



WI Publication No. WI-2019-06

10 August 2019

The Watershed Institute

Applied Environmental
Science Department

California State University Monterey Bay

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Hollister Hills SVRA

Trail Erosion Surveys

Summer 2019

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Acknowledgements

Thanks to:

- Wes Gray and Hollister Hills SVRA park staff.

This report may be cited as:

Bogdan M, Smith D, Klein J, Somilleda N, and Soares S. 2019. Hollister Hills SVRA Trail Erosion Surveys: Summer 2019. The Watershed Institute, California State Monterey Bay, Publication No. WI-2019-06, 39 pp.

Executive Summary

In 2012 environmental scientists at Hollister Hills State Recreational Vehicle Area (SVRA) issued a report prioritizing trail condition and sustainability based upon a three-level visual assessment and professional judgment. In collaboration with the park's environmental scientists, a representative subset of those trails (18 sites) was selected for more detailed work aimed at quantifying trail erosion through annual topographic surveys. The sample sites were selected to include variability in trail use: road, all-terrain vehicle (ATV), and single-track; soil type: clay and granitic; and trail sustainability: green, yellow, and red. In 2013 a baseline digital elevation model was created for each site using a programmable total station. Each site has been annually resurveyed since that time. The current report presents and analyzes data from June 2018. Changes in the elevation of sites were computed by raster subtraction in ArcGIS. Plots and statistical analyses were done in RStudio.

Annual trail erosion in 2019 was driven by annual rainfall of 21.25 inches. Five of the 18 sites were mechanically-, or hand-graded in 2019. All 18 sites were surveyed and analyzed this year. The overall average topographic change for the entire study area was 0.03 m of erosion. Green sites experienced 0.01 m of erosion while yellow and red sites both showed average erosion of 0.03 m. On average, clay soil sites eroded 0.03 m, while granitic soil sites eroded 0.02 m. Sites with Roads, ATV, and Single-track use respectively lost 0.04 m, 0.01 m, and 0.02 m of soil. Average erosion of unmanaged sites was 0.02 m while managed sites lost an average of 0.03 m.

Six years of data are summarized and plotted to indicate that:

- Red trails erode significantly more than yellow or green trails when six-year cumulative change is computed,
- rainfall does not correlate with erosion rates,
- trail use and soil type do not greatly influence erosion rates, and
- management activities reduce annual erosion rates to near 0 m/yr.

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1 Introduction

In 2012 Hollister Hills State Recreational Vehicle Area (SVRA) (Fig. 1) environmental scientists created an index to rate the sustainability of the trails in the park: green (acceptable), yellow (marginal), and red (action needed). The rating index was based on a visual assessment of the trail physical context and condition (HHSVRA 2012), as outlined in California Department of Parks and Recreation Soil Conservation Guidelines/Standards for Off-Highway Vehicle Recreation Management (CDPR 2008). This effort was undertaken to inform best management practices that would optimize soil conservation in the park. While the rating system was based upon observations of parameters that are commonly understood to foster or retard erosion, the park staff recognized the need to quantitatively validate and calibrate the system.

In 2013, park staff collaborated with Cal State Monterey Bay to study the annual erosion of a subset of trails that had been visually indexed. The study included 18 sites across the SVRA to account for geologic substrate (Granitic and Clay), vehicle use types (Single Track, ATV, and Road), and trail erodibility index (Green, Yellow and Red) (Fig. 2). The first trail surveys set the baseline topography in 2013 (Teaby et al. 2013). In each year thereafter, repeat surveys have estimated the annual and cumulative vertical erosion in each study site (Silveus et al. 2014; Chow et al. 2015, 2016; Smith et al. 2016; Morris et al. 2018, Smith et al. 2019).

Trails were also analyzed based upon whether they were “managed” in a given year. Trail management, whether done by hand-tool or mechanical means, is restricted to replacing the side-cast erosion berm back into the tread of the trail. For our study, a trail is considered “managed” if the activity occurred at any time between two consecutive surveys. The Rancho assessment site (Fig. 2) is the only site to have been regraded with imported material during the study period. In 2015, before the 2016 surveys, the Rancho site was raised approximately 1 m by the addition of material imported from the cleanout of Lodge Lake retention basin. The 2016 survey from that site has been excluded from further analysis.

The survey methods used in the study have evolved through time, but local elevation changes have been consistently linked to 3D benchmarks established at each site in 2013. A programmable total station was used in the 2013 and 2014 surveys. Thereafter, very low altitude (~3 m) photogrammetry has been achieved by attaching a gimbaled Go-Pro camera to a long pole. The switch to photogrammetric techniques produced much denser topographic data sets, and fostered a gradual increase in assessment area of each site. Agisoft PhotoScan software was used to create orthomosaic images and digital elevation models from 2015 to 2017. In 2018 we transitioned to Pix4D software for data processing.

This report documents the topographic changes between May 2018 and May 2019.



Figure 1. Hollister Hills State Vehicular Recreation Area is found northeast of Salinas.

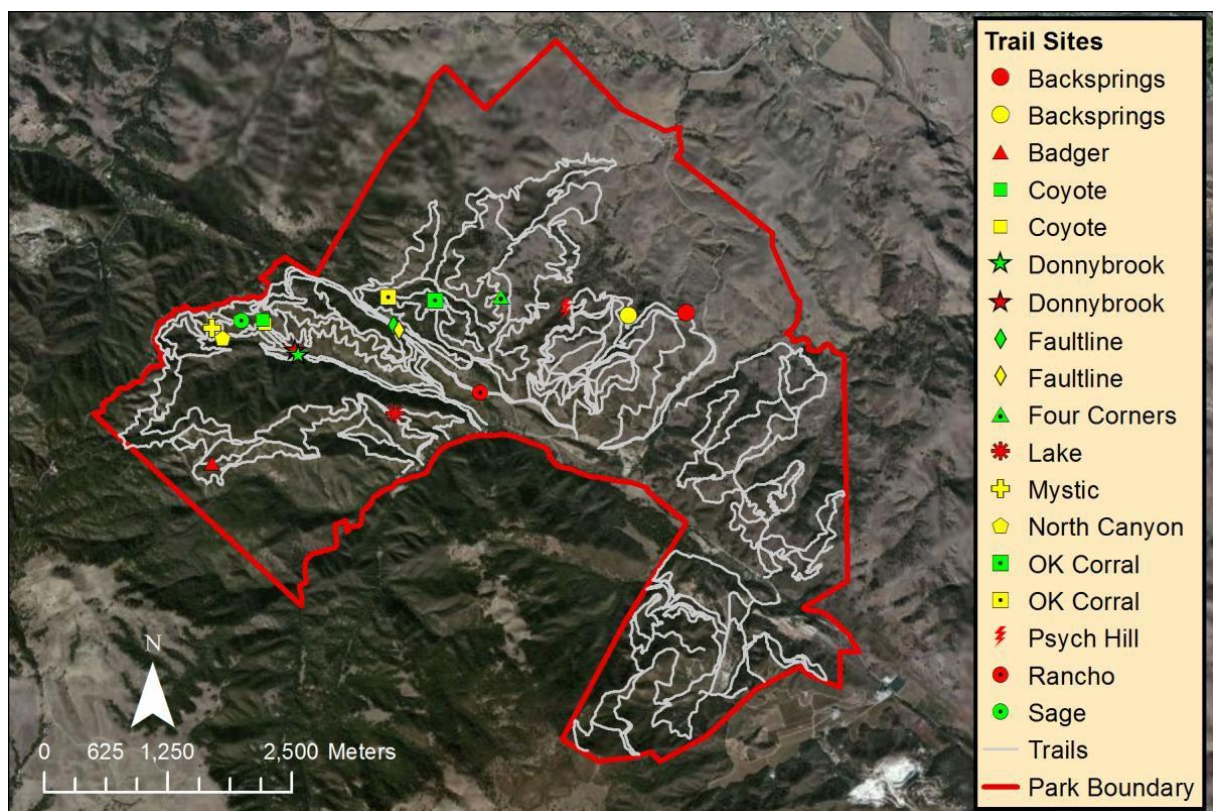


Figure 2. Trail site locations within Hollister Hills State Vehicular Recreation Area, Hollister, CA. Colors correspond to visual rating index.

Approximately 21.25 inches of rain fell between the 2018 and 2019 trail surveys. That value is approximately double the median for 8 years of record, and is much wetter than the

average of 14.91 inches (Table 1; Fig. 3).

Table 1. Hollister Hills SVRA precipitation data obtained from Western Weather Group (2019).

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
2011	0.89	2.29	4.15	1.81	4.07	4.57	0.20	1.11	0.37	0.00	0.00	0.00	19.46
2012	0.83	1.96	0.11	2.28	0.62	2.62	2.18	0.03	0.06	0.03	0.00	0.00	10.72
2013	0.27	2.54	4.35	0.98	0.75	0.60	0.21	0.00	0.00	0.00	0.00	0.08	9.78
2014	0.11	0.28	0.34	0.20	2.72	1.56	0.76	0.00	0.00	0.00	0.00	0.08	6.05
2015	1.05	0.51	5.23	0.00	1.26	0.17	1.14	1.24	0.00	0.02	0.06	0.08	10.76
2016	0.18	3.42	2.97	5.67	0.88	5.23	0.87	0.08	0.00	0.00	0.00	0.00	19.30
2017	2.76	1.53	2.20	9.70	6.27	1.91	1.55	0.06	0.06	0.00	0.00	0.05	26.09
2018	0.23	1.43	0.29	2.48	0.27	4.62	1.43	0.00	0.00	0.00	0.00	0.00	10.75
2019	0.30	3.78	1.94	3.54	7.56	2.35	0.30	1.48	0.00	0.00	0.00	0.00	21.25

Monthly Average	0.74	1.97	2.40	2.96	2.71	2.63	0.96	0.44	0.05	0.01	0.01	0.03
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Annual Average **14.91**

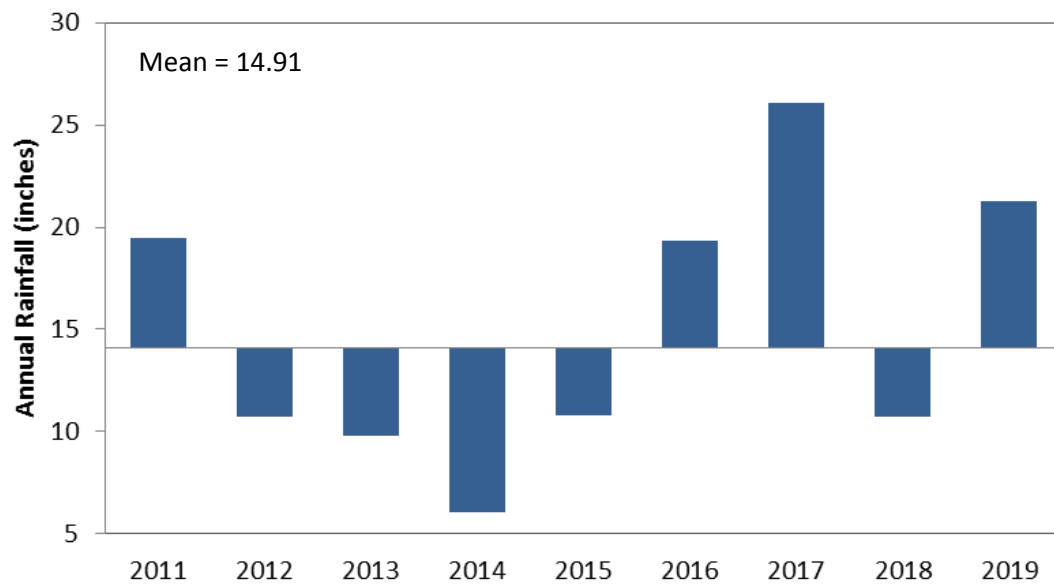


Figure 3. Annual precipitation at Hollister Hills SVRA. Values shown with respect to the mean value of 14.91 inches.

2 Methods

2.1 Field Survey

All 18 sites surveyed in 2018 were revisited in 2019 and surveyed using the same local benchmarks (BM) for horizontal and vertical referencing. At each site, one BM with known 3D position was occupied with a 3" Nikon total station. A backshot to a second BM established the horizontal control.

Within the survey footprint of the 2017 survey, 10 cm x 10 cm, plastic square ground control points (GCPs) were placed in a zig-zag pattern throughout the trail and temporarily nailed in place. The local 3D coordinate of each GCP was found using the total station. Surveys were closed with errors typically under 0.01 m in each dimension.

Low-altitude aerial photos were captured with a Hero 3+ GoPro in a “mowing the lawn” pattern at different angles to ensure sufficient photo overlap and that each photo contained multiple GCPs. We processed the photos for each site using Pix4D (<https://www.pix4d.com/>).

2.2 Surface Modeling

For each site, we selected photos that contained multiple GCPs, and had a clear view of the trail from different locations with minimal vegetation interference. We uploaded the best subset of photos into Pix4D Software and exported a digital surface model (DSM) and orthophoto for each site.

Table 2 summarizes the site parameters and root mean square error (RMSE) on GCP location. Horizontal ground resolution is generally between two and four mm/pixel, and the vertical RMSE of GCPs was typically a few mm (Table 2).

Table 2. Table showing the locations, site condition, usage, soil type, 2018 analysis area and input parameters (number of photos, number of GCPs), and resulting GCP 3D and vertical (Z) root mean square error (RMSE) and ground resolution for each site's DEM.

