IRAQI WATER TREATMENT PLANTS PROCESS CONTROL BY MEASURING EFFLUENT TURBIDITY

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ABSTRACT

The Al-Dewanyia Water General Authority (DWGA) operates and maintains four water treatment plants to produce potable water for 300,000 inhabitations in Al-Dewanyia city. Surface water from Al-Dewanyia river is treated by aluminum sulphate (alum) coagulation, flocculation, sedimentation, filtration, and chlorine disinfection (clearwell). DWGA has set goals for turbidity for clarified and filtered water. These goals pertain to water inside the Water Treatment Plant (WTP), outside the water treatment plant, and in the distribution system, DWGA continues to meet the Iraqi Ministry of Health Standard of 5 NTU. Each day at DWGA WTPs, chemists measure the turbidity of water from each individual clarifier and from each individual filter. The WTP Manager reviews this data and uses it to make process control decisions about chemical dosage and filter backwash. This paper explains DWGA's Turbidity Goal for filtered water, presents recent data, and describes how WTP managers use this data for process control. Any water treatment plant in Iraq can use these procedures. The results can be better process control and higher quality water.

Keywords
Turbidity, filter, water treatment plant, water quality, drinking water.

السيطرة على وحدات معالجة مياة الشرب في العراق بقياس كمية العكورة الناتجة

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الملخص

مديرية ماء الديوانية تشغل و تصين اربعة محطات لمعالجة مياه الشرب في مدينة الديوانية و التي تخدم ٣٠٠,٠٠٠ ألف نسمة. ان مصدر المياه المعالج هو نهر الديوانية و تستخدم وسائل التلبيد (إضافة الشب) و التخثير و الترسيب و الترشيح و التعقيم في تصفية المياه. مديرية ماء الديوانية و ضعت أهداف لإزالة العكورة من حوضي الترسيب و الترشيح. هذة الأهداف تتمثل

بالحصول على ماء صالح للشرب و مطابق للمواصفات العراقية و البالغة NTU ٥ . تم قياس تركيز العكورة يوميا من أحواض الترسيب و أحواض الترشيح. المهندسين المسئولين عن تشغيل المشروع قاموا بتحليل تلك القياسات لاتخاذ قرار حول مقدار الشب المضاف و عملية غسل الفلاتر. من خلال هذا البحث تم توضيح وسيلة فعالة من خلال القياسات اليومية لتركيز العكورة للحصول على ماء مطابق للمواصفات العراقية.ان هذة التقنية يمكن استخدامها في أي محطة معالجة لمياه الشرب في العراق.

INTRODUCTION

Most drinking water treatment plants in Iraq are already built. With few exceptions, the major focus for most end-users will be on how to secure safe and sustainable, cost-efficient operation of existing facilities. Retrofitting and up-grading are also important issues. In addition, there will always be a drive for developing new processes and technologies to meet new demands and regulations. Unfortunately, sub-optimum operation of water treatment facilities is a rather widespread phenomenon, thereby compromising water supply safety, sustainability, and cost-efficiency. Numerous studies on turbidity in clarifier and filtration (Kavanaugh, 1978, Kaeding et al., 1997, Clancy. 2000, Ghawi and Al-Jeebory 2009) have demonstrated that turbidity is the major determining factor with respect to process operation conditions.

