Appendix E

Area-Normalized Stormflow Loading Rates

Appendix E. Area-Normalized Stormflow Loading Rate Estimates

To better understand the differences between subbasins, the stormflow sample loading rate estimates were divided by the contributing basin area. This was only done for stormflow loading rates and did not address differences in impervious surface area or other potential influences on stormflow loading rates because distinguishing these influences was not a study objective. This appendix contains detailed discussion, data tables and box plot figures to complement the short summary presented in Section 7.3 of the main report.

For all parameters but TOC, DOC, and benzyl butyl phthalate, normalizing the stormflow loading rates to drainage basin area decreased loading rate variability between sites. To evaluate this decrease in variability, the relative standard deviation in median stormflow loading rates between sites was calculated for each parameter using the original loading rates and the area-normalized loading rates. Prior to area-normalization, the RSD ranged from 0.68 to 1.56 RSD, whereas the RSD for area-normalized medians ranged between 0.12 to 1.17 RSD. Area-normalized median stormflow loading rates had RSDs less than 1.0 RSD between sites for 29 of 32 parameters, but for the original loading rates, RSDs were less than 1.0 RSD for only 10 of 32 parameters.

Conventionals

For each sampling location, conventional parameter loading rates during stormflow sampling are summarized (Table E-1). The highest median area loading rates for all conventional parameters occurred in the East Marginal basin whereas non-area normalized rates were highest at Brandon Regulator. Sample loading rates for TSS were much more similar between sites after area-normalization, but this was not true for TOC and DOC (RSDs between medians were equal or greater after area-normalization for TOC and DOC). Figures E-1 through E-3 illustrate these results.

Table E-1. Summary of Area-Normalized Conventional Stormflow Loading Rates by location

Analyte	Location	Basin (km^2)	Minimum Loading Rate ($kg/hr/km^2$)	Maximum Loading Rate ($kg/hr/km^2$)	Mean Loading Rate ($kg/hr/km^2$)	Median Loading Rate ($kg/hr/km^2$)
TOC	Utah	0.125	0.91	16.0	6.91	6.42
	East Marginal	0.344	7.17	71.1	33.1	26.8
	Brandon Regulator	0.987	4.65	35.5	14.5	10.0
DOC	Utah	0.125	0.441	5.78	2.55	2.76
	East Marginal	0.344	1.08	58.5	21.0	17.9
	Brandon Regulator	0.987	2.48	22.7	7.91	5.34

Analyte	Location	Basin (km^2)	Minimum Loading Rate ($kg/hr/km^2$)	Maximum Loading Rate ($kg/hr/km^2$)	Mean Loading Rate ($kg/hr/km^2$)	Median Loading Rate ($kg/hr/km^2$)
TSS	Utah	0.125	3.27	59.0	26.8	23.9
	East Marginal	0.344	5.73	71.5	35.1	38.2
	Brandon Regulator	0.987	10.4	125	39.9	27.0

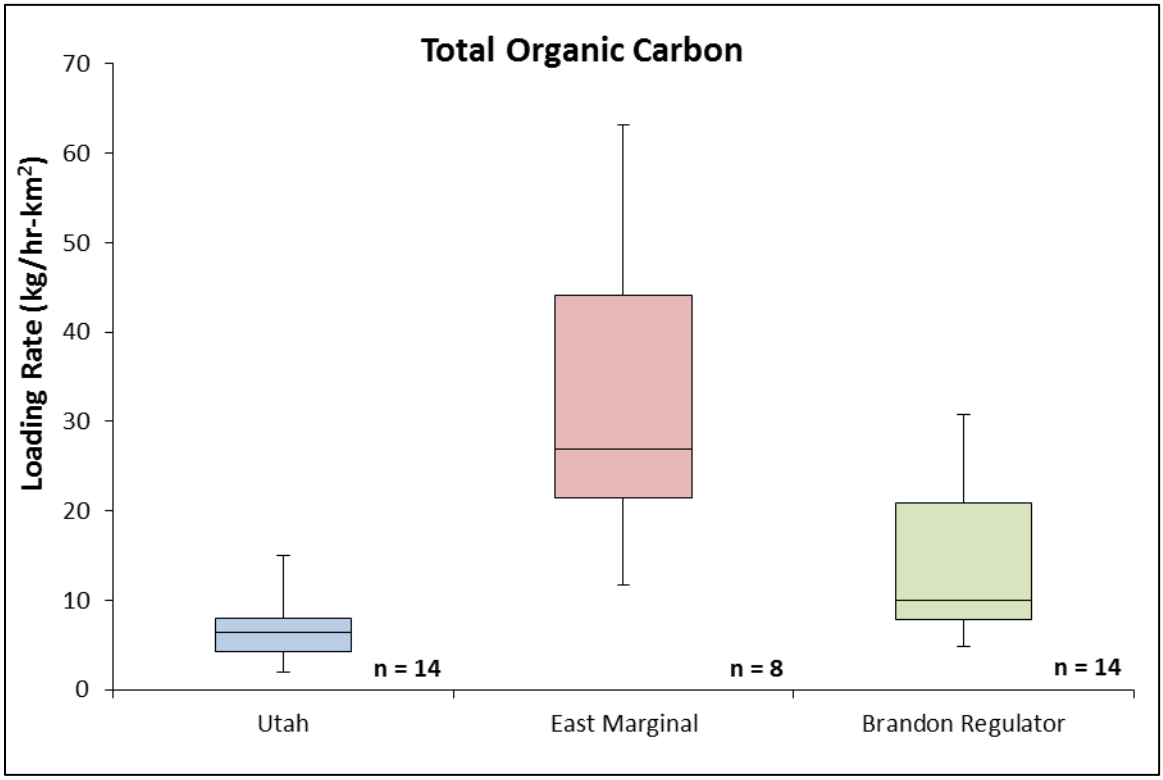

Figure E-1. Boxplots of Total Organic Carbon Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

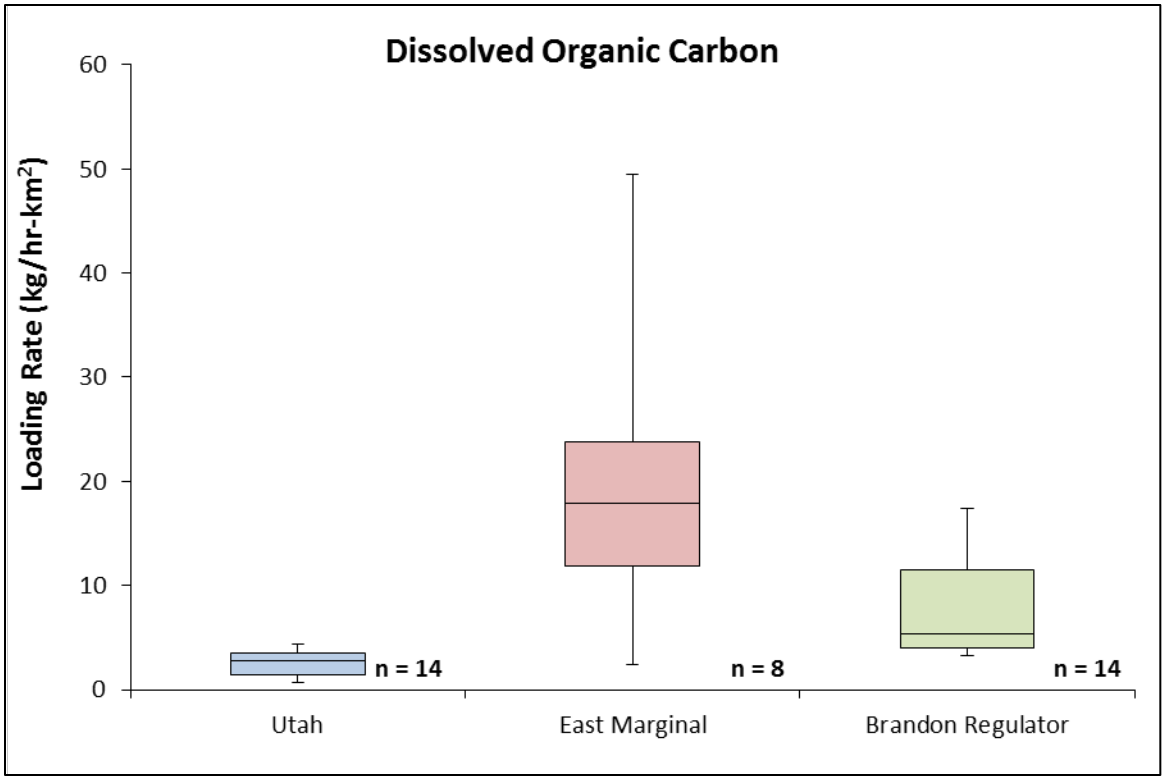

Figure E-2. Boxplots of Dissolved Organic Carbon Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

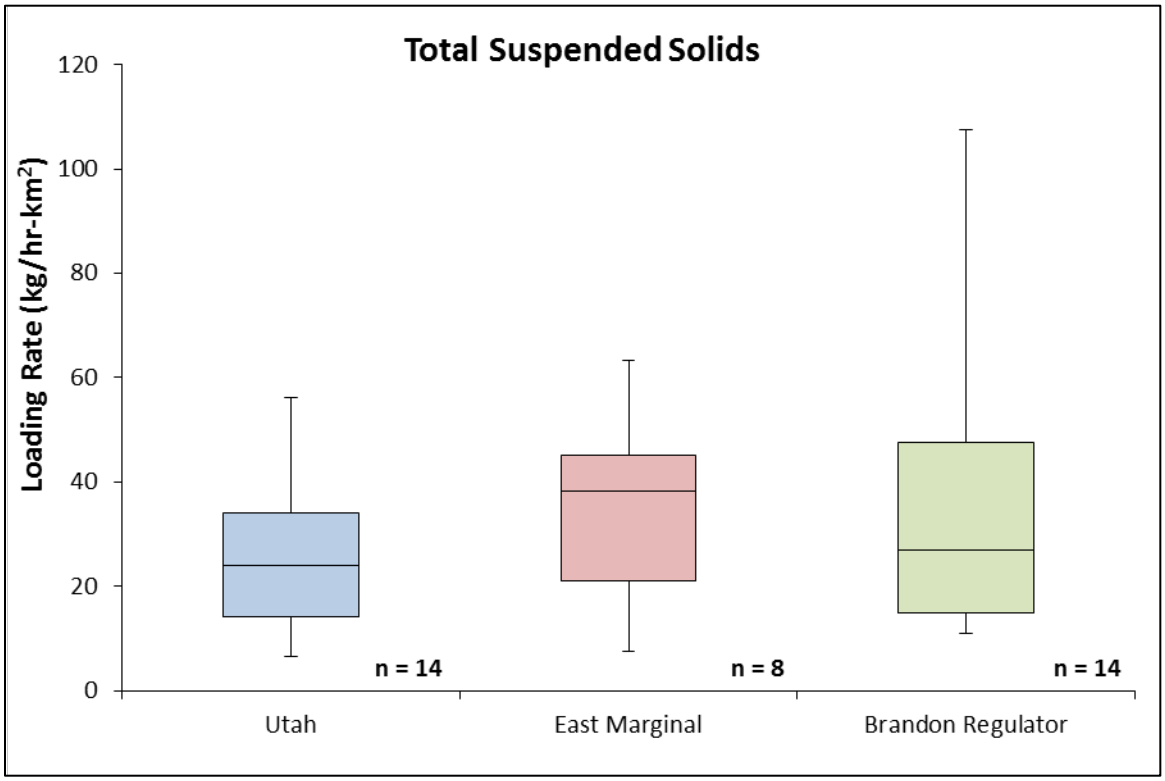

Figure E-3. Boxplots of Total Suspended Solids Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

Metals

For each sampling location, metals area-normalized loading rates during stormflow sampling are summarized (Table E-2). Sample loading rates were much more similar between sites after area-normalization, although total and dissolved nickel loading rates were still always higher at Brandon Regulator. Figures E-4 through E-21 illustrate these results.

