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The Effects of Channel Incision and Land Use on Surface-Water/Groundwater Interactions in the Teanaway River Basin, Washington, USA

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THE EFFECTS OF CHANNEL INCISION AND LAND USE ON SURFACE-WATER/GROUNDWATER INTERACTIONS IN THE TEANAWAY RIVER BASIN, WASHINGTON, USA

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Geological Sciences

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by

Joseph C. Petralia

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CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

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ABSTRACT

THE EFFECTS OF CHANNEL INCISION AND LAND USE ON SURFACE-WATER/GROUNDWATER INTERACTIONS IN THE TEANAWAY RIVER BASIN, WASHINGTON, USA

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The Teanaway River basin, a major tributary to the Yakima River, is host to several restoration projects with the intention of returning the river channel to a more natural state and improving riparian habitat. These projects may also increase aquifer storage and potentially increase summertime streamflows. This study of the Teanaway Valley Family Farm, an 88-hectare parcel on the main-stem Teanaway River that was recently purchased by Washington Department of Fish and Wildlife, provides hydrogeologic data that will inform these restoration projects. Following the purchase of this land, ten wells were installed within and slightly above the floodplain in order to determine seasonal variations in groundwater level, in part to investigate the mortality of a cottonwood grove near the Teanaway River. Well cuttings revealed that the upper third of the floodplain in this region is underlain by a thick clay deposit above the bedrock, which limits the extent of river water interaction and reduces the overall aquifer storage potential. In this study, groundwater level and temperature data from pressure transducers for a 15-month period for all ten wells is analyzed and compared to river elevations. This data showed that there were two distinct “pulses” of groundwater recharge, occurring

during warm spells in January and February 2020. Water elevation within the alluvial aquifer then declines over a 4-month period towards baseflow conditions so that during the summer months, groundwater in the cottonwood grove was at least two meters below the surface. Thus, the cottonwood grove does not have access to groundwater during the dry summer months. Stable isotope analyses were performed on the groundwater, soil water, and river water in order to determine the extent of river water infiltration into the unconfined alluvial aquifer adjacent to the river. The stable isotope composition of the river and well water from the four wells closest to the stream were nearly identical, whereas groundwater from three wells further up the floodplain appears to be a mixture of river water and pre-existing groundwater. Thus, the river naturally supplies water to the cottonwood grove area throughout the year. However, the stream incision and pumping from upstream ponds for irrigation has resulted in a lower water table within the floodplain during the dry summer/early fall months. The cottonwoods likely survived the challenges of the stream incision with a supply of water from prior irrigation practices that artificially raised the water table during the dry season.

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CHAPTER I

INTRODUCTION

Overview and Problem Statement

Throughout the last century, human land use, such as, logging, over-grazing, railroads, and agricultural practices, within the Teanaway River watershed have resulted in an incised stream and disconnected floodplain for many reaches of the river and its tributaries. When a river incises, the water flowing within the stream is far less likely to enter the surrounding floodplain aquifer, leading to a decrease in water stored within those aquifers. On the contrary, if streams are connected to their floodplains, water can be stored within the aquifers and retained later into the summer season. In order to reconnect the river to its floodplain, restoration measures are necessary.

Beginning in 2014, several partners, including the Washington Department of Ecology (Ecology), Washington Department of Fish and Wildlife (WDFW), the Washington Department of Natural Resources (DNR), the Yakama Nation, the Kittitas Conservation Trust (KCT), and Mid-Columbia Fisheries Enhancement Group (MCFEG) began working on restoring the Teanaway River watershed. These restoration partners have been involved in many projects throughout the Teanaway River watershed. Indian Creek, for example, is a Teanaway tributary that naturally contained wood and other debris throughout the stream. Much of this wood was removed through logging leaving an incised, straight channel. Indian Creek has been a target of restoration through large wood emplacement. Large wood naturally enters rivers and streams from channel boundaries, floodplains, and adjacent uplands. The effects of having large wood in streams includes resistance to erosion, obstruction of flow, retention of sediment and organic matter, and habitat diversity (Wohl, 2017). The goal of emplacing wood along stream banks is to mitigate stream bed incision by increasing sedimentation and slowing the velocity of water around strategically positioned log jams.

The West Fork (WFTR), Middle Fork (MFTR), and North Fork (NFTR) are the three main tributaries to the main stem TR. Before the 20th century, all these stream beds were covered in dense log jams which kept the stream bed intact. In the 1920s logging operations began with the removal of these log jams from stream channels. Logs stripped from the forests were then transported downstream in “log drives” that led to a mill downstream along the Yakima River (Figure 1). This process was highly abrasive to stream banks and stream beds (Collins et al., 2016). At present, all reaches of the Teanaway River have experienced rapid erosion to the stream bed and the creation of strath terraces (Figure 2) in the lower reaches (Collins et al., 2016). To slow the rates of erosion to the stream bed and stream bank, LWD has been emplaced in several reaches of the TR. An example of LWD emplacement is Indian Creek where the Yakama Nation began emplacing wood in the stream and on the floodplain in 2017.

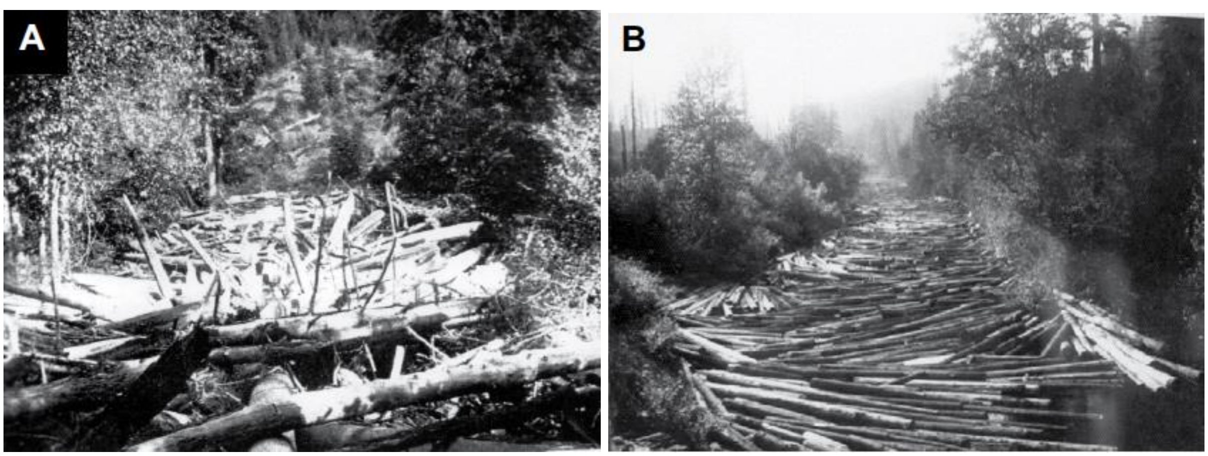


Figure 1. (A) Wood jam in MFTR, from (Russell, 1898). (B) Log drive in main-stem TR “ca. 1920.” Photo from Central Washington University Library Archive, http://digital.lib.cwu/items/show/11687 (Collins et al., 2016).

Figure 2. Strath terrace near the Teanaway River and Indian Creek confluence. Photo taken June 2020.

Along the main-stem of the Teanaway River at River Mile 8, lies a property known as the Teanaway Valley Family Farm (TVFF). This land was purchased by WDFW and is being restored by MCFEG. Within this property, near the river, a grove of cottonwood trees has been dying off. It is hypothesized that this die-off could be due to a change in irrigation practices that occurred around 2012. This decrease in summer recharge, combined with the incised channel, result in a situation where the roots of the trees do not reach the water table in the summer months. Cottonwood tree roots can follow declining water table elevations at a rate of 20mm/day, but when the water table elevations fall at ~40mm/day, significant dieback occurs (Grismer, 2018). Restoring the stream beds to a completely natural state shown in Figure 1 may not be possible, but log jams are already being put in place along the banks of the TR stems.

