City of Middleton

Natural Treatment System

Reuse Pilot Study

2020 Annual Report

Prepared for: City of Middleton

Prepared by: Jack Harrison. PhD, P.E., HyQual

Mike Martin, P.E., Civil Dynamics

Date: April 30, 2021

Photo: Pilot study alfalfa in spring of 2020 looking to northeast across OZ-4 and OZ05 (by Chad Beverage)

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PROFESSIONAL ENGINEER
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STATE OF IDAHO
JACK R. HARRISON

Date: April 30, 2021

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Acknowledgements

This annual report was prepared under the direction of Mayor Steve Rule, City Administrator Becky Crofts and City Engineer Rachel Speer. Supporting information and input was provided by Middleton city staff including Chad Beverage, Bruce Bayne, and Rodger Hawker. Kirby Cook with Civil Dynamics provided supporting analyses. Without all their ongoing support and efforts this study would not be possible.

Purpose

This pilot study is intended to demonstrate use and assess feasibility of a subsurface drip irrigation (SDI) system for agronomic and high-rate reuse on an alfalfa crop. If this study project is successful, expansion of this natural treatment system (NTS) would be part of the final wastewater treatment system allowing for reuse and discharge of the City's reclaimed wastewater well into the future.

The intent of this first Pilot Study Annual Report is to provide DEQ information on how the pilot study has been implemented, present 2020 monitoring results with a general assessment of results, and present information on planned 2021 operations.

The City is hopeful that with continued operation, monitoring and reporting DEQ will fully accept the use of a subsurface drip reuse application system and the proposed non-growing season (NGS) operations. The City is also planning to work toward acquiring a reuse permit for long operation of a reuse facility.

Introduction

The City of Middleton is anticipating an IPDES permit with new phosphorus limits consistent with the Lower Boise River TMDL (IDEQ 2015). It is also expected that the next permit will require temperature management (IDEQ 2019). To help determine a long-term and economical approach for meeting these future discharge limits, the City is conducting a natural treatment system (NTS) pilot study on crop land located adjacent to their wastewater treatment facility (Figure 1). The study is intended to demonstrate and assess the feasibility of subsurface drip irrigation (SDI) for agronomic and high-rate reuse on an alfalfa crop. If this study project is successful, expansion of the NTS would be a final wastewater treatment step for reuse of their reclaimed wastewater.

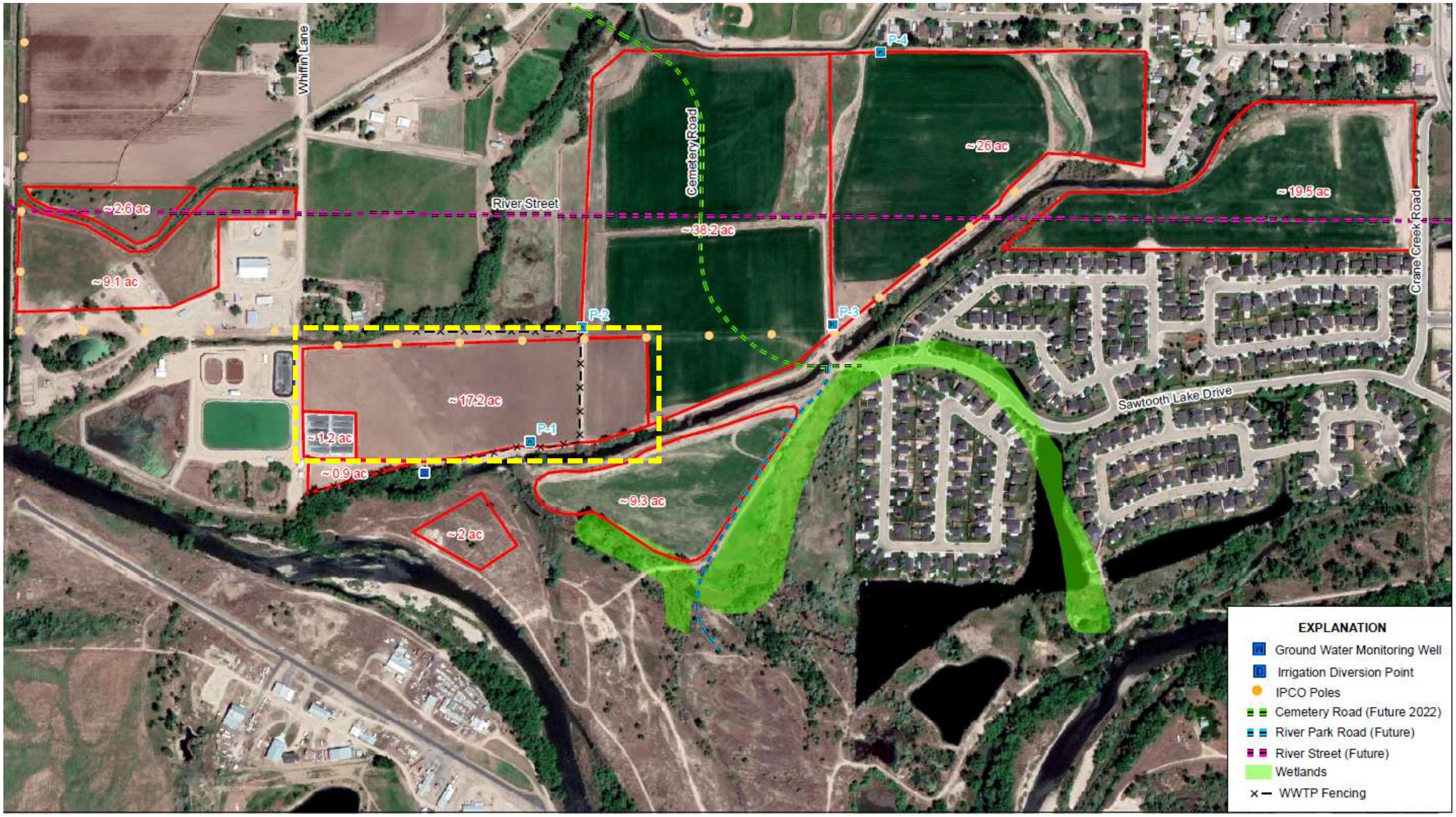


Figure 1 – City owned land (red) and area identified for reuse pilot studies; pilot study area is shown as ~17.2 ac (dashed yellow outline).

The Pilot Study was designed using available information on the characteristics of reclaimed water and the environmental setting that indicated the following conditions:

- Currently the City's reclaimed water is discharged into the Boise River at the mouth of the Mill Slough under an NPDES permit. The reclaimed water to be applied in the study area will meet all the current permit conditions.
- The reclaimed water will be applied to crop land that was previously surface irrigated. This reuse through the SDI system can provide environmental benefits to both the surface and shallow groundwater, including reductions in sediment, nutrient and thermal loads.
- All available groundwater information indicates that the shallow groundwater in the Pilot Study area is not used as a potable water source and discharges into surface water. This would imply that any water that leaches into the shallow groundwater would then discharge into the Boise River.

The Idaho Department of Environmental Quality (DEQ) approved a Pilot Study Work Plan (Harrison and Martin 2020) on September 9, 2020. The approval was subject to conditions including monitoring and annual reporting.

In this first Annual Report, site specific environmental data collected in 2020 prior to any reuse will be presented. This baseline data were used to verify or revise the above stated conditions, and to plan operations (and loading rates) to meet the goals and objectives listed below.

Pilot Study Goals and Objectives

The primary goal of the study is to demonstrate the feasibility of subsurface drip irrigation (SDI) for a forage crop, to quantify the uptake of phosphorus applied to soils, and assess potential approaches to manage the thermal load. The objectives identified to meet these goals include:

1. Obtain operational experience with system operations and management
2. Demonstrate water application tracking methods that can be used to identify irrigation system problems with limited uncontrolled discharge of water (Phase 1)
3. Collect environmental data to support DEQ acceptance of proposed NTS approaches
    - nutrient reduction with summertime agronomic applications (Phase 2)
    - nutrient reduction with fall and spring high rate applications (Phase 3)
    - temperature reduction (future phase)
4. Provide information to support future planning decisions and permitting, and refinement of costs for full implementation of reuse and discharge.

Pilot Study Status and Changes

A Pilot Study Work Plan approval letter, which was sent to Mayor Rule from Adam Bussan with DEQ dated September 9, 2020(Attachment A), provided approval to proceed with the Pilot Study based on submittal of the Work Plan and QAPP (Martin and Harrison, 2020 dft) (dated August 25, 2020 and August 28, 2020, respectively).

Project Specific Conditions for continued operations were as follows:

- An annual report will need to be submitted to DEQ by April 30 of each year. (Note: this submittal is the first Annual Report). Also an Operations Plan (OP) was requested to be submitted by April 30, 2021. However, because construction and startup of the SDI system was delayed, Middleton is planning to delay submittal of the OP until the end of May.

- A Preliminary Engineering Report (PER) with Plans and Specifications for any wastewater facility modification that may remain in service after the end of the Pilot Study will need to be submitted (Note: this has been submitted and approved; Attachment A)).

- The approval for operation of the Pilot Study is for 5 years. To continue operation past September 9, 2025, the City will need either re-approval of the Work Plan or an approved reuse permit.

Additionally, DEQ approval is needed for any modifications to the Work Plan and QAPP. The following is an updated project schedule and discussion of modifications.

Updated Pilot Study Schedule

The updated schedule for the pilot study (Figure 2) shows that the crops and SDI system is in, DEQ has approved submittals, the delivery system has been constructed, and reuse is scheduled to begin in May 2021. Then, after 2 to 3 years of study, the City will need to decide how to proceed with reuse. If reuse is to continue, a reuse permit or revised study plan will be needed after 5 years (i.e., September 2025).