Trail Location	Condition	Usage	Soil Type	Area (m ²)	Photos #	GCPs #	3D RMSE (m)	Z RMSE (m)	Resolution (mm/pix)
OK Corral_1	Green	Single Track	Clay	10	81	9	0.008	0.016	2
Donnybrook_2	Green	Single Track	Granite	11	53	8	0.003	0.002	4
4 Corners	Green	ATV	Clay	72	131	8	0.008	0.010	2
Coyote_1	Green	ATV	Granite	31	103	7	0.006	0.008	3
Faultline_2	Green	Road	Clay	22	40	3	0.002	0.000	2
Sage	Green	Road	Granite	36	74	5	0.002	0.001	4
OK Corral_2	Yellow	Single Track	Clay	10	114	9	0.008	0.008	2
Mystic	Yellow	Single Track	Granite	13	64	7	0.003	0.003	9
Backsprings_2	Yellow	ATV	Clay	52	136	7	0.005	0.008	2
Coyote_2	Yellow	ATV	Granite	48	71	6	0.006	0.004	3
Faultline_1	Yellow	Road	Clay	68	77	6	0.007	0.011	2
North Canyon	Yellow	Road	Granite	126	97	8	0.007	0.008	3
Psych Hill	Red	Single Track	Clay	27	90	12	0.012	0.015	3
Donnybrook_1	Red	Single Track	Granite	14	66	9	0.009	0.012	2
Backsprings_1	Red	ATV	Clay	59	98	8	0.006	0.005	3
Badger	Red	ATV	Granite	53	101	8	0.010	0.010	2
Rancho	Red	Road	Clay	76	53	5	0.007	0.009	2
Lake	Red	Road	Granite	96	76	10	0.007	0.008	4

2.3 Analysis

We used ArcMap (v. 10.6) to create a difference of DSMs (DODs) for every site by using Raster Calculator to subtract the 2018 DSM from the 2019 DSM. A mask was created for each raster to restrict the DOD analysis to the trail tread and to avoid overhanging vegetation. We acquired area of each mask and average vertical change of each site from ArcMap (v. 10.6). The 2019 elevations, areas, and volumes obtained from this process were compared with those of 2018, 2017, 2016, 2015, 2014, and 2013 values to quantify both annual and total change. We used R Software to analyze and generate graphs of the data using the “ggplot2” package (R Core Team 2013). Precipitation data were obtained from the Radio Ridge Hollister Hills Weather Monitoring Station within the park boundary (Western Weather Group 2017).

Sites were analyzed to assess the reliability of the sustainability index to predict relative erosion rates. Sites were then grouped to assess the relative importance of soil type, use category, maintenance and annual precipitation on soil erosion rate. Lastly, the study was summarized by cumulative change over the six years of observation.

3 Results

Table 3 provides the spatially-averaged annual elevation changes measured at each site, parsed by soil type, vehicle usage, classification, and whether or not the site was managed. The erosion history of each site is located in Appendix A. The annual averages for each of the six years shows minor net erosion occurred in each year, except for 2017 when the average response was trail deposition (Table 4; Fig. 4).

Table 3. Annual elevation change at each site. Site condition is from HHSVRA (2012). Positive numbers indicate deposition and negative numbers indicate erosion. Grey indicates sites that were managed before the annual survey. Blue value is site with imported material—excluded from analysis.

Trail Location	Condition	Usage	Soil Type	Δ Elev (m)					
				18-19	17-18	16-17	15-16	14-15	13-14
OK Corral_1	Green	Single Track	Clay	0.020	-0.031	0.037	-0.039	0.000	-0.007
Donnybrook_2	Green	Single Track	Granite	-0.001	0.022	-0.016	0.007	-0.036	-0.045
Four Corners	Green	ATV	Clay	-0.012	-0.092	0.082	0.009	-0.085	-0.009
Coyote_1	Green	ATV	Granite	-0.016	-0.050	0.033	-0.031	-0.001	-0.023
Faultline_2	Green	Road	Clay	-0.048	-0.020	0.046	-0.026	-0.044	-0.019
Sage	Green	Road	Granite	-0.023	-0.007	0.031	-0.026	-0.001	-0.008
OK Corral_2	Yellow	Single Track	Clay	-0.053	-0.009	-0.009	-0.079	-0.001	-0.022
Mystic	Yellow	Single Track	Granite	-0.008	-0.023	0.010	-0.021	-0.016	-0.002
Backsprings_2	Yellow	ATV	Clay	-0.035	-0.016	-0.014	0.065	-0.005	-0.012
Coyote_2	Yellow	ATV	Granite	-0.010	0.066	-0.018	0.029	-0.016	-0.016
Faultline_1	Yellow	Road	Clay	-0.022	-0.050	0.021	-0.031	-0.052	-0.041
North Canyon	Yellow	Road	Granite	-0.027	0.001	0.035	0.079	-0.021	-0.060
Psych Hill	Red	Single Track	Clay	-0.064	N/A	-0.171	0.040	0.040	0.040
Donnybrook_1	Red	Single Track	Granite	-0.013	-0.023	0.008	-0.170	-0.055	-0.038
Backsprings_1	Red	ATV	Clay	0.022	-0.226	0.191	-0.173	0.000	-0.006
Badger	Red	ATV	Granite	-0.031	0.011	0.006	-0.170	-0.036	-0.038
Rancho	Red	Road	Clay	-0.036	-0.013	-0.025	1.286	-0.031	-0.023
Lake	Red	Road	Granite	-0.058	0.013	-0.020	0.022	-0.039	-0.083

Table 4. Annual average elevation change (m) summarized by year, sustainability rating, soil, use and management. “NA” represents sites with no data for a particular category. Positive numbers indicate deposition and negative numbers indicate erosion.

2013-2014

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.02	-0.02	-0.03	-0.02	-0.01	-0.03	-0.01	-0.02	-0.04
Managed Sites	NA	NA	NA	NA	NA	NA	NA	NA	NA
Unmanaged Sites	-0.02	-0.02	-0.03	-0.02	-0.01	-0.03	-0.01	-0.02	-0.04

2014-2015

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	-0.01	-0.02	-0.03
Managed Sites	NA	NA	NA	NA	NA	NA	NA	NA	NA
Unmanaged Sites	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	-0.01	-0.02	-0.03

2015-2016

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.03	-0.09	0.01	-0.02	-0.03	-0.03	-0.04	-0.05	0.00
Managed Sites	-0.02	-0.07	0.07	0.01	0.04	-0.07	NA	-0.03	0.02
Unmanaged Sites	-0.03	-0.10	0.00	-0.02	-0.05	-0.02	-0.04	-0.06	0.00

2016-2017

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	0.01	0.00	0.00	0.04	0.02	0.01	-0.02	0.05	0.01
Managed Sites	0.02	0.04	0.00	0.03	0.04	0.01	-0.01	0.04	0.01
Unmanaged Sites	0.00	-0.08	0.02	0.04	0.00	0.00	-0.03	0.08	0.03

2017-2018

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.03	-0.05	-0.01	-0.03	-0.06	0.00	-0.01	-0.05	-0.01
Managed Sites	0.00	0.00	0.01	-0.03	-0.02	0.01	-0.02	0.00	0.00
Unmanaged Sites	-0.06	-0.12	-0.04	-0.03	-0.10	-0.01	-0.01	-0.16	-0.04

2018-2019

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.02	-0.03	-0.03	-0.01	-0.03	-0.02	-0.02	-0.01	-0.04
Managed Sites	-0.03	-0.05	-0.02	-0.02	-0.04	-0.03	NA	-0.01	-0.04
Unmanaged Sites	-0.02	-0.02	-0.03	-0.01	-0.02	-0.02	-0.02	-0.01	-0.03

Topographic change is more variable starting in 2016 (Fig. 4). At that time, the analysis areas at each site were expanded through the use of photogrammetry, and site management increased. According to a one-way ANOVA with unequal variance, mean elevation changes do not significantly differ through time, ($df = 5/45.3$, $F=0.9$, $P=0.5$), despite the great differences in annual precipitation (Fig. 4).

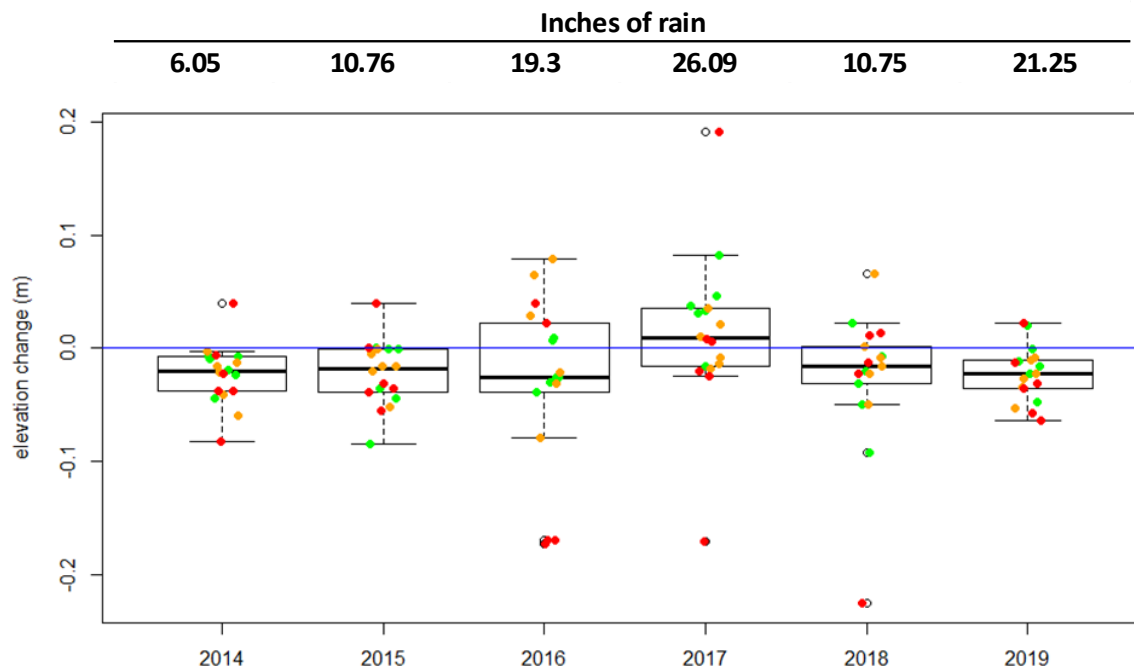


Figure 4. Annual average elevation change for six years of assessment with corresponding annual precipitation . Dots show individual sites colored by sustainability index (Green, yellow, red). ANOVA $P= 0.5$.

Table 5 summarizes the results over the six years as annual averages parsed by classification, soil type, vehicle usage, and whether the site was managed. When managed and unmanaged sites are examined together, a one-way ANOVA with unequal variance does not distinguish among the annual erosion rates of red, yellow and green rated trails ($df = 2/63.1$, $F=1.3$, $P=0.3$). Figure 5a illustrates the similarity in median values among the three trail classification levels, while Table 5 reports the similarity in mean values. The standard deviation of red sites (0.08 m/yr) is almost twice that of yellow (0.03 m/yr) and green sites (0.03m/yr). A Levene's test for homogeneity of variance shows that red site annual variability is significantly higher than annual variability of other color categories ($df=2$, $F=5.6$, $P=0.005$). Extreme annual values in red sites are more often erosional than depositional (Fig. 5a).

When six-year cumulative elevation change is computed, red sites show more erosion than the other two color categories (Fig. 5b). A one-way ANOVA with unequal variance and subsequent Tukey test indicate that red sites are significantly different from the other sites ($df = 2/8.8$, $F=6.6$, $P=0.02$), with red sites showing 0.12 m more erosion than green sites and 0.13 m more erosion than yellow sites over the six-year span.

Table 5: Summary of six-year average annual elevation changes (m) for all study sites. Notes as in Table 4.

2013-2019

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.02	-0.04	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02
Managed Sites	-0.01	-0.02	0.01	0.00	0.00	-0.02	-0.01	0.00	0.00
Unmanaged Sites	-0.03	-0.06	-0.02	-0.01	-0.03	-0.02	-0.02	-0.03	-0.02

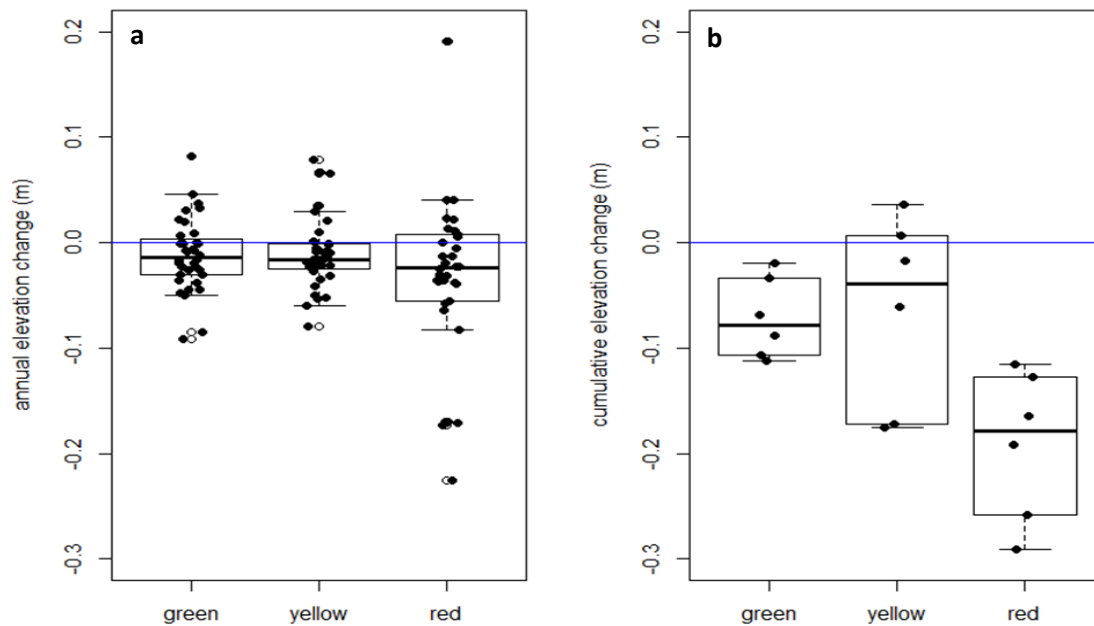


Figure 5. Boxplots of all study sites parsed by sustainability index. (a) annual elevation change of all sites (ANOVA $p = 0.3$). (b) six-year cumulative elevation change of all sites (ANOVA $p=0.02$).

Trail management decreases median annual erosion rates to nearly 0 m/yr in all sustainability groups. The positive impact of management is also supported by the average values for each year (Tables 4 and 5) and the median values in most years (Fig. 7). The wide range of elevation changes noted in red sites is present in both managed and unmanaged sites (Figs. 6 and 7).

