JORDAN RIVER WATERSHED *E. COLI* TMDL

Appendices

UTAH DEPARTMENT *of* ENVIRONMENTAL QUALITY

WATER QUALITY

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Appendix A: Big Cottonwood Creek Assessment Unit-1 *E. coli* TMDL

Waterbody Name	Big Cottonwood Creek -1
Waterbody / Assessment Unit (AU)	UT16020204-019_00
AU Description	Big Cottonwood Creek and tributaries from Jordan River to Big Cottonwood WTP
Impaired Beneficial Use	Infrequent primary contact recreation (2B)
Applicable Season	May through October
Defined Endpoint/Water Quality Standard	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL
Percent Reduction Needed	83%, based on a geometric mean of 1,243 MPN/100 mL calculated for 4992972 (Big Cottonwood Creek @ 300W) in the month of August.
Probable Sources	Stormwater, recreationists, pets, wildlife, canal diversions

Assessment Unit Description

The Big Cottonwood-1 Assessment Unit (AU) includes Big Cottonwood Creek from Salt Lake City's drinking water treatment plant at the mouth of Big Cottonwood Canyon as it flows 10 miles downstream to the confluence with the Jordan River. The AU (5.8 mi^2) falls within the cities of Cottonwood Heights, Holladay, Murray, and Millcreek Township in Salt Lake County. Land ownership is 97% privately owned and 3% federally owned. The Big Cottonwood Creek-1 AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) beneficial use due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2014 Integrated Report.

Table A-1. Impairment summary of the Big Cottonwood Creek-1 Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
Big Cottonwood Creek-1 UT16020204-019	*E. coli*	Infrequent primary contact recreation (2B)	2014–2022
	Macroinvertebrates* Maximum temperature*	Cold water aquatic life (3A)	2014–2022 2006–2022
*Will be addressed in future TMDLs			

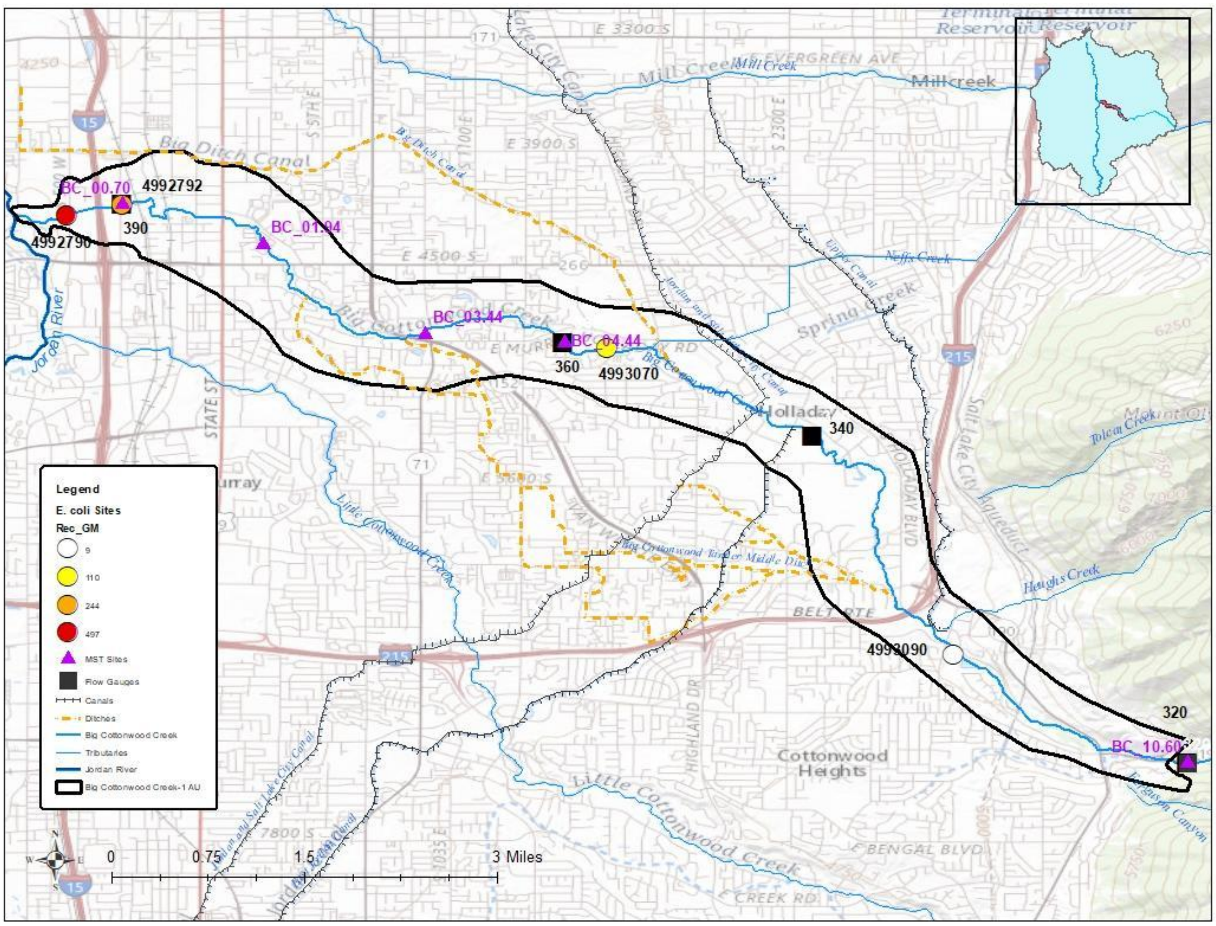

Figure A-1. Monitoring locations and hydrology of Big Cottonwood Creek-1 Assessment Unit.

Hydrology

Big Cottonwood Creek originates in two high mountain reservoirs (Twin Lakes and Lake Mary) at the top of Big Cottonwood Canyon and flows 25 miles through the canyon and Salt Lake Valley before joining the Jordan River (Figure A-1). It is the largest tributary to the Jordan River in terms of annual volume (Schwager and Cowley, 2000), with a mean flow of 51 cubic feet per second (cfs) during the TMDL period of record (2011–2021) at Salt Lake County Gauge #390 near the confluence with the Jordan River. Neffs, Tolcat, Heughs, and Ferguson tributaries augment flow to Big Cottonwood Creek via piped stormwater conveyance systems.

Big Cottonwood Canyon is predominantly managed by the Uinta-Wasatch-Cache National Forest, with strict watershed protection regulations enforced by Salt Lake City to protect this drinking water source. Hydrologic modifications of Big Cottonwood Creek within the canyon (Big Cottonwood Creek-2 AU) exist to support power production (Stairs Station and Granite Hydroelectric Power Plants) and drinking water treatment plants (Big Cottonwood Creek Water Treatment Plant).

Water below Salt Lake City's drinking water plant is treated and piped to the Salt Lake valley for use as municipal water or returned to the creek for downstream uses. Salt Lake City diverts up to 92% of the first 120 cfs of the stream flow for municipal purposes during the irrigation season and up to 98% during the non-irrigation season.

The first four miles of the Big Cottonwood Creek-1 AU are often dewatered in the late summer months due to diversions. Water is diverted from Utah Lake and pumped into the Jordan, Salt Lake, and East Jordan Extension canals (Figure A-1) that feed into Big Cottonwood Creek-1 to satisfy exchange agreements (MWDSLC 1982). During the non-irrigation season, instream flows below the canal inputs (Big Cottonwood Creek @ Cottonwood Lane, Gauge #340/East Jordan Canal Extension) increase due to groundwater and/or subsurface recharge.

The creek's hydrograph in the valley is highly altered due to the major diversions located near the mouth of Big Cottonwood Canyon. One hundred percent of the instream flow of Big Cottonwood Creek in this AU is either reduced or interrupted by hydrologic modifications even though the portion of the creek upstream of the AU experiences high spring runoff from snowmelt within the canyon (SLCo 2017).

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 95.77% of the land in the Big Cottonwood Creek-1 AU is developed (Figure A-2). The rest of the land cover in this AU is 3.76% natural (forest, grassland, wetlands, shrubland, and barren), 0.45% agricultural (pasture and crops) and 0.01% open water. Most of the riparian buffers along the main stem of Big Cottonwood Creek are developed/urban land use. There are no major agricultural operations within this AU. Developed open space is predominantly associated with parks and golf courses. The urban land cover is primarily residential and industrial.

Approximately 29% of the AU is covered by impervious surfaces from developed land use (NLCD). This level of impervious surface leads to increased runoff which results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase in this AU by 6% in 2040, which will likely result in an increase in impervious surfaces in this AU (SLCo 2017). See Section 5.3.1 in the main report for more information on the effects of impervious surfaces on pollutant loading.

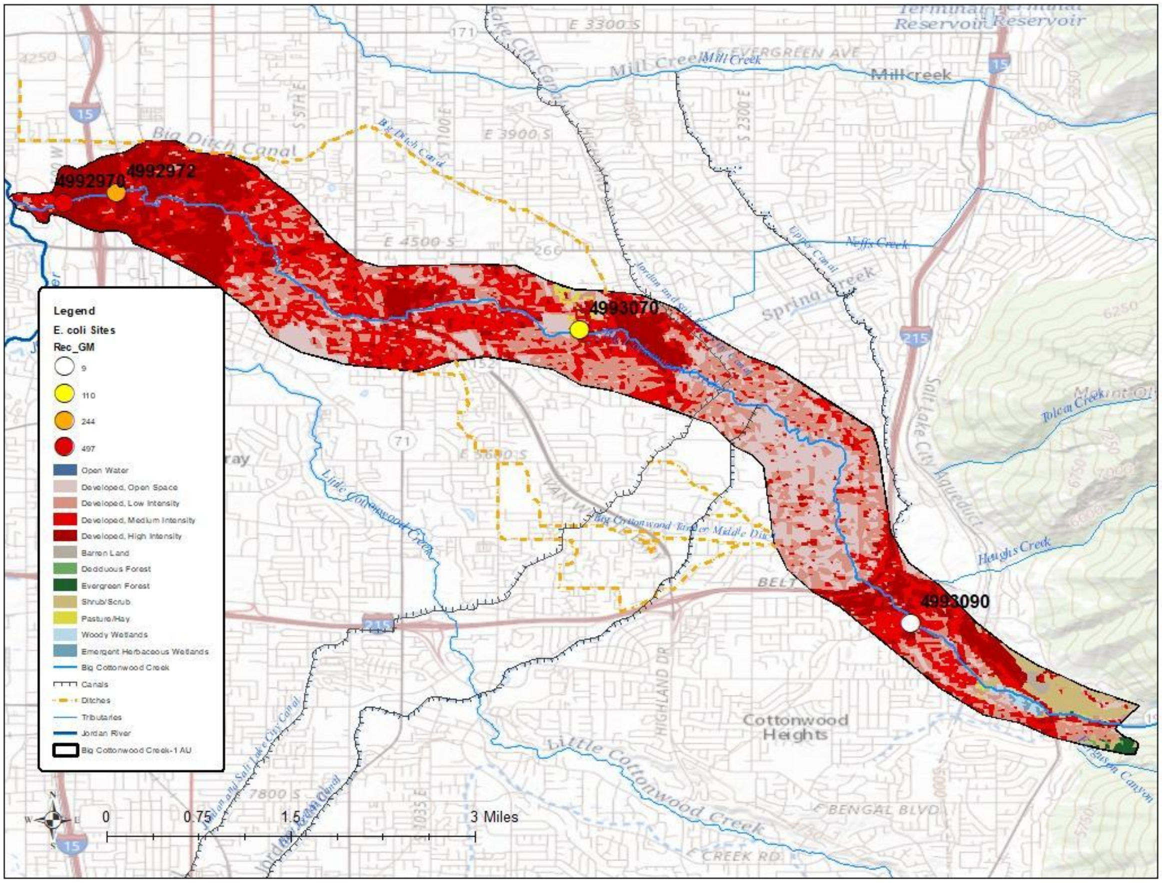

Figure A-2. Land cover (NLCD 2019) in Big Cottonwood Creek-1 Assessment Unit.

E. coli Data Summary

Four routine monitoring locations on Big Cottonwood Creek-1 were studied for spatial and temporal patterns of *E. coli* levels (Figure A-1). Samples were collected year-round at Big Cottonwood Creek at 300 West (4992972), Big Cottonwood Creek at Creekside Park (4993070), and Big Cottonwood Creek below Old Mill (4993090), with the latter two sites sampled from 2011–2021. Big Cottonwood Creek at 500 West (4992970) was sampled during the recreation season in 2009–2012, and again in 2018, before being dropped in favor of sampling Big Cottonwood Creek at 300 West (4992972).

The three most downstream sites had maximum *E. coli* concentrations that exceeded the laboratory test threshold of 2,420 MPN/100 mL (Table A-2). The recreational season (May–October) geometric means for these sites exceeded the recreational standard of 206 MPN/100 mL (Table A-2). The average *E. coli* concentration increased downstream, and Big Cottonwood Creek below Old Mill (4992970) and Big Cottonwood Creek at 300 West

(4992972) had overall geometric mean *E. coli* concentrations that exceeded 206 MPN/100 mL (Figure A-3). This indicates that sources of *E. coli* are more prevalent downstream of 4993090, a site that is often dry during the late summer due to upstream diversions.

Monthly geometric mean *E. coli* concentrations showed strong seasonal variation, with an increase during the recreation season in June–October at the three most downstream sites (Figure A-5). The most upstream site below Old Mill (4993090) is consistent across the months. The increase in concentration during the warmer months (April–October) also corresponds with the water delivery system to Big Cottonwood Creek-1 from the East Jordan Canal and the Jordan and Salt Lake Canal.

Table A-2. *E. coli* summary statistics for Big Cottonwood-1 Assessment Unit.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4992970/NA	Big Cottonwood Creek @ 500W	NA	6/2009 to 9/2018	24	144	497	497	2,420*	83	46
4992972/ BC_00.70	Big Cottonwood Creek @ 300W	Not meeting criteria	1/2017 to 10/2021	62	13	231	244	2,420*	56	19
4993070/ BC_04.73	Big Cottonwood Creek @ Creekside Park	Not meeting criteria	2/2011 to 10/2021	107	0.5**	104	110	2,420*	39	16
4993090/ BC_08.83	Big Cottonwood Creek below Old Mill	Insufficient data	2/2011 to 8/2021	53	0.5**	8	9	388	6	0

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL
** Used half the detection limit (1 MPN/100 mL) for samples with non-detects

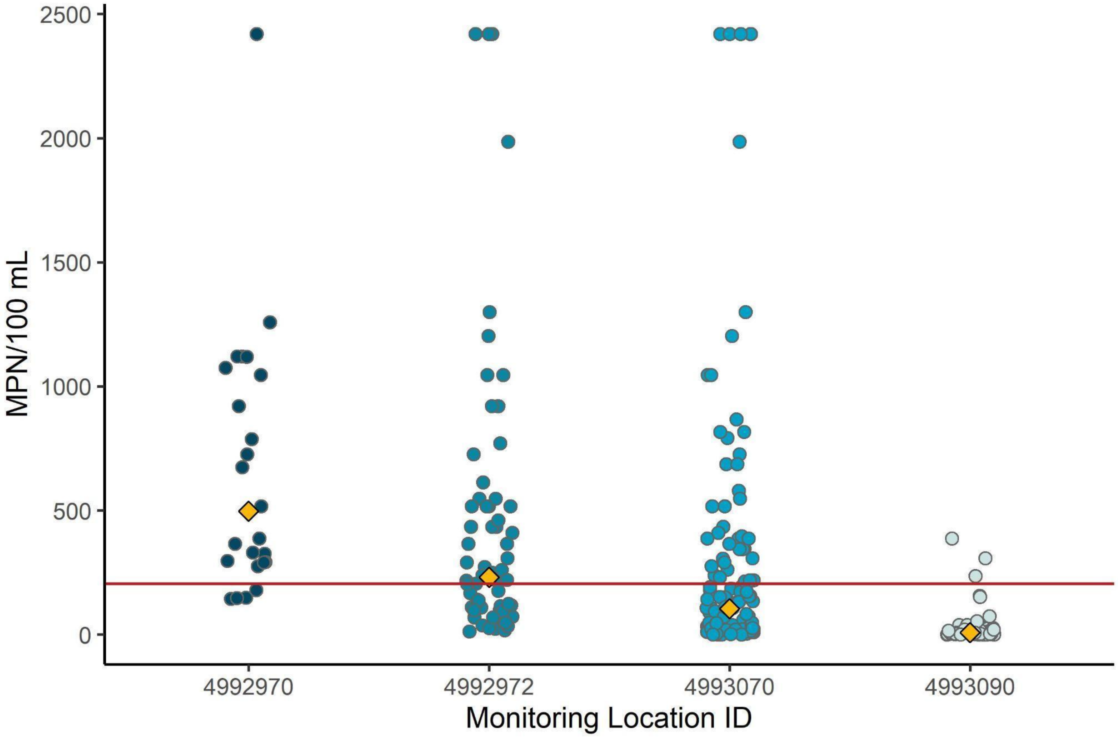

Figure A-3. ***E. coli*** **concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Big Cottonwood-1 Assessment Unit. Concentration points are "jittered," meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.**

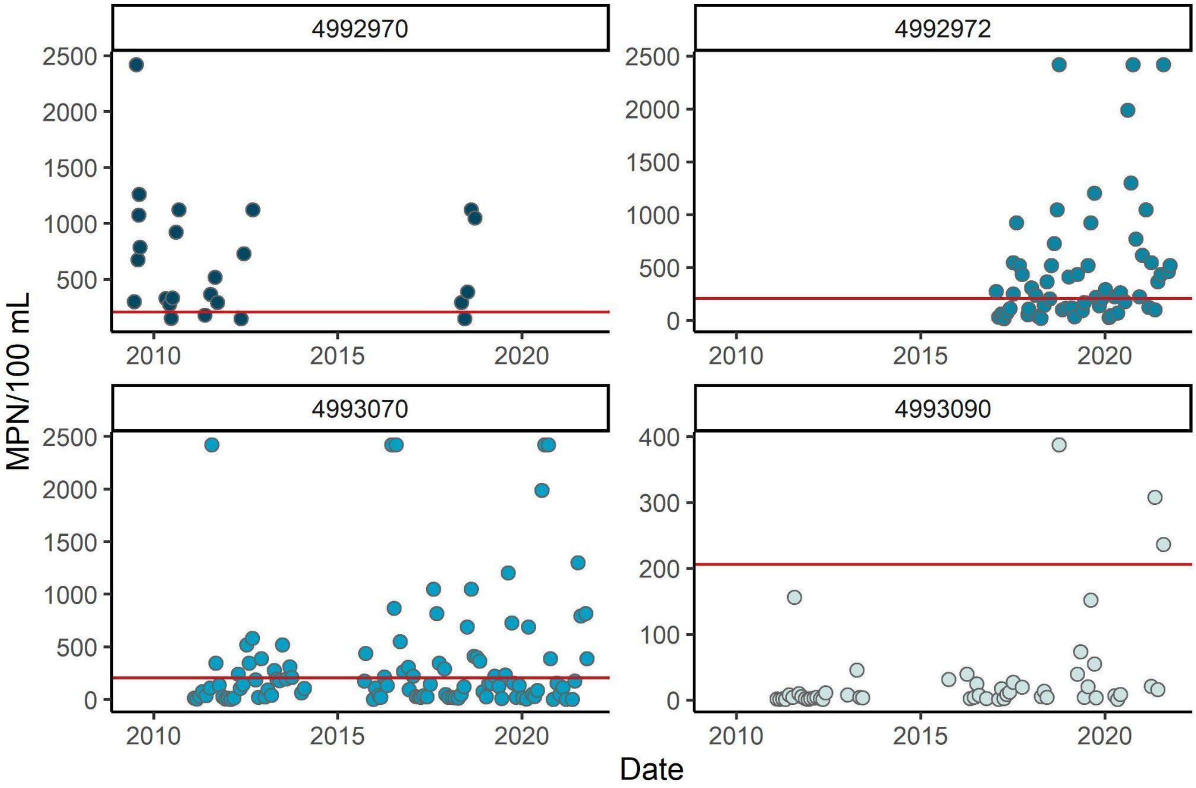

Figure A-4. ***E. coli*** **concentrations at each routine monitoring location through time within the Big Cottonwood Creek-1 Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).**

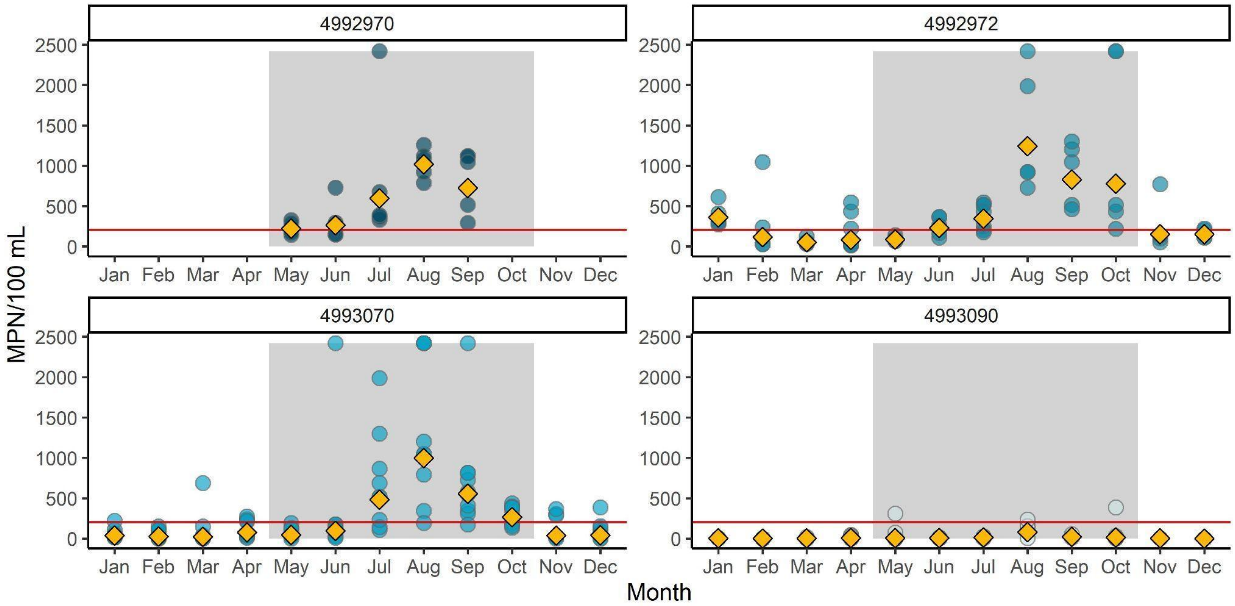

Figure A-5. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDCs), microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. Potential sources, and recommended implementation strategies to address them, are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curves

Load duration curves (LDCs) are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at the lower end of this AU (Big Cottonwood Creek at 300 West, Gauge #390). This site corresponds to the *E. coli* monitoring site Big Cottonwood Creek at 300 West (4992792) (Figure A-1). Flow data during the TMDL period of record (January 2011–September 2021) are summarized in Table A-3, Figure A-6, and Figure A-7. The daily mean flows are highest during May and June, which corresponds with spring runoff. Flow decreases in the late summer, mainly due to the upstream water diversions at the mouth of the canyon and general baseflow conditions. A large portion of Big Cottonwood Creek during this time period comes from diverted waters from exchange agreements (SLCo 2017).

Table A-3. Summary statistics for Big Cottonwood Creek at 300 West, Gauge #390 (4992972).

Gauge Name	SLCO Gauge Number/DWQ MLID	Drainage Area (mi^2)	Mean Flow (cfs)	Maximum Flow (cfs)
Big Cottonwood Creek at 300 West	390/4992972	78	51	713

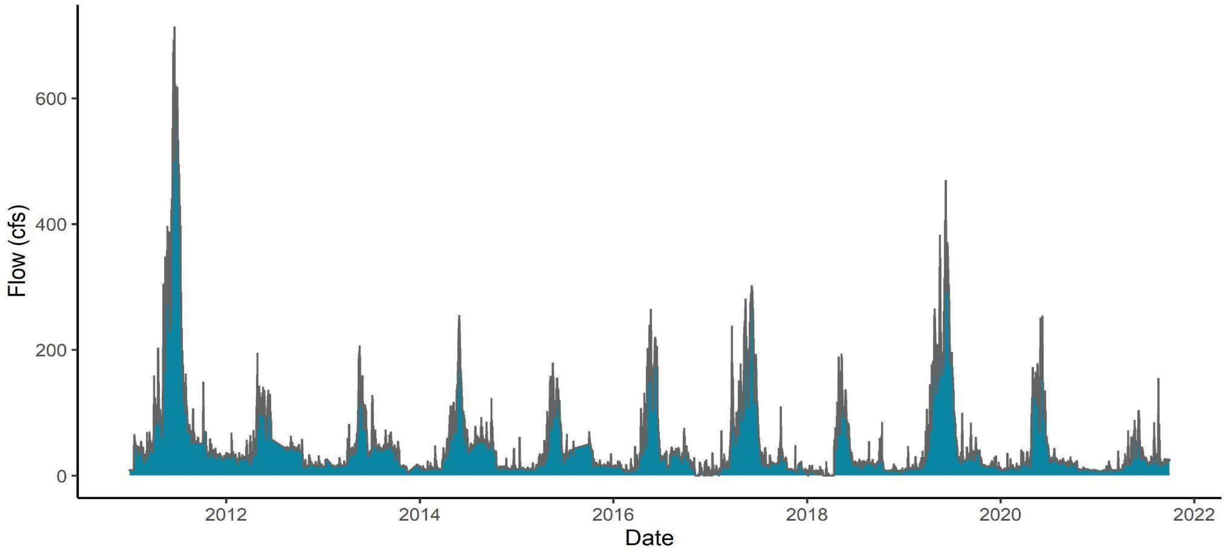

Figure A-6. Daily mean flows at Salt Lake County Gauge #390, Big Cottonwood Creek at 300 West (4992972) from January 1, 2011, to September 30, 2021.

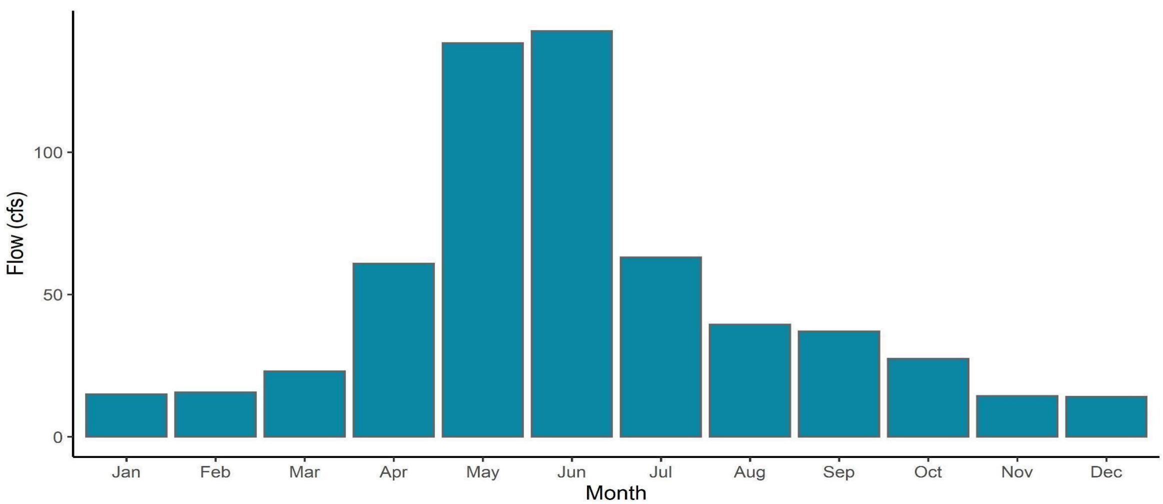

Figure A-7. Monthly means flows (cfs) at Salt Lake County Gauge #390, Big Cottonwood Creek at 300 West (4992972) from January 1, 2011, to September 30, 2021.

Using this site's corresponding *E. coli* and flow data, the LDC shows exceedances occurring at all flow regimes (Figure A-8). Exceedances of the TMDL threshold (solid line) in high-to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. These sources include point sources (low-flow conditions), onsite septic systems (dry flows), and riparian areas and impervious stormwater sources (mid-range). Upland stormwater and bank erosion are likely sources for the higher flow conditions. The percent of *E. coli* loading measurements that exceed the TMDL in each flow regime is provided in parentheses under each flow-regime label in Figure A-8. Load reductions are needed primarily in the mid-range flow regimes, indicating both point and nonpoint source *E. coli* loading in Big Cottonwood Creek-1 AU.

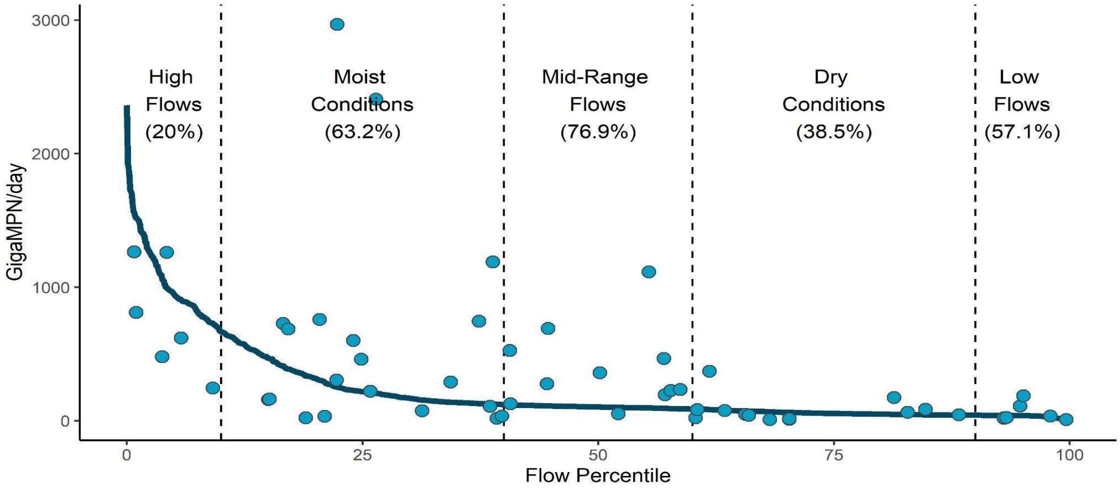

Figure A-8. Load duration curve for Big Cottonwood Creek at 300 West (4992972).

Microbial Source Tracking

Samples were collected once a month at four locations during July, August, and September of 2018–2020, resulting in approximately nine samples per site and a total of 35 samples collected (Figure A-9). All four MST markers (avian, human, canine, and ruminant) were detected at all four sampling locations in the AU. When the presence or absence of each marker was considered across all locations, avian was the most common at 91%. This means that of the 35 samples collected, 32 of them were positive for the avian marker. The human marker was present at 74%, canine at 51%, and ruminant at 37%. Three of the 35 samples exhibited no MST markers but had *E. coli* concentrations that exceeded 206 MPN/100mL, indicating that there may be other sources of fecal contamination in the environment not captured by the current suite of MST markers.

Determining the presence or absence of markers at each individual sampling location can also be useful for understanding areas in the watershed where sources may be contributing more or less to the impairment. Figure A-9 illustrates the presence/absence pattern of the four markers at each sampling location in the AU, as well as a sampling location just upstream of the AU boundary included for comparison. Most concerning is the steady increase in the presence of the human marker from upstream to downstream, since human contamination poses the greatest risk to human health. The pervasiveness of the avian marker throughout the reach is also of note. MST results for this AU highlight the need to focus on further identifying and controlling human and avian sources of fecal contamination through additional investigations and monitoring of stormwater outfalls and canals/ditches that discharge into Big Cottonwood Creek. More information on MST can be found in Section 5.3.3 in the main report.

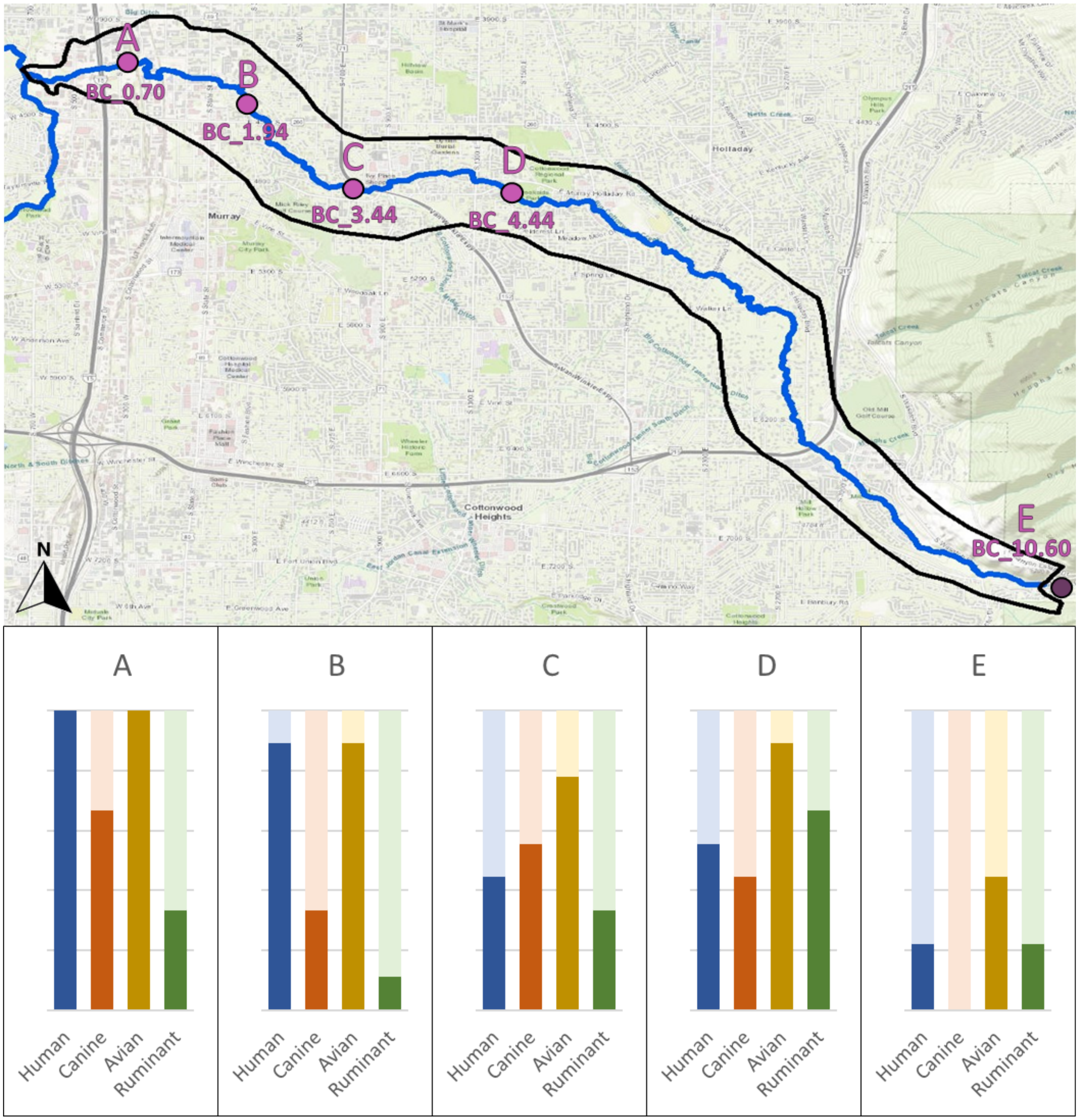

Figure A-9. The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades represent absence.

Source Assessment

The probable sources of *E. coli* in the Big Cottonwood Creek-1 AU come from both point and nonpoint sources based on the LDC analysis, MST results, data analysis, land-use patterns, and hydrologic information. Point sources are limited to stormwater runoff.

Nonpoint sources include onsite septic systems, irrigation canals, avian wildlife, domestic pets, wildlife/nuisance species, and recreationists/unhoused.

Table A-4 provides a list of specific potential point and nonpoint sources in the Big Cottonwood Creek-1 AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. For more information on each potential source, please see Chapter 5.1 and 5.2 in the main report.

Table A-4. Potential sources of *E. coli* contamination in Big Cottonwood Creek-1 Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	Yes	UTR000000		
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities, including Cottonwood Heights, Holladay, Murray, Millcreek, Salt Lake County	UTS000001		
		Utah Department of Transportation	UTS000003		
Nonpoint source	Onsite septic systems	Yes		Section 5.2.1	Table 8
	Agricultural: livestock	No		Section 5.2.2	
	Agricultural: canals	Yes			

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	
	Recreationists/ unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

While there are several Utah Pollutant Discharge Elimination System (UPDES) permitted discharges within Big Cottonwood Creek-1, municipal stormwater is the likely source of *E. coli* in this AU. This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the LDC that pointed to point sources during low-flow regimes, urbanized land uses and increased impervious surfaces in the valley, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see Chapter 5.1 in the main report for more information.

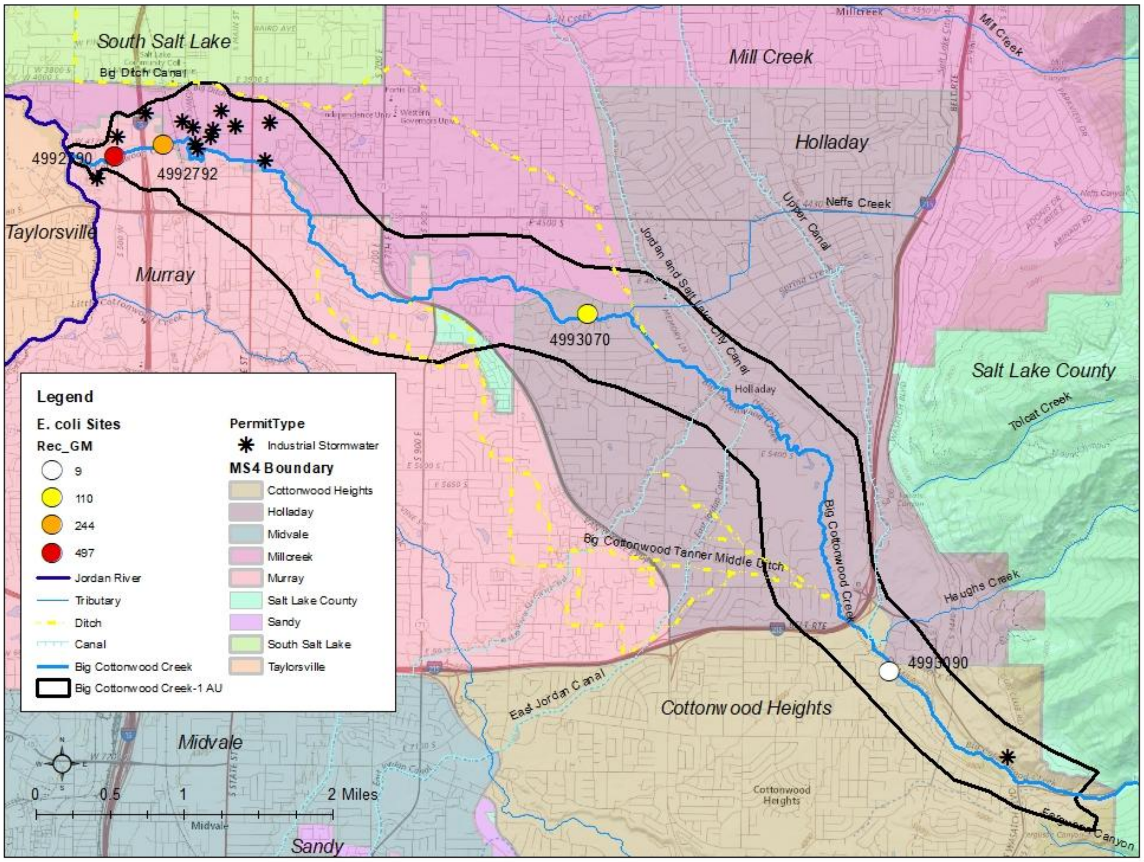

Figure A-10. Possible point sources of *E. coli* contamination within Big Cottonwood Creek-1 Assessment Unit.

Stormwater

Three potential sources of stormwater pollution (construction activities, industrial activities, and MS4s) occur within the Big Cottonwood Creek-1 AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were 25 construction and 15 industrial active stormwater permits in the Big Cottonwood Creek-1 AU. Most of the current industrial stormwater permits occur in the lower portion of the AU near the confluence with the Jordan River (Figure A-10, Table A-4). Construction permits are short-lived and change over time, and most industrial sites are not a potential source of *E. coli*. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Big Cottonwood Creek-1 AU by issuing MS4s permits to the corresponding municipalities whose stormwater discharges into the main stem of Big Cottonwood Creek. There are two MS4 permits (Jordan Valley Municipalities and Utah Department of Transportation) applicable to this AU. The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. Salt Lake County and the cities of Cottonwood Heights, Holladay, Murray, and Millcreek have jurisdictional boundaries in the AU (Figure A-10). The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the state. UDOT's Region 2 geographical area covers the Wasatch Front.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Table A-4 provides a list of specific potential point and nonpoint sources in the Big Cottonwood Creek-1 AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. Please see Chapter 5.1 and 5.2 in the main report for more information on each potential source.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Big Cottonwood Creek-1 AU include humans, wildlife, agricultural canals, and dogs (Figure A-11). Please see Chapter 5.2 in the main report for more information on nonpoint sources.

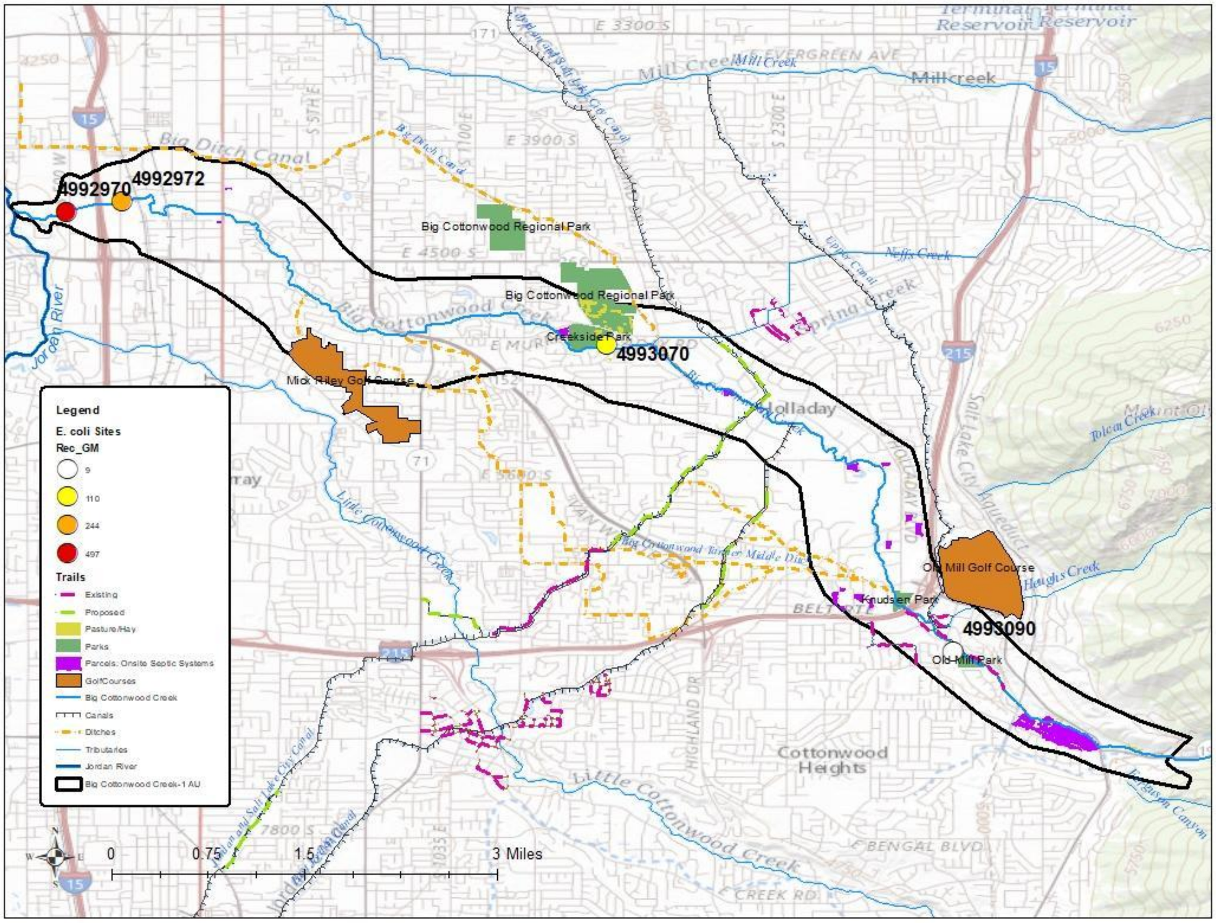

Figure A-11. Possible nonpoint sources of *E. coli* contamination within Big Cottonwood Creek-1.

Onsite Septic Systems

According to the Salt Lake County’s Assessor's Office, there are 29 onsite septic system parcels within this AU as of 2021. These sites are mostly clustered in the upper section of the Big Cottonwood Creek-1 AU. Most parcels associated with this reach of Big Cottonwood Creek are sewered. There are no large underground wastewater disposal systems in this area. *E. coli* loading from failing onsite septic systems is assumed to be minimal in this AU since the Old Mill monitoring site (4993090) below the parcels is not impaired. Please see Chapter 5.2.1 in the main report for more information on onsite septic systems and Chapter 7 on suggested BMPs.

Agricultural Activity

Livestock and grazing practices within the Big Cottonwood Creek-1 AU are minimal (<1% land use) and are not considered to be a significant source. However, canals delivering Utah Lake water to the local irrigators through exchange agreements with Salt Lake City could be a possible source of contamination. Though the canal source water (Utah Lake outlet) is not currently impaired for *E. coli*, outfalls and/or runoff with elevated *E. coli* concentrations could drain into the canals between their intake at the Jordan River Narrows and the outlet at Big Cottonwood Creek.

Recreation, Pets, and Nuisance Wildlife

Big Cottonwood Creek flows through several parks and open space areas. Based on the MST results for this AU, nonpoint sources of *E. coli* originate from human, avian, ruminant, and canine sources. There is an increased prevalence of all four markers downstream of the Big Cottonwood Creek below Old Mill (4993990) monitoring location near the mouth of the canyon, indicating that *E. coli* sources increase once the creek reaches the more urbanized land uses within the valley.

MST results show that the avian marker is the most prevalent throughout the AU. Parks, stormwater detention basins, and ponds in golf courses can attract waterfowl and other avian species and cause them to congregate. Nuisance species management is a requirement as part of the MS4 UPDES permit.

There are several parks (Old Mill, Knudsen, Creekside, and Big Cottonwood Creek Regional) along the main stem utilized by humans and their pets. Local ordinances require all dogs to be on a leash at these parks. There are no off-leash dog parks within this AU. However, a 2016 survey for Cottonwood Heights Trails Master Plan noted that the detention pond at the Old Mill Park served as an unofficial wading pool for dogs; this has since been prohibited. MST data shows that human-specific markers were found throughout this AU. There are hiking trails along the main stem of Big Cottonwood Creek (between Old Mill and Knudsen), as well as the Jordan and Salt Lake canal. Those areas could contribute to the *E. coli* loading from both recreationists and their pets. Pet waste may also be coming from stormwater runoff from private residences.

There are two flood-control basins along Big Cottonwood Creek operated and maintained by Salt Lake County Flood Control (SLCo 2017). The Old Mill pond near the canyon mouth is a detention basin to capture debris and sediment during storms and spring runoff. The Creekside Park detention basin downstream of the Old Mill collects and stores water when stormwater conveyance systems are overwhelmed during peak flows. Efforts could be taken to minimize nuisance wildlife at all these locations.

Please see Table 8 in the main report for suggested BMPs to employ to manage these particular nonpoint sources of *E. coli* contamination.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Big Cottonwood Creek-1 AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Appendix B. Little Cottonwood Creek-1 Assessment Unit *E. coli* TMDL

Waterbody Name	Little Cottonwood Creek -1
Waterbody / Assessment Unit (AU)	UT16020204-021
AU Description	Little Cottonwood Creek and tributaries from Jordan River confluence to Metropolitan WTP
Impaired Beneficial Uses	Infrequent primary contact recreation (2B)
Applicable Season	May through October
Defined Endpoint/Water Quality Standard	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL
Percent Reduction Needed	74%, based on a geometric mean of 792 MPN/100 mL calculated for 4993580 (Little Cottonwood Creek 4900 South 600 West SLC) in the month of August.
Probable Sources	Stormwater, recreationists, pets, wildlife, canal diversions

Assessment Unit Description

The Little Cottonwood-1 Assessment Unit (AU) includes Little Cottonwood Creek, which flows from the Metropolitan Water District of Salt Lake and Sandy Treatment plant at the mouth of Little Cottonwood Canyon 9.7 miles downstream to the confluence with the Jordan River. The AU (6.3 mi²) includes portions of the cities of Cottonwood Heights, Sandy, Midvale, and Murray, and is entirely within Salt Lake County. The land is 100% privately owned. The Little Cottonwood-1 AU was included on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B infrequent primary contact recreation beneficial use due to elevated levels of *E. coli*. The AU was originally listed in the 2014 Integrated Report.

Table B-1. Impairment summary of the Little Cottonwood Creek-1 Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
UT16020204-021	*E. coli*	Infrequent primary contact recreation (2B)	2014–2022
	Cadmium*	Cold water aquatic life (3A)	2014–2022
	Macroinvertebrates*		2008–2022
	Temperature*		2006–2022
	Total dissolved solids*	Agriculture (4)	2006–2022
* Will be addressed in future TMDLs			

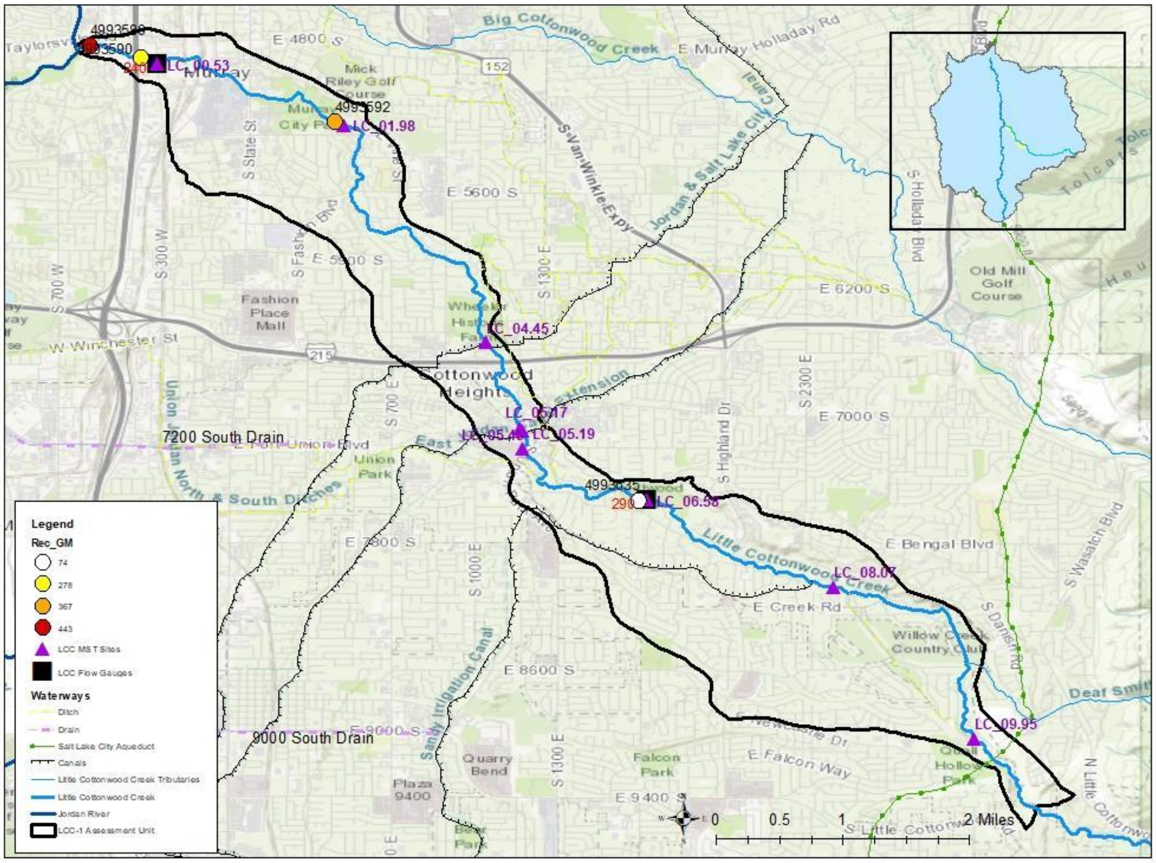

Figure B-1. Monitoring locations and hydrology of Little Cottonwood Creek-1 Assessment Unit.

Hydrology

Little Cottonwood Creek originates in Albion Basin at Cecret Lake and flows 22 miles before reaching the Jordan River. The headwaters and upper reaches are managed by the Uinta-Wasatch-Cache National Forest and have strict watershed protection regulations enforced by Salt Lake City to protect this drinking water source. The entire Little Cottonwood Creek basin drains approximately 46 mi² of forested and developed landscape. It is the second largest contributor in terms of volume (46,000 ac-ft) per year to the Jordan River, second to Big Cottonwood Creek. It had a mean flow of 37 cubic feet per second (cfs) during the TMDL period of record (2011–2021) at Salt Lake County Gauge #290 near the confluence with the Jordan River. Though this creek experiences high spring runoff associated with snowmelt within the canyon, the Little Cottonwood Creek-1 AU hydrograph lower in the valley is flattened due to major diversions near the mouth of Little Cottonwood Canyon.

Figure B-1 shows the inputs and outputs of this complex hydrologic system. One hundred percent of the instream flow of Little Cottonwood Creek in this AU is impacted by hydrologic modifications (SLCo 2017). Channelization, stormwater conveyance systems, diversions, and rip-rapped streambanks are common throughout the AU. There are two major hydrologic modifications of Little Cottonwood Creek in the canyon upstream from the impaired AU: a hydroelectric power plant (Columbus Power Plant) operated by the city of Murray, and a drinking water plant (Little Cottonwood Water Drinking Plant) managed by the Metropolitan Water District of Salt Lake and Sandy.

Murray City's Columbus Hydroelectric Power Plant, located at the mouth of the canyon, does not have a Federal Energy Regulatory Commission (FERC) permit due to its small size, and as a result does not need to maintain any minimum instream flows in the main channel. In base flow regimes (July–April), the plant completely dewaters Little Cottonwood Creek. The Little Cottonwood Water Treatment Plant diverts and treats approximately 143 million gallons per day from the power plant tailrace, Little Cottonwood Creek, and Salt Lake City Aqueduct for culinary purposes. The reach directly below these two major diversions is dewatered during the non-irrigation season.

As Little Cottonwood Creek enters the Little Cottonwood-1 AU (valley floor), it becomes a naturally losing stream reach. Deaf Smith Fork discharges to this losing reach, as do springs that increase the flow several miles downstream of the mouth of the canyon near Crestwood Park (Gerner and Waddell 2003).

During the irrigation season (April-October), exchange agreements allow Salt Lake City to use high-quality mountain stream water to address municipal demands, while local agricultural producers switch to using lower quality Utah Lake/Jordan River water for irrigation (SLCo 2017). Salt Lake City diverts Utah Lake/Jordan River water from the Jordan River Narrows through both the East Jordan Canal and Jordan and Salt Lake Canal into Little Cottonwood Creek to fulfill these exchange agreements (Figure B-2).

Figure B-2. Jordan and Salt Lake City Canal crossing Little Cottonwood Creek (USGS 2011).

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 98.02% of the land in Little Cottonwood Creek-1 AU is developed (Figure B-3). The rest of the land cover in this AU is 1.86% natural (i.e., forest, grassland, wetlands, shrubland, and barren), 0.08% agricultural (pasture and crops), and 0.04% open water. Most of the riparian buffers along the main stem of Little Cottonwood Creek are characterized by developed/urban land use. There are no major agricultural operations within this AU. Developed open space is predominantly associated with parks and golf courses. Urban land cover is primarily residential and industrial.

Approximately 39% of the AU is covered by impervious surfaces from developed land use (NLCD). This level of impervious surface leads to increased runoff and results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase in this AU by 20% in 2040 (SLCo 2017), which will result in an increase in the impervious surfaces in this AU. See Section 5.3.1 in the main report for more information on the effects of impervious surfaces on pollutant loading.

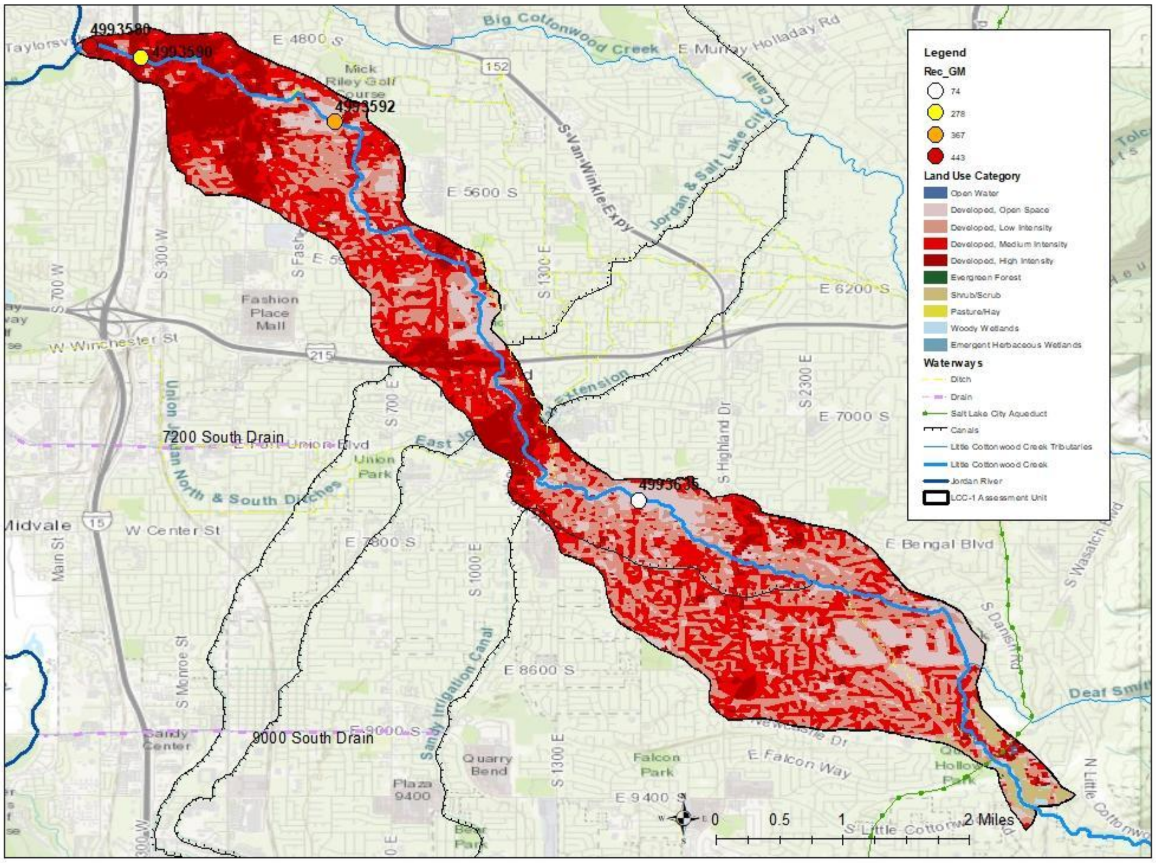

Figure B-3. Land cover in Little Cottonwood Creek-1 Assessment Unit (2019)

E. coli Data Summary

Four routine monitoring locations in Little Cottonwood Creek-1 were studied for spatial and temporal patterns of *E. coli* levels (Figure B-1). Little Cottonwood Creek at 4900 South 600 West (4993580) was sampled during the recreation season from 2009–2012 and in 2018, while the other three sites were sampled year-round 2012–2021. All three of the downstream sites had a maximum *E. coli* concentration that exceeded the laboratory test threshold of 2,420 MPN/100 mL. The recreation season geometric means for these sites exceeded 206 MPN/100 mL between 56–75% of the time (Table B-2).

The average *E. coli* concentration increased from the upstream to downstream sites (Figure B-4). The most upstream site in the AU, Little Cottonwood Creek at Green Lane (4993635), is often dry during late summer due to upstream diversions and is not impaired, which indicates sources of *E. coli* are primarily downstream of this site.

When aggregated by month, geometric mean *E. coli* concentrations varied seasonally, increasing in June–October at the three most downstream sites (Figure B-6). The Green Lane site (4993635) was fairly consistent across the months. An increase in concentration during the warmer months corresponded with both the recreation season (May–October) and the water delivery system to these lower reaches (April–October) from the East Jordan Canal and Jordan and Salt Lake Canal.

Table B-2. *E. coli* summary statistics for Little Cottonwood-1 Assessment Unit.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4993580 / NA	Little Cottonwood Creek at 4900 South 600 West SLC	NA	05/2009 to 09/2018	24	40	443	443	1,414	75	33
4993590 / LC_00.53	Little Cottonwood Creek below 300 West	Insufficient data	01/2017 to 10/2021	60	3	121	278	2,420*	42	12
4993592 / LC_01.98	Little Cottonwood Creek at Murray Park	Not meeting criteria	02/2011 to 10/2021	108	15	230	367	2,420*	56	22
4993635 / LC_06.58	Little Cottonwood Creek at Green Lane Xing	Meeting criteria	02/2011 to 10/2021	106	0.5**	28	74	2,420*	16	6

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL
** Used half the detection limit (1 MPN/100 mL) for samples with non-detects

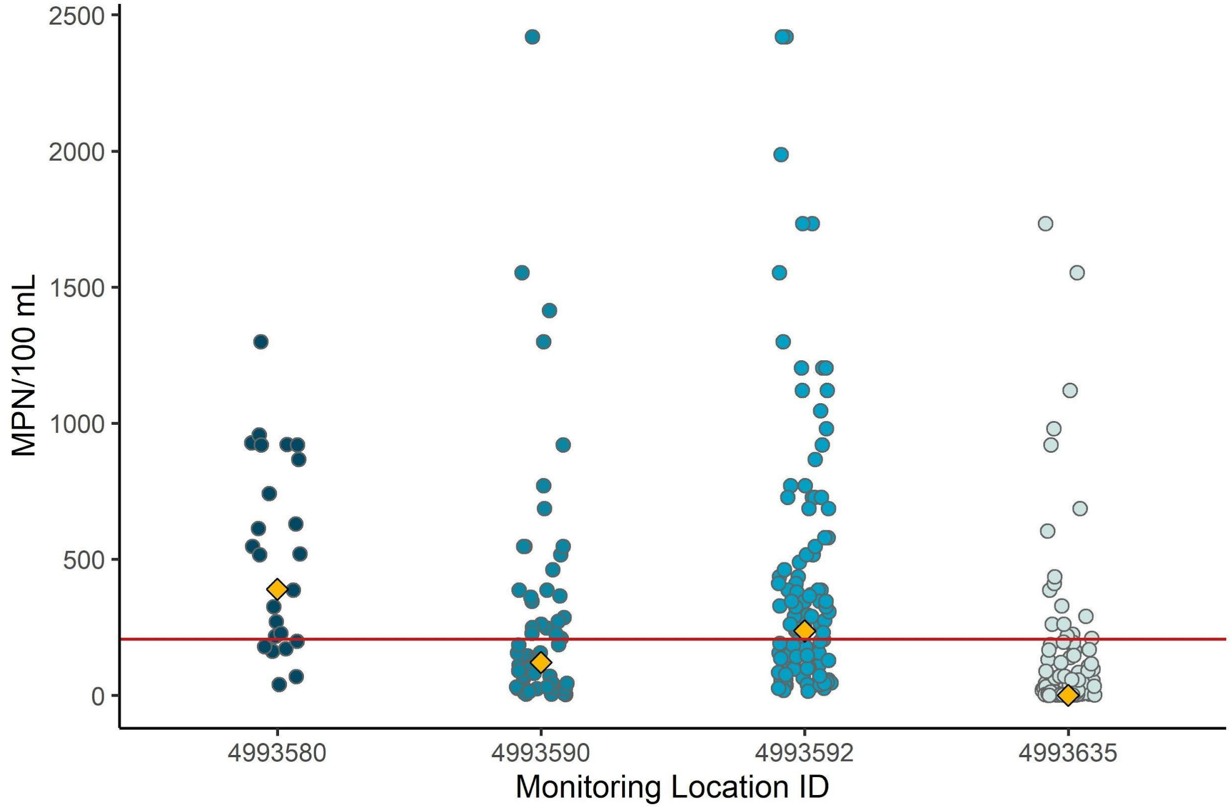

Figure B-4. *E. coli* concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Little Cottonwood-1 Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

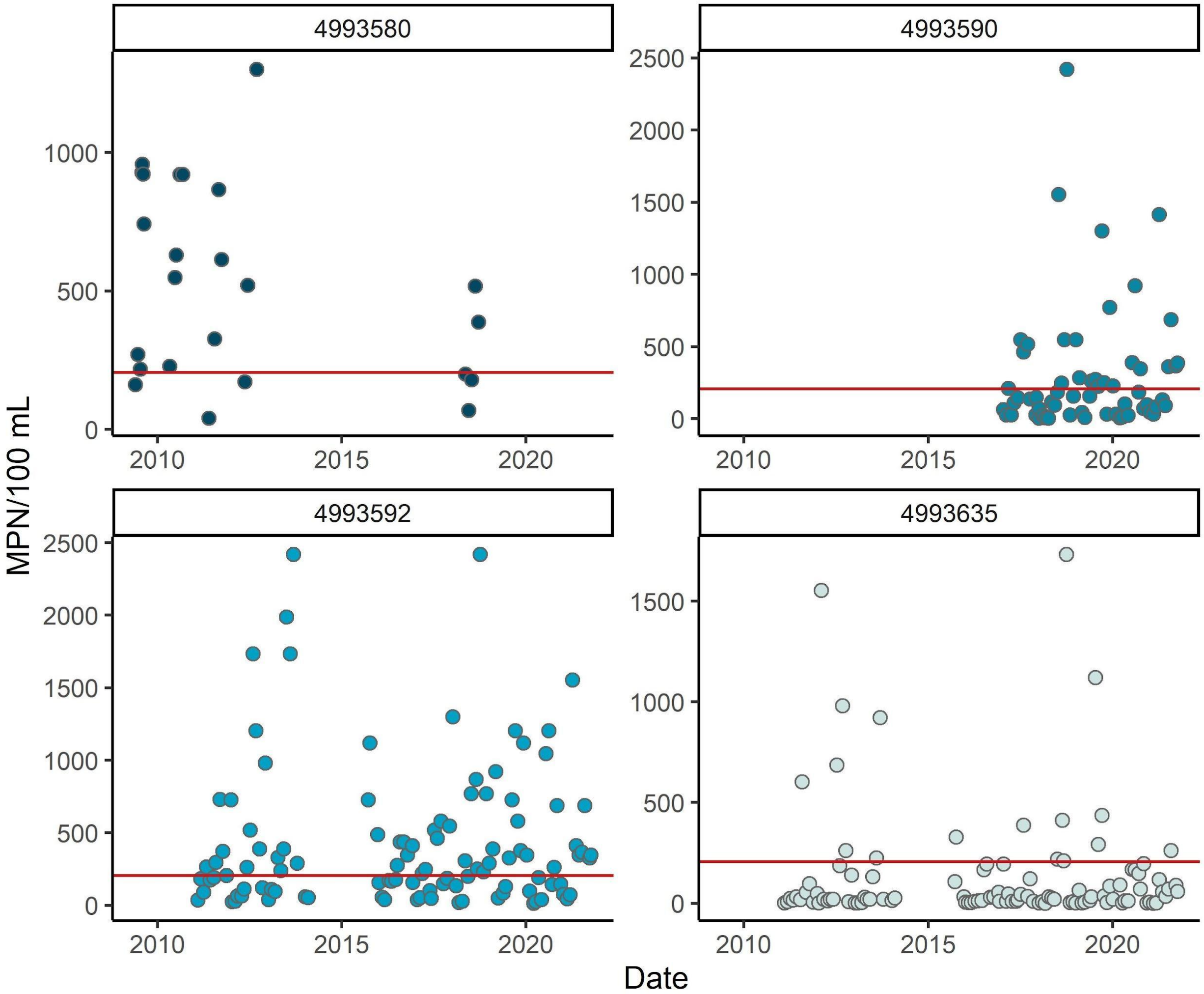

Figure B-5. *E. coli* concentrations at each routine monitoring location through time within the Little Cottonwood Creek-1 Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

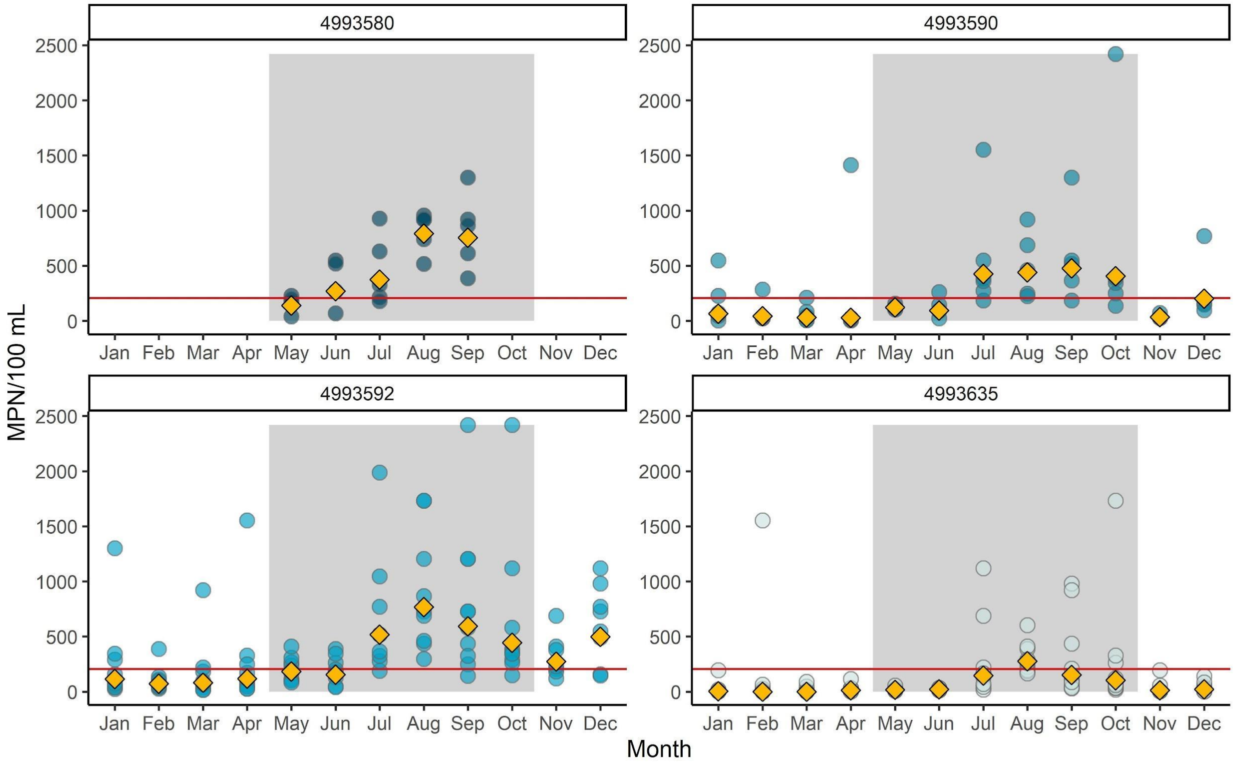

Figure B-6. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDCs), microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. Potential sources and recommended implementation strategies to address them are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curves

Load duration curves (LDCs) are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at the lower end of this AU (Little Cottonwood Creek at 300 West, Gauge #290). This site corresponds to an *E. coli* monitoring station (4993590) (Figure B-1). Flow data during the TMDL period of record (January 2011–September 2021) are summarized in Table B-3, Figure B-7, and Figure B-8. The daily mean flows are higher during May and June, which corresponds to spring runoff and irrigation season. Flow decreases in the late summer mainly due to the upstream water diversions at the mouth of the canyon and general baseflow conditions. A large portion of Little Cottonwood Creek comes from diverted waters from exchange agreements during this time period (SLCo 2017).

Table B-3. Summary statistics for Little Cottonwood Creek at 300 West, Gauge #290 (4993590).

Gauge Name	SLCO Gauge Number/DWQ MLID	Drainage Area (mi^2)	Mean Flow (cfs)	Maximum Flow (cfs)
Little Cottonwood Creek at 300 West	290/4993590	46	37	769

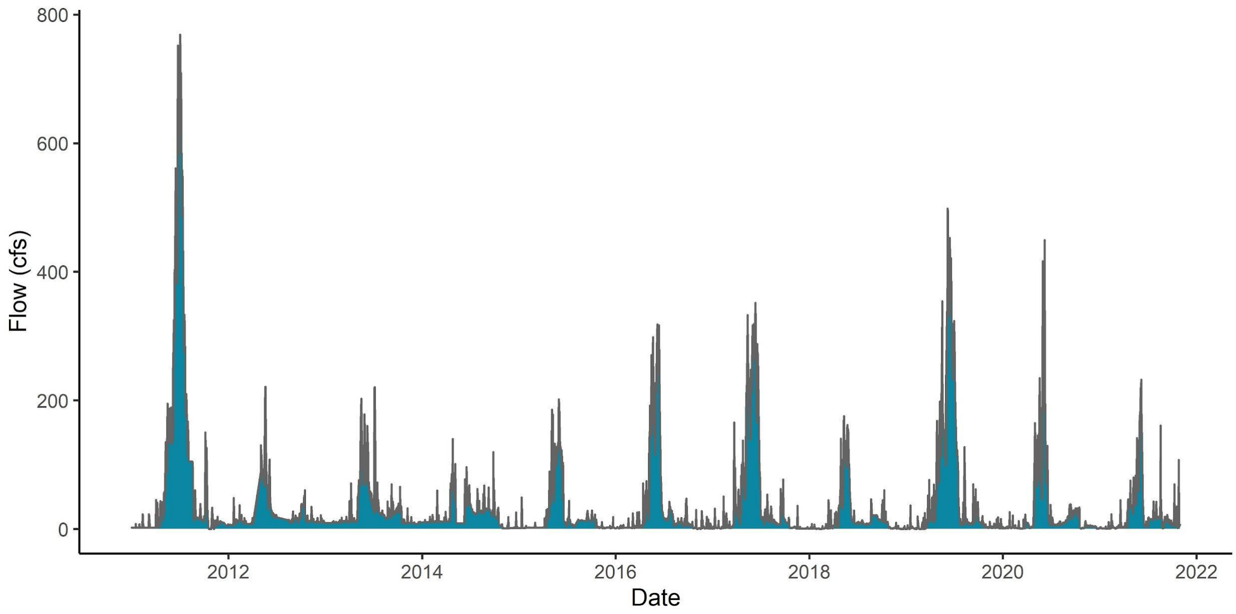

Figure B-7. Daily mean flows at Salt Lake County Gauge #290, Little Cottonwood Creek at 300 West (4993590) from January 1, 2011, to September 30, 2021.

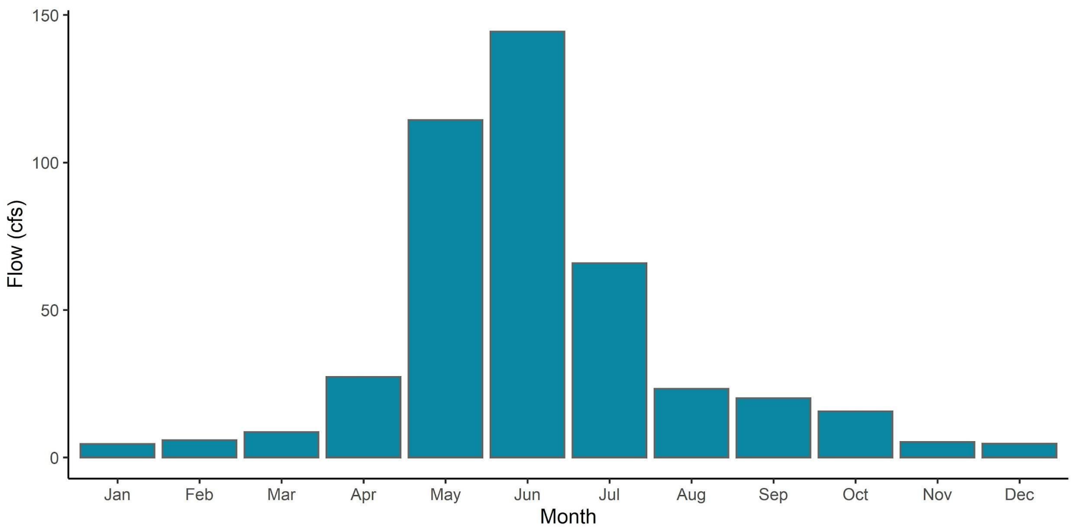

Figure B-8. Monthly mean flows (cfs) at Salt Lake County Gauge #290, Little Cottonwood Creek at 300 West (4993590) from January 1, 2011, to September 30, 2021.

Using this site's corresponding *E. coli* and flow data, the LDC shows exceedances occurring at all flow regimes (Figure B-9). Exceedances of the TMDL threshold (solid line) in high to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. These sources include point sources (low-flow conditions), onsite septic systems (dry flows), and riparian areas and impervious stormwater sources (mid-range). Upland stormwater and bank erosion are likely sources during higher flow conditions. The necessary load reduction by flow regime is provided in parentheses under each flow-regime label in Figure

B-9. Most of the reductions are needed in the mid-range flow regimes at 67%, indicating that Little Cottonwood Creek is dominated by both point and nonpoint source delivery methods of *E. coli* loading.

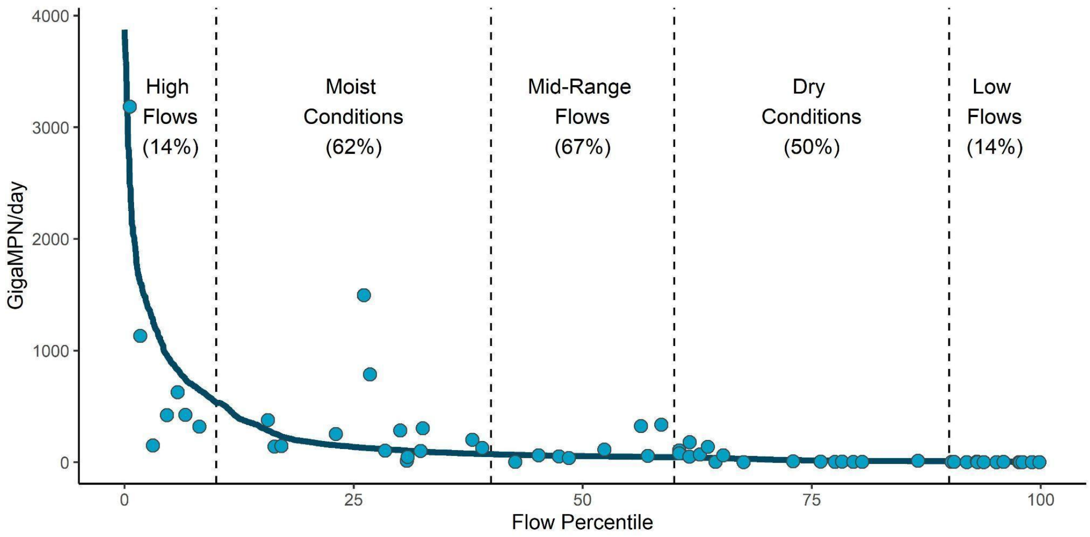

Figure B-9. Load duration curve for Little Cottonwood Creek at 300 West (4993590).

Microbial Source Tracking

Samples were collected once a month at nine locations during July, August, and September in 2019–2020, resulting in approximately six samples per site and a total of 56 samples collected (Figure B-10). All four MST markers were detected at all nine sampling locations in the AU. When the presence or absence of each marker was considered across all locations, avian was the most common at 91%, meaning of the 56 samples collected, 51 of them were positive for the avian marker. The human marker was present at 50%, canine at 46%, and ruminant at 45%. Three of the 56 samples exhibited no MST markers, but two of those samples had *E. coli* concentrations that exceeded the criterion of 206 MPN/100mL, indicating that there may be other sources of fecal contamination in the environment not captured by the current suite of MST markers.

Determining the presence or absence of markers at each individual sampling location can also be useful for understanding areas in the watershed where sources may be contributing more or less to the impairment. Figure B-10 illustrates the presence/absence pattern of the four markers at each sampling location in the AU, as well as a sampling location just upstream of the AU boundary included for comparison. Site D represents a combination of two sites— LC_05.17 and LC_05.19—since results were similar and the sampling locations were in close proximity to one another. The human and canine markers were not present upstream of the AU but did increase steadily downstream. The avian marker is almost 100% at all sites, both in and upstream of the AU. Implementation strategies should focus primarily on controlling human and avian sources, including additional monitoring of stormwater outfalls and irrigation canal flows to pinpoint sources. More information on MST can be found in [Section 5.3.3](#) in the main report.

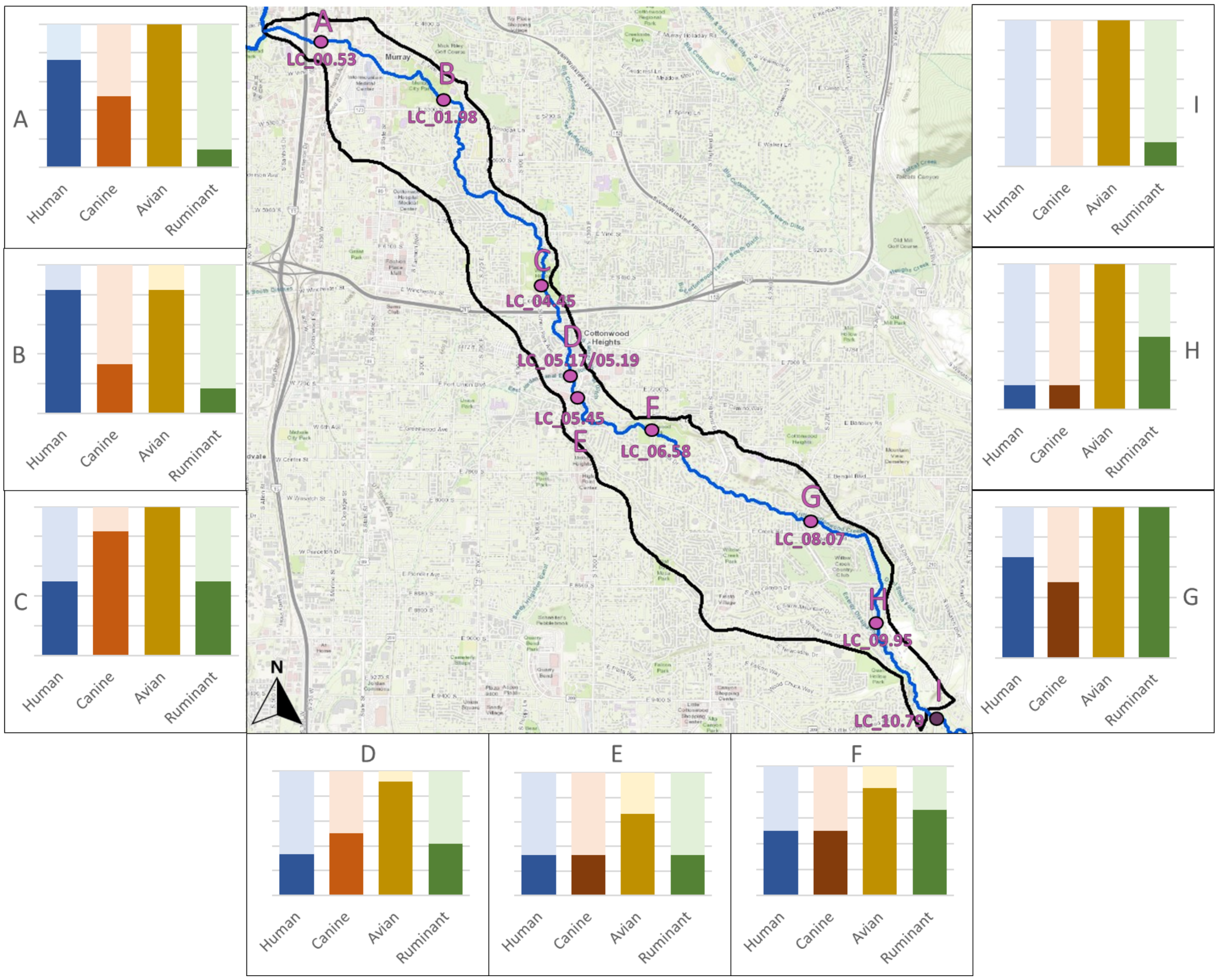

Figure B-10. The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades represent absence.

