The image is a composite of three horizontal panels. The top panel shows a dark, cloudy sky. The middle panel is a wide landscape shot of a mountain valley. In the foreground, there are steep, rocky slopes covered with patches of green and yellowish-brown vegetation. A dense forest of evergreen trees lines the lower slopes. In the center of the valley, a calm lake reflects the surrounding mountains. The background features several rugged, brownish-grey mountain peaks under a blue sky with scattered white clouds. The bottom panel shows a close-up of a rocky, gravelly ground surface.

Digging Deeper at Bonita Peak: The Mining District's Aquatic Environmental Impacts

Andrew Todd, Ph.D.
Ecotoxicologist, EPA Region 8

BPMD's Aquatic Environmental Impacts: Overview of Presentation

- Ecological Risk Assessment (ERA)
 - Status, Biological Technical Assistance Group
- Ecological Risk Assessment Tools
- Results in the Upper Animas River and Mineral Creek
- Next Steps

Ecological Risk Assessment Status

- Draft Aquatic ERA (2015)
 - From Cement Creek to Bakers Bridge
 - Not discussed in detail today
- Aquatic ERA (2016-2018)
 - **Rest of Site above Silverton**
 - **Upper Animas River and Tributaries**
 - **Mineral Creek**
 - Bakers Bridge to Purple Cliffs
 - In development, not discussed in detail today
- Terrestrial ERA (2017-2018)
 - BPMD Sitewide
 - Brian Sanchez talk

Biological Technical Assistance Group

- Bureau of Land Management
- CO Dept. Public Health and the Environment
- CO Parks and Wildlife
- Mountain Studies Institute
- Navajo Nation
- New Mexico Environment Department
- Southern Ute Indian Tribe
- Sunnyside / Kinross
- Trout Unlimited
- U.S. Fish and Wildlife Service
- U.S. Forest Service
- U.S. Geological Survey
- New Mexico Office of Natural Resources Trustee

Aquatic ERA Lines of Evidence / Tools

- Measurement Endpoints / Tools
 - Hazard Quotient (HQ) Approach- Comparison of chemical concentrations to known benchmarks
 - Site-Specific Toxicity Testing
 - Exposing laboratory organisms to site environmental media
 - Community Surveys
 - Organism surveys
 - Habitat assessments
- All information weighed to develop a conclusion regarding the potential for harmful effects on relevant aquatic populations in the BPMD

ERA Tools: Calculating Hazard Quotients

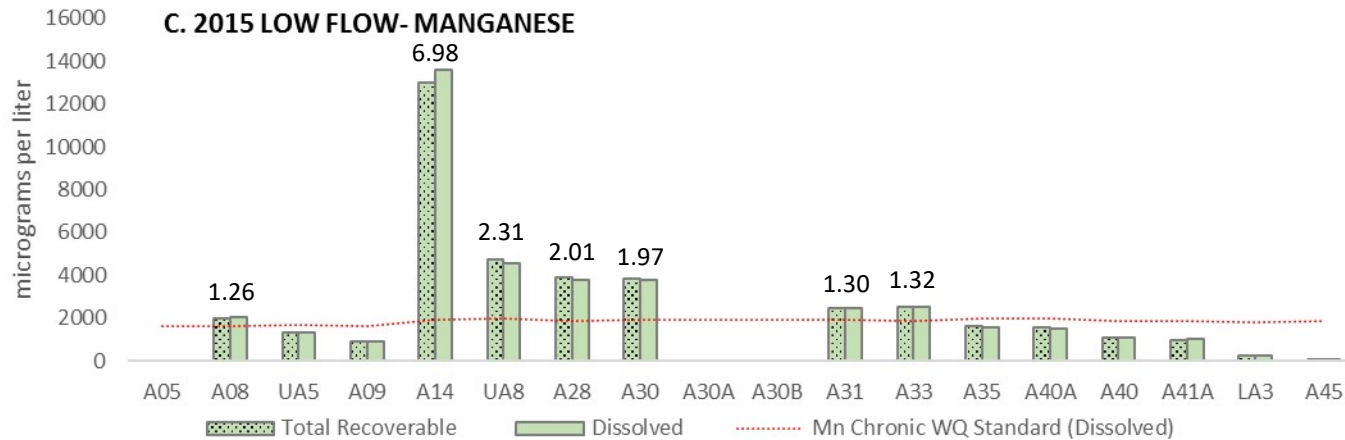
Hazard Quotient (HQ)

$$\text{HQ} = \text{Exposure} / \text{Benchmark}$$

HQ<1 = Acceptable risk

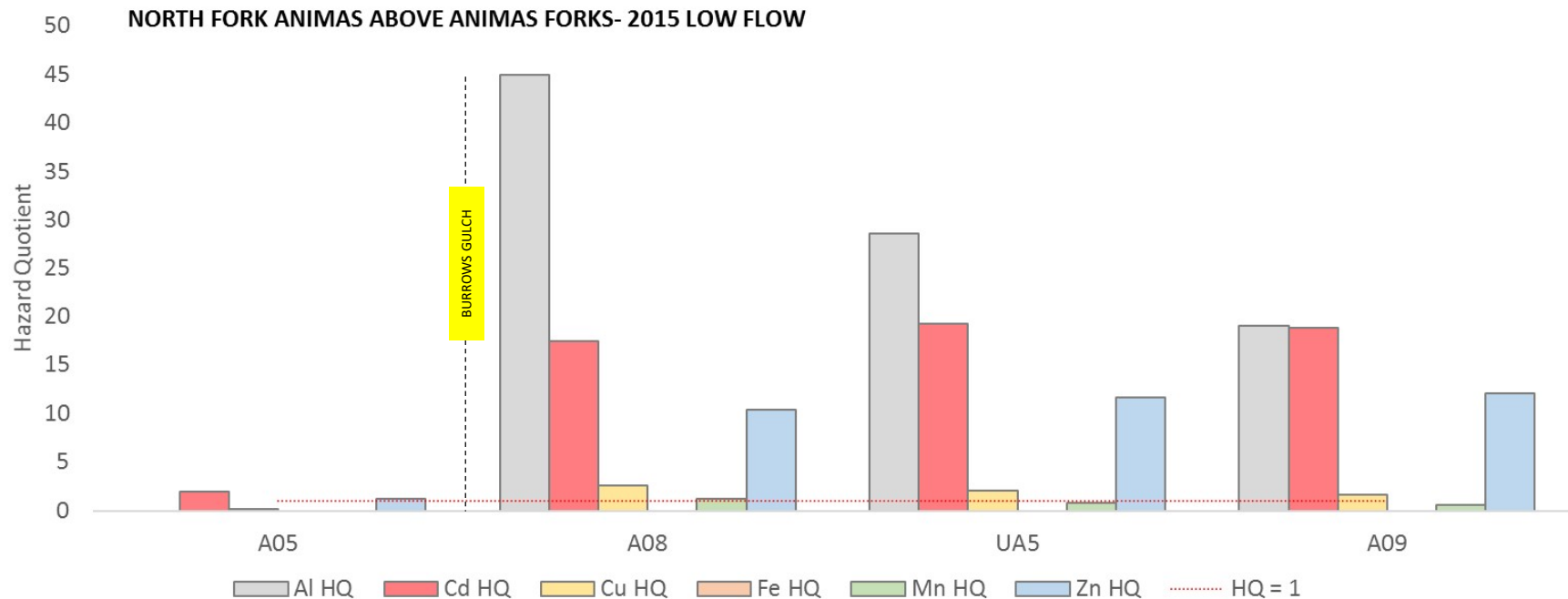
HQ>1 = Further evaluation warranted *or* unacceptable risk

ERA Tools: Calculating Hazard Quotients



- Surface Water HQs
 - Comparison of measured water concentrations to applicable Colorado Water Quality Control Commission water quality criteria
 - HQ reflect “how many times” the instream concentrations are compared to the applicable WQ criteria

Hazard Quotients- Longitudinal Comparisons



- Allows comparison of relative risk of each metal at each site
- Facilitates evaluation of metal loading / reduction between sites

ERA Tool: Site-Specific Toxicity Testing



Sediment Toxicity Testing
(*Hyalomma azteca*)



Surface Water Toxicity Testing
(Rainbow trout)

