Hydrology and Water Quality of the Big Sur Land Trust Property in Carr Lake

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Executive Summary

The Big Sur Land Trust, a non-profit land trust organization working in Monterey County, purchased land in a historic lake bed in the center of Salinas, CA with the plan of converting it to a multi-use park. This park will include active and passive recreation opportunities for residents and through a restored wetland system, provide flood mitigation and water quality improvement services to the city.

The idea of creating a multi-use park in the middle of an urban area with high population density has been in existence for decades. Local non-profits, universities, and city planners have included what is called the Carr Lake Project in many plans for restoration and recreation in Salinas. The BSLT is the first organization to obtain land in the central, farmed section of Carr Lake and begin the process of converting agricultural land into a restored, natural landscape.

Four studies have been conducted investigating the benefits of turning Carr Lake into a multi-use flood basin (SWCCE 2002, Cameron et al. 2003, Casagrande and Watson 2007, JLJA 2011), but with the new acquisition of land by the BSLT, more site-specific studies were needed.

The wetland restoration portion of the land is intended to serve four main purposes: water quality improvement, flood mitigation, habitat restoration and recreation. The opportunities for passive, nature-based recreation in the restored areas of the property will be facilitated by trails and boardwalks that encourage visitors out into the natural landscape and give them an opportunity to see native wildlife and plants. Habitat restoration on site should be conducted with a few special status species in mind: the California Tiger Salamander, the California Red-legged Frog, and the South-Central California Coast steelhead. All three of these special status species have been observed higher up in the watersheds that feed into Carr Lake (Casagrande and Watson 2007).

This report focuses on the remaining two restoration goals of water quality improvement and flood mitigation. In order to inform the design of the wetland restoration, a better understanding of the hydrology of the creeks flowing into the BSLT site was needed. A detailed watershed delineation, adding in the city stormwater drainage system, showed that Hospital Creek is a larger watershed than previously understood. It is indeed a flashy system, with entirely urban runoff feeding the creek. The watershed delineation showed that Gabilan Creek has a similarly sized impervious surface area to Hospital Creek, creating an element of fast, urban runoff in that creek as well. The Gabilan Creek watershed is larger in size than Hospital Creek and includes a large portion of agricultural land and mountainous land. This leads to a longer flow period. At the beginning of a rainfall event, Gabilan Creek can begin flowing quickly with water from the urban section of the watershed, but the water from the upland areas will take longer to reach Carr Lake.

Informal observations were made at the site and at upstream creek crossings during rain events. As rainfall increased on both sampling days, the water began backing up at the downstream Reclamation Ditch culvert at Main St. The creeks were all responsive to the rainfall and began flowing and then backing up quickly. Streams flooded, and the landscape became a lake, which is its historic and periodic condition.

Analysis of the data and reflecting on observations after the rain events led us to make multiple conclusions about the site: while being completely dry in summer, there is an element of baseflow coming from urban runoff and agriculture irrigation (Ballman et al. 2015). Hospital Creek is a substantial watershed that is flashy, while Gabilan Creek has a flashy component similar to Hospital Creek but also a larger long-term component. The channels in Carr Lake flood early and become connected due to the backwater effect from the North Main St. culvert, and this makes it impossible to estimate discharge from the stage. Carr Lake lives up to its name and functions as a lake once the channels fill. These key findings need to be taken into account when designing wetland and landscape features at this site.

Baseline water quality monitoring was needed to inform how the treatment wetland-element of the site should be designed. A comprehensive spectrum of samples was collected and examined for the presence of various water quality analytes. Sampling took place during a “first flush” event on November 21, 2018 and during a high-flow event on November 29, 2018. Notable results are the high count of fecal coliforms, the high amount of Total Suspended Solids (TSS), detection of several pesticides, and high ammonia and orthophosphate levels, but lower than expected nitrate. A follow-up analysis explained the low nitrate levels in terms of dilution by high levels of urban runoff (not normally considered a substantial source of nitrate) as well as seasonal timing (samples were collected at a time of year when in-stream nitrate concentrations are typically at their lowest, very late in the annual agricultural cycle).

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Glossary

Term	Definition
Aggradation	deposition of sediment in a channel
Analyte	the chemical being analyzed
Baseflow	streamflow discharge generally arising from subsurface flow pathways (i.e. groundwater), as opposed to direct surface runoff during and immediately after rainfall events.
Discharge (Q)	the volume of water passing a section of a stream in unit time
Dissolved Organic Carbon (DOC)	measure of organic carbon that can pass through a filter
Dissolved Oxygen (DO)	the amount of oxygen dissolved in water
Elevation (Z)	height above sea level
First Flush	initial runoff from a rainstorm where pollutants are most concentrated
GEOID12B Model	well accepted geoid model of the earth
Stage	water level above some arbitrary point, determined by a staff plate (measurement stick) or pressure logger
Thalweg	a line along the lowest point of a river channel
Total Dissolved Solids (TDS)	measure of total organic and inorganic substances (other than H_2O) dissolved in a water sample such as minerals, salts and organic matter
Total Organic Carbon (TOC)	measure of carbon, both fine and coarse
Total Suspended Solids (TSS)	solids, like clay particles and slit, suspended in the water column
Water Surface Elevation (WSE)	elevation of water surface above sea level

1.0 Introduction

1.1 Background for Carr Lake Area

Much of the history of Carr Lake may be gleaned from previous reports relating to development of the Carr Lake area into a multi-use park. This introduction is summarized from Cameron et al. (2003), Casagrande and Watson (2005, 2007), and Senter et al. (2017).

Carr Lake was the largest of seven small lakes that existed along the western slope of the Gabilan Range in the Salinas Valley in central California (Fig. 1). At the turn of the 20th century, European settlers began to drain the lakes and wetlands to create farmland. Jesse D. Carr did so in 1890 with the area that came to be called Carr Lake (Anderson 2000; Breschini et al. 2000). In total, about 182-hectares (450 acres) was reclaimed. The recurrent flooding of the City of Salinas from spillover from Carr Lake

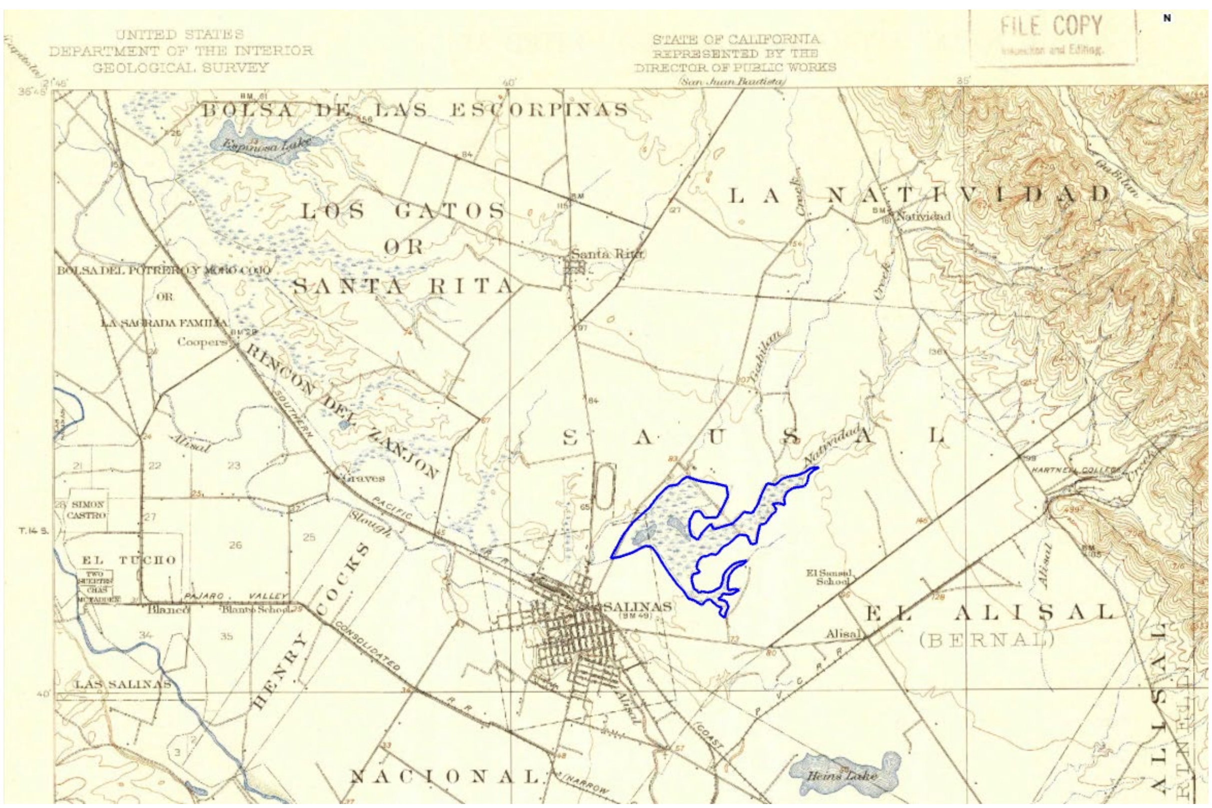


Figure 1. United States Geological Survey (USGS) Topographical map from 1912, Carr Lake is highlighted in blue.

prompted the construction of the Reclamation Ditch, which was completed in 1920. This ditch was built at a time when the population of Salinas was about 3,000 people and the land cover was still mostly wetland and agricultural fields. This ditch channelized the creeks to more effectively move water out of the fields and towns and quickly out to the sea. The Gabilan, Natividad, and Alisal Creeks that fed Carr Lake were also channeled into ditches and flowed through the converted agricultural field, keeping the fields as dry as possible. Jesse Carr sold the land to three Japanese families in the 1920s, some who still farm the land today.

Due to the topography of the area, the reclaimed Carr Lake area still floods frequently. The FEMA regulatory floodplain overlays the historic area of lake bed perfectly (Fig. 2) and any changes that are made in future development must maintain the current flood capacity. Carr Lake sits in the middle of Salinas and serves as a critical water detention

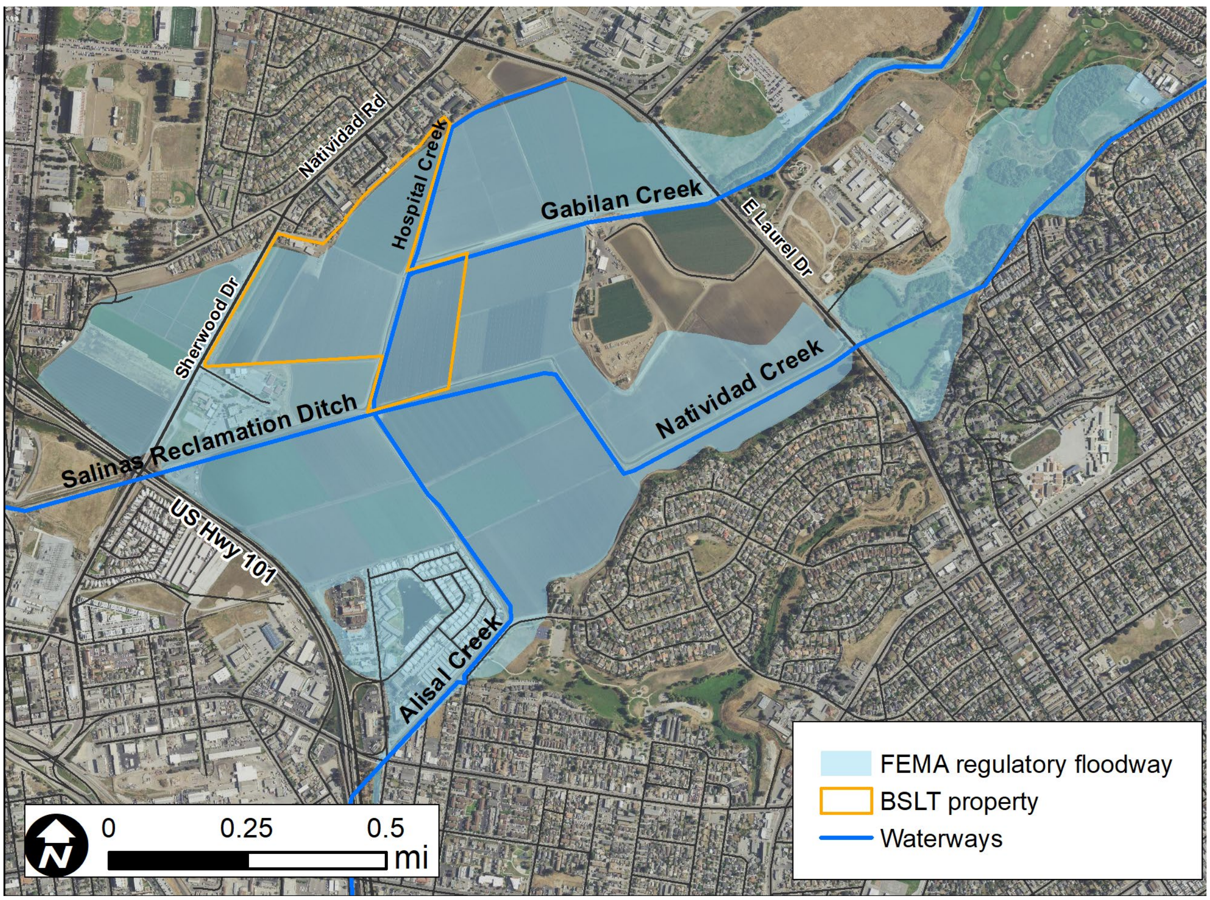


Figure 2. Extent of the Big Sur Land Trust (BSLT) property and corresponding FEMA floodway zone. Most of the BSLT property and all of Carr Lake is within a FEMA regulatory floodway zone. This means that all changes to the landscape must maintain the current flood capacity.

area and the Gabilan, Natividad, and Alisal watersheds drain into the lake during rainy winters (Kennedy/Jenks Consultants 2006). The Carr Lake site is now almost completely surrounded by impervious, urban land cover, which quickly transports any rainfall directly into the creeks and ditches shortly after rainfall begins. Once the water leaves the Carr Lake site, it is conveyed by the Reclamation Ditch to Tembladero Slough and eventually out to the Monterey Bay National Marine Sanctuary via the Old Salinas River and Moss Landing Harbor.

1.2 Long Term Objectives for Carr Lake Project

The entirety of Carr Lake has long been identified as a potential opportunity for flood mitigation, water quality improvement, habitat restoration, and open space development. The City of Salinas has included "The Carr Lake Project" in its Economic Development Element of its General Plan (City of Salinas 2014). The project has many stakeholders, including the residents of Salinas, the City of Salinas, the Watershed Institute of California State University Monterey Bay, and the Big Sur Land Trust.

With major flooding events in 1995 and 1998, the community became aware of the need for a change in stormwater and runoff management. More development is predicted to occur upstream of the Carr Lake site (City of Salinas 2014), creating even more impervious surface area that will drain directly into Gabilan and Natividad creeks before flowing to the lake. As urbanization increases, urban flooding increases in tandem, threatening lives, property and the economy (Nirupama and Simonovic 2007). This is offset by increases in stormwater management within the City of Salinas, but the fields in Carr Lake are still greatly affected by large precipitation events.

1.3 Long Term Objectives for 73-acre Site

The Big Sur Land Trust (BSLT) is a non-profit, accredited land trust organization with a mission to inspire a love of the land, conserve unique Monterey County landscapes, and provide outdoor access to all. They had been communicating with the Ikeda family, one of the three original landowners in the Carr Lake area, for nearly 10 years about purchasing a portion of their land (Wu 2016). In January 2016, the trust purchased 73-acres from the Ikeda Farms Partnership for $3.95 million with funding provided by California State Coastal Conservancy, the California Natural Resources Agency River Parkways Program, David and Lucile Packard Foundation, Monterey Peninsula

Foundation, and Barnet Segal Charitable Trust (BSLT 2018). In January 2017, BSLT took ownership of the land.

The BSLT's conserved properties have historically been located in more remote locations and focused on protecting unique and sensitive landscapes. The Carr Lake site is the trust's first urban project. BSLT have stated that converting the farmland into a multi-benefit park will be transformative for the City of Salinas and its residents. BSLT staff have organized a series of community meetings with the goal of co-designing the park with the local residents. While the property was purchased with the goal of mitigating floods and improving water quality, the plan is to make it a multi-benefit park that also serves to bring residents outside and into nature. A 7-acre portion of naturally high ground has been set aside to be developed with active recreation options, possibly including picnic areas, basketball courts, and other features. This area will also include passive water quality treatment and flooding mitigation installations to help reach the goals set for the whole property of improving water quality. The remaining 66 acres of park will consist of the restored wetland habitat, and will include more passive recreation opportunities, including walking paths and raised boardwalks through the natural habitat. Four community meetings were held in Fall 2018, with presentations in both English and Spanish and input from participants was integrated into the development plans. A final park plan will be designed in 2019 and fundraising for park construction will likely begin in 2020/2021 (BSLT 2018).

1.4 Objectives

Our goal was to contribute to the knowledge of existing ("baseline") conditions at the 73-acre BSLT site with respect to hydrology and water quality. This baseline data is critical in determining the success of the proposed wetland habitat that the BSLT will be creating in the near future. A secondary goal was to inform the BSLT and their consultants about site-specific trends, like the propensity to flood and aggrade with sediment, that will help guide the design process.

1.5 Study Area

Carr Lake currently consists of agricultural fields surrounded by urban lands in Salinas, California (Fig. 3). Gabilan, Natividad, and Alisal Creeks capture water from the Gabilan

Range, bringing in runoff from steep mountains, grazing, row-crops, and agricultural areas, including urban runoff. Hospital Creek primarily captures urban runoff. These creeks collect in the Salinas Reclamation Ditch. Water flow is limited at four culverts around the BSLT parcel. These are located where Gabilan and Hospital creeks meet, on Gabilan creek upstream the BSLT parcel, and two on the Salinas Reclamation Ditch. Where all four creeks meet is a bridge that is commonly known as the "Four Corners".

We chose four sites where we collected data and preformed fieldwork (Fig. 3). These sample sites were on the BSLT parcel located on Hospital Creek, Gabilan Creek, downstream both creeks, and just upstream of the "Four Corners".

