Temperature Total Maximum Daily Load (TMDL) for Upper Nine Mile Creek Watershed

EPA Approval Date:

Prepared for:
US Environmental Protection Agency, Region 8

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UTAH DEPARTMENT of ENVIRONMENTAL QUALITY

Upper Nine Mile Creek TMDL

Waterbody ID	14060005-002
Location	Carbon and Duchesne Counties, Utah
Pollutant of Concern	Temperature
Impaired Beneficial Use	Class 3A: Protected for cold water species of game fish and other cold water aquatic life
Current Loading Loading Capacity (TMDL) Load Reduction	835,045.6 kWh/day 231,637.6 kWh/day 603,408 kWh/day (72.3%)
Wasteload Allocation Load Allocation Margin of Safety	0 kWh/day 231,637.6 kWh/day Implicit
Defined Targets/Endpoints	1. Water quality target of 20° C 2. Total maximum load of 231,637.6 kWh/d 3. 36% increase in riparian shade
Implementation Strategy	Stormwater, grazing, and riparian best management practices
This document is identified as a TMDL for waters of Upper Nine Mile Creek watershed and is submitted under §303d of the Clean Water Act to U.S. EPA for review and approval.	

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1.0 Introduction

Section 303(d) of the Clean Water Act and US Environmental Protection Agency (EPA's) Water Quality Planning and Management Regulations (40 CFR 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting applicable water quality standards, guidelines, or designated uses under technology-based controls. TMDLs specify the maximum amount of a pollutant which a waterbody can contain and still meet water quality standards. TMDLs allocate this allowable load to sources of the pollutant and also must account for uncertainty in the analysis by specifying a margin of safety (MOS).

This study for Nine Mile Creek determines allowable limits of pollutant loading to meet water quality and designated uses for the Upper Nine Mile Creek watershed. Pollutant load reductions are allocated among the significant sources and provide a scientific basis for restoring surface water quality. In this way, the TMDL process links the development and implementation of control actions to the attainment and maintenance of water quality standards and designated uses.

This document presents a TMDL for Nine Mile Creek, which is listed on Utah's 1998 303(d) List as impaired due to water temperatures that exceed the cold water fisheries temperature standard of 20^{o}C (Utah Division of Water Quality, 2014). Nine Mile Creek will be included on subsequent 303(d) lists as requiring a TMDL until the TMDL has been approved by EPA. This TMDL process requires local focus in terms of restoring and maintaining beneficial uses. Successful implementation of the measures outlined in this study will require cooperation and collaboration between agencies and local stakeholders.

Utah's Division of Water Quality (UDWQ) has assessed data collected from Nine Mile Creek at multiple locations along its course to the Green River including tributaries, and has determined that the river is not supporting its cold water aquatic life due to violations of the water quality criterion for water temperature. Table 1 shows the information contained on the 303(d) list for Nine Mile Creek.

Table 1. Classifications of Impaired Waters in the Nine Mile Creek Watershed

Name	Year First Listed	Impaired Beneficial Use	Cause of Impairment
Nine Mile Creek and tributaries from Green River confluence to headwaters	1998	Protected for cold water species of game fish and other cold water aquatic life (Beneficial Use Class 3A)	Temperature

The Nine Mile Creek watershed is located in northeastern Utah in Duchesne and Carbon Counties and drains into the Green River (Figure 5). Elevation ranges from 5,000 feet at the confluence of Nine Mile Creek and the Green River to over 10,000 feet at the north-east border of Argyle Canyon and Antelope Canyon. Bureau of Land Management (BLM) and private landowners manage the majority of the watershed's lands at 63% and 25% respectively. Major land uses in the watershed include agriculture, energy development, and recreation. Irrigation practices make up 50% of all the water-related land uses in the watershed.

Humans have occupied and altered Nine Mile Creek's landscape for thousands of years. Fremont and Ute occupation, Nine Mile Creek Road construction, fur trapping, homesteading, energy development, ranching/agriculture, tourism, and recreation all have modified the watershed to some extent. Valley bottoms, once dominated by multiple channels, beaver dams, and wetland vegetation are now defined by single thread channels that have become incised and wide, with narrow strips of riparian vegetation providing little shade. The creek has been dewatered, confined to a single channel and disconnected from its flood plain in several locations, resulting in eroded streambanks, down cutting, and loss of aquatic habitat. These flow and channel modifications are the primary factors leading to a decrease in riparian shading and increase in water temperature. The goal of this water quality study is to restore the natural riparian vegetation that provides areas of refugia for the aquatic community.

Water temperature is an important factor for Nine Mile Creek's aquatic life beneficial use. Water temperature is affected by vegetation cover, flow alterations, ambient air temperature, groundwater recharge, and direct sunlight. Potential sources of the temperature impairment include hydrologic changes, channel morphology, storm water runoff from roadways, and lack of riparian vegetation and shade. Channelization of Nine Mile Creek has resulted in the loss of riparian vegetation compromising water quality and overall riparian health. There are no permitted point sources of pollution in the watershed.

Dry conditions make irrigation necessary for nearly all forage crops grown in the watershed. The transport and distribution of water for agricultural irrigation is complex and an important factor affecting in-stream temperatures in the Upper Nine Mile Creek watershed. Irrigation water is diverted along both the main stem and tributaries and is delivered to farms via irrigation canals and laterals. There are several reaches of stream that are seasonally dewatered when irrigation demands exceed stream flow.

Nine Mile Creek is an important source of water for livestock grazing on private and federal/state lands. Livestock with direct access to the stream however can lead to streambank erosion. Unstable banks do not provide the necessary habitat to support woody vegetation and are more prone to erosion during storm events.

Impervious, hardened surfaces such as roads and well pads can increase runoff into Nine Mile Creek. Increased volumes of stormwater lead to excessive streambank erosion resulting in greater sediment loads and other pollutants in the stream.

Riparian vegetation helps to maintain and improve water quality by functioning as a buffer, filtering out pollutants. It provides shade from solar heating and helps maintain water temperature. It provides habitat for aquatic organisms and dissipates stream energy reducing streambank erosion. Restoration of this watershed must include vegetated streambanks that will prevent erosion during intense summer storms and increasing shade by planting woody vegetation.

Figure 1. Nine Mile Creek Watershed (The American Southwest).

Nine Mile Canyon is known as "the longest art gallery in the world" and is home to over 1,000 rock art sites containing more than 10,000 individual images dating back to the Archaic period (earliest periods of culture 8000BC – 2000BC) to current (Liesik, 2012). It has been intermittently occupied for at least 8,000 years. The sheer volume of art means the watershed was the focus of a large, thriving Fremont community. In addition to numerous panels of petroglyphs, evidence of Fremont settlements, such as pit houses, rock shelters, and granaries, is prevalent within the canyon. These rock shelters provide a plausible explanation for the use of Nine Mile Canyon as a trading route to the Uinta Basin through Gate Canyon. The Fremont Native Americans also farmed along the valley bottoms using flood irrigation to grow corn, squash, and beans. Their irrigation ditches, some spanning miles long, were visible as late as the 1930's. Fremont occupation spanned from AD 950-1250. By the 16th century, Utes migrated into this region and contributed to the rock art though there is no archaeological evidence of their settlements (Spangler J. D., 2003).

Fur trappers were next to enter the Uinta Basin. Generally, trapping episodes were brief and streams were quickly emptied of beavers in the area. "J.F. 1818" inscription near Nutter's Ranch suggests the presence of fur trappers traveling across the Tavaputs. In 1825, William Ashley camped north of the Tavaputs and reported that the beaver population was poor (Barton, 1998), however early reports of Fort Robidoux, fur trading post established along the Uinta River, dated in 1837 stated that many streams flowing from the Uinta Mountains all produced beaver (Loosle, 2007). Aggressive trapping continued into late 1800's until they were considered rare. The Utah State Legislature closed beaver harvest in 1889 but began again in 1957 due to an increase in beaver distribution and abundance (Utah Division of Wildlife Resources, 2010).

Figure 2. Fremont Pit House Ruins in Nine Mile Canyon (Eddins, 2002).

Nine Mile Canyon has been a conduit to the Uinta Basin for thousands of years. The road from linking Ft Duchesne to Price was officially constructed in 1886 by the Buffalo Soldiers of the 9th Cavalry Regiment. Road traffic surged in 1889 after the discovery of Gilsonite in the Uinta Basin. Most stagecoach, mail, and freight traffic into the Uinta Basin travelled via this route until after arrival of the Uintah Railway in 1905. The only town built in Nine Mile Creek watershed, Harper, was a stagecoach stop with maximum of 130 residents by 1910. By 1920, it was a ghost town (Loosle, 2007).

This road was heavily used by the Army for 20 years and nicknamed “Lifeline of Uintah Basin” (Barton, 1998). Lawrence Odekirk recalls in 1905: “you could stand on a high peak at the head of Gate Canyon and trace the old stage road all the way to Vernal, 60 miles or more, by the dust churned up by hoofs and wheels” (Spangler J. D., 1993). Indian Canyon Road to the west opened up by 1916 and traffic decreased on Nine Mile Road. Ranchers settled into the area and the town of Harper disappeared.

Figure 3. Great Hunt Panel in Nine Mile Canyon (Eddins, 2002).

Nine Mile Canyon was designated by BLM as Scenic Backcountry Byway in 1990. Being an outside art gallery, it is protected by the Antiquities Act which states historic/prehistoric ruins or dwellings are to be preserved. In 2009, 63 archaeological sites in the canyon were listed on the US National Register of Historic Places.

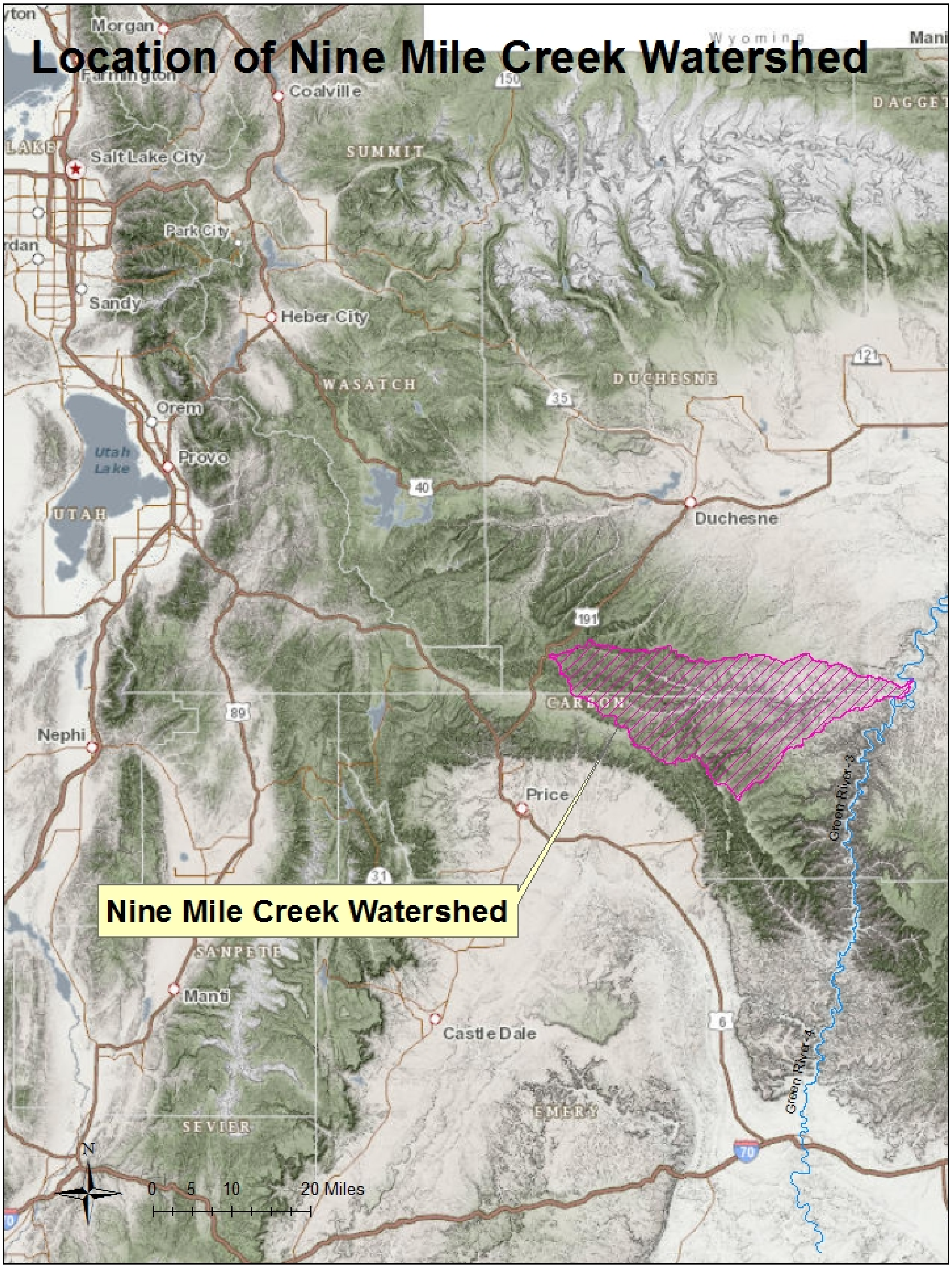
Energy exploration began in the early 2000's in the Tavaputs Plateau. In 2002, rich deposits of natural gas were discovered; findings estimated that approximately 1 trillion cubic feet of natural gas reserves are located within this area (Henetz, 2008). With the increase in drilling, Nine Mile Canyon Road began to see an increase in truck traffic that the once dirt road could not handle. By 2014, 36 miles of Nine Mile Canyon Road were improved by increasing the road width, hardening it to decrease dust, and installing drainage BMPs to direct runoff to the main stem and away from the road itself Carbon County, Duchesne County, State of Utah, and Bill Barrett Corporation paid $36 million dollars for this improvement project (United States Bureau of Land Management, 2016).

This TMDL determined the pollutant load capacity and necessary reductions required to meet the temperature water quality standard. Since there are no point sources in Nine Mile Creek, all thermal load reductions should be applied only to nonpoint sources of pollution. The results of a stream temperature model for Nine Mile Creek supports the development of a TMDL for the upper part of the watershed while a designated use change or site specific temperature criteria is warranted for the lower reaches. Lower Nine Mile Creek regularly exceed the cold-water aquatic life temperature standard of 20° C due to natural and uncontrollable conditions which is also supported by recent and historic fish surveys that do not show any historic presence of cold water species such as trout. This water quality report recommends a use attainability analysis (UAA) for the lower reach. This UAA will be developed in coordination with stakeholders and submitted for approval to EPA after the temperature TMDL is approved.

A project implementation plan for Upper Nine Mile Creek outlines a strategy to decrease water temperature where feasible, attain water quality standards, and restore the river to supporting status. The implementation plan, in conjunction with portions of the TMDL, contains the 9 key elements identified by the EPA that are considered critical for achieving improvements in water quality and obtaining 319 funds. These elements will help provide assurance that the non-point source load allocations identified in the TMDL will be achieved.

Figure 4. Nine Mile Canyon Back County Byway (Crane) .

Figure 5. Location of Nine Mile Creek Watershed.



2.0 Watershed Characteristics

2.1 Location

The Nine Mile Creek watershed is located in northeastern Utah spanning Duchesne, Carbon, and Uintah Counties. It is located in the eastern portion of the Lower Green-Desolation Canyon hydrologic unit (HUC 14060005-002). Nine Mile Creek flows into the Green River, and ultimately, into the Colorado River (Figure 5).

The Nine Mile Creek watershed encompasses 446 mi^2 and is bordered by the Tavaputs Plateau to the northeast, Green River valley (Desolation Canyon) to the southeast, and Pariette Draw watershed to the north. It is a rugged and remote canyon stretching 46 miles along the northern side of the Book Cliffs. For the purpose of this study, the Nine Mile Creek drainage area is divided into two watersheds, Upper and Lower Nine Mile Creek. The Upper Nine Mile watershed extends from the headwaters of both Minnie Maud and Argyle Creeks down to the confluence of Argyle Creek and Nine Mile Creek. The drainage area of Upper Nine Mile Creek watershed is 199 mi^2 or 45% of the entire watershed. Lower Nine Mile Creek watershed consists of 55% of the watershed (247 mi^2) and extends from the confluence of Argyle and Nine Mile Creeks downstream to the confluence of the Green River (Figure 6).

The town of Wellington, though not directly in the watershed, is located 20 miles to the south and has 1,676 residents (2010 consensus). The canyon is not considered to be a significant source of water with an average annual flow of 298 cfs and baseline estimate of 10 cfs. It is a reliable perennial source since prehistoric times.

This TMDL applies to the Upper Nine Mile Creek watershed only (see TMDL Chapter). Watershed characterization information will focus on this portion of the watershed unless otherwise stated.

2.2 Topography

Topography is an important factor in watershed management because stream types, precipitation, and soil types can very drastically by elevation. Figure 2 displays the general topography in the Upper Nine Mile Creek watershed. Elevation ranges from 6,500 ft (1,981 m) at the confluence of Nine Mile Creek and the Argyle Creek to over 10,000 ft (3,048 m) at the north-east border of Argyle Canyon and Antelope Canyon.

Topography and slope affect the river's velocity, infiltration and runoff rate. Surface runoff occurs when the amount of precipitation is greater than the infiltration rate causing the water to flow overland. It is also the main cause of soil erosion by water. Watershed topography determines the slope of the stream channel. Steeper terrain allows the force of gravity to quickly accelerate the flow rate (more energy) leading to increased erosion. Nine Mile Creek watershed is comprised of such rugged terrain where a high proportion of precipitation can be rapidly delivered to the creek during a localized storm event causing flooding and soil erosion. The increase of the creek velocity and runoff has eroded streambanks and debris flow has covered roads.

2.3 Land Use and Land Use Cover

Nine Mile Creek watershed is different than it was 100 years ago. Changes that have occurred include timber harvest, livestock grazing, land clearing for agriculture, road and homesite development, water diversions, water withdrawals, and a general decline in the beaver population.

Streamside tree cover along Nine Mile Creek includes willow and cottonwood. While the lower half of the watershed's riparian vegetation is becoming similar to the natural potential vegetation, much of the vegetation is composed of small trees and shrubs, which are insufficient to provide good shading. Based on satellite imagery our assessment shows an average of 37% riparian shade for Upper Nine Mile Creek.

2.3.1 Land Cover

General land use and land cover data were gathered from USGS' Gap Analysis Project (GAP) completed for the State of Utah. GAP classifications for the Nine Mile Creek are summarized in Table 2 and displayed in Figure 8.

Upper Nine Mile Creek's watershed is dominated by vegetated (93%) land cover. Pinyon-Juniper accounts for the majority of the land cover at 48%. Barren lands make up 6.5%. Agricultural lands, consisting mostly of developed pasture, accounts for less than 1% of the watershed's area and are found along the riparian areas.

2.3.2 Water Related Land Cover

A detailed spatial database of water related land use is available from the Utah Department of Natural Resources, Division of Water Resources (Utah AGRC Water Related Land Use, 2015). The database provides information on land uses associated with irrigation practices. The 2006 data shows that a total of 1.4 mi^2 (892 acres) or approximately 1% of the watershed, were devoted to water related land uses in the Upper Nine Mile Creek watershed. Distinct water related land use types for the watershed and their associated area are given in Table 3.

Water related land use is predominantly associated with irrigation and riparian zones and is typically along the stream corridors. Figure 9 shows that most irrigated lands in the Upper Nine Mile Creek watershed are along the riparian areas of lower Argyle Creek and Nine Mile, below the confluence of Argyle Creek and Nine Mile Creek. Lands are irrigated for pasture, alfalfa, potatoes, and grass hay. Table 3 shows that the 642 acres of irrigated lands account for 72% of the total water related land uses in the watershed. While irrigated lands account for less than 1% of the total watershed area, the effect of irrigation diversions on flow and stream temperatures during low flow conditions in Nine Mile Creek is potentially greater than that small amount of irrigated lands might suggest. Pockets of the riparian (19%) water related land use exists in various parts of the watershed including Upper Argyle, Minnie Maud Creek above Nine Mile Creek, Nine Mile Creek close to both Cow Canyon and Butts Canyon. Most of the idle land (6%) use occurs close to the confluence of Nine Mile Creek and Argyle Creek.

Figure 6. Map of Nine Mile Creek Watershed.

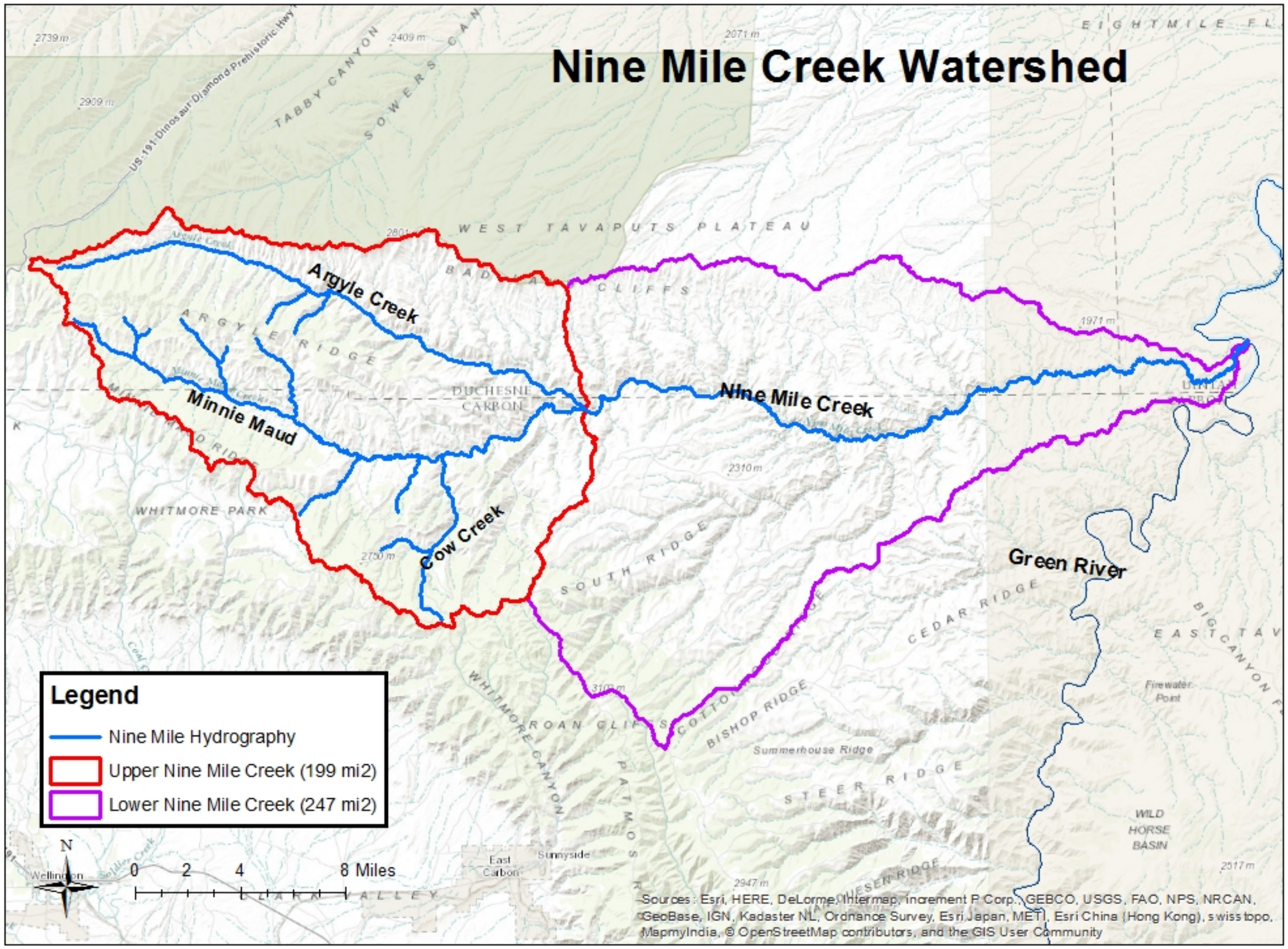


Figure 7. Topography in the Upper Nine Mile Creek Watershed.

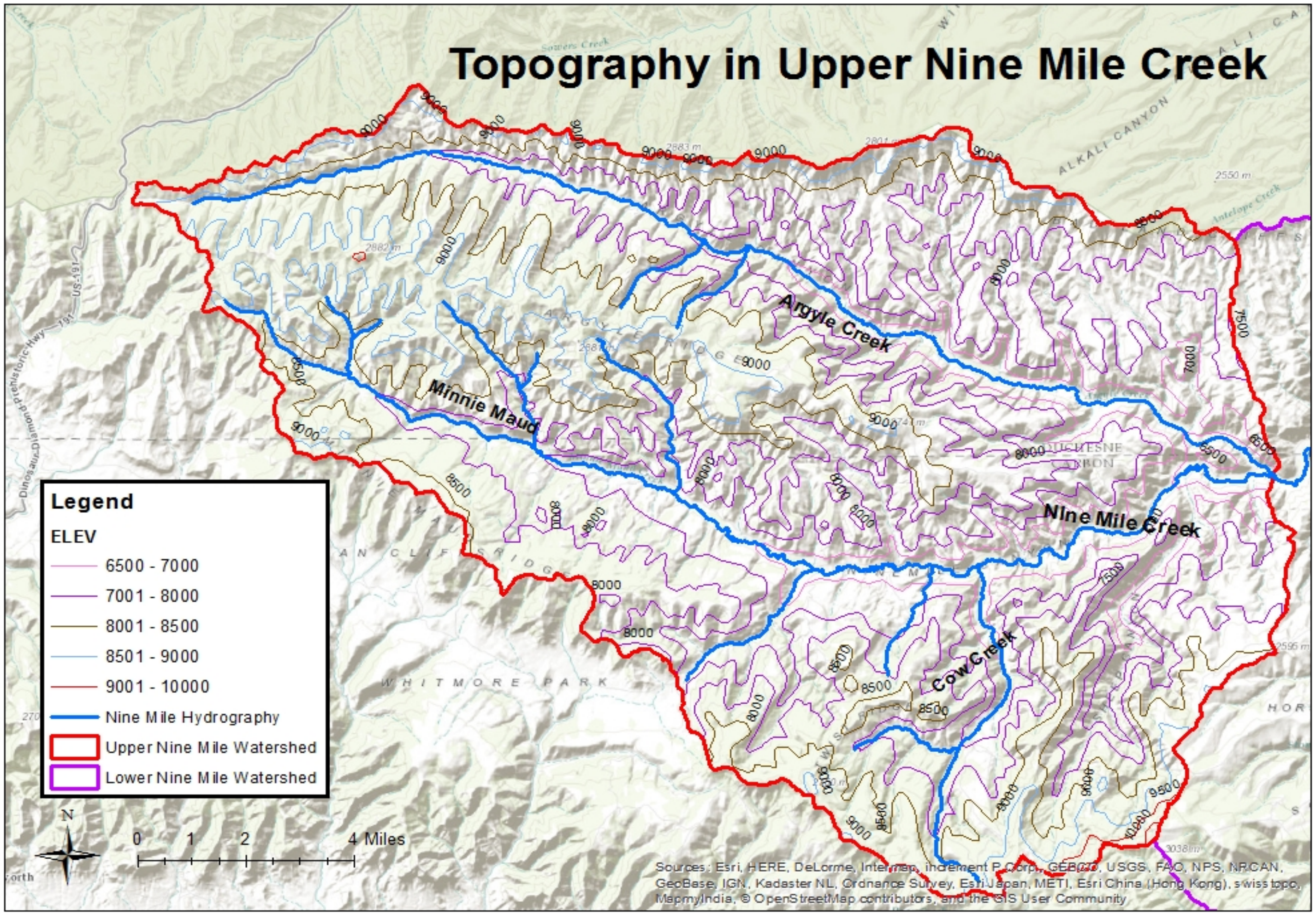


Figure 8. Land Cover in the Upper Nine Mile Creek Watershed.

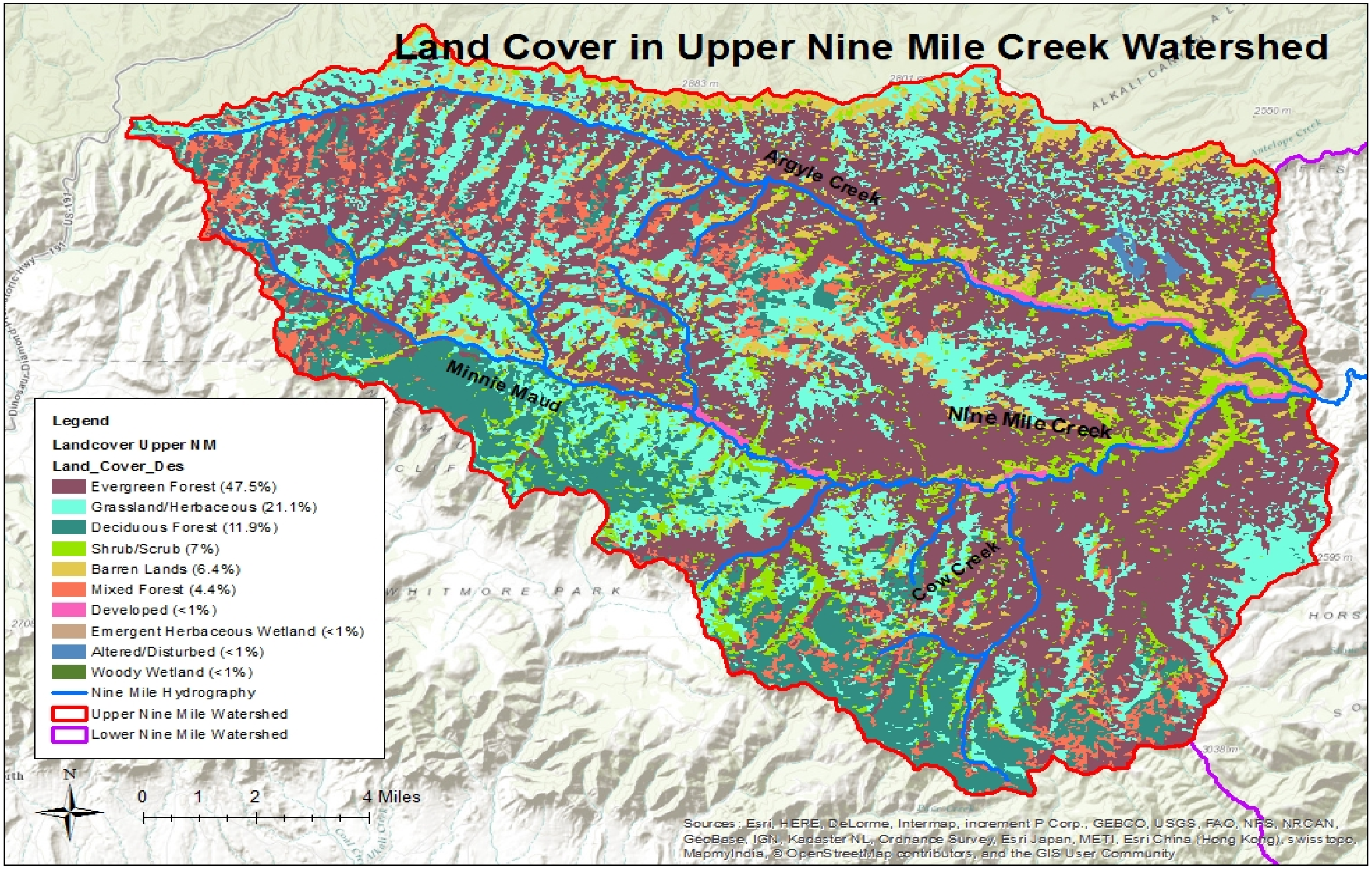


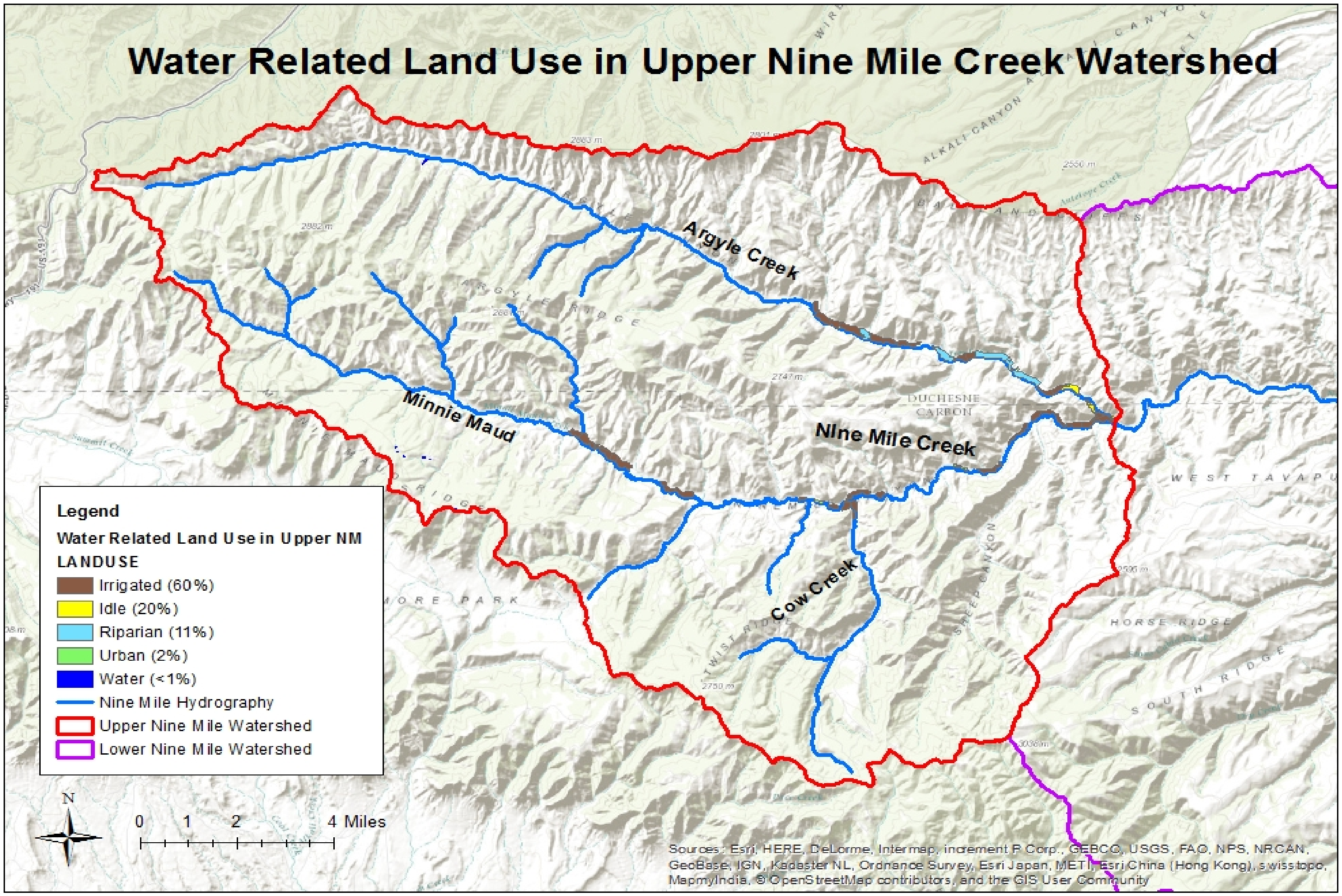
Table 2. Land Cover in the Upper Nine Mile Creek Watershed.

