Groundwater Memorandum

To: Karin Baldwin and Keith Stoffel

From: Llyn Doremus

Date: January 12, 2017

Re: Walla Walla Aquifer Recharge Water Quality report review

Introduction

This memo presents an evaluation of the Washington Walla Walla Basin Aquifer Recharge Project water quality impacts using the information presented in reports submitted by the Walla Walla Basin Watershed Council (WWBWC) completed July 2007, January 2009, December 2009, August 2013, August 2015 and listed in the Attachment 1 to this memo. The WWBWC reports present groundwater and surface water quality analyses results and soils sample test results collected during the infiltration episodes at the Locher Road and Stiller Pond sites. The remaining two sites (Last Chance Road and Mud Creek) have not yet started infiltration operations; soil and groundwater samples were collected from the Last Chance Road recharge site, and soil samples were collected from the Mud Creek recharge site to characterize background conditions. Aquifer recharge site locations are shown in Figure 1.

The Walla Walla River and its tributaries are regulated under a number of Total Maximum Daily Load Studies and Implantation Plans (TMDLs are listed in Attachment 1). TMDLs have been completed for:

- Chlorinated Pesticides and PCBs
- Fecal Coliform
- pH and Dissolved Oxygen
- Temperature.

With the documented water quality impairments in the Walla Walla watershed, extensive sampling and analyses of groundwater, source water and soils were prescribed in order to gather the information necessary to assess whether aquifer recharge operations were negatively impacting water quality. This memo assesses the full set of data submitted to Ecology by the Walla Walla Basin Watershed Council documenting the water and soil quality over the course of the infiltration operations.

Summary of Recommended Data Collection

Generally, the source water quality used for recharge operations is excellent, providing an overall beneficial effect on groundwater quality, with some notable exceptions. Source water appears to flush constituents present in soils as it passes through them generating temporary increases in nitrate and total dissolved solids (TDS) in the underlying aquifer at the start of the recharge events. Overall, the surface water infiltrated at the Locher Road and Stiller Pond Recharge Sites is of good quality and is not degrading groundwater in the underlying aquifer.

Analyses of organochlorine pesticides, chlorinated herbicides volatile organic compounds and synthetic organic compounds show that very little, if any of these constituents are present in groundwater and soils at all sites. As a consequence analyses for all of these constituents can be discontinued immediately at Stiller Pond (and were discontinued as of 2015 for Locher Road). Analyses for chlorinated herbicides and volatile organic compounds in surface water and groundwater should be initiated before, during and/or after infiltration at Last Chance Road and Mud Creek recharge sites.

Analyses for Polychlorinated Biphenols (PCBs) in groundwater and source water shows that PCBs are present at concentrations that exceed the groundwater and surface water standards. Ecology directed that PCB analyses be discontinued at the Locher Road recharge site. However, PCB analyses in source water and groundwater should continue at the Stiller Pond, Last Chance Road and Mud Creek recharge sites.

Analyses for nitrate, TDS, phosphorus in groundwater and source water should continue at all sites. Water quality analyses should be done on samples collected three times annually: before, during and after infiltration events. Analyses for nitrate, total phosphorus and PCBs should continue in soils at Stiller Pond, Last Chance Road and Mud Creek recharge sites. One set of soils samples from each site should be analyzed for these constituents annually.

Table 1. Recommended Analytes for 2017 Infiltration Operations

Locher Road	***Stiller Pond***	***Last Chance Road and Mud Creek***
Source water and groundwater		
Nitrate	Nitrate	Chlorinated Herbicides
Total Dissolved Solids	PCBs	Volatile Organic Compounds
Total Phosphorus	Total Dissolved Solids	Organochlorine Pesticides
	Iron	Metals (including iron)[1]
	PCBs	Nutrients (total phosphorus and nitrate)
		TDS
		Anions[2]
		pH
		Dissolved oxygen
[1] Metals are: Barium, Cadmium, Chromium, Lead, Mercury, Selenium, Copper, Iron, Manganese, Zinc, Arsenic		

[2] Anions are: Nitrate, Fluoride, Chloride, Sulfate, Carbonate and bicarbonate		
Soil		
nitrate	nitrate	nitrate
Total dissolved solids	Total dissolved solids	Total dissolved solids
Total phosphorus	Total phosphorus	Total phosphorus
	PCBs	PCBs

Project Overview

The four recharge projects evaluated in this memo are located in the 1,760 square mile Walla Walla watershed. The Walla Walla River flows for 61 miles, generally from east to west into the Columbia River 30 miles west of the recharge sites. The watershed is underlain by unconsolidated glacial and alluvial sediments that are highly permeable. The unconsolidated sediments extend to an approximate depth of 200 feet below the ground surface, and are deposited on the extensive Columbia River Basalts. Groundwater discharges to the Walla Walla River from all of the recharge sites. The recharge sites in Washington, and the duration of recharge activities are shown listed below and shown in Figure 1.

- Locher Road (2007 to 2015)
- Stiller Pond (2012 to 2015)
- Mud Creek (recharge not started as of 2015)
- Last Chance Road (recharge not started as of 2015).

Water quality samples are collected from the source water infiltrated at each site and groundwater wells installed for the purpose of monitoring the water quality in the receiving aquifers. Sampling and analyses to characterize groundwater responses to infiltration events at these four sites has evolved during the project duration. For the 2007, 2008 and 2009 Locher Road infiltration event data was collected on conventional parameters in surface and groundwater (analytes are listed in Attachment 2). During the 2011 and 2012 infiltration events at Locher Road and Stiller Pond samples were analyzed for conventional parameters (anions, cations and secondary drinking water criteria parameters), synthetic organic compounds (SOCs), herbicides, and chlorinated pesticides. A Quality Assurance Project Plan (QAPP) was approved and implemented in 2013, which standardized the groundwater and source water analytes, and initiated soils sampling from the infiltration ponds bottoms. With the approval of the QAPP Polychlorinated Biphenols (PCBs) were added to the list of analytes. Additionally: soil samples from the ground surface and one-foot below ground were analyzed for nitrate, phosphate and PCBs.

Nitrate (NO_3), total dissolved solids content (TDS) and total Polychlorinated Biphenols (PCBs) were used to assess the recharge sites operations impacts to groundwater quality in this memo. These parameters were selected because they are often influenced (increased) by human activities. Phosphorus in soils and groundwater were also evaluated because of its importance to

dissolved oxygen depletion in surface water (there is not a water quality standard for phosphorus content in groundwater or surface water). The groundwater quality standards and the sediment management standard for the other constituents evaluated are:

- Nitrate (in groundwater) - 10 mg/L
- Total Dissolved solids (in groundwater) - 500 mg/L
- PCBs (in groundwater) – 10 ng/L
- PCBs (in surface water) – 7 pg/L
- PCBs (in soil) – 110 ug/kg
- Total phosphorus (in groundwater) - 22ug/L *EPA recommended maximum.*

Locher Road Recharge Site

Site information

The Locher Road recharge site is located approximately 100 feet north of the Oregon Border at T6N, R35E. Section 18 (shown in Figures 1 and 2). The infiltration area is 2.5 acres of a previously excavated gravel pit, and sustains infiltration rates of 3.5 cubic feet per second (cfs) through highly permeable alluvial sediments. Water is diverted from the Walla Walla River, through the Gardena Farms Canal for infiltration at the site. Samples drawn from the canal were analyzed for source water characterization. Groundwater ranges in depth from fifteen to thirty feet below the ground surface (BGS) in the four wells monitored for the project (MW-57, MW-70, MW-71 and MW-72). Water level elevations measured in the wells during aquifer recharge events increase by up to eleven feet. Well locations, the diversion point from the Gardena Farms Canal and the soil sample collection site locations are shown in Figure 2.

Water is available for diversion to the Locher Road infiltration pond when flow in the Walla Walla River falls below 1,000 cubic feet per second (cfs), and exceeds the minimum flows established in Ch 173-532 WAC: 350 cfs in March and April, and 250 cfs in May. Infiltration events are summarized in Table 2.

Table 2. Locher Road recharge site infiltration events

Locher Rd	**2007**	**2008**	**2009**	**2011**	**2012**	**2013**	**2014**	**2015**
Duration	Mar 29 - Apr 20	Apr 15– May 31	Mar 6- Jun 1	Apr 8 - May 31	Mar 12 - May 26	May 14 - Jun 1	Apr 6 - May 20	Apr 12 - May 5
amount recharged (acre feet)	14.8	47	176	93	334	104	180	36

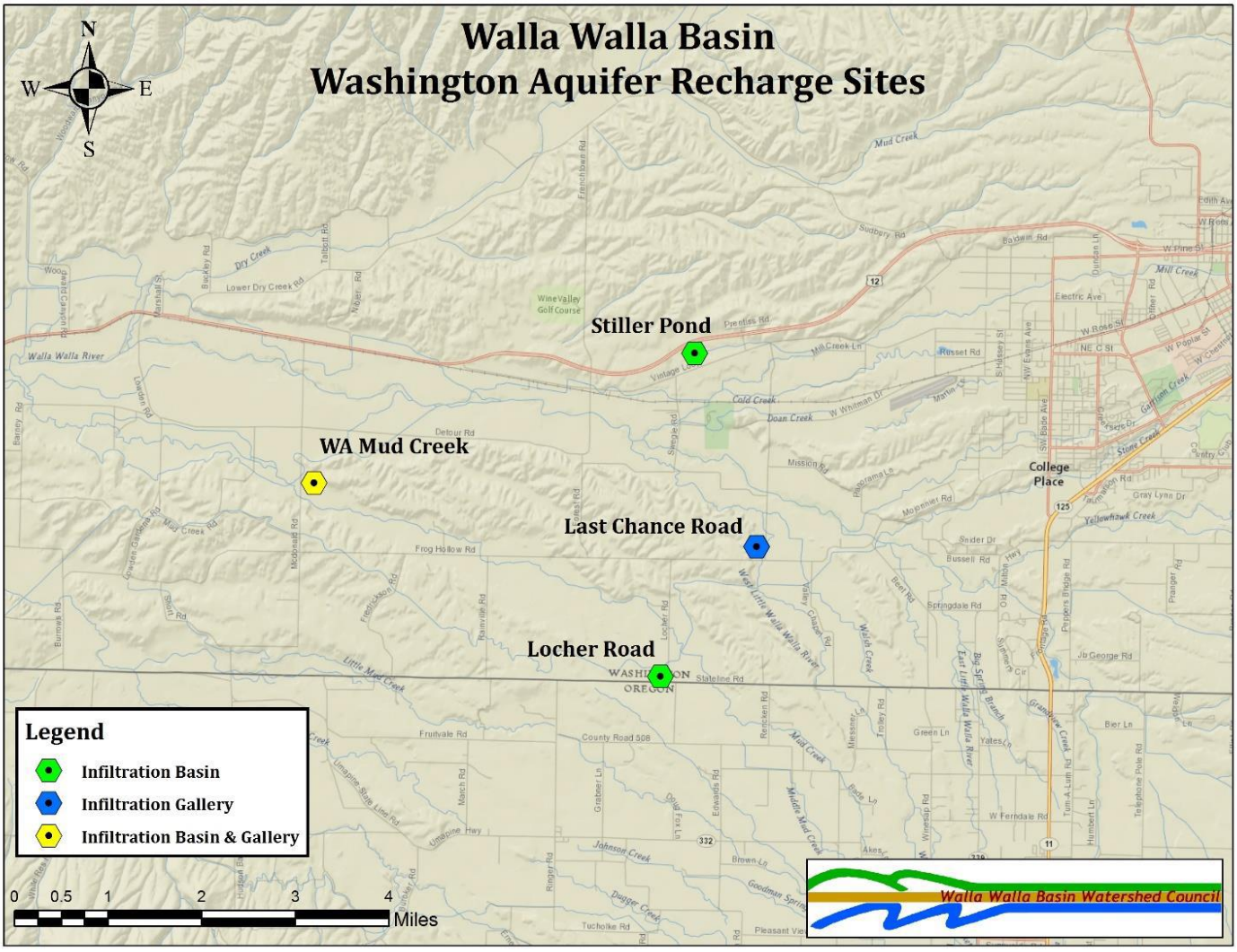


Figure 1. Walla Walla Watershed Aquifer Recharge Sites (in Washington)

Generally, groundwater migrates in the unconfined aquifer beneath this site from southeast to northwest. This direction of groundwater movement establishes monitoring well GW-70 as the upgradient well, GW-57 as cross-gradient, and GW-71 and GW-72 downgradient.

Water Quality and Soil Characterization

The constituents analyzed for water quality characterization varied over the eight infiltration events, and are listed by year in Attachment 2. For this water quality assessment nitrate, total dissolved solids (TDS), phosphorus and PCBs concentrations in source water and groundwater were considered. Herbicides, synthetic organic compounds, and chlorinated pesticide analyses results showed that for the vast majority of constituents analyzed low to non-detectable concentrations were present. As such, they were not considered for detailed analyses of groundwater quality. Metals analyses also showed very low concentrations for all those that were

analyzed. Monitoring of PCBs and chlorinated pesticides was discontinued in 2015, per Ecology's direction (letter included in Attachment 3).

