

Class Notes: Gallinas Creek Environmental Problem
GEOS 4606, Summer, 2010¹

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¹see this document online at http://www.utdallas.edu/~brikowi/Teaching/Field_Camp/

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Chapter 1

GEOS 4606 Field Camp, Gallinas Creek

These handouts roughly describe the environmental problem for Field Camp, the evolution of water quality and quantity on Gallinas Creek outside of Las Vegas, NM. Students gain hands-on experience in the field observation and measurement of processes and phenomena in environmental geology. Activities include stream and groundwater flow and chemistry measurements. We will visit a number of field sites along the creek (Fig. 1.1), from the head of the watershed to points below Las Vegas. Gallinas Creek provides almost all of the water supply of Las Vegas (taking no more than half the flow of the Gallinas). In normal years irrigation water is stored temporarily in Storrie Lake, forming an artificial branch of the river which terminates at McAlester Lake (Fig. 1.2).

1.0.1 Basis for Grade

Grading will be based on participation in gathering and reporting field data individual final analysis of the data summarized in a class spreadsheet. In the field, students will be broken up into small groups, each tasked with a different evaluation at the field site. The groups will report their results to the data collection group, including and low-level interpretation where appropriate (e.g. computing stream discharge from cross-sectional area measurement and velocity determination). The course TA will provide an official summary (spreadsheet) of field data for use in your final report.

Individual grades will be given for a final analysis, not to exceed 5 pages examining the origins and impacts of stream flow and chemistry changes along the watershed. Points on the final report will be allocated as follows (plus 10% for participation in field and lab activities):

30% Introductory Material

10% Purpose statement

10% Listing of methods used (1-2 paragraphs)

10% Readability/Presentation

⁰See this file online at http://www.utdallas.edu/~brikowi/Teaching/Field_Camp

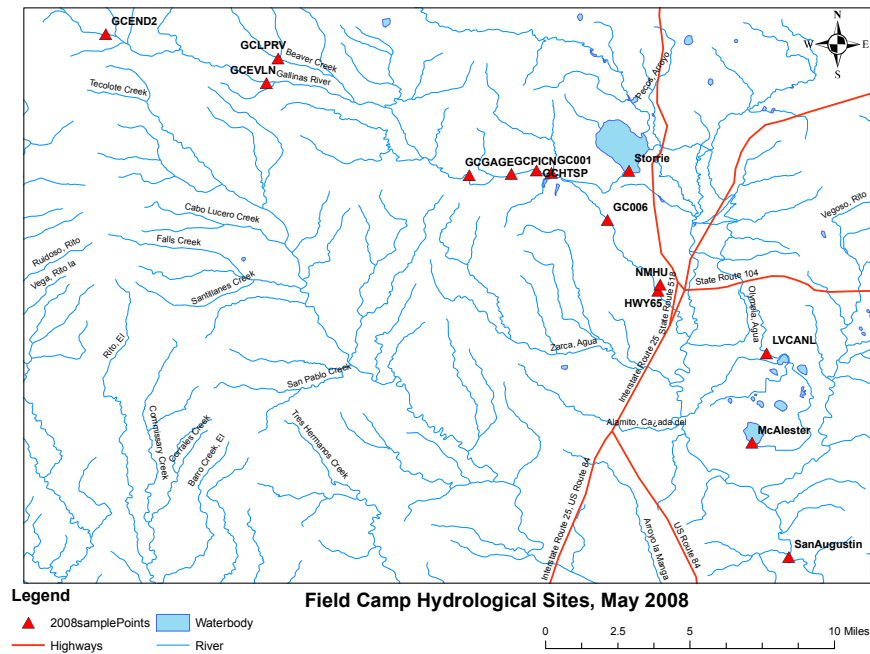


Figure 1.1: Map of sample locations, Gallinas Creek. Subject to change depending on field conditions. Available as separate file from the TA or professor's website.

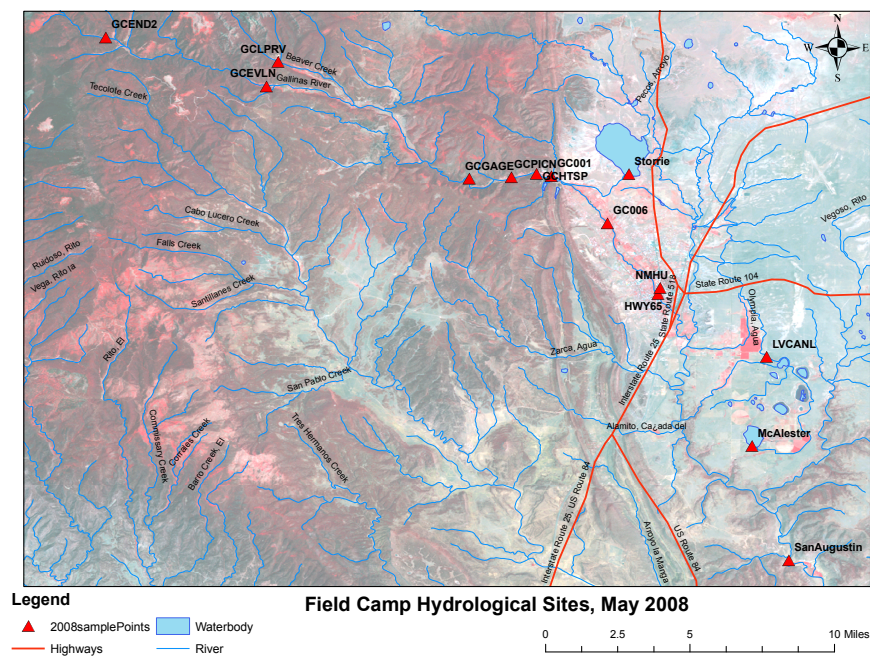


Figure 1.2: Gallinas Creek field sites and Landsat image

10% Data tables/list

50% Discussion/Conclusions (2-3 pages)

15% Graphical data summary/comparison (at least this year's)

25% Discuss variability, trends, possible data errors, etc.

10% Discuss significance for water resources, water science, etc.

1.0.2 Textbook

An optional textbook that can assist in carrying out this problem is “A Manual of Field Hydrogeology” by L. S. Sanders, ISBN 0132279274. (Publishers description). The professor's copy will be available on the writeup/office day.

1.1 Background

We will be concerned with two basic aspects of the surface water hydrology in the Gallinas Creek watershed: changes in streamflow and stream chemistry along the creek. This section contains basic background information that will help you understand these issues. Specific techniques and instructions are given in subsequent chapters of the notes.

1.1.1 Climate

The Las Vegas area is relatively high-elevation (6430 ft) and semi-arid (precipitation $16 \frac{\text{in}}{\text{yr}}$). Typical climate is:

- dry, cool and somewhat windy in May
- streamflow (from snowmelt) typically peaks in May
- snow is typically gone from all but the highest elevations by the time we arrive

1.1.2 Importance of Rio Gallinas

The Gallinas provides almost all (95%) of the water supply for Las Vegas, NM. It is also crucial for local agriculture, mostly on former Spanish land grant areas referred to in general as “acequias” (really the Spanish word for “canal”). As Las Vegas grows, it becomes more difficult to satisfy increasing municipal water demand, and as throughout the U.S. balancing the various water needs is becoming increasingly difficult. Added to these pressures are downstream demands (i.e. Pecos River Compact with Texas, recently enforced by Federal lawsuit). Finally, the effects of climate change (earlier average snowmelt, Fig. 1.3) increase reliance on reservoir storage, which is relatively inefficient and inadequate in Las Vegas.

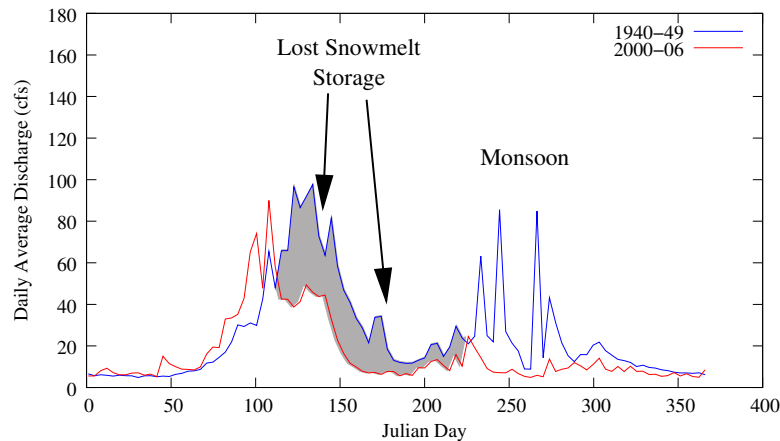


Figure 1.3: Comparison of mean monthly discharge, Rio Gallinas, 1940-50 and 2000-2006. Earlier snowmelt pulse and unchanged monsoon onset make for longer dry period in mid-summer. Some indication that monsoon has become less reliable. Date conversion: May 15 = Julian Day 135, Aug. 15 = day 227.

