Community Science Institute **www.communityscience.org**
Volunteer Monitoring Watershed Science Risk Communication

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Rough Guide to Red Flag Monitoring
A training manual for volunteers

About CSI

The mission of the Community Science Institute (CSI) is to empower citizens to understand their local water resources and manage them sustainably. CSI recruits and trains groups of volunteers as our community partners in monitoring local streams and lakes. Red Flag monitoring is one of several types of CSI-volunteer monitoring partnerships. For more information, please visit our website at www.communityscience.org.

Red Flag Monitoring Summary

The goal of Red Flag monitoring is to understand baseline water quality in local streams. Having a baseline makes it possible to detect contamination if and when it occurs, not only catastrophic contamination events but also low-level contamination that can degrade water quality gradually over time.

CSI recommends five Red Flag indicators of water quality that trained volunteers can measure accurately in the field. They are temperature, pH, dissolved oxygen, conductivity and total hardness. The first three, temperature, pH and dissolved oxygen, are general water quality characteristics that can be impacted by many different stressors. Conductivity and total hardness, on the other hand, are believed to be good indicators of contamination from high volume horizontal hydraulic fracturing or “hydrofracking.” If "hydrofracking" is approved in New York, having baseline data on these five red flag indicators should make it possible to detect whether or not streams are being contaminated from nearby "hydrofracking" operations.

CSI trains Red Flag volunteers in two half-day workshops. By the end of the second workshop, the group will have selected monitoring locations, organized itself into sampling teams of two to six volunteers each, and be ready to perform accurate field measurements of temperature, pH, dissolved oxygen, conductivity and total hardness on a monthly basis and report results to CSI. CSI will screen volunteers’ results based on specific data quality criteria, and data that meet acceptance criteria will be entered in CSI’s open, publicly accessible database at www.communityscience.org. Experience has shown that with practice, field measurements performed by trained volunteers satisfy CSI’s acceptance criteria about 90% of the time.

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Additional Options - Red Flag Monitoring

Expanded Baseline Testing
In addition to monitoring the five red flag indicators on a monthly basis, CSI recommends a comprehensive set of certified baseline tests at least once a year for as many Red Flag monitoring locations as funding permits. A comprehensive baseline for possible "hydrofracking" contamination costs about $275 plus travel for paid lab staff to collect the samples and includes the following tests: Temperature, pH, conductivity, total hardness, alkalinity, turbidity, total dissolved solids, chloride, sulfate, chemical oxygen demand, total Kjeldahl nitrogen, barium, strontium, and gross alpha and gross beta radioactivity. Methane and volatile organic compounds (VOCs) are not included because they are expected to volatilize quickly from streams and therefore be difficult to detect.

Biological Monitoring (BMI)
In addition to monthly Red Flag monitoring and annual comprehensive baseline testing at a subset of Red Flag locations, CSI also recommends biological monitoring using aquatic insects known as benthic macroinvertebrates, or BMI. The composition of the BMI community is an excellent indicator of a stream's overall health. BMI monitoring complements chemical monitoring and is used extensively by NYSDEC and other agencies as a cost-effective strategy for tracking basic water quality. CSI offers a separate BMI workshop and ongoing technical support for Red Flag volunteers who are interested in BMI monitoring. CSI also offers a BMI module for high school teachers and their classes.

First Red Flag Training Workshop (4 hours)

Goals and Objectives
The first workshop will introduce the Red Flag monitoring program and the rationale for its approach. During the workshop volunteers will be introduced to the test kits that will be used for monitoring, select sampling teams, learn how to select monitoring sites, and how to use online mapping systems to aid site selection.

Background
Stream monitoring is based on an understanding of a stream and its watershed as a whole. Streams are aquatic ecosystems that incorporate interacting physical, biological and chemical characteristics. Red Flag monitoring focuses on chemical indicators of pollution that are found in the stream itself. BMI monitoring focuses on the biological indicators of pollution. However, the physical environment of a stream, such as the

stream's own physical features as well as the hydrogeology and land uses in its watershed, shape a stream's chemistry and biology. Becoming familiar with a stream's physical environment is a big help when interpreting chemical and biological monitoring results. The Visual Assessment Manual published by the Alliance For Aquatic Resource Monitoring (ALLARM) at Dickinson College in Carlisle, PA (http://www.dickinson.edu/uploadedFiles/about/sustainability/allarm/content/Visual%20Assessment%20Manual.pdf) provides a good introduction to the physical characteristics of streams and how human activities can degrade them. A visual survey is not absolutely required for Red Flag monitoring, but is suggested. Red Flag volunteers are encouraged to read the ALLARM manual and to conduct visual surveys of the streams they choose to monitor.

