Central Coast Watershed Studies

CCoWS

2023 Post-San Clemente Dam Removal Morphological Monitoring of the Carmel River in Monterey County, California.

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3. Introduction

The San Clemente Dam was removed from the Carmel River in 2015 due to seismic hazard, low storage capacity, and ecological impacts (Boughton et al. 2016). The dam removal project was designed to minimize downstream impacts to fish habitat and flood frequency by sequestering a large fraction of reservoir sediments on site (East et al., 2023; SCDRP, 2014). This was achieved by rerouting the river around a stabilized sediment stockpile contained within the primary former reservoir, thereby reducing export of dam-associated sediments downstream (Mussetter, 2005). In collaboration with the U.S. Geological Survey and NOAA Fisheries Service, Leiker et al. (2014) established several study reaches in 2013 to monitor downstream impacts of the dam removal project (Fig. 1; Harrison et al., 2018; East et al., 2023). Monitoring includes cross sectional surveys to detect changes in channel morphology and pebble counts to detect changes in particle size of the river substrate. The study reaches include eight "impact" reaches located downstream, and one "control" reach located upstream of the former dam. The "control" reach is located directly downstream from the currently operating Los Padres Dam, approximately 1-2 km upstream from the former San Clemente Dam. The 2013 and 2015 surveys assessed the natural geomorphic variability in the Carmel River prior to dam removal (Leiker et al. 2014 and Chow et al. 2016). Those surveys were conducted during severe drought years, so they likely do not represent the full range of geomorphic change in the Carmel River during wet years.

The first survey following the dam removal was conducted after the average 2016 WY. The study found minimal changes to geomorphology or grain size at the six study reaches (Chow et al. 2017). A separate 2016 study focusing on near-dam sediment transport noted that a significant sand wave, likely sourced from an unstable reach of river passing through old reservoir sediment, had extended 3.5 km downstream from the dam site (Chow et al. 2016). The second survey after the dam removal was conducted after the 2017 WY. This survey showed large changes to both the morphology and grain size composition at the survey reaches (Steinmetz and Smith 2018), with mean grain size decreasing at all sites downstream of the dam removal site. In contrast to previous years, the 2017 water-year included flows reaching the 10-year flood on two occasions, and one storm peaking near the 25 to 30-year flood (Harrison et al. 2018). Preceding the high flows of 2017, the 2016 Soberanes Fire extended into the southern Carmel Watershed and above the former San Clemente Dam. However, suspended sediment studies indicate that the fire did not significantly impact Carmel River's channel structure

(Harrison et al. 2018). Rather, the drastic geomorphological change resulted from the rapid growth and extension of the sediment wave first noted in 2016. Harrison et al. (2018) interpret the source to that sediment to be a combination of base level fall, knickpoint migration, and channel avulsion through the unstable river channel located in old reservoir sediments above the old dam site, triggered by the high flows of WY 2017.

The third survey after the dam removal took place after the 2018 WY. 2018 was a relatively dry WY, and geomorphic changes were minimal. Some cross sections that were not surveyed in 2017 showed significant changes, but the changes were likely the result of the larger 2017 flows. The trend of particle size reducing downstream from the dam continued in 2018, with all downstream sites lowering in mean particle size.

The 2019 survey found minimal changes in channel morphology and substrate size, and the fining trend seen in 2017 and 2018 was not as consistent in 2019. The large influx of fine sediment deposited below the dam in 2017 largely stayed in place during 2019 with percentages varying at each site, but without a clear trend. The overall temporal and spatial patterns emerging in the grain size analysis is consistent with a large pulse of fine sediment generated in high 2017 flows, slowly moving downstream toward the mouth of the Carmel River. The change was less consistent in 2019 than in previous years, so there is still not enough evidence to say with certainty that the sediment pulse had begun clearing by that date. The unstable reroute reach was beginning to stabilize through natural colonization of willows and other riparian species. In summary, observations indicated highest flow in 2017, lowest flow in 2018, marginally higher flows in 2019, and modest flows from 2020-2022.

This report presents results from surveys conducted after the 2023 water-year. Peak flows in 2023 were 11,000 cfs (USGS, 2023; Fig 1). Precipitation at the San Clemente Dam gauge reached 35.28 inches (MPWMD, 2024), which is above the long term (1922 – 2023) average of 21.29 inches. The 2023 precipitation reflects a 14-year annual exceedance event. Runoff generated a peak flow near 11,000 cfs at the Robles del Rio gauge, equating to a ~21 year flood using standard flood frequency techniques (IACWD, 1982). Our data indicates incision in many reaches and overbank deposition of sands and smaller gravels, including the upstream-most Control Reach. Preliminary analysis also suggests recovery of possible steelhead spawning gravels at some sites.

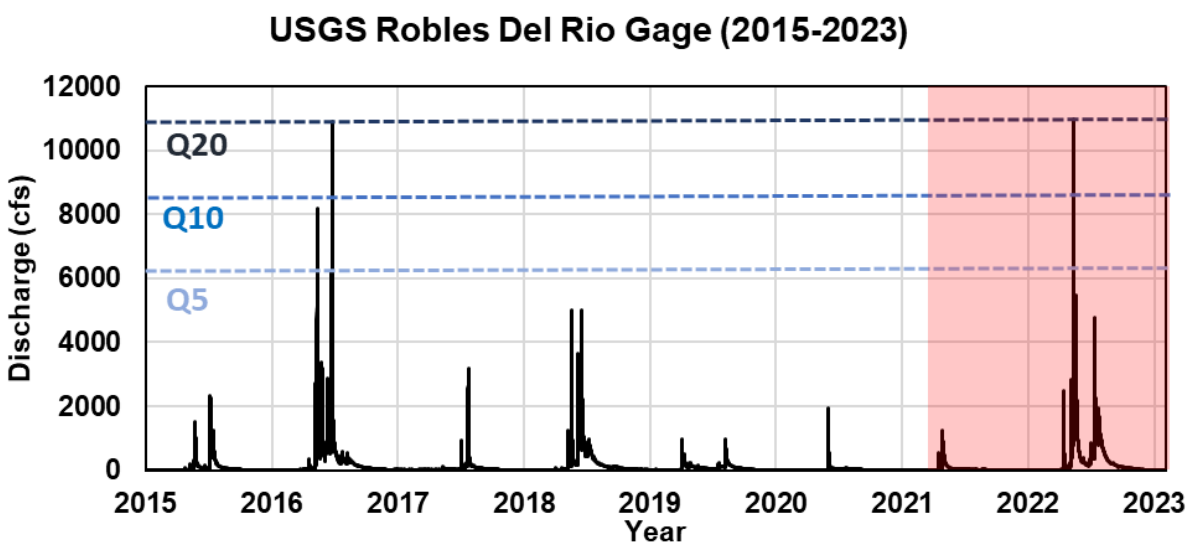

Figure 1. 15-min resolution hydrograph from USGS Carmel River Robles Del Rio gage (11143200) spanning post-dam removal project. Q20, Q10, and Q5 are the recurrence intervals (RIs) of the 20, 10, and 5-year floods, respectively. RIs were derived from Log-Pearson III frequency analysis of historical data through WY2023 using multiple Grubbs-Beck outlier removal (IACWD, 1982). The red shaded area denotes flows bracketed by the most recent monitoring campaign in 2021 and those performed in the present study.

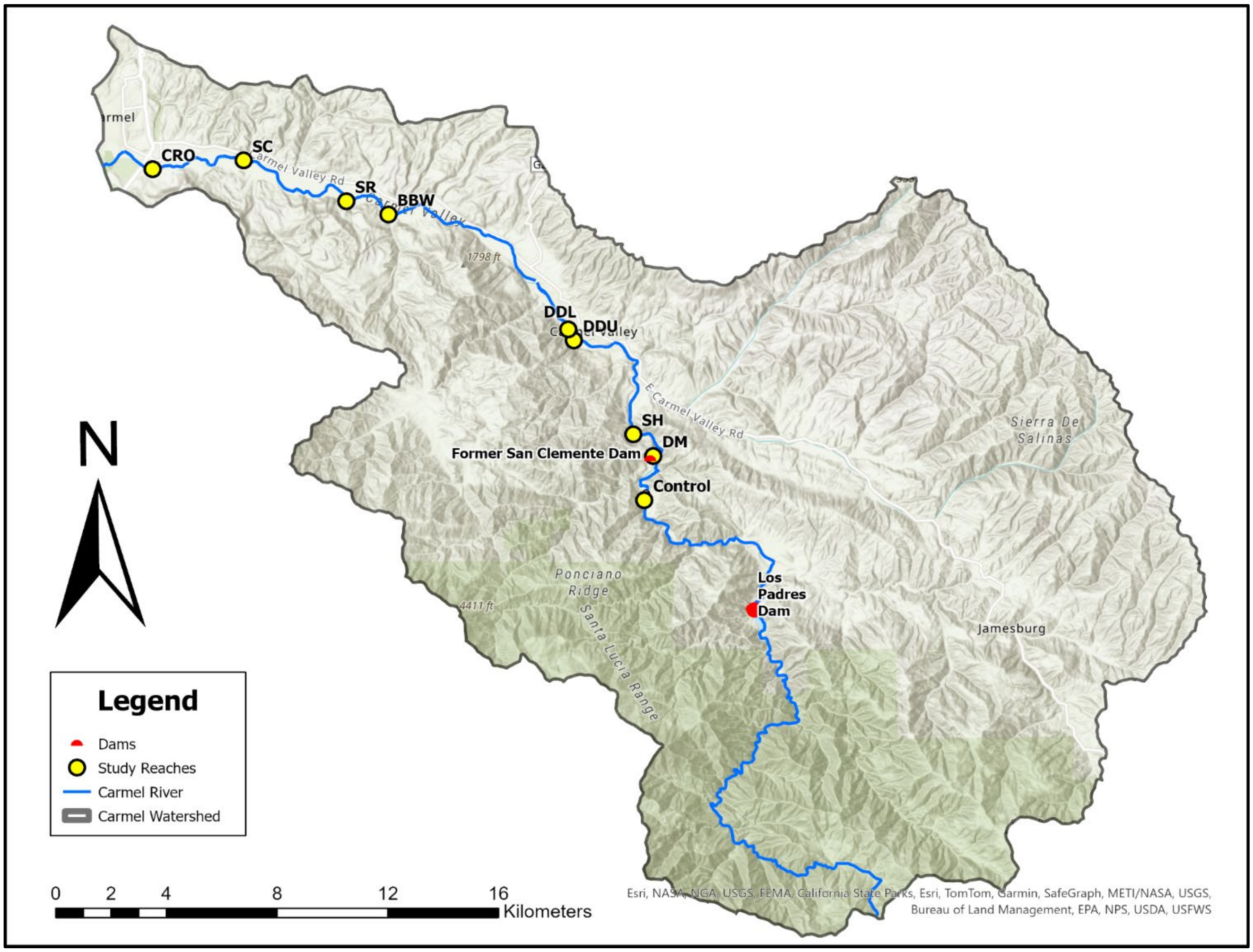

Figure 2. Map of the Carmel Watershed with Carmel River flowline showing the nine reaches monitored in 2023.

4. Methods

This study of the San Clemente Dam removal replicated the following methods from the 2013 study (Leiker et al. 2014) and all subsequent monitoring studies (e.g., Harrison et al., 2018). These geomorphic measurements were collected from nine unique reaches along the lower 33 km of the river, with most sites situated below the dam removal site

(Fig. 2). The cross sections were surveyed and pebble counts were performed in Fall 2023. Each study reach that was monitored is briefly described below:

- Control Reach (CR): Located 2 km upstream of the former San Clemente dam above the former reservoir. This site represents a “control” reach to compare against post-dam downstream riverine response.
- Dam (DM): Established in 2013, this is located just downstream of the former San Clemente Dam.
- Sleepy Hollow (SH): Established in 2013, this is near the Sleepy Hollow Steelhead Rearing Facility ~2km downstream of the Dam Reach.
- DeDampierre Upper (DDU): Located in the upper portion of DeDampierre Park in Carmel Valley, this reach extends from the footbridge past the baseball fields. This reach contains several pieces of large wood installed for a restoration project by the Monterey Peninsula Water Management District.
- DeDampierre Lower (DDL): This reach begins at the lower end of DeDampierre Park and extends to the Carmel Valley Trail and Saddle Club downstream of the park.
- Berwick (BW): Established in 2015, this reach is located on California American Water property near the mid-valley shopping center.
- Schulte Road (SR): Located upstream of the Schulte Road Bridge. This reach begins in land owned by the Big Sur Land Trust and extends to 100m upstream of the Schulte Bridge.
- San Carlos (SC): Located just downstream of the San Carlos Road Bridge. The reach extends from the bridge to the California American Water San Carlos production well.

- Crossroads (CR): Located adjacent to the Crossroads Shopping Center ~2km upstream of the mouth of the Carmel River. This is the most downstream reach included in this study.

Each reach is approximately 300 m in length and contains four to six cross sections with two benchmarks each, approximately spaced at 60 m intervals. Cross sections were set in a variety of geomorphic units, but mainly in riffles and pools. Using the previous benchmarks established in 2013, 2015, 2019, and 2023, most cross sections were resurveyed using an auto level, leveling rod, and 50-meter transect tape (Harrelson et al. 1994). The Control Reach, where three of six cross sections had re-surveyed, was surveyed using a Nikon 3" total station. For each cross section, a taut tape was set between the left and right benchmarks. Shots were taken at similar intervals along the tape as in previous years, if slope breaks remain unchanged. Surveys were opened and closed on the left benchmark, and closing errors were below 0.03 m or the survey was repeated. Cross sections were plotted using RStudio with the left benchmark (LBM) set at the reference distance of zero. Due to high flows in 2023, we were unable to locate the LBM, RBM, or both at many sites due to burial from sediment, vegetation, or removal. We re-established these benchmarks as close as possible to their original locations using either real-time kinematic (RTK) GPS or total station stakeouts, often shortening or lengthening the cross section along the same bearing if vegetation or topographic changes necessitated it. Vertical registration of benchmarks was performed relative to known benchmarks using NAVD88 Geoid 12 as the vertical reference frame. Horizontal coordinates remained in the original horizontal reference frame of NAD 1983

(2011) UTM Zone 10N. Cross section data were plotted and visually compared with previous surveys to assess the changes that occurred in the WY 2023.

Pebble counts were performed along each cross section to determine average particle size distribution. Pebble counts included particles within the bankfull channel, but excluded eroding banks where old floodplain deposits were exposed instead of recently transported material. We employed the sampling technique from Bunte and Abt (2001) that uses a 60 x 60 cm sampling quadrant. This method reduces serial correlation by adjusting the spacing between intersections on the frame to equal the dominant large particle size (≈D95). The 60 x 60 cm square sampling frame was constructed from 1" PVC pipe with notches every 5 cm. Elastic bands were then attached to notches to create 20 equal areas within the quadrant. The sampling grid was randomly placed repeatedly across the estimated low flow channel at fived fixed intervals to achieve a sample size of ≥ 100. A gravelometer was used to measure particle sizes for pebble counts. Particle size histograms were generated for each cross section, and averaged for each reach. Gradistat v9.1 (Blott and Pye, 2001) was used to develop grain size statistics, such as median grain diameter and fraction of fines vs gravels averaged across each reach. The data collected in 2023 are then compared to the previous data sets.

5. Results

6.1. Control Reach

Three cross sections out of six were surveyed (Fig 3) at CR. Cross section data from the Control Reach shows that the main channel primarily experienced erosion in response to high flows in WY2023 (Fig 4). Most notably, CR4 experienced a ~1m of incision.

