The BioWin Advantage

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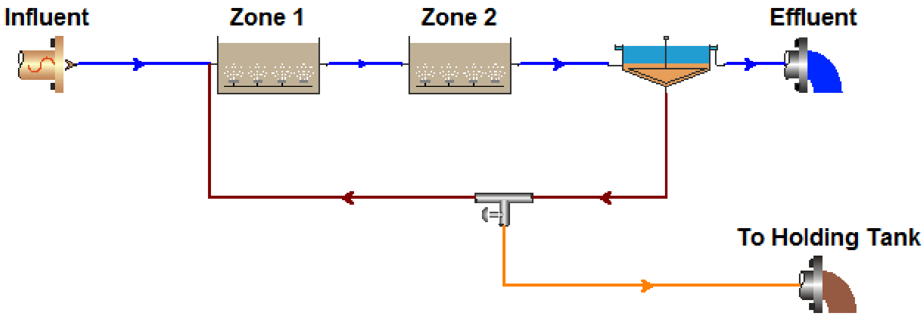
BW Controller is a powerful way to extend BioWin's functionality for plant design analysis, optimization, etc. In this edition, we are going to start with a few simple examples that focus on using the BW Controller to investigate plant operating strategies within the context of mixed liquor control. In future editions, we'll look at more advanced control strategies geared toward process optimization and cost savings.

Controlling a Plant's MLSS

For many years, BioWin has had the ability to tell users what the average waste activated sludge (WAS) flow is required to achieve a desired steady state solids retention time (SRT). However, if you do a dynamic simulation under varying flow and load, BioWin will not vary the WAS flow automatically. Over the years, many users have asked us "can I get BioWin to control the aeration tank MLSS levels?" Now it is possible to explore this operating strategy - using BW Controller! The following scenarios will illustrate and explore some of the concepts surrounding this.

The Base Plant

In the spirit of keeping things simple, let's look at a basic aerobic plant that is designed to nitrify. A process flowsheet is shown below:



Some pertinent design features of the system are listed in the table below.

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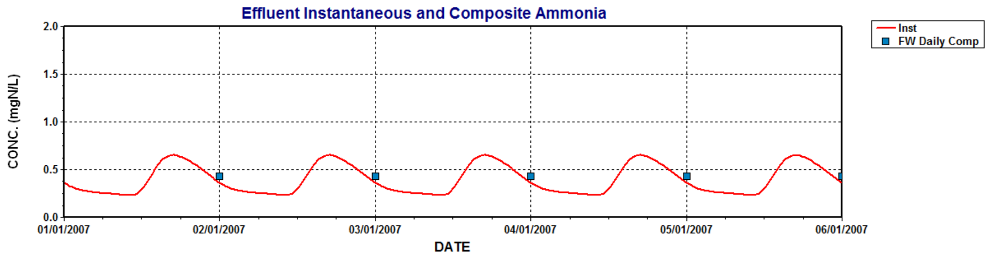
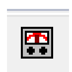
ATTRIBUTE	VALUE
Average Influent Flow	1 mgd
Maximum Daily Flow	1.59 mgd
Average Influent BOD Load	2536 lb/d
Average Influent TSS Load	2485 lb/d
Average Influent VSS Load	2087 lb/d
Average Influent TKN Load	426 lb/d
Minimum Design Temp	14°C
Total Aeration Volume	0.66 mil. gal.
SRT	10 days
Average Zone 2 MLSS	3,264 mg/L
Average WAS Flow	33,610 gpd
Average Clarifier SLR	23 lb/ft^2/d
Average Clarifier SOR	420 gal/ft^2/d
RAS Flow	1 mgd
Average Effluent Ammonia	0.20 mgN/L

If we take the system above, which was sized based on steady state analysis, and subject it to varying flow and load, we can evaluate its performance by looking at the effluent ammonia response (both instantaneous and daily composites). For example, the figure below shows the effluent response if we keep the WAS flow constant and let the MLSS (and SRT) vary slightly.



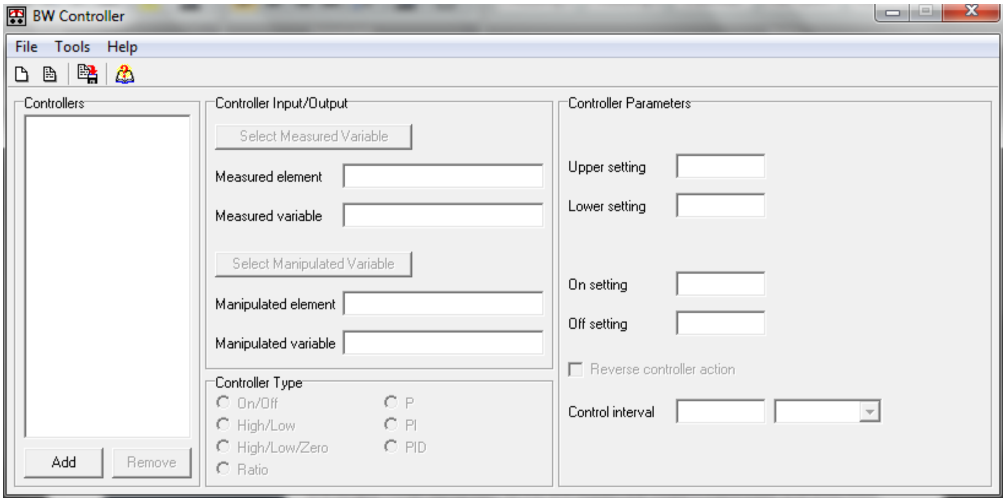
Example 1 : Periodic Wasting

Suppose we want to simulate the conditions where our plant is a small, remote plant that is only partially manned and does not have its own solids processing infrastructure. One scenario that might arise in this situation that we've been asked about is "***can I simulate the situation where I let the MLSS build up to a certain level, and then have BioWin tell me when to turn on wasting and for how long?***" With the BW Controller, we can!