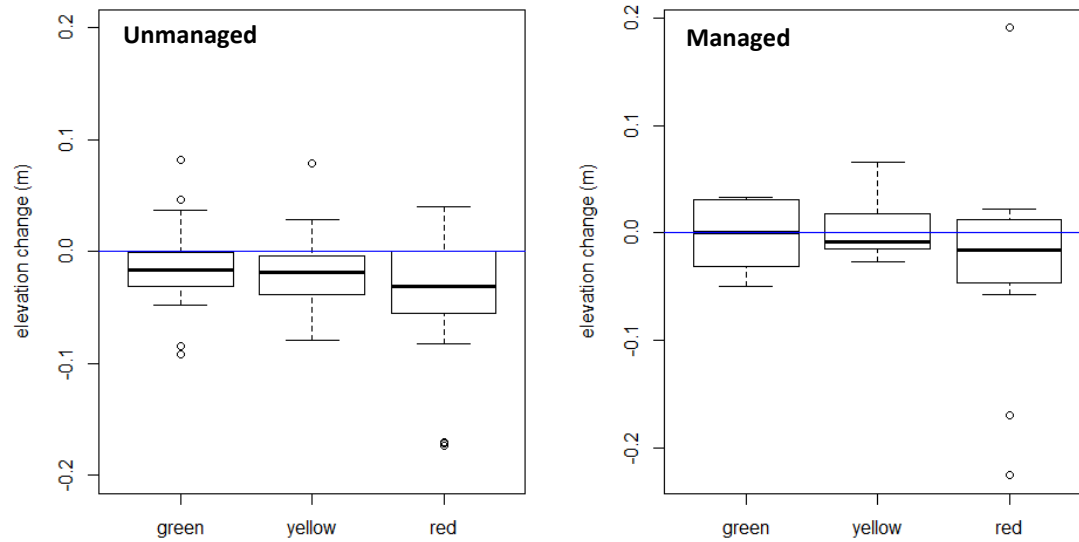


Figure 6: Boxplots of annual elevation change for all sites separated by management activity and sustainability index.

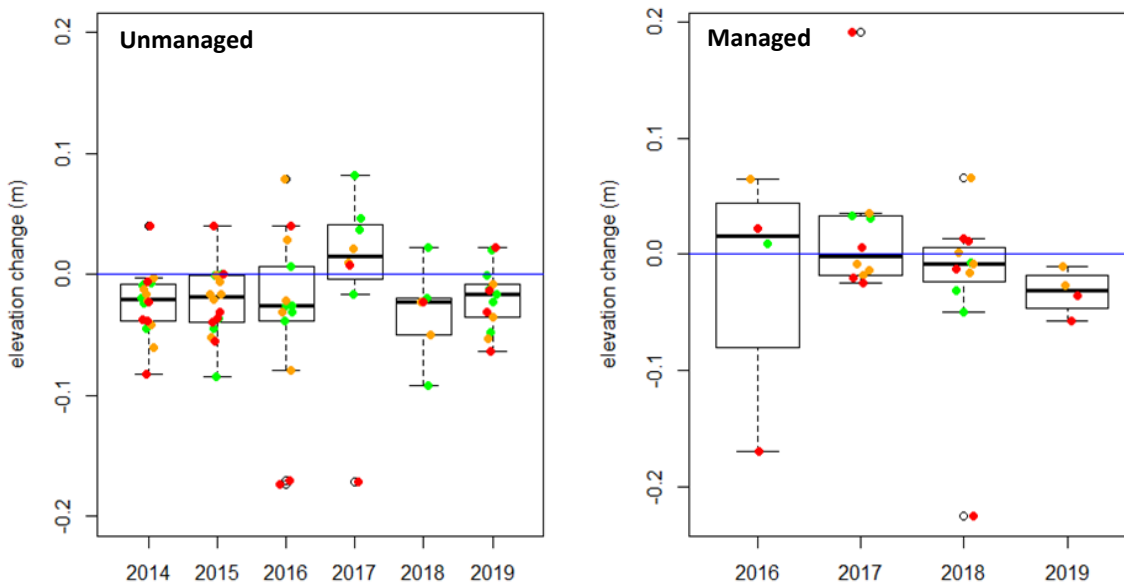


Figure 7: Boxplots of annual elevation change for all sites separated by year and management activity. Dots show individual sites colored by sustainability index (green, yellow, red).

Substrate type (clay soils and granitic soils) did not influence median erosion rates annually (Fig. 8a) and the overall mean erosion rates are practically the same for both soil types (Table 5). Sustainability indices (green, yellow, red) do not display a clear pattern (Fig. 8), even when parsed by soil type. Similarly, a two-sample t-test cannot distinguish differences in cumulative elevation change between clay and granitic soils ($p=0.8$, Fig. 8b)

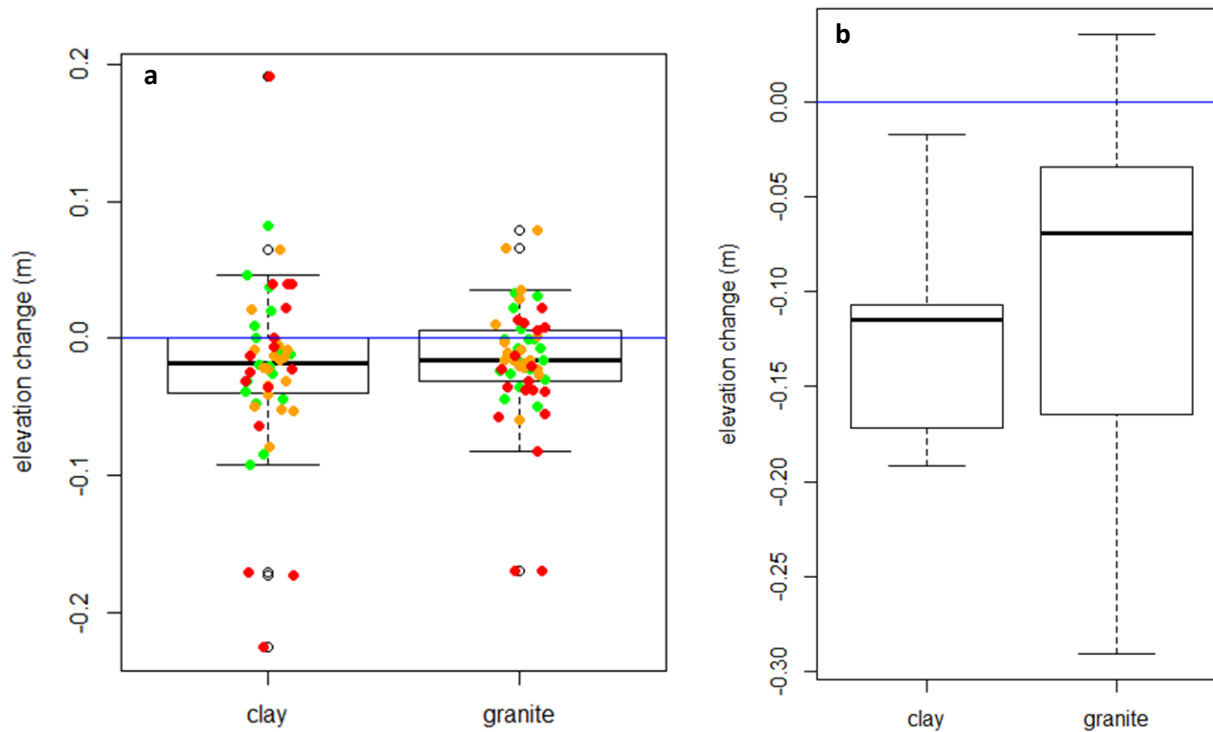


Figure 8. (a) Annual elevation change of all sites separated by soil type. Dots show individual sites colored by sustainability index (green, yellow, red). (b) Cumulative elevation change of all sites separated by soil type.

Annual erosion rates are plotted with respect to trail use category (ATV, road, single-track) in Figure 9. There is little difference between median erosion rates (Fig. 9) or mean rates (Table 5) among the three use classes. Managed sites in the ATV and road categories yield mean elevation changes of zero, while management of single-track sites had a slightly smaller impact on elevation change (Table 5). As previously noted, the three sustainability levels (green, yellow, red) do not show the expected correspondence with low, medium and high erosion rates, but red sites are notably more extreme than yellow or green.

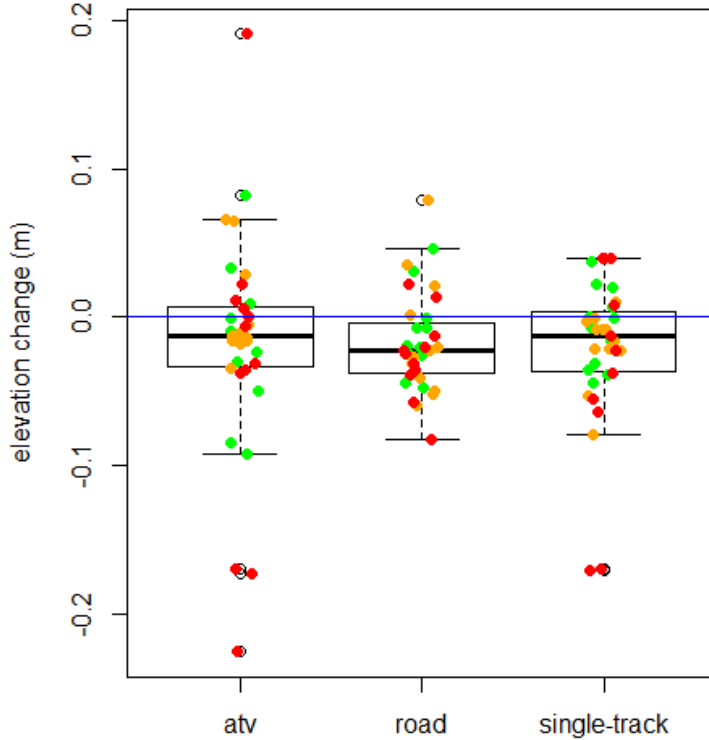


Figure 9. Boxplot of study sites divided by trail use category. Dots show individual sites colored by sustainability index (green, yellow, red).

4 Discussion

Six years of high-resolution surveys of 18 trail sites at Hollister Hills SVRA have produced the following general results:

- 1) We expected the Green, Yellow, Red trail sustainability index to correlate with low, intermediate, and high rates of trail erosion (CDPR 2008; HHSVRA 2012). While no statistical differences between the categories are present at the annual scale, red sites erode significantly more than green or red sites when the cumulative effects of six years are considered ($p < 0.05$). Green and yellow sites have similar annual and cumulative erosion rates (Fig. 5).
- 2) The Universal Soil Loss Equation and other soil conservation models normally predict higher soil erosion rates with higher rainfall. Rainfall has varied from 6 inches to 26 inches during the study but the average annual erosion rate was

lowest following the highest rain year (2017) when net topographic response was 0.01 m of deposition. There appears to be no correlation between rainfall and erosion rates (Fig. 4; Table 4). Further analysis shows that the poor correlation between rainfall and erosion rates applies to subsets of graded and non-graded sites.

- 3) Clay and granite sites erode at approximately equal rates when averaged over several years (Fig. 8).
- 4) Trail use category did not highly influence the time-averaged erosion rates (Fig. 9; Table 4).
- 5) Trail management that mainly consists of replacing the sidecast berm back into the trail tread is an effective strategy for improving trail sustainability (Table 4; Table 5; Figs. 6 and 7).

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- Western Weather Group [Internet]. 2019. Hollister SVRA Weather Information and Data. Accessed Aug.

5 2019: <http://westernwx.com/hollisterhills/>.

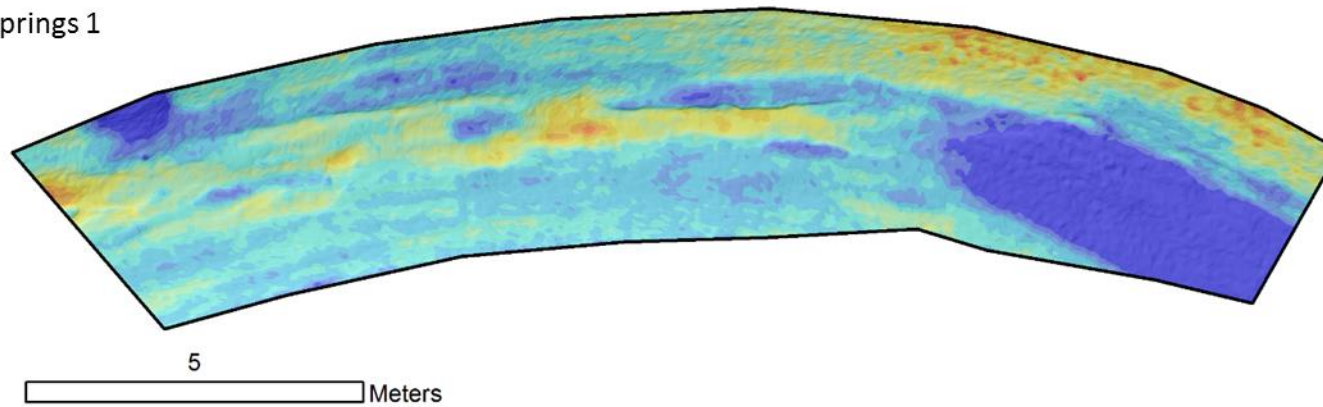
6 Appendix A

The following appendix shows the results of analysis of the surveys with Pix4D Software for all 18 sites.

The top image for each site shows 2018 (black polygon) extent overlaid on the photomosaic photo of the site. The bottom image shows 2018 extent over a “difference of DEM” (DOD) raster generated by subtracting the 2018 raster from the 2017 raster. Positive values indicate sediment deposition and negative values indicate erosion.

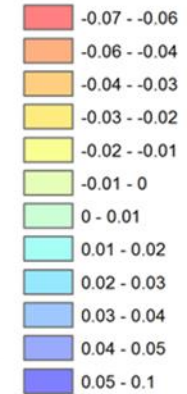
Each site has a table describing the overall change in elevation (2013 – 2018) for all years, graded years, and ungraded years, in addition to the 2018 GCP Z error. The graph shows the annual and cumulative elevation change for each site.

