California Environmental Protection Agency

Central Coast Regional
Water Quality Control Board

Water Quality
Restoration and Reference
Site Selection
Report

Gabilan Creek Watershed
Monterey County California
(8/8/2019)

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LIST OF ACRONYMS AND ABBREVIATIONS

Basin Plan	Water Quality Control Plan for the Central Coastal Basin
CCAMP	Central Coast Ambient Monitoring Program
Central Coast Water Board	Central Coast Regional Water Quality Control Board
CCoWS	Central Coast Watershed Studies
CCWQP	Central Coast Water Quality Preservation, Inc.
CDFW	California Department of Fish and Wildlife
cfs	Cubic Feet per Second
CIMIS	California Irrigation Management Information System
CMP	Cooperative Monitoring Program for Irrigated Agriculture
CWA	Clean Water Act
GIS	Geographic Information System
MCWRA	Monterey County Water Resources Agency
SWAMP	Surface Water Ambient Monitoring Program
State Water Board	State Water Resource Control Board
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey

1. Purpose and Scope

1.1. Introduction

Numerous waterbodies in the Gabilan Creek watershed are identified on the federal Clean Water Act section 303(d) List of impaired waters (303(d) List) as impaired for turbidity. They are listed as impaired due to stream turbidity levels frequently exceeding water quality guidelines protective of aquatic life (refer to Table 2). This report outlines an approach for establishing TMDL targets for the impaired streams based on natural turbidity water quality levels and aquatic habitat goals, which equate to attainment of the water quality standard for turbidity. This report supports the development of turbidity TMDLs and numeric targets for the Gabilan Creek watershed. The purpose of the Gabilan Creek turbidity TMDLs will be to restore water quality to unimpaired natural turbidity levels and to restore aquatic life beneficial uses. Streams in the lower portions of the Gabilan Creek watershed are highly modified and impacted from current and historic human activities such as the channelization of streams, draining of lakes and wetlands, and vegetation management. Due to extensive stream habitat modifications and impairments in the watershed, turbidity and habitat goals, must be established at least in part from reference sites with similar geomorphology (geology, slopes, and hydrology).

Turbidity is an optical characteristic of water and is a measure of its relative clarity. Higher turbidity reduces water clarity and subsequently reduces light penetrating water, which reduces plant photosynthesis and production of dissolved oxygen. Higher turbidity also reduces the ability of fish to find prey and concentrations of suspended sediments can also clog fish gills (USEPA, 2012). In slower moving water, sediments can deposit on the stream bottom and smother fish eggs and benthic macroinvertebrate habitats. According to a 2012 U.S. Environmental Protection Agency (USEPA) document, sources of turbidity include:

- *Soil erosion*
- *Waste discharge*
- *Urban runoff*
- *Eroding stream banks*
- *Large numbers of bottom feeders (such as carp), which stir up bottom sediments*
- *Excessive algal growth*

The Gabilan Creek watershed is located in the lower portion of the lower Salinas River watershed in Monterey, California. The Gabilan Creek watershed includes several waterbodies including Gabilan Creek, the Salinas Reclamation Canal, Tembladero Slough, and Old Salinas River Channel which are the mainstem waterbodies in the watershed that connect the mountain headwaters down to the sea (refer to Figure 6). These waterbodies along with the major tributaries drain to Moss Landing Harbor, Elkhorn Slough, Moro Cojo Slough, and Monterey Bay.

The major tributaries are Alisal Creek, Natividad Creek, Santa Rita Creek, Espinosa Slough, Merritt Ditch and Alisal Slough. These tributaries are also listed as impaired for turbidity on the 303(d) List and the tributaries and adjacent lands are highly modified from natural conditions (refer to Figure 6).

In addition to being identified on 303(d) List as impaired for turbidity, the waterbodies are identified on the federal Clean Water Act section 305(b) Report (305(b) Report) as needing the development of TMDLs. Turbidity TMDLs are challenging to develop. On the central coast, 55 waterbodies are listed as impaired for turbidity and none are addressed by an adopted TMDL (CCRWCB, 2019). One challenge facing the development of turbidity TMDLs is the lack of turbidity water quality objectives for surface waters in the Water Quality Control Plan for the Central Coastal Basin (Basin Plan).

The Basin Plan's turbidity water quality objective states that controllable sources may only marginally elevate turbidity above natural levels and any elevated levels must also not affect beneficial uses such as municipal and domestic water supply and protection of both recreation and aquatic life. The challenge for this project is how to interpret the "natural" turbidity conditions in waters, such as in the Gabilan Creek watershed, that are highly modified and extensively polluted.

This report outlines strategies for determining when water quality is restored by identifying healthy reference water quality and habitat monitoring sites and conditions. For the purpose of this project, restoration and reference sites are defined as follows:

Restoration Monitoring Sites: *are water quality and aquatic habitat monitoring sites representative of impaired waterbodies or waterbody segments in the Gabilan Creek watershed.*

Reference Sites: *are monitoring sites with comparable watershed characteristics to restoration monitoring site watersheds for determining natural water quality and/or aquatic habitat conditions. These watersheds are less degraded or impaired by turbidity but are not necessarily in healthy condition.*

For this report, central coast reference sites were selected from watersheds with similar topography, geology, and hydrology to the Gabilan Creek watershed . Water board staff evaluated the turbidity conditions from restoration and reference sites and summarized dry season turbidity levels. The dry season represents a period when there is no natural surface runoff caused by precipitation into streams and perennial streams are naturally fed by base flow. During this period reference site turbidities were generally low and much lower than at the restoration monitoring sites.

Wet season turbidity monitoring data was not analyzed for this report because flows and suspended sediments concentrations are highly variable and episodic in this watershed.. However, wet season turbidity levels in the watershed should correlate with the rise and fall of the hydrograph. As surface runoff subsides, turbidity should be restored to low levels. Additional continuous storm event flow and turbidity monitoring at restoration and reference sites is recommended to develop storm-based flow and turbidity duration curves.

In addition to directly addressing water quality impairments with turbidity thresholds, the report identifies a strategy for setting restoration goals to address the effects of turbidity on the aquatic ecosystem. This strategy is based on an USEPA framework for developing suspended and bedded sediment water quality criteria (USEPA, 2006). Turbidity causes decreased light penetration in the water column, consequently reducing the productivity of primary producers such as algae and plants that produce food from sunlight and nutrients and in turn support primary consumers such as invertebrates and fish (USGS, 2013). To restore aquatic ecosystems, this report outlines a framework for setting goals for wetlands and biological communities, which are direct measures of stream health in the Gabilan Creek watershed.

Turbidity is one of many potential factors causing biological habitat degradation in the watershed and impacting aquatic life. Other factors contributing to habitat degradation include loading of pesticides and nutrients and the physical removal of sediment and clearing of vegetation.

1.2. Beneficial Uses

The protection of beneficial uses of water is the foundation of water quality protection and is the basis used to establish water quality objectives. The beneficial uses of turbidity impaired waters in the Gabilan Creek watershed are listed below in Table 1.

Table 1. Basin Plan beneficial use designations for waterbodies in the Gabilan Creek watershed.

Waterbody/Subwatershed	Beneficial Use	
	Code	Name
Old Salinas River	REC1	Water contact recreation
	REC2	Non-contact water recreation
	WILD	Wildlife habitat
	COLD	Cold fresh water habitat
	WARM	Warm fresh water habitat
	MIGR	Migration of aquatic organisms
	SPWN	Spawning, reproduction, and/or early development
	BIOL	Preservation of biological habitats of special significance
	RARE	Rare, threatened, or endangered species

Waterbody/Subwatershed	Beneficial Use	
	Code	**Name**
	EST	Estuarine habitat
	COMM	Commercial and sport fishing
Tembladero Slough	REC1	Water contact recreation
	REC2	Non-contact water recreation
	WILD	Wildlife habitat
	WARM	Warm fresh water habitat
	MIGR	Migration of aquatic organisms
	SPWN	Spawning, reproduction, and/or early development
	RARE	Rare, threatened, or endangered species
	EST	Estuarine habitat
	COMM	Commercial and sport fishing
	SHELL	Shellfish harvesting
Alisal Slough	MUN	Municipal and domestic water supply
	REC1	Water contact recreation
	REC2	Non-contact water recreation
	COLD	Cold fresh water habitat
	WARM	Warm fresh water habitat
	SPWN	Spawning, reproduction, and/or early development
Salinas Reclamation Canal	REC1	Water contact recreation
	REC2	Non-contact water recreation
	WILD	Wildlife habitat
	WARM	Warm fresh water habitat
	MIGR	Migration of aquatic organisms
	COMM	Commercial and sport fishing
Merritt Ditch	MUN	Municipal and domestic water supply
	REC1	Water contact recreation
	REC2	Non-contact water recreation
	COLD	Cold fresh water habitat
	WARM	Warm fresh water habitat
	SPWN	Spawning, reproduction, and/or early development
Espinosa Slough	REC1	Water contact recreation
	REC2	Non-contact water recreation
	WILD	Wildlife habitat

Waterbody/Subwatershed	Beneficial Use	
	Code	Name
	WARM	Warm fresh water habitat
	COMM	Commercial and Sport Fishing
Santa Rita Creek	MUN	Municipal and domestic water supply
	REC1	Water contact recreation
	REC2	Non-contact water recreation
	COLD	Cold fresh water habitat
	WARM	Warm fresh water habitat
	SPWN	Spawning, reproduction, and/or early development
Gabilan Creek	MUN	Municipal and domestic water supply
	AGR	Agricultural supply
	GWR	Ground water recharge
	REC1	Water contact recreation
	REC2	Non-contact water recreation
	WILD	Wildlife habitat
	COLD	Cold fresh water habitat
	WARM	Warm fresh water habitat
	MIGR	Migration of aquatic organisms
	SPWN	Spawning, reproduction, and/or early development
	RARE	Rare, threatened, or endangered species
	COMM	Commercial and Sport Fishing
Natividad Creek	MUN	Municipal and domestic water supply
	REC1	Water contact recreation
	REC2	Non-Contact water recreation
	COLD	Cold fresh water habitat
	WARM	Warm fresh water habitat
	SPWN	Spawning, reproduction, and/or early development
Alisal Creek	MUN	Municipal and domestic water supply
	AGR	Agricultural supply
	GWR	Ground water recharge
	REC1	Water contact recreation
	REC2	Non-Contact water recreation
	WILD	Wildlife habitat

Waterbody/Subwatershed	Beneficial Use	
	Code	Name
	COLD	Cold fresh water habitat
	WARM	Warm fresh water habitat
	SPWN	Spawning, reproduction, and/or early development
	COMM	Commercial and Sport Fishing

1.3. Water Quality Objectives

The Basin Plan contains the following water quality objective for turbidity. It is a general objective that applies to all waters of the state within the jurisdictional boundaries of the Central Coast Water Board (Basin Plan, 2019, section 3.3.2.1).

Turbidity

Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increase in turbidity attributable to controllable water quality factors shall not exceed the following limits:

1. *Where natural turbidity is between 0 and 50 Nephelometric Turbidity Units (NTU), increases shall not exceed 20 percent.*
2. *Where natural turbidity is between 50 and 100 NTU, increases shall not exceed 10 NTU.*
3. *Where natural turbidity is greater than 100 NTU, increases shall not exceed 10 percent.*

The turbidity objective protects water quality by establishing numeric limits based on the natural turbidity of a waterbody. It also protects water quality by establishing that increases in turbidity shall not adversely affect beneficial uses. Waterbodies were listed as impaired for turbidity based on exceedances of turbidity evaluation guidelines used to interpret the impacts to either cold or warm water habitats (see Table 2).

To evaluate if controllable sources contribute to unacceptable increases in turbidity, reference sites must be established to define natural turbidity levels for the Gabilan Creek watershed and the desired habitat conditions necessary to restore the biological integrity of the impaired waters.

1.4. Impaired Waters

In the Gabilan Creek watershed, ten waterbodies were identified on the 303(d) List as impaired for turbidity and needing the TMDL to address the impairment (see 2014/2016 California Integrated Water Report CWA 303(d) / 305(b) Report) . In the entire central coast region, there are 55 waterbodies on the 303(d) List as impaired for turbidity and needing TMDLs. However, not turbidity TMDLs have been developed or approved in the central coast region. The turbidity impaired waterbodies in the Gabilan Creek watershed are identified in Table 2 along with the applicable COLD or WARM water beneficial use designated to each waterbody in the Basin Plan. The turbidity water quality guidelines used to identify impaired waters are summarized in Table 3 according to the Beneficial Use.

Table 2. Turbidity impaired waterbodies in the Gabilan Creek watershed.

Sub-watershed ID	Waterbody Segments	Decision ID	Beneficial Use
1	Old Salinas River	41633	COLD, WARM
2	Tembladero Slough	39813	WARM
3	Alisal Slough	46617	COLD, WARM
4	Salinas Reclamation Canal	40698	WARM
5	Merritt Ditch	42084	COLD, WARM
6	Espinosa Slough	40301	WARM
7	Santa Rita Creek	37391	COLD, WARM
8	Gabilan Creek	40095	COLD, WARM
9	Natividad Creek	41039	COLD, WARM
10	Alisal Creek	46605	COLD, WARM

Table 3. The turbidity water quality guidelines used to identify impaired waters.

Beneficial Use	Water Quality Objective/Criterion
COLD	Turbidities of 25 NTU's or greater caused reduction juvenile salmonid growth due to interference with their ability to find food Sigler et al. (1984).
WARM	Turbidities of 40 NTU’s or greater can cause a reduction in piscivorous fish (e.g., largemouth bass) growth due to interference with their ability to find food (Shoup, D.E. and Wahl D.H., 2009).

1.5. Biological Integrity

The federal Clean Water Act provides the basis for water quality protection and TMDL development. The objective of the federal Clean Water Act is to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters. This TMDL project follows a holistic approach to watershed health and protection by planning to restore both the water quality conditions and biological integrity of impaired waters. It proposes water quality targets (i.e., numeric turbidity targets) and biological integrity targets (i.e., benthic inveterate community scores) for the impaired waters.

Biological integrity is the overall health a waterbody and is a balance of five factors: habitat structure (natural features that support plants and animals), water quality (physical and chemical properties of water), energy source (nutrients supporting the food chain), flow regime, and biotic interactions (links between species in food chain) (Murdoch et. al, 1999). The five factors are shown in Figure 1 and defined in Table 4. Aquatic vegetation has a variety of functions; plants collect energy and produces organic matter that serve as energy sources and plants provide habitat for invertebrates, fish, and wildlife. Turbidity directly impacts primary producers (algae and plants) in aquatic environments by reducing the availability of sunlight for photosynthesis and aquatic life by reducing habitat quality and functionality.

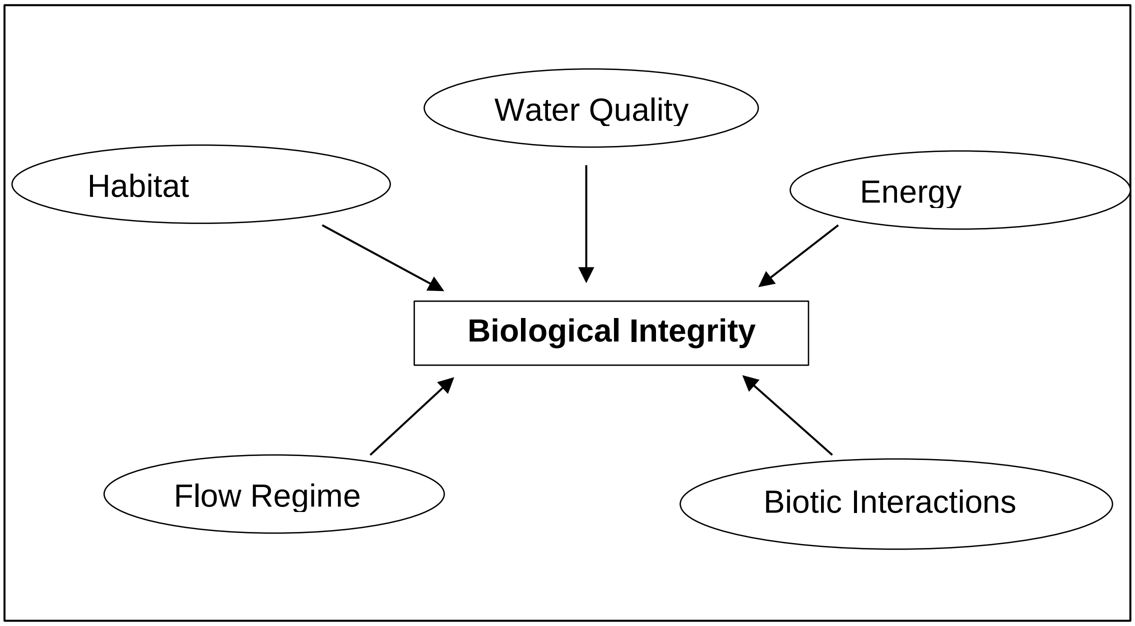

Figure 1. Five factors of biological integrity based on a model developed by Dr. James Karr (Murdoch et. al, 1999).

Table 4. The five factors of biological integrity and their descriptions

Factor	**Description**
Water Quality	*The extent to which a stream strays from its natural chemical makeup due to human impacts.*
Energy Source	*The source of Biotic nutrients for the stream's food chain. These sources may be natural such as decaying leaves and woody debris, or human caused, such as sewage and fertilizer runoff.*
Biotic Interactions	*The links between species in the food chain (or simply who's eating whom), and an awareness of the impacts on one species when another disappears. For example, caddisflies, mayflies, and stoneflies are primary food sources for salmon, steelhead, and trout. If these insects are no present in your stream, those fish dependent on them will not be present.*
Flow Regime	*The volume of water flowing through a stream over time. Changes in flow regimes and attendant impacts of fish and*

	wildlife must evaluated on par with flooding, erosion, and municipal/industrial/agricultural uses of water
Habitat Structures	*The types and amounts of natural features that provide fish and wildlife habitat structures, e.g. instream logs, pools and riffles, and undercut banks for fish; and abundant and diverse vegetation for wildlife.*

2. NATURAL TURBIDITY WATER QUALITY CONDITIONS

The Basin Plan's turbidity water quality objective protects water quality from controllable sources causing turbidity increases above natural levels. The Gabilan Creek watershed is highly modified from its natural watershed conditions and there are numerous discharges into its waterbodies from controllable sources such as irrigated agricultural runoff, urban stormwater, and surface water pumps. There are two sources of natural flows into streams; over land surface runoff that naturally occurs after large storms, and base flow in streams from soil moisture or groundwater .

