

August 2026

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

Queen Creek Watershed HSPF Modeling Report

FINAL

Queen Creek Watershed Dissolved Copper and Lead TMDL



Prepared by:

lwa

LARRY WALKER
ASSOCIATES



Prepared for:



Contents

SECTION	PAGE
SECTION 1: INTRODUCTION _____	1
SECTION 2: QUEEN CREEK WATERSHED _____	4
2.1 Location and size of watershed _____	4
2.2 Climate _____	4
2.3 Slope _____	4
2.4 Land use/land cover _____	6
2.5 Soil characteristics _____	7
SECTION 3: DATA AVAILABILITY AND UTILIZATION _____	8
3.1 Digital Elevation Model _____	8
3.2 Meteorological data _____	9
3.3 Streamflow Data _____	10
3.4 Water Quality Data _____	12
3.5 Soil Chemistry Data _____	17
SECTION 4: HSPF MODEL OF QUEEN CREEK WATERSHED _____	19
4.1 Watershed Segmentation _____	20
4.2 Point Sources _____	21
4.3 Model Parameterization _____	22
4.3.1 Initial estimates from literature or guidance manuals _____	23
4.3.2 Calibrated Parameters _____	25
SECTION 5: CALIBRATION METHODOLOGY _____	26
5.1 Calibration Approach _____	26
5.2 Calibration Targets _____	27
SECTION 6: HYDROLOGIC CALIBRATION _____	27
6.1 Annual Water Balance _____	27
6.2 Storm Peaks _____	27
6.2.1 Average Storm Volume _____	29
SECTION 7: WATER QUALITY CALIBRATION _____	29
7.1 Sediment _____	29
7.2 Dissolved Copper _____	31
7.3 Dissolved Lead _____	32
7.4 Total Lead _____	33
SECTION 8: SOURCE ASSESSMENT _____	35
SECTION 9: CURRENT LOADINGS _____	38
9.1 Dissolved Copper _____	38
9.2 Total Lead _____	41

SECTION 10: LIMITATIONS AND UNCERTAINTY _____	44
SECTION 11: CONCLUSIONS AND RECOMMENDATIONS _____	45
SECTION 12: REFERENCES _____	45

APPENDICES

Appendix A. Hydrology Calibration Figures

List of Tables

Table 1 Queen Creek Watershed listed waterbodies _____	1
Table 2 Water quality data for Superior WWT 2019 through 2025 _____	13
Table 3 Available total and dissolved copper water quality data _____	15
Table 4 Available total and dissolved lead water quality data _____	16
Table 5 Available total hardness and total suspended solids data _____	17
Table 6. Point source dischargers having NPDES permits within the Queen Creek watershed. _____	21
Table 7 PERLND classes in the Queen Creek Watershed HSPF model _____	23
Table 8 Assignment of UZSN value based on slope, depression storage, and vegetation characteristics _____	24
Table 9 Precipitation and evaporation potential multipliers to PRISM nodes _____	27
Table 10 Queen Creek at Highway 60 observed vs simulated storm peak August 7 to 8, 2007 _____	28
Table 11 Average storm volume over four storms. _____	29
Figure 25. Relative lead loading to Queen Creek (15050100-014A). _____	36
Figure 26. Relative area and copper loading contribution to Queen Creek (15050100-014B). _____	36
Figure 27. Relative area and copper loading contribution to Queen Creek (15050100-014C). _____	37
Table 12. Load weighted percent contribution of in-stream dissolved copper load to the outlet of each impaired watershed. _____	38
Table 13. Cumulative load weighted percent contribution of in-stream dissolved copper load to the outlet of each impaired watershed. _____	39
Table 14. Load weighted percent contribution of in-stream total lead load to the outlet of impaired watershed (014A). _____	42
Table 15. Cumulative load weighted percent contribution of in-stream total lead load the outlet of impaired watershed (014A). _____	42
Table A-1 Queen Creek at Highway 60 observed vs simulated peak for storm #1 on August 7 to 8, 2007 _____	A-1
Table A-2 Queen Creek at Highway 60 observed vs simulated peak for storm #2 on December 1 to 2, 2007 _____	A-2
Table A-3 Queen Creek at Highway 60 observed vs simulated peak for storm #3 on December 8 to 9, 2007 _____	A-3
Table A-4 Queen Creek at Highway 60 observed vs simulated peak for storm #4 on December 11 12, 2007 _____	A-4
Table A-5 Oak Flat observed vs simulated peak for storm #1 on August 7 to 8, 2007 _____	A-5
Table A-6 Oak Flat observed vs simulated peak for storm #2 on December 1 to 2, 2007 _____	A-6
Table A-7 Oak Flat observed vs simulated peak for storm #3 on December 8 to 9, 2007 _____	A-7
Table A-8 Observed vs Simulated Peak for storm #4 on December 8 to 9, 2007 _____	A-8
Table A-9 Magma Ave observed vs simulated peak for storm #1 on August 7 to 8, 2007 _____	A-9
Table A-10 Magma Ave observed vs simulated peak for storm #2 on December 1 to 2, 2007 _____	A-10
Table A-11 Magma Ave observed vs simulated peak for storm #3 on December 8 to 9, 2007 _____	A-11
Table A-12 Magma Ave observed vs simulated peak for storm #4 on December 11 to 12, 2007 _____	A-12
Table A-13 Silver King Wash observed vs simulated peak for storm #1 on August 7 to 8, 2007 _____	A-13
Table A-14 Silver King Wash observed vs simulated peak for storm #2 on December 1 to 2, 2007 _____	A-14

Table A-15 Silver King Wash observed vs simulated peak for storm #3 on December 8 to 9, 2007	A-15
Table A-16 Silver King Wash observed vs simulated peak for storm #4 on December 11 to 12, 2007	A-16
Table A-17 Arnett Creek observed vs simulated peak for storm #1 on August 6 to 9, 2007	A-17
Table A-18 Arnett Creek observed vs simulated peak for storm #2 on December 1 to 5, 2007	A-18
Table A-19 Arnett Creek observed vs simulated peak for storm #3 on December 8 to 9, 2007	A-19
Table A-20 Arnett Creek observed vs simulated peak for storm #4 on December 11 to 12, 2007	A-20
Table A-21 Potts Canyon observed vs simulated peak for storm #1 on August 6 to 10, 2007	A-21
Table A-22 Potts Canyon observed vs simulated peak for storm #2 on November 30 to December 4, 2007	A-22
Table A-23 Potts Canyon observed vs simulated peak for storm #3 on December 7 to 10, 2007	A-23
Table A-24 Potts Canyon observed vs simulated peak for storm #4 on December 11 to 13, 2007	A-24

List of Figures

Figure 1 303(d) Listed waterbodies in the Queen Creek Watershed	2
Figure 2 Land slopes in the Queen Creek Watershed	6
Figure 3 Land use within the Queen Creek Watershed	7
Figure 4 SSURGO distribution of soil types and mined land	8
Figure 5 PRISM coverage in the watershed at 6,400 m resolution	9
Figure 6 Precipitation gauges, NLDAS nodes, and PRISM nodes	10
Figure 7 Offset in Mary Drive gauge streamflow data during August of 2007	11
Figure 8 Available stream flow gauges	12
Figure 9 Water quality monitoring sites on HSPF reaches in the Queen Creek Watershed	14
Figure 10 Soil copper measurement in the Queen Creek Watershed	18
Figure 11 Soil lead measurement in the Queen Creek Watershed	19
Figure 12 Queen Creek Watershed subbasins and reaches	20
Figure 13. Locations of NPDES permitted discharges within the Queen Creek watershed.	22
Figure 14 Upper zone storage (UZSN) estimates as a percent of lower zone storage (LZSN)	25
Figure 15 Observed and simulated streamflow in Queen Creek at Highway 60, precipitation measured at Omya gauge and disaggregated PRISM node 9 precipitation for storm #1 on August 7 to 8, 2007	28
Figure 16 Scatterplot of observed and simulated sediment concentrations for all subbasins with observations.	30
Figure 17 Hydrograph of simulated and observed sediment concentrations for subbasin 260.	30
Figure 18 Scatterplot of observed and simulated dissolved copper concentrations for all subbasins with observations.	31
Figure 19 Hydrograph of simulated and observed dissolved copper concentrations for subbasin 243.	32
Figure 20 Scatterplot of observed and simulated dissolved lead for all subbasins with observations.	33
Figure 21 Hydrograph of simulated and observed dissolved lead concentrations for subbasin 243.	33
Figure 22 Scatterplot of observed and simulated total lead for all subbasins with observations.	34
Figure 23 Hydrograph of simulated and observed total lead concentrations for subbasin 243.	34
Figure 24. Relative area and copper loading contribution to Queen Creek (15050100-014A).	35
Figure 25. Relative lead loading to Queen Creek (15050100-014A).	36
Figure 26. Relative area and copper loading contribution to Queen Creek (15050100-014B).	36

Figure 27. Relative area and copper loading contribution to Queen Creek (15050100-014C).	37
Figure 28. Relative area and copper loading contribution to Arnett Creek (15050100-1818).	37
Figure 29. HSPF-modeled dissolved copper daily load (mg/d) for the Queen Creek watershed. Value represents 95 th percentile from distribution of daily values for 2021-2025.	40
Figure 30. HSPF-modeled dissolved copper concentration (µg/L) for the Queen Creek watershed. Value represents 95 th percentile from distribution of daily values for 2021-2025.	41
Figure 31. HSPF-modeled total lead daily load (mg/d) for the Queen Creek watershed. Value represents 95 th percentile from distribution of daily values for 2021-2025.	43
Figure 32. HSPF-modeled total lead concentration (µg/L) for the Queen Creek watershed. Value represents 95 th percentile from distribution of daily values for 2021-2025.	44
Figure A-1 Observed and simulated streamflow in Queen Creek at Highway 60, precipitation measured at Omya gauge and disaggregated PRISM node 9 precipitation for storm #1 on August 7 to 8, 2007	A-1
Figure A-2 Observed and simulated streamflow in Queen Creek at HW 60, precipitation measured at Omya gauge and disaggregated PRISM node 9 precipitation for storm #2 on December 1 to 2, 2007	A-2
Figure A-3 Observed and simulated streamflow in Queen Creek at HW 60, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #3 on December 8 to 9, 2007	A-3
Figure A-4 Observed and simulated streamflow in Queen Creek at HW 60, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #4 on December 11 to 12, 2007	A-4
Figure A-5 Observed and simulated streamflow in Oak Flat, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #1 on August 7 to 8, 2007	A-5
Figure A-6 Observed and simulated streamflow in Oak Flat, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #2 on December 1 to 2, 2007	A-6
Figure A-7 Observed and simulated streamflow in Oak Flat, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #3 on December 8 to 9, 2007	A-7
Figure A-8 Observed and simulated streamflow in Oak Flat, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #4 on December 11 to 12, 2007	A-8
Figure A-9 Observed and simulated streamflow in Magma Ave, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #1 on August 7 to 8, 2007	A-9
Figure A-10 Observed and simulated streamflow in Magma Ave, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #2 on December 1 to 2, 2007	A-10
Figure A-11 Observed and simulated streamflow in Magma Ave, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #3 on December 8 to 9, 2007	A-11
Figure A-12 Observed and simulated streamflow in Magma Ave, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #4 on December 11 to 12, 2007	A-12
Figure A-13 Observed and simulated streamflow in Silver King Wash, precipitation measured at Boyce gauge and disaggregated PRISM precipitation at nodes 6 and 9 for storm #1 on August 7 to 8, 2007	A-13
Figure A-14 Observed and simulated streamflow in Silver King Wash, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 6 and 9 for storm #2 on December 1 to 2, 2007	A-14
Figure A-15 Observed and simulated streamflow in Silver King Wash, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 6 and 9 for storm #3 on December 8 to 9, 2007	A-15
Figure A-16 Observed and simulated streamflow in Silver King Wash, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 6 and 9 for storm #4 on December 11 to 12, 2007	A-16

Figure A-17 Observed and simulated streamflow in Arnett Creek, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 7, 8, and 10 for storm #1 on August 6 to 9, 2007 _____	A-17
Figure A-18 Observed and simulated streamflow in Arnett Creek, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 7, 8, and 10 for storm #2 on December 1 to 5, 2007 _____	A-18
Figure A-19 Observed and simulated streamflow in Arnett Creek, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 7, 8, and 10 for storm #3 on December 8 to 9, 2007 _____	A-19
Figure A-20 Observed and simulated streamflow in Arnett Creek, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 7, 8, and 10 for storm #4 on December 10 to 14, 2007 _____	A-20
Figure A-21 Observed and simulated streamflow in Potts Canyon, precipitation measured at Omya and Boyce gauges, and disaggregated PRISM precipitation at nodes 3, 5, and 6 for storm #1 on August 6 to 10, 2007 _____	A-21
Figure A-22 Observed and simulated streamflow in Potts Canyon, precipitation measured at Omya and Boyce gauges, and disaggregated PRISM precipitation at nodes 3, 5, and 6 for storm #2 on November 30 to December 4, 2007 _____	A-22
Figure A-23 Observed and simulated streamflow in Potts Canyon, precipitation measured at Omya and Boyce gauges, and disaggregated PRISM precipitation at nodes 3, 5, and 6 for storm #3 on December 7 to 10, 2007 _____	A-23
Figure A-24 Observed and simulated streamflow in Potts Canyon, precipitation measured at Omya gauge and disaggregated PRISM precipitation at nodes 3, 5, and 6 for storm #4 on December 11 to 13, 2007 _____	A-24

SECTION 1:INTRODUCTION

A Hydrologic Simulation Program – FORTRAN (HSPF) model for hydrology and water quality is developed for decision support of the development of a TMDL for dissolved copper and lead in the Queen Creek Watershed located in Pinal County, Arizona. The Queen Creek watershed has a long history of mining with numerous abandoned/inactive mines, historic smelter operations, and mineral prospects. The current 303(d) List includes three reaches of Queen Creek, an Unnamed Tributary, and Arnett Creek as impaired for exceedances of the dissolved copper surface water quality standards for aquatic life. Additionally, the upper reach of Queen Creek is listed as impaired for total lead exceeding the body contact water quality standard. Specific impairments in the watershed are listed in **Table 1**. The listed waterbodies are shown in **Figure 1**.

Table 1 Queen Creek Watershed listed waterbodies

Name	WBID	Beneficial Use ⁽¹⁾	Reach Description
Dissolved Copper			
Queen Creek	15050100-014A	AWW (Chronic)	Headwater to Superior WWTP Outfall
Queen Creek	15050100-014B	AWEDW (Chronic)	Superior WWTP Outfall to Potts Canyon
Queen Creek	15050100-014C	AWW (Chronic)	Potts Canyon to Whitlow Canyon
Unnamed Tributary (UQ3)	15050100-1843	AWE (Acute)	Headwaters to Queen Creek
Arnett Creek	15050100-1818	AWW (Chronic)	Headwaters to Queen Creek
Total Lead			
Queen Creek	15050100-014A	PBC	Headwater to Superior WWTP Outfall

1. Aquatic Wildlife Warmwater (AWW), Aquatic Wildlife Effluent Dependent (AWEDW), Aquatic Wildlife Ephemeral (AWE), Partial Body Contact (PBC).

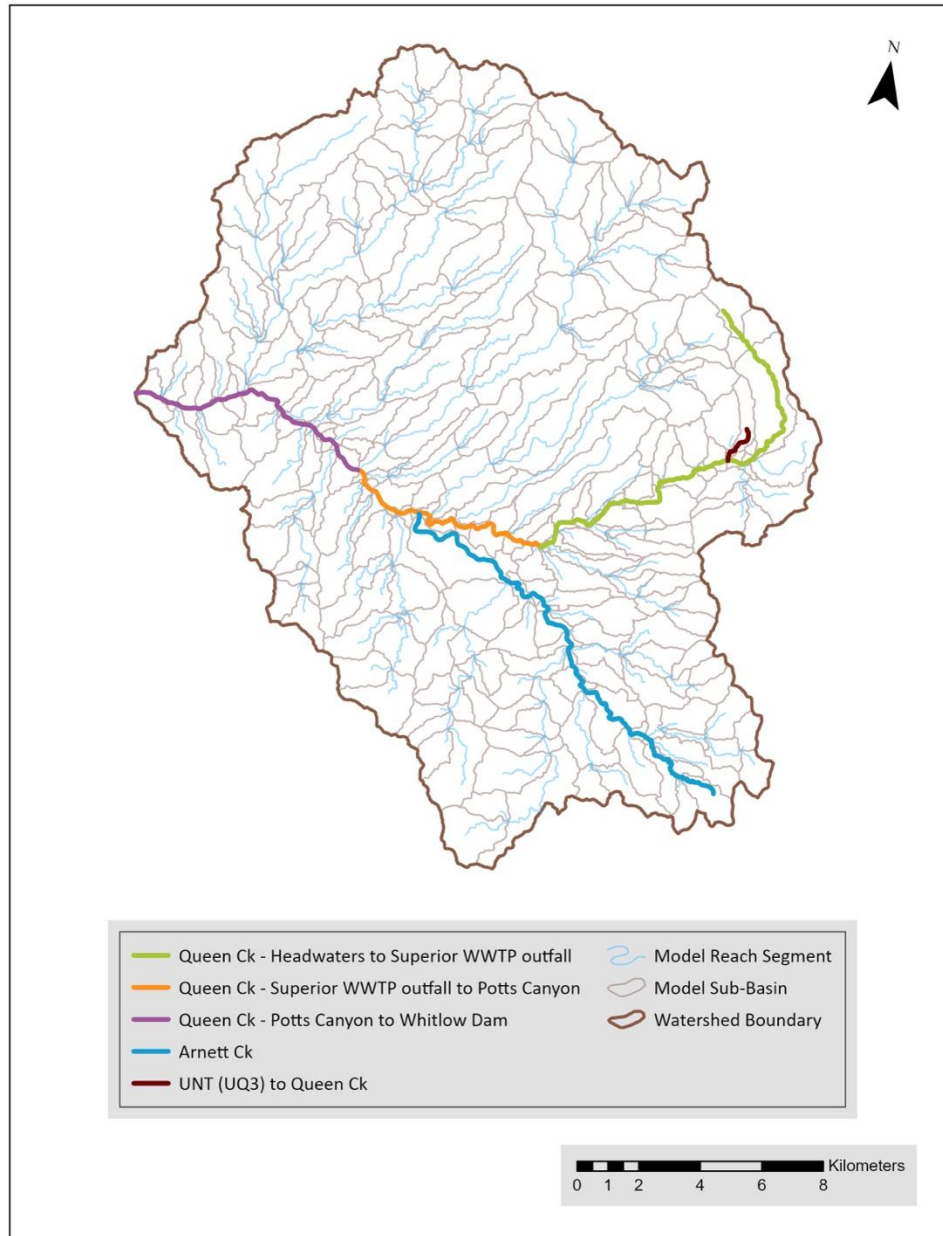


Figure 1 303(d) Listed waterbodies in the Queen Creek Watershed

Per Title 18 of the Arizona Administrative Code (A.A.C.) Chapter 11, Department of Environmental Quality – Water Quality Standards, (18 A.A.C. 11) the Aquatic Wildlife Warmwater (AWW) and Aquatic Wildlife Effluent dependent (AWEDW) chronic dissolved copper water quality standard (WQS) is an equation based on the concurrently collected hardness, as follows:

AWW and AWEDW chronic dissolved copper WQS ($\mu\text{g/L}$): $e(0.8545 \cdot \text{LN}(\text{Hardness}) - 1.702) \cdot (0.96)$.

The AWE dissolved copper WQS is evaluated for acute effects and is calculated as follows:

AWE acute dissolved copper ($\mu\text{g/L}$): $e(0.9422 \cdot \text{LN}(\text{Hardness}) - 1.1514) \cdot (0.96)$.

Where the hardness¹ is measured in mg/L as CaCO₃. For AWW the hardness is measured in the receiving water, and for AWEDW and AWE the hardness is evaluated in the effluent discharging to the receiving water.

The 303(d) listed impairment for total lead is based on the Partial Body Contact (PBC) use with WQS:

PBC total lead: 15 µg/L.

In an initial TMDL process, the Arizona Department of Environmental Quality (ADEQ) implemented various monitoring programs and modeling studies to identify and quantify the diverse sources of copper and lead in the watershed causing these impairments. ADEQ staff calibrated and validated a HSPF model for dissolved copper in the Queen Creek watershed (Arizona DEQ, 2010). In support to this initial modeling effort, ADEQ implemented a comprehensive and extensive sampling and analysis plan, using automated instrumentation, geared towards developing the needed parameters to populate the HSPF model. ADEQ collected numerous water quality grab samples across the watershed to characterize water quality from various sources, land use types and bedrock lithologies. The HSPF model was calibrated for streamflow at numerous stations within the watershed. The water quality monitoring data was used to develop the HSPF copper loading factors along with the calibration of the water quality component of the model.

However, data limitations did not allow the model to resolve copper loading from various sources in the watershed. To address these issues and to further understand and discern between natural and anthropogenic sources of dissolved copper and total lead in the Queen Creek watershed, ADEQ implemented a supplemental and extensive monitoring program and collected additional copper and lead water quality and lithologic data. These additional data were incorporated into the HSPF model (ADEQ 2013). A third-party evaluation of the modeling and TMDL for the Queen Creek Watershed identified several recommended model modifications and loading calculation methodologies (RESPEC 2017). The primary model limitations identified in the review are as follows:

- The three-month modeled time span is too short for spin up and effective calibration. Recommended to simulate at least five to ten years, or longer.
- Extend the model domain to Whitlow Dam
- Sediment parameterization from land to stream requires additional investigation and elaboration
- Certain hydrologic parameters, interception storage and land slope, were not adequately parameterized
- Hydrologic and sediment parameters were not varied over different land uses or cover categories
- In stream sediment parameters were not investigated
- Loading calculations in the model were not implemented correctly.

The HSPF model developed herein will provide decision support and linkage analysis for the Queen Creek TMDL currently under development. To the ability the available data and watershed information were used to address the concerns identified in RESPEC 2017. As will be discussed below, data limitations required the complex HSPF model to be used simply. Acknowledgement is given upfront to the fact that limited data exists to fully parameterize the HSPF model where parameter effects are correlated,

¹ Per footnote d to Table 1 of 18 A.A.C. 11: Hardness, expressed as mg/L CaCO₃, is determined according to the following criteria:

- i. If the receiving water body has an A&Wc or A&Ww designated use, then hardness is based on the hardness of the receiving water body from a sample taken at the same time that the sample for the metal is taken, except that the hardness may not exceed 400 mg/L CaCO₃.
- ii. If the receiving water has an A&Wedw or A&We designated use, then the hardness is based on the hardness of the effluent from a sample taken at the same time that the sample for the metal is taken, except that the hardness may not exceed 400 mg/L CaCO₃.

they are fixed in relation to each other and only one value is calibrated. The benefit of selecting HSPF over a Load Duration Curve approach is that with additional data collection, the current HSPF model can be updated and refined allowing more of the functionality to be utilized. This approach allows the model to inform the TMDL at this time and facilitates future enhancement of the model as additional data becomes available.

SECTION 2: QUEEN CREEK WATERSHED

2.1 Location and size of watershed

The upper Queen Creek Watershed is approximately 64 miles from Phoenix, AZ. The watershed includes the drainage area to Whitlow Dam, just upstream from Queen Valley, AZ. Superior, AZ is located within the watershed at the intersection of highways 60 and 177. The headwaters of Queen Creek begin in the northeast edge of the watershed below Fortuna Peak as a high gradient, intermittent, arid mountain stream. Queen Creek descends southwesterly towards and through the town of Superior and continues into the Roosevelt Irrigation Canal. The upper watershed is dominated by bedrock outcrops and shallow soils. A second high elevation tributary originates on the easterly side of a prominent ridge known as Apache Leap and joins Queen Creek in the area known as Oak Flat. From here Queen Creek flows steeply approximately 2.5 miles along US Highway 60 toward the Town of Superior. From Superior to the Whitlow flood control dam, the stream takes on the characteristics of a low gradient, desert foothill stream dominated by thick piedmont sediments and infrequent undulating bedrock.

2.2 Climate

Climate in the Queen Creek watershed varies with elevation. Higher elevations in the mountains are cooler and substantially wetter than the desert lower elevation areas of the watershed. There are two regional wet seasons, a summer monsoon season with intense precipitation characterized by spotty and short duration convective thunderstorms, and the winter with longer duration lower intensity events associated with passing low-pressure cold fronts. Snow may fall in the higher elevations areas of the watershed but typically melts within a few days.

2.3 Slope

The land slopes range from nearly-vertical in the highest reaches in the north and east portion of the watershed to generally flat gentle foothills in the middle and western areas. The slopes within the watershed are presented in **Figure 2**.

Topographic slope, measured in tangent units (distance of rise divided by distance of run), was computed using the ESRI ArcGIS Pro Surface Parameters Tool. The result represents the rate of change of elevation for each digital elevation model (DEM) cell. A 10 m resolution DEM, obtained from the USGS The National Map (TNM) download tool², was used as the input topographic dataset. Once slope was computed for each cell, an area-weighted average slope was computed for each of the PERLND and IMPLND segments within each model sub-basin unit. More details on slope computation for each cell of the DEM follows.

² TNM download center at <https://apps.nationalmap.gov/downloader/> using 3D Elevation Program Products and Services and a 1/3 arc second data source (~ 10 m). Subsequently downloaded in a GeoTIFF file format.

Slope Computation from the Digital Elevation Model

The quadratic option of the Surface Parameters Tool was selected, though it does not fit the neighborhood cells exactly. The quadratic surface minimizes the effect of noisy surface data. This is the default and recommended option for most data and applications. The quadratic surface option must be used when specifying a neighborhood size that is larger than the cell size and when using the adaptive neighborhood option, both of which were used in this application.

A *neighborhood distance* parameter determines the neighborhood size and calculates the surface parameter over this distance from the target cell center. A smaller neighborhood distance captures more local variability in the landscape, such as characteristics of smaller landscape features. With high resolution elevation data like that used in this application, larger distances are more appropriate. In this application, a 7 x 7 neighborhood was selected for calculating slope (7-cells by 7-cells for a possible use of 48 DEM cells total).

The adaptive neighborhood parameter was also selected in this application which allows the neighborhood distance to change with variability in the terrain. The neighborhood distance will shrink if there is too much variability in the calculation window. The maximum window size is the neighborhood size while the minimum window is the cell resolution (i.e., 10 m).

In summary, the Surface Parameters tool was applied to a 10 m DEM using a 7 x 7 neighborhood, with a quadratic surface estimator and an adaptive neighborhood to produce a 10 m slope dataset.

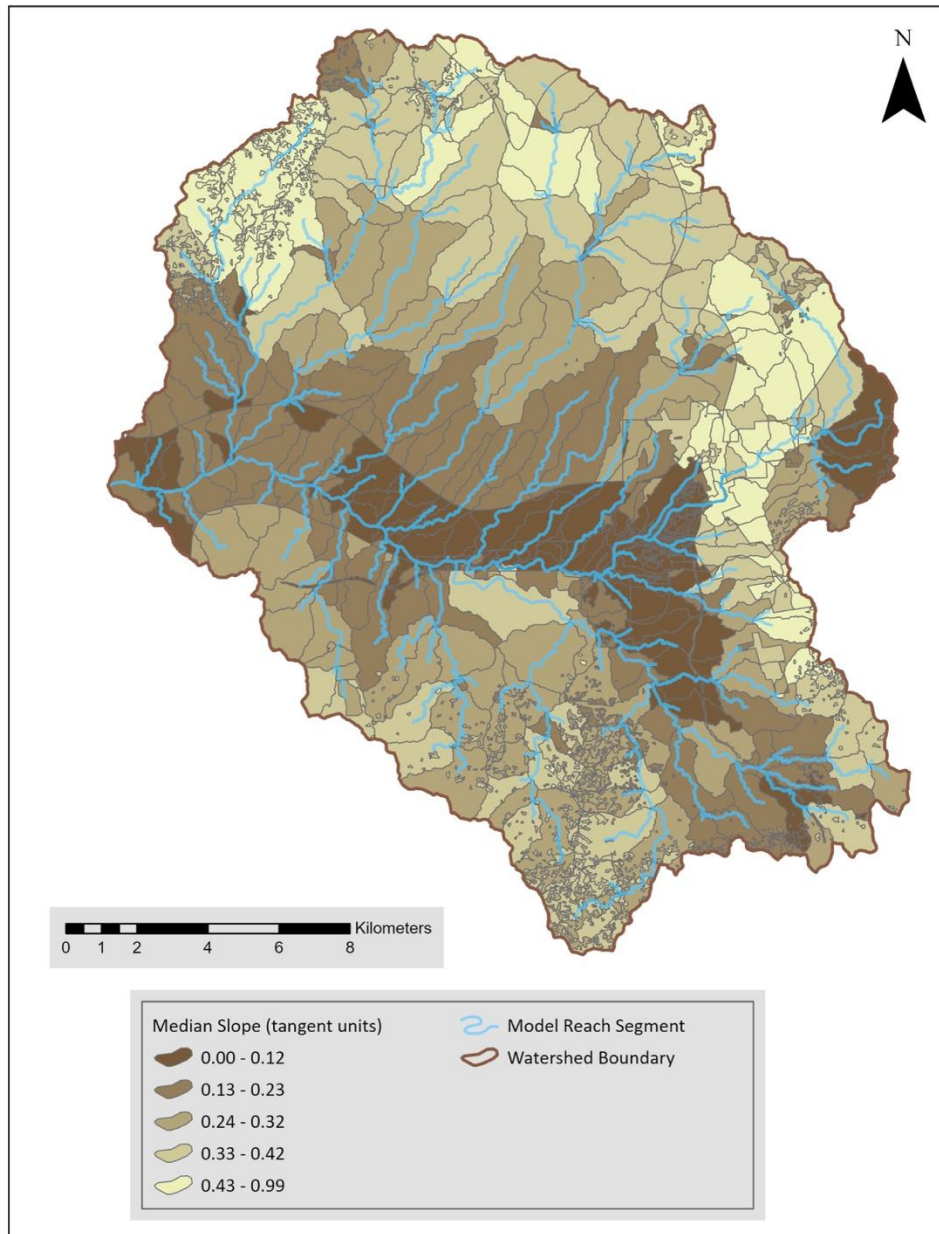


Figure 2 Land slopes in the Queen Creek Watershed

2.4 Land use/land cover

Land use and land cover are displayed in **Figure 3**. The watershed is dominated by shrub/scrub, greater than 90% coverage, with herbaceous cover approximately 5% of the area. All other land uses are less than 1% of the area. In and around the Town of Superior consists of Developed Open Space, and low to high density residential and commercial buildings. Farther downstream, the Queen Creek watershed becomes less channelized due to changes in topography and human-made flood mitigation structures resulting in portions of emergent wetland features, according to the National Land Cover Database (NLCD) provided by the U.S. Geological Survey (USGS) (USGS 2018). Mining land areas are shown as part of the soil mapping in the next section.