Source Assessment

The probable sources of *E. coli* in the Little Cottonwood Creek-1 AU come from both point and nonpoint sources based on the data analysis, LDC analysis, MST results, land-use patterns, and hydrology. Point sources are limited to stormwater runoff. Nonpoint sources include onsite septic systems, irrigation canals, avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused.

Table B-4 provides a list of specific potential point and nonpoint sources in the Little Cottonwood Creek-1 AU. Suggested BMPs for implementation by source are provided in

Table 8 and Table 9 in the main report. For more information on each potential source, please see Chapter 5.1 and 5.2.

Table B-4. Potential sources of *E. coli* contamination in Little Cottonwood Creek-1 Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
Point Source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	Yes	UTR000000		
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities, including Cottonwood Heights, Murray, Midvale, Sandy, Salt Lake County	UTS000001		
		Utah Department of Transportation	UTS000003		
Nonpoint Source	Onsite septic systems	Yes		Section 5.2.1	Table 8
	Agricultural: livestock	No		Section 5.2.2	
	Agricultural: canals	Yes			
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
	Recreationists/ unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

While there are several Utah Pollutant Discharge Elimination System (UPDES) permitted discharges within the Little Cottonwood Creek-1 Assessment Unit, municipal stormwater is the likely source of *E. coli* in this AU (Figure B-11). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the LDC that pointed to point sources during low-flow regimes, urbanized land uses and increased impervious surfaces in the valley, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. For more information, please see Chapter 5.1 in the main report.

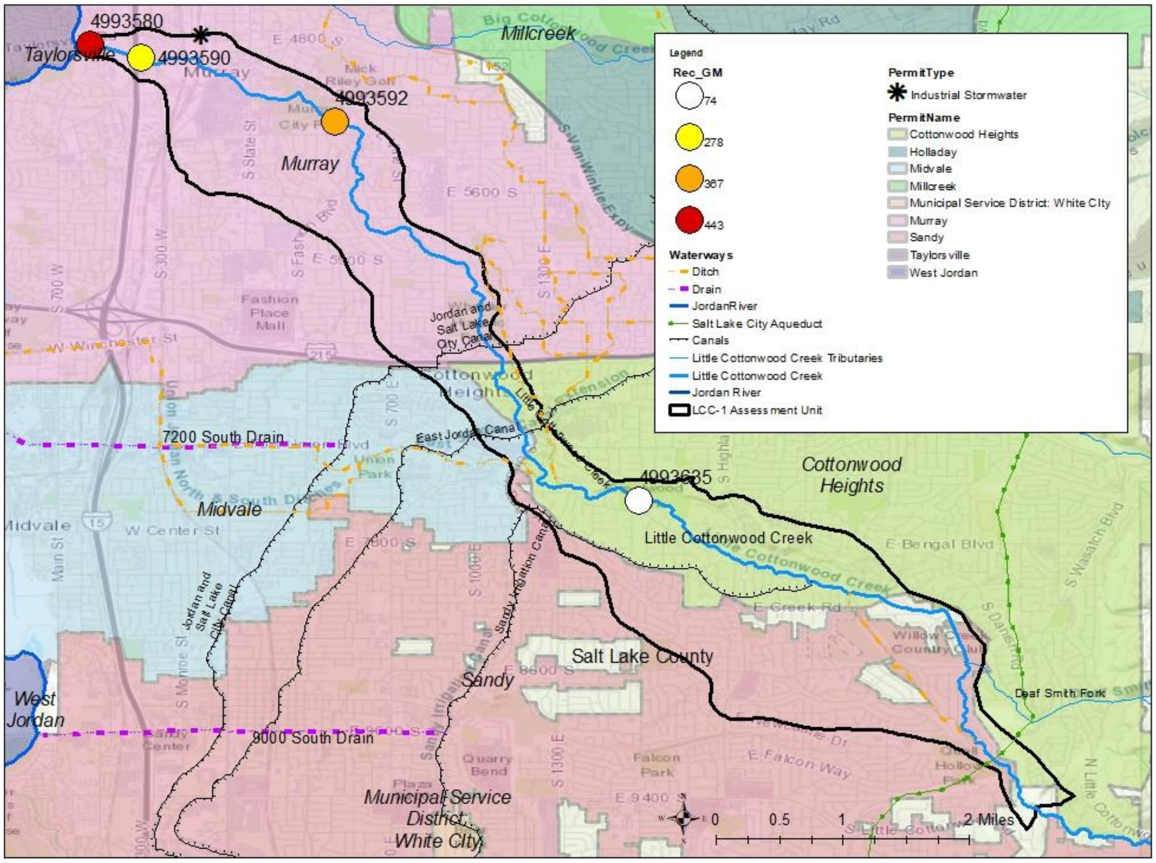

Figure B-11. Possible point sources of *E. coli* contamination within Little Cottonwood Creek-1 Assessment Unit.

Stormwater

Three potential sources of stormwater pollution (construction activities, industrial activities, and MS4s) occur within the Little Cottonwood Creek-1 AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were 21 construction permits and one industrial stormwater permit within the Little Cottonwood Creek-1 AU. Construction permits are short-lived and change over time, and most industrial sites are not a potential source of *E. coli*. The only industrial stormwater permit exists in the lower portion of the AU near the confluence with the Jordan River (Figure B-11, Table B-4). See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Little Cottonwood Creek-1 AU by issuing MS4 permits to the corresponding municipalities whose stormwater discharges into Little Cottonwood Creek. There are two MS4 permits (Jordan Valley Municipalities and Utah Department of Transportation) applicable to this AU. The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. Salt Lake County and the cities of Cottonwood Heights, Murray, Sandy, and Midvale have jurisdictional boundaries within the AU (Figure B-11). The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT. UDOT's Region 2 geographical area covers the Wasatch Front.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of nonpoint source *E. coli* pollution within the Little Cottonwood Creek-1 Assessment Unit include canal inputs, humans, wildlife, and dogs (Figure B-12). Please see Chapter 5.2 in the main report for more information on nonpoint sources.

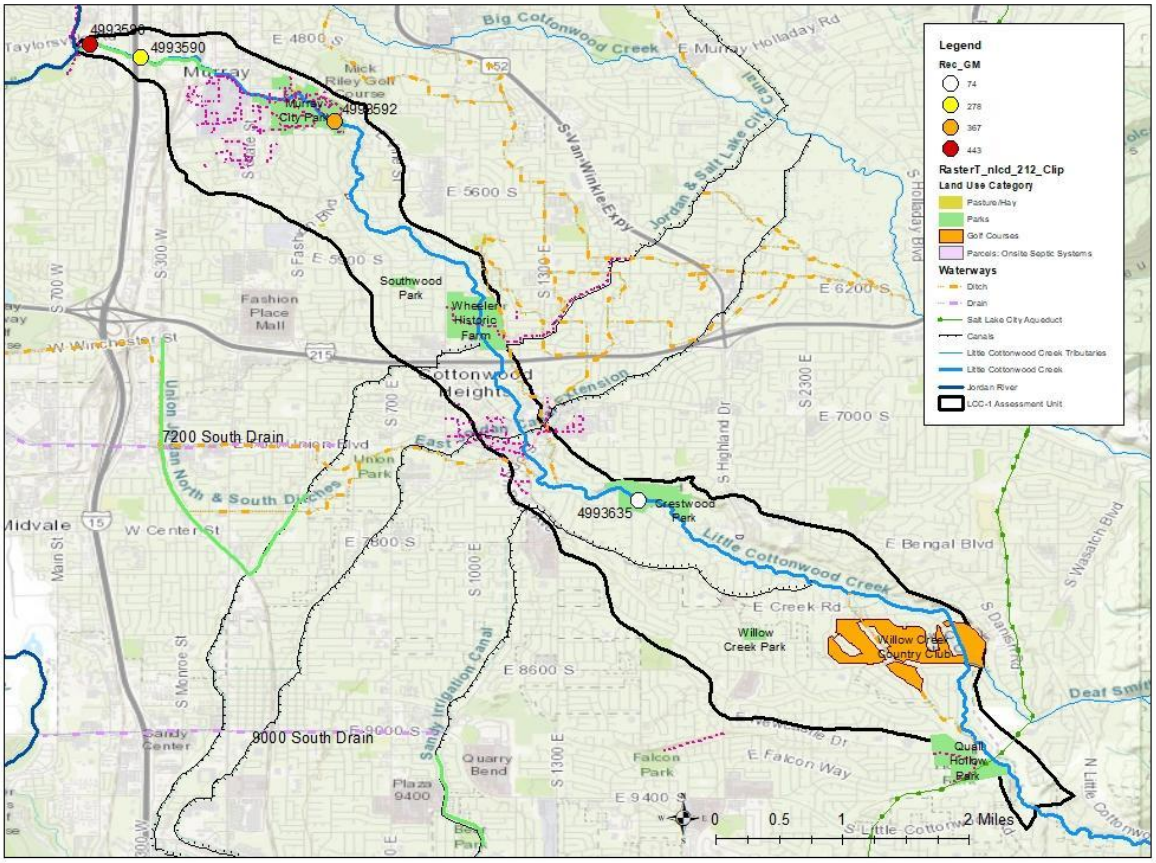

Figure B-12. Possible nonpoint sources of *E. coli* contamination in Little Cottonwood Creek-1 Assessment Unit.

Onsite Septic Systems

According to the Salt Lake County's Assessor's Office, there are three onsite septic system parcels within this AU as of 2021. Most of the parcels associated with this reach of Little Cottonwood Creek are sewered. There are no large underground wastewater disposal systems in this area. *E. coli* loading from failing onsite septic systems is likely minimal in this AU. Please see Chapter 5.2.1 in the main report for more information on onsite septic systems and Chapter 7 on suggested BMPs.

Agricultural Activity

Though land use associated with cultivated practices within the Little Cottonwood Creek-1 AU is minimal (<1% land use), there are two potential agricultural related sources: canal input and Wheeler Farm. Both of these sources (Figure B-12) are located upstream of the impaired site, Little Cottonwood Creek at Murray Park (4993592). MST analysis shows ruminant species present in this reach of the creek, though exact species are unknown (Figure B-10). Wheeler Historic Farm, located along the main stem of Little Cottonwood Creek, serves as an outdoor education center focusing primarily on historic and current farming practices. The 75-acre working farm is managed by Salt Lake County. Though livestock do not have direct access to surface waters, runoff from pastures and corrals can enter ditches that reach the creek. Vegetative BMPs should be implemented to limit direct runoff into the creek. Outreach and education campaigns targeted at watershed health should be included within the nature center's current education curriculum.

Canals delivering Utah Lake water to the local irrigators through exchange agreements with Salt Lake City could be a possible source of contamination. Though canal source water (Utah Lake outlet) is not impaired for *E. coli,* outfalls and/or runoff with elevated *E. coli* concentrations could drain into the canals between their intake at the Jordan River Narrows and the outlet at Little Cottonwood Creek. The Salt Lake County Integrated Watershed Plan (2016) states that these canals have the potential to deliver polluted water. Note that these canals are also used as flood control conveyance systems. *E. coli* could be deposited to these canals during runoff from both developed areas (stormwater runoff) and agricultural lands. More testing is needed to determine their relative contribution.

Recreation, Pets, and Nuisance Wildlife

Individuals recreate throughout the watershed, and it is likely that a small percentage of those that recreate do not properly dispose of their waste. As previously stated, MST data show that both human and canine-specific markers generally increase downstream throughout this AU. There are several parks (Quail Hollow, Crestwood, Wheeler Farm, and Murray Park) along the main stem that are utilized by humans and their pets. Local ordinances require all dogs to be on a leash at these parks. There are no off-leash dog parks within this AU,; but this ordinance may not always be followed. Direct stream access is available at all parks. Existing and proposed trails along the canals could also be a potential source from both recreationists and their pets. Pet waste may also be coming from stormwater runoff from private residences.

MST analysis shows that ruminant species are present in the AU, though marker presence decreases as the creek flows downstream from the mouth of the canyon. MST analysis does not differentiate between hooved species, though it is assumed that both cows and deer are present. This marker is prevalent below the Willow Creek Golf Course and Wheeler Farm. With the exception of Murray City Park, parks within this AU are forested, providing suitable habitat for deer and other wildlife. There are no wildlife management units in Little Cottonwood Creek-1 AU, however, given the open space in Quail Hollow, Crestwood, and Wheeler Farm, these animals could be contributing to the impairment.

The avian MST marker was prevalent throughout the entire AU, so managing areas where waterfowl congregate should be a priority. There are three flood control basins along lower Little Cottonwood Creek operated and maintained by Salt Lake County Flood Control: Willow Creek Country Club, Wheeler Farm, and Murray Park (SLCo 2017). The Willow Creek Country Club is a detention basin positioned to capture flow from Deaf Smith Fork. Wheeler Farm has two ponds to mitigate flood waters; flow is diverted from Little Cottonwood Creek through these ponds and rerouted back into the creek. These ponds could serve as hotspots for *E. coli* because they often attract large numbers of waterfowl. The flood control basin at Murray Park is located along Little Cottonwood Creek where the channel widens allowing instream flows to slow. This shallow, slow-moving water attracts waterfowl. Please see Table 8 in the main report for suggested BMPs to employ to manage these particular nonpoint sources of *E. coli* contamination.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Little Cottonwood Creek-1 AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Appendix C. Mill Creek1-SLCity and Mill Creek2-SLCity Assessment Units *E. coli* TMDLs

Waterbody Name	Mill Creek-1-SLCity	Mill Creek-2-SLCity
Waterbody/Assessment Unit (AU)	UT16020204-026	UT16020204-017
AU Description	Mill Creek from confluence with Jordan River to Interstate 15 crossing	Mill Creek and tributaries from Interstate 15 to USFS Boundary
Impaired Beneficial Uses	Infrequent primary contact recreation (2B)	Infrequent primary contact recreation (2B)
Applicable Season	May through October	May through October
Defined Endpoint/Water Quality Standard	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL
Percent Reduction Needed	83%, based on a geometric mean of 1202 MPN/100 mL calculated for 4992505 (Mill Creek above Central Valley WWTP outfall) in the month of August.	83%, based on a geometric mean of 1205 MPN/100 mL calculated for 4992560 (Mill Creek southwest of Nibley Park) in the month of August.
Probable Sources	Stormwater, avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused	Stormwater, avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused

Mill Creek1-SLCity Assessment Unit

Assessment Unit Description

The Mill Creek1-SLCity-Assessment Unit (AU) includes Mill Creek from the intersection with Interstate I-15 as it flows 1.1 miles downstream to the confluence with the Jordan River. This small AU (0.5 mi^2) is within the city of South Salt Lake and entirely in Salt Lake County. The land is 100% privately owned. The Mill Creek1-SLCity AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) designated beneficial uses due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2014 Integrated Report.

Table C-1. Impairment summary of the Mill Creek1-SLCity Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
UT16020204-026	*E. coli*	Infrequent primary contact recreation (2B)	2014–2022
	Macroinvertebrates*	Cold water aquatic life (3A)	2014–2022
*Will be addressed in a future TMDL			

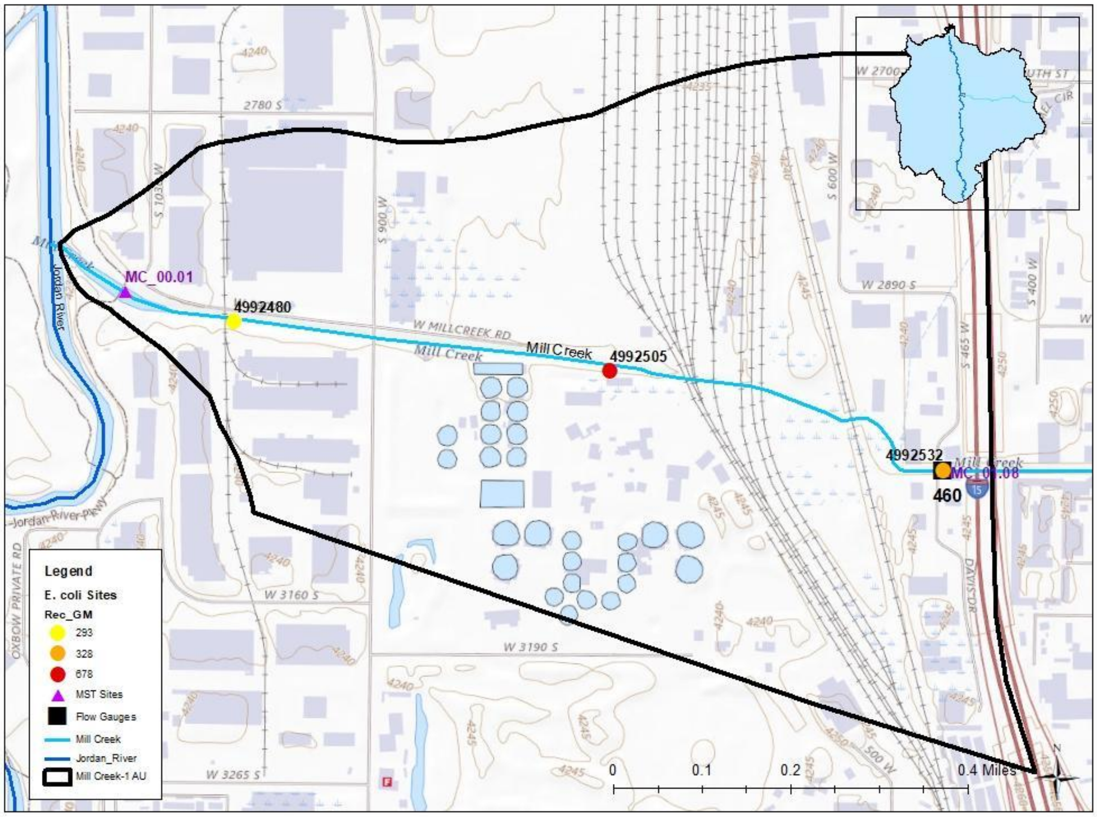

Figure C-1. Monitoring locations and hydrology of Mill Creek1-SLCity Assessment Unit.

Hydrology

Mill Creek originates in the Murdoch Basin of the Wasatch Mountains and flows 19.7 miles before draining into the Jordan River (Figure C-1). The headwaters and upper reaches are managed by the Uinta-Wasatch-Cache National Forest. The canyon does not have strict watershed protection regulations. The entire Mill Creek basin drains approximately 36.8 mi² of forested and developed landscape. The mean daily flow is 27 cubic feet per second (cfs) at Salt Lake County Gauge #490 (Mill Creek at 460 West during the TMDL period of record (2011–2021), with a maximum daily mean of 173 cfs (Table C-4). Salt Lake City holds most of the water rights of the creek for culinary purposes. There are no significant diversions at the mouth of this canyon.

Figure C-1 shows the hydrology within this small AU. Ninety-two percent of the instream flow of Mill Creek in the valley is either reduced or interrupted by hydrologic modifications (SLCo 2017). Hydrologic modifications, such as channelization, stormwater conveyance systems, diversions, and rip-rapped streambanks alter the stream's hydrograph. Utah Lake water is imported into Mill Creek via the Jordan and Salt Lake Canal and Upper Canal through an exchange agreement between Salt Lake City and local irrigators. The percentage of exchanged waters in these two AUs is unknown during the irrigation season (SLCo 2017).

Mill Creek flows for approximately 1.1 miles in the Mill Creek1-SLCity AU before entering the Jordan River. Instream flow is augmented by the effluent discharge from Central Valley Water Reclamation Facility (CVWRF). The current design capacity is 75 million gallons per day (MGD) (116 cfs) as an average daily flow. Refer to the UPDES section in this appendix and Chapter 5 in the main report for more information on this facility and discharge permit. Note that the north side of Mill Creek is designed as a flood-control levee and is managed by Salt Lake County Flood Control.

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 100% of the land in the Mill Creek1-SLCity AU is developed (Figure C-2). The riparian buffers along the main stem of Mill Creek are developed/urban land use. There are no agricultural operations within this AU. The urban land cover is primarily commercial and industrial.

Approximately 57% of the AU is covered by impervious surfaces from developed land use (NLCD). This significant level of impervious surface leads to increased runoff and results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase in this AU by 2% in 2040, which may further increase impervious surfaces in this AU (SLCo 2017). See Section 5.3.1 in the main report for more information on the effects of impervious surfaces on pollutant loading.

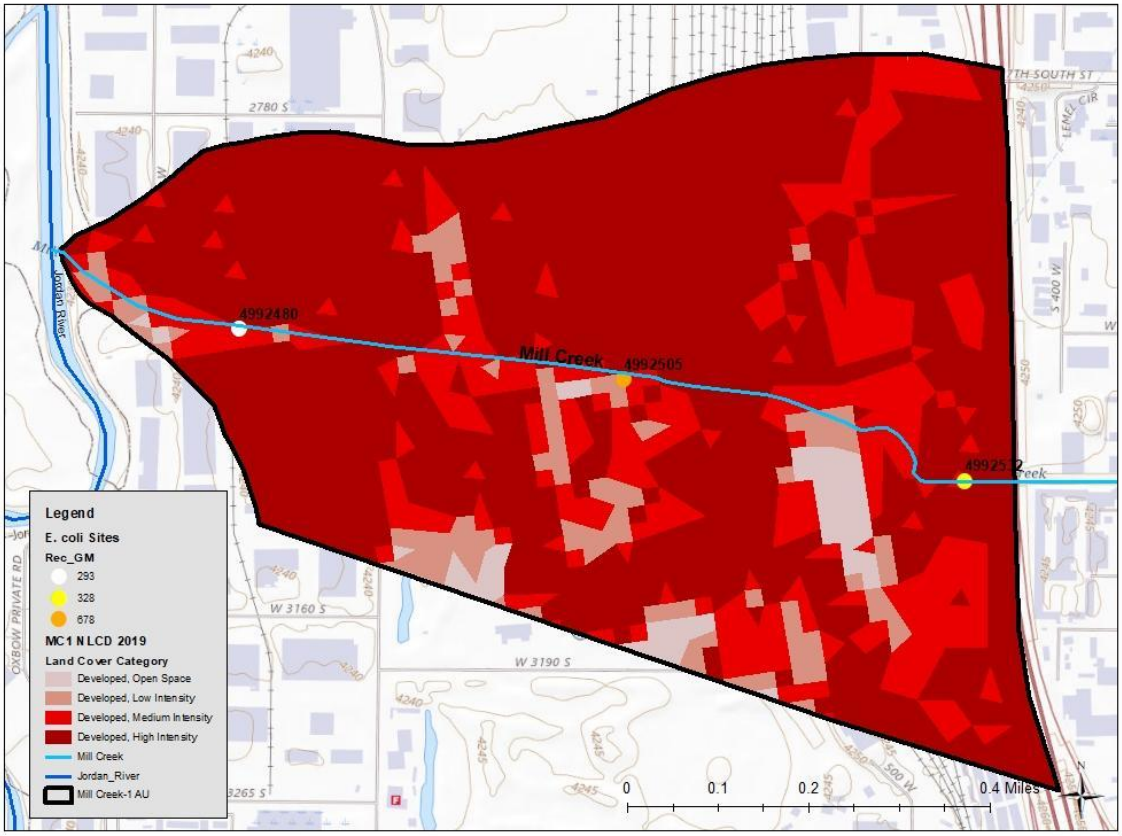

Figure C-2. Land cover in Mill Creek1-SLCity Assessment Unit (2019).

E. coli Data Summary

Three routine *E. coli* monitoring locations on Mill Creek1-SLCity AU were sampled to determine spatial and temporal *E. coli* trends (Figure C-1). Mill Creek above confluence Jordan River below Central Valley WWTP (CVWRF) (4992480) and Mill Creek above Central Valley WWTP (CVWRF) Outfall (4992505) were sampled during the recreation season 2009–2012 and again in 2018–2020, while Mill Creek at 460 West (4992532) was sampled year-round from 2017–2021. The recreational geometric means for these sites exceeded 206 MPN/100 mL, and all sites had a maximum *E. coli* concentration that exceeded the laboratory test threshold of 2,420 MPN/100 mL (Table C-2). Upstream to downstream, the average *E. coli* concentration remained elevated across all sites, but was slightly higher at 4992505 (Figure C-3). Concentration at 4992480 (below CVWRF) is diluted due to the effluent discharge of the treatment plant.

E. coli concentrations regularly exceeded the standard over the entire sampling period. Monthly geometric mean *E. coli* concentrations showed strong seasonal variation, increasing from July–October (Figure C-5) at these sites. An increase in concentration during the warmer months corresponded with both the recreation season (May–October) and the water delivery system to these lower reaches from the Upper Canal and Jordan and Salt Lake Canal.

Table C-2. *E. coli* summary statistics for Mill Creek1-SLCity Assessment Unit.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4992480 /MC_00.01	Mill Creek above confluence Jordan River (below Central Valley WWTP)	Insufficient data	06/2009 to 09-2020	35	6	293	293	2,420*	74	9
4992505 / NA	Mill Creek above Central Valley WWTP outfall	NA	06/2010 to 09/2018	14	272	678	678	2,420*	100	57
4992532 / MC_01.08	Mill Creek at 460 West gauge	Not meeting criteria	01/2017 to 10/2021	60	1	300	528	2,420*	73	27

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL
** Used half the detection limit (1 MPN/100 mL) for samples with non-detects

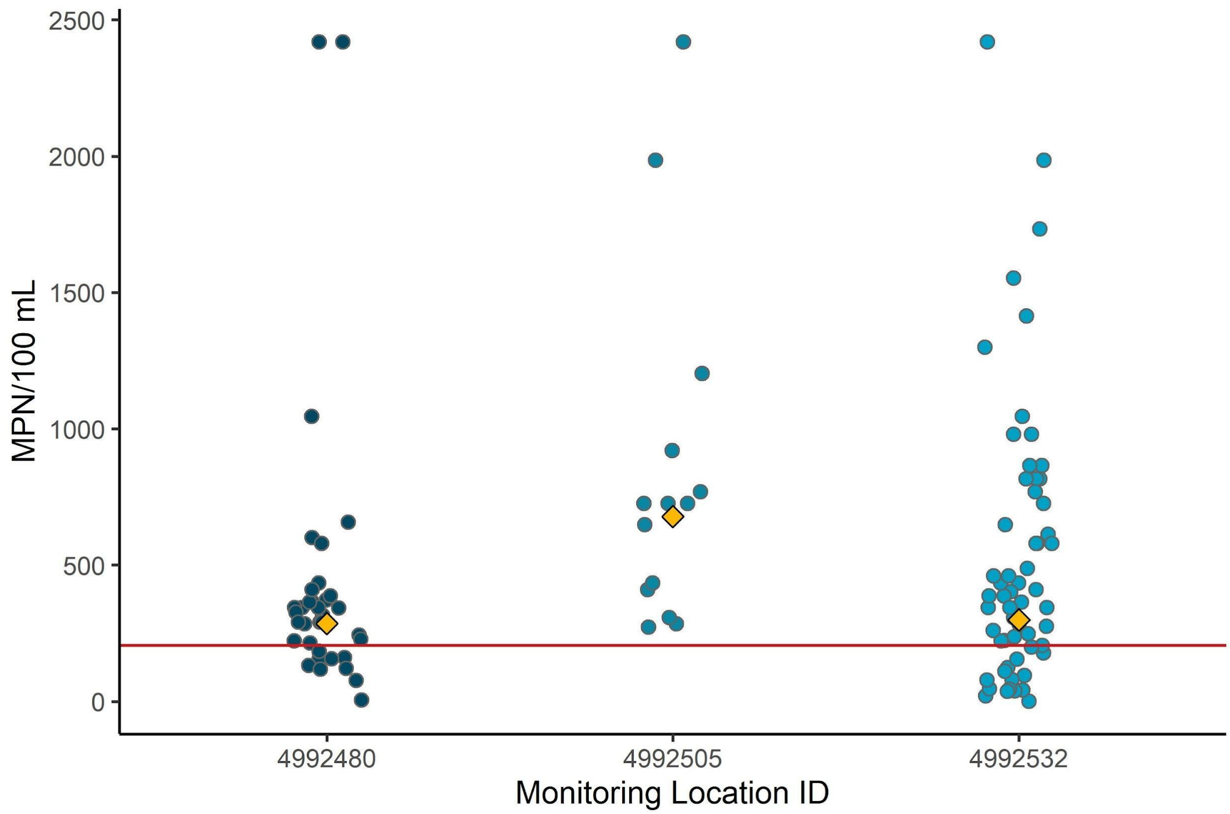

Figure C-3. *E. coli* concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Mill Creek1-SLCity Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

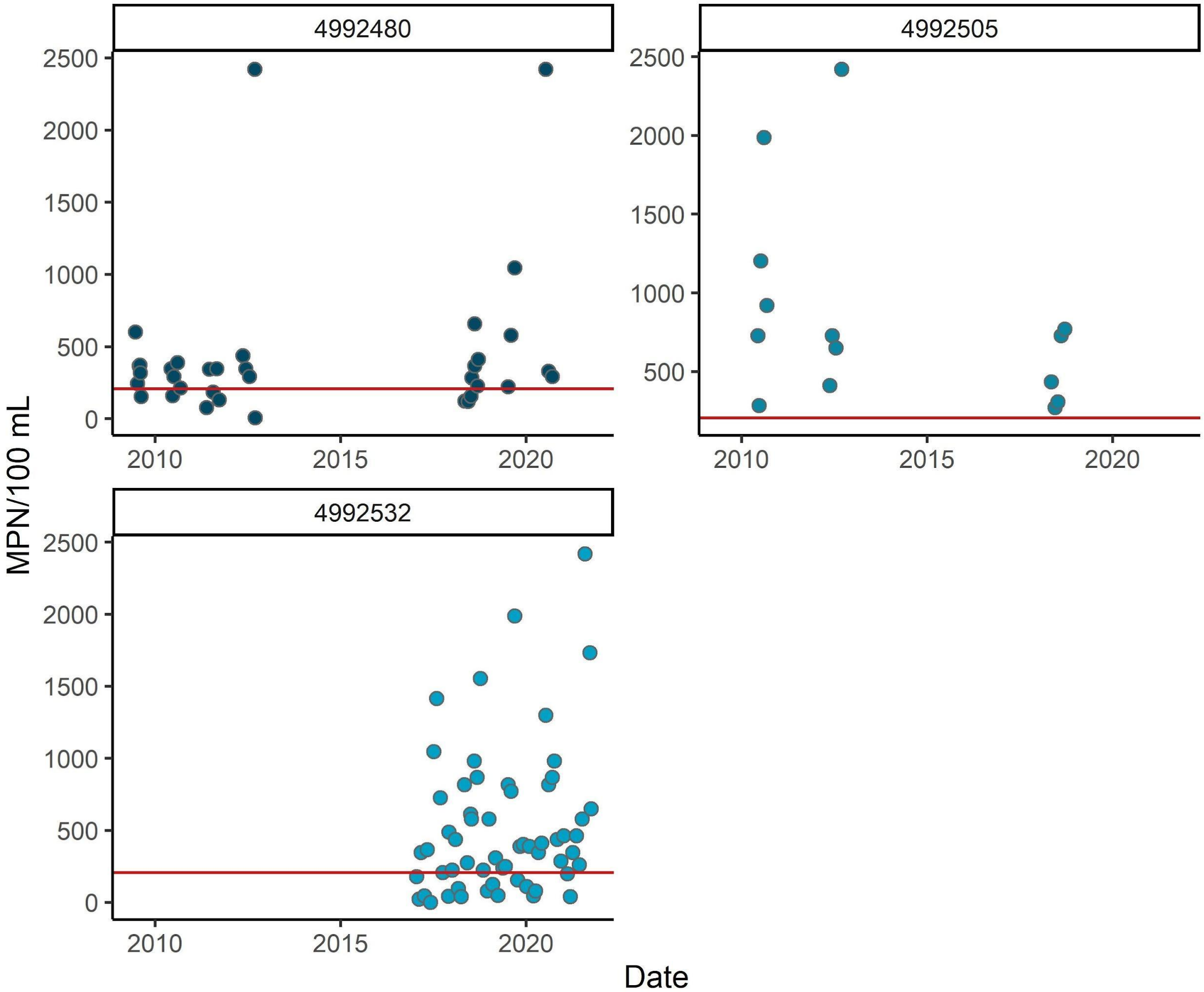

Figure C-4. *E. coli* concentrations at each routine monitoring location through time within the Mill Creek1-SLCity Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

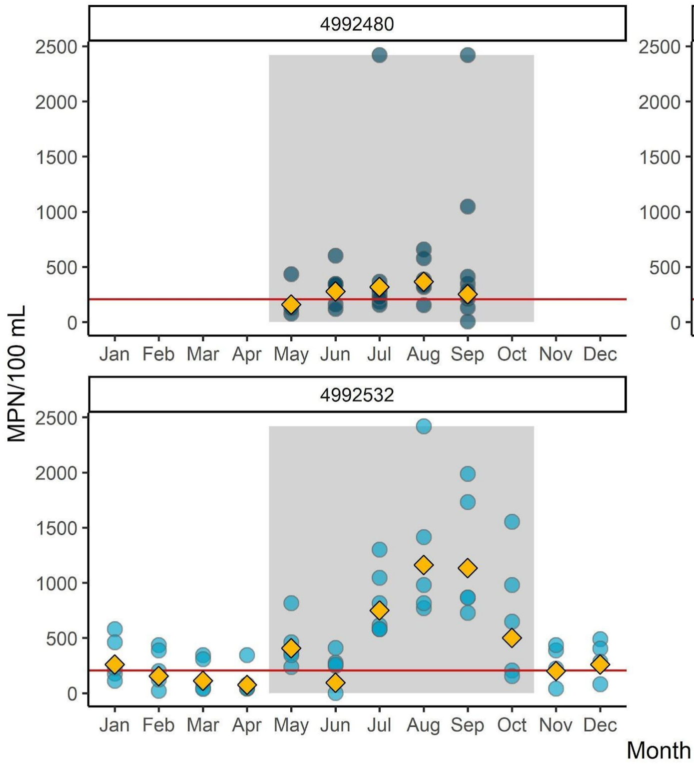

Figure C-5. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDCs), microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. Potential sources and recommended implementation strategies to address them are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curve

Load duration curves are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships

between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at the upper end of this small AU (Mill Creek at 460 West, Gauge #490). This site corresponds to an *E. coli* monitoring station (4992532) that shows impairment and is located above the influence of the CVWRF outfall. Flow data during the TMDL period of record (January 2011–September 2021) is summarized in Table C-3, Figure C-6, and Figure C-7. The daily mean flows are higher during May and June, which corresponds to spring runoff and irrigation season. Flow decreases in the late summer mainly due to the upstream water diversions and general baseflow conditions.

This flow gauge is used for both Mill Creek1-SLCity AU and Mill Creek2-SLCity AU TMDL analyses due to the close proximity of both AUs. No significant hydrologic impacts exist between the two.

Table C-3. Summary statistics for Mill Creek at 460 West, Gauge #490 (49932532).

Gauge Name	SLCO Gauge Number /DWQ MLID	Drainage Area (mi^2)	Mean Flow (cfs)	Maximum Flow (cfs)
Mill Creek at 460 West*	490/4992532	32	27	173

*Flow site was used for both MC1 and MC2 analyses

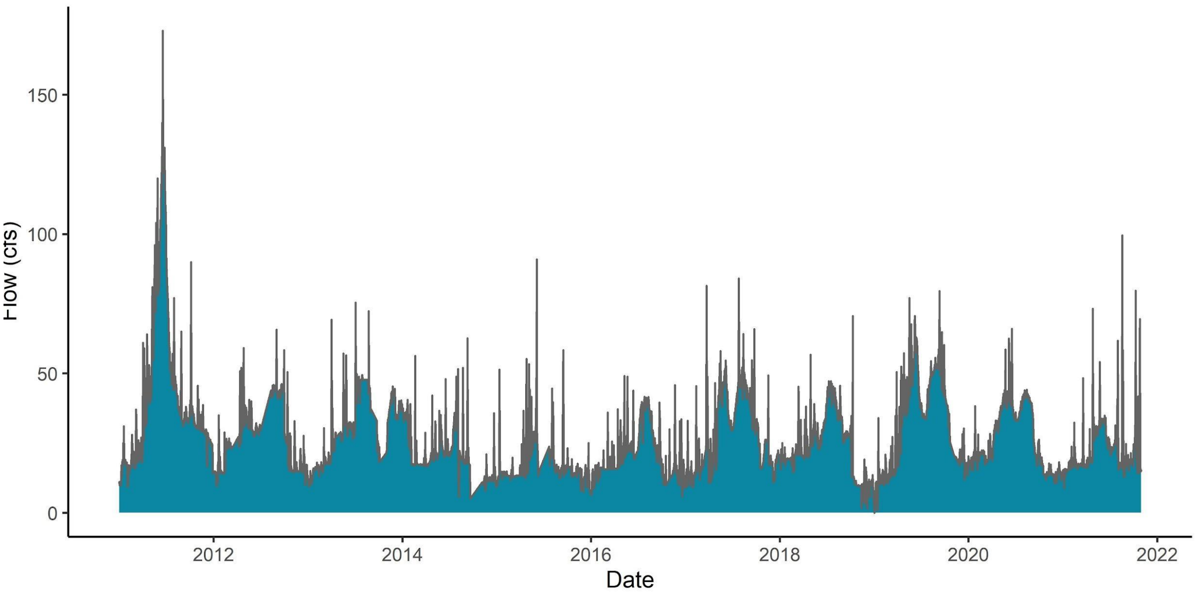

Figure C-6. Daily means flows at Salt Lake County Gauge #490, Mill Creek at 460 West (4992532) from January 1, 2011, to September 30, 2021.

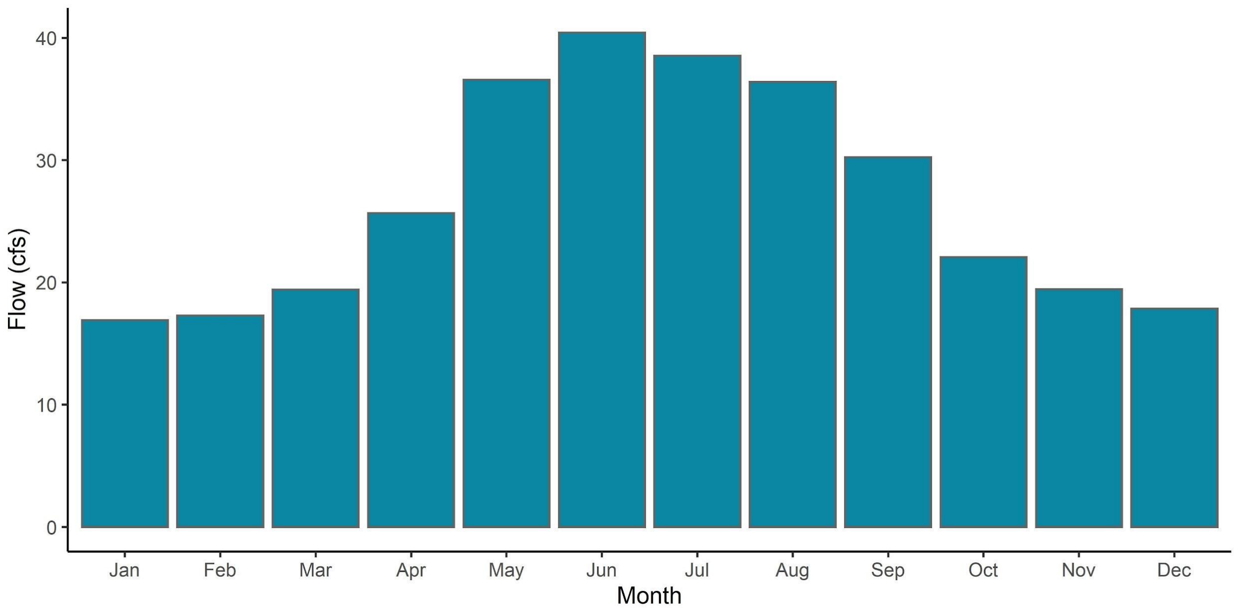

Figure C-7. Monthly means flows (cfs) at Salt Lake County Gauge #490, Mill Creek at 460 West (4992532) from January 1, 2011, to September 30, 2021.

Using this site's corresponding *E. coli* and flow data, the LDC shows exceedances occurring at all flow regimes (Figure C-8). Exceedances of the TMDL threshold (solid line) in high to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. These sources include point sources (low-flow conditions), onsite septic systems (dry flows), and riparian areas and impervious stormwater sources (mid-range). Upland stormwater and bank erosion are likely sources when exceedances occur in the high-flow conditions. The percent of *E. coli* loading measurements exceeding the TMDL in each flow regime is provided in parentheses under each flow-regime label in Figure C-8. The greatest loading reductions are needed primarily in the higher flow regimes, indicating that Mill Creek is dominated more by nonpoint source loading than point source delivery methods, though point sources should still be considered.

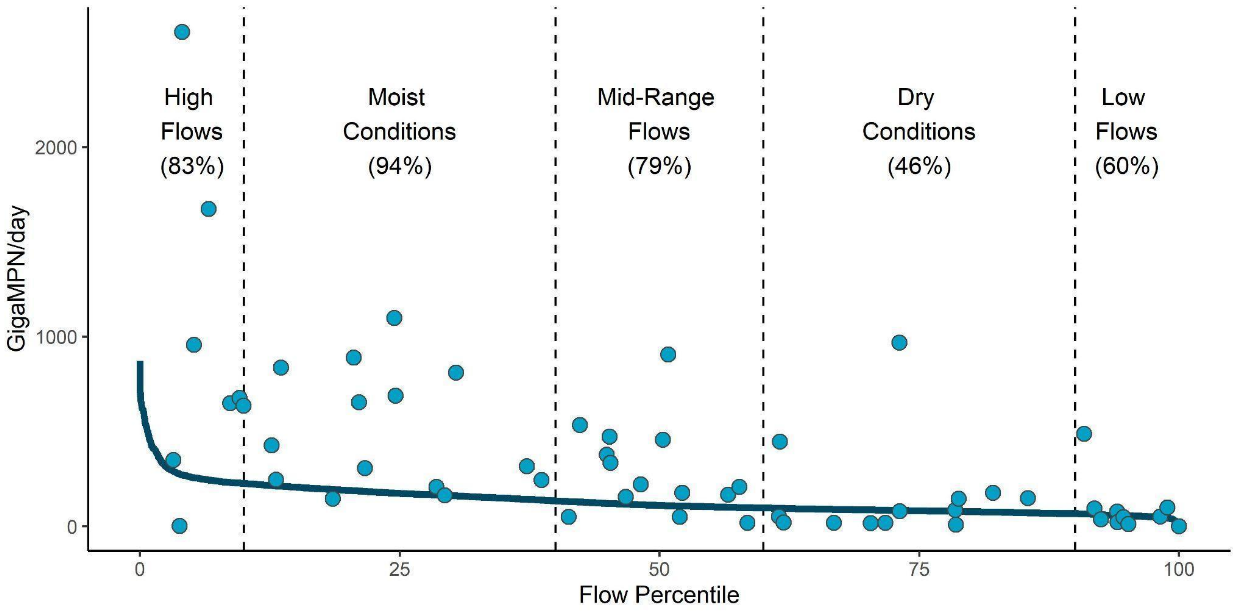

Figure C-8. Load duration curve for Mill Creek at 460 West (4992532).

Microbial Source Tracking

Samples were collected once a month at two locations during July, August, and September from 2018–2020, resulting in nine samples per site and a total of 18 samples collected (Figure C-9). All four MST markers were detected in the AU. When the presence or absence of each marker was considered across all locations, human was the most common at 100%, meaning of the 18 samples collected, 18 of them were positive for the human marker. The avian market was present at 94%, canine marker at 44%, and ruminant at 11%. All samples exhibited at least one marker. Figure C-9 illustrates a similar presence/absence pattern of the four markers at each of the two sampling locations and indicates that human and avian sources should be the primary focus in this AU. More information on MST can be found in Section 5.3.3 in the main report.

Figure C-9. The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades absence.

Source Assessment

The probable sources of *E. coli* in the Mill Creek1-SLCity AU come from stormwater runoff and other nonpoint sources including avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused based on the data analysis, LDC analysis, MST results, land-use patterns, and hydrology.

Table C-4 provides a list of specific potential point and nonpoint sources in the Mill Creek1-SLCity AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. For more information on each potential source, please see Chapter 5.1 and 5.2.

Table C-4. Potential sources of *E. coli* contamination in Mill Creek1-SLCity Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	Yes	UTR000000		
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities, including South Salt Lake City, Salt Lake County	UTS000001		
		Utah Department of Transportation	UTS000003		
	Municipal	Central Valley Water Reclamation Facility	UT0024392		
	Construction dewatering	Yes			
Nonpoint source	Onsite septic systems	No		Section 5.2.1	Table 8

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
	Agricultural: livestock	No		Section 5.2.2	
	Agricultural: canals	Yes			
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	
	Recreationists/ unhoused	Yes		Section 5.2.5 Section 5.2.6	

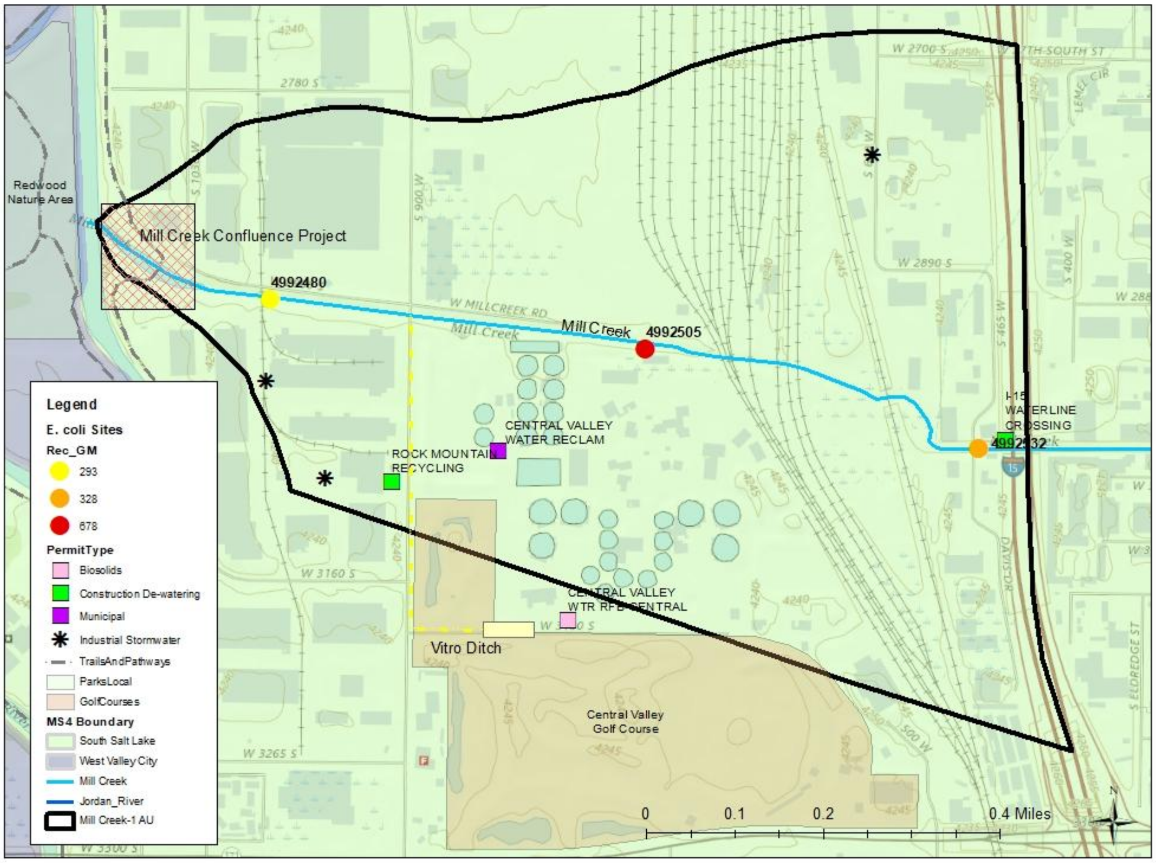

Figure C-10. Possible sources of E. coli contamination to Mill Creek1-SLCity Assessment Unit.

Point Sources

While there are several Utah Pollutant Discharge Elimination System (UPDES) permitted discharges within the Mill Creek1-SLCity Assessment Unit, municipal stormwater is the most likely source of *E. coli* in this AU (Figure C-10). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the LDC that pointed to point sources during low-flow regimes, urbanized land uses and increased impervious surfaces in the valley, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see Chapter 5.1 in the main report for more information.

Utah Pollutant Discharge Elimination System (UPDES)

The Central Valley Water Reclamation Facility (CVWRF, UT0024392) is the only permitted facility with the potential to discharge *E. coli* into this assessment unit (Table C-4, Figure C-10). CVWRF is a domestic wastewater treatment facility with a maximum design flow rate of 75 million gallons per day (MGD). The effluent is discharged directly into Mill Creek approximately 800 feet upstream from the Jordan River. *E. coli* exceedances are unlikely because the facility upgraded from the traditional chlorination/dechlorination system to an ultraviolet-light disinfection system in 2009. *E. coli* limits are included in the UPDES permit and are set at 126 MPN/100 mL as a monthly average and 157 MPN/100 mL as a weekly maximum average, both of which are below the *E. coli* TMDL target for Mill Creek.

CVWRF operates a sand filter to produce Type I reuse water during the spring and summer months. Reuse water fills a pond west of the facility, which is then used to irrigate its golf course. The facility processes approximately 0.75–1.0 MGD of Type I water, or 1.3% of the total flow while in operation. Other ponds at the golf course are filled with post-disinfected effluent that flows to Mill Creek via Vitro Ditch during these months (see Stormwater section below). The ditch joins Mill Creek less than 100 feet downstream of the plant outfall. DWQ has determined this flow does not constitute a new outfall and does not require monitoring limits or a permit.

Stormwater

Three potential sources of stormwater pollution (construction activities, industrial activities, and MS4s) occur within the Mill Creek1-SLCity AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there are two construction and three industrial stormwater permits in Mill Creek1-SLCity AU. The industrial stormwater permits occur throughout the entire assessment unit (Figure C-10, Table C-4). Construction permits are short-lived and change over time, and most industrial sites are not a potential source of *E. coli*. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Mill Creek1-SLCity AU by issuing MS4s permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of Mill Creek. There are two MS4 permits—Jordan Valley Municipalities and Utah Department of Transportation—that apply to this AU. The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River Watershed. South Salt Lake City has jurisdictional boundaries that are within the AU (Figure C-12). The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT. UDOT's Region 2 geographical area covers the Wasatch Front.

Vitro Ditch has been identified as a section of a stormwater conveyance system with high levels of *E. coli*, especially during precipitation events (U of U, 2019). The ditch is located to the north of Central Valley's golf course (Figure C-10). Stormwater from the surrounding area enters into the ditch at the east end. Water flows through this ditch to Mill Creek, approximately 100 feet upstream of CVWRF's effluent outfall. Trash, oil, grease, and debris have been observed in Vitro Ditch after precipitation events. This ditch is also utilized by CVWTF to discharge its reuse water from their golf course. *E. coli* samples collected by the University of Utah in 2019 during high flow events were at or above the laboratory detection limits (2,420 MPN/100 mL). Vitro Ditch is currently being monitored for stormwater parameters by DWQ, and *E. coli* will be added to the parameter list in 2022.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Mill Creek1-SLCity Assessment Unit include humans, wildlife (avian), and canine (dogs) (Figure C-9). There are no designated dog parks, wildlife management areas, agricultural lands, or parcels with onsite septic systems within this small AU.

The avian MST marker was prevalent throughout the AU. MS4 permits must address nuisance wildlife species that congregate at stormwater control structures such as detention basins and ponds.

MST data show that both human and canine markers are detected in this AU. There is high recreational use along the Jordan River Parkway near the confluence of Mill Creek. It is likely that a small percentage of those recreating do not properly dispose of their own waste as well as their pet waste. Local ordinances require dogs to be on leashes along the Jordan River Parkway.

Seven Canyons Trust is currently working on a restoration project at the confluence of Mill Creek and the Jordan River to restore both aquatic and terrestrial habitat. One of the project goals is to create an artificial wetland to filter out pollutants and increase recreation access to the proposed Mill Creek trail system.

Given the *E. coli* exceedances seen at the upstream boundary of this AU, sources exist farther upstream in Mill Creek. The adjacent upstream reach (Mill Creek2-SLCity AU) is also impaired for *E. coli* and is discussed below.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Mill Creek1-SLCity AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Mill Creek2-SLCity Assessment Unit

Assessment Unit Description

The Mill Creek2-SLCity Assessment Unit (AU) includes Mill Creek from the Forest Service boundary 6.6 miles downstream to the intersection with Interstate I-15. This small AU (4.5 mi^2) is located in Millcreek Township, city of South Salt Lake, and Salt Lake County. The land is 100% privately owned. The Mill Creek2-SLCity AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) designated beneficial uses due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2002 Integrated Report due to elevated levels of fecal coliform. The listing was updated in the 2008 Integrated Report after DWQ adopted the *E. coli* water quality standard and revised the assessment methodology.

Table C-5. Impairment summary of the Mill Creek2-SLCity Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
UT16020204-017	*E. coli*	Infrequent primary contact recreation (2B)	2002–2022
	Macroinvertebrates*	Cold water aquatic life (3A)	2010–2022
*Will be addressed in a future TMDL			

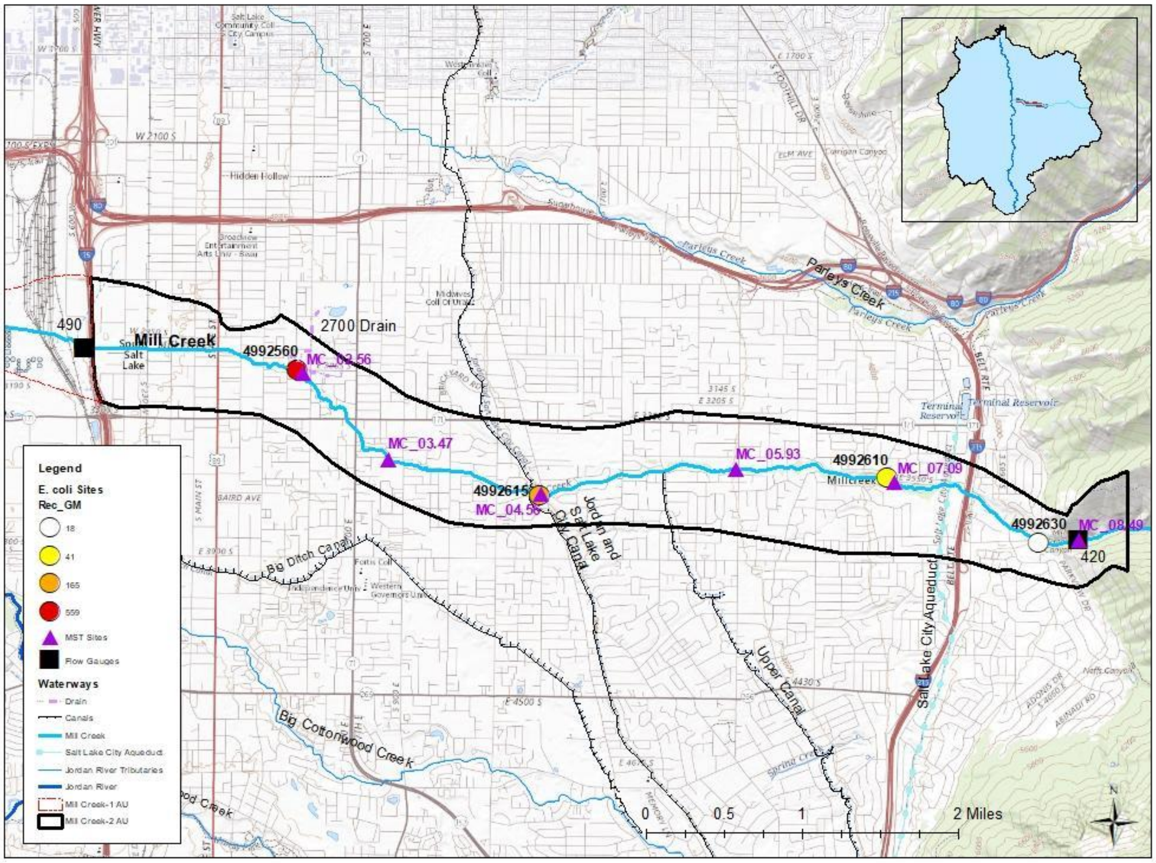

Figure C-11. Monitoring locations and hydrology within Mill Creek2-SLCity Assessment Unit.

Hydrology

Mill Creek originates in the Murdoch Basin and flows 19.7 miles before draining into the Jordan River (Figure C-11). The headwaters and upper reaches are managed by the Uinta-Wasatch-Cache National Forest. The canyon does not have strict watershed protection regulations. The entire Mill Creek basin drains approximately 36.8 mi^2 of forested and developed landscape. The mean daily flow is 27 cubic feet per second (cfs) at Salt Lake County Gauge #490 (Mill Creek at 460 West during the TMDL period of record (2011–2021), with a maximum daily mean of 173 cfs (Table C-4). There are no significant diversions at the mouth of this canyon. Salt Lake City holds most of the water rights for culinary purposes.

Figure C-11 shows the Mill Creek system in the valley, where 92% of the instream flow of Mill Creek is either reduced or interrupted by hydrologic modifications (SLCo 2017). Hydrologic modifications, such as channelization, stormwater conveyance systems, diversions, and rip-rapped streambanks alter the stream's hydrograph. Mill Creek extends 6.6 miles from the mouth of the canyon down to the Mill Creek1-SLCity AU boundary.

The reach directly below the canyon mouth is considered to be a losing reach. There are three major diversions along the main stem in this AU: Upper Canal, Jordan and Salt Lake Canal, and the 2700 Storm Drain. During the irrigation season (April-October), exchange agreements allow Salt Lake City to use high-quality mountain stream water to address municipal demands, while local agricultural producers switch to using lower quality Utah Lake/Jordan River water for irrigation. Sections of Mill Creek can be completely dewatered during the irrigation season.

Another input into Mill Creek occurs at Fitts Community Park, where stormwater stored at the pond at Nibley Park Golf Course is directed into the creek via the 2700 South Drain (Figure C-11). Instream flow is augmented by the effluent discharge from the Central Valley Water Reclamation Facility in the downstream Mill Creek1-SLCity AU. The current design capacity is 75 million gallons per day (MGD) (116 cfs) as an average daily flow. Note that the north side of Mill Creek in Mill Creek1-SLCity AU is designated as a flood-control levee and is managed by Salt Lake County Flood Control.

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 93.4% of the land in the Mill Creek2-SLCity AU is developed (Figure C-12). The rest of the land cover in this AU is 6.3%

natural (forest, grassland, wetlands, shrubland, and barren) and 0.3% agricultural (pasture and crops). Most of the riparian buffers along the main stem of Mill Creek are characterized by developed/urban land use. There are no major agricultural operations within this AU. Developed open space is limited to designated parks. Urban land cover is primarily residential and industrial.

Approximately 39% of the AU is covered by impervious surfaces from developed land use (NLCD). This level of impervious surface leads to increased runoff and results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase in this AU by 2% in 2040, which may increase impervious surfaces in this AU (SLCo Watershed Plan, 2015). See Section 2 in the main report for more information on the effects of impervious surfaces on pollutant loading.

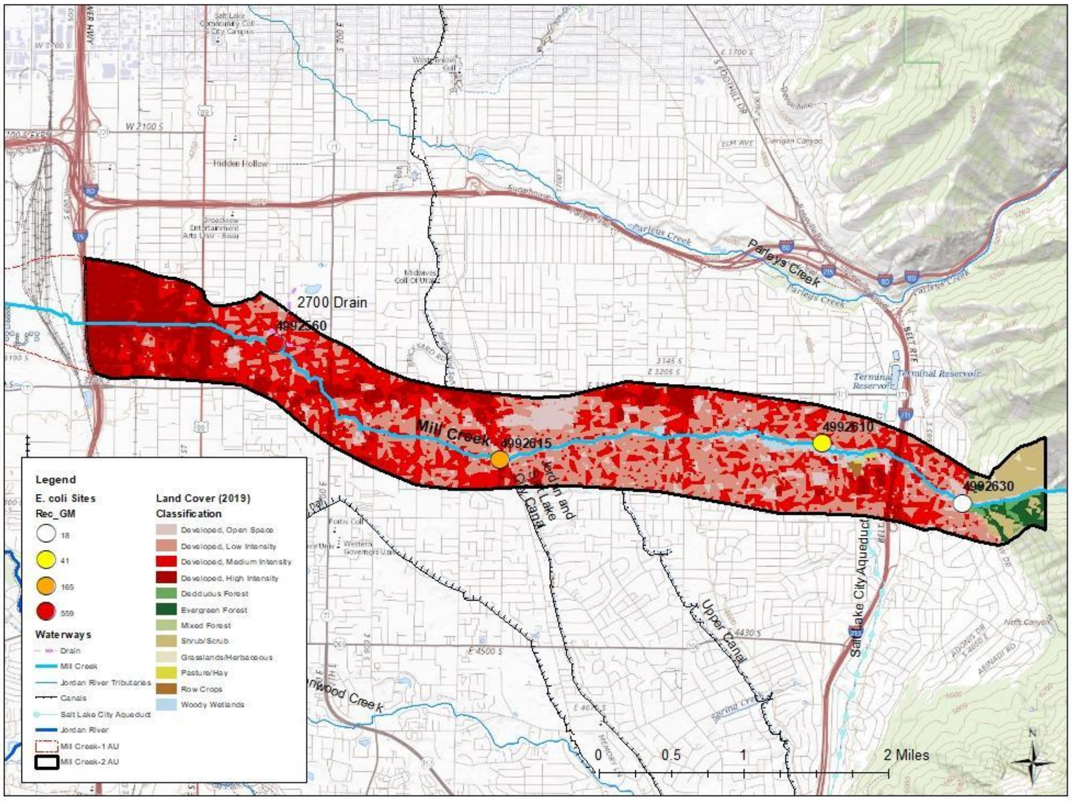

Figure C-12. Land cover in Mill Creek2-SLCity Assessment Unit.

E. coli Data Summary

Four routine *E. coli* monitoring locations on Mill Creek2-SLCity AU were studied for spatial and temporal patterns of *E. coli* levels (Figure C-11). All sites were sampled year-round from 2011–2021 (Table C-6). All sites had a maximum *E. coli* concentration that exceeded the laboratory test threshold of 2,420 MPN/100 mL.

The average *E. coli* concentration increased moving downstream (Figure C-13). The two upper sites, Mill Creek at the Mouth of the Canyon (4992630) and Mill Creek at 3550 South 3120 East (4992610) had *E. coli* concentrations well below the standard, with only 3% and 6% of samples, respectively, exceeding the geometric mean standard, indicating that sources of contamination increase downstream of Highland Drive. *E. coli* concentrations regularly exceeded the standard at the two most downstream sites (Figure C-13).

Monthly geometric mean *E. coli* concentrations at the two most downstream sites, Mill Creek southwest of Nibley Park (4992650) and Mill Creek below Highland Drive (4992615), increased considerably during the recreation season, when instream flows are low (Figure C-15). The increase in concentration during the warmer months at these sites corresponded with both the recreation season (May–October) and the water delivery system to these lower reaches from the Upper Canal and Jordan and Salt Lake Canal. The two sites above Highland Drive (4992630 and 4992610) had a more consistent monthly trend.

Table C-6. *E. coli* summary statistics for Mill Creek2-SLCity Assessment Unit.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4992560 / MC_02.56	Mill Creek southwest of Nibley Park	Not meeting criteria	02/2011 to 10/2021	113	9	260	559	2,420*	61	36
4992615 / MC_04.56	Mill Creek below Highland Drive	Insufficient data	02/2011 to 10/2021	108	1	63	165	2,420*	33	11
4992610 / MC_07.09	Mill Creek at 3550 South ~ 3120 East	Meeting criteria	02/2011 to 10/2021	109	1	20	41	770	6	1
4992630 / MC_08.49	Mill Creek at Mouth of Canyon	Insufficient data	06/2009 to 10/2021	106	0.5**	8	18	411	3	0

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL
** Used half the detection limit (1 MPN/100 mL) for samples with non-detects

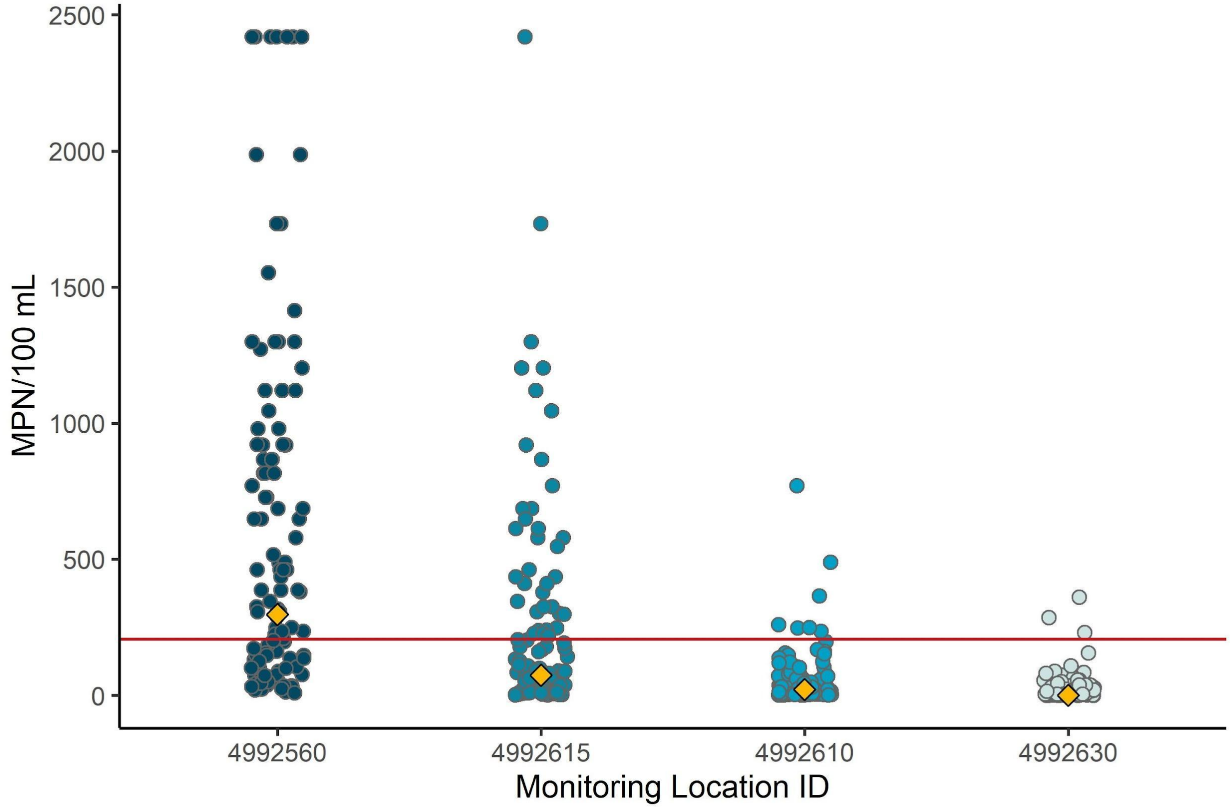

Figure C-13. *E. coli* concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Mill Creek 2 Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

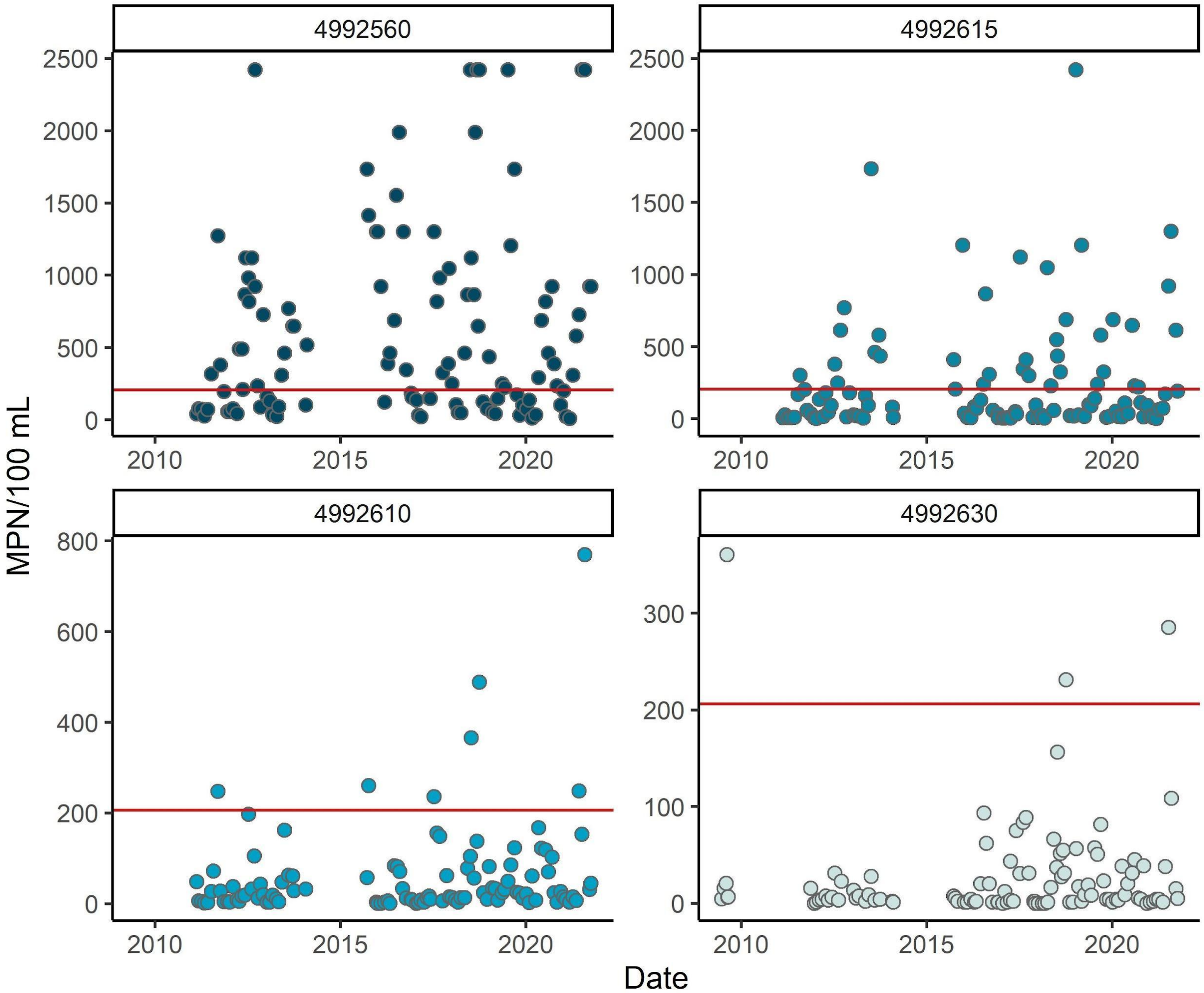

Figure C-14. *E. coli* concentrations at each routine monitoring location through time within the Mill Creek2-SLCity Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

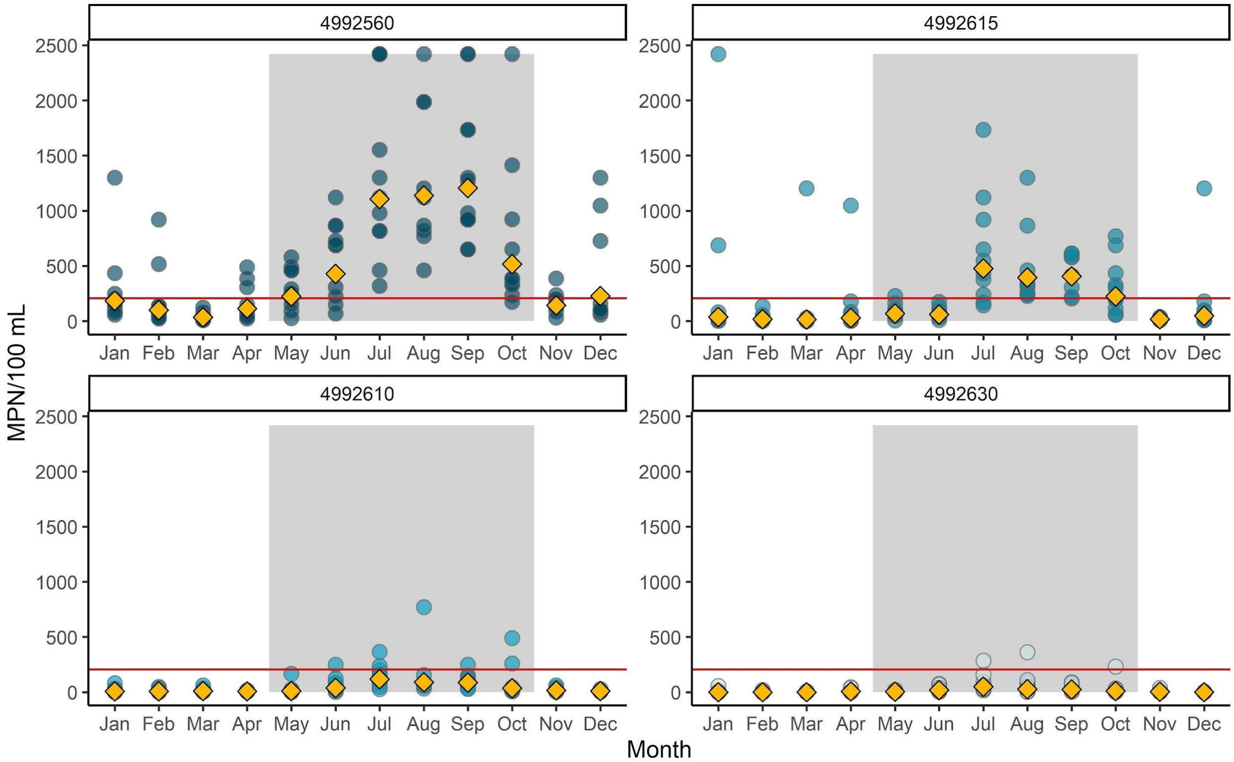

Figure C-15. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDCs), microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. Possible sources for this AU include stormwater runoff, illicit discharges, animals, failing onsite systems, and irrigation diversions (Table C-7). Potential sources and recommended implementation strategies to address them are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curves

Load duration curves are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships

between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDC analysis requires both observed *E. coli* and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at the upper end of this small AU (Mill Creek at 460 West, Gauge #490). The closest impaired *E. coli* site, Mill Creek southwest of Nibley Park (4992560), was used in conjunction with this flow site. There are no major hydrologic differences or land-use changes between these two sites. Flow data during the TMDL period of record (January 2011–September 2021) are summarized in Table C-3, Figure C-6, and Figure C-7. The daily mean flows are higher during May and June, which corresponds to spring runoff and irrigation season. Flow decreases in the late summer mainly due to the upstream water diversions and general baseflow conditions.

The LDC for Mill Creek southwest of Nibley Park (4992560) shows exceedances occurring at all flow regimes (Figure C-19). Exceedances of the TMDL threshold (solid line) in high to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. The necessary load reduction by flow regime is provided in parentheses under each flow-regime label. The greatest reductions are needed in the high and moist flow regimes at 80% each. Mill Creek has both point and nonpoint source delivery methods of *E. coli* loading.

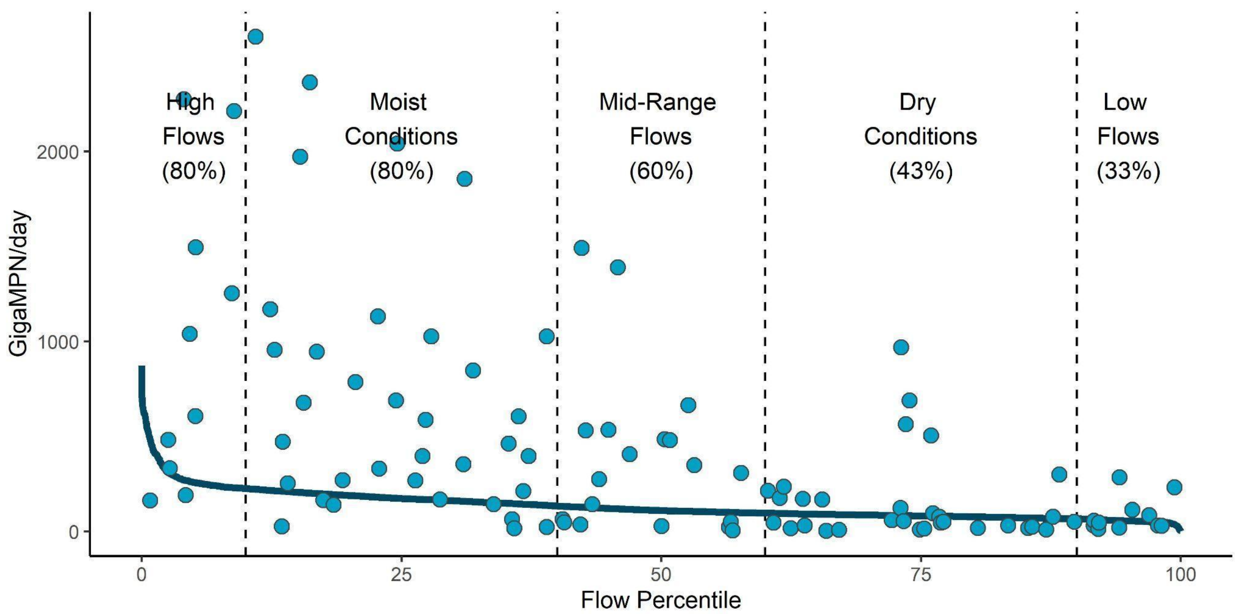

Figure C-16. Load duration curve for Mill Creek southwest of Nibley Park (4992560).

Microbial Source Tracking

Samples were collected once a month at six locations during July, August, and September from 2018–2020, with approximately nine samples per site and a total of 53 samples collected (Figure C-17). All four MST markers were detected in the AU. When the presence or absence of each marker was considered across all locations, avian was the most common at 91%, meaning of the 53 samples collected, 48 of them were positive for the avian marker. The human marker was present at 58%, canine at 40%, and ruminant at 40%. Five of the 53 samples exhibited no MST markers. Figure C-17 illustrates the presence/absence pattern of the four markers at each sampling location in the AU. The human marker becomes more commonly present at site C and then remains high downstream and through the lower AU. Similar to Mill Creek1-SLCity, human and avian sources should be the primary focus of source control measures.

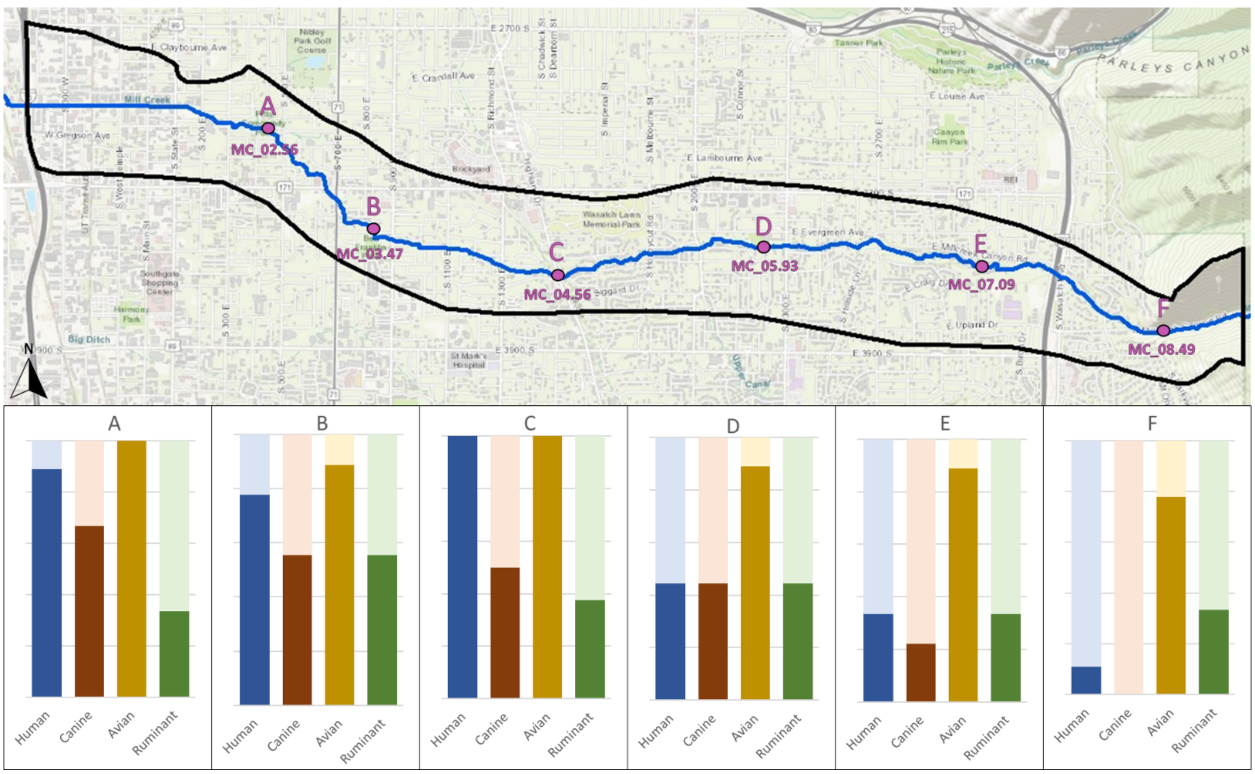

Figure C-17. The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades absence.

