provided in tabular form in Appendix 4.

Reaches with significant rates of change were further explored at a site level ($\alpha = 0.10$). Sites were investigated by running a Mann-Kendall test on the individual sites of those significant reaches to determine if the change was occurring over the entire reach or more localized at a specific site. Results were presented as the percentage of sites with significant trends within a reach. Higher percentages can be interpreted to indicate more spatially homogenous change was occurring within that reach. Again, significant sites were reported based on $\alpha = 0.10$.

Block design

Block design was recommended by the EMC and included in data analysis in 2016. The Block design was intended to investigate trends by larger groups of reach "types," as opposed to individual reaches. Each reach was categorized into one of four Block types:

1. Reference – Reaches identified as reference for assessment in this Program.
2. Historical exposure – Reaches with mine exposure originating before the start of the regional calcite monitoring Program (i.e., pre-2013).
3. Recent exposure - Reaches with mine exposure originating after the start of the regional calcite monitoring Program (i.e., post-2013).
4. Treated – Reaches downstream of a water treatment facility to a point where stream order increases appreciably.
5. Future exposure – Reaches currently in the reference condition but are expected to become exposed after a mine extension. Currently, only Wolf Creek Reach 1 fits into this category.

As with trend analysis of reaches over time, linear regression was replaced with Mann-Kendall to test for significant trends in *CI* over time within each of the five Blocks.

ANOVA

Changes in mean *CI* values between years within a Reach were evaluated using one-way Analysis of Variance (ANOVA) using *Year* as the independent variable (2013 - 2017). A significant result suggests that the difference in mean *CI* for at least one year-to-year pairing was greater than within-reach variability (Robinson and Atherton 2016). Reaches found to have significant differences in the mean between years were further investigated using Tukey's post-hoc assessment. An alpha value of $\alpha = 0.05$ was used in this assessment (Robinson and Atherton 2016). This assessment was run to detect step-wise trends throughout the entire data set. It would also be capable of detecting trends over time by qualitatively assessing the results to identify sequential year-to-year changes in the same direction (i.e., increase or decrease). Appendix 5 provides ANOVA results for reaches with significant effect of year and significant year-to-year pairings identified from Tukey's HSD. Similar to the Mann-Kendall test for trend, the repeated measurements on the same site over time were treated as independent observations because of the high observed variability.

Contrast Analysis

The EMC recommended Contrast Analysis as another potential method to detect step-wise changes following a one-way ANOVA. Reaches found to have significant differences in the mean between years were further investigated using contrasts. Two sets of contrasts were run for each Reach. One contrast tested for significant differences in mean *CI* values in each specific year relative to all prior years sampled. This would test to see if the mean in the current year was significantly different from the preceding dataset (i.e. a step-wise change). The second contrast tested for significant differences of mean *CI* values in one specific year relative to all years sampled (prior and following the year in question). P-values in each set of contrast analyses were adjusted for multiple comparisons using the Holm method (Holm 1979), which controls the family-wise error rate. The tests were performed in R using the "lsmeans" package (Lenth 2016).

2.6.3 Inter-program comparisons

Teck has incorporated calcite monitoring into programs other than this Program. The 2016 Calcite Monitoring Program annual report presented results from various programs and identified areas of differing results. At request of the EMC, a correlation table has been included for all sites sampled from multiple programs (Section 3.2.7).

2.6.4 Data quality assurance

Data quality assurance steps follow that of the earlier Programs (e.g., Smithson and Robinson 2017; Robinson *et al.* 2016). Quality assurance steps included:

- Having field crews perform calcite measurements at multiple sites as a group during the onset of the Program. The exercise is used to calibrate observers, standardize collection methods, and review changes to the current Program.
- *CI* scores were calculated in the field to compare with previous *CI* scores and determine if more sampling sites needed to be added.
- A computer script using Python was written to check that cells were populated with values acceptable (e.g., calcite presence score can only be 0 or 1; concreted scores can only be 0, 1, or 2; concreted score must be 0 if calcite presence is 0). Any cells that had errors or were left blank were flagged and corrected.

3 Results

3.1 *2017 Calcite Index and general distribution*

The Program was conducted from October 10 – November 3, 2017. In 2017, a total of 85 indicator reaches and 232 sites were surveyed. A total of 358.5 km of stream segments were assessed and mapped. A total of 295.1 km were considered exposed and downstream of mining activities (Table 3). A total of 63.4 km were considered reference. Results are presented by four stream categories as either mainstem Fording River and Elk River sections versus tributaries, and reference versus exposed.

Table 3. Stream calcite distribution (km) estimates for the four stream categories, by *CI* ranges for 2017.

	Reference				***Exposed***			
	Fording and Elk		***Tributaries***		***Fording and Elk***		***Tributaries***	
CI Range	***km***	***%***	***km***	***%***	***km***	***%***	***km***	***%***
0.00 - 0.50	21.8	100%	41.6	100%	123.4	81%	100.7	71%
0.51 - 1.00	0	0%	0	0%	29.6	19%	8.7	6%
1.01 - 1.50	0	0%	0	0%	0.0	0%	3.4	2%
1.51 - 2.00	0	0%	0	0%	0.0	0%	5.3	4%
2.01 - 2.50	0	0%	0	0%	0.0	0%	3.8	3%
2.51 - 3.00	0	0%	0	0%	0.0	0%	20.3	14%
Total 2016	**21.8**	**100%**	**41.6**	**100%**	**153.0**	**100%**	**142.1**	**100%**

Calcite distribution observed in 2017 was consistent with previous observations, with the majority of exposed stream kilometers in the 0.00 - 0.50 *CI* bin for both mainstem and tributary categories (Figure 2). The following changes are qualitative and do not indicate a statistically significant change. The Fording and Elk mainstem stream categories had 81% of exposed stream length occur in the 0.00 - 0.50 *CI* bin, which is the same as in 2016 (Smithson and Robinson 2017). The amount of exposed mainstem in the 0.51 – 1.00 *CI* bin also remained the same as 2016 at 19%. Comparably, 71% of tributary stream kilometers occurred in the 0.00 - 0.50 *CI* bin in 2017 versus 75% in 2016. The largest change occurred in the exposed tributaries. The percentage of stream kilometers increased from 5% to 14% in the 2.51-3.00 bin, while reducing in the 1.51-2.00 and 2.01-2.50 bins.

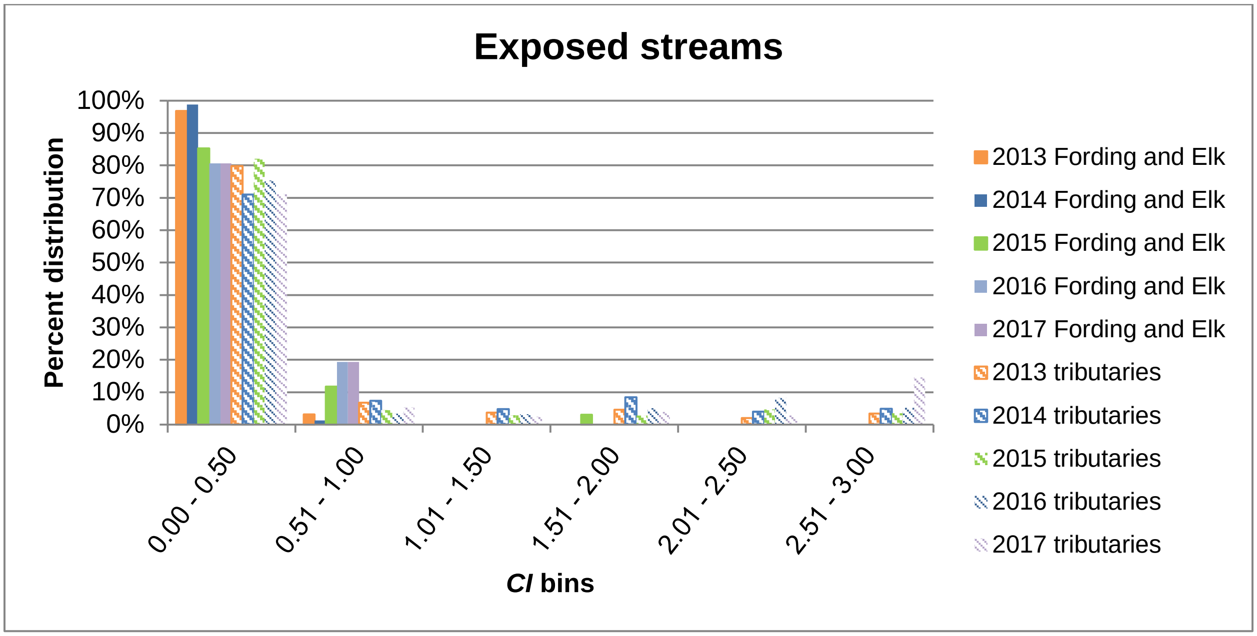


Figure 2. Percent distribution of exposed stream kilometers among *CI* bins by stream category and year (each year sum to 100% for the stream category).

The reference mainstem and tributaries had 100% of the 21.8 km classified into the 0.00 - 0.50 *CI* bin (Figure 3). This is consistent with all previous years.

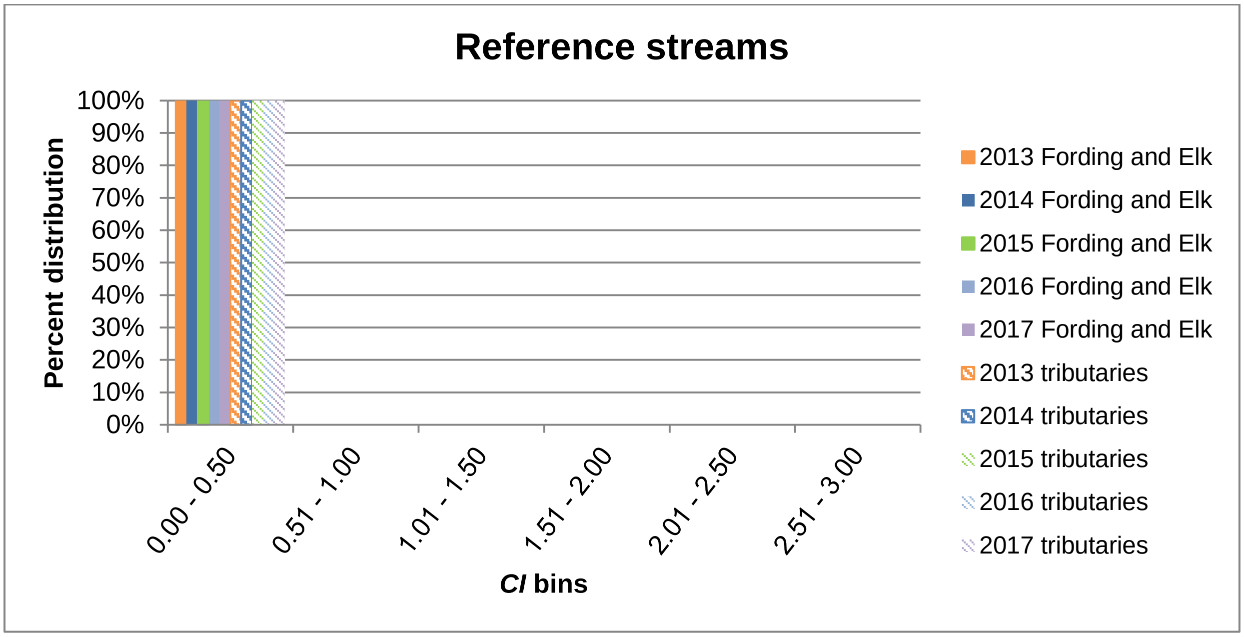


Figure 3. Percent distribution of reference stream kilometers among *CI* bins by stream category and year (each year sum to 100% for the stream category).

3.2 *Rate of change in calcite deposition*

3.2.1 Mann-Kendall

Of the 85 indicator reaches sampled in 2017, 22 reaches had a constant *CI* value of *CI* = 0.00 since 2013 and one reach (CATA1) had a constant *CI* value of 3.00. Those 23 reaches were excluded from the Mann-Kendall analysis. Also excluded were the three new reaches added from Sparwood Ridge in 2017. The remaining indicator reaches were assessed using the Mann-Kendall analysis. A total of 12 reaches were found to have significant changes in *CI* over the five year period (α=0.10) (Figure 4). In 2016, there were 10 reaches found to have significant trends over time and of them EPOU1, PORT3, PORT1, PENG1, and GATE2 were again significant in 2017 (Smithson and Robinson 2017).

Four of the 12 reaches showed a decreasing trend and eight had increased over time (Table 4). Reaches EPOU1, PORT1, and PENG1 were sampled at only one site for each reach. Therefore, the decreasing trend observed at these reaches was interpreted to represent a homogenous decrease over time across the entire reach. The increase at GATE2 was significant at two of three sites, suggesting it is likely occurring over much of the reach. The remaining reaches (DRYE3, FORD5, KILM1, FORD1, and FORD12) all reported a significant increase at only one site. This suggests that the increases are being driven by portions of the reach.

The reference Reach FORD12 reported a significant increase in *CI* since 2013. In 2016, only FORD12-75 had a calcite present with a *CI* value of 0.08. In 2017, all three sites had a *CI* value ranging from 0.08 – 0.16. Only FORD12-75 was significant at α=0.1 from the site level Mann-Kendall.

Table 4. Reaches with significant changes in *CI* from 2013 – 2017 using Mann-Kendall.

Reach	Exposure	# sites	p-value	tau value	Change	% significant sites (α=0.1)
EPOU1	Exposed	1	0.086	-0.80	Decreasing	100
PORT1	Exposed	1	0.086	-0.80	Decreasing	100
PORT3	Exposed	3	0.086	-0.80	Decreasing	0
PENG1	Exposed	1	0.068	-0.89	Decreasing	100
GODD3	Exposed	3	0.027	1.00	Increasing	100
DRYE3	Exposed	3	0.086	0.80	Increasing	33
FORD5	Exposed	3	0.086	0.80	Increasing	33
GATE2	Exposed	3	0.086	0.80	Increasing	67
KILM1	Exposed	5	0.086	0.80	Increasing	25
LEAS2	Exposed	3	0.086	0.80	Increasing	0
FORD1	Exposed	3	0.096	0.84	Increasing	33
FORD12	Reference	3	0.096	0.84	Increasing	33

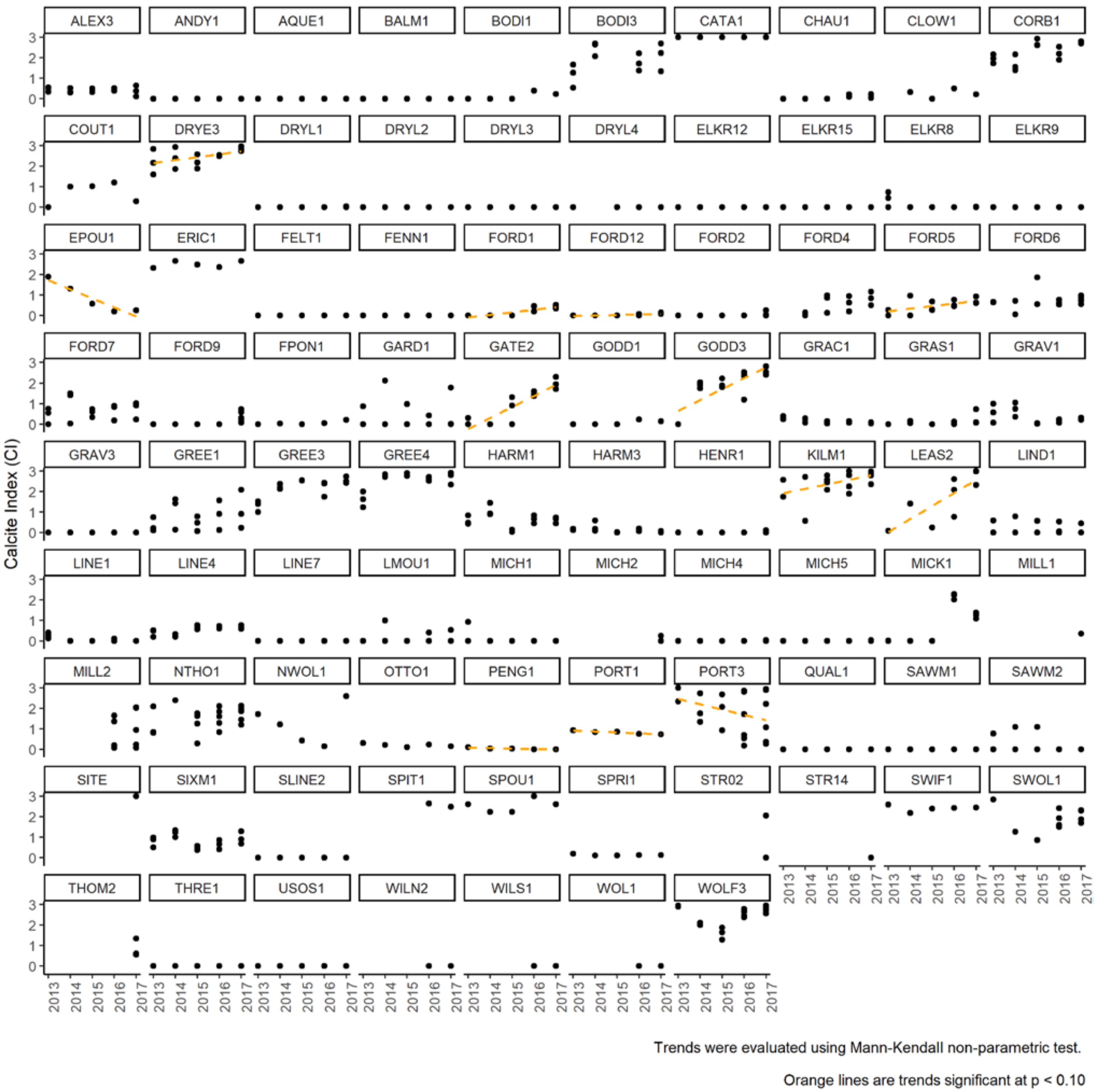


Figure 4. Mean reach *CI* from 2013 – 2017 from the Mann-Kendall test.

3.2.2 Block design

Mann-Kendall analysis was run on Historical exposure, Reference exposure, Treated Block, and Recent exposure site types (Figure 5). Mann-Kendall could not be run on the Future exposure Block because all of the *CI*-values were consistently 0.00 for all years sampled. The Historical Block was found to be significantly predicted by *Year* (p=0.008, tau= 0.10). The positive tau value indicates an increasing calcite trend for that Block type. This increase within the Historical Block was also reported in 2016. Calcite treatment began in Greenhills Creek on October 23, 2017. This was the same day that the calcite surveys were completed. As such, Greenhills Creek remained in the Historical Block, but will be moved to treated in 2018.

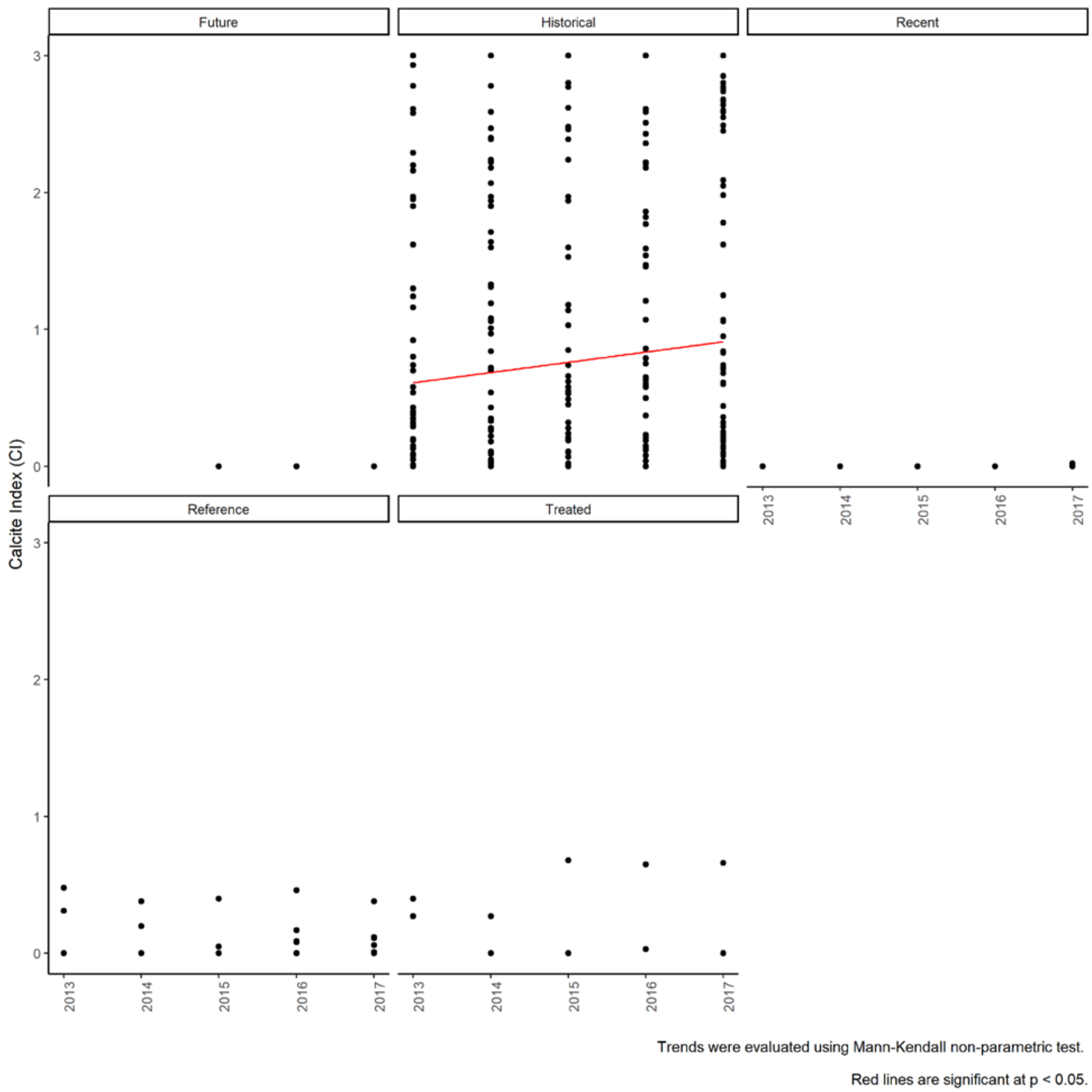


Figure 5. Mann-Kendall box-plot of Block design.

3.2.3 ANOVA (Tukey's HSD post-hoc)

An ANOVA assessment was completed on 50 of the 85 indicator reaches sampled in 2017. The 50 reaches were selected for ANOVA as they were sampled with two or more sites in all five years (2013 to 2017). Results showed the reach mean *CI* varied significantly by *Year* in 17 reaches (Figure 6). The results of the 2017 ANOVA analyses indicated significant variation in reach mean *CI* for the same number of reaches and nearly the identical reaches reported as significant in 2016 (Smithson and Robinson 2017). Two exceptions were:

- BOD3 had significantly different reach mean *CI* in 2016 but not 2017, and
- FORD12 had significantly different reach mean *CI* only in 2017.

Indicator Reaches CHAU1, FORD1, and MICK1 had calcite reported for the first time in 2016. Reference reaches CHAU1 and FORD12 both had significant year effects detected. In nearly all reaches, the significant year-to-year pairings appear to be the results of one to three years from 2013-2015 significantly differing in *CI* score from the 2016 and 2017 years, but rarely within these two arbitrary time periods (i.e., 2013-2015 and 2016-2017). Some exceptions do occur.

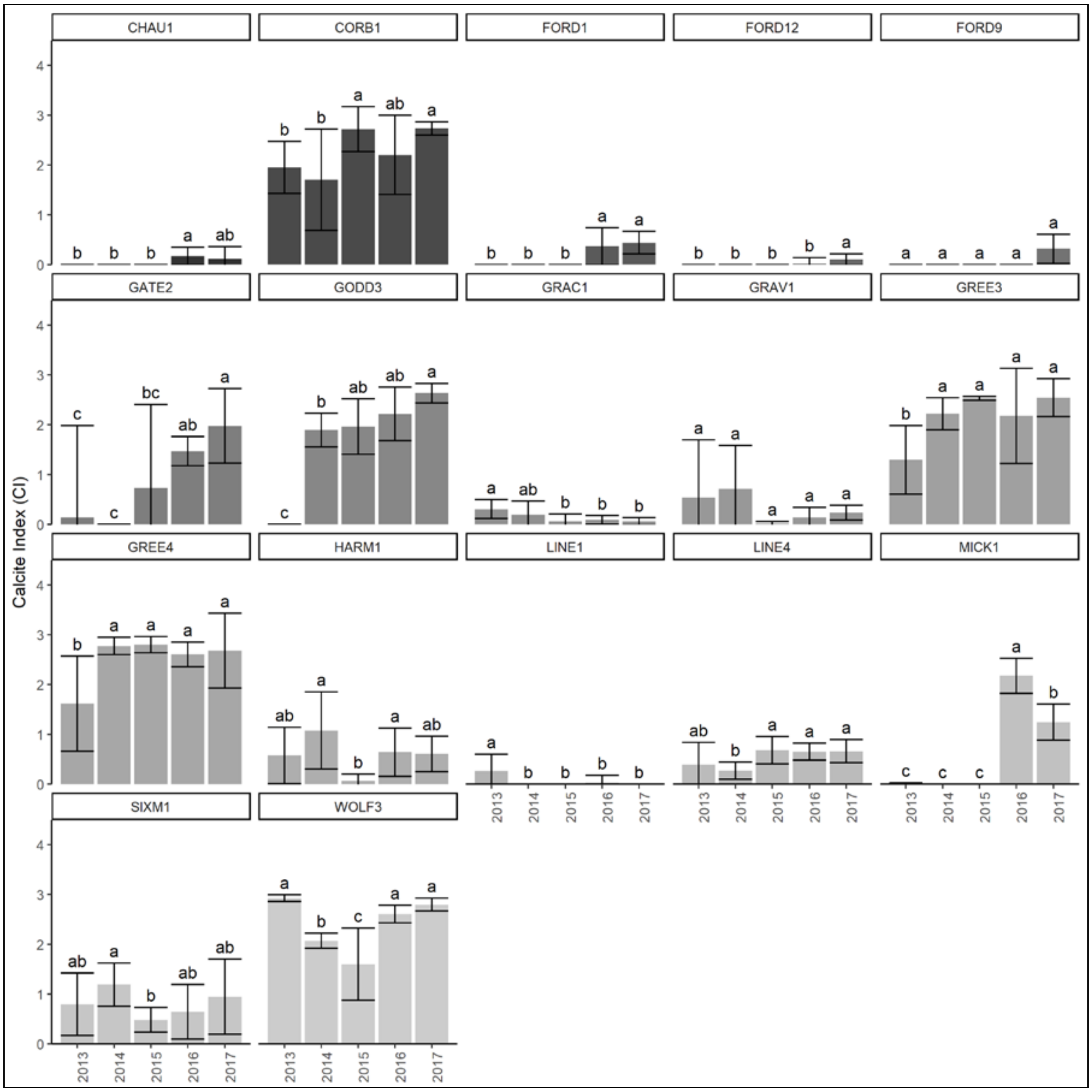


Figure 6. Bar graphs showing results of significant one-way ANOVA tests. Same letters on graphs denotes no significant differences in mean *CI* among years, with reach.

3.2.4 Contrast – each year against all previous years

Contrast tests were ran on all reaches found to have significant *Year* effects in ANOVA. The first contrast model was to assess each year against all previous years in that reach. Therefore, results were not generated for 2013. The mean *CI* for 2014 was compared against the mean for 2013. The mean *CI* for 2015 was compared against the average of 2013 and 2014 means. This was continued until the final test of the mean *CI* of 2017 against all means from 2013-2016. Results were tabulated for all reaches by showing p-values for each assessment ran (Table 5).

Table 5. P-values of contrast analysis of each year's mean compared to all previous years, by reach (Red cells = significantly higher year. Green cells = significantly lower year).

Reach	Exposure	2013	2014	2015	2016	2017
CHAU1	Reference	n/a	1.00	1.00	**<0.01**	0.14
CORB1	Exposed	n/a	0.56	**<0.01**	0.66	**0.02**
FORD1	Exposed	n/a	1.00	1.00	**<0.01**	**<0.01**
FORD12	Reference	n/a	1.00	1.00	0.60	**<0.01**
FORD9	Exposed	n/a	1.00	1.00	1.00	**0.01**
GATE2	Exposed	n/a	n/a	**0.04**	**0.01**	**<0.01**
GODD3	Exposed	n/a	**<0.001**	**<0.01**	**<0.01**	**<0.001**
GRAC1	Reference	n/a	0.13	**0.01**	0.13	0.13
GRAV1	Exposed	n/a	0.88	**0.03**	0.42	0.88
GREE3	Exposed	n/a	**<0.01**	**<0.01**	0.31	**0.02**
GREE4	Exposed	n/a	**<0.01**	**0.01**	0.29	0.29
HARM1	Exposed	n/a	**0.04**	**<0.01**	1.00	1.00
LINE1	Exposed	n/a	**<0.01**	**0.05**	0.23	0.21
LINE4	Exposed	n/a	0.21	**0.01**	**0.07**	**0.10**
MICK1	Exposed	n/a	1.00	1.00	**<0.001**	**<0.001**
SIXM1	Exposed	n/a	0.16	**0.04**	0.51	0.51
WOLF3	Exposed	n/a	**<0.001**	**<0.001**	**<0.01**	**<0.001**

3.2.5 Contrast – each year against all years

A second contrast model compared each year's mean against the mean of the means from all other years, excluding the year of interest (Table 6). In this model, results for 2013 were generated. Results were tabulated for all reaches by showing p-values for each assessment ran

Table 6. P-values of contrast analysis of each year's mean compared to the mean of the mean of all previous years, by reach (Red cells = significantly higher year. Green cells = significantly lower year).

Reach	2013	2014	2015	2016	2017
CHAU1	0.18	0.18	0.18	**0.01**	0.18
CORB1	**0.09**	**0.01**	**0.02**	0.68	**0.02**
FORD1	**0.01**	**0.01**	**0.01**	**<0.01**	**<0.01**
FORD12	0.43	0.43	0.43	1.00	**<0.01**
FORD9	1.00	1.00	1.00	1.00	**0.01**
GATE2	n/a	**<0.01**	0.14	0.11	**<0.01**
GODD3	**<0.001**	0.37	0.37	**<0.01**	**<0.001**
GRAC1	**0.00**	0.31	0.18	0.31	0.18
GRAV1	0.46	**0.09**	0.18	0.46	0.51
GREE3	**<0.001**	1.00	**0.03**	1.00	**0.03**
GREE4	**<0.001**	0.12	0.11	0.37	0.29
HARM1	1.00	**<0.01**	**<0.01**	1.00	1.00
LINE1	**<0.01**	0.43	0.43	0.45	0.43
LINE4	0.12	**0.01**	0.11	0.12	0.12
MICK1	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
SIXM1	0.88	**0.04**	**0.07**	0.52	0.53
WOLF3	**<.001**	**<0.01**	**<0.001**	**<0.01**	**<.001**

3.2.6 Other Observations

There were some sites that had calcite reported for the first time in 2017, but were not found to produce significant reach-level changes with either an ANOVA or Mann-Kendall analysis. These sites included:

- DRYL1-25 (*CI*=0.02, DRYL1-50 (*CI*= 0.05), and DRYL3-25 (*CI*=0.01)
- FORD2-25 – which had a *CI* presence score of 0.04;
- FORD2-50 – which had a *CI* of 0.25, and had a concretion score of 0.01;
- HENR1-75 – which had a *CI* presence score of 0.11 and was sampled downstream of the riffles created in 2016;
- MICH4-75 – which had a *CI* presence score of 0.03; and
- MICH5-25 – which had a *CI* presence score of 0.04.

3.2.7 Inter-program comparisons

Calcite measurements are collected for aquatic monitoring programs other than this Program to support evaluation of specific questions within those programs. By incorporating calcite measurements into other programs, an increased understanding and awareness of potential changes in *CI* can be built. However, these other programs have produced results that at times vary from those presented in this report, at a limited number of reaches. As a result Teck has identified the importance of aligning these methods for consistency between programs. To address potential differences in sampling methods, Teck accompanied each field team from the other programs to standardize the observations of calcite presence and concretion, prior to data collection within those programs. For each team, several sites were visited displaying a range of calcite conditions, including observations of calcite presence and concretion on fine sediments. Teck observed that all programs were consistent in that calcite was detected using visual methods (i.e., not the use of chemical detection methods) and that fines (i.e., sand, silt, clay) were reported as such and with a calcite presence score of zero. Key differences between programs are presented in Table 7.

Table 7. Key differences between Teck calcite monitoring programs methodologies.

Item	Regional	Other*
Site length	Sampled over 100 metres of stream length	Sample length matched habitat being studied (typically single riffles)
Purpose of sampling	Purpose is to characterize the reach	Purpose is to characterize the site
Site selection	Site selection based on location in reach	Site selection based on focus of specific study

Other* includes: Regional Aquatic Effects Monitoring Program (RAEMP), Local Aquatic Effects Monitoring Program (LAEMP), Calcite Biological, etc.

At request of the EMC, a correlation matrix has been provided for each stream sampled as part of more than one program (Figure 7). The *CI* scores generated from the various monitoring programs generally agreed well. Where they disagreed, this Program typically produced lower *CI* scores.

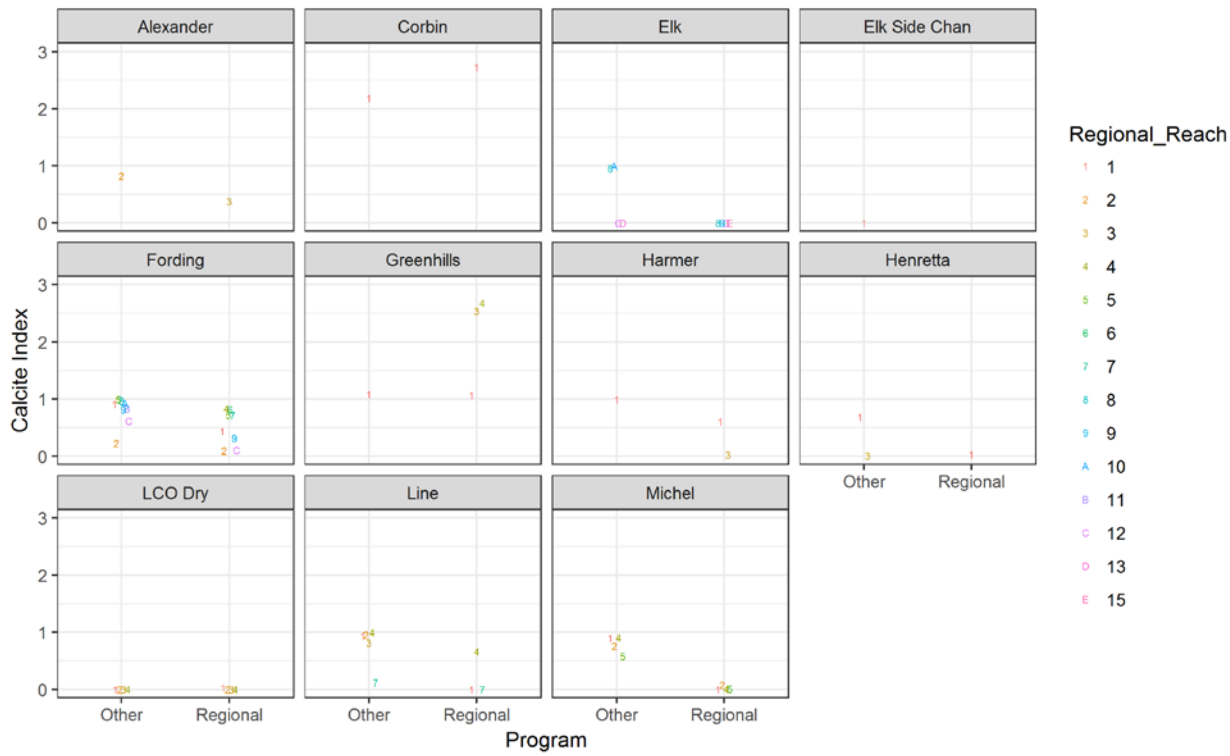


Figure 7. Correlation table of *CI* values for reaches sampled during multiple programs.

In 2016, FORD9 was identified as a reach with varied results between programs. As such, the Program added three additional sites (i.e., FORD9-12.5, FORD9-37.5, FORD9-62.5) to help investigate variability in calcite scores between other projects. The additional effort was helpful in explaining a potential source of variance. Recall that reaches, defined as morphological homogeneous river units, have been selected as a sampling unit. Fording River – Reach 9 is an exposed section of channel that extends from the southern limit of FRO property upstream to where the Fording River becomes confined by the South Tailings Pond. While a correct morphologic reach, FORD9 may not be homogeneous in terms of water quality. The additional sites showed that FORD9 increases in *CI* as one moves upstream towards the confluence with Cataract Creek, but then values drop upstream of Cataract Creek (Figure 8). Cataract Creek is a heavily calcified watercourse that has had a *CI* of 3.00 since 2013. This Program appears to be detecting the input of Cataract Creek into FORD9. This change is not as abrupt in the other sampling programs. It is possible that the riffle-based sampling used in the other programs is over-estimating *CI* in this reach.

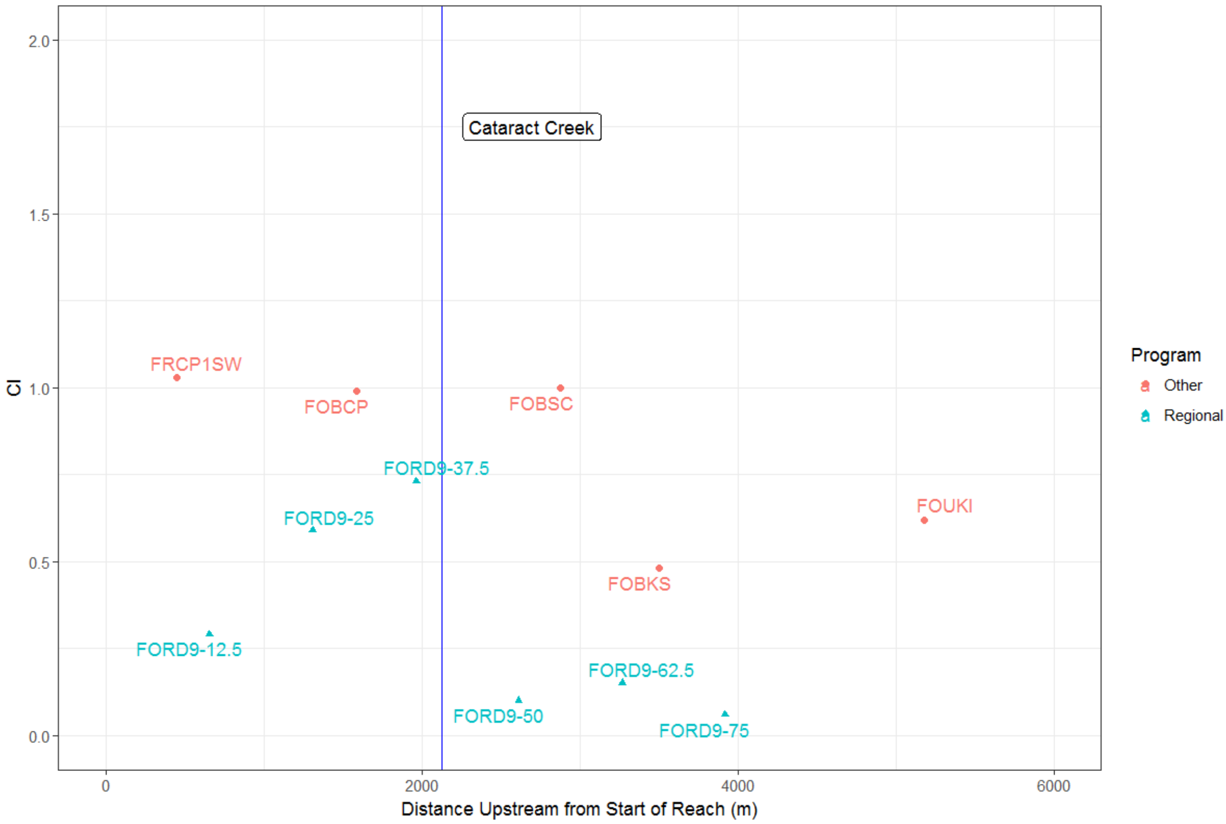


Figure 8. *CI* values from FORD9 for regional and other calcite sampling programs.

3.3 *Data quality assurance*

Data quality assurance steps were completed as described in Section. 2.6.4. Crews visited sites as a group to calibrate calcite observations and data collection. All raw pebble count data were screened for data entry errors using the Python computer script to confirm that cells were populated with acceptable (i.e., valid) values. Data entry errors were less than 2%. All errors were corrected before mapping and statistical analyses.

4 Discussion

The use of stream segment sampling and adaptive sample size selection per reach were effective at streamlining the Program and in focusing more sampling into the areas that had higher calcite range variability. In 2017, 232 sites were sampled as opposed to 348 sites sampled in 2015.