1.1.3 Stream Gauging Background

Stream gauging is performed to accurately determine the volume of water moving past a given point per time. This information is crucial for flood planning and prevention, as well as prediction of sediment or contaminant transport, total contaminant or sediment load, prediction and control of erosion, etc. The U.S. Geological Survey maintains a number of real-time stream gauging sites in the U.S. (accessible online) for these purposes.

Gallinas Creek near Montezuma The nearest such gauge is about 10 miles upstream from Las Vegas ([click here to see this month's data](#))

Map of New Mexico Gauges Map showing current surface water summary and station locations for New Mexico

Mississippi River at Baton Rouge Gauge height data for last 30 days. Note that maximum annual discharge averages 300,000 cubic ft/sec (cfs).

Map of US Real-Time Data Map showing current surface water summary and station locations for U.S.

Definitions

Discharge is the volume per unit time that passes any point in a stream. Direct measurement of discharge is not possible, but must be calculated from velocity and cross-sectional area of the stream, i.e. from the [Discharge Equation](#)

$$\underbrace{Q \left(\frac{L^3}{t} \right)}_{\text{Discharge}} = \underbrace{V \left(\frac{L}{t} \right)}_{\text{Velocity}} \cdot \underbrace{A \left(L^2 \right)}_{\text{Cross-Sectional Area}} \quad (1.1)$$

Velocity is the rate of water movement (Fig. 2.4), but doesn't specify how much (volume of) water is moving. The volume rate is needed to determine flooding, etc.

Cross-sectional Area is the area on a vertical plane cutting the stream (Fig. 2.1)

Stage is the elevation of the river above its bed, i.e. water depth

You've had direct experience with discharge when using a garden hose with a nozzle. For a given faucet setting (constant input discharge) water shoots farther out of the end of the hose (has higher velocity) when the nozzle is narrowed (cross-sectional area is reduced). Velocity varies along a stream because of changes in cross-sectional area, but discharge varies **only** if there is addition or removal of water (e.g. tributaries, evaporation, etc.)

1.1.4 How Real-Time Stream Gauges Work

The links in Section 1.1.3 show up-to-the-minute discharge at USGS and Army Corp of Engineers stream gauges. The procedure described above is too cumbersome to provide such data, instead it is derived from constant stream level (stage) monitoring using "stilling wells" (Fig. 1.4), from which discharge is estimated using a "rating curve" (Fig. 1.5) for that site. The rating curve is derived by using the procedure we'll use in this lab for a variety of discharge levels.

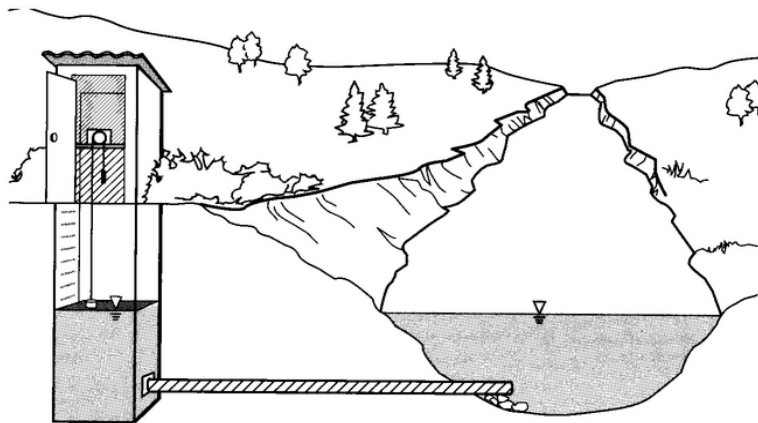


Figure 1.4: Schematic of stream water level monitoring station [after Fig. 3.17, Sanders, 1998]. The configuration shown is known as a "stilling well", most stations simply have a PVC tube in place of the well.

1.1.5 Water Chemistry Background

Water Analyses

- collection methods important, see USGS manual [USGS, 1998]

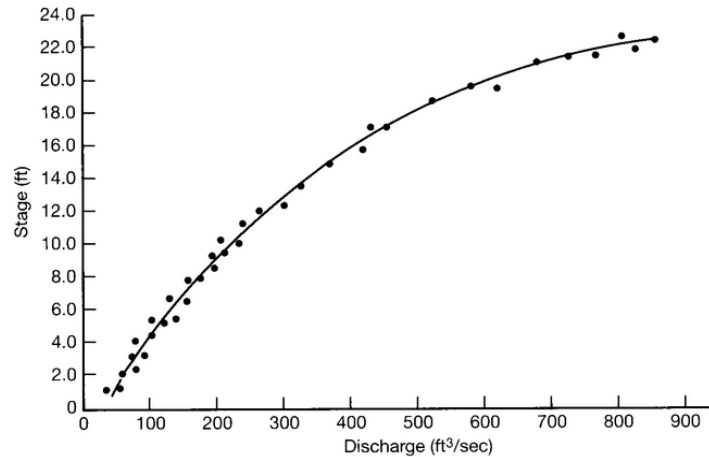


Figure 1.5: Example rating curve for a stream gauging station [after Fig. 3.22, Sanders, 1998]. Given measurements of discharge at various river levels (stage), the rating curve can be obtained and used to estimate discharge given a stage measurement.x

- generally reported in concentrations of actual ions, some (like SiO_2 , nitrate NO_3) are lumped together, and/or reported as oxides
- Analytic methods standardized for EPA and environmental applications in general [USGS, 1979, WEF, 1998]
- check error in analysis by performing charge balance (sum of cations and anions expressed as milli-equivalents). This sometimes fails, e.g. for strongly colored fluids which may contain organic complexes)

Graphical Analysis

- Piper diagram
 - plot natural groupings on two trilinear diagrams (one for cations, one for anions), the combination of these two plots is made by projecting these onto the quadrilateral diagram above (Fig. 1.6)
 - classification of the water chemistry is based on the sum of cation and anion classifications Fetter [Fig. 9.9, 2001]
 - some ions are “diagnostic” of particular settings:
 - * bicarbonate (HCO_3^-) is characteristic of meteoric waters, and arises from the combination of CO_2 and H_2O in the atmosphere
 - * NaCl is characteristic of seawater, and formation water derived from seawater
 - evolution of waters along flow path is often revealed by these diagrams [e.g. Floridan aquifer, p 377-9, Fetter, 2001]
 - try free GW-Chart software from USGS

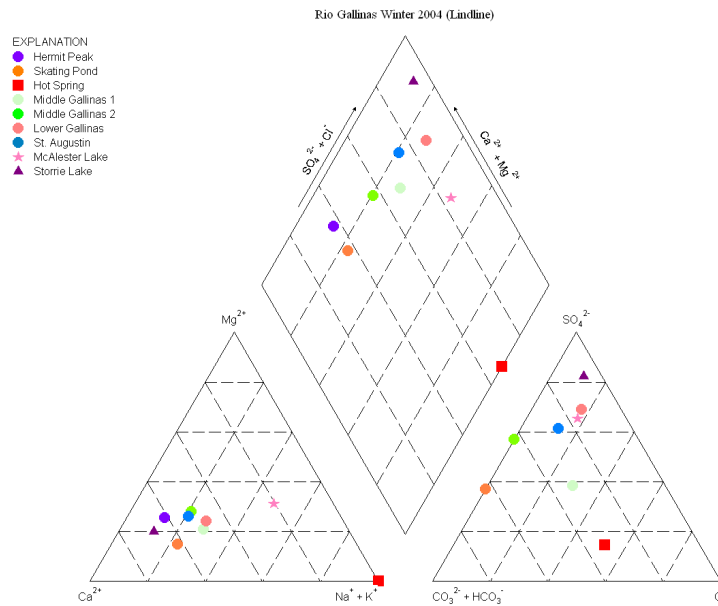


Figure 1.6: Piper diagram of samples of Gallinas Creek, 2004. Meteoric waters (Ca-HCO_3^- dominated) tend to plot in lower-right corner of ternary diagrams, formation and hydrothermal waters in lower-left (Na-Cl). See Johns-Kaysing and Lindline [2006], Jones et al. [2006].

Indicators of Chemical State

We'll measure field variables to indicate the chemical state of the water when collected. In addition to dissolution of materials (e.g. solid salt dissolves and exists as ions), other reactions can occur, including:

pH and Dissociation of Water

Dissociation each water molecule can “come apart” (termed dissociation or ionization of water)

Acid-Base dissociation creates acids (the H^+ ion) and bases (the OH^- ion)

Acid-Base Reactions the exchange (i.e. donation by the acid or acceptance by the base) of the proton (H^+) is the basis of many chemical reactions (acid-base reactions), especially in water

Examples e.g. eating citric acid (tangy sensation), using muriatic acid on concrete (dissolves stains that water alone can't get out), taking “Tums” (a base) to neutralize gastric acid

pH the measure of concentration of protons (H^+ ion) in water, or essentially the strength of the proton donation reaction.

pH Definition pH is the negative logarithm of the concentration of H^+ . So an acid has low pH, and therefore high concentrations of H^+ , and can participate more readily in reactions that require donation of a proton.

neutral pH at neutral pH there are equal “concentrations” of H^+ and OH^- in the solution. At room temperature neutral pH is 7. “Neutral” really means that there is equal tendency solution for donation or acceptance of protons.

