Research Project Technical Completion Report
OWRR Project No. A-060-Oklahoma

AUTOMATED POND WATER TREATMENT UNIT

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AUTOMATED POND WATER TREATMENT UNIT

Objectives and Extent of Achievement of the Objectives:

The objectives of the study were:

1. To develop an outdoor pond water treatment unit.
2. Evaluate the performance of the unit on a typical farmstead using pond water as a domestic source.

Both objectives were achieved satisfactorily. An automated pond water treatment unit was designed, constructed and evaluated. It was designed as an exterior unit to be located in the vicinity of a pond or lake. The unit was self-contained and furnished filtered and chlorinated water under pressure.

The unit was located on a small lake and tests were conducted for evaluation. Mechanically, the unit performed very well. However, the unit did not perform satisfactorily in filtering the water and in the backflushing operation. Additional testing suggested other minor changes were needed. After the design was modified and changes made, the unit produced a good quality water. However, the results indicated changes which are not feasible in the present unit that should be made on future units.

Background:

Water is necessary for the continuation of life, but there are some areas which do not have a source of good quality water. This problem is sometimes solved by rural water districts, and in some instances, by the transport of water by tank truck. If a great distance exists between a source of good quality water and the point of use, these alternatives may not be economically feasible.

Another alternative is the use of a small water treatment unit to provide water from existing surface water sources. This unit might resemble municipal water treatment installations on a greatly reduced size and capacity. This unit would produce water for a few households at the most. The unit could also be used by cabins or other small recreational facilities near lakes or streams which could serve as a suitable water source.

Since lakes and ponds are the result of runoff form the surrounding watershed, the condition of the lake water is dependent on the land use to a large extent. If the land is cultivated, erosion conditions might cause the water to be quite turbid. If the land is pasture, the water would probably be less turbid.

As the water travels over the ground, there are many chances for it to be contaminated by the soil and possibly animal waste products. Bacteria may be picked up from the animal waste and possibly from the air. If undesirable constituents are present in the water source, the treatment unit must reduce the quantity of foreign material and other constituents in the finished water to values acceptable for potable water as directed by the United States Public Health Service. Recommended Standards are presented in Figure 1.

Other specifications which are important are ease in maintenance, operation and repair. The unit should be self-contained and should be weatherproofed to withstand the extremes of the weather.

Objectives:

The objectives of the research were:

1. To develop an outdoor and pond water treatment unit; and
2. To evaluate the performance of the unit on a typical household using pond water as the source.

The following table lists the drinking water standards established by the U. S. Public Health Service as of April, 1962. The Oklahoma State Department of Health recommends that these standards be followed for all public water supplies.

If a particular sample of household water does not meet the standards a recommendation may be obtained from the county health officer. Total dissolved solids in a water sample may be considerably higher than shown below and may still be safe to drink, however a recommendation should be obtained. Tests run by the Soil and Water Service Analytical Laboratory at OSU cover only a few of the major constituents. However a relatively complete list is given in the following table.

Constituent	Recommended Maximum Amount in ppm	Mandatory Limits for Rejection of Water in ppm
Total Dissolved Solids	500	
Chloride (cl)	250	
Sulphate (SO4)	250	
Iron (Fe)	.3	
Nitrates (NO_3)	45.0	
Manganese	.05	
Copper	1.0	
Magnesium	50.0	
Zinc	5.0	
Arsenic	.01	.05
Floride	1.7	3.4
Lead		.05
Selenium		.01
Silver		.05
Barium		1.0
Cadmium		.01
Chromium		.05
Cyanide		.2

pH 7.0 to 10.6

Hardness (expressed as calcium carbonate ($CaCO_3$)

Soft water	0 to 8.55 ppm*
Slightly hard water	8.55 to 60 ppm
Moderately hard water	60 to 119.7 ppm
Hard water	119.7 to 180 ppm
Very hard water	above 180 ppm

*Grains per gallon X 17.1 = ppm

Figure 1. Recommended Drinking Water Standards

Limitations:

The water treatment unit was located and tested at Ham's Lake, a SCS flood detention reservoir located about eight miles (13 kilometers) west of Stillwater, Oklahoma. The watershed for Ham's Lake is grassland so the water is usually fairly clear.