Base flow is most apparent during dry seasons in the perennial streams found in the lower Gabilan Creek watershed (e.g., lower Salinas Reclamation Canal, Tembladero Slough, and Old Salinas River). The Gabilan Creek watershed and the Central Coast Region are in a Mediterranean climate zone with annual dry and wet seasons. Base flow occurs year-round into central coast streams and natural surface runoff (overland flow) occurs during the wet season after significant storm events.

Wet season surface runoff and sediment erosion is highly variable depending on watershed conditions such as rainfall, vegetation cover, soils, and slopes. Wet season stream flows also vary dramatically on the central coast with wide the range in flows and velocities that can in turn greatly vary the turbidity levels. These factors make defining wet season natural turbidity levels in the highly modified Gabilan Creek watershed nearly impossible without complex modeling and continuous stream monitoring.

In contrast, dry season flows are naturally supported by base flow, which steadily enters streams at low velocities with minimal bed and bank erosion. Additionally, base flow dominated natural dry season flows lack the contribution surface landscape erosion and sedimentation. These characteristics of base flow and storm runoff are described in the following excerpt from the United States Geologic Survey (USGS)Water Science School.

> *During periods of low flow (base flow), many rivers are a clear green color, and turbidities are low, usually less than 10 NTU. During a rainstorm, particles from the surrounding land are washed into the river making the water a muddy brown color, indicating water that has higher turbidity values. Also, during high flows, water velocities are faster and water volumes are higher,*

> *which can more easily stir up and suspend material from the stream bed, causing higher turbidities.(USGS, 2018)*

This report summarizes dry season turbidities for the Gabilan Creek restoration monitoring sites and central coast reference monitoring sites on streams with similar watershed characteristics but with less disturbance and subsequent better water quality in terms of turbidity. The watershed characteristics used for comparison include topography, geology, and stream flow. Base flow is predominant on the central coast during the dry season.

Dry season months

- May
- June
- July
- August
- September

2.1. Water Quality Monitoring

Turbidity water quality monitoring data from eleven monitoring sites in the Gabilan Creek watershed are summarized in this report. The monitoring sites are listed below in Table 5 and shown in Figures 4 and 5. The physical conditions of the sites are further illustrated in site photos found in Section 9. Turbidity and instantaneous flow monitoring data was obtained for this report from the California Environmental Data Exchange Network (CEDEN). Two programs conducted most of the water quality monitoring data obtained from CEDEN: the Cooperative Monitoring Program for Irrigated Agriculture (CMP) and Central Coast Ambient Monitoring Program (CCAMP).

Table 5. Gabilan Creek watershed water quality monitoring sites.

Site Code	Monitoring Site Description
309OLD	Old Salinas River at Monterey Dunes Way
309TDW	Tembladero Slough at Molera Road
309TEM	Tembladero Slough at Preston
309TEH	Tembladero Slough at Haro
309ASB	Alisal Slough at White Barn
309ESP	Espinosa Slough upstream from Alisal Slough
309MER	Merritt Ditch upstream from Highway 183
309JON	Salinas Reclamation Canal at San Jon Road
309ALD	Salinas Reclamation Canal at Boronda Road
309GAB	Gabilan Creek at Independence Road and East Boranda Road
309NAD	Natividad Creek up stream of Salinas Reclamation Canal
309ALG	Salinas Reclamation Canal at La Guardia
309RTA	Santa Rita Creek at Santa Rita Park

The dry season turbidity water quality monitoring data from these sites are summarized by percentile rankings in Table 18 and in Figure 18. These waterbodies are categorized as either main or tributary dry season channels. Figure 18 illustrates that turbidity levels are lowest in the Salinas Reclamation Canal (sites 309ALD and 309JON) and then are elevated downstream at sites in Tembladero Slough (sites 309TEH and 309TDW). Tributaries including Merritt Ditch and Espinosa Slough that drain into lower portions of the lower Salinas Reclamation Canal and Tembladero Slough, also have high dry season turbidities.

2.2. Watershed and Subwatershed Catchment Boundaries

The Gabilan Creek watershed and subwatersheds are shown in Figure 6 and Figure 7 and the subwatershed areas are summarized in Table 6. The total watershed area is 102,185 acres, which equals about 160 square miles. The watershed is comprised of ten subwatersheds.

Table 6. Subwatersheds in the Gabilan Creek watershed.

Watershed ID	Subwatershed	Acres	Square Miles
1	Old Salinas River	1,492	2.3
2	Tembladero Slough	2,154	3.4
3	Alisal Slough	4,621	7.2
4	Salinas Reclamation Canal, Lower	5,729	9.0
5	Merritt Lake	14,236	22.2
6	Espinosa Slough	2,655	4.1
7	Santa Rita Creek	6,348	9.9
8	Gabilan Creek	27,957	43.7
9	Natividad Creek	7,337	11.5
10	Alisal Creek	29,656	46.3
	TOTAL	102,185	159.6

2.3. Gabilan Creek Hydrology

The Gabilan Creek flows from its headwaters in the Gabilan Range to Carr Lake, which is inside the City of Salinas. Flow is channelized in Carr Lake where it converges with two major tributaries, Alisal and Natividad Creeks. The Salinas Reclamation Canal begins at the convergence of these streams and flows westerly from the City of Salinas towards the Castroville. During summer months the primary flow into Carr Lake and the Salinas Reclamation Canal is from Alisal Creek (MCWRA, 2015). During the dry season water pools in the flat modified channels within Carr Lake (refer to Figure 26 and Figure 27) and then outlets into the Salinas Reclamation Canal at the Main Street.

Flow leaving Carr Lake was monitored for a special study during the 2014 dry season and was measured at an average rate of 0.7 cubic feet per second (cfs). Stream flow in the Salinas Reclamation Canal is continuously monitored downstream of the city by the USGS at the San Jon Road crossing. During the 2014 dry season study period, flow measured at the San Jon Road gauge averaged 1.3 cfs, which indicates that the Salinas Reclamation Canal gains about half its dry season flow downstream of Carr Lake. An evaluation of stream and base flow from the USGS gage on the Salinas Reclamation Canal indicates that the majority of the gaged streamflow during the summer months is from base flow as opposed to runoff (refer to Table 7).

Table 7. Streamflow and baseflow in the Salinas Reclamation Canal

Date	Streamflow (CFS)	Baseflow (CFS)	Runoff (CFS)	Baseflow (%)
Jan-14	1.4	0.88	0.52	63
Feb-14	13.3	1.42	11.92	11
Mar-14	10.6	1.44	9.13	14
Apr-14	4.6	1.5	3.1	33
May-14	1.2	0.98	0.25	79
Jun-14	1.2	1.01	0.22	82
Jul-14	1.3	1.14	0.19	86
Aug-14	1.5	1.06	0.48	69
Sep-14	1.4	0.91	0.48	65
Oct-14	2.4	0.75	1.69	31
Nov-14	7.1	1.11	6.01	16
Dec-14	74.5	29.2	45.3	39

Downstream of the USGS gage at Jon Road and near the City of Castroville, the Salinas Reclamation Canal drains into Tembladero Slough. The stream velocity slows in Tembladero Slough, which is a wider low gradient waterbody (refer photos in Figure 31) as is the Old Salinas River at the bottom the watershed. There are several perennial tributaries that drain into the Salinas Reclamation Canal including Santa Rita Creek, Espinosa Slough, Merritt Ditch, and Alisal Slough. Waters from several points in the watershed including Santa Rita Creek, Espinosa Slough, Merritt Ditch, Alisal Creek are lifted by surface water pumps and discharged into the Gabilan Creek stream system (refer to Figure 10). The pumps are operated by the Monterey County Water Resources Agency (MCWRA). An example of a lift pump on Alisal Creek is shown in Figure 28. The lift pump systems are also described in Appendix B, which is an excerpt from a report on the Reclamation Canal watershed (MCWRA, 2005).

The Gabilan Creek and the entire central coast region has a Mediterranean climate as evident from rainfall data collected in the watershed that shows minimal precipitation during dry summer months, May to September (refer to Figure 2).

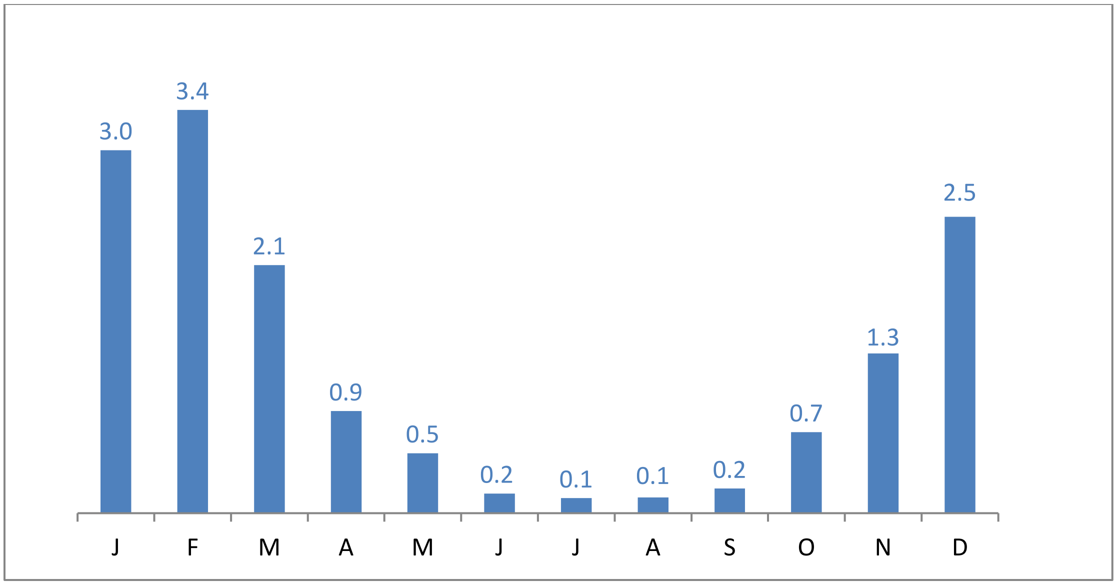

Figure 2. Average monthly rainfall in the lower Gabilan Creek watershed. Source Castroville California Irrigation Management Information System (CIMIS) station.

2.4. Geology and Topography (Slopes)

Granitic igneous rock is the dominant lithology in the Gabilan Mountains, which are the headwaters of Gabilan Creek on the northeastern side of the watershed. Gabilan Creek drains from the mountains into the large flat alluvial valley that extends from the foothills to the coast and coastal sand dunes, which frames the western edge of the watershed (refer to Figure 8 and Figure 9).

The Central Coast Watershed Studies (CCoWS) team, from the Watershed Institute of California State University Monterey Bay assessed, mapped, and reported on stream channel conditions and hydrology in the Gabilan Creek watershed for a project titled the Salinas Reclamation Canal Watershed Assessment & Management Strategy (MCWRA, 2005). The project was primarily funded with an USEPA Clean Water Act grant but also received local financial contributions from the MCWRA and the City of Salinas. Staff from the Central Coast Water Board participated in technical advisory committee along with grower representatives and other technical experts.

The CCoWS team mapped the channel locations from aerial imagery and along with extensive on the ground surveillance. Photos from their on the ground surveillance work are shown in Figure 24 and Figure 25. The channel slope gradients were analyzed with 30-meter digital elevation models. The waterbodies and channel classifications for turbidity impaired waterbodies are listed in Table 8 and mapped in Figure 7 . Below the foothills, the stream channels in the Gabilan Creek watershed are generally low gradient with all slopes classified at less than 2% with many having slopes less than 1%. While some channels have vegetation, many do not. Streams in the lower watershed are perennial. CCoWs classified lower Espinosa Slough and Merritt ditch as perennial ditch/canals with less than 2% channel slopes; these channels are shown in Figure 30. CCoWs classified Tembladero Slough and the Old Salinas River as sloughs with less than 1% channel slopes; these channels are shown in Figure 31.

Table 8. Channel classifications of turbidity impaired waters.

Channel Classifications	Waterbodies
Foothill, 2 - 4% Slope	Merritt Ditch, Santa Rita Creek, Gabilan Creek, Natividad Creek, Alisal Creek
Vegetated, < 2% Slope, Low-gradient, Perennial	Gabilan Creek, Natividad Creek
Vegetated, <2% Slope, Non-perennial	Merritt Ditch, Santa Rita Creek, Gabilan Creek, Natividad Creek, Alisal Creek
Ditch, <2% Slope, Non-perennial	Merritt Ditch, Espinosa Slough, Santa Rita Creek, Gabilan Creek, Alisal Creek
Ditch/Canal. < 2% Slope, Perennial	Salinas Reclamation Canal, Merritt Ditch, Espinosa Slough, Santa Rita Creek
Slough (fresh), < 1% Slope	Tembladero Slough, Alisal Slough
Slough (brackish), < 1% Slope	Old Salinas River

In addition to mapping the streams in the valley floor, CCoWS classified and mapped the channel conditions of the Gabilan headwaters, steep canyon streams, and mountain plateau waterbodies. Since they are not identified as impaired for turbidity, they were not included in this project. CCoWs also mapped lakes and ponds in the watershed but did not classify them. Appendix B - CCoWS - Hydrology and Channel Condition Assessment, includes detailed descriptions of conditions of the channels.

2.5. Reference Watersheds and Monitoring Sites

For this report, reference monitoring sites in watersheds with similar hydrogeomorphic characteristics to the ones found in the Gabilan Creek watershed were identified using GIS. Key characteristics include low gradient slopes and streams, alluvial features, and gaining perennial streams. Reference watersheds and monitoring sites are listed in Table 9 and water quality monitoring data are summarized in Table 19, Figure 19, Figure 20, and Figure 21.

Table 9. Central coast reference watersheds and monitoring sites

Reference Watershed	Monitoring Site ID(s)
Lower Llagas Creek	305LCS
Lower Uvas Creek	305CAN, 305CAR

Reference Watershed	Monitoring Site ID(s)
Watsonville Slough	305WSA
Lower Pajaro River	305CHI
Salsipuedes Creek	305COR
San Juan Creek	305SJA, 305SJN
Elkhorn Slough (Watsonville Creek)	306WAC
Chorro Creek	310CCC, 310TWB
San Luis Obispo Creek	310PRE, 310SLB
Pismo Creek	310PIS
Oso Flaco Creek	312OFN
Corralitos Canyon (Crcutt Creek)	312ORI
Lower San Antonio Creek	313SAI
Santa Lucia Canyon-Santa Ynez River	314SYN, 314SYF
San Miguelito Creek-Santa Ynez River	314SYL
Dos Pueblos Canyon (Devereux Slough)	315DEV

2.6. Dry Season Turbidity Water Quality Assessment

The purpose of this report is to identify reference sites necessary to determine the natural turbidity (or most natural condition) for impaired waters in the Gabilan Creek watershed. Defining natural turbidity is necessary for assessing the Basin Plan’s numeric turbidity water quality objective that sets limits from natural conditions. Natural turbidity is determined using levels from reference streams in watersheds with comparable slopes and hydrogeomorphology to the Gabilan Creek watershed. To further narrow the comparison, staff used turbidity data from the dry season, when flows are naturally dominated by base flow, for comparison. Dry season turbidity levels are summarized for restoration sites in Table 18 and for reference sites in Table 19. The dry season turbidity levels for several restoration sites are displayed in Figure 18 and for reference sites are displayed in Figure 19, Figure 20, and Figure 21.

The following examples show how data from reference sites can be used to evaluate natural turbidity conditions of restoration sites. Streamflow and base flow were analyzed for the Salinas Reclamation Canal at the USGS gage at Jon Road (site 309JON). Dry season flows were dominated by base flow (refer to Table 7). The median dry season turbidity at this site (309JON) and at the neighboring upstream site 309ALD were both below the warm water threshold of 40 NTU (refer to Figure 29). The median turbidity at 309JON was 24 NTU, which is also below the COLD water beneficial use fish threshold of 25 NTU and the median level of 309ALD was 38 NTU.

The median dry season turbidities of Gabilan Creek watershed restoration sites and central coast reference sites are described in Figure 22 and the median dry season turbidity levels in the Gabilan Creek watershed were much higher than comparable central coast reference sites. For example in the Oso Flaco and Orcutt Creek watersheds, Little Oso Flaco Creek, site 312OFN, had a median turbidity of 8.4 NTU and Orcutt Creek, site 312ORI, had a median turbidity of 11.1. Both of these sites are in areas with high agricultural land use. In less turbidity impacted reference watersheds the median turbidities were even lower than the restoration. For example, the median turbidity in the Chorro Creek (Morro Bay) watershed was 1.5 NTU at site 310CCC and 1.2 NTU at site 310TWB.

Turbidity levels in Gabilan Creek watershed were highly variable, which leads to the conclusion that dry season, anthropogenic discharges into the creek systems may be driving up turbidity. For example , the 25th percentile turbidity at site 309MER on Merritt Ditch was 42 NTU and the 75th percentile turbidity was 122 NTU. Which is a difference of 80 NTU.