Land Cover	Description	Area (mi^2)	Area (%)
Evergreen Forest	Rocky Mountain Subalpine Dry-Mesic Fir Forest and Woodland Rocky Mountain Subalpine Mesic Spruce Fir Forest and Woodland Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland Colorado Plateau Pinyon-Juniper Woodland	94.5	47.5
Grassland/Herbaceous	Inter-Mountain Basins Montane Sagebrush Steppe Inter-Mountain Basins Semi-Desert Shrub Steppe Southern Rocky Mountain Montane-Subalpine Grassland	42.1	21.1
Deciduous Forest	Rocky Mountain Aspen Forest and Woodland	23.7	11.9
Shrub/Scrub	Rocky Mountain Gambel Oak-Mixed Montane Shrubland Colorado Plateau Pinyon-Juniper Shrubland Inter-Mountain Basins Big Sagebrush Shrubland Colorado Plateau Mixed Low Sagebrush Shrubland Inter-Mountain Basins Mixed Salt Desert Scrub	14.0	7.0
Barren Lands	Rocky Mountain Cliff and Canyon Colorado Plateau Mixed Bedrock Canyon and Tableland	12.7	6.4
Mixed Forest	Inter-Mountain West Aspen Mixed Conifer Forest and Woodland Complex	8.8	4.4
Developed	Developed, Medium-High Intensity Agriculture	1.5	0.7
Emergent Herbaceous Wetland	Rocky Mountain Alpine-Montane Wet Meadow	0.8	0.4
Altered/Disturbed	Recently Chained Pinyon-Juniper Areas	0.5	0.3
Woody Wetland	Rocky Mountain Lower Montane Riparian Woodland and Shrubland Inter-Mountain Basins Greasewood Flat	0.4	0.2
Total		199.2	100%

Table 3. Water Related Land Use in Upper Nine Mile Creek Watershed.

Water Related Land Use	Description	Area (acres)
Irrigation 642 acres (72%)	Grass/Hay	162
	Pasture	480
Idle 53 acres (6%)	Idle	53
Riparian 170 acres (19%)	Riparian	170
Urban 22 acres (2%)	Urban	12
	Parks	10
Water 5 acres (1%)	Reservoirs	5

Figure 9. Water Related Land Use in Upper Nine Mile Creek Watershed.



2.4 Geology and Soils

2.4.1 Geologic Formations

Upper Nine Mile Creek watershed is composed of mostly five geologic formations: alluvial, landslide, Colton, Green River, and Uinta formations (Utah AGRC, 2015). Alluvial and landslide deposits belong to the Quaternary period beginning 2 million years ago. The rest of the formations belong to the Tertiary period of 65-2 million years ago. The most predominant geologic formation is the Green River, an organic-rich limestone/shale/sandstone conglomerate, compromising 78% of the watershed that underlies the Colton and Uinta formations. Landslide deposits include debris flows of unconsolidated earth. Alluvial deposits occur along riparian areas and are made up of unconsolidated detrital material deposited by streams.

The Green River Formation contains the largest oil shale deposits in the world and has been estimated to have reserves up to 3 trillion barrels (US Department of the Interior, 2006). It is also a major source of sodium carbonate which is a main constituent of the pollutant total dissolved solids (TDS). Intense precipitation events cause erosion from such formations leading to increased turbidity in receiving waters.

Table 4. Geologic Formations in the Upper Nine Mile Creek Watershed.

Geologic Formation	Area (mi^2)	Percent
Green River Formation	155.4	78
Colton Formation	18.6	9
Landslide Formation	15.7	8
Alluvium	8.5	4
Uinta Formation	1	1
Total	199.1	100%

2.4.2 Soil Erodibility Factor

The soil erodibility factor (K factor) is a measure of the susceptibly of soil particles to detach and transport by rainfall and runoff. Different soils types erode at varying rates dependent on localized soil properties such as include texture, organic matter, structure, permeability, and infiltration. Soil structures affect both their likelihood to erode and infiltration capacity. This permeability of the soil profile affects K because if affects runoff. Soils high in clay have a low K factor (0.05- 0.15) because they do not slough easily. Medium textures (silt loam) soils have moderate K values (0.25 – 0.4) since they are susceptible to detachment and produce moderate runoff. High silt soils have the highest K values (> 0.4) because they tend to crust and are easily eroded.

Soil data for the Nine Mile Creek were collected from the US Department of Agriculture (USDA) Soil Conservation Service (United States Department of Agriculture, 1988). The soils vary in texture but generally have moderate k factors ranging from 0.02 to 0.32 (Figure 11). Soils in the western part of the watershed are more susceptible to erosion. These soils have low infiltration rate, higher clay content, and loamy texture (Figure 12). Past management can increase soil's erodibility. K factor will increase if subsoil is exposed, organic matter depleted, or soil compaction has decreased permeability. Impacts to water quality from soils are due to streambank erosion and excess sediment associated with runoff especially during intense summer storms. Erosion along Nine Mile Creek occurs when riparian vegetation is sparse and there is direct disturbance to the streambank from livestock, recreation, or roadways.

2.4.3 Soil Texture

Soil texture is determined by the relative proportion of sand, silt, and clay found in the fine earth fraction (soil particles less than 2mm in size). It influences infiltration, runoff, erosion, available water holding capacity, and cation exchange. Surface soil texture determines the way water moves through and is retained in the soil, which in turn affects leaching potential of various nutrients, minerals, and potential pollutants. It may also include a descriptive prefix that provides information about the size, shape, and amount of rocks greater than 2 mm in size.

Surface textures are summarized in Table 5 and a map showing the spatial distribution of surface textures is shown in Figure 12. The information is based on the dominant (most representative) soil surface texture for the map unit. All the soils in Upper Nine Mile Creek (Carbon County) are considered to be loamy. NRCS defines loamy soils to have 7-27% clay, 28-50% silt, <52% sand (U.S. Dpartment of Agriculture, 1993). Loam soils generally tend to contain more moisture and nutrients than sandy soils, have better drainage and infiltration of water than silty soils, and easier to till that clay soils. The different types of loamy soils each have slightly different characteristics. The fine-loamy soils (44%) can be found along the valley floors, smaller drainages, and riparian areas. The fine soils are also found along the headwaters of the watershed and then transported downstream during precipitation events. The loamy soils (36%) are found along the forested or hillier terrain. Surface texture is most important in influencing infiltration and runoff characteristics of a soil. While subsurface textures (including contrasting textures, hardpans, clay pans) influence permeability, drainage, leaching, water holding capacity and available water supply.

Figure 10. Geologic Formations in the Upper Nine Mile Creek Watershed.

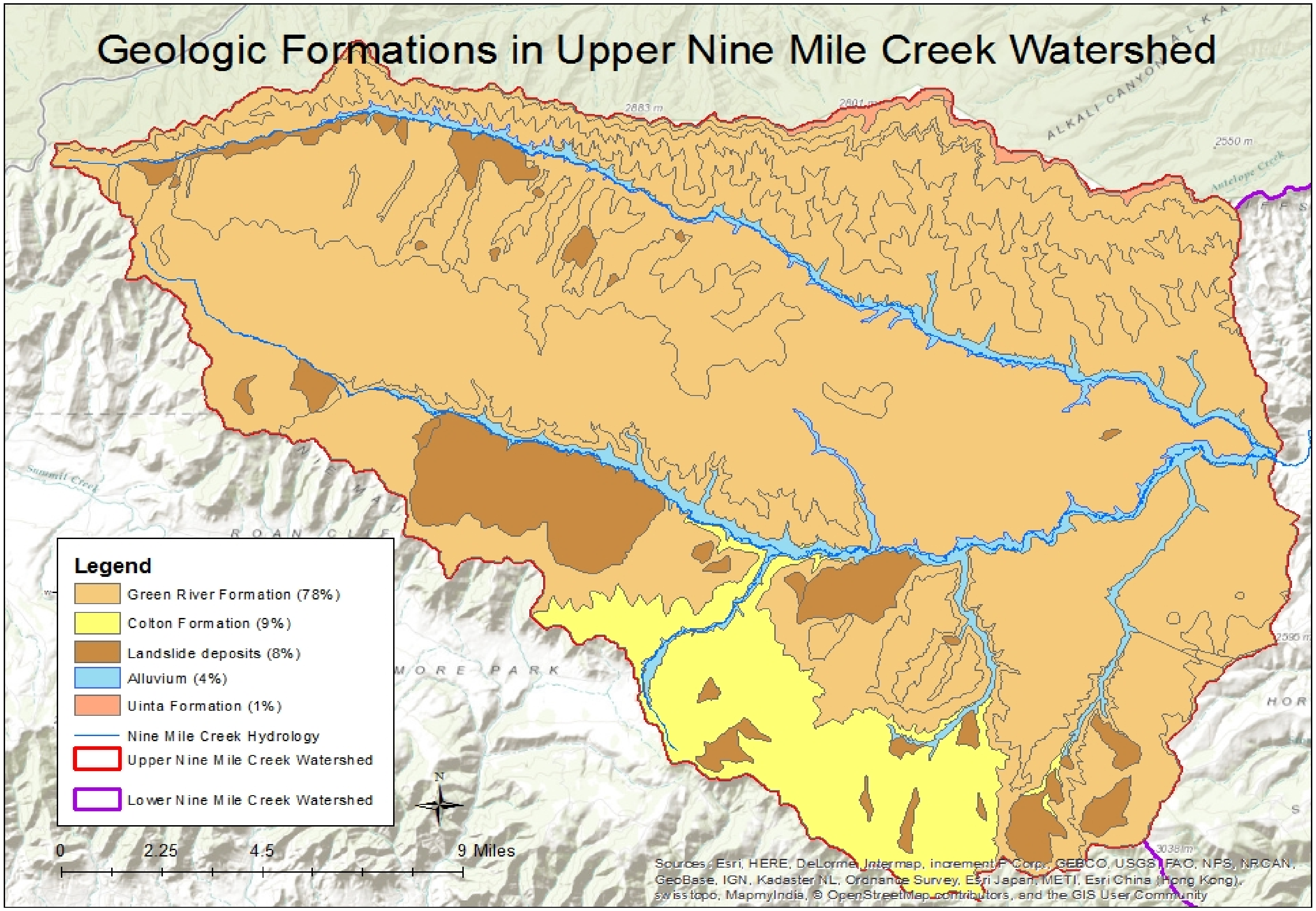


Figure 11. Soil Erodibility (K) Factor in Upper Nine Mile Creek Watershed.

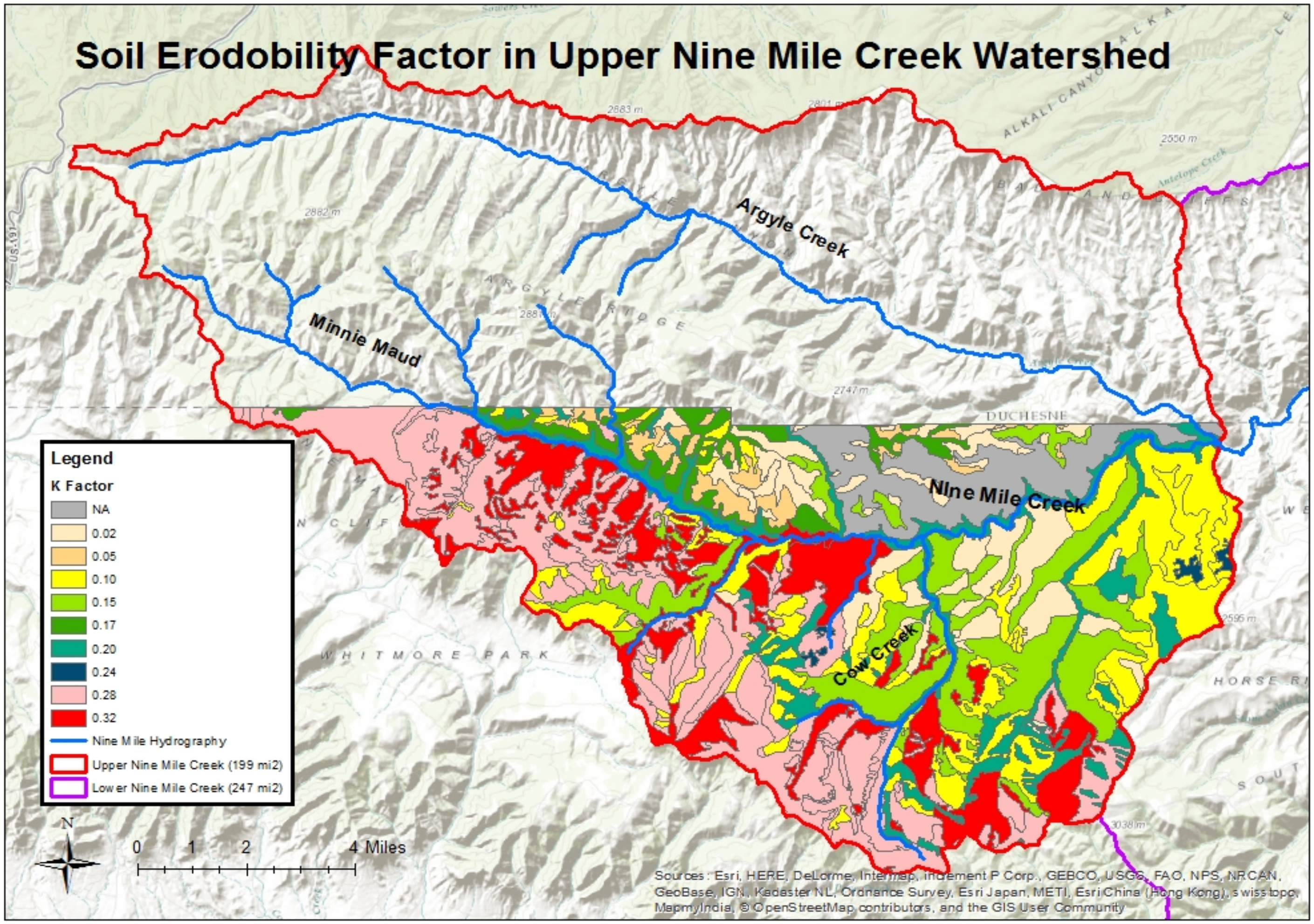


Table 5. Soil Surface Texture in Upper Nine Mile Creek Watershed.

Surface Texture	Area (mi^2)	% Area
Fine-Loamy	40.8	44
Loamy	33.2	36
Loamy-Skeletal	19.1	20
Coarse-Loamy	0.1	0.1
Total	93.2	100%

2.4.3 Hydrologic Soil Groups

Hydrologic soil groups are used to estimate the potential for runoff from precipitation events. Soils not protected by vegetation are assigned to one of four groups based on their infiltration and runoff characteristics (Table 6). Clay soils that are poorly drained have lower infiltration rates, while well-drained, sandy soils have higher infiltration rates. Hydrologic soil group data were summarized on the basis of the representative or most common hydrologic group within the map unit and are displayed in Figure 13. Duchesne County has not made their soil surveys available yet so the data is only analyzed for Carbon County.

The most common hydrologic soil groups are C (38%) and D (39%) within the watershed, with some B (23%) groups scattered throughout. The riparian areas, ephemeral side canyons, and the plateau tops generally fall within Group C. They have slow infiltration rates meaning that the soil is more prone to wash off into the riparian bottoms. Group D soils are prevalent on both sides of Nine Mile Creek. These soils have very slow infiltration rates and poor drainage that result in high amounts of runoff. Intense storms observed in this watershed commonly cause gully washers from such soils.

Table 6. Hydrologic Soil Groups.

Hydrologic Soil Group	Description
A	Soils with high infiltration rates. Usually deep, well drained sands or gravels. Little Runoff.
B	Soils with moderate infiltration rates. Usually moderately deep, moderately well-drained soils.
C	Soils with slow infiltration rates. Soils with finer textures and slow water movement.
D	Soils with very slow infiltration rates. Soils with high-clay content and poor drainage. High amounts of runoff.

Figure 12. Soil Surface Texture in the Upper Nine Mile Creek Watershed.

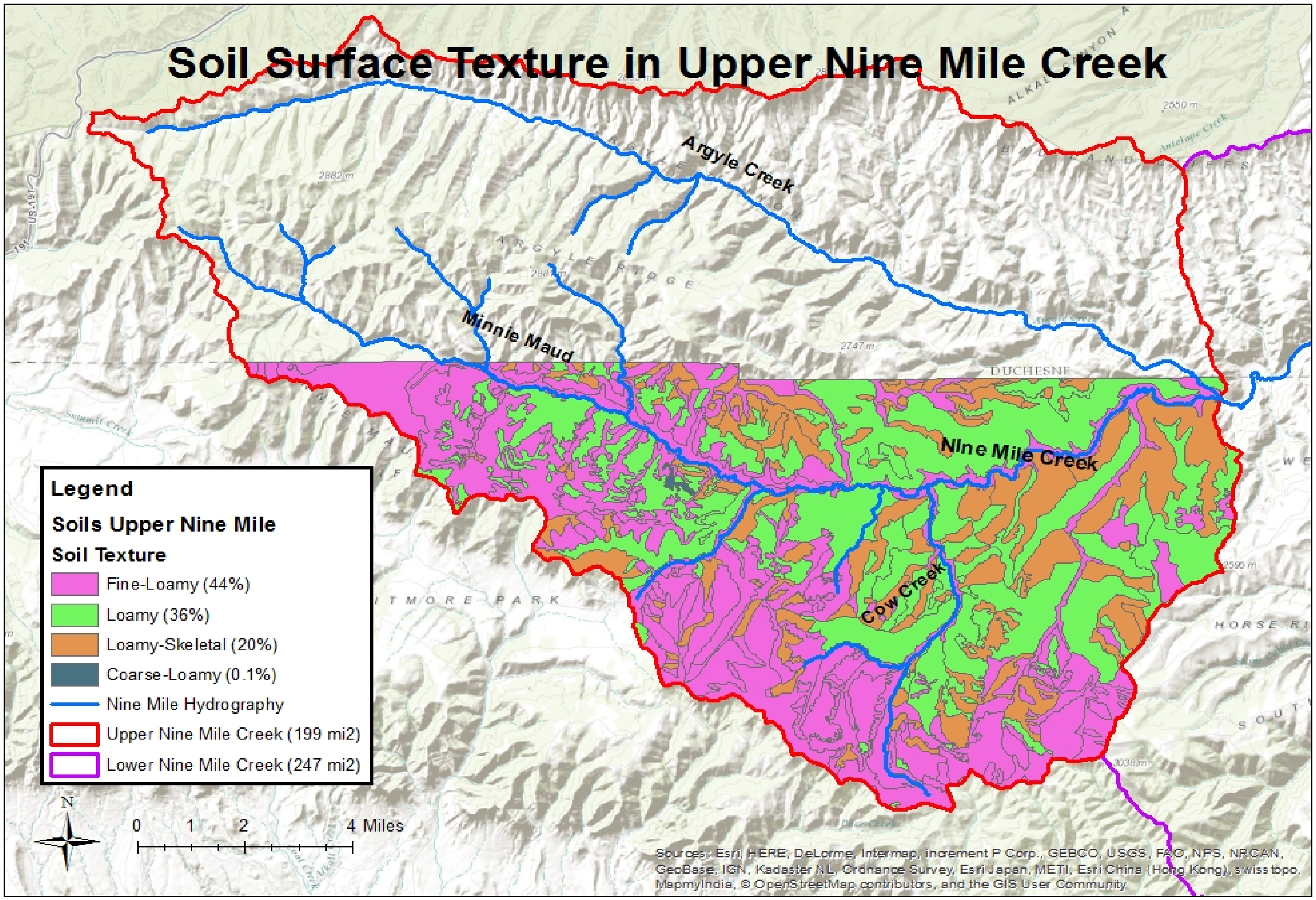
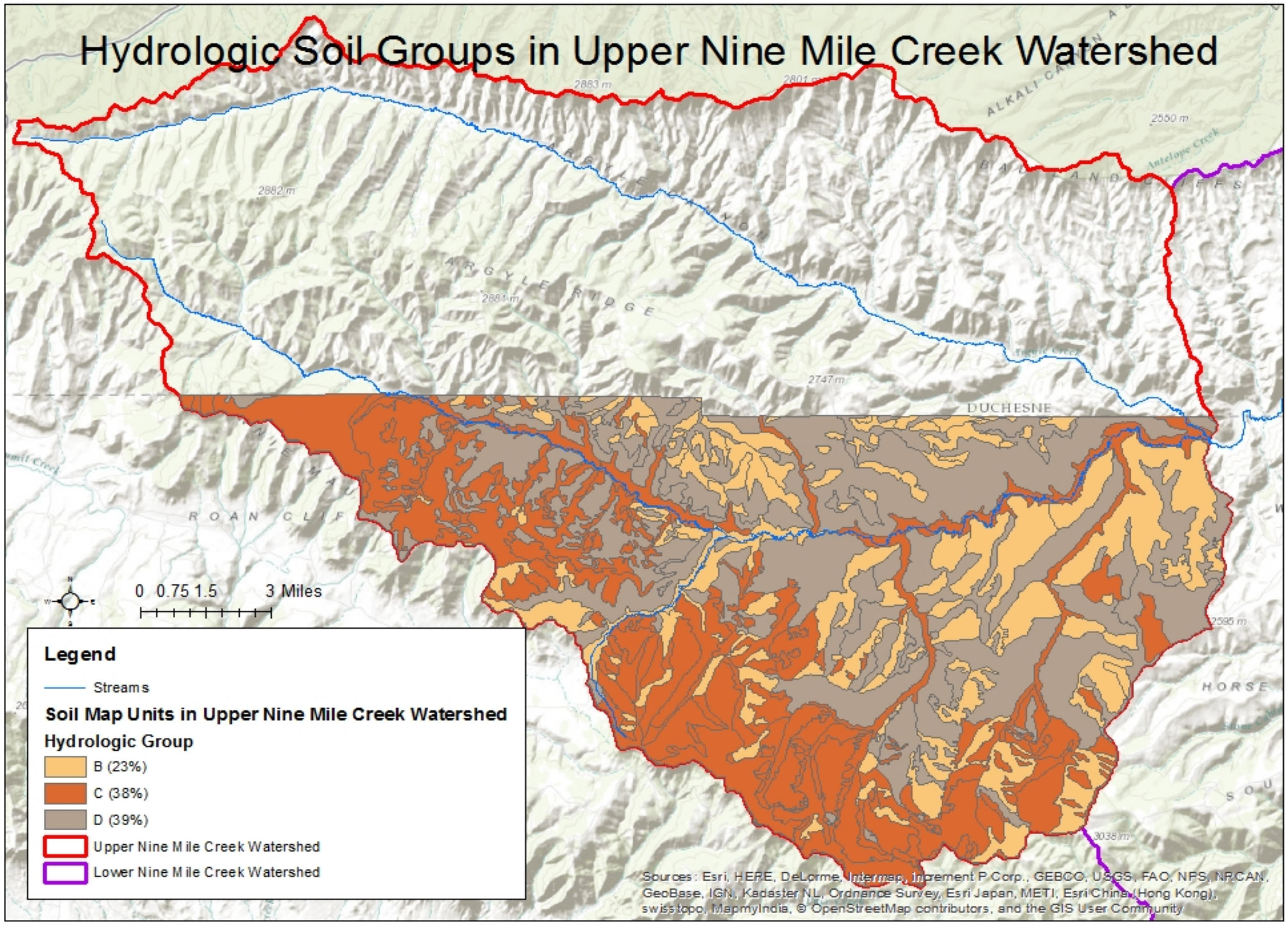


Figure 13. Hydrologic Soil Groups in Upper Nine Mile Creek.



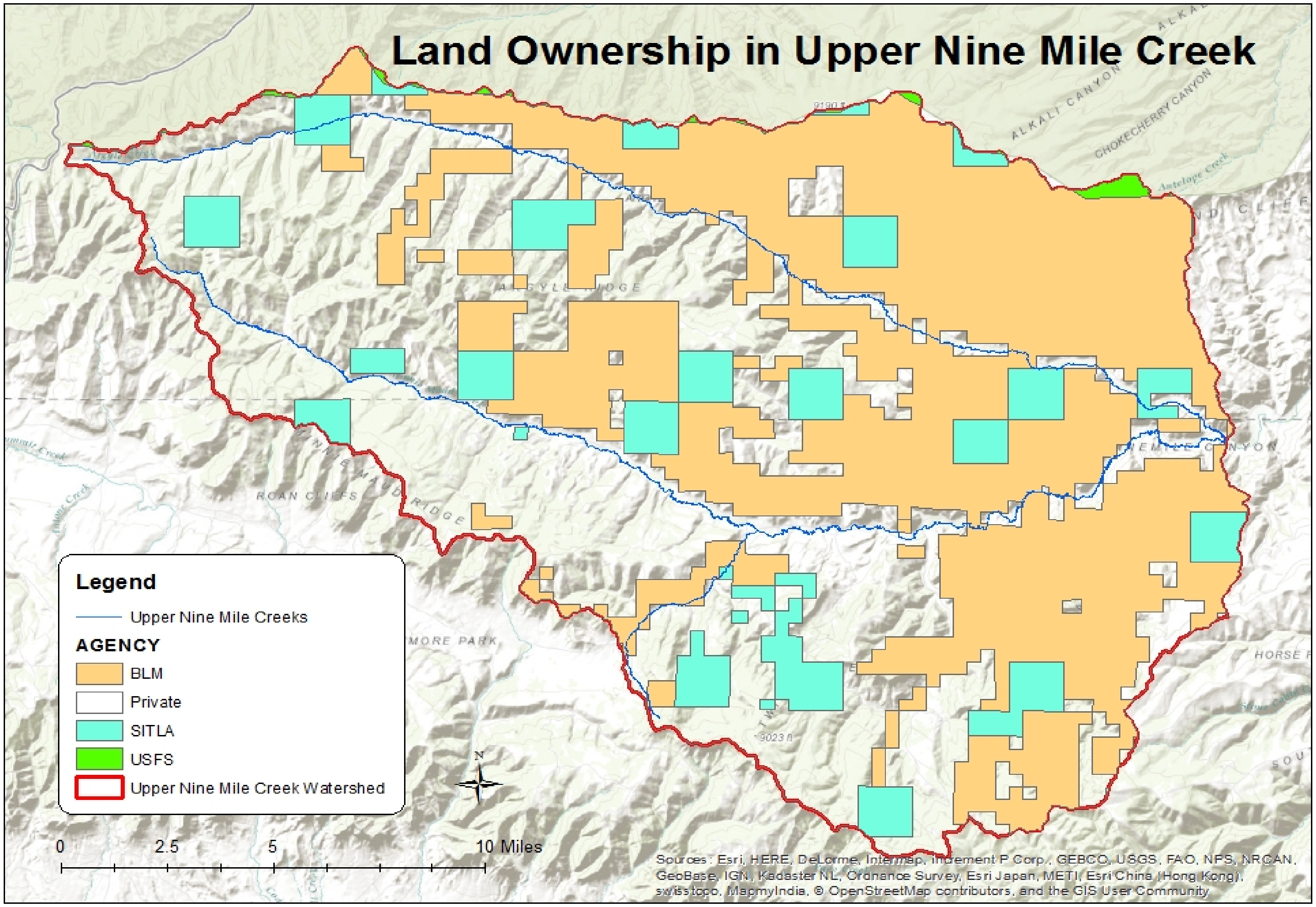
2.5 Land Ownership

Nine Mile Creek watershed is owned and administered by several different entities including federal and state agencies and private landowners. BLM administers most of the land in the watershed. Upper Nine Mile Creek Watershed is managed almost equally by BLM (44%) and private landowners (46%). Most of the private landowners lie in the headwaters area of Minnie Maud and Argyle Canyon.

Table 7. Landownership in Upper Nine Mile Creek Watershed.

Landowner	Area (mi^2)	% Watershed
BLM	87	44
Private	92	46
State	20	10
USFS	1	<1
Total	199	100

Figure 14. Landownership in Upper Nine Mile Creek Watershed.



2.6 Climate

Precipitation, temperature, and hence evaporation potential are strongly influenced by topography. Western Regional Climate Center (WRCC) has a weather station located within the Upper Nine Mile Creek watershed at Nutter's Ranch (426340). This site is located at an elevation of 5,790 feet. The site has been in operation since August 1963 to present, and data are available through 1986 (WRCC, 2016). Average and extreme minimum and maximum temperatures recorded over the period of record for the Nutter's Ranch WRCC site are displayed in Table 8 and Figure 15. Average annual temperature is 46ºF but extremes range from -25 to 100. Average total monthly precipitation for this site is displayed in Table 9 and Figure 16. Average annual precipitation is 11.5 inches but ranges from 6.4 to 24.8.

The local climate varies greatly with elevation and location relative to the mountain ranges that border to the west and north. Snowfall characterizes winter precipitation, while thunderstorms dominate during the summer season when a northerly flow of warm, moist air from the Gulf of Mexico prevails. The Uintah Basin gets little precipitation from the frontal systems coming from the northwest or west because fronts weaken as they descend the slopes of the Wasatch Range and Uinta Mountains.

A distribution of annual average precipitation in the Upper Nine Mile Creek watershed is available from the NRCS Water and Climate dataset (NRCS 1998). The NRCS climate dataset is a continuous distribution of average annual precipitation interpolated from precipitation measurements made at local climate stations. This interpolated method, Parameter-elevation Regressions on Independent Slope (PRISM), uses precipitation measurements and Digital Elevation Models (DEMs) to generate a gridded system of precipitation that incorporates spatial scale and the effects of precipitation. Precipitation distribution estimates and elevation are presented in Figure 17. The average annual precipitation in Upper Nine Mile Creek watershed ranges from less than 10 inches at the mouth of Nine Mile Creek to 20-25 inches at the higher elevations of Argyle Creek Canyon.

Table 8. Nutter's Ranch: Average Monthly Air Temperature Data Summary (1963 – 1986)

	Monthly Average			Extreme High (ºF)		Extreme Low (ºF)	
	Max (ºF)	Min (ºF)	Average (ºF)				
Annual	62.1	30.2	46.2	100	Jul-76	-25	Jan-71
Winter	38	9	23.5	70	Feb-86	-25	Jan-71
Spring	61.6	30.3	45.9	93	May-67	-5	Jun-76
Summer	84.8	50.4	67.6	100	Jul-76	28	Jun-76
Fall	63.9	31.2	47.6	96	Sep-77	-5	Nov-79

Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November

Table 9. Nutter's Ranch: Average Monthly Precipitation Data Summary (1963 – 1986)

	Average (inches)	High (Inches)		Low (Inches)	
Annual	11.57	24.83	1965	6.4	1974
Winter	1.93	4.89	1967	0.44	1970
Spring	3.27	6.82	1965	0.46	1974
Summer	3.42	10.89	1965	0.85	1976
Fall	2.95	6.08	1981	1.21	1968

Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November

Figure 15. Average Monthly Air Temperature Conditions at the Nutter's Ranch (426340).