The observed spatial deposition patterns for 2017 were generally consistent with that reported since the onset of the Program in 2013, with exceptions described in paragraphs below. For general consistencies, the Fording and Elk mainstem stream categories had 81% of exposed stream length occur in the 0.00 - 0.50 *CI* bin, which is the same as in 2016 (Smithson and Robinson 2017). The amount of exposed mainstem in the 0.51 – 1.00 *CI* bin also remained the same as 2016 at 19%. Similarly, 71% of tributary stream kilometers occurred in the 0.00 - 0.50 *CI* bin in 2017 versus 75% in 2016.

One notable change from 2017 to previous years occurred in the 2.51 – 3.00 bin for the exposed tributaries. Prior to 2017, this bin comprised between 3.4 - 5.1% of the total for exposed tributaries, while in 2017 this bin increased to 14%. Considering that the reaches with significant linear increases includes streams from Fording River Operations (FORD5, KILM1), Greenhills Operations (LEAS2), Elkview Operations (GODD3, DRYE3, GATE2), as well one regional (FORD1) and one reference reach (FORD12), there appears to be no spatial distinction for where increases are occurring. Increases appear to be ubiquitous throughout the watershed suggesting a larger, regional factor may be influencing trends in calcite deposition. Previous reports speculated on the potential influence that a large flood in June 2013 may have had on calcite deposition throughout the Elk Valley (Robinson and MacDonald 2015). Heavy rainfall fell over much of the Elk River Watershed producing the highest flows on record, as indicated by the Water Survey of Canada station on the Fording River (WSC Station # 08NK018). Stream channels moved substantial amounts of sediment as the flood caused new channels to form and large-scale bank erosion. It is logical to expect that much of the substrate monitored in 2013 was relatively newly exposed along the stream beds.

Calcite occurrence is increasing in reference areas as well. Calcite appeared in CHAU1 and FORD12, two of this Program's reference reaches, for the first time in 2016. Both reaches were found to have 2017 *CI* scores significantly higher than previous years. Another reference reach on upper Michel Creek (MICH5) also reported calcite for the first time in 2017. The fact that this monitoring Program is detecting increasing trends in both exposed and reference streams supports the concept that many of the changes observed may be in response to the 2013 flood and not entirely related to mine activity. Additionally, the effects of other environmental variables such as flow and discharge on temporal variability of calcite have yet to be investigated as part of this program. Continued monitoring will help to investigate if many streams in the system are in fact affected by high flow events that mobilize sediments and "reset" calcite indices, or if a long-term increasing trend is occurring. Monitoring over a range of flood events will also help confirm the suspected role floods play in changing the amount of calcite in a given year. Also, of consideration were the relatively small freshets recently. Qualitative observations of flows in the Elk River watershed suggest freshets have not exceeded bankfull flow events in 2015-2017. These lower flow years are less able to transport sediment/bedload compared to higher flow events.

Some of the significant changes in calcite deposition that were found on streams, may be explained by changes to the mine activity in the watershed including new spoil development and increasing flows throughout the year from pit dewatering. Tributaries in the Fording and Elk that received increased pit pumping volumes in 2017 include Mickelson Creek, Wolfram Creek, Bodie Creek, and Gate Creek. Also of note was the observation of calcite in Dry Creek (LCO). The LCO Phase II project began spoiling waste rock into the Dry Creek watershed in 2014. This program appears to have detected the first occurrences of calcite in response to the new mine activity.

Revisions to data analysis were made for 2017. One change was the use a Mann-Kendall analysis instead of linear regression. Mann-Kendall is better suited to the calcite data as it does not require the data to be normally distributed. An ANOVA with Tukey's HSD was still used as in previous years to assess changes in the mean *CI*. Together the Mann-Kendall and ANOVA give the ability to test for different types of changes, linear and step-wise, respectively in the mean. These are the analyses that have been conducted since the beginning of the Program. The need for multiple assessments came from the fact that the way in which calcite depositions changed over time was unknown. In 2017, the EMC recommended Contrast Analysis as another potential method to detect step-wise changes following a one-way ANOVA. Two contrast models were ran and compared to the Tukey's HSD test by looking at what conclusions were made following interpretation of the test results (Table 8). Contrast(p) is used to denote the Contrast test of a year's mean against the mean of all previous years only. Contrast(a) is used to denote the Contrast test of a year's mean against the mean of all other years (pre and post).

General agreement among the three ANOVA post-hoc methods was found in eight of 17 reaches with significant *Year* effects on mean *CI*. Both Tukey's and Contrasts appeared effective in identifying the same year where statistically significant step-wise change occurred. Where the methods differed was the number of steps identified and a change in direction of the step. In nine of the 17 cases Tukey's test correctly identified a step where Contrast(p) would often indicate a significant step in the year's mean or two following the initial significant change. Consecutive significant changes in the mean calcite required additional investigation to determine if the consecutive changes were accurate or if the effect of initial step was being statistically detected in the following year(s). In other words, additional effort is needed to see if multiple steps occurred or if the effect of the first step carry over into subsequent years). Correct interpretations could be made, but required this additional investigation. By comparison, Contrast(a) appeared to agree more closely with Tukey's test results in that one significant step change identified in Tukey's test matched results of Contrast(a) generally indicating there were two similar groups of years separated by the year in which the significant step occurred. However, the results were just that, general.

Tukey's test was found to accurately identify sequential steps in opposite directions. In other words, Tukey's was found to accurately detect a step-wise decrease in the mean *CI* that was immediately preceded by an increase. Using MICK1 as an example, Tukey's test detected that the 2016 mean *CI* was significantly higher that all previous years and that 2017 mean *CI* was significantly lower than 2016, but not as low as all previous years. Contrast(p) also correctly suggested that both 2016 and 2017 had means that were significantly higher than all previous years. However, without additional investigation, the significantly higher mean of 2017 suggests that there were significant increases in both 2016 and 2017.

In summary, Tukey's HSD post-hoc assessment appears to provide the more reliable detection of step-wise changes with the least amount of subsequent statistical and qualitative investigation. We recommend continuing with ANOVA with Tukey's as the one method to assess step-wise changes in subsequent years.

The review completed by Teck found that calcite sampling was being conducted in a similar fashion between monitoring programs in terms of how calcite was being detected, but also that differences in site selection was occurring. Site selection is specific to the key questions being answered in each of the programs and it is possible that the differences in site selection due to differing project scopes may be producing different results between programs. Sampling over longer lengths in this regional Program is likely producing results that are more representative of the reach, whereas channel unit based sampling (e.g., within one riffle) could easily over- or under-report calcite, relative to what is occurring over the reach.

Table 8. Comparison of statistical analyses, significant results and interpretation.

Reach	M-K	Tukey's *post-hoc*	Contrast (previous years) (Contrast(p))	Contrast (all years) (Contrast(a))	Comments
CHAU1	-	Increase in 2016. No change to 2017.	Increase in 2016. No change to 2017.	2016 higher.	Good agreement
CORB1	-	Increase in 2015. No change to 2017.	Increase in 2015. Increase 2017.	2013-2014 lower. 2015 and 2017 higher.	Tukey's suggests one step. Contrast(p) suggests two steps. Contrast(a) suggests two groups.
DRYE3	Increase	-	-	-	
EPOU1	Decrease	-	-	-	
FORD1	Increase	Increase in 2016. No change to 2017.	Increase in 2016. Increase 2017.	2013-2015 lower. 2016 and 2017 higher.	Tukey's suggests one step. Contrast(p) suggests two steps. Contrast(a) suggests two groups. Mann-Kendall detected increase.
FORD5	Increase	-	-	-	
FORD9	-	Increase in 2017.	Increase in 2017.	2017 higher.	Good agreement
FORD12	Increase	Increase in 2017.	Increase in 2017.	2017 higher.	Good agreement. Mann-Kendall detected increase.
GATE2	Increase	Increase in 2015. Increase in 2017.	Increase in 2015, 2016, and 2017.	2017 higher.	Tukey's suggests two steps. Contrast(p) suggests three steps. Mann-Kendall detected increase.
GODD3	Increase	Increase in 2014. Increase in 2017.	Increase in 2014, 2015, 2016, and 2017.	2013 lower. 2016 and 2017 higher.	Tukey's suggests two steps. Contrast(p) suggests four steps. Contrast(a) suggests two groups. Mann-Kendall detected increase.
GRAC1	-	Decrease in 2015. No change to 2017.	Decrease in 2015. No change to 2017.	2013 higher.	Good agreement
GRAV1	-	Decrease in 2015. No change to 2017.	Decrease in 2015. No change to 2017.	2014 higher.	Good agreement
GREE3	-	Increase in 2014. No change to 2017.	Increase in 2014, 2015, and 2017.	2013 lower. 2015 and 2017 higher.	Tukey's suggests one step. Contrast(p) suggests three steps. Contrast(a) suggests two groups.
GREE4	-	Increase in 2014. No change to 2017.	Increase in 2014. Increase 2015.	2013 higher.	Tukey's suggests one step. Contrast(p) suggests two steps.
HARM1	-	Variable. No pattern.	Increase in 2014. Decrease in 2015	2014 higher. 2015 lower.	Good agreement
KILM1	Increase	-	-	-	
LEAS2	Increase	-	-	-	
LINE1	-	Decrease in 2014. No change to 2017.	Decrease in 2014. Decrease in 2015	2013 higher.	Tukey's suggests one step. Contrast(p) suggests two steps.
LINE4	-	Variable. No pattern.	Decrease in 2015. Increase in 2016 and 2017.	2014 lower.	Good agreement
MICK1	-	Increase in 2016. Decrease in 2017	Increase in 2016. Increase 2017.	2013-2015 lower. 2016-2017 higher.	Tukey's suggests one increasing and one decreasing step. Contrast(p) suggests two increasing steps. Contrast(a) suggests two groups.
PENG1	Decrease	-	-	-	
PORT1	Decrease	-	-	-	
PORT3	Decrease	-	-	-	
SIXM1	-	Variable. No pattern.	Decrease in 2015. No change to 2017.	2014 higher. 2015 lower.	Good agreement
WOLF3	-	Decrease in 2014. Decrease in 2015. Increase in 2016. No change to 2017.	Decrease in 2014 and 2015. Increase in 2016 and 2017.	2013 higher. 2014-2015 lower. 2016-2017 higher	Tukey's suggests two decreasing steps followed one increasing step. Contrast(p) suggests two decreasing steps followed by two increasing steps. Contrast(a) suggests three groups.

5 Future Monitoring

The 2018 monitoring program will repeat sampling of all reaches included in the 2013 – 2015 full site level evaluation. Every reach and site will be sampled where possible after considerations of safety and access in 2018; 119 reaches will be sampled instead of the 85 visited in 2016 and 2017 (Table 9). The purpose of returning to every reach and site in 2018 is to assess how accurately the indicator reach represents *CI* over the full segment.

Table 9. Recommended sampling sites for the 2018 Sampling Program.

Segment Name	Indicator Reach sampled in 2017 for each segment	Reaches to be sampled in 2018 for each segment	Mean 2017 CI	Number of sites per reach to be sampled in 2017	Number of sites per reach to be sampled in 2018
ALEX_A	ALEX3	ALEX3	0.38	3	3
ANDY_A	ANDY1	ANDY1	0.00	3	3
AQUE_A	AQUE1	AQUE1	0.00	1	1
		AQUE2	-	0	2
		AQUE3	-	0	3
BALM_A	BALM1	BALM1	0.00	1	1
BODI_A	BODI1	BODI1	0.23	1	3
BODI_B	BODI3	BODI3	2.09	3	3
CATA_A	CATA1	CATA1	3.00	1	1
		CATA3	-	0	1
CHAU_A	CHAU1	CHAU1	0.12	3	3
CLOW_A	CLOW1	CLOW1	0.21	1	1
CORB_A	CORB1	CORB1	2.74	3	3
		CORB2	-	0	3
COUT_A	COUT1	COUT1	0.29	1	1
CSEE_A	CSEE1	CSEE1	-	Removed from sampling plan	Removed from sampling plan
DRYE_A	DRYE3	DRYE1	-	0	1
		DRYE3	2.85	3	3
		DRYE4	-	0	1
DRYL_A	DRYL1	DRYL1	0.02	3	3
DRYL_B	DRYL2	DRYL2	0.00	3	3
DRYL_C	DRYL3	DRYL3	0.00	3	3
DRYL_D	DRYL4	DRYL4	0.00	3	3
ELKR_B	ELKR12	ELKR11	-	0	3
		ELKR12	0.00	3	3
ELKR_D	ELKR15	ELKR15	0.00	3	3
ELKR_A	ELKR8	ELKR8	0.01	3	3
ELKR_C	ELKR9	ELKR9	0.00	3	3
		ELKR10	-	0	3
EPOU_A	EPOU1	EPOU1	0.25	1	1
ERIC_A	ERIC1	ERIC1	2.67	1	2
		ERIC2	-	0	1
		ERIC3	-	0	1
		ERIC4	-	0	3

Segment Name	Indicator Reach sampled in 2017 for each segment	Reaches to be sampled in 2018 for each segment	Mean 2017 CI	Number of sites per reach to be sampled in 2017	Number of sites per reach to be sampled in 2018
FELT_A	FELT1	FELT1	0.00	3	3
FENN_A	FENN1	FENN1	0.00	3	3
FORD_G	FORD12	FORD12	0.11	3	3
FORD_A	FORD1	FORD1	0.44	3	3
FORD_B	FORD2	FORD2	0.10	3	3
		FORD3	-	0	3
FORD_C	FORD4, FORD5	FORD4	0.84	3	3
		FORD5	0.73	3	3
FORD_D	FORD6	FORD6	0.68	5	3
FORD_E	FORD7	FORD7	0.71	3	3
		FORD 8	-	0	3
FORD_F	FORD9	FORD9	0.32	6	3
		FORD10	-	0	3
		FORD11	-	0	3
FPON_A	FPON1	FPON1	0.20	1	3
GARD_A	GARD1	GARD1	0.60	3	3
GATE_A	GATE2	GATE2	1.98	3	3
GODD_A	GODD1	GODD1	0.13	1	1
GODD_B	GODD3	GODD3	2.64	6	3
GRAC_A	GRAC1	GRAC1	0.06	3	3
		GRAC2	-	0	3
		GRAC3	-	0	3
GRAS_A	GRAS1	GRAS1	0.29	3	3
GRAV_A	GRAV1	GRAV1	0.24	3	3
		GRAV2	-	0	3
GRAV_B	GRAV3	GRAV3	0.00	3	3
GREE_A	GREE1	GREE1	1.07	3	3
GREE_B	GREE3	GREE3	2.55	3	3
GREE_C	GREE4	GREE4	2.68	3	3
HARM_A	HARM1	HARM1	0.61	3	3
HARM_B	HARM3	HARM3	0.03	3	3
		HARM4	-	0	3
		HARM5	-	0	3
HENR_A	HENR1	HENR1	0.04	3	3
		HENR2	-	0	3
		HENR3	-	0	3
KILM_A	KILM1	KILM1	2.77	5	3
LEAS_A	LEAS2	LEAS2	2.76	3	3
LIND_A	LIND1	LIND1	0.15	3	3
LINE_A	LINE1	LINE1	0.00	3	3
		LINE2	-	0	3
		LINE3	-	0	3
LINE_B	LINE4	LINE4	0.66	3	3
LINE_C	LINE7	LINE7	0.00	3	3
LMOU_A	LMOU1	LMOU1	0.18	2	2
		LMOU3	-	0	3
		LMOU4	-	0	3

Segment Name	Indicator Reach sampled in 2017 for each segment	Reaches to be sampled in 2018 for each segment	Mean 2017 CI	Number of sites per reach to be sampled in 2017	Number of sites per reach to be sampled in 2018
MICH_A	MICH1	MICH1	0.00	3	3
		MICH2	0.08	3	3
MICH_B	MICH4	MICH3	-	0	3
		MICH4	0.01	3	3
MICH_C	MICH5	MICH5	0.01	3	3
MICK_A	MICK1	MICK1	1.25	3	3
		MICK2	-	0	3
MILL_A	MILL1 & MILL2	MILL1	0.36	1	1
		MILL2	1.06	5	6
NTHO_A	NTHO1	NTHO1	1.78	6	6
NWOL_A	NWOL1	NWOL1	2.59	1	1
OTTO_A	OTTO1	OTTO1	0.14	1	1
		OTTO3	-	0	3
PENG_A	PENG1	PENG1	0.00	1	2
PORT_A	PORT1	PORT1	0.74	1	1
PORT_B	PORT3	PORT3	1.62	6	6
QUAL_A	QUAL1	QUAL1	0.00	1	1
SAWM_A	SAWM1	SAWM1	0.00	1	2
SAWM_B	SAWM2	SAWM2	0.00	2	2
SITE_A	SITE18	SITE18	3.00	1	1
SIXM_A	SIXM1	SIXM1	0.95	3	3
SLIN_A	SLIN2	SLIN2	0.00	3	3
SPIT_A	SPIT1	SPIT1	2.49	1	1
SPIT_B	SPIT2	SPIT2	-	Removed from sampling plan	Removed from sampling plan
SPOU_A	SPOU1	SPOU1	2.60	1	1
SPRI_A	SPRI1	SPRI1	0.13	1	1
SPSE_A	SPSE1	SPSE1	-	Removed from sampling plan	Removed from sampling plan
STR02_A	STR02	STR02	0.68	3	3
STR14_A	STR14	STR14	0.00	3	3
SWIF_A	SWIF1	SWIF1	2.45	1	1
		SWIF2	-	0	3
SWOL_A	SWOL1	SWOL1	2.05	4	4
THOM_A	THOM2	THOM1	-	Removed from sampling plan	Removed from sampling plan
		THOM2	0.83	3	3
		THOM3	-	0	3
THRE_A	THRE1	THRE1	0.00	2	2
USOS_A	USOS1	USOS1	0.00	2	2
WILN_A	WILN2	WILN2	0.00	2	2
WILS_A	WILS1	WILS1	0.00	2	2
WOL1_A	WOL1	WOL1	0.00	2	2
WOLF_A	WOLF2	WOLF2	-	0	1
WOLF_B	WOLF3	WOLF3	2.80	6	3

* Field logistics such as stream length preclude sampling at more sites.

6 Literature Cited

Berdusco, J. 2009. Teck Coal Ltd. Mine Site Calcite Deposition Mapping Project. Consultant report prepared for Teck Coal Ltd. Prepared by Interior Reforestation Co. Ltd., Cranbrook, BC.

Hipel, K.W. and McLeod, A.I., (2005), Time Series Modelling of Water Resources and Environmental Systems. Electronic reprint of our book orginally published in 1994. http://www.stats.uwo. ca/faculty/aim/1994Book/.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics 6, 65–70.

Lenth, R V (2016). Least-Squares Means: The R Package lsmeans. Journal of Statistical Software, 69(1), 1-33

Pohlert, T (2017). trend: Non-Parametric Trend Tests and Change-Point Detection. R package version 1.0.1. https://CRAN.R-project.org/package=trend

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Robinson, M.D. and K. Atherton. 2016. Teck Coal Ltd – 2016-2018 Calcite Monitoring Program. Prepared by Lotic Environmental Ltd. and Teck Coal Ltd. 10 pp + appendices.

Robinson, M.D. and R.J. MacDonald. 2015. Teck Coal Ltd 2013 Calcite Monitoring Program – Elk Valley operations summary report. Prepared by Lotic Environmental Ltd. 14 pp + appendices.

Robinson, M.D. 2013. Teck Coal Ltd - Calcite Monitoring Plan Field Manual. Prepared by Lotic Environmental Ltd. 11 pp.

Smithson, J. and M. D. Robinson. 2017. Teck Coal Ltd – Elk Valley 2017 Calcite Monitoring Program Annual Report and Program Assessment. Prepared for Teck Coal Ltd. by Lotic Environmental Ltd. 26 pp + appendices.

Teck. 2014. Elk Valley Water Quality Plan. Teck Coal Limited. 290 pp.

Wolman, MG. 1954. A Method of Sampling Coarse River-Bed Material. Transactions of the American Geophysical Union. 35(6):951-956.

Personal communications

Atherton, K. 2017. Teck Coal. Email Conversation on December 6, 2017.

7 Appendices

Appendix 1. Summary of reach-level results by program year

Stream name	Reach Site Code	Site type	Block type	2013 CI	2014 CI	2015 CI	2016 CI	2017 CI	Mann-Kendall p-value (sig = 0.10)
Alexander	ALEX3	Reference	Reference	0.48	0.38	0.40	0.46	0.38	0.613
Andy Good	ANDY1	Reference	Reference	0.00	0.00	0.00	0.00	0.00	n/a
Aqueduct	AQUE1	Exposed	Historical	0.00	0.00	0.00	0.00	0.00	n/a
Balmer	BALM1	Exposed	Historical	0.00	0.00	0.00	0.00	0.00	n/a
Bodie	BODI1	Exposed	Historical	0.00	0.00	0.00	0.79	0.23	0.267
Bodie	BODI3	Exposed	Historical	1.16	2.47	N/A	1.77	2.09	0.734
Cataract	CATA1	Exposed	Historical	3.00	3.00	3.00	3.00	3.00	n/a
Chauncey	CHAU1	Reference	Reference	0.00	0.00	0.00	0.17	0.12	0.267
Clode Pond Outlet	COUT1	Exposed	Historical	0.00	1.01	1.03	1.21	0.29	0.462
Clode West Infiltration	CLOW1	Exposed	Historical	N/A	0.18	0.00	0.50	0.21	1.00
Corbin	CORB1	Exposed	Historical	1.95	1.71	2.62	2.21	2.74	0.220
Dry (EVO)	DRYE3	Exposed	Historical	2.20	2.40	2.48	2.51	2.85	0.086
Dry (LCO)	DRYL1	Proposed	Recent	0.00	0.00	0.00	0.00	0.02	0.289
Dry (LCO)	DRYL2	Proposed	Recent	0.00	0.00	0.00	0.00	0.00	n/a
Dry (LCO)	DRYL3	Proposed	Recent	0.00	0.00	0.00	0.00	0.00	0.289
Dry (LCO)	DRYL4	Proposed	Recent	0.00	N/A	0.00	0.00	0.00	n/a
Eagle Pond Outlet	EPOU1	Exposed	Historical	1.90	1.31	0.58	0.20	0.25	0.086
Elk	ELKR12	Exposed	Historical	0.00	0.00	0.00	0.00	0.00	n/a
Elk	ELKR15	Reference	Reference	0.00	0.00	0.00	0.00	0.00	n/a
Elk	ELKR8	Exposed	Historical	0.40	0.00	0.00	0.00	0.01	1.00
Elk	ELKR9	Exposed	Historical	0.00	0.00	0.00	0.00	0.00	n/a
Erickson	ERIC1	Exposed	Historical	2.29	2.59	2.77	2.36	2.67	0.613
Feltham	FELT1	Exposed	Historical	0.00	0.00	0.00	0.00	0.00	n/a
Fennelon	FENN1	Exposed	Historical	0.00	0.00	0.00	0.00	0.00	n/a
Fish Pond	FPON1	Exposed	Historical	0.00	0.03	0.00	0.08	0.20	0.129
Fording	FORD1	Exposed	Historical	0.00	0.00	0.00	0.37	0.44	0.096
Fording	FORD12	Reference	Reference	0.00	0.00	0.00	0.08	0.11	0.096
Fording	FORD2	Exposed	Historical	0.00	0.00	0.00	0.00	0.10	0.289
Fording	FORD4	Exposed	Historical	N/A	0.05	0.66	0.60	0.84	0.308
Fording	FORD5	Exposed	Historical	0.32	0.35	0.53	0.58	0.73	0.086
Fording	FORD6	Exposed	Historical	0.74	0.43	1.53	0.64	0.68	0.462
Fording	FORD7	Exposed	Historical	0.43	0.97	0.55	0.63	0.71	0.462
Fording	FORD9	Exposed	Historical	0.00	0.00	0.00	0.00	0.32	0.289
Gardine	GARD1	Exposed	Historical	0.29	0.70	0.32	0.14	0.60	1.00
Gate	GATE2	Exposed	Historical	0.15	0.00	0.74	1.47	1.98	0.086
Goddard	GODD1	Exposed	Historical	0.00	0.00	0.00	0.22	0.13	0.267
Goddard	GODD3	Exposed	Historical	0.00	1.90	1.97	2.22	2.64	0.027
Grace	GRAC1	Reference	Reference	0.31	0.20	0.05	0.09	0.06	0.130
Grassy	GRAS1	Exposed	Historical	0.00	0.09	0.00	0.04	0.29	0.312
Grave	GRAV1	Exposed	Historical	0.54	0.72	0.02	0.14	0.24	0.807

Grave	GRAV3	Reference	Reference	0.00	0.00	0.00	0.00	0.00	n/a
Greenhills	GREE1	Exposed	Historical	0.35	1.06	0.45	0.86	1.07	0.221
Greenhills	GREE3	Exposed	Historical	1.30	2.22	2.46	2.18	2.55	0.221
Greenhills	GREE4	Exposed	Historical	1.62	2.78	2.80	2.61	2.68	0.806
Harmer	HARM1	Exposed	Historical	0.58	1.08	0.07	0.64	0.61	1.00
Harmer	HARM3	Exposed	Historical	0.15	0.28	0.01	0.12	0.03	0.462
Henretta	HENR1	Exposed	Historical	0.00	0.00	0.00	0.00	0.04	0.289
Kilmamock	KILM1	Exposed	Historical	2.16	1.64	1.97	2.59	2.77	0.086
Lake Mountain	LMOU1	Exposed	Historical	0.00	0.33	0.00	0.15	0.18	0.613
Leask	LEAS2	Exposed	Historical	0.13	1.60	0.24	1.82	2.76	0.086
Lindsay	LIND1	Exposed	Historical	0.19	0.26	0.19	0.19	0.15	0.448
Line	LINE1	Exposed	Treated	0.27	0.00	0.00	0.03	0.00	0.579
Line	LINE4	Exposed	Treated	0.40	0.27	0.68	0.65	0.66	0.462
Line	LINE7	Reference	Reference	0.00	0.00	0.00	0.00	0.00	n/a
Michel	MICH1	Exposed	Historical	0.31	0.00	0.00	0.00	0.00	0.289
Michel	MICH2	Exposed	Historical	0.05	0.05	0.00	N/A	0.08	n/a
Michel	MICH4	Exposed	Historical	0.00	0.00	0.00	0.00	0.01	0.289
Michel	MICH5	Reference	Reference	0.00	0.00	0.00	0.00	0.01	0.289
Mickelson	MICK1	Exposed	Historical	0.01	0.00	0.00	2.18	1.25	0.613
Milligan	MILL1	Exposed	Historical	0.00	0.00	0.00	N/A	0.36	n/a
Milligan	MILL2	Exposed	Historical	0.00	0.00	0.00	1.07	1.06	n/a
North Thompson	NTHO1	Exposed	Historical	1.24	2.39	1.18	1.54	1.78	0.462
North Wolfram	NWOL1	Exposed	Historical	0.70	1.33	0.21	0.14	2.59	0.807
Otto	OTTO1	Exposed	Historical	0.30	0.22	0.10	0.23	0.14	0.462
Pengally	PENG1	Exposed	Historical	0.09	0.02	0.02	0.00	0.00	0.068
Porter	PORT1	Exposed	Historical	0.92	0.84	0.85	0.75	0.74	0.086
Porter	PORT3	Exposed	Historical	2.78	1.94	1.94	1.46	1.62	0.086
Qualteri	QUAL1	Exposed	Historical	0.00	0.00	0.00	0.00	0.00	n/a
Sawmill	SAWM1	Exposed	Historical	0.00	0.00	0.00	0.00	0.00	n/a
Sawmill	SAWM2	Exposed	Historical	0.38	0.54	0.62	0.00	0.00	n/a
SITE18	SITE18	Exposed	Historical	N/A	N/A	N/A	N/A	3.00	n/a
Six Mile	SIXM1	Exposed	Historical	0.80	1.19	0.49	0.65	0.95	1.00
Smith Pond Outlet	SPOU1	Exposed	Historical	2.61	2.24	2.24	3.00	2.60	1.00
South Line	SLINE2	Reference	Reference	0.00	0.00	0.00	0.00	0.00	0.371
South Pit	SPIT1	Exposed	Historical	0.00	0.00	1.14	1.59	2.49	n/a
South Wolfram Creek	SWOL1	Exposed	Historical	1.97	1.97	0.28	1.86	2.05	1.00
Spring	SPRI1	Exposed	Historical	0.20	0.11	0.11	0.12	0.13	1.00
Stream 02	STR02	Exposed	Historical	N/A	N/A	N/A	N/A	0.68	n/a
Stream 14	STR14	Exposed	Historical	N/A	N/A	N/A	N/A	0.00	n/a
Swift	SWIF1	Exposed	Historical	2.58	2.18	2.39	2.43	2.45	0.807
Thompson	THOM2	Exposed	Historical	0.08	0.00	0.01	N/A	0.83	n/a
Thresher	THRE1	Exposed	Historical	0.00	0.00	0.00	0.00	0.00	n/a
Unnamed South of Sawmill	USOS1	Exposed	Historical	0.00	0.00	0.00	0.00	0.00	n/a
Willow North	WILN2	Exposed	Recent	N/A	N/A	0.00	0.00	0.00	n/a
Willow South	WILS1	Exposed	Recent	N/A	N/A	0.00	0.00	0.00	n/a
Wolf	WOL1	Reference	Future	N/A	N/A	0.00	0.00	0.00	n/a
Wolfram	WOLF3	Exposed	Historical	2.93	2.07	1.60	2.61	2.80	1.00

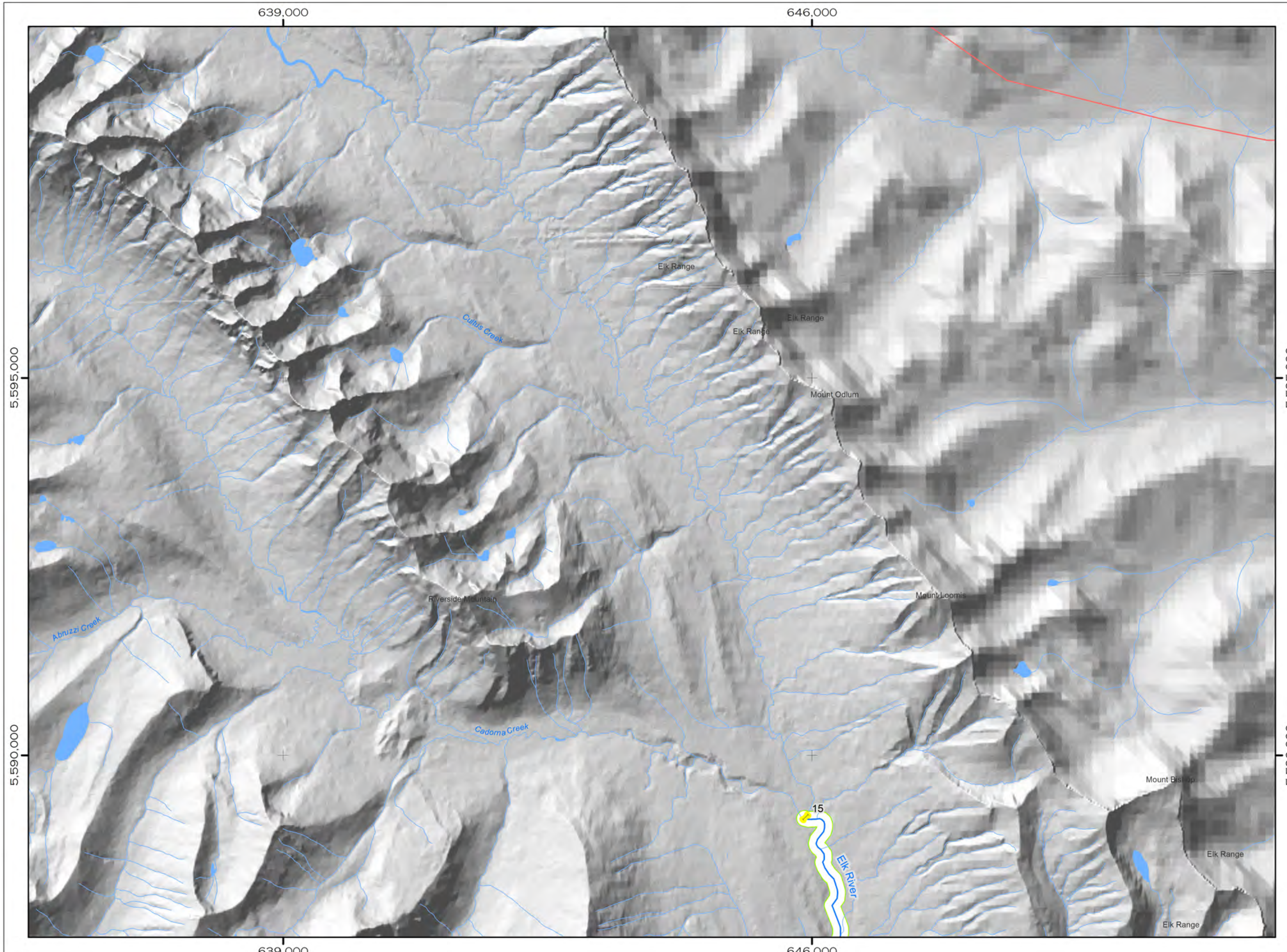
Highlighted rows are the sites with significant changes ($\alpha = 0.10$) in *CI* from linear regression in 2017

Appendix 2. 2017 Elk Valley calcite monitoring results by stream reach

Type (exposed or reference)	Stream	Reach	Mean CI_p Score (0-1)	Mean CI_c Score (0-2)	CI (C_p+C_c)
Reference	Alexander	ALEX3	0.37	0.01	0.38
Reference	Andy Good	ANDY1	0.00	0.00	0.00
Exposed	Aqueduct	AQUE1	0.00	0.00	0.00
Exposed	Balmer	BALM1	0.00	0.00	0.00
Exposed	Bodie	BODI1	0.06	0.01	0.23
Exposed	Bodie	BODI3	0.78	1.31	2.09
Exposed	Cataract	CATA1	1.00	2.00	3.00
Reference	Chauncey	CHAU1	0.08	0.04	0.12
Exposed	Clode Pond Outlet	COUT1	0.24	0.05	0.29
Exposed	Clode West Infiltration	CLOW1	0.21	0.00	0.21
Exposed	Corbin	CORB1	0.99	1.74	2.74
Exposed	Dry (EVO)	DRYE3	1.00	1.85	2.85
Proposed	Dry (LCO)	DRYL1	0.02	0.00	0.02
Proposed	Dry (LCO)	DRYL2	0.00	0.00	0.00
Proposed	Dry (LCO)	DRYL3	0.00	0.00	0.00
Proposed	Dry (LCO)	DRYL4	0.00	0.00	0.00
Exposed	Eagle Pond Outlet	EPOU1	0.21	0.04	0.25
Exposed	Elk	ELKR12	0.00	0.00	0.00
Reference	Elk	ELKR15	0.00	0.00	0.00
Exposed	Elk	ELKR8	0.01	0.00	0.01
Exposed	Elk	ELKR9	0.00	0.00	0.00
Exposed	Erickson	ERIC1	0.94	1.73	2.67
Exposed	Feltham	FELT1	0.00	0.00	0.00
Exposed	Fennelon	FENN1	0.00	0.00	0.00
Exposed	Fish Pond	FPON1	0.20	0.00	0.20
Exposed	Fording	FORD1	0.35	0.09	0.44
Reference	Fording	FORD12	0.11	0.00	0.11
Exposed	Fording	FORD2	0.09	0.00	0.10
Exposed	Fording	FORD4	0.72	0.12	0.84
Exposed	Fording	FORD5	0.73	0.00	0.73
Exposed	Fording	FORD6	0.64	0.05	0.68
Exposed	Fording	FORD7	0.68	0.03	0.71
Exposed	Fording	FORD9	0.23	0.09	0.32
Exposed	Gardine	GARD1	0.31	0.28	0.60
Exposed	Gate	GATE2	0.83	1.15	1.98
Exposed	Goddard	GODD1	0.13	0.00	0.13
Exposed	Goddard	GODD3	0.99	1.65	2.64
Reference	Grace	GRAC1	0.06	0.00	0.06
Exposed	Grassy	GRAS1	0.18	0.11	0.29
Exposed	Grave	GRAV1	0.24	0.00	0.24
Reference	Grave	GRAV3	0.00	0.00	0.00
Exposed	Greenhills	GREE1	0.66	0.42	1.07

Type (exposed or reference)	Stream	Reach	Mean CI_p Score (0-1)	Mean CI_c Score (0-2)	CI (C_p+C_c)
Exposed	Greenhills	GREE3	0.99	1.56	2.55
Exposed	Greenhills	GREE4	1.00	1.68	2.68
Exposed	Harmer	HARM1	0.45	0.16	0.61
Exposed	Harmer	HARM3	0.03	0.00	0.03
Exposed	Henretta	HENR1	0.04	0.00	0.04
Exposed	Kilmarnock	KILM1	0.96	1.81	2.77
Exposed	Lake Mountain	LMOU1	0.18	0.00	0.18
Exposed	Leask	LEAS2	0.99	1.77	2.76
Exposed	Lindsay	LIND1	0.12	0.03	0.15
Exposed	Line	LINE1	0.00	0.00	0.00
Exposed	Line	LINE4	0.66	0.00	0.66
Reference	Line	LINE7	0.00	0.00	0.00
Exposed	Michel	MICH1	0.00	0.00	0.00
Exposed	Michel	MICH2	0.05	0.03	0.08
Exposed	Michel	MICH4	0.01	0.00	0.01
Reference	Michel	MICH5	0.01	0.00	0.01
Exposed	Mickelson	MICK1	0.93	0.32	1.25
Exposed	Milligan	MILL1	0.21	0.15	0.36
Exposed	Milligan	MILL2	0.52	0.54	1.06
Exposed	North Thompson	NTHO1	0.91	0.87	1.78
Exposed	North Wolfram	NWOL1	0.97	1.62	2.59
Exposed	Otto	OTTO1	0.12	0.02	0.14
Exposed	Pengally	PENG1	0.00	0.00	0.00
Exposed	Porter	PORT1	0.74	0.00	0.74
Exposed	Porter	PORT3	0.67	0.95	1.62
Exposed	Qualteri	QUAL1	0.00	0.00	0.00
Exposed	Sawmill	SAWM1	0.00	0.00	0.00
Exposed	Sawmill	SAWM2	0.00	0.00	0.00
Exposed	Site18	SITE	1.00	2.00	3.00
Exposed	Six Mile	SIXM1	0.73	0.22	0.95
Exposed	Smith Pond Outlet	SPOU1	0.94	1.66	2.60
Reference	South Line	SLINE2	0.00	0.00	0.00
Exposed	South Pit	SPIT1	0.90	1.59	2.49
Exposed	South Wolfram Creek	SWOL1	0.99	1.05	2.05
Exposed	Spring	SPRI1	0.12	0.01	0.13
Exposed	Stream 02	STR02	0.24	0.44	0.68
Exposed	Stream 14	STR14	0.00	0.00	0.00
Exposed	Swift	SWIF1	0.98	1.47	2.45
Exposed	Thompson	THOM1	0.69	0.15	0.83
Exposed	Thresher	THRE1	0.00	0.00	0.00
Exposed	Unnamed South of Sawmill	USOS1	0.00	0.00	0.00
Exposed	Willow North	WILN2	0.00	0.00	0.00
Exposed	Willow South	WILS1	0.00	0.00	0.00
Exposed	Wolf	WOL1	0.00	0.00	0.00
Exposed	Wolfram	WOLF3	1.00	1.80	2.80

Appendix 3. Calcite distribution maps



2016 Calcite Monitoring Program

Elk Valley - Map #1

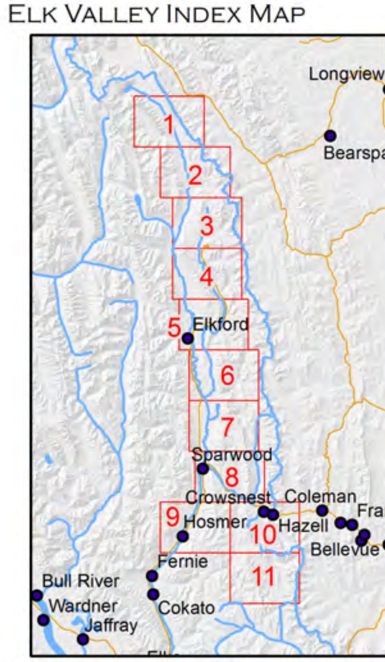
- Reach Break
- Reference Stream
- Proposed Stream
- Exposed Stream
- Stream Segments
- Road - Regional
- Railway
- Teck Coal Operations

Label Examples:

- 1.50 → Current Calcite Index (with neutral trend)
- 1.50 → Current Calcite Index (with increasing trend)
- 1.50 → Current Calcite Index (with decreasing trend)