The extreme ranges in turbidity were not prevalent at the reference stream sites. For example, at site 305SJA on San Juan Creek in the Pajaro River watershed, an agriculturally influenced site, the 25th percentile turbidity was 5.6 NTU and 75th percentile turbidity was 29.0 NTU. Which is a difference of around 23 NTU. Reference sites in even less turbidity impacted reference watersheds had much narrower ranges of dry season turbidities. At site 313SAI in the San Antonio Creek watershed, the 25th percentile turbidity was 0.2 NTU and the 75th percentile turbidity was 9.0 NTU. Which is a difference of around 9 NTU.

The median dry season turbidity levels of reference and restoration sites were also compared. For example, the median dry season turbidity level for Gabilan Creek watershed site, 309JON, was 24 NTU and the median at reference sites (312ORI and 312OFN) in the Santa Maria River watershed were about 10 NTU. Therefore, a reasonable interim dry season median target level for 309JON could be around 10 NTU. The turbidity water quality objective allows for an increase of 20%, which would allow levels up to 12 NTU. Less impacted reference sites have median turbidities of less than 5 NTU and the final dry season turbidity target for 309JON could be at that level. The variation from the median should also be improved in the Gabilan Creek watershed. A possible interim TMDL turbidity target is that sites on the Salinas Reclamation Canal should not vary more than 5 to 10 NTU between the 25th and 75th percentiles. However, the final target would need to be much lower since the Basin Plan’s numeric turbidity objective allows for only a 20% increase above natural turbidities in the range of 0 and 50 NTU.

Waterbodies at the bottom of the Gabilan Creek watershed are sloughs and their water quality was compared to two other sloughs in the region, Watsonville Slough (305WAS) and Devereaux Slough (315DEV) in Figure 23. The turbidity levels at these sloughs were high and ecological conditions were degraded in them. However, the dry season turbidity conditions were much worse in the Gabilan Creek with the turbidity levels much higher at each percentile ranking than at the reference sites. For example, the median turbidity at the Old Salinas

River, site 309OLD, in the Gabilan Creek watershed was 75 NTU and the median turbidity at 305WSA in Watsonville Slough was 22 NTU. Although Watsonville Slough is degraded, 22 NTU could be applied as an interim turbidity goal for the Old Salinas River Channel and Tembladero Slough. Another comparable site in the Gabilan Creek watershed is 309ASB in Alisal Slough that has a median turbidity of 23 NTU.

3. WETLAND/BIOLOGICAL MONITORING AND ASSESSMENT

Aquatic life and habitats are impacted by turbidity in the Gabilan Creek watershed and in addition to setting targets for turbidity, this project sets targets for restoring wetland/biological conditions of the wetlands in the watershed.

Wetlands provide a range of important ecological and hydrological functions in a watershed. In the Gabilan Creek watershed, wetlands are ecologically important habitats for fish, wildlife and plants. Streams are also important migration corridors for endangered anadromous steelhead that spawn in the headwaters of the Gabilan Creek. The estuaries and sloughs in the lower watershed are important fish rearing habitat and habitat for migratory birds. Wetlands also detain runoff and degrade pollutants.

The existing biological conditions of wetlands in the Gabilan Creek watershed have been extensively monitored and assessed following three different strategy levels supported by USEPA (USEPA, 2019) and historic conditions have been thoroughly researched and described. The three strategy levels of existing wetland monitoring assessment include:

- Level 1 – Landscape Assessment
- Level 2 – Rapid Assessment
- Level 3 – Intensive Site Assessment.

The three levels vary in spatial scale and level detail in the biological assessment.

Level 1 assessment provides biological information at the landscape scale with information about general types of wetlands such as estuary, stream, lake, and marsh wetlands and their extent in the watershed. Wetlands present in the Gabilan Creek watershed are described in the channel classification and conditions section and in the wetland habitat classification and inventory of this report.

Level 2 is a rapid assessment method that occurs at the wetland site scale. Two rapid assessment protocols were used to characterize wetlands in the Gabilan Creek watershed, the California Rapid Assessment Method (CRAM) and the Riparian Rapid Assessment Method for California (RipRAM). Both methods were specifically developed for wetland types of California and are very applicable for conditions in the Gabilan Creek watershed. These standardized methods can be applied to the general types of wetlands identified in the Level 1 assessment. Rapid assessment methods score the conditions of entire wetland area including the land around wetland, hydrology, physical structure, and biotic structure. The assessment uses the scores from several categories and then combines them into a single overall site score. To evaluate sites, scores can be compared to conditions of other wetlands such as specific reference sites or conditions at broader scales such as average statewide scores.

Riparian Areas are transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes and biota. They are areas through which surface and subsurface hydrology connect water bodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems. Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes and estuarine-marine shorelines" (National Research Council 2002).

The Central Coast Wetland Group (CCWG) has been involved in the development of these rapid assessment methods and has conducted numerous assessments in the Gabilan Creek watershed and the central coast region. The results of their monitoring are incorporated in this assessment.

Level 3 is an intensive site assessment that provides detailed information about the physical and biological condition of a wetland. Bioassessment monitoring is conducted to evaluate the integrity of the aquatic ecosystems through concurrent physical habitat and benthic macroinvertebrate (BMI) assessment monitoring.

In addition to the three levels of wetland assessment providing information on healthy biological conditions in the watershed, historical ecology provides background information on the special extent and function of wetlands in the Gabilan Creek watershed.

3.1. Historical Ecology Wetland Assessment

Historical ecology is a way to understand past and present wetland ecology and hydrology in a watershed. The historical ecology of Elkhorn Slough and lower Salinas River watersheds, including the Gabilan Creek watershed, was researched and mapped by the staff of the Elkhorn Slough Foundation and Elkhorn Slough National Estuarine Research Reserve (Elkhorn Slough Foundation). The Elkhorn Slough Foundation developed a draft historical ecology GIS layer of the lower Salinas River watershed and Salinas Reclamation Canal watersheds that is shown in Figure 13. For comparison, a coinciding map of currently existing wetlands is shown in Figure 14. The historic ecology map is based on historic accounts and maps of the watershed including: Mexican rancho maps from the early 1800s, early American land surveys, newspaper accounts, soil surveys, and engineering maps and plans (Elkhorn, 2015).

Development and land reclamation have significantly altered the hydrology and wetland habitats in the watershed. In the early 1900s plans were drawn by the Chief Engineer of Salinas, Lou. G Hare, to construct canals and lateral and reclaim sloughs and lakes in the Gabilan Creek watershed (refer to Figure 15). Some of the reclaimed open water lakes are Merrit Lake, Espinosa Lake, Santa Rita Slough, Vierra Lake, Boronda Lake, Mill Lake, Carr Lake, Mud Lake, and Heinz Lake. In addition to draining the lakes, the reclamation project drained extensive freshwater marsh wetlands that surrounded the lakes and filled adjacent lands. The currently, the Salinas Reclamation Canal continues to drain these former wetlands.

3.2. Wetland Habitat Classification and Inventory

The U.S. Fish and Wildlife Service developed wetland map layers that are based on the Cowardin wetland classification system (Cowardin, 1979). U.S. Fish and Wildlife Service's Wetland geographic information system (GIS) layers were digitized into map layers from high-resolution imagery and field verified (refer to Figure 13). The Gabilan Creek watershed has a diverse mix of Level 1 type wetlands including estuarine, freshwater emergent, freshwater forested, lakes, and riverine wetlands that are summarize in Table 10.

Table 10. Gabilan Creek watershed and subwatershed wetland inventory and acreage.

	Estuarine and Marine Deep water	Freshwater Emergent	Freshwater Forested /Shrub	Freshwater Pond	Lake	Riverine	Total Wetlands
Alisal Creek		62.9	147.7	54.0		396.9	661.5
Alisal Slough		22.7	1.4	1.4		16.6	42.1
Espinosa Slough		63.9	44.7	2.3	56.8	10.8	178.5
Gabilan Creek		168.9	543.8	64.1		273.0	1049.8
Merritt Lake		136.4	117.1	32.6		82.6	368.7
Natividad Creek		75.8	81.8	52.1		71.7	281.4
Old Salinas River	28.3	178.6		2.3		20.3	229.5

Salinas Reclamation Canal		12.1	7.2	3.4		37.1	59.8
Santa Rita Creek		15.6	11.5	14.9		52.1	94.1
Tembladero Slough		3.8	3.5	6.4		26.5	40.2
Watershed Total	28.3	740.7	958.7	233.5	56.8	987.6	3005.6
% Total Wetlands	1%	25%	32%	8%	2%	33%	100%

Note: The inventory does not include mapped wetlands that are actively farmed.

3.3. California Rapid Assessment Method - CRAM

The California Rapid Assessment Method (CRAM) is a standardized Level 2 framework for holistically mapping and assessing wetland conditions and stressors. CRAM provides a framework for assessing and scoring of the overall condition of a wetland referred to as the Index Score, which is an average of four site scores. CRAM has methodologies for assessing and scoring wetland landscape buffers, hydrology, physical structure, and biotic structure. The CRAM approach allows for the comparison of individual attribute scores at regional levels. Of these four scoring methodologies, biotic structure is the most relevant to biological assessment metric for turbidity impacts on the aquatic ecosystems in the Gabilan Creek watershed and for comparison of regional reference sites.

The overall CRAM index score can range from 0 to 100 and this relative scoring system can be compared to the distribution scores in comparable watersheds. In the Gabilan Creek watershed, 49 sites have been assessed using CRAM (refer to Table 11, Figure 11, Figure 16, and Figure 17). The site numbers in the table correspond the mapped site locations. An Index Score of 100 indicates the best possible condition. In the Gabilan Creek watershed, the average CRAM Index Score is 51 and the average biology score was 54.

Table 11. CRAM Site numbers, locations, index scores and biotic structure scores in the Gabilan Creek watershed.

SITE No.	Location	Index Score	Biotic Structure
1	Tembladero Lower Marsh	66	77
2	Elkhorn Slough	66	78
3	Lower Natividad	59	67
4	Tembladero Upper	47	36
5	Tembladero Lower	57	72

SITE No.	Location	Index Score	Biotic Structure
6	Cesar Chavez	42	33
7	Lower Natividad 1	67	81
8	Lower Natividad 2	61	83
9	Lower Natividad 3	55	78
10	Old Salinas River Channel	82	75
11	Natividad Creek	58	72
12	Natividad Creek - u/s Freedom Pkwy	56	81
13	Gabilan Creek - 100 m south of dirt farm road	63	69
14	Natividad Creek - at park, above footbridge	62	81
15	Gabilan Creek - 2nd Cul de Sac of Londonderry Way	73	64
16	Gabilan Creek - 150 m u/s Constitution Blvd.	63	69
17	Gabilan Creek - 130 m u/s of bridge at Sports Complex	51	64
18	Natividad Creek at Barton Elementary School	49	44
19	Natividad Creek Upper / Agricultural	39	50
20	Santa Rita Creek at elementary school	48	33
21	Santa Rita Creek Restoration (Upstream)	44	50
22	Santa Rita Creek Restoration (downstream)	39	39
23	Santa Rita Creek Restoration (downstream)	43	33
24	Santa Rita Creek Above N Main St	27	25
25	Santa Rita Creek at Santa Rita Elementary	43	28
26	Santa Rita Creek 140m Upstream of Van Buren	52	44
27	Santa Rita Creek along San Juan Grade Rd	54	42
28	Lower Natividad	64	83
29	Alisal Creek at Old Stage Rd.	47	39
30	Alisal Creek at Alisal Rd.	42	42
31	Alisal at work St.	30	25
32	Rec Ditch at San Jon Rd.	39	39
33	Rec Ditch at 101	30	25
34	Alisal at Cesar Chavez	41	44
35	Rec Ditch at Victor St.	39	39
36	Rec Ditch at 183	47	39
37	Espinosa at 183	50	58
38	Prunedale Creek	59	67

SITE No.	Location	Index Score	Biotic Structure
39	Gabilan at Natividad Rd.	63	75
40	Alisal Slough at McFadden Rd.	41	81
41	Natividad at Old Stage rd	62	58
42	Santa Rita at Herbert Rd.	33	25
43	Santa Rita at Golf Course	34	36
44	Upper Gabilan at Vierra Ranch	70	75
45	Tembladero at Highway 1	41	39
46	Gabilan at Old Stage Road	62	67
47	Gabilan at Crazy Horse	40	33
48	Alisal Slough at Cooper	38	36
49	Marklee Swamp	52	67
	Average	51	54
	Median	50	50

3.4. Riparian Rapid Assessment Method for California-RipRAM

The Riparian Rapid Assessment Method (RipRAM) provides a method for rapid Level 2 wetland assessment of sites with limited access. It is similar to CRAM but sites can be visually assessed without direct “on the ground” or “in the creek access.” For example, RipRAM can be conducted from a bridge crossing and CRAM requires direct field measurements (CCWG, 2018). The RipRAM metrics assessed include:

1. Total Riparian Cover
2. Vegetation Cover Structure
3. Vegetation Cover Quality
4. Age Diversity and Natural Regeneration
5. Riparian Vegetation Width
6. Riparian Substratum Condition and Vertical Connectivity
7. Macroinvertebrate Habitat Patch Richness
8. Anthropogenic Alterations to Channel Morphology

Of the eight RipRAM metrics, metric 7 provides the most direct nexus between chronic turbidity and potential impacts to aquatic life. Metric 7 is a measure of the macroinvertebrate habitat patch richness in the bankfull zone of a stream (refer to Figure 4).

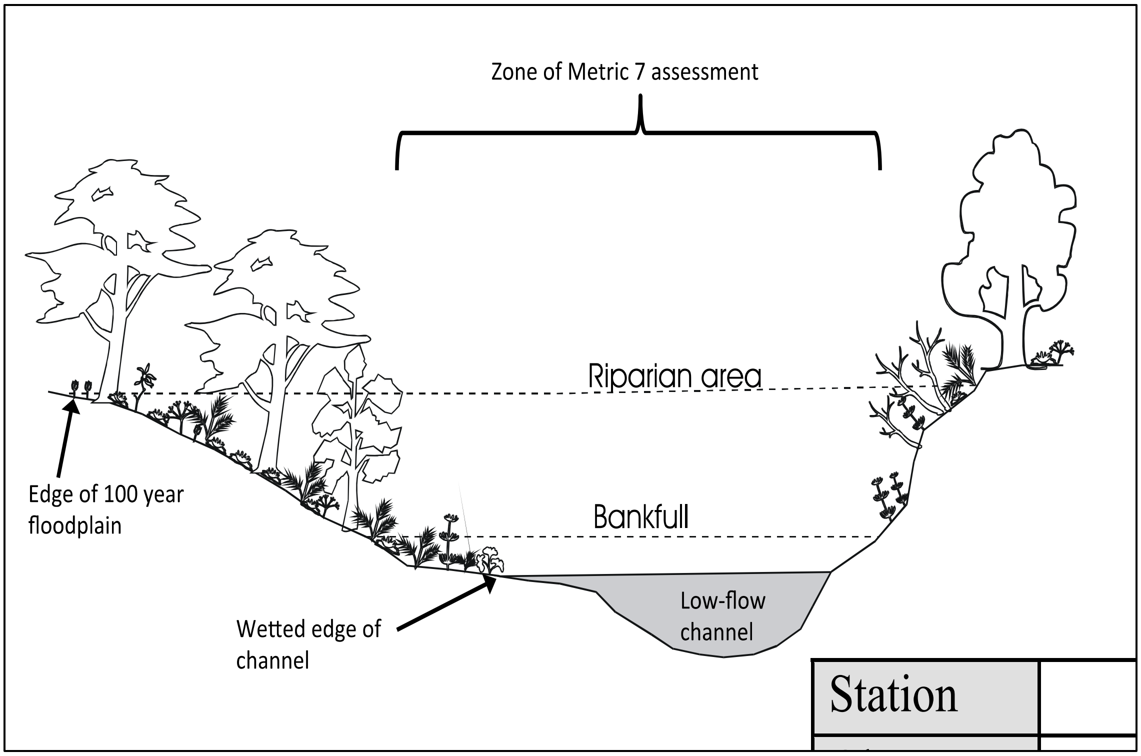

Figure 3. Diagram of riparian area and the bankfull zone of Metric 7 assessment.

Patch habitat richness is a composite of the many types of physical surface features in the bankfull area of a stream including the following:

- Cobbles and boulders;
- Course gravel;
- Fines and sand;
- Fine woody debris;
- Large (or course) woody debris;
- Overhanging vegetation; and
- Aquatic vegetation-helophytes

RipRAM assessments were conducted at 9 water quality monitoring sites in Gabilan Creek watershed (refer to Figure 12) and the Index and Metric 7, patch habitat richness assessment scores are summarized in Table 12. RipRAM scores can range from 0 to 100 for metric and Index Scores (CCWG, 2017). In the Gabilan Creek watershed Index Scores ranged from 9 in the Salinas Reclamation Canal to 45 in Gabilan Creek and Metric 7 scores ranged from 25 to 75. Based on the RipRAM evaluation scale found in Table 13 and most sites had very poor Index Scores and most Metric 7 evaluation scores were poor.

Table 12. RipRAM scores for Gabilan Creek restoration sites.

Site Id	Site Description	Index Score	Metric 7 Score

309ALG	Salinas Reclamation Canal at La Guardia	9	25
309ALU	Salinas Reclamation Canal at Airport Road	17	25
309ASB	Alisal Slough at White Barn	25	25
309GAB	Gabilan Creek at Independence Road and East Boranda Rd	45	75
309JON	Salinas Reclamation Canal at San Jon Road	13	25
309MER	Merritt Ditch above Hwy 183	16	25
309NAD	Natividad Creek at Boranda	39	50
309OLD	Old Salinas River at Monterey Dunes Way	16	50
309TEH	Tembladero Slough at Haro	19	25

Table 13. RipRAM Index and metric scale evaluation.

Index Scale	Evaluation
0 to less than equal to 20	Very Poor
21 to less than equal to 40	Poor
41 to less than equal to 60	Fair
61 to less than equal to 80	Good
80 to less than equal to 100	Excellent

RipRAM assessments have also been conducted at reference sites outside of the Gabilan Creek watershed. RipRAM reference site index and metric 7 scores are summarized in Table 14.