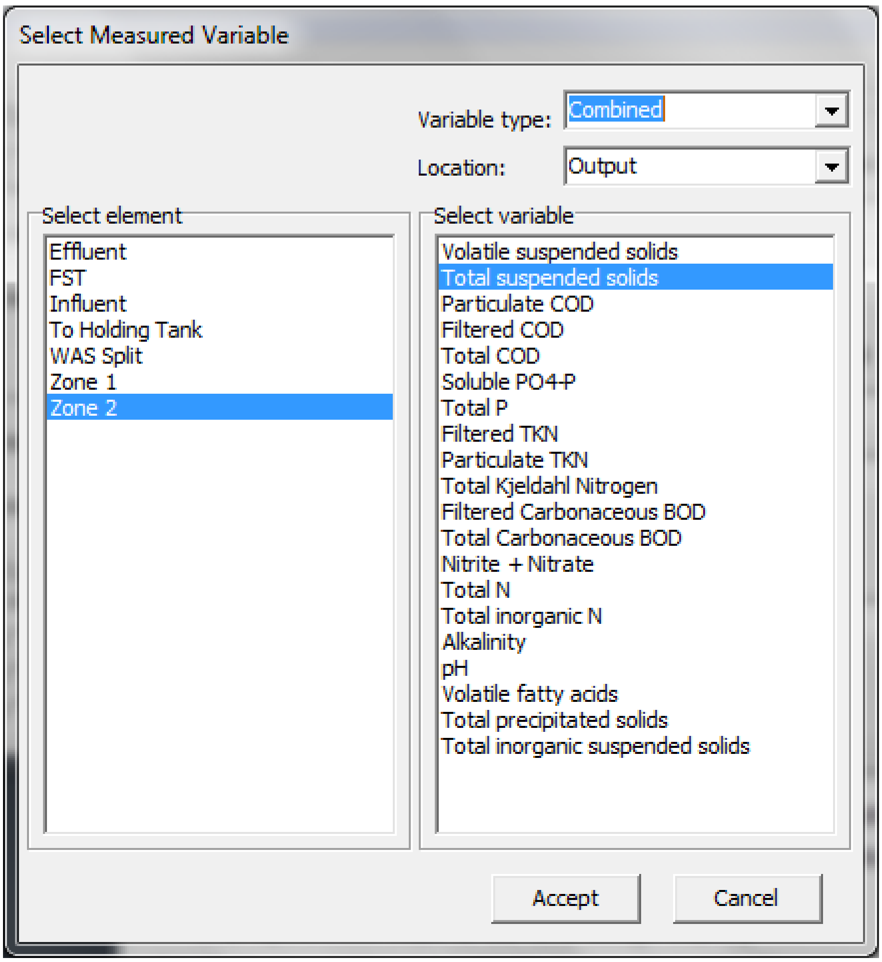
First, we launch BW Controller from our base system by clicking the BW Controller button located on the **Main** toolbar. When we do this, we'll see the BW Controller interface, which will allow us to set up the control strategy we want to investigate. That is, we want to monitor MLSS in one of our aeration zones, and once that builds up to a certain level, we want to turn the WAS flow on until the MLSS comes down to a lower level. Once we've achieved the lower MLSS level, we want to turn the WAS flow off again.

Once we click the BW Controller button, the Controller will link to BioWin and load the names of elements and process information. Next, we'll see the blank BW Controller interface:

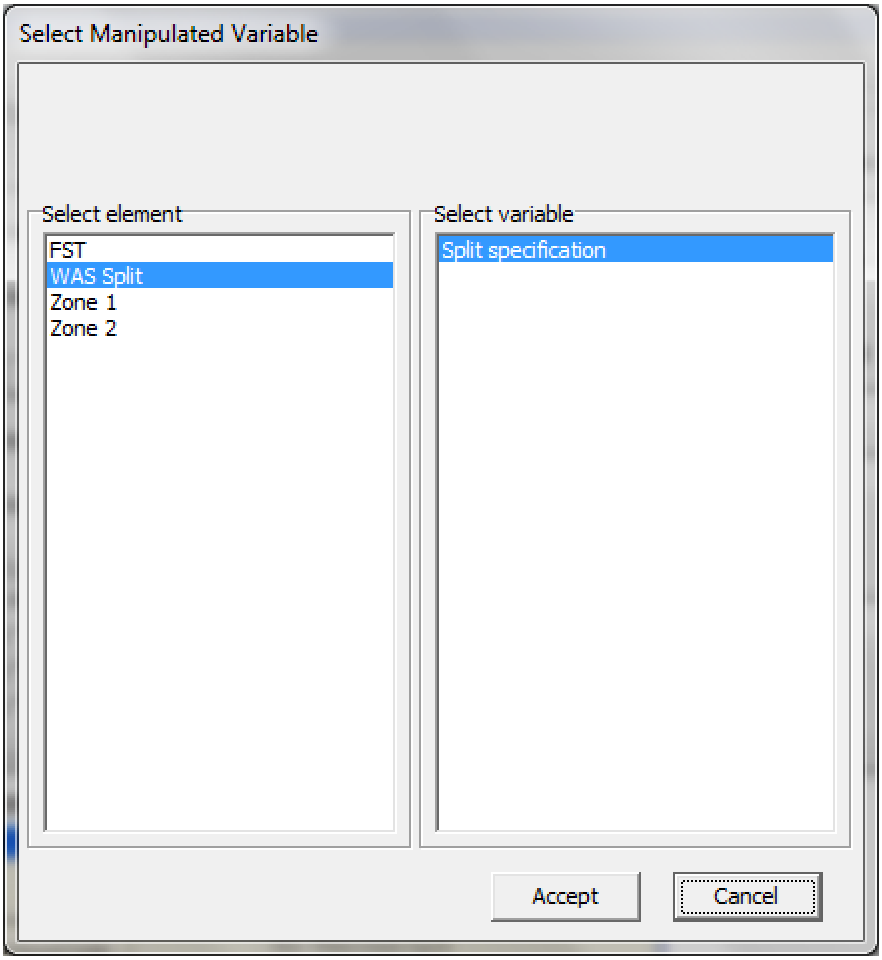


Click on the **Add** button at the lower left. A dialog box opens prompting you to enter a name for the controller. Name this controller **MLSS Control (WAS ON OFF MLSS 3500-2500**), and click on the **OK** button