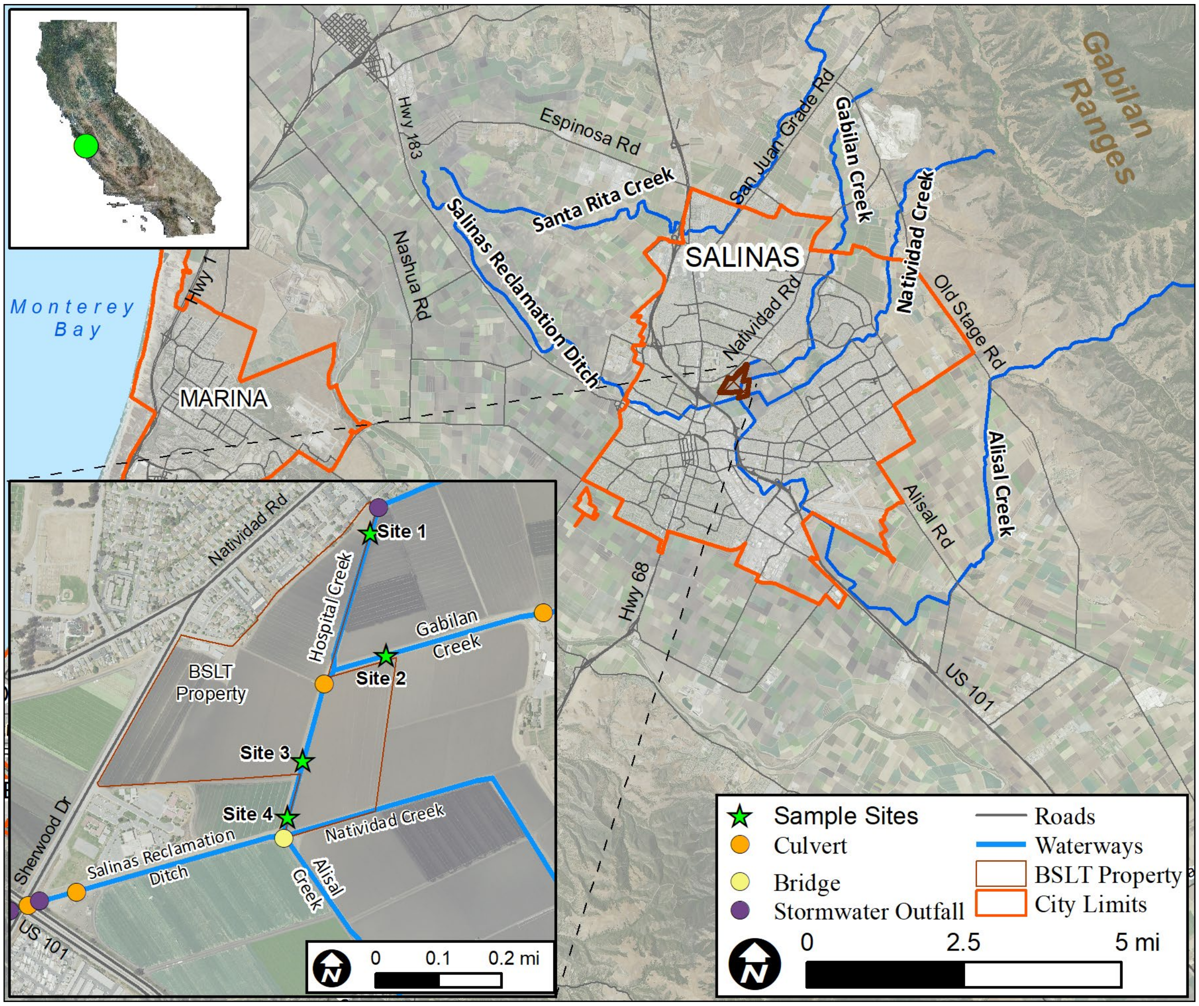


Figure 3: Study area in Salinas, CA with a zoom inset on the BSLT property and water quality sampling sites.

2.0 Watershed Delineation and Urban Land Area Calculation

Watershed delineation is an important component of understanding the hydrology of a specific area. In order to assess land use impacts on a watershed, an accurate delineation of the watershed extent is required. We delineated the watersheds of the two primary creeks, Gabilan and Hospital, that carry water through the BSLT's property in Carr Lake. Contrary to previous delineations, we incorporated the city of Salinas' stormwater drain system into the delineation model, which improves the accuracy of the watershed boundaries. Once the extents of the watersheds were determined, we calculated the areas of their respective landcover classes. We focused on impervious surface cover because it produces more surface runoff than most landcover types during precipitation events. Runoff from impervious surfaces such as concrete and asphalt consequently increase the flashiness of streams and also transports pollution directly to surface waters. (Kayembe and Mitchell 2018).

2.1 Previous Watershed Estimates

The entire watershed for the reclamation ditch which includes Gabilan, Hospital, Natividad, and Alisal Creeks was determined by Casagrande and Watson (2006) (Fig. 4) but there is still some ambiguity for the subwatersheds of Hospital Creek and the lower portion of Gabilan Creek. We delineated the Hospital Creek and lower Gabilan Creek watersheds because their boundaries were poorly understood. Hospital Creek may be a potential substantial source of runoff to the BSLT site in addition to Gabilan Creek. Previous watershed delineations include Hospital Creek as a part of the Gabilan Creek watershed (CRWQB 2013) but did not incorporate city infrastructure into the analysis. Using storm drains to specify flow direction allows Hospital Creek to be distinguished as a separate subwatershed from Gabilan and improves the accuracy of the delineation.

2.2 Methods

The watershed delineation procedure was characterized by two notable technical elements: (1) use of high-resolution LiDAR (AMBAG 2010) terrain data, and (2) 'burning' municipal storm drain information into the terrain data. We mosaiced the LiDAR dataset using ArcMap (ESRI 2017) to cover the extent of the city of Salinas and the area north of East Boronda Road. A hillshade layer was then created from the mosaic to emphasize

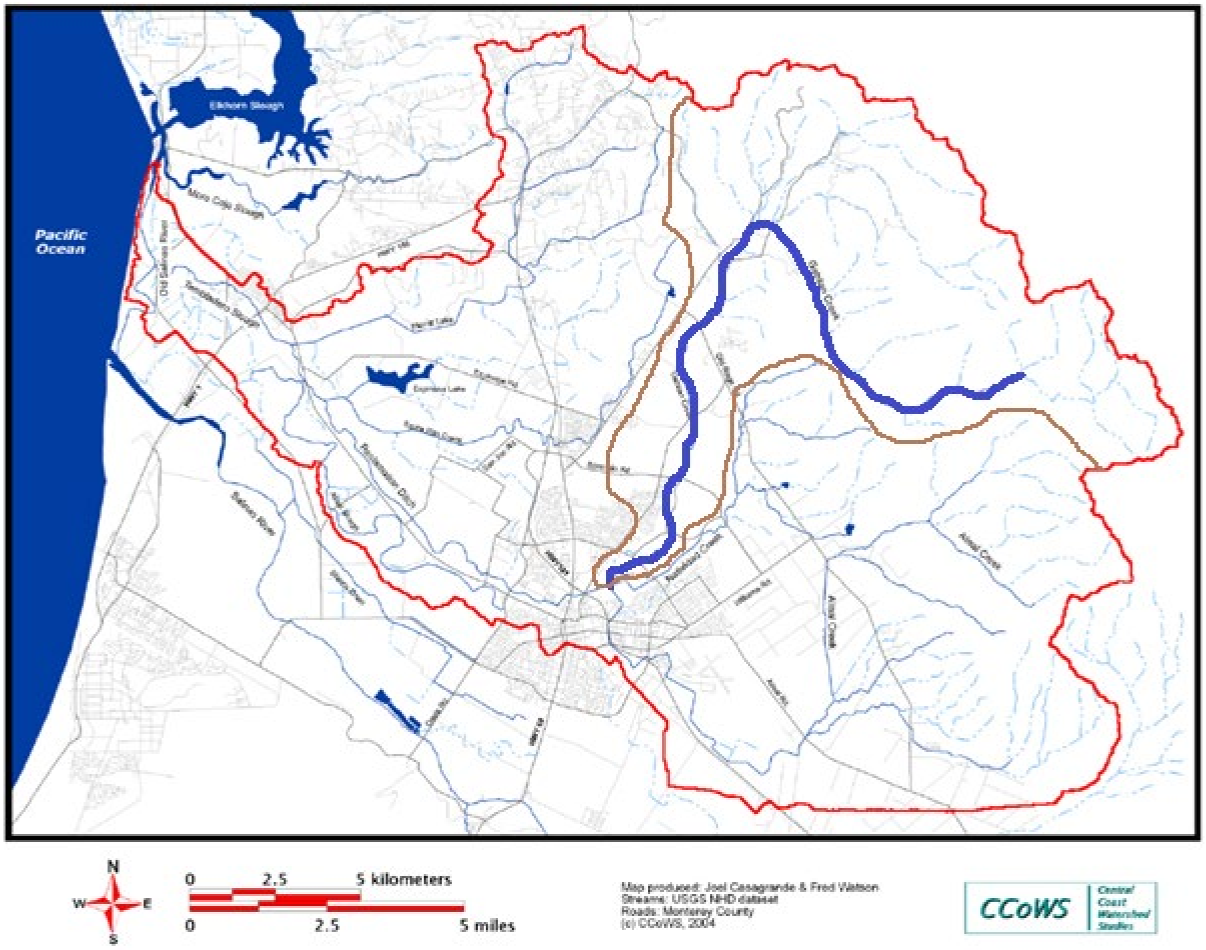


Figure 4. Previous watershed delineation of the entire watershed for the Reclamation Ditch which includes Gabilan, Hospital, Natividad, and Alisal Creeks (Casagrande and Watson 2006). The brown line represents the general extent of the Gabilan watershed with Gabilan Creek highlighted by the thick, blue line (Rose et al. 2013).

elevation features. Storm drain shapefiles provided by the City of Salinas (2018) were merged to one shapefile, then transformed to a raster. To create a more accurate subwatershed of Hospital Creek, storm drains were incorporated in the LiDAR dataset by "burning" (subtracting from the original LiDAR elevation) 33 feet deep. We added a 30 ft buffer to the storm drain layer to account for potential errors in the burning process. Additionally, bridges were burned at junctions where water flowed beneath them, and some riparian vegetation was burned to allow the flow to follow the most accurate path. We filled spurious holes and assigned flow direction. The final steps of the delineation were flow accumulation and designation of subwatershed boundaries (Fig. 5).

We calculated percent impervious cover based on the National Land Cover Database (NLCD) land cover classes (USDA 2011). Categories of development were tabulated within Hospital and Gabilan Creek watersheds and results were exported to Microsoft Excel. High, medium, and low intensity development were combined and used to calculate the percent and area of impervious cover (Table 1).

The following is a breakdown of the specific steps constructed in ArcMap's Model Builder:

- Mosaic LiDAR tiles
- "Burn" storm drains into DEM. Burn gaps through bridges, riparian areas and other manually identified areas where the surface DEM failed to represent the actual flow pathway.
- Fill spurious sinks using Hydrology Fill tool
- Make Flow direction map using Hydrology Flow Direction tool
- Make Flow accumulation map using Hydrology Flow Accumulation tool
- Make stream vectors from accumulation raster using MapAlgebra, and convert resulting raster to stream vector using Hydrology Stream to Feature tool
- Verify streams and set pour points to LiDAR-implied streams in a manual edit session
- Make watershed raster map using Hydrology Watershed tool
- Convert watershed raster to polygon using the Raster to Polygon tool
- Inspect watershed polygons and use Dissolve tool to eliminate false boundaries
- Compute watershed area by adding a new field and calculating the area
- Summarize the NLCD developed categories within subwatersheds using the Tabulate Area tool

2.3 Conclusion

Hospital Creek is not just a ditch for agricultural drainage but has a substantial watershed of 0.76 mi^2. This watershed is highly impervious, with 0.63 mi^2 of roads, buildings, and parking lots creating a flashy system that moves water quickly through the region. Gabilan Creek, while often thought of as being largely agricultural and mountainous, has an equally substantial and highly flashy impervious urban component (0.87 mi^2). Due to this rapid flow, wetland development in Carr Lake must have the capacity to accommodate a quick influx of large amounts of water. Hospital Creek watershed and Gabilan Creek watershed can now be seen as two separate flow and pollution inputs to Carr Lake as opposed to one system.

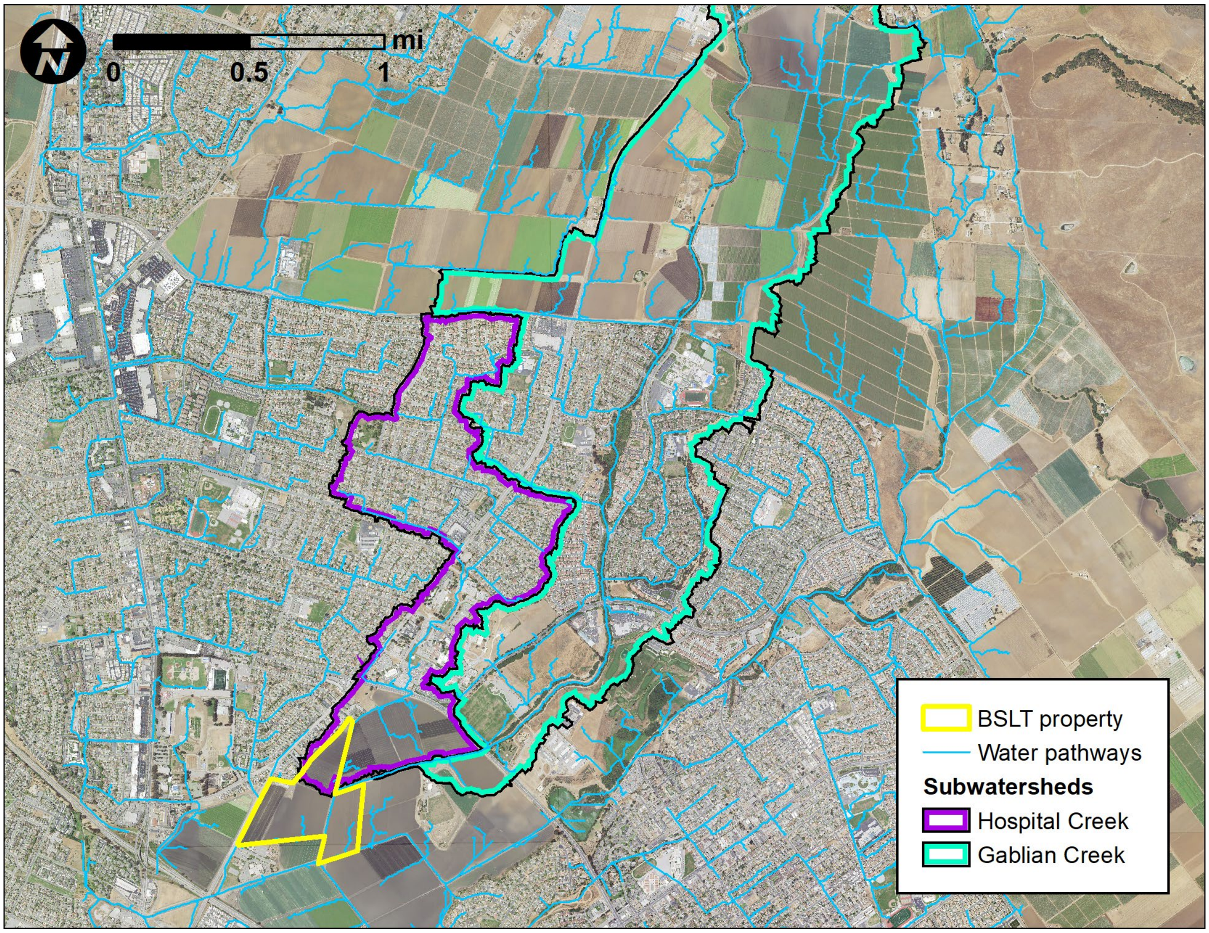


Figure 5. Hospital Creek and lower Gabilan Creek watershed extents with water pathways in relation to the BSLT property location in Carr Lake. Note that the majority of the Gabilan Watershed lies beyond the northern boundary of this figure.

Table 1. Summarized total area, city area, and impervious cover of subwatersheds south of East Boronda Rd. Gabilan and Hospital Creeks have comparable impervious surface cover.

Feature	Gabilan Creek	Hospital Creek
Total Watershed area	43.7 mi^2	0.76 mi^2
Watershed area south of E. Boronda Rd.	1.17 mi^2	0.76 mi^2
Impervious cover	0.87 mi^2	0.63 mi^2

3.0 Longitudinal Profile

A longitudinal profile of creeks in the study area with the elevations of culverts gives insight to the hydraulic constraints present at Carr Lake. Balance Hydrologics (2015) produced a similar product, however, the survey from that document spans several pages for each creek. The goal of this chapter is to show all channel profiles and culverts in a single figure so that the hydraulic interactions among them may be better understood.

3.1 Methods

We used LiDAR data from 2010 (AMBAG) to extract thalweg elevations along each of the five stream segments (Hospital, Gabilan, Alisal, Natividad, Reclamation Ditch) within Carr Lake. The minimum elevation along perpendicular lines every 10 meters along each segment was extracted to represent the thalweg elevation along each stream at a distance from Four Corners. The steps we took to extract thalweg elevation in ArcMap 10.6 (ESRI 2017) included:

- Create a polyline for each segment starting from Four Corners based on LiDAR raster
- Convert each polyline to a merged route layer using "Create Routes" tool
- Create excel sheet for each segment with a column for ID, Location, and Offset
    - Divide total length of stream by 100 and list distance along stream (starting from 0, ending with total length of stream) in "Location" column
    - "Offset" of five meters from the stream indicated as '5' and '-5' for perpendicular points' location
- Import Excel as '.csv' sheet into ArcMap Table of Contents
- Use "Location" and "Offset" columns within the "Make Event Route" tool to create perpendicular points offset by five meters on both sides of each route layer
- Export these event points as a shapefile using "Feature Class to Shapefile" tool
- Create lines between these points to create perpendicular lines along each route using "Point to Line" tool

- Use “Zonal Statistics” to extract minimum elevation value from LiDAR along each of these perpendicular lines
- Convert resulting thalweg elevations to feet
- Export table of elevations at a distance from Four Corners

The elevations and descriptions of the Sherwood Drive and North Main Street culverts were taken from Balance Hydrologics (2015). We used our surveyed elevation of the culvert on BSLT property. The longitudinal profile was plotted in R (R Core Team 2017).

3.2 Results

The longitudinal profile of the study area is displayed in Figure 6. The 2018 surveyed elevation on Gabilan Creek upstream from the BSLT culvert is several feet lower than apparent from the 2010 LiDAR elevation. We attribute this to recent excavation of the channel bottom as evidenced by a ~1300 ft long pile of excavated material placed next to the channel.

The North Main Street culverts are a two-level system consisting of a lower 36-inch culvert which transports low flows and two upper 8 ft box culverts which become the outflow during high flow conditions (Fig. 7). It is well documented that the North Main Street Culverts are a choke point for water exiting Carr Lake (Schaaf and Wheeler 1999). The North Main Street culverts have the greatest control of stage at Carr Lake, with the invert of the upper 8 ft box culverts being 0.5 feet higher than the most upstream and highest thalweg elevation on BSLT property at Hospital Creek, suggesting that the entire BSLT property experiences backwater effects during flooding conditions.

The lower 36-inch culvert at North Main Street has become obstructed with dirt and muck. Removal of this material to expose more of the culvert to flow could slow the effect of backwatering on site, however the small size of the lower culvert, even free from obstruction, does not have the capacity to convey flows compared to upstream and downstream culverts. The two 13-foot box culverts at Sherwood Drive are not of great concern because of the large cross-sectional area and invert being well below the elevation of the thalweg. The BSLT culvert will be removed during construction of the park, so any backwater that it currently causes will no longer occur.

