# Sediment Monitoring Report
# Water Years 2020 and 2021


Morro Bay National Estuary Program
601 Embarcadero
Morro Bay, CA 93442


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# LIST OF ACRONYMS

| | |
|---|---|
| ACOE | Army Corps of Engineers |
| BMI | Benthic macroinvertebrate |
| BMP | Best management practices |
| Cal Poly | California Polytechnic State University, San Luis Obispo |
| CFS | Cubic feet per second ($ft^3/s$) |
| CSLRCD | Coastal San Luis Resource Conservation District |
| EPA | Environmental Protection Agency |
| EPT | Ephemeroptera, Plecoptera, Trichoptera |
| D50 | Median gravel size diameter |
| ITRC | Irrigation Training and Research Center |
| MLLW | Mean lower low water |
| NMP | National Monitoring Program |
| NTU | Nephelometric turbidity unit |
| SET | Surface elevation table |
| SNARL | Sierra Nevada Aquatic Research Laboratory |
| SSC | Suspended sediment concentration |
| SWAMP | Surface Water Ambient Monitoring Program |
| TMDL | Total maximum daily load |
| TSS | Total suspended solids |
| USF | University of San Francisco |
| USGS | United States Geological Survey |
| WY | Water year |

## EXECUTIVE SUMMARY

The Morro Bay estuary is impaired by accelerated sedimentation rates. The Morro Bay National Estuary Program (Estuary Program) compiles data annually to assess sedimentation in the watershed and the bay. To that end, the following data are detailed in this report.

- Sediment transport indicators: ambient water quality data, surface elevation table data, precipitation data, and discharge were compiled to assess the potential for sediment transport on an annual basis.
- Streambed sediment impairment indicators: watershed-wide bioassessment data was assessed to determine the impacts of sedimentation on aquatic health. Of the six sites assessed by this method, five frequently have scores indicating some level of impairment.

## INTRODUCTION

The Central Coast Regional Water Quality Control Board adopted the Central Coast Basin Plan (Basin Plan) on March 14, 1975. The Basin Plan included a broad array of water quality objectives, beneficial use designations, discharger implementation plans, and incorporated statewide plans and policies. Section 303(d) of the Clean Water Act requires that states create a list of water bodies that do not meet water quality objectives and establish load and waste load allocations. Total Maximum Daily Load (TMDL) documents detail the impairment of the listed water bodies and are incorporated into the Basin Plan upon approval. In California, this action is the responsibility of the Regional Water Quality Control Boards.

In 1998, the Central Coast Regional Water Quality Control Board (Water Board) identified Chorro Creek, Los Osos Creek, and the Morro Bay Estuary as impaired by sediment and listed the water bodies under Clean Water Act Section 303(d). The TMDL identified accelerated sedimentation due to anthropogenic disturbance as the primary cause for listing. TMDL documentation cited the 1998 Tetra Tech report estimates that the Chorro and Los Osos Creeks sub-watersheds deliver an average of approximately 70,000 tons per year of sediment into the Morro Bay estuary. The report indicated that the Chorro Creek watershed was estimated to contribute 86 percent of the total sediment delivered to Morro Bay, approximately 60,689 tons.

The *Morro Bay Total Maximum Daily Load for Sediment* was formally adopted by the Environmental Protection Agency (EPA) on December 3, 2003. The TMDL calls for a 50% reduction in the annual loading to Morro Bay. Sediment loads less than 34,885 tons per year would comply with the TMDL targets. This TMDL would be achieved by an average reduction of 607 tons per year over a 50-year time schedule, for compliance by 2052.

The TMDL identified five targets for monitoring and plans to track the progress of voluntary and required implementation actions (Table 1). The Morro Bay National Estuary Program (Estuary Program) was identified as a key monitoring and reporting partner. This report details progress on monitoring to assess sediment conditions in the Morro Bay watershed and estuary during water years 2020 and 2021.

Four numeric targets were established for the streams in the Morro Bay watershed: pool volume, median gravel size diameter (D50), percent fines in substrate, and percent of coarse fines in substrate. The TMDL identified tidal prism volume as the primary numeric target for Morro Bay.

Tidal prism volume assessments are not conducted frequently, due to the high cost and because of the time needed between surveys to obtain meaningful results. The most recent survey was conducted in 2019 and final tidal prism calculations are expected in 2023.

Table 1: Morro Bay Sediment TMDL numeric targets for Chorro and Los Osos creeks and tributaries.

| Parameter | Numeric Target |
|---|---|
| Residual Pool Volume | v* = (a ratio)<br>Mean values ≤ 0.21 (mean of at least 6 pools per sampling reach)<br>Max values ≤ 0.45 |
| Median Diameter (D50) of sediment Particles in Spawning Gravels | D50 =<br>Mean values ≥ 69 mm<br>Minimum values ≥ 37 mm |
| Percent of Fine Fines (< 0.85 mm) in Spawning Gravels | Percent fine fines ≤ 21% |
| Percent of Coarse Fines (all fines < 6.0 mm) in Spawning Gravels | Percent course fine ≤ 30% |
| Morro Bay Estuary | |
| Tidal Prism Volume | 4,200 acre-ft |

## MORRO BAY WATERSHED

The Morro Bay watershed is located in San Luis Obispo County on California's central coast and encompasses a drainage area of approximately 75 square miles. The inland watershed drains west to the Morro Bay estuary and Pacific Ocean via two primary creeks: Chorro Creek and Los Osos Creek.

The Chorro Creek subwatershed encompasses a drainage area of 43.4 square miles. Land use in the subwatershed is primarily agricultural, with much of the area used as rangeland for beef cattle operations. Notable urban areas include the City of Morro Bay, Cuesta College, the California Men's Colony prison complex, and Army National Guard Base Camp San Luis Obispo. Chorro Creek receives drainage from tributary drainages: Dairy Creek, Pennington Creek, Walters Creek, San Luisito Creek, and San Bernardo Creek.

The Los Osos Creek subwatershed encompasses a drainage area of 23.1 square miles. Land use in the subwatershed is primarily agricultural and residential. In contrast to the Chorro Creek subwatershed, agriculture in the Los Osos subwatershed is characterized by plowed rotational fields generating a variety of forage and truck crops. Much of the intensive farming operations in the watershed occur in the Warden Creek drainage area.

## MORRO BAY ESTUARY

The Morro Bay estuary is comprised of approximately 2,300 acres of shallow, semi-enclosed intertidal and sub-tidal habitat. The estuary is bordered to the west by a four-mile vegetated natural sandspit that separates Morro Bay from the Pacific Ocean (Figure 1).