The Al-Dewanyia Water General Authority (DWGA) operates and maintains four water treatment plants to produce potable water for 500,000 inhabitations in Al-Dewanyia city in Medial of Iraq. Surface water from Al-Dewanyia river is treated by aluminum sulphate (alum) coagulation, flocculation, sedimentation, filtration, and chlorine disinfection (clearwell). Annual production in 2008/2009 averaged 206000 cubic meters per day. Data measurements and analysis was taken in Al- Dewanyia Water Treatment Plant in Iraq (DWTP). Al- Dewanyia Water Treatment Plant in Iraq (DWTP) was built in 1973. The untreated water is pumped from the Al-Dewanyia River to the DWTP by five large pumps and is then dispatched into flash mixer. The water then flows through a four calriflaculaters (flocculation, and sedimentation tank) and filtered through a sand bed (20 unit) as shown in **Figure 1.** After chlorination, the water is stored in two underground reservoirs (clear well). Five booster pumps, connected to the last reservoir, ensure the water supply in the Al-Dewanyia city network. The raw water is coagulated continuously with aluminum sulphate in flash mixer tank of 13.3 3 m^3 with a retention time of 22 seconds. Next, the water flows through the 4 clariflocculator of 38 m diameter (clarifier) with a retention time of 1.5 hr and 14 m diameter of flocculater with a retention time of 18 minutes and arrive to twenty rapid filters. also, surface loading rate of 42 $m^3/m^2/d$ was maintained (a higher loading rate limit) (**Figure 2**). Twenty filters are used, flow of each is about 83 L/s (eighteen are working and two for washing). Surface area of each is 42.5 m2. The rate of filtration was found to be about 235 $m^3/m^2/d$, while standard is to be about 120-180 $m^3/m^2/d$. Sand analysis were conducted on sand samples and it was found that the effective size of the sand is about 1.2 mm, where the standard is 0.45 to 0.55 mm. This shows that sand used inside filters is coarse. Also, uniformity coefficient was found to be 2, where standard is 1.75 to 2. This also proves that sand used is a coarse media and out of the standard limits (**Figure 3**) .This paper reviews optimization strategies adopted at Al-Dewanyia Water Treatment Plants in Iraq operated conventional water treatment plants to meet contractual and Iraqi national water quality requirements.

MATERIAL AND METHODS

In Al-Dewanyia in Iraq, the DWTP, meeting seasonal water demands, provides water to the city, and some villages around, supplying around 96 000 m^3/day serving about 300 000 consumers. The water to the Al-Dewanyia city comes from the Al-Dewanyia River (**Figure 4**) source and treatment in the Water treatment plant.. As it is typical of the rivers of the Iraq, the flow is very irregular, having a high flow level in the months of December to April and a Low flow in the remain months. The wealth comes prepared with a high turbidity (about 50 - 1000 NTU), being the turbidity a very important parameter in the process of drinking Water.

The surface water from Al-Dewanyia River very often contains suspended clay, sand and lime particles, various organic dissolved solids and other materials, which manifest themselves as turbidity, dissolved solids and other chemical parameters. This water has to be treated properly to make it suitable for drinking and domestic use.

Samples of turbidity were collected from clarifiers, filters and from the clearwell where full analysis were carried out in the laboratory of DWTP. Analysis were conducted for physical, analysis (turbidity measurement). All experiments were done and results were determined in accordance to the Standard Methods (APHA). Water turbidity was measured with the portable turbidimeter HACH Model 2100P from October 1th, 2008 to January 31th, 2009. This turbidimeter operates on the nephelometric principle of turbidity measurement (scatter light ratio to transmitted light). The measuring range is 0–1000 NTU with an accuracy of +/- 2% of readings (HACH 2004). The calibration of the turbidimeter is based on three samples of standard turbidity (20, 100, 800 NTU). Past practice for filter effluent turbidity was to measure turbidity of clarifiers, combined filters and from the clearwell. These were averaged and a single turbidity value reported for the water treatment plant for the day. This kind of averaging is simple but it can hide the problems of individual filters. A malfunctioning individual filter could allow the passage of sufficient microbial contamination to threaten public health despite the plant as a whole producing low finished water turbidity. Once each day, DWGA WTPs Laboratory staff collects a sample from each filter's effluent line, measure turbidity in the laboratory using a Hach Turbidimeter calibrated with Gelex (secondary) standards, and record results. The results are given to the WTPs Manager who investigates turbidity values $\geq$5.0 NTU, and as needed stops a filter and backwashes.