Soil samples were collected from five locations distributed around the floor of the infiltration pond (shown in Figure 2) and from one foot below the surface locations of all five sampled sites in 2013, 2014 and 2015. They were analyzed for nitrate and phosphate content, and PCBs. However, PCBs were not analyzed in 2015. Soils analyses results are shown in Figure 4, 6(a) and listed in Table 3.

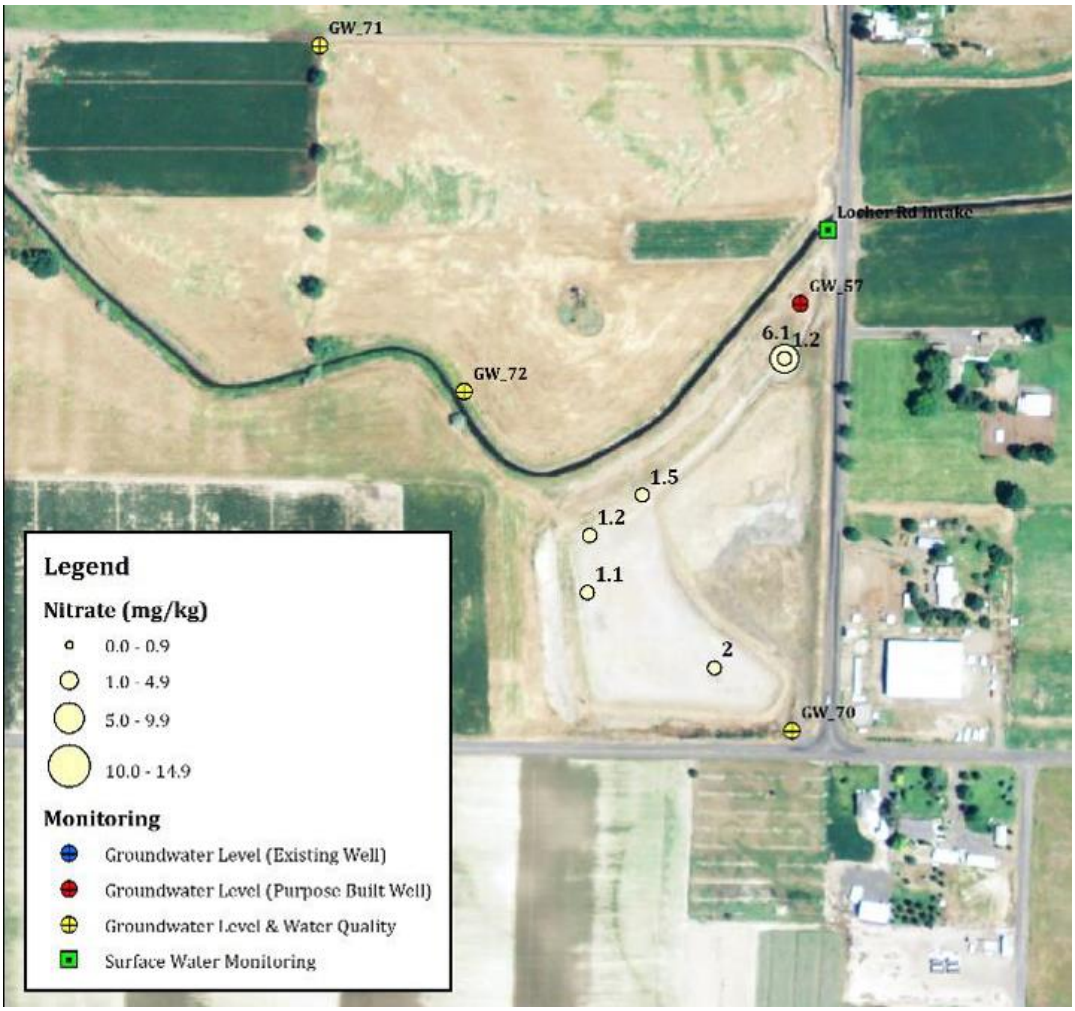


Figure 2 (above). Locher Road infiltration site, with five soil sample sites shown and suface soil nitrate concentrations for 2014. Black numbers correspond to the nitrate concetnrations measured in soil at the ground surface. Blue and purple numbers signify the sample site number at the ground surface (blue), and at one foot depth below the ground surface (purple). Soil concentration data for each site number is plotted for nitrate (figure 4), and phosphorus (figure 5).

Nitrate in soil and groundwater

Nitrate concentrations in groundwater in all monitored wells responded to the initiation of infiltration. Generally concentrations increased at the beginning of recharge episodes, and declined subsequently (shown in Figure 3). Initial groundwater and maximum nitrate concentrations for each year are listed in Table 2.

Table 2. Nitrate concentrations in groundwater at the Locher Road site (listed by year)

Year	**Initial (mg/L)**	**Maximum (mg/L)**	**Well where max concentration detected**
2011	2.9 - 10.4 mg/L	14.8	GW-71
2012	4.0 - 7.14 mg/L	17.7	GW-71
2013	1.5 - 7.8 mg/L	17.4	GW-71
2014	3.2 - 6.7 mg/L	22	GW-72
2015	0.9 - 6.6 mg/L	6.7	GW-71

Nitrate concentrations regularly exceeded the water quality standard during infiltration events in every monitoring well. The greatest increases in concentrations occur in GW-70 (the upgradient well) and GW-71 (the downgradient well furthest from the infiltration facility). Nitrate concentrations are generally lower in GW-72, the closer downgradient well showing a more subdued response to infiltration.

The higher nitrate concentrations observed in the upgradient well (GW-70) during infiltration events signifies that groundwater sampled from GW-70 does not actually represent upgradient conditions. The well is located within about 50 feet (upgradient) of the infiltration basin (as interpreted from the 2013 report site map), which is apparently close enough to be affected by the groundwater mound generated by infiltrating water. The groundwater elevation increases in GW-70 (4 to 11 feet during the 2011 to 2015 recharge events) support an interpretation that groundwater mounding is extending upgradient and temporarily reversing the direction of groundwater flow in the GW-70 vicinity, southeast of the infiltration basin. The reversal in flow direction transports water temporarily in the upgradient direction, increasing nitrate concentrations in GW-70 (observed in 2009 and 2011). During the 2013, 2014 and 2015 recharge events corresponded with decreases in nitrate concentrations in GW-70, potentially resulting from rapid upgradient migration of the infiltrating low nitrate concentration source water. An alternative explanation for the nitrate concentration decreases in GW-70 is that prior infiltration events flushed nitrate from shallow soils removing it from the soil and groundwater system in the GW-70 vicinity.

Whatever the processes that are influencing nitrate concentration fluctuations in GW-70, groundwater data collected from the well cannot be expected to represent background conditions.

Groundwater samples collected prior to initiation of infiltration (Specifically on April 5, 2011 and Feb 2, 2012) might be considered to represent background nitrate conditions. Nitrate concentrations ranged from 2.8 to 10.4 mg/l in 2011, and 4.0 to 7.1 mg/l in 2012 in the four wells monitored. Together these data suggest that background nitrate concentrations are elevated in the groundwater in the Locher Road recharge site vicinity, and increase during infiltration events.

Source water nitrate concentrations are consistently lower than the nitrate concentrations of groundwater (evident in Figure 3), ranging from 0.12 to 2.57 mg/L, indicating that it is not the cause of the increases groundwater nitrate concentrations observed during the infiltration events.

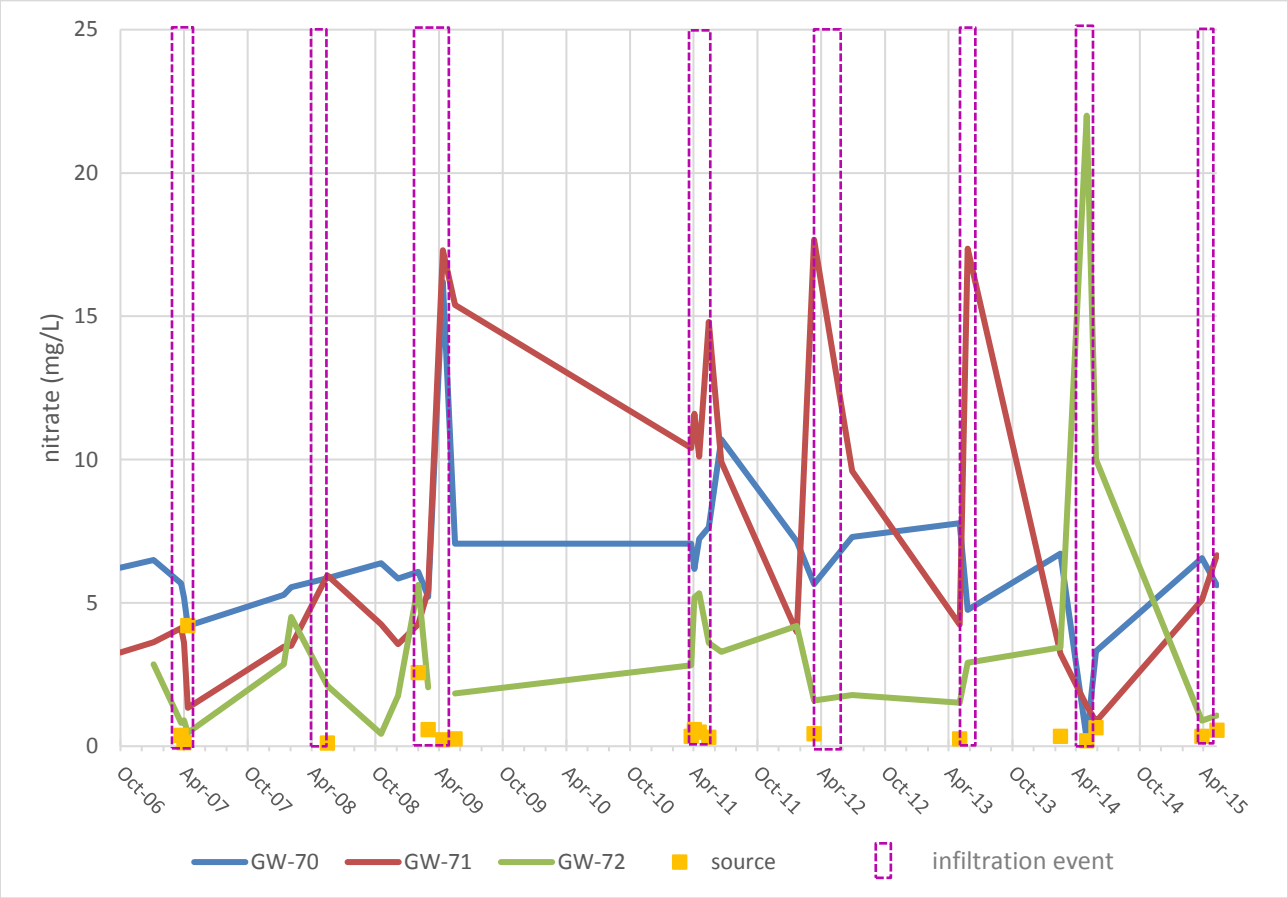


Figure 3. Locher Road nitrate concentrations monitored in groundwater, with infiltration event durations shown as purple boxes

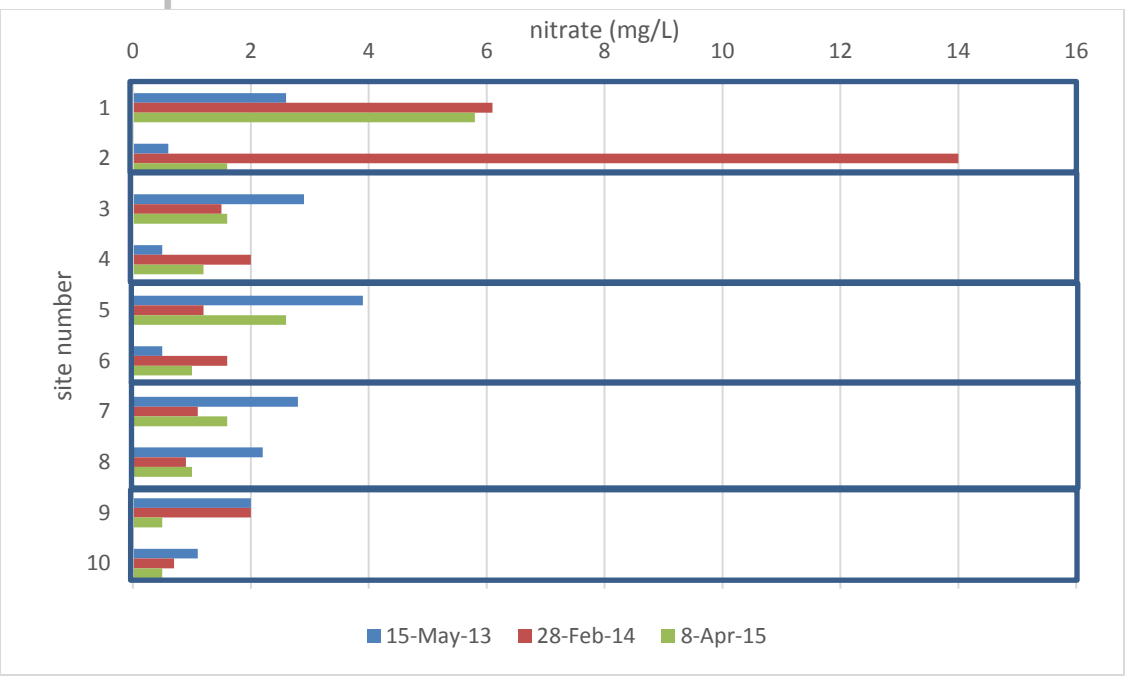


Figure 4. Locher Rd nitrate content in soil at 5 sites (surface and 1- foot depth), grouped in navy rectangles. Soil samples location shown in Figure 2.