Consequences for example metals (which can often be toxic) tend to be immobile in acid environments. If we want to understand the chemical state of a water, we must measure its pH as well as concentrations of dissolved species.

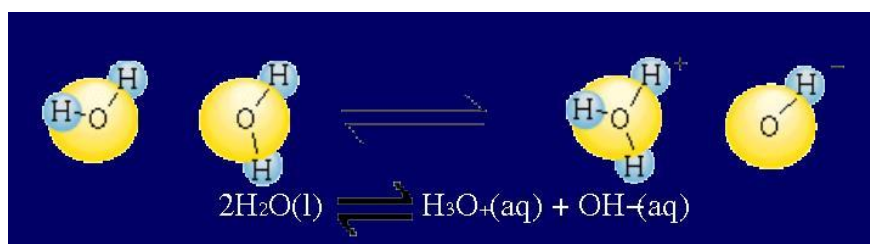


Figure 1.7: Dissociation reaction of H_2O .

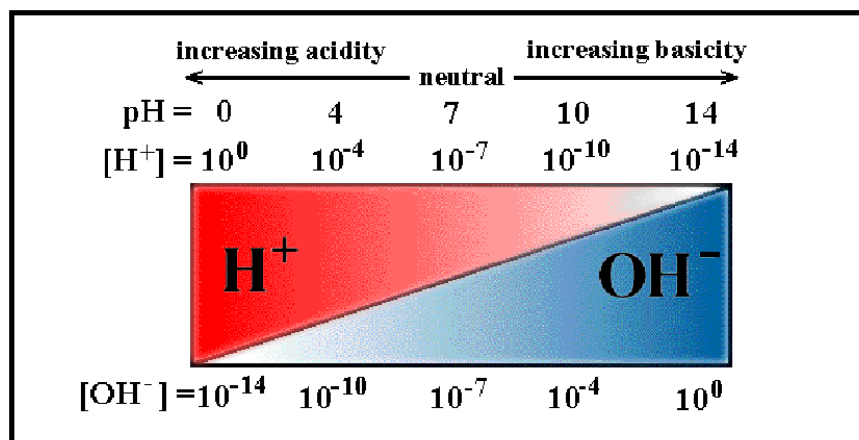


Figure 1.8: The pH scale, where high pH indicates high concentrations of protons (H^+ ions), and a high potential for proton donation.

Chemical Reactions and Temperature

We must also measure temperature of our water because:

- **Equilibrium state** in all chemical reactions depends on temperature

- e.g. its easier to dissolve sugar in a hot drink than a cold one, because the **solubility** of sugar (and most chemicals) in water increases with temperature
- similarly, pH depends strongly on temperature Fig. 1.9

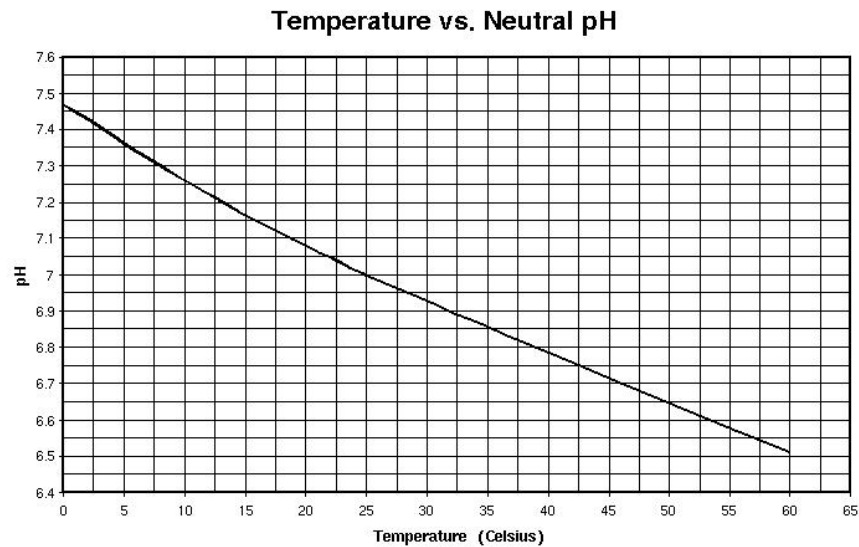


Figure 1.9: Variation of pH vs. temperature.

Oxidation-Reduction

Since many dissolved species of interest are metals, we must also characterize the oxidation (“rusting” and transport) potential of the water. This is essentially the tendency of the solution to transfer electrons, with oxidation representing donation of electrons from the dissolved species under consideration.

- rust is the familiar process of iron (Fe^{2+}) **oxidizing** (donating electrons to oxygen) to form (Fe^{3+})
- in general the reduced form of metals (e.g. Fe^{2+}) is more mobile/soluble in water (left-hand member of metal pairs, Fig. 1.10)
- oxidation state is best characterized by **oxidation potential** or **Eh** (ORP)
- we’ll use a proxy for this, which is to measure the **dissolved oxygen** or **DO** of the water
- waters with high DO are good for animals (lots of O_2 to breathe), and don’t transport as many metals
- waters with lots of dead organic matter consume oxygen by converting the carbon to CO_2 , and therefore tend to have low values of DO

- DO saturation is elevation and temperature dependent

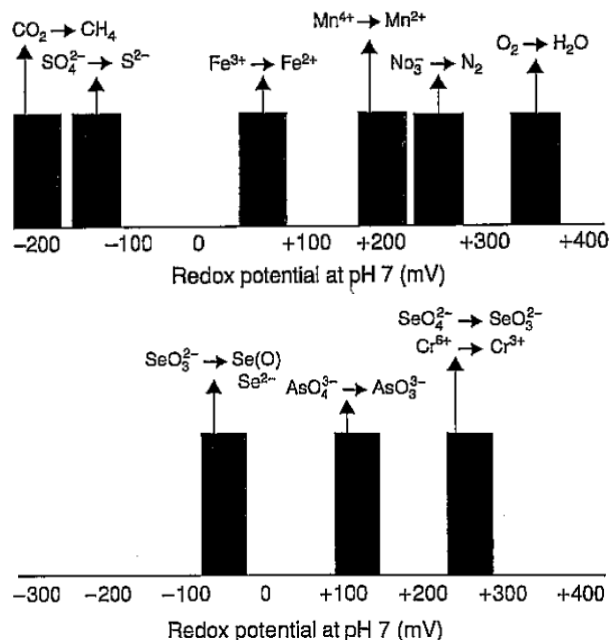


Figure 1.10: Eh dependence of redox pairs, and typical metals mobilized or demobilized by redox changes (e.g. Cr^{+6} quite soluble and toxic in groundwater, Cr^{+3} is much less soluble. From Delaune & Reddy (2004).

Other Parameters

Some other parameters are useful:

Turbidity the cloudiness of the water. An indicator of suspended particulates, which can transport bacteria. EPA Drinking Water limit is 1 NTU (nephelometric turbidity units). Easily controlled by settling or filtration.

Electrical Conductivity is an indication of the amount of dissolved ions. The more ions, the easier it is for electricity to move through the water (essentially electrons hop from ion to ion, the more ions, the easier that is). Typical values for drinking water are around $300 \frac{\mu\text{S}}{\text{cm}}$ (e.g. Fine Waters website). **Specific Conductance** is the electrical conductivity adjusted to 25°C , to allow direct comparison of waters that have differing temperatures.

Salinity also known as **TDS** or total dissolved solids, given in ppm. Often inferred from specific conductance or computed as the sum of all dissolved species. The Safe Drinking Water Act limit for TDS is 1000 ppm.

Hardness the potential to form carbonate scale, this is the sum of Ca and Mg, usually dominated by Ca

Alkalinity essentially the concentration of the anion HCO_3^- , which is dominant in many surface water systems. Alkalinity is reported as ppm CaCO_3

1.1.6 Soil Moisture Background

Water movement through the **unsaturated** or **vadose zone** is complicated by the presence of two mobile phases, air and water, as well as a compressible medium, the soil particles 1.11. Surface tension of the water against the air holds the soil particles together via **cohesion**. Recall when building sand castles sand cannot be too wet or too dry, because only at intermediate **moisture contents** does it have the right cohesiveness. This surface tension produces negative pressure (relative to atmospheric) as water surfaces shrink away from trapped air bubbles.

