INCREASED PRODUCTIVITY THROUGH BETTER HEALTH
Belize, Central America

Final Report of the
Water Quality Lab Consultant
By: Patsy Allen

February 11 - March 19, 1987

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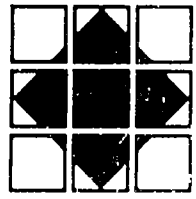

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Belize: Increased Productivity through Better Health Project

(505-0018)

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FOREWORD

This report is written in accordance with the Terms of Reference developed by the Pragma/MCD Technical Assistance Team assigned to the Ministry of Health in Belize under the Increased Productivity through Better Health Project (IPTBH #505-0018).

The principal author of the report was Patsy Allen - Water Quality Laboratory Consultant to the Project. Editorial input was provided by the Project Technical Officer, Joseph Carter.

CONTENTS

I. OBJECTIVES OF THE CONSULTANCY

STATEMENT OF WORK FOR THE WATER QUALITY LABORATORY CONSULTANT

A. OBJECTIVE:

Develop a laboratory capability to do inorganic, chemical and microbiological analysis, in order for the Environmental Health Service to monitor water quality.

B. SCOPE OF WORK

1. Check the list of equipment, reagents and glassware, that the project has acquired. If necessary, present a new list of complementary materials that the laboratory will still need for its operation.

2. Make recommendations about the fitting out of the water quality lab space.

3. Establish general procedures for the analytical laboratory techniques and the water sampling in the field; i.e set up protocols.

4. Develop schedules for monitoring the drinking water quality in rural areas and prepare a general program for the water quality surveillance appropriate to the rural areas of Belize.

5. Conduct a training course for the technicians of the water quality laboratory and the Ministry of Health, to enhance their technical capability to conduct physical, chemical and microbiological analyses. Make them familiar with the principles of Standard Methods and the use of the portable laboratory kit.

6. Hold a work-shop for personnel concerned with water sampling and water quality, to outline protocols and the system of testing and reporting.

7. Prepare a final report addressed to the Ministry of Health and AID Mission giving an evaluation of the technical capability of lab personnel, the capacity of the actual lab in terms of analysis, and the feasible action to improve the water quality laboratory efficiency.

II. EXECUTIVE SUMMARY

The advisor was able to successfully perform all tasks enumerated in the SOW within a reduced time frame of six weeks. Among the significant accomplishments were:

- a thorough inventory of lab equipment and supplies
- the preparation of procurement lists for additional supplies
- on-the-job training of the water quality lab technician
- an analysis of water samples obtained from rural sites in various districts, using protocols established for physical, chemical and micro-biological analyses.
- the presentation of a workshop for District Public Health Inspectors during which a water quality monitoring system was introduced, to include sampling schedules by district.

An operational water quality lab will permit the MOH to systematically monitor existing water sources as well as those proposed under the IPTBH project. If the close operational relationship recommended for the lab and the Ministry of Natural Resources is established and maintained, improved consumption of potable water should ultimately prevail in rural Belize. An ancillary recommendation worthy of the attention of the MNR but unrelated to rural water supplies, pertains to the potential for introducing technology to soften the water produced by the Belize City water treatment facility; owing to consumer perceptions that the municipal water is hard, city residents indicate a preference for rainwater. The technology does exist to rectify this aesthetic perception.

The report is organized into a brief discussion of activities and recommendations, with operational protocols governing testing procedures, sampling runs and other technical notes presented in the Appendices.

III. OVERVIEW OF TASKS PERFORMED

Background

The goals of the water quality lab consultancy were to organize and prepare the existing water quality laboratory to accept and analyze drinking water samples from all districts of Belize; and to prepare the existing Public Health Inspectors to sample all public drinking water supplies in the country and interpret the results they received.

The Water Quality Laboratory was well prepared when the consultancy began. The majority of the equipment and reagents necessary to begin analyses were present. Supplies of reagents for different tests were available, and some reagents and equipment not necessary for routine water quality testing were also available. Space and layout were adequate and the laboratory was clean.

Ms. Beverly Clare, the laboratory technician, was even more well prepared than the lab itself. Ms. Clare's recent laboratory experience at Belize Technical College and at the Water and Sewage Authority (WASA) was very helpful and was evidenced by her excellent lab techniques. At WASA, she had performed all of the necessary inorganic analyses on the same type of equipment as that supplied in the new water quality laboratory.

The Public Health Inspectors (PHIs), who were to assume responsibility for collecting samples from each district, had varying levels of training, and others were scheduled for future training. Some of the PHIs knew their districts well and were able to locate the villages with handpumps to be tested, others had very little opportunity to date to travel in their assigned districts.

Lab Conditions and Procedures

Given these starting conditions, work began in the laboratory. An essential supplies list was developed immediately, including reagents, stock chemicals for cleaning, and a cartridge type water filter to improve the quality and quantity of distilled water available. Ms. Clare worked with the Advisor to determine how many tests each reagent package would perform, and in making a list of reagents to supplement the current stock for a six month's supply. A second list was submitted after one week's lab work, including miscellaneous tubing and glassware to simplify lab procedure, and standards for quality assurance. A third list, a model list for six month's of lab work, was drawn up and is included in Appendix B. It must be reviewed before an order is placed to make sure that the rate of usage has changed. The list is based upon an anticipated workload of thirty samples per week, fifty weeks per year. It includes all materials needed to run alkalinity, chloride, chlorine, conductivity, hardness, iron, fluoride nitrate, pH, sulfate, turbidity, and total coliform on each sample, and fecal coliform when necessary.

For the first year of the water quality lab's operation, each analysis should be run on each sample. At that rate, every existing public well (presently counted at five hundred sixty) can be sampled within six months. The new wells and rudimentary systems which have been planned have also been included in the first year's estimate of work, bringing the total to eight hundred thirty. It is reasonable to assume that at the beginning of the program, about thirty percent of all routine samples will have to be repeated; (preliminary samples confirm this rate of resampling), requiring the lab to analyze one thousand and eighty samples per year, still within its capacity. After the first year,

when questionable wells have been disinfected or replaced, the rate of check samples should decrease to fifteen percent or fewer.

Written procedures were developed for all analyses, with Ms. Clare's assistance for some of the tests with which she was familiar. General procedures were outlined, for the sake of any employee without a solid laboratory background; and quality control checks were established for the inorganic analyses. Laboratory procedures are included as Appendix A. A copy of each of these procedures is in the laboratory analysis notebook. The notebook also contains a recording form for each type of analysis to be filled out at the time that the test is run. The recording forms contain some details that are not needed in the laboratory reports but serve to remind the analyst of proper procedures and possible interferences, and they will provide a record of all tests run in case one of the sample reports is lost. The Hach Water Analysis Handbook also covers all of these procedures and will serve as a good backup when needed.

Files were developed for each piece of laboratory equipment with the exception of glassware. All warranties were mailed in and serial numbers recorded. These files must be maintained in case service is needed, and will be useful if replacement of operation and maintenance manuals becomes necessary or if spare parts are needed. Equipment needing routine maintenance in the laboratory is discussed in Appendix A, and a preventive maintenance schedule laid out. The instructions included with the autostill and sterilizer are readable, and I have supervised Ms. Clare's servicing of these instruments.

Training for Ms. Clare was limited to familiarization with the new equipment and the procedures involved in the total coliform and fecal coliform tests, using the membrane filter method. She ran all of the inorganic analyses to my satisfaction the first time she was asked. She learned how to prepare and sterilize the media, glassware, and dilution water necessary for the performance of the membrane filter tests, and ran them competently several times with my supervision. She has read and understands all the procedures for running the laboratory tests, as well as the necessary record keeping and reporting procedures.

Monitoring and Sampling Schedules

Monitoring schedules began with an inventory of villages with public water systems. Each PHI was asked to provide as much information as possible about the villages in his district, including location, number of handpumps, population, and plans for future wells or rudimentary systems. Mr. Arthurs supplemented this information with a national count of handpumps. In some cases the exact number of wells was not known, so the schedules were developed conservatively, allowing for the highest likely number of present future wells. Priority was assigned as follows: existing wells in non-project villages are to be sampled first; next will be existing wells in non-project villages; and new wells or rudimentary systems last. The sampling dates for all future systems are tentative, depending upon their existence at the time of sampling. A copy of each

district's sampling schedule is included in Appendix C. The schedules allow yearly sampling of all existing and planned wells and water systems, and allow for resampling of thirty percent of the water sources if necessary. To accomplish the scheduled monitoring, each PHI will need to have access to a vehicle for one day every three weeks. This was the minimum amount of travelling necessary to check all the wells. In most cases, a vehicle is available within the district, or will be within the year, and by planning ahead, the PHI should be able to use it for a day. To get the samples to the laboratory within the required twenty-four hours, air transport will be used from Punta Gorda, Dangriga, and perhaps Corozal. In these cases, the PHI will call the lab and notify the technician that samples are being flown in. The same arrangements must be made when the samples are bussed in, as from San Ignacio.

Sampling Procedures Workshop

Following the development of sampling schedules, a workshop was held for the PHIs, to instruct them on sampling procedures. The significance of each test routinely run in the lab was discussed, and each participant ran the necessary field tests and collected a set of water samples from a tap in the lab. The PHIs also filled out sample reporting forms and discussed how the samples would be transported to the laboratory within the required twenty four hour time limit. One PHI from each district received a field testing kit, and as soon as sufficient ice boxes and sample bottles have been received, the PHIs will be ready to begin sampling the wells in their districts.