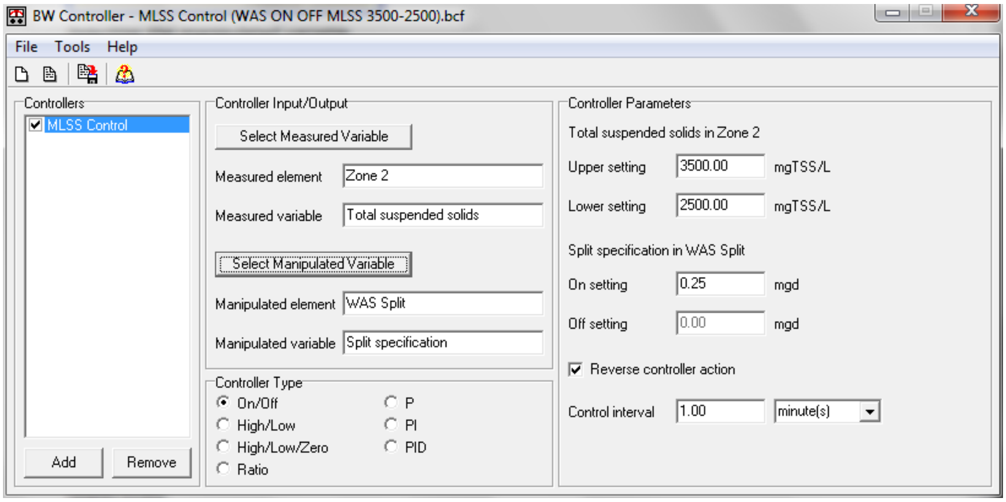
We need to select our measured variable. To select the measured variable (TSS in Zone 2 for this case), click on the **Select Measured Variable** button. A dialog box opens listing all the BioWin elements on the left, and 'combined' variables that can be measured on the right. [Other variables can be selected via the **Variable type** pull-down list at the upper right].



To select the manipulated variable (the WAS splitter flow for this case), click on the **Select Manipulated Variable** button. A dialog box opens listing all the BioWin elements on the left and operating parameters that can be adjusted for the selected element on the right.



Now we can define our controller type and parameters. Once we're finished, the controller interface will look like this:

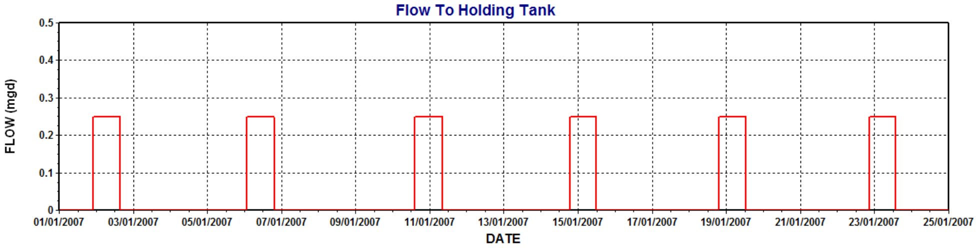


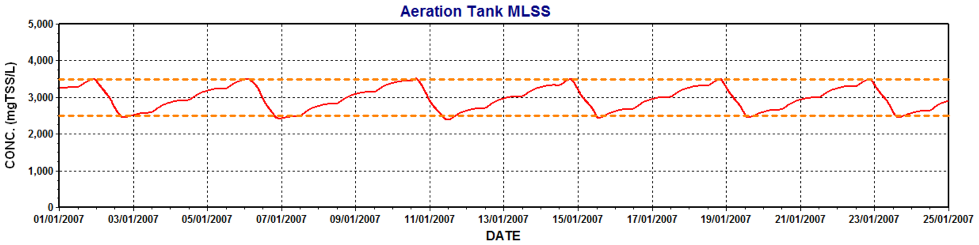
To complete the Controller setup, we go through the following steps:

1. In the **Controller Type** section select **On/Off**.
2. In the **Controller Parameters** section enter upper and lower setpoints for Zone 2 TSS as 3500 and 2500 mg/L, respectively.
3. Enter the **On setting** for WAS flow as 0.25 mgd.
4. Check the **Reverse controller action** option - we do this because for this control case, turning our manipulated variable on will drive our measured variable toward the lower setting, and vice versa.
5. Let's accept the default **Control interval** setting of 1 minute for now.

Now we can test out our Controller! Open up the BioWin Album, and click the F7 key to open the dynamic simulation interface. Let's run a dynamic simulation, starting from the **Project**