Other research is being conducted at the lake. A destratification research project is run in the summer months to evaluate the effect of destratifying a lake on the chemical and biological properties of the lake. This research should not affect the water treatment study. However, destratification of a lake in the summer in general improves the water quality in the lake. Ham's Lake is closed to the general public so very little fishing and almost no swimming occurs at the lake.

Equipment:

An automated pond water treatment unit was constructed, tested and its performance evaluated. It was designed as an exterior unit to be located in the vicinity of a pond or lake. The unit was self-contained and furnished filtered and chlorinated water under pressure. The unit was constructed following the plans shown in Figures 2 and 3. Some variations from the plans were made.

The unit consisted of a pond water pump, chlorine and alum solution containers with metering pumps, a sand filter, a time clock and electric solenoid valve for backflushing the unit, storage for treated water and a water pressure pump and pressure storage tank. The unit required an a.c. electric source.

The pond water pump was a submersible type and was floated so that the intake was about 42 inches (1.1 m) below the surface. The pump was located near the surface so that the raw water pumped would be of good quality and

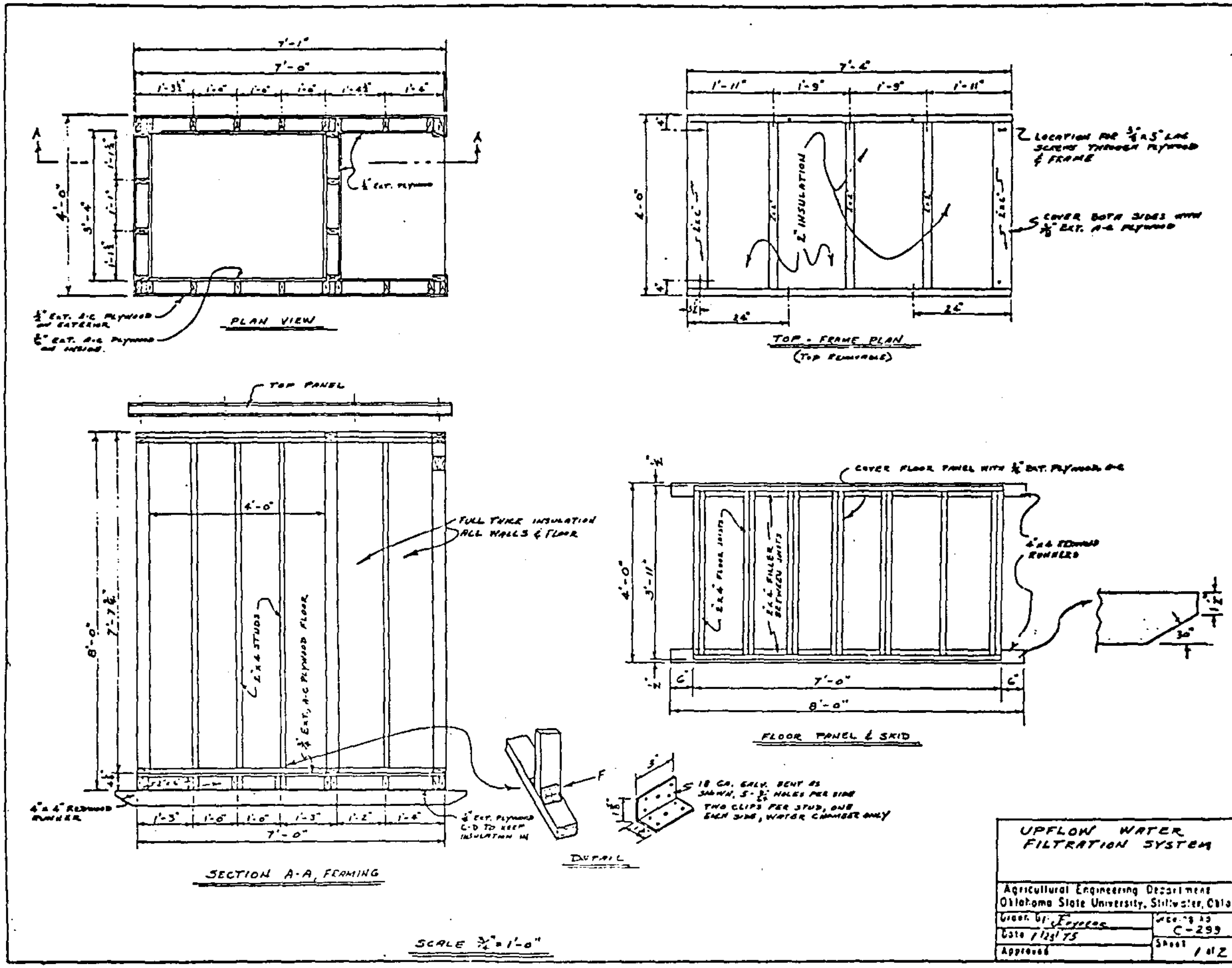

Figure 2. Construction Drawing for Water Treatment Unit

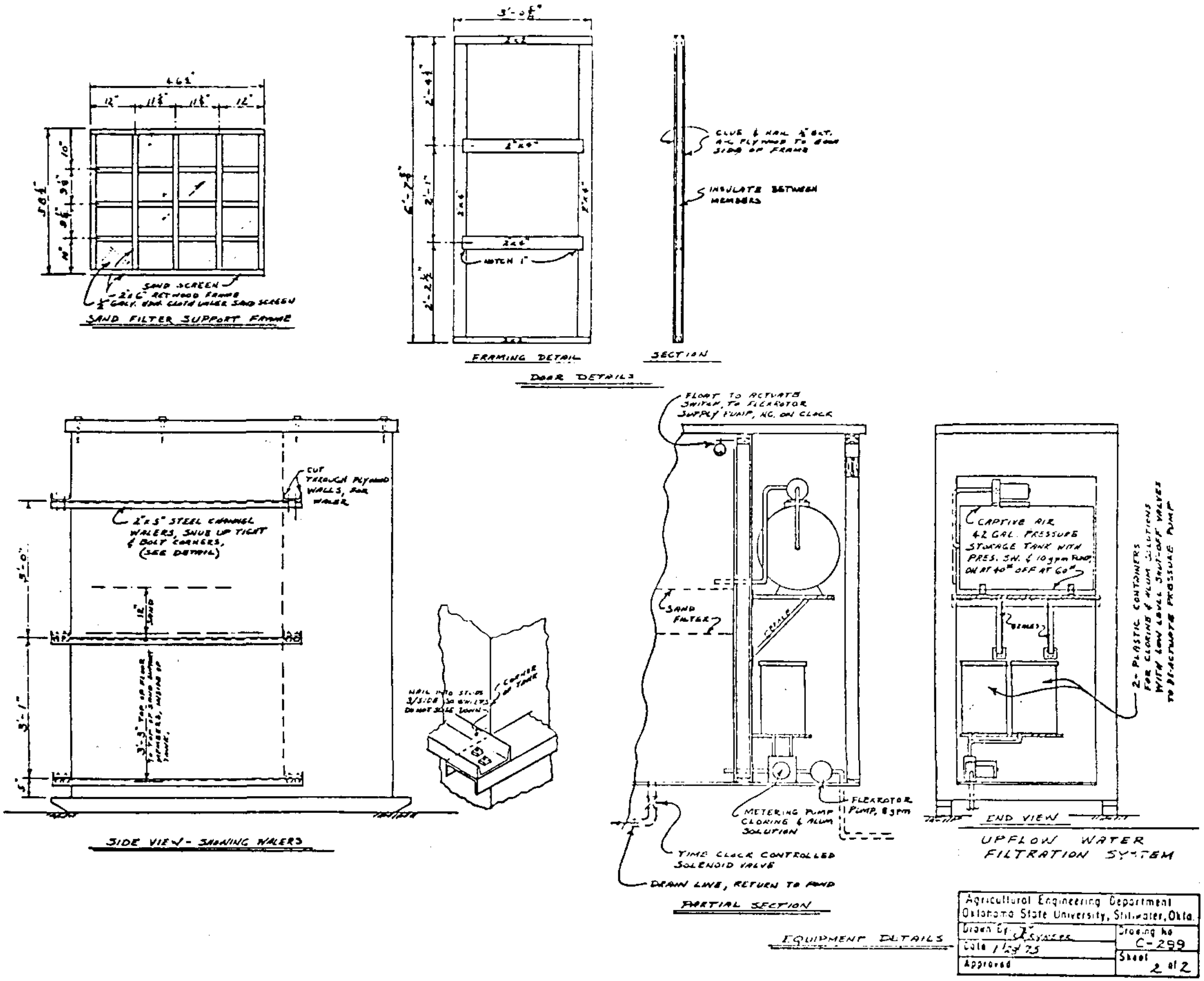

Figure 3. Construction Drawing for Water Treatment Unit.