Laboratory reporting of sample results is a simple procedure; a sample reporting form is sent to the laboratory with each sample for identification. It contains the results from the field tests run by the PHIs. At the lab, the remaining results are filled in, the form is copied and mailed back to the PHI, with the original remaining in the laboratory files.

Repeat samples, or check samples, will be run on all supplies which test positive for more than 20 coliform colonies. Both total and fecal coliform will be run for all check samples as soon as the lab is equipped with a second incubator. Check samples will also be run on any well that has nitrate levels of more than 10 mg/l.

The PHIs will continue to receive supplies for field test kits from the central laboratory. When they run out of reagents, Ms. Clare will replenish their supply and will split a sample with them to make sure that the results they are reporting in the field are accurate.

Once the existence of the laboratory is better known, both the PHIs and Ms. Clare will be requested to test private wells. Ms. Clare will direct all such inquiries to the PHI in the district involved. In cases of health problems arising for which the water is a suspected cause, the PHI should make every attempt to collect a sample from the site in question on his next sampling day. If there is a public supply in the area which has been shown to be uncontaminated, the resident should be

advised to get his drinking water from that public source. Sampling of every existing hand dug well and vat will overload the laboratory very quickly and should be discouraged.

Equipment Requirements

In order to begin the drinking water sampling program, reagents, sampling bottles, and ice boxes are needed. The Ministry of Health will supply the ice boxes as soon possible. The necessary reagents were on the first equipment list submitted by the consultant. Some bottles were requested on the second equipment list, based on a sampling schedule of six samples from every district every ten days. The schedule has been changed to fifteen samples from each district every three weeks to minimize transportation needs, but this requires an additional order of sampling bottles and graduated cylinders, from the Fisher catalog:

24 1 liter bottles	02-923F	$ 39.53
36 100 ml cylinders	08-549-10C	$120.24

IV. RECOMMENDATIONS

1. The water quality analysis program is entirely dependent upon Ms. Beverly Clare. Her sickness, vacation, or departure for any reason will require the suspension or termination of the sampling program. Ms. Clare has all the skills and materials necessary to train someone to substitute for her on a part time basis. The present time, before the PHIs have the necessary materials for sampling, could be profitably used to train someone in the methods and procedures of the water quality laboratory. Perhaps such an arrangement could be made in cooperation with WASA, who might also be interested in a part time lab technician.

2. The Ministry of Health has expressed an interest in the identification of specific microorganisms in drinking water systems in Belize. These identifications are not generally done in countries with treated drinking water systems, with the emphasis being placed on the elimination of all coliform bacteria from water. Because the majority of water systems in Belize are not and will not be treated in the near future, the identification of specific disease causing organisms may be of value. Belize might benefit considerably from further microbiological studies undertaken by Ms. Clare. The Advisor cannot yet recommend any particularly valuable course, but will attempt to identify one upon her return to the U.S.A.

3. The usefulness of the data generated in the water quality laboratory is dependent upon its proper application. The large percentage of wells testing positive for 20 or more total coliform colonies/100 ml suggests that many of the wells and handpumps must be properly sealed and disinfected. A yearly disinfection program might be needed.

4. The water sampling and analysis program should be evaluated after approximately one year of operation, or once all wells have been sampled. Questions that should be answered at that time are:

a. Should other microbiological analyses be added to the total and fecal coliform tests now performed by the laboratory?

b. Is field set up of total coliform tests useful? These tests were not instituted now because the delayed analyses they allow was not advantageous at this point in the program. Chemical samples to collect background information on all the wells need to be delivered to the lab within 24 hours so that alkalinity, conductivity, and nitrates may be accurately determined. Once that data has been compiled, the use of field set ups should be reevaluated.

c. Which chemical tests can be run at less frequent intervals? Unless levels are problematic, these will include chloride, fluoride, alkalinity, nitrate, and sulfate.

d. Can bacterial samples be collected and run more frequently? Such a change would increase the level of protection offered by the drinking water quality testing program.

e. Can a screening program for metals be carried out? Once well data has been collected and compared to well locations and depths, it should be possible to estimate the number of aquifers in use for drinking water. Analyses of several wells in each aquifer would assure the Ministry of Health that there are no naturally occurring levels of metals that could present a health risk, and repeated testing would not be necessary. Samples could be sent away for these analyses.

5. Samples were collected in several districts during the course of the consultancy, and two problems were noted in the Cayo district. The only working handpump in San Antonio had a high level of nitrates (12 mg/l, more than 10 mg/l can cause health problems). High nitrates are particularly dangerous for infants and small children as they can interfere with the body's utilization of oxygen. No working handpumps were found in Cristo Rey. The priority of work in these two villages should be reconsidered.

6. The city of Belize has an efficient, modern drinking water treatment plant. Many residents do not drink the water that is piped into their homes because they do not like the taste of the hard water or the deposits it leaves on pots and pans when used for cooking. Technology

is available to soften the water, and it is possible that the city treatment plant could be modified to include softening without adding too much to the cost of treating the water.

APPENDICES

A. General Laboratory Notes and Procedures
   (i) Alkalinity
   (ii) Chlorides
   (iii) Chlorine
   (iv) Fecal Coliform
   (v) Total Coliform
   (vi) Total Hardness
   (vii) Iron
   (viii) Nitrogen, Nitrates
   (ix) ph
   (xii) Turbidity

B. Model Laboratory Supply List

C. Surveillance Workshop Agenda

D. Protocols for Sampling and Analysis
   (1) Water Quality Parameters
   (ii) Revisions to Sampling Procedures
   (iii) Sampling Runs by District

GENERAL LABORATORY NOTES

The laboratory is a place for careful and precise work, and for careful handling of equipment and chemicals. Proper technique is necessary not only to ensure the reliability of your results, but also to ensure your safety and the useful life of all equipment.

1. Glassware

All glassware must be washed in soapy water. Rinse at least twice or until all evidence of soap is gone. Rinse again in distilled water. When performing a series of samples using the spectrophotometer or one of the titration methods, rinsing the glassware between samples with distilled water is sufficient. Proper washing between series of tests is essential.

Use the pipet or graduated cylinder that corresponds most closely to amount of sample or chemical being measured. Avoid using more than two measurements where one would be adequate. (Ex. To measure a 3 ml portion, a 5 ml pipet is preferable to either a 10ml pipet or repeated use of a 1 ml pipet.)

When preparing stock solutions, use a volumetric flask if possible. When connecting glassware to rubber tubing, use lubricant and do not force. Do not attempt to disconnect tubing from glassware. Instead, cut tubing. Incorrect handling of glassware is the most common cause of laboratory accidents.

A pipet should always be filled using a pipet filler. It may be emptied with a squeeze bulb or by using a finger to regulate flow from the pipet into the receiving container.

2. Dilutions

To determine the proper dilution of a given chemical or solution, you must know the strength of the chemical or solution available, the strength you need, and the volume you need. Multiply the amount of final solution needed by the strength of final solution needed, and divide by the strength of available chemical or solution.

For example, to dilute a 4000 FTU formazin solution for turbidity measurement to 4 FTU for standardization,

$$\frac{4 \text{ FTU} \times 25 \text{ ml}}{4000 \text{ FTU}} = 0.025 \text{ ml formazin solution in 25 ml total solution}$$

Never make a direct dilution of less than 1 in 100. The accuracy of the measurement cannot be depended upon. To dilute the above standard, first start with 1ml of formazin in 100 ml of total solution. You will need (100 ml - 1 ml) distilled water, or 99 ml distilled water. Calculate the strength of this solution as you will be using it for your next dilution. (100 ml was chosen merely as a convenient quantity for further dilution)

$$\frac{400\text{FTU} \times 1\text{ ml}}{100\text{ ml}} = 40\text{ FTU}$$

Calculate how much of this new solution you will need.

$$\frac{4\text{ FTU} \times 25\text{ ml}}{40\text{ FTU}} = 2.5\text{ ml in 25 ml total solution}$$

You will need (25 ml - 2.5 ml) distilled water, or 22.5 ml of distilled water.

3. Accuracy of tests

All tests should be run on a standard monthly to check the accuracy of reagents, methods, and equipment. Standards are available and should be run as explained on the instruction page for each test.

When standard results differ from the expected values, they should be checked as follows.

a. Clean all glassware thoroughly.
b. Reread procedures for the test, and perform again, following the procedures step by step, making all measurements carefully.
c. Check reagents against newest batch available.
d. Perform standards check using a new standard, if available.
e. If two or more standards will not check out using the DREL/5, the instrument may need servicing.

4. Maintenance

Daily maintenance includes:

Record temperatures of refrigerator and incubator if in use.
Change recording temperature chart on sterilizer.

Weekly maintenance

Clean the autostill as mineral deposits become visible. Current need is twice a week. After the installation of cartridge filters, continue to check its condition every week. Instructions are in the Autostill manual. Be sure to check the pH before using the distilled water.
Clean the sterilizer, following the instructions on the bottle of Tec Cleaner. More than two rinse cycles may be required. Rinse until no detergent is evident.
Check liquid level in pH electrode, fill if necessary.
Check distilled water for conductivity and total residual chlorine every week, following the normal procedures for these tests.

Monthly maintenance

Run standards on each analytical method and record in result book.
Clean refrigerator.
Clean incubator.
Wipe out sterilizer and check pressure relief valve.

Maintenance, as necessary
Clean pH electrode as instructed in Digital pH Meter instruction manual.

5. Quality control for field tests
Replenish chemicals in Public Health Inspectors' field testing kits as necessary. At such times, run split samples with PHIs to ensure the accuracy of the kits and their methods. Any available sample, including tap water, will suffice for this verification.