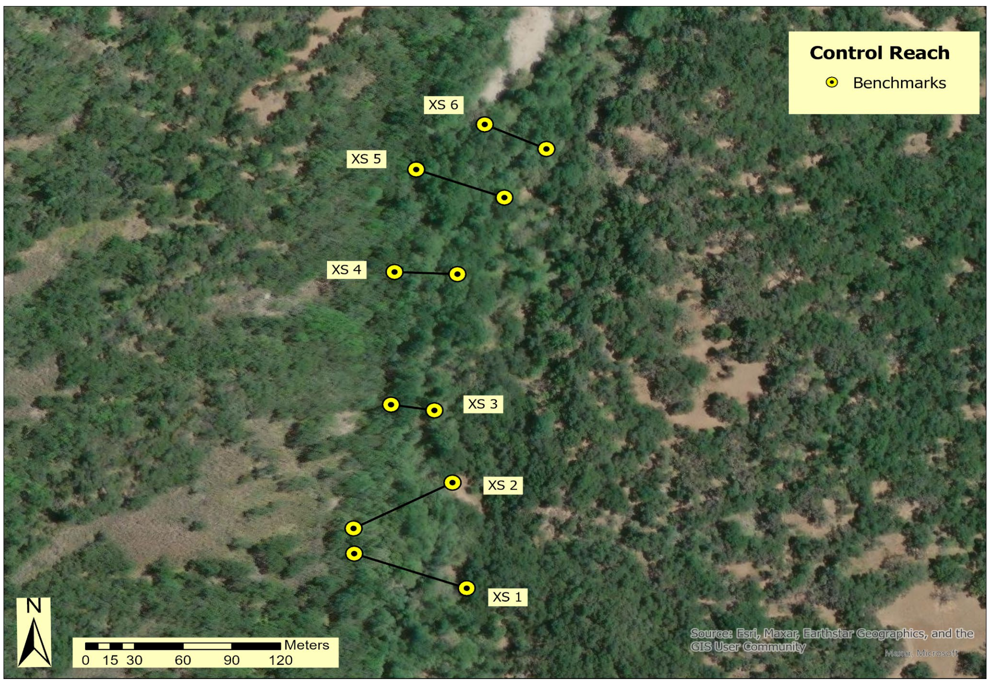

Figure 3. Map of cross sections in CR where the three total station surveys and six pebble count surveys were performed in 2023.

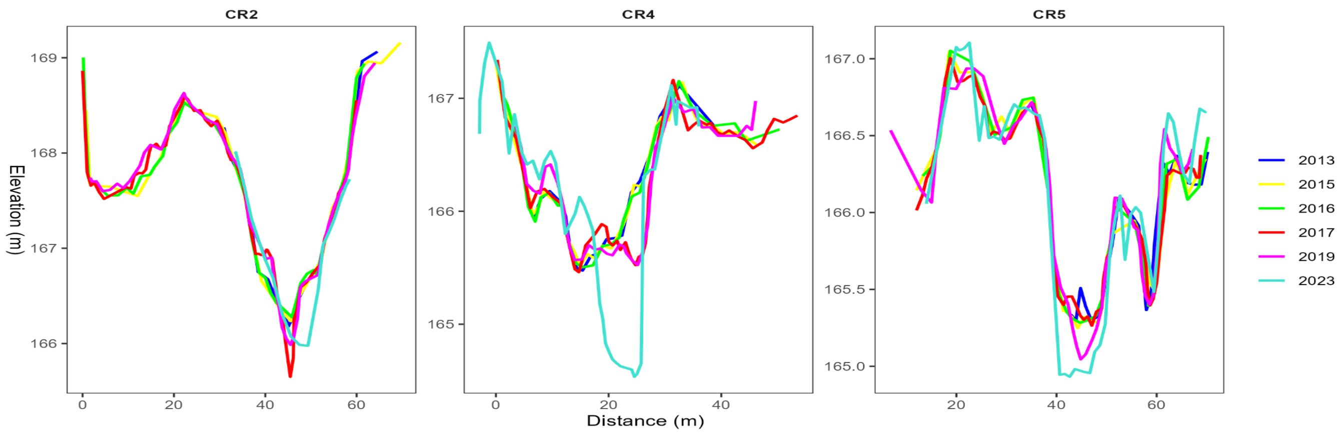

Figure 4. Three of the six cross sections of CR showing comparison of 2023 to previous years.

Pebble count data, which was obtained for all six cross sections, indicated relatively drastic coarsening of the bed (Figs 5-7) in response to high flows in WY2023. Between 2021 and 2023, median grain diameter increased from 20 mm to ~90mm. All together, these data indicate a potential winnowing of finer material coincident with net erosion found in surveyed cross sections. Although coarsening was the dominant shift in the bed material grain size, there were observations of fresh patches of sand deposited during overbank flows in WY2023.

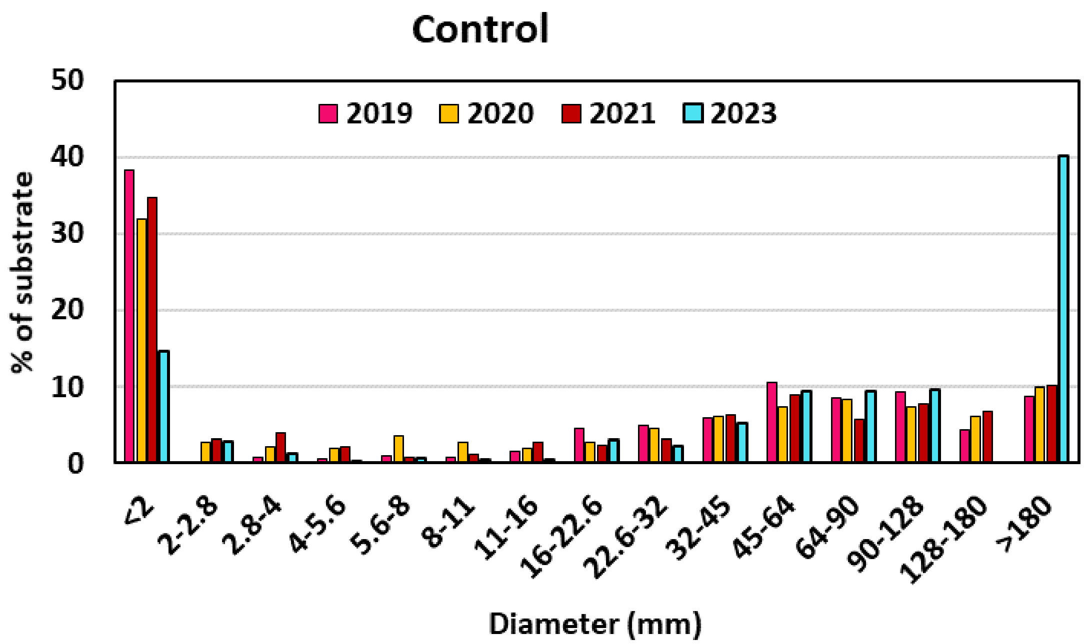

Figure 5. Summary pebble count distribution for the Control reach displayed as individual bins for the most recent survey water years (2019, 2020, 2021, and 2023).

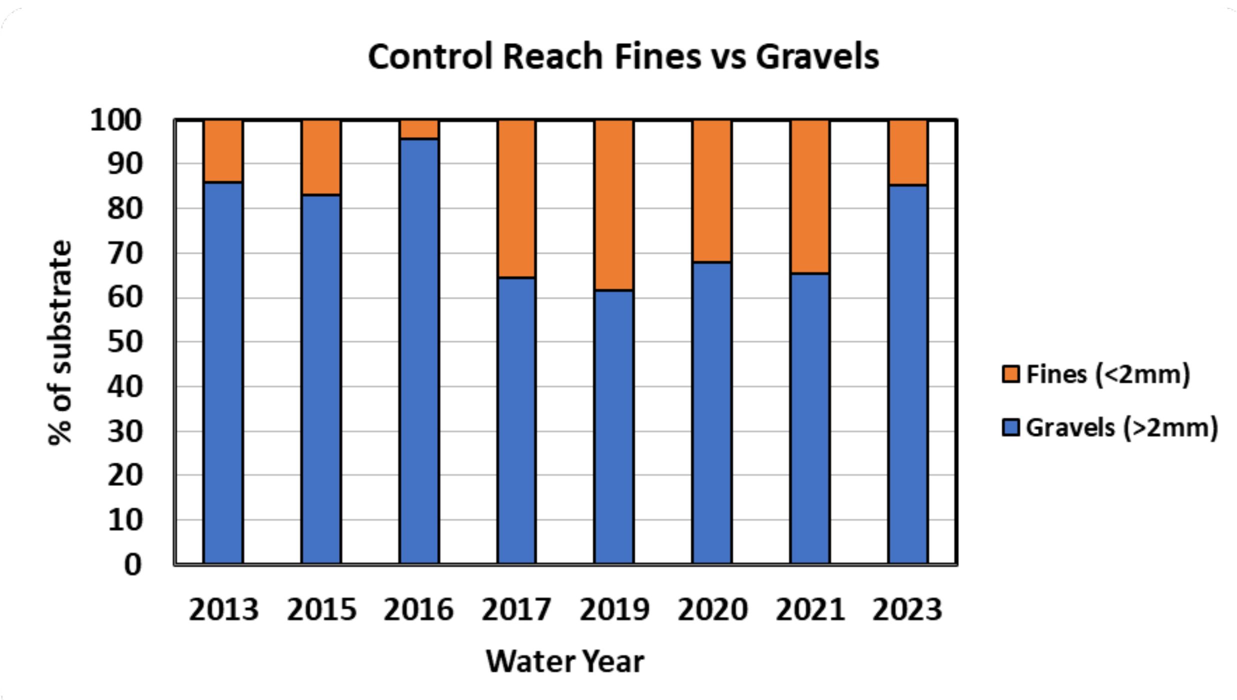

Figure 6. Summary of fines vs. gravels for CR displayed by water year.

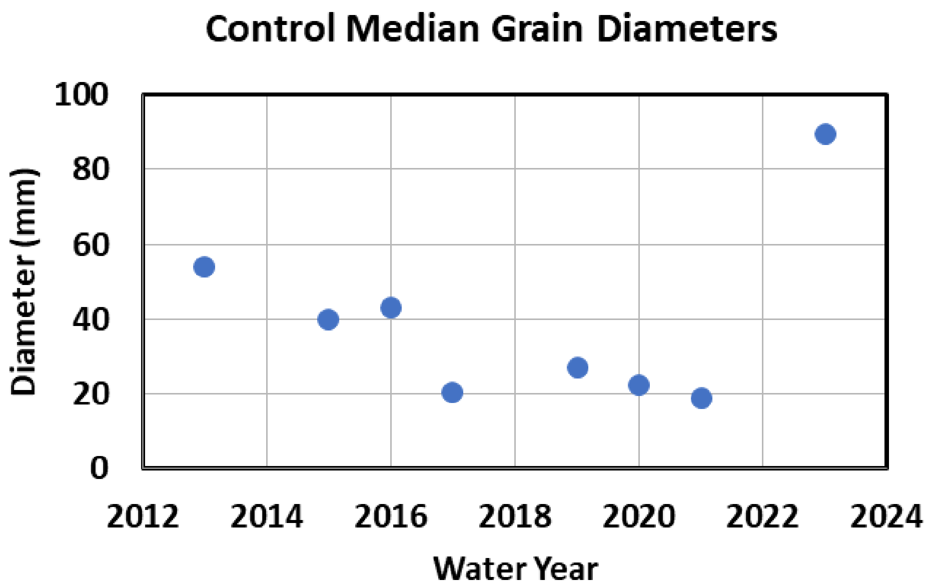

Figure 7. Median grain size trends across all water years for CR.

6.2. Dam Reach

The Dam reach is located immediately downstream of the former dam site (Fig 8). No cross-sectional data was collected in WY2023 for the Dam reach (DM, Fig 8). Following a slight fining of the bed from 2016 to 2019, grain size has remained largely steady since 2021 (Figs 9-11).

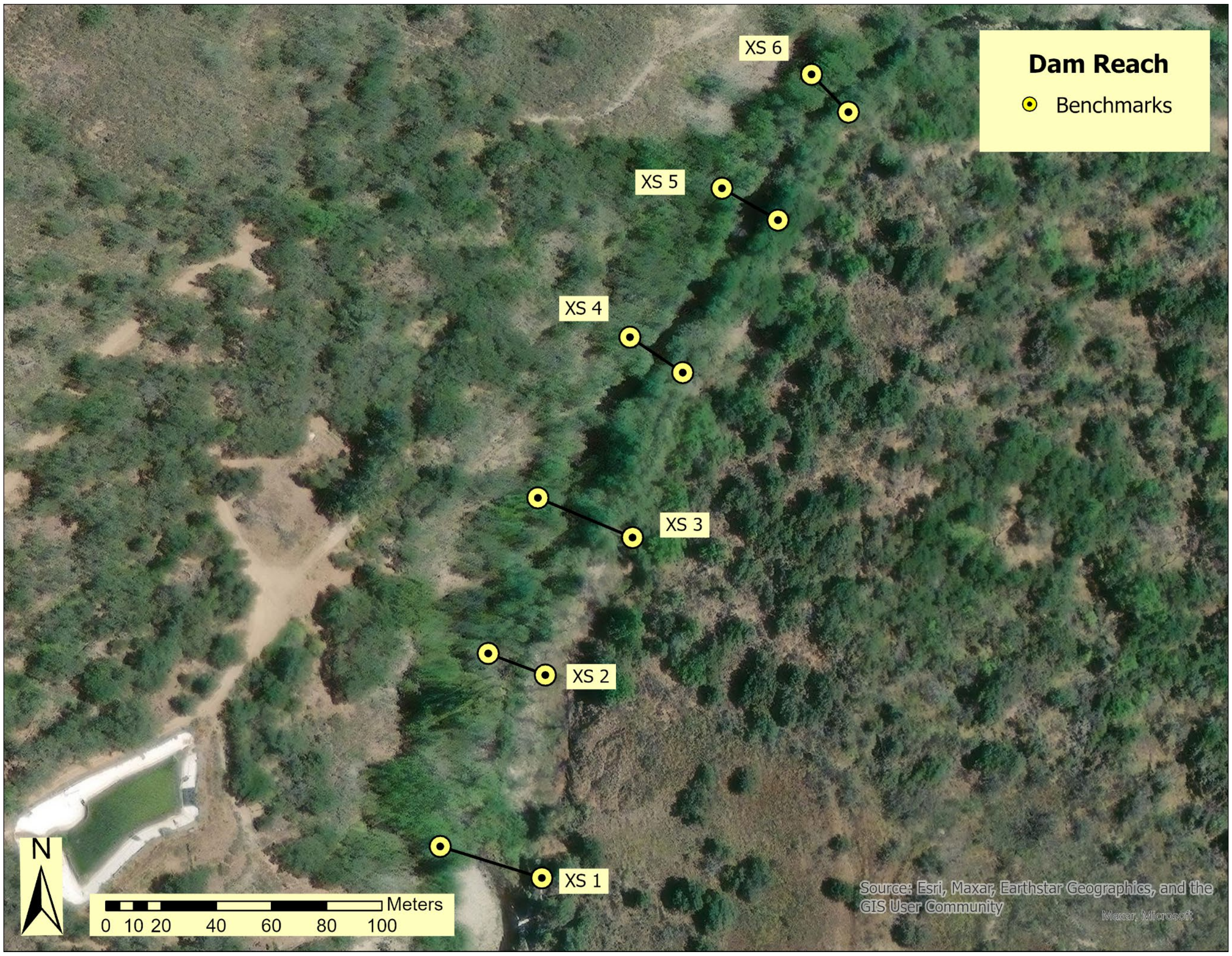

Figure 8. Map of cross sections in DM where pebble counts were performed in 2023.