Following are a few basic concepts that frame Red Flag monitoring:

1. *Watershed* – The land which water moves through and over to a surface water body such as a creek, stream, river or lake. "Land" includes subsurface geology as well as surface features such as forests, agricultural fields and urban areas. At base flow, or under normal conditions, nearly 100% of the water in a stream comes from groundwater. A stream's natural chemistry results from minerals leaching out of subsurface rocks into groundwater as it moves downgradient by gravity and enters the stream. Whereas hydrogeology determines a stream's basic chemistry, the features of a watershed on the land surface determine the quantity and chemistry of the runoff that results from rain and snowmelt. Pollutants transported to the stream in runoff include sediment, nutrients such as phosphorus and nitrogen and pathogenic bacteria.
2. *Point source pollution* – Refers to pollution that originates from a specific source such as a pipe or outfall, and enters a stream directly, for example, from a factory or a sewage treatment plant. Point-source pollution is regulated under the Clean Water Act by a system of permits (see below).
3. *Non-point source pollution* – Refers to "diffuse" pollution that originates from diverse sources in a stream's watershed as opposed to single identifiable points. Examples are fertilizers like phosphorus and nitrogen from agricultural fields, lawns, and golf courses, and sediment from eroding streambanks.
4. *Land uses* – Forested, agricultural, and urban are examples of broad land use categories. These can be broken down into smaller categories, for example, cropland and pasture (agricultural uses) and residential and commercial (urban uses). Land uses can contribute to non-point and point source pollution.
5. *Clean Water Act* – A federal law passed in 1972 that continues to govern the protection of surface water. States implement the Clean Water Act jointly with the EPA. Two important features of the law are: a) The State Pollution Discharge Elimination System (SPDES) requiring point sources to obtain permits enforced by the state government that specify the quantities of pollutants they are

allowed to discharge. The point source permitting system has cleaned up discharges nation-wide and is considered a big success; and b) Anti-degradation provisions that require states to monitor surface water bodies and take steps to remediate those which are found to be impaired. Every water body has a specific "designated use," for example, as a source of drinking water, for contact recreation, natural habitat, or for trout fishing. A water body is considered to be impaired if it can no longer serve its designated use. The anti-degredation provisions require remediation if a water body is impaired. Red Flag monitoring is designed to tie into government regulation of water quality under the Clean Water Act.

6. *NYSDEC's 2011 draft Supplemental Generic Environmental Impact Statement (dSGEIS)* – This document does not explicitly address stream contamination by "hydrofracking" operations except to ban the industry from the New York City and Syracuse watersheds based on the potential contamination of their unfiltered drinking water supplies by sediment, phosphorus, pathogenic organisms and toxic chemicals. The 2011 dSGEIS proposes that contamination of surface water and groundwater be addressed in four ways: a) By treating drill pads as point sources subject to SPDES permits and stormwater regulations; b) by treating waste from shale gas wells as "industrial wastewater" (i.e., not hazardous waste) that may be disposed of at appropriately retrofitted Publicly Owned Treatment Works (POTWs or wastewater treatment plants); c) by requiring "closed loop" handling of flowback at the drill site, i.e., no open storage pits; and d) by requiring gas companies to pay to test private drinking water wells within 1,000 feet of the drill pad for a list of "signature chemicals." These and other proposed strategies may or may not be sufficient to hold the environmental impacts of shale gas wells to acceptable levels.

Selection of monitoring locations

Selecting Red Flag monitoring locations is as much art as it is science. Selection criteria include (in no particular order):

1. Proximity to volunteers' homes
2. Safe and legal access
3. Position in a watershed relative to land uses of interest
4. Proximity to existing or permitted gas wells or to leased land
5. The size of the upstream drainage area
6. Road density
7. Distance and relationship to other Red Flag monitoring locations
8. Proximity to an agency monitoring site, e.g., an SRBC remote sonde

CSI will assist the group in using both paper maps and electronic maps to select monitoring locations. The process for selecting locations will begin in the first workshop. Volunteers will visit locations between workshops to assess their suitability as monitoring locations. The process will be finalized in the second workshop.