Yakima River Basin Integrated Water Management Plan

In addition to land-use practices altering the landscape of the Upper Yakima River Basin, climate change has also affected Yakima River Basin, and will continue to affect the region. The economy and people of the Yakima River Basin rely on the water stored in the snow pack from the Cascade Mountains, as well as the five surface reservoirs (Keechelus Lake, Kachess Lake, Cle Elum Lake, Bumping Lake, and Rimrock Lake). As the snowpack decreases due to climate change, and the population of the Yakima Basin increases, more water will need to be stored in the case of a drought year (Vose et al., 2017). Water rights throughout the Yakima River basin have been established primarily for irrigation of the agriculture, which is the primary economic driver in the Yakima Basin. These issues led to the creation of the Yakima River Basin Integrated Water Management Plan (YRBIP, summarized in Figure 3), which was passed through legislature in 2013 with the goal of finding sustainable water solutions for the region. The plan is currently in its initial implementation phase and has millions of dollars dedicated to water resource projects throughout the basin. Aquifer storage and watershed enhancement are the two goals outlined by the YRBIP that can be informed by this research.

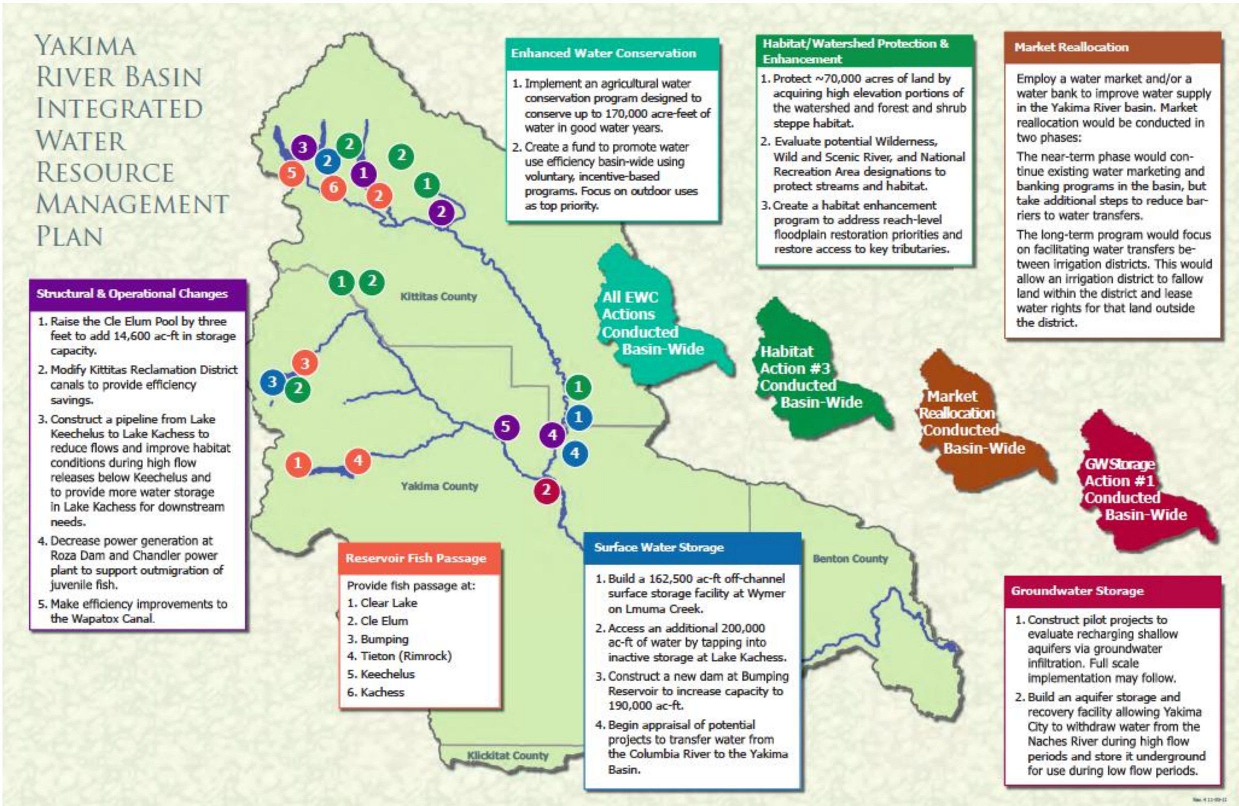


Figure 3. The framework of the Yakima River Basin Integrated Water Management Plan (Bureau of Reclamation, 2012).

Study Area

For the purpose of this study, I am using two of the goals stated by the YRBIP, aquifer storage and watershed enhancement, in order to observe changes in the Teanaway River watershed caused by recent restoration projects in the basin. The Teanaway River watershed is in the Upper Yakima River basin and is a major tributary of the Yakima River (Figure 4). The study site for this project is the TVFF. Some methods are described for a nearby study site, Indian Creek, but the data and results are the subject of Stephen Bartlett's 2022 M.S. thesis.

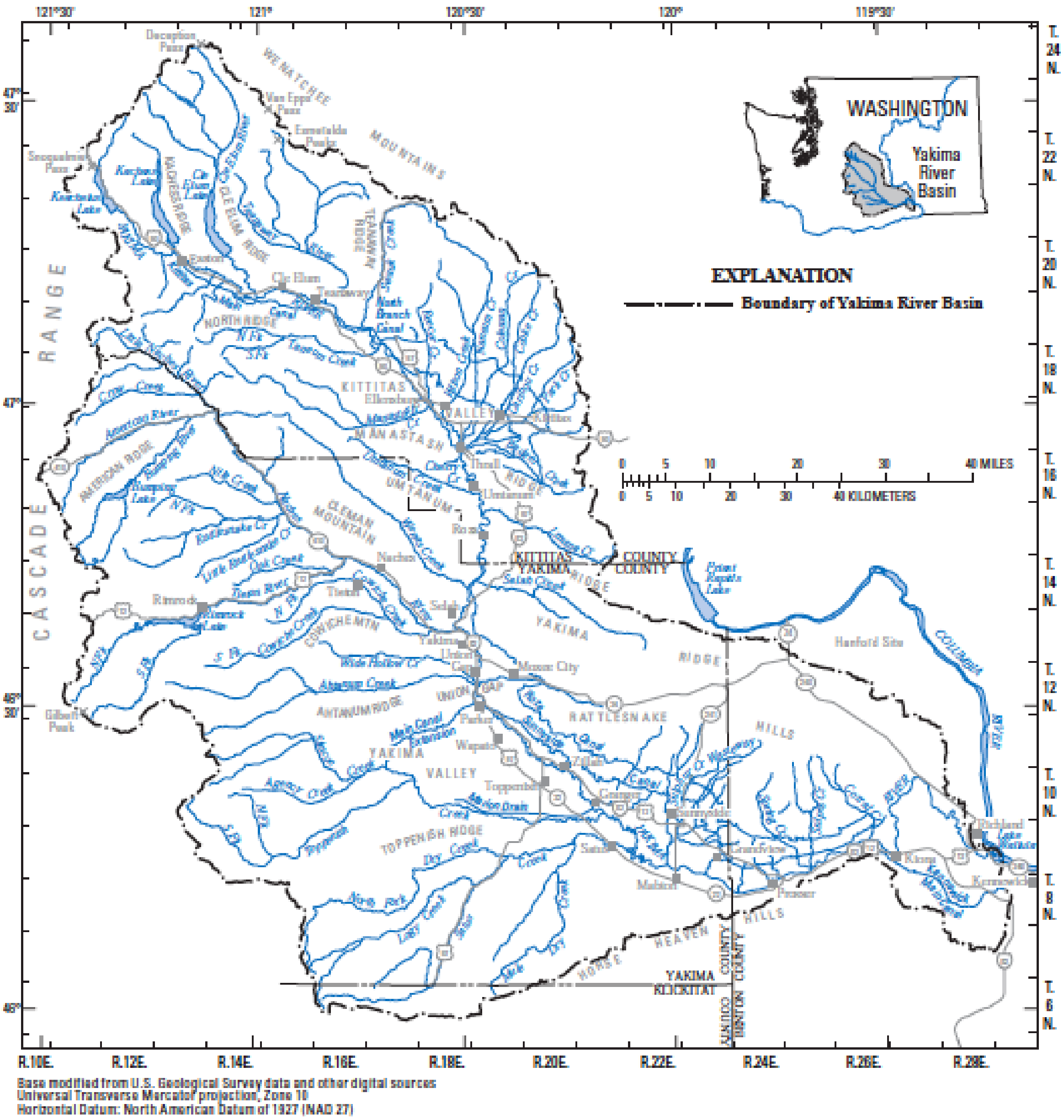


Figure 4. The Yakima River basin, Washington. Teanaway River watershed highlighted in black (Vacarro, 2009).