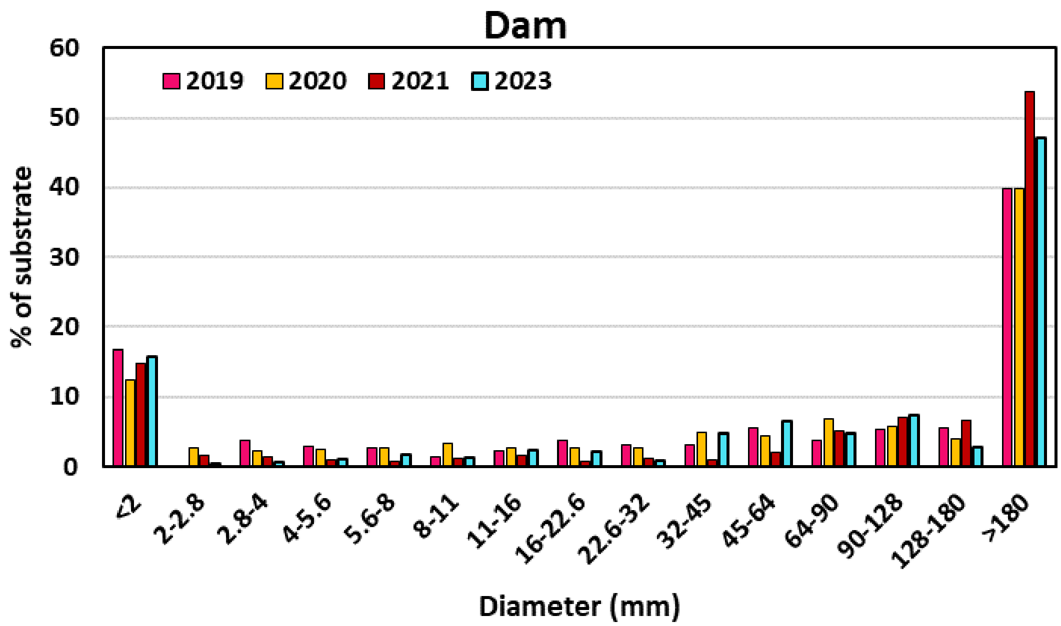

Figure 9. Summary pebble count distribution for the Dam Reach displayed as individual bins for 4 most recent years: 2019, 2020, 2021, and 2023.

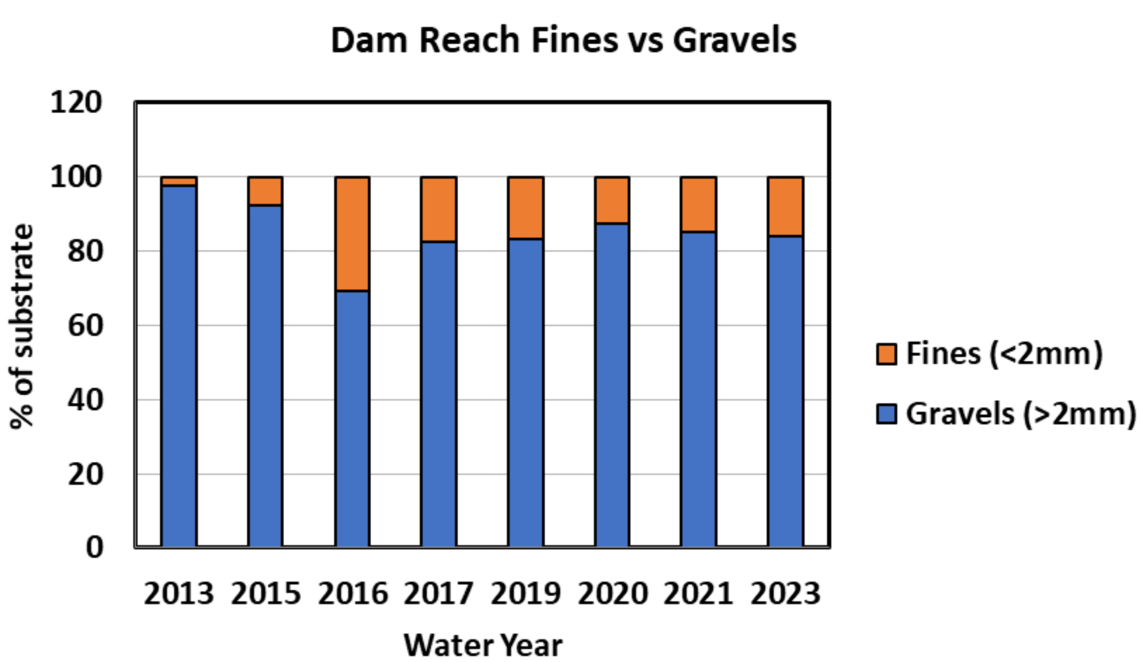

Figure 10. Summary of fines vs gravels for the Dam Reach displayed by water year.

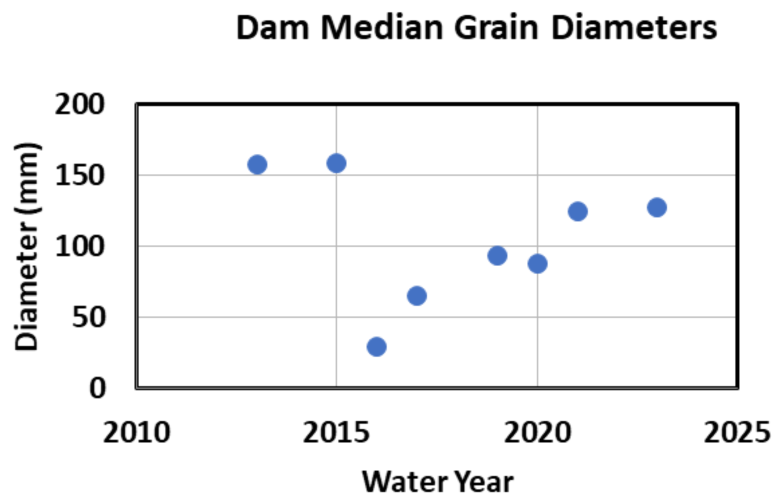

Figure 11. Median grain size across all water years for DM.

6.3. Sleepy Hollow Reach

Sleepy Hollow is located a few km downstream of the former dam site (Fig 12). No cross-sectional data was collected in WY2023. Comparing most recent bed grain size distribution data to recent trends, it is clear that SH has a complex response compared to DM upstream (Figs 12-14). These plots indicate that SH has coarsened somewhat since WY2021, including an overall reduction in the amount of finer (<2mm) material.

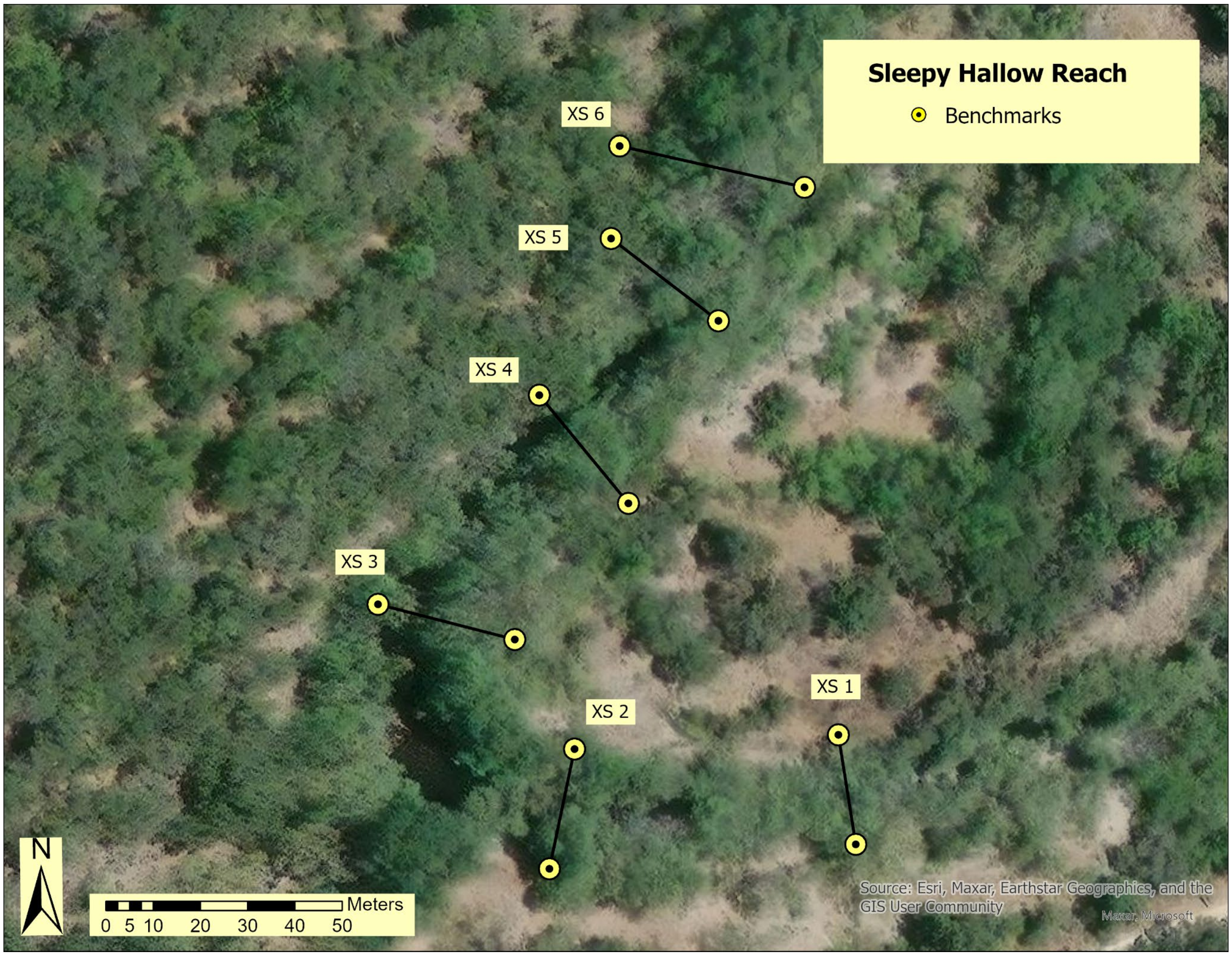

Figure 12. Map of cross sections in SH where pebble counts were performed in 2023.

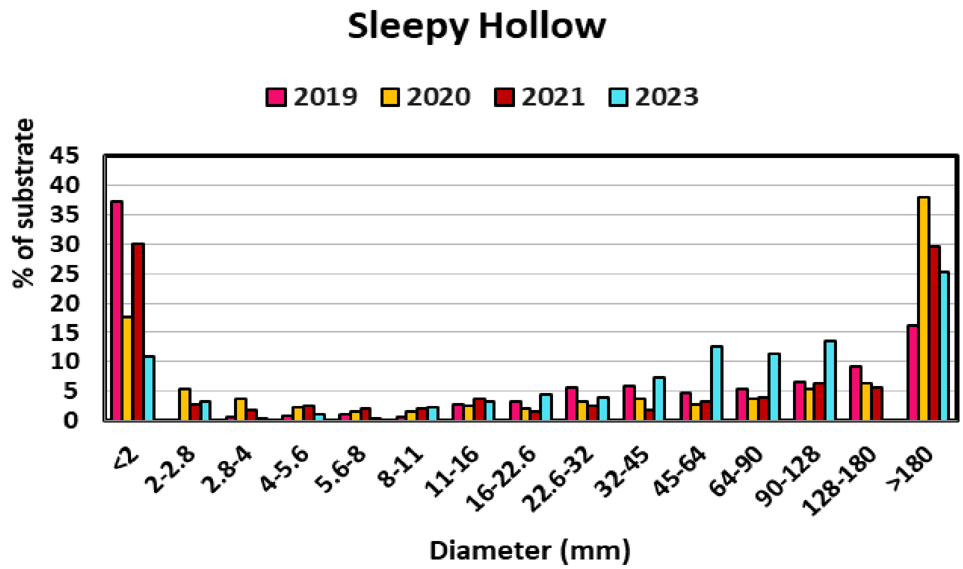

Figure 13. Summary pebble count distribution for the Sleepy Hollow reach displayed as individual bins for most recent years: 2019, 2020, 2021, and 2023.

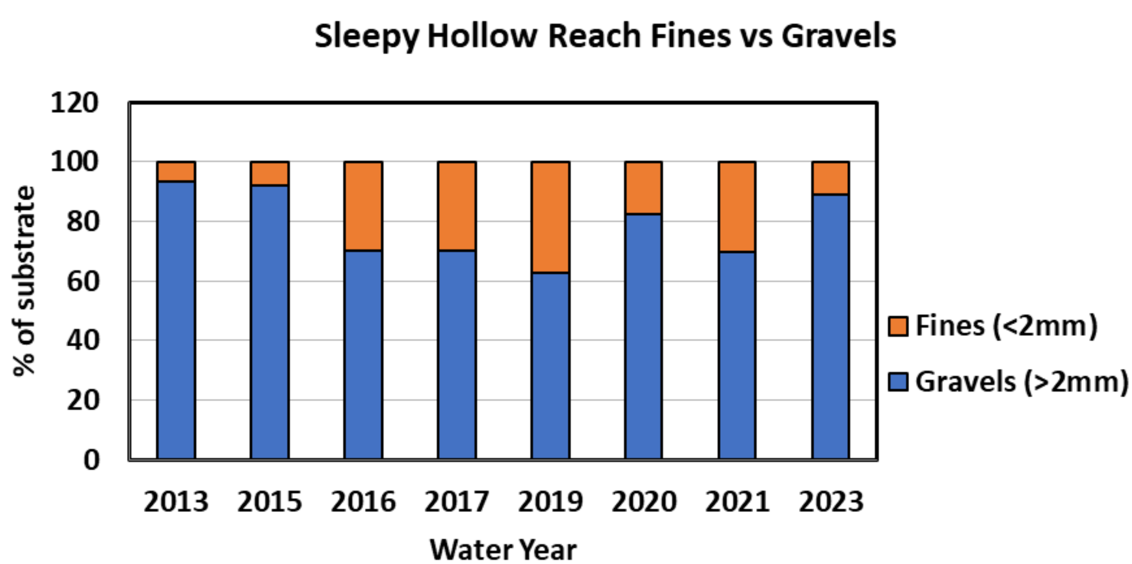

Figure 14. Summary of fines vs gravels for the Sleepy Hollow Reach displayed by water year.

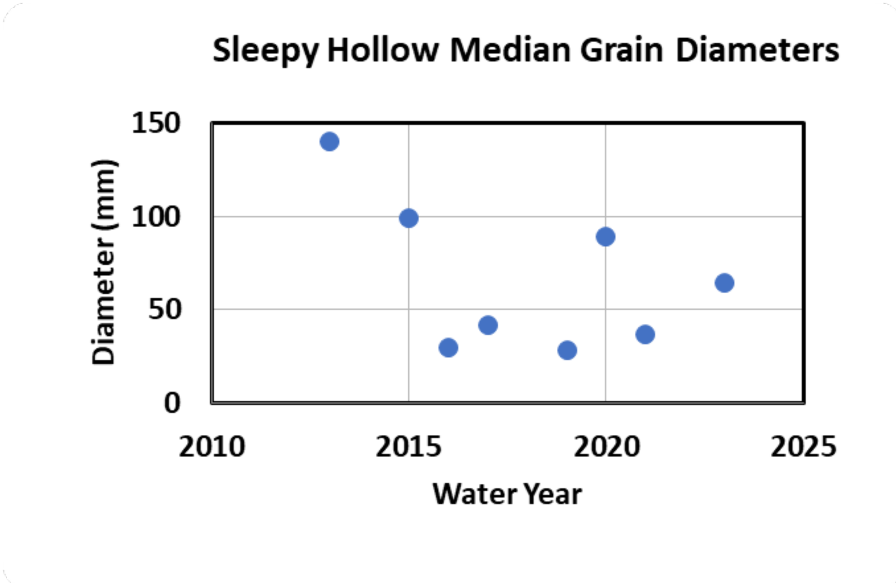

Figure 15. Median grain size across all water years for SH.

