# Fresh Ideas for Fresh Water: Using Innovative Technology to Obtain High-Quality Drinking Water from Lake Okeechobee

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The Okeechobee Utility Authority (OUA) Water Treatment Plant was originally constructed in 1926. The plant was last expanded in 1992, and the treatment process included aeration, coagulation, flocculation, sedimentation, pH adjustment, filtration, and chloramime disinfection. In the year 2000, the plant reached 80 percent of its permitted capacity of 3.2 million gallons per day (MGD) and thus needed to be expanded.

The recent expansion and modification increased plant capacity to 5.0 MGD. The age of the plant and the surrounding facilities restricted the amount of space available for expansion, and the new design utilized a limited footprint. Figure 1 shows the plant site and the new treatment processes (outlined in red) that were constructed on the existing property while still keeping the existing plant online.

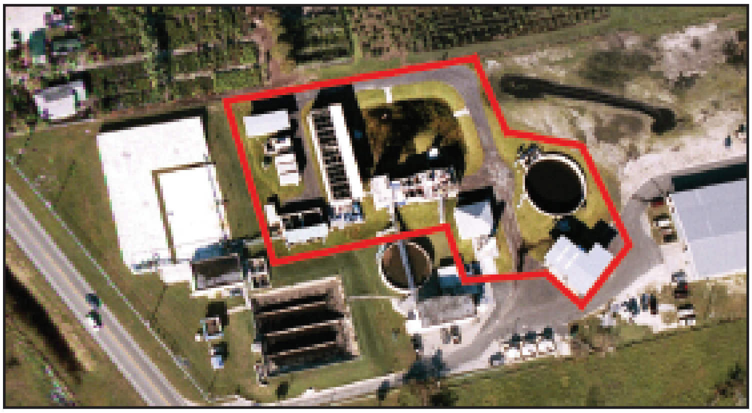

Figure 1: New Water Treatment Plant Facilities

## Expansion Options

### Source Water

The three important factors to consider when choosing a potable water source are availability, quality, and cost. The OUA had the option of meeting future demand by utilizing groundwater from either the surficial or Floridan aquifers, or by using surface water from Lake Okeechobee. Lake Okeechobee provides a reliable, adequate quantity of source water and is a Class I water, meaning it is suitable as a potable water source.

The small amount of head loss associated with pumping from the lake makes surface water cheaper to pump than groundwater, but surface water is typically more contaminated than groundwater. Major contaminants include microbes such as blue-green algae and bacteria, turbidity, and various minerals.

Turbidity, total hardness, odor, and color create the greatest concern in Lake Okeechobee. Harmful algal blooms and the varying water quality also make the lake water difficult to treat.

In Okeechobee, groundwater is not as readily available as surface water, and it can have high concentrations of iron, manganese, and hydrogen sulfide. It is also more expensive to pump because of the high head pressure it must overcome, although it is typically cleaner with a lower bacteria count and has a more uniform quality than surface water. Based on the comparison of the two alternatives for source water for the expansion, surface water from Lake Okeechobee was chosen as the most viable option.

### Clarification Options

Several different options were investigated for primary clarification including the Actiflo® system. Actiflo is a microsand ballasted coagulation/flocculation, settling water treatment process that was evaluated because of its small footprint and ability to remove turbidity, algae, cryptosporidium, and other undesirable water contaminants. This was selected as the preferred option, and a two-week trial was performed at the OUA water treatment plant.

The first week was spent identifying the type and dosage of coagulant and polymer needed. The second week was used to gather data that could be compared against the results of the existing treatment process. The pilot test results showed that a feed rate of 0.45 milligrams per liter (mg/l) of polymer, 95 mg/l of alum coagulant, and 105 mg/l of coagulant produced a settled water turbidity of 0.45 to 0.48 NTU.

The pilot study also analyzed the removal of Total Organic Carbons (TOC). EPA guidelines state that TOC removal must be at least 40 percent when, in the case of Lake Okeechobee, the source water contains a TOC greater than 8 mg/L and the alkalinity is between 60 and 120 mg/L. The Actiflo process consistently removed at least 44 percent of the TOCs.

The study also investigated the Trihalomethane formation potential ($THM_{fp}$). The study found that the process removed an average of 74% of the $THM_{fp}$ while using 21 percent less alum than the existing clarification process.