Source Assessment

The probable sources of *E. coli* in the Mill Creek2-SLCity AU come from both point and nonpoint sources, including stormwater runoff, onsite septic systems, avian wildlife, domestic pets, wildlife/nuisance species, and recreationists/unhoused based on LDC analysis, MST analysis, data analysis, land-use patterns, and hydrology.

Table C-7 provides a list of specific potential point and nonpoint sources in the Mill Creek2-SLCity AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. For more information on each potential source, please see Chapter 5.1 and 5.2.

Table C-7. Potential Sources of *E. coli* Contamination in Mill Creek2-SLCity Assessment Unit.

Source Permit	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
Point Source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial Stormwater	Yes	UTR000000		
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities, including South Salt Lake, Millcreek, Salt Lake County	UTS000001		
		Utah Department of Transportation	UTS000003		
Nonpoint source	Onsite septic systems	Yes		Section 5.2.1	Table 8
	Agricultural: livestock	No		Section 5.2.2	
	Agricultural: canals	Yes			
	Domestic pets	Yes		Section 5.2.4	
	Wildlife/nuisance species	Yes		Section 5.2.4	

Source Permit	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
	Recreationists/ unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

While there are several Utah Pollutant Discharge Elimination System (UPDES) permitted discharges within Mill Creek2-SLCity Assessment Unit, stormwater is the likely source of *E. coli* in this AU (Figure C-18). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the LDC that pointed to point sources during low-flow regimes, urbanized land uses and increased impervious surfaces in the valley, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see Chapter 5.1 in the main report for more information.

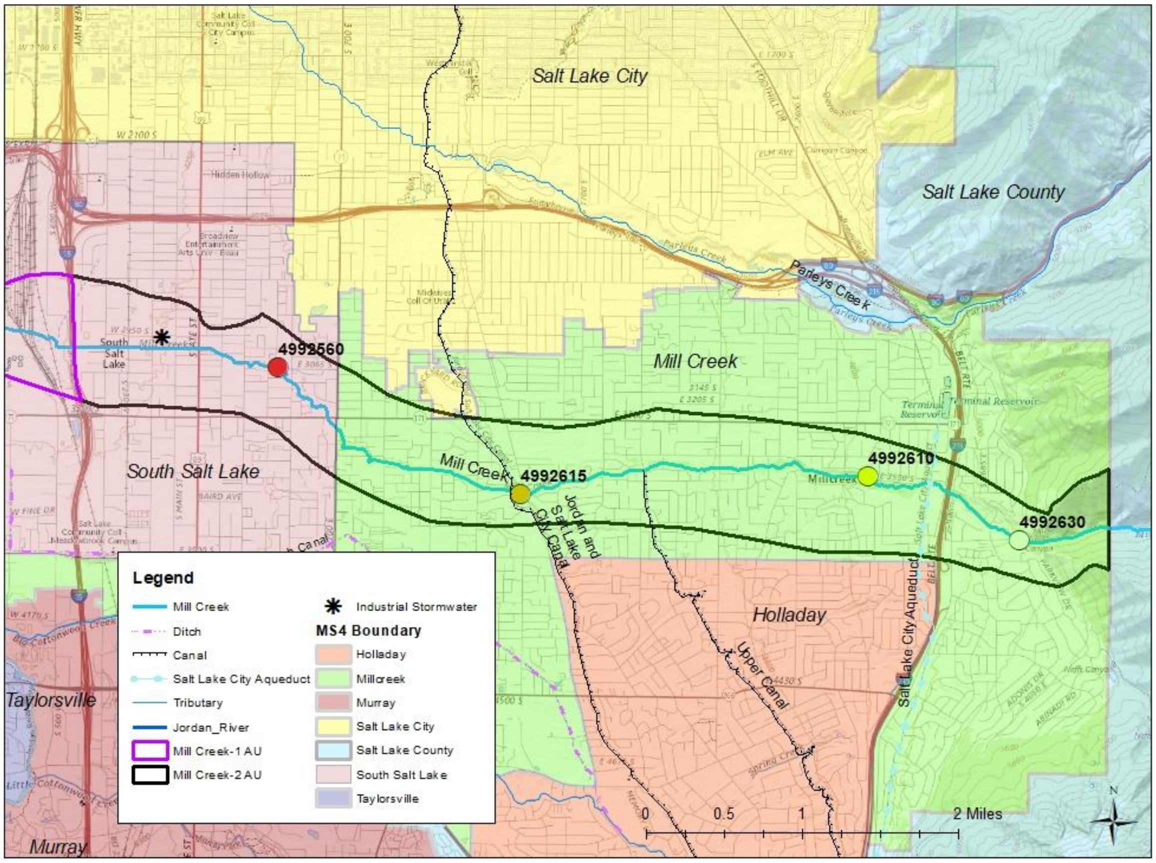

Figure C-18. Possible point sources of E. coli contamination within Mill Creek2-SLCity Assessment Unit.

Stormwater

Three potential sources of stormwater pollution (construction activities, industrial activities, and MS4s) occur within the Mill Creek2-SLCity AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there are 26 construction stormwater permits and one industrial stormwater permit within Mill Creek2-SLCity AU. The only industrial stormwater permit exists in the lower portion of the AU below the *E. coli* monitoring site Mill Creek southwest of Nibley Park (4992560) (Figure C-18). Construction permits are short-lived and change over time, and most industrial sites are not a potential source of *E. coli*. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Mill Creek2-SLCity AU by issuing MS4 permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of Mill Creek. There are two MS4 permits—Jordan Valley Municipalities and Utah Department of Transportation—applicable to this AU. The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. South Salt Lake City, Millcreek Township, and Salt Lake County have jurisdictional boundaries within the AU (Figure C-18). The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT. UDOT's Region 2 geographical area covers the Wasatch Front.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Mill Creek2-SLCity AU include canal inputs, humans, wildlife, and dogs (Figure C-19). Agricultural activity is not considered to be a significant source since it is minimal within this AU. Please see Chapter 5.2 in the main report for more information on nonpoint sources.

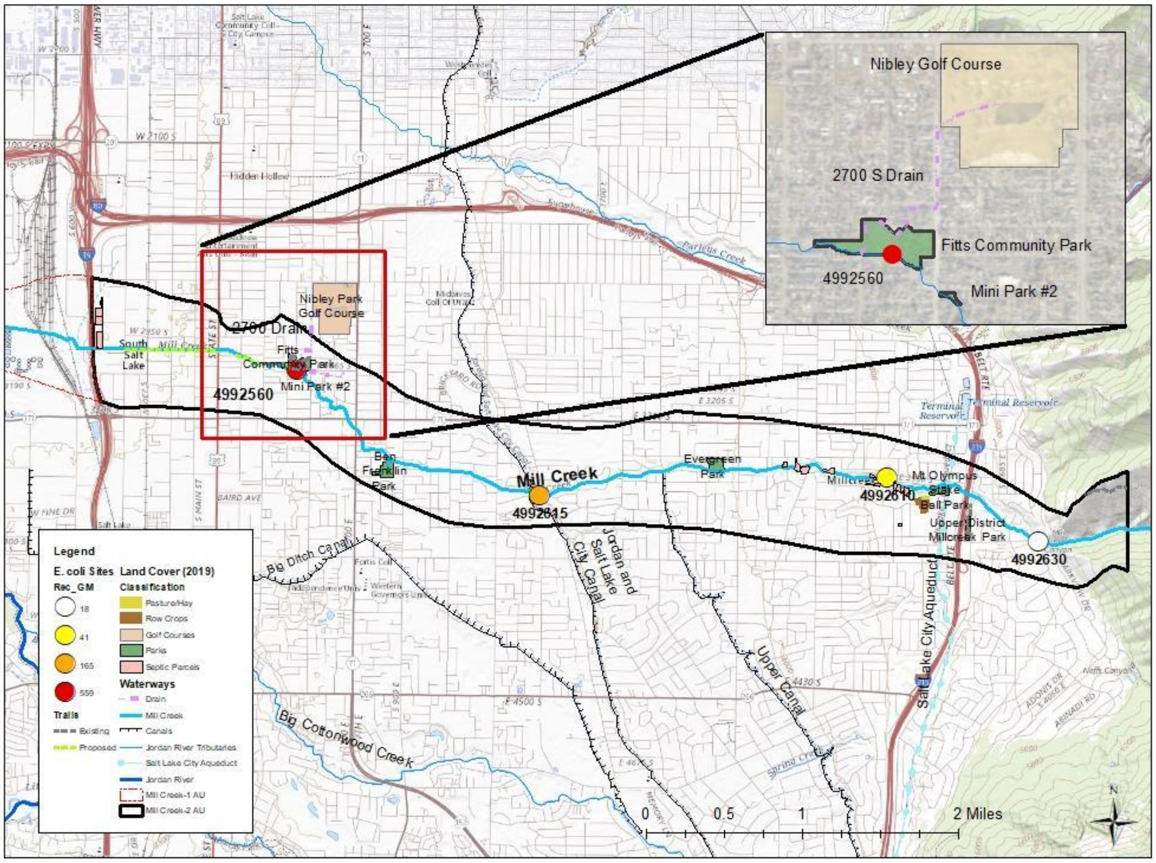

Figure C-19. Possible nonpoint sources of *E. coli* contamination within Mill Creek2-SLCity Assessment Unit.

Onsite Septic Systems

According to the Salt Lake County's Assessor's Office, there are 13 onsite septic system parcels within this AU as of 2021. Most parcels associated with this reach of Mill Creek are sewered. There are no large underground wastewater disposal systems in this area. MST human markers increased in the lower half of this AU.

Agricultural Activity

Livestock and grazing practices within the Mill Creek2-SLCity AU are minimal (<1% land use) and are not considered to be a significant source. However, canals delivering Utah Lake water to the local irrigators through exchange agreements with Salt Lake City could be a possible source of contamination. Though the canal source water (Utah Lake outlet) is not impaired for *E. coli*, outfalls and/or runoff with elevated *E. coli* concentrations could drain into the canals between their intake at the Jordan River Narrows and the outlet at Mill Creek.

Recreation, Pets, and Nuisance Wildlife

MST data shows that both human and canine markers generally increase throughout this AU. There are six parks (Upper District Millcreek Park, Mt. Olympus Stake Ball Park, Ben Franklin Park, Evergreen Park, Mini Park #2, and Fitts Community Park) along the main stem utilized by recreationists and their pets. Local ordinances require all dogs to be on a leash at these parks. Hiking trails and parks could contribute to the *E. coli* loading from both recreationists and their pets. Pet waste could also be coming from stormwater runoff from private residences.

The *E. coli* monitoring site at Fitts Park (Mill Creek SW of Nibley Park 4992560) has some of the highest *E. coli* concentrations in the AU and requires the greatest reduction to meet the TMDL target. Fitts Community Park has high recreational use, slowed flows which attract waterfowl, and possible *E. coli* loading from the pond at Nibley Park Golf Course via the 2700 S drain (Figure C-19).

MST analysis shows that ruminant species are present in the AU. MST analysis does not differentiate between hooved species, but it is assumed that deer, not cattle, are the primary source. Given the high development within this AU, it is likely that the ruminant contribution originates in upper Mill Creek and is being transported downstream.

MST analysis shows high levels of the avian marker throughout the AU. MS4 permits must address nuisance wildlife species that congregate at stormwater control structures such as detention basins and ponds.

Please see Table 8 in the main report for suggested BMPs to employ to manage these particular nonpoint sources of *E. coli* contamination.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Mill Creek2-SLCity AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and

- 668 MPN/100 mL as a daily maximum during the recreational season

Appendix D. Parleys Canyon Creek-1 and Parleys Canyon Creek- 2 Assessment Units *E. coli* TMDLs

Waterbody Name	Parleys Canyon Creek-1	Parleys Canyon Creek-2
Waterbody/Assessment Unit (AU)	UT16020204-025	UT16020204-013
AU Description	Parleys Canyon Creek and tributaries from 1300 East to Mountain Dell Reservoir	Parleys Canyon Creek and tributaries from Mountain Dell Reservoir to headwaters
Impaired Beneficial Uses	Domestic/drinking water (1C) Infrequent primary contact recreation (2B)	Domestic/drinking water (1C) Infrequent primary contact recreation (2B)
Applicable Season	May through October	May through October
Defined Endpoint/Water Quality Standard	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL
Percent Reduction	24%, based on a geometric mean of 270 MPN/100 mL calculated for 4992205 (Smith's Fork at Mt. Aire Canyon Road) in the month of August.	52%, based on a geometric mean of 431 MPN/100 mL calculated for 4992278 (Parleys Creek below I-80 Interchange and above Lamb's Canyon Creek) in the month of October.
Probable Sources	Stormwater, onsite septic, wildlife, pets	Stormwater, onsite septic, recreationists, wildlife

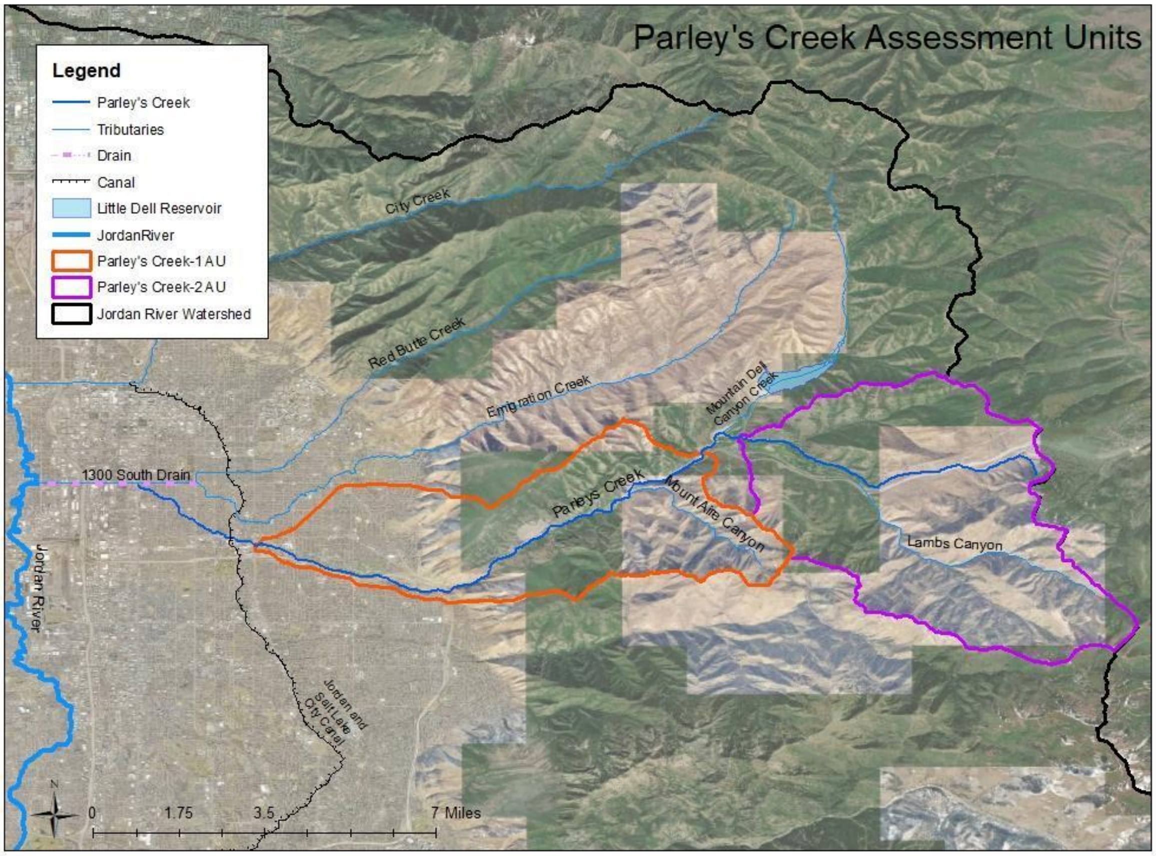

Figure D-1. Assessment units in Parleys Canyon Creek watershed.

Parleys Canyon Creek-1 Assessment Unit

Assessment Unit Description

The Parleys Canyon Creek-1 Assessment Unit (AU) contains Parleys Creek from Mountain Dell Reservoir 13.6 miles downstream to the intersection with 1300 East, Salt Lake City. The AU (16.6 mi^2) is located in Salt Lake City and Millcreek Township, and is entirely in Salt Lake County. Land ownership is 90% privately owned, 10% federally owned and managed by the Forest Service, and <1% managed by the Bureau of Land Management. The Parleys Canyon Creek-1 AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 1C (drinking water) and Class 2B (infrequent primary contact recreation) designated beneficial uses due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2010 Integrated Report.

Table D-1. Impairment summary of the Parleys Canyon Creek-1 Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
Parleys Canyon Creek-1 UT16020204-025	*E. coli*	Domestic/drinking water (1C) Infrequent primary contact recreation (2B)	2010–2022
	Dissolved oxygen* Macroinvertebrates*	Cold water aquatic life (3A)	2022 2014–2022
*Will be addressed in future TMDLs			

Hydrology

Parleys Creek originates in the Wasatch Mountains and flows 31.6 miles before joining Emigration and Red Butte Creeks into the 1300 South Drain and finally into the Jordan River (Figure D-1). The headwaters and upper reaches are managed by the Uinta-Wasatch-Cache National Forest and have strict watershed protection managed by Salt Lake City for drinking water purposes. Parleys Creek watershed drains 58.4 mi² of forested and developed landscape. The mean daily flow is 14 cubic feet per second (cfs) at Salt Lake County Gauge #520 (Parleys Creek at Canyon Mouth) during the TMDL period of record (2011–2021), with a maximum daily mean flow of 272 cfs (Table D-3).

Figure D-2 shows the inputs and outputs of the Parleys Creek riverine system in Parleys Canyon-1 AU. Instream flow in Parleys Creek is 100% reduced or interrupted by hydrologic modifications (SLCo 2017). Approximately 61% of the main channel is piped within this lower section (SLCo 2009). Hydrologic modifications, such as channelization, stormwater conveyance systems, diversions, and rip-rapped streambanks alter the stream's hydrograph.

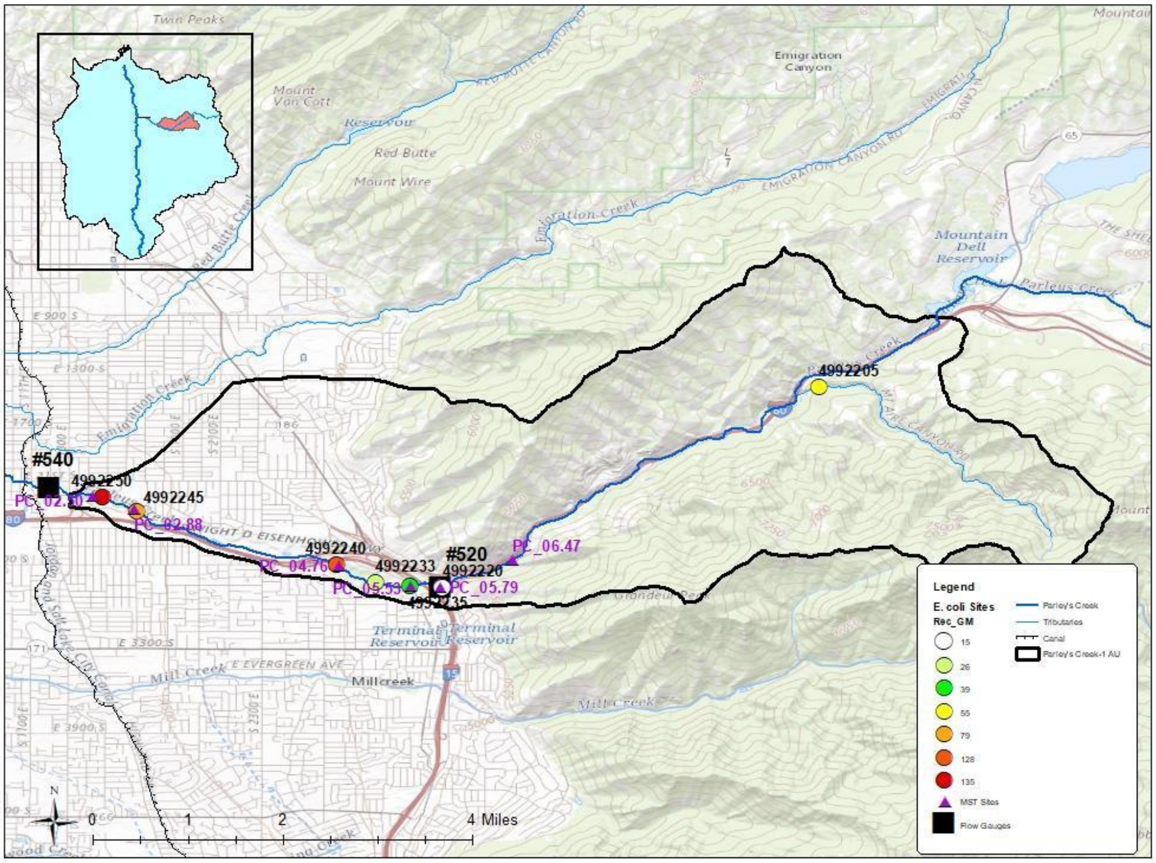

Figure D-2. Monitoring locations and hydrology of Parleys Canyon Creek-1 Assessment Unit.

The flows in this lower section of Parleys Creek originate mainly from the outlet of Parleys Canyon Drinking Water Treatment Plant and a small tributary (Smith Fork). Salt Lake City owns all the water rights in this reach and can divert 100% of the flow for domestic needs. On average, the treatment plant diverts approximately 6 to 23 cfs from Parleys Creek. The creek is piped approximately 4.9 miles from the plant to the mouth of the canyon. Geologic features at the nexus between the canyon and valley floor cause instream flows to decrease once Parleys Creek enters the valley.

Parleys Creek flows another 3.1 miles in the valley through parks and urban centers to Sugarhouse Park, where it is stored (140 ac-ft capacity) in a pond to regulate flows downstream. It is piped approximately 1.8 miles below Hidden Hollow Park until it reaches the 1300 South drain, joining flows from Red Butte and Emigration Creeks and eventually draining into the Jordan River in Salt Lake City (Figure D-1).

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 75.5% of the land in the Parleys Canyon Creek-1 AU is natural (i.e., forest, grassland, wetlands, shrubland, and barren) (Figure D-3). The rest of the land cover in this AU is 24.3% urban, 0.2% cultivated (i.e., pasture and crops) and 0.01% open water. Forested areas dominate the headwaters but not the riparian areas. Most of the riparian buffers along the main stem are largely urbanized due to Interstate 80 in the canyon and the developed areas in the valley. There are no major agricultural operations within this AU. Developed open space is predominantly associated with parks and golf courses. The urban land cover is primarily residential and industrial.

Approximately 44% of the AU is covered by impervious surfaces from developed land use, with most of those surfaces located within the valley. This level of impervious surface leads to increased runoff which results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase in this AU by 3% in 2040, which will likely result in an increase in impervious surfaces in this AU (SLCo 2017). See Section 5.3.1 in the main report for more information on the effects of impervious surfaces on pollutant loading.

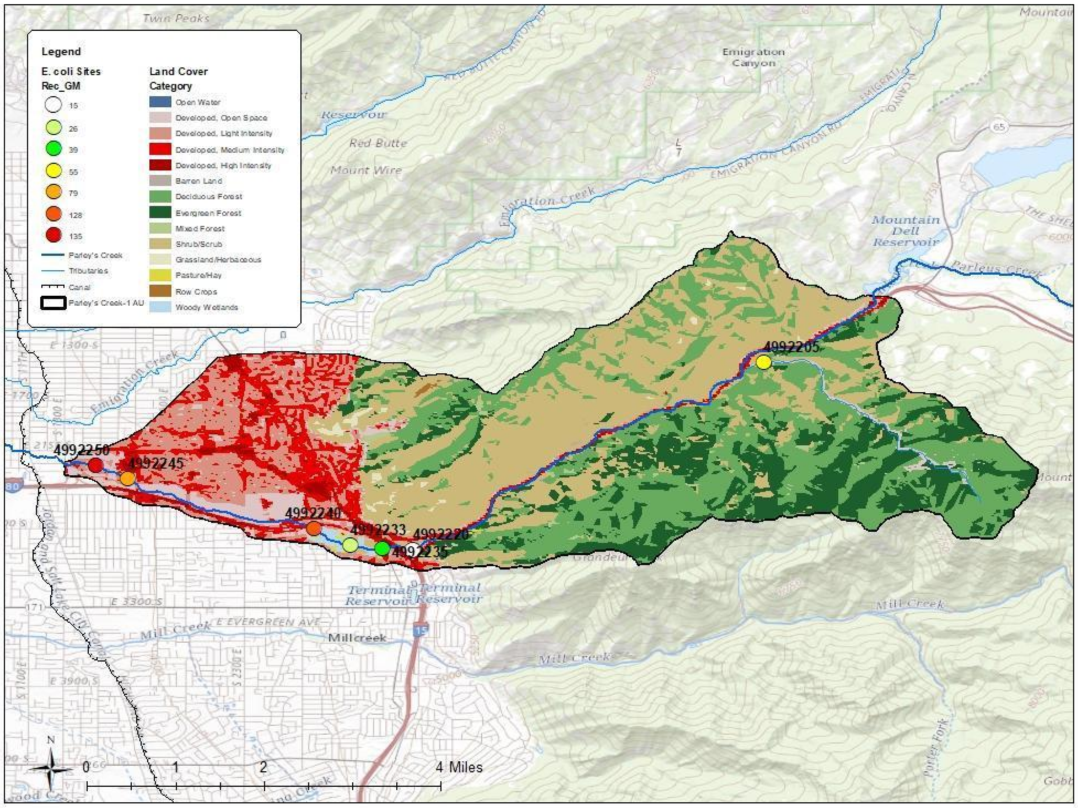

Figure D-3. Land cover in Parleys Canyon Creek-1 Assessment Unit (2019).

E. coli Data Summary

Seven routine monitoring locations on Parleys Canyon Creek-1 were studied for spatial and temporal patterns of *E. coli* levels (Table D-2). Samples were collected year-round at all sites except the most downstream site, Parleys Creek above the pond at Sugarhouse Park (4992250), which was sampled only during the recreation season. Most sites were sampled consistently from 2009–2021, with a gap in 2015, though the Parleys Creek at Pedestrian Bridge in Parleys Historic Nature Preserve (PHNP) (4992233) site was only sampled from 2010–2013 (Figure D-4).

All sites except Parleys Creek at Pedestrian Bridge in PHNP (4992233) had samples greater than 206 MPN/100 mL, and 21-25% of samples at the three most downstream sites (Parleys Creek below Historic Nature Preserve at bottom culvert, Parleys Creek at the top of Sugarhouse Park, Parleys Creek above pond at Sugarhouse Park) exceeded the standard, the highest number of exceedances in the AU (Figure D-4). Interestingly, the site highest in the watershed, Smith's Fork at Mt. Aire Canyon Road (4992205), also frequently had samples exceeding the standard, with 18% of samples above 206 MPN/100 mL (Figure D-5).

E. coli samples generally remained at or below the standard at all sites, with sparsely scattered exceedances throughout the period sampled (Figure D-5). Figure D-6 shows that monthly geometric mean concentrations were generally below the standard at all sites, except at the most upstream site, Smith's Fork at Mt. Aire Canyon Road (4992205).

Overall, a majority of sample concentrations were below the standard at all sites in this AU, but scattered high levels of *E. coli* indicate a diffuse source throughout the watershed.

Table D-2. Parleys Canyon Creek-1 Assessment Unit *E. coli* data summary all year.

Site ID (DWQ/ SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4992205 / SF_00.11 / SF_00.14	Smith's Fork at Mt. Aire Canyon Road	Insufficient data	04/2010 to 10/2021	113	0.5**	13	55	2,420 *	18	4
4992220 / PC_05.79	Parleys Creek near Suicide Rock	Meeting criteria	05/2010 to 10/2021	115	0.5**	6	15	921	1	1
4992233 / PC_05.13	Parleys Creek at Pedestrian Bridge in PHNP	NA	10/2010 to 10/2013	36	0.5**	10	26	184	0	0
4992235 / PC_05.53	Parleys above Historic Nature Preserve at top of culvert	Meeting criteria	06/2007 to 10/2021	136	0.5**	15	39	2,420 *	2	1
4992240 / PC_04.76	Parleys below Historic Nature Preserve at bottom culvert	Not meeting criteria	06/2007 to 10/2021	145	0.5**	39	128	2,420 *	21	7
4992245 / PC_02.88	Parleys top of Sugarhouse Park	Not meeting criteria	09/2009 to 10/2021	126	0.5**	50	79	2,420 *	25	13
4992250 / PC_02.50	Parleys above pond at	Insufficient data	06/2007 to 09/2020	37	32	135	135	2,420 *	24	11

	Sugarhouse Park									

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL
** Used half the detection limit (1 MPN/100 mL) for samples with non-detects

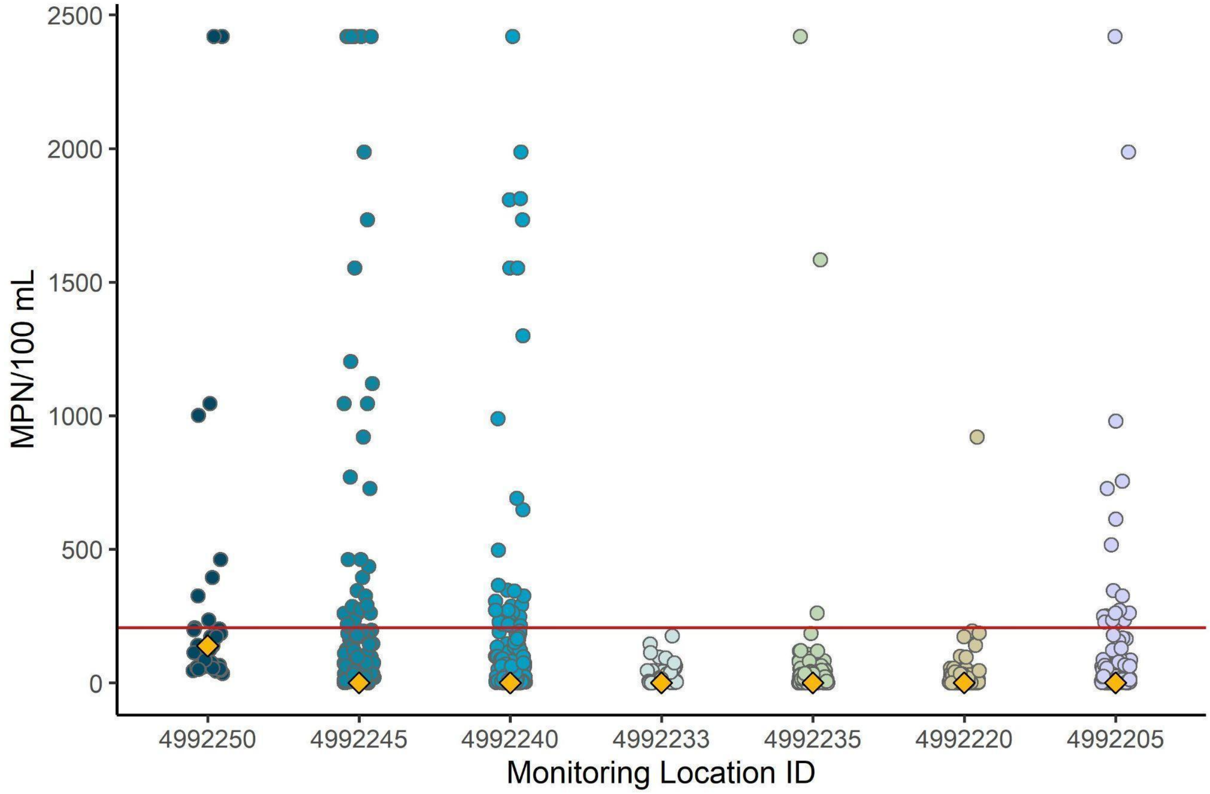

Figure D-4. *E. coli* concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Parleys Canyon Creek-1 Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

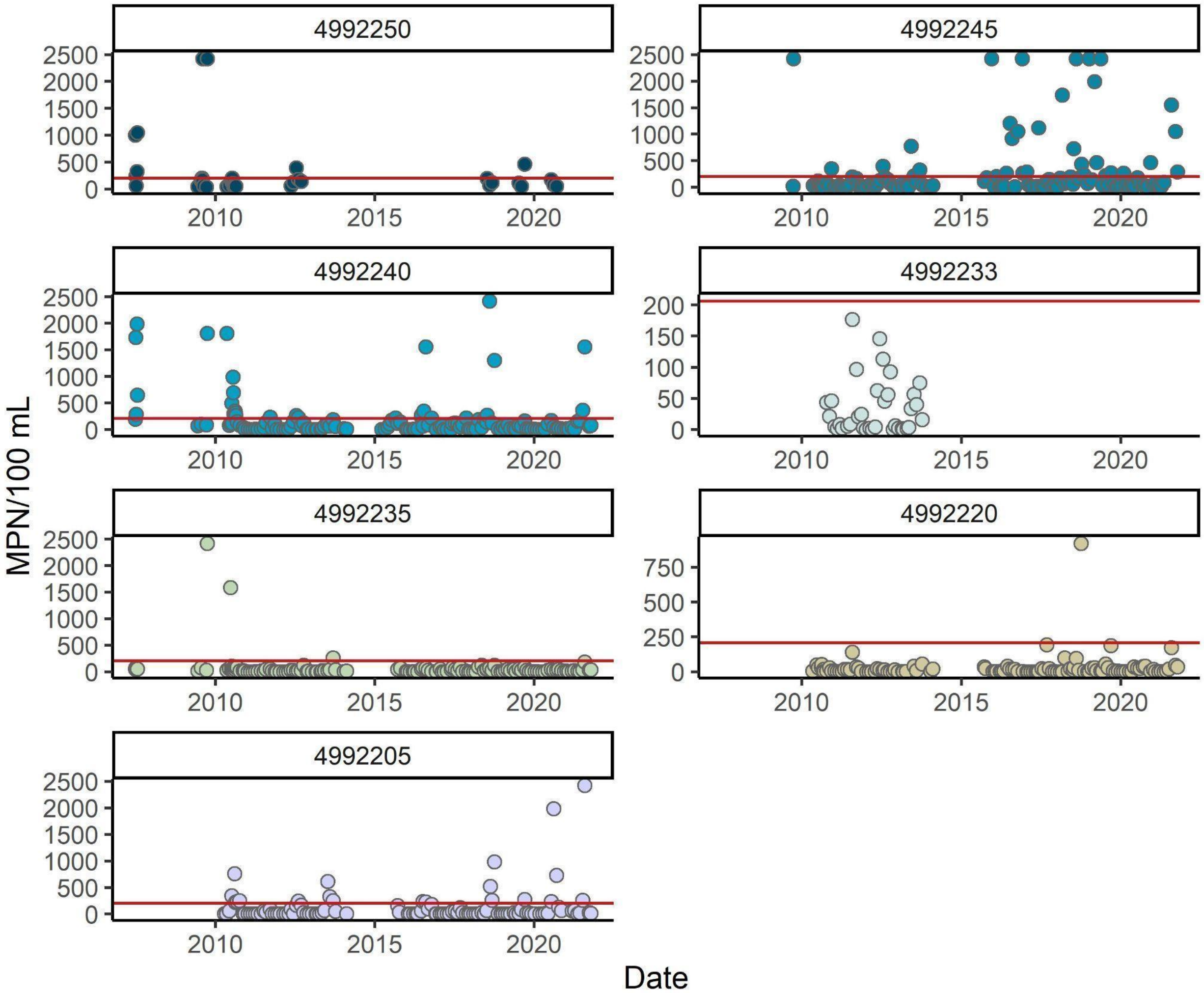

Figure D-5. *E. coli* concentrations at each routine monitoring location through time within the Parleys Canyon Creek-1 Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

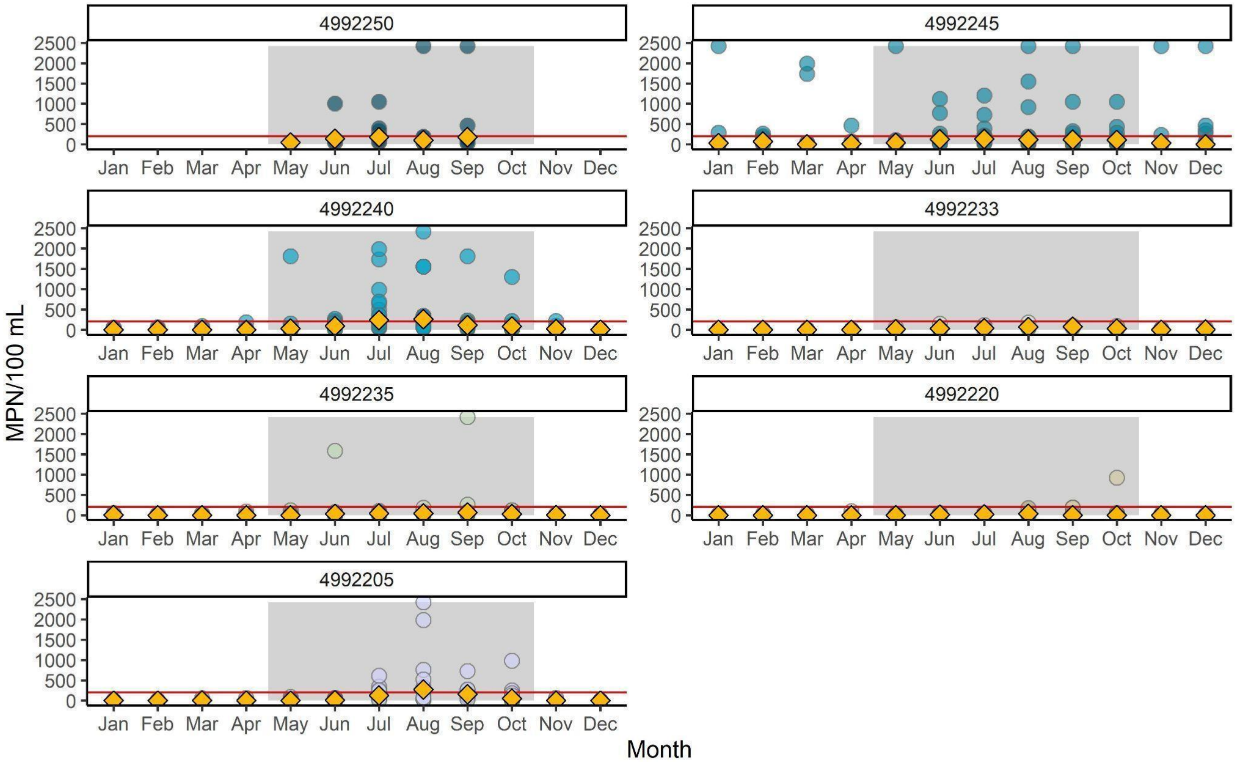

Figure D-6. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDCs), microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. Potential sources and recommended implementation strategies to address them are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curves

Load duration curves are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships

between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* concentrations and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at the canyon mouth (Parleys Creek at Canyon Mouth, Gauge #520). This site corresponds to an *E. coli* monitoring station, Parleys Creek near Suicide Rock (4992220). Flow data during the TMDL period of record (January 2011–September 2021) are summarized in Table D-3, Figure D-7, and Figure D-8. The daily mean flows are higher during May and June, which corresponds to snowmelt and spring runoff. Flow decreases in the late summer mainly due to upstream water diversions at the mouth of the canyon and general baseflow conditions. Typical baseline conditions return in the warmer months. While the hydrograph depicts a mountain stream, flows are impacted by upstream reservoirs and diversions from the drinking water plant.

Table D-3. Summary statistics for Parleys Creek at Canyon Mouth, Gauge #520 (4992220).

Gauge Name	SLCO Gauge Number/DWQ MLID	Drainage Area (mi²)	Mean Flow (cfs)	Maximum Flow (cfs)
Parleys Creek at Canyon Mouth	520/4992220	50.7	14	272

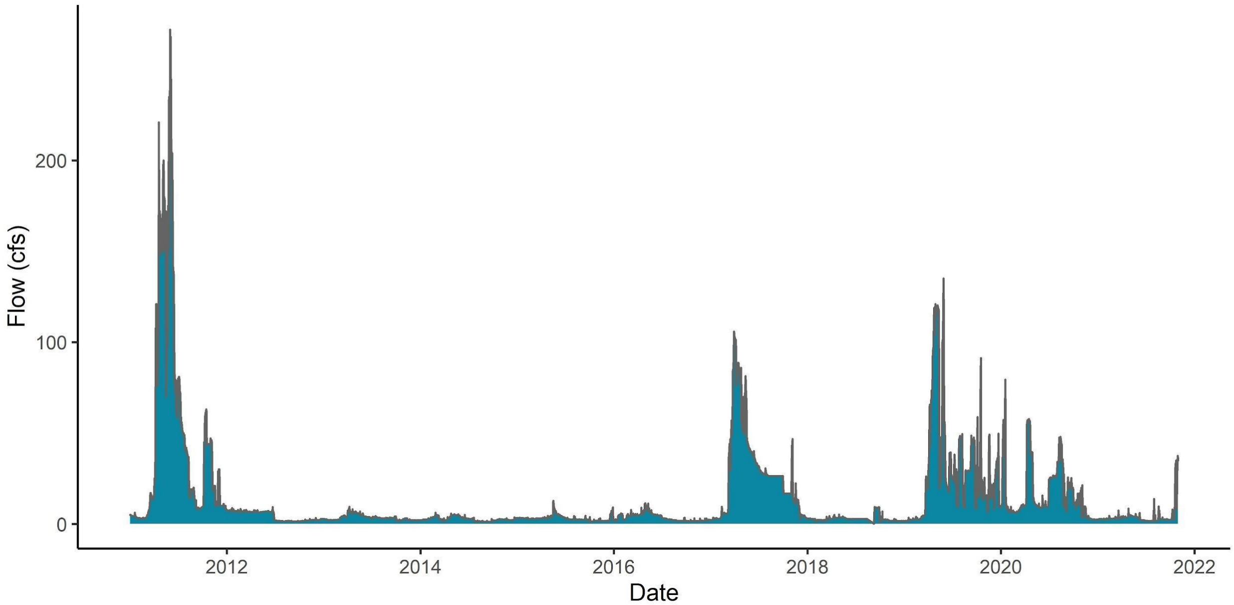

Figure D-7. Daily mean flows at Salt Lake County Gauge #520, Parleys Canyon Creek at Canyon Mouth (4992220) from January 1, 2011, to September 30, 2021.

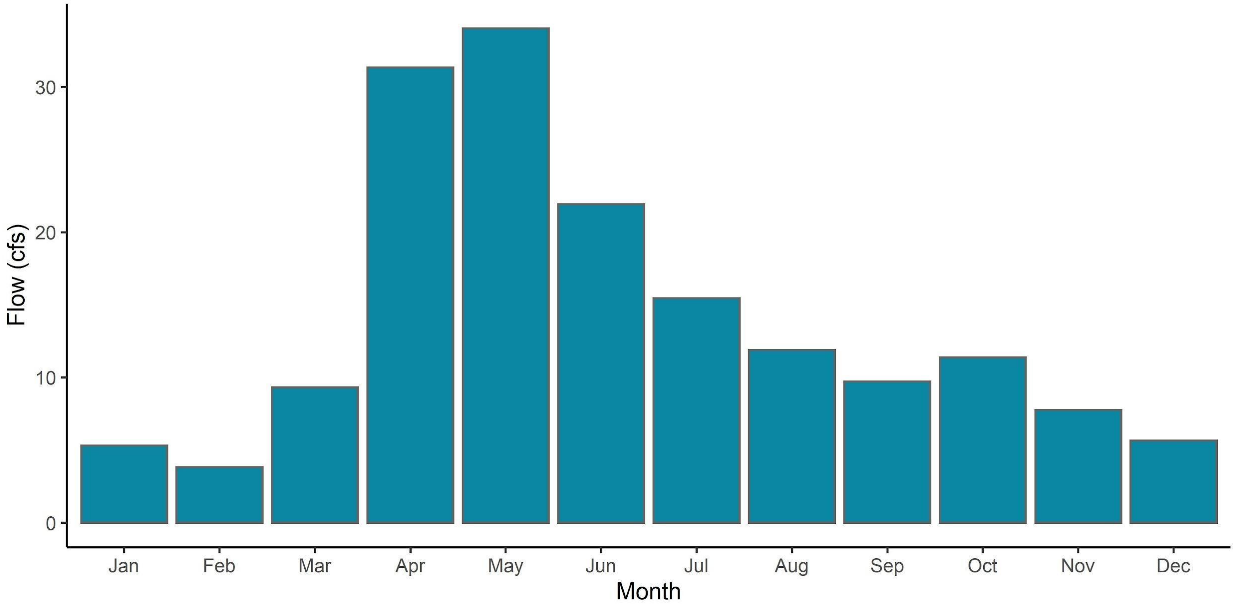

Figure D-8. Monthly mean flows (cfs) at Salt Lake County Gauge #520, Parleys Canyon Creek at Canyon Mouth (4992220) from January 1, 2011, to September 30, 2021.

Using this site's corresponding *E. coli* and flow data, the LDC shows exceedances occurring during dry flow regimes (Figure D-9). Exceedances of the TMDL threshold (solid line) in "dry" flow conditions indicate a high likelihood that the source originates from riparian areas and/or stormwater and impervious surfaces and a medium likelihood that it comes from point sources or onsite septic systems. The percent of *E. coli* loading measurements exceeding the TMDL in each flow regime is provided in parentheses under each flow regime in Figure D-9. Most load reductions are needed primarily in the drier flow regimes, which indicates that Parleys Canyon Creek-1 AU is dominated by localized (point) sources of *E. coli* loading, not diffuse nonpoint sources.

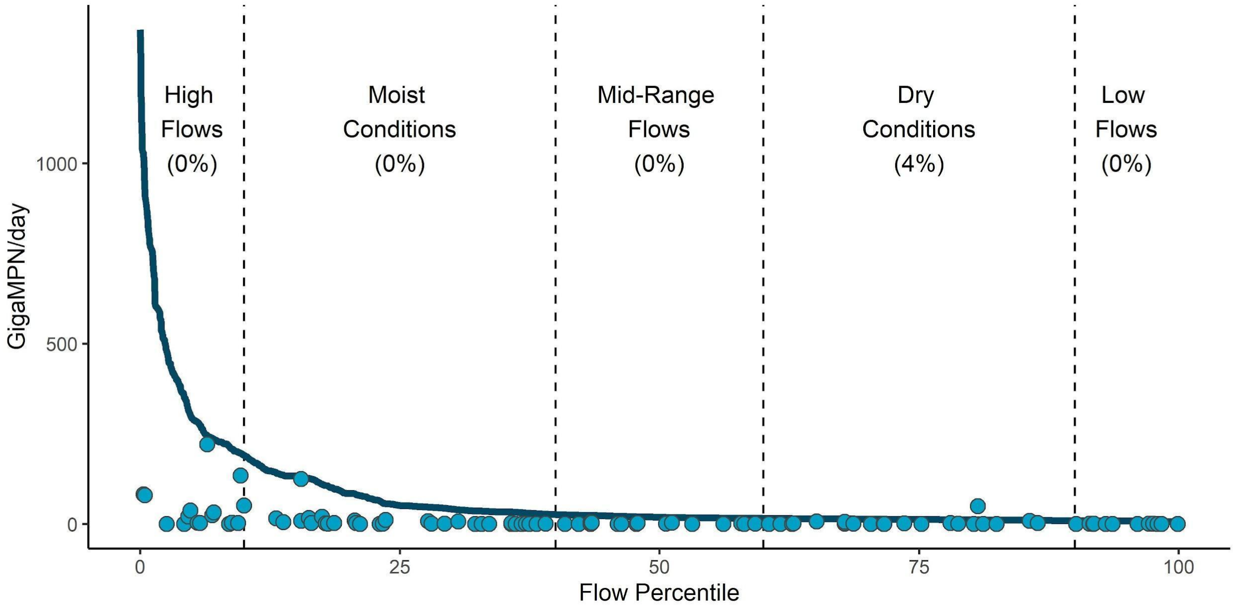

Figure D-9. Load duration curve for Parleys Canyon Creek at Canyon Mouth (4992220).

Microbial Source Tracking

Samples were collected once a month at six locations during July, August, and September from 2018–2020, resulting in nine samples per site and a total of 54 samples collected (Figure D-10). All four MST markers were detected in this AU. When the presence or absence of each marker was considered across all locations, avian was the most common at 46%, meaning of the 54 samples collected, 25 of them were positive for the avian marker. The human marker was present at 17%, canine at 19%, and ruminant at 39%. Twenty of the 54 samples exhibited no MST markers.

Figure D-10 illustrates the presence/absence pattern of the four markers at each sampling location in the AU. While some canine and human markers are present at several locations, the avian and ruminant markers persist throughout most of the sampling locations, even as the stream transitions from the foothills (site F) to the more urbanized landscape. Source controls should focus primarily on avian and ruminant sources where possible, although any presence of a human source should be further investigated, particularly at site B where the marker was present over 50% of the time. More information on MST can be found in Section 5.3.3 in the main report.

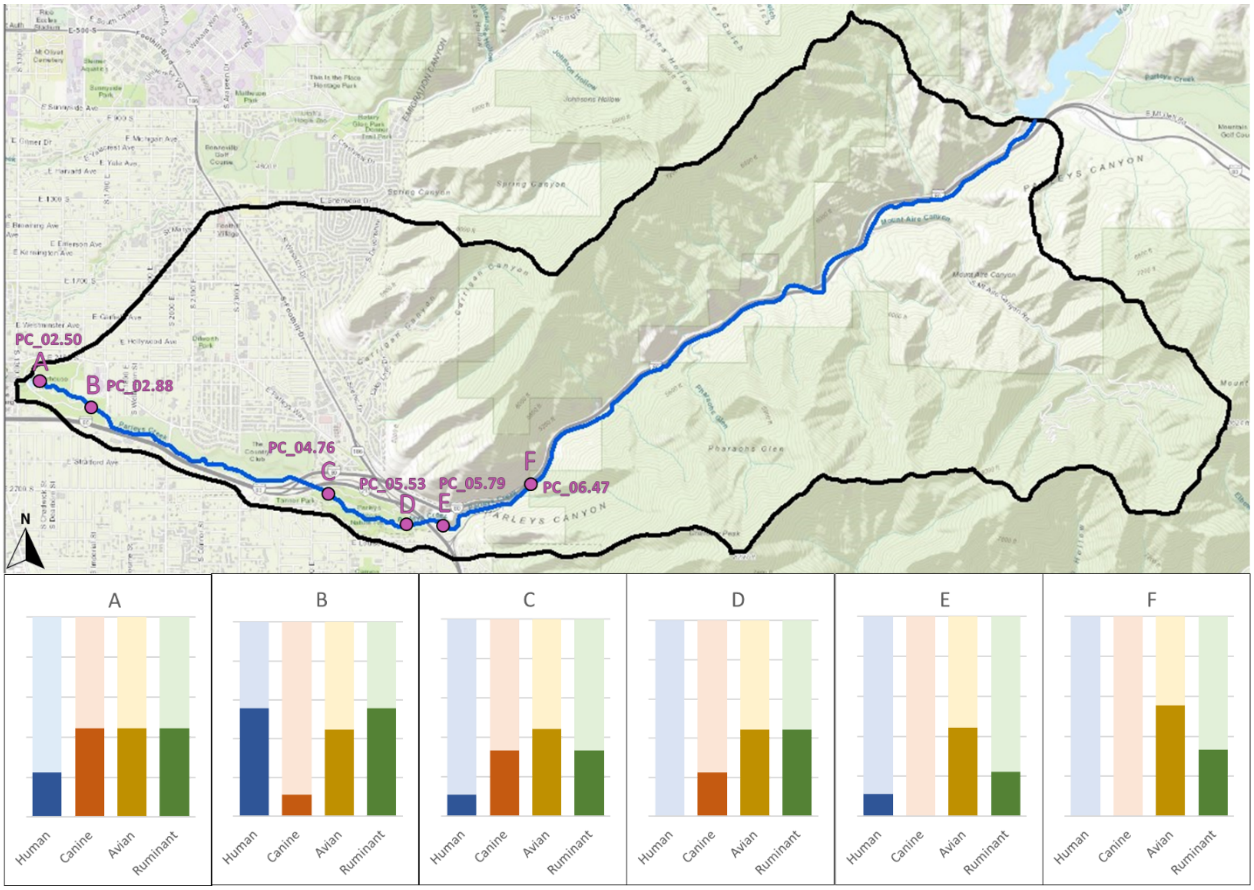

Figure D-10. The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades absence.

Source Assessment

Based on the data analysis, LDC analysis, land-use patterns, and hydrology, the probable sources of *E. coli* in the Parleys Canyon Creek-1 AU come from point sources, most notably stormwater runoff. Nonpoint sources include onsite septic systems, avian wildlife, domestic pets, wildlife/nuisance species, and recreationists/unhoused.

Table D-4 provides a list of specific, potential point and nonpoint sources in the Parleys Canyon Creek-1 AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. Please see Chapter 5.1 and 5.2 for more information on each potential source.

Table D-4. Potential sources of *E. coli* contamination in Parleys Canyon Creek-1 Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	Yes	UTR000000		
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities, including Cottonwood Heights, Holladay, Murray, Millcreek, Salt Lake County	UTS000001		
		Utah Department of Transportation	UTS000003		
		Salt Lake City	UTS000002		
Nonpoint source	Onsite septic systems	Yes		Section 5.2.1	Table 8
	Agricultural: livestock	No		Section 5.2.2	
	Agricultural: canals	No			
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	
	Recreationists/ unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

While there are several Utah Pollutant Elimination Discharge Permit (UPDES) permitted discharges within Parleys Canyon Creek-1 Assessment Unit, municipal stormwater is the likely source of *E. coli* in this AU (Figure D-11). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the LDC that pointed to point sources during low-flow regimes, urbanized land uses and increased impervious surfaces in the valley, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see [Chapter 5.1](#) in the main report for more information.

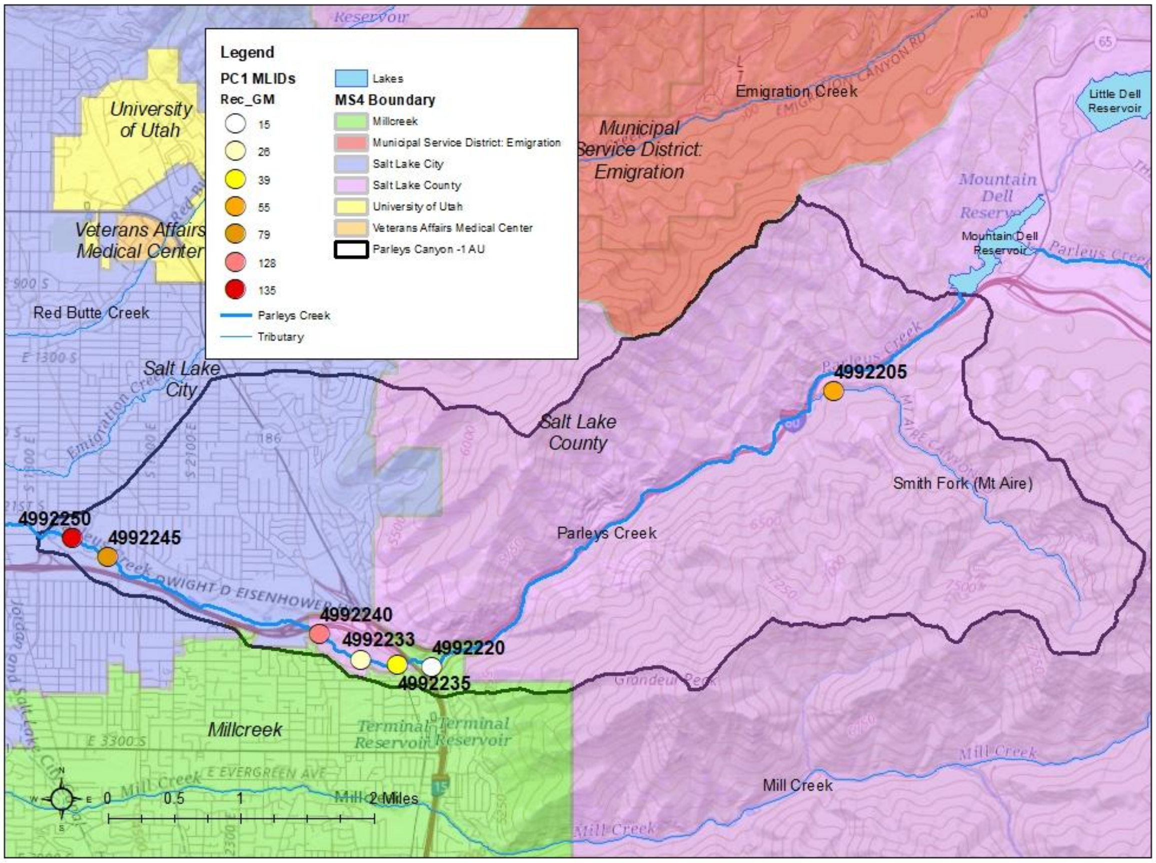

Figure D-11. Possible point sources of *E. coli* contamination within Parleys Creek-1 Assessment Unit.

Stormwater

Three potential sources of stormwater pollution (construction activities, industrial activities, and MS4s) occur within the Parleys Canyon Creek-1 AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were 10 construction permits and one industrial UPDES stormwater permit in the Parleys Canyon Creek-1 AU. The industrial stormwater permit is for a quarry pit located near the mouth of Parleys Canyon and is not considered to be a source of *E. coli* pollution. Construction permits are short-lived and change over time, and most industrial sites are not a potential source for *E. coli*. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within Parleys Canyon Creek-1 AU by issuing MS4s permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of Parleys Creek. There are three MS4 permits (Jordan Valley Municipalities, Salt Lake City, and Utah Department of Transportation) applicable to this AU (Figure D-11). The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. Salt Lake County and Millcreek Township have jurisdictional boundaries within the AU. Salt Lake City's MS4 Permit allows for discharge of stormwater within its jurisdictional boundaries. The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the state. UDOT's Region 2 geographical area covers the Wasatch Front.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Parleys Canyon Creek-1 AU include humans, wildlife, and dogs (Figure D-12). Since there is no agricultural activity within this AU, this is not considered to be a plausible source. Cultivated land uses are specific to local parks, (i.e., Parleys Historic Nature Park and Sugarhouse Park). Please see Chapter 5.2 in the main report for more information on nonpoint sources.

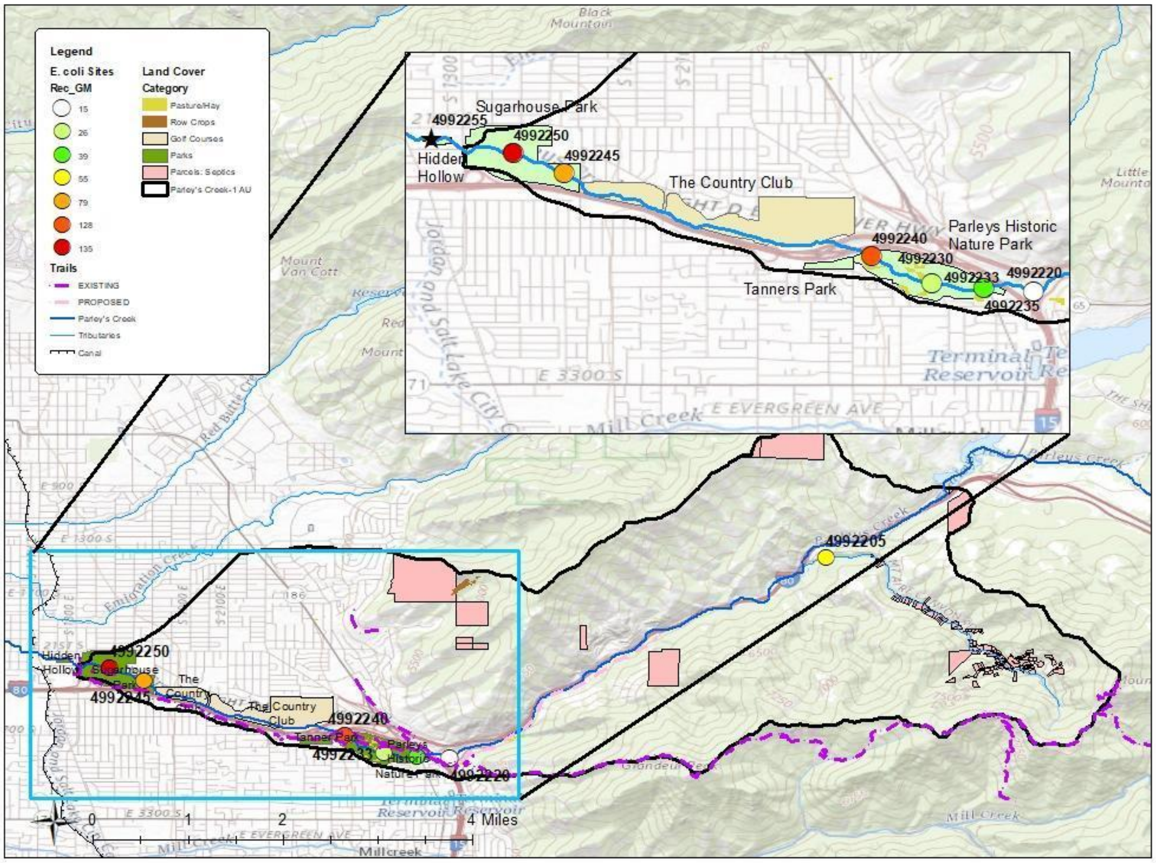

Figure D-12. Possible nonpoint sources of *E. coli* contamination in Parleys Creek-1.

Onsite Septic Systems

According to the Salt Lake County's Assessor's Office, there are 102 onsite septic system parcels within this AU as of 2021. These parcels are clustered primarily in the Smith Fork tributary (Figure D-12).

Most parcels associated with the urbanized portion of this AU are sewered. There are no large underground wastewater disposal systems in this area. *E. coli* loading from failing onsite septic systems is a plausible source, because *E. coli* concentrations exceed the standard 18% of the time during the recreational season at the Smith's Fork at Mt. Aire Canyon Road (4992205) site, which is directly downstream of these septic parcels (Table D-2). *E. coli* concentrations at this site peak during the warmer months when flows are at baseline conditions and there is less dilution (Figure D-6). Salt Lake County Health Department has responded to reports of failing onsite septic systems in the past in this subwatershed. Please see Chapter 5.2.1 in the main report for more information on onsite septic systems and Chapter 7 on suggested BMPs.

Recreation, Pets, and Nuisance Wildlife

Parleys Creek flows through several popular parks, a golf course, and highly recreated open space areas once it enters the Salt Lake valley. Based on the MST results, nonpoint sources of *E. coli* are primarily from avian and ruminants, but also canines. The MST analysis shows that canine markers are present at site D (4992235/PC_05.53) at the top of the Parleys Historic Nature Park along with ruminant and avian markers. This nature preserve is a highly recreated open space for both recreationists and their pets. It is considered an off-leash dog park. The park is managed by Salt Lake City through an adaptive management plan to mitigate water quality concerns such as high recreational use, unlimited dog access to Parleys Creek, and barren riparian soils. Project work has been implemented to address these concerns, such as the installation of vegetated riparian buffers and localizing dog access to the creek.

E. coli concentrations increase downstream of the nature preserve in Parleys Creek (4992240). This forested open space is suitable habitat for wildlife such as deer. MST analysis shows animal markers are prevalent throughout Parleys Historic Nature Park. *E. coli* concentrations increase at the bottom of the nature park downstream to Sugarhouse Pond relative to the rest of the AU. The data suggest probable sources exist between these parks.

MST results show that the avian marker is the most prevalent throughout the AU. Parks, stormwater detention basins, and ponds in golf courses can attract and cause waterfowl and other avian species to congregate. Nuisance-species management is a requirement as part of the MS4 UPDES permit. The Country Club Golf Course directly downstream from the nature park has a pond adjacent to Parleys Creek. Waterfowl were observed in this pond, and MST analysis corroborates this observation. *E. coli* concentrations in Parleys Creek downstream of the golf course (4992245) remain elevated.

Sugarhouse Park is directly below the Country Club Golf Course. The 110-acre park has a large pond, numerous sports fields, and walking trails, and is highly used year-round. Based on MST analysis, avian and canine markers were present in Parley Creek within

Sugarhouse Park. Salt Lake County uses the pond at Sugarhouse Park as a stormwater and flood-control basin. This pond attracts a significant number of waterfowl and other avian species.

Parleys Creek directly below the Parleys Canyon Creek-1 AU boundary flows through another smaller park, Hidden Hollow, before it enters the 1300 South drain. *E. coli* concentrations exceed the standard 49% of the time (Parleys Creek at Hidden Hollow, MLID: 4992255) during the recreational season, with concentrations often exceeding the laboratory detection limit of 2,420 MPN/100 mL (2011–2022, n =112). These data were not included in the assessment of Parleys Canyon Creek-1 AU because this site is not located in the AU. The Parleys Creek at Hidden Hollow data suggests that Sugarhouse Park Pond is a source of *E. coli* contamination. This monitoring location will be incorporated into the assessment unit boundary of Parleys Creek-1 in the 2024 Integrated Report.

Human markers are observed in the lower section of the AU. Adequate restroom facilities are present at the parks. Improper human waste disposal from recreationists is considered a low concern. There are no parcels with onsite septic systems located within the valley section of the AU.

Please see Table 8 in the main report for suggested BMPs to employ to manage these particular nonpoint sources of *E. coli* contamination.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Parleys Canyon Creek-1 AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Parleys Canyon Creek-2 Assessment Unit

Assessment Unit Description

The Parleys Creek-2 Assessment Unit (AU) contains Parleys Creek from its headwaters in the Wasatch mountains 15.7 miles downstream to Mountain Dell Reservoir. The AU (21.4 mi²) is located in Salt Lake County. Land ownership is 94% privately owned and six percent federally owned and managed by the Forest Service. The Parleys Canyon Creek-2 AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 1C (drinking water) and Class 2B (infrequent primary contact recreation) designated beneficial uses due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2022 Integrated Report.

Table D-5. Impairment summary of the Parleys Canyon Creek-2 Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
Parleys Canyon Creek-2 UT16020204-013	*E. coli*	Domestic/drinking water (1C) Infrequent primary contact recreation (2B)	2022
	Cadmium	Cold water aquatic life (3A)	2014–2022

Hydrology

Parleys Creek originates in the Wasatch Mountains and flows 19.1 miles downstream before joining Emigration and Red Butte Creeks into the 1300 South Drain and finally into the Jordan River (Figure D-1). The headwaters and upper reaches are managed by the Uinta-Wasatch-Cache National Forest and have strict watershed protection managed by Salt Lake City for drinking water purposes. The Parleys Creek watershed encompasses 58.4 mi² of forested and developed land. There is no continuous flow gauge within the Parleys Canyon Creek-2 AU.

Figure D-13 shows the inputs and outputs of the Parleys Creek riverine system. Thirty-seven percent of the instream flow in Parleys Creek in the Parleys Canyon Creek-2 AU is either reduced or interrupted by hydrologic modifications (SLCo 2017). Hydrologic modifications, such as channelization, stormwater conveyance systems, diversions, and rip-rapped streambanks, alter the stream's hydrograph.

There are two major tributaries to Parleys Creek in the upper part of the watershed: Lamb's Creek and Mountain Dell Canyon Creek. Mountain Dell Canyon Creek drains from the northwest into Little Dell Reservoir. Most of the instream flow in Parleys Canyon Creek-2 AU originates from the Lambs Creek tributary, which is diverted to Mountain Dell Reservoir above the natural confluence of Parleys Creek. Salt Lake City Department of Public Utilities manages a diversion on Parleys Creek, approximately 1.5 mi above Mountain Dell Reservoir, and maintains a minimum flow of 5 cfs to protect the fish downstream (email correspondence with Patrick Nelson (SLCDPU) on June 1, 2022).

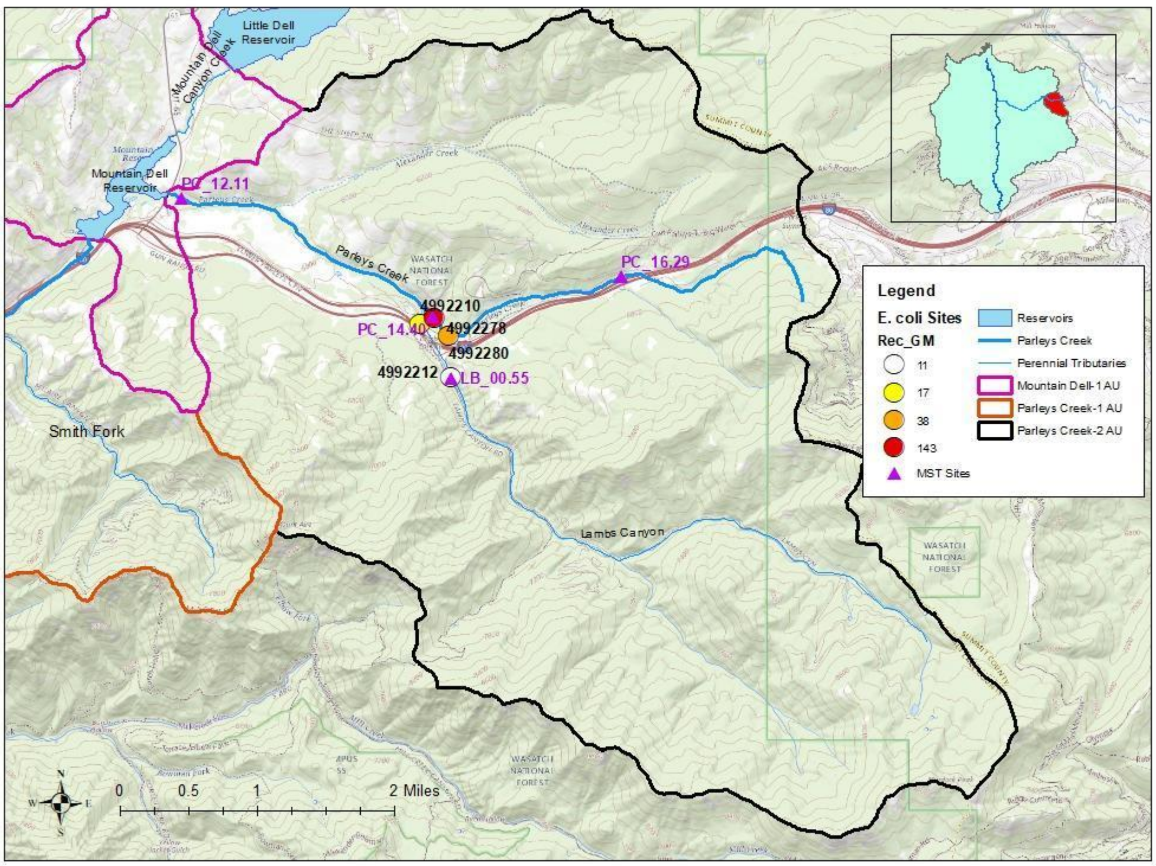

Figure D-13. Monitoring locations and hydrology of Parleys Canyon Creek-2 Assessment Unit.

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 96.5% of the land in Parleys Canyon Creek-2 AU is natural (i.e., forest, grassland, wetlands, shrubland, and barren) (Figure D-14). Developed land accounts for 3.3% of the land cover, and agricultural (pasture and crops) accounts for less than 1%. There are no open water features in this AU. The riparian buffers along the main stem of Parleys Creek are characterized as natural land. There are no major agricultural operations within this AU. Developed open space is limited to designed parks. Urban land cover is primarily residential and industrial.

Most of the Parleys Canyon Creek-2 AU has a low amount of impervious surfaces (approximately 1%). Most of these surfaces are along Interstate 80 and along the riparian corridor of Parleys Creek. Population growth is predicted to remain the same in this AU by 2040 (SLCo 2017). Impervious surfaces are not likely to increase within this AU.

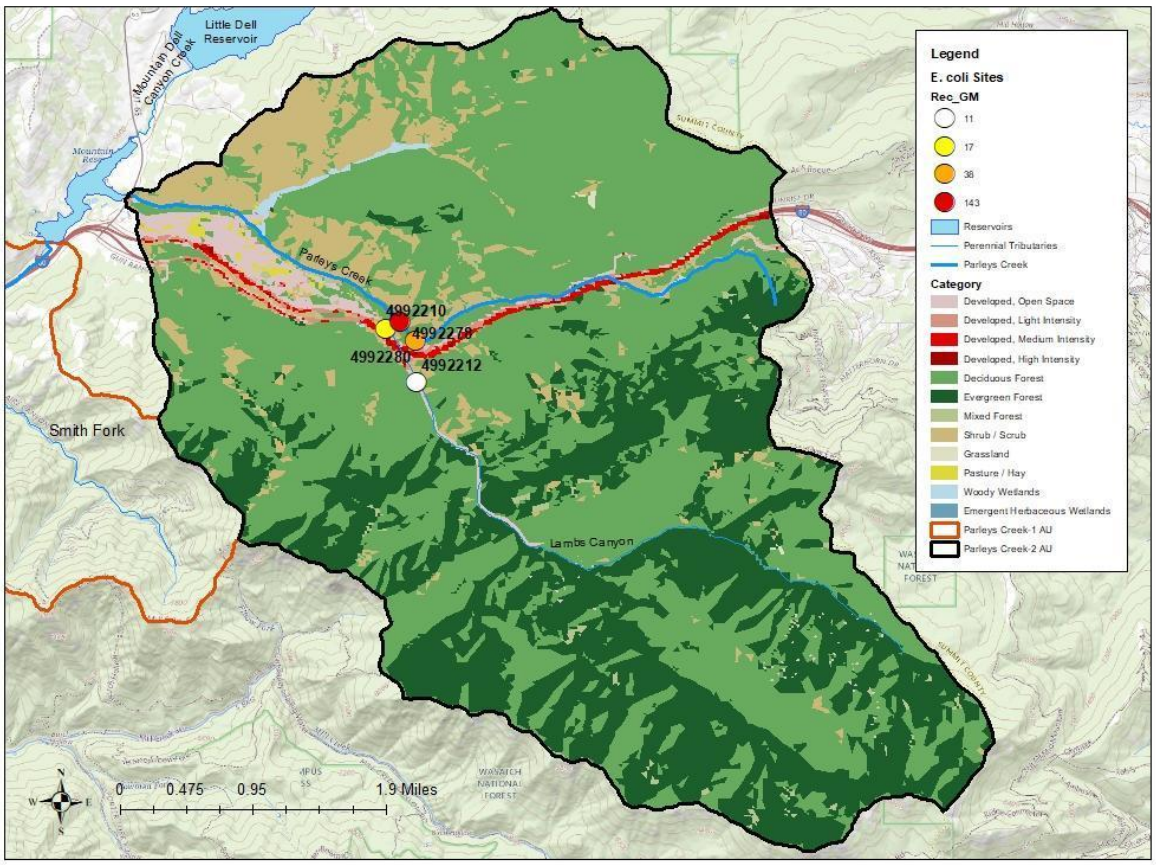

Figure D-14. Land cover in Parleys Canyon Creek-2 Assessment Unit (2019).

E. coli Data Summary

Four routine monitoring locations on Parleys Canyon Creek-2 were studied for spatial and temporal patterns of *E. coli* levels (Table D-6). Parleys Creek above I-80 and Lambs Canyon (4992278) and Lambs Canyon at the restoration site (4992212) were sampled consistently year-round between 2009 and 2021, while the upper site on Parleys Creek (4992280) was only sampled during the recreation season 2010–2012, and the lower Lambs Canyon site

(4992210) was sampled April–September in 2010, 2011, 2015, and 2016. Several samples at 4992278 (the most downstream site) exceeded the standard, though a majority of samples across all sites were below 206 MPN/100 mL (Figure D-15).

Parleys Creek above I-80 and Lambs Canyon (4992278) showed consistent exceedances of the 206 MPN/100 mL standard over the sampling period, while the most upstream site, Lambs Canyon at the restoration site (4992212), was consistently below the standard (Figure D-16). The smaller dataset at 4992280 had four exceedances in 2010–2012, and 4992210 did not exceed the standard over the limited sampling period.

Monthly geometric mean concentrations at most sites did not exceed the standard, but over the recreation season, Parleys Creek above I-80 and Lambs Canyon (4992278) had geometric means slightly at or above 206 MPN/100 mL (Figure D-17).

Table D-6. Parleys Canyon Creek-2 Assessment Unit *E. coli* data summary all year.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4992278 / PC_14.40	Parleys Creek below I-80 Interchange and above Lamb's Canyon Creek	Not meeting criteria	04/2010 to 10/2021	104	0.5**	53	143	2,420*	31	13
4992280	Parleys Creek above Confluence/ Lambs Canyon Creek	NA	05/2010 to 09/2012	16	1	38	38	649	31	0
4992210	Lamb's Canyon Creek below I-80 at weir	NA	05/2010 to 07/2016	12	1	15	17	322	0	0
4992212 / LB_00.55	Lamb's Canyon Creek Restoration Site	Meeting criteria	04/2010 to 10/2021	114	0.5**	8	11	921	3	1

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL
** Used half the detection limit (1 MPN/100 mL) for samples with non-detects

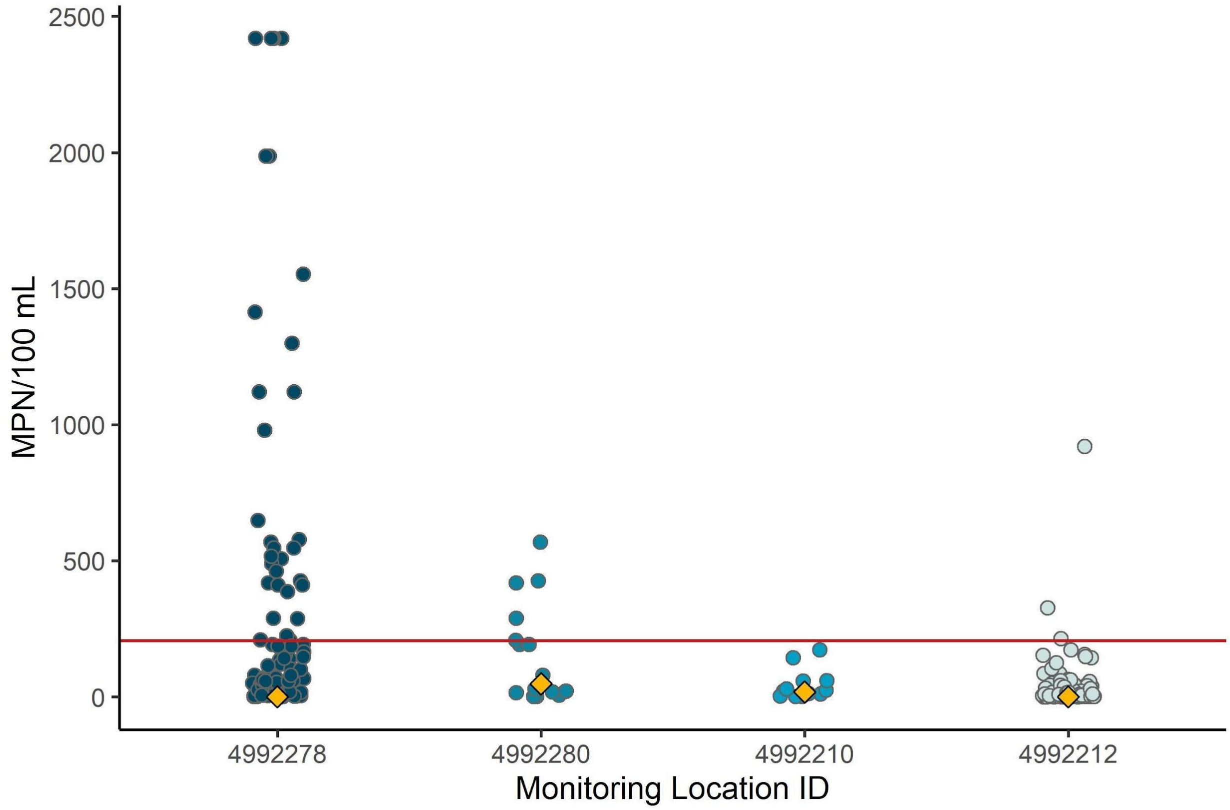

Figure D-15. *E. coli* concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Parleys Canyon Creek-2 Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

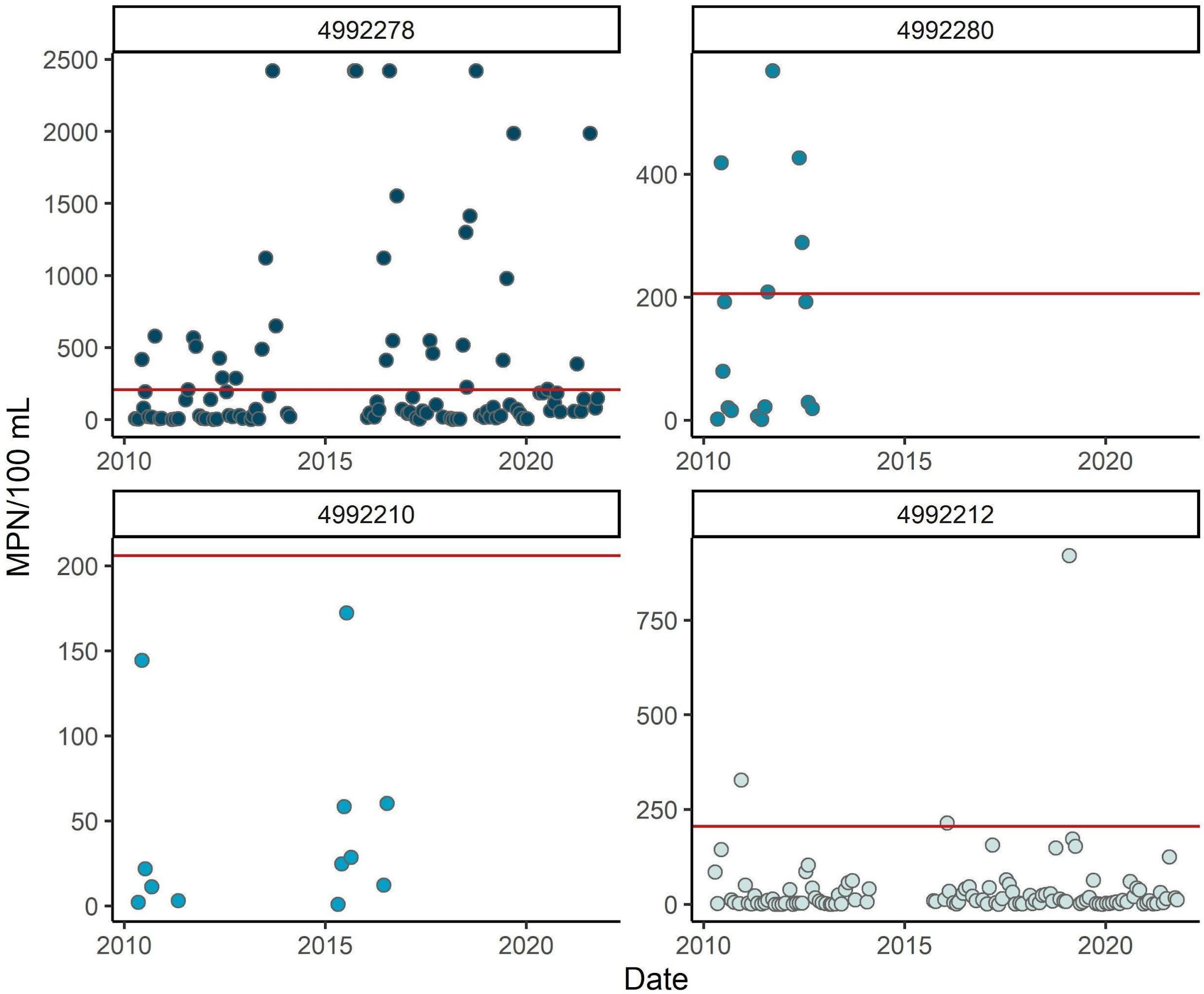

Figure D-16. *E. coli* concentrations at each routine monitoring location through time within the Parleys Canyon Creek-2 Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

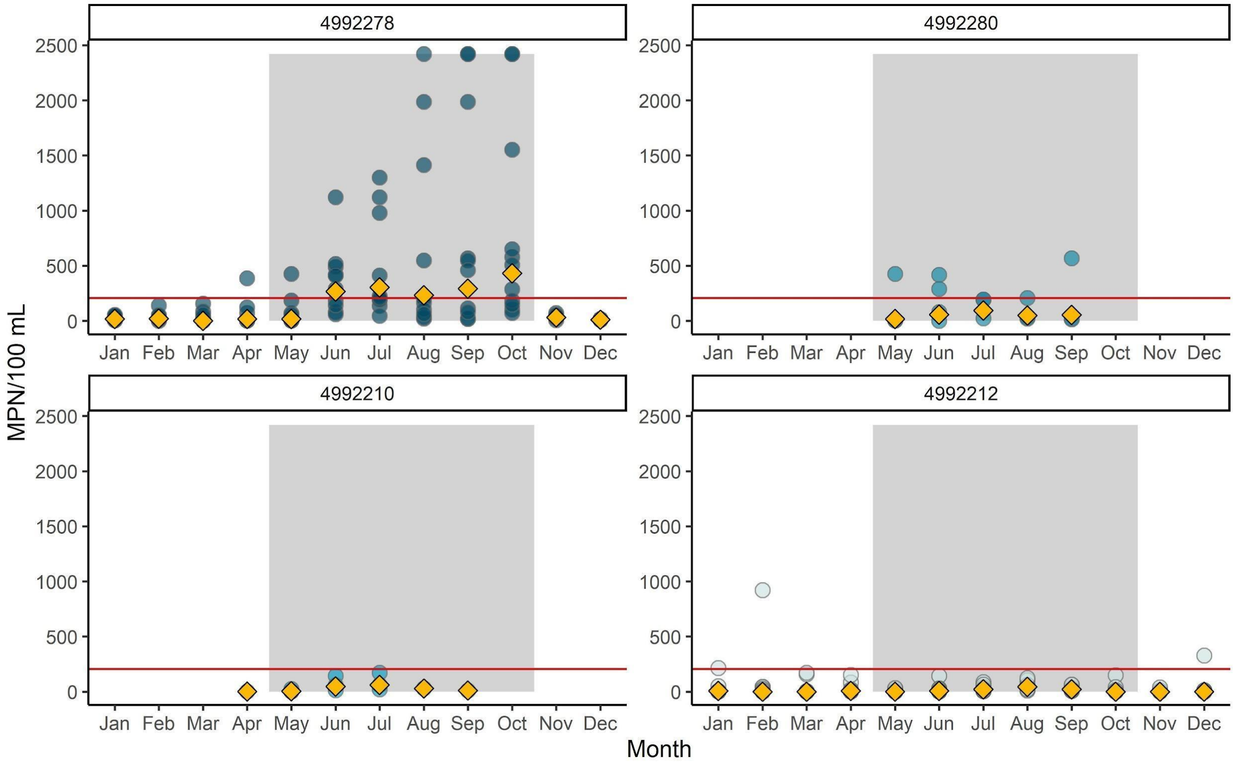

Figure D-17. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downtreat (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. A load duration curve source analysis was not possible because there is no continuous flow gauge in the Parleys Canyon Creek-2 AU to use to develop the curve. Potential sources and recommended implementation strategies to address the source are discussed in the main report in Chapter 5 and Chapter 7.