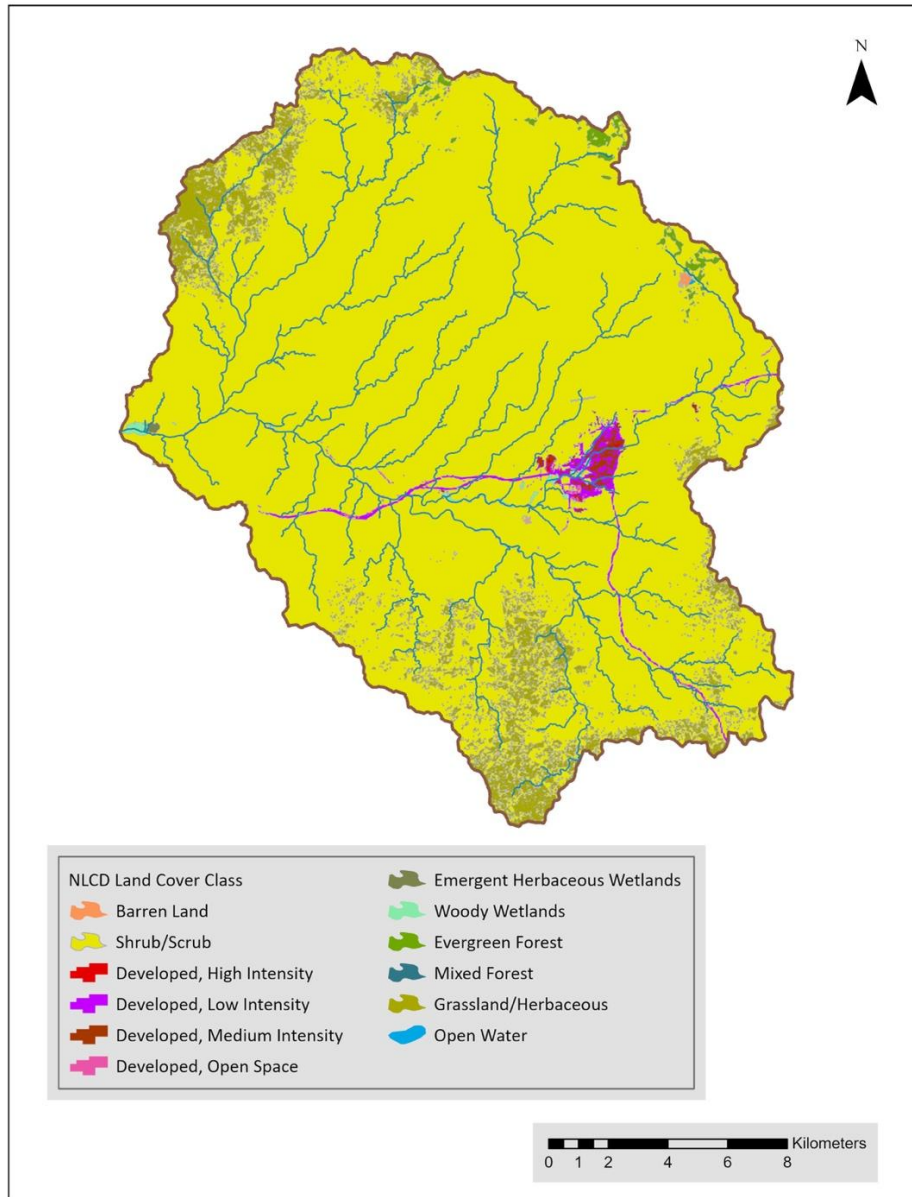


Figure 3 Land use within the Queen Creek Watershed

2.5 Soil characteristics

Soil type and characteristics from Soil Survey Geographic Database³ (SSURGO) were used to inform the HSPF model. The soil types for the watershed are presented as **Figure 4**. The SSURGO data was used to inform model parameterization.

³ Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at <https://websoilsurvey.nrcs.usda.gov/>.

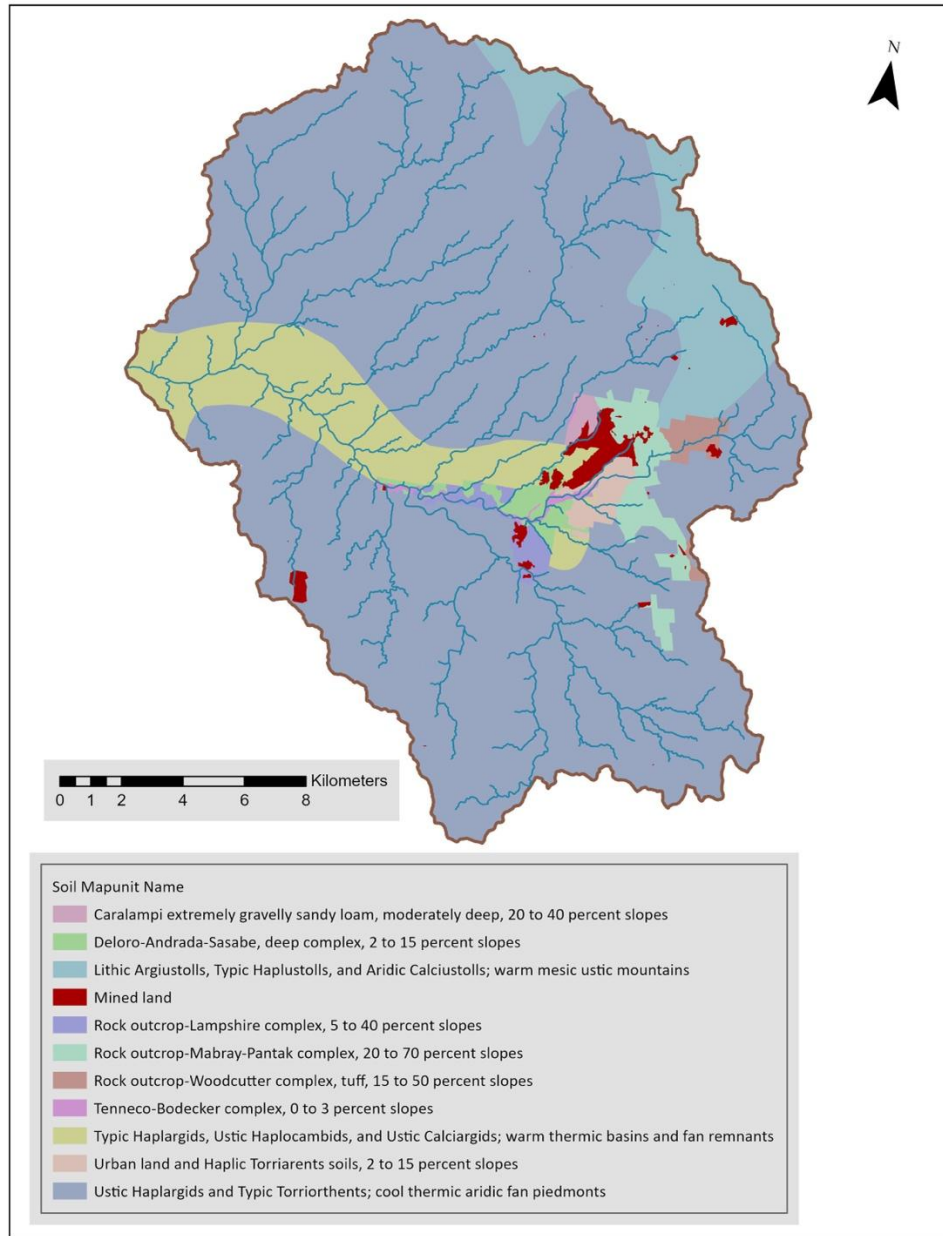


Figure 4 SSURGO distribution of soil types and mined land

SECTION 3: DATA AVAILABILITY AND UTILIZATION

3.1 Digital Elevation Model

The original digital elevation model (DEM) for the model prepared in 2010 was not available but given that the model domain was extended to an outlet near Whitlow Dam, a new DEM was built for this TMDL effort. The same DEM (10 m resolution) described in Section 2.3 (Slope) was employed for building model characteristics.

3.2 Meteorological data

The Parameter-elevation Regressions on Independent Slopes Model⁴ (PRISM) data were used to define the meteorological data for the watershed. The default resolution of PRISM is 800 m cells, resulting in 588 cells intersecting the model subbasins. Since the disaggregation tool in BASINS allows for processing only one node at a time, the grid was resampled to a coarser 6,400 m to provide a manageable number of cells for a manual disaggregation workflow. The 6,400 m grid is shown over the delineated watershed in **Figure 5**.

BASINS contains built-in methods for disaggregating data depending on the time series. Daily precipitation is distributed to hourly values based on hourly time series from up to five nearby MET stations. For time periods where MET data are unavailable North American Land Data Assimilation System (NLDAS) time-series were used for the disaggregation. The method distributes the data according to one of several secondary hourly stations, using the one whose daily total is closest to the daily value. If the daily total for the hourly stations being used are not within a user-specified tolerance of the daily value, the daily value is distributed using a triangular distribution centered around the middle of the day. Daily max and min temperatures are distributed to hourly values assuming that the minimum occurs at 6 am and the maximum at 4 pm. Evapotranspiration was calculated using the BASINS implementation of the Hamon method with the PRISM T_{min} and T_{max} as inputs. Daily evapotranspiration is distributed to hourly values assuming a distribution based on latitude and time of the year.

Long term meteorological stations in the watershed would reduce the uncertainty in the model by providing actual precipitation distributions over the area.

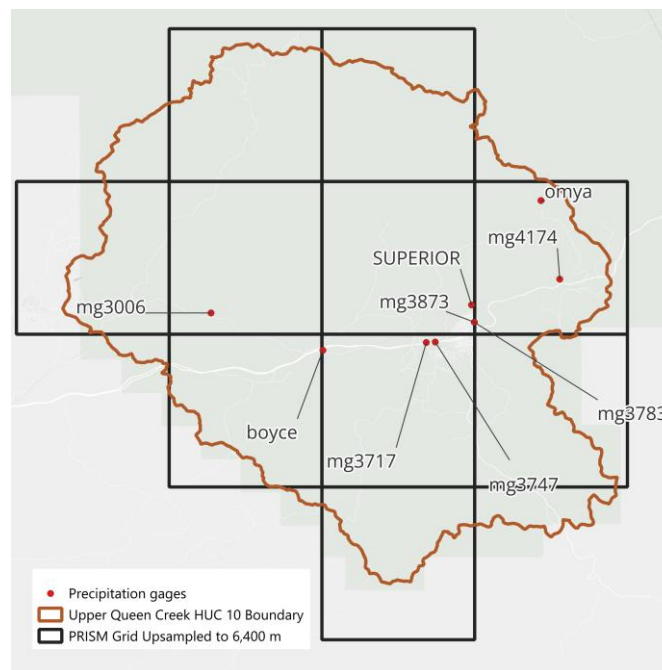


Figure 5 PRISM coverage in the watershed at 6,400 m resolution

⁴ PRISM Group, Oregon State University, <https://prism.oregonstate.edu>.

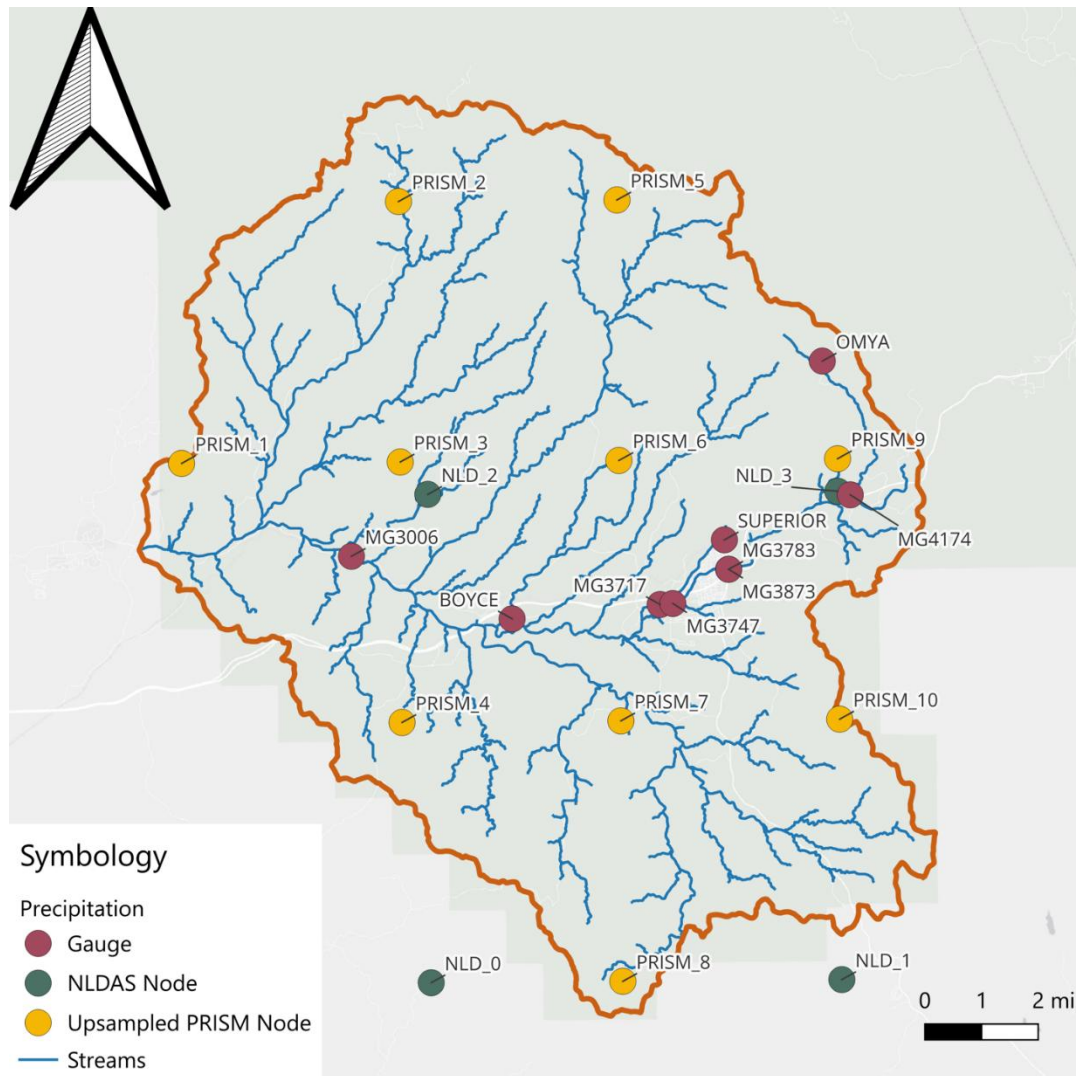


Figure 6 Precipitation gauges, NLDAS nodes, and PRISM nodes

3.3 Streamflow Data

For the 2010 HSPF model run, the lack of USGS-maintained stream gaging stations within the project watershed represented a significant data gap. To address this, ADEQ installed eight electronic stage recorders (four on Queen Creek and four on selected tributaries) to collect stage data at 15-minute intervals. Continuous stream discharge records were then developed by converting stage data using rating tables, which were established through manual flow measurements, surveyed cross sections, and the WinXSPRO program.

Since the 2010 model, flow data is even more limited. The only existing gage is a USGS station located below a dam and outside the project boundary, making it of limited value for this watershed. Additionally, the eight ADEQ stream gages previously used are no longer deployed, resulting in a lack of continuous flow data for the area. The only new flow data available are grab samples collected during water quality sampling events; however, these are infrequent and limited in scope.

Stream gauges with available data are presented in **Figure 8**. The following gauges were used in model calibration and typically had data available from October 1, 2006 through February 29, 2008.

- Queen Creek at Highway 60
- Oak Flat
- Magma Ave
- Mary Drive
- Silver King Wash
- Arnett Creek
- Potts Canyon

The gauge at Mary Drive was removed from consideration due to an unexplained offset in the summer of 2007. As it was not possible to determine if the offset values were correct or if the lower flow values were correct the data were not used. The offset is shown in **Figure 7**.

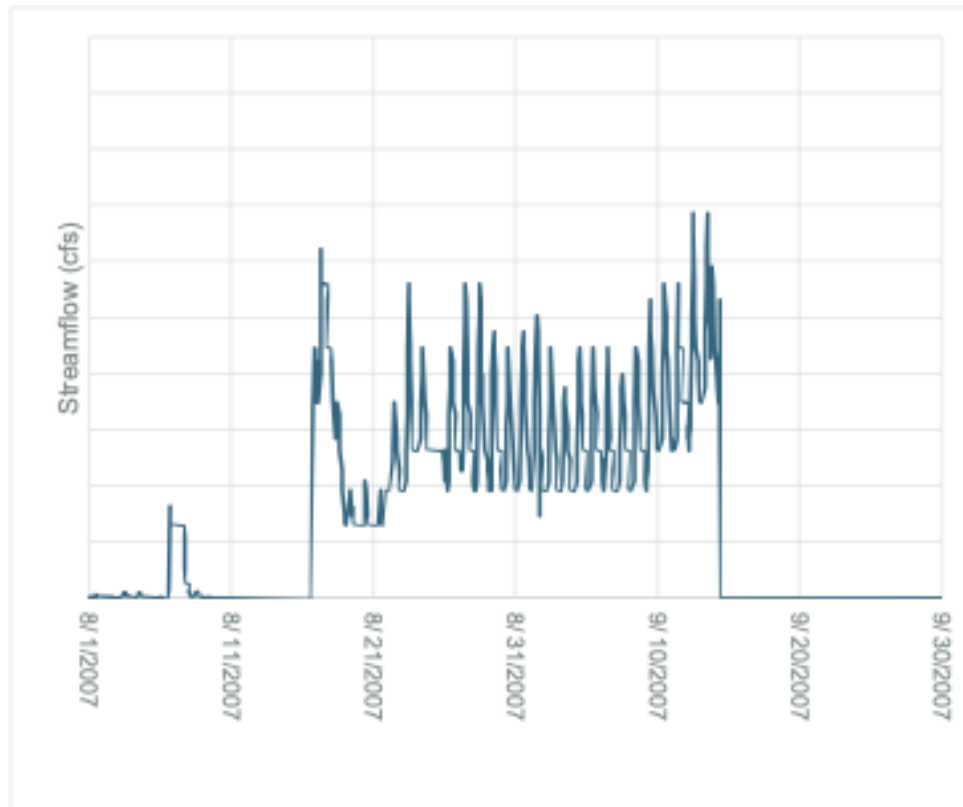


Figure 7 Offset in Mary Drive gauge streamflow data during August of 2007

Additionally, to increase the data available for model calibration several gauges were installed across the watershed. However, these gauges showed significantly more flow, up to 20 times the flowrates measured in other gages (SWCA 2025), than those available in 2006 to 2008. It was not possible to determine the cause of the higher flowrates. Pictures of the waterways imply low flow creeks, so these high flow gauges were removed from consideration in the model calibration. These gauges were deployed for two stretches totaling under one year, and while utilizing the data would have added to the time for calibration, removing them from consideration does not remove a large timespan. The following gauges were not considered in the model calibration.

- MGQEN030.06
- MGQEN034.25
- MGQEN037.17
- MGQEN037.83
- MGQEN038.73

- MGQEN041.74

Limited flowrate data over the watershed is a constraint for any model created to simulate the watershed. In the future, if additional flow gauges are set in the watershed, the collected data could enhance the HSPF calibration.

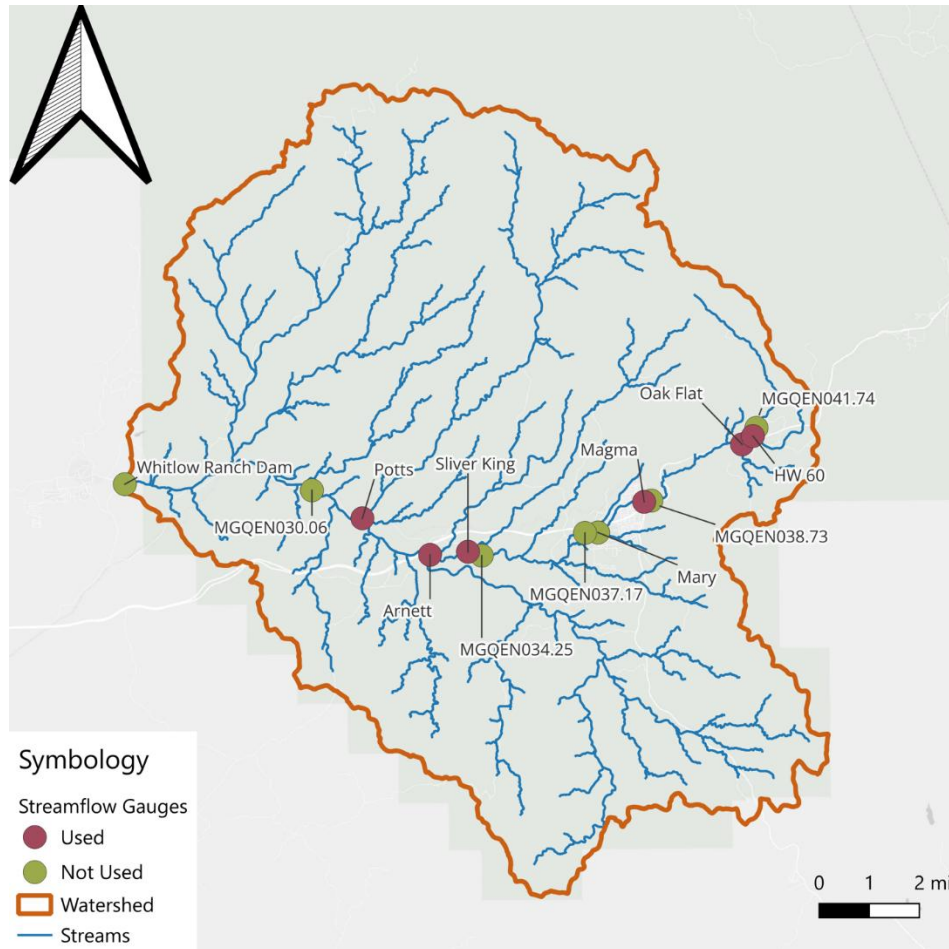


Figure 8 Available stream flow gauges

3.4 Water Quality Data

Superior WWTP monitoring data from 2019 through 2025 are summarized in **Table 2**. Water quality monitoring for metals and hardness is performed quarterly, and total suspended solids are measured monthly. More recent reported effluent copper concentrations were three orders of magnitude less than earlier values and were assumed to have incorrect unit conversions which were corrected prior to summarizing for **Table 2**. All lead measurements resulted in non-detect at a detection limit of 1 µg/L, so a low value of 0.01 µg/L, is assumed for the model input. The average discharge flowrate is approximately 0.21 mgd (0.32 cfs). However, there are two abnormally large values in the monthly average flowrate data for the Superior WWTP, February 2023 with a flow of 1.84 mgd (2.87 cfs), and August 2023 with a flow of 1.03 mgd (1.59 cfs). Without these two values the measured monthly average flowrate average 0.170 mgd (0.263 cfs).

Table 2 Water quality data for Superior WWT 2019 through 2025

Parameter	units	n	Mean	25 th Percentile	Median	75 th Percentile
Copper, total recoverable	µg/L	26	8.5	5.1	6.3	11.8
Lead, total recoverable	µg/L	16	0.5 ^[1]	0.5 ^[1]	0.5 ^[1]	0.5 ^[1]
Hardness, total	mg/L ^[2]	28	158	140	150	170
Solids, total suspended	mg/L	66	6.6	0.5	3.0	8.9

¹ All measurements not detected at 1 µg/L. One half detection limited used to fill in for analysis.

² Measured as CaCO₃

Water quality sampling locations on HSPF model reaches are shown in **Figure 9**. All sample locations on tributaries to the HSPF model reaches were not considered in the model calibration as they may be unrepresentative of the larger “blue line” reach. The bulk of water quality data were collected prior to 2014 with only occasional sampling events between 2014 and 2025. Available total and dissolved copper water quality monitoring data are summarized in **Table 3**. Available total and dissolved lead water quality data are summarized in **Table 4**. Receiving water data for total hardness and total suspended solids are presented in **Table 5**. For both copper and lead the total concentrations show a higher degree of variability than dissolved due to the high level of metals associated with soil particles. In some locations, the mean concentration is greater than the 75th percentile implying extremely high concentrations in the dataset. The data were previously reviewed for quality and not further assessed here.

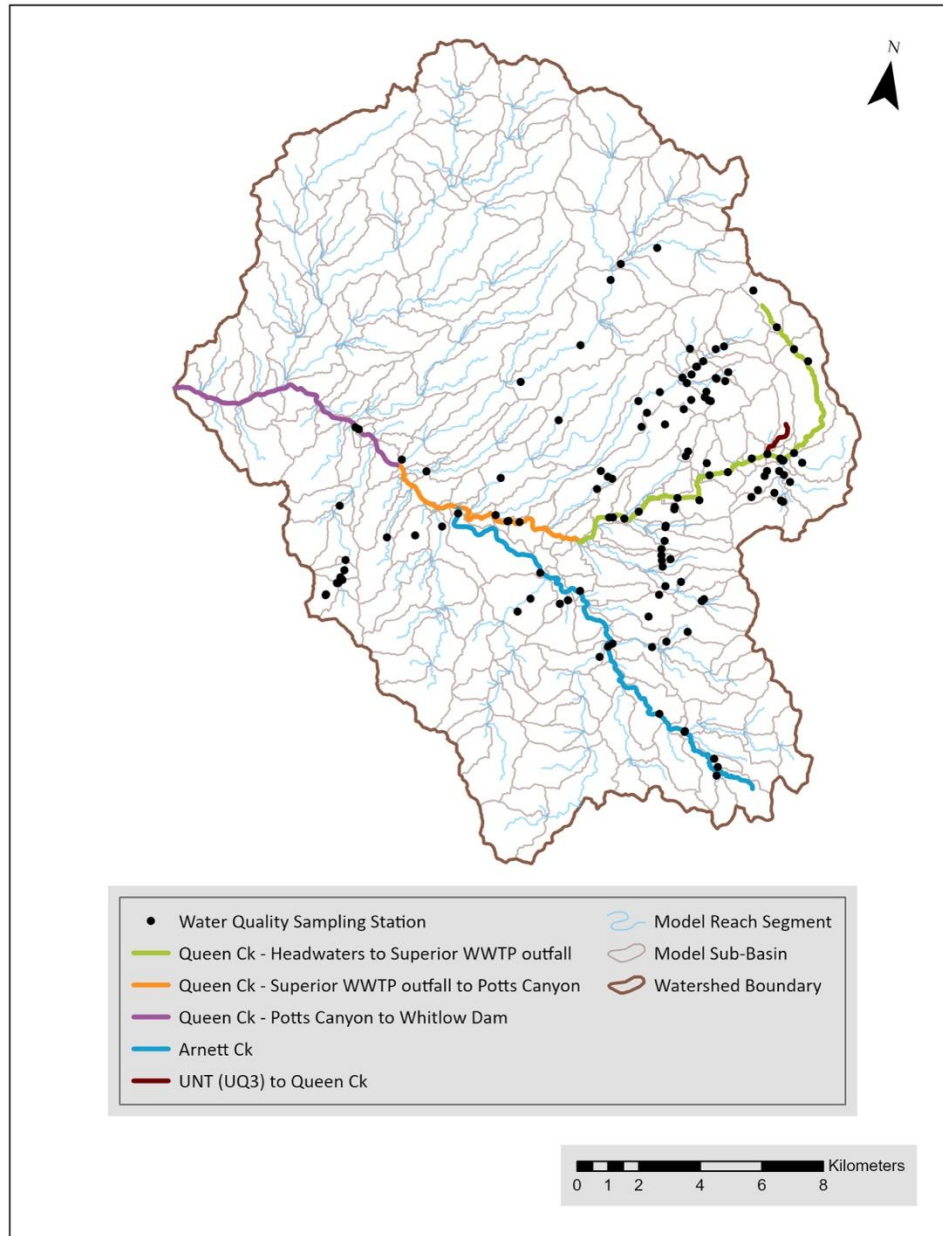


Figure 9 Water quality monitoring sites on HSPF reaches in the Queen Creek Watershed

Table 3 Available total and dissolved copper water quality data

Parameter/Location	n	Concentration (µg/L)			
		Mean	25th Percentile	Median	75th Percentile
Total Copper					
014A ^[1] 303d	103	173	24.5	63.0	147
014A Tributaries	13	273	35.9	137	380
014B ^[2] 303d	51	175	36.0	89.0	200
014B Tributaries	126	156	10.0	32.9	148
014C ^[3] 303d	12	655	65.5	175	300
014CTributaries	199	262	44.5	88.0	243
Arnett ^[4] 303d	29	49.8	10.0	22.0	32.0
Arnett Tributaries	40	397	53.8	150	530
UQ3 ^[5] 303d	3	38.9	34.2	38.0	43.3
Dissolved Copper					
014A 303d	112	13.9	8.4	11.0	14.3
014A Tributaries	13	58.9	8.4	11.3	26.3
014B 303d	52	15.3	9.3	11.5	17.0
014B Tributaries	122	13.8	6.7	11.0	18.0
014C 303d	12	20.6	10.0	17.5	26.3
014CTributaries	205	31.8	20.0	32.8	41.0
Arnett Creek 303d	24	21.1	4.7	18.9	26.0
Arnett Tributaries	45	11.3	7.1	9.8	13.0
UQ3 303d	3	27.6	25.3	26.4	29.3

¹ Queen Creek from headwaters to Superior WWTP outfall

² Queen Creek from Superior WWTP outfall to Potts Canyon

³ Queen Creek from Potts Canyon to Whitlow Dam

⁴ Arnett Creek from headwaters to confluence with Queen Creek

⁵ Unnamed Tributary to Queen Creek

Table 4 Available total and dissolved lead water quality data

Parameter/Location	n	Concentration (µg/L)			
		Mean	25th Percentile	Median	75th Percentile
Total Lead					
014A ^[1] 303d	108	1,317	2.5	30.4	140
014A Tributaries	13	339	2.8	33.0	213
014B ^[2] 303d	53	49.9	5.0	26.0	64.0
014B Tributaries	126	117	2.5	11.5	82.6
014C ^[3] 303d	12	221	10.3	70.5	130
014CTributaries	205	178	2.5	20.0	62.0
Arnett ^[4] 303d	26	19.7	1.5	2.5	6.8
Arnett Tributaries	43	189	21.5	81.0	235
UQ3 ^[5] 303d	3	4.1	3.1	4.9	5.5
Dissolved Lead					
014A 303d	26	10.7	0.2	0.5	13.9
014A Tributaries	13	2.4	0.2	0.2	0.4
014B 303d	3	0.3	0.3	0.3	0.3
014B Tributaries	24	1.9	0.2	0.4	1.1
014C 303d	1	2.5	2.5	2.5	2.5
014CTributaries	51	3.1	0.2	0.3	0.6
Arnett Creek 303d	18	1.1	0.3	0.9	1.5
Arnett Tributaries	15	0.5	0.2	0.4	0.6
UQ3 303d	3	0.4	0.4	0.4	0.5

¹ Queen Creek from headwaters to Superior WWTP outfall

² Queen Creek from Superior WWTP outfall to Potts Canyon

³ Queen Creek from Potts Canyon to Whitlow Dam

⁴ Arnett Creek from headwaters to confluence with Queen Creek

⁵ Unnamed Tributary to Queen Creek

Table 5 Available total hardness and total suspended solids data

Parameter/Location	n	Concentration (mg/L)			
		Mean	25th Percentile	Median	75th Percentile
Total Harness (mg/L as CaCO ₃)					
014A ^[1] 303d	67	174	75	110	165
014A Tributaries	12	375	110	190	553
014B ^[2] 303d	45	189	89	120	183
014B Tributaries	111	1,110	83	135	507
014C ^[3] 303d	8	131	96	120	160
014CTributaries	114	166	29	81	168
Arnett ^[4] 303d	15	222	94	129	221
Arnett Tributaries	40	261	130	205	323
UQ3 ^[5] 303d	3	29	20	23	35
Total Suspended Solids (mg/L)					
014A 303d	17	13	4	6	10
014A Tributaries	---	---	---	---	---
014B 303d	9	234	2	2	26
014B Tributaries	12	13	3	5	22
014C 303d	2	49	27	49	71
014CTributaries	19	32	5	5	5
Arnett Creek 303d	20	10	3	5	6
Arnett Tributaries	2	3	3	3	3
UQ3 303d	---	---	---	---	---

¹ Queen Creek from headwaters to Superior WWTP outfall

² Queen Creek from Superior WWTP outfall to Potts Canyon

³ Queen Creek from Potts Canyon to Whitlow Dam

⁴ Arnett Creek from headwaters to confluence with Queen Creek

⁵ Unnamed Tributary to Queen Creek

3.5 Soil Chemistry Data

Measured copper concentrations on soil surrounding select receiving waters are shown on **Figure 10**. The magnitude of the measurements is shown graphically by the size of the symbol. The lead concentrations on soils are shown in **Figure 11**. As is discussed in the parameterization, these soil measurements are used to set the HSPF model potency factors.