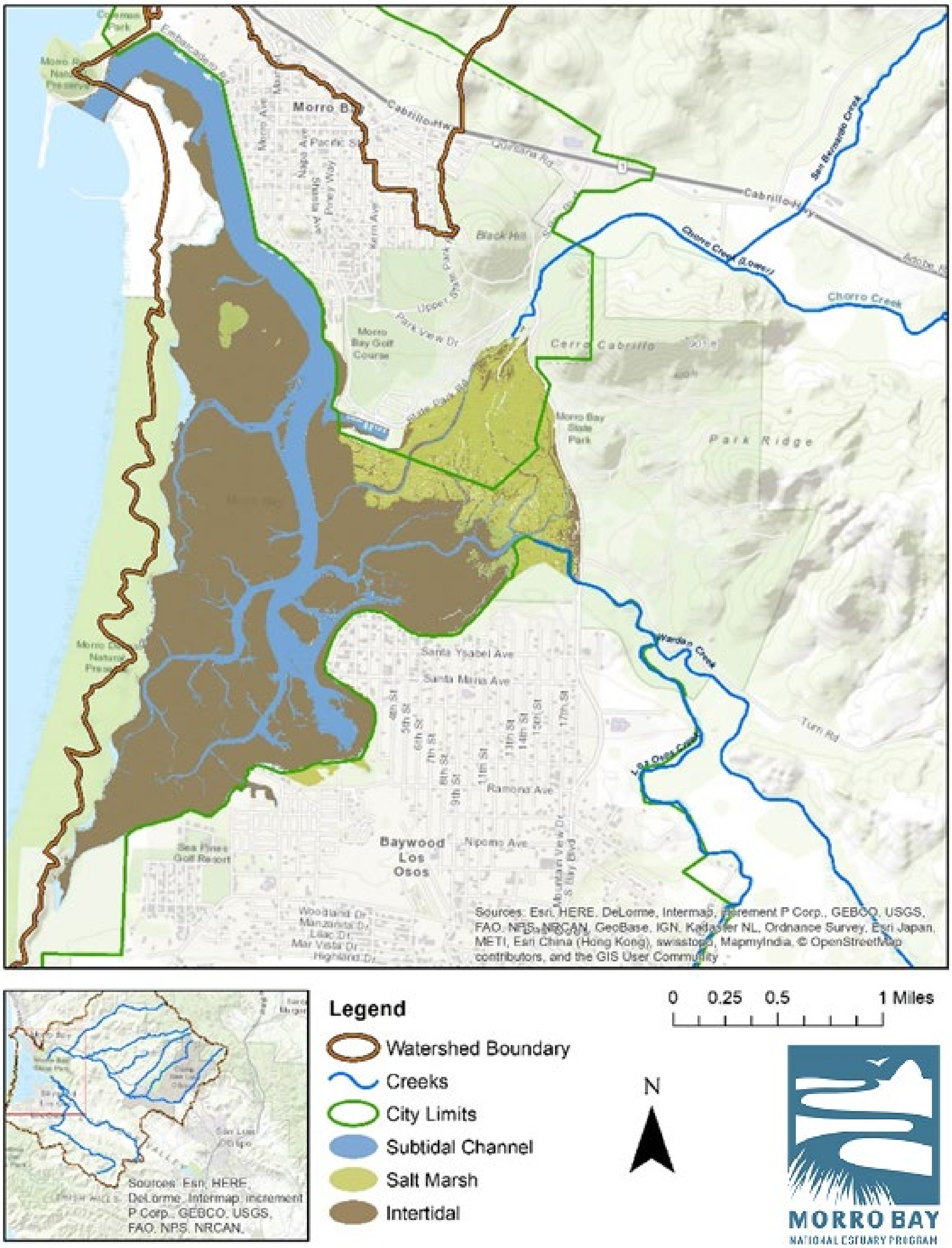


Figure 1: Map of Morro Bay estuary habitat types

Habitats and beneficial uses within the estuary are protected through numerous regulatory frameworks. Morro Bay was established as California's first State Estuary in 1994 and was accepted into the National Estuary Program in 1995. Today, Morro Bay is one of the Environmental Protection Agency's 28 recognized National Estuaries. In 2007, the Morro Bay Estuary was incorporated into the California Department of Fish and Game's Marine Protected Areas. Through the Marine Protected Area designations, the intertidal and subtidal habitats within Morro Bay are protected as either a State Marine Recreational Management Area or a State Marine Reserve. All of these frameworks serve to protect important habitat for marine and migratory species.

*Zostera marina* (eelgrass) is an important component of coastal habitat and provides diverse benefits to coastal marine and migratory species as well as substantial benefit in the form of ecosystem services. Eelgrass meadows are known to be highly sensitive to water clarity degradation. The Morro Bay estuary once supported the third largest remaining eelgrass beds in Southern California (Bernstein, et. al. 2011). Historic monitoring of eelgrass extent indicates that intertidal eelgrass beds may have spanned up to 500 acres in Morro Bay during the 1970s. In 2010, the Estuary Program estimated that eelgrass covered 176 acres. A survey from December 2017 estimated that just over 13 acres of eelgrass remained in Morro Bay (MBNEP, 2019). More recent eelgrass surveys from November 2020 indicated approximately 146 acres of eelgrass bay-wide (MBNEP, 2021a). This improvement is likely the result of multiple factors, including eelgrass restoration efforts, changing water quality conditions, shifting bay elevations, etc.

In addition to providing critical marine habitat, Morro Bay is also a popular destination for outdoor recreation. Recreational uses in the bay include kayaking, sailing, fishing, wildlife observing, and waterfowl hunting. Many of these uses are noted and protected as designated "Beneficial Uses" within the Central Coast Regional Basin Plan administered by the Water Board.

Morro Bay is also an important center for commercial fishing and aquaculture operations. The bay is designated as a Harbor of Safe Refuge and is the only safe harbor between Santa Barbara and Monterey. Maintenance of the harbor as a port for fishing and recreational vessels requires frequent dredging operations. The harbor entrance is dredged annually by the Army Corps of Engineers (ACOE) to maintain a channel depth of approximately 40 feet mean lower low water (MLLW). More information on annual dredging can be found in the Estuary Program's annual Eelgrass Reports.

## SEDIMENT RETENTION AND EROSION PREVENTION PROJECTS

Numerous projects have been undertaken throughout the Morro Bay watershed to prevent further sediment erosion and maximize sediment capture and retention within the watershed. The Estuary Program has worked with many local partners to implement projects to help meet TMDL goals.

The Coastal San Luis Resource Conservation District (CSLRCD) implemented the Chorro Flats Enhancement Project in 1997, a floodplain restoration project to capture sediment from the Chorro Creek watershed. The project was designed to capture approximately 610,000 cubic yards of sediment over a 61-year timeframe. An unusual reoccurrence of high magnitude storm flows during the 1990s resulted in large sediment loads reaching the site. By 2001, it was estimated that only 412,000 cubic yards of potential storage area remained (CSLRCD, 2002). Since 2001 there has been limited work to quantify storage capacity or sediment trapping efficiency at the site.

The CSLRCD has also implemented a broad array of agricultural best management practices (BMPs) throughout the Morro Bay watershed from 2001 to 2008. Work completed as part of "Project Clearwater" included several projects that targeted erosion and sediment loading. Efforts included road drainage improvements, stream bank stabilization and stream crossing improvements. It is estimated that the work completed through Project Clearwater reduced sedimentation by approximately 9,041 tons (CSLRCD, 2010).

The Estuary Program has worked with public and private landowners to install thousands of feet of riparian fencing within the rangeland area of the Chorro Creek watershed. The installation of fences in riparian areas can yield up to a 66% reduction in sediment load from stream banks and riparian areas (CCRWQCB, 2003). Fencing installations have resulted in the protection of important stream corridors like those of Dairy Creek, Walters Creek, Pennington Creek, and San Luisito Creek.

In addition to riparian fencing work, a suite of restoration efforts and BMPs have been installed throughout the Walters Creek watershed. The Walters watershed served as the 'control' site in the National Monitoring Program (NMP) paired watershed study during the 1990s. Following the completion of the NMP in 2001, substantial in-stream restoration work was undertaken. Changes were also made to the grazing regime and ranch road management practices in the watershed.

The Estuary Program completed construction of the Morro Bay Watershed Road Erosion Prevention project from October 2014 through April 2016. This project treated approximately 11 miles of roads within California Polytechnic State University (Cal Poly), Camp San Luis Obispo Army Base (Camp SLO), and U.S. Forest Service properties. Over fifty sites were treated with culverts, sediment settling basins, rolling dips, and other measures to reduce sediment delivery to nearby stream systems. Estimates show that this project will eliminate 1,225 tons per year of sediment erosion over ten years.

In 2019, the Chorro Creek Ecological Reserve restoration project was completed, which restored 1,000 linear feet of a side channel at the base of Hollister Peak. This project was designed to utilize the historical floodplain to allow high-energy creek flows to spread out and drop sediment in areas outside of the main channel, thereby lowering the total load to the estuary and reducing the amount of fine sediments that can degrade habitat quality for sensitive species. As part of this project, approximately 24,000 cubic yards of sediment were removed, a large portion of which would have been flushed down Chorro Creek into the estuary over time. The Estuary Program continues to work with public and private landowners to identify properties that could be converted back to active floodplain.

## SEDIMENT TRANSPORT INDICATORS

Since the adoption of the TMDL in 2003, numerous monitoring efforts have been undertaken to quantify sediment transport and delivery to Morro Bay. In order to better understand sediment depositional trends in the watershed, the Estuary Program compiles annual data related to sediment transport through ambient water quality site visits, surface elevation table monitoring in Morro Bay, and by analyzing annual precipitation and discharge data.

## HISTORIC SEDIMENT MONITORING

From 2007 to 2019, the Estuary Program monitored SSC during storm events using stream gauges and automated samplers. This monitoring spanned nearly a decade, with the exception of very low-flow or drought years. Collected SSC data was analyzed by a statistician to create a predictive relationship between sediment concentration and discharge. While this work provided key understanding to sediment transport in the watershed, SSC monitoring was put on hold indefinitely after 2019, due to the labor associated with processing samples and maintaining equipment.

## AMBIENT WATER QUALITY

The Estuary Program's Monitoring Program has been conducting routine water quality monitoring throughout the estuary and watershed since 2002. Data is collected on a monthly basis by staff and trained volunteers in compliance with the program's rigorous Quality Assurance Project Plan. Due to safety issues and monitoring constraints, data is collected only during base flow conditions when streams are wadeable. Volunteers and staff measure a variety of water quality parameters including nephelometric turbidity and instantaneous flow volume. While this data is important for understanding long-term ambient trends across the watershed, it does not capture data during major winter storm events.

Figure 3 illustrates a subset of ambient water quality monitoring sites located throughout the watershed. The sites shown are either perennial or semi-perennial and have long running datasets.

