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Draft Technical Memorandum

To:	Said Amali, IRZ Consulting		
From:	Bryan Black, HDR Anna Zaklikowski, HDR	Project:	Umatilla Basin Recharge Project
Date:	May 29, 2009	Job No:	86502
Re:	Task 1.H - Natural Filtration Evaluation Memorandum		

The agricultural economy of Umatilla and Morrow counties is critically dependant on availability of water for irrigation. Due to overdraft of the groundwater aquifers in the area, the Oregon Water Resources Department (OWRD) designated four ~~groundwater aquifers within the Umatilla Basin as~~ Critical Groundwater Areas (CGAs) in the Umatilla Basin (OWRD 2003). Additionally, surface water sources within the Umatilla Basin are unavailable for further appropriation between June 1 and October 31 as defined in Oregon Administrative Rules (OAR) 690-507-0070. To increase water availability in the CGAs, OWRD has begun a technical assessment of the feasibility of storing water from the Columbia River, and other surface water sources, during high flow periods in shallow sediment and deep basalt aquifers for recovery of the stored water during the irrigation season. This technical memorandum includes a summary of information and findings regarding the potential for shallow sediments at two locations in the CGAs to provide natural filtration capacity for recharged surface water before its potential injection in to the deeper basalt aquifer.

Executive Summary

The recharge system at near the County Line Water Improvement District ~~line~~ has been in continuous operation (for how long?) and is assumed to be at steady state with respect to surface water mixing with native groundwater at the groundwater sampling location. A sample of native groundwater was not available so it was not possible to infer the degree of surface water mixing. Based on an assumed percentage of surface water at the well of 100%, log removal of all organisms was between 2.3 (99.5% removal) and 7.2 (greater than 99.99999% removal) (I read this that the assumption is that all of the water sampled at the well was recharged by surface water, and that no mixing has occurred. Is this reasonable? Is it possible to confirm the surface water/groundwater percentage through some geochemical method such as isotope geochemistry, or perhaps through a tracer test?).

The recharge system at Echo Meadows was operated for a period of about 40 days. Based on chemical comparisons of native ground water (spelled as groundwater elsewhere in document), surface water, and well samples, the well sample is inferred to contain about 30% surface water. Despite containing surface water, the sample did not contain the organisms initially present in

surface water (no MPA organisms were detected in the sampled well water). This indicates that the native soil horizon may effectively filter the applied surface water in the recharge system tested. (This statement assumes the microscopic particulates move as a "slug" through the system, correct? Is it possible that this is not the case, and that the chemistry of the water simply reflects the "front" of the groundwater "plume" and that the microscopic particulates have not arrived yet at the sampling location?)

Both sites contain fine soils and should provide effective filtration if the soil is homogeneous (I am concerned that there is no such thing as "homogeneous" soils). The fine soils could be a hydraulic limitation for recharge and could require frequent maintenance to maintain permeability.

Objectives

Soil and water quality data were collected for the following objectives:

- Determine the fate of surface water and filtration effectiveness through the subsurface using geochemical and biological indicators
- Characterize soil conditions and compare with conventional filtration techniques

Introduction

In spring of 2008, a pilot study was conducted in the Echo Meadows area of the Stage Gulch CGA in Umatilla County to evaluate the potential for aquifer recharge and natural filtration through the application of surface water. Additionally, through the annual recharge activities by the County Line Water Improvement District (CLWID), water from the Umatilla River is diverted during the times of excess flow and is transported via an irrigation canal (Hunt Canal) to a recharge canal which straddles the Umatilla-Morrow County border. The canal is designed to maximize leakage as the main mechanism for recharge. The recharge canal ends in a pond in Morrow County where any remaining water infiltrates the soil. Figure 1 shows the locations of the Echo Meadows area and CLWID recharge system. (Figure 1 not attached)

The pilot test at Echo Meadows involved conveying water to several parcels of unfarmed land (IRZ 2009). One property, Field 1, was instrumented for further evaluation. Field 1 comprises an area of approximately 20 acres in size. Surface water was applied to this area over the course of the period April 17 through May 27, 2008. A total volume of 58 acre feet (AF) was applied during this time. Field 1 is shown on Figure 2.