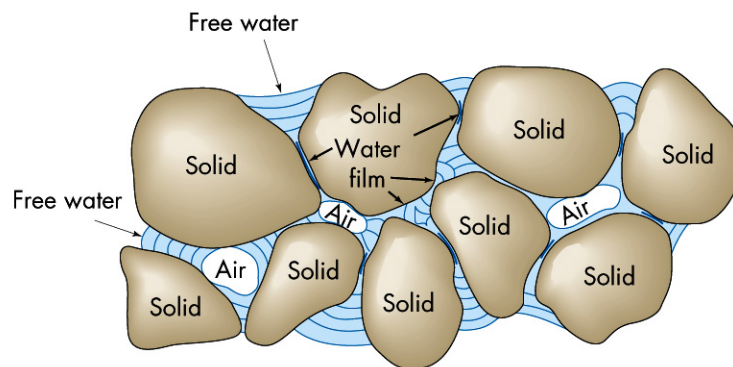


Figure 1.11: Air-water-particle relationships in soil [Fig. 16.5, Keller, 2008]. Changes in the distribution of air and water generally control soil behavior.

Soil Moisture Balance

- as in the saturated zone, a water (moisture) mass balance can be performed for the soil (Fig. 1.12)
- this is an important activity in agriculture, rangeland and forest management
- Definitions:
 - **field capacity** of soil: minimum soil moisture content resulting from pure gravity drainage [Fig. 6.5, Fetter, 2001]
 - **wilting point**: minimum soil moisture content produced by gravity drainage + plant evapotranspiration. Always lower than field capacity (Fig. 1.14)

- groundwater recharge cannot occur unless soil moisture content exceeds field capacity

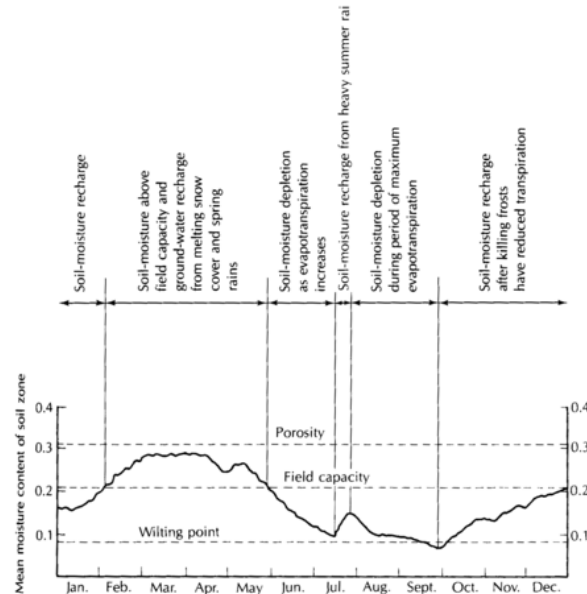


Figure 1.12: Hypothetical annual variation of soil moisture Fetter [Fig. 6.4, 2001]. Note especially groundwater and soil moisture recharge periods

Pressure Head and Tension

- because of capillary forces, fluid pressure (or pressure head ψ) are generally negative (when given as gage pressures)
- soil scientists often refer to these as **suction** or *tension* head, and omit the negative sign. We won't do that in this class.
- fluid pressure and soil moisture content are directly related because of capillary forces
- soil moisture content is related to soil suction, and is typically illustrated in a **soil moisture retention curve** (Fig. 1.15)
- a **tensiometer** measures the soil suction directly by equilibrating a porous cup with the soil (Fig. 1.16)

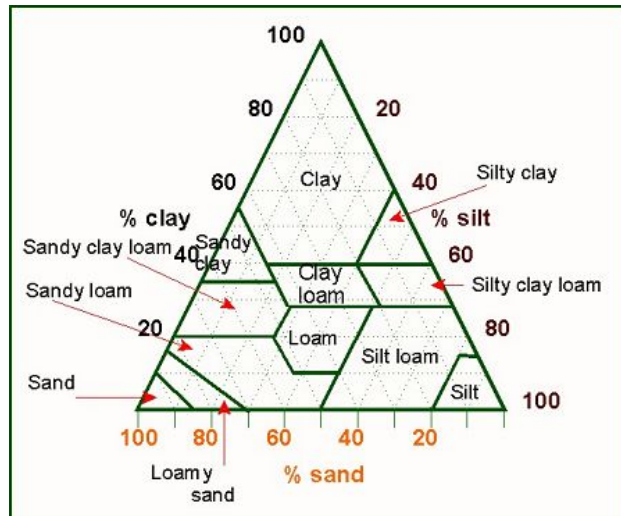


Figure 1.13: Soil texture classification, based **ONLY** on grainsize. See also [Fig. 16.3, Keller, 2008].

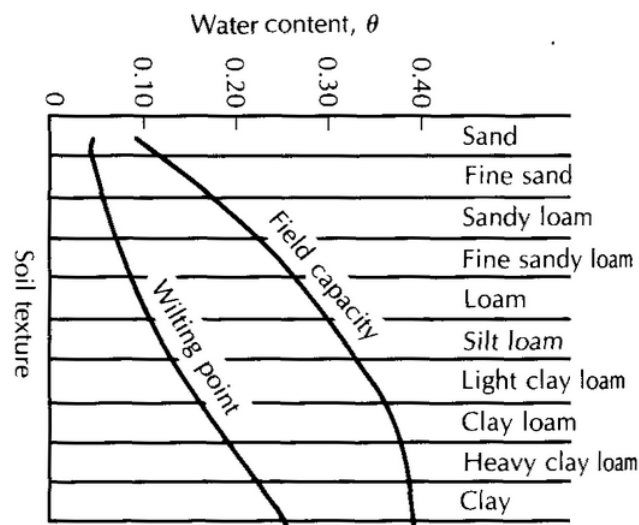


Figure 1.14: Dependence of water content on grain size. Field capacity is maximum storage possible under gravity drainage, wilting point is minimum storage under gravity drainage only. After Fetter [Fig. 6.5, 2001].

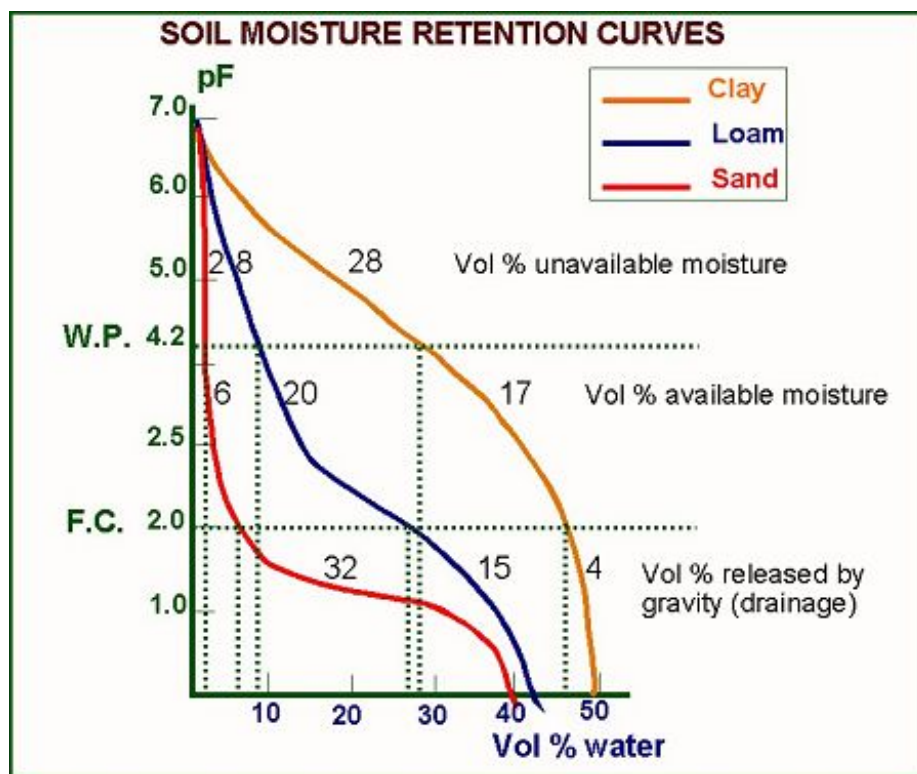
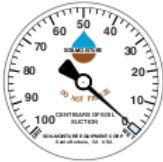


Figure 1.15: Moisture retention curve. Moisture content depends on soil texture (Fig. 1.13), numbers show moisture availability distribution in soil, gravity drainage becomes groundwater recharge. After Netherlands Potato Foundation.

GAUGE READINGS / IRRIGATION SCHEDULING



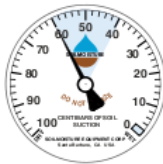
ZERO:
A gauge reading of zero means the surrounding soil is completely saturated with water, regardless of the type of soil. Zero readings can be expected after a heavy rain or deep irrigation. If the zero reading persists after a long period of time, there will be oxygen starvation to plant roots and development of diseases. A persistent zero reading after irrigation indicates poor drainage conditions which should be investigated and corrected.



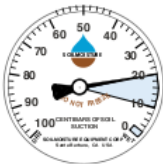
20-40 CENTIBARS:
Available moisture and aeration good for plant growth.
HEAVY CLAY SOILS: No irrigation required.
MEDIUM TEXTURED SOILS: No irrigation required.
SANDY SOILS: Irrigation started for coarser sandy soils in the 20-30 cb range. For finer sandy soils in the 30-40 cb range.