ERA Tool: Community Surveys



Benthic Macroinvertebrate Collection

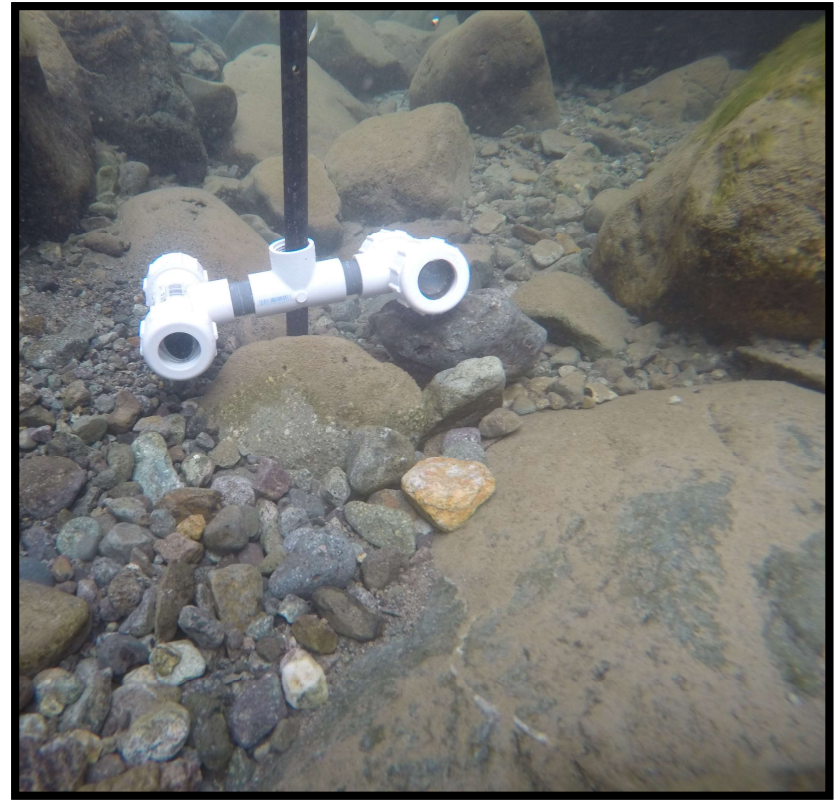


Electrofishing

ERA Tool: Habitat Surveys



Physical Habitat Characterization



Thermal Regime

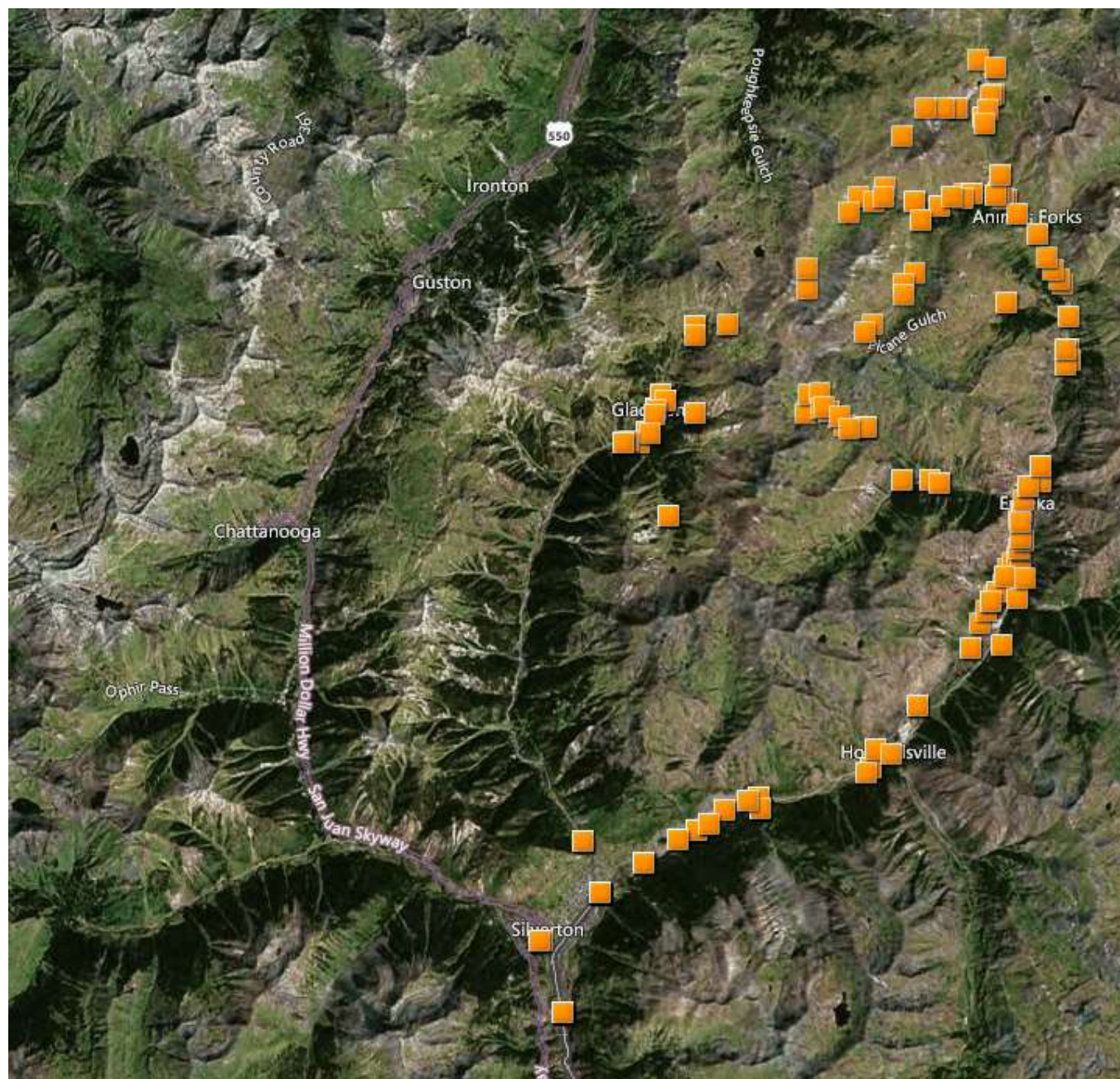
Recent EPA Data Collection Efforts



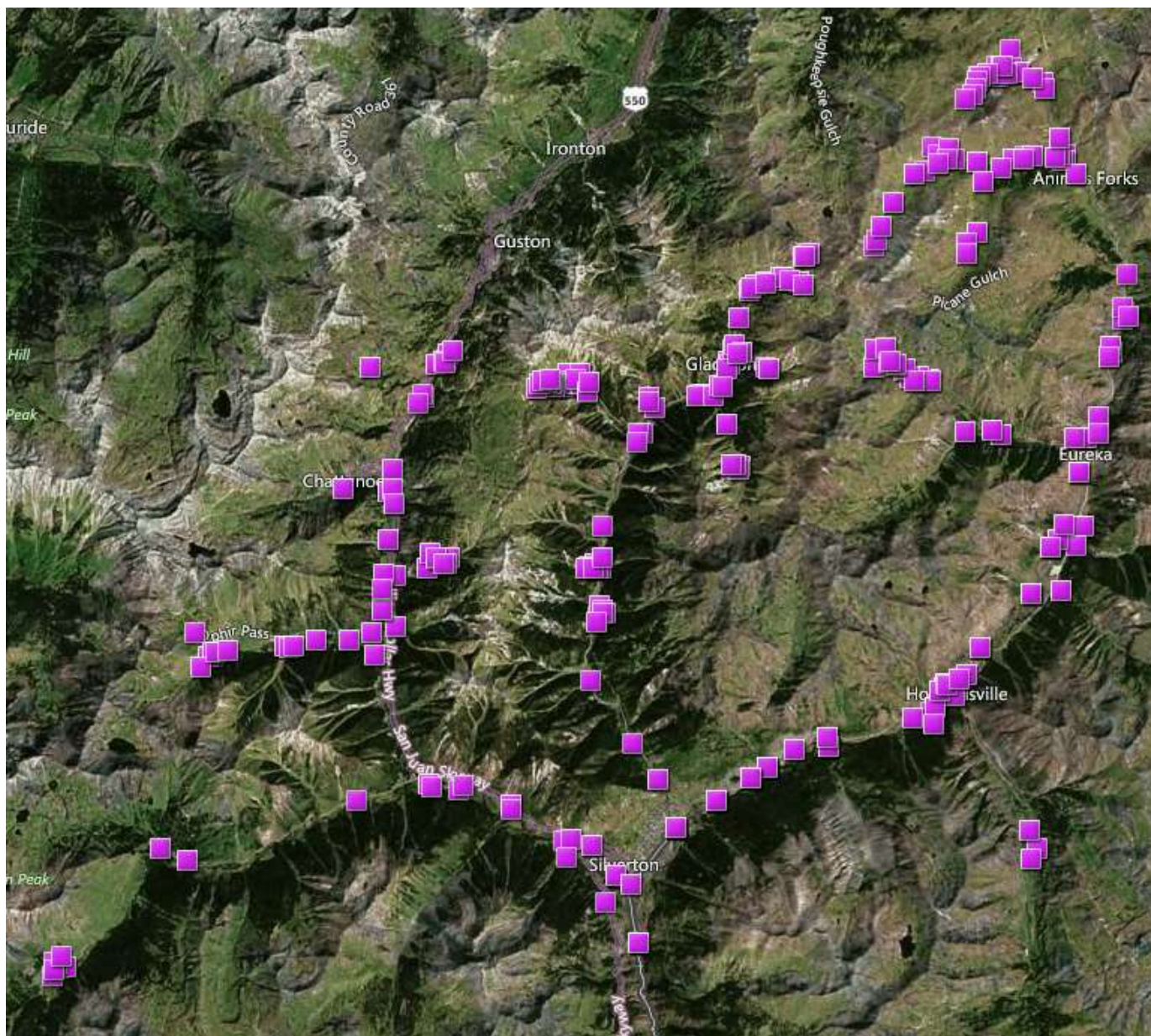
Photo Credit: Sherry Skipper

EPA Sampling Efforts: 2015-2017

- Multi-media
 - **Surface Water**
 - Sediment
 - Porewater- Interstitial water in the sediments
 - **Fishery Information (presence/absence and tissue concentrations)**
 - **Benthic Macroinvertebrates (community composition and tissue concentrations)**
 - **Toxicology (acute surface water toxicity and sediment toxicity)**
 - **Habitat Suitability Information (thermal suitability, habitat suitability)**
- Spatially comprehensive
 - Locations selected to characterizing spatially variability of environmental impacts and importance of different sources
- Temporally comprehensive
 - Intra-annual variability- High flow and low flow sampling events
 - Inter-annual variability- 2015, 2016, and 2017
 - Comparability with older data- USGS Professional Paper 1651 and ARSG database



2015 Surface Water Sampling Locations



2016 Surface Water Sampling Locations

Aquatic Exposure Units (EUs)

Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

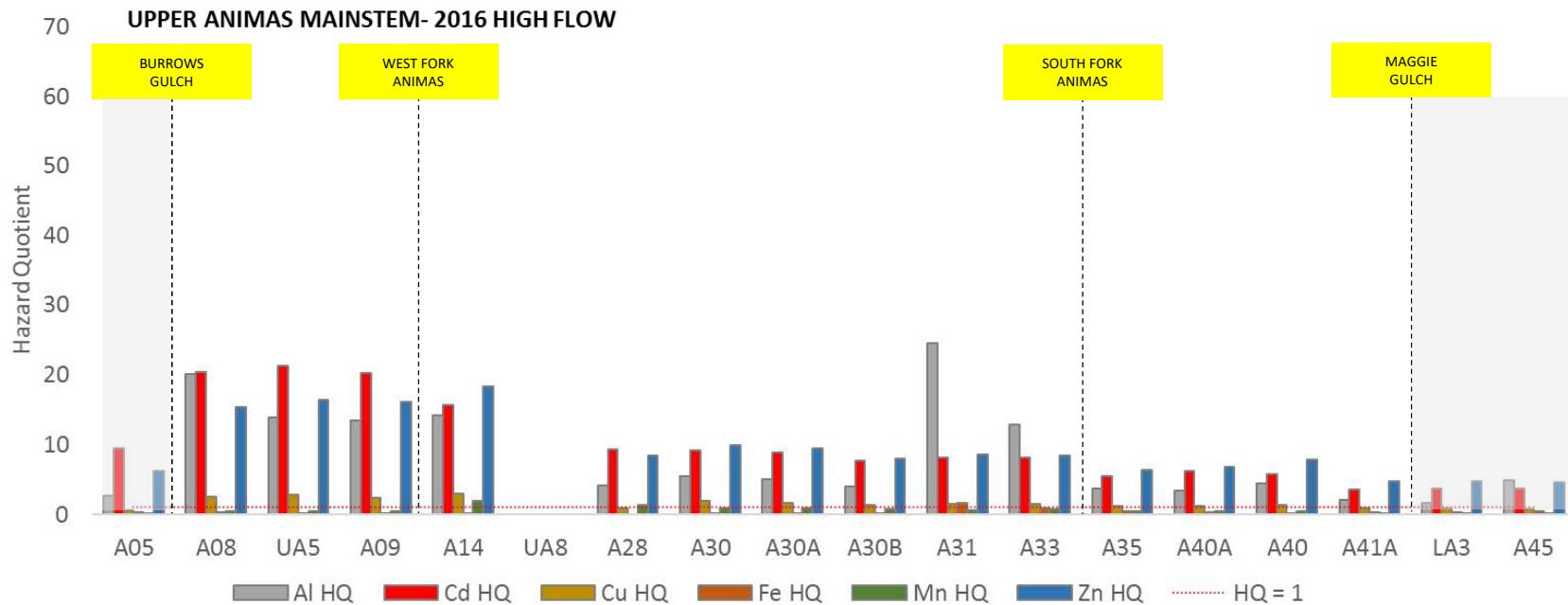
Lines of Evidence of Ecological Risk: Upper Animas and Mineral Creek