Algae samples were also collected to aid in the evaluation of phytoplankton and potentially toxigenic blue-green algae (Cyanobacteria). It was determined that the Actiflo process removed greater than 99 percent of the phytoplankton and 95 percent of the toxigenic algae. See Table 1 for more detailed information regarding the effectiveness of Actiflo.

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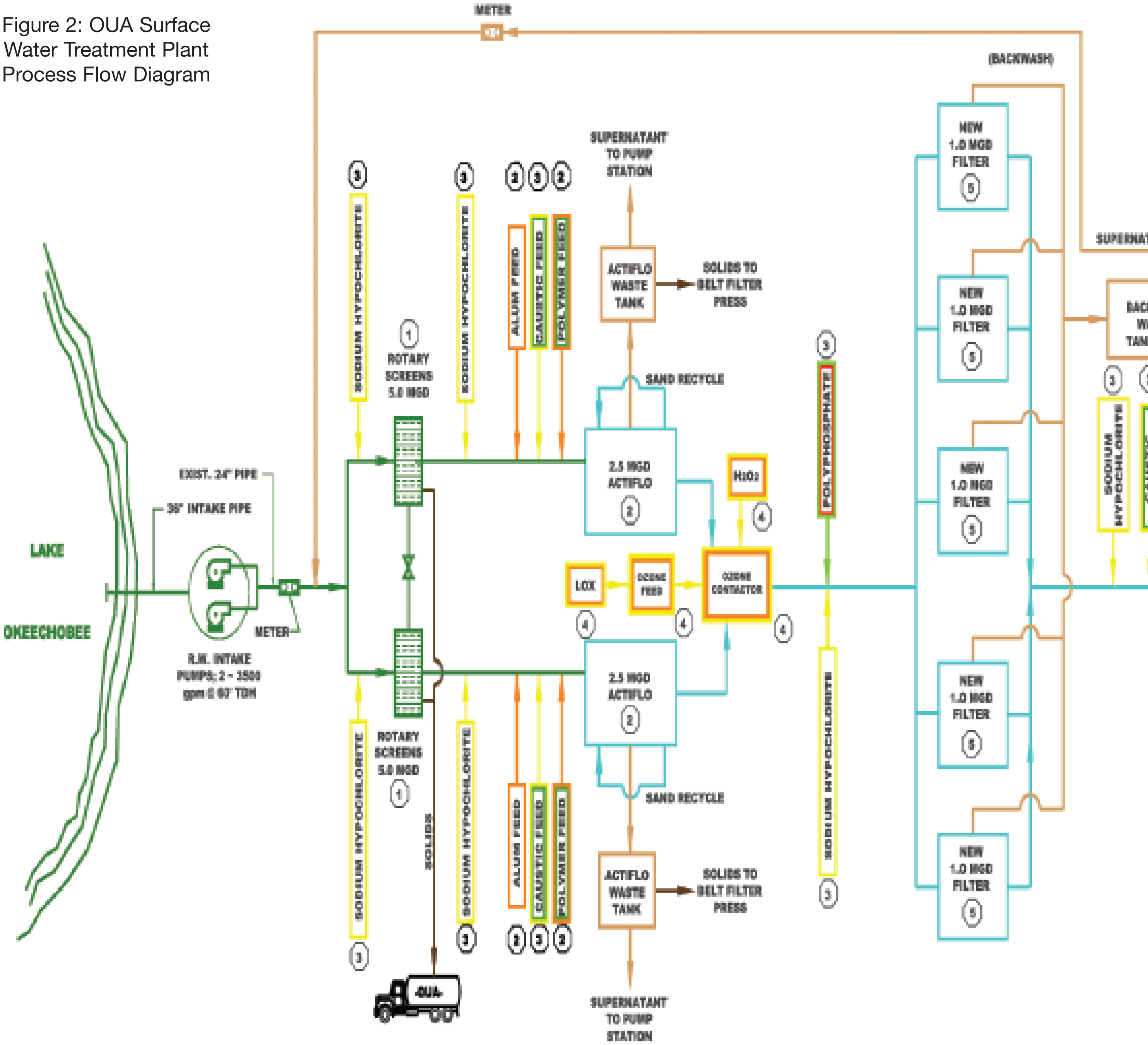
| Algae | Lake units/ml | Actiflo Effluent units/ml | Filter Effluent units/ml |
|---|---|---|---|
| Phytoplankton | 38,753 | 125 | 63 |
| Toxigenic Cyanobacteria | 6 - 100 | < 1 - 4.3 | < 1 - 4.3 |