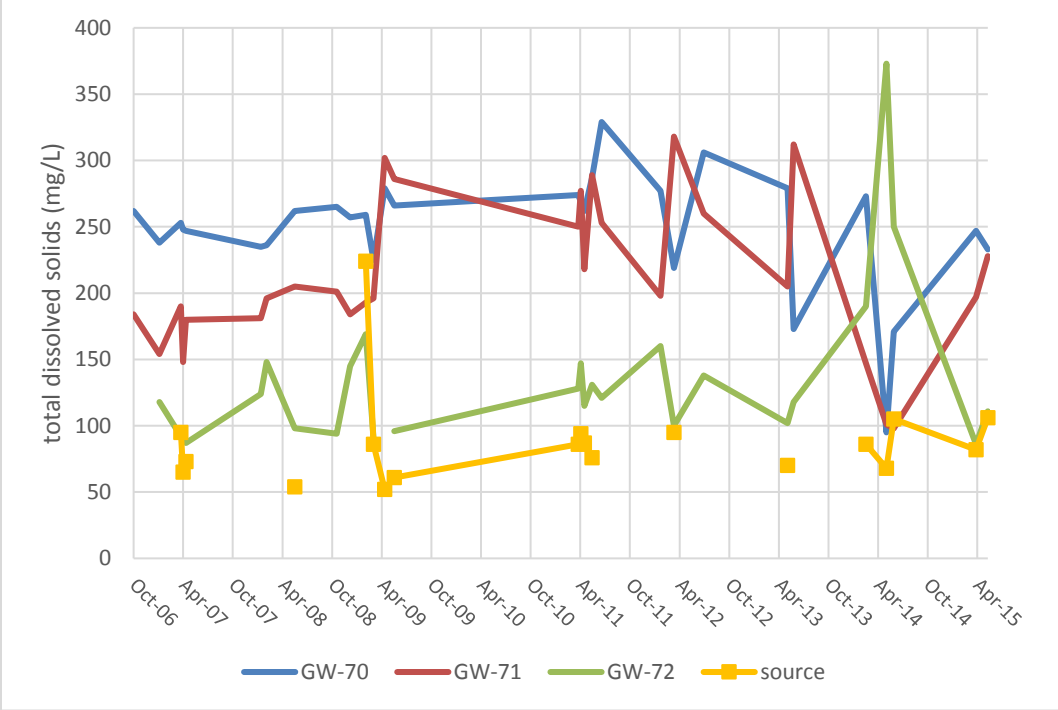


Figure 5 (above). Locher Rd total dissolved solids concentrations in groundwater and source water

The source of the nitrate concentration spikes at the initiation of infiltration events is more likely the infiltrating water dissolving and transporting nitrogen (and other constituents) from the ground surface and shallow unsaturated sediments to groundwater. This is supported by the high soil nitrate concentration of 14 mg/L measured in soil sample no. 2 on February 28, 2014 (shown in Figure 4); and the corresponding spike of 22 mg/L in groundwater nitrate concentration in GW-72 on May 2014 (the highest measured in groundwater). High soil and groundwater phosphorus concentrations, and total dissolved solids measured in groundwater in spring 2014 indicate that more constituents than just nitrate were present at the ground surface, and subsequently transported to and in groundwater. A similar phenomenon was detected at the Stiller Pond in February 2014, and is discussed in the Stiller Pond section of this memo.

Total Dissolved Solids in Groundwater

Total dissolved solids (TDS) concentrations were analyzed in groundwater and source water for every infiltration event. In every case TDS concentrations were below the groundwater quality standard of 500 mg/l (shown in Figure 5). Source water concentrations of TDS are uniformly low (100 mg/L or less), consistently less than the groundwater concentrations measured with one exception of February 2009 (224 mg/L). TDS concentrations in groundwater varied with the infiltration events, reflecting a similar pattern to the nitrate concentration variations. The lowest concentrations were typically present in GW-72 (the downgradient well closest to the infiltration pond), GW-70 and GW-71 TDS concentrations increase with the initiation of infiltration and then decrease. Similar to the process influencing nitrate concentrations, it appears that TDS are being transported by water infiltrating from the ground surface through shallow sediments to groundwater at the initiation of infiltration. After the initial flush, the TDS concentrations decrease to values closer to the source water being infiltrated. TDS content was not measured in soils for the project.

Phosphorus in Soil and Groundwater

Phosphorus content was measured in water in various forms (total phosphorus, ortho-phosphate and soluble reactive phosphorus) at different times over the duration of the recharge operations. Soluble reactive phosphorus was analyzed in 2007, 2008 and 2009, orthophosphate in 2011 and 2012 and total phosphorus in 2013, 2014 and 2015. Soluble Reactive phosphorus is the fraction of ortho-phosphate that passes through a filter. Total phosphorus includes all ortho-phosphate and all organic phosphate. Because there are no overlapping analyses of the various forms of phosphorus over the course of the project, it is difficult to assess the relative content of each in relation to the other. As a consequence, the measured concentrations in groundwater are compared here as if they were the same form, with an emphasis on the relative concentrations and patterns, and not the absolute concentration values.

Phosphorus measured in groundwater in all wells follows a similar pattern to the phosphorus concentrations detected in source water (shown in Figure 6A). Generally, groundwater concentrations increase in the first sample of an infiltration event and subsequently decreasing over the recharge season. However, phosphorus concentrations in groundwater are consistently higher than source water being infiltrated.

Over the duration of aquifer recharge operations phosphorus concentration in groundwater has progressively decreased, ranging from a high of 360 ug/l to a low of 10 ug/L. Phosphorus concentrations in groundwater are progressing towards compliance with the EPA recommended maximum of 22 ug/L.

Soil total phosphorus content has similarly decreased in concentration over the 2013 to 2015 period that soil analyses were conducted (shown in figure 6B). Highest concentrations were measured in 2013 (936 – 1195 ug/kg). Lowest concentrations measured in 2015 (range of 520 to 898 ug/kg). The exception was the February 28, 2014 sample from site no. 7 (1553 ug/kg), the highest concentration detected. The high value coincides with the highest nitrate soil concentration measured at site no. 2 on February 28, 2014. These are interpreted to result from a soil deposition event prior to February 2014 that flushed through the soil surface to the aquifer (apparent also in the Locher Road nitrate content in soil and groundwater, and in the total dissolved solids content in groundwater).

Phosphorus adsorbs more permanently to soil, and is less likely to be mobilized during the infiltration process. However, the higher phosphorus concentrations in groundwater than the source water combined with the increases in phosphorus content in groundwater with the initiation of infiltration events suggests that soils are not adsorbing the phosphorus in the infiltrating source water, but instead are releasing it. This may be a result of soils in the Locher Road infiltration basin being saturated with respect to phosphorus, and/or the higher pH of the source water than the groundwater acting to de-sorb and dissolve phosphorus from soils as it infiltrates. The progressive decrease in soil phosphorus content measured from 2013 – 2015 suggests that phosphorus is being removed from soils in the Locher Road infiltration basin by the recharge operations. Overall the progressive decrease in groundwater phosphorus concentrations throughout successive infiltration events supports an interpretation of groundwater concentrations reductions resulting from infiltration operations.

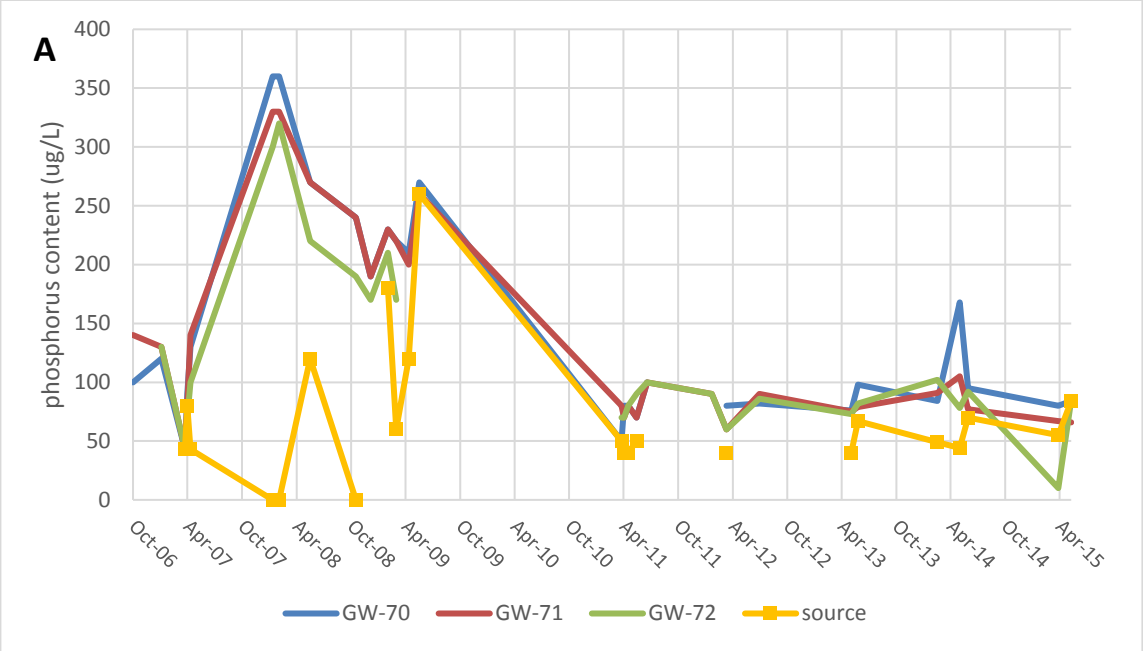
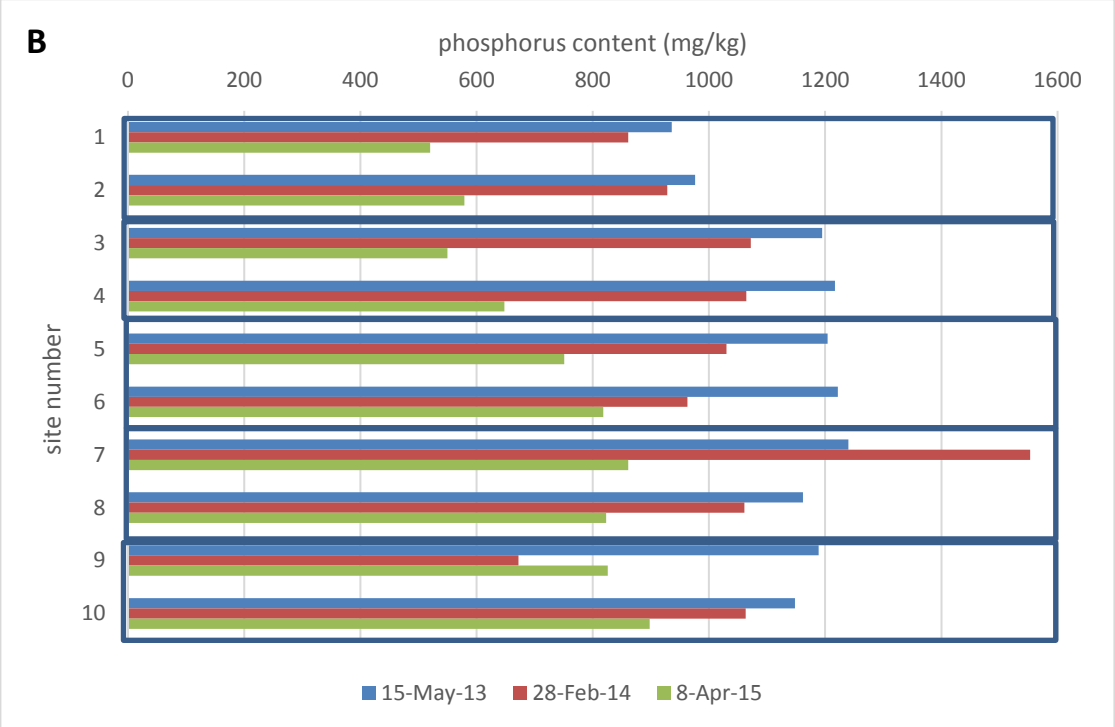


Figure 6(A) and 6(B). Locher Road phosphorus content measured in groundwater and source water (A- above), and measured in soil from samples collected at five locations in the infiltration basin (B- next page), at locations shown in Figure 2. Each soil sample site includes analyses of samples collected at the ground surface and one foot directly below, shown grouped in the navy blue box outlines.



