



July 18, 2014

Steve Tedesco
Tetra Tech
17885 Von Karman Ave., Suite 500
Irvine, CA. 92614

Subject: July 2014 WBMWD Pipe Rack Biofouling Test

Dear Steve:

Attached are my notes from my inspection of the first three pipe spools from the WBMWD Pipe Rack Biofouling Test. The macrofouling found within the pipe spools was quite limited with only a few barnacles found in two of the three spools and none present in the third. Possible factors contributing to the lack of fouling are presented in my notes. We should also remember that the test apparatus had only been in operation for 54 days, running from May through June, and that barnacle settlement may have been limited during this period. I would recommend that we continue the test through the next two to three month period and then reassess how to proceed following the next inspections. The Wedgewire test racks were deployed at the intake on June 17, 2014 and are scheduled to be inspected in mid-September. They will provide us with additional information on barnacle and mussel settlement and growth during the summer. The combined data should provide us with the information we need to make a decision regarding the continued operation of the pipe rack.

Sincerely,

Fred Steinert
Tenera Environmental

West Basin Pipe Rack Biofouling Test First Pipe Spool Inspections July 1, 2014

Duration of Testing: May 7, 2014 – June 30, 2014 (54 days)

Biofouling Inspection Notes

Pipe Spool Description

- This is the first time that we have seen the pipe spools. Here is a description (photos were taken):
 - Each is 18 inches long with a pair of ring-flanges.
 - Each spool is actually constructed of three 6 inch sections; an inlet and outlet ring-flanged section and a middle pipe section.
 - The pipe material of all three sections is black high density polyethylene (HDPE).
 - The rings for the ring-flanges are metal (galvanized steel?).
 - There is some sort of double O-ring or gasket where the inlet and outlet sections connect with the middle section. These seals extend both inward into the pipe and outward above the pipe exterior. The total width of these double-seals is about 7-8 mm and they extend into the pipe interior about 3 mm. These will be referred to as “ridges”, such as the first ridge or second ridge from the inlet.
 - The inlet and outlet sections surfaces are not smooth, but have small ribs around the pipe’s circumference, perpendicular to the direction of flow.
 - There are about three ribs per mm and they are about 0.25 mm in height.
 - The middle section has a smooth surface, no ribs.
- The surface irregularities caused by the ribs and the ridges will induce some turbulence at the pipe surface and may promote settlement by some macrofouling species, like barnacles, as has been observed in the past at pipe joints and other substrate surface anomalies (pits, bumps, scratches, old shells, etc.).

Pipe Spool A1 (Control)

- This is the first pipe spool in spool row A. No chemical injection; this is the “Control” spool row.
- First impression is that the inner surface of the spool is very clean, no macrofouling initially observed.
- Photos taken from inlet and outlet ends.

- Pipe surface has a very slight slime feeling to the touch. Tissue wipe made of the surface shows a brown tinge that is probably diatoms, but not enough can be collected for a microscopic inspection.
- Further inspection with a lighted-mirror tool finds two small acorn barnacles (1.5 and 2.5 mm basal diameter). The smaller of the two is on the downstream side of the first ridge and the other is about 5 cm further downstream in the middle section.
- One barnacle was removed for microscopic ID and photographing. It was a Balanid barnacle, probably *Balanus glandula*, but it is too early in its development to be sure.
- No other macrofouling.
- No sand.
- Some mussel shell debris was found when the spool was removed from the pipe rack and was included in a separate bag with spool A1. This is old debris that must have originated in the seawater supply line to the test apparatus.

Pipe Spool B1 (Continuous Chloramine Injection)

- Photos taken from inlet and outlet ends.
- No macrofouling organisms were found.
- No slime/diatoms detected by touch or tissue wipe.
- Fine sand covers approximately the bottom 1/3 of the pipe spool.
 - Some old, empty, barnacle and mussel shell fragments mixed in with the sand.

Pipe Spool C1 (Shock Chlorination)

- Photos taken from inlet and outlet ends.
- No slime/diatoms detected by touch or tissue wipe.
- About 75 to 80 very small acorn barnacles (Balanidae) were observed.
 - Size (maximum basal diameter) range from about 0.5 mm to 3.0 mm.
 - Barnacles are concentrated near the two ridges with the most (45 to 50) being at or downstream of the second ridge, in the outlet section. Only two individuals were in the smooth middle section.
- Fine sand covers approximately the bottom 1/2 of the pipe spool.
 - Some old, empty, barnacle and mussel shell fragments mixed in with the sand.
 - Sand as deep as about 3 mm (sand depth is probably limited by the height of the ridges).