Teanaway Valley Family Farm is a 87-hectare plot of land along the main-stem Teanaway River (Figure 5). This land was purchased by the Washington Department of Fish and Wildlife. Mid-Columbia Fisheries Enhancement Group has been tasked with restoring the land, including a grove of dead cottonwood trees within the floodplain of the Teanaway River, and a field that was farmed for hay. Because of concerns about cottonwood die-off and to better understand the hydrologic characteristics of the site, ten wells were emplaced near the Teanaway River by the MCFEG to characterize groundwater level variation through time (Figure 6).

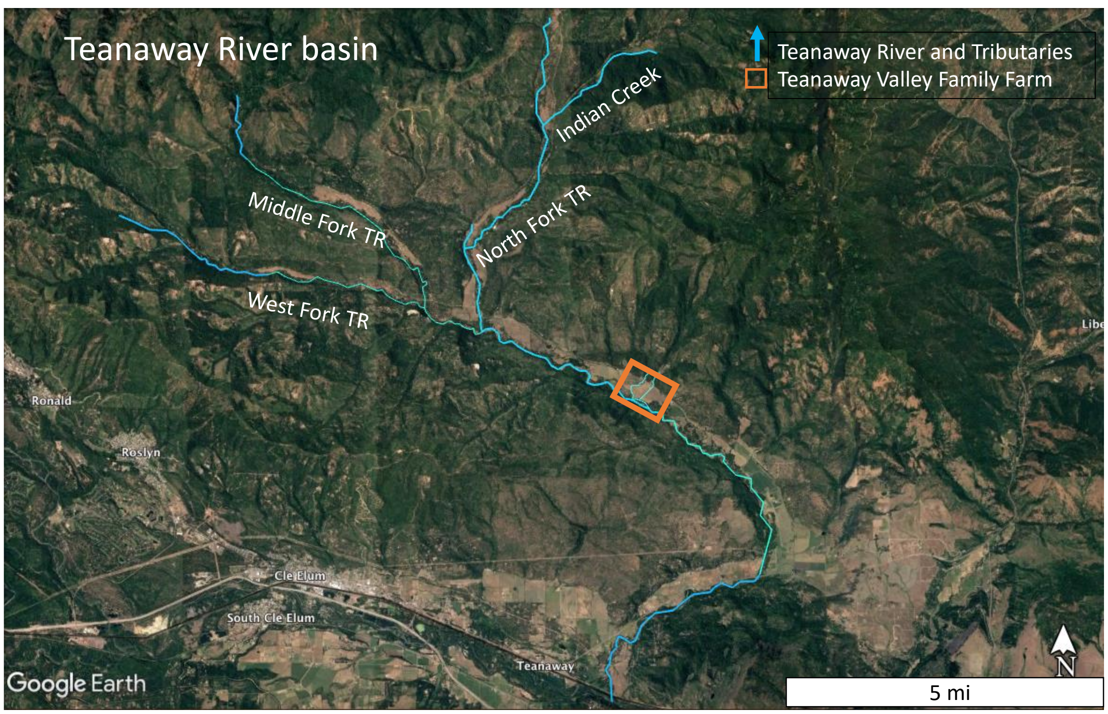


Figure 5. Google Earth Image of the Teanaway River basin and its main tributaries. TVFF highlighted in orange box.

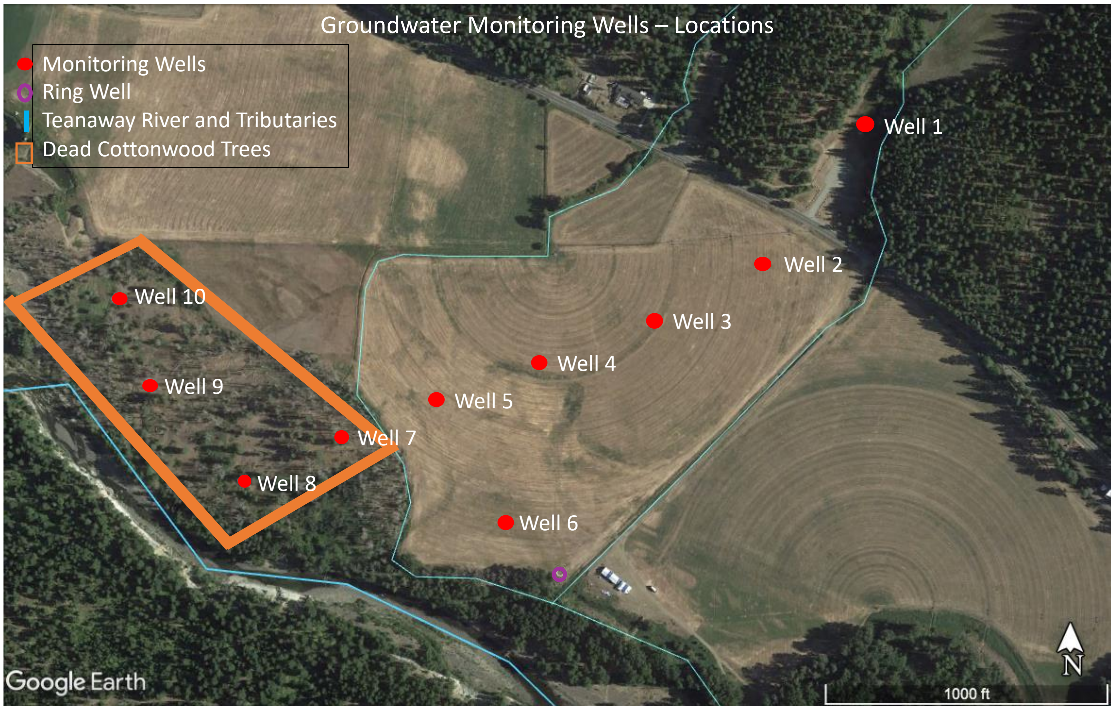


Figure 6. Aerial image of the Teanaway Valley Family Farm with wells plotted and dying cottonwood grove outlined. (Google Earth Image).

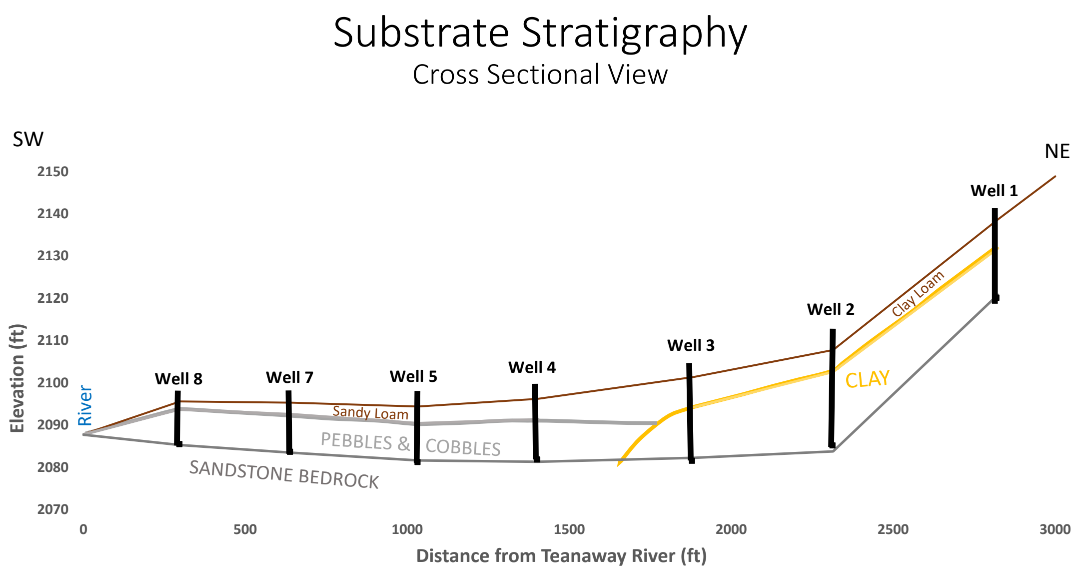


Figure 7. Cross section of subsurface at the Teanaway Valley Family Farm.

The stratigraphy for TVFF was determined by observations of drilling and analysis on well cuttings at each well location by Dr. Carey Gazis and her students on November 13-14, 2018. All wells except well 2 were drilled down to Roslyn sandstone bedrock of the area. Above the bedrock there are two distinct stratigraphic zones. Wells 1-3 are emplaced in a region containing a ~5-m thick impermeable confining clay layer. Wells 4-10 are all emplaced within an unconfined alluvial aquifer comprised of gravels, sand, and boulders with an approximate porosity of 0.25-0.40 (Figure 7). This contradicts the previous knowledge of the stratigraphy within the Teanaway River basin, which omits the confining clay aquitard (Dickerson-Lange et al., 2019). Overlying the unconfined alluvial aquifer is a sandy loam similar to what would be found in a temperate forest. This zone is recognized as the river floodplain. These two reaches of the property are separate aquifer systems, and act as such.