Maps

CSI will bring a paper map of watersheds to the first workshop to help launch the site selection process. CSI will also provide a Google Maps tutorial that interested volunteers can use to begin exploring possible monitoring sites. Electronic maps like Google and ARCGIS have the potential to enhance and facilitate the site selection process. Locations can also be selected on the basis of paper maps and volunteers' own knowledge of their local streams. Usually a combination works well.

Field Equipment

CSI staff will bring Red Flag test kits to the first workshop and demonstrate their use. Volunteers will have an opportunity to try the tests themselves at the first workshop. The second workshop will have more focused time to practice the Red Flag tests and record and report results.

Field equipment includes: a thermometer, LaMotte pH Kit 5858, LaMotte Total Hardness Kit 4484-DR-LT, LaMotte Dissolved Oxygen Kit 5860 and Hanna Instruments Conductivity meter HI98303.

One of the goals of Red Flag training is for the group to organize themselves into teams of 2-6 volunteers each who will share a set of test kits. Teams are responsible for purchasing their field equipment. The cost for a set of field equipment is $200 or $225 with a thermometer. The team can use any thermometer they wish as long as they calibrate it (see second workshop for calibration procedure). CSI asks that teams take responsibility for ordering replacement chemicals as they expire every year or two (see expiration dates on bottles). Replacement chemicals may be ordered directly from LaMotte or purchased from CSI. Refills are significantly cheaper than the complete test kits.

Please Note: CSI asks volunteer teams to purchase their own equipment, however, if purchasing equipment is not feasible due to financial circumstances, CSI is able to provide a limited number of test kits at reduced or no cost. If the cost of equipment will prevent you from getting involved, talk to Becky about getting your equipment for free or at a reduced cost.

Second Red Flag Training Workshop (4 hours)

Goals and objectives

This workshop will focus on the collection of stream samples, the use of test kits to perform measurements in the field or at home, data quality objectives and documentation, CSI's criteria for accepting results and posting them in our open online database , and reporting results to CSI with field data sheets .

Volunteers will finalize the selection of monitoring locations and the organization of teams with the aid of paper maps and electronic maps. CSI staff will provide one-on-one assistance with electronic mapping and site selection.

The second workshop will also include:

- Naming the group and teams
- Setting up an additional workshop for BMI monitoring if there is enough interest; and
- A discussion of strategies for raising funds from local sources to continue Red Flag monitoring beyond 2013 and to conduct comprehensive baseline testing at a subset of Red Flag locations at least once a year.

Data quality objectives

The quality of monitoring data needs to be sufficient to convince government agencies to act when there are changes in the water that indicate contamination. To this end, Red Flag volunteers working in the field follow certified lab quality control protocols. Data quality is evaluated using three kinds of quality control: **standards, duplicates, and split samples**.

Standards- Volunteers must test 3 calibration solutions prior to sampling to ensure equipment is working properly and accurate test results can be achieved. Calibration standards for pH, total hardness, and conductivity are provided by CSI at no charge. No standards are required for temperature and dissolved oxygen.

pH - Volunteers are given a standard solution with a pH of 7. Test the solution following test kit instructions. Result should be 6.50-7.50. Record result on field data sheet.

Total Hardness - Volunteers are given a standard solution with a total hardness concentration of 50 mg/L. Test the solution following test kit instructions. Result should be 46-60 mg/L. Record result on field data sheet.

Conductivity- Volunteers are given a standard solution with a conductivity of 353 µs/cm. Pour solution into a small container so that the meter's probe is submerged. Using the provided yellow screwdriver, adjust the meter until it reaches 353. If the meter is not completely stable, results can range from 350-356. Record result on field data sheet.

Temperature- Once per year, volunteers must calibrate their thermometers using boiling water. Boil water to a rolling boil, place thermometer in the water and read result. Result should be 100°C at sea level. If not at sea level, subtract 0.5 °C for every 500 feet above sea level or add 0.5 °C for every 500 feet below sea level. For example, if you live at 1000 feet above sea level, your thermometer should read 99°C at boiling. Adjust as needed. For example, if temperature reads 98°C at sea level, volunteers will add 2°C to each reading. If the temperature reads 101°C at sea level, volunteers will subtract 1°C from each reading. Some thermometers can be adjusted. If this is the case, adjust your thermometer to 100°C at boiling at sea level.