Table E-2. Summary of Area-Normalized Metals Stormflow Loading Rates by location

Analyte	Location	Basin (km^2)	Minimum Loading Rate ($mg/hr/km^2$)		Maximum Loading Rate ($mg/hr/km^2$)		Mean Loading Rate ($mg/hr/km^2$)		Median Loading Rate ($mg/hr/km^2$)	
Total Arsenic	Utah	0.125	47.5		861		252		130	
	East Marginal	0.344	64.1		734		247		152	
	Brandon Regulator	0.987	64.1		880		368		259	
Dissolved Arsenic	Utah	0.125	30.5	J	334	J	117	J	76.6	J
	East Marginal	0.344	38.4	J	638	J	173	J	108	J
	Brandon Regulator	0.987	42.6	J	507	J	188	J	166	J
Total Cadmium	Utah	0.125	10.4	J	188		56.2	J	36.3	
	East Marginal	0.344	10.8		170		61.3		40.4	
	Brandon Regulator	0.987	16.5		216		78.7		53.2	
Dissolved Cadmium	Utah	0.125	2.00	J	36.3	J	9.72	J	6.01	J
	East Marginal	0.344	2.22	J	44.8	J	14.4	J	8.36	J
	Brandon Regulator	0.987	3.09	J	59.6	J	14.4	J	9.53	J
Total Chromium	Utah	0.125	160		3,710		1,110		651	
	East Marginal	0.344	214		1,300		595		520	
	Brandon Regulator	0.987	273		5,20		1,590		912	
Dissolved Chromium	Utah	0.125	24.2	J	487	J	114	J	45.5	J
	East Marginal	0.344	47.6	J	114	J	112	J	97.2	J
	Brandon Regulator	0.987	50.9	J	458	J	191	J	143	J
Total Copper	Utah	0.125	1,130		19,900		6,760		5,130	
	East Marginal	0.344	1,480		7,300		4,450		4,210	
	Brandon Regulator	0.987	2,860		47,200		10,400		5,730	
Dissolved Copper	Utah	0.125	390	J	5,000	J	1,490	J	1,000	J
	East Marginal	0.344	502	J	1,610	J	1,220	J	1,380	J
	Brandon Regulator	0.987	629	J	4,100	J	2,040	J	2,020	J

Analyte	Location	Basin (km^2)	Minimum Loading Rate ($mg/hr/km^2$)		Maximum Loading Rate ($mg/hr/km^2$)		Mean Loading Rate ($mg/hr/km^2$)		Median Loading Rate ($mg/hr/km^2$)	
Total Lead	Utah	0.125	531		10,100		3,350		2,030	
	East Marginal	0.344	541		4,020		1,830		1,400	
	Brandon Regulator	0.987	473		10,500		3,660		2,260	
Dissolved Lead	Utah	0.125	36.0	J	286	J	117	J	75.6	J
	East Marginal	0.344	71.7	J	295	J	151	J	125	J
	Brandon Regulator	0.987	43.6	J	553	J	189	J	185	J
Total Nickel	Utah	0.125	189		3,890		1,200		725	
	East Marginal	0.344	247		1170		598		507	
	Brandon Regulator	0.987	1,120		83,700		10,000		2,860	
Dissolved Nickel	Utah	0.125	78.1	J	776	J	295	J	220	J
	East Marginal	0.344	94.4	J	315	J	244	J	278	J
	Brandon Regulator	0.987	535	J	69,300	J	7,660	J	1,800	J
Total Silver	Utah	0.125	7.26	J	174		39.0	J	24.9	
	East Marginal	0.344	2.02	J	14.1	J	9.16	J	10.1	J
	Brandon Regulator	0.987	10.7	J	341		73.6	J	26.7	J
Dissolved Silver	Utah	0.125	2.36	J	27.4	J	13.1	J	13.2	J
	East Marginal	0.344	—		—		—		—	
	Brandon Regulator	0.987	3.02	J	26.6	J	12.7	J	8.43	J
Total Vanadium	Utah	0.125	156		4,120		1,150		496	
	East Marginal	0.344	207		1,290		549		433	
	Brandon Regulator	0.987	161		2,790		1,030		802	
Dissolved Vanadium	Utah	0.125	33.6	J	532	J	194	J	108	J
	East Marginal	0.344	49.6	J	215	J	104	J	84.7	J
	Brandon Regulator	0.987	35.5	J	402	J	160	J	128	J
Total Zinc	Utah	0.125	4,350		90,700		26,000		17,200	
	East Marginal	0.344	6,620		32,500		21,000		22,100	
	Brandon Regulator	0.987	8,260		95,400		31,400		20,100	
Dissolved Zinc	Utah	0.125	1,790	J	22,400	J	7,260	J	3,960	J
	East Marginal	0.344	2,130	J	10,300	J	7,520	J	7,990	J
	Brandon Regulator	0.987	2,360	J	20,200	J	8,750	J	6,440	J

J = estimated value

Means calculated only with two or more detections; medians calculated only with three or more detections.

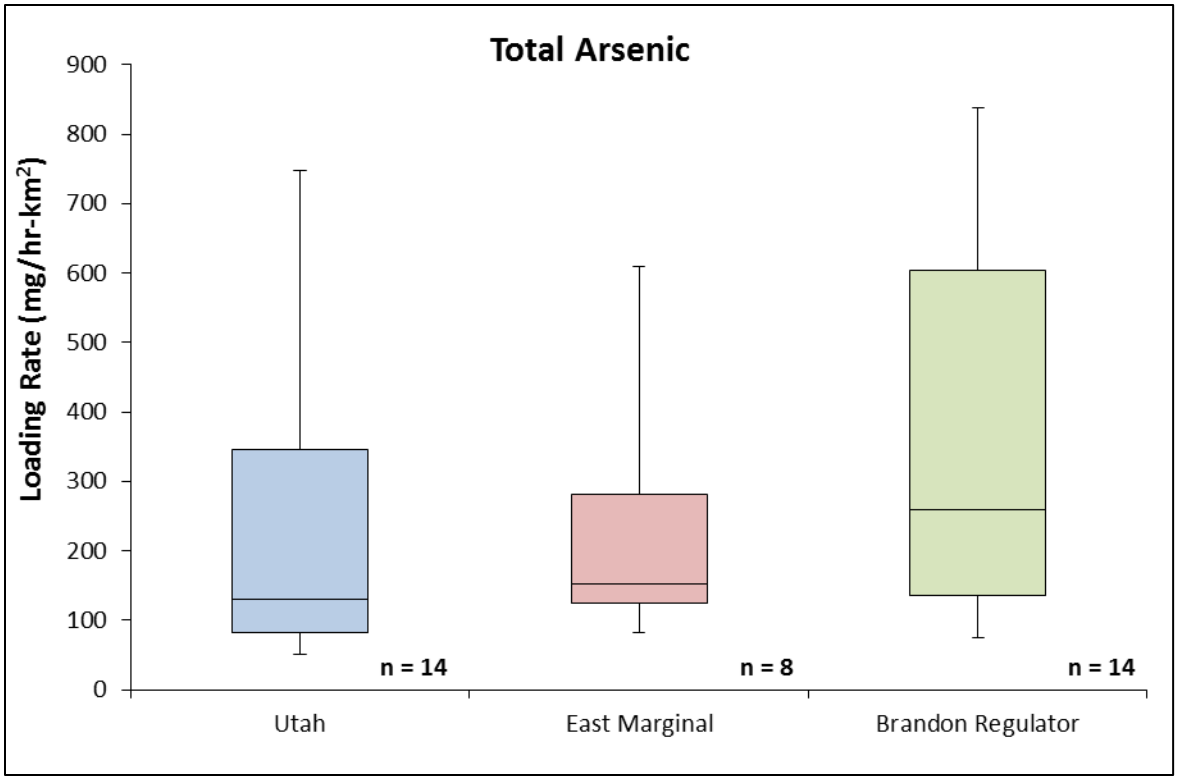

Figure E-4. Boxplots of Total Arsenic Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

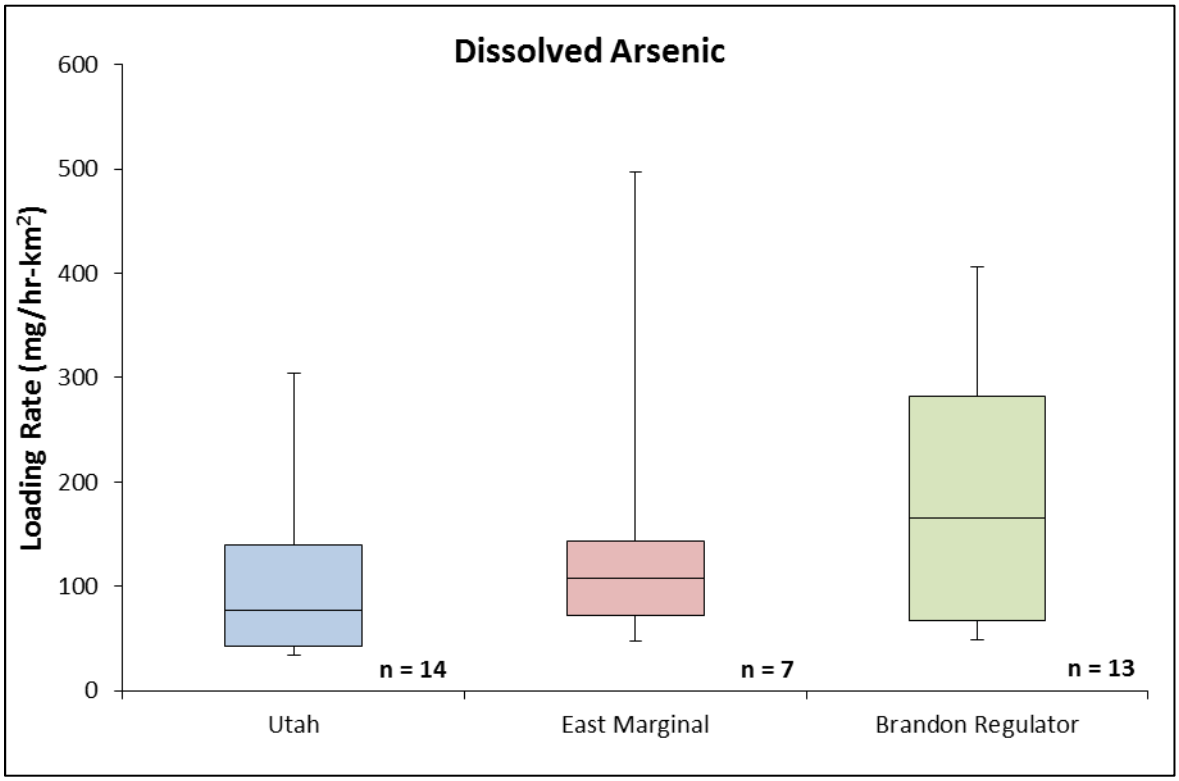

Figure E-5. Boxplots of Dissolved Arsenic Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

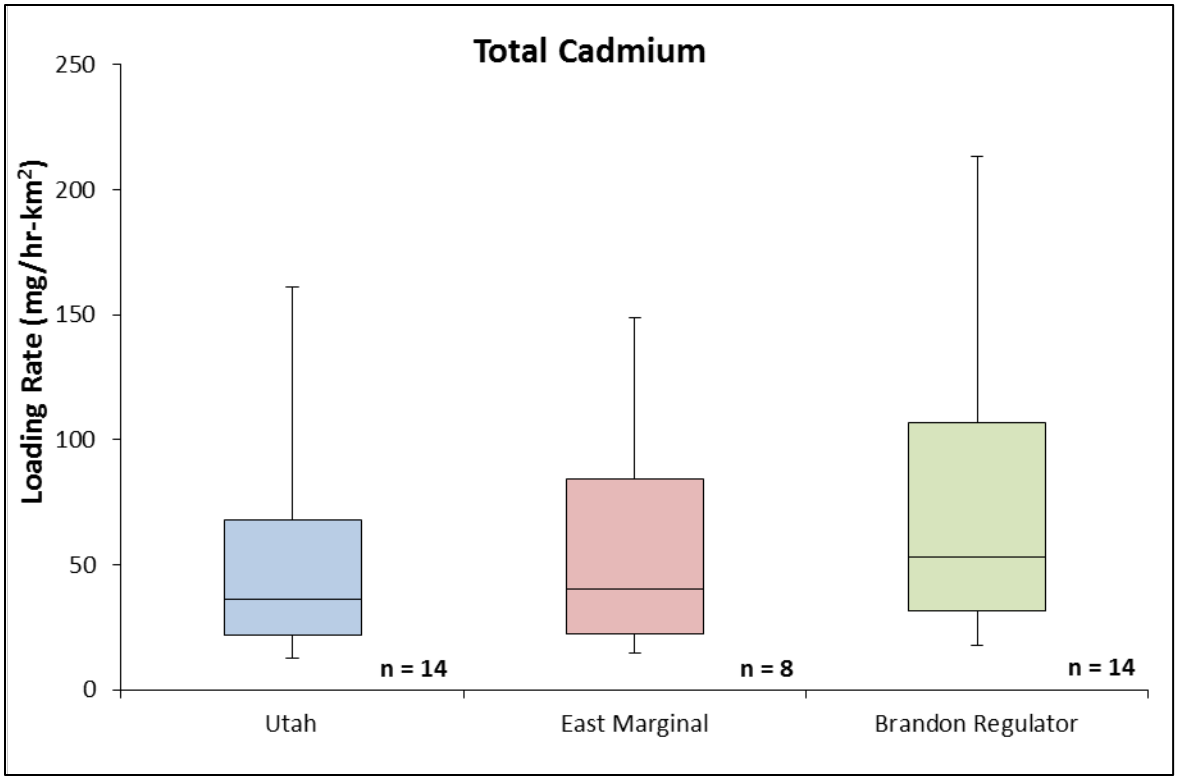

Figure E-6. Boxplots of Total Cadmium Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

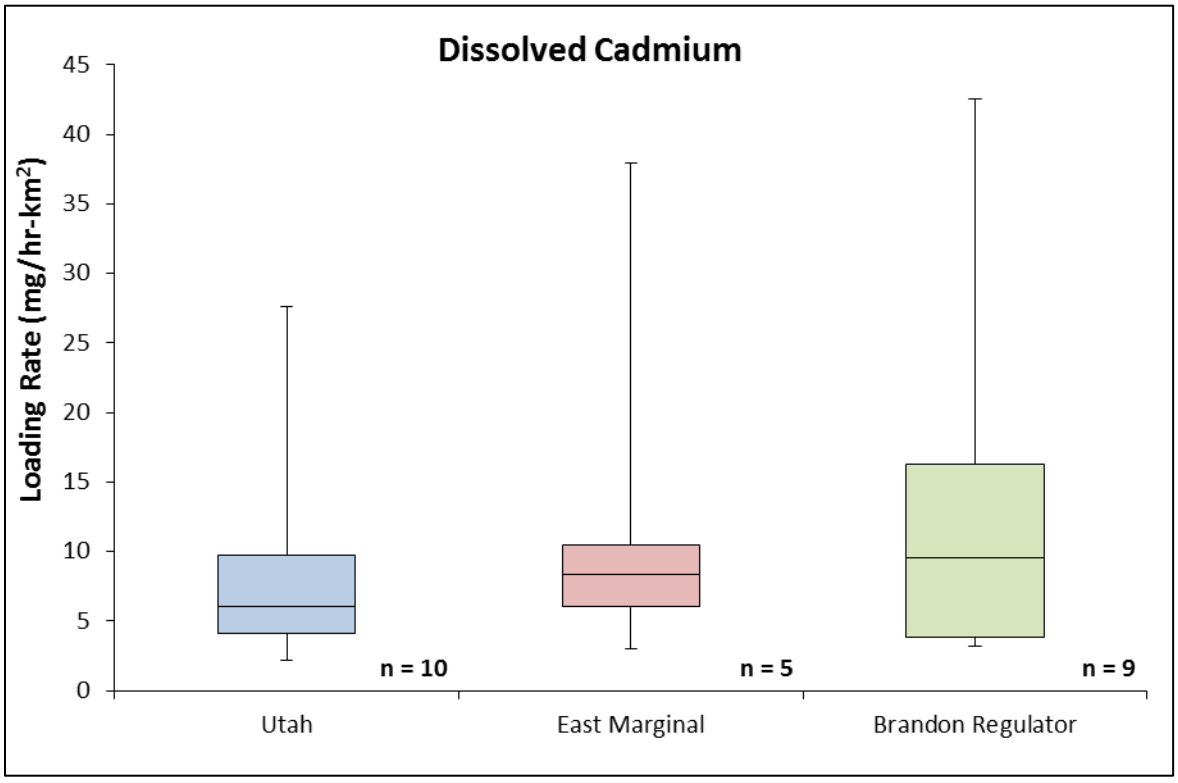

Figure E-7. Boxplots of Dissolved Cadmium Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

