



*Central
Coast
Watershed
Studies*

CCoWS

Protocols for Water Quality and Stream Ecology Research

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1 Introduction

This document is a continuing compilation of all protocols relating to the research activities of the Central Coast Watershed Studies (CCoWS) team at the Watershed Institute, California State University Monterey Bay (CSUMB).

The document is intended as a reference point for work in a number of areas, and for a number of research projects.

The protocols are grouped into five major areas, described in the following sections:

- Management protocols
- Monitoring protocols
- Sampling protocols
- Laboratory protocols
- Protocols for data analysis

A final section presents a number of ‘methodological comparisons’, including results of instrument calibration, and comparisons of measurement techniques for key variables.

2 Management protocols

This section contains protocols relating to general research management activities, including:

- Sample management (bottles, ID numbers, etc.)
- Database management
- Staff training
- Equipment management

2.1 Protocol for sample management

- Sample containers shall be labeled with a unique ID before being taken into the field.
- Containers that may be used include:
 - *Nalgene* bottles (1L)
 - *Nalgene* bottles (500 mL)
 - *Nalgene* bottles (125 mL)
 - *Nalgene* bottles (100 mL)
 - *Nalgene* beakers (1000 mL)
 - Bedload bags
 - Amber glass jars w/Teflon lined lids (60 & 120mL)
 - Sterile bottles provided by external laboratories (various)
- Containers shall be kept in groups, where all containers in a group have a similar ID.
- Re-useable, cleanable containers shall be weighed before use. The weight shall be recorded in the CCoWS database for recurring use.
- Upon taking a sample, the container ID shall be recorded in a *Rite-in-the-Rain* field book (see Section 3.9).
- The combination of Site Code (see Section 3.1.1), Date/Time, and container ID shall serve as the unique identifier of a sample.
- Large samples may be distributed between more than one container, in which case all container IDs shall be recorded.
- Samples shall be transported directly to the CCoWS laboratory. If necessary (see relevant Sections), samples shall be kept on ice in a cooler during transport.
- Upon returning from the field, all samples shall be deposited in the CCoWS laboratory. When necessary, samples shall be refrigerated or frozen. Frozen or refrigerated samples shall be logged in and out on the *Sample Storage Management Log* (Appendix A).
- On the first office day following field sample collection, all available data for each sample shall be entered into the CCoWS MS Access database (see Section 2.2). Fields for results of laboratory analyses shall be left blank.
- If necessary, certain samples (see relevant Sections) shall be analyzed without delay.
- If samples are to be analyzed at a laboratory other than CCoWS, samples shall be transported to the external laboratory and transferred according to that laboratory's chain of custody procedures. An additional container

- ID for the external laboratory may be given to the original container, which would then have two container IDs.
- Samples analyzed in the CCoWS laboratory may also result in the use of additional containers and/or container IDs.
 - Samples may be split in the CCoWS laboratory, such that the resulting fractions may be analyzed using either multiple techniques and/or multiple laboratories. Any fractional sample shall be transferred to new containers, with new container IDs.
 - Upon completion of laboratory analysis, the analysis results shall be immediately recorded in the CCoWS *MS Access* database. The sample container shall then be cleaned and prepared for future sampling, or discarded.

2.2 Protocol for data management

2.2.1 All data

- The primary data storage shall be on a central University server.
- The data shall be backed up on CD at least every 6 months. Backup CDs shall be stored at the Watershed Institute building in a fireproof safe.
- The data file names shall contain the last date on which they were significantly modified (in the format Name_YYMMDD_initials of user.*).
- Previous versions (with earlier dates) shall be maintained on the server as intermediate backups until they are backed up to CD (see above).
- All initial data shall be entered into the appropriate database on the day following field sample collection.
- After laboratory analysis is complete, all results should be immediately entered into the database record for that particular field monitoring campaign.
- All data entered into the database will be later verified by the project leader during the data analysis phase.
- CCoWS shall keep all original data sheets and field books on file at the Watershed Institute.

2.2.2 Primary water quality data

- Primary water quality data include all data pertaining to monitoring of streams and agricultural runoff.
- Primary water quality data shall be maintained in the CCoWS *MS Access* database.
- The following exception applies:
 - Individual flow and depth measurements within stream flow cross-sections shall be maintained in *MS Excel* spreadsheets (as opposed to the total calculated discharge that results from these measurements which is maintained in the CCoWS *MS Access* database).
- The CCoWS *MS Access* database shall be a relational database, with tables for:
 - Site information (e.g. site code, Bridge/Road crossing, GPS coordinates)

- Site visit information (e.g. Date/Time, container ID, sample type)

2.2.3 Other data

- Other data include: Regional lagoon monitoring and stream ecology data (stream reconnaissance, detailed stream habitat assessment, and fish population assessment).
- These data shall be maintained in separate *MS Access* databases.

2.3 Protocol for staff training and responsibility

2.3.1 Staff structure

The CCoWS staff hierarchy is as follows:

- Team leader
- Research manager
- Field coordinator
- Lab manager
- Senior technicians x 2
- Technicians x 2
- Students x 4

2.3.2 Laboratory training

- The laboratory manager shall oversee the development of new laboratory procedures, training of staff for new laboratory procedures, and laboratory training for new staff.
- Technicians shall be knowledgeable of all equipment and tests before analyzing samples independently. This should include both training with the laboratory manager and/or an experienced technician as well as the study of instrument and procedure manuals. This training shall be documented on the *Technician Training Tracking Sheet* (Appendix B) and kept on file by CCoWS.
- The laboratory manager shall be responsible for laboratory safety. It is their responsibility to assure that all technicians performing lab analysis have participated in a safety training session.
- Training on laboratory safety procedures is provided by the Earth Systems Science and Policy (ESSP) laboratory staff at CSU Monterey Bay and is a requirement prior to laboratory use. Documentation of lab safety training is kept on file by the ESSP laboratory staff.
- All accidents and incidents shall be reported to the lab manager and the ESSP lab director. Accidents and incidents shall be documented on the *Accident/Incident Report Form* (Appendix C).
- Students shall not undertake any potentially dangerous activity without staff supervision.

- Management and senior staff shall be responsible for the accuracy of analyses performed by students.

2.3.3 Field training

- The field coordinator shall oversee development of new field procedures, training of staff in new field procedures, and field training for new staff.
- The field coordinator or a senior technician shall be responsible for safety in the field.
- Staff shall not undertake any field activity without prior training by the field manager or designee.
- Staff shall be responsible for the accuracy of field data collected by students.

2.4 Protocols for equipment management

Various pieces of CCoWS equipment require periodic calibration and maintenance to assure accuracy and reliability. This equipment includes:

- *YSI 556 MPS* (measures dissolved oxygen, temperature, salinity, oxidation/reduction potential, conductivity, and pH)
- *EL301* strip-reader (microwell photometer for ELISA use)
- *Hach DR/2500* Spectrophotometer (nutrient analysis)
- *Hach 2100P* Turbidimeter
- *Micromeritics* OptiSizer Particle Size Distribution Analysis (PSDA)
- *Oakton* Total Dissolved Solids (TDS) probes
- *Oakton* pH probes
- *Global Water* and *CCoWS* water velocity meters (flow probes)
- Pipettes, various brands

The scheduling of the calibration and maintenance varies according to the amount of use and manufacturer's requirements. All equipment used by CCoWS is calibrated according to instructions provided by the manufacturer, with the exception of the water velocity meters constructed by CCoWS. The protocol for calibrating CCoWS flow probes is presented in Section 7.1. CCoWS maintains an "Equipment Calibration & Maintenance Records" document that outlines specific calibration and maintenance schedules/procedures along with logs for the recording of calibrations and all maintenance performed. These records may be reviewed upon request.

3 Monitoring Protocols

This section contains protocols relating to field activities, including:

- Site selection and preparation for source analysis monitoring
- Storm event water quality monitoring
- ‘Snapshot’ ambient water quality monitoring
- Water quality monitoring on agricultural fields
- Lagoon water quality monitoring
- Field notes and data sheets
- Stream reconnaissance
- Detailed stream habitat assessment
- Fish population assessment

3.1 Protocols for site selection and preparation for source analysis

3.1.1 Site selection

With respect to the objective of conducting a sediment source analysis based on stream monitoring, sediment loads should be measured at as many sites as possible. Site selection is subject to the following goals and constraints:

- Sites should be established at multiple locations along major rivers.
- Sites should be established on major tributaries.
- Sites should be established near confluences (ideally one on each of the two streams above each major confluence, and one below the confluence).
- Sites should be established at major breaks in stream class (e.g. between headwater, foothill, and floodplain reaches).
- Sites should be established at bridges, to allow for monitoring during flood events.
- Bridges should be safe from traffic, with broad shoulders, and few vehicles.
- Sites should be safe from nighttime social dangers.
- Sites should be accessible by public roads.
- A single vehicle should be able to visit all sites in a single day.
- Sites should allow convenient parking.
- If site is privately owned, permission to access shall be obtained from the landowner.
- Each selected site shall be given a unique Site Code (e.g. SAL-DAV). The first three letters of the Site Code are the first three letters of the water body or stream name. The second three letters of the Site Code are the first three letters of the bridge or nearest road crossing. For instance, the Site Code SAL-DAV represents the monitoring location on the Salinas River at Davis Road bridge.

3.1.2 Site preparation

Staff plates measure river ‘stage’ and are the most robust, accurate record of river level available. Their permanency is vital.

- Except for existing USGS sites, sites shall be equipped with a set of one or more 1-meter metric metal staff plates.

- Where possible, these should be mounted on the concrete of bridge foundations. In cases where the concrete is too hard, or there is no bridge, staff plates should be mounted on steel piles driven into the substrate.
- Note that “zero” stage does not need to be set to any particular level, such as the level of zero river discharge recorded at a particular time.

3.2 Protocol for storm–event water quality monitoring

3.2.1 Introduction

Storm water quality monitoring is based around rainfall during storm events. A storm event is a subjectively defined, discrete period of rainfall lasting between a few hours and many days. The objective of storm–event monitoring is to estimate the event total and peak flow and pollution load passing all sites of interest. Resource and personnel limitations dictate that a compromise is involved between the number of sites, and the number of times that each site can be visited during the event. The techniques presented below differ from many previously published techniques by being optimized as much as possible for maximization of useful information with the available labor resources.

Storm–based monitoring shall be planned as follows:

1. Prepare for rapid response.
2. Follow weather forecasts until precipitation is forecast a few days in advance.
3. Determine team availability.
4. Observe WWS weather radar animations every six hours.
5. Observe WWS quantitative precipitation forecasts (QPFs).
6. If more than 10 mm is forecast, notify team of impending mobilization.
7. Prepare round–the–clock field staffing schedule.
8. Take pre–event samples.
9. Watch WWS USGS stream–flow reports and radar to identify runoff areas.
10. Target field trips to runoff areas at regular intervals for duration of runoff.
11. Take post–event samples.

Each of these steps is described in detail as follows.

3.2.2 Rapid response

- The monitoring team shall be able to respond rapidly after extended breaks in fieldwork. The first 8 steps above can occur within a few hours. If pre–event samples are not taken before the event, total loads will not be able to be determined from the resulting data. This is particularly so for urban sites, which have a very short time of concentration of runoff.

Distant sites are also critical because of the time taken to reach them once a significant event has been determined to be likely.

- All storm-sampling equipment shall be prepared in color-coded sampling kits. The contents of each kit are listed in Table 3-1. Kits should be kept in vehicles throughout the storm season.
- Sample bottles shall be pre-numbered (see Section 2.1) and stored in bins ready to be taken in to the field. Pre-numbering saves valuable time in the field, where it can be difficult to number wet bottles with markers or tape, especially during nighttime monitoring. It also saves time in the lab, as the dry weight of each bottle can be stored on file indefinitely.

Table 3-1. Contents of storm monitoring kits

Storm Monitoring Equipment List		
Item Type	Item	
General	<i>Rite-in-the-rain</i> field book	funnel
	pencils x 4	hammer
	permanent marker	Stopwatch
	stakes	<i>Zip-loc</i> bags
	duct tape	towels
Safety	orange cones x 2	antibacterial lotion
	reflective vests x 3	gloves
	first aid kit	cellular phone
	flash light	head lamp
Sampling	TDS probe	<i>Nalgene</i> sample bottles
	pH probe	DH-48 sample bottles
	thermometer	DH-48 sampler
	optical range finder	flow probe
	measuring tape	flow probe top setting rod
	transparency tube	Helly-Smith bedload sampler
	ice chest w/ ice	bedload bags

3.2.3 Weather forecasts

Central Coast winter storms usually arrive from the west, northwest, or north. Typically, a low-pressure system moves generally southward along the coast from Oregon, spiraling anti-clockwise. This means that individual storm cells

arrive from the west, as arms of the spiral. They often dissipate around the latitude of the Salinas Valley. It can be difficult to predict whether cells will cross the coastline and precipitate, or whether coastal effects, including the Coast Range, will block their progress.

- Team members should be aware that numerous false alarms are to be expected. A number of unexpectedly small, insignificant events may need to be monitored before a large event occurs.

3.2.4 The sampling team and their safety

For a typical event, the sampling roster may contain over 10 names.

- For each event, the team shall be divided into smaller field teams operating in sequence, such that a team is always in the field during peak days. Teams of two are economical, but three is safer and better for morale.
- Team members shall be made aware of safety hazards such as:
 - *Suspicious activity.* Over time, certain places become recognized as areas where suspicious or criminal activity is frequently observed, often at night or at dawn. Such sites shall be avoided outright, avoided at night, or only visited by teams of three or more, including at least one male.
 - *Trash.* Certain sites are frequent dumping grounds for trash. Trash may pose biological, physical, and mental hazards – such as large decapitated animals. Rubber gloves should always be used to protect the skin during sampling. Hands shall be cleaned with antibacterial cream at the completion of each site visit.
 - *Wading in fast and deep water.* In fast-flowing water, streams shall not be waded (particularly in waders) when the water is above thigh-height.
 - *Bridge-based sampling of floodwaters.* Sampling of floodwaters from bridges involves suspending heavy instruments into the water from a bridge. One team member shall be dedicated to ‘spotting’ large floating debris that may place equipment or personnel at risk. Additionally, bridge-based sampling should always be conducted from the downstream side of the bridge.

3.2.5 Weather radar

The United States has exceptional coverage by weather radar stations. The dissemination of radar data is licensed to private purveyors, each of whom choose to present the data in different ways. The [weather.com](http://www.weather.com) site¹ offers an easily readable animated display covering a large area that merges data from multiple radar transceivers. The [wx.com](http://www.wx.com) site² displays more detail over a shorter time period and smaller area.

- Weather radar shall be used to predict imminent, significant runoff producing events.
- Radar rainfall measurements should be ignored until significant patches or yellow, orange, or red coloring form a trajectory toward the study area.
- Multiple sources of radar information should be used in conjunction.

3.2.6 Quantitative precipitation forecasts

Radars only display precipitation that is currently occurring at a site, or that is occurring elsewhere from storm cells that are traveling towards a site of interest. They can be used to predict runoff in areas of interest with about two hours notice.

Longer notice is given by a number of quantitative precipitation forecast (QPF) products on the World Wide Web, which are produced by mesoscale computer simulation models. Total 6-hour precipitation depths for individual sites are given by a National Weather Service web site³. This site also produces a useful 72-hour animation for the western US⁴.

- QPFs should be used to plan for storm events between about 4 hours and 2 days in advance.

¹ [weather.com](http://www.weather.com): <http://www.weather.com/weather/map/USCA0724>

² [wx.com](http://www.wx.com): <http://www.wx.com/wxradar/wxradarSS.cfm?radar=MUX>

³ NWS 6-hour QPF: <http://www.wrh.noaa.gov/cnrfc/prods/RNOHD1RSA.htm>

⁴ NWS 72-hour QPF animation: <http://www.wrh.noaa.gov/cnrfc/qpfloopfill.htm>

3.2.7 Mobilization threshold

Almost any Central Coast rainfall amount will lead to runoff in urban areas. However, significant pollution loads are not usually generated until event totals exceed approximately 10 mm. Most agricultural areas do not typically generate runoff that reaches streams with sampling sites until over 20 mm of rainfall has been received. Depending on the antecedent conditions, the large tributaries of non-perennial rivers do not connect with the main stem of the rivers until a few events around 30 mm have occurred in any given season. Until then, all rainfall either evaporates or infiltrates into dry riverbeds.

- These thresholds, as predicted in the QPFs, should be used to determine whether or not to mobilize sampling teams.

3.2.8 Staffing schedule

During peak days of large monitoring campaigns, multiple teams may be required to be in the field at any one time in order to cover the major provinces of the study area. Rostered field trips generally last from between four and twelve hours. During pre-event and post-event days, a single team will often suffice, as most river stages will then only change gradually.

- Upon mobilization, a staffing schedule should be drawn up on a white-board (Fig 3.1).
- Compatible field teams should first be identified, with groups of workers that live near each other, have at least one experienced member, and at least one usable vehicle.

3.2.9 Tracking the peak

For a given sampling site during a given event, the most important result is an estimate of the total pollutant load passing that site during the event. This estimate is made using the integration of instantaneous load measurements made at several times during the event.

- At least three samples shall be taken per event: one before the event, one at the time of peak load, and one afterwards. The pre- and post-event samples define the start and end of the event, where both river stage and pollutant concentration should be at near ambient levels. If these samples are not taken, it is impossible to calculate the magnitude of the event when analyzing the results.
- Preferably, six or more samples should be taken. There may be two or three pre-event samples taken, in an effort to identify the exact moment that the river stage began to rise. Most of the load is generally transported near or before the time of peak discharge. This is also normally the time of peak sediment concentration. It is vital to take frequent samples and measurements of river stage during the peak. This ensures that the data clearly reveal that the peak was actually sampled, and did not occur sometime before or after a sample that was presumed to have been taken at the peak. Often, additional information can be

gathered, such as the level of wetting on the concrete surrounding the staff plate. This will suggest whether or not the stage is still rising, or is falling. At times, there are multiple peaks, which complicates sample planning. Post-event samples are required to define the point at which the event is declared “complete”. This can take many days, as river stages recede much more gradually than they rise.

For large watersheds, the peak occurs at different times in different places. This is both due to different timing of incident rainfall, and to the time it takes the peak to travel downstream. For instance in the Salinas River watershed, rainfall timing introduces discrepancies of about 2 days, and travel time adds a further 7 days for the full length of the Salinas River. This is useful, as it allows a more even distribution of sampling resources. On most days, crews will be moving back and forth between a site that is currently peaking, a site 20 miles upstream that has already peaked and needs post-peak samples, and a site 10 miles downstream that has not yet peaked.