Backsprings 1

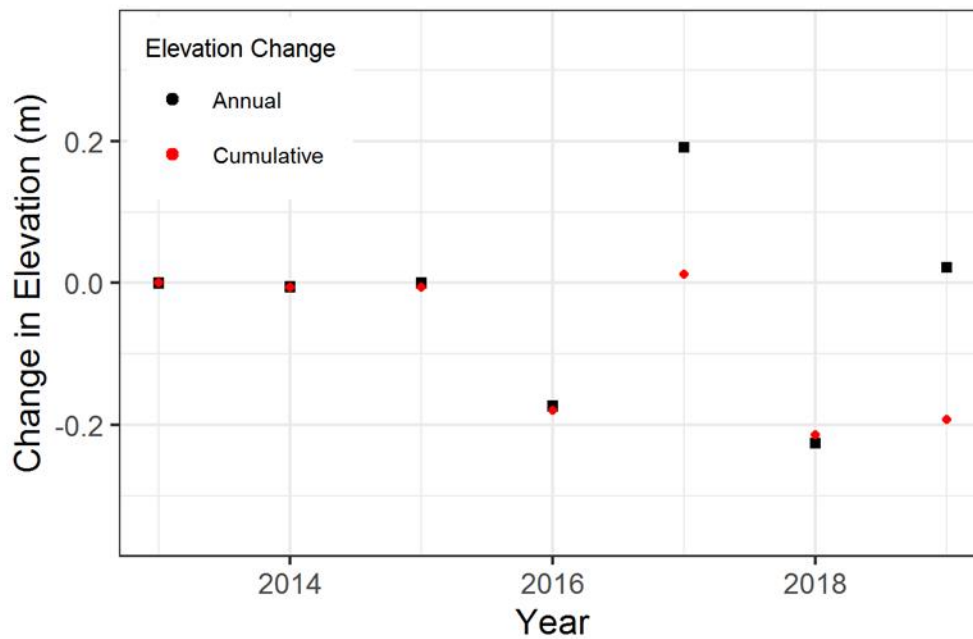


Change in Elevation
2019-2018

meters



Elevation Change at Backsprings 1 (CAR)



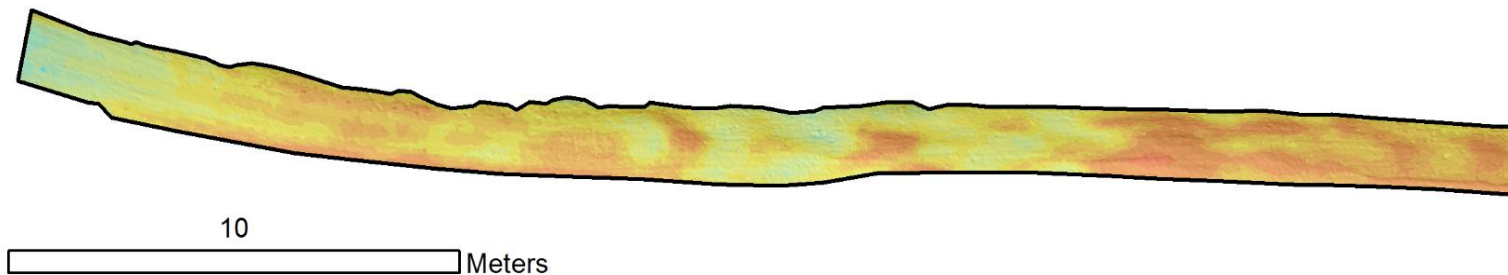
2013-2019 Elevation Change (m)

Cumulative change	Annual Average
-0.192	0.022

Backsprings 1 (CAR)

2019 GCP Z RMSE (m)
0.005

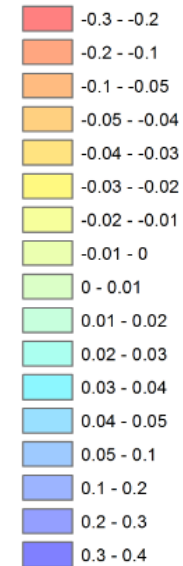
Backsprings 2



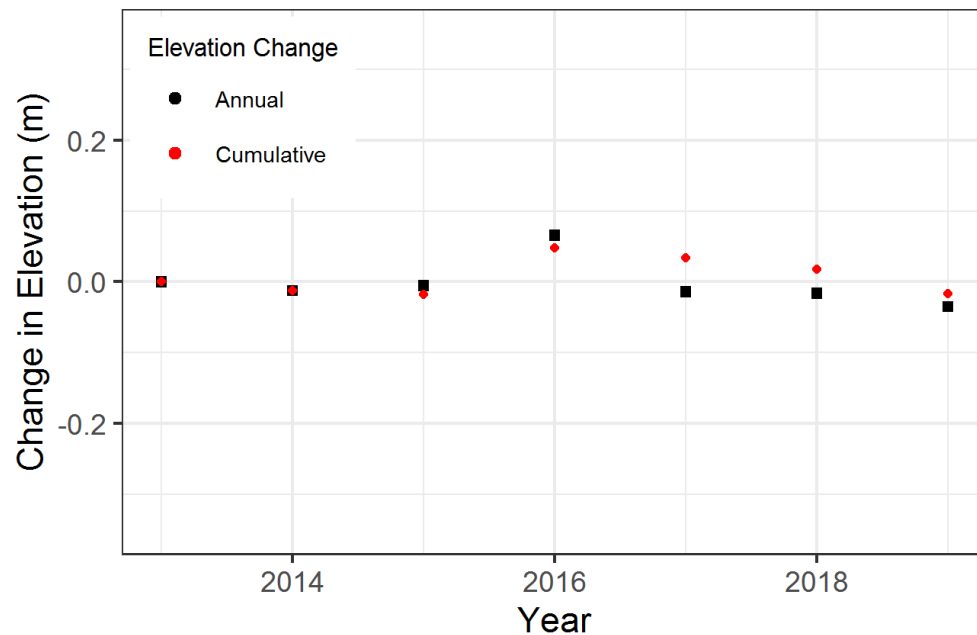
Change in Elevation

2019-2018

meters

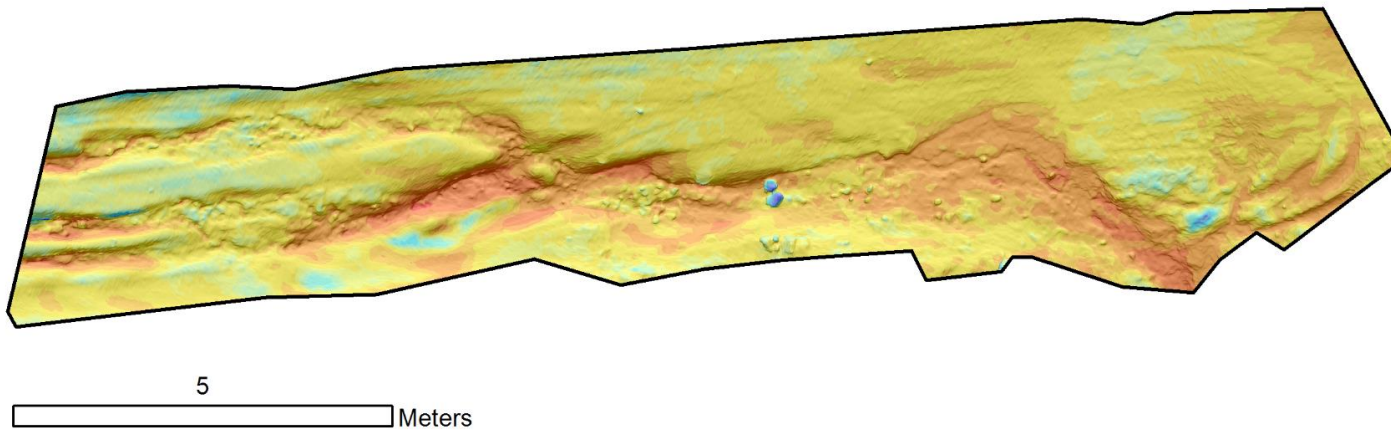


Elevation Change at Backsprings 2 (CAY)



2013-2019 Elevation Change (m)		Backsprings 2 (CAY)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.017	-0.035	0.008

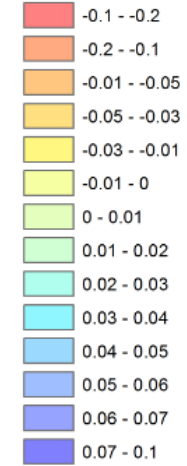
Badger



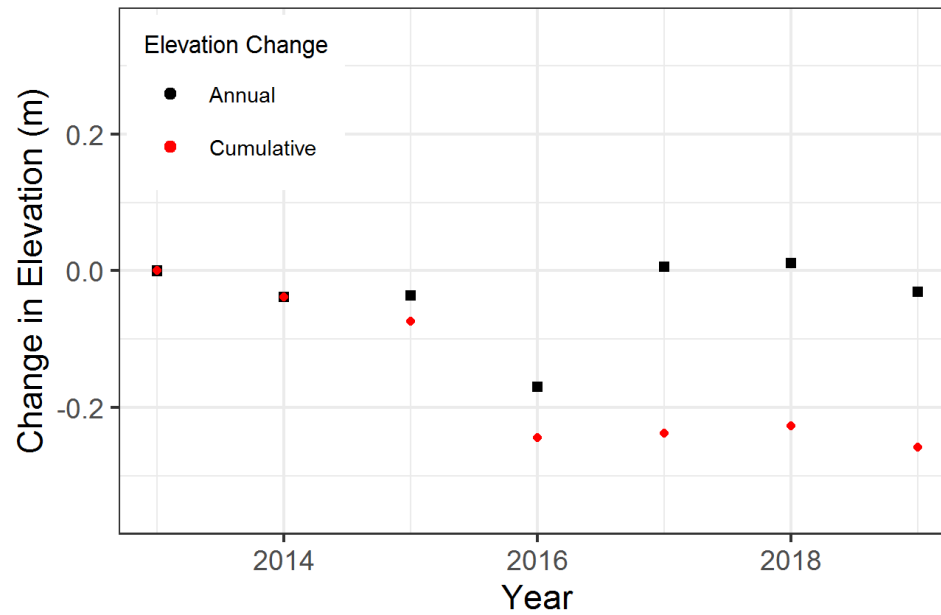
Change in Elevation

2019-2018

meters

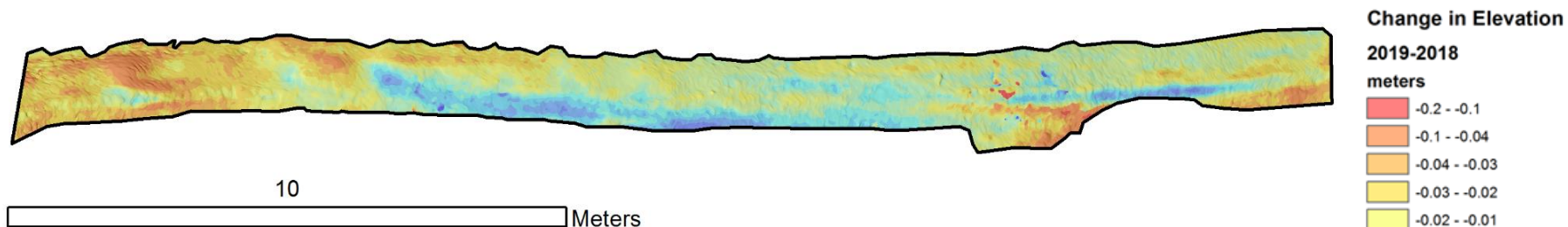


Elevation Change at Badger (GAR)

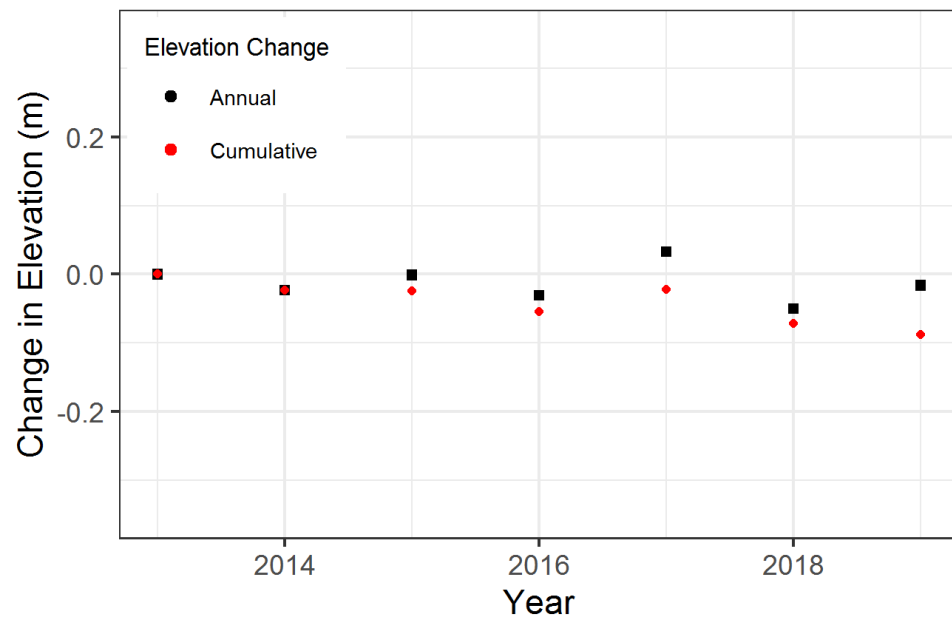


2013-2019 Elevation Change (m)		Badger (GAR)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.258	-0.031	0.010