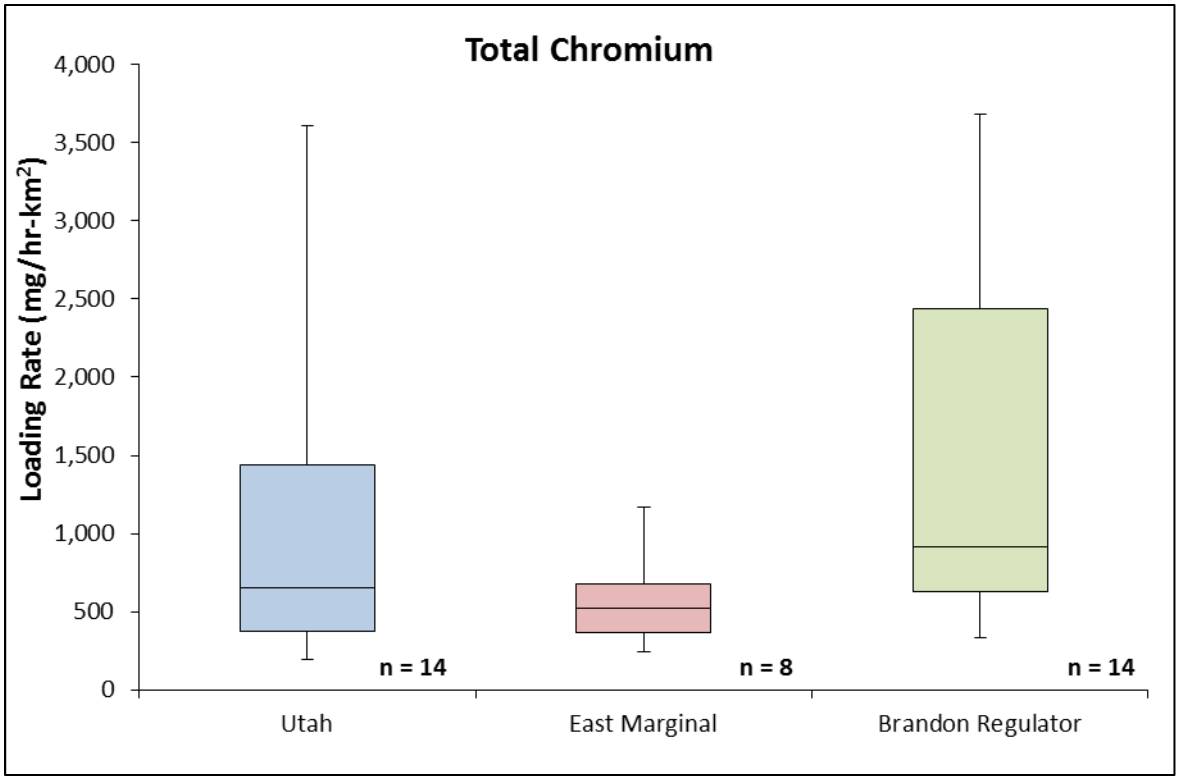

Figure E-8. Boxplots of Total Chromium Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

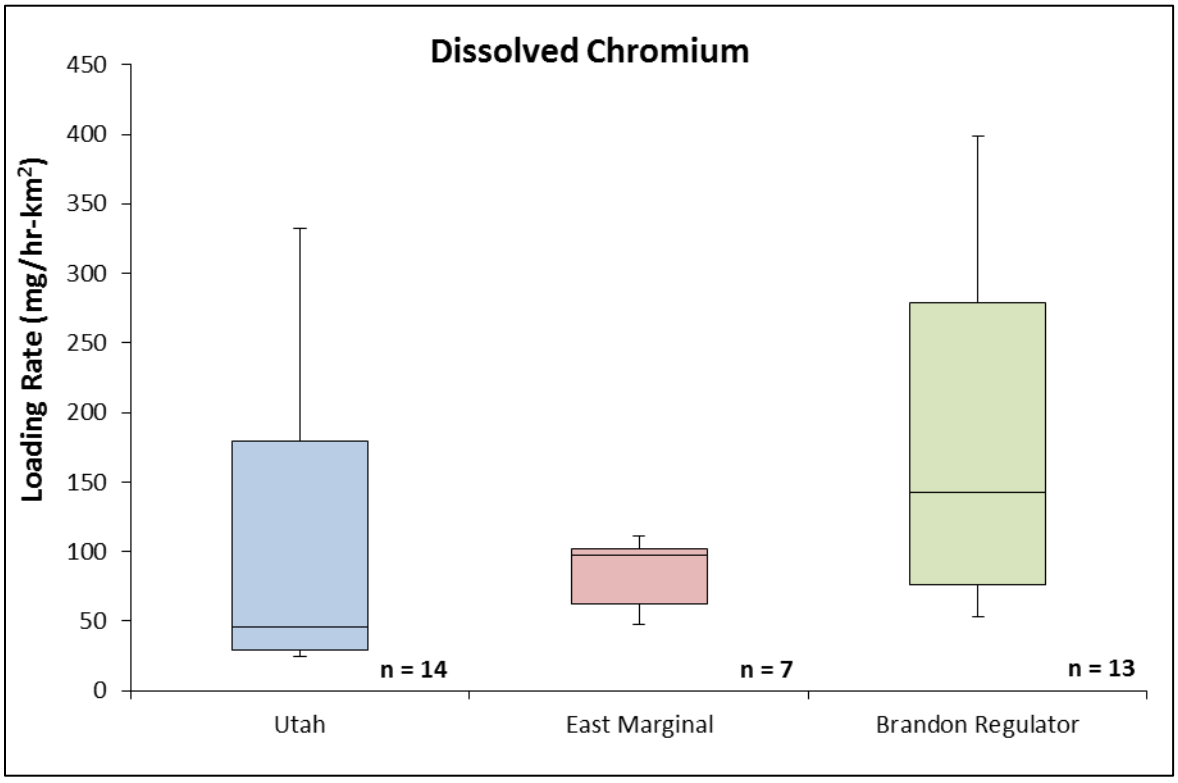

Figure E-9. Boxplots of Dissolved Chromium Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

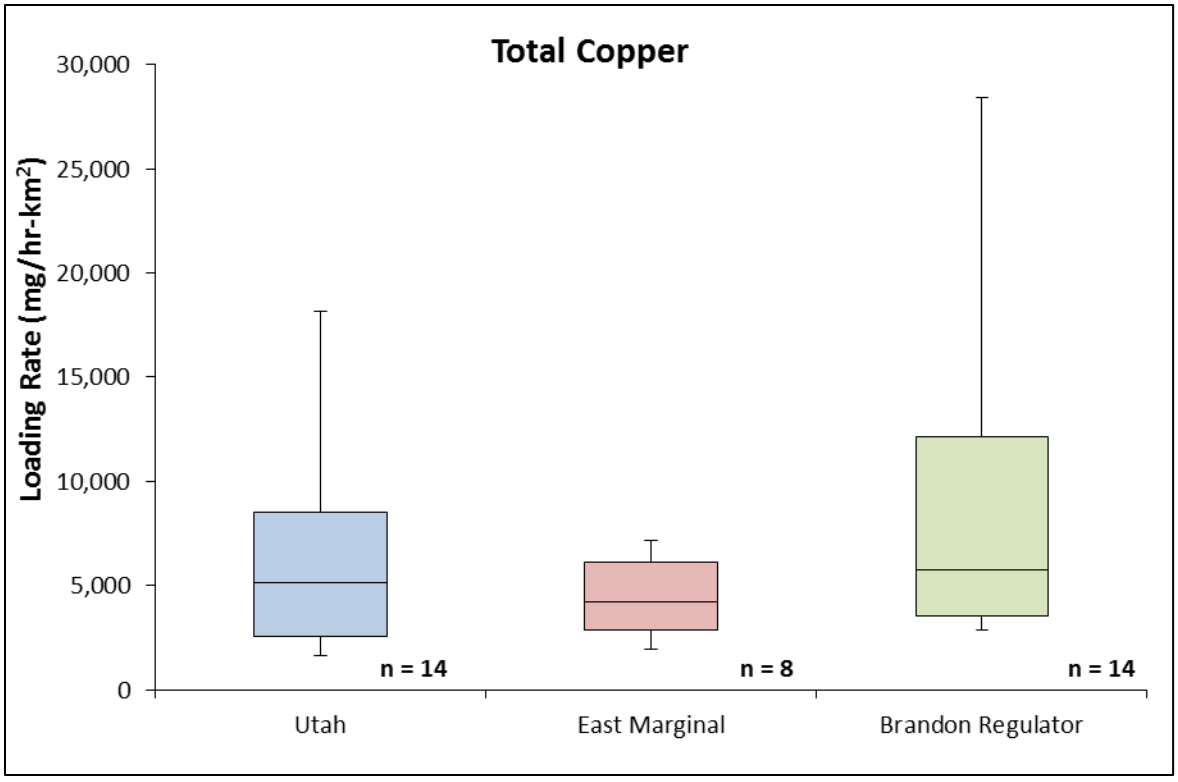

Figure E-10. Boxplots of Total Copper Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

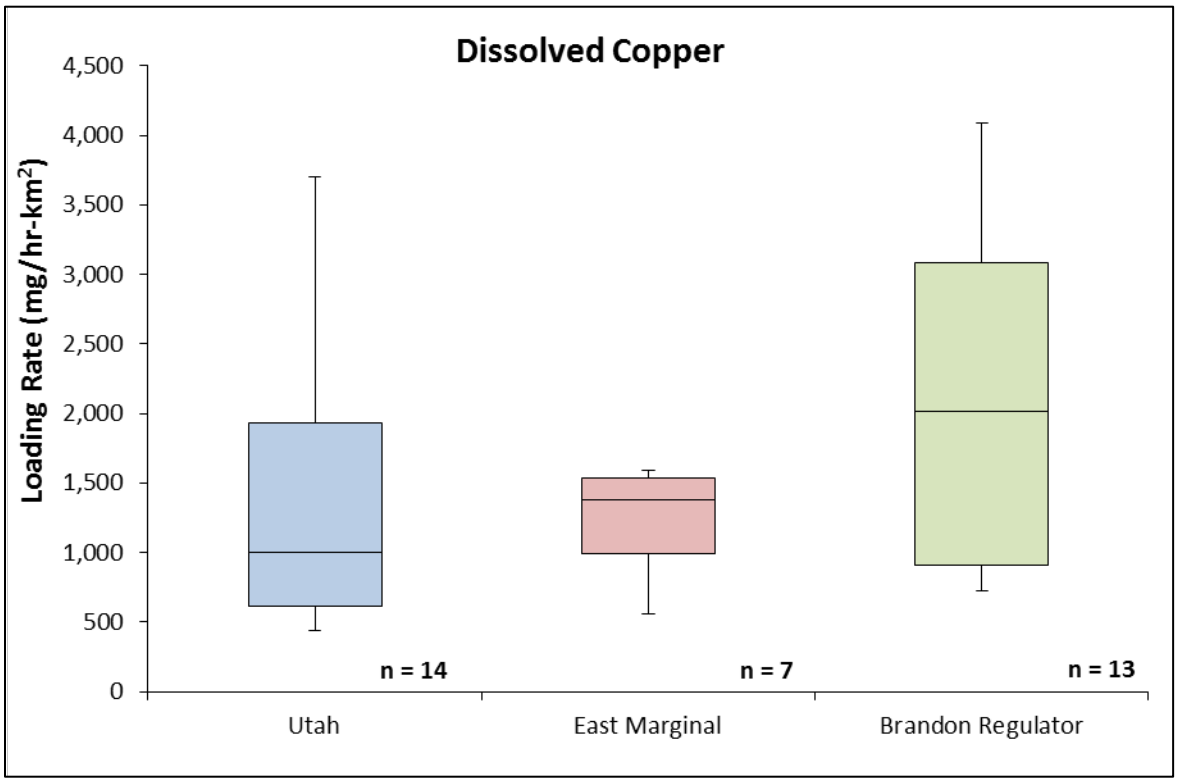

Figure E-11. Boxplots of Dissolved Copper Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