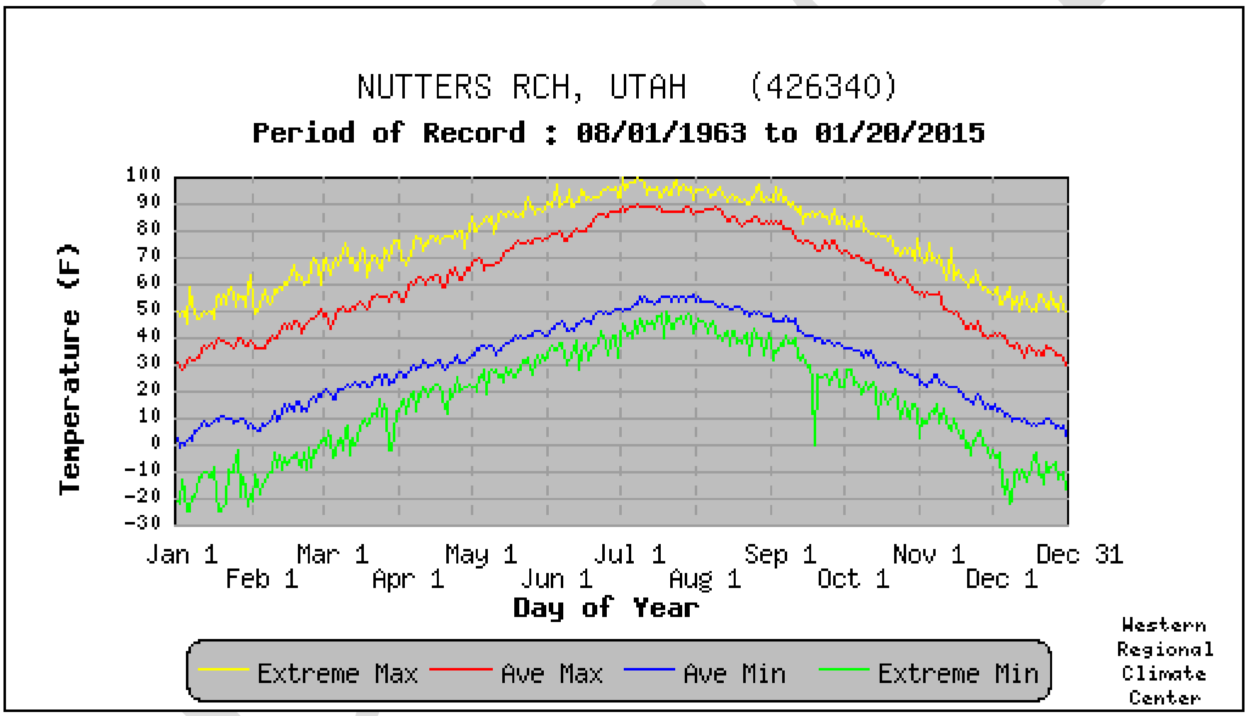
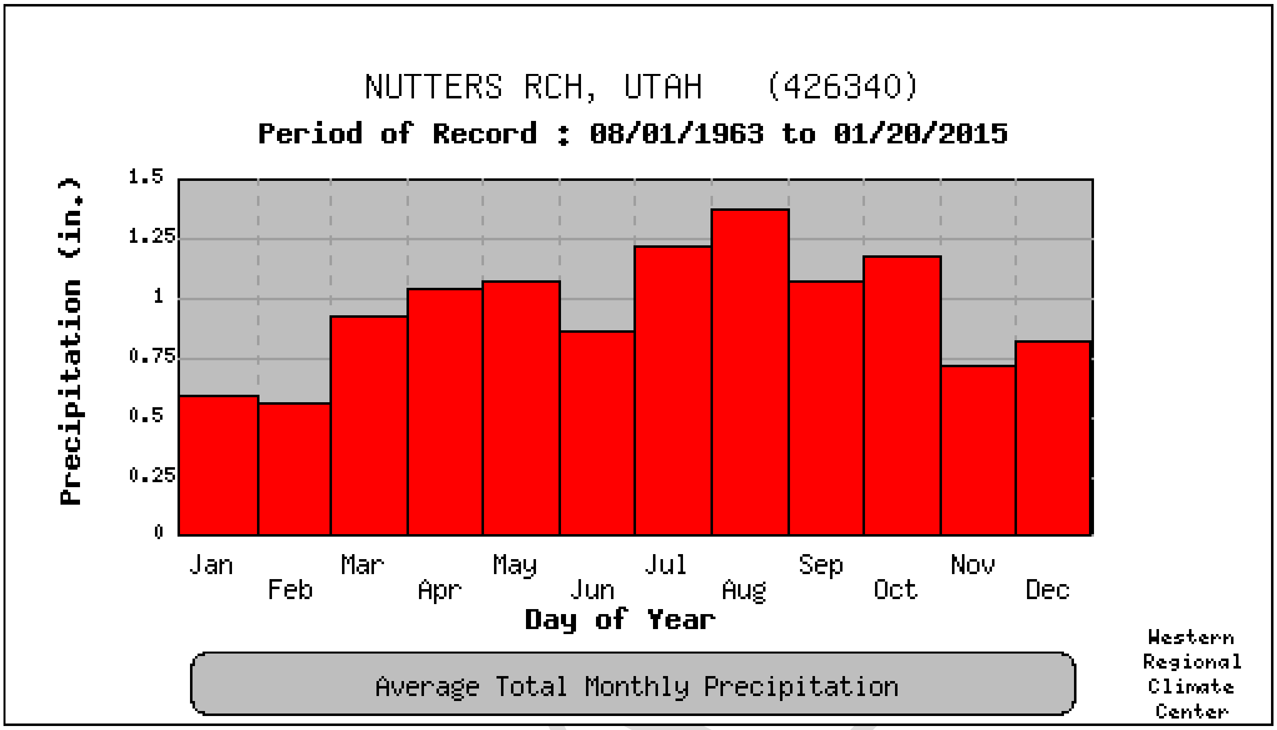


Figure 16. Average Monthly Precipitation at the Nutter's Ranch (426340).



2.7 Watershed Hydrology

The hydrology of Nine Mile Creek is dominated by spring runoff and brief, intense storms occurring in late summer. Diversions from the river have altered natural flows leading to a reduction in both high spring and base summer flows. Stream flows below water diversions are often dry or minimally augmented by subsurface return flows. The National Hydrography Dataset (NHD) created by EPA and USGS, indicate 4 different stream types in this watershed (Figure 18). Most of the streams are classified as intermittent. Intermittent streams flow only for short periods during the course of the year following precipitation events. Perennial streams flow continuously and originate from both springs and groundwater intrusion along the streambed. Many stream reaches are classified as "interrupted" because water in them flows for some distance underground before resurfacing further down the drainage. In Upper Nine Mile Creek, there are 337 miles of intermittent streams and 102 miles of perennial streams.

There are 3 subwatersheds within the Upper Nine Mile Creek Watershed: Minnie Maud Creek, Nine Mile Creek, and Argyle Creek (Table 11).

Table 10. Summary of Stream Types in Upper Nine Mile Creek Watershed.

Stream Type	River Miles	% Total
Intermittent	336.8	76
Perennial	101.6	23
Connector	1.6	<1
Artificial Path	0.1	<1
Total	440.8	100%

Table 11. Perennial Stream Summary in Upper Nine Mile Creek Watershed.

Perennial Streams	Tributaries	River Miles
Minnie Maud Creek Subwatershed Drainage Area = 44.9 mi^2	Minnie Maud Main Stem	18.6
	Upper Water Hollow Canyon	5.0
	Lower Water Hollow Canyon	5.1
	Sorensen Hollow	1.5
	Total	30.1
Nine Mile Creek Subwatershed Drainage Area = 75.9 mi^2	Nine Mile Main Stem	21.2
	North Hollow	3.1
	Cow Canyon	11.3
	Pole Canyon	2.2
	Total	37.8
Argyle Creek Subwatershed Drainage Area = 78.2 mi^2	Argyle Main Stem Pinnacle Canyon	27.7 2.8
	Water Canyon	3.3
	Total	33.8

Figure 17. Precipitation in the Nine Mile Creek Watershed.

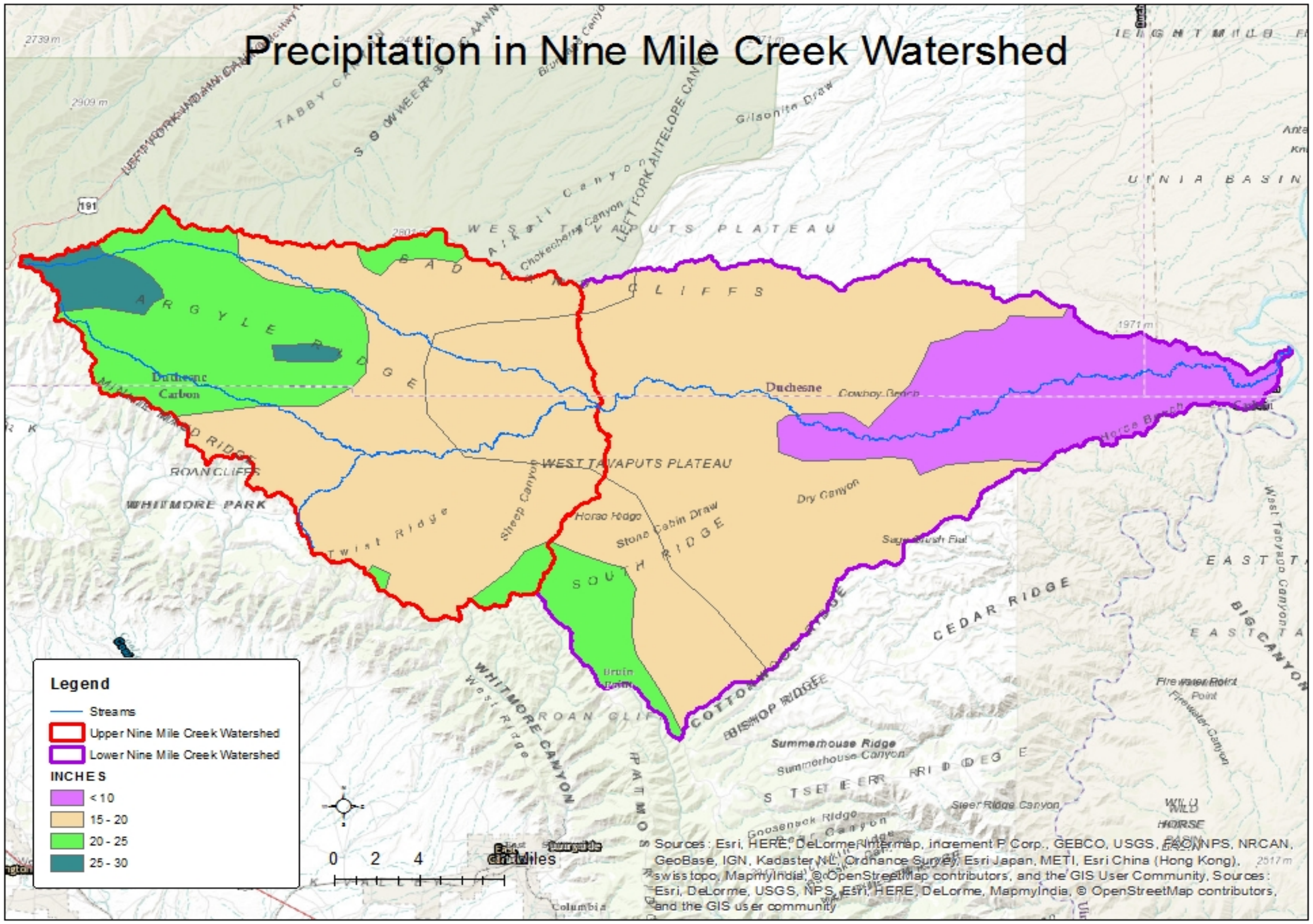
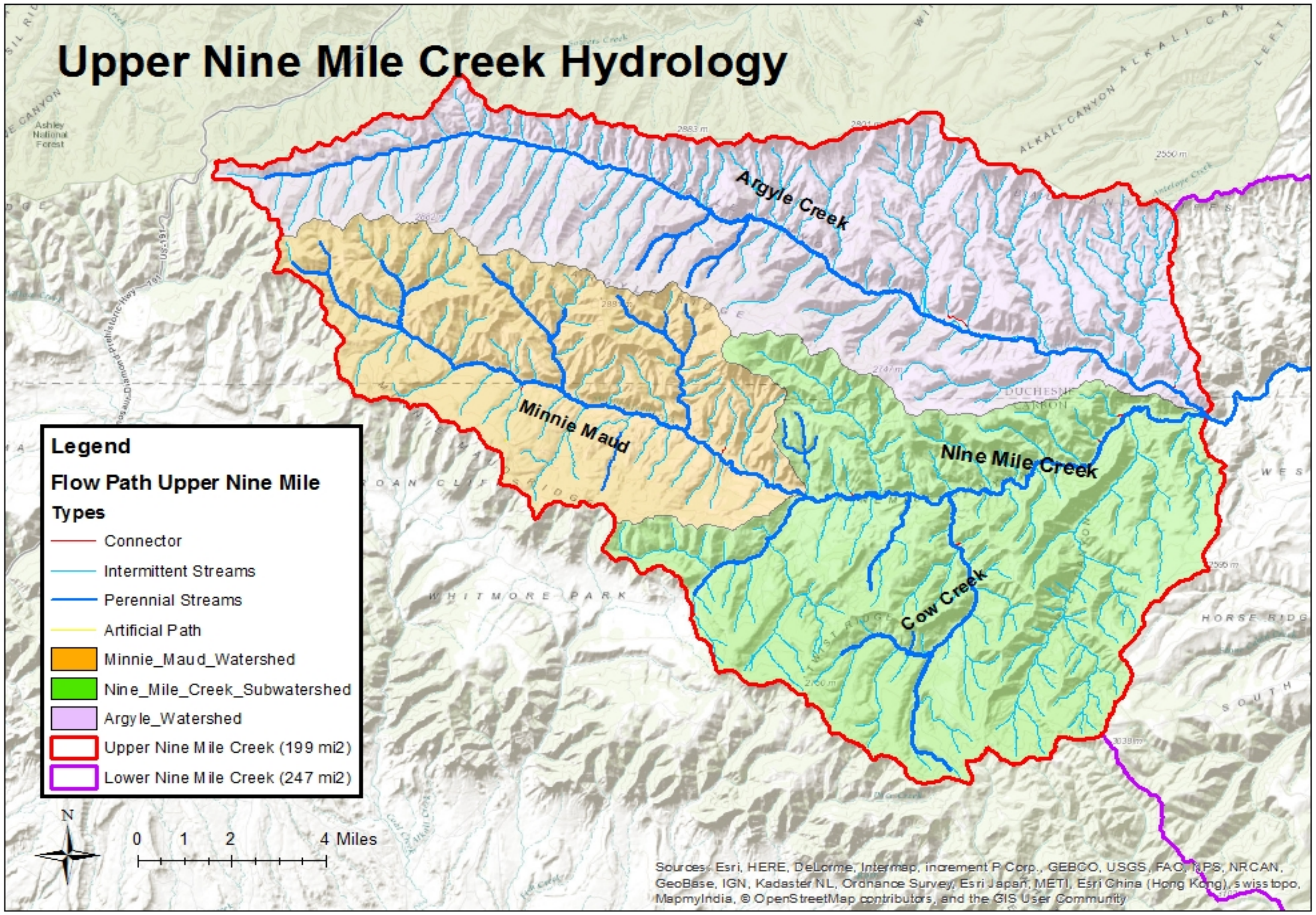


Figure 18. Upper Nine Mile Creek Hydrology



2.8 Water Supply and Uses

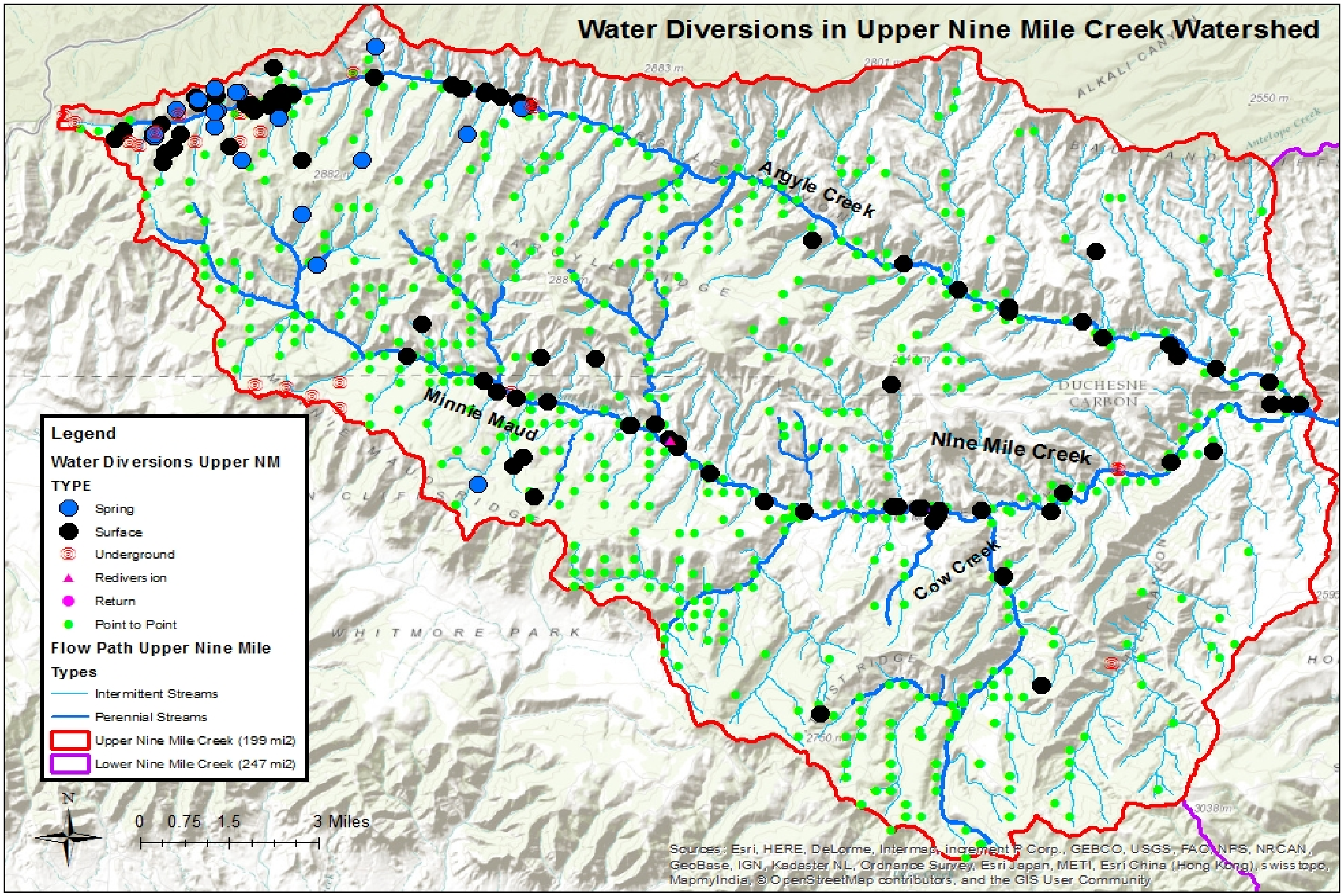
Water from Nine Mile Creek is used for pasture and hayland irrigation, livestock watering, wildlife, recreation, industrial (energy), and municipal uses. There are over 1,200 points of diversion with associated water rights located in the Upper Nine Mile Creek Watershed. There are six different types of diversions in the watershed. In Upper Nine Mile Creek, there are 186 surface diversions totaling 293 acre feet per day (ac-ft/day). The main permittees include private, energy industry, BLM, and Minnie Maud Irrigation Company. There are 27 underground diversions totaling 99 ac-ft/day annually. Price River Water Improvement District has the right to divert 55 ac-ft/day from groundwater wells along the Minnie Maud Ridge. Private landowners, SITLA, and BLM own 1,007 point to point diversions totaling 44 ac-ft/day. Point to point diversions are not developed but rather only reference a stream segment from which livestock may drink. The headwaters of both Minnie Maud and Argyle Creeks have 27 spring diversions owned by the private sector totaling 0.8 ac-ft/day. There are 3 re-diversions in this watershed owned by private landowners and energy industry totaling 0.08 ac-ft/day. A re-diversion refers to a diversion point which diverts water that was previously diverted and released upstream. The energy industry owns the only return diversion located on Nine Mile Creek totaling less than 1 ac-ft/day cfs per year. A return diversion is a point where water that has been non-consumptively used is returned to the stream.

There is currently no data to show how many acres are irrigated and by which irrigation occurs. Both flood and sprinkler water delivery systems are observed in the watershed. It is assumed from conservations with the landowners that each landowner along the main stem of Nine Mile can divert 100% of the flow. Agricultural fields along the creek temporarily store the irrigated water which is slowly returned back to the stream. Irrigation return flow could be cooler than the original diverted water (Bjornberg, 2015).

Table 12. Water Diversions in Upper Nine Mile Creek Watershed.

Type of Diversion	Number	Volume (ac-ft/day)	Flow (cfs)
Surface	186	292.9	147.70
Underground	27	99.6	50.21
Point to Point	1,007	42.6	21.48
Spring	27	>1	0.39
Re-diversion	3	>1	0.04
Return	1	>1	0.00
Total	1,251	436	219.82

Figure 19. Water Diversions in Upper Nine Mile Creek Watershed.



3.0 Water Quality Standards and TMDL Target

The ultimate goal of a TMDL is to restore a waterbody to meet water quality standards established to protect the designated beneficial uses. One of the primary components of a TMDL is the establishment of an instream numeric target to evaluate the attainment of water quality goals. Instream numeric targets, therefore, represent the water quality goals to be achieved by implementing the load reductions specified in the TMDL. The targets allow for a comparison between instream conditions and conditions required to support designated uses. The targets are established on the basis of numeric or narrative criteria from state water quality standards. If applicable numeric water quality standards are available, they can serve as a TMDL target. If only narrative criteria are available, a numeric target is developed to represent conditions resulting in the attainment of designated beneficial uses.

3.1 Overview of 303(d) List Status

The assessment unit (AU), UT14060005-003: Nine Mile Creek and tributaries from the Green River confluence to headwaters, was assessed for temperature and listed on Utah's Section 303(d) list of impaired waters in 1998 (Table 13).

Table 13. Classification of Impaired Waters in the Nine Mile Creek Watershed.

Name	Year First Listed	Impaired Beneficial Use	Cause of Impairment
Nine Mile Creek and tributaries from Green River confluence to headwaters	1998	3A	Temperature

3.2 Parameter of Concern

In-stream temperature is a water quality factor that is vital to the life cycle of aquatic species. All life stages can be affected when temperature is elevated, especially if other habitat limitations co-exist such as low dissolved oxygen or poor habitat conditions. Ambient water temperature is the most important factor affecting the success of trout and other cold water aquatic life. Temperature influences growth and feeding rates, metabolism, development of embryos/juveniles, and timing of upstream migration, spawning, rearing, and food availability.

Temperature is important to both the aquatic biological community and riverine chemical properties. Aquatic life is governed by temperature; they have a preferred temperature range for growth, reproduction, and survival. Temperature influences water chemistry. The rate of chemical reactions increases at higher temperatures, which in turn affects the biological community. For example, warm water holds less oxygen which might not be enough to support aquatic life. Some compounds are also more toxic at higher temperatures.

The aquatic life community can be affected by both acute and chronic exposure to elevated water temperatures. Acute high temperatures can result in death if they persist for an extended length of time. For example, chronic exposure to adult fish can result in reduced body weight, reduced oxygen exchange, increased susceptibility to disease, and reduced reproductive capacity. Early life stages and juvenile fish are even more sensitive to temperature variations than adult fish, and can experience negative impacts at a lower threshold value than the adults, manifesting in retarded growth rates. High temperatures also affect embryonic development of fish before they even emerge from the substrate. Aquatic life can withstand some short-term exposure to higher temperatures without significant adverse effects but there are maximum temperatures above which adverse effects occur after short exposures. The Maximum Weekly Maximum (MWMT) is a measure of both chronic and acute exposure. For this TMDL, DWQ is establishing MWMT as the summary measure for which to assess high frequency temperature readings. It is the measure of the highest 7-day moving average of the maximum temperature. Like Utah, many water quality agencies have not updated their water quality standards to specify which temperature calculation applies to the standard. However, after initial review, there are a number of thermal threshold studies for salmonids that suggests that MWMT is commonly used to understand both the acute and chronic exposure effects at varying life stages (Isaak et al. 2010; Sullivan et al. 2000; Welsh et al. 2001). Finally, there is little information identifying specific MWMT values optimal for cutthroat trout. However, a review by Dunham (1999) identified and recommended to Oregon Division of Environmental Quality (OR DEQ) 20°C MWMT as the optimal temperature standard for the ESA-listed Lahontan Cutthroat Trout (Oncorhynchus clarkii henshawi). The value identified by Dunham (1999) not only matches UT DWQ's numeric temperature standard and goal for this TMDL, but is tied to the same species expected to occur in Nine Mile Creek: *Oncorhynchus clarki pleuriticus* (Colorado River cutthroat trout--CRCT. This water quality study addresses the excess heating to freshwater salmonid habitat (CRCT) related to water temperature in Nine Mile Creek. Partners are currently planning restoration efforts to address other factors, such as habitat, which will aid in the coldwater fishery population recovery.

3.3 Climate Change

It would be remiss to discuss excess heating of a stream system without discussing global climate change. A warming climate influences stream water temperature in a variety of known and unknown direct and indirect pathways. Directly, convective heating of water through air temperature is the most important variable predicting average annual stream temperature (Hill, Hawkins, & Carlisle, 2013); as average annual air temperatures climb, so too, would average stream temperatures. However, fluctuating levels of convective heating play a minor role in determining maximum stream temperatures (Boyd & Sturdevant, 1997) Indirect effects, such as changes in precipitation patterns (Hansen, et al., 2005), wildfire (Westerling, Hidalgo, Cayan, & Swetman, 2006), and cloud cover (Norris, et al., 2016) to name a few, appear to have stronger, yet, less clearly linked, effects on stream temperature maximums. Most prominently (and better understood and observed), is the effect that climate change has influencing the type and timing of precipitation (Mote 2006, Bardsley, et al, 2013, Isaak & Rieman 2013). In particular, warming air temperatures play a larger role affecting mid-elevation mountain systems (1500-2000 m) like Nine Mile Creek due to decreased quantity and timing of snowpack and dependency on seasonal rainfall (Stewart, 2009) . In the Intermountain-West, mid-elevation streams typically rely on a sizable snowpack (Hornbach, Richards, Blackwell, Mauroner, & Brokaw, 2016). However, at these elevations, the effects of a changing snowpack are more pronounced: 1. the amount of precipitation entering the system is increasingly in the form of rain and 2. the water that does enter from snowpack is becoming more limited to the early spring season and has minimal impact to water temperature during critical summer months (Stewart, 2009). To make matters worse, the change from snowpack to rain may not be the most important effect quantified thus far. A recent model suggests that the reduction of mountain stream flows is driven largely by increased evapotranspiration from warming air temperatures rather than snowpack changes (Foster, Bearup, Molotch, Brooks, & Maxwell, 2016)

It has been long understood how these climate change effects could impact cold water aquatic life (Eaton & Scheller 1996, Rieman *et al.* 2007). Today, these consequences have been increasingly verified as well as the precision of predicting future stream temperature changes at finer resolution. When evaluating climate change impacts to CRCT in the Colorado Basin, Roberts (2013) predicts that a 1.3°C increase of MWMT will occur in the Lower Green River sub-basin (sub-basin containing Nine Mile Creek) by 2080. Overall, however, the direct risks associated with a warming climate to the current populations of CRCT are minimal compared to the indirect, stochastic effects on these fragmented populations (Roberts, Fausch, Peterson, & Hooten, 2013) . Nonetheless, since Nine Mile Creek is located on the elevational fringe of dramatic snowpack fluctuations and it is vulnerable to wild weather events, restoring a systemic riparian ecosystem is the most logical response to build thermal stream resiliency.

It is therefore, incredibly important that mid-elevation watersheds, like Nine Mile Creek have more robust features such as adequate riparian widths consisting of the 3 levels of vegetative cover: ground-level vegetation slow runoff, whereas the understory and canopy provide bank stability and stream shading. Although this TMDL does not specifically account for warming air temperatures, riparian restoration is critical to building resiliency to warming air temperatures and extreme weather (Perry, Reynolds, Beechie, Collins, & Shafroth, 2015). If restoration plan is fully implemented, Upper Nine Mile Creek watershed would likely become a reference system and if successful could be a template for other mid-elevation systems that harbor CRCT.

Both anthropogenic and natural factors can influence water temperature. Human-influenced factors include point source discharges, riparian and channel alterations, and flow modifications. Natural factors include climate, riparian vegetation (shade), altitude, and channel morphology. Section 5 covers potential sources in more detail.

3.4 Applicable Water Quality Standards

Under the Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nations' surface waters. These standards represent a level of water quality that will support the CWA's goals of "swimmable and fishable" waters. Water quality standards (WQS) consist of three major components:

- Beneficial uses reflect how humans can potentially use the water and how well it supports those uses. Examples of beneficial uses include aquatic life support, agriculture, drinking water supply, and recreation. Every waterbody in Utah has at least two or more designated uses; however, not all uses apply to all waters.
- Criteria express the condition of the water that is necessary to support the beneficial uses. Numeric criteria represent the maximum concentration of a pollutant that can be in the water and still protect the beneficial use of the waterbody. Narrative criteria are the general water quality criteria that state that all waters must be free from sludge, floating debris, oil/scum, color and odor producing materials, substances that are harmful to human, animal, or aquatic life, and nutrients in concentrations that may cause algal blooms.

- The anti-degradation policy establishes situations under which the state may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to demonstrate an important social or economic need.

The Utah Water Quality Board (UWQB) is responsible for creating the water quality standards that are then enforced by the Utah Department of Environmental Quality, Division of Water Quality. Utah has numeric criteria for temperature. This standard is found in the Utah Administrative Code, Standards of Quality for Waters of the State R317-2-14 and varies based on the beneficial use assignment of the waterbody (UDWQ 2009). Table 11 summarizes the standards pertaining to the 303(d) listed segment in the Nine Mile Creek watershed.

Table 14. Water Quality Standard for Impaired Waterbodies in the Nine Mile Creek Watershed.

Parameter	Designated Use & Description	Water Quality Standard
Temperature	3A: Coldwater aquatic life	20°C

3.5 Utah's Listing Methodology and 303(d) Status

The beneficial use support status for streams in Utah is determined using the water quality standards. Utah has defined guidelines for assessing each beneficial use as listed in Table 11. UDWQ defines temperature as a conventional parameter and assesses it against the beneficial use-specific criteria established in UAC R317-2-14. A minimum of 10 samples are required to determine if a waterbody is attaining or not attaining WQS (Figure 14). Where locations that have sample sizes of 10 or greater, 10% of the total samples are calculated. This 10 % calculation becomes the maximum number of samples that can exceed the numeric criteria (20C°). If more than 10 % of the total samples collected exceed the criterion, the site is not attaining the beneficial use. If 10 % or less of the total samples collected exceed the criterion, the site is attaining its beneficial uses. Where locations have insufficient samples to make an attaining or non-attaining determination, UDWQ prioritizes the sites and parameters for future monitoring, depending on whether the dataset contains criterion exceedances. (Utah Division of Water Quality, 2016).

3.6 TMDL Endpoints

TMDL endpoints represent water quality targets used in quantifying TMDLs and their individual components. Different TMDL goals are necessary when streams are impaired for temperature including a numeric water quality criterion, shade targets, and biological goals. These targets all serve as varying ways to measure attainment of the cold-water sport fish designated use and to provide verifications of the assumptions made in calculating the TMDL.

The first and ultimate endpoint is Utah's numeric water quality criterion for cold water aquatic life of 20°C. This number was adopted into Utah's numeric criteria (UAC R317-2-14) because it was derived as the maximum allowable threshold for cold water gamefish and their associated food web to fulfill their life cycles.

The second goal is the calculated shade targets for each of the 169 common identifier (ComID) reaches established by the National Hydrography Dataset (NHD). While excess instream temperature is the listed parameter, the pollutant is heat. Since there are no permitted point source discharges in the watershed, the focus of this TMDL will be on nonpoint sources. Increased solar radiation caused by the absence of riparian vegetation is often the primary cause of stream warming. Hence, effective shade is a suitable surrogate measure for nonpoint source allocations. Potential natural vegetation (PNV) refers to the expected state of vegetation given site specific constraints such as climate and geomorphology (United States Department of Agriculture, 2011). Because of the direct correlation between riparian vegetation and stream temperature, shade targets for each reach of Nine Mile Creek has been determined. Shade targets take into account the relationship between vegetation height, density, width, stream aspect, stream channel width, and resulting solar radiation that Nine Mile Creek receives.

The third TMDL goal is biological in nature. Within the study area, the two most sensitive biological analogs for temperature are the Least Salmonfly (*Pteronarcella badia*) and the Colorado River Cutthroat Trout (CRCT- *Oncorhynchus clarkii pleuriticus)*. From DWQ's Statewide database which contains over 40,000 samples, only 243 samples (0.6%) at 165 locations contained at least one *P.badia.* Although the population is widespread throughout the State, *P. badia* do require specific habitat that is largely temperature dependent. They are relatively long-lived taxa in the aquatic environment requiring two years of development before emerging as adults. Specimens have been collected from lower Argyle Creek historically and as recently as 2014. These observations suggest that Argyle Creek may be near suitable for other cold-water aquatic life such as CRCT. Therefore with the successful implementation of this TMDL, there should be an increase in distribution and abundance of Least Salmonfly in both Argyle and Nine Mile Creeks compared to the baseline conditions noted in Appendix B. The CRCT have limited documented history in the study area. However, UT DWR along with UT DWQ have classified and protect the upper watershed area as potential CRCT habitat. When the TMDL is fully implemented, water quality conditions, particularly temperature, should be sufficient for the successful reintroduction of CRCT into the study area.