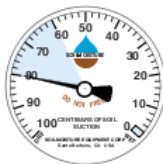
0-10 CENTIBARS:
Gauge readings in the range of 0-10cb indicated a surplus of water for plant growth. Water held by the soil in this range drains off within a few days. Persistent readings in this range indicate poor drainage conditions which should be corrected to obtain healthy plant growth.



40-60 CENTIBARS:
Available moisture and aeration are good for plant growth in finer textured soils.
HEAVY CLAY SOILS: No irrigation required.
MEDIUM TEXTURED SOILS: Irrigation started in this range. The finer the texture the higher the reading before start of irrigation.
SANDY SOILS: Too dry. Hot windy conditions can force soil suction to high reading quickly and damage plants.



10-20 CENTIBARS:
Gauge readings in the range of 10-20cb indicate that there is ample moisture and also air in the soil for healthy plant growth in all types of soils. This range is often referred to as the “field capacity” range for soils, which means that the soil has reached its “capacity” and cannot hold anymore water for future plant growth. When soils are at “field capacity”, any additional water that is added drains out of the root zone within a day or two—before it can be used by the growing plant. If irrigation has been in process, it should be stopped when gauge drops to this level, since any further additional water will be quickly drained from the root zone and wasted, carrying with it valuable fertilizer.



60-80 CENTIBARS :
Readily available moisture scarce, except in heavy clay soils.
HEAVY CLAY SOILS: Start of irrigation desirable as soil suction values reach 70-80 cb.
MEDIUM TEXTURED SOILS: Too dry. Hot, windy conditions can force soil suction to high reading quickly and damage plants.
SANDY SOILS: Too dry. Damage to plants will occur before irrigation can be applied.

Figure 1.16: Interpretation of tensiometer readings. Moisture content depends on soil texture, so these interpretations are only approximate. After SoilMoisture, Inc..

Chapter 2

Task 1: Stream Hydrology

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The goal of this task is to make field measurements of stream flow and general chemistry. We will determine the **discharge** (volume of water per cross-sectional area per time) of Gallinas Creek at several locations, and measure field chemistry parameters. These will vary significantly from head to mouth of Gallinas Creek, and you will interpret the significance of those changes.

⁰See this file online at http://www.utdallas.edu/~brikowi/Teaching/Field_Camp

2.1 Task 1 Activities

2.1.1 Task 1 Parameters to be Measured

Please refer to the textbook [Chapter 3, Sanders, 1998] for a detailed description of the measurement of each parameter listed below. In the field, we will break up into groups of two or more, each group will be responsible for measuring the parameters listed below at a station assigned by the TA or professor.

Parameters to be measured:

Stream Cross-Section measured directly using simple surveying techniques (Fig. 2.2). Used to determine the cross-sectional area of the stream, also hydraulic radius and wetted perimeter (see text p. 53-55).

Stream Velocity determined by float method (Fig. 2.4) and direct measurement when possible (impeller velocity meter, Fig. 2.7 and Section 2.2.2). Used to compute discharge (see also text p. 73-74).

Parameters to be calculated:

Discharge given cross-section and stream velocity measurements described above

2.1.2 Tasks

Our main tasks are to measure:

1. Discharge
 - (a) measure channel cross-section
 - (b) measure velocity
2. Hydrolab Quanta (water quality meter) stream health
3. pH (Hanna meter)
4. Turbidity
5. General Water Quality (swimming pool) test strips
6. Bacteria test
7. Take water samples

2.2 Stream Discharge (Gauging)

2.2.1 Measuring Cross-Sectional Area

The simplest approach to measuring cross-sectional area is to locate a number of points on the stream bottom by measuring down from the tagline (or yardstick) at regular intervals (see “ d_i ” in Fig. 2.1). Then draw these locations (and the water surface) to scale on graph paper, and count the squares to determine the area. A second method is to approximate the area by a series of rectangles, as shown in Fig. 2.1 and Sanders [Table 3.2, 1998]. If you measure depth at regular intervals (e.g. 2 cm), then the width b_i of each rectangle is constant.

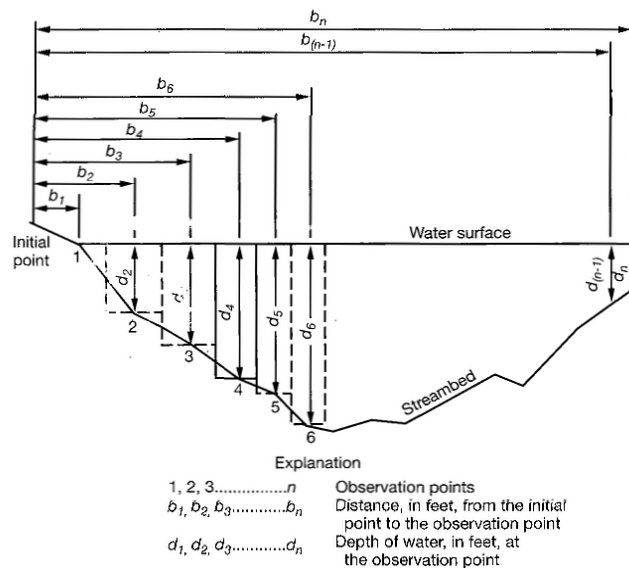


Figure 2.1: Measurement of stream cross-sectional area [after Fig. 3.21, Sanders, 1998].

1. We will install a tag line (a distance-marked string or and/or measuring tape) approximately perpendicular to the stream.
2. The group will use yardsticks or rulers provided by the TA to measure the height of the water column at suitable intervals along the line. These intervals must be spaced closely enough to allow accurate determination of the stream cross-section (see Figs. 2.1–2.2) (i.e at least 10 points).
3. A second line will be installed an appropriate distance downstream from the tag line, to allow velocity determination by the float method
4. The group will divide the stream cross-section into 3 or more channels as appropriate and determine the discharge for each channel (i.e. velocity for each channel, use a subset of the cross-section results to determine channel cross-sectional area).



Figure 2.2: Students gauging Cottonwood Creek, UTD. Taglines are used to provide reference elevation, yardsticks or gauging staff are used to measure distance to water and streambed from the tagline.

- use float method in each channel (Figs. 2.4–2.5).
- If there is sufficient water depth, the group will also utilize the s-flowmeter to determine the variation of velocity with depth, and to compare to their float-method velocity values. The flowmeter can be used to measure an i-average flow across small stream cross-sections

5. Calculate discharge **for each channel** and report the total in your group report

Suggested form for recording stream cross section data (height of water column is distance from stream bottom to top of water):

Stream Cross Section Measurements			
Name:		Date:	
Team Members:			
Location:			
Tag line endpoints (lat, long, elev):			
Point Number	Horizontal Position	Height of Water Column	Notes

2.2.2 Measuring Velocity

Velocity can be measured directly, using a flowmeter (essentially a speedometer for water, Fig. 2.7 and Section 2.2.2) or inferred by timing the movement of a float in the water (Fig. 2.4). Velocity varies across a stream and with depth, depending primarily on the proximity of the streambed (Fig. 2.3). When using a flowmeter, a single measurement at approximately 60% of the depth of the stream will give a reliable vertical average.

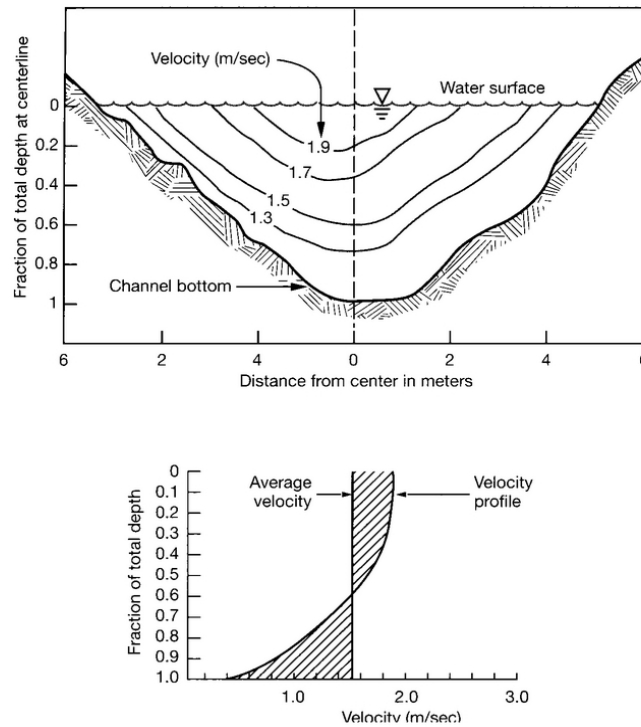


Figure 2.3: Variation of stream velocity with depth [after Fig. 3.16, Sanders, 1998].