have a high level of dissolved oxygen. The pump was located about 35 feet (10.7 m) from the shore where the water depth was about 12 feet (3.7 m). The pump had a capacity of about nine GPM (34 l/min) for these conditions.

The chlorine and alum containers hald 30 gallons (113 l) each. This should supply chlorine and alum for a minimum of two weeks even at high levels of use for the average household. The metering pumps had infinite adjustment for metering the solutions into the raw water.

The sand filter had a fine layer and a coarse layer. It was an upflow type which permitted the floc to settle out and be removed by backflushing. The sand filter was about 12 inches (0.3 m) thick. The sand was a washed, concrete type sand. One layer was sifted and the finest particles removed. The effective diameter and the uniformity coefficient of the sand layers were:

Sand	Uniformity Coefficient	D_{50} Particle Diameter, mm
Fine	0.27	0.490
Coarse	0.41	1.950

An electric solenoid valve with a time clock was used to backflush the unit to remove the sediment deposition. The unit was initially set to backflush automatically once a week at a time when no water would probably be used from the system.

The treated water storage held about 340 gallons (1286 l) between operations of the pond water pump. The water level was controlled by liquid level sensors.

The pressure pump had a capacity of about eight GPM (30 l/min) and the pressure tank had a capacity of 60 gallons (227 l).

Clocks were installed in the pressure pump and the pond water pump circuits to obtain the operating time of each of the pumps.

The only external connections to the unit were the electrical cable, the raw water line, the treated water line and the backflush line.

Construction and Installation:

The water treatment unit was constructed at the Oklahoma State University Agricultural Engineering Department Laboratory. After construction, the unit was transported to the lake on a trailer. A forklift was used to load and to set the unit in place at the lake. The unit was set on a concrete pad and was located about 150 feet (45.7 m) from the water edge and about 15 feet (4.57 m) higher than the water surface elevation.

Data Collection and Presentation:

Data taken or determined periodically included: water temperature; dissolved oxygen; conductivity; alkalinity; pH; turbidity; chlorine residual; time of operation of pumps; lake elevation; and general observations about the lake and the weather conditions. When applicable, data were determined for both raw and treated water. In addition to these data, water samples were taken and sent to the Oklahoma State Department of Health for analysis. Figures 4 and 5 are forms showing the analyses made by them. The health department checks for safety of the treated water for a domestic supply (Figure 5). Figures 6 and 7 give the results of the raw and treated water, respectively, from an analysis by the Soil and Water Service Laboratory, Agronomy Department, Oklahoma State University. These results show that for the analyses done, the water is within the standards as recommended in Figure 1.