Table 14. RipRAM scores for reference sites.

Site Id	Site Description	Index Score	Metric 7 Score
305CHI	Pajaro River at Chittenden Gap	81	75
305COR	Corralitos Creek at Riverside Dr.	39	25
305LCS	Llagas Creek at southside	80	75
305SJN	San Juan Creek at Anzar Rd for RWB3 Site	33	50
305WSA	Watsonville Slough upstream Harkins Slough	34	50
306WAC	Wastonville Creek at Elkhorn Rd	11	25
310PRE	Prefumo Creek at Calle Joaquin	41	25

310SLB	San Luis Obispo Creek at San Luis Bay Drive	73	75
310TWB	Chorro Creek at South Bay Boulevard	81	75
314SYI	Santa Ynez River at Hwy 101	52	75

3.5. Physical Habitat and Biological Assessments

Physical habitat and biological assessments are intensive in stream Level 3 methods for evaluating the health of aquatic ecosystems. The physical habitat and biological conditions of stream habitats in the Gabilan Creek watershed and throughout the central coast region have been monitored by CCAMP, the CMP, and the Water Board. Additionally, the Morro Bay Nation Estuary Program (MBNEP) has also extensively monitored streams in the Morro Bay watershed.

Benthic macroinvertebrates are key biological indicators of stream health and the effects of water quality. Along with water quality, the physical habitat condition of a stream has a strong impact on the biological community. The Water Board's Surface Water Ambient Monitoring Program (SWAMP) has developed standardized procedures for collecting benthic macroinvertebrate samples and associated physical habitat data (SWAMP, 2007). Physical habitat conditions evaluated include stream size, substrate type and diversity, diversity of current velocities, canopy shading, and channel gradient.

Key physical habitat and bioassessment elements for evaluating turbidity impacts to aquatic health and for comparison between restoration and reference sites are:

- Taxa richness (total number of all benthic invertebrate tax in stream)
- EPT richness (total number of unique taxa from three orders of common benthic invertebrate taxa in a stream)
    - E – Ephemeroptera (mayflies)
    - P – Plecoptera (stoneflies)
    - T – Tricoptera (caddisflies)
- % EPT (ratio of EPT taxa to total taxa)
- % Fines and sands in streambed substrate
- Qualitative physical habitat characteristics (epifaunal substrate/cover, sediment deposition, and channel alteration)

The key physical habitat and biological conditions in the Gabilan Creek watershed restoration and at central coast reference sites are summarized in Table 15. The CMP collected data from the sites in the Pajaro River, Gabilan Creek, and the Santa Maria River watershed in 2013 and 2014. The MBNEP annually collects data in the Morro Bay watershed and samples from 2008 to 2016 are averaged in the table.

Table 15. Key physical habitat and biological conditions of streams.

Sites	% Fines	%Sand	%Fines and Sands	Taxa Richness	EPT Taxa
Pajaro River watershed (CMP 2013/14) – reference sites					
305CAN	2	20	22	21	0
305CHI	0	95	95	38	0
305COR	20	36	56	28	0
305LCS	65	18	83	27	0
305PJP	9	91	100	42	0
Gabilan Creek watershed (CMP 2013/14) – restoration sites					
309ALG	100	0	100	9	0
309ASB	100	0	100	13	0
309ESP	100	0	100	19	0
309ESP -Dup			100	24	0
309JON	18	0	18	18	0
309MER	100	0	100	16	0
309OLD	100	0	100	14	0
309TEH	100	0	100	14	0
Santa Maria River watershed (CMP 2013/14) – reference sites					
312GVS	100	0	100	10	0
312ORI	100	0	100	11	0
312SMA	91	9	100	24	0
Morro Bay watershed (MBNEP average 2008 to 2016) – reference sites					
310MNO	4.6	15.8	20.4	57.3	13.7
310UPN	2.7	9.9	11.4	62.2	19.5
310LSL	12.2	13.6	25.8	49.3	49.3
310TWB	12.3	21.6	33.9	45.0	7.0
310CER	19.0	18.3	37.3	42.9	8.1

Fines and sands are in general poor habitats for EPT benthic invertebrates. Figure 5 shows the correlation of the overall benthic invertebrate community integrity score (the CSCI Score) with the percent of the substrate that is comprised of sand and fine grained sediment. CSCI scores shown in green indicate sites where the benthic community is “likely intact” or unaltered from its natural condition. CSCI scores shown in orange and red indicate sites where the benthic community is “likely altered” or “very likely altered” from its natural condition. Figure 5 also indicates that sites where the benthic community is “likely intact” have percent sand and fines typically below 40% total coverage. Stream surveys found that stream substrates in the lower Gabilan Creek watershed were comprised of 100% fines (silt, clay, muck).

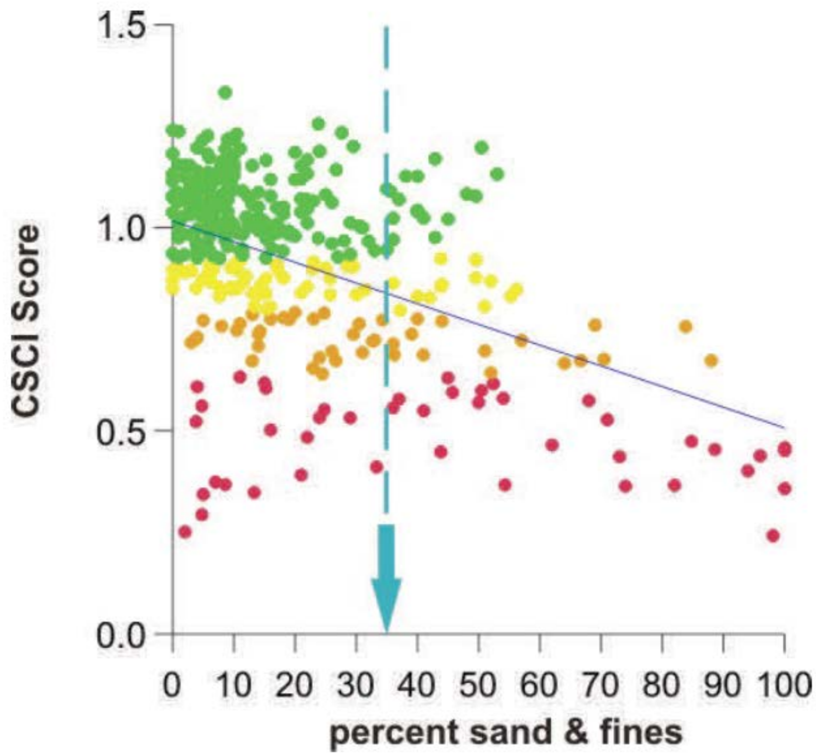

Figure 4. An example of a correlation between percent sand and fines and CSCI scores (SWAMP, 2015). The dashed blue arrow indicates the 90th percentile of sites in good condition (green dots) have percent sand & fines of 35%. This is example is from sites in the California North Coast and Sierra Nevada.

3.6. Herbst Study Stream Sediment Thresholds

The relationship between stream sediment and aquatic health was evaluated and sediment water quality thresholds protective of aquatic life were developed in a Pajaro River watershed study conducted by the Sierra Nevada Aquatic Research Laboratory (Herbst et. al, 2015). The resulting threshold levels and methods are referred to as the Herbst study. In the Herbst Study, streams in the Pajaro River watershed were surveyed for benthic macroinvertebrate and stream physical habitats were assessed. The data analysis found a relationship between deposited fine and sand sediments and BMI species composition and diversity. Impacts to species were found in and above the range of 20 to 40% fine and sand cover.

Although the Herbst study was conducted in the Pajaro River watershed the methods are applicable for assessing habitat conditions throughout the central coast. The Herbst study considered the influence of flow regulation from structures such as dams on stream substrate and habitat conditions and the result are more applicable for reaches with unregulated flows. The Gabilan Creek headwaters and upper reached have unregulated natural flows and are suitable for this method. Flows below Carr Lake are regulated, and this method does not apply to streams in the lower watershed.

As part of the Herbst study a guidance table and an assessment procedure were developed for evaluating SWAMP habitat and bioassessment data and assessing impacts to BMI (refer to Table 16).

Table 16. Herbst study guidance for evaluating sediment levels as TMDL targets.

EPT Richness	Percent Fines and Sands	Impacts to BMI from Sediment
>16	0-20	No
	>20-40	No determination
	>40	No determination
12 to ≤ 16	0-20	No determination
	>20-40	Yes
	>40	Yes
<12	0-20	No determination
	>20-40	Yes
	>40	Yes

The procedure for evaluating SWAMP habitat and bioassessment surveys is as follows:

- From the SWAMP physical habitat data calculate the percent fines and sand (sum of percent sand (0.06 mm-2mm) and percent fines (<0.06mm)).
- From the SWAMP 500 count taxa list, calculate EPT richness (number of EPT taxa).
- Compare percent FS to the EPT richness and use Table 10 to assign a determination of whether impaired condition from sediment is likely

4. Glossary

Aggradation. The rising of a stream bed due to sediment deposition (NCSE).

Alluvial features. Landforms created by rivers, such as floodplains, Sediments are typically round and smooth from water erosion (NCSE).

Base Flow. The flow in a channel due to soil moisture or ground water. (OSU, 2005)

Benthic macroinvertebrates. Small stream-inhabiting creatures that lack backbones, are small enough to be seen with the naked eye (larger than 0.05mm) and spend at least part of their life cycle in or on stream bottoms (WSI).

Biological integrity. the ability to support and maintain a balanced, integrated, adaptive biological system having the full range of elements (genes, species, and assemblages) and processes (mutation, demography, biotic interactions, nutrient and energy dynamics, and metapopulation processes) expected in the natural habitat of a region" (Karr 1996).

Biomonitoring. Evaluation of the condition of a waterbody, using biological surveys and other direct measures of the resident biota in surface waters (WSI).

Ephemeral streams. Streams that flow with water only after precipitation events and the stream are well above the water table.

Intermittent streams. Streams that have water flowing only part of the year however, the stream is still in direct contact with water table .

Perennial streams. Streams that have water flowing in the channel year around and the stream is in direct contact with water table.

Streamflow (Discharge). The rate of water flow (volume/unit time) passing a given cross section of a stream. (OSU, 2005) Some common units include:

- cubic feet per second, cfs, ft3/s
- cubic meters per second, m3/s
- gallons per minute, gpm

Richness. The total number of different taxa of aquatic organisms such as fish or benthic macroinvertebrates in a sample, generally increases with increase water quality. Taxa richness + total abundance (WSI)

Taxa. A group of organisms such as a group of macroinvertebrates, which is used to represent the diversity within a sample (WSI).

5. RECOMMENDED NEXT STEPS

This report outlines a strategy for identifying turbidity water quality goals in the Gabilan Creek watershed and during its development several data and information gaps were identified that are needed to fully protect aquatic life beneficial uses in the watershed from turbidity. These items are outlined as follows:

- Develop wet season storm event driven turbidity targets. This report addresses turbidity during the dry season, when natural flows are from baseflow and it address turbidity impacts to aquatic life in a broad sense through biological integrity. However, it does directly address excess turbidity from stormwater runoff. Stormwater turbidity is complex to evaluate since it is a natural process but magnified in the watershed through land use impacts and stormwater management. A stormwater model should be developed to evaluate healthy watershed conditions.

- Improve access availability of regional biological assessment monitoring data. Biological assessments have been conducted at many central coast streams but not all data has been entered into CEDEN and the data that has been entered cannot be readily accessed and interpreted.

- Study the dry season variability of stream turbidity and flow/velocity in the Gabilan Creek watershed using continuous monitoring equipment at sites with high turbidity and variable flows.

- Evaluate the contribution of algae to turbidity. Particularly at monitoring sites in the lower watershed such as found on Tembladero Slough and the Old Salinas River Channel.

- For reference, monitor water quality in the Old Salinas River Channel upstream of the confluence with Tembladero Slough.

6. REFERENCES

Central Coast Regional Water Quality Control Board (CCRWQCB). 2019. Staff Report for Regular Meeting of May 15-17, 2019. Total Maximum Daily Load Program Update

Central Coast Watershed Studies (CCoWS). 2003. Salinas Valley Sediment Sources

Central Coast Wetlands Group (CCWG). 2018. Riparian Rapid Assessment Method for California – Bridge/onsite scale strategy

Central Coast Wetlands Group (CCWG). 2017. Development of New Tools to Assess Riparian Extent and Condition – A Central Coast Pilot Study, Final Report.

DiVinere V.J. 2017. Introduction to Earth Sciences I, Stream Processes http://www.columbia.edu/~vjd1/streams_basic.htm

Herbst D.B., Medhurst R.B., and I.D. Bell. 2014. Benthic Invertebrate and Deposited Sediment TMDL Guidance for the Pajaro River Watershed. Sierra Nevada Aquatic Research Laboratory, University of California, Santa Barbara.

Karr J.R. 1996. Ecological integrity and ecological health are not the same. Pp. 97-109 in P.C. Schulze, ed. Engineering Within Ecological Constraints. National Academy Press, Washington, D.C. [14] https://www.nap.edu/read/4919/chapter/8

Karr J.R. 1997. Measuring biological integrity. In *Principles of conservation biology*, ed. G.K. Meffe and C.R. Carroll, 483-485. Sunderland, MA: Sinauer. http://www.cbr.washington.edu/salmonweb/pubs/IBI.html

Monterey County Water Resources Agency (MCWRA). 2005. Reclamation Ditch Watershed Assessment and Management Strategy: Part A Watershed Assessment

Monterey County Water Resources Agency (MCWRA). 2015. Preliminary Engineering Design Report for Control of Non-Winter Drainage at Carr Lake, Prepared by Balance Hydrologics, Inc.

Morro Bay National Estuary Program (MBNEP). 2016. Morro Bay National Estuary Program – Sediment Monitoring Report 2016

Murdoch T., Cheo M., and K. O'Laughlin. 1999. The Streamkeeper's Field Guide, Watershed Inventory and Stream Monitoring Methods.

North Carolina State Extension Publications (NCSE). 2019. Natural Stream Processes River Course. https://content.ces.ncsu.edu/natural-stream-processes

Oregon State University (OSU). 2005. Streamflow Evaluations for Watershed Restoration and Design, An interactive guide and tutorial, with examples for Oregon Streams. https://streamflow.engr.oregonstate.edu/index.htm

Shoup, D.E. and D.H. Wahl. 2009. Effects of chronic turbidity on density and growth of steelhead and coho salmon. Transactions of the American Fisheries Society 113:142-150 https://www.waterboards.ca.gov/water_issues/programs/tmdl/records/state_board/2010/ref3752.pdf

Siegler J.W., Bjornn T.C., and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelhead and coho salmon. Transactions of the American Fisheries Society 113:142-150 https://www.waterboards.ca.gov/water_issues/programs/tmdl/records/state_board/2006/ref64.pdf

State of Alaska Department of Environmental Conservation (DEC). 2006. Guidance for the Implementation of Natural Condition-Based Water Quality Standards

Surface Water Ambient Monitoring Program (SWAMP). 2015. The Perennial Streams Assessment (PSA): An Assessment of Biological Condition using the new California Stream Condition Index (CSCI)

Surface Water Ambient Monitoring Program (SWAMP). 2007. Standard Operating Procedures for Collecting Benthic Macroinvertebrate Samples and Associated Macroinvertebrate Samples and Associated Physical and Chemical Data for Ambient Bioassessments in California

Stein E. D., Fetscher A. E., Clark R.P., Wiskind A., Grenier J. T., Sutula M., Collins J. N., and C. Groso. 2009. Validation of a Wetland Rapid Assessment Method: Use of EPA's Level 1-2-3 Framework for Method Testing and Refinement. Wetlands 29:648-664 https://www.cramwetlands.org/sites/default/files/2009-06_Stein%20et%20al_CRAMValidation.pdf

United States Environmental Protection Agency (USEPA). 2012. Water: Monitoring & Assessment, 5.5 Turbidity What is turbidity and why is it important. https://archive.epa.gov/water/archive/web/html/vms55.html

United States Environmental Protection Agency (USEPA). 1998. EPA Wetland Bioassessment Fact Sheet 1, Assessing Biological Integrity of Surface Waters https://nepis.epa.gov/Exe/ZyPDF.cgi/200053VA.PDF?Dockey=200053VA.PDF

United States Environmental Protection Agency (USEPA). 2019. Wetlands Monitoring and Assessment https://www.epa.gov/wetlands/wetlands-monitoring-and-assessment

United States Environmental Protection Agency (USEPA). 2012. Clean Water Act 40th Anniversary - The Clean Water Act: Protecting and Restoring our Nation's Waters http://water.epa.gov/action/cleanwater40/cwa101.cfm

United State Geological Survey (USGS). 2013. The Quality of our Nation's Waters – Ecological Health in the Nation's Streams, 1993-2005: U.S. Geological Survey Circular 1391. https://pubs.usgs.gov/circ/1391/

United State Geological Survey (USGS). 2018. Water Science School, Turbidity and Water. https://www.usgs.gov/special-topic/water-science-school/science/turbidity-and-water?qt-science_center_objects=0#qt-science_center_objects

University of Arizona Cooperative Extension (UACE). 2006. Stream Processes for Watershed Stewards https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1378g.pdf

Watershed Science Institute (WSI). Watershed Condition Series Technical Note 2, Index of Biotic Integrity (IBI). https://www.wcc.nrcs.usda.gov/ftpref/wntsc/strmRest/wshedCondition/IndexOfBioticIntegrity.pdf