BPMD's Aquatic Environmental Impacts: Surface Water Hazard Quotients

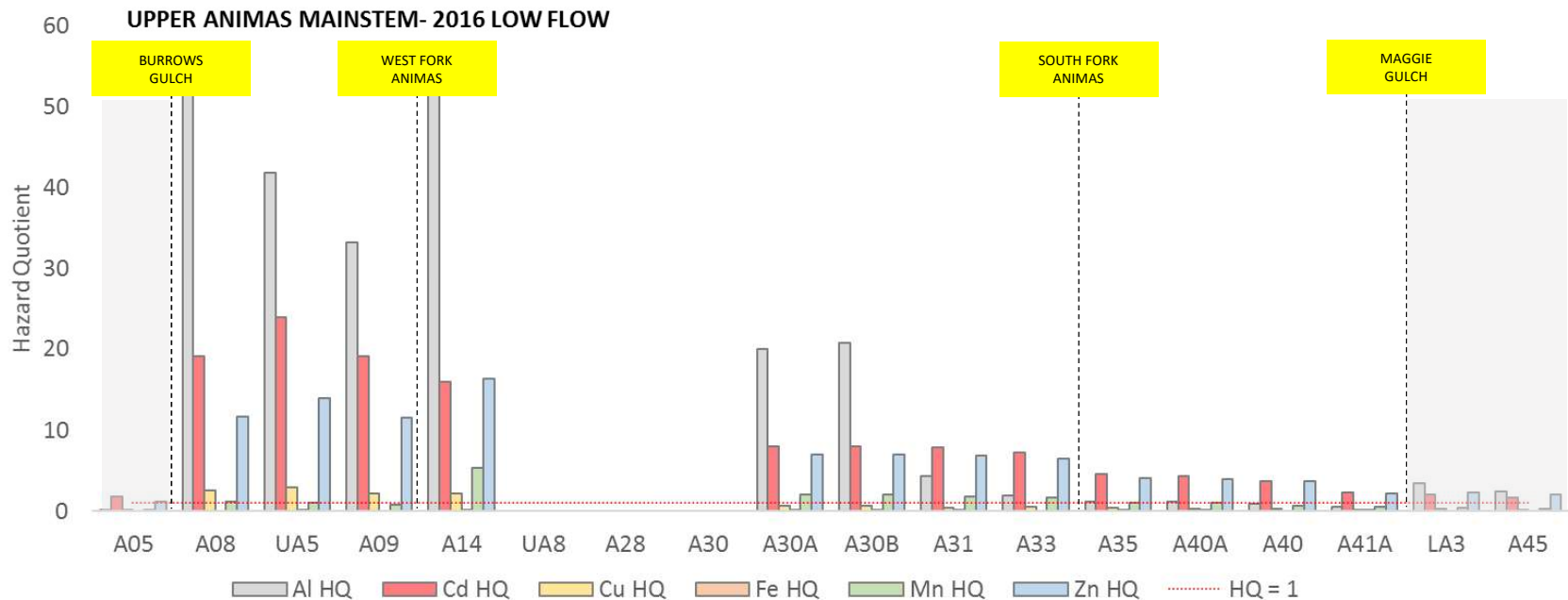
- Surface Water HQs
 - Upper Animas River
 - Calculated using surface water data from 2015, 2016, and 2017 (results pending)
 - High flow and low flow sampling events
 - Mineral Creek
 - Calculated using surface water data from 2016 and 2017 (results pending)
 - High flow and low flow sampling events

Upper Animas: Hazard Quotients- High Flow



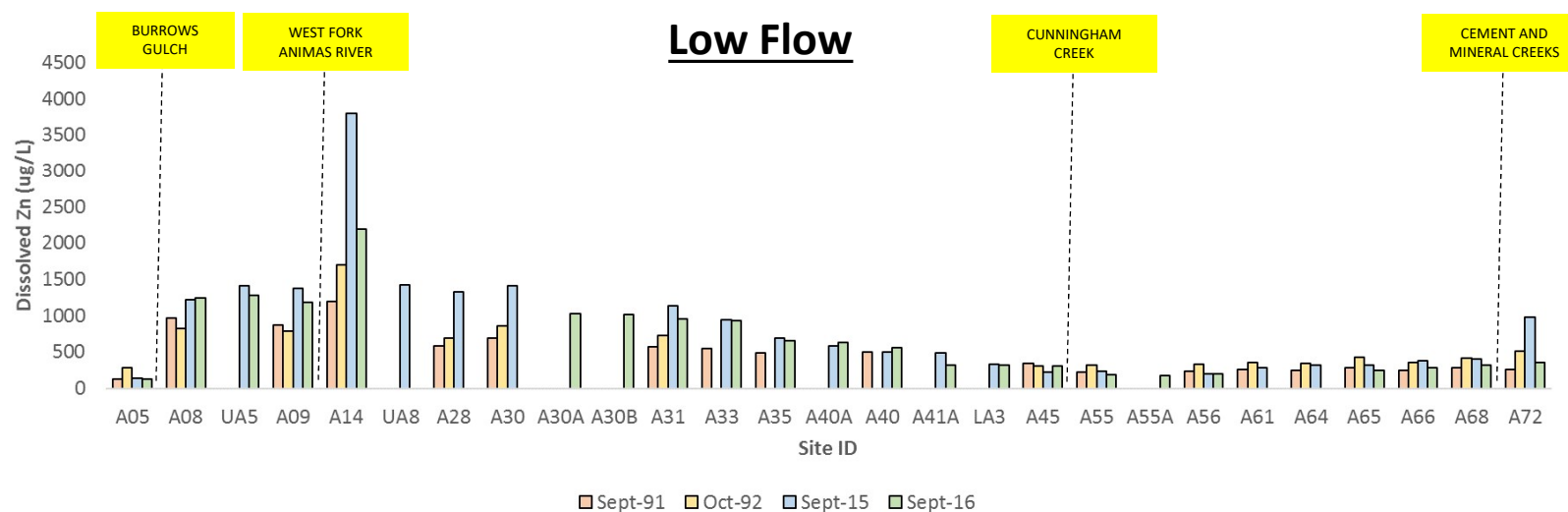
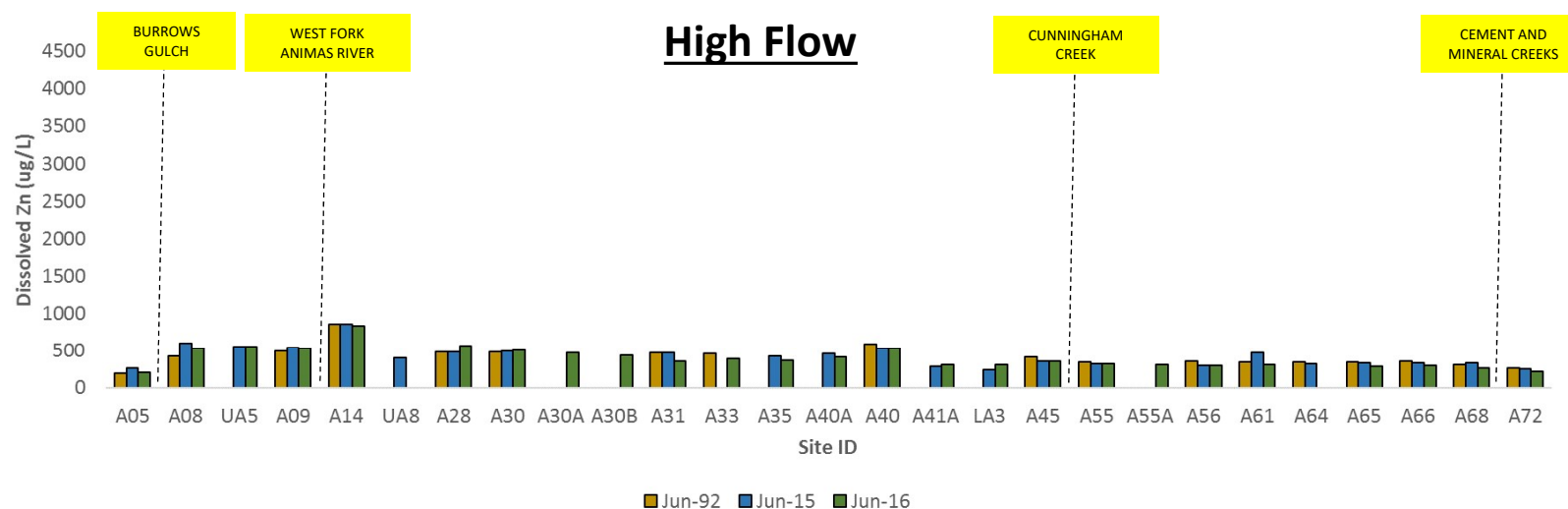
- Metal loading occurs primarily in headwater reaches of the Animas and water quality generally improves towards town
- Zinc, cadmium, and aluminum are primary drivers of aquatic risk during the spring in the upper Animas River