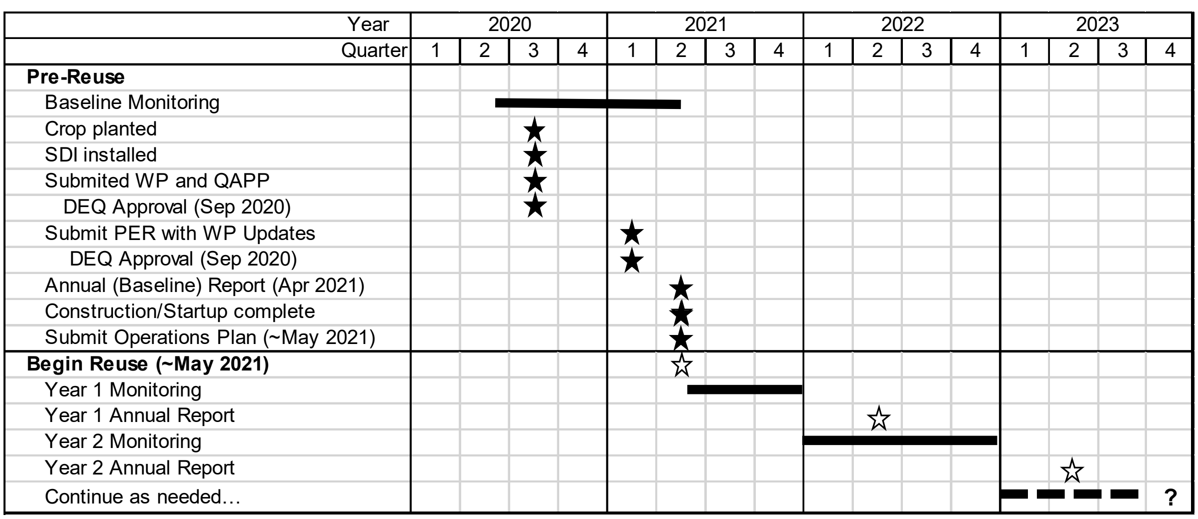


Figure 2 Updated schedule for the pilot study phases and activities

Note that Middleton is planning to delay submittal of the OP until the end of May because construction and startup of the SDI system was delayed.

Preliminary Engineering Report with Work Plan Modifications

The Preliminary Engineering Report (PER) with Plans and Specifications was submitted and approved (March 18, 2021). As required by the PER, an Injection Well Application has been submitted to IDWR.

Changes to the Pilot Study Work Plan were included as part of the Preliminary Engineering Report approved by DEQ. These changes include:

- Use of Mill Slough water for supplemental water
- Changes to pump station to allow for diversion from the Mill Slough
- Changes to the delivery system to allow for diversion from the Mill Slough

Canyon County ditch water was initially proposed for supplemental irrigation. Instead, the City decided to use water from the Mill Slough as this provides more consistent access. This resulted in design changes to the pumping and distribution systems. Agreements with Canyon County Ditch Company (CCDC) and Drainage District 2 (DD2) for this diversion have been completed and are on file with the City (Attachment A).

Other Proposed Work Plan Modifications

Proposed changes to the Work Plan (including monitoring plan) include:

- A more secure location for Boise River temperature monitoring will be selected, and a probe installed
- Mill Slough water level upstream of Rubicon will be recorded monthly and when any changes to gate settings occur

QAPP Changes

A few minor deficiencies were identified while assessing implementation of quality control and assurance (QAQC) procedures during the preparation of this annual report (Attachment B). These deficiencies will be corrected for future monitoring and additional procedures will be established to facilitate full QAPP compliance. The following modification to the QAPP and/or Monitoring Section of the Work Plan are proposed:

- Quarterly data and QC review meetings will be conducted
- Crop tissue samples for OZ1, 2 and 3 will be collected and analyzed individually (i.e., not composited); this change will improve assessment a baseline uptake and removal of “non-reuse” zones

Study Area and Environmental Characteristics

The City owns a wastewater treatment facility and over 200 acres of land located along the Boise River (Figure 1). Much of this land is available for reclaimed water management. Other planned uses of this property include cropping, new roads, utility right of ways, and a riverside park/natural treatment system.

Study Area

The study area (Figure 2) is located north of the Mill Slough between the City’s wastewater treatment facilities and other farm properties that the city owns. The area includes the agricultural land east of the WWTF that will be used for the pilot study. This area has been recently cleared of trees and brush to increase farmable area, which is not evident in the background image.

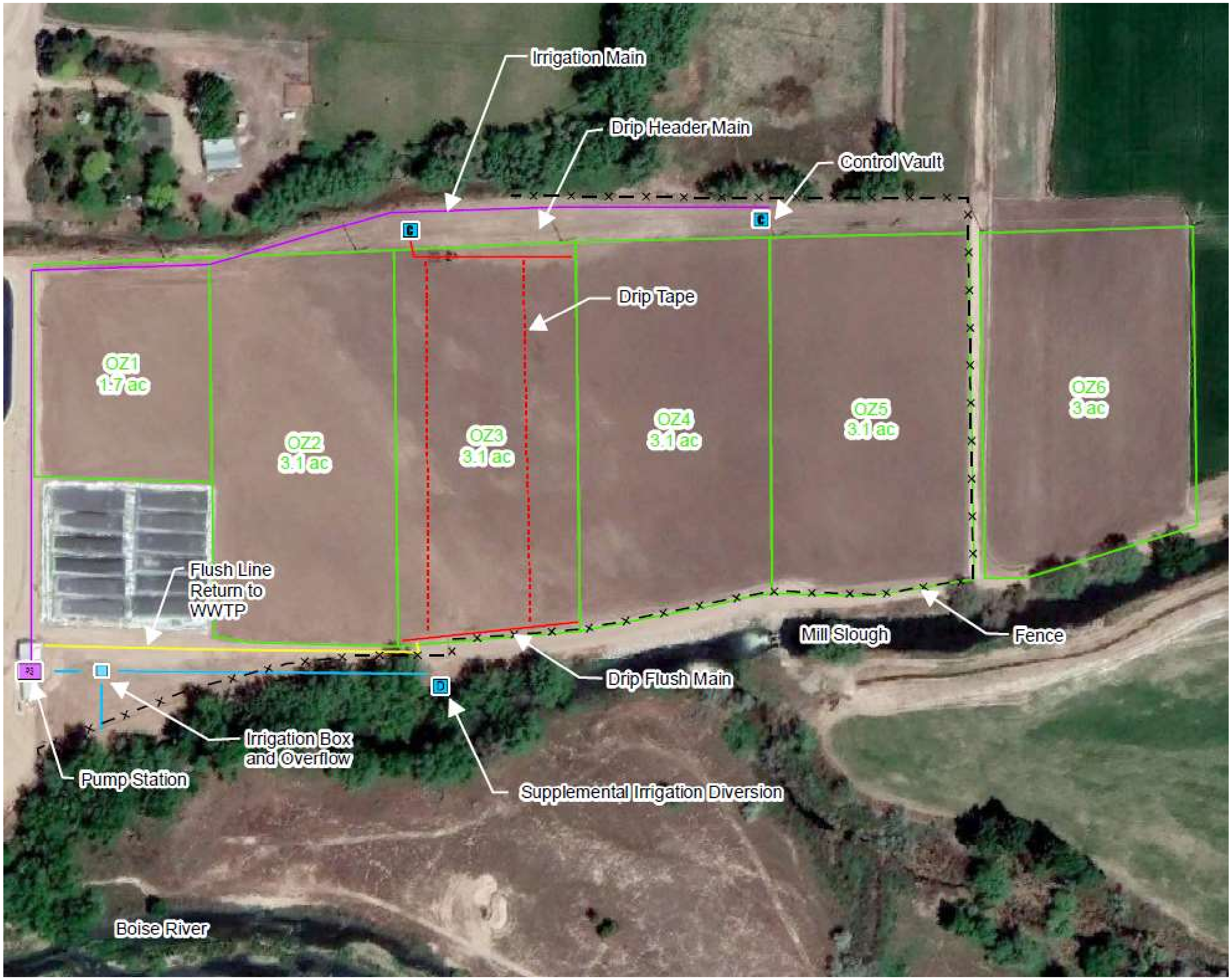


Figure 3 – Reuse pilot studies occur within fenced area. Operational zone 6, which is outside the fenced area, will be used as a study control site.

The two operational zones located furthest to the east (OZ 4 and OZ 5) are proposed for reuse study (Figure 3). As discussed in detail in the Pilot Study and Loading sections, reuse water would be applied at or below agronomic rates during the irrigation season on OZ 4, and a higher non-growing season hydraulic loading rate using reclaimed water is planned for OZ 5.

The study area is approximately 14 acres divided into 5 operational zones (Figure 2) within the fenced study area. Four of these zones are just over 3 acres in size, and there is one smaller zone of about 1.7 acres. Operational zone 6, which is about 3 acres and located east of the fenced study area, will be operated as a control with no reuse water applied. The other operational zones (OZ 1, 2 and 3) will also be used as "controls" or for future study phases. Controls will be used to assess SDI under more typical irrigation practices using supplemental irrigation water only.

Environmental Monitoring and Characterization

One of the stated objectives of the study is to collect environmental data to support DEQ acceptance of proposed NTS approaches. This will require data to help determine:

- nutrient removal with summertime agronomic reuse
- nutrient removal with fall and spring high rate reuse
- thermal load reductions with both types of reuse

The key metrics are phosphorus and thermal loads to the soils, crop phosphorus removal and changes in groundwater temperature in response to thermal loads applied to the operational zones.

Water quality samples and temperature data were collected from reclaimed water and supplemental irrigation water to determine phosphorus and thermal loading to each operational zone from each application. These data were compared to soils sample results for individual operational zones annually. To provide context for these data, water levels were collected, surface water and groundwater quality were sampled, and temperature was monitored.