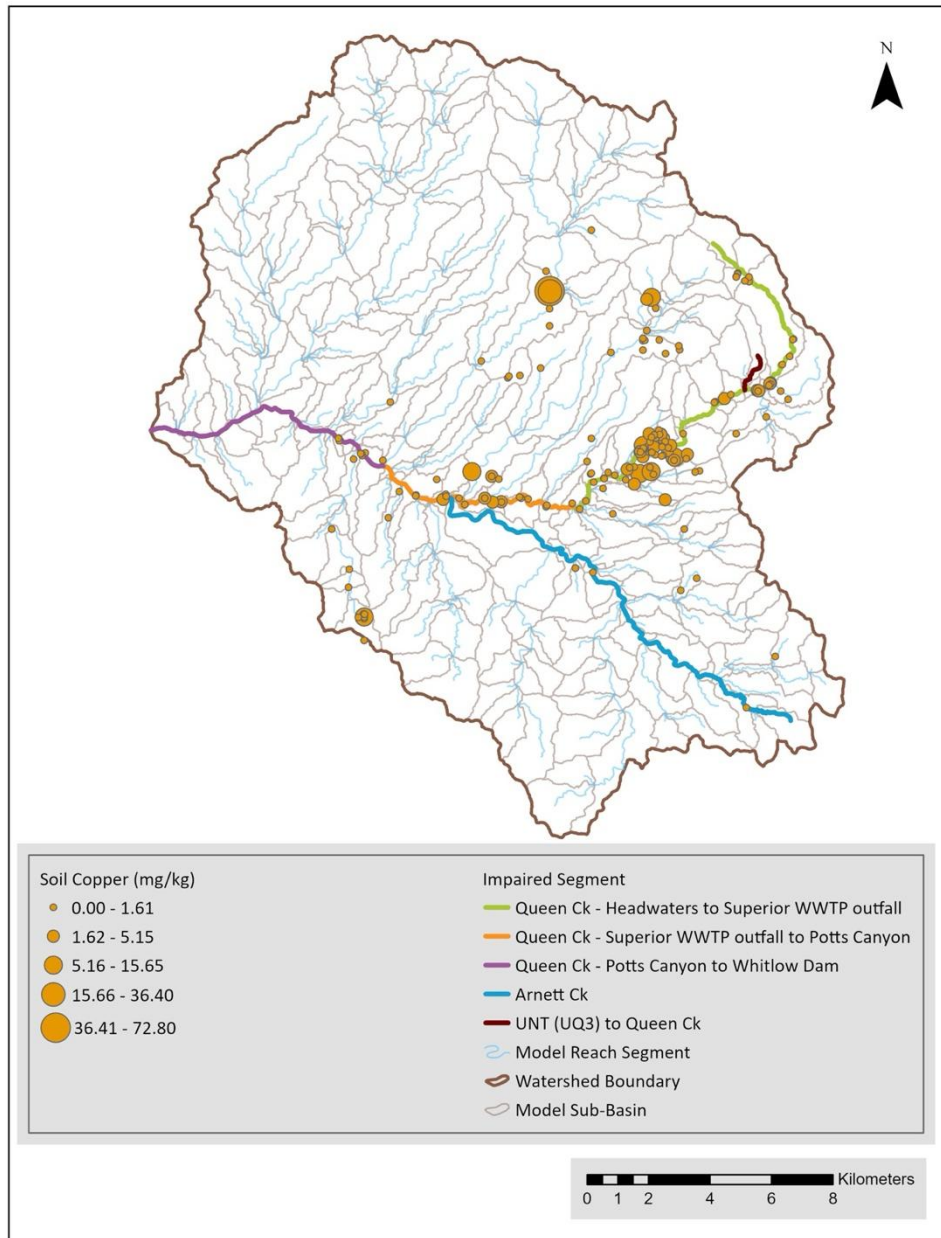


Figure 10 Soil copper measurement in the Queen Creek Watershed

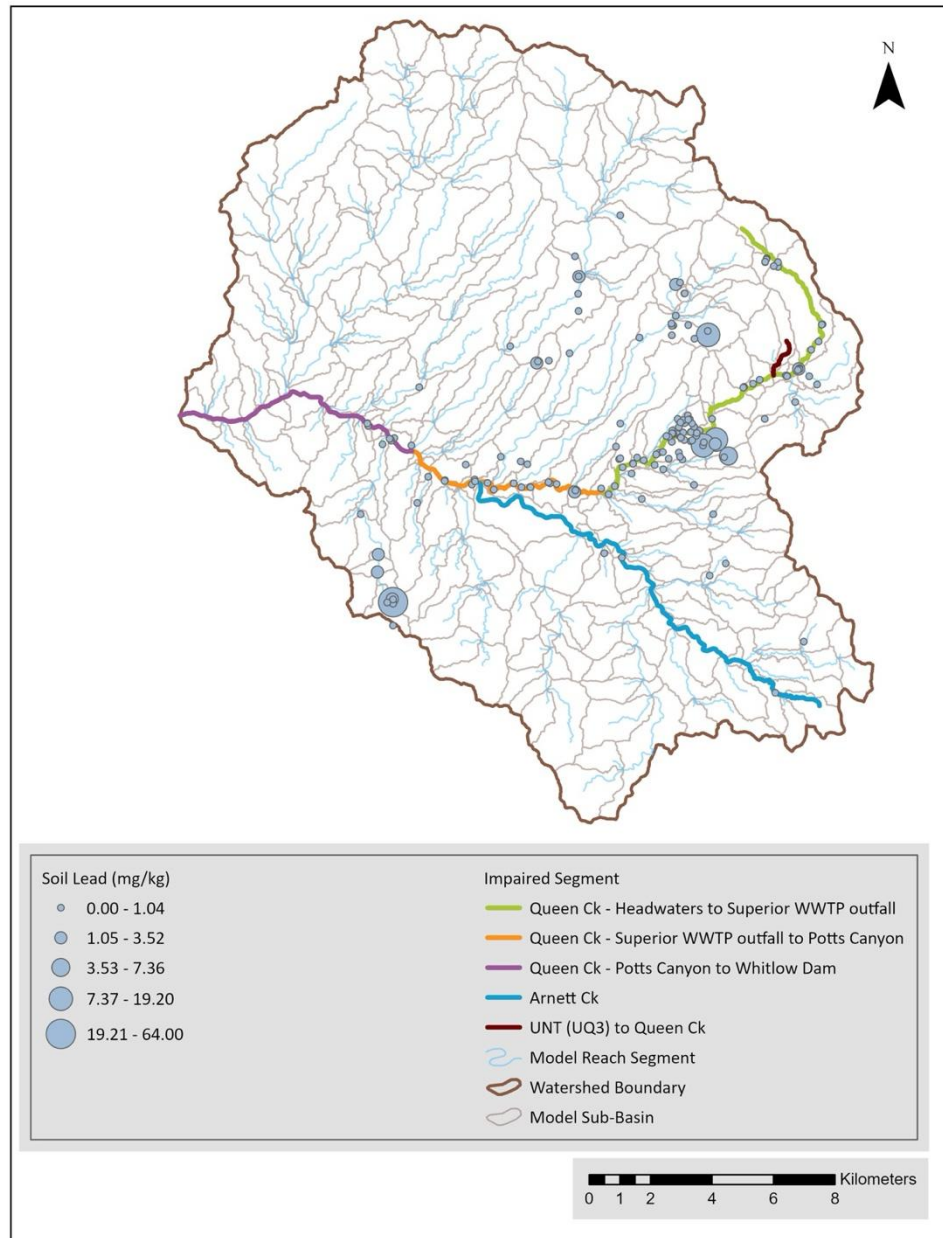


Figure 11 Soil lead measurement in the Queen Creek Watershed

SECTION 4: HSPF MODEL OF QUEEN CREEK WATERSHED

The HSPF model is set to simulate October 1, 2001 through September 29, 2025 at a timestep of 1 hour. While the bulk of data available to calibrate the model fall within 2006 to 2010, the longer model run provides a “spin up” period allowing the model to equilibrate from initial conditions. Additionally, while performing loading analyses for the TMDL, the model run period will cover a range of water type years.

The model is developed to simulate flow, dissolved copper, and total recoverable lead in the watershed reaches. As copper and lead are strongly associated with sediment, the model also simulates the wash off of soil from land surfaces to the reach, and sediment transport within the reach. The fractionation

between dissolved and particle associated metal is calculated via a partitioning model internal to HSPF. The total recoverable metal is calculated by summing the dissolved and particle associated concentrations.

4.1 Watershed Segmentation

The domain for the HSPF model extends from the headwaters of Queen Creek to Whitlow Dam, allowing simulation of all three impaired reaches of Queen Creek. The size of the subbasins was refined to encapsulated mined areas, where they exist, and balanced by limiting the total number operations to within the hard-coded limit of HSPF. The final model contained 296 subbasins. The subbasins and associated reaches are shown in **Figure 12**.

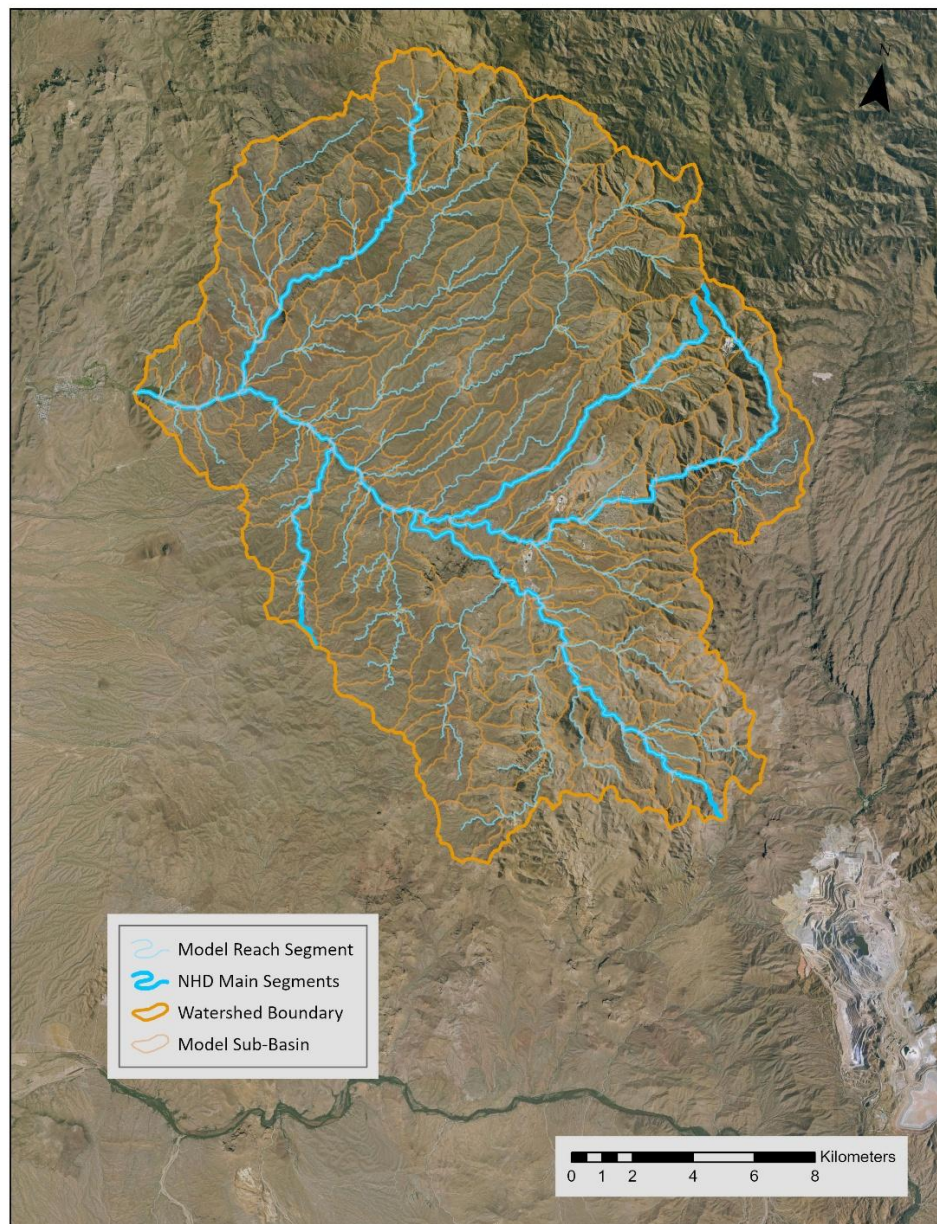


Figure 12 Queen Creek Watershed subbasins and reaches

4.2 Point Sources

A number of point sources are permitted to discharge to Clean Water Act receiving waters in the upper Queen Creek watershed including wastewater treatment plants (WWTP), and industrial facilities subject to multi-sector general permits (MSGP). **Table 6** lists and describes the point sources and their locations are illustrated in **Figure 13**. Of the facilities with individual AZPDES permits, only Superior WWTP outfall 001 is currently discharging to the upper Queen Creek watershed and is present in the model. Superior WWTP outfall 002 is not currently operational. The Resolution Copper Mining outfall 001 is the overflow from their stormwater retention pond, and 002 is the discharge from the Mine Water Treatment Plant. Neither of the Resolution Copper Mining outfalls are included in the model because they have not discharged for over 10 years (Outfall 002 was last monitored December 2016). Treated water from this facility is currently pumped outside the watershed for irrigation purposes. MSGP facilities in **Table 6** are modeled as their land area within the watershed.

Table 6. Point source dischargers having NPDES permits within the Queen Creek watershed.

AZPDES individual permit				
AZ-0021199	Superior WWTP	Minor WWTP	001	Queen Creek (15050100-014B)
			002 ⁽¹⁾	Queen Creek (15050100-014A)
AZ-0020389	Resolution Copper Mining	Major WWTP	001 ⁽²⁾	Queen Creek (15050100-014A)
			002 ⁽²⁾	Queen Creek (15050100-014A)
MSGP (general permit)				
Not renewed in 2026 cycle	Gila Rock Products	MSGP	No name ⁽³⁾	Reymert Wash
Not renewed in 2026 cycle	Kalamazoo Materials	MSGP	Superior KMI ⁽³⁾	Unnamed Trib x2 (UAU) to Arnett Creek
AZI107055	OMYA AZ-Limestone Quarry	MSGP	Outfall 1	Queen Creek (15050100-014A)
			Outfall 2	Queen Creek (15050100-014A)
AZI107056	OMYA- Processing Facility	MSGP	Outfall 1	Unnamed Trib (UQ1) to Queen Creek
			Outfall 2	Unnamed Trib (UQ1) to Queen Creek
			Outfall 3	Unnamed Trib (UQ1) to Queen Creek
AZI106994	Imerys Perlite USA Inc.	MSGP	Outfall 1	Unnamed Trib (UQ1) to Queen Creek
			Outfall 2	Unnamed Trib (UQ1) to Queen Creek
			Outfall 3	Unnamed ephemeral tributary
AZI108987	Resolution Copper Mining (East Plant)	MSGP	EP-SW-01	Unnamed ephemeral tributary
			EP-SW-03	Unnamed ephemeral tributary
AZI108986	Resolution Copper Mining (West Plant)	MSGP	WP-SW-03	Unnamed ephemeral tributary
MS4 (municipal stormwater)				
AZS000018	ADOT MS4 2021	MS4	Superior Office	Unnamed Trib (UQ8) to Queen Creek
			Superior Fuel	Unnamed ephemeral tributary

¹ Outfall permitted, but not currently operational

² No discharge since before 2017

³ Outfall does not discharge to a Water of the United States and will not receive a TMDL allocation.

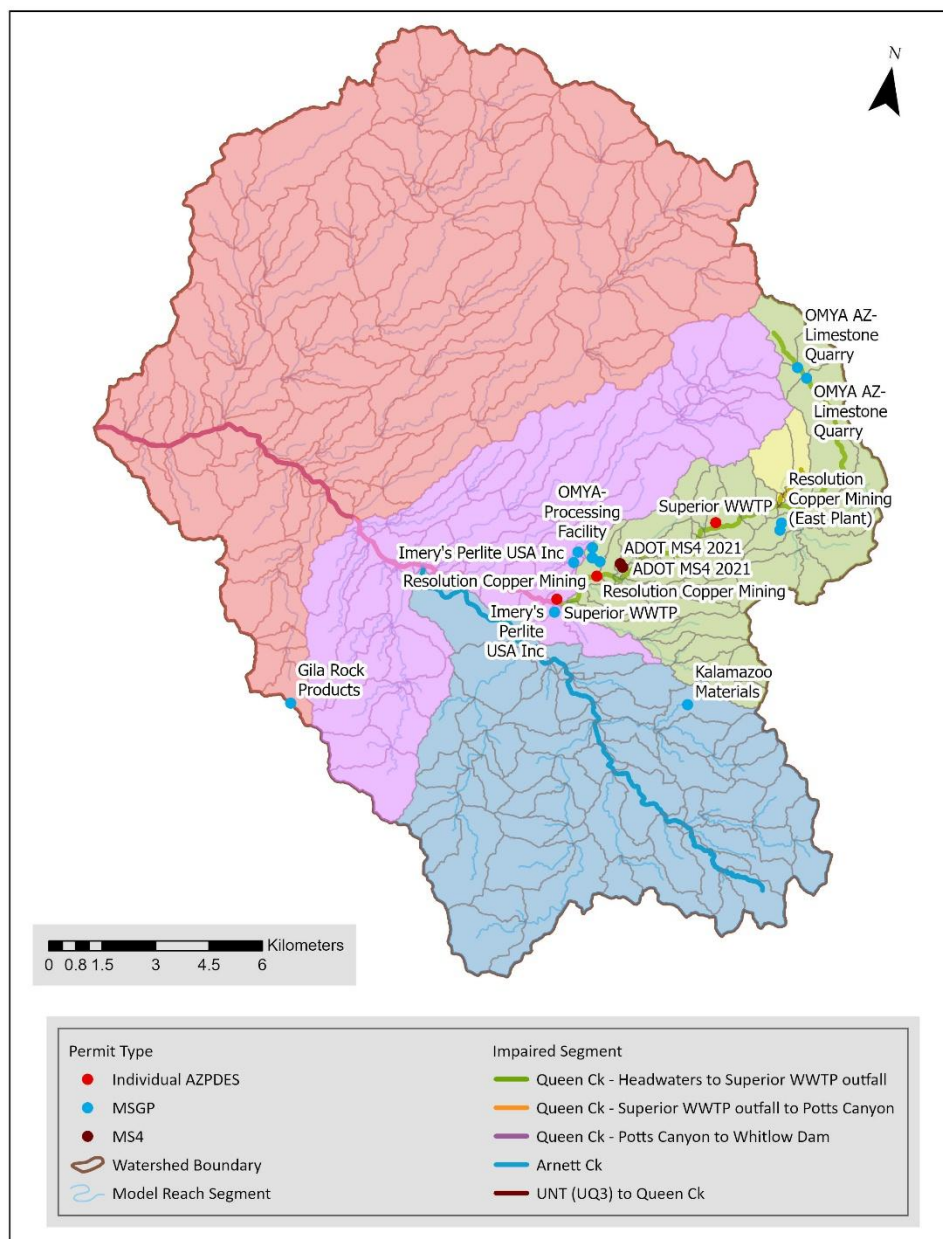


Figure 13. Locations of NPDES permitted discharges within the Queen Creek watershed.

4.3 Model Parameterization

HSPF has three computational element types, pervious land (PERLND), impervious land (IMPLND), and stream reaches (RCHRES). PERLND allows water to run off the surface, infiltrate, move through shallow ground, migrate to active groundwater, and ultimately lost to deep groundwater. IMPLND only allows surface runoff. RCHRES route flow downstream and provides mechanisms for in reach transformations, and sediment settling and scour. The parameterization of these elements is discussed below.

PERLND classes were developed from the unique combinations of soil type and the associate land use. The 15 classes are listed in **Table 7**. These classes were grouped by PRISM area incrementing the label by 50, allowing parameterization to be varied where appropriate. The IMPLND uses the same numbering and naming as PERLND, but are limited to the urban land uses, including: ust_dlo, u21_dlo, u21_dmi. RCHRES are simply numbered from 1 to 269 as each reach has different length, slope, rating curve, among others that warrant unique identifiers.

Table 7 PERLND classes in the Queen Creek Watershed HSPF model

PERLND	Short Name	SSURGO Map Unit Name	NLCD Land Use Description
001	caa_shr	Caralampi extremely gravelly sandy loam, moderately deep, 20 to 40 percent slopes	Shrub/Scrub
002	del_shr	Deloro-Andrada-Sasabe, deep complex, 2 to 15 percent slopes	Shrub/Scrub
003	l_5_shr	Rock outcrop-Lampshire complex, 5 to 40 percent slopes	Shrub/Scrub
004	m_p_shr	Rock outcrop-Mabray-Pantak complex, 20 to 70 percent slopes	Shrub/Scrub
005	tnc_shr	Tenneco-Bodecker complex, 0 to 3 percent slopes	Shrub/Scrub
006	hpl_shr	Typic Haplargids, Ustic Haplocambids, and Ustic Calciargids; warm thermic basins and fan remnants	Shrub/Scrub
007	ust_shr	Ustic Haplargids and Typic Torriorthents; cool thermic aridic fan piedmonts	Shrub/Scrub
008	min_shr	Mined land	Shrub/Scrub
009	ust_dlo	Ustic Haplargids and Typic Torriorthents; cool thermic aridic fan piedmonts	Developed, Low Intensity
010	u21_dlo	Urban land and Haplic Torriarents soils, 2 to 15 percent slopes	Developed, Low Intensity
011	u21_dmi	Urban land and Haplic Torriarents soils, 2 to 15 percent slopes	Developed, Medium Intensity
012	art_eve	Lithic Argiustolls, Typic Haplustolls, and Aridic Calciustolls; warm mesic ustic mountains	Evergreen Forest
013	art_shr	Lithic Argiustolls, Typic Haplustolls, and Aridic Calciustolls; warm mesic ustic mountains	Shrub/Scrub
014	ust_grs	Ustic Haplargids and Typic Torriorthents; cool thermic aridic fan piedmonts	Grassland/Herbaceous
015	wct_shr	Rock outcrop-Woodcutter complex, tuff, 15 to 50 percent slopes	Shrub/Scrub

Each RCHRES requires a stage-flow relation, F-TABLE. The HSPF model relies on BASIN to generate the F-TABLES for each reach. A more accurate approach would be to perform Light Detection and Ranging (LiDAR) survey of the channels with which to build the F-TABLES.

4.3.1 Initial estimates from literature or guidance manuals

Where possible the model parameters were set through measured values, published data, and literature estimates. The approach to determining select parameters is as follows:

- Infiltration (INFILT) from SSURGO Hydrologic Group
- Lower zone nominal storage (LZSN) estimated as 1/4 mean annual rainfall + 4 in for arid regions from BASINS Technical Note 6 (USEPA 2000)
- Upper zone nominal storage (UZSN) calculated from land slope, curvature, and vegetation density (USEPA 2000)
- Lower zone E-T parameter (LZETP) set to sinusoidal function within barren land range
- Coefficient in the soil detachment equation (KRER) from SSURGO erodibility
- Washoff potency factors (POTFW) based on sequential extractions and soil samples for metals
- Concentration of the constituents in interflow outflow (IOQC) and active groundwater outflow (AOQC) based on water quality observations
- Initial sediment concentrations for constituents (SQUAL) based on sequential extractions and soil samples
- Leakage to mine from Queen Creek upstream of Superior (Reach 244) based on GeoSystems 2022

Parameterization of UZSN was based on a percentage of LZSN (EPA 2000, BASINS/HSPF manual p. 15) (Donigian and Davis 1978, ARM manual pp. 54-55). Both manuals suggest three classes for UZSN based on the topographic slope, depression storage and vegetation density (**Table 8**). A summative index of percent of LZSN was produced by an areal-weighted average approach. The various combinations of slope/depression/vegetation that exist in a given subwatershed are weighted by the area they occupy in the subwatershed and then summed (**Figure 14**).

Table 8 Assignment of UZSN value based on slope, depression storage, and vegetation characteristics

Value of UZSN	Slope	Depression	Vegetation
6% of LZSN	steep	low	limited
8% of LZSN	moderate	moderate	moderate
14% of LZSN	shallow (low)	high	heavy

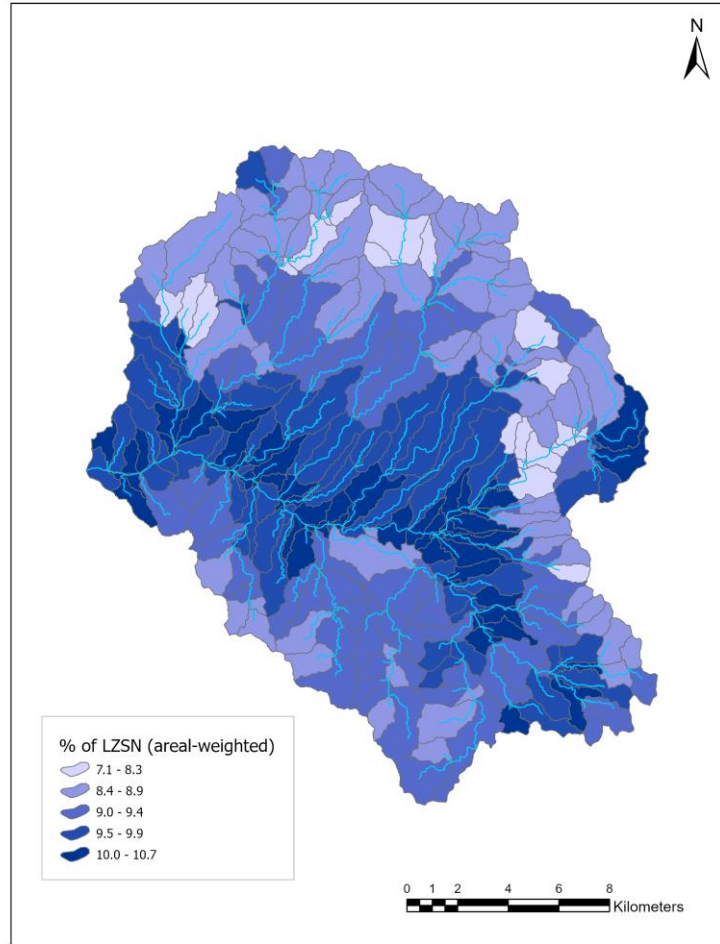


Figure 14 Upper zone storage (UZSN) estimates as a percent of lower zone storage (LZSN)

4.3.2 Calibrated Parameters

Many of the model parameters required calibration. The approach and results of the calibration are discussed below in the next three sections.

- Precipitation and ETo multipliers to refine the mapping of PRISM data to the watershed
- Interflow inflow (INTFW)
- LZSN the estimated values are calibrated
- UZSN the estimated values are calibrated
- LZETP the estimated values are calibrated
- IOQC the estimated values are calibrated
- AOQC the estimated values are calibrated
- SQUAL the estimated values are calibrated
- Interflow recession parameter (IRC)
- Remaining potential that can be satisfied with baseflow (BASETP)
- Coefficient in the soil detachment equation (KSER)
- Coefficient in the rate of washoff equation (KEIM)
- Solids accumulation rate (ACCSDP)
- Fraction of solids storage removed per day (REMSDP)
- Coefficient defining a reach carrying capacity for sand (KSAND)

- Exponent of the sandload power function (EXPSND)
- Critical erodibility coefficient (KRER)
- Coefficient for rate of compaction (AFFIX)
- Metals partitioning coefficients (KD)
- Stream leakage at reach 244 the estimated values are calibrated

Many of the parameters requiring calibration relate to sediment transport. SSURGO can provide estimates for erodibility and sorting fraction. However, a dedicated sediment study of the watershed would better inform these model parameters. Additionally, a sediment study would estimate the watershed yield allowing a better calibration target than the total suspended solids used here.

SECTION 5: CALIBRATION METHODOLOGY

Flowrate data are generally only available from October 1, 2006 through February 29, 2008. This range provided the focus for the calibration.

5.1 Calibration Approach

The model was sequentially calibrated first for hydrology, followed by sediment, and finally metals. Additionally, the calibration generally proceeded from upstream to downstream. As the calibration proceeded downstream, the upstream parameters were further refined for improved balance of model performance.

The calibration was performed by manually guiding automated calibration tools. Both HSPEXP (Lumb, et al, 1994) and HSPEXP+ (Mishra, et al, 2018) were used to evaluate model performance and suggest parameter modification to improve the fit to observations. The recommended modifications were run through the Model-independent Parameter Estimation tool (PEST) leveraging the general Time Series Processor (TSPROC) to quickly optimize and modify values. PEST also provides the sensitivity of the solution to each parameter under evaluation pointing to which variables are best calibrated first. The sensitivity analysis also calculates the level of correlation between model parameters. In a data rich environment, it may be possible to independently calibrate correlated parameters, however in a data limited environment it is necessary to either fix the ratio between correlated parameters or set constant all but one of the correlated parameters.

The calibration process followed best practices to leverage available data and ensure the model was not being over parameterized. The approach followed two guiding principles. The first was to only calibrate sensitive parameters which include those with a composite sensitivity (CS) greater than 0.5% of the most sensitive parameter. Limiting the parameters ensures the automatic calibration tool would be able to find real endpoints (Doherty, 2025). The second was how to treat correlated parameters. In a complex model like HSPF there are parameters representing different mechanistic processes that can have a similar effect on model output. The correlation of the parameters in HSPF were determined with the calibration tool and those related by 95% or greater were held constant and only the most sensitive of that group was calibrated. Calibrating only one parameter in a correlated group while holding the others constant to literature or best estimates has been shown to result in all parameters estimated uniquely (Hill and Tiedeman, 2007). Following this approach the model is giving mechanistic results based on the available data, instead of trying to calibrate every parameter that would result in a model that fits the data but would not necessarily respond to changes in the watershed conditions as the actual watershed. With a richer set of data, the model could be recalibrated to refine the performance.

5.2 Calibration Targets

Ideally, sufficient data would exist to calculate typical performance metrics such as the Nash-Sutcliffe Efficiency, coefficient of determination, root mean square error, and percent bias. Each of these measures are essentially statistical measures of the model fit to the data. With limited data, calculation of these measures may lead to incomplete or incorrect conclusions of model performance.

SECTION 6: HYDROLOGIC CALIBRATION

6.1 Annual Water Balance

Calibration of the annual water balance is performed through applying multipliers to the precipitation and evaporation potential. The calibrated multipliers are listed in **Table 9**. For some PRISM nodes, a discrete step in the multipliers is presented due to one node spanning multiple catchments each with potentially different calibration outcomes. For example, node 9 covers the high elevation headwater section of Queen Creek, upper reaches of Silver King Wash, and Oak Flat.

Table 9 Precipitation and evaporation potential multipliers to PRISM nodes

PRISM Node	Precipitation Multiplier	Evaporation Potential Multiplier
1	1.0	1.0
2	1.0	1.0
3	1.0	1.0 or 1.5
4	1.0	1.0
5	0.72 or 1.0	1.0 or 1.5
6	1.0	1.0 or 1.6
7	0.94 or 1.0	1.0 or 1.5
8	1.0	1.5
9	0.74, 1.0, or 1.2	1.0, 1.6, or 1.8
10	1.0 or 1.2	1.0

6.2 Storm Peaks

Because the mobilization of metals into the receiving water is dependent on mobilizing soil from the land area, the calibration was weighted to favor matching storm peaks over either winter or summer total volumes. In general, the flowrates in the watershed reaches diminish substantially during dry weather and trying to match low flows tends to reduce the storm peak response. A richer flow dataset may allow a more refined calibration to match both summer dry weather flows and storm flows.