0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83

Elk Valley Index Map



Client: Teck

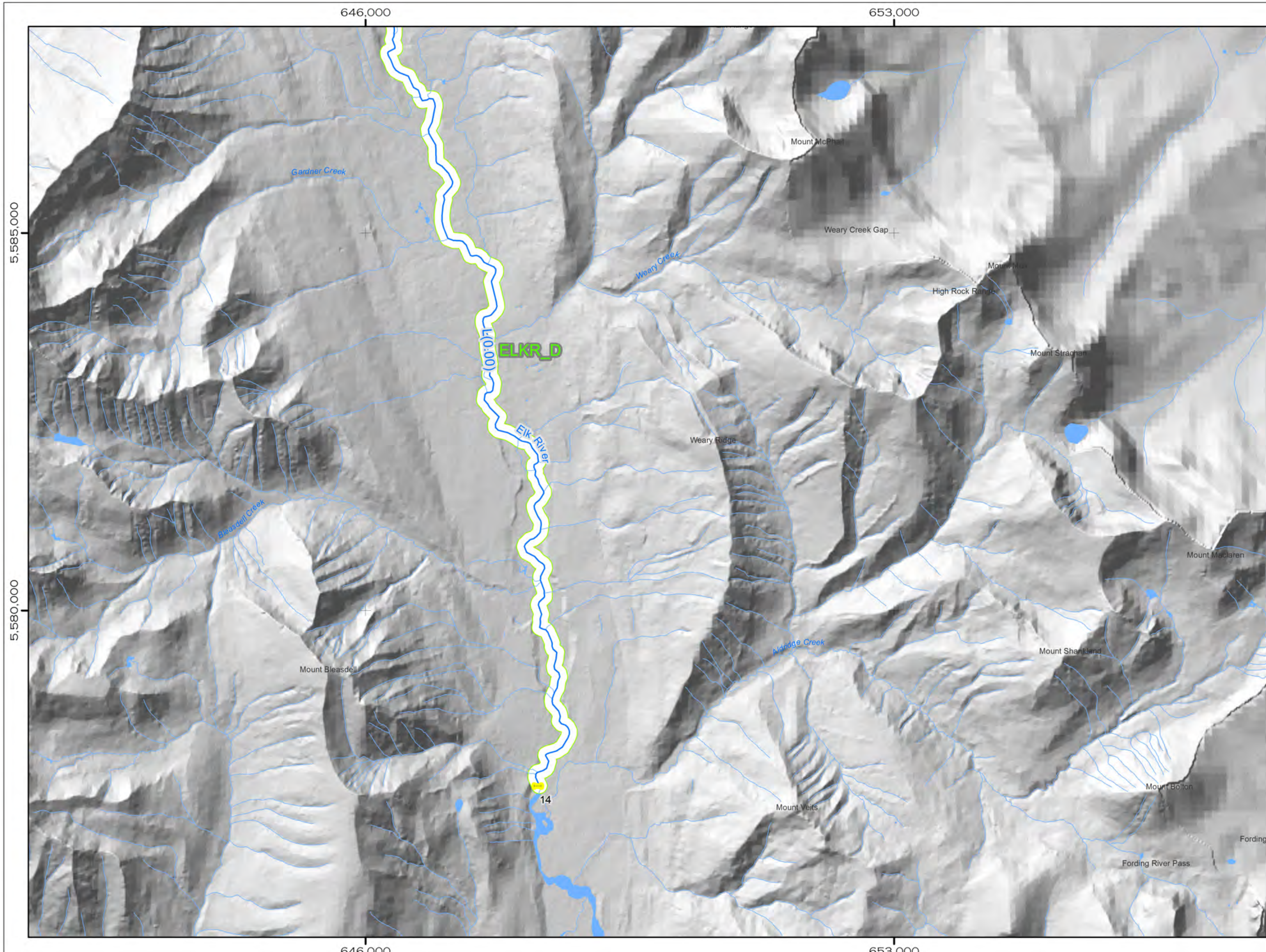
Mapping by: Lotic Environmental

Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE

Date Last Revised: Jan 30, 2017

2016 Calcite Monitoring Program

Elk Valley - Map #2



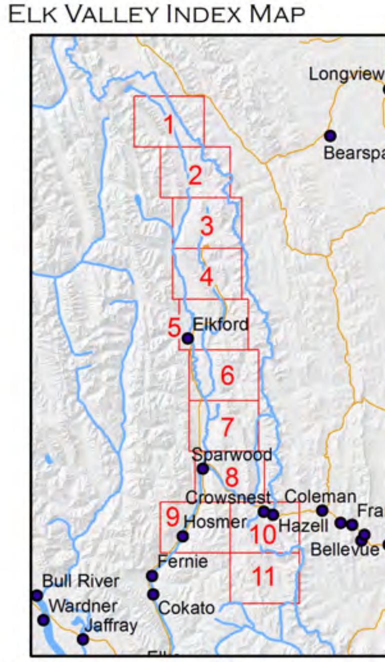
Reach Break
Reference Stream
Proposed Stream
Exposed Stream
Stream Segments
Road - Regional
Railway
Teck Coal Operations

Label Examples:

1.50 → Current calcite index (with neutral trend)
1.50 → Current calcite index (with increasing trend)
1.50 → Current calcite index (with decreasing trend)

0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83

Elk Valley Index Map



Client: Teck

Mapping by: Lotic Environmental

Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE

Date Last Revised: Jan 30, 2017

2016 Calcite Monitoring Program

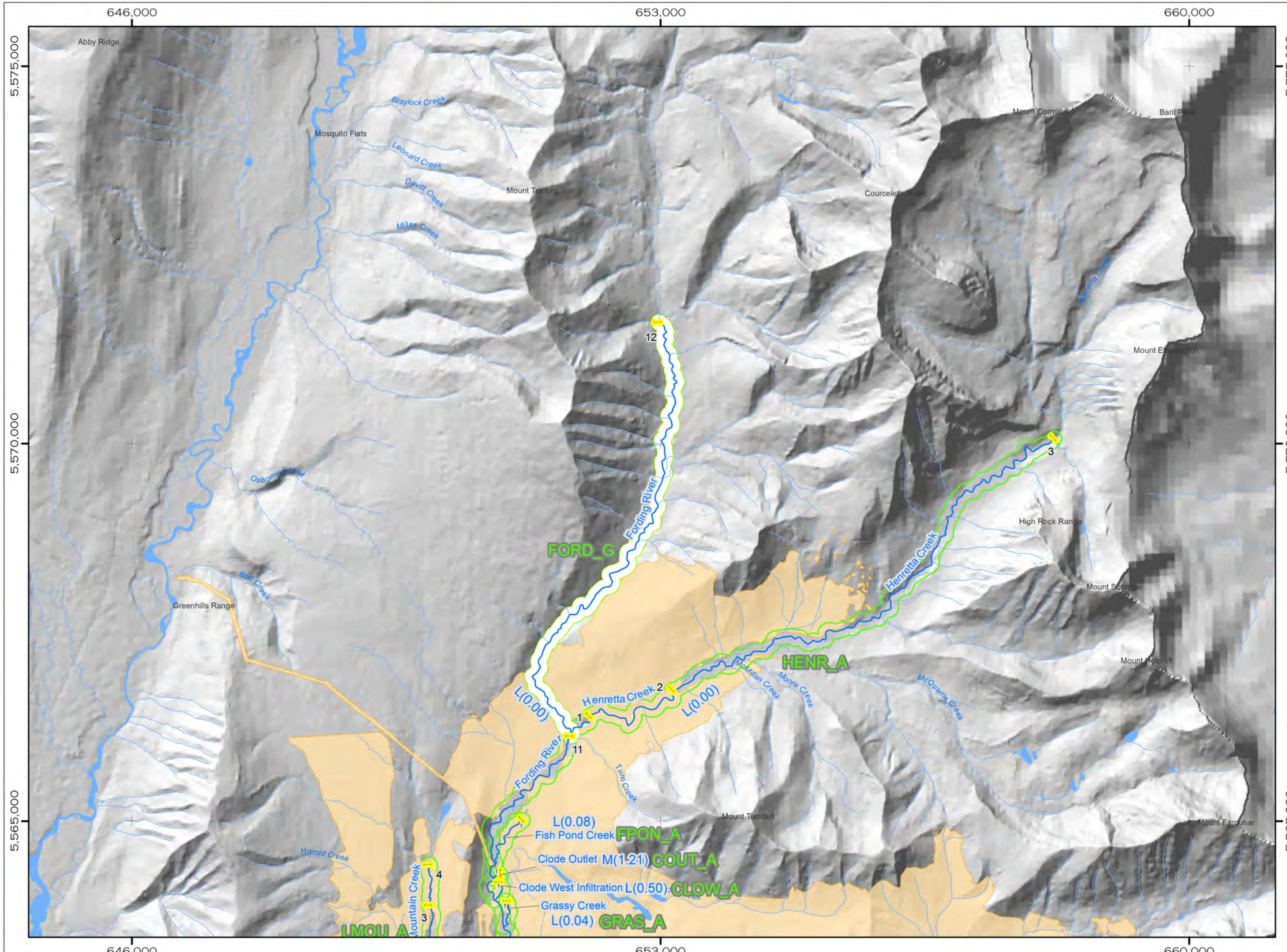
Elk Valley - Map #3

Reach Break
Reference Stream
Proposed Stream
Exposed Stream
Stream Segments
Road - Regional
Railway
Teck Coal Operations

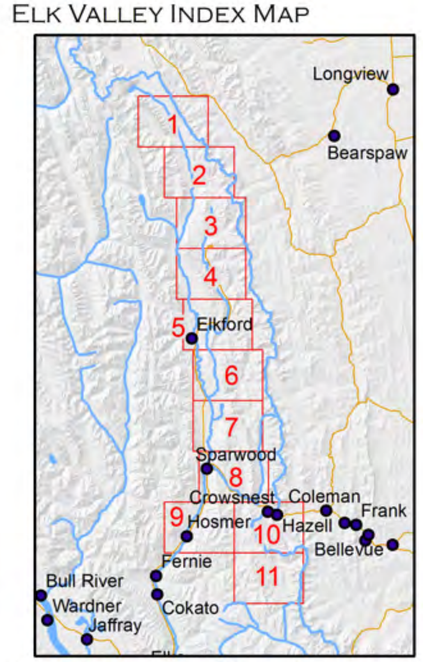
Label Examples:

1.50 → Current calcite index (with neutral trend)
1.50 → Current calcite index (with increasing trend)
1.50 → Current calcite index (with decreasing trend)

0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83



Elk Valley Index Map

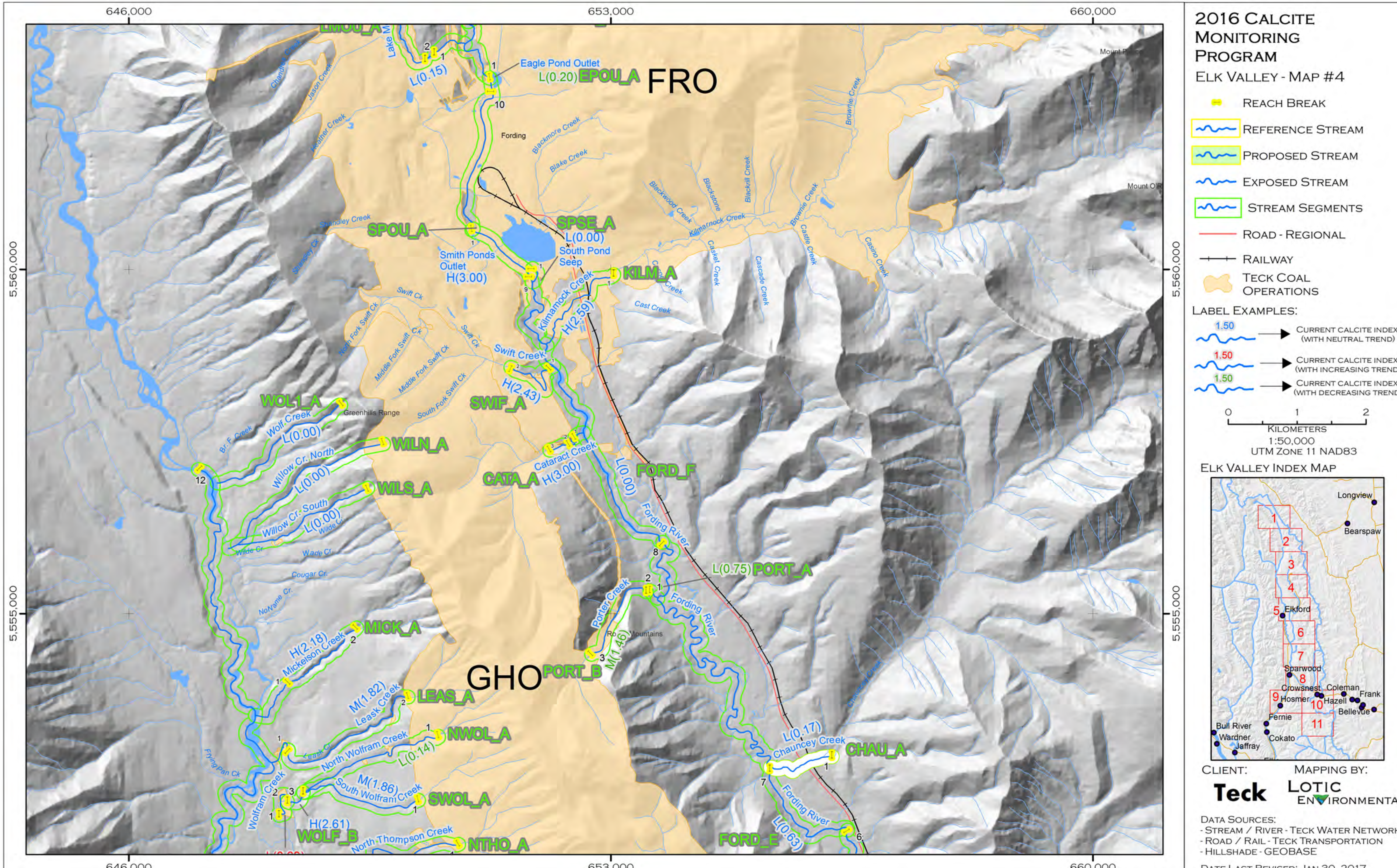


Client: Teck

Mapping by: Lotic Environmental

Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE

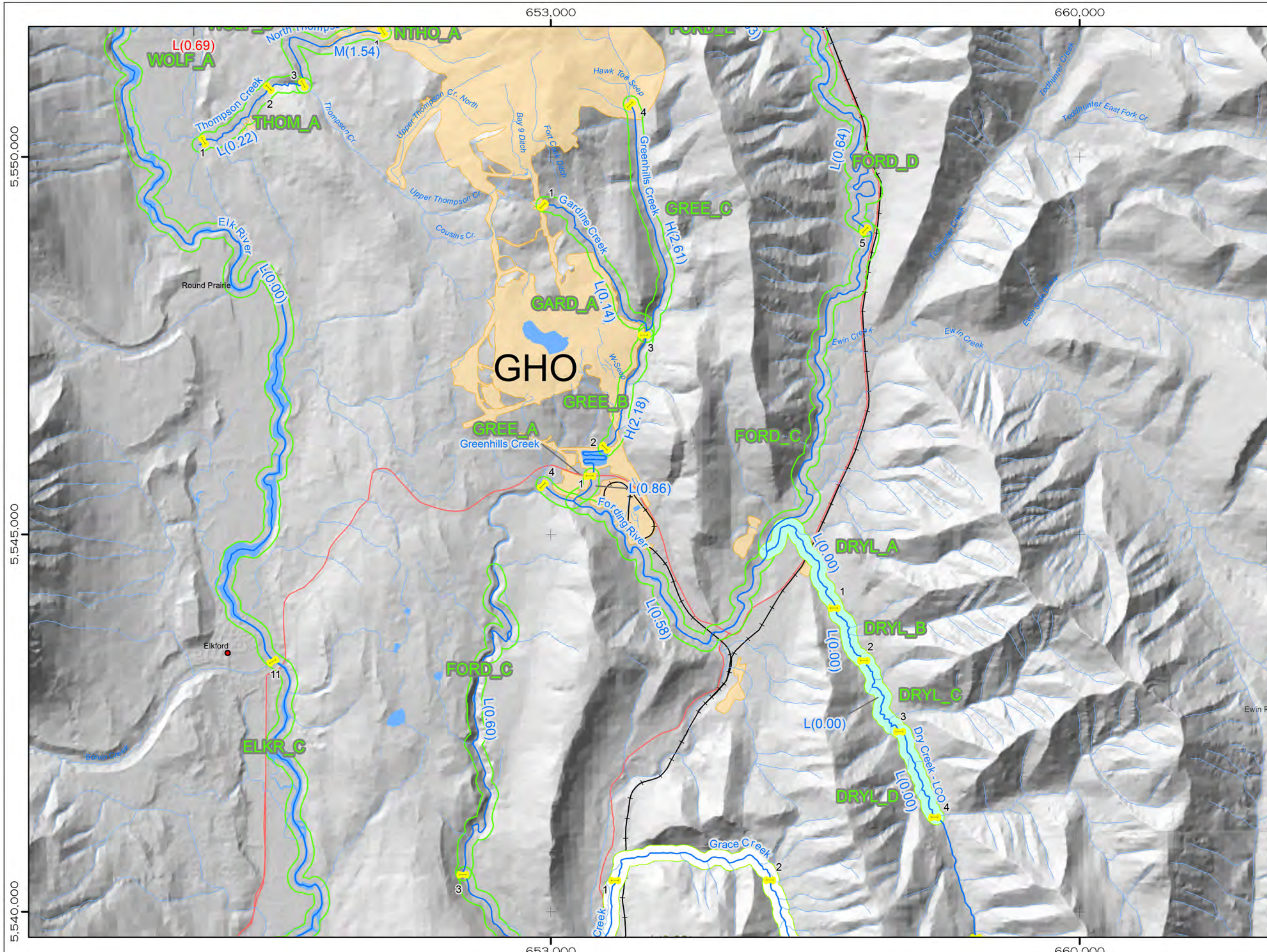
Date Last Revised: Jan 30, 2017



2016 Calcite Monitoring Program
Elk Valley - Map #4
Reach Break
Reference Stream
Proposed Stream
Exposed Stream
Stream Segments
Road - Regional
Railway
Teck Coal Operations
Label Examples:
1.50 Current calcite index (with neutral trend)
1.50 Current calcite index (with increasing trend)
1.50 Current calcite index (with decreasing trend)
0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83
Elk Valley Index Map
Longview
Bearspaw
Elkford
Sparwood
Crowsnest
Coleman
Frank
Hosmer
Hazell
Bellevue
Fernie
Bull River
Wardner
Cokato
Jaffray
Client:
Teck
Mapping by:
Lotic Environmental
Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE
Date Last Revised: Jan 30, 2017
646,000
653,000
660,000
5,560,000
5,555,000
FRO
GHO
Eagle Pond Outlet
L(0.20) EPOU_A
L(0.15)
Fording
SPOU_A
SPSE_A
L(0.00)
South Pond Seep
Smith Ponds Outlet
H(3.00)
KILM_A
Kilmarnock Creek
H(2.59)
Swift Creek
H(2.43)
SWIF_A
WOL1_A
Wolf Creek
L(0.00)
WILN_A
Willow Cr. North
L(0.00)
WILS_A
Willow Cr. South
L(0.00)
CATA_A
Cataract Creek
H(3.00)
FORD_F
L(0.00)
Fording River
L(0.75) PORT_A
Porter Creek
M(1.46)
PORT_B
MICK_A
H(2.18)
Mickelson Creek
LEAS_A
M(1.82)
Leask Creek
NWOL_A
North Wolfram Creek
L(0.14)
SWOL_A
M(1.86)
South Wolfram Creek
H(2.61)
WOLF_B
Wolfram Creek
NTHO_A
North Thompson Creek
CHAU_A
L(0.17)
Chauncey Creek
FORD_E
L(0.63)
Greenhills Range

2016 Calcite Monitoring Program

Elk Valley - Map #5



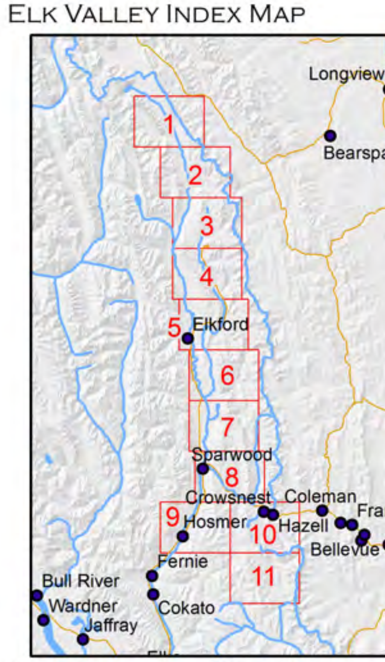
- Reach Break
- Reference Stream
- Proposed Stream
- Exposed Stream
- Stream Segments
- Road - Regional
- Railway
- Teck Coal Operations

Label Examples:

- 1.50 → Current calcite index (with neutral trend)
- 1.50 → Current calcite index (with increasing trend)
- 1.50 → Current calcite index (with decreasing trend)

0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83

Elk Valley Index Map

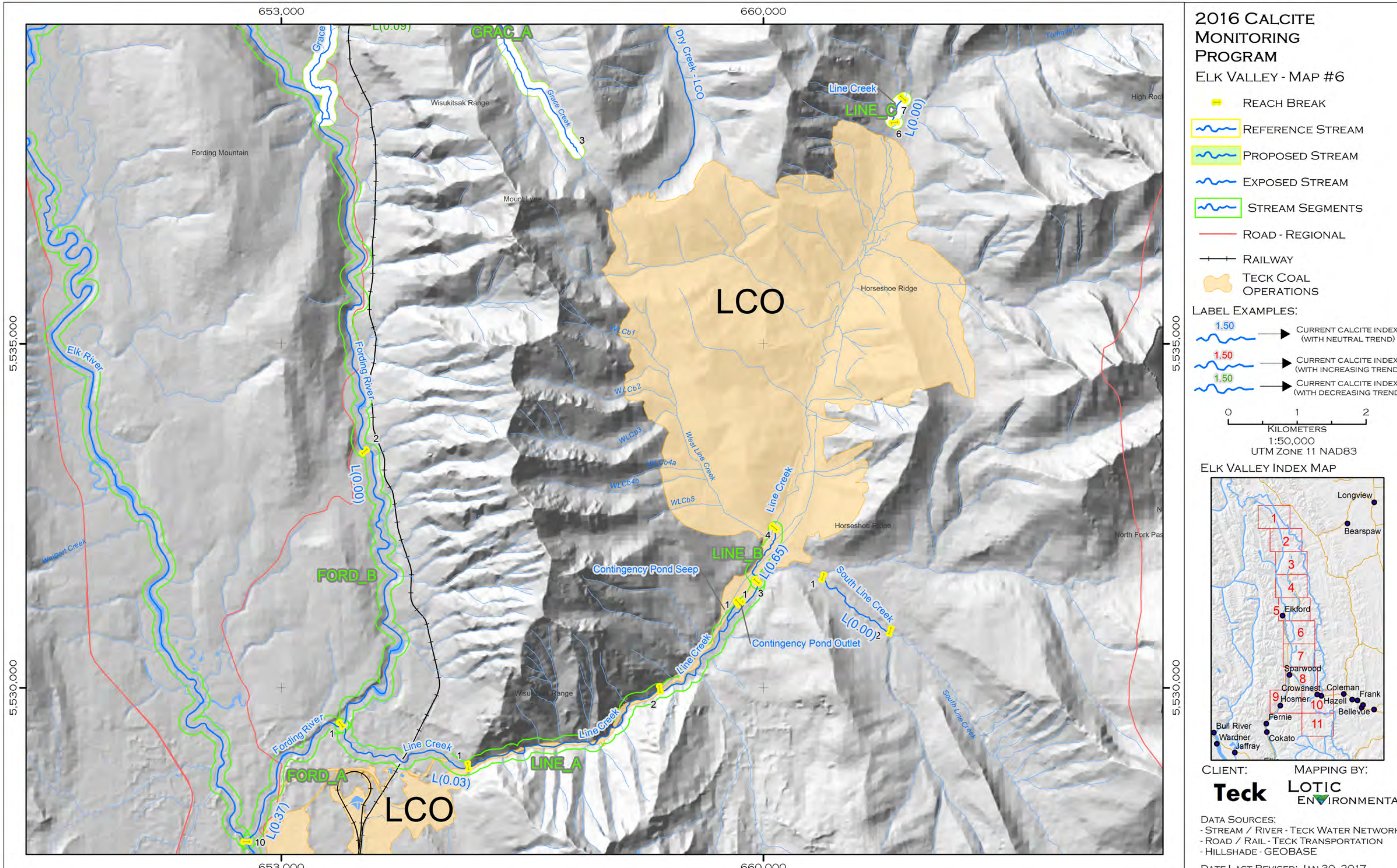


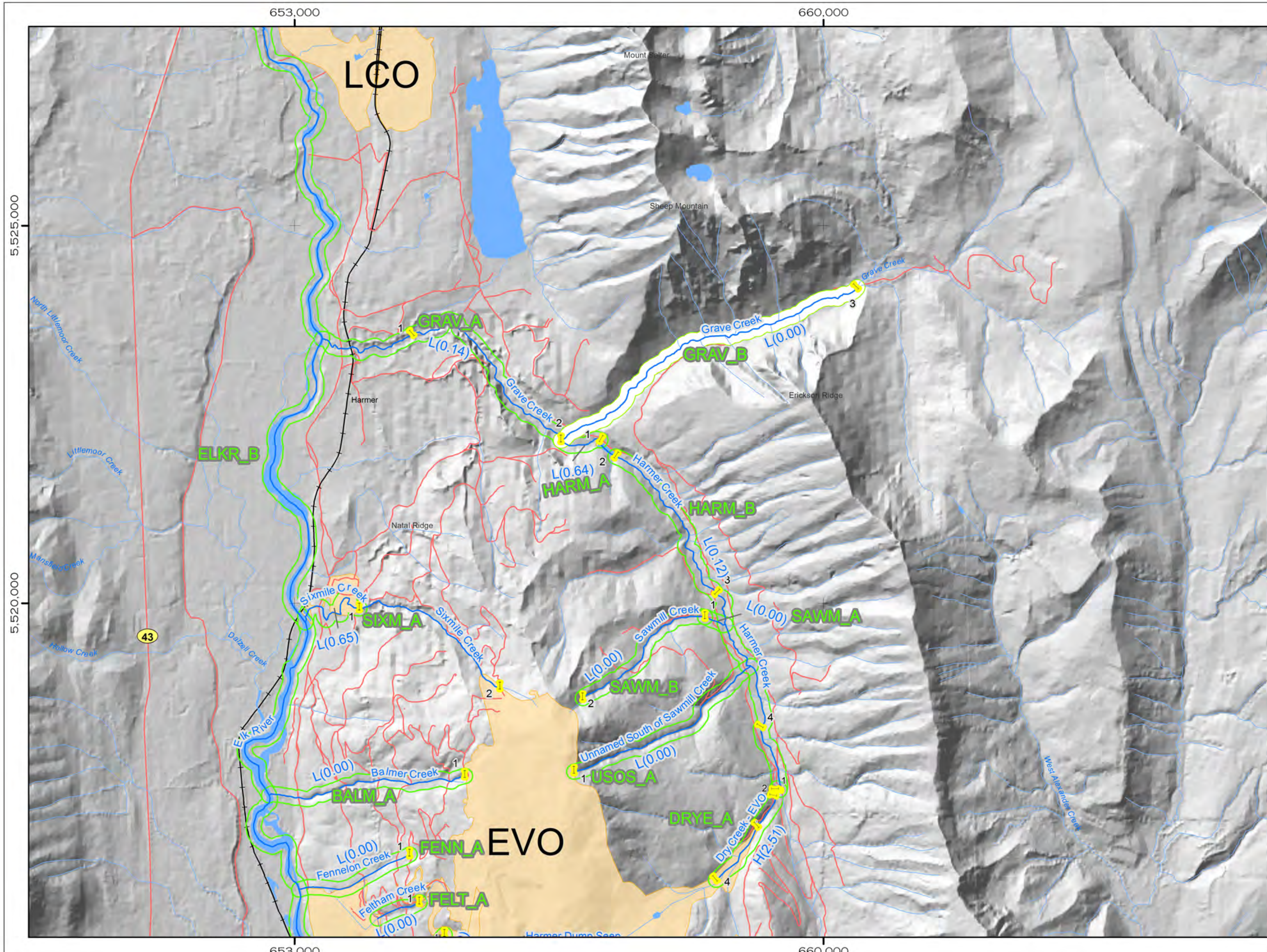
Client: Teck

Mapping by: Lotic Environmental

Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE

Date Last Revised: Jan 30, 2017


2016 Calcite Monitoring Program
Elk Valley - Map #6
Reach Break
Reference Stream
Proposed Stream
Exposed Stream
Stream Segments
Road - Regional
Railway
Teck Coal Operations
Label Examples:
1.50
Current calcite index (with neutral trend)
1.50
Current calcite index (with increasing trend)
1.50
Current calcite index (with decreasing trend)
0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83
Elk Valley Index Map
Longview
Bearspaw
Elkford
Sparwood
Crowsnest
Coleman
Frank
Hosmer
Hazell
Bellevue
Fernie
Bull River
Wardner
Jaffray
Cokato
1 2 3 4 5 6 7 8 9 10 11
Client:
Teck
Mapping by:
Lotic Environmental
Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE
Date Last Revised: Jan 30, 2017
653,000
660,000
5,535,000
5,530,000
LCO
LCO
GRAC_A
FORD_B
FORD_A
LINE_A
LINE_B
LINE_C
L(0.09)
L(0.00)
L(0.00)
L(0.65)
L(0.00)
L(0.03)
L(0.37)
Elk River
Fording River
Grace Creek
Dry Creek - LCO
Line Creek
West Line Creek
South Line Creek
WLCb1
WLCb2
WLCb3
WLCb4a
WLCb4b
WLCb5
Contingency Pond Seep
Contingency Pond Outlet
Wisukitsak Range
Fording Mountain
Mount Lyne
Horseshoe Ridge
North Fork Pass
Weigert Creek



2016 Calcite Monitoring Program

Elk Valley - Map #7

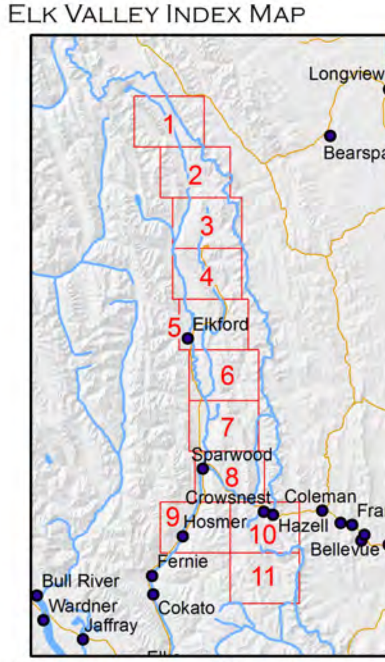
- Reach Break
- Reference Stream
- Proposed Stream
- Exposed Stream
- Stream Segments
- Road - Regional
- Railway
- Teck Coal Operations

Label Examples:

- 1.50 → Current calcite index (with neutral trend)
- 1.50 → Current calcite index (with increasing trend)
- 1.50 → Current calcite index (with decreasing trend)

0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83

Elk Valley Index Map

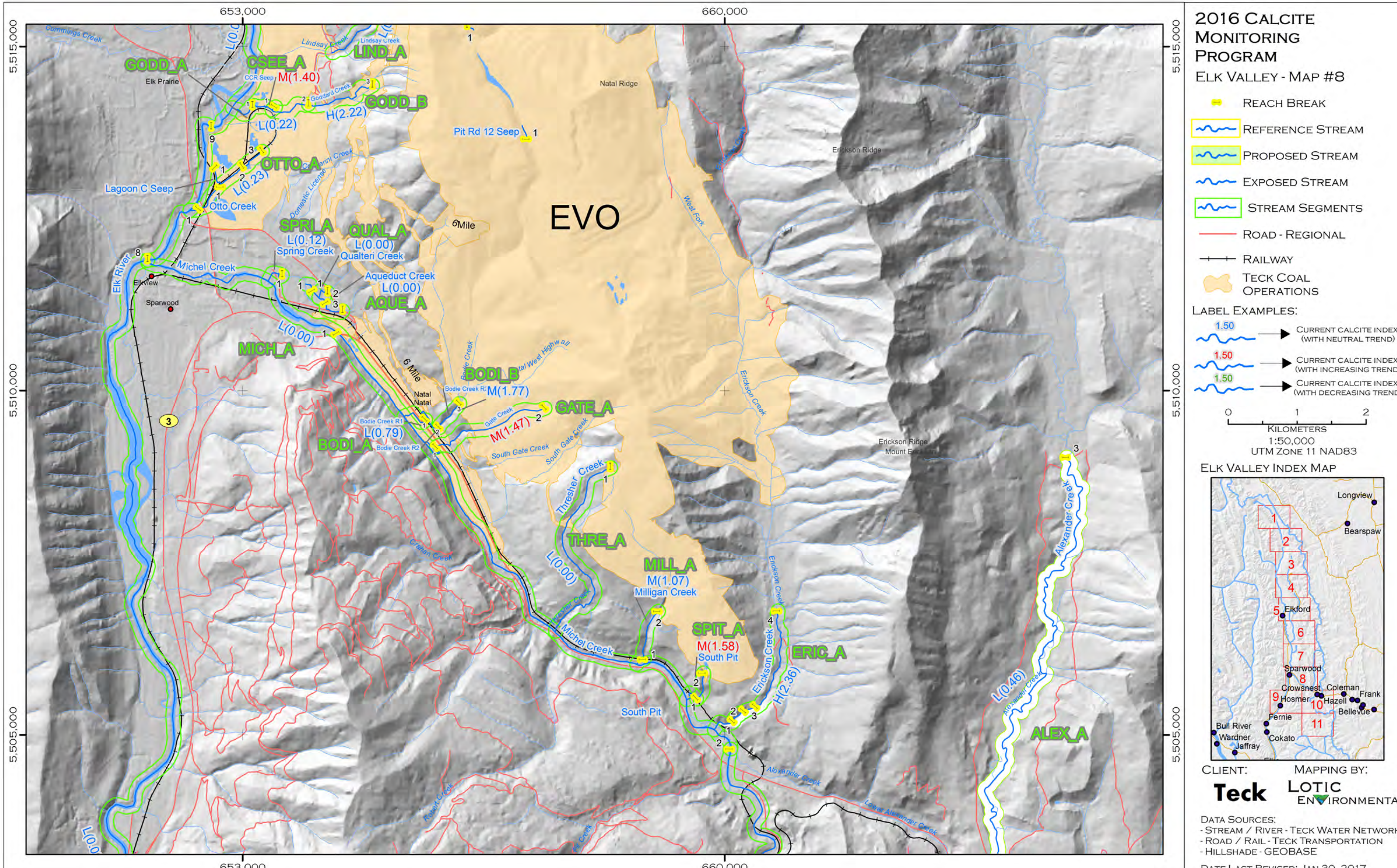


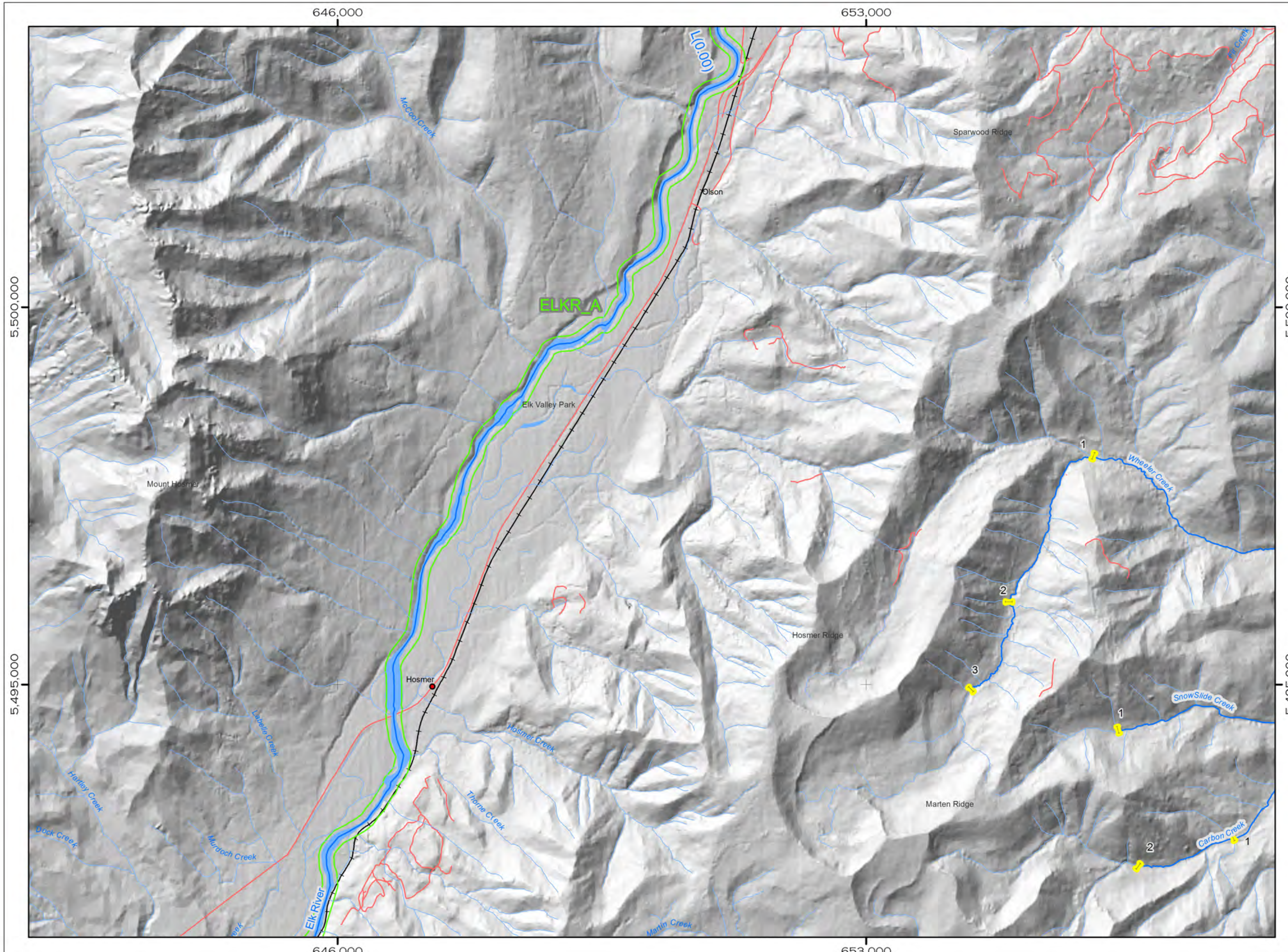
Client: Teck

Mapping by: Lotic Environmental

Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE

Date Last Revised: Jan 30, 2017


2016 Calcite Monitoring Program
Elk Valley - Map #8
Reach Break
Reference Stream
Proposed Stream
Exposed Stream
Stream Segments
Road - Regional
Railway
Teck Coal Operations
Label Examples:
1.50 Current calcite index (with neutral trend)
1.50 Current calcite index (with increasing trend)
1.50 Current calcite index (with decreasing trend)
0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83
Elk Valley Index Map
Longview
Bearspaw
Elkford
Sparwood
Crowsnest
Coleman
Frank
Hosmer
Hazell
Bellevue
Fernie
Bull River
Wardner
Cokato
Jaffray
Client:
Teck
Mapping by:
Lotic Environmental
Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE
Date Last Revised: Jan 30, 2017
653,000
660,000
5,515,000
5,510,000
5,505,000
EVO
GODD_A
CSEE_A
M(1.40)
LIND_A
GODD_B
H(2.22)
L(0.22)
OTTO_A
L(0.23)
Lagoon C Seep
Otto Creek
SPRI_A
L(0.12)
Spring Creek
QUAL_A
L(0.00)
Qualteri Creek
Aqueduct Creek
L(0.00)
AQUE_A
Michel Creek
Elk River
Elkview
Sparwood
L(0.00)
MICH_A
BODI_B
M(1.77)
GATE_A
M(1.47)
BODI_A
L(0.79)
South Gate Creek
Thresher Creek
THRE_A
L(0.00)
MILL_A
M(1.07)
Milligan Creek
SPIT_A
M(1.58)
South Pit
ERIC_A
H(2.36)
Erickson Creek
ALEX_A
L(0.46)
Alexander Creek
Natal Ridge
Pit Rd 12 Seep
Erickson Ridge
6 Mile
Natal
South Pit



2016 Calcite Monitoring Program

Elk Valley - Map #9

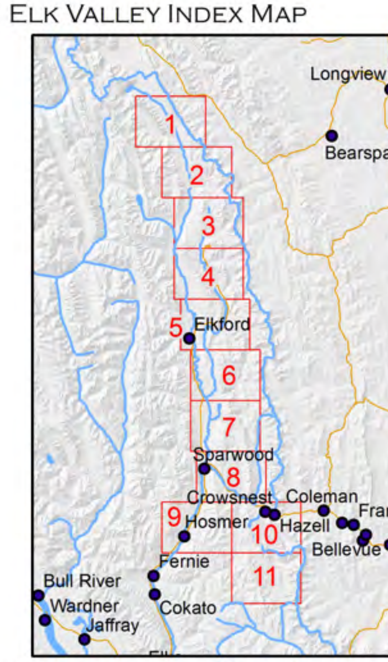
- Reach Break
- Reference Stream
- Proposed Stream
- Exposed Stream
- Stream Segments
- Road - Regional
- Railway
- Teck Coal Operations

Label Examples:

- 1.50 → Current calcite index (with neutral trend)
- 1.50 → Current calcite index (with increasing trend)
- 1.50 → Current calcite index (with decreasing trend)