Upper Animas: Hazard Quotients- Low Flow



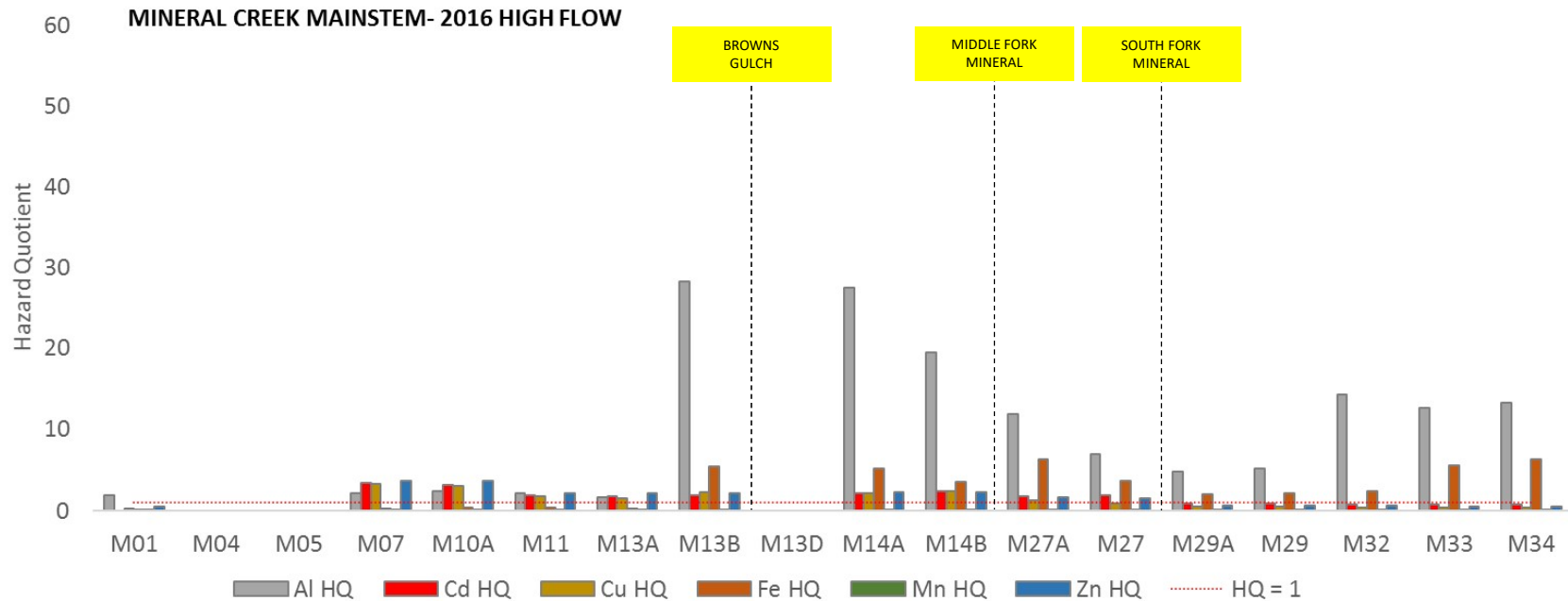
- Metal loading occurs primarily in headwater reaches of the Animas and water quality generally improves towards town
- Zinc, cadmium, and aluminum are primary drivers of aquatic risk during low flow in the upper Animas River

Upper Animas: Interannual Variability



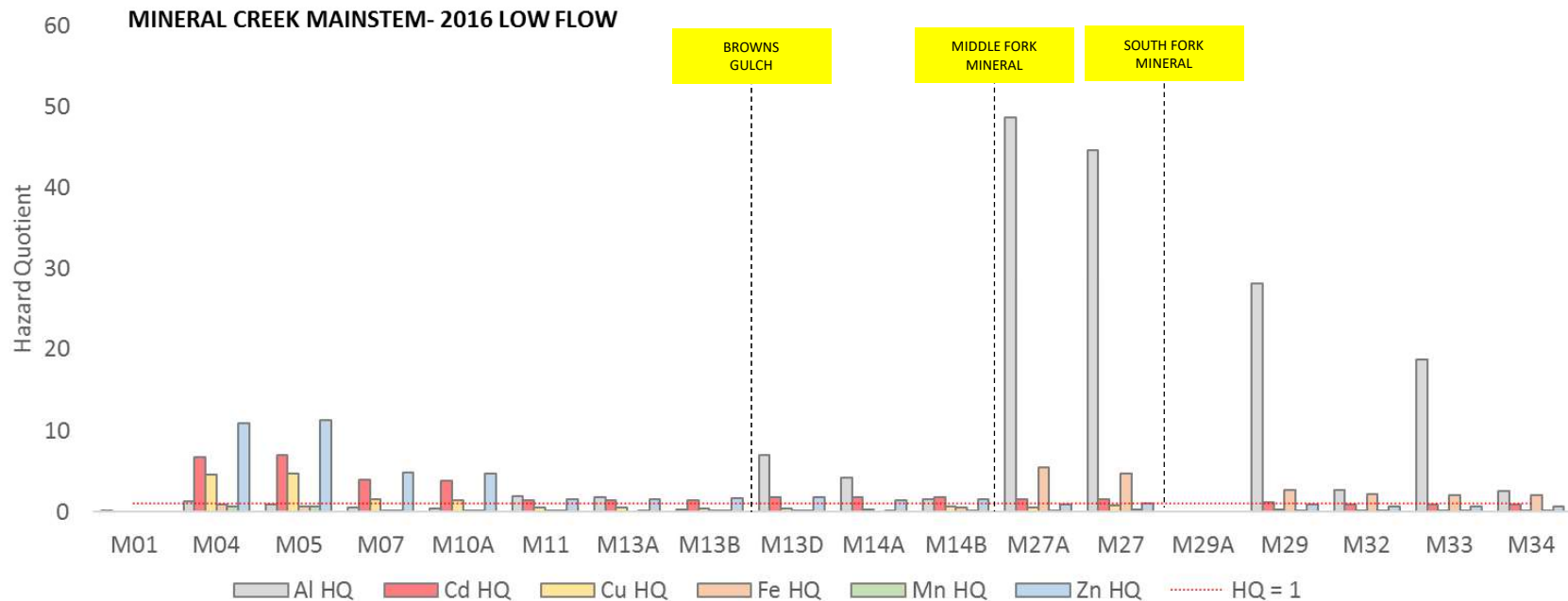
*1991 and 1992 CDPHE data obtained from ARSG spreadsheet

Mineral Creek: Hazard Quotients- High Flow



- Spring aluminum and iron loading in the vicinity of Browns Gulch
- Aluminum and iron appear to drive risk below Browns Gulch to the Animas confluence during run-off
- A second year of data collection (2017) will allow assessment of inter-annual variability

Mineral Creek: Hazard Quotients- Low Flow



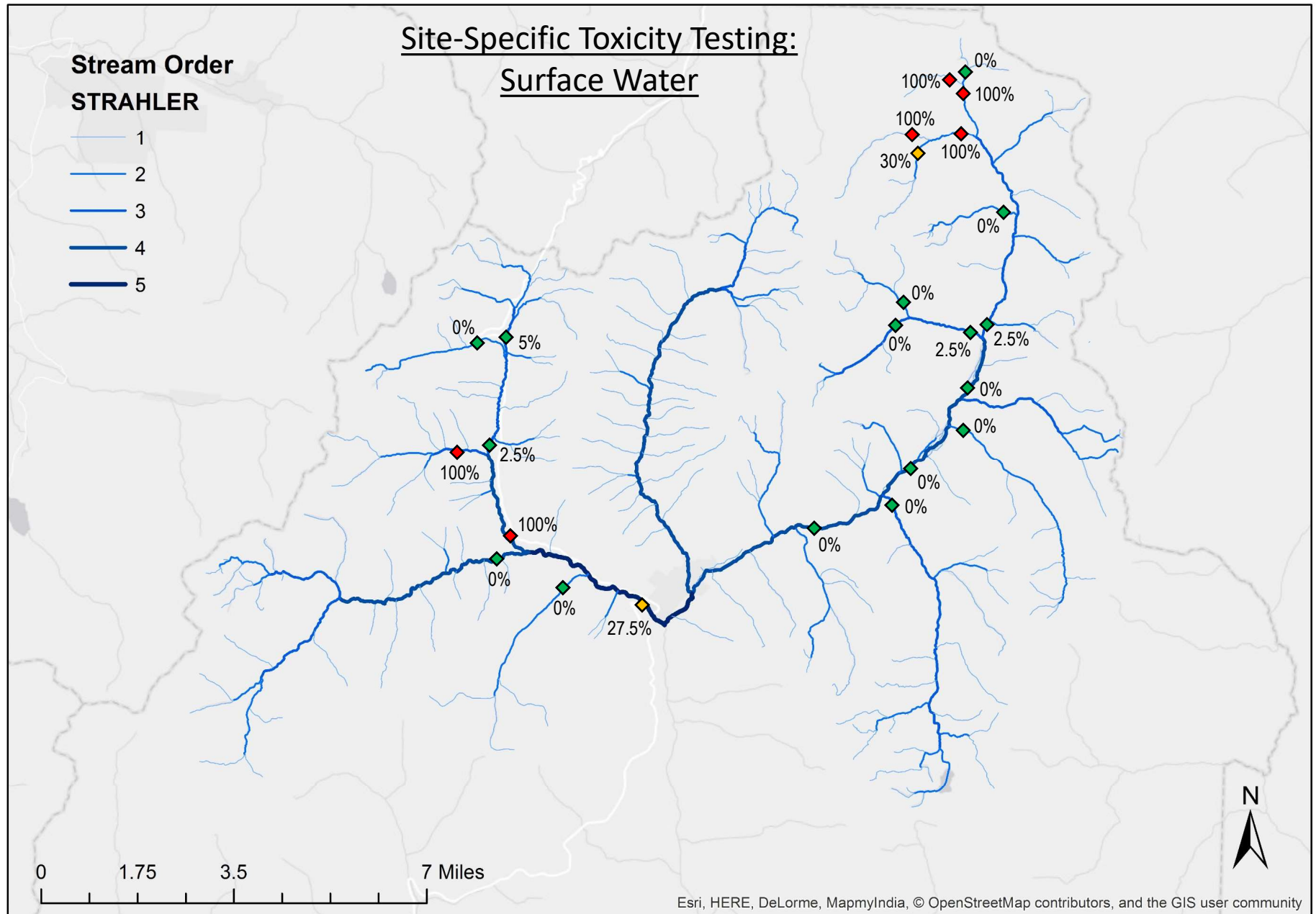
- Loading of cadmium, copper, and zinc appears to drive low- flow risk in the upper Mineral Creek watershed
- Aluminum and iron appear to drive risk below the inflow of the Middle Fork of Mineral Creek to the Animas confluence