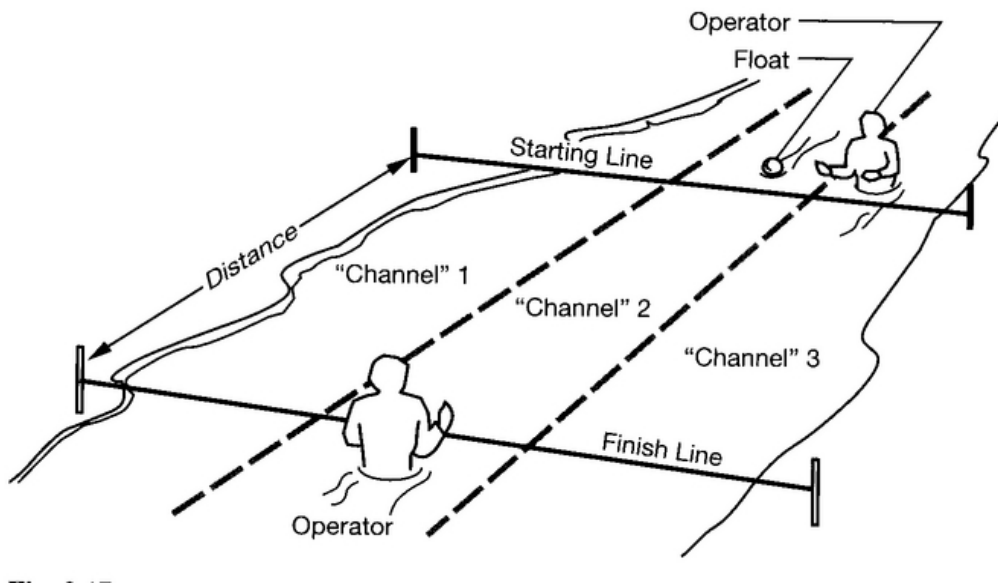


Figure 2.4: The float method for velocity determination [after Fig. 3.17, Sanders, 1998].



Figure 2.5: Students using the float method for velocity measurement (click on image for full-sized version). Fall '98 class, at Spring Creek, Richardson, Texas.

Using the Flowmeter

The flowmeter can be used to determine average velocity at a point, or across the entire stream (for small streams, see online manual). The device is waterproof, but try to avoid submerging the LCD display. In the field, divide the stream into three channels across, and determine the discharge for each channel! To use the flowmeter to measure stream velocity:

1. make sure the prop turns freely
2. point the prop directly along the flow, with the black arrow on the prop housing pointing downstream (with the flow). The prop should be fully submerged, flowmeter **upstream** from operator (Fig. 2.7).
3. press the bottom button until “AVGSPEED” appears The instantaneous velocity (in meters/sec) is displayed as the top number on the LCD screen. If needed, hold the bottom button for 3 seconds to zero the average speed value.
4. for point measurements, hold in the flow until the average velocity is constant, then remove the probe. Measurement (averaging) ceases when the prop stops turning, so the displayed value is the true average at the point.
5. for areal measurements (average velocity over a stream cross-section) move the probe in the flow in a steady back-and-forth motion, as if you were spray-painting. When the entire cross-section has been covered, remove the probe from the flow, and record the displayed value. You should keep the probe moving for 20-40 seconds.

Suggested form for recording stream velocity data, float method [after p. 63, Sanders, 1998]):

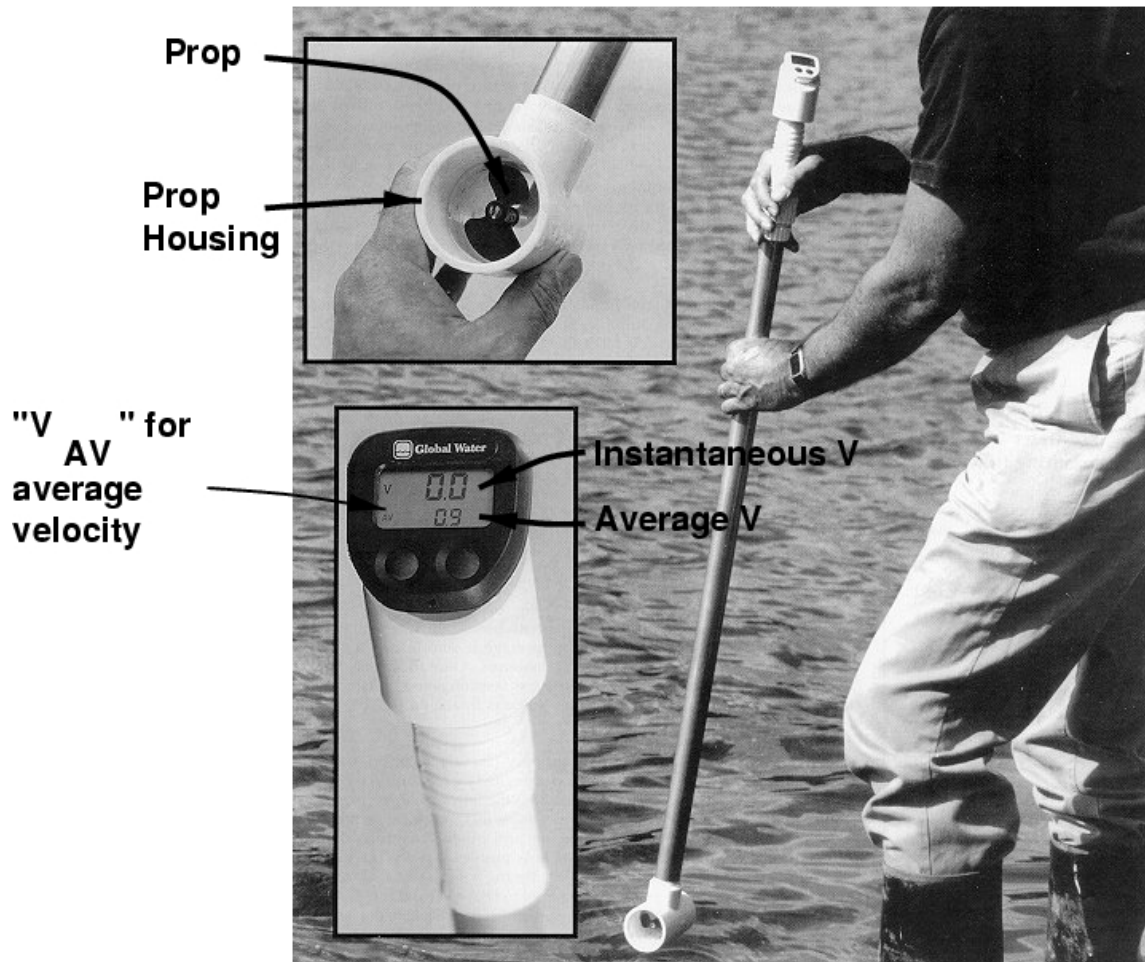


Figure 2.6: Impeller flowmeter. After <http://www.globalw.com/graphics/flow.jpg>.



Figure 2.7: Students using an impeller flowmeter. Streamflow from left to right.

Stream Velocity Measurements (float method)							
Name:					Date:		
Team Members:							
Location:							
Stream Section Number	Section Width	Downstream Distance	Trial Number	Time	Surface Velocity	Average Surface Velocity in Section	Notes

See Sanders [page 67, 1998] for a suggested form for recording stream velocity data, velocity meter method.

2.3 Field Water Quality: Instrumental Measurements

One group will assess water quality (chemistry) using hand-held electronic instruments.

2.3.1 Calibration of Instruments

In general electronic instruments are used to measure chemical properties of water. As such, they are indirect methods of measurement, and therefore must be **calibrated**. This is essentially the same as synchronizing watches; each watch may tell *time differences* accurately, but the true time requires resetting or calibrating each watch to an agreed-upon standard. To calibrate chemical probes/instruments, two or more samples of known concentration are measured, and then a calibration factor is entered into the device (or applied to the final result) to adjust the output to agree with standard values. To save time, we will calibrate only the pH meter while out in the field.

2.3.2 Using the Turbidimeter

The turbidimeter measures the light transmittance of a sample in NTU's (Nephelometric Turbidity Units, a standard measure). It needs no field calibration. Handle the sample vials only by their ends (preferably the lid) so as not to affect the transmittance; wipe any fingerprints, spots, etc. from the outside of the vial; and be sure to close the vial-compartment lid when taking a measurement. The turbidimeter should display "AUTO RNG" (for auto-range selection) and "SIG AVG" (for take an average reading) when ready for use (Fig. 2.8).

Use the following procedure when measuring the turbidity of your sample:

1. Fill turbidity vial (has white line around top of glass with downward arrow) to the line (about 15 mL) with **unfiltered** water. Take care to handle the sample cell by the top. Cap the cell.
2. Wipe the cell with a soft, lint-free cloth to remove water spots and fingerprints.