Conclusions and Questions

- Ribs and ridges probably promote settlement in comparison with the smooth middle section.
- Decreasing quantity of sand in the spools as you move upward from Row C to Row A is indicative of the decreasing flow velocity as the water moves upward in the 6 inch vertical manifold.

- If you start with an initial flow of 150 gpm at the bottom of the manifold the average water velocity would be about 1.7 fps. After shunting 1/3 of the flow off into Row C, that would drop to about 1.1 fps. After losing another ½ of the remaining flow to Row B, the velocity would drop to about 0.6 fps.
- It appears that the velocity at the inlet of Row A is no longer sufficient to suspend the sand grains.
- Why are there only 2 barnacles in the control spool (Row A) and 75 to 80 in the shock chlorination spool (Row C)?
 - Is this related to the loss in water velocity as the flow progresses up the vertical manifold (see above)? Is there a similar effect on the larval densities reaching Row A?
 - Is this related to the accelerated seasoning of the HDPE pipe in Row C because of the shock chlorination and abrasion by the sand?
 - Is it related to both?
- Continuous chloramine treatment appears to be effective at this time.
- Shock chlorination has not eliminated all barnacle settlement and growth.
- No slime detected by touch in Rows B & C.
 - It could be the continuous treatment in Row B, but would weekly shock chlorination be sufficient to eliminate it? (probably not).
 - Is the sand also reducing any diatoms / slime on the pipe walls- abrasion?



September 2, 2014

Steve Tedesco
Tetra Tech
17885 Von Karman Ave., Suite 500
Irvine, CA. 92614

Subject: August 29, 2014 WBMWD Pipe Rack Biofouling Test:
Pipe Spool Inspections

Dear Steve:

Attached are the notes from my inspection of the three pipe spools removed from the WBMWD Pipe Rack Biofouling Test on August 28, 2014, after 144 days of operation. The macrofouling found within the pipe spools was very similar to that observed after 54 days of operation. Fouling was quite limited with only a few small barnacles found in two of the three spools and none present in the third. Possible factors contributing to the lack of fouling are presented in my notes. The near absence of macrofouling in the Control pipe spool provides little against which you can compare the efficacy of the two treatment regimes. I would recommend that we continue the test through the retrieval of the first Wedgewire test rack in about two weeks. The Wedgewire test racks were deployed at the intake on June 17, 2014 and will provide us with additional information on barnacle and mussel settlement and growth during the past three months. If the Wedgewire test racks are heavily fouled with macrofouling organisms (barnacles, mussels, etc.) then I would conclude that the macrofouling larvae are not making it from the intake to the pipe test, most likely due to cropping by macrofouling in the supply line, and that the pipe test should be discontinued. If fouling is absent or limited on the intake racks, then the problem may be an overall lack of macrofouling larvae in the vicinity of the intake.

Sincerely,

Fred Steinert
Tenera Environmental

West Basin Pipe Rack Biofouling Test Second Pipe Spool Inspections August 29, 2014

Duration of Testing: May 7, 2014 – August 28, 2014, 114 days)

Biofouling Inspection Notes

Pipe Spool A2 (Control)

- This is the second pipe spool in spool row A. No chemical injection; this is the “Control” spool row.
- First impression is that the inner surface of the spool is very clean, little macrofouling observed.
- Photos taken from inlet and outlet ends.
- Pipe surface has a slime feeling to the touch. Slime is visible in the photos with a brownish tinge. Samples were removed and inspected under a microscope; samples include diatoms and entrapped silt particles. Layer was not of measureable thickness or of a quantity that would allow removal for a weight determination.
- Inspection with lighted-mirror tools found a total of 14 small acorn barnacles (0.5 – 2.0 mm basal diameter). The barnacles are located near areas of surface discontinuity or turbulence, such as the inlet to the spool and the ridges that divide the spool into three section (inlet, middle, and outlet).
- Two barnacles were removed for microscopic ID. They were a Balanid barnacles, probably *Balanus glandula*, but it was too early in their development to be sure.
- No other macrofouling.
- No sand.