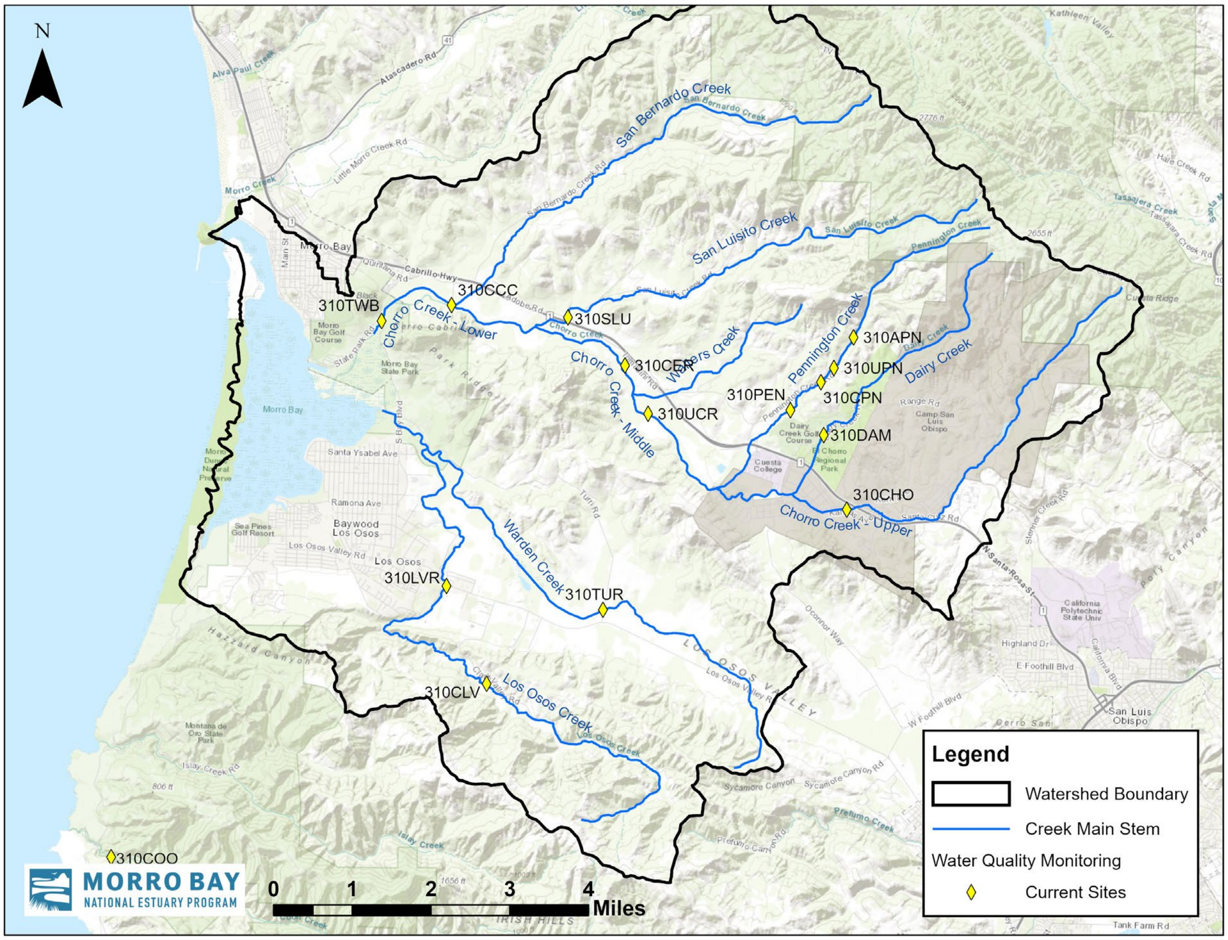


Figure 2: Map of the Estuary Program's ambient monitoring sites

Outside of storm events, the ambient turbidity levels rarely exceeded the Central Coast Basin Plan levels of concern of 25 nephelometric turbidity units (NTU) for protection of aquatic life in cold water (beneficial use COLD) and 40 NTU in warm waters (beneficial use WARM). Of the 4,004 turbidity readings collected since 2002, 2.4% exceeded 25 NTU and 1.2% exceeded 40 NTU.

Multiple studies have analyzed the accuracy of measuring turbidity as a surrogate for monitoring for SSC or total suspended solids (TSS). Turbidity monitoring is significantly faster and less expensive than monitoring SSC or TSS, and has generally proven to be more accurate than other surrogate measures. However, there are limitations to its usefulness in quantifying suspended sediment load in surface waters (Ankcorn, 2003). This being the case, turbidity data collected by the Estuary Program is not used as a predictor of the total sediment load. Additional information on ambient water quality data can be found in the program's [2020 Creek Health Memo] and [2021 Creek Health Memo.]

## SURFACE ELEVATION TABLES

The U.S. Geological Survey (USGS) monitors sediment deposition in Morro Bay as part of a larger study of sedimentation rates on the west coast. There are four monitoring locations in the Morro Bay salt marsh, including two high marsh and two low marsh sites. Sites were established in 2013 and are monitored each year during the dry season. Elevation change is monitored using two methods: feldspar marker horizons and surface elevation tables (SETs).

A USGS progress report from September 2021 shows that the cumulative elevation change over the course of the eight-year study period is +8.84 mm. In the two low marsh sites, the accumulation rate is +1.16 mm per year, with an average elevation change of 11.56 mm over the study period. In the high marsh sites, the accumulation rate is +0.77 mm per year, with an average elevation change of 6.12 mm over the study period.

Between 2004 and 2015, the Estuary Program coordinated similar SET and marker horizon monitoring in partnership with staff the University of San Francisco. Numerous sampling stations were established in the Morro Bay mudflats and salt marsh (Figure 3). The most recent SET survey with University of San Francisco (USF) was conducted in 2015 and showed that the higher elevations of the marsh were accreting sediment at low rates, around 1.2mm per year, while the lower elevation mudflats were accreting sediment slightly higher and more variable rates. These rates ranged from 0.65 to 3.85mm per year over the 11-year study period, and are similar to the 2 to 3mm per year rate of sea level rise (Callaway, 2015)[1].

It is important to note that while these two studies overlap geographically, the extent of the University of San Francisco's study is much larger, so terms of relative elevation such as 'high' or 'low' are not necessarily interchangeable when considering results of both studies.

[1] This 2015 report is available in Appendix A of the Estuary Program's 2016 Sediment Monitoring Report.

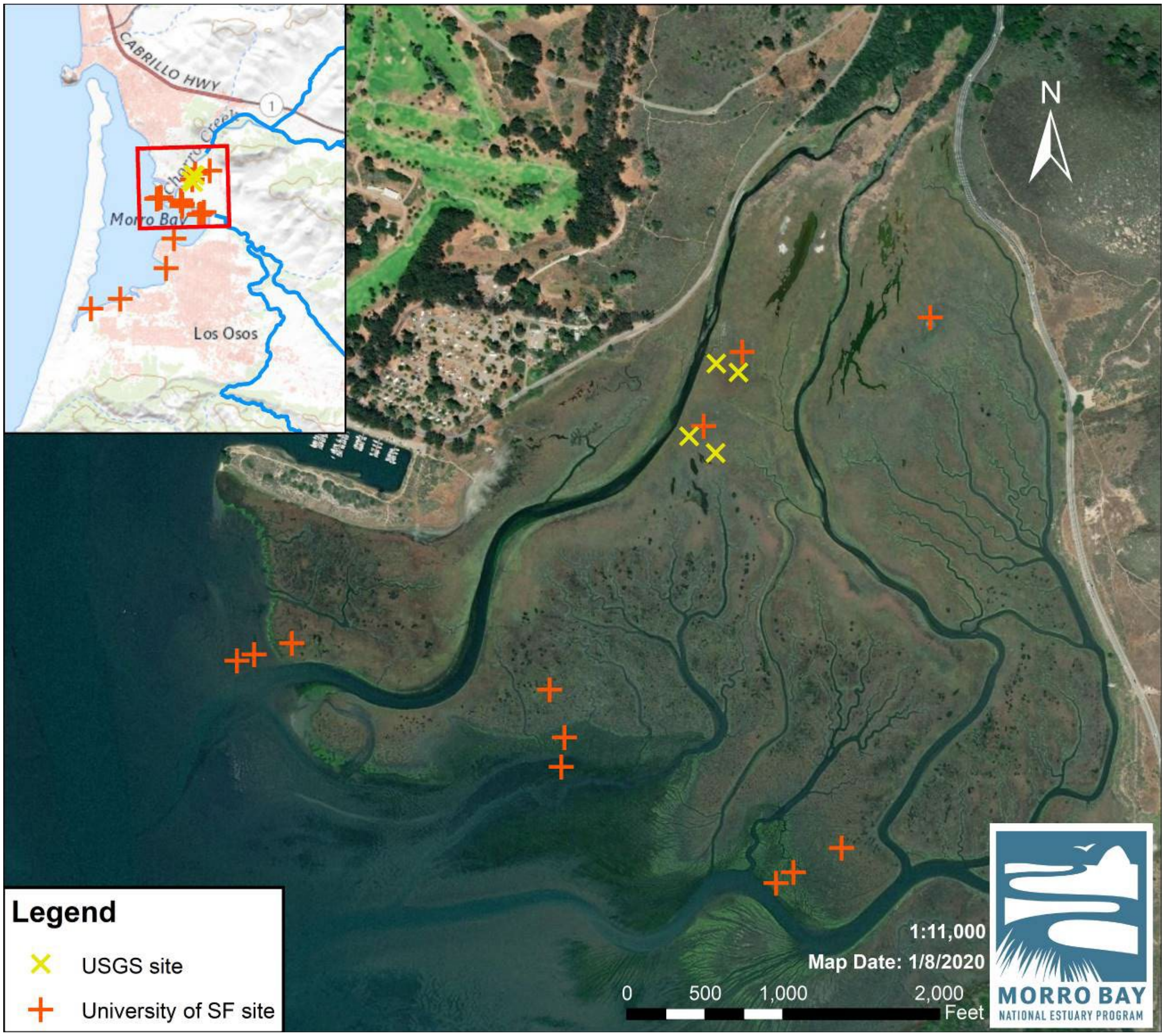


Figure 3: Plotted points of SET locations in the marsh area. Note that this map excludes USF sites that were also monitored in the southern extent of the bay (not shown) but includes all USGS SET sites in Morro Bay.