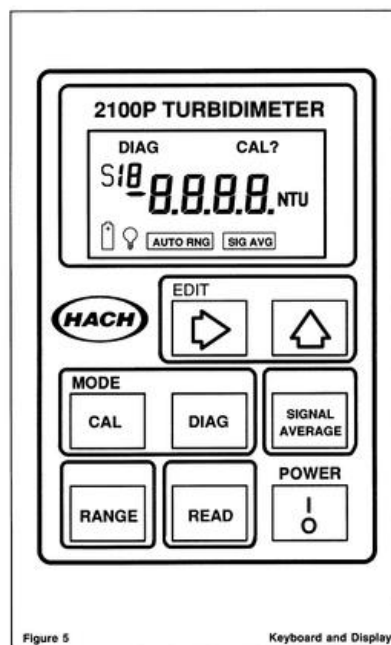


Figure 2.8: Turbidimeter controls and display. Press “READ” when ready to take a measurement. After Hach Model 2100P Turbidimeter Instruction Manual, 1997, p. 24.

3. Press I/O - the instrument will turn on. Place the instrument on a flat surface. Do not hold the instrument while making readings.
4. Put the sample vial in the instrument cell compartment so its diamond mark aligns with the raised orientation mark in front of the cell compartment. **Close the cover.**
5. Set automatic range by pressing the RANGE key. The display will show “AUTO RNG”.
6. Select signal averaging (reports average of 10 measurements) by pressing “Signal Average” key, display should show “SIG AVG”
7. Press READ - the display will show “—NTU” and the light bulb icon will flash 10 times (once for each reading). The final average will be displayed as numbers in NTU after the lamp symbol turns off.

2.3.3 Using the pH Meter

This meter is used to measure the acidity of the water by comparing readings from a reference electrode and a sample electrode. To determine pH the output of these electrodes must be temperature-compensated, so most pH meters also measure temperature. On the Hanna pH probe (Fig. 2.9), pH is displayed in the center right of the LCD screen, temperature ($^{\circ}\text{C}$)

is displayed in the lower right. pH meters generally require frequent calibration in the field, if time permits we will calibrate the pH probe..



Figure 2.9: pH Meter display and controls.

pH Measurement

The procedure for making a pH-temperature reading is:

1. rinse the electrode tip in deionized water
2. depress the dispenser button on the top of the electrode until a click is heard (releases reference electrolyte at tip of electrode)
3. wait until the readings become steady (“READY” indicator shows, and meter beeps once)
4. record results (including temperature)
5. if readings become erratic, dispense more electrolyte

2.3.4 Using the Hydrolab Quanta

The Hydrolab Quanta is used to measure multiple water quality parameters simultaneously (Fig. 2.10), using a single probe. The Quanta is intended for use in boreholes or surface water bodies.



Figure 2.10: Quanta water quality meter display and transmitter. Display shows multiple parameter readings, transmitter contains multiple water quality sensors. Transmitter (large black multi-probe) is placed in stream or sample container for measurement.

On/Off Press the lowest key (“O—I”) on the display to turn on the device, self-test countdown should begin in the bottom center of the display (stops at 30)

Screen 1 the first screen displays the following parameters from top to bottom. Record these in your notes.

Temp temperature in °C

SpC **specific conductance**, the electrical conductivity at 25°C

DO **dissolved oxygen** content of the water in $\frac{\text{mg}}{\text{l}}$ (same as ppm in most cases)

pH acid-base state

Screen 2 press return (top key, \leftrightarrow) and new parameters are displayed. Record the last three in your notes.

Batt ignore, battery voltage of display

TDS estimated **total dissolved solids**, sum of cations and anions in solution in $\frac{\text{grams}}{\text{Liter}}$

DO% percent saturation of DO (higher than 30% needed for fish survival)

ORP **oxidation reduction potential** in milliVolts

On/Off turn Quanta off by holding bottom key until countdown in bottom center of LCD display reaches 0

2.4 Field Water Quality: Test Strips

One group will assess water quality (chemistry) using test strips (low precision).

2.4.1 Using the Basic Chemistry Test Strips

These test strips work just like the pH test strips you probably used at one time in your life. Strip technology has advanced to the point where they are highly useful for reconnais-

sance field chemistry and process control. We're using them in this project to allow rapid determination of geochemistry. To use the strips:

1. open the bottle and shake out one strip. **DO NOT** put wet fingers into the bottle, you'll ruin the rest of the strips.
2. dip the strip into the water and remove immediately
3. hold the strip **horizontally** for 15 seconds, **DO NOT** shake off excess water from the strip
4. compare the colors on the strip to the chart on the bottle. Feel free to interpolate if an intermediate color appears. The pad at the end of the strip corresponds to total hardness.

2.4.2 Using the Bacteria Test Strips

These strips use an antibody test to check for the presence of common harmful bacteria. Drinking water standards are one bacterium per liter, and of course bacteria are unique in being able to change their own concentration with time. To use these strips:

1. open foil pouch and remove all contents
2. with clean dropper place **EXACTLY ONE** dropper-full of water into the sample vial
3. gently swirl vial. Let stand 7 minutes, swirl again, place on flat surface
4. place test strip into sample vial with arrows pointing down
5. wait 10 minutes, **DO NOT DISTURB** sample or strip. Reddish lines will appear on strip
6. take strip out and read results:

NEGATIVE only one line, next to number 2 is present

POSITIVE two lines present. Line next to number 1 may be lighter

INVALID if no lines appear, the test was invalid and must be repeated

2.5 Sampling for Laboratory Water Quality Analysis

One group will assess water quality (chemistry) using test strips (low precision).

2.5.1 Water Sampling Protocol

For the purposes of publication, etc., more thorough analysis of samples will be required. At key locations, we will collect samples for laboratory analysis using the following protocol. The purpose of this protocol is to address the issues of sample container types, labeling, filtration, preservation, QA/QC, and in-field analysis. We will collect three bottles: cation (C), filtered cation (FC), and anion (A). For more information see online standard protocols for the EPA and USGS.

Sample Container

With the exception of some specialized isotope analyses, all samples should be collected in high density polyethylene bottles (e.g. Nalgene bottles). Separate bottles should be used for the cations and anions. Generally 125 ml bottles are adequate. The bottle should be filled so that a positive meniscus is formed at the top then the cap is screwed down tightly (it is impossible to strip the threads on the Nalgene bottles so give a good hard twist). It is important that contamination is not introduced into the bottle during sampling, especially the cap of the bottle. For cations, however, leave enough space in the bottle for addition of ultrapure nitric acid (1.25 ml; see below).

Labeling

The bottle should be labeled with a permanent marker (e.g. a Sharpie) and covered with clear tape. It is IMPORTANT that you label the bottle and tape over it with scotch tape BEFORE you fill it with water as the bottle will condense moisture on the outside after sampling and label/tape will not stick. The following numbering system should be used:

GC061001-C = cation sample (unfiltered)

GC061001-FC (filtered cation)

GC061001-A = anion sample (unfiltered)

GC061001-FA (filtered anion, generally not needed)

GC = Gallinas Creek, 06 = year 2006, 1xxx = water sample number which increases incrementally.

If you collect a precipitate or sediment sample use the same number for both the water and the sediment, but change the 1 to a 2 e.g., a sediment collected with water sample N031015 would have a number of N032015.

Filtration

Use the disposable cartridge filters (especially Millipore Stervex-HV filters, catalog # SVHV010RS) and the all-plastic syringes. A new filter and syringe for each sample, filter the cation sample first and then the anion sample. The same filter and syringe can be used for both the cation and anion sample. Plastic gloves should be worn at all times during sampling, new gloves for every sample.

Bottles should be rinsed with 20-30 ml of filtered water 3x before filling the bottle.

QA/QC

In order to ensure internally consistent data, data that can be used with confidence by all members of the program, and pain free analytical procedures; the following QA/QC procedures will be followed:

1. Within every batch of 20 samples a duplicate sample should be taken. If only small numbers of samples are being collected, a duplicate should be taken for every ten samples collected.
2. Within every batch of 20 samples leave a bottle empty. This will be for a blank or standard.

Note Taking

At each sample location, the person collecting the sample should take detailed notes as to:

Sample # Number of bottles used and collected Number of filters used to filter the sample and note color of any sediment on the filter. Type and depth of well Year the well was constructed, if possible Weather conditions Location (preferably using a GPS with lat-long or UTM) Note any problems with sampling (difficult to filter, windy and dusty day etc)

2.6 Task 1 Things to Note

In field notes you may wish to observe the following factors that can affect stream discharge [after p. 50 Sanders, 1998]:

1. General topographic setting
2. Site-specific topography and relief (a sketch or profile may be helpful)
3. Character of the floodplain and floodplain development.
4. Description of the stream banks and bed.
5. Sediment and rock exposed in cuts and in the stream bed.
6. Soils on the bank and washover deposits.
7. Vegetation: plant species, density and condition
8. Evidence of animal activity in the stream
9. Field observation of moisture content of the floodplain soils.
10. Depositional features
11. Erosional features
12. Human development

13. Evidence of flooding events

14. Bank stability

Chapter 3

Task 2: Irrigation Hydrology

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The goal of this task is to analyze the water balance for a single farm field. About 70% of water use in the U.S. is for agriculture, and similarly along the Gallinas the major water use is for small-farm irrigation. The inflow and outflow from the field is via ditches, and **discharge** is measured as in Section 2. The major additional outflow is via evapotranspiration, which is typically estimated using the Blaney-Criddle or FAO Penman-Monteith equations. We'll skip that this year. We will monitor soil conditions before, during and after an irrigation release to help the landowner and the state understand how much water is sufficient. One characteristic of the flood irrigation practiced by the acequias is over-irrigation, and our data can help limit that problem.