6. Safety
Before servicing any equipment, such as replacing batteries or heating element, be sure it is unplugged. The exception is the sterilizer, which must be cleaned while on.
The reagents you are using can be dangerous if accidentally ingested.
Never pipet by mouth. The acid solution used for cleaning the still is caustic and should not be allowed to touch your skin. Immediate flushing with water will prevent any danger.
Always wash your hands before leaving the lab, especially before eating. Some of the water you analyze may be contaminated.

ALKALINITY

TEST PROCEDURES

Apparatus:

2 (or 3) 250 ml Erlenmeyer flasks
2 100 ml graduated cylinders
1 digital titrator

Reagents:

100 ml sample
100 ml distilled water
1 Buffer Powder Pillow, pH 4.5
1 pillow or 6 drops Bromcresol Green-Methyl Red indicator
1 titration cartridge Sulfuric Acid, 1.600N
(Phenolpthalein indicator)

Titration Method
Instructions:
Sample must be analyzed within 24 hours of collection.

1. Note the pH of the sample on the record sheet. Also record the date, sample number, and other information.
   Warm sample to room temperature.

2. If the sample pH is 8.3 or less, proceed to step 7.

3. Mix 100 ml distilled water with one buffer powder pillow, pH 8.3, and one pillow or six drops of Phenolpthalein indicator in Erlenmeyer flask.

4. Transfer 100 ml of sample to a 250 ml Erlenmeyer flask, add 1 pillow or 6 drops Phenolpthalein indicator.

5.a. Attach a tube labelled ALK to the mouth of the titration cartridge. Rotate the dial until a drop of acid is on the tip of the applicator, wipe it off.

b. Attach a titration cartridge of 1.600N Sulfuric Acid to the digital titrator.

6. Rotate the dial of the digital titrator, dispensing Sulfuric Acid into the sample while swirling. Continue until the pink color disappears completely. Record the Phenolpthalein alkalinity. The color should match that of the buffer prepared in step 3.

7. Mix 100 ml distilled water with one Buffer Powder Pillow (pH 4.5) and 1 pillow or 6 drops Bromcresol green-Methyl Red indicator.

8. Transfer 100 ml of sample to a 250 ml Erlenmeyer flask, add 1 pillow or 6 drops Bromcresol Green-Methyl Red indicator.

9. Attach a tube labelled ALK to the mouth of a titration cartridge of 1.600N Sulfuric Acid. Attach the cartridge to the digital titrator. Rotate the dial until a drop of acid is on the tip of the applicator. Wipe it off and re-zero the dial.

10. Repeat 6.

Standardization

Needed: 1 voluette ampule standard for alkalinity

Procedures:

1. Open voluette. Pipet 0.10 ml standard into one sample for which alkalinity has already been determined. Titrate to the endpoint.

2. Pipet 0.20 ml standard into the same sample or another for which alkalinity has been determined. Titrate to the endpoint again and record digital titrator reading. Repeat, using 0.30 ml of standard.

3. Results should be as follows:

0.10 ml standard	25 mg/l alkalinity
0.20 ml standard	50 mg/l alkalinity
0.30 ml standard	75 mg/l alkalinity

CHLORIDES

TEST PROCEDURES

Apparatus:

1 250 ml Erlenmeyer flasks
1 100 ml graduated cylinders
1 digital titrator
1 50 ml beaker

Reagents:

130 ml sample
1 pillow Diphenyl carbazone Reagent
1 titration cartridge Mercuric Nitrate, 2.256N
1 Sulfuric Acid Standard Solution, 5.25N

Instructions (Mercuric Nitrate method)

1. Calibrate pH meter.
2. Adjust sample pH to approximately 2.5 w/5.25N Sulfuric Acid. Do not use a pH electrode in the sample container-pour off 15 ml in a 50 ml beaker to measure pH.
3. Note the drops of Sulfuric Acid needed on record sheet.
4. Transfer 100 ml of sample to a clear 250 ml Erlenmeyer flask.
5. Add one pillow Diphenylcarbazone Reagent and swirl to mix.
   a. Attach a tube labelled Cl to the mouth of 2.256N Mercury Nitrate titration cartridge. Rotate the dial until a drop of the titrate is on the tip of the tube, wipe it off. Reset dial to 0000.
   b. Attach a titration cartridge to the digital titrator.
6. Slowly rotate dial to titrate while swirling sample to mix. Stop titration when color of sample solution changes from yellow to pink.
7. Record the concentration of chloride in mg/l from digital counter.

Chloride Standardization

Needed: Sodium Chloride standard solution, 1000 mg/l as Cl

Procedures:

1. Dilute 25 ml standard with 75 ml distilled water for a solution containing 250 mg/l as Cl.

2. Run the chloride test as described on the preceding page, using the 250 mg/l standard solution.

CHLORINE

Test Procedures

A. **Free Available Chlorine**

Apparatus:

spectrophotometer
2 sample cells
Chlorine (DPD Method) Meter Scale
graduated cylinder

Reagents

50 ml sample
DPD Free Chlorine Reagent Powder Pillows

Instructions

1. Samples must be analyzed immediately upon collection. Any holding time invalidates results.
2. Fill each sample cell with 25 ml of sample.
3. Insert the Chlorine meter scale and press the DR/3 switch. Set wavelength to 530 nm.
4. Set the meter to LEFT SET, place one of the sample cells in the cell holder, and close the light shield. Adjust the LEFT SET control if necessary.
5. Switch the meter to NORM. Adjust the RIGHT SET controls for a reading of 0.0 mg/l.
6. Add the contents of one DPD Free Chlorine Reagent Powder Pillow to the remaining sample. Swirl to mix and immediately put sample into cell holder.
7. Close light shield and take reading. Record results along with sample, number, date, and district.

B. **Total Available Chlorine**

1. Samples must be analyzed immediately upon collection.
2. Follow above instructions 2 through 5.
3. Add the contents of one DPD Total Chlorine Reagent Powder Pillow to the sample. Swirl to mix and immediately put sample into cell holder.
4. Close light shield and take reading. Record.

C. **Combined Chlorine**

1. First determine both free and total available chlorine.
2. Subtract the free available chlorine from the total available chlorine to get the combined chlorine.

STANDARDIZATION

Additional reagent: Voluette Ampule Standard for Chlorine

Instructions:

1. Open Voluette. Pipet 0.10 ml into one 25 ml sample, 0.20 ml into another 25 ml sample, and 0.30 ml into a third 25 ml sample. Distilled water or a sample which has already been analyzed for chlorine is satisfactory.
2. Analyze sample again, as described above, and record the difference between the first result and the result with the standard added. The differences in the readings should be as follows:

0.10 ml standard	0.4 mg/l chlorine
0.20 ml standard	0.8 mg/l chlorine
0.30 ml standard	1.2 mg/l chlorine

This method is for checking either free or total chlorine residuals.

Fecal Coliform

Test Procedures

Apparatus

Please refer to the Total Coliform Procedures for the list of equipment needed for the fecal coliform test.

Reagents

m FC Broth Base
1.1 L distilled water
100 ml sample collected in sterile bottle
magnesium chloride
potassium dihydrogen phosphate
0.2N sodium hydroxide
rosolic acid
disinfectant

Preparations

1. Please refer to the Total Coliform Procedures for preparation of sterile buffered dilution water, sterilization of glassware, and sample dilutions.

2. m FC Broth
   a. Dissolve 1.0g rosolic acid in 50 ml 0.2N sodium hydroxide. Fill to 100 ml with 0.2N sodium hydroxide.
   b. Weigh out 1.85 g of m FC Broth Base on a pre-weighed dish or weighing paper. Mix in 50 ml distilled water.
   c. Add 0.5 ml of the rosolic acid-sodium hydroxide solution.
   d. Heat slowly just to boiling and remove from heat.
   e. Using a sterile 1 ml pipet, add 1.8 to 2 ml broth to each pre-sterilized petri dish assembly and close immediately.
   f. Petri dishes with media or covered media can be refrigerated for up to 96 hours (4 days).

Procedures

1. Turn on incubator to 44.5°C.
2. Follow procedures for total coliform test 2-10.
11. Remove lid and count colonies after 24 hours. Fecal coliform colonies will be blue. No verification is necessary.

STANDARDIZATION

Filter and incubate a 100 ml sample of sterile buffered dilution water to verify the sterilized glassware, media, and buffered water.

Total Coliform

Apparatus- general

1 incinerator
1 sterilizer
1 filtration assembly
1 vacuum pump
1 pair forceps
1 1 ml pipet with bulb
4 250 ml Erlenmeyer flasks or autoclavable wash bottles
2 vacuum flasks with rubber stoppers
tubing

Apparatus for each sample

1 100 ml graduated cylinder or beaker
1 pre-sterilized petri dish with media pad
1 pre-sterilized membrane filter (45um)

Reagents

M-Endo Broth
.1 L distilled water
100 ml sample collected in sterile bottles
magnesium chloride
potassium dihydrogen phosphate
95% ethanol
1 Coli-firm kit
disinfectant (10 ml Chlorox in 1L tap water)

For highly contaminated samples, extra buffered dilution water, sterile bottles, petri dishes, and filters will be needed.