0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83

Elk Valley Index Map

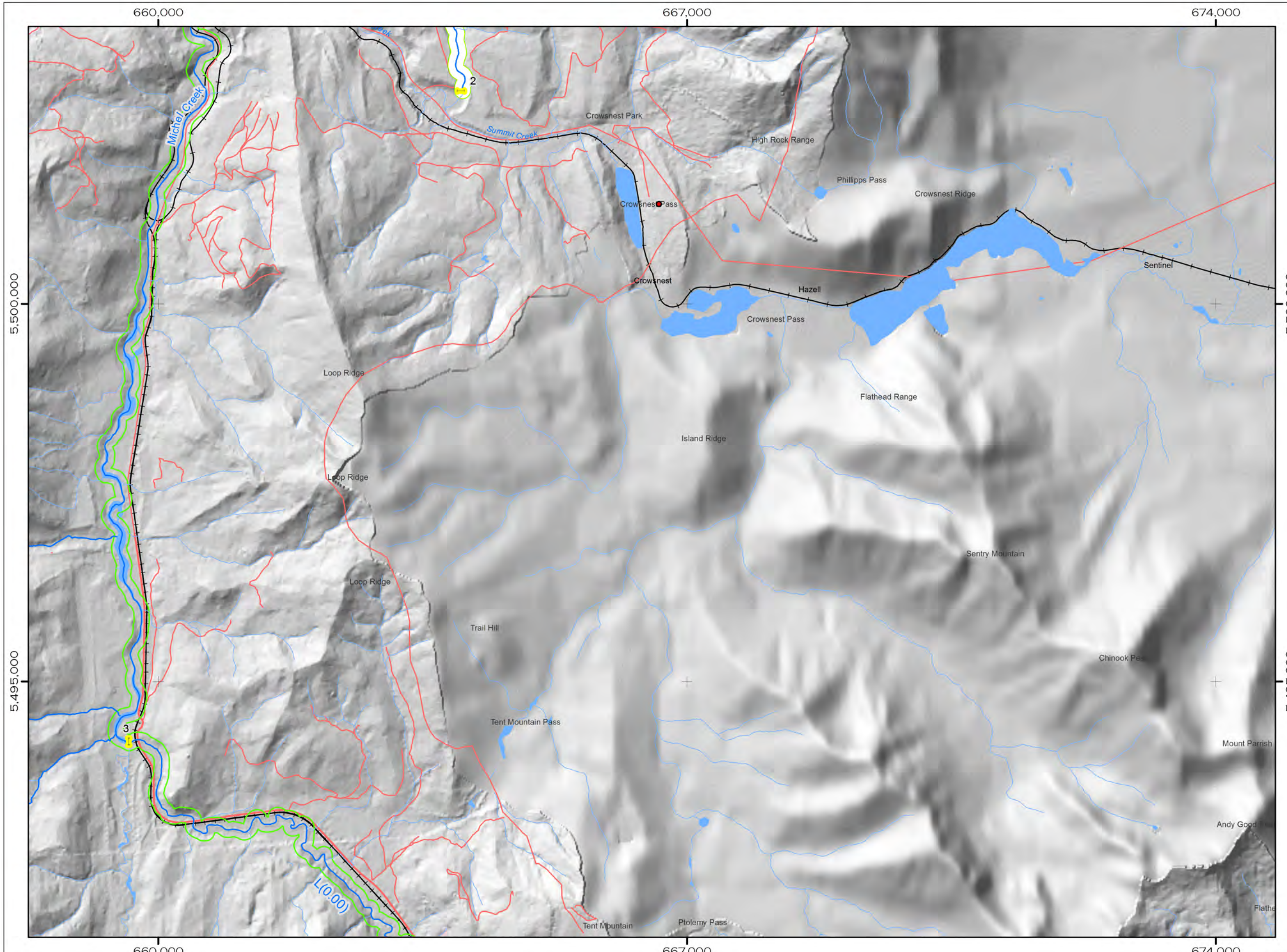


Client: Teck

Mapping by: Lotic Environmental

Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE

Date Last Revised: Jan 30, 2017



2016 Calcite Monitoring Program

Elk Valley - Map #10

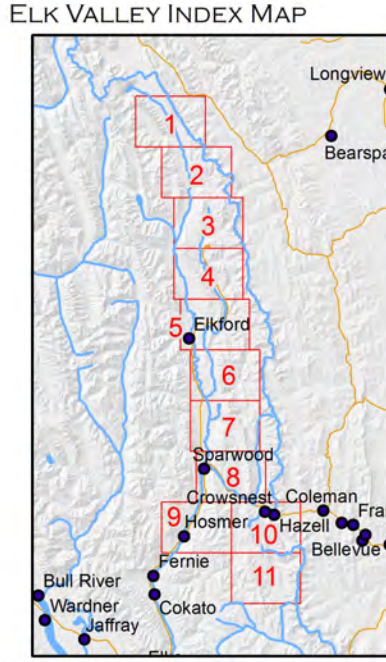
- Reach Break
- Reference Stream
- Proposed Stream
- Exposed Stream
- Stream Segments
- Road - Regional
- Railway
- Teck Coal Operations

Label Examples:

- 1.50 → Current calcite index (with neutral trend)
- 1.50 → Current calcite index (with increasing trend)
- 1.50 → Current calcite index (with decreasing trend)

0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83

Elk Valley Index Map

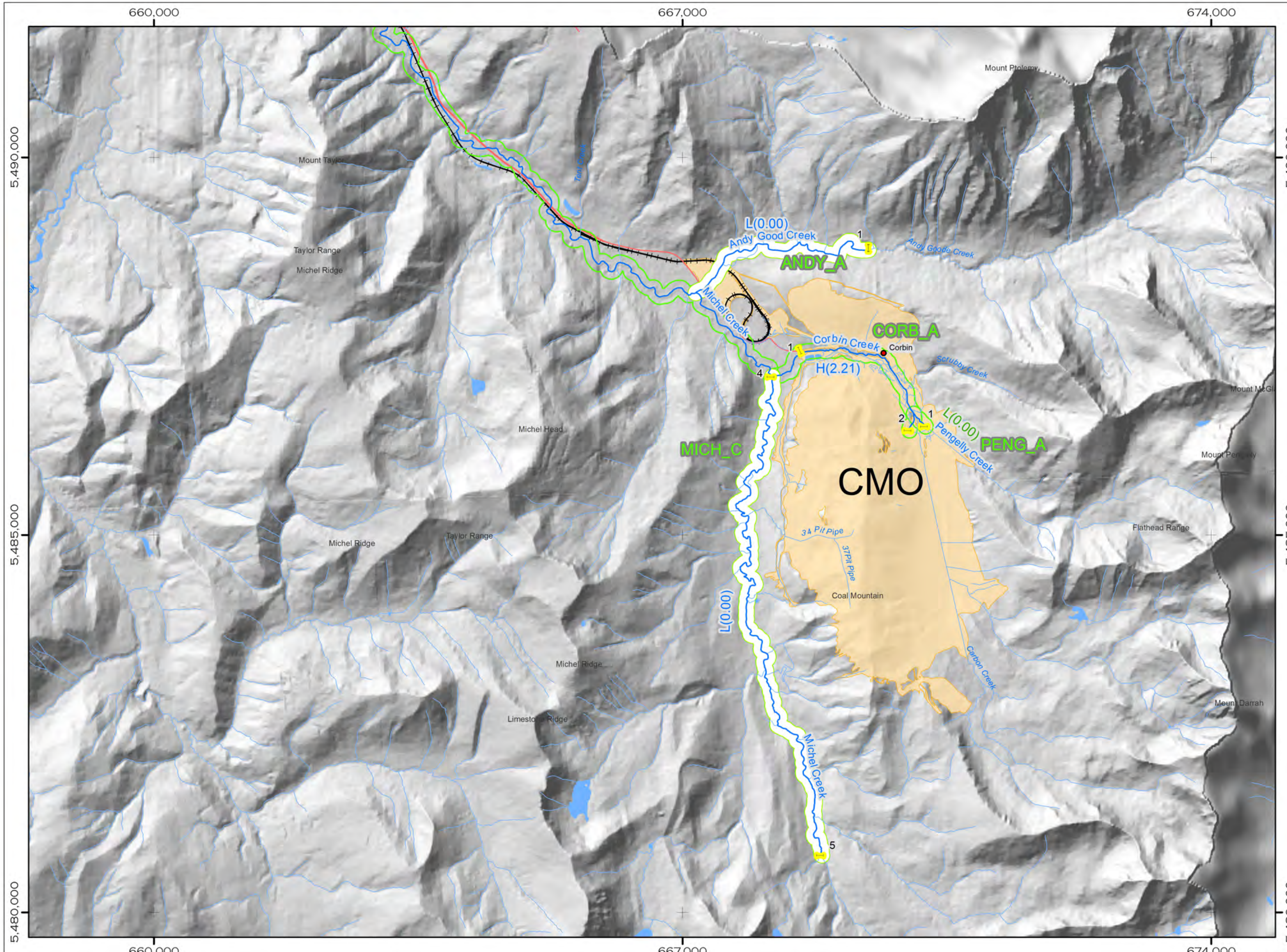


Client: Teck

Mapping by: Lotic Environmental

Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE

Date Last Revised: Jan 30, 2017



2016 Calcite Monitoring Program

Elk Valley - Map #11

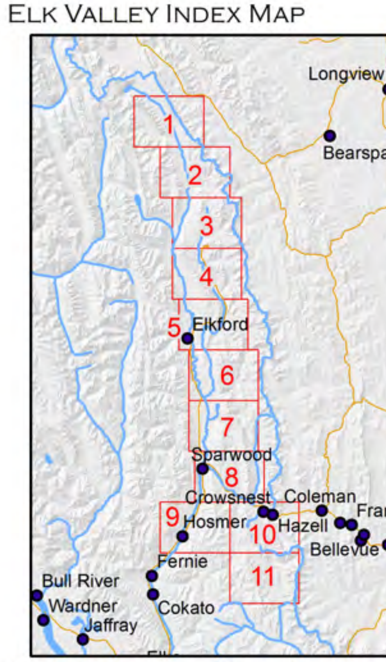
- Reach Break
- Reference Stream
- Proposed Stream
- Exposed Stream
- Stream Segments
- Road - Regional
- Railway
- Teck Coal Operations

Label Examples:

- 1.50 → Current calcite index (with neutral trend)
- 1.50 → Current calcite index (with increasing trend)
- 1.50 → Current calcite index (with decreasing trend)

0 1 2
Kilometers
1:50,000
UTM Zone 11 NAD83

Elk Valley Index Map



Client: Teck

Mapping by: Lotic Environmental

Data Sources:
- Stream / River - Teck Water Network
- Road / Rail - Teck Transportation
- Hillshade - GEOBASE

Date Last Revised: Jan 30, 2017

Appendix 4. Mann-Kendall results

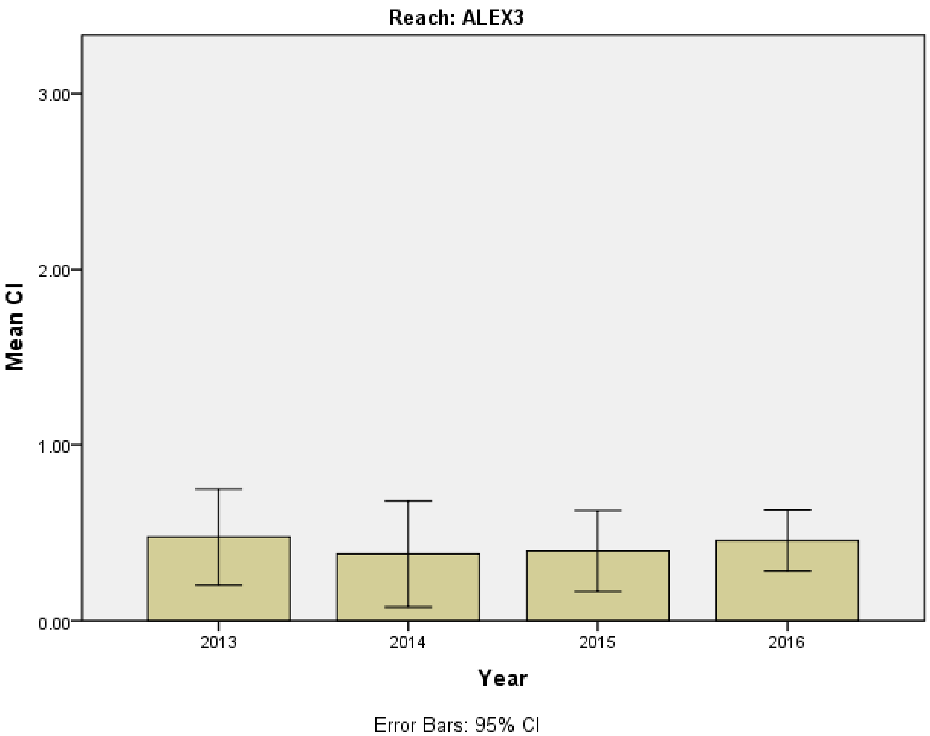
Reach	p-value
ALEX3	0.61
BODI1	0.27
BODI3	0.27
CHAU1	0.73
CLOW1	1.00
CORB1	0.27
COUT1	0.46
DRYE3	0.09
DRYL1	0.29
DRYL3	0.29
ELKR8	1.00
EPOU1	0.09
ERIC1	0.61
FORD1	0.10
FORD2	0.29
FORD4	0.31
FORD5	0.09
FORD6	0.46
FORD7	0.46
FORD9	0.29
FORD12	0.10
FPON1	0.13
GARD1	1.00
GATE2	0.09
GODD1	0.27
GODD3	0.03
GRAC1	0.13
GRAS1	0.31
GRAV1	0.81
GREE1	0.22
GREE3	0.22
GREE4	0.81
HARM1	1.00
HARM3	0.46
HENR1	0.29
KILM1	0.09
LEAS2	0.09
LIND1	0.45
LINE1	0.58
LINE4	0.46
LMOU1	0.61
MICH1	0.29
MICH4	0.29
MICH5	0.29
MICK1	0.61
NTHO1	0.46
NWOL1	0.81
OTTO1	0.46
PENG1	0.07
PORT1	0.09
PORT3	0.09
SAWM2	0.43
SIXM1	1.00
SLINE2	0.37
SPOU1	1.00
SPRI1	1.00
SWIF1	0.81
SWOL1	1.00
WOLF3	1.00

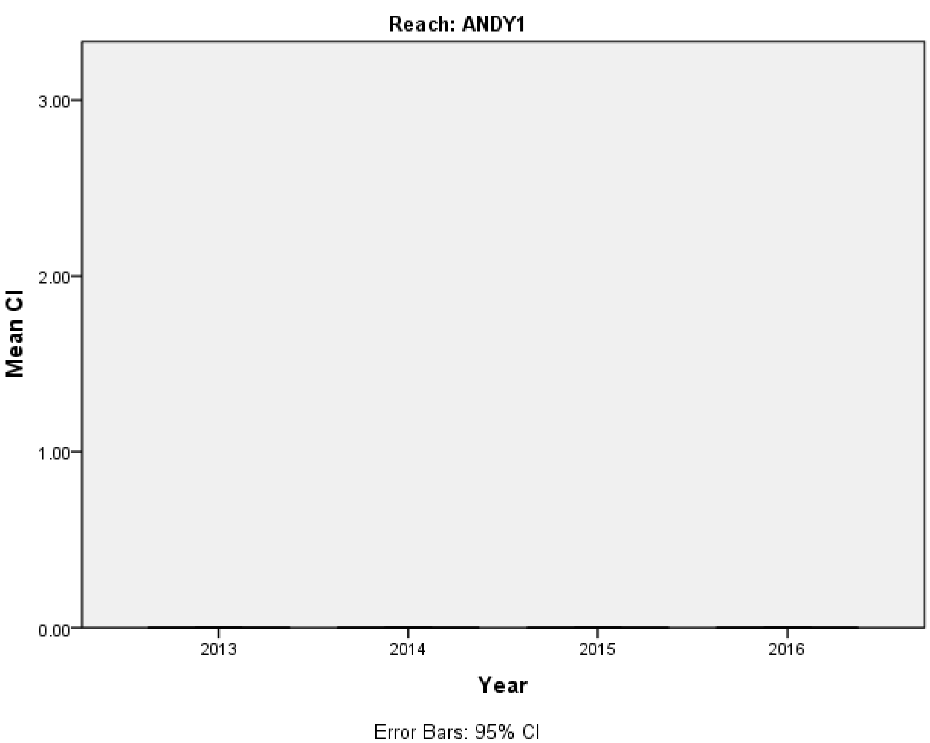
Appendix 5. ANOVA results for reaches with significant effect of year and significant year-year pairings identified from Tukey's HSD.

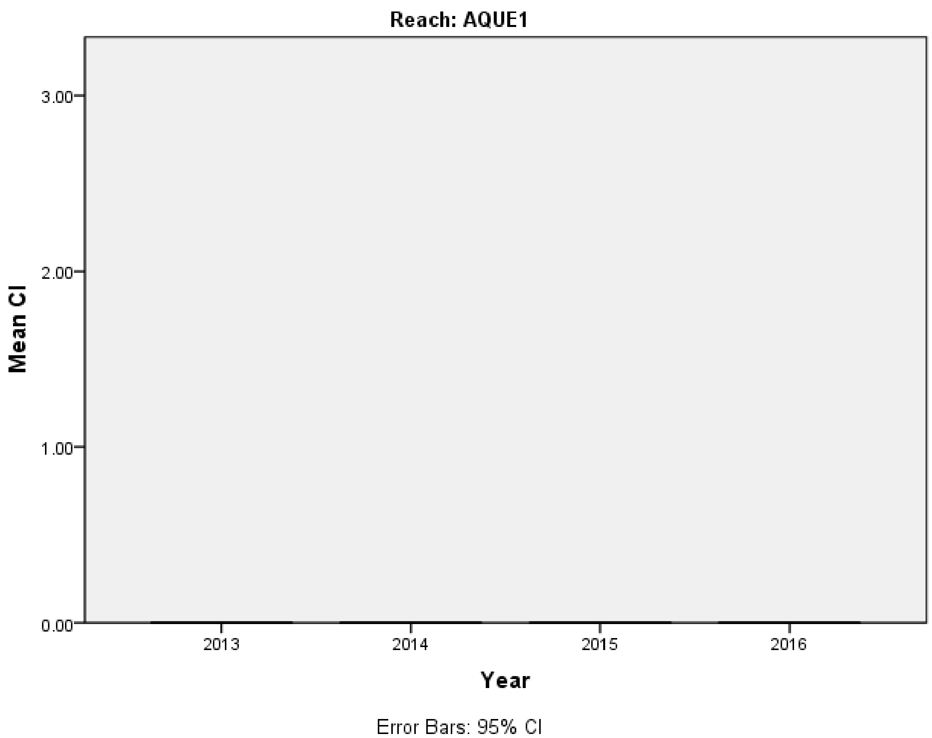
Reach	p-value	Tukey's HSD results
CHAU1	0.006	2013<2016 (p=0.019) 2014<2016 (p=0.019) 2015<2016 (p=0.019)
CORB1	0.002	2013<2015 (p=0.033) 2013<2017 (p=0.030) 2014<2015 (p=0.006) 2014<2017 (p=0.005)
FORD1	0.000	2013<2016 (p=0.001) 2013<2017 (p=0.000) 2014<2016 (p=0.001) 2014<2017 (p=0.000) 2015<2016 (p=0.001) 2015<2017 (p=0.000)
FORD12	0.009	2013<2017 (p=0.027) 2014<2017 (p=0.014) 2015<2017 (p=0.014)
FORD6	0.017	2014<2015 (p=0.013) 2015>2016 (p=0.022)
GATE2	0.000	2013<2016 (p=0.018) 2013<2017 (p=0.002) 2014<2016 (p=0.005) 2014<2017 (p=0.001) 2015<2017 (p=0.014)
GODD3	0.000	2013<2014 (p=0.000) 2013<2015 (p=0.000) 2013<2016 (p=0.000) 2013<2017 (p=0.000) 2014<2017 (p=0.032)
GRAC1	0.005	2013>2015 (p=0.009) 2013>2016 (p=0.019) 2013>2017 (p=0.009)
GREE3	0.000	2013<2014 (p=0.004) 2013<2015 (p=0.000) 2013<2016 (p=0.006) 2013<2017 (p=0.000)
GREE4	0.000	2013<2014 (p=0.001) 2013<2015 (p=0.001) 2013<2016 (p=0.002) 2013<2017 (p=0.001)
HARM1	0.002	2014>2015 (p=0.001)

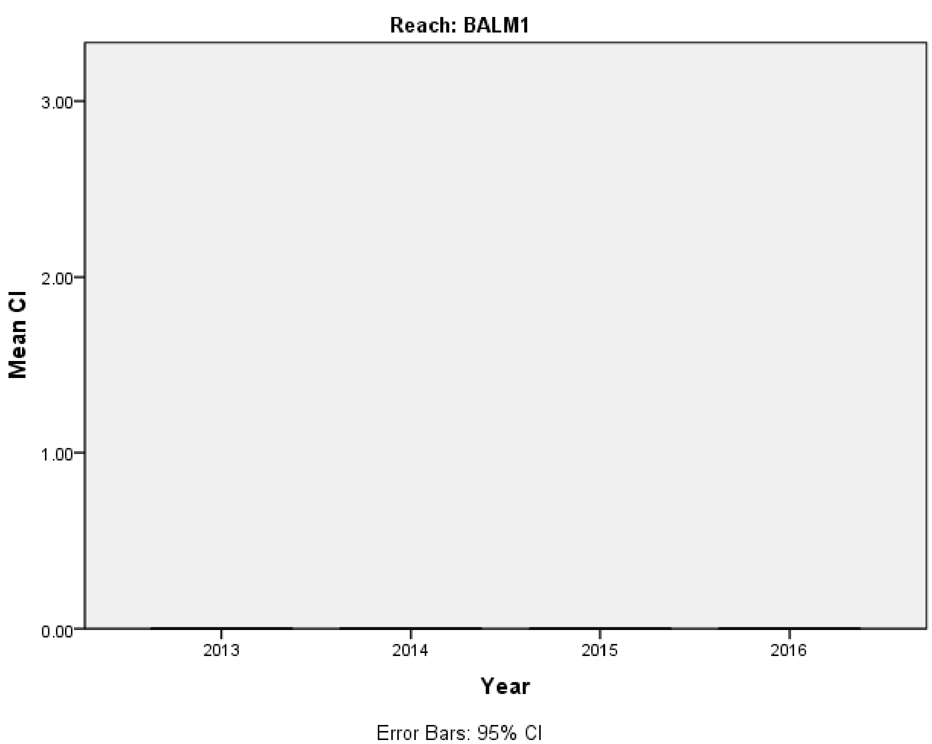
Reach	p-value	Tukey's HSD results
		2015<2016 (p=0.040)
LINE1	0.002	2013>2014 (p=0.004) 2013>2015 (p=0.004) 2013>2016 (p=0.010) 2013>2017 (p=0.004)
LINE4	0.003	2014<2015 (p=0.008) 2014<2016 (p=0.013) 2014<2017 (p=0.011)
MICK1	0.000	2013<2016 (p=0.000) 2013<2017 (p=0.000) 2014<2016 (p=0.000) 2014<2017 (p=0.000) 2015<2016 (p=0.000) 2015<2017 (p=0.000) 2016>2017 (p=0.000)
SIXM1	0.024	2014>2015 (p=0.019)
WOLF3	0.000	2013>2014 (p=0.000) 2013>2015 (p=0.000) 2014>2015 (p=0.016) 2014<2016 (p=0.000) 2014<2017 (p=0.000) 2015<2016 (p=0.000) 2015<2017 (p=0.000)

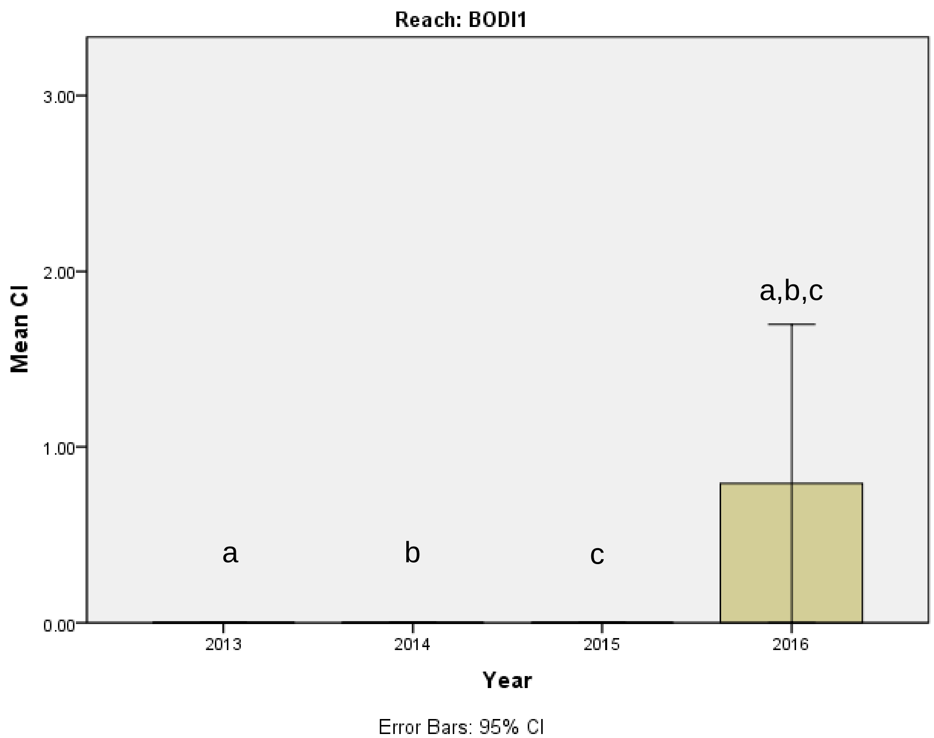
* Tukey's post-hoc adjusts p-values for multiple comparisons.

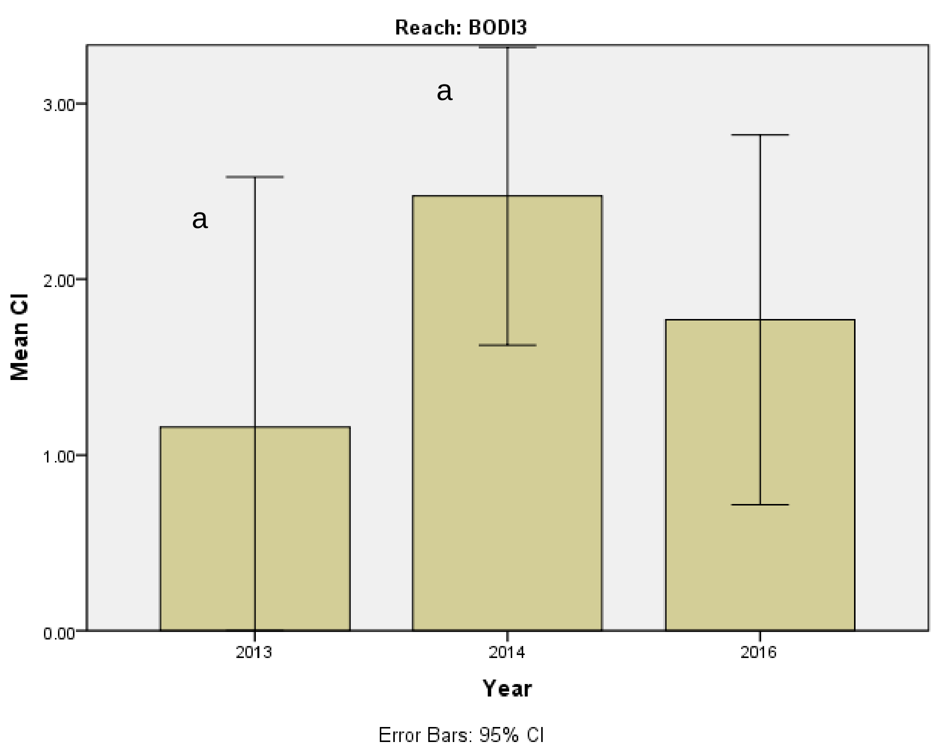

Reach: ALEX3
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

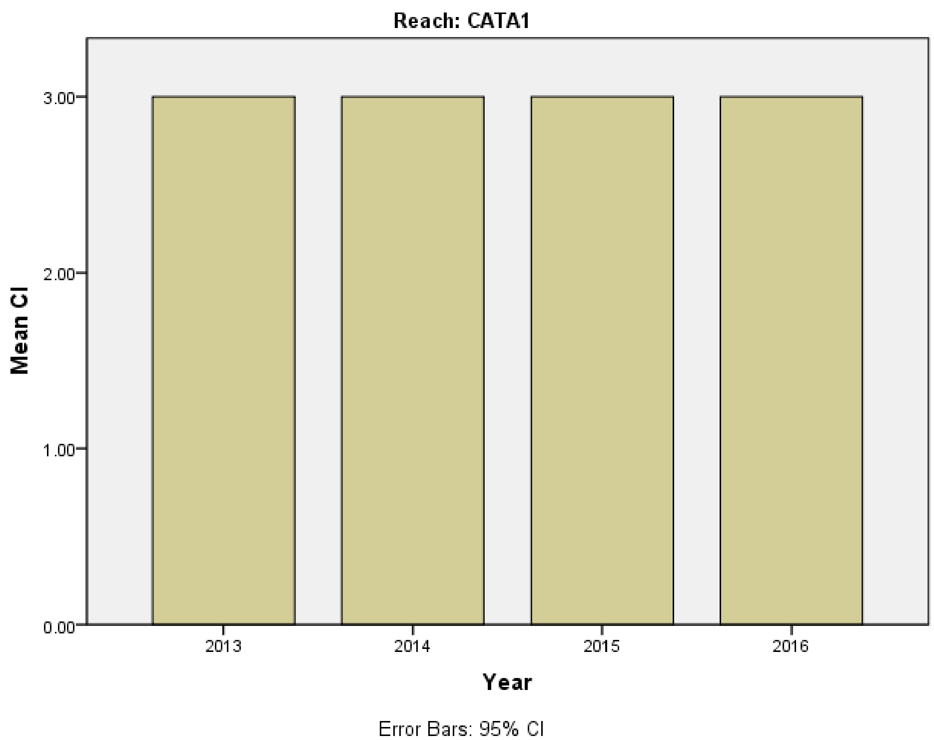

Reach: ANDY1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

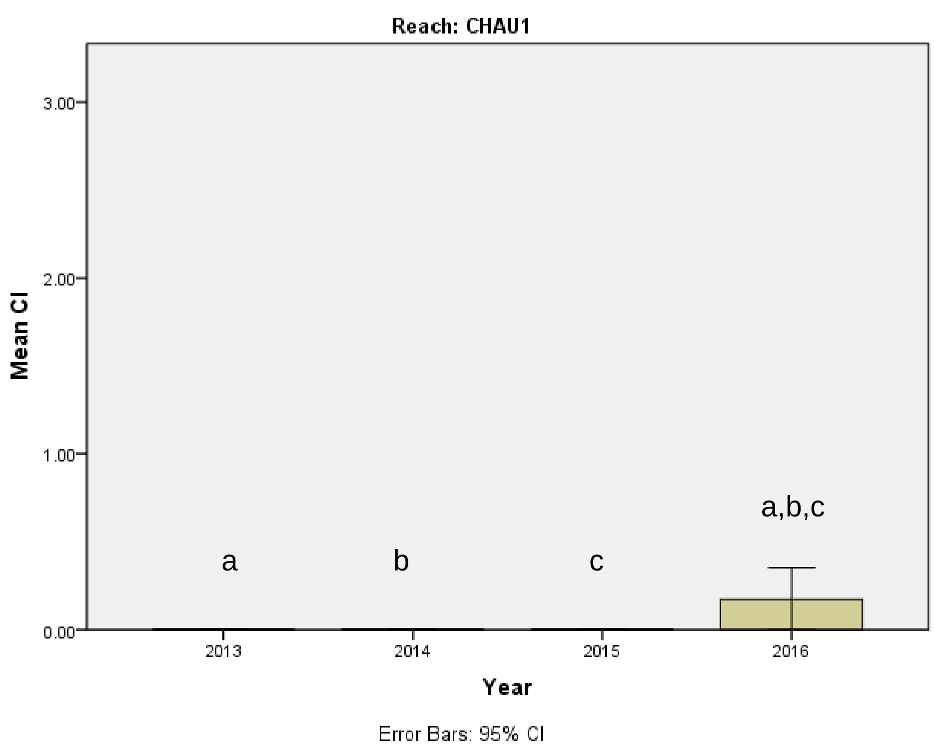

Reach: AQUE1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

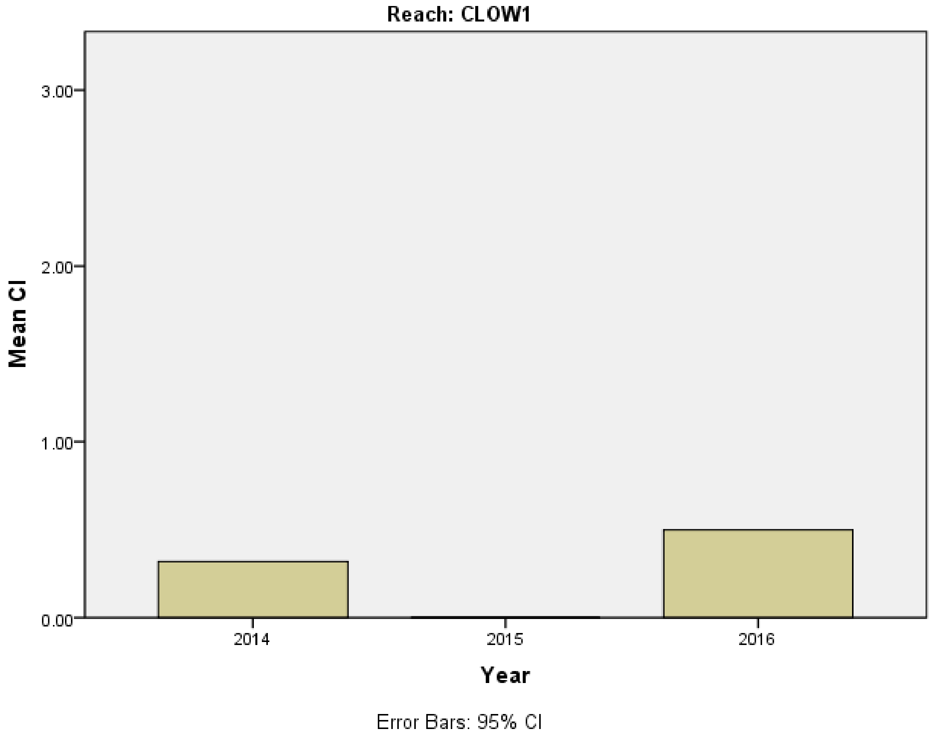

Reach: BALM1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

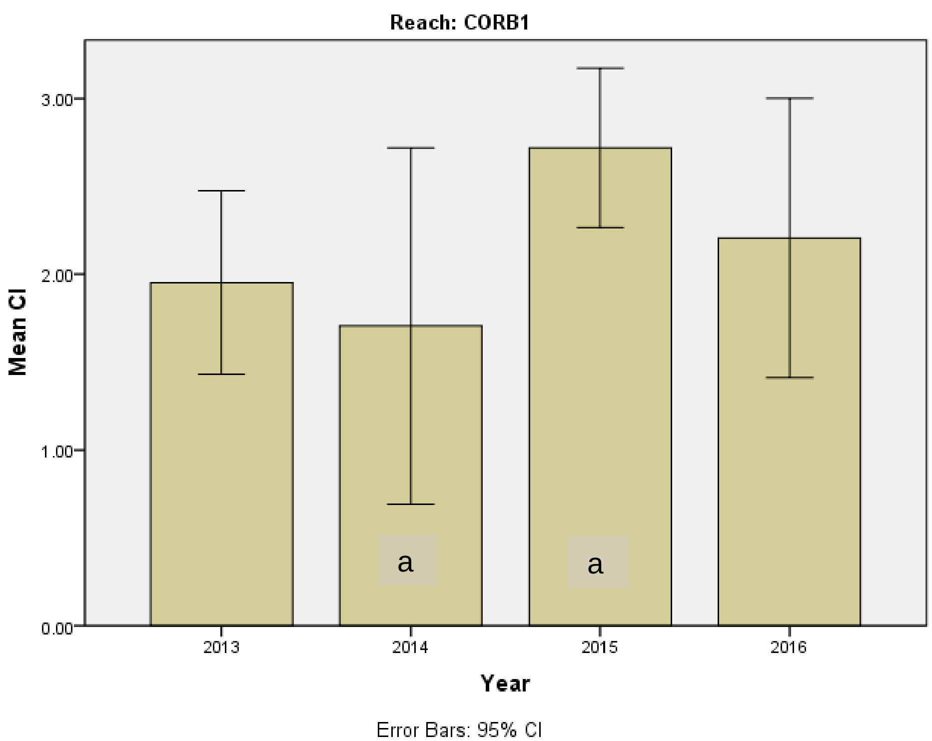

Reach: BODI1
Mean CI
3.00
2.00
1.00
0.00
a,b,c
a
b
c
2013
2014
2015
2016
Year
Error Bars: 95% CI

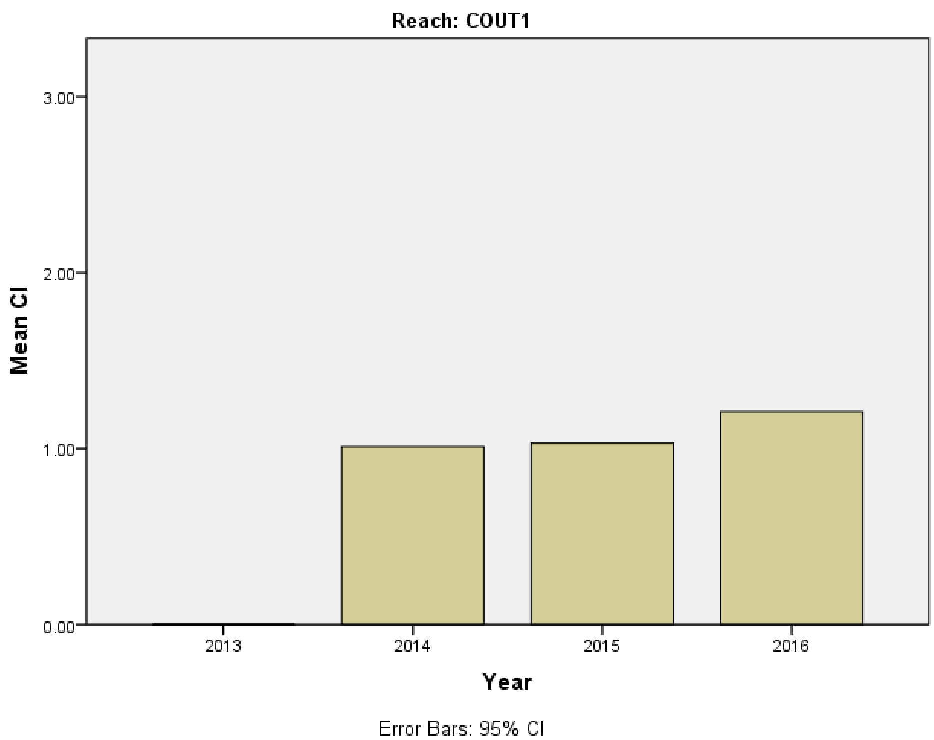

Reach: BODI3
Mean CI
3.00
2.00
1.00
0.00
a
a
2013
2014
2016
Year
Error Bars: 95% CI