6.4. DeDampierre Upper Reach

The DeDampierre Upper (DDU) Reach (Fig. 16) is the most upstream reach consistently monitored by CSUMB below the San Clemente Dam removal. All sites had surveys and bed substrate counts performed in 2023. DDU had a complex response to high flows between the 2021 and 2023 surveys (Fig 17). DDU cross sections 1 and 3 experienced either little change or some slight aggradation. DDU6 experienced ~0.4m of incision on the right side of the channel. DDU 3 and 5 experienced ~0.1m scale erosion along with minor deposition on the right bank of both DDU3 and DDU5 in 2023, supported by observations of overbank flows and associated sand and gravel deposits. Interestingly, DDU4 likely experienced significant infill within the active channel. However, with DDU4, we caution that some of this may have resulted from human modification of the channel for recreational purposes (e.g., pool building by stacking rocks).

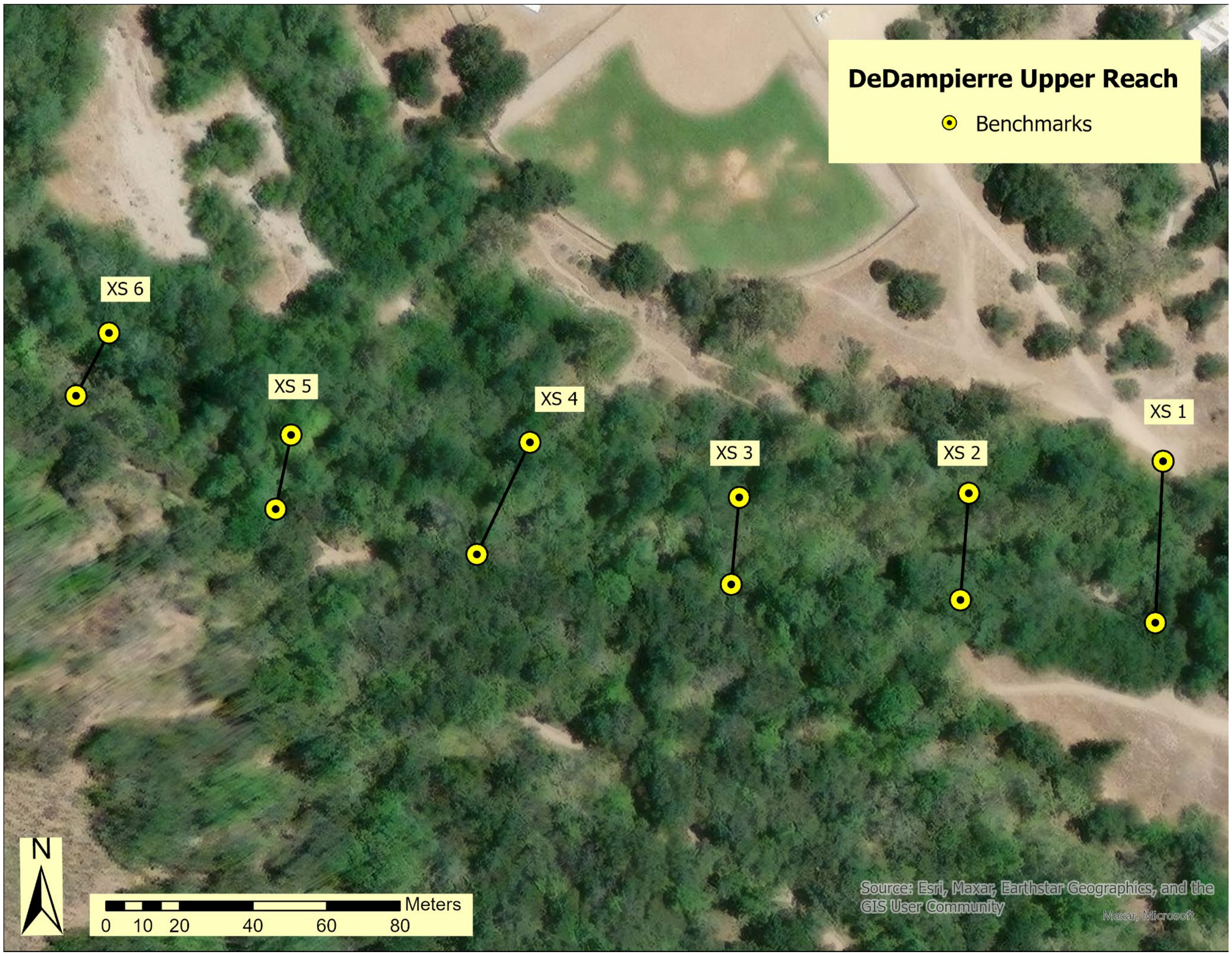

Figure 16. Map of cross sections in DDU where autolevel surveys and pebble counts were performed in 2023.

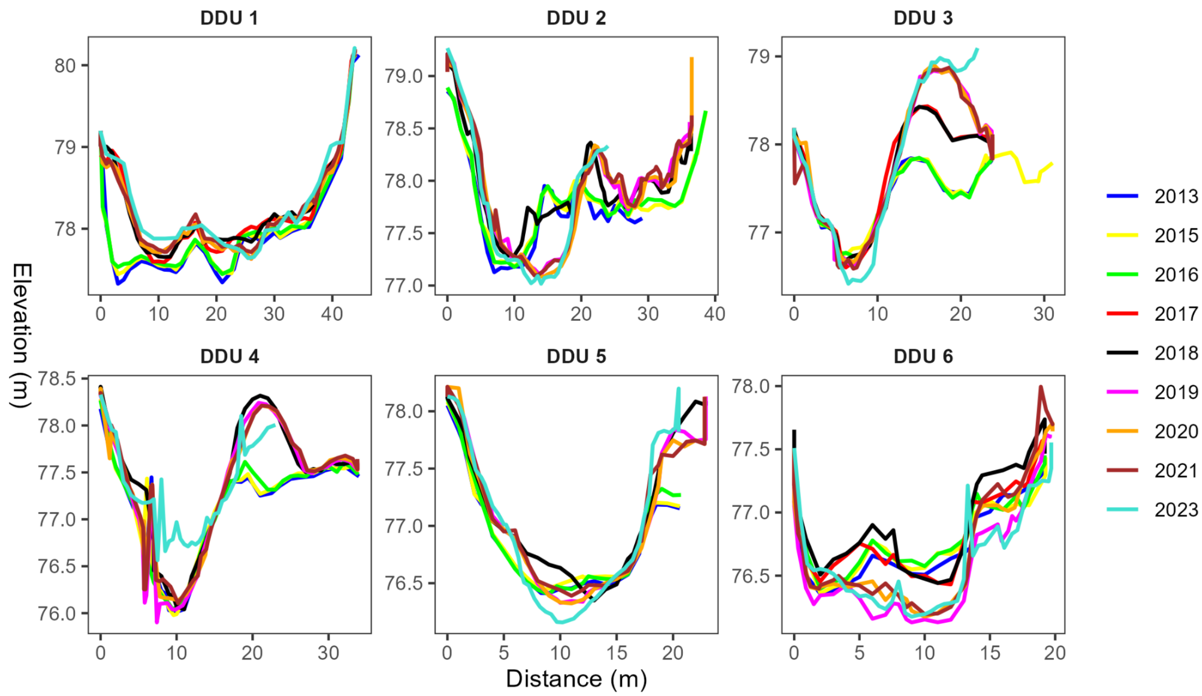

Figure 17. All six cross sections of DDU showing comparison of 2023 to previous years.

DDU had an overall coarsening of bed material. In particular, there was a notable increase in the largest grains (>180 mm cobbles, Fig 18) compared to the previous 3 years. This resulted in a shift of median grain size in 2021 of ~3mm to a present value of ~22mm.

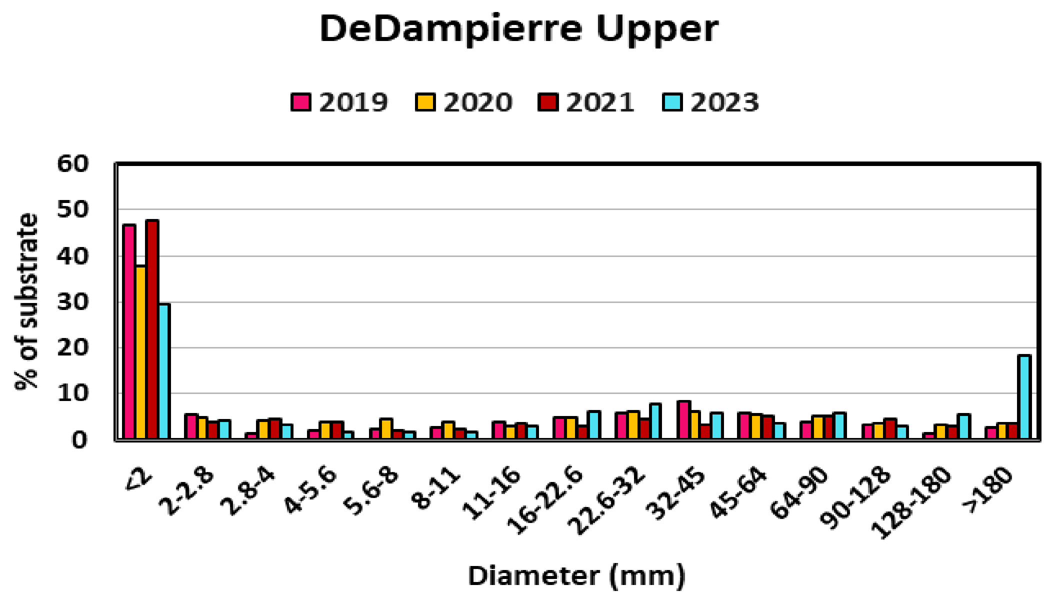

Figure 18. Summary pebble count distribution (DDU 1 – DDU 6) for the DeDampierre Upper reach displayed as individual bins for 2019, 2020, 2021, and 2023.

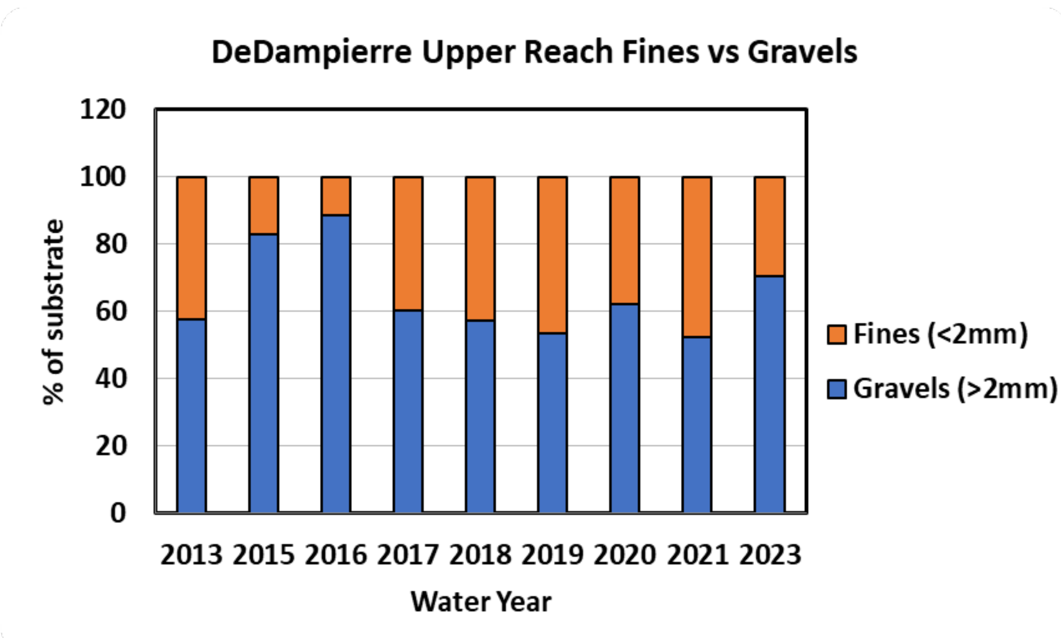

Figure 19. Summary of fines vs gravels for the DDU displayed by water year.

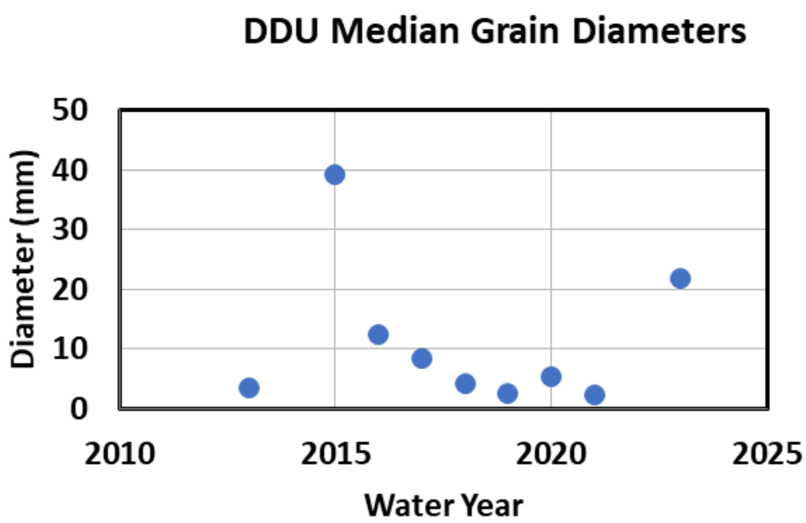

Figure 20. Median grain size across all water years for DDU.

6.5. DeDampierre Lower Reach

DeDampierre Lower Reach (DDL) is located just downstream of DDU and contains 4 cross sections which were fully surveyed in 2023 (Fig 21). Overall from 2019 to 2023, we observed minor net erosion (~0.1– 0.2 m) in DDL1, 2, and 4 (Fig 22), while DDL3 remained largely stable. Similar to DDU reach above, there was an increase in the coarsest material (Fig. 23) but fines fraction has remained stable since 2021 (Fig 24). There is a smaller relative increase in median grain size compared to DDU (Fig 25).