RESULTS AND DISCUSSION

Figure 5 summarizes Daily Turbidity Readings (DTR) for the 20 filters at DWTP. **Figure 5** shows the percent of readings that reach a particular turbidity value. For December 2008, there were 1010 readings of which 87% are $\leq$ 5 NTU and 97% are $\leq$10 NTU. **Figure 6** shows the percentage (%) readings for the period October 2008 through January 2009 for DWTP. DWGA uses the computer software spreadsheet program Microsoft Excel to tabulate and graph data. The data show individual variations among filters for the same day. When we reported only one value for the WTP we did not see this so clearly. The WTP Manager studies the results to understand what caused the high turbidity reading. For example, during November and December some high turbidity readings were caused by stoppage of the aluminum sulphate chemical feed system due to electrical power outages also was high inlet raw water turbidity.

DWGA uses the computer software spreadsheet program Microsoft Excel to tabulate and graph data (**Figure 7**). A computer makes data analysis easier, but it is possible to do this manually. A table across the top of the worksheet contains a summary of the unit treatment process performance data by month. This worksheet shows the 95 percentile values calculated for the individual sedimentation and filtration processes and the percentage of monthly values meeting specific performance goals. Calculation of the percentile for sedimentation uses the data for all the individual sedimentation basins, while the calculation of the filtered water percentile uses the combined filtered water data. Charts located on the lower part of the report also plot these data.

For each month, the worksheet highlights in red the sedimentation basin and filter with the highest turbidity value. Since the example plant has only one sedimentation basin, all of the monthly values are red. For the month of June, however, filter 4 at this plant had the highest turbidity of all the filters (0.21 NTU). A closer inspection of the data for all of the filters shows that the range of values for all five filters was essentially the same. Looking at filter 4, one can see that it had the highest turbidity for five of the 12 months, with three months above 0.2 NTU. In addition, one can see, at the bottom of the table, that Filter 4 met the goal of 0.10 NTU only 83% of the time, compared to 93.7%, 89.3%, 92.9%, and 87.7% for Filters 1, 2, 3, and 5, respectively. Filter 4 also had the highest 95th percentile over the entire year (0.17 NTU) of all of the 5 filters. To optimize this plant, the plant staff may try to determine if there are reasons for this filter consistently having the highest turbidity.

The "Optimization Report" contains two trend graphs across the bottom, with the "Settled Water Optimization Trend" on the left and the "Filtered Water Optimization Trend" on the right. Each of these graphs trend the same two sets of data, one related to the sedimentation basins and the other to the filters.

The most prevalent feature of these graphs is the various colored areas that are layered on top of each other. For each month, all of the data for the respective treatment process are sorted and placed into four categories: For the sedimentation basins the categories are >3 NTU, <3 NTU, <2 NTU and <1 NTU. For the filters the categories are >0.3 NTU, <0.3 NTU, <0.2 NTU and <0.1 NTU. The percentage of time the data for that month is in each of the four categories is then plotted using the vertical axis on the left. Each category is plotted as a separate area on the chart, so that the 0.1 NTU data (and then 0.2 NTU data, etc.) is on top of the other categories. Looking at the "settled water optimization trends" graph in January 2002, the settled water was <1 NTU 61% of time, <2 NTU 84% of time and <3 NTU 100% of the time. Since none of the data was >3 NTU (the plant met < 3 NTUI 100% of the time in January), there is no white area showing in January. In April, the plant met <3 NTU only 96.67% of the time; therefore, there is a small white area showing in April.

Though these trend graphs appear confusing at first, their main purpose is to allow the plant to quickly see how it performs throughout the year with respect to the optimization goals (to make process control decisions about chemical dosage and filter backwash). There is a tendency to try and read more into them than is necessary. In looking at these graphs, it is important to notice how much of the graph is covered with the layer representing the highest level of performance. In the "Settled Water Optimization Trends" graph the plant was almost completely optimized in November, but had less than optimum performance in August. It is also important to look at the trend in the different layers. Between September and November, the performance of the sedimentation basins greatly improved. Between, July and September, however, there were problems with the sedimentation basin performance. The plant staff can use this information to assess changes in the plant during these time periods to determine what results in the best performance.

These graphs also have a solid line that plots the 95% value each month, shown on the right vertical axis, for the sedimentation basins and filters. The intent of the trend line is to allow the plant to observe whether or not the performance is improving based on the slope of the line. If the line is sloping downward, then performance is improving. If it is sloping upward, then the changes in the plant are taking the performance in the wrong direction.