The turbidity and chlorine residual were measured with Hach instruments. The pH was measured with a Sargent-Welch pH meter. Conductivity was measured with a Yellow Springs instrument. The temperature was measured with a mercury thermometer and the dissolved oxygen and alkalinity were determined using procedures found in Standard Methods (1).

RETURN TO: ZIP ______

NAME ______ ADDRESS ______ CITY & STATE ______

WATER QUALITY CONTROL DIVISION

ANALYSIS REQUEST AND WORK SHEET

GROUND WATER /4 /4. /4 SEC ______ T ______ N S R ______ E W SAMPLE NUMBER ______

DEPTH ______ WELL NO. ______ FORMATION ______ LABORATORY NO. ______

SURFACE WATER /4 /4 /4 SEC ______ T ______ N S R ______ E W DATE COLLECTED ___ / ___ / ___

NAME ______ LAKE ______ STREAM ______ DATE RECEIVED ___ / ___ / ___

SUPPLY FOR ______ CITY ______ CITIZEN ______ DATE COMPLETED ___ / ___ / ___

COUNTY ______ RAW ___ TREATED ___ PUBLIC ___ PRIVATE ___

SAMPLE COLLECTED BY ______ REPRESENTING ______

METHOD(S) OF PRESERVATION ______ BASIN NO. ______

PARAMETERS TO BE ANALYZED ______

Titrametric Parameters	Dilution Factor	Titrant Used ml	Titrant Factor	Average Conc. mg/l
Total Hardness				
Calcium Hardness				
"P" Alkalinity				
Total Alkalinity				
Chlorides				
Dissolved Oxygen				
Ammonia				
Organic Nitrogen				

Specialized Titrametric Parameters	Sample Size ml	Dilution Factor	Titrant Used: Sample	Titrant Used: Blank	Titrant Factor	Avera Con mg
Biochemical						
Oxygen						
Demand						
COD						

Direct Determinations: pH ______ Dissolved Solids ______ Settleable Solids ______ S.C. ______ T. Odor ______ T. Taste ______

Gravimetric Techniques	Wt. Tare + Sample mg	Weight Tare mg	Difference mg	Samp Size ml	Factor	Conc. mg/l
Total Solids						
Suspended Solids						
Volatile Solids						
Chloroform Extractable						

Colorimetric Parameters	Dilution Factor	% T	Standard Curve mg/l	Average Conc. mg/l
Sulfate				
Phenol				
Total Phosphate				
Nitrate				
Nitrite				
Ammonia				
Color				
Turbidity				
Iron				
Manganese				
Chromium + 6				
Fluoride				
Copper				

Field Tests: pH ______ Temperature ______ Chloride ______ D.O. ______

Other ______

Comments: ______

Mail Sample with this form to:
Oklahoma State Department of Health, Environmental Services
Water Quality Laboratory, N. E. 10th & Stonewall, Oklahoma City, Oklahoma 73105

ODH Form No. 818

Figure 4. Water Sample Analysis Form, Oklahoma State Department of Health

OKLAHOMA STATE DEPARTMENT OF HEALTH
DIVISION OF LABORATORIES
Oklahoma City
Branch Laboratories: Elk City, Hugo, Lawton, Muskogee

BACTERIOLOGICAL WATER ANALYSIS

ODH Form 407 Rev. 10-69

FILL OUT COMPLETELY DOWN TO BLACK LINE

☐ PRIVATE
☐ NON-PRIVATE

SYSTEM CLASS
- ☐ Municipal Supply
- ☐ Rural Water Supply
- ☐ Dairy
- ☐ Restaurant, Park School, Motel
- ☐ Individual

SAMPLE CLASS
- ☐ Drinking Water
- ☐ Line Test (New or Repair)
- ☐ Ice
- ☐ Swimming Pool
- ☐ Raw Water
- ☐ Waste Water

OWNERSHIP ______ (NAME OF CITY, CORPORATION, DISTRICT, INDIVIDUAL, ETC.)