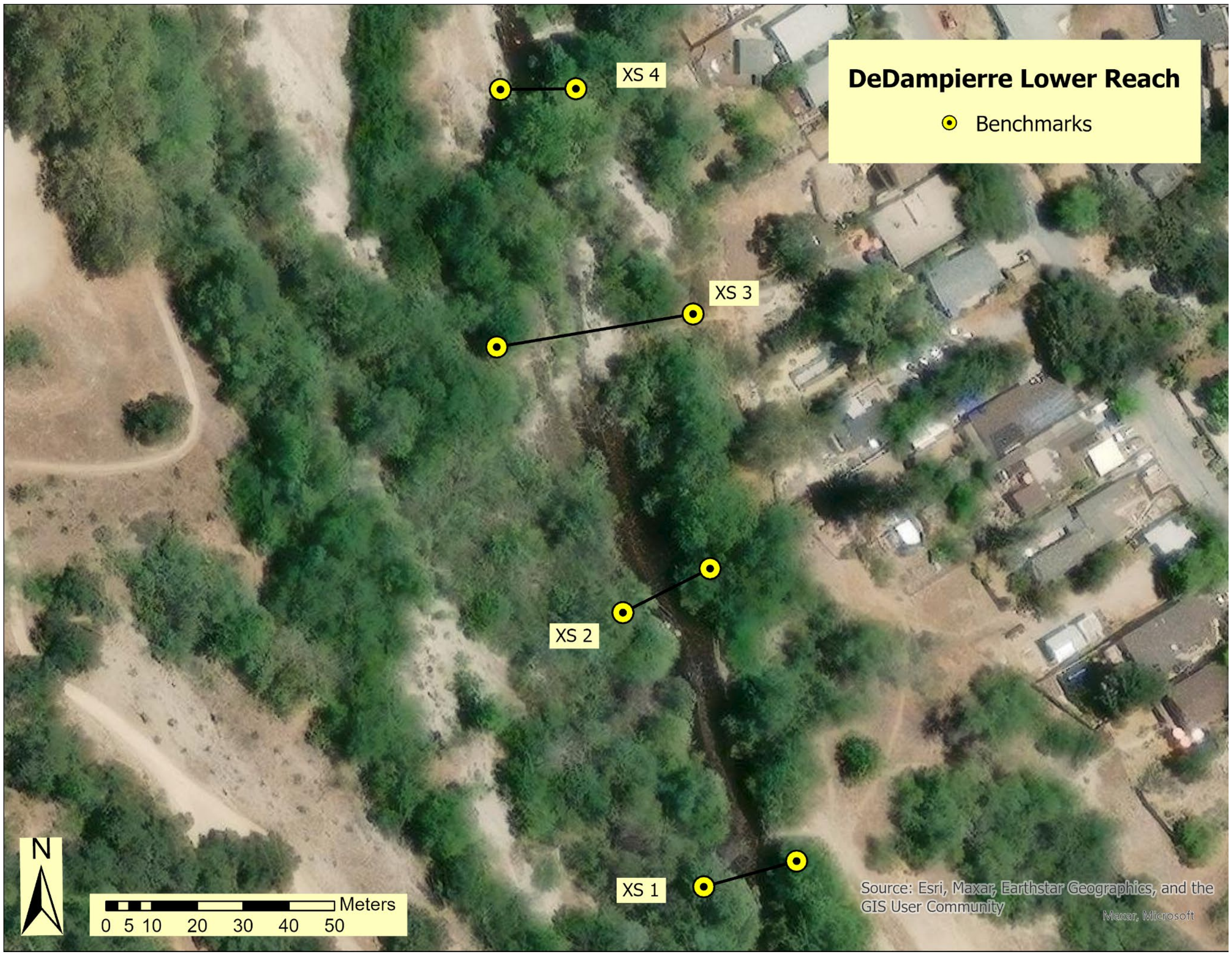

Figure 21. Map of cross sections in DDL where autolevel surveys and pebble counts were performed in 2023.

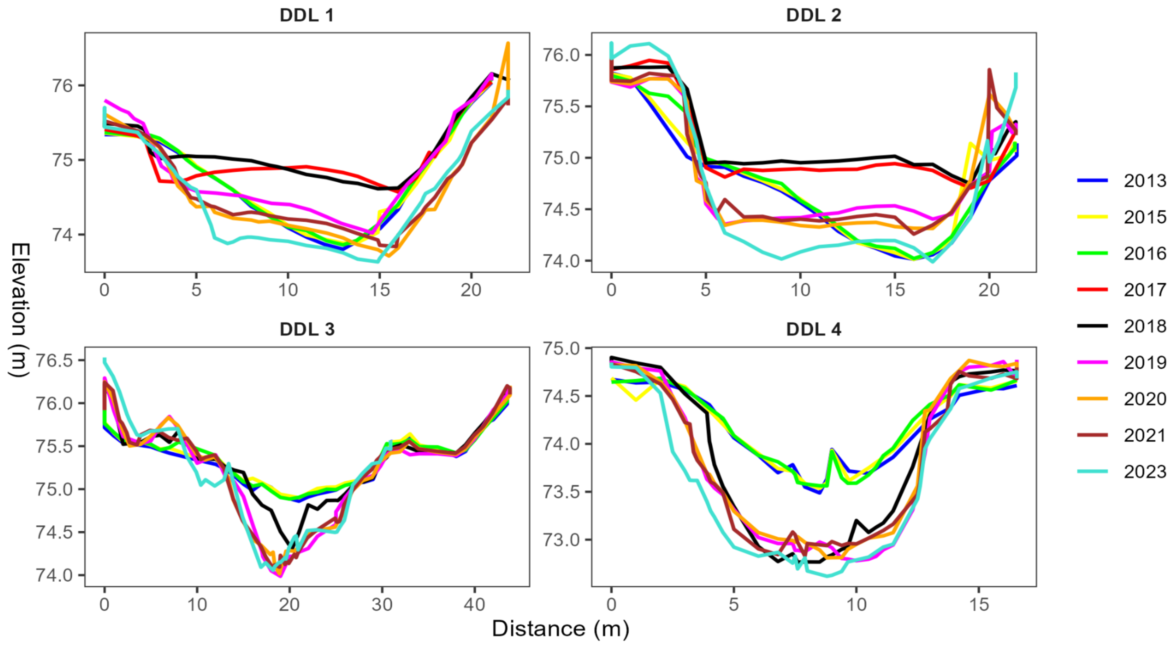

Figure 22. All six cross sections of DDL showing comparison of 2023 to previous years.

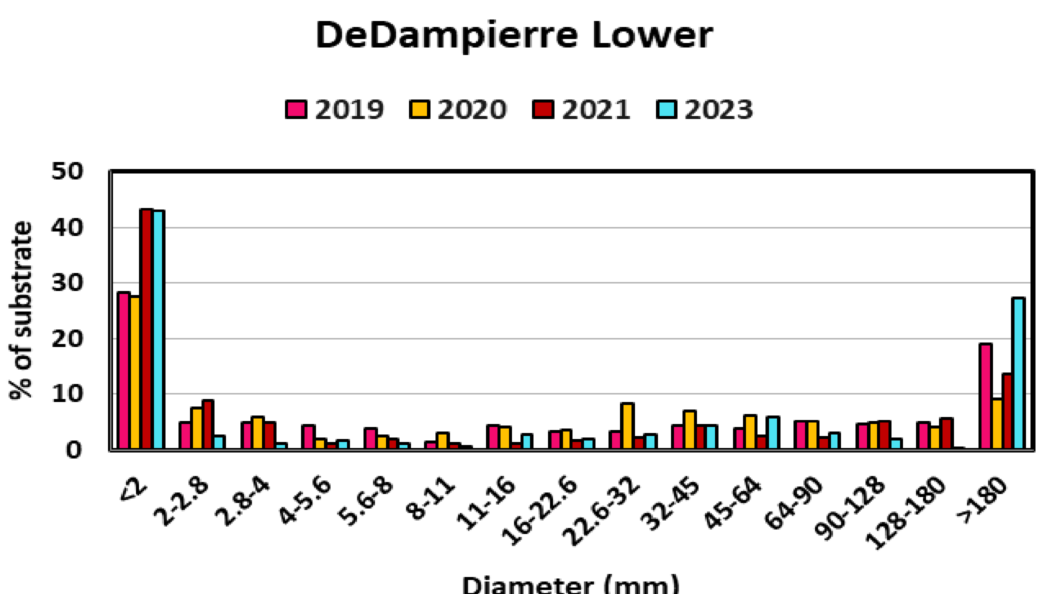

Figure 23: Summary pebble count distribution (DDL 1 – DDL 4) for the DeDampierre Lower reach displayed as individual bins for 2019, 2020, 2021, and 2023.

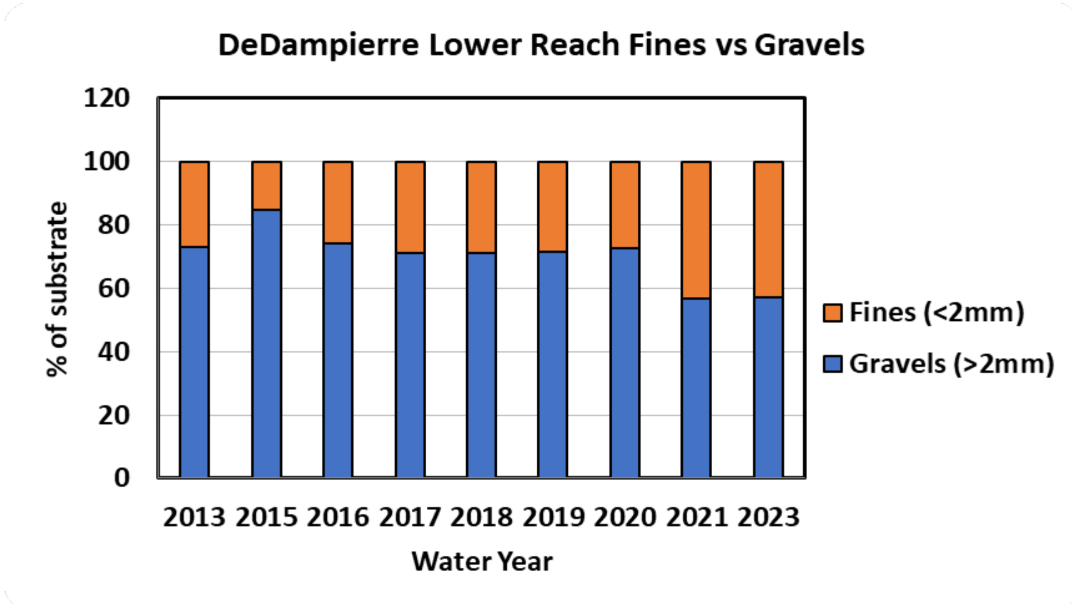

Figure 24: Summary of Fines vs Gravels for the DeDampierre Lower Reach displayed by water year.

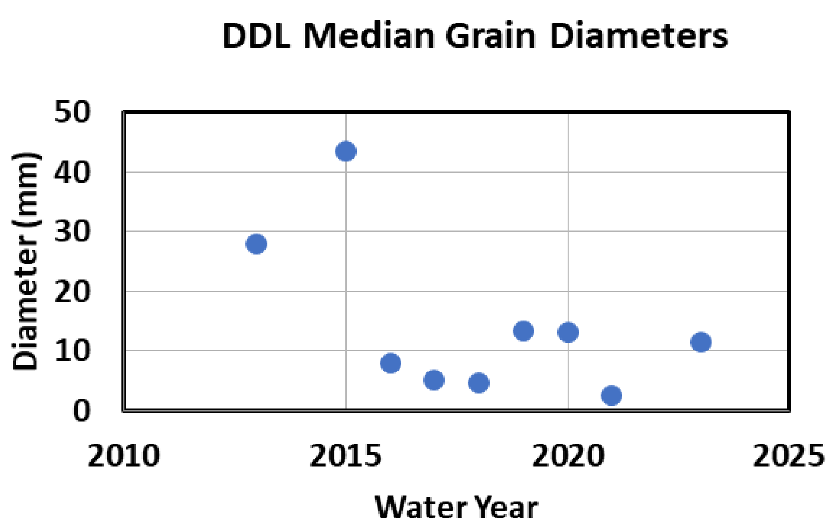

Figure 25. Median grain size across all water years for DDL.

6.6. Berwick Reach

The Berwick Reach is located on California American Water property, northwest of the DeDampierre reaches (Fig. 26). Berwick experienced primarily erosional geomorphic changes across the different cross sections. BW4, BW5, and BW6 experienced little change from 2020 to 2023 besides erosion ranging from 0.1 to 0.3 m in the centerline of the channel (Fig 27). BW1 was the most eroded, showing incision ranging from 0.2 to 0.8 m across the entire channel (Fig 27). BW2 and BW3 right banks show deposition ranging from 0.1 m to 0.6 m, while the channels experience minor erosion from ~0.1 m to 0.2 m.

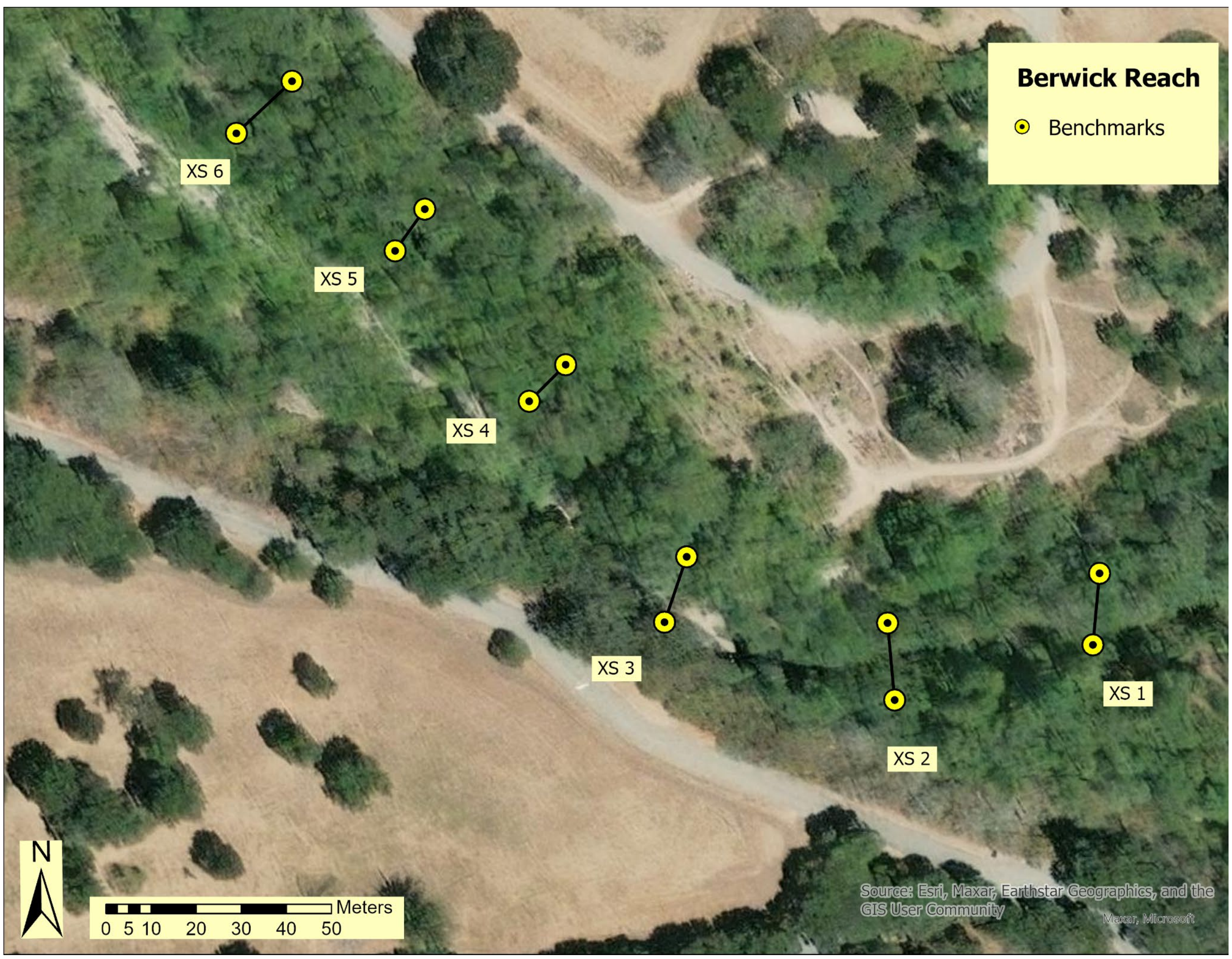

Figure 26. Map of cross sections in BW where autolevel surveys and pebble counts were performed in 2023.