Assuming the North Main Street culverts remain in place, the Carr Lake Park design must consider that much of the park will be frequently inundated with flood water. The backwater resulting from the North Main Street culvert causes sluggish flow through Carr Lake and likely results in high sediment deposition rates which in time could raise the elevation of flooding. The Park design should consider implementing a strategy to capture sediment. Otherwise, sediment trapped behind the North Main Street culverts would need to be removed periodically. In some respect the backwater effect poses a challenge, but it also provides an opportunity to transform Carr Lake closer to what it once was. A more constant level of water in Carr Lake could provide the proper conditions to create a flourishing wetland.

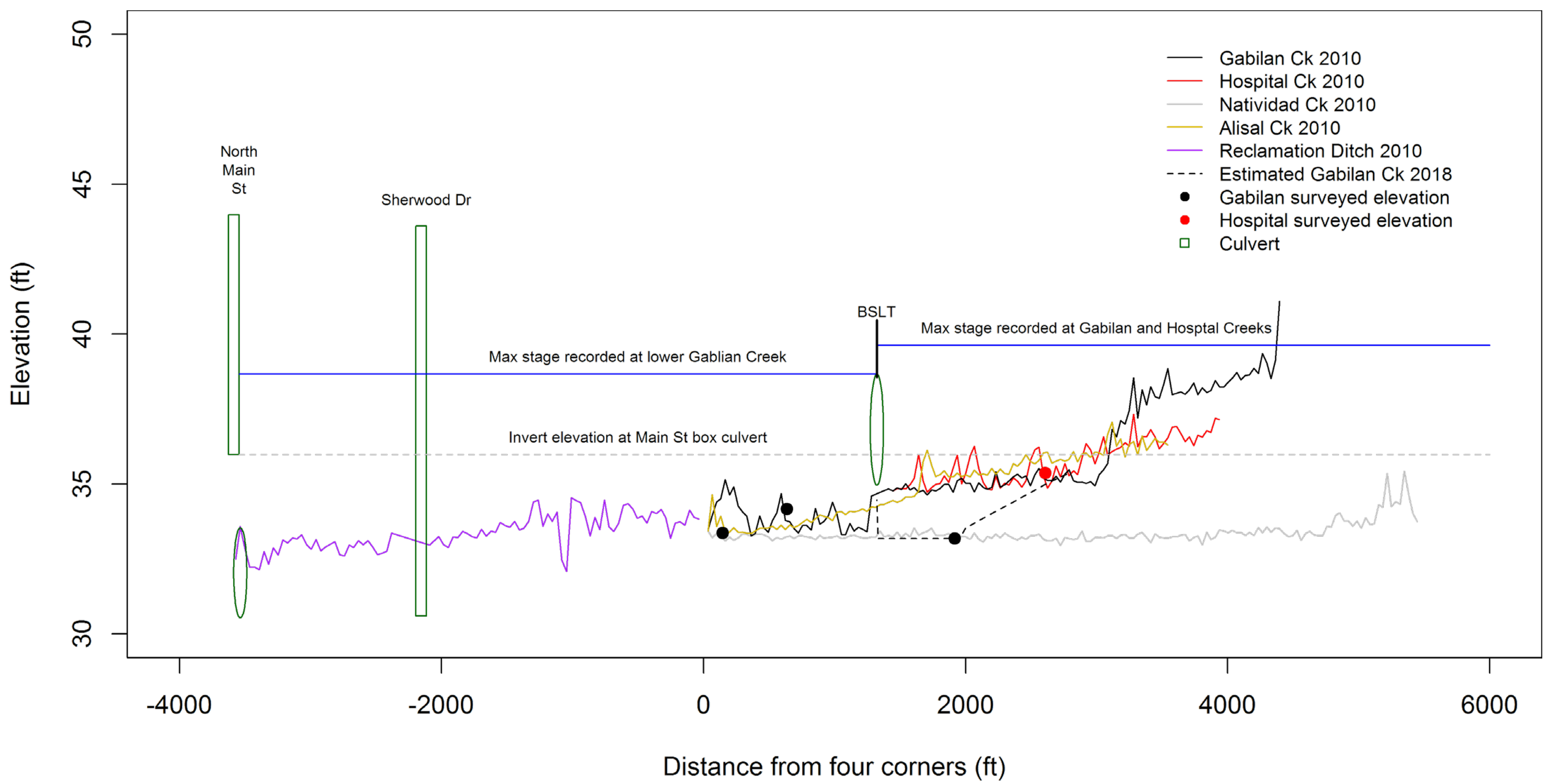


Figure 6. Longitudinal Profile of streams in Carr Lake, showing hydraulic controls such as culverts. The jagged lines of the stream profiles are probably a result of sampling variation due to limitation in the spatial resolution of the LiDAR data. "Real" profiles likely have more gradual elevation changes.

Figure 7. North Main Street culverts on November 29, 2018 after heavy rain. The small 36-inch culvert is under water.

4.0 System Hydraulics

Efficient restoration and management of Carr Lake depends on a sufficient understanding of its complex hydrology - involving the confluence of multiple flashy non-perennial streams, disparate watershed land uses, backwater effects, historic land reclamation, and recent channel excavation. We examined certain aspects of the hydraulics of the system using event-based storm analysis, precipitation analysis, cross-section surveying, stage logging, flow measurements and discharge.

4.1 Baseline Measurements

We conducted fieldwork before the first flush event to prepare each of the four sites for surveys and data collection. Benchmarks, staff plates, and pressure transducers were set up and georeferenced to identify the corrected elevation at sample sites one through four. We established benchmarks which were marked with rebar to identify sites for potential future monitoring (Table 2).

One cross section was surveyed per site using an auto level, stadia rod, and transect tape. These surveys used standard auto level methods to capture existing cross-sectional geometry (Harrelson et al. 1994). Depth measurements were recorded when a large change in slope was detected along the cross-section (Fig. 8).

Site 4 was ultimately excluded from flow and water quality sampling because it was experiencing backwater effects before the first flush event and did not provide any additional data that other sites did not possess (Fig. 9).

Table 2. Latitude, longitude and elevation of established rebar benchmarks. Elevation data had an accuracy of about 4 cm, however latitude and longitude have low accuracy since they were obtained from a cellular device, not the Trimble 5700.

	Left benchmark			Right benchmark		
Site	Latitude	Longitude	Elevation (ft)	Latitude	Longitude	Elevation (ft)
1	36.6936	−121.6388	39.65	36.6936	−121.6388	42.76
2	36.6908	−121.6383	44.98	36.6907	−121.6382	39.39
3	36.6883	−121.6405	39.02	36.6883	−121.6406	38.49
4	36.6870	−121.6409	38.40	36.6870	−121.6410	38.55

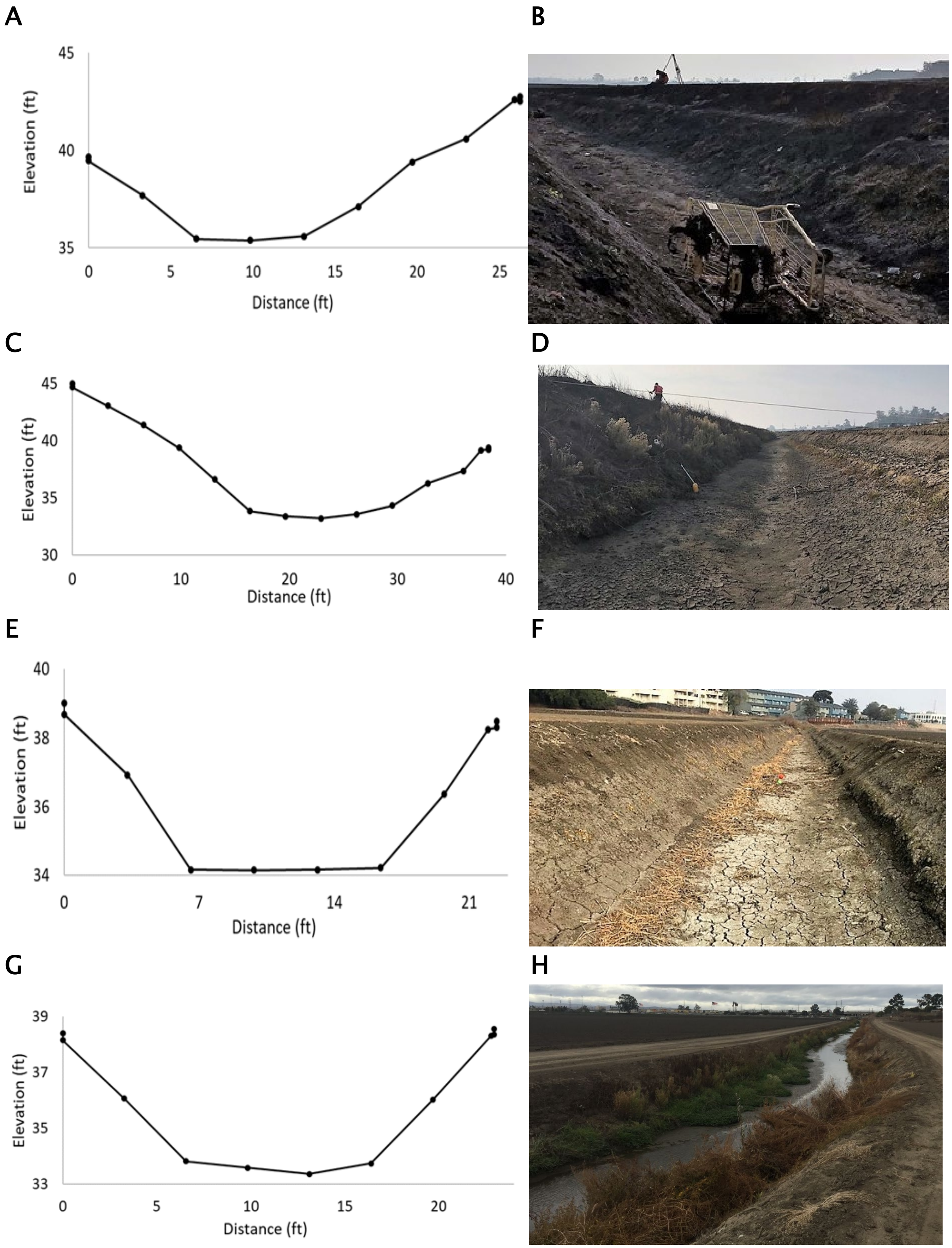


Figure 8. Cross sections and respective images of Site 1 (A, B), Site 2 (C, D), Site 3 (E, F), and Site 4 (G, H).

Figure 9. Site 4 experiencing dry-season ponding before first flush event.

We established a survey control point in the study area using a Trimble 5700 which was set up for three hours on November 17, 2018. The raw file was sent to Online Positioning User Service (OPUS) for a corrected solution of the Global Navigation Satellite System (GNSS) collected point. The vertical datum used for georeferencing was NAVD88, computed using the GEOID12B model. These elevations were used to correct positions of staff plates, cross sections and pressure transducers.

4.2 Discharge Measurements

We established staff plates prior to the rainfall events that were georeferenced using the established survey control point. Discharge was calculated combining depth, cross section measurements and flow measurements.

We established flow measurement protocols for three levels of flow (low, moderate, and high flow conditions), from which one was chosen based on anticipated water levels prior to the site visit (Appendix B). Precipitation predicted at weather stations provided a reference for which protocol to consider. The moderate flow protocol was used (implementing the impeller flow probe) at one site during a sampling interval on the 21st. Due to the flashiness of the sites and high water levels during sampling intervals, the high flow protocol was used during the remaining survey events.

Under the high flow protocol, the float method was utilized to measure average velocity (Appendix B). We threw a buoyant object in the creek to measure flow since water levels were too high and unsafe for wading. We recorded the rate at which the buoyant object traveled 10 meters downstream (Fig. 10). The float method was repeated three times and averaged before calculating velocity.

Ideally the buoyant object was thrown at different distances from left bank to right bank to account for the change in velocity across the width of the stream. But this was not always possible, and in such cases, we assumed that the mean channel velocity was 0.425 times the measured mid-channel surface velocity (Watson et al. 2005). No correction was used for velocity measured using the moderate flow protocol (impeller method) since we sampled equal interval distances along the cross section (Appendix B).

Figure 10. A 10-meter measuring tape at Site 1 for measuring flow on November 29, 2018.

4.3 Precipitation Events

We compiled precipitation data from seven regional weather stations (Fig. 11) including Weather Underground and the California Irrigation Management Information System (CIMIS) to help inform our analysis of how water was captured in the watershed system between 11/20 and 11/30. By using the average precipitation of seven stations we were able to determine a more accurate estimate of the magnitude of each storm event than if we chose to incorporate only one or two stations. Three main precipitation events occurred during the study period (Table 3). We surveyed water quality during the two largest events on November 21st and 29th.

To determine the magnitude of each storm event we:

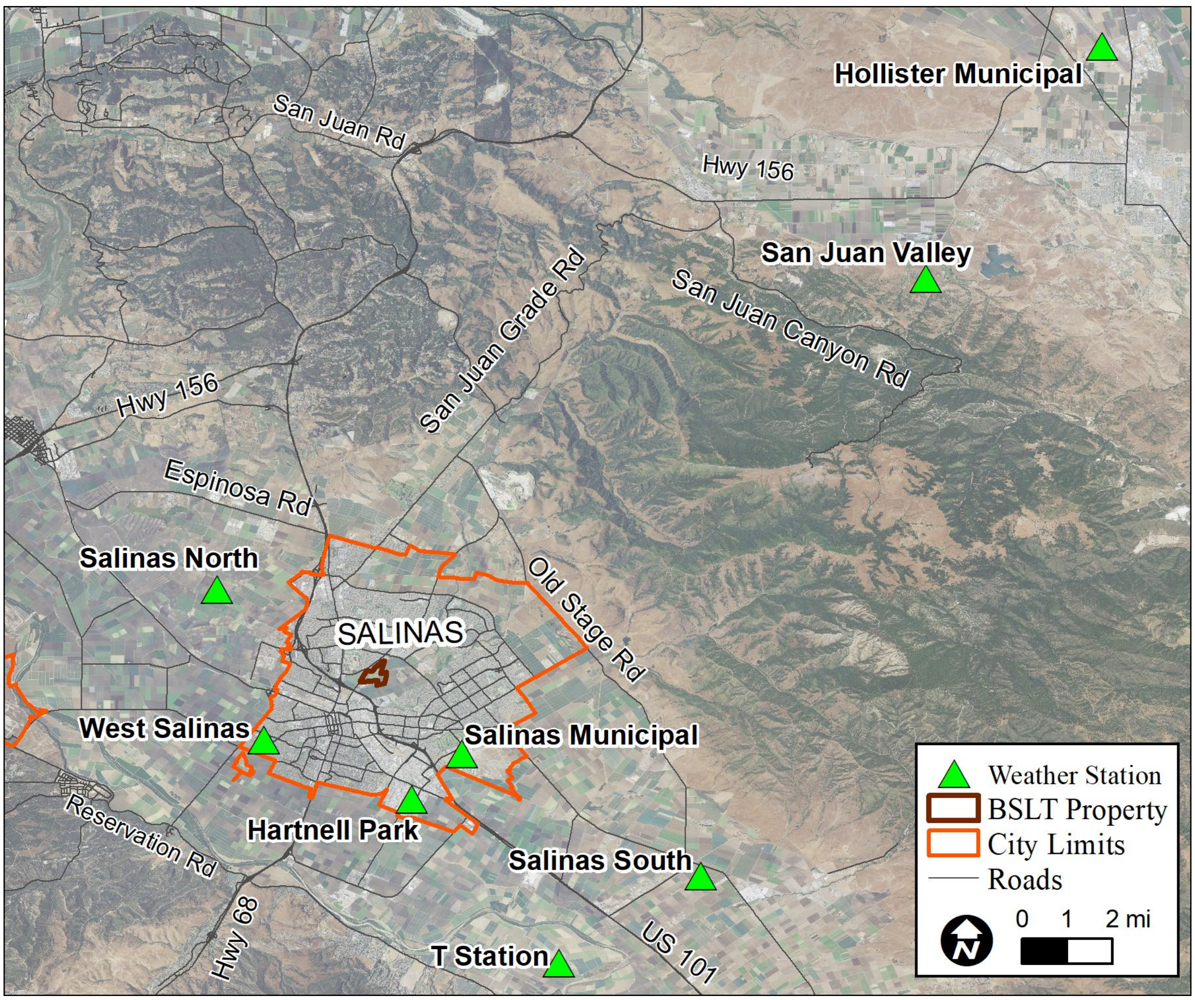


Figure 11. Map of the seven weather stations around the Salinas City Area. We incorporated data from both the Weather Underground and the California Irrigation Management Information System (CIMIS).

- Compiled and calculated the hourly rate of precipitation at each of the seven stations in Microsoft Excel
- Averaged the hourly rate across the seven stations
- Summed the rates for each event period (Table 3)

We created individual plots of the precipitation recorded at each weather station (Fig. 12) and a stacked plot of the proportion of the average precipitation recorded at each weather station (Fig. 13). All plots were created using R (R Core Team 2017). We plotted the average precipitation and water surface elevation (WSE) at sites one and two to compare the response of the system to the storm events (Fig. 14). The slight lag between peak precipitation and WSE confirms the flashy nature of the system.

Table 3. Magnitude of each storm event based on the average of precipitation recorded at seven different weather stations.

Event	Precipitation (in)
11/21	0.84
11/22-11/23	0.50
11/27-11/29	1.83

4.4 Storm Events Narrative

Understanding the flow dynamics of the watershed was important for the timing of sampling. We tracked flow and took photographs of Gabilan Creek at bridge crossings and storm water outlets throughout the watershed during the three storm events (Fig. 12). East Boronda Road at the northern end of the City of Salinas divides the mostly urban part of the watershed from agricultural and rural areas (Fig. 15). This boundary gave us the opportunity to describe water flowing into Carr Lake as mostly urban runoff if there was no flow upstream from East Boronda Road, or a mix of urban and agricultural runoff if there was continuous flow from Hebert Road through East Boronda Road.