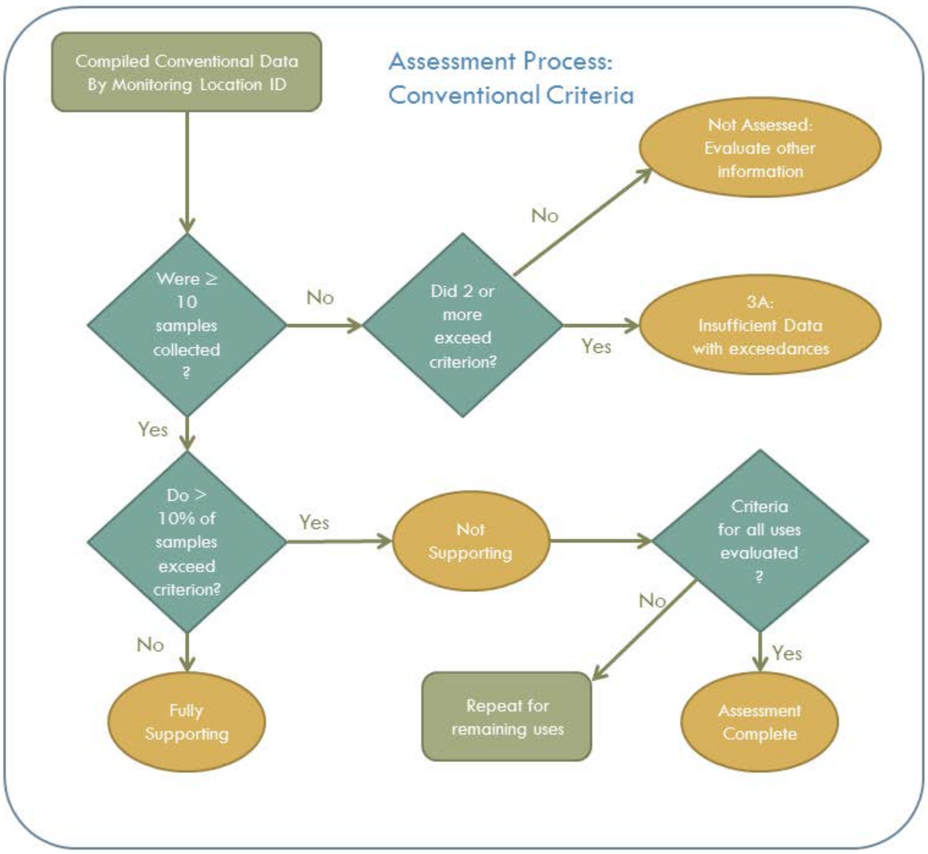
4.0 Data Inventory and Review

4.1 Discrete Temperature Data

There are 16 UDWQ water quality stations in the Nine Mile Creek Watershed. Monitoring locations considered to be critical to the TMDL process are listed in Table 15. Cumulatively, these sites represent adequate spatial coverage throughout the watershed (Figure 21). There are 8 located in the Upper part of the watershed and 9 in the Lower. Though data was collected at each of these sites, only 5 had enough temperature data for further analyses. Table 15 highlights these monitoring sites. Additional temperature grab sample data is located in Appendix A.

Water quality data assessed from monitoring site, Nine Mile Creek above Bulls Canyon (4933330) triggered the 1998 303(d) listing. According to UDWQ's Assessment Methodologies (Utah Division of Water Quality, 2016), a waterbody is considered impaired if the water quality standard of 20 °C is exceeded over 10% of the time. Temperature grab samples collected from 1992 to 2014 at 22 sampling events averaged 20.3 °C and spanned from 12 to 28 °C. Figure 23 shows that during this time period, the water quality standard of 20 °C was exceeded 50% of the time. Nine Mile Creek at Mouth (4933310) exceeded the WQS 36% from 1977 to 2009 (Figure 24). Temperature measurements taken from Minnie Maud Creek above the confluence of Nine Mile Creek (4933420) from 2005 to 2009 showed no impairments (Figure 25).

Figure 20. Overview of the Assessment Process for Conventional Parameters.



Average summer monthly temperature readings from grab samples from these monitoring sites are displayed in Figures 26 and 27. Summer temperature in Upper Nine Mile Creek does not exceed the water quality standard. In Lower Nine Mile Creek, this standard is exceeded in both July and August at Nine Mile Creek above Bulls Canyon and at the mouth. The general trend of water temperature increasing during the summer is observed at these monitoring sites. This trend is also seen in the air temperature (Table 8 and Figure 15) where summer temperatures can climb to 100 °F (38 °C). The impairments in Lower Nine Mile Creek triggered subsequent, more in-depth temperature monitoring to better define the spatial and temporal aspects of the exceedances.

Table 15. Temperature Summary Statistics from Grab Samples for Water Quality Monitoring Stations in Nine Mile Creek Watershed.

Watershed	MLID	Site Description	Sample Size	Date Range	Minimum	Average	Maximum
Upper Nine Mile	4933620	Argyle Ck AB Garder Cyn	1	1999	11.1	11.1	11.1
	4933610	Argyle Creek Lower	4	1999 - 2014	11.1	14.4	16.7
	4939135	Argyle Ck BL Parley Cyn	1	2014	10.8	10.8	10.8
	4933380	Argyle Ck AB Confl Nine Mile Ck	6	2005 - 2014	4.5	13.4	18.6
	4933420	Minnie Maud Ck AB Confl Nine Mile Ck	13	2005 - 2014	0.3	11.6	19.7
	4933410	Cow Canyon Ck AB Confl Nine Mile Ck	5	1999 - 2009	11.1	14.2	18.8
	4933390	Sheep Canyon Ck AB Confl Nine Mile Ck	1	1999	10.0	10.0	10.0
	4933405	Nine Mile Ck at Cottonwood Glen	4	2008 - 2014	13.2	16.4	19.7
Lower Nine Mile	4933345	Nine Mile Ck BL Campground	1	2007	15.6	15.6	15.6
	4933290	Dry Canyon	3	1992 - 2009	10.0	11.3	12.8
	4933288	Nine Mile Canyon BL Dry Canyon	8	2006 - 2009	2.8	8.5	15.3
	4939139	Nine Mile Ck BL Daddy Cyn	1	2014	10.6	10.6	10.6
	4933335	Nine Mile Ck AB Cottonwood Cyn	4	2007 - 2014	8.2	16.1	18.8
	4933280	Cottonwood Creek	5	2001 - 2008	2.4	7.3	16.8
	4933330	Nine Mile Ck AB Bulls Canyon	22	1992 - 2014	12.0	20.3	28.0
	4939121	Nine Mile Ck 0.5 mi AB Green River	1	2014	17.0	17.0	17.0
	4933310	Nine Mile Ck at Mouth	23	1977 - 2009	4.5	16.9	28.0

Figure 21. Map of Water Quality Monitoring Stations in Nine Mile Creek Watershed.

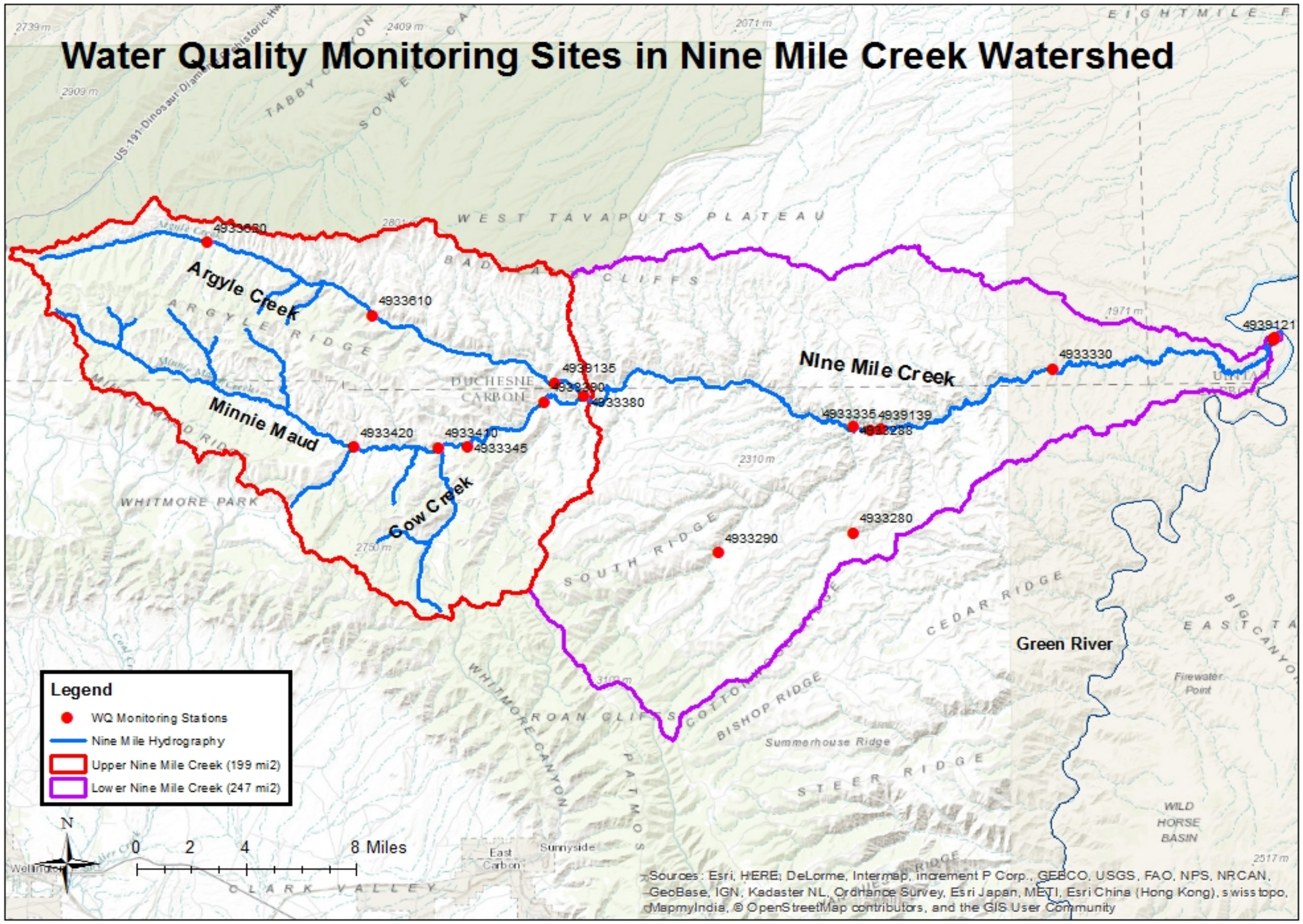


Figure 22. Picture of Nine Mile Creek at Cottonwood Glen.

Figure 23. Temperature Measurements in Minnie Maud Ck above Nine Mile Ck (4933420).

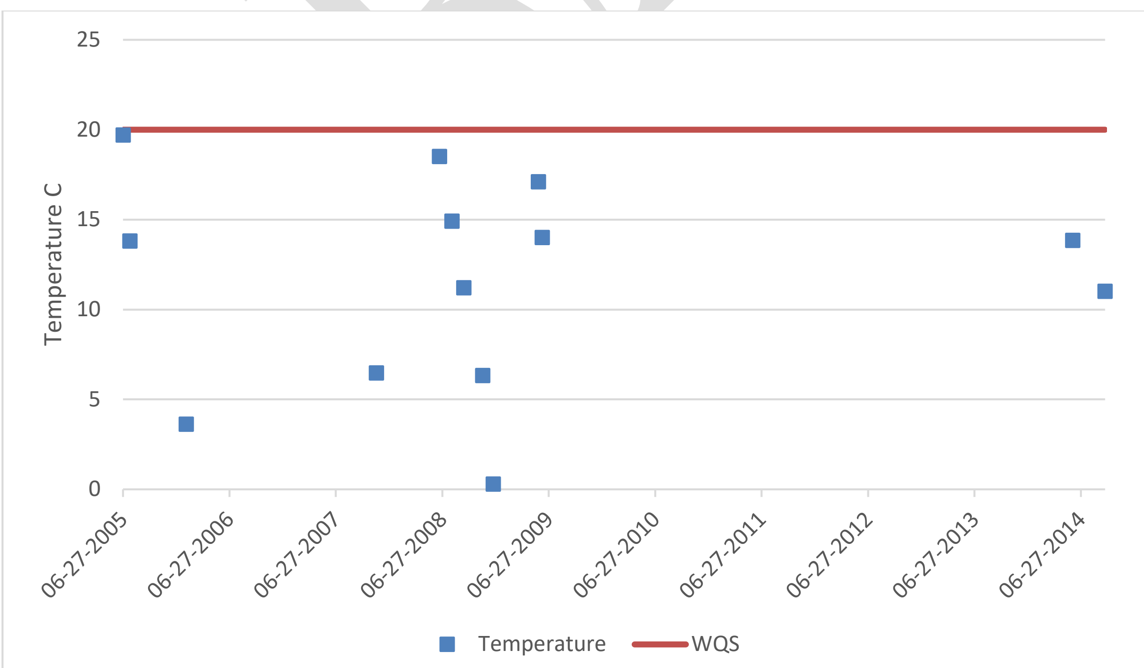


Figure 24. Monthly Summer Average Temperature Readings in Upper Nine Mile Creek Watershed.

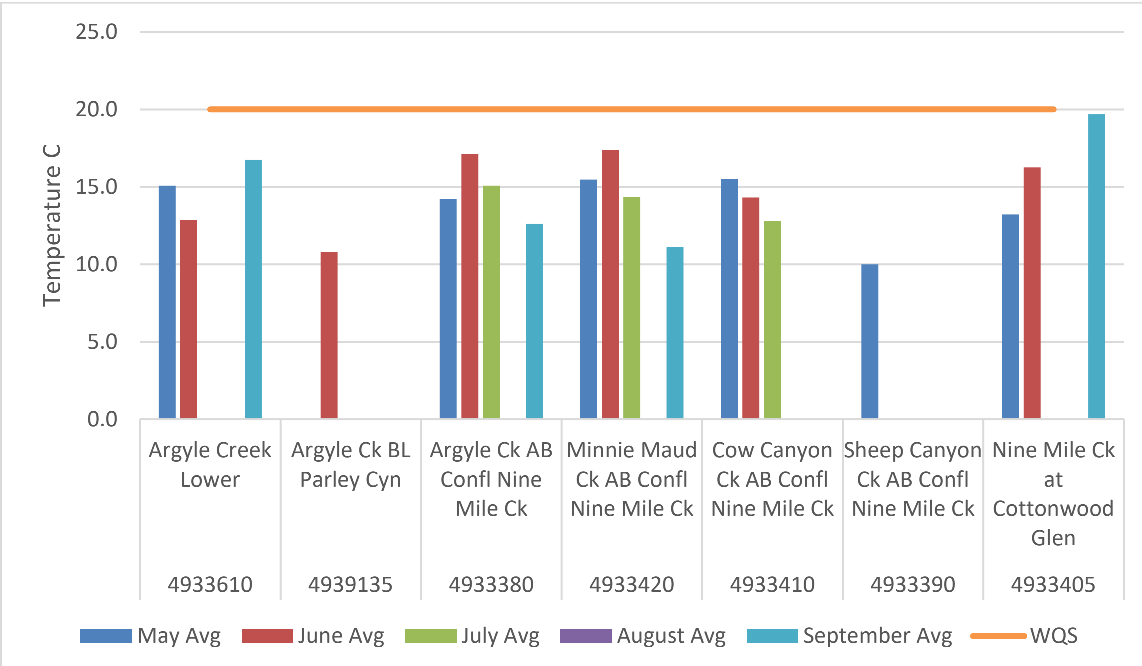


Figure 25. Monthly Summer Average Temperature Readings in Lower Nine Mile Creek Watershed.

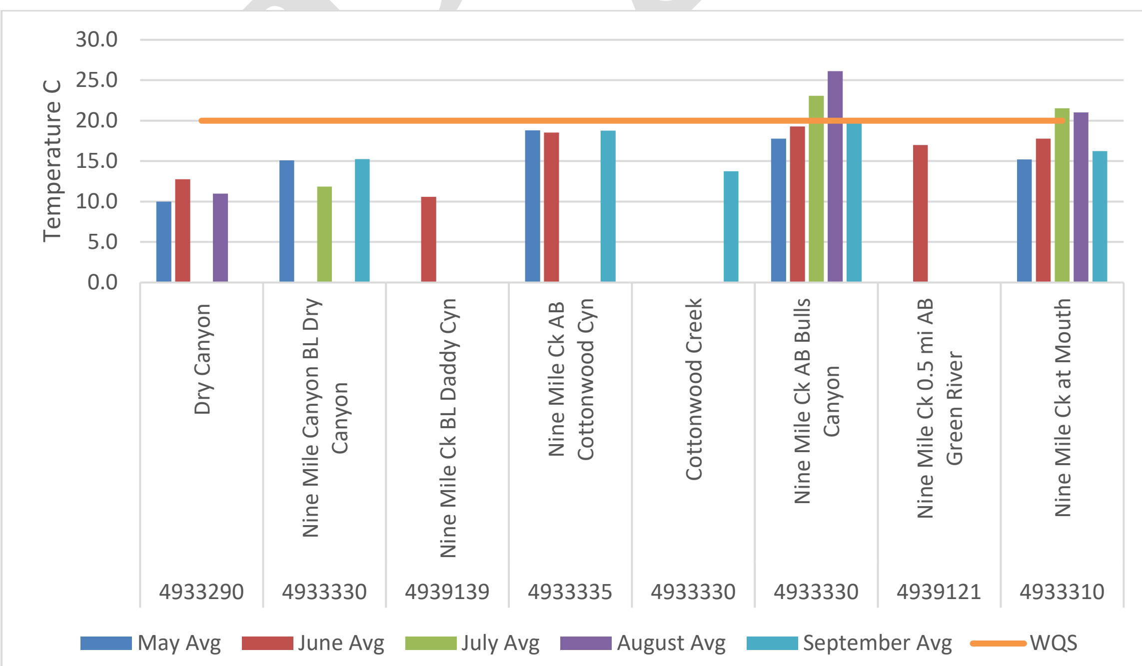
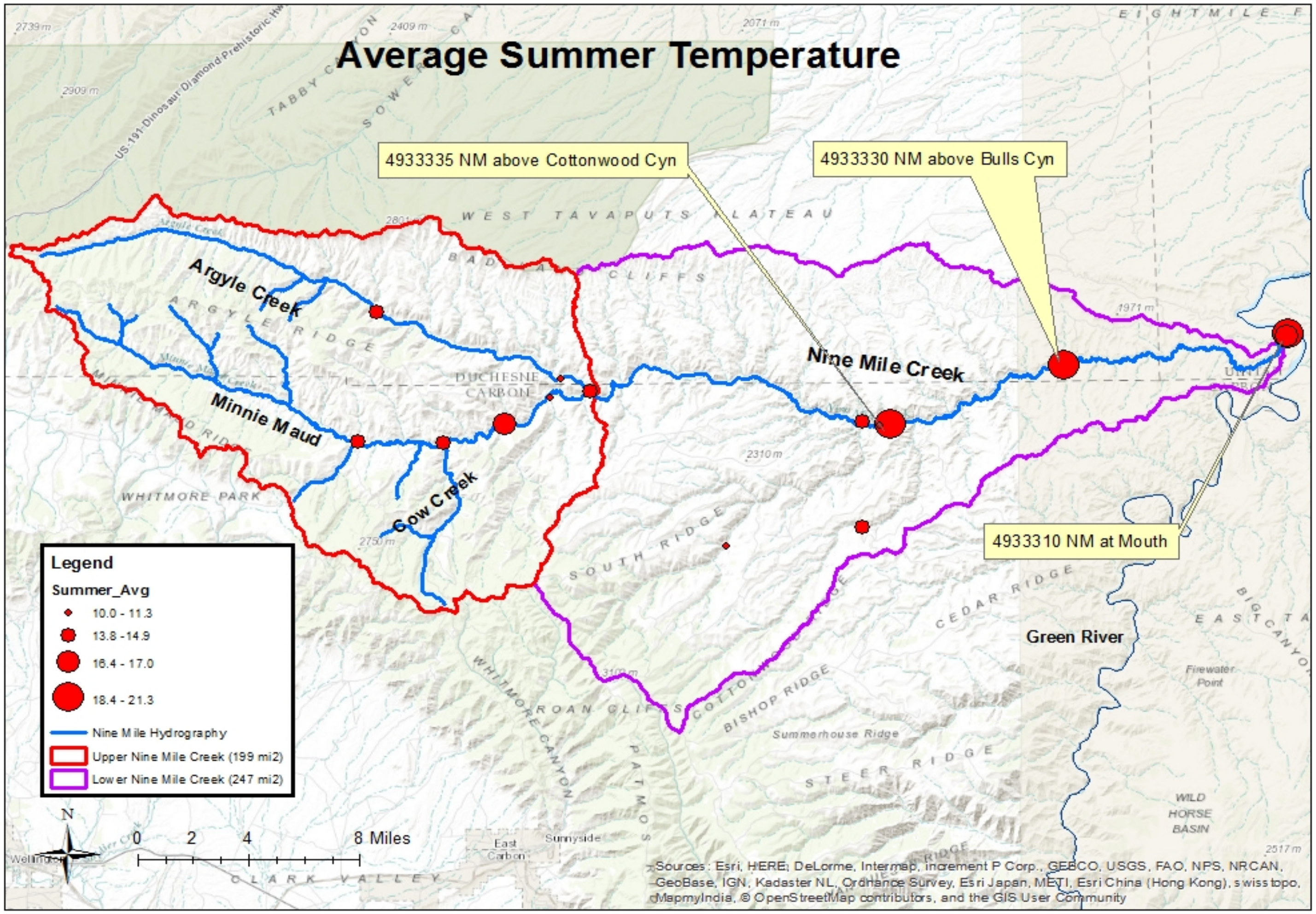


Figure 26. Average Summer Temperature for Nine Mile Creek Watershed.



4.2 High Frequency Temperature Data

UDWQ's current assessment methodology is based on data obtained from discrete water quality measurements (e.g., grab samples). DWQ acknowledges that there are important water quality parameters where instantaneous measurements are insufficient. For instance, discrete samples are difficult to interpret for parameters that exhibit strong diel variation, such as temperature, which can result in either over- or under-protection of water quality, depending on the time of day when the samples were collected.

Recent technological advances continue to make obtaining high-frequency data (i.e., data collected on intervals of 1 minute to 1 hour to several hours) for field parameters more affordable and therefore readily available. In many cases, these data offer the potential of more ecologically meaningful water quality information, particularly temporally variable water quality parameters. They are more likely to reveal patterns of daily, weekly, monthly, or seasonal variation. Similarly, high frequency data can more accurately quantify important water quality summary statistics such as maximum or minimum that is equally important determinants of support for biological communities. In an assessment context, these more accurate characterizations of water quality more closely mirrors the duration and frequency components of water quality standards, which should lead to a reduction of both false positive and false negative impairment decisions.

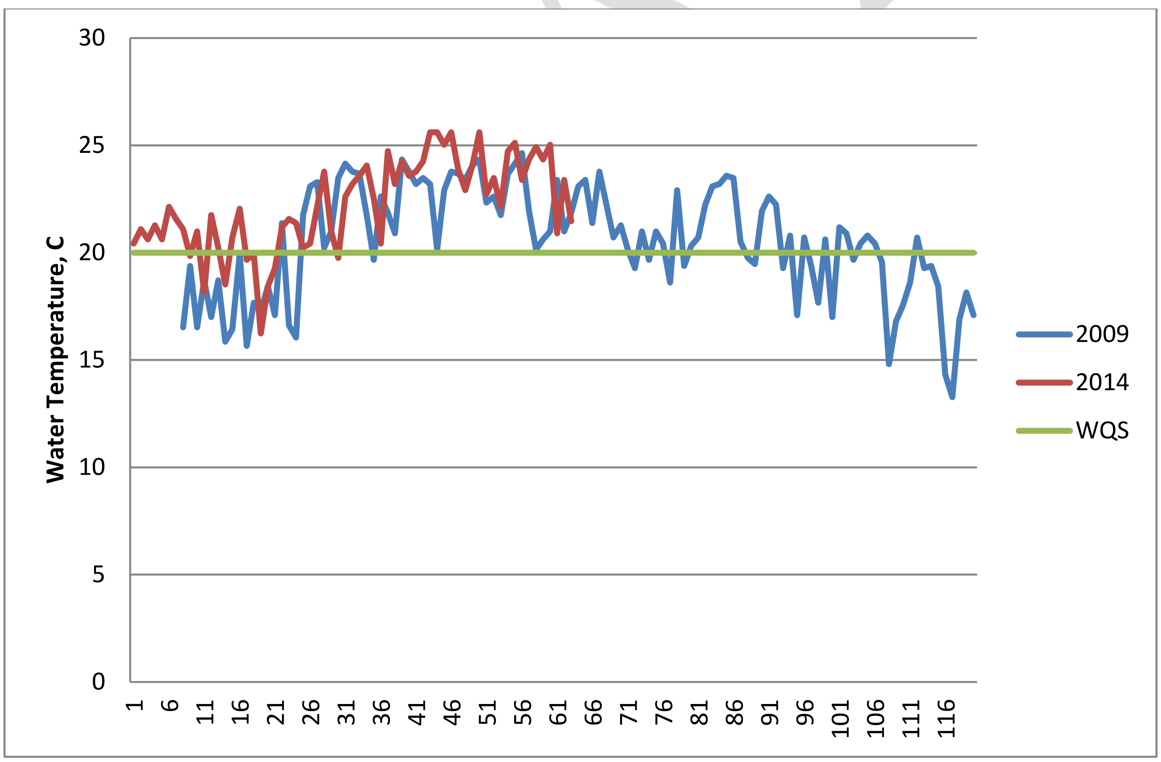
While high frequency data offer numerous potential advantages, there are several unique challenges with the analysis and interpretation of these data. For instance, the large data sets generated by such monitoring can be a challenge to manage, apply Quality Assurance/Quality Control (QA/QC) procedures to, and ultimately to interpret. For example, drift (systematic bias) sometimes occurs during long-term deployment of high frequency data collection instruments and methods are required for identifying and addressing suspect data. Care must also be taken to ensure that summary statistics generated from these data sets quantify conditions that are consistent with the studies or investigations that were originally used to support water quality criteria. Together, the unique characteristics of these data translate into a need for fundamentally different assessment procedures.

Following USDA's protocol (Dunham, Chandler, Rieman, & Martin, 2005) for measuring stream temperature using data loggers, several Onset HOBO loggers were deployed throughout Nine Mile Creek watershed in 2008, 2009, and 2014 (Table 16). These data aid in the determination of the diurnal fluctuations in the creek during the critical season (warmer months) highlighting specific reaches were both impairments and suitable fishery habitat occurs. It is also used to determine the impacts on water quality from both natural (storm events) and manmade (hydrologic modifications) factors stressing the watershed.

Figure 28 shows the spatial distribution of these high frequency temperature monitors. Site selection was not random but reaches were targeted specifically for appropriate refugia for cold water fish. In June 2008, seven high frequency temperature monitoring loggers were deployed throughout the watershed and only 4 were retrieved in September. Table 16 red highlighted cells shows which sites loggers were retrieved. A major summer storm hit this remote watershed causing major streambank erosion and several loggers were lost. Pictures of Minnie Maud taken at both deployment (Figure 29) and retrieval (Figure 30) show the damage such a storm causes. These storms are frequent in the summer. Eleven loggers were deployed in 2009 yet only 10 retrieved. Nine loggers were set out in 2014 and 3 were recovered. These small data loggers were lost for several reasons such as streambank erosion from runoff and cattle.

Loggers deployed in all three survey years recorded water temperature every thirty minutes. High frequency temperature in Argyle Creek exceeded the WQS in every year surveyed with the MWMT ranging from 21.1 (33%) to 24.8 °C (63%). Minnie Maud Creek high frequency temperature in 2008 exceeded the standard 73% of the time with the MWMT of 25.3 °C. In 2009, data from Nine Mile Creek below confluence on Cow Canyon was assessed and only had a 2% exceedance. Unknowingly at the time, this site was immediately downstream of a significant subsurface flow input to the creek that influenced the stream with its cooler temperature. The sample size from this site collected data only to end of July (see Appendix A) so it did not capture the critical month of August. Nine Mile Creek at Cottonwood Glen also had exceedances in both 2009 (63%) and 2014 (86%). This site displayed in Figure 22 has over 15 ft banks though there are old cottonwood trees spanning the creek. This site could serve a "reference" site for further monitoring efforts. Figures 27 and 28 display the high frequency temperature data at both Cottonwood Glen and in Argyle Creek over the survey years and show consistent exceedances of the water quality standard.

Figure 27. High Frequency Temperature Data in Nine Mile Creek at Cottonwood Glen (49333405).*



*X-axis pertains to number of days since deployment.

Table 16. Locations of High Frequency Temperature Loggers Deployed * *in Nine Mile Creek.*

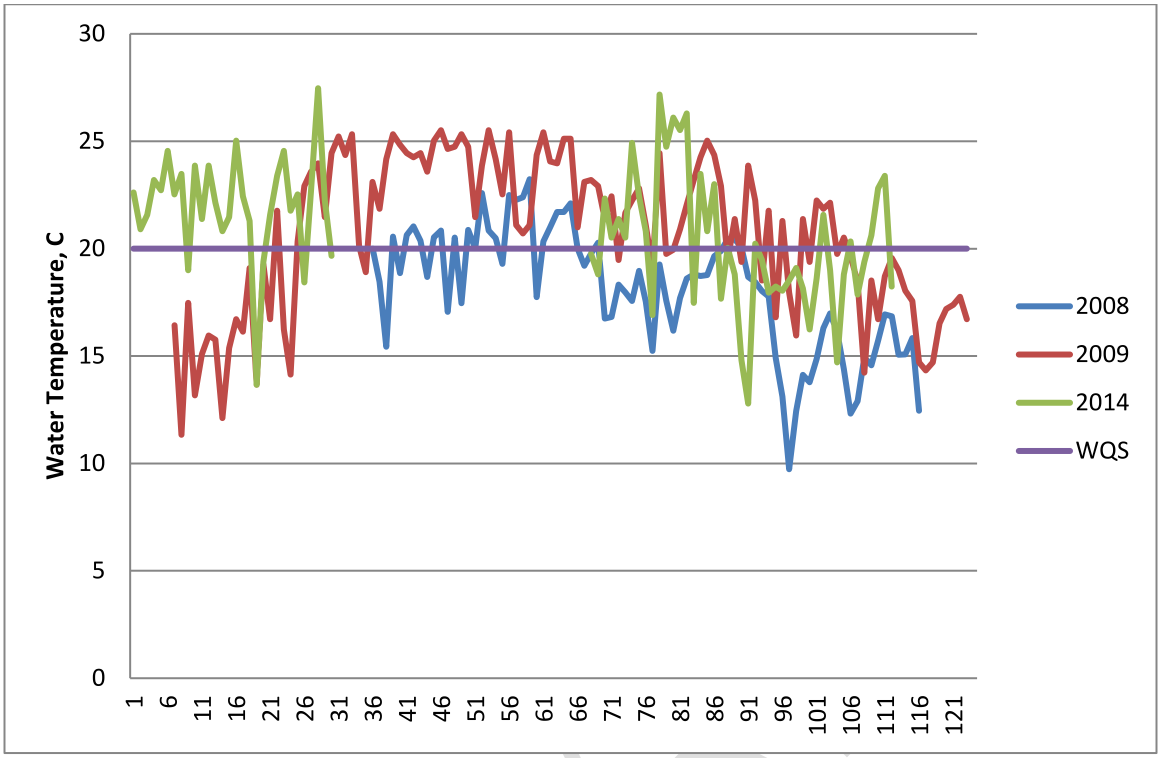
Watershed	MLID	Site Description	2008	2009	2014
Upper Nine Mile	4933610	Argyle Creek Lower	X	X	X
	4933380	Argyle Ck AB Confl Nine Mile Ck		X	X
	4933420	Minnie Maud Ck AB Confl Nine Mile Ck	X	X	X
	NA	Nine Mile above Cow Cyn		X	
	4933405	Nine Mile Ck at Cottonwood Glen		X	X
	NA	Nine Mile Ck at Sheep Cyn			X
Lower Nine Mile	NA	Nine Mile Ck above Harmon Cyn	X	X	X
	NA	Nine Mile Ck at Prickly Pear Cyn	X	X	X
	4933290	Dry Canyon	X	X	
	4933335	Nine Mile at Cottonwoood Cyn		X	X
	4933310	Cottonwood Creek			
	NA	Nine Mile Ck AB North Franks Cyn	X	X	X
	4933310	Nine Mile Ck at Mouth	X	X	

*Red highlighted cells indicate monitoring locations were loggers were retrieved.

Table 17. Summary of High Frequency Temperature Data in Upper Nine Mile Watershed.

MLID	Site	Year	Sample Size	7-day Avg	7-day Max	60-day Avg	Date of Max	% Exceedance
4933610	Argyle Ck Lower	2008	81	16.0	21.1	14.9	7/26/2008	33%
		2009	118	16.6	24.8	15.3	7/13/2009	58%
		2014	75	20.9	24.4	21.3	6/25/2014	63%
4933380	Argyle Ck AB Confl Nine Mile Ck	2009	117	17.3	23.0	16.2	6/24/2009	47%
49333420	Minnie Maud Ck AB Confl Nine Mile Ck	2009	118	17.8	25.3	16.0	6/28/2009	73%
NA	Nine Mile Ck AB Cow Cyn	2009	63	14.1	18.1	13.2	6/24/2009	2%
49333405	Nine Mile Ck at Cottonwood Glen	2009	113	18.3	23.4	16.9	7/23/2009	63%
		2014	63	20.6	24.7	18.4	7/11/2014	86%

Figure 28. High Frequency Temperature Data in Argyle Creek (4933610).*



*X-axis pertains to number of days since deployment.

Figure 29. High Frequency Temperature Loggers Deployed Throughout the Watershed.