Four storms were selected to calibrate the storms, these included events occurring on the following dates:

- August 7 to 8, 2007
- December 1 to 2, 2007
- December 8 to 9, 2007
- December 11 to 12, 2007

A graphical comparison between the measured and modeled storm in Queen Creek at Highway 60 is presented in **Figure 15**. The numerical comparison with errors is listed in **Table 10**. The fit of individual storms varies, with percent errors ranging from -43% to +28%. On average the error over four storms at this location is 4%.

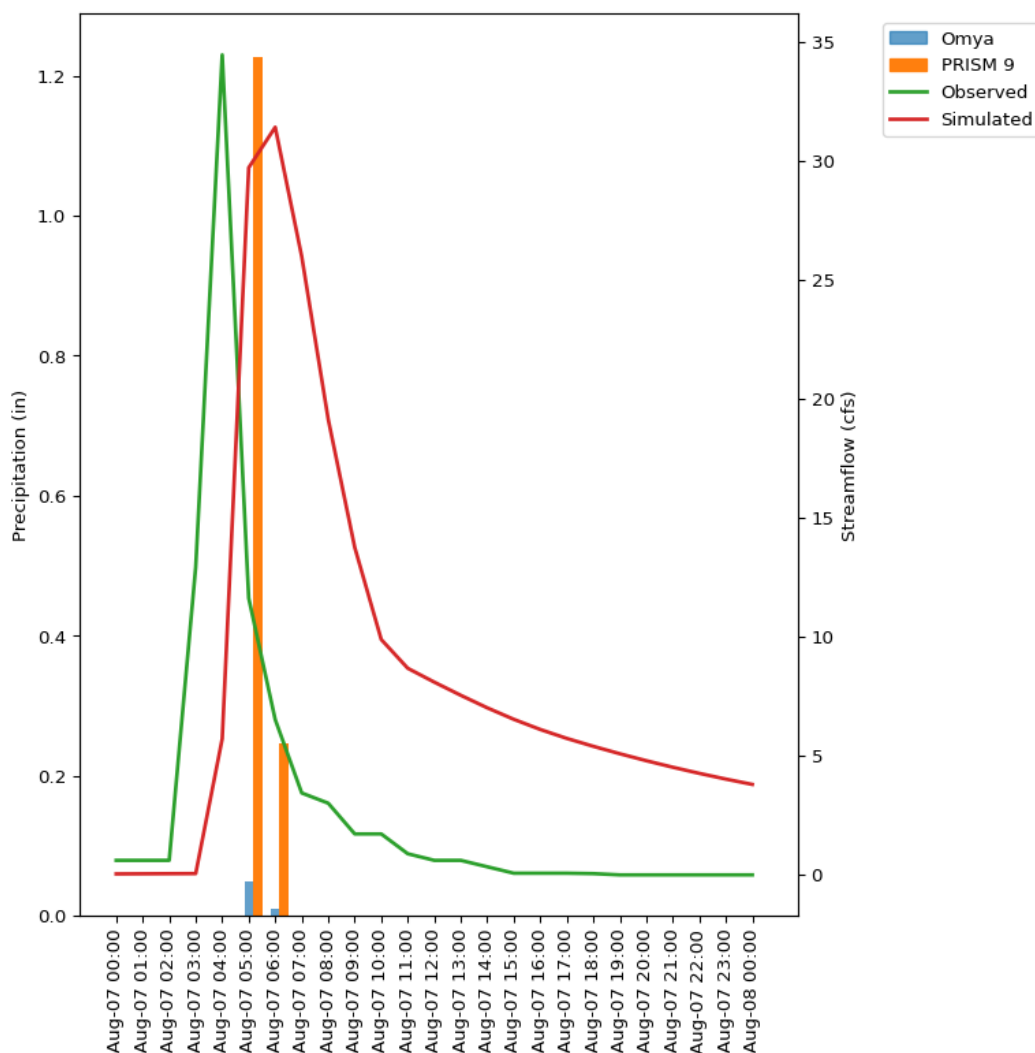


Figure 15 Observed and simulated streamflow in Queen Creek at Highway 60, precipitation measured at Omya gauge and disaggregated PRISM node 9 precipitation for storm #1 on August 7 to 8, 2007

Table 10 Queen Creek at Highway 60 observed vs simulated storm peak August 7 to 8, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
34.44	31.4	-3.04	-8.82

6.2.1 Average Storm Volume

The four storms were evaluated for at the six gauge locations with the resulting comparison presented in **Table 11**. The simulated storm volumes are in the proper magnitude as observed, however there can be relatively high variances. Longer term records at these gauges will allow a more refined calibration. The individual storm comparisons are presented in **Appendix A**.

Table 11 Average storm volume over four storms.

Gauge	Observed (AF)	Simulated (AF)	Error (AF)	Error (%)
Queen Creek at Highway 60	34	36	1	4
Oak Flat	60	28	-31	-52
Magma Avenue	241	172	-68	-28
Silver King Wash	5	10	4	95
Arnett Creek	71	104	33	46
Potts Canyon	67	61	-5	-7

SECTION 7:WATER QUALITY CALIBRATION

7.1 Sediment

Sediment calibration is limited by available data. The SSURGO dataset is used to set soil erodibility. As indicated in **Table 5**, reaches with total suspended solids data are sparse. A watershed sediment yield study could provide additional solids loading calibration targets in future model enhancements. A targeted monitoring program that collects flowrate, total suspended solids, and total and dissolved metals would add to the power of future calibration of the model.

The scour potential is estimated in the model. Most of the channel reaches are sharply incised indicating a high scour potential. Additionally, visual inspection of the stream beds reveals coarse gravels and cobbles further indicating a high level of bed scour. A more detailed study would be beneficial if a watershed yield study were to occur.

The HSPF model was calibrated with available data and soil information from SSURGO. A scatterplot of all measured data compared to the corresponding model calculations is presented as **Figure 16**. An example time series of total suspended solids for model reach 260 (Queen Creek upstream of the Superior WWTP outfall) is presented in **Figure 17**. In both figures the modeled total suspended solids are the proper order of magnitude and capture the dynamics of the observed water quality.

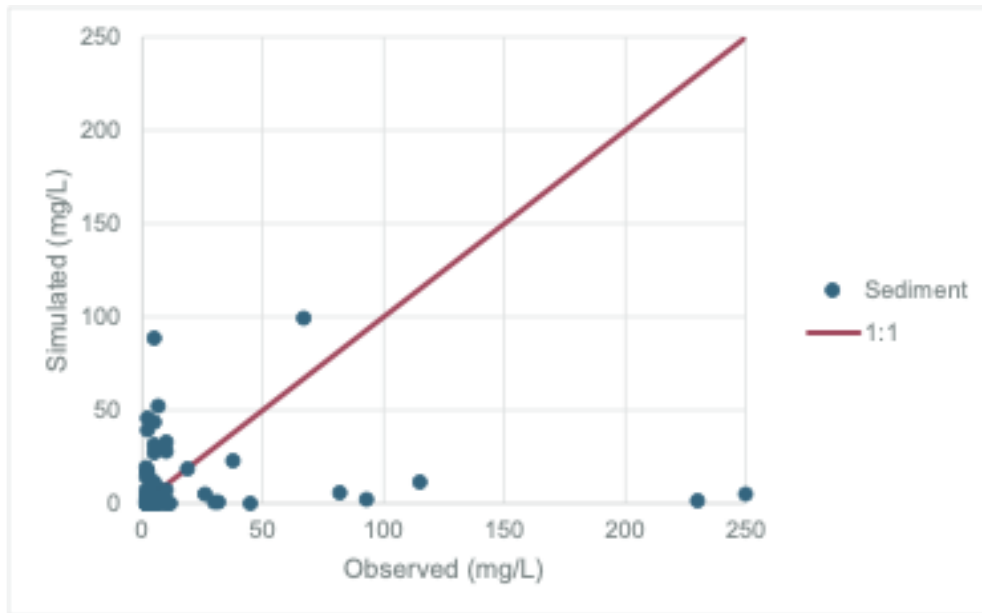


Figure 16 Scatterplot of observed and simulated sediment concentrations for all subbasins with observations.

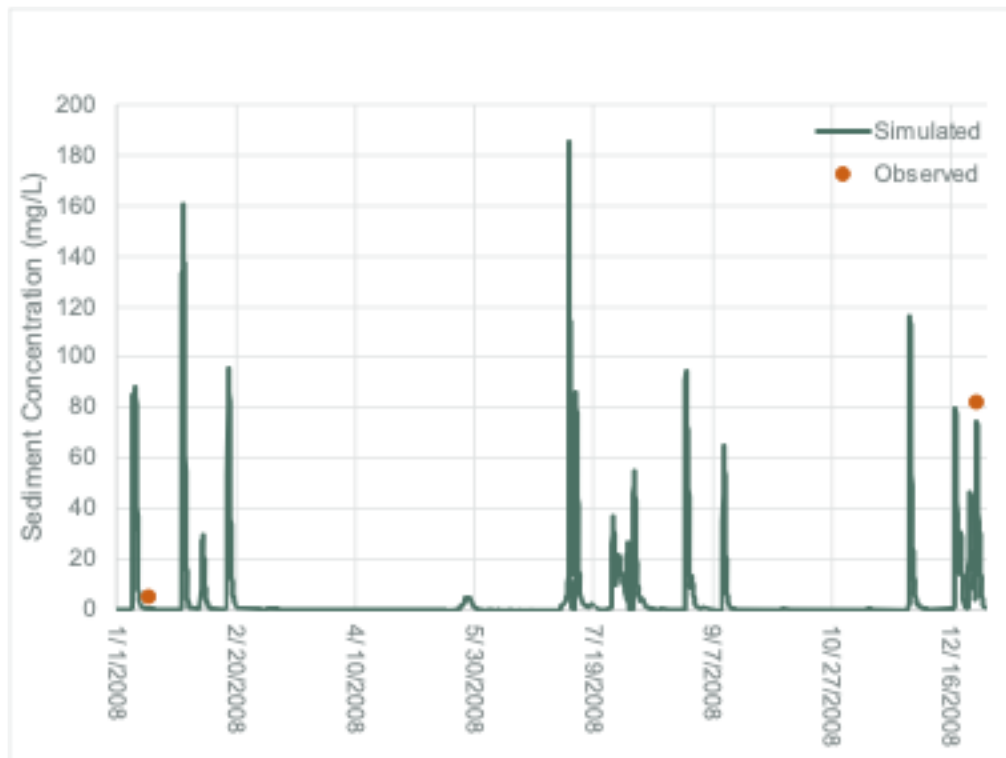


Figure 17 Hydrograph of simulated and observed sediment concentrations for subbasin 260.

7.2 Dissolved Copper

A scatter plot of all available observed dissolved copper concentrations compared to the simulated values is presented in **Figure 18**. An example times series of dissolved copper with the available measured values for model reach 243 (Queen Creek above the know lossy section upstream of Superior). As with total suspended solids, the model is capturing the dynamics of dissolved copper and simulating the appropriate magnitudes.

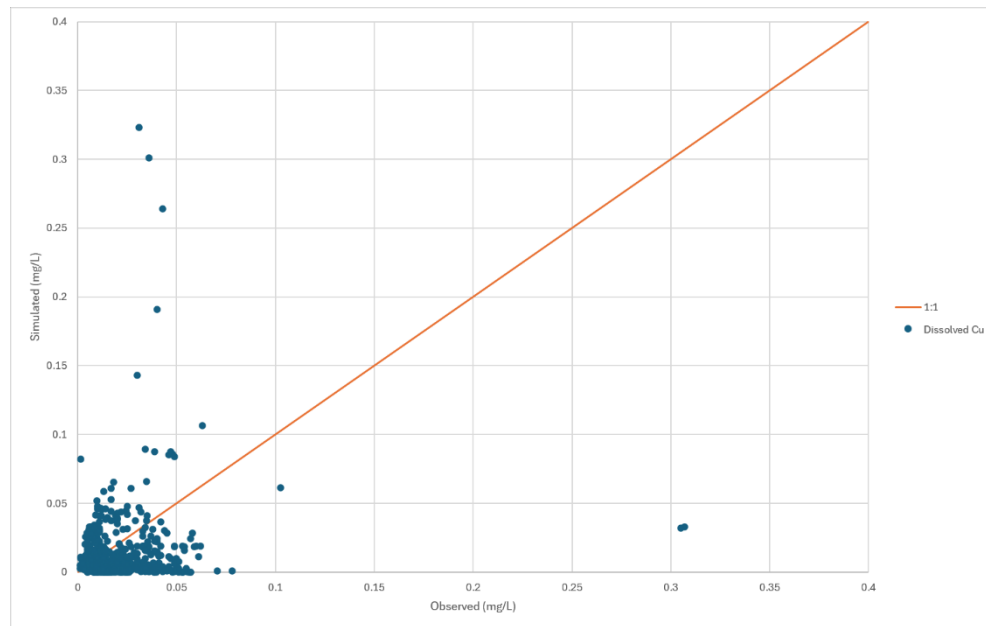


Figure 18 Scatterplot of observed and simulated dissolved copper concentrations for all subbasins with observations.

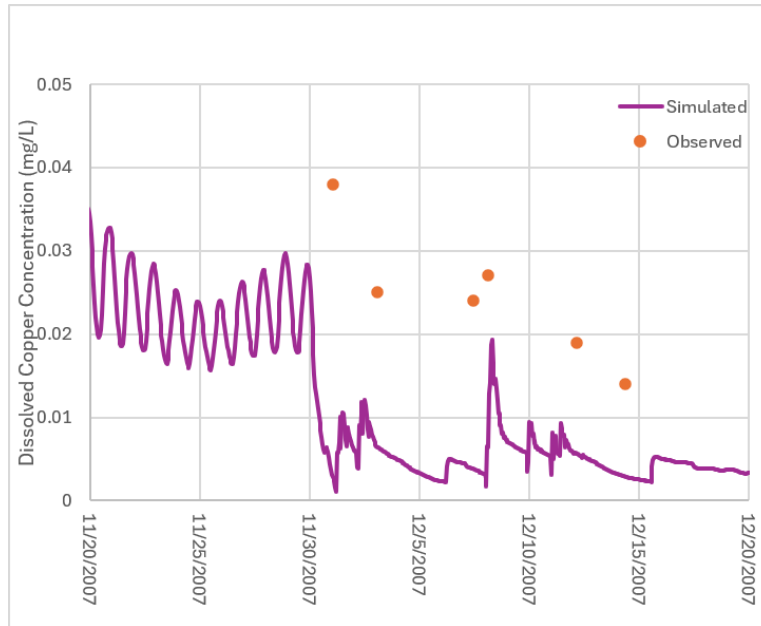


Figure 19 Hydrograph of simulated and observed dissolved copper concentrations for subbasin 243.

7.3 Dissolved Lead

The scatter plot of all dissolved lead measurements compared to the simulated values is presented in **Figure 20**. The time series of simulated and observed dissolved lead in model reach 243 is shown in **Figure 21**. As with dissolved copper the dissolved lead is of the appropriate magnitude and captures the dynamics of the measured values.

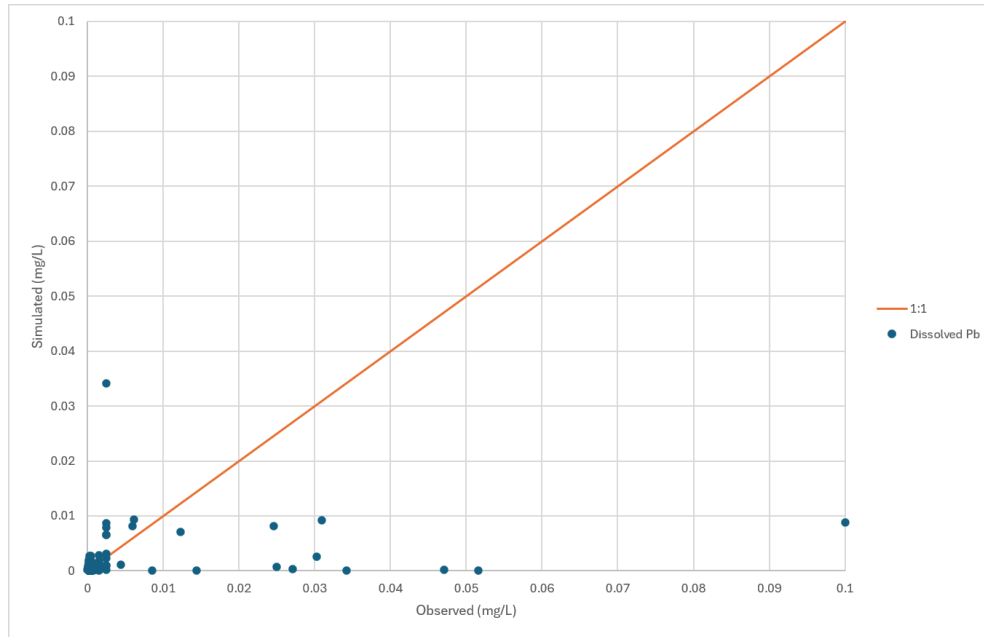


Figure 20 Scatterplot of observed and simulated dissolved lead for all subbasins with observations.

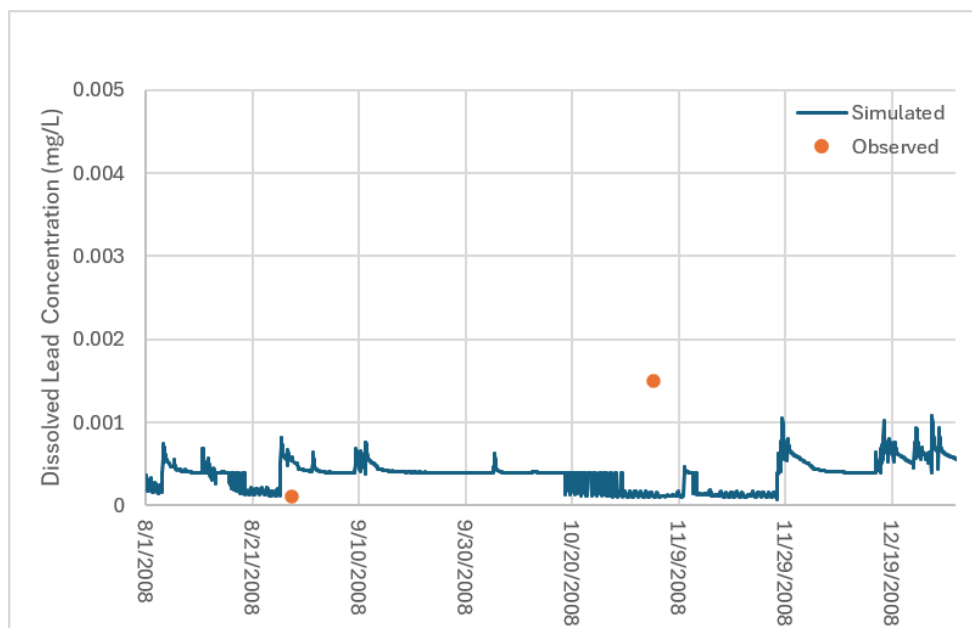


Figure 21 Hydrograph of simulated and observed dissolved lead concentrations for subbasin 243.

7.4 Total Lead

A scatterplot of all observed total lead measurements compared to the corresponding modeled values is shown in **Figure 22**. The simulated time series of total lead compared to measured values is presented in **Figure 23**. As with the other water quality parameters, the modeled total lead captures the dynamics of the measurements and is of the proper magnitude.

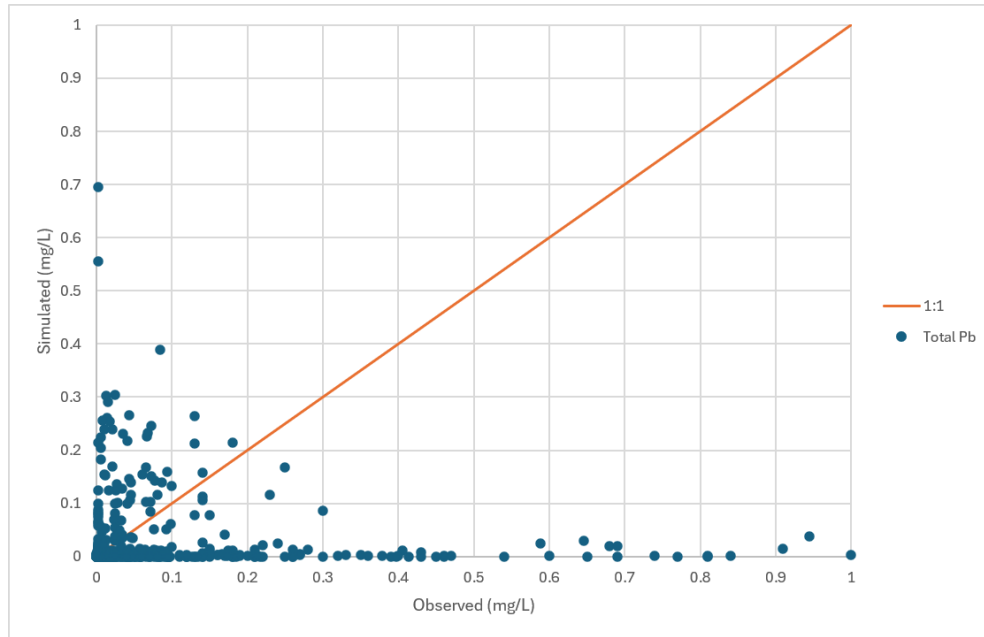


Figure 22 Scatterplot of observed and simulated total lead for all subbasins with observations.

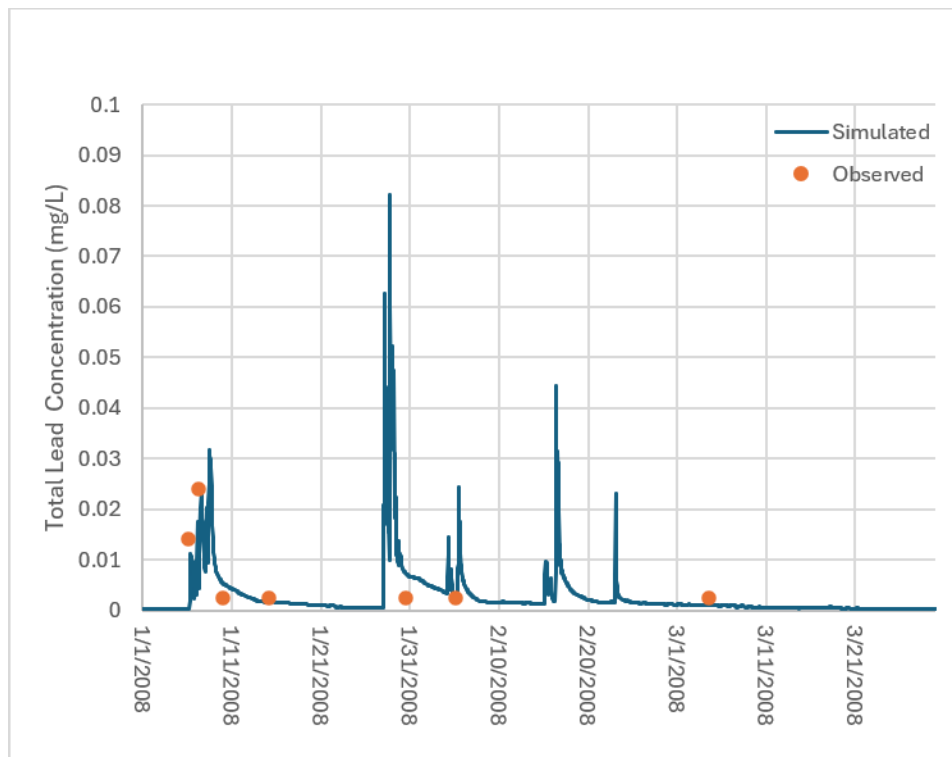


Figure 23 Hydrograph of simulated and observed total lead concentrations for subbasin 243.

SECTION 8: SOURCE ASSESSMENT

The available data to characterize source contributions were integrated into the HSPF model which was used to evaluate the relative metals contribution of land use categories to the impaired reaches. To evaluate the loading of sources in the watershed a modeled day of the year corresponding to the 95th percentile calculated load was selected. A high percentile loading captures the storm loading to the waterbodies. Further, MSGP facilities would not discharge during small storms or dry weather. AZPDES permittees are allocated the TMDL target at their design flowrate so they are assumed to be discharging in compliance with water quality objectives.

The relative land area of sources contributing metals to Queen Creek (15050100-014A) are shown in **Figure 24** along with the corresponding copper loading. The relative lead loading to the reach is shown in **Figure 25**. The developed, mined, and undeveloped land areas were calculated with the model, whereas the MSGP discharge loads were estimated by their TMDL allocation (TMDL water quality target multiplied by facility flow). Outfalls that are currently not discharging are set to zero load in the load-based charts, which include the Superior WWTP outfall 002, and the Resolution Copper Mining NPDES discharges through their outfalls 001 and 002.

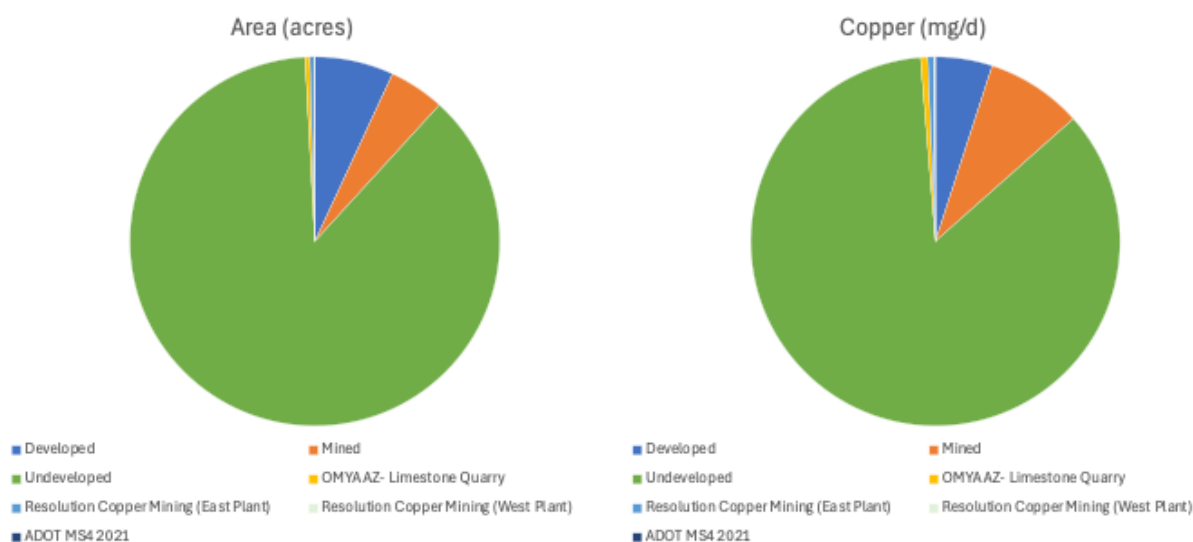


Figure 24. Relative area and copper loading contribution to Queen Creek (15050100-014A).

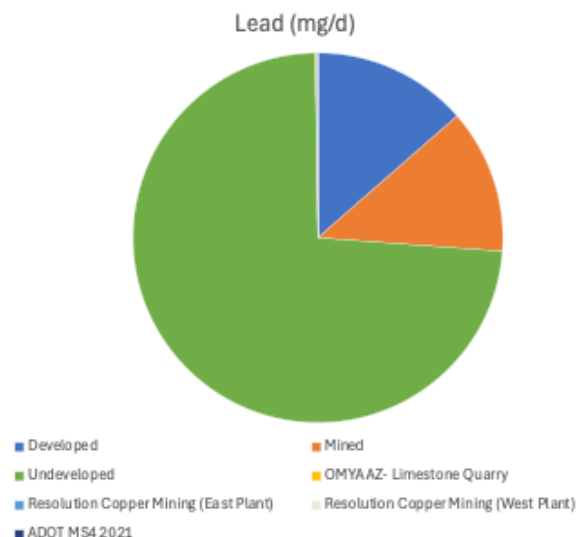


Figure 25. Relative lead loading to Queen Creek (15050100-014A).

The relative land area of sources contributing metals to Queen Creek (15050100-014B) are shown in **Figure 26** along with the corresponding copper loading. Note for all pie-charts (**Figures 24 to 28**), individual permittees are not included in the area plot as it is a point source discharge and have no associated watershed area contribution. The area of MSGP permitted facilities contributes loading, so they appear in both the area and loading figures.

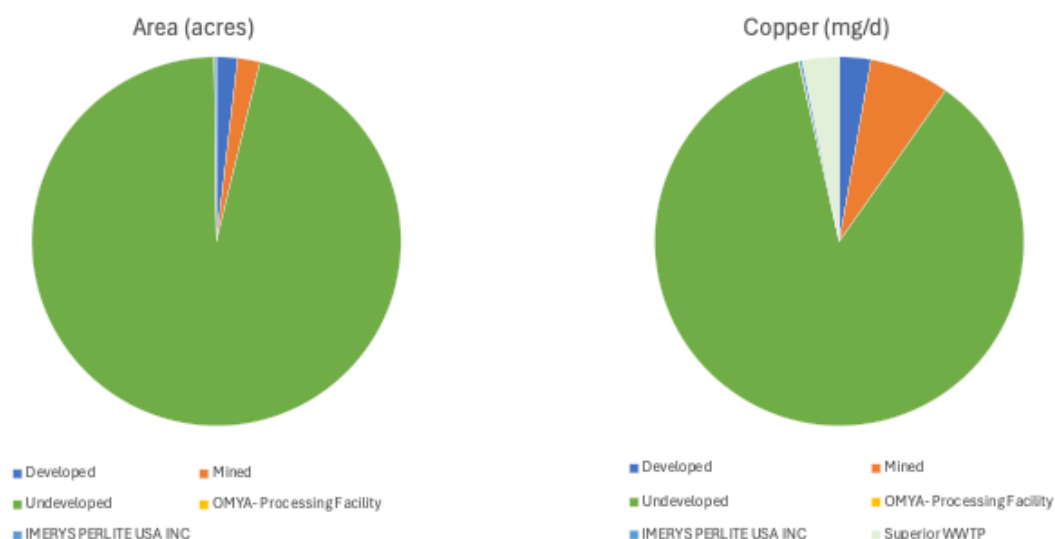


Figure 26. Relative area and copper loading contribution to Queen Creek (15050100-014B).

The relative land area of sources contributing metals to Queen Creek (15050100-014C) are shown in **Figure 27** along with the corresponding copper loading.