TABLE 1 - Effectiveness of Actiflo ® in Removing Algae

Figure 2: OUA Surface Water Treatment Plant Process Flow Diagram



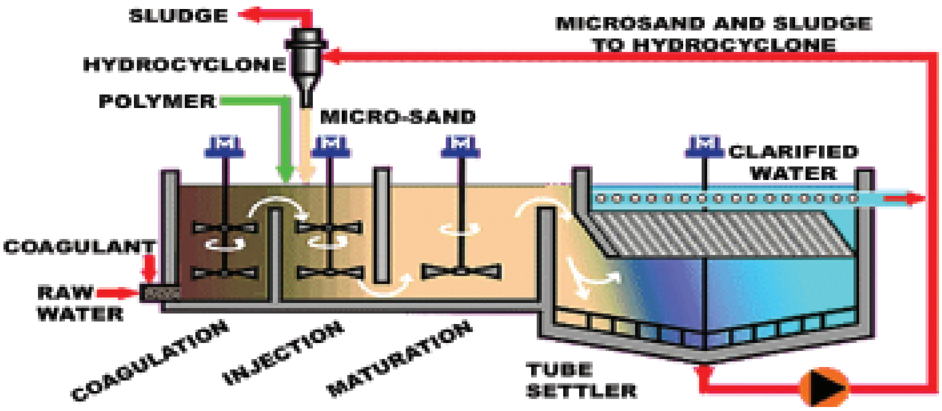


Figure 3: Actiflo® Clarification Process

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## *Selected Design*

The preliminary engineering, which consisted of site visits, pilot studies, and research, resulted in an innovative design for a surface water treatment plant. This design combines several processes to compensate for the limited amount of space and to remove contaminates associated with surface water.

These processes include rotary screening, Actiflo clarification, chemical addition, peroxone disinfection, and filtration (Figure 2). This combination of Actiflo clarification and peroxone disinfection is a first in the treatment of surface water in Florida.

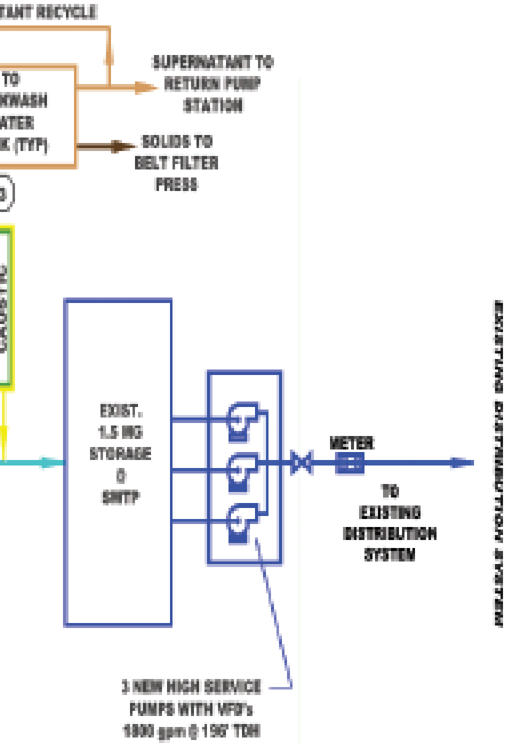

Table 2: Polymer Use in the Actiflo System

| Month | Average Treated Water (MG) | Average Pounds Used | Average Dosage (mg/L) |
|---|---|---|---|
| Month 1 | 1.41 | 5.50 | 0.45 |
| Month 2 | 1.40 | 5.60 | 0.46 |
| Month 3 | 1.27 | 5.50 | 0.55 |
| Month 4 | 1.20 | 4.60 | 0.45 |
| Month 5 | 1.42 | 5.90 | 0.50 |
| **Average** | **1.34** | **5.42** | **0.48** |