Sampling Locations

As stated above, samples were collected from reclaimed water, supplemental irrigation water, surface water and groundwater (Figure 4). Temperature data collected below the UV process unit was used for the reclaimed water. In the future, continuously temperature monitoring of reclaimed and supplemental water is planned at a pump station where two separate pump sumps allow samples to be collected from each water source.

Surface water samples were collected from 5 locations (Figure 4):

- BR-UP – Boise River: flow at Middleton Bridge (measured by Idaho Power); water quality and temperature near Middleton Bridge
- MS-UP – Mill Slough upstream of City property boundary (near Paradise Street)
- MS-DS – Mill Slough downstream of Rubicon gate
- WC – Willow Creek at WWTF bridge
- IRR-PS – irrigation pump station (Note: future reclaimed water monitoring will occur here)

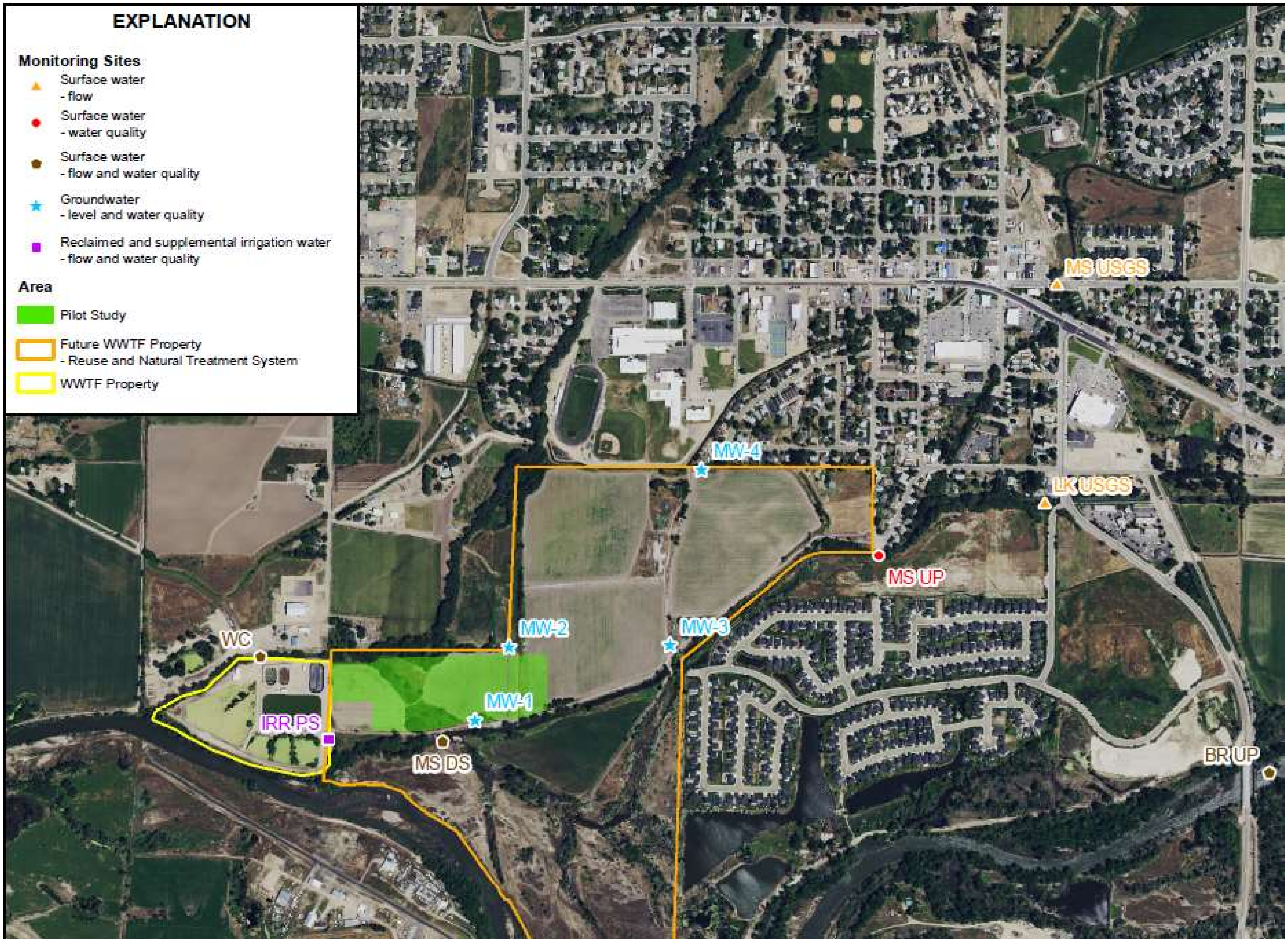


Figure 4 Sampling locations for Pilot Study

Groundwater was sampled at four monitoring well locations (Figure 4) as described below:

- MW-1 – Downstream of the Operational Zone (OZ) 5; near the end of the field and north of Mill Slough
- MW-2 – Upstream of OZ 5; near the supplemental irrigation ditch and power lines
- MW-3 – Downstream of city farm property; north of the Mill Slough, north of double culverts
- MW-4 – Upstream of the City's property; located along the north property line near the center of the property

Wells MW-1 and MW-2 are located to assess for changes in groundwater quality caused by Pilot Study operations. Wells MW-3 and MW-4 are located to assess for changes in groundwater quality caused by City farming operations, and provide a broader context to help understand groundwater flow and quality.

Constituents and Frequency

Sampling constituents and frequency vary by type of source, purpose, risk and need (Table 1). The constituents proposed for monitoring were selected to allow annual phosphorus and thermal loading analyses, the primary focus of the study, and to establish and track environmental conditions around the study site.

Table 1 Sampling Frequency

Type	#	Elev.	Temp	Flows	TP	DOP	NO3	NH4	TN	TSS	TDS	Other
Water												
Reclaimed	1		C	C	W	W	W	W	W	W	W	
Irrigation	1		C	C	M	M	M	M	M	M	M	
Surface	4	M	C	C	Q	Q	Q	Q		Q	Q	EC, pH
Groundwater	4	M	C		Q	Q	Q	Q			Q	EC, pH
Soils	3				BA		BA	BA	BA			% Moisture, EC
Crop	3				H		H	H	H			As-harvested weight, % moisture, and dry weight,

Notes: W= weekly, M = monthly, C = continuous, Q = quarterly, BA = Bi-annual in spring and fall, H = each harvest

The frequency for reclaimed water sampling is based on typical permit requirements, while supplemental frequency is lower due to its relatively low level of environmental concern. The frequency for surface and groundwater sampling was selected to provide data to help identify seasonal changes in hydrology. Note that water level monitoring will be collected monthly, which will provide a greater understanding of groundwater flow and direction variability. While study results are needed within a few years, the monitoring framework is structured to allow longer term monitoring if operations of natural treatment systems are continued in this area. Additional discussion of sampling type and use of data are provided below.

Data Analyses and Management

Details on sampling methods and protocols, and QA/QC are provided in a Quality Assurance Procedures Plan (QAPP) with 2020 information included in Attachment B.

Baseline Environmental Conditions

Environmental monitoring results from data primarily collected in 2020 are presented below. These data were collected prior to reuse (i.e., pre-reuse) and thus provide a pre-study baseline. Additionally, general environmental characteristics and data previously presented in the Work Plan (and associated attachments) has been included to provide context of these baseline results.

Soils

Natural Resource Conservation Service identify the Pilot Study site soils as generally suitable for moderate agricultural production (NRCS 1972). Based on the NRCS classifications, soil types are primarily Multon soils, which are relatively shallow loam and fine sandy loam soils. The permeability is listed as moderate to moderately rapid (i.e., 0.6 to 6.3 and greater than 20 inches per hr., respectively) with available water holding capacity in the 4 to 5-inch range and sufficient adsorption properties (e.g., cation exchange capacity) to support moderate crop yields. Crops can include sugar beets, silage corn, small grains and alfalfa, the latter with moderate yields of about 5 tons/ac. Recent crops include onions (via drip irrigation in 2018) and beets. Historically, furrow irrigation (via siphon tube) was used on many of these fields.

In the spring of 2020 before site activities began, and again in spring of 2021 after the fall 2020 alfalfa planting, soil samples were collected per the Pilot Study QAPP (Martin and Harrison 2020). These procedures are generally consistent with the soil sampling procedures outlined in Mahler and Tindall 1997 and IDEQ guidance. The soil samples were submitted to an agricultural soils laboratory for chemical analyses (Attachment C). While the planned fall 2020 samples were not collected because crop planting and SID system construction was delayed, the soils data collected in April of 2020 and 2021 provide a suitable “pre-reuse” baseline data.

The soil samples were collected at 3 depths (i.e., 0-12, 12-24 and 24 to 36 inches) from each operational zone (OZ). Samples from OZ 1, 2 and 3 were mixed to form one representative sample. To assess current levels of phosphorus storage, the phosphorus concentration for each OZ was averaged and converted into load units (i.e., lb/ac-ft) (Table 2).

Table Soils 2 Average soil phosphorus levels in lb/ac-ft for each operational zone prior to reuse.

Date	OZ 4	OZ 5	OZ 6	OZ 1-3
5/28/2020	108	117	93	144
4/7/2021	117	144	99	105
Baseline (avg)	113	131	96	125

The soil sampling results presented above, which represents per-reuse phosphorus levels, provides a baseline for soil phosphorus levels prior to reuse and crop production. It also provides an indication of soils chemical variability by site and sampling event.