7. MAPS

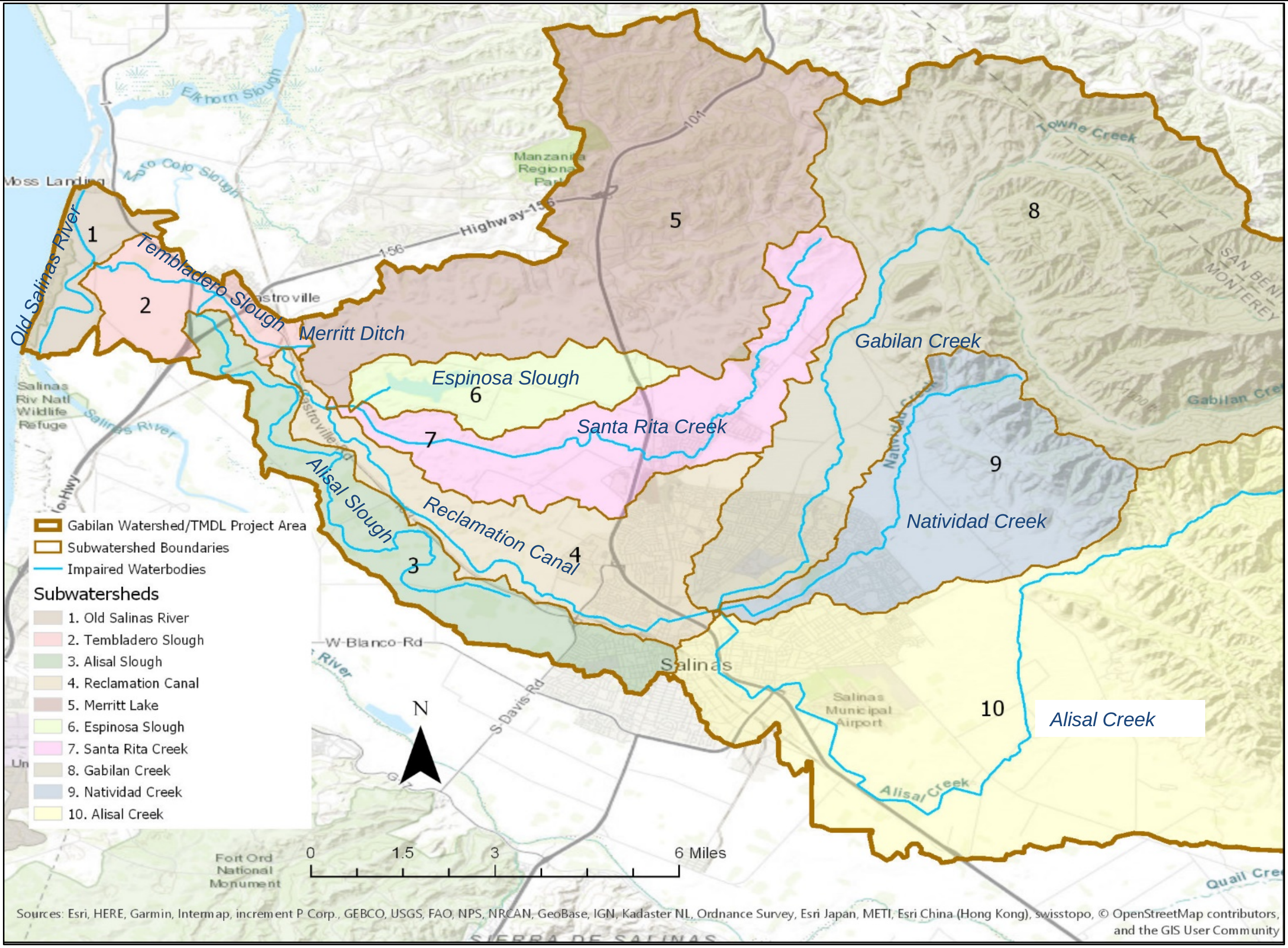

Figure 5. Map of impaired waterbodies in the Gabilan Creek watershed and subwatersheds.

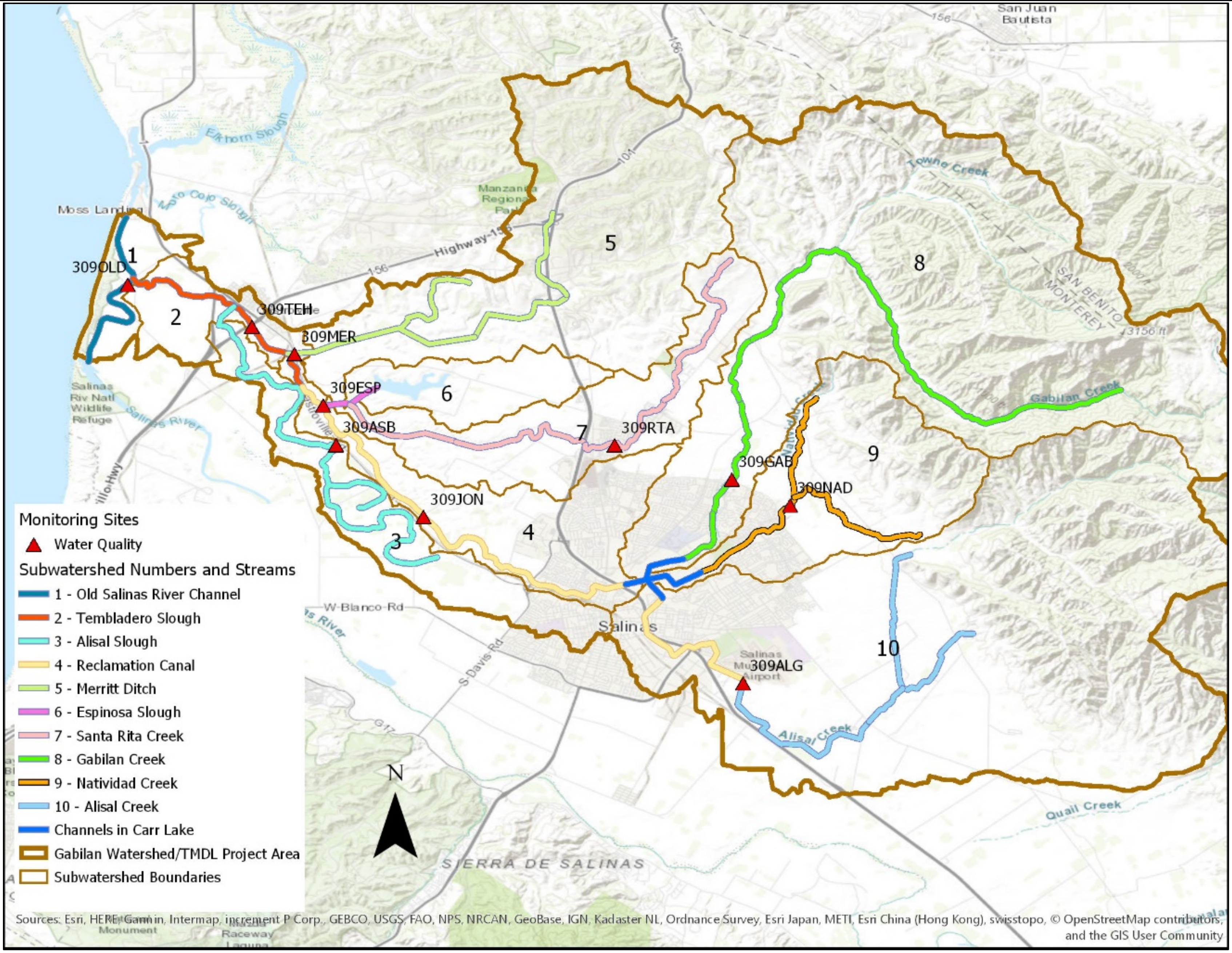

Figure 6. Map of streams, subwatersheds, and monitoring sites in the Gabilan Creek watershed.

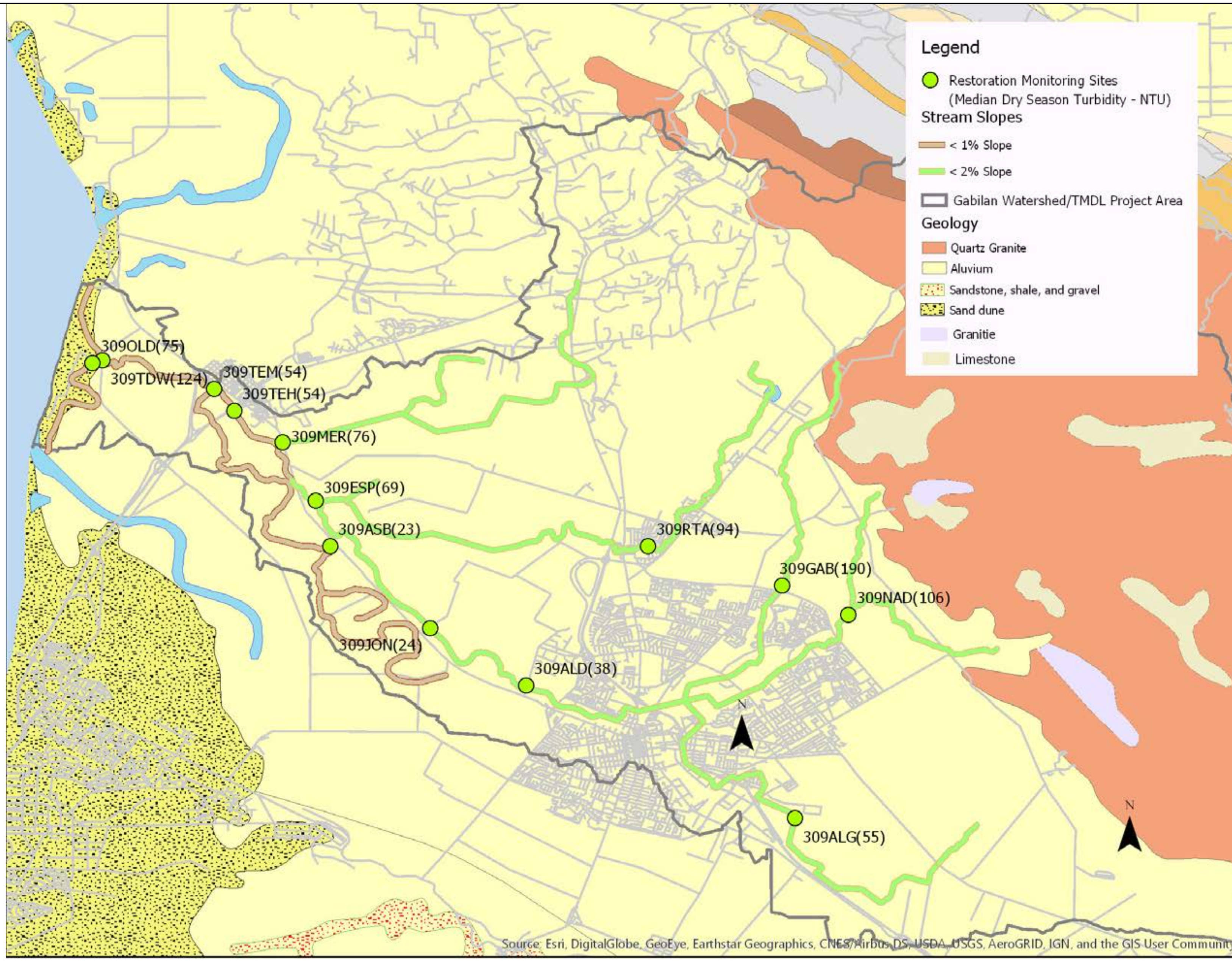

Figure 7. Map of surface geology, stream slopes, and monitoring sites with median dry season turbidity levels in parenthesis.

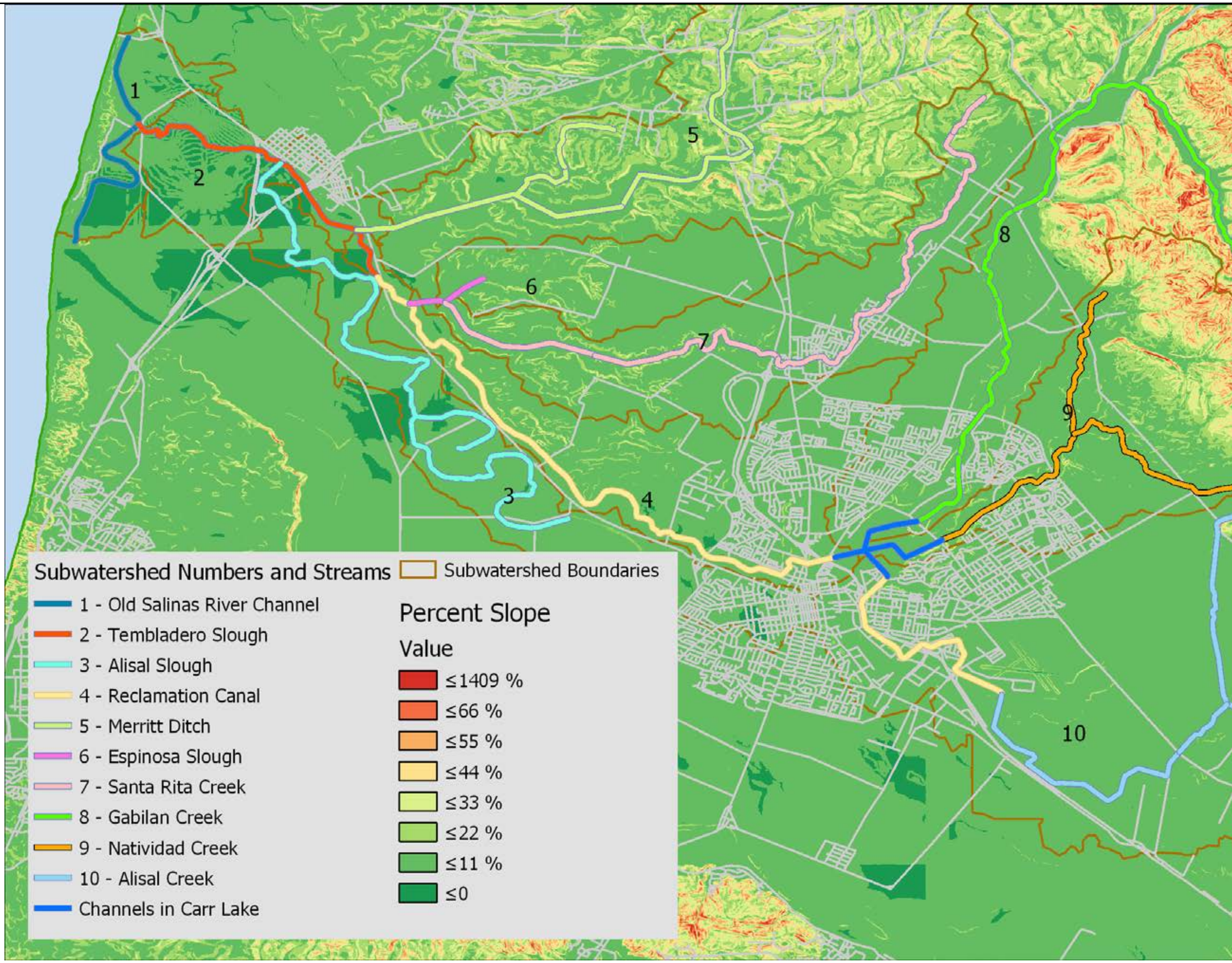

Figure 8. Map of % slopes of lands in the Gabilan Creeek watershed and streams and subwatershed boundaries.

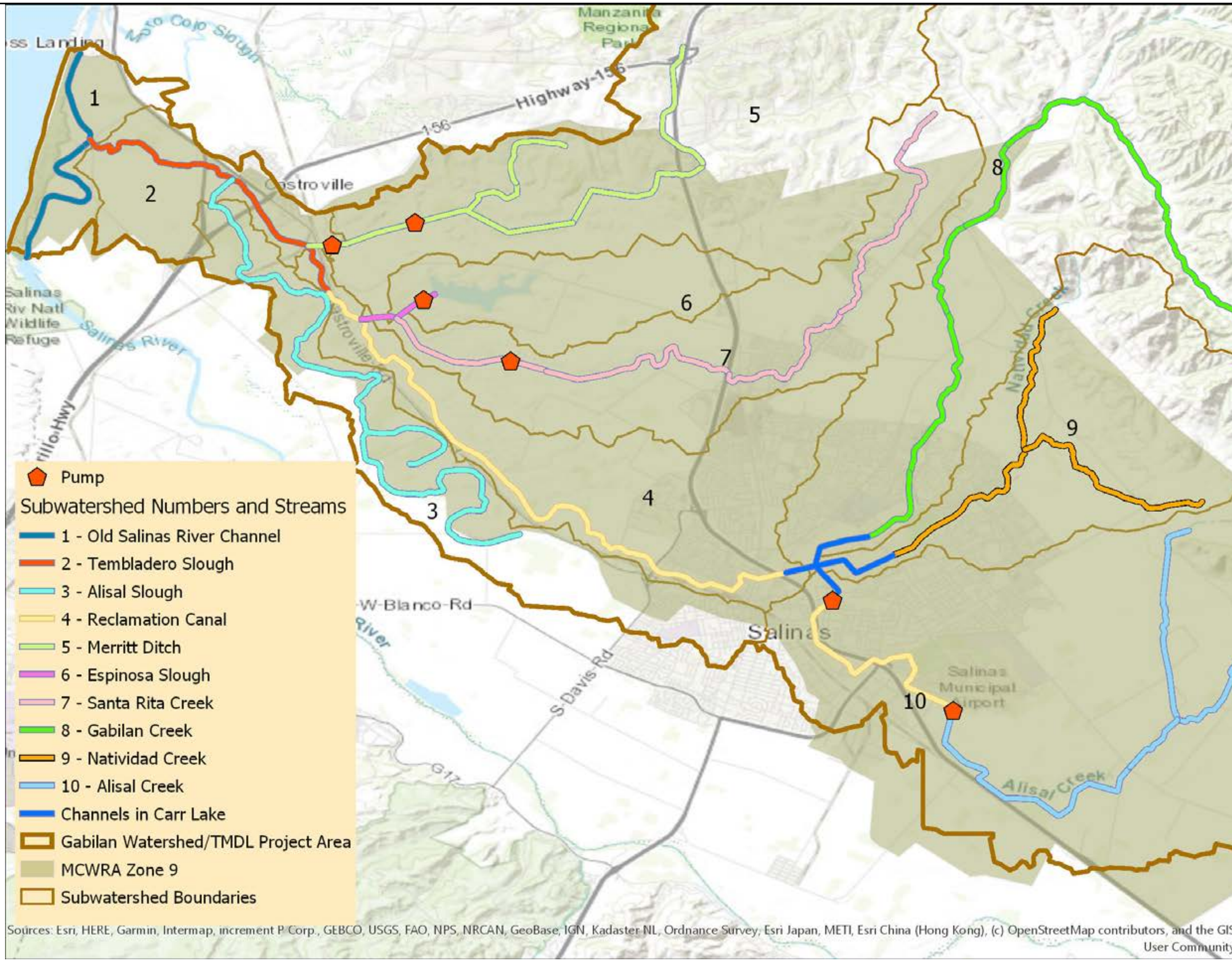

Figure 9. Map showing locations of major surface water pump station in the watershed (MCWRA, 2005).