The first storm was a 0.84 in. event in the late afternoon of November 21, 2018 (Fig. 12). Heavy rain began at approximately 16:00 and within the hour flow was observed in Hospital Creek in Carr Lake (Fig. 14). During this time, water was seen pouring from several major stormwater outlets in the general area of Independence Blvd. and Laurel Drive. By 18:00, flow was observed in Gabilan Creek in Carr Lake. Observations from upstream of East Boronda Road confirm that the rural reach of Gabilan Creek had no

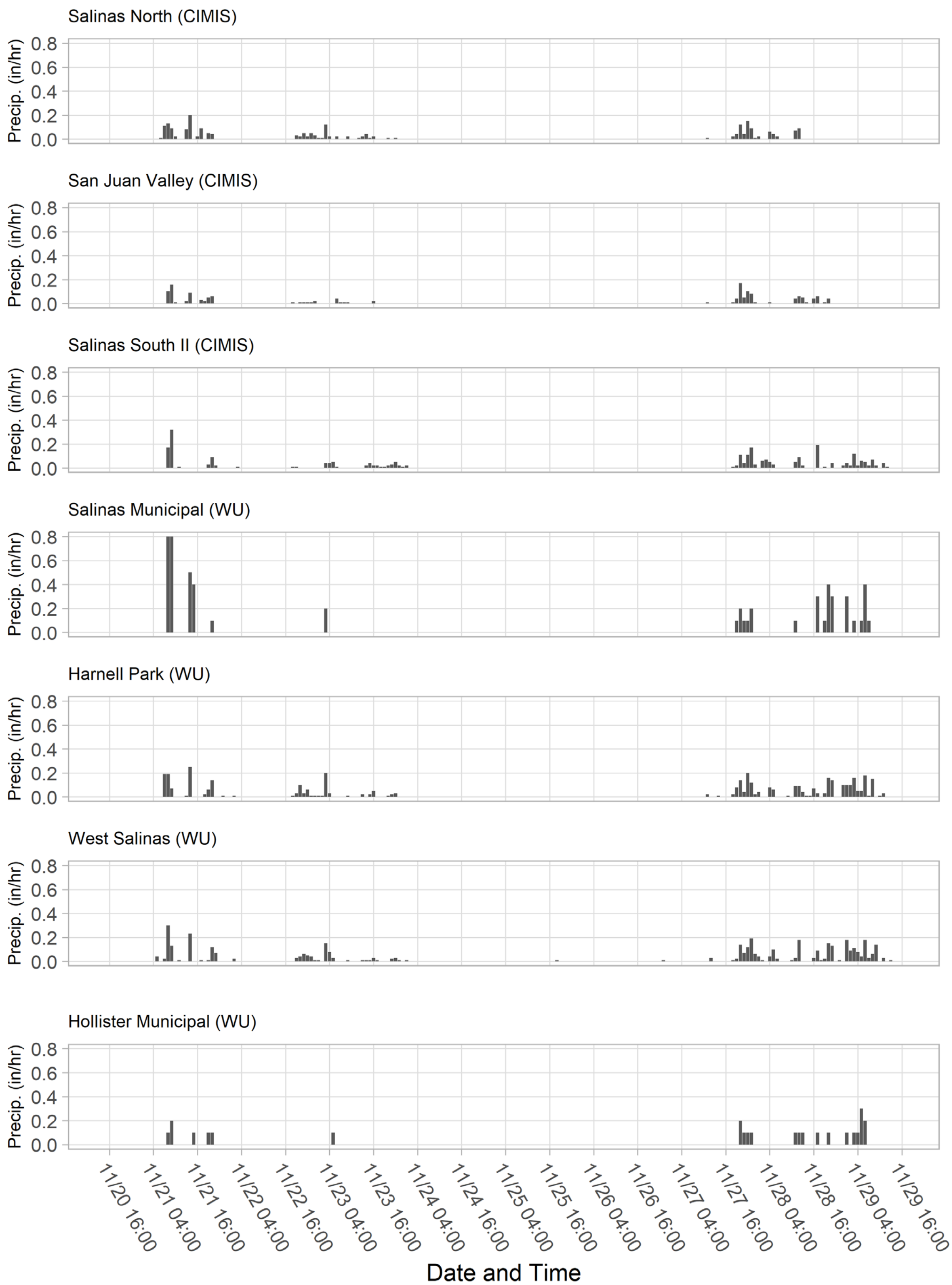


Figure 12. Precipitation data compiled from seven Weather Underground (WU) and California Irrigation Management Information System (CIMIS) stations within the study time frame. The three storm events occurred on 11/21, 11/22-23, and 11/27-29.

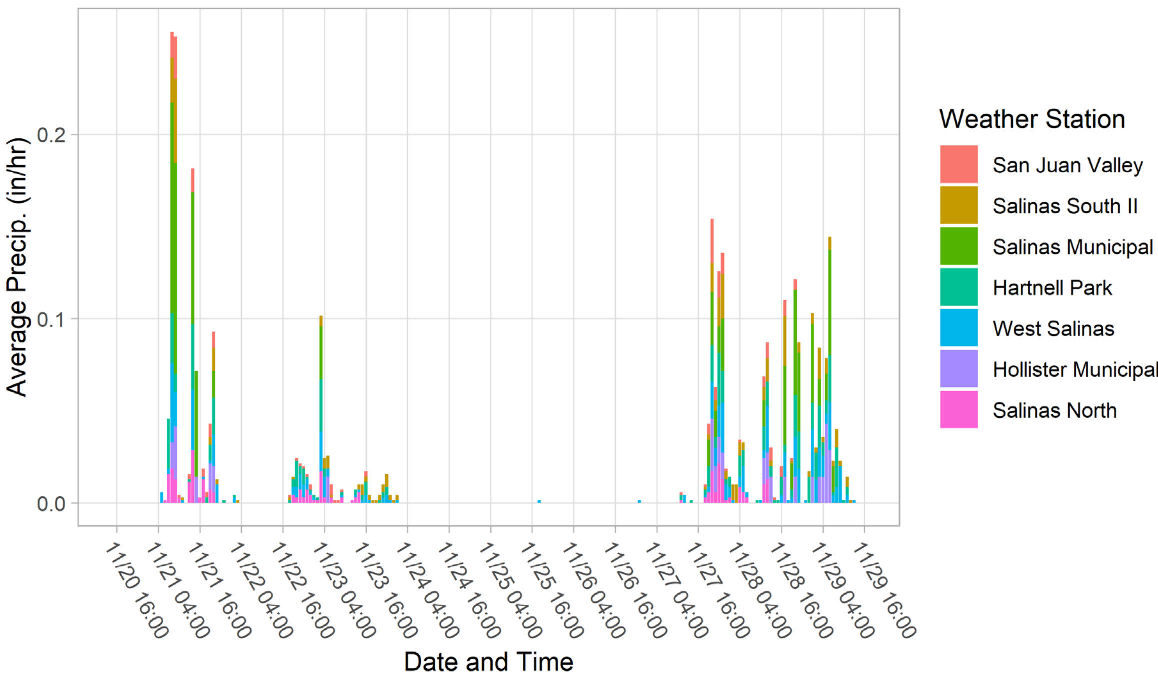
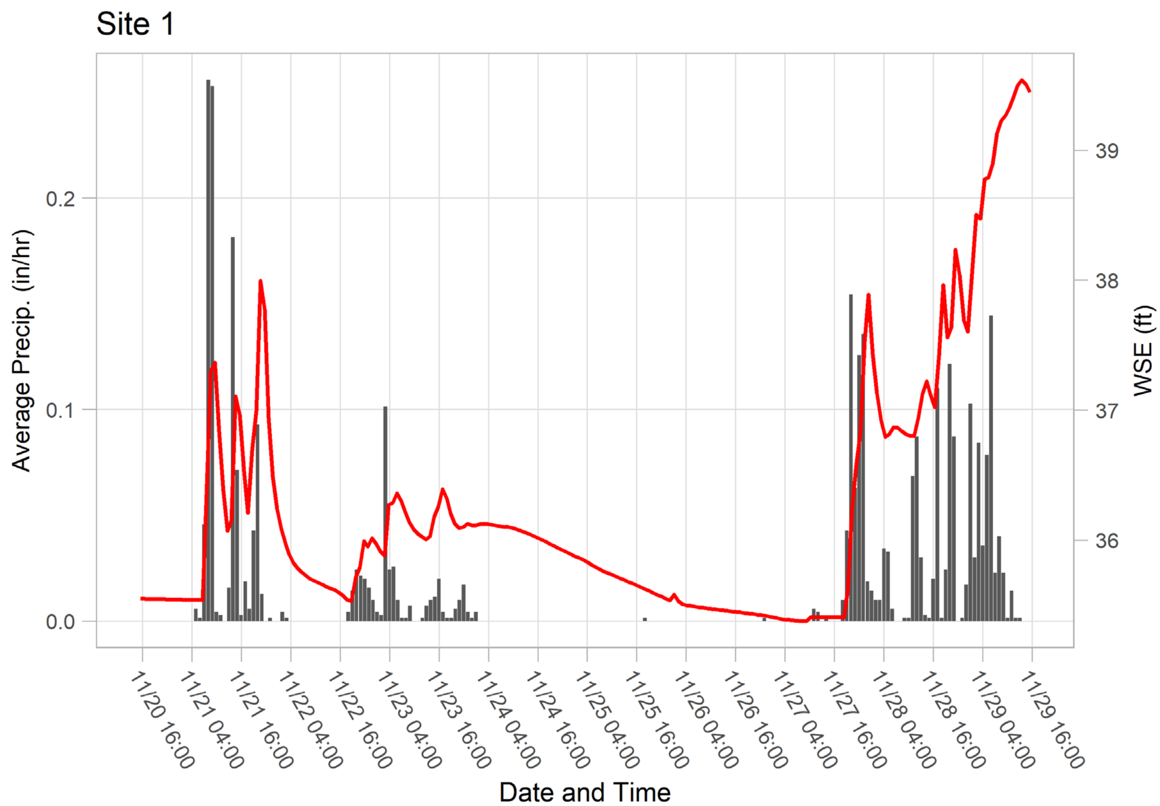


Figure 13. Comparison of the proportion of the average precipitation recorded at each of the seven Weather Underground and California Irrigation Management Information System weather stations. Because of the high variability among stations, the magnitude of each storm event is best represented by the average precipitation of all seven stations.

flow at this time, suggesting that water in the channels was mostly generated from urban runoff (Fig. 16). Water quality samples were collected during this event.

The second storm was a 0.5 in. event on the night of November 22 and during the day on November 23, 2018 (Fig. 12). This storm consisted of mostly light rain. Observations made on the afternoon of November 23 show that there was water in the channel but no flow at Hebert and Natividad Roads, and minimal flow at East Boronda Road (Fig. 17). Littered leaves and trash in the channel suggest that if there was any connected flow during this storm, it was not a significant flow of water. Water quality samples were not collected during this storm.

The third storm was the largest storm during the study time frame where 1.83 in. fell between November 27 through November 29, 2018, with the most rain occurring on the 29th. At 12:30 on November 29, strong flow (>30 CFS) was observed at Hebert Road and appeared to connect through to East Boronda Road. This was the first documented throughflow from the upper watershed during the study. At that time Carr Lake was



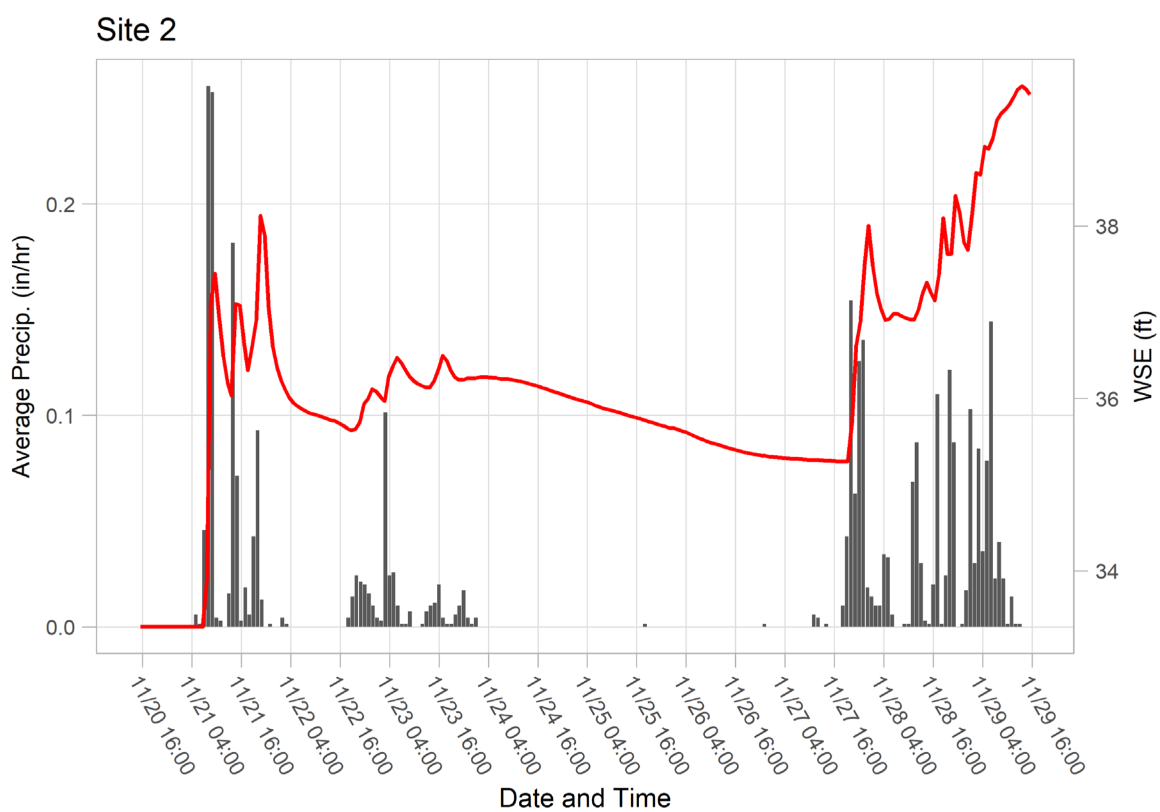


Figure 14. System response to storm events at sites 1 and 2. There is a slight lag in water surface elevation (WSE – red line) increase after precipitation peaks.

flooding with turbid water. While we believe that the water flooding Carr Lake was a mix of agricultural and urban runoff, we can't be certain that water observed coming from upstream of East Boronda Road had enough time to flow to Carr Lake due to the timing of our photographic evidence (Fig. 18). Photographs of the agricultural runoff were taken while samples were collected, leaving no proof that this water was flowing long enough to reach Carr Lake. However, the turbidity of the water, the rising hydrograph and a picture of urban and agricultural runoff mixing upstream suggest that this water likely included agricultural mixing (Fig. 18).

From our observations we learned that the urban and rural parts of the watershed behave very differently. The urban area that drains into Gabilan and Hospital Creeks is a flashy

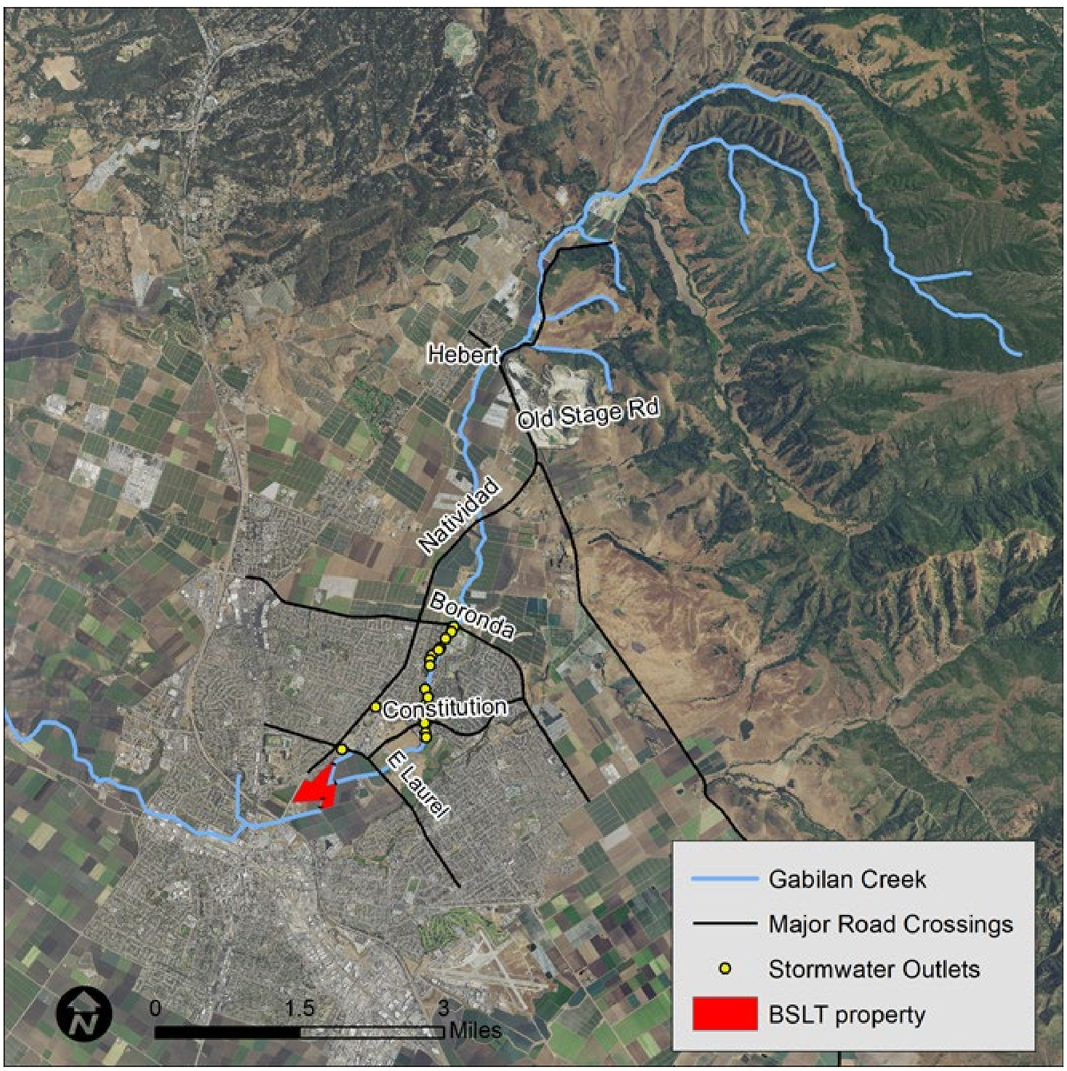


Figure 15. Gabilan Creek with road crossings used to make flow observations. Boronda Road shows a clear distinction between the urban and rural parts of the Gabilan Watershed.

system, with runoff entering Carr Lake less than an hour after precipitation. Connection with the rural watershed happens much more slowly and less frequently. This early in the water year, not all storms produce runoff into Carr Lake from the upper watershed. In order to understand the magnitude of agricultural and mountain inputs it is important to wait for a substantial storm.

Figure 16. On November 21, 2018 sampling event, the Gabilan creek is dry at East Boronda Road (left) indicating water sampling may not be from agricultural runoff. Gabilan creek does have water flowing at Coventry Street (right) showing urban runoff.

Figure 17. On the November 29, 2018 sampling event, the Gabilan creek at East Boronda Road (left) indicating agricultural runoff. Gabilan creek at Coventry Street and Hyannis Circle (right). High water flow in both areas indicates water sampling may be from both agricultural and urban runoff.

4.5 Water Level and Discharge Variation at Carr Lake

We used water pressure loggers and manually calculated discharge measurements to describe the response of streams in Carr Lake to the three major precipitation events described above. The pre-installed pressure loggers measured depth every 3 minutes. We converted this logger data to WSE using survey data. These conversions were completed to place all water level data on the same scale in order to understand the hydraulic interaction between the water levels at the three sampling sites. The elevation data collected was corrected based on the georeferenced height established by the Trimble 5700, and converted to elevation in feet.

As mentioned previously, field observations and precipitation measurements indicated that Carr Lake experiences flashy flow events. We observed large WSE fluctuations at Site 1-3 where on November 21st there was an increase then quick recession indicative of a flashy flow event (Fig. 19). Potentially due to water pumping, dumping or flux in sediment load, we observed deviations in WSE measurements at Site 3 after November 25th (Fig. 19).