Table 3: Actiflo Performance

| Month | Average Raw Water Turbidity (NTU) | Average Settled Water Turbidity (NTU) | Percent Removal |
|---|---|---|---|
| Month 1 | 48.96 | 0.26 | 99.47% |
| Month 2 | 51.44 | 0.35 | 99.32% |
| Month 3 | 24.24 | 1.11 | 95.42% |
| Month 4 | 22.37 | 0.76 | 96.60% |
| Month 5 | 46.46 | 0.81 | 98.26% |
| **Average** | **38.69** | **0.66** | **97.81%** |

Table 4: Polyphosphate Utilized in Treatment Process

| Month | Average Treated Water (MG) | Average Pounds Used | Lbs/Million Gallons |
|---|---|---|---|
| **Existing Average** | **1.46** | **6.60** | **4.51** |
| Month 1 | 1.41 | 5.40 | 3.83 |
| Month 2 | 1.40 | 5.30 | 3.79 |
| Month 3 | 1.27 | 4.50 | 3.54 |
| Month 4 | 1.20 | 4.80 | 4.00 |
| Month 5 | 1.42 | 4.90 | 3.45 |
| **New Average** | **1.34** | **4.98** | **3.72** |

| | |
|---|---|
| **Percent Reduction** | **17.60%** |

## *Rotary Screens*

The Actiflo clarification process has a maximum solids diameter limit of three millimeters; therefore, the screen is sized to prevent passage of particles greater than two millimeters in diameter. The rotary drum screen design is self-cleaning and also aerates the raw influent. The screenings are collected in a hopper and sent to a solid waste disposal site.

## *Actiflo Clarification*

Cyanobacteria, commonly known as blue-green algae, are simple, photosynthetic plants that live in shallow, warm, slow-moving water. The removal of these blue-green algae has long been a problem within the water treatment industry. Actiflo® is a microsand ballasted, coagulation/flocculation, lamella settling water treatment process. The microsand provides a large contact area and acts as ballast, accelerating the settling of the flocs. It also allows the process to handle sudden variations in water quality, such as turbidity and temperature (Figure 3).

One advantage of this ballasted floc treatment process is that it is able to remove algae from the water while leaving the algal cells intact. This is important because toxins are released when the algae cells are ruptured. The other advantage which makes it ideal for the restricted site is that the process requires a much smaller footprint than a conventional clarification process (approximately 1/5th to 1/20th the size).

The Actiflo process is made up of four major components: the coagulation tank, the injection tank, the maturation tank, and the settling tank. In the coagulation tank, alum, which acts as a coagulant, is mixed with the influent water and induces the formation of flocs. Microsand and polymer are added in the injection tank. The microsand provides a media with a large surface area to which the flocs can adhere. The polymer acts as "glue" and binds the flocs to the microsand with polymer bridges.

Table 2 shows the polymer use for the first five months of operation. Note that the average dose is similar to the findings of the

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pilot study.

The microsand/sludge particles combine to form higher-density flocs known as microsand ballasted flocs in the maturation tank. In the settling tank, flow velocity is decreased and the microsand ballasted flocs settle quickly under their own weight. The lamella tubes provide a large clarifier surface area. Table 3 shows the turbidity removal performance of the Actiflo system during five months of plant operation.

## Chemicals

The OUA water treatment plant uses a variety of chemicals in the treatment process. Sodium hypochlorite is introduced at the headworks to prevent algae from growing on equipment and piping. It is also injected before storage to maintain disinfection residual throughout the distribution system. Caustic solution is added at the beginning and end of the plant to control pH and neutralize the water. Polyphosphate is injected before the filter to prevent calcium deposition in the filter media, commonly referred to as "mud balls."

Although the expansion included the addition of new filters, the amount of polyphosphate that was required decreased because of cleaner filter influent—a result of the Actiflo process providing better removal than the previous clarifier process. Table 4 shows the polyphosphate required prior to the expansion, along with that required after the plant improvements.

## Peroxone Oxidation

Ozone is a powerful oxidant that reacts with pollutants, eliminates color and odor, and inactivates microorganisms. In the treatment plant, however, peroxone (ozone combined with hydrogen peroxide) is used to remove taste- and odor-causing compounds because many of these compounds are very resistant to oxidation—even ozone-oxidation.