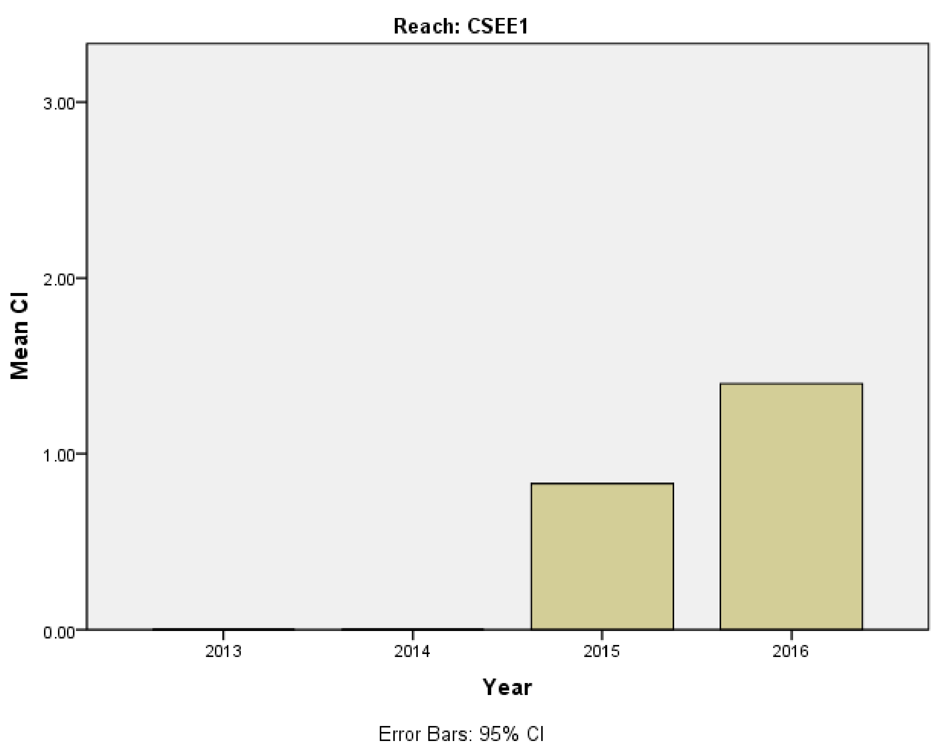

Reach: CATA1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

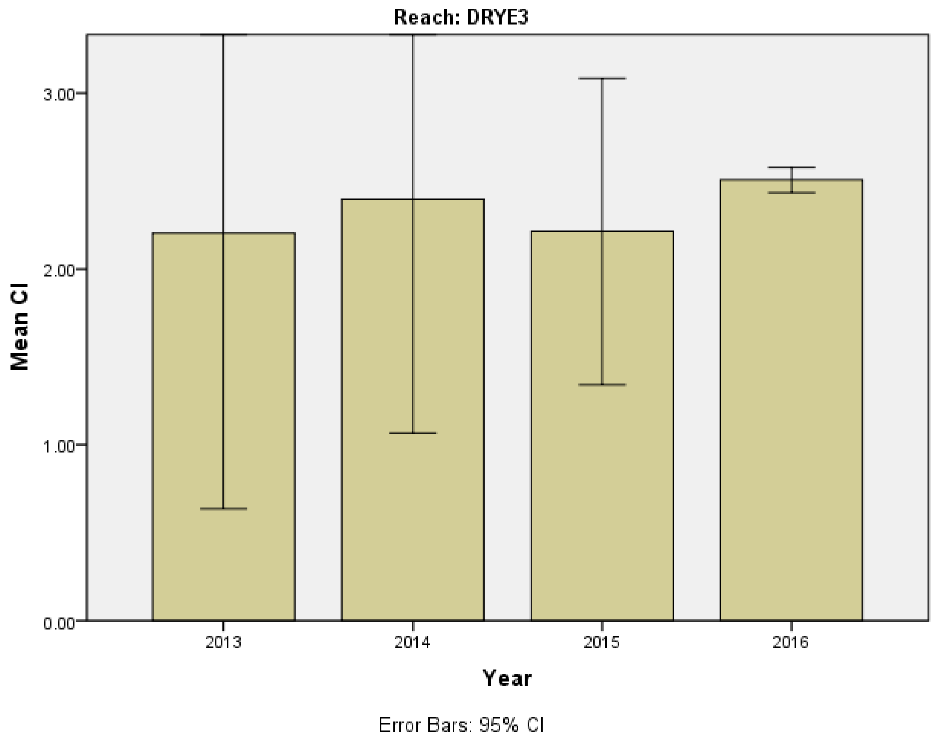

Reach: CHAU1
Mean CI
3.00
2.00
1.00
0.00
a
b
c
a,b,c
2013
2014
2015
2016
Year
Error Bars: 95% CI

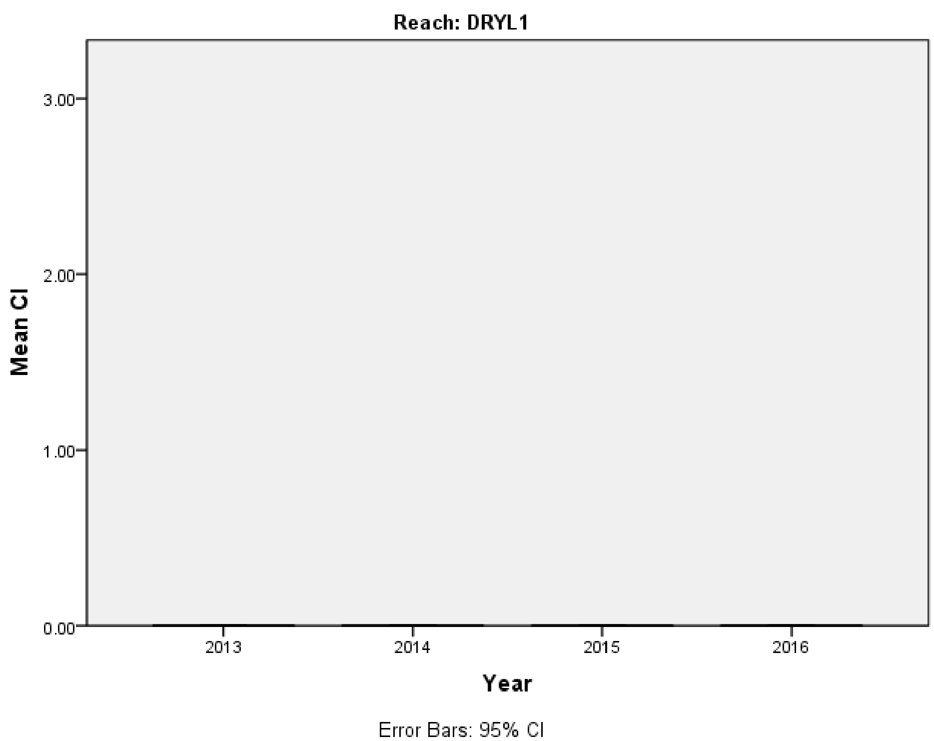

Reach: CLOW1
Mean CI
3.00
2.00
1.00
0.00
2014
2015
2016
Year
Error Bars: 95% CI

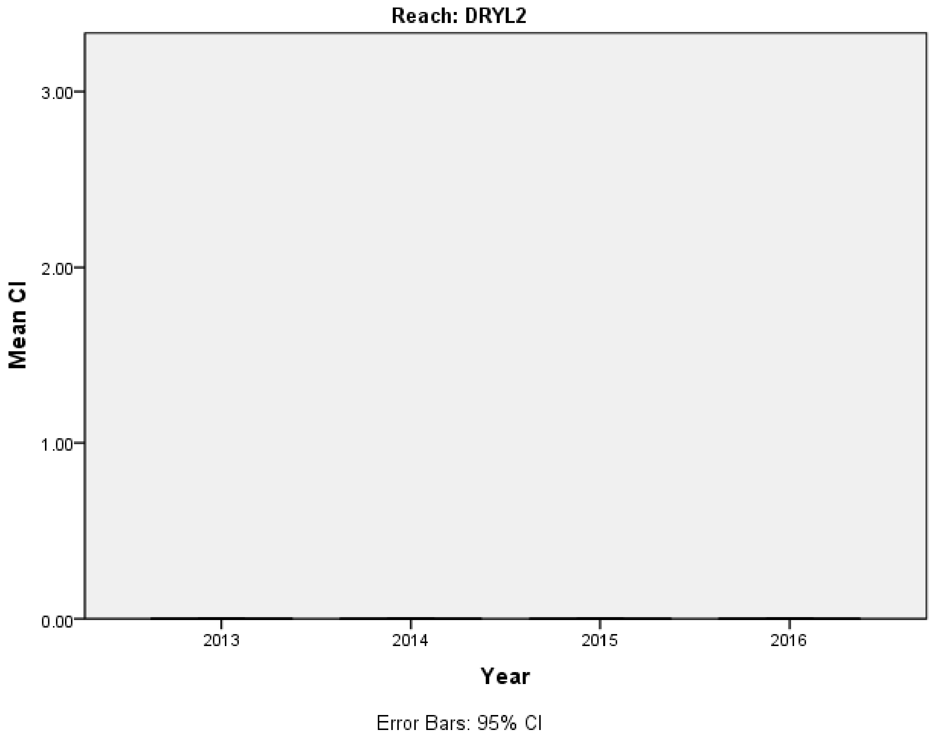

Reach: CORB1
Mean CI
3.00
2.00
1.00
0.00
a
a
2013
2014
2015
2016
Year
Error Bars: 95% CI

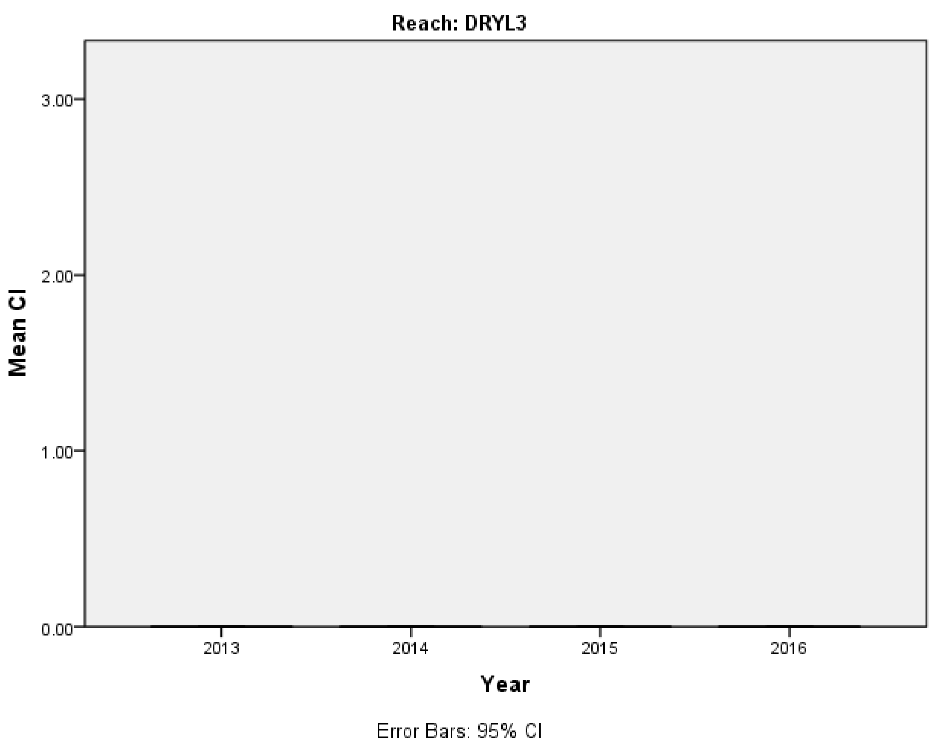

Reach: COUT1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

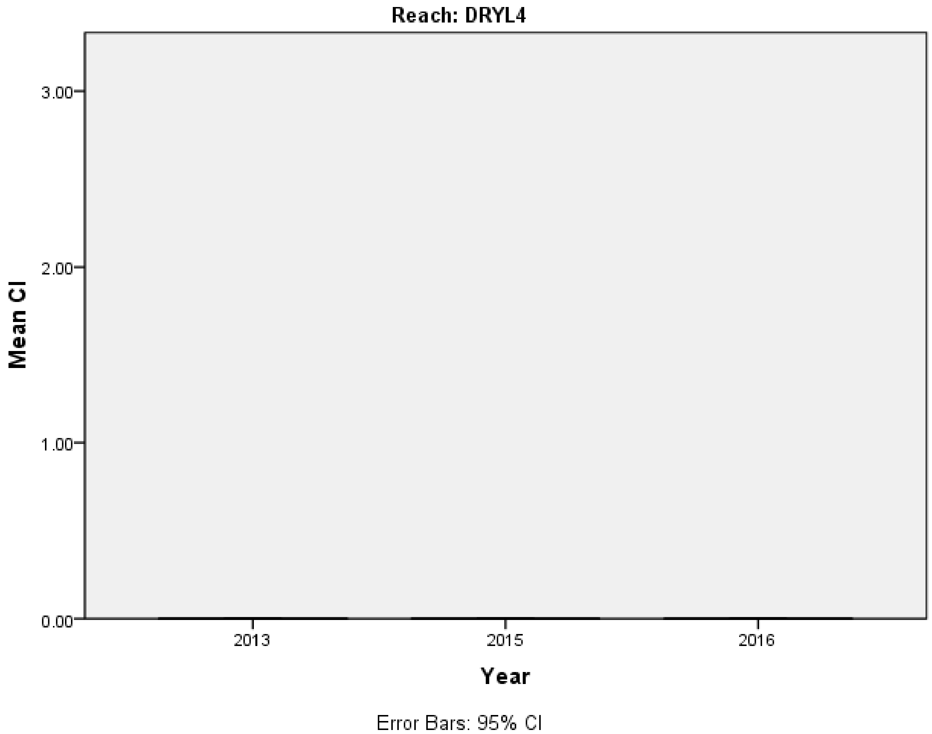

Reach: CSEE1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

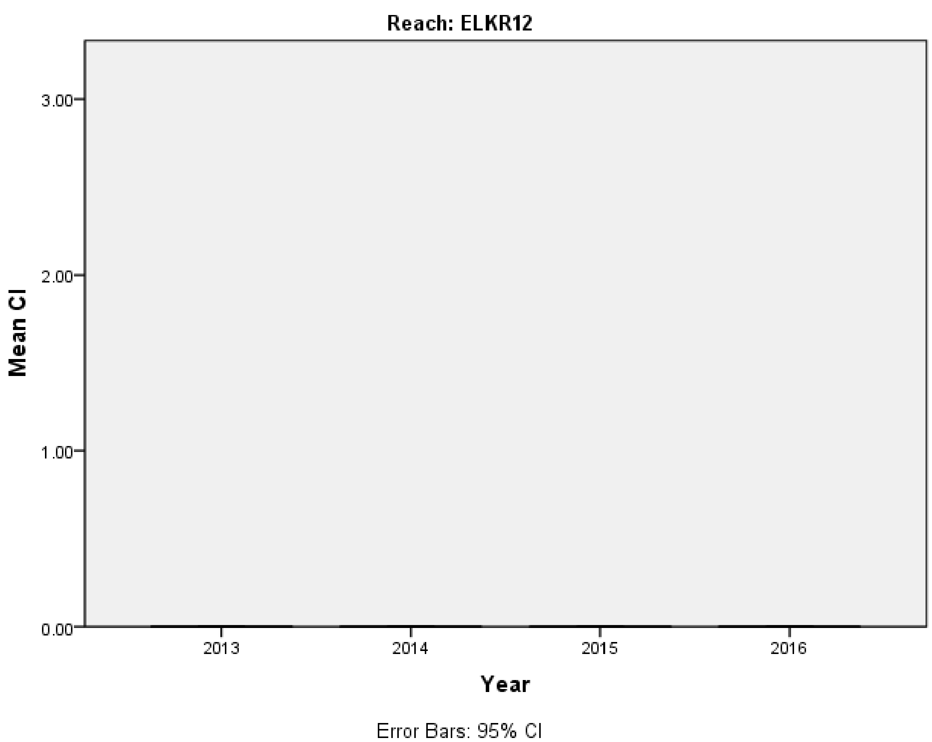

Reach: DRYE3
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

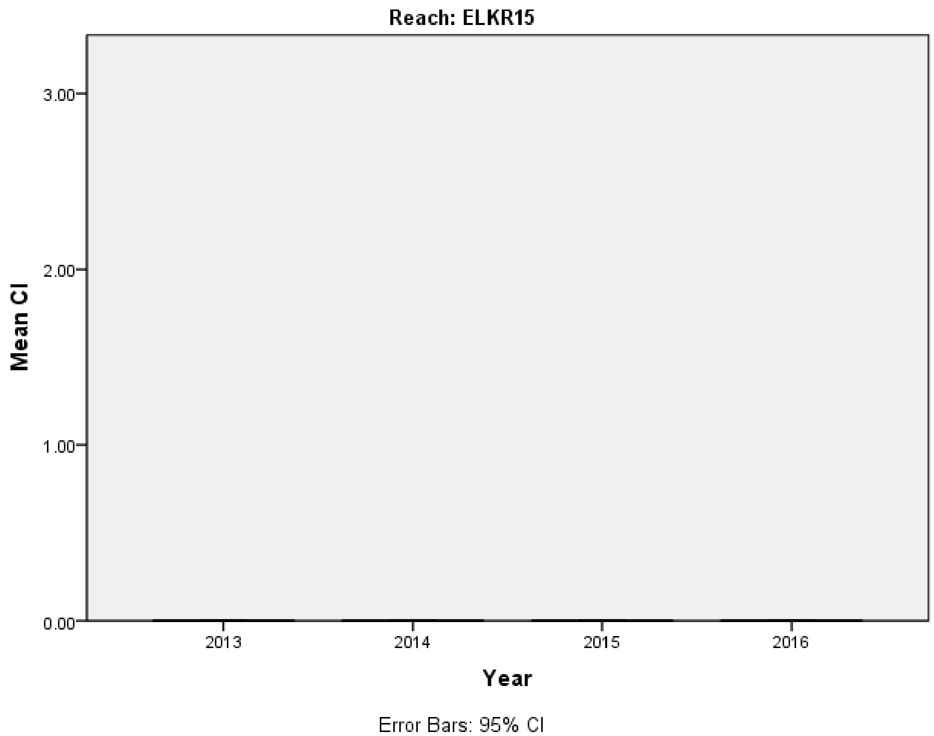

Reach: DRYL1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

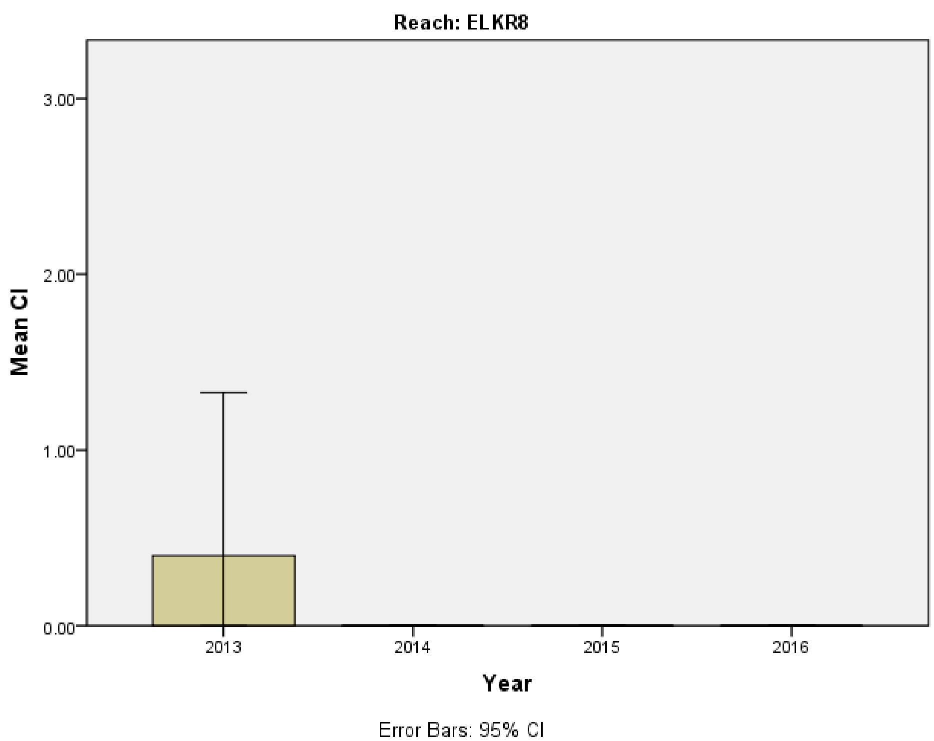

Reach: DRYL2
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

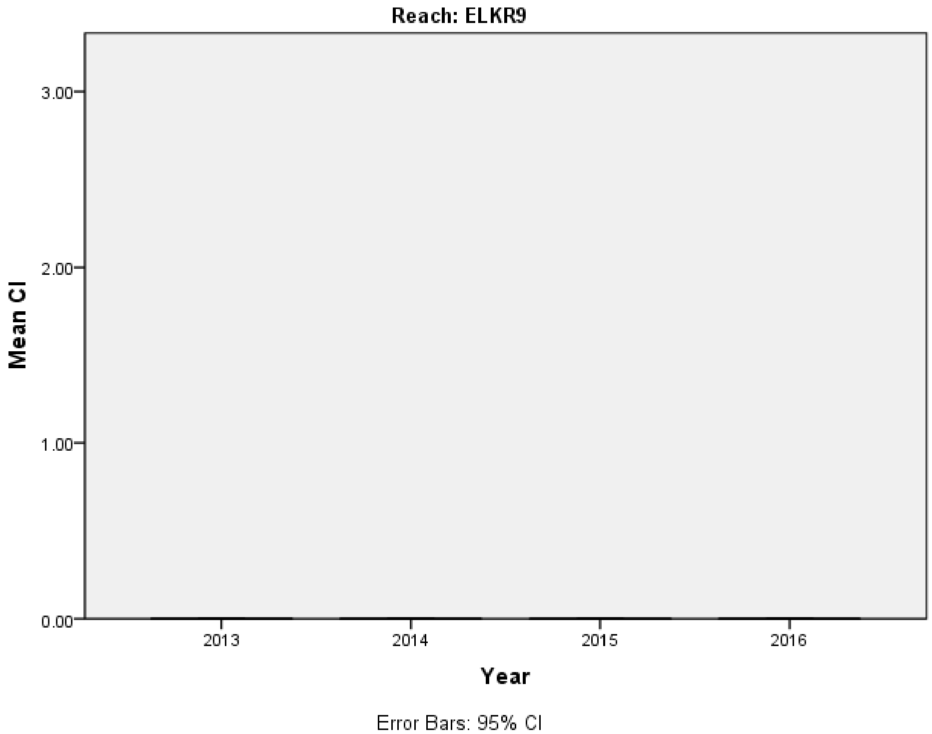

Reach: DRYL3
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

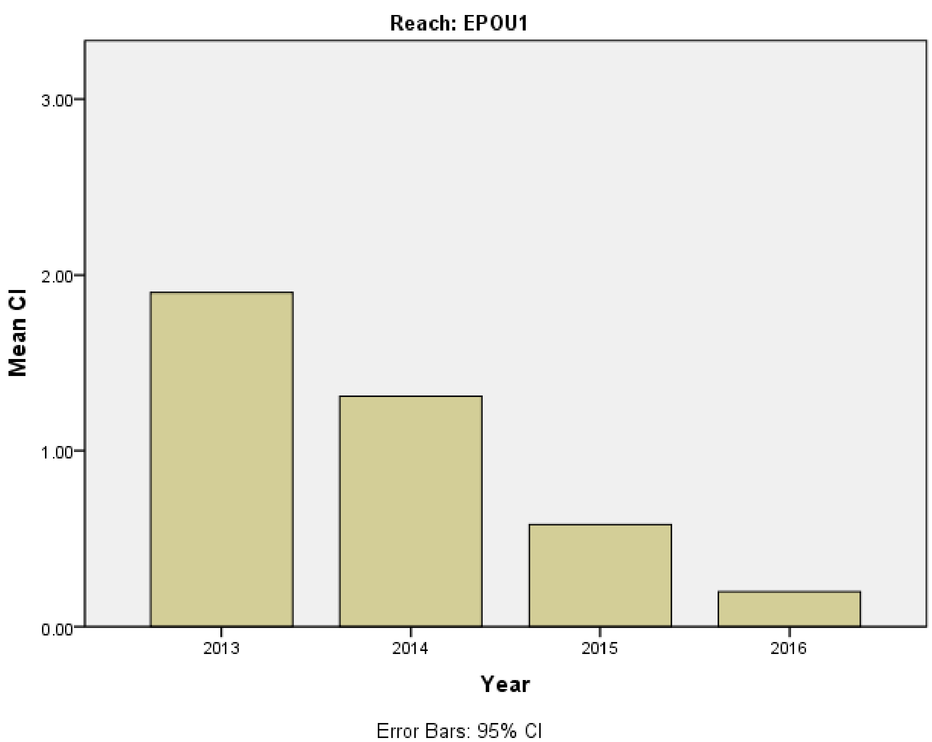

Reach: DRYL4
3.00
2.00
1.00
0.00
Mean CI
2013
2015
2016
Year
Error Bars: 95% CI

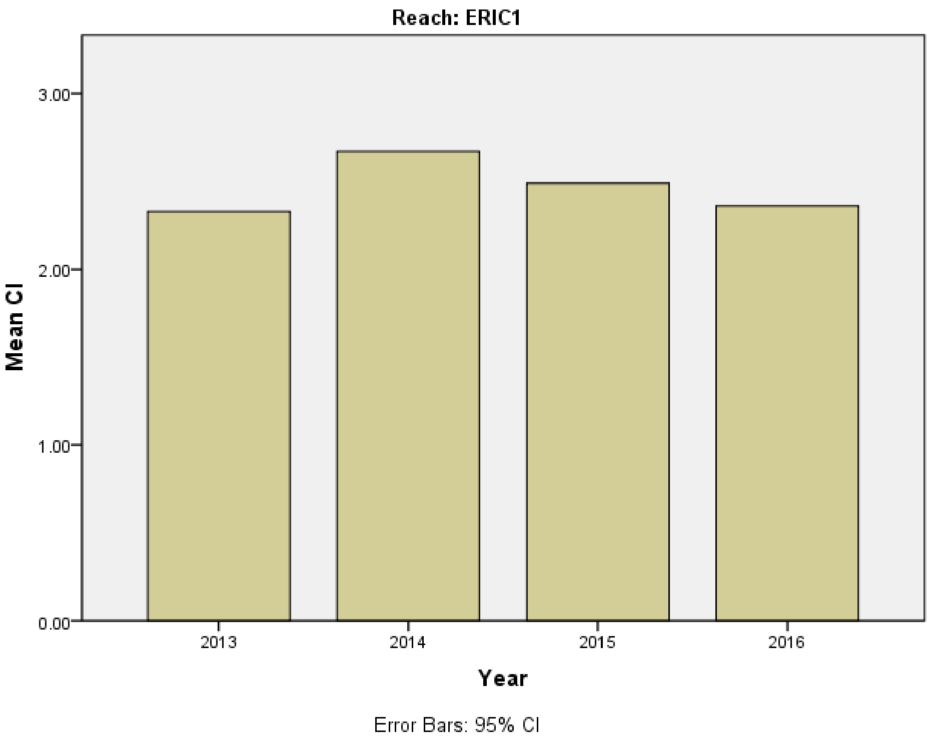

Reach: ELKR12
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

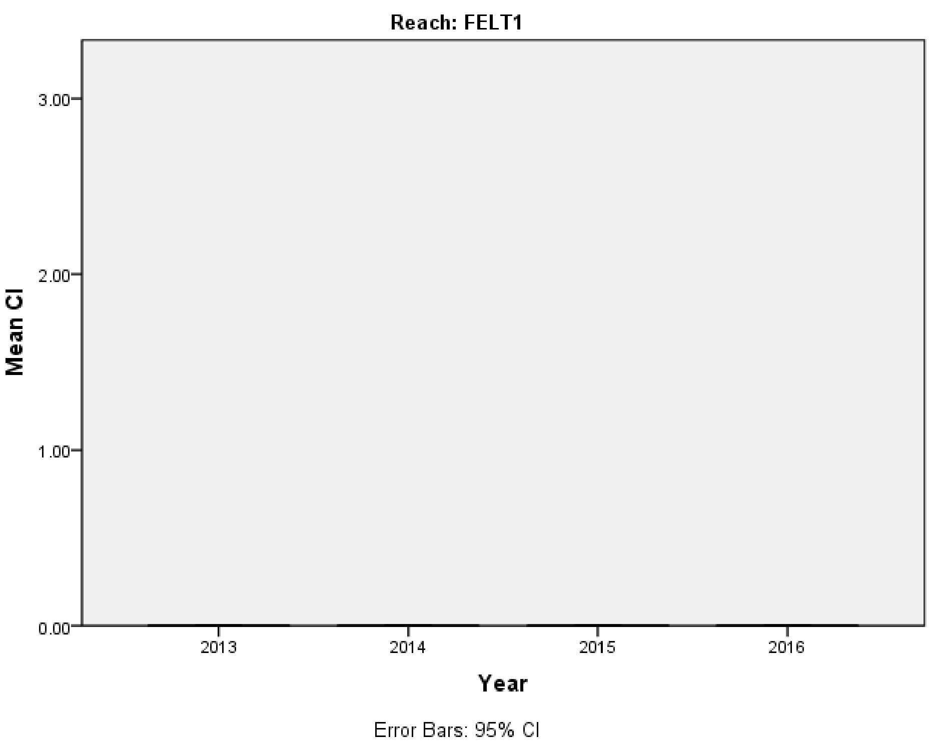

Reach: ELKR15
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

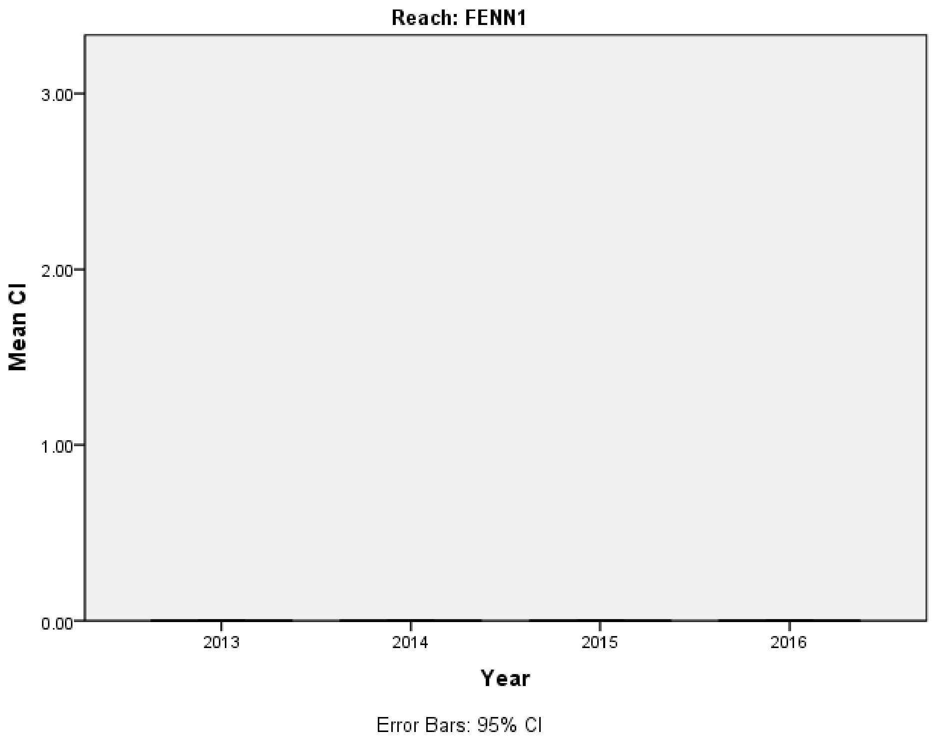

Reach: ELKR8
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

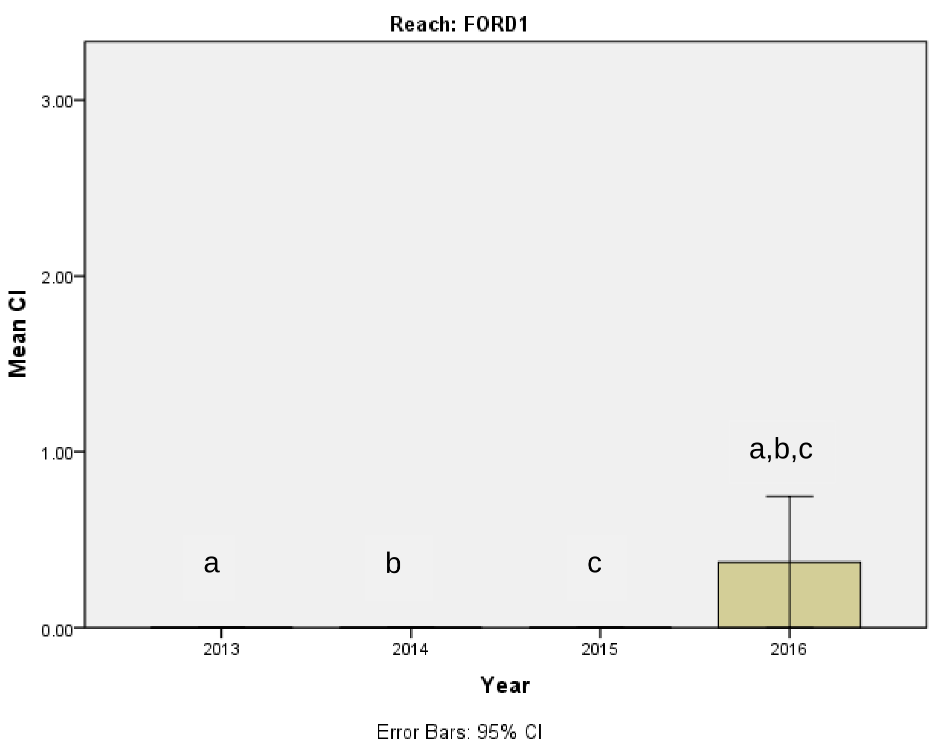

Reach: ELKR9
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

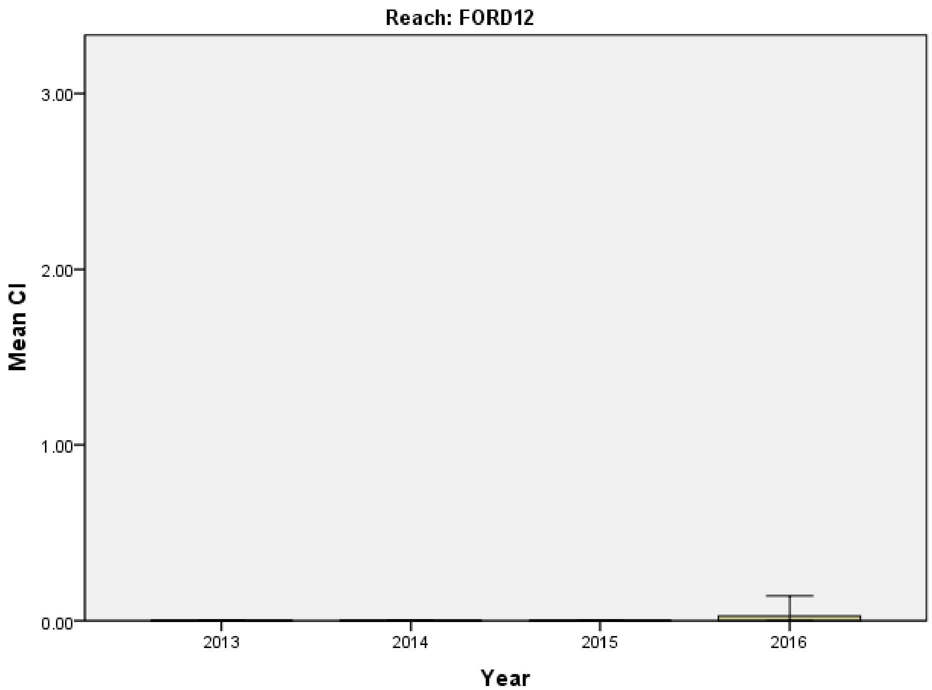

Reach: EPOU1
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI


Reach: ERIC1
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

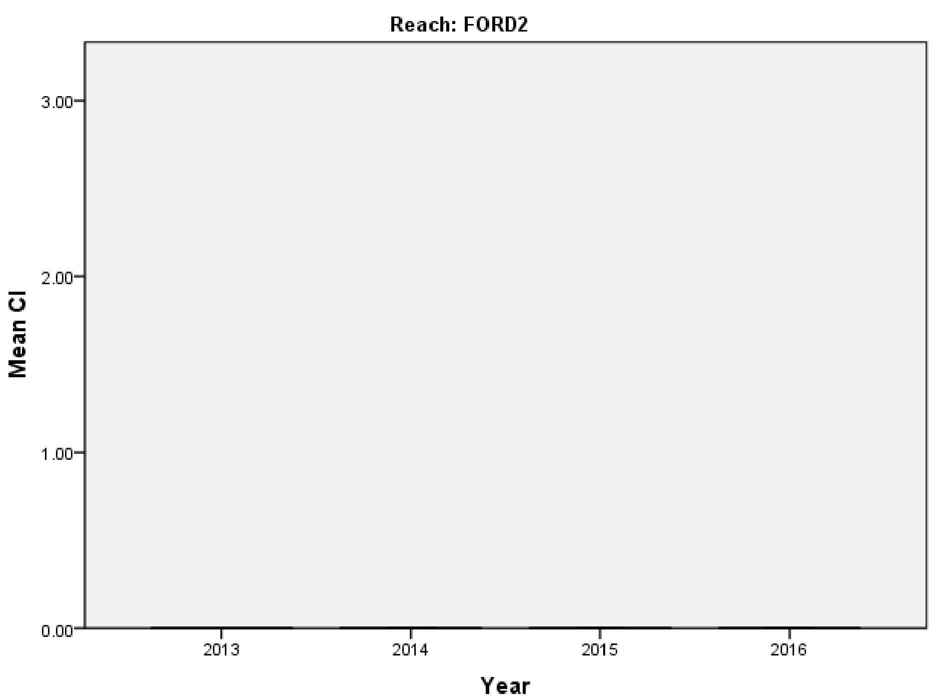

Reach: FELT1
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI


Reach: FENN1
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

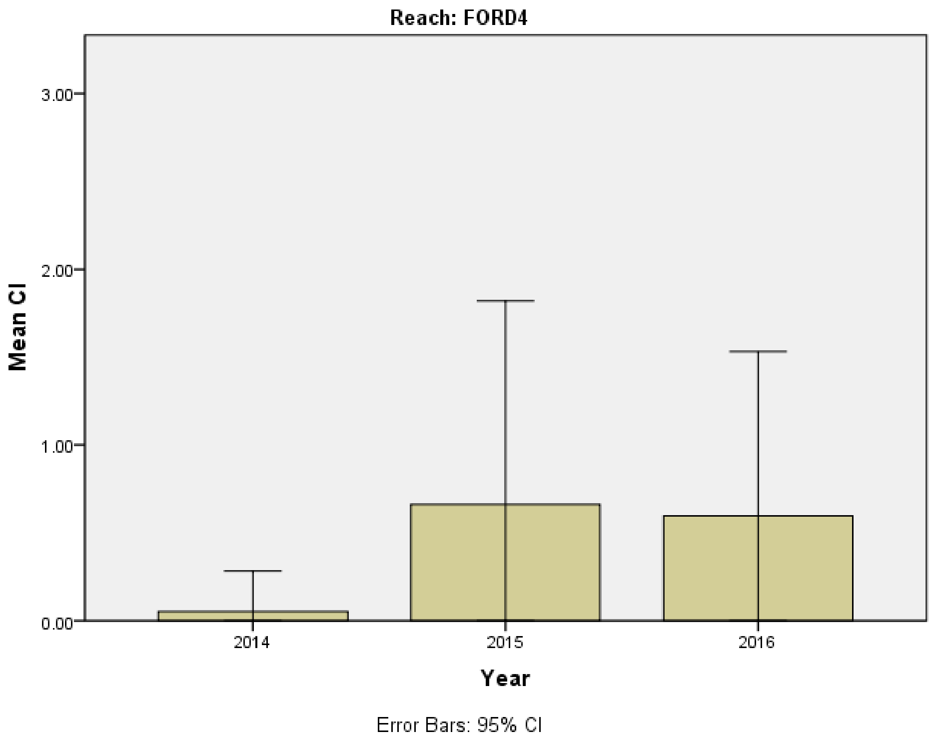

Reach: FORD1
3.00
2.00
1.00
0.00
Mean CI
a,b,c
a
b
c
2013
2014
2015
2016
Year
Error Bars: 95% CI