3.1 Task 2 Activities

3.1.1 Task 2 Parameters to be Measured

Please refer to the textbook [Chapter 3, Sanders, 1998] for a detailed description of the measurement of each parameter listed below. In the field, we will break up into groups of two or more, each group will be responsible for measuring the parameters listed below at a station assigned by the TA or professor.

Parameters to be measured:

Ditch Cross-Section measured directly using simple surveying techniques (Fig. 2.2).

Used to determine the cross-sectional area of the stream, also hydraulic radius and wetted perimeter (see text p. 53-55).

⁰See this file online at http://www.utdallas.edu/~brikowi/Teaching/Field_Camp

Ditch Velocity determined by direct measurement when possible (impeller velocity meter, Fig. 2.7 and Section 2.2.2) or by float method if necessary (Fig. 2.4) . Used to compute discharge (see also text p. 73-74).

Soil Moisture Profile determined by measuring **soil suction** (matric potential)

Parameters to be calculated:

Discharge given cross-section and stream velocity measurements described above

3.1.2 Tasks

Our main tasks are to measure:

1. Discharge
 - (a) measure channel cross-section
 - (b) measure velocity
2. Soil moisture profile:
 - (a) use tensiometer to measure soil moisture at 6, 12 and 24 inches depth
 - (b) describe soil core (thickness of O horizon, depth of apparent wetting)

3.1.3 Measuring Soil Moisture

1. core hole to desired depth using coring tool
2. remove core from tool and describe (using cleaning tool for any stuck material)
3. insert tensiometer probe
 - (a) while still in case turn Null Knob clockwise as far as possible, then turn counterclockwise by $\frac{1}{2}$ turn (Fig. 3.1)
 - (b) remove probe from case and insert into cored hole so sensing tip is in firm contact with soil
4. let probe rest for one minute, then observe dial reading
5. speed-up equilibration (minimize water released from probe to soil) by bracketing measurements:
 - turn the Null Knob counterclockwise to bring the pointer up to a value, which is one and one-half times the initial reading after the one-minute period
 - observe the pointer movement after 15 to 30 seconds. Tapping the dial dial lightly with your finger while observing the pointer movement will speed equilibration at this new setting

- if dial now moves lower turn Null Knob clockwise until dial reads halfway between first and second readings
 - if dial continues moving higher immediately turn Null Knob counterclockwise until reading is 10 centibars higher
 - repeat bracketing until dial doesn't move
6. record this final (correct) suction value
 7. remove probe, wipe tip free of soil, reinsert into carrying case (dial should return to zero)

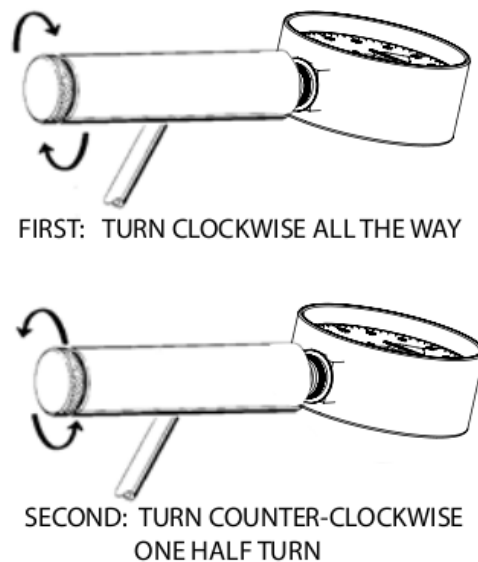


Figure 3.1: Initial setting of tensiometer “Null Knob”. After SoilMoisture, Inc..

Chapter 4

Task 3: Lab Analysis for Piper Diagram

Contents

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Gallinas Creek is unusual in its tremendous variation in water chemistry in the vicinity of Las Vegas, NM. In this task you will quantitatively analyze the six parameters needed to plot these samples on a Piper Diagram (see Sec. 1.1.5).

In this exercise we will measure several water quality (chemistry) parameters at the same site where we measured stream discharge. We will use the chemistry results to plot the geochemical evolution of the water along the stream. Because of the size of this year’s class, we split into two **Sections**. While one section is out measuring stream discharge in the field and collecting water samples, the other section will analyze samples back at the dorm. We are doing “reconnaissance” or benchtop geochemistry (limited accuracy) in order to see results immediately. Working hydrologists generally use ICP analyses for such a task.

4.1 Task 3 Activities

TA’s notes follow for the analyses. We will analyze using ppm-level precision instruments for the following 6 ions used in the Piper diagram (sec. 1.1.5): Ca^+ , Mg^+ , Na^+ , HCO_3^- (carbonate should be zero in this setting), SO_4^- and Cl^- . We will map the evolution of Gallinas Creek water from its head to the point where flow often disappears in the summer.

⁰See this file online at http://www.utdallas.edu/~brikowi/Teaching/Field_Camp

4.1.1 General Procedures (A. Neku)

Station 1: Titration

Hardness (Calcium, Total and Magnesium) Hardness in water is the sum of Calcium and Magnesium ion concentrations. We will measure Calcium (Ca^{2+}) and Total Hardness using titration method then Magnesium (Mg^{2+}) is calculated as [Total Hardness (mg/l) minus Calcium Hardness (mg/l)]. For detailed procedure to measure calcium hardness please refer to Method 8204 handout (page 121-122) and for total hardness please refer to Method 8213 handout (page 127-128).

Alkalinity Alkalinity of water is the sum of OH^- , HCO_3^- and CO_3^{2-} ion concentrations. If reagents are available we measure Bicarbonate (HCO_3^-) and Total alkalinity referring to Method 8203 handout otherwise we use the test strip result.

Station 2: Ion-Selective Electrodes

Testing for Sodium (Na^+) and Chloride (Cl^-) using probes connected to the Passport Xplorer equipment. These require relatively restrictive chemical environments, and we are ignoring many of the standard protocols (e.g. adjusting ionic strength). So our analyses of these elements may be more inaccurate than for the other parameters.

These probes have already been calibrated using standard solutions and the standard curves have been prepared. We make use of these standard curves (expressed as linear equations below) in order to determine sodium and chloride ions in our samples given the electrical potential reading (mV) from the device.

1. Connect the sodium probe into the Passport Xplorer (“blue TV remote”)
2. Turn on Passport Xplorer
3. Select mV mode
4. Read off the reading in mV
5. Find out the corresponding concentration using the standard curve equation (where M_{Na} is the molality or moles/liter sodium)

$$\begin{aligned} \log(M_{\text{Na}}) &= 0.0109 * (\text{mVreading}) + 0.7152 & (4.1) \\ C_{\text{Na}} \left(\frac{\text{mg}}{\text{l}} \right) &= 10^{\log(M_{\text{Na}})} * 22.9898 \end{aligned}$$

(equation will be available in a spreadsheet)

6. If the value is showing negative it means the sample has less Na^+ than the lower standard so stop measuring it and take out the probe from the sample (record as $\leq 1.5 \frac{\text{mg}}{\text{l}}$)

Repeat the same procedure for Cl⁻ by using the Pasport Xplorer equipment connected to chloride probe. The standard equation curve for chloride is

$$\begin{aligned}\log(M_{\text{Cl}}) &= -0.0042 * (mV\text{reading}) + 1.3465 \\ C_{\text{Cl}} \left(\frac{\text{mg}}{\text{L}} \right) &= 10^{\log(M_{\text{Cl}})} * 35.453\end{aligned}\tag{4.2}$$

Station 3: Spectrophotometer

Measuring Sulfate (SO₄⁻) ion concentration using Spectrophotometer

Please refer to Method 8051 handout (Page 795-796)

4.1.2 Task-2 Instructions for Discussion

The group report for this task should consist of a summary table, and any notes made that might impact the results (e.g. Joe spilled his drink into our sample...).

For your individual report discuss any variability you see in the results, including any significant potential sources of error. Please make use of the Piper diagram if at all possible! Discuss what influences are evident in the variation in stream chemistry, implications for the quality of Las Vegas water supply, steps that might be taken to improve or maintain the quality, limitations on where future water supplies should be extracted or stored, etc. Advanced students may wish to calculate the relative contributions of various sources (e.g. the Hot Springs) based on the stream gauging and water quality results.

4.2 Miscellaneous Information

SNOTEL near-Gallinas snowpack site

Hardness Maps of U.S. water hardness and alkalinity are available from the USGS

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