- For large watersheds, sites should be located such that floodwater peaks move approximately one or two sites per day.

Logistics are more difficult toward the end of the event so it is important to stay organized. The team is often exhausted and need to catch up with their home lives. The vehicles become disorganized. Sample-bottle stocks are declining, and equipment is in need of calibration. On the positive side, it is usually sunny after the storm has passed.

3.2.10 Measurements at a single site

On a given site visit, one of four levels of measurement shall be used:

1. If time is limited and sampling has recently been conducted at the site, only a stream stage reading shall be taken (2–10 minutes).
2. Normally, this is not the case, and so a suspended sediment or other pollutant sample shall be taken from the river (5–15 minutes).
3. Where possible, a bedload sample should also be included (15–30 minutes).
4. If the river is flowing at a stage that has not previously been observed, a full stream discharge measurement should be taken (30–120 minutes).

3.3 Protocol for ‘snapshot’ ambient water quality monitoring

Whole valley snapshots are sometimes conducted during non-storm event periods. Snapshots provide information on the ambient flow conditions and pollutant concentrations throughout the long, low-flow periods that are typical of the Central Coast.

- Representative sites distributed widely throughout the study area shall be selected.
- Each site shall be monitored once during the snapshot.
- The duration of the snapshot should not be such that regional flow conditions change greatly.
- Variables to be monitored at each site shall include: stage, discharge, TSS, bedload, temperature, conductivity, pH, and any other pollutants or variables of concern.

3.4 Protocol for water quality monitoring on agricultural fields

In order to better understand how potential pollutants such as suspended sediment are transported on agricultural fields or how effective management practices are at retaining these pollutants, CCoWS often conducts on-farm monitoring. Agricultural fields experience two types of flow events that can be monitored: irrigation events and storm events.

3.4.1 Field selection and setup

Fields shall be selected according to the following requirements:

- The field shall drain to a well-defined point where runoff can be sampled. This may be at the end of a furrow or gutter, at the inflow or from the outflow a sump, the outflow from a pipe drain, or the outflow from a sediment detention basin.
- The type of sampling point shall be recorded, and each sampling point shall be given a confidential code in the CCoWS *MS Access* database.
- A map of the field shall be drawn up, including:
 - orientation of north
 - location within the farm parcel
 - orientation of furrows, gutters, and drains
 - location of sumps
- The drainage area of the runoff shall be determined, and its boundaries shall be well defined. The area shall be measured using farm maps and/or surveyed using a theodolite and an electronic distance meter (EDM).
- The slope of the field shall be measured, both along furrow lines and gutter lines. Undulating fields with variable slope should be surveyed using a theodolite and EDM, and the major slope classes should be mapped accordingly.
- The following shall be inquired of the farm manager and recorded:
 - type and condition of any crop
 - recent irrigation history of the soil
 - any expectations of runoff or infiltration based on the sealing state of the soil
 - date and type of last tillage
 - soil type

- Additionally, the soil type shall be determined from county soil maps and shall be recorded.
- If necessary, a system for sampling runoff from the site shall be installed at least one day prior to monitoring. The runoff sampling system may include devices such as PVC sheeting for confining the flow to a narrow stream.
- The act of measuring the runoff should not alter the runoff rate or the ability of the overall flow system to carry sediment past the sampling point.
- Multiple sampling points may be used.
- The level of sediment in any sumps, catch basins, or detention basins shall be recorded by placing a reference pin marked at the sediment surface.

3.4.2 Runoff sampling strategy

- The sampling strategy for the site shall be finalized at least one day before the storm or irrigation event.
- The initiation of runoff shall be observed. Reliable estimates of load are of limited accuracy if the sampling team arrives after the initiation of runoff.
- The time of initiation and cessation of both runoff and rainfall or irrigation shall be recorded.
- Sample collection shall commence at the initiation of runoff, and shall continue until runoff has ceased.
- Samples shall be taken every 5 to 30 minutes. This frequency should be increased during and before times of peak runoff, and decreased during runoff decline.
- The time shall be recorded for every sample, measurement, or observation of any kind.
- Runoff rate shall be measured using a vessel that can capture the entire field runoff for at least 2 seconds. A 5-gallon bucket with pre-marked volume increments may be used. Both the duration and volume of the sample shall be recorded.
- Water quality samples shall be taken by placing a pre-labeled sample bottle under the flow. Where the width of the flow stream exceeds the size of the opening on the bottle, the bottle shall be moved within the flow stream at an even rate so as to uniformly sample the flow stream.

- A water quality sample shall be taken immediately after each runoff measurement, except when runoff rates are relatively constant, in which case a water quality sample should be taken at least once for every 5 runoff measurements taken.
- After runoff ceases, the level of sediment in any sumps, catch basins, or detention basins shall be re-recorded against the reference pin placed earlier.

3.4.3 Rainfall or irrigation sampling

- The time of initiation of irrigation or rainfall shall be recorded.

3.4.3.1 Rainfall

- The amount of rainfall shall be measured using either one or more storage rain gauges, and/or one or more tipping bucket rain gauges with electronic loggers.
- The level of manual rain gauges shall be recorded at half-hourly intervals, and more frequently during periods of intense rain. The maximum rate of application of water to the soil is a critical variable in prediction of erosion.
- Rainfall may be measured at multiple points, in order to determine the average over spatially heterogeneous rainfall fields.
- Rainfall measured at the field should also be compared with hourly data obtained from the nearest three *NWS* or *CIMIS* sites published on the WWW.

3.4.3.2 Irrigation

The rate of application of irrigation water should be measured in *all* of the following ways:

- The farm manager should be asked to state the total irrigation amount (in inches), and to note whether this is expected to agree with pump measurements.
- The pumping rate shall be recorded in gallons per minute.
- The total amount of pumping shall be recorded in gallons.

- The total area under irrigation from the measured pump shall be recorded, as shall the fraction of the runoff-sampled area that is subject to this irrigation.
- The type of irrigation shall be recorded (e.g. sprinkler, linear, center pivot, drip, or flood).
- The rate of travel of linear irrigation systems shall be enquired of the farm manager, and verified by placing a reference pin and measuring the distance traveled over approximately one hour.
- The instantaneous width of the area under direct irrigation beneath linear systems shall be recorded periodically. This width is used to calculate instantaneous application rates per unit area.
- Care shall be taken to note whether the irrigation rate or the rate of travel of a linear system is deliberately increased or decreased at any time by the farm staff.
- The diameter of any sprinkler nozzles shall be recorded (in fractions of an inch).
- The total number of sprinkler nozzles in use shall be recorded.
- The rate of flow from a typical sprinkler nozzle shall be recorded by capping it with a calibrated bucket.
- The rate at which sprinkled water hits the field shall be recorded using one or more buckets periodically moved around the field. Note that wind may significantly enhance evaporation or otherwise remove water from the area to be irrigated.

3.5 Protocol for lagoon water quality monitoring

3.5.1 Monitoring

CCoWS monitors water quality in regional lagoons. Sites are chosen to evenly sample the lagoons with respect to the following likely correlates of variation in water quality:

- distance from ocean
- depth to bottom
- proximity to aquatic vegetation
- proximity to river
- windward/leeward side of lagoon

At each site, the following parameters shall be measured:

- Location
- Depth to bottom
- Water temperature (every 50 cm depth to bottom)
- Salinity (every 50 cm depth to bottom)
- Dissolved oxygen (every 50 cm depth to bottom)

Sampling location is determined by using a *Garmin eTrex Summit* global positioning system (GPS) unit. By using GPS coordinates we are able to return to the same locations in the lagoon with approximately 10-meter accuracy.

Physical water quality data shall be collected using *YSI Environmental 556* MPS Multiple Probe System. Accuracy, range, and resolution for temperature, dissolved oxygen, and salinity are listed in Table 3-2. Each parameter is measured at the surface and then downward at 50 cm intervals until the bottom is reached. To measure every 50 cm, the cable used for the *YSI* is marked at 50 cm intervals. The final overall depth is measured based on the amount of cable released into the water.

The necessary equipment required to conduct this type of monitoring is listed in Table 3-3.

Table 3–2. YSI 556 MPS Sensor Specifications

Sensor Type	Accuracy	Range	Resolution
Temperature (YSI Precision™ thermistor)	± 0.15 °C	-5 to 45 °C	0.1 °C
Dissolved Oxygen (% saturation) (Steady state polarographic)	0 to 200%: ±2% of reading or air saturation 200 to 500%: ±6% of reading	0 to 500% air saturation	0.1% air saturation
Dissolved Oxygen (mg/L) (Steady state polarographic)	0 to 20 mg/L: ±2 of reading or ±2 mg/L 20 to 50 mg/L: ± 6% of reading	0 to 50 mg/L	0.01 mg/L
Conductivity (4-electrode cell w/ autoranging)	±1% of reading or ±0.001 mS/cm whichever is greater	0 to 200 mS/cm	0.001 mS/cm to 0.1 mS/cm (range-dependent)
Salinity (Calculated from conductivity and temperature)	±1% of reading or ±0.1 ppt whichever is greater	0 to 70 ppt	0.01 ppt

Table 3–3. Lagoon monitoring field equipment

Field Equipment	
kayak	gps unit
mounted storage bin	YSI 556 MPS
duct tape	secchi disc
camera	pencils
2 meter stadia rod	<i>Rite-in-the-Rain</i> notebook

3.5.2 Access

The shallow waters of the lagoons are easily accessible by kayak. The use of a tandem kayak allows for easy launching, ability to maneuver between sites with

ease and efficiency, and it also allows for transportation and support of monitoring instruments.

3.5.3 Mapping

A Global Positioning System (GPS) logging unit is used to locate sampling sites, measure the lagoon perimeter, and assist in the collection of bathymetrical data. The *Garmin eTrex Summit* handheld data logger normally results in horizontal positioning errors around ± 5 –6 m with no differential correction needed.

3.5.4 Bathymetry

Bathymetric transects are measured and mapped in lagoons. The locations of the transects are pre-selected to cover all major geomorphic provinces of their respective lagoon. Measurements are taken with a two-meter stadia rod in the shallow sections of the lagoons. In the deep-water areas a measuring tape weighted with a lead sinker is used to measure all sites deeper than two meters.

Access is achieved by foot for the shallow transects and a tandem kayak with anchor is used in the deeper areas. The anchor is used to minimize drift caused by wind. Use of a transect tape for measuring distance from the bank is often not practical. Instead, a GPS unit is used to estimate the distance from the previous measurement and orange markers, placed on both banks, are used for navigation.

3.5.5 Benthic Sediment

Benthic sediment samples are randomly collected in areas of the lagoon that are pre-selected based on the same likely correlates of variation as the water quality sites.

Sediments are collected from a kayak using a lightweight bottom-sediment sampling dredge with a 36 square-inch capacity. The location of each collected sample is mapped with a GPS unit. In the field, each collected sample is poured directly into a pre-numbered cloth oven-drying bag.

In the lab, all samples are dried at 70° C for at least 48 hours before a total weight is measured. After drying, each sample is weighed to the nearest

milligram. Next, each sample is dry sieved through a 25 mm sieve. All particles >25 mm are weighed and recorded. All samples are then wet sieved through 0.063 mm sieve to measure the distribution of particles smaller than 0.063 mm. The remainder of the each sample, or the median particle sizes, is then placed into a numbered tin and dried again as before.

After the second drying, all samples are re-weighed to find the weight percentage of particles smaller than 0.063 mm. The median classes of each sample, if one exists, are then processed through a *Micromeritics* (R) OptiSizer Particle Size Distribution Analysis (PSDA).

3.6 Protocol for stream reconnaissance

Stream reconnaissance involves detailed stream and habitat surveys with the main goal of locating perennial water and any obstructions that may prevent the migration of anadromous fish. This involves first, determining the exact location of the portion of the creek to be surveyed and the adjacent land ownership. If necessary, landowners shall be contacted in order to gain permission to access the creek. The next step of the field survey involves assembling the necessary field equipment, listed in Table 3–4.

Table 3–4. Stream reconnaissance field equipment

Field Equipment	
GPS: <i>Garmin eTrex Summit</i>	Optical range finder
Reconnaissance data sheets	Reel measuring tape
Digital Camera	2-meter measuring tape
Topographic maps	Ruler and grain size card
Plant and fish guides	Thermometer
Waterproof field book	Stopwatch
Boots and waders	Small dowels

Teams (usually of two) then conduct the survey. The survey includes walking and mapping portions of the creek using GPS, while also taking detailed field notes. These notes shall include general descriptions of the creek pattern (for example meandering, braided, or straightened), creek profile, and roughness followed by a determination of a Rosgen stream type classification (Rosgen 1998). In addition, total channel width and depth shall be measured using an optical rangefinder and/or measuring tape. Surface substrate composition (i.e. boulder, cobble, gravel, sand, or silt) within each section shall be determined by visual estimation. Estimates for average percent overhead cover shall also be made and all plant species observed shall be noted. If perennial water is present, low flow width and depth shall be measured using a measuring tape. Surface velocity (m/s) shall be measured using a 2-meter measuring tape, stopwatch, and dowel. Water temperatures shall be periodically taken throughout the survey. For major pools encountered, length, width, and depth measurements will also be taken. For each reach, pools and large woody debris counts shall be made. Important features such as large pools, areas with unstable bank conditions or visible erosion, invasive plant species, obstructions,

road crossings, pollution sources, and all fish, amphibian, reptile, crustacean, and mammal species encountered shall be noted and marked with GPS. This information shall be recorded on the *CCoWS Stream Reconnaissance Data Sheet* (Appendix D).

3.7 Protocol for detailed stream habitat assessment

Following stream reconnaissance, previously outlined in Section 3.6 of this report, habitat assessment for steelhead/rainbow trout rearing shall be performed. Table 3–5 lists field equipment needed to perform habitat assessment:

Table 3–5. Detailed stream habitat assessment field equipment

Field Equipment	
Habitat assessment data sheets	Ruler and grain size card
Boots or waders	Pin flags
GPS unit— <i>Garmin eTrex Summit</i>	V* rod
Optical range finder	<i>Raytek</i> laser thermometer
Reel measuring tape	Stakes and clamps
2–meter measuring tape	Digital camera
Stopwatch	Random number chart
Small dowels	Densitometer

Habitat assessment shall be performed as follows:

- Stratify the entire stream into bio–geomorphic provinces based on information gathered from the stream reconnaissance (Section 3.6), such as presence or absence of perennial water, major breaks in stream class, temperature, and density of riparian vegetation.
- Identify a random set of reaches within each province. Each reach shall contain 500 meters of stream and shall be representative of its province.
- GPS the start and end of each 500–meter reach.
- Within each 500–meter reach, 10–meter intervals shall be determined using a measuring tape or a 10–meter rope.
 - At each 10–meter location, cross–sectional transects shall be made.
 - Begin taking measurements on the right bank. All measurements shall be made within the boundaries of the wetted area and recorded on a *CCoWS Habitat Assessment Data Sheet* (Appendix E).
 - If entire transect is dry, no measurements shall be made. Record as “dry” on the field sheet and move on to the next transect.
 - Note habitat type (pool, glide, run, or riffle).

- Rate the instream shelter complexity (0 to 3) for the wetted area including 5 meters upstream and 5 meters downstream using the California Department of Fish and Game Method (Flosi et. al 1998).
- Record the wetted width of the transect.
- Within the transect, measure the surface temperature of the thalweg.
- Measure the surface velocity (m/s) at the thalweg using a stopwatch, 2-meter measuring tape, and orange dowel. If water velocity is less than or equal to 0.01 m/s, record as 0.01 m/s.
- Divide the transect into approximately 9 evenly spaced points.
 - At each point, measure and record the overhead vegetative cover using a densitometer. Data shall be recorded as ‘yes’ or ‘no’.
 - At each point, measure and record the depth of water using the V* rod. If water is too deep to be measure with the V* rod, use a weighted measuring tape. If the point is dry, record as “0”.
 - At each point, measure the amount of fine sediment accumulation overlying the coarser substrate by inserting the rod until a change in resistance is observed as the rod contacts coarse material. Total depth (water depth plus fine sediment accumulation depth) shall be recorded. If total depth is greater than the length of the V* rod record as “>180 cm”.
 - At each point, randomly select one sediment particle and measure along the intermediate axis using a ruler or grain size card. If bedrock, record as “999”. If no sediment is present and substrate is LWD or a root mass, record as “0”.
 - Find the thalweg of the transect and repeat the same measurements.

All habitat assessment data shall be entered into the CCoWS Habitat Assessment *Microsoft Access* database.

3.8 Protocol for fish population assessment

The following methods (adaptation of California Department of Fish and Game method, Flosi et. al 1998) detail the procedures for performing stream bank and underwater fish observations. This procedure will provide information on species composition, distribution, and abundance for a given reach of stream. Population assessment shall be performed following previous stream reconnaissance and habitat assessment. Table 3–6 lists the field equipment needed to perform population assessment.

Table 3–6. Fish population assessment field equipment

Field Equipment	
Snorkel	Pencil
Dive mask	Thermometer
Slate board	Wet suit and booties
Waterproof camera	Polarized sunglasses

Population assessment shall be performed as follows:

- Navigate to the start location of the 500–meter reach to be assessed.
- 1 or 2 divers, depending on width of stream, shall survey the entire reach of stream either by snorkel or a combination of snorkel and stream bank observation.
- Starting at the downstream end of the reach, diver(s) shall swim/crawl in an upstream direction and record # and species of fish observed within a given habitat type (i.e. riffle, run, or pool) on an underwater slate. Immediately after the survey, all data shall be transferred to a *CCoWS Population Assessment Data Sheet* (Appendix F).
- If 2 divers are needed, divers shall swim side by side while each observing fish on either the left or right half of the stream channel.
- If sections of the reach are too shallow to snorkel (depth less than 10 inches or from chin to top of head), observations shall be made above the water either from within the channel or along the stream bank using polarized glasses.
- Continue until entire reach is surveyed.
- Any observations of fish behavior and habitat utilization as well as a brief summary of the assessment shall be recorded in the notes section of the *CCoWS Population Assessment Data Sheet* (Appendix F).

Fish shall be counted as follows:

- Only fish ≥ 4 inches shall be counted except for the following:
 - Rainbow Trout/Steelhead
 - Smaller species that can be easily identified (i.e. speckled dace, sculpins, and threespine stickleback)

- Size classes for Rainbow Trout/Steelhead are as follows:
 - <3 inches = young-of-the-year (0+)
 - 3–6 inches = yearling (1 + yr)
 - >6 inches = yearling (2+ yr)

All population assessment data shall be entered into the CCoWS *Microsoft Access* database.