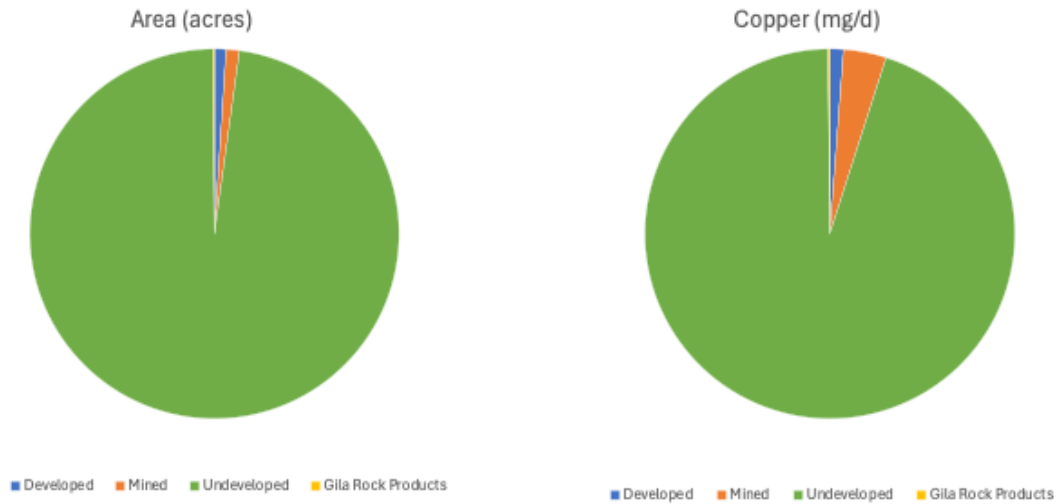


Figure 27. Relative area and copper loading contribution to Queen Creek (15050100-014C).

The relative land area of sources contributing metals to Arnett Creek (15050100-1818) are shown in **Figure 28** along with the corresponding copper loading.

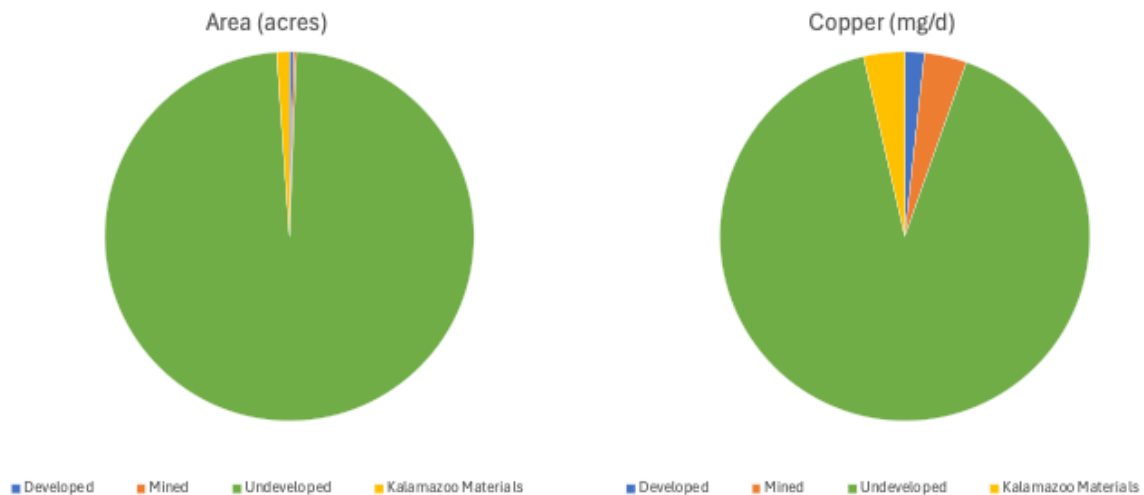


Figure 28. Relative area and copper loading contribution to Arnett Creek (15050100-1818).

Relative contributions for the unnamed tributary to Queen Creek (UQ3, 15050100-1843) are not shown in this report as that watershed is 100 percent undeveloped land.

SECTION 9: CURRENT LOADINGS

HSPF model simulations were performed with meteorology from October 1, 2001 to September 30, 2025. Model output for the last five years was analyzed to determine the 95th percentile loads to evaluate the waterbodies under storm and post-storm conditions.

9.1 Dissolved Copper

Model results for the 95th percentile dissolved copper loading in the watershed is presented in Error! Reference source not found.. The corresponding 95th percentile concentration of dissolved copper in the receiving water is shown in **Figure 30**. While the tributary copper concentrations increase in the vicinity of higher soil concentrations, the tributary flowrates appear to be low enough to result in significant load increases.

HSPF results were used to evaluate the relative contribution to dissolved copper load by land sources and upstream reaches. The analysis is performed for February 25, 2023, the day corresponding to the 95th percentile load in Queen Creek reach 014A. Other reaches may have 95th percentile loads occurring on different days; however, this analysis requires selecting a day so the loads flowing through the watershed will sum. The in-stream load weighted percent contribution of dissolved copper for each impaired reach is presented in **Table 12**. This analysis is a simplified by not considering the scour/deposition in the stream bed and changes due partitioning. Each row in **Table 12** lists the percent contribution of dissolved copper in that specific impaired reach, for example of the dissolved copper load at Whitlow Dam (Queen Creek Reach 014C), 57 percent is from the upstream impaired reaches and 42 percent is from undeveloped lands draining to 014C. The cumulative load weighted percent contribution of dissolved copper is presented in **Table 13** which carries the source information downstream. For example, for the load in Queen Creek reach 014C, mined areas generated 4 percent, developed areas produced 2 percent, undeveloped areas produced 92 percent, 1 percent was from MSGP discharges, and 1 percent was from AZPDES discharges. Note in both tables, the rows may not add to 100 due to rounding.

As was illustrated in the source assessment summary (**Section** Error! Reference source not found.) while mined and developed areas may have higher loads per acre, their size is dwarfed by the surrounding undeveloped lands in the watershed. The majority of the copper loading for each of the impaired reaches is the undeveloped lands.

Table 12. Load weighted percent contribution of in-stream dissolved copper load to the outlet of each impaired watershed.

Impaired Reach	Load Weighted Percent Contribution of Total Reach Load ⁽¹⁾ (%)					
	Reach Contribution					Upstream Contributions
	Mined	Developed	Undeveloped	MSGP ⁽²⁾	AZPDES	
UQ3	0	0	100	0	0	0
Arnett Creek	4	2	91	4	0	0
Queen Creek (014A)	8	5	84	1	0	2 ⁽³⁾
Queen Creek (014B)	5	2	57	0	2	34 ⁽⁴⁾
Queen Creek (014C)	0	0	42	0	0	57 ⁽⁵⁾

¹ Ignoring stream bed scouring and deposition. Loading from simulation of February 25, 2023.

² Loading estimated by TMDL target concentration multiplied by calculated flowrate.

³ UQ3

⁴ UQ3, Queen Creek 014A, and Arnett Creek

⁵ UQ3, Queen Creek 014A, Arnett Creek, and Queen Creek 014B

Table 13. Cumulative load weighted percent contribution of in-stream dissolved copper load to the outlet of each impaired watershed.

Impaired Reach	Cumulative Load Weighted Percent Contribution ⁽¹⁾ (%)					Upstream Contributions
	Mined	Developed	Undeveloped	MSGP ⁽²⁾	AZPDES	
UQ3	0	0	100	0	0	Headwater
Arnett Creek	4	2	91	4	0	Headwater
Queen Creek (014A)	8	5	86	1	0	Headwater and UQ3
Queen Creek (014B)	6	3	88	1	2	UQ3, 014A, and Arnett Creek
Queen Creek (014C)	4	2	92	1	1	UQ3, 014A, 014B, and Arnett Creek

¹ Ignoring stream bed scouring and deposition. Loading from simulation of February 25, 2023.

² Loading estimated by TMDL target concentration multiplied by calculated flowrate.

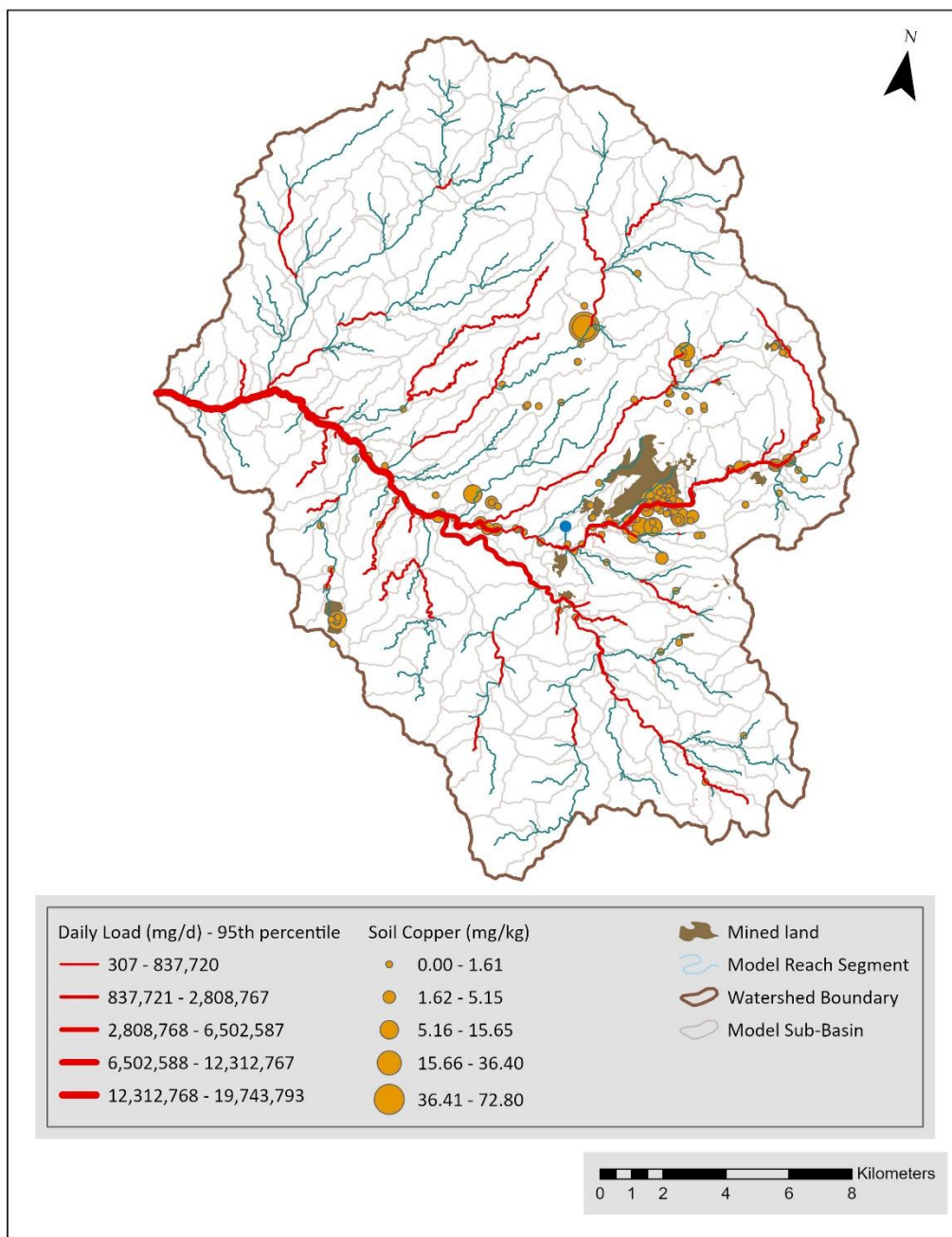


Figure 29. HSPF-modeled dissolved copper daily load (mg/d) for the Queen Creek watershed. Value represents 95th percentile from distribution of daily values for 2021-2025.

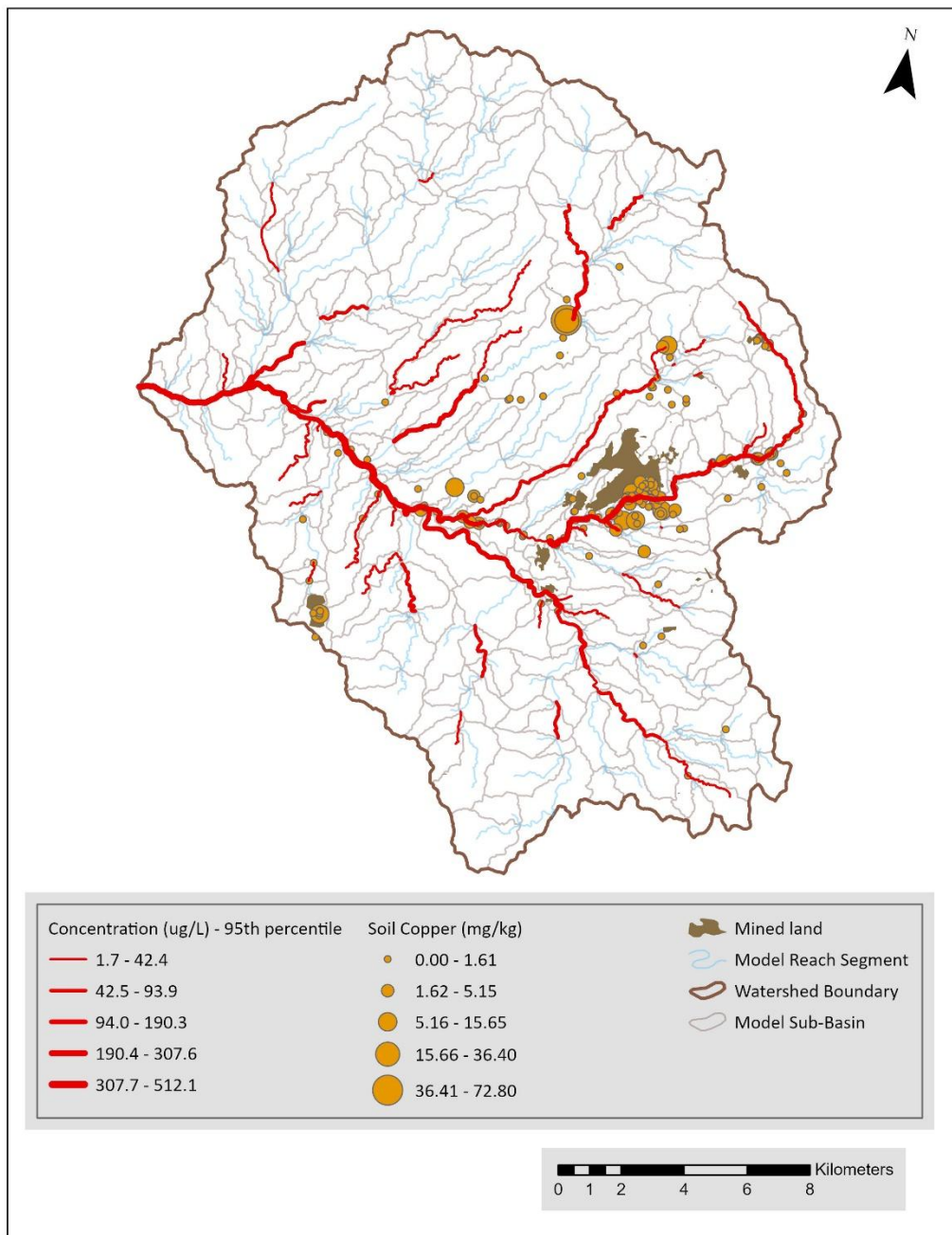


Figure 30. HSPF-modeled dissolved copper concentration (µg/L) for the Queen Creek watershed. Value represents 95th percentile from distribution of daily values for 2021-2025.

9.2 Total Lead

Modeled 95th percentile results for total lead loading are presented in Error! Reference source not found., and the corresponding modeled total lead concentration is shown in **Figure 32**. As with copper, the

concentration of lead appears to increase near land areas with high soil concentrations. However, the flowrate in those tributaries appears to be low enough to prevent significant increases in loading of total lead. The source contributions of total lead to Queen Creek 014A are listed in **Table 14**. The reach UQ3 contributes a negligible load of lead, so the cumulative percent contribution by source to Queen Creek 014A presented in **Table 15** is within rounding to those listed in **Table 14**.

Table 14. Load weighted percent contribution of in-stream total lead load to the outlet of impaired watershed (014A).

Impaired Reach	Load Weighted Percent Contribution of Total Reach Load ⁽¹⁾ (%)					
	Reach Contribution					Upstream Contributions
	Mined	Developed	Undeveloped	MSGP ⁽²⁾	AZPDES	
Queen Creek (014A)	13	14	73	<1	0	<1 ⁽³⁾

¹ Ignoring stream bed scouring and deposition. Loading from simulation of February 25, 2023.

² Loading estimated by TMDL target concentration multiplied by calculated flowrate.

³ UQ3

Table 15. Cumulative load weighted percent contribution of in-stream total lead load the outlet of impaired watershed (014A).

Impaired Reach	Cumulative Load Weighted Percent Contribution ⁽¹⁾ (%)					Upstream Contributions
	Mined	Developed	Undeveloped	MSGP ⁽²⁾	AZPDES	
Queen Creek (014A)	13	14	73	<1	0	Headwater and UQ3

¹ Ignoring stream bed scouring and deposition. Loading from simulation of February 25, 2023.

² Loading estimated by TMDL target concentration multiplied by calculated flowrate.

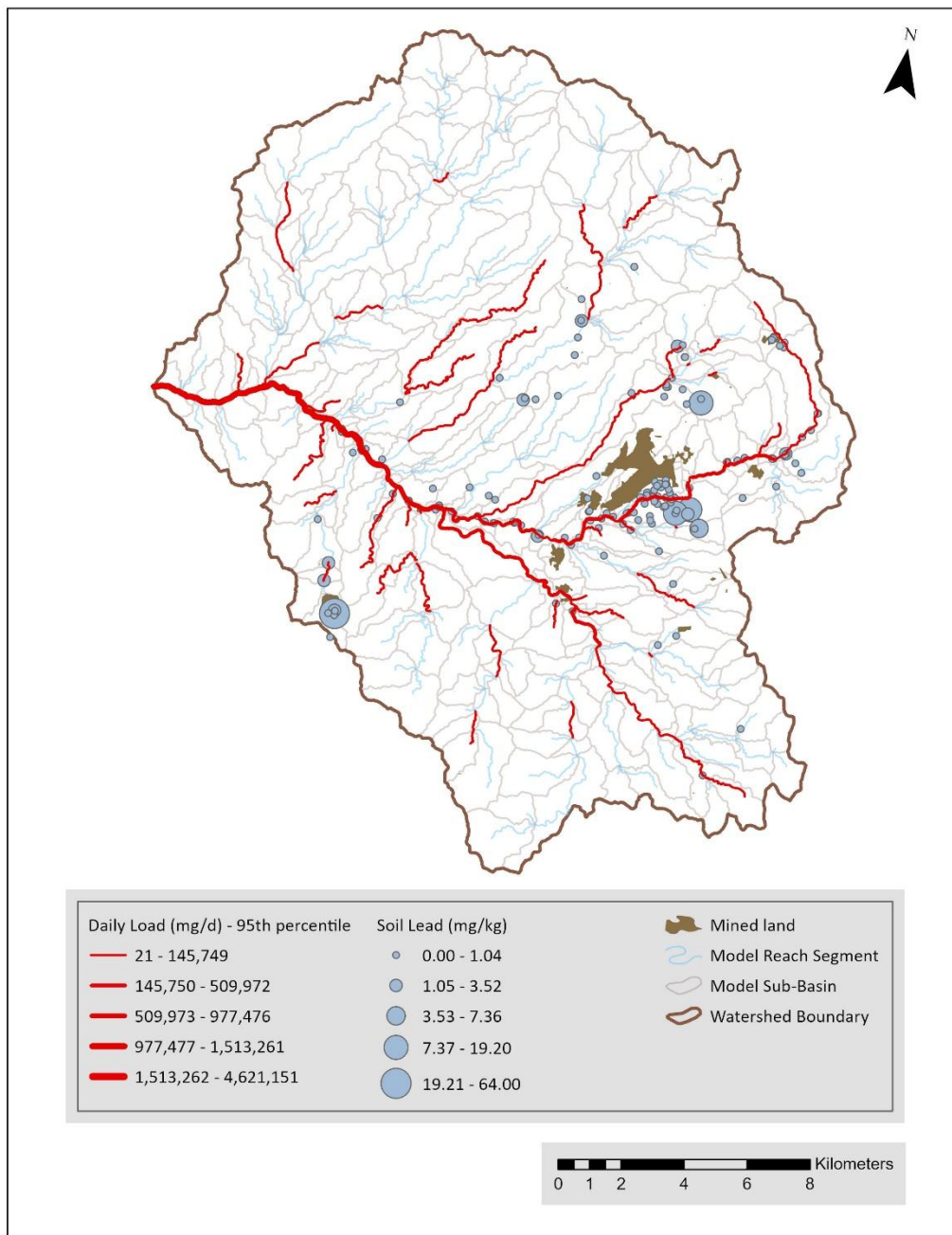


Figure 31. HSPF-modeled total lead daily load (mg/d) for the Queen Creek watershed. Value represents 95th percentile from distribution of daily values for 2021-2025.

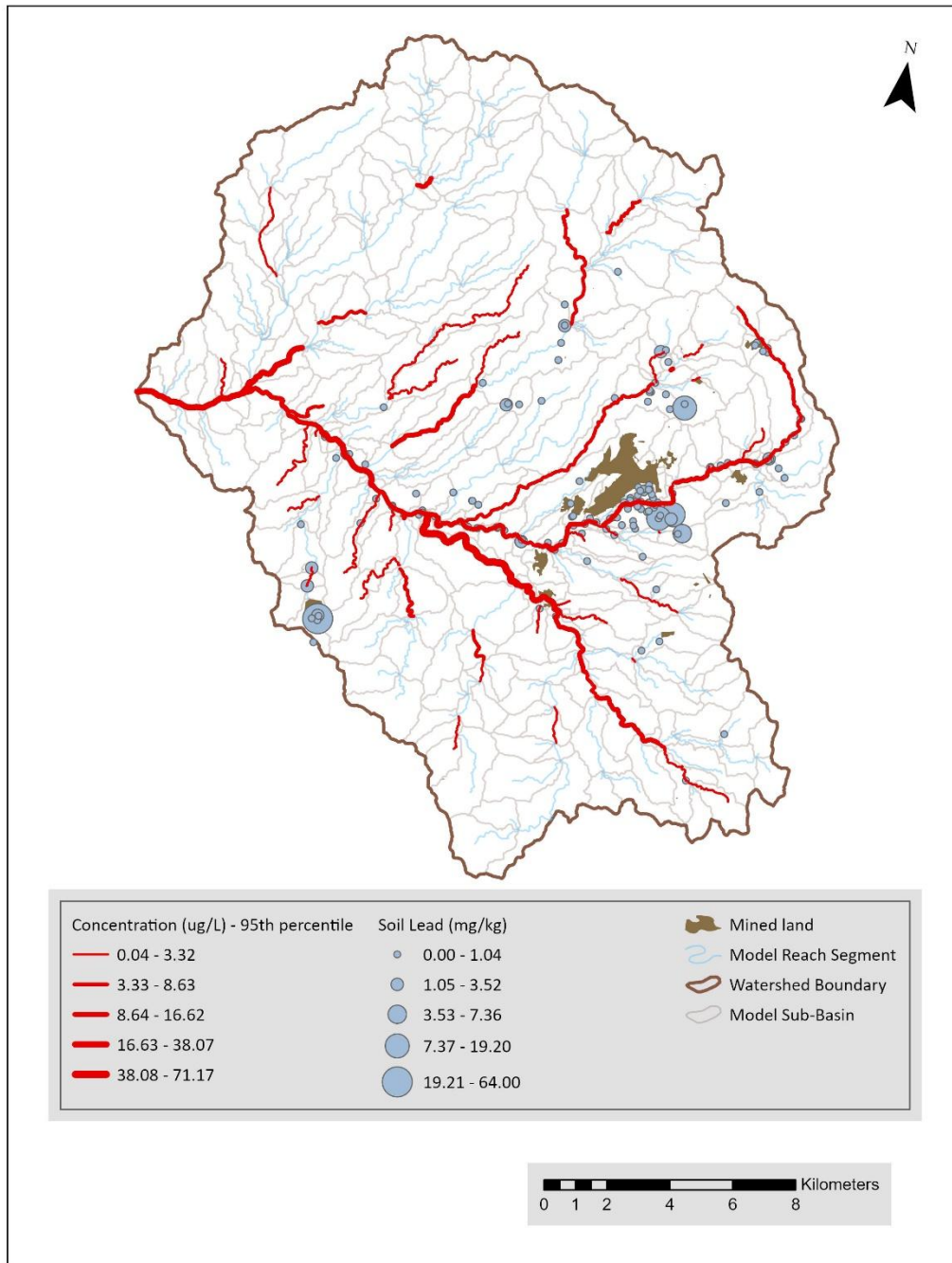


Figure 32. HSPF-modeled total lead concentration (µg/L) for the Queen Creek watershed. Value represents 95th percentile from distribution of daily values for 2021-2025.

SECTION 10: LIMITATIONS AND UNCERTAINTY

Meteorological data are limited in the watershed. While gridded datasets are used to develop a model with a domain spanning approximately 20 years, the data are largely disaggregated with standard routines in BASIN with limited assistance from in-watershed precipitation stations. Establishing

meteorological stations in the watershed would allow refinement of model inputs and reduce the model uncertainty.

There is limited flowrate data available for the waterways in the watershed. A program to set and maintain permanent gauges would allow enhancement of the HSPF model calibration.

Queen Creek is known to have losing reaches upstream of Superior. The estimates developed in GeoSystems 2022 were used in the model and slightly calibrated to improve low flow performance as measured by the Magma gauge. However, additional study would inform us of the likely rate of infiltration in that area and whether other areas are lossy.

A sediment study of the watershed would allow refined calibration of the sediment transport mechanisms in HSPF. This, combined with assessment of the scour potential within the reaches would improve the water quality calibration effort of this study.

A concurrent water quality monitoring program capturing flowrate, total suspended solids, and total and dissolved metals over each 303(d) listed reach would add to the ability to refine calibration if determined necessary.

The ability to refine calibration is affected by the limitation of data. This introduced uncertainty can be ameliorated by increasing the margin of safety when developing a TMDL with the model.

SECTION 11: CONCLUSIONS AND RECOMMENDATIONS

The HSPF model of the Queen Creek Watershed simulates receiving water flowrate, total suspended solids, dissolved copper, and total recoverable lead. The simulations capture the dynamics observed in the measured variables. A refined calibration is limited by the available data in the watershed. The model utilizes the existing data to allow watershed simulations and source loading calculations. Due to data limitations, the model cannot take advantage of the full power of the HSPF modeling system. However, as additional data are collected in the watershed the model can be refined and HSPF features implemented fully.

The recommendations of RESPEC 2017 were implemented to the extent practicable when developing the HSPF model for the upper Queen Creek Watershed. Data limitations were still present while building the model, however, those limitations are called out and an increased margin of safety is warranted during the TMDL development.

The calibrated HSPF model captures the dynamics of the measured flowrate and water quality parameters. The simulations are of the proper magnitude. The model is appropriate to use in the evaluation of watershed loading of constituents and the effects of watershed controls. The developed HSPF model is appropriate for use in evaluating the watershed TMDL.

SECTION 12: REFERENCES

Arizona Department of Environmental Quality, Surface Water Section (ADEQ). 2006. Pinto Creek Phase II TMDL Modeling Report

Arizona Department of Environmental Quality, Surface Water Section (ADEQ). 2010. Interim Queen Creek TMDL Modeling Report

Arizona Department of Environmental Quality, Surface Water Section (ADEQ). 2013. Queen Creek TMDL Modeling Report, Louis Berger Group, Inc.

Doherty, J. 2025. *Calibration and Uncertainty Analysis for Complex Environmental Models*. Second Edition. Watermark Numerical Computing.

GeoSystems. 2022. Evaluate the effects of historic mine workings, continued dewatering, and drought on the nature of flow in Queen Creek, Prepared for: Queen Creek Working Group, July 1, 2022. Provided by Arizona Department of Environmental Quality.

Haley & Aldrich. 2025. Site-Specific Soil Remediation Levels (SSRLs), Superior Soil Study Area. Prepared by Haley & Aldrich for BHP Copper Inc. File No. 132654-011. Provided by Arizona Department of Environmental Quality.

Lumb, A. M., R. B. McCammon, and J. L. Kittle, Jr., 1994. User' s Manual for an Expert System (HSPEXP) for Calibration of the Hydrological Simulation Program-FORTRAN, Water-Resources Investigations Report 94-4168, prepared by the US Geological Survey, Reston, VA.

Mary C. Hill and Claire R. Tiedeman. 2007. *Effective Groundwater Model Calibration*. John Wiley & Sons, Ltd. <https://doi.org/10.1002/9780470041086.index>.

Mishra, A., A.S. Donigian, Jr, P.B. Duda. 2018. HSPEXP+ User's Manual, version 2.0.0. prepared for Minnesota Pollution Control Agency.

RESPEC. 2017. Revised Review of ADEQ Queen Creek TMDL HSPF Model

SWCA 2025. QUEEN CREEK TECHNICAL APPROACH MEMORANDUM, SWCA Environmental Consultants.

U.S. Environmental Protection Agency (EPA). 2000. Estimating Hydrology and Hydraulic Parameters for HSPF. EPA-823-R00-012

U.S. Geological Survey (USGS). 2018. National Land Cover Database. Available at: <https://www.usgs.gov/centers/eros/science/national-land-cover-database>.