Preparations

1. Sterile buffered dilution water
   a. Weigh out 3.4 g of potassium dihydrogen phosphate (KH_2PO_4) on a pre-weighed dish or weighing paper. Mix in 50 ml distilled water, and adjust pH to 7.2± 0.5 with 5.0N sodium hydroxide. Fill to 100 ml with distilled water. This is a stock solution and can be kept for 6 months unless growth develops.
   b. Weigh out 8.11 g of magnesium chloride $MgCl_2$) as above. Mix in 50 ml distilled water, then fill to 100 ml with distilled water. This is also a stock solution which can be kept for six months.
   c. Mix 1.25 ml of the KH_2PO_4 solution with 500 ml distilled water. Add 5 ml of $MgCl_2$ stock solution, and fill to 1 L with distilled water.
   d. Pour the completed solution into 4 250 ml Erlenmeyer flasks. Cover the top of each flask with foil and sterilize for 20 min at 250°C. Be sure to vent slowly.

2. **M-Endo Broth**
   a. Weigh out 2.4 g of BBL M-Endo Broth. Dissolve in 50 ml distilled water, then add 1 ml of 95% ethanol. Heat slowly just to boiling and remove from heat.
   b. Using a sterile 1 ml pipet, add 1.8 to 2 ml media to each pre-sterilized petri dish assembly and close immediately.
   c. Petri dishes with media can be refrigerated up to 96 hours (4 days). Covered media can also be refrigerated for use up to 96 hours later.
3. **Sterilize Glassware**
   Sterilize filtration assembly, 1 pipet, and graduated cylinders or beakers. Cover the tops of graduated cylinders or beakers with foil, and wrap pipet and filtration assembly completely with foil before sterilizing. Sterilize for 15 min at 250° C. Glassware may be vented at the rapid setting. All utensils must be cooled to room temperature before contacting sample.
4. **Dilutions**
   If sample is believed to be grossly contaminated, it should be diluted with sterile buffered dilution water. Dilution is indicated in cases where previous samples from the same source have yielded high numbers or coliform or non-coliform organisms, or where surface water (river water) is used without treatment. Highly turbid samples should be

   a. Measure 99 ml of sterile dilution water into a sterile sample bottle. Using a sterile pipet, add 11 ml of sample to the bottle and shake vigorously. If source is a well, this dilution is probably sufficient. Filter 100 ml of diluted sample. If not, proceed.

   b. Measure 11 ml of sample into a sterile sample bottle. Add 99 ml sterile dilution water and shake vigorously.

   c. Measure 11 ml of sample b and add to 99 ml sterile dilution water. Shake vigorously.

   d. Measure 10 ml of sample c and add to 99 ml sterile dilution water. Shake vigorously.

   e. Filter dilutions b, c, and d above. Label them 1 ml, 0.1 ml, and 0.01 ml, respectively.

Procedures
1. Turn on incubator to 35°C.
2. Before unwrapping any sterilized equipment, wash hands thoroughly and clean work area with a disinfectant.
3. Set up filtration assembly in vacuum flask or multiple assembly. If filtration assembly was not sterilized with a membrane filter in place or for repeat filtrations, remove clamp and funnel. Sterilize forceps in alcohol, then flame (or incinerator), and place filter, grid side up on the base.

Replace funnel and clamp, being sure not to touch top of base or inside of funnel.

4. Shake sample vigorously for 30 sec to 1 min. Remove foil from a graduated cylinder or beaker and measure 100 ml of sample.
5. Turn on vacuum pump and pour sample into funnel.
6. Rinse funnel with 20-30 ml sterile dilution water. Rinse again, to make sure all of original sample goes through filter. Turn off vacuum pump.
7. Remove clamp and funnel. Open petri dish. Sterilize forceps. Remove filter from base gently and roll onto media pad, making sure not to trap air bubbles between pad and filter. Replace lid and label dish with sample #.
8. Place petri dish in incubator, upside down. Record time and temperature.
9. If there are further samples to filter, repeat steps 3 through 8.
10. After 18 - 24 hours, remove dish from incubator.
11. Remove lid and count coliform colonies. Avoid direct sunlight and tilt the plate until you see a greenish gold sheen. Count sheen colonies and record as presumptive. If no colonies are found, report 1, and the test is complete. Otherwise, continue with step 12.
12. Open one Coli-firm kit. Remove the top from one tube of water, and pipet it into each of the center wells and the four wells in the last row.
13. With a wooden applicator, touch one of the sheen colonies. Now put the applicator into the first center well and stir. With a new pipet, transfer half of the liquid into the well on the left and half into the well on the right.
14. Repeat step 13 with all sheen colonies if there are five colonies or colonies or less. If there are more than five colonies, transfer 10% of the colonies into Coli-firm kits.
15. Cover the kit with the applicators to punch a small hole into each well on the right side.
16. Label each kit with the sample # and incubate at 35°C for 4 hours.
17. After 4 hours, remove Coli-firm kit from incubator. Each row which has a yellow well on the left and black well on the right is a confirmed coliform colony. If not all colonies are confirmed, adjust your original count by multiplying it by the percentage of colonies that were confirmed. After some practice, all colonies should be confirmed every time the test is run.

STANDARDIZATION

Additional equipment needed: One petri dish with pad
one membrane filter
1 100 ml graduated cylinder
100 ml sterile buffered dilution water

Filter the sample of sterile buffered dilution water just as you would another sample. Incubate for twenty four hours and read. Any coliforms signify contamination of sample.

At the conclusion of all total and fecal coliform tests, confirmation, standardizations, all petri dishes and confirmation trays must be wrapped in foil and sterilized for thirty minutes before disposal.

TOTAL HARDNESS

TEST PROCEDURES

Apparatus:

1 250 ml Erlenmeyer flask
1 100 ml graduated cylinder
1 digital titrator

Reagents:

2 ml Buffer Sol^{n} Hardness 1
1 pillow Manver 2, Hardness Indicator
1 titration cartridge EDTA, 0.800M

Instructions:

1. Warm samples to 25°C before analyzing.
2. Transfer 100 ml of sample to a clear Erlenmeyer flask.
3. Using the 1-ml calibrated dropp, add 2 ml of Buffer Sol^{n}, hardness 1 and swirl to mix.
4. Add one pillow Manver 2, Hardness Indicator to sample and swirl to mix.
5. First attach a tube labelled EDTA to the mouth of 0.800M EDTA 2 titration cartridge. Rotate the dial until a drop of the titrant is on the tip of tube, wipe it off. Reset the dial to 0000. Then attach a titration cartridge to the digital titrator.
6. Slowly rotate dial to titrate while swirling sample to mix, until color of sample Sol^{n} changes from red to pure blue.
7. Record the concentration of total hardness (as mgle $CaCo_3$) from digital counter.

STANDARDIZATION

Needed: 1 voluette ampule standard for hardness

Procedures:

1. Open voluette. Pipet 0.10 ml standard into a sample for which hardness has already been determined by the above method. Titrate to the endpoint again, and record the number on the digital titrator. Reset titrator.

2. Repeat above, using 0.20 ml standard, and again with 0.30 ml. Results should be as follows:

0.10 ml standard	10 mg/l hardness
0.20 ml standard	20 mg/l hardness
0.30 ml standard	30 mg/l hardness

IRON

Test Procedures

Apparatus

spectrophotometer
2 sample cells
graduated cylinder
Iron (Ferro Ver Method) Meter Scale

Reagents

50 ml sample
Ferro Ver Iron Reagent Powder Pillow

Instructions

1. Sample must be analyzed immediately upon collection. Any holding time will invalidate sample results.
2. Add 25 ml of sample to each cell.
3. Set spectrophotometer to DR/3, insert Iron meter scale, and set wave-length to 510 nm.
4. Add contents of one Ferro Ver powder pillow to one sample. Wait three minutes for the color to develop.
5. Put untreated sample in cell holder and close light shield. Turn meter to LEFT SET, and use LEFT SET knob to adjust if necessary so that needle is at far left on scale.
6. Switch meter to NORM, and use RIGHT SET controls to set meter reading at 0.0.
7. Place treated sample into sample cell holder and close light shield. Take reading and record.

STANDARDIZATION

Needed: Iron standard solution, 100 mg/l as Fe

Procedures:

1. Dilute standard to 1.0 mg/l by adding 1 ml standard to 99 ml distilled water.
2. Run standard as described in above test procedures. Result should be 1.0 mg/l iron.

Nitrogen, Nitrate

Test Procedures

Apparatus

spectrophotometer
2 sample cells
graduated cylinder
Nitrogen, Nitrate (NitraVer 5 Method) Meter Scale

Reagents

50 ml sample
NitraVer 5 Nitrate Reagent Powder Pillow

Instructions (Cadmium Reduction Method)

1. Sample may be held for 24 hours if kept at 4°C or lower.
2. Warm sample to room temperature.
3. Fill each sample cell with 25 ml sample
4. Add the contents of one NitraVer 5 Reagent Powder to one sample. Shake vigorously for exactly one minute. Wait five minutes to analyze.
5. Press DR/3 switch on spectrophotometer, insert Nitrogen, Nitrate (NitraVer 5 Method) meter scale, and adjust wavelength to 500 nm.
6. Place untreated sample in cell holder and close light shield. Set meter to LEFT SET. Adjust LEFT SET until needle is at left on scale.
7. Switch to NORM and adjust to a reading of 0.0 mg/l with RIGHT SET controls.
8. The treated sample will contain a deposit of unoxidized metal. This will not affect sample results. Place sample in cell holder and read the Nitrogen, Nitrate concentration off the scale. Record along with sample information.