Site-Specific Toxicity Testing

- Surface Water Toxicity Test
 - October 2016 test with juvenile rainbow trout
 - 96-hour static renewal acute toxicity test
 - Waters collected from Upper Animas locations
 - Site Locations: A07, A08, A10, A15, A20, A33, A34, A36, A37, A40, A45, A48, and A56
 - Reference Locations: A05 (North Fork Animas above Burrows Gulch), A26 (Picayne Gulch), and A43 (Maggie Gulch)
 - Waters collected from Mineral Creek locations
 - Site Locations: M10A, M14B, M20, M27, M28, M34
 - Reference Locations: M30 (Bear Creek) and M08 (Mill Creek)

Site-Specific Toxicity Testing: Surface Water

Stream Order STRAHLER



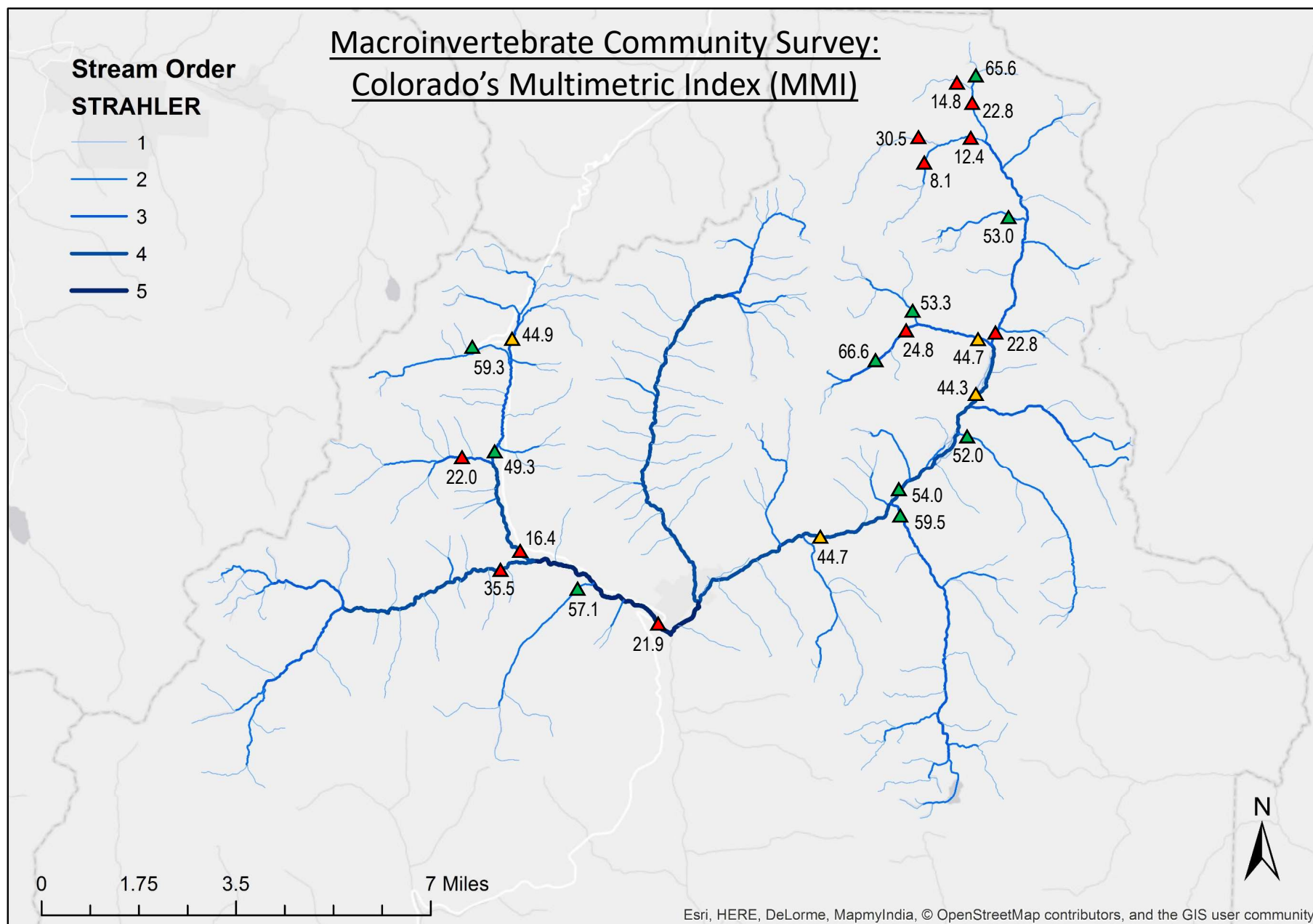
- ◆ Limited mortality observed during 96-hr test
- ◆ Partial mortality observed during 96-hr test
- ◆ Complete mortality observed during 96-hr test

Community Surveys (Bugs)

- Mountain Studies Institute
 - October 2016 sampling (Roberts 2017)
 - Replicated sampling method used previously within the Animas River Watershed (Anderson 2007)
 - Numerous benthic macroinvertebrate (BMI) metrics calculated
 - **MMI Score- State of Colorado bioassessment tool**
 - Biotype 2 (Mountains) Impairment Threshold = 40
 - EPT Taxa
 - EPT species (mayflies, stoneflies, caddisflies) are considered sensitive to pollution
 - EPT Richness
 - Taxa Richness
 - Taxa richness has been found to be reduced in streams with elevated metal concentrations

Macroinvertebrate Community Survey: Colorado's Multimetric Index (MMI)

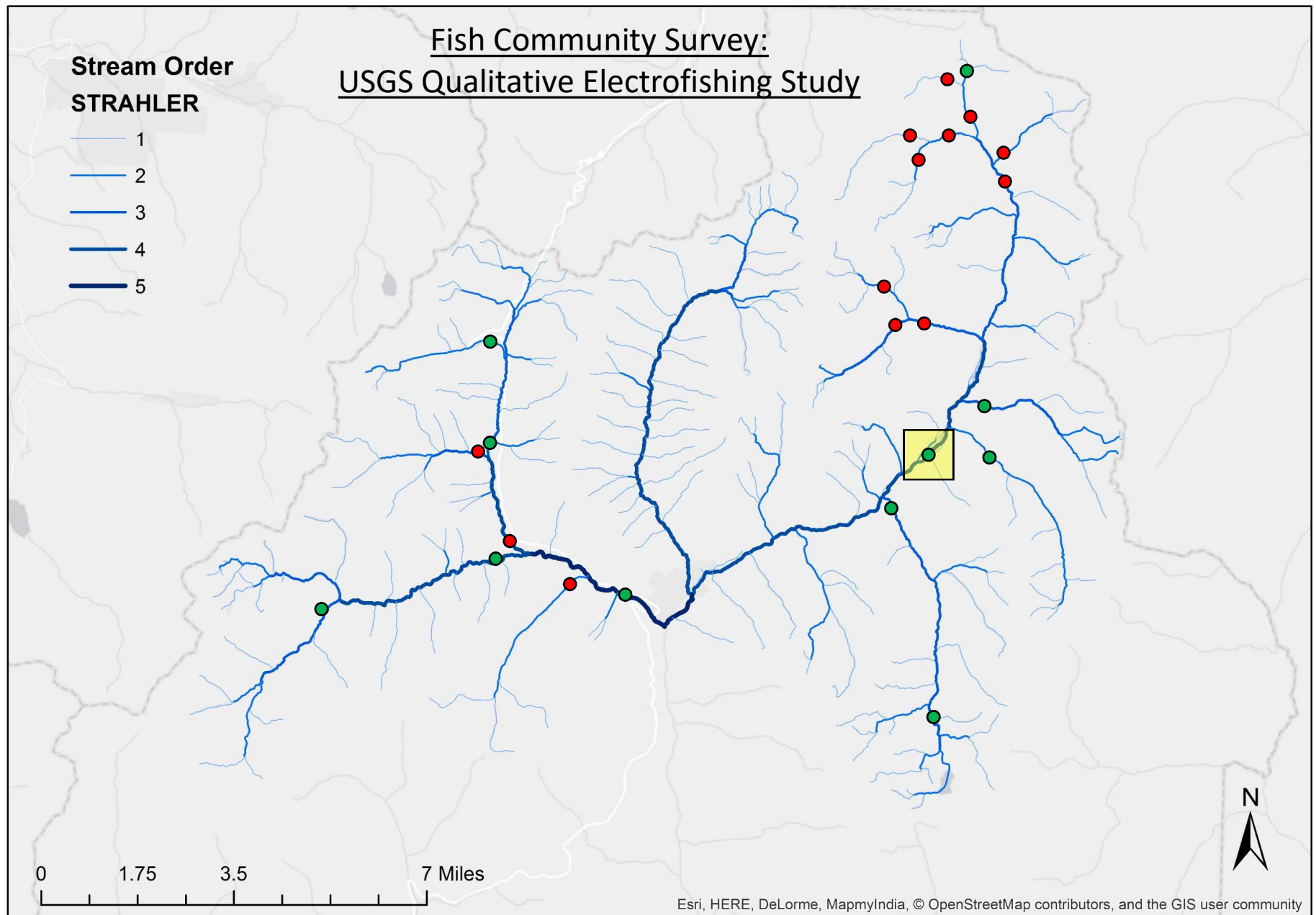
Stream Order STRAHLER



- ▲ MMI score exceeds attainment threshold (48) for Mountains biotype.
- ▲ MMI score falls below the impairment threshold (40) for the Mountains biotype.
- ▲ MMI score falls between the impairment and attainment thresholds for the Mountains biotype (i.e. the "Gray Zone")