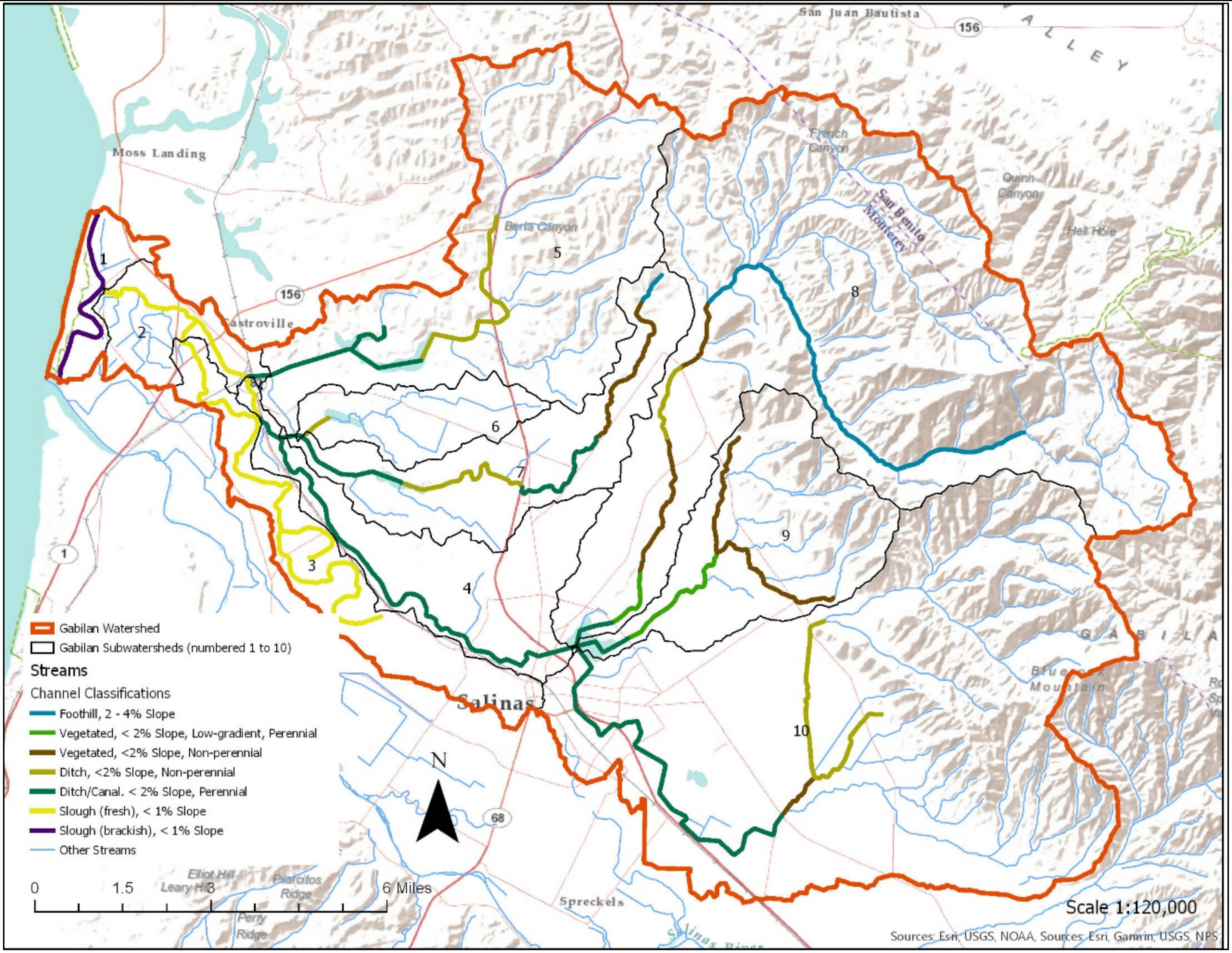

Figure 10. Map of steam channel classifications and subwatersheds in the Gabilan Creek watershed (MCWRA, 2005).

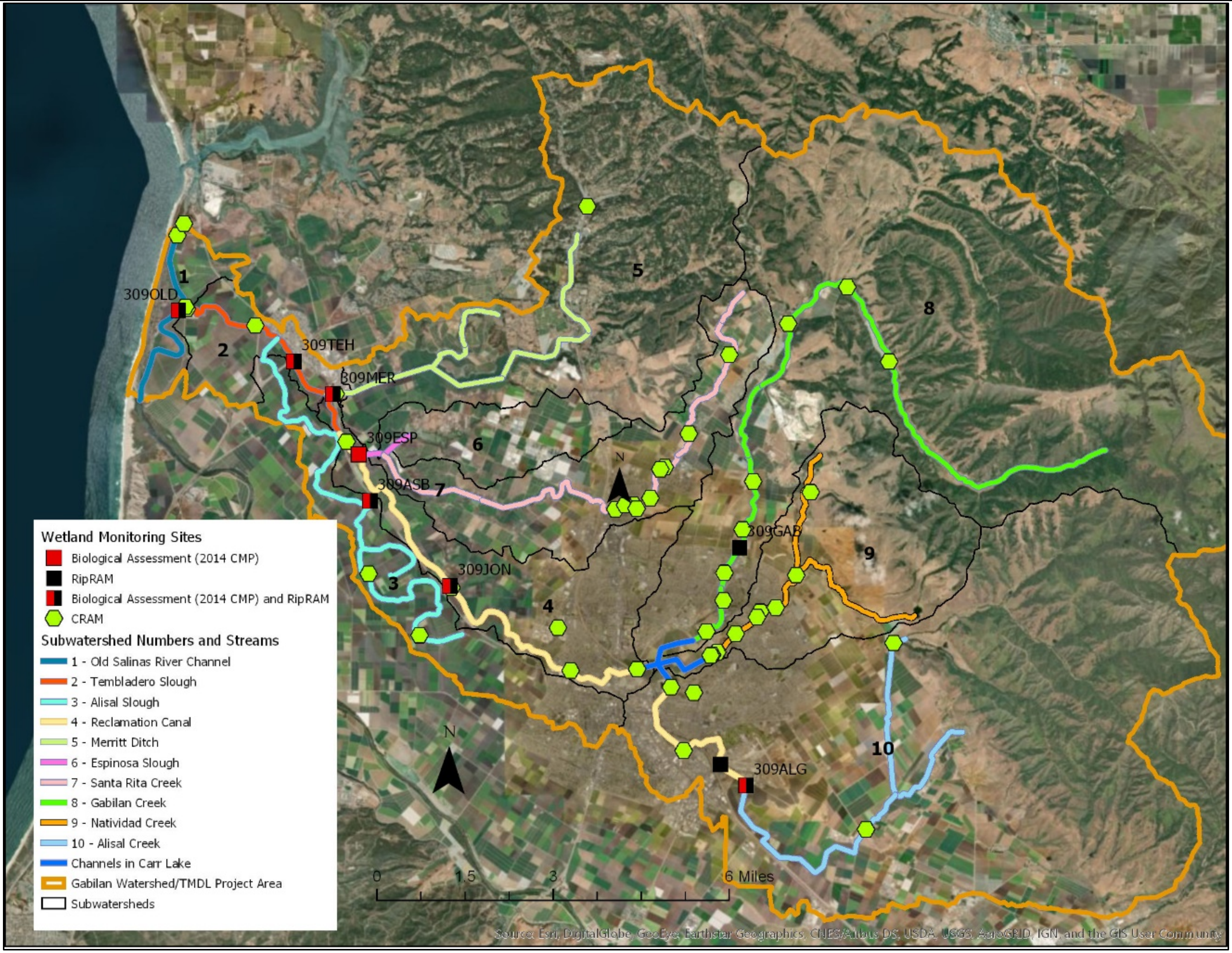

Figure 11. Map of biological assessment, RipRAM, and CRAM wetland monitoring sites.

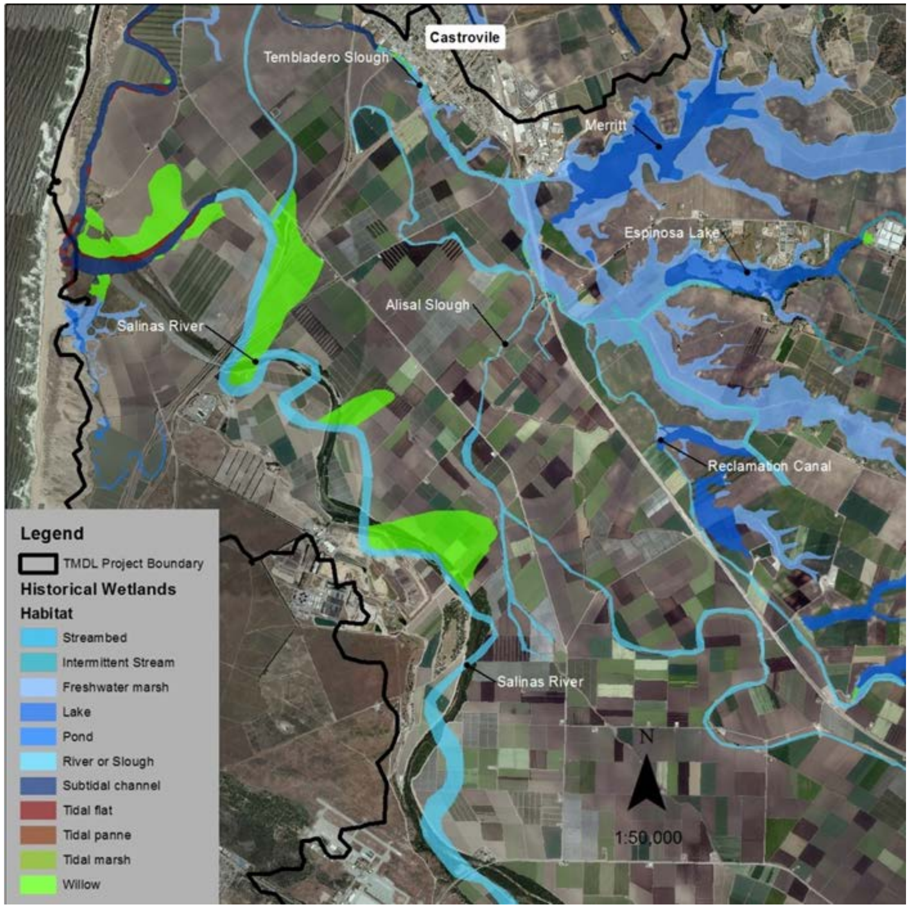

Figure 12. Map of historic wetland in the lower Gabilan Creek and lower Salinas River watersheds.

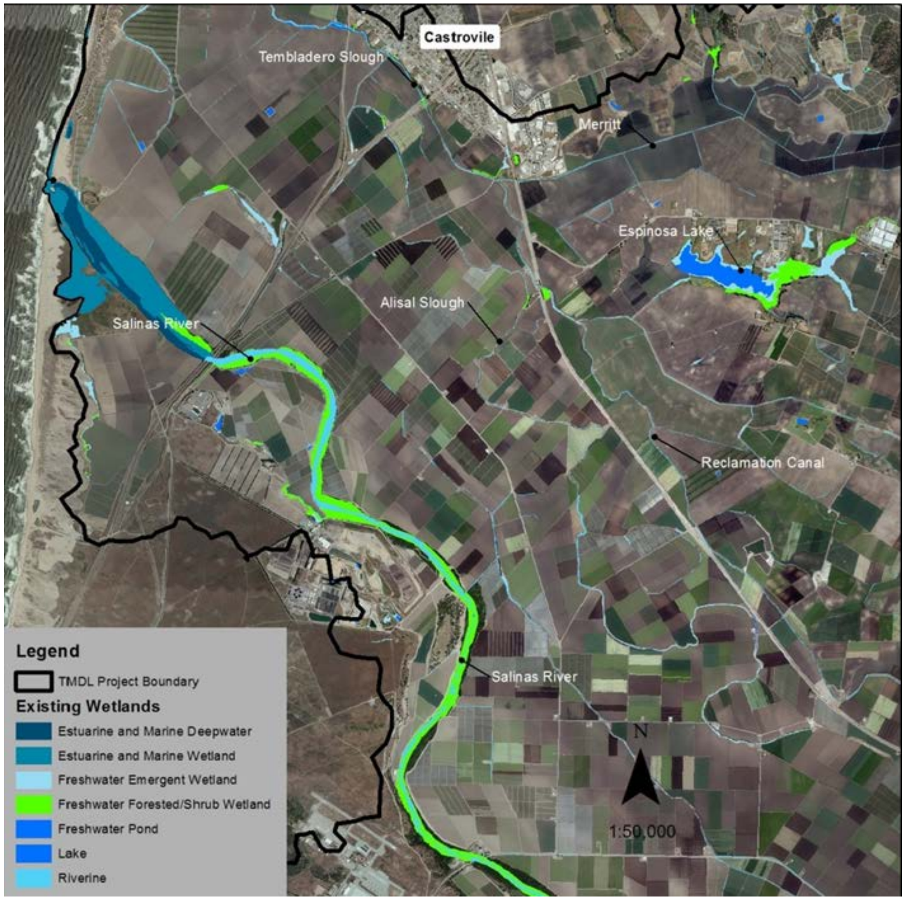

Figure 13. Map of existing wetlands in the Gabilan Creek and lower Salinas River watersheds.

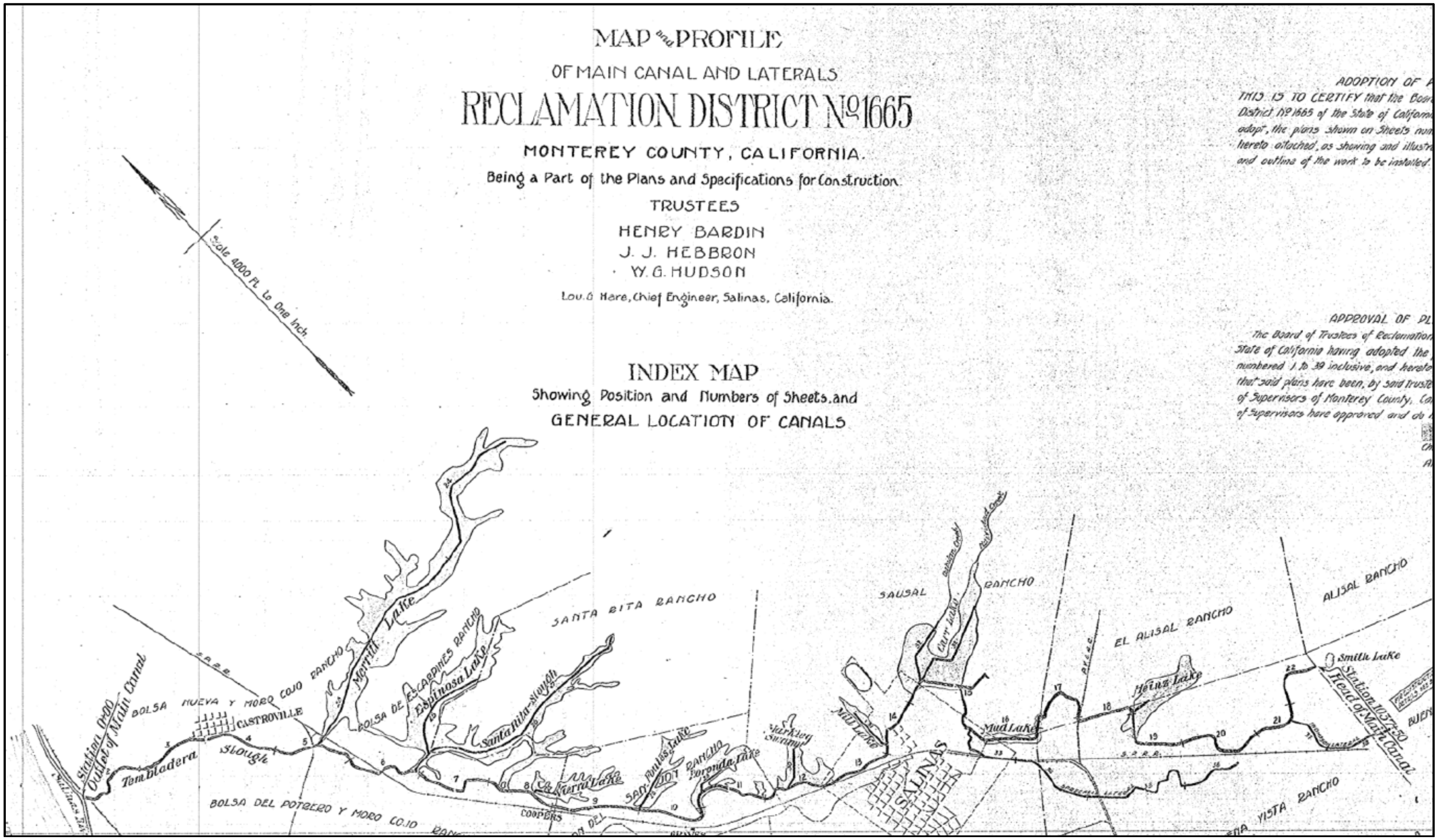

Figure 14. Historic map of the Salinas Reclamation Canal showing historic lakes (light polygons) and constructed drainage channels (darker lines).