We captured the elevation and water quality data before, during and after the first flush peak on November 21st (Fig. 19). Unlike the short recession seen during the first flush event, the recession on November 29th decreased at a much slower rate, which is why only measurements before the peak were captured (Fig. 19). Ideally, sampling would have happened before, during and after the hydrologic peak. However, we did not anticipate the longer and slower recession which can be attributed to water flowing from the upper watershed.

As previously mentioned, water surface elevation is expected to respond to storm events in unison across all three sites (Fig. 14). Deviation from the general fluctuations seen in precipitation hydrographs (Fig. 14) can explain physical differences between stream segments, and even anthropogenic influence.

We compared the USGS Reclamation Ditch Gage (REC-JON) discharge values to the sites' sampled discharges to verify that the methodology used was accurate (Fig. 20). Additionally, we expected to observe a similar pattern between stage and pressure logger elevation data (Fig. 19). The sampling intervals occurred during flow events that carried sizable loads from the watershed into the Lower Salinas River and the Marine Sanctuary (approximately 40 cfs) (Fig. 20).

There was no clear relationship between discharge and stage (Fig. 20). Such a relationship is typical for steeper systems without backwater effects, where stage can be used as a proxy for subsequent discharge calculations. We investigated the influence of the backwater effects on discharge further and plotted discharge against water surface elevation above the thalweg (Fig. 21).

In the absence of backwater effect, there would be a clear power function relationship between depth above the thalweg and discharge. However, there is not a clear relationship and therefore no power function relationship observed. We see low discharge calculations at varying depths for Site 1 and Site 3 which is indicative of a backwater effect (Fig. 21). More discharge measurements are needed during low flow magnitudes to help understand which events could lead to stream-like or lake-like behavior.

Figure 18. During the November 29th sampling event, water mixing was observed between clear urban runoff and turbid upper watershed runoff at Coventry Street and Hyannis Circle.

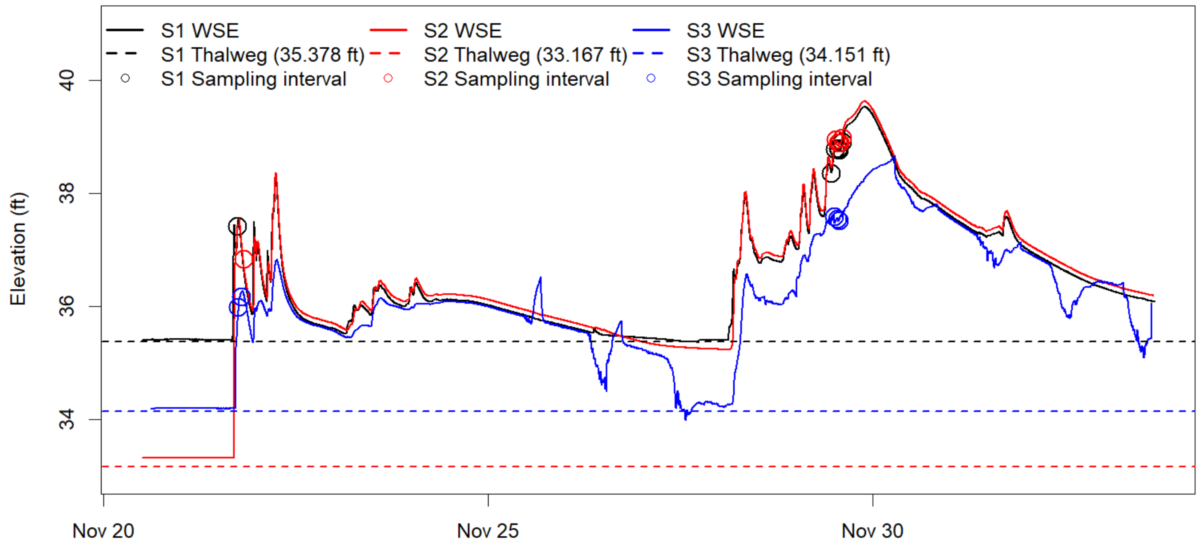


Figure 19. Water Surface Elevation (WSE) in feet of Sites 1-3 with associated sampling intervals. Thalweg elevation acquired from cross section surveys.

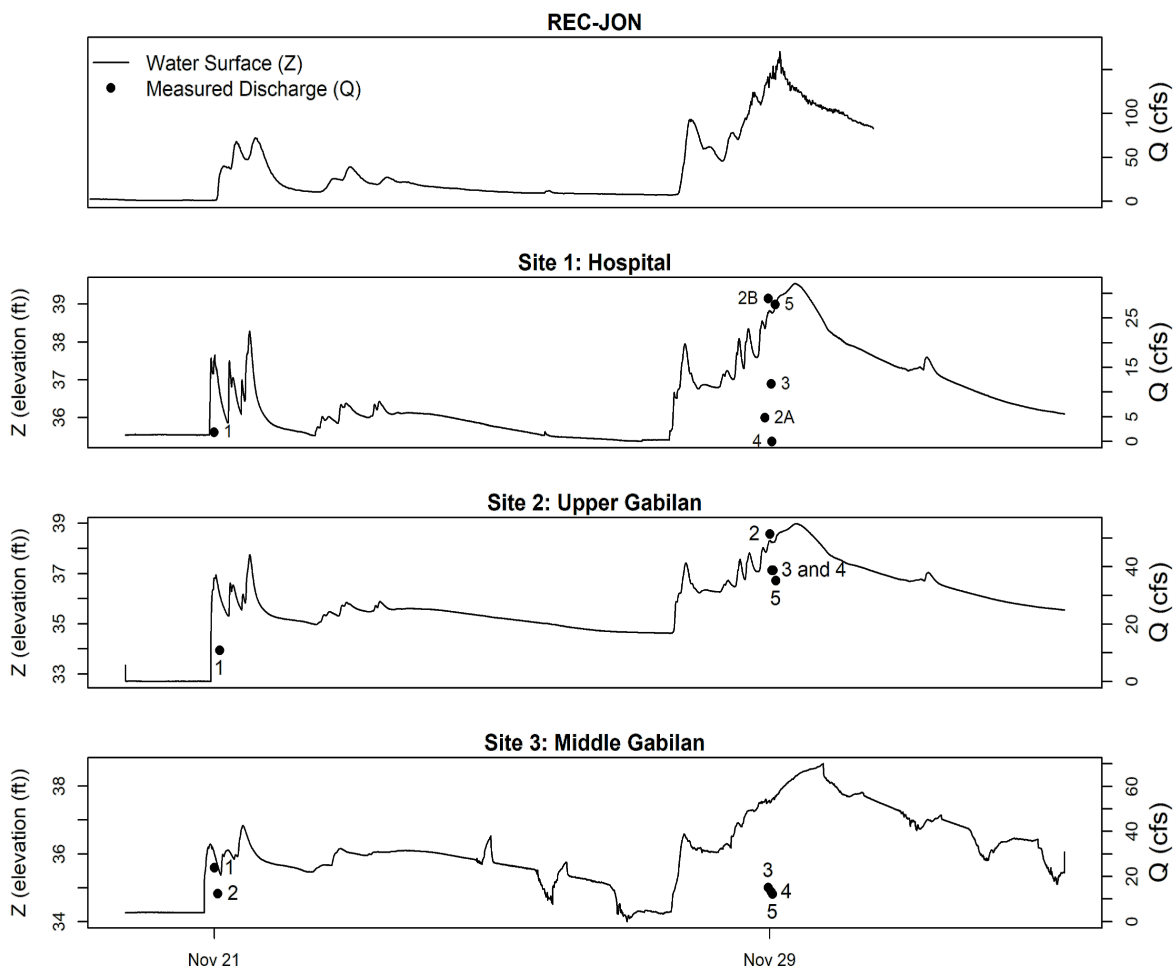


Figure 20. Water Surface Elevation (WSE) and calculated discharge at sites 1-3 compared to USGS Reclamation Ditch gage downstream.

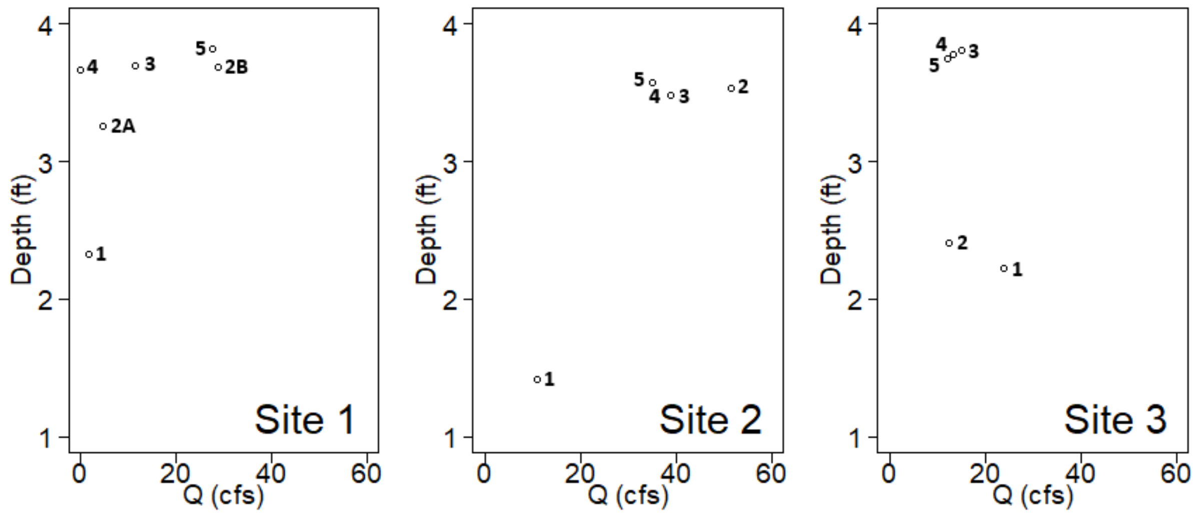


Figure 21. Relationship between Water Surface Elevation (WSE) and discharge (Q) at sites 1-3. Q intervals numbered 1-5, with two Q measurements (2A, 2B) taken at site 1 due to a stage increase.

4.6 Conclusion

Precipitation, discharge and WSE findings from system hydraulics indicate some key conclusions that could impact the BSLT site and potential wetland development including:

- Precipitation data and WSE can help predict peak and recession timing
- Discharge calculations from this study are similar to discharge downstream at REC-JON
- WSE cannot be used as a proxy for discharge
- Magnitude flows (40 cfs) are seen in this preliminary sampling and are expected to be carrying pollutant loads to the lower Salinas River and out into the Marine Sanctuary

The extent of backwater at the site needs to be further investigated to help in the development of future treatment wetlands. We recommend collecting subsequent cross section surveys between storm events to account for possible degradation and aggradation of sediment. More frequent sampling intervals are recommended to capture low flow conditions to better explore the numerous hydrologic aspects of Carr Lake.

5.0 Water Quality Monitoring

5.1 Introduction

We collected water samples over a total of 16 sampling intervals and had them analyzed for nutrients, pesticides, sediment, and pathogens.

Nutrients are important to monitor for their effects on both humans and the environment. Ammonia can be released by livestock operations, or bacterial decomposition. Ammonia levels play an important role in fish health. Elevated ammonia can lead to acute toxicity, especially at high pH levels (Kadlec and Wallace 2009). Nitrates and phosphates appear in high concentrations in agricultural runoff containing fertilizer. Cumulatively, these nutrients can lead to poor environmental conditions through a process called eutrophication (Kadlec and Wallace 2009), whereby dissolved oxygen decreases after algal blooms due to decay of the dead algae. Extremely low dissolved oxygen levels are known as “hypoxia” and can stress and kill aquatic life (Jeppesen et al. 2015). The primary concern about human contact with high nutrient concentrations is toxicity in drinking water, such as methylglobanemia in infants (Kadlec and Wallace 2009).

Other parameters are important to monitor to understand the components that are transported by the creeks passing through Carr Lake. Total Suspended Solids (TSS) help give insight to how much sediment is transported. High TSS levels are harmful to fish as it can interfere with their gill functionality and can deposit on spawning habitat (Watson et al. 2003). Other important components of the stream are total organic carbon (TOC) and dissolved organic carbon (DOC). TOC and DOC indicate how much plant or animal matter is being transported downstream. Fecal coliforms are different from the other analytes in that they are live bacteria that may indicate contamination by fecal matter. Presence may elevate the risk of gastrointestinal disease in humans after exposure and can include bacteria such as E. coli (EPA 2012).

As a wide range of pesticides have been detected in Gabilan Creek, it was important to run a full pesticide panel as part of our sampling.

5.2 Water Quality Sample Collection and Preparation

We collected four liters of for each sampling interval in order to meet the sample volume requirements to properly conduct the analysis for each target analyte (Table 4). Prior to sampling, we acquired the appropriate number of 500 mL DH-48 sampling bottles and labeled each container with a unique identification signifying the site number and sampling interval. Due to the sample storage requirements for TOC and DOC, each DH-48 bottle was acid washed using a 10% hydrochloric acid solution (Table 4). DH-48 bottles designated for each sampling site were then segregated into ice chests, which were then used to both transport and preserve samples during collection.

Water quality sampling took place during two precipitation events on November 21st, 2018 and November 29th, 2018. November 21st, 2018 produced first flush conditions with measurable flow in both Hospital and Gabilan Creeks. We were able to capture these conditions by collecting a total of four water quality samples, one sample from both sites 1 and 2 and two samples from site 3. On November 29th, 2018, we conducted synchronous sampling by gathering a total of 12 samples from each site, in

Table 4. Analytical service provider sample collection requirements for proper analysis of Nutrients (Nitrate, Nitrite, Ammonia, and Phosphate), Dissolved Organic Carbon (DOC), Total Organic Carbon (TOC), Total Suspended Solids (TSS), Pesticides (Chlorpyrifos and Diazinon), and Fecal Coliform. These requirements may vary based on individual service provider.

Analyte	Sample Size (L)	Stroge Container	Maximum Storage Time	Storeage Location	Method
DOC	0.01	Acid washed vial	1 Week	Refrigerator	
TOC	0.01	Acid washed vial	1 Week	Refrigerator	
TSS	1.00	Plastic contianer	1 Week	Refrigerator	EPA 300.0
TDS	0.50	Plastic contianer	1 Week	Refrigerator	SM2540C
Pesticides	2.00	Amber glass bottle	1 Week	Refrigerator	EPA 525.2
Fecal Coliform	0.10	Plastic contianer Sterile w/ NaS2O3	Same day	Refrigerator	SM9223
Nutrients	0.02	Falcon Tube	1 Week	Freezer	
Nitrate					EPA 353.2
Nitrite					EPA 353.2
Ammonina					EPA 350.1
Phosphate					Gordon, Jennings, and Ross 2001

effort to evaluate variation in analyte concentration that may be occurring between each location at a given moment. Due to required sampling technique for TSS, each sample was collected using a DH-48 sampler. Initially, each sample was collected at equally spaced intervals along the width of the channel surface water. However, due to the flashy nature of both tributaries wading became unsafe, resulting in sample collection that took place from the streambank. Each DH-48 bottle was labeled with the date and time the sample was collected (Fig. 22). In addition to samples collected using the DH-48 sampler, a dip sample was also collected for each sampling interval and later used during sample preparation to triple rinse buckets used to consolidate samples.

Once all samples had been collected the water was transported to a campus laboratory at CSUMB. To begin sample preparation a 5 L mixing container was acid washed using a 10% hydrochloric acid solution then triple rinsed using water from the dip sample collected at each sampling interval. Water from each DH-48 bottle designated for a specific sampling site and interval were combined in a mixing container to produce

Figure 22. Water quality sampling on November 29, 2018 at Site 1.

one homogeneous solution that represented that specific sampling event. Starting with TSS and TDS, each sample was measured and stored in the correct container under the proper conditions specified for that analyte (Table 4).

We defined a target level (Table 5) for each analyte based on regional regulatory literature (RWQCB 2017 and Hoover 2003).

5.3 Water Quality Results

The target levels for ammonia and phosphate were exceeded at all three sample sites (Figure 23). Ammonia levels were comparable to previous sampling while orthophosphate levels were generally higher (Casagrande and Watson 2006). Nitrate and nitrite target levels did not exceed target levels, which is unusual compared to previous sampling (Casagrande and Watson 2006). This is discussed below.

TSS levels at sites two and three greatly exceeded the target level, while levels at site one did not exceed the target (Figure 24). This is typical of watersheds in the region with high amounts of unmitigated agricultural runoff, as well as steep erodible mountainsides in the headwaters.

Fecal coliform results indicated that sites one and two greatly exceeded the target level while site three fell below. This was comparable to previous water quality reports (Casagrande and Watson 2006).

Five pesticides were detected (Table 7). Dichlorvos, malathion, and stirophos were detected at all three sites; ethoprop was detected only at Site 1; and dimethoate was detected only at Site 3.

Physicochemical testing resulted in an average pH of 8, salinity of 0.1 PPT, conductivity of 93 uS, temperature of 14 degrees C, and DO of 8 mg/L (Table 6). Dissolved oxygen levels were generally higher than previously reported levels (Casagrande and Watson 2006), presumably because the present study experienced very recent cool-weather storm flow, as opposed to flows in warmer weather that may have been subject to some biological oxygen demand. pH levels fell within the target range (7 and 8.5, RWQCB 2016). Salinity and TDS levels fell below targets, as would be expected for storm water (RWQCB 2016).

As noted above, nitrate levels appeared anomalously low when compared with context to previous sampling. However, closer examination of the context revealed evidence that – based on data from previous studies – nitrate levels could be expected to be at their lowest in late fall and during strong rainfall – both of which were the case for all of the samples taken during this study (Figs 25 & 26).

Table 5. Target levels for analytes as listed by the Water Quality Control Plan for the Central Coast Basin (2016, 2017) and (Casagrande and Watson 2006). Most probable number (MPN) is calculated as a geometric mean.

Analyte	Target Level	Units
Ammonia	0.025	mg/L
Phosphates	100	mg/L
Nitrates	8	mg/L
Nitrites	10	mg/L
TDS	300	mg/L
TSS	500	mg/L
Fecal Coliform	400	MPN/100 mL
pH	7-8.5	
Salinity	< 0.75	ppt
DO	> 5	mg/L

5.4 Conclusion

Water quality at the BSLT property in Carr Lake is impaired due to contamination by pesticides, fecal matter (or at least indicators thereof), suspended sediment, ammonia and orthophospate. Nitrate contamination is likely to exist – based on previous sampling, and the sampling presented here after accounting for seasonal timing and stormflow dilution effects.

Water quality testing should be a primary focus throughout the park development. We suggest sampling of sites upstream and downstream of the wetland to observe the effects of wetland filtration at Carr Lake in eliminating contaminants. We established three sampling sites that may continue to be used for future testing. If these sites are to be used in future, we suggest that a means be developed for accessing the stream from above during high water (e.g. a bridge, or sampling crane). Bridges would allow safe sampling to occur in high discharge sampling sessions. Unsafe sampling conditions severely restrict the number and type of samples that can easily be collected.

