Appendix

Copy of EWB-Tufts Internal Trip Report

ENGINEERS WITHOUT BORDERS-USA
TUFTS UNIVERSITY STUDENT CHAPTER

El Cristal, Ecuador Summer 2010 Trip Report

Travel Dates: August 17, 2010 – August 29, 2010

EWB-Tufts

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Preface

In the summer of 2010 a group of five students, one professor, and his wife traveled to El Cristal in an effort to quantify the impact of the Tufts chapter of Engineers Without Borders involvement with the community since their first visit in 2006. Travel team members with contact information are provided below:

- Douglas Matson – professor, douglas.matson@tufts.edu
- Russell Hyatt- project leader with focus on water quality testing and filter assessment, Russell.hyatt@gmail.com
- Anna Chute – project leader with focus on community health surveys, anna.chute@tufts.edu
- Maren Frisell – focus on water quality testing and filter assessment, maren.frisell@tufts.edu
- Daniella Dominguez – translator with focus on community health surveys, daniella.dominguez@tufts.edu
- Andrew Espinosa – translator with focus on community health surveys, Andrew.espinosa@tufts.edu
- Chris Matson – wife of Douglas Matson, assisted on all aspects of trip

Mark Youngstrom, although unable to travel, was instrumental in the analysis of the slow sand filtration unit. Mark Youngstrom is an expert on slow sand filtration who has designed the slow sand filtration unit for Rutland, VT. The travel team communicated with Mark Youngstrom during the trip via Skype and email.

This report provides future members of the EWB-Tufts Ecuador project a detailed account of the trip including extensive information regarding water quality and effectiveness of the filters, current and desired filter loading rates, summary community health data, meeting minutes, recommendations made to the community, travel logistics, and the future of the project. The appendix of this report contains valuable raw data and documentation acquired on the trip.

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1.0 EWB-Tufts in El Cristal, Ecuador

The Tufts EWB group began working with the community of El Cristal in Ecuador in 2006. The agricultural community consists of roughly 120 families, relatively spread out in a very rural, mountainous area. The purpose of the first trip was to establish a solid relationship with our NGO contact in the area, Fundación Brethren y Unida (FBU), as well as to assess the possibilities of implementing a green building design for future trips. Water quality testing was also conducted on the community's drinking sources, and community health surveys were conducted with community members (*Refer to 2006 trip report for details*).

By 2007, the Ecuador EWB-Tufts group had identified water as one of the main problems in the community that we would be able to help with. In the summer of 2007, six students, one professor, and his wife returned to Ecuador with a primary goal to develop a relationship with the community, identify its needs, and jointly define a project for the next year. Additionally, the team had designs for a rainwater collection, storage, and a bio-sand filtration system to prototype and use for educational dissemination at FBU's hacienda. The group was met with welcome arms in El Cristal, and built two prototypes of the household bio-sand filter during their stay. The group again collected water quality tests, and were able to share the results during a community meeting. All of the water sources were seriously contaminated, and the community was able to visibly see the poor quality of their water by the sheer number of bacterial colonies that had grown on the water testing films. These tests were given to the community. (*Refer to 2007 trip report for details*).

Between our 2007 and 2008 trips, El Cristal, empowered with knowledge and evidence about their water quality, were able to bring these results to their local government in order to improve their water situation. The local government devoted $25,000 to the construction of two slow sand filters that serve roughly half of the community. By the 2008 trip, the slow sand filters were under construction. During this student-led trip, rainy season water quality and flow rate data were gathered. (*Refer to 2008 trip report for details*).