Pipe Spool B2 (Continuous Chloramine Injection)

- Photos taken from inlet and outlet ends.
- No macrofouling organisms were found.
- No slime/diatoms detected by touch or tissue wipe.
- 15 small mussel shells were found in the spool (3 – 10 mm in length). All of the shells were empty and none of them were attached to the pipe surface (no byssal threads). All of the shells are new in appearance with clean dark outer surfaces and a shiny inner nacreous layer (mother of pearl).
 - These shells did not originate in the spool and there is no evidence of mussel attachment in any of the three spools (no remnants of byssal threads or signs of past byssus attachment on the pipe surfaces). Shells are probably from the seawater supply line.
- No sand

Pipe Spool C2 (Shock Chlorination)

- Photos taken from inlet and outlet ends.
- No slime/diatoms detected by touch or tissue wipe.
- 12 small acorn barnacles (Balanidae) were observed.
 - Size (maximum basal diameter) range from about 0.5 mm to 3.0 mm.
 - Only one barnacle each found in the inlet and middle sections of the spool, the other ten were in the outlet section.
- Three of the larger (2 to 3 mm) barnacles were identified as *Megabalanus californicus*, the others appear to be *Balanus glandula*.
- No sand

Conclusions

- Little or no macrofouling in any of the three spools.
- Although there is a complete lack of fouling in the Continuous Chloramine treatment spool (spool B2), the paucity of fouling in the Control spool (spool A2) provides little comparison against which to evaluate the efficacy of any of the treatments.
- The lack of macrofouling in the Control spool is most likely due to the cropping of macrofouling larvae from the water supply by established filter-feeding organisms (mussels, barnacles, etc.) in the seawater supply line. There may be other contributing factors including the low flow velocities in portions of the system, and cropping of food items from the seawater flow as it passes through the supply line (reducing survival and growth of any organisms settling in the pipe spools).



November 3, 2014

Steve Tedesco
Tetra Tech
17885 Von Karman Ave., Suite 500
Irvine, CA. 92614

Subject: October 28, 2014 WBMWD Pipe Rack Biofouling Test:
Pipe Spool Inspections

Dear Steve:

Attached are the notes from my inspection of the three pipe spools removed from the WBMWD Pipe Rack Biofouling Test on October 27, 2014, after 174 days of operation. The macrofouling found within the pipe spools was very similar to that observed during the two prior pipe spool inspections following 54 and 114 days of operation. Fouling was again quite limited with only a few small barnacles found in two of the three spools and none present in the third. The largest barnacles found in the pipe spools were only 3-4 mm in diameter. This differs greatly from the macrofouling found on the coupon test racks deployed at the intake, which were inspected in mid-September. The test racks were heavily fouled with hydroids, acorn barnacles, mussels, and a variety of other fouling organisms. Although the test racks had only been in the water for 92 days, some of the barnacles were as large as 12 mm in diameter. This leads me to conclude that the larvae of fouling organisms in the seawater are not surviving the long passage through the supply line from the intake to the test apparatus. Macrofouling organisms already established within the supply line are probably feeding on the larvae, thereby removing them from the water prior to their arrival at the pipe spools. The small size of the few barnacles found in the untreated "control" pipe spool is probably an indication that most of the food items in the seawater are also being consumed during their passage through the supply line, hence limited barnacle growth.

While much of this is speculative, without the capability of inspecting the entire length of the supply line, the fact remains that without substantial macrofouling growth in the control pipe spools there is nothing against which to gauge the efficacy of the antifouling treatments.

Sincerely,

Fred Steinert
Tenera Environmental

West Basin Pipe Rack Biofouling Test Third Pipe Spool Inspections October 28, 2014

Duration of Testing: May 7, 2014 – October 27, 2014, (174 days)

Biofouling Inspection Notes

Pipe Spool A3 (Control)