Wetland design should promote some level of water quality treatment.

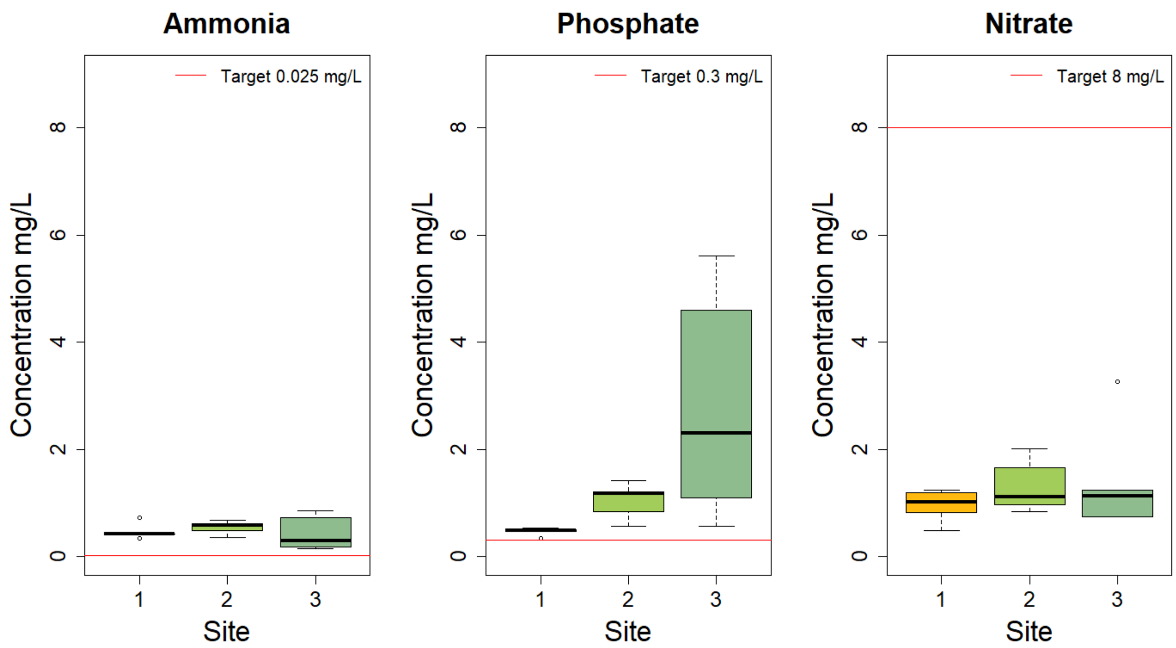


Figure 23. Nutrient levels at the three sites. Ammonia and phosphate levels were consistently greater than the target level of water, for all sites. The opposite is true for nitrate, falling below the recommended threshold.

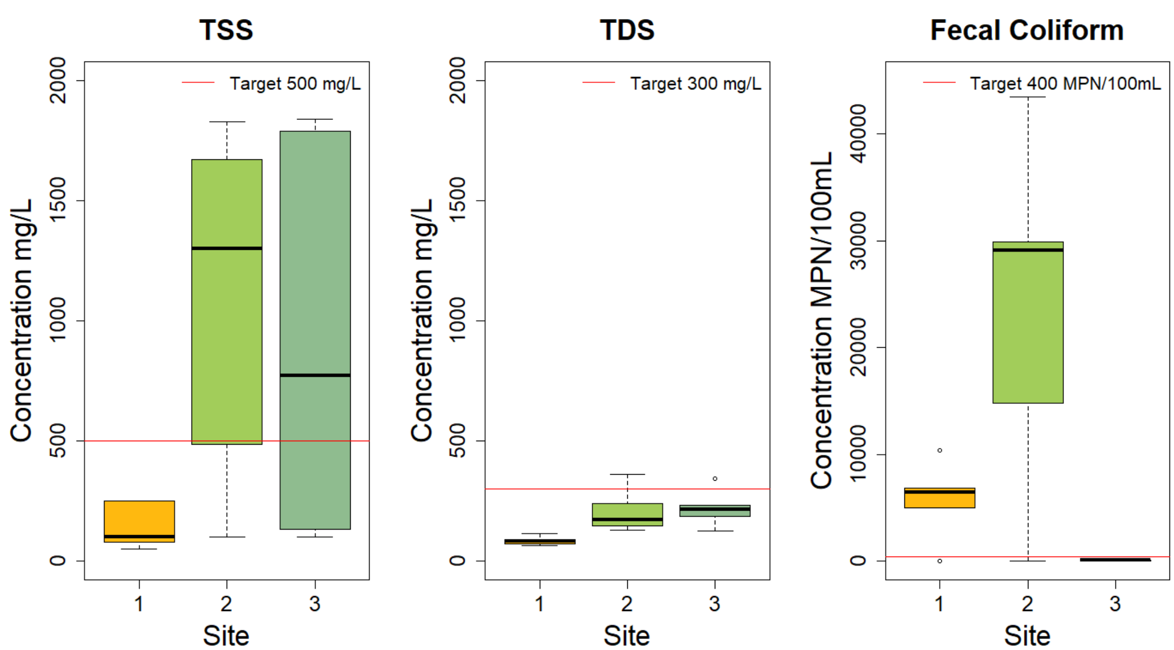


Figure 24. Levels of total suspended solids (TSS), total dissolved solids (TDS), and fecal coliform for the three sites. High levels of sediment were transported, indicated by the high TSS, especially at sites 2 and 3. TDS is within the target range. Fecal coliforms are much higher than the threshold at sites 1 and 2, mostly due to elevated levels on the second day of sampling.

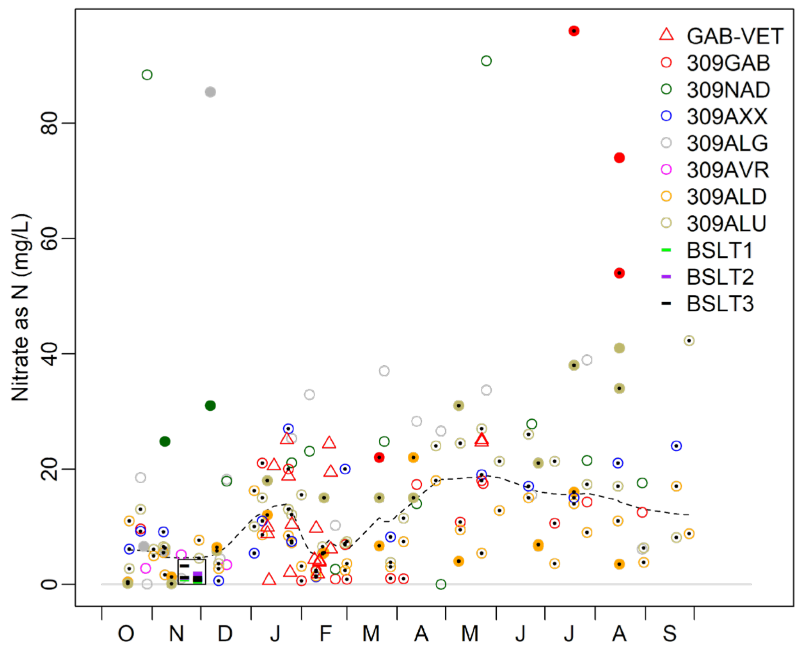


Figure 25. Nitrate comparison between the present study and prior data sets: (1) Casagrande & Watson (2006) (GAB-VET), (2) CCAMP (309GAB, etc.), (3) CEDEN (small black dots), (4) present study (BSLT). Notes: (a) GAB-VET and 309GAB are the same site, (b) solid symbols denote data collected since 2010; (c) dashed line indicates a LOWESS fit to the prior data.

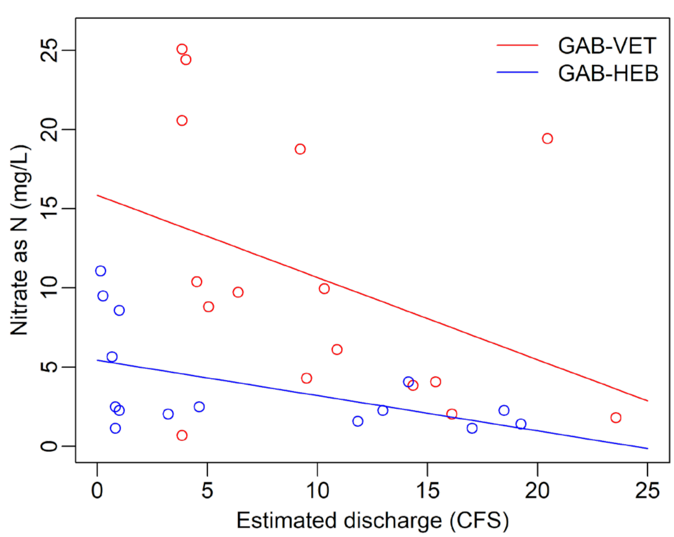


Figure 26. Evidence for dilution of nitrate concentration by high flows derived directly from rainfall and surface runoff. Discharge was estimated from stage based on a rating curve derived from actual discharge measurements. Data source: Watson & Casagrande (2006). Best-fit lines are based on simple linear regression.

Table 6. Carr Lake water quality results for sampling events that took place on November 21st, 2018 and November 29th, 2018. Analytes assessed during this studying include Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Fecal Coliform (FC), Dichlorvos (DIV), Malathion (MAL), Stirophos (STP), Dimethoate (DMT), Ethoprop (ETP), Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC), Ammonia (NH_3), Nitrite (NO_2^-), Nitrate (NO_3^-), Phosphate (PO_4^{-3}), pH, Salinity (SAL), Conductivity (CTD), Temperature (Temp), and Dissolved Oxygen (DO).

Site	Sampling Interval	Date / Time	TDS mg/L	TSS mg/L	FC MPN/100mL	DIV ng/L	MAL ng/L	STP ng/L	DMT ng/L	ETP ng/L	TOC mg C	DOC mg C	NH_3 mg/L	NO_2^- mg/L	NO_3^- mg/L	PO_4^{-3} mg/L	pH	SAL ppt	CTD uS	Temp C	DO mg/L
1	1	11/21/18 17:45	114.0	49.0	1.0	12.0	170.0	6.1			0.005	0.001	0.730	0.037	0.815	0.502	8.60	0.00	76.10	16.0	9.16
1	2	11/29/18 12:00	64.0	249.0	4960.0								0.416	0.062	0.484	0.334	7.60	0.00	0.10	13.6	8.61
1	3	11/29/18 13:01	82.0	100.0	10400.0					13.0			0.420	0.075	1.021	0.464	7.80	0.00	0.10	14.4	8.46
1	4	11/29/18 13:35	88.0	80.0	6440.0								0.420	0.061	1.183	0.486	7.60	0.00	0.00	14.6	7.84
1	5	11/29/18 14:30	70.0	251.0	6830.0								0.342	0.099	1.245	0.528	8.00	0.00	112.00	14.2	8.40
2	1	11/21/18 19:40	146.0	102.0	4.0	9.0	150.0	5.0			0.006	0.002	0.680	0.093	1.107	0.560	7.80	0.10	154.50	15.4	5.03
2	2	11/29/18 12:04	130.0	486.0	14800.0								0.356	0.178	2.002	0.840	8.50	0.10	134.80	13.4	8.62
2	3	11/29/18 13:01	240.0	1300.0	29900.0								0.576	0.578	0.838	1.168	8.30	0.10	101.40	13.2	8.72
2	4	11/29/18 13:32	362.0	1670.0	43500.0								0.606	0.810	0.960	1.414	8.30	0.10	142.30	13.5	9.19
2	5	11/29/18 14:29	170.0	1830.0	29100.0								0.478	0.466	1.654	1.204	8.30	0.10	112.40	13.7	9.20
3	1	11/21/18 17:55	344.0	132.0	5.0	15.0	220.0	4.0			0.002	0.002	0.848	0.096	3.264	0.562	8.70	0.10	105.40	16.1	8.76
3	2	11/21/18 20:20	124.0	102.0	< 1	12.0	150.0	4.6	7.5		0.002	0.002	0.722	0.092	1.228	1.848	8.30	0.10	153.20	15.6	8.14
3	3	11/29/18 12:06	198.0	360.0	< 100								0.410	0.045	1.245	1.086	8.10	0.10	96.00	13.9	9.02
3	4	11/29/18 13:03	232.0	1840.0	< 100								0.176	0.048	0.746	2.740	7.90	0.10	98.80	13.4	8.76
3	5	11/29/18 13:30	186.0	1180.0	< 100								0.174	0.025	0.744	4.600	7.70	0.10	97.70	13.4	8.76
3	6	11/29/18 14:30	232.0	1790.0	< 100								0.151	0.028	1.032	5.605	7.50	0.10	108.40	13.7	8.62
Result Averages																					
1			83.6	145.8	5726.2	12.0	170.0	6.1	NA	13.0	0.005	0.001	0.466	0.067	0.949	0.463	7.92	0.00	37.66	14.6	8.49
2			209.6	1077.6	23460.8	9.0	150.0	5.0	NA	NA	0.006	0.002	0.539	0.425	1.312	1.037	8.24	0.10	129.08	13.8	8.15
3			219.3	900.7	NA	13.5	185.0	4.3	7.5	NA	0.002	0.002	0.414	0.056	1.376	2.740	8.03	0.10	109.92	14.4	8.68
Cumulative			173.9	720.1	13267.3	12.0	172.5	4.9	7.5	13.0	0.004	0.002	0.469	0.175	1.223	1.496	8.06	0.07	93.33	14.3	8.46

Table 7. Results for Carr Lake pesticide panels for sampling conducted on November 21, 2018. Only four pesticides were detected: dichlorvos, dimethoate, malation, and stirophos.

Analyte	MRL	MDL	Site1 Interval 1	Site 2 Interval 1	Site 3 Interval 1	Site 3 Interval 2	Units
Azinphos methyl (Guthion)	10	5.5	ND	ND	ND	ND	ng/L
Bolstar	10	4.6	ND	ND	ND	ND	ng/L
Chlorpyrifos	10	6.9	ND	ND	ND	ND	ng/L
Coumaphos	10	5.1	ND	ND	ND	ND	ng/L
Demeton-o	10	10	ND	ND	ND	ND	ng/L
Demeton-s	10	10	ND	ND	ND	ND	ng/L
Diazinon	10	5.2	ND	ND	ND	ND	ng/L
Dichlorvos	10	2.9	**12**	**9.0**	**15**	**12**	ng/L
Dimethoate	10	6.2	ND	ND	ND	**7.5**	ng/L
Disulfoton	10	10	ND	ND	ND	ND	ng/L
Ethoprop	10	6.7	ND	ND	ND	ND	ng/L
Ethyl parathion	10	5.4	ND	ND	ND	ND	ng/L
Fensulfothion	10	2.9	ND	ND	ND	ND	ng/L
Fenthion	10	3.8	ND	ND	ND	ND	ng/L
Malathion	10	7.6	**170**	**150**	**220**	**150**	ng/L
Merphos	10	5.8	ND	ND	ND	ND	ng/L
Methyl parathion	10	6.3	ND	ND	ND	ND	ng/L
Mevinphos	10	4.2	ND	ND	ND	ND	ng/L
Naled	10	7.6	ND	ND	ND	ND	ng/L
Phorate	10	3.0	ND	ND	ND	ND	ng/L
Ronnel	10	4.1	ND	ND	ND	ND	ng/L
Stirophos	10	3.1	**6.1**	**5.0**	**4.4**	**4.6**	ng/L
Tokuthion (Prothiofos)	10	7.8	ND	ND	ND	ND	ng/L
Trichloronate	10	6.7	ND	ND	ND	ND	ng/L

6.0 Suggestions for Long-Term Approach

6.1 Re-surveying Cross-sections for Channel Aggradation Rates

Sediment deposition at Carr Lake likely occurs at a high rate due to the sluggish, turbid water that often occupies the channels. It is important to know how much sediment is deposited in Carr Lake so that the park design can address issues that might arise from excess sediment, such as rising flood levels. To understand the dynamics of sediment deposition in Carr Lake, we resurveyed cross-sections at sites 1-3 to capture any geomorphic change that occurred between storm events (Figs. 27-29). The surveys between pre- and post-storm events show no significant geomorphic change in the channels at Carr Lake, suggesting that, contrary to our predictions, there was minimal sediment deposited during these early storms. Site 3 showed some erosion on the left bank, but it is unclear if this erosion occurred during storms, or if it was human induced erosion from when surveyors climbed up and down wet, slippery banks, sometimes eroding material into the channel. It is clear that high deposition rates were not detected from just a few early storms. It is important that cross-sections are frequently re-surveyed so that depositional rates can be constrained. Large scale deposition might occur at a longer time scale than the length of this study. The initial surveys were obtained during dry conditions, when the elevation of the channel bottom

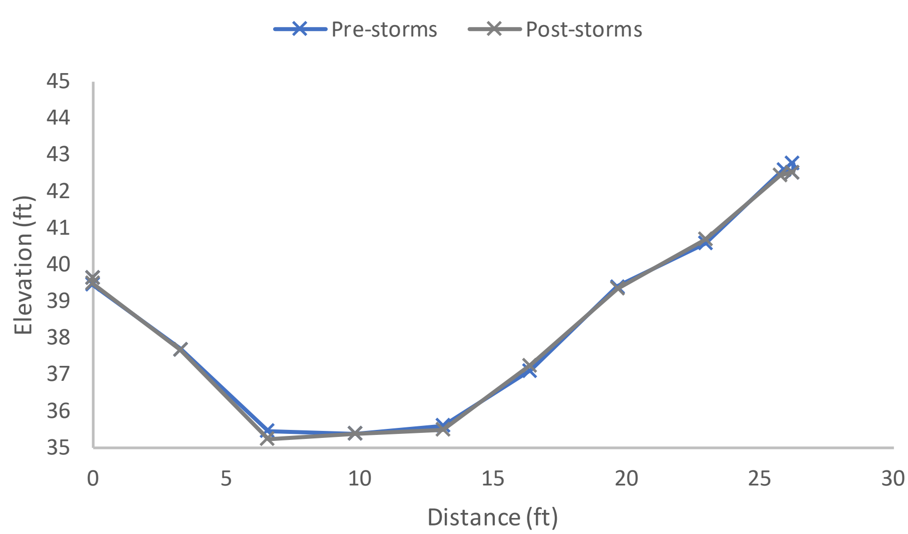


Figure 27. Pre- and post-storm surveys at Site 1 on Hospital Creek. The “x” indicates survey shots.

was a hard, easy to distinguish surface. The post-storm surveys were conducted while the channel was wet, and the channel bottom was less clearly defined due to an upper layer of muck and swelling of the soil. This may have had an effect on the results of our survey.