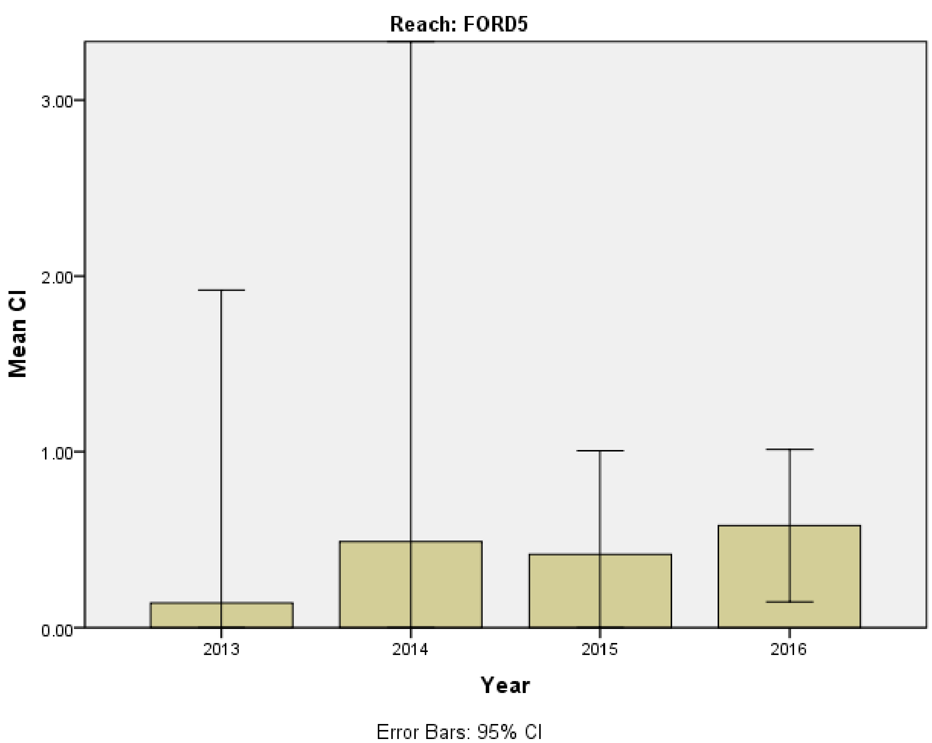


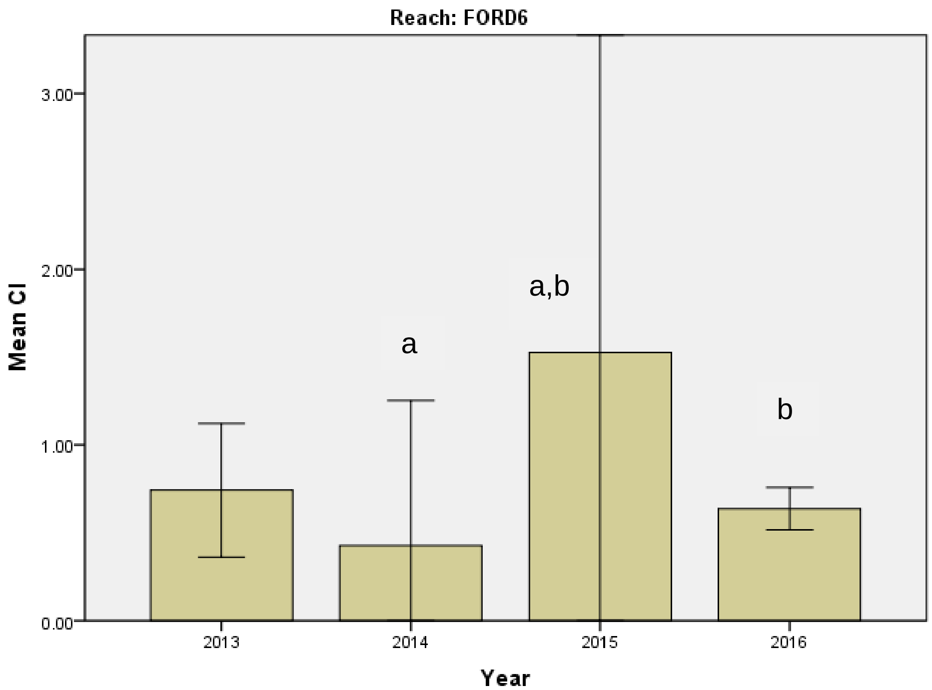
Error Bars: 95% CI



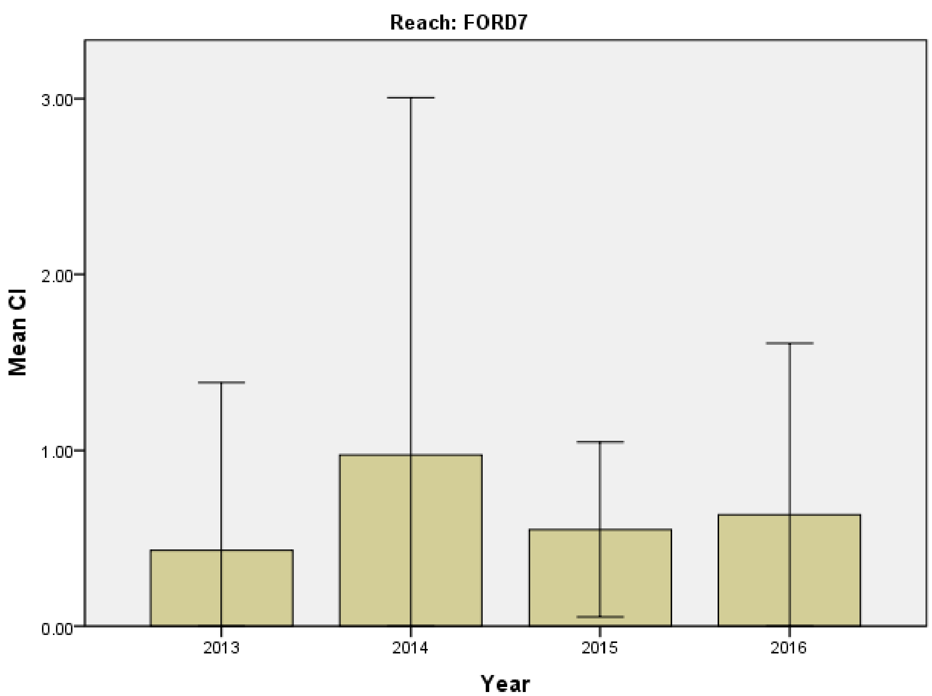
Error Bars: 95% CI


Reach: FORD4
Mean CI
3.00
2.00
1.00
0.00
2014
2015
2016
Year
Error Bars: 95% CI

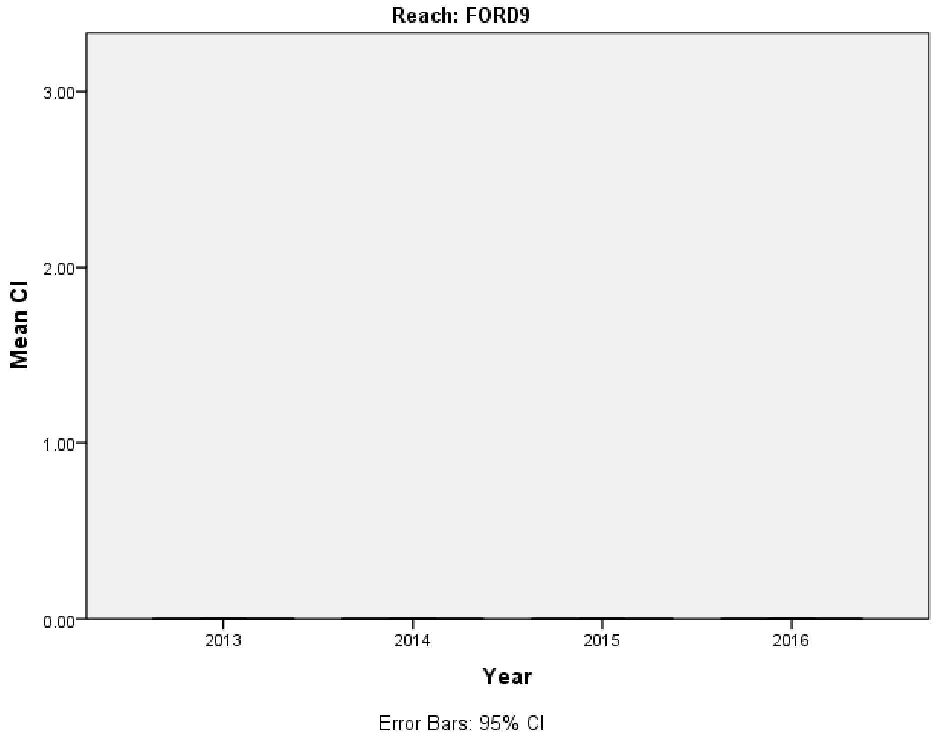

Reach: FORD5
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

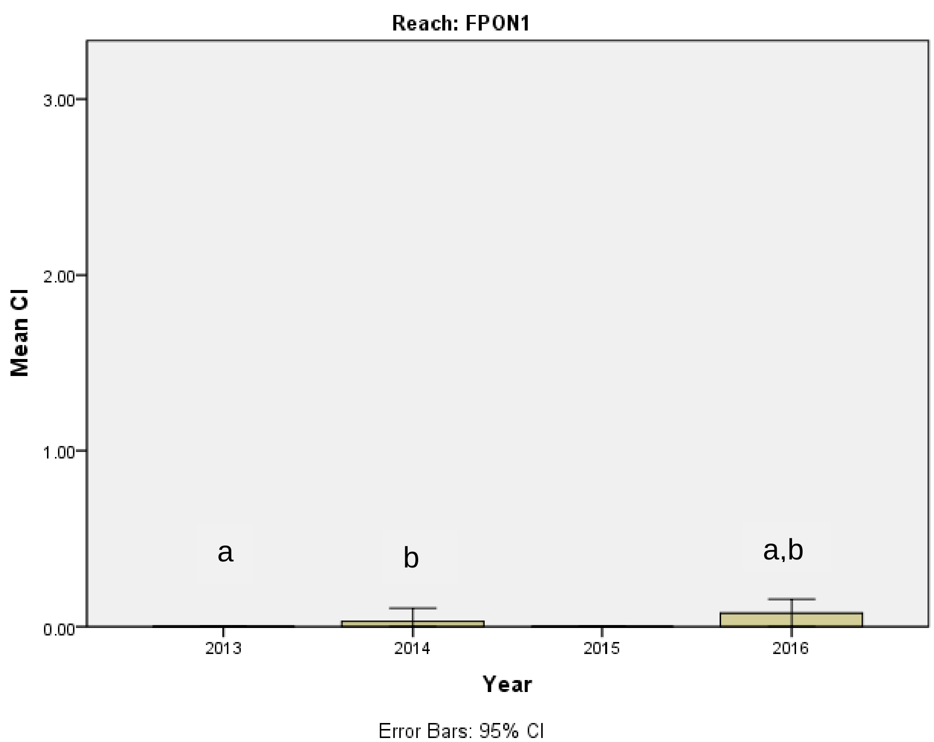


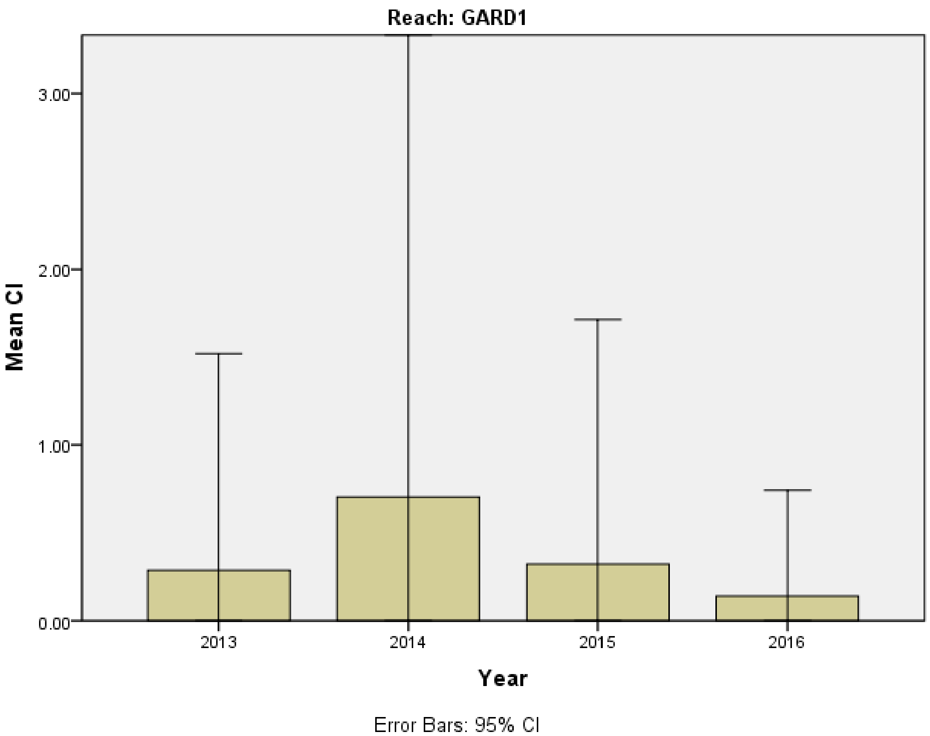
Error Bars: 95% CI

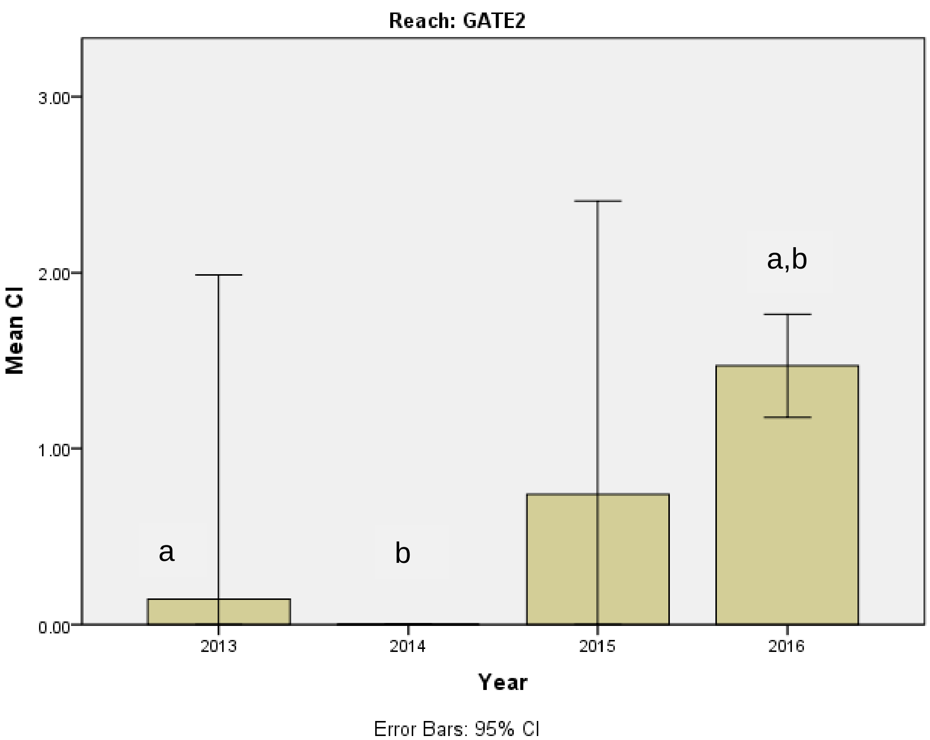


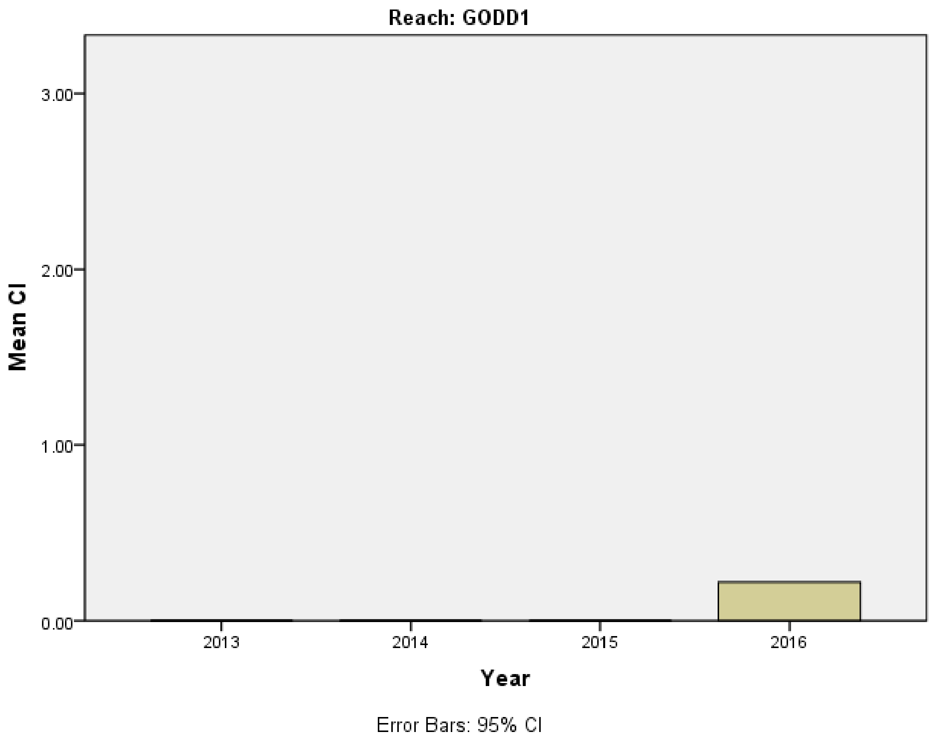
Error Bars: 95% CI

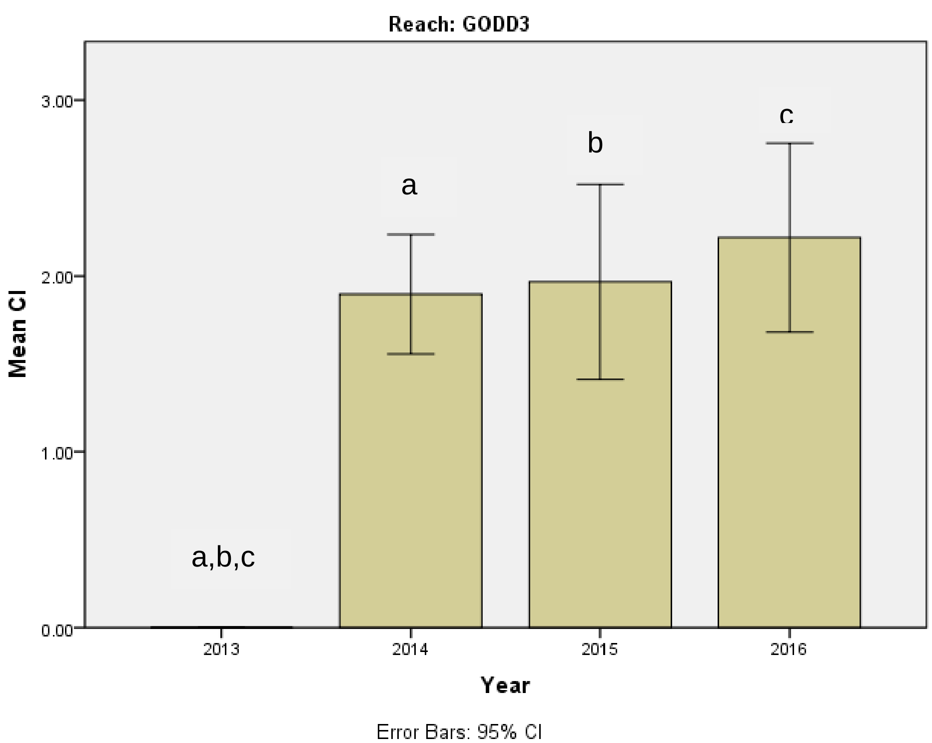

Reach: FORD9
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

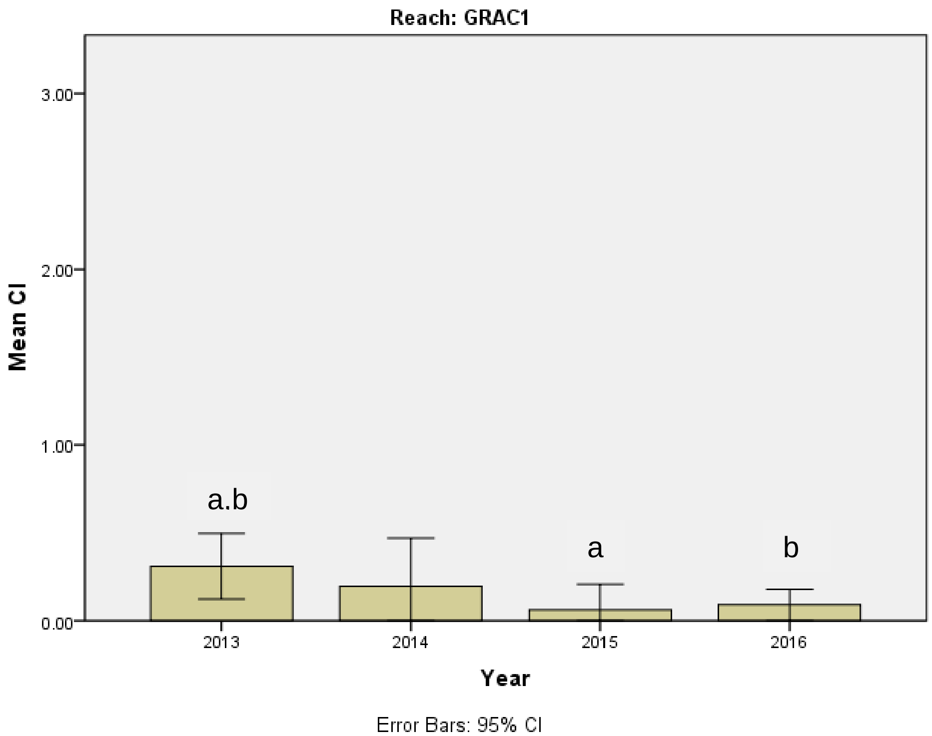

Reach: FPON1
Mean CI
3.00
2.00
1.00
0.00
a
b
a,b
2013
2014
2015
2016
Year
Error Bars: 95% CI

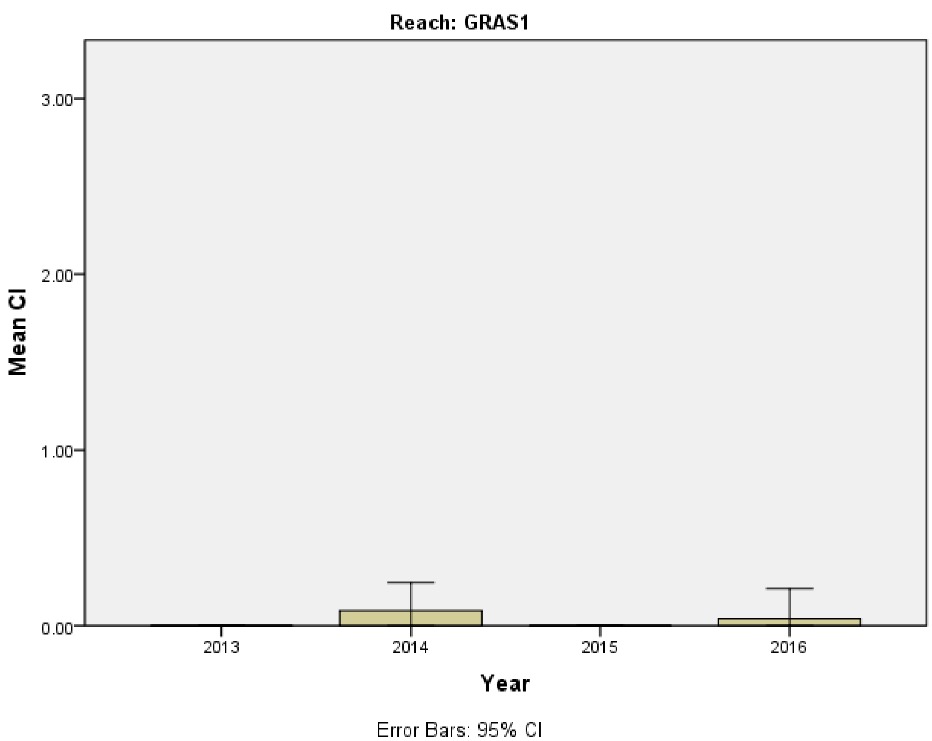

Reach: GARD1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

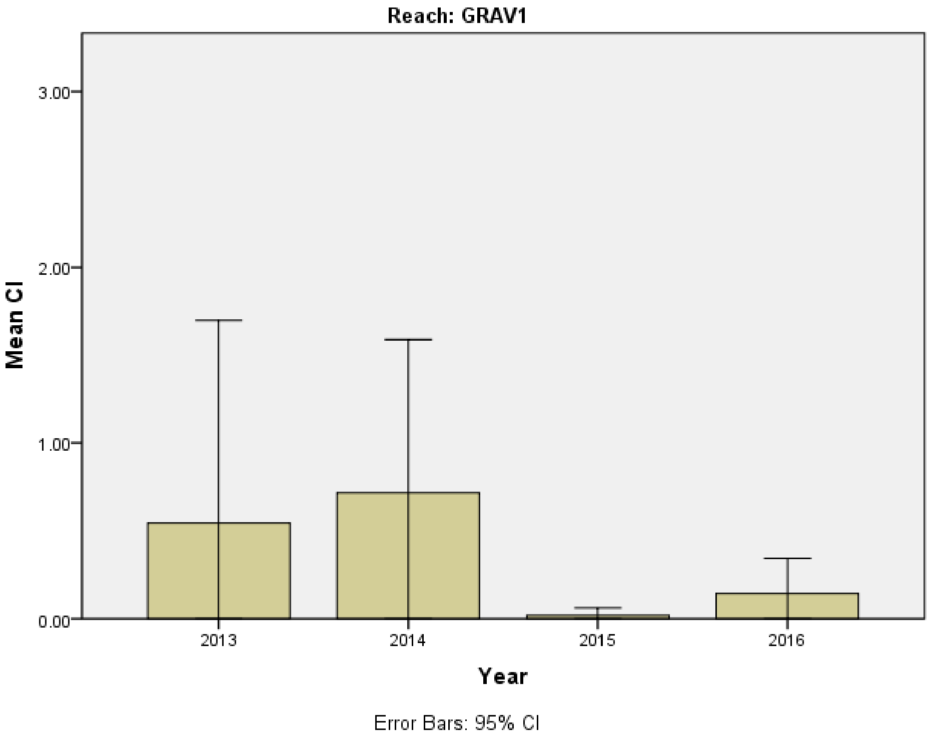

Reach: GATE2
Mean CI
3.00
2.00
1.00
0.00
a
b
a,b
2013
2014
2015
2016
Year
Error Bars: 95% CI

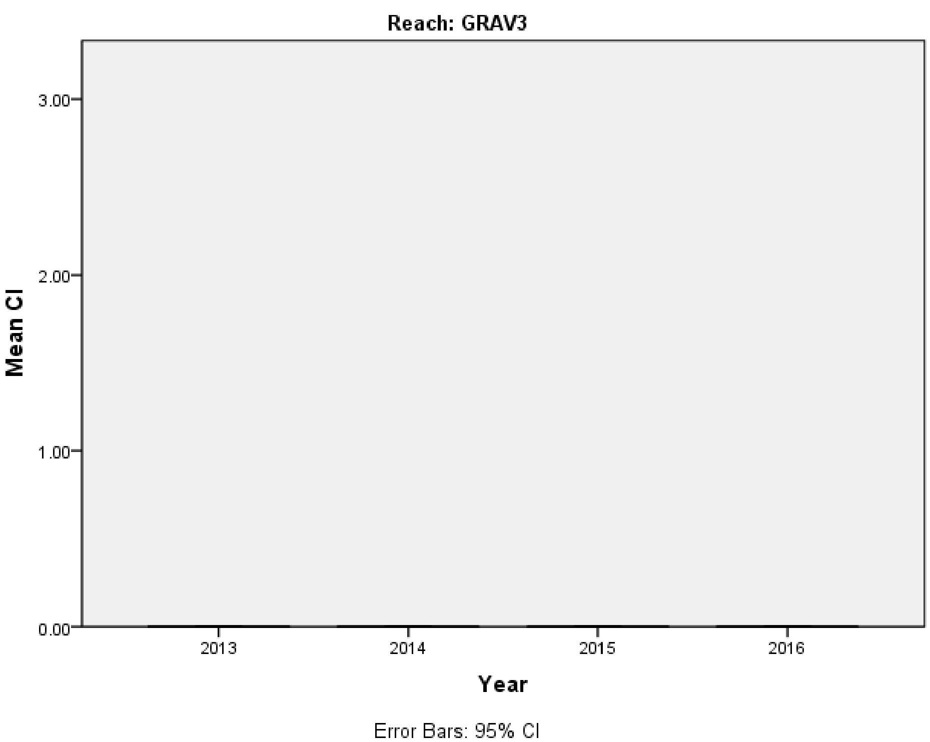

Reach: GODD1
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

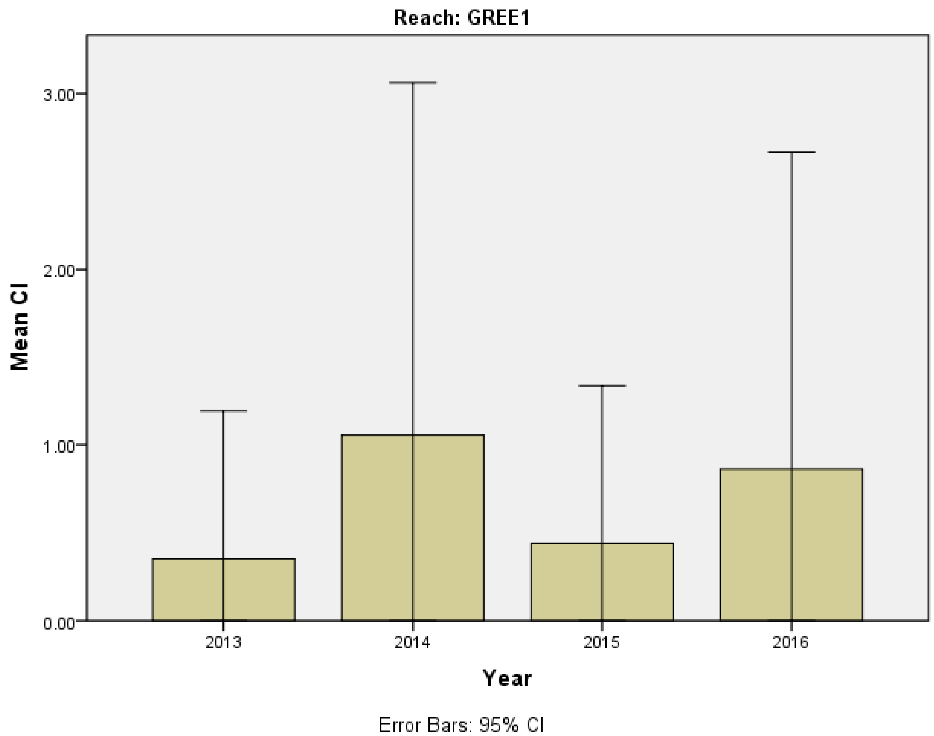

Reach: GODD3
3.00
2.00
1.00
0.00
Mean CI
a,b,c
a
b
c
2013
2014
2015
2016
Year
Error Bars: 95% CI

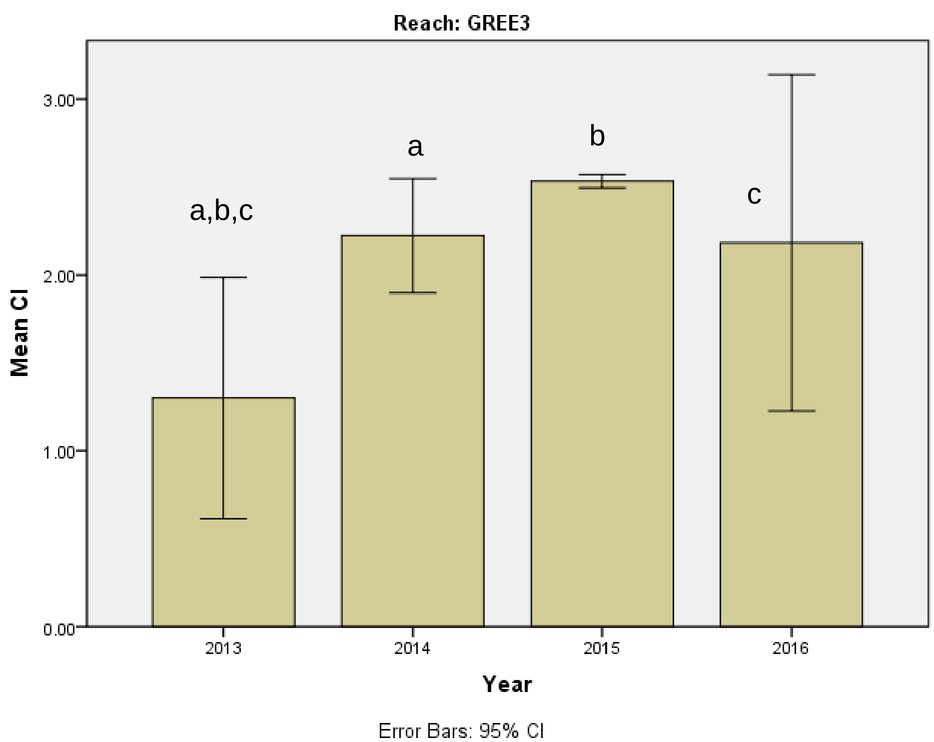

Reach: GRAC1
Mean CI
3.00
2.00
1.00
0.00
a.b
a
b
2013
2014
2015
2016
Year
Error Bars: 95% CI

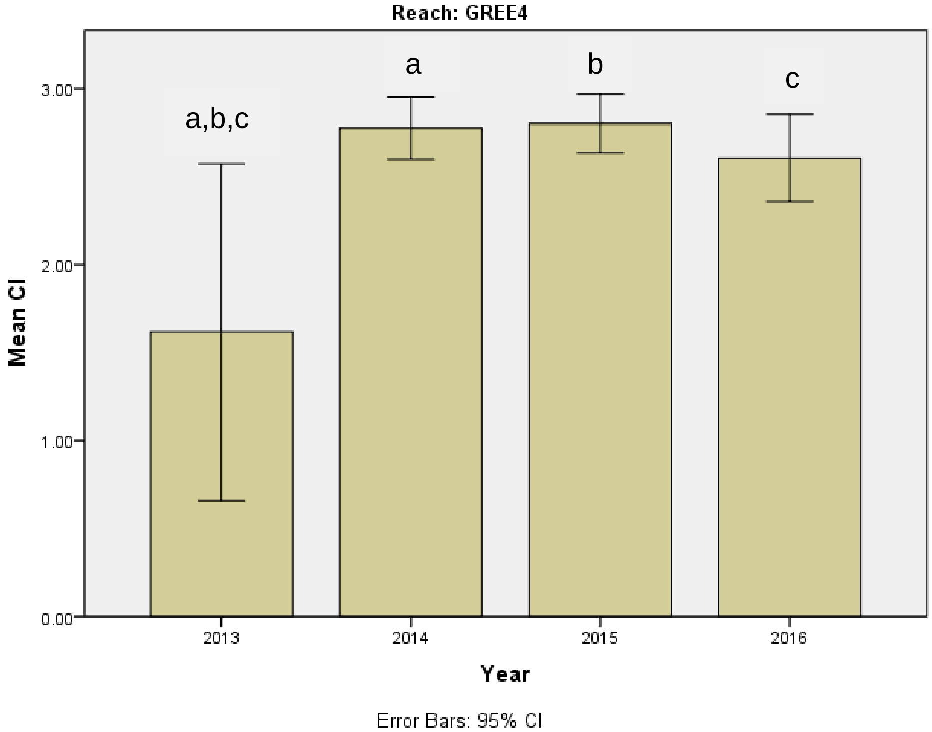

Reach: GRAS1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

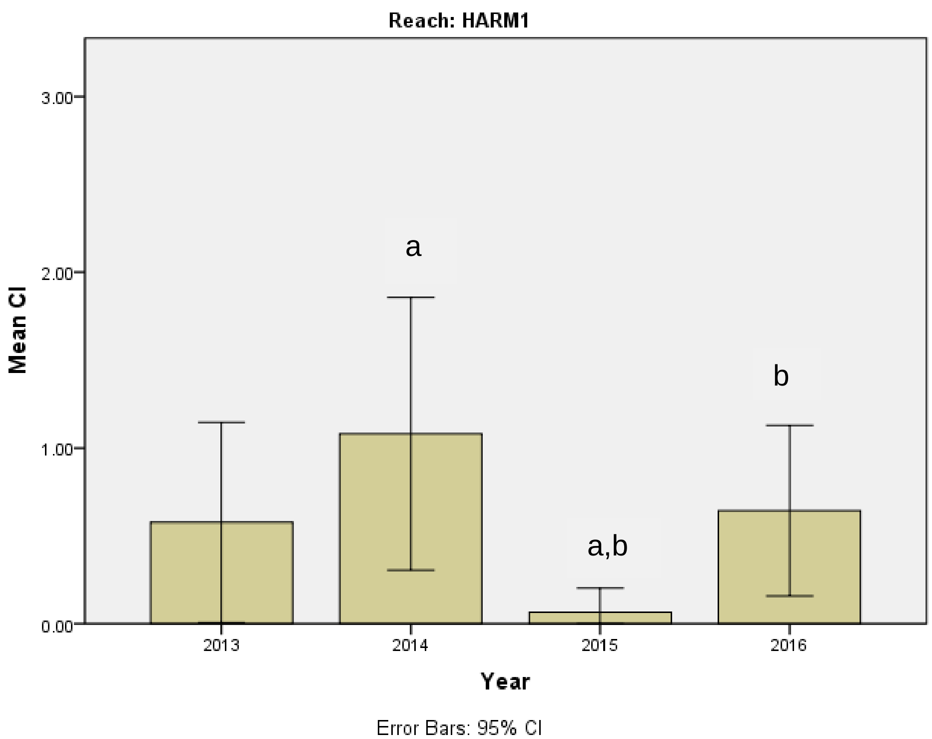

Reach: GRAV1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

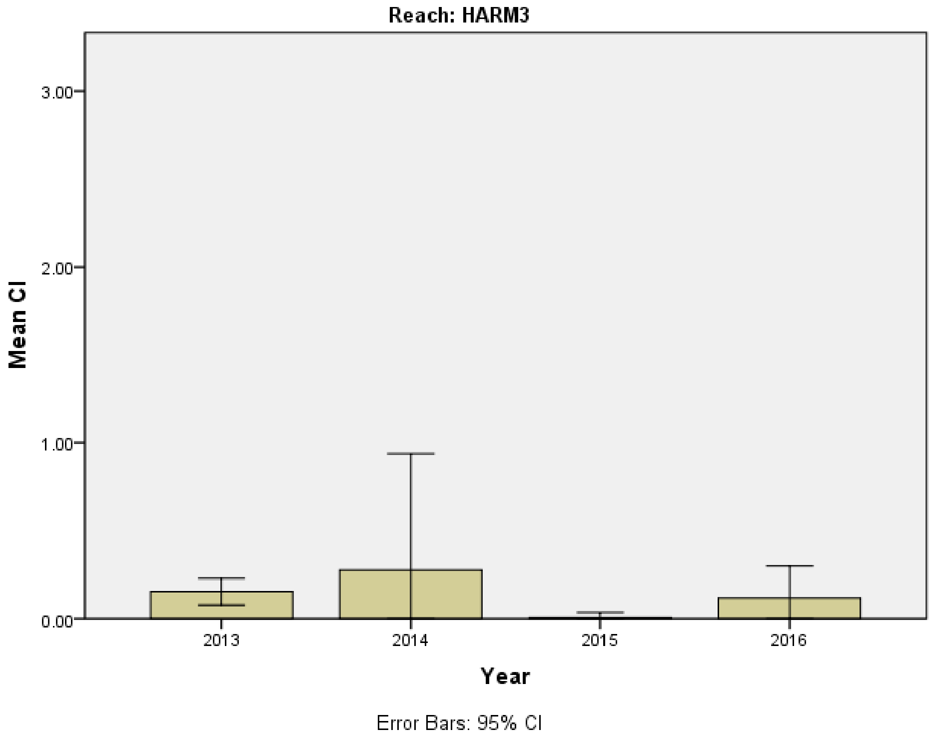

Reach: GRAV3
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

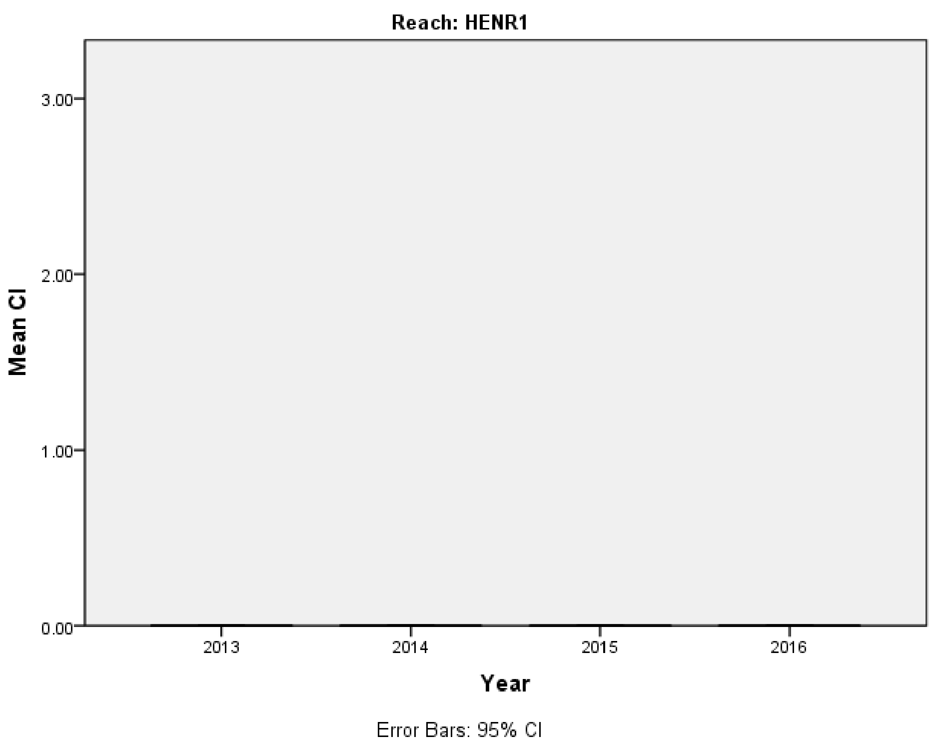

Reach: GREE1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

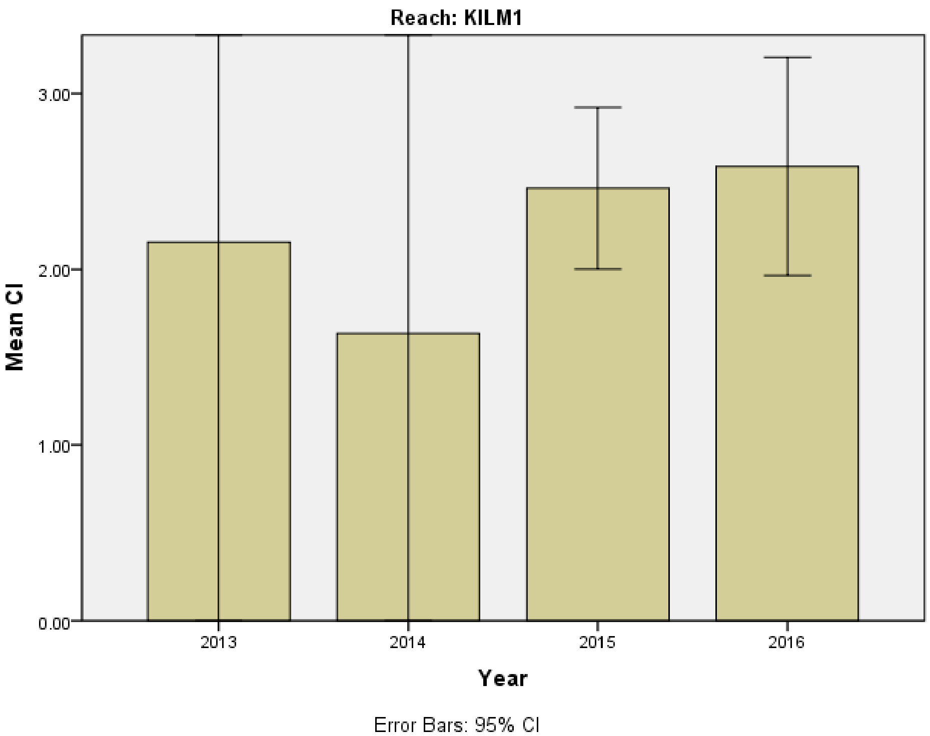

Reach: GREE3
Mean CI
3.00
2.00
1.00
0.00
a,b,c
a
b
c
2013
2014
2015
2016
Year
Error Bars: 95% CI