STANDARDIZATION

Needed: Nitrogen, Nitrate Standard Solution, 19 mg/l as N

Procedures:

Measure 25 ml of standard and analyze as directed above. Results should be 10 mg/l.

pH

Test Procedures

atus

pH meter
pH electrode
4 50 ml beakers

nts

pH 4 buffer powder pillow or liquid buffer
pH 9 or 7 buffer powder pillow or liquid buffer
100 ml distilled water
30 ml sample

ctions

The pH test must be performed immediately after sample collection. Any holding time will invalidate the test.
Connect pH probe and temperature probe to pH meter. Make sure that temperature probe is completely on.
Measure 50 ml distilled water into each of 2 beakers. Add 1 pH4 buffer powder pillow to one beaker and 1 pH 9 (or 7) buffer powder pillow to the other. (Alternatively, measure 30 ml liquid buffer solution pH 4 and 30 ml liquid buffer solution pH 9 or 7 into separate beakers).
Place the pH and temperature probes into the beaker containing pH 4 buffer. Set the pH meter to temperature, and read the temperature. Switch the meter to the pH setting, and use the calibration knob to set the meter at 0.00.
Read the chart on page 11 of the pH instruction manual to determine the actual pH difference between the two buffers at the current temperature. At 25°C, the differences will be 2.99 for pH buffers 4 and 7, and 4.99 for pH buffers 4 and 9.
Rinse the probes thoroughly with distilled water. Put them in the pH 9 or 7 buffer solution. Using the Span knob, adjust the meter to read 2.99 for pH 7, or 4.99 for pH 9 if the samples are at 25°C. For any other temperature, get the value from the chart.
Now use the calibration knob to adjust the pH to the actual pH of the buffer solution. At 25°C the value would be 7.00 or 9.00.
Rinse the probes with distilled water. Pour 30 ml of sample into a 50 ml beaker and place the probes into the sample. Read the pH.

SULFATE

Test Procedures

Apparatus

spectrophotometer
2 sample cells
graduated cylinder
Sulfate (SulfaVer 4 Method) Meter Scale

Reagents

50 ml sample
Sulfa Ver 4 Sulfate Reagent Powder Pillow

Instructions (Turbidimetric Method)

1. Samples may be kept up to seven days if stored at 4°C or lower.
2. Warm sample to room temperature before analyzing.
3. Record turbidity of sample in record book. If turbidity of sample is 25 NTU or more, filter 60 ml of sample.
4. Fill each sample cell with 25 ml of sample, filtered through paper if necessary.
5. Add one Sulfa Ver 4 Reagent powder pillow to one sample. Wait five minutes for color to develop before analyzing.
6. Press DR/# switch on spectophotometer, insert Sulfate meter scale, and adjust wavelength to 450 nm.
7. Place untreated sample in cell holder and close light shield. Set meter to LEFT SET. Adjust LEFT SET if necessary, until needle is at left mark on scale.
8. Switch to NORM and adjust to a reading of 0.0 mg/l with RIGHT SET controls.
9. Place the treated sample in cell holder and close light shield. Read the concentration of sulfate from the scale, and record.
10. If repeated samples are analyzed, be sure to clean sample cells very carefully. Turbid glassware will invalidate results.

STANDARDIZATION

Needed: Sulfate Standard Solution, 50 mg/l as SO_4

Procedures:

Measure out 25 ml of standard and analyze as above. Result should be 50 mg/l.

TURBIDITY

Test Procedures

Apparatus

spectrophotometer
2 sample cells
graduated cylinder
Turbidity (Absorptometric Method) Meter Scale

Reagents

25 ml sample
25 ml distilled water, filtered

Instructions

1. Samples may be kept for up to seven days if kept at 4°C or lower.
2. Use filter paper to filter 30 ml of distilled water. Measure 25 ml and put in one sample cell.
3. Set the spectrophotometer to DR/3 and insert the Turbidity meter scale. Adjust the wavelength to 450 nm.
4. Put the distilled water sample into the cell holder and close the light shield. Set meter to LEFT SET. Adjust LEFT SET until needle is at left mark on scale.
5. Switch controls to NORM and adjust to a reading of 0.0 with RIGHT SET controls.
6. Measure 25 ml of sample and pour into sample cell. Put sample cell in holder and close light shield. Read turbidity from scale and record.
7. If sample has much color, filter 30 ml of sample and use in place of filtered distilled water in step 2.

STANDARDIZATION

Needed: Formazin Stock Solution, 400 NTU

Procedures:

1. Prepare one 40 NTU solution by diluting 1 ml stock solution in 99 ml distilled water.
2. Prepare a 4 NTU solution by diluting 2.5 ml 40 NTU solution in 22.5 ml distilled water.
3. Run both solutions as directed above. The results should be 40 FTUs and 4 FTUs, respectively.

Note: NTU refers to the nephelometric method of turbidity testing and approximates the results obtained by the Absorptometric method.

Model Laboratory Supply List

DPD Free Chlorine Reagent Powder Pillows (1000)
DPD Total Chlorine Reagent Powder Pillows (1000)
2 EDTA Titration Cartridge 0.800M
11 Mercuric Nitrate Titration Cartridge 2.256N
18 Sulfuric Acid Titration Cartridge 1.600N
2 Potassium dihydrogen phosphate pillows
2 magnesium chloride pillows
9 SPADNs Reagent (1 pint)
3 Buffer powder pillows, 4.5
1 calcium chloride standard
1 fluoride standard solution
1 Nitrogen, Nitrate standard solution
1 sulfate standard solution
16 NitraVer 5
16 Sulfa Ver 4
2 sodium chloride standard
16 diphenylcarbazone pillows
6 bottles Tec Cleaner
2 boxes recording charts
6 cartridge filters
8x100 petripads
4 boxes membrane filters
1 jar M Endo media

Yearly

voluette ampule standards for alkalinity
voluette ampule standards for chlorine
voluette ampule standards for iron
Formalin stock solution
1 pH buffer 4
1 pH buffer 7
1 Bromcresol Green-Methyl Red
1 Bromthymol Blue
1 jar m Fc media

WATER QUALITY SURVEILLANCE WORKSHOP

March 11th. and 12th, 1987

Venue: Central Lab in the Water Quality Lab Room

AGENDA

Wednesday March 11:

8:30 - 5:00:	Meeting with all District Public Health Inspectors, (Stann Creek, Cayo, Toledo, Orange Walk and Corozal) in order to develop sampling schedules.

Thursday March 12:

9:00 - 9:15:	Introduction
9:15 - 10:00:	Explanation of parameters tested.
10:00 - 10:30:	Discussion and demonstration of field tests.
10:30 - 10:45:	Reading and filling out sampling sheets.
10:45 - 11:15:	Sampling techniques for handpumps. Handling of samples during transport.
11:15 - 12:00:	Field tests run by each participant.
12:00 - 1:30:	Lunch.
1:30 - 2:15:	Sampling techniques for small systems (map system).
2:15 - 2:45:	Significance of free and total chlorine residuals.
2:45 - 3:15:	Each participant collects water samples from tap.
3:15	Discussion of proposed sampling schedule.

PUBLIC HEALTH BUREAU OF BELIZE

DRINKING WATER SAMPLING AND ANALYSIS

The new Water Quality Laboratory in Belize has been set up to determine the quality of drinking water throughout the country. Analyses will include total and fecal coliform, alkalinity, hardness, iron, fluoride, and other measures of water quality. The laboratory is only one part of the water quality program. It will run tests on every drinking water sample delivered to it. The other crucial part of the water quality program is the input of the Public Health Inspectors, who will be collecting and delivering the drinking water samples to the laboratory and evaluating the results of the laboratory testing. The Public Health Inspectors will also be performing field tests of some water characteristics which change rapidly over time. The role of the PHI is critical because samples must be collected and delivered with the least possible alteration, so that the results that the laboratory reports will be truly representative of the water supplied for drinking.

The water quality parameters which will be tested describe both the safety and the desirability of a particular drinking water source. A safe supply of water which contains very high levels of iron will probably not be used by area residents. Each analysis run by the water quality laboratory serves a separate purpose, and together they supply the information needed to evaluate the safety and utility of a particular water source.

The total coliform test is an estimate of the degree of pollution of the water source. The presence of any coliform organisms indicates that the water is not fully protected. The contamination may exist in the source itself (a shallow well located too near a latrine might contain polluted water), or the water may have become contaminated between the time it left the source and the time it reached the sampling container. A leaking handpump or water distribution system may be at fault in the latter case. Coliform organisms are not dangerous to human health. They are indicator organisms, chosen because of their presence in quantity in contaminated water, their greater resistance to the effects of chlorine or storage time than that of actual disease causing organisms, and the ease with which they can be isolated and identified in the laboratory. Coliforms are measured in colonies per 100 milliliters. Clean, well protected water sources will have 1 colonies /100 ml. The presence of any coliforms in a water sample is undesirable. Another sample should be collected from the same source if 20 or more coliforms are detected, and repeated counts which are > 1 and < 20 should be investigated. The well should be checked for a proper seal and should be disinfected. If disinfection does not solve the contamination problem, the source must be abandoned.

The fecal coliform test is a more specific test than the total coliform test. Coliforms can be found in soil and vegetation, but fecal coliforms can be found only in the intestines or waste products of warm blooded animals. The presence of fecal coliform is a dangerous signal

and should be acted upon quickly . Any source which tests positive for total coliform will be retested for both total and fecal coliform. Disinfection of the source will kill any fecal coliform present, but the pathway by which they gained access to the water source must be blocked to ensure the future purity of the source. Fecal coliforms are also measured and reported as colonies/100 ml.