Cottonwood Tree Roots and the Water Table

Cottonwood trees are widespread across semi-arid landscapes around North America despite their sensitivity and likelihood of mortality being high during a drought (Scott, 1999). Cottonwood trees are able to persist within these regions because of their ability to reproduce rapidly with small wind-dispersed seedlings, and rapid germination process. These populations of trees generally establish their roots in alluvial soils with shallow groundwater (Scott, 1999). Seedlings generally require a water table at no more than 2m depth, and groves of cottonwood have been observed surviving with a water table depth of 7-9m. However, most mature cottonwood groves thrive in conditions where the water table is roughly 3.5m depth (Scott, 1999). Channel incision and sediment deposition, as has happened in the Teanaway River, can lead to a disconnect between the river and the water table.

Figure 8 shows a rapid change in the health of Cottonwood forest on the TVFF property. Focusing on the tree coverage and not the fields, there is a drastic difference in lush, green, living trees, to barren, dead, or dying trees between 2011 and 2017. Present day conditions are similar to the image from 2017.

Figure 8. Satellite images of the TVFF Cottonwood groves from 2011 (left) and 2017 (right) White dots are well locations, wells not emplaced during the time of these images (Google Earth Image).

Irrigation and Land Use Practices

Irrigation water from the west of the property and flood waters from overland flow are drained into the west tributary, Fred Creek, which is constrained to a man-made irrigation ditch where it crosses the fields. This ditch remains full of water well into the early summer while the soils surrounding it are barren and dry by that time of year. The field was turned-over in the fall of 2019. This was done to remove any remnant agricultural vegetation and allow for natural vegetation to repopulate the field. By spring of 2021 the field has already begun repopulating with vegetation.

The neighbor upstream irrigates his field annually and obtains three cuttings of alfalfa per year. He utilizes pump irrigation, pumping from one of a series of ponds on his property to supply a pivot irrigation system to spread the water. TVFF had a similar set up, pumping from a shallow ring well in the southeast corner of the field before the land was purchased by WDFW.

Prior to this pump irrigation, the primary method for irrigation was flood irrigation. This practice took place during the early 20th century. Water was removed from a canal, Ballard Ditch, near the road and applied to the high side of the field so that it was dispersed throughout the fields. In 1964, the farmers established their pivot irrigation system and began pumping from the canal to supply this system. In 1978, the water sources were switched to their current ones, which are surface water ponds and shallow ring wells, in order to maintain streamflow in the Teanaway River, which was supplying the canal water. Ballard ditch was destroyed due to flooding in years 1996-1997.

Stable Isotope Fundamentals

The stable isotopes of hydrogen (D and H) and oxygen (^{16}O, ^{17}O, and ^{18}O) can be used to understand an array of hydrological processes. For the purpose of this study, they will be used to determine interactions between groundwater and surface water. A stable isotope is a nuclide of an element that does not undergo radioactive decay. Stable isotopes in water are measured as ratios of a heavy, uncommon isotope (D, ^{18}O) over a lighter, common one (H, ^{16}O) and expressed in the delta notation:

$$\delta = \frac{(R_{smp} - R_{std})}{R_{std}} * 1000$$

where R is the isotope ratio (D/H for δD, $^{18}O/^{16}O$ for $\delta^{18}O$), smp is the sample and std is a standard, Vienna Standard Mean Ocean Water (V-SMOW). The units for this measure are per mil (‰), where one per mil is equivalent to a tenth of a percent difference between the ratio in the sample and the ratio in V-SMOW.

When water evaporates, the water molecules with the lighter isotopes preferentially evaporate. When water condenses and precipitates, the heavier composition stable isotope compounds preferentially rain-out (Faure, 2005). Figure 9 demonstrates this rainout process.

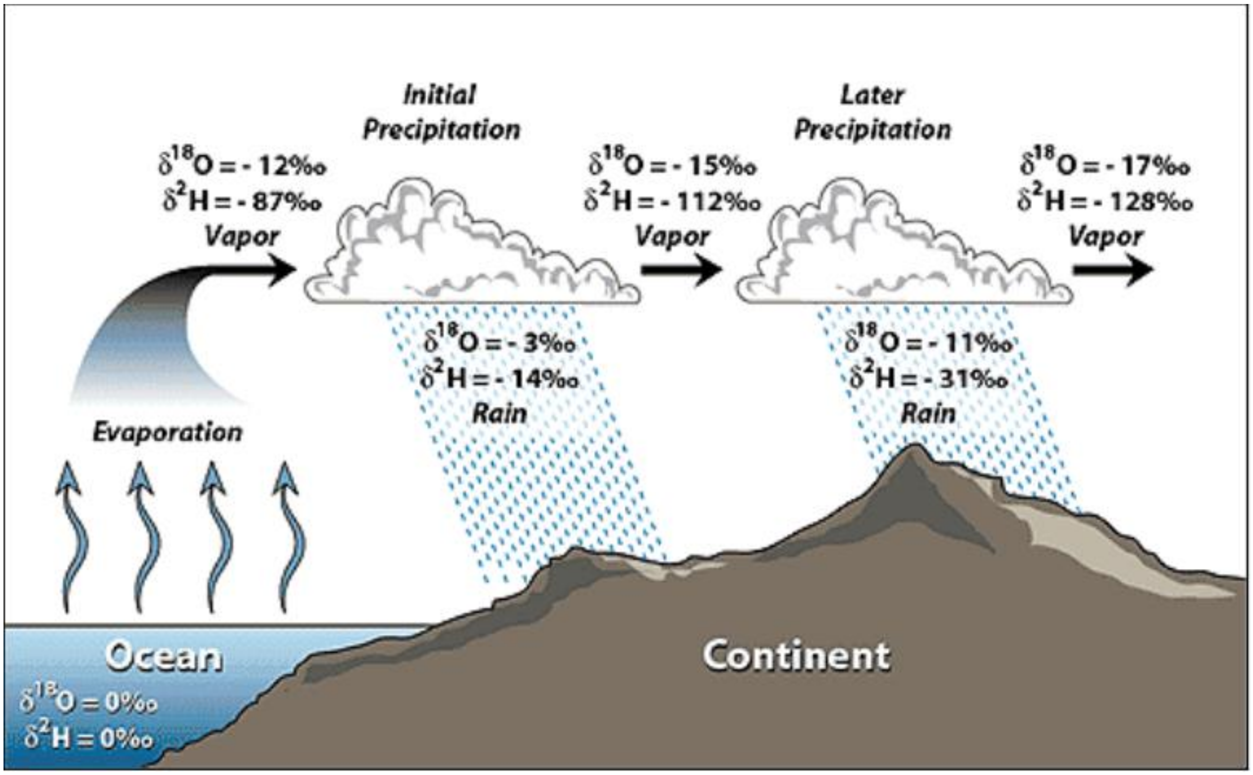


Figure 9. Preferential rainout of heavier isotopes (Sahara, 2005).

Stable isotopes of hydrogen (δD) and oxygen (δ18O) are used as a natural integrator of water cycling processes in a given ecosystem (Guatam, 2018). Surface waters such as streams and lakes are highly variable due to their exposure to precipitation and evaporation. Groundwater generally, remains at a constant stable isotope composition due to a lack of exposure to evaporation and precipitation. Generally, streams and neighboring, stored groundwater have distinct isotopic compositions. However, when groundwater and surface water compositions are similar it is perceived to be a potential mixing event.

Isotopically, the precipitation within a specific region and climate fall along what is called a Local Meteoric Water Line (LMWL) on a $\delta^{18}O$- δD plot. LMWLs are determined by the isotopic composition of all the precipitation within a specified area. LMWLs established across the world contribute to greater average called the Global Meteoric Water Line (GMWL), the line that describes the trend for all of the precipitation in the world (Figure 10).