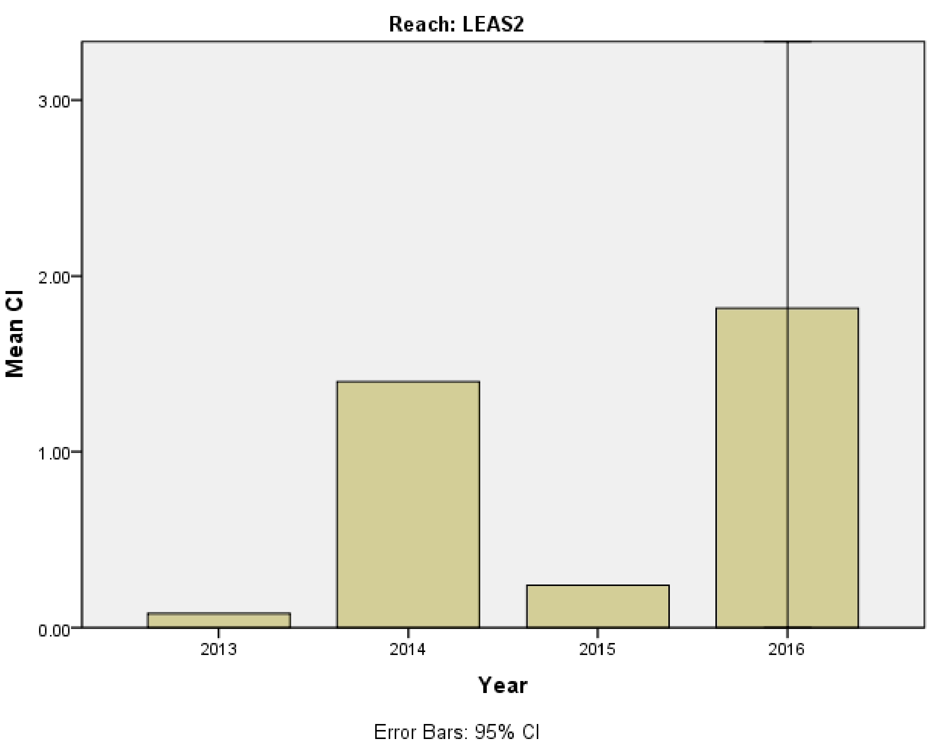

Reach: GREE4
a,b,c
a
b
c
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

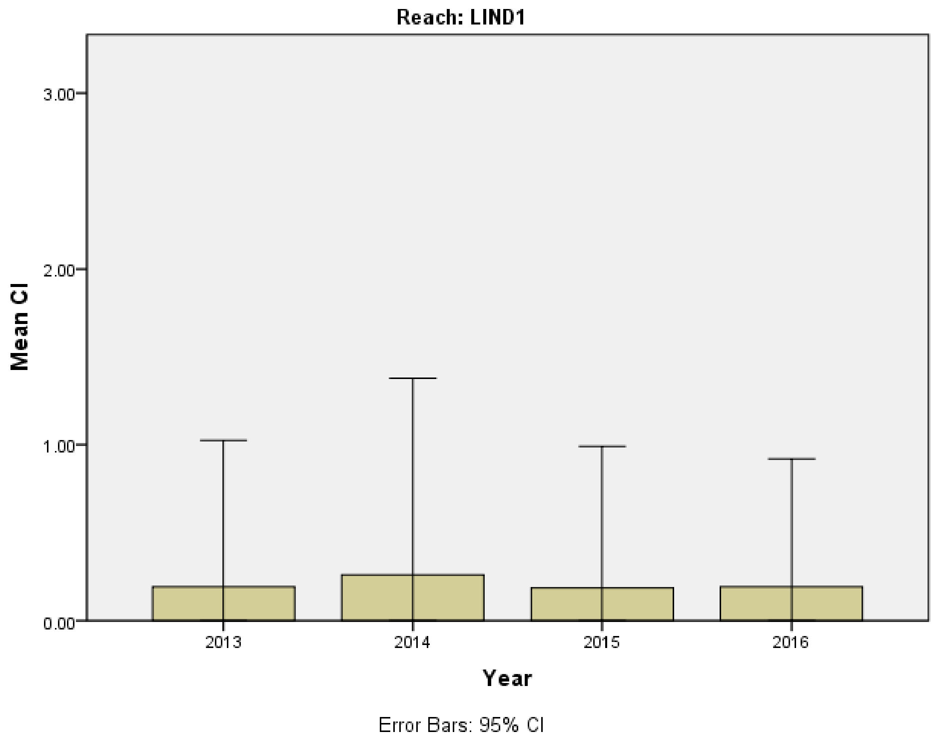

Reach: HARM1
a
b
a,b
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

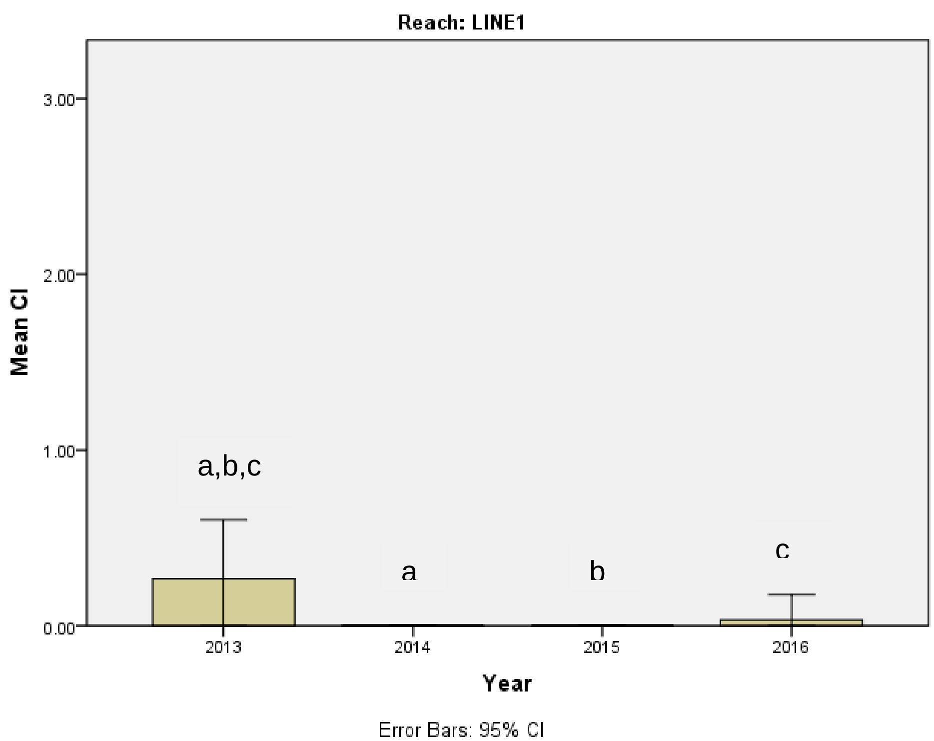

Reach: HARM3
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

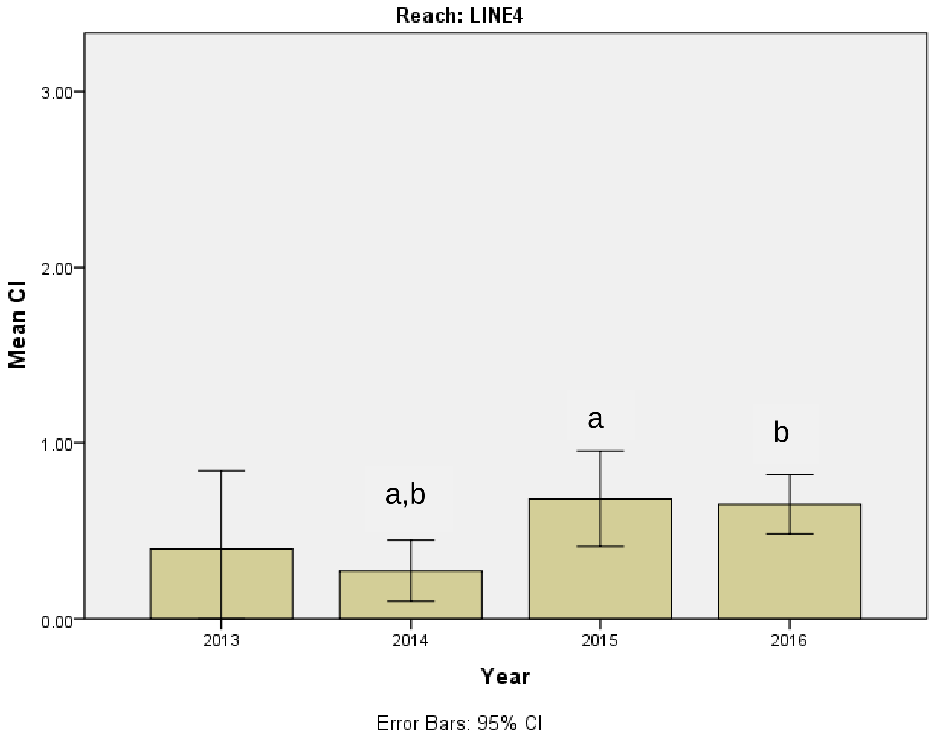

Reach: HENR1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

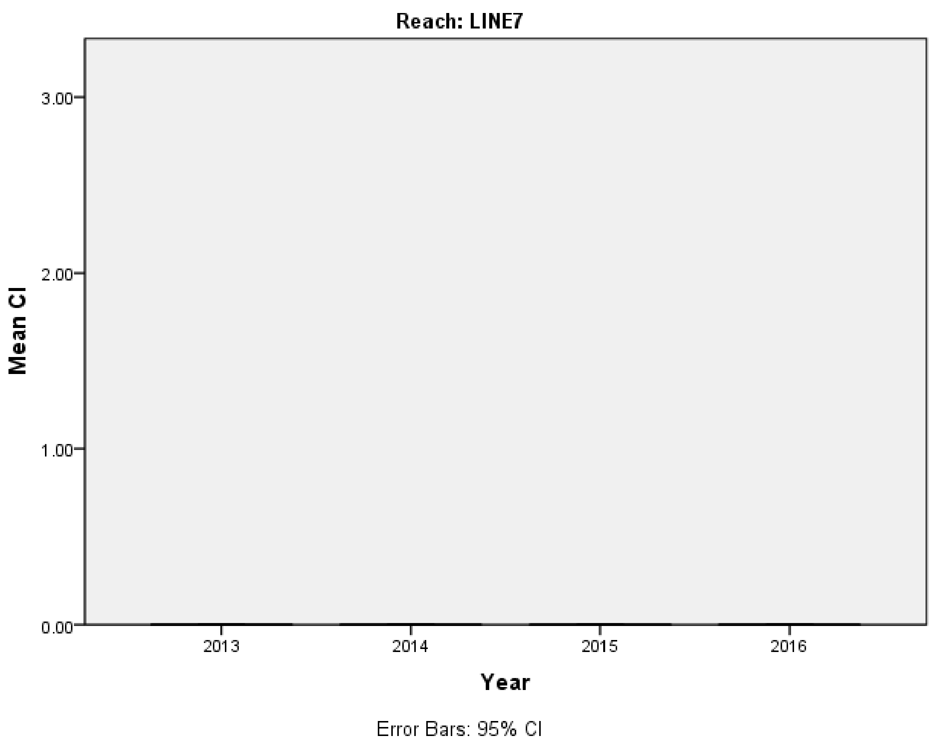

Reach: KILM1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

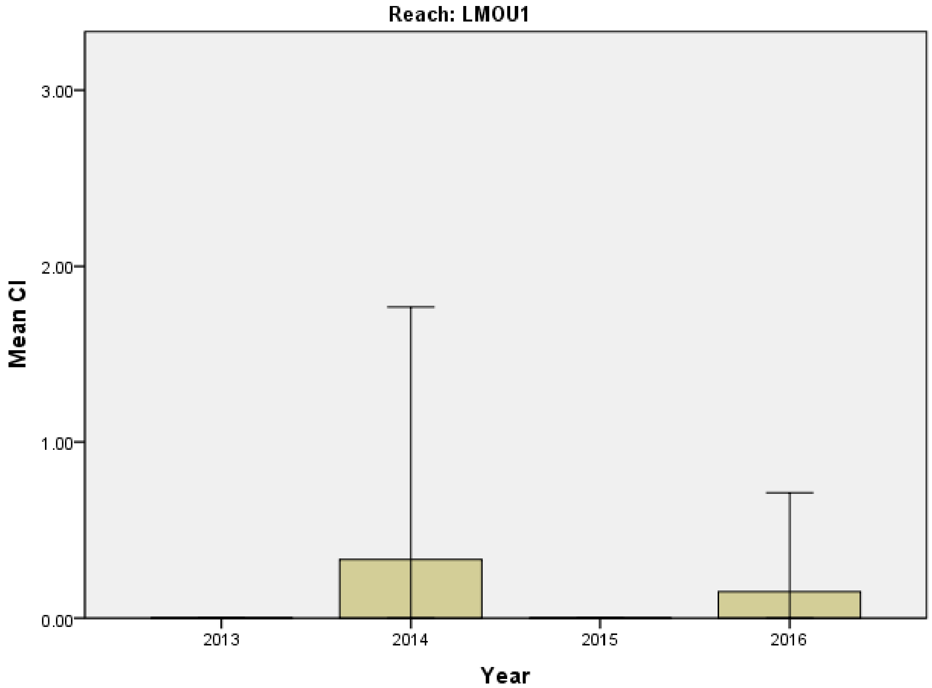

Reach: LEAS2
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI


Reach: LIND1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

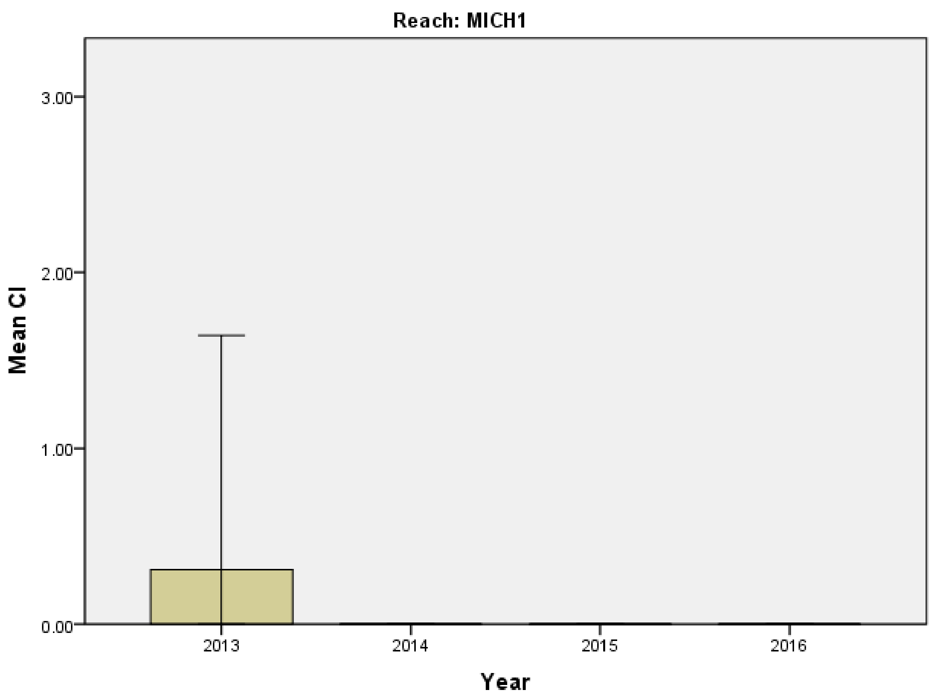

Reach: LINE1
Mean CI
3.00
2.00
1.00
0.00
a,b,c
a
b
c
2013
2014
2015
2016
Year
Error Bars: 95% CI


Reach: LINE4
Mean CI
3.00
2.00
1.00
0.00
a,b
a
b
2013
2014
2015
2016
Year
Error Bars: 95% CI

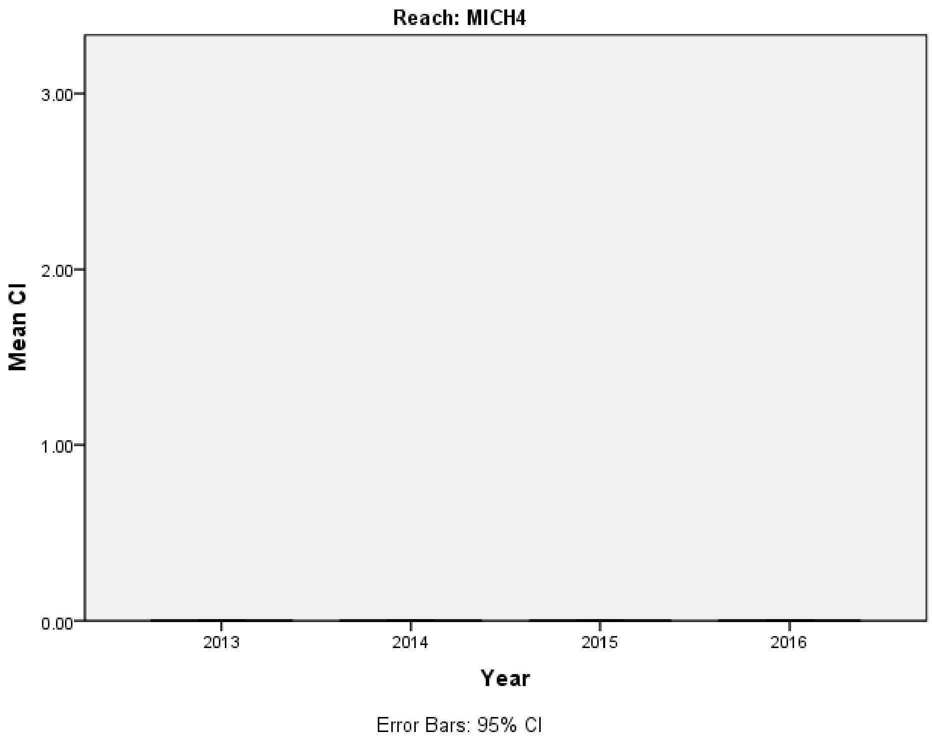

Reach: LINE7
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

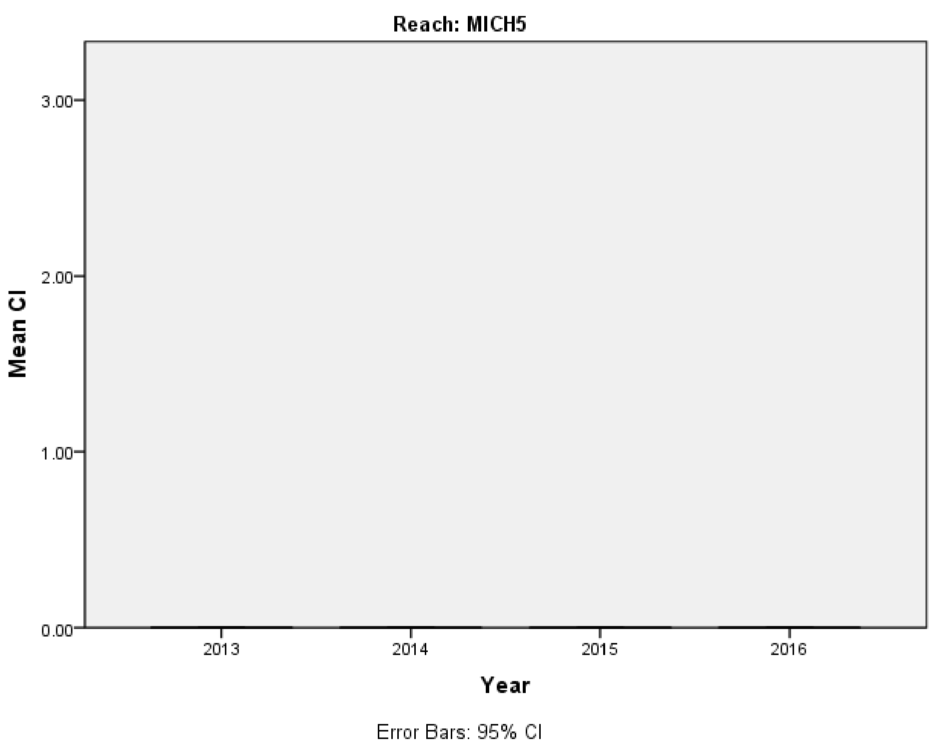


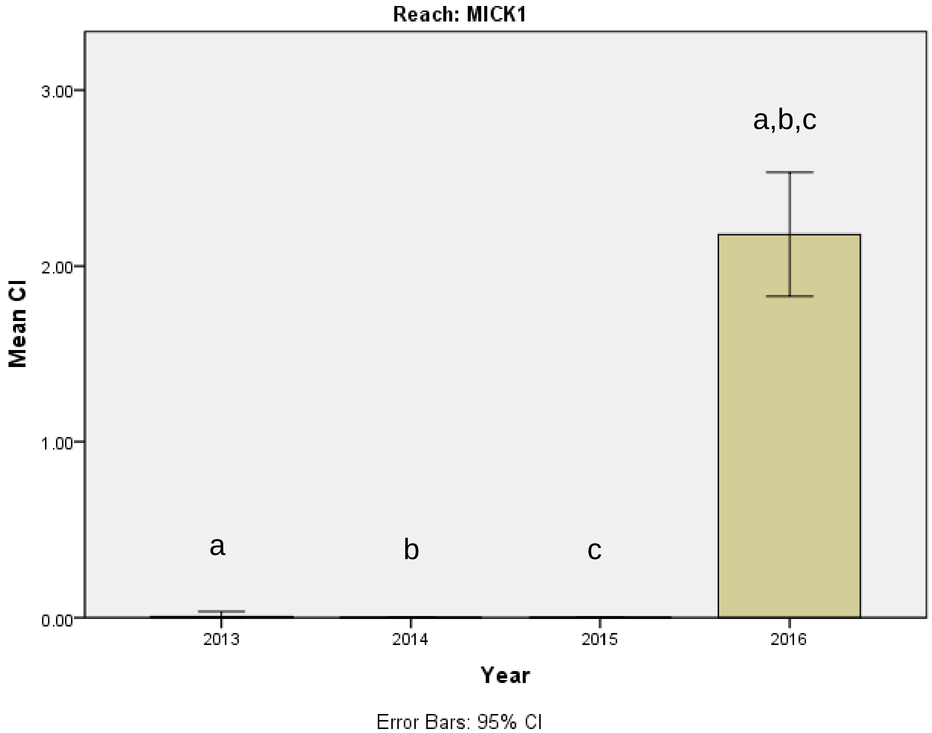
Error Bars: 95% CI

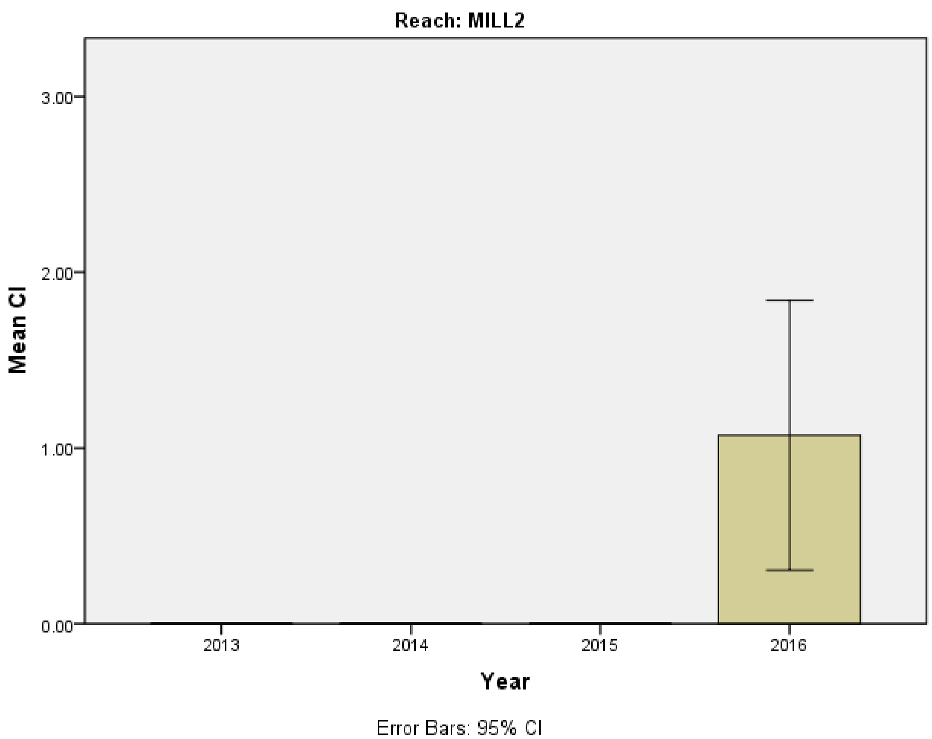


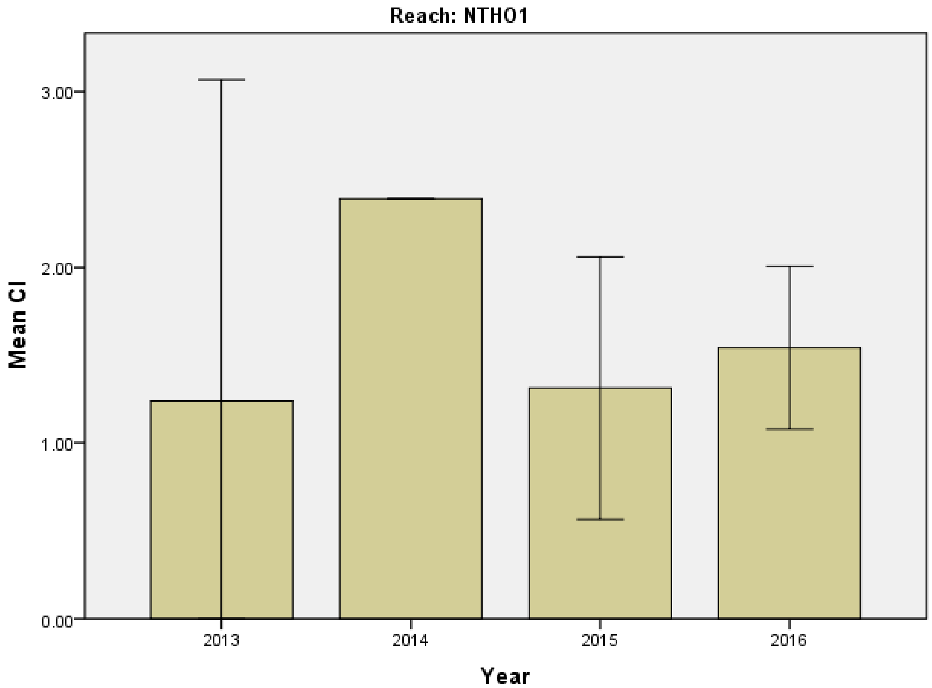
Error Bars: 95% CI


Reach: MICH4
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

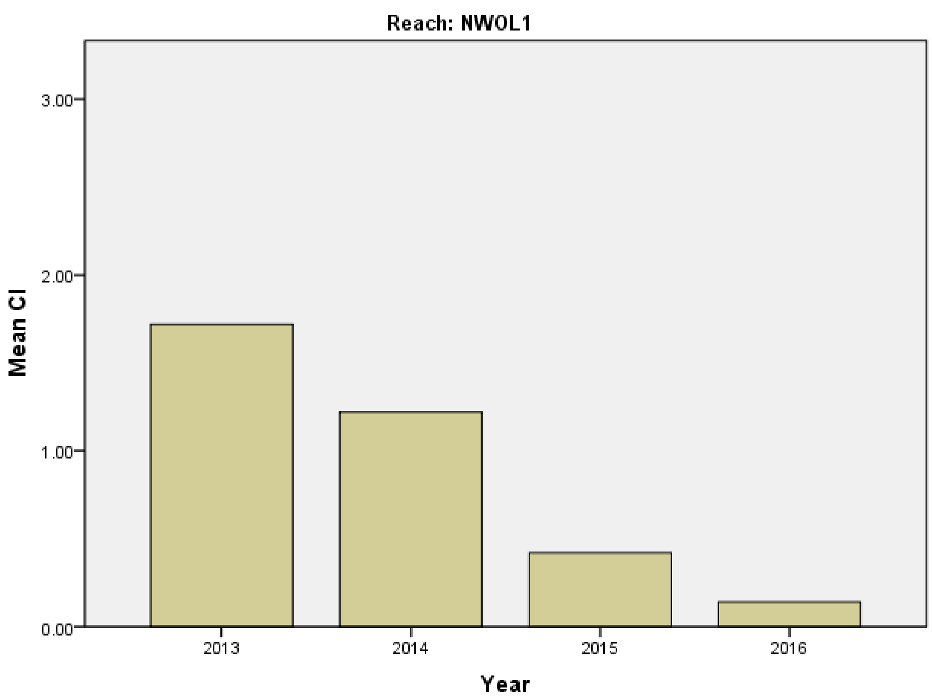

Reach: MICH5
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI


Reach: MICK1
Mean CI
3.00
2.00
1.00
0.00
a
b
c
a,b,c
2013
2014
2015
2016
Year
Error Bars: 95% CI