The Optimization Trend Worksheet only allows the analysis of one year of data at a time. Optimization of a treatment plant, however, occurs over several years and looking at trends between the different years can be beneficial. There is a separate long-term trends spreadsheet that will allow development of the settled and filtered water optimization trend charts for a three-year period. **Figure 8** shows the output of the long-term trends spreadsheet.

CONCLUSIONS

Turbidity is a fast, easy, inexpensive parameter to measure. Measuring turbidity from each filter each day provides the WTP Manager with useful data for process control, specifically to evaluate the effectiveness of the clarification and filtration processes and to determine when to backwash the filter. The conclusions drawn from this research outlines the importance of accurate engineering design and need for continuous monitoring and analysis of each unit performance. Finished water is not conforming to World Health Organization (WHO) Standard for Drinking water. For DWGA the next steps are to install on-line analyzers that will provide continuous turbidity measurement.

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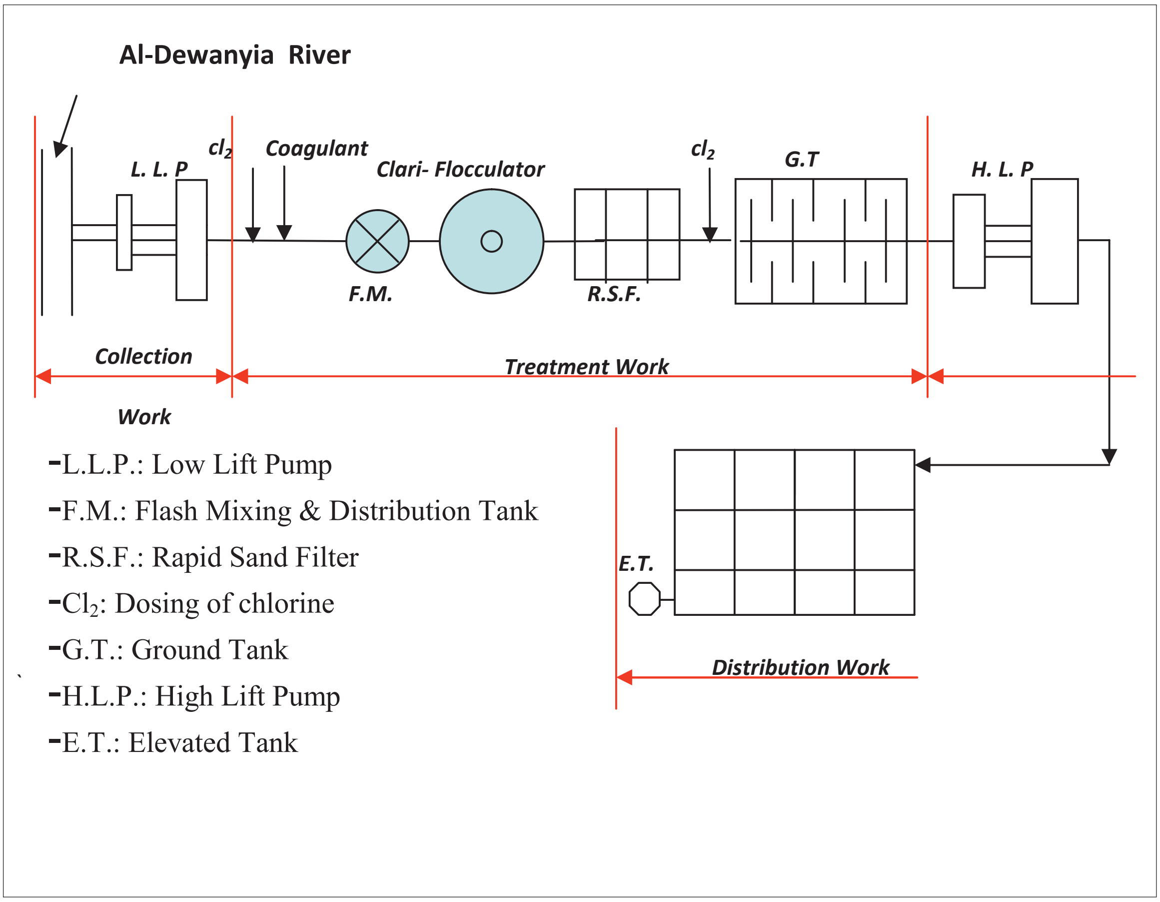