Microbial Source Tracking

Samples were collected once a month at three locations during July, August, and September from 2018–2020 on the mainstem and one location on Lamb's Canyon tributary, resulting in approximately nine samples per site and a total of 28 samples collected (Figure D-18). All MST markers were detected in the AU except for the canine marker. When the presence or absence of each marker was considered across all locations, avian was the most common at 96%, meaning of the 28 samples collected, 27 of them were positive for the avian marker. The human marker was present at 18%, canine at 0%, and ruminant at 79%. One of the 28 samples exhibited no MST markers.

Figure D-18 illustrates the presence/absence pattern of the four markers at each sampling location in the AU. Considering this AU is primarily forested land cover, the spatial trends in MST markers is not surprising, with high avian and ruminant presence and lower human and canine presence. Avian and ruminant sources should be the primary focus of source control measures in this AU where possible.

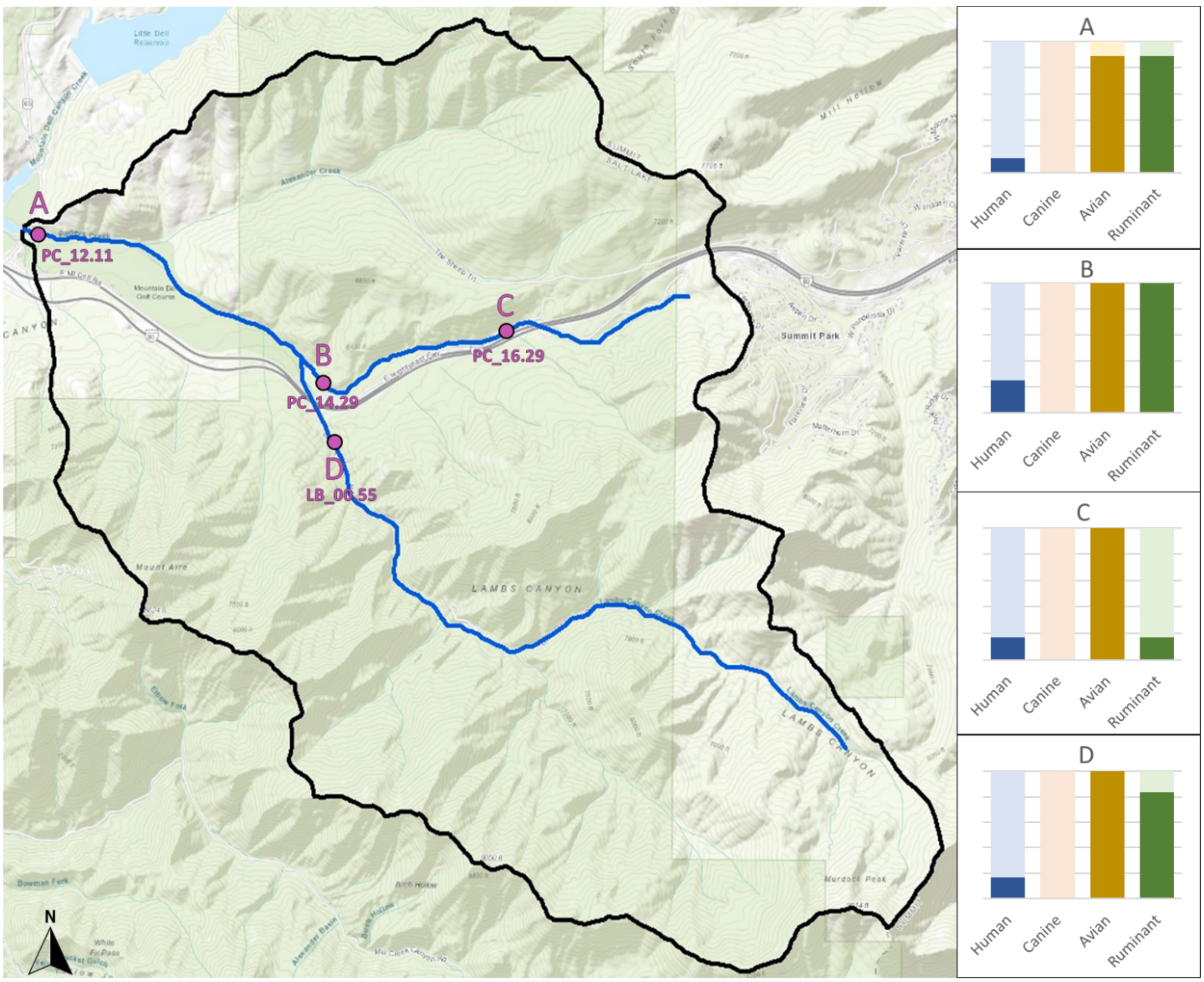

Figure D-18. The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades absence.

Source Assessment

The probable sources of *E. coli* in the Parleys Canyon Creek-2 AU are point sources (including stormwater) and nonpoint sources (including onsite septic systems, domestic pets, wildlife/nuisance species and recreationists/unhoused) based on the data analysis, land-use patterns, and hydrology.

Table D-7 provides a list of specific potential point and nonpoint sources in the Parleys Canyon Creek-2 AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. Please see Chapter 5.1 and 5.2 for more information on each potential source.

Table D-7. Potential Sources of *E. coli* Contamination in Parleys Canyon Creek-2 Assessment Unit.

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities including Salt Lake County	UTS000001		
		Utah Department of Transportation	UTS000003		
Nonpoint source	Onsite septic systems	Yes		Section 5.2.1	Table 8
	Agricultural: livestock	No		Section 5.2.2	
	Agricultural: canals	No			
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	
	Recreationists /unhoused	Yes		Section 5.2.5	

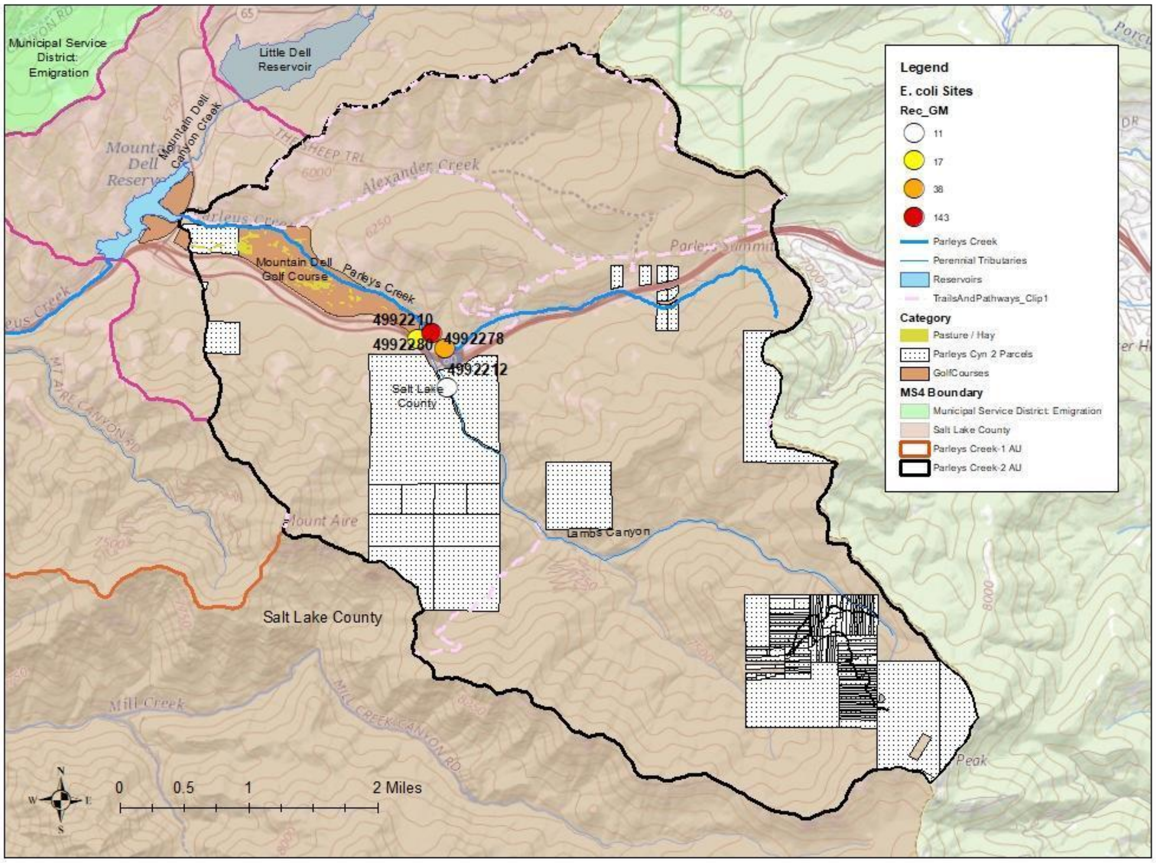

Figure D-19. Possible sources of *E. coli* contamination within Parleys Canyon Creek-2 Assessment Unit.

Point Sources

The only Utah Pollutant Discharge Elimination System (UPDES) permitted discharges in the Parleys Canyon Creek-2 AU are stormwater-related. Based on the land-use analysis, urbanized development along the riparian corridor of Parleys Creek and Interstate 80 may contribute stormwater runoff and could either directly or indirectly contribute to the *E. coli* contamination in this AU (Figure D-19). Please see Chapter 5.1 in the main report For more information.

Stormwater

Two potential sources of stormwater pollution (construction activities and MS4s) occur within the Parleys Canyon Creek-2 AU. Specific permits and activities are detailed below.

Construction Stormwater

As of March 1, 2022, there were two construction stormwater permits in the Parleys Canyon Creek-2 AU. They are both located at the bottom of the AU near the inlet to Mountain Dell Reservoir. Construction permits are short-lived and change over time. See Chapter 5.1 in the main report for more information regarding construction stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Parleys Canyon Creek-2 AU by issuing MS4s permits to the corresponding municipalities whose stormwater eventually discharges into the main stem of Parleys Creek. There are two MS4 permits (Jordan Valley Municipalities and Utah Department of Transportation) applicable to this AU (Figure D-19). The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. Salt Lake County has the only jurisdictional boundaries within the AU. The Utah Division of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the state. UDOT's Region 2 geographical area covers the Wasatch Front.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Parleys Canyon Creek-2 Assessment Unit include humans and wildlife. MST results show no canine presence within this AU. Since there is no agricultural activity within this AU, this is not considered a plausible source. Cultivated land uses are specific to the Mountain Dell Golf Course (Figure D-19). Please see Chapter 5.2 in the main report for more information on nonpoint sources.

Onsite Septic Systems

According to a 2009 survey by Salt Lake County Health Department, there are 146 onsite septic system parcels within this AU, predominantly clustered along the Lambs Canyon tributary (Figure D-19). There are no large underground wastewater disposal systems in this AU. *E. coli* loading from failing onsite septic systems is a plausible source because *E. coli* concentrations exceed the standard 31% of the time during the recreational season at the Parleys Creek above I-80 and Lambs Canyon site (4992278), which is directly downstream of onsite septic systems parcels (Table D-6, Figure D-19). *E. coli* concentrations at this site peak during the warmer months when flows are at baseline conditions and there is less dilution (Figure D-17). Salt Lake County Health Department has responded to reports of failing onsite septic systems in the past in this subwatershed.

Some of the Lambs Canyon parcels are not built out but are slated for onsite septic systems as their primary mode of wastewater treatment once construction begins. Lambs Canyon does not currently show elevated levels of *E. coli;* however, when development begins, BMPs should be employed to ensure there is no degradation of Lamb Canyon's water quality. Please see Chapter 5.2.1 in the main report for more information on onsite septic systems and Chapter 7 on suggested BMPs.

Recreation and Nuisance Wildlife

MST analysis for the Parleys Canyon Creek-2 AU shows a heavy presence of avian and some ruminant and human markers (Figure D-18). This AU is considered to be within the Salt Lake City watershed boundary. Dogs are prohibited in this area to protect drinking water sources. MST analysis shows compliance with this ordinance, as no canine markers were found in Parleys Canyon Creek-2 AU.

Both Lambs Canyon and Alexander Creek are popular hiking trails. Though unlikely, improper human waste disposal can occur along the trails during the warmer months when recreation is heavy.

Mountain Dell Golf Course is directly downstream of the Parleys Creek above I-80 and Lambs Canyon (4992278) site that shows elevated levels of *E. coli*. Nuisance wildlife such as waterfowl could congregate here, impacting water quality. However, since the monitoring sites are upstream of the golf course, the golf course contribution is unknown.

Even though the Parleys Canyon Creek-2 AU is mostly forested, the site at Parleys Creek (Parleys Creek below I-80 Interchange and above Lamb's Canyon Creek (4992278)) has *E.*

coli concentrations exceeding the standard 31% of time (Figure D-17). Wildlife (avian and ruminant) and human markers are present above this site on Parleys Creek. Possible sources could include direct deposition from humans and/or failing onsite septic systems. Suggested BMPs could include reducing nuisance wildlife and improper human waste removal.

Please see Table 8 in the main report for suggested BMPs to employ to manage these particular nonpoint sources of *E. coli* contamination.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Parleys Canyon Creek-2 AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Appendix E. Emigration Creek Lower Assessment Unit *E. coli* TMDL

Waterbody Name	Emigration Creek Lower
Waterbody / Assessment Unit (AU)	UT16020204-033
AU Description	Emigration Creek and tributaries from 1100 East (below Westminster College) to stream gauge at Rotary Glen Park above Hogle Zoo
Impaired Beneficial Uses	Infrequent primary contact recreation (2B)
Applicable Season	May through October
Defined Endpoint/Water Quality Standard	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL
Percent Reduction Needed	78%, based on a geometric mean of 920 MPN/100 mL calculated for 4992135 (Emigration Creek at Westminster College) in the month of July.
Probable Sources	Stormwater, onsite septic systems, recreationists, pets, wildlife

Assessment Unit Description

The Emigration Creek Lower Assessment Unit (AU) includes Emigration Creek from Rotary Glen Park 1.1 miles downstream to the intersection with 1100 East, Salt Lake City. The AU (3.1 mi^2) is within Salt Lake City and Emigration Canyon Metro Township, and is entirely in Salt Lake County. Land ownership is 97% privately owned, 2.9% federally owned and managed by the Forest Service, and 0.1% state owned. The Emigration Creek Lower AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) designated beneficial uses due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2014 Integrated Report.

Note that the upstream AU, Emigration Creek (UT16020204-012), has an approved *E. coli* TMDL (2011) which requires an average reduction of 56% in *E. coli* loading from nonpoint sources during July, August, and September to meet water quality standards.

Table E-1. Impairment summary of the Emigration Creek Lower Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
UT16020204-023	*E. coli*	Infrequent primary contact recreation (2B)	2014–2022

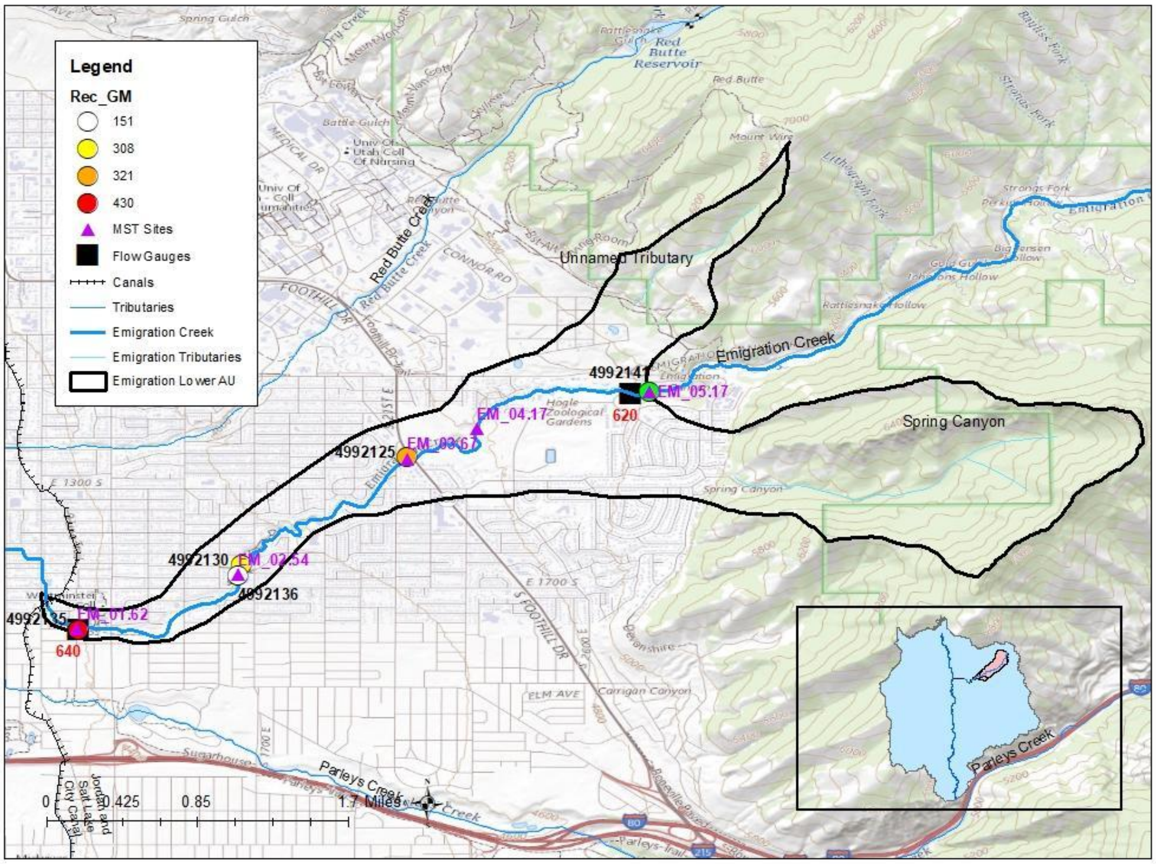

Figure E-1. Monitoring locations and hydrology of Emigration Creek Lower Assessment Unit.

Hydrology

Emigration Creek originates in the Wasatch Mountains and flows approximately 14 miles before joining Parleys and Red Butte Creeks into the 1300 South Drain and finally into the Jordan River (Figure E-1). The headwaters and upper reaches are managed by the Uinta-Wasatch-Cache National Forest, and some tributaries have strict watershed protection managed by Salt Lake City for drinking water purposes. Emigration Creek watershed drains 21 mi² of forested and developed landscape. Salt Lake County Gauge #640 (Emigration Creek below Westminster College Campus) has a mean daily flow of seven cubic feet per second (cfs) during the TMDL period of record (2011–2021), with a maximum daily mean of 47 cfs (Table E-3).

Figure E-1 shows the inputs and outputs of the Emigration Creek riverine system in Emigration Creek Lower AU. Instream flow in Emigration Creek is 88% reduced or interrupted by hydrologic modifications (SLCo 2017). Approximately 40% of the main channel is piped within this lower section (SLCo 2009). Hydrologic modifications, such as channelization, stormwater conveyance systems, diversions, and rip-rapped streambanks alter the stream's hydrograph.

Stream flows peak naturally in early spring (April and May) due to the low elevation and wide width of the canyon (Salt Lake City Department of Public Utilities 1999). Instream flow of Emigration Creek in the lower canyon is often dewatered in late summer due to natural geologic features, and it reaches its lowest flow periods in late September. Groundwater and springs augment streamflows as the stream enters the valley floor Upper Emigration Creek *E. coli* TMDL). Emigration Creek flows approximately four miles through the heart of Salt Lake City in this lower AU, including several parks, Hogle Zoo, and golf courses. Below Westminster College, Emigration Creek is predominantly piped until it joins Parleys and Red Butte Creeks in the 1300 South storm drain, though a small section is daylighted in Liberty Park, and eventually drains into the Jordan River.

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 58.2% of the land in the Emigration Creek Lower Assessment Unit is natural (i.e., forest, grassland, wetlands, shrubland, and barren), and 41% is developed (Figure E-2). Cultivated lands (pasture and crops) are 0.6%. The riparian buffer along the main stem of Emigration Creek is more vegetated upstream and transitions to a more developed/urban cover downstream. There are no major agricultural operations within this AU. Developed open space is limited to designed parks. Urban land cover is primarily residential and industrial.

Approximately 16% of the AU is covered by impervious surfaces from developed land use, with most of those surfaces located within the valley. This level of impervious surface leads to increased runoff, which results in increased loading of pollutants, including *E. coli*. Population growth is predicted to decrease in this AU by 3% in 2040, which isn't likely to change the amount of impervious surface (SLCo 2017). See Section 5.3.1 in the main report for more information on the effects of impervious surfaces on pollutant loading.

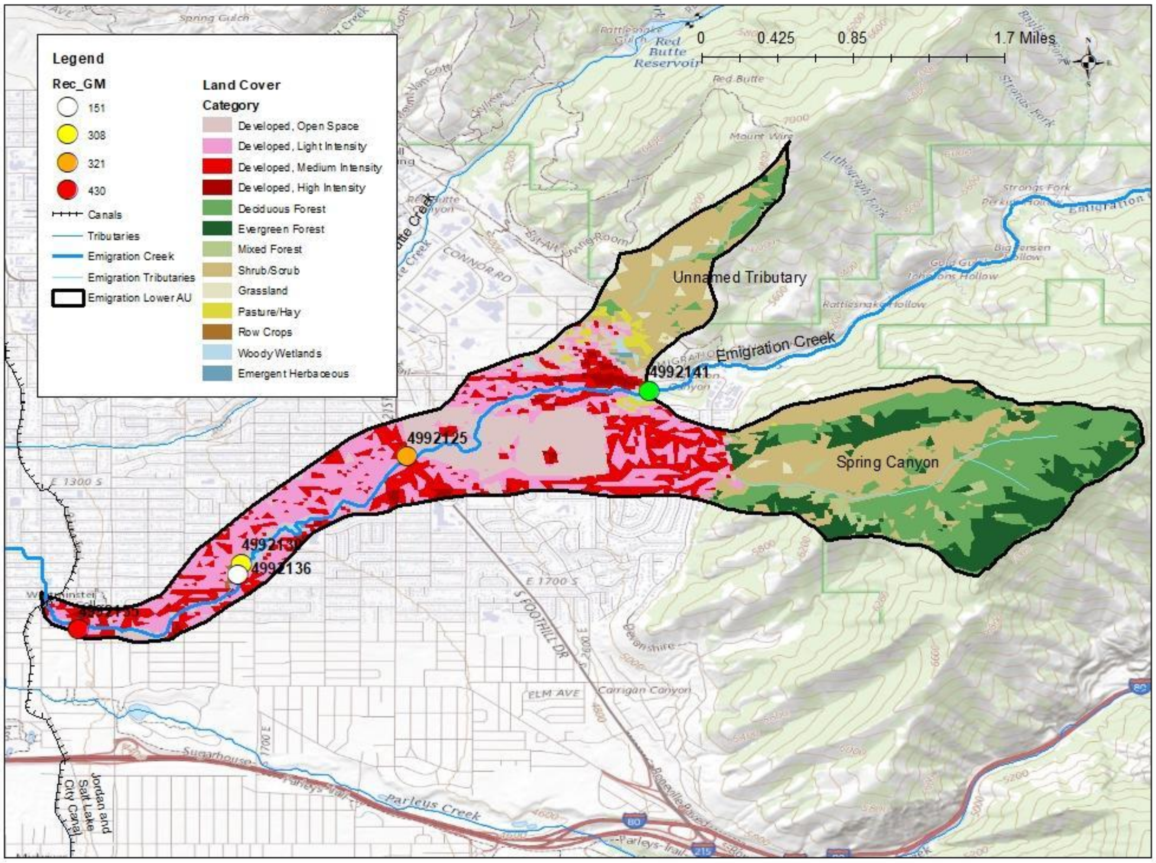

Figure E-2. Land cover in Emigration Creek Lower Assessment Unit (2019).

E. coli Data Summary

Four routine monitoring locations on Emigration Creek Lower were studied for spatial and temporal patterns of *E. coli* levels (Table E-2). Emigration Creek at Westminster Campus (4992135), near Wasatch Hollow (4992136), and below the Bonneville Golf Course (4992125) were sampled consistently year-round between 2009–2021, while Emigration Creek at Wasatch Hollow (4992130) was only sampled during the recreation season 2009–2012. Sampling at this site occurred when *E. coli* concentrations were high, resulting in exceedances of the geometric mean standard (Figure E-3).

At the sites sampled year-round, *E. coli* concentrations consistently exceeded the single-sample maximum standard (50% at 4992125, 48% at 4992135, and 30% at 4992136), but a large number of samples collected with concentrations below 206 MPN/100 mL pulled the overall geometric mean at or just below the geomean standard (Figure E-3). Samples exceeding the standard were observed throughout the entire sampling period, indicating no apparent changes in the *E. coli* source over time (Figure E-4). Monthly geometric mean concentrations were above the standard July–September at all sites except Emigration Creek near Wasatch Hollow (4992136) (Figure E-5).

Note that the monitoring site located just upstream of Emigration Creek Lower AU boundary, Emigration Creek below Rotary Park (4992141 and MST site EM-05.17), is also impaired. The approved Upper Emigration Creek *E. coli* TMDL stated this site required a 56% reduction in loading to meet the water quality criterion during July, August, and September. Figure E-5 shows the highest concentrations in the same months as the critical period defined in the upstream TMDL. Though sources of *E. coli* exist in this lower AU, upstream sources also contribute greatly to the downstream impairments.

Table E-2. Emigration Creek Lower Assessment Unit *E. coli* data summary all year.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4992135 / EM_01.62	Emigration Creek at Westminster college campus	Not meeting criteria	09/2009 to 10/2021	122	3	208	430	2,420*	48	27
4992136 / EM_02.54	Emigration Creek near Wasatch Hollows	Not meeting criteria	08/2010 to 10/2021	110	1	64	151	2,420*	30	12
4992130 / NA	Emigration Creek at Wasatch Hollow	NA	09/2009 to 09/2012	26	10	308	308	2,420*	73	23
4992125 / EM_03.67	Emigration Creek below [Bonneville] golf course	Not meeting criteria	09/2009 to 10/2021	123	2	171	321	2,420*	50	24

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL

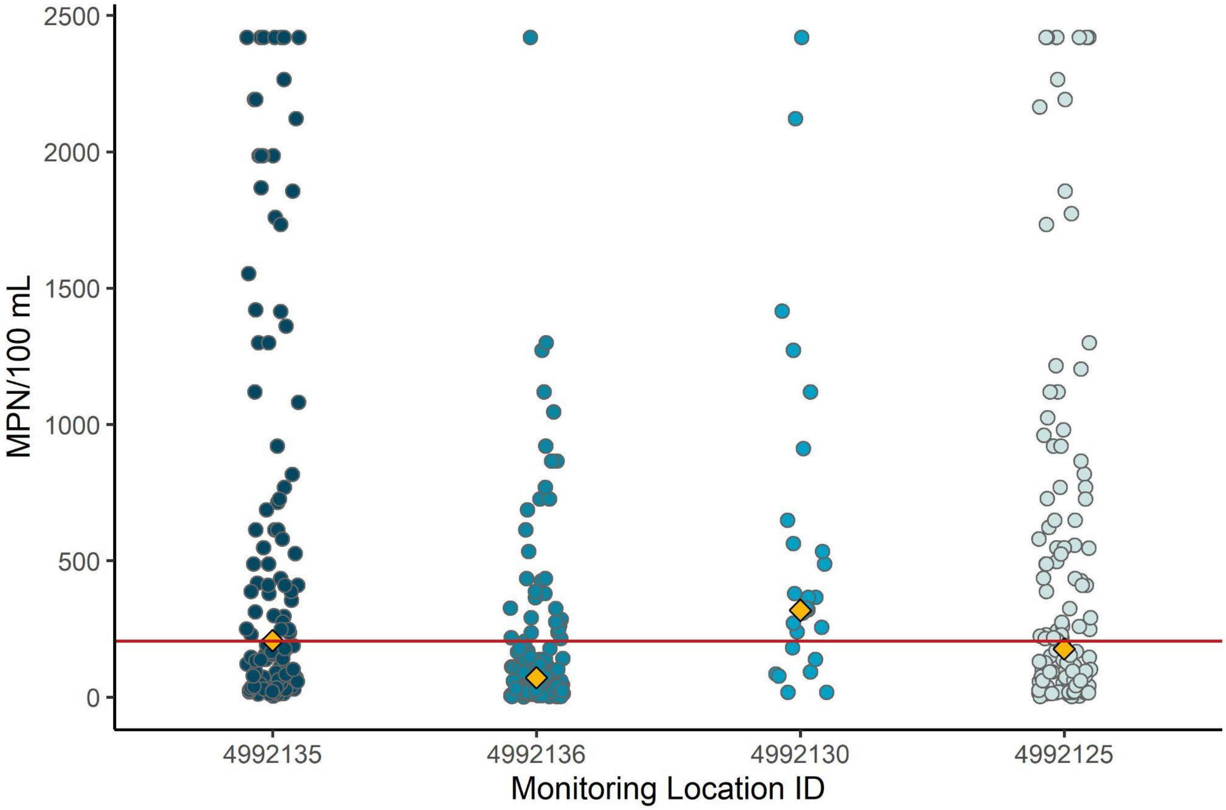

Figure E-3. ***E. coli*** **concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Emigration Creek Lower Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.**

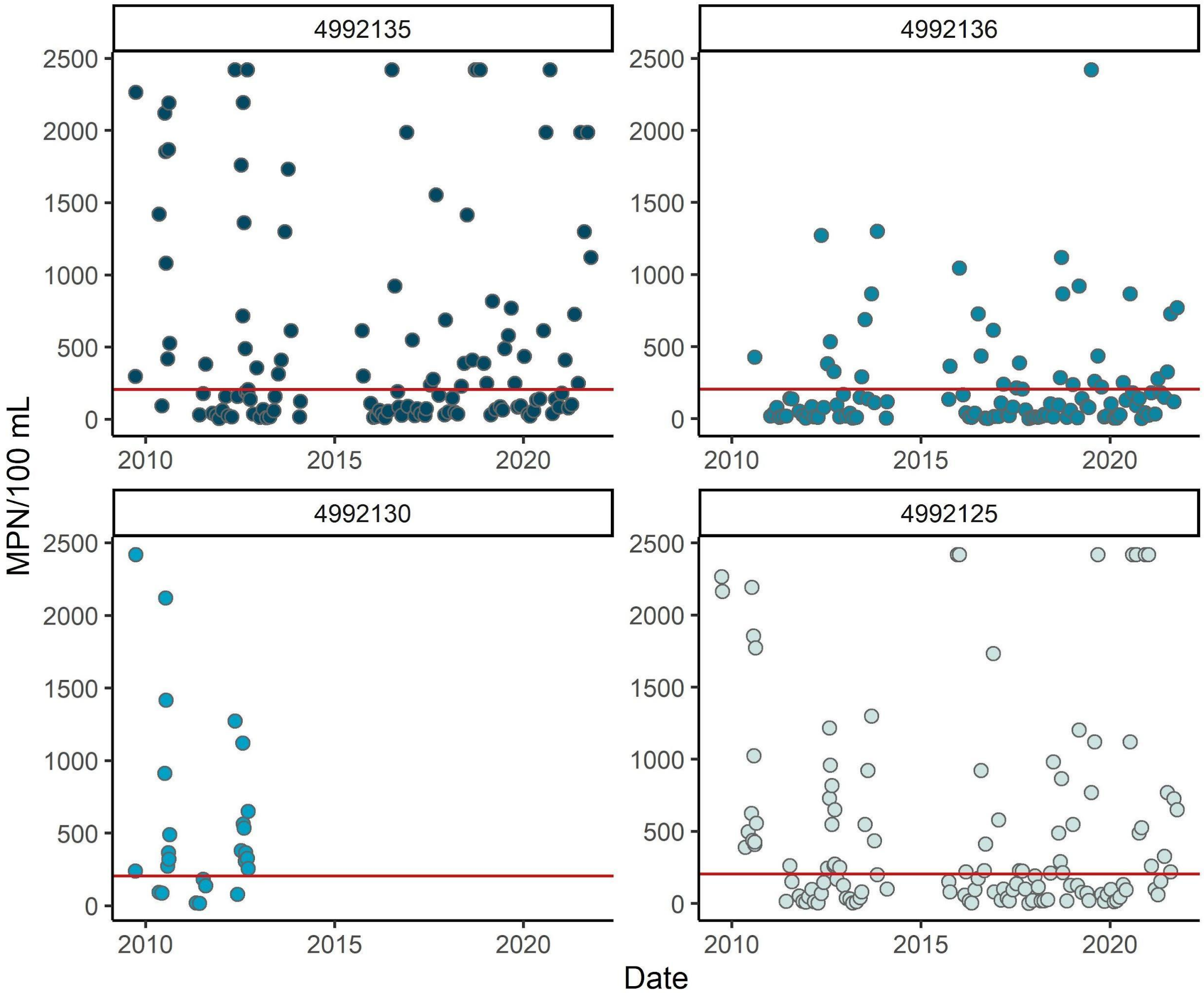

Figure E-4. *E. coli* concentrations at each routine monitoring location through time within the Emigration Creek Lower Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

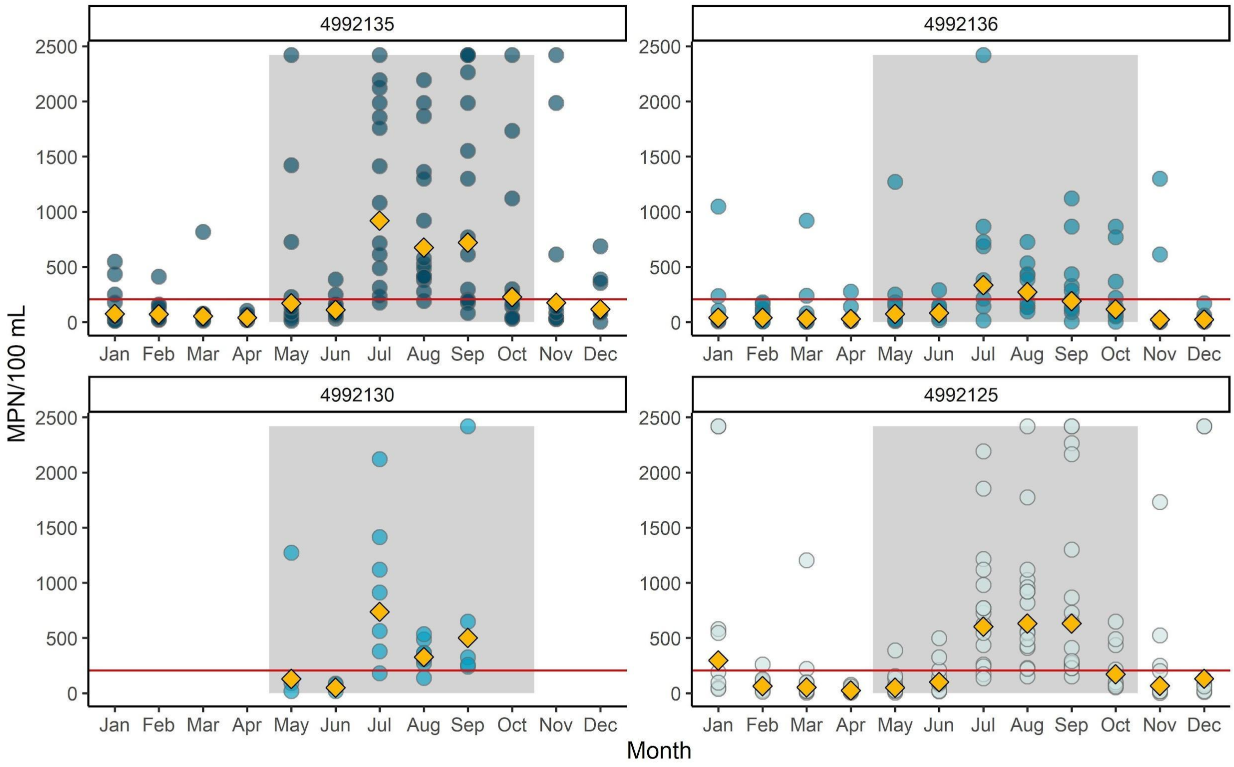

Figure E-5. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

Synoptic Monitoring

Synoptic monitoring for *E. coli* was conducted in 2011 and 2012 along the entire main stem of Emigration Creek and its perennial tributaries. The Upper Emigration Creek *E. coli* TMDL showed two hotspots in the Emigration Creek Lower AU near the Bonneville Golf Course and at Wasatch Hollow Park.

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDCs), microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. Potential sources and recommended implementation strategies to address the source are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curves

Load duration curves are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* concentrations and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at the terminus of the daylighted portion of the creek (Emigration Creek at Westminster #640). This site corresponds to an *E. coli* monitoring station (Emigration Creek at Westminster) (4992135). Flow data during the TMDL period of record (August 2018–September 2021) are summarized in Table E-3, Figure E-6, and Figure E-7. The daily mean flows are higher during April and May, which corresponds to snowmelt and spring runoff. Flow decreases in the late summer due to upstream water diversions, losing reaches due to natural geologic conditions, and general baseflow conditions.

Table E-3. Summary statistics for Emigration Creek at Westminster, Gauge #640 (4992135).

Gauge Name	SLCO Gauge Number/DWQ MLID	Drainage Area (mi²)	Mean Flow (cfs)	Maximum Flow (cfs)
Emigration Creek at Westminster	640/4992135	21	7	47

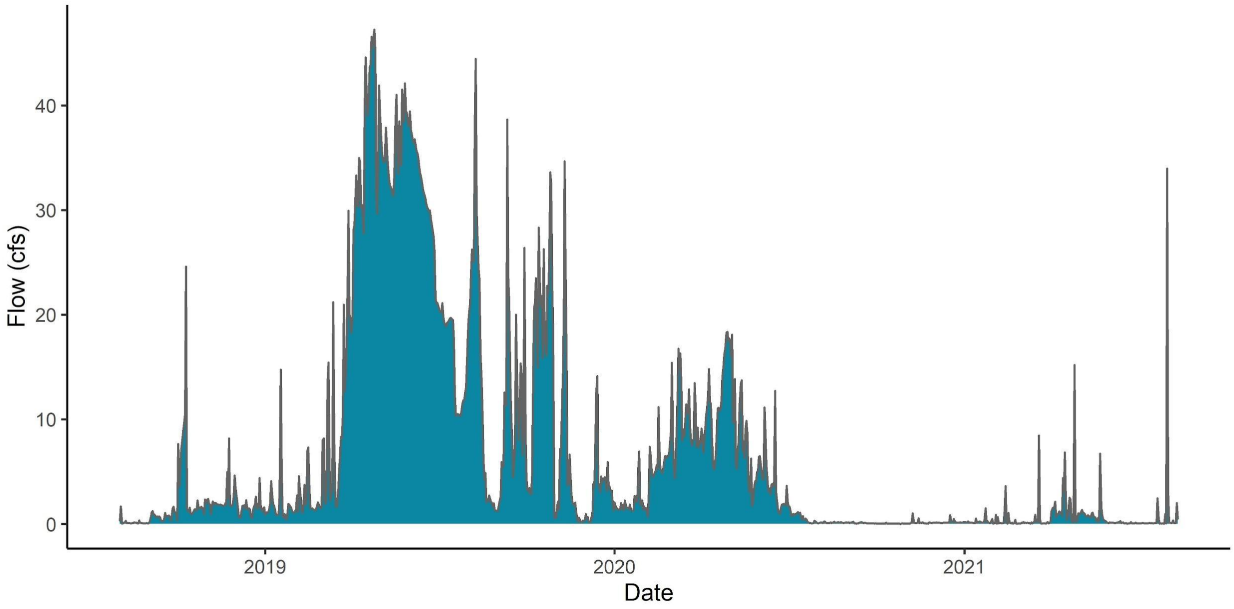

Figure E-6. Daily means flows at Salt Lake County Gauge #640, Emigration Creek at Westminster (4992135) from August 2, 2018, to September 30, 2021.

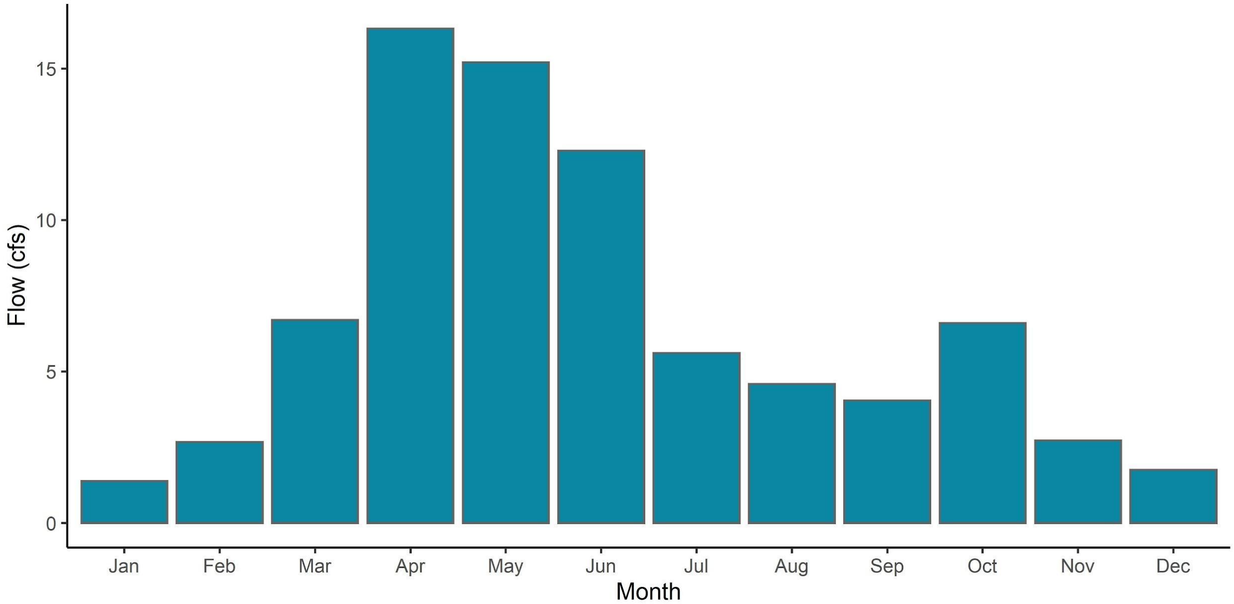

Figure E-7. Monthly means flows (cfs) at Salt Lake County Gauge #640, Emigration Creek at Westminster (4992135) from August 2, 2018, to September 30, 2021.

Using this site's corresponding *E. coli* and flow data, the LDC shows exceedances occurring during all flow regimes (Figure E-8). Exceedances of the TMDL threshold (solid line) in high to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. These sources include point sources (low-flow conditions), onsite septic systems (dry flows), and riparian areas and impervious stormwater sources (mid-range). Upland stormwater and bank erosion are likely sources for the higher flow conditions. The percent of *E. coli* loading measurements exceeding the TMDL in each flow regime is provided in parentheses under each flow-regime label in Figure E-8. Loading reductions are needed primarily in the mid-range flow regimes, which indicates that Emigration Creek Lower AU is dominated by both point and nonpoint source delivery methods of *E. coli* loading.

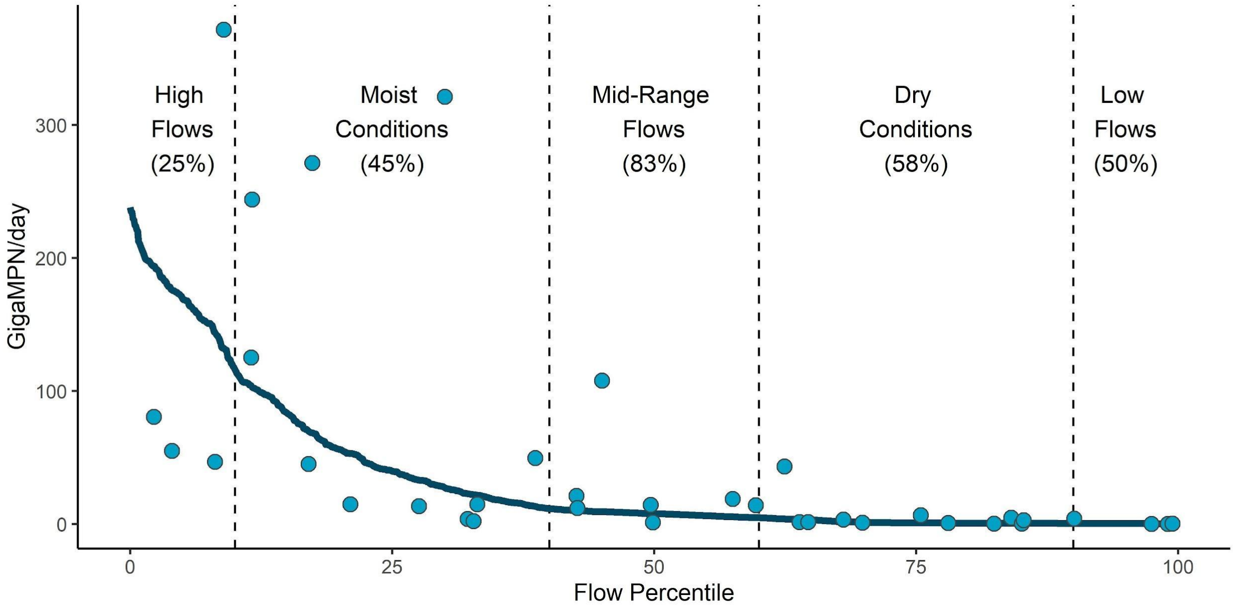

Figure E-8. Load duration curve for Emigration Creek at Westminster College (4992135).

Microbial Source Tracking

Samples were collected once a month at five locations during July, August, and September 2021, resulting in approximately three samples per site and a total of 14 samples collected (Figure E-9). All four MST markers were detected in the AU, although no single marker was detected at all sampling locations. When the presence or absence of each marker was considered across all locations, human was the most common at 43%, meaning of the 14 samples collected, six of them were positive for the human marker. The canine marker was present at 29%, ruminant at 21%, and avian at 14%. Four of the 14 samples exhibited no MST markers, but three samples had *E. coli* concentrations that exceeded the criterion of 206 MPN/100mL, indicating that there may be other sources of fecal contamination in the environment not captured by the current suite of MST markers.

Figure E-9 illustrates the presence/absence pattern of the four markers at each sampling location in the AU, although no clear trend is present. Based on overall prevalence, MST results for this AU highlight the need to focus on further identifying and controlling human and canine sources of fecal contamination.

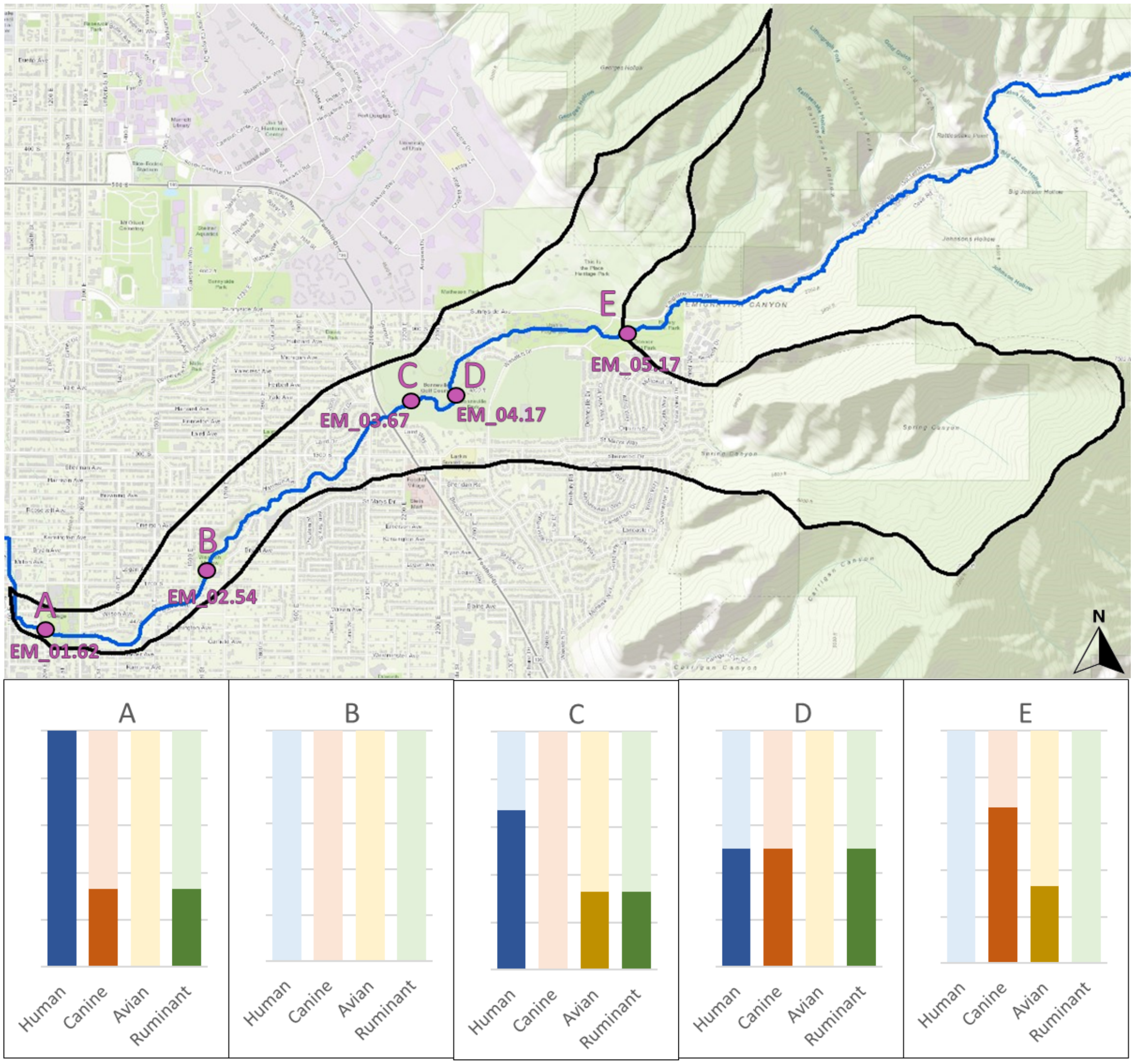

Figure E-9.The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades absence.

Source Assessment

The probable sources of *E. coli* in the Emigration Creek Lower AU come from both point and nonpoint sources based on the data analysis, LDC analysis, land-use patterns, and hydrological information. Point sources are limited to stormwater runoff. Nonpoint sources include onsite septic systems, avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused.

Table E-4 provides a list of specific potential point and nonpoint sources in the Emigration Creek Lower AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. For more information on each potential source, please see Chapter 5.1 and 5.2.

Table E-4. Potential sources of *E. coli* contamination in Emigration Creek Lower Assessment Unit.

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities, including Salt Lake County, Emigration Municipal Service District	UTS000001		
		Utah Department of Transportation	UTS000003		
		Salt Lake City	UTS000002		
Nonpoint source	Onsite septic systems	Yes		Section 5.2.1	Table 8
	Agricultural: livestock	No		Section 5.2.2	
	Agricultural: canals	No			
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
	Recreationists /unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

There are no Utah Pollutant Discharge Elimination System (UPDES) permitted discharges within the Emigration Creek Lower Assessment Unit besides municipal stormwater, which is the likely source of *E. coli* in this AU (Figure E-10). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the LDC that points to point sources during low-flow regimes, urbanized land uses and increased impervious surfaces in the valley, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see Chapter 5 in the main report for more information.

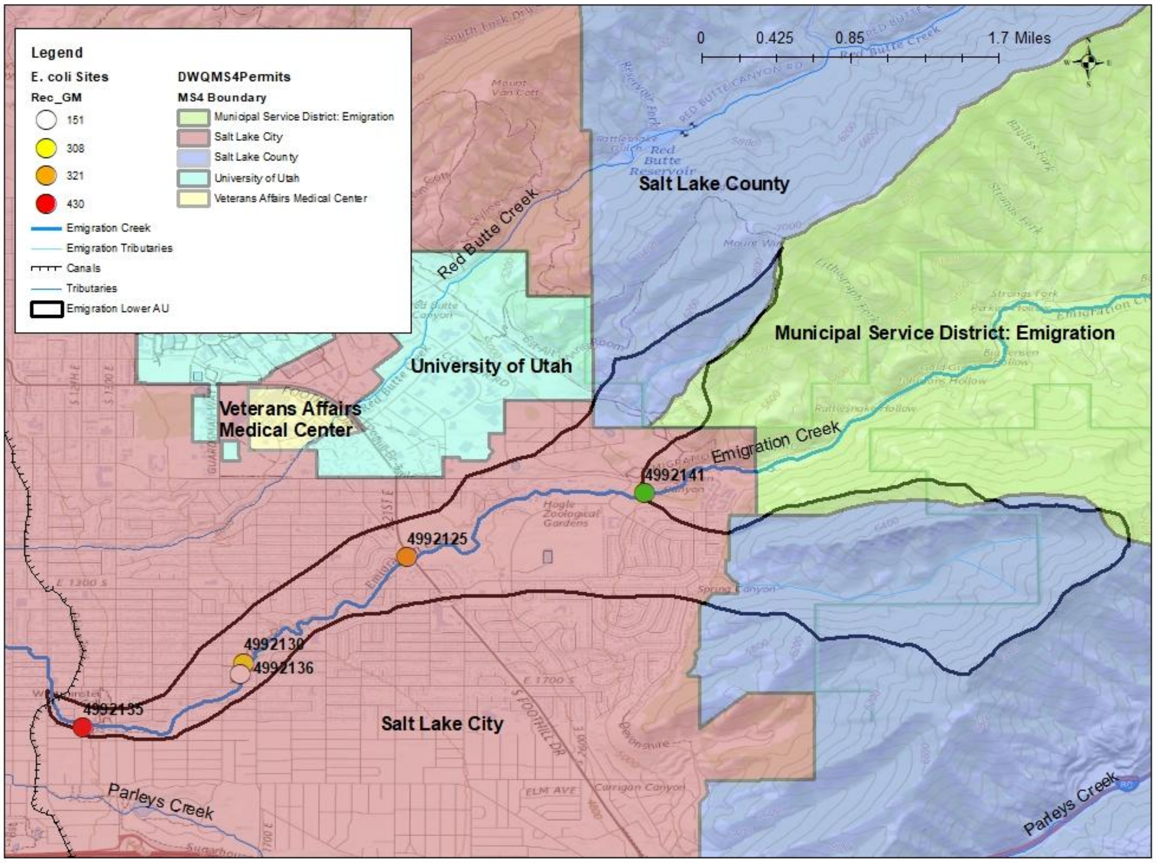

Figure E-10. Possible point sources of *E. coli* contamination within Emigration Creek Lower Assessment Unit.

Stormwater

Two potential sources of stormwater pollution (construction activities and MS4s) occur within the Emigration Creek Lower AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were two construction UPDES stormwater permits in the Emigration Creek Lower AU. There are no industrial stormwater permits. Construction permits are short-lived and change over time. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Emigration Creek Lower AU by issuing MS4s permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of Emigration Creek. There are three MS4 permits (Jordan Valley Municipalities, Salt Lake City, and Utah Department of Transportation) applicable to this AU (Figure E-10). The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. Salt Lake County and Emigration Municipal Service District have jurisdictional boundaries in the AU. Salt Lake City's MS4 permit allows for discharge of stormwater within its jurisdictional boundaries. The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the State. UDOT's Region 2 geographical area covers the Wasatch Front.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Emigration Creek Lower AU include humans, wildlife, and dogs (Figure E-11). Since there is no agricultural activity within this AU, this is not considered to be a plausible source. Cultivated land uses are specific to local parks (i.e., This is the Place Heritage Park and Wasatch Hollow). Please see Chapter 5.2 in the main report for more information on nonpoint sources.

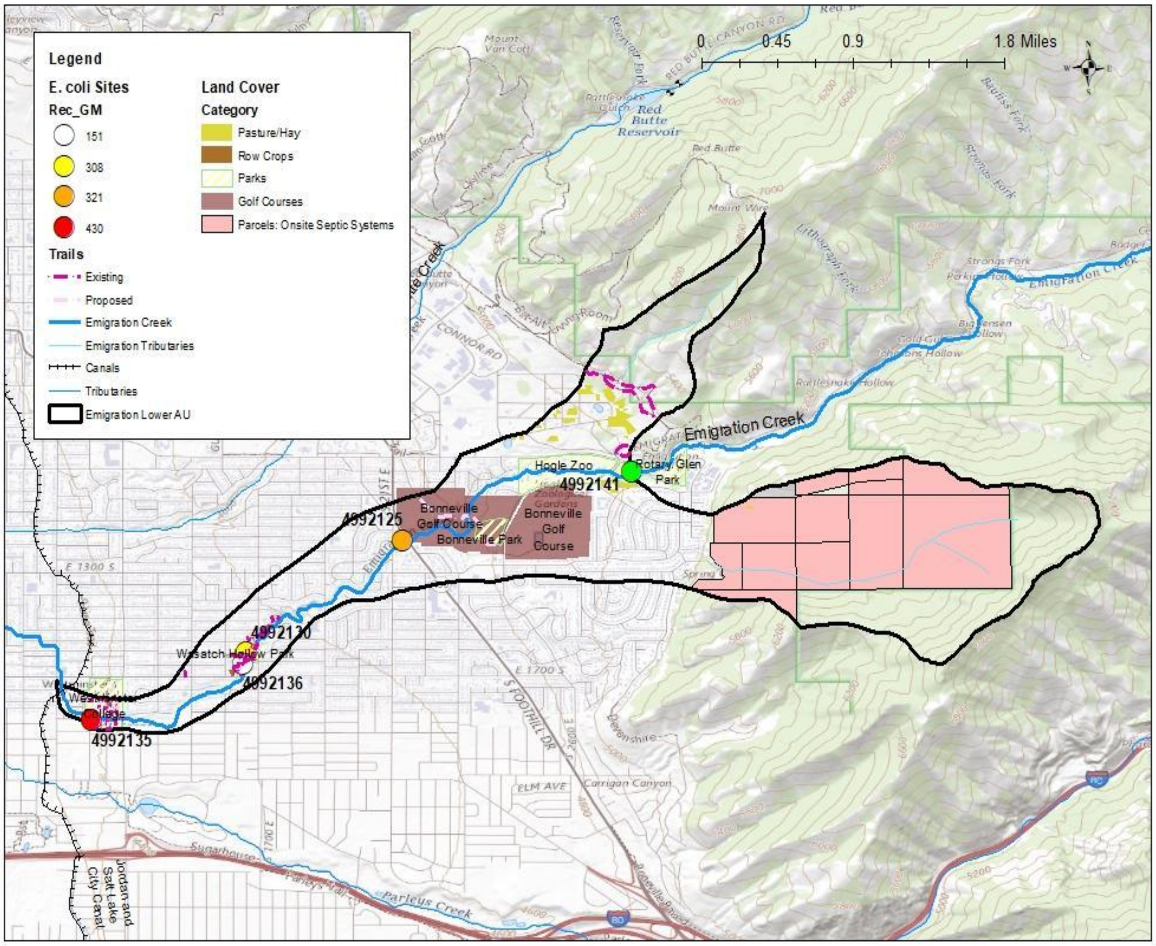

Figure E-11. Possible nonpoint sources of *E coli* contamination in Emigration Creek Lower Assessment Unit.

Onsite Septic Systems

According to the Salt Lake County's Assessor's Office, there are 12 onsite septic system parcels within this AU as of 2021. These parcels are clustered primarily in the foothills close to Emigration Canyon (Figure E-11). Most parcels associated with the urbanized portion of this AU are sewered. Note that upstream Emigration Creek AU has the largest number of onsite septic systems for an AU within the Jordan River watershed. The Emigration Creek *E. coli* TMDL states that these systems are a likely source. Given the elevated concentrations at the upstream AU boundary site (4992141), it is probable these onsite septic systems are contributing to the downstream impairment. *E. coli* concentrations exceed the standard 50% of the time during the recreational season at the Emigration Creek below Bonneville Golf Course site (4992124), which is the most upstream monitoring location within this AU (Table E-2). MST results show human markers present below Bonneville Golf Course (Figure E-9). There are no large underground wastewater disposal systems in this area; however, one does exist in the upstream AU.

Salt Lake County Health Department continues to respond to reports of failing onsite septic systems in Emigration Canyon. Emigration Metro Township is in the process of developing an EPA Nine-element Watershed Plan that will address the *E. coli* impairment in the upstream AU. It is assumed by addressing the upstream impairments, water quality violations downstream from these sources will decrease. Please see Chapter 5.2.1 in the main report for more information on onsite septic systems and Chapter 7 on suggested BMPs.

Recreation, Pets, and Nuisance Wildlife

Once Emigration Creek enters the Salt Lake valley, it flows through several popular parks, a golf course, a zoo, and highly recreated open space areas. As previously noted, upstream sources contribute to the downstream impairment, which can be seen at the Emigration Creek below Rotary Glen site (4992141). This monitoring location is located directly downstream of Rotary Glen Park, which is an off-leash dog park. Both canine and avian MST markers are present at this site. Following approval of the Emigration Creek *E. coli* TMDL, the detention basin located within the park was remediated with vegetative buffers, and direct domestic pet access is now limited.

Emigration Creek then flows directly through Hogle Zoo. Stormwater management within the zoo's boundaries are part of a closed system, and no stormwater runoff enters into Emigration Creek. Though the creek is piped under most of the zoo, it daylights near the north end above the Event Pavilion and at the south end near the Oasis Cafe. Runoff could occur at the northern end near the temporary enclosure, though it is fenced and slightly vegetated. Streambanks near the south end of the zoo are steep and access is limited. MST results below Hogle Zoo show markers for canines, ruminants, and humans. The synoptic monitoring events in 2011 and 2012 did not indicate that *E. coli* loading is coming from Hogle Zoo.

Emigration Creek below Bonneville Golf Course (4992125) requires a 50% reduction in exceedances to meet water quality standards. Elevated concentrations occur in the warmer months (July–September) when water levels are low and there is minimal dilution. Synoptic monitoring within the golf course suggested it could serve as a hotspot for contamination, and MST analysis reports human, avian, and ruminant presence. This area could provide suitable habitat for ruminants due to the vegetation within the riparian corridor.

Emigration Creek travels approximately one mile downstream from the golf course to Wasatch Hollow Park. This Salt Lake City park is highly utilized by recreationists and their pets. Though efforts have been made to improve the riparian corridor in this area by improving streambank vegetation, humans and dogs have direct creek access. Emigration Creek at the northern end of the park serves as an unofficial off-leash dog park during the warmer months. Two downstream *E. coli* monitoring sites (4992136 and 4992130) both require a reduction in concentration to meet water quality standards, especially during the late summer months (July–September). The 2011–2012 synoptic events also cited this park as a hotspot for contamination. MST results showed no markers present at this site (EM_02.54), though corresponding *E. coli* concentrations were high.

Emigration Creek below Westminster College (4992135 and EM_01.62) requires a 48% reduction in concentration to meet water quality standards, especially during the warmer months from July–September. This site (Site A in Figure E-9) has MST markers for canines, humans, and ruminants. Ruminant habitat exists within the AU and riparian corridors in the Bonneville Golf Course. Waterfowl can congregate along the slowed stream reaches and detention basins. Several parks along Emigration Creek within the heart of Salt Lake City attract recreationists and dogs. However, each park offers restroom facilities, so the chance of recreationists contributing to the impairment is low.

Three of the four *E. coli* monitoring sites (below Golf Course, near Wasatch Hollow, and below Westminster Campus) show exceedances of the standard during July–September, which corresponds directly to the critical season defined in the Emigration Creek *E. coli* TMDL. Potential sources do exist within the Emigration Creek Lower AU. However, a majority of the contamination originates from the upstream AU. *E. coli* concentrations should decrease in Emigration Canyon once the watershed plan for Emigration Canyon has been implemented and sources are addressed. Note that several projects are currently underway to restore Emigration Creek, including the recent Seven Canyons Trust project daylighting the confluence of the 1300 South drain and the Jordan River Three Creeks Confluence project.

Please see Table 8 in the main report for suggested BMPs to employ to manage these particular nonpoint sources of E. coli contamination.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Emigration Creek Lower AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Appendix F. Red Butte Creek Lower Assessment Unit *E. coli* TMDL

Waterbody Name	Red Butte Creek Lower
Waterbody / Assessment Unit (AU)	UT16020204-035
AU Description	Red Butte Creek and tributaries from 1100 East Street to Red Butte Reservoir
Impaired Beneficial Uses	Infrequent primary contact recreation (2B)
Applicable Season	May through October
Defined Endpoint/Water Quality Standard	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL
Percent Reduction Necessary	80%, based on a geometric mean of 1,041 MPN/100 mL calculated for 4992091(Red Butte Creek above Sunnyside) in the month of August.
Probable Sources	Stormwater, avian wildlife, domestic pets, wildlife/nuisance species, and recreationists/unhoused

Assessment Unit Description

The Lower Red Butte Creek Assessment Unit (AU) includes Red Butte Creek from Red Butte Reservoir 2.3 miles downstream to the intersection with 1100 East in Salt Lake City, Utah. The small AU (3 mi^2) is entirely within Salt Lake City and Salt Lake County. Land ownership is 98% privately owned, 1.9% federally owned and managed by the Forest Service, and 0.1% state-owned. The Lower Red Butte Creek AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) designated beneficial uses due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2022 Integrated Report.

Table F-1. Impairment summary of the Red Butte Creek Lower Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
UT16020204-023	*E. coli*	Infrequent primary contact recreation (2B)	2022
	Dissolved oxygen*	Cold water aquatic life (3A)	2022
	Macroinvertebrates*	Cold water aquatic life (3A)	2014–2022
*Will be addressed in future TMDLs			

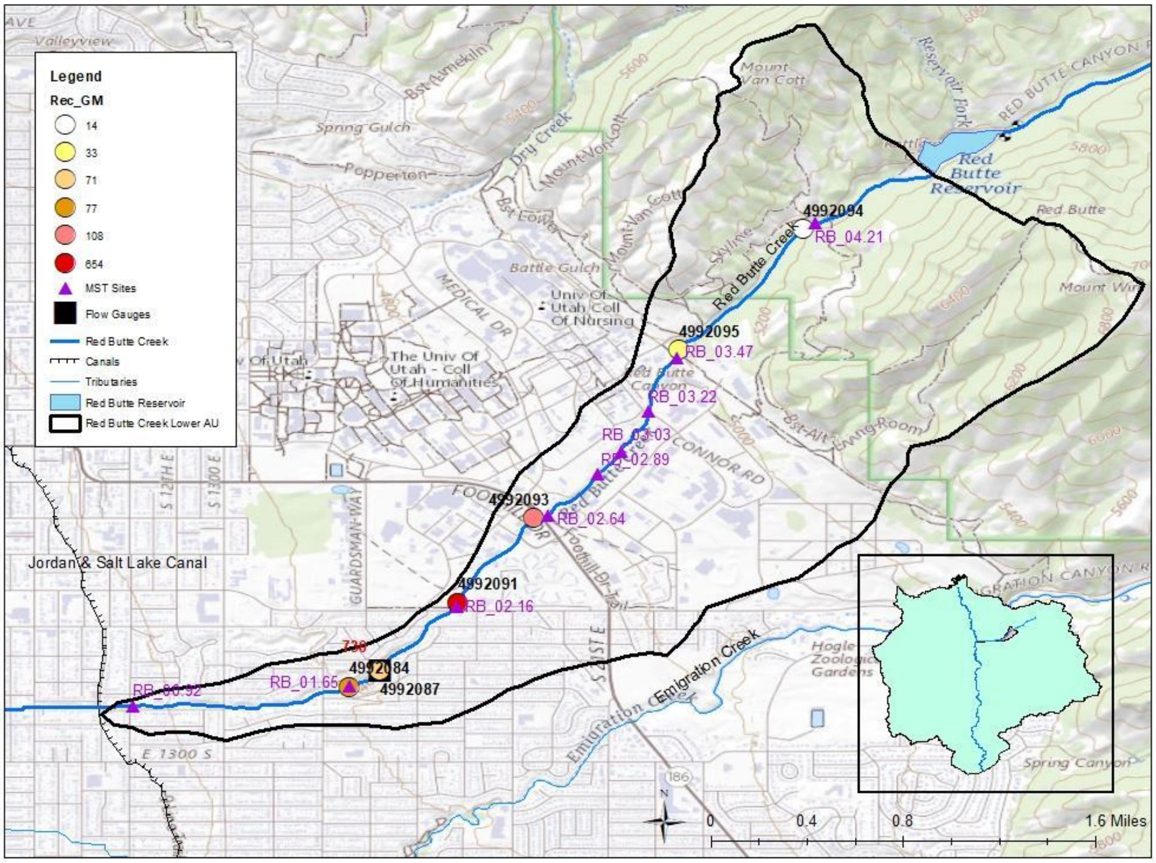

Figure F-1. Monitoring locations and hydrology of Red Butte Creek Lower Assessment Unit.

Hydrology

Red Butte Creek originates in the Wasatch Mountains and flows approximately 14.3 miles before joining Parleys and Emigration Creeks into the 1300 South Drain and finally into the Jordan River (Figure F-1). The headwaters and upper reaches are managed by the Uinta-Wasatch-Cache National Forest and are protected as a Research Natural Area. This federal designation protects both Red Butte Canyon and Red Butte Reservoir from public access. Red Butte is considered to be the most pristine canyon within the Jordan River watershed. Red Butte Reservoir, built in the 1930s and managed by the Central Utah Water Conservancy District, provides municipal storage and a fish nursery for the endangered June sucker.

Figure F-1 shows the inputs and outputs of the Red Butte Creek riverine system in Red Butte Creek Lower AU. Instream flow in Red Butte Creek is 100% reduced or interrupted by hydrologic modifications (SLCo 2017). Approximately 29% of the main channel within this lower section is piped (SLCo 2009). Hydrologic modifications, such as channelization, stormwater conveyance systems, the reservoir, diversions, and rip-rapped streambanks alter the stream's hydrograph.

Red Butte Creek flows 1.1 miles from Red Butte Reservoir through the canyon, then quickly transitions from a pristine riparian zone to an urbanized, entrenched corridor. The reach directly below the canyon mouth is a losing reach due to natural geologic features with the nexus of mountains to valley floor. Stream flows are augmented by groundwater and springs. Red Butte Creek flows 3.5 miles in the valley through the heart of Salt Lake City, including several parks and the University of Utah. The creek eventually joins Emigration Creek at Liberty Park (pond) and Parleys Creek in the 1300 South drain before discharging into the Jordan River.

Red Butte Creek watershed drains 11 mi^2 of forested and developed landscape. Stream flows peak in early spring (April) and return to base flows in September. The valley reaches can be completely dewatered due to the irrigation diversion by Mount Olivet Cemetery. Salt Lake County Gauge #730 (Red Butte Creek at Miller Park) has a mean daily flow of 3 cubic feet per second (cfs) during the TMDL period of record (2011–2021), with a maximum daily mean of 52 cfs (Table F-3).

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 56.6% of the land in the Red Butte Creek Lower AU is natural (forest, grassland, wetlands, shrubland, and barren), 42.3% developed, and 1.05% cultivated lands (pasture and crops)(Figure F-2). Most of the riparian buffers along the main stem of Red Butte Creek transition from vegetated in the upper reaches to developed/urban downstream. There are no major agricultural operations within this AU. Developed open space is limited to designated parks. Urban land cover is primarily residential and industrial.

Approximately 17% of the AU is covered by impervious surfaces from developed land use, with most of those surfaces located within the valley. This level of impervious surface leads to increased runoff which results in increased loading of pollutants, including *E. coli*. Population growth is predicted to decrease in this AU by 3% in 2040 (SLCo 2017). See Section 5.3.1 in the main report for more information on the effects of impervious surfaces on pollutant loading.

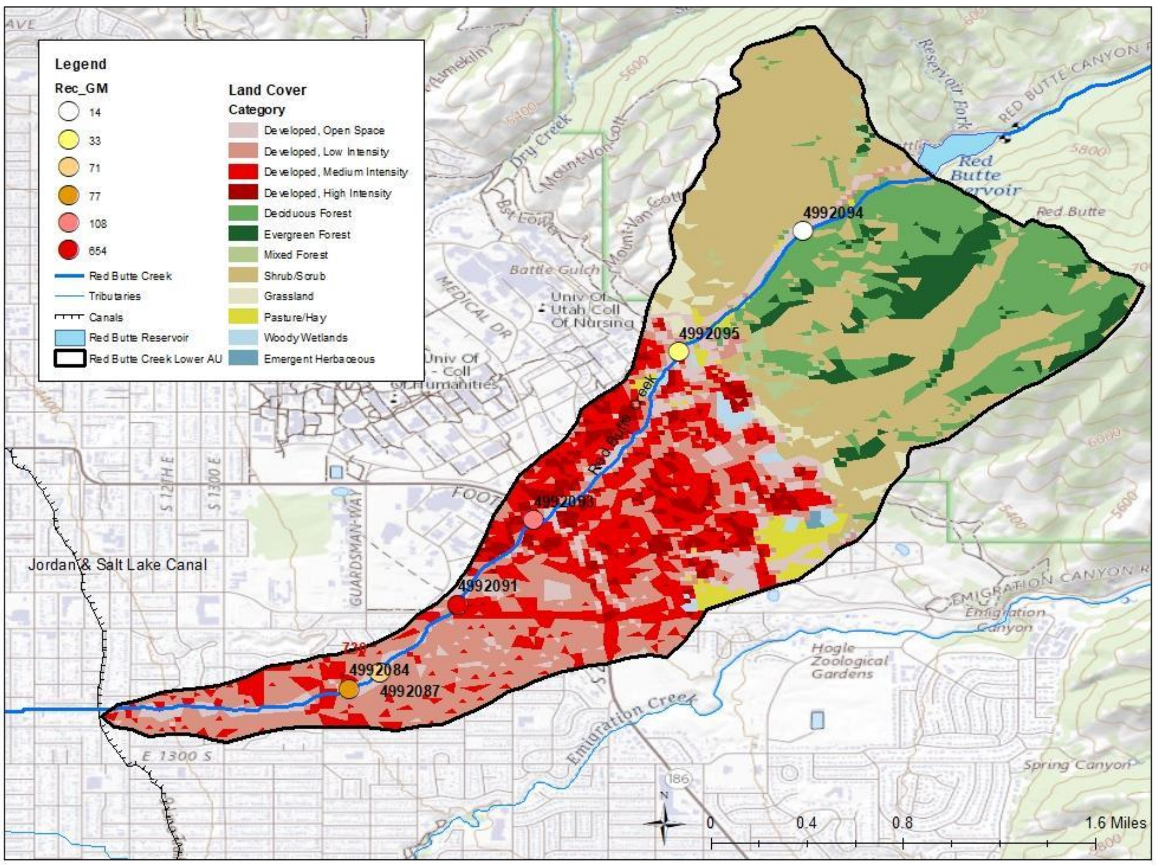

Figure F-2. Land cover in Red Butte Creek Lower Assessment Unit (2019).

E. coli Data Summary

Six routine monitoring locations in Red Butte Creek Lower AU were studied for spatial and temporal patterns of *E. coli* (Figure F-1). Samples from all sites exceeded the water quality standard (206 MPN/100mL), and in some cases, the maximum reporting limit (Table F-2), but a large proportion of high *E. coli* concentrations at Red Butte Creek above Sunnyside Drive (4992091) pushed the overall geometric mean of the site above the standard (Figure F-3). This site requires the greatest reduction (68%) to meet the water quality standard during the recreational season.

The number of *E. coli* samples exceeding the standard increased after 2018, especially at the most downstream site, Red Butte Creek at 1500 East (4992084), indicating a more recent increase in contamination (Figure F-4).

Monthly *E. coli* geometric mean concentrations generally showed small peaks in the recreation season, but of note is that the three most downstream sites (Red Butte Creek above Sunnyside, at the County Gauge, and at 1500 East (Miller Park)) yielded samples exceeding the standard January–April outside of the recreation season months (Figure F-5).