SAMPLE FROM
- Town ______
- County ______
- Collection Point ______

Send Reports to:
Name Joan K. Leavitt, M.D., Director
Payne County ~~Health Department~~
Address P. O. Box 471
City Stillwater, Oklahoma, Okla 74074 ZIP

Date Collected

Collector's Initials

Water for analysis is: ☐ Treated (ppm Cl_2 ____) or ☐ Untreated
Source of supply: ☐ Well ☐ Lake or Stream ☐ Cistern

	LABORATORY REPORT		
	24 HOURS	48 HOURS	LABORATORY NUMBER
Lactose Broth			
B.G.B. Broth			DATE RECEIVED
EMB Agar			DATE REPORTED
Lactose and Agar Slant			
Coliform Tubes Confirmed per five planted			
Total Coliform per 100 ml	☐ MPN	☐ MF	
Fecal Coliform per 100 ml	☐ MPN	☐ MF	
Standard Plate Count (35 degrees C)			
Other			

Coliform bacteria ☐ Found ☐ Not Found

Drinking water, to be bacteriologically safe, should be free from coliform bacteria. Assistance in interpretation of this report may be obtained from your county health department, county agent, or the Environmental Health Service of the Oklahoma State Department of Health.

Figure 5. Bacteriological Water Analysis Form, Oklahoma State Department of Health

HOUSEHOLD WATER ANALYSIS REPORT   № 767 BH

Soil and Water Service Laboratory
Agronomy Department

Oklahoma State University Extension
Stillwater, Oklahoma 74074

DATE RECEIVED June 8, 1976   DATE REPORTED June 11, 1976

NAME Larry Jarrell   LAB NO. 312B

ADDRESS Agriculture Engineer Department, OSU Campus   SAMPLE IDENTIFICATION Lake, Raw sample

Cost $10.00

Constituent	ppm*	epm**	Constituent	ppm*	epm**
Calcium	31.9	1.6	Chlorides	30.2	0.9
Magnesium	21.5	1.8	Sulphates	36.0	0.8
Sodium	23.0	1.0	Nitrates	< 4.4	< 0.1

Total Dissolved Solids (ppm)* 293.7   pH 8.5

Hardness expressed as $CaCO_3$ (ppm)* 170.0

For human consumption refer to the enclosed sheet on recommended drinking water standard as established by the U.S. Public Health Service.

NOTE: This analysis does not determine whether or not the water is bacteriologically safe for human use. A sterile sample bottle should be obtained from your County Sanitarian and a water sample sent to the Oklahoma State Health Department for a bacterial analysis.

COMMENTS:
Please refer to the enclosed memographed sheet for interpretation of the results shown above.

*Parts per million
**Equivalents per million

County Copy
Accounting Copy
Office Copy
Customer Copy

Raymond Ward

Raymond Ward
Extension Soil Specialist

Figure 6. Household Water Analysis Report, Raw Water Sample, by the Soil and Water Service Laboratory, Agronomy Department, OSU.