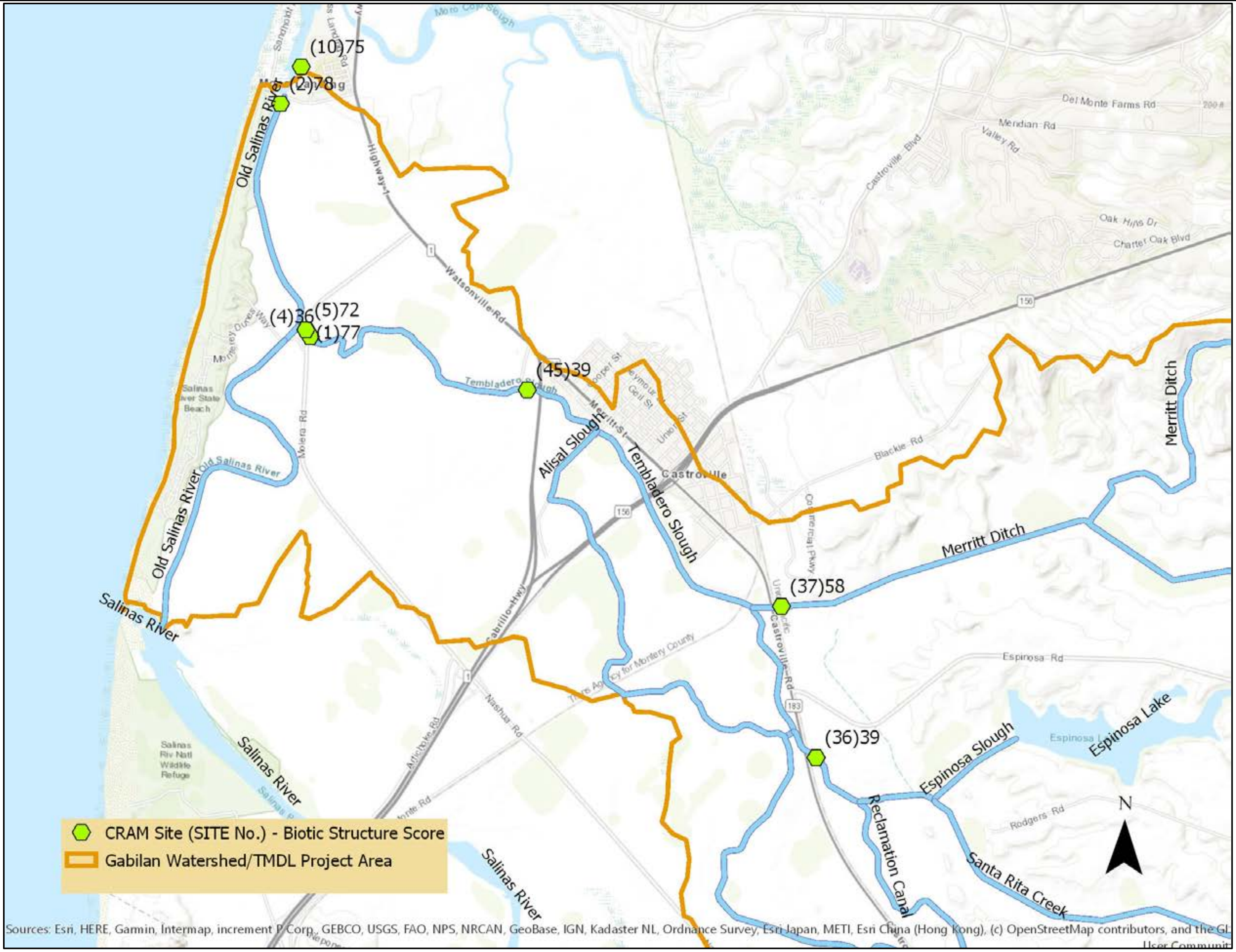

Figure 15. Map of CRAM monitoring sites and the CRAM biotic structure scores in the lower Gabilan Creek watershed. The CRAM site numbers are in parenthesis.

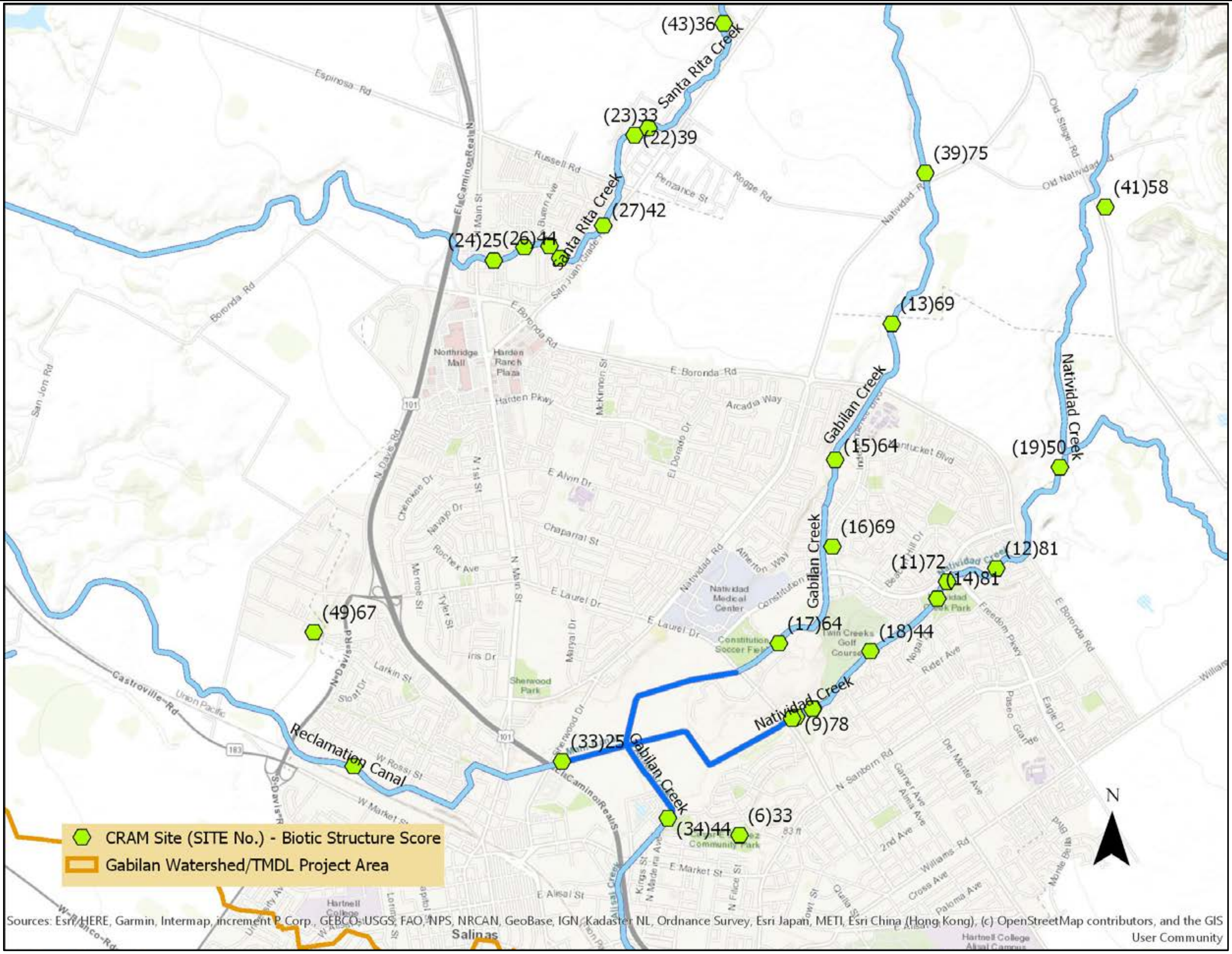

Figure 16. Map of CRAM monitoring sites and the CRAM biotic structure scores in the middle Gabilan Creek Watershed. The CRAM site numbers are in parenthesis.

8. DATA TABLES AND CHARTS

Table 17. Summary of dry season turbidity monitoring data with results as NTU from restoration sites in the Gabilan Creek watershed

Station Code	Number of Samples	10th percentile (NTU)	25th percentile (NTU)	Median (NTU)	75th percentile (NTU)	90th percentile (NTU)	Mean (NTU)	Channel Order
309OLD	131	12	29	75	152	239	127	Main
309TDW	76	29	59	125	183	252	135	Main
309TEM	17	25	38	54	87	126	75	Main
309TEH	69	27	57	88	159	221	158	Main
309ASB	67	6	12	23	42	72	79	Tributary
309ESP	67	6	13	69	217	507	211	Tributary
309MER	69	22	42	76	122	183	131	Tributary
309JON	71	5	17	24	44	86	78	Main
309ALD	47	11	20	38	60	81	44	Main
309GAB	33	6	41	190	371	1911	561	Tributary
309NAD	72	27	53	106	246	523	256	Tributary
309ALG	67	14	27	55	157	244	105	Main
309RTA	20	32	51	94	214	443	542	Tributary

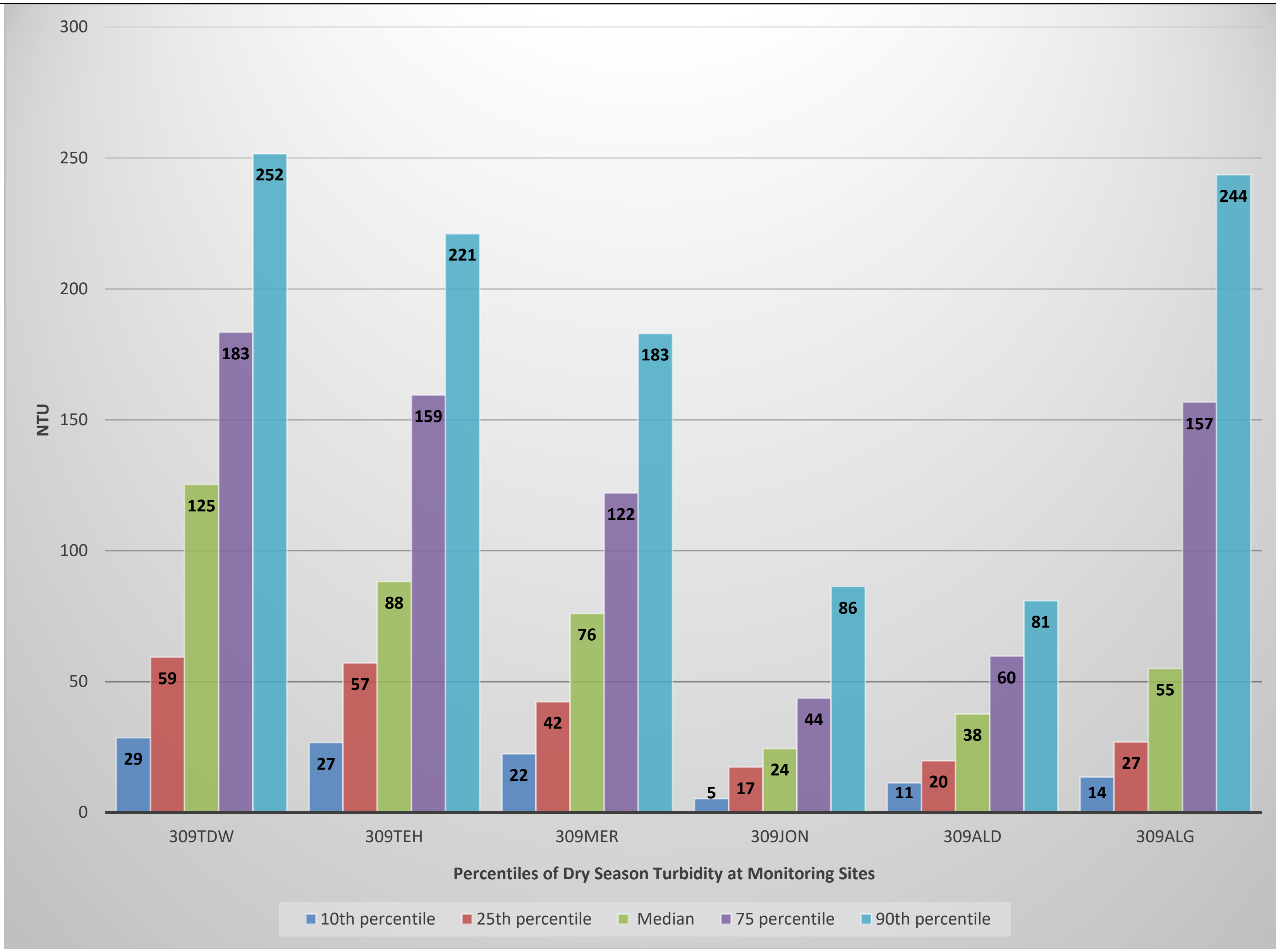

Figure 17. Chart of dry season turbidity levels in NTUs at various percentiles and at five monitoring sites in the Gabilan Creek watershed.

Table 18. Summary of dry season turbidity data from central coast reference sites.

Station Code	Number of Samples	10th Percentile (NTU)	25th percentile (NTU)	Median (NTU)	75 Percentile (NTU)	90th percentile (NTU)	Mean (NTU)
305CAN	31	0.1	1.6	4.6	14.5	32.3	15.1
305CAR	12	1.9	2.55	6.45	15.4	21.82	9.85
305CHI	90	4.6	10.4	29.7	51.1	96.0	65.0
305COR	72	1.6	5.4	13.2	35.2	71.5	33.3
305LCS	64	0.1	1.4	3.6	6.2	12.2	6.4
305SJA	72	0.0	5.6	9.0	16.1	29.0	14.3
305SJN	11	0.9	2.1	3.2	5.1	8.4	4.3
305WSA	52	6.1	12.7	22.2	66.4	152.7	62.1
306WAC	13	0	0	1.3	5.2	10.72	3.4
310CCC	118	0.6	0.9	1.5	2.6	4.0	2.5
310PIS	72	0.0	0.1	2.3	6.5	36.7	10.4
310PRE	80	4.6	7.2	9.9	13.6	19.7	12.1
310SLB	79	0.0	0.0	0.2	1.5	3.1	1.1
310TWB	161	0.0	0.5	1.2	2.4	5.3	2.2
312OFN	80	3.6	4.5	8.4	20.4	50.3	31.8
312ORI	86	4.1	7.6	11.1	29.9	74.6	44.8
313SAI	68	0.0	0.2	2.1	9.0	21.8	7.4
314SYF	63	0.1	1.2	4.0	7.5	13.5	5.9
314SYL	26	0.1	0.2	1.7	3.6	4.1	2.1
314SYN	81	0.1	0.4	1.9	5.6	13.1	4.7
315DEV	10	0.1	11.0	22.6	36.5	183.9	87.6

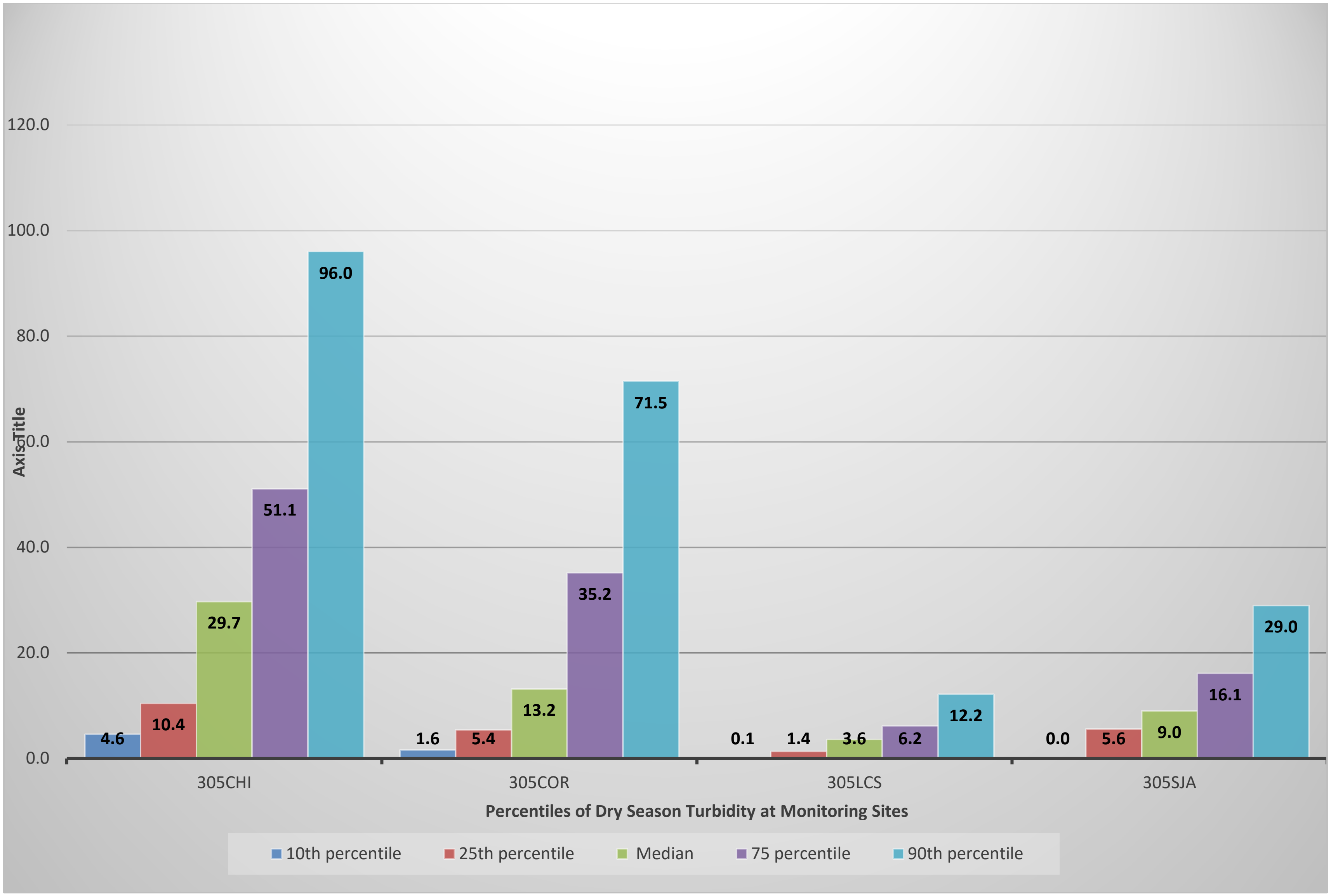

Figure 18.Chart of dry season turbidity at various percentiles and at four monitoring sites in the Pajaro River watershed.