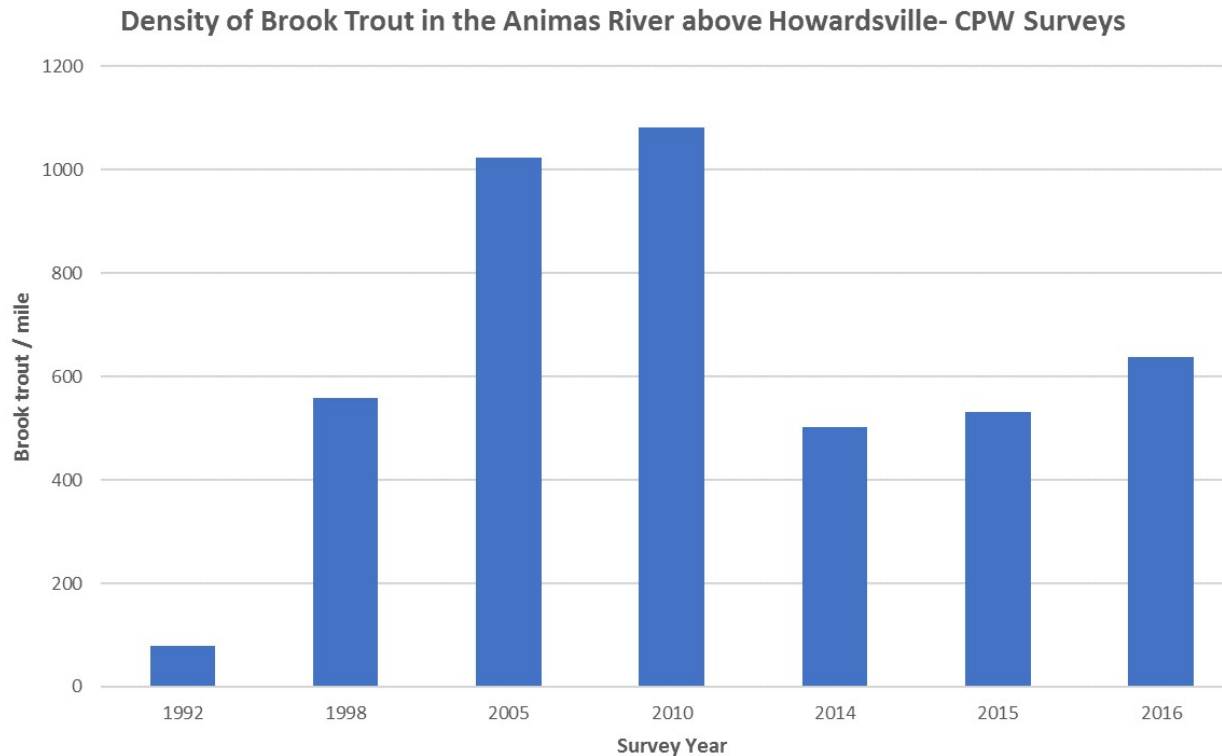
Community Surveys (Fish)

- USGS- Electrofishing and Other Fishery Observations
 - October 2016 sampling
 - Occurred during fish collection for human health risk assessment and downloading of water temperature loggers
 - Qualitative Assessments
 - Only serve as documentation of the presence / absence of fish at the time of sampling
 - More quantitative studies would be necessary to measure fish abundance and biomass (two-pass removal studies) or persistence of fishery at a given location (multiple years of fish presence, tagged fish studies)
 - Quantitative Assessments
 - Colorado Parks and Wildlife has a routine electrofishing location at Howardsville



- Fish determined to be absent in Fall 2016 via qualitative electrofishing survey
- Fish determined to be present in Fall 2016 via qualitative electrofishing survey and/or observation

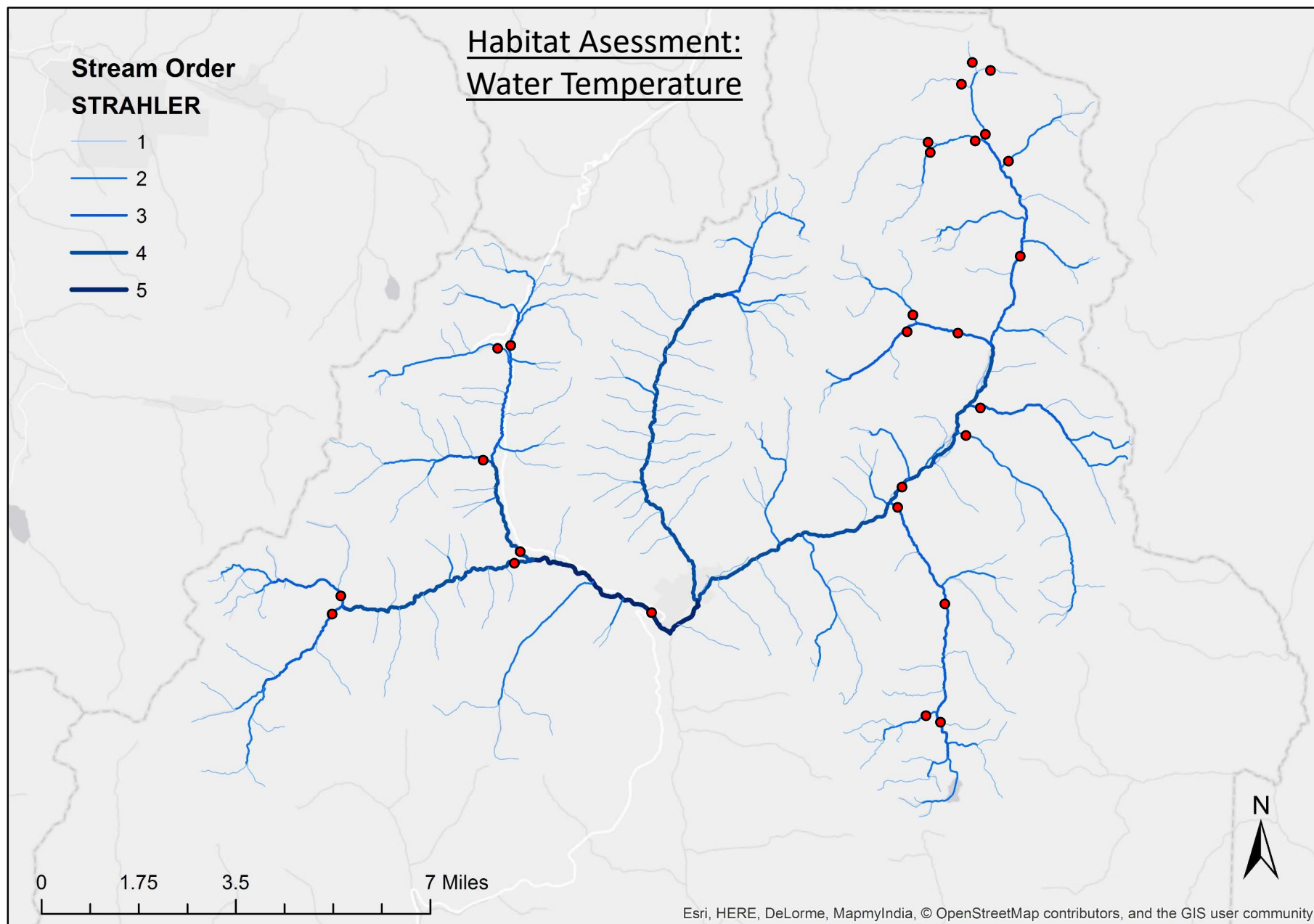
Community Surveys (Fish)- Quantitative



- Population of brook trout has remained relatively stable over the last several decades
- Drop in density between 2010 and 2015 attributed to angling pressure and not to metal toxicity (biomass has not changed much)

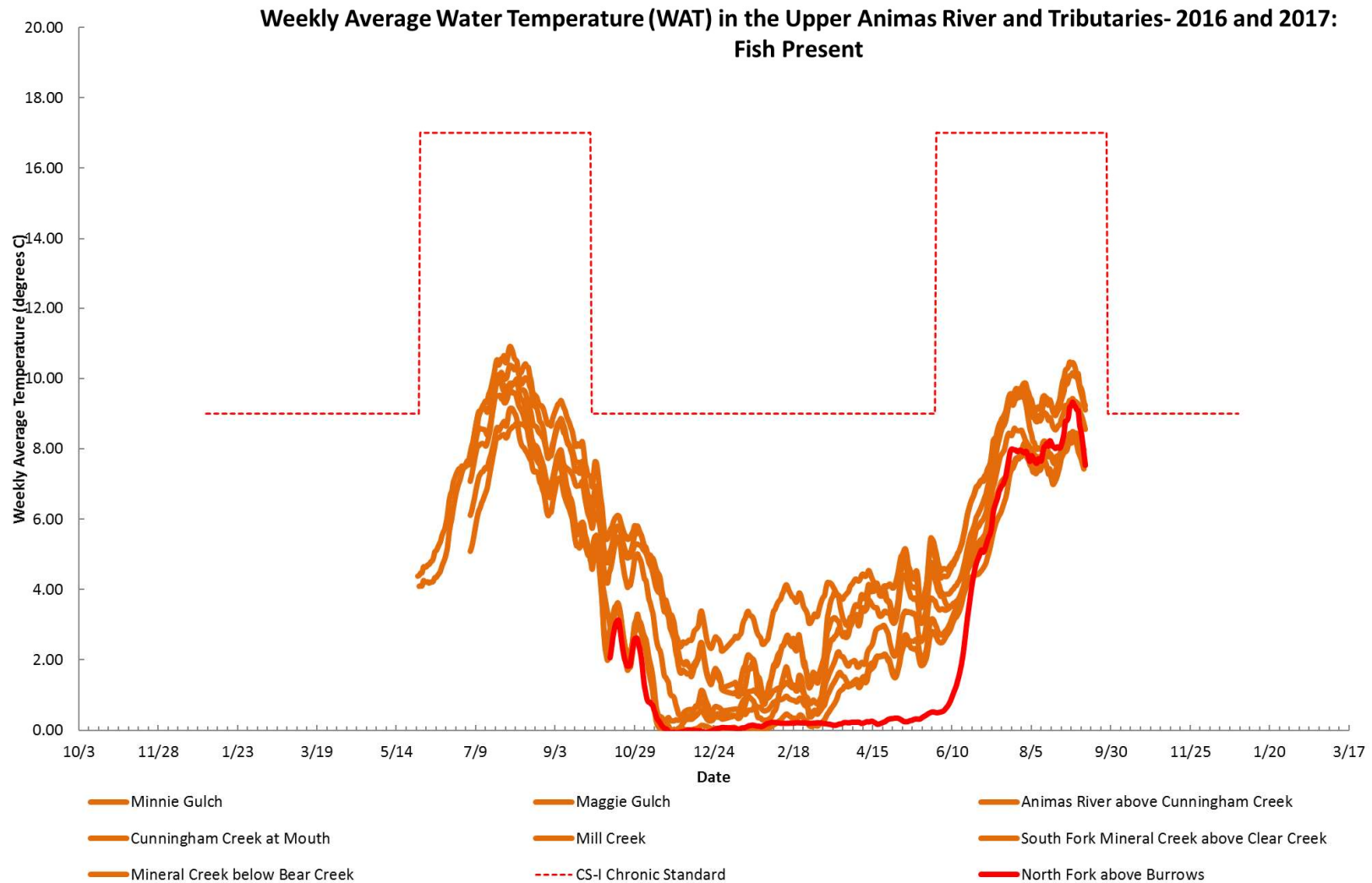
Habitat Information

- USGS Upper Animas Habitat Suitability Assessment
 - Measurement of suitability of thermal regime in upper Animas and Mineral Creek for trout (2016 – 2017)
 - Measurement of stream intermittency / freezing in upper Animas and Mineral Creek (2016 – 2017)
 - Qualitative assessment of instream macrohabitat quality in 12 sites in the *Upper Animas River* only