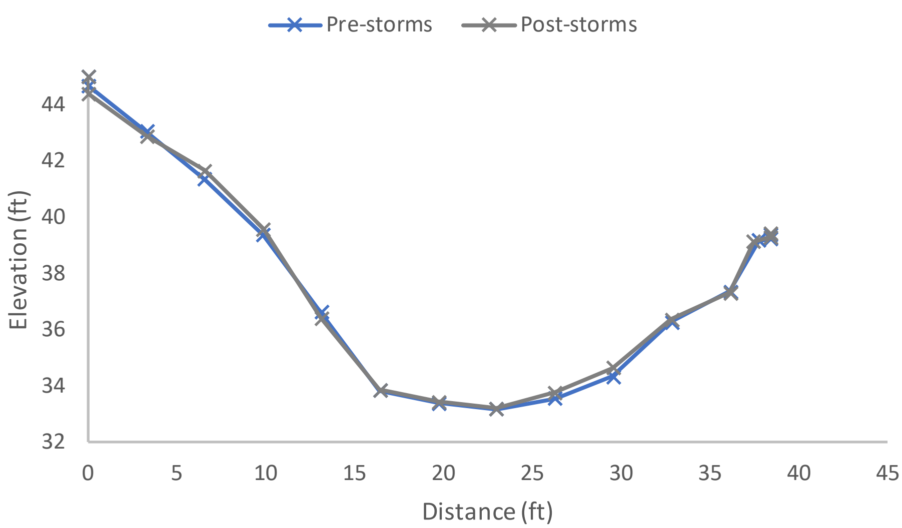


Figure 28. Pre- and post-storm surveys at Site 2 on Gabilan Creek. The “x” indicates survey shots.

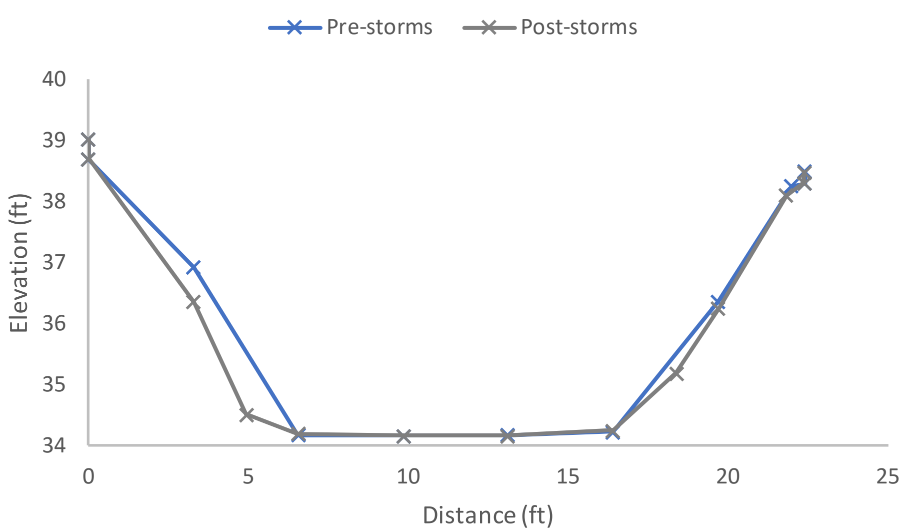


Figure 29. Pre- and post-storm surveys at Site 3 on Gabilan Creek. The “x” indicates survey shots.

6.2 Continued Water Quality Monitoring

To obtain reliable baseline water quality data, more samples should be taken throughout the range of flows that occur in these streams. The range of flows observed during our sampling was from 0 CFS to approximately 50 CFS. One of the main gaps in this range is low flows, from approximately 5 to 15 CFS, and especially at Site 2 on Gabilan Creek. As we learned during our monitoring of water surface elevation, large rainfall events such as the event on November 27-29 will have a much longer flow recession time compared to the initial first flush. In order to sample more thoroughly throughout the range of the hydrograph, sampling is expected to take place over multiple days.

There needs to be a better system for water quality sampling at high water levels for the remaining years before the construction of the new park. The best option would be to construct temporary bridges at the monitoring sites, allowing for sampling across the width of the streams even when wading is unsafe. Another possible option is to set up a system of cables to lower the containers into the stream for sampling.

6.3 Incorporate Sampling Sites into Park Design

The design of the future Carr Lake water treatment wetland should include infrastructure for conducting safe, repeatable water quality monitoring. Accessibility will remain a challenge during high flows after the property is restored. It would be most effective to construct crossings over Hospital Creek and Gabilan Creek from which equipment can be lowered. Currently, designs for the passive recreation area already include several suggested crossings. This is an opportunity to take advantage of the design to improve the efficiency and safety of monitoring used to assess the success of the future treatment wetland.

6.4 Mitigative Strategies for Sediment Deposition

As a result of the low gradient and poor drainage exhibited at Carr Lake combined with the erosive agricultural landscape in the upper Gabilan Watershed, high sediment deposition should be expected to occur within the restoration site. The excessive sediment input may eventually alter the system's hydraulic properties, influencing the treatment wetlands capability to meet the initial design objectives (Koskiaho, 2003).

Continued monitoring efforts should be applied to better examine the rate at which sediment deposition is occurring. Additionally, mitigative strategies to manage the excessive sediment load should be taken into consideration when implementing restoration designs. One possible solution is the installation of a retention basin at the system inputs to capture suspended sediment before it enters the restoration site. If retention basins are constructed, they should be located near surface streets where routine removal of accumulated sediment can easily be conducted. Alternatively, suspended sediment could be allowed to enter the restoration area unimpeded and accumulated deposits routinely excavated from the channel (Ton et al, 1998). However, if this approach is taken, stable paved roads would need to be included in the restoration design to allow access of the heavy machinery required to remove the compounded sediment.

6.5 Carr Lake Pooling Effect

Once the 8' x 8' box culvert at Main St. reaches one-hundred percent capacity, Carr Lake returns to its roots and becomes a proper lake. Water from Natividad and Alisal Creeks will end up flowing into the future wetland site. This is important to note because no initial baseline water quality data was collected from these two inputs. The water that the future wetland is going to be treating will include the creeks that were sampled in this project plus the water from the other creeks not on the BSLT property. Interpretation of future water quality results will need to bear this in mind. Once water begins to back up, there is going to be mixing, and determining which water came from which creek is going to be challenging.

7.0 Conclusion

Our team was able to document important hydrological dynamics at the BSLT site and collect water quality samples during the first flush and first large precipitation event of the 2018 season. A few key findings discussed in the previous sections are summarized here.

- Hospital Creek is a historic creek, not simply a channelized, man-made ditch. It now mostly flows through underground storm water pipes beneath the urban areas of north Salinas, but can be seen as a small, meandering creek in the 1912 topographical map from the USGS. It has a greater influence on the hydrology of Carr Lake than recognized in previous reports, where it has been included in the Gabilan Creek watershed.
    - The impervious surface area in the Hospital Creek watershed is similar in size to the impervious surface in Gabilan Creek watershed south of East Boronda Road (0.63 mi^2 in Hospital and 0.87 mi^2 in Gabilan).
    - Since it is almost entirely composed of urban land cover, Hospital Creek is a flashy system and very reactive to rainfall.
- Gabilan Creek has a flashy component due to the amount of impervious surface area, but also has a longer flow period due to its larger watershed that includes agricultural and upland areas.
- The longitudinal profile shows that Carr Lake is still functionally a perennial lake that fluctuates between a lake, a flowing stream, and a dry bed.
    - As water begins to back up during a rain event, the four creeks become connected.
    - During our 2018 sampling period, the 0.84-inch event on November 21st made water backup. On October 3rd 0.67 inches of rain fell, but that was the only preceding rain event before sampling. Antecedent rainfall will certainly influence when the water begins backing up, as it does with non-winter flows in Carr Lake (Ballman et al. 2015).
- We cannot use stage as proxy for discharge due to flow restrictions at the BSLT and Main St. culverts. The culverts cause flooding and backwater effect that alters the stage in abnormal ways.
    - The disconnect between stage and discharge may be a challenge to

wetland design.

- Water quality at the BSLT property is impaired due to high levels of nutrients, pesticides, fecal indicator bacteria, and sediment.
- The future treatment wetland will be receiving water from Natividad and Alisal Creeks due to backwater effect and flooding. Nutrients and pesticides in those creeks were not analyzed during this survey and may skew the results of future water quality sampling, underestimating the effectiveness of the treatment wetland.

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Appendix A – Final Scope of Work

Final Scope of Work (from 12/15/18), modified throughout project timeline
CSUMB ENVS 660 class Fall 2018. Module C

Possible project title: *Water quality baseline for anticipated land-use conversion of 73 acres of agricultural fields and ditches in Carr Lake, Salinas, California*

1. Deliverables
    a. Web-published pro-bono consulting research report
    In the style of these reports: http://sep.csumb.edu/class/ENVS660/
    b. Web-posted water quality & hydrologic data
    c. Web-posted geospatial data

2. Milestones
    a. Thursday 11/8. Project kickoff
    b. Get water samples to Kim at MLML by Dec. 2nd (will get results back by Dec 6th)
    c. TBD. Various intermediate milestones.
    d. Thursday 12/13. Final presentation
    e. Shortly after 12/13, and definitely before Friday 12/21. Final web-publication & web-posting.

3. Parties
    a. Client: Big Sur Land Trust
    b. Consultant to BSLT: Balance Hydrologics, BFS Landscape Architects
    c. Educational / pro-bono consultant to BSLT: CSUMB student team
    d. Stakeholders:
        i. Residents of Salinas
        ii. The broader public interest: water quality, species habitat

4. Context
    a. BSLT has acquired land and seeks to restore it.
    b. Balance and BFS are preparing Design Alternatives for restoration, which may include elements such as:
        i. Ponds
        ii. Bench

    iii. Channel sinuosity
    iv. Bench areas for low-intensity floods
    v. Flood benches for first-flush conditions

5. Client's goals for site
    a. Water quality improvement downstream of creeks flowing through Carr Lake
       "evaluate and quantify the water quality improvement benefits associated with the different conceptual designs (e.g., storm water flow rates, reduction in sediment, nutrient, bacterial and other contaminant loads)"
    b. Species habitat
    c. Recreation – e.g. nature-based places for families to visit – wetlands, trails, nature-viewing

6. Core goal for report
    a. Use field measurements to document water quality baseline against which future water quality improvements would be measurable

7. Ideas for components of written report
    a. Title page
    b. Acknowledgements page
    c. Table of contents
    d. Executive summary
    e. Introduction
        i. Background
            1. Site history from 1900s to future
            2. Land use
            3. Planning processes
            4. Potential futures involving more acquisition of private land
        ii. Long term objectives for Carr Lake
        iii. Long term objectives for 73-acre site
        iv. Objectives for this project / report
        v. Pull from old CCoWS reports, TMDL report, Balance white papers
    f. Site description
        i. Land ownership
        ii. Hydrology
            1. Location of streams, ditches, & storm drains
            2. What areas have flooded, how often

3. Cross-sections
4. Longitudinal sections / thalweg profiles

g. Watershed delineation with storm drain tie-ins
    i. Balance did basic delineation, but one may be needed that incorporates storm drains
    ii. Check what Heidi already has (contacted 11/12 by AP)
h. Survey control – Just enough now to tie-in staff plates
    i. Would be great to get solid survey control on elevations of staff plates etc.
    Establish benchmarks and do an RTK-GPS survey
i. Topography / geomorphology
    i. LIDAR terrain map from Fred
    ii. Channel cross-sections
j. Flow regime – as much as possible given storms, and note gaps to be filled by future work
    i. From new data
        1. Staff plates – Big question: how to install staff plates (or equivalent) without interfering with flood flow
        2. Pressure transducers
        3. Discharge measurement
            a. Doppler?
            b. Orange peel?
            c. Flume?
k. Sampling plan and QAPP for this & future sampling activities
l. WQ baseline
    i. Dry & storm
    ii. Measurements
        1. Stage
        2. Temperature
        3. Specific conductance
        4. pH
        5. Turbidity
        6. Visuals – water color, algae etc.
    iii. Sampling design for chems
        1. 4 sites, 5 times each = 20 samples of water
    iv. Analytes
        1. Nutrients
        2. Pesticides

    v. Analytical labs
        1. MLML Can do:
            a. Ammonium
            b. Nitrate
            c. Nitrite
            d. Phosphorus
            e. Dissolved silica
            f. Total and dissolved organic carbon
            g. (Could potentially also do TSS and TDS if MBAS not used)
        2. Monterey Bay Analytical Services
            a. Total suspended solids
            b. Total dissolved solids
            c. Pesticides (2 sites, 1 or more times each)
    vi. From existing data
        1. See Balance docs
    vii. From new data
        1. WQ sampling
            a. Instrument prep
            b. Site prep
            c. Bottle prep
            d. Lab heads-up
            e. Scheduling
            f. Radar prep
            g. Data storage

m. Suggestions for long-term approach at this site
n. References
o. Appendices
    i. Scope of Work
    ii. Raw data – if not already presented in the main body of the report
    iii. Quality assurance details

Appendix B – Recommended Methodology for Field Sampling

Listed below are the recommended techniques established for consistently conducting visual observations, flow measurements, and analyte sampling at Carr Lake. These protocols were developed prior to sampling by integrating previously derived methodology for monitoring water quality and stream ecology into a site-specific procedure that can be implemented to observe the success of the restoration efforts over time (Watson et al. 2005). Although the dynamic hydraulic properties observed at Carr Lake during this study prevented the consistent application of these procedures, we believe the methodology listed below is the best approach to monitoring the site pre- and post-restoration. Proper sampling techniques should be taking into consideration when implementing the restoration design to ensure that safe and consistent sampling techniques can be applied on site.

Visual Observations Methodology

Objective: Observe and record sample site of agricultural ditch visually

- Sampling team of two (or three) brings minimal gear, but should bring all necessary safety equipment and a Rite in the Rain notebook and/or data sheet
- Recording on the data sheet prior to visual assessment should be the following (Sample Visual Assessment Notebook Page):
    - Names/initials of individuals sampling
    - Date
    - Time
    - Site number
    - Sampling interval
- Sampling team stands at a safe location at sample site (on the bank and never in the ditch)
- Team then faces upstream for initial visual assessment at a prime location where they have an unobstructed view
- During visual assessment, the following visual assessments shall be recorded on the data sheet or Rite in the Rain notebook (Sample Visual Assessment Notebook Page):
    - Presence/absence of water
    - Color of water

- Discharge/flow speed (no flow, low, medium, high)
  - Turbidity (low, medium, high)
  - Algal presence or absence
  - Presence of large obstructions in the ditch and proximity to water
  - General sediment class (silt, sand, gravel, cobble, boulder)
  - Level of erosion on banks
  - Estimated channel width
  - Estimated channel depth
  - Turbulent features (waves, riffles, rapids, etc.)
  - Sound
  - Presence/absence of litter or debris
  - Presence/absence of manmade features (culverts, bridges, etc.)
- Repeat the previous step visually assessing the downstream portion of the sample site, and record all information on the data sheet or Rite in the Rain notebook
- Once all data is recorded, proceed as a sampling team to other sample sites and repeat the upstream and downstream assessments until all sample sites are assessed

Sample Visual Assessment Notebook Page

Date					
Researchers					
Site #					
Sample Interval					
Time					

Visual Observation	**Description**
Water present or absent?	
Water color?	
Flow speed?	
Turbidity level?	
Algae present or absent?	
Large obstructions?	
Dominant sediment class?	
Erosion level?	
Approximate channel width?	
Approximate channel depth?	
Turbulent features?	
Sound?	
Litter present or absent? Location?	
Manmade features present or absent? Location?	

Protocol for Taking Stage Measurements

Several techniques for stage (water surface elevation) measurement may be used, depending on the nature of the flow. Protocols for each technique are listed below.

Stage is always recorded. **Stage is recorded both before and after other sampling (YSI, pH, flow)** and recorded as in sample data sheet Sample Stage, pH, and YSI. The stage for each discharge measurement is represented by the average of the before and after stage levels. The quicker the stage is changing, the shorter the time interval between water sampling intervals. The first method of measuring stage is with an established staff plate. The staff plates used have marks every 2 cm that are 1 cm wide. Water level can be estimated to the nearest 0.1 cm.

For example, the stage reading at the arrow on the image would be 41.6
The staff plate should be hydraulically connected to the lowest flows – this means that there should be a channel connecting the staff plate to the channel bottom.

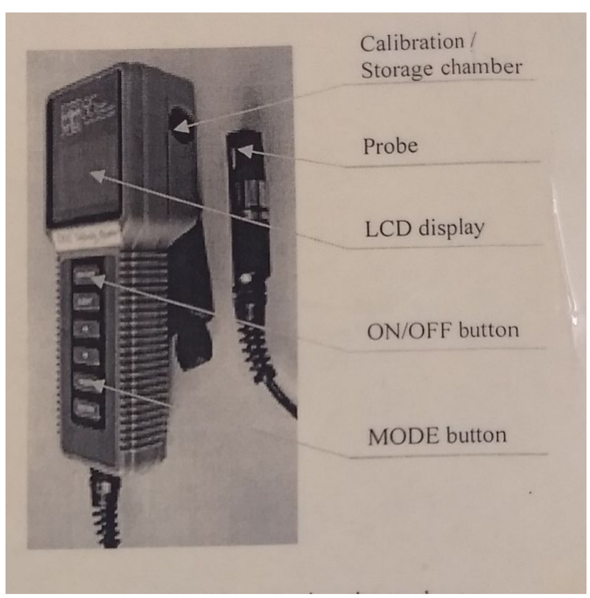
If the staff plate has been washed away and if wading is safe, stage can be measured using an auto level and stadia rod.

1. Set up auto level
2. Take a shot using the stadia rod at the left benchmark
    - Measurement on stadia rod + elevation of benchmark (from previous survey) = instrument height
3. Take a shot at the thalweg
    - Instrument height – measurement on stadia rod at thalweg = elevation of thalweg
4. Record the surface water height on the stadia rod
    - Elevation of thalweg + surface water height = water surface elevation

Protocol for Taking Conductivity/Salinity and DO Measurements with YSI 85

In order to allow time for stabilization while measuring in the field, YSI 85 probe can be submerged before taking other measurements. Conductivity/salinity and dissolved oxygen measurements shall be made with the YSI 85 as follows and recorded as in sample data sheet Sample Stage, pH, and YSI:

1. Measurement shall be taken directly in stream if possible.
2. Turn the meter on using the ON/OFF button
3. Remove the probe from the calibration/storage chamber
4. Rinse the probe with DI water and blot with a Kimwipe
5. Insert probe directly into water so that the metal band around the top of the probe is submerged
6. Press the MODE button until the display shows the units for the desired measurement.
7. Water should be moving past the probe at approximately 1 foot/second for an accurate DO reading. If water is flowing at a low velocity, the probe should be lightly shaken while remaining submerged.
8. After reading has stabilized, record temperature in the lower right as degrees C, salinity as ppt, conductivity reading as µS or mS (and **the degrees C after the temperature reading will NOT be flashing**), DO as saturation %, and DO as mg/L.