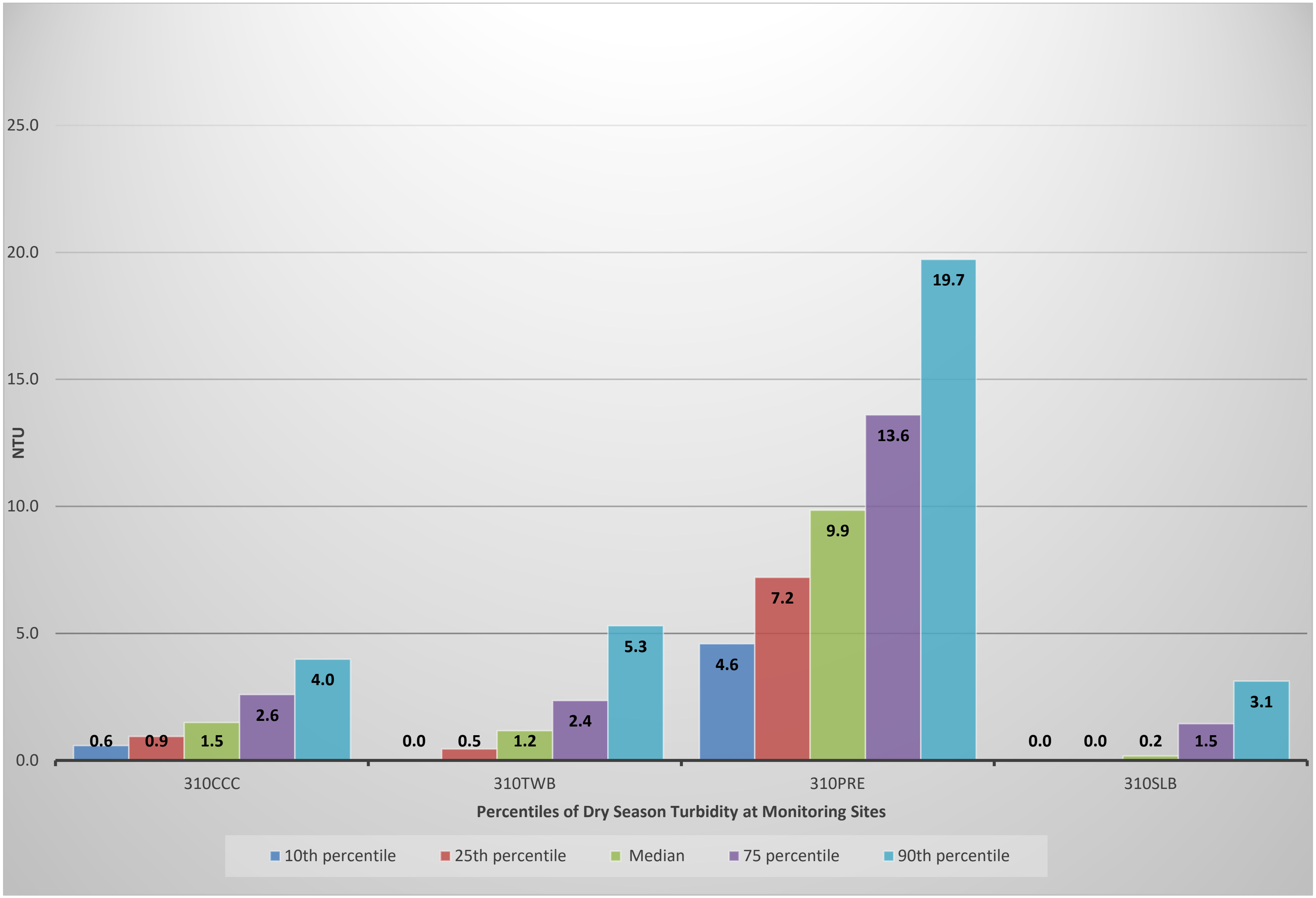

Figure 19. Chart of dry season turbidity at various percentiles and at four monitoring sites in the Chorro Creek and San Luis Obispo Creek watersheds.

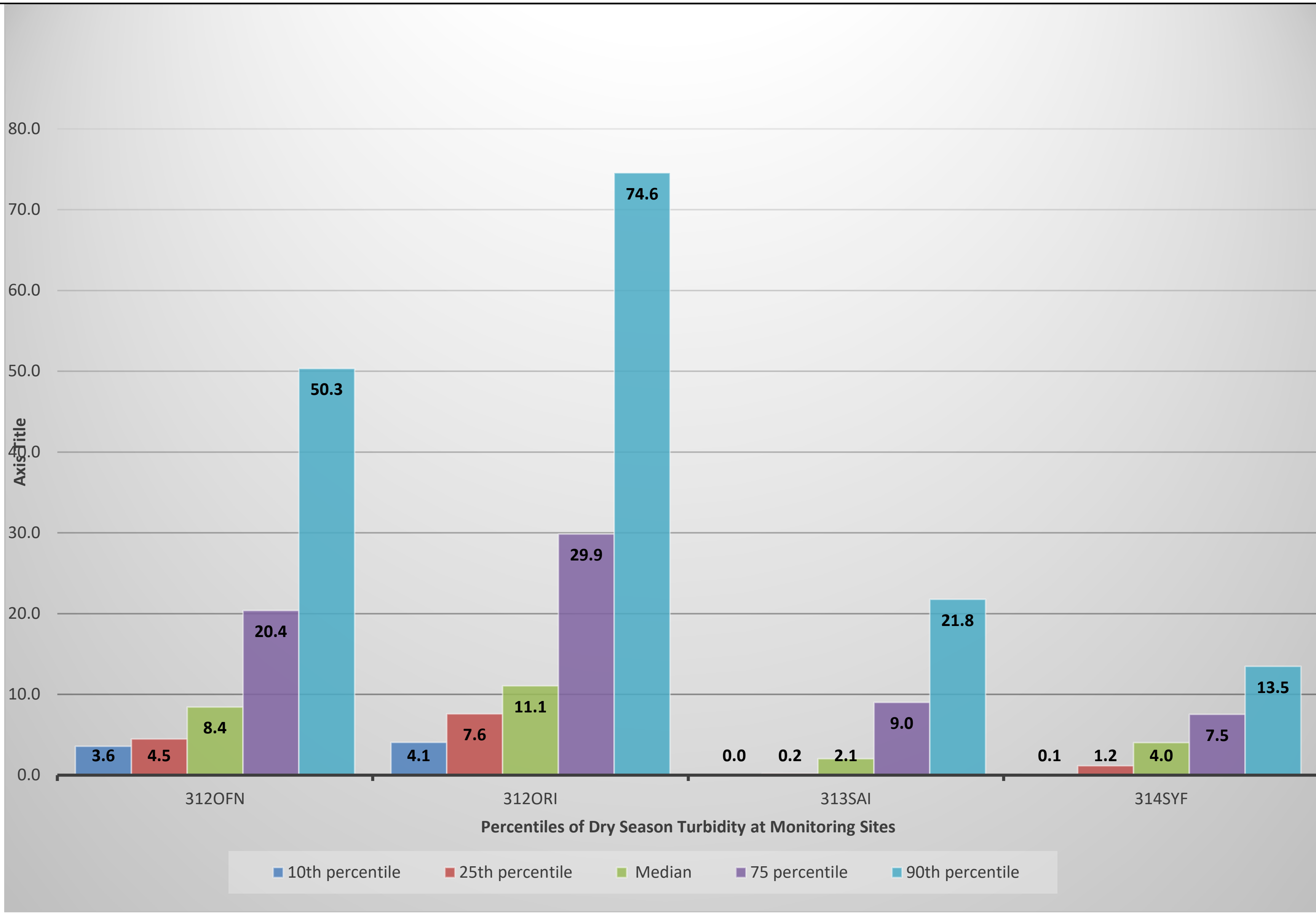

Figure 20. Chart of dry season turbidity at various percentiles and at four monitoring sites in the Oso Flaco Creek, Orcutt Creek, San Antonio Creek, and Santa Ynez River watersheds.

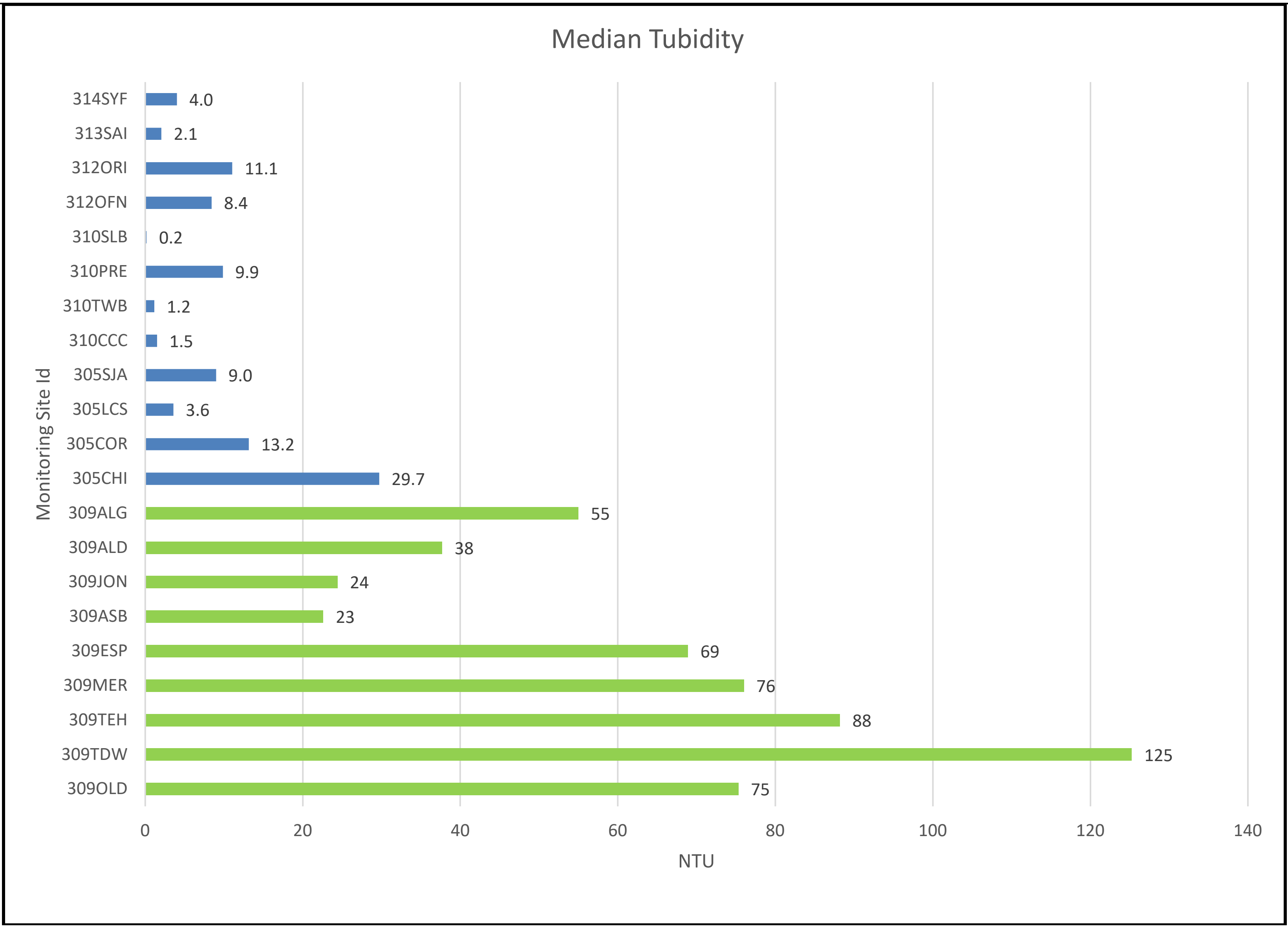

Figure 21. Chart of median turbidity at monitoring sites in the Gabilan Creek watershed (green) and at select reference sites on the central coast (blue).

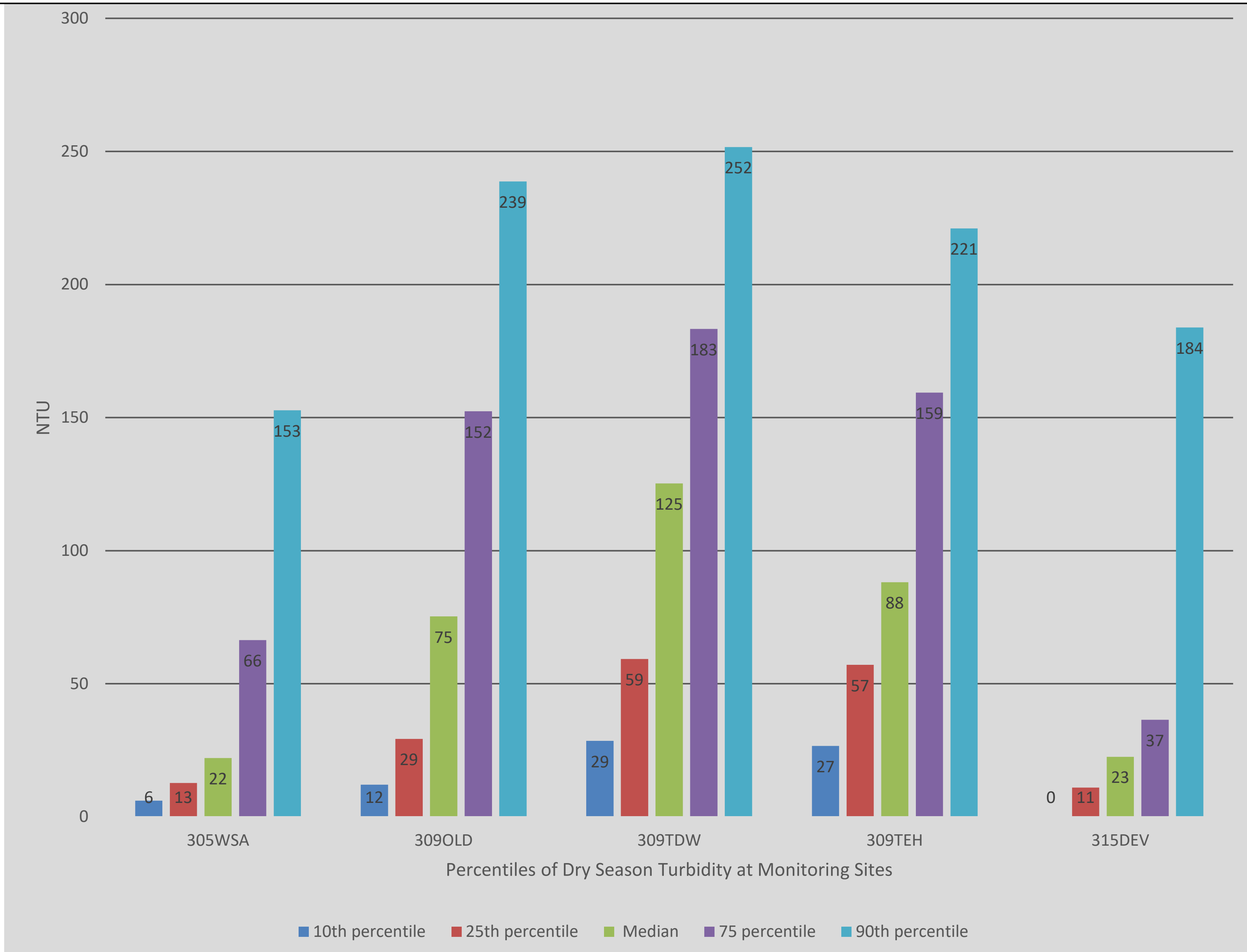

Figure 22. Chart of dry season turbidity at various percentiles and at five slough monitoring sites. Sites 309OLD, 309TDW, and 309TEH are in the Gabilan Creek Watershed and the other two, 305WSA and 315DEV are reference sites.

9. PHOTOS

Figure 24 Upper Gabilan Creek. Photo Julie Hager, Fall 2002, (CCoWS, 2003)

Figure 23. Gabilan Creek downstream from Herbert Road Bridge. Photo: Joel Casagrande, Summer 2000 (CCoWS, 2003)

Figure 25. Photo taken of the Carr Lakebed and channel facing west towards the Pacific Ocean. Source (MCWRA, 2015)

Figure 26. Photo of the Carr Lakebed and channel facing the Gabilan Range. Source (MCWRA, 2015)

Figure 27. Staff photo taken upstream and downstream of Alisal Creek monitoring site 309ALG. The downstream photo on right shows flood control lift pump along bank of Alisal Creek (October 22, 2018)

Figure 28. Staff photos taken of the Salinas Reclamation Canal at the 309ALD site on left and site 309JON on right.

Figure 29. Staff photos of Espinosa Slough (site 309ESP) on the left and Merritt Ditch (site 309MER) on the right.

Figure 30. Staff photos of Tembladero Slough (site 309TEH) on the left and the Old Salinas River (Site 309OLD) on the right.