The hardness of a drinking water source is a measure of the soluble salts in the water, primarily calcium and magnesium. Hardness is also directly related to people's reports of "heavy" testing water. As well as the taste problem in hard water, it causes difficulty in lathering soaps. The hardness of a particular water source is determined by the geology of the area, and will not change appreciably over time. There is no health problem associated with hard water, but most people find water with a hardness of more than 300 milligrams/liter (mg/l) unpleasant.

Alkalinity is closely related to hardness. It is a measure of carbonates, bicarbonates, and hydroxides, with bicarbonates prevailing in this area. A water which has a high alkalinity is generally more stable and less corrosive than a water with a low alkalinity. Alkalinity of a particular source will not change much over time. It is reported in mg/l.

Because hardness measures the most common cations in water (Ca^{++}, Mg^{++}), and alkalinity measures the common anions in water (HCO_3^-, CO_3^-), they are often very close. When the alkalinity is much higher than the hardness, the water probably contains large amounts of sodium or potassium. When the hardness is much greater than the alkalinity, the water most likely contains significant amounts of sulfates or chlorides.

Conductivity is a general measure of the total ionic activity in water, composed of inorganic salts. Conductivity is usually 1000 umhos/cm, with very hard waters sometimes higher. The conductivity of different waters varies greatly, so original measurements are not very informative. Once a background level of conductivity has been established, a significant change from the background level may indicate contamination and should be investigated.

Nitrates are measured because they have the potential of causing health problems, particularly in infants and very young children. Nitrates can cause methemoglobinemia, a condition which is sometimes called "blue baby" because it prevents the utilization of oxygen. Levels over 10 mg/l can cause problems. The residents of an area can be told not to give the water to their infants or use it in baby formulas, or a new source of water can be located. Nitrates are also an important indicator of pollution, either in the past or upstream of the water source. Levels over 5 mg/l should be monitored for change. The use of fertilizers in the vicinity of a water source can increase the level of nitrates.

Chlorides are monitored because they may indicate salt water intrusion, especially for wells near the coast. High chlorides may also be present because the source was contaminated at some past time. The recommended limit for chlorides is 250 mg/l, because water with more chlorides often tastes salty. Chloride levels will change if a source becomes contaminated, though not as quickly as coliform levels.

Sulfates occur naturally in waters over a wide range of concentrations. Sulfates are measured in mg/l, and the recommended limit is 250 mg/l because higher levels can cause diarrhea. The sulfate content of a ground water source is usually quite constant over time.

Fluoride also occurs naturally in varying concentrations, and is fairly stable over time. Fluoride level of 1.0 to 1.5 mg/l help prevent tooth decay, and dentists may inquire about the fluoride in a patient's drinking water source to decide whether supplements should be given.

The pH of water is a measure of the concentration of hydrogen ions in the sample. It is expressed in Standard Units (SU) and is fairly constant over time in ground water. There is no health significance attached to the pH of water, unless it is very high (9.5) or very low (4.5), but the recommended range for pH is 6.5 to 8.5, because water is less corrosive in this range.

Turbidity is a measure of the light scattered by particles in the water. Most ground waters have low turbidity, and water with high turbidity (5NTU) may be unappealing for drinking. Turbidity may be measured in Nephelometric Turbidity Units or Formazin Turbidity Units, which are approximately equivalent. A change in the turbidity of a water source may indicate recent contamination, and high levels of turbidity are also undesirable because they decrease the effectiveness of chlorine as a disinfectant.

Iron occurs naturally in varying concentrations. No health problems are believed to be caused by even very high levels of iron (5 mg/l), but levels above 0.3 may have an unpleasant effect upon the taste of water and will stain clothing washed in hot water. To get an accurate measurement of the iron content in the water from a well, it must be pumped until all the water in the well casing has been expelled, usually at least five minutes. Water remaining in the casing for a period of time may pick up rust from the casing itself, but the concentration of iron in the natural ground water is quite stable over time.

Chlorine does not occur naturally in water. Free and total chlorine levels should be tested in any public water system where it is used to be sure that the proper dose is being applied. Chlorine should also be tested whenever it is used to disinfect a tap prior to collecting a sample. Chlorine is measured in mg/l.

A few of the above tests will be run routinely in the field at the time of sample collection. Field tests are especially valuable in testing water characteristics which change very rapidly over time. pH, chlorine residuals, iron, and hardness are in this category. Test kits are being provided to one Public Health Inspector in each district for these parameters. Each test kit contains an instruction manual which includes the following instructions.

1. **pH:** First rinse both matching tubes. Fill each with 5 ml of sample. Add six drops of Wide Range pH indicator to one tube, and place both tubes in the comparator, the clear one in the outside compartment. Put the pH wheel in the comparator and rotate until the colors in the viewing areas match. Hold a blank index card behind the comparator to make color comparison easier. Record the number at the pointer.

2. **Iron:** First rinse both matching tubes. Fill each with 5 ml of sample Add the contents of one Ferro Ver pillow to one tube and swirl to mix. Place the untreated tube in the outside compartment of the comparator, the treated one on the inside. Put the Iron color wheel in the comparator and rotate until the colors in the viewing areas match. Hold a blank index card behind the comparator to make color comparison easier. Record the number at the pointer.

3. **Hardness:** First rinse the square sample holder and narrow measuring tube. Fill the narrow tube and empty its contents into the square bottle. Add three drops of hardness #1, buffer, and one drop of hardness #2, indicator. Then add hardness #3, titrant, one drop at a time. Swirl (Hardness) sample to mix after each drop, and stop adding titrant when sample color changes from pink to light blue. Record the number of drops used on the sample form. This represents hardness in grains per gallon. To find the hardness in mg/l, you would multiply the number of drops used by 17.1.

4. **Total chlorine:** Rinse the matching tubes. Fill each with 5 ml of sample. Add the contents of one total chlorine pillow to one sample. Put the untreated sample in the outside compartment of the comparator and the treated one in the inside compartment. Put the chlorine color wheel in the comparator and rotate until the colors match. If there is any pink color in the treated sample, continue to flush until there is no chlorine evident.

5. **Free chlorine:** Run the free chlorine test whenever the water system you are sampling uses chlorine. The procedures are the same as for the total chlorine test except that you will use a free chlorine pillow. For chlorinated water systems, you will report a value for both free and total chlorine. The difference between the free chlorine and the total chlorine is the combined chlorine.

The next page is a sample reporting sheet. This will be filled out and given to the laboratory when a sample is brought in for analysis. The top of the form includes information form the field, and the bottom of the form will be used in the laboratory. Be sure to identify the sample location as completely as possible so that someone else would be able to collect a sample from the same location. If the sample is collected inside a building, be sure to identify the room and tap from which it was taken. The laboratory will supply you with a copy of the form when the analysis is complete. In some cases, the lab will request a repeat sample from the same site to verify results. Such repeat samples will be designated as "check" samples, and you may be requested to collect two bacteria samples for total and fecal coliform analysis or to collect two samples from within the same system to determine whether the problem is with the water supply or just with one tap. Please collect these samples on your next scheduled sampling days.

Sampling Techniques

1. Handpumps

Be sure that you have enough ice and an insulated cooler large enough to hold all your samples. Block ice is preferable to cubes as it does not melt as quickly and will keep your samples cold longer.

Disinfect the tap or pipe from which you are sampling to be sure that local contamination will not give a false result. Flush the tap thoroughly. Check for total chlorine residual. If any chlorine is present, continue flushing until a chlorine residual of 0.0 is read. The minimum flushing time for a good sample is five minutes.

Fill the chemical bottle first. This bottle may be rinsed with the sample if desired. Fill the bottle completely, there should be no remaining air space. Next fill the bacteria bottle. This bottle has been pre-sterilized and should not be rinsed. Collect the sample as quickly as possible to avoid contaminating the bottle, but be careful to avoid splashing. Do not touch the inside of the lid or bottle, or the threads. Fill bacteria bottle only to line around shoulder of bottle. Stand both bottles upright in ice box, wedging them in. The bottles for one water source should have matching numbers.

Record bottle numbers, date, time, name, and place of sampling. Run field tests and record results. Record any comments, such as: standing water at handpump, sample collected as a special due to illness in the village, residents complain of high iron content and are not using water.

PUBLIC HEALTH BUREAU

BELIZE WATER QUALITY LAB

Sample Collection

Bottle No. _____ Sampler Name _____

Date of collection _____ Time _____ a.m p.m.

Sample Type: Treated _____ Untreated _____

Routine _____ Check Sample _____ Special

Location: District _____ Village _____

Street _____

Tap Identification _____

Preserved with: Ice _____ Sodium thiosulfate _____

Field Results: pH _____ SU Hardness _____ gr/gal _____ Iron _____ mg/l

Free chlorine _____ mg/l Total chlcrine _____ mg/l

Comments _____

_____

_____

LAB RESULTS

Date Received _____ Time _____ a.m. p.m. _____ Temp. _____

Total Coliform: mls water filtered _____

Presumptive _____ colonies/100 ml Confirmed _____

Fecal Coliform: mls water filtered _____ _____ colonies/100 ml

Alkalinity _____ mg/l
Conductivity _____ umhos/cm
Chloride _____ mg/l
Fluoride _____ mg/l

Nitrates _____ mg/l
Sulfates _____ mg/l
Turbidity _____ mg/l

_____

_____

_____

Lab Analyst _____

Transportation of the samples is as critical as the sampling itself. Make sure bottles remain upright during transport, and that the entire ice box is kept at 4oC or colder. as ice melts, drain water from cooler.

All samples must arrive at the laboratory within 24 hours of collection. To allow time for analysis, samples must arrive no later than 4 pm and no earlier then 8 am. No samples will be accepted on Fridays. Samples must be at 4°C or colder upon arrival at the laboratory, and each set must be accompanied by a report form. When you leave a set of samples at the lab, you will be given the same number of clean bottles and reporting forms if possible.