3.9 Protocol for field notes and data sheets

- Field data collection at a site shall be organized as a sequence of discrete ‘visits’ made during ‘excursions’ to the field
- A record of each visit shall be made in either:
 - a numbered *Rite-in-the-Rain* field book, or
 - a previously prepared datasheet
- The record for each visit shall included the following information:
 - Name of field trip leader
 - Name/s of field party
 - Date of visit, with month written in letters (e.g. 2–April–2002)
 - Time of visit, using 24 hr time **and** AM/PM notation (to reduce possibility of ambiguity)
 - Site code
 - Site observations and notes
 - Present weather conditions
- For stream visits, the following information shall also be recorded:
 - Presence/absence of water
 - Presence/absence of flow
 - Stage (where a staff plate is installed)
 - Type of sample collected
 - Collection or measurement time
 - Instrument type and ID, if applicable
 - Container ID (Section 2.1)
 - Method of collection (e.g. “grab” or “DH-48”)

4 Sampling Protocols

This section contains protocols for collection or measurement of the following types of water quality constituents:

- Flow
- Suspended sediment
- Bedload
- pH
- Conductivity/Salinity
- Temperature
- Dissolved Oxygen
- Dissolved nutrients
- Pesticides
- Pathogens
- Benthic macroinvertebrates

4.1 Protocol for taking flow measurements

A number of techniques for flow (discharge) measurement may be used, depending on the nature of the flow. Protocols for each technique are listed below, in increasing order of flow magnitude. In all cases, the type of measurement used shall be recorded.

4.1.1 Presence absence

The simplest possible measurement pertaining to flow is whether or not any water is present. This should be a visual observation usually made by an observer standing at a site. It may be made from a vehicle, although there are times when this is inaccurate. It may be made by interpolation between observations made above and/or below the site, although again, this can be inaccurate at times.

4.1.2 Flow / no-flow

The next simplest measurement of flow is whether or not the water in a channel can be seen to be moving in a net downstream direction. Again, this should be a visual observation made by an observer standing at a site. Unless obvious, the observation shall not be made from a vehicle. The observation shall never be made by interpolation. On one instance in a central coast stream, approximately 30 m³/s of flow was observed at a site below which there was no flow or water present at a site approximately 5 km downstream along the same, single channel.

4.1.3 Visual estimation

In situations where logistics prevents all the methods listed below, flow rate should be visually estimated based on personal experience. Conversely, personal experience should be calibrated by memorizing the visual characteristics of flows for which discharges are known. Appropriate visual characteristics are the estimated width, depth, and surface velocity of a flow. Additional characteristics include turbulent features and standing waves, turbidity, sound, and the presence of waterborne litter and debris.

4.1.4 Calibrated bucket

A 5-gallon bucket may be used to measure discharge from flows falling over a vertical drop under which the bucket can be placed. The bucket should be marked on the inside surface at 1 liter intervals by pouring twenty 1-liter water samples into it. Care should be taken to record the exact duration and volume of each sample. The longer the duration, the more accurate the measurement will be.

Smaller flows with small vertical drops may be measured using a calibrated jug.

4.1.5 Rapid filling bucket

Where flows are so great as to overtop a bucket or jug in less than 2 seconds, a number of repeated measurements of the time taken to fill the bucket completely should be made using a stopwatch. Estimates made in this way are relatively inaccurate.

4.1.6 Rapid filling bin

Flows overtopping a bucket or jug in less than half a second may be measured using a 20-gallon bin. If the bin is overtopped in less than half a second, the bin may be placed successively under separate parts of the flow. Estimates made in this way are relatively inaccurate, but may be more accurate than current meter measurements where very slow flowing streams spill over broad crested weirs.

4.1.7 Estimation based on surface velocity and depth

In many natural channels, the mean velocity of a stream at a given point across its width is 85% of the surface velocity at that point (Gordon, McMahon, & Finlayson, 1992). Bright, floating objects such as a fluorescent wooden dowel may be used to estimate the surface velocity. In large rivers, orange peels may be thrown from bridges and the velocity estimated from a) the time taken for a peel to traverse under the bridge, and b) the measured width of the bridge. In smaller streams, a useful measuring device a fluorescent orange 5 cm wooden dowel, measured against a 2 m stadia rod. Where possible, the velocity at three points across the width of the stream should be measured. In this case, the flow rate (m^3/s) shall be estimated as the sum of the products of the width

represented by each surface velocity measurement, the depth of the water at each measurement, and 85% of the surface velocity. In cases where only one surface measurement is possible, the flow rate shall be estimated as half of the sum of the products of the width, depth, and estimated mean velocity in the center of the channel.

4.1.8 Cross section with a current meter

The most common method of measuring flow rate in small streams is to wade and record cross-sectional measurements using a current meter (flow probe). A number of different types of current meter may be used:

- Pygmy meter. This is the standard meter for small streams in the US. Three stainless steel cones are mounted on arms extending from a vertical axle with pointed ends mounted within a precision smooth conical bearing. The meter is sensitive to very slow flow but works well in fast flow. It is very expensive. It easily becomes un-calibrated when bumped during transport from a vehicle to the stream, or when in contact with bedload of significant size. It is expensive to re-calibrate. It requires partial dismantling before transport, and partial assembly before use; a small pin must be re-installed. It is thus generally unsuitable for conditions where:
 - - Many measurements must be taken at many sites
 - At night
 - By new operators
 - Transport by small vehicles
 - Streams with large bedload particles
 - Extremely muddy conditions

However, it is useful for calibration of more robust meters.

- Plastic impellor meters. CCoWS uses plastic impellor meters purchased from retailers such as *Global Water*, but also has developed the capability to construct this type of plastic impellor meter (flow probe) by using model boat propellers. These can be fitted inside PVC plumbing housings of various sizes and mounted on various tubes for handheld use. Bike computers may be used to count the rotations of the propellers, and calibrated internally to display flow rate in m/s. Methods

for the calibration of CCoWS constructed flow probes are summarized in Section 7.1). Additionally, a comparison study of the three types of current meters was conducted. The results are summarized in Section 7.1. The impellers can sometimes become blocked or jammed with sand or leaves, but are easily cleared. Short mounting tubes may be constructed for wading use. Longer, triple-extendible tubes are useful for reaching in from stream banks, or down from low bridges. Impellers may also be mounted on heavy instrument packages suspended from large bridges. The instruments are inexpensive, easily repairable, and robust.

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

- 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.
- 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.
- A table shall be drawn up in a notebook with columns for 'offset', 'depth', and 'velocity'.
- The times of commencement and completion of measurements shall be recorded, as shall the river stages at those times.
- Two people shall be employed, one as recorder, the other as measurer.
- 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.
- Starting from one bank, preferably the left bank, the offset at which the free water surface begins shall be recorded.
- 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.
- Streams with multiple channels shall be measured as the sum of multiple streams.

- Each velocity measurement shall be taken as follows:
 - The measurer should stand well downstream of the instrument
 - The instrument should be placed in the water and rested against the bed such that the flow depth shall be recorded.
 - 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.
 - The impellor shall be checked for blockages and free-running operation, and the computer shall be reset to zero average velocity.
 - 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:

- The field book table shall be copied to the spreadsheet.
- 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.
- The flow rate for each measurement point shall be the product of the velocity and the representative width.
- The total stream flow rate shall be the sum of that for all measurement points across the stream.

4.2 Protocol for sampling suspended sediment

This section describes field-monitoring protocol for collecting a suspended sediment sample. Depending on a number of factors such as stream conditions, safety, equipment availability, and time, the method for collecting a suspended sediment sample in a stream may vary.

Depending on the magnitude of stream flow, the concentration of suspended sediment can range from well mixed to a vertically and horizontally stratified solution. To ensure that an accurate representation of the water column is collected, a DH-48 integrated suspended sediment sampler is used. When using a DH-48 sampler, a vertically integrated sample should be taken from several evenly spaced stations along a transect. At each collection station, insert the instrument, with the in-take nozzle facing upstream, vertically downward through the water column and then back to the surface in a uniform motion. Special caution should be taken not to disturb sediment on the channel bottom. The same motion should be used at each station along the transect. However, due to the nature of the continuous sampling method used and the resulting restraints on time, a single sample may be taken in the thalweg, or the deepest portion of the stream channel. Each sample is taken immediately following the stream height, or stage reading.

When stream conditions are too dangerous for wading, the thalweg cannot be accessed, or the water is too shallow for the instrument, a surface water sample or 'grab' is collected. Grab samples are taken by simply reaching out from the bank and inserting the sample bottle into the water column in a quick downward motion with the mouth of the bottle facing upstream. A quick downward motion will facilitate the collection of a relatively integrated sample, rather than only water from the surface. Once again, special caution should be taken not to disturb bottom sediment. If a bridge is present, a sample bottle may be strapped to a rope and lowered into the thalweg to collect a 'grab' sample. Fast moving streams tend to be well mixed as opposed to slower moving streams, which are more stratified. A grab sample is not as accurate as a DH-48 sample. However, when collected in fast moving streams it can provide a fairly accurate representation of the stream concentration.

4.3 Protocol for sampling bedload

Bedload measurements are taken using a Helly-Smith bed sampler. The technique used on site is dependent on the stream flow, water clarity, and absence or presence of bed material. The standard USGS protocol for collecting bedload samples requires taking a minimum of 20 samples at equally spaced stations along a cross-section. This method is used on larger streams during moderate to low flow conditions.

For smaller streams, if the stream bottom and bedload movement are visible, then a technique known as the representative width may be used. Samples are taken in areas of equal visual bed movement. These areas are measured for their widths, and the mass of material collected in that width is its representative sample. For both techniques, bedload samples are collected for a pre-determined amount of time; based on visual observations and stream flow. The amount of time, in addition to the mass and representative width, is later used to estimate the load for that station in the stream.

Bedload samples are also analyzed for load per time. Width interval loads are calculated by dividing the product of the sample mass and its representative width by the width of the instrument (0.075m). The width interval loads are divided by the number of seconds that the sample was collected to find an estimated load per time (g/s). These values are then given time slots that they represent (same method as TSS) to calculate a load per day. The final data for bedload is tonnes.

4.4 Protocol for taking a pH measurement

The pH, negative logarithmic (base 10) hydrogen ion concentration, shall be measured in the field using an *Oakton pHTestr* probe. This probe is capable of measuring pH in the range of -1.0 to 15.0 using the SM 4500B technique (APHS Standard Methods, 1998). Instrument specifications and calibration instructions are kept on file by CCoWS. pH probes should be calibrated after each field campaign or storm event monitored.

A pH measurement should be made as follows:

- Use a clean Nalgene beaker (1000mL) for sample collection
- Rinse beaker in sample water 3 times
- To collect sample, insert beaker into water column just long enough to collect approximately 100 mL of water (enough to submerge the electrode on the pH probe). Take caution not to disturb sediment on the bottom of the channel.
- Remove cap of probe, turn instrument ON, rinse with DI water, and insert into sample container.
- After reading has stabilized, approximately 1 minute, record reading in the field book.

4.5 Protocol for taking a conductivity/salinity measurement

Water conductivity shall be measured in the field by either an *Oakton TDSTestr* 10 conductivity probe with automatic temperature compensation or a *YSI* 556 MPS. The *Oakton TDSTestr* 10 is capable of measuring conductivity in the ranges of 0 to 1990 μS and 2.0 to 19.90 mS using the SM2510 technique (APHS Standard Methods, 1998). The specifications for the *YSI* 556 MPS are presented in Table 3–2.

Conductivity measurements shall be made with the Oakton TDSTestr 10 as follows:

- Using a clean Nalgene beaker (1000mL) for sample collection
- Rinse beaker in sample water 3 times
- To collect sample, insert beaker into water column just long enough to collect approximately 100 mL of water (enough to submerge the electrode on the conductivity probe). Take caution not to disturb sediment on the bottom of the channel.
- Remove cap of probe, turn instrument ON, rinse with DI water, and insert into sample container.
- After reading has stabilized, approximately 1 minute, record reading (μS or mS) in the field book.

Conductivity/salinity measurements shall be made with the *YSI* 556 MPS as follows:

- The *YSI* 556 MPS instrument should be calibrated before entering the field according to directions provided by the manufacturer.
- Measurement shall be taken directly in stream if possible.
- Insert probe directly into water.
- After reading has stabilized, approximately 30 seconds, record conductivity reading as (μS or mS) and salinity as (ppt).
- If conducting depth profile, continue measurements at desired depths recording both conductivity/salinity reading and depth at which taken.

4.6 Protocol for sampling dissolved nutrients

CCoWS currently monitors streams for the following dissolved nutrients:

- Oxidized nitrogen–nitrogen ($\text{NO}_x\text{-N}$)
- Ammonia–nitrogen ($\text{NH}_3\text{-N}$)
- Reactive phosphorus as Orthophosphate (PO_4^{3-})

When sampling for these nutrients, the following shall apply:

- Use sample bottles that have been cleaned in Liquinox™ or similar phosphate free detergent and acid rinsed. If samples are to be analyzed by an external lab, use sterile bottles provided by that laboratory.
- Rinse sample bottle & cap in sample water 3 times prior to taking sample.
- Technician shall wear latex gloves to prevent contamination of the sampling container and for health safety.
- Insert the sample bottle just below the water surface with the mouth of the bottle facing upstream & fill bottle. Take caution not to disturb bottom sediment.
- Pour off a little sample to leave room for expansion if frozen.
- Place sample in cooler with ice for return to laboratory.
- Record time & sample bottle # used in field book.
- If any samples are to be analyzed externally (Monterey County Consolidated Environmental Laboratory), they shall be delivered to the external laboratory immediately following the sampling run. Remember the chain of custody form.

Upon returning to the lab, samples shall be initially processed in the following manner:

- Immediately vacuum filter the samples using glass fiber filters. Discard filters.
- Return sample to its original sample bottle.
- Place in refrigerator (if analysis is to take place within 48 hours) or freezer until lab analysis is performed.
- Thoroughly wash all filtering equipment in Liquinox™, rinse in warm tap water, and then finally rinse in DI.
- Record campaign and sample information on the *Sample Storage Management Log* (Appendix A).

4.7 Protocol for sampling pesticides

This section describes the collection of samples for the analysis of pesticides from various water bodies. It covers the collection of water, suspended sediment (SS) and benthic samples. The types of sample that may be taken depend upon the dynamics of the specific water body. For example, an SS sample may not be indicated for receiving water bodies, or a benthic sample may not be indicated during high flow, storm events. Particular strategies will be dictated by the specific project/task.

It is important to determine the fraction of pesticides transported by adsorption to suspended sediments, in addition to that transported in an aqueous manner. Because of the low concentrations of adsorbed pesticides involved, techniques must be used that both maximize the weight of samples obtained in the field, and that allow extraction of pesticides from samples that may be smaller than would otherwise be ideal. Katznelson and Feng (1998) indicate that 10 grams of sediment are normally required in order to obtain detectable levels of pesticides from the resulting methanol extractions. This is the limit used under the present protocol for benthic samples, where large sample weights are not difficult to obtain. However, it is often not possible to obtain 10 grams of filtered, suspended sediment, and so modified procedures are described below for performing extractions on samples smaller than 10 grams.

A further constraint is that adsorption concentrations must be expressed with respect to the dry weight of the sediment sample, but oven drying of samples potentially alters the molecules of interest. Dry weights must therefore be determined by sacrificing a sub-sample for oven drying. The full sample must therefore include sufficient material for both dry-weight analysis, and the actual pesticide extraction and analysis.

As explained below, a new technique for obtaining filtered samples in the field is used (Sandstrom, 1995).

4.7.1 Pre-sampling preparation

Table 4-1 list the field equipment required to conduct this type of pesticide sampling. Pre-sampling preparation is as follows:

- 1) Check that pump batteries are charged
- 2) Fill:
 - One carboy and one bucket with *Liquinox* solution
 - One carboy and one bucket with hot tap water
 - One carboy and two buckets with de-ionized water
- 3) Dry filters to be used in a 100°C oven for 15 minutes. Cool for 5 minutes, label filter with a pencil, weigh and record filter weights.
- 4) Place ice pads in chests
- 5) Gather necessary field equipment

Table 4-1. Pesticide sampling field equipment

Field Equipment	
Benthic sediment sampler	60 mL amber glass, Teflon lid water sample containers
0.7 µm 142 mm glass fiber filters	125 mL amber glass, Teflon lid sediment sample containers
142mm <i>Geotech</i> aluminum filter holder	Ice chest with ice pads
Teflon sampling tube assemblies (9)	Stainless steel sediment scraper (spatula)
Sampling tube weight	Cleaning brush
Peristaltic <i>Geotech Geopump Series II</i>	Forceps
Pump battery, 12v DC	C-clamp vise grips w/steel pressing plates
25 L carboy containing <i>Liquinox</i>	Glass or stainless mixing spoon and bowl
25 L carboy containing tap water	Wash bottle with DI water
25 L carboy containing DI water	<i>Rite-in-the-Rain</i> field book

4.7.2 Sampling excursions

This protocol assumes that an excursion to the field shall be made, during which time a number of visits shall be made to a number of sites. A sample or samples shall be taken from each site. Depending on the aims of the work, samples may be taken directly, or filtered from the water column, or they may be taken from the benthos beneath a water column. The samples may then be analyzed at the CCoWS laboratory using ELISA techniques (Section 5.4) or sent to external laboratories for ELISA or GC/MS analysis.

4.7.3 General points relating to pesticide sampling excursions

Cleanliness shall be kept in mind at all times during the sampling excursion. This will prove challenging given the environmental conditions under which sampling occurs. However, every effort must be made to avoid the potential for sample cross-contamination. The aim is to measure pesticide concentrations in the order of parts per *trillion*, so a misplaced drop of water can be important.

4.7.4 Sample management and bottle labeling

Samples shall be assigned a unique Sample ID as follows:

Sample ID = Site Code + Date + Type + Bottle ID

- The Site Code shall follow the CCoWS convention described in Section 3.1.1.
- The Date shall be in the format: DD–MMM–YY, e.g. 12–May–02.
- The Type shall be “W”, “S”, or “B” for samples extracted from water, samples extracted from suspended sediment, and samples extracted from benthic sediment respectively.
- The Bottle ID is unique number assigned to each bottle in perpetuity (see below).

Example: “SAL–DAV, 20–Jul–02, W, P16” indicates a water sample taken on July 20, 2002 from the Salinas River at Davis Rd. in Pesticide Bottle 16.