Soil Phosphorus Storage Capacity

After reviewing the draft Work Plan, DEQ requested soil phosphorus isotherm analyses (e.g., Cook 2018) to assess the pre-reuse, long term phosphorus storage capacity of the Pilot Study site soils. This assessment includes:

- Additional laboratory analyses of pre-reuse soil samples
- Preparations of soils phosphorus isotherms
- Estimate of maximum soil storage capacity

Soil Samples

As discussed above, soil samples were collected in April 2020 from Zone 4, 5 and 6, at depths of 0-12, 12-24 and 24 to 36 inches. The portion of each sample remaining after the agricultural analyses were performed were packaged and shipped to UI for the P isotherms analyses. While the procedure only requires ~10 g of dried and milled soil, over 100 grams of soil was sent to ensure a representative sample was used.

Laboratory Analyses

The samples were analyzed at the University of Idaho via a 5-point P isotherm test (UI 2019). The following is an excerpt from the procedure:

> A phosphorus sorption isotherm can be used to describe the relationship between available and adsorbed P in soils. A known amount of soil is allowed to react with a succession of P solutions over a period of 24 h. The difference between the initial and final (equilibrium) P concentrations is used to calculate the amount of sorbed P.

The lab results for each zone, , were plotted for general comparison of the laboratory results, the final solution P concentration was plotted against the sorbed P for the samples from each OZ and depth (Figure 4). The plots show the amount of P sorbed to the soil (mg P/kg soil; y-axis), versus the P concentration (mg/L; x-axis) in the water mixed with the soil. In general, the plots indicate that as the concentration of the solution mixed with soil increases, the amount P sorbed in the soils increases.

Langmuir P Isotherms

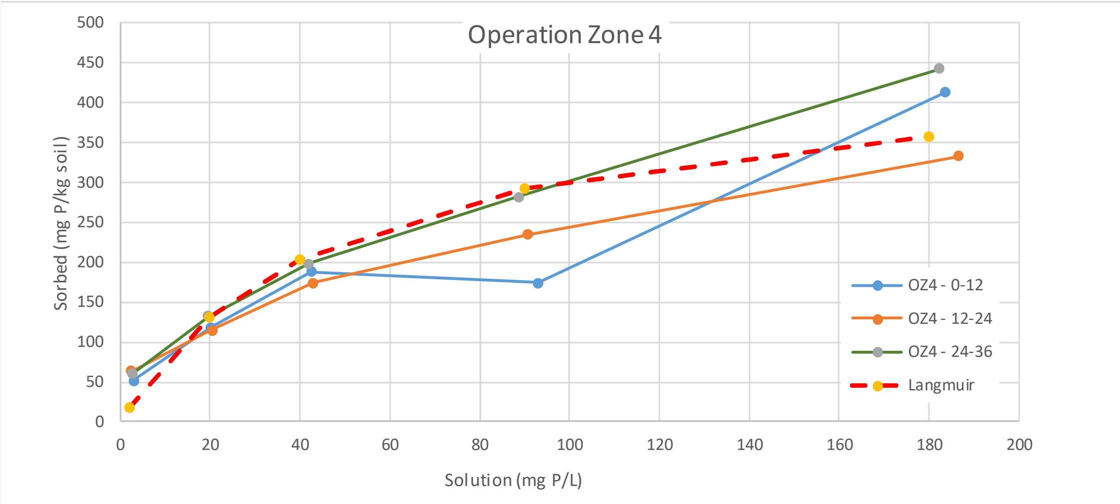
The Langmuir equation for the adsorption (Stumm and Morgan 1995) is often used to represent the soil P sorption processes.

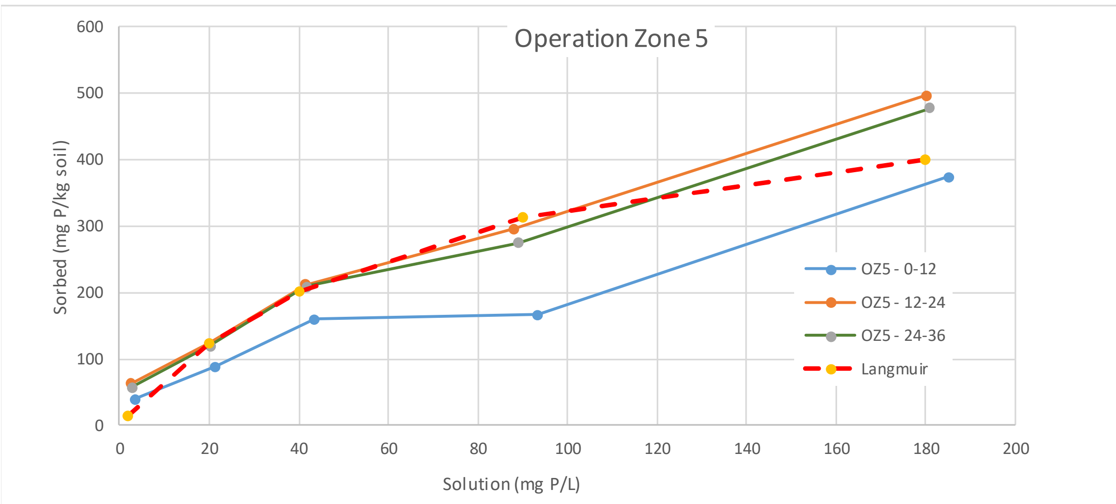
$$SA = Sm*(K*A)/((1+K*A))$$

Where:

- SA = Adsorbate on surface
- A = Adsorbate in solution
- Sm = Maximum adsorbate on surface (i.e. sorbed)
- K = Constant of adsorption

Bohn et al 2001 provides procedures for calculating the Langmuir isotherm parameters (i.e., Sm and K) from the soils data. Using this procedure and the averaged UI data for each OZ, average Langmuir phosphorus adsorption isotherms for each OZ were derived and plotted on Figure 5. As with the raw lab data, this curve shows the amount of P sorbed to the soil (x/m, or mg P/kg soil) is on the y-axis, and the equilibrium P concentration (C) in the soil water (mg/L) is on the x-axis.





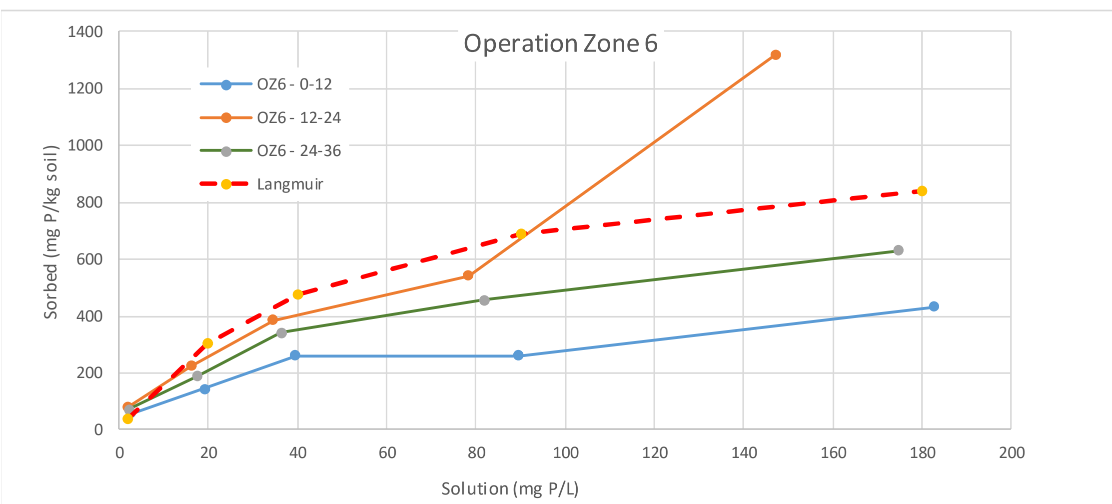


Figure 5 Plots of UI lab data and Langmuir isotherms (dashed red) for Pilot Study OZ 4, 5 and 6

The estimated average maximum P sorbed (per Bohn et al 2001) for each operational zone (Table 3) represents a rough (though potentially non-conservative) estimate for maximum P that the soils could hold.

Table 3 Estimated average maximum P sorbed for OZ-4, 5 and 6.

	Max P Sorbed	
Zone	mg/Kg	lb/ac-ft
4	455	1365
5	556	1668
6	1082	3245

The Pilot Study planned annual P loading rate for the OZ 4 and 5 is 20 lb/ac/yr, while the estimated maximum soil sorbed is well over an order of magnitude higher that this loading rate. Additionally, the planned annual P loading rate to the reuse operational zones (20 lb/ac/yr) will be less than the anticipated crop uptake rates (e.g., 30-50 lb/ac/yr).

Based on these annual loading rates and the considerable capacity of the soils to hold phosphorus, reuse operations should result in an "infinite site life" with limited phosphorus leaching from the soils. This pre-reuse assessment of phosphorus storage capacity provides additional assurance that the soils have the capacity to store phosphorus over the winter.

Surface Water Hydrology

The Boise River forms the southern boundary of the City's River District property (Figures 1). Willow Creek discharges to the Boise River just downstream of the WWTF (west), and Mill Slough bisects the City's River District property and discharges to the Boise just upstream (east) of the WWTF. The City's treated wastewater discharges into the Mill Slough approximately 50 yards upstream of the confluence with Boise River.

Average annual flows in the Boise River near Middleton average around 1100 cfs (MacCoy 2004), while average flows in Willow Creek and Mill Slough are about 42 and 84 cfs, respectively. For comparison, Middleton's current wastewater discharge averages a little over 1 cfs (i.e., 0.72 Mgd).

Surface Water Quality

The designated uses for the Boise River from Middleton to Indian Creek (Assessment Unit # ID17050114SW001_06) are cold water aquatic life (COLD), salmonid spawning (SS), and primary contact recreation (PCR). Based on discussions with DEQ, it appears that DEQ also applies these uses to the Mill Slough. Willow Creek is undesignated. For undesignated waters DEQ presumes that most Idaho waters will support cold water aquatic life and either primary or secondary contact recreation (IDAPA 58.01.02.101.01). To protect these *presumed uses*, DEQ typically applies the numeric cold water and recreation criteria.