HOUSEHOLD WATER ANALYSIS REPORT

Nº 768 BH

Soil and Water Service Laboratory
Agronomy Department

Oklahoma State University Extension
Stillwater, Oklahoma 74074

DATE RECEIVED June 8, 1976 DATE REPORTED June 11, 1976

NAME Larry Jarrell LAB NO. 313B

ADDRESS Agriculture Engineer Department, OSU Campus SAMPLE IDENTIFICATION filter treated

Cost $10.00

Constituent	ppm*	epm**	Constituent	ppm*	epm**
Calcium	32.5	1.6	Chlorides	24.9	0.7
Magnesium	21.5	1.8	Sulphates	66.0	1.4
Sodium	27.0	1.2	Nitrates	< 4.4	< 0.1

Total Dissolved Solids (ppm)* 330.0 pH 8.2

Hardness expressed as $CaCO_3$ (ppm)* 170.0

For human consumption refer to the enclosed sheet on recommended drinking water standard as established by the U.S. Public Health Service.

NOTE: This analysis does not determine whether or not the water is bacteriologically safe for human use. A sterile sample bottle should be obtained from your County Sanitarian and a water sample sent to the Oklahoma State Health Department for a bacterial analysis.

COMMENTS:
Please refer to the enclosed memographed sheet for interpretation of the results.

*Parts per million
**Equivalents per million

County Copy
Accounting Copy
Office Copy
Customer Copy

Raymond Ward

Raymond Ward
Extension Soil Specialist

Figure 7. Household Water Analysis Report, Filter Water Sample, by the Soil and Water Service Laboratory, Agronomy Department, OSU.

Table I presents data obtained after all modifications and changes had been made to the unit.

<u>Operation of the Unit and Results</u>:

The Oklahoma State University water treatment plant was consulted to obtain initial chlorine and alum concentration levels. These concentrations were four ppm (four mg/l) and 20 ppm (20 mg/l) respectively. This alum concentration was used but the chlorine concentration was reduced to two ppm (two mg/l) since the water treatment plant had some destruction of chlorine by exposure to sunlight which did not occur with the water treatment unit.

Problems were encountered from the beginning. Excessive leakage of water occurred from the water chamber. Also, the treated water was very turbid. In fact, the treated water appeared more turbid than the raw water. The poor quality water may have been due in part to the suspension of fine particles that were removed from the sand filter. However, later results showed that this was probably not the cause for the high turbidity of the treated water. The major cause was probably due to the channeling that occurred through the filter. Channeling is the flowing of water up through the filter through a small area instead of uniformly through the total filter area. If the water flowed uniformly through the filter, the velocity was about 0.08 feet/sec (0.025 m/sec). This is equivalent to 0.6 GPM per square foot of filter area (2.11 l/min per square meter). At these flows the floc would not penetrate the filter sand. However, with channeling, the velocities may be many times the normal velocities and these would permit the floc to pass through the filter sand and into the treated water storage area resulting in very turbid water.

Because of these problems, the sand filter material was removed to inspect the water chamber and to make changes. The excessive leakage was

TABLE I. Data from Ham's Lake

Date	Temperature Air °C	Temperature Inlet °C	Temperature Filter °C	Conductivity Raw µmho/cm	Conductivity Filter µmho/cm	D.O. Raw mg/l	D.O. Filter mg/l	pH Raw	pH Filter	Turbidity Raw NTU	Turbidity Filter NTU	Total Alk. Raw mg/l $CaCO_3$	Total Alk. Filter mg/l $CaCO_3$	Chlorine Residual ppm mg/l	Flow To House gpm (1)
6-2	30.5	24.5	22.5	-	-	-	-	8.5	7.5	7.0	6.7	-	-	-	
6-3	33.0	25.6	26.0	-	-	8.5	7.7	8.7	7.6	6.1	1.1	-	-	-	
6-4	29.5	24.5	25.5	477	572	8.3	8.5	8.7	7.5	8.4	2.8	-	-	-	
6-7	29.0	24.0	24.0	452	485	7.5	7.5	8.3	7.1	7.0	3.4	-	-	1.8	0.96 (3.63)
6-8	30.0	26.8	25.0	448	491	7.7	7.1	8.7	7.5	4.0	2.5	-	-	-	
6-9	31.5	26.0	25.0	403	518	7.8	7.1	8.5	7.4	4.8	3.6	-	-	-	
6-11	32.0	25.5	27.0	565	482	5.5	6.5	8.5	7.5	7.1	4.1	100	169	-	
6-12	32.0	26.0	26.3	424	464	6.7	7.1	8.6	7.7	7.5	3.3	116	106	-	1.58 (5.98)
6-14	26.0	25.5	26.0	488	537	6.5	6.8	8.3	7.4	8.0	4.8	94	79	-	