Table F-2. Red Butte Creek Lower Assessment Unit *E. coli* data summary all year.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4992084 / RB_01.65	Red Butte Creek at 1500 East (end of Miller Park)	Not meeting criteria	05/2010 to 10/2021	124	0.5**	63	77	2,420*	27	13
4992087 / RB_01.74	Red Butte Creek at County Gauge	Insufficient data	06/2010 to 11/2018	56	2	66	71	2,420*	21	7
4992091 / RB_02.16	Red Butte Creek above Sunnyside	Not meeting criteria	07/2018 to 10/2021	28	65	496	654	2,420*	68	50
4992093 / RB_02.64	Red Butte Creek above Foothill Drive	Insufficient data	01/2017 to 09/2020	20	1	53	108	2,420*	40	35
4992095 / RB_03.47	Red Butte Creek at Red Butte Gardens	Insufficient data	06/2011 to 09/2020	13	4	33	33	980	23	7
4992094 / RB_04.21	Red Butte Creek 0.5 mi above canyon mouth	Meeting criteria	05/2010 to 10/2021	119	0.5**	6	14	727	3	2

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL
** Used half the detection limit (1 MPN/100 mL) for samples with non-detects

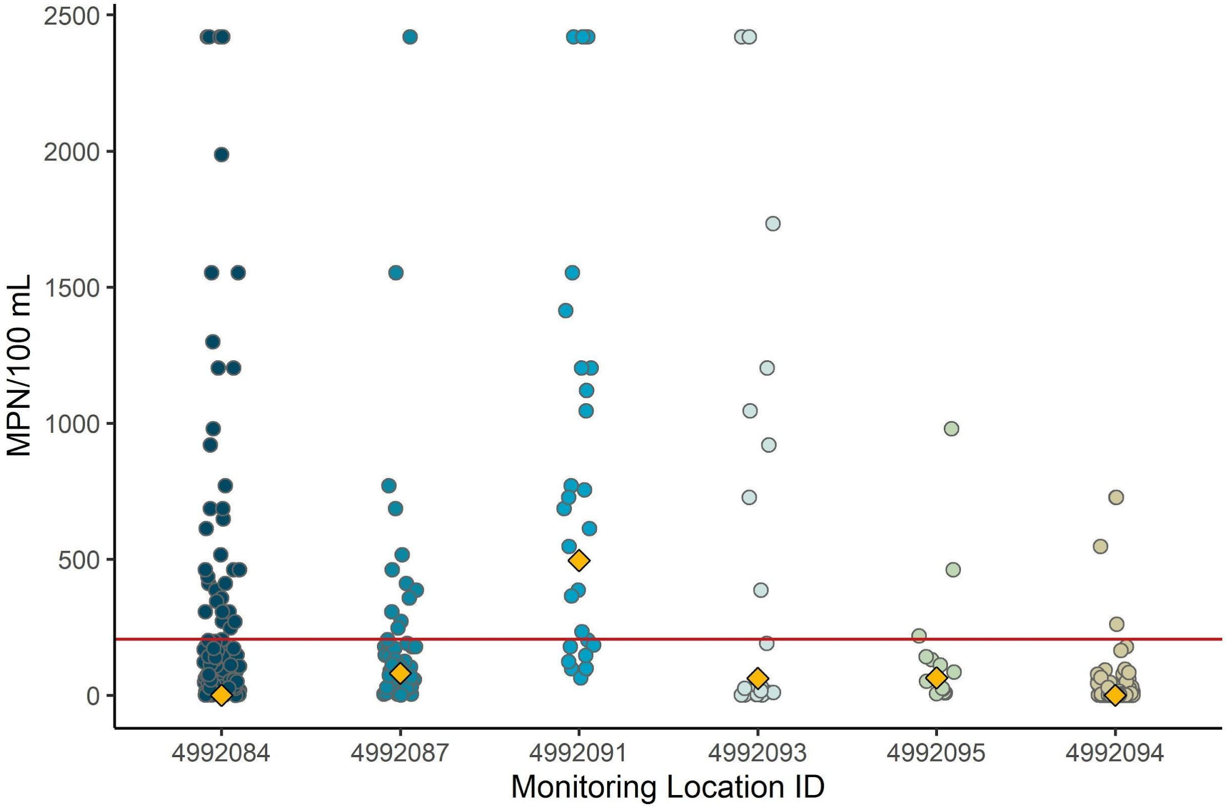

Figure F-3. *E. coli* concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Red Butte Creek Lower Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

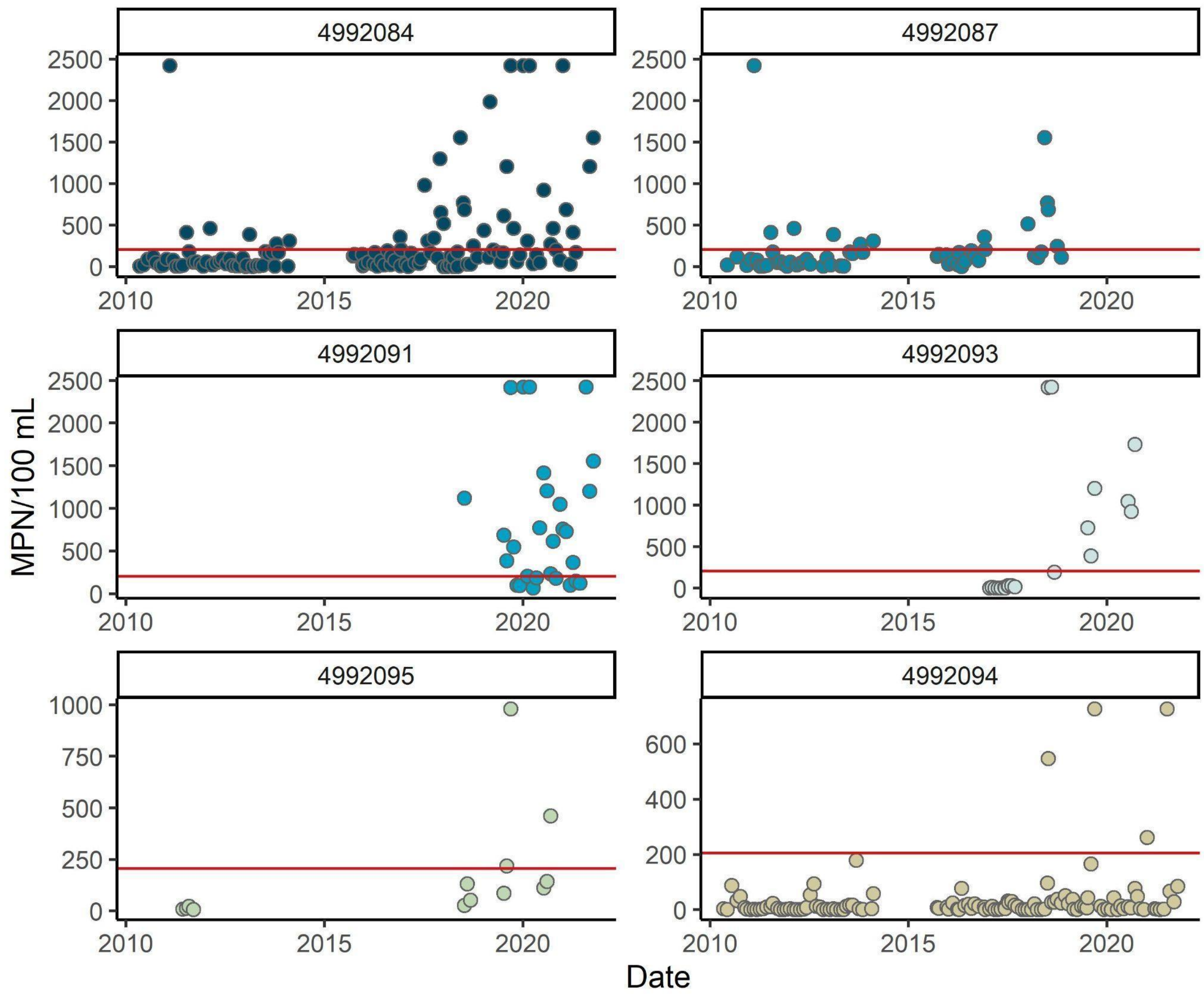

Figure F-4. *E. coli* concentrations at each routine monitoring location through time within the Red Butte Creek Lower Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

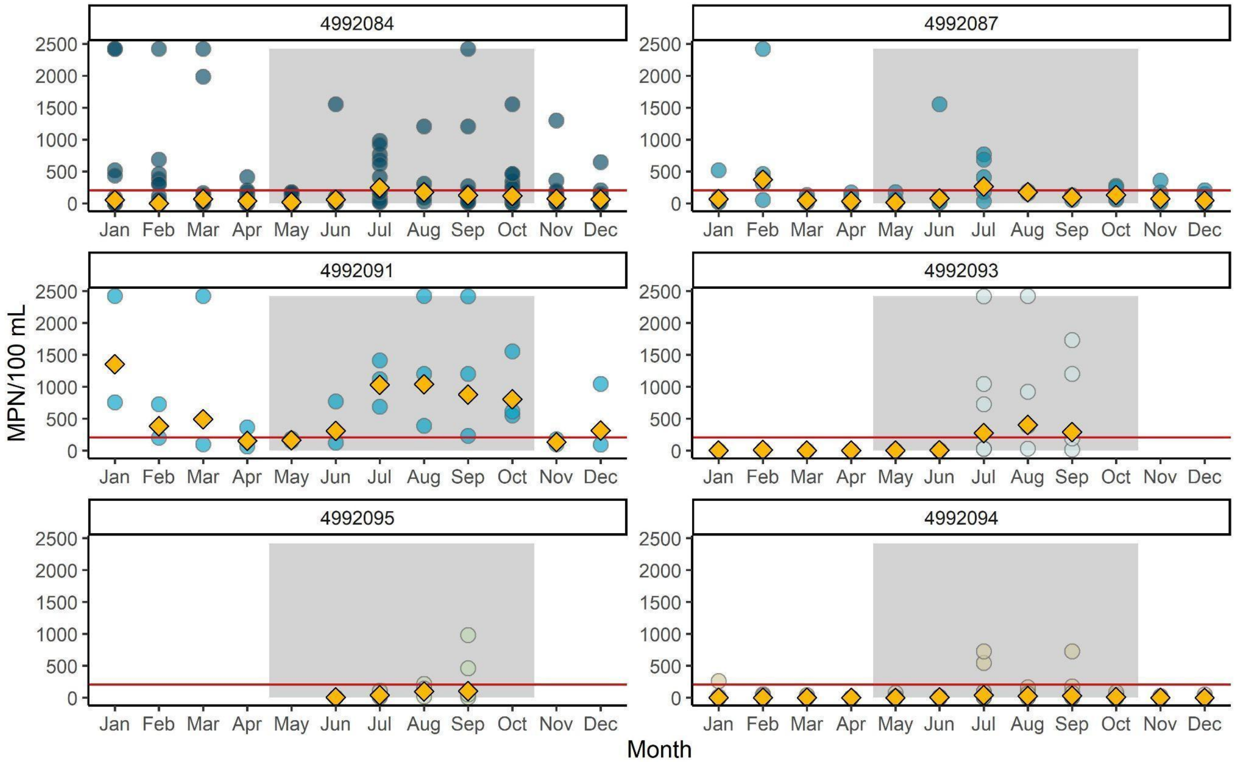

Figure F-5. ***E. coli*** **concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).**

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDCs), microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. Potential sources and recommended implementation strategies to address the source are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curve

Load duration curves are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* concentrations and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at Red Butte Creek at Miller Park Gauge #730. This site corresponds to an *E. coli* monitoring station, Red Butte at Miller Park (4992087). Flow data during the TMDL period of record (May 2015–September 2021) are summarized in Table F-3, Figure F-6, and Figure F-7. The daily mean flows are higher during April, which corresponds to snowmelt and spring runoff. Flow decreases slightly in the late summer mainly due to upstream water diversions, reservoirs, and general baseflow conditions. Flows remain fairly consistent through the year due to the releases from the upstream Red Butte Reservoir (Figure F-7).

Table F-3. Summary statistics for Red Butte at Miller Park, Gauge #730 (4992087).

Gauge Name	SLCO Gauge Number / UDWQ MLID	Drainage Area (mi^2)	Mean Flow (cfs)	Maximum Flow (cfs)
Red Butte at Miller Park	730/4992087	7.3	3	52

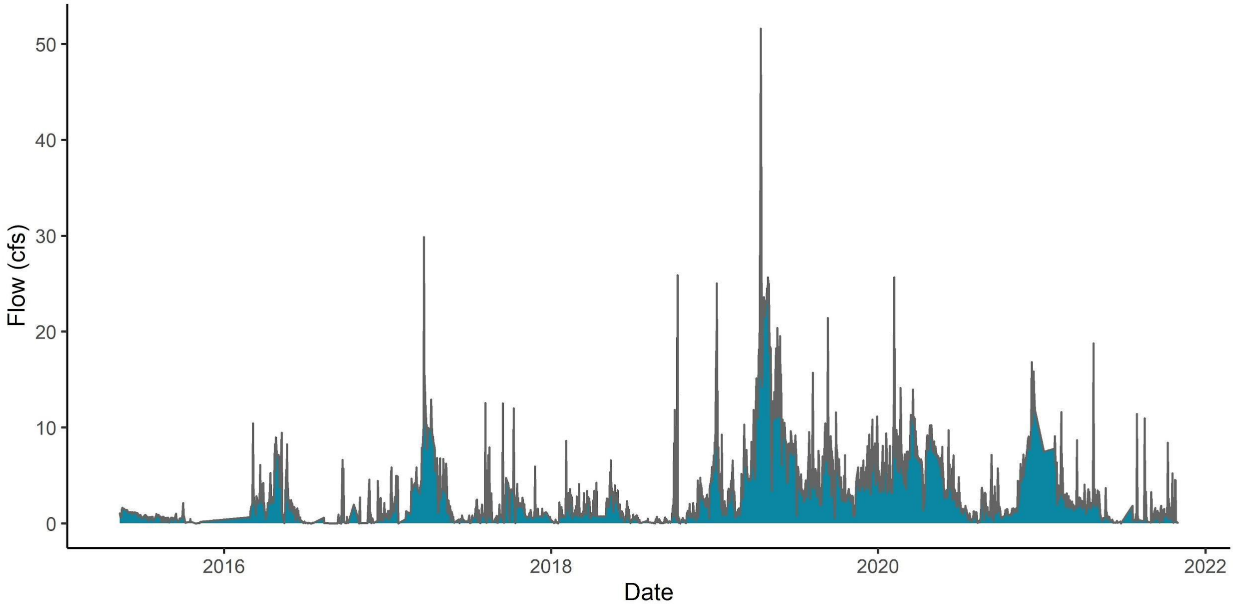

Figure F-6. Daily means flows at Salt Lake County Gauge #730, Red Butte Creek at Miller Park (4992087) from May 14, 2015, to September 30, 2021.

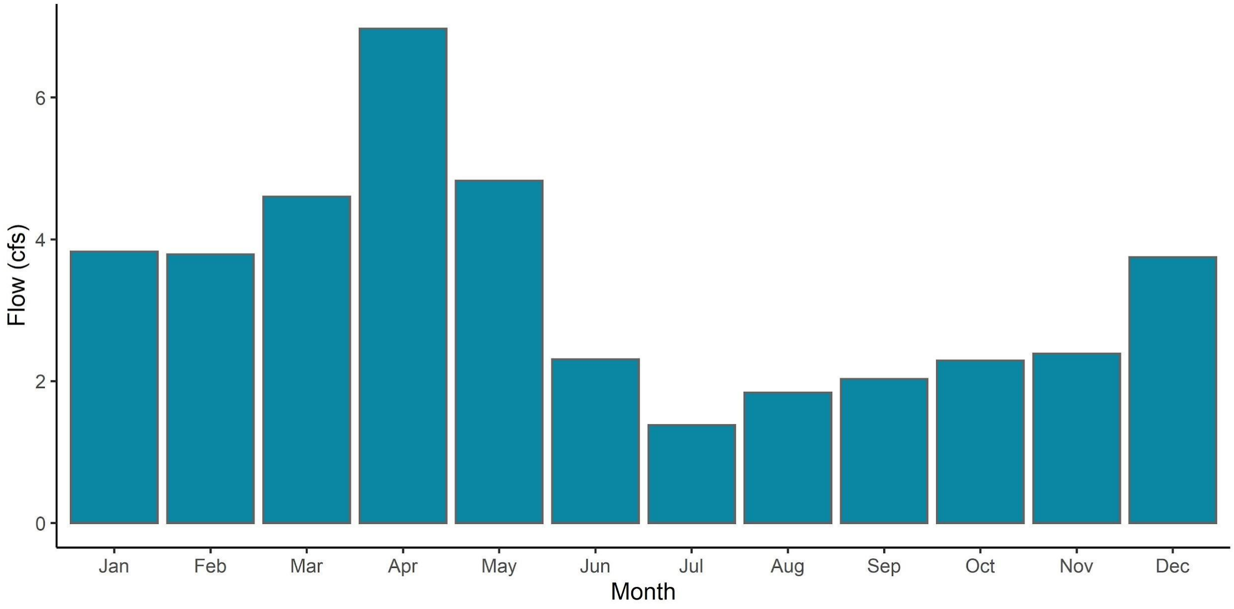

Figure F-7. Monthly means flows (cfs) at Salt Lake County Gauge #730, Red Butte Creek at Miller Park (4992087) from May 14, 2015, to September 30, 2021.

Using this site's corresponding *E. coli* and flow data, the LDC shows exceedances occurring at all flow regimes (Figure F-8). Exceedances of the TMDL threshold (solid line) in high to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. These sources include point sources (low-flow conditions), onsite septic systems (dry flows), and riparian areas and impervious stormwater sources (mid-range). Upland stormwater and bank erosion are likely sources during higher flow conditions. The percent of *E. coli* loading measurements exceeding the TMDL in each flow regime is provided in parentheses under each flow-regime label in Figure F-8. Loading reductions are needed the most in the moist flow regimes, indicating that Red Butte Creek Lower AU is dominated by both point and nonpoint source delivery methods of *E. coli* loading.

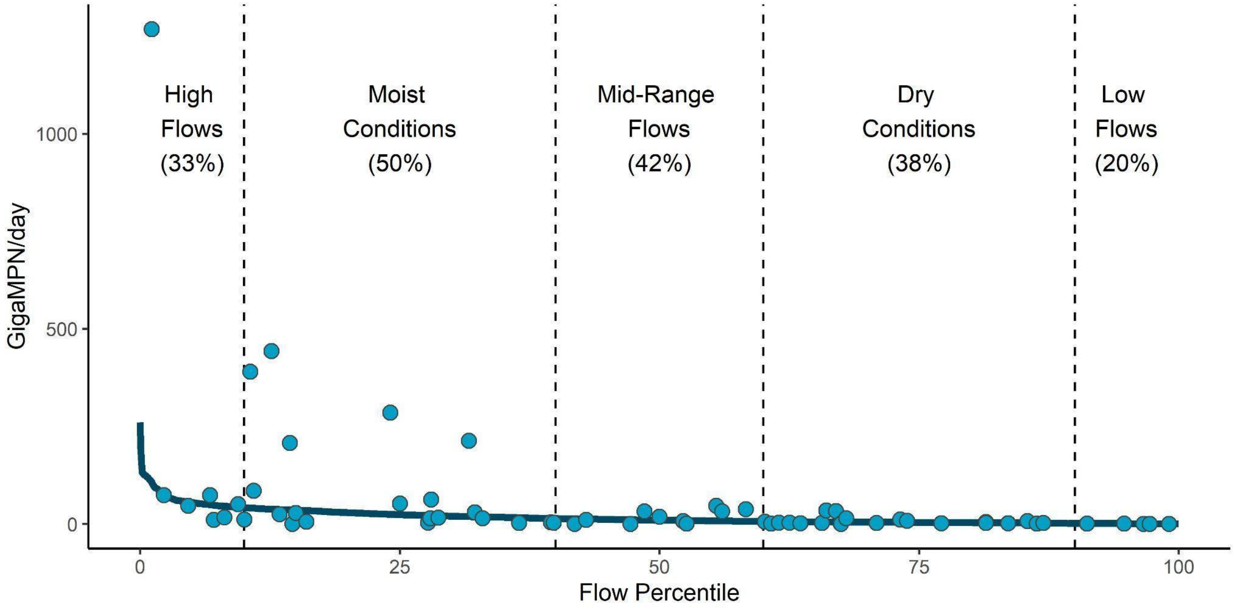

Figure F-8. Load duration curve for Red Butte Creek at Miller Park (4992087).

Microbial Source Tracking

Samples were collected once a month at nine locations during July, August, and September from 2018–2020, resulting in approximately nine samples per site and a total of 75 samples collected (Figure F-9). All four MST markers were detected in the AU, although only the avian marker was detected at all sampling locations. When the presence or absence of each marker was considered across all locations, avian was the most common at 45%, meaning of the 75 samples collected, 34 of them were positive for the avian marker. The human marker was present at 41%, canine at 5%, and ruminant at 28%. Twenty of the 75 samples exhibited no MST markers, but seven samples had *E. coli* concentrations that exceeded the criteria of 206 MPN/100mL, indicating that there may be other sources of fecal contamination in the environment not captured by the current suite of MST markers.

Determining the presence or absence of markers at each individual sampling location can also be useful for understanding areas in the watershed where sources may be contributing more or less to the impairment. Figure F-9 illustrates the presence/absence pattern of the four markers at each sampling location in the AU. All markers become more consistently present once the stream exits the foothills and enters a more urbanized zone around site F (RB_03.03). The human marker is more often detected in the downstream direction, while the avian marker is prevalent throughout. The data indicate that focus should be placed on controls for both human and avian sources where possible.

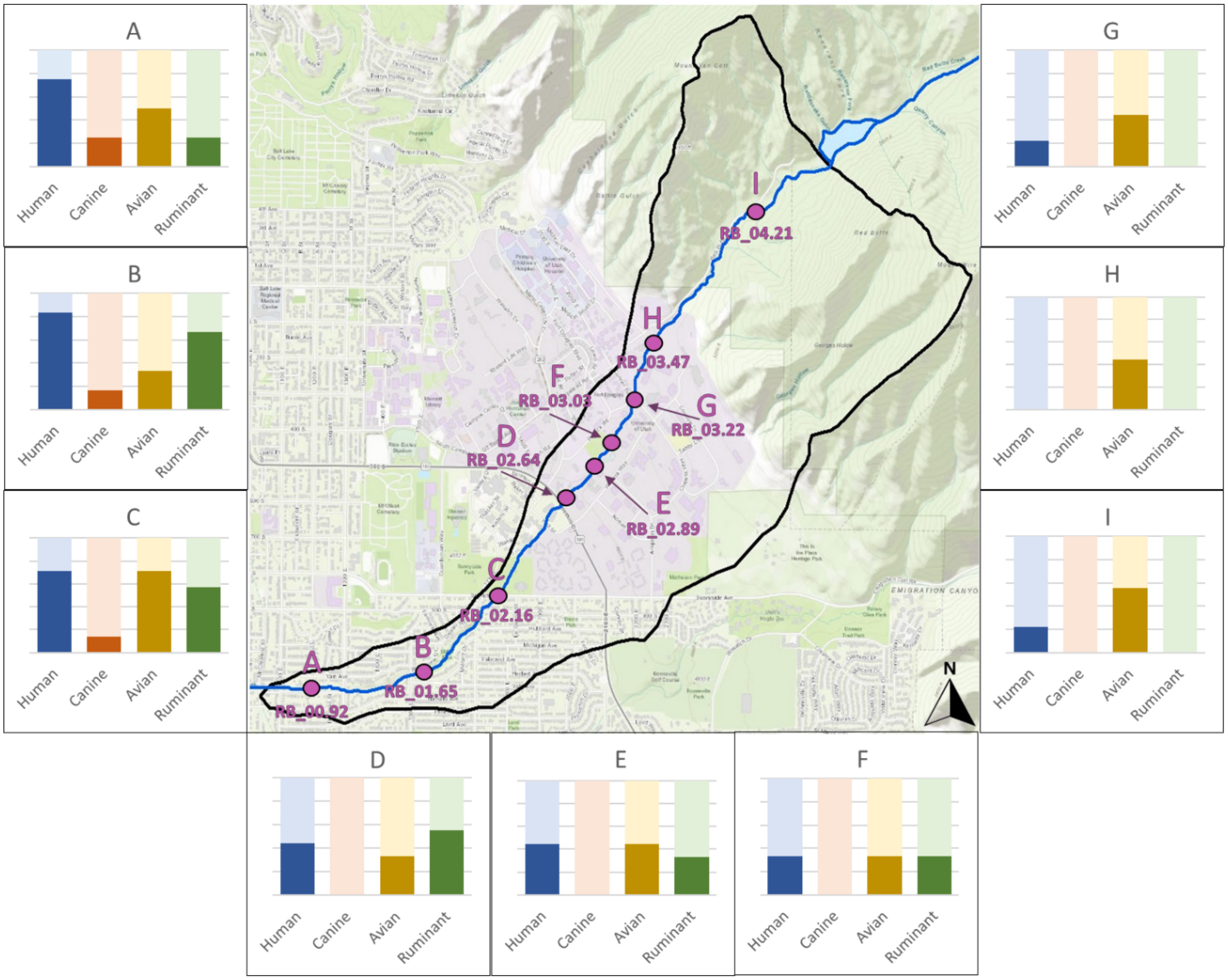

Figure F-9. The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades absence.

Source Assessment

The probable sources of *E. coli* in the Red Butte Creek Lower AU come from both point and nonpoint sources based on the data analysis, LDC analysis, land-use patterns, and hydrology. Point sources are limited primarily to stormwater runoff. Nonpoint sources include avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused.

Table F-4 provides a list of specific potential point and nonpoint sources in this AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. For more information on each potential source, please see Chapter 5.1 and 5.2.

Table F-4. Potential sources of *E. coli* contamination in Red Butte Creek Lower Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	Yes	UTR000000		
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities, including Salt Lake County	UTS000001		
		Utah Department of Transportation	UTS000003		
		Salt Lake City	UTS000002		
		University of Utah	UTR090024		
		Veterans Affairs Medical Center	UTR090025		
Nonpoint source	Onsite septic systems	No		Section 5.2.1	Table 8
	Agricultural: livestock	No		Section 5.2.2	
	Agricultural: canals	No			
	Domestic pets	Yes		Section 5.2.3	

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
	Wildlife/ nuisance species	Yes		Section 5.2.4	
	Recreationists/ unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

The only Utah Pollutant Discharge Elimination System (UPDES) permitted discharges within Red Butte Creek Lower Assessment Unit are from municipal stormwater, which is a likely source of *E. coli* in this AU (Figure F-10). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the LDC that pointed to point sources during low-flow regimes, urbanized land uses and increased impervious surfaces in the valley, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see Chapter 5 in the main report for more information.

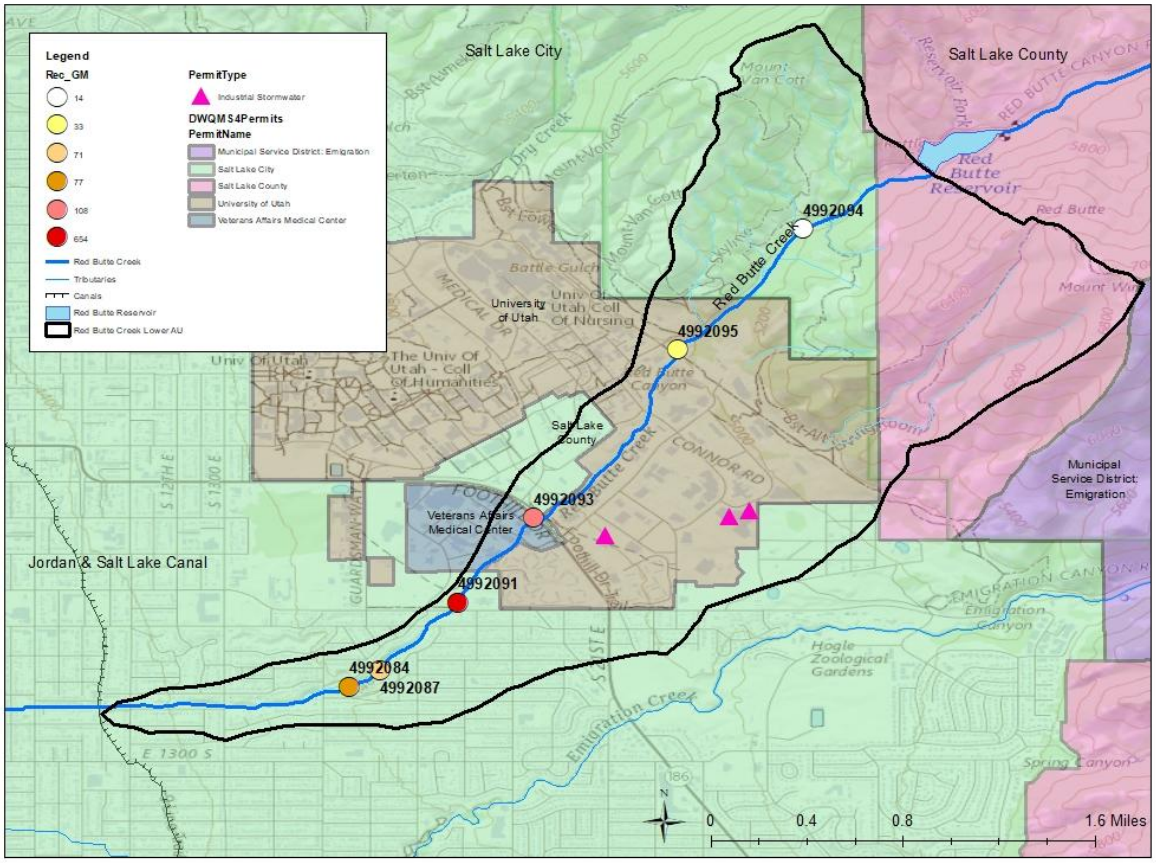

Figure F-10. Possible point sources of *E. coli* contamination within Red Butte Creek Lower AU.

Stormwater

Three potential sources of stormwater pollution (construction activities, industrial activities, and MS4s) occur within the Red Butte Creek Lower AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were nine construction and three industrial UPDES stormwater permits in the Red Butte Creek Lower AU. The industrial stormwater permits at this time occur above Foothill Drive (Figure F-10). Construction permits are short-lived and change over time, and most industrial sites are not potential sources of *E. coli*. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Red Butte Creek Lower AU by issuing MS4s permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of Red Butte Creek. There are five MS4 permits applicable to this AU: Jordan Valley Municipalities, Salt Lake City, Utah Department of Transportation, University of Utah, and the Veterans Affairs Medical Center (Figure F-10). The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. Salt Lake County is the only entity within the joint Jordan Valley MS4 that has jurisdictional boundaries within the AU. Salt Lake City's MS4 permit allows for discharge of stormwater within its jurisdictional boundaries. The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the state. UDOT's Region 2 geographical area covers the Wasatch Front. University of Utah and the Veterans Affairs Medical Center have a general permit for discharges from small MS4s.

LDC analysis suggests that riparian areas and impervious surfaces are likely sources since exceedances exist in the mid-range flow regimes. It also suggests that upland stormwater and bank erosion could be sources since there are exceedances in the higher flow regimes. Salt Lake County has identified Red Butte Creek as having poor bank stability (SLCo 2017), which could yield more erosion from the flashiness of this urban stream with high impervious surfaces in the valley (Red Butte Creek Vision 2018).

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Red Butte Creek Lower AU include humans, wildlife, and dogs (Figure F-11). There is no agricultural activity present in this AU, so it is not considered to be a source. Cultivated land uses are specific to local parks (i.e., This is the Place Heritage Park, Matheson Park, and Red Butte Gardens). Note that this AU, as well the Red Butte Creek Upper AU, do not have any parcels with onsite septic systems, so they are not considered a source. Probable nonpoint sources include pets, wildlife (nuisance species), recreationists, and the unhoused community known to utilize the riparian area. Please see Chapter 5.2 in the main report for more information on nonpoint sources.

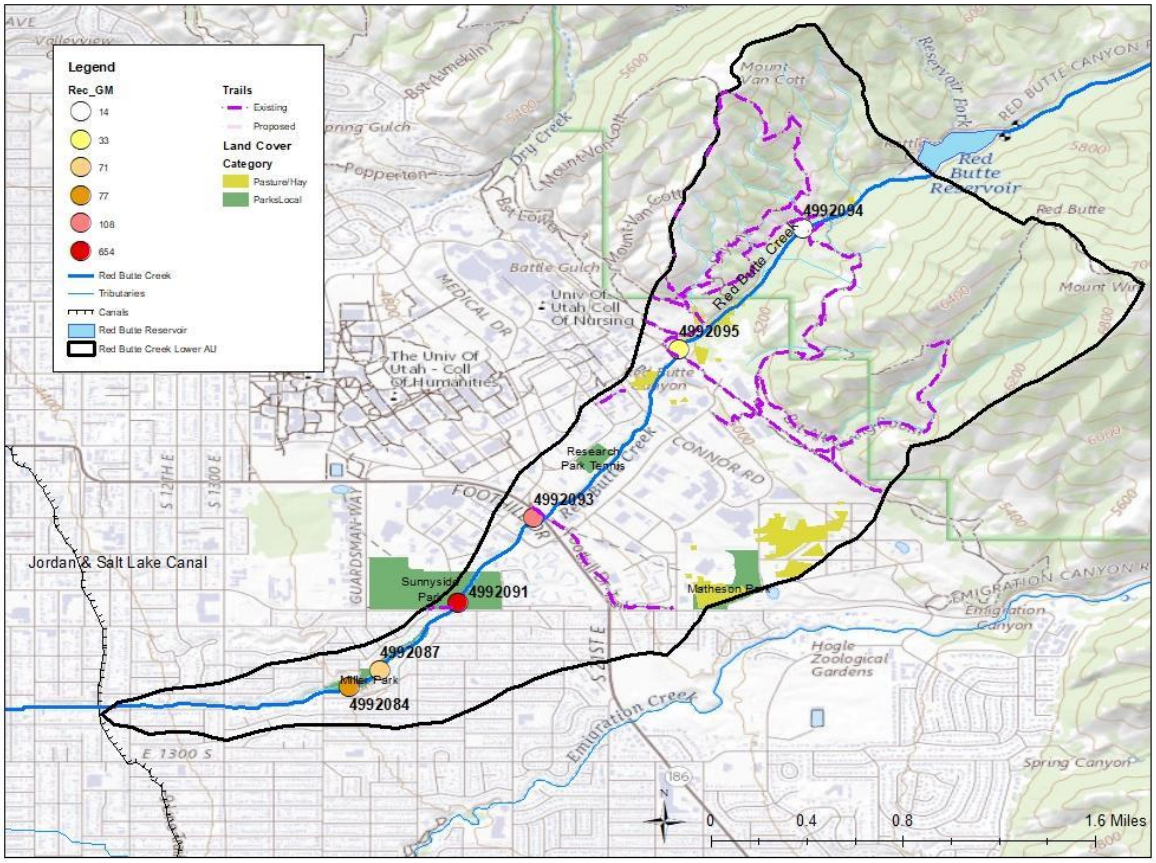

Figure F-11. Possible nonpoint sources of E. coli contamination within Red Butte Creek Lower AU.

Recreation, Pets, Nuisance Wildlife

Red Butte Creek above Sunnyside has the highest recreation season geometric mean concentration of *E. coli* within this lower AU. The geomean above Foothill Drive (4992093) is 108 MPN/100mL, and less than half a mile downstream above Sunnyside (4992091), the geomean increases to 654 MPN/100mL. This localized hotspot contributes to the impairment of Red Butte Creek through Miller Park. Red Butte Creek above Foothill Drive (4992093) has elevated levels of *E. coli* but not in exceedance of the geometric mean water quality standard. Sources above this site could contribute to the downstream impairments; however, a significant source input exists between these two sites.

Salt Lake City's Riparian Corridor Study (2010) provides some detail of the half-mile section of Red Butte Creek from Foothill Drive (4992093) down to Sunnyside Park (4992091).

> "This reach flows between Veterans Administration and University of Utah facilities, ending at a diversion structure and bridge at the upstream end of Sunnyside Park. The reach contains seven storm drain outfalls, a utility pipe crossing, and a nearly clogged culvert at a trail crossing that does not appear to receive much use. Portions of the reach are in good condition."

MST analysis confirms that canine markers are not present within the Red Butte Creek Lower AU until the Sunnyside site (Site C on Figure F-9). All four markers show an increase between sites D and C. Figure F-5 shows two distinct seasonal patterns at the Sunnyside site: a winter exceedance and summer exceedance. High *E. coli* concentrations in low-flow conditions, such as winter conditions, represents a discrete source of pollution given the lack of dilution in the stream.

Possible sources near Sunnyside include stormwater, bank erosion (overland flow), recreationists, and pets. Red Butte Creek slows in Sunnyside Park and could provide more preferable habitat for the waterfowl and beaver observed in the slower reaches of the creek. Avian and ruminant markers are present at this site, and deer have been observed at this park. These sites are located within or downstream of Miller Creek Bird Refuge, an area where waterfowl congregate.

This AU boosts numerous recreational opportunities due to the close proximity to downtown Salt Lake City and the foothills. There are four parks within this area, including several trails above the monitoring location at Red Butte Garden (4992095). MST results included the human marker, though public access is limited in the canyon. With the focused management of the unhoused community along the Jordan River, more transient populations have been documented in the Red Butte Creek canyon and along the creek in the valley. The increased presence of human markers below Foothill Drive indicates human waste could be a probable source from direct defecation or runoff from either the riparian corridor or impervious surfaces.

The canine marker was not prevalent throughout this AU. It was absent in the upper parts of the AU (above Foothill) but was found in the Sunnyside site and downstream. While there are no established dog parks, dogs often accompany their owners while recreating. Dog-waste stations should be included at all parks and major trailheads to promote proper waste disposal.

E. coli data shows more exceedances during the warmer months when stream flows are less and more people and animals recreate within the riparian corridor. MST analysis did not show any ruminants until the Sunnyside site (Site C). Ruminants are considered to be natural, and no BMPs are recommended for this type of wildlife.

Water is diverted from Red Butte Creek via pipe to the Mount Olivet Cemetery pond for irrigation purposes. Water from the pond can enter the city storm sewer system during times of flooding. The University of Utah Red Butte Creek Strategic Vision (2018) targets restoration in Red Butte Creek from approximately the canyon mouth down to Sunnyside (4992091). The University of Utah recognizes that having the creek running through campus provides unique opportunities for fostering and enhancing natural resource education. The university's objectives and goals to increase Red Butte Creek's ecological function, engage in stewardship, restore the watershed, and raise awareness will improve the aquatic health of the creek. *E. coli* was identified in the plan as a priority pollutant for further research (including stormwater runoff and control) even though the Red Butte Creek Lower AU was not impaired for *E. coli* at the time of the 2018 plan.

Please see Chapter 5.2 in the main report for more information on nonpoint sources.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Red Butte Creek Lower AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Appendix G. Midas Creek Assessment Unit *E. coli* TMDL

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Waterbody Name	Midas Creek
Waterbody/Assessment Unit (AU)	UT16020204-024_01
AU Description	Midas Creek and tributaries from confluence with Jordan River to headwaters
Impaired Beneficial Uses	Infrequent primary contact recreation (2B)
Applicable Season	May through October
Defined Endpoint/Water Quality Standard	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL
Percent Reduction Needed	88%, based on a geometric mean of 1,658 MPN/100 mL calculated for 4994420 (Butterfield/Midas Creek above Jordan River) in the month of September.
Probable Sources	Stormwater, recreationists, pets, wildlife, canal diversions, onsite septic systems

Assessment Unit Description

The Midas Creek Assessment Unit (AU) includes Midas Creek from its headwaters in the Oquirrh Mountains as it flows 10 miles downstream to the confluence with the Jordan River. The Midas Creek AU (27.8 mi^2) is within the cities of Herriman, Riverton, and South Jordan as well as the southwestern portion of Salt Lake County. Land ownership is 100% privately owned. The Midas Creek AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) designated beneficial use due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2014 Integrated Report.

Butterfield Creek AU (UT16020204-024_02) upstream from Midas Creek was also listed as impaired for *E. coli* in the 2014 Integrated Report. However, current data shows no impairment and Butterfield Creek was delisted in the 2022 Integrated Report.

Table G-1. Impairment summary of the Midas Creek Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
Midas Creek UT16020204-024_01	*E. coli*	Infrequent primary contact recreation (2B)	2014–2022
	Selenium*	Waterfowl, shorebirds, and other aquatic wildlife (3D)	2014–2022
	Total dissolved solids*	Agriculture	2014–2022
*Will be addressed in future TMDLs			

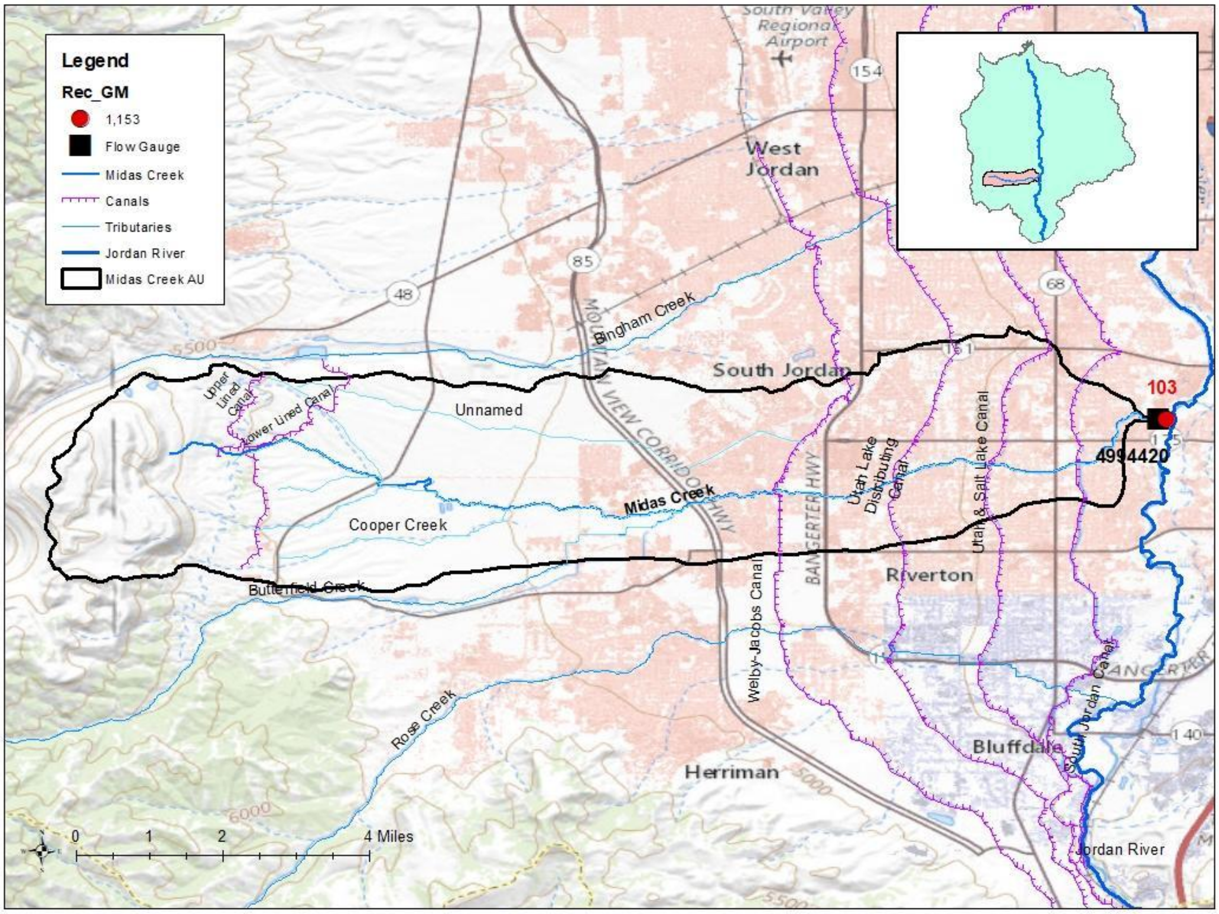

Figure G-1. Monitoring locations and hydrology in the Midas Creek Assessment Unit.

Hydrology

Midas Creek originates in the Oquirrh Mountains and flows approximately 10.1 miles before discharging into the Jordan River (Figure G-1). As the creek flows downstream through the increasingly urbanized valley, the losing-flow reaches are supplemented by intermittent streams that include Copper Creek as well as four canals (Welby-Jacobs Canal, Utah Lake Distributing Canal, Utah and Salt Lake Canal, and South Jordan Canal). These canals have overflow structures to the creek that flow during storm events (SLCo 2009). These canals carry Utah Lake water diverted at the Jordan River Narrows to satisfy exchange agreements with Salt Lake City. Located close to the Jordan River, these canal flows are perennial due to irrigation return flows, groundwater accretion, and stormwater.

Figure G-1 shows the inputs and outputs of the Midas Creek riverine system in the Midas Creek AU. Instream flows are 13% reduced or interrupted by hydrologic modifications in the developed areas of the AU (SLCo 2017). Approximately 7% of the main channel is piped within this AU (SLCo 2009). Hydrologic modifications, such as channelization, stormwater conveyance systems, diversions, and rip-rapped streambanks alter the stream's hydrograph.

Midas Creek watershed drains 27 mi² of natural and developed landscape. Salt Lake County Gauge #103 (Midas Creek at Jordan River) has a mean daily flow of three cubic feet per second (cfs) during the TMDL period of record (2011–2021), with a maximum daily mean of 42 cfs (Table G-3).

Butterfield Creek was historically a major tributary to Midas Creek but is no longer hydrologically linked due to extensive hydrological modifications. The channel becomes less defined as it moves downstream and is no longer evident just north of Herriman (near 6000 West). Flows from storm events terminate in the Utah Lake Distributing Canal and Utah and Salt Lake Canal.

Land Use

According to the 2019 National Land Cover Dataset (NLCD), both natural (i.e., forest, grassland, wetlands, shrubland, and barren) and developed land cover comprise 39% of the Midas Creek AU (Figure G-2). Cultivated lands (pasture and crops) are 21%, and open water is 0.1%. Most of the riparian buffers along the main stem of Midas Creek are natural (vegetated) in the upper reaches and switch to developed/urban lower in the AU. Urban land cover is primarily residential and industrial. Cultivated land cover exists in the middle of the AU close to the confluence of Copper Creek. Developed open space is limited to designated parks.

Approximately 22% of the AU is covered by impervious surfaces from developed land use, with most of those surfaces located within the valley. This level of impervious surface leads to increased runoff, which results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase significantly in this AU, 1,240% in the upper portion of Midas Creek and 165% in the lower portion by 2040 resulting in a 20.9% increase in impervious surface and a greater than 50% decrease in natural land cover (SLCo 2017). See Section 5.3.1 in the main report for more information on the effects of impervious surfaces on pollutant loading.

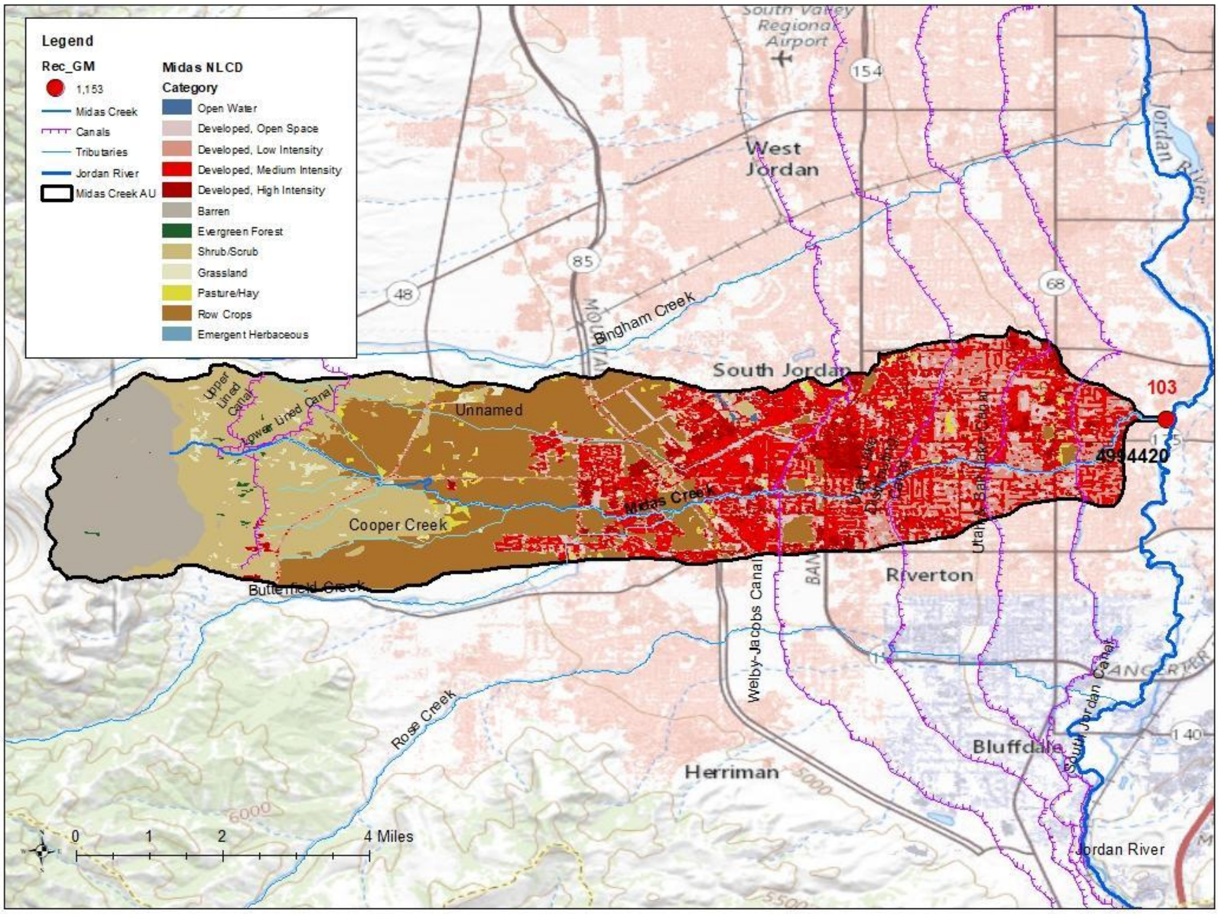

Figure G-2. Land cover in Midas Creek Assessment Unit (2019).

E. coli Data Summary

One routine monitoring location on Midas Creek (4994420) was studied for spatial and temporal patterns of *E. coli* levels (Table G-2). *E. coli* samples collected at this site between 2010–2021 exceeded the water quality standard (206 MPN/100mL) 88% of the time (Figure G-3). The maximum reporting limit of 2,420 MPN/100 mL was also exceeded many times (Figure G-3). Exceedances of the standard were evenly distributed over the entire sampling period of record (Figure G-4). When aggregated by month, *E. coli* geometric mean concentrations exceeded the standard in all months except March, with July–September geometric means reaching 1,500 MPN/100 mL (Figure G-5), indicating a seasonal increase during the summer.

Table G-2. Midas Creek Assessment Unit *E. coli* data summary all year.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4994420	Butterfield/ Midas Creek above Jordan River	Not meeting criteria	05/2010 to 10/2021	120	20	698	1153	2,420*	88	54

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL

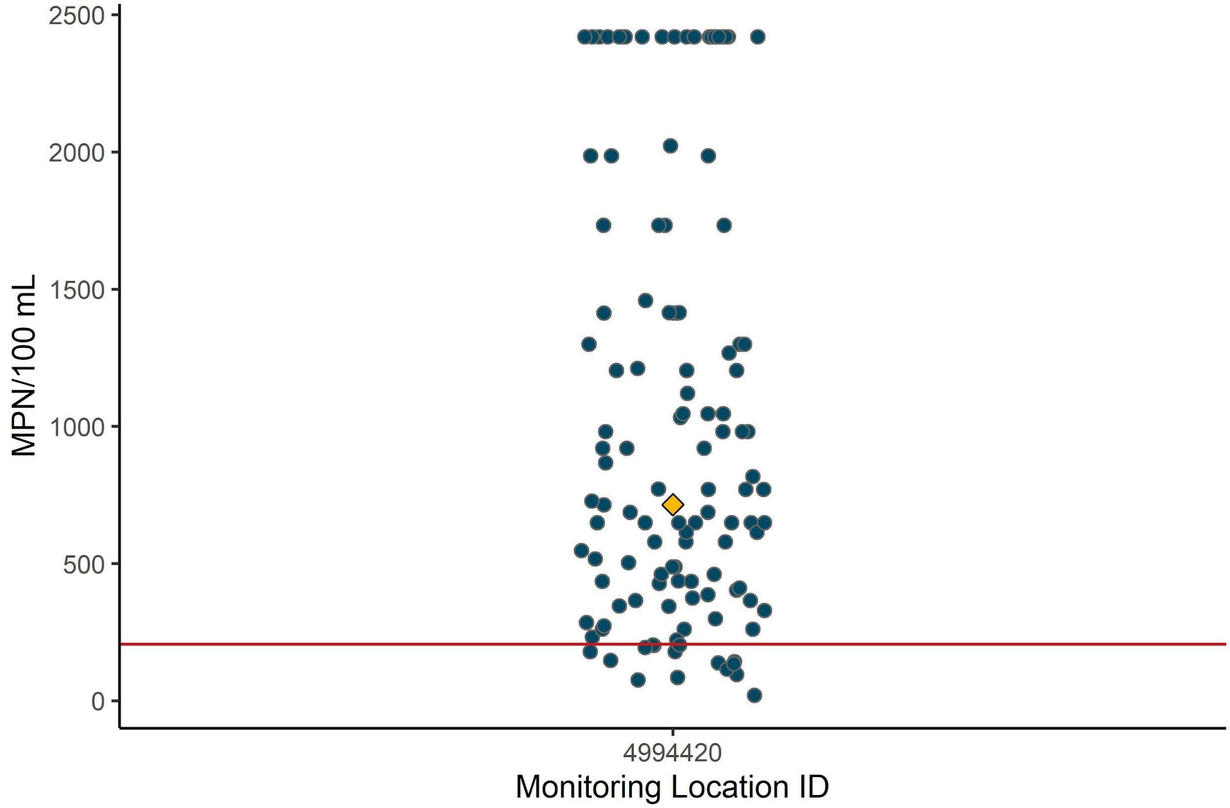

Figure G-3. *E. coli* concentrations at the routine monitoring location in the Midas Creek Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. The yellow diamond indicates the overall geometric mean for the site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

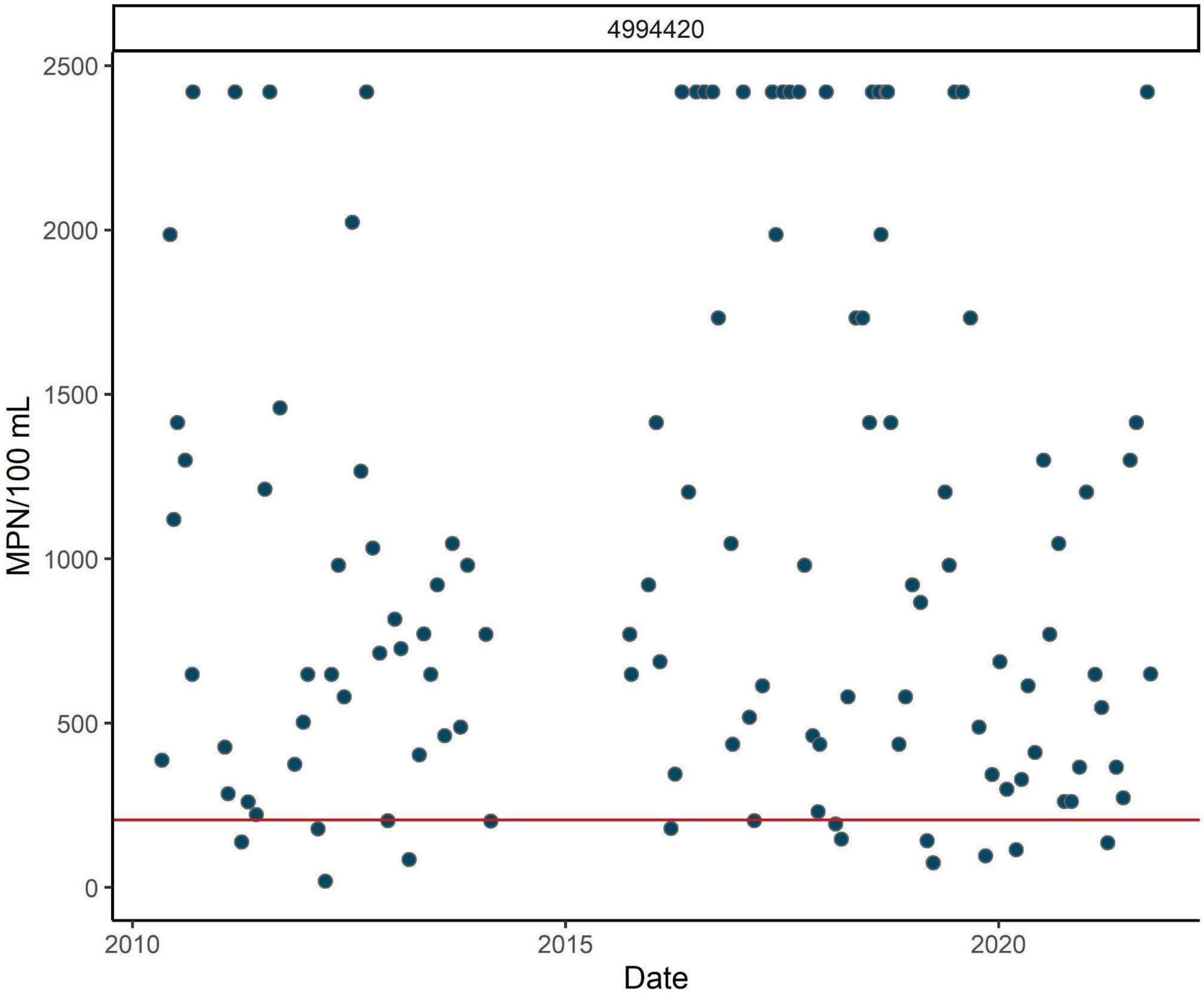

Figure G-4. *E. coli* concentrations at the routine monitoring location through time within the Midas Creek Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

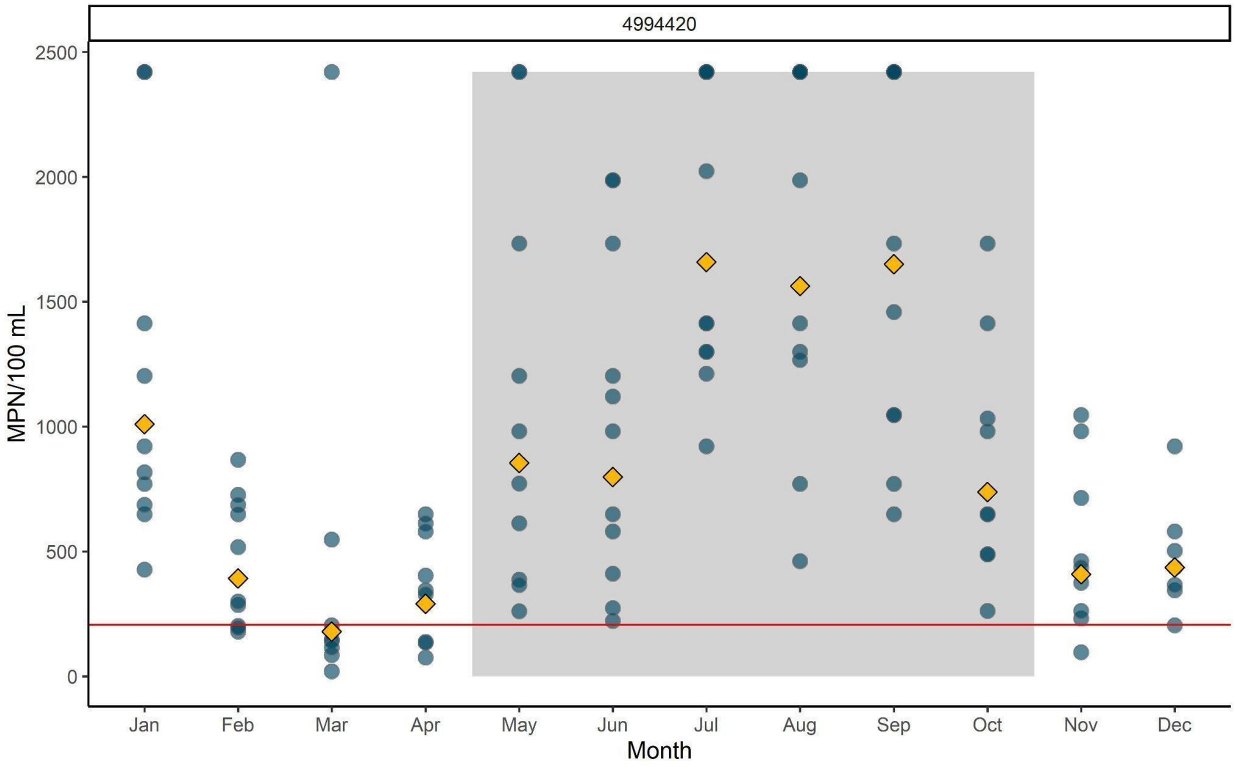

Figure G-5. *E. coli* concentrations at the routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season.

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDCs), data analysis, land-use patterns, and hydrologic information. Potential sources and recommended implementation strategies to address them are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curve

Load duration curves are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at the lower end of this AU, Midas Creek at Jordan River, Gauge #103. This site corresponds to an *E. coli* monitoring station, Midas Creek above Jordan River (4994420) (Figure G-1). Flow data during the TMDL period of record (April 2014–September 2021) are summarized in Table G-3, Figure G-6, and Figure G-7. Flow at this site varies from 2–4 cfs. Flows are fairly consistent throughout the year, with no true peak in the spring from snowmelt due to large sections of the natural channel being completely dewatered (SLCo 2017).

Table G-3. Summary statistics for Midas Creek at Jordan River, Gauge #103 (4994420).

Gauge Name	SLCO Gauge Number/DWQ MLID	Drainage Area (mi^2)	Mean Flow (cfs)	Maximum Flow (cfs)
Midas Creek at Jordan River	103/4994420	1.07	3	42

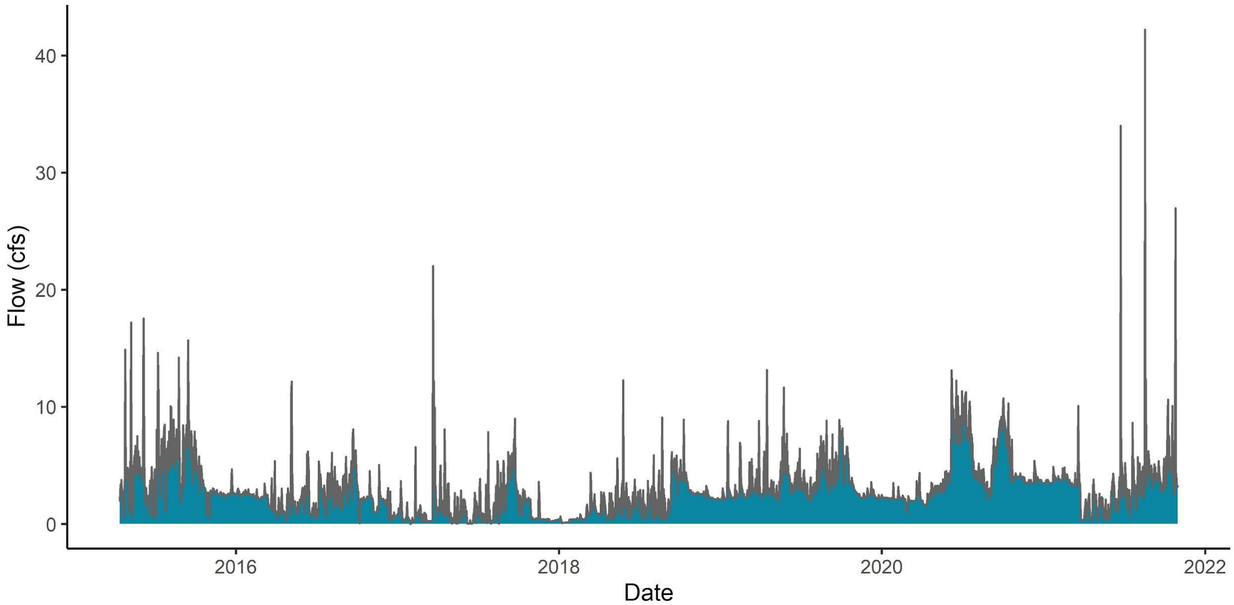

Figure G-6. Daily means flows at Salt Lake County Gauge #103, Midas Creek at Jordan River (4994420) from April 4, 2015, to September 30, 2021.

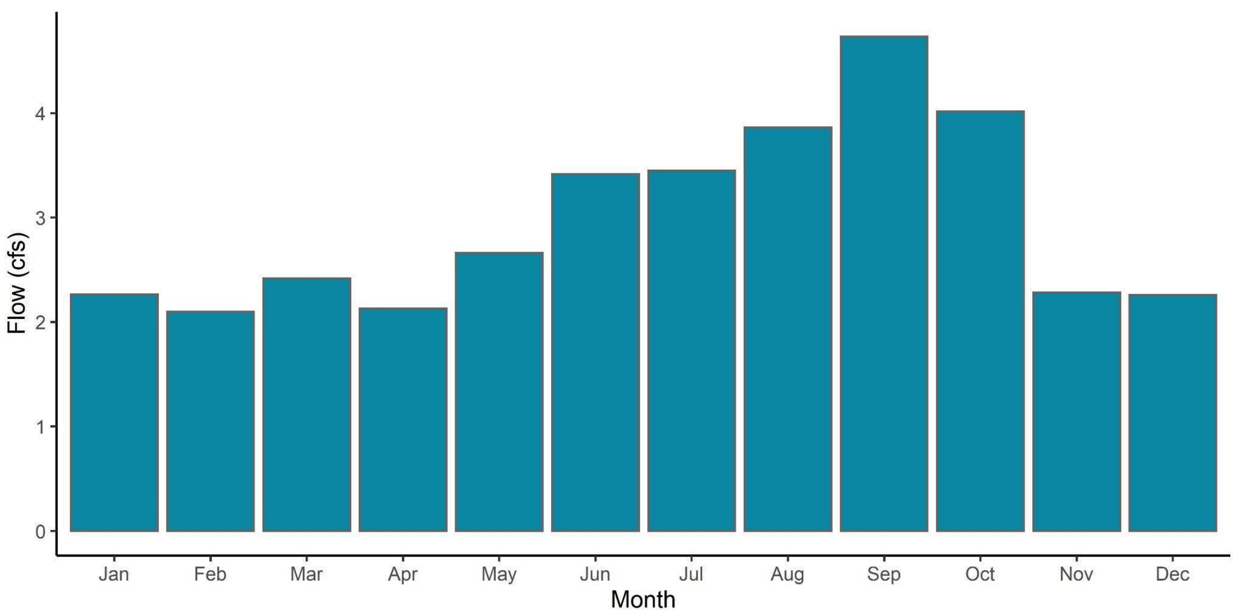

Figure G-7. Monthly means flows (cfs) at Salt Lake County Gauge #103, Midas Creek at Jordan River (4994420) from April 4, 2015, to September 30, 2021.

Using this site's corresponding *E. coli* and flow data, the LDC shows exceedances occurring at all flow regimes (Figure G-8). The percent of *E. col*i loading measurements exceeding the TMDL in each flow regime is provided in parentheses under each flow-regime label in Figure G-8. Exceedances of the TMDL threshold (solid line) in high to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. These sources include point sources (low-flow conditions), onsite septic systems (dry flows), and riparian areas and impervious stormwater sources (mid-range). Upland stormwater and bank erosion are likely sources for the higher flow conditions. Though the higher flow regimes require the most reduction, exceedances in all flow regimes indicate that the Midas Creek AU has both point and nonpoint source delivery methods of *E. coli* loading.

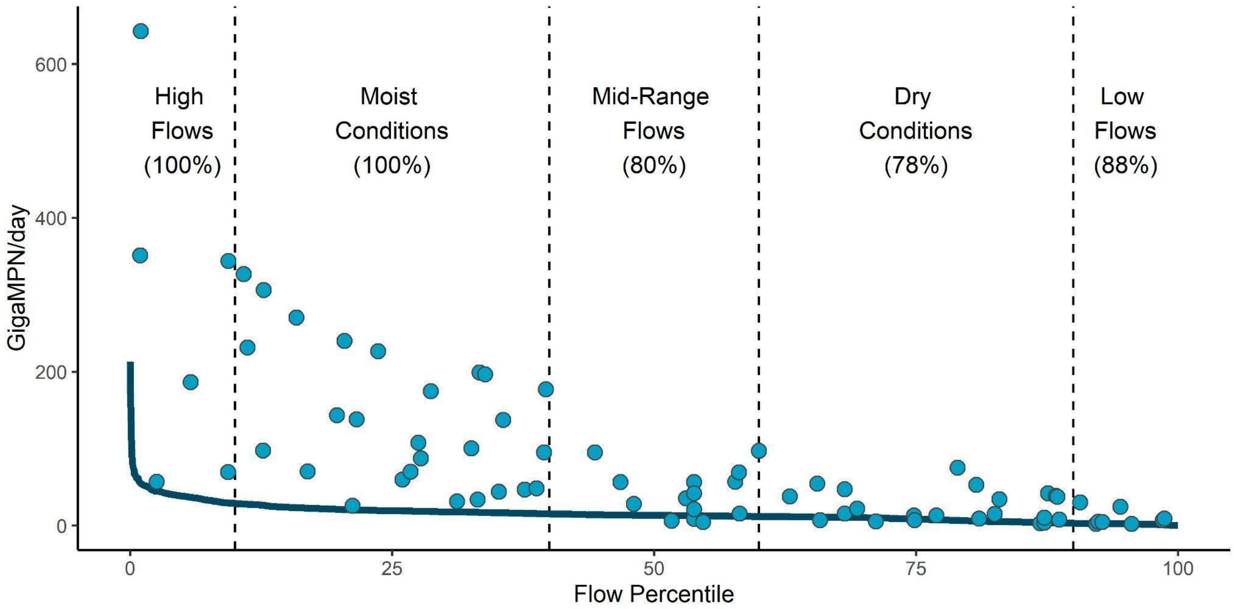

Figure G-8. Load duration curve for Midas Creek at Jordan River (4994420).

Source Assessment

The probable sources of *E. coli* in the Midas Creek AU come from point sources, most notably stormwater runoff, based on the data analysis, LDC analysis, land-use patterns, and hydrology. Nonpoint sources include onsite septic systems, avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused.

Table G-4 provides a list of specific potential point and nonpoint sources in the Midas Creek AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. Please see Chapter 5.1 and 5.2 for more information on each potential source.

Table G-4. Potential sources of *E. coli* contamination in Midas Creek Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	No			
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities including Riverton, Herriman, South Jordan, Salt Lake County	UTS000001		
		Utah Department of Transportation	UTS000003		
Nonpoint source	Onsite septic systems	No			Table 8
	Agricultural: livestock	Yes		Section 5.2.2	
	Agricultural: canals	Yes			
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	
	Recreationists/ unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

The only Utah Pollutant Discharge Elimination System (UPDES) permitted discharges within Midas Creek Assessment Unit are from municipal stormwater, which could be a likely source of *E. coli* contamination in this AU (Figure G-9). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the LDC that pointed to point sources during low-flow regimes, urbanized land uses and increased impervious surfaces in the valley, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see [Chapter 5](#) in the main report for more information.

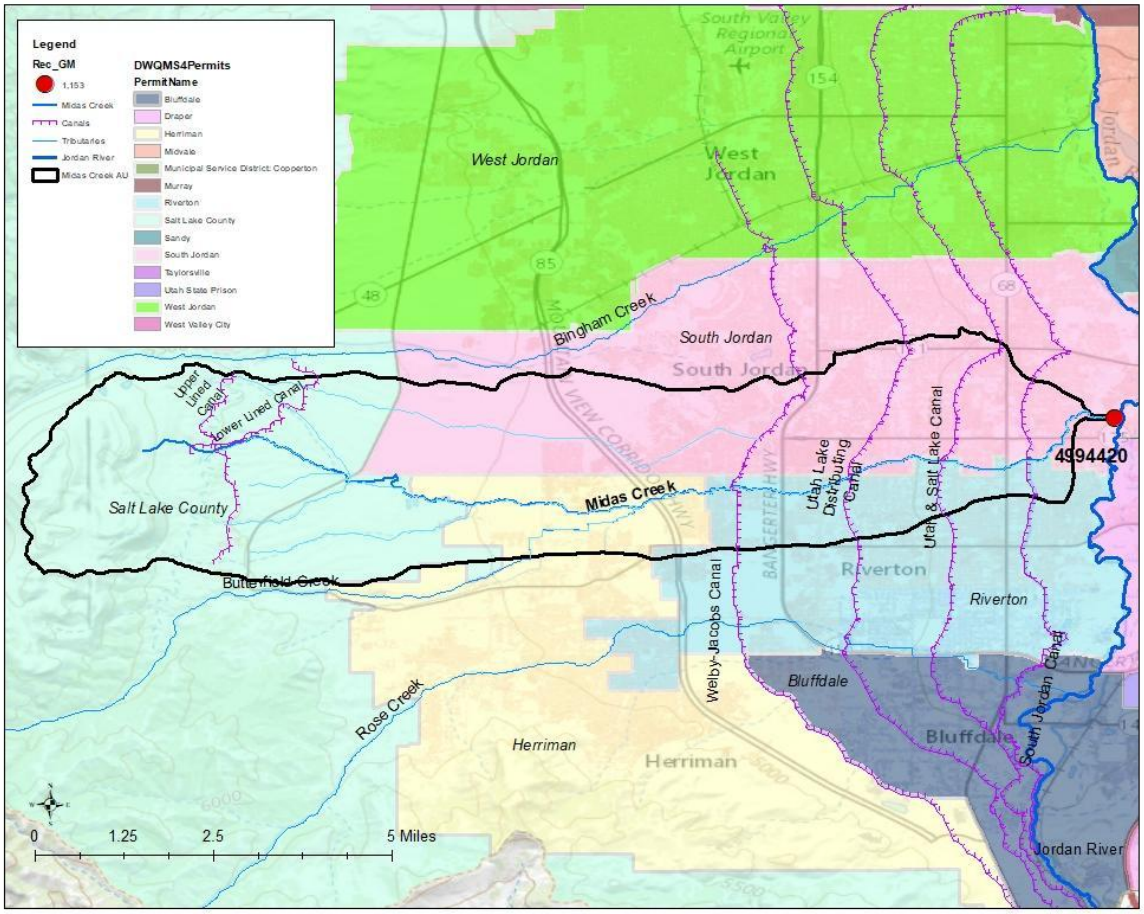

Figure G-9. Possible point sources of *E. coli* contamination within Midas Creek Assessment Unit.

Stormwater

Two potential sources of stormwater pollution (construction activities and MS4s) occur within the Midas Creek AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were 160 construction UPDES stormwater permits in the Midas Creek AU. Construction permits are scattered throughout the lower two-thirds of the AU and are short-lived and change over time. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Midas Creek AU by issuing MS4s permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of Midas Creek. There are two MS4 permits applicable to this AU: Jordan Valley Municipalities and Utah Department of Transportation (Figure G-9). The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. Salt Lake County and the cities of Riverton, South Jordan, and Herriman have jurisdictional boundaries within the AU. The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the state. UDOT's Region 2 geographical area covers the Wasatch Front.

LDC analysis suggests that since exceedances exist in the mid-range and higher flow regimes, impervious stormwater and upland stormwater are likely sources of *E. coli* contamination. This westside tributary is predicted to experience one of the most rapid transitions from natural to urban land cover by 2040 given the current development pressure. Stormwater management will be critical to avoid further degradation of water quality in Midas Creek.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Midas Creek AU include agricultural activity, humans, wildlife, and dogs (Table G-4, Figure G-10). According to the Salt Lake County's Assessor's Office, there are only five onsite septic system parcels within this AU as of 2021, so onsite septic is not considered a significant source of *E. coli* contamination. Most parcels are sewered and no large underground wastewater disposal systems lie within the Midas Creek AU boundary. Please see [Chapter 5.2](#) in the main report for more information on nonpoint sources.

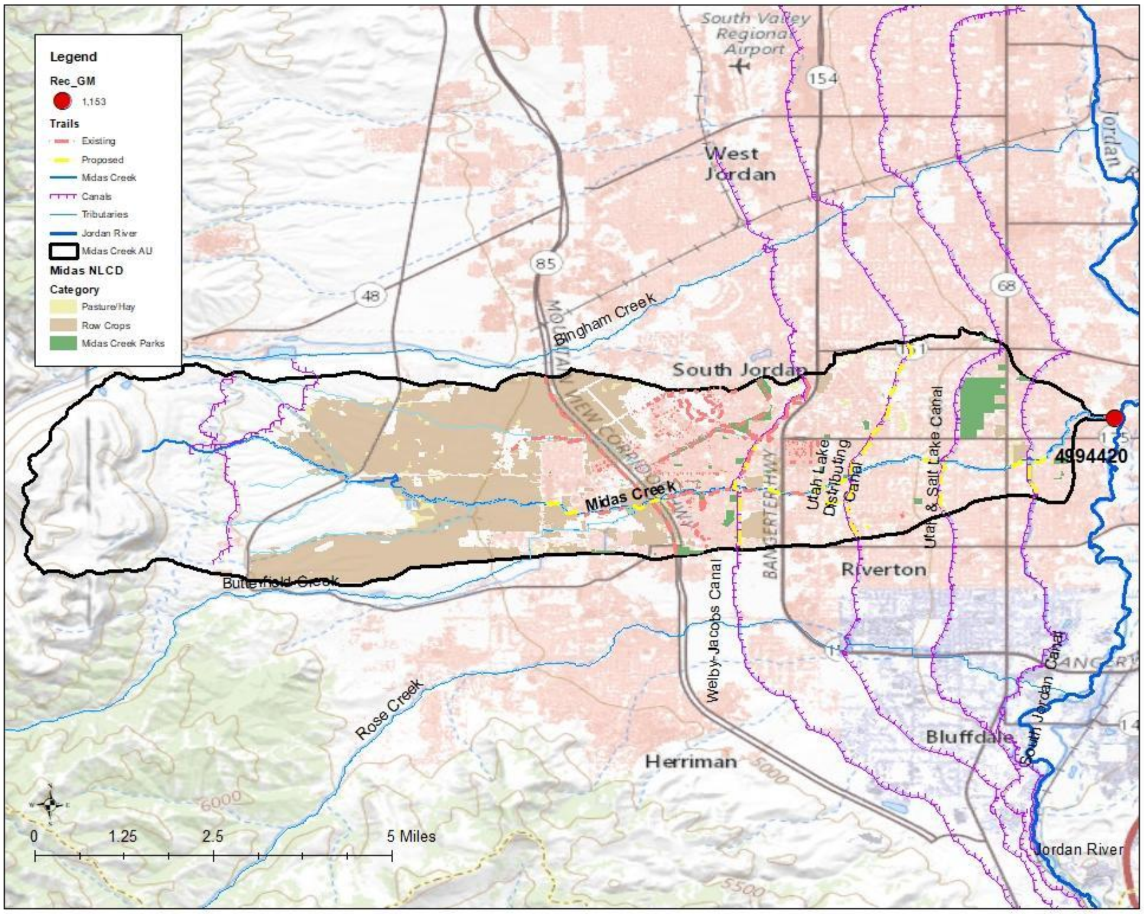

Figure G-10. Possible nonpoint sources of *E. coli* contamination within Midas Creek Assessment Unit.

Agricultural Activities

Agricultural activity comprises 21% of the total land cover within the Midas Creek AU (Figure G-2). Agricultural activity includes crops, pasture, livestock, and irrigation. There are no permitted concentrated animal feeding operations (CAFOs) within this AU. Crops make up a majority of the cultivated land use and occur in the middle third of the AU near the confluence of Copper Creek and Midas Creek (Figure G-10). Pasture lands lie in the same general location as the croplands. Fourteen miles of Midas Creek, along with canals with the potential to discharge to the creek, lie within 100 feet of cultivated lands. Approximately one-third (32%) of the irrigated acres are flood-irrigated.

E. coli may enter Midas Creek and the canals discharging into Midas Creek from grazing lands where livestock have direct access to surface waters. There may also be instances where livestock grazing occurs on flood-irrigated pastures with return flows that lead to the surface waters. Landowners are not required to report the number of animals on their property, so the exact livestock count for the AU is unknown. Proper grazing and irrigation management should be implemented to limit runoff from fields, where feasible.

As previously stated in the hydrology section, Midas Creek spans four major canals (Figure G-2). These canals could import water with elevated *E. coli* concentrations from outside the AU and deposit it in the creek during storm events or runoff from the surrounding earthen canals. These canals are utilized more frequently for stormwater conveyance than irrigation delivery due to development pressure and the rate of land conversion from cultivated/natural to developed. Riverton City's Stormwater Management Plan states these canals are not suitable for stormwater conveyance since the "canal capacities decrease from upstream to downstream, while runoff flow rates increase from upstream to downstream." The plan also states that water quality, debris, and sediment are ongoing problems when these canals are used for stormwater conveyance. Table 8 in the main report lists suggested BMPs to address *E. coli* contamination from agricultural activity.

Recreation, Pets, and Nuisance Wildlife

Recreational use is high within the Midas Creek AU, both in the Oquirrh Mountains and the 38 parks in the valley. An exhaustive network of trails exists within this AU (Figure G-10). Salt Lake County recently began development of a recreational master plan for the Rose Creek area that will increase recreational opportunities. It is likely that a small percentage of those who recreate do not properly dispose of human waste. While it is a challenge to quantify this behavior, improper disposal of human waste does not appear to be a problem throughout the AU based on field observations. People hiking and fishing in the assessment unit are considered an unlikely source of significant *E. coli* contamination to the creek for the purposes of this TMDL. However, proper management of human waste should be highlighted at all parks and trailheads.

Pets

Improper management of domestic pet waste is another potential source of *E. coli* contamination in waterbodies. Dog waste in the immediate vicinity of a waterway can contribute to local water quality impacts. While there are no designated off-leash dog parks within the Midas Creek AU boundary, dogs often accompany their owners on both trail and parks. Dog waste BMPs should be employed to ensure proper pet waste management.

Nuisance Wildlife

Wildlife could also be a source of *E. coli* loading in this assessment unit. Transport of animal waste to surface waters is dependent on animal habitat and proximity to surface waters. Waterfowl and riparian mammals often deposit waste directly into streams, while other riparian species deposit waste in the floodplain where it can be transported to surface waters by runoff during precipitation events. Animal waste deposited in upland areas can also be transported to waterways.

Since almost 40% of the land in Midas Creek AU is considered natural, large numbers of warm-blooded animals will be in close proximity to the creek, especially in the upper portion of the AU near the mountains. These animals have the potential to be a source of *E. coli* pollution. However, they are considered natural or background sources, so no further implementation is needed.

Nuisance wildlife species, however, should be considered as a potential source of *E. coli* in this AU. MS4 permits must address nuisance wildlife species due to certain stormwater control structures (basins and ponds) that can attract and encourage nuisance wildlife to congregate and degrade water quality. Common nuisance species include, but are not limited to, deer, waterfowl and small mammals such as beaver and muskrats. These areas include parks, golf courses, and detention basins. Preventing waterfowl from congregating and limiting public feeding opportunities can reduce avian-based contamination.

LDC analysis suggests that it's highly likely that overland flow, riparian areas, and bank erosion are sources of *E. coli* within this AU. Warmer months lead to increased human-health exposure due to wildlife in close proximity to people (Figure G-5). Suggested BMPs in Table 8 of the main report should be prioritized to restore the water quality in Midas Creek.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Midas Creek AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Appendix H. Rose Creek Assessment Unit *E. coli* TMDL

Waterbody Name	Rose Creek
Waterbody/Assessment Unit (AU)	UT16020204-029
AU Description	Rose Creek and tributaries from confluence with Jordan River to headwaters
Impaired Beneficial Uses	Infrequent primary contact recreation (2B)
Applicable Season	May through October
Defined Endpoint/Water Quality Standard	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL
Percent Reduction Needed	83%, based on a geometric mean of 1222 MPN/100 mL calculated for 4994660 (Rose Creek above Confluence with Jordan River at Stream Gage) in the month of September.
Probable Sources	Stormwater, recreationists, pets, wildlife, canal diversions, onsite septic systems

Assessment Unit Description

The Rose Creek Assessment Unit (AU) includes Rose Creek as it flows from its headwaters (Rose Canyon Spring) in the Oquirrh Mountains 11 miles downstream to the confluence with the Jordan River. The Rose Creek AU (27.2 mi²) is within Bluffdale, Herriman, and Riverton Cities as well as the southwestern portion of Salt Lake County. Land ownership is 97% privately owned,with 3% federally owned. The Rose Creek AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) designated beneficial use due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2014 Integrated Report.