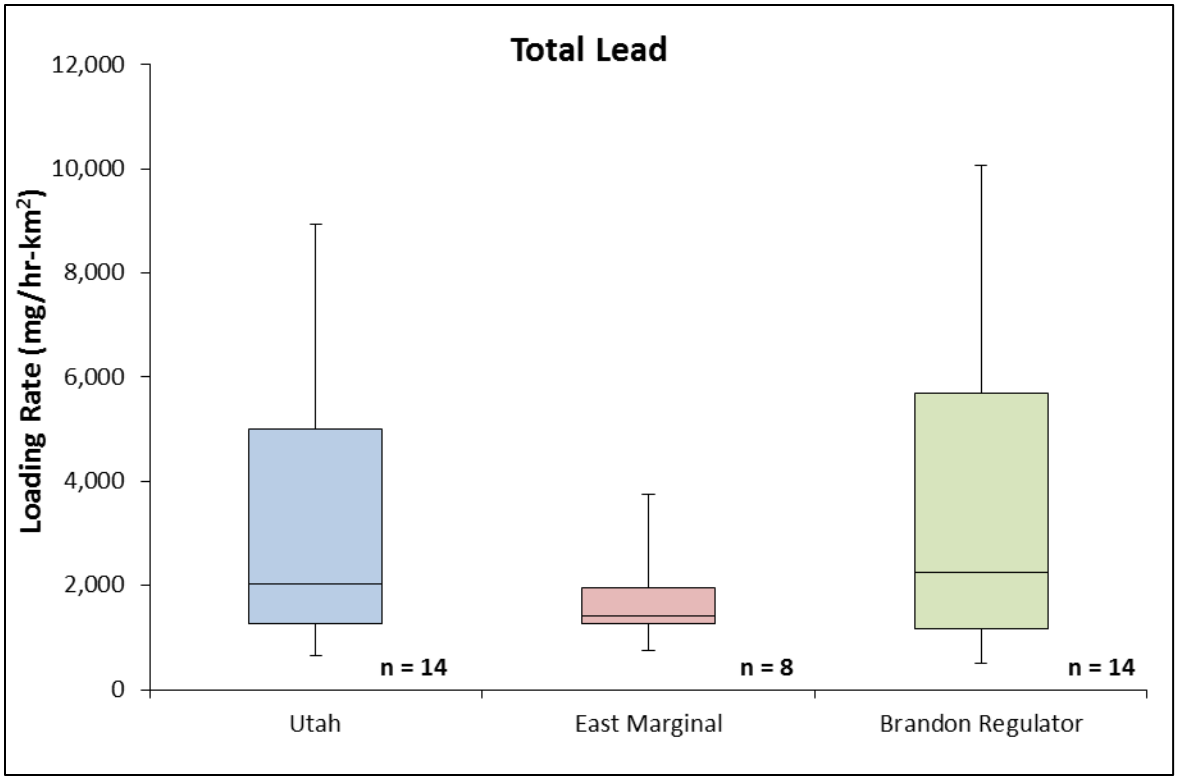

Figure E-12. Boxplots of Total Lead Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

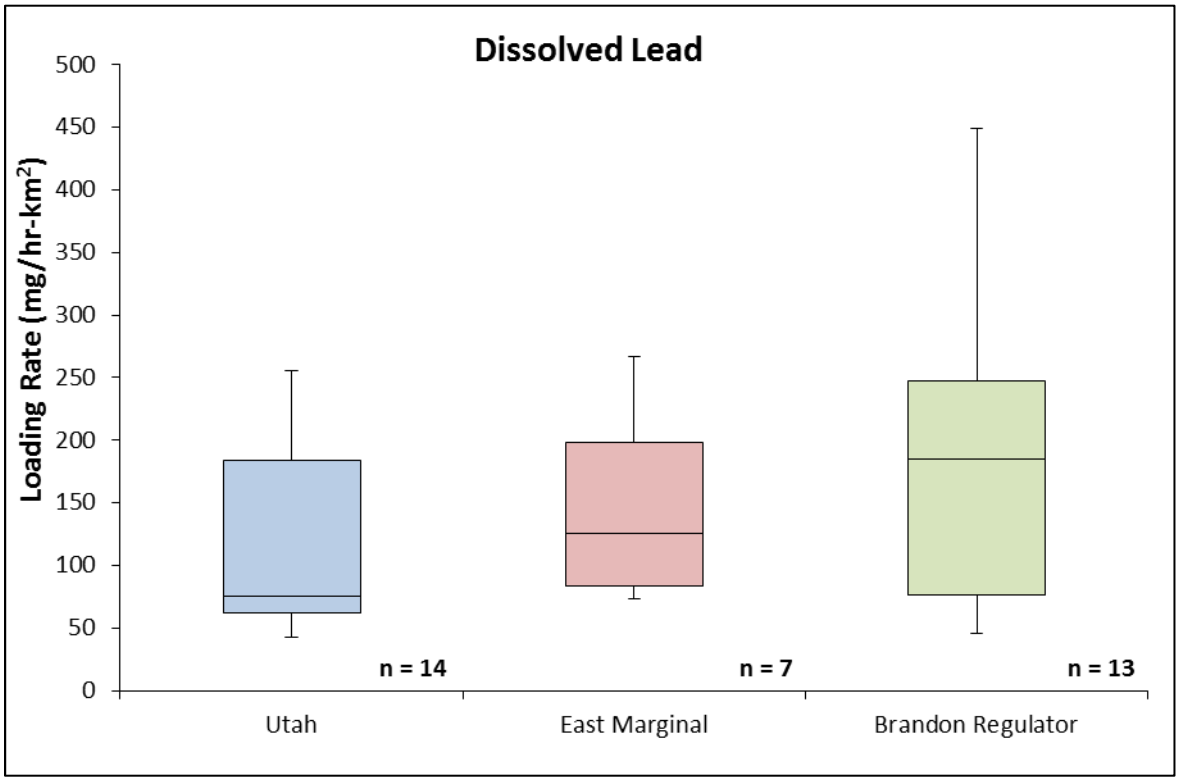

Figure E-13. Boxplots of Dissolved Lead Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

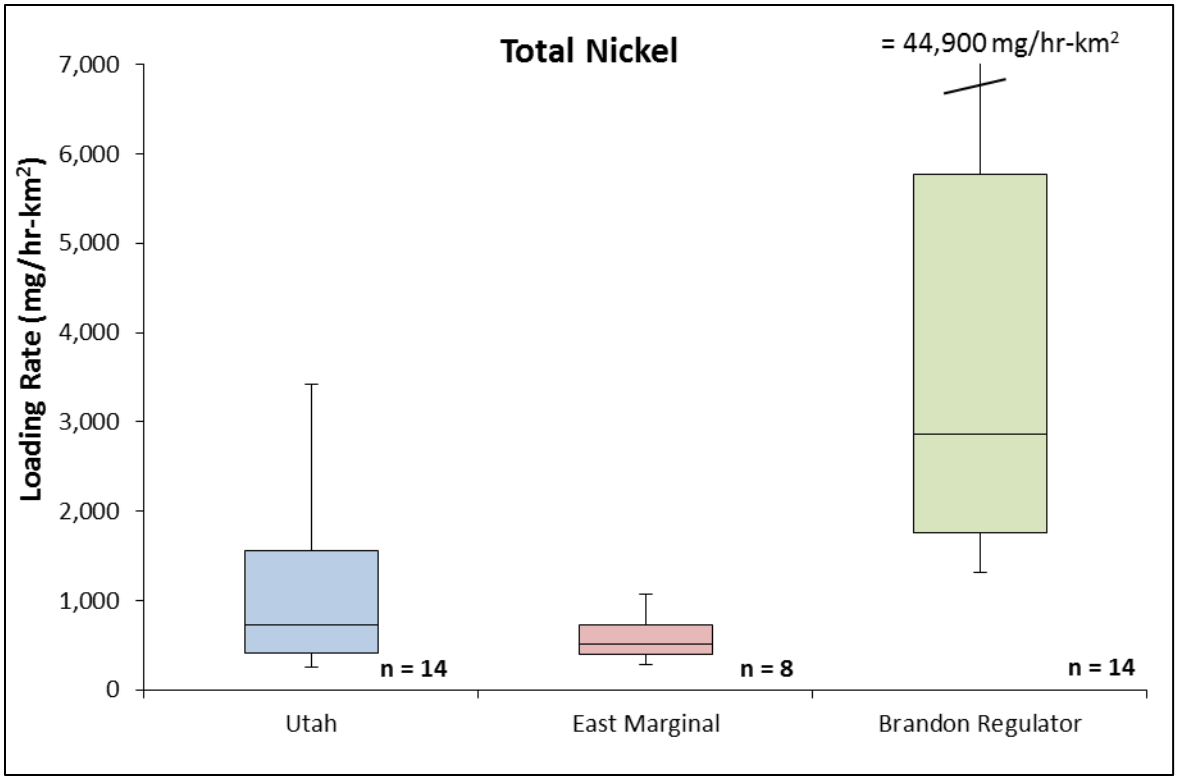

Figure E-14. Boxplots of Total Nickel Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

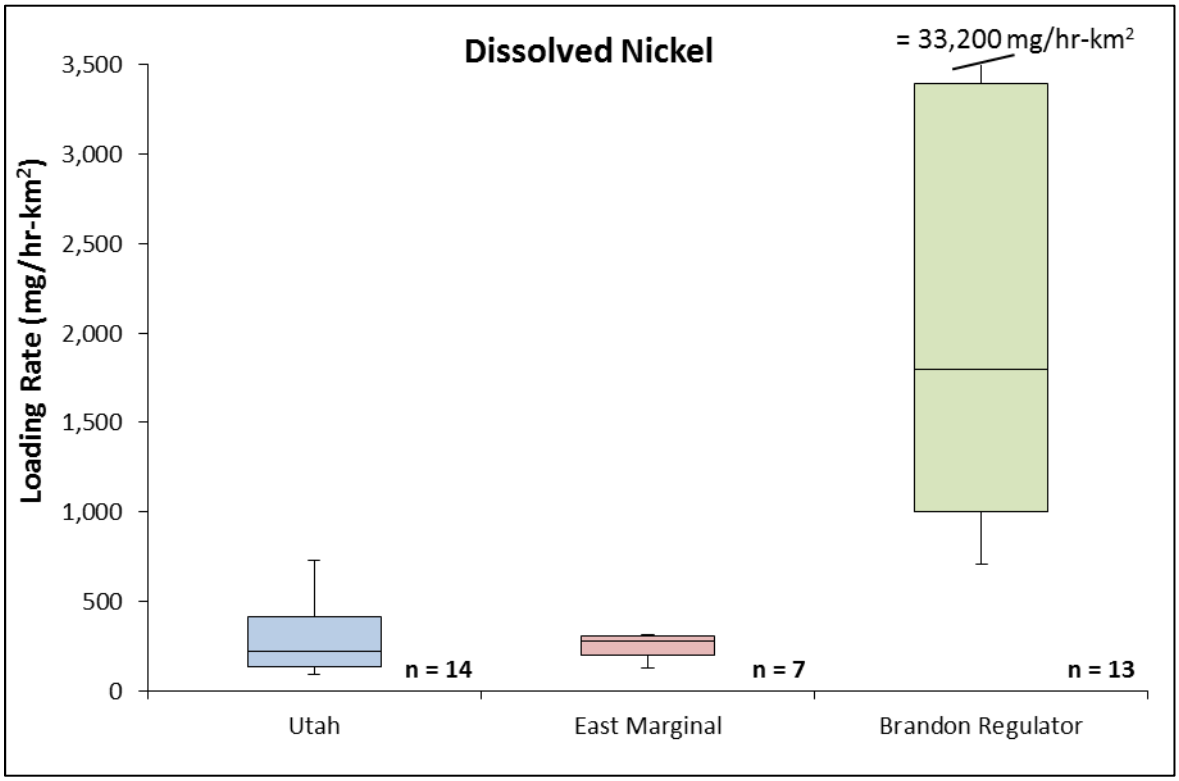

Figure E-15. Boxplots of Dissolved Nickel Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

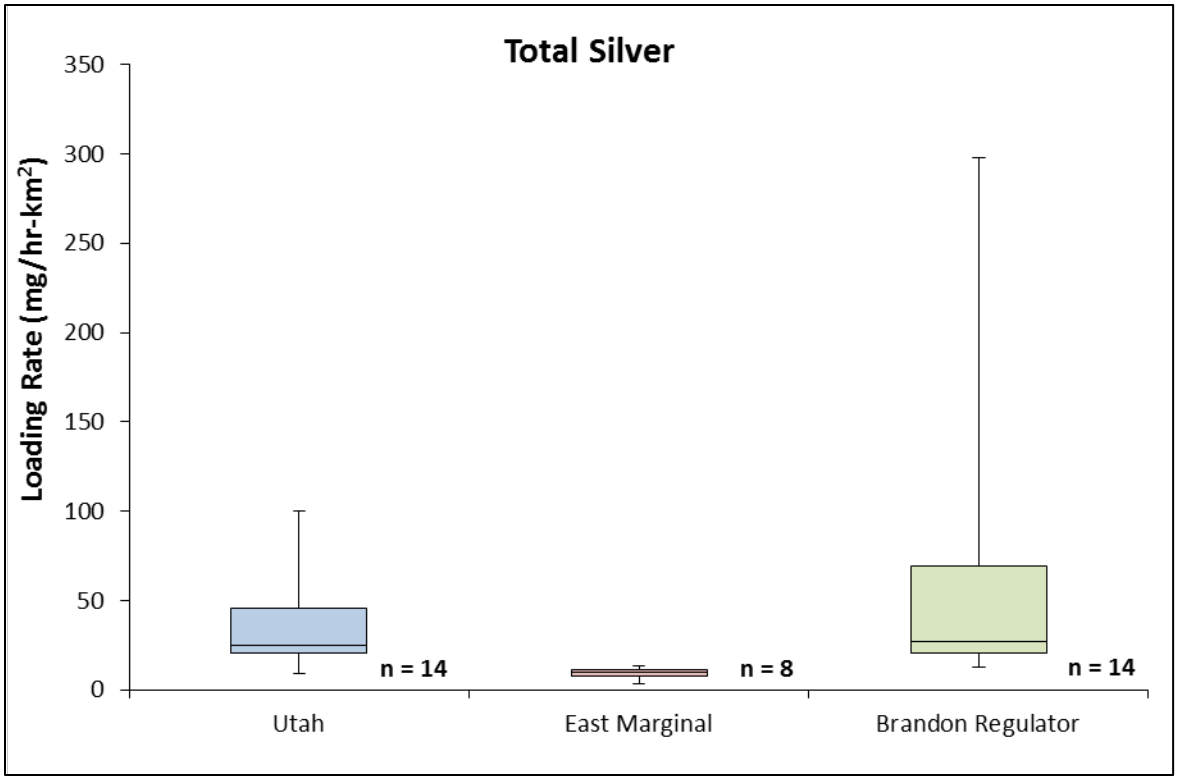

Figure E-16. Boxplots of Total Silver Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