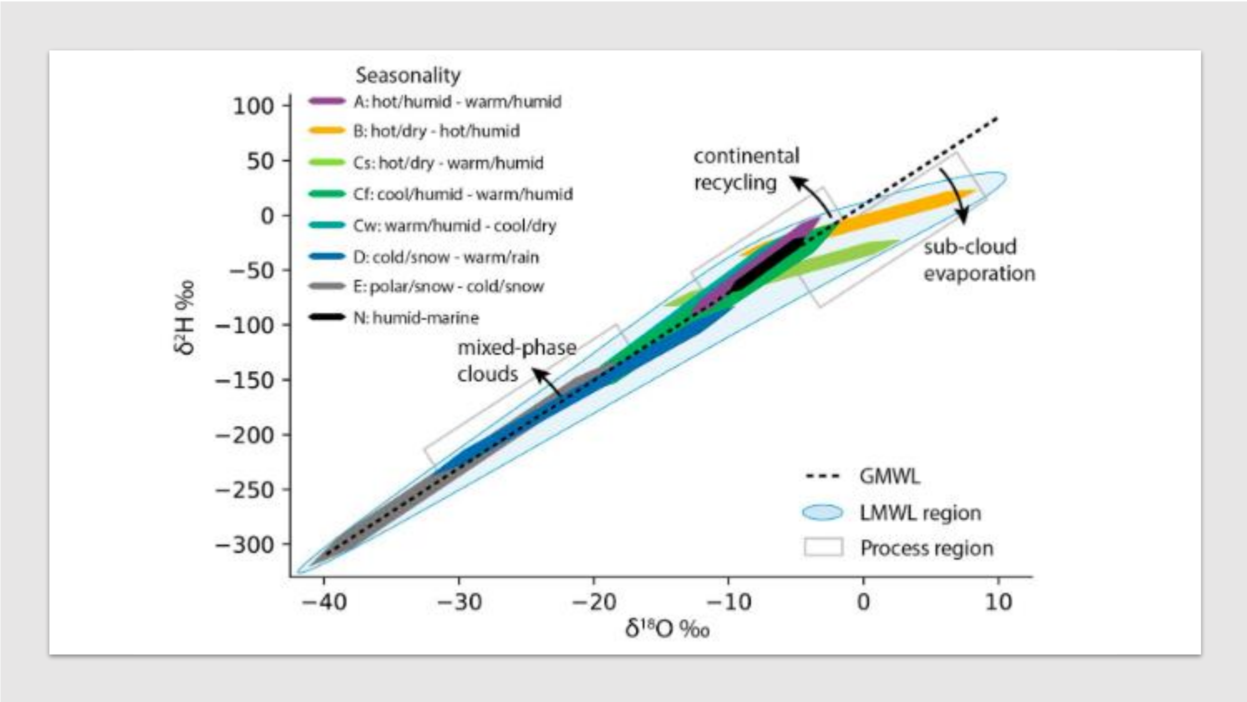


Figure 10. Global meteoric water line with various LMWL regions included for context. (Putman et al., 2019).

In the case of TVFF, stream water from the main stem Teanaway River receives input from three tributaries north and west of the property from the North Fork Teanaway River, Middle Fork Teanaway River, and West Fork Teanaway River (Figure 5). This indicates an expected heavier isotope (less negative) composition for the river as compared to the groundwater that is derived from precipitation from a closer, more easterly source. The more easterly source is further from the point of origin of the precipitation and so the groundwater is anticipated to generally have a lighter isotope (more negative) composition. Isotopes are also useful for determining mixing ratios of two isotopically distinct waters (Christophersen and Hooper, 1992). Figure 11 demonstrates a mixing event between two end members.

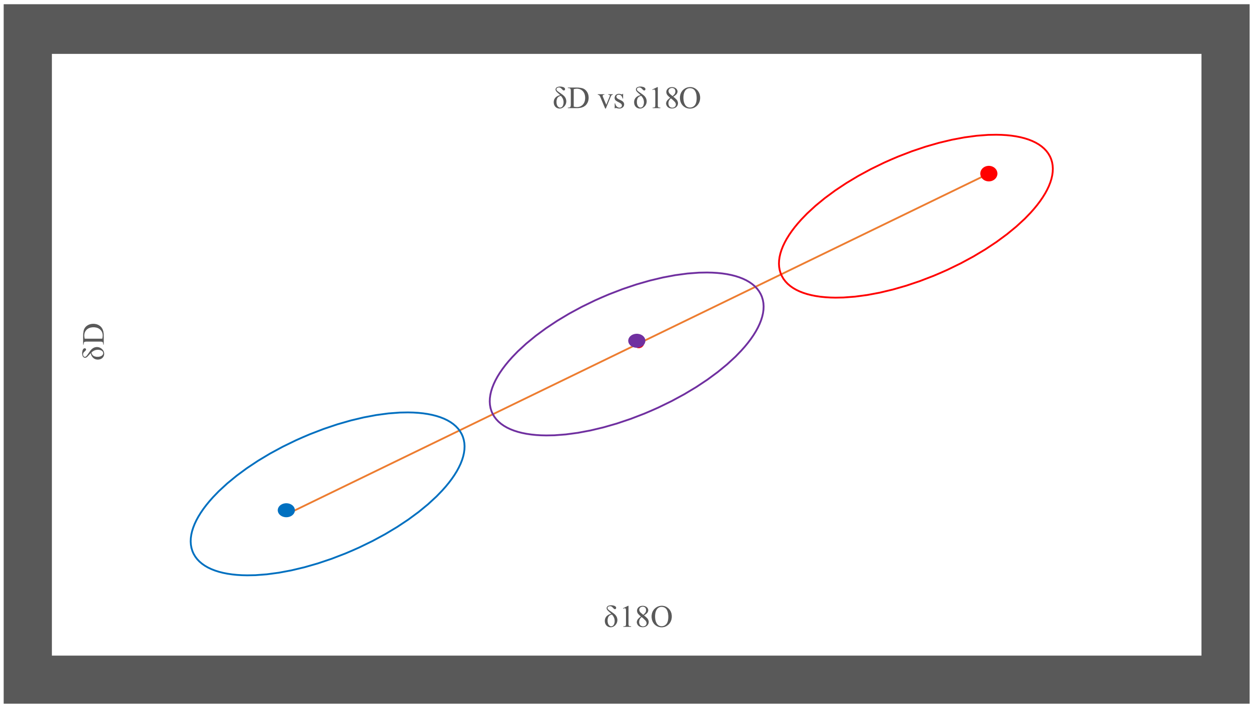


Figure 11. Two end members (red and blue) falling on a line with a value that signifies mixing (purple) has occurred.

A mixing event can be identified in what is based on the idea that there is 'pre-event' water, and 'event water' (Klaus et al., 2013). For example, in this study, water can be identified as water that is travelling downstream though the river, and water that has been in situ within the groundwater aquifers in TVFF. If the isotopic composition of these end members can be determined, then the mixing ratios can be calculated for any mixed sample.

Surface-water/Groundwater Interaction in the Alluvial Aquifer

As discussed previously, one of the goals of the YRBIP is to increase shallow aquifer recharge in strategic locations such as in floodplains of tributaries like the Teanaway River. One way of accomplishing this goal is to increase interaction between groundwater and surface water. The constraints on groundwater and surface water interaction include seasonal and long-term air temperatures, depth to bedrock, and preferential groundwater flow paths (Briggs, 2016). Groundwater entering streams reduces stream temperatures and provides higher flow later into the summer when water becomes scarce. Lower stream temperatures also provide better quality habitat for fish species seeking breeding grounds later in the summer (Johnson, 2017).

Streams are generally in a state of losing or gaining, but stream water is omni-present within adjacent alluvial aquifers. Because the porosity and permeability of the unconfined alluvial aquifer is high, stream water is either flowing into the aquifer, and/or mixing with groundwater from upgradient in the basin. There are three distinct periods of seasonal groundwater patterns: recharge, groundwater recession, and baseflow. Recharge in the Teanaway River basin is dictated by snow melt, which generally initiates as soon as air temperatures begin to rise above freezing. Groundwater recession takes place in the spring to early summer when the groundwater elevations begin to recede towards their lowest levels. It is similar to baseflow recession in streams, but can occur over a distinctly different period. Baseflow conditions take place in the mid-summer through early fall. At this time, groundwater levels are at their lowest levels and groundwater inputs sustain streamflow; streams are generally gaining at this time.

Questions Addressed

This study will answer a few questions that are integral to understanding the nature of the alluvial aquifer at the TVFF site and its potential use for groundwater storage and habitat restoration.

1. How does the elevation and direction of flow of the water table change seasonally? How long does the water table remain at high levels after spring recharge for TVFF?
2. How do thick-clay sequences impact groundwater flow and storage potential?
3. What is the primary source of water for the shallow aquifer in TVFF, and how does the stream interact with the surrounding groundwater? How far does river water infiltrate into the alluvial aquifer and what are typical travel times?
4. Can the cottonwood grove on the south side of the property, where trees have been dying over the last decade, be restored?