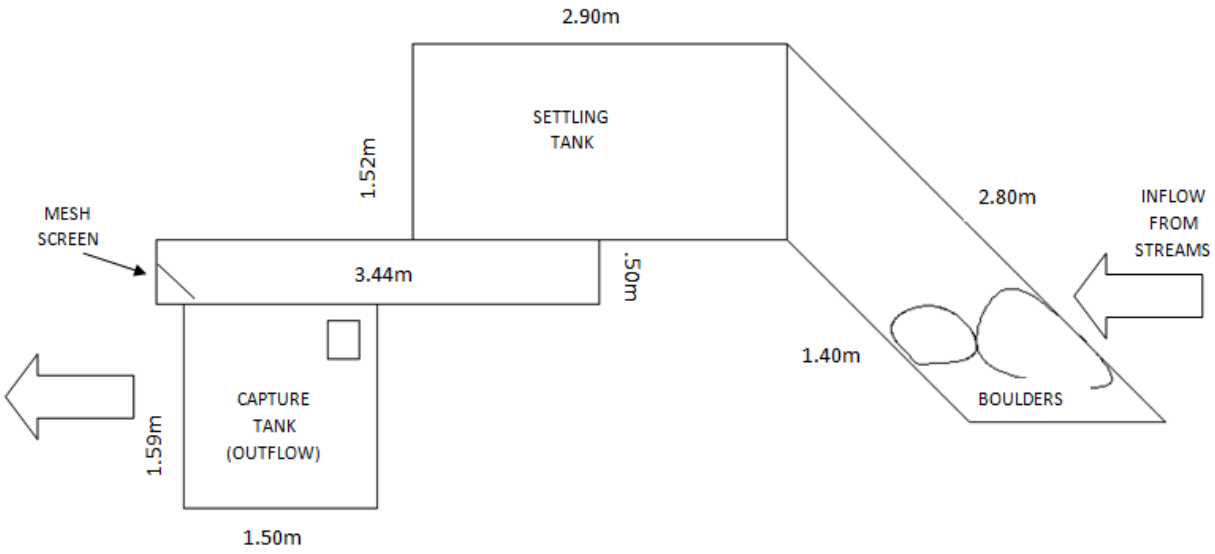
On this trip to El Cristal the travel team assessed the effectiveness of the slow sand filtration unit by conducting water quality tests, measuring water flow rate through the filters, and communicating with the operators of the system and members of the community and water boards of Peñaherrera and El Cristal. After finding that the filtration unit was not properly functioning due to over-usage and subsequent improper maintenance, the travel team provided recommendations to the community and will design modifications to the system to improve cleaning operations. Community health surveys were also administered in order to quantifiably compare the health of the community before and after EWB-Tufts involvement as well as quantifiably compare behavior changes with regards to household treatment of water due to changes in their perception of the importance of clean water.

2.0 Overview of Water System 1

A more detailed overview of the water systems of Cristal can be found in the 2007 trip report. This overview summarizes System 1 and focuses on the changes made to the system due to the addition of the slow sand filtration unit and any additional information obtained through conversations with the operators.

The central water system of El Cristal serves approximately 75 households with five residents per household. The water source of this system is shared between El Cristal and Peñaherrera, a significantly larger neighboring community. Although three water systems provide for El Cristal, the central system is the only system discussed in this report as it is the only system that runs through the slow sand filtration unit.

The source of this central water supply is located an hour walk from the center of town at a point where two streams, the Florida and San Francisco, converge. At this point, an uncovered capture tank serves also as a settling tank before the water passes through to an adjacent narrow uncovered tank that also allows for some settling. The water then passes through a screen to remove any large debris before entering an enclosed tank. However, large particles greater than the screen pore size can pass through between the side of the tank and the edge of the screen. The water then flows down by gravity to the slow sand filtration unit via black plastic piping. Additional drainage pipes and gates have been installed in order to allow for ease of cleaning of all three tanks.



Tank	Depth (m)
First settling tank	0.69
Second settling tank	0.615
Capture tank	1.43

Sketch of La Toma source capture tank system. Depths of each tank are indicated in table.

The condition of the watershed is uncertain. The high levels of bacteria in the source streams contrast the operators' claim that upstream of the source streams is a nature reserve which protects their watershed. Along the path leading to the source capture tank from the filter, cattle dung was

prevalent. The operators claimed that the cattle are eventually herded away from the streams and the nature reserve upstream of the source capture tank.

View looking downstream of converging streams at capture tank system. Large tank at bottom of picture is the first settling tank. Water moves from this tank to the long skinny tank in between the first two men, then through the screen and into the covered tank before flowing to the SSF unit.

Screen used to remove large debris with space between edge of screen frame and side of enclosed tank allowing for larger particles to pass through.