Figure 1. Al-Dewanyia WTP Layout

Figure 2. Coagulation and ClariFlocculator Tanks in DWTP

Figure 3. Rapid Sand Filters in DWTP

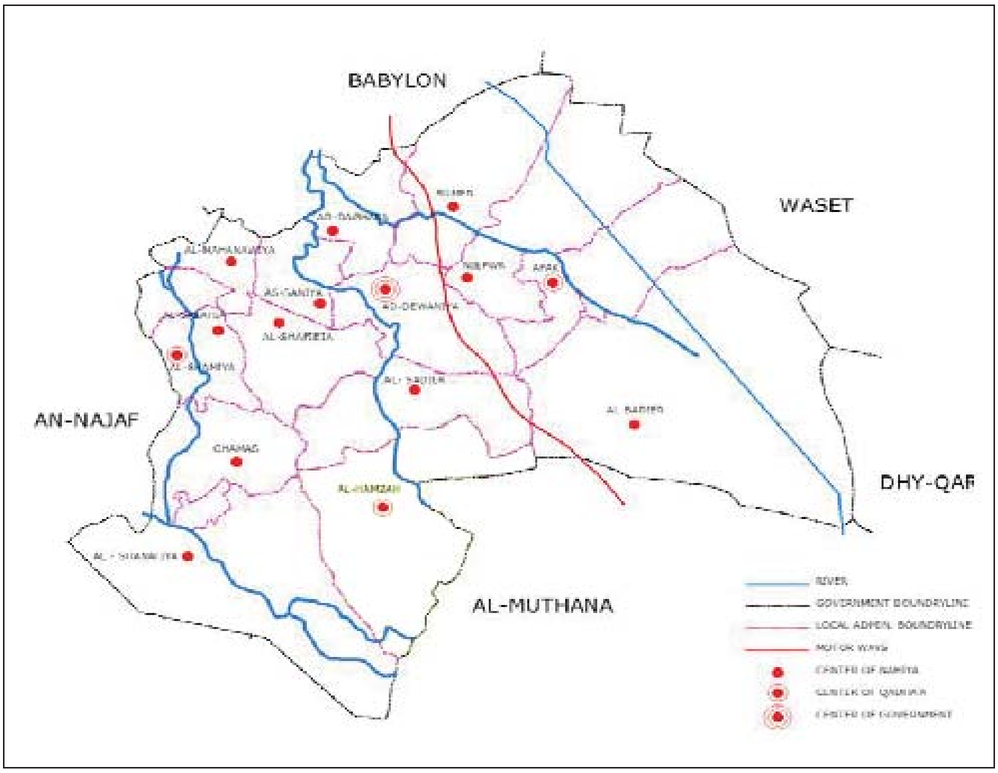

Figure 4. Al-Dewanyia Rivers Map

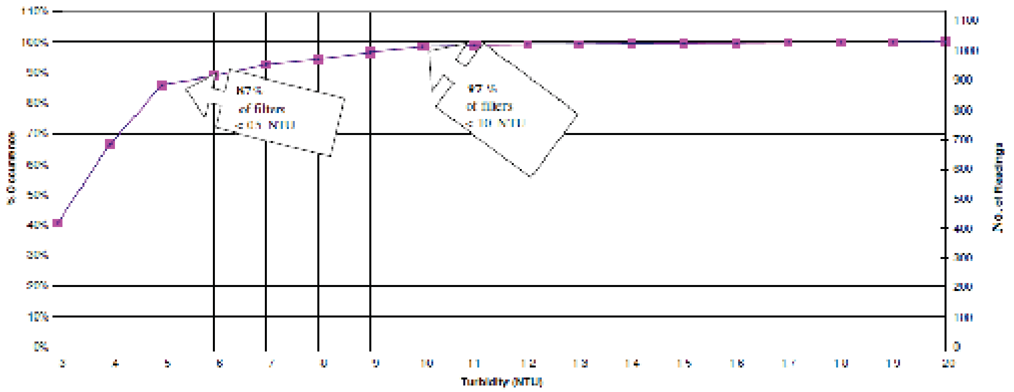

Figure 5. Percent of readings that reach a particular turbidity value.