Table H-1. Impairment summary of the Rose Creek Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
UT16020204-029	*E. coli*	Infrequent primary contact recreation (2B)	2014–2022

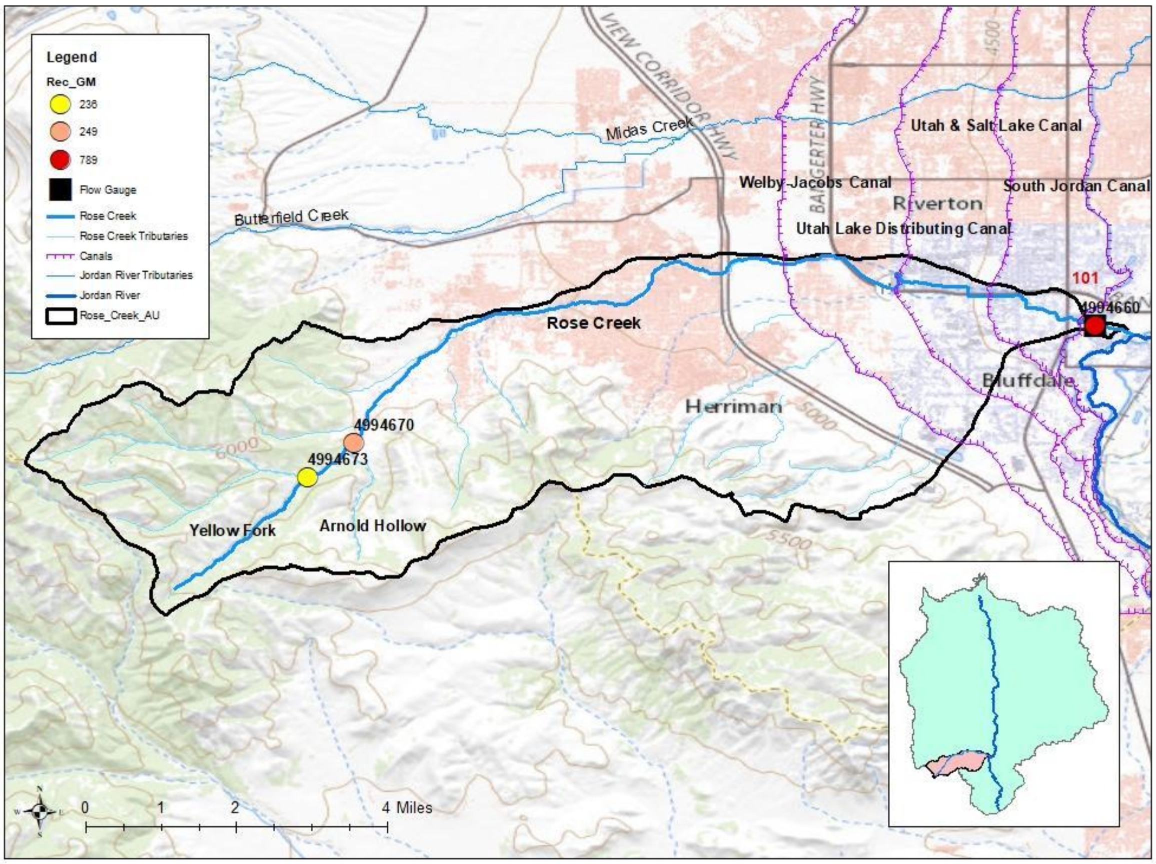

Figure H-1. Monitoring locations and hydrology for Rose Creek watershed.

Hydrology

Rose Creek originates in the Oquirrh Mountains and flows approximately 11.2 miles before discharging into the Jordan River (Figure H-1). A large portion of the instream flow originates in Yellow Fork Canyon. The losing-flow reaches are supplemented by four canals (Welby-Jacobs Canal, Utah Lake Distributing Canal, Utah and Salt Lake Canal, and South Jordan Canal) as the creek flows downstream through the increasingly urbanized valley.

These canals (with the exception of the Welby-Jacobs Canal) have overflow structures to the creek that flow during storm events (SLCo 2009). These canals carry Utah Lake water diverted at the Jordan River Narrows to satisfy exchange agreements with Salt Lake City. Other major diversions include Rose Creek Irrigation Company and Herriman City Municipal Water Department that divert spring water from Rose Creek.

Figure H-1 shows the inputs and outputs of the Rose Creek system in the AU. Instream flows are 50% reduced or interrupted by hydrologic modifications in the upper reaches and 100% in the valley reaches (SLCo 2017). Approximately 8% of the main channel is piped in this AU, and 29% has an engineered channel path (SLCo 2009). Hydrologic modifications such as channelization, stormwater conveyance systems, diversions, and rip-rapped streambanks alter the stream's hydrograph.

As Rose Creek approaches the confluence with the Jordan River, flows become perennial due to irrigation return flows, groundwater accretion, and stormwater. Rose Creek watershed drains 27.6 mi^2 of natural and developed landscape. Salt Lake County Gauge #101 (Rose Creek at Jordan River) has a mean daily flow of 0.72 cubic feet per second (cfs) during the TMDL period of record (2011–2021), with a maximum daily mean of 50 cfs (Table H-3).

Land Use

According to the 2019 National Land Cover Dataset (NLCD), natural land cover (i.e., forest, grassland, wetlands, shrubland, and barren) dominates the Rose Creek AU at 76% coverage (Figure H-2). Developed (urban) land cover is 19%, agricultural (pasture and crops) is 4%, and open water is 0.08%. Most of the riparian buffer along the main stem of Rose Creek is natural (vegetated) in the upper reaches, then transitions to developed/urban lower in the AU. Cultivated land cover occurs in the middle of the AU close to the Welby-Jacobs Canal and Utah Lake Distributing Canal. Developed open space is limited to designed parks. Urban land cover is primarily residential and industrial.

Approximately 13% of the AU is covered by impervious surfaces from developed land use, with most of those located within the valley. This level of impervious surface leads to increased runoff, which results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase significantly in this AU, by 290% in the upper portion of Rose Creek and 60% in the lower portion by 2040, which will result in an increase in impervious surfaces and decrease in natural land cover in this AU (SLCo 2017). See Section 5.3.1 in the main report for more information on the effects of impervious surfaces on pollutant loading.

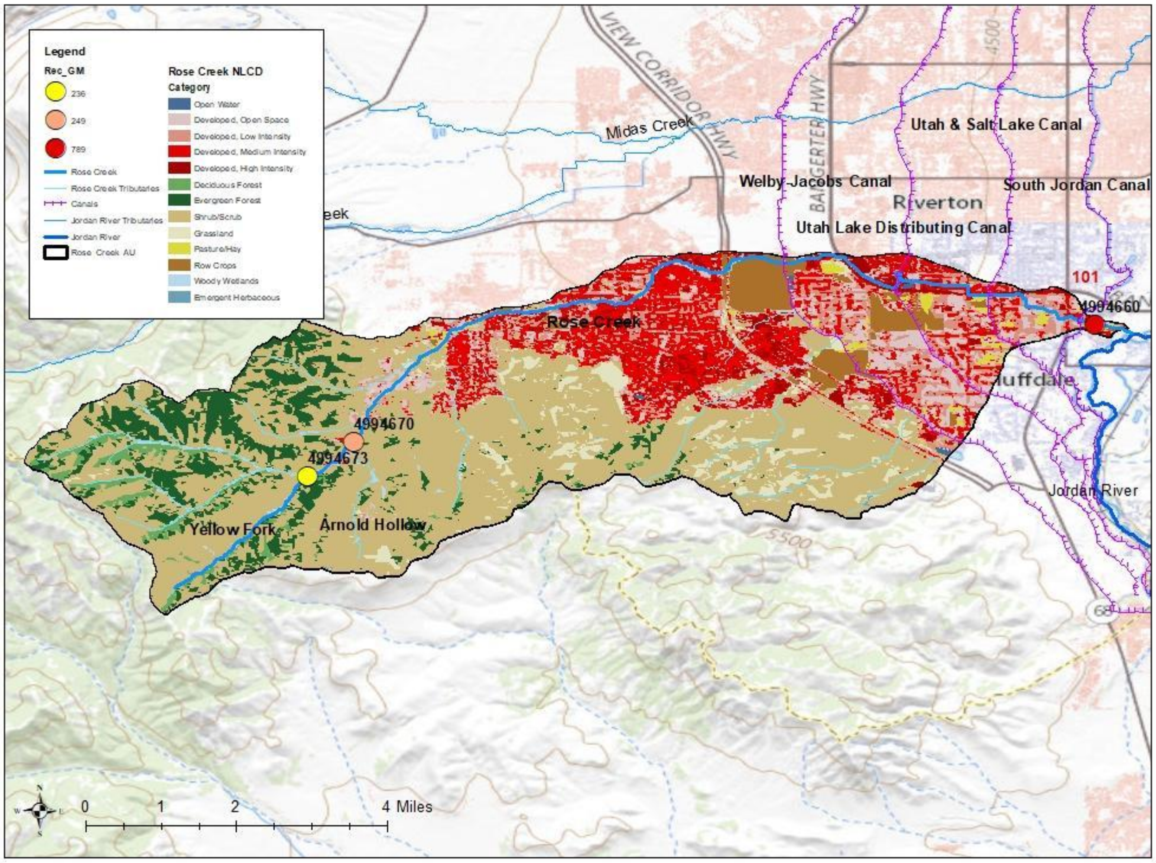

Figure H-2. Land cover in Rose Creek Assessment Unit (2019).

E. coli Data Summary

Three routine monitoring locations on Rose Creek were studied for spatial and temporal patterns of *E. coli* (Figure H-1). Two sites (Rose Creek at Yellow Fork Canyon trailhead and Rose Creek at Arnold Hollow Crossing) are located in the upper portion of the watershed, while the most downstream site, Rose Creek above Confluence with Jordan River (4994660), is just above the confluence with the Jordan River (Figure H-1, Table H-2). The highest levels of *E. coli* occurred at the most downstream site, Rose Creek above the confluence of the Jordan River (4994660), with the overall geometric mean above the standard, though samples from all locations regularly exceeded 206 MPN/100 mL (Figure H-3).

From 2012 to 2021, 89% of samples collected at the lowest site in the AU (4994660) exceeded the standard. Samples collected at the upstream sites (4994670 and 4994673) between 2016 and 2021 consistently exceeded the standard, but these exceedances represent a lower proportion of the overall dataset at each site (31–34%) compared to 4994660 (Figure H-4).

Monthly *E. coli* geometric mean concentrations at all sites were elevated in the recreation season months, particularly July–September. Rose Creek above the confluence of the Jordan River site exceeded the standard in all months except April (Figure H-5).

Table H-2. Rose Creek Assessment Unit *E. coli* data summary all year.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4994660 / RC_00.41	Rose Creek above Confluence with Jordan River at Stream Gauge	Not meeting criteria	03/2011 to 10/2021	55	44.1	739	789	2,420*	89	58
4994670 / RC_10.58	Rose Creek at Arnold Hollow Road Xing	Not meeting criteria	06/2016 to 10/2021	64	0.5**	60	249	2,420*	34	11
4994673 / RC_11.32	Rose Creek at Yellow Fork Canyon Trailhead	Not meeting criteria	06/2016 to 10/2021	65	0.5**	52	236	2,420*	31	14

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL
** Used half the detection limit (1 MPN/100 mL) for samples with non-detects

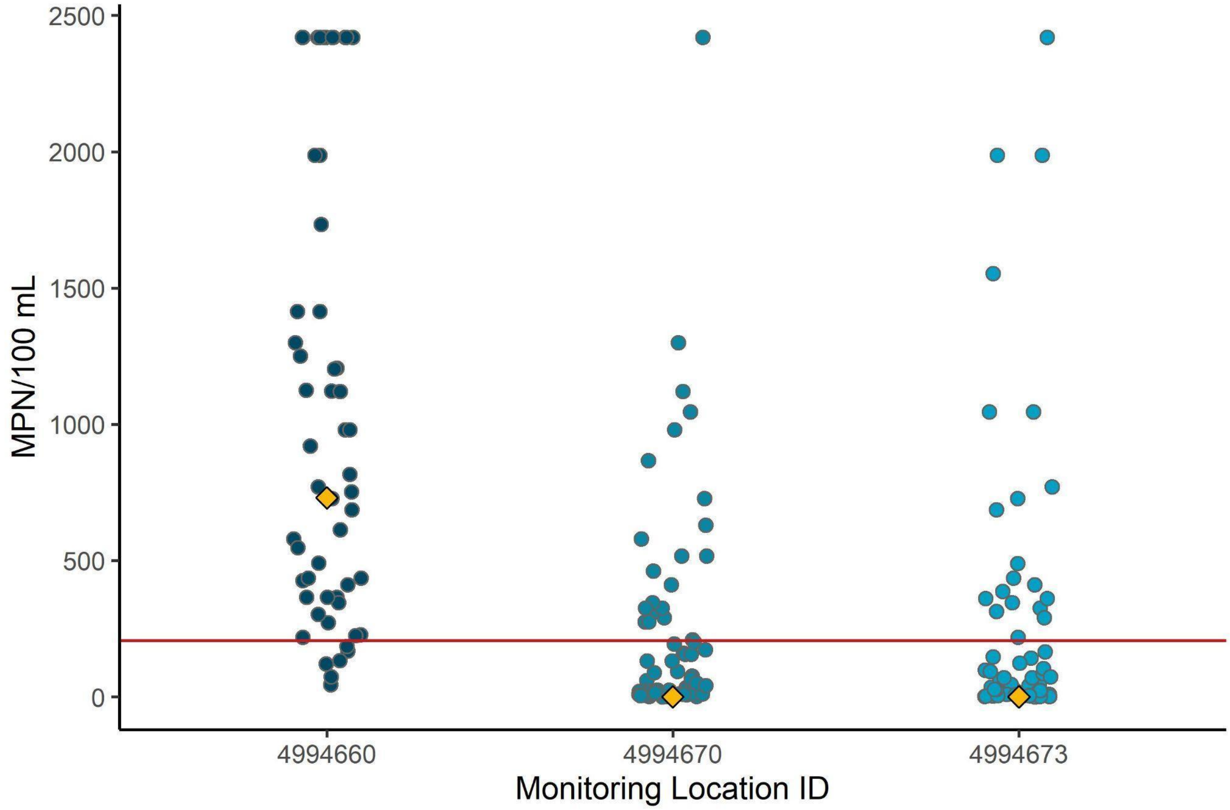

Figure H-3. *E. coli* concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in the Rose Creek Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

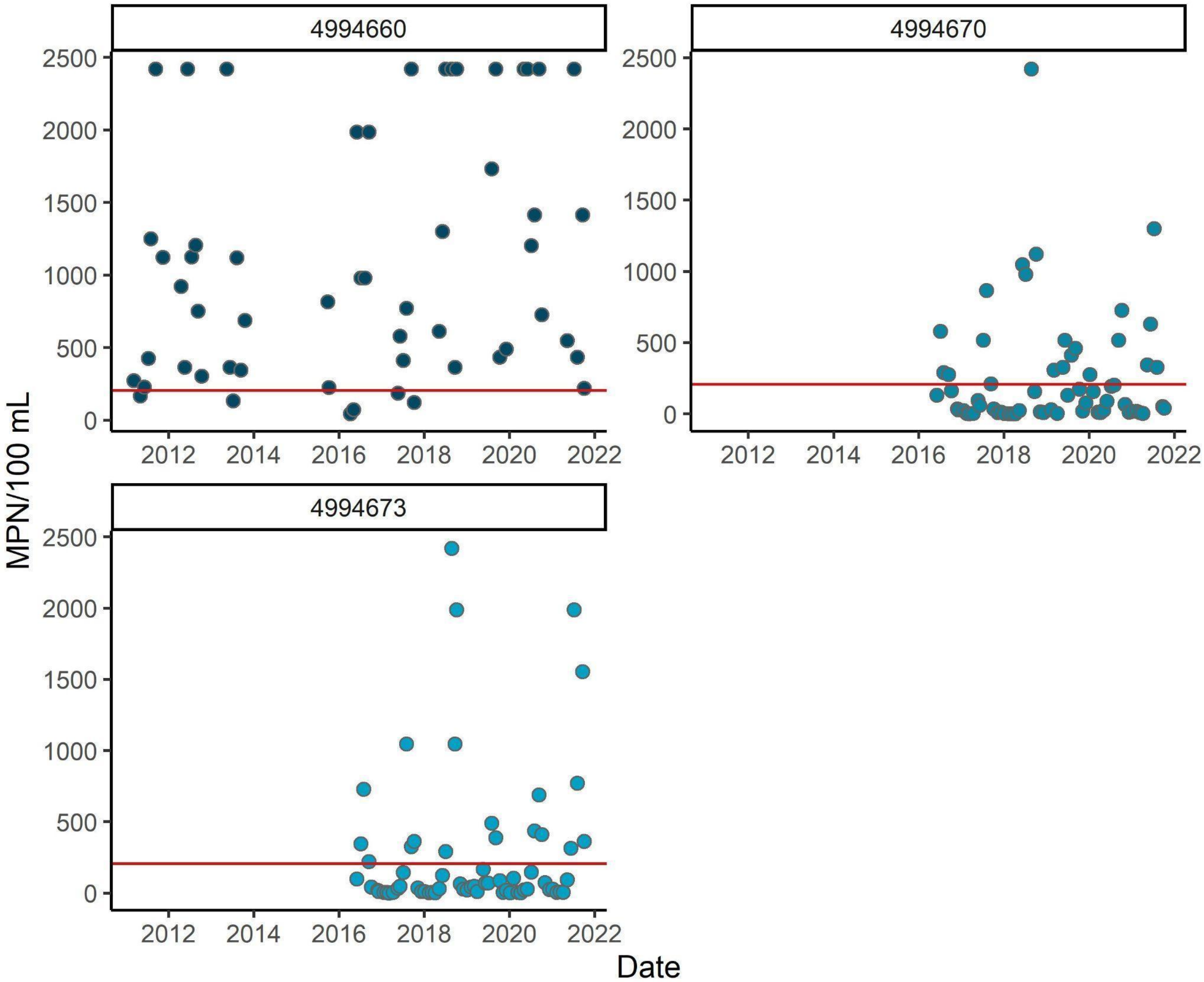

Figure H-4. *E. coli* concentrations at each routine monitoring location through time within the Rose Creek Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

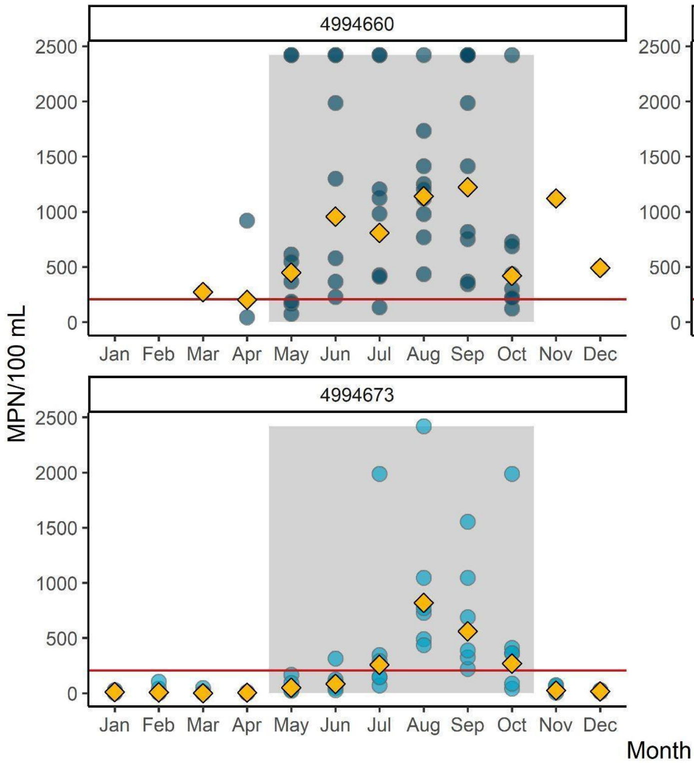

Figure H-5. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downtreat (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDCs), data analysis, land-use patterns, and hydrologic information. Microbial source tracking was not conducted in this AU. Potential sources and recommended implementation strategies to address them are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curve

Load duration curves are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships

between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at the lower end of this AU, Rose Creek at Jordan River, Gauge #101. This site corresponds to an *E. coli* monitoring station, Rose Creek above confluence with Jordan River at Stream Gauge (4994660) (Figure H-1). Flow data during the TMDL period of record (June 2016–September 2021) are summarized in Table H-3, Figure H-6, and Figure H-7. The daily mean flows are slightly higher during the winter months of January and February. Monthly mean flows are between 1–4 cfs (Figure H-7). Rose Creek is often dewatered during the irrigation season (SLCo 2017). Rose Creek has consistent flows and no true peak in spring due to snowmelt.

Table H-3. Summary statistics for Rose Creek at Jordan River, Gauge #101 (4994660).

Gauge Name	SLCO Gauge Number/DWQ MLID	Drainage Area (mi^2)	Mean Flow (cfs)	Max Flow (cfs)
Rose Creek at Jordan River	101/4994660	13.9	0.72	50

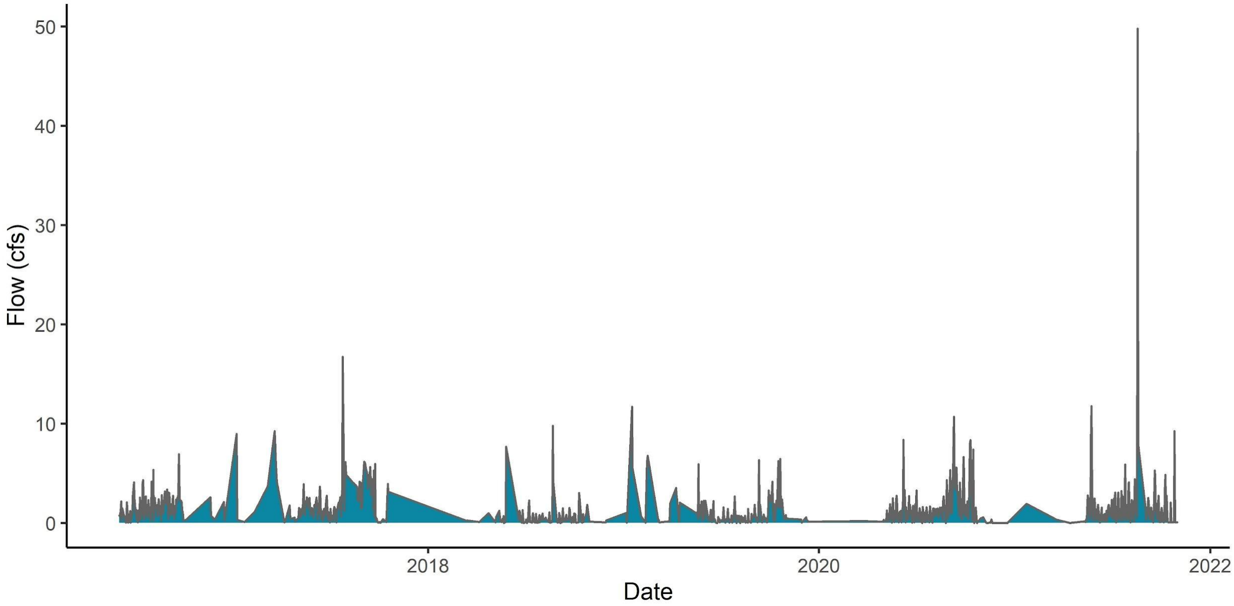

Figure H-6. Daily means flows at Salt Lake County Gauge #101, Rose Creek at the Jordan River (4994660) from June 4, 2016, to September 30, 2021.

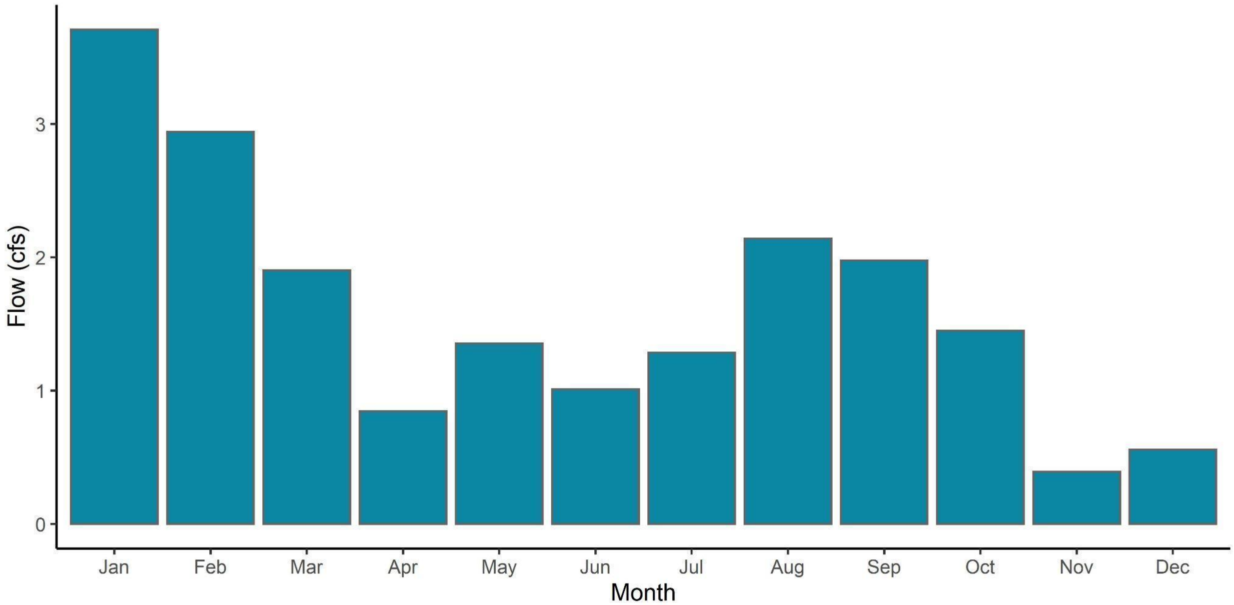

Figure H-7. Monthly means flows (cfs) at Salt Lake County Gauge #101, Rose Creek at the Jordan River (4994660) from June 4, 2016, to September 30, 2021.

Using this site's corresponding *E. coli* and flow data, the LDC shows exceedances occurring at all flow regimes (Figure H-8). Exceedances of the TMDL threshold (solid line) in high to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. These sources include point sources (low-flow conditions), onsite septic systems (dry flows), and riparian areas and impervious stormwater sources (mid-range). Upland stormwater and bank erosion are likely sources during the higher flow conditions. The percent of *E. coli* loading measurements exceeding the TMDL in each flow regime is provided in parentheses under each flow-regime label in Figure H-8. Large reductions needed in all flow regimes indicate that the Rose Creek AU is dominated by both point and nonpoint source delivery methods of *E. coli* loading.

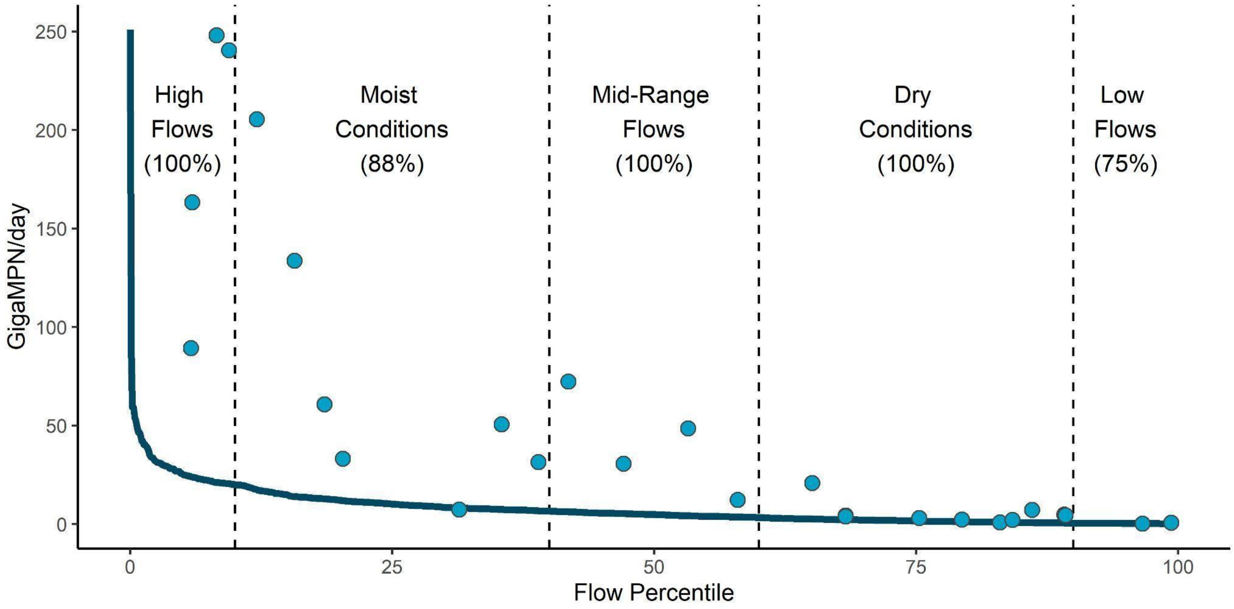

Figure H-8. Load duration curve for Rose Creek at the Jordan River (4994660).

Source Assessment

The probable sources of *E. coli* in the Rose Creek AU come from point sources, most notably stormwater runoff, based on the LDC analysis, data analysis, land-use patterns, and hydrologic information. Nonpoint sources include onsite septic systems, avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused.

Table H-4 provides a list of specific potential point and nonpoint sources in the Rose Creek AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. For more information on each potential source, please see Chapter 5.1 and 5.2.

Table H-4. Potential sources of *E. coli* contamination in Rose Creek Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	BMP Guidance
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	No			
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities including Herriman, Bluffdale, Riverton, Salt Lake County	UTS000001		
		Utah Department of Transportation	UTS000003		
Nonpoint source	Onsite septic systems	Yes		Section 5.2.1	Table 8
	Agricultural: livestock	Yes		Section 5.2.2	
	Agricultural: canals	Yes			
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	
	Recreationists/ unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

There are no Utah Pollutant Discharge Elimination System (UPDES) discharges within Rose Creek Assessment Unit besides municipal stormwater, which could be a source of *E. coli* contamination in this AU (Figure H-9). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the LDC that pointed to point sources during low flow regimes, urbanized land uses and increased impervious surfaces in the valley, as well as the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see Chapter 5 in the main report for more information.

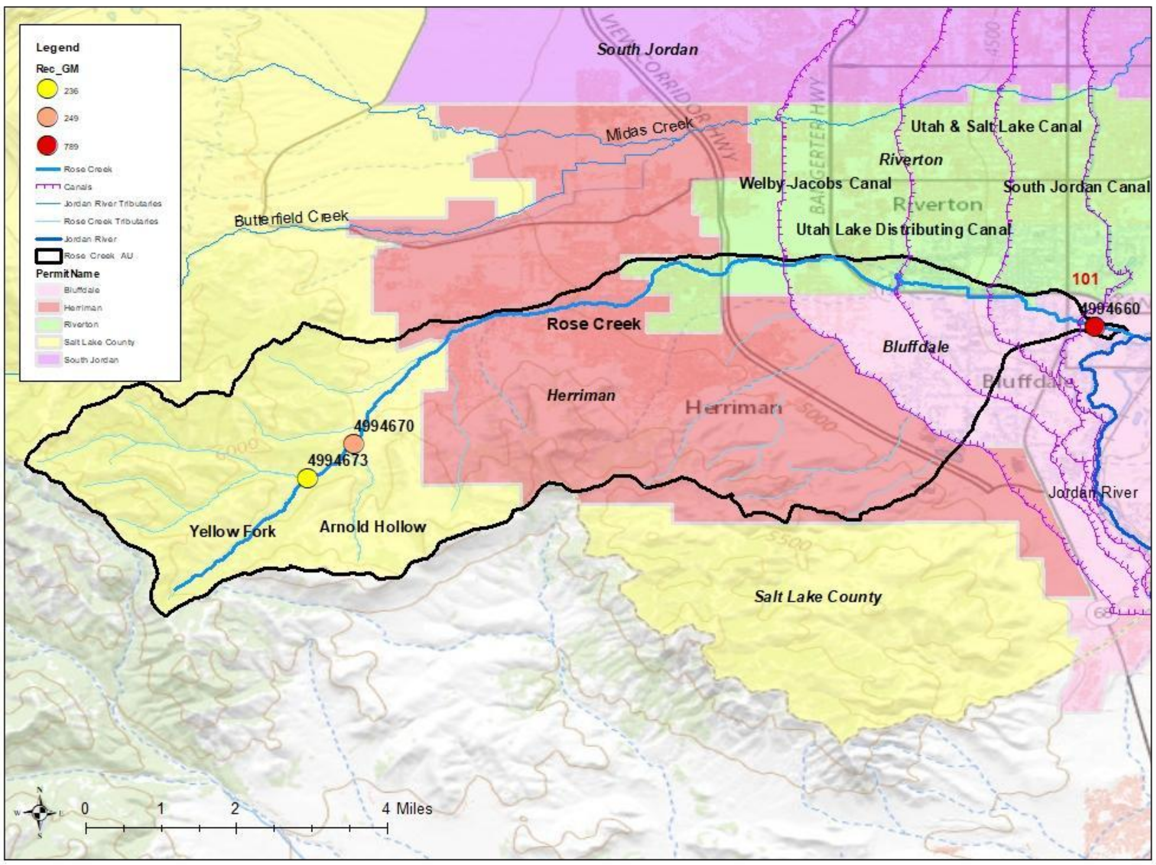

Figure H-9. Possible point sources of *E. coli* contamination within Rose Creek Assessment Unit.

Stormwater

Two potential sources of stormwater pollution (construction activities and MS4s) occur within the Rose Creek AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were 118 construction UPDES stormwater permits in the Rose Creek AU. Although construction stormwater permits are scattered throughout the lower two-thirds of the AU, these permits are short-lived and change over time. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Rose Creek AU by issuing MS4 permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of Rose Creek. The two MS4 permits applicable to this AU include Jordan Valley Municipalities and Utah Department of Transportation (Figure H-9). The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. Salt Lake County and the cities of Herriman, Bluffdale, and Riverton have jurisdictional boundaries within the AU. The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the state. UDOT's Region 2 geographical area covers the Wasatch Front.

LDC analysis suggests that since exceedances exist in the mid-range and higher flow regimes, impervious stormwater and upland stormwater are likely sources of *E. coli* contamination. This westside tributary is predicted to experience one of the most rapid transitions from natural to urban land cover by 2040 given current development pressure. Stormwater management will be critical to avoid further degradation of water quality in Rose Creek.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Rose Creek AU include agricultural activity, humans, wildlife, and dogs (Table H-4, Figure H-10). Please see Chapter 5.2 in the main report for more information on nonpoint sources of pollution.

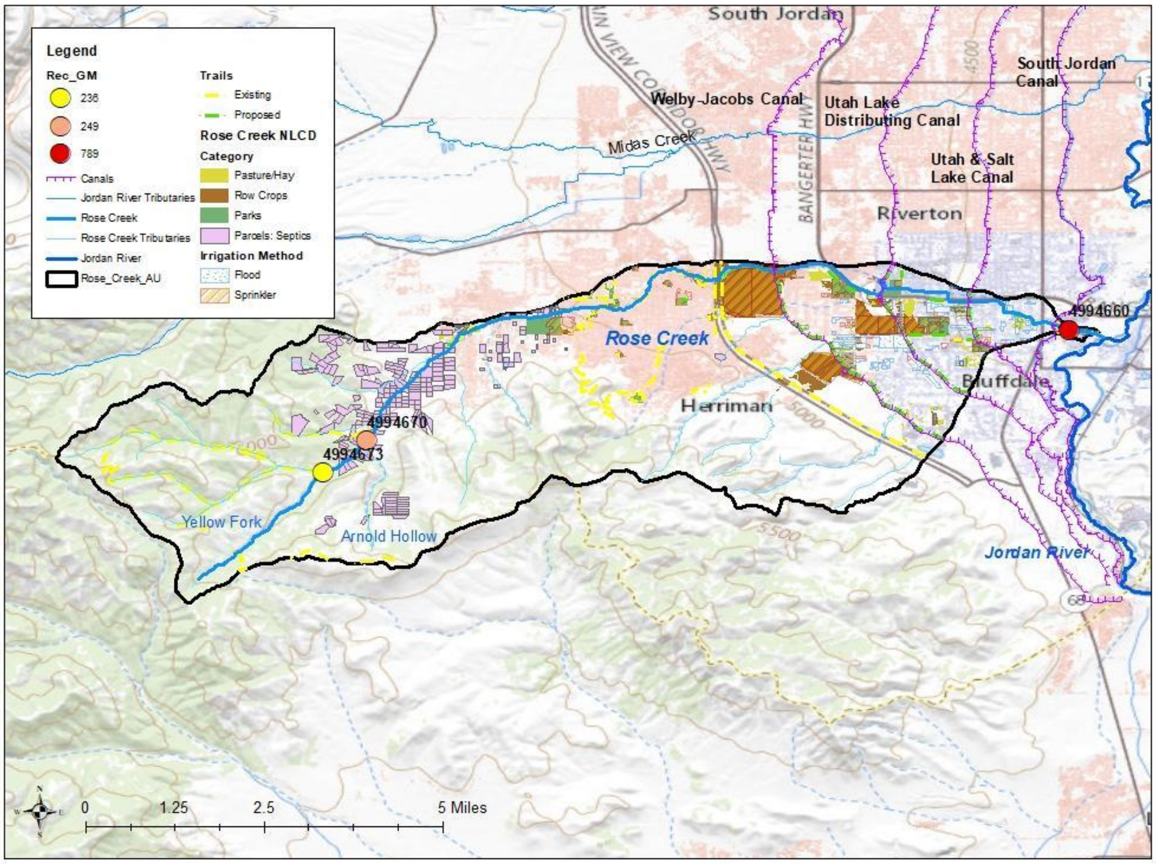

Figure H-10. Possible nonpoint sources of *E. coli* contamination within Rose Creek Assessment Unit.

Onsite Septic Systems

According to the Salt Lake County's Assessor's Office, there are 260 onsite septic system parcels within this AU as of 2021, predominantly in the reaches above Mountain View Corridor Highway (Figure H-10). Most parcels associated with the urbanized portion of this AU are sewered. There are no large underground wastewater disposal systems in this area. *E. coli* loading from failing onsite septic systems is a plausible source because *E. coli* concentrations exceed the standard 34% of the time during the recreational season at the Rose Creek at Arnold Hollow Road Xing (4994670) site, which is downstream of some of these septic parcels (Table H-2). *E. coli* concentrations at this site peak during the warmer months when flows are at baseline condition and there is less dilution (Figure H-5). Since *E. coli* concentration increases downstream, additional sources exist between Arnold Hollow (4994670) and the above Jordan River (4994660) sites. The highest onsite septic system density is between these two sites, thus possibly contributing to the increase in concentration (Figure H-10).

Salt Lake County Health Department has responded to reports of failing onsite septic systems in the past in this subwatershed. Please see Chapter 5.2.1 in the main report for more information on onsite septic systems and Chapter 7 on suggested BMPs.

Agricultural Activities

Agricultural activity makes up 4% of the total land cover within the Rose Creek AU (Figure H-2). Agricultural activities include crops, pasture, livestock, and irrigation. There are no permitted concentrated animal feeding operations (CAFOs) within this AU. Crops comprise a majority of the cultivated land use and are generally located in the lower third of the AU, close to the three canal crossings (Figure H-10). Pasture lands are in the same general location as the croplands. Thirteen miles of Rose Creek, and canals with the potential to discharge to Rose Creek, are within 100 feet of irrigated lands. Approximately one-third (32%) of the irrigated acres are flood-irrigated.

E. coli may enter Rose Creek and the canals discharging into Rose Creek from lands where livestock have direct access to surface waters. There may also be instances where livestock grazing occurs on flood-irrigated pastures with return flows that enter surface waters. Landowners are not required to report the number of animals on their property, so an exact livestock count for this AU is unknown. County statistics on livestock numbers are not comparable for this AU since most of Salt Lake County is developed. Proper grazing and irrigation management should be implemented to limit runoff from these fields.

Rose Creek intersects four major canals (Figure H-2). These canals could import water with elevated *E. coli* concentrations from outside the AU and deposit it into the creek during storm events or runoff from the surrounding earthen canals. These canals are utilized more for stormwater conveyance than irrigation delivery due to development pressure and the rate of land conversion from cultivated or natural to developed. Riverton City's Stormwater Management Plan states these canals are not suitable for stormwater conveyance since the "canal capacities decrease from upstream to downstream, while runoff flow rates increase from upstream to downstream." The plan also states that water quality, debris, and sediment are ongoing problems when these canals are used for stormwater conveyance. Table 8 in the main report lists suggested BMPs to address *E. coli* contamination from agricultural activity.

Recreation, Pets, and Nuisance Wildlife

Recreational use is high within the Rose Creek AU, both in the Oquirrh Mountains and in the 22 parks in the valley. An exhaustive network of trails exists within this AU (Figure H-10). Salt Lake County recently began development of a recreational master plan for the Rose Creek area that will increase recreational opportunities. It is likely that a small percentage of those who recreate do not properly dispose of human waste. While it is a challenge to quantify this behavior, improper disposal of human waste does not appear to be a problem throughout the AU based on field observations. People recreating in the assessment unit are considered an unlikely source of significant *E. coli* contamination to the creek for the purposes of this TMDL. However, proper management of human waste should be encouraged at all parks and trailheads through signage and placement of restroom facilities where feasible.

Improper management of domestic pet waste is another potential source of *E. coli* contamination in waterbodies. Dog waste in the immediate vicinity of a waterway can contribute to local water quality impairment. While there are no designated off-leash dog parks currently within the Rose Creek AU boundary, Wardle Fields Regional Park has been selected as a future site. Off-leash dog park site selection should avoid any access to water to prevent contamination. Dog waste management campaigns should be employed to ensure proper pet-waste management.

Wildlife are also a potential source of *E. coli* loading in this AU. Transport of animal waste to surface waters is dependent on animal habitat and proximity to these waters. Waterfowl and wildlife often deposit waste directly into streams, while other wildlife deposit waste in the floodplain where it can be transported to surface waters by runoff during precipitation events. Animal waste deposited in upland areas can also be transported to waterways.

Since almost 76% of the land in Rose Creek AU is considered natural, it is likely that a large number of warm-blooded animals are within close proximity to the creek, especially in the upper portion of the AU near the mountains. These animals have the potential to be a source of *E. coli* pollution; however, wildlife are considered a natural or background source, so no further implementation is needed.

Nuisance wildlife species, however, should be considered as a potential source of *E. co*li in this AU. Common nuisance species include, but are not limited to, deer, waterfowl and small mammals such as beaver and muskrats. MS4 permits must address nuisance wildlife species due to certain stormwater control structures (basins and ponds) that can attract nuisance wildlife and subsequently degrade water quality. These areas include parks, golf courses, and detention basins. Preventing waterfowl from congregating and limiting public feeding opportunities will reduce avian-based contamination.

Please see Table 8 in the main report for suggested BMPs to employ to manage these particular nonpoint sources of *E. coli* contamination.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Rose Creek AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Appendix I. Jordan River-2, Jordan River-3, Jordan River-4 and Jordan River-5 Assessment Units *E. coli* TMDLs

Waterbody Name	Jordan River-2	Jordan River-3	Jordan River-4	Jordan River-5
Waterbody / Assessment Unit	UT16020204-002	UT16020204-003	UT16020204-004	UT16020204-005
AU Description	Jordan River from Davis County line upstream to North Temple Street	Jordan River from North Temple to 2100 South	Jordan River from 2100 South to the confluence with Little Cottonwood Creek	Jordan River from the confluence with Little Cottonwood Creek to 7800 South
Impaired Beneficial Uses	Infrequent primary contact recreation (2B)	Infrequent primary contact recreation (2B)	Infrequent primary contact recreation (2B)	Infrequent primary contact recreation (2B)
Applicable Season	May through October	May through October	May through October	May through October
Defined Endpoint/Water Quality Standard	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL	30-day geometric mean of 206 MPN/100 mL Recreation season geomean of 206 MPN/100 mL Daily maximum of 668 MPN/100 mL
Percent Reduction Needed	69%, based on a geometric mean of 672 MPN/100 mL calculated for 4991900 (Jordan River at 300 North) in the month of July.	76%, based on a geometric mean of 863 MPN/100 mL calculated for 4992320 (Jordan River at 1100 West and 2100 South) in the month of July.	75%, based on a geometric mean of 816 MPN/100 mL calculated for 4992880 (Jordan River at 3300 South Xing) in the month of August.	73%, based on a geometric mean of 765 MPN/100 mL calculated for 4994100 (Jordan River at 6400 South Xing) in the month of August.

Probable Sources	Stormwater, canals, avian wildlife, domestic pets, wildlife/nuisance species, and recreationists/ unhoused	Stormwater, canals, avian wildlife, domestic pets, wildlife/nuisance species, and recreationists/ unhoused	Stormwater, canals, avian wildlife, domestic pets, wildlife/nuisance species, and recreationists/ unhoused	Stormwater, canals, avian wildlife, domestic pets, wildlife/nuisance species, and recreationists/ unhoused

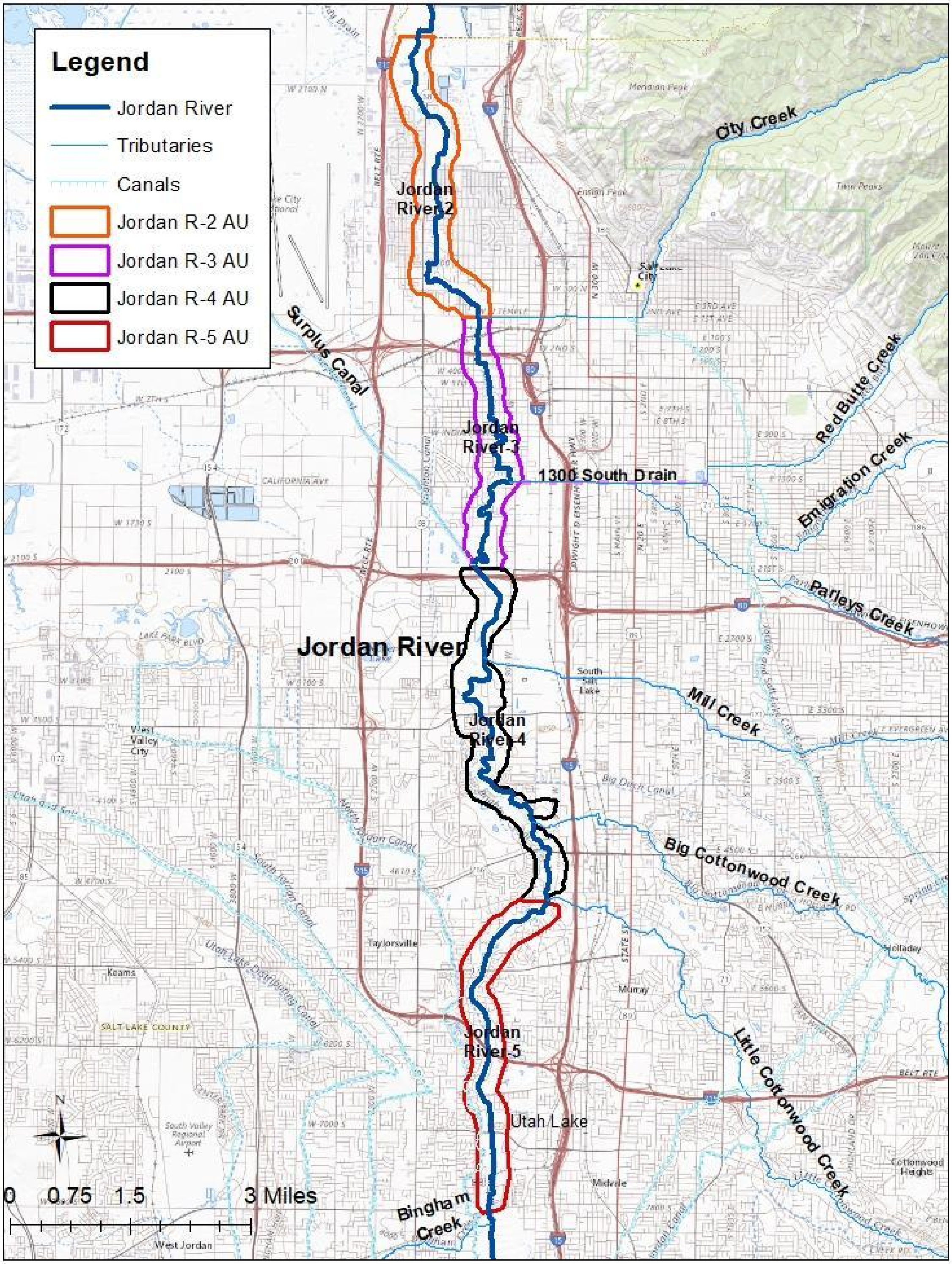

Figure I-1. Location of impaired assessment units along the main stem of the Jordan River.

Jordan River-5 Assessment Unit

Assessment Unit Description

The Jordan River-5 Assessment Unit includes the Jordan River from the intersection with 7800 South downstream approximately 4.6 miles to the confluence with Little Cottonwood Creek. The Jordan River-5 AU (1.8 mi^2) is within the cities of Taylorsville, Murray, West Jordan, and Midvale, and is solely in Salt Lake County. The land ownership is 100% privately owned. The Jordan River-5 AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) designated beneficial use due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2006 Integrated Report.

Table I-1. Impairment summary of the Jordan River-5 Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
Jordan River-5 UT16020204-005	*E. coli*	Infrequent primary contact recreation (2B)	2006–2022
	Total dissolved solids*	Agriculture	2006–2022
*Will be addressed in a future TMDL			

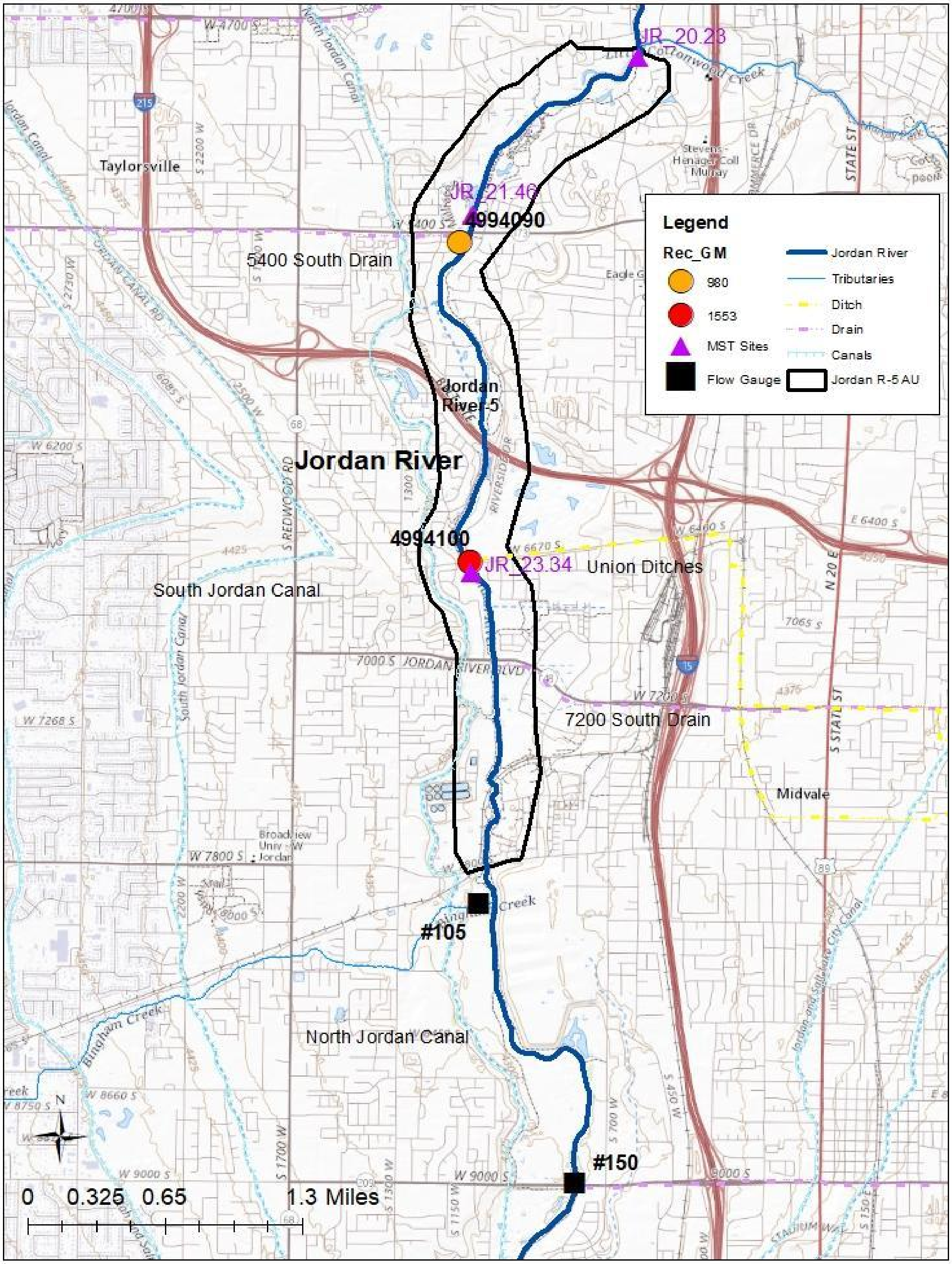

Figure I-2. Hydrology and monitoring locations within Jordan River-5 Assessment Unit.

Hydrology

The Jordan River is approximately 51 miles long, originating at Utah Lake and flowing north where it terminates in wetlands that eventually discharge to the Great Salt Lake. It is highly managed due to the regulation of discharge from Utah Lake, tributary flows, irrigation diversions, stormwater contributions, and flood control. The topography within the Jordan River watershed contributes to a very complex precipitation pattern with great variability in amounts and timing of flows. Although Utah Lake is the single largest source of flows to the Jordan River, much of this water is diverted at the Jordan River Narrows for agricultural and municipal use via canals serving both the east and west sides of the valley. The releases and diversions occur primarily during the irrigation season (April 15–October 15). Flows from the Jordan River's seven major eastside and three minor westside tributaries are also subject to a complex network of diversions, return flows from canals, stormwater discharge, and exchange agreements between culinary and agricultural users. More information on the complex hydrology of the Jordan River can be found in the Lower Jordan River Dissolved Oxygen TMDL and Salt Lake County's Watershed Plans (2009 and 2015).

The hydrology of the Jordan River has been impacted by several hydrologic modifications. Though the main channel is fully open (not piped), 13% of the stream channel has been engineered (SLCo 2009). Figure I-2 shows the inputs and outputs of the Jordan River system within the Jordan River-5 AU boundary. The mean daily flow at Salt Lake County Gauge #150 (Jordan River at 9000 South), is 162 cubic feet per second (cfs) during the TMDL period of record (2016–2021), with a maximum daily mean of 1,700 cfs (Table I-3).

The upstream boundary of this AU is approximately 900 feet downstream of the confluence of Bingham Creek, which is not impaired for *E. coli*. (Note that this AU is also downstream of two impaired tributaries: Midas and Rose Creeks.) There are no direct perennial stream inputs into this section of the Jordan River.

Existing inputs include both storm drains and ditches. There are two eastside inputs into the Jordan River-5 AU: 7200 South drain and Union ditches. The 7200 South drain collects water from the surrounding urbanized areas and canals, such as the East Jordan Canal, and transports it to the main stem of the Jordan River. The Union ditch system is a diverse irrigation system transporting water through the Little Cottonwood Creek and Jordan River-5 AU areas, then ultimately draining back into the main stem. The only westside input is from the 5400 South drain that diverts water from the surrounding urbanized areas and canals such as the Utah and Salt Lake Canal into the main stem.

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 85% of the land in the Jordan River-5 AU is developed (Figure I-3). Cultivated land cover (pasture and crops) is 5.7% of the AU, natural land cover (forest, grassland, wetlands, shrubland, and barren) is 8.5%, and open water is 0.28%. Most of the riparian buffers along the main stem of Jordan River-5 are characterized by developed/urban and cultivated land use. There are no major agricultural operations within this AU. However, open space within the AU is considered cultivated land. The urban land cover is primarily residential and industrial.

Approximately 34% of the AU is covered by impervious surfaces due to developed land use. This level of impervious surface leads to increased runoff, which results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase in the entire Jordan River corridor by 30% in 2040 (SLCo 2017), which will result in an increase in impervious surfaces in this AU. See Section 5.3.1 in the main report for more information on the effects of impervious surfaces on pollutant loading.

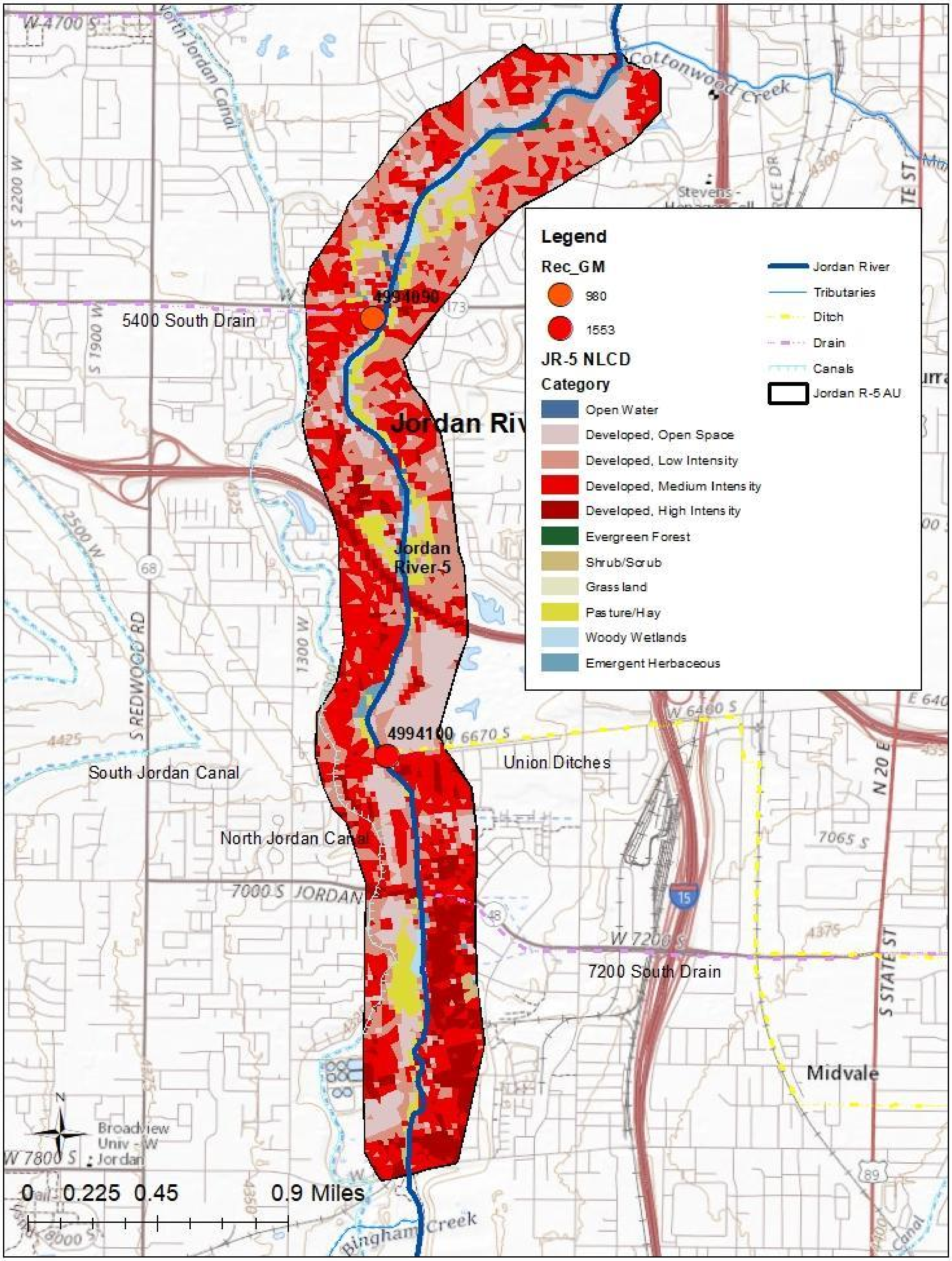

Figure I-3. Land cover in Jordan River-5 Assessment Unit (2019).

E. coli Data Summary

Two routine monitoring locations on Jordan River-5 were studied for spatial and temporal patterns of *E. coli* levels (Table I-2). Samples at the upstream site, Jordan River at 6400 South (4994100), were collected throughout the entire calendar year. Samples collected at the downstream site, Jordan River above 5400 South (4994090), were collected only during the recreation season. Despite a difference in sampling timing and frequency, both sites had similar overall geometric mean *E. coli* concentrations above 206 MPN/100 mL, and at least 70% of the samples collected at each site exceeded the standard (Figure I-4). Both sites showed consistent temporal patterns of *E. coli* over the sampling period (Figure I-5). Monthly geometric mean concentrations were above the standard June–September at both sites, peaking in July–August (Figure I-6). Monthly geometric mean *E. coli* concentrations at Jordan River at 6400 South (4994100) remained high October–January, indicating a constant winter source, though concentrations decreased below 206 MPN/100 mL February–May (Figure I-6).

Table I-2. Jordan River-5 Assessment Unit *E. coli* data summary all year.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4994090/ JR_21.46	Jordan River above 5400 South at Pedestrian Bridge	Insufficient data	05/2009 to 09/2018	23	18	305	305	980	70	7
4994100/ JR_23.34	Jordan River at 6400 South Xing	Not meeting criteria	05/2009 to 10/2021	91	23	324	376	1,553	74	15

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL

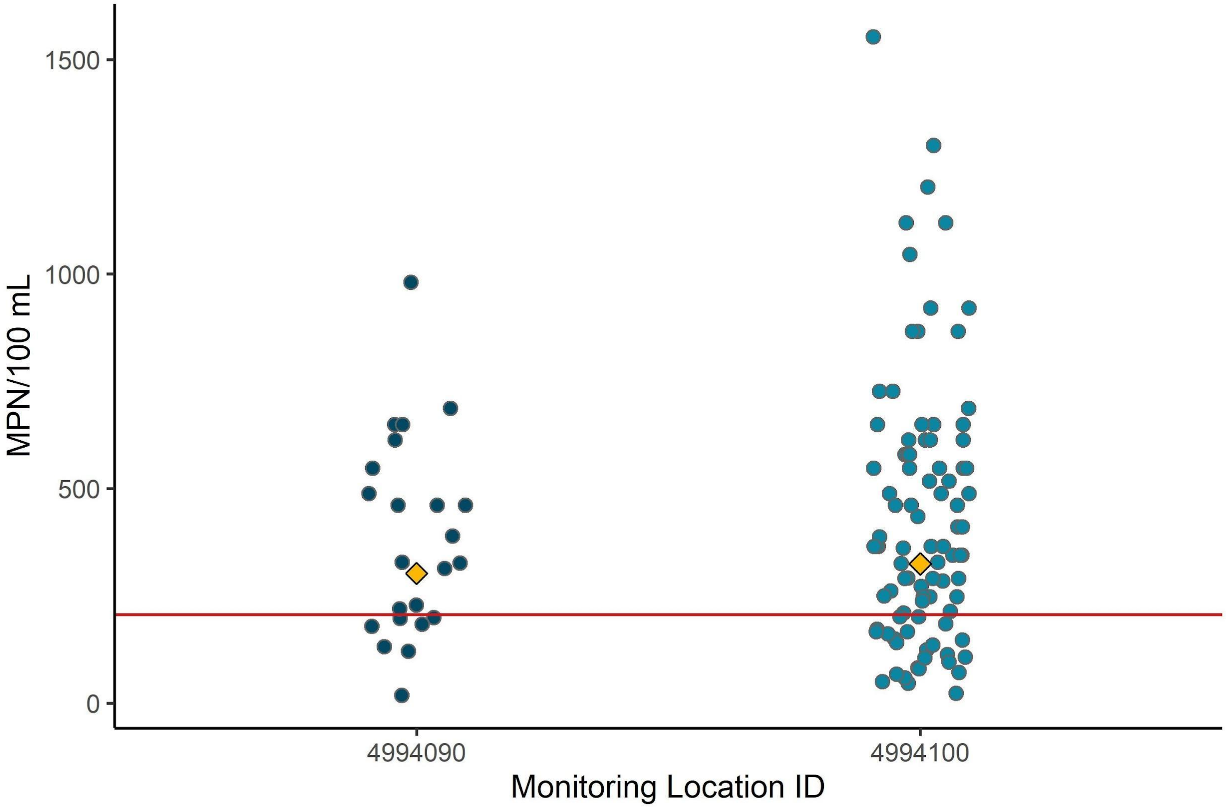

Figure I-4. ***E. coli*** **concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Jordan River-5 Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.**

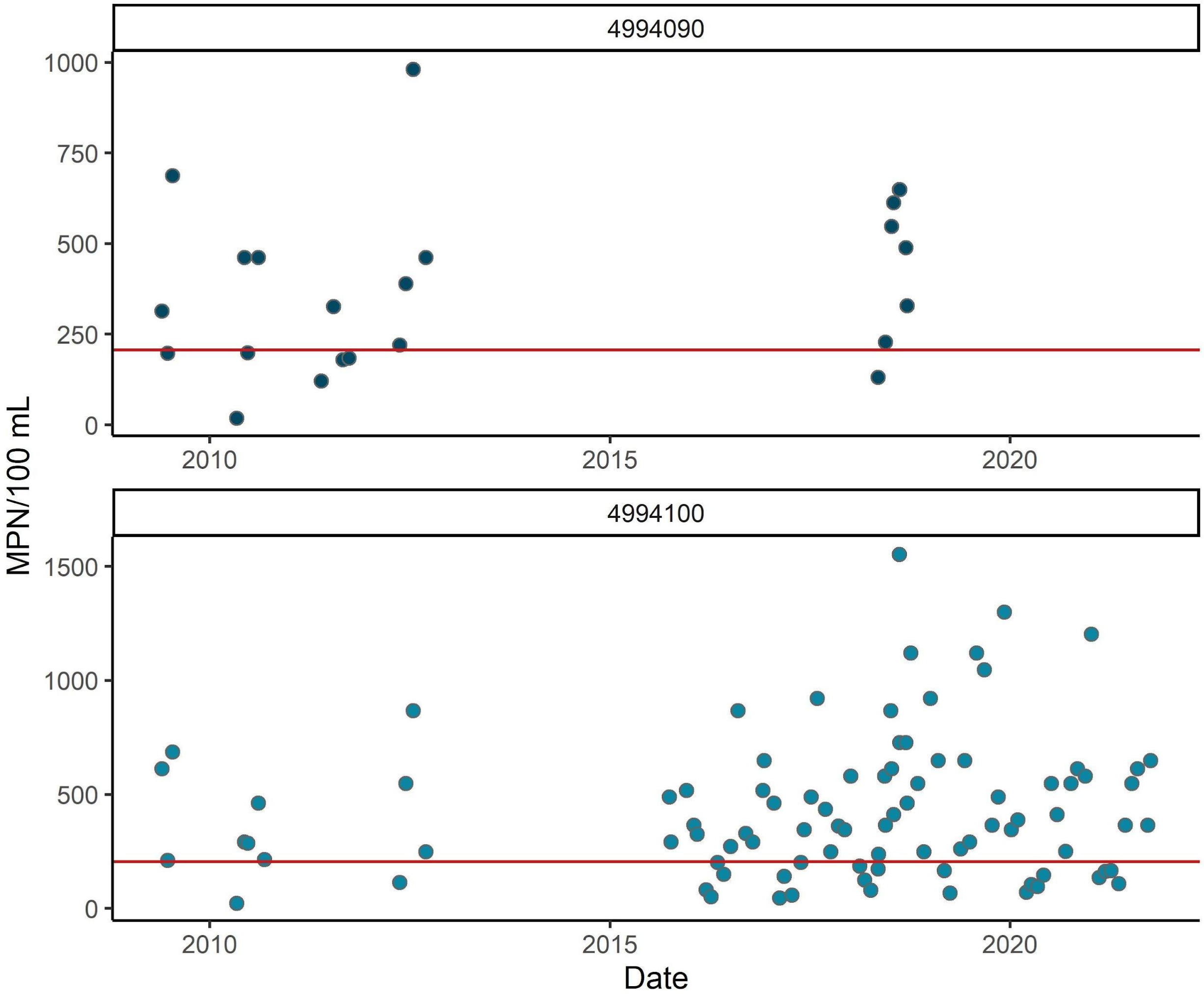

Figure I-5. *E. coli* concentrations at each routine monitoring location through time within the Jordan River-5 Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

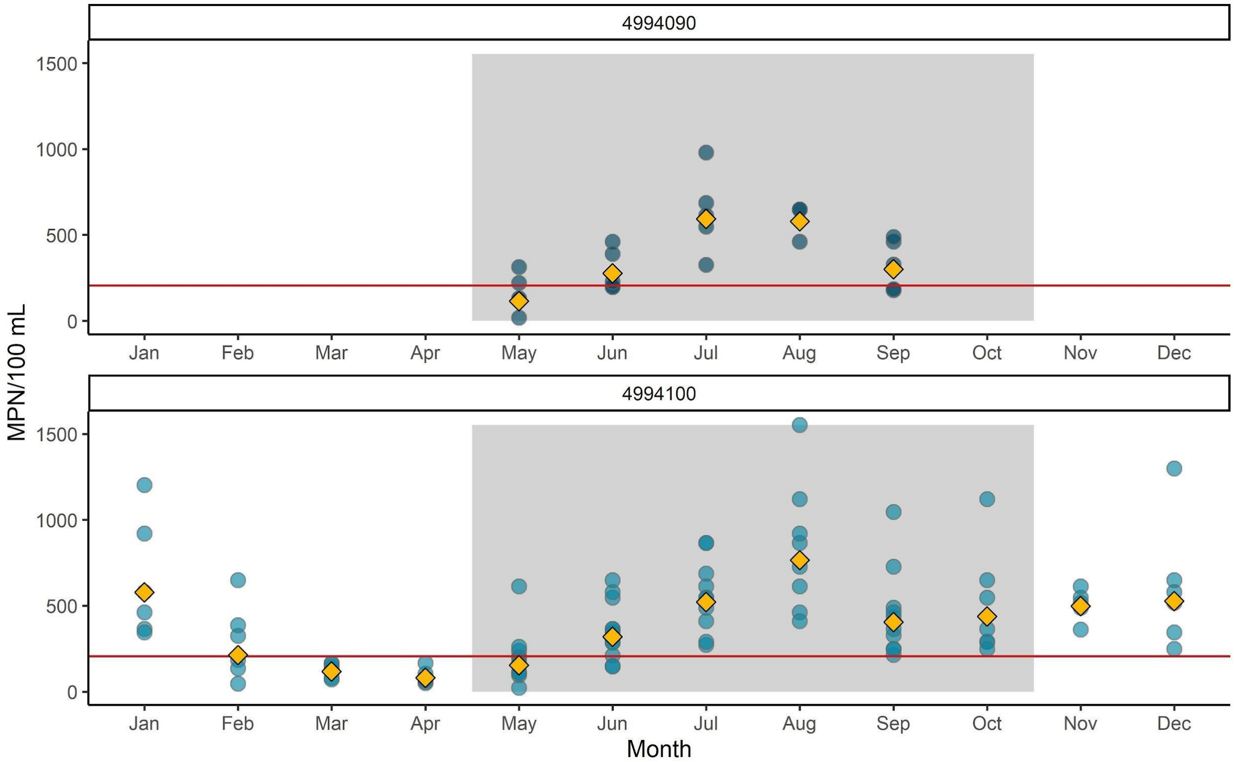

Figure I-6. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDC), microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. Potential sources and recommended implementation strategies to address the source are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curves

Load duration curves are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships

between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* concentrations and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at Jordan River at 9000 South, Gauge #150 (Figure I-2). This gauge location and the *E. coli* site Jordan River at 6400 South (4994100) were used for the LDC analysis for Jordan River-5 AU. Note that the gauge is located approximately three miles upstream of the *E. coli* monitoring site at 6400 South crossing (4994100). Bingham Creek enters the Jordan River between these two sites. Bingham Creek flows (Gauge #105) were subtracted from the Jordan River at 9000 South gauge for the flow analysis for this AU. This analysis is summarized below in Table I-3, Figure I-7 and Figure I-8. The daily mean flows are higher during February and June–July, which corresponds with the agreed-upon release schedule of water from Utah Lake. Flow decreases and stabilizes in the late summer primarily due to the managed water delivery systems.

Table I-3. Summary statistics for Jordan River at 90th South, Gauge #150.

Assessment Unit	Gauge Name	SLCO Gauge Number/DWQ MLID	Drainage Area (mi^2)	Mean Flow (cfs)	Maximum Flow (cfs)
Jordan River-5	Jordan River at 90th South	150/4994100 (three miles downstream of flow gauge)	3,160	162	1,700

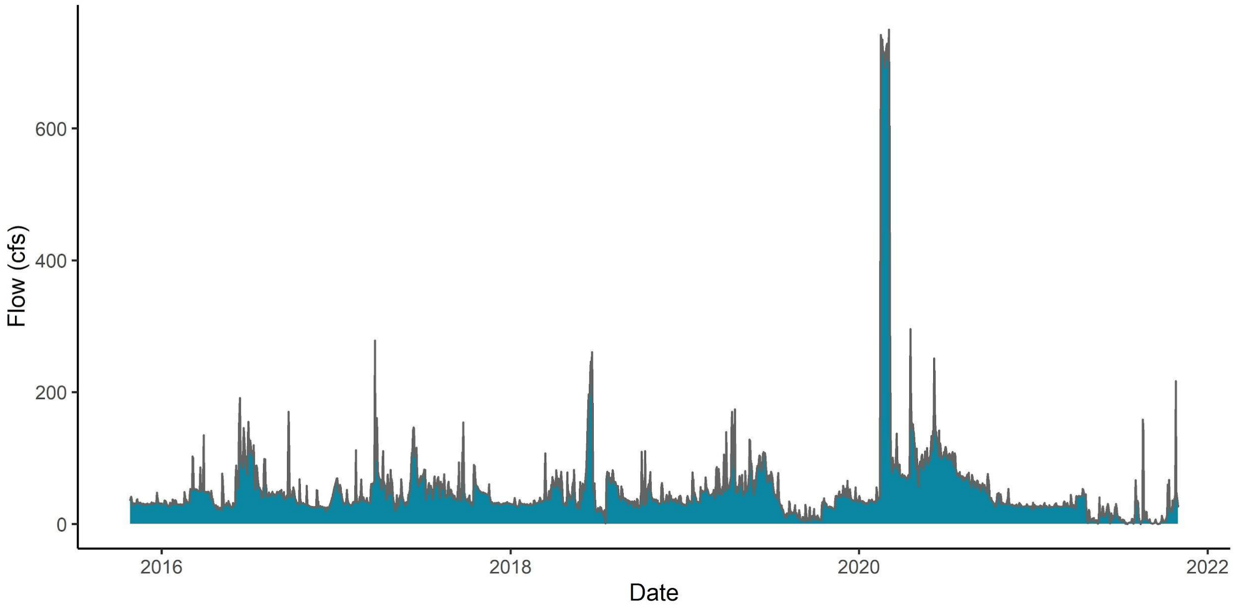

Figure I-7. Daily means flows at Salt Lake County Gauge #150, Jordan River at 90th South from October 1, 2015, through September 30, 2021.

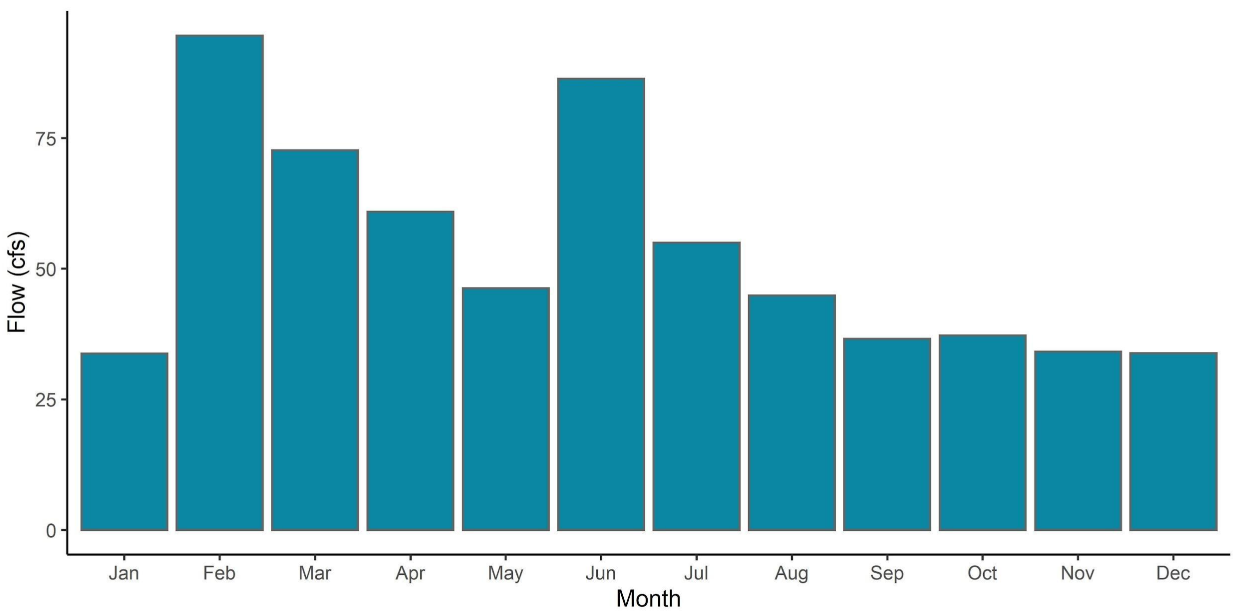

Figure I-8. Monthly means flows (cfs) at Salt Lake County Gauge #150, Jordan River at 9000 South, from October 1, 2015, through September 30, 2021.

Using the corresponding *E. coli* and flow data from Jordan River at 6400 South (4994100), the LDC shows exceedances occurring at all flow regimes (Figure I-9). Exceedances of the TMDL threshold (solid line) in high- to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. These sources include point sources (low-flow), onsite septic systems (dry conditions), and riparian areas and impervious stormwater sources (mid-range flows). Upland stormwater and bank erosion are likely sources for the high flow conditions. The percent of *E. coli* loading measurements exceeding the TMDL in each flow regime is provided in parentheses under each flow-regime label in Figure I-9. Though the high-flow regime requires the greatest reduction at 80%, exceedances in all flow regimes indicate that the Jordan River-5 AU is dominated by both point and nonpoint source delivery methods of *E. coli* loading.

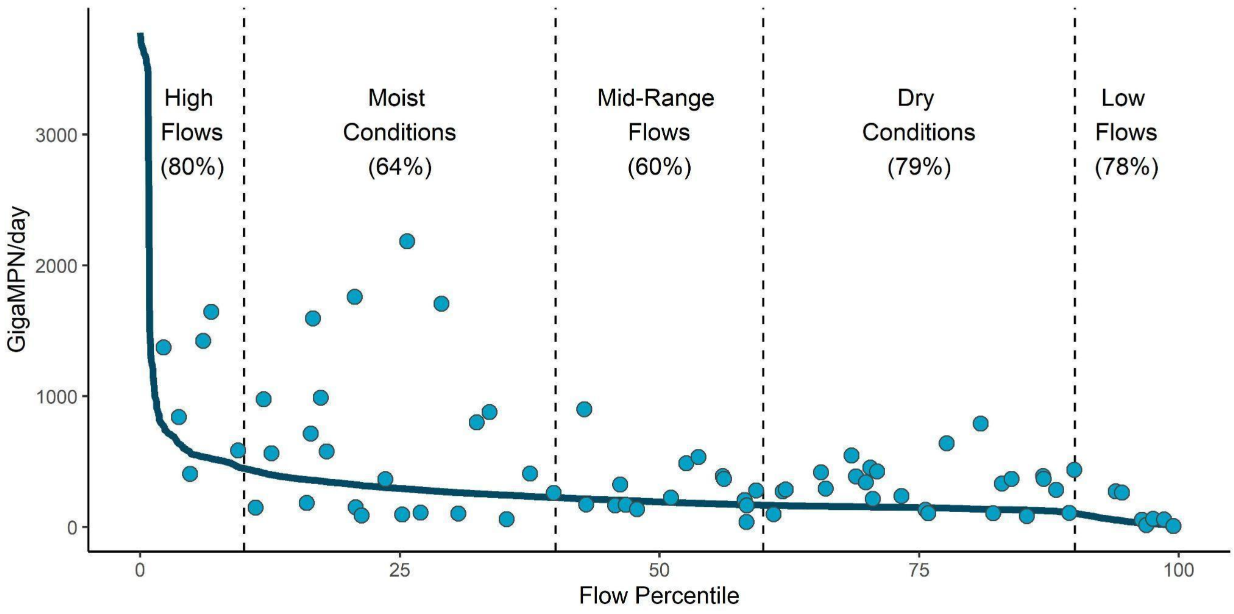

Figure I-9. Load duration curve for Jordan River at 6400 South (4994100).

Microbial Source Tracking

Samples were collected once a month at three locations during July, August, and September in 2018, resulting in three samples per site and a total of nine samples collected (Figure I-10). Three of the four markers (canine, avian, human, and ruminant) were detected in the AU. When the presence or absence of each marker was considered across all locations, human and avian were the most common at 100%, meaning of the nine samples collected, all of them were positive for the human and avian marker. The ruminant marker was present at 78%, and the canine marker was not detected at all. Figure I-10 illustrates the presence/absence pattern of the four markers at each sampling location in the AU. Most concerning is the consistent presence of the human marker from upstream to downstream, since human contamination poses the greatest risk to human health. Also of note is the pervasiveness of the avian marker throughout the reach. MST results for this AU highlight the need to focus on further identifying and controlling human and avian sources of fecal contamination through additional investigations of nuisance wildlife and unhoused populations in parks along the river.

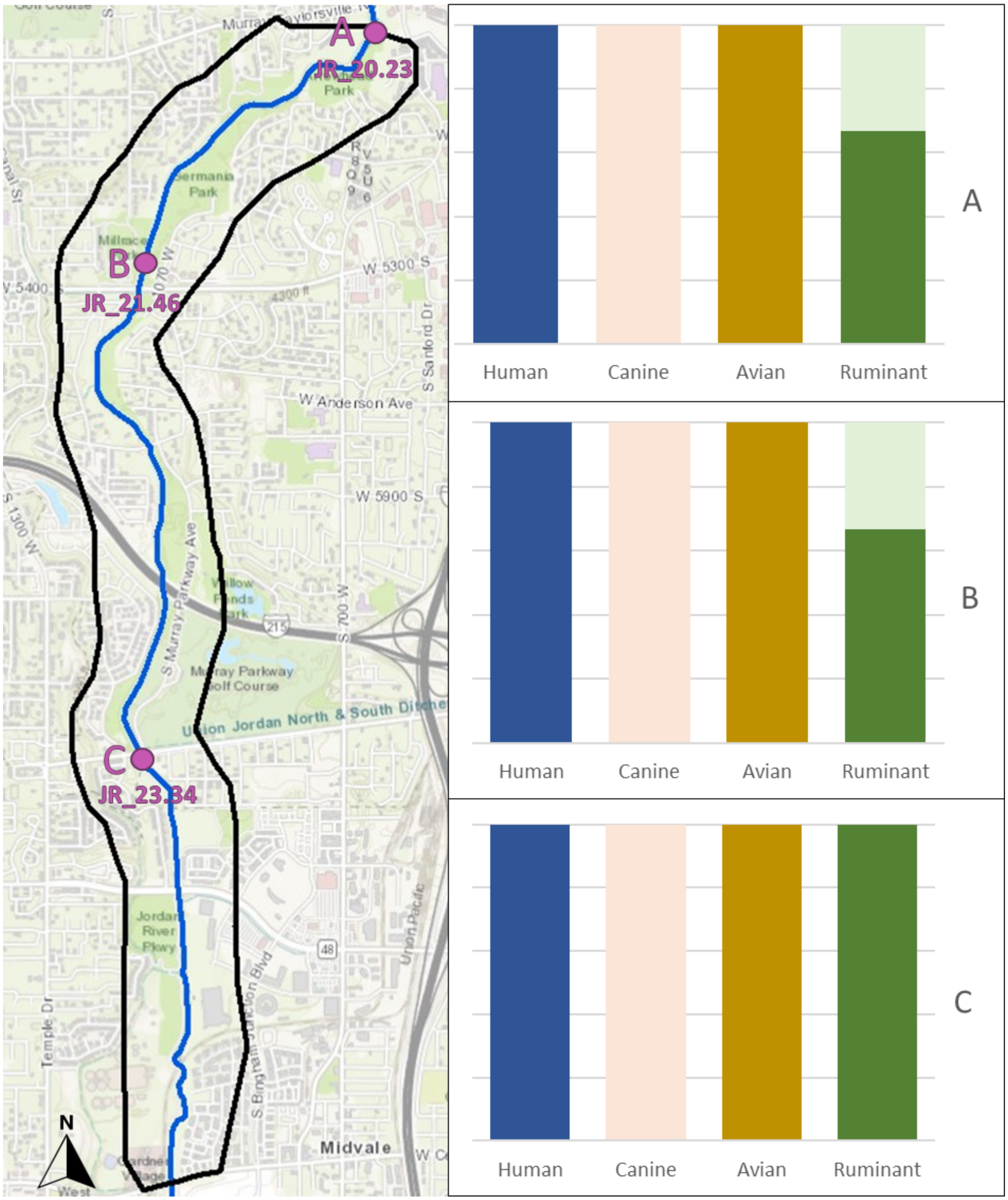

Figure I-10. The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades absence.