Unnatural changes to the Teanaway River watershed have caused several reclamation partners to begin funding projects within the basin in order to solve the issues of future water scarcity, increasing groundwater recharge, and increased interactivity between streams and their groundwater basins. This study uses two general methods to address the questions above. Comparison of stable isotope compositions of surface water and groundwater allow us to understand how surface water is entering the groundwater systems, and vice versa. Using groundwater level monitoring techniques, we can see the seasonal changes in groundwater storage and flow and determine how much water is available within the unconfined aquifer and its future potential for groundwater storage.

CHAPTER II

METHODS

Sampling sites

All samples were collected on the TVFF property with the exception to river samples collected downstream of the property on Red Bridge Rd. (RB). The coordinates and elevations of the wells are shown in Table 1. RB was used primarily for access during times of heavy snow accumulation, but later in the project became a fixture of comparison for river samples. Soil/snowmelt sampling locations were chosen for the contrast of barren soil to soil within the floodplain. Figure 12 shows all snow/snowmelt sampling locations and the location of the wells. Water sampled from the creek on the west side of the property was only collected while the stream was flowing. Stillwater was not collected due to evaporation effects on isotopic composition.

Table 1. Well locations for all wells in TVFF. Well stratigraphy determined depth to bedrock using well cuttings.

Well #	Latitude	Longitude	Depth to Bottom of Well (ft)	Depth to Bedrock (ft)
Well 1	47.2392	-120.821	19.2	18.0
Well 2	47.2392	-120.822	22.8	>22.8
Well 3	47.2387	-120.823	19.9	19
Well 4	47.2382	-120.825	14.8	15
Well 5	47.2374	-120.827	13.6	13
Well 6	47.2366	-120.826	13.4	13
Well 7	47.2373	-120.828	12.2	12
Well 8	47.2369	-120.829	10.7	10.5
Well 9	47.2379	-120.831	10.1	10
Well 10	47.2388	-120.831	12.8	12.5
Teanaway River	47.2363	-120.830	-	-
Ring Well	47.2361	-120.825	>6.5	~12

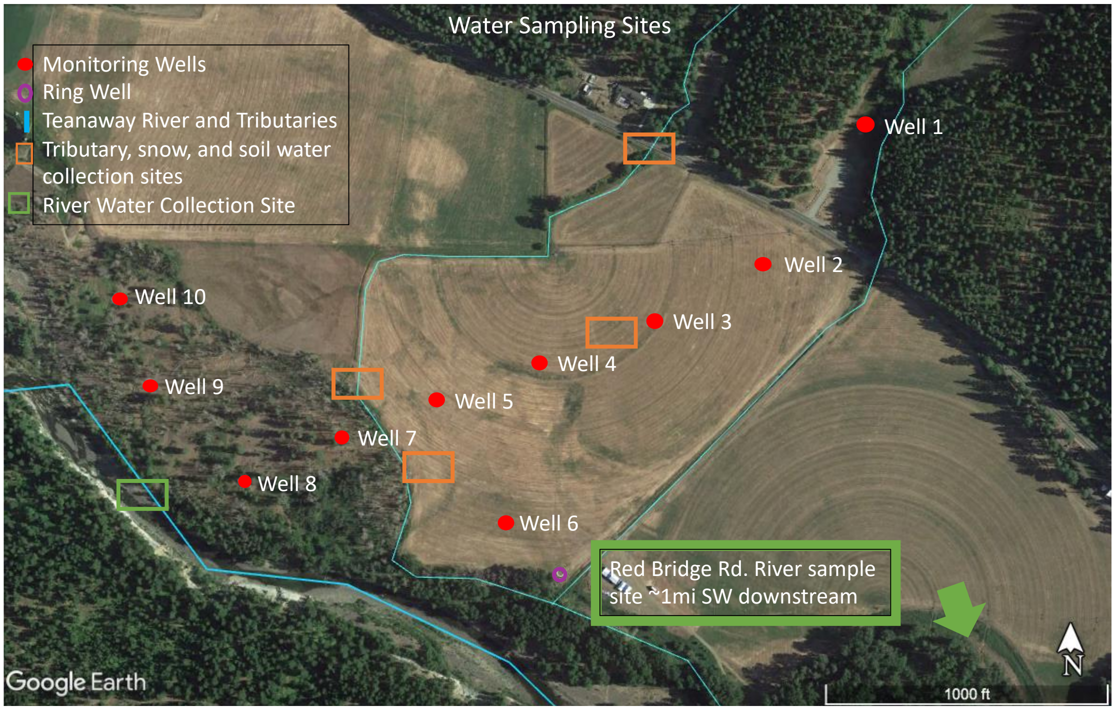


Figure 12. TVFF water sampling sites.

Two new piezometers were installed at the Indian Creek site and were equipped with HOBOware pressure transducers. More information on piezometer installation in Appendix A.

Pressure Transducer Measurements

Each of the ten wells in TVFF are equipped with HOBOware pressure transducers (U20-001-01). An additional equivalent transducer was installed at the top of well 1 to collect barometric data. The pressure transducers were set to take a measurement of pressure and temperature every fifteen minutes. The data from these pressure transducers were downloaded once every 3-6 weeks from October 2019 until February 2021. The transducers were removed from the wells and connected to a shuttle to transfer the data from the transducer to the computer software. Once the data is extracted from all the transducers, the barometric data was used to compensate for changes in the overlying air pressure in the wells. After all data was collected for each well in TVFF and compensated using the barometric pressure, the data was then transferred to Microsoft Excel in order to organize, and to reduce the data to daily averages.

A pressure transducer was installed with a stream gage in the Teanaway River west-southwest of well 8 in August, 2019 (Teanaway river collection site on Figure 12). Readings from this gage were downloaded through December 2019 and then the transducer was lost in the high flows of spring 2020. This data was compared to discharge data from the Department of Ecology gaging site on Red Bridge Road (figure 12) and the following equations were used to calculate TVFF river elevations from the Red Bridge discharges:

For discharge < 100 cfs: $E = -1.13*10^{-5}*D2 + 3.45*10^{-3}*D + 636.3$

For discharge > 100 cfs: $E = 1.08*10^{-2}*D + 636.4$

where E is the elevation of the river in meters at the TVFF gage site and D is the discharge at the Red Bridge station.

Manual Water Level Monitoring

At the time of each pressure transducer download, manual water level measurements were made in order to reference a water level at the time the pressure transducer is removed from the well and verify that the calculated water levels were correct. If the manual water level measurement matches the water level determined by the pressure transducer at the time of removal, then the data is properly referenced. This is a crucial component to ensuring the pressure transducer data set is not 'drifting', or slowly changing due to error within the device. Manual measurements occurred more frequently than data downloads because the water in each of the wells was sampled for stable isotope analysis on separate occasions.

Table 2. Manual water depth measurements (in meters) from top of well casing.

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10	Ring Well
10/31/2019	3.61	Dry	5.36	3.40	2.29	2.19	2.15	1.91	2.27	2.99	2.94
12/3/2019	3.69	Dry	5.35	3.65	2.58	2.30	2.39	2.39	2.53	3.26	3.05
1/24/2020	3.81	5.63	3.88	3.23							
2/5/2020	2.93	3.58	1.61	1.62	1.24	1.61	1.50	1.79	2.14	2.20	1.89
3/18/2020	2.78	4.54	2.61	1.92	1.36	1.66	1.66	1.89	2.41	2.66	1.97
4/23/2020	3.04	5.90	3.88	2.57	1.73	1.76	1.83	1.96	2.44	2.67	2.01
5/7/2020	3.11	6.15	4.25	2.97	2.08	2.04	2.19	2.24	2.74	3.03	2.28
6/1/2020	3.25	6.44	4.75	3.52	2.41	2.25	2.44	2.43	2.91	3.24	2.44
6/28/2020	3.44	6.77	5.21	4.01	2.88	2.69	2.87	2.81	3.33	3.79	2.85
7/28/2020	3.55	7.37	5.68	4.69	3.74	3.20	3.66	3.47	4.08	4.69	3.27
9/1/2020	3.98	Dry	6.35	5.03	3.65	3.24	3.50	3.33	3.78		3.37
11/2/2020	4.23	Dry	5.80	4.06	2.88	2.72	2.84	2.78	3.24	3.68	2.88
2/2/2021	3.09	4.66	2.95	2.77	2.06	2.19	2.21	3.24	2.69	3.06	2.44

Water Sampling

A total of 100 groundwater, river water, and floodplain water (including snow and soil water) samples were collected from December 3, 2019 to February 2, 2020 during this study. An additional 99 samples were collected prior to this study between November 14, 2018 and October 3, 2019 and are included in the dataset. Sampling dates and related notes are presented in Table 3. Well water samples were collected in 30 ml bottles from each well during every visit. After the pressure transducers were removed and water levels were manually measured, a plastic bailer was used to remove water from the wells. Soil water samples were collected using soil lysimeters. Lysimeters were emplaced 0.5 m into the soil, the surrounding soil was compacted to ensure no water seeped around the edges. Air was removed from the lysimeter using a pump. The lysimeters were removed from the ground during the following sampling date. Additionally, the Teanaway River, John Creek, and Indian Creek were also sampled for stable isotopes. Samples were also taken from the Teanaway River at Red Bridge Rd. stream gage location, ~1 river mile downstream of TVFF for comparison. Lastly, snowmelt was also collected from TVFF in order to assess a broader range of inputs. Water sample bottles were labeled and stored in a lab refrigerator until analysis took place.