## PRECIPITATION AND DISCHARGE

In order to better understand the potential for sediment transport in the Morro Bay watershed, the Estuary Program compiles annual precipitation and stage data from a San Luis Obispo County gauging station at Canet Road[2]. This gauging station was established by the County in 1978, and established as a SSC monitoring location by the Estuary Program in 2007. The site is referenced throughout this report and previous reports, as Canet or site code CAN.

The Canet Road monitoring station includes a drainage area of approximately 21.8 square miles, out of the 43 square mile Chorro watershed, and includes flows from the Pennington Creek, Dairy

[2] Rainfall and stage data from the Canet Road gauge can be viewed in real-time or downloaded from the County of San Luis Obispo's website at wr.slocountywater.org.

Creek, and Walters Creek tributaries, as shown in Figure 4. The area in the map highlighted in yellow is the area that drains to the Canet gauging station, which collects stage readings at fifteen-minute intervals on a continuous basis.

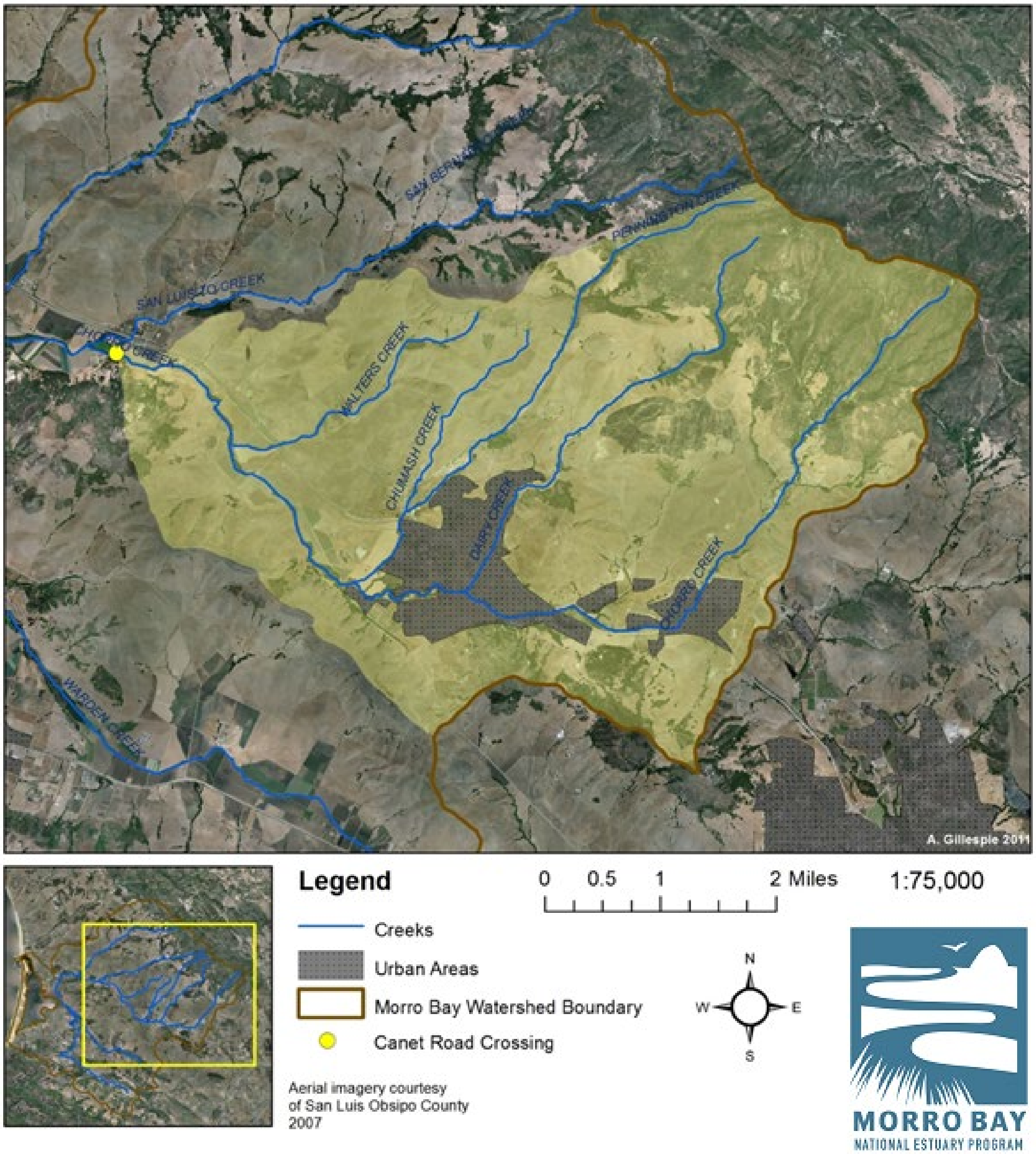


Figure 4: Map of watershed area that drains to Canet Road monitoring site.

In 2010, Irrigation Training and Research Center (ITRC) engineers at Cal Poly developed a rating curve to better estimate peak flows at Canet. Analysis of field measurements determined that three unique equations were necessary to approximate flow rates (Q) in cubic feet per second (cfs) at the site, depending on stage height.

The following equations were used to calculate discharge in this report, and previous versions of this report[3]:

- For stage heights below 12.10 feet, discharge can be approximated by**:**
  **Q (cfs) = 20.907Y² - 5.8341Y**
  where Y is the depth of water (in feet, recorded by the bubbler gauge) minus channel bottom elevation (3.75 ft) above the reference datum.

- For stage heights between 12.1 feet and 13.2 feet, the discharge is approximated by:
  **Q (cfs) = 1200 cfs**.
  This is the case when the culverts are full, and the water is not overtopping the bridge.

- When the water has overtopped the bridge at heights above 13.2 feet, the following equation is applied:
  **Q (cfs) = 1200 + 88 [(H -13.2) + 0.326]^2.1**
  where H is the staff gauge reference without adjustment for the channel bottom elevation.

$$Q\ (cfs) = 20.907Y^2 - 5.8341Y$$

$$Q\ (cfs) = 1200 + 88\,[(H - 13.2) + 0.326]^{2.1}$$

Peak discharge describes the highest rate of flow during a given water year. Review of nearly 40 years of peak discharge data indicates large inter-annual variability in peak discharge at the Canet gauging station, with a range of approximately 7,427 cfs. In comparison to prior years, water year[4] 2020 had the fifth lowest peak discharge, and 2021 had the seventh highest peak discharge since 1979 (Figure 5).

[3] Hydrographs generated by MBNEP for the Canet Road gage prior to 2011 used a different rating curve than the rating curve shown above. Therefore, more recent results are not directly comparable with pre-2011 results.
[4] The water year (WY) is defined as the 12-month period between October 1 and September 30 of a given year.