Pesticide sample bottles are amber glass, with an opaque Teflon-lined plastic lid. In preparation for the time of first use, bottles to be analyzed in the CCoWS

laboratory shall be labeled with an ID code that is unique to the bottle in perpetuity (Prefix “P”) (see Section 2.1). Bottles to be analyzed by external laboratories may be obtained prior to sampling from these laboratories. These bottles shall also be labeled with a unique ID in a similar fashion to the CCoWS bottles (Prefix “EP”), however this ID should be retired once the results have been obtained from the external laboratory.

The samples shall be physically separated from other equipment. As each sample is taken, the sample ID and time shall be recorded, along with all additional information noted in Section 3.9.

4.7.5 Duplicate samples

For each excursion to eight or more sites, an additional sample shall be taken for the purposes of analysis at a laboratory other than the laboratory used for the majority of samples. This ‘control’ laboratory may also use different analytical techniques to those used for the majority of samples. For example, if the majority of samples are to be analyzed in the CCoWS laboratory using ELISA techniques, the additional samples could be sent to an external control laboratory for GC/MS analysis. These control samples shall be stored in a separate ice-filled cooler, and shall be labeled with their own unique Sample ID.

4.7.6 Taking samples from the water column and from suspended sediments

- 1) Assemble filter unit, placing pre-weighed filter into holder with forceps, wet the filter with DI water. Use a fresh tubing assembly for each site.
- 2) Record filter and SS sample bottle #.
- 3) Lower sampler weight with tube down to the water and turn on the pump
- 4) Raise and lower the sampler weight through the vertical water column continuously to obtain an integrated SS sample.
- 5) During filtration, collect a water sample by placing a labeled sample bottle underneath the exit stream of the filter unit, do not fill to full, and cap. Record the container number and give it a sample name according to the naming convention described below. CARE SHALL ALWAYS BE TAKEN TO NOT CONTAMINATE THE INTERIOR OF SAMPLE BOTTLES WITH ANYTHING OTHER THAN INTENDED SAMPLE. Put sample on ice.
- 6) Experience with the filter sampler and differing SS loads will give some indication when enough of the SS sample has been acquired; typically the

exiting water stream will start to drip when the filter is near fully loaded (approx. 1 gram of sample). When enough sample has been obtained stop the pump.

- 7) Open the filtering unit and remove the sample and filter with FRESHLY GLOVED HANDS. Fold the filter in half, then into quarters with filtrate to the inside using forceps as much as possible. Place filter into pressing plates and use the C-clamp vise grips to squeeze the water from the filter and sample. Place filter into the jar and put sample on ice.
- 8) Now, CLEAN, CLEAN, CLEAN! Wash the filter unit and tubing weight in the five-gallon bucket of *Liquinox™*, rinse in warm tap water bucket, then final rinse in DI water bucket.

4.7.7 Taking benthic samples

- 1) Set the jaws in place on the sampler and lower through the water column, rinsing the sampler in local water a little before sending it to the bottom.
- 2) Quickly retrieve the sampler unit, getting the sampler out of the water column as quickly as possible/practical.
- 3) Carefully open the sampler and with a stainless steel spoon retrieve an aliquot of sample that, to the best of your ability, has not been in contact with either the jaws of the sampler or the water column. In other words, try to obtain the aliquot from the center of the larger sample. Place this sample in a glass or stainless bowl.
- 4) Obtain 3 such aliquots, sampling from the same location but separated by a couple meters.
- 5) Homogenize the 3 aliquots and from this sample take an aliquot and put into a labeled sediment jar. Record the sample number and name the sample. Put sample on ice.
- 6) Rinse all of the solid sediment material off the sampler in local water, using a cleaning brush if necessary
- 7) Now, CLEAN, CLEAN, CLEAN! Wash the bowl, spoon and sampler in the buckets as described above.
- 8) Take the sampler and rinse it once again in the fourth bucket, the final DI rinse for the benthic sampler ONLY. The unit is now ready for the next sampling site.

4.7.8 Steps to be taken in the field and laboratory at the conclusion of each field excursion

- 1) Obtain a sample of water from the benthic sampler second DI rinse. This will be used as a field blank to test the effectiveness of the sampler washing technique. Record the sample bottle id, give it a name and put it on ice.
- 2) On the final DI rinse of the TSS sampler, assemble the whole unit (pump, filter holder and tubing) with a fresh filter in place and run some DI water through the unit. Obtain a sample of this water. This will be used as a field blank to test the effectiveness of the filter unit/tubing assembly washing techniques. Record the sample bottle id, give it a name and put it on ice.
- 3) Place samples in the refrigerator to be kept until ELISA analysis.
- 4) Wash the Teflon tubing assemblies back at the lab by placing the tube in the *Liquinox™* carboy and running the solution through it by turning on the pump for approx. 30 sec. Do the same with warm tap water carboy and then DI carboy.
- 5) Dry off the equipment. Hang the Teflon hose to dry.
- 6) Fed-Ex the certified lab samples to the lab ASAP. Remember the chain of custody form.

4.8 Protocol for sampling pathogens

CCoWS monitors water bodies for the following pathogens:

- *E. coli*
- Total coliform
- Fecal coliform

When sampling for these pathogens, the following steps shall be taken:

- Sterile, sealed sampling containers with preservative shall be obtained from the external laboratory. These shall remain sealed until the sample is taken.
- The container shall be labeled and the ID shall be recorded in the field notebook along with the time of collection.
- Technician shall wear latex gloves to prevent contamination of the sampling container and for health safety.
- Remove seal from bottle.
- Insert the sample bottle just below the water surface with the mouth of the bottle facing upstream & fill bottle. Take caution not to disturb bottom sediment.
- The sample shall be placed into a cooler with ice.
- The sample shall be immediately delivered to the external laboratory with an accompanying chain-of-custody form after the sampling run is complete.

4.9 Protocol for collecting benthic macroinvertebrate samples

Benthic macroinvertebrate samples shall be collected according to sampling protocols described in Harrington and Born (2000). A unique sample ID shall be given to the sample container and shall be recorded in the field book along with date and time of sample collection. Samples shall be transported immediately to the CCoWS laboratory following the monitoring run. Samples will be preserved according to the protocols described in Harrington and Born (2000).

5 Laboratory protocols

This section contains protocols relating to laboratory analyses, including:

- Sediment analysis
- Chemical water quality analysis
- Macro-invertebrate analysis

Training on laboratory safety procedures is provided by the Earth Systems Science and Policy (ESSP) laboratory staff at CSU Monterey Bay and is a requirement prior to laboratory use. Documentation of lab safety training is kept by the ESSP laboratory staff. It is CCoWS responsibility to assure that all technicians performing the following tests have attended a safety training session.

Technicians shall be familiar with the equipment and tests before analyzing samples on their own. This should include both training with the laboratory manager and/or an experienced technician and study of the instrument and procedure manuals. This training shall be documented and kept on file *Technician Training Tracking Sheet* (Appendix B).

A log of current samples within the refrigerator/freezer will be kept taped to the door of the cooler and updated as the status of samples changes. This form *Sample Storage Management Log* (Appendix A) will be saved to file when full. Nutrient sample preservation status will be recorded on the *Nutrient Sample Run Data* sheet (Appendix G).

5.1 Protocol for analyzing Total Suspended Solids (TSS)

The following TSS procedure is employed to determine the concentration of suspended sediment in a water sample. A filtration process is used, based on Woodward and Foster (1997). The procedure is summarized here.

- 1) Measure & record conductivity ($\mu\text{S}/\text{cm}$)
- 2) Measure & record transparency
- 3) Sample bottles are pre-weighed (to the nearest 0.01g) and assigned a container ID.
- 4) After the sample is obtained, the outside of the sample bottle is rinsed and dried, then weighed to the nearest 0.01g.
- 5) A small amount (literally a pinch) of sodium hexametaphosphate is added to the sample and shaken thoroughly. This helps suspend particles and keep them from flocculating.
- 6) Samples are first filtered through a 63-micron sieve to remove the sand component.
- 7) Pre-dried and pre-weighed (to the nearest .001g), disposable glass filters (filter size, 1.5 micron) are used to vacuum filter the water sample and the sand component.
- 8) The filters containing the sediment portion of the water sample are then dried for 2 hours at 100°C to evaporate any remaining water.
- 9) The filters are reweighed to determine the amount of sediment in the sample (to the mg).
- 10) The volume of the sample is determined from its weight and the density of water.
- 11) Concentrations of samples are recorded in mg/L.
- 12) All information shall be recorded on the *Lab Processing of TSS Water Samples* data sheet (Appendix H).

Estimated error of the results is dependent upon mass and volume of the sample. The error associated with a large sample (approximately one liter) with highly concentrated sediment will be approximately 2%. Small samples (approximately 1/4 liter) with small sediment concentrations can have errors near 100%. This large error in “clean” samples is not viewed as a problem, because a 100% error in small sediment concentrations has little affect on estimated loads. Furthermore, most samples taken are large enough and “dirty” enough to keep errors low.

5.2 Protocol for analyzing bedload samples

All bedload samples are transferred into a cloth oven bag or tin for drying. Bedload samples are dried in an oven for 24 hours at 70°C. Samples are allowed to cool for two hours and then weighed for their total mass (g), which is later used to get an instantaneous bedload concentration.

Additionally, samples may be processed and analyzed to determine particle size distribution. The procedures for particle size analysis are as follows:

Dry or Wet Sieve

- Dry sample in oven for 24 hours at 70°C.
- Record dry weight of total sample.
- Dry sieve (using manual sieve shaker) or wet sieve sample using the U.S.A. standard sieve series.
- Weigh (may require drying if wet sieve method is used) and record the weight for each class size.
- Take a subsample of approximately 50 grams (up to 100 grams for more sandy samples) by repeatedly splitting all classes under 2mm.
- Record weight.

Dispersing Solution (5% solution of Sodium Hexametaphosphate)

- Weigh 50 grams of sodium hexametaphosphate.
- Add 1 liter of water and shake until dissolved.

Dispersion of Sample

- Add 250ml of distilled water and 100 ml of 5% dispersing solution to the 50 gram subsample.
- Thoroughly mix and allow sample to stand overnight

Hydrometer Procedure

- Shake dispersion solution and soil subsample for 5 minutes.
- Transfer sample to 1000ml-graduated cylinder.
- Fill to ~970 ml mark with distilled water.
- Shake (in up and down motion, not circular) for approximately 20 seconds.

- Record time and use remaining 30ml of water to rinse sides of cylinder.
- Take and record hydrometer readings at 40 seconds, 80 seconds, 4.5 minutes, 2.5 hours, and 24 hours
- Take and record temperature immediately after each hydrometer reading.
- Take blank reading (see calibration below) after every hydrometer reading.

Calibration of Hydrometer (Blank Value)

- Add 100ml of dispersing solution to cylinder and fill with DI to 1000ml mark.
- Mix and let stand until temperature is constant.
- Take and record temperature.
- Take and record hydrometer reading.

5.3 Protocol for analyzing dissolved nutrients samples

This section describes the laboratory procedures used by CCoWS to analyze dissolved nutrients in water samples including oxidized nitrogen–nitrogen, ammonia–nitrogen and orthophosphate.

5.3.1 General

Each set of samples will have incorporated into them the appropriate amount of QA/QC sample checks including:

- Field blanks: 1 per sample run
- Method blanks: 1 per sample run
- Sample replicates: at least 1 per sample run or 10% of samples
- Sample spikes: 1 set per sample run
- Samples to be sent to outside lab: at least 1 per sample run or 10% of samples

Samples may have already been filtered as per field protocols (except those going to an outside laboratory for analysis). If not, then samples shall be filtered by vacuum filtration before analysis, thoroughly washing equipment with *Liquinox*TM between filtrations.

In all cases, the most accurate data will result from the immediate processing of the samples upon return to the lab. QA/QC samples to be sent to an outside lab for comparison should be sent immediately after sampling or no later than the following day. Should this prove impractical or impossible, the next best option is to refrigerate the sample to 4°C and process within 48 hours from the time they entered the lab.

If samples are not to be analyzed within 48 hours of collection, they should be frozen for later analysis. In the case of frozen samples, they should be analyzed within one month of collection.

All samples should be placed in plastic *Ziploc* bags after filtration with the sample collection date/time and campaign title written on the bag. If samples are to be frozen, the date of initial freezing should also be noted on the bag. A log of current samples within the refrigerator/freezer will be kept taped to the

door of the cooler and updated as the status of samples changes. This form *Sample Storage Management Log* (Appendix A) will be saved to file when full. Sample preservation status will be recorded on the *Nutrient Sample Run Data* sheet (Appendix G).

Samples shall be brought to room temperature before analysis. This may be done by thawing overnight or by a warm-water bath. However, if a bath is used care must be taken to not raise the sample temperature above room temperature at any time. Overnight thawing is preferred.

Technicians shall be familiar with the equipment and tests before analyzing samples on their own. This should include both training with an experienced technician and study of the instrument and procedure manuals. This training shall be documented and kept on file *Technician Training Tracking Sheet* (Appendix B).

5.3.2 Nitrate Nitrogen (NO₃⁻-N)

CCoWS uses the *HACH Odyssey DR/2500 Spectrophotometer*, Cadmium Reduction Method and the Chromotropic Acid Method for the determination of NO₃⁻-N. There are two ranges of tests available as needed based on sample concentration:

1. Method 8192, Low Range (LR), .01 – .50 mg/L NO₃⁻-N*,
2. Method 10020, High Range (HR), 0.2 – 30.0 mg/L NO₃⁻-N.

In most cases of unknown Nitrate values, the HR test will be used for the initial analysis as it is likely that most samples will fall within the HR, especially if analyzing agriculturally influenced water sources. Should the HR test indicate an under-range value, a LR test will be performed. If the HR test indicates an over-value, then a multiple dilution of the sample will be performed and retested using the HR test.

Procedures for the HR and LR Nitrate tests are detailed in the *HACH Odyssey DR/2500 Spectrophotometer Procedure Manual* (te/dk 04/01 2ed) under the above mentioned methods. These procedures will be followed with the following additions and emphasis:

1. Be sure to run a reagent blank as suggested in “Tips and Techniques”. Instructions for this procedure are on page 34 of the procedure manual. Note that once the program is exited from, the blank re-zeros and the value is lost. A new blank must be run each time a sample run is performed. Record the blank value on the sample run data sheet.
2. The statement is made that this method is technique-sensitive (color development depends upon shaking time and technique). Shaking technique will be standardized by the use of a vortex mixer and should be used when mixing sample and reagent, unless otherwise indicated. To assure consistency and accuracy, use this technique and test a series of standards before a sample run is made. The standards should consist of:
 - a. For the HR test:
 - i. 1 mg/L NO_3^- -N
 - ii. 10 mg/L NO_3^- -N
 - iii. 25 mg/L NO_3^- -N
 - b. For the LR test:
 - i. .25 mg/L NO_3^- -N
 - ii. .50 mg/L NO_3^- -N
3. Shake for the amount of time suggested in the procedure. Each of the values obtained should fall within 10% of the standard value for the HR test and 12.5% for the LR test. If one should fall outside this limit, recheck procedures and do the standard again. If the value still falls outside the limit, try adjusting the shaking time to obtain the desired value. Once this shaking time has been established, use it throughout the sample run. Record the shaking time and standard values on the sample run data sheet.
4. Used sample that has been processed with reagent is a regulated hazardous waste. Dispose of the empty reagent powder-pillows into an appropriately labeled *Ziploc* bag. Dispose of liquid reagent-tainted sample into an appropriately labeled container. Waste will be managed according to the Hazardous Waste Management document.
5. Choose a sample at random to perform a spike analysis. Record the spike recovery percentages on the sample run data sheet.

*Note: Technically, the LR test is an oxidized nitrogen–nitrogen tests ($\text{No}_x\text{-N}$). Nitrates are reduced to nitrites, then total nitrites are measured. However, the amount of nitrite in the sample is expected to be much smaller than the nitrate.

5.3.3 Phosphate (PO_4^{3-})

CCoWS uses the *HACH Odyssey* DR/2500 Spectrophotometer and the PhosVer 3 method for phosphate determination. This is Method 8048 in the *HACH Odyssey* procedure manual, which measures phosphate (PO_4^{3-}) levels ranging from .06 to 5.00 mg/L. This procedure is equivalent to USEPA Method 365.2 and Standard Method 4500–PE for wastewater. These procedures will be followed with the following additions and emphasis:

1. Be sure to run a reagent blank as suggested in “Tips and Techniques”. Instructions for this procedure are on page 34 of the procedure manual. Note that once the program is exited from, the blank re-zeros and the value is lost. A new blank must be run each time a sample run is performed. Record the blank value on the sample run data sheet.
2. To assure consistency and accuracy, test a standard before a sample run is made. The standard should be mixed to 3 mg/L. The value obtained for the standard should fall within 4% of the standard value. If it should fall outside this limit, recheck procedures and do the standard again. Record the standard value on the sample run data sheet.
3. Used sample that has been processed with reagent is a regulated hazardous waste. Dispose of the empty reagent powder–pillows into an appropriately labeled zip–lock baggy. Dispose of liquid reagent–tainted sample into an appropriately labeled container. Waste will be managed according to the Hazardous Waste Management document.
4. Choose a sample at random to perform a spike analysis. Record the spike recovery percentages on the sample run data sheet.

5.3.4 Ammonia Nitrogen (NH₃-N)

CCoWS uses the *HACH Odyssey* DR/2500 Spectrophotometer and Salicylate Method for the determination of NH₃-N. There are two ranges of tests available as needed based on sample concentration:

1. Method 10023, Low Range (LR), .02 – 2.50 mg/L NH₃-N,
2. Method 10031, High Range (HR), 0.4 – 50.0 mg/L NH₃-N.

In most cases of unknown Ammonia values, the LR test will be used for the initial analysis. Should the LR test indicate an over-range value, a HR test will be performed. If the HR test indicates an over-value, then a multiple dilution of the sample will be performed and retested using the HR test.

Procedures for the HR and LR Ammonia tests are detailed in the *HACH Odyssey* DR/2500 Spectrophotometer Procedure Manual (te/dk 04/01 2ed) under the above-mentioned methods. These procedures will be followed with the following additions and emphasis:

1. To assure consistency and accuracy, test a series of standards before a sample run is made. The standards should consist of:
 - a. For the HR test:
 - i. 1 mg/L NH₃-N
 - ii. 20 mg/L NH₃-N
 - iii. 40 mg/L NH₃-N
 - b. For the LR test:
 - i. .05 mg/L NH₃-N
 - ii. 2.00 mg/L NH₃-N
2. The values obtained for the standards should fall within 10% of the standard value for the HR test and 4% for the LR test. If values should fall outside these limits, recheck procedures and do the outside standards again. Record the standard values on the sample run data sheet.
3. Used sample that has been processed with reagent is a regulated hazardous waste. Dispose of the empty reagent powder-pillows as normal trash. Dispose of liquid reagent-tainted sample into an appropriately labeled container. Waste will be managed according to the Hazardous Waste Management document.