Table 3. Water sampling dates and field notes.

Date	Pressure Transducer Download	Water Sampled	Dry Wells	Field Notes
10/31/2019	Yes	Yes	Well 2	
12/3/2019	No	Yes		
1/24/2020	Yes	Yes		Snow pack too dense to sample beyond well 4
2/5/2020	Yes	Yes		New logger placed in well 4
2/26/2020	No	Yes		Slug tests performed on wells 1-2, 5
3/18/2020	Yes	Yes		Well 4 logger working properly. Snow melted up to well 6
4/23/2020	No	Yes		River gage pressure transducer housing was bent but still present
5/7/2020	Yes	Yes		River gage pressure transducer was destroyed at this point
6/1/2020	No	Yes		Hornets nest in well 10 removed
6/28/2020	Yes	Yes		All loggers removed due to deteriation on the crimps
7/28/2020	No	Yes		Fishing line added to each logger for additional support
9/1/2020	Yes	Yes	Well 2	Well 4 water sample high in sediment. Well 10 covered in hornets: no measurements made
11/2/2020	Yes	Yes	Well 2	Crimps corroded once again
2/2/2021	Yes	Yes		Well 4 crimp completely broken, fishing line saved logger. Well 5 logger removed due to battery failure.

Stable Isotope Analysis

Water samples were analyzed for stable isotopes of hydrogen and oxygen, reported as δD and $\delta^{18}O$, respectively, using a Picarro water isotope analyzer that uses cavity ring-down spectrometry. Figure 13 is a diagram of the Picarro analyzer. The Picarro uses a syringe to extract the water sample and places the sample in a vaporization chamber where the liquid experiences a phase change to gas. The gas is loaded into the cavity chamber where a laser is used to refract off the gas molecules. The laser is then shut off, and the time of decay of the laser determines the isotopic composition of the gas molecules in the chamber. This process is repeated for every sample in the tray. The result of this process is an isotopic composition for both hydrogen and oxygen for each water sample. Each water sample analysis consists of 10-12 injections of the same water sample. The first three injections were discarded because of memory effects and the δD and $\delta^{18}O$ for the remaining injections were averaged. Water samples were filtered for sediment and debris that may have been in the well water, and then transferred to 1.5ml septum-cap vials. Runs were made in batches of 20-30 samples plus an additional ten internal laboratory standards. The internal laboratory standards have a known isotopic composition that is similar to the waters that were measured. Five of these standards were used to create calibration curves for the δD and δ18O values. The remaining five internal standards served as quality control checks. In addition, a replicate measurement was performed on every fifth unknown sample. These standards and replicates served to determine the measurement precision and accuracy. Uncertainties are 1 per mil for δD and 0.1 per for $\delta^{18}O$.

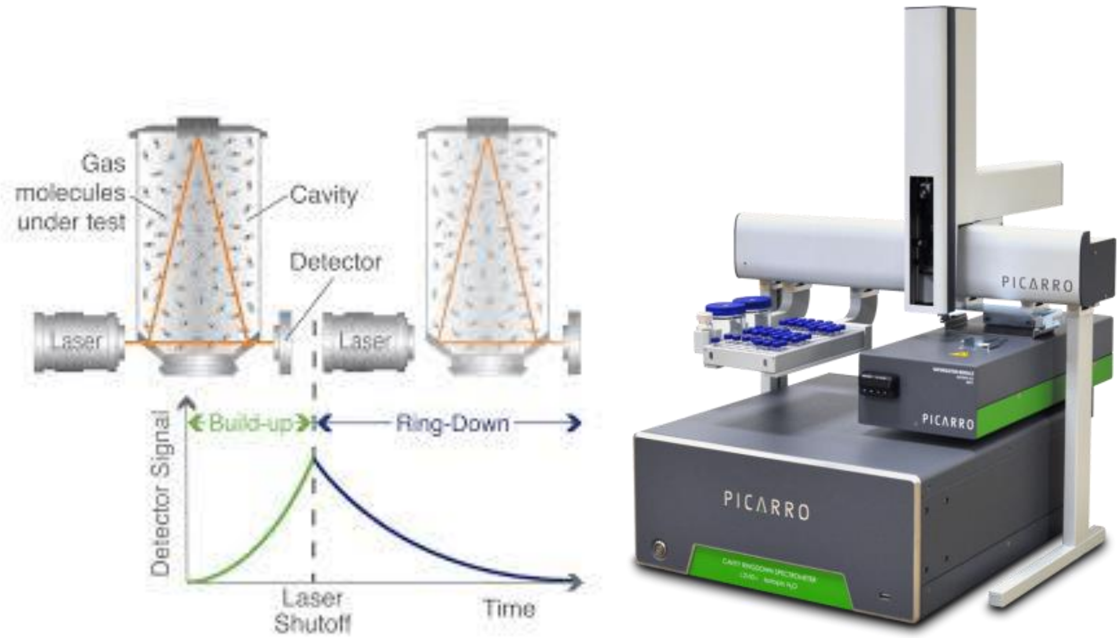


Figure 13. Cavity ring-down spectrometer schematic and Picarro L2140-I device (Picarro.com).

CHAPTER III

RESULTS

Groundwater Elevations

Figure 14 shows the groundwater elevation monitored by HOBOware pressure transducers for all wells. Figure 15 shows the same data with Well 1 excluded due to its disparity in elevation. The 15-minute interval data was used to calculate daily average groundwater elevation and temperature. The daily average elevation and temperature data are presented in Appendix B. A summary of the elevation data is provided in Table 3, including minimum, maximum, mean, and range for each well and for the Teanaway River at TVFF. 15-minute data are being stored on CWU Department of Geological Sciences server and will be made downloadable on a dedicated department web page. The groundwater elevation data show two groundwater recharge events during the study period, one in February of 2020 and a second in January of 2021. The beginning of the data series starts in a baseflow period followed by the first recharge event in 2020. The next baseflow period takes place from June 2020 to November 2020. Figures 14 and 15 can be found at the bottom of the section. All daily average groundwater elevation and temperature can be found in Appendix B.

Stable Isotope Analysis

All stable isotope values can be found in Tables 4 and 5, and in Figure 16. On Figure 16, the LMWL for Ellensburg is shown for comparison. A majority of the groundwater samples fall on or below that line, indicating a similarity between Teanaway River watershed water and precipitation collected in Ellensburg. Generally, Teanaway River samples have higher δD and $\delta^{18}O$ values than groundwater samples. Tables 4 and 5, and figure 16 can be found at the bottom of the section.

Water Temperatures

Water temperatures recorded by the HOBOware pressure transducers were also combined to obtain daily average temperatures. These daily averages are shown in Figure 18 and reported in Table B1.

Table 4. Statistical Measures of Distribution of Water Elevations Above Mean Sea Level for Wells and Teanaway River at TVFF.