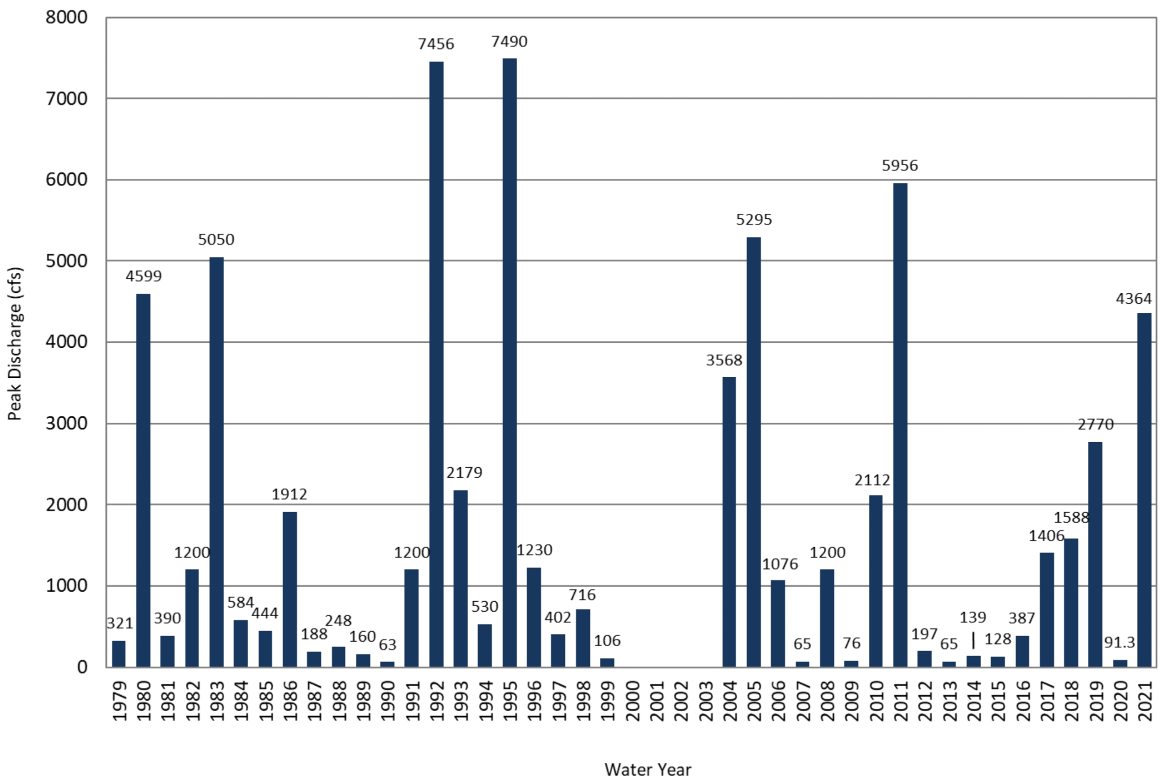


Figure 5: Chorro Creek, Canet Road peak flow records, from 1979 to 2021

According to the San Luis Obispo County Department of Public Works precipitation contours, Canet Road receives an average of 20 inches of rainfall per year (Appendix A). The rain contours are a map of the county that describe what the expected average annual rainfall will be in any given area. Table 3 summarizes the rainfall totals from Canet Road, from WY 2017 through WY 2021.

Table 2: Summary hydrology statistics for WY 2017 through WY 2021

| Water Year | Peak Flow (cfs) | Total Annual Discharge (AF) | Total Annual Rainfall (in) | Percent of 20 inch Average Rainfall |
|---|---|---|---|---|
| 2017 | 1,405 | 26,865 | 25.68 | 128% |
| 2018 | 1,587 | 7,829 | 13.16 | 66% |
| 2019 | 1,259 | 15,581 | 19.91 | 99.6% |
| 2020 | 91.3 | 6,749 | 12.27 | 61.4% |
| 2021 | 4,364 | 8,644 | 11.60 | 58% |

While the relative magnitude of peak discharge is a function of rainfall intensity and volume (Rankl, 2004), total annual rainfall is not strongly correlated with peak discharge. Figure 10 illustrates the discontinuity between peak flow magnitude and annual rainfall totals.

For example, WY 2017 presents as a high peak on the annual rain total graph (at 25.4 inches) but corresponds with a relatively low peak discharge (1,406 cfs). Conversely, WY 2021 had a low annual accumulated rainfall (11.6 inches) but one of the highest peak flows in the last decade. In the case of WY 2017, the rain events were spread out enough over time and did not lead to rapid concentrations of overland flow that typically contribute the largest inputs of sediment in a surface water system. Thus, annual rainfall totals are unlikely to be a reliable indicator of the relative sediment contribution to Morro Bay in a given year. Previous analyses by the Estuary Program also show that annual rainfall is a poor predictor of suspended sediment loads (MBNEP, 2011).

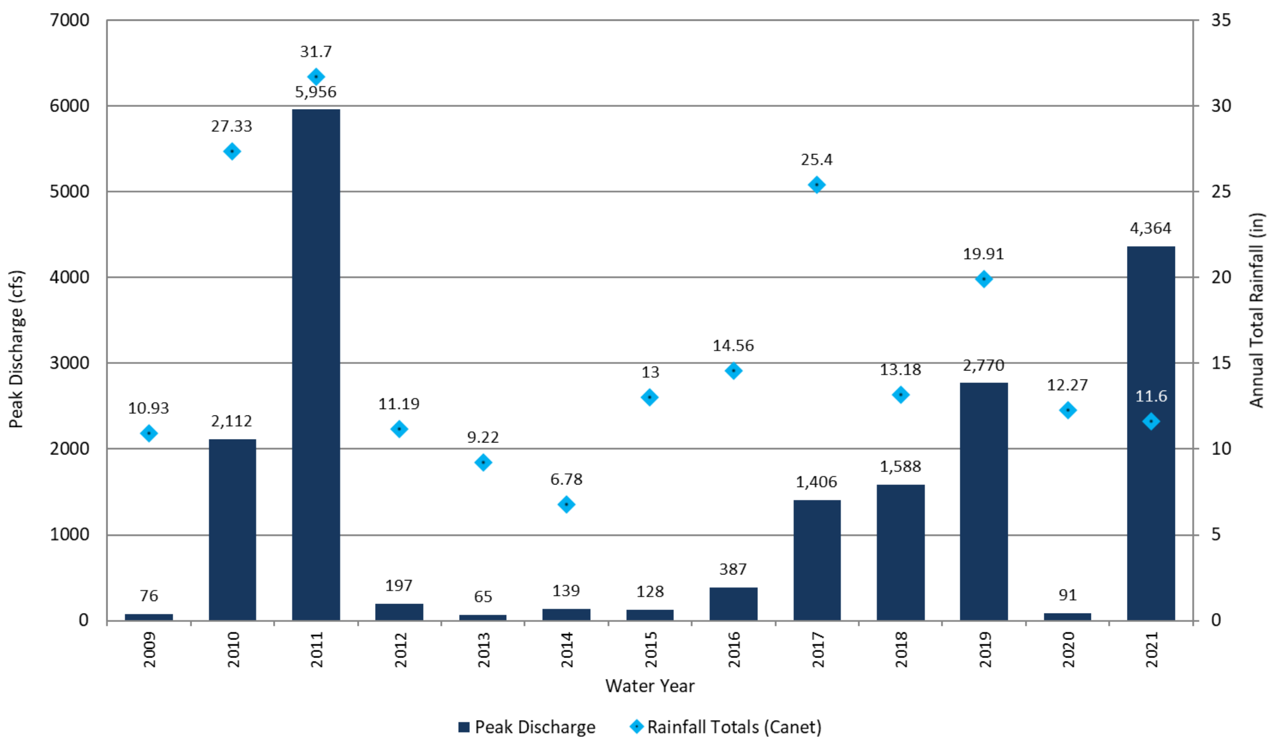


Figure 6: Chorro Creek at Canet Road, peak flow and annual rainfall totals from WY 2009 to WY 2021

While storm events that generate peak flows are brief when compared to the entire length of the water year, they have dramatic influence on the amount of sediment transported through creeks. Previous analyses have concluded that although rainfall and discharge alone are not strong enough predictors to quantify total load, they can provide valuable insight to sediment transport.

## STREAMBED SEDIMENT IMPAIRMENT INDICATORS

Since 2008, the Estuary Program has conducted Surface Water Ambient Monitoring Program (SWAMP) Bioassessment surveys annually at a variety of creek monitoring sites throughout the watershed. The data collected during these surveys generates metrics for several physical and biological characteristics of the survey reach. Methods under development by the Water Board and UC Davis researchers use habitat survey scores as indicators of sedimentation impact. Within this report, the physical habitat data collected during the spring 2020 and 2021 bioassessment surveys are compared with proposed sediment indicator criteria.

The relationship between aquatic health in a watershed and impacts due to sediment loading is of great interest in the regulation of sediment. Over a three-year period, researchers from the Sierra Nevada Aquatic Research Laboratory (SNARL), which is associated with the University of California, conducted research to develop numeric targets for sediment impairment and biological thresholds in riverine systems in the Central Coast region. Although these criteria were not specifically developed for the Morro Bay watershed, they are being evaluated for assessments throughout the Central Coast region. Initial analysis shows that the indicators are likely relevant in the Central Coast region.

An extensive number of indices were tested across a gradient of test sites. The outcome included 16 indicators of sediment impairment on aquatic habitat. The indicators cover both the physical characteristics (sediment) and the benthic macroinvertebrate (BMI) community.

A significant data collection effort is required to determine the status of all 16 sediment and biological indicators for a study reach. The current SWAMP Bioassessment Protocol (SWAMP, 2007) metrics can be used to generate seven of the nine sediment indicators, and six of the seven biological indicators. Since Estuary Program monitoring is conducted per the SWAMP protocol, only the indicators in bold in the list below are collected and can be included in the analysis. There are three threshold criteria for comparison of each of these indicators, shown in Table 7.