Section 303(d) of the Clean Water Act (US Congress 1972) states that waters that are unable to support their beneficial uses and do not meet water quality standards must be *listed* as water quality limited. Subsequently, these waters are required to have TMDLs developed to bring them into compliance with water quality standards.

Regarding status of the Lower Boise River, DEQ's 2016 Integrated report finds that, "Sediment, temperature, flow, and habitat conditions contribute to the impairment of the cold water biota." (IDEQ, 1999). The lower Boise River from Middleton to the confluence with the Snake River was listed as impaired from phosphorus or nutrients suspected in the 2012 Integrated Report. To address these water quality impairments, DEQ has developed sediment, bacteria and phosphorus TMDL's for the lower Boise River, extending below Diversion Dam to the Snake River (IDEQ 1999 and IDEQ 2015). The phosphorus TMDL Addendum set targets of 0.07 mg/L for tributaries and groundwater discharging to this reach of the Boise River. The Boise River is also listed as water quality limited for temperature. However, DEQ has yet to develop a TMDL to address temperature.

Previous Studies

Data collected by USGS (Etheridge 2013) and used by DEQ to develop the Lower Boise Phosphorus TMDL (IDEQ 2015) (Table 4), shows that Mill Slough and Willow Creek have phosphorus levels well above the 0.07 mg/L TMDL target. The data showed that for the major tributaries that discharge to the Boise River Mill Slough and Willow Creek have the fifth and the eight highest phosphorus loads, respectively,.

Table 4 Annual and summer average flows and total phosphorus (P) concentrations and loads for Mill Slough and Willow Creek (Etheridge 2013)

	Flow (cfs)	P Conc. (mg/L)	P Load (lb/d)
Annual Average			
Mill Slough	76.5	0.20	84.0
Willow Creek	27.6	0.28	42.1
Summer Average			
Mill Slough	104.9	0.21	118.2
Willow Creek	36.1	0.23	44.0

2020 Monitoring Results

The primary focus of this pilot study is the treatment of phosphorus consistent with the Lower Boise River TMDL allocations. For this reason' TP monitoring results from this study were plotted (Figure 6) for comparison with other studies. All surface water quality data collected in 2020 are provided in Appendix E.

Mill Slough TP concentrations 2020 (Figure 6) generally ranges from about 0.12 to 0.19 mg/L. These concentrations are consistent with the concentrations reported by USGS (Etheridge 2013) and then used by DEQ to develop the Lower Boise Phosphorus TMDL (IDEQ 2015). Note that for these data TP concentrations are highest in November (i.e., 0.16 to 0.19 mg/L) and the range is smaller (i.e., variation in concentration between locations is about 0.02 mg/L). Because high baseline surface water flows in the winter flows are primarily drainage from shallow groundwater, the consistent TP concentrations indicate relatively uniform groundwater TP concentrations.

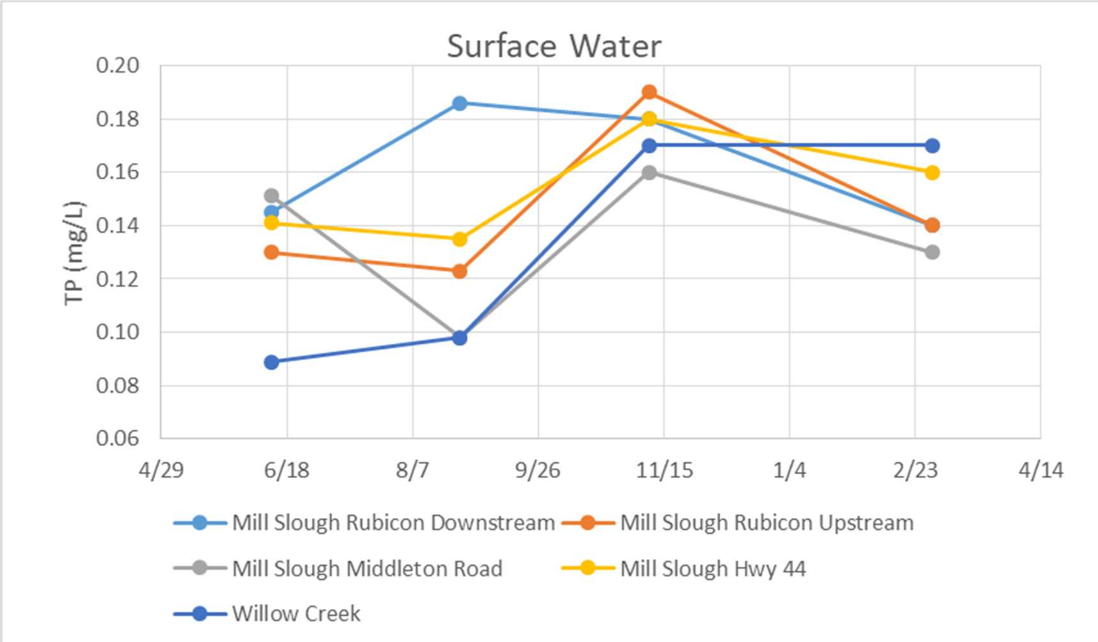


Figure 6 2020 Pilot Study surface water quality total phosphorus concentration (mg/L).

Groundwater Hydrology

In general, the Treasure Valley overlies a thick sequence of interbedded, tilted, faulted, and eroded sediments. These sediments extend to depths of up to 6,000 feet below ground surface (Wood and Clemens, 2004). Surficial geology in the City of Middleton vicinity consists of sandy silt materials deposited by Bonneville Flood slack water and more recent alluvial sediments (Othberg, 1994).

Aquifers are present in saturated sediments underlying the City of Middleton. These aquifers are part of local-, intermediate-, and regional-scale ground water flow systems identified by Petrich and Urban (2004) in their characterization and modeling reports. Recharge to shallow, water table aquifers occurs as seepage from canals and laterals, seepage from ponds and lakes, infiltration of excess irrigation water, infiltration from precipitation (Petrich and Urban, 2004). Discharge from shallow aquifers occurs as discharge to drains, discharge to the Boise River, discharge to other surface channels, withdrawals via wells, and evapotranspiration in areas where ground water levels are near ground surface.

An upward hydraulic gradient was also apparent in simulations of regional ground-water flow (Petrich, 2004a; Petrich, 2004b). This is observed in the Caldwell area through measurement of water levels in a multi-level completion monitoring well (i.e., the data show water levels in deeper wells are higher than water levels in shallower wells). However, the upward groundwater flow is somewhat inhibited by layers of clay and other fine-grained sediments.

Local Groundwater Levels

As part of this study, local water level data were collected from the four monitoring wells (Figure 3) and converted to elevations for review and assessment (Figure 7).

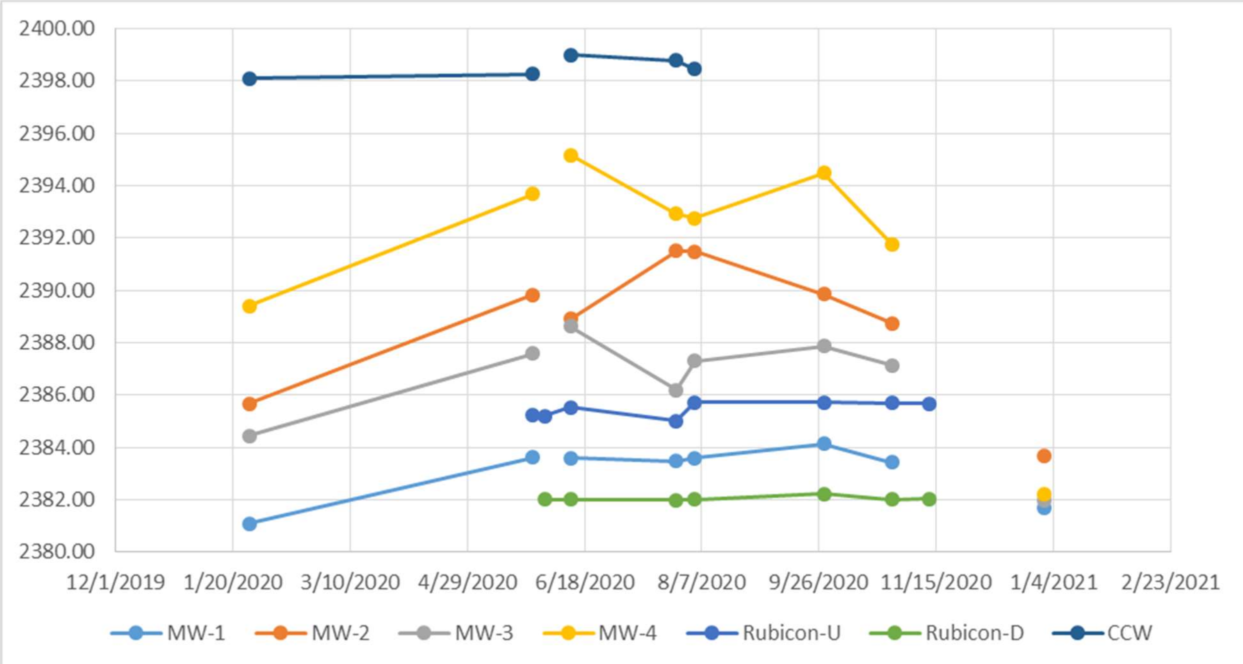


Figure 7 Water level elevations

General observations based on the 2020 data include:

- MW-4 is consistently upgradient with MW-1 lowest GW level (located downstream near the Rubicon gate).
- Comparing Canyon County ditch water (CCW) with MW-4, the shallow groundwater is about 8 feet below the land and surface water.
- MW-3 has higher water level compared to Mill Slough above the Rubicon gate
- MW-1 has higher water level compared to Mill Slough level below of Rubicon gate

These data and observations are all consistent with shallow groundwater flowing south toward the Mill Slough, and with discharge to either the Mill Slough or the Boise River.