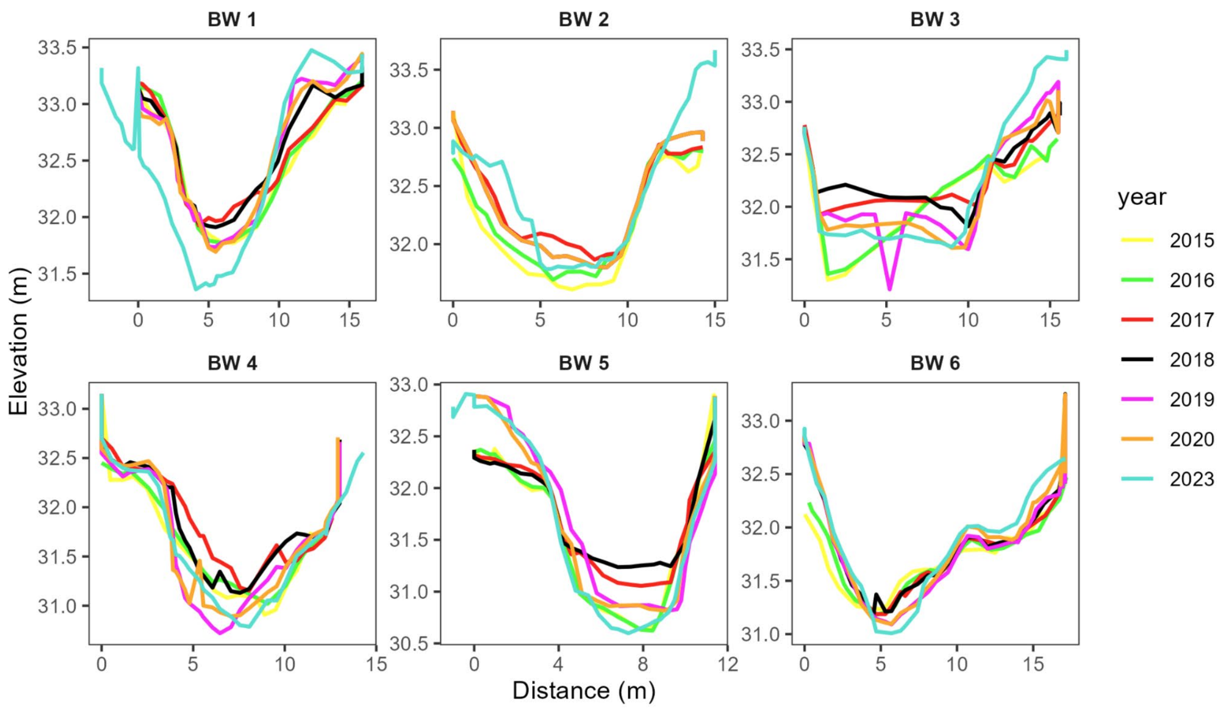

Figure 27. All six cross sections of BW showing comparison of 2023 to previous years.

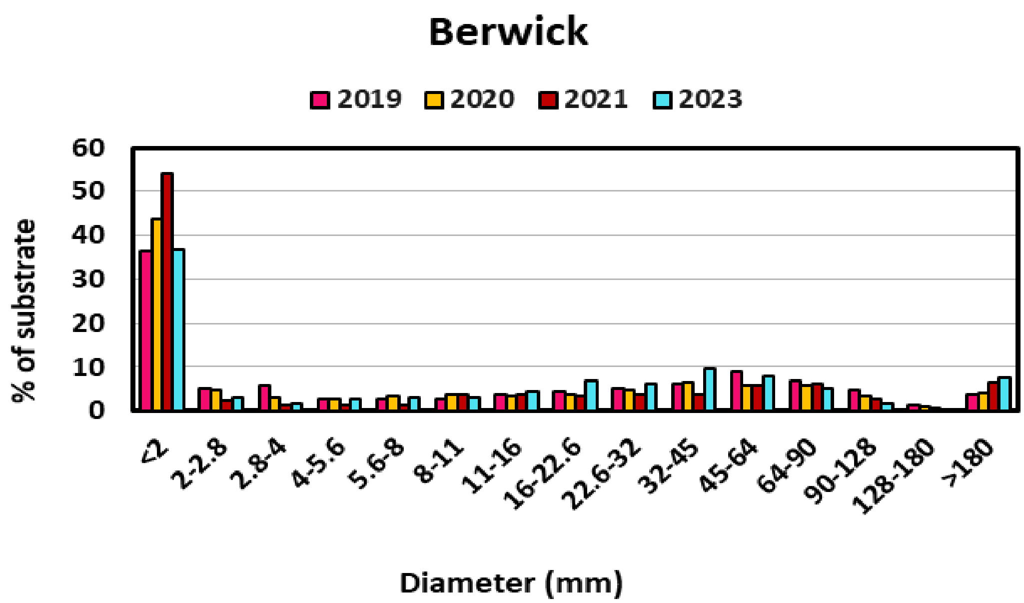

Figure 28: Summary pebble count distribution (BW 1 – BW 6) for the Berwick reach displayed as individual bins for 2019, 2020, 2021, and 2023.

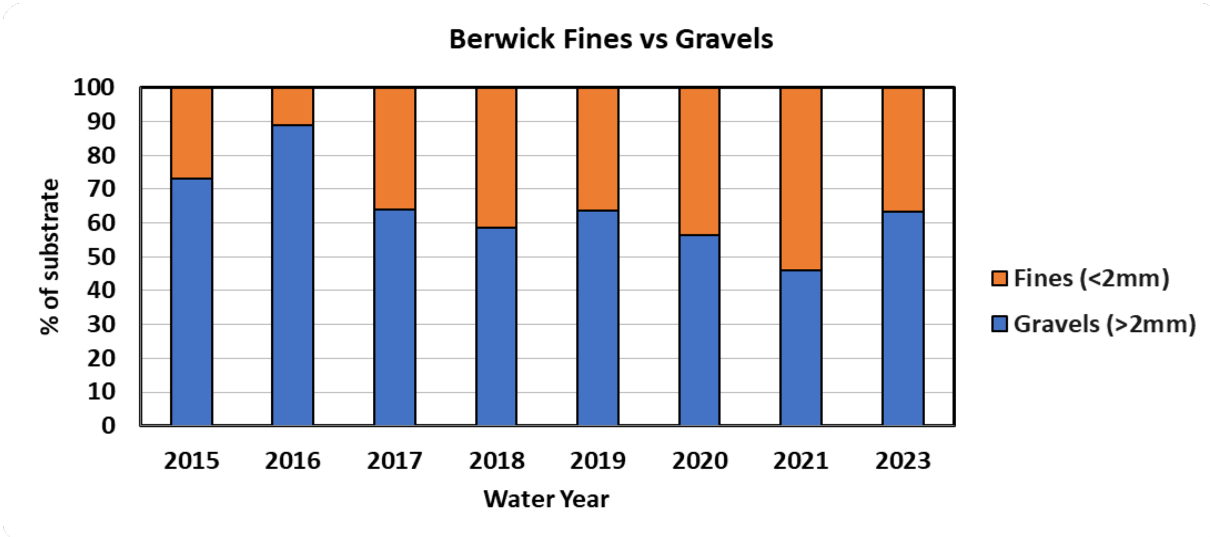

Figure 29: Summary of Fines vs Gravels for the Berwick Reach displayed by water year.

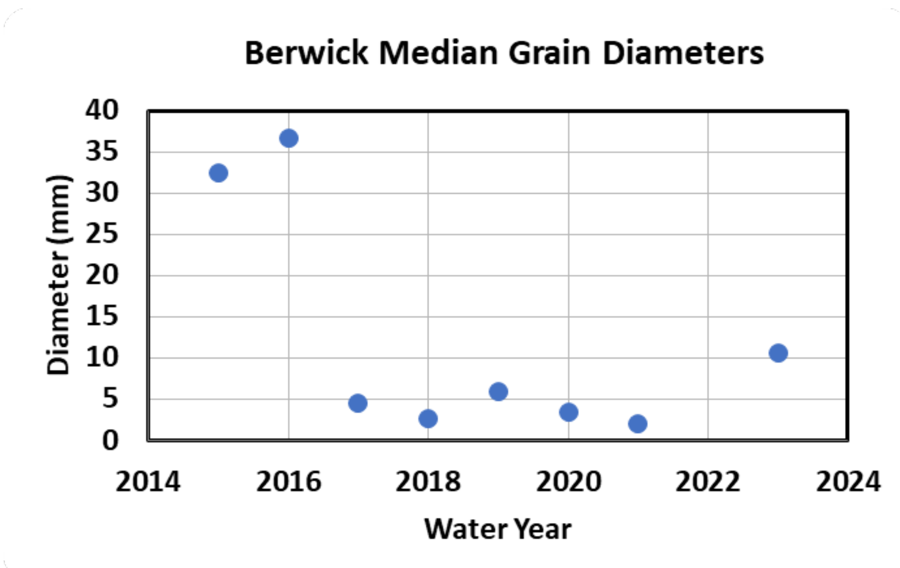

Figure 30. Median grain size across all water years for BW.

6.7. Schulte Road Reach

The Schulte Road (SR) reach is located approximately 200 m upstream of the Schulte Bridge and extends above the 'Steinbeck Pool' which is located between cross sections

2 and 3 (Fig. 31). We found that SR 2, 3, and 4 experienced very significant changes in the river channel. The primary channels shifted in SR 2 and 3 due to a combination of significant deposition (~0.3 to ~1m) on the right side of the channel and incision up to 1m on the left side. SR 1 showed a complex response of channel widening and aggradation along the centerline (Figure 32). The amount of fine material and overall gravel fraction increased in SR (Figs 33 and 34) and median grain size increased from ~8mm to ~18mm. In line with previous years, there were virtually no cobbles present in SR (Fig. 33).

Figure 31. Map of cross sections in SR where autolevel surveys and pebble counts were performed in 2023.

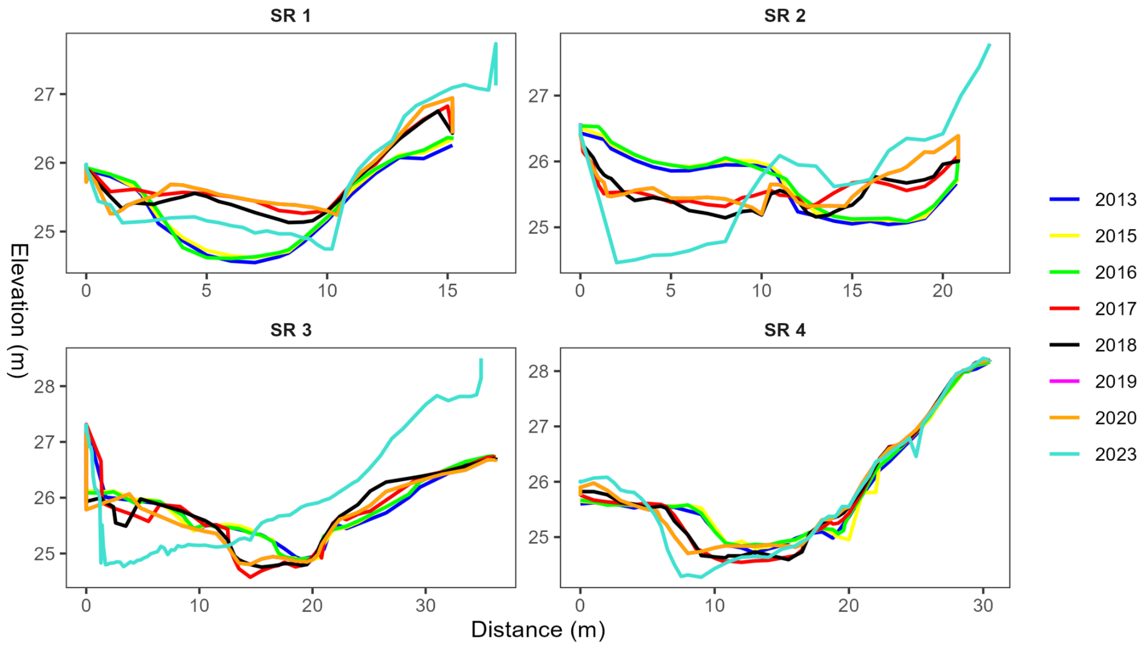

Figure 32. All four cross sections of Schulte Road showing comparison of 2023 to previous years.

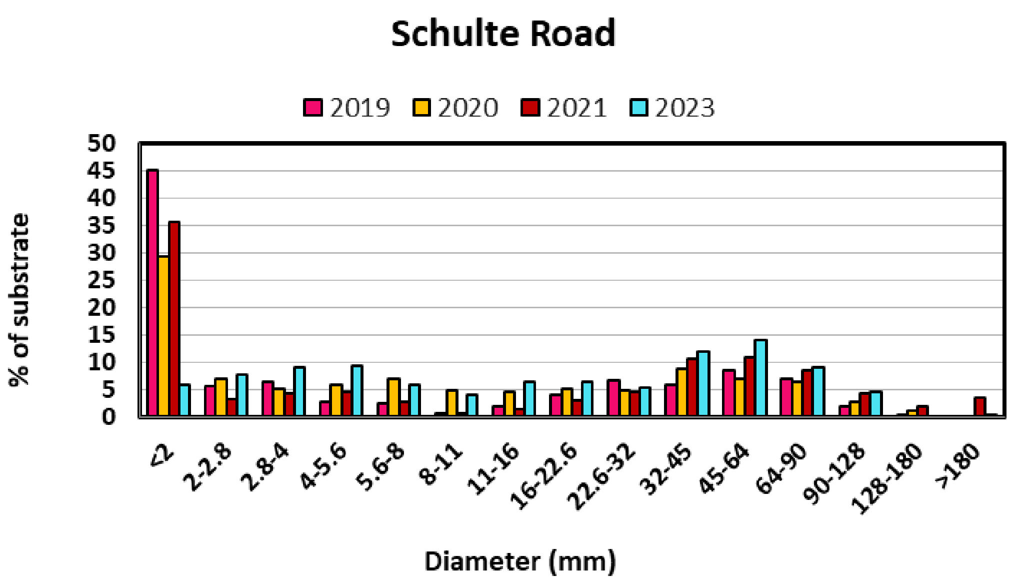

Figure 33: Summary pebble count distribution (SR 1 – SR 4) for the Schulte Road reach displayed as individual bins for 2019, 2020, 2021, and 2023.

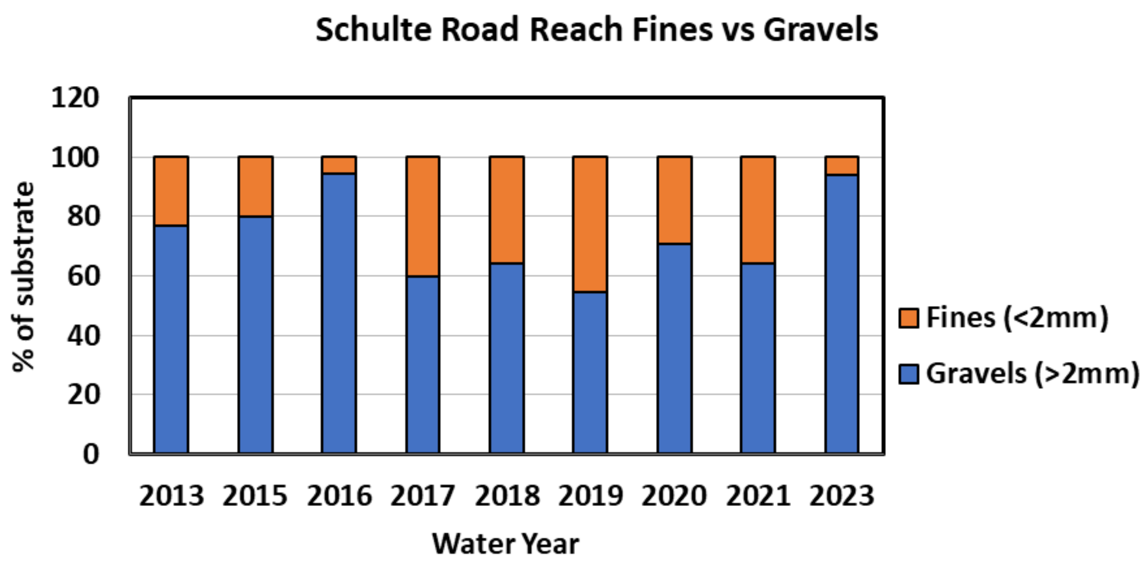

Figure 34: Summary of Fines vs Gravels for the Schulte Road Reach displayed by water year.