Polychlorinated Biphenols in Soil and Water

Polychlorinated Biphenols (PCBs) are present in the Walla Walla watershed in soil, source water and groundwater (PCB content is summarized in Table 3). Soil samples from the ground surface and from one foot below ground surface collected from each of five locations in the infiltration basin ranged in concentrations from 3 to 1010 ng/kg, below the 110 ug/kg (110,000 ng/kg) cleanup standard for PCBs in soil. Groundwater and source water were analyzed for PCB content twice during the recharge event in 2013 and three times during the 2014 event. Groundwater concentrations ranged from 710 to 1130 ng/L. Source water concentrations ranged from 33 to 1490 ng/L. It is difficult to discern from this data whether the infiltration operations affect transport of PCBs from soil or surface water to groundwater. PCB analyses will not be conducted in the future, per Ecology's direction (as specified in memo in Attachment 3).

Table 3. Locher Road Aquifer Recharge site PCB content in groundwater, source water and soil

Date	**14-May-13**	**6-Jun-13**	**27-Feb-14**	**13-May-14**	**9-Jun-14**
water (ng/L)					
source	830	1080	32.9	68.5	1490
GW-70	385	996	713	1110	1120
GW-71	781	831	681	699	1130
GW-72	856	807	710	1120	984
soil (ng/Kg)					
soil (surface)					
1			1010		
3			91.9		
5			523		
7			12.6		
9			3.03		
soil (sub-surface)					
2			105		
4			6.4		
6			377		
8			5.9		
10			17.1		

Locher Road Summary

Overall, the quality of surface water infiltrated at Locher Road is of good quality, and its infiltration is not degrading groundwater in the underlying shallow aquifer. The variations in groundwater nitrate and TDS appear to derive from constituents contained in the overlying soil and sediments that the source water infiltrates through. Source water concentrations are significantly lower for these constituents than the concentrations measured in groundwater. Soil nitrate concentrations is likely the

source for spikes in groundwater nitrate concentration detected after initiation of infiltration. Subsequent decreases in groundwater nitrate and TDS concentration indicate that after an initial flush of constituents from the ground surface and shallow sediments, nitrate and TDS concentrations return to previously detected levels. The flush of these constituents through the soil column to groundwater does not significantly impact to groundwater quality. Groundwater moves rapidly through the receiving aquifer, and reverts to initial concentrations over the relatively short duration of the annual recharge events (two months or less). Monitoring for nitrate in soils, surface water and groundwater should be maintained during future infiltration events. TDS monitoring in source water and groundwater should also be continued.

Phosphorus content in groundwater correlates with source water concentrations. Phosphorus adsorbs more permanently to soil, and appears to be mobilized during the infiltration process by higher pH source water infiltration. The fact that phosphorus concentrations in groundwater are greater than the source water concentrations suggests that phosphorus is desorbing from soils with the infiltrating source water and transporting it to groundwater. The progressive decrease in groundwater phosphorus concentrations (and soil phosphorus content) throughout successive infiltration events supports an interpretation of groundwater phosphorus concentrations reductions resulting from infiltration operations. Phosphorus content in soils, source water and groundwater should be continued.

Concentrations detected of the remaining constituents analyzed in Locher Road infiltrated source water and groundwater (metals, herbicides, pesticides, and organic compounds) are relatively minor to non-detects, signaling that these constituents are not degrading groundwater during infiltration events. Monitoring for these constituents can be discontinued.

Stiller Pond Recharge Site

Site Information

Stiller Pond is located to the south of Highway 12, about half a mile north of Mill Creek (Section 29 of T7 N, R 35 E), shown in Figure 7. The Stiller Pond infiltration area is eight acres, and infiltrates water at a rate of 0.75 cubic feet per second (cfs) to the underlying alluvial aquifer. Water infiltrated at Stiller Pond is diverted from Mill Creek through a pipeline (at River Mile 2) to the site, about one mile from the diversion point. Source water samples are collected from Mill Creek at the point of diversion.

Infiltration events are permitted when the flows in Mill Creek and the Walla Walla River exceed the minimum instream flows established in WAC 173-532. For the months of March and April the minimum instream flow for Mill Creek is 150 cubic feet per second (cfs), and 350 cfs for the Walla Walla River. For May the minimum flow is 125 cfs for Mill Creek and 250 cfs for the Walla Walla River. Both streams are closed to any withdrawals from June through November. The 2012 recharge event infiltrated 32 acre feet (the maximum allowed under the existing permit). The next two recharge events (2014 and 2015) increased the permitted water available for recharge by 991 acre feet. Recharged quantities are listed for each infiltration season on Table 4.

Table 4. Stiller Pond recharge events

Stiller Pond	2012	2014	2015
duration	Mar 10 - 29	Apr 16 - May 29	Mar 24 - 31
amount recharged (acre-feet)	32	300	214

Hydrogeology of Stiller Pond area

Water in the shallow alluvial aquifer underlying the Stiller Pond recharge site migrates to the southwest, parallel to Mill Creek, and toward the Walla Walla River. The depth to groundwater is 10 to 25 feet below the ground surface, and varies seasonally. During the 2012 recharge event groundwater was monitored in a single well, GW-136. Three additional wells were installed subsequently (GW-145- GW-146 and GW-147) at locations shown on Figures 7 and 8. Well GW-147 is upgradient, and judging from the constituent concentrations in the other three wells GW-145 is cross gradient. The GW-136 and GW-146 wells show similar patterns in constituent concentrations, suggesting they are aligned along the same flow path, downgradient and in line with the groundwater gradient, with GW-136 located closest to Stiller Pond.

Maximum groundwater level changes were recorded in GW-136 during infiltration events. For the 2012 event groundwater rose in GW-136 about three feet, followed by a gradual decline over the next month. During the 2014 and 2015 infiltration events water levels rose in all four monitoring wells prior to initiation of infiltration, so the actual effect of infiltration on water levels was more difficult to define. The GW-136 and GW-145 wells showed a rapid decline in water levels of about five feet after infiltration terminated in 2014, suggesting a larger change in water level was associated with the increase in the amount infiltrated (300 acre feet) over the 2012 amount infiltrated (32 acre feet). Water level variations in GW-146 are not definitely correlated with infiltration events, and water levels in GW-147 appear to be primarily influenced by pumping from the aquifer.

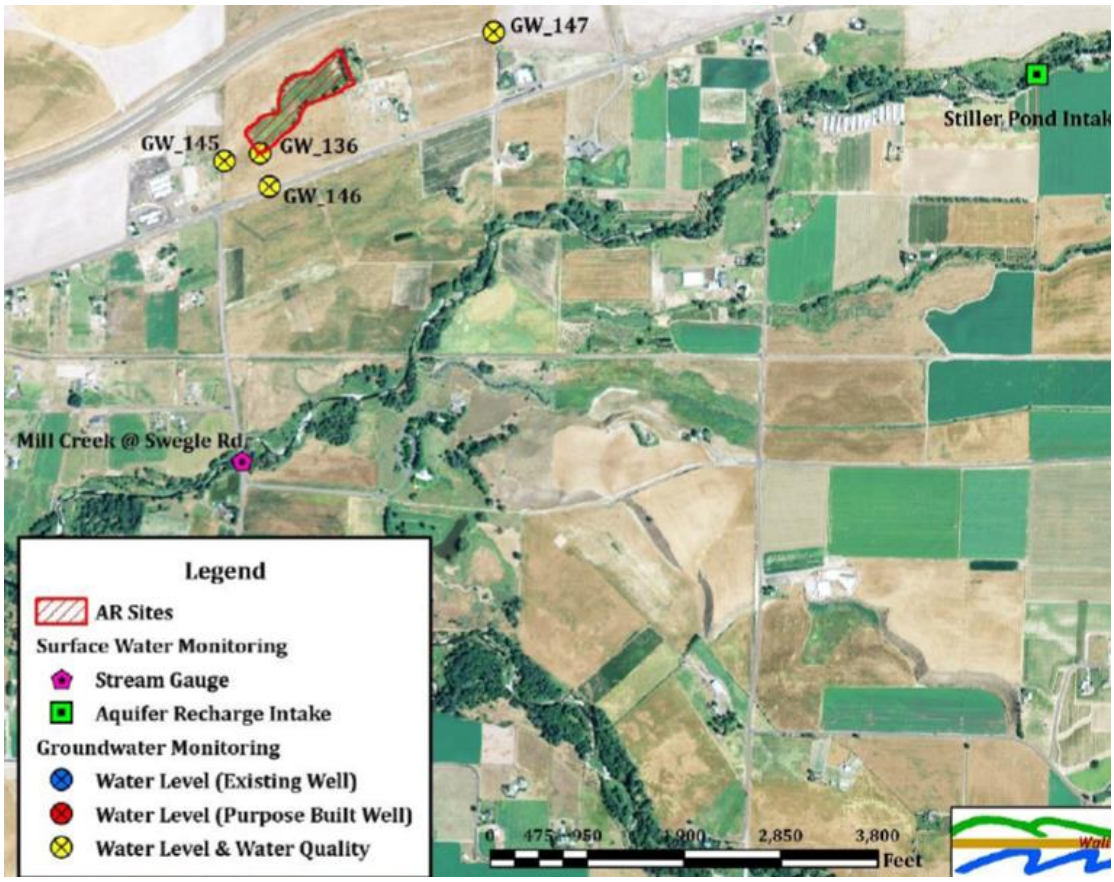


Figure 7. Stiller Pond groundwater and source water (designated as Stiller Pond Intake) monitoring locations

Water Quality and Soil Characterization

The water and soil quality record for the Stiller Pond Recharge site is not as long as for the Locher Road site. Groundwater was collected from one well (GW-136), and one source water sample was analyzed in 2012. During the 2014 and 2015 infiltration events groundwater was analyzed from four wells (including GW-136). Soil samples were collected and analyzed from five locations within the Stiller Pond infiltration area, and from one foot below the ground surface from each of the five surface sites (locations shown in Figure 8). The constituents analyzed in groundwater and source water are listed in Attachment 2. Concentrations of chlorinated herbicides, organochlorine pesticides, volatile organic compounds and metals (with the exception of iron) were consistently low to non-detect in all water samples analyzed from the 2014 and 2015 infiltration events. This analysis of Stiller Pond water quality focuses on nitrate, phosphorus, iron TDS and PCBs content in groundwater and surface water.

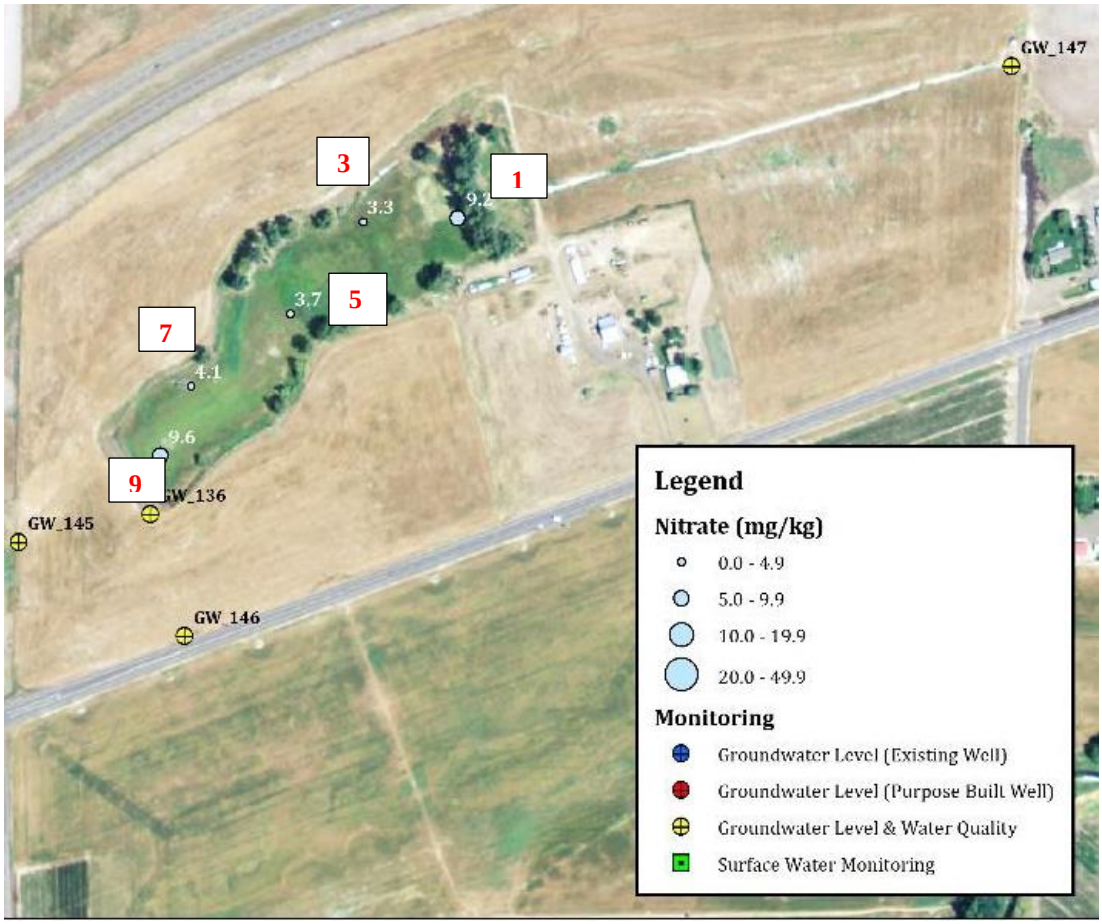


Figure 8. Stiller Pond soil monitoring sites (illustrated for nitrate content in 2014 by the light blue dots) At each site two soil samples are analyzed, one from the ground surface and one from one foot below the ground.