The slow sand filtration unit (near the center of El Cristal) consists of a capture box, two slow sand filter tanks so that one is operating while the other is being cleaned, a splitter box that sends about 2/3 of the filtered water to Peñaherrera and 1/3 to El Cristal, a weir box, and a large surge tank. Piping from the surge tank distributes the water to each receiving household. There is also

bypass piping from the first capture tank that goes directly to the splitter box. The following is a step by step description of each component of the slow sand filtration unit. Designs of the unit with dimensions can be found in Appendix D.

Capture box:

The capture box, covered with a metal lid, consists of an inflow pipe from the source, an outflow pipe to the slow sand filters, and a bypass outflow pipe positioned below the level of the outflow pipe feeding into the slow sand filters. This suggests that when the bypass is on, most if not all of the water bypasses the filter in operation. The bypass is turned on when there is not enough water flowing through the slow sand filters to provide for the needs of the towns. This is judged by viewing the water level at the surge tank downstream and presumably the holding tank in Peñaherrera. Although the capture box has no overflow pipe, excess water is able to escape the box through a hole in the lid and gap in the lip that the lid fits inside. For water quality testing, samples were collected from the capture box and are referred to as water samples from the inlet capture box.

Slow sand filters:

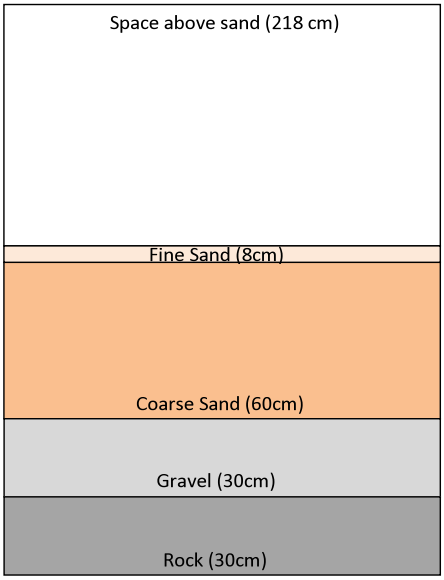
West filter when drying

East filter in operation

The capture box feeds into two slow sand filters of approximately equal dimensions. The filters are referred to as West filter and East filter in accordance with their geographic positioning for ease of reference. Relevant tank dimensions are as follows:

Length	**Width**	**Area**
6m	4.48m	26.88m^2

Layering is as follows:



As will be described in Section 7.0 of this report, current practice is to shut off the flow to one of the filters for cleaning while the other filter is operating. Both filters are currently never in operation simultaneously.

Split box:

After treatment, the outflow water enters the covered split box depicted on the left. As suggested by the photograph, 2/3 of the water coming from the slow sand filter is directed to Peñaherrera while 1/3 of the filtered water is directed to Cristal's water distribution system. The level of water in the Peñaherrera side and the Cristal side are usually different. More commonly, the water on the Peñaherrera side of the split box was at a lower level than the water on the Cristal side.

Weir box:

The filtered water flows through the covered weir box before entering the large surge tank for distribution. This weir box serves as a capture tank for the surge tank. Samples for water quality testing denoted as water after filter treatment were taken from this weir box. The flowrate of water used to calculate the superficial velocity of water moving through the operating filter was also measured at this weir box. An inlet pipe enters the box near the top, making it possible to measure flowrate with a bucket and stopwatch. Also, the weir appears to be at a right angle, allowing for another method of flowrate measurement. The weir box has an overflow pipe and an outflow pipe that leads to the surge tank.

Surge tank:

Filtered water is stored in the covered surge tank before being distributed to households connected to System 1. Residence time in this tank varies. In the morning this tank was usually observed to be full while at night it was usually observed to near empty. Particulate matter in the tank is visible upon opening the lid. Small insects are also seen on the water surface. Also, the ladder leading to the bottom of the tank is substantially rusted. It is likely that metal is dissolving into the water.

3.0 Water Board Structure

El Cristal:

- President: Héctor Ruiz
- Secretary: Huilo Villalba
- Treasurer: Norma Villalba
- 1st vocal: Irma Herrera
- 2nd vocal: Carlos Torres
- Operators:
    - Guillermo Enriquez
    - Enrique Sinbaña

Peñaherrera:

- President: Luis Pareja
- Secretary: Sonia Córdova
- Treasurer: Rosalia Benalcázar
- 1st vocal: Gladys Vallejo
- 2nd vocal: Nelly Navarrete
- Operator: Alberto Navarrete

4.0 Community health

4.1 Community Health Surveys

We found that the majority of people we surveyed were born in El Cristal and had lived there their entire lives.