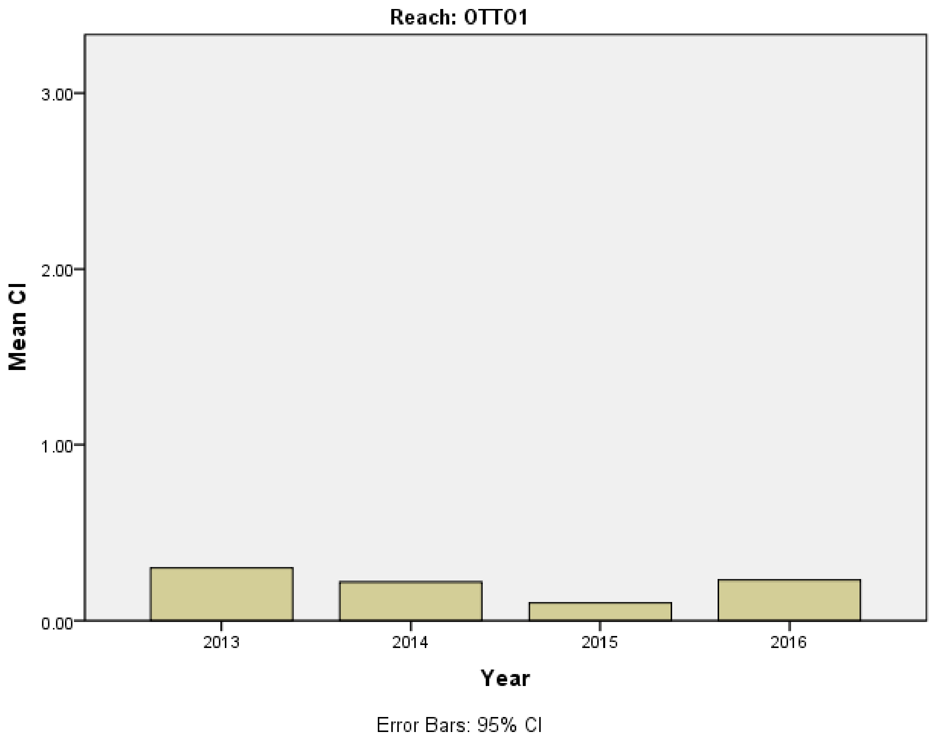

Reach: MILL2
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

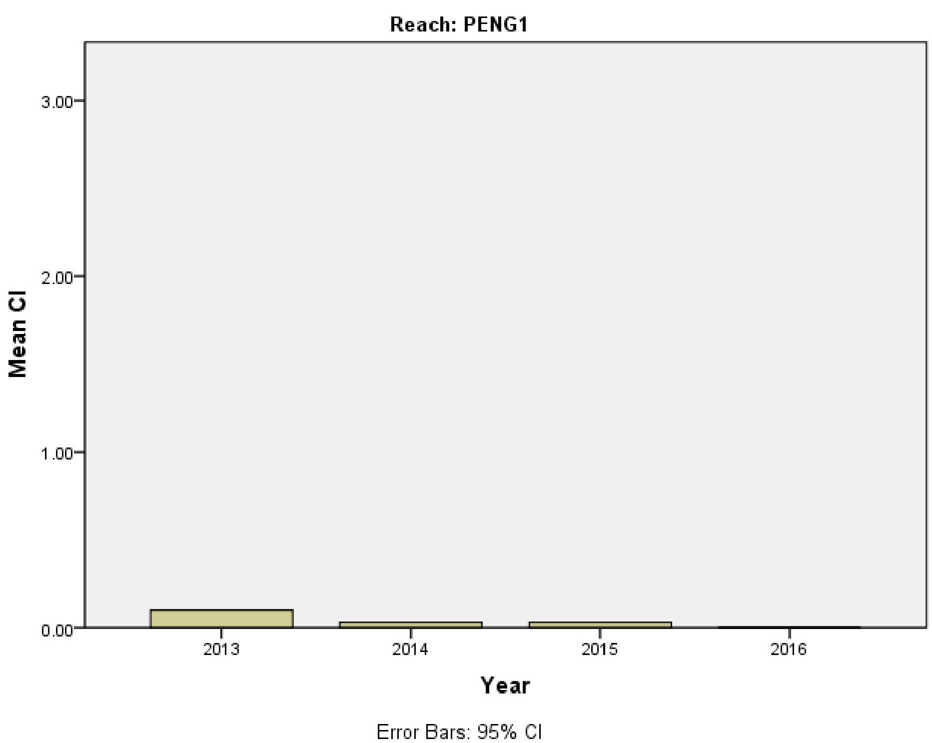


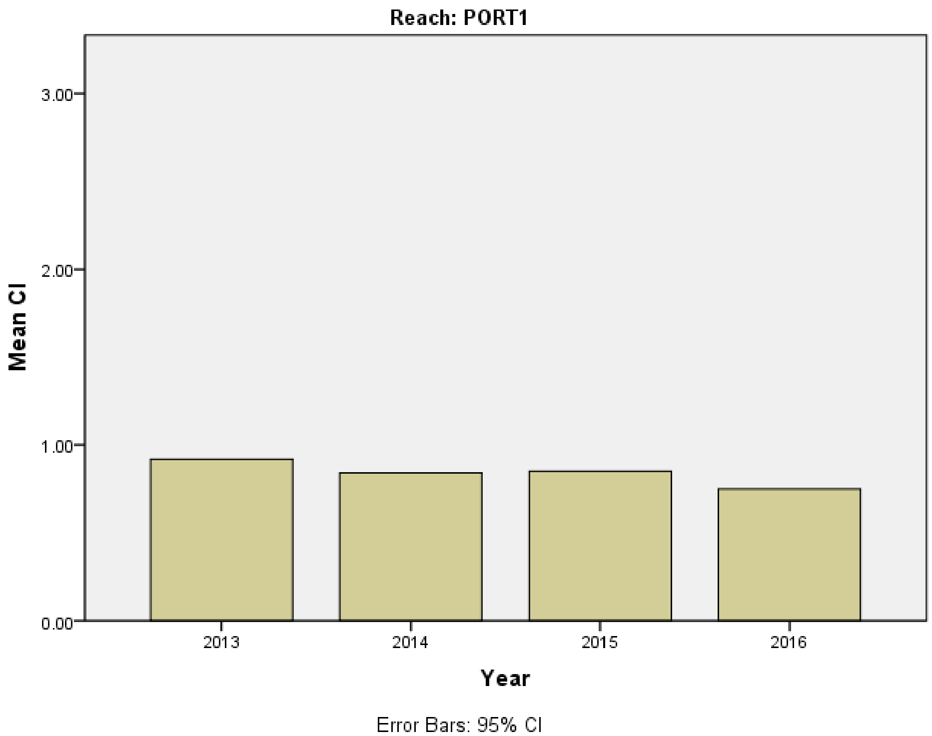
Error Bars: 95% CI

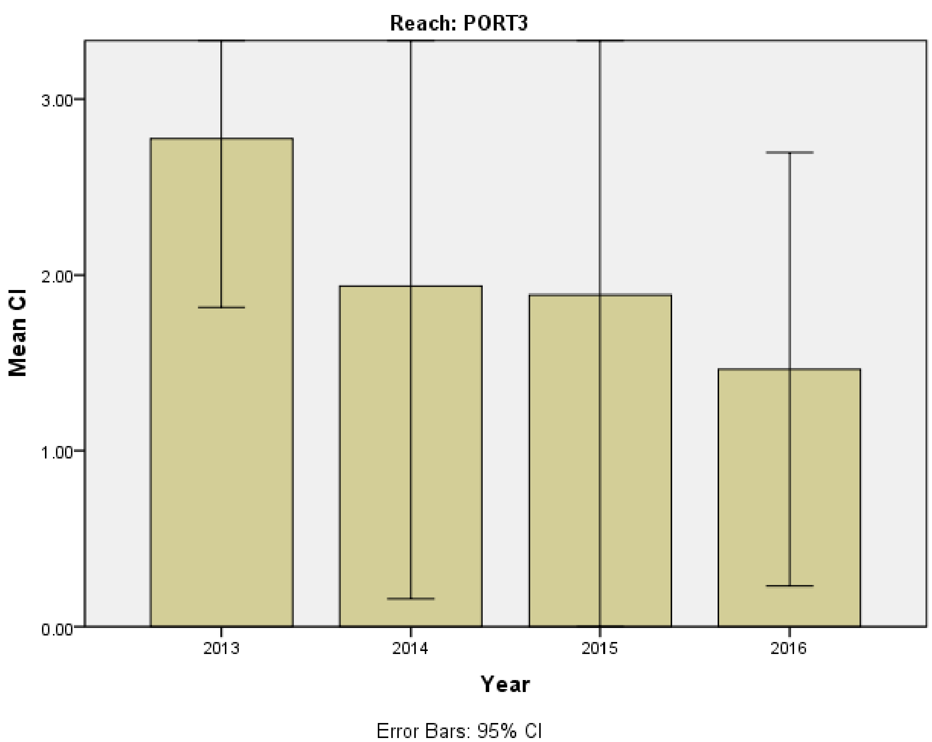


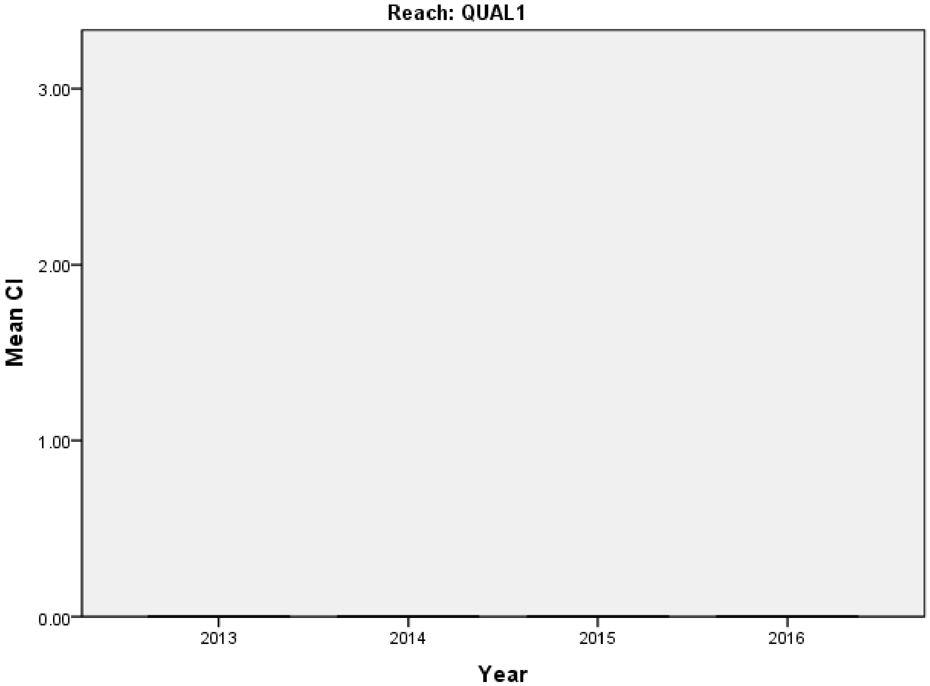
Error Bars: 95% CI


Reach: OTTO1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

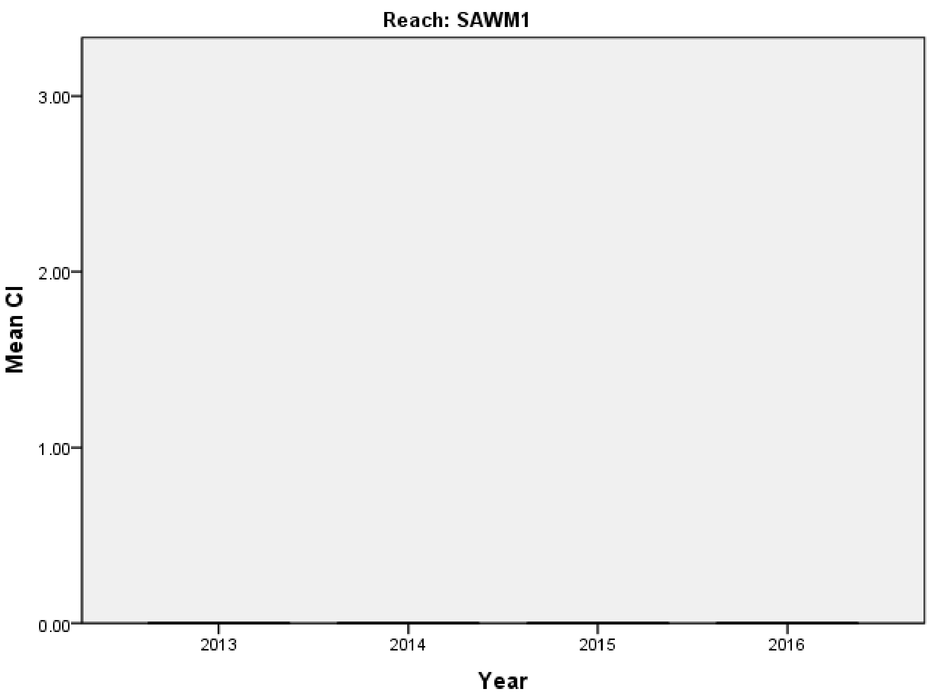

Reach: PENG1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI


Reach: PORT1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

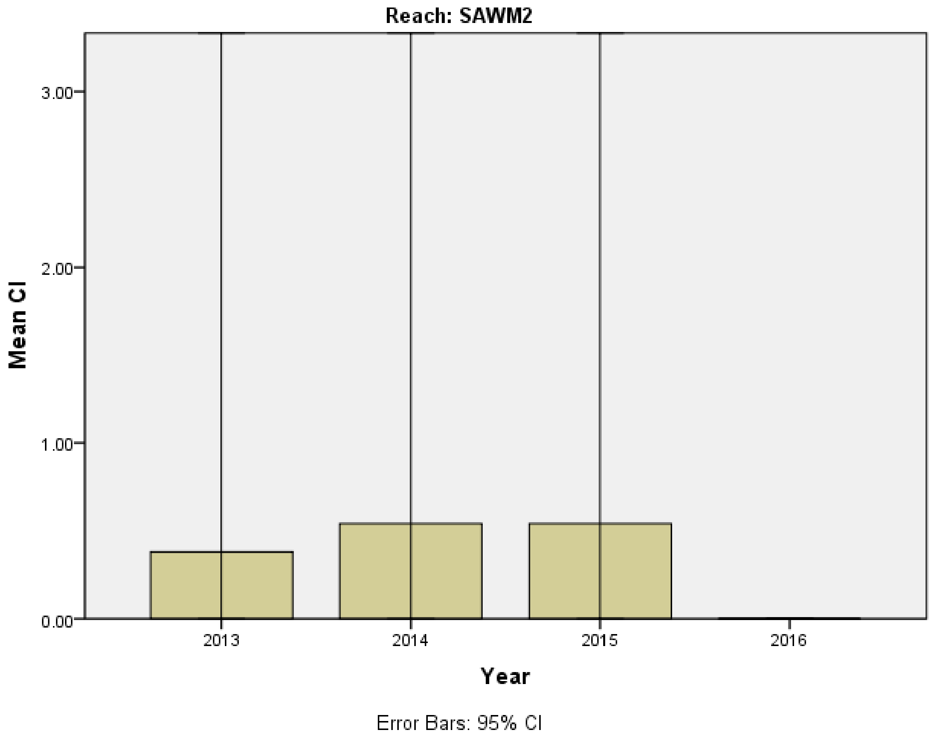

Reach: PORT3
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

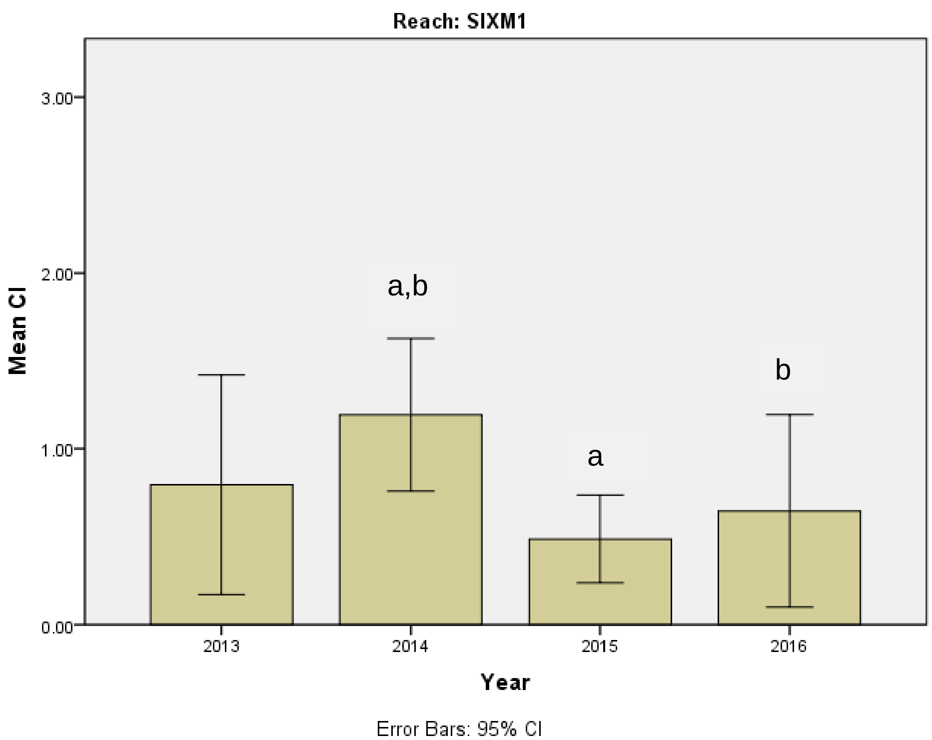


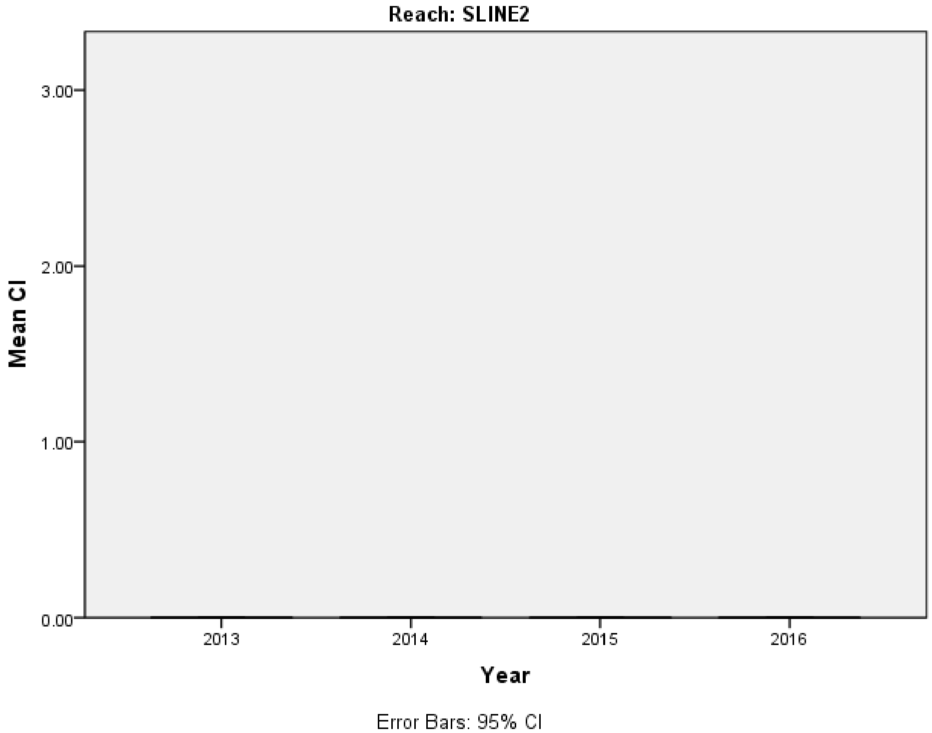
Error Bars: 95% CI

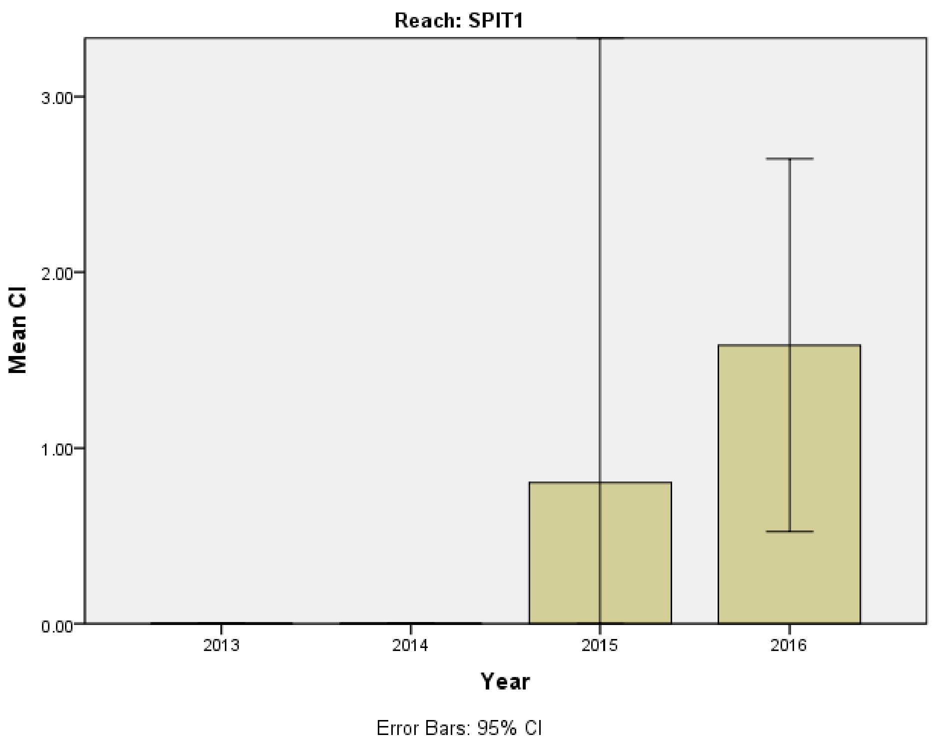


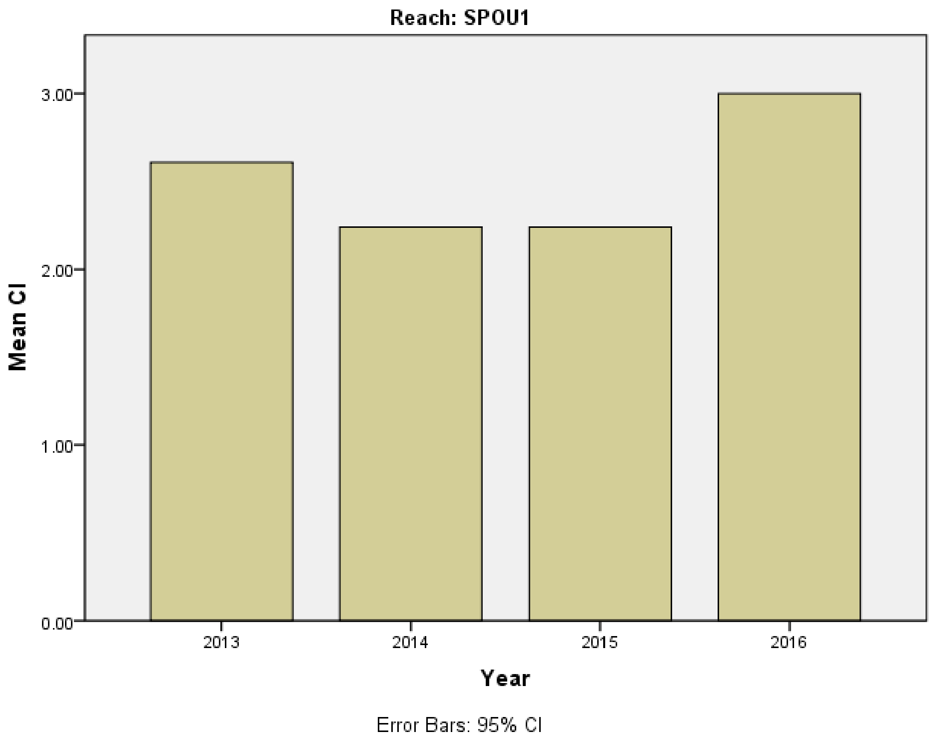
Error Bars: 95% CI

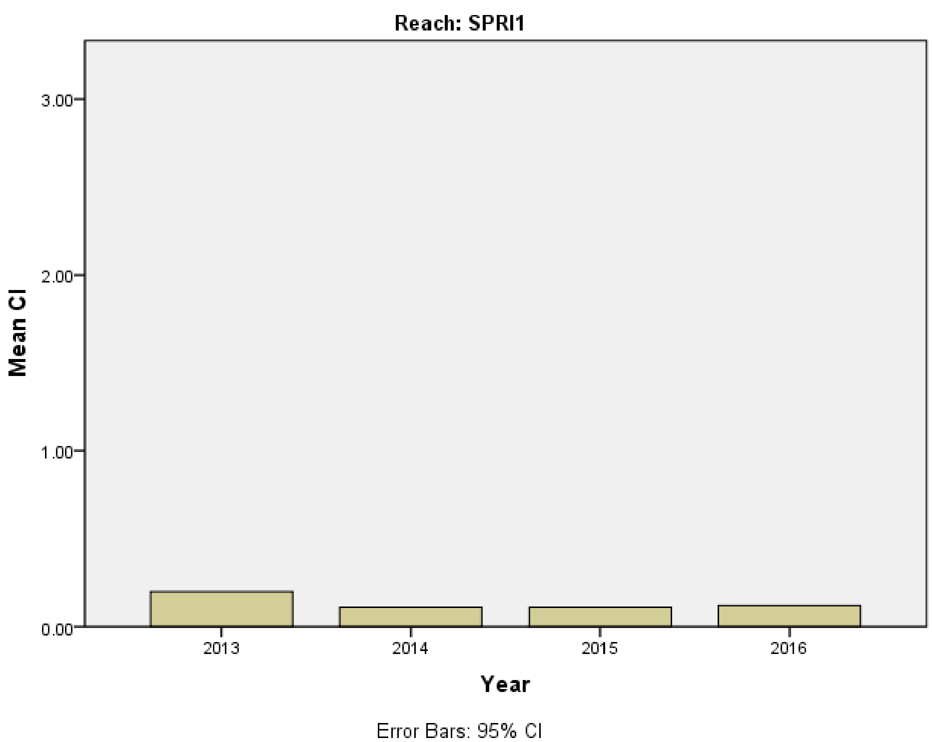

Reach: SAWM2
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI

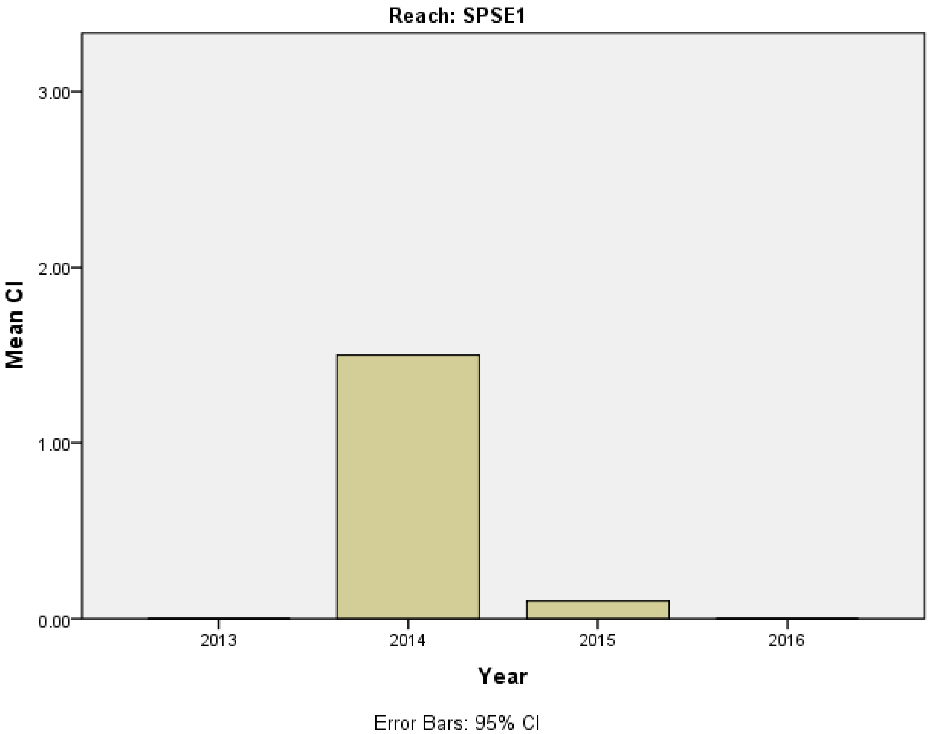

Reach: SIXM1
3.00
2.00
1.00
0.00
Mean CI
a,b
b
a
2013
2014
2015
2016
Year
Error Bars: 95% CI

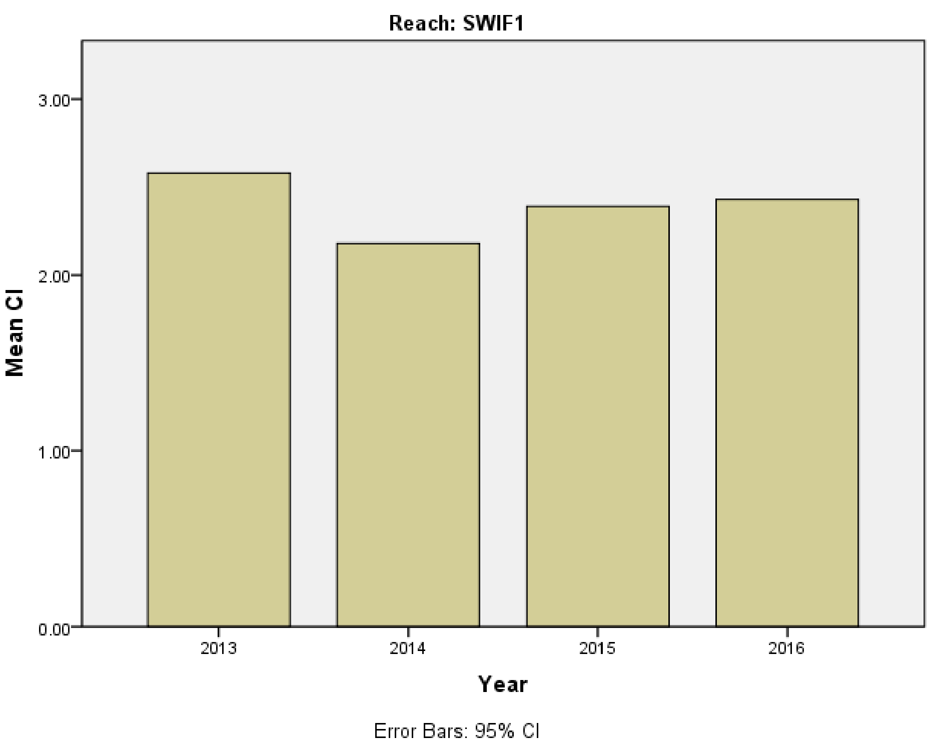

Reach: SLINE2
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

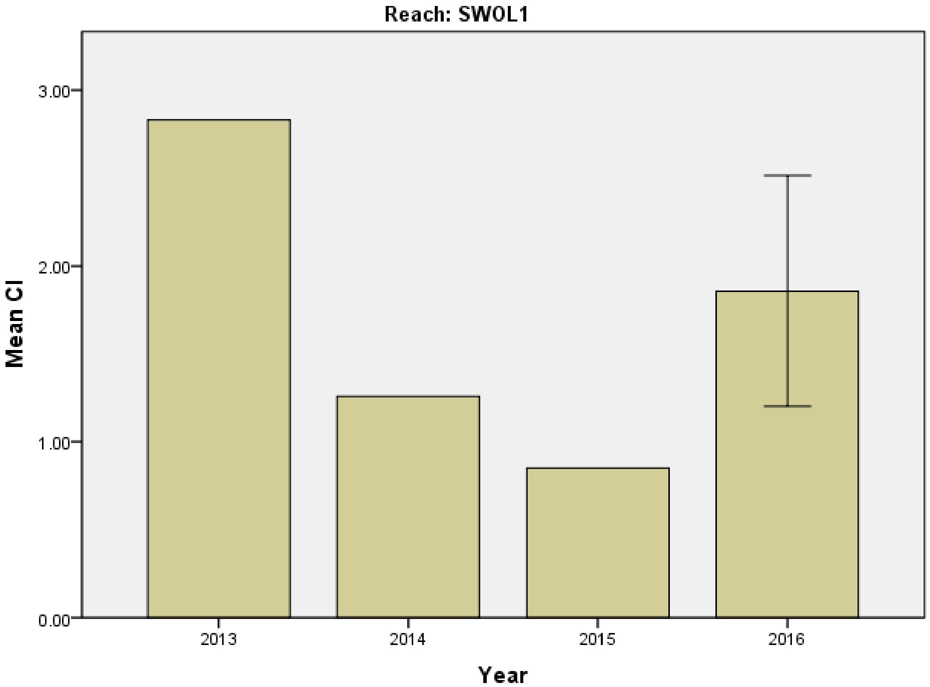

Reach: SPIT1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI


Reach: SPOU1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

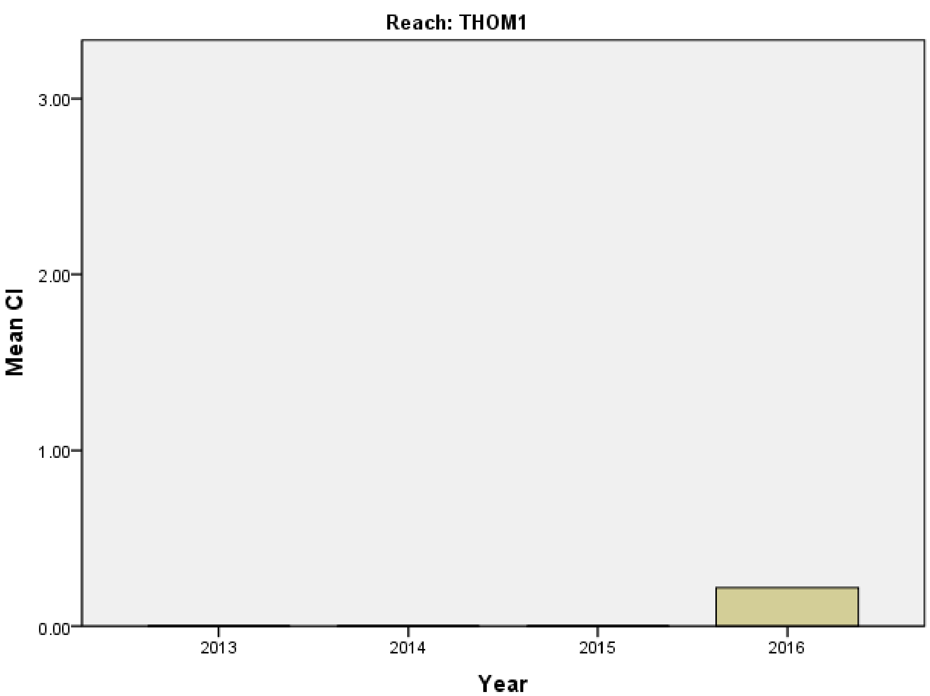

Reach: SPRI1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI


Reach: SPSE1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

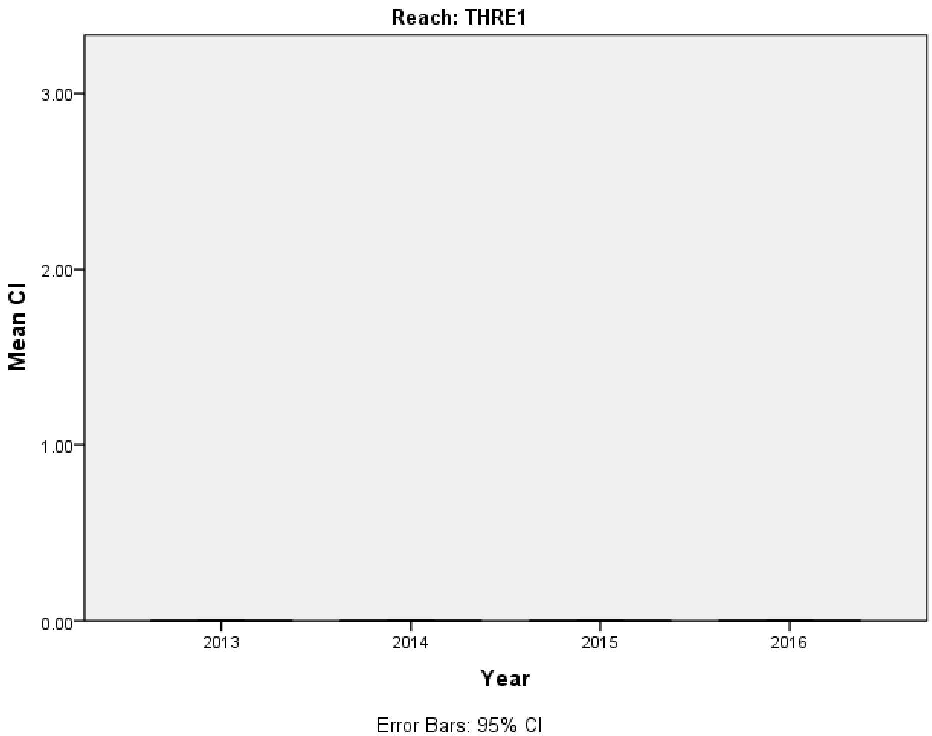

Reach: SWIF1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

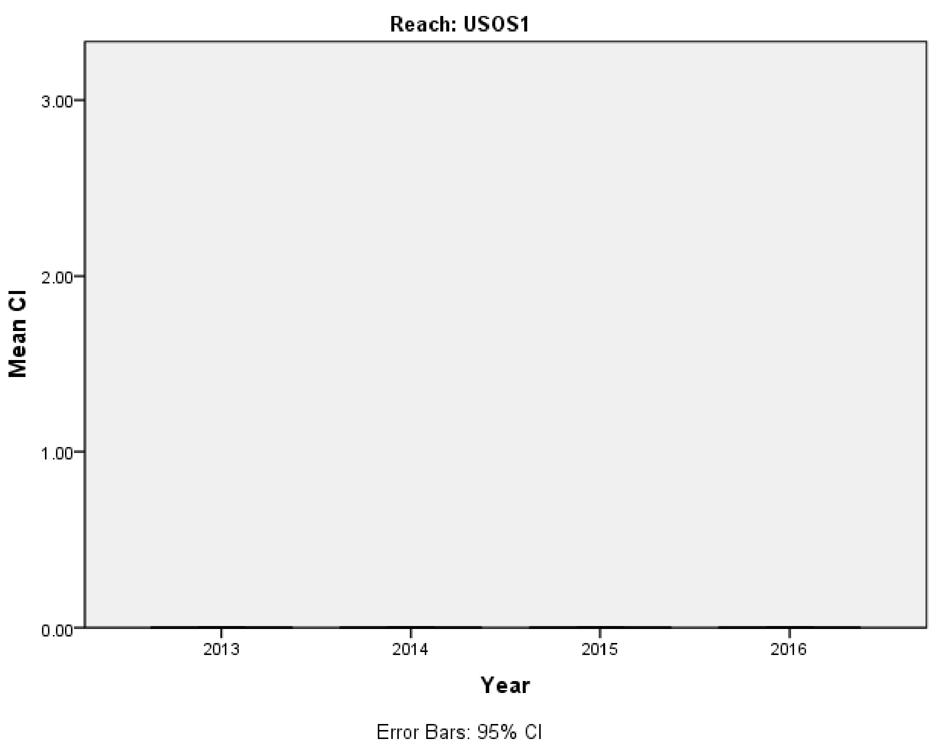


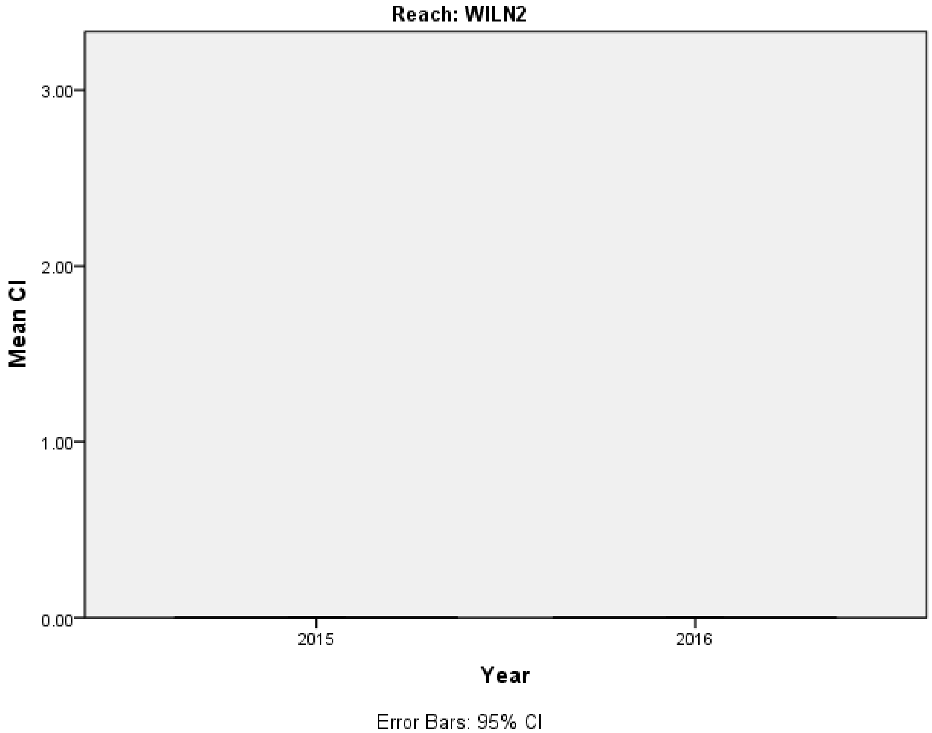
Error Bars: 95% CI

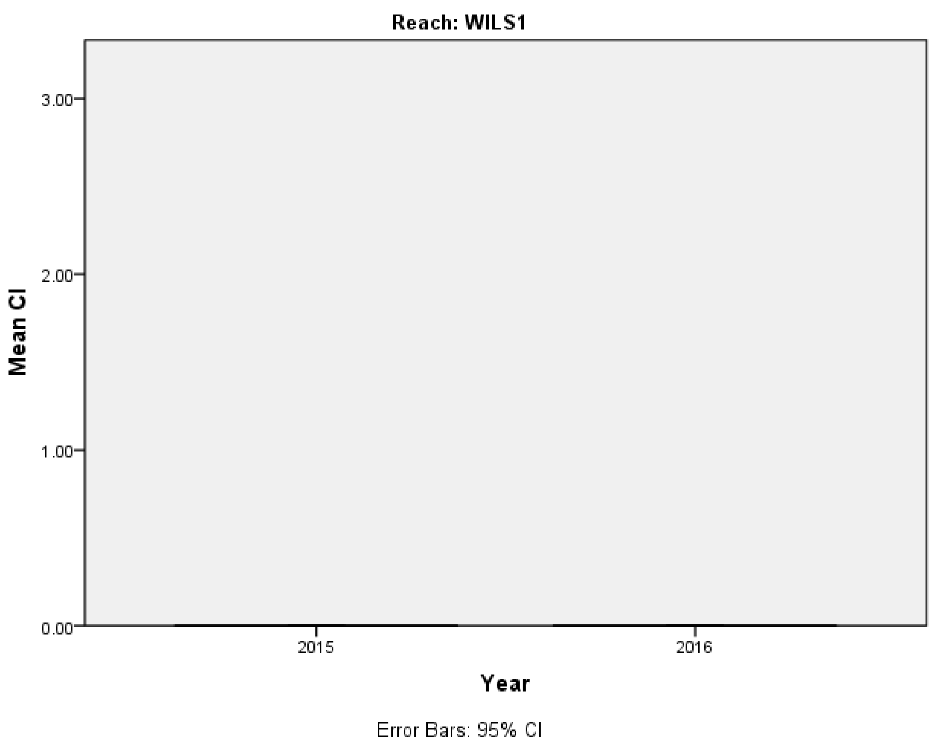


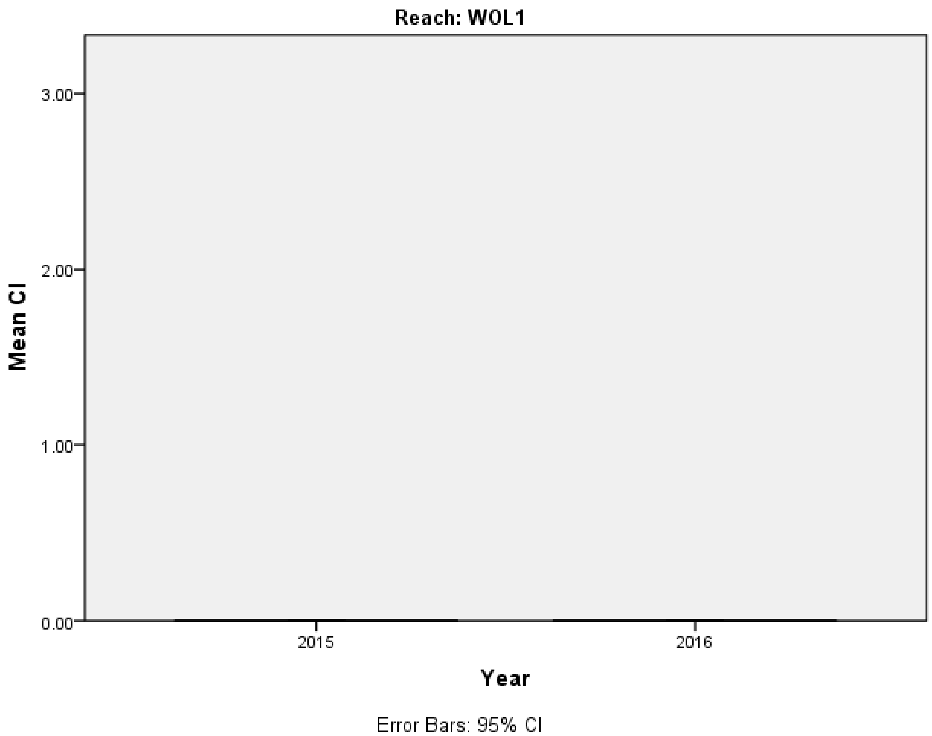
Error Bars: 95% CI

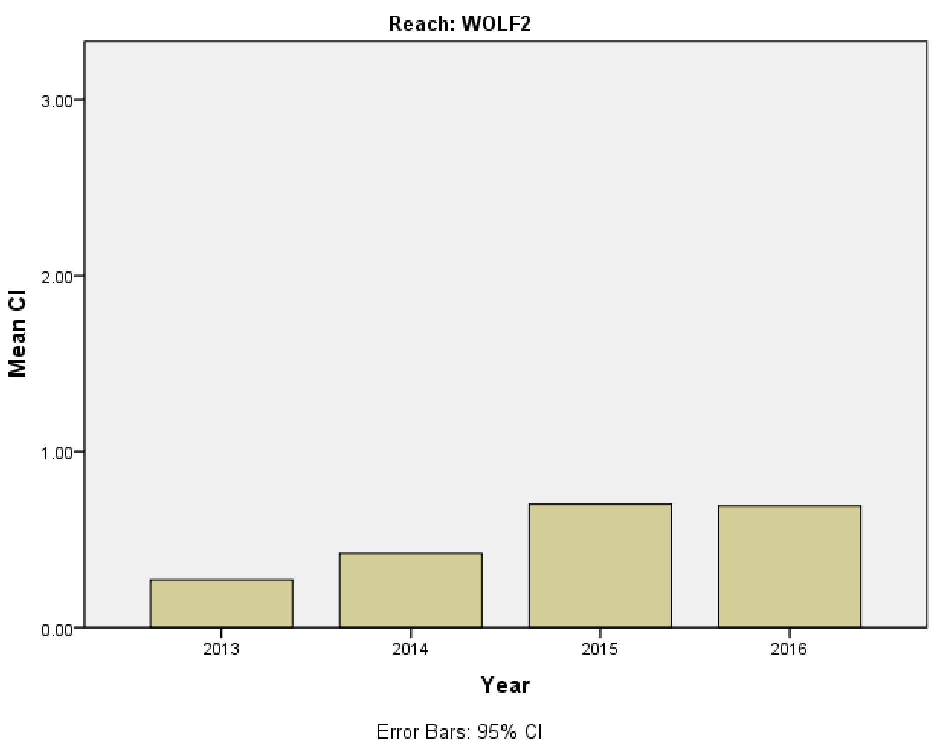

Reach: THRE1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI

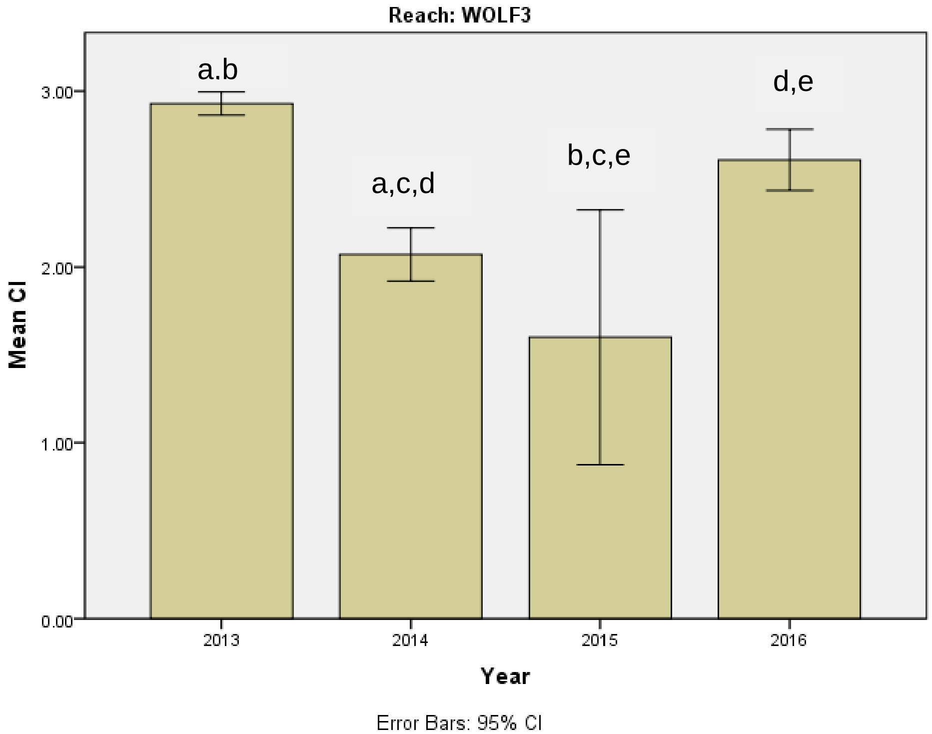

Reach: USOS1
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI


Reach: WILN2
3.00
2.00
1.00
0.00
Mean CI
2015
2016
Year
Error Bars: 95% CI


Reach: WILS1
3.00
2.00
1.00
0.00
Mean CI
2015
2016
Year
Error Bars: 95% CI


Reach: WOL1
3.00
2.00
1.00
0.00
Mean CI
2015
2016
Year
Error Bars: 95% CI


Reach: WOLF2
3.00
2.00
1.00
0.00
Mean CI
2013
2014
2015
2016
Year
Error Bars: 95% CI


Reach: WOLF3
a.b
a,c,d
b,c,e
d,e
Mean CI
3.00
2.00
1.00
0.00
2013
2014
2015
2016
Year
Error Bars: 95% CI