Duplicates- Volunteers must perform duplicate tests at least once per day for each of the five Red Flag tests. It is recommended that volunteers perform duplicates at their first site to be confident of accurate results throughout the day. Duplicate tests are simply a repeat test of the same sample. Results must be within the following acceptance ranges:

Temperature- within +/-1°C
Acceptable: 3°C, 3.4°C Unacceptable: 3°C, 4.2°C
pH- within +/- 0.5 pH units
Acceptable: 6.5, 7.0 Unacceptable: 6.5, 7.25
Conductivity - within 10% of each other
Acceptable: 248, 259 Unacceptable: 248, 285
Total Hardness- within 20% of each other or 8 mg/L, whichever is greater
Acceptable: 60 mg/L, 68 mg/L Unacceptable: 60 mg/L, 76 mg/L
Acceptable: 20 mg/L, 28 mg/L Unacceptable: 20 mg/L, 30 mg/L
Dissolved Oxygen - within 20% of each other
Acceptable: 8.9 mg/L, 9.4 mg/L Unacceptable: 8.0 mg/L, 10.8 mg/L

Hint To check the 20% range, take the difference of your results (1st result - 2nd result) and multiply by 100. Divide by the average of your results (1st result + 2nd result divided by 2). If the number is between -20 and 20, your results are good! To check the 10% range for conductivity, do the same calculation but the number should be between -10 and 10.

Split Samples - Volunteer teams must split samples with CSI's certified laboratory on a regular basis to confirm accurate testing and troubleshoot problems. Split samples should be sent to CSI in the mail or dropped off in person within 1 week of sample collection. Split samples can be collected in a separate container at the same time as volunteer's sample is collected; alternatively, volunteers can collect a single sample, use it for field testing, and send the remainder of the sample to CSI, as long as it is at least 100 ml.

During sampling teams' first two months of monitoring, volunteers must send split samples to CSI from all of their sites as a way of establishing proficiency. Once proficiency has been established (typically after 2-3 months) volunteers will submit one split sample on a quarterly basis, or every three months. CSI will test the samples for conductivity and total hardness and compare results with volunteer data. Results that meet acceptance criteria will be entered in the CSI database. If results do not meet this criteria, CSI will work with volunteers to troubleshoot the problem.

The criteria CSI uses to assess the quality of Red Flag data reported by volunteers are presented in Table 1, below. These criteria are roughly comparable to those used by certified labs.

Please note: Results will be automatically rejected for an entire monitoring day if a team does not document the performance of acceptable standards and duplicates on the field data sheets for that event. For example, failure to perform and record a pH standard test at one location invalidates pH results at all locations on that day; failure to perform and record a dissolved oxygen duplicate test invalidates dissolved oxygen tests at all locations on that day; and so on. This is a tough restriction but is necessary to ensure that data is considered credible by scientists and regulatory agencies.

Table 1. Quality control criteria used to evaluate field data reported by Red Flag volunteer teams

	Temperature	pH	Dissolved Oxygen	Conductivity	Total Hardness
Data Acceptance Criteria					
Precision - Acceptance of Duplicates	± 1°C	± 0.5 pH Units	± 20%	± 10%	± 20% or 8 mg/L, whichever is greater
Accuracy - Acceptance of Standards	N/A	± 0.5 pH Units	N/A	± 1%	± 20% or 8 mg/L, whichever is greater
Splits - Comparison with certified lab	N/A	± 0.5 pH Units	N/A	± 20%	± 20% or 8 mg/L, whichever is greater

Collection of water samples:
When collecting a water sample from a stream, the goal is to obtain water that is representative of the stream at the point where the sample is taken. Volunteers collect what are known as "grab" samples: They place a sample bottle in the stream and allow it to fill with water. Specifically, volunteers do not use specialized equipment that integrates sample water across the width and depth of a stream. Under almost all conditions, carefully collected grab samples are equivalent to width- and depth-integrated samples with respect to Red Flag parameters. Volunteers may use mason jars or other sample containers from home as long as they are thoroughly clean.

Here are the different ways to collect a water sample:

Wading into the stream: In order for a grab sample to be representative of the stream at the sampling site, the water in the sample should be well mixed and free of extraneous debris. Assuming the stream is not too deep, a representative sample can be collected by wading into the center of the stream; facing in an upstream direction so that the water is flowing toward you; immersing the bottle half-way down; and opening the bottle under water, allowing the air to bubble out as it fills to the shoulder, and capping it under water.