Local Groundwater Flow Direction

Ground water in the general vicinity of Middleton flows in a southwesterly direction toward the Boise River based on Lindholm et al., (1988). Shallow ground water flow directions inferred from more recent water level measurements collected in the spring and fall of 1996, 1998, 2000, and 2001 (Petrich and Urban, 2004) are consistent with those of Lindholm et al. (1988).

Potentiometric surface contours (i.e., groundwater isopleths maps) were prepared using the 2020 water level data collected by Middleton (Attachment F). The isopleths provide an indication of the local flow direction for the shallow water table groundwater. During the irrigation season the flow appears to be generally south with a slight eastern component. In the fall, the direction appears to shift a bit more to the eastward. At all times of available data, the direction is shown to be toward the Mill Slough.

Conclusions

The shallow, local groundwater flows south and likely discharges to either the Mill Slough or the Boise River. As discussed above, the deeper groundwater underlying the site flows in a more westerly direction (Petrich and Urban, 2004), and there is also an upward hydraulic gradient between deeper and shallower aquifers in the western portion of the Treasure Valley.

These data and analyses support the following: leachate from irrigation and reuse will discharge into the shallow groundwater, and then into the Mill Slough. And, as stated above, there tends to be a general upward groundwater gradient in the city's River District area that will limit the potential for deeper migration of infiltrating water.

Ground Water Quality

While groundwater quality data for the shallow water table aquafer in the vicinity of the City's property are not generally available, it is anticipated that parameters often related to agricultural practices, including nitrogen, pesticides and bacteria, could be elevated after decades of farming and seepage from creeks, drains and ditches. This is a primary reason that shallow groundwater is not used as a drinking water source. This limits the concerns regarding protection of groundwater as a drinking water source (e.g., nitrate and TDS), and shifts focus on protection of surface water (e.g., ammonia, phosphorus, and temperature).

As stated above for surface water, the primary focus of this pilot study is treatment of phosphorus consistent with the Lower Boise River TMDL allocations. For this reason TP results from the groundwater monitoring were plotted (Figure 8) for general comparison with surface water (Figure 6). All groundwater quality data collected in 2020 are provided in Appendix E.

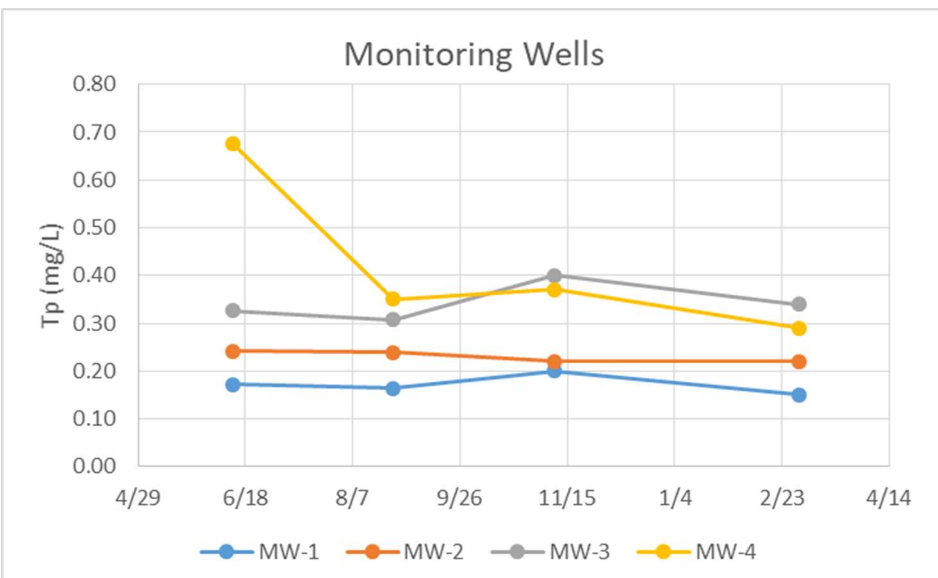


Figure 8 2020 Pilot Study groundwater total phosphorus concentration (mg/L).

Groundwater TP concentrations generally ranges about 0.18 to 0.40 mg/L in the Pilot Study site (Figure 8). Note that the groundwater TP levels are generally higher that surface water (Figure 6) with MW-3 and 4 having elevated TP levels compared to MW-1 and 2

The water quality results provide data on background conditions prior to reuse application. Under the proposed natural treatment approach, nutrient loadings on agricultural lands will be limited to crop uptake, and pilot studies are planned to assess soil treatment and groundwater quality. It is anticipated that improved management could over time lower phosphorus levels in the shallow groundwater below the reuse site, and improve groundwater quality overall.

Reuse Systems

For this NTS pilot study, reuse with subsurface drip irrigation is proposed to provide a high level of treatment and irrigation water control in areas with close proximity to an urban/residential area. Two types of reuse are proposed for this study:

1. Summer slow rate reuse (on OZ-5)
2. Winter high rate reuse (on OZ-4)

For both reuse types, reclaimed water will be applied using a SDI system for natural treatment of phosphorus and temperature. This additional treatment step is expected to reduce effluent loads that are currently discharged to Mill Slough. The summer slow rate reuse study is focused on testing the SDI systems for production of an alfalfa crop. The winter high rate reuse is intended to reduce phosphorus and temperature levels in the recycled water prior to subsurface discharge to the Mill Slough and storing most of the applied phosphorus in the soils for summer uptake. Both systems will reduce direct discharge from the wastewater treatment facility that goes into the Mill Slough and then to the Boise River, and thus provide ongoing environmental benefits during the demonstration and testing period.

Reclaimed Water

The City currently owns and operates a mechanical wastewater treatment facility that is located at 824 Whiffin Lane Middleton, ID, along the Boise River and west of the Study Area (Figure 2). The facility includes a headworks with screening, a grit removal facility, two SBR basins with blowers, a waste activated sludge basin, and an ultraviolet (UV) disinfection unit. The wastewater is collected from approximately 3357 service connections (i.e., about 10,000 residents), mechanically treated to levels needed to exceed the requirements of the city's current NPDES permit. The treatment processes produce reclaimed water that exceeds the requirements for Class C reuse per DEQ Reuse Guidance (IDEQ 2007) and Idaho regulations (IDAPA 58.01.17).

Currently all this reclaimed water is discharged via a pipeline into the Mill Slough at a location about 300 feet upstream of the confluence with the Boise River. Based on 2020 wastewater data (Attachment G), the current average annual discharge rate is approximately 0.72 Mgd. Selected reclaimed water characteristics, based on monthly wastewater data collected downstream of the UV treatment unit, are compared to potential future discharge limits in Table 5. The future phosphorus limits are based on TMDL allocations (IDEQ 2015) and the temperature limits are based on criteria (IDAPA 58.01.02). Additional information on reclaimed water characteristics is provided in Attachment G.

Supplemental Irrigation

Mill Slough water will be used for all supplemental (and any future temporary) irrigation. As stated early in this report, this is a modification of the DEQ approved Work Plan (Harrison and Martin 2000) that had indicated use of Canyon County Ditch Company water for supplemental irrigation.

The intake from the Mill Slough into the reuse pump station is located just downstream of Rubicon gate and upstream of the wastewater treatment plant discharge (Figure 1).

Table 5 Current (2020) reclaimed water characteristics and potential future discharge limits

	~Current	Potential / Future Limits	UNITS	Notes on limits
Total Phosphorus	Avg			Based on TMDL allocations
May 1 - Sep 30	3.6	0.1	mg/L	Future monthly limit
Oct 1 - Apr 30	3.4	0.35	mg/L	Future monthly limit
Temperature	Max			Based on criteria
Nov 1 - May 31	20.7	13	Deg C	Future weekly limit
Jun 1 - Oct 31	22.1	19	Deg C	Future weekly limit

The diversion is located south of the pilot study area. Water is diverted into a subsurface inlet and buried pipe to the Reuse and Supplemental Irrigation Pump Station (pump station). The diversion, pump station and water delivery system is discussed further in the Operations Plan. Water quality data collected from the Mill Slough upstream of the site (i.e., Figure 3; location MS-UP) provides data for estimating loading to the site from the supplemental water.

Alfalfa Crop

Alfalfa hay, which can have relatively high water use and nutrient uptake rates, has been planted in all Study operational zones. The alfalfa was planted in the fall of 2020 and was irrigated with a temporary sprinkler system (e.g., handlines). Mill Slough water was used to help establish the crop in the fall of 2020.

The alfalfa crop will be harvested 4 to 5 times per season, and removed from the field for storage or sale. The potential yield, which is expected to range from 6 to 9 tons/acre, and the nutrient content will be verified by weighing the crop removed and by sampling crop tissue from each of the zones under study (per the Pilot Study QAPP, Martin and Harrison, 2020 dft).

Subsurface Drip Irrigation System

The SDI system used for irrigation in all zones and phases was installed in the fall of 2020. Startup and testing should be complete by May of 2021, and then the system will be fully operational. As planned, the drip tape was installed using an injection tool bar at a depth of about 8-10 inches and a line spacing of 22 inches was selected to increase surface soil wetting.

Maximum hydraulic loading rates for drip irrigation system are controlled by SDI drip tubing emitter size, spacing and line spacing. The drip tubing installed has an emitter flow rate of 0.25 gph, which is typical for this area, and an emitter spacing of 18-inches. Based on these design specifications and a line spacing of 22 inches, the maximum irrigation rate would be 0.29 in/hr.