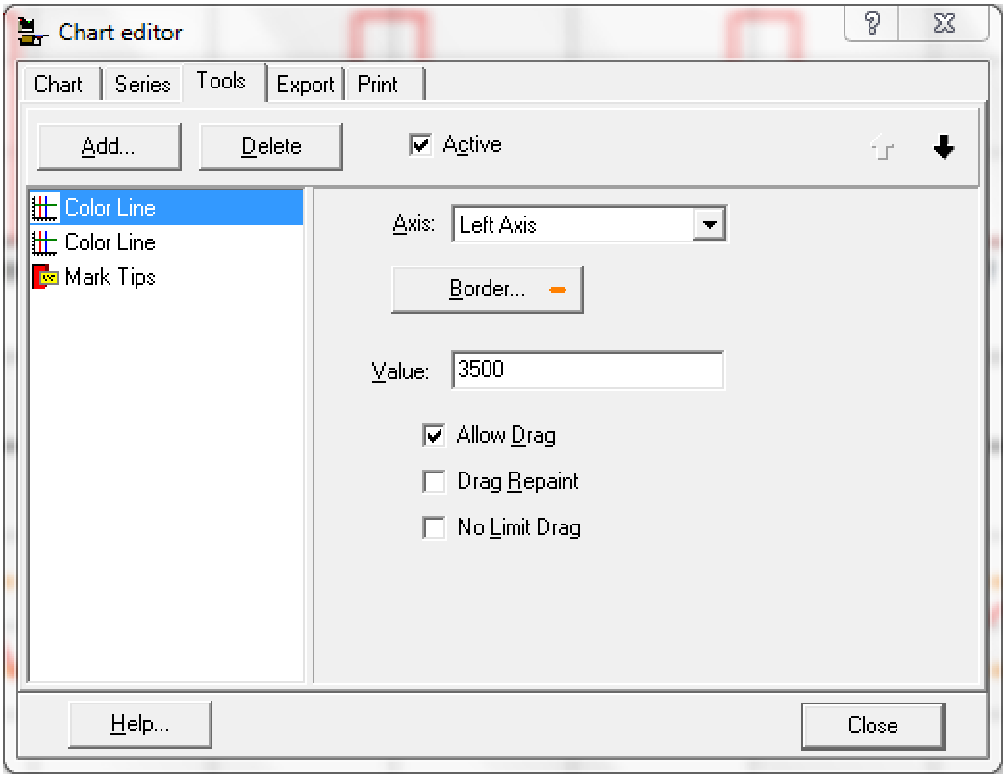
start date, for a duration of **12 days**, from the **Current conditions** (which represents a steady state situation). If we look at the WAS flow and Zone 2 MLSS plots below, we can see that initially the MLSS is at the steady state value which is below our upper setpoint of 3,500 mg/L. Hence, the Controller ensures that the WAS flow is maintained at zero. However, as the MLSS builds up and reaches the level of 3,500 mg/L, we see that BW Controller ***turns on the WAS flow for us***! Accordingly, the MLSS begins to drop and continues to do so until the lower MLSS value of 2,500 mg/L is obtained. Because we have a regularly repeating daily loading pattern, we see this wasting pattern repeated.





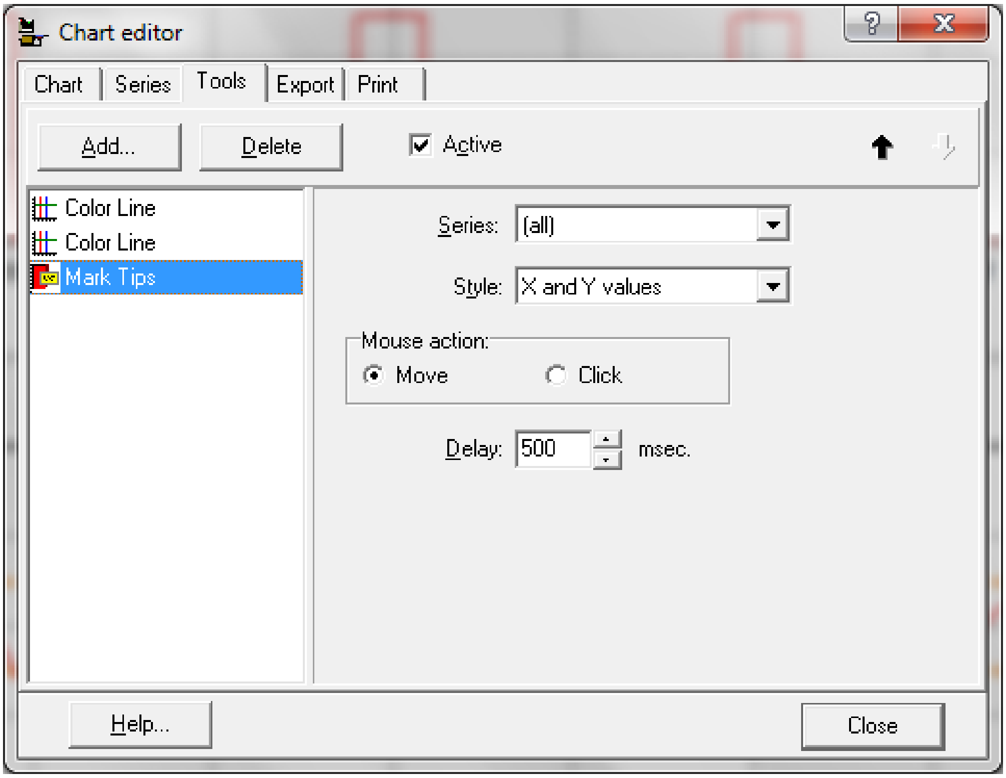
If you open the BioWin file **MLSS Control (Fixed RAS WAS OFF MLSS 3500-2500).bwc** that accompanies this document, you should find that when you point at the lines in the above Album charts, you should get a small hover-tip that tells you the value of the area on the line you are pointing at, and also the time when this occurs. Also, you'll notice that we have placed orange dashed lines on the MLSS chart to indicate the upper and lower values. Both of these features are available with the **Tools** that come as part of the Album charting package. Since both features are active on the MLSS chart, let's see how these are accessed:

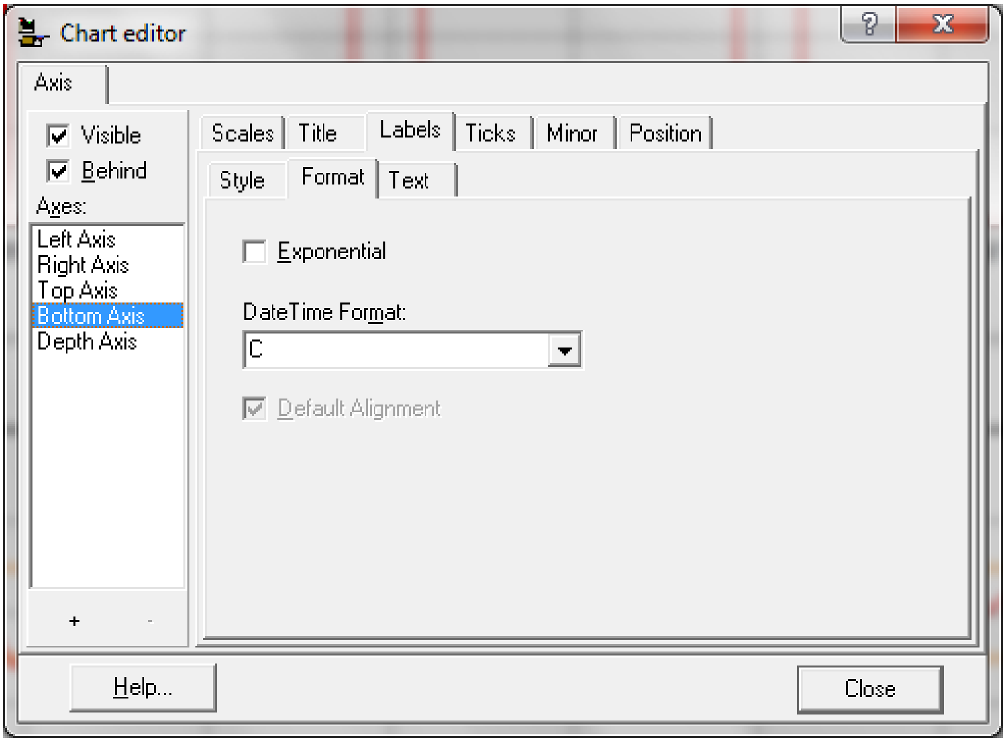
1. Go to the MLSS chart, right-click, and select **Edit Options**...
2. Click on the **Tools** tab. When you do, you will see that three "tools" have been added to this chart: two **Color Lines**, and one **Mark Tips**. We can have many "tools" on a given chart; try clicking the **Add** button to see those available. The **BioWin Help** has further information about these tools.
3. If you click on the **Color Line** tools, you can see that for these we have selected to originate them from the **Left Axis** at **Values** of 3500 and 2500. We've also drilled down using the **Border** button to change the line to a thick dashed orange line. We've used this Color Line tool to visually show other people looking at our results the upper and lower setpoints in our MLSS control strategy.



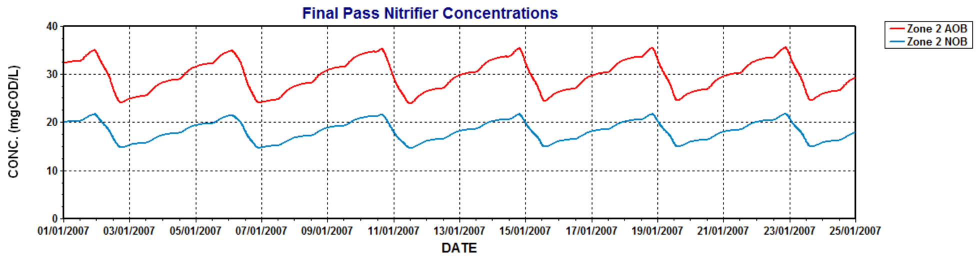
4. Now try clicking on the **Mark Tips** tool. This tool is what gives us the little "hover-tip" that shows the X/Y coordinates when we point to a spot on one of our plotted lines. You can see that we've selected this tool for **all** series in our chart (we could select just one if we wanted), and we've selected **X and Y values** as our style. This is the most useful setting in that we can see both the value of a point on the line and when it occurs.

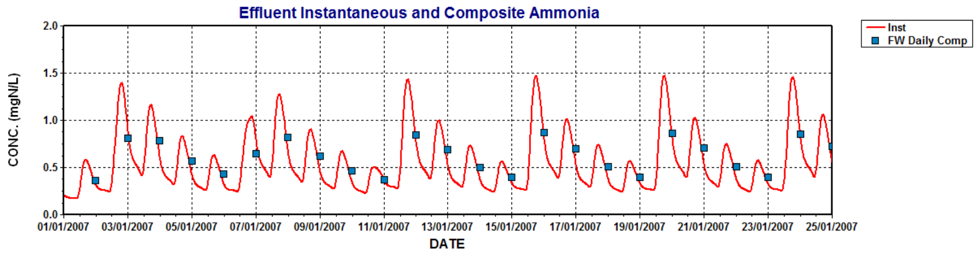
[**Hint**: the formatting for the "**x value**" that is shown when you point at a series is picked up from the formatting that you apply to the x-axis in your chart. So if you format the x-axis as **day/month/year**, you'll see that format in your **Mark Tips**. A very simple, yet powerful format to apply in your bottom axis is "C". This setting will show the date and the time in your **Mark Tips**; only the date usually will be shown on the axis due to space constraints! If you right-click on the MLSS chart, and look at the formatting on the bottom axis, you will see a simple "C" entered! Other date formats are listed in the BioWin online help.]





So how is the process doing? Recall that our steady state simulation showed a completely nitrifying system, with an average effluent ammonia of 0.20 mgN/L, and that it also performed well under the dynamic loading with constant wasting. Open up the BioWin Album, and take a look at the last tab - **Nitrifiers/Eff NH3**.