	Min (m)	**Date (min)**	**Max (m)**	**Date (max)**	**Mean (m)**	**Range**
Well 1	648.21	10/13/2020	650.26	2/11/2020	649.14	2.05
Well 2	<635.99	8/8/2020	640.00	2/6/2020	637.14	4.01
Well 3	635.41	10/16/2020	640.08	2/6/2020	636.94	4.61
Well 4	634.66	8/31/2020	638.26	2/18/2020	636.16	3.6
Well 5	635.39	8/10/2020	638.18	2/9/2020	636.67	2.79
Well 6	634.74	8/11/2020	636.51	2/9/2020	635.52	1.77
Well 7	635.92	8/10/2020	638.14	2/9/2020	636.94	2.22
Well 8	636.34	8/10/2020	638.15	2/9/2020	637.22	1.81
Well 9	637.65	7/7/2020	639.32	1/17/2021	638.25	1.67
Well 10	638.24	7/8/2020	640.61	1/16/2021	639.13	2.37
TR	636.32	9/10/2020	637.24	2/8/2020	636.67	0.83

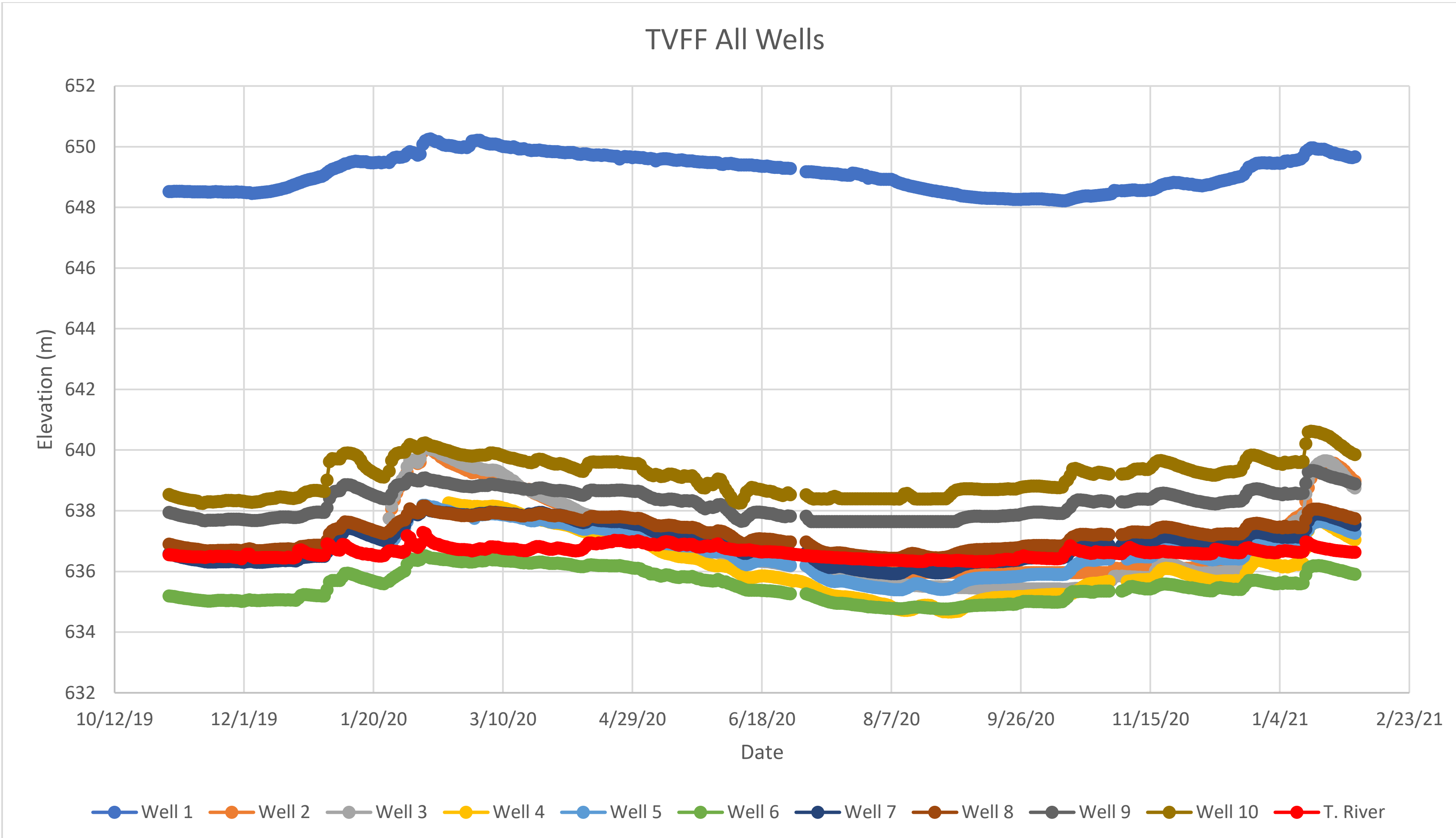


Figure 14. Groundwater elevation for all wells in TVFF.

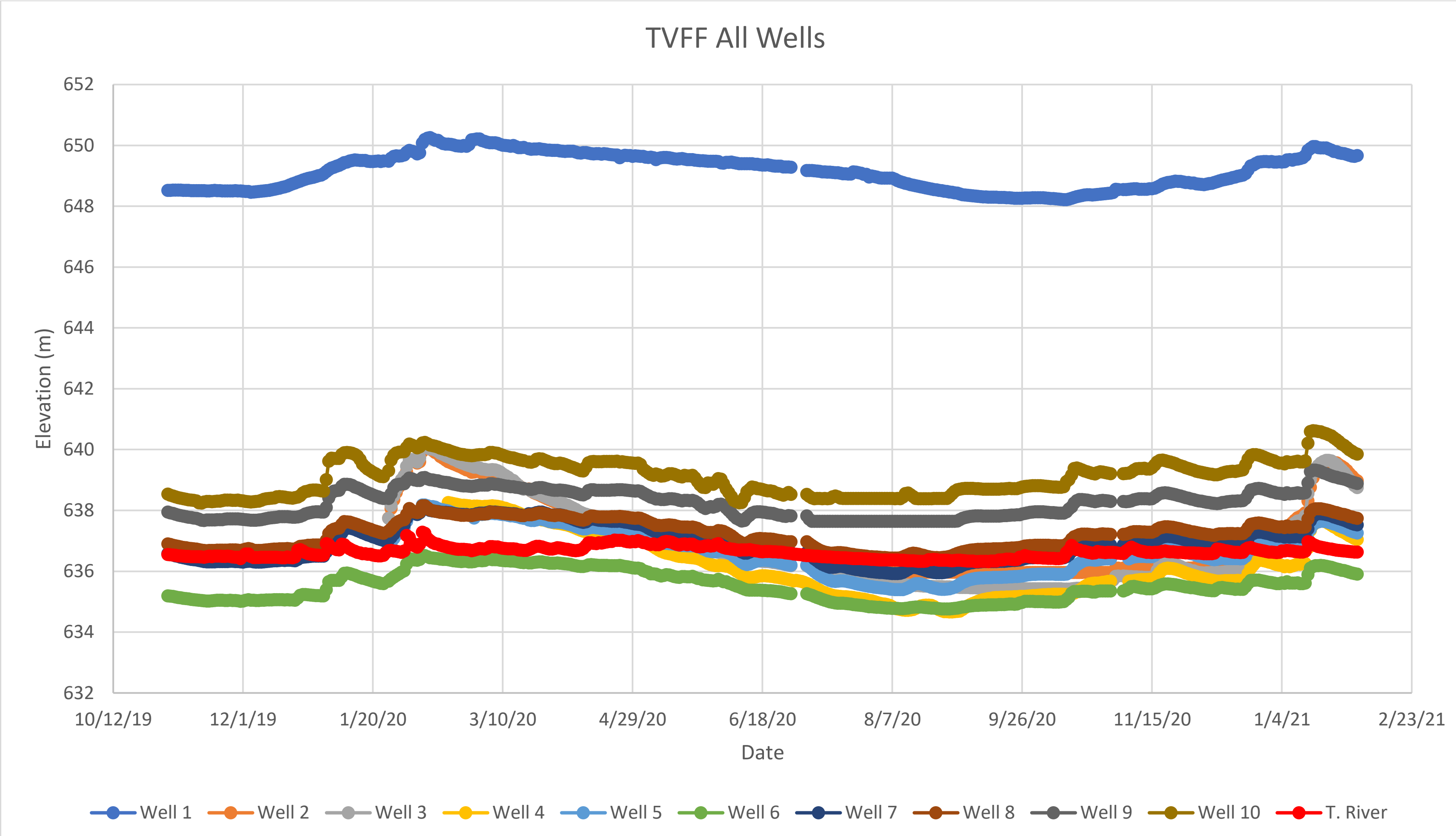


Figure 15. Groundwater elevation for all wells in TVFF.