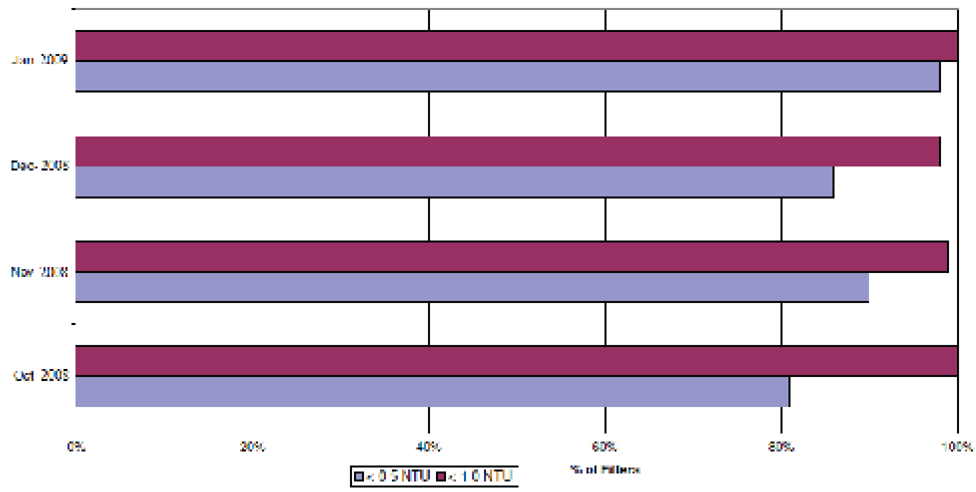

Figure 6. Percentage (%) readings for the period October 2008 through January 2009.