Coyote 1

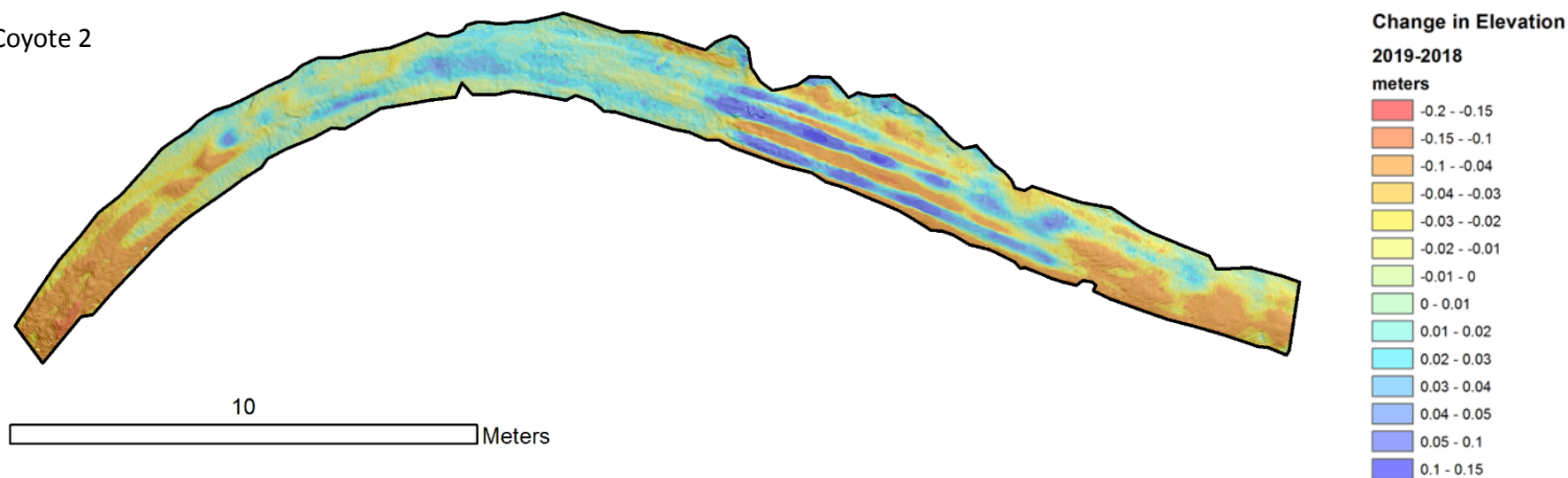


Elevation Change at Coyote 1 (GAG)

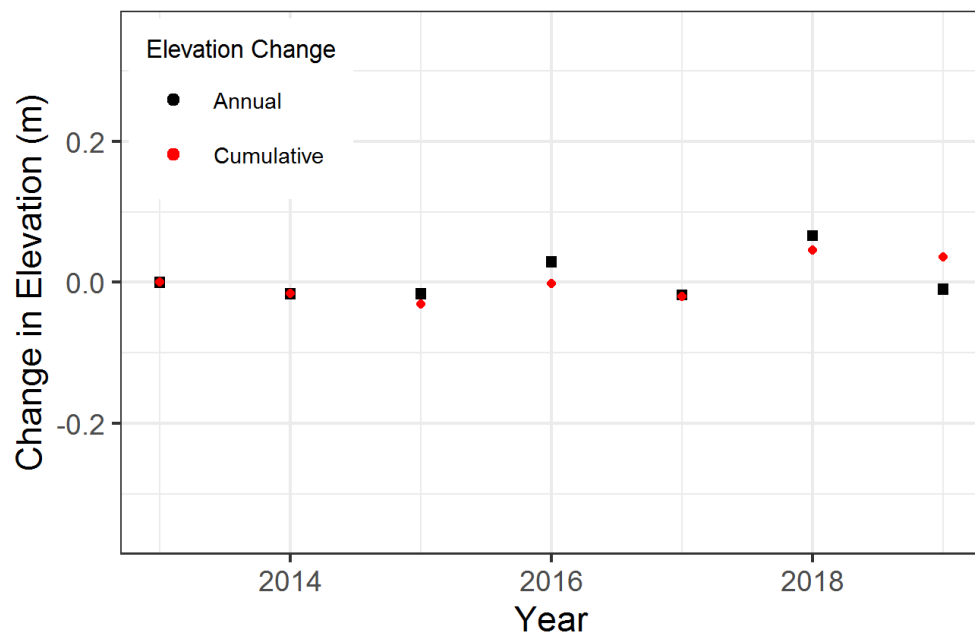


2013-2019 Elevation Change (m)		Coyote 1 (GAG)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.088	-0.016	0.008

Coyote 2

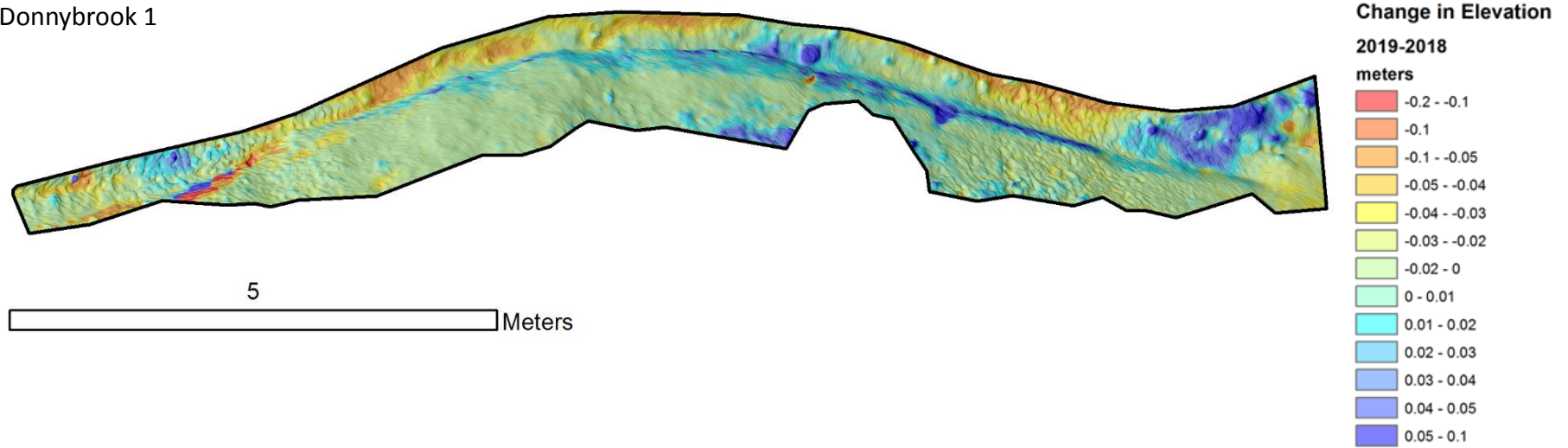


Elevation Change at Coyote 2 (GAY)

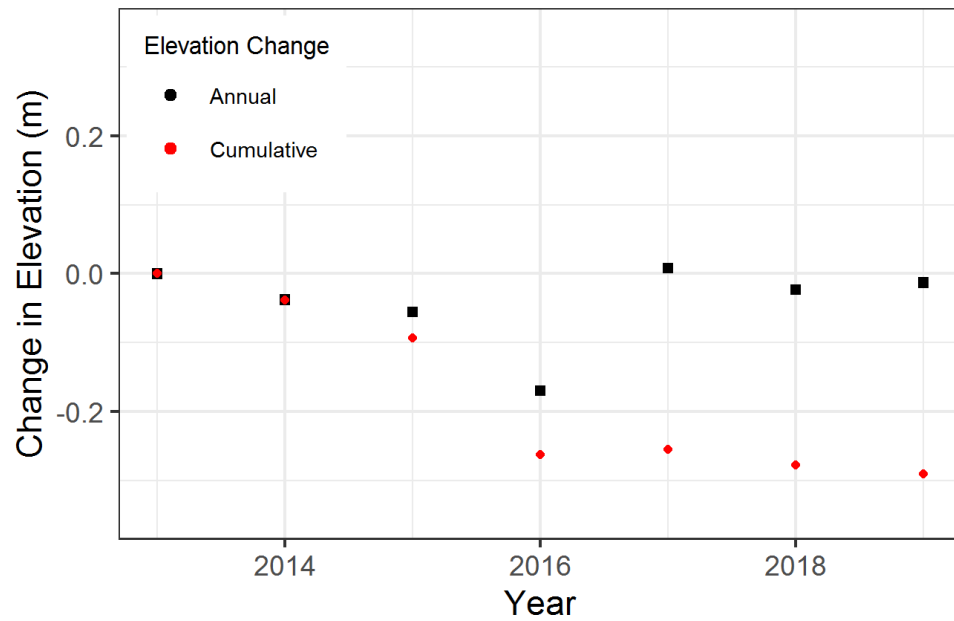


2013-2019 Elevation Change (m)		Coyote 2 (GAY)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
0.036	-0.010	0.004

Donnybrook 1

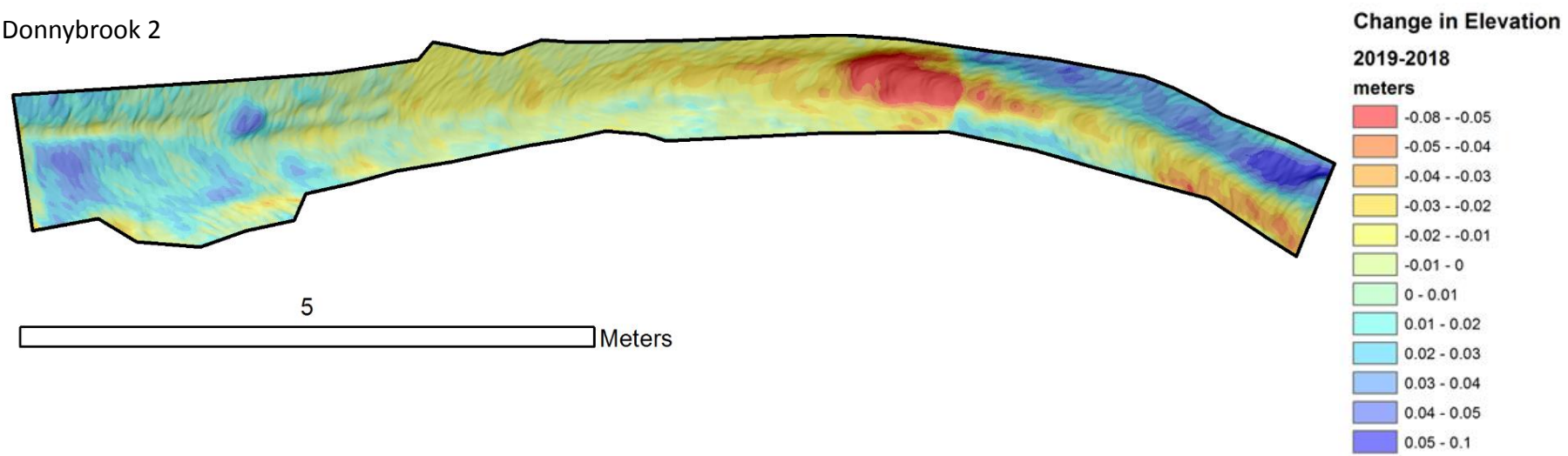


Elevation Change at Donnybrook 1 (GSR)

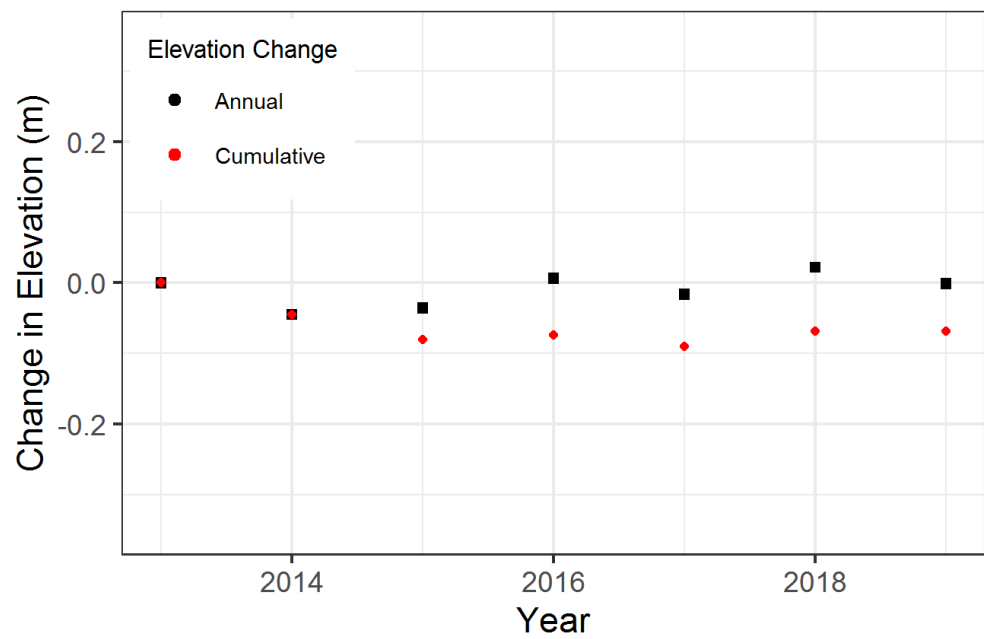


2013-2019 Elevation Change (m)		Donnybrook 1 (GSR)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.291	-0.013	0.012

Donnybrook 2

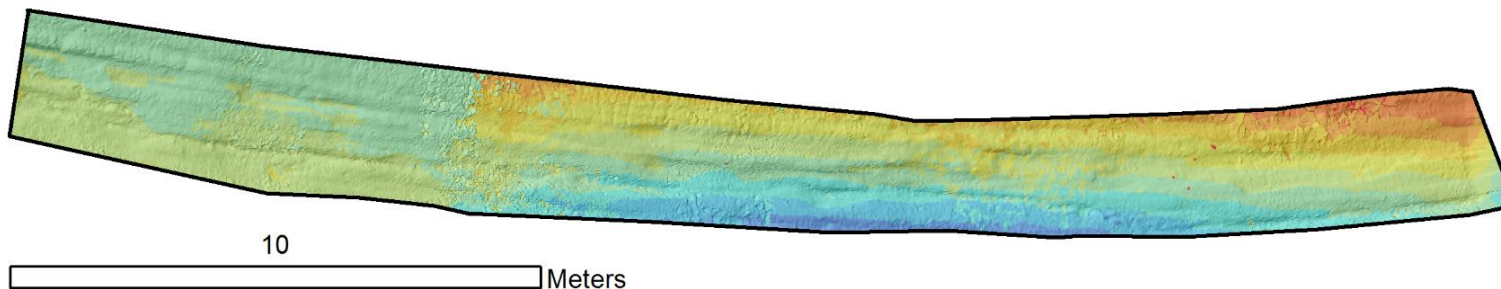


Elevation Change at Donnybrook 2 (GSG)



2013-2019 Ellevation Change (m)		Donnybrook 2 (GSG)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.069	-0.001	0.002