Sampling from shore: If the stream is too deep, or if the current is too swift, a grab sample can be collected from the stream bank. To make sure the sample is representative, collect it from a point where the current is flowing well and the water appears well mixed. *Avoid sampling from a pool, an eddy or a back-current.* Collect the sample the same as when wading into a stream: Face the bottle upstream; immerse it; uncap it, allow it to fill to the shoulder, and recap it underwater to avoid surface debris.

Sampling from a bridge: As a rule, Red Flag monitoring is conducted under base flow conditions. In the unusual event that samples are collected under stormwater conditions, the current may be so swift that it would be unsafe to attempt to sample by wading into the stream or by leaning out over the stream from the stream bank and risking falling into the current. Some sites may only be accessible from bridges year-round due to steep banks or private property. If there is a bridge nearby, a sample can be collected by lowering a clean bucket into the current, then filling the sample bottles by dipping them in the bucket. The bucket should be rinsed with stream water at least once before collecting the sample. Care must be taken to swirl the bucket and make sure the sample is well mixed before filling the sample bottles from the bucket.

Recording sampling information: As soon as the sample is collected, record the date and time of sample collection on the sample bottle and on the field data sheet. Also on the field data sheet, record the name and initials of the sample collector, note how the sample was collected, and make "eyeball" estimates of stream flow volume and velocity, the water level, and how the water appears to you. Record your estimates in the spaces provided on the field data sheet. Use the margins and the back of the field data sheet to record additional observations of any conditions that catch your eye and that might impact water quality, for example, a construction site nearby, cattle or other farm animals in the stream, or an outfall pipe.

Supplies:

Standards: The CSI lab will provide a continuous supply of standards for the pH, conductivity and total hardness tests. If you suspect that a standard has become contaminated, discard it immediately and ask CSI to replace it with a fresh standard.

Field data sheets and tracking sheets: CSI provides field data sheets for volunteers to report results. In order to maximize the credibility of your data, we ask that teams fill out the field data sheets carefully and completely and mail the original hard copies to CSI. Volunteers are encouraged to make copies for their own records. CSI will keep the original field data sheets, first, as a permanent record of your results, and second, to assess data quality. Data that meet the criteria in Table 1 will be accepted and entered in CSI's open online database. CSI also provides tracking (chain of custody) sheets for volunteers to use to document the collection of split samples. Split samples can be as small as 100 ml (roughly 3/8 of a cup) and may be sent to CSI through the mail.

Chemical waste: Most of the chemicals in the Red Flag tests are not hazardous. Exceptions are concentrated sulfuric acid and azide in the dissolved oxygen test. However, the quantities are so tiny that the waste from the dissolved oxygen test can be disposed of or by pouring down the sink at home without harming aquatic life or your septic system. If you are unable to transport the waste home, it will not be harmful to dispose of a tiny amount of waste near or in the stream. It is noted that Tompkins County residents have the option of dropping off hazardous waste at the county recycling facility in Ithaca, and other counties may have similar programs for their residents, as well.

Use of field equipment for Red Flag testing

After collecting the water sample, three things need to happen right away:

- Measure temperature (twice at first site)
- Measure pH (twice at first site)
- Fix Dissolved Oxygen sample by adding first two chemical reagents

Completing the Dissolved Oxygen test can happen later in the day; tests for total hardness can be performed up to 14 days later and conductivity tests can be performed up to 28 days later. Many volunteers prefer to "grab and run" at their sites and complete the analysis at home or another covered location with a table.

Temperature: Immerse the thermometer directly in the stream or into sample bottle, check every 10-15 seconds until it's stable, and record the result on the field data sheet. Perform and record a duplicate temperature measurement for at least one of your sampling locations every day your team conducts a sampling event. This measurement should be done within a minute or less because the temperature of the sample changes quickly.

pH: Measure the pH of stream samples at the stream, and record and initial the result, date and time on your field data sheet.

LaMotte Kit Instructions - pH (Kit Code 5858)

1. Fill test tube to 10 ml line with sample water.

2. Add 10 drops of pH Wide Range Indicator

3. Insert test tube into the test tube reader, choose the color that matches best and record your result in the pH section of the field data sheet. If the color is in between two results, you can record an intermediate of .25 or .75.