Unlike the Echo Meadows site, recharge of the County Line site occurs continuously and was not piloted for a distinct period of time. ~~Field 1 is shown on Figure 2.~~ The boundary of the County Line recharge ponds are shown on Figure 3. (Figures 2 and 3 not attached)

In late May, near the end of the available recharge period for Echo Meadows, surface water and well water samples were collected at both Echo Meadows Field 1 and County Line recharge pond sites and analyzed for geochemical and biological parameters. In addition, soil sieve analysis was performed on soil samples collected at both sites to characterize soil conditions. Sample locations are identified on Figures 2 and 3. The County ~~line~~ Line pond sampling site was located adjacent to Desert Road and designated sample "CLWID B-Line" and the groundwater sample was collected from well MORR 972, located approximately ¼ mile south of the surface water sample site. At Echo Meadows, surface water samples were collected from Hunt Canal and groundwater samples were collected from well UMAT 1269, located approximately 0.5 miles downgradient of Hunt Canal. Figure 4 shows the groundwater potentiometric levels indicating direction of groundwater flow at Field 1 and the locations of well UMAT 1269 relative to the Field 1 water application site. (Figure 4 not attached)

Water Quality Analysis Results

Geochemical and Field Parameters

Results of the analysis of field and geochemical parameters for the County Line and Echo Meadows sites are presented in Tables 1 and 2, respectively. Field parameters included temperature, conductivity, pH, redox potential (ORP), and dissolved oxygen (DO). Seven geochemical parameters were analyzed: bicarbonate, calcium, chloride, magnesium, potassium, sodium, and sulfate. Details of sampling and laboratory analysis procedures, as well as laboratory reports, are provided in IRZ (2009).

Surface water and groundwater samples at County Line were collected on May 21, 2008. Samples were collected at the Echo Meadows site before the pilot test began (March 5-6, 2008) and immediately following the conclusion of surface water application (June 3, 2008). This was intended to provide a baseline so that the effect of applying surface water could be compared with the native groundwater.

Comparison of analysis results for surface water and well water samples at the County Line site shows a significant difference in the seven geochemical parameters tested. Concentrations are much higher in well samples than in surface water samples, as is to be expected in ground water (groundwater spelled as one word elsewhere). Dissolved oxygen and pH are similar for both samples; however, ORP and conductivity are higher in well samples. Because no data are~~is~~ available that describes the ground water (groundwater) chemistry before the canal was built, it is difficult to evaluate the impact of applied surface water on groundwater. Comparison with the background well sample taken at the Echo Meadows site suggests that the groundwater at County Line could have originally been much higher in cations, anions, and conductivity prior to the influence of canal water.

For Echo Meadows, the mineral content of well samples decreased significantly following application of surface water for recharge. Because surface water is less mineralized, the decrease in minerals in well samples is inferred to be due to mixing of surface water with native ground water (groundwater). The Echo Meadows data for the seven geochemical parameters ~~was~~ were analyzed using a least squares approach to estimate the potential relative contribution of surface water in the well sample (is there a reference to this method? I know there are other techniques to quantify mixing – this one is new to the reviewer). This approach suggested that the well sample consisted of a mixture that contained one-third surface water and two-thirds groundwater.

Microscopic Particulate Analysis

Microscopic Particulate Analysis (MPA) was performed by CH Diagnostics and Consulting Service, Inc. Berthoud, Colorado, on samples collected from surface water and well sites in the County Line and Echo Meadows CGAs. The MPA results are used to detect bio-indicators that normally only occur in surface water as opposed to groundwater sources. These bio-indicators

may include diatoms, algae, coccidian, plant debris, pollen, rotifers, crustaceans, ameba, nematodes, and insects/larvae. The ~~MAP~~ MPA analysis results are summarized in Table 3. The laboratory reports are enclosed in Appendix A.

The MPA results can be used to estimate the effectiveness of a filtration technology or natural filtration mechanism by comparing the filtered to the raw water sample and determining the reduction in various groups of bio-indicators. As required by the analysis guidelines, MPA results for surface water and ground water (groundwater) are reported in units per 100 Liter and per 100 gallons, respectively.

To determine the reduction of organisms/particles present in surface water as it was filtered through the soil, log removals for each of the biological parameters were calculated using the methodology in "Microscopic Particulate Analysis (MPA) for Filtration Plant Optimization" (EPA, 1996). These results are presented in Table 4. Many of the parameters included in the analysis were not detected in well water samples. To calculate the log removal in these instances, a protocol described in "ICR Protozoan Method for Detecting *Giardia* Cysts and *Cryptosporidium* Oocysts in Water by a Fluorescent Antibody Procedure" (EPA, 1995) was used to estimate the minimum log removal. The log removals presented serve as an indication of the soil's natural ability to filter particles and organisms in the applied surface water. However, the well samples collected were partially influenced by groundwater supplies and as such any conclusions that are based on these results should consider the groundwater influence.

According to Oregon Administrative Rules (OAR) 333-061-0032-8.a, "Requirements for groundwater sources under the direct influence of surface water with a natural filtration credit," for a groundwater source to be eligible for natural filtration credit, the MPA risk scores must be less than 20. This criterion was met for well samples collected at both sites. In the "Long Term 2 Enhanced Surface Water Treatment Rule" (LT2ESWTR), the EPA assigns credit of one log treatment of Cryptosporidium for wells that have at least a ~~50-foot~~ groundwater flow path great than 50 feet as measured from the surface water source.