4. Choose a sample at random to perform a spike analysis. Record the spike recovery percentages on the sample run data sheet.

5.4 Protocol for analyzing chlorpyrifos and diazinon pesticide samples using ELISA

The following section describes procedures of analyzing for the specific pesticides diazinon (D) and chlorpyrifos (C) collected as described in Section 4.7 using Enzyme Linked ImmunoSorbent Assays, or ELISA. The theory of this analysis is documented in Katznelson and Feng (1998).

Water samples can be analyzed directly using ELISA technology; however, benthic and suspended sediment (SS) samples must first have any pesticide extracted using methanol. The two methods are distinct and must be treated separately throughout the entire procedure. Furthermore, extraction of pesticides from SS samples is a different procedure than extraction of sediment samples. Once extracted, SS and benthic samples can be analyzed concurrently using the same methods. Any single analysis (water or methanol extracted) of a field excursion is considered an ELISA ‘run’.

Many pesticides, including D & C, hydrolyze. Therefore, analysis on water samples should be performed within a day of collection for most accurate results. Samples shall be kept refrigerated until analysis. Benthic and SS samples that have been extracted with methanol are quite stable and may be stored for weeks if kept in a cool (4°C), dark place (refrigerated).

Each batch of samples shall have incorporated into them the appropriate amount of QA/QC sample checks including:

- Field method blanks: 3 per field excursion
- Lab method blanks: 1 per run
- Sample replicates: at least 1 per run or 10% of samples
- Sample spikes: 1 set per run
- Samples to be sent to outside lab: at least 1 per field excursion or 10% of samples

5.4.1 Equipment/materials

- Gloves, goggles, lab coat
- ELISA plate kit with all components
- High-Performance Liquid Chromatography (HPLC) water

- Methanol, Optima grade, *Fisher Scientific*
- 10 mL glass syringe w/pipette needle
- 10 mL glass syringe w/Luer–lock hub
- Syringe filters, teflon
- Parafilm
- Multi–channel pipette OR repeater pipette, with appropriate tips
- Reagent wells for multi–channel use
- 20 mL glass scintillation vials
- Test tubes (12x75mm) & rack
- 000 size rubber stoppers
- 20–200 μ L pipette with tips
- 100–1000 μ L pipette with tips
- Positive displacement micro–dispenser
- Mixer/vortexer
- EL301 strip reader, Bio–tek
- Sample press
- Laboratory blender
- Sample dehydrator

5.4.2 Initial Preparation

Samples to be analyzed, the necessary number of kit well strips, and reagents shall be brought to room temperature before performing the test. Unused well strips shall remain refrigerated. Benthic and SS samples take longer to warm and process, so should be started earlier. The maximum number of wells to be used at any one time shall be 36, or 3 strips.

The ideal scheduling of an entire ELISA excursion would be as follows:

- First day: collect field samples, store in refrigerator
- Second day: run ELISA analysis on water samples, perform sediment/SS extractions
- Third day: run ELISA analysis on extracted samples

There is potential to fill 36 separate micro–wells during an ELISA run. It is easy to get confused as to what samples are placed into which wells. An *ELISA Run Plan* (Appendix K) is a form to help organize samples to keep the technician on track and to help avoid confusion. The *ELISA Run Plan* (Appendix K) shall be filled out with all necessary information. Determine position of calibrators,

samples, replicates, spikes, blanks, and controls using the *ELISA Run plan* (Appendix K) along with consideration of QA/QC samples. First runs of unknown samples are always undiluted. If, after the first run, a sample is deemed too concentrated, dilution procedures described later shall be followed.

5.4.3 Sample preparation

5.4.3.1 Water samples

Water samples are filtered in the field (see section 4.7.7) into an amber glass bottle and therefore are ready to place directly into the wells. Sample bottles shall be arranged in the pattern that they will fill the wells in to help avoid confusion. Samples that look murky or otherwise in need of filtering shall be filtered using a dedicated glass syringe and a syringe filter. The sample shall be delivered to a test tube labeled with the Bottle ID#. Equipment shall be cleaned between each sample preparation.

5.4.3.2 Methanol extraction of pesticides from suspended sediment samples

The sample is a filter with suspended sediment placed into a labeled amber glass bottle (Section 4.7.7). The sample shall be removed from the bottle, weighed and the weight recorded. It shall then be placed in a dehydrator for 2 hours. The sample shall be reweighed and weight again recorded. The sample shall then be cut into strips and placed into a lab blender with 5 mL of 100% methanol to homogenize and aerate. It shall be immediately returned to its sample bottle, covered and allowed to stand for 1 hour. Place sample into the press and squeeze the sample over a beaker to collect the methanol extract. Immediately pour the extract into a glass syringe with filter tip and dispense into a labeled (same as Bottle ID) scintillation vial. The sample is now extracted and ready for analysis. Carefully record all information on the *TSS & Benthic Methanol Extraction* plan (Appendix I). Clean all equipment used between each sample preparation.

5.4.3.3 Methanol extraction of pesticides from benthic samples

The sample is a grab of benthic material, homogenized and placed into an amber glass bottle (Section 4.7.8). After it has sat for some time (overnight), pour out excess overlaying water from the sample. Weigh out approximately 10 g of sample, record wet weight, and return to the original rinsed and dried

sample bottle. Add 20 mL pure methanol (15.82 g weighed out) to sample bottle, shake vigorously but occasionally (every 5–10 min) for 30 minutes. Let stand for 1 hour. The methanol extract will rise to the top of the sample. Decant clean methanol off the top to a dedicated filtering syringe. Filter to a labeled (same as Bottle ID) scintillation vial. The sample is now extracted and ready for analysis. Discard waste sediment. Weigh out another portion of the sample in a drying tin, record weight, dry in oven at 100°C for 2 hours, cool for 5 minutes, and re-record weight. Record all information on the *TSS & Benthic Methanol Extraction* plan (Appendix I). Clean all equipment used between each sample preparation.

5.4.3.4 Dilution of Samples

If the first round of analysis shows that a particular sample is too concentrated to fall into the calibration curve (indicated by a relatively clear sample well after incubation and a flag from the ELISA Excel spreadsheet, described later), dilution of the sample will be necessary. Prepare sample dilutions as follows:

- Prepare 12 X 75 mm glass test tubes, 2 for each sample, by labeling the test tubes with the sample Bottle ID and dilution (25% or 6.25%)
- Dispense 300 µL HPLC water (for water sample) or 300 µL methanol (for extraction sample) in each tube
- Use serial dilutions of 25% at each step: transfer 100 µL of sample into the first (25%) tube with 300 µL HPLC water (or methanol) and mix well (pipetor pumping & vortex). Then, using the same tip, transfer 100 µL from first (25%) tube to the second (6.25%) tube and mix well with existing HPLC water (or methanol).
- Repeat ELISA routine.

The sample methanol extract for both SS & benthic samples must be diluted with HPLC water before being placed in the sample wells. As with the dilution for the calibrators, place 500 µL of HPLC water into as many test tubes as there are samples and label the tubes with the Bottle ID. Then, place 55 µL of sample extract into the labeled tube with HPLC water and mix. This ratio of 55 µL of sample to 500 µL of HPLC water is maintained for all other QA/QC samples also (ie. method blanks, spikes, control, etc.)

5.4.4 Standards (calibrators & control) Preparation

5.4.4.1 Standards for ELISA analysis of water samples

To make the CALIBRATOR *STANDARD* for the calibrators:

Note: “D” stands for diazinon, “C” for chlorpyrifos.

Mix in clean 20 mL scintillation vial labeled “400 ng/L D”, **OR** “1000 ng/L C”:

- 10 mL HPLC water: (use dedicated syringe)
- 40 µL diazinon stock solution (100 ng/mL), **OR** 10 µL chlorpyrifos stock solution (1 ppm): (use micro-dispenser)
- Mix by vortex.

To make the *CONTROL* solutions:

Mix in clean 20 mL scintillation vial labeled “300 ng/L D”, **OR** “500 ng/L C”:

- 10 mL HPLC water: (use dedicated syringe)
- 30 µL diazinon stock solution (100 ng/mL), **OR** 5 µL chlorpyrifos stock solution (1 ppm)
- Mix by vortex.

This will create 300 ng/L D (500 ng/L C) *CONTROL* solutions to be used as controls and spike analytes.

Calibrators:

- Label 4 test tubes; “400 ng/L D (1000 ng/L C), 100 ng/L D (250 ng/L C), 25 ng/L D (62.5 ng/L C) and 0 ng/L D (0 ng/L C)”
- In the 400 ng/L D (600 ng/L C) tube, dispense 500 µL of 400 ng/L D (1000 ng/L C) from the vial
- Dispense 300 µL of HPLC water into each of the remaining tubes.
- Into the 100 ng/L D (250 ng/L C) tube, dispense 100 µL of 400 ng/L D (1000 ng/L C) standard. Mix by pipette and vortex.

- In the 25 ng/L D (62.5 ng/L C) tube, dispense 100 μ L of 100 ng/L D (250 ng/L C) standard. Mix by pipette and vortex.
- Put nothing in the 0 ng/L tube, except 300 μ L HPLC water
- Place all tubes in their proper locations of tube holders according to the *ELISA Run Plan* (Appendix K).

5.4.4.2 Standards for the ELISA analysis of SS/benthic samples extracted using methanol

Methanol will evaporate readily and the volumes dispensed are crucial. Therefore, test tubes containing methanol must be covered with a rubber stopper when not being used.

- Prep 4 test tubes labeled: 4,000 ppt D (10,000 ppt C); 1,000 ppt D (2,500 ppt C); 250 ppt D (625 ppt C), 0 ppt D or C.
- Prep 4 more test tubes labeled: 400 ppt D (1,000 ppt C); 100 ppt D (250 ppt C); 25 ppt D (62.5 ppt C), 0 ppt D or C.
- In the 4,000 ppt D (10,000 ppt C) tube, add 1 mL methanol (0.791 g weighed out) and 40 μ L D (10 μ L C) stock solution, mix by vortex. This is the 4,000 ppt D (10,000 ppt C) standard.
- Add 300 μ L of methanol to the other 3 test tubes.
- Take 100 μ L of 4,000 ppt D (10,000 ppt C) standard and pipette into the 1,000 ppt D (2,500 ppt C) tube. Mix by pipette and vortex.
- Take 100 μ L of 1,000 ppt D (2,500 ppt C) standard and pipette into the 250 ppt D (625 ppt C) tube. Mix by pipette and vortex.
- Put nothing but 300 μ L methanol in the 0 ppt calibrator.
- Put 500 μ L of HPLC water into each of the other tubes labeled: 400 ppt D (1,000 ppt C); 100 ppt D (250 ppt C); 25 ppt D (62.5 ppt C), 0 ppt D or C.

- Take 55 μL from each of the 4,000 ppt D (10,000 ppt C); 1,000 ppt D (2,500 ppt C); 250 ppt D (625 ppt C), 0 ppt D or C tubes and put into each of the respective 400 ppt D (1,000 ppt C); 100 ppt D (250 ppt C); 25 ppt D (62.5 ppt C), 0 ppt D or C tubes. Mix by pipette and vortex. These further diluted samples are the calibrators.

To make a control solution, place 30 μL D (5 μL C) stock solution into a tube with 1 mL methanol (0.791g weighed out), mix by vortex. Then take 55 μL of that solution and dilute into 500 μL HPLC water, mix by vortex. This will make a 300 ng/L D, (500 ng/L C) control standard. This will be used as a QA/QC check for accuracy of the method. There shall be a control solution sample for each ELISA run.

Spikes:

The control standard can be used to spike a sample to be used as a QA/QC procedure for evaluation of extraction efficiency and as another measure of precision. Mix 100 μL of control standard with 100 μL of sample to create a spike. Comparisons are then made between the spike, original sample and the control. Spikes should be performed/analyzed at a frequency of about 1 in 20 real samples (1 per 3 strips).

5.4.5 Performing an ELISA run

Align calibrators, samples, control, spikes, and field/lab method blanks for rapid, efficient deployment to sample wells in the order of the *ELISA Run Plan* (Appendix K). Label the well rows.

Step 1: Note time. Pipette 100 μL of test solution into each well according to plan. Immediately add 100 μL of conjugate solution supplied in the kit to each well (using multi-channel or combitip repeater). Note time. Cover with parafilm, gently mix wells with circular motions on countertop and incubate in the incubator (room temp, 23°C) for 60 minutes beginning from the average of the two before-noted times. Remove the samples from the incubator and gently mix with circular motions every 15 minutes.

Step 2: After 60 min, remove from incubator and remove parafilm. At this point all of the sample that is necessary is attached to the antibodies on the sides of

the micro-wells. Pour out the rest of the sample from the wells into a waste container and rinse the wells with tap water 4–5 times. Tap out remaining water in wells & blot off water from strip undersides.

Step 3: Add 100 μ L substrate solution supplied with the kit to each well (multi-channel or repeater), cover, mix & incubate for 30 minutes. This time can be increased slightly if color development is slow, or sooner if fast. At the end of incubation, add 100 μ L stop solution supplied by the kit to each well (multi-channel or repeater), cover & mix.

Step 4: Remove parafilm from the wells. Insert well strips into the strip reader. Read strips at 450 nm within 30 minutes of stop solution addition. Print all readings from the plate reader (“data out”). Clean up.

Step 5: Enter ELISA information into the appropriate place on the ELISA Run Spreadsheet template. Double-check for errors and that the figures make sense.

Step 6: Address QA/QC samples & checks. Katznelson and Feng (1998) give a detailed account of quality checks and controls based on QA/QC samples and data from the regression model. We shall follow the procedures addressed in their report.

5.4.6 ELISA Run Spreadsheet template

Absorbance readings with corresponding well numbers are entered into an Excel spreadsheet specifically designed as a template for the ELISA analysis. An example of this sheet is presented in Appendix I. Using a regression curve established by the calibrators, absorbance readings are translated into concentrations of diazinon or chlorpyrifos in either ng/L for water samples or ng/kg for sediment samples.

5.5 Protocol for analyzing pathogen samples

At present, CCoWS does not analyze pathogen samples. Samples are currently analyzed by:

Monterey County Health Department Consolidated Chemistry Laboratory
1270 Natividad Rd.
Salinas, CA 93906
(831)755-4516

The county laboratory is state certified and uses a multiple tube fermentation technique (SM 9221 B & E). Specifics of their protocols can be obtained from the above address.

5.6 Protocol for analyzing benthic macroinvertebrate samples

CCoWS currently uses the techniques found in the following manual for the analysis of benthic macroinvertebrates:

Harrington, J. and M. Born. 2000. Measuring the Health of California Streams and Rivers, A Methods Manual for: Water Resource Professionals, Citizen Monitors, and Natural Resource Students. Sustainable Land Stewardship International Institute. Sacramento, CA.

6 Protocols for Data Analysis

6.1 Protocol for constructing stage–discharge curves and rating tables

After a collection of discharges at different stage levels is obtained, stage discharge curves are created for each site. It then becomes necessary to only collect a discharge measurement for stages that have not been measured before. After taking a discharge measurement, stage is recorded again. The stage for that discharge measurement is represented by the average of the before and after stage levels. If stage level changed significantly between the time that the discharge measurement began and ended then a second TSS sample is collected.

6.2 Protocol for estimating total event fluxes from a number of samples

The total flux of either water or some entrained constituent such as sediment is determined by numerical integration of a number of measurements or samples taken at discrete time intervals over the entire course of the event. Usually, the sampling interval is variable from sample to sample. Thus, the following procedure is used:

- List all samples taken during the event, including the samples immediately before and after the event.
- Assign a start time and end time for each sample within the event (excluding the samples immediately before and after the event). The start time for each sample is the mean of the time at which that sample was taken, and the time at which the previous sample was taken; and similarly for the end time for each sample.
- Compute the duration of time (seconds) to which each sample is assumed to apply as the difference between its end time and its start time.
- Multiply the duration by the flux for each sample (the flux being the water discharge in m^3/s , or the load of some water quality constituent such as sediment in kg/s).
- In the case of discharges, the instantaneous discharge for each sample may be either directly measured (see Section 4.1), or estimated by inputting a measured stage into a previously prepared stage–discharge curve or rating table (see Section 6.1).
- In the case of loads, the instantaneous load for each sample is the concentration of that sample (kg/m^3 , perhaps converted from mg/L) multiplied by the discharge (m^3/s).
- Sum the duration–flux products over all samples to yield the total discharge (m^3) or load (kg or tonnes) for the event.

7 Methodological comparisons

This section contains the results of several methodological comparison exercises conducted in relation to the protocols described previously in the document. This includes:

- Comparison of various types of flow meters including calibration techniques
- Comparison of suspended sediment/turbidity measurement techniques
- Comparison of dissolved oxygen measurement techniques

7.1 Flow meter calibration and comparison

CCoWS uses several types of current meters (flow probes) for measuring stream velocity: *Gurley Precision Instruments* Price Type AA and Pygmy current meters, the *Global Water* flow probes (plastic propeller), or the most commonly used CCoWS manufactured flow probes (plastic propellor).

The specifications for *Global Water* flow probes and *Gurley Precision Instruments* current meters are summarized in Table 7-1 to Table 7-2.

Table 7-1. *Global Water* Flow Probe Specifications

<i>Global Water</i> Flow Probe Specifications	
Range	0.3 to 25 ft/sec (0.1 to 8 m/s)
Accuracy	0.1 ft/sec
Averaging	True digital running average; Readings taken once per second
Sensor Type	Protected Turbo-Prop propeller with electro-magnetic pickup

Table 7-2. *Gurley Precision Instruments* Current Meter Specifications

<i>Gurley Precision Instruments</i> Current Meter Specifications		
	Price Type AA	Pygmy Type
Accuracy	2%	2%
<i>Minimum depth required</i>		
Rod suspended	6 inches	3 inches
<i>Dimensions</i>		
Bucket open end diameter	2 inches	0.78 inches
Bucket wheel diameter	5 inches	2 inches
<i>Operating Range</i>		
Feet per second	0.2 to 25	0.05 to 3.0* 0.02 to 15.00
Meters per second	0.06 to 7.6	0.02 to 0.9* 0.02 to 4.57
*The range of the pygmy meter can be extended to 11 fps with the 611 hand counter (headphone model) and 15 fps with the Model 1100 flow indicator. However, the Price AA is recommended for velocities in this range.		