Hydroxyl radicals are produced during the spontaneous decomposition of ozone. By adding hydrogen peroxide into the ozone contactor, the ozone decomposition rate is accelerated and the hydroxyl radical concentration is increased, also increasing the oxidation rate.

While the ozone oxidation process relies on the direct oxidation of aqueous ozone, the peroxone process utilizes oxidation with the hydroxyl radical. Peroxone oxidation is not only more reactive, but it is also much faster.

Peroxone is used in the treatment plant as a disinfectant because it effectively inactivates and reduces cyanotoxins, turbidity, tastes, and odors—all of which are problems associated with algae in the water source.

| Month | Average Finished Water Turbidity (NTU) | Average Finished Water Total Hardness (NTU) | Average Finished Water Color |
|---|---|---|---|
| **Existing Average** | **0.43** | **143.04** | **1.35** |
| Month 1 | 0.07 | 92.07 | 0.10 |
| Month 2 | 0.08 | 102.71 | 0.19 |
| Month 3 | 0.15 | 84.20 | 0.07 |
| Month 4 | 0.15 | 67.71 | 0.39 |
| Month 5 | 0.12 | 117.03 | 0.03 |
| **New Average** | **0.11** | **92.74** | **0.16** |
| **Percent Reduction** | **74%** | **35%** | **88%** |

Table 5: Finished Water Quality

Peroxone also provides pathogen inactivation, but the process does not provide a measurable disinfectant residual; therefore, it is not possible to calculate CT (disinfectant contact time) values similar to other disinfectants, and no CT credits are granted.

Ozone is very reactive and thus is very unstable, so it can not be stored and must be produced as needed. Liquid oxygen is the main ingredient used for generating ozone gas in the generator. A 6,000-gallon tank supplies the liquid oxygen to the ozone generator.

Within the ozone generator, high voltage is applied to the pure oxygen, causing some of the oxygen molecules to break down in the electric field and immediately attach themselves to free oxygen molecules, forming ozone. Liquid hydrogen peroxide stored in a tank near the ozone contactor is added to the ozonated water in the ozone contact chamber, forming peroxone. Ozone destructors located on the top of the contact chamber remove and break down excess ozone from the system.

## Filters

Five 1-MGD dual-media filters provide further treatment. Gravity forces the water through two layers of anthracite and sand at a high rate. The solids are removed within the depth of the granular material. The filter media are cleaned with an up-flow of backwash water and the addition of air scour.

## Finished Water Quality

The new water treatment plant completed a successful startup and has been online for several months, during which time it has proven to be an effective method for treating surface water. The new design has significantly improved the finished water quality, especially taste and odor. The plant has been able to handle the varied water quality from the lake, as well as the algal blooms. Table 5 shows the finished water quality from five monthly operating reports as compared the averages of the old plant.

While the new plant is able to treat influent of varying water quality, it does have its limitations. These limits were tested during and after Hurricane Wilma, which passed directly over the plant in October 2005.

Hurricane Wilma's northeast track brought it over virtually all of Lake Okeechobee, causing two major effects that reduced water quality. The first was that the force of the hurricane created a seiche that was approximately 4.0 to 4.5 feet of setup and 4.0 to 6.5 feet of set down. This seiche caused the lake to "turn over," and the nutrients and solids that had settled on the lake bottom became suspended. The second effect was the increased rainfall, which caused extremely high amounts of runoff to enter the lake. Lake levels rose approximately 1.5 feet after Wilma because of the additional runoff entering the lake, as opposed to rainfall on the lake.

The TSS and nutrient levels were greatly elevated as a result of Hurricane Wilma. TSS levels rose from approximately 19 mg/l before the hurricane to approximately 69 mg/l after the event. As a result of these effects, the treatment process was not able to handle the large amount of suspended solids, and a new, temporary source of raw water had to be found.

Lake Okeechobee is surrounded by a rim canal, which is a shallow canal running around the outer lake boundary. This canal also had increased levels of TSS and nutrients, but the suspended solids settled much faster in this smaller body of water.

The OUA was able to place temporary piping into the rim canal and use the existing influent pumps to draw water from the canal and pump it to the plant for treatment. This provided a source water of sufficient quality to be treated. OUA is currently in the process of installing permanent emergency piping to the rim canal for use during and after future storm events.