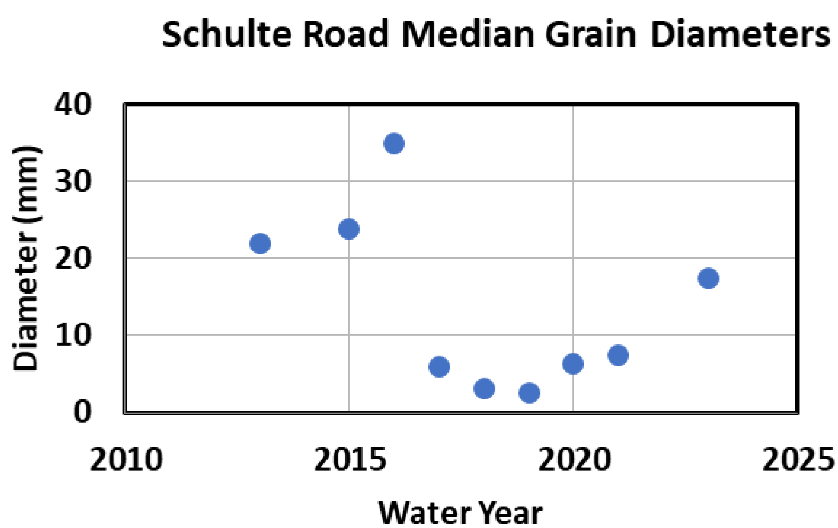

Figure 35. Median grain size across all water years for SR.

6.8. San Carlos Reach

The San Carlos Reach is located downstream of the Rancho San Carlos Bridge (Fig. 36). We obtained cross sectional data and pebble count data at all transects, except SC3.

Figure 36: Map of cross sections in SC where autolevel surveys and pebble counts were performed in 2023 (excluding SC 3).

At SC4, there was approximately 0.2m erosion on the river bed and SC5 experienced general deposition of approximately 0.6m and lateral shift to the right from bank erosion. SC3 was not surveyed, as this site was abandoned prior to 2019 due to significant woody material along the transect line. There is an increase in grain size and a reduction of fine sediment between the years 2021 and 2023 (Fig 38-39).

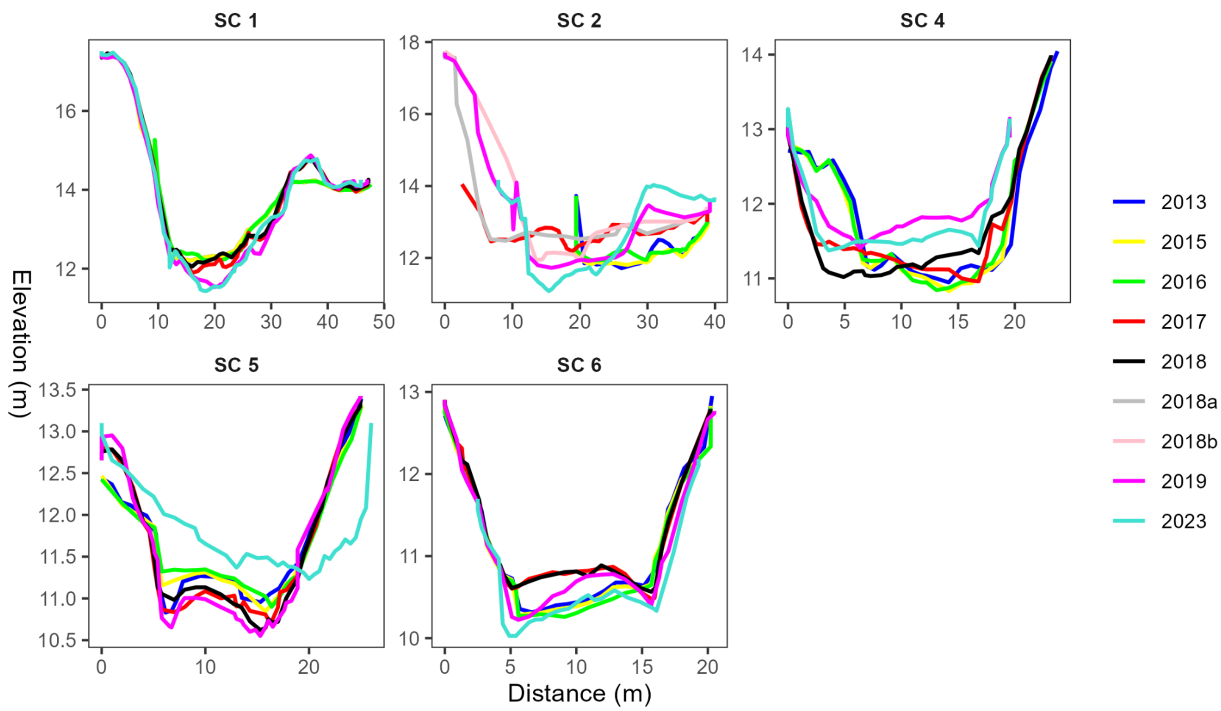

Figure 37. All six cross sections of San Carlos Reach showing comparison of 2023 to previous years.

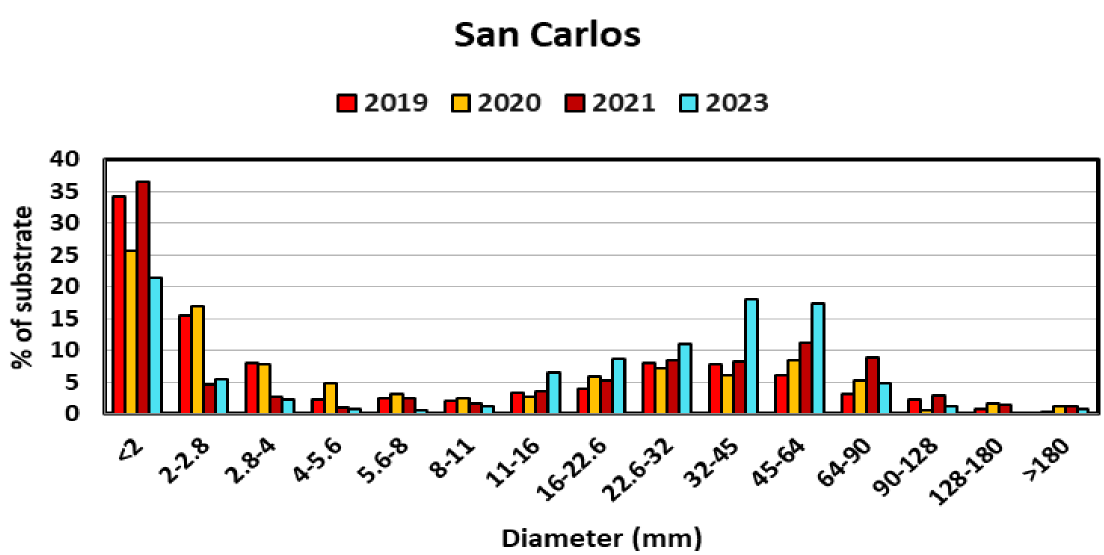

Figure 38: Summary pebble count distribution (SC1-SC2, SC4-SC6) for the San Carlos reach displayed as individual bins for 2019, 2020, 2021, and 2023.

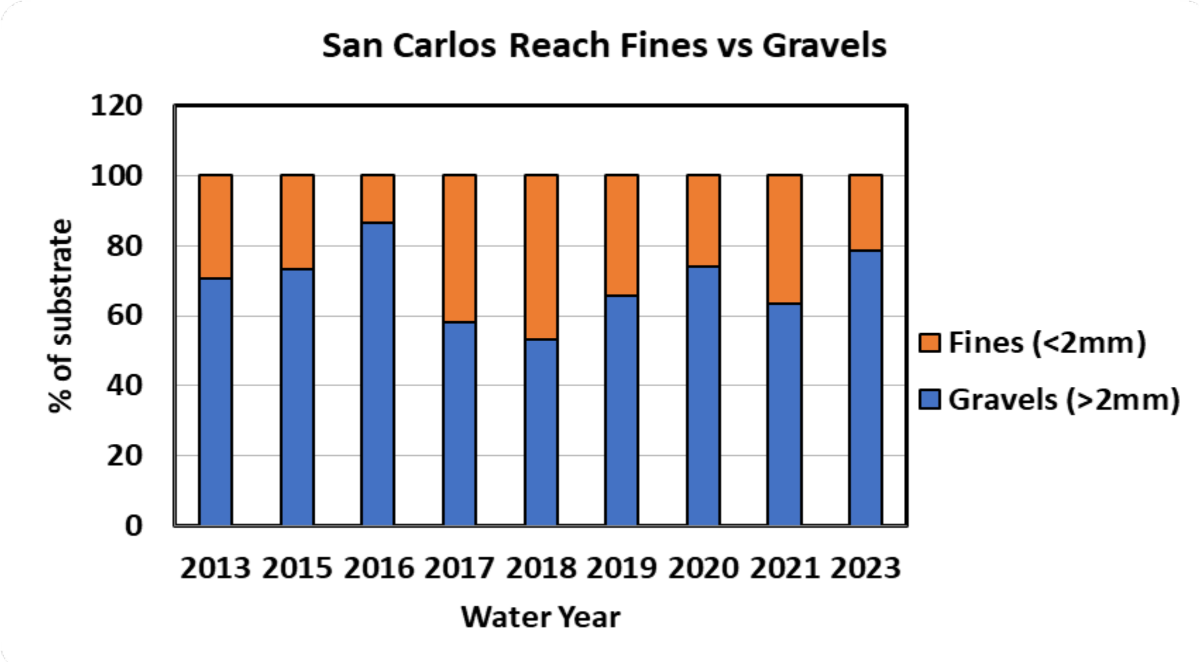

Figure 39: Summary of Fines vs Gravels for the San Carlos Reach displayed by water year.

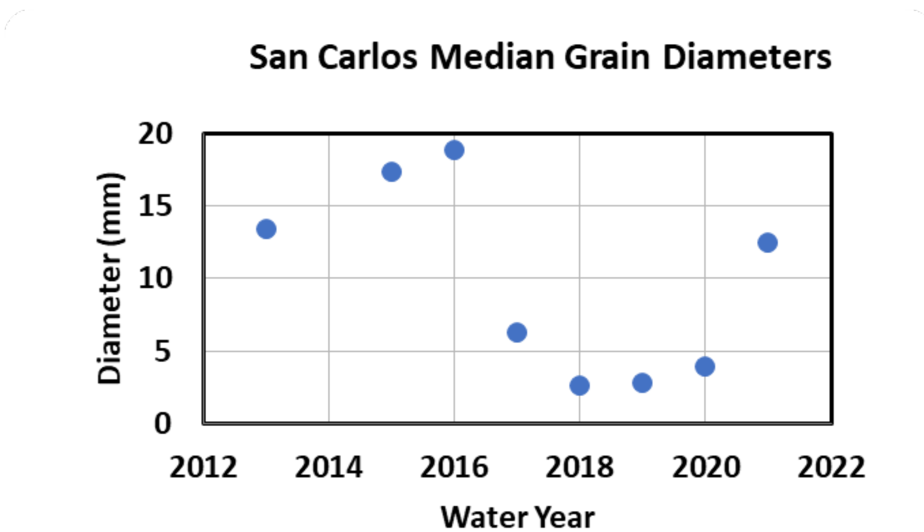

Figure 40. Median grain size across all water years for SC.

6.9. Crossroads Reach

Crossroads is located at the downstream end of the study, located adjacent to the Crossroads Shopping Center near the mouth of Carmel Valley (Fig. 41). We obtained survey and pebble count data at all cross section locations.

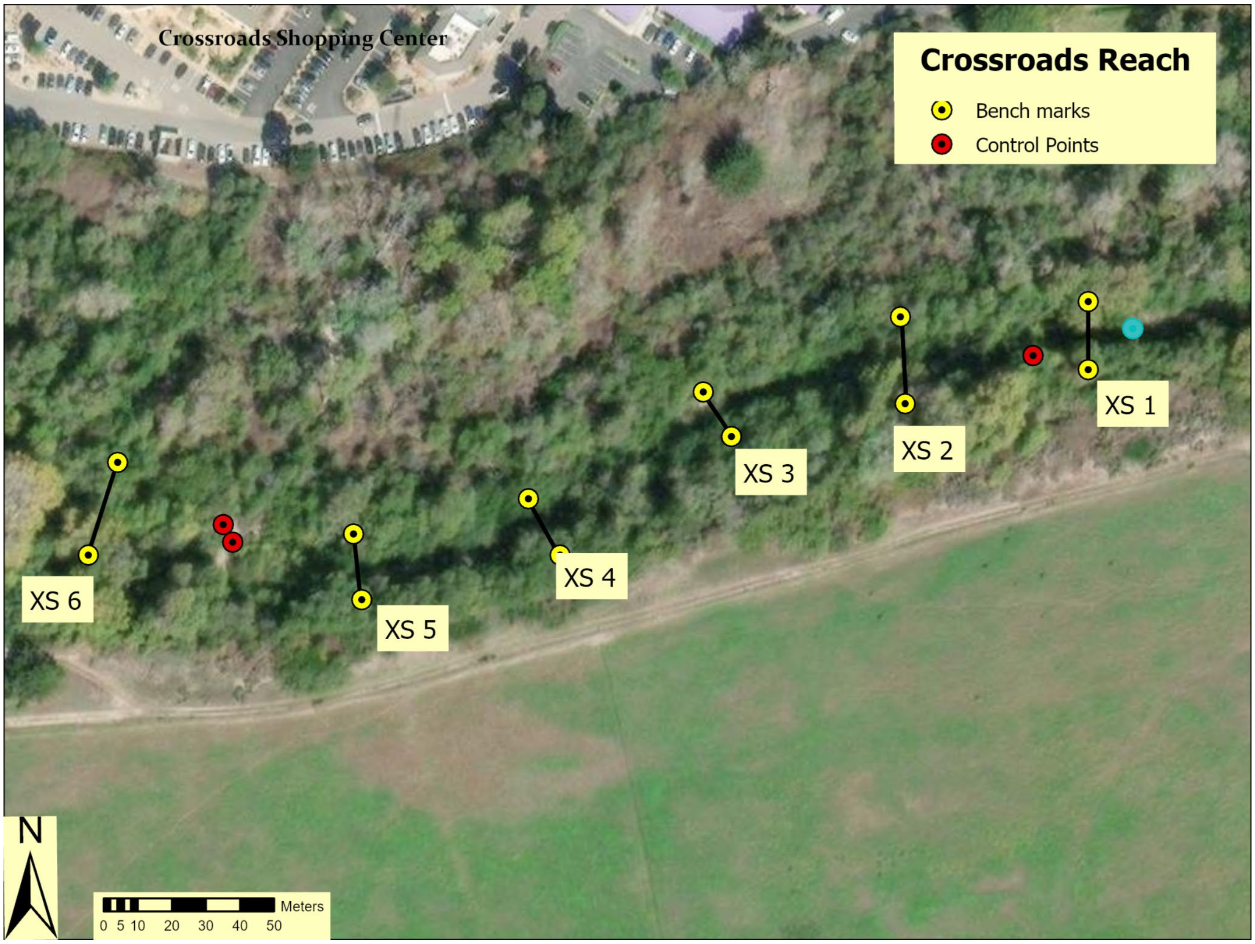

Figure 41: Georeferenced control points and cross sections within CRO.

There was notable geomorphic change in the CRO reach during 2023. CRO1, CRO3, CRO4, and CRO5 experienced erosion with different degrees, with approximately 0.5m of erosion on the left bank for CRO1, with approximately 0.5m of erosion at CRO3, and approximately 0.2m of erosion significantly throughout the bed at CRO4, and at approximately 1.0m at CRO5. There was less erosion at CRO2 and CRO6, with no indication of bank deposition. The particle size increased only slightly from 2019 to 2023 (Fig.43) but has largely remained stable since 2018.