The *Global Water* and *Gurley Precision Instruments* current meters shall be maintained and calibrated according to instructions provided by the manufacturer. The ESSP laboratory/equipment staff at CSU Monterey Bay maintains all *Gurley Precision Instruments*, and the CCoWS field manager maintains all *Global Water* instruments as well as those constructed by CCoWS. Prior to each use of *Global Water* and CCoWS flow probes, the calibration function on the digital readout display should be checked. Single magnet probes should read “1603” and double magnet probes should read “2538”.

Additional accuracy checks of all probes are also conducted regularly by CCoWS. These accuracy checks should be performed annually prior to the rainy season and anytime in which repairs have been made or problems have been detected. The procedures for flow probe accuracy checks are as follows:

- Calibration shall be conducted at a swimming pool.
- Along the edge of the pool, a fixed distance shall be determined and marked (approximately 8 to 10 meters).
- The flow probe shall be placed in the top 0.5 meter of the swimming pool while the operator walks along the edge recording the amount of time taken to travel the fixed distance.
- A wide range of velocities should be measured.
- At least 20 to 30 trials should be made.
- For each trial, the metered velocity (flow probe reading) as well as the actual reading (fixed distance traveled per time) shall be recorded and then compared.

For each current meter assessed, the average of all trials should be within 10% accuracy. If the % accuracy is greater than 10%, the calibration/accuracy check should be repeated to detect potential error in the calibration procedure. If the error is repeatedly high, then the current meter should be returned to the manufacturer for maintenance or repairs by CCoWS should be made. Potential sources of error in this pool type calibration could be flow probe computer malfunction, low battery power, loose parts, human reaction time with a stopwatch in the actual velocity measurement, and/or interferences in metered velocities due to possible currents in the pool created by the pump and filtration systems. However, these procedural interferences should be minimal.

The results of several comparisons are presented in Fig. 7.1 to 7.2. For all types of flow probes, the accuracy was within 12%. The results indicate that at velocities ranging between 0.2 and 2, the current meters are least precise at measuring velocities at the lower and upper ends of that range, although all of the R^2 values were greater than 0.97. Accuracy has not been checked for velocities greater than 2 m/s.

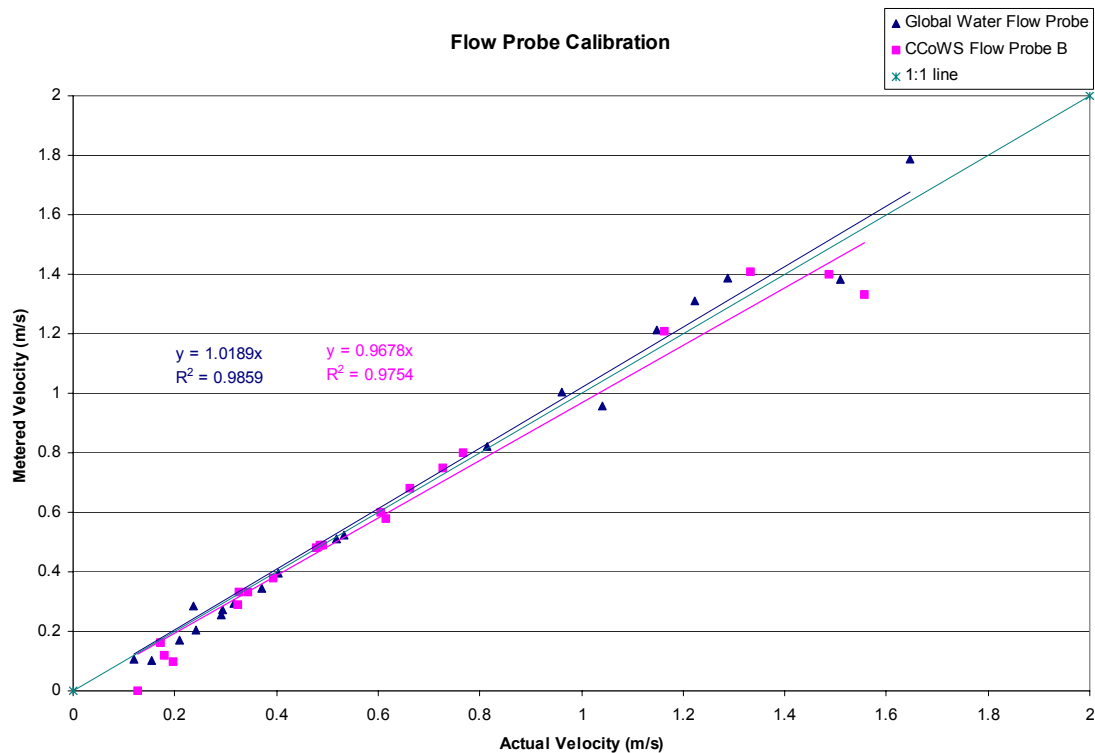


Figure 7.1. Results of CCoWS and Global Water flow probe calibration.

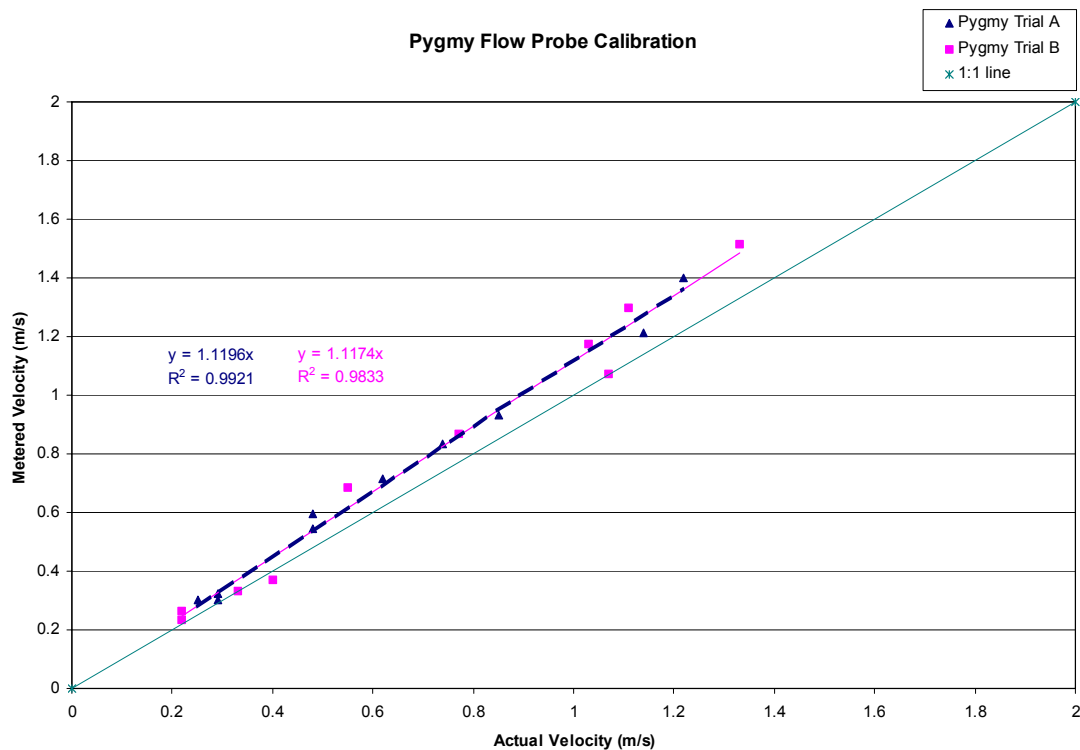


Figure 7.2. Results of Pygmy flow probe calibration.

7.2 Comparison of results from sediment and turbidity analyses

7.2.1 Introduction

Four different laboratory methodologies were conducted on 20 different water samples to determine a correlation between each of the different methods for detecting a sample's turbidity. The following methodologies were used :

- Vacuum Filtering
- Imhoff Cone (Nalgene Inc.)
- Turbidity Tube
- NTU-Turbidimeter (*Hach 2100P*, Hach Inc.)

Twenty samples, collected at different times of the year, were taken at 8 different locations. Different locations, or water bodies, were chosen in order to cover a wider range of sediment concentrations and/or turbidity.

Often ranch managers or property owners use simple devices such as Imhoff Settling Cones or Turbidity Tubes to estimate the level of turbidity in their water. However, it is not efficient or economically feasible for them to run complete analysis on their water to detect suspended sediment concentrations. The main objective of this study was to see how closely related each of the four methodologies are for indicating how much suspended sediment is in a sample of the water column. In addition, this section seeks to see if one methodology performed on each sample can provided strong estimates about the others without actually having to perform them. For example, can a transparency reading from a Turbidity Tube reveal a strong estimate of suspended sediment concentration, or the samples turbidity?

7.2.2 Methods

The first of the four methodologies used on each sample was a Turbidity Tube. Each sample, after a minute of vigorous shaking, was poured into the tube. Some samples were diluted for better accuracy. The samples were slowly released from the tube into the original container until the secchi disk at the bottom of the tube was first visible. The water level at the moment the secchi disk is first visible is the final reading. This is a crude method of indicating the cloudiness or sediment concentration of a sample.

The second methodology used was a turbidity meter. The maximum range for the *Hach 2100P* is 1000 Nephelometric Turbidity Unit (NTU). Several of the collected samples exceeded the 1000 NTU limit. Therefore, a dilution of these samples was necessary. A small representative sub-sample from each sample was taken for this analysis leaving the remainder of the sample intact. A turbidimeter measures the amount of light that is able to pass through a column of water. The more suspended particles in the water the higher the NTU value.

After completing each turbidity measurement, the remainder of each sample was weighed for its official volume. The sample weighing was done before the Imhoff Cone analysis because during the Imhoff Cone analysis, there is a tendency for fine particles to statically adhere to the walls of the cones. Therefore, to ensure that all of the sediment material is contained within the sample, a rinse is required, thus diluting the original sample. The samples could not be diluted without knowing their original volumes before vacuum filtering.

After being weighed, each sample was poured into an Imhoff Cone. The total volume was recorded. Measurements of all settleable material were recorded after twenty-four hours. The final readings of this analysis were a ratio of settleable solids to volume of water (L/L).

The final methodology used in this study was the vacuum filtering. Each sample was filtered through a 63 micron sand break (when needed), then both a coarse (2.4–6 μm) and fine (1.5 μm) grain filters. After sediment filtering, the samples are dried for two hours at 100°C and then weighed for their final total. This procedure measures the actual concentration, in mg/L, of suspended sediment in a water sample.

7.2.3 Results and Discussion

Final data from each of the different comparisons is listed in Table 7-3.

Table 7-3. Data results for each of the four methodologies.

Sample Source	Sample ID	Turbidity (NTU)	Imhoff Cone Ratio (L/L)	Transparency (cm)	Total Suspended Sediment (mg/L)
Irrigation runoff from a lettuce field in the Salinas Valley	IRR-JON	13770	0.016	0.22	9158
Irrigation runoff from a lettuce field in the Salinas Valley	IRR-JON	13740	0.015	0.28	8777
Chualar Creek at Chualar Creek Road	CHU-CHU	2935	0.0082	0.69	1804
Chualar Creek at Chualar Creek Road	CHU-CHU	3078	0.004	0.71	1754
Chualar Creek at Foletta Rd	CHU-FOL	2622	0.013	0.91	1649
Chualar Creek at Foletta Rd	CHU-FOL	2949	0.0069	0.63	1612
Agricultural drain at Foletta Rd	DRA-FOL	1368	0.0039	1.19	1077
Agricultural drain at Foletta Rd	DRA-FOL	1389	0.012	0.95	1081
Agricultural drain at Foletta Rd	DRA-FOL	1146	0.0072	1.41	879
Agricultural drain at Foletta Rd	DRA-FOL	1209	0.0086	1.51	834
Chualar Creek at Foletta Rd	CHU-FOL	920	0.000082	1.81	681
Chualar Creek at Foletta Rd	CHU-FOL	949	0.004	1.59	681
Chualar Creek at Chualar Creek Rd	CHU-CHU	497	0.003	2.44	451
Chualar Creek at Chualar Creek Rd	CHU-CHU	479	0.004	2.66	431
Agricultural drain at San Juan Grade Rd	DIT-SJU	152	0.0004	10.4	336
Agricultural drain at San Juan Grade Rd	DIT-SJU	184	0.0005	10.1	339
Salinas River at Chualar River Rd	SAL-CHU	33	0	26.2	53
Salinas River at Chualar River Rd	SAL-CHU	33	0	27	36
Gabilan Creek at Crazy Horse Rd	GAB-CRA	2.4	0	60	16
Gabilan Creek at Crazy Horse Rd	GAB-CRA	0	0	60	5

Turbidity vs. Suspended Sediment Concentration

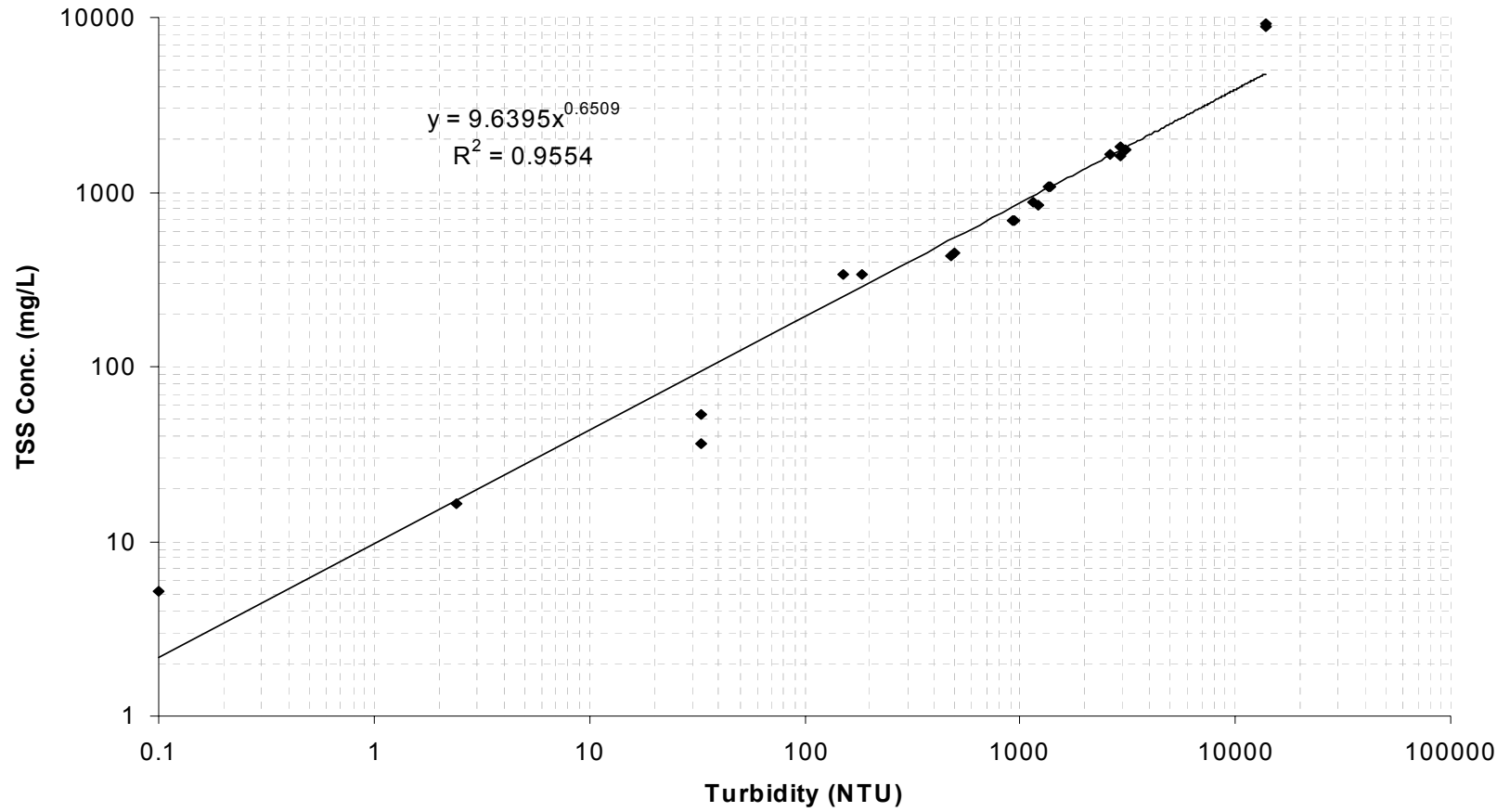


Figure 7.3. Turbidity vs. Total Suspended Sediment Concentration

Fig 7.3 suggests that there is a significant correlation between TSS concentration and the turbidity (NTU) measurements. Fig 7.4 suggests that there is strong a correlation between a sample's inverse transparency and its turbidity. In addition, the data suggests that a sample's inverse transparency is strongly correlated to the amount of suspended sediment—Fig 7.5.

The data results from the Imhoff analysis were not as significant. Fig. 7-6 to Fig 7.8 illustrate that there is significant amounts of scatter among data points for the cleaner samples in all methodology comparisons.

Table 7.4 summarizes the conversion coefficients to convert from one methodology to another.