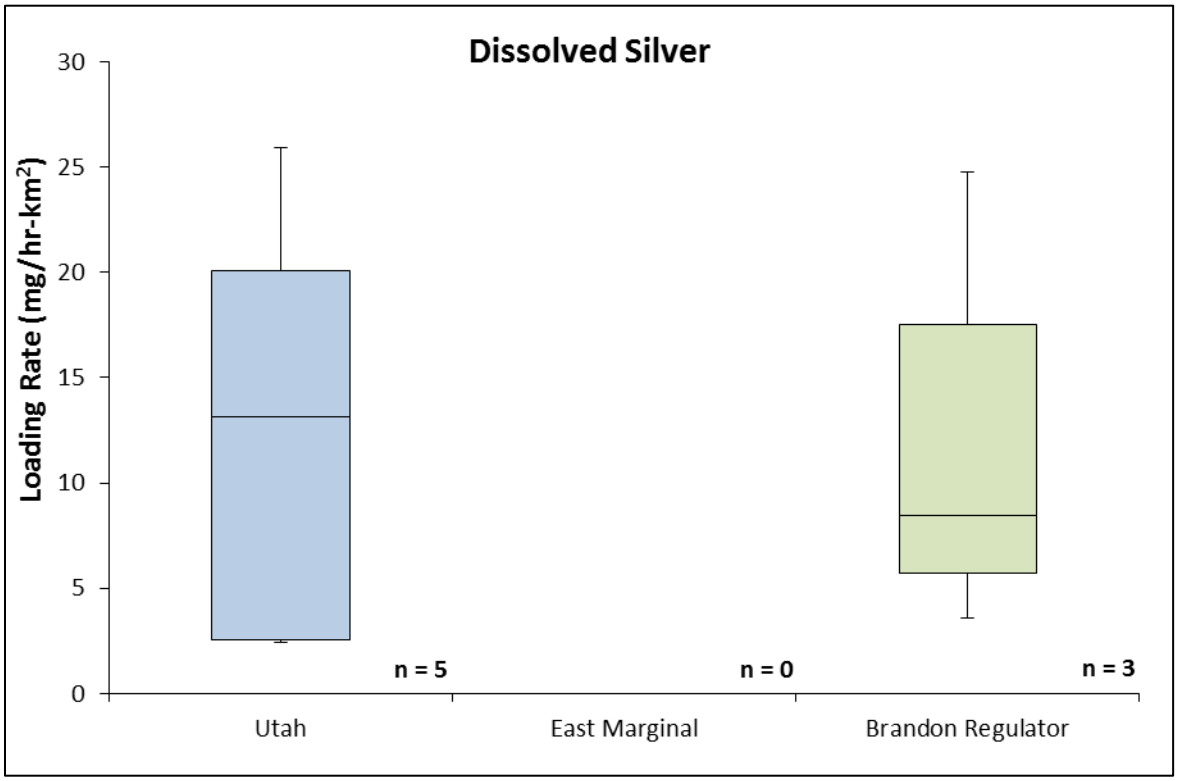

Figure E-17. Boxplots of Dissolved Silver Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

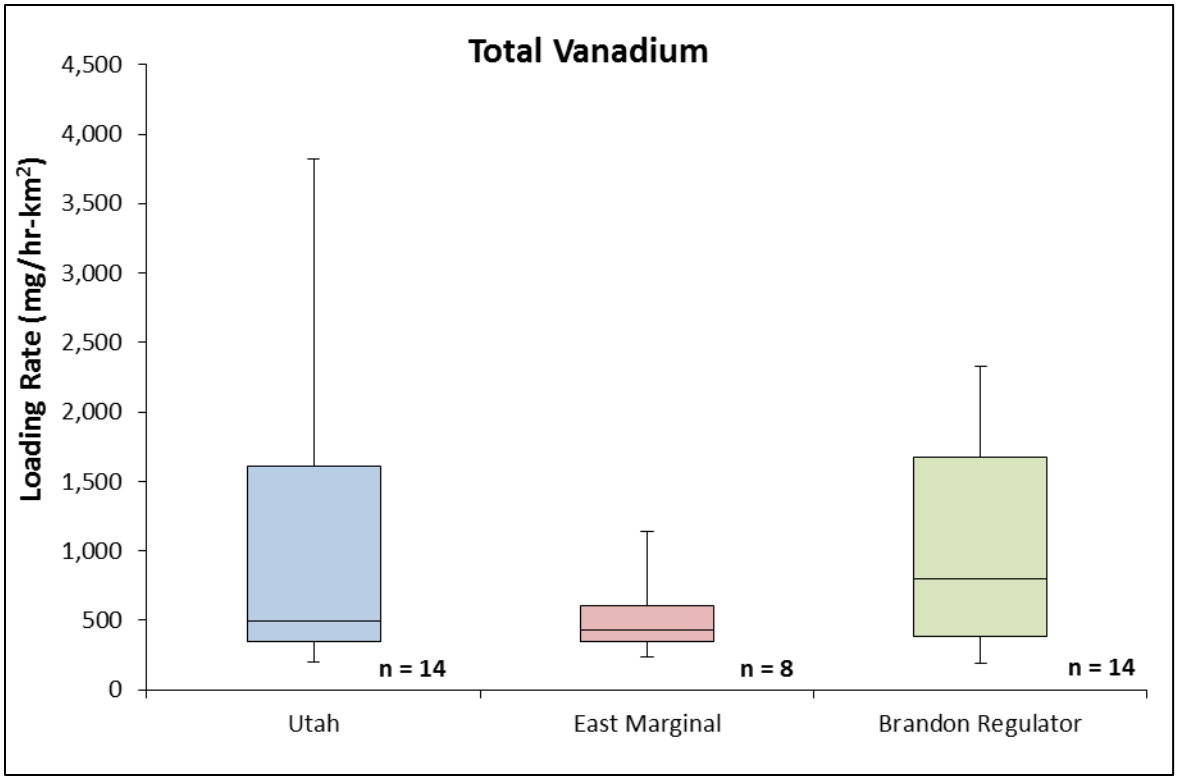

Figure E-18. Boxplots of Total Vanadium Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

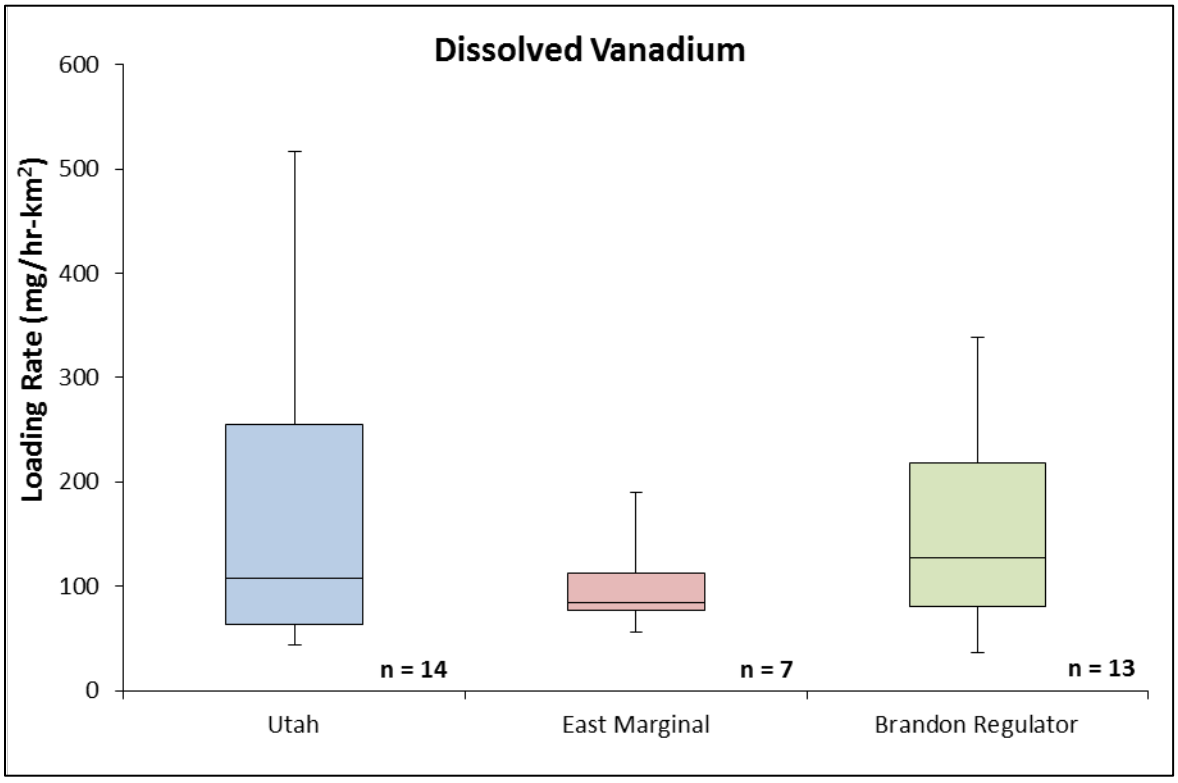

Figure E-19. Boxplots of Dissolved Vanadium Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

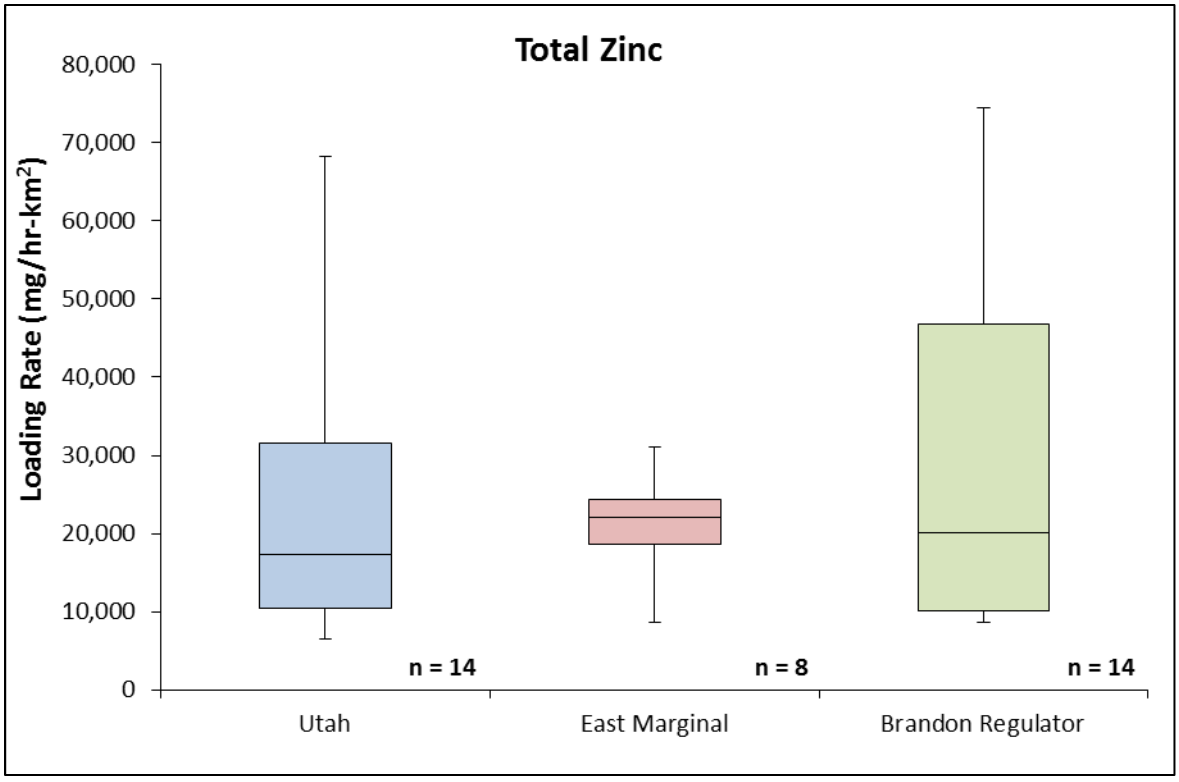

Figure E-20. Boxplots of Total Zinc Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