- This is the third pipe spool in spool row A. No chemical injection; this is the "Control" spool row.
- First impression is that the inner surface of the spool is very clean, little macrofouling observed.
- Photos were taken from inlet and outlet ends (**Figure 1**).
- Pipe surface has a slimy feeling to the touch. Slime layer is visible in the photos with a brownish appearance. Samples were removed and inspected under a dissecting microscope. The samples appeared to be comprised of filamentous material (probably algal filaments) with entrapped detritus (silt, etc.). The layer was not of measureable thickness (less than 0.5 mm) or of a quantity that would allow its removal for a weight determination. Following photographs and inspection, this layer was easily removed from the pipe surface by either a gentle swipe with a finger or soft instrument, or by flushing with water from a hose.
- Inspection with lighted-mirror tools found a total of 18 small acorn barnacles (2 mm to 4 mm basal diameter). The barnacles are located near areas of surface discontinuity or turbulence, such as the inlet to the spool and the ridges that divide the spool into three sections (inlet, middle, and outlet). Barnacles that were large enough to be identified were *Megabalanus californicus*, the others were Balanid barnacles, possibly *Balanus glandula* or *M. californicus*, but it was too early in their development to be sure.
- Six small acorn barnacles (1 mm) were found on the face of the outlet flange – not within the pipe spool (**Figure 1**).
- No other macrofouling was found.
- No sand.

Pipe Spool B3 (Continuous Chloramine Injection)

- This is the third pipe spool in spool row B and was treated with continuous injection of a chloramine solution.
- Photos taken from inlet and outlet ends (**Figure 2**).
- No macrofouling organisms were found.
- No slime/diatoms detected by touch or tissue wipe.
- No sand

Pipe Spool C3 (Shock Chlorination)

- This is the third pipe spool in spool row C and received a weekly shock treatment with sodium hypochlorite.
- Photos taken from inlet and outlet ends (**Figure 3**).
- The pipe walls have a slight brown tinge, but do not feel slimy to the touch. The material can be easily removed with a tissue wipe. This could be fine silt trapped in a bacteria layer, or a thin layer of diatoms
- 9 small acorn barnacles (Balanidae) were observed; 3 in the inlet section and 6 in the outlet section.
 - Size (basal diameter) ranged from about 1 mm to 3 mm.
 - No barnacles found in the middle section of the spool.
- A small ball of plastic shavings were found at the ring between the middle and outlet section.
- No sand

Conclusions

- Little or no macrofouling in any of the three spools.
- Although there is a complete lack of fouling in the Continuous Chloramine treatment spool (spool B3), the paucity of fouling in the Control spool (spool A3) provides little comparison against which to evaluate the efficacy of any of the treatments.
- The lack of macrofouling in the Control spool is most likely due to the cropping of macrofouling larvae from the water supply by established filter-feeding organisms (mussels, barnacles, etc.) in the seawater supply line. There may be other contributing factors including the low flow velocities in portions of the system, and cropping of food items from the seawater flow as it passes through the supply line (reducing survival and growth of any organisms settling in the pipe spools).

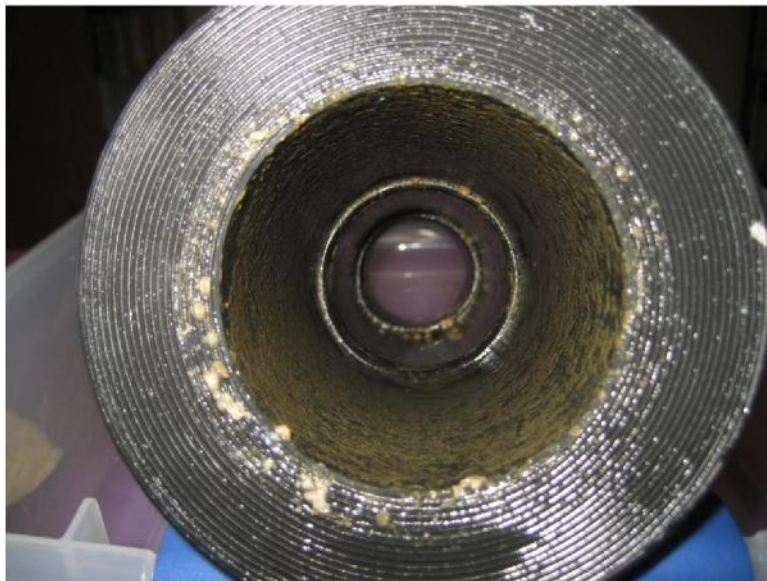
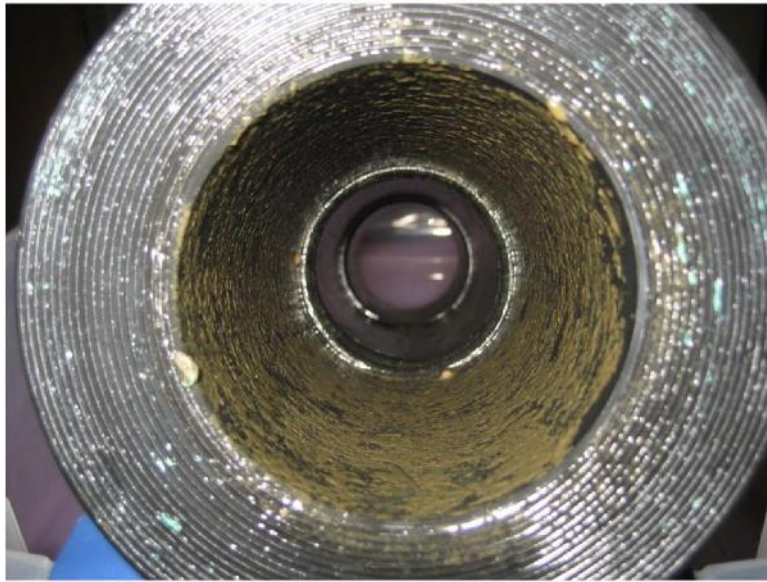