Dissolved oxygen (DO): Collect a sample by completely filling the small glass bottle provided in the LaMotte kit, cap and invert to check for air bubbles. If there are bubbles, discard the sample and collect another sample. "Fix" the dissolved oxygen by adding eight drops of each of the first two chemicals as described in the instructions provided by LaMotte. You can either complete the test immediately or store the sample cold and in the dark and complete the test up to eight hours later. The duplicate test should be performed from a second glass bottle.

LaMotte Kit Instructions - Dissolved Oxygen (Kit code 5860-01)

1. Fill water sampling bottle completely with no air bubbles. The easiest way to do this is to hold the bottle upright underwater and screw on the lid while submerged.

2. Add 8 drops of Manganous Sulfate Solution.

3. Immediately add 8 drops of Alkaline Potassium Iodide Azide.

***Note* At this point the sample has been "fixed" and the remainder of the test can be completed up to 8 hours later. These first two steps MUST take place immediately!**

4. Replace the cap and invert the bottle several times to mix the solutions. Allow the precipitate to settle below the shoulder of the bottle before continuing.

5. Add 8 drops of Sulfuric Acid.

6. Replace the cap and invert the bottle to mix until all of the precipitate has dissolved. This may take up to 30 minutes, especially when the water is cold. Any sediment in the bottle will not dissolve.

7. Once the precipitate has completely dissolved, fill the test tube to the 20 ml line with your sample water and cap.

8. Fill the titrator (plunger) with Sodium Thiosulfate solution.

9. Add drops of Sodium Thiosulfate from the titrator until the sample becomes pale yellow and place the titrator to the side. *Do not add or remove any more drops from the titrator - you will come back to this!*

10. Add 8 drops of Starch Indicator.

11. Continue adding drops of the Sodium Thiosulfate from the titrator until the blue color just disappears and solution is colorless.

12. If you use all of the Sodium Thiosulfate in the titrator and the blue color is still present, refill the titrator and continue the titration. When recording your result add 10 to your result to account for the first full titrator.

13. Read your result where the green ring touches the outside of the plunger.

14. Record your result on your field data sheet in the Dissolved Oxygen section.

If you make a mistake with the titration (Steps 7-13) repeat the titration two more times using the remaining sample. Begin at step 7 to repeat the titration.

Conductivity: Measure conductivity either streamside or up to 28 days after sample collection if the sample is refrigerated.

To measure conductivity, pour approximately 20 ml of sample into a small wide-mouth container. Turn on the meter and submerge the probe in the sample. The probe does not need to be fully submerged. Wait 10-15 seconds or until the meter stabilizes. Some drifting (+/- 1-5 µs/cm or about 1%) can be expected. If the meter has not stabilized after 1 minute and has not drifted more than +/- 1%, record the result in the middle of the drifting range. Meter can also be submerged directly in the stream but is not recommended, particularly in swiftly moving waters.

Total hardness: Measure total hardness either streamside or up to 14 days after sample collection if the sample is refrigerated.

LaMotte Instructions -Total Hardness (Kit Code 4482-DR-LT)

1. Fill test tube to the 12.9 ml line with sample water.

2. Add five (5) drops of Hardness Reagent #5 and mix.

3. Add one (1) Hardness Reagent #6 tablet. Cap and swirl test tube until tablet dissolves. Solution will turn red if hardness is present. If solution is blue there is no hardness present.

4. Fill the titrator (plunger) with Hardness Reagent #7 and insert into the center hole of the test tube.

5. While gently swirling the test tube, **slowly** press the plunger to add Hardness Reagent #7 one drop at a time until the red color changes to blue.

**Note* Red color will turn purple before turning blue and this is a signal that you are approaching the endpoint and should slow down. Once the solution is blue, it will stay blue no matter how many additional drops you add. The blue color is deep blue, similar to the color of the test kit boxes. Holding the test tube up to natural light or a white piece of paper will help catch this color change. If you are unsure if you've reached the blue, take note of the reading on the titrator, add one more drop, and see if the color continues to change. If it doesn't change, use your* *original reading. If it continues to change, keep adding drops until you reach the blue endpoint.*

6. If you use all of the Hardness Reagent #7 in the titrator and the color change still has not happened, refill the titrator and continue the titration. When recording your result add 200 to your result to account for the first full titrator.

7. Read your result where the green ring touches the outside of the plunger.

8. Record your result on your field data sheet under the Total Hardness section.