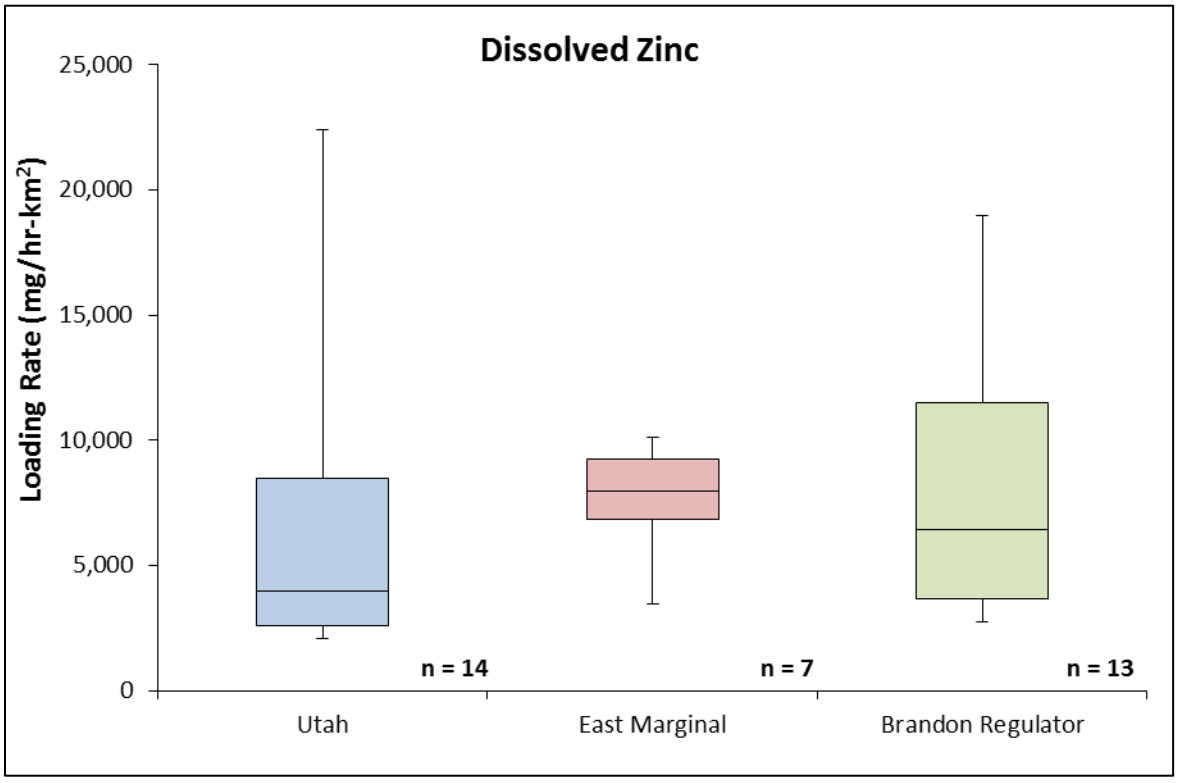

Figure E-21. Boxplots of Dissolved Zinc Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

Mercury

For each sampling location, mercury area-normalized loading rates during stormflow sampling are summarized (Table E-3). Median sample loading rates for total mercury were much more similar between sites after area-normalization. Figures E-22 and E-23 illustrate these results.

Table E-3. Summary of Area-Normalized Mercury Stormflow Loading Rates by Location

Analyte	Location	Basin (km^2)	Minimum Loading Rate ($mg/hr/km^2$)		Maximum Loading Rate ($mg/hr/km^2$)		Mean Loading Rate ($mg/hr/km^2$)		Median Loading Rate ($mg/hr/km^2$)	
Total Mercury	Utah	0.125	0.981		22.2		6.76		4.20	
	East Marginal	0.344	1.05	J	11.3		5.12	J	3.87	
	Brandon Regulator	0.987	1.64		126		16.7	J	6.49	
Dissolved Mercury	Utah	0.125	0.245	J	1.32	J	0.674	J	0.500	J
	East Marginal	0.344	0.396	J	1.92	J	1.08	J	0.931	J
	Brandon Regulator	0.987	0.245	J	3.35	J	1.14	J	0.415	J

J = estimated value

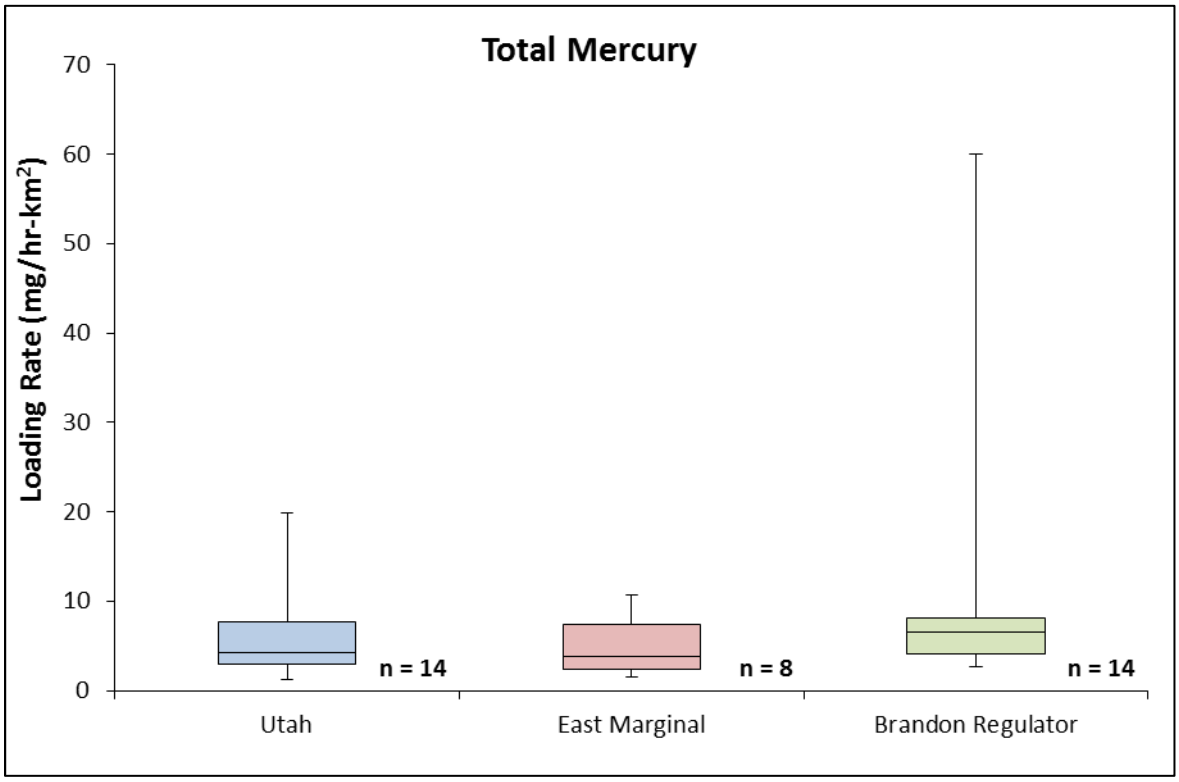

Figure E-22. Boxplots of Total Mercury Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

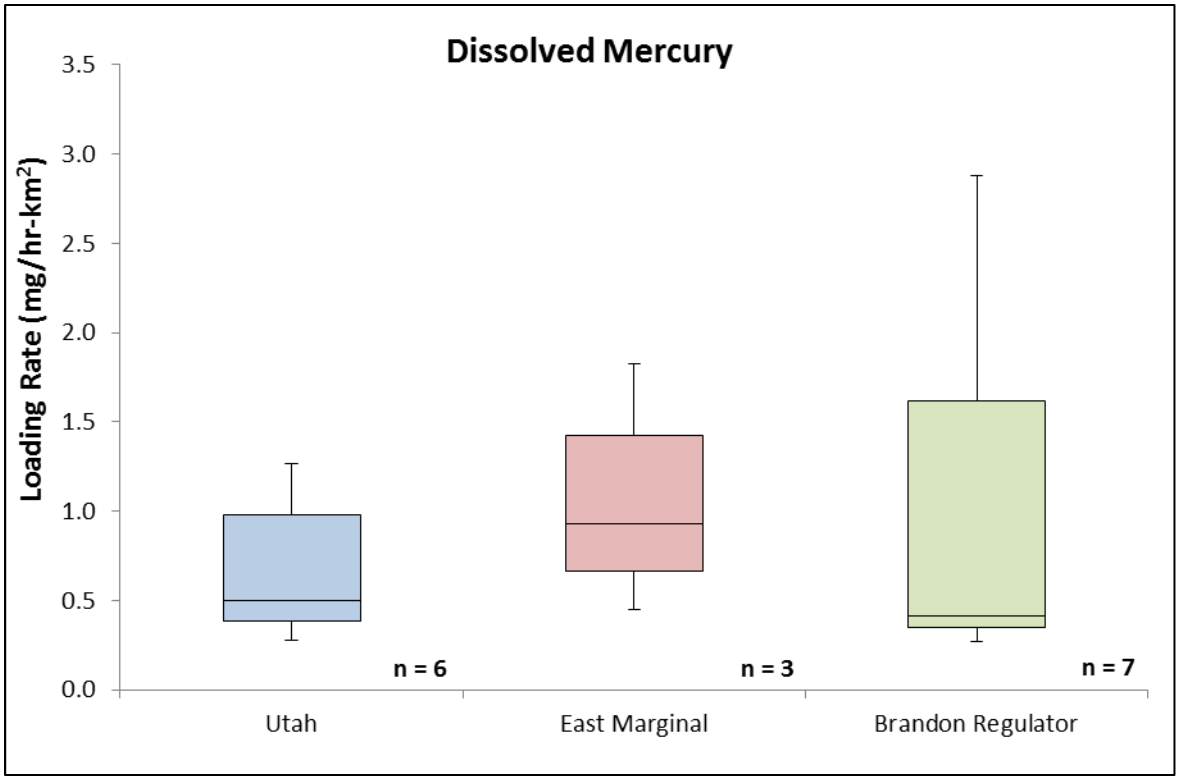

Figure E-23. Boxplots of Dissolved Mercury Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

PAHs

Table E-4 summarizes area-normalized loading rates during stormflow sampling for example PAHs at each location. Figures E-24 through E-26 illustrate these results. After area-normalization, mean and median areal loading rates were more similar across all sites for PAHs. Prior to area normalization, all loading rate estimates were greatest at Brandon Regulator likely because of greater flows.

Table E-4. Summary of Area-Normalized Example PAH Stormflow Loading Rates by Location

Analyte	Location	Basin (km^2)	Minimum Loading Rate ($mg/hr/km^2$)	Maximum Loading Rate ($mg/hr/km^2$)	Mean Loading Rate ($mg/hr/km^2$)	Median Loading Rate ($mg/hr/km^2$)
Phenanthrene	Utah	0.125	2.15 J	64.0	18.0	12.9
	East Marginal	0.344	7.38	24.4	13.3	11.7
	Brandon Regulator	0.987	3.20	58.2	22.3	15.8
Fluoranthene	Utah	0.125	2.56	90.7 J	30.4 J	19.7
	East Marginal	0.344	7.52	25.1	13.3	11.7

Analyte	Location	Basin (km^2)	Minimum Loading Rate ($mg/hr/km^2$)	Maximum Loading Rate ($mg/hr/km^2$)	Mean Loading Rate ($mg/hr/km^2$)	Median Loading Rate ($mg/hr/km^2$)
	Brandon Regulator	0.987	2.83 J	74.7	28.0 J	19.6
Total HPAH	Utah	0.125	9.80 J	544 J	151 J	90.1 J
	East Marginal	0.344	25.5 J	103 J	50.5 J	36.7 J
	Brandon Regulator	0.987	9.76 J	314 J	125 J	81.9 J

J = estimated value

Means calculated only with two or more detections; medians calculated only with three or more detections.

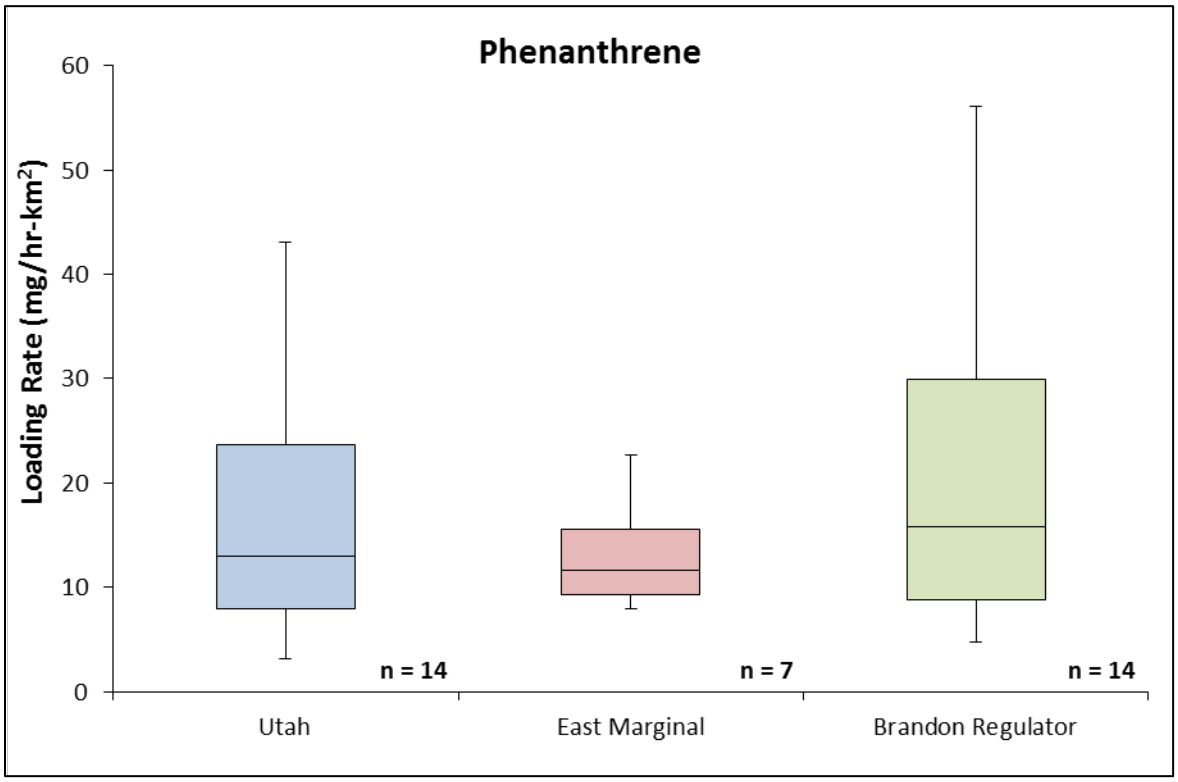

Figure E-24. Boxplots of Phenanthrene Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