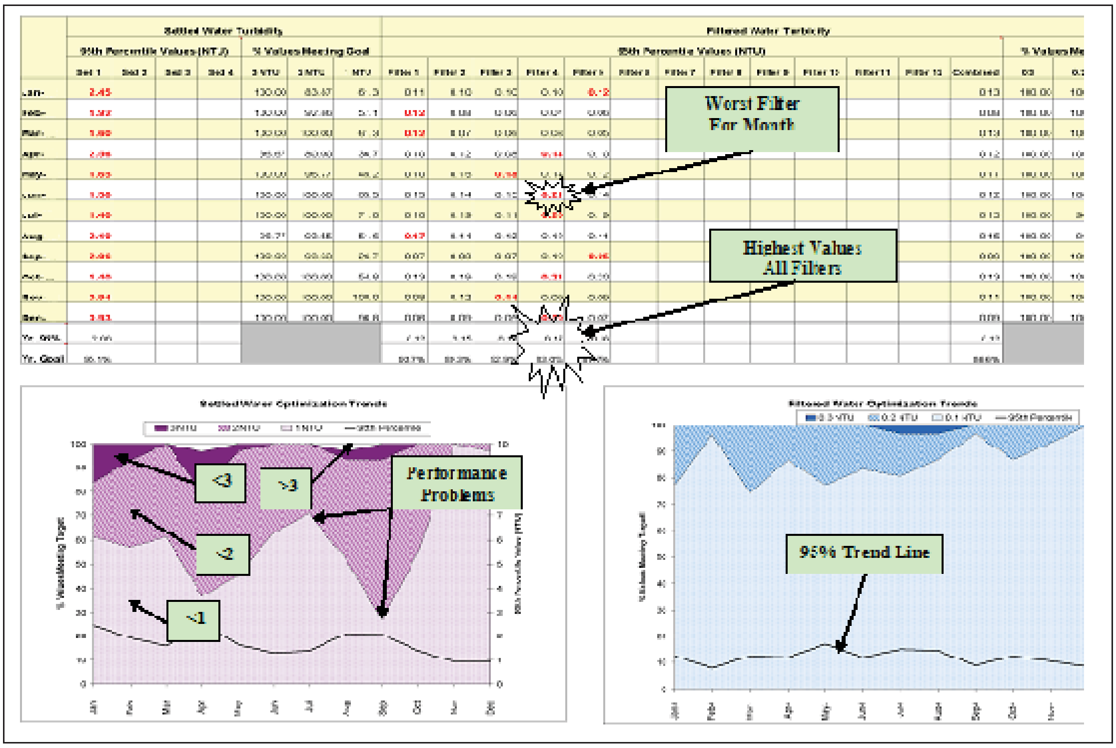

Figure 7. The Optimization Trend Worksheet

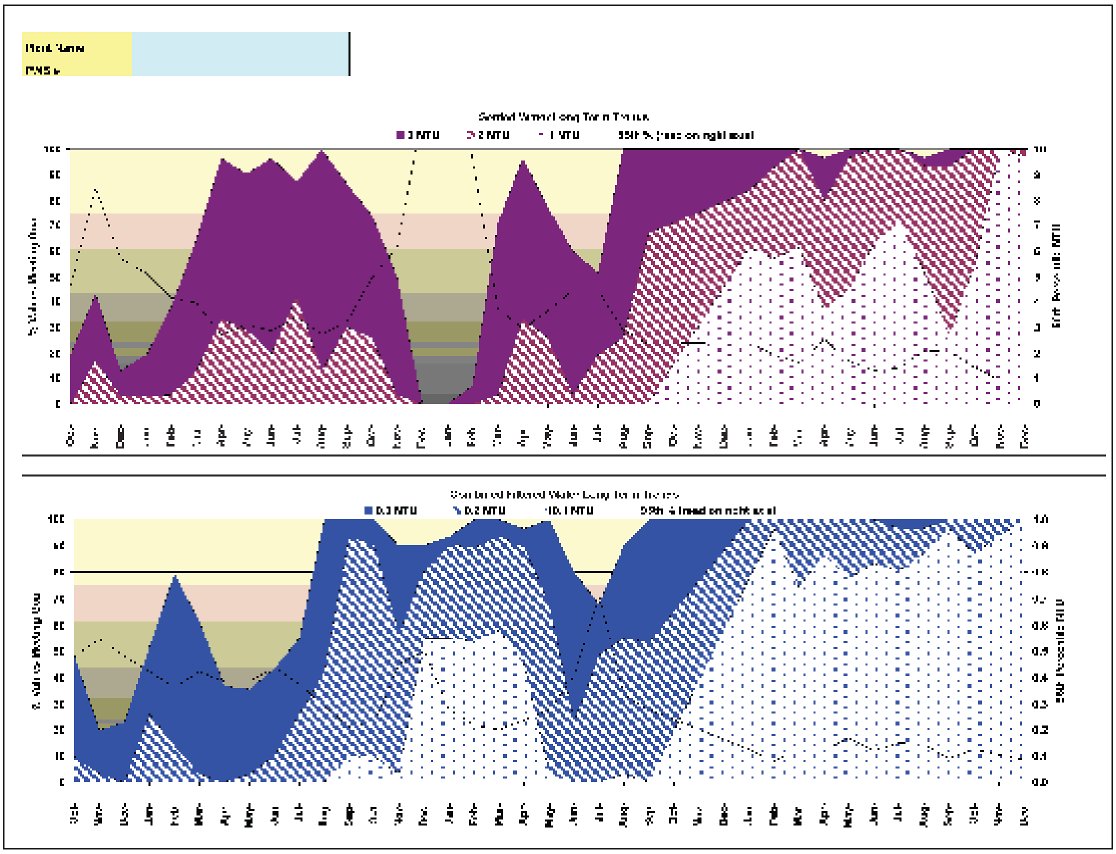

Figure 8. The output of the long-term trends spreadsheet