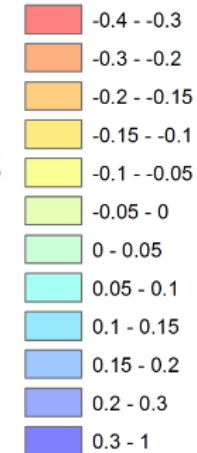
Faultline 1



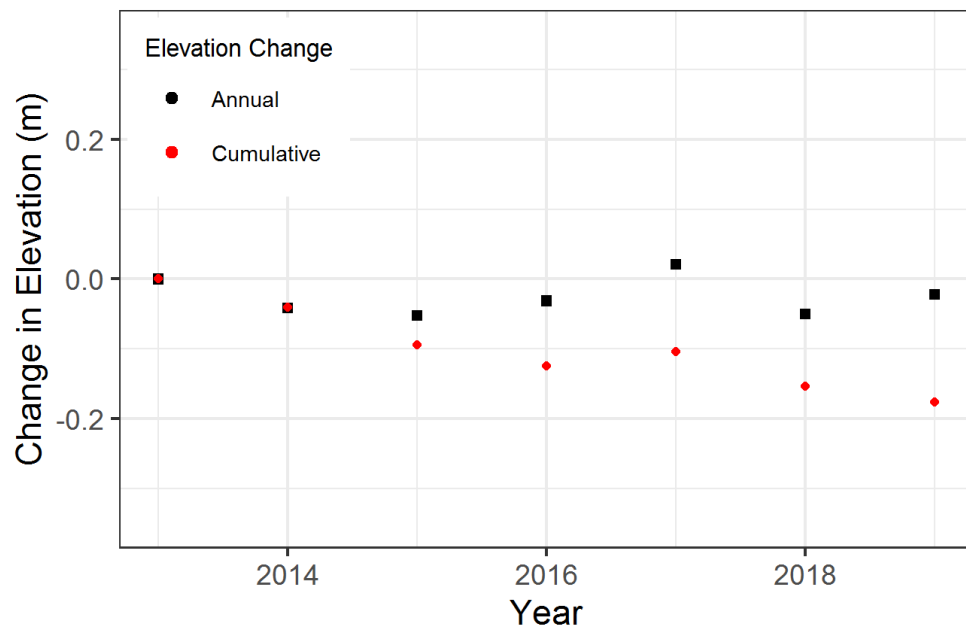
Change in Elevation

2019-2018

meters

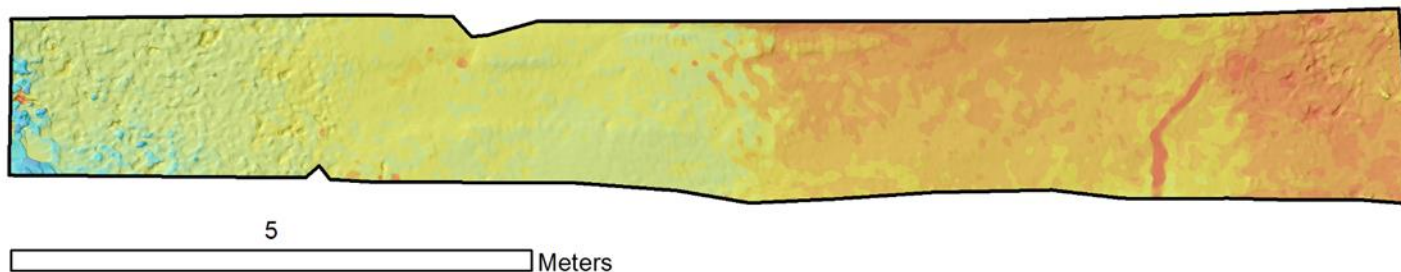


Elevation Change at Faultline 1 (CRY)

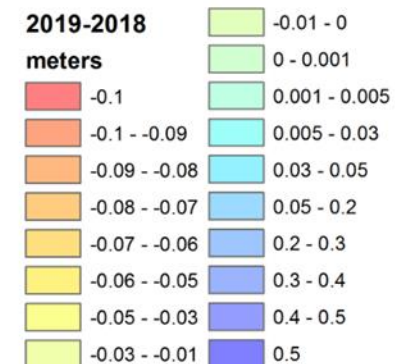


2013-2019 Elevation Change (m)		Faultline 1 (CRY)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.176	-0.022	0.011

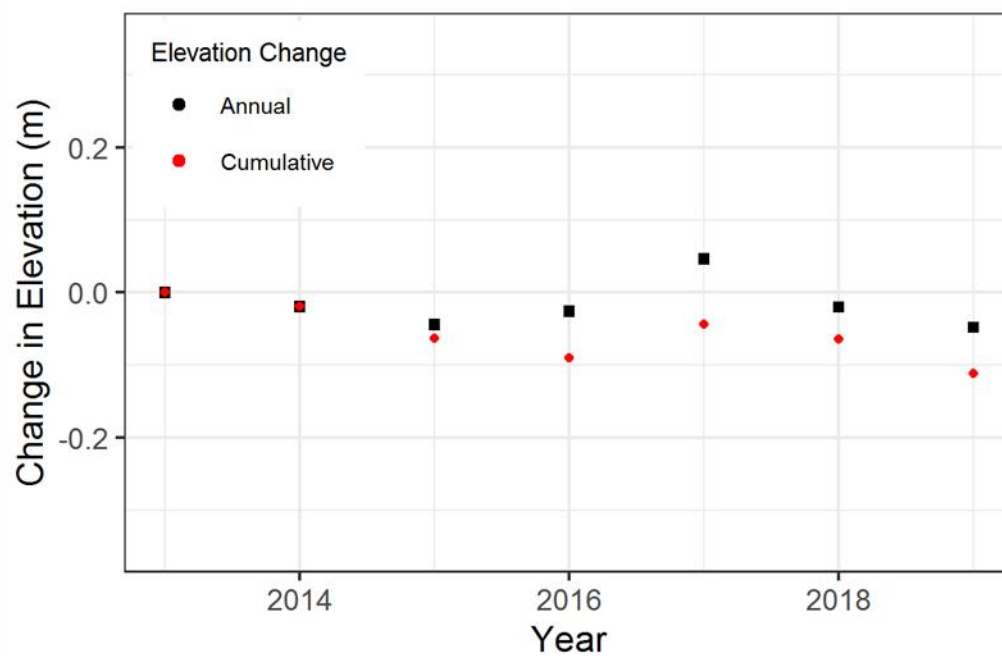
Faultline 2



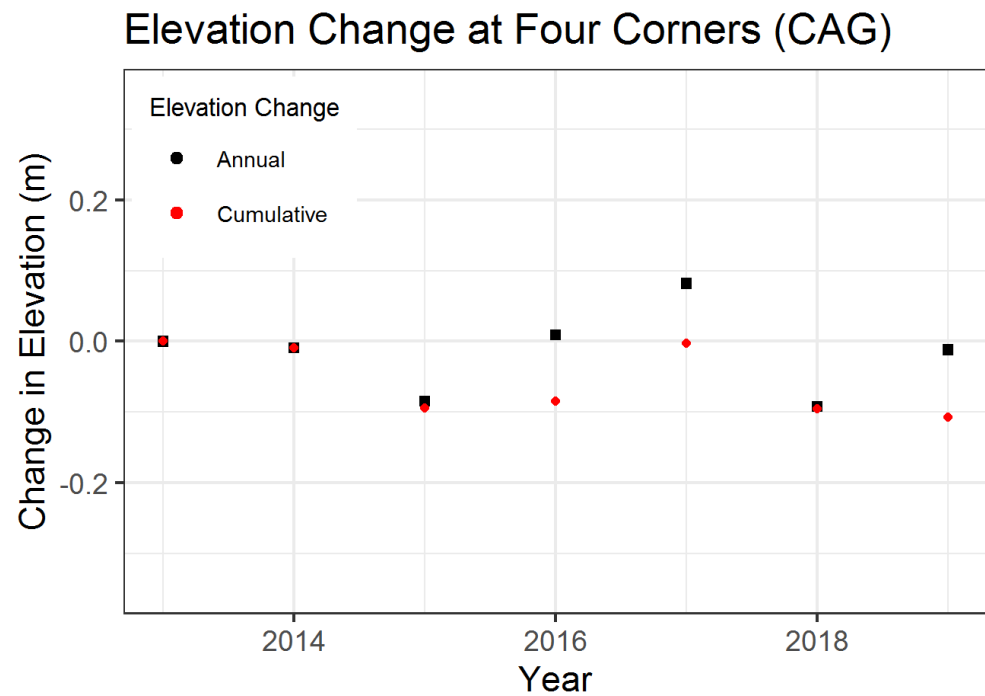
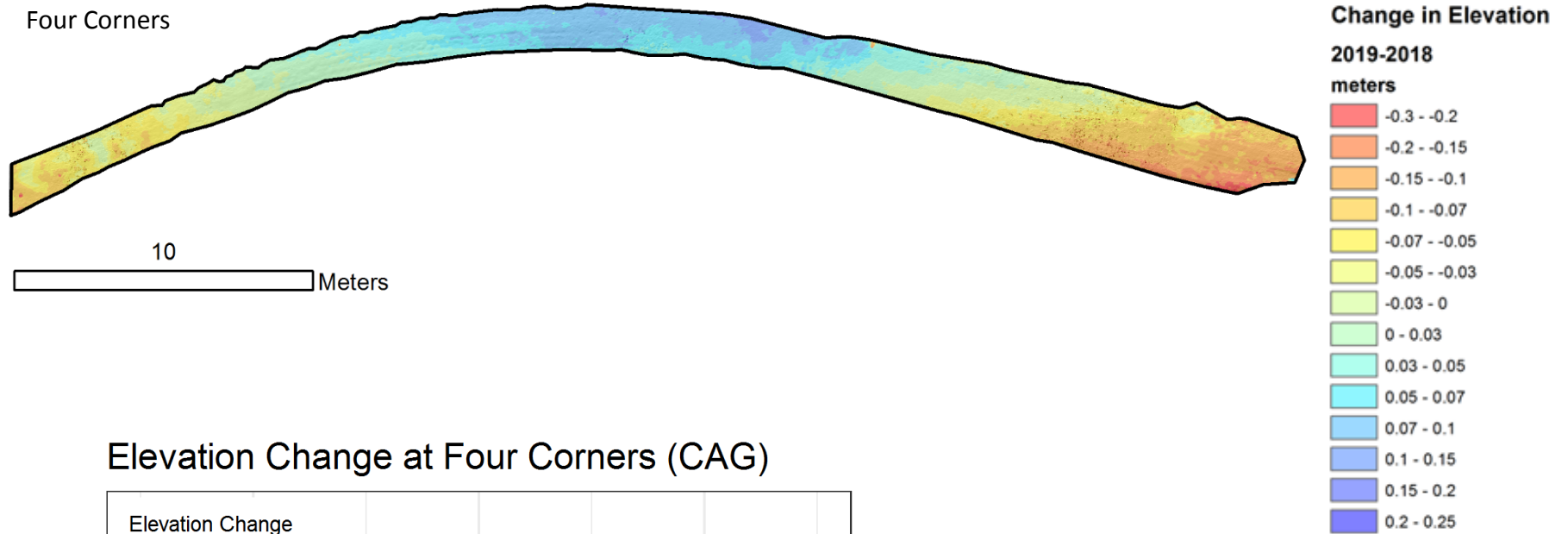
Change in Elevation



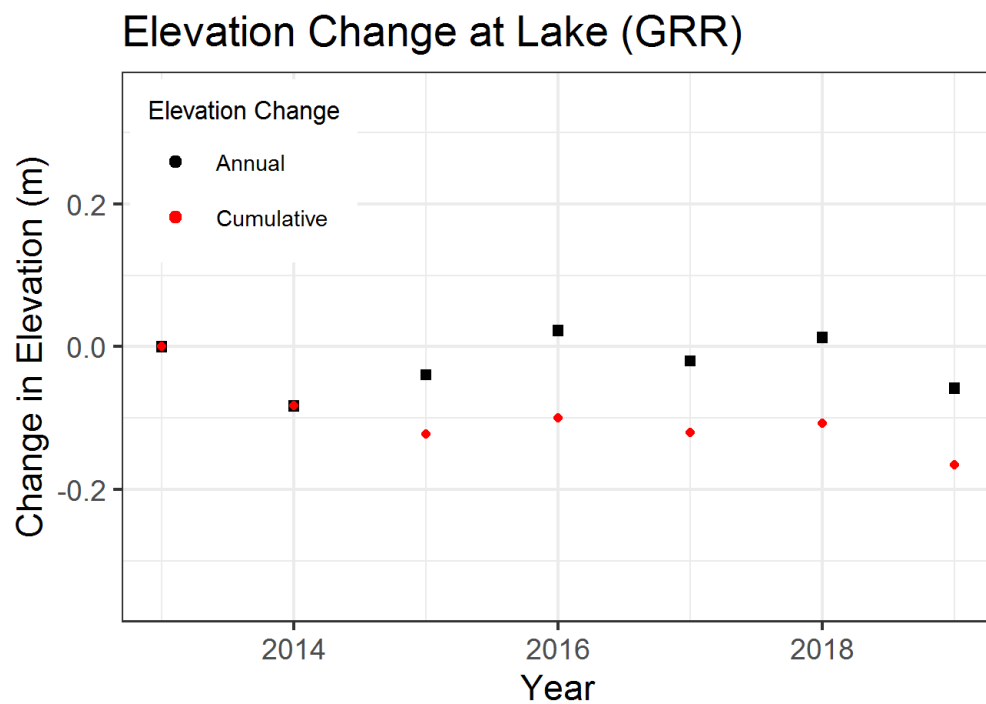
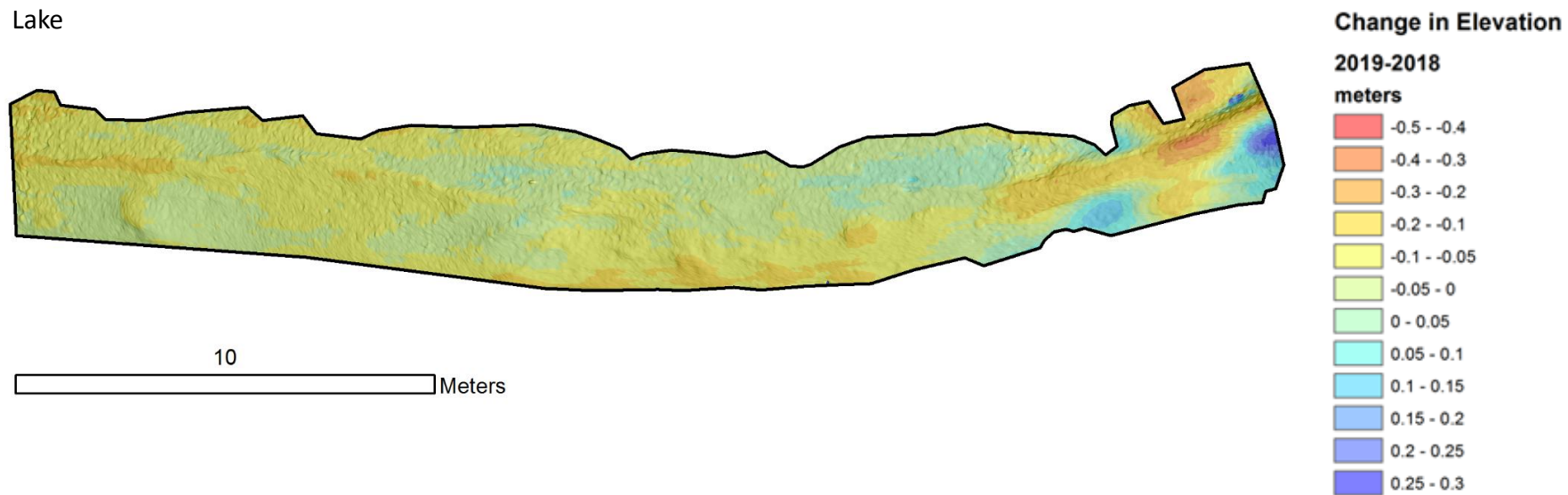
Elevation Change at Faultline 2 (CRG)