Also per specifications for the 0.25 gph emitter rate, the nominal flow rate is 0.27 gpm /100ft. And, with the 5/8-inch (15-mil) wall thickness, the maximum operational pressure would be 32 psi, with a flushing pressure of up to about 48 psi.

The SDI Monitoring section includes additional discussion on how flows and pressures will be monitored to provide real time feedback on the operation of SDI system to identify potential leaks or plugs. More detailed information will also be provided in the Operations Plan.

Pilot Study Operations for 2021

The pilot study is divided into 3 phases to gain SDI operational experience prior to the next phase. Each phase is outlined below with additional discussion on the planned hydraulic loading rates for each phase, followed by discussion of planned phosphorus loading targets.

- **Phase 1**: In this initial phase, the City will beginning demonstrating environmentally effective operation of the SDI system. This initial operation will start with irrigation using supplemental water on all of the 6 operational zones (OZ) (Figure 1). This will allow time for the alfalfa crop to become more fully established, complete testing of the SDI system, and determining environmentally safe operational parameters that will be used to help identify problems.

- **Phase 2**: After the first phase of operation using supplemental water, reclaimed water will be applied on OZ-4 at agronomic rates using the SDI system. The proposed hydraulic load rate will match crop irrigation requirements, while the nutrient loading rate is limited to a level well below crop uptake.

- **Phase 3**: In this phase, the City will test non-growing season (NGS) application of reclaimed water. Operational Zone 5 will shift from supplemental water to fall, winter and spring application of reclaimed water. This will occur after the SDI system is tested by irrigating during the growing season with supplemental irrigation water. While the proposed NGS hydraulic load rate will exceed soil water holding capacity, nutrient loading levels will be well below annual crop uptake.

2021 Hydraulic Loading Rates

The SDI system will be used for supplemental irrigation of the alfalfa crop on all operational zones (OZ) and for reclaimed water application on OZ-4 and OZ-5. The monthly average hydraulic loading rates were estimated based on monthly consumptive use rates for alfalfa hay estimated from weather data for Caldwell, ID (Allen and Brockway 1983), which were adjusted for crop production and efficiency. Also shown for all zones are estimated monthly TP loading rates based on the monthly crop irrigation requirements.

Phase 1 (Start up).

The City completed initial SDI system startup in late April and Phase 1 operations are beginning in May

- During startup of the SDI system, the City is irrigating all of the 6 operational zones (OZ) with supplemental water (Mill Slough).

- On OZ-1, 2, 3 and 6, irrigation with supplemental water should continue throughout the growing season at a rate needed to meet peak and monthly irrigation demands (Figure 9).

- The estimated annual TP load on these fields (Table 6) was estimated using an average Mill Slough TP concentration of 0.2 mg/L.

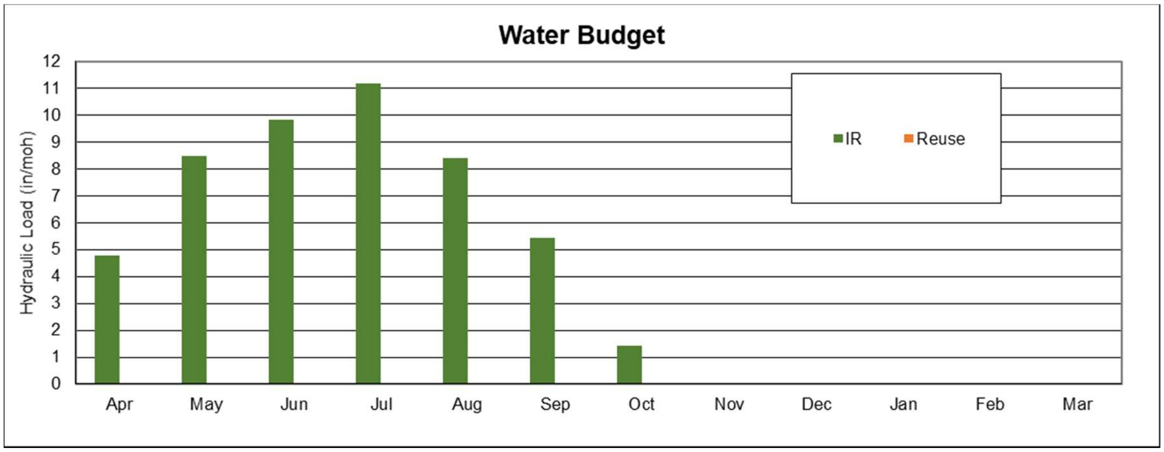


Figure 9 Planned monthly supplemental SDI with Mill Slough water on OZ 1,2,3 and 6

Table 6 Monthly TP loading on Operation Zones 1, 2, 3 and 6

Supp only	Average Irr. Demand	Reuse Water	Supp Water	Total Water	2020 TP	Target TP Load
	in/mon	in/mon	in/mon	in/mon	(mg/L)	(lb/ac/mon)
Apr	4.8	0	4.8	4.8	0.20	0.22
May	8.5	0	8.5	8.5	0.20	0.38
Jun	9.8	0	9.8	9.8	0.20	0.45
Jul	11.2	0	11.2	11.2	0.20	0.51
Aug	8.4	0	8.4	8.4	0.20	0.38
Sep	5.4	0	5.4	5.4	0.20	0.25
Oct	1.4	0	1.4	1.4	0.20	0.07
Total	49.5	0.0	49.5	49.5	--	2.2

Phase 1 Hydraulic Loading Rate. The average monthly agronomic rates (Table 6 and Figure 9) are a guide and actual irrigation rates will need to be adjusted based on the weather and condition of the crop.

Phase 2.
Beginning in Mid-May, the City is planning to start testing SDI reuse at agronomic rate on OZ-4.

- After the startup, **reclaimed water will be applied at agronomic rates for TP** using the SDI system **on OZ-4** (Figure 10).
- Additionally, supplemental water will be applied to OZ-4 to satisfy crop water demands (Table 7). As with other zones, total hydraulic load rate should match the monthly crop irrigation requirements.
- The **annual TP target is 20 lb/ac/yr and should not be exceeded.** The annual nutrient loading will be controlled by tracking the reclaimed TP load applied each month, and then adjusting the reuse application as needed for the following month.

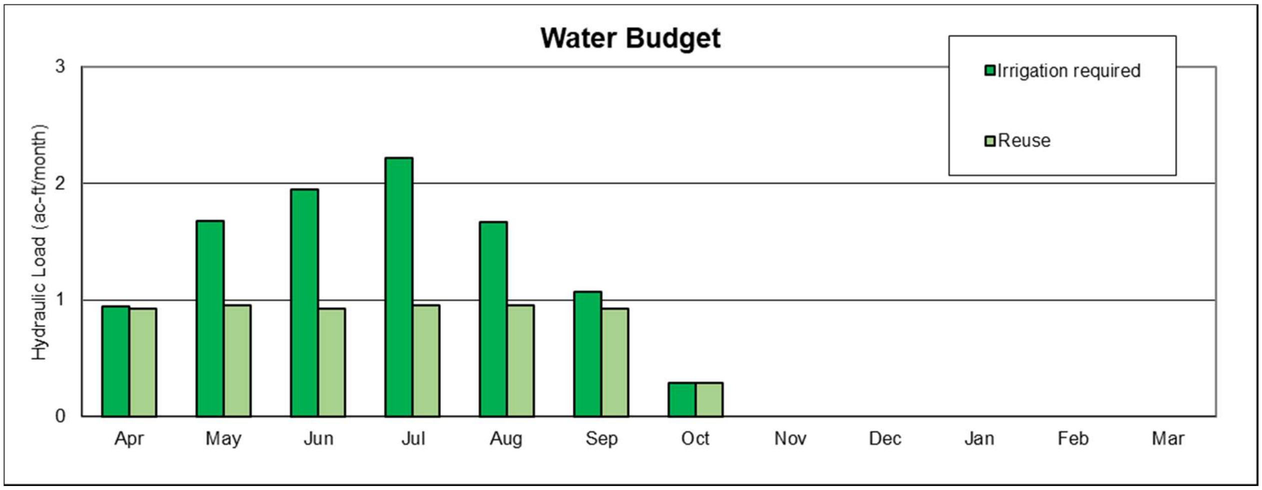


Figure 10 Planned monthly SDI of OZ 1,2,3 and 6 with Mill Slough water

Table 7 Monthly TP targets for Operation Zone 4

Growing season	Average Irr. Demand	Reuse Water	Supp Water	Total Water	2020 TP	Target TP Load
	in/mon	in/mon	in/mon	in/mon	(mg/L)	(lb/ac/mon)
Apr	4.8	3.7	1.0	4.8	4.01	3.4
May	8.5	3.9	4.6	8.5	3.19	2.8
Jun	9.8	3.7	6.1	9.8	2.99	2.5
Jul	11.2	3.9	7.3	11.2	3.03	2.6
Aug	8.4	3.9	4.6	8.4	3.66	3.2
Sep	5.4	3.7	1.7	5.4	4.02	3.4
Oct	1.4	1.4	0.0	1.4	3.62	1.2
Total	49.5	24.2	25.3	49.5	--	19.1

Phase 2 Hydraulic Loading Rate. Similar to the other operational zones, the hydraulic loading rates for OZ4 are a guide and actual irrigation rates need to be adjusted based on the weather and condition of the crop. As shown in (Table 7 and Figure 10), the planned hydraulic loading rate include reclaimed and supplemental water. Note that the total hydraulic should matched the actual irrigation requirements. On this reuse zone, the annual TP target is 20 lb/ac/yr and should not be exceeded. This will require adjusting the volume of reclaimed water applied rates on at least a monthly basis.

Phase 3.