Appendices

APPENDIX A: HYDROLOGY CALIBRATION FIGURES

Appendix A

Hydrology Calibration Figures

A. Hydrology Calibration Figures

A.1 Queen Creek at Highway 60

Storm 1: 2007/08/07 to 2007/08/08

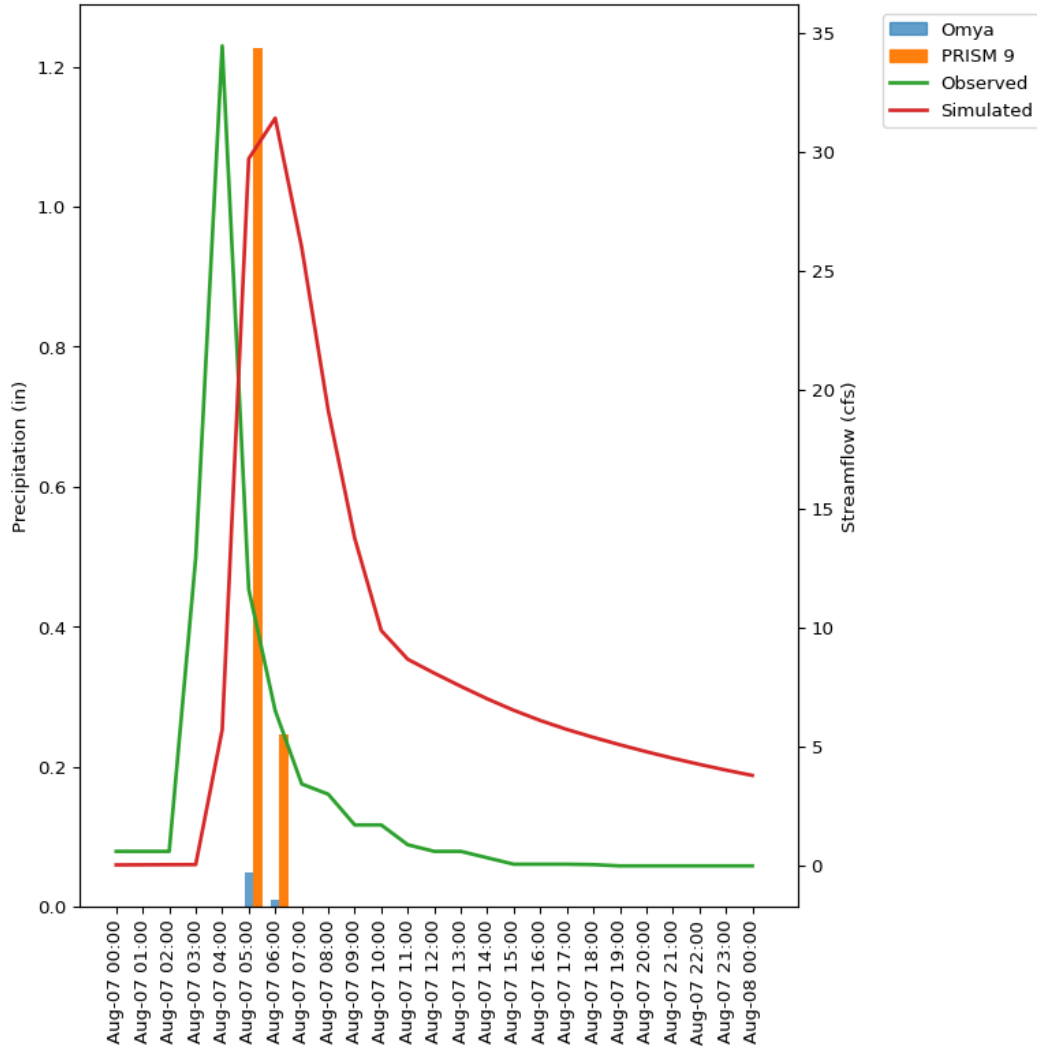


Figure A-1 Observed and simulated streamflow in Queen Creek at Highway 60, precipitation measured at Omya gauge and disaggregated PRISM node 9 precipitation for storm #1 on August 7 to 8, 2007

Table A-1 Queen Creek at Highway 60 observed vs simulated peak for storm #1 on August 7 to 8, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
34.44	31.4	-3.04	-8.82

Storm 2: 2007/12/01 to 2007/12/02

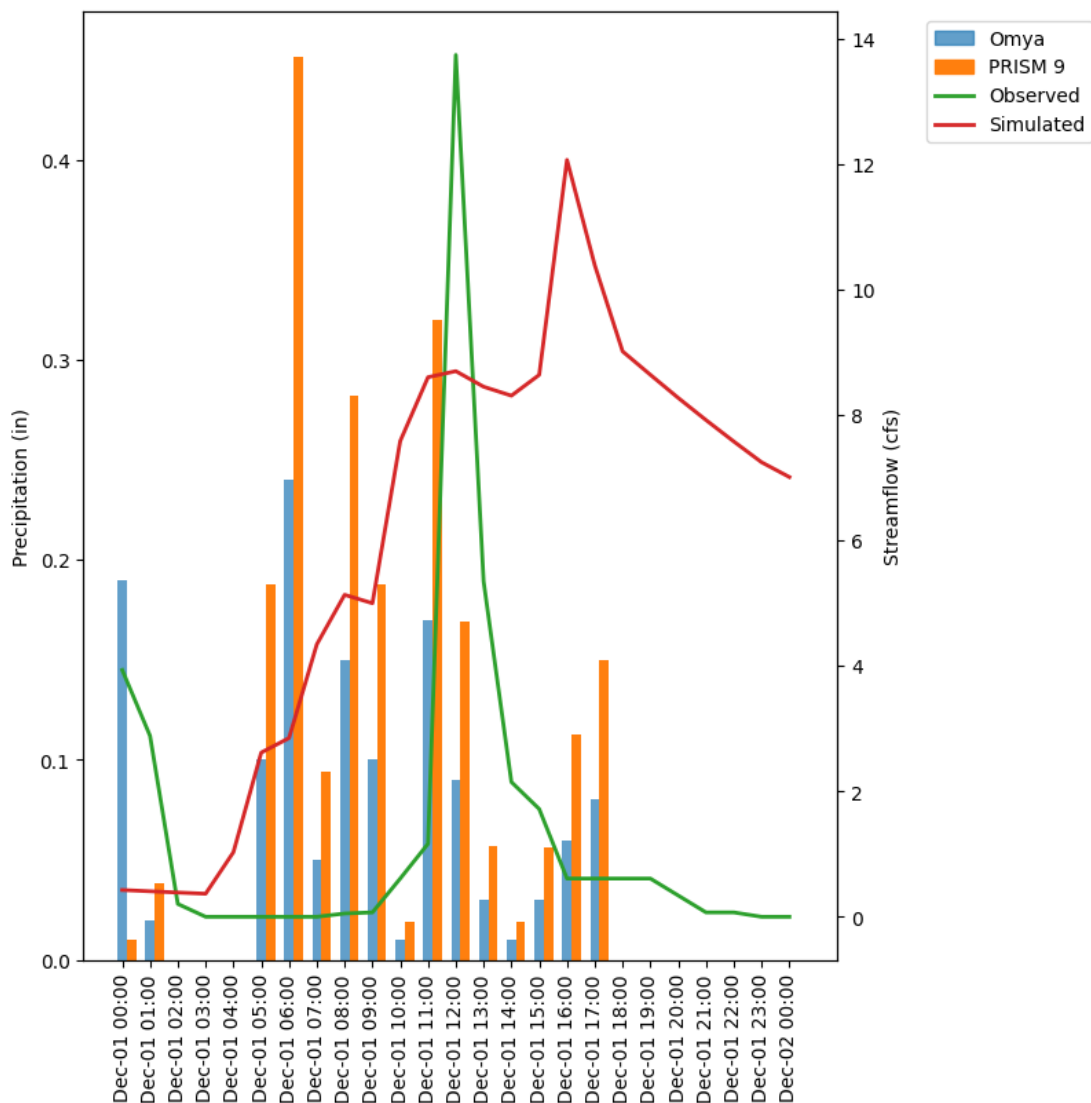


Figure A-2 Observed and simulated streamflow in Queen Creek at HW 60, precipitation measured at Omya gauge and disaggregated PRISM node 9 precipitation for storm #2 on December 1 to 2, 2007

Table A-2 Queen Creek at Highway 60 observed vs simulated peak for storm #2 on December 1 to 2, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
13.75	12.08	-1.67	-12.18

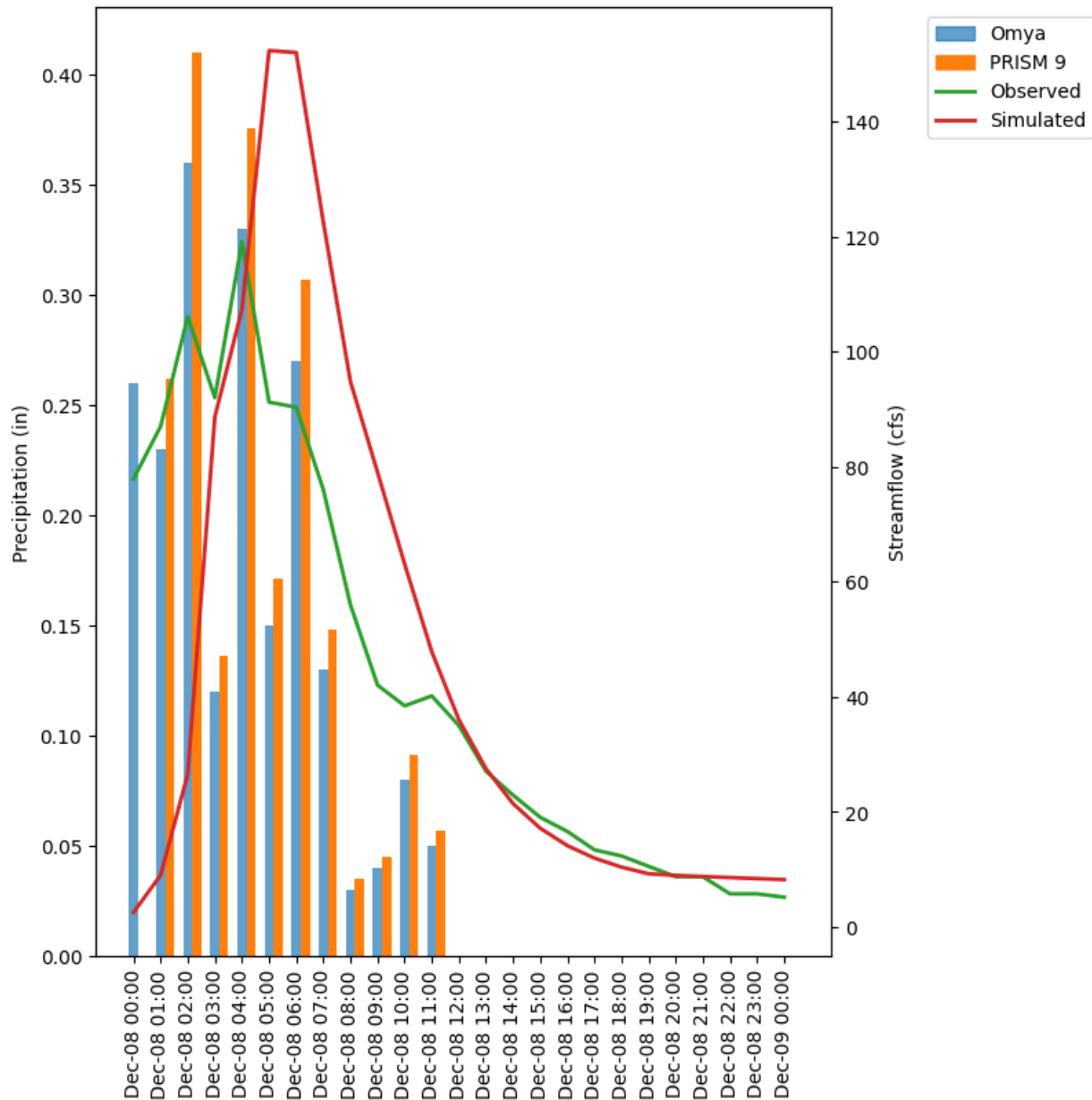


Figure A-3 Observed and simulated streamflow in Queen Creek at HW 60, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #3 on December 8 to 9, 2007

Table A-3 Queen Creek at Highway 60 observed vs simulated peak for storm #3 on December 8 to 9, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
119.06	152.27	33.21	27.89

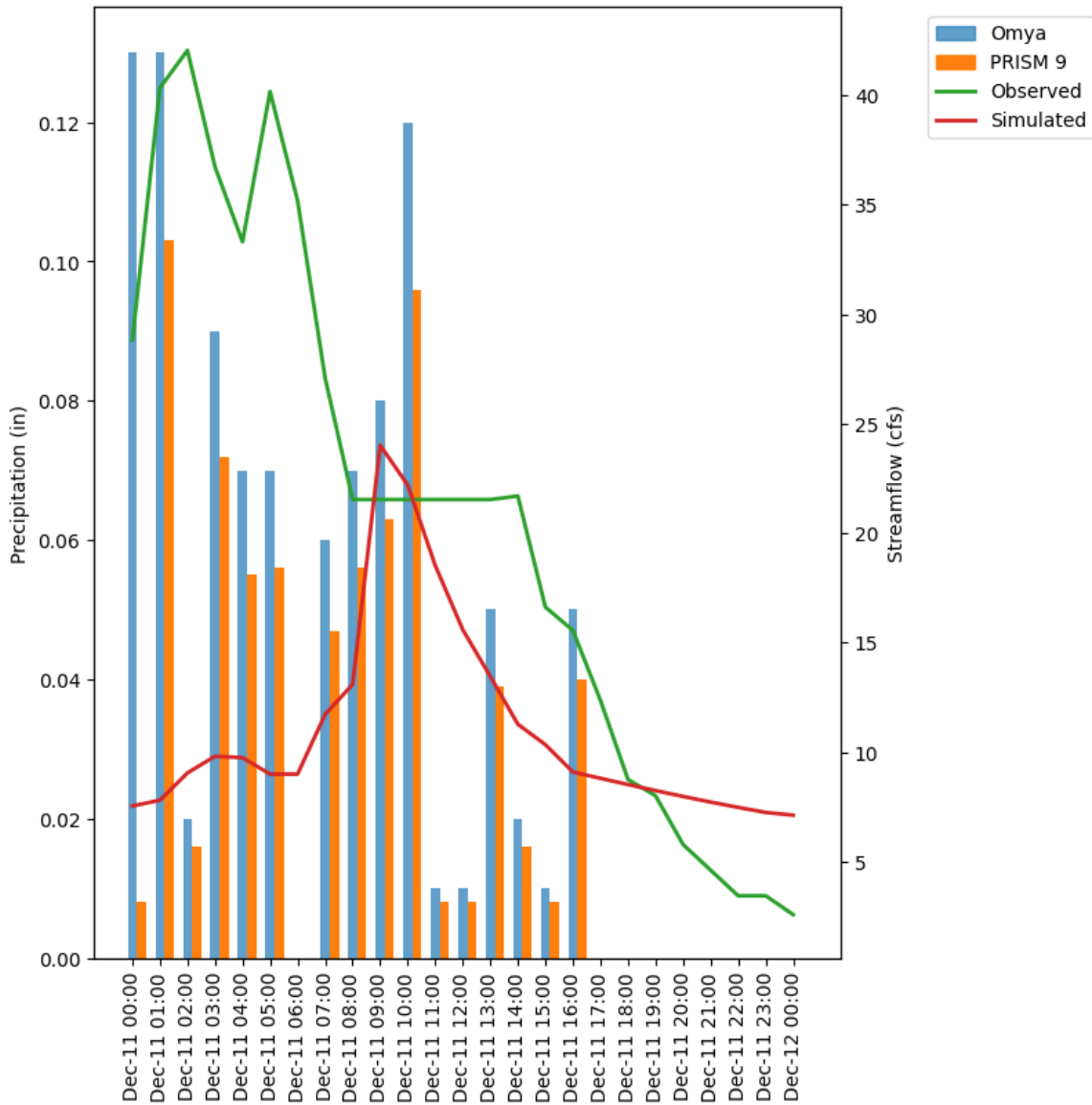


Figure A-4 Observed and simulated streamflow in Queen Creek at HW 60, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #4 on December 11 to 12, 2007

Table A-4 Queen Creek at Highway 60 observed vs simulated peak for storm #4 on December 11 12, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
42.04	24.01	-18.03	-42.89

A.2 Oak Flat

Storm 1: 2007/08/07 to 2007/08/08

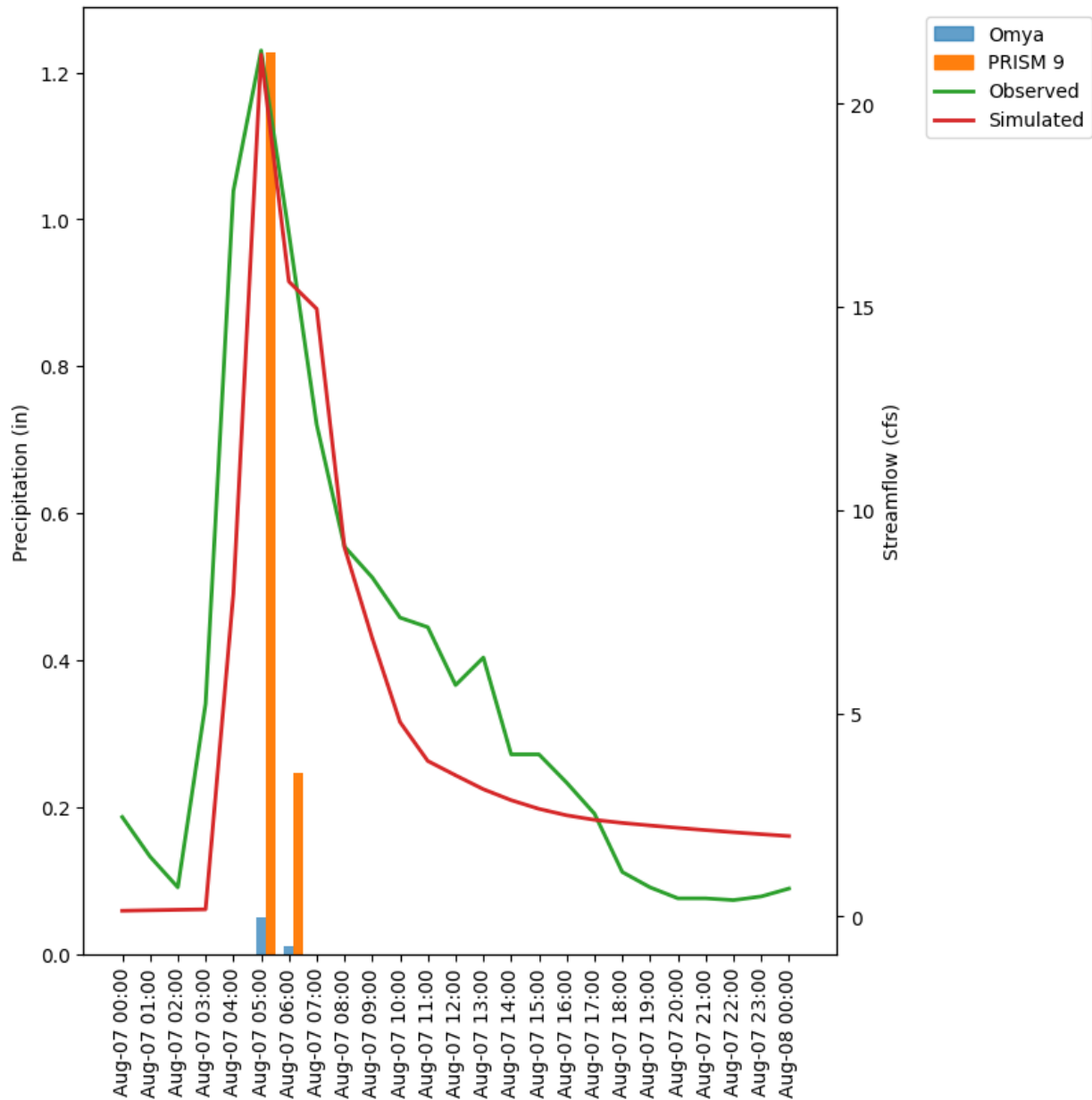


Figure A-5 Observed and simulated streamflow in Oak Flat, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #1 on August 7 to 8, 2007

Table A-5 Oak Flat observed vs simulated peak for storm #1 on August 7 to 8, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
21.32	21.21	-0.1	-0.48

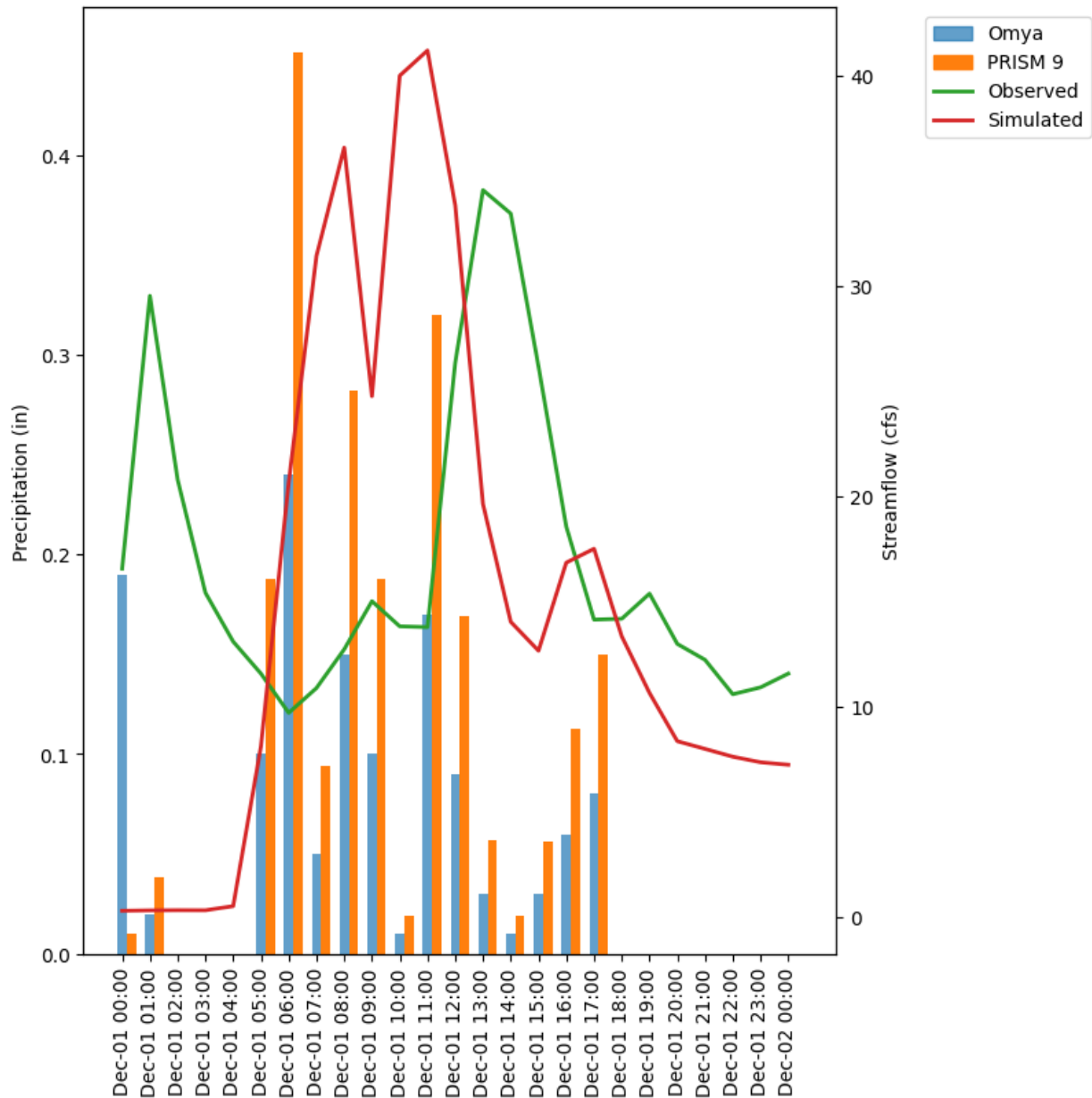


Figure A-6 Observed and simulated streamflow in Oak Flat, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #2 on December 1 to 2, 2007

Table A-6 Oak Flat observed vs simulated peak for storm #2 on December 1 to 2, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
34.56	41.2	6.64	19.21

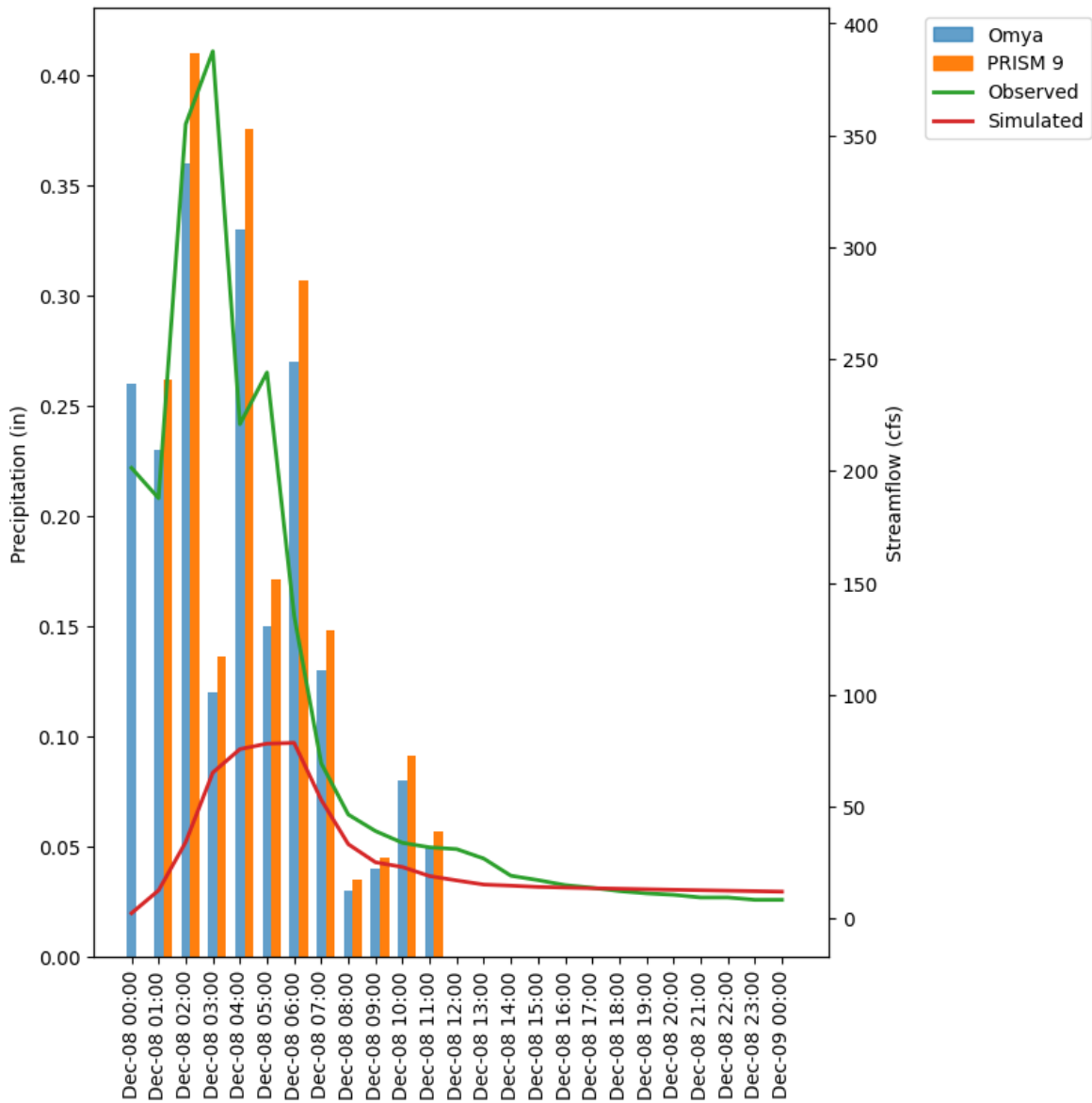


Figure A-7 Observed and simulated streamflow in Oak Flat, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #3 on December 8 to 9, 2007

Table A-7 Oak Flat observed vs simulated peak for storm #3 on December 8 to 9, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
387.55	78.47	-309.08	-79.75

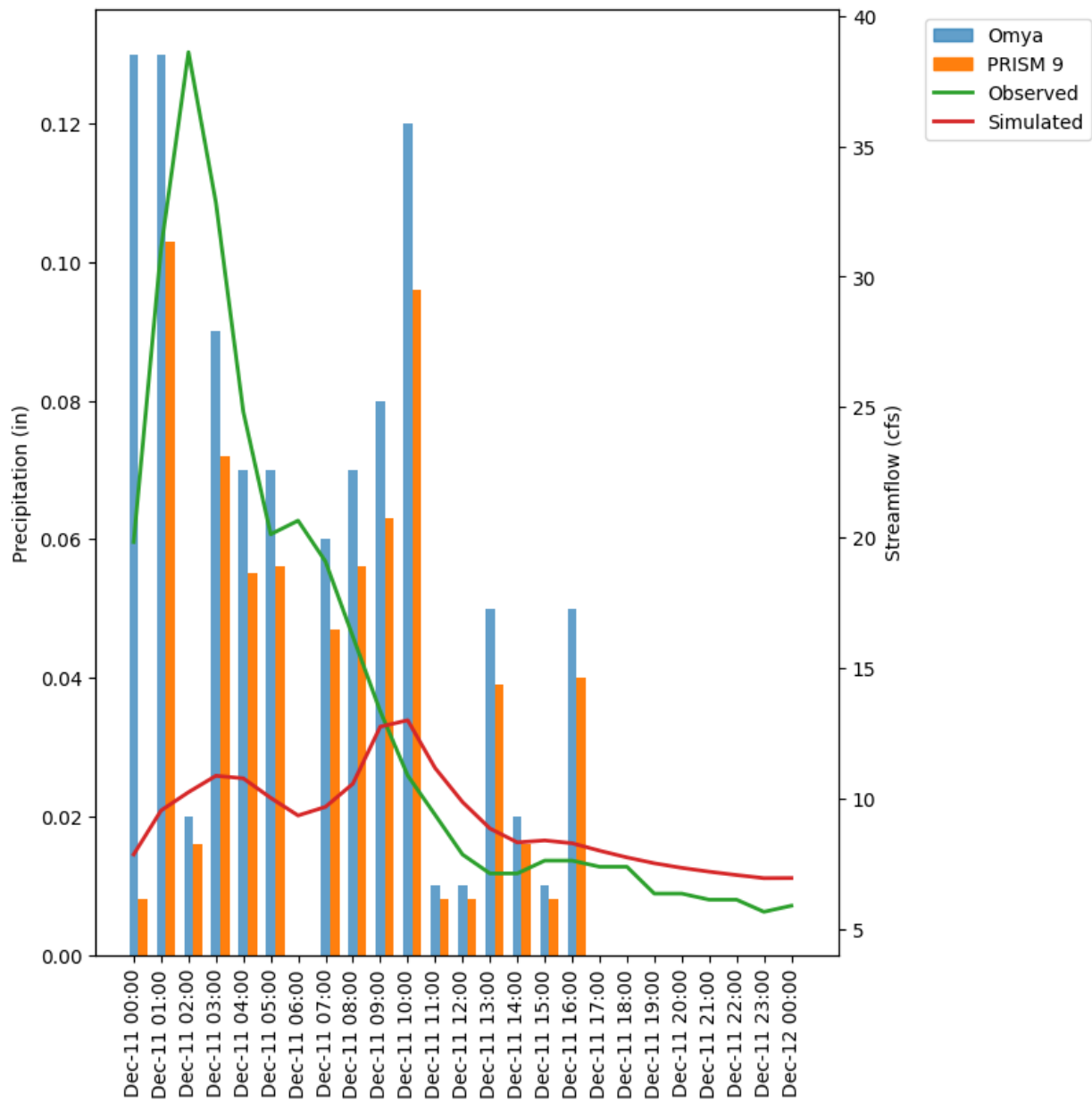


Figure A-8 Observed and simulated streamflow in Oak Flat, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #4 on December 11 to 12, 2007

Table A-8 Observed vs Simulated Peak for storm #4 on December 8 to 9, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
387.55	78.47	-309.08	-79.75

A.3 Magma Ave

Storm 1: 2007/08/07 to 2007/08/08

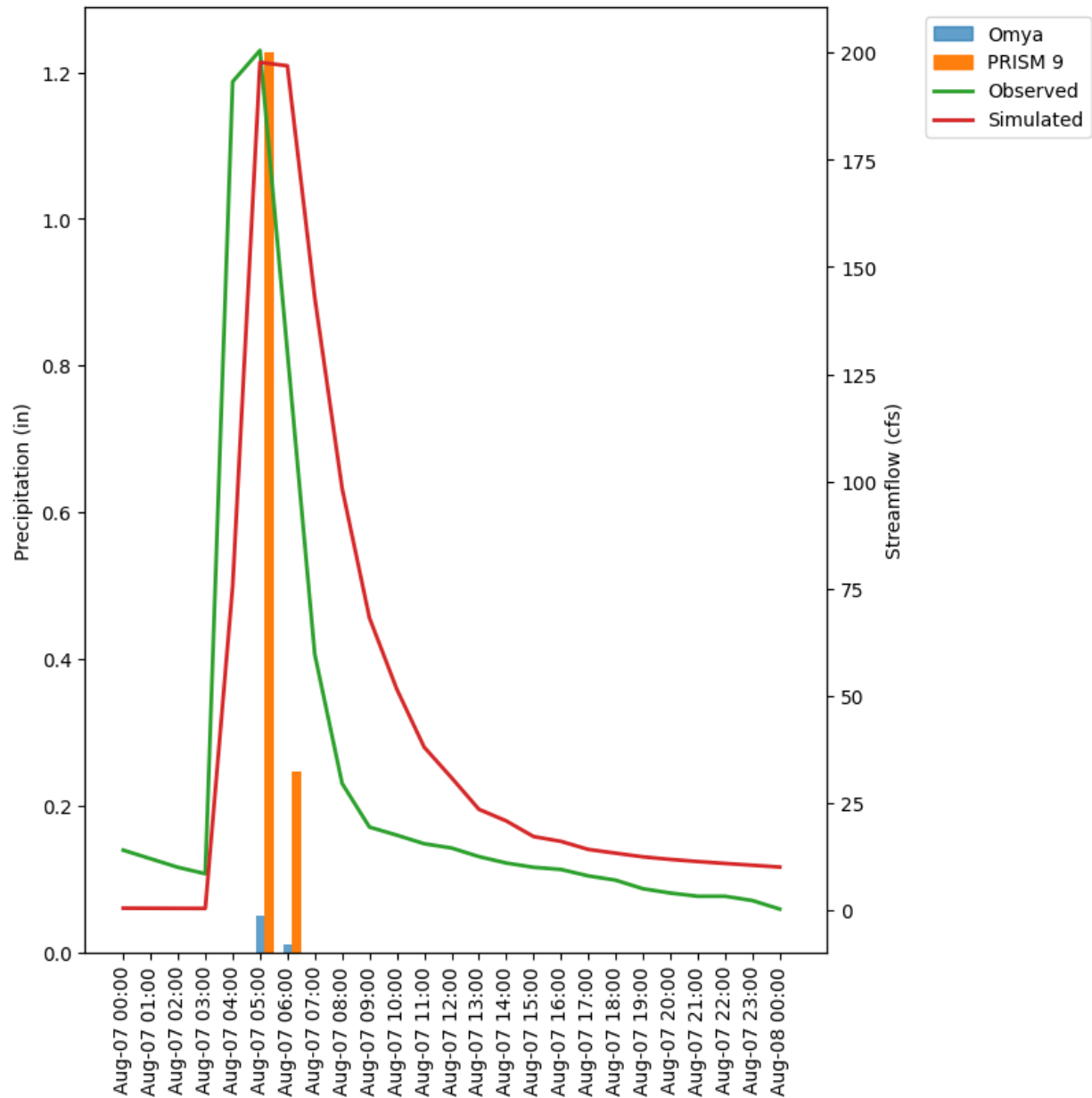


Figure A-9 Observed and simulated streamflow in Magma Ave, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #1 on August 7 to 8, 2007