Sediment Indicators:

1. **Percent of Fines (F) on transects**
2. **Percent of Sand (S) on transects**
3. **Percent of Fines (F) + Percent of Sands (S) on transects**
4. **Percent of Fines, Sands and Gravels < 8mm on transects**
5. **D50 Median particle size**
6. Percent patch-scale grid Fines and Sands
7. Log Relative Bed Stability
8. **Percent of Fines (Steelhead)**
9. **Percent Cover of Fines and Sands (BMI Limits)**

Biological Indicators

1. **Total Richness**
2. **EPT[5] Richness**
3. **% EPT**
4. **Biotic Index**
5. **Percent Tolerant**
6. **Sensitive Number**
7. Crayfish Number and Size

[5] EPT refers to three macroinvertebrate species orders: Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies), which are considered indicators of favorable habitat and water quality conditions.

Table 3: Sediment and biological indicator criteria

| | Recommended Numeric Targets To Support Beneficial Uses | Recommended Numeric Targets to Support Preliminary 303(d) Listing (lower priority) | Recommended Numeric Targets To Support 303(d) Listing (high priority) |
|---|---|---|---|
| **Sediment Indicators** | | **75/25** | **90/10** |
| Percent Fines on transects | <8.5% | 8.5 to 15.2% | >15.2% |
| Percent Sands on transects | <27.5% | 27.5 to 35.3% | >35.3% |
| Percent Fines + Sands on transects | <35.5% | 35.5 to 42.0% | >42.0% |
| Percent Fines, Sands, Gravel <8mm on transects | <40.0% | 40.0 to 50.2% | >50.2% |
| D50 median particle size | >15 mm | 7.7 to 15 mm | <7.7 mm |
| Percent Fines (steelhead) | <6% | 6 to 10% | >10% |
| Percent cover of FS (BMI limits) | <30% | 30 to 40% | >40% |
| **Biological Indicators** | | **75/25** | **90/10** |
| Total Richness | >50.0 | <50.0 | <44.2 |
| EPT Richness | >16.5 | <16.5 | <11.6 |
| Biotic Index | <5.48 | >5.48 | >5.92 |
| Percent Tolerant | <26.3% | >26.3% | >37.7 |
| Sensitive Number | >9.5 | <9.5 | <5.8 |

## METHODS

The Estuary Program has conducted bioassessment per the SWAMP protocol on an annual basis since 2007. Sites are typically selected for monitoring based on program data needs and hydrologic conditions. Thus, many sites are monitored on a rotating basis, and data is not available across all sites each year. Further alterations were also made for the 2020 and 2021 bioassessment seasons, due to the COVID-19 pandemic. These changes resulted certain sites being dropped due to staff limitations and site inaccessibility.

Five representative bioassessment monitoring sites were selected to be included in this analysis. This is a representative subset of the larger number of bioassessment sites that are monitored each year. Four of the five sites including are located in the Chorro subwatershed, and one is located in the Los Osos subwatershed. The sites within the Chorro subwatershed include Pennington Creek (site code 310UPN), San Bernardo Creek (310MNO), San Luisito Creek (310LSL), and Lower Chorro Creek (310TWB). One site from the Los Osos subwatershed, along upper Los Osos Creek (310CLK) is also included, although no data was collected during 2021. These monitoring locations can be seen in more detail in Figure 19. Scores from representative sites are outlined from 2008 to 2021 in Table 8, and averaged scores from 2008 to 2021 are detailed in Table 9.

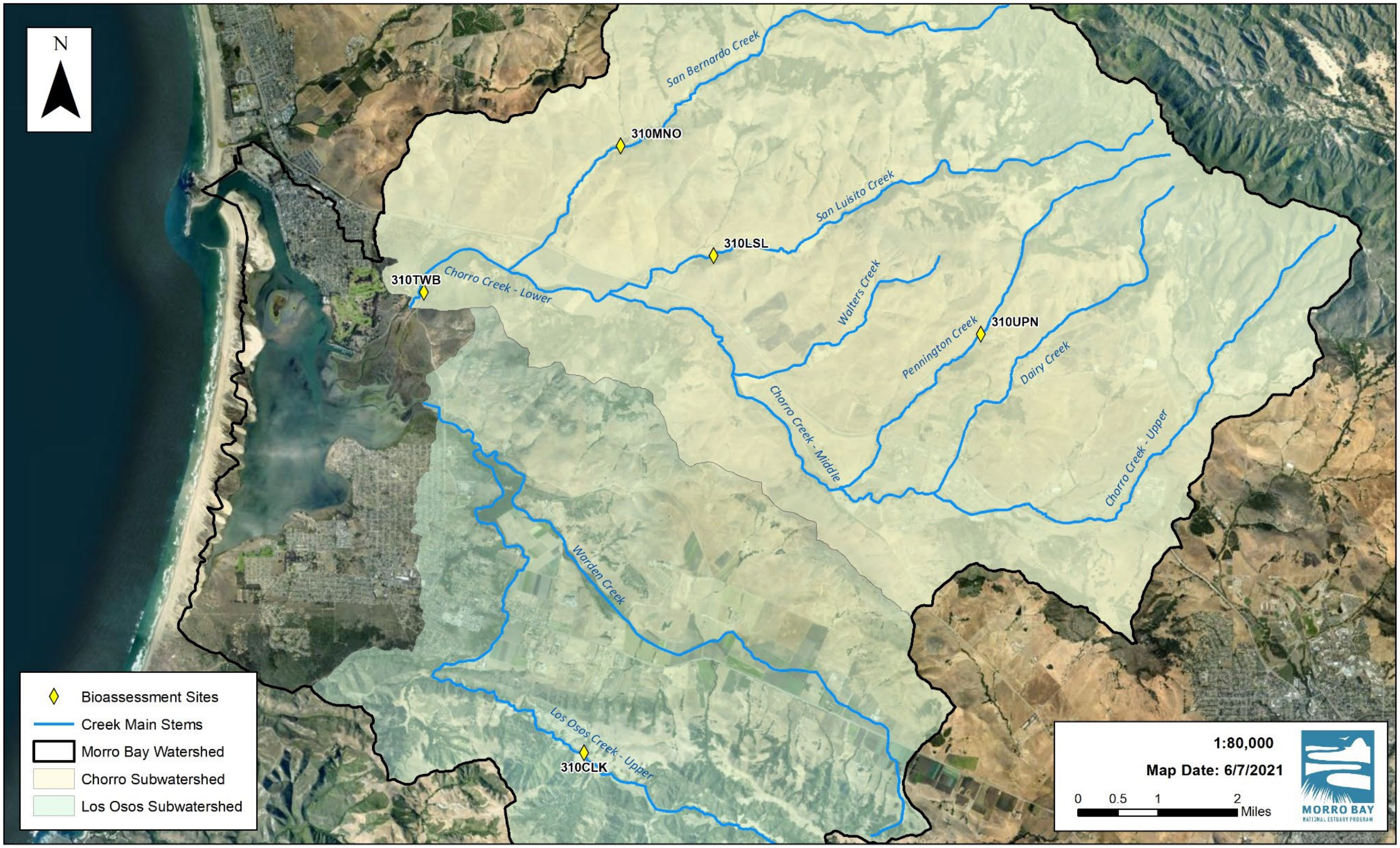


Figure 7: Five representative bioassessment sites, including four sites in the Chorro subwatershed, and one site in the Los Osos subwatershed

Table 4: Sediment indicators for a selection of Morro Bay watershed sites from 2008 to 2021