Figure 1. Pipe spool A3 (Control) October 28, 2014. Inlet (top) and Outlet (bottom).

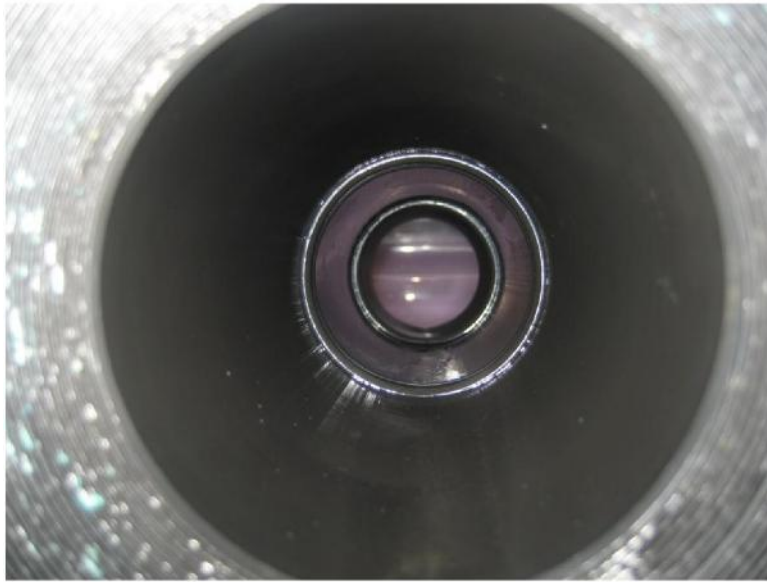


Figure 2. Pipe spool B3 (Continuous Chloramine Injection) October 28, 2014. Inlet (top) and Outlet (bottom).



Figure 3. Pipe spool C3 (Shock Chlorination) October 28, 2014. Inlet (top) and Outlet (bottom).

January 5, 2015

Steve Tedesco
Tetra Tech
17885 Von Karman Ave., Suite 500
Irvine, CA. 92614

Subject: December 23, 2014 WBMWD Pipe Rack Biofouling Test:
Pipe Spool Inspections

Dear Steve:

Attached are the notes from my inspection of the three pipe spools removed from the WBMWD Pipe Rack Biofouling Test on December 22, 2014, after 230 days of operation. The macrofouling found within the pipe spools was very similar to that observed during the three prior pipe spool inspections following 54, 114 and 174 days of operation. Fouling was again quite limited with only a few small barnacles found in two of the three spools and none present in the third. The largest barnacles found in the pipe spools were only 4 mm in diameter. This differs greatly from the macrofouling found on the coupon test racks deployed at the intake, which were inspected on December 29 and 30, 2014. The test racks were heavily fouled with hydroids, acorn barnacles, mussels, and a variety of other fouling organisms. Although the test racks had only been in the water for 196 days, some of the barnacles were as large as 18 mm in diameter. In addition, a temperature recorder that was attached to one of the test racks on September 16, 2014 and then retrieved on December 29, 2014 (105 days) had barnacles as large as 18 mm in diameter growing on the surface of its housing, indicating continued barnacle settlement and growth during this time period.