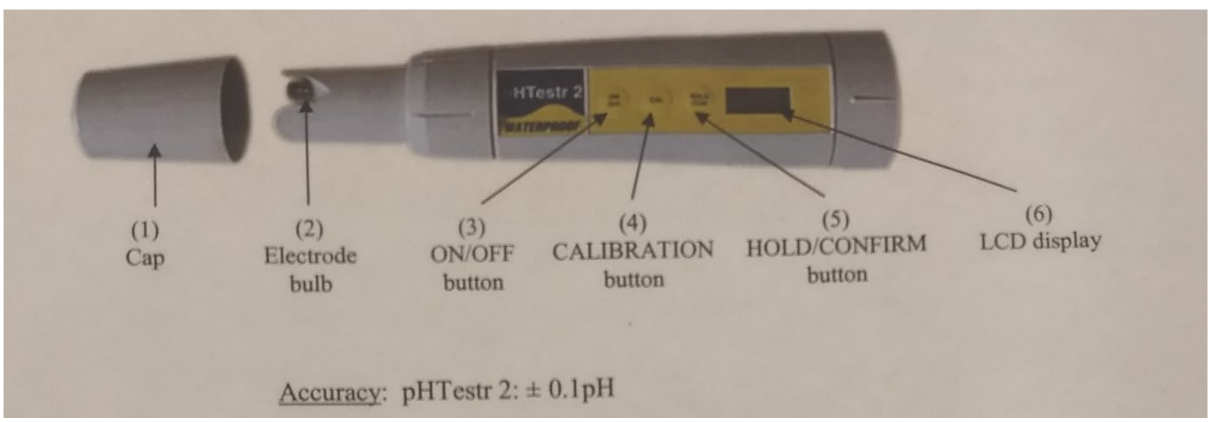


Protocol for Taking pH Measurements

The pH shall be measured in the field using an Oakton pHTestr2 probe. pH probes should be calibrated before each field campaign or storm event monitored.

A pH measurement should be made as follows and recorded as in sample data sheet Sample Stage, pH, and YSI:

1. Remove cap of probe
2. Turn instrument ON,
3. Insert ½ to 1 inch into stream
4. Stir once
5. Let the reading stabilize (approximately 1 minute)
6. Record pH
7. Rinse with DI water and blot with a Kimwipe (don't wipe)
8. Turn pH tester OFF
9. Cap pHTestr2



Sample Stage, pH, and YSI Notebook Page

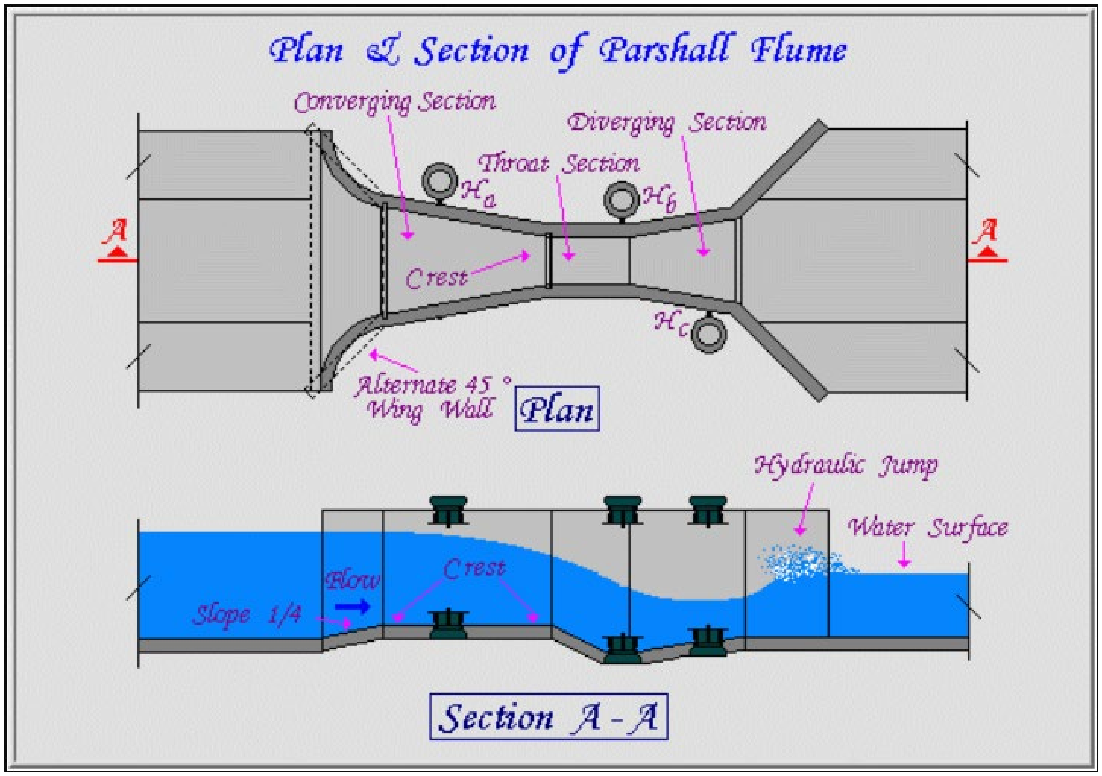
Date					
Researchers					
Site #					
Sample Interval					
Start Time					
Stage					
pH					
Temperature (°C)					
Salinity (ppt)					
Conductivity (uS) (degrees are NOT flashing)					
DO (%)					
DO mg/L					

Protocol for Taking Flow Measurements

Low Flow Conditions

If flow conditions are too low to provide adequate depth for functionality of flow monitoring probes or they impede flow path of visible floating objects, then a Parshall flume should be used to determine stream discharge. This method should only be implemented when all flow can be adequately captured within the Parshall flume.

Parshall Flume Procedure



Parshall flume diagram. Image obtained from http://web.deu.edu.tr/atiksu/ana52/ani4022-1.html

The following steps shall be taken when measuring stream flow rate by Parshall flume:

1. A table shall be drawn in a notebook with columns for 'Measurement #', 'Time', and 'Submerged height'.
2. The times of commencement and completion of measurements shall be recorded, as shall the river stages at those times.
3. Parshall flume throat width shall be recorded.
4. Parshall flume will be placed in the river thalweg in the direction of flow as indicated by the arrow on the side of the instrument.

5. A leveling instrument shall be placed along both the length and width of the Parshall flume to ensure the instrument is level.
6. Sand bags should be on either side of the Parshall flume to ensure that all flow is funneled through the instrument.

Each velocity measurement shall be taken as follows:

1. The Parshall flume shall be placed level in the channel thalweg such that all flow can be captured within the instrument.
2. The submerged height of the instrument will be observed using the indicated measurements located in the flume throat near the junction of the discharge section.
3. The water level shall be overserved until a constant value has been reached, at which point the height of submergence will be recorded.

The total stream discharge shall be estimated in using Microsoft Excel workbooks as follows:

1. Notes collected in the field notebook shall be transferred to an Excel spreadsheet.
2. Total stream discharge will be calculated using the following equation;

$$Q = KxH_a^n$$

where the flowrate (*Q*) is equal to the product of the flume discharge constant (*K*) multiplied the instrument submersion depth (H_a) raised to the power of the discharge exponent (*n*). Note; both the flume discharge constant and discharge exponent vary depending on the Parshall flume throat width.

Sample Parshall flume Notebook Page

Date					
Researchers					
Site #					
Sample Interval					
Start Time					
Staff Plate Reading					
Instrument Throat width					
Measurement #	Time	Submersion Height (m)			
1					
Time of Completion					
Staff Plate Reading					

Moderate Flow Conditions

- Under moderate/wadable flow conditions where all discharge cannot be adequately captured by the Parshall flume, a flow meter should be used to determine discharge.

Impellor Flow Meter

The following steps shall be taken when measuring stream flow rate by wading with a current meter:

1. It shall be determined that the deepest part of the stream is safe to wade, and that no dangerous debris is likely to enter the site. One team member should serve as a spotter for any debris moving downstream.
2. One end of a tape measure shall be firmly anchored at any low point on one bank of the stream. The other end shall be firmly anchored to the other bank. Intermediate supports shall be used in wide streams, such as metal stakes driven into the streambed, with clamps on the upper ends.
3. The distance of the left and right edge of the water's surface will be recorded.
4. A table shall be drawn up in a notebook with columns for 'distance', 'depth', and 'velocity'.
5. The times of commencement and completion of measurements shall be recorded, as shall the river stages at those times.
6. Two people shall be employed, one as recorder, the other as measurer
7. Where time permits, an even measurement interval shall be used, and at least 10 velocity measurements should be taken across the width of the stream. When time is scarce, an uneven measurement interval may be used, with most measurements taken at points of rapid change in velocity, and at points of high velocity and/or high depth.
8. Starting from one bank, preferably the left bank, the offset at which the free water surface begins shall be recorded
9. Velocity measurements shall then be taken across the width of the stream until the opposite bank is reached and the offset at which point the free water surface end is recorded.
10. Streams with multiple channels shall be measured as the sum of multiple streams.

Each velocity measurement shall be taken as follows:

1. The measurer should stand well downstream of the instrument.
2. The instrument should be placed in the water and rested against the bed to record flow depth.
3. The current meter shall be mounted on a top-setting rod such that it may be held steadily at 60% of the flow depth above the bed.
4. The impellor shall be checked for blockages and free-running operation, and the computer shall be reset to zero average velocity.
5. The impellor shall be allowed to run freely while the average velocity is observed over a period of 10 seconds to 1 minute in order to measure a steady mean value. This value shall be recorded as the (vertically-averaged) mean velocity of the stream at that offset across the stream.

The total flow rate for the stream shall be estimated in the laboratory using a Microsoft Excel spreadsheet as follows:

1. The field book table shall be copied to the spreadsheet.
2. Each velocity measurement is assigned a representative width, calculated as the difference in offset between the halfway points to adjacent measurement points either side of the point at which the velocity was measured.
3. The flow rate for each measurement point shall be the product of the velocity and the representative width.
4. The total stream flow rate shall be the sum of that for all measurement points across the stream.

Sample Impeller Flowmeter Notebook Page

Date					
Researchers					
Site #					
Sample Interval					
Start Time					
Staff Plate Reading					
Distance left water edge					
Distance right water edge					
Reading	Distance	Depth	Velocity		
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Time of Completion					
Staff Plate Reading					

High Flow Conditions

Under high flow conditions where wading would be considered unsafe, flow should be determined using the float method, by measuring the amount time it takes a visible buoyant object to travel a specific distance.

Float Method

The following steps shall be taken when measuring stream flow rate using the float method:

1. A table shall be drawn up in a notebook with columns for 'Trial Number', 'Downstream Distance', 'Time', 'Velocity', 'Note'.
2. The times of commencement and completion of measurements shall be recorded, as shall the river stages at those times.
3. A distance of 3 times the channel width or minimum of 10 m shall be measured along the length of the channel and a marker placed at the 0 m and 10 m mark.
4. Two people shall be employed, one as time recorder, the other as observer. One located at the 0 m marker and one at the 10 m marker.

Each velocity measurement shall be taken as follows:

1. Visible buoyant object, such as a florescent dowel or orange peel, should be place upstream of the 0 m marker, preferably in the most rapid flowing stream segment.
2. The recorder will begin recording time the instant the observer verbally indicates when the object has passed the 0 m marker.
3. The time recorder will stand by the 10 m marker and observer will visually follow the floating object, informing the recorder when the object is near the 10 m marker.
4. The recorder will then visually observe the object, stopping the recorded time the instant the object passes the 10 m marker.
5. The time it took the object to travel 10 m shall be recorded in field notebook.
6. This procedure shall be conducted for a minimum of 3 trials and the average flow of the trials calculated.

The total stream discharge shall be estimated in the laboratory using a Microsoft Excel spreadsheet as follows:

1. Notes collected in the field notebook table shall be copied to the spreadsheet.
2. Flow will be calculated based off the average time it took the object to travel 10 m.
3. This value will then be multiplied by a flow variation coefficient (0.425) to account for variation in surface water velocity across the channel width.
4. Discharge will be determined based of the calculated flow rate multiplied by the cross-sectional channel volume as measured at the observed staff plate reading.

Sample Float Method Notebook Page

Date					
Researchers					
Site #					
Sample Interval					
Start Time					
Staff Plate Reading					
Trial #	Downstream Distance	Time	Velocity	Note	
1					
2					
3					
Time of Completion					
Staff Plate Reading					

Bedload Sample Collection

Objective: Collect bedload measurements using the Helley-Smith bedload sampler

- Sampling team of two (or three) brings the following gear to the sample site:
    - Rite in the Rain notebook
    - Bedload datasheet
    - 1 Helley-Smith bedload sampler
    - Bedload sample collection oven bags OR Ziploc bags (if oven bags are unavailable)
    - Proper safety equipment
- Recording on the data sheet prior to visual assessment should be the following:
    - Names/initials of individuals sampling
    - Date
    - Time
    - Site number
    - Sampling interval

The next steps are for larger streams with moderate to low flow conditions:

1. Safely accessing the sample site may require climbing, scrambling, or traversing down steep banks. **Always be aware of your surroundings and the safest way to access the stream.**
2. When safely at your sampling point, visually assess the width of the stream.
3. Determine the width of the stream, and at the sample site cross section, visually mark or estimate where the Helley-Smith bedload sampler will be placed. In narrow streams, spacing between samples should be approximately two feet (0.6 m) for a total of four to six samples.
4. Attach a sample collection bag to the Helley-Smith bedload sampler.
5. When the bedload sample locations are determined at a cross section, the Helley-Smith bedload sampler is lowered carefully into the stream and placed on the streambed.
6. Sample time should be between one and two minutes with each sample the same duration.
7. Once the sample is collected, the sample is removed from the Helley-Smith bedload sampler and placed into an oven bag OR Ziploc bag (if oven bags are not available). Make sure to record the mass of an oven bag prior placing the wet sediment sample inside.

The following steps are for smaller streams with stream bottom and/or visible bedload movement

1. Safely accessing the sample site may require climbing, scrambling, or traversing down steep banks. **Always be aware of your surroundings and the safest way to access the stream.**
2. When safely at your sample point, visually assess the width of the stream.
3. Samples are taken in areas of equal visual bed movement. This technique is called the representative width. These locations are measured for their widths, and the mass of sediment collected in that width is the representative sample.
4. Bedload samples are collected using the Helley-Smith bedload sampler for a pre-determined amount of time (between one and two minutes) based on visual observations and stream flow.
5. Once the sample is collected in the sample collection bag, the sediment is transferred to an oven bag OR Ziploc bag if oven bags are not available.
6. Make sure to record the mass of an oven bag prior to placing the wet sediment sample inside.

Drying bedload sample

1. When all samples are collected and placed in oven bags, take the oven bags to a lab or location with a convection oven.
2. Samples will be placed in the oven at 60 degrees Celsius (140 degrees Fahrenheit) for a duration of 12-24 hours.
3. Maintain a periodic visual assessment of the drying; drying times should take no more than 24 hours.
4. When the sediment samples are completely dry, remove from the oven to cool.
5. Measure the masses of the sediment bags with sediment inside, record and subtract the mass of the initial oven bag from the mass of the dried oven bag with sediment inside to calculate the mass of sediment collected.

Analyzing samples (load per time)

1. Once all bedload/sediment masses are recorded, width interval loads are calculated. The product of the sample mass and its representative width is divided by the width of the Helley-Smith bedload sampler (0.075 mm).
2. The width interval loads are then divided by the duration of the sample collection to find an estimated load per time (g/s).
3. Finally, these values are given time slots that they represent to calculate a load per day. The final value for bedload is tonnes.

Sample Bedload Samples Notebook Page

Date					
Researchers					
Site #					
Sampling Interval					
Time					
Representative width (m):					
Initial bag mass (kg):					
Sample duration (s):					
Mass of dried bag (kg):					
Date					
Researchers					
Site #					
Sampling Interval					
Time					
Representative width (m):					
Initial bag mass (kg):					
Sample duration (s):					
Mass of dried bag (kg):					
Date					
Researchers					
Site #					
Sampling Interval					
Time					
Representative width (m):					
Initial bag mass (kg):					
Sample duration (s):					
Mass of dried bag (kg):					

Water Quality Sample Collection

The following procedure steps should be followed only under low to moderate flow conditions when safe river wading practices can be implemented. In high flow conditions, where wading is to be considered unsafe, alternative measures should be taken to ensure that water quality samples can be collected in a safe and consistent manner.

DH-48 Sample Collection

The following steps shall be taken prior to sample collection:

1. Proper storage containers for each sample analysis shall be obtained from the diagnostic service.
2. Obtain a DH-48 integrated suspended sediment sampler for sample collection.
3. Proper quantity of DH-48 bottles (~500 mL) to meet the required sample volumes should be collected and labels attached for sample collection and identification.
4. Prepare an adequate number of ice chests to be deployed at multiple sites capable of holding all DH-48 bottles standing upright to prevent leakage, while still maintaining enough additional room for ice.
5. A table shall be drawn up in a notebook with columns for 'Sample #', 'Bottle ID', 'Distance', Sample method (DH-48 or Dip)', and 'Notes'.
6. The times of commencement and completion of measurements shall be recorded in the notebook, as well as the river stages at those times.
7. One end of a 50-meter tape measure shall be firmly anchored at any low point on one bank of the stream. The other end shall be firmly anchored to the other bank. Intermediate supports shall be used in wide streams, such as metal stakes driven into the streambed, with clamps on the upper ends.
8. The distance of the left and right edge of the water's surface should be recorded to determine the width of the surface water in the channel.
9. The surface water width shall be divided into equal intervals where sampling will occur.
10. Label each DH-48 bottle before sample is collected with a specific ID# that includes Site # (1-4), Sample Interval (1-5), and Sample # (1-10). Label ID for each bottle shall be recorded in field notes.

11. Depending on the desired analysis, a total of 6-10 DH-48 bottles will be filled at each site sample interval for 5 sampling intervals accounting for a total number of 30-50 samples / site.
12. Obtain enough ice to cover all DH-48 bottles for storage and transportation in the ice chest once water samples have been collected. In order to assure that the bottles stay upright, do not add ice until all of the used sample bottles are placed in the ice chest.

Each water quality sample shall be collected as follows:

1. Before sample is collected confirm that the sample bottle has been properly labeled (See step 10 above).
2. Include the time and date of sample collection on the sample bottle.
3. Attach DH-48 bottle to the DH-48 sampler.
4. When using a DH-48 sampler, a vertically integrated sample should be taken from several evenly spaced stations along a transect.
5. At each collection station, insert the instrument, with the in-take nozzle facing upstream, pushing the bottle vertically downward through the water column and then back up to the surface in a uniform motion. Special caution should be taken not to disturb sediment on the channel bottom.
6. This process shall be repeated at equally spaced intervals across the channel at locations where the water depth allows for the proper use of the DH-48 sampler.
7. If proper DH-48 sampling technique cannot be applied samples will be collected through a dip method. Each DH-48 bottle will be gently dipped into the stream with the mouth of the bottle titled slightly upward, facing into stream flow.
8. During each sampling interval one dip sample will also be collected in a DH-48 bottle to be used later for sample preparation.

Water Quality Sample Collection Notebook Page

Date					
Researchers					
Site #					
Sample Interval					
Start Time					
Staff Plate Reading					
Distance left water edge					
Distance right water edge					
Sample #	Bottle ID	Sample Method	Distance	Note	
1					
2					
3					
4					
5					
6 (Dip Sample)					
Time of Completion					
Staff Plate Reading					