2013-2019 Elevation Change (m)		Faultline 2 (CRG)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.112	-0.048	0.000

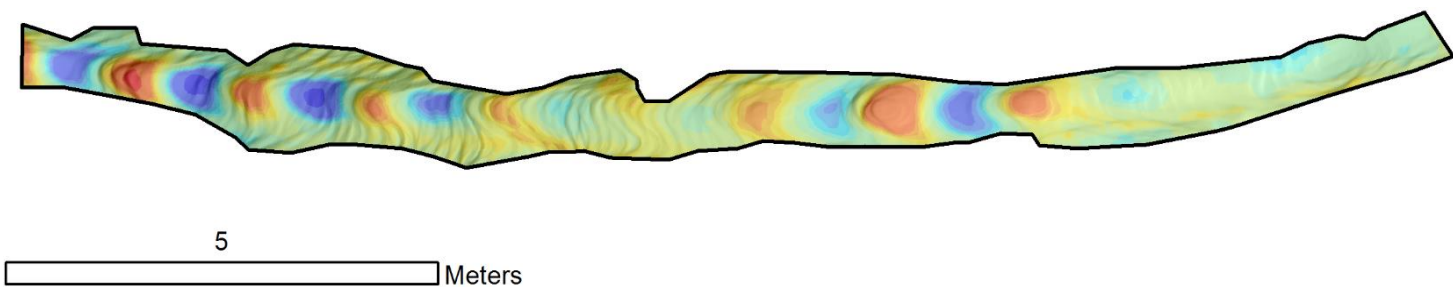


2013-2019 Elevation Change (m)		Four Corners (CAG)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.107	-0.012	0.010



2013-2019 Elevation Change (m)		Lake (GRR)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.165	-0.058	0.008

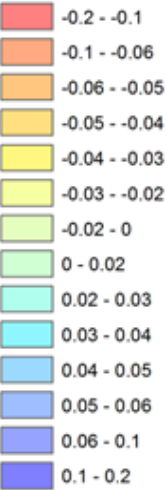
Mystic



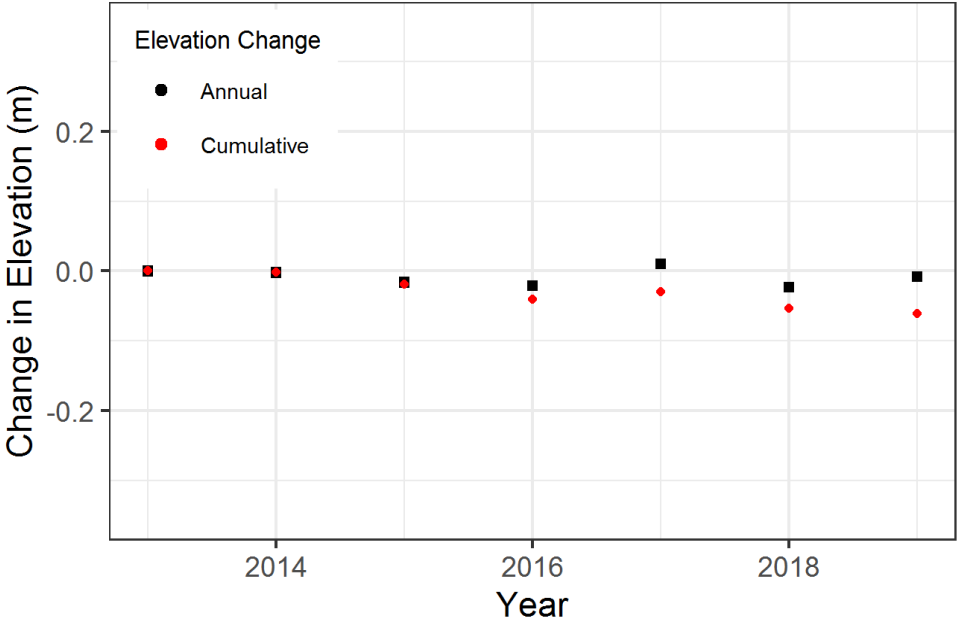
Change in Elevation

2019-2018

meters

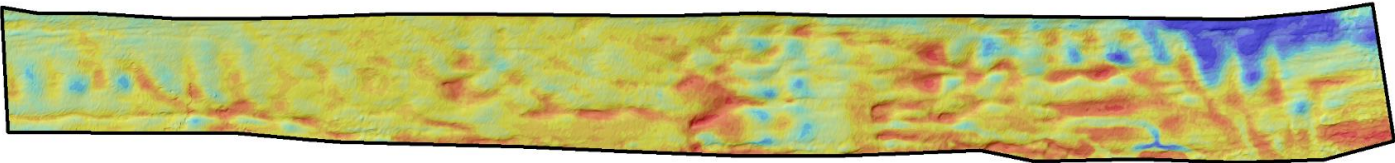


Elevation Change at Mystic (GSY)



2013-2019 Elelvation Change (m)		Mystic (GSY)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.061	-0.008	0.003

North Canyon



10

Meters

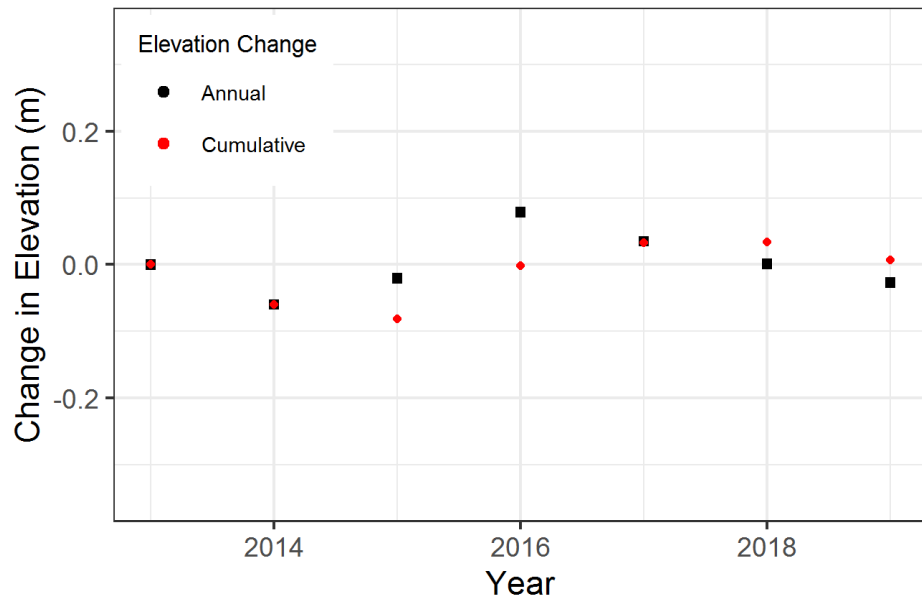
Change in Elevation

2019-2018

meters

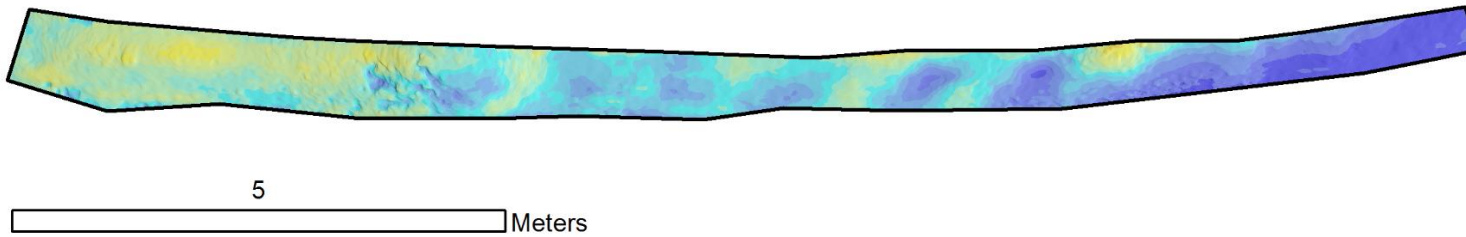


Elevation Change at North Canyon (GRY)



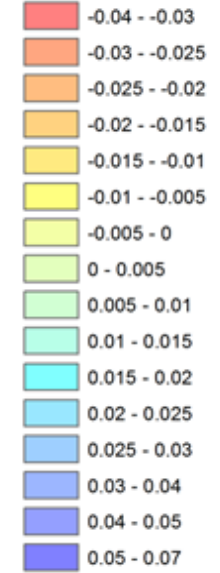
2013-2019 Ellevation Change (m)		North Canyon (GRY)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
0.007	-0.027	0.008

OK 1

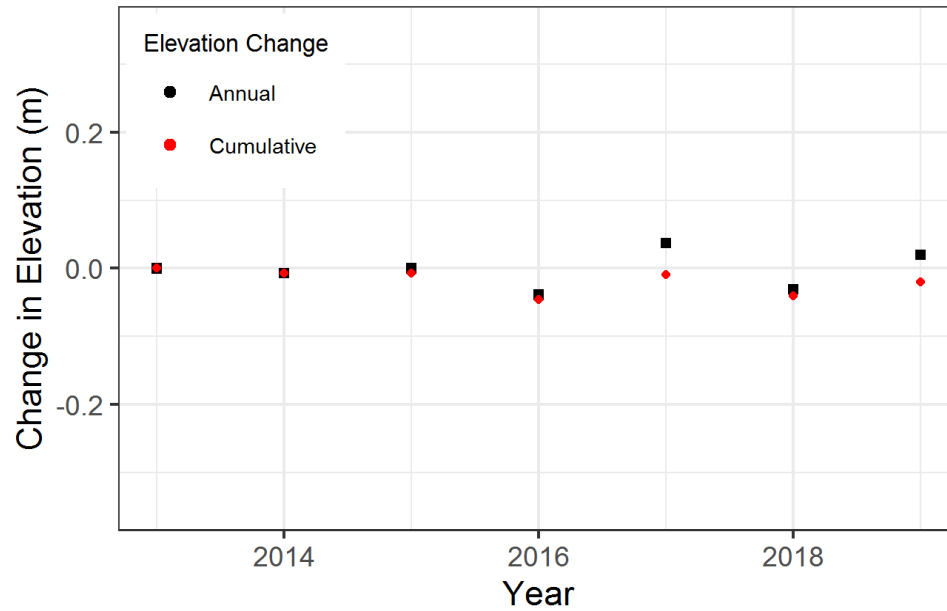


2019-2018

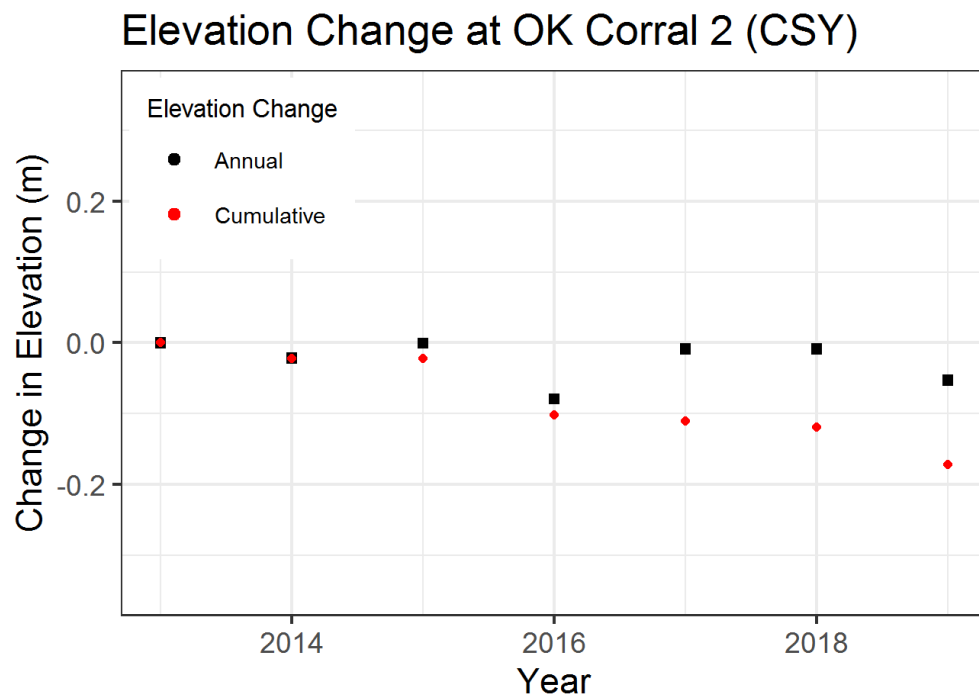
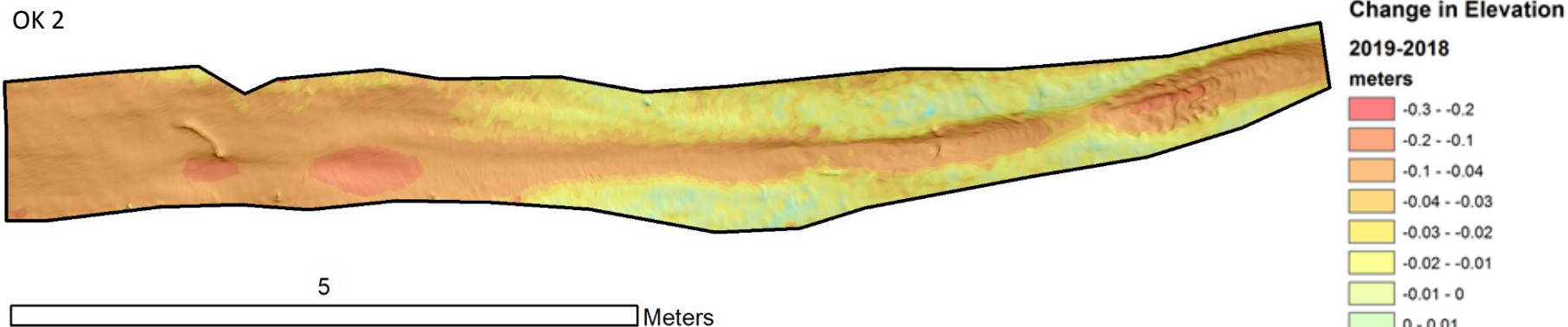
meters