We got varied responses to the question, ¨ Is malnutrition a problem in El Cristal?¨ The majority of those surveyed replied that malnutrition is a problem, citing poverty and not enough food as contributing to the problem.

We found that people in El Cristal, both adults and children, seek out medical care when they get sick or have health problems. The closest health center is the Seguro Campesino in the center of El Cristal. This clinic is open only during three days of the week until 2 p.m. When doctors are not at this clinic, also known as the ¨dispensario,¨ residents reported visiting health centers in other towns such as Peñaherrera and Apuela. There are hospitals in Ibarro and Otavalo, which are both relatively far away from El Cristal. Normally, people arrive at the clinics either by foot or by car. Those surveyed reported that they almost always go to the clinic if someone in their family needs treatment, but that they also use home remedies such as herbal teas to try to cure illness.

We found that transportation could act as an obstacle to people getting medical treatment when the health center is closed in El Cristal. Some reported that transportation is not a barrier because they can walk to Peñaherrera, but the walk is about 1 hour long which can be difficult for people when they are sick. Some also reported arriving at clinic by car, but that the cost could act as a barrier since they have to pay a truck $10 to travel to Peñaherrera and $60 to go to the hospital in Ibarra. The cost of care in the clinics did not generally act as a barrier since treatment and medications from the health clinics in Peñaherrera do not cost residents anything. Families have to pay a modest annual fee to be a member of El Seguro Campesino, and then are covered for all medical care received at the health center during that year. All parents reported that their children had been vaccinated, either in school or at the health clinic in Peñaherrera.

We found that general sanitation was good in El Cristal. People regularly washed the containers in which they store water with soap and water. Most people only cooked food that would be eaten that day, and stored extra in a refrigerator or fed the leftovers to dogs or pigs. People reported that they wash their hands regularly and have flush toilets either in or close to their houses. Garbage disposal methods included composting food remains, burning paper and plastic, or burying trash in the ground.

Not many families surveyed reported having a stable income. The community is primarily an agricultural community, and it seemed that their income depended on the season and month. Older community members received pensions from the government of $35 per month. Some families pay property taxes, while others said they do not pay any taxes.

Most adults completed schooling ranging between grades two and seven. Most adults reported being able to read and write, although some reportedly could not. All adults with children said that their kids go to school which is five days a week between April and January.

Our surveys showed that having clean water is desired by the people of El Cristal and that they are concerned about the status of the filtration system. Opinions were varied about whether or not the addition of the water filtration system has improved the health of the community, although our results suggest a notable improvement. We found that almost half of the community boils their water to purify their drinking water. This shows that people understand the connection between dirty water and sickness and are aware that boiling their water kills harmful bacteria. Awareness about this issue has increased substantially since last time we did the surveys two years ago, which shows a promising trend.

Most people said that they have enough water for all of their necessities and during all seasons of the year. However, people said that sometimes there is not enough water when the operators clean the tanks, and when heavy rain damages water pipes. People also noted that sometimes dirty water (containing sediments) flowed from the taps following rain and when the operators clean the tanks. Some also complained that the system is still not chlorinated.

4.2 Comparisons to previous health surveys

We compared the surveys that were done three years ago to the ones that we took during this trip. We asked community members to provide us with information on certain health conditions they may have experienced in the past three months. In total we completed 20 surveys, interviewing 19 adults who had a total of 18 kids among them. We also interviewed a nurse at the community clinic in El Cristal who gave us a more accurate account of the people who went into the clinic presenting certain symptoms. Overall, there were fewer reported cases of diarrhea and stomach problems after the filters were implemented, however there was in increase in flu like symptoms. The results are summarized in the tables below.

Table 1. Information gathered from community surveys

	Condition	Before filters (3 yrs ago)	After filters
Gastrointestinal complaints	Diarrhea and dehydration	85%	41%
	Stomach problems	69%	57%
Other common complaints	Flu	54%	79%

Table 2. Information from clinic nurse

Condition	Number of patients
Flu	±30
Parasites	±13
Cough	±13
Fever	±8
Headache	±3
Diarrhea	±2

We also asked people if they took any extra precautions to further purify there water, to which 47% said that they boiled their water, compared to only 15% three years ago. This shows that there is an increased consciousness about waterborne illness, however these types of diseases are still present in the community.