Nitrate in Soil and Water

The groundwater quality below the Stiller Pond recharge site responds differently during infiltration events between the four wells monitored. Nitrate concentrations in GW-136 and GW-146 (both directly downgradient from the infiltration site) decreases with the initiation of infiltration (shown in Figure 9A). The upgradient well GW-147 does not evidence any changes in nitrate content associated with infiltration events; nitrate concentration remains relatively constant at around 6 mg/L. Well GW-145 shows a different pattern in nitrate concentrations from the other four wells monitored, suggesting that it is in a cross-gradient position influenced by processes that are not affecting the other three wells. Nitrate concentrations in GW-145 measured in 2014 and 2015 are closer to the background concentration of 6 mg/L than the two downgradient wells, supporting the interpretation of a cross gradient position for this well.

The highest soil nitrate concentrations were measured in February 2014 (shown in Figure 9B), a similar circumstance to soil nitrate detections at the Locher Road site. Coincident with the high soil

concentrations, groundwater nitrate concentrations in the two downgradient and cross-gradient wells were the highest of all concentrations measured during the three infiltration events monitoring at Stiller Pond. The source of high nitrate in soil in February 2014 is not apparent, but the soil nitrate concentrations were consistently higher in the February 2014 samples than subsequent samples collected in June 2015. The high February 2014 groundwater concentrations substantiate the interpretation that soil nitrate is the source of nitrate loading to groundwater.

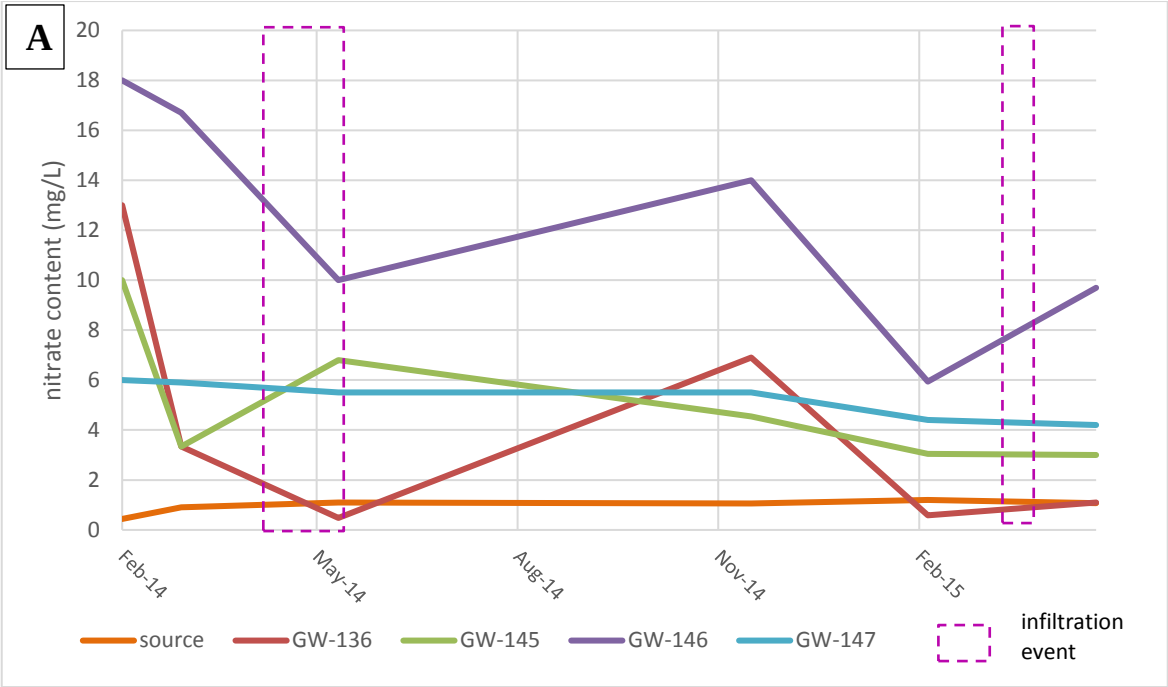
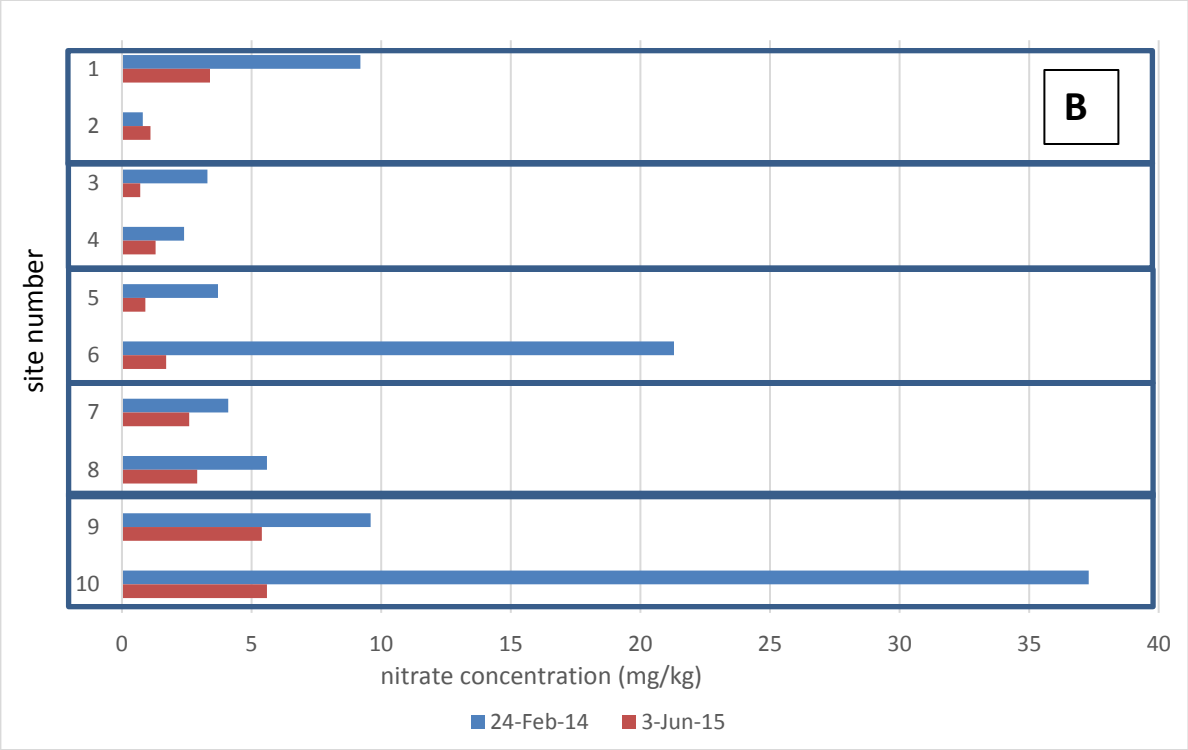


Figure 9A (above) and 9B (below) 9A Stiller Pond nitrate concentration in source water and groundwater;9B Soil nitrate content for paired sites at ground surface (odd site numbers) and 1-foot below surface (even site numbers), paired in blue boxes. Soil sample location sites shown on Figure 8



Total Dissolved Solids in Groundwater

Groundwater concentrations of total dissolved solids (TDS) beneath the Stiller Pond recharge site ranged from 178 to 560 mg/L. With the exception of the single February 25, 2014 GW-146 groundwater sample (560 mg/L), all TDS concentrations measured were below the water quality standard of 500 mg/L. Source water concentrations ranged from 84 to 161 mg/L (shown in Figure 10). The pattern of TDS variation in groundwater concentrations between the four monitored wells is identical to that of the nitrate concentration pattern. TDS content in soils was not measured for this project, but with the similar nitrate concentration patterns, it is likely that TDS in groundwater is derived from the same soil source that nitrate is.

Phosphorus in Soil and Groundwater

Total phosphorus was measured in groundwater and source water in two sample sets collected in 2014. Analyses for phosphorus in soil was completed on one sample set collected in 2014 and one in 2015. Phosphorus concentrations were similar in groundwater and surface water, ranging from 114 to 406 ug/L. With only two sample sets to interpret from, only a tentative interpretation can be made that infiltration of the source water is not degrading groundwater quality, despite the fact that phosphorus content in groundwater exceeds the EPA recommended concentration of 22 ug/L

Soils phosphorus concentrations in the two sets of ten samples collected from the floor of the infiltration pond ranged from 545 to 1030 ug/kg are shown in Figure11. Phosphorus analyses in soil, surface water and groundwater should continue during future recharge events at Stiller Pond.

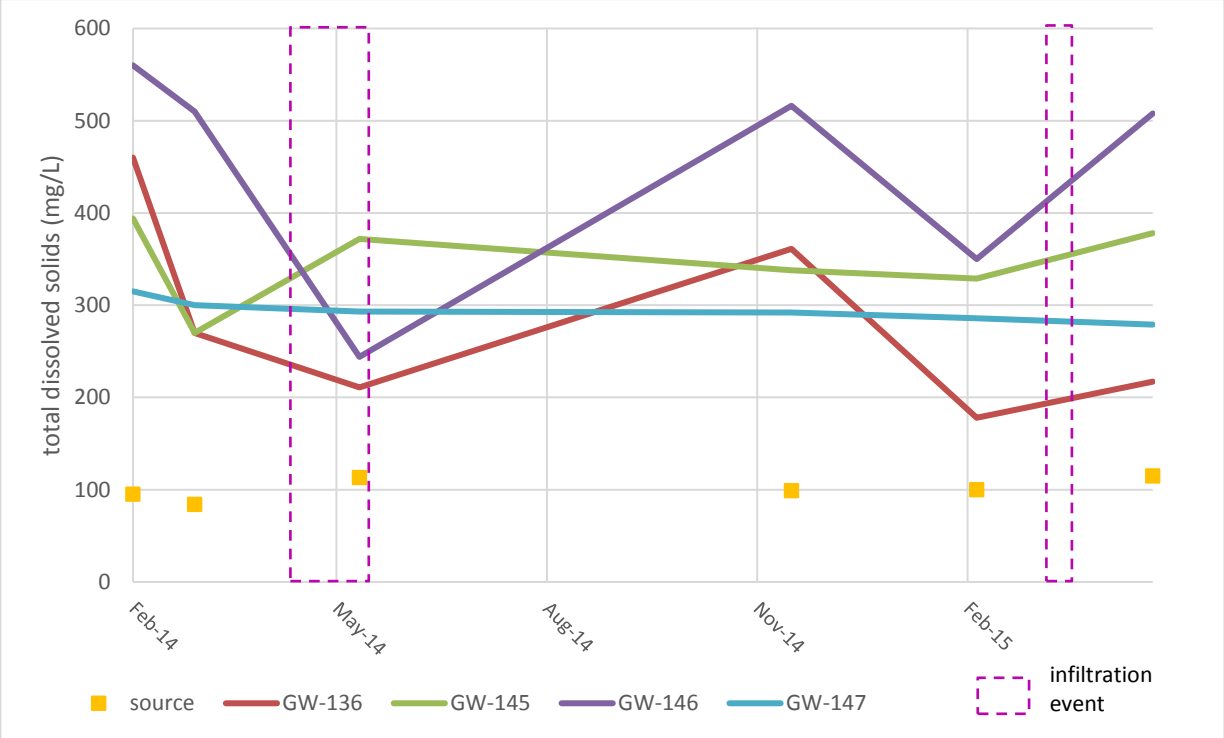


Figure 10. Total Dissolved Solids Concentrations detected in source water and groundwater at Stiller Pond (2014-2015)

Iron concentration in Groundwater

Total iron was measured in all four wells and in source water in 2014 and 2015. Iron concentrations in groundwater ranged from non-detections to 8,300 ug/L (shown in figure 12). In samples from the background well (GW-147) iron concentrations ranged from non-detections to 40 ug/L, significantly lower than that measured in source water or any of the other wells. Source water concentrations ranged from 150 to 760 ug/L, also higher than background groundwater concentrations but lower than the downgradient iron concentrations. Source water may be influencing the iron content of the receiving aquifer. Changes in oxidation state associated with oxygenated source water infiltrating to the aquifer likely affect the reaction of groundwater with iron in the aquifer matrix resulting in iron release to groundwater. Future analyses of iron content in source and groundwater is warranted for the Stiller Pond recharge operations, although iron is only regulated as a secondary contaminant in Washington with a recommended limit of 300 ug/L in drinking water.