Elevation Change at OK Corral 1 (CSG)

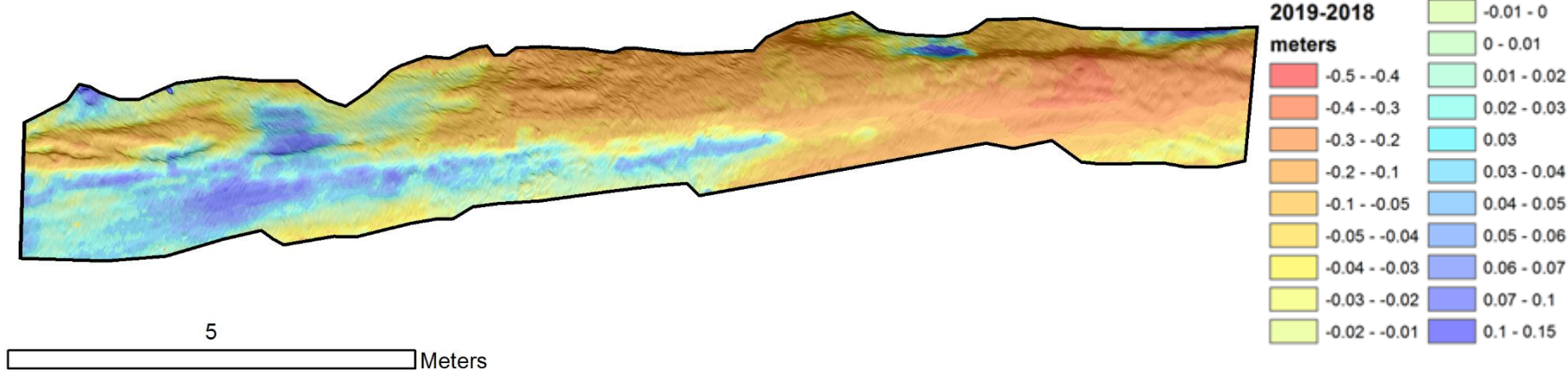


2013-2019 Ellevation Change (m)		OK Corral 1 (CSG)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.020	0.020	0.016

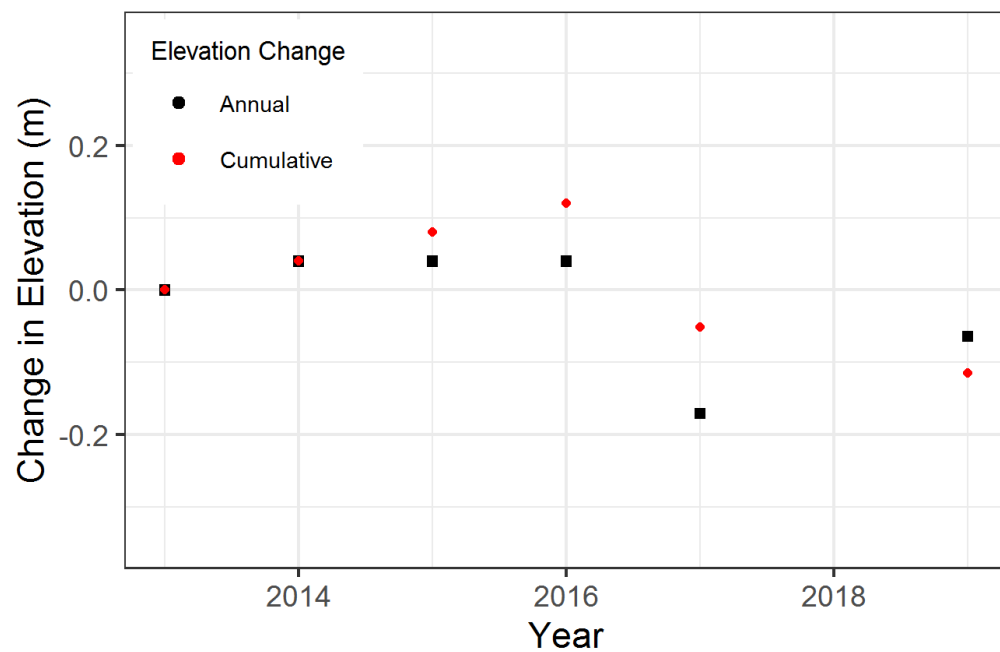


2013-2019 Elevation Change (m)		OK Corral 2 (CSY)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.172	-0.053	0.008

Psych

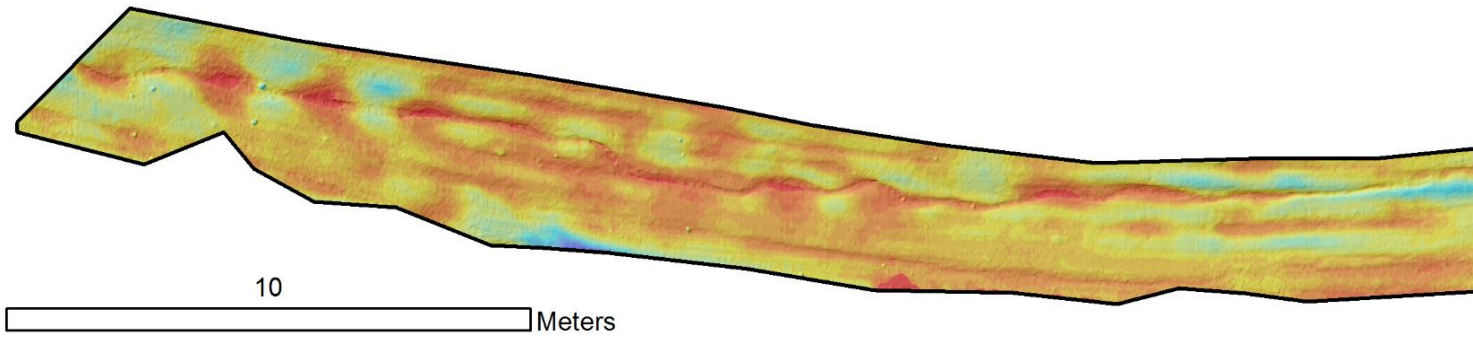


Elevation Change at Psych Hill (CSR)



2013-2019 Elevation Change (m)		Psych Hill (CSR)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
-0.115	-0.064	0.015

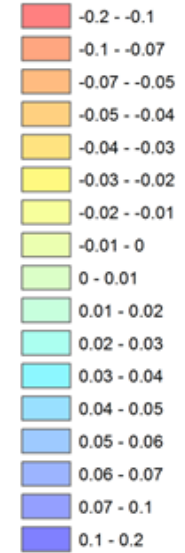
Rancho



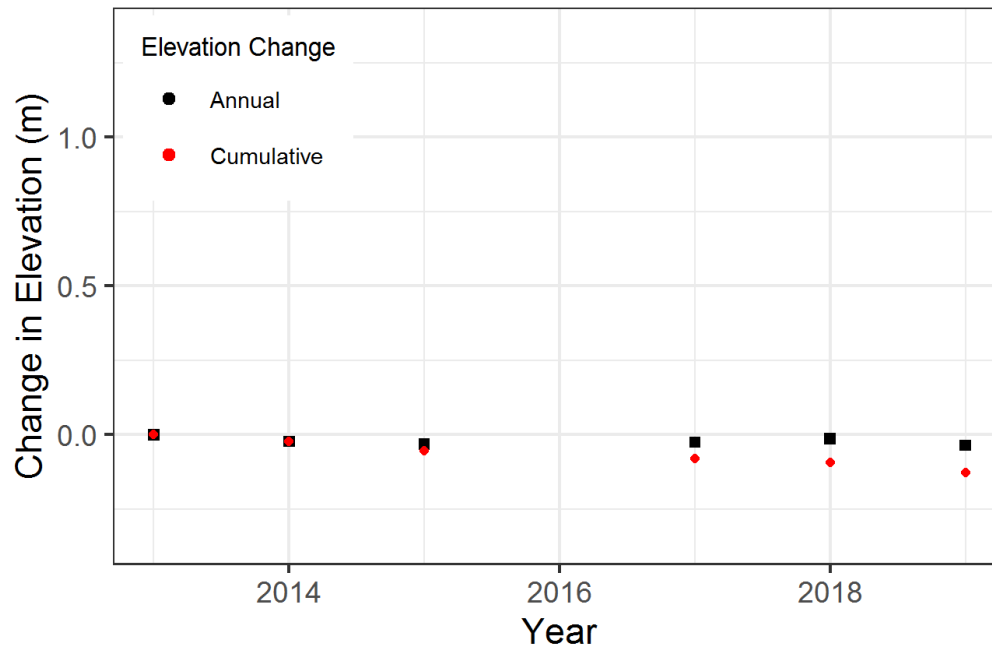
Change in Elevation

2019-2018

meters

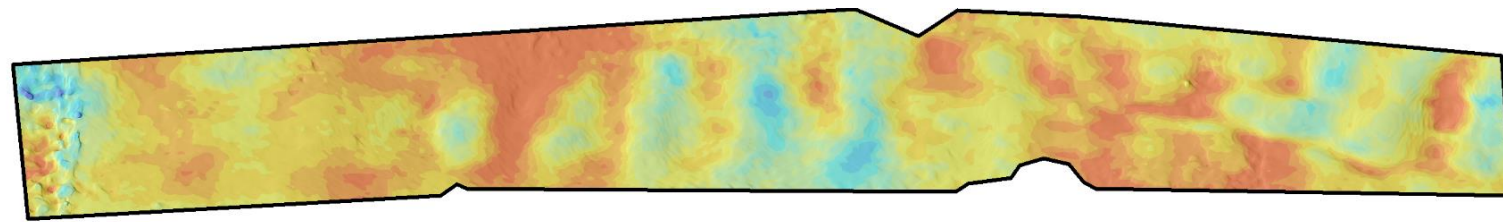


Elevation Change at Rancho (CRR)



2013-2019 Elevation Change (m)		Rancho (CRR)
Cumulative change	Annual Average	2019 GCP Z RMSE (m)
1.158	-0.036	0.009

Sage



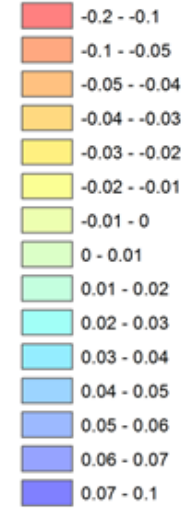
5

Meters

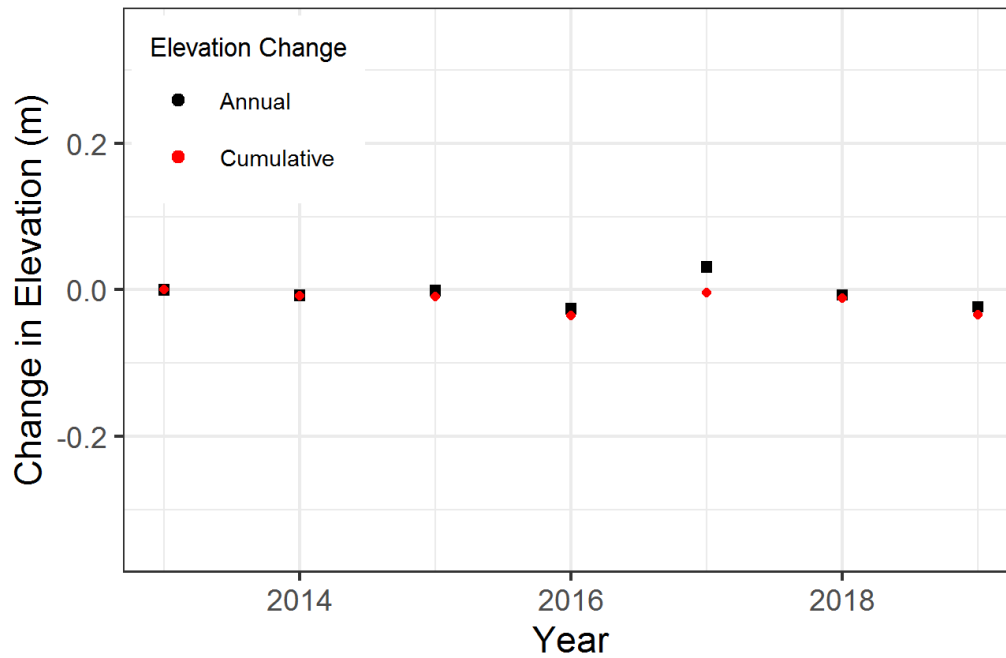
Change in Elevation

2019-2018

meters



Elevation Change at Sage (GRG)



2013-2019 Elevation Change (m)

Sage (GRG)

Cumulative change

Annual Average

2019 GCP Z RMSE (m)

-0.034

-0.023

0.001