All of this leads me to conclude that the larvae of fouling organisms in the seawater are not surviving the long passage through the supply line from the intake to the test apparatus. Macrofouling organisms already established within the supply line are probably feeding on the larvae, thereby removing them from the water prior to their arrival at the pipe spools. The small size of the few barnacles found in the untreated "control" pipe spool is probably an indication that most of the food items in the seawater are also being consumed during their passage through the supply line, hence the limited barnacle growth.

While much of this is speculative, since we lack the capability of inspecting the entire length of the supply line, the fact remains that without substantial macrofouling growth in the control pipe spools there is nothing against which to gauge the efficacy of the antifouling treatments.

Sincerely,

Fred Steinert
Tenera Environmental

West Basin Pipe Rack Biofouling Test Fourth Pipe Spool Inspections December 23, 2014

Duration of Testing: May 7, 2014 – December 22, 2014, (230 days)

Biofouling Inspection Notes

Pipe Spool A4 (Control)

- This is the fourth pipe spool in spool row A. No chemical injection; this is the "Control" spool row.
- First impression is that the inner surface of the spool is very clean, little macrofouling observed.
- Photos were taken from inlet and outlet ends (**Figure 1**).
- The pipe surface had a dull brown appearance, but no slimy feeling to the touch as had been detected at the end of October when the last set of spools were inspected. Following photographs and inspection, an attempt was made to remove some of the brown discoloration with a tissue wipe, but no material came off the surface of the pipe.
- Inspection with lighted-mirror tools found a total of 11 small acorn barnacles in the inlet section of the pipe spool, 19 barnacles in the middle section and 25 in the outlet section. The barnacles ranged in size from <1 mm to 4 mm. The barnacles were located near areas of surface discontinuity or turbulence, such as the inlet to the spool and the ridges that divide the spool into three sections (inlet, middle, and outlet). Barnacles that were large enough to be identified were *Megabalanus californicus*, the others were Balanid barnacles, possibly *Balanus glandula* or *M. californicus*, but it was too early in their development to be sure.
- No other macrofouling was found.
- No sand or debris was observed in the spool.

Pipe Spool B4 (Continuous Chloramine Injection)

- This is the fourth pipe spool in spool row B and was treated with continuous injection of a chloramine solution.
- Photos taken from inlet and outlet ends (**Figure 2**).
- No macrofouling organisms were found.
- No slime/diatoms detected by touch or tissue wipe.
- No sand or debris, although a rust stain was observed in the inlet section (**Figure 2**).

Pipe Spool C4 (Shock Chlorination)

- This is the fourth pipe spool in spool row C and received a weekly shock treatment with sodium hypochlorite.
- Photos taken from inlet and outlet ends (**Figure 3**).

- No slime/diatoms detected by touch or tissue wipe.
- 9 small acorn barnacles (Balanidae) were observed; 5 in the inlet section, 2 in the middle section, and 2 in the outlet section.
 - Size (basal diameter) ranged from about <1 mm to 3 mm.
- No sand or other debris was observed.

Conclusions

- Little or no macrofouling in any of the three spools.
- Although there is a complete lack of fouling in the Continuous Chloramine treatment spool (spool B3), the paucity of fouling in the Control spool (spool A4) provides little comparison against which to evaluate the efficacy of any of the treatments.
- The lack of macrofouling in the Control spool is most likely due to the cropping of macrofouling larvae from the water supply by established filter-feeding organisms (mussels, barnacles, etc.) in the seawater supply line. There may be other contributing factors including the low flow velocities in portions of the system, and cropping of food items from the seawater flow as it passes through the supply line (reducing survival and growth of any organisms settling in the pipe spools).



Figure 1. Pipe spool A4 (Control) December 23, 2014. Inlet (top) and Outlet (bottom).



Figure 2. Pipe spool B4 (Continuous Chloramine Injection) December 23, 2014. Inlet (top) and Outlet (bottom).



Figure 3. Pipe spool C4 (Shock Chlorination) December 23, 2014. Inlet (top) and Outlet (bottom).