2. Small Water Systems

The first step in sampling a small water system s to get a map of the system and determine good sampling sites. The following page is a sample distribution system map. The best sites for routine sampling are those midway between the source and the end of the line, which are accessible at all times. Public buildings are good choices, especially those with high water usage, such as schools. Several alternate sites should be chosen in case one becomes unsuitable. Alternate sites occasionally to include a site near the end of a line.

Make sure to identify the source completely when filling out report. Note the building address, location of room where sample was collected, and which tap was used. (Ex. medical laboratory building, 3rd floor water lab, tap on north side of building.)

Choose a tap which is clean, does not leak, and does not swivel. Remove aerator and disinfect tap with chlorine solution. Flush thoroughly. Run free and total chlorine residuals and record. Residuals need not be 0.0.

Fill bottles as for handpump sampling, but be sure to use a bottle with a number beginning with a "T". These bacteria bottles contain sodium thiosulfate to neutralize any chlorine in the sample.

Run remaining field tests and transport samples to the lab within 24 hours, at or below 4°C.

3. Vats

Special sampling requests may require the sampling of vats or cisterns. Where the vats are connected to internal plumbing, the sampling method is the same as for small water systems, except that no free chlorine test is necessary.

When a vat is not connected to a plumbing system, the sample bottle must be dipped directly into the vat and filled. The sampler should first wash his hands, and should dip the bottle under the surface of the water to fill it. Care must be taken to avoid scraping the bottom or sides of vat with the bottle. For bacteria samples, the excess water is poured out (to the line) before the cap is replaced. There will seldom be a need to run any field tests on water from a vat, or to take a

chemical sample. Transportation and reporting are the same as for routine samples. The sampler should wash his hands as soon as possible after sampling.

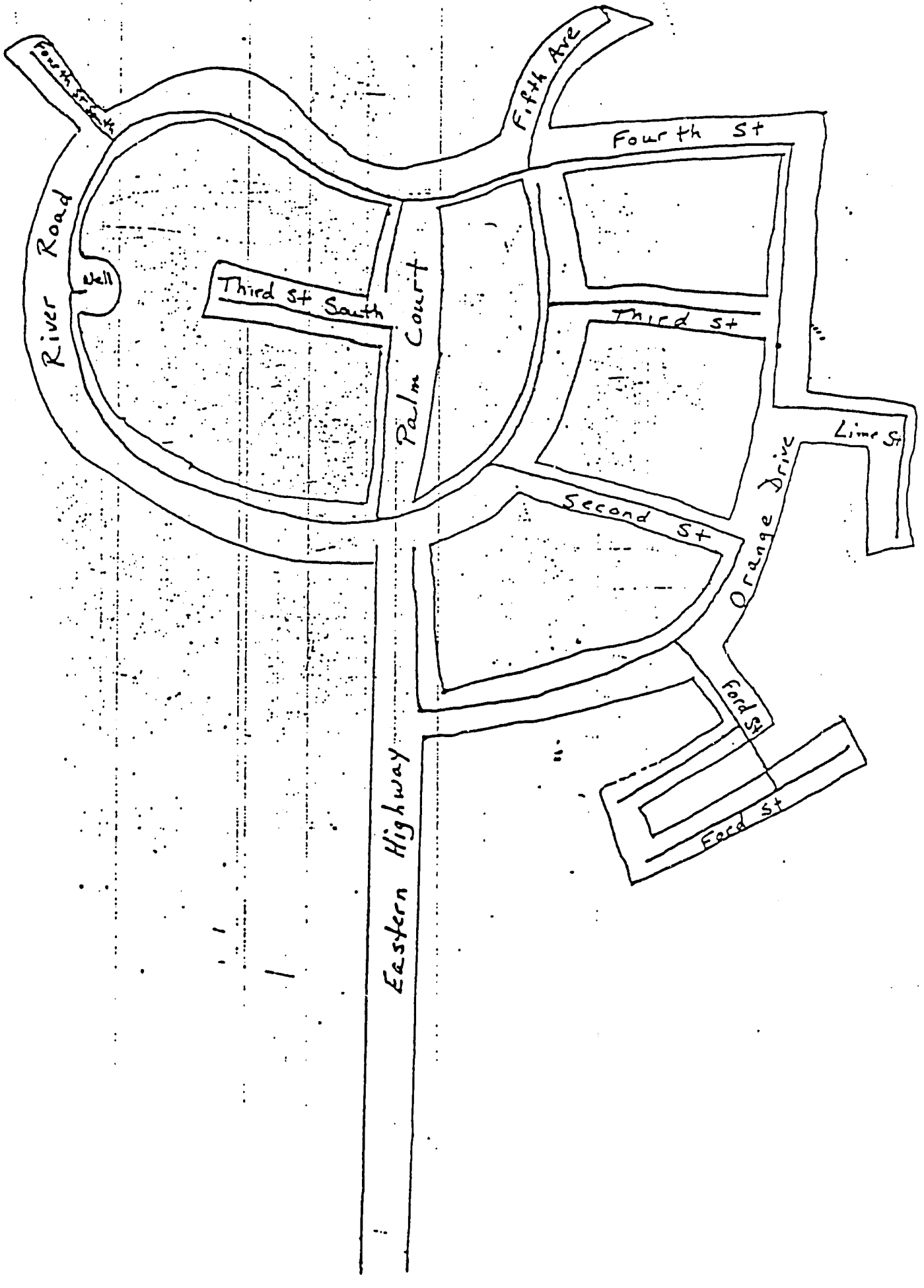
4. River Water

To collect samples from a creek or river, the sample bottle is dipped into the water with its mouth facing upstream. The bottle is pulled through the water in an upstream direction to fill it. Chemical tests, including field tests of pH, iron, and hardness, should be run to compare the water quality to that of area well supplies. The sampler may wish to use rubber gloves to avoid skin contact with questionable water, and in any case must be sure to wash his hands as soon as possible, avoiding any contact with eyes, mouth, nose or ears in the meantime.

5. Spring Water

Springs may be a good source of water if they are well protected from contamination at the source and at the point of use. Without proper protection, the water quality will be inconsistent and should not be used for drinking. The sample is collected by dipping the bottle or by holding it under a running spring, as appropriate.

Anyone drinking water from a vat, river or unprotected spring should be strongly encouraged to boil the water for ten minutes before drinking it or cooking with it. The quality of water from such an unprotected source cannot be predicted on the basis of one or even several samples showing good water quality. The questionable nature of the water from such sources must be impressed upon people who request samples.


Fourth St South
Fifth Ave
Four th St
River Road
Well
Third St South
Palm Court
Third St
Lime St
Second St
Orange Drive
Ford St
Ford St
Eastern Highway

Public Health Bureau
Belize Water Quality Lab
March 16, 1987

Dear

Some of the sampling and laboratory procedures described in our sampling workshop must be revised to accommodate short term limitation in the laboratory and further information received on current and anticipated wells in each district. A modified sampling schedule for your district in enclosed. In case of conflicting information received on a village, the largest possible number of present or future wells was assumed, so that you may have fewer samples to collect than are indicated on your schedule. Your schedule has been arranged to coordinate with the National Water Quality Laboratory and the schedules of Public Health Inspectors in other districts. If you need to change a sampling day, or wish to collect more than two extra samples on your scheduled day, please call Ms. Beverly Clare at the laboratory to make sure that she can accommodate these changes. Her phone numbers are 44095 and 45212.

Ms. Clare will mail you copies of all sample results from your district approximately one week after samples are delivered to her. This should allow you to arrange for check samples. Routine procedures for check samples will be as follows:

1. Water sources which contain more than 20 total coliform colonies per 100 ml will be resampled.

2. The best time to resample is on your next scheduled sampling day.

3. Two bacteria bottles will be collected from the same sampling point so that both total and fecal coliform tests can be run.

4. In case of a positive coliform sample at a rudimentary system, check samples will be taken at the original sampling location (same tap), and at another location which is as close as possible to the actual source of water. The person or authority in charge of water treatment in the area should be notified immediately.

5. Chemical samples are not necessary when check samples are taken unless requested by the laboratory.

Currently the laboratory is unable to run tests for total coliform and fecal coliform on the same day. Until you are notified otherwise, check samples are best collected on the days set aside for them on your schedule. On these days, fecal coliform tests will be run, total coliform tests will not, and only one bacteria bottle will be needed. Ms. Clare will notify you when the lab is ready to follow the routine procedures.

Ms. Clare will notify you when the lab is ready to follow the routine procedures.

The dates printed on your schedule are conditional upon the receipt of more sampling bottles, ice boxes, and reagents. It is likely that you will not have the equipment necessary to begin sampling on your first scheduled day. Ms. Clare will notify you when all necessary equipment has been received, and you will begin sampling on your next scheduled sampling day. Begin with run A, proceed to run B, and so on.

Several of you were unsure about your ability to procure transportation on your scheduled sampling days. If you are unable to make satisfactory arrangements, Mr. Fred Smith will attempt to make these arrangements with the coordinator or public health doctor in your district. If you need his assistance, please call him at 7170 or 7176.

I appreciate having had the opportunity to work with all of you and wish you success in your new drinking water quality testing program.