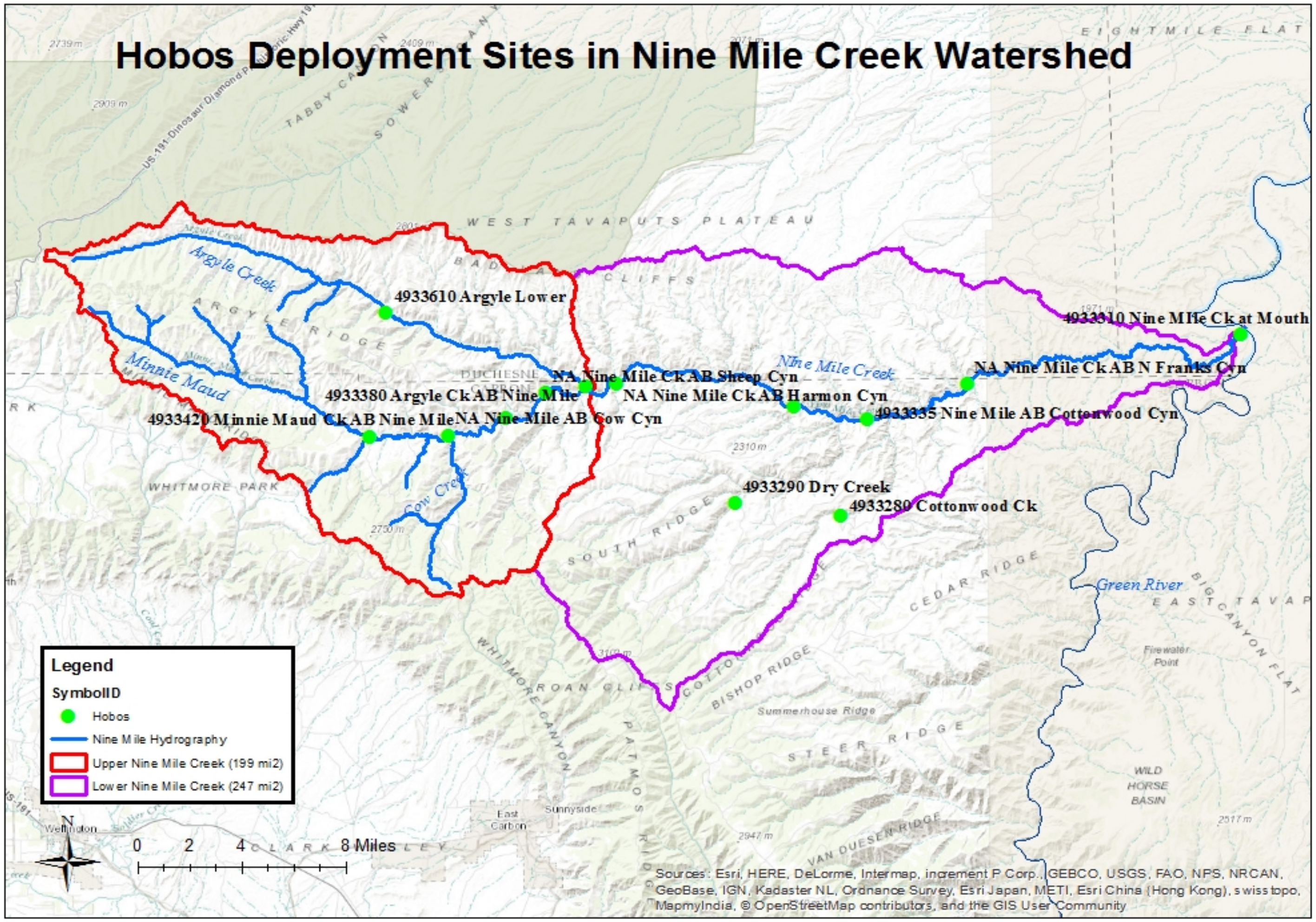


Figure 30. Deploying loggers in Minnie Maud Creek in 2008.

Figure 31. Retrieving loggers in Minnie Maud Creek in 2008 after storm.

4.2 Flow Data

The hydrology of Nine Mile Creek drainage is dominated both by precipitation events and subsurface recharge. Though historical records note that the creek is perennial, numerous hydrologic modifications leave the river dewatered especially during summer months thus the flow is considered to be inconsistent.

UDWQ and BLM have measured instantaneous flow periodically throughout the watershed from 1977 to 2014. There are 2 monitoring sites in the Lower Nine Mile Creek watershed that have 17 flow measurements recorded but most sites in the upper watershed have a small sample size of 3 (Table 18). Flow measurements range from less than 1 to 9 cfs.

In order to estimate flow for the purposes of this TMDL, USGS StreamStats was used. This model delineates a drainage area using online map application and comparing it to similar drainage areas with gaging stations. It provides estimates of various flow statistics for a selected site using regression equations. Nine Mile Creek has no recent flow gaging data so StreamStats used another algorithm specific to watersheds with no gaging sites.

The model generates Peak-Flow, Flow Duration, and General Flow statistics using the entire period of record. The 2-year peak flow is estimated to be 479 cfs. Figure 32 depicts that annual pattern by month for Nine Mile Creek below confluence of Argyle Creek (lowest point in Upper Nine Mile Creek watershed). Nine Mile Creek peaks in May with an estimated flow of 71cfs (50%) and June which is associated with snow melt and spring runoff (Table 19). Estimated flows are fairly stable during the fall and winter with an average of 15.1 cfs. These consistent flows suggest that during fall and winter, flow is dominated by recharge.

Table 18. Instantaneous Flow (cfs) Measurements in Nine Mile Creek Watershed.

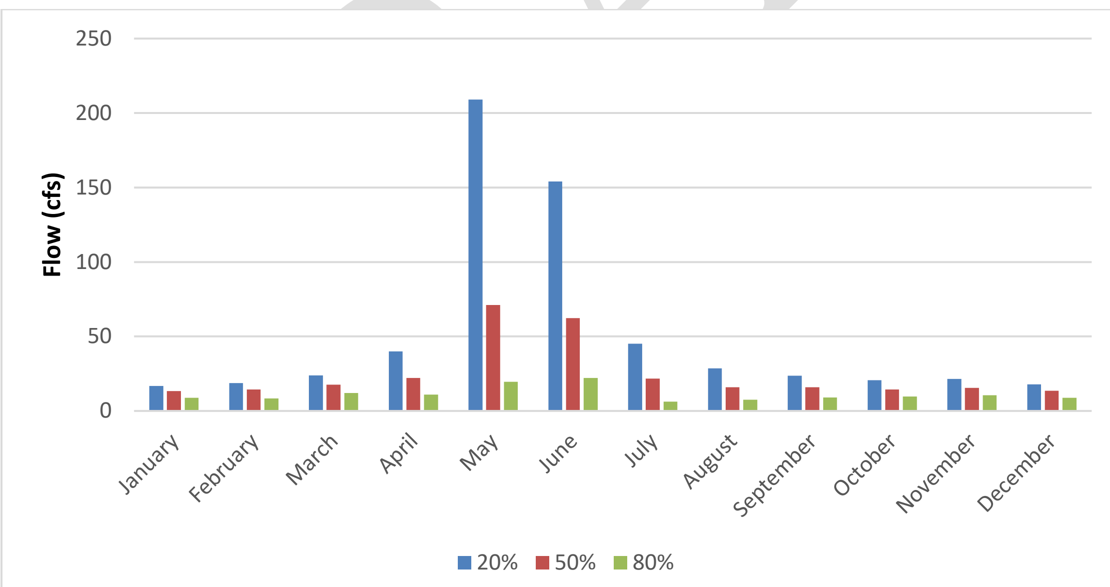
Watershed	MLID	Site Description	Sample Size	Date Range	Minimum	Average	Maximum
Upper Nine Mile	4933610	Argyle Creek Lower	3	2009 - 2014	0.5	2.0	4.4
	4933380	Argyle Ck AB Confl Nine Mile Ck	3	2009 - 2014	2.3	5.3	9.0
	4933420	Minnie Maud Ck AB Confl Nine Mile Ck	3	2009 - 2014	0.7	1.2	1.8
	NA	Nine Mile Ck AB Cow Cyn	1	2009	2.1	2.1	2.1
	NA	Nine Mile Ck AB Sheep Cyn	1	2014	1.7	1.7	1.7
	4933405	Nine Mile Ck at Cottonwood Glen	2	2014	1.3	1.8	2.3
Lower Nine Mile	4933290	Dry Canyon	2	1992 - 1998	0.5	1.0	1.5
	4933288	Nine Mile Canyon BL Dry Canyon	8	2006 - 2009	5.0	18.4	25.0
	4933335	Nine Mile Ck AB Cottonwood Cyn	1	2007	16.7	16.7	16.7
	4933280	Cottonwood Creek	6	1991 - 2008	0.01	2.6	15.0
	4933330	Nine Mile Ck AB Bulls Canyon	17	1992- 2005	0.0	53.5	280.0
	4933310	Nine Mile Ck at Mouth	17	1977 - 1995	0.01	50.7	600.0

Table 19. Average Monthly Flow (cfs) Data at Nine Mile Creek Below Confluence of Argyle Creek.*

Month	20%	50%	80%
January	16.7	13.4	8.79
February	18.7	14.4	8.44
March	23.8	17.6	12
April	39.9	22.2	11
May	209	71.1	19.6
June	154	62.3	22.2
July	45.1	21.7	6.26
August	28.6	15.9	7.47
September	23.7	15.9	8.96
October	20.6	14.4	9.76
November	21.4	15.5	10.5
December	17.8	13.6	8.76
Total (cfs)	**619.3**	**298.0**	**133.7**
Total (ac-ft/yr)	448,621	215,871	96,881

*Based on USGS StreamStats Model.

Figure 32. Average Monthly Flow (cfs) Data at Nine Mile Creek Below Confluence of Argyle Creek.*



*Based on USGS StreamStats Model.

Figure 33. Measuring Instantaneous Stream Flow in Nine Mile Creek.

4.3 Fishery Data

Like many of Utah's waterbody use designations, the designation of Nine Mile Creek to support aquatic life use (ALU) Category 3A is not well understood. It is difficult to ascertain whether cold-water sport fish were an existing use in Nine Mile Creek during the passage of the CWA. Nonetheless, there are several compelling lines of evidence that provide a reasonable potential for ALU Category 3A to be an existing use or at least the highest attainable use upstream from the confluence of the two main headwater tributaries.

Currently, cold-water habitat conditions in Nine Mile Creek and tributaries are not adequate to support all of the expected cold water aquatic life. This degradation in freshwater habitat conditions has contributed to a decline in the populations of trout from historical levels. Anthropogenic activities, such as water development projects, agriculture, energy developments, and introduction of nonnative species, have altered the demographics of Colorado River Cutthroat Trout populations (Utah Division of Wildlife Resources, 1997). Conservation Agreements preserving and enhancing Colorado River cutthroat trout (CRCT) were finalized in the 1990's by several signatories including UDWR, USFWS, USFS, BLM, Bureau of Reclamation, and the Utah Reclamation Mitigation and Conservation Commission. These agreements have branched out to incorporate both Colorado and Wyoming forming the Tri-State Agreement. Conservation objectives focus on the genetic purity of CRCT, identifying populations and suitable introduction locations. Monitoring, nonnative fish control and habitat enhancement became later goals.

The UT Division of Wildlife Resources (UDWR) relies on a general elevation rule of thumb of 4500' elevation and above to determine whether waterbodies potentially maintain cold-water habitat suitable for native trout reintroduction. That elevation is located near the confluence of Argyle Creek in the Nine Mile watershed. Through that determination, UDWR has conducted initial explorations into the suitability of reintroducing the native *Oncorhynchus clarki pleuriticus* (Colorado River cutthroat trout--CRCT) into the Nine Mile Creek watershed, specifically the Argyle Creek tributary. Although, not directly specified, DWR's focus on Argyle Creek for reintroduction rather than Upper Nine Mile/Minnie Maud Creek (UN/MM) is due to better existing habitat. The UN/MM section is nearly devoid of instream and riparian vegetation that is expected in headwaters of this ecoregion. The CRCT is likely the most sensitive aquatic life for this unit and therefore a biological goal for this TMDL. According to UDWR, "Argyle Creek, historically, contains flows and habitat suitable for CRCT introduction" (Colorado River Cutthroat Trout Conservation and Management in the Southeastern Region During, 2003). An earlier report from the 1960s verified CRCT populations in Argyle Creek. However, recent surveys (2007, UDWR; 2013, DWQ) could not document the presence of CRCT, only *Rhinichthys osculus* (Speckled dace) in both tributaries. Additional recent surveys have found fish life throughout the Nine Mile watershed below the confluence of Argyle Creek such as the native *Rhinichthys osculus* (Speckled dace) and the state-sensitive native species *Catostomus discobolus* (Bluehead sucker). Both populations are patchily distributed throughout the watershed, but the varying size classes observed indicate the populations are stable. *C. discobolus*, part of a "Three Species" conservation and management plan (Utah Division of Wildlife Resources, 2006), prefers cool water temperatures rather than traditionally defined "cold" or "warm" water fish. However, depending on the species range, it has been found in streams reaching 28^{o}C. Nonetheless, an overall cooler Nine Mile Creek could benefit this species as improved natural water temperature has been identified as a key management strategy (Ptacek, Rees, & Miller, 2005). Near the confluence with the Green River, non-natives have been found such as *Pimephales promelas* (Fathead minnow), *Notropis stramineus* (Sand shiner), *Cyprinella lutrensis* (Red shiner), *Lepomis cyanellus* (Green sunfish), and *Ameiurus melas* (Black bullhead).

4.4 Benthic Invertebrates Data

Biological assessments are a direct measure of the aquatic life use. This evaluation focuses on the benthic macroinvertebrate community in rivers and streams: an aquatic life group that is sensitive to human-caused stressors, easy to measure, and exist locally for an extended period of time (up to 3-4 years). Therefore, assessing the composition of this aquatic life group provides a water quality analysis that integrates multiple stressors (with and without WQ standards) through a length of time. DWQ subscribes to a River Invertebrate Prediction and Classification System (RIVPACS) modeling approach which provides site-specific comparisons of the Observed (O) species assemblage to the predicted Expected (E) assemblage based on region-wide, least-disturbed river and stream locations. A perfect score of 1 indicates that there is no difference between a tested location to least-disturbed locations. A significant departure from 1, which incorporates known error and year-year variability at least-disturbed locations, indicates that the location is not meeting the expected macroinvertebrate community assemblage and thus not meeting the aquatic life use.

Benthic macroinvertebrate (BMI) collections within these tributaries have been limited to a few sites in Argyle Creek and one location on upper Nine Mile. Samples collected within upper Nine Mile Creek reflect "fair" to "good" conditions (Table 20). Therefore, Nine Mile Creek is meeting the biological beneficial use as measured by BMI. Nonetheless, a more in-depth evaluation of the BMI assemblage can help understand the potential stressors for samples that are scoring less than "good". The BMI in Argyle Creek is more diverse and reflects more of a cold-water aquatic community than the assemblage observed in upper Nine Mile (Appendix B). Within Argyle Creek, among sensitive Orders, the Plecoptera (stoneflies) are best represented with four different genera including *Pteronarcella badia* (Least salmonfly). *P. badia* was absent in upper Nine Mile and only two Plecoptera genera were collected. The BMI assemblage from these samples reflect similar conclusions from the high-frequency temperature data: the Minnie Maud section of Nine Mile Creek is clearly warmer than Argyle.

Table 20. Locations and Assessment Scores for Benthic Macroinvertebrate Samples Collected in Upper Nine Mile Creek.

MLID	Site Description	Latitude	Longitude	Date	O/E	Condition
4933345	Nine-Mile Creek below campground	39.775556	-110.432222	10/3/2007	0.758	FAIR
G304O2	Argyle Creek-BLM	39.824036	-110.417917	9/21/2011	1.06	GOOD
4933345	Nine-Mile Creek below campground	39.775556	-110.432222	7/10/2013	0.975	GOOD
4933610	ARGYLE CREEK LOWER	38.847740	-110.497660	7/11/2013	0.898	GOOD
4939135	Argyle Creek (UT09ST-435)	39.810340	-110.372740	6/17/2014	0.928	GOOD

5.0 Source Assessment

5.1 Point Sources

There are no permitted point source dischargers in the Nine Mile Creek watershed. All pollutant loading is attributed to nonpoint and natural sources. Oil and gas developments must adhere to the BLM's best management practices (BMPs) standards and specifications to prevent runoff from the pads into surface waters and must obtain a permit from Utah Division of Oil Gas and Mining (UDOGM). The industry is required to collect and transport produced wastewater to approved disposal facilities. There is some evidence of illicit discharges of produced water occurring in the past throughout the Uintah Basin because regulatory fines have been levied.

Though natural gas well pads are prevalent in the watershed, they are not considered a major source based on observations of BMPs in place during site visits to the Nine Mile Creek watershed. Figure 37 shows that placement of natural gas wells are mainly located in the Lower Nine Mile Creek watershed. Though the demand for this industry has slowed, there are several hundred more leases that have not been developed yet. BLM estimates there are 1 trillion cubic feet of natural gas reserves in the watershed. Rich deposits of gas deep within the Tavaputs Plateau have increased truck traffic since 2002. The county maintained canyon road was not built to handle such heavy truck traffic. Since 2014, 36 miles of Nine Mile Canyon Road were improved to not only handle the increase traffic but to properly direct runoff off the road and back to the creek. This improvement totaled 36 million dollars and was paid for by Carbon County, Duchesne County, and Bill Barrett Corporation (United States Bureau of Land Management, 2016).

There are localized impacts to water quality by energy exploration and mining activities. These include road and pad infrastructure associated with sedimentation during runoff or spills, increase road traffic, and water diversions for withdrawal (Figures 34 and 35). Energy Industry should follow recommended BMPs to reduce runoff and erosion leading to an increase in riparian vegetation and ultimately to shade. UDWQ does not permit the oil pad footprint themselves but does require a stormwater construction permit for any new roads created leading to the pads. These stormwater permit requirements include BMPs to control runoff and erosion. See Chapter 8 for more recommended BMPs.

Figure 34. Water Withdrawal Staging Area for Energy Development Along Banks of Nine Mile Creek.

Figure 35. Nine Mile Creek Dammed for Water Withdrawal for Energy Development.

5.2 Non-Point Sources

This section summarizes potential and expected sources of excess water temperature in the Nine Mile Creek watershed. Since there are no point sources in the watershed, all thermal reductions will come from nonpoint sources. Both anthropogenic and natural factors can influence water temperature. Human-influenced factors include riparian and channel alterations and flow modifications. Natural factors include climate, riparian vegetation (shade), altitude, and channel morphology.

5.2.1 Agriculture/Grazing

Characteristics such as fertile soils and close proximity to water have led to the conversion of the Nine Mile Creek riparian corridor to other land uses like agriculture fields. Most of the agriculture occurs along the floodplains and riparian areas (Figure 9) and approximately 72% of all water related land use is associated with irrigation (Table 3). Water withdrawals, stream channelization, and removing riparian vegetation can lead to increasing instream temperature.

Given the dry climate condition in this watershed, agriculture is only sustained by using water diverted from both surface and groundwater sources. There are over 1,200 points of diversion (Table 12) in Upper Nine Mile Creek watershed allowing approximately 219 cfs to be diverted for consumptive uses. Water withdrawals from shallow alluvial groundwater sources can have detrimental impacts on riparian vegetation due to loss of water available for uptake. Groundwater withdrawals can deepen the water table causing streams to lose water instead of gain due to the decreased levels of recharge. Lower groundwater levels can also lead to more favorable conditions for exotic, drought tolerant plants.

Figure 36. Intense Storm Washes Out Nine Mile Canyon Road in 2014 (Salt Lake Tribune, 2014).

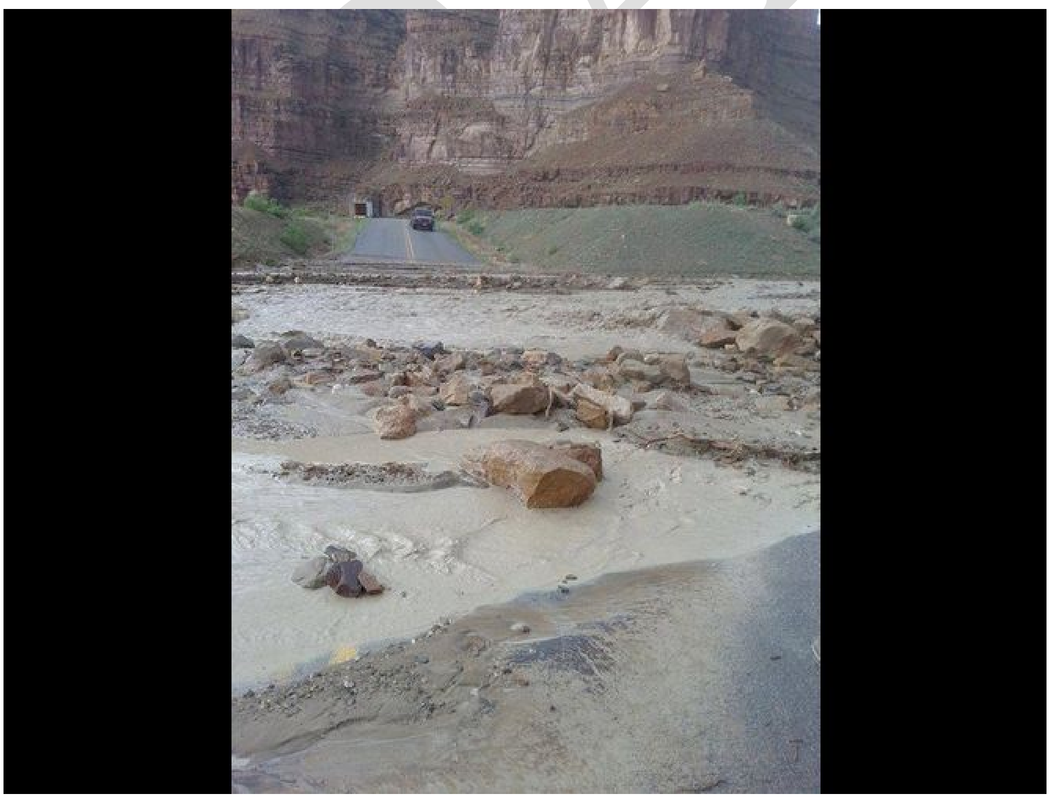
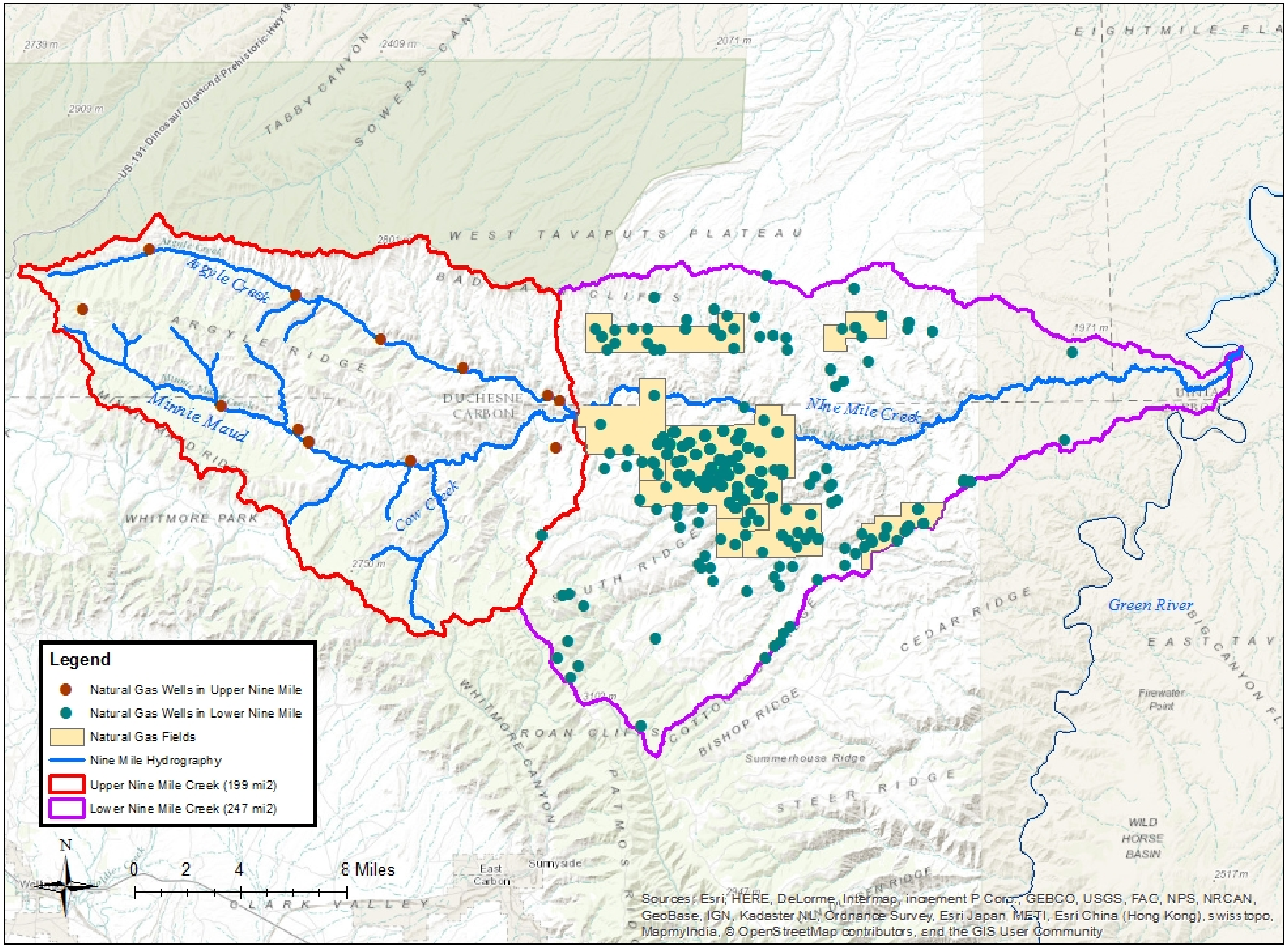


Figure 37. Energy Development in the Nine Mile Creek Watershed.



Stromberg (1998) found that Fremont cottonwood populations have declined while salt cedar has increased due to lowering of the ground water table in Arizona. Water withdrawals are one of the main reasons why perennial streams in the Western US have been transformed into intermittent and ephemeral which cannot maintain a healthy riparian condition (Luckey, Gutentag, Heimes, & Weeks, 1988).

Riparian vegetation has been lost during the floodplains' conversion to agricultural fields. Near stream vegetation provides effective shade, bank stability, floodplain roughness and wildlife habitat. They protect soils along the streambank from eroding more efficiently than most crops because their root systems are deeper and thus hold more soil intact. Machinery used to till agricultural fields compact and alter the soil structure causing lower water infiltration rates and increase runoff to the stream. Open water (little to no shade) has a higher annual water loss from evaporation than riparian trees via evapotranspiration.

Streams are often channelized to more efficiently convey water to nearby agricultural fields either for drainage or irrigation purposes. Channelization often involves alteration such as widening, deepening, and/or straightening of the stream channel. Stream channels that are straightened are often steeper increasing the slope and velocity of flowing water leading to streambank erosion. Deepening the channel increases the water table (Gordon, McMahon, & Finlayson, 1992) and reduces the out of banks flows critical for a healthy riparian corridor. Streams channelization also leads to flashier systems because less water storage available in the channel. These streams still do show limited signs of natural channel processes and will naturally move back to their meandering pattern if left alone.

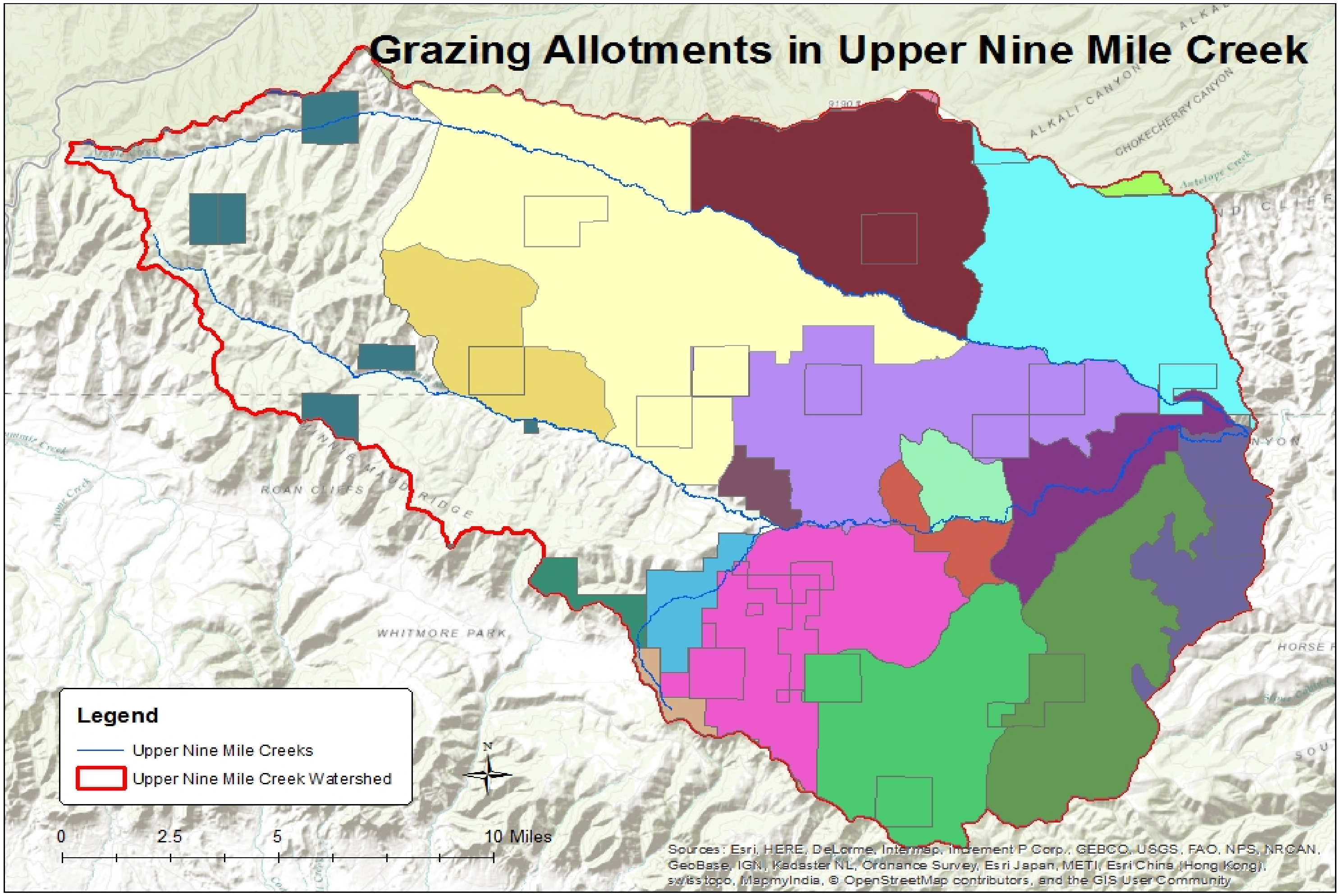
There are 68 grazing allotments in the Nine Mile Creek Watershed managed by three agencies, BLM, USFS, and SITLA. The BLM manages 27 allotments spanning 89,355 ac (139.6 mi^2), SITLA 30 covering 12,998 ac (20.3 mi^2), and USFS 11 spanning 433 ac (0.1 mi^2). The largest allotment is the Argyle Ridge allotment with pastures spread over 19,179 acres (29.9 mi^2) managed BLM and is located in the Argyle Creek subwatershed. Minnie Maud and Upper Argyle Creek are private (39 ac) and do not belong to a grazing allot; however, these lands could be grazed. See Figure 38 for a visual display.

Domestic livestock is attracted to riparian areas like wildlife due to high forage abundance and water availability. Grazing can have both direct and indirect impacts on water temperature. Direct impacts include increasing soil compaction and decreasing infiltration due to trampling causing an increase in erosion. Direct river access by livestock can remove critical riparian vegetation by grazing. Excessive forage removal can lead to a change in plant composition. Ranching is an important aspect of the agricultural economy in Nine Mile Creek Watershed. Proper livestock management can be compatible with a healthy riparian corridor. See Chapter 8 for proposed Implementation Strategies including grazing and irrigation best management practices (BMPs).

5.2.2 Streambank Erosion and Channel Widths

There are several physical parameters that influence in-stream temperature such as slope, sinuosity, channel geometry, substrate, and width/depth ratios. Of these, measuring current and determining appropriate channel width targets is a critical component to understanding excess solar loading. Excess widths are an indication that stream banks are actively eroding. Not only does this process create wider and shallower channel morphology, it is also sending the excess sediment downstream to areas more

Figure 38. Grazing Allotments in the Nine Mile Creek Watershed.



prone to increasing temperature. Sedimentation of streams also contributes to elevated water temperatures. Sediment can fill pools and cause the width-to-depth ratio of a stream to increase, which can facilitate heat exchange (Poole & Berman, 2001). Hagans et al. (1986) reported that sedimentation caused stream temperatures to increase, as dark-colored fine sediment replaced lighter- colored course gravels. The darker sediment stored more solar radiation. Fine sediment may block exchange between surface waters and intragravel flows, also contributing to warming.

Additionally, physically straightened or channelized stream reaches are more prone to heating as there is less water pushed into the hyporheic zone of the floodplain compared to more sinuous stream reaches (Torgersen, Faux, McIntosh, & Poage, 2001) . There are relatively minor areas where channelization has occurred in upper Nine Mile Creek, so it is assumed this phenomenon plays a less important role in changing temperature than other factors discussed above. Figure 39 illustrates the measured bankfull widths in Upper Nine Mile Creek watershed. Section 6.3 provides more details.

5.2.3 Riparian Cover

Effective shade is highly sensitive to human activities and can significantly affect in-stream temperature. Effective shade is controlled by near-stream vegetation and channel width. Shade is more effective at maintaining low temperatures in narrow streams than in wider streams, given the same flow of water at a given point, because shadows cast by trees cover a greater percentage of the stream surface in narrow streams. On smaller streams, shade can effectively screen the water surface from direct rays of the sun. Identifying stream locations that have limited slope and lack riparian shade are critical to effectively reducing the amount of solar radiation that reaches the water surface.

6.0 Technical Approach

6.1 Overview

The majority of U.S. waters not meeting beneficial uses due to elevated in-stream temperature occur in the Pacific Northwest (US EPA Region10) (https://iaspub.epa.gov/waters10/attains_impaired_waters.control?p_cause_group_id=1035). US EPA Region 10 is the only regional office to provide water temperature guidance to the States in their region. This guidance was primarily driven by the many interpretations of various State water temperature standards and the large number of temperature-dependent Endangered Species Act (ESA) listed salmonid stocks in those States (Environmental Protection Agency, 2003) The continental States (ID, OR, WA) of the region adopted “natural conditions” criteria into their water quality standards that establish if a waterbody under natural conditions exceed water temperature standards, then the potential, natural conditions of the waterbody become the applicable standard. As a result, those States have developed surrogate measures such as solar load, effective shade and potential natural vegetation as water temperature targets. This TMDL will take a similar approach in designing and determining loads, targets, and surrogate measures. However, this TMDL will validate these targets to ensure a reasonable expectation of achieving the in-stream water temperature standard of 20 ^{o}C.