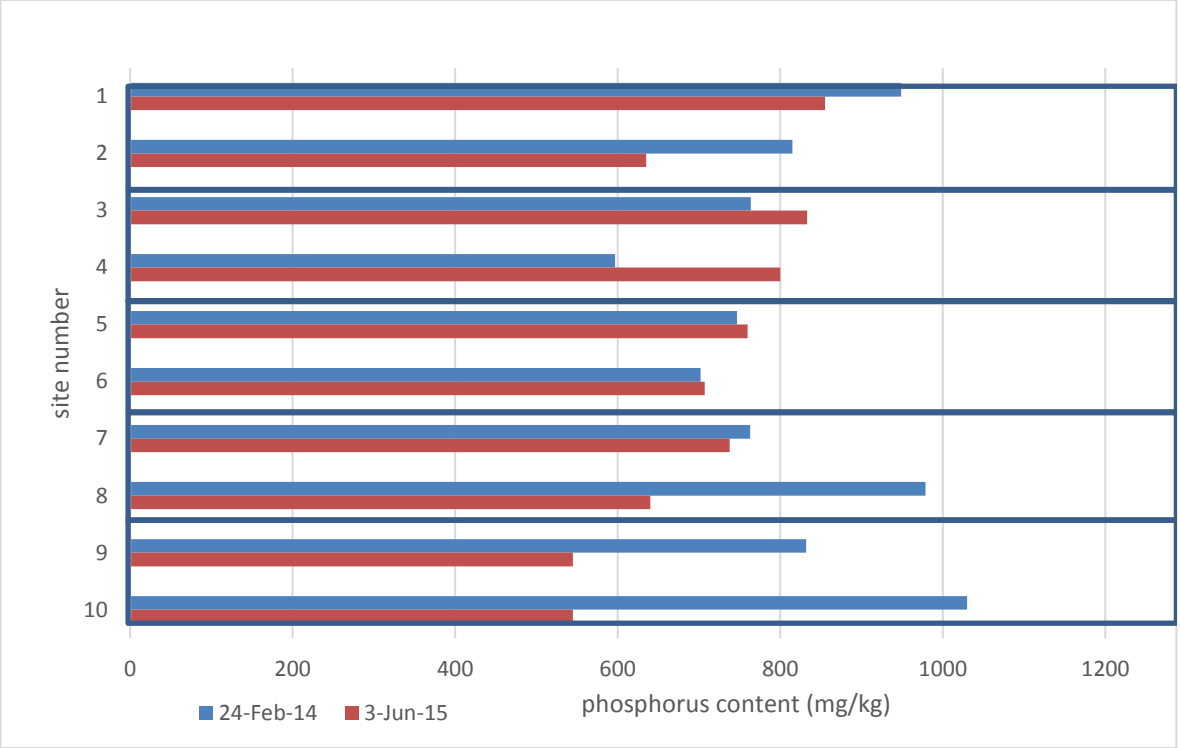


Figure 11. Stiller Pond phosphorus content in soils, soil sample locations shown in Figure 8

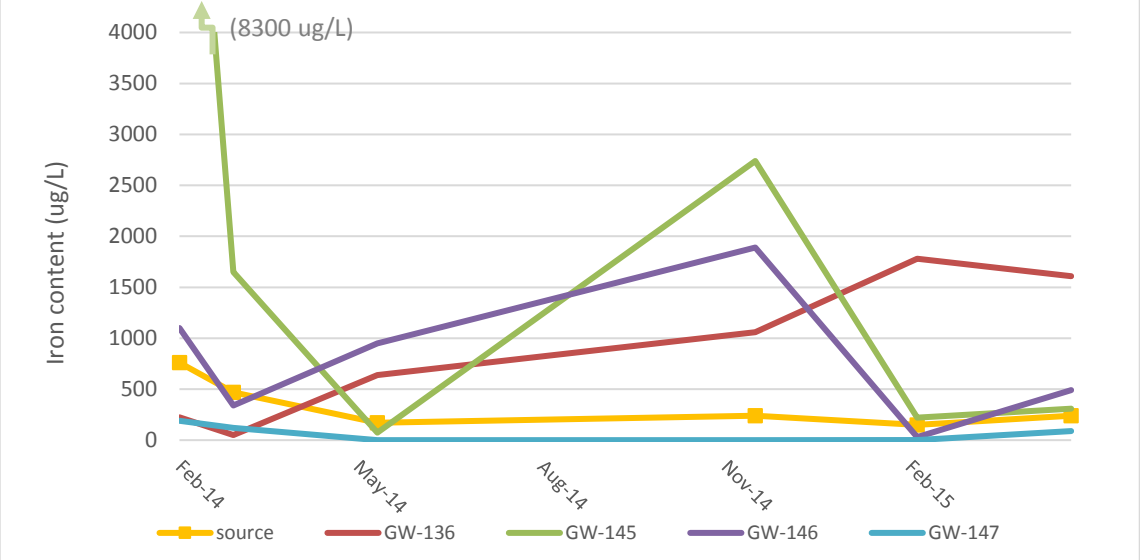


Figure 12. Iron concentration measured in groundwater and source water at Stiller Pond recharge site. Note: the graph is truncated and cuts off the first measured value for the GW-145 February 2014measurement of 8,3000 ug/L

Polychlorinated Biphenols Content in Soil and Groundwater

Polychlorinated Biphenols (PCBs) were measured in soil and groundwater in 2014 and 2015 (concentrations are shown in Figure 13). Sediment concentrations measured range from 174 to 29,000 ng/kg at the same locations sampled for the nitrate and phosphate analyses (locations shown in Figure 8). All soil samples analyses results were below the Washington sediment management standard of 110 ug/Kg (110,000 ng/kg)

The groundwater quality standard for total PCBs is 10 ng/L. Concentrations in groundwater ranged from 634 to 1030 ng/L, with every groundwater and source water sample exceeding the groundwater quality standard. Source water concentrations are significantly less than those detected in groundwater (14- 106 ng/L), still exceeding the surface water standard of 7 pg/L (0.007 ng/L). Background concentrations measured in GW-147 are similar to those detected in the other three monitoring wells indicating that infiltrating source water is not a means of PCB transport to groundwater. Infiltrating source water is likely diluting PCB content in groundwater, providing a beneficial water quality effect.

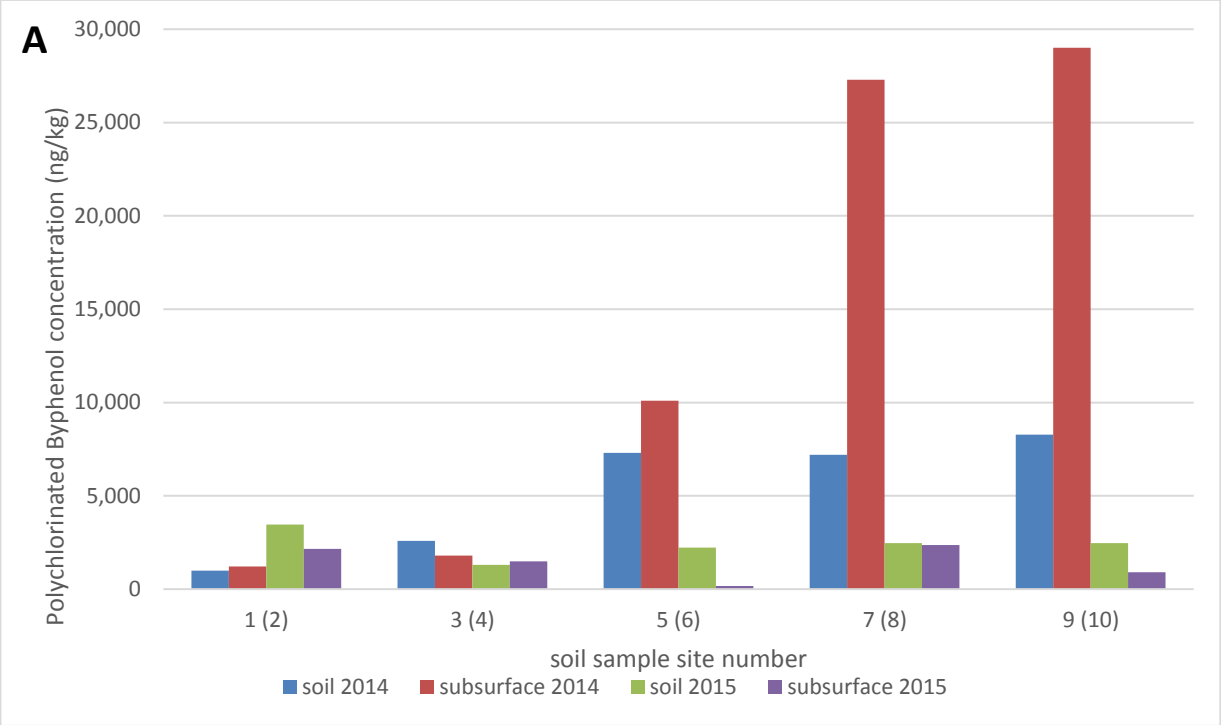
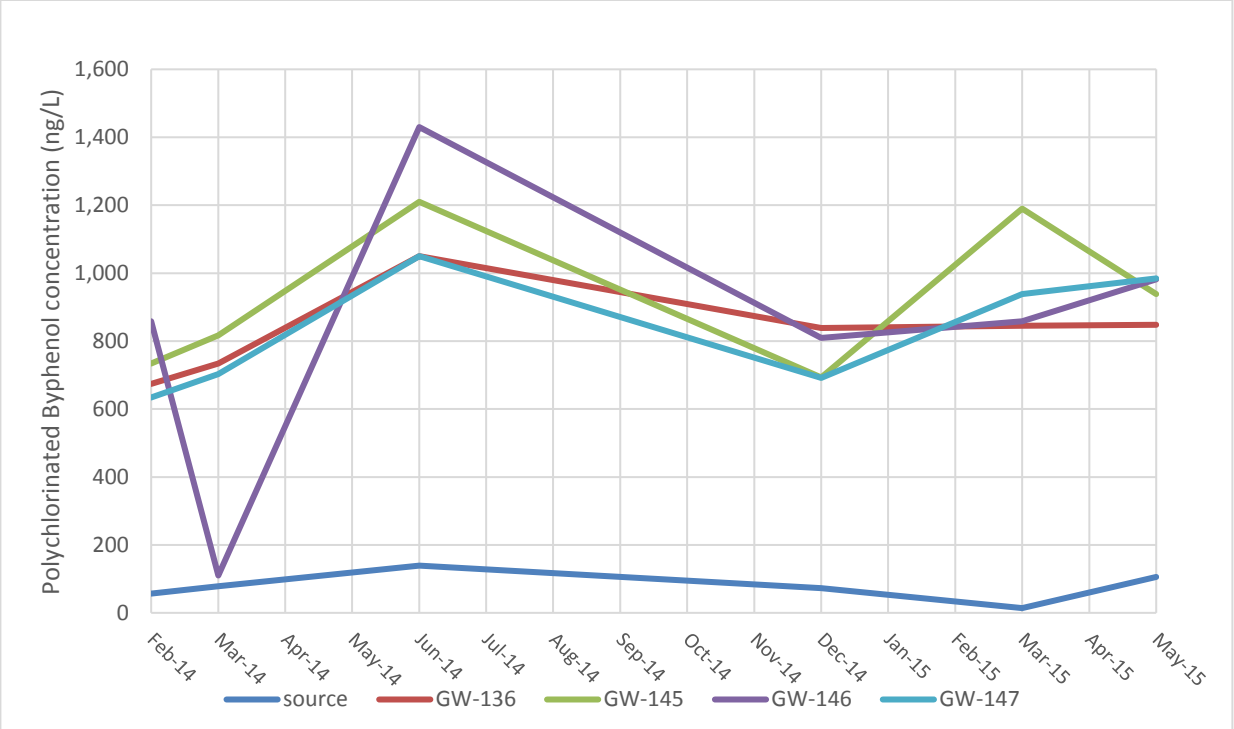


Figure 13A (above) & 13B (below). (A) PCB concentrations measured in soil collected from five locations in the Stiller Pond bottom, and at a 1-foot depth below the pond bottom. Odd numbered samples are from the ground surface and even numbered samples are collected directly below the previously numbered sample. (B). Groundwater and source water PCB concentrations in 2014 and 2015.



Stiller Pond Summary

For the most part, water quality in the receiving aquifer beneath the Stiller Pond recharge site is good, with the exception of nitrate and PCBs concentration. Herbicides, pesticides and volatile organic compounds were rarely detected in groundwater or source water. Monitoring for these constituents can be discontinued. Parameters to be monitored during future infiltration events are listed in Table 1, and discussed in detail for specific constituents below. Soil monitoring should continue for nitrate, phosphorus and PCBs. Groundwater and source water monitoring for total iron and for total dissolved solids should be continued.