Sincerely,

Patsy Allen
Water Quality Lab

SAMPLING RUNS - BELIZE DISTRICT

Run A	# of samples
Maskall	2
St. Ann's	2
Corozalito	4
Santana	6
Luck Strike	1

Run B	
La Democracia	1
Scotland Halfmoon	3
Bermudian Landing	2
Flowers Bank	2
Isabella Bank	3
Willows Bank	5

Run C	
Crooked Tree	3
Biscayene Village	2
Sand Hill	10

Run D
check samples

Run E	
Boston	5
Rockstone Pond	3
Maskall	7

Run F	
Northern Hwy, mi. 16	1
Northern Hwy, mi. 13	1
Northern Hwy, mi. 10 1/2	1
Double Head Cabbage	12

Run G	
Maksall	5
Rockstone Pond	4
Chichiquate (Chicago)	2
Salt Creek	3

Run H
check samples

Run I	
Camp Oakley	1
St. Paul's Bank	6
Burrel Boom Village	7
Burrel Boom Road	1

Run J	
Ladyville	12 (R)
Freetown - Sibun	

Run K	
Maskall	1 (R)
St. Ann's	4
Corozalito	1
Santana	5
Rockstone Pond	4

Run L
check samples

Run M	
St. Ann's	5
Lucky Strike	4
Boston	4

Run N	
Crooked Tree	8
Rockstone Pond	6

Run O	
Scotland Halfmoon	2
Flowers Bank	5
Bermudian Landing	5
La Democracia	4

Run P
check samples

Sampling Dates
March 25, 1987
April 21
May 11
June 1
June 22
July 13
August 3
August 24
September 24
September 14
October 5
October 26
November 16
December 7
December 28
January 18. 1988
February 8
March 1

Sampling Runs, Belize District. Run J completes sampling for all currently existing wells in Belize district. Runs K through P should be scheduled as the new systems are completed.

SAMPLING RUNS - THE CAYES

Run A	# of samples	Sampling Dates
San Pedro	6 (R)	June 27, 2987
Caye Chapel	2 (R)	August 12
		December 16
Run B		January 13, 1988
check samples		

Because of the large number of people using these water systems, each run will be done twice a year.

SAMPLING RUNS - CAYO DISTRICT

Run A	# of samples	Sampling Dates
Benque Viejo	1 (R)	September 9, 1987
San Jose Succotz	1 (R)	October 7
San Antonio	3	November 25
San Ignacio	1 (R)	December 9
Bullet Tree	3	January 6. 1988
Central Farm	1 (R)	February 17
Young Gal	1	March 10
Esperanza	1 (R)	March 22
Red Creek	1 (R)	

Run D completes sampling for all existing wells in Cayo district. Runs E through G should be scheduled as the systems are completed.

Run B	
Unitedville	7
Georgeville	1
Blackman Eddy	3
Ontario	3
Chiquebul Road	1

Run C	
Carmelita	1
Valley of Peace	1
Roaring Creek	6
Teakettle	6

Run D	
St. Margaret	1
Las Flores	1
Camalotte	1 (R)
Cotton Tree	1
Wester Hwy mi. 32	1
check samples	

Run E	
San Antonio	1 (R)
Cristo Rey	3
Santa Familia	3
Unitedville	2
Georgeville	1
Blackman Eddy	4
Ontario	3

Run F	
Teakettle	2
Valley of Peace	5
Las Flores	4
St. Margaret	3

Run G	
check samples	

SAMPLING RUNS - COROZAL DISTRICT

Run A	# of samples
San Jacquin	1 (R)
Libertad	1 (R)
Carolina	5
Ranchito	8
Run B	
Caledonia	1
Buena Vista	4
San Roman	6
Santa Clera	3
Run C	
Chunox	5
Progresso	5
Run D	
check samples	
Run E	
Xaibe	10
San Pedro	6
Run F	
Chan Chen	4
Patchachachan	13
Run G	
Yo Chen	1
Cristo Rey	11
San Narciso	3
Run H	
check samples	
Run I	
San Victor	15
Run J	
Paraiso	4
San Antonio	4
San Andres	4
Run K	
Concepcion	8
Louisville	7
Run L	
Calcutta	5
check samples	

Run M	
Chan Chen	8
San Pedro	5
Run N	
Cristo Rey/Yo Chen	11
San Pedro	2
Santa Clera/San Roman	1 (R)
Run O	
Louisville	10
Buena Vista	5
Run P	
Chunox	5
check samples	

Sampling Dates

April 4, 1987
May 6
May 27
June 17
July 8
July 29
August 19
September 30
October 21
November 4
December 2
December 21
January 20, 1988
February 10
March 3
March 24
April 7

Run L completes sampling for all existing wells in Corozal district. Runs M through P should be scheduled as the ne systems are completed.

SAMPLING RUNS - ORANGE WALK DISTRICT

Run A	# of samples	
Chan Pine Ridge Proper	6	
Chan Pine Ridge Road	2	
Belize Corzal Road	7	
Run B		
San Felipe	7	(R)
August Pine Ridge	2	
Trinidad	6	
Run C		
San Lazaro	7	(R)
Trinidad	7	
Run D		
check samples		
Run E		
Nuevos San Juan	5	
San Pueblo	9	
San Luis	5	
Run F		
Santa Marta	9	
Sketz Lagoon	1	
Carmelita New	2	
Carmelita Old	2	
Run G		
Santa Cruz		
San Antonio Rio Hondo	2	
Yo Creek	1	(R)
San Lorenzo Proper	3	
San Lorenzo Rural	1	
Run H		
check samples		
Run I		
Pal Mal	1	(R)
San Francisco	1	
Guinea Grass Proper	2	(R)
Guinea Grass Road	2	
Louisiana Farm	2	
Run J		
Trial Farm	17	
San Esteban	1	(R)

Run K		
Douglas	1	(R)
San Jose		
check samples		
Run L		
Douglas	1	
Nuevo San Juan	6	
San Luis	5	
Santa Cruz	4	
San Antonio	1	(R)
Run M		
Chan Pine Ridge	7	
Santa Marta	7	
Run N		
Trinidad	7	
check samples		

Sampling Dates

March 23, 1987
April 27
May 18
June 8
June 29
July 20
August 10
August 31
September 22
October 27
November 24
December 14
January 11, 1988
February 1
February 22

Run J completes sampling of all existing wells in Orange Walk district. Runs K through N should be scheduled as the new systems are completed.

SAMPLING RUNS - STAN CREEK DISTRICT

Run A	# of samples
Independence	1 (R)
Red Bank	2
Savana	1 (R)
Cowpen	2
Georgetown	3
Maya Mopan	2
South Stan Creek	2
Valley Rd, mi. 19	1
Valley Rd, mi. 18	1

Run B	
Valley Rd, mi. 17	1
Valley Rd, mi. 16	1
Valley Rd, mi. 15	1
San Roman	1
Santa Rosa	2
Valley Rd, mi. 11	1
Valley Rd, mi. 9	1
Cabbage Hall (Maya Center)	2
Kendall	1
Sittee River	3
Valley Rd, mi. 7	1

Run C	
Hopkins	2
Hopkins Rd.	1
Valley Rd, mi. 6	1
Valley Rd, mi. 4	1
Freshwater Creek	1
Silk Grass	4 (R)
Valle Rd. Three	3
Saree Wee	2

Run D
check samples

Run E	
Hummingbird	3
Middlesex	1
Pomona	1
PWD Quarry	3
Hope Creek	3
Melinda	1
Lynam	3

Run F	
Joe Meighan Rd.	1
Long Bank	2
San Jose Creek	2
Forest Tree Rd.	3 (R)
Santa Marta	1
Mullins River Rd.	2
Mullins River (R)	2

Run G	
Maya Center	1
Maya Mopan	1
Georgetown	2
Red Bank	4
San Roman	2
Santa Rosa	2
Hopkins	1 (R)

Run H	
Sittee River	6
check samples	

Sampling Dates
May 20, 1987
June 24
July 15
August 5
August 26
September 16
October 16
November 11
December 1
December 22

Run F completes sampling for all existing wells in Stan Creek district. Runs G and H should be scheduled as the new systems are completed.

SAMPLING RUNS - TOLEDO DISTRICT

Run A	# of samples
Santa Elena	1
Pueblo Viejo	2
Aquacate	3
Santa Theresa	2
Laguna	4
Mafredi	2
San Felipe	1

Run B	
San Miguel	3
San Pedro Col.	8
Silver Creek	4
Crique Troso	1

Run C	
Santa Anna	2
Forest Home	8
Cattle Landing	2
Elridgeville	3

Run D	
Punta Gorda Coastal Rd.	8
check samples	

Run E	
Indian Creek	2
Big Falls	10
San Marcos	1
Hacientaville	3

Run F	
San Jose	3
Crique Jute	2
Santa Elena	2
Pueblo Viejo	2
Santa Cruz	2
Jalacte	2

Run G	
San Antonio	5
Santa Theresa	1
San Pedro Col.	5
San Miguel	2
Silver Creek	1

Run H
check samples

Run I	
Indian Creek	5
Big Falls	2
Elridgeville	1
Laguna	1
San Pedro	3

Run J	
San Pedro Col.	3
San Antonio	3
San Jose	3
Santa Cruz	3
Jalacte	3

Run K	
Pueblo Viejo	4
San Antonio	4
Santa Cruz	3
Santa Elena	1

Run L
check samples

Run M	
Nimu Punit	3
San Antonio	4
San Jose	6

Sampling Dates
April 29, 1987
May 13
May 25
June 15
July 27
August 17
September 7
September 28
October 19
November 9
November 30
January 4
January 25
February 15

Run E completes sampling for all existing wells in Toledo district. Runs F through M should be scheduled as the new systems are completed.