Establishing a relationship between in-stream water quality target and source loading is a critical component of TMDL development. Identifying the cause and effect relationship between pollutant loads and the response in water quality concentrations is necessary to evaluate the loading capacity of the receiving waterbody. The loading capacity is the amount of pollutant that can be assimilated by the waterbody while still attaining water quality standards. This section discusses the linkage between solar radiation, potential natural (riparian) vegetation, and water temperature.

6.2 Use Attainability Assessment Method

The first approach was to determine if the 3A aquatic life use (ALU) is the appropriate use class for the Nine Mile Creek watershed assessment unit (AU). If so, is it applicable throughout the AU and where is it clearly applicable. Rieman *et.al* (2007) describe a simple regression model that predicts in-stream temperature throughout a system based on discretely located temperature as the response and several geospatial-based predictor variables. For the Nine Mile Creek model, Rieman's concepts were applied by using similar four predictor variables: stream slope (NHDplus), area upstream (NHDplus), elevation (DEM), and modeled summer air temperature (PRISM). The first run used the 60-day summer average temperature as the response variable. The regression was highly successful and explained >71% of the variability ($p<0.04$). By applying the regression equation to the NHD shape file, it was revealed that the lowest two HUC 12s of Nine Mile Creek were predicted to have average temperatures above 20°C. However, UT DWQ's numeric temperature standards are based on 20°C as the maximum (Figure 44). The regression was then run based on the same predictors except the modeled summer air temperature was substituted with the modeled maximum summer temperature and the response variable was changed to the MWMT measure. This model expectedly predicted less favorably (>56%) because extreme values are notably tougher to predict. Nonetheless, the regression performed quite well despite not including riparian cover in the model which is the one variable that natural resource management can improve. Rutherford (2004) found a strong relationship with the changes in stream temperature maximums to the amount of riparian shade particularly in small streams. He found that increasing riparian shade decreased stream temperature maximums in headwaters. The resulting regression equation was applied to the NHD shapefile in ArcGIS which revealed a predicted MWMT break point of 22.5°C at the confluence of Argyle and Nine Mile Creek (Figure 45). A 2.5°C reduction in temperature appeared as a reasonable reduction of instream temperature by improving riparian canopy cover and narrowing widths. Therefore, the following rationale and implementation considerations were used to justify splitting the Nine Mile Creek AU at the confluence of Argyle and Nine Mile Creeks:

1. Historical accounts of salmonid reproduction are limited to the upper section
2. UDWR considers only the upper section as a potential cold-water fishery; the mainstem is managed for the "Three Species": Bluehead Sucker, Flannelmouth Sucker, and Roundtail Chub.
3. Broad stakeholder support: DWQ has received positive feedback from landowners, environmental groups, and land management agencies for this approach.
4. A 2.5°C reduction is achievable to meet the 20°C endpoint.

The lower portion of the Nine Mile Creek assessment unit will remain in ALU class 3A until a use attainability analysis and site specific temperature standard is conducted for that portion of the AU. The remaining discussion of this TMDL will focus on the upper portion of the Nine Mile Creek AU identified throughout the document.

Figure 39. Spatial Illustration of Current Bankfull Widths in Upper Nine Mile Creek Watershed.

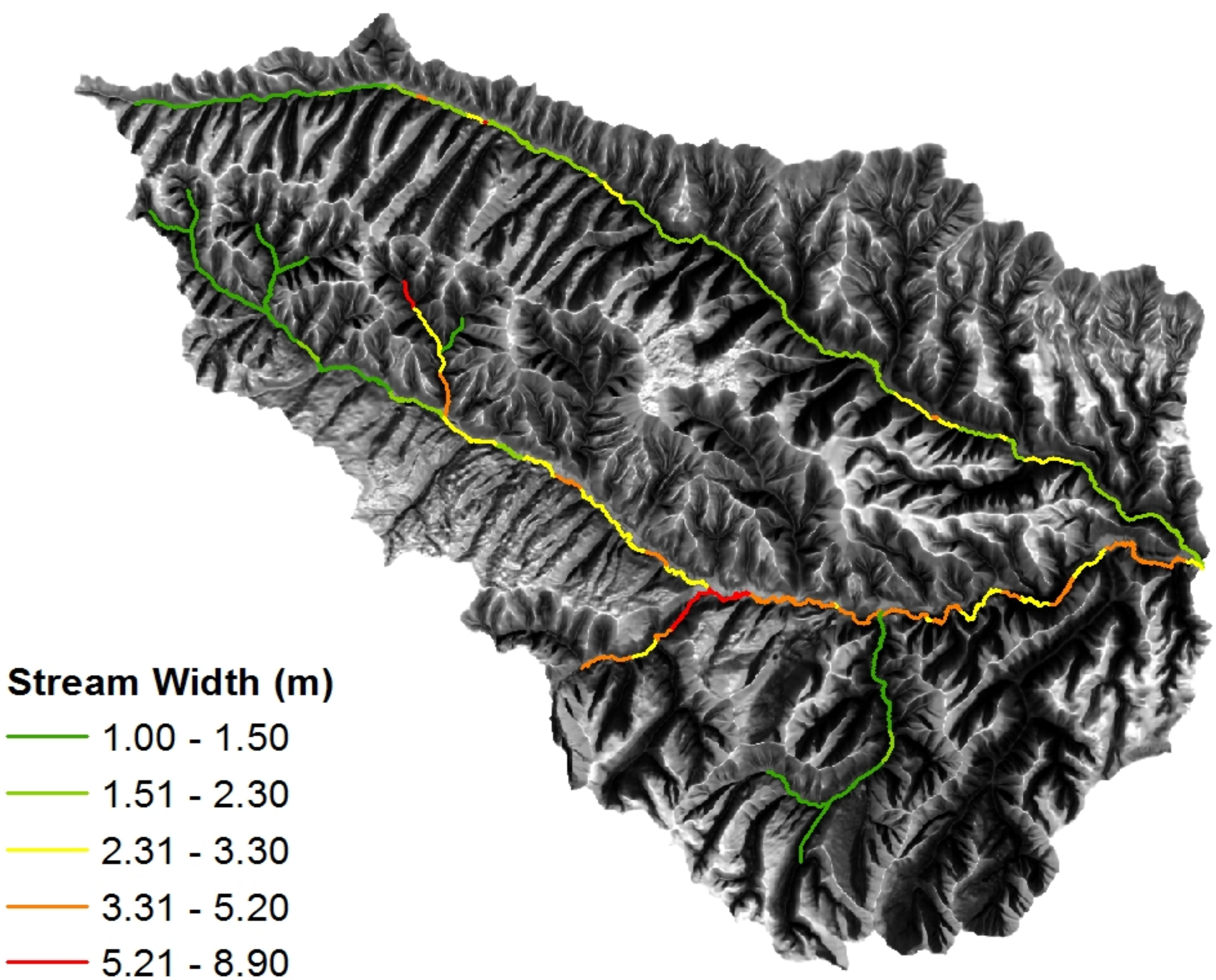


Figure 40. Example of Collecting Stream Widths (yellow hash mark) in Google Earth Pro. This example has an estimated 2.05m width.

Figure 41. Channel Width Targets Identified for Various Reaches of Upper Nine Mile Creek.

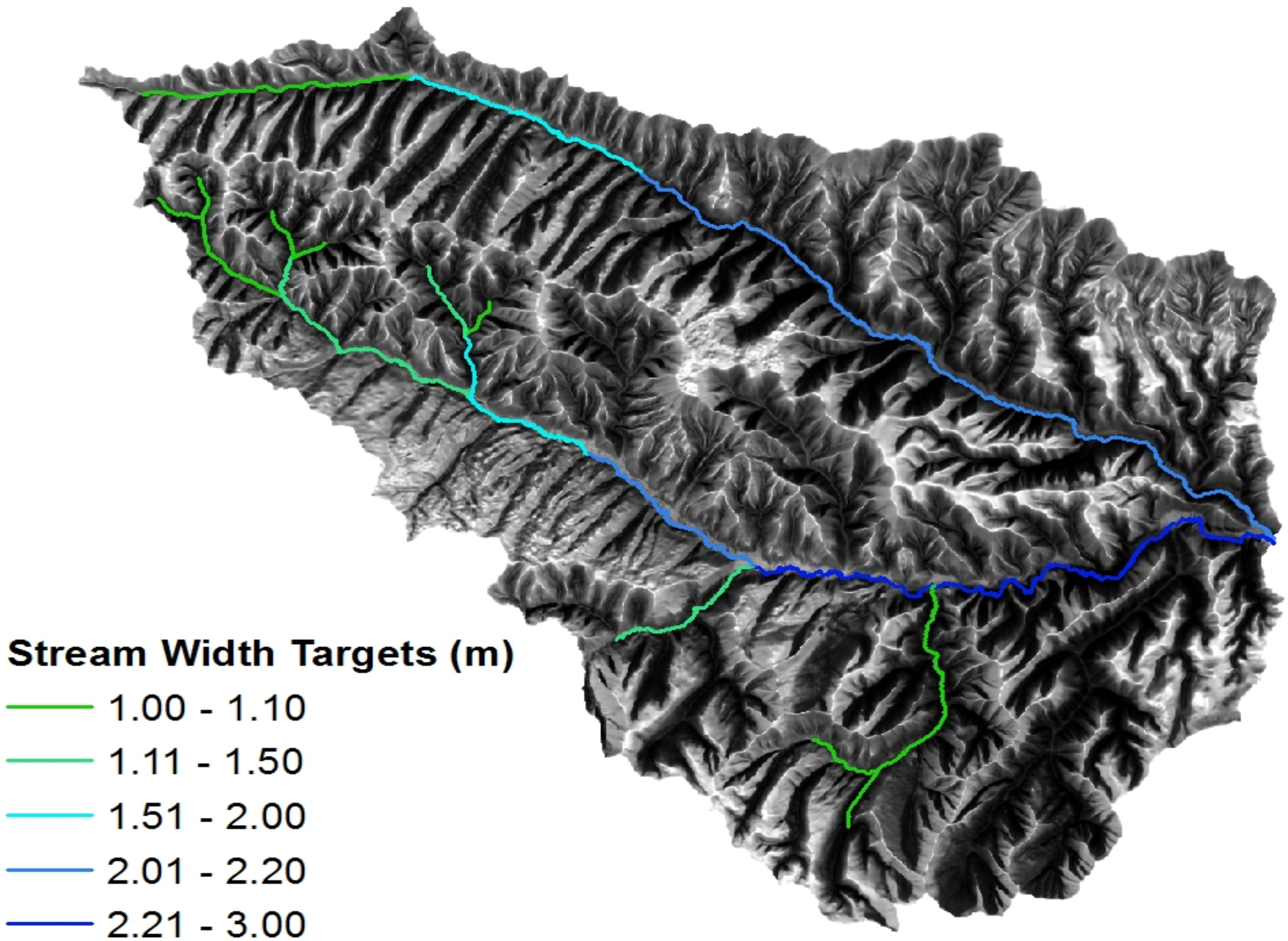


Figure 42. Riparian Shade Targets (Percent) for Upper Nine Mile Creek.

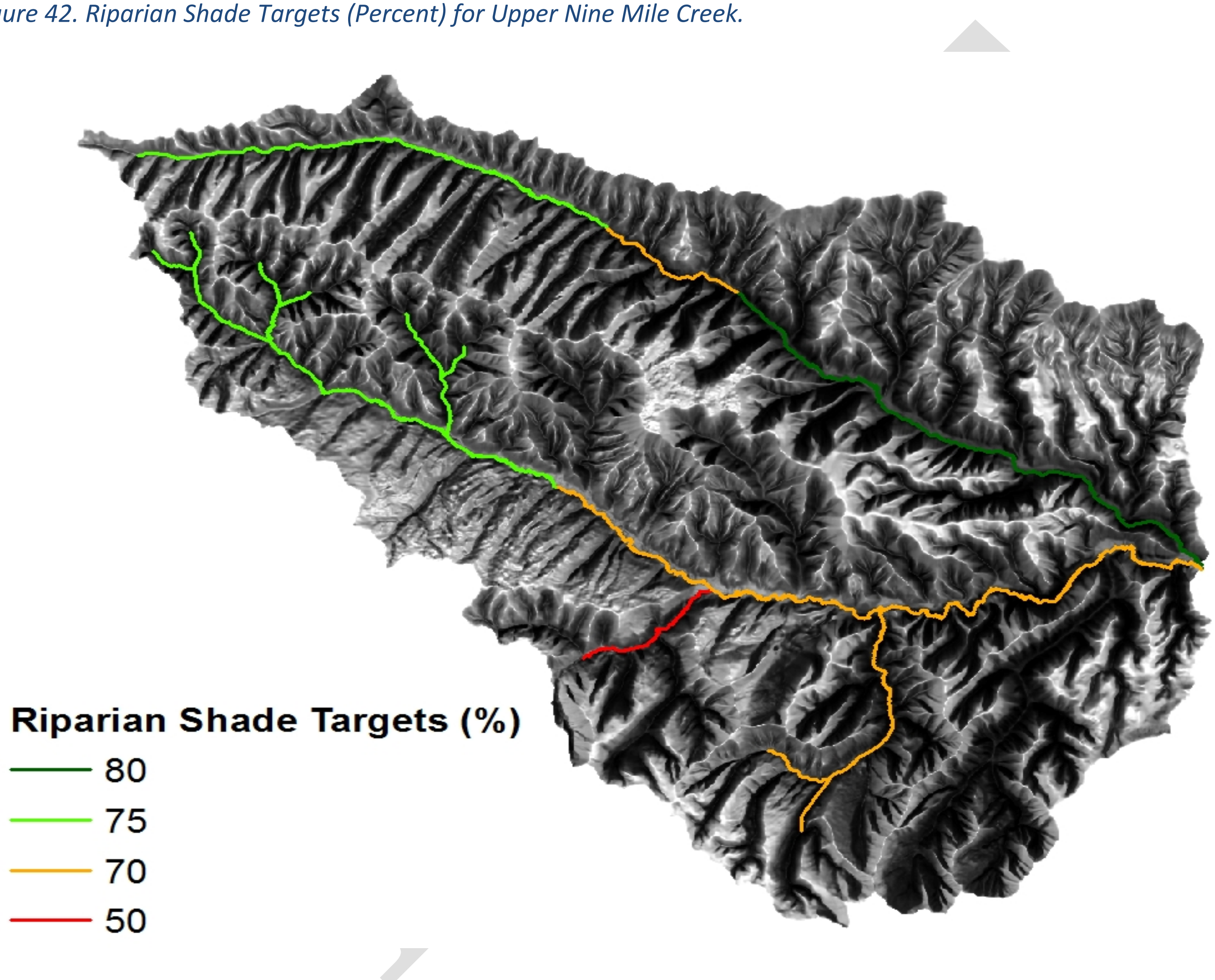


Figure 43. Current Riparian Shade Difference (Percent) from Target in Upper Nine Mile Creek.

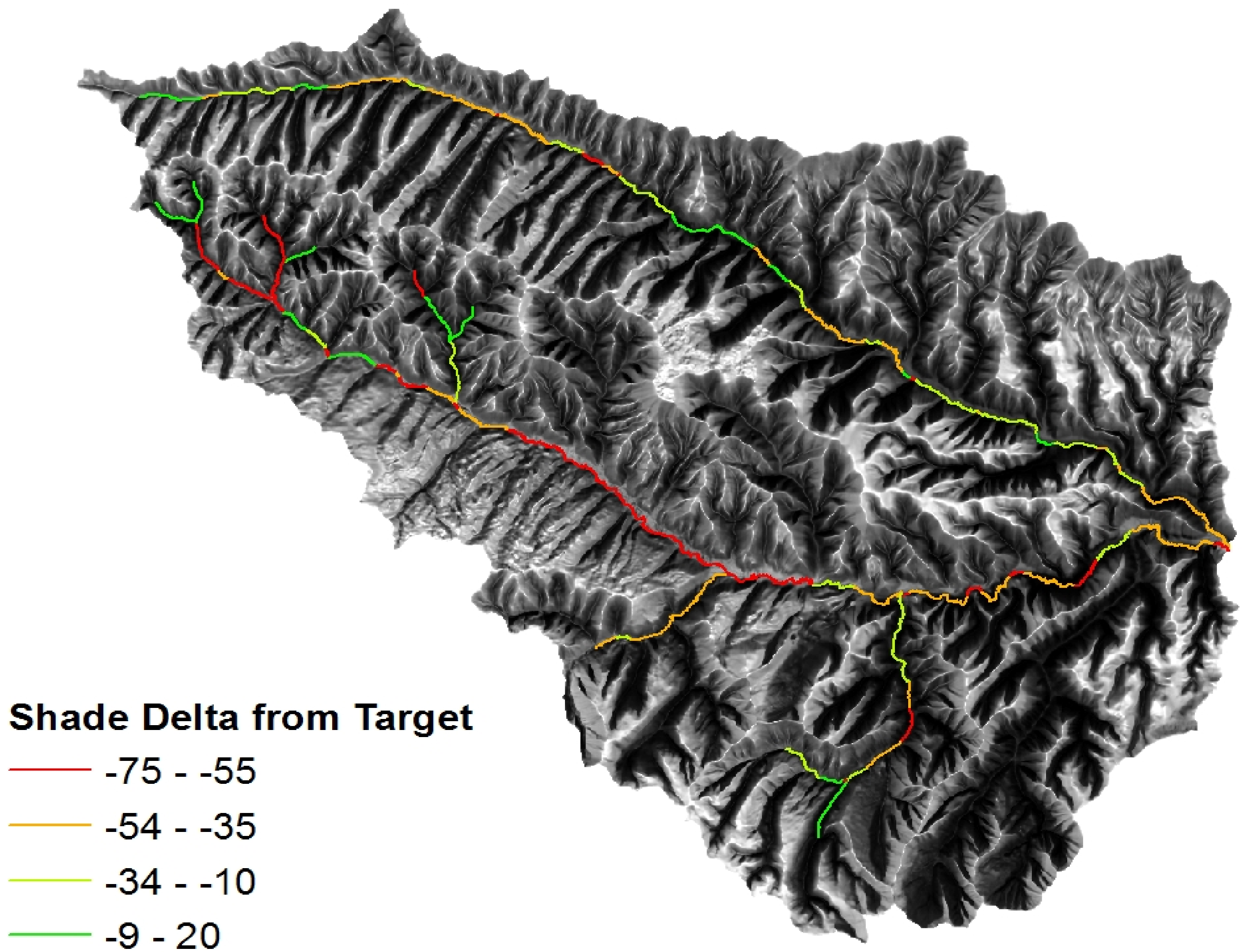


Figure 44. Spatial Representation of Predicted Mean Summer Stream Temperature in Nine Mile Creek Watershed.

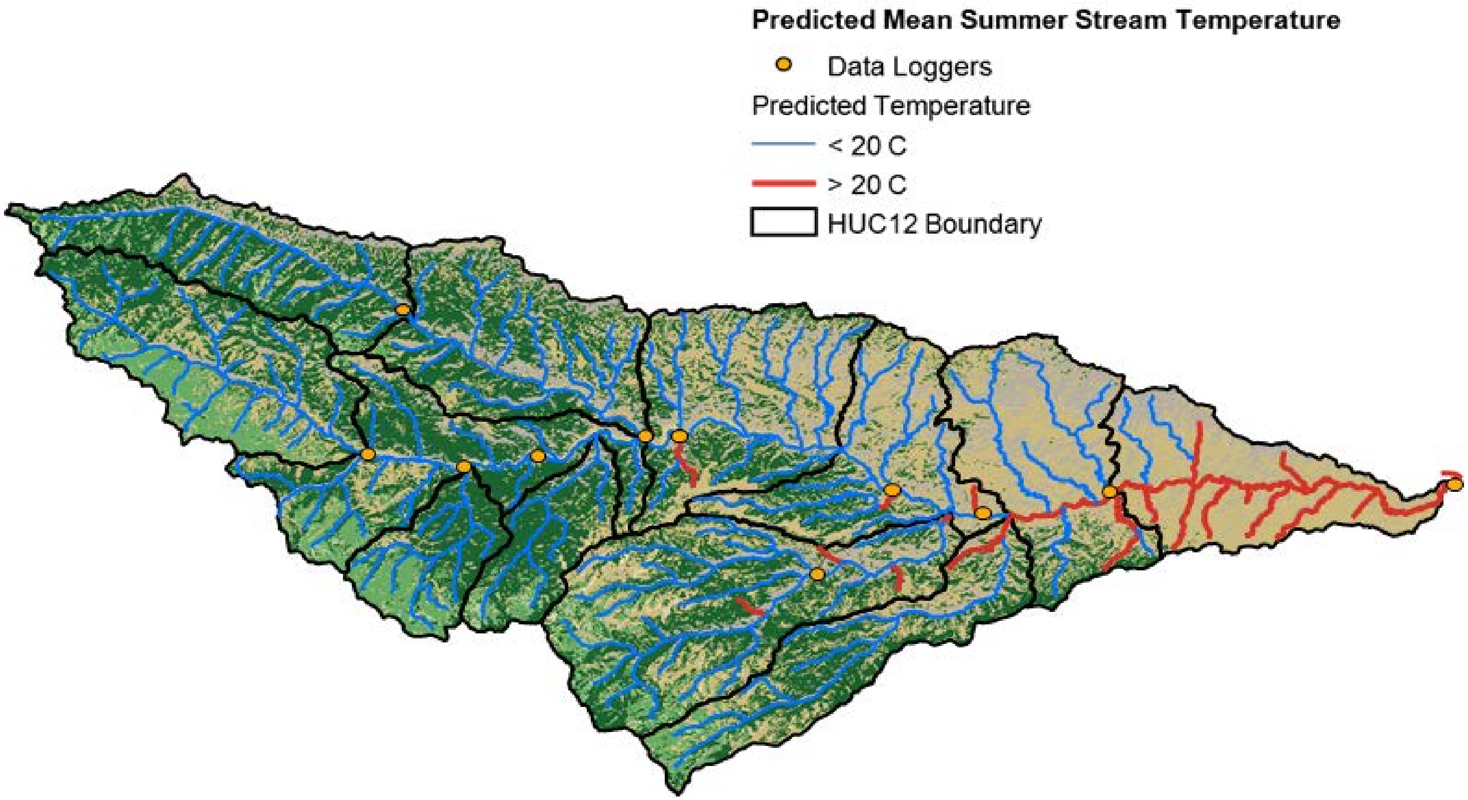
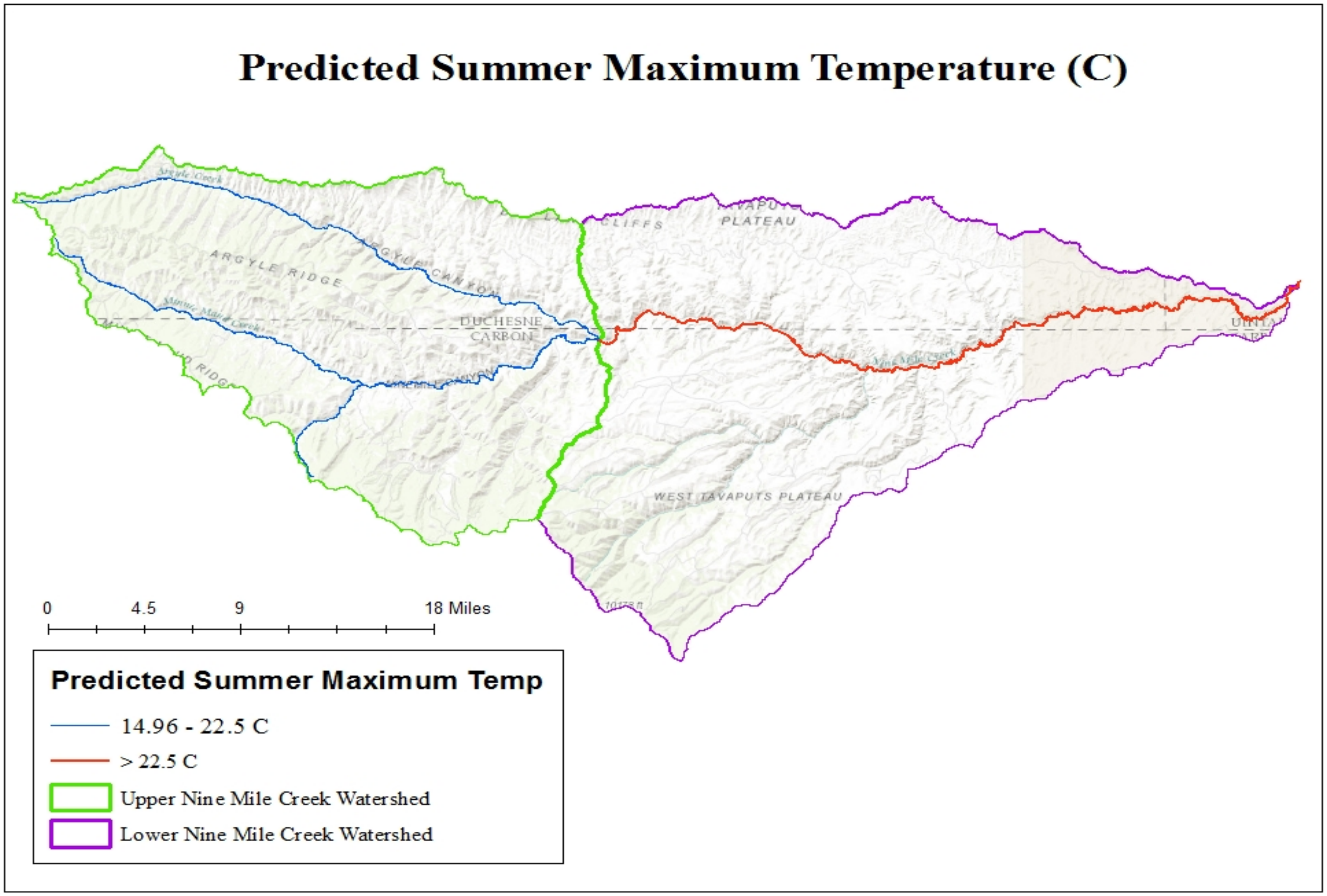


Figure 45. Spatial Representation of Predicted Maximum Summer Stream Temperature in Nine Mile Creek.



6.3 Solar Radiation, Shade, Channel Widths, and Water Temperature

Decreased effective shade levels result loss of expected riparian vegetation. This leads to increased incident solar radiation on the water surface and therefore increased energy loading. Wider stream channels also increase the stream surface area exposed to sunlight and heat transfer. Riparian area and channel morphology disturbances are attributed to historical and perhaps, current landuse practices. These practices have resulted in a lack of riparian vegetation and widening, unstable streambanks. In the West, the legacy of some of these practices remains for decades unless intercepted by restoration actions. These nonpoint sources of pollution primarily affect temperature through increased solar radiation

Riparian vegetation, stream morphology, hydrology, climate, geographic location and aspect influence stream temperature. Although climate, geographic location, and aspect are outside human control, the condition of the riparian area can be affected by land use activities. Specifically, the elevated summertime stream temperatures attributable to anthropogenic causes in Nine Mile watershed result from the following conditions:

1. Channel widening (increased width to depth ratio) increases the stream surface area exposed to incident solar radiation
2. Riparian vegetation disturbances reduces stream surface shading, riparian vegetation height and density
3. Reduce summertime base flows that result from instream withdrawals

Analysis presented in this TMDL will demonstrate that defined loading capacities will ensure attainment of Utah's temperature WQS. Specifically, the relationship between shade, solar radiance, and water quality attainment will be demonstrated. Riparian canopy cover increases will provide necessary shading, as well as encourage bank building processes in severe hydrologic events.

Bankfull channel widths were measured for each COMID using Google Earth Pro Version 7.1.2.2041 and validated at a few locations where physical measurements were collected in the field. Imagery dates were 10/15/2013 in the upper six HUC-12s of the watershed and 6/18/2015 for the lower HUCs. For each COMID, a minimum of three measures were performed and until average conditions were observed and quantified at a tenth of a meter (Figure 39). Priority was given to measures that occurred where the stream segment was not affected by sharp bends and confluences (Figure 40). During this analysis geomorphic patterns emerged that helped classify channel width targets. Channel width targets were identified for each of these areas based on reference conditions within each area (Figure 41).

The riparian shade was estimated similarly to the stream channel widths using Google Earth Pro. Riparian cover that could provide effective shade was estimated as percent cover for each ComID in the upper Nine Mile Creek unit. Similar to the bankfull width targets, riparian targets based on reference conditions within the area were identified for each geomorphic region of the subwatersheds (Figure 42). For example, Argyle Creek has three regions: lower, canyon mid-section, and upper. Comparing the existing conditions to target conditions at the ComID scale helps visualize where priority restoration implementation should occur (Figure 43).

6.4 Solar Radiation Calculation Method

Solar radiation was estimated by using the solar radiation tool in ArcGIS 10.3.1. This tool allows a user to define a specified time-series to evaluate solar radiation across a specified geographic area. Seasonal effective riparian shade was considered to begin on May 1 according to "leaf out" estimates (https://www.usanpn.org/data/spring). The effective riparian shade season has limited influence by the end of August when night air temperatures and thus stream temperatures begin to drop. Additionally, solar radiation peaks during the summer solstice. Therefore, the solar radiation tool was run from May 1 to August 17 (Figure 46) which is precisely 51 days before and after the summer solstice. The next GIS exercise calculated the average solar radiation per ComID (Figure 47). This result is multiplied by the existing (and potential) stream widths and existing (and potential) riparian cover to identify the current and expected solar loads for each stream section (Figure 48).

Figure 46. Solar Radiation Received in Upper Nine Mile Creek from May 1 to August 17.

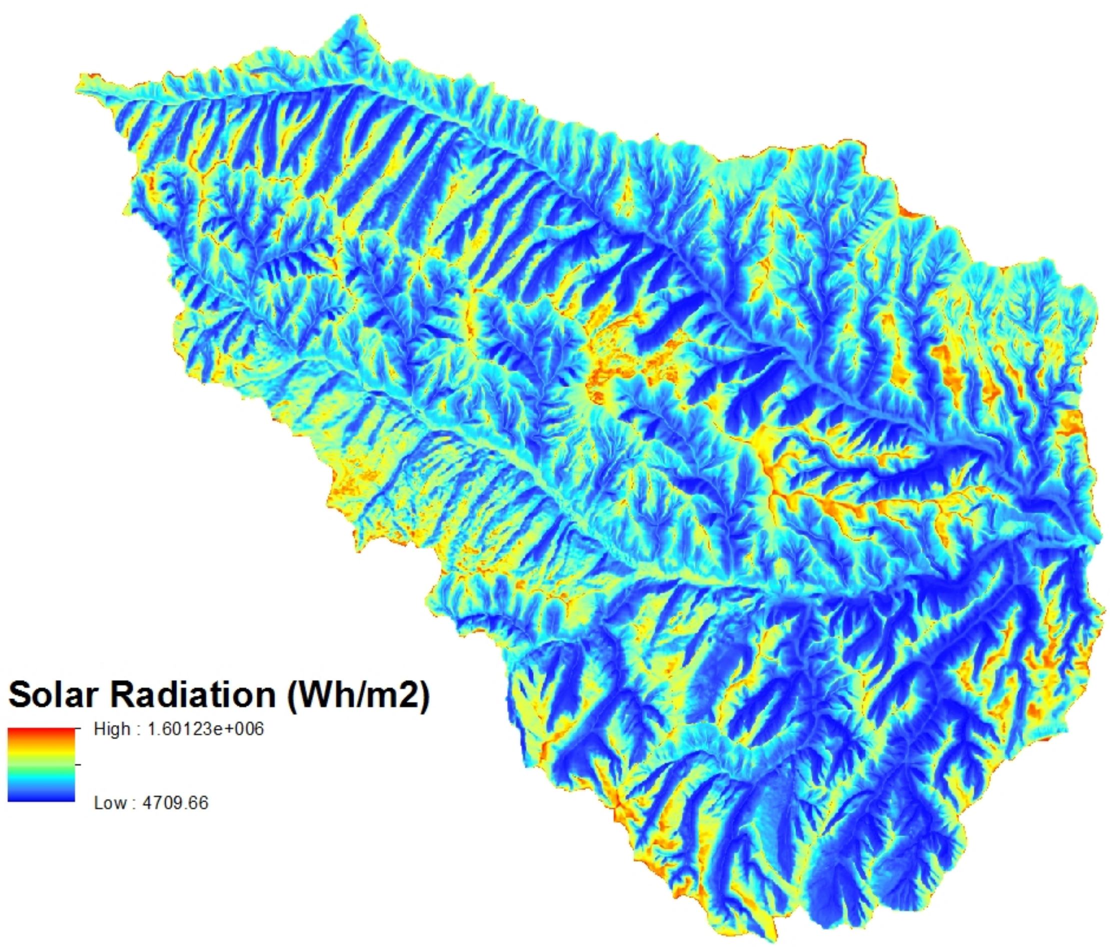


Figure 47. Average Solar Load for Each ComID in Upper Nine Mile Creek from May 1 to August 17.