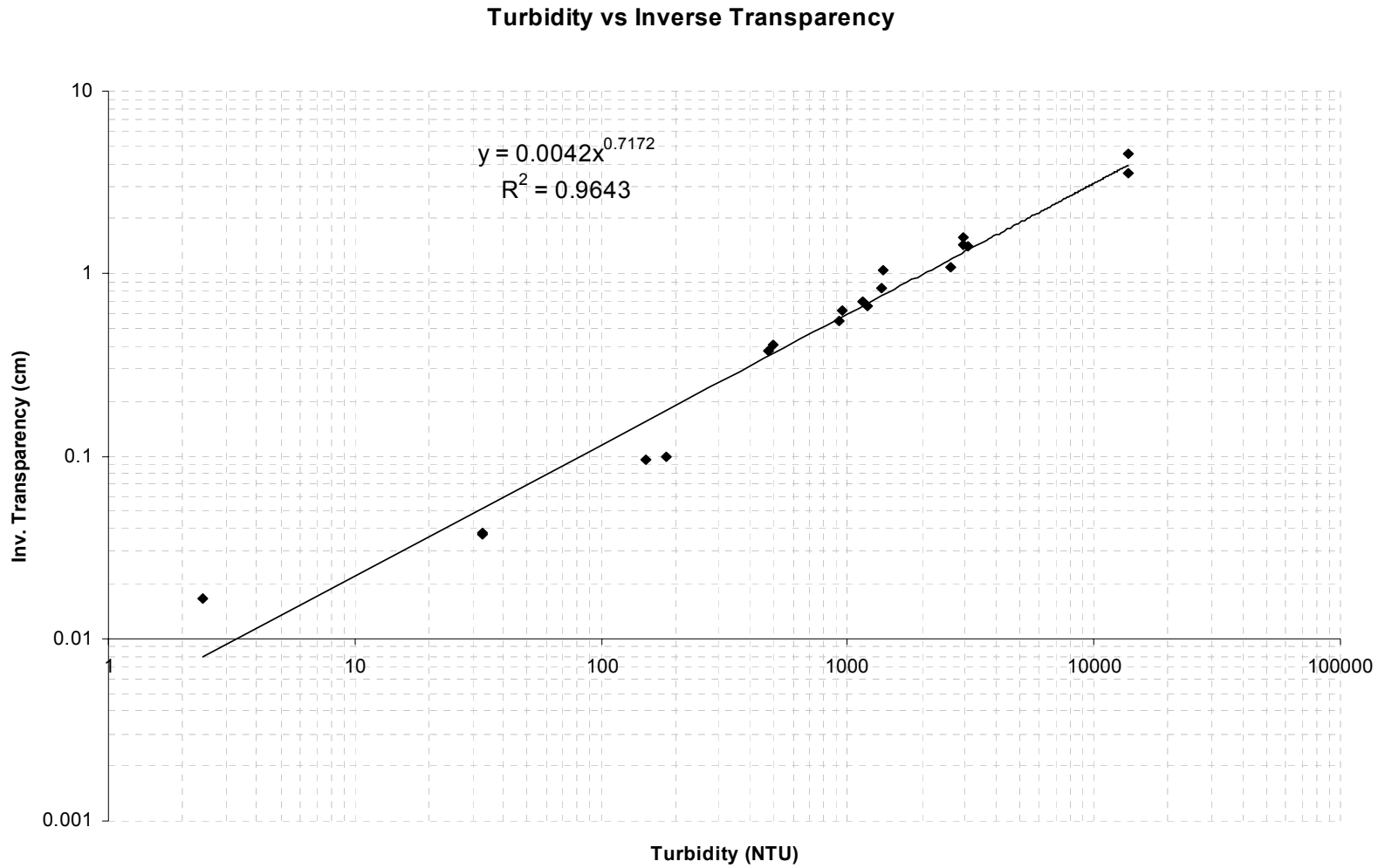


Figure 7.4. Inverse Transparency vs Turbidity

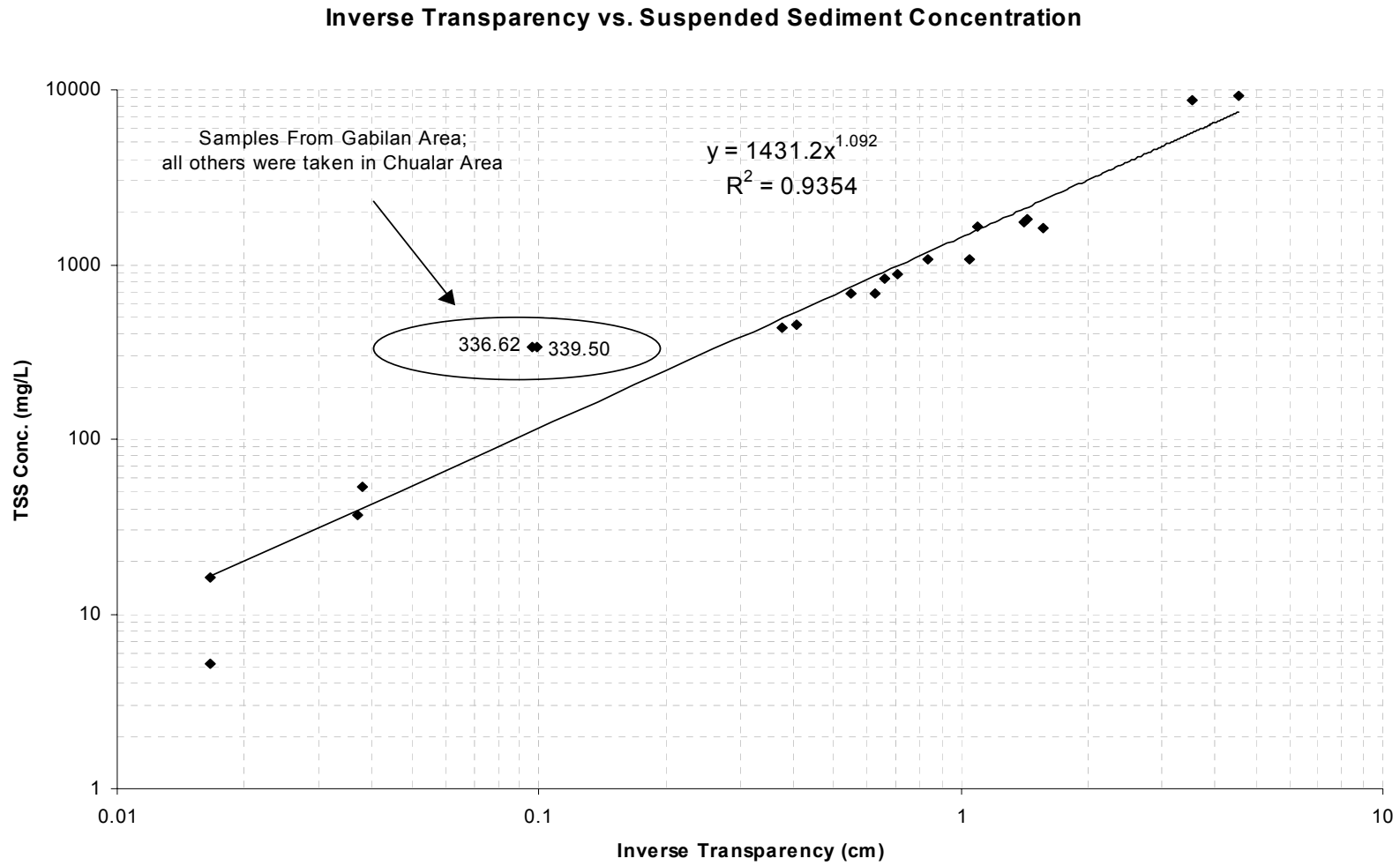


Figure 7.5. Inverse Transparency vs. Total Suspended Sediment Concentration

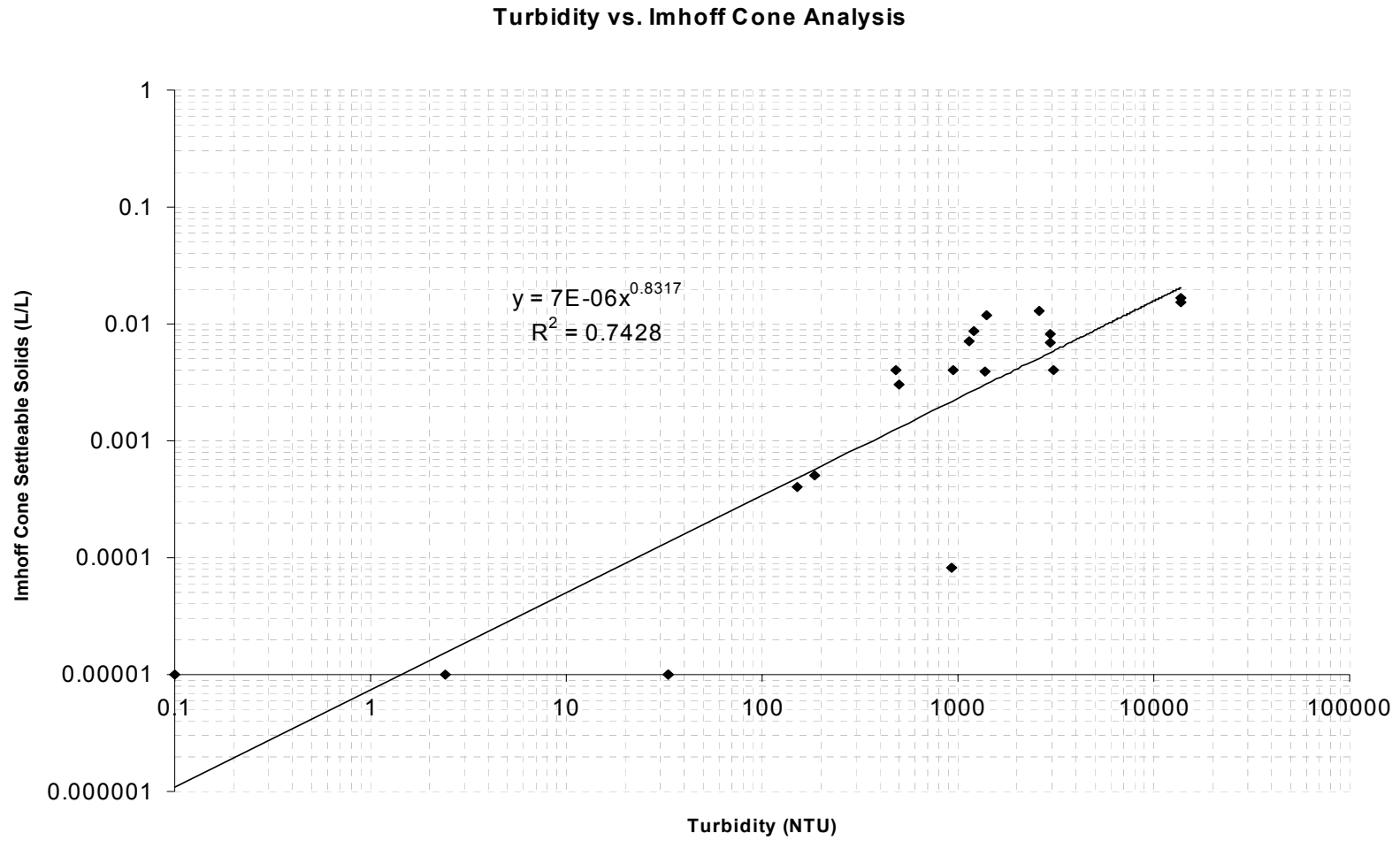


Figure 7.6. Turbidity vs. Imhoff Cone Analysis

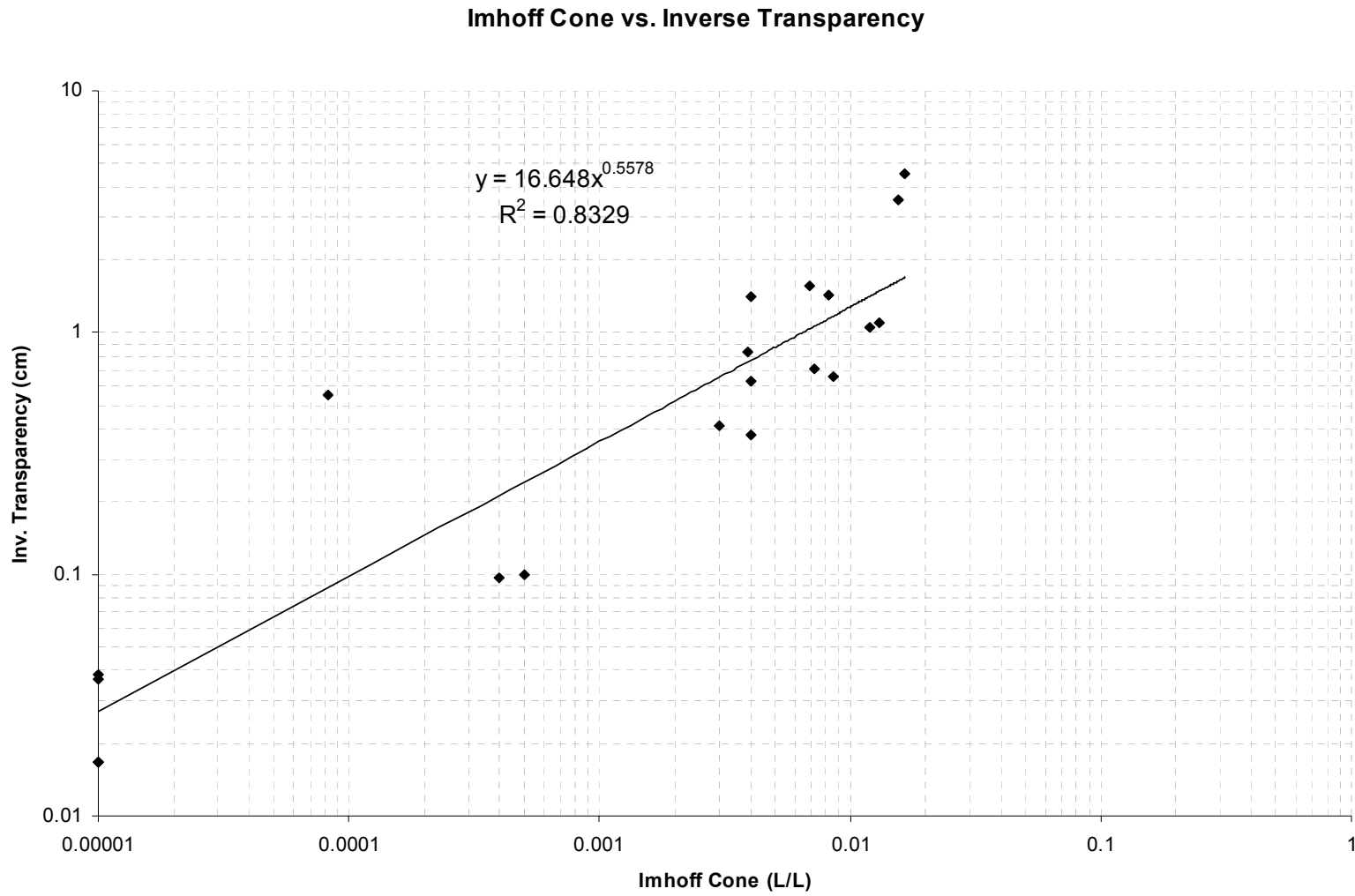


Figure 7.7. Imhoff Cone vs. Inverse Transparency

Imhoff Cone Analysis vs. Suspended Sediment Concentration

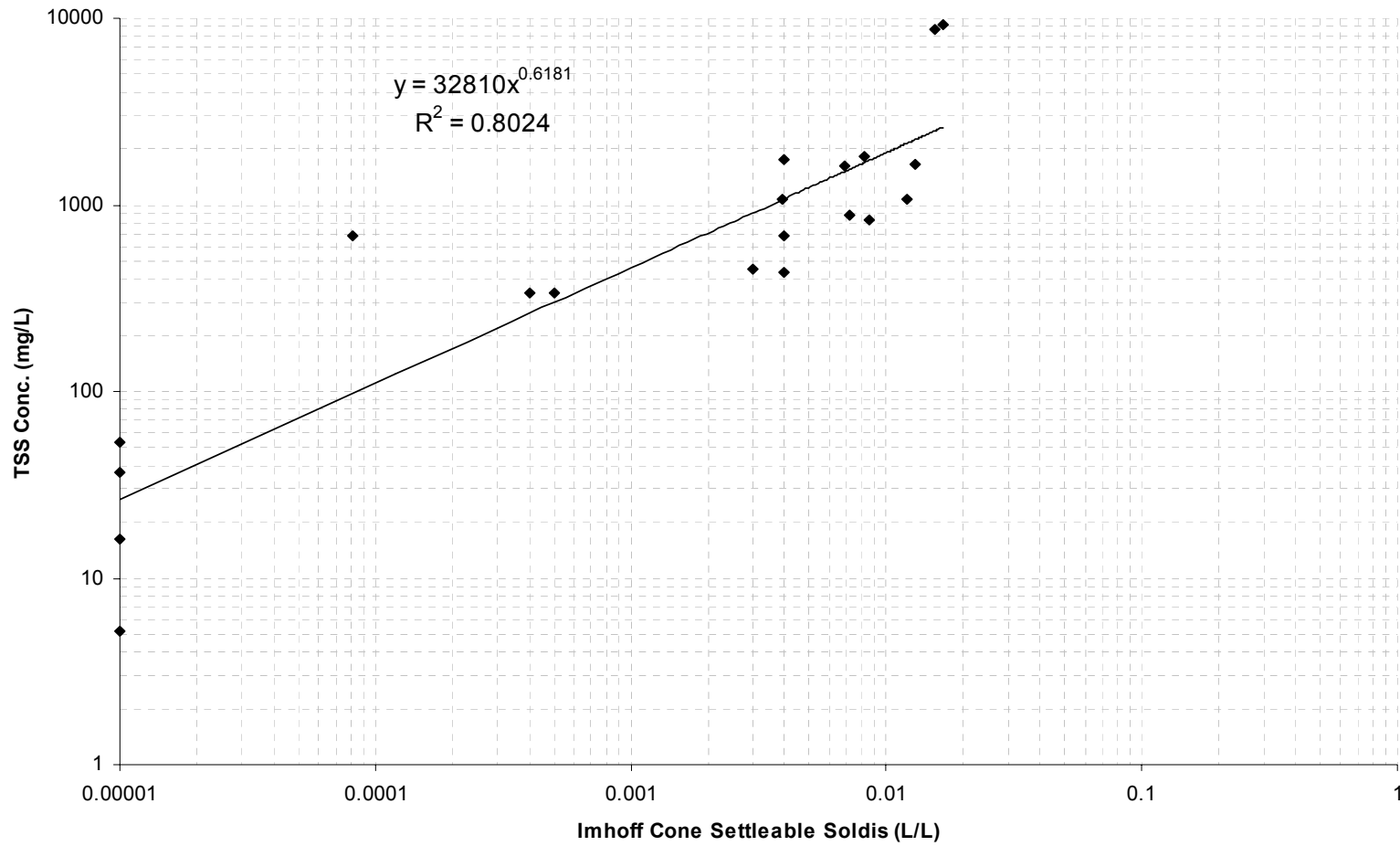


Figure 7.8. Imhoff Cone Analysis vs. Total Suspended Sediment Concentration

Table 7-4. Conversion coefficients and R² values for each of the methodology comparisons using a standard power function.