| | | Sediment Indicators | | | | | | | Biological Indicators | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site Code | Survey Date | Percent Fines | Percent Sands | Percent <8mm | FS Sum Percent | D50 Median particle size | Percent Fines (steelhead) | Percent Cover of FS (BMI limits) | Total Richness | EPT Richness | Percent EPT | Biotic Index | Percent Tolerant | Sensitive Number |
| 310MNO | 2008 | 0.0 | 24.8 | 26.7 | 24.8 | 20.0 | 0.0 | 24.8 | 64.0 | 20.0 | 50.4 | 4.7 | 9.4 | 10.0 |
| 310MNO | 2010 | 1.0 | 23.3 | 30.1 | 24.3 | 14.0 | 1.0 | 24.3 | 42.0 | 14.0 | 61.8 | 4.7 | 7.1 | 5.0 |
| 310MNO | 2012 | 2.9 | 9.8 | 14.7 | 12.8 | 37.0 | 2.9 | 12.8 | 69.0 | 22.0 | 42.8 | 4.8 | 8.7 | 10.0 |
| 310MNO | 2013 | 2.9 | 7.8 | 18.6 | 10.8 | 31.0 | 2.9 | 10.8 | 66.0 | 18.0 | 19.0 | 5.7 | 9.1 | 14.0 |
| 310MNO | 2014 | 5.0 | 24.0 | 35.0 | 29.0 | 24.0 | 5.0 | 29.0 | 46.0 | 3.0 | 3.4 | 7.3 | 17.4 | 3.0 |
| 310MNO | 2015 | 6.7 | 9.5 | 24.8 | 16.2 | 17.0 | 6.7 | 16.2 | 57.0 | 5.0 | 4.3 | 6.9 | 14.0 | 4.0 |
| 310MNO | 2016 | 13.5 | 11.0 | 36.5 | 12.4 | 12.5 | 13.5 | 12.4 | 70.0 | 16.0 | 23.6 | 5.91 | 14.3 | 9.0 |
| 310MNO | 2017 | 6.7 | 20.0 | 34.3 | 26.7 | 23.0 | 6.7 | 26.7 | 37.0 | 12.0 | 52.7 | 4.9 | 10.8 | 4.0 |
| 310MNO | 2018 | 7.6 | 17.1 | 30.5 | 24.8 | 27.0 | 7.6 | 24.8 | 52.0 | 19.0 | 21.2 | 5.7 | 15.4 | 9.0 |
| 310MNO | 2019 | 9.5 | 26.7 | 46.7 | 36.2 | 9.0 | 9.5 | 36.2 | 52.0 | 17.0 | 32.2 | 5.4 | 5.8 | 6.0 |
| 310MNO | 2020 | 12.4 | 21.0 | 49.5 | 33.3 | 8.0 | 12.4 | 33.3 | 61.0 | 14.0 | 25.9 | 5.6 | 14.8 | 48.3 |
| 310MNO | 2021 | 3.8 | 32.4 | 45.7 | 36.2 | 11.0 | 3.8 | 36.2 | 47.0 | 11.0 | 12.2 | 6.2 | 21.3 | 5.0 |
| 310LSL | 2008 | 5.7 | 19.1 | 33.3 | 24.8 | 12.0 | 5.7 | 24.8 | 55.0 | 14.0 | 25.2 | 4.5 | 12.7 | 9.0 |
| 310LSL | 2010 | 11.8 | 10.9 | 33.7 | 22.8 | 13.0 | 11.8 | 22.8 | 48.0 | 18.0 | 50.7 | 4.6 | 6.3 | 9.0 |
| 310LSL | 2012 | 2.9 | 23.3 | 32.1 | 26.2 | 14.0 | 2.9 | 26.2 | 61.0 | 22.0 | 18.3 | 4.5 | 9.8 | 16.0 |
| 310LSL | 2013 | 10.5 | 9.5 | 25.7 | 20.0 | 17.0 | 10.5 | 20.0 | 39.0 | 4.0 | 0.9 | 5.2 | 15.4 | 2.0 |
| 310LSL | 2014 | 16.2 | 11.4 | 34.3 | 27.6 | 20.0 | 16.2 | 27.6 | 44.0 | 8.0 | 4.3 | 5.5 | 9.1 | 6.0 |
| 310LSL | 2015 | 14.4 | 11.5 | 37.5 | 26.0 | 11.0 | 14.4 | 26.0 | 54.0 | 14.0 | 17.8 | 5.3 | 9.3 | 6.0 |
| 310LSL | 2016 | 23.8 | 9.5 | 40.0 | 33.3 | 9.0 | 23.8 | 33.3 | 44.0 | 15.0 | 36.0 | 4.54 | 8.9 | 9.0 |
| 310LSL | 2017 | 9.8 | 12.7 | 27.5 | 22.5 | 20.5 | 9.8 | 22.5 | 37.0 | 12.0 | 28.8 | 5.0 | 13.5 | 6.0 |
| 310LSL | 2018 | 1.9 | 30.5 | 32.4 | 32.4 | 14.0 | 1.9 | 32.4 | 55.0 | 22.0 | 51.4 | 4.2 | 7.3 | 12.0 |
| 310LSL | 2019 | 15.5 | 17.5 | 47.6 | 33.0 | 9.0 | 15.5 | 33.0 | 52.0 | 19.0 | 39.7 | 4.9 | 7.7 | 10.0 |
| 310LSL | 2020 | 12.4 | 11.4 | 39.0 | 23.8 | 11.0 | 12.4 | 23.8 | 55.0 | 15.0 | 7.7 | 5.4 | 7.3 | 28.2 |
| 310LSL | 2021 | 5.8 | 19.4 | 33.0 | 25.2 | 12.0 | 5.8 | 25.2 | 48.0 | 16.0 | 42.4 | 4.9 | 10.4 | 10.0 |
| 310UPN | 2008 | 1.9 | 12.4 | 20.0 | 14.3 | 25.0 | 1.9 | 14.3 | 62.0 | 17.0 | 18.4 | 5.0 | 9.7 | 14.0 |
| 310UPN | 2011 | 2.9 | 15.2 | 19.1 | 18.1 | 120.0 | 2.9 | 18.1 | 59.0 | 25.0 | 64.4 | 4.3 | 5.1 | 13.0 |
| 310UPN | 2012 | 1.0 | 16.5 | 17.5 | 17.5 | 63.5 | 1.0 | 17.5 | 56.0 | 21.0 | 48.5 | 4.0 | 8.9 | 15.0 |
| 310UPN | 2013 | 2.9 | 7.7 | 14.4 | 10.6 | 100.5 | 2.9 | 10.6 | 70.0 | 24.0 | 32.6 | 4.5 | 5.7 | 17.0 |
| 310UPN | 2014 | 1.9 | 3.8 | 9.5 | 5.7 | 87.0 | 1.9 | 5.7 | 73.0 | 20.0 | 17.6 | 4.9 | 6.9 | 15.0 |
| 310UPN | 2015 | 5.8 | 4.8 | 16.3 | 10.6 | 55.5 | 5.8 | 10.6 | 53.0 | 10.0 | 16.1 | 5.4 | 9.4 | 5.0 |
| 310UPN | 2016 | 2.9 | 9.0 | 24.8 | 2.9 | 24.0 | 2.9 | 2.9 | 42.0 | 3.0 | 2.9 | 7.2 | 21.4 | 3.0 |
| 310UPN | 2017 | 1.0 | 15.2 | 23.8 | 16.2 | 21.0 | 1.0 | 16.2 | 50.0 | 15.0 | 58.4 | 4.7 | 6.0 | 8.0 |
| 310UPN | 2018 | 1.9 | 24.8 | 29.5 | 26.7 | 30.0 | 1.9 | 26.7 | 57.0 | 21.0 | 45.0 | 4.0 | 3.5 | 16.0 |
| 310UPN | 2019 | 2.9 | 6.7 | 16.2 | 9.5 | 34.0 | 2.9 | 9.5 | 60.0 | 16.0 | 26.4 | 5.0 | 6.7 | 11.0 |
| 310UPN | 2020 | 1.0 | 13.3 | 19.0 | 14.3 | 55.0 | 1.0 | 14.3 | 67.0 | 20.0 | 24.9 | 4.8 | 9.0 | 46.0 |
| 310UPN | 2021 | 2.9 | 10.5 | 19.0 | 13.3 | 53.0 | 2.9 | 13.3 | 61.0 | 15.0 | 19.7 | 5.4 | 8.2 | 11.0 |
| 310TWB | 2008 | 18.8 | 7.9 | 31.7 | 26.7 | 13.0 | 18.8 | 26.7 | 55.0 | 14.0 | 27.3 | 5.4 | 14.6 | 7.0 |
| 310TWB | 2012 | 8.0 | 29.0 | 44.0 | 37.0 | 9.5 | 8.0 | 37.0 | 46.0 | 8.0 | 6.8 | 6.7 | 21.7 | 3.0 |
| 310TWB | 2013 | 9.7 | 18.5 | 44.7 | 28.2 | 9.0 | 9.7 | 28.2 | 52.0 | 9.0 | 3.7 | 6.4 | 21.2 | 4.0 |
| 310TWB | 2014 | 24.8 | 11.4 | 53.3 | 36.2 | 6.0 | 24.8 | 36.2 | 41.0 | 4.0 | 6.9 | 6.5 | 24.4 | 2.0 |
| 310TWB | 2015 | 12.5 | 41.0 | 59.0 | 41.0 | 5.0 | 0.0 | 41.0 | 31.0 | 0.0 | 0.0 | 7.6 | 29.0 | 0.0 |
| 310TWB | 2016 | 12.4 | 24.8 | 51.4 | 37.1 | 12.5 | 13.5 | 37.1 | 31.0 | 9.0 | 34.1 | 5.5 | 19.4 | 4.0 |
| 310TWB | 2017 | 12.5 | 21.2 | 34.6 | 33.7 | 16.0 | 12.5 | 33.7 | 31.0 | 9.0 | 34.1 | 5.5 | 19.4 | 4.0 |
| 310TWB | 2018 | 14.3 | 35.2 | 63.8 | 49.5 | 3.0 | 14.3 | 49.5 | 46.0 | 11.0 | 14.6 | 6.3 | 17.4 | 5.0 |
| 310TWB | 2019 | 16.3 | 35.6 | 63.5 | 51.9 | 1.0 | 16.3 | 51.9 | 43.0 | 10.0 | 22.8 | 6.6 | 18.6 | 1.0 |
| 310TWB | 2020 | 21.0 | 29.5 | 66.7 | 50.5 | 2.0 | 21.0 | 50.5 | 47.0 | 9.0 | 26.7 | 5.8 | 19.2 | 44.3 |
| 310TWB | 2021 | 22.9 | 21.9 | 46.7 | 44.8 | 9.0 | 22.9 | 44.8 | 40.0 | 6.0 | 7.4 | 6.9 | 17.5 | 2.0 |
| 310CLK | 2017 | 3.9 | 10.7 | 19.4 | 14.6 | 35.0 | 3.9 | 14.6 | 51.0 | 8.0 | 5.0 | 6.4 | 15.7 | 5.0 |
| 310CLK | 2018 | 3.8 | 18.1 | 31.4 | 21.9 | 14.0 | 3.8 | 21.9 | 59.0 | 10.0 | 21.6 | 6.2 | 17.0 | 6.0 |
| 310CLK | 2019 | 4.8 | 18.1 | 25.7 | 22.9 | 29.0 | 4.8 | 22.9 | 40.0 | 11.0 | 23.4 | 4.9 | 10.0 | 4.0 |
| 310CLK | 2020 | 5.7 | 21.0 | 40.0 | 26.7 | 10.0 | 5.7 | 26.7 | 59.0 | 15.0 | 51.8 | 4.7 | 11.9 | 61.0 |