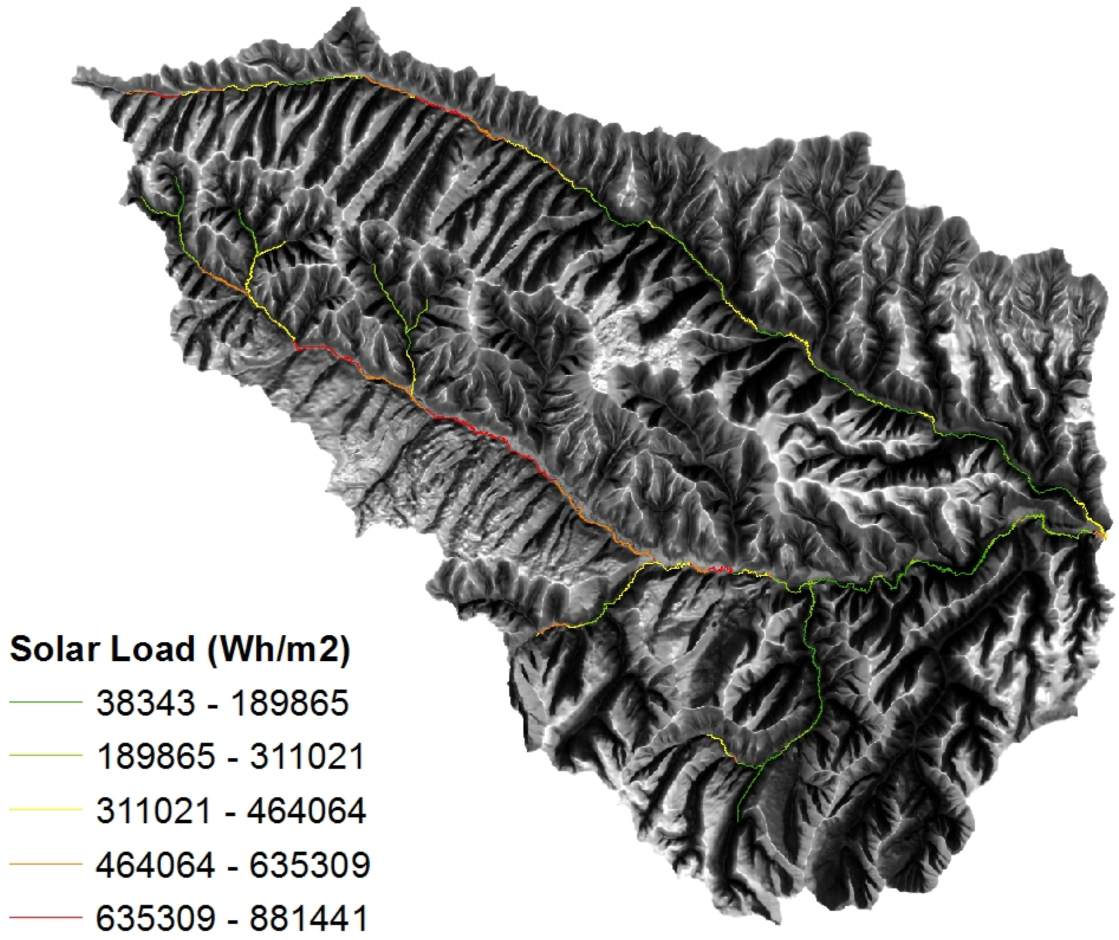
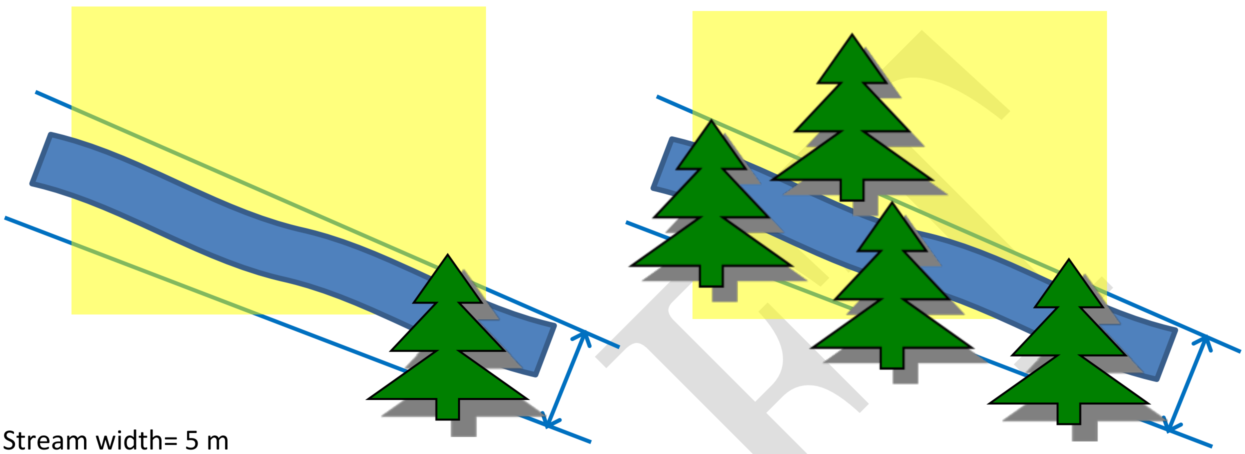


Figure 48. Schematic Example of Calculating Solar Load.



6.5 USGS SSTEMP

A USGS SSTEMP model was used to validate the riparian shade targets required to meet the 20 °C in-stream temperature (Figures 49-52). The model was developed by USGS to understand water flow scenarios from reservoir releases, changes in riparian shade and physical stream characteristics and water withdrawals and returns (Bartholow, 2004). The model is ideally suited smaller stream temperature TMDLs like Nine Mile Creek. It requires simple inputs like stream temperature, channel geometry, flows, vegetative shade, and weather information for single stream segments. Therefore, the model was run individually for Argyle Creek and Nine Mile Creek. The model predicts mean, minimum, and maximum water temperatures. Local climate condition inputs for SSTEMP were gained from this website: (https://weatherspark.com/averages/31327/Price-Utah-United-States) including: cloud cover (% sun), relative humidity and wind speed. All others were obtained from the local (Nutter's Ranch) weather station referenced in Chapter 2.6. The hydrology and geometry sections were collected during the critical time period (late summer) to simulate worse-case scenario conditions. All scenarios of the model were run for the month of July (7/15); the most critical month for elevated water temperature. Estimated maximum temperatures were predicted and compared from changes in total shade (%) from "current" conditions to "expected" conditions based on the riparian shade targets for each reach (Table 21 & 22).

The SSTEMP model for the upper Nine Mile Creek reach (Figure 49) predicted remarkably similar to the regression model used to demarcate an attainable maximum water temperature as illustrated in Figure 45. The model output predicted a maximum of 22.8 °C under the current 20.4% average vegetated shade calculated for this reach. For the future scenario (Figure 50), the 70% riparian shade goal for this reach was predicted to result in a 19.96°C maximum water temperature. Thus, predicting to meet DWQ's water temperature standard of 20°C during critical time periods for this reach. The SSTEMP model results for the Argyle Creek reach (Figure 51) under-predicted the maximum water temperature (17.7°C) than what was expected in the reach. There is a water diversion in this reach that likely has an influential effect that could not be considered accounted for in the model. Nonetheless, as evidenced by the biological organisms (Chapter 4.4) found there, Argyle Creek is very close to achieving the water temperature standard. The improvement of the riparian shading from 50% to the target 80% appears to have a limited effect as predicted by the future conditions model (Figure 52); which decreased maximum water temperatures to 17.1°C.

Table 21. SSTEMP Model Outputs Linking Percent Shade to Instream Temperature in Upper Nine Mile Creek Subwatershed.

Subwatershed: Upper Nine Mile Creek		
	Current Conditions	*Expected Conditions*
Percent Shade	*20.4%*	*70%*
Mean Temperature	*14.97*	*13.13*
Max Temperature	*22.80*	*19.96*
Minimum Temperature	*7.13*	*6.29*

Table 22. SSTEMP Model Outputs Linking Percent Shade to Instream Temperature in Argyle Creek Subwatershed.

Subwatershed: Argyle Creek		
	Current Conditions	*Expected Conditions*
Percent Shade	*50%*	*80%*
Mean Temperature	*12.28*	*12.00*
Max Temperature	*17.68*	*17.12*
Minimum Temperature	*6.88*	*6.89*

Figure 49. SSTEMP Output Screenshot for the Current Condition of Nine Mile Creek Above the Confluence of Argyle Creek.

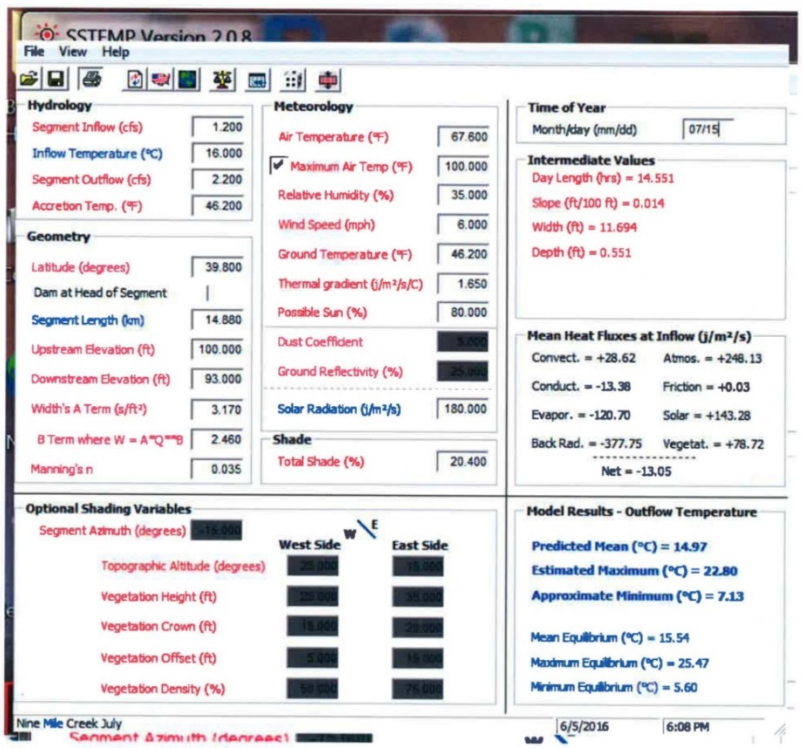


Figure 50. SSTEMP Output Screenshot for the Future Expected Condition of Nine Mile Creek Above the Confluence of Argyle Creek.

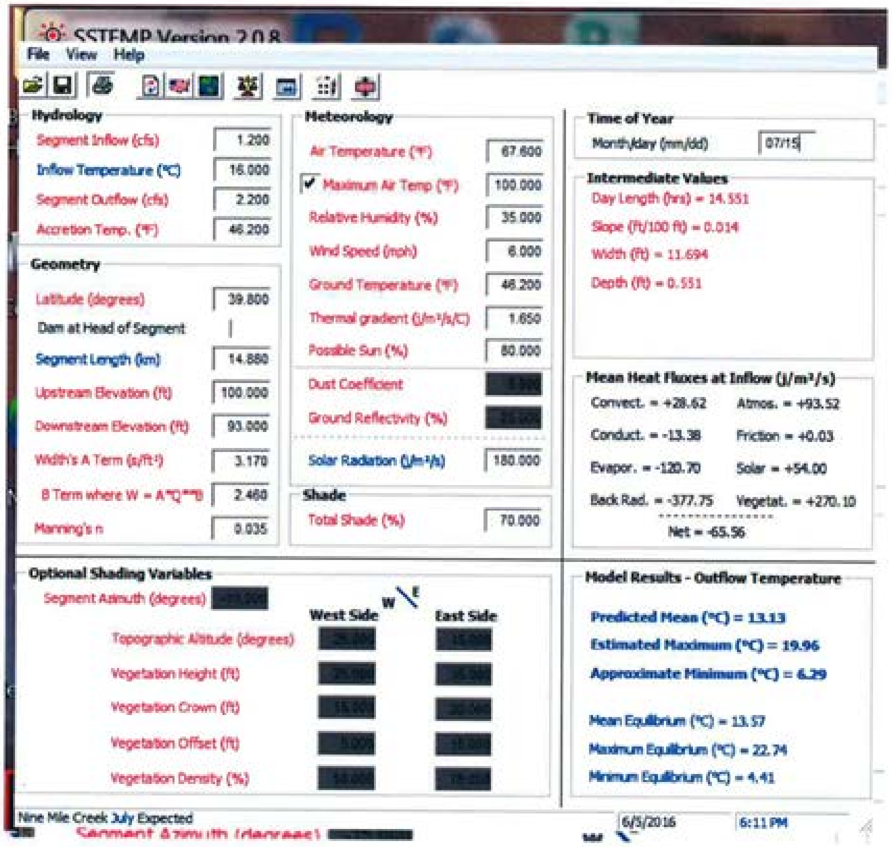


Figure 51. SSTEMP Output Screenshot for the Current Condition of Argyle Creek Above the Confluence of Nine Mile Creek.

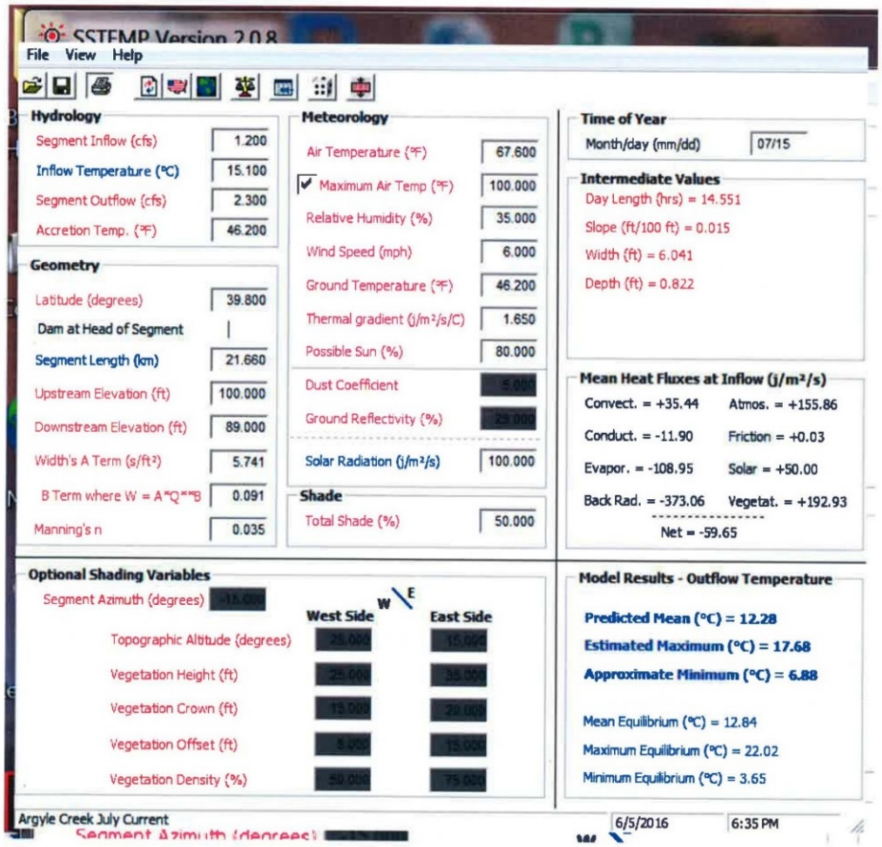
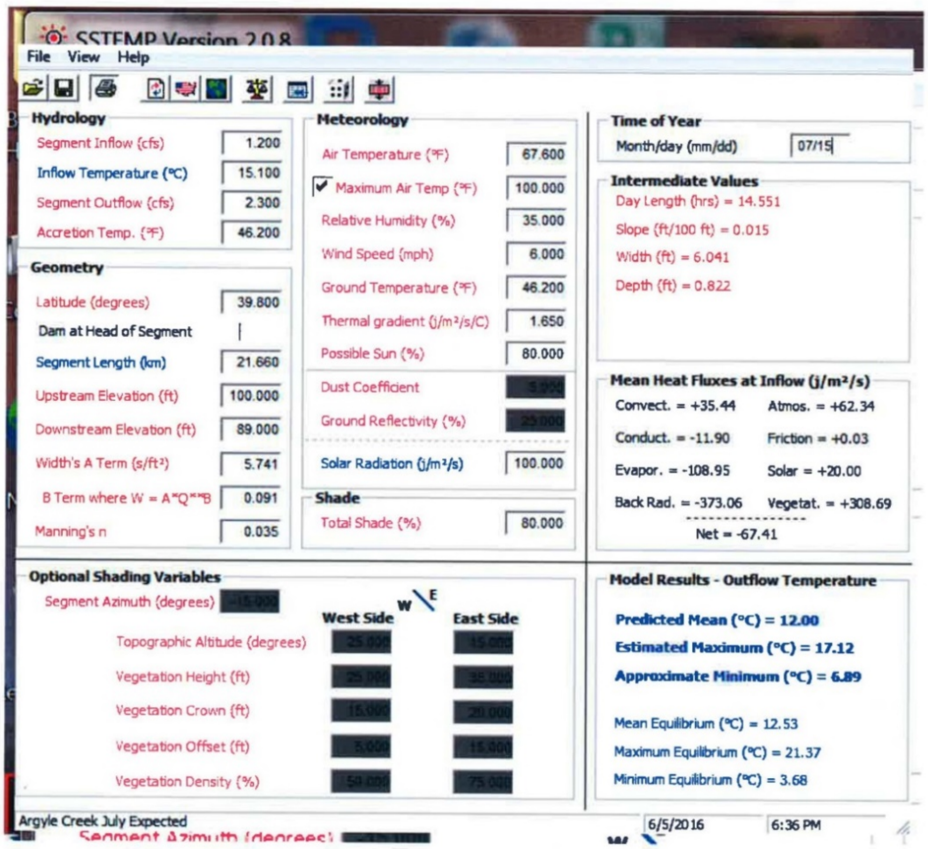


Figure 52. SSTEMP Output Screenshot for the Future Expected Condition of Argyle Creek Above the Confluence of Nine Mile Creek.



7.0 Temperature Total Maximum Daily Load (TMDL)

7.1 Description of TMDL Allocation

A TMDL is composed of the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for non-point sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

$$TMDL = \Sigma\ WLAs + \Sigma\ LAs + MOS$$

The TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. The Temperature TMDL for Upper Nine Mile Creek is expressed on a mass loading basis. The TMDL process is designed to establish the total loading a stream can assimilate without causing violation of the water quality standards. Because of the complex hydrology, the interconnectedness of the sources, and the location and temporal record of the monitoring data, these TMDLs do not distinguish between the contributions of solar loading from the various tributaries. Therefore, the TMDL analyses will focus on and establish the TMDL for the upper watershed of Nine Mile Creek based on critical season (warmer months). The TMDL is calculated on a daily basis to account for complex and varying hydrology and critical conditions in the watersheds and consistent violations of temperature water quality standards.

This TMDL directly compares the water quality standard for a cold water fishery into a thermal load. There are no point sources and the entire allowable load is allocated to natural and human sources that influence temperature.

7.2 Margin of Safety (MOS)

Calculating a numeric margin of safety is not easily performed with the methodology presented in this document. The margin of safety in this TMDL is considered implicit in the design. Besides riparian shading, the hillside shading is built-in to the ArcGIS solar radiation calculation thereby incorporating those natural background conditions into the loading capacity. The riparian target is essentially background conditions; therefore, loads (shade levels) are allocated to lands adjacent to these streams at natural background levels. It is unrealistic to set shade targets at higher or more conservative levels than natural background or system potential levels. In fact, the basis for the loading capacities and allocations is the definition of site potential conditions. It is unreasonable to presume that anything more than site potential riparian conditions are possible or feasible.

7.3 Allocation Summary

The current total solar radiation load affecting the TMDL area of Nine Mile Creek is 835,045.6 kWh/day (Table 23). Based on the targets identifying the potential natural effective riparian shade condition which have been validated to meet the DWQ water temperature standard, the solar radiation load for this area should be 231,637.6 kWh/day. Meeting this load will require a 72.3% reduction of solar radiation reaching the water surface.

7.4 Temperature TMDL

7.4.1 Wasteload Allocation
There are no permitted point sources in this watershed so no wasteloads allocations were required.

7.4.2 Load Allocation
The goal of the load allocation for this TMDL is to achieve natural background conditions of solar heating. In this instance, the upper Nine Mile Creek watershed is receiving solar heating in excess of natural background conditions. Attainable, riparian vegetation and width targets have been established to meet expected natural background conditions for riparian shading and solar loading (Table 21). There were eight reach areas delineated in the TMDL area based on geomorphic characteristics. These reaches were given specific shade targets based on achievable conditions within the reach. This shade target is used to determine the solar radiation load target of the particular reach. The average shade disparity is the proportional lack of shade within the reach area. For example, lower Minnie Maud lacks 65.2% of the background riparian shade. If the shade target was met, it would result in a 78.4% reduction in the amount of solar radiation reaching the stream surface of this reach. The average lack of riparian shade for the TMDL area is 36%. Fully implementing the vegetative shade targets would result in a 72.3% reduction in solar radiation reaching the water surface.

7.4.3 Total Maximum Daily Load (TMDL)
The following table summarizes individual load allocations of solar heat loading (kWh/day) for 8 separate reaches of Nine Mile Creek and tributaries based on the achievable shading target and resulting reductions to achieve a total 72.3% reduction in existing loads and attainment of the cold-water temperature standard of 20° C.

7.4.4 Seasonality
The TMDL is directed towards the critical time period of May to September as determined by empirical data. This period is when solar radiation and air temperatures are at maximum values and water flows are lowest.

Table 23. Thermal TMDLs of Eight Distinct Reaches of Upper Nine Mile Creek watershed.

Reach Name	Shade Target (%)	Average Shade Disparity (%)	Existing Load (kWh/day)	Load Capacity (kWh/day)	Load Reduction (kWh/day)	Load Reduction (%)
Argyle-Lower	80	-29.9	53,976.4	22,320.6	31,655.7	58.6
Argyle-Canyon	70	-5.3	10,566.0	7,465.1	3,100.9	29.3
Argyle-Upper	75	-28.0	84,450.6	32,204.7	52,245.9	61.9
Minnie Maud-Lower	70	-65.2	156,499.6	33,835.0	122,664.6	78.4
Minnie Maud-Upper/Tribs	75	-37.3	177,301.6	48,431.7	128,869.9	72.7
Nine Mile-Lower*	70	-46.4	253,631.2	64,725.5	188,905.7	74.5
Nine Mile-Upper	50	-41.4	83,543.1	15,490.7	68,052.4	81.5
Cow Creek	70	-22.8	15,077.2	7,164.1	7,913.0	52.5
Totals		**-36.0**	**835,045.6**	**231,637.6**	**603,408.0**	**72.3**

*This reach is located in the Upper watershed. It is located below the confluence of Minnie Maud and above Argyle Creek.

8.0 Implementation Plan

In order to achieve water quality targets and TMDL endpoints, it will be necessary to implement Best Management Practices (BMP). BMPs are practices used to protect the physical and biological integrity of surface and groundwater, primarily with regard to nonpoint sources of pollution. BMPs are most effective when combined to create a BMP system that will comprehensively reduce or eliminate pollution from a single source. It should be noted that no single BMP system is considered to be the most effective way of controlling a particular pollutant in all situations. Rather, the design of a BMP system should consider local conditions that are known to influence the production and delivery of nonpoint source pollutants, including the reduction of temperature where appropriate. The design of a BMP system should not only account for the type and source of pollutant, but should also consider background factors such as the physical, climatic, biological, social, and economic setting.

BMPs applied to the Nine Mile Creek watershed should include both structural and nonstructural techniques. Structural BMPs require a physical structure and a cash outlay to install and include the restoration of vegetative buffer strips, consisting of trees that will shade stream channel. It can also include restricting cattle access to stream channels, reinforcing or stabilizing eroded areas along these same water bodies.

Nonstructural techniques include practices such as improved irrigation water management and developing grazing management plans where appropriate. The BMPs recommended in this chapter are based upon NRCS-approved conservation practices provided in the Field Office Technical Guide (USDA, 2016) used by Utah NRCS field offices. This guide contains practices that are specific to the State of Utah as well as those that are generally applied to all states.

A list of BMPs specific to reducing temperature in Nine Mile Creek, and the costs associated with those BMPs can be found in Table 24. Figure 53 in this chapter also shows the priority stream reaches where re-vegetative work is needed as well as the locations that currently have good vegetative cover. These priority areas were identified using a linear regression model constructed by UDWQ. BMP cost estimates are based upon summaries obtained from the FY 2016 Practice Cost List (USDA, 2016) utilized by the NRCS and reflects the cost of supplies, as well as the labor that is needed to install those practices. BMPs should be applied to lower the temperature identified in three main categories identified in the project area including channel morphology, hydrologic modifications, and near stream vegetation. Finally, tables indicating the expected temperature reductions to result from implementation of these practices are provided in Appendix C.

8.1 Riparian Restoration

One of the major issues on Nine Mile Creek is that riparian vegetation is lacking thus reducing the amount of shading that is occurring throughout the upper reaches of the watershed. Ideally, vegetative cover should shade 70-80% of the stream, however as identified in Table 23, the existing shading encountered in most of the upper watershed is much lower than this. The linear regression model was used to determine the amount of vegetative cover needed to obtain the TMDL endpoints. Figure 36 shows the priority planting areas in the Upper Nine Mile Creek Watershed. These priority areas were developed based on the amount of vegetation present and the amount of vegetative plantings needed to meet the water quality endpoints identified in this TMDL. Table 24 shows the number of acres of riparian restoration needed in each watershed to reduce the temperature to 20°C, which is required to support a cold-water fishery.

Using the linear regression model, it is anticipated that nearly 197 acres of riparian planting will need to occur to achieve the temperature endpoints identified in this TMDL. At an estimated $418.91 per acre, it has been determined that it will cost approximately $82,366 to effectively reestablish the riparian corridor.

8.2 Beavers and Their Purpose in the Nine Mile Creek Watershed

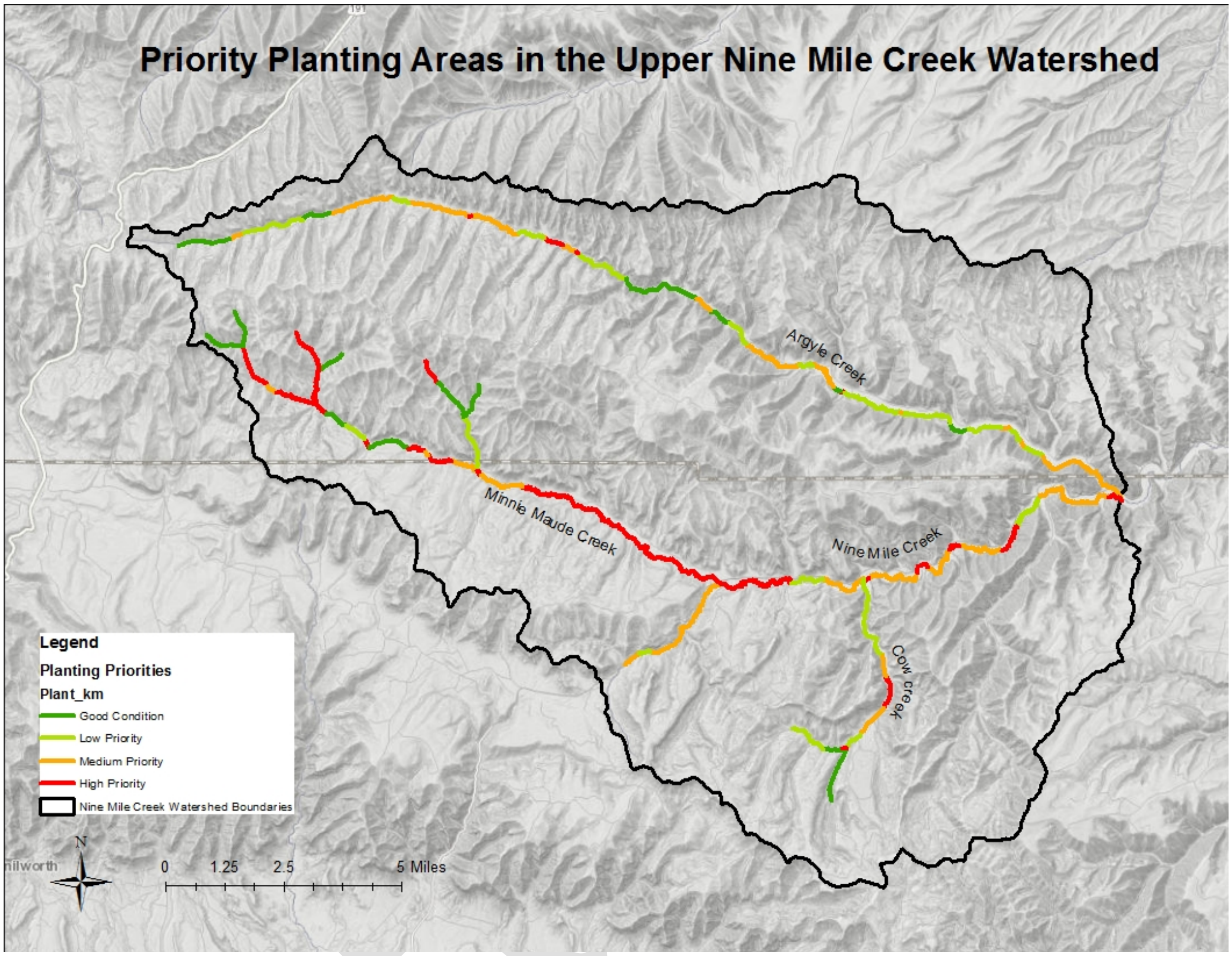
Beaver have the ability to improve the water quality of streams by reducing suspended sediments in the water column, moderating stream temperatures, improving nutrient cycling, and removing and storing contaminants. Beaver dams can affect the water quality of streams in ways that often mimic common restoration project goals (Pollock, Lewallen, Woodruff, Jordan, & Castro, 2015).

While some people believe that beaver dams can actually raise water temperature due to the increase in solar radiation on the larger pools. Research has actually shown that if beavers are able to create large deep ponds (deeper than 6 feet), usually stratify, with cooler water near the bottom of the pond and a thin layer of warm water at the surface. This stratification creates ideal conditions for species of salmonids (Hoffman & Recht, 2013).

Beavers are already present through much of the Nine Mile Creek watershed. During recent visits it has been found that a fairly healthy population of beavers is found in the lower and upper ends of the watershed. Due to the lack of vegetation through much of the middle sections of the watersheds the beavers have been unable to establish viable colonies. It is predicted that once the vegetation begins to recover in the middle sections of the watershed, the beavers above and below the restoration sites will begin to inhabit those sections of the watersheds as well.

To better understand the impacts of beavers in the watershed beaver populations within the watershed should be continually surveyed. By doing this the Division of Water Quality will be able to better document the benefits of having beavers in the watershed, and identify locations where beavers should be introduced, or where beaver populations are growing too quickly.

Figure 53. Priority Planting Areas in Upper Nine Mile Creek Watershed.



8.3 Grazing Management

To properly address the grazing management issues present in the watershed, it will require a combination of structural and non-structural practices. While proper grazing management is a viable option in the upper reaches of the watershed where landowners are able to distribute their cattle across a very large landscape, this may not be as effective in the lower sections of the watershed where cattle are concentrated in smaller areas, such as the irrigated pastures found in the lower reaches of the watershed. In these situations, it may be necessary to install riparian fences along the creek, and restrict access to the stream. The section inside the riparian fencing may still be grazed, but the animals will need to be removed when the plants within the riparian area become stressed, or over grazed.

When fencing animals from the riparian corridor watering sites need to be constructed, providing water for the livestock that will continue to graze those pastures. This can be accomplished by constructing hardened access points. Watering troughs could also be installed where appropriate. When installing any structures that allow livestock to drink special attention should be given to the water rights of the landowner that is grazing the cattle. The size of the structures that are installed are dependent on the number of the cattle in that pasture, size of the pasture, and the distance of the fence from the river. For the purpose of this document it will be assumed that access points will be roughly 120 square feet in size, and will be installed every 2,000 feet.

It should also be noted that fencing animals from the riparian area does not mean that cattle will permanently be excluded from grazing the riparian area. Landowners can continue to graze the riparian corridor after resting it for two years. After two years the riparian vegetation should be well established, and will actually benefit from properly grazing it. A grazing management plan should be written for the riparian pastures, and adhered to maximize both the agricultural and environmental benefits of the riparian fencing.

Using aerial photography, the locations that will require riparian fencing were identified. Most of the areas where this fencing will be required were found in the Argyle and Minnie Maud Creek watersheds. The tributaries did not seem to appear over grazed, and sufficient riparian vegetation was present.

It is anticipated that 10.9 miles of riparian fencing will be needed to effectively protect the riparian corridor from excessive grazing. In some instances, both sides of the river will need to be fence to properly protect the riparian resources present. The overall cost to install this fence is $78,589.

8.4 Storm Water Runoff Control

The Nine Mile watershed is located in a region where large storm events can often result in flash floods. In the Nine Mile Canyon watershed this is especially the case where a paved roadway has created an impervious surface stretching along that reach of the river. As a result of the runoff from the highway, large gullies have formed between the road and the river contributing to the erosion problem that is found in the upper end of the Nine Mile Creek watershed. The lack of infiltration caused by the impervious surfaces has also resulted in increased velocity during storm events. This increased velocity has resulted in a widening of the stream, and reduced the amount of riparian vegetation present. In an attempt to fix the problem that the storm water runoff has created various practices will need to be installed, including culverts that will allow water to pass under the roadway, thus allowing the flows to be evenly distributed into Nine Mile Creek, and reduce the large concentrated flows that have caused much of the large gullies to scour out.

In an attempt to slow the velocity in the stream, gabion baskets will be installed along Nine Mile Creek to help the channel as determined by engineers. It is anticipated that over time this will allow the creek channel to narrow, and become a more suitable location for a riparian corridor to be established.

It is anticipated that 400 acres will need to be addressed to properly fix the storm water management issues that are currently present in Nine Mile Canyon. According to the NRCS cost list storm water runoff control (practice 570) (USDA, 2016) will cost approximately $385 per acre, totaling $153,988 to implement. The NRCS cost list states that the storm water runoff control consists of a variety of BMPs identified by the engineers that will correct the problem.