Methodologies	a	b	R ²
Turbidity vs. TSS	9.6395	0.6509	0.9554
Turbidity vs. Inv. Transparency	0.0042	0.7172	0.9643
Turbidity vs. Imhoff Cone	7E-06	0.8317	0.7428
Inv. Transparency vs. TSS	1431.2	1.092	0.9354
Imhoff Cone vs. Inv. Transparency	16.648	0.5578	0.8329
Imhoff Cone vs. TSS	32810	0.6181	0.8024

7.2.4 Conclusions

Four different methodologies were compared to see how effective each was at detecting the amount of suspended sediment in a field sample. Results of the study suggest that the Imhoff Cone analysis is the least accurate for estimating the suspended sediment concentration or the level of turbidity. Therefore, it appears that a transparency tube is the quickest and most economical method of detecting a reasonably accurate estimate of suspended sediment concentration and or turbidity.

7.3 Comparison of techniques for measuring dissolved oxygen

CCoWS generally uses the *YSI* 556 MPS to measure dissolved oxygen (DO) levels. Occasionally in agricultural areas, the *YSI* 556 MPS has recorded very high (super-saturated) DO levels in the region of 20 to 30 mg/L. This is consistent with observations of high algal abundance, and the inferred dominance of photosynthesis over respiration. The manufacturer's specifications for the *YSI* 556 MPS specify a maximum measurable dissolved oxygen concentration of 50 mg/L or approximately 500% saturation, depending on water temperature (Table 3-2).

In order to confirm the accuracy of the *YSI* 556 MPS when measuring high DO levels in local waters, CCoWS conducted a comparison using a *Hach* OX-2P DO meter, which incorporates a modified Winkler titration method. The manufacturer's specifications for the *Hach* OX-2P specify a maximum measurable dissolved oxygen concentration of 20 mg/L. Results of the comparison are summarized in Table 7-5. When possible, future tests will be conducted in waters with higher dissolved oxygen levels and using a different method that has the capability to measure concentrations greater than 20 mg/L.

Additionally, several replicate measurements were made using the *Hach* OX-2P. The results of those replications are presented in Table 7-6.

Table 7-5. *YSI* 556 MPS and *Hach* OX-2P Comparison

Date	YSI 556 MPS DO (mg/L)	Hach OX-2P Avg. DO (mg/L)	Difference (%)
31 Jul 02	11.96	12.50	4.5
15 Aug 02	16.50	15.75	4.5

Table 7-6. *Hach* OX-2P Replication Results

Date	Hach OX-2P DO (mg/L)						
	#1	#2	#3	#4	Average	St. Dev.	Coef. Of Variance (%)
31 Jul 02	12	13	-	-	12.5	0.71	5.7
15 Aug 02	16	16	15	16	15.75	0.5	3.2

8 References

- American Public Health Association, American Water Works Association, Water Environment Federation, 1998. Standard methods for the examination of water and wastewater (20th edition). Washington, DC: American Public Health Association.
- Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 1998. California Salmonid Stream Habitat Restoration Manual (3rd edition). California Department of Fish and Game: Inland Fisheries Division.
- Gordon, N. D., T. A. McMahon, B.L. Finlayson. Stream hydrology: an introduction for ecologists. John Wiley & Sons Ltd., 526pp.
- Harrington, J. and M. Born. 2000. Measuring the Health of California Streams and Rivers, A Methods Manual for: Water Resource Professionals, Citizen Monitors, and Natural Resource Students. Sustainable Land Stewardship International Institute. Sacramento, CA.
- Katznelson, R. and A. Feng. 1998. ELISA measurement of diazinon in water and sediment: principles and operating procedures. Alameda County Flood Control and Water Conservation District, California.
- Rosgen, D. and L. Silvey. 1998. Field guide for stream classification. Wildland Hydrology, 193pp.
- Sandstrom, M. 1995. Filtration of water-sediment samples for the determination of organic compounds. USGS Water-Resources Investigations Report 95-4105. Denver, Colorado.
- Woodward, J. and I. Foster. 1997. Erosion and suspended sediment transfer in river catchments. *Geography* 82:4, pp. 353-376.

Appendix C

Earth Systems Science & Policy
California State University, Monterey Bay
Accident/Incident Report Form

Date of Incident: _____ Time of Incident: _____

Location Where Incident Occurred: _____

Identity of any involved persons:

Name _____

Address _____

Contact Info _____

Identity of any witnesses:

Name _____

Contact Info _____

Description of Incident: _____

Actions Taken: _____

Name of Person Completing Report _____ Date _____

Staff/Faculty Signature _____ Date _____

Supervisor Signature _____ Date _____

Appendix D

CCoWS Stream Reconnaissance Data Sheet

Reach #: _____ Stream Name: _____
 Start Location: _____ Team: _____
 Date: _____ Start Time: _____ Slope: _____ Water Present: (Y/N)
 Water Temp: _____ (°C) Surface Velocity: _____ (m/s) Avg. Water Depth: _____ (m)
 Rosgen Stream Type: _____ Stream Type Notes: _____

 Estimated Channel Width: _____ (m) Estimated Channel Depth: _____ (m)
 Measured Low Flow Width: _____ (m) Measured Low Flow Depth: _____ (m)
 Small Pool Count (length < 4m): _____
 Medium Pool Count (length 4 to 10m): _____
 Large Pool Count (length > 10m): _____
 LWD Count: _____
Surface Substrate Composition:
 Bedrock _____ (%) Gravel _____ (%)
 Boulder _____ (%) Sand _____ (%)
 Cobble _____ (%) Silt _____ (%)
 Clay _____ (%)
Overhead Cover: _____ (%) ***check all plant species on back
Land Use: Left _____ Right _____
Bank Erosion: Left (Y/N) Right (Y/N) **Litter:** Left (Y/N) Right (Y/N) Channel (Y/N)
Rip-Rap: Left (Y/N) Right (Y/N) **Ag/Urban Drains:** Left (Y/N) Right (Y/N)
Fish: (Y/N) list species _____
Reptiles: (Y/N) list species _____
Amphibians: (Y/N) list species _____
Mammals: (Y/N) list species _____
Crustaceans: (Y/N) list species _____
GPS Points and Descriptions: _____

Plant Species List

- | | |
|--------------------|---------------------|
| _____Alder | _____Mule fat |
| _____Anise | _____Mustard |
| _____Arundo | _____Nettle |
| _____Burmuda grass | _____Oak |
| _____Buckeye | _____Oat |
| _____Buckwheat | _____Pampas grass |
| _____Cape ivy | _____Pepper tree |
| _____Cat tail | _____Pineapple weed |
| _____Cocklebur | _____Poison Oak |
| _____Cottonwood | _____Rushes/Reeds |
| _____Coyote brush | _____Rush rose |
| _____Cypress | _____Sage |
| _____Dogwood | _____Salt bush |
| _____Eucalyptus | _____Sedges |
| _____Ferns | _____Seep Willow |
| _____Grasses | _____Sword grass |
| _____Gray pine | _____Sycamore |
| _____HemLock | _____Tamarix |
| _____Jimson weed | _____Thistle |
| _____Madrone | _____Tree tobacco |
| _____Manzanita | _____Watercress |
| _____Maple | _____Wild berry |
| _____Mint | _____Willow |
| _____Monterey pine | _____Yerba |
| _____Mugwort | |

Other species: _____

Dominant Species (List 1): _____

Write all additional notes in field book!!!!!!!!!!

Appendix E

CCoWS Habitat Assessment Data Sheet

Stream: _____
 Location: _____
 Province ID: _____ Reach ID: _____
 Team: _____
 Date: _____ Start time: _____ End time: _____
 Start GPS ID: _____ End GPS ID: _____
 Observations: _____

Transect ID: _____ Start time: _____
 Habitat type: _____ (Pool, Glide, Run, Riffle)
 If pool, downstream riffle crest thalweg water depth: _____ (cm)
 Thalweg Surface Water Temp: _____ (°C) Thalweg Surface Velocity: _____ (m/s)
 Transect Width: _____ (m)
 Fish Sightings: _____

Point ID (#)	Particle Size (mm)	Overhead Veg. Cover (yes/no)	Water Depth (cm)	Total Depth (cm)
Thalweg				
1				
2				
3				
4				
5				
6				
7				
8				
9				

Instream Shelter Components:

1 to 5 boulders >6 boulders root mass
 single root wad LWD >12" diam, 6' long SWD <12" diam
 LWD + SWD undercut bank <12in. undercut bank >12in.
 bedrock ledge bubble curtain branches near water
 limited submersed vegetation extensive submersed vegetation
 undercut bank <12in. + root mass LWD + boulders + root wads
 ≥3 LWD + SWD ≥3 boulders + LWD + SWD
 undercut bank >12" + root mass or LWD b. curtain + LWD or boulders

Salinas River Basin Fish List & Codes:

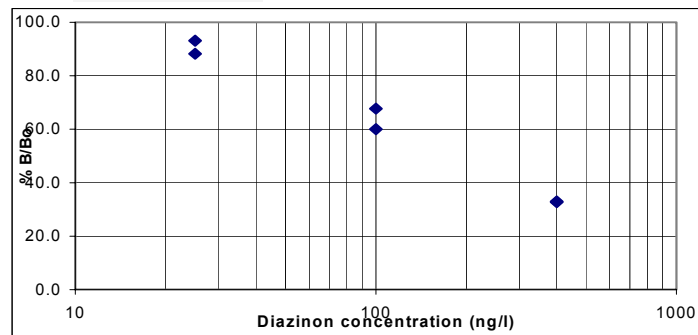
<u>Code</u>	<u>Common Name</u>	<u>Scientific Name</u>
LP	Pacific lamprey	<i>Lampetra tridentate</i>
RCH	California roach	<i>Hesperoleucus symmetricus</i>
HCH	Hitch	<i>Lavinia exilicauda</i>
BLK	Sacramento blackfish	<i>Orthodon microlepidotus</i>
PM-S	Sacramento pikeminnow	<i>Ptychocheilus grandis</i>
DC	Speckled dace	<i>Rhinichthys osculus</i>
SKR-S	Sacramento sucker	<i>Catostomus occidentalis</i>
RT	Rainbow trout/steelhead	<i>Oncorhynchus mykiss</i>
STB	Threespine stickleback	<i>Gasterosteus aculeatus</i>
PSCP	Prickly sculpin	<i>Cottus asper</i>
CSCP	Coastrange sculpin	<i>Cottus aleuticus</i>
RSCP	Riffle sculpin	<i>Cottus gulosus</i>
TP	Tule perch	<i>Hysterocarpus traski</i>
GSH	Goldfish	<i>Carassius auratus</i>
CP	Carp	<i>Cyprinus carpio</i>
BLB	Black bullhead	<i>Ameirus melas</i>
GAM	Mosquitofish	<i>Gambusia affinis</i>
WHB	White bass	<i>Morone chrysops</i>
GSF	Green sunfish	<i>Lepomis cyanellus</i>
BG	Bluegill	<i>Lepomis macrochirus</i>
LMB	Largemouth bass	<i>Micropterus salmoides</i>
BCR	Black crappie	<i>Pomoxis nigromaculatus</i>

Appendix J

Kit Lot #: **2D1035** Vendor: **SDI** Operator: **koz/larson**
 expiration date **Feb-03**
CALIBRATION CURVE for Diazinon in Water

Elisa date: **13-Jun-02**
 Sample date: **n/a**

calibrator #	CLP conc. added (ng/l)	well #	Absorbance at 450 nm	Average Bo	% B/Bo	Log ng/l added	Log ng/l by curve	Conc. by curve (ng/l)	% CV	% error value to stated
Zero	0	A1	1.167	1.203					4.18	
Zero	0	C9	1.238							
1	25	A2	1.061		88.2	1.4	1.5	29.1	3.83	16.3
1	25	C10	1.120		93.1	1.4	1.4	23.0		-8.1
2	100	A3	0.722		60.0	2.0	2.1	112.4	8.47	12.4
2	100	C11	0.814		67.7	2.0	1.9	77.9		-22.1
3	400	A4	0.394		32.8	2.6	2.6	416.0	0.54	4.0
3	400	C12	0.397		33.0	2.6	2.6	411.1		2.8
Lab Control	300	B3&C	0.484		40.2		2.5	291.1		-3.0



number of calibrator pairs with %CV exceeding 15%: 0

Sample ID	sample conc. in well (%)	well (#)	Absorbance at 450 nm	B/Bo (%)	Log ng/l	DZN in test tube (ng/l)	Flag*	DZN in orig. sample (ng/l)	Sample ID
7	100%	A5	0.577	48.0	2.3	200		200	7
20	100%	A6	0.570	47.4	2.3	206		206	20
11	100%	A7	0.584	48.6	2.3	195		195	11
9	100%	A8	0.570	47.4	2.3	206		206	9
23	100%	A9	0.537	44.7	2.4	235		235	23
22	100%	A10	0.566	47.1	2.3	209		209	22
13	100%	A11	0.473	39.3	2.5	304		304	13
24	100%	A12	0.508	42.2	2.4	264		264	24
15	100%	B1	0.584	48.6	2.3	195		195	15
18	100%	B2	0.595	49.5	2.3	187		187	18
7	100%	B4	0.589	49.0	2.3	191		191	7
20	100%	B5	0.590	49.1	2.3	190		190	20
11	100%	B6	0.583	48.5	2.3	196		196	11
9	100%	B7	0.589	49.0	2.3	191		191	9
23	100%	B8	0.566	47.1	2.3	209		209	23
22	100%	B9	0.585	48.6	2.3	194		194	22
13	100%	B10	0.537	44.7	2.4	235		235	13
24	100%	B11	0.512	42.6	2.4	260		260	24
15	100%	B12	0.588	48.9	2.3	192		192	15
18	100%	C1	0.537	44.7	2.4	235		235	18
7	100%	C3	0.597	49.6	2.3	185		185	7
11	100%	C4	0.559	46.5	2.3	215		215	11
23	100%	C5	0.578	48.1	2.3	200		200	23
13	100%	C6	0.552	45.9	2.3	221		221	13
24	100%	C7	0.580	48.2	2.3	198		198	24
18	100%	C8	0.615	51.1	2.2	172		172	18

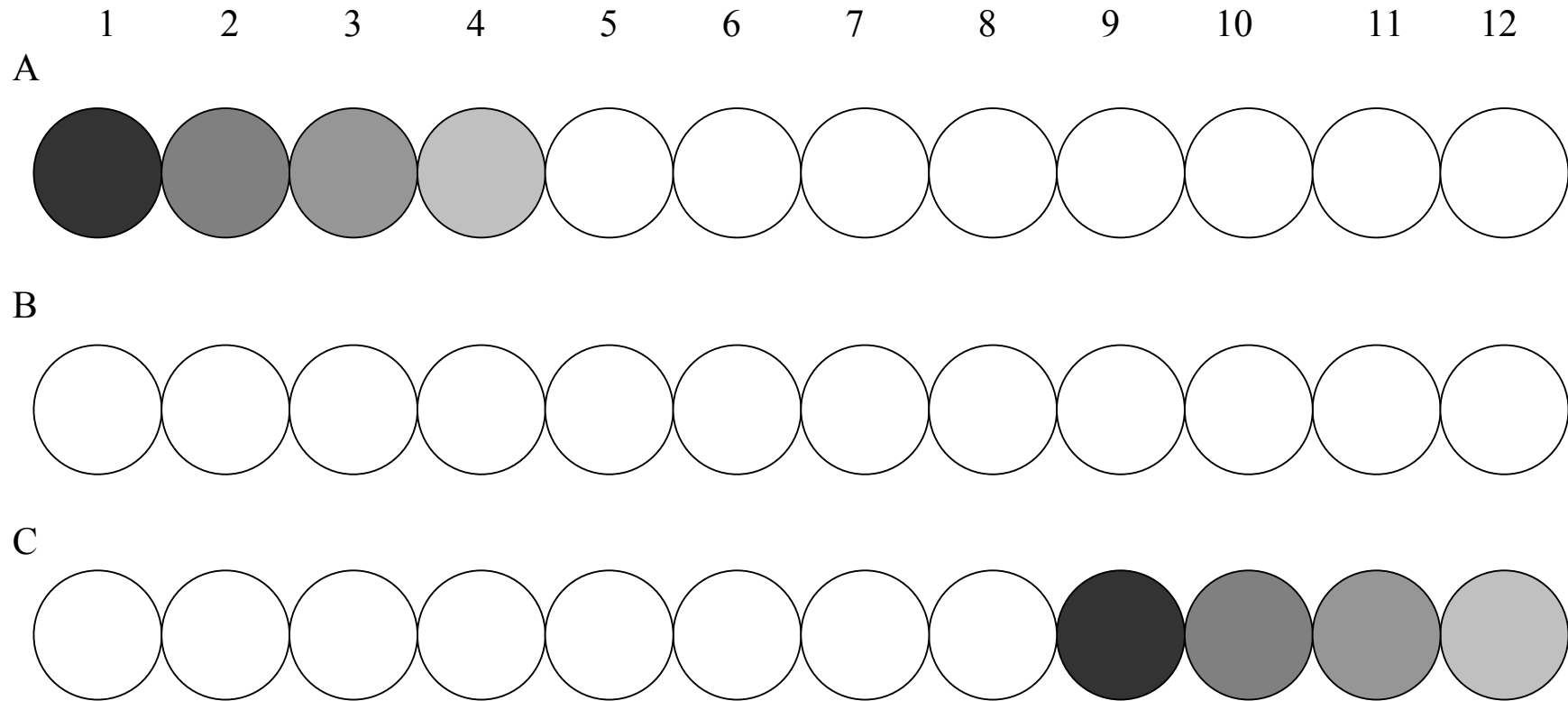
r² = **0.99** Slope **mean** **-48.00** Intercept **158.5** QA/QC date:

sample replicates	mean B/Bo	mean sample value	mean treatment value
7	48.9	192.1	
20	48.2	198.1	
11	47.8	201.8	
9	48.2	198.5	1st batch
23	46.6	214.2	200.94
22	47.9	201.7	
13	43.3	251.0	
24	44.4	238.6	
15	48.7	193.4	2nd batch
18	48.4	196.2	216.18

*OoR = out of range of calibration curve, using either replicate of lowest and highest calibrators; L,H indicates whether beyond low or high end of curve

Appendix K

ELISA Run Plan



ROOM TEMP		Circle one:	Diazanon	Chlorpyrifos	Incubation	TEMP		calibrators	R = replicate	SP = spike
LOT #		Circle one:	water	methanol	Start time	(60min)		0	C = control	D = dilution
DATE		Pipette timing			End time			25/62.5	MB = method blank (filtered)	
Name		Start time			Start time	(30min)		100/250	FFB = filtered field bank	
Name		End time			End time			400/1000	RFB = rinsed field blank	