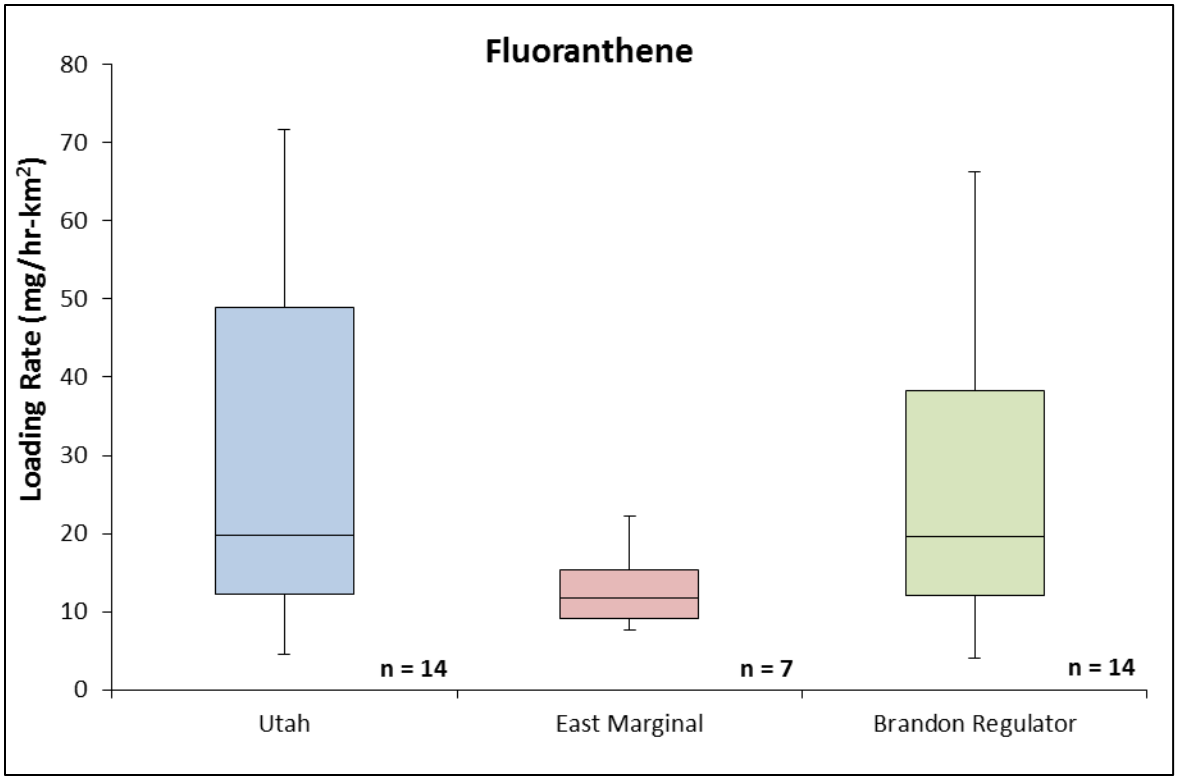

Figure E-25. Boxplots of Fluoranthene Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

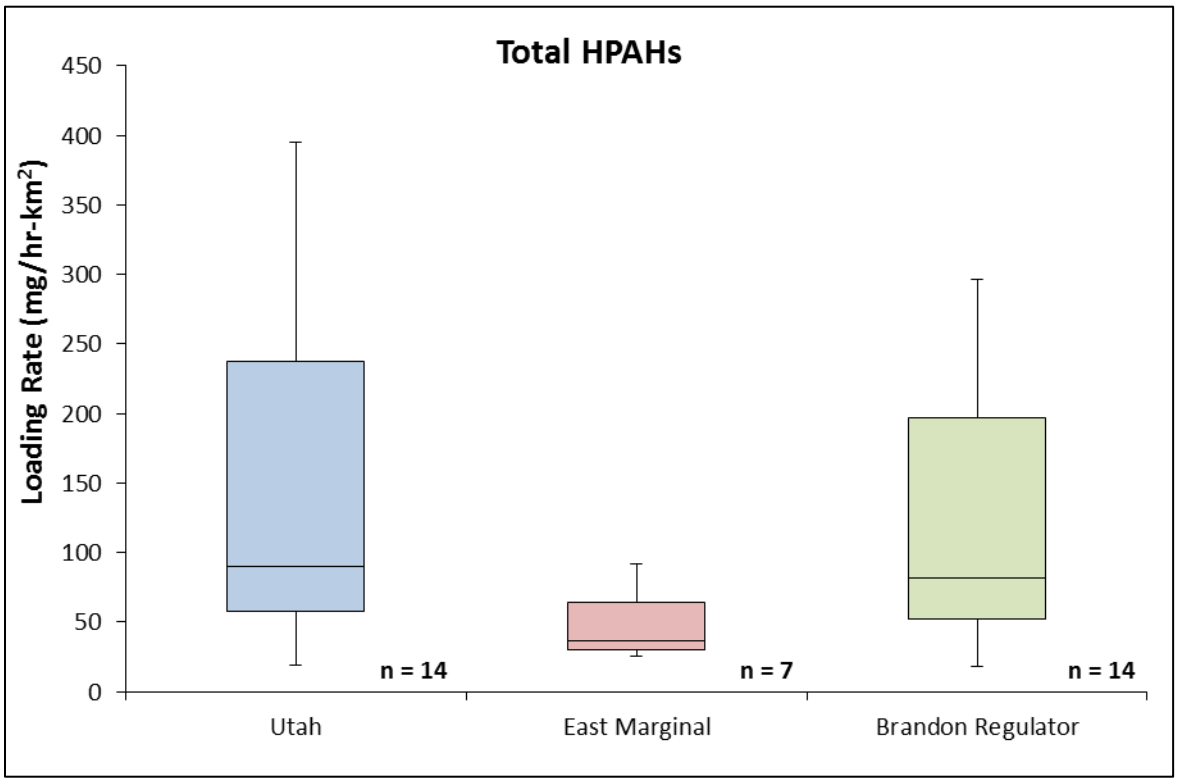

Figure E-26. Boxplots of Fluoranthene Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

Phthalates

Table E-5 summarizes areal loading rates during stormflow sampling for example phthalates at each location. Sample loading rates for bis(2-ethylhexyl)phthalate and diethyl phthalate were much more similar across sites as compared to sample loading rates prior to area-normalization. Benzyl butyl phthalate loading rates varied, with East Marginal having the highest mean but lowest median areal loading rates, indicating high variability at that site. Figures E-27 through E-29 illustrate these results.

Table E-5. Summary of Area-Normalized Benzyl Butyl Phthalate Stormflow Loading Rates by Location

Analyte	Location	Basin (km^2)	Minimum Loading Rate ($mg/hr/km^2$)	Maximum Loading Rate ($mg/hr/km^2$)	Mean Loading Rate ($mg/hr/km^2$)	Median Loading Rate ($mg/hr/km^2$)
Benzyl Butyl Phthalate	Utah	0.125	78.1 J	2795	1025 J	976
	East Marginal	0.344	18.6	8979	1345	53.6
	Brandon Regulator	0.987	114	2977	585 J	257
Bis (2-ethylhexyl) phthalate	Utah	0.125	161 J	2,100 J	643 J	473 J
	East Marginal	0.344	252 J	979 J	527 J	486 J
	Brandon Regulator	0.987	172 J	2,610 J	881 J	346 J
Diethyl Phthalate	Utah	0.125	53.1	409	189	195
	East Marginal	0.344	36.2	163	95.9	88.5
	Brandon Regulator	0.987	54.3	350	147	99.3

J = estimated value

Means calculated only with two or more detections; medians calculated only with three or more detections.

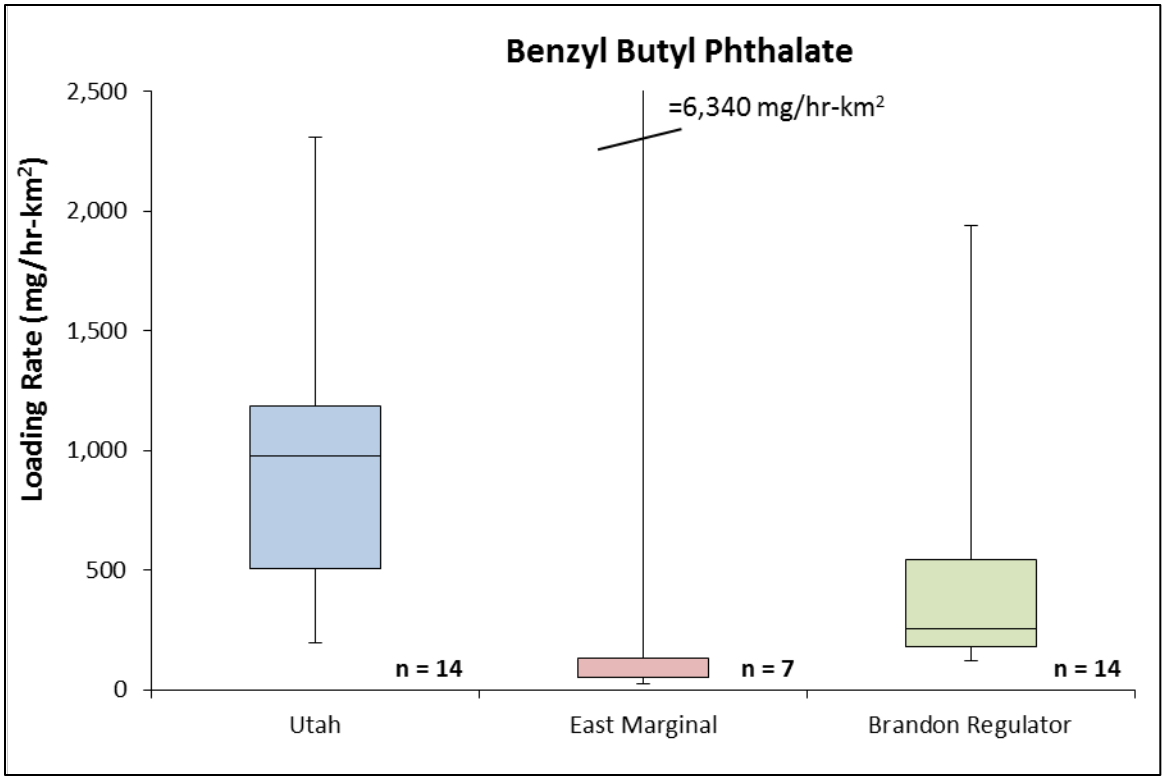

Figure E-27. Boxplots of Benzyl Butyl Phthalate Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

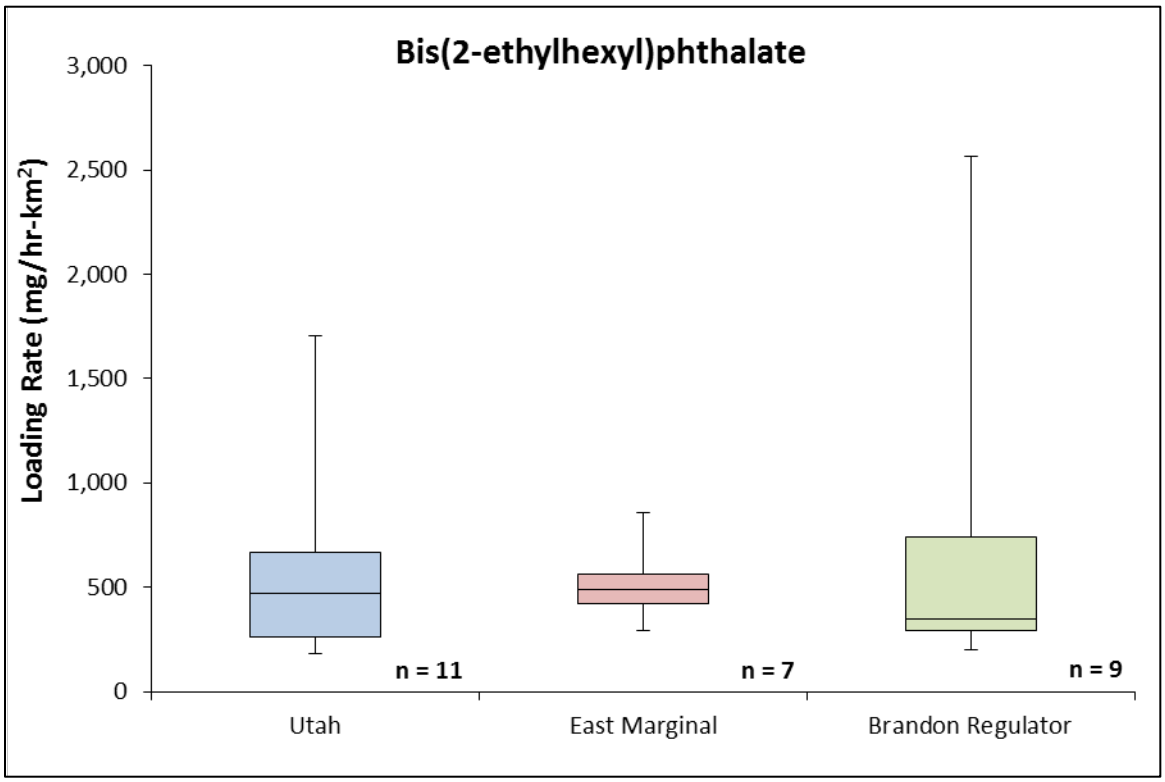

Figure E-28. Boxplots of Bis(2-ethylhexyl)phthalate Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