Soil Characterization

Soil sieve ~~analysis was~~analyses were performed on three samples each from the County Line and Echo Meadows sites to determine the soil characteristics of the sites and compare with conventional filtration technologies. Echo Meadows samples were collected from Field 1 at locations shown on Figure 2. The sample designations and depths included FD1-1 from 6 inch to 3 feet below ground surface (ft bgs), two samples at FD1-2 from 6 inch to 2.5 and 2.5 to 4 ft bgs, FD1-3 from 6 inch to 3 ft bgs. At County Line samples CL SSD-1, CL SS-2, and CL SS-3 were collected from 6 inch to 3 ft bgs, the locations of which are shown on Figure 3. The samples were collected by soil augers and were composited prior to shipping to Northwest Testing, Inc., Wilsonville, Oregon for analysis. The laboratory reports are enclosed in Appendix A.

The s~~S~~oil sieve analysis results for County Line and Echo Meadows sites are ~~shown~~ listed in Table 5. Soil grain effective sizes (D_{10}) and uniformity coefficients (D_{60}/D_{10}) are calculated in Table 6.

The soil grain effective size is defined as the sieve opening diameter that will pass the percentage of particles in a soil sample specified by the subscript. The sieve analysis shows that for all the of samples, more than 97% of the soil passed through the #16 sieve, indicating that the soil samples were primarily comprised of soil of grain size 1.2 mm and smaller. For all samples except for County Line soil sample 2, the effective size was less than the opening of the smallest sieve size (0.075 mm). For this reason, the uniformity coefficients for these samples could not be calculated and are expressed as greater than a uniformity coefficient having a D_{10} less than 0.075 mm.

Uniformity coefficients for slow sand filters typically range from 1.5 to 3.6 (2 is most common) with effective sizes (D_{10}) ranging from 0.15 to 0.40 mm (AWWA, 1999). The soil test results for the County Line and Echo Meadows sites indicate that the native soil is much finer and more stratified (has a higher uniformity coefficient) than what is specified for a typical slow sand filter. The low effective size of the soil will result in better filtration of the water; however, the soil characteristics are such that the soil will restrict the flow rate of water through the soil, limiting the amount of water can be applied. It is expected that the filtration rate through the CGAs would be substantially less than through a slow sand filter, which typically ranges from 0.016 to 0.16 gpm/ft^2 (1 -10 MGD per acre) (AWWA, 1999). The application rate of water at the Echo Meadows site was estimated to be 0.002 gallons per minute per square foot (gpm/ft$^{2)}$, an order of magnitude less than the value given on the lower end of the range for slow sand filters used in municipal water treatment. As a consequence, the site (will or will not) be suitable for water spreading?

In its "Long Term 2 Enhanced Surface Water Treatment Rule" (LT2ESWTR), the EPA requires that only wells in granular aquifers are eligible for bank filtration treatment credit. This is defined as those aquifers comprised of sand, clay, silt, rock fragments, pebbles, or cement where in at least 90 percent of a core sample length, grains less than 1.0 mm in diameter constitute at least 10 percent of the core material. All soil samples evaluated from the two sites meet this requirement, per Table 6.

References

American Water Works Association. 1999. *Water Quality and Treatment: A Handbook of Community Water Supplies*. McGraw Hill, Inc., New York, NY.

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Oregon Water Resources Department. 3 April 2003. *Ground Water Supplies In The Umatilla Basin*. OWRD Ground Water Section, Pendleton, Oregon.

U.S. EPA. April 1996. *Microscopic Particulate Analysis (MPA) for Filtration Plant Optimization*. Region 10 Office of Environmental Assessment.

U.S. EPA. June 1995. *ICR Protozoan Method for Detecting Giardia Cysts and Cryptosporidium Oocysts in Water by a Fluorescent Antibody Procedure*. Office of Ground Water and Drinking Water, Washington DC.

Table 1: Geochemical and Field Data for County Line Recharge Site

Parameter	CLWID B-Line	Well MORR 972
Bicarbonate (mg/L)	7.34	70.4
Calcium (mg/L)	4.22	18.6
Chloride (mg/L)	0.67	1.95
Magnesium (mg/L)	1.53	5.36
Potassium (mg/L)	1.44	2
Sodium (mg/L)	2.86	6.64
Sulfate (mg/L)	0.874	2.56
Temperature (°C)	12.8	16.3
Conductivity (µS/cm)	65	145
DO (mg/L)	7.6	7.6
pH	7.3	7.2
ORP (mV)	56	29.9
Turbidity (NTU)	20.1	0.33