8.5 Information and Education component

In the Upper Nine Mile Creek Watershed only 11% is privately owned. However, many of the reaches in these privately owned sections are the reaches that need to be treated. The Utah Nonpoint Source Information and Education Strategy developed in 2013 in conjunction with the updating of the State Nonpoint Source Management Plan (Utah Department of Water Quality, 2013) states that land owners need to:

- Understand the importance of managing for clean water and the potential benefits proper management can have on their operations and other landscape-scale resources including soil, forage, animal health, and water availability on their lands).
- Understand and be trained on the Best Management Practices (BMPs) that can be used to improve or protect water quality.
- Be aware of the various sources of funding and other technical assistance available to help in implementing best management practices;
- Be aware of changes in regulatory requirements.
- Understand TMDLs and other watershed-based management approaches.

One of the best ways to educate all interested parties that currently use the watershed is to establish a local working group where all of the relevant topics that are impacting the watershed can be discussed. This can include the importance of beavers, concerns of local landowners, current status of water quality, and the short term and long term goals of each of the members of the working group.

To better help landowners understand the importance of water quality in their watersheds and what they can do to help improve the beneficial uses on Nine Mile Creek various techniques will be used. It has found that demonstration projects are very effective when helping landowners decide to implement BMPs on their property, especially when those projects are located on their neighbor's property. This allows the landowner to gain trust in the governmental agencies that typically help fund those BMPs. It also allows other landowners to see what exactly will be implemented on their property and how it can improve their agricultural operations.

One of the important components of educating landowners in the watershed will need to focus on beavers, and how their presence can have a positive impact in the watershed. While beavers can be considered as a pest by many people, they can also be a very valuable resource in the watershed. This educational component will need to focus on what is considered a nuisance beaver, and how these beavers will be dealt with. It would also be beneficial to distribute educational pamphlets to the landowners highlighting the benefits that can be achieved by allowing the beavers to continue to inhabit the watershed.

In other watersheds across the state it has also been helpful to do demonstration projects within a watershed before launching a large effort to recruit private landowners to implement NPS projects on their property. These demonstration projects should be projects that are representative of the projects that will likely be implemented on a large scale throughout the watershed. This will allow landowners that are hesitant to implement projects to come and see how the final product will look, and talk to the landowners about their interactions with the state and federal entities that helped implement them.

Every six years the State of Utah targets a large amount of their funding at specific basins throughout the state. The Nine Mile Creek Watershed will be eligible for this targeted funding in FY-2019. These demonstration projects should be completed at least one year prior to the year that they will be the targeted basin.

Much of the land in the Nine Mile Watershed is managed by BLM, the Utah Grazing Improvement Program (UGIP), and DWQ will provide workshops and projects demonstrating proper grazing of riparian areas and will monitor grazing impacts throughout the watershed.

Much of the land in the Nine Mile Watershed is managed by BLM, but is grazed by permittees, especially in the upper reaches of the watershed. The BLM will need to verify that their permittees understand the details of their grazing permits, and help them know when the cattle should be removed from the riparian corridor.

Nine Mile Canyon is a popular recreation site due to the petroglyphs and public land present in the watershed. It would be beneficial for the general public to be made aware of the project work that is taking place within the watershed to improve water quality. By doing so, the relationships between the individuals recreating in the watershed and the landowners will improve over time.

In summary, the Information and Education Strategy for the Nine Mile Creek TMDL consists of three main elements. These elements are as follows:

- Develop a local work group that helps educate local landowners, state and federal agencies, and environmental groups on the pertinent issues within the watershed.
- Prior to receiving NPS funding during the targeted basin funding cycle implement various demonstration projects that allow local landowners see the benefits of restoring the riparian corridor.
- Place signage on public lands informing the general public about project work that is taking place.
- Educate landowners on the importance of the presence of beavers within the watershed.
- Select one or two demonstration projects in the watershed that are representative of the project types that will be implemented on private property.

It would be beneficial to include the Utah Department of Agriculture and Food (UDAF) when working to inform the private landowners of practices that can be implemented to improve water quality, specifically UDAF's Grazing Improvement Program (UGIP) coordinators.

8.6 Implementation Cost and Technical Assistance

To generate the estimated cost for the Best management practices recommended in this TMDL, the Natural Resource Conservation Service Cost list for FY-2014-2016 (USDA, 2016) was used. The costs identified in this cost list include the cost for materials and labor to install the BMPs listed in Table 24.

In addition to the cost of the BMPs that are recommended in this implementation plan, there will also be costs associated with the technical assistance needed to help plan the projects and oversee the management of the grants that are used to fund this plan. The technical assistance needs include the engineering designs that will be needed in areas where a harder fix will be required such as the segment of Nine Mile Creek, where rock gabions and culverts will need to be installed. Additional technical support will include obtaining the proper permits and clearances need such as stream alteration permits, Archeological clearances, and NEPA clearances.

The State of Utah typically allows a grant recipient to apply for up to 20% of the total grants awarded to subrecipients for the use of technical support of a project. In many situations local watershed coordinators that are funded by DEQ will provide this technical assistance. However, there are currently no local watershed coordinators assigned to the basin where Nine Mile Creek is Located.

The overall cost to implement the Nine Mile Creek TMDL can be found in Table 24 below.

Due to the cost that is associated with implementing watershed plans and TMDLs, funding for implementation seldom comes from one location. This will be the case with the Nine Mile Creek Temperature TMDL. Currently there are several entities that are interested in conducting implementation work in the Nine Mile Watershed. Each of these entities have funding programs that can help with the implementation of this plan. Table 21 shows the entities that are anticipated to participate in the implementation activities that will take place in the Nine Mile Watershed, as well as the programs that can potentially award funding to the projects.

Due to the amount of funding that will be required to implement this plan in its entirety it will be necessary to fund this project in three phases over a prolonged period of time. Table 22 in Section 8.7 shows the phases of implementation and the predicted timeline associated with the implementation of those phases.

Table 24. Proposed Practices and Cost to Implement TMDL.

Stream Reach	Practice	Cost/Unit	Amount	Total Cost
Argyle Creek	Tree/Shrub Establishment (612)	$418.91/acre	56.78 Acres	$23,786
	Riparian Fencing (382)	$1.37/ft	30,662 Feet	$42,007
	Hardened Stream Access (561)	$0.69/Sqft	18,000 Sq Feet	$12,420
		Subtotal		**$78,213**
Minnie Maud and Tributaries	Tree/Shrub Establishment (612)	$418.91/acre	87.02 Acres	$36,454
	Riparian Fencing (382)	$1.37/ft	26,702 Feet	$36,582
	Hardened Stream Access (561)	$0.69/Sqft	15,600 Sq Feet	$10,764
		Subtotal		**$83,800**
Nine Mile Creek	Tree/Shrub Establishment (612)	$418.91/acre	69.33 Acres	$29,043
	Storm Water Runoff Control (570)	$384.97/acre	400 Acres	$153,988
	Grade Stabilization Structure (410)	$8,666 per structure	25 Structures	$216,650
		Subtotal		**$399,681**
Cow Creek	Tree/Shrub Establishment (612)	$418.91/acre	13.72 Acres	$5,738
		Subtotal		**$5,738**

Total Cost of BMPs	**$567,432**
20% Technical Assistance	**$113,486**
Total Cost of Watershed Implementation	**$680,918**

Table 25. Potential Funding Opportunities for Nine Mile Creek.

Entity	Grant program
Utah Division of Water Quality	Section 319 Grant Funding, Utah Nonpoint Source Pollution Grants
Utah Division of Natural Resources	Utah Watershed Restoration Initiative, Habitat Council Funding
Bureau of Land Management	Utah Watershed Restoration Initiative Funding, BLM General funds.
Private Landowners	N/A

8.7 Implementation Schedule and Milestones

One of the key elements of any implementation plan is the ability of the entity implementing the plan to measure progress and make adjustments (Environmental Protection Agency, 2008). To help determine if the local working group is accomplishing all of the activities identified in the implementation in a timely manner it is beneficial to develop milestones. These milestones identify what should be accomplished and when to help stay on task and complete the tasks identified in the implementation schedule.

Table 26. Implementation Schedule and Milestones.

Activity	Agency Responsible	Timeline
Development of Local Working Group	UDWQ	By 2017
Begin project monitoring	UDWQ, UDWR, BLM	2018-2035
Milestones		

Sampling Analysis Plan Developed in coordination with the Local Working Group	*UDWQ*	*Spring of 2018*
Implement Phase 1 (Nine Mile and Cow Creek)	**UDWQ, UDWR, BLM, UDAF, Local Conservation District, Private Landowners**	**2019-2023**
Milestones		
Identify and implement a demonstration project that is a good representative of the project type that will be implemented on private land	*UDWQ, UDWR, UDAF, Local Conservation District*	2019
Identify landowners willing to implement BMPs within the Nine Mile Creek and Cow Creek subwatersheds,	*UDWQ, UDWR, UDAF, Local Conservation District*	*2020*
Solicit funding for Phase 1 of the Nine Mile Creek Project- $405,419	*UDWQ, UDWR, BLM, Local Conservation District*	*Fall of 2020*
Reduce temperature in Nine Mile and Cow Creek by Implementing 83.05 acres of riparian Improvements, and manage storm water runoff on 9 Mile Creek.	*UDWQ, UDWR, BLM, UDAF, Local Conservation District, Private Landowners*	*Fall of 2023*
Implement Phase 2 (Argyle Creek)	**UDWQ, UDWR, BLM, UDAF, Local Conservation District, Private Landowners**	**2024-2028**
Milestones		
Identify landowners willing to implement BMPs within the Argyle Creek subwatershed,	*UDWQ, UDWR, UDAF, Local Conservation District*	*2024*
Solicit funding for Phase 2 in the Argyle Creek subwatershed- $65,793	*UDWQ, UDWR, BLM, Local Conservation District*	*Fall of 2024*
Reduce temperature in Argyle Creek by Implementing 56.78 acres of riparian Improvements, and installing 30,662 feet of riparian fencing	*UDWQ, UDWR, BLM, UDAF, Local Conservation District, Private Landowners*	*Fall of 2028*

Implementation Phase 3 (Minnie Maude Creek and Tributaries)	**UDWQ, UDWR, BLM, UDAF, Local Conservation District, Private Landowners**	**2029-2033**
Milestones		
Identify landowners willing to implement BMPs within the Minnie Maud Creek subwatershed,	*UDWQ, UDWR, UDAF, Local Conservation District*	*2029*
Solicit funding for Phase 2 in the Minnie Maud subwatershed- $73,036	*UDWQ, UDWR, BLM*	*Fall of 2030*
Reduce temperature in Minnie Maud Creek and tributaries by Implementing 87.02 acres of riparian Improvements, and installing 26,702 feet of riparian fencing	*UDWQ, UDWR, BLM, UDAF, Local Conservation District, Private Landowners*	*Fall of 2033*
Revaluation of Watershed Plan/TMDL	**UDWQ**	**2033**

To help determine if the local working group is accomplishing all of the activities identified in the implementation in a timely manner it is beneficial to develop milestones. These milestones identify what should be accomplished and when to help stay on task and complete the tasks identified in the implementation schedule.

9.0 Future Monitoring

Long-term monitoring of water quality including both grab and high frequency data should be conducted throughout the watershed to evaluate the effects of BMPs and any progress toward meeting the water quality goals and supporting beneficial uses. Continued monitoring will allow for the periodic reevaluation of the implementation strategies and goals defined in this TMDL document. Future monitoring efforts should include:

- Characterization of irrigation return flows
- Photo documentation to compare changes in geomorphology, streambanks, riparian conditions, flow levels, and shade
- Aerial photo analysis to monitor the overall health of the riparian corridor and composition of riparian vegetation
- Biological monitoring should include both macroinvertebrate, fishery, and beaver communities

- Deployment of high frequency monitoring probes to measure both temperature and flows especially in the Upper Nine Mile Creek where flow data is lacking
- Continue baseline water quality sampling at critical locations: Minnie Maud above Confluence of Nine Mile Creek, Argyle Creek above Confluence Nine Mile Creek, Nine Mile Creek at Cottonwood Glen, and new additional site of Nine Mile Creek below Confluence of Argyle Creek

10.0 Public Participation

Local stakeholder participation for this draft TMDL was accomplished through stakeholder meetings starting in 2013. The first Nine Mile Creek watershed TMDL meeting was held at the Carbon County Office in Price in March 2014. This meeting was designed to present the issues and bring all the stakeholders to the table. The second stakeholder meeting was held in September 2015 and discussed the data summary and approach for technical analysis. The draft TMDL was given to the stakeholders for comments on August 18, 2016. Stakeholder comments were due to UDWQ on September 1, 2016. The stakeholder comments were addressed before the public stakeholder meeting scheduled on September 13th in Price. The draft TMDL report was available for public review and comment from October 31st though December 1st. Public notice was published in the Uintah Basin Standard in the Basin Briefs on X date 2016 and also in the Salt Lake Tribune and Deseret News the week X date 2016.

Participants included: Carbon County, Duchesne County, Uintah County, BLM, NRCS, UDWQ, UDWR, SITLA, UDAF, local land owners, and Enervest Company. It is important to have local input to affect water quality improvements and practices.

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Appendix A. Nine Required Elements of a Watershed Plan

a. Identify causes and sources of pollution

Section 3-5 of this document focus on the possible causes of the temperature impairment on 9 Mile creek. Section 5 focuses heavily on the source identification for the increase in temperature.

b. Estimate load reductions expected

Section 7 in the main body of the TMDL identifies reaches of the creek that need to increase shading, as well as the shading percentage required to meet water quality standards throughout each reach.

c. Describe management measures and targeted critical areas

Section 8 of the TMDL identifies the (BMP) Best Management Practices that will be used to help reduce temperature throughout the Upper Nine Mile Creek watershed. It also identifies the high priority areas where implementation should take place, and those practices will need to be installed.

d. Estimate technical and financial assistance needed

Table 24 in Section 8.6 identifies the amount of each BMP that will need to be installed to meet the TMDL endpoints. This table also shows the expected cost of implementing those BMPs.

e. Develop an information and education component

Section 8.5 of this document highlights the informational and educational components that will be implemented to help the general public and local landowners understand the issues that are present in the watershed, and what they can do to help solve those issues.

f. Develop a project schedule

Section 8.7 of this document proposes the schedule that should be followed to properly implement this TMDL.

g. Describe interim, measureable milestones

The Milestones associated with the implementation of this TMDL can be found in Table 26 in Section 8.7.

h. Identify indicators to measure progress

Section 9.0 highlights the future monitoring needs that will be required to determine the effectiveness of the BMPs that are installed, and determine if the milestones developed for this TMDL are being met.

i. Develop a monitoring component

Section 9.0 highlights the future monitoring needs that will be required to determine the effectiveness of the BMPs that are installed, and determine if the milestones developed for this TMDL are being met.

Appendix B. Temperature Data for Nine Mile Creek Watershed

Temperature Data from Grab Samples in Upper Nine Mile Creek

Watershed	Monitoring Location	Date	Temperature
Upper Nine Mile	4933620 Argyle Ck AB Garder Cyn	6/15/1999	11.1
	4933610 Argyle Creek Lower	6/4/2009	14.6
		6/15/1999	11.1
		5/29/2014	15.1
		9/17/2014	16.7
	4939135 Argyle Ck BL Parley Cyn	6/17/2014	10.8
	4933380 Argyle Ck AB Confl Nine Mile Ck	6/27/2005	18.6
		7/20/2005	15.1
		1/30/2006	4.5
		6/4/2009	15.6
		5/29/2014	14.2
		9/17/2014	12.6
	4933420 Minnie Maud Ck AB Confl Nine Mile Ck	6/27/2005	19.7
		7/20/2005	13.8
		1/30/2006	3.6
		11/13/2007	6.5
		6/17/2008	18.5
		7/29/2008	14.9
		9/8/2008	11.2
		11/12/2008	6.3
		12/18/2008	0.3
		5/22/2009	17.1
		6/4/2009	14.0
		5/29/2014	13.8

		9/17/2014	11.0
	4933410 Cow Canyon Ck AB Confl Nine Mile Ck	5/19/1999	15.5
		6/22/1999	11.1
		6/27/2005	18.8
		7/20/2005	12.8
		6/4/2009	13.1
	4933390 Sheep Canyon Ck AB Confl Nine Mile Ck	5/19/1999	10.0

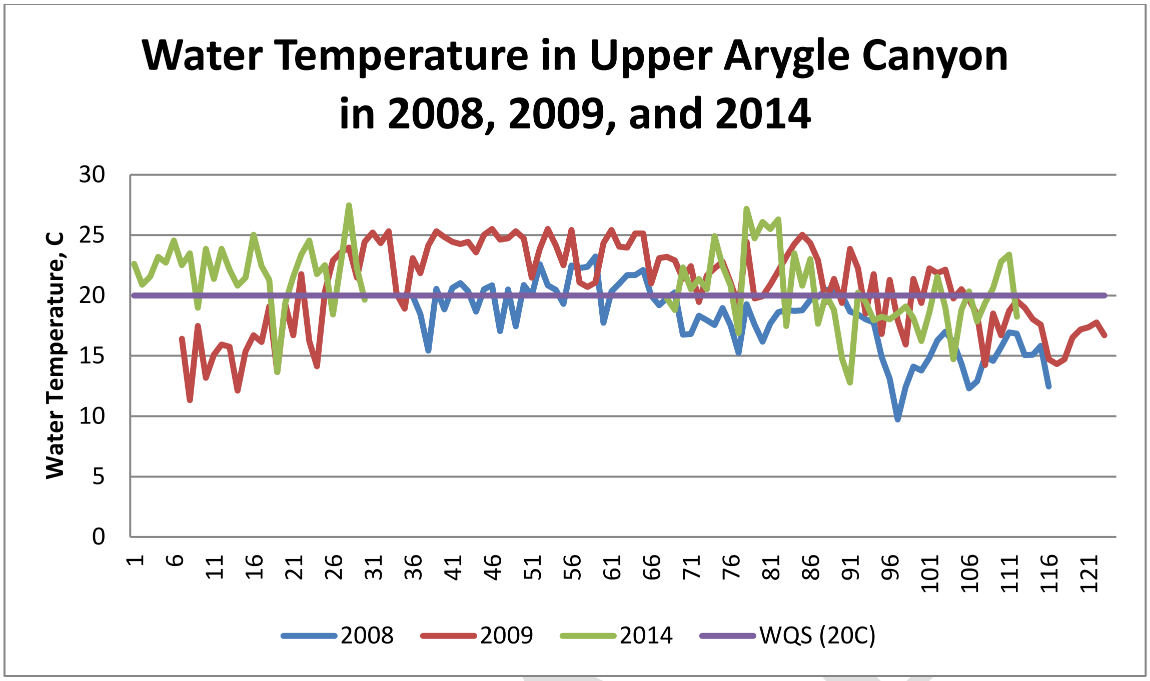
Temperature Data from Grab Samples in Lower Nine Mile Creek

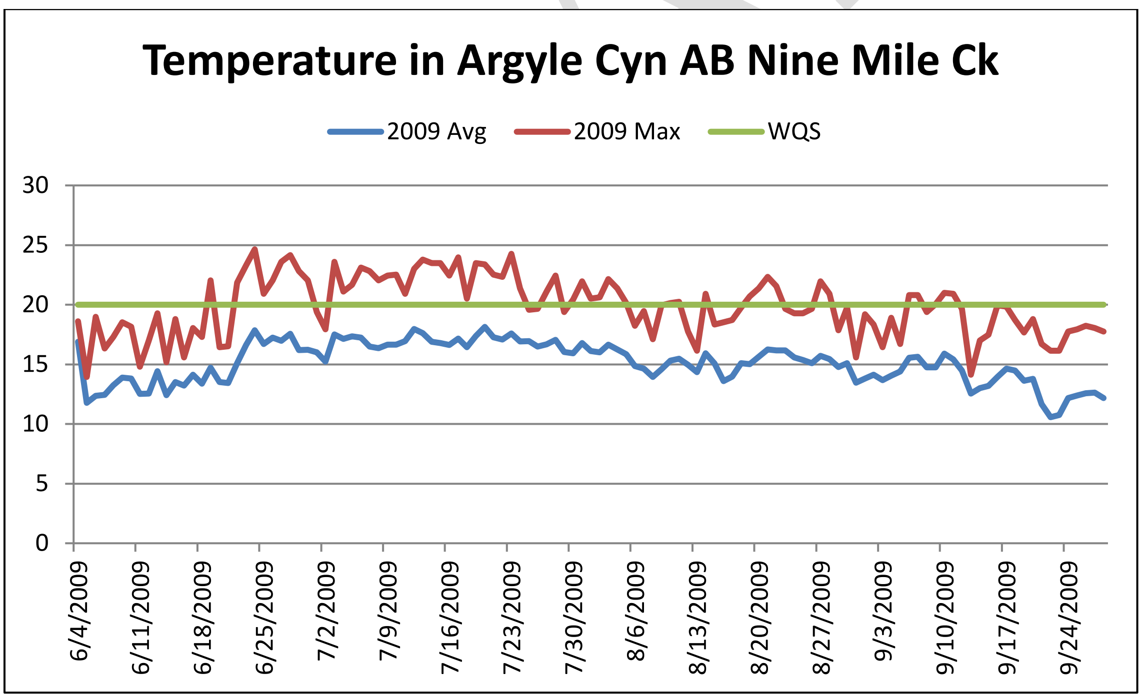
Watershed	**Monitoring Location**	**Date**	**Temperature**
Lower Nine Mile	4933405 Nine Mile Ck at Cottonwood Glen	6/17/2008	19.1
		6/4/2009	13.4
		5/29/2014	13.2
		9/17/2014	19.7
	4933345 Nine Mile Ck BL Campground	10/3/2007	15.6
	4933290 Dry Canyon	5/28/1992	10.0
		8/11/1998	11.0
		6/4/2009	12.8
	4933288 Nine Mile Canyon BL Dry Canyon	1/30/2006	2.8
		11/13/2007	5.1
		3/3/2008	7.8
		7/29/2008	11.8
		9/8/2008	15.3
		11/12/2008	5.7
		12/18/2008	4.5
		5/22/2009	15.1
	4939139 Nine Mile Ck BL Daddy Cyn	6/19/2014	10.6
		10/3/2007	8.2

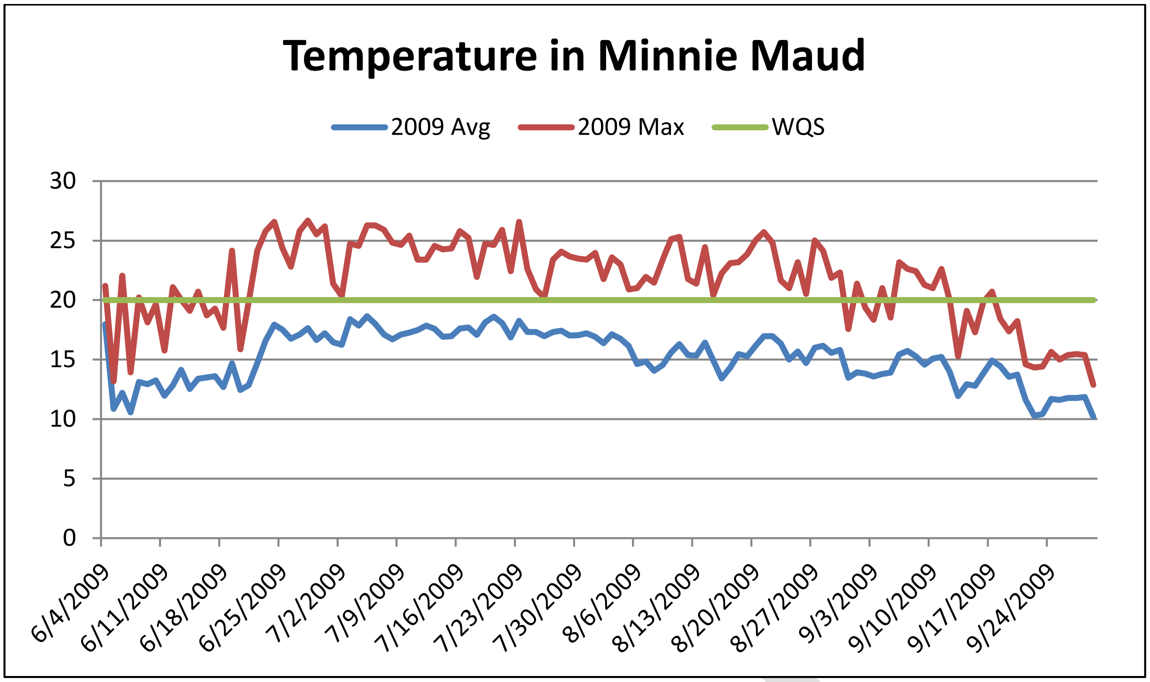
	4933335 Nine Mile Ck AB Cottonwood Cyn	6/4/2009	18.5
		5/28/2014	18.8
		9/17/2014	18.8
	4933280 Cottonwood Creek	9/24/1991	10.7
		11/13/2007	2.7
		1/14/2008	2.4
		9/8/2008	16.8
		11/12/2008	4.0
	4933330 Nine Mile Ck AB Bulls Canyon	9/9/1992	24.6
		6/10/1993	22.0
		5/19/1994	25.2
		7/13/1995	19.0
		5/29/1997	13.0
		7/22/1997	26.1
		7/21/1998	25.9
		5/27/1999	16.0
		8/4/1999	27.4
		9/1/1999	23.8
		9/29/1999	12.0
		5/25/2000	20.0
		8/24/2000	28.0
		5/15/2001	12.7
		6/9/2001	17.1
		8/14/2001	23.0
		6/7/2002	18.7
		10/2/2002	14.2
		5/20/2005	16.7
		7/6/2005	21.4
		6/4/2009	19.3

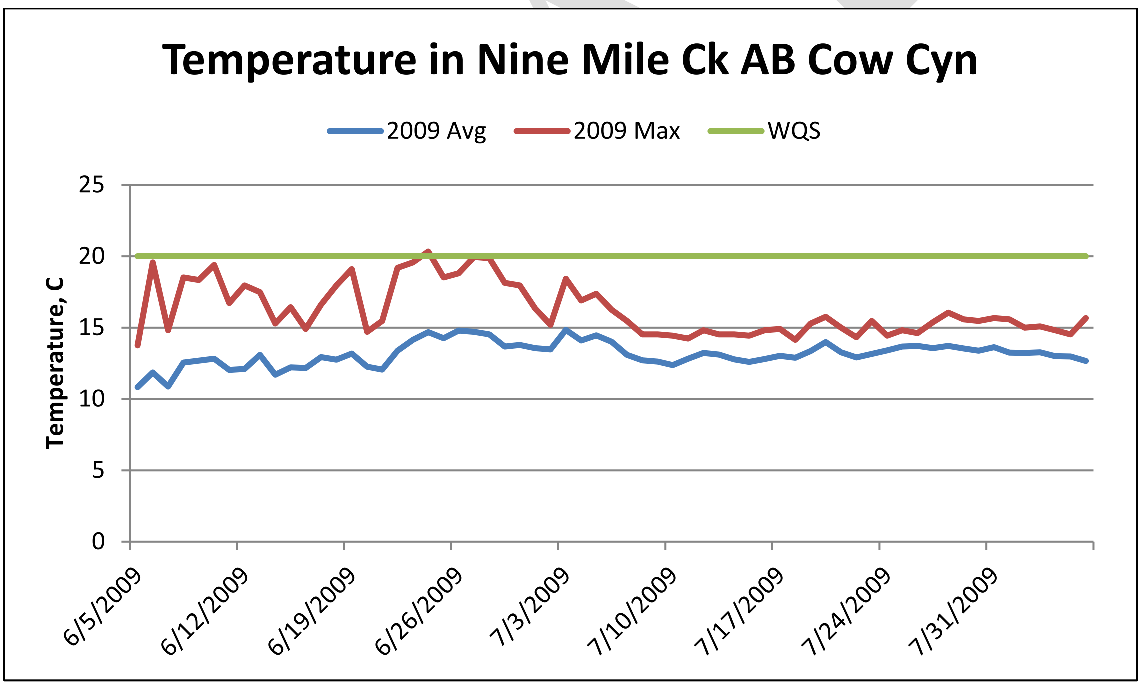
		5/28/2014	20.8
	4939121 Nine Mile Ck 0.5 mi AB Green River	6/18/2014	17.0
	4933310 Nine Mile Ck at Mouth	9/19/1977	11.3
		5/23/1978	13.5
		6/29/1978	28.0
		4/4/1979	4.5
		8/7/1979	21.0
		9/13/1979	14.5
		5/5/1982	10.0
		7/24/1985	23.3
		8/21/1986	24.0
		7/22/1987	18.4
		8/19/1988	19.7
		6/7/1989	20.8
		9/13/1989	18.0
		4/20/1992	19.7
		7/21/1993	22.9
		6/1/1995	13.9
		8/11/1995	19.4
		5/14/1996	22.1
		4/9/1997	6.5
		10/15/1997	9.6
		6/17/1998	9.2
		9/16/1998	21.2
		6/4/2009	17.0

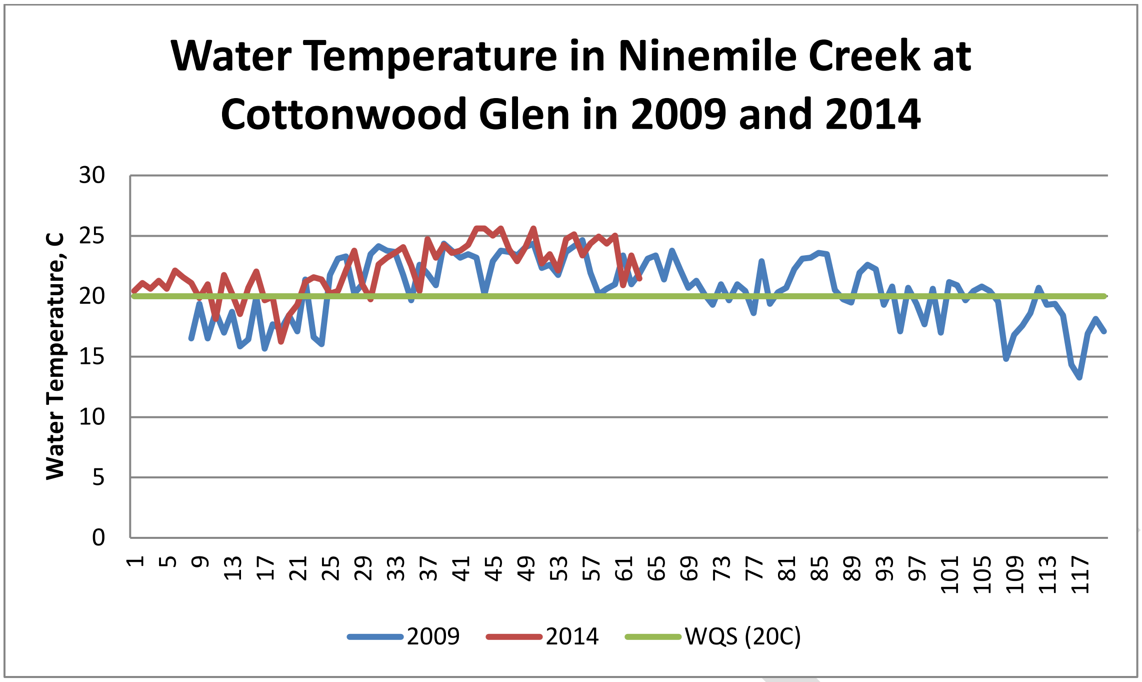
Continuous Temperature Data Graphs in Upper Nine Mile Creek Watershed






Temperature in Minnie Maud
2009 Avg
2009 Max
WQS
30
25
20
15
10
5
0
6/4/2009
6/11/2009
6/18/2009
6/25/2009
7/2/2009
7/9/2009
7/16/2009
7/23/2009
7/30/2009
8/6/2009
8/13/2009
8/20/2009
8/27/2009
9/3/2009
9/10/2009
9/17/2009
9/24/2009


Temperature in Nine Mile Ck AB Cow Cyn
2009 Avg
2009 Max
WQS
Temperature, C
25
20
15
10
5
0
6/5/2009
6/12/2009
6/19/2009
6/26/2009
7/3/2009
7/10/2009
7/17/2009
7/24/2009
7/31/2009


Water Temperature in Ninemile Creek at Cottonwood Glen in 2009 and 2014
Water Temperature, C
30
25
20
15
10
5
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101 105 109 113 117
2009
2014
WQS (20C)

Appendix C. Modeling Data and Spreadsheets

COMID	**Unique NHD "common identifier"**
REACHNAME	Group name to classify reach
TMDLREACHNAME	Group name to classify TMDL reach
CANOPY_AVG	The current average percent effective shade provided by riparian canopy cover
CANOPY_TARGET	The reachwide average percent effective shade target
CANOPY_DELTA	The difference between current canopy_AVG and Canopy_target
CD_KM	The canopy delta scaled (divided) by total reach length
WIDTH_M	The current average stream width (meters)
WIDTH_TARGET	The reachwide average stream width (meters) target
WIDTH_DELTA	The difference between width_m and width_target
WD_KM	The width delta scaled (divided) by total reach length
LENGTHKM	The length of the COMID in kilometers
LENGTHM	The length of the COMID in meters
CURRENT_EFFECTIVE_SHADED_AREA_M2	The current stream area of COMID effectively shaded
EXPECTED_EFFECTIVE_SHADED_AREA_M2	The target stream area of COMID expected to be shaded
EFF_SHADE_DELTA	The difference between current and expected effective shade
RIPAR_EXP_WIDTH	The expected riparian width
RIPAR_PLANT_NEEDS_ACRES	The amount of riparian plants required per acre
SmrLoadLWM	The May-September solar radiation watts/m2
SmrLD_Kw/m/day	The May-September solar radiation Kw/m/day
LoadCur	The current May-September solar radiation reaching the stream surface kWh/day
LoadExp	The expected May-September solar radiation reaching the stream surface kWh/day
LoadRed	The difference between current solar load and the expected future load
Comments	COMID comments from satellite imagery analysis

See attached Excel spreadsheets for modelling spreadsheets.