Source Assessment

Based on the data analysis, LDC analysis, land-use patterns, and hydrology, the probable sources of *E. coli* in the Jordan River-5 AU are point sources (including stormwater) as well as nonpoint sources including water (irrigation) conveyance systems, avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused. Jordan River-5 AU is the most upstream of the *E. coli*-impaired assessment units within the Jordan River watershed. It is probable that significant sources exist upstream in the main stem or tributaries, including Rose and Midas Creeks. Addressing these sources, as outlined in the previous appendices, will aid in the reduction of *E. coli* concentrations within the Jordan River-5 AU. The following source assessment focuses on potential sources specific to this AU. Upstream sources are addressed in their respective appendices.

Table I-4 provides a list of specific potential point and nonpoint sources in the Jordan River-5 AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. Please see Chapter 5.1 and 5.2 for more information on each potential source.

Table I-4. Potential sources of *E. coli* contamination in Jordan River-5 Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	Suggested BMPs
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	No			
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities, including Taylorsville, Murray, West Jordan, and Midvale,	UTS000001		

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	Suggested BMPs
		Utah Department of Transportation	UTS000003		
	Municipal	South Valley Water Reclamation Facility	UT0024384		
Nonpoint source	Onsite septic systems	No			Table 8
	Agricultural: livestock	No			
	Agricultural: canals	Yes		Section 5.2.2	
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	
	Recreationists /unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

While there are several Utah Pollutant Discharge Elimination System (UPDES) permitted discharges within the Jordan River-5 Assessment Unit, municipal stormwater is the most likely point source of *E. coli* in this AU (Figure I-11). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the LDC that pointed to point sources during low-flow regimes, urbanized land uses and increased impervious surfaces in the valley during the mid-range flows, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see Chapter 5.1 in the main report for more information.

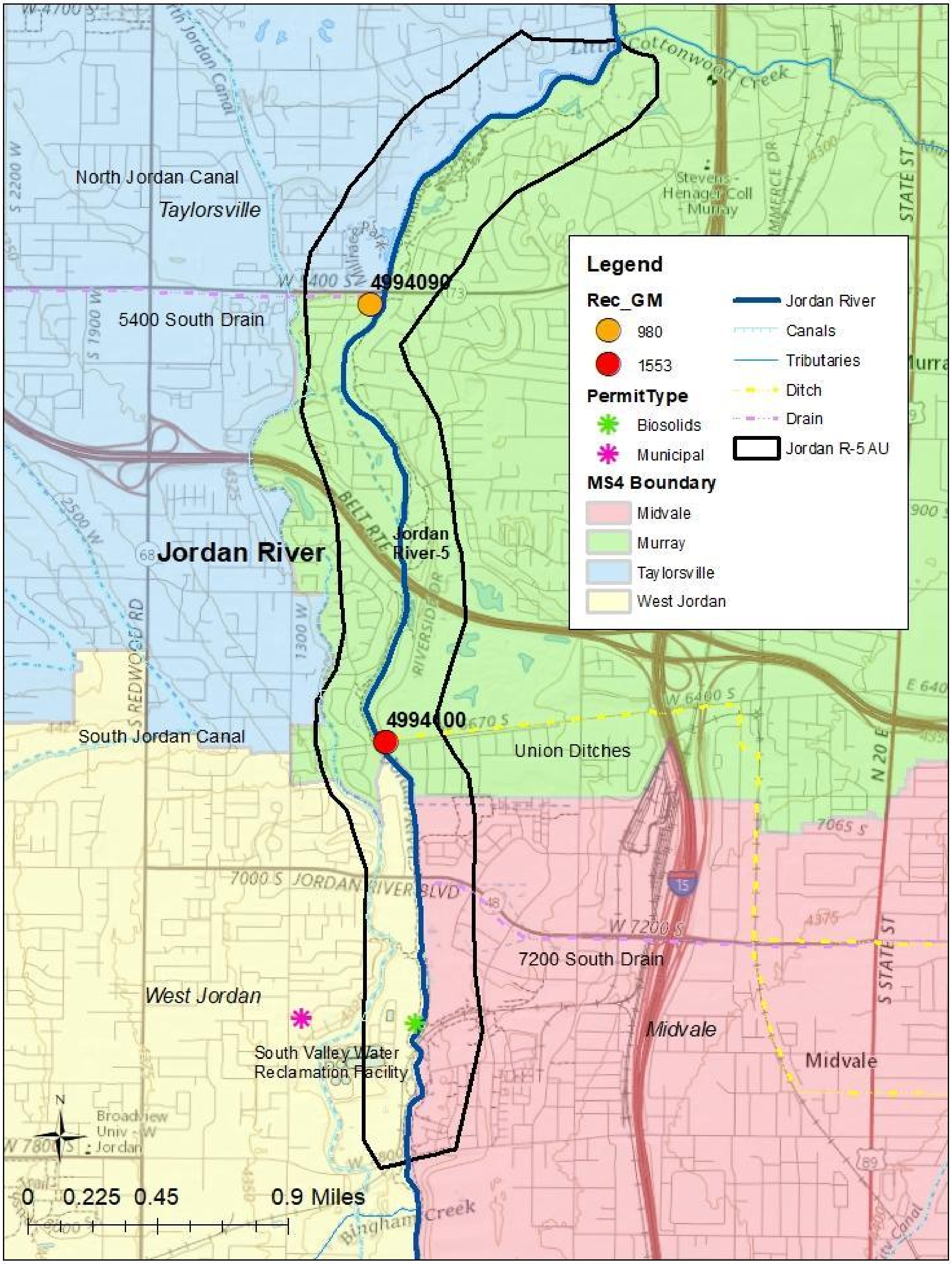

Figure I-11. Possible point sources of *E. coli* contamination within Jordan River-5 Assessment Unit.

Utah Pollutant Discharge Elimination System (UPDES)

The South Valley Water Reclamation Facility (SVWRF, UT0024384) is the only permitted facility with the potential to discharge *E. coli* into this assessment unit (Table I-4; Figure

I-11). SVWRF is a domestic wastewater treatment facility with a maximum design flow rate of 82.5 million gallons per day (mgd). The effluent is discharged directly into the Jordan River. Its biosolids treatment includes disposal to the landfill or sale for agricultural purposes. The facility employs several techniques to treat the wastewater, including ultraviolet disinfection with chlorine contact basins as back-up, so *E. coli* exceedances are extremely unlikely. SVWRF is required to conduct routine *E. coli* testing and report those values to DWQ. *E. coli* limits are included in the UPDES permit and are set at 126 MPN/100 mL as a monthly average and 157 MPN/100 mL as a weekly maximum average, both of which are below the *E. coli* TMDL target for the Jordan River. If this facility meets their existing limits for *E. coli,* then SVWRF will be meeting its TMDL endpoints for the Jordan River-5 AU.

Stormwater

Two potential sources of stormwater pollution (construction activities and MS4s) occur within the Jordan River-5 AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were two construction UPDES stormwater permits in this AU. There are no industrial stormwater permits. Construction permits are short-lived and change over time. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Jordan River-5 AU by issuing MS4s permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of the Jordan River. There are two MS4 permits— Jordan Valley Municipalities and Utah Department of Transportation—applicable to this AU (Figure I-11). The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. The cities of Murray, Midvale, West Jordan, and Taylorsville have jurisdictional boundaries within the AU. The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the state. UDOT's Region 2 geographical area covers the Wasatch Front.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Jordan River-5 AU include humans, wildlife, and dogs (Figure I-12). Agricultural activity (livestock and pasture) accounts for approximately 6% of the land use within this AU and falls primarily along the riparian corridor (Figure I-3). Cultivated land in the AU includes some local parks and open space. According to the Salt Lake County's Assessor's Office, there is one onsite septic system parcel within this AU as of 2021. Since most parcels are sewered and no large underground wastewater disposal systems lie within AU boundary, failing septic systems are not considered to be a source of *E. coli* pollution. Please see Chapter 5.2 in the main report for more information on nonpoint sources.

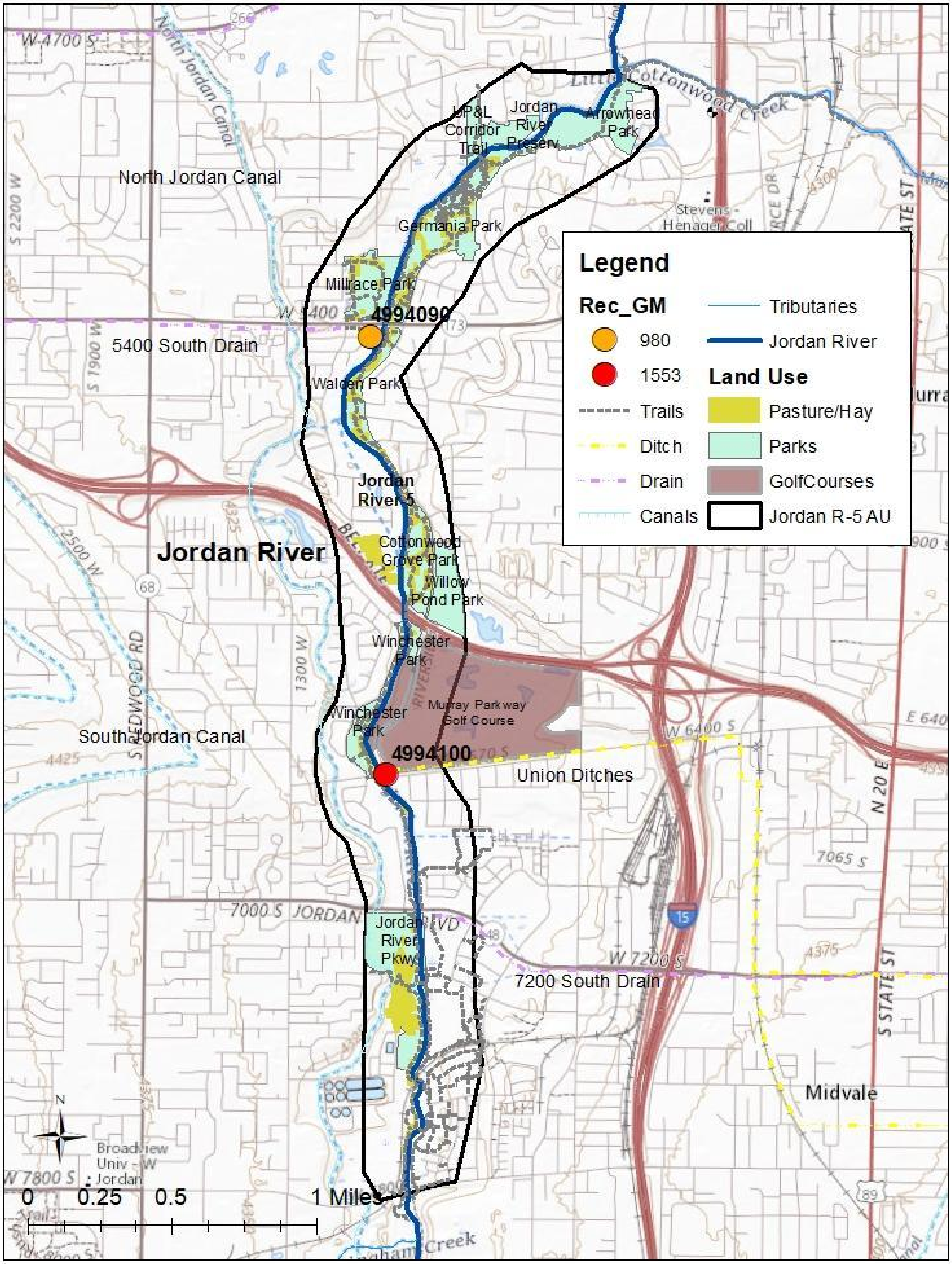

Figure I-12. Possible nonpoint sources of *E. coli* contamination in Jordan River-5 AU.

Water Conveyance Systems: Canals and Drains

Utah Lake water is diverted upstream of this AU at the Jordan River Narrows into several canals and ditches and moved through conveyance systems across the entire Jordan valley

(Figure I-1). These canals have the potential to discharge into several Jordan River tributaries that are impaired for *E. coli,* including Rose and Midas Creeks. These exchanges could import water with elevated *E. coli* concentrations from outside the AU and deposit it during storm events or runoff from the surrounding earthen canal channel.

Two storm drains, 7200 South and 5400 South, collect stormwater runoff from the surrounding developed areas (mostly impervious surfaces) and transport it directly into the Jordan River. The earthen Union Ditch system transports the Utah Lake water to the main stem upstream of the 7200 South Drain. Precipitation events carrying water over impervious surfaces with little infiltration opportunities are also a likely source of *E. coli* loading to nearby surface waters. The LDC analysis suggests that upland stormwater and bank erosion are likely sources during the high-range flows, and riparian areas and impervious surfaces during the mid-range flows.

These conveyance systems will collect and transport more stormwater into the Jordan River in the future given the development pressure and expected increase in impervious surfaces. See Section 7.1 in the main report for suggested BMPs to manage these potential sources.

Recreation, Pets, and Nuisance Wildlife

The Jordan River corridor contains several parks, golf courses, nature centers, and open spaces that are highly utilized. The Jordan River Parkway is a multi-use trail that parallels a majority of the main channel and provides recreational opportunities for people and their pets. Human MST markers were found at both sampling sites within the Jordan River-5 AU boundary (Figure I-10). Figure I-6 shows most of the exceedances occur during the warmer months when baseflows are lower (Figure I-8). LDC analysis suggests that during lower flows, discrete and localized sources are likely from the riparian areas. These could be from parks or the golf course within this section of the Jordan River corridor.

Possible human sources could be from recreationists as well as unhoused populations. Jordan River-5 AU's direct connection with the heart of Salt Lake City via the Jordan River Parkway provides easy access for the unhoused population. It is likely that a small percentage of those who recreate or take refuge near the river do not properly dispose of human waste. While it is a challenge to quantify this behavior, improper disposal of human waste does not appear to be a problem along the main stem, given the available facilities provided along the Jordan River Parkway. Though not a significant source, proper management of human waste could be outlined and highlighted at parks and trailheads.

Improper management of domestic pet waste is another potential source of *E. coli* contamination in waterbodies. Dog waste in the immediate vicinity of a waterway can contribute to local water quality impacts. While there are no designated off-leash dog parks within the Jordan River-5 AU boundary, dogs often accompany their owners to trails and parks. While MST results conducted in 2018 did not show canine markers, dog waste BMPs should still be implemented to ensure proper pet waste management.

Wildlife are also a source of *E. coli* loading in this assessment unit, with MST results showing ruminant presence. Transport of animal waste to surface waters is dependent on animal habitat and proximity to surface waters. Waterfowl and riparian mammals often deposit waste directly into streams, while other riparian species deposit waste in the floodplain where it can be transported to surface waters by runoff during precipitation events. Animal waste deposited in upland areas can also be transported to waterways.

Warm-blooded animals are present, especially in the more natural areas, since most of the AU borders the main stem of the Jordan River. These animals have the potential to be a source of *E. coli* pollution but are considered natural or background sources, so no further implementation is needed.

Nuisance wildlife species, however, should be considered as a potential source of *E. coli* in this AU. MS4 permits must address nuisance wildlife species that congregate around certain stormwater control structures. Basins and ponds can attract wildlife whose waste degrades water quality. Other areas include parks and golf courses. Common nuisance species include, but are not limited to, deer, waterfowl, and small mammals such as beaver and muskrats. Preventing waterfowl from congregating and limiting public feeding opportunities could reduce avian-based contamination.

LDC analysis suggests that *E. coli* likely originates from overland flow, riparian areas, and bank erosion within this AU. Improving the riparian corridor condition will help filter out pollutants reaching the Jordan River.

The Jordan River Commission recently conducted a survey to update its Blueprint Jordan River Strategic Plan, which states that water quality is one of the public's main priorities for the Jordan River corridor. *E. coli* concentrations within the river will decrease and beneficial uses will be restored if recommended BMPs as suggested in Table 8 of the main document are implemented both in this AU and upstream.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Jordan River-5 AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Jordan River-4 Assessment Unit

Assessment Unit Description

The Jordan River-4 Assessment Unit (AU) includes the Jordan River from the confluence with Little Cottonwood Creek downstream approximately 5.7 miles to the intersection with 2100 South. This assessment unit has three tributary inflows from the east: Little Cottonwood Creek, Big Cottonwood Creek, and Mill Creek. The Jordan River-4 AU (2 mi^2) is within the cities of West Valley, South Salt Lake, Taylorsville, Murray, Salt Lake City, and Millcreek Township, and is entirely within Salt Lake County. The AU is 100% privately owned. The Jordan River-4 AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) designated beneficial use due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2014 Integrated Report.

Table I-5. Impairment summary of the Jordan River-4 Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
Jordan River-4 UT16020204-004	*E. coli*	Infrequent primary contact recreation (2B)	2014–2022
	Macroinvertebrates*	Warm water aquatic life (3B)	2010–2022
	Total dissolved solids*	Agriculture	2008–2022
*Will be addressed in future TMDLs			

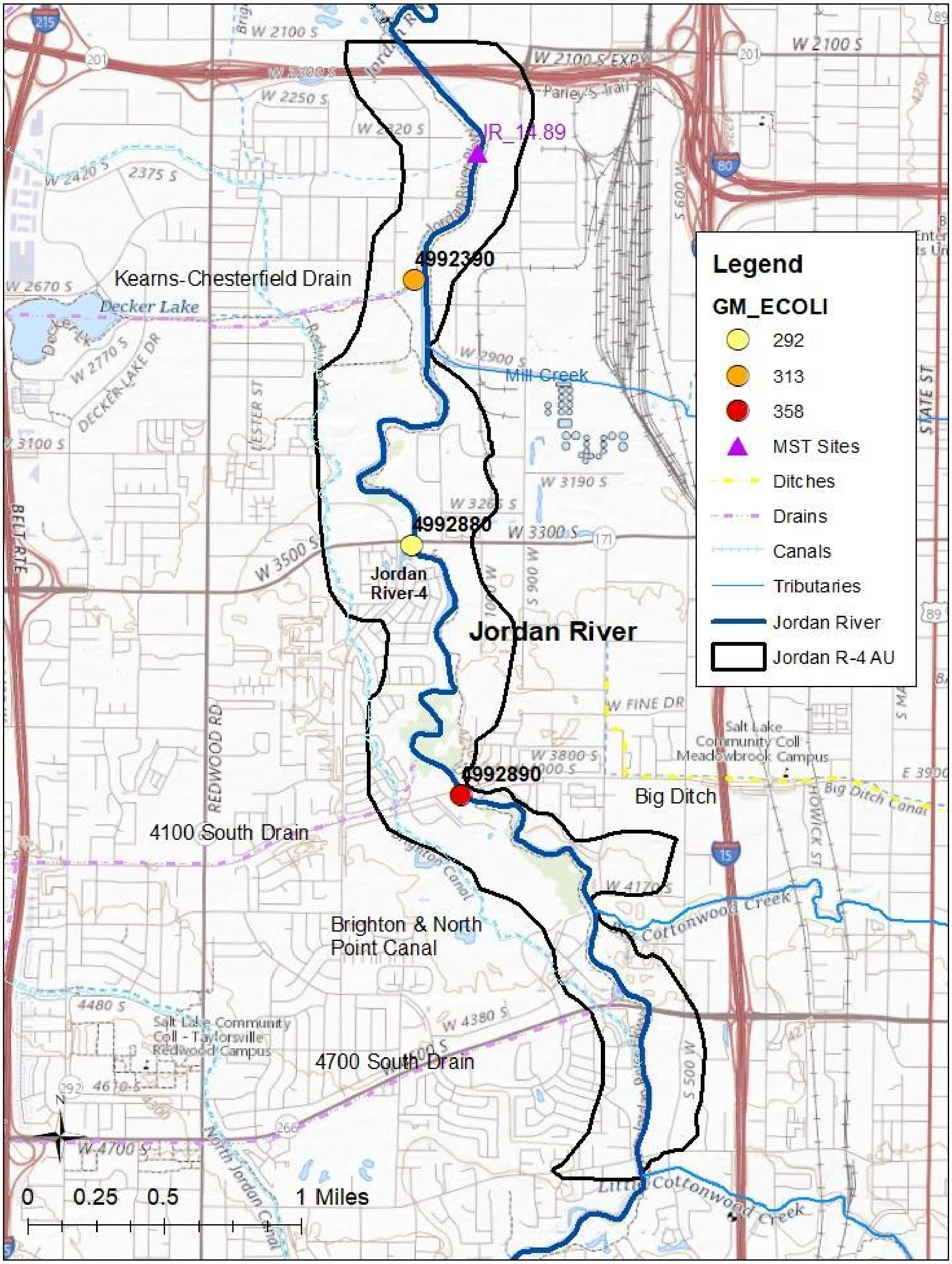

Figure I-13. Hydrology and monitoring locations within the Jordan River-4 Assessment Unit.

Hydrology

The Jordan River is approximately 51 miles long, originating at Utah Lake and flowing north where it terminates in wetlands that eventually discharge to the Great Salt Lake. It is highly managed due to the regulation of discharge from Utah Lake, tributary flows, irrigation diversions, stormwater contributions, and flood control. The topography within the Jordan River watershed contributes to a very complex precipitation pattern with great variability in amounts and timing of flows. Although Utah Lake is the single largest source of flows to the Jordan River, much of this water is diverted at the Jordan River Narrows for agricultural and municipal use via canals serving both the east and west sides of the valley. The releases and diversions occur primarily during the irrigation season (April 15–October 15). Flows from the Jordan River's seven major eastside and three minor westside tributaries are also subject to a complex network of diversions, return flows from canals, stormwater discharge, and exchange agreements between culinary and agricultural users. More information on the complex hydrology of the Jordan River is found in both the Lower Jordan River Dissolved Oxygen TMDL and Salt Lake County's Watershed Plans (2009 and 2015).

Jordan River's hydrology has been impacted by several hydrologic modifications. Though the main channel is fully open (not piped), 13% of the stream channel has been engineered (SLCo 2009). Figure I-13 shows the inputs and outputs of the Jordan River system within the Jordan River-4 AU boundary. While there are no continuous flow gauges along the main stem of the Jordan River within this AU, it does contain three gauged tributary inflows: Little Cottonwood Creek, Big Cottonwood Creek, and Mill Creek. Flows within this AU increase dramatically due to these tributary inputs.

The upstream boundary of this AU begins at the confluence with Little Cottonwood Creek, which is impaired for *E. coli* (Appendix B). There is a major diversion from the Jordan River directly downstream from the confluence of Little Cottonwood Creek, sending flow to the Brighton Canal and North Point Canal. It is unknown how much water is diverted from the main stem during the irrigation season serving the westside agricultural community. The 4700 and 4100 South drains transport local stormwater to the AU, as does westside canal water which originates from Utah Lake.

Big Cottonwood Creek enters from the east approximately one mile downstream of Little Cottonwood Creek. Big Cottonwood Creek is also impaired for *E. coli* and is further discussed in Appendix A. Mill Creek enters from the east, three river miles below the confluence of Big Cottonwood Creek (Appendix C). Note that Central Valley Water

Reclamation Facility discharges into lower Mill Creek just upstream of the Jordan River confluence.

The Kearns-Chesterfield drain collects stormwater from the surrounding urban area and Decker Lake and drains into the main stem 1.1 miles upstream of the lower AU boundary, which is at the 2100 South Crossing and directly upstream of the major diversion to the Surplus Canal.

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 93% of the land in the Jordan River-4 AU is developed (Figure I-14). Cultivated land cover (pasture and crops) makes up 3.5% of the AU, natural land cover (forest, grassland, wetlands, shrubland, and barren) is 2.8%, and open water is 0.4%. Most of the riparian buffers along the main stem of Jordan River-4 are characterized by developed/urban and cultivated land use. There are no major agricultural operations within this AU; however, the cultivated lands percentage includes open space. The urban land cover is primarily residential and industrial.

Approximately 50% of the AU is covered by impervious surfaces due to developed land use (NLCD). This level of impervious surface leads to increased runoff, which results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase in the entire Jordan River corridor by 30% in 2040, which will likely result in an increase in impervious surfaces in this AU (SLCo 2017). See Section 5.3.1 in the main report for more information on the effect of impervious surfaces on pollutant loading.

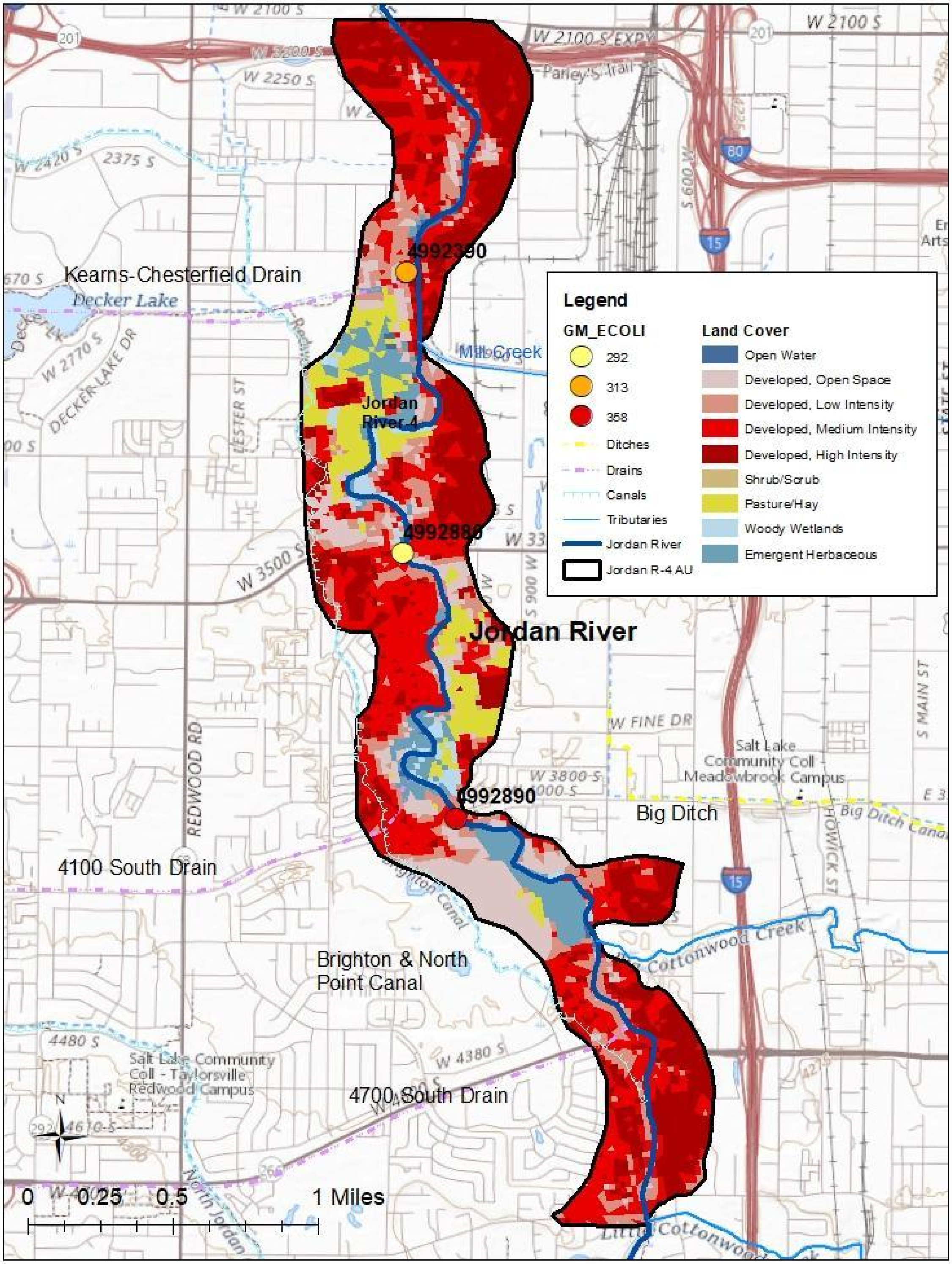

Figure I-14. Land cover in Jordan River-4 Assessment Unit (2019).

E. coli Data Summary

Three routine monitoring locations on Jordan River-4 were studied for spatial and temporal patterns of *E. coli* levels (Table I-6). Samples at all locations were collected during the recreation season. Jordan River at 3300 South (4992880) was only sampled five times in 2018. The percentage of samples at each site exceeding the standard was 80–81%, indicating consistent *E. coli* impairment throughout this reach of the Jordan River. Upstream to downstream, all sites had overall geometric mean *E. coli* concentrations above 206 MPN/100 mL (Figure I-15), and exceedances of the standard occurred throughout the entire sampling period (Figure I-16). Monthly geometric mean concentrations were above the standard in July–September at all sites, but low sample sizes, particularly at Decker Pond Outlet above the Jordan River (4992390) and Jordan River at 3300 South crossing (4992880) caused high variation in summary statistics (Figure I-17).

Table I-6. Jordan River-4 Assessment Unit *E. coli* data summary all year.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4992390	Decker Pond Outflow above Jordan River	NA	05/2009 to 09/2012	10	42	313	313	1,414	80	10
4992880	Jordan River at 3300 South Xing	NA	05/2018 to 09/2018	5	172	292	292	816	80	20
4992890	Jordan River at 3900/4100 South Xing	NA	05/2009 to09/2018	22	115	358	358	1,120	82	14
*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL										

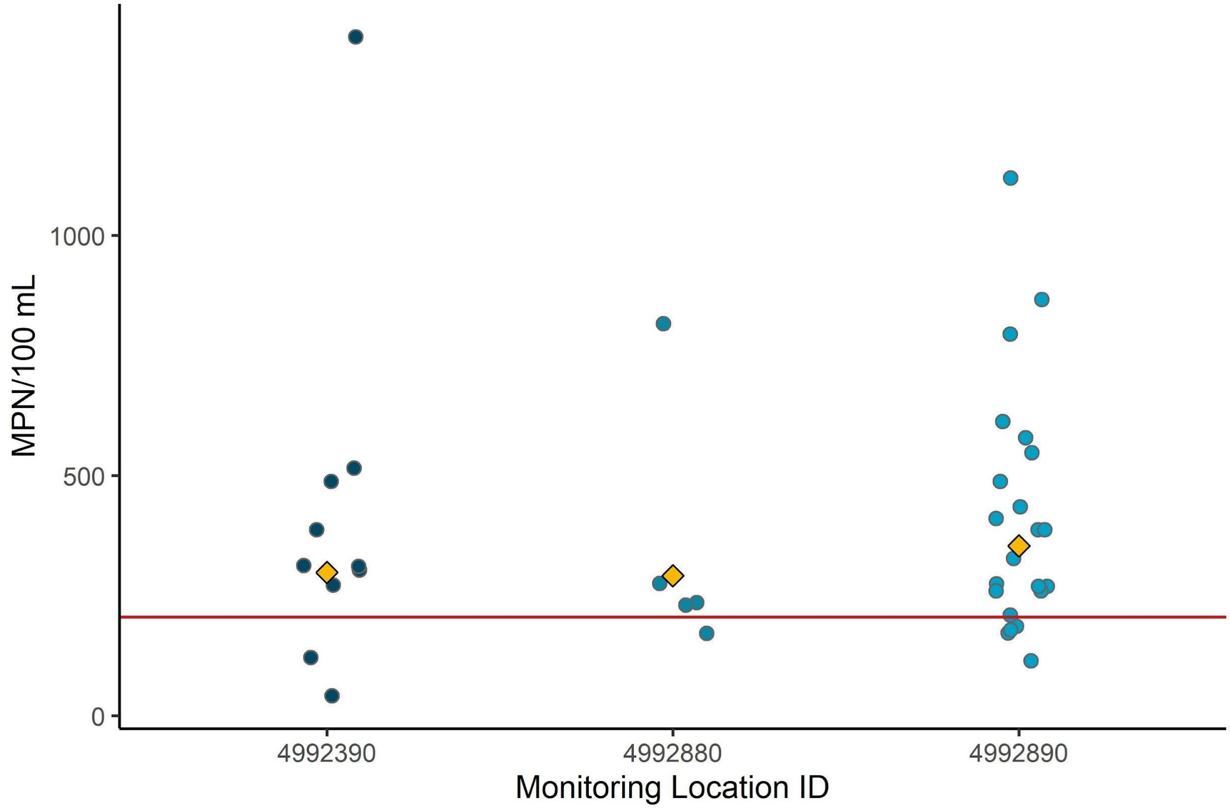

Figure I-15. *E. coli* concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Jordan River-4 Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

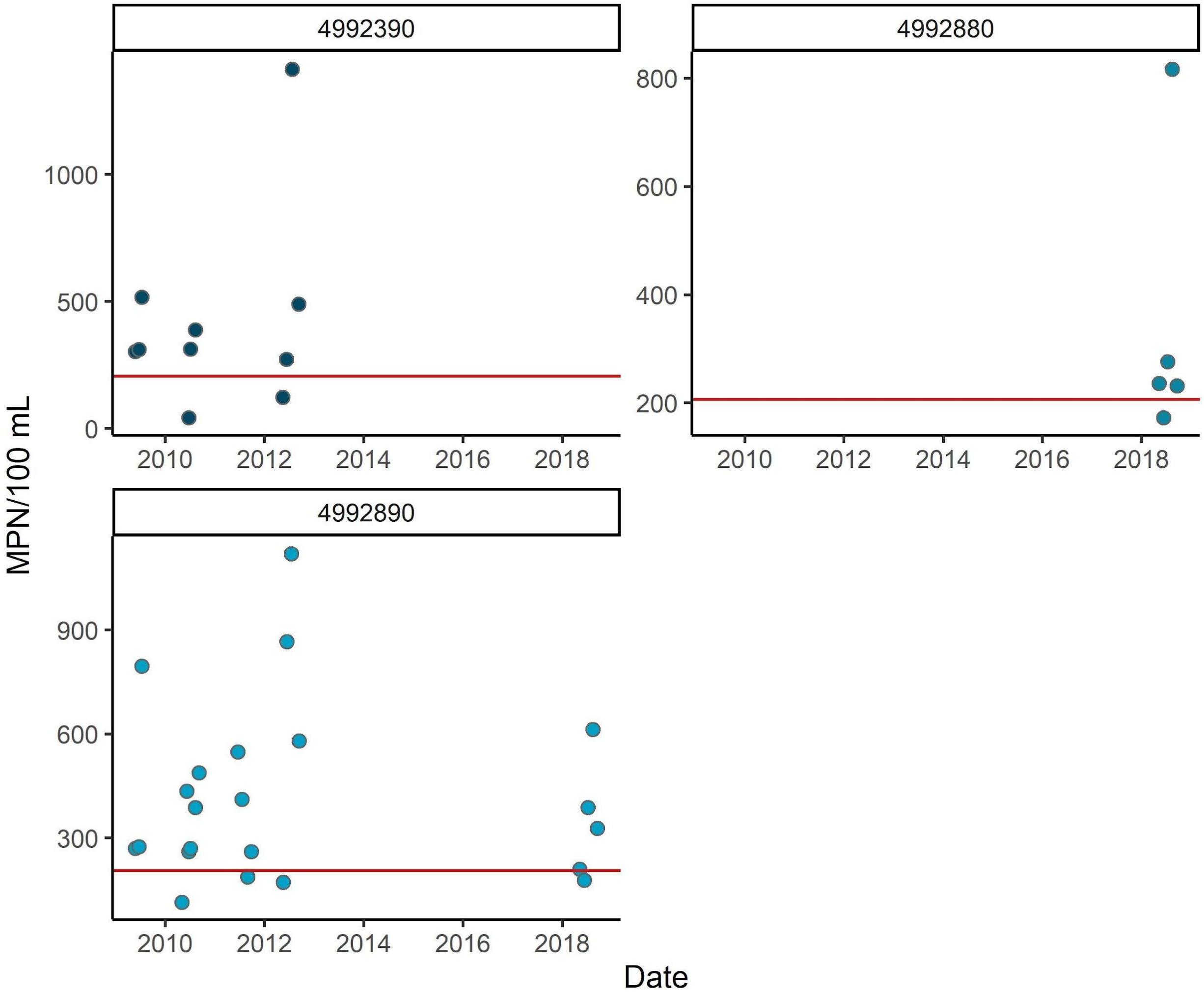

Figure I-16. ***E. coli*** **concentrations at each routine monitoring location through time within the Jordan River-4 Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).**

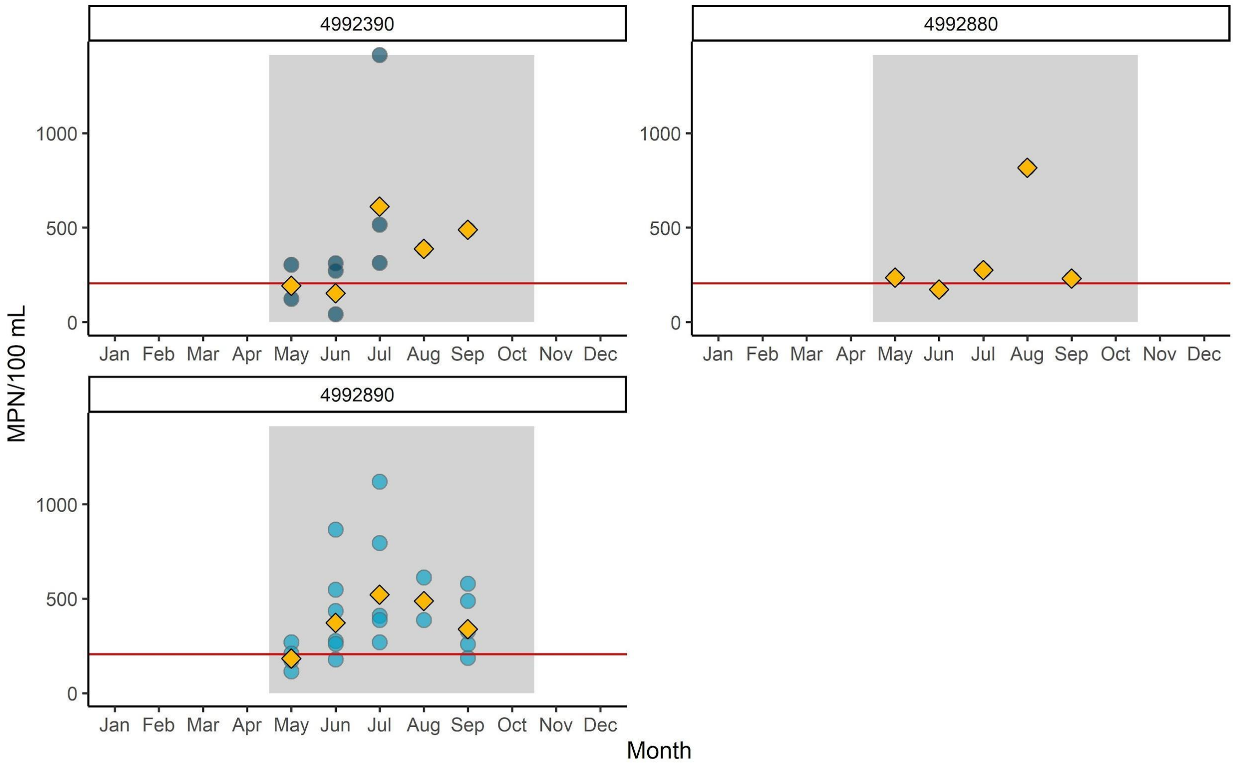

Figure I-17. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. There is no continuous flow gauge within this AU, so the load duration curve source analysis was not possible. Potential sources and recommended implementation strategies to address them are discussed in the main report in Chapter 5 and Chapter 7.

Microbial Source Tracking

Samples collected in this AU were limited and only occurred at one location (JR_14.89) during July, August, and September 2018, resulting in three samples total. Three of the four markers were detected, with human and avian as the most common at 100%, meaning of the three samples collected, all of them were positive for human and avian sources. The ruminant marker was detected in one of the three samples, and no canine markers were detected (Figure I-18). Similar to the other impaired Jordan River AUs, human and avian sources continue to be consistently present in the mainstem of the Jordan River and should be the primary focus of source-control efforts. Additional investigation is warranted to further pinpoint hotspots of contamination that should include any parks where the unhoused population is present, as well as ponded areas that allow for large avian populations to congregate. It may be helpful to conduct MST sampling on any major stormwater outfalls as well.

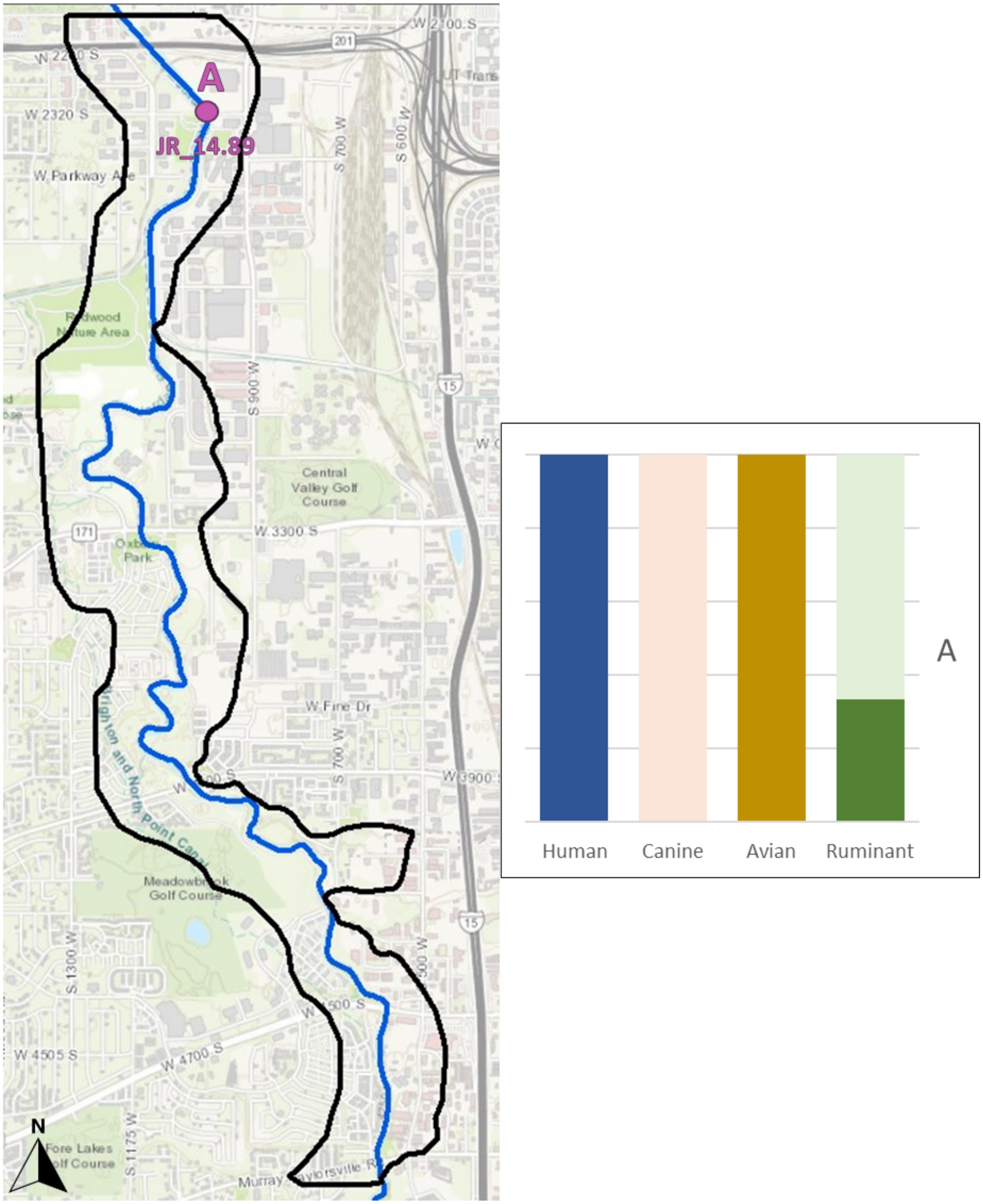

Figure I-18.The proportion of presence and absence of the four MST markers at the sampling location. The darker shades of color indicate presence and the lighter shades absence.

Source Assessment

Based on the data analysis, MST analysis, land-use patterns and hydrology, the probable sources of *E. coli* in the Jordan River-4 AU come from both nonpoint and point sources, most notably stormwater runoff. Nonpoint sources include water (irrigation) conveyance systems, avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused. The Jordan River-4 AU is downstream of several *E. coli*-impaired assessment units, including Jordan River-5, Little Cottonwood Creek, Big Cottonwood Creek, and Mill Creek. Significant sources of *E. coli* exist upstream in the main stem and tributaries. Addressing these sources as outlined in the previous appendices will aid in the reduction of *E. coli* concentration within the Jordan River-4 AU. The following source assessment primarily focuses on potential sources specific to this AU.

Table I-7 provides a list of specific potential point and nonpoint sources in the Jordan River-4 AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. For more information on each potential source, please see Chapter 5.1 and 5.2.

Table I-7. Potential sources of *E. coli* contamination in Jordan River-4 Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	Suggested BMPs
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	Yes	UTR000000		
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities, including West Valley City, Taylorsville, Murray, Millcreek, and South Salt Lake	UTS000001		
		Salt Lake City	UTS000002		
		Utah Department of Transportation	UTS000003		

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	Suggested BMPs
Nonpoint source	Onsite septic systems	Yes		Section 5.2.1	Table 8
	Agricultural: livestock	No			
	Agricultural: canals	Yes		Section 5.2.2	
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	
	Recreationists/ unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

While there are several Utah Pollutant Discharge Elimination System (UPDES) permitted discharges within the Jordan River-4 Assessment Unit, municipal stormwater is the likely source of *E. coli* in this AU (Figure I-19). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including the urbanized land uses and increased impervious surfaces in the valley, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see Chapter 5.1 in the main report for more information.

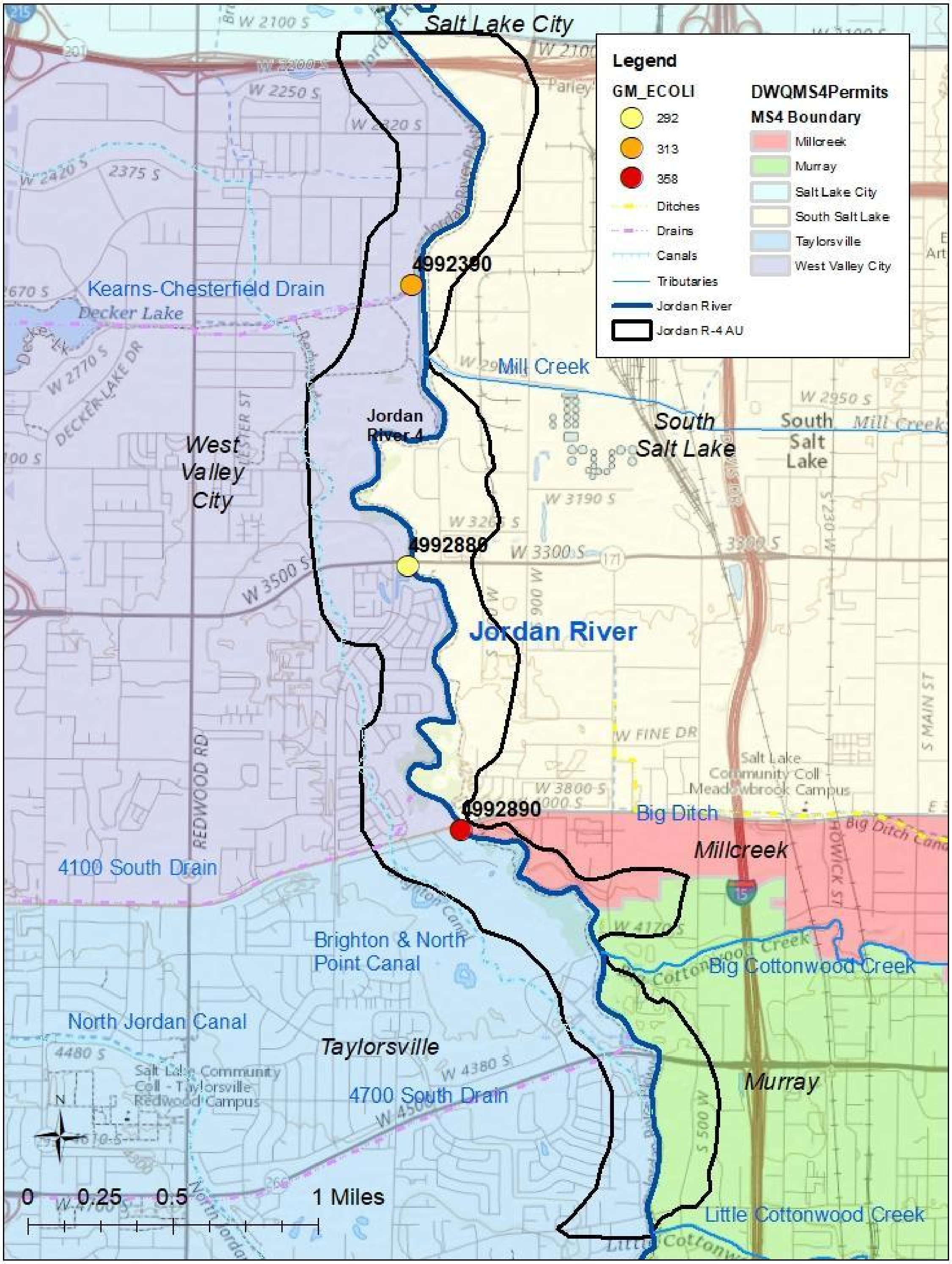

Figure I-19. Possible point sources of *E. coli* contamination within Jordan River-4 Assessment Unit.

Stormwater

Three potential sources of stormwater pollution (construction activities, industrial activities, and MS4s) occur within the Jordan River-4 AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were seven construction and two industrial UPDES stormwater permits in this AU. Construction permits are short-lived and change over time, and most industrial sites are not a potential source of *E. coli*. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses stormwater within the Jordan River-4 AU by issuing MS4s permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of the Jordan River. There are three MS4 permits—Jordan Valley Municipalities, Salt Lake City and Utah Department of Transportation—applicable to this AU (Figure I-19). The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. The cities of West Valley, Taylorsville, Murray, Millcreek, and South Salt Lake have jurisdictional boundaries within the AU. Salt Lake City's MS4 permit allows for discharge of stormwater within its jurisdictional boundaries. The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the state. UDOT's Region 2 geographical area covers the Wasatch Front.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Jordan River-4 AU include humans, wildlife, and dogs (Figure I-20). Since there is no agriculture activity within this AU, this is not considered to be a source. Cultivated land uses are specific to local parks and golf courses. According to the Salt Lake County’s Assessor's Office, there are only eight onsite septic system parcels within this AU as of 2021, so they are not considered to be a significant source of *E. coli* contamination. Most parcels are sewered, and no large underground wastewater disposal systems lie within AU boundary. Please see Chapter 5.2 in the main report for more information on nonpoint sources.

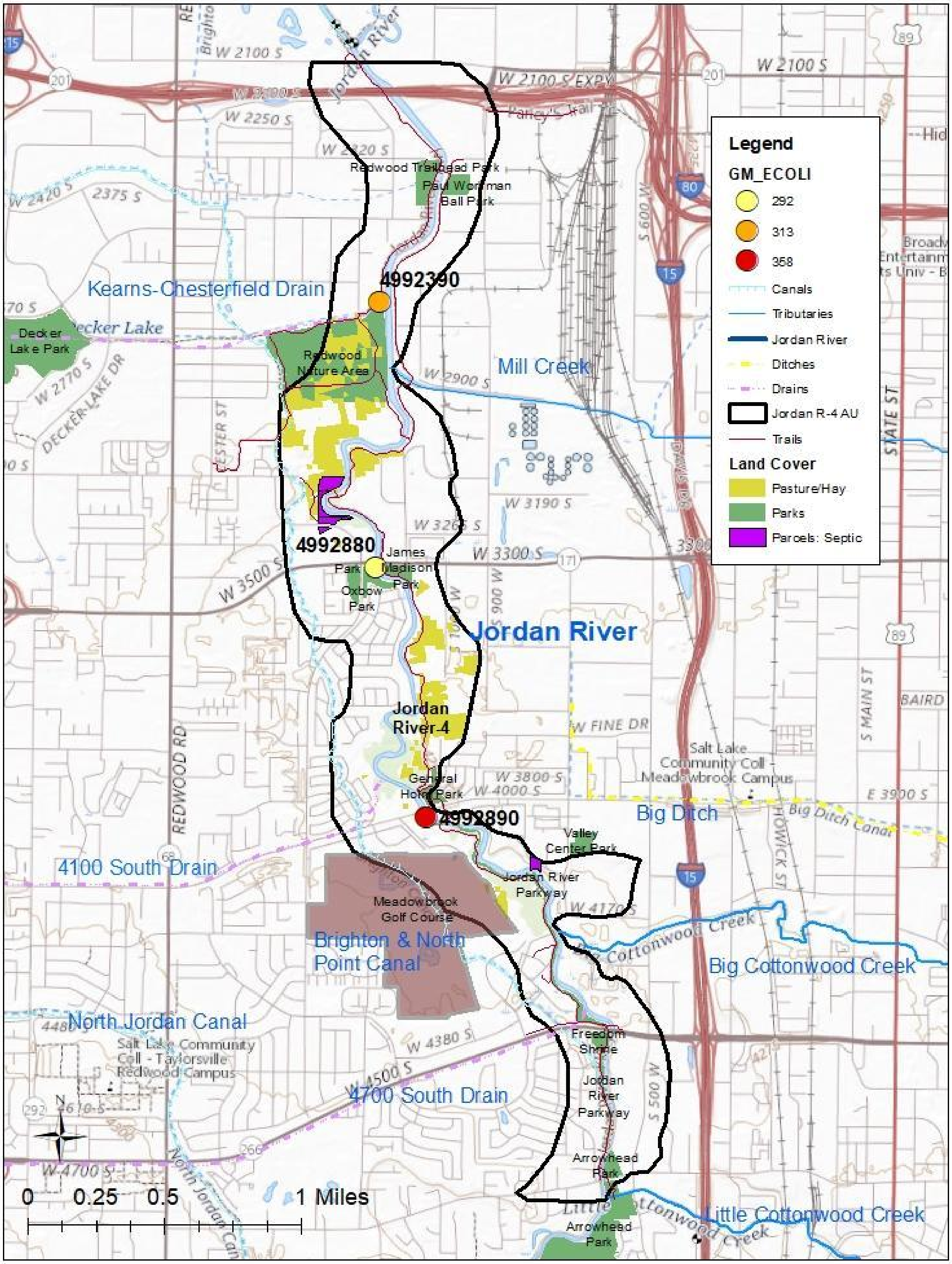

Figure I-20. Possible nonpoint sources of *E. coli* contamination in Jordan River-4 Assessment Unit.

Water Conveyance Systems: Canals and Drains

Utah Lake water is diverted upstream of this AU at the Jordan River Narrows into several canals and ditches and moved through conveyance systems across the entire Jordan valley (Figure I-1). These canals have the potential to discharge into several *E. coli*-impaired Jordan River tributaries, including Big Cottonwood Creek, Little Cottonwood Creek, and Mill Creek. These exchanges could import water with elevated *E. coli* concentrations from outside the AU and deposit it during storm events or runoff from the surrounding earthen canal channel.

Two storm drains, 4700 South and 4100 South, collect stormwater runoff from the surrounding developed areas (mostly impervious surfaces) and transport it directly into the Jordan River. Decker Lake is fed by two storm drains, 2700 West and Kearns-Chesterfield, that transport Utah Lake water from the North Jordan Canal. The Decker Lake Outlet site (4992490) is impaired for *E. coli,* indicating that sources come from its two drain inputs.

These conveyance systems will collect and transport more stormwater into the Jordan River, given the development pressure and expected increase in impervious surfaces. See Section 7.1 in the main report for suggested BMPs to manage these potential sources.

Recreation, Pets, and Nuisance Wildlife

The Jordan River corridor includes several highly utilized parks, golf courses, nature centers and open spaces. The Jordan River Parkway, a multi-use trail, parallels a majority of the main channel and provides opportunities for reactionists and their pets. Based upon the MST results in 2018, human markers were present at all sampling locations within the Jordan River-4 AU (Figure I-18). Figure I-15 shows most of the *E. coli* exceedances occur during the warmer months when base flows are generally lower.

Possible human sources could be from both recreationists and unhoused populations. Since this AU is located within the heart of Salt Lake City, its close proximity provides easy access for the unhoused population. It is likely that a small percentage of those who recreate or take refuge near the river do not properly dispose of human waste. While it is a challenge to quantify this behavior, improper disposal of human waste does not appear to be a problem along the main stem, given the available facilities provided along the Jordan River Parkway.

Improper management of domestic pet waste is another potential source of *E. coli* contamination into waterbodies. Dog waste in the immediate vicinity of a waterway can contribute to local water quality impacts. While there are no designated off-leash dog parks within the Jordan River-4 AU, dogs often accompany their owners to the trail and parks. While the MST survey conducted in 2018 did not show canine markers, dog waste BMPs should still be implemented to ensure proper pet waste management.

Wildlife are also a source of *E. coli* loading in this assessment unit, with MST results showing the presence of ruminant markers. Transport of animal waste to surface waters is dependent on animal habitat and proximity to surface waters. Waterfowl and riparian mammals often deposit waste directly into streams, while other riparian species deposit waste in the floodplain where it can be transported to surface waters by runoff during precipitation events. Animal waste deposited in upland areas can also be transported to waterways.

Large numbers of warm-blooded animals are present, especially in the more natural areas, along the main stem of the Jordan River. These animals do have the potential to be a source of *E. coli* pollution.

Nuisance wildlife species should be considered a potential source of *E. coli* in this AU. MS4 permits must address nuisance wildlife species that congregate as a result of certain stormwater control structures. Basins and ponds can attract wildlife whose waste degrades water quality. Other areas include parks and golf courses. Common nuisance species include, but are not limited to, deer, waterfowl, and small mammals such as beaver and muskrats. Preventing waterfowl from congregating and limiting public feeding opportunities could reduce avian-based contamination.

E. coli is likely originating from overland flow, riparian areas, and bank erosion within this AU. Improving the riparian corridor condition will help filter out pollutants reaching the Jordan River.

The Jordan River Commission recently conducted a survey to update its Blueprint Jordan River Strategic Plan, which states that water quality is one of the public's main priorities for the Jordan River corridor. *E. coli* concentrations within the river will decrease and beneficial uses will be restored if recommended BMPs as suggested in Table 8 of the main document are implemented both in this AU and upstream.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Jordan River-4 AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Jordan River-3 Assessment Unit

Assessment Unit Description

The Jordan River-3 Assessment Unit (AU) includes the Jordan River from the intersection of 2100 South downstream approximately 4.4 miles to the intersection with North Temple Street. The Jordan River-3 AU (1.4 mi^2) is located in Salt Lake City and Salt Lake County, and the land is 100% privately owned. The Jordan River-3 AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) designated beneficial use due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2006 Integrated Report.

Table I-8. Impairment summary of the Jordan River-3 Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
Jordan River-3 UT16020204-003	*E. coli*	Infrequent primary contact recreation (2B)	2006–2022
	Macroinvertebrates*	Warm water aquatic life (3B)	2008–2022
	Dissolved oxygen*	Warm water aquatic life (3B)	2008–2022
	Total phosphorus*	Warm water aquatic life (3B)	2008–2022
*Will be addressed in future TMDLs			

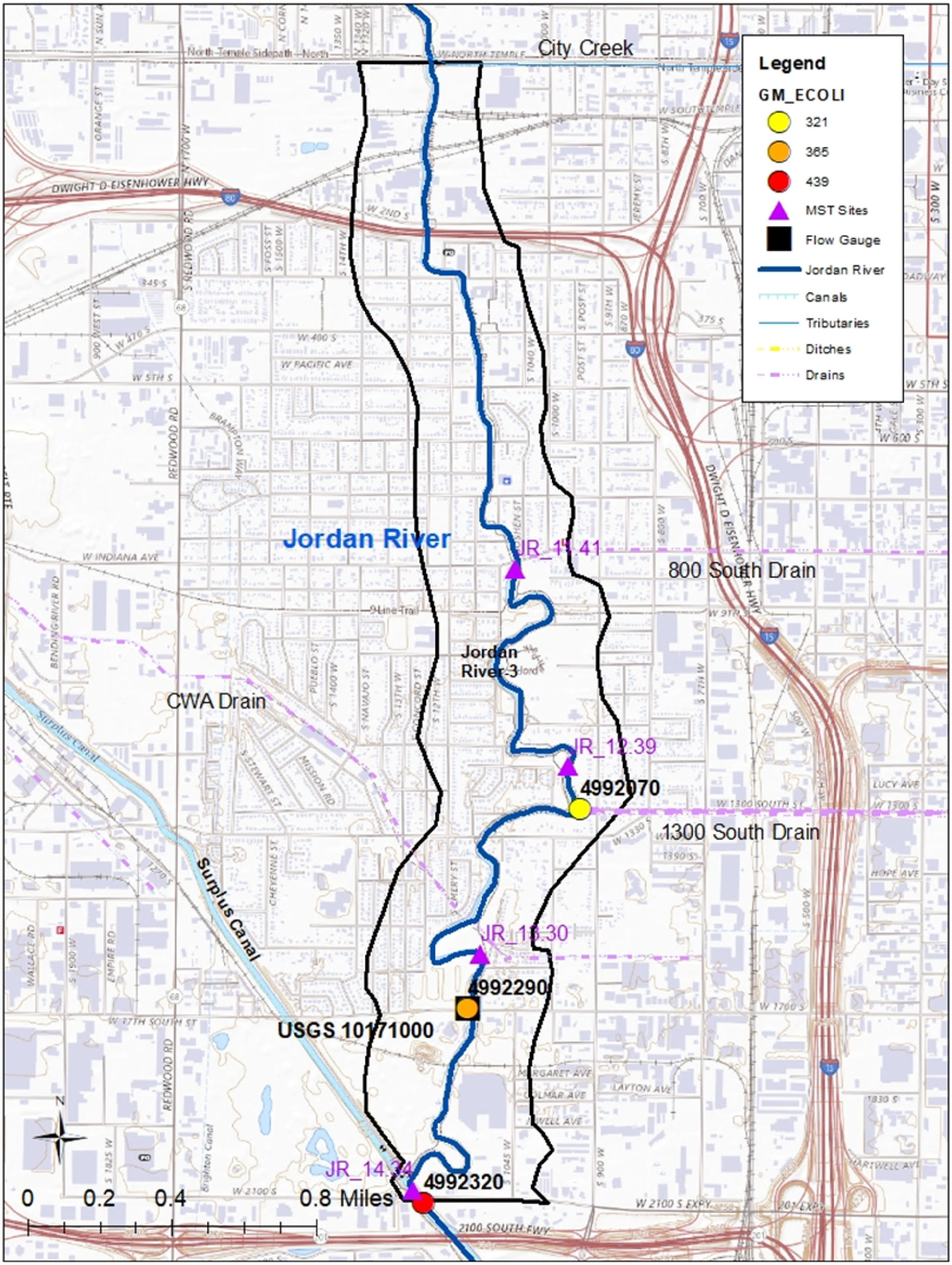

Figure I-21. Monitoring locations and hydrology of the Jordan River-3 Assessment Unit

Hydrology

The Jordan River is approximately 51 miles long, originating at Utah Lake and flowing north where it terminates in wetlands that eventually discharge to the Great Salt Lake. It is highly managed due to the regulation of discharge from Utah Lake, tributary flows, irrigation diversions, stormwater contributions, and flood control. The topography within the Jordan River watershed contributes to a very complex precipitation pattern, with great variability in amounts and timing of flows. Although Utah Lake is the single largest source of flows to the Jordan River, much of this water is diverted at the Jordan River Narrows for agricultural and municipal use via canals serving the east and west sides of the valley. The releases and diversions occur primarily during the irrigation season (April 15–October 15). Flows from the Jordan River's seven major eastside and three minor westside tributaries are also subject to a complex network of diversions, return flows from canals, stormwater discharge, and exchange agreements between culinary and agricultural users.

Jordan River's hydrology has been impacted by several hydrologic modifications. Though the main channel is fully open (not piped), 13% of the stream channel has been engineered (SLCo 2009). Figure I-21 shows the inputs and outputs of the Jordan River system within the Jordan River-3 AU boundary. Inputs include upstream main channel flows and four stormwater drains. The Surplus Canal, which is directly upstream of this AU boundary, diverts up to 90% from the Jordan River to the Great Salt Lake to protect downstream neighborhoods and developments from flooding. Jordan River-3 AU begins the designation of the "Lower Jordan River," as the hydrology below this major diversion differs vastly from the upstream reaches. The mean daily flow is 133 cubic feet per second (cfs) at the USGS Gauge #101710000 (Jordan River at 1700 South) during the TMDL period of record (2011–2021), with a maximum daily mean of 303 cfs (Table I-10).

Inputs into the Jordan River within the Jordan River-3 AU includes upstream flows of the Jordan River downstream of the Surplus Canal, stormwater drains, and tributary flows (Figure I-21). The CWA drain from the west and the 800 South drain from the east only contribute flow to the main stem during stormwater events. The 1300 South drain combines both local developed flows and tributary flows from Red Butte, Emigration, and Parleys Creeks. Note that all three of these creeks are impaired for *E. coli* and are addressed in the appendices.

More information on the complex hydrology of the Jordan River is found in the Lower Jordan River Dissolved Oxygen TMDL and Salt Lake County's Watershed Plans (2009 and 2015).

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 99% of the land in the Jordan River-3 AU is developed (Figure I-22). Cultivated land cover (pasture and crops) makes up 0.68% of the AU, natural land cover (forest, grassland, wetlands, shrubland, and barren) is 0.02%, and open water is 0.07%. Most of the riparian buffers along the main stem of Jordan River-3 are characterized by developed/urban land use. There are no major agricultural operations within this AU; however, open space within the AU is considered cultivated land. The urban land cover is primarily residential and industrial.

Approximately 49% of the AU is covered by impervious surfaces due to developed land use. This level of impervious surface leads to increased runoff, which results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase in the entire Jordan River corridor by 30% in 2040 (SLCo 2017), which will likely result in an increase in impervious surfaces in this AU. See Section 5.3.1 in the main report for more information on the effect of impervious surfaces on pollutant loading.

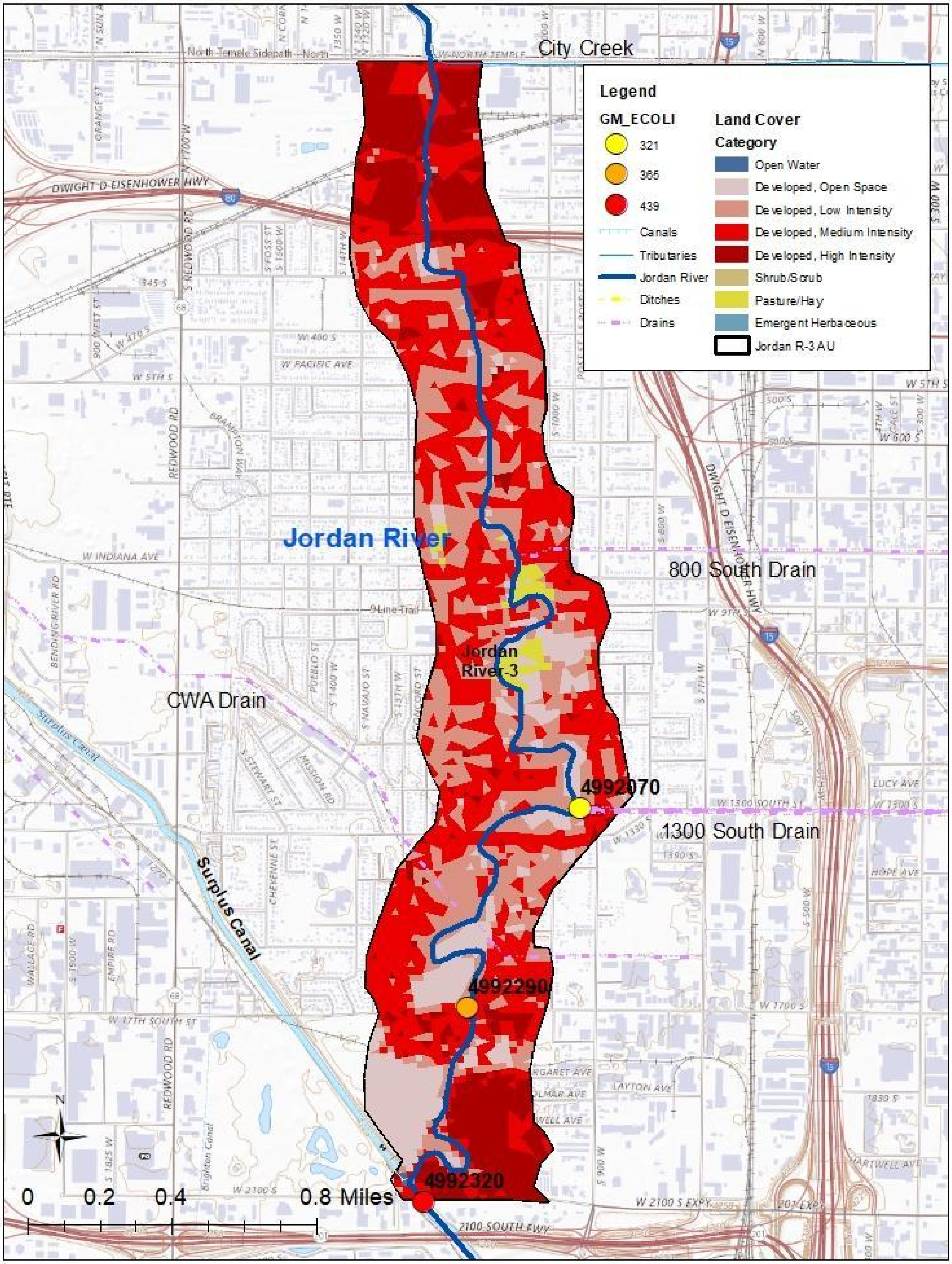

Figure I-22. Land cover in Jordan River-3 Assessment Unit (2019).

E. coli Data Summary

Three routine monitoring locations in Jordan River-3 were studied for spatial and temporal patterns of *E. coli* levels (Table I-9). Those sites include Jordan River at 2100 South (4992320), Jordan River below the 1700 S Drain (49992290), and Jordan River at 1300S Drain (4992070). Samples at all locations were collected during the recreation season only. The overall geometric mean *E. coli* concentration at all sites exceeded the standard, and samples at all sites regularly exceeded the maximum reporting limit of 2,419.6 MPN/100mL. Throughout the sampling period (2009–2012, 2018) all sites had exceedances of the geometric mean standard, with exceedance percentages of 74% and above.

Figure 1-23 shows *E. coli* concentrations are fairly consistent across these three monitoring locations, with a slight decrease in the recreation season geometric mean at Jordan River at 1300 S Drain site, which is the combined [impaired] tributary flow input of Red Butte, Parleys, and Emigration Creeks. Concentrations across the sampling period did not reveal any significant temporal trends (Figure I-24). Monthly geometric mean concentrations were above 206 MPN/100 mL June–September (Figure I-25).

Table I-9. Jordan River-3 Assessment Unit *E. coli* data summary all year.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4992070	Jordan River at 1300 South Storm Sewer Mouth	NA	06/2009 to 09/2018	18	99	321	321	2,420*	78	22
4992290/ JR_13.30	Jordan River at 1700 South above Drain Outfall	NA	05/2009 to 09/2018	23	105	365	365	2,420*	74	22
4992320 / JR_14.34	Jordan River at 1100 West and 2100 South	NA	05/2009 to 09/2018	25	115	439	439	2,420*	84	36

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL

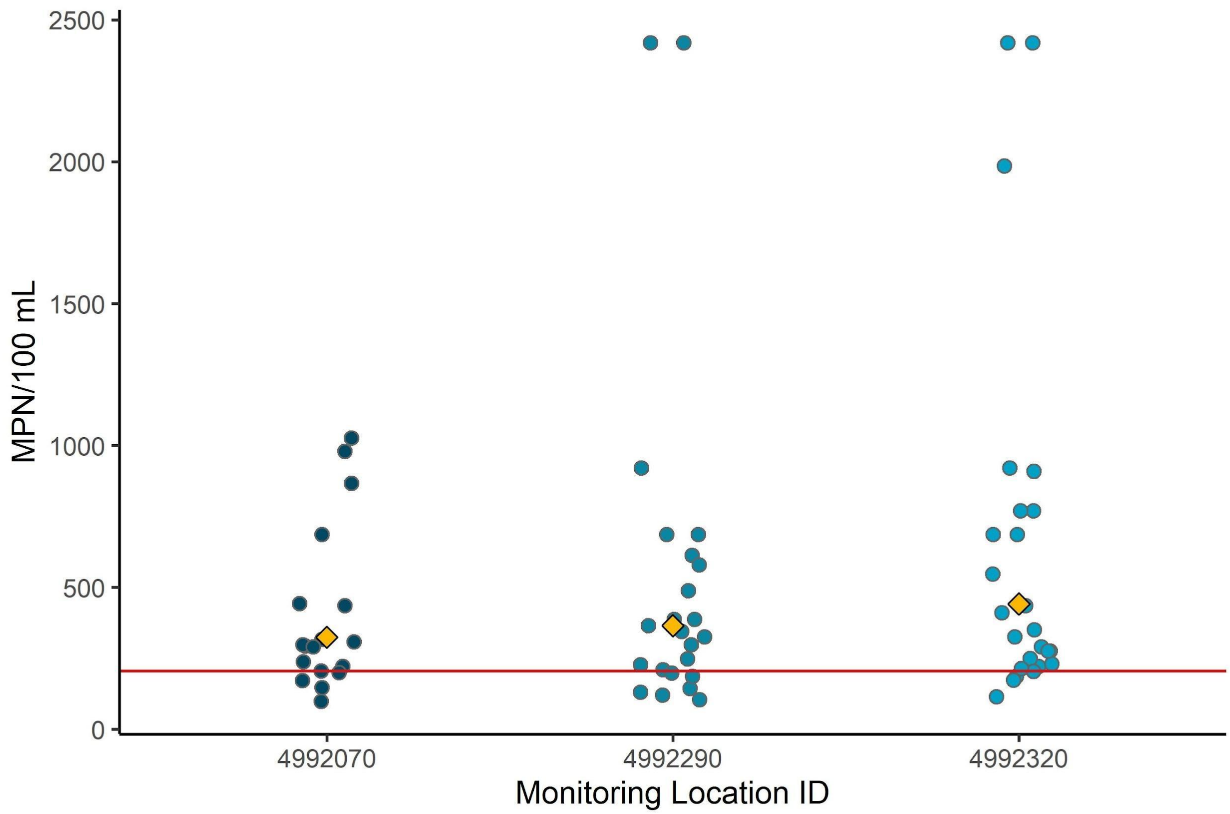

Figure I-23. *E. coli* concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Jordan River-3 Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

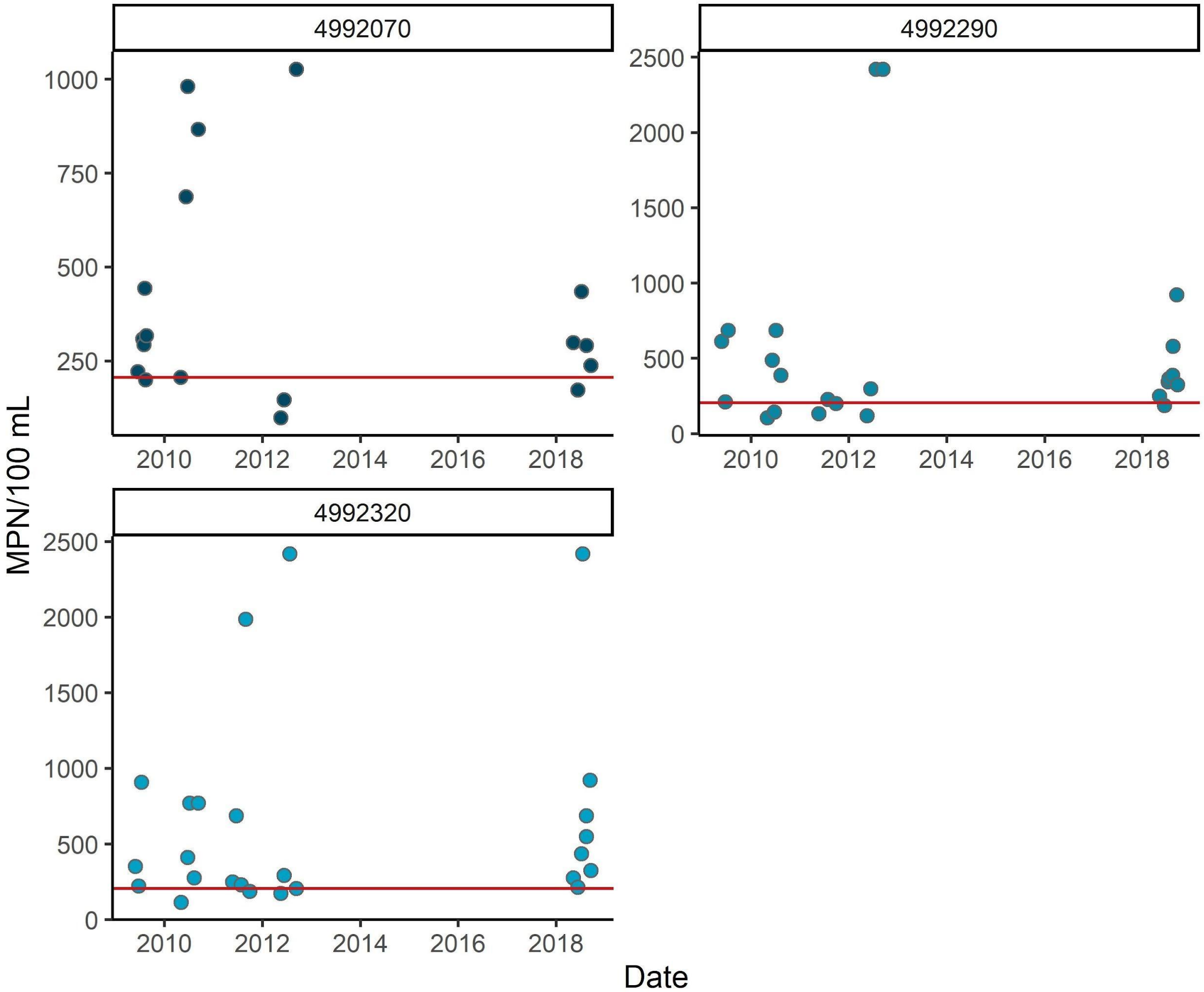

Figure I-24. *E. coli* concentrations at each routine monitoring location through time within the Jordan River-3 Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

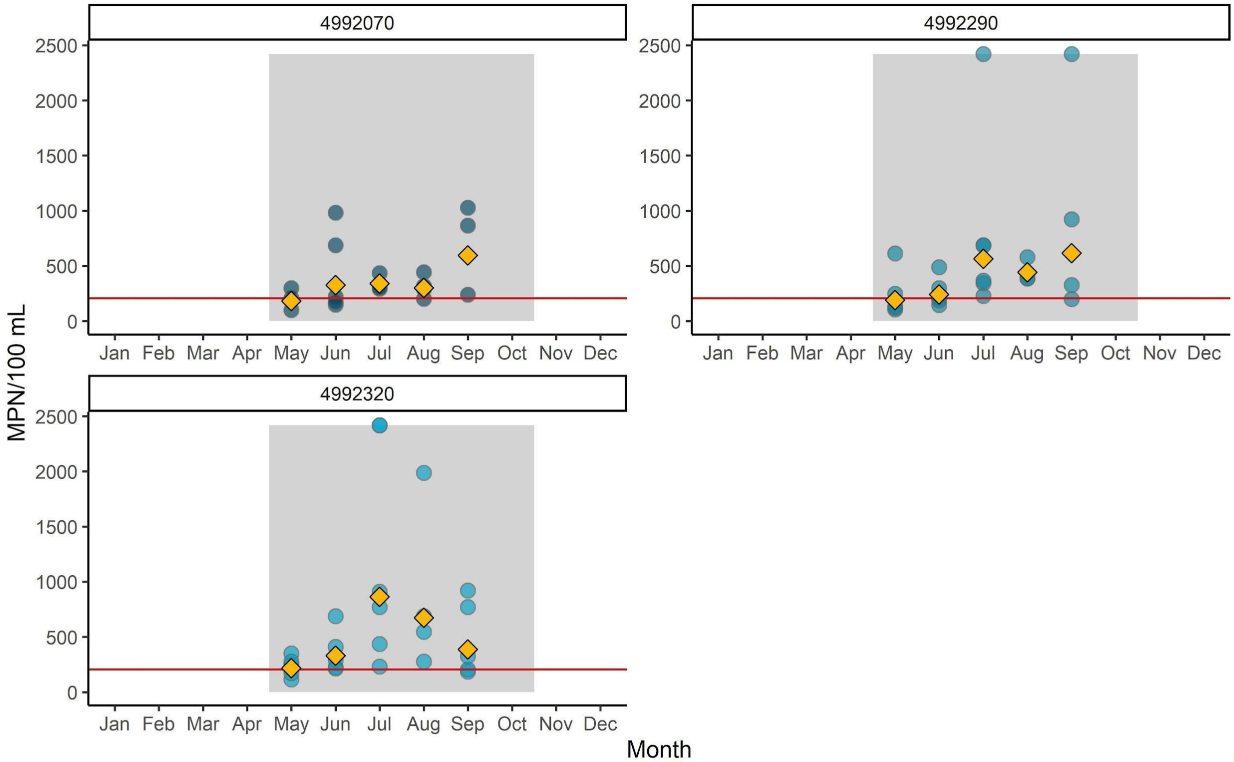

Figure I-25. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDC), microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. Potential sources and recommended implementation strategies to address them are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curves

Load duration curves are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* concentrations and measured (or instantaneous) flow data to plot the load capacity curve. USGS operates a continuous flow gauge directly below the Surplus Canal diversion along the mainstem Jordan River at 1700 South (10171000). This site corresponds to the *E. coli* monitoring station on the Jordan River above 1700 S Drain (4992290). Flow data during the TMDL period of record (January 2011–September 2021) is summarized in Table I-10, Figure I-26, and Figure I-27. The daily mean flows are slightly higher in the late summer and early fall. This hydrograph is atypical, with no higher flows during snowmelt due to the highly managed system of the Jordan River. The lower Jordan River begins downstream of the largest diversion to the Surplus Canal, which redirects up to 90% of the flow from the Jordan River directly to the Great Salt Lake. This area is designated a Federal Emergency Management Agency (FEMA)-controlled levee.