If the plant has a requirement to nitrify, the answer might be - not very well! The key to interpreting this lies in looking at the nitrifier concentrations. When we move the overall mass in the system up and down, we are effectively moving the average solids retention time around. In this system, that translates to an unstable mass of nitrifiers, which in turn translates to an unstable effluent ammonia response. A point to keep in mind is that we're doing this with a nicely repeating influent flow and load; it is quite probable that under real-world flow and load variations that the response may well be even more unstable. So we might be able to use BW Controller to illustrate how this strategy is not good for a plant that has a nitrification requirement. Other things that we could use this example for include:

- Sizing estimates for the sludge holding tank, by noting the length of "WAS on" events (our charting **Mark Tips** will be of help here!).
- By extending the example to include a variable volume bioreactor as the holding tank we could explore pump-out timing/strategies for scheduling tanker haulage.
- We could explore possible benefits of RAS pacing, to reduce the concentration variability of our waste sludge.
- We could explore alternate MLSS levels as our control setpoints. For example, suppose we had a MLSS probe installed at the plant that we confidently feel could measure MLSS between 3,000 and 3,500. All we need to do is open our file **MLSS Control (Fixed RAS WAS ON OFF MLSS 3500-2500).bwc**, launch the BW Controller, open the Controller file **MLSS Control (WAS ON OFF MLSS 3500-2500).bcf** that is attached with this edition, and change the setpoints accordingly.

Next, we'll look at what is perhaps a more broadly applicable example.

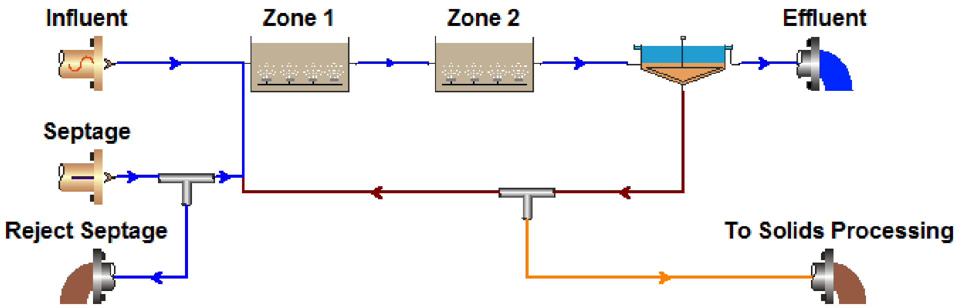
Example 2 - Wasting in Response to Additional Load

Let's consider the case where our plant from the previous example has its own solids processing facilities that it wastes to continuously. However, we want to explore a scenario where the plant is subjected to some additional transient load, e.g. in the form of septage. The septage loading will be quite significant in terms of BOD and solids, and not as significant in terms of additional TKN (refer to the table above for a summary of the normal influent loads for BOD, TSS, TKN, *etc*.). The septage characteristics are summarized below:

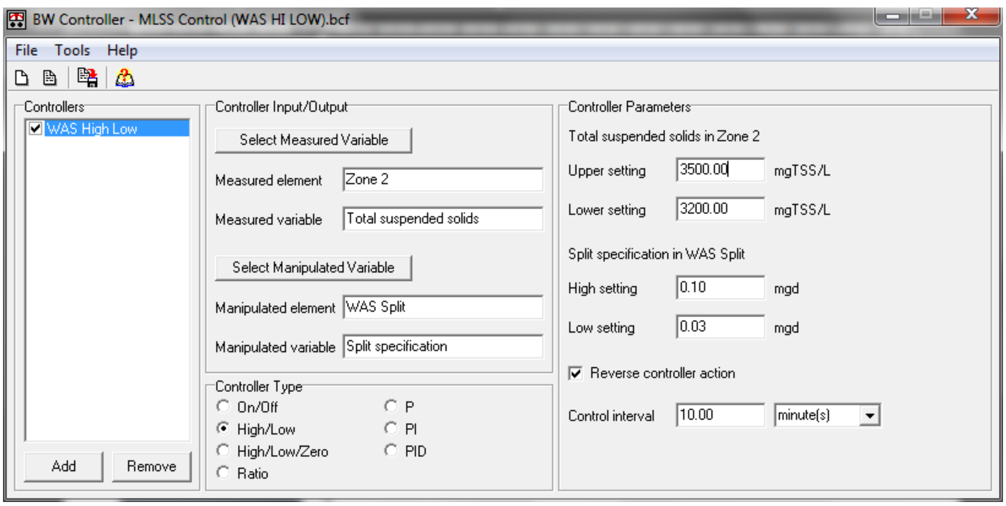
[the septage characteristics here are based on work done by EnviroSim for a ***particular plant****; as such they should not be considered as definitive as far as septage characteristics go]*

ATTRIBUTE	VALUE
Flow	6,000 gpd
BOD (Load)	24,000 mg/L (1202 lb/d)
TSS (Load)	22,000 mg/L (1102 lb/d)
VSS (Load)	20,000 mg/L (1002 lb/d)
TKN (Load)	1050 mg/L (53 lb/d)

We'll modify our plant layout to include the additional septage input, and we'll use a flow splitting element so that we can control when it comes into the main process (when we don't want it, we'll simply send it to a **Septage Reject** output. Admittedly this could have been accomplished more elegantly, e.g. by using a schedule in the septage input, however this simple technique will work fine for now). The flowsheet in the attached BioWin file **MLSS Control (Fixed RAS Vary WAS).bwc** is shown here:

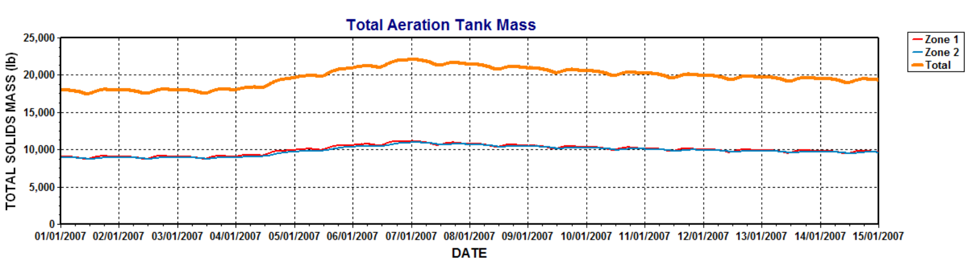


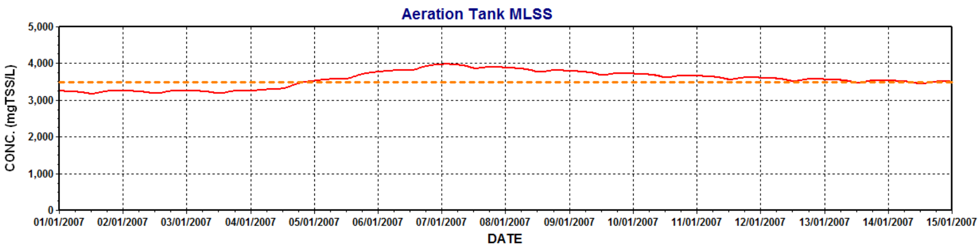
The scenario we would like to investigate is slightly different from our previous one where wasting was intermittent. In this case, we'll look at the situation where we have constant wasting such that the plant MLSS stays near our steady state design value. However, we'll investigate the plant response to the septage input for three days, with the possible response to the septage input being an increased WAS flow rate such that we stay below a target MLSS, i.e. we try to maintain a constant plant mass throughout the increased loading period. One way we can accomplish this is to set up a High/Low controller, to simulate wasting between two upper and lower limits (which might physically represent the upper and lower flow limits on a WAS pump, or running one or more WAS pumps each at a fixed rate). Setting up a High/Low controller is quite similar to the on/off controller we set up before. The screen shot below shows the finished controller:



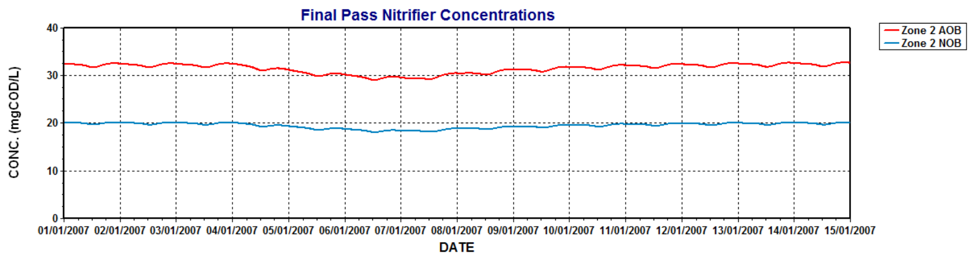
Notice that we've set the Zone 2 TSS **Lower setting** and the **Low setting** on the WAS flow quite close to our steady state values, since we're mainly concerned with investigating what happens under increased plant loading conditions.

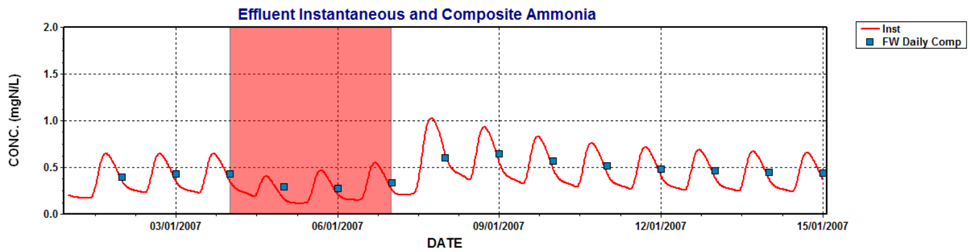
Before looking at how the plant responds to our control action, let's take a quick look at the response when no control action is taken in response to the septage input, i.e. constant wasting. We'll simulate 3 days of normal loading, followed by 3 days of septage input, followed by 7 days of normal loading. First, as expected we can see the total aeration tank mass (and consequently MLSS) increase with the increased loading and no additional wasting action.





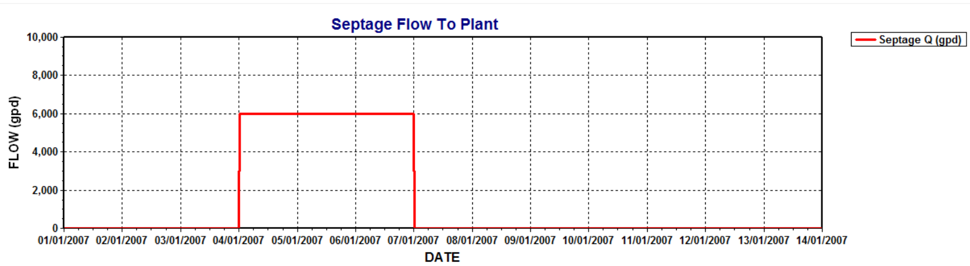
Next, consider the effluent ammonia response below. The red line represents the instantaneous ammonia values, and the blue squares represent the daily flow-weighted composites. The red band (another chart Tool!) represents the days where septage input occurred; the two blue points within and the third blue point at the end of the red band represent the daily composites from those three days. The Zone 2 nitrifying bacteria concentrations also are shown in the top chart:

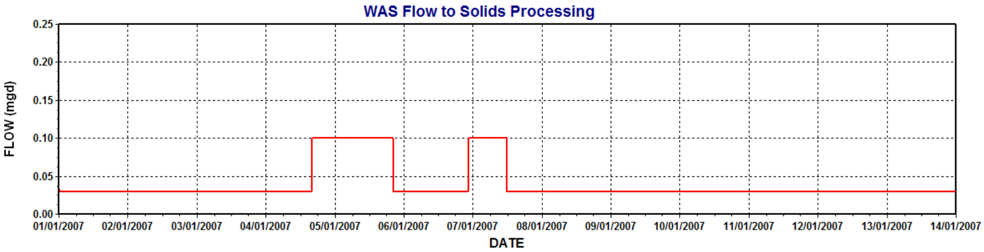




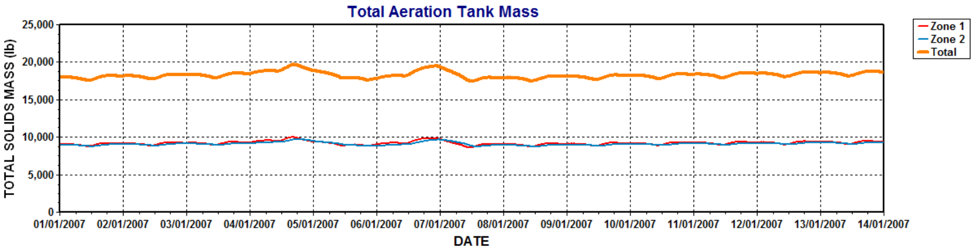
After 3 days of stable operation, we see that there is initially a ***drop*** in effluent ammonia under the additional septage loading. From the previous discussion we know that the septage represents an ***increase*** in TKN loading, so why does the effluent ammonia ***drop***? The septage used in this example represents a very significant additional BOD input. Accordingly, we grow more ordinary heterotrophs in the system. These additional organisms mean that more nitrogen is incorporated into the sludge mass, which is being wasted at a higher rate. This explains the slight drop in nitrifier concentrations shown in the top chart; the high BOD:N ratio of our septage input actually results in less ammonia available for the nitrifiers. Consequently, we see that the effluent ammonia goes up slightly ***even after*** the septage input ceases as the nitrifier population grows back to the pre- septage input levels.

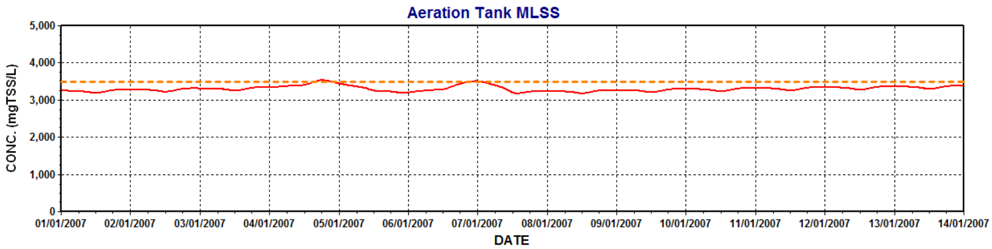
Now, let's look at how the system responds to our control action, which will be to waste to maintain a constant plant mass under the increased septage loading. Once again, we'll simulate 3 days of normal loading, followed by 3 days of septage input, followed by 7 days of normal loading. First, let's look at the septage input flows and resulting WAS flows:



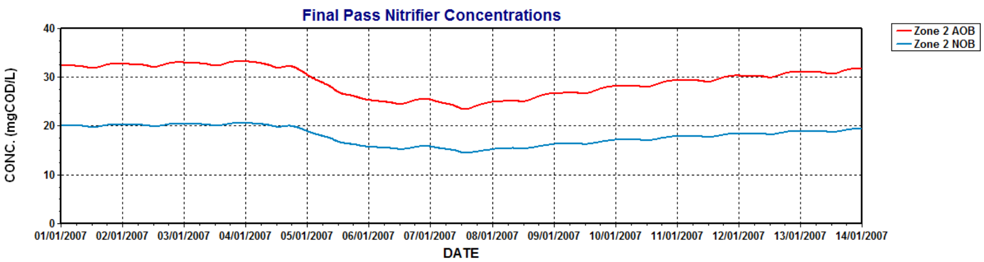


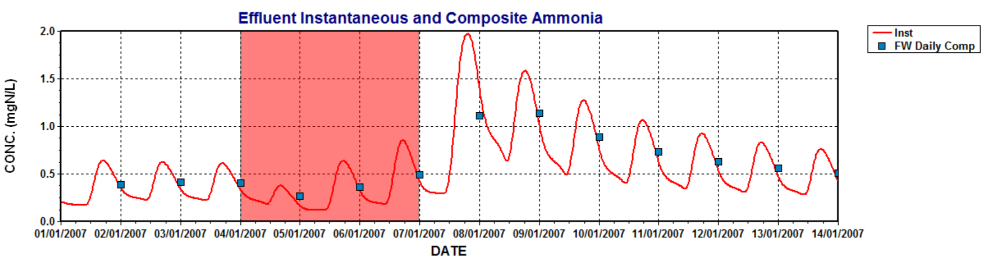
We can see that BW Controller has taken action! The WAS flow is turned on twice during the additional septage loading event! So let's see if the plant mass (and MLSS levels) remained relatively constant:





So it looks as though the goal of maintaining a constant plant mass (and MLSS) has been achieved! Now, let's look at the effluent response; once again the red band represents the days where septage input occurred; the two blue points within and the third blue point at the end of the red band represent the daily composites from those three days. The Zone 2 nitrifying bacteria concentrations also are shown:





From looking at the effluent ammonia response under the WAS control action, it is apparent that the system performance in terms of effluent ammonia is ***worse***. Initially, we see a slight drop in effluent ammonia, as in the previous case; this once again is attributable to the high BOD:N ratio of the septage input. However, if we look at the nitrifier concentrations, we see that for this case they drop much more precipitously than before - due to the additional wasting! The result is that by the time the additional septage input has ceased, the nitrifier mass in the system is much lower than for our previous "no WAS control" case. As a result, the post-septage input recovery period has much higher instantaneous and composite ammonia levels than what we saw before.

Admittedly, the analysis here is somewhat simplistic - we're not looking at airflows and whether we can deliver the air we need, we're paying no mind to solids loading rate and its potential impacts on effluent quality, etc. However, we can do all of this when BioWin and BW Controller are working together to expand our plant analysis capabilities!

In Conclusion

In this edition of the **BioWin Advantage**, we've started to explore how we can harness the combined modelling power of BioWin and BW Controller to enhance our plant analysis capabilities. In future editions, we'll look at more complex control applications, and also continue to explore other features of BioWin.

We trust that you found this technical topic both interesting and informative.

Please feel free to contact us at **info@envirosim.com** (Subject: The BioWin Advantage) with your comments on this article or suggestions for future article.

Thank you and good modeling

The EnviroSim Team

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