caused by the sagging of the floor between the bottom supports. The original design was not rigid enough to support the load of water. The maximum weight of water contained in the unit was about 5500 pounds (2495 kg).

The water chamber floor was reinforced and the cracks sealed. Bands were placed around the outside of the water chamber at three locations near the bottom to assist the unit in support against the lateral pressures caused by the water load.

A tee fitting was placed on the end of the raw water inlet line to split the entering raw water and reduce the velocity of the water entering the chamber. It was hoped this would stop the channeling action through the filter.

The sand filter was replaced and the unit was put back into operation. The unit operated for a time with varying degrees of success, but the results were never completely satisfactory. After four or five weeks the filter began channeling again resulting in turbid water in the treated water storage area.

A problem also occurred with backflushing. The solenoid valve, a globe-type valve, restricted the backflush flow too much. Thus, it was removed and a manually operated gate valve was installed. This improved the backflushing some, but it now had to be done manually. This is not a severe limitation as the unit can be backflushed every two or three weeks when the chlorine and alum solutions are prepared.

The sand filter was removed again and a four-fingered manifold installed on the raw water inlet line to further reduce the velocity of the entering raw water. The manifold extended the length and width of the water chamber cross-section. One-half inch (1.27 cm) holes were evenly spaced along the length of each finger to distribute the entering water uniformly over the entire water chamber. Twenty-seven holes were used and the velocity of flow from each hole was about 0.6 foot/sec. (0.18 m/sec).

The unit had been backflushed just prior to the removal of the sand. However, there was a large enough sediment deposition around the backflushing intake manifold to obstruct the backflush flow. In an attempt to solve this, pressurized water was used to stir the sediment deposition and force the material into suspension. With the sediment material in suspension, a satisfactory removal of the material should occur with backflushing.

The sand filter was again replaced but before the unit was put back into operation, a jar test was run on the raw water. The test indicated that the 20 ppm (20 mg/l) alum concentration being used was too low. The tests indicated that 100 to 125 ppm (100 to 125 mg/l) was needed for optimum floculation of the raw water. Thus, an alum concentration of 100 ppm (100 mg/l) was used.

After these adjustments and changes, the unit was put back into operation. From the standpoint of turbidity, the unit then performed satisfactorily. The treated water appeared to be of very good quality.

<u>Summary and Conclusions</u>:

This project was initiated to develop an outdoor pond water treatment unit and to evaluate the performance of this unit on a typical household using pond or lake water as the source.

An automated pond water treatment unit was designed, constructed and evaluated. It was located and tested at Ham's Lake, a SCS flood detention reservoir that usually had fairly clear water. Initial tests showed that the unit was not filtering the water properly and indicated needed modifications to improve the performance of the unit. These modifications and changes were made. As additional tests were run, other changes were noted that would improve performance of the unit.

The unit is operating satisfactorily and apparently producing a good quality water. However, the evaluation of the unit and the results point out changes that should be made on future units which are not feasible on the present unit. A metal tank should be tried to replace the wooden unit for the water storage. The bottom of the tank should be sloped some way to aid in the sediment removal when backflushing. If the sand filter was restrained at the top, this might stop the channeling action since the sand particles, when channeling, appear to be in suspension and displaced slightly upward. Also, an artificial filter material should be tested to compare its performance with the concrete sand.

References:

1. ____________________. 1971. Standard Methods for the Examination of Water and Wastewater. 13th Edition, Washington, D.C., American Public Health Association.