Regular nitrate exceedances of the water quality standard in the downgradient well GW-146, and the relatively constant nitrate concentration of 6 mg/L in in upgradient well GW-147 (background) indicate that Stiller Pond infiltration operations are negatively affecting groundwater quality. To better manage understand and manage those impacts, nitrate monitoring should continue in all four wells and source water on a quarterly basis.

Phosphorus concentrations in surface water and groundwater indicate that phosphorus is not transported to groundwater during the infiltration events. However, there is insufficient data to draw firm conclusions. Monitoring of phosphorus should continue in source water and groundwater quarterly.

Monitoring of PCBs in groundwater and source water should continue. Annual monitoring will provide data with which to better evaluate the processes influencing PCB accumulation and transport

in groundwater and soils. Monitoring for chlorinated herbicides, organochlorine pesticides, volatile organic compounds in groundwater and source water can be discontinued.

Last Chance Road Aquifer Recharge Site

The Last Chance Road recharge site is located adjacent to the West Little Walla Walla River, about 1.5 miles northeast of the Locher Road recharge site (Section 5, T 6 N, R 35 E). Two infiltration areas make up the recharge site, each of which are one acre in area separated by approximately 800 feet, shown in Figure 67 of the 2015 report (reproduced here as Figure 14). One location is an infiltration gallery, and the other is a recently constructed ditch. Source water for infiltration is planned for diversion from the West Little Walla Walla River, about 400 feet south of the southernmost infiltration area. Diversion from the West Little Walla Walla River is restricted by the minimum flow of one cubic foot per second (cfs). Recharge of up to 250 acre feet is possible annually, with an estimated infiltration rate of one cfs. Infiltration under the shallow groundwater conditions present at this site may result in surface water ponding when the pore spaces in the relatively shallow unsaturated zone are inundated by infiltrating surface water. The site(s) was scheduled to start infiltrating in 2016, although data on recharge operations has not been received as of the writing of this memo.

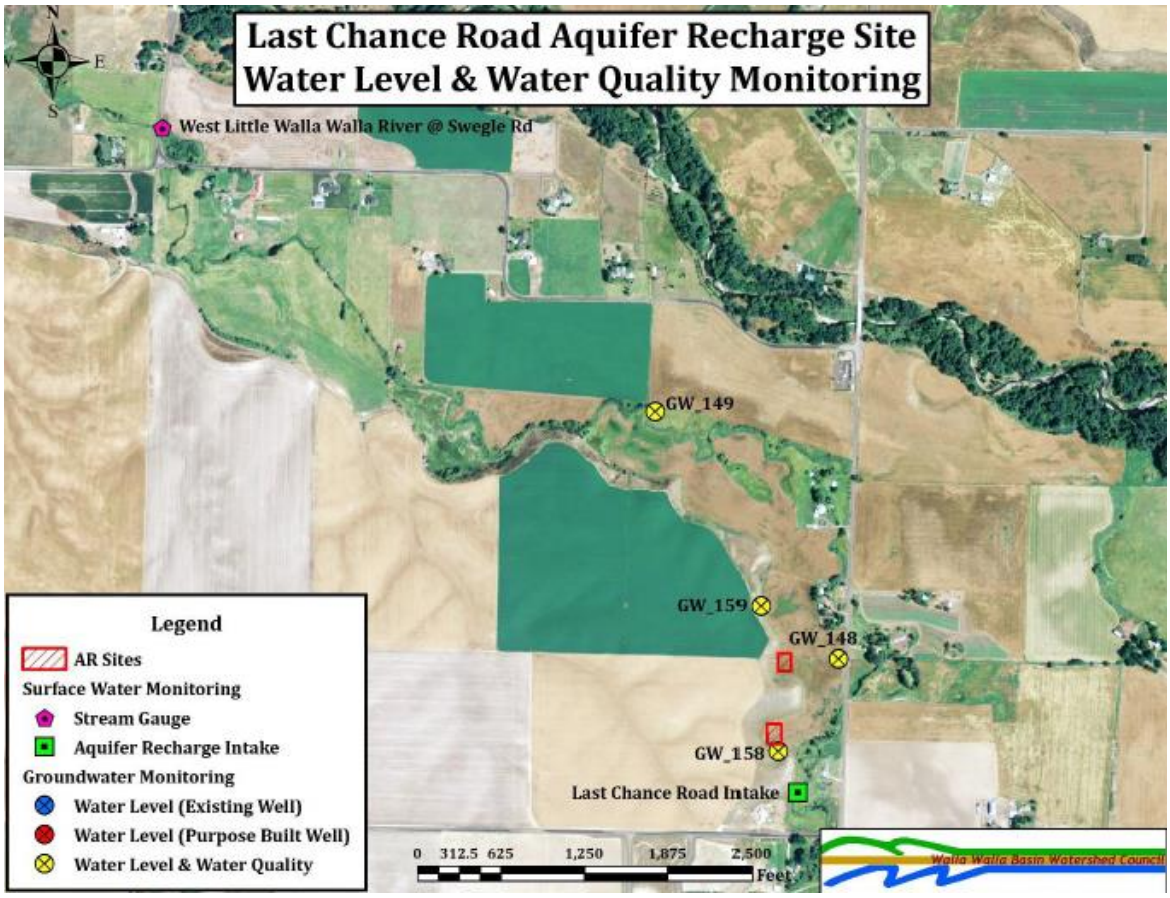


Figure 14 (above). Last Chance Road recharge site, with infiltration areas and coincident soil sample sites identified by red hatched squares

Water Quality and Soil Characterization

To prepare for initiation of infiltration, groundwater was collected from two groundwater monitoring wells (GW-148, GW-149), the West Little Walla Walla River and from the intake diversion. The samples were analyzed for PCBs content; analyses results listed in Table 5. No water quality data was submitted for these wells besides the PCB concentrations. No data (water quality or groundwater levels) was submitted for the GW-158 and GW-159 wells that monitor this site.

Table 5. PCB concentration in groundwater and source water prior to initiation of recharge at the Last Chance Road recharge site. Groundwater levels were reported on borehole logs, measured when the wells were installed.

sample site name	**PCBs (pg/L)**	**Groundwater level**
	20-May-14	Feb 20 & 21, 2014
source water (intake pipe)	59.4	(feet below
source water (West Little Walla Walla River)	87.2	ground surface)
GW-148	1,030	4.7
GW-149	1,680	1.1
GW-158	NA	10
GW-159	NA	6

One soil sample collected from the floor of each of the two infiltration areas, and from one foot below each of those two surface samples sites (total of four samples) were analyzed for PCBs, organochlorine pesticides, nitrate and phosphorus. Lab reports from Edge Analytical Laboratory were not included in the 2015 report for the nitrate and phosphorus analyses. Results presented in Table 6 for nitrate and phosphate were interpreted from the 2015 report figures listed in the table and the Vista Laboratory Reports for total PCB concentrations.

Table 6. Last Chance Road Recharge site, pre-infiltration soils concentrations (June 3, 2015 samples). Figure numbers are those listed in the 2015 Report.

	PCBs (Figures 72 & 73)	**Nitrate (Figures 68 & 69)**	**Phosphate (Figures 70 & 71)**
Site name	*ng/kg*	*mg/kg*	*mg/kg*
LCR #1	212	10.4	1697
LCR #2	0	47.6	986
LCR #3	365	10.4	1086
LCR #4	36.3	47.6	86.3

Soil concentrations of PCBs were below the regulatory limits. Nitrate and phosphate concentrations in soil were relatively high. Organochlorine pesticides in the four soil samples analyzed were for the most part non-detected. Small concentrations of DDT, DDE, and DDD were present, typically the only organochlorine pesticides detected in any of the soils analyzed for this project. The small concentrations present are sufficient to demonstrate that recharge operations do not present a threat to water quality from organochlorine pesticides at these sites, and no additional soils analyses for these constituents is warranted.

Last Chance Road Summary

Groundwater and source water have not been fully characterized for this recharge site. Sampling and analyses for the full set of analytes identified in the QAPP should be conducted when the first recharge event is initiated. The list of parameters is included in Table 1, and pages 26 – 30 of the 2015 QAPP.

Soil sample analyses for Herbicides and carbamates will be required prior to initiation of infiltration, and after one infiltration season is completed. Analyses of PCBs content in soils after the first infiltration event is completed will be required. Nitrate and phosphorus content in soil should be analyzed after the next infiltration is completed.

Mud Creek Recharge Site

Site Information

The Mud Creek site is located adjacent to Mud Creek, extending both north and south of the Creek, about one mile to the south of the Walla Walla River (Section 3, T6 N, R 34 E), and east of McDonald Road. Three infiltration areas are illustrated in Figure 74 of the 2015 report (reproduced as Figure 15 in this memo). Each area will infiltrate water from a different source: Lowden 2 Intake (from the Lowden No. #2 canal, also call the Mud District No. 2 Canal on Google Earth), Mud Creek Intake, and GFID Intake, from the Gardena Farms Irrigation District Canal (also called the Burlingame Ditch on Google Earth). The total GFID and Lowden # 2 ditch areas infiltration capacity is estimated at 1.5 to 2 cubic feet per second, with 783.7 acre-feet available for recharge. Infiltration is scheduled to start in 2016, although no information has been received as of the writing of this memo on the infiltration at this site. The areal extent of the infiltration areas were not presented in the reports received from the Walla Walla Basin Council.

Groundwater in the shallow unconsolidated aquifer beneath these the Mud Creek infiltration sites most likely flows to the west-northwest, towards the Walla Walla River. Groundwater in the aquifer underlying recharge site is monitored in wells that characterize:

- Lowden No. 2 Ditch intake infiltration area: GW-156, GW-157
- Mud Creek Intake infiltration area: GW-155
- Gardena Farms Irrigation Ditch Intake infiltration area: GW-153, GW-154.

Monitoring wells were installed in February 2015. At that time groundwater levels in the Lowden no. 2 monitoring wells were within five feet of the ground surface. The shallow groundwater levels can be attributed to the fact that they are located within one hundred feet of the canal, or that the site is located at the base of a steep slope (where runoff migrates downslope and infiltrates). Groundwater levels below the ground surface in the GW-154 and GW-155 wells were slightly deeper, at about seven feet below the ground surface, and in GW-153 at 20 feet below ground surface. Groundwater levels that are within ten feet of the ground surface during infiltration have the potential to rise to the ground surface generating surface accumulation and limiting the amount infiltrated.

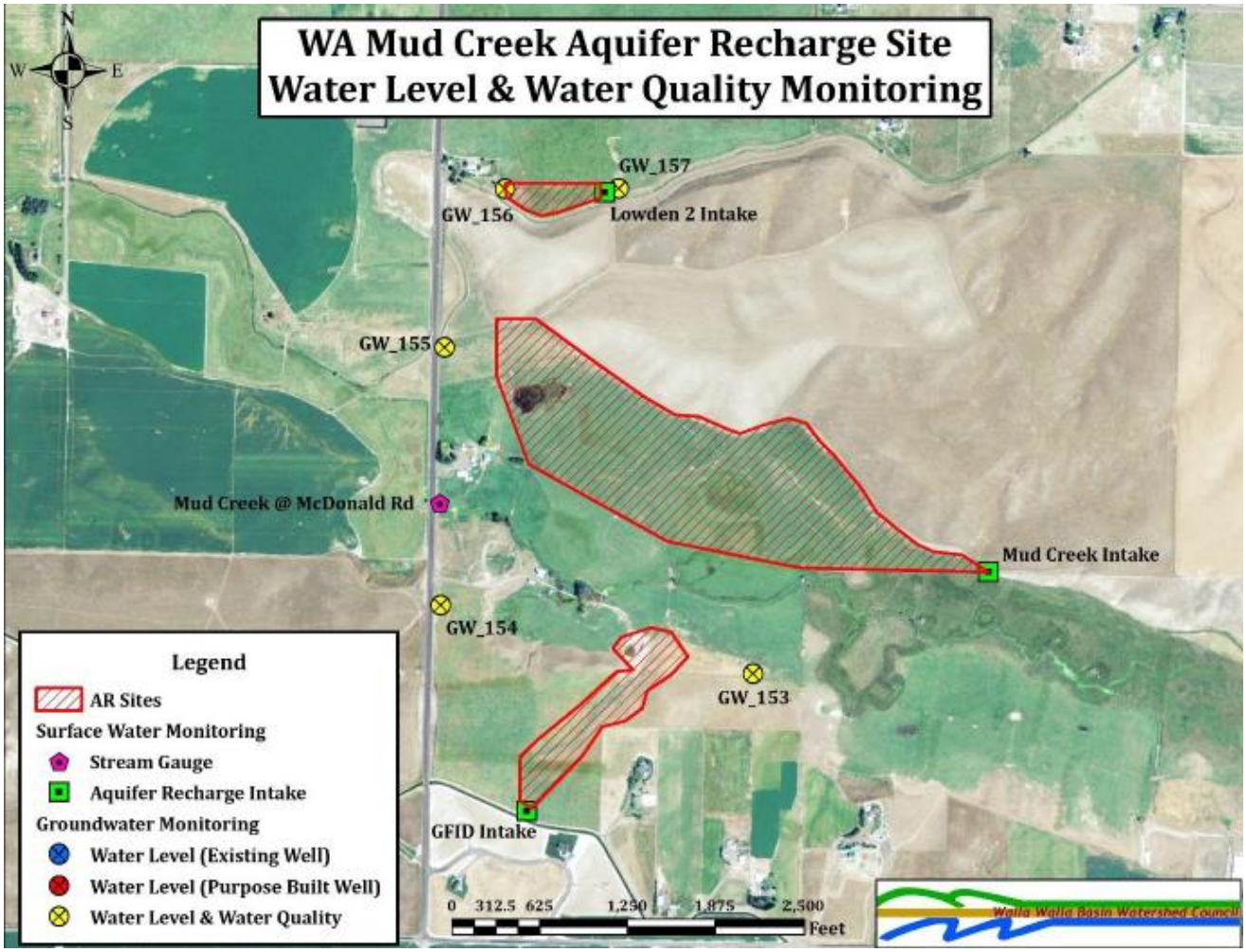


Figure 15. Mud Creek Recharge areas and groundwater monitoring well locations. Aquifer Recharge has not been initiated at these sites at the time this memo was completed