5.0 Water Quality

5.1 Methodology

5.1.1 Sample collection methodology

Almost all water samples were collected from locations within system 1 with exceptions consisting of samples collected from Carlos Ruiz's tap before and after household treatment. Samples were collected in 250 mL HDPE narrow mouth sample bottles. Sample bottles were washed between each usage by rinsing bottles with 70% IPA followed by bottled water. Water samples were collected by first rinsing the bottle twice with the water to be sampled before collection. Once the water sample was collected, tests were performed as soon as possible with waiting durations between time of collection to time of incubation lasting no longer than 2 hours.

5.1.2 Water quality testing methodology

Bacterial testing methodology:

All water samples were tested for both total coliform and *Escherichia coli* (*E. coli*) using a Coliscan Membrane Filter apparatus with 47mm gridded white 0.45um filter paper and Millipore m-ColiBlue24 Broth[1]. Cultures were incubated using a HACH portable incubator.

Testing procedures adapted throughout the site visit. During the first day of testing, 3M Petrifilms were used in addition to the more rigorous Coliscan MF test. However, results of these petrifilm tests were negative and discarded. During the first two days of testing, samples were diluted by a factor of 0, 20, and 50 using boiled water originating from Carlos Ruiz's tap. However, control tests of this boiled water tested positive for coliform. Afterwards, samples were not diluted and boiled water was not used for washing unless water was boiled by a travel team member.

The following testing procedure was used in order to perform the Coliscan MF test. All tests were performed in the house of Carlos Ruiz. Nutrient broth was stored in the refrigerator of Hector Ruiz. Two Coliscan MF apparatuses were used for bacterial testing in order to speed up the testing process. The same testing procedure was used for both apparatuses. First, the petri dishes, with absorbent pads pre-added, were labeled. Two milliliters of the Millipore m-ColiBlue24 broth was added to the absorbent pad. Administers of bacteria tests wore latex gloves. The funnel of the apparatus was washed by first wiping the inside, lips, and outside with a Kimwipe soaked in 70% IPA. Then the funnel was wiped again with a Kimwipe soaked in bottled water[1] and rinsed with bottled water[1]. Using forceps sterilized by wiping with 70% IPA and heated under a flame, the filter paper was placed onto the Coliscan apparatus followed by the funnel, making sure that the o-ring formed a water-tight seal around the funnel. One hundred milliliters of sample water was poured into the funnel using the 100 mL mark etched into the funnel. The sampl[2]e water was forced through the filter paper using the syringe plunger to induce a pressure drop. The plunger was slowly pulled out to draw the water through the membrane at a slow

[1] During travel broth was accidentally frozen for one night at hostel in Otavalo.

[2] Boiled water was used during the first two days of testing before coliform was discovered in the boiled water control. Afterwards, either boiled water prepared by a travel team member or, more commonly, bottled water was used to wash funnels when needed.

drop by drop flow rate in order to minimize the risk of pinhole formation. This process lasted approximately 5-8 minutes. Once all the water passed through the filter paper, the funnel was removed and the filter paper was placed into the petri dish on top of the pad soaked in broth. The time of incubation initiation was recorded and the pertri dish was placed into the incubator which was set at 35˚C throughout the duration of testing. The sample water at the base of the apparatus was then discarded. If a sample of a different origin was to be tested next using the same apparatus, the apparatus was cleaned again using the same cleaning procedure as previously stated. The Coliscan MF apparatus was cleaned at the end of each session's testing and the lid was placed on top of the funnel to protect the apparatus when unused. After approximately 24 hours of incubation, the cultures were removed for counting. Two travel team members counted each culture and the results of the two counters were averaged. Colonies of general coliform were red in color while *E. coli* were blue.