Recommended numeric targets to support beneficial uses

Recommended numeric targets to support preliminary 303d Listing (low priority)

Recommended numeric targets to support 303d listing (high priority)

Table 5: Averages for sediment indicators for a selection of sites, using values from Table 8

| Site Code | Sediment Indicators | | | | | | | Biological Indicators | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Percent Fines | Percent Sands | Percent <8mm | FS Sum Percent | D50 Median particle size | Percent Fines (steelhead) | Percent Cover of FS (BMI limits) | Total Richness | EPT Richness | Percent EPT | Biotic Index | Percent Tolerant | Sensitive Number |
| 310MNO | 6.0 | 18.9 | 32.8 | 23.9 | 19.5 | 6.0 | 23.9 | 55.3 | 14.3 | 29.1 | 5.6 | 12.3 | 10.6 |
| 310LSL | 10.9 | 15.6 | 34.7 | 26.5 | 13.5 | 10.9 | 26.5 | 49.3 | 14.9 | 26.9 | 4.9 | 9.8 | 10.3 |
| 310UPN | 2.4 | 11.7 | 19.1 | 13.3 | 55.7 | 2.4 | 13.3 | 59.2 | 17.3 | 31.2 | 4.9 | 8.4 | 14.5 |
| 310TWB | 15.7 | 25.1 | 50.8 | 39.7 | 7.8 | 14.7 | 39.7 | 42.1 | 8.1 | 16.8 | 6.3 | 20.2 | 6.9 |
| 310CLK | 4.5 | 17.0 | 29.1 | 21.5 | 22.0 | 4.5 | 21.5 | 52.3 | 11.0 | 25.4 | 5.5 | 13.6 | 19.0 |

Recommended numeric targets to support beneficial uses
Recommended numeric targets to support preliminary 303d Listing (low priority)
Recommended numeric targets to support 303d listing (high priority)

## SEDIMENT IMPAIRMENT ANALYSIS

Preliminary analysis of this data indicates that physical characteristics are variable across sites in the Morro Bay watershed. Certain sites indicate greater levels of impairment than others, especially along the mainstem of Chorro Creek. It is important to note that these results do not include the full suite of sixteen metrics that comprise the analytical approach.

Pennington Creek at 310UPN has consistently met all sediment indicator targets since 2008, and met nearly all targets for both sediment and biological indicators during 2020 and 2021. With the averaged data from 2008 through 2021 (Table 5), 310UPN also met all numeric targets that support beneficial use. Prior to 2016, San Bernardo Creek at 310MNO supported beneficial uses across the board as well, but has since declined in various sediment indicators. Los Osos Creek at 310CLK was not monitored during 2021, but has historically met most indicator targets. 310CLK has shown some variability in the biological indicators, with lower scores for EPT Richness but consistently high scores for Percent Tolerant species. Chorro Creek at 310TWB has had several indicators meet the lower priority criteria and several other indicators met the criteria for the high priority 303(d) listing.

These indicator criteria are still being assessed for incorporation in the 303(d) listing process and TMDL assessment process in the Central Coast region. These criteria differ greatly from the D50 and percent sands/percent fines criteria listed in the approved sediment TMDL for Morro Bay. Further guidance is needed from the Water Board for future assessments of the status of the Morro Bay Sediment TMDL.

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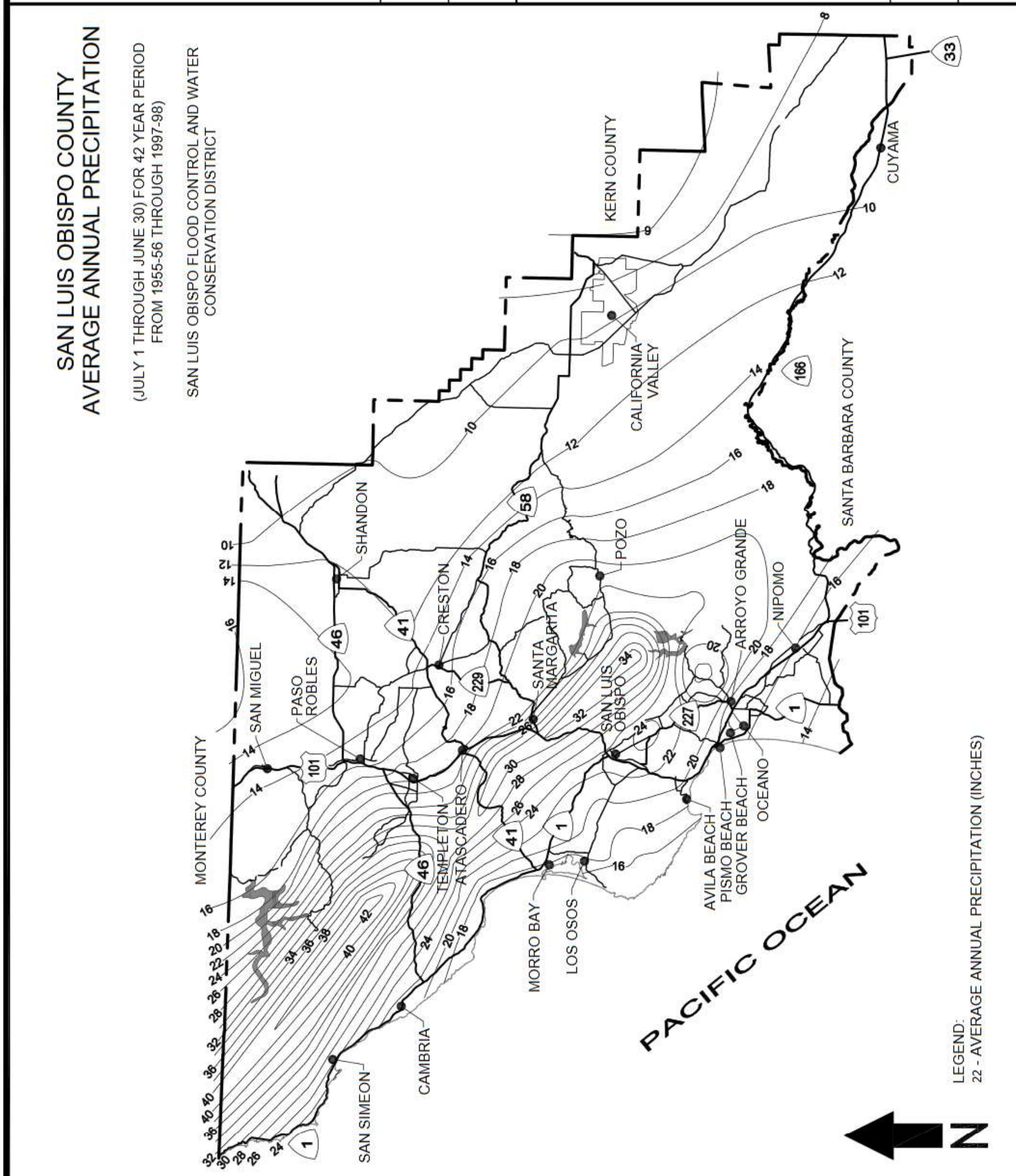
# APPENDIX A: SLO COUNTY PRECIPITATION CONTOURS

| Revisions | | | | | |
|---|---|---|---|---|---|
| Description | Approved | Date | Description | Approved | Date |
| | | | | | |
| | | | | | |




DEPARTMENT OF PUBLIC WORKS & TRANSPORTATION

AVERAGE ANNUAL RAINFALL

| Scale: NTS | Adopted: 2011 |
|---|---|
| Drawing No: | H-1 |
| Sheet No: | 1 OF 1 |