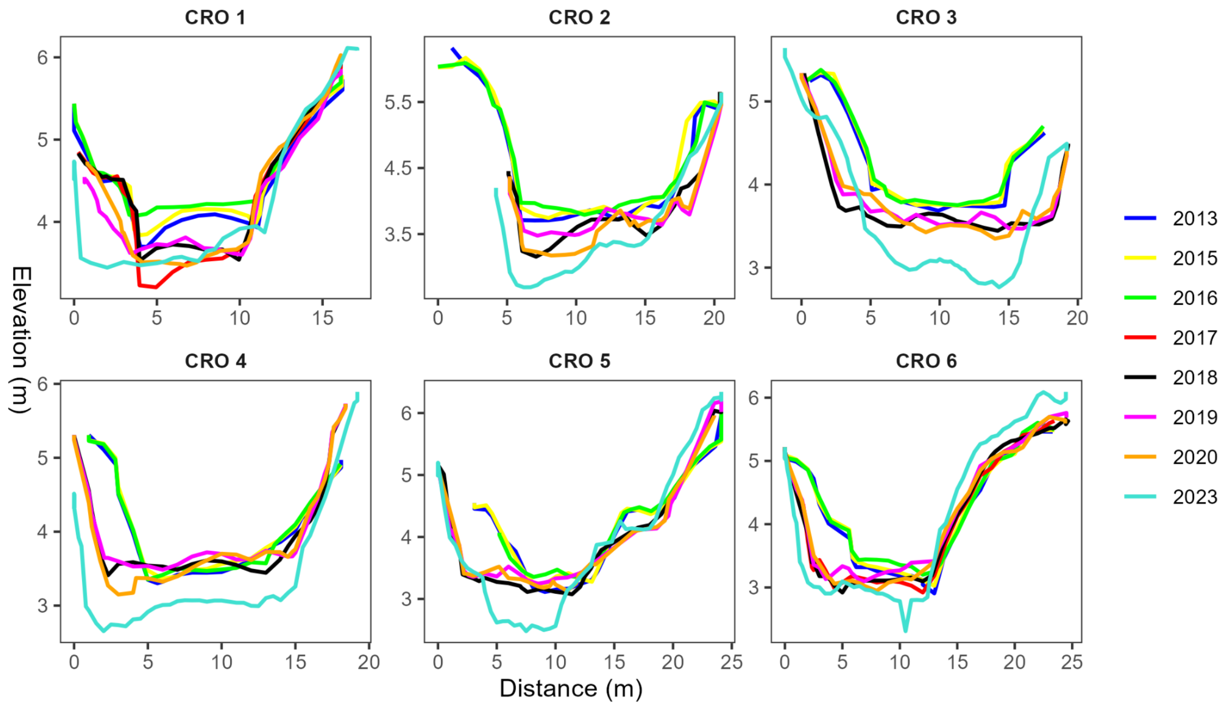

Figure 42. All six cross sections of Crossroads Reach showing comparison of 2023 to previous years.

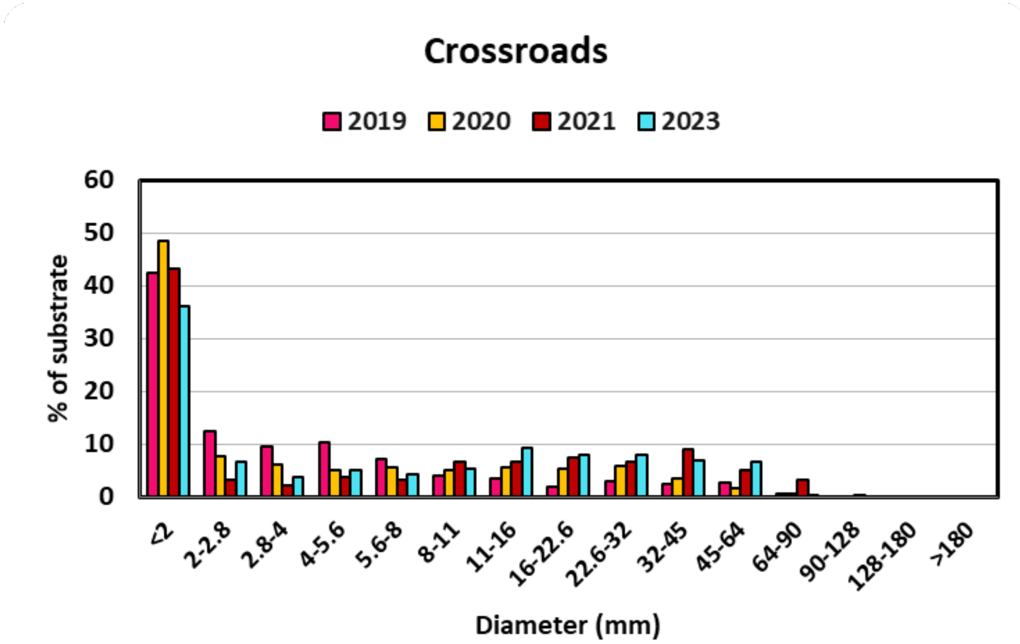

Figure 43: Summary pebble count distribution (CRO 1 – CRO 6) for the Crossroads reach displayed as individual bins for 2019, 2020, 2021, and 2023.

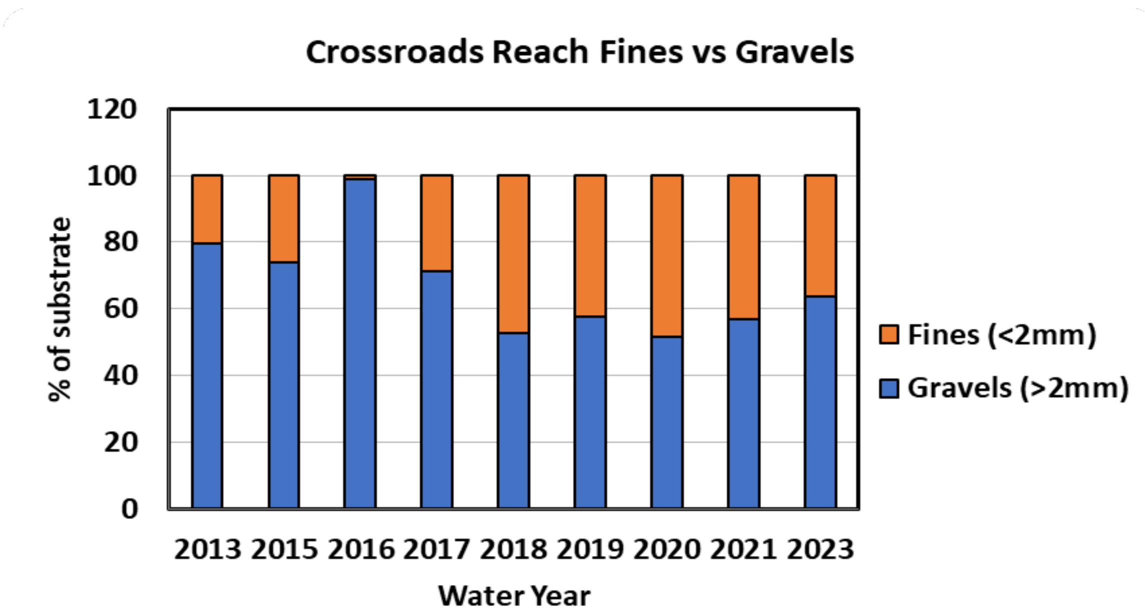

Figure 44: Summary of fines vs gravels for the Crossroads Reach displayed by water year.

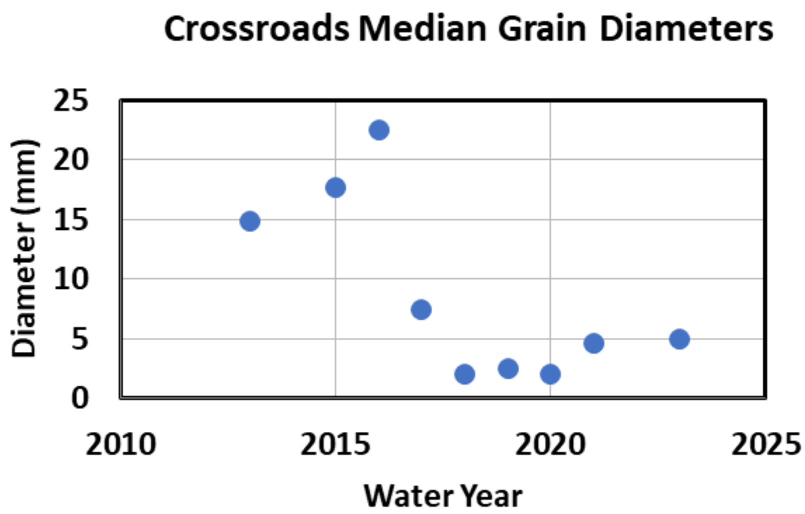

Figure 45. Median grain size across all water years for CRO.

6.10. Lower Carmel Spawning Gravel Trends

Overall, spawning gravel recovery appears to be occurring in many reaches along the lower Carmel River (Fig 46). Since 2020, the greatest increases have been occurring at SH downstream of the former dam and BW, SR, and SC between river km 13 and 8. Additionally, CR has also increased during this time period but with no clear trend through time over the project. DDU and DDL appear to be largely consistent over the full study period, including in 2023. Although it is not within the scope of this report, future work could consider variation of spawning gravels by morphologic unit (e.g., pool, riffle, and run) through time in future studies.

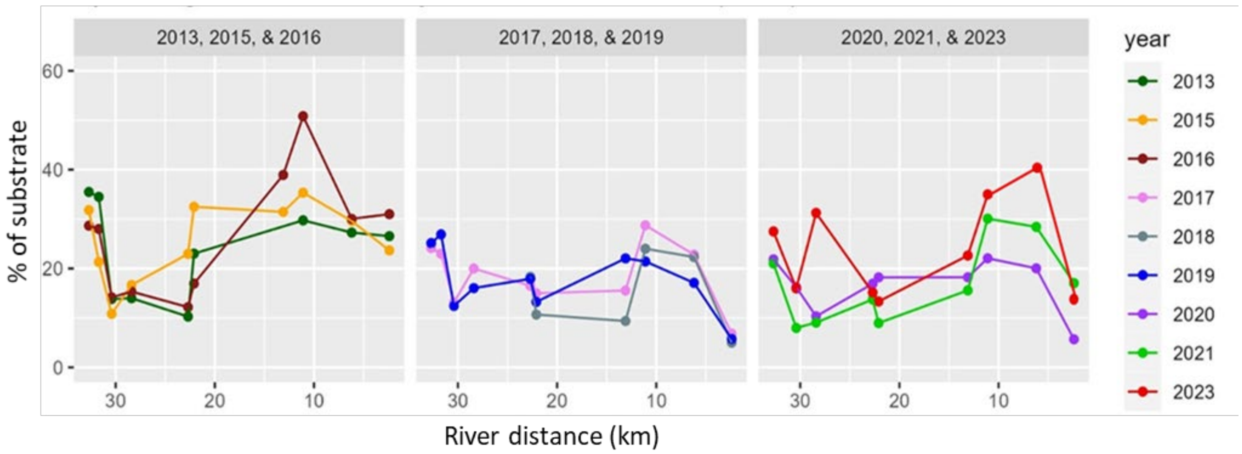

Figure 46. Spawning gravel fractions (defined as >32 and <90 mm sizes) averaged by reach for 3-year blocks since long-term monitoring began in 2013. Note that axes are reversed with upstream most sites on left (beginning with CR) and mouth of the Carmel River on the right at 0.

6. Discussion

6.1. Morphologic Changes

This report is part of a multi-year effort to quantify channel bed grain size and geomorphic change in the Carmel River following the removal of the San Clemente dam in 2015. WY2023 represented an important year to document change on the river because the largest flows since the San Clemente Dam was removed occurred this year (11,000 cfs at Robles Del Rio USGS Gage). Surveys were performed at seven of the nine reaches and we found that many cross sections experienced net erosion within the active channel along with consistent observations of overbank deposition of sands and gravels. These data do not indicate systematic aggradation that could potentially reduce flood capacity, although site-specific analyses would need to be performed to determine this.

6.2. Bed Material Trends

Pebble counts were performed in 2023 across all 9 reaches of the study. These data indicated that most sites experienced a coarsening of their bed material since 2021. This could be due to winnowing and flushing of fines deposited in earlier years that were derived from reservoir sediments associated with the dam removal (East et al., 2023). Additionally, high flows could have had the competency to transport gravels from reservoir-associated material and possibly renewed sediment sources along the mainstem and tributaries downstream of Los Padres Dam reconnected to the system following dam removal. Looking at spawning gravels specifically, the largest increases were at SH near the former dam site and SR as well as SR and SC lower along the river. These observations fit previous work by East et al. (2023) who found that a sand pulse sourced from the former reservoir was primarily flushed out by 2021. Field observations of the reroute show that there was incision into bedrock along steeper gradients of the project site. This indicates that this reach has become supply-limited, in addition to willow growth further stabilizing channel banks. Overall, these trends show promise of continued passive restoration of spawning gravels in the lower Carmel River 8 years following the dam removal. Given the increasing interest in dam removals across the US due to aging dam infrastructure and concerns about ecological impacts (East & Grant, 2023), this work represents a useful long-term case study on lower-impact dam removals.

7. Conclusions and Future Work

This report presents findings from WY2023 from 9 reaches along the lower Carmel River as part of a long-term monitoring project of river morphology (for 7 reaches) and bed grain size (for all 9 reaches) following the San Clemente Dam Removal Project in 2015. Grain size and morphologic changes documented in this report were primarily driven by flood discharges during a very wet year with multiple atmospheric river events impacting the watershed and region. This included the largest flood on the river since the removal of the dam (~21 year flood event). We place this updated data in context with the previous 10 years of monitoring. Our findings show that the river primarily experienced net erosion at most surveyed cross sections. Some areas displayed significant lateral migration since the previous monitoring efforts in 2021. These results do not suggest a large aggradational sediment pulse that could increase flood risk as might be the case with unmitigated erosion and export of reservoir sediments. These findings are in line with previous studies that show that the San Clemente Dam removal project met its aims of mitigating downstream flood risk (e.g., East et al., 2023) and WY2023 is no exception. Though impacts to channel flood capacity are not obvious due to the management approach, further work such as hydraulic modeling using input data from evolving cross sections over the monitoring project lifetime could reveal potential subtleties in shifting flood regimes across different reaches.

Additionally, we found a general system-wide coarsening of bed material. This included an increase in beneficial spawning gravels at many sites downstream of the former dam. The coincident net erosional response of many cross sections and increasing grain size implies that winnowing of finer material may have been an important process. Additionally, the flux of gravels originally derived from the former dam site, mainstem river or tributaries upstream of the former reservoir, or inputs from lateral sources (e.g. bank erosion or tributaries) downstream of the dam during high flow events could have also contributed to these trends. Given the continued evolution of the channel and paucity of longer-term monitoring projects assessing habitat and flood conveyance dynamics following dam removals, we recommend continued monitoring in WY2024 in order to continue evaluating channel conveyance capacity and trends in spawning gravels.

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9. Data Supplements

All data is hosted at this Open Science Framework Repository DOI: https://osf.io/9vmxf/?view_only=42a87bb8541e45e2a0719552243f48a0

A list and description of datasets are as follows:

- **2023_PC_data_pivoted_all_plots_FINAL.xlsx:** Grain size data from WY 2023 and all previous years dating back to 2013, excluding reservoir reach (which is no longer surveyed).
- **Carmel_2013_2023_XS_GGross.csv:** Cross section survey data from WY 2023 and all previous years dating back to 2013, excluding reservoir reach (which is no longer surveyed).
- **Carmel_XS_Plots_2023_GGross.R**: R Script for plotting cross-section data in report.
- **Carmel_Q_LPIII.xlsx**: USGS streamflow data from WY2015 through WY2023 for Carmel Robles Del Rio gage, peak flow data from same gage, and Log-Pearson III flood frequency analysis (with outliers removed)
- **Carmel_XS_UTM**: GIS shapefiles of CSUMB cross section benchmarks.