Physiochemical testing methodology:

Turbidity, water hardness, nitrate/nitrite levels, and iron levels were measured for each water sample. Turbidity was measured using a Model 2100P Portable Turbidimeter. Team members involved in the testing wore latex gloves to avoid leaving fingerprints on the test and secondary standard cells. Without formazin primary standard available, the factory calibration was used. The calibration was checked using the Gelex Secondary Turbidity Standards of values of 0-10 NTU, 0-100 NTU and 0-1000 NTU according to section 3.6.4.1 of the instruction manual. After the default calibration was compared to these secondary standards, the turbidity of the sample was measured according to the following procedure. In order to eliminate the effect of differences in cell glass surfaces on turbidity measurement only one cell was used for all turbidity testing. Between tests, this cell was carefully washed with soap, repeatedly rinsed with bottled water, and rinsed once with sample water before adding the sample water to be tested. Sample bottles were shaken for at least five minutes before testing in order to break up any floccules or otherwise conglomerated suspended particles. Once the water sample was poured into the cell, the cell was cleaned with silicon oil using an oiling cloth. The cell was held inverted briefly to reduce settling. The turbidimeter was set to AUTORANGE and SIGNAL AVERAGE and the cell was placed inside in the proper orientation. For each sample, three measurements were taken and averaged.

Water hardness, nitrate/nitrite levels, and iron levels all involved dipping a test strip into a sample for a set length of time and matching the resulting color of the strip to the corresponding color on the bottle.

Table 1. Summary of the samples collected, conditions during sampling, tests performed for each sample and number of repetitions for each test.

Sample location	Collection time	Date	Conditions during sampling	Tests performed
Inflow capture box	14:00	20-Aug	bypass on	0x,10x,50x dilution Coliscan Petrifilm Turbidity Hardness, nitrate/nitrite, iron

Sample location	Collection time	Date	Conditions during sampling	Tests performed
Outflow weir box	14:00	20-Aug	bypass on East filter operating West filter drying	0x,10x,50x dilution Coliscan Petrifilm Turbidity Hardness, nitrate/nitrite, iron
Inflow capture box	7:00	21-Aug	bypass shut off immediately before collection	0x,10x,50x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
Outflow weir box	7:00	21-Aug	bypass shut off immediately before collection East filter operating West filter drying	0x,10x,50x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
San Francisco River	13:00	21-Aug		0x,10x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
Florida River	13:00	21-Aug		0x, 10x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
Inflow capture box	18:50	21-Aug	bypass off	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
Outflow weir box	18:50	21-Aug	bypass off cleaning took place in morning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
Inflow capture box	7:18	22-Aug	bypass off	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
Outflow weir box	7:15	22-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
Inflow capture box	17:30	22-Aug	bypass off	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
Outflow weir box	17:30	22-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
Inflow capture box	7:35	23-Aug	bypass off	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
Outflow weir box	7:35	23-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron

Sample location	Collection time	Date	Conditions during sampling	Tests performed
House #1	11:41	23-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
House #2	11:30	23-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
House #3	12:25	23-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
House #4	11:15	23-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
House #5	11:20	23-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
Carlos Ruiz kitchen tap	18:20	23-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
Inflow capture box	7:25	24-Aug	bypass off	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
Outflow weir box	7:22	24-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
Inflow capture box	7:30	25-Aug	bypass off	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
Outflow weir box	7:42	25-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
Surge Tank	7:43	25-Aug	bypass off post-cleaning West filter operating East filter drying tank full	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
Carlos Ruiz kitchen tap	8:55	25-Aug		0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron

Sample location	Collection time	Date	Conditions during sampling	Tests performed
Carlos BSF	8:58	25-Aug	filter not used previously for long time flushed for 1.5 days	0x dilution Coliscan (2) Turbidity Hardness, nitrate/nitrite, iron
House #1	11:47	25-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
House #2	11:22	25-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
House #3	12:02	25-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
House #4	11:33	25-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
House #5	11:27	25-Aug	bypass off post-cleaning West filter operating East filter drying	0x dilution Coliscan Turbidity Hardness, nitrate/nitrite, iron
Carlos Ruiz kitchen tap	8:30-15:00	25-Aug	Sodis method with clear plastic bottle partially cloudy day 6.5 hour exposure	0x dilution Coliscan (2)
Carlos Ruiz kitchen tap	12:45	25-Aug	chlorinated using Clorox 3 drops in 1 L	0x dilution Coliscan