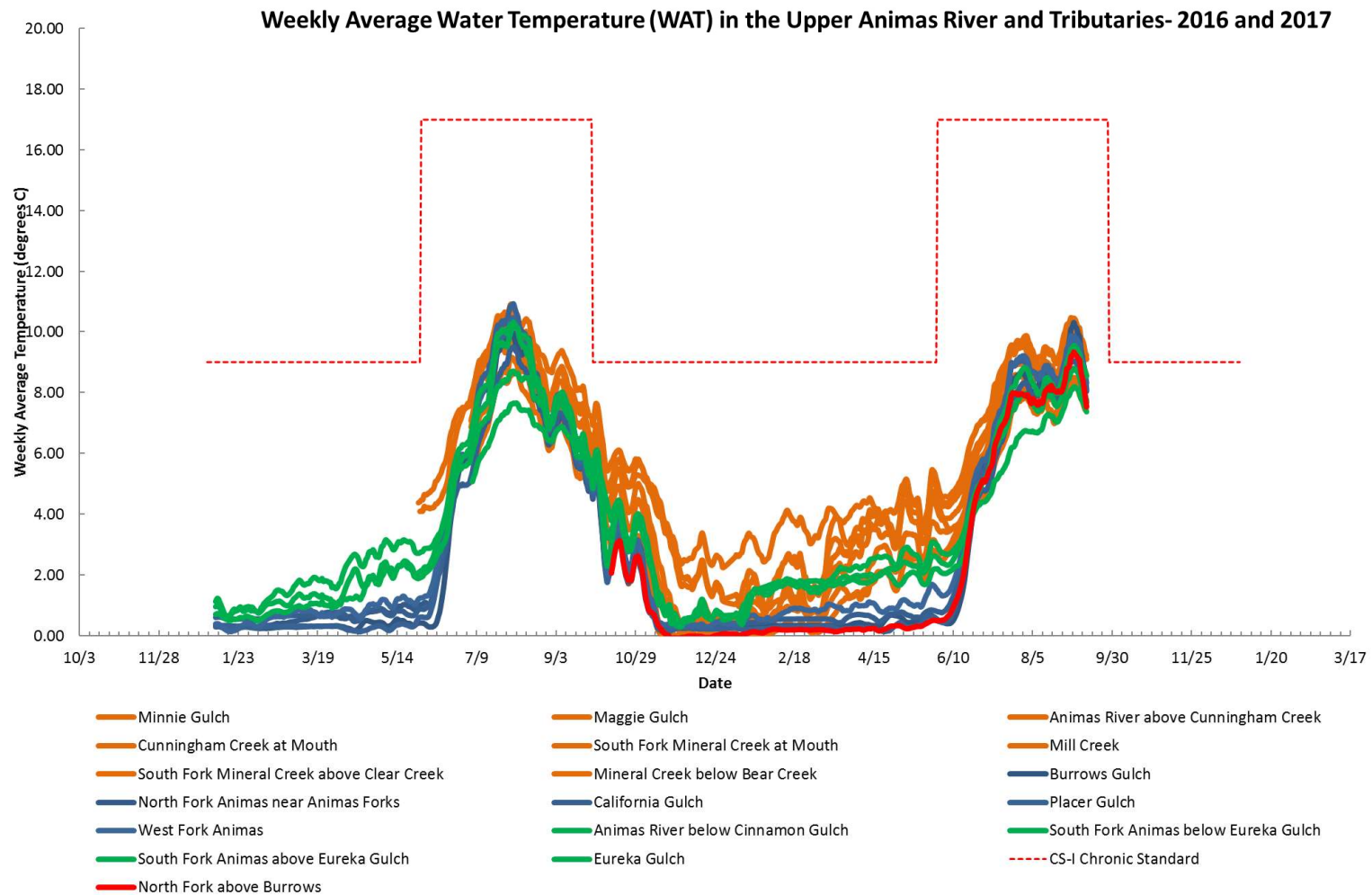


- 2016 / 2017 Stream Temperature Intermittency Conductivity Sensor Locations

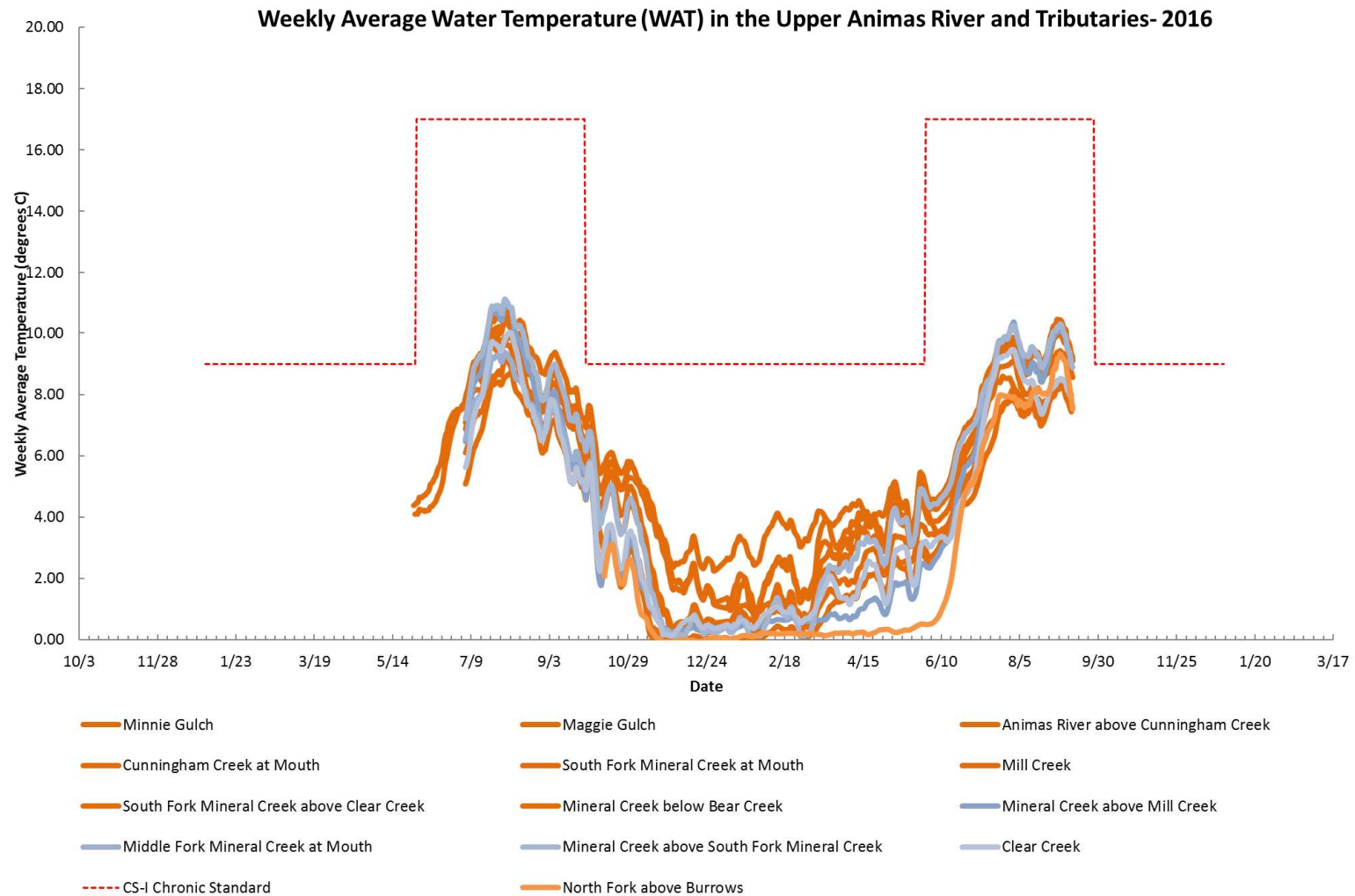
Water Temperatures in Brook Trout Streams