Table A-9 Magma Ave observed vs simulated peak for storm #1 on August 7 to 8, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
200.52	197.92	-2.6	-1.3

Storm 2: 2007/12/01 to 2007/12/02

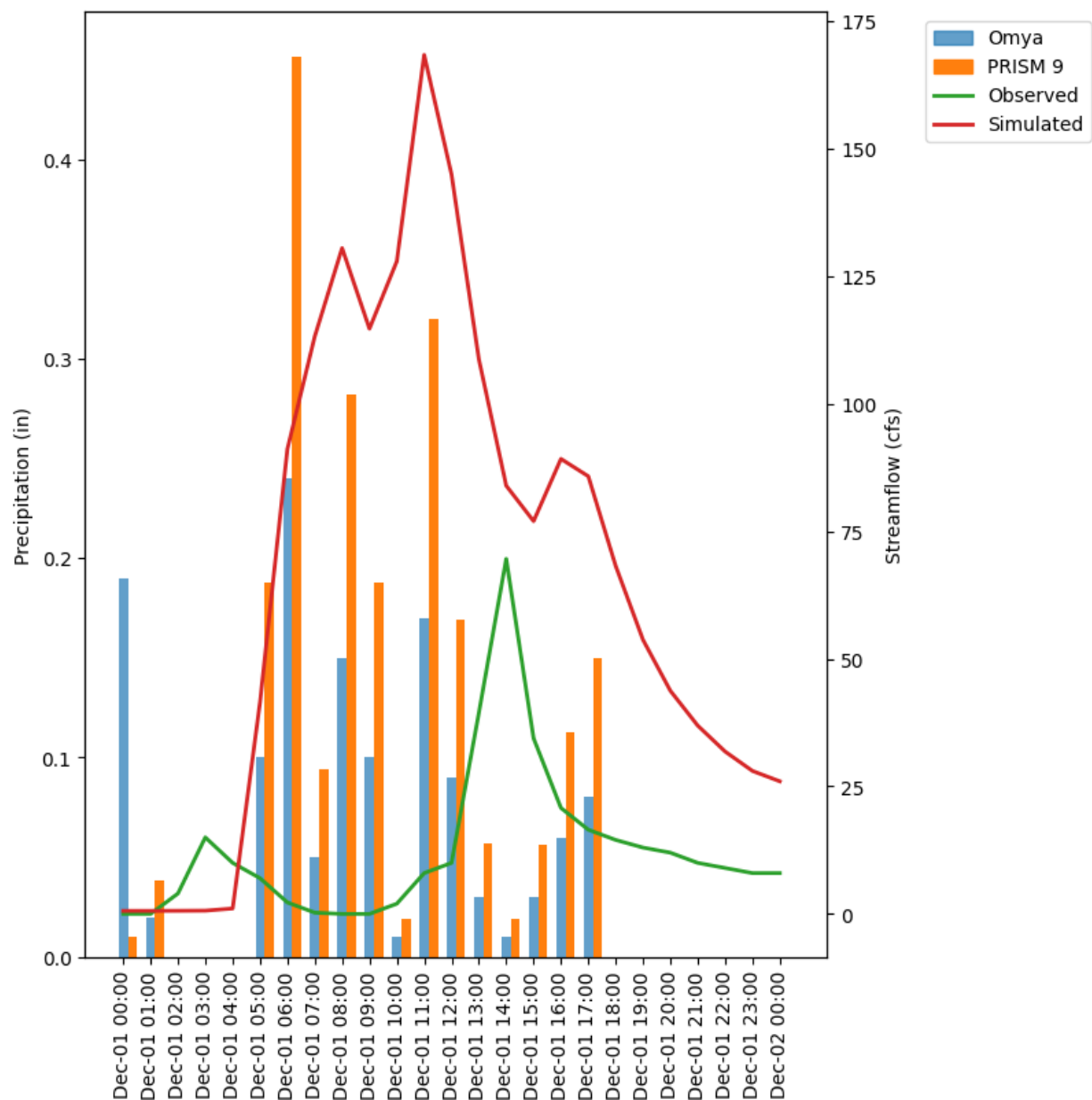


Figure A-10 Observed and simulated streamflow in Magma Ave, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #2 on December 1 to 2, 2007

Table A-10 Magma Ave observed vs simulated peak for storm #2 on December 1 to 2, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
69.59	168.36	98.78	141.95

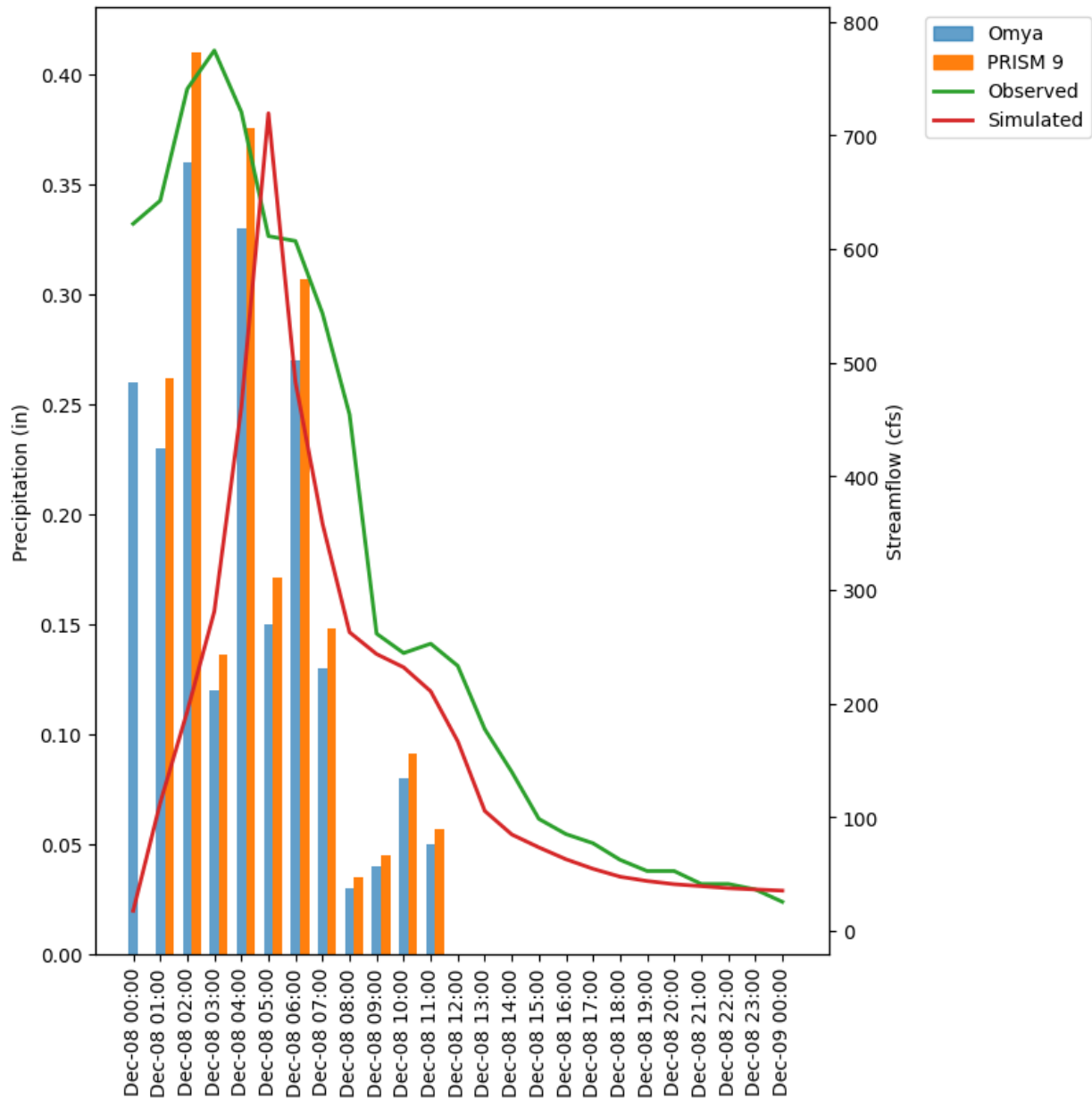


Figure A-11 Observed and simulated streamflow in Magma Ave, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #3 on December 8 to 9, 2007

Table A-11 Magma Ave observed vs simulated peak for storm #3 on December 8 to 9, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
774.85	719.57	-55.28	-7.13

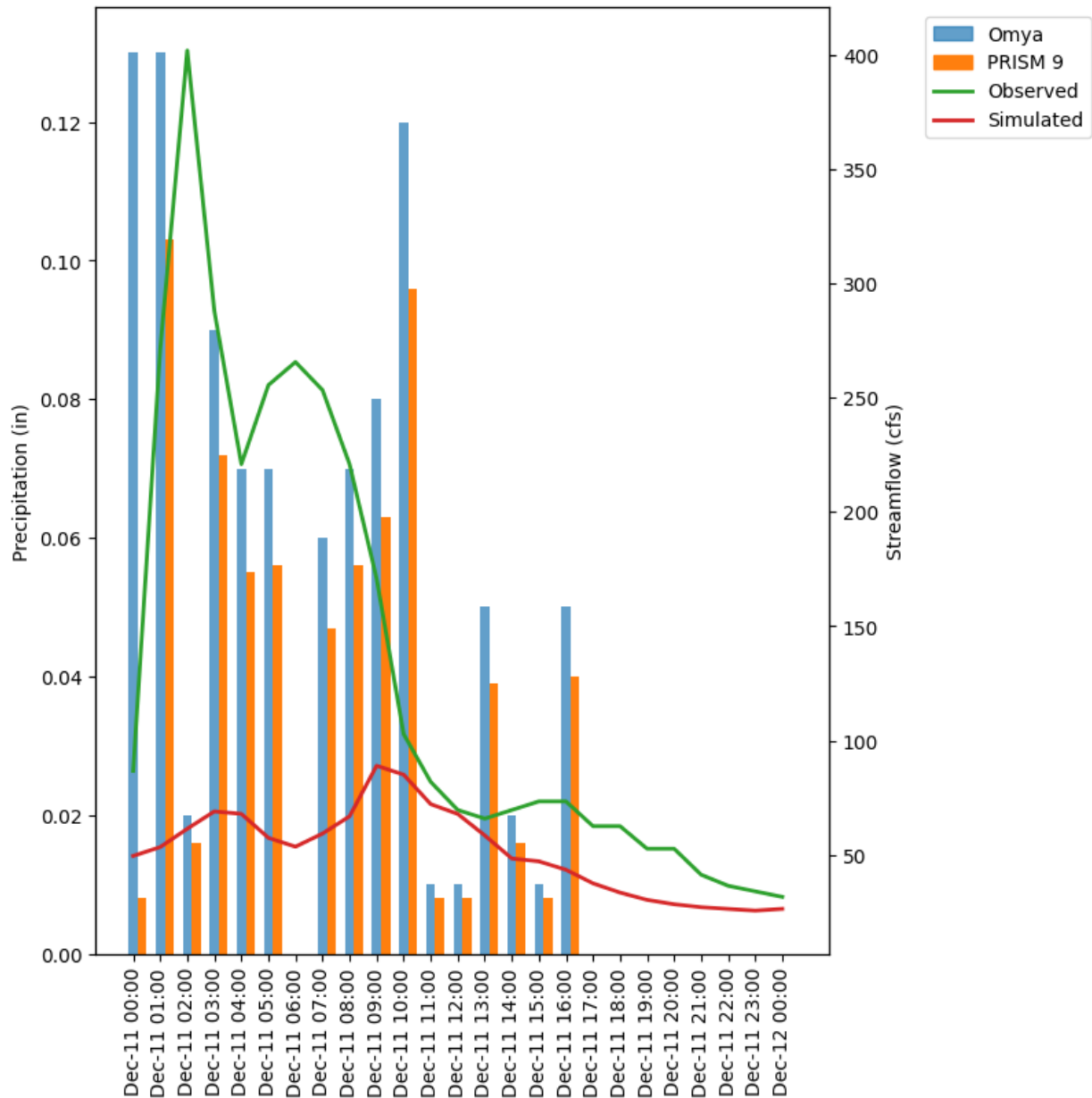


Figure A-12 Observed and simulated streamflow in Magma Ave, precipitation measured at Omya gauge and disaggregated PRISM precipitation at node 9 for storm #4 on December 11 to 12, 2007

Table A-12 Magma Ave observed vs simulated peak for storm #4 on December 11 to 12, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
401.84	88.97	-312.88	-77.86

A.4 Silver King Wash

Storm 1: 2007/08/07 to 2007/08/08

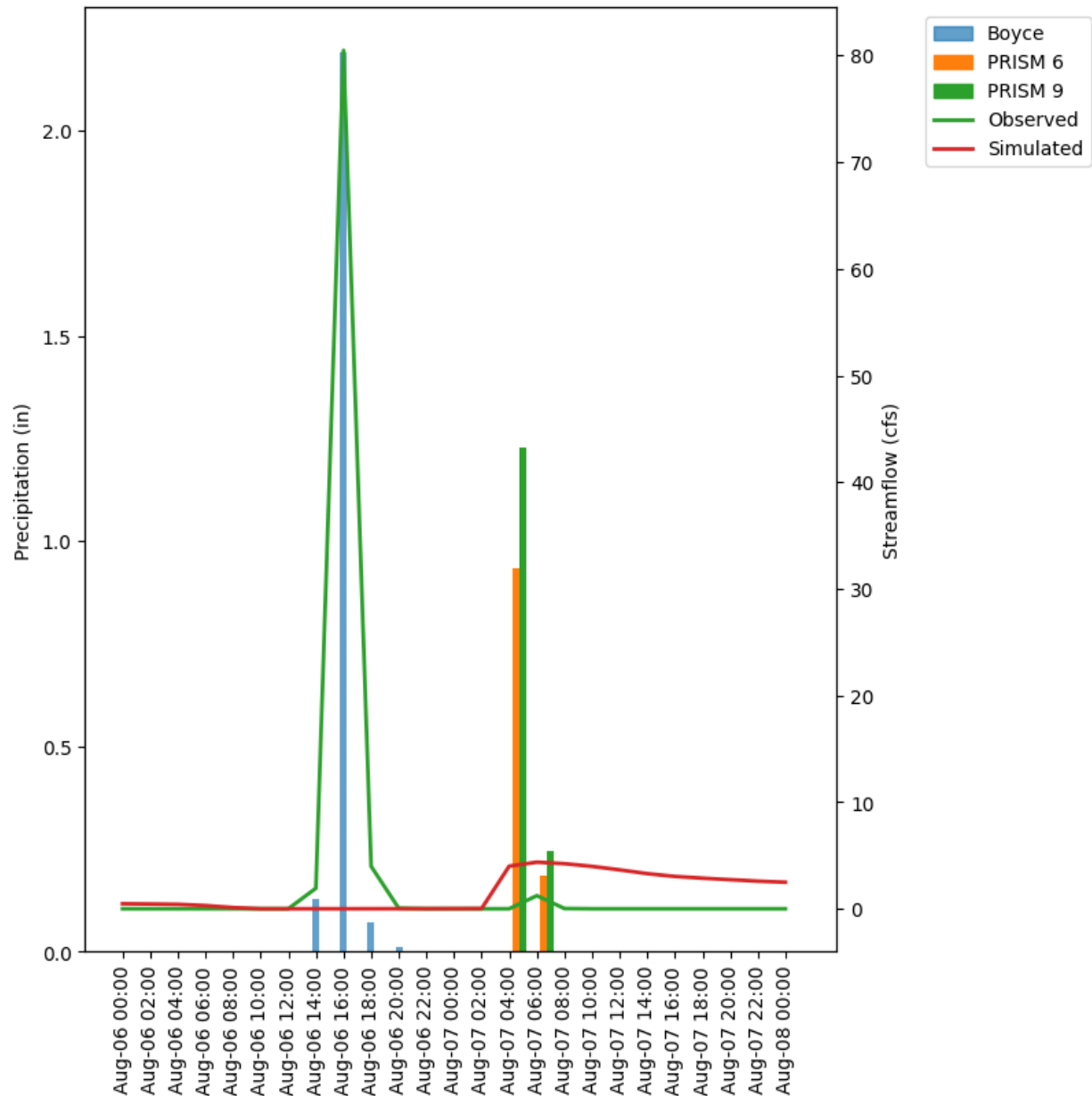


Figure A-13 Observed and simulated streamflow in Silver King Wash, precipitation measured at Boyce gauge and disaggregated PRISM precipitation at nodes 6 and 9 for storm #1 on August 7 to 8, 2007

Table A-13 Silver King Wash observed vs simulated peak for storm #1 on August 7 to 8, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
2.02	4.38	2.37	117.45

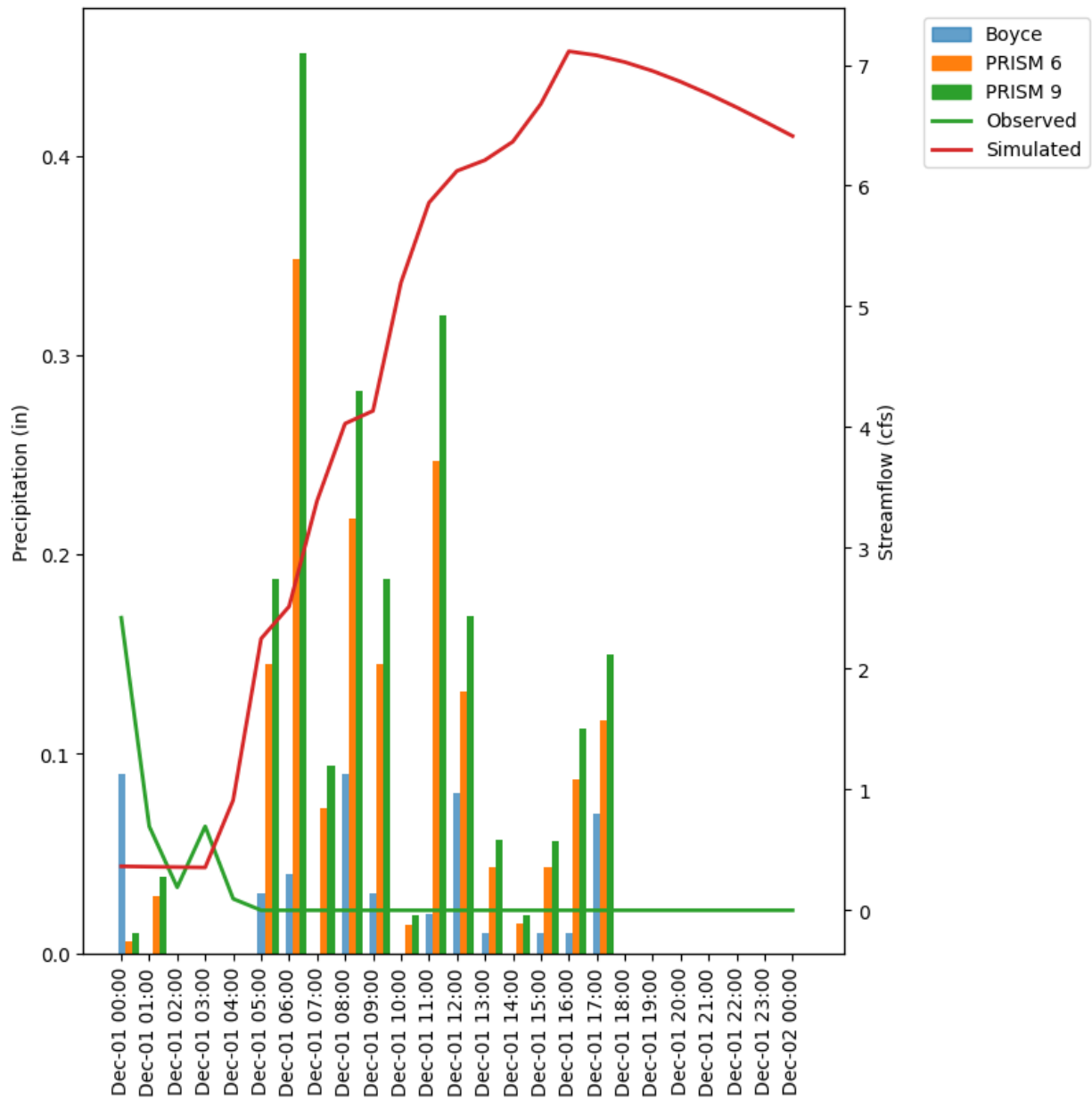


Figure A-14 Observed and simulated streamflow in Silver King Wash, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 6 and 9 for storm #2 on December 1 to 2, 2007

Table A-14 Silver King Wash observed vs simulated peak for storm #2 on December 1 to 2, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
2.42	7.11	4.69	193.59

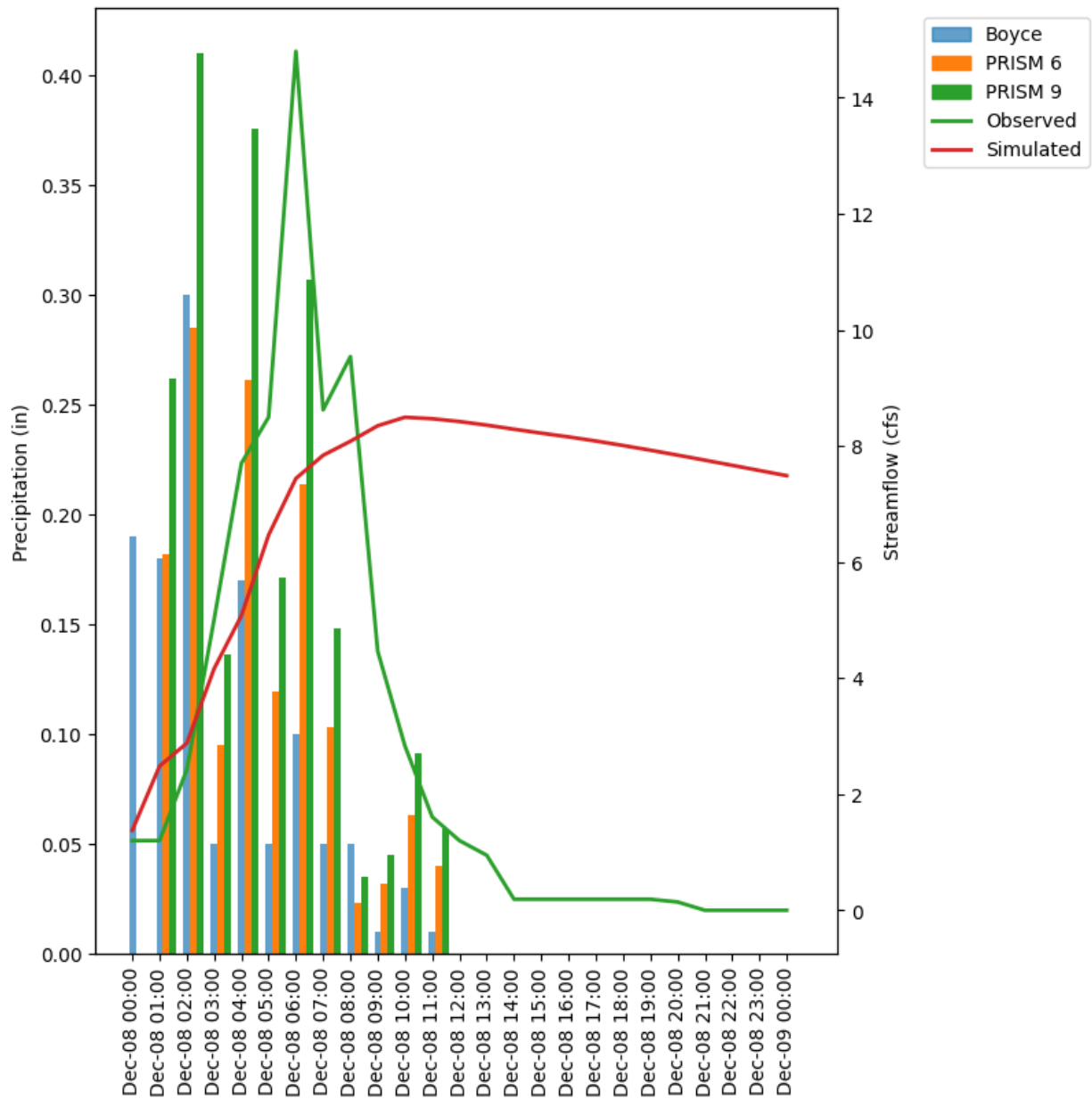


Figure A-15 Observed and simulated streamflow in Silver King Wash, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 6 and 9 for storm #3 on December 8 to 9, 2007

Table A-15 Silver King Wash observed vs simulated peak for storm #3 on December 8 to 9, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
14.8	8.49	-6.31	-42.6

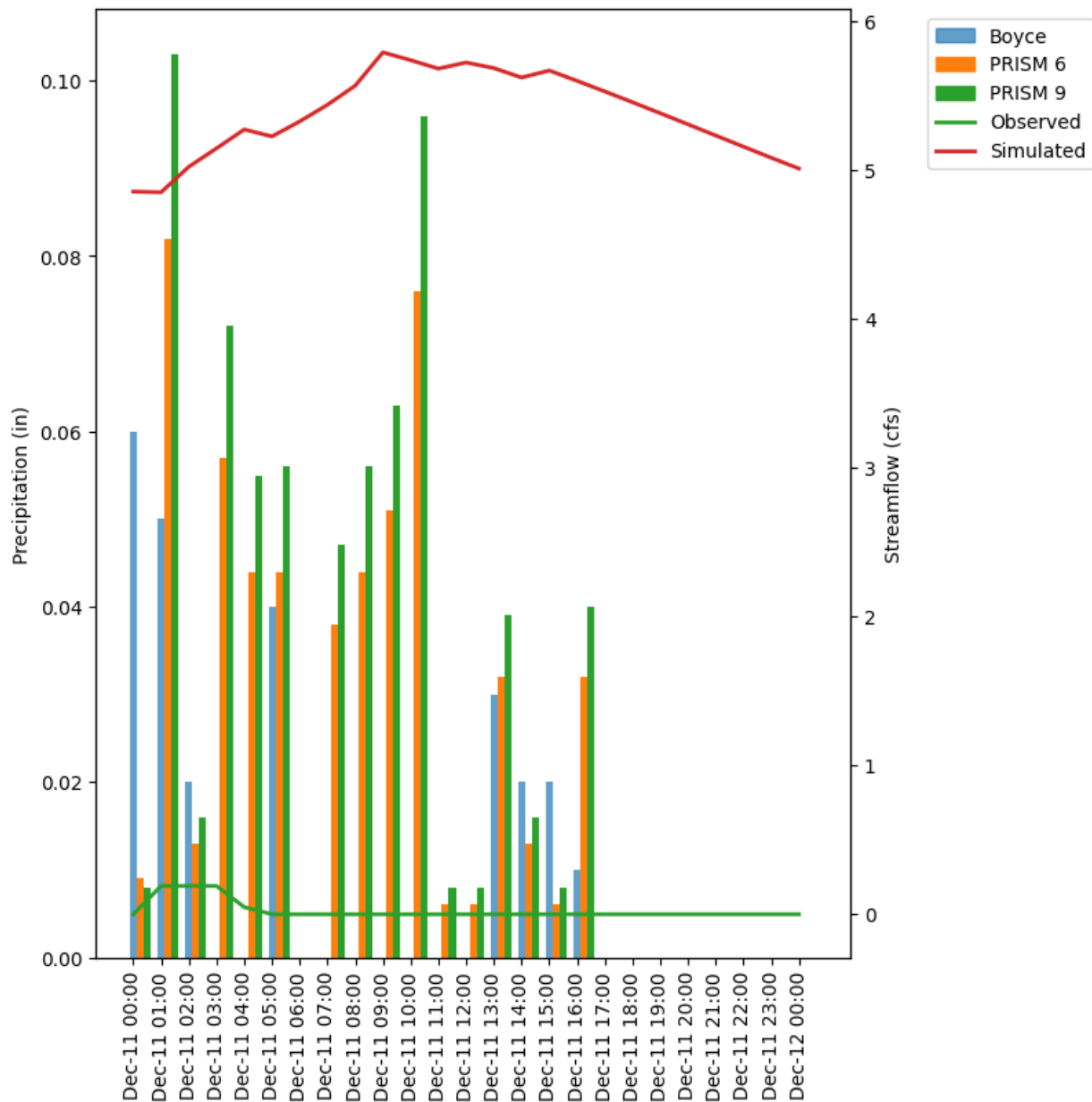


Figure A-16 Observed and simulated streamflow in Silver King Wash, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 6 and 9 for storm #4 on December 11 to 12, 2007

Table A-16 Silver King Wash observed vs simulated peak for storm #4 on December 11 to 12, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
0.19	5.79	5.6	2946.86