Table 2: Geochemical and Field Data for Echo Meadows Recharge Site

Parameter	Hunt Canal Samples[(a)]		Well UMAT 1269	
	3/6/08	6/3/08	3/5/08	6/3/08
Bicarbonate (mg/L)	34	30.1	253	215
Calcium (mg/L)	6.99	4.09	72.8	51.8
Chloride (mg/L)	2.04	1.03	64.6	52.7
Magnesium (mg/L)	2.76	1.64	35	23.1
Potassium (mg/L)	16.4	1.37	11.2	8.65
Sodium (mg/L)	5.01	2.63	55	40.1
Sulfate (mg/L)	2.09	1.19	83.3	75.4
TDS (mg/L)	88.74	--	588.5	--
Alkalinity (mg/L as CaCO3)	34	--	253	--
Hardness (mg/L as CaCO3)	28.8	--	326	--
Biological Oxygen Demand (mg/L)	<2	<2	<2	<2/<2
pH	7.2	4.22	7.7	6.14
Temperature (°C)	7.7	13	14.5	12.7
Specific Conductivity (µs/cm)	90	60-215	860	790
ORP (mV)	--	162	--	88
Dissolved Oxygen (mg/L)	8.2	12.6	0.6	2.58
Turbidity (NTU)	--	42.6	--	ND

Notes:

(a) The sample dated 3/6/08 corresponds to sample HCSW1 and sample dated 6/3/08 to sample HCSW2 in Table 3 of IRZ (2009).

Table 3: MPA Log Removal Results for Echo Meadows and County Line Sites

Parameter	County Line		Echo Meadows	
	CLWID B-Line (per 100 L)	Well MORR 972 (per 100 gal)	Hunt Canal (per 100 L)	Well UMAT 1269 (per 100 gal)
Algae	5,000,000	6.0	100,000	ND
Diatoms	9,000,000	2.0	500,000	ND
Plant Debris	ND[(a)]	ND	ND	ND
Rotifers	ND	ND	ND	ND
Nematodes	3,000	54.0	500	ND
Pollen (Pine)	1,000	1.0	2,000	ND
Ameba	2,000	34.0	1,000	ND
Ciliates	ND	ND	ND	ND
Colorless Flagellates	ND	4.0	ND	ND
Crustaceans	ND	ND	ND	ND
Other Arthropods	ND	ND	ND	ND
Other	ND	ND	ND	ND

Notes:

(a) ND: Not Detected

Table 4: MPA Log Removal Results for Echo Meadows and County Line Sites

Parameter	Log Removal (per 100 gallons)	
	Echo Meadows	County Line
Algae	>3.4	6.5
Diatoms	>4.1	7.2
Plant Debris	ND[(a)]	ND
Rotifers	ND	ND
Nematodes	>1.1	2.3
Pollen (Pine)	>1.7	3.6
Ameba	>1.4	2.3
Ciliates	ND	ND
Colorless Flagellates	ND	3.0
Crustaceans	ND	ND
Other Arthropods	ND	ND
Other	ND	ND

Notes:

(a) ND: Calculation could not be performed since parameter was not detected in surface water sample

Table 5: Soil Analysis Results for Echo Meadows and County Line Sites

Sieve Size	Opening Size (mm)	Percent Passing						
		CL SS1 6" - 3'	CL SS2 6" - 3'	CL SS3 6" - 3'	FD 1-1 6" - 3'	FD 1-2 6" - 2.5'	FD 1-2 2.5' - 3'	FD 1-3 6" - 3'
1/2"	12.5					100	100	100
3/8"	9.50	100	100	100	100	100	99	100
1/4"	6.35	99	100	100	100	99	98	100
#4	4.75	99	100	99	100	99	98	100
#8	2.36	98	100	99	100	99	98	100
#10	2.00	98	99	98	100	99	98	99
#16	1.18	95	98	97	100	98	97	99
#30	0.60	73	80	80	99	97	95	96
#40	0.43	49	60	55	97	94	92	93
#50	0.30	27	36	32	91	89	86	86
#100	0.15	16	14	17	53	61	66	67
#200	0.08	12.7	9.8	10.8	31.5	40.4	50.7	44.3

CLSS: County Line Site Sample
FD: Echo Meadows

Table 6: Effective Sizes and Uniformity Coefficients for Soil Samples

Sample	Effective Size, D_{10} (mm)	Uniformity Coefficient, D_{60}/D_{10}
CL SS1 6" – 3'	<0.075	>6.74
CL SS2 6" – 3'	0.079	5.41
CL SS3 6" – 3'	<0.075	>6.13
FD 1-1 6" - 3'	<0.075	>2.37
FD 1-2 6" - 2.5'	<0.075	>1.95
FD 1-2 2.5' - 3'	<0.075	>1.61
FD 1-3 6" - 3'	<0.075	>1.69