Upper Animas: Water Temperatures

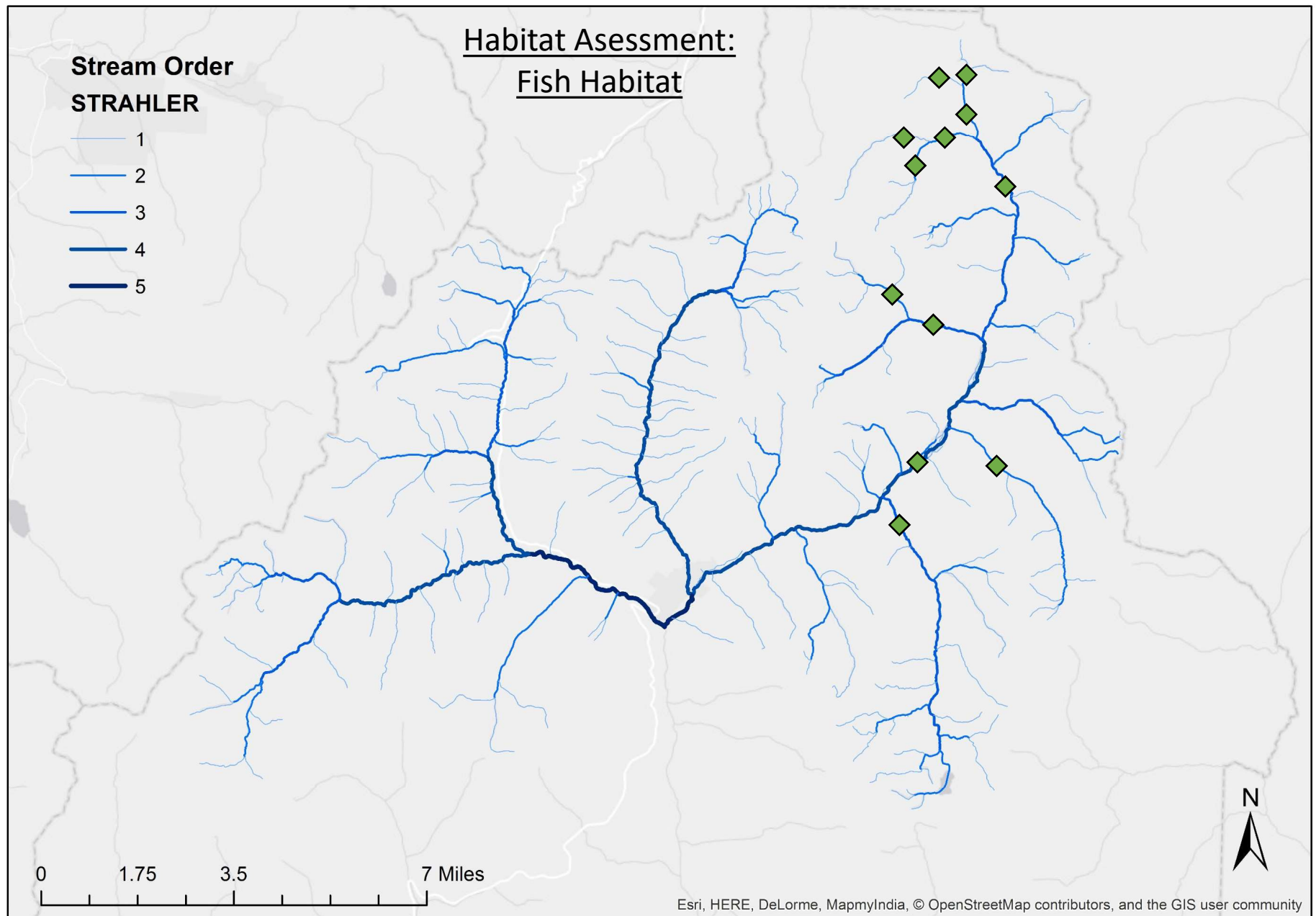


Mineral Creek: Water Temperatures



Stream Permanence and Water Temperature

- No evidence of intermittency or freezing
 - Drying and / or freezing likely not limiting potential fisheries
- Burrows Gulch and West Fork Animas (and tributaries)
 - Similar in thermal regime to North Fork above Burrows
 - Only adult brook trout found in North Fork
 - Cold water temperatures would possibly preclude brook trout recruitment in these creeks
- South Fork Animas and Mineral Creek (and tributaries)
 - Winter temperatures are warmer during the winter months than North Fork above Burrows, similar to streams with reproducing brook trout populations
 - Water temperature less likely to be limiting in these streams



◆ 2016 Habitat Assessment Locations

SITE ID	EXPOSURE UNIT (EU)	Average Wetted Width (ft)	Measured Average Reach Slope	Measured Discharge (cfs)	Fast Water Habitat (%)	Average Wetted Depth (ft)	Pocket Pools Density (#/mile)	Average Pocket Pool Maximum Depth (ft)
Sites with Fish Presence Confirmed								
NFA3	Reference	5.2	5.8%	0.4	97%	0.3	606	0.6
MAG1	Reference	8.7	6.4%	3.7	85%	0.5	630	0.9
ANI3	EU-09	31.5	0.6%	34.5	88%	0.7	156	1.7
CUN1	EU-08	15.2	2.4%	7.7	96%	0.5	602	0.9
Observed Range		5.2 - 15.2	0.6 - 6.4%	0.4 - 34.5	85-97%	0.3 - 0.7	156 - 630	0.6 - 1.7
Literature Value			1-7%^A					0.6^B
Sites with Fish Absence Confirmed								
BUR2	EU-19	6.3	0.7%	0.3	73%	0.4	151	0.7
NFA2	EU-18	7.8	4.0%	0.7	95%	0.3	518	0.6
CAL1	EU-17	6.3	4.7%	2.0	91%	0.4	630	0.6
PLC1	EU-16	8.1	4.4%	1.5	93%	0.3	683	0.6
WFA1	EU-15	10.7	4.3%	2.6	83%	0.5	779	0.9
ANI10	EU-14	18.2	2.8%	10.7	94%	0.6	764	0.9
SFA3	EU-13	8.1	3.0%	3.6	99%	0.5	409	0.9
EUR2	EU-12	6	7.7%	1.1	79%	0.3	623	0.6

^A Speas 2009

^B Harig and Fausch 2002

FAST WATER HABITAT

- Most impacted sites have key habitat metrics that fall within observed ranges for sites with fish presence confirmed and/or within habitable ranges documented in the literature
- Burrows Gulch (BUR2) has low density of pocket pools, low measured baseflow discharge, low average reach slope



Burrows Gulch

SITE ID	EXPOSURE UNIT (EU)	Average Wetted Width (ft)	Measured Average Reach Slope	Measured Discharge (cfs)	Slow Water Habitat (%)	Pool Average Maximum Depth (ft)	Pool Average Residual Depth (ft)
Sites with Fish Presence Confirmed							
NFA3	Reference	5.2	5.8%	0.4	3%	1.2	0.7
MAG1	Reference	8.7	6.4%	3.7	15%	1.7	1.1
ANI3	EU-09	31.5	0.6%	34.5	12%	4.5	3.3
CUN1	EU-08	15.2	2.4%	7.7	4%	1.2	0.4
Observed Range		5.2 - 15.2	0.6 - 6.4%	0.4 - 34.5	3 - 15%	1.2 - 4.5	0.4 - 3.3
Literature Value			1-7%^A				1.0^B
Sites with Fish Absence Confirmed							
BUR2	EU-19	6.3	0.7%	0.3	27%	1.9	1.4
NFA2	EU-18	7.8	4.0%	0.7	5%	1.3	1.0
CAL1	EU-17	6.3	4.7%	2.0	9%	2.0	1.7
PLC1	EU-16	8.1	4.4%	1.5	7%	1.2	0.7
WFA1	EU-15	10.7	4.3%	2.6	17%	1.8	1.1
ANI10	EU-14	18.2	2.8%	10.7	6%	2.4	1.3
SFA3	EU-13	8.1	3.0%	3.6	1%	1.1	0.4
EUR2	EU-12	6	7.7%	1.1	21%	1.5	1.0

^A Speas 2009

^B Harig and Fausch 2002

SLOW WATER HABITAT

- Most impacted sites have key habitat metrics that fall within observed ranges for sites with fish presence confirmed
- The South Fork of the Animas (SFA3) has a small % of slow water habitat, lack of deep pools



09/15/2016

South Fork Animas

Upper Animas: Summary

		Hazard Quotients (Low Flow 2016)						Toxicity Testing	Community Surveys	
Exposure Unit	Description	Al	Cd	Cu	Fe	Mn	Zn	Rainbow Trout (% mortality)	Fish?	MMI
<i>Mainstem</i>										
Headwaters	North Fork above Burrows	0.2	1.8	0.1	---	---	1.1	0.0%	Yes	65.6
EU-18	North Fork above Animas Forks	54.0	19.1	2.6	---	1.2	11.7	100.0%	No	20
EU-14	Animas above South Fork	1.9	7.2	0.6	---	1.6	6.5	2.5%	No	22.8
EU-10	South Fork to Minnie Gulch	1.0	3.7	0.3	---	0.6	3.7	0.0%	Unknown	44.3
EU-09	Minnie to Cunningham	2.5	1.7	0.2	---	0.3	2.1	0.0%	Yes	54
EU-07	Below Cunningham Gulch	0.2	1.3	0.2	---	0.2	1.5	0.0%	Yes	44.7
<i>Tributaries</i>										
EU-19	Burrows Gulch	136.8	55.8	8.4	0.1	3.2	34.5	100.0%	No	14.8
EU-17	California Gulch	126.4	17.8	1.8	0.2	12.5	19.5	100.0%	No	30.5
EU-16	Placer Gulch	11.1	6.9	1.2	0.2	0.6	11.2	30.0%	No	8.1
EU-15	West Fork Animas	63.0	14.7	2.3	0.2	7.1	17.6	100.0%	No	12.4
Picayne	Picayne Gulch	0.1	---	0.1	---	0.1	---	0.0%	Unknown	53
EU-13	South Fork below Eureka	0.2	1.1	0.4	0.1	0.1	1.3	2.5%	No	44.7
EU-11	South Fork above Eureka	0.5	0.4	0.2	0.5	0.1	0.3	0.0%	No	24.8
EU-12	Eureka Gulch	0.1	1.2	0.5	---	0.1	1.8	0.0%	No	53.3
Maggie	Maggie Gulch	0.2	---	0.1	---	---	---	0.0%	Yes	52
EU-08	Cunningham Gulch	0.1	0.4	0.2	---	---	0.2	0.0%	Yes	59.5

Mineral Creek: Summary

		Hazard Quotients (Low Flow 2016)						Toxicity Testing	Community Surveys	
Exposure Unit	Description	Al	Cd	Cu	Fe	Mn	Zn	Rainbow Trout (% mortality)	Fish?	MMI
<i>Mainstem</i>								% mortality		
EU-04	Above Mill Creek	0.47	3.9	1.47	0.2	0.16	4.91	5.0%	Unknown	44.9
EU-03	Mill Creek to Middle Fork	1.59	1.81	0.66	0.58	0.12	1.53	2.5%	Yes	49.3
EU-02	Middle Fork to South Fork	44.6	1.54	0.85	4.7	0.24	1.08	100.0%	No	16.4
EU-01	South Fork to Confluence	2.63	0.95	0.15	2.04	0.13	0.7	27.5%	Yes	21.9
<i>Tributaries</i>										
Mill Creek	Mill Creek	1.2	0.8	0.18	---	0.06	0.52	0.0%	Yes	59.3
EU-06	Middle Fork	121.8	1.07	0.2	17.2	0.4	0.4	100.0%	No	22
EU-05	South Fork	1.39	0.35	0.06	0.45	0.05	0.15	0.0%	Yes	35.5
Bear Creek	Bear Creek	0.22	---	0.08	---	---	---	0.0%	Unknown	57.1

BPMD's Aquatic Environmental Impacts: Next Steps

- 2017 Sampling Results
 - Fall 2017 samples are currently being processed / analyzed
- Incorporate 2017 into lines of evidence analysis
 - Inter-annual variability
 - Spatial variability
- Write up draft aquatic risk assessment
- Present to BTAG for feedback
- Finalize



Questions?