A.5 Arnett Creek

Storm 1: 2007/08/06 to 2007/08/09

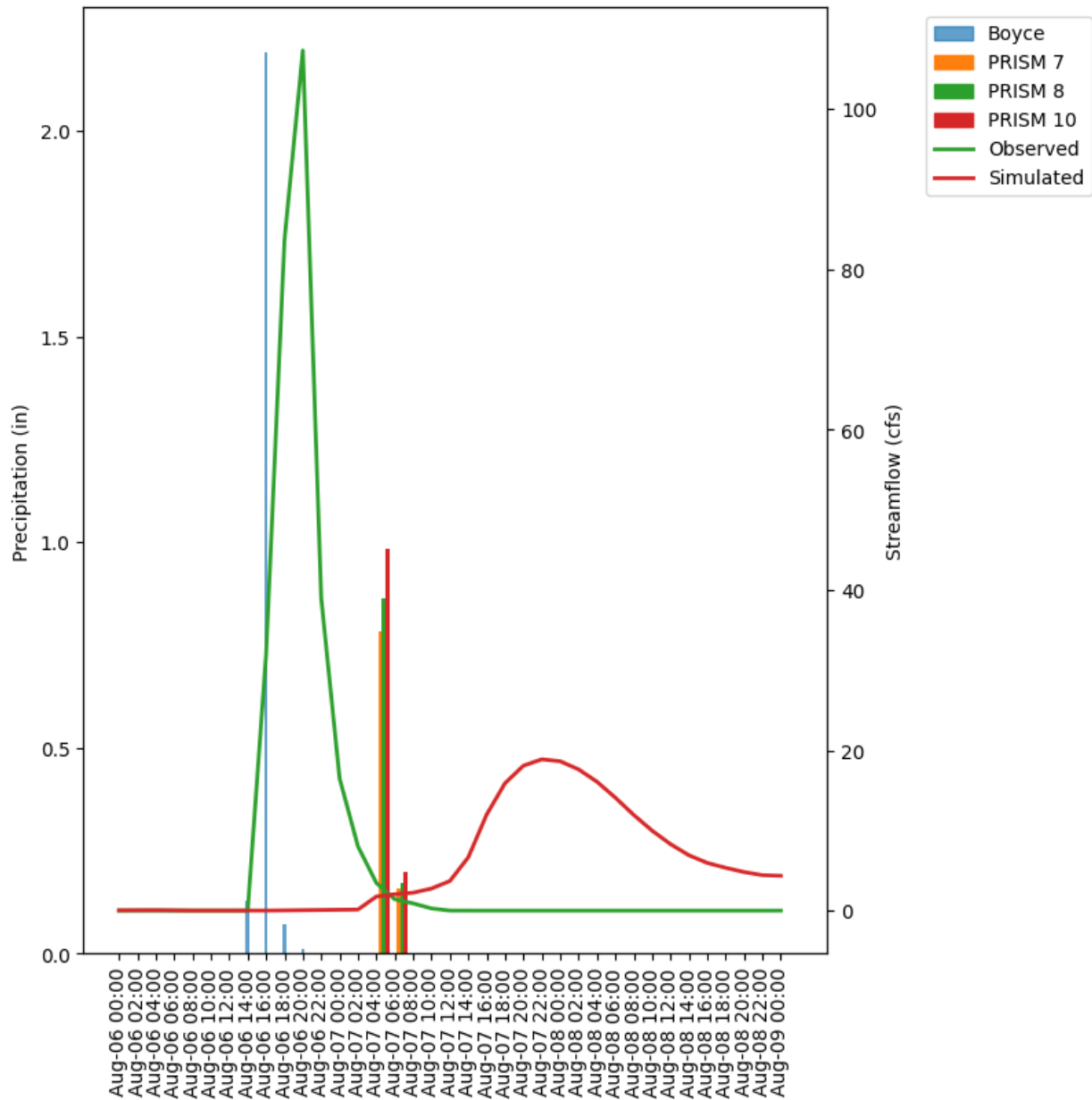


Figure A-17 Observed and simulated streamflow in Arnett Creek, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 7, 8, and 10 for storm #1 on August 6 to 9, 2007

Table A-17 Arnett Creek observed vs simulated peak for storm #1 on August 6 to 9, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
152.67	18.93	-133.74	-87.6

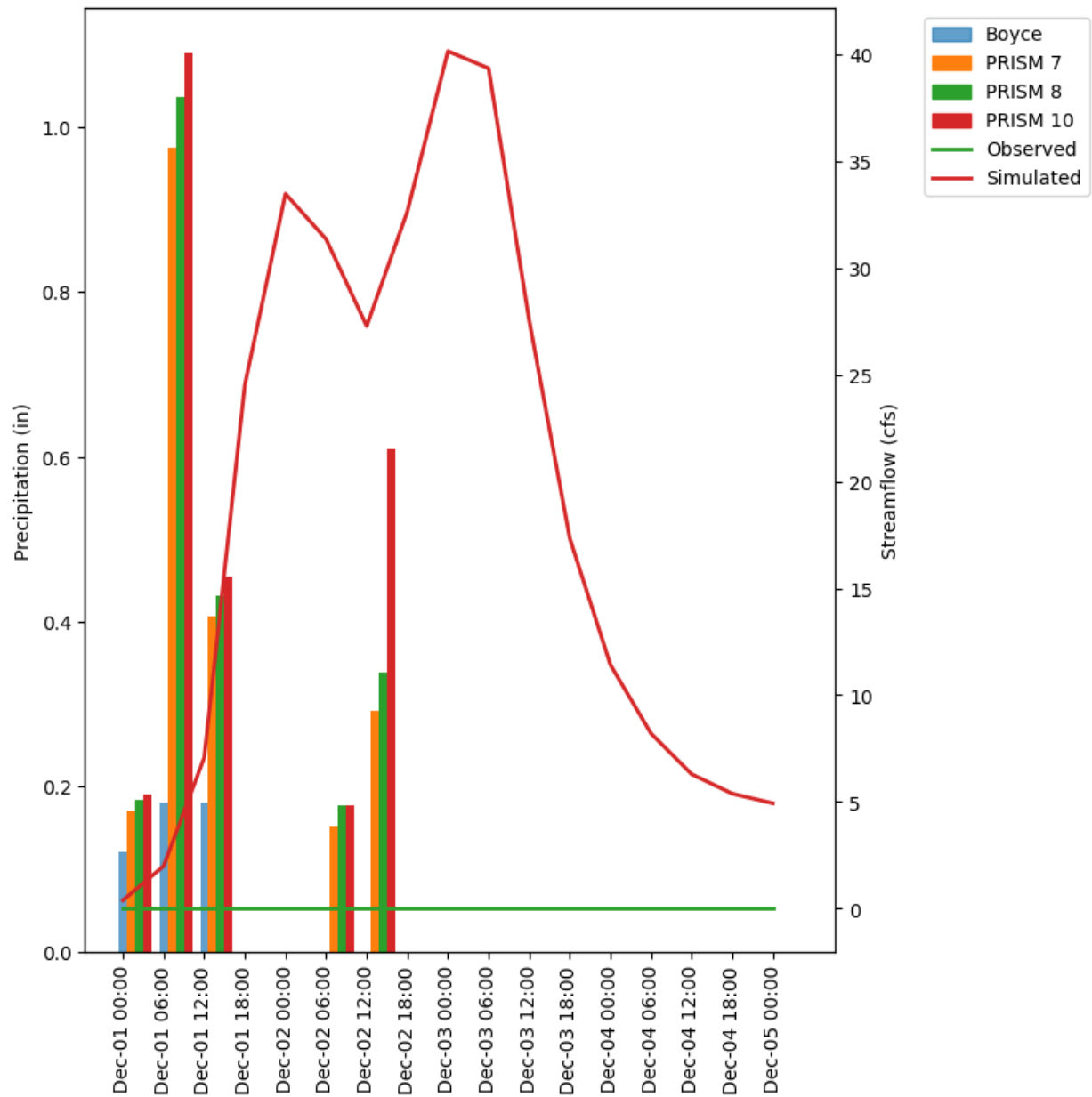


Figure A-18 Observed and simulated streamflow in Arnett Creek, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 7, 8, and 10 for storm #2 on December 1 to 5, 2007

Table A-18 Arnett Creek observed vs simulated peak for storm #2 on December 1 to 5, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
0	41.53	41.53	-

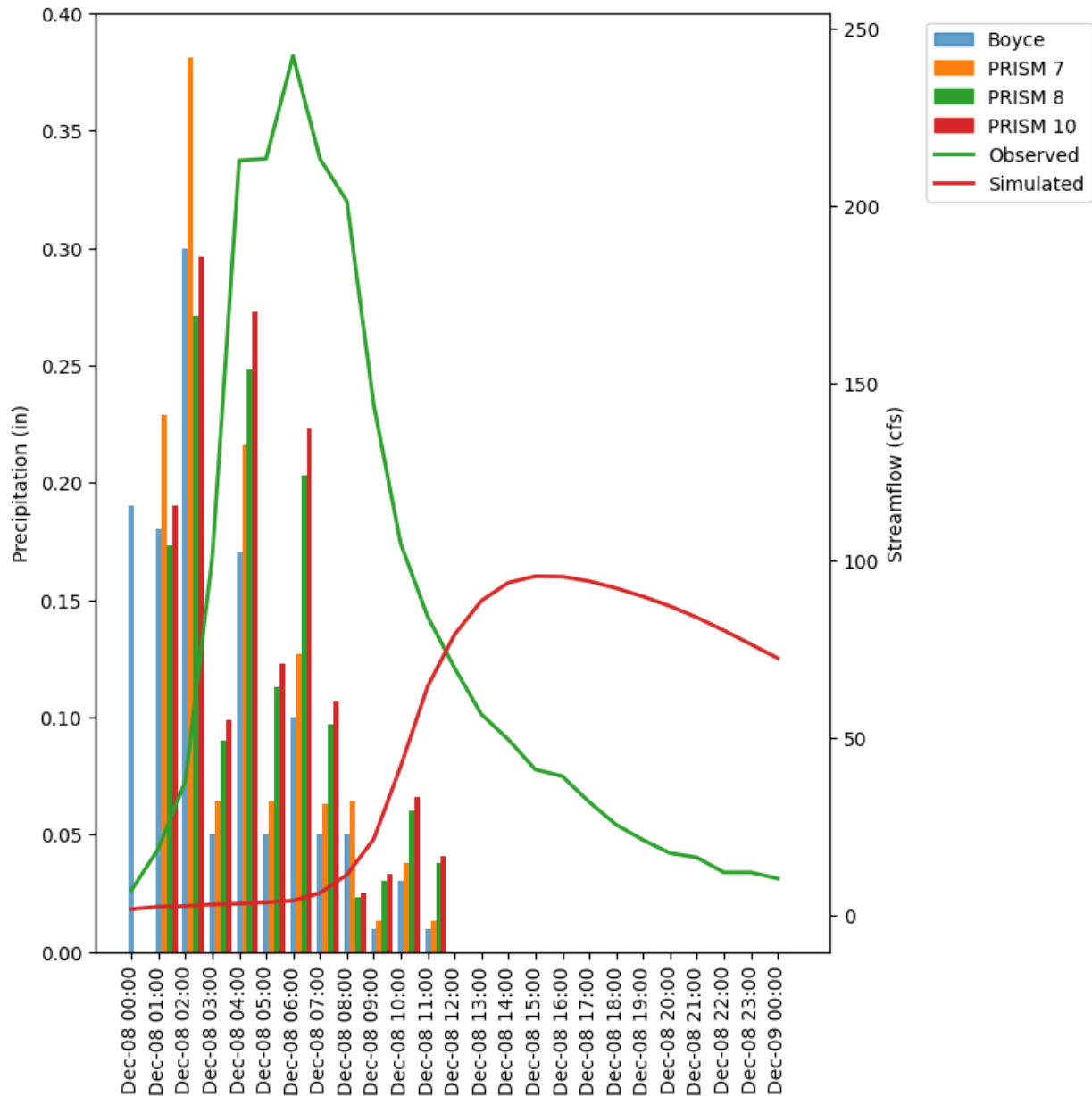


Figure A-19 Observed and simulated streamflow in Arnett Creek, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 7, 8, and 10 for storm #3 on December 8 to 9, 2007

Table A-19 Arnett Creek observed vs simulated peak for storm #3 on December 8 to 9, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
242.43	95.66	-146.77	-60.54

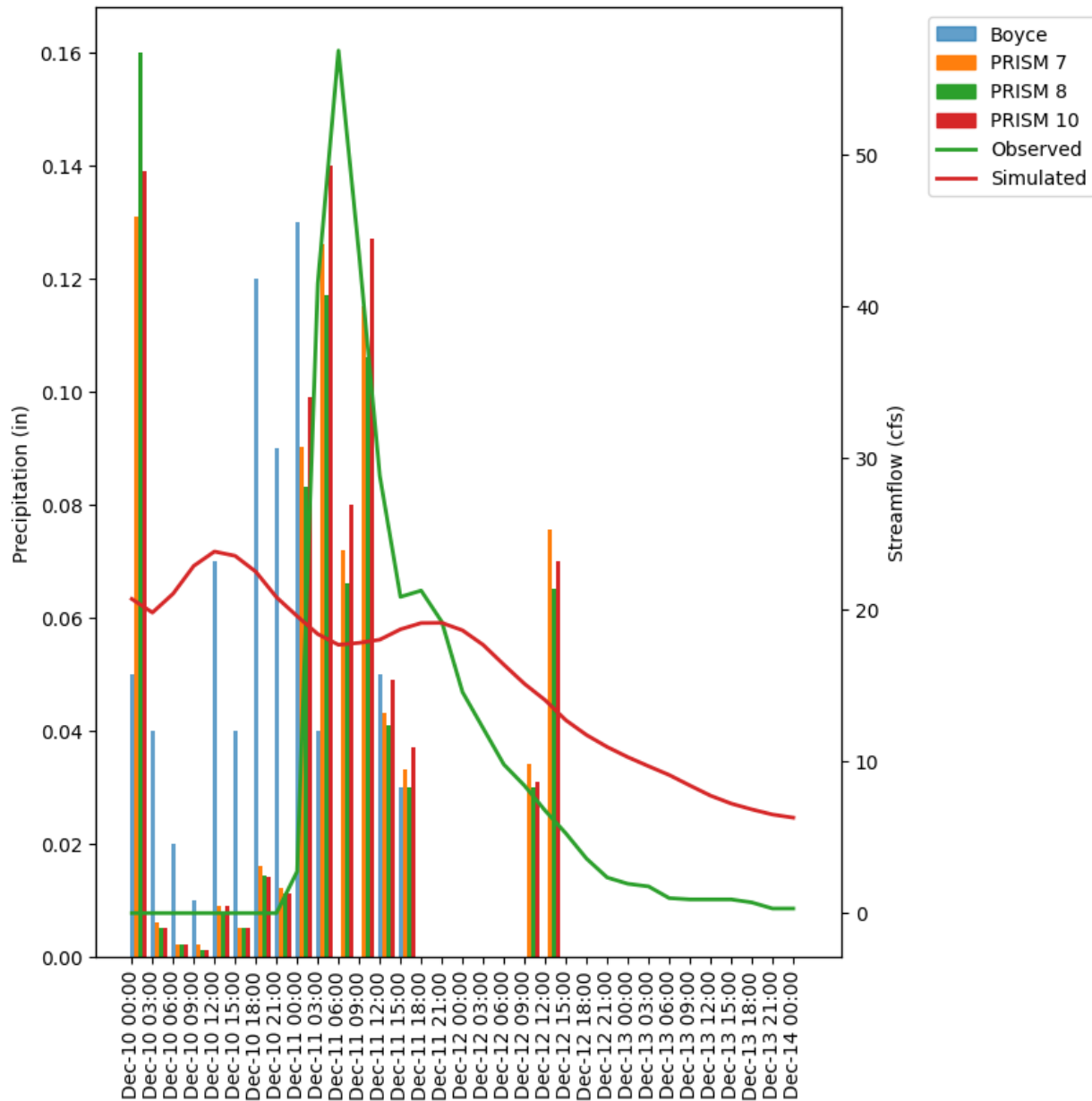


Figure A-20 Observed and simulated streamflow in Arnett Creek, precipitation measured at Boyce gauge, and disaggregated PRISM precipitation at nodes 7, 8, and 10 for storm #4 on December 10 to 14, 2007

Table A-20 Arnett Creek observed vs simulated peak for storm #4 on December 11 to 12, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
61.64	23.88	-37.76	-61.26

A.6 Potts Canyon

Storm 1: 2007/08/06 to 2007/08/10

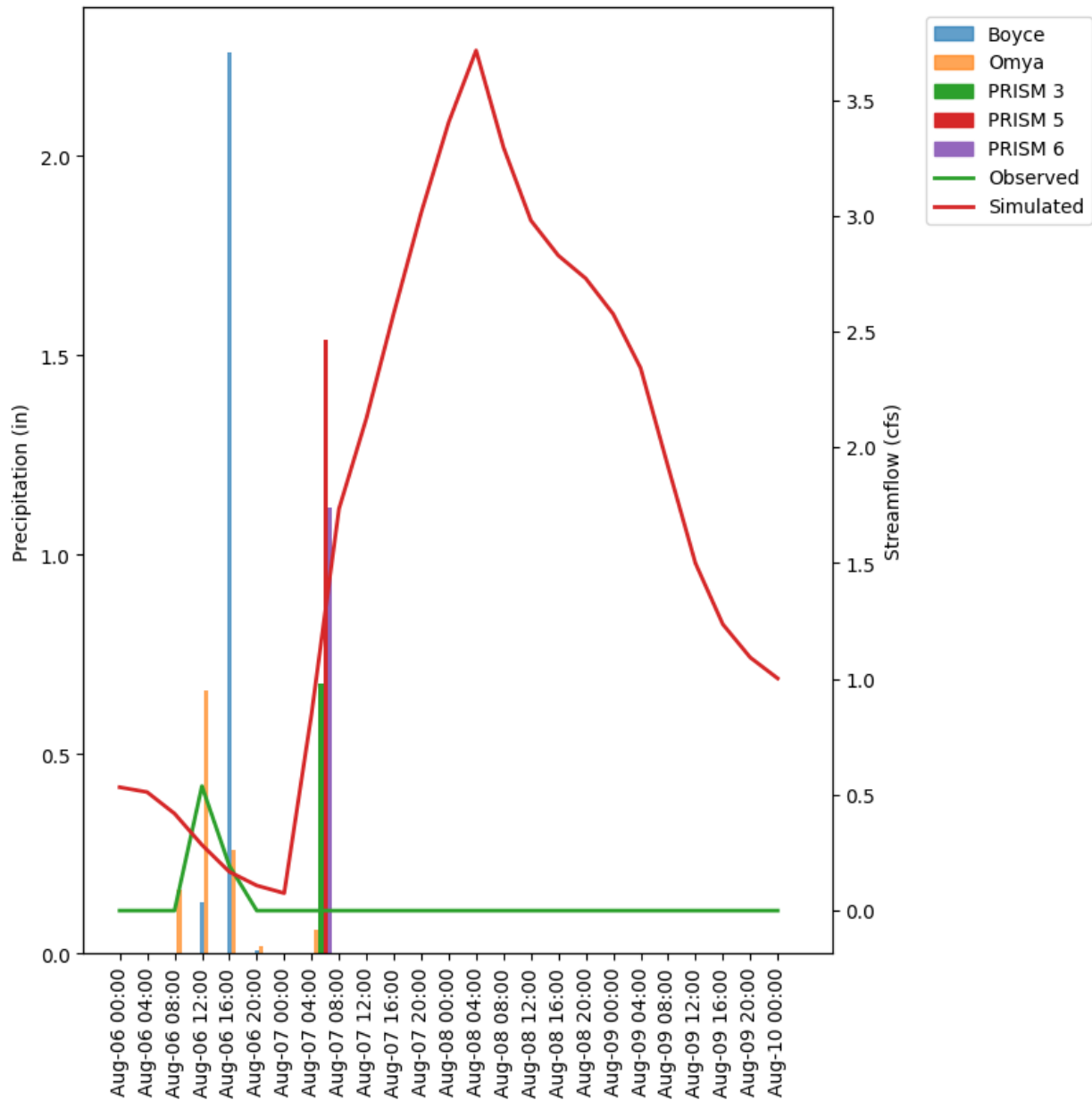


Figure A-21 Observed and simulated streamflow in Potts Canyon, precipitation measured at Omya and Boyce gauges, and disaggregated PRISM precipitation at nodes 3, 5, and 6 for storm #1 on August 6 to 10, 2007

Table A-21 Potts Canyon observed vs simulated peak for storm #1 on August 6 to 10, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
1.92	3.76	1.84	95.51

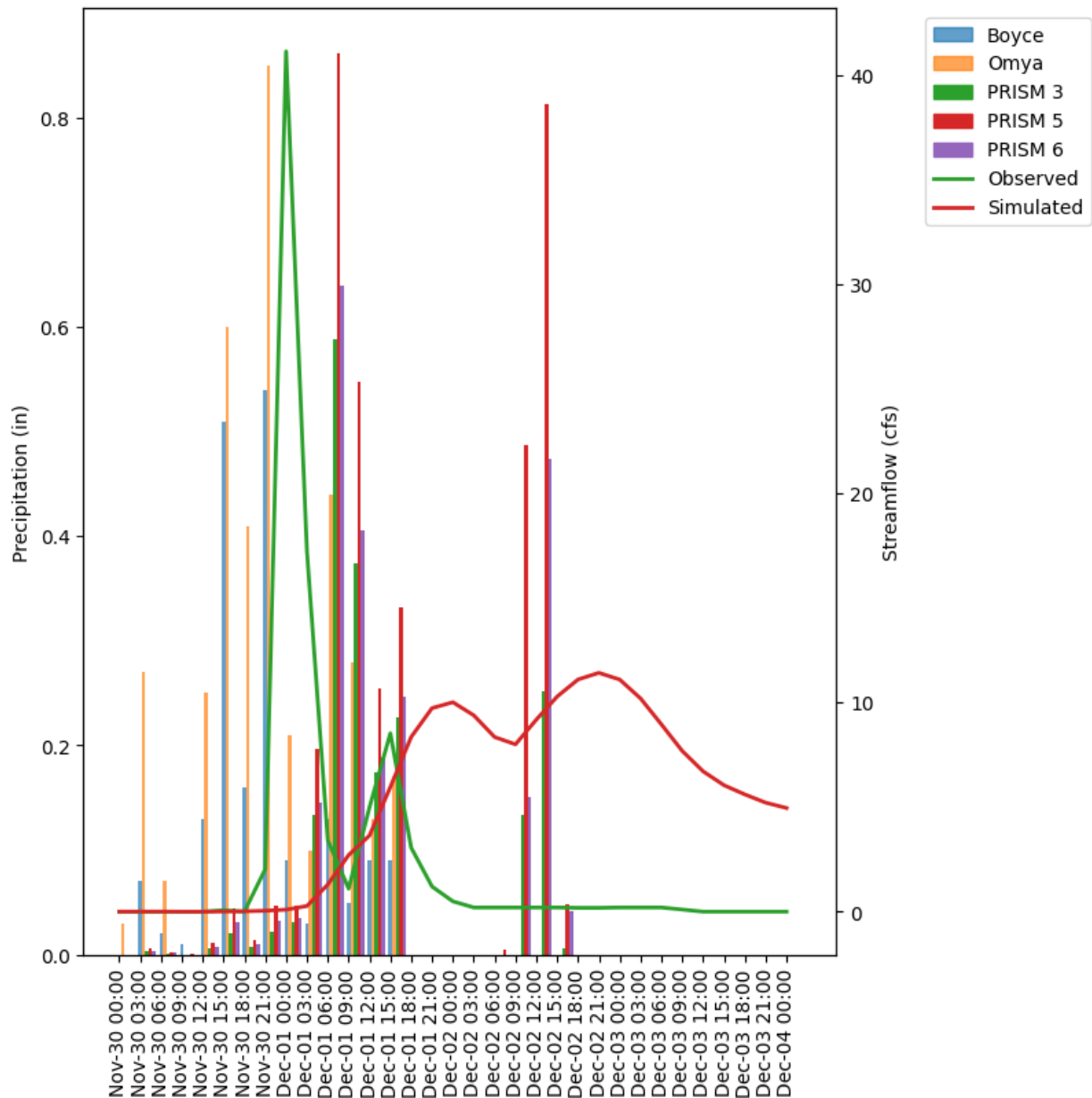


Figure A-22 Observed and simulated streamflow in Potts Canyon, precipitation measured at Omya and Boyce gauges, and disaggregated PRISM precipitation at nodes 3, 5, and 6 for storm #2 on November 30 to December 4, 2007

Table A-22 Potts Canyon observed vs simulated peak for storm #2 on November 30 to December 4, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
62.32	11.45	-50.87	-81.63

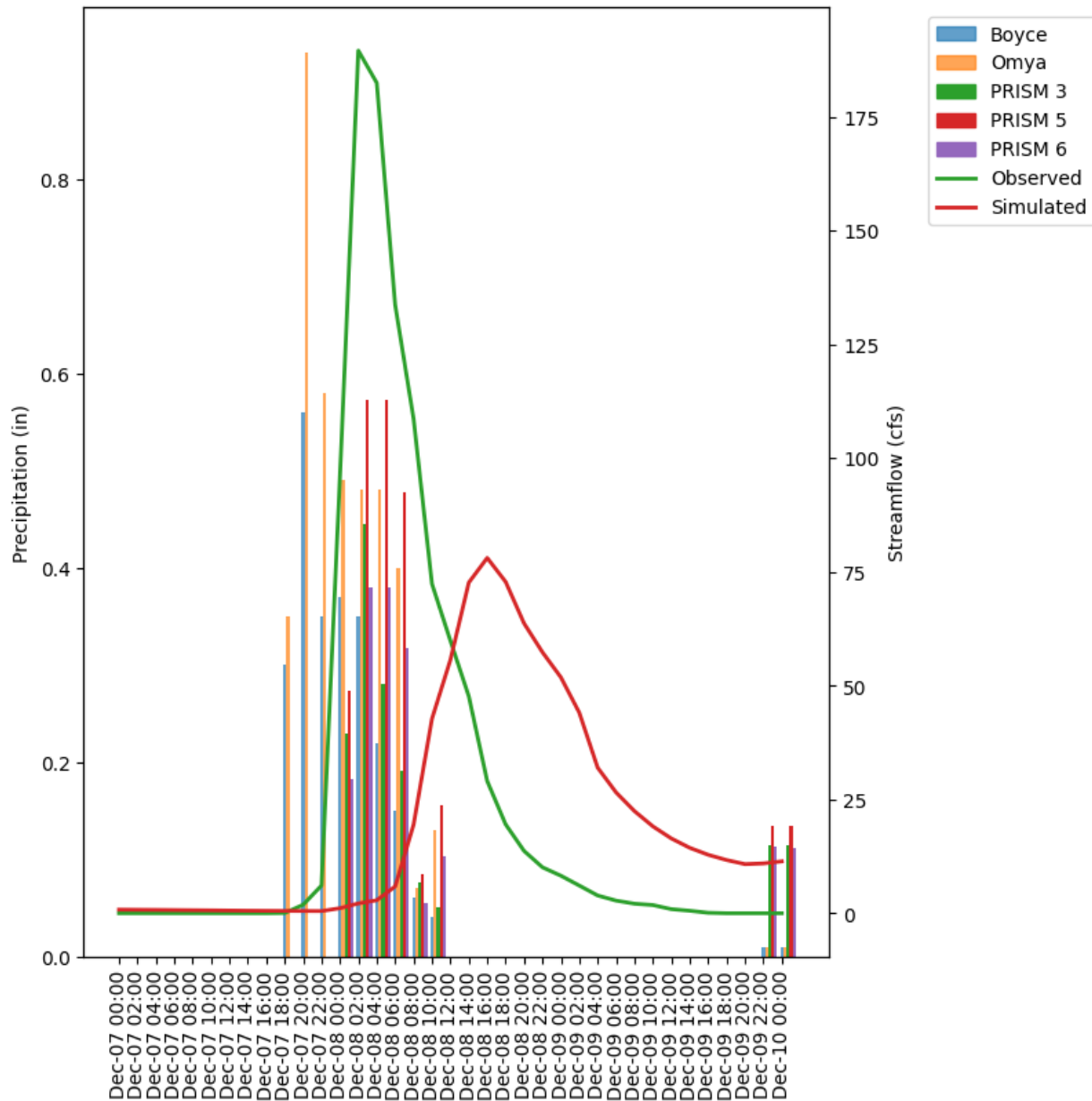


Figure A-23 Observed and simulated streamflow in Potts Canyon, precipitation measured at Omya and Boyce gauges, and disaggregated PRISM precipitation at nodes 3, 5, and 6 for storm #3 on December 7 to 10, 2007

Table A-23 Potts Canyon observed vs simulated peak for storm #3 on December 7 to 10, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
227.1	78.55	-148.55	-65.41

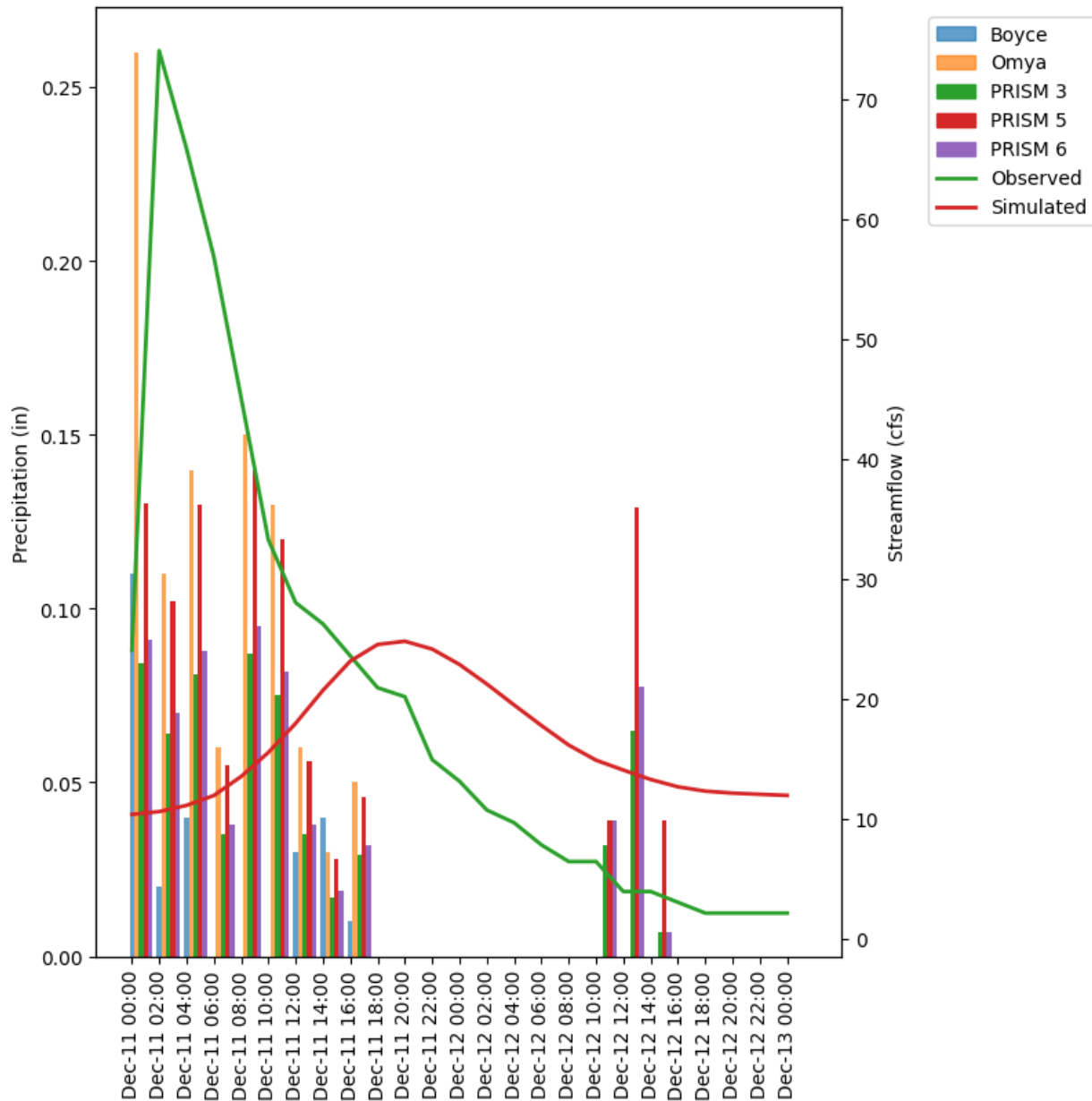


Figure A-24 Observed and simulated streamflow in Potts Canyon, precipitation measured at Omya gauge and disaggregated PRISM precipitation at nodes 3, 5, and 6 for storm #4 on December 11 to 13, 2007

Table A-24 Potts Canyon observed vs simulated peak for storm #4 on December 11 to 13, 2007

Observed (cfs)	Simulated (cfs)	Error (cfs)	Error (%)
82.2	24.84	-57.36	-69.78