Water Quality and Soil Characterization

Soil samples were collected at the Lowden 2 intake recharge area, and at the GFID intake recharge area in 2015. Four samples were collected from the Lowden no. 2 ditch intake area and four from the

Gardena Farms Irrigation Ditch intake area. At both sites two paired samples collected from the ground surface and at one foot directly below the ground surface sample (eight samples total). The Mud Creek Intake infiltration area soils were not characterized during the 2015 sampling. Soil sample analyses results are listed in Table 7. Soil samples were also analyzed for organochlorine pesticides. Very small amounts of the pesticides DDT, DDE and DDD were detected in soils, in every case the amount detected was less than 0.09 mg/kg. In one sample 0.003 mg/kg of Dieldrin was detected. The small concentrations present are sufficient to demonstrate that recharge operations do not present a threat to water quality from organochlorine pesticides at these sites, and no additional soils analyses for these constituents is warranted.

No data on groundwater or source water was submitted for this site.

Table 7. Mud Creek Recharge Sites soils characterization.

Mud Creek Site	PCBs	Nitrate	phosphorus
SOILS	ng/kg	mg/kg	mg/kg
GFID #3	183	92.1	1360
GFID #4	110	11.1	856
GFID #2	40.8	4	1139
GFID #1	19.4	19.4	1079
L2 #1	320	9.7	1103
L2 #2	0	4.1	1007
L2 #3	120	346	1106
L2 #4	554	347	1138

Mud Creek Recharge Site Monitoring Recommendations

The full suite of Organochlorine Pesticides, Volatile Organic Compounds, Chlorinated Herbicides, and PCBs should be measured in source water and groundwater and soils when infiltration operations start up at this site. Groundwater and source water should be analyzed for nutrients, total dissolved solids, total phosphorus, metals and anions (as listed in Table 1). Soils should also be analyzed for nitrate and total phosphorus content.

General Recommendations

For clarity, I recommend that future project reports be submitted with page numbers on every page. The appendices with the analytical results should be separated with a distinct appendix presenting laboratory reports for each infiltration site. The set of data for each site should be assigned a unique appendix number or letter; the pages in the appendices should also be numbered. Data should be submitted in tabulated format and it must be submitted to Ecology from the analytical laboratory in the *electronic data deliverable format*. Soil sample collection sites should be assigned site numbers (i.e. LCR-1A and LCR-1B for samples collected at the same location, from the surface and at depth),

and those sample numbers should be used in presenting results in the report. The site numbers should be located on the maps presented in the annual project reports so that the laboratory analytical report results can be linked to the sites that they represent. Additionally, it would be helpful if a map was included in the report for each site which showed the extent of the ponded water on the site during the infiltration event(s), the soil sample collection sites numbers, and the groundwater monitoring wells locations. Source water quality samples should be collected at the location where water derives from the delivering water body (creek, ditch or pipe) before entering the ponded water. This site should also be identified on the site map.

Additionally, future project reports should include a table with all of the sampled sites (water, groundwater and soil) listed for each site, the infiltration facility they were collected from, the dates that samples were collected from those sites, and the analyses conducted on each of the sample sites. A separate set of tables should present all sample analyses results completed for the project by year, instead of leaving the reader to page through hundreds of pages of analytical laboratory reports in an un-paginated, unorganized appendix.

ATTACHMENT 1 –

Walla Walla Basin Watershed Council Reports Used in these Analyses

Results of the First Season of Shallow Aquifer Recharge Testing at the Locher Road Site, Walla Walla County, Washington. Prepared for: Gardena Farms Irrigation District #13 and Washington department of Ecology by GSI Water Solutions, July 2007. 175 pp

Results of the 2008 Shallow Aquifer Recharge Season at the Locher Road Site, Walla Walla County, Washington. Prepared for: Gardena Farms Irrigation District #13 and Washington department of Ecology by GSI Water Solutions, January 2009. 169 pp

2009-2013 Washington Walla Walla Basin Aquifer Recharge Report, August 2013. Walla Walla Basin Watershed Council; 54 pp plus appendices

Water Years 2014 & 2015 Washington Walla Walla Basin Aquifer Recharge Report, August 2015. Walla Walla Basin Watershed Council; 59 pp plus appendices

Patten, S, 2015. Walla Walla Basin Aquifer Recharge Water Quality and Water Level Quality Assurance Project Plan, Version 1.3. Walla Walla Basin Watershed Council. 61 pp plus appendices

Proposed Monitoring Plan for the Stiller Pond Aquifer Recharge Environmental Enhancement Project (EEP), prepared for the Walla Walla Conservation District and the Walla Walla Basin Watershed Council; submitted by GWI Water Solutions, Inc. in May 2013. 16 pp plus appendices

Walla Walla Watershed TMDLs

Baldwin, K., D. Gray and J. Jones. 2008. Walla Walla Watershed PCBs, Chlorinated Pesticides, Fecal Coliform, Temperature, pH and Dissolved Oxygen Total Maximum Daily Load, Water Quality Implementation Plan, WA Dept of Ecology Pub. No. 08-10-094. 56 pp.

Gray, D., K. Baldwin and A. Johnson, 2006. Walla Walla River Chlorinated Pesticides and PCBs Total Maximum Daily Load (Water Cleanup Plan) Submittal Report, WA Dept of Ecology Pub. No. 05-10-079, 59 pp plus appendices.

Johnson, A., B Era-Miller, R. Coots and S. Golding, 2004. A Total Maximum Daily Load Evaluation for Chlorinated Pesticides and PCBs in the Walla Walla River, WA Dept of Ecology Pub no. 04-03-032,

Joy, J., G. Pelletier and K. Baldwin, 2007. Walla Walla River Basin pH and Dissolved Oxygen Total Maximum Daily Load: Water Quality Improvement Report. WA Dept of Ecology, Pub. No. 07-03-010,

Stohr, A., M. LeMoine and G. Pelletier, 2007. Walla Walla River Tributaries Temperature Total Maximum Daily Load Study, WA Dept of Ecology Pub No. 07-03-014., 104 pp plus appendices

ATTACHMENT 2 –

Constituents analyzed in source water and groundwater

Locher Road Recharge Site (2007 – 2009)

pH
Temperature
Specific conductance
Turbidity
Nitrate and nitrite
Hardness
Total dissolved solids (TDS)
Chloride
Soluble reactive phosphorus
Chemical oxygen demand
Total coliform and E Coli

Stiller Pond Recharge Site (2012) and Locher Road Recharge Site (2011- 2012)

Stiller Pond

Nitrate and nitrite
Total Kjeldahl Nitrogen
Ortho-phosphate
Total dissolved solids (TDS)
Chloride
Magnesium
Calcium
Hardness
Chemical oxygen demand
Fecal Coliform
Total coliform
Specific conductance

Locher Road

Bromate
Ortho-phosphate
Chloride
Nitrate and nitrite
Specific Conductance
Total Dissolved Solids
pH
Chemical oxygen Demand
Turbidity
TDS
Hardness
Chloride
Orthophosphate
Total Coliform, E coli
Synthetic organic compounds (PCBs & Pesticides)
Herbicides
Carbamates

Locher Road Recharge Site (2013-2015), and Stiller Pond Recharge Site (2014 & 2015)

Total phosphorus
Nitrate and nitrite
Sulfate
Alkalinity, Hydroxide, Carbonate and Bicarbonate
Chloride
Bromate
Hardness
Total dissolved solids
Specific Conductance
PCBs*
Organochlorine pesticides*
Chlorinated Herbicides
Volatile Organic Compounds
1,1,1-Trichloroethane
2-4 D
barium
Calcium
cadmium
chromium
Lead
mercury
selenium
silver
fluoride
copper
iron
manganese
zinc
Corrosivity
Turbidity & color
Odor
Surfactants
Fecal Coliform & Total coliform, E coli

Last Chance Road

PCBs

Recommended Groundwater and Source Water Quality Monitoring Parameters for 2017 Recharge Operations

Locher Road	***Stiller Pond***	***Last Chance Road and Mud Creek***
Source water and groundwater		
Nitrate Total Dissolved Solids Total Phosphorus	Nitrate PCBs Total Dissolved Solids Iron PCBs	Chlorinated Herbicides Volatile Organic Compounds Organochlorine Pesticides Metals (including iron)[1] Nutrients (total phosphorus and nitrate) TDS Anions[2] pH Dissolved oxygen

[1] Metals are: Barium, Cadmium, Chromium, Lead, Mercury, Selenium, Copper, Iron, Manganese, Zinc, Arsenic

[2] Anions are: Nitrate, Fluoride, Chloride, Sulfate, Carbonate and bicarbonate		
Soil		
nitrate Total dissolved solids Total phosphorus	nitrate Total dissolved solids Total phosphorus PCBs	nitrate Total dissolved solids Total phosphorus PCBs

ATTACHMENT 3 –

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
4601 N Monroe Street • Spokane, Washington 99205-1295 • (509)329-3400

January 14, 2015

Mr. Steven Patten
Senior Environmental Scientist
Walla Walla Basin Watershed Council
PO Box 68
Milton-Freewater, OR 97862

RE: Request to reduce water quality monitoring requirements at Locher Road SAR site

Dear Mr. Patten:

In 2013, the Washington State Department of Ecology (Ecology) worked with you to develop a Quality Assurance Project Plan (QAPP) [1] for monitoring water quality at shallow aquifer recharge sites in the Washington portion of the Walla Walla Watershed. The Walla Walla Watershed has a history of PCBs and chlorinated pesticide use. Water quality monitoring detected these toxic chemicals throughout the watershed, particularly near the City of Walla Walla. In 2006, Ecology developed a Total Maximum Daily Load (TMDL) water cleanup plan to address these issues.

Washington Administrative Code (WAC) 173-201a-240(2) requires Ecology to "employ or require chemical testing, acute and chronic toxicity testing, and biological assessments, as appropriate… to ensure that aquatic communities and the existing and designated uses of waters are being fully protected." To achieve compliance with this rule, Ecology required soil testing and water quality monitoring to assess the potential effects of the Locher Road SAR operations on groundwater quality. This included monitoring for PCBs and chlorinated pesticides because of the known pollution issues in the watershed.

Walla Walla Basin Watershed Council monitored water quality at the Locher Road SAR site during the 2013 and 2014 recharge seasons. Chlorinated pesticides were not detected in groundwater samples. PCB levels in groundwater remained relatively consistent, well below the state groundwater quality standard (0.01 ug/l). PCBs in groundwater are likely the result of past contamination from adjacent surface water given the high level of hydraulic continuity between the shallow gravel aquifer and streams and irrigation ditches. PCBs and chlorinated pesticides monitoring costs thousands of dollars and the Watershed Council have requested to discontinue monitoring these parameters at the Locher Road SAR site.

Based on two years of results of water quality monitoring data at the Locher Road SAR site, Ecology has concluded that operation of the site is not contaminating groundwater with PCBs and chlorinated pesticides. Monitoring of PCBs and chlorinated pesticides will no longer be required at the Locher Road SAR site, but monitoring of all other parameters specified in the QAPP will continue.

Thank you for your work collecting monitoring data to ensure that water quality in the Walla Walla Watershed is protected.

Sincerely,

Mike Kuttel, Jr.

Water Quality Program
Eastern Regional Office

MK:jab
cc: Dave Knight, Ecology Water Quality Watershed Unit Supervisor, Eastern Region
Victoria Leuba, Ecology Water Resources Permitting, Eastern Region

1. Patten, S. May 2013. Walla Walla Basin Aquifer Recharge Water Quality and Water Level Monitoring Quality Assurance Project Plan. Final Plan. Walla Walla Basin Watershed Council.