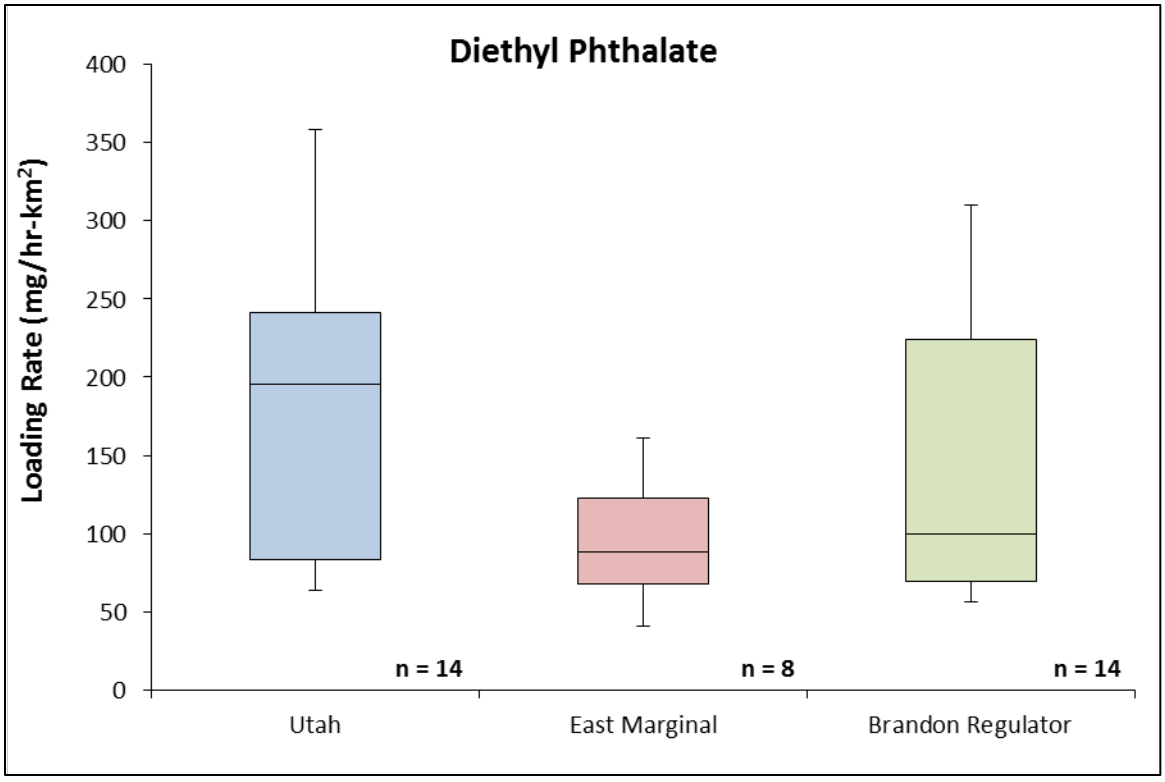

Figure E-29. Boxplots of Diethyl Phthalate Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

PCBs and Dioxin/Furans

Table E-6 summarizes areal loading rates during stormflow sampling for total PCBs and total dioxin/furan at each location. Median areal loading rates for both compounds were highest at Brandon Regulator and lowest at East Marginal. This same pattern was observed prior to area-normalization; however, after area-normalization the differences between sites were much less compared to sample loading rates prior to area-normalization. Figures E-30 and E-31 illustrate these results.

Table E-6. Summary of Area-Normalized PCBs and Total Dioxin/Furan Stormflow Loading Rates by Location

Analyte	Location	Basin (km^2)	Minimum Loading Rate ($\mu g/hr/km^2$)	Maximum Loading Rate ($\mu g/hr/km^2$)	Mean Loading Rate ($\mu g/hr/km^2$)	Median Loading Rate ($\mu g/hr/km^2$)
Total PCBs	Utah	0.125	1,850	44,100	13,600	5,970
	East Marginal	0.344	1,360	5,690	3,430	3,350
	Brandon Regulator	0.987	1,820	57,500	22,600	24,100
Total Dioxin/ Furans	Utah	0.125	72.6	1,440	412	154
	East Marginal	0.344	55.3	192	102	89.3
	Brandon Regulator	0.987	28.6	575	337	405

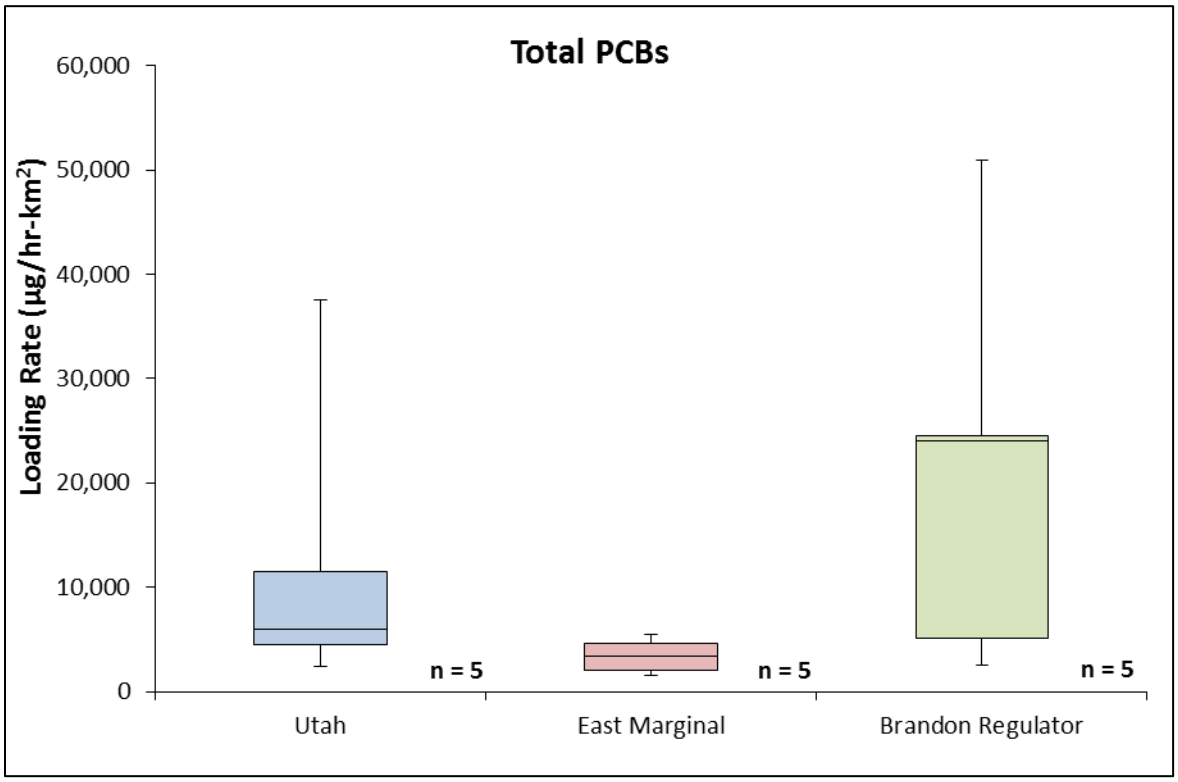

Figure E-30. Boxplots of Total polychlorinated biphenyls (PCBs) Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

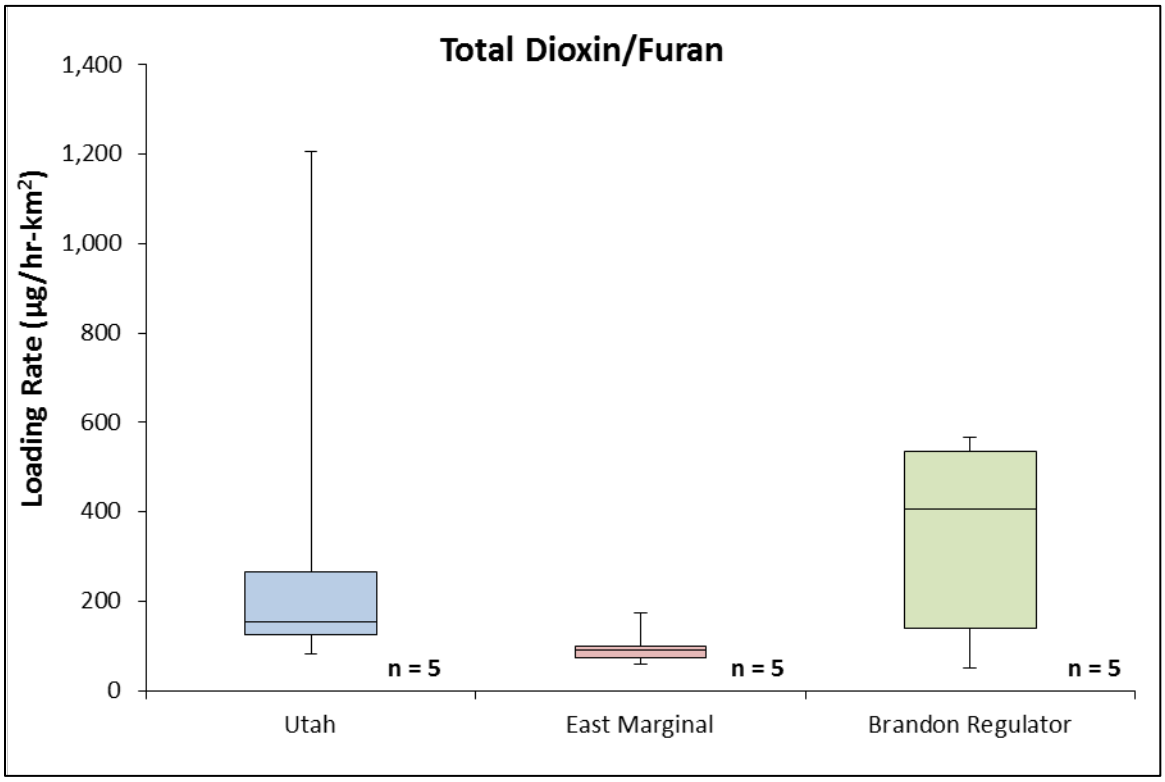

Figure E-31. Boxplots of Total Dioxin/Furans Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.

Median and mean areal loading rates for total dioxin TEQs were highest at Brandon Regulator and lowest at East Marginal (Table E-7). Variability between sites was greatly reduced compared to sample loading rates prior to area-normalization. Figure E-32 illustrates these results.

Table E-7. Summary of Area-Normalized Total Dioxin TEQ Stormflow Loading Rates by Location

Analyte	Location	Basin (km^2)	Minimum Loading Rate (ng TEQ/ hr/km^2)	Maximum Loading Rate (ng TEQ/ hr/km^2)	Mean Loading Rate (ng TEQ/ hr/km^2)	Median Loading Rate (ng TEQ/ hr/km^2)
Total Dioxin TEQs	Utah	0.125	459	6,760	2,110	951
	East Marginal	0.344	321	1,580	710	550
	Brandon Regulator	0.987	205	3,280	1,570	1,550

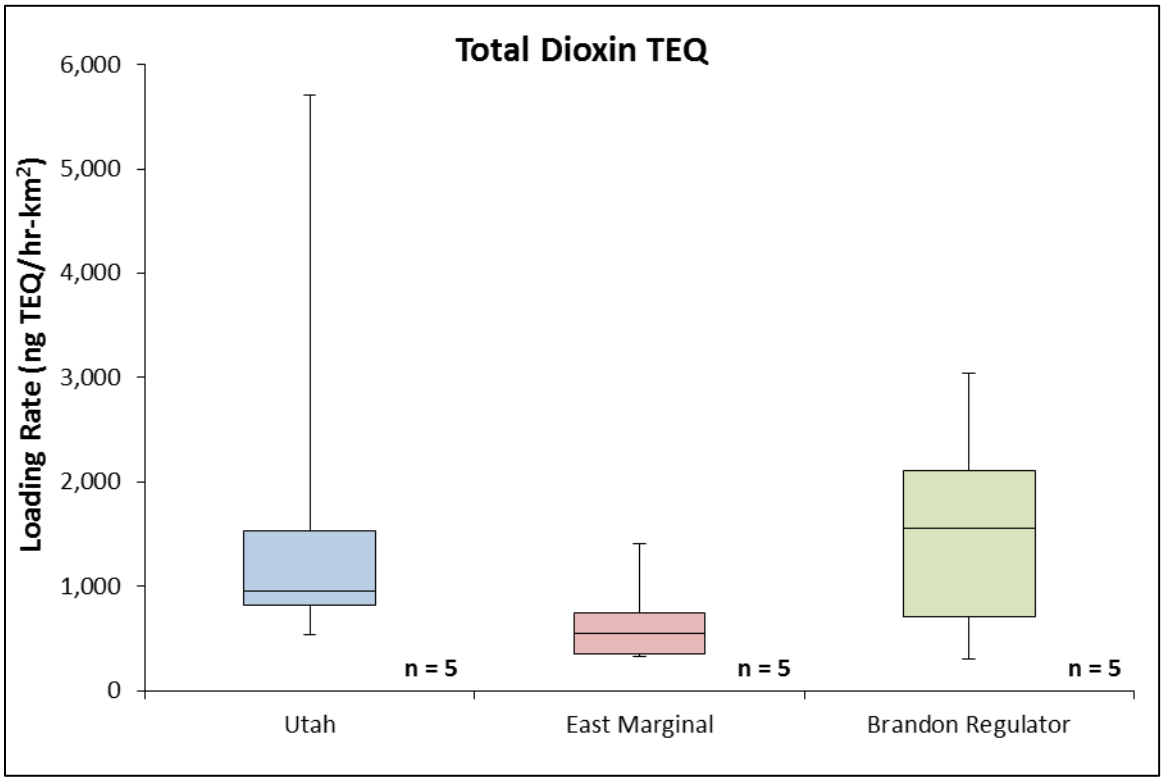

Figure E-32. Boxplots of Dioxin Toxicity Equivalencies (TEQs) Stormflow Loading Rates Normalized by Drainage Basin Area for Each Site.