Table I-10. Summary statistics for Jordan River at 1700 South (4992290), USGS Gauge #10771000.

Assessment Unit	Gauge Name	USGS Gauge Number/DWQ MLID	Mean Flow (cfs)	Maximum Flow (cfs)
Jordan River-3	Jordan River at 1700 South	10171000/ 4992290	133	303

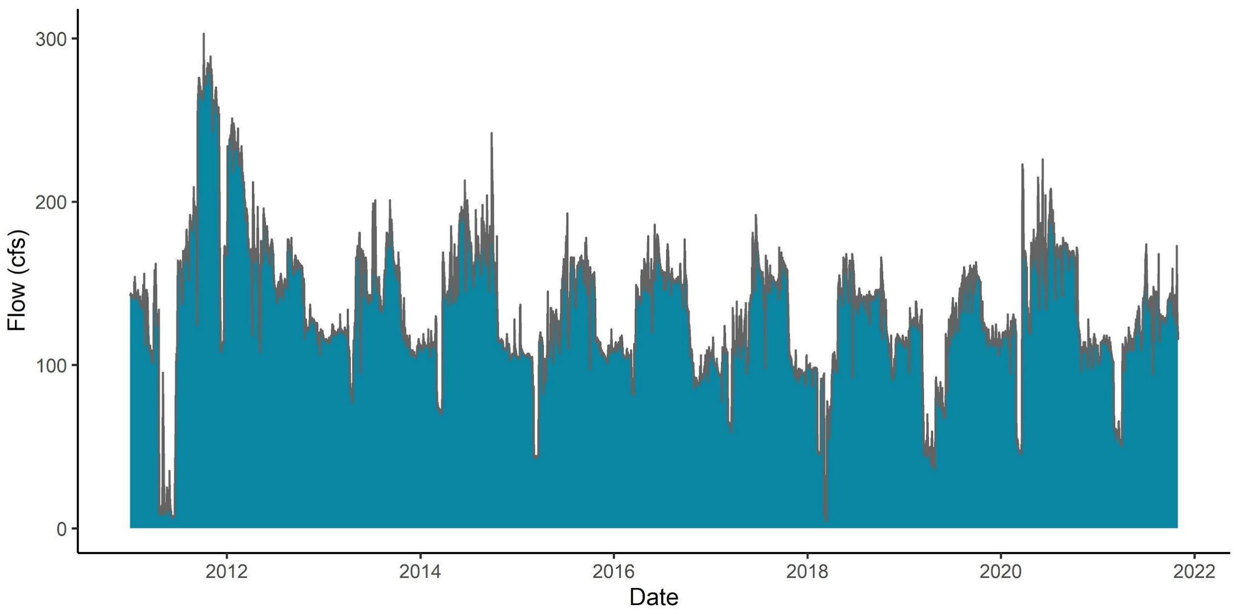

Figure I-26. Daily means flows at USGS Gauge #10171000, Jordan River at 1700 South (4992290) from January 1, 2011, to September 30, 2021.

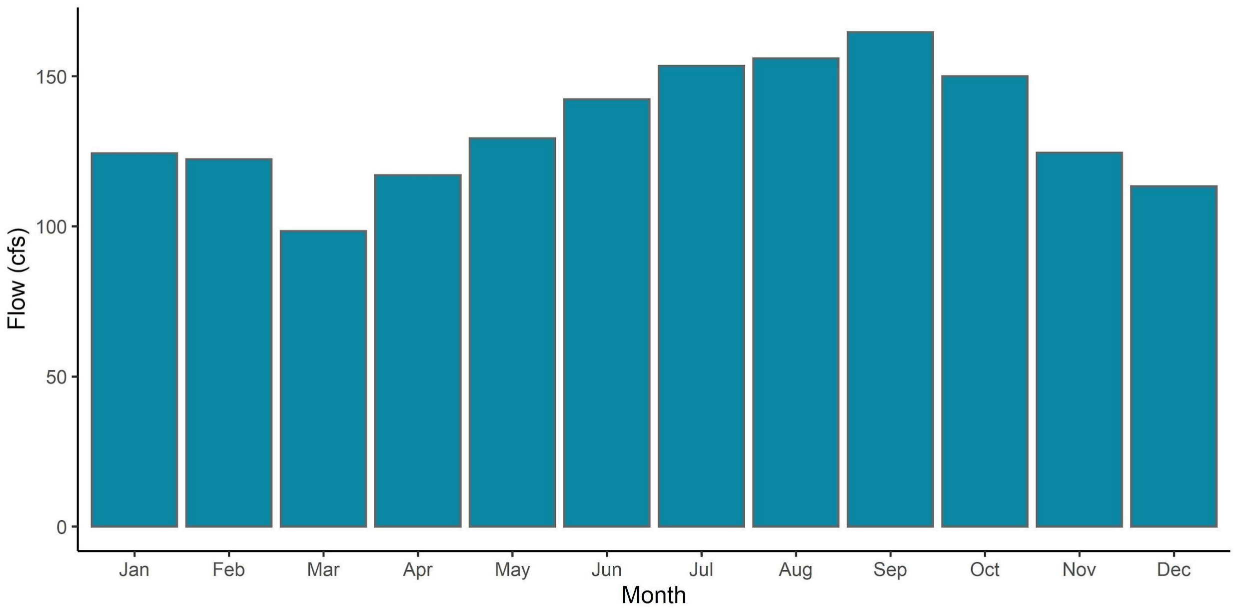

Figure I-27. Monthly means flows (cfs) at USGS Gauge #10171000, Jordan River at 1700 South (4992290) from January 1, 2011, to September 30, 2021.

Using this site's corresponding *E. coli* and flow data, the LDC shows exceedances occurring at the moist and mid-range flow regimes (Figure I-28). Exceedances of the TMDL threshold (solid line) in high to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. These sources include riparian areas and impervious stormwater sources (mid-range). Upland stormwater and bank erosion are likely sources during the high flow conditions. The percent of *E. coli* loading measurements exceeding the TMDL in each flow regime is provided in parentheses under each flow-regime label in Figure I-28. Though the mid-range flow regimes require the most reduction, there is not enough data to analyze this relationship in the other flow regimes. Jordan River-3 AU has both point and nonpoint source delivery methods of *E. coli* loading. More data is needed to fully understand *E. coli* loading during high and low-flow regimes.

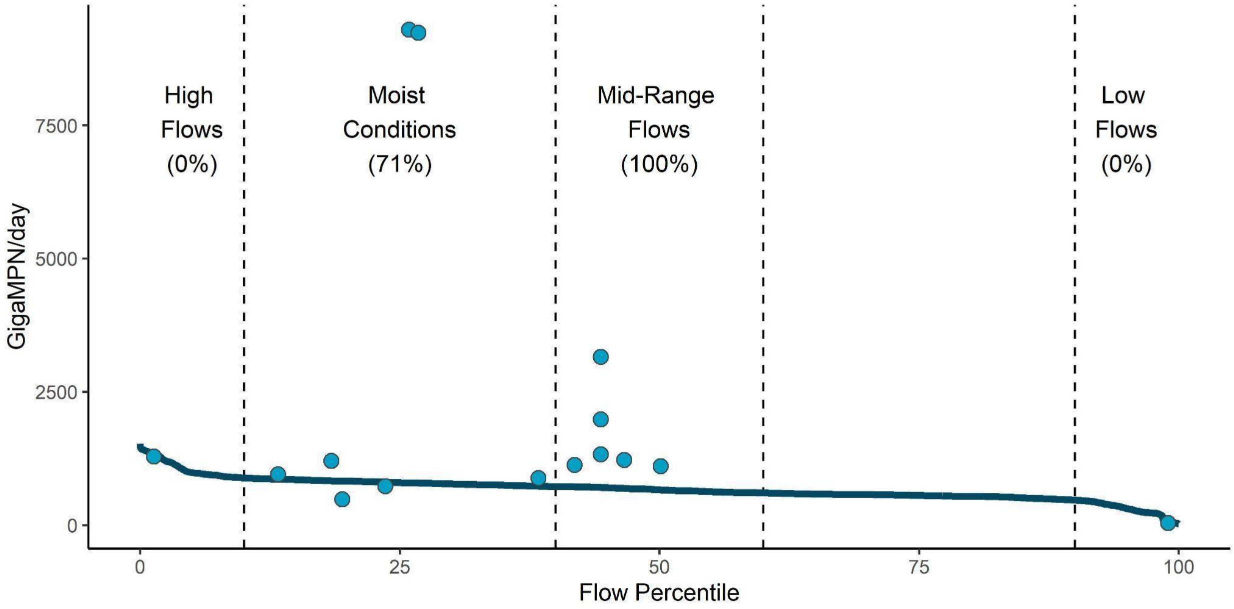

Figure I-28. Load duration curve for Jordan River at 1700 South (4992290).

Microbial Source Tracking

Samples were collected once a month at four locations during July, August, and September in 2018, resulting in three samples per site and a total of 12 samples collected (Figure I-29). All four markers (human, canine, ruminant, and avian) were detected in the AU. When the presence or absence of each marker was considered across all locations, human and avian were the most common at 100%, meaning of the 12 samples collected, all of them were positive for the human and avian marker. The canine marker was present at 25%, and the ruminant marker at 33%. Figure I-29 illustrates the presence/absence pattern of the four markers at each sampling location in the AU. Most concerning is the consistent presence of the human marker from upstream to downstream, since human contamination poses the greatest risk to human health. Also of note is the pervasiveness of the avian marker throughout the reach. MST results for this AU highlight the need to focus on further identifying and controlling human and avian sources of fecal contamination.

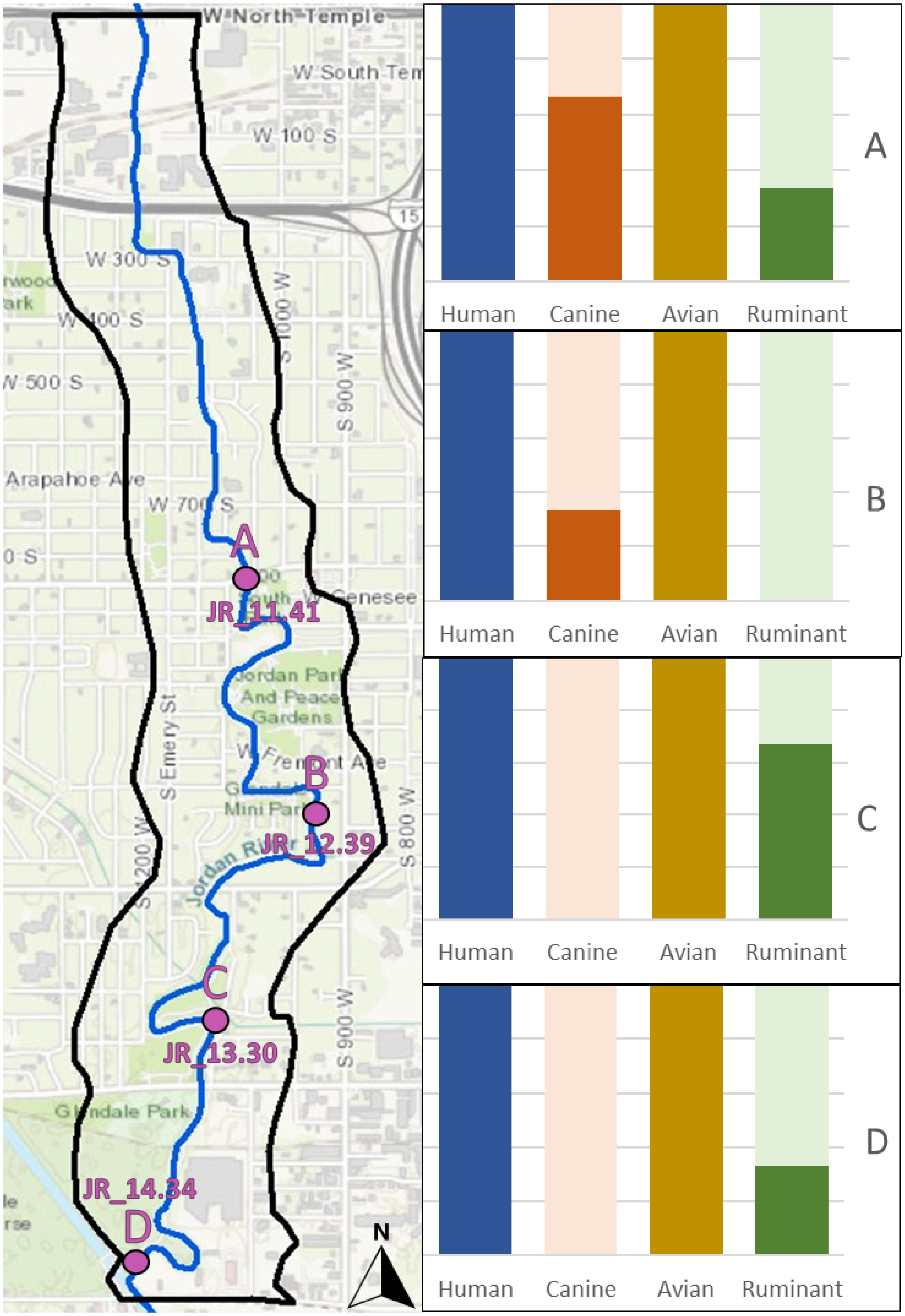

Figure I-29. The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades absence.

Source Assessment

Based on the data analysis, LDC analysis, land-use patterns and hydrology, the probable sources of *E. coli* in the Jordan River-3 AU come from point sources, most notably stormwater runoff. Nonpoint sources include water (irrigation) conveyance systems, avian wildlife, domestic pets, wildlife/nuisance species and recreationists/unhoused. Jordan River-3 AU is below the inputs of all the major impaired tributaries within the Jordan River watershed. Significant sources of *E. coli* loading exist upstream in the main stem or tributaries. Addressing these sources as outlined in the previous appendices will aid in the reduction of *E. coli* concentration within the Jordan River-3 AU. The following source assessment focuses on potential sources specific to this AU.

Table I-11 provides a list of potential point and nonpoint sources in the Jordan River-3 AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. Please see Chapter 5.1 and 5.2 for more information on each potential source.

Table I-11. Potential sources of *E. coli* contamination in Jordan River-3 Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	Suggested BMPs
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	Yes	UTR000000		
	Municipal (MS4) stormwater	Yes Salt Lake City	UTS000002		
		Utah Department of Transportation	UTS000003		
Nonpoint Source	Onsite septic systems	No			Table 8

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	Suggested BMPs
	Agricultural: livestock	No			
	Agricultural: canals	Yes		Section 5.2.2	
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	
	Recreationists /unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

While there are several Utah Pollutant Discharge Elimination System (UPDES) permitted discharges (mainly construction dewatering) within Jordan River-3 Assessment Unit, municipal stormwater is the likely source of *E. coli* in this AU (Figure I-30). This conclusion is based on the multiple lines of evidence identifying sources in the AU, including urbanized land uses and increased impervious surfaces in the valley, as well as the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see Chapter 5.1 in the main report for more information.

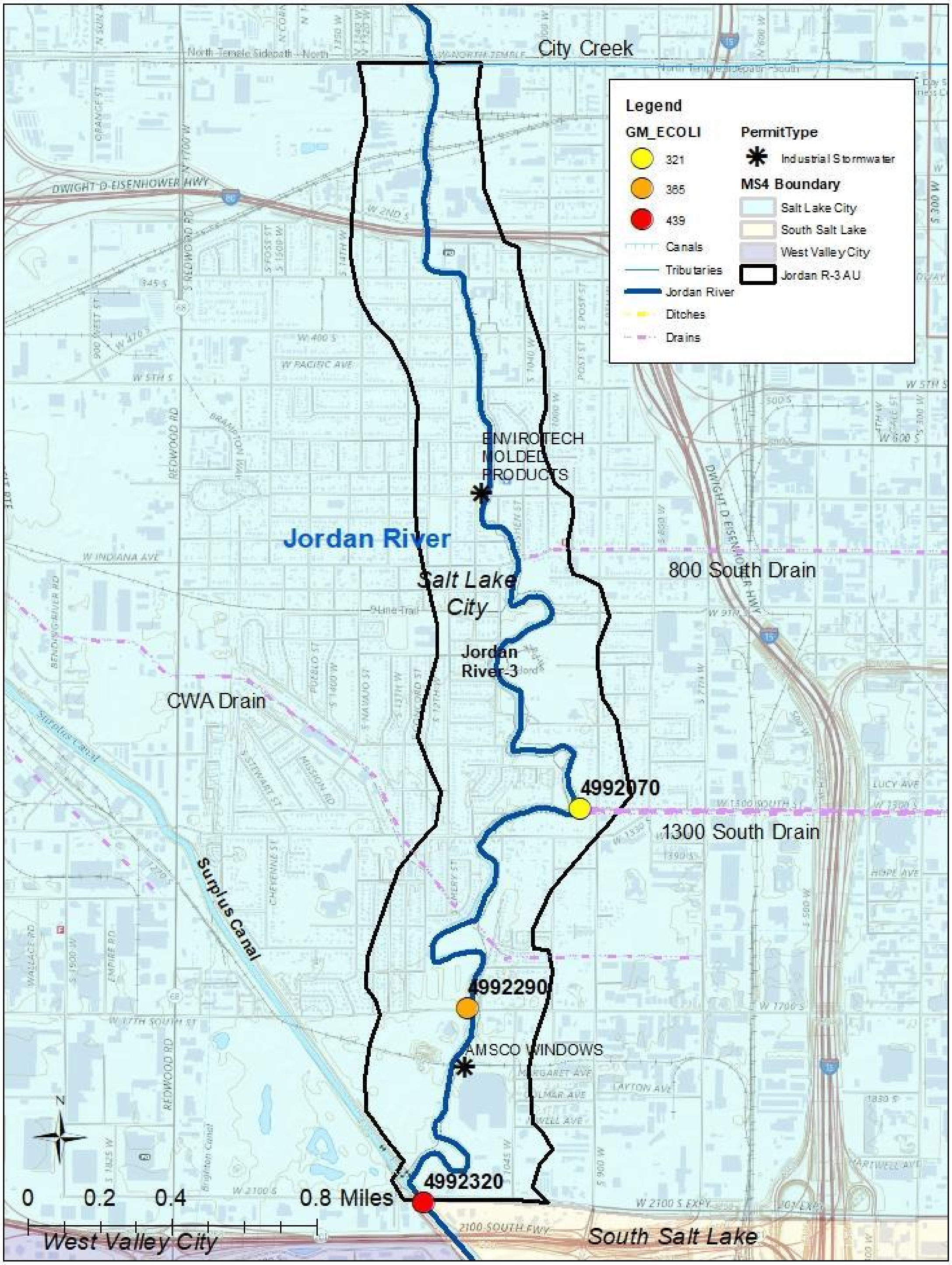

Figure I-30. Possible point sources of *E. coli* contamination within Jordan River-3 Assessment Unit.

Stormwater

Three potential sources of stormwater pollution (construction activities, industrial activities, and MS4s) occur within the Jordan River-3 AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were six construction and two industrial UPDES stormwater permits in this AU. Construction permits are short-lived and change over time, and most industrial sites are not a potential source of *E. coli*. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Jordan River-3 AU by issuing MS4s permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of the Jordan River. There are two MS4 permits—Salt Lake City and Utah Department of Transportation—applicable to this AU (Figure I-30). Salt Lake City's MS4 permit allows for discharge of stormwater within its jurisdictional boundaries. The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the state. UDOT's Region 2 geographical area covers the Wasatch Front.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Jordan River-3 AU include humans, wildlife, and dogs (Figure I-31). Since there is no agriculture (livestock and pasture) activity within this AU, it is not considered as a source. Cultivated land uses in this AU include local parks and golf courses. According to the Salt Lake County's Assessor's

Office, there are no onsite septic system parcels within this AU as of 2021. All parcels are sewered, and no large underground wastewater disposal systems are within the AU boundary. Please see Chapter 5.2 in the main report for more information on nonpoint sources.

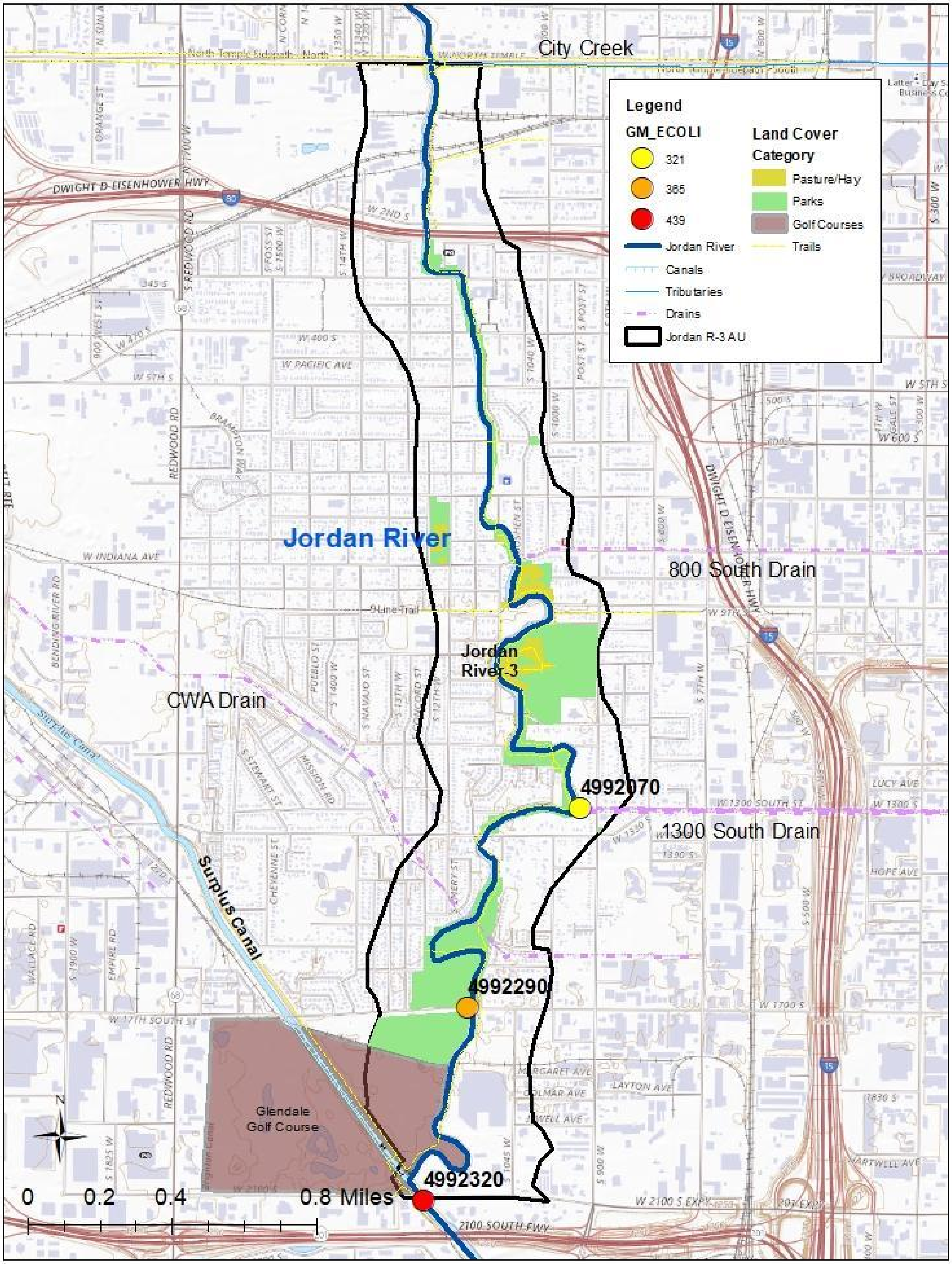

Figure I-31. Possible nonpoint sources of E. coli contamination in Jordan River-3 Assessment Unit.

Water Conveyance Systems: Canals and Drains

Utah Lake water is diverted upstream of this AU at the Jordan River Narrows into several canals and ditches and moved through conveyance systems across the entire Jordan valley. Due to exchange agreements between Salt Lake City and the agricultural community, these diverted waters are imported into several Jordan River tributaries, including Parleys, Emigration, and Red Butte Creeks via the Jordan and Salt Lake Canals and ultimately into the Jordan River via the 1300 South Drain. This combined tributary flows through the pond at Liberty Park, which has high numbers of waterfowl. These exchanges could import water with elevated *E. coli* concentrations from outside the AU and deposit it during storm events or runoff from the surrounding earthen canal channel.

The Salt Lake City Clean Water Act (CWA) storm drain and 800 South storm drain collect stormwater runoff from the surrounding developed areas (mostly impervious surfaces) and transport it directly into the Jordan River. Precipitation events carrying water over impervious surfaces with little infiltration opportunities are also a likely driver of *E. coli* loading to nearby surface waters. These conveyance systems will collect and transport more stormwater into the Jordan River in the future given the development pressure and anticipated increase in impervious surfaces.

Recreation, Pets, and Nuisance Wildlife

The Jordan River corridor includes several parks, golf courses, nature centers, and open spaces that are highly utilized. The Jordan River Parkway is a multi-use trail that parallels a majority of the main channel and provides recreational opportunities for people and their pets. Based upon the MST results in 2018, human markers were found at all MST sites within the Jordan River-3 AU (Figure I-29). LDC analysis suggests that riparian areas and bank erosion are likely sources during mid-range flows. These could be from parks and trails within the Jordan River corridor.

Possible human sources are recreationists and the unhoused population. Since this AU is located within the heart of Salt Lake City, its close proximity provides easy access for the unhoused population. It is likely that a small percentage of those who recreate or seek refuge near the river do not properly dispose of human waste. While it is a challenge to quantify this behavior, improper disposal of human waste does not appear to be a problem along the main stem given the available facilities provided along the Jordan River Parkway.

Improper management of domestic pet waste is another potential source of *E. coli* contamination in the Jordan River-3 AU. Dog waste in the immediate vicinity of a waterway can contribute to local water quality impacts. While there are no designated off-leash dog parks within the Jordan River-3 AU, dogs often accompany their owners to both trail and parks (Figure I-29). Dog waste BMPs should be employed to ensure proper pet waste management.

Wildlife could also be a source of *E. coli* loading in this assessment unit, as indicated by the presence of the ruminant MST marker at all three monitoring locations. Transport of animal waste to surface waters is dependent on animal habitat and proximity to surface waters. Waterfowl and riparian mammals often deposit waste directly into streams, while other riparian species deposit waste in the floodplain where it can be transported to surface waters by runoff during precipitation events. Animal waste deposited in upland areas can also be transported to waterways.

Warm-blooded animals are present, especially in the more natural areas, since most of the AU borders the main stem of the Jordan River. These animals do have the potential to be a source of *E. coli* pollution.

Nuisance wildlife species should be considered a potential source of *E. coli* in this AU. MS4 permits must address nuisance wildlife species that congregate as a result of certain stormwater control structures. Basins and ponds can attract wildlife whose waste degrades water quality. Other areas include Liberty Park and the Glendale golf course. Common nuisance species include, but are not limited to, deer, waterfowl and small mammals such as beaver and muskrats. Preventing waterfowl from congregating and limiting public feeding opportunities could reduce avian-based contamination.

LDC analysis suggests that *E. coli* is likely to originate from overland flow, riparian areas, and bank erosion within this AU. Addressing the riparian corridor will help filter out pollutants reaching the Jordan River. Though the monitoring locations within the Jordan River-3 are impaired, upstream sources of *E. coli* loading likely contribute to their impairment.

The Jordan River Commission recently conducted a survey to update its Blueprint Jordan River Strategic Plan, which states that water quality is one of the public's main priorities for the Jordan River corridor. *E. coli* concentrations within the river will decrease and beneficial uses will be restored if recommended BMPs as suggested in Table 8 of the main document are implemented in this AU and upstream.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Jordan River-3 AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season

Jordan River-2 Assessment Unit

Assessment Unit Description

The Jordan River-2 Assessment Unit includes the Jordan River from the intersection of North Temple Street downstream approximately 4.4 miles to the Davis County boundary with Salt Lake County. City Creek, Jordan and Salt Lake Canal, and the 4th Avenue storm drain merge together and enter the Jordan River from the east at North Temple Street (Figure I-1). The Jordan River-2 AU (1.9 mi^2) is located in Salt Lake City and Salt Lake County, and the land ownership is 99.9% privately owned, with 0.1% owned by the state of Utah. The Jordan River-2 AU was listed on Utah's 303(d) list of impaired waterbodies for failing to protect the Class 2B (infrequent primary contact recreation) designated beneficial use due to elevated levels of *E. coli*. The AU was originally listed on the 303(d) list of impaired waters in the 2006 Integrated Report.

Table I-12. Impairment summary of the Jordan River-2 Assessment Unit.

Assessment Unit	Cause of Impairment	Impaired Beneficial Use	Years 303(d) Listed
Jordan River-2 UT16020204-002	*E. coli*	Infrequent primary contact recreation (2B)	2006–2022
	Macroinvertebrates*	Warm water aquatic life (3B)	2008–2022
	Dissolved oxygen*	Warm water aquatic life (3B), waterfowl, shorebirds, and other aquatic life (3D)	2002–2022
*Will be addressed in future TMDLs			

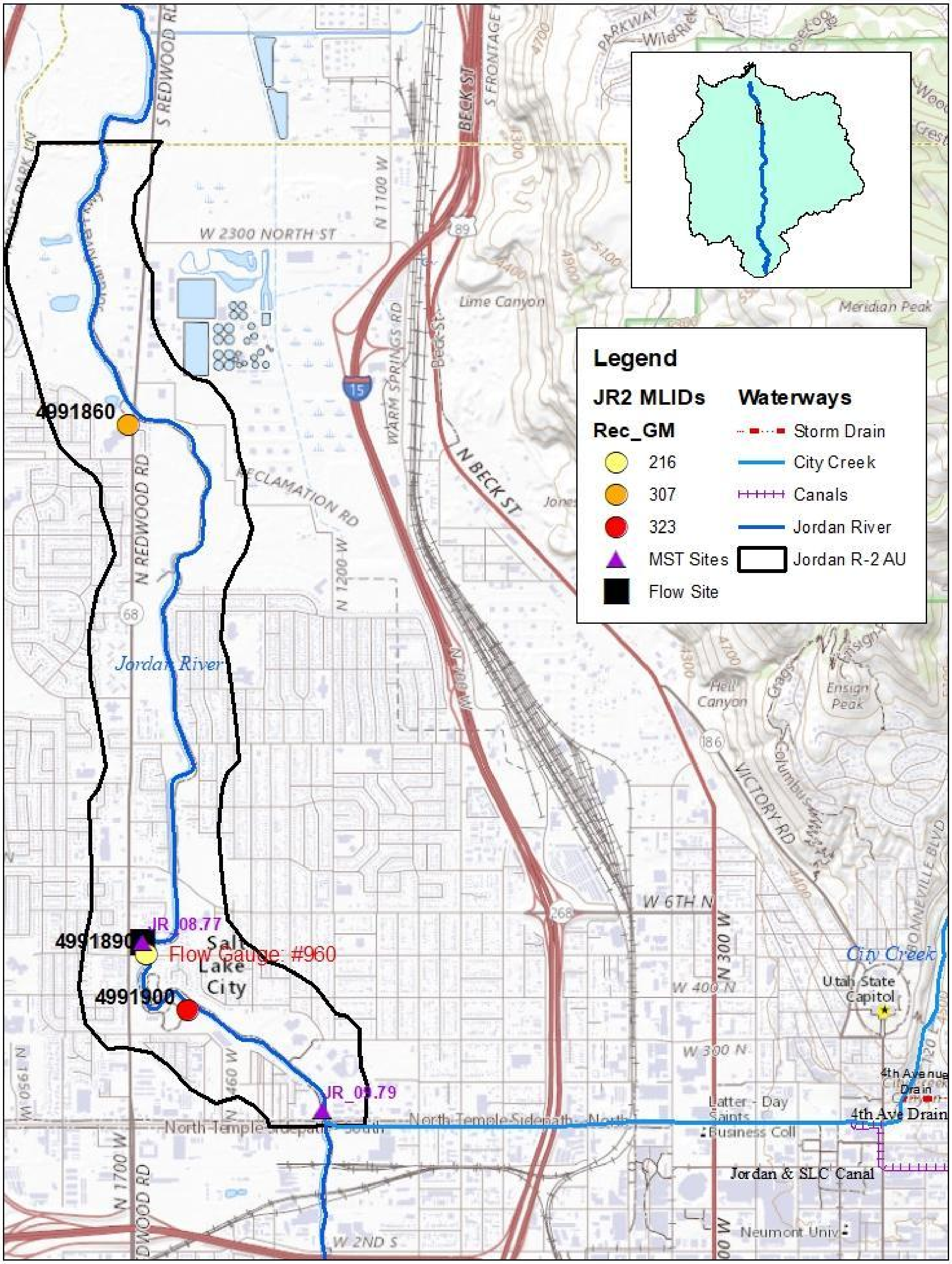

Figure I-32. Monitoring locations and hydrology of Jordan River-2 Assessment Unit.

Hydrology

The Jordan River is approximately 51 miles long, originating at Utah Lake and flowing north where it terminates in wetlands that eventually discharge to the Great Salt Lake. It is highly managed due to the regulation of discharge from Utah Lake, tributary flows, irrigation diversions, stormwater contributions, and flood control. The topography within the Jordan River watershed contributes to a very complex precipitation pattern with great variability in the amounts and timing of flows. Although Utah Lake is the single largest source of flows to the Jordan River, much of this water is diverted at the Jordan River Narrows for agricultural and municipal use via canals serving the east and west sides of the valley. The releases and diversions occur primarily during the irrigation season (April 15–October 15). Flows from the Jordan River's seven major eastside and three minor westside tributaries are also subject to a complex network of diversions, return flows from canals, stormwater discharge, and exchange agreements between culinary and agricultural users.

The lower Jordan River begins downstream of the largest diversion, the Surplus Canal, which redirects up to 90% of the flow from the Jordan River directly to the Great Salt Lake to protect neighborhoods and developments from flooding. More information on the complex hydrology of the Jordan River is found in the Lower Jordan River Dissolved Oxygen TMDL and Salt Lake County's Watershed Plans (2009 and 2015).

Jordan River's hydrology has been impacted by several hydrologic modifications. Though the main channel is fully open (not piped), 13% of the stream channel has been engineered (SLCo 2009). Figure I-32 shows the inputs and outputs of the Jordan River system within the Jordan River-2 AU boundary. The mean daily flow at the Salt Lake County Gauge #960 (Jordan River at 500 North), is 184 cubic feet per second (cfs) during the TMDL period of record (2011–2021), with a maximum daily mean of 616 cfs (Table I-14).

Inputs into the Jordan River within the Jordan River-2 AU include upstream flows on the Jordan River and tributary flow from the City Creek drainage on the east (Figure I-32). City Creek is joined by the 4th Avenue storm drain and diverted irrigation water from the Jordan and Salt Lake City Canal and then piped 2.4 miles to the Jordan River at the southern AU boundary. There are no inputs from the west side. Note that City Creek is not impaired for *E. coli* based on the 2022 Integrated Report.

Land Use

According to the 2019 National Land Cover Dataset (NLCD), 95% of the land in the Jordan River-2 AU is developed (Figure I-33). Cultivated land cover (pasture and crops) makes up

3.8% of the AU, natural land cover (forest, grassland, wetlands, shrubland, and barren) is 1.45%, and open water is 0.08%. Most of the riparian buffers along the main stem of Jordan River-2 are characterized by developed/urban and cultivated land use. There are no major agricultural operations within this AU; however, the cultivated lands percentage includes open space. The urban land cover is primarily residential and industrial.

Approximately 44% of the AU is covered by impervious surfaces due to developed land use . This level of impervious surface leads to increased runoff, which results in increased loading of pollutants, including *E. coli*. Population growth is predicted to increase in the entire Jordan River corridor by 30% in 2040 (SLCo 2017), which will likely result in an increase in impervious surfaces in this AU. See Section 5.3.1 in the main report for more information on the effects of impervious surfaces on pollutant loading.

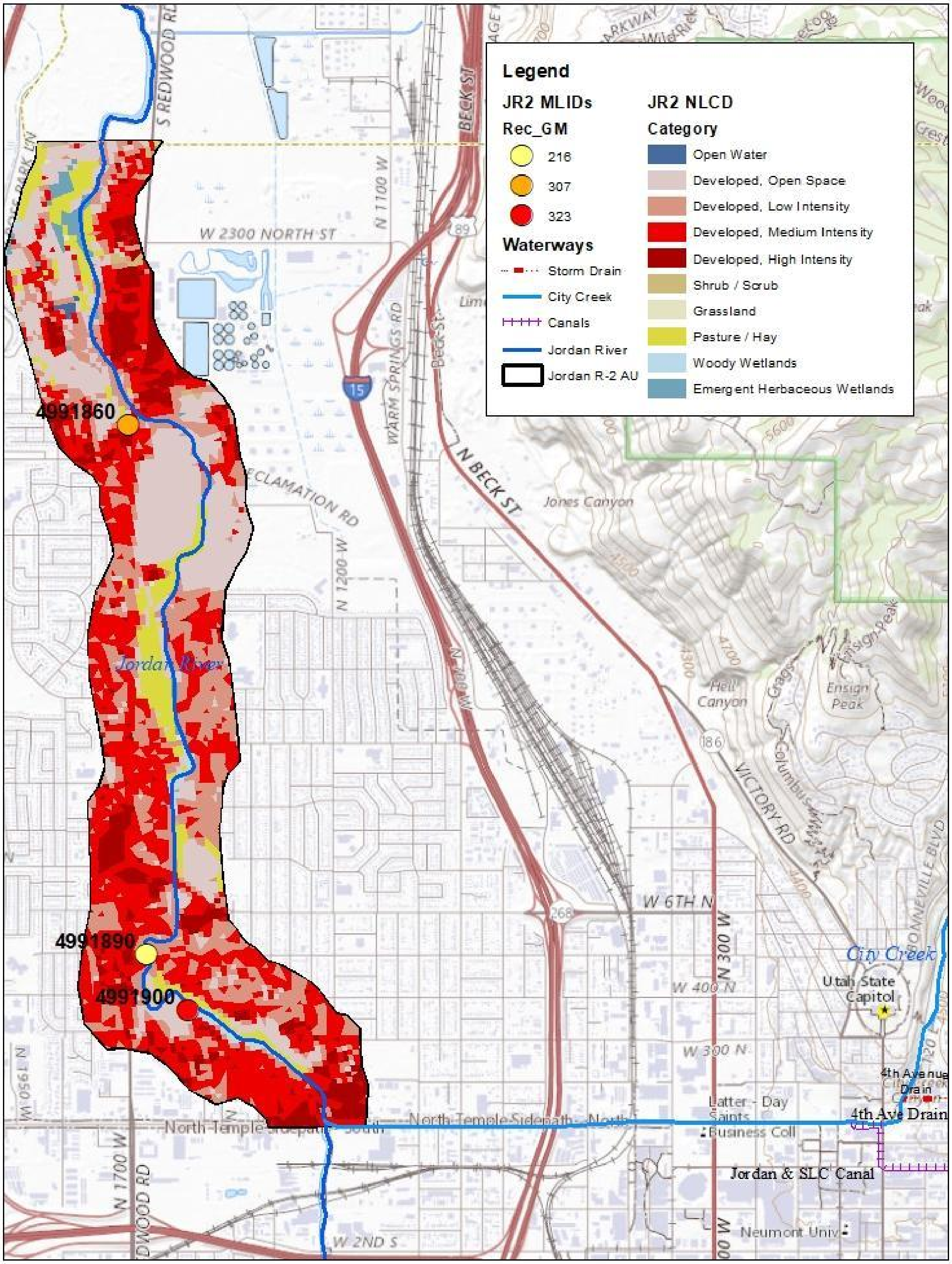

Figure I-33. Land cover in Jordan River-2 Assessment Unit (2019).

E. coli Data Summary

Three routine monitoring locations on Jordan River-2 were studied for spatial and temporal patterns of *E. coli* levels (Table I-13). Samples were collected year-round at the middle site Jordan River at 500 North (4991890), while the upstream Jordan River at 300 North (4991900) and downstream Jordan River at Redwood Road Xing (4991860) sites were sampled only during the recreation season. Note that all three monitoring locations are downstream of the City Creek confluence (Figure I-32). At each site, the overall geometric mean *E. coli* concentration across all samples collected exceeded the standard, and one sample at Jordan River at 500 North (4991890) exceeded the maximum reporting limit (Table I-13).

There were no clear upstream to downstream patterns, but the middle site, Jordan River at 500 North (4991890), was sampled more frequently between 2009 and 2021 than the other two sites and had a lower overall percent exceedance (39% exceeded the standard at 4991890, versus 64% at 4991860 and 73% at 4991900) (Figure I-34). Additionally, the number of samples exceeding the standard was generally consistent through time across sites, indicating a steady source of *E. coli* over the period sampled (Figure I-35). Monthly *E. coli* geometric mean concentrations at all three sites were elevated in the recreation season months, particularly July–September (Figure I-36). However, a large number of recreation season samples at Jordan River at 500 North (4991890) did not exceed the standard, pulling the monthly geometric mean values closer to 206 MPN/100 mL compared to the other two sites.

Table I-13. Jordan River-2 Assessment Unit *E. coli* data summary all year.

Site ID (DWQ / SLCo)	Name	2022 IR Assessment	Date Range	Sample Size	Min	Overall Geomean	Rec Season Geomean	Max	% of samples exceeding 206 MPN/100 mL	% of samples exceeding 668 MPN/100 mL
4991860	Jordan River 1800 N Xing Redwood Road BDG	NA	05/2010 to 09/2012	11	102	307	307	816	64	18
4991890 /JR_08.77	Jordan River at 500 North Xing	NA	05/2009 to 10/2021	94	19	161	216	2,420*	39	9
4991900	Jordan River at 300 North	NA	05/2010 to 09/2018	11	63	323	323	1,120	73	18

*Too numerous to count; exceeds maximum reporting limit of 2,419.6 MPN/100 mL

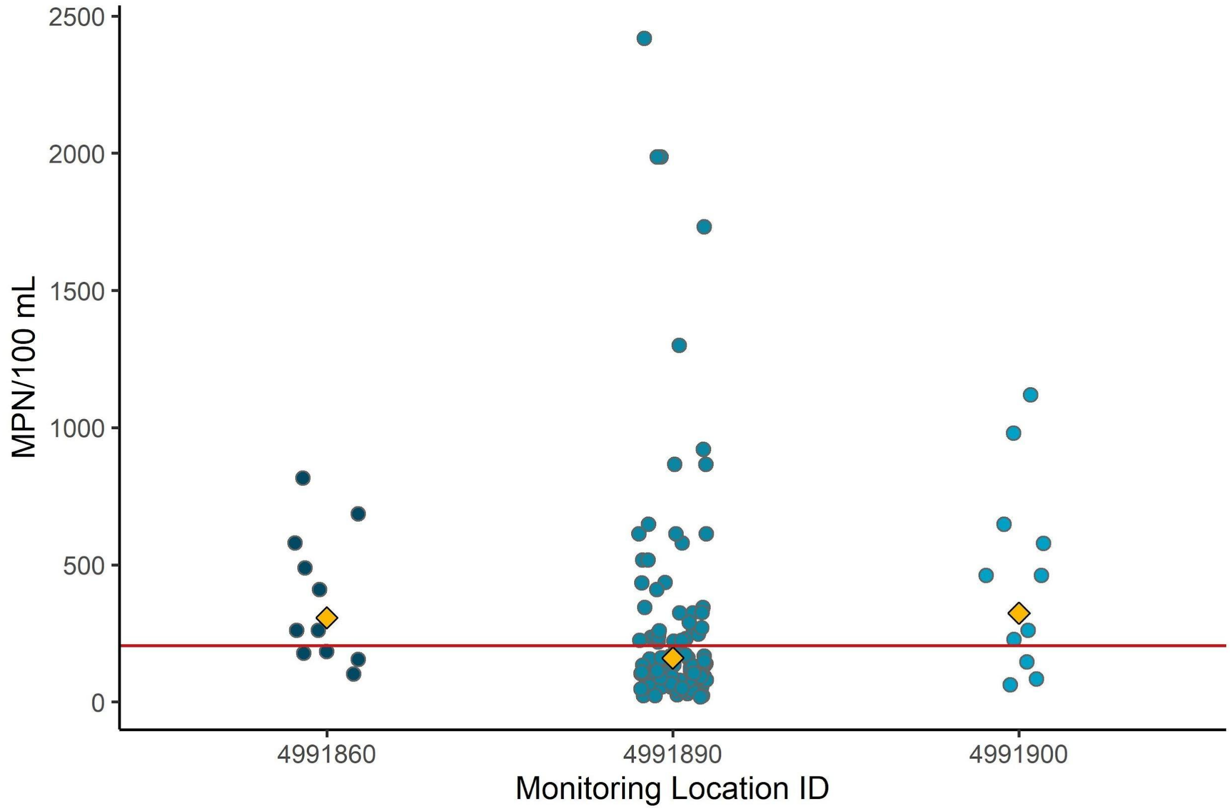

Figure I-34. *E. coli* concentrations at each routine monitoring location, organized from downstream (left) to upstream (right) in Jordan River-2 Assessment Unit. Concentration points are "jittered", meaning that they are randomly spread out along the x axis to reduce point overlap for easier viewing. Yellow diamonds indicate the overall geometric mean for each site. The red line denotes the geometric mean criterion of 206 MPN/100 mL.

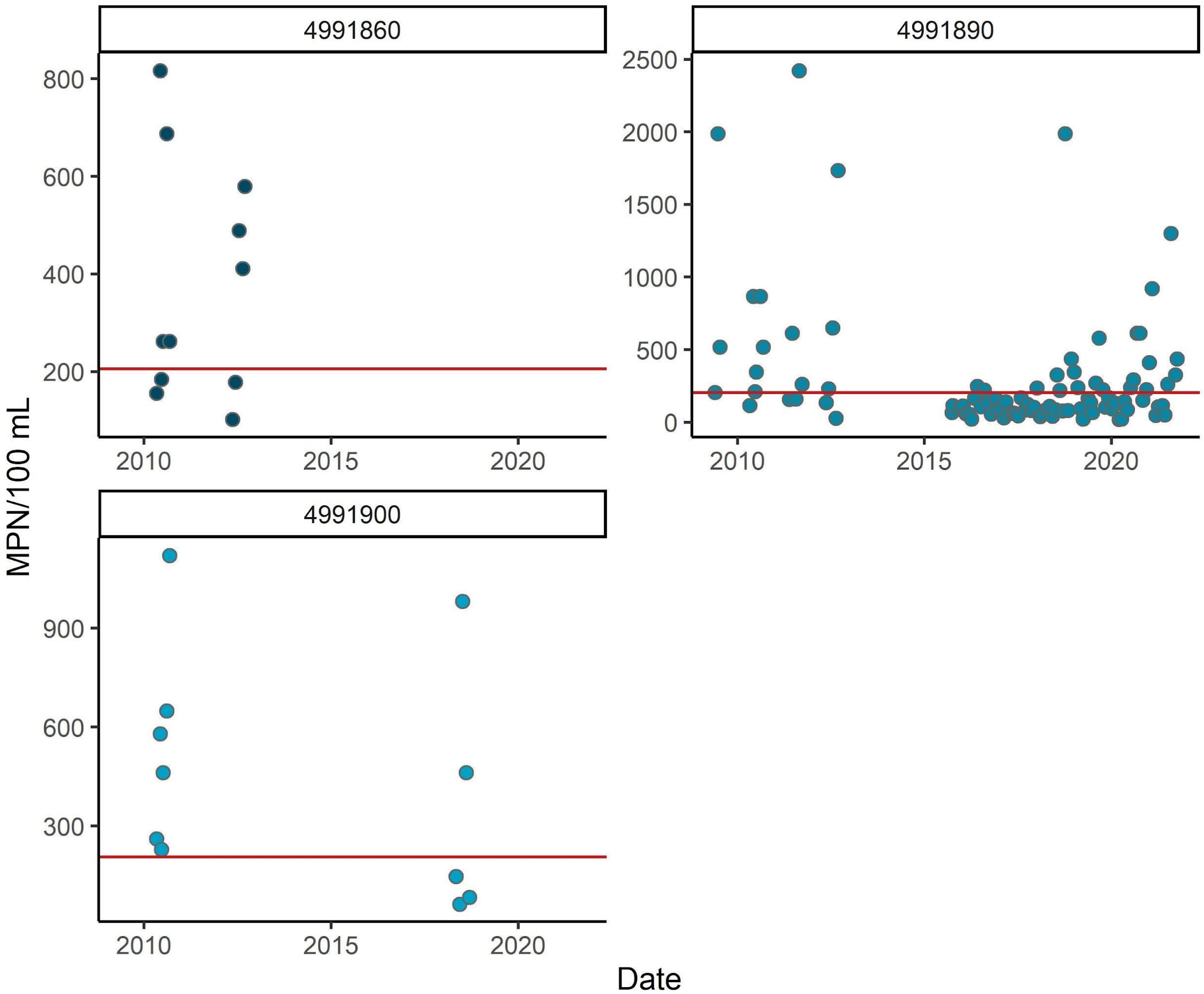

Figure I-35. *E. coli* concentrations at each routine monitoring location through time within the Jordan River-2 Assessment Unit. The red line denotes the geometric mean criterion of 206 MPN/100 mL. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

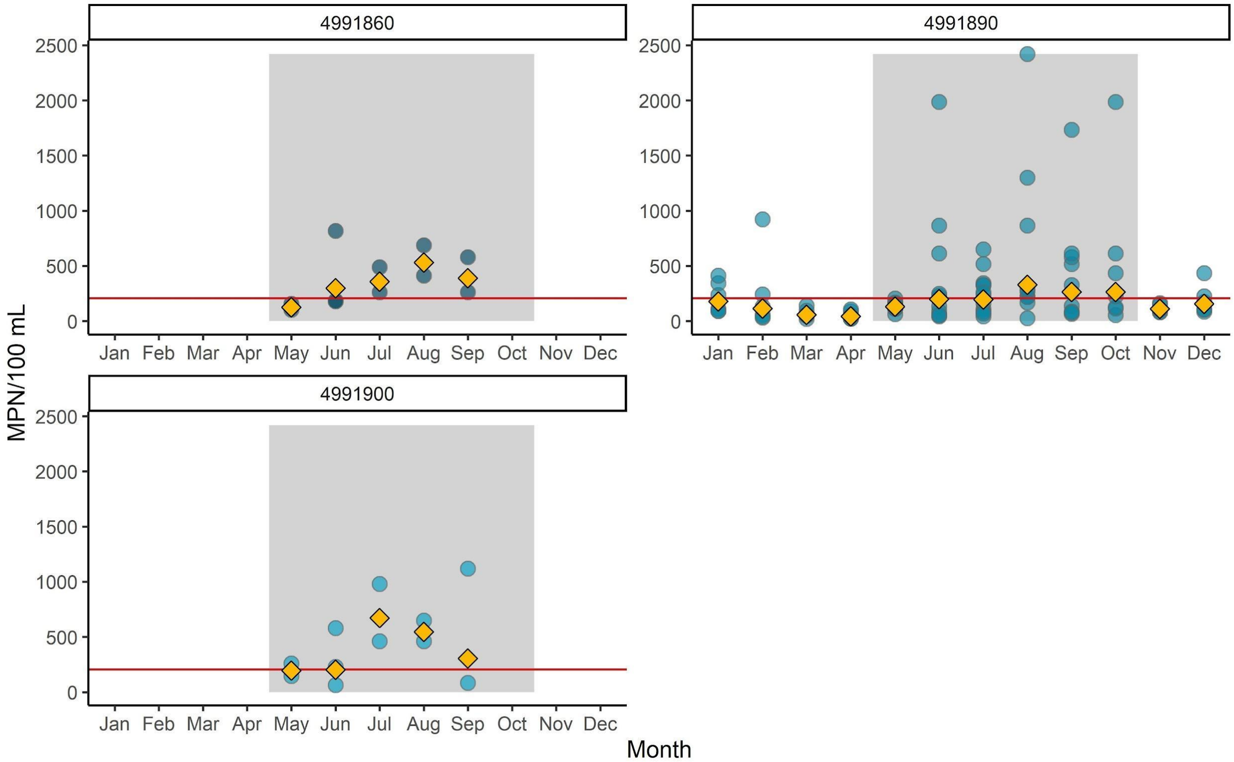

Figure I-36. *E. coli* concentrations at each routine monitoring location, grouped by the month in which they were collected. Each circular point represents a daily geometric mean. Yellow diamonds show the overall geometric mean for each site by month. The red line denotes the geometric mean criterion of 206 MPN/100 mL. The gray shading indicates the recreation season. Sites are ordered downstream (upper left panel) to upstream (lower right panel).

Potential Sources

A variety of tools were used as multiple lines of evidence to assess potential sources of *E. coli* in this AU, including load duration curves (LDC), microbial source tracking (MST), data analysis, land-use patterns, and hydrologic information. Potential sources and recommended implementation strategies to address the source are discussed in the main report in Chapter 5 and Chapter 7.

Load Duration Curves

Load duration curves are typically used in TMDLs to determine the loading capacity of the stream. Since this TMDL is concentration-based rather than load-based, LDCs are used to determine probable sources based on the correlation between water quality exceedances and flow regimes. Table 7 in Section 5.3.2 of the main report illustrates the relationships

between hydrologic flow regimes and the probability of contribution from possible sources (EPA 2007).

LDCs require both observed *E. coli* concentrations and measured (or instantaneous) flow data to plot the load capacity curve. Salt Lake County operates a continuous flow gauge at [Jordan River at 500 North, Gauge #960](). This site corresponds to an *E. coli* monitoring station, Jordan River at 500 North (4991890). Flow data during the TMDL period of record (January 2011–September 2021) is summarized in Table I-14, Figure I-37, and Figure I-38. The daily mean flows are higher during June and July, which corresponds to the agreed-upon release schedule from Utah Lake as opposed to snowmelt and spring runoff. Flow decreases in the late summer mainly due to upstream water diversions and general baseflow conditions, which return in the warmer months. Jordan River's flow within the Jordan River-2 AU is not a typical hydrograph, but one of a complex managed system.

Table I-14. Summary statistics for Jordan River at 500 North, Gauge #960 (4991890).

Gauge Name	SLCO Gauge Number/DWQ MLID	Drainage Area (mi^2)	Mean Flow (cfs)	Maximum Flow (cfs)
Jordan River at 500 North	960/4991890	3562	184	616

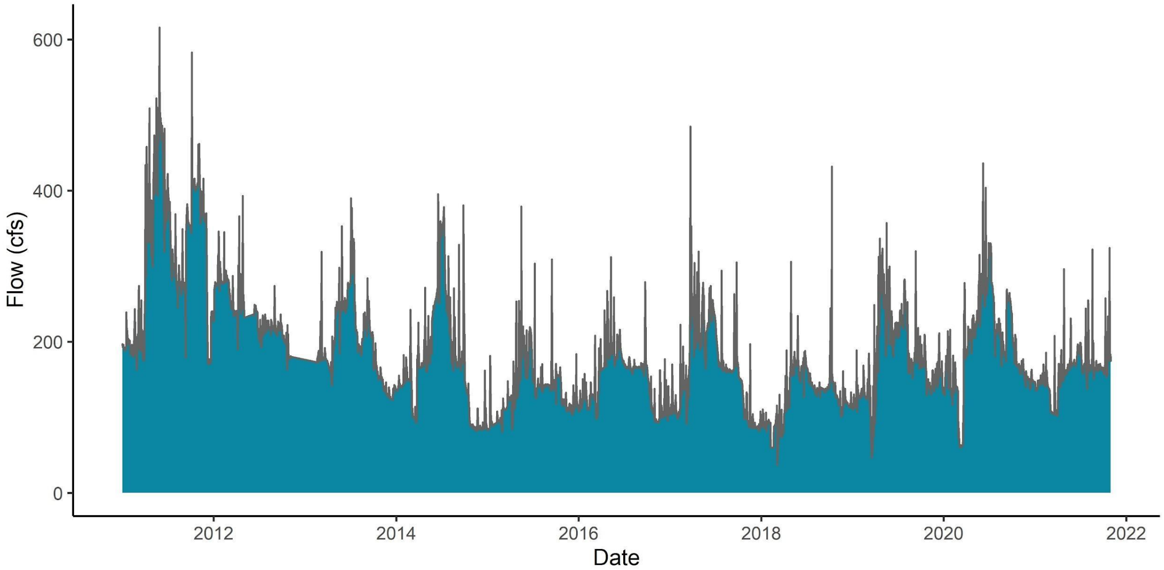

Figure I-37. Daily means flows at Salt Lake County Gauge #960, Jordan River at 500 North (4991890) from January 1, 2011, to September 30, 2021.

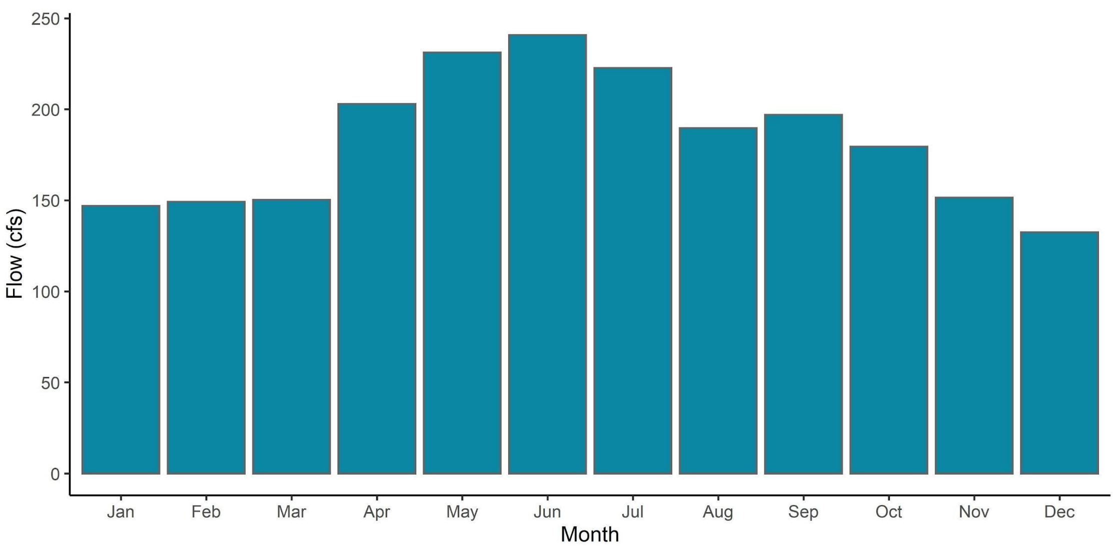

Figure I-38. Monthly means flows (cfs) at Salt Lake County Gauge #960, Jordan River at 500 North (4991890) from January 1, 2011, to September 30, 2021.

Using this site's corresponding *E. coli* and flow data, the LDC shows exceedances occurring at all flow regimes (Figure I-39). Exceedances of the TMDL threshold (solid line) in high to low-flow conditions indicate the potential for multiple sources of *E. coli* in the AU. These sources include point sources (low-flow conditions), onsite septic systems (dry conditions), and riparian areas and impervious stormwater sources (mid-range flows). Upland stormwater and bank erosion are likely sources during the high flow conditions. The percentage of *E. coli* loading measurements exceeding the TMDL in each flow regime is provided in parentheses under each flow-regime label in Figure I-39. Though the higher flow regimes require the most reduction, exceedances in all flow regimes indicate that the Jordan River-2 AU has both point and nonpoint source delivery methods of *E. coli* loading.

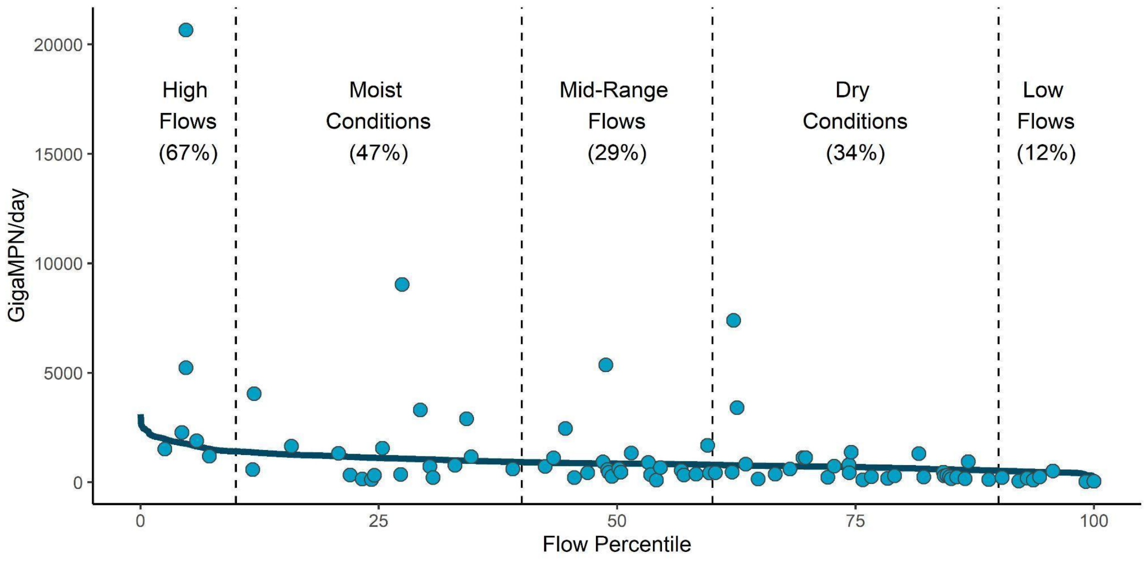

Figure I-39. Load duration curve for Jordan River at 500 North (4991890).

Microbial Source Tracking

Samples were collected once a month at two locations during July, August, and September in 2018, resulting in three samples per site and a total of six samples collected (Figure I-40). Only human and avian markers were detected at the two sampling locations in the AU. When the presence or absence of each marker was considered across all locations, human was the most common at 100%, meaning of the six samples collected, all of them were positive for the human marker. The avian marker was present at 67%. Canine and ruminant markers were not detected in any of the samples. This same pattern of presence or absence occurred even when each site was examined individually, highlighting the need to focus on controlling both human and avian sources in this AU.

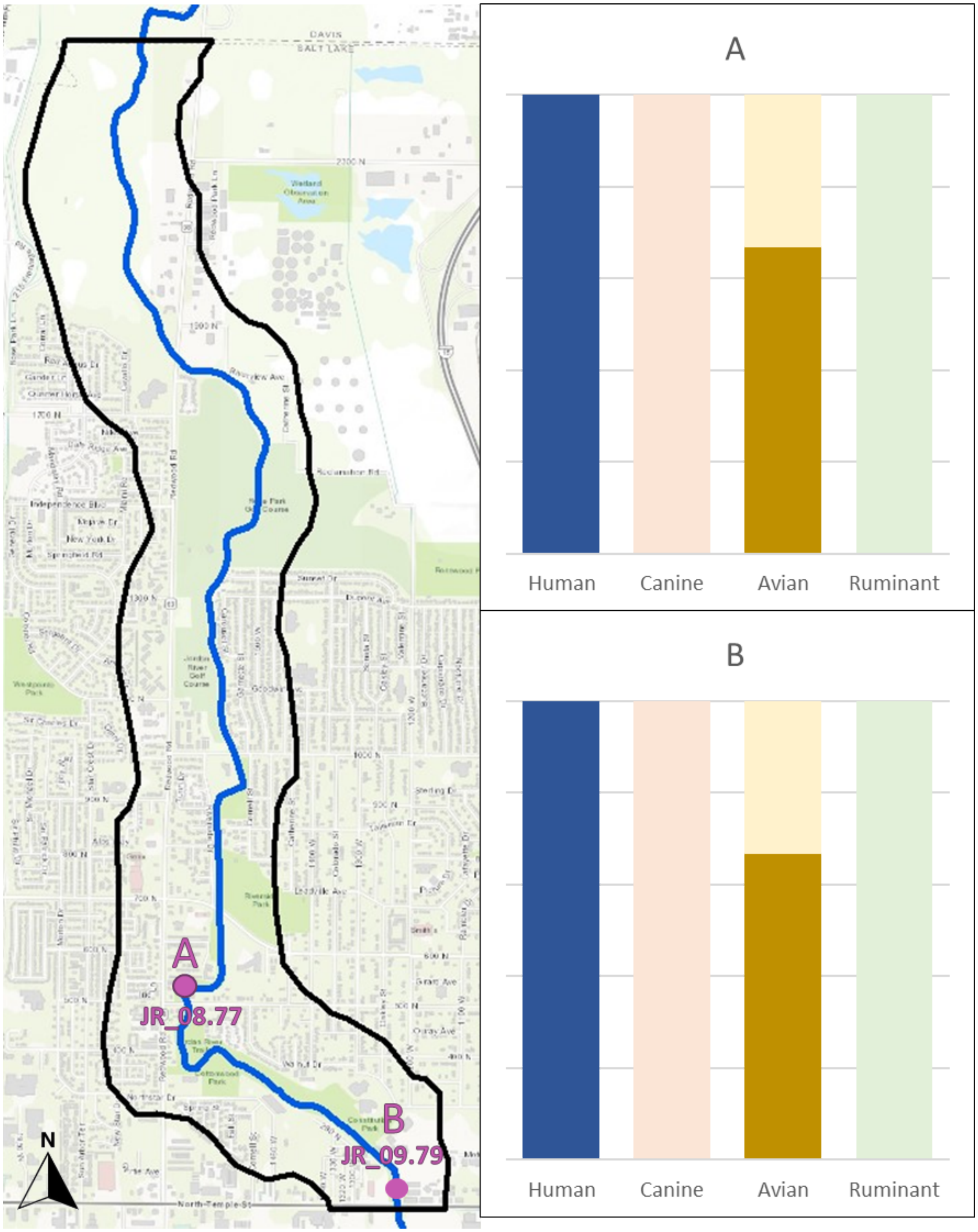

Figure I-40. The proportion of presence and absence of the four MST markers at each sampling location. The darker shades of color indicate presence and the lighter shades absence.

Source Assessment

Based on the data analysis, LDC analysis, land-use patterns and hydrology, the probable sources of *E. coli* in the Jordan River-2 AU come from point sources, most notably stormwater runoff. Nonpoint sources include water (irrigation) conveyance systems, avian wildlife, domestic pets, wildlife/nuisance species, and recreationists/unhoused. Jordan River-2 AU is the most downstream *E. coli*-impaired assessment unit within the Jordan River watershed. Significant sources of *E. coli* loading exist upstream in the main stem or tributaries. Addressing these sources, as outlined in the previous appendices, will aid in the reduction of *E. coli* concentration within the Jordan River-2 AU. The following source assessment primarily focuses on potential sources specific to this AU.

Table I-15 provides a list of specific potential point and nonpoint sources in the Jordan River-2 AU. Suggested BMPs for implementation by source are provided in Table 8 and Table 9 in the main report. Please see Chapter 5.1 and 5.2 for more information on each potential source.

Table I-15. Potential sources of *E. coli* contamination in Jordan River-2 Assessment Unit (as of March 1, 2022).

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	Suggested BMPs
Point source	Construction stormwater	Yes	UTRC00000 UTRH00000	Section 5.1.1	Table 9
	Industrial stormwater	No			
	Municipal (MS4) stormwater	Yes Jordan Valley municipalities, including Cottonwood Heights, Holladay, Murray, Millcreek, and Salt Lake County	UTS000001		
		Utah Department of Transportation	UTS000003		
		Salt Lake City	UTS000002		
Nonpoint source	Onsite septic systems	No			Table 8
	Agricultural: livestock	No			
	Agricultural: canals	Yes		Section 5.2.2	
	Domestic pets	Yes		Section 5.2.3	
	Wildlife/ nuisance species	Yes		Section 5.2.4	

Source Type	Permit Type	Present Permittee	UPDES Permit #	Source Information	Suggested BMPs
	Recreationists /unhoused	Yes		Section 5.2.5 Section 5.2.6	

Point Sources

While there are several Utah Pollutant Discharge Elimination System (UPDES) permitted discharges within Jordan River-2 Assessment Unit, municipal stormwater is the likely source of *E. coli* in this AU (Figure I-41). This conclusion is based on the multiple lines of evidence identifying sources in the AU including the LDC that pointed to point sources during low-flow regimes, urbanized land uses and increased impervious surfaces in the valley, and the low likelihood of *E. coli* contributions from industrial and construction stormwater. Please see Chapter 5.1 in the main report for more information.

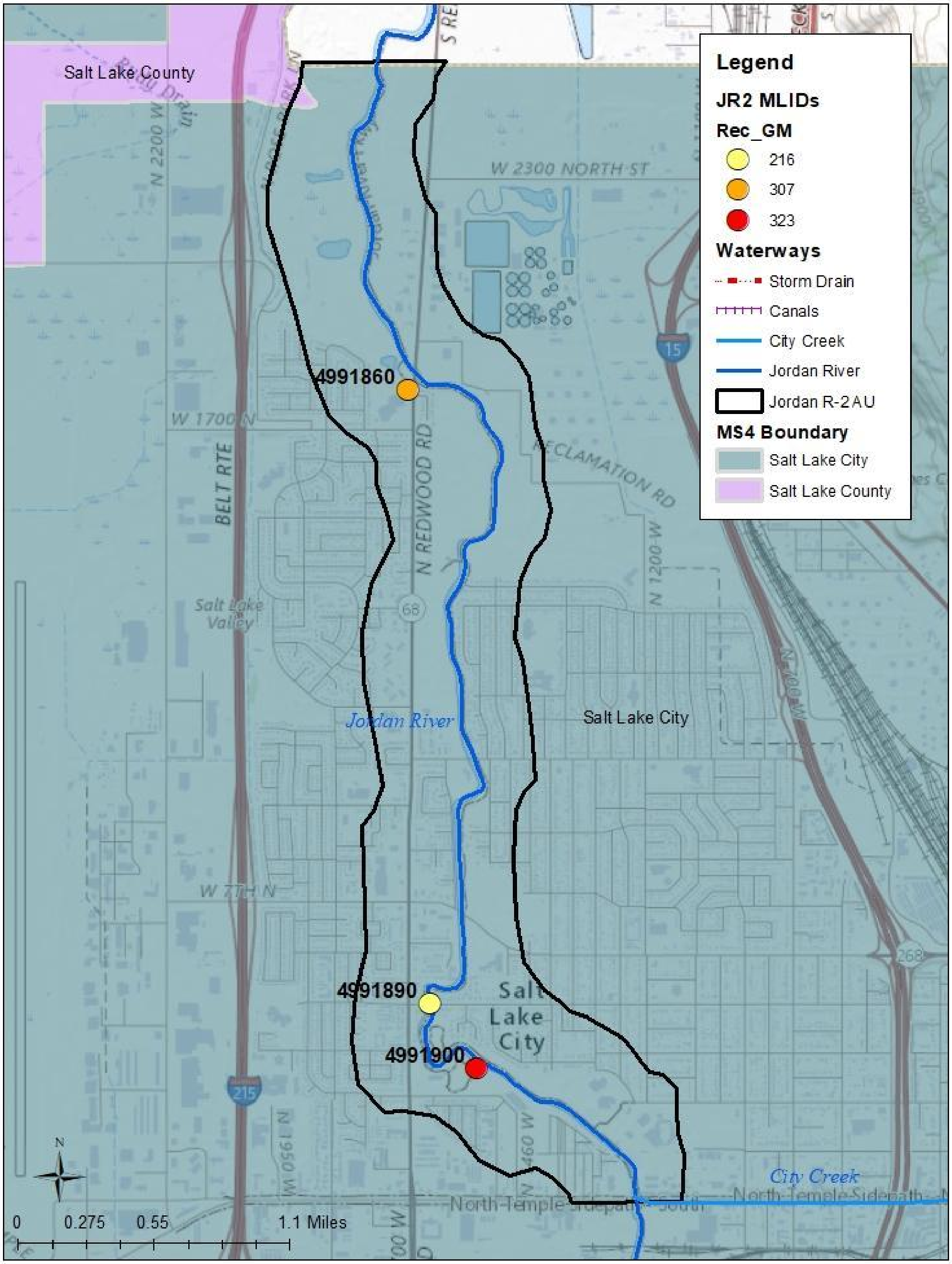

Figure I-41. Possible point sources of *E. coli* contamination within Jordan River-2 Assessment Unit.

Stormwater

Two potential sources of stormwater pollution (construction activities and MS4s) occur within the Jordan River-2 AU. Specific permits and activities are detailed below.

Construction and Industrial Stormwater

As of March 1, 2022, there were five construction UPDES stormwater permits in this AU. There are no industrial stormwater permits. Construction permits are short-lived and change over time. See Chapter 5.1 in the main report for more information regarding construction and industrial stormwater sources.

Municipal Separate Storm Sewer Systems (MS4s)

DWQ addresses municipal stormwater within the Jordan River-2 AU by issuing MS4s permits to the corresponding municipalities whose stormwater [eventually] discharges into the main stem of the Jordan River. There are three MS4 permits—Jordan Valley Municipalities, Salt Lake City, and Utah Department of Transportation—applicable to this AU (Figure I-41). The Jordan Valley Municipalities MS4 permit is a comprehensive permit covering many municipalities within the Jordan River watershed. Salt Lake County is the only permittee that has the jurisdictional boundaries within the AU, albeit a small portion. Salt Lake City's MS4 permit allows for discharge of stormwater within its jurisdictional boundaries. The Utah Department of Transportation (UDOT) MS4 permit allows for discharge into Utah waters from existing outfalls of the drainage system operated by UDOT across the state. UDOT's Region 2 geographical area covers the Wasatch Front.

All MS4 permittees will be required to implement additional BMPs beyond the standard six minimum control measures currently required in their permit. While water quality monitoring for BMP effectiveness is not necessary, permittees will be required to provide a list of the BMPs identified and prioritized in the TMDL Compliance Plan required by their MS4 permit. Each permittee will also be required to show how they are in compliance with the *E. coli* reduction requirements of this TMDL in a TMDL Compliance Report that will be submitted with their annual report. Refer to Chapter 5.1 in the main report for more information on MS4s and Table 8 on suggested BMPs.

Nonpoint Sources

Potential contributors of *E. coli* pollution from nonpoint sources within the Jordan River-2 AU include humans, wildlife, and dogs (Figure I-42). Since there is no agriculture (livestock and pasture) activity within this AU, this is not considered to be a source. Cultivated land uses include parks and golf courses. According to the Salt Lake County's Assessor's Office, there are no onsite septic system parcels within this AU as of 2021. All parcels are sewered, and no large underground wastewater disposal systems lie within AU boundary. Please see Chapter 5.2 in the main report for more information on nonpoint sources.

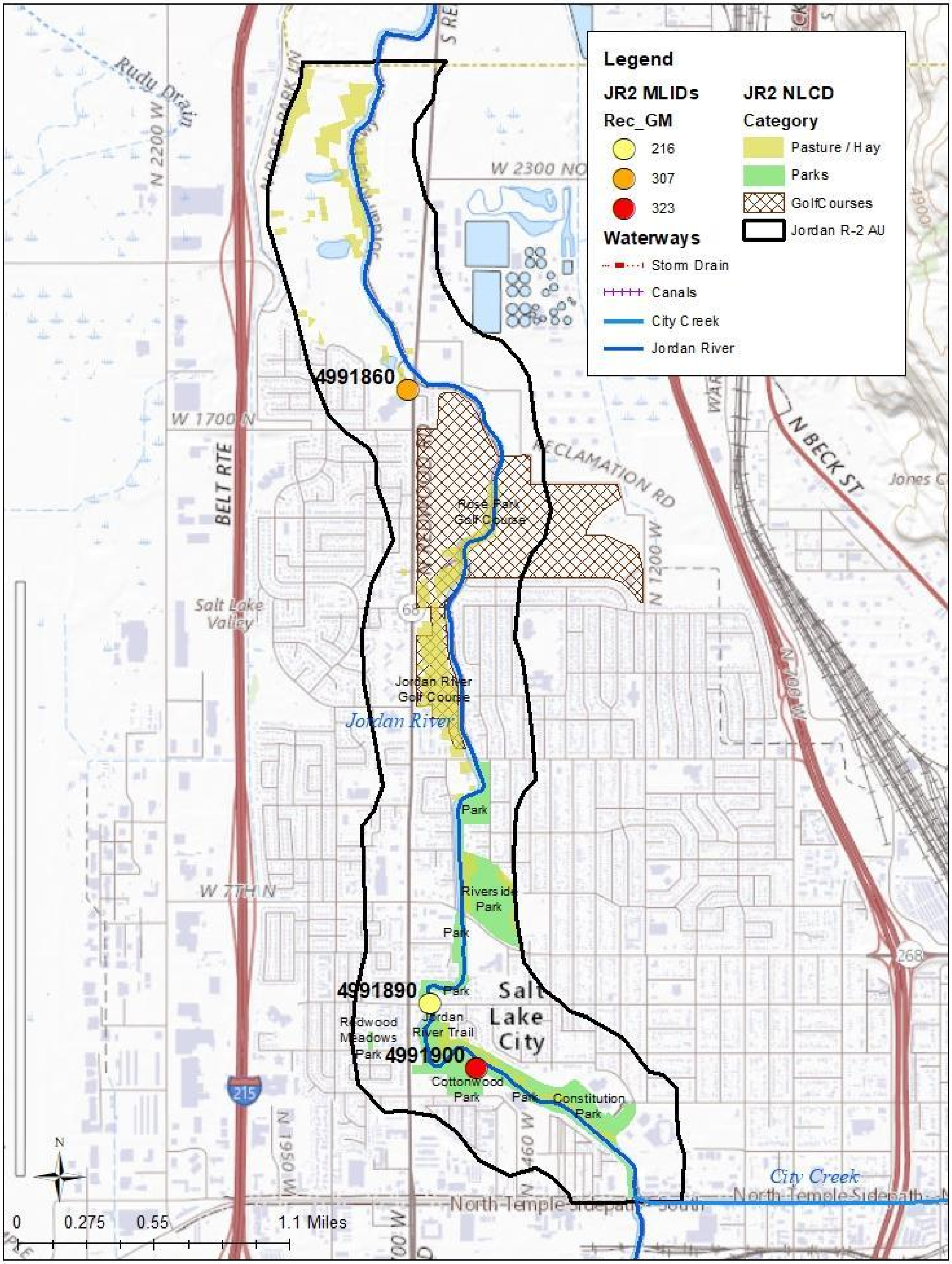

Figure I-42. Possible nonpoint sources of E. coli contamination in Jordan River-2 AU.

Water Conveyance Systems: Canals and Drains

Utah Lake water is diverted upstream of this AU at the Jordan River Narrows into several canals and ditches and moved through conveyance systems across the entire Jordan valley. Due to exchange agreements between Salt Lake City and the agricultural community, these diverted waters are imported into several Jordan River tributaries, including Parleys, Emigration, and Red Butte Creeks. The 4th Avenue storm drain collects stormwater runoff from the surrounding developed areas (mostly impervious surfaces) and transports it to City Creek. These exchanges could import water with elevated *E. coli* concentrations from outside the AU and deposit it during storm events or runoff from the surrounding earthen canal channel.

Recreation, Pets, and Nuisance Wildlife

The Jordan River corridor includes several parks, golf courses, nature centers, and open spaces that are highly utilized. The Jordan River Parkway is a multi-use trail that parallels a majority of the main channel and provides recreational opportunities for people and their pets. Based upon the MST results in 2018, human markers were found at both sites within the Jordan River-2 AU (Figure I-40). Figure I-36 shows most of the exceedances occur during the warmer months when baseflows are lower (Figure I-38). LDC analysis suggests that during these lower flows, discrete and localized sources are likely from the riparian areas. These could be from the parks or golf courses within the Jordan River corridor.

Possible human sources could be from both the recreationists and unhoused populations. Since this AU is located within the heart of Salt Lake City, its close proximity provides easy access for the unhouse population. It is likely that a small percentage of those who recreate or find shelter near the river do not properly dispose of human waste. While it is a challenge to quantify this behavior, improper disposal of human waste does not appear to be a problem along the main stem given the available facilities provided along the Jordan River Parkway.

Improper management of domestic pet waste is another potential source of *E. coli* contamination into waterbodies. Dog waste in the immediate vicinity of a waterway can contribute to local water quality impacts. While there are no designated off-leash dog parks within the Jordan River-2 AU boundary, dogs often accompany their owners to trails and parks. Although the MST survey conducted in 2018 did not show canine markers, proper dog waste BMPs should be employed to ensure proper pet waste management.

Wildlife could also be a source of *E. coli* loading in this assessment unit, as indicated by the presence of avian MST markers in the 2018 sampling. Transport of animal waste to surface waters is dependent on animal habitat and proximity to surface waters. Waterfowl and riparian mammals often deposit waste directly into streams, while other riparian species deposit waste in the floodplain where it can be transported to surface waters by runoff during precipitation events. Animal waste deposited in upland areas can also be transported to waterways.

Warm-blooded animals are present, especially in the more natural areas, since most of the AU borders the main stem of the Jordan River. These animals have the potential to be a source of *E. coli* pollution.

Nuisance wildlife species should be considered as a potential source of *E. coli* in this AU. MS4 permits must address nuisance wildlife species that congregate around certain stormwater control structures. Basins and ponds can attract wildlife whose waste degrades water quality. Common nuisance species include, but are not limited to, deer, waterfowl, and small mammals such as beaver and muskrats. Preventing waterfowl from congregating and limiting public feeding opportunities could reduce avian-based contamination.

LDC analysis suggests that *E. coli* likely originates from overland flow, riparian areas, and bank erosion within this AU. Addressing the riparian corridor will help filter out pollutants reaching the Jordan River. Though the monitoring locations within the Jordan River-2 are impaired, upstream sources of *E. coli* loading likely contribute to their impairment.

The Jordan River Commission recently conducted a survey to update its Blueprint Jordan River Strategic Plan, which states that water quality is one of the public's main priorities for the Jordan River corridor. *E. coli* concentrations within the river will decrease and beneficial uses will be restored if recommended BMPs as suggested in Table 8 of the main document are implemented in this AU and upstream.

TMDL

Chapter 4 of the main report details the rationale and methodology for concentration-based *E. coli* TMDLs. All sources, both point and nonpoint, within the Jordan River-2 AU must meet the following water quality criteria:

- 206 MPN/100 mL as a 30-day geometric mean,
- 206 MPN/100 mL as a recreational season geomean, and
- 668 MPN/100 mL as a daily maximum during the recreational season