Beginning in October 2021, the City will begin testing non-growing season (NGS) SDI reuse **on OZ-5**.

- After startup, i**rrigation with supplemental water on OZ-5 should continue throughout the growing season** at a rate needed to meet peak and monthly irrigation demands (Figure 10).

- In the fall, the SDI will be used for nongrowing season (NGS) application of reclaimed water (Figure 11). Note that the proposed NGS hydraulic load rate will exceed the NGS soil water holding capacity, but not the annual TP soil storage capacity.

- Planned monthly NGS reclaimed water hydraulic loading rates are similar to monthly growing season rates (Table 8). The total TP loading target is set just below annual crop uptake levels of 20 lb/ac.

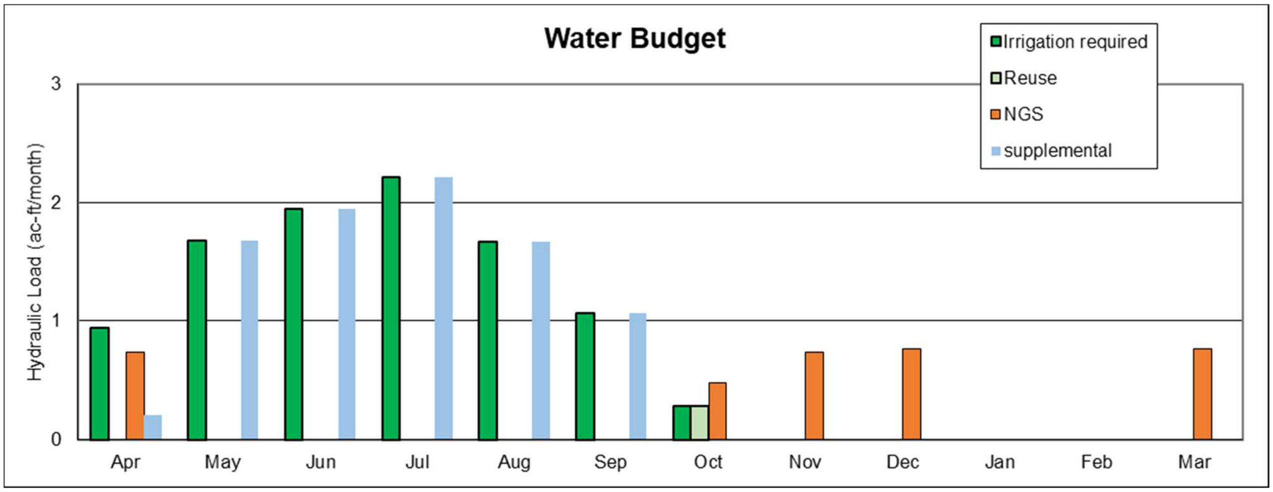


Figure 11 Planned monthly SDI with Mill Slough and reclaimed water (high rate and NGS) reuse from October through April, except during freezing periods

Table 8 Monthly TP targets for Operation Zone 5

Nongrowing Season	Average Irr. Demand	Reuse Water	Supp Water	Total Water	2020 TP	Target TP Load
	in/mon	in/mon	in/mon	in/mon	(mg/L)	(lb/ac/mon)
Apr	4.8	0.7	4.0	4.8	--	2.8
May	8.5	0.0	8.5	8.5	0.2	1.2
Jun	9.8	0.0	9.8	9.8	0.2	1.4
Jul	11.2	0.0	11.2	11.2	0.2	1.6
Aug	8.4	0.0	8.4	8.4	0.2	1.2
Sep	5.4	0.0	5.4	5.4	--	0.8
Oct	1.4	3.1	--	3.1	3.62	2.6
Nov	0.0	3.0	--	3.0	2.06	2.5
Dec	0.0	3.1	--	3.1	2.56	2.6
Jan	0.0	0.0	--	0.0	4.49	0.0
Feb	0.0	0.0	--	0.0	4.55	0.0
Mar	0.0	3.1	--	3.1	4.28	2.6
Total	49.5	12.5	47.4	60.6	--	19.0

Phase 3 Hydraulic Loading Rate. High rate NGS reuse (i.e., hydraulic loading rate above normal irrigation rates) will be studied in Phase 3. As discussed in Middleton's Facilities Plan (Keller 2018), this natural treatment is proposed to help meet future wastewater treatment compliance requirements for phosphorus (and temperature), and to control capital and annual wastewater treatment costs. A key component of the proposed alternative is non-growing season high rate natural treatment on City-owned agricultural land located north of the Mill Slough. While there may be water leaching below the root zone carrying some soluble P, the intent is to store most of the phosphorus that is applied in the soil for crop production the next summer. It should also be noted that this reuse, with its expected natural treatment, will reduce direct discharge (and pollutant loading) into the Boise River.

As shown above, the planned "high rate" hydraulic loading totals about 53 inches for the year. This includes 40 inches of supplemental water applied in the summer, and 13 inches of reclaimed water applied during the NGS.

As shown in Table 8, the recycled water will be applied during NGS at monthly hydraulic rates that exceed the soil's water holding capacity. However, actual application rate (controlled by the SDI design) will be similar to the slow rate system as discussed in the SDI section. And, per the planned operations and testing, no recycled water will be applied during the growing season, only supplemental with its relatively low P concentration of 0.2 mg/L.

2021 Nutrient Loading Rates

The City's land provides the opportunity for testing and study of an innovative approach to NGS reuse of reclaimed water. The agricultural soils located along the north of Mill Slough are suitable for crop production. In the past, land application facilities have used soils to store and treat reuse water over winter (i.e., soil moisture storage). This proposed NTS approach will rely on loamy soil's capacity to store phosphorus applied over winter to help meet crop requirements during the summer.

Planned nutrient loading rates for OZ 4, 5 and 6, are shown in Tables 7, 8 and 6, respectively. These loading rates were estimated based on:

- Monthly 2020 reclaimed water concentrations, with the moderately high strength (the reclaimed water TP averages about 3.5 mg/L; (Appendix G)
- Supplemental water TP of 0.2 mg/L was used; data show that the Mill Slough TP concentrations 2020 generally ranges from about 0.12 to 0.19 mg/L (Attachment E).

No additional P loading (i.e., fertilization) is planned. NRCS 1974 estimated potential alfalfa production of 5 tons per acre. However, current production levels in the Treasure Valley can exceed 10 tons per acre. For this project we anticipate about 7 ton per acre, assuming nutrients are sufficient, as indicated by the soil analyses (Table 2). With a typical phosphorus content of alfalfa of about 6 lb/ton (Undersander et.al. No Date), this equates to an annual uptake of 42 lb/ac/yr, which is comparable to the removal rate (i.e., 40 lb/ac/yr) given in the Idaho's Guidelines (IDEQ 2007). The planned reclaim water TP loading rates for this study (Table 6, 7 and 8) are well below the typical alfalfa crop uptake

Conclusions

In this first Pilot Study Annual Report, site specific environmental data collected in 2020 prior to any reuse are presented to help establish baseline conditions for the Pilot Study area. In May the City of Middleton is planning to begin reuse on the Pilot Study area as authorized by DEQ per a Work Plan approved on September 9, 2020. The following are proposed changes to the Work Plan:

- A more secure location for Boise River temperature monitoring will be selected, presented to DEQ for approval, and a probe installed
- Mill Slough water level upstream of Rubicon will be recorded monthly and when any changes to gate setting occur.

Additionally, Middleton is planning to conduct quarterly data and QC review meetings to facilitate full QAPP compliance.

The 2020 data were also used to re-assess the environmental conditions previously presented and used to the design this study. Based on our review, the baseline data is consistent with these previously stated conditions:

- Currently the City's reclaimed water is discharged into the Boise River at the mouth of the Mill Slough under an NPDES permit. The reclaimed water, which will be applied in the study area, currently meets all permit conditions and the Class C treatment criteria established in Idaho's reuse rules and guidance.

- The reclaimed water, to be applied to crop land that was previously surface irrigated, will be applied on an established crop of alfalfa via a SCADA controlled subsurface drip irritation (SDI) system. The SDI system that has been installed and tested, and is now ready to provide the environmental benefits of reuse by reducing nutrient and thermal loads currently discharged to the Mill Slough, which then discharges to the Boise River.

- All available groundwater information, including the 2020 monitoring data, indicate that the shallow groundwater in the Pilot Study area is not used as a potable water source and discharges into nearby surface water. Based on this information, any water that leaches below the root zone and into the shallow groundwater will then be discharged into the Boise River with a net reduction in nutrient and thermal loads (compared to direct discharge).

The 2020 reclaimed water data were also used to plan monthly hydraulic and phosphorus loading rates for the 2021 operational period (i.e., April 2021 through March of 2022) for each of the Pilot Study operational zones. The SDI system, operated under the SCADA system control, will be used to irrigate all operational zones at agronomic hydraulic rates during the growing season using supplemental water from the Mill Slough. The estimated TP loading from the Mill Slough water is about 2 lb/ac/yr.

The target TP loading rate is 20 lb/ac/yr, including the supplemental water loading. Beginning in May, growing season reuse is planned for OZ-4 with reclaimed water applied at below agronomic rates (both hydraulic and nutrient).

The non-growing season high rate reuse, planned for OZ-5 is scheduled to begin in October. Reclaimed water will be applied with the SDI in the non-freezing months at hydraulics rates based on the SDI design. To limit the phosphorus loading to below the 20 lb/ac/yr target, the planned reclaimed water application rate is expected to be about 20% greater than the growing season rate.

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Attachments

Provided in separate document available upon request.

Attachment A – DEQ Approvals and Water Transfer Agreements
Attachment B - QAQC
Attachment C – Soils
Attachment D – Soil Phosphorus Storage
Attachment E– Water Quality
Attachment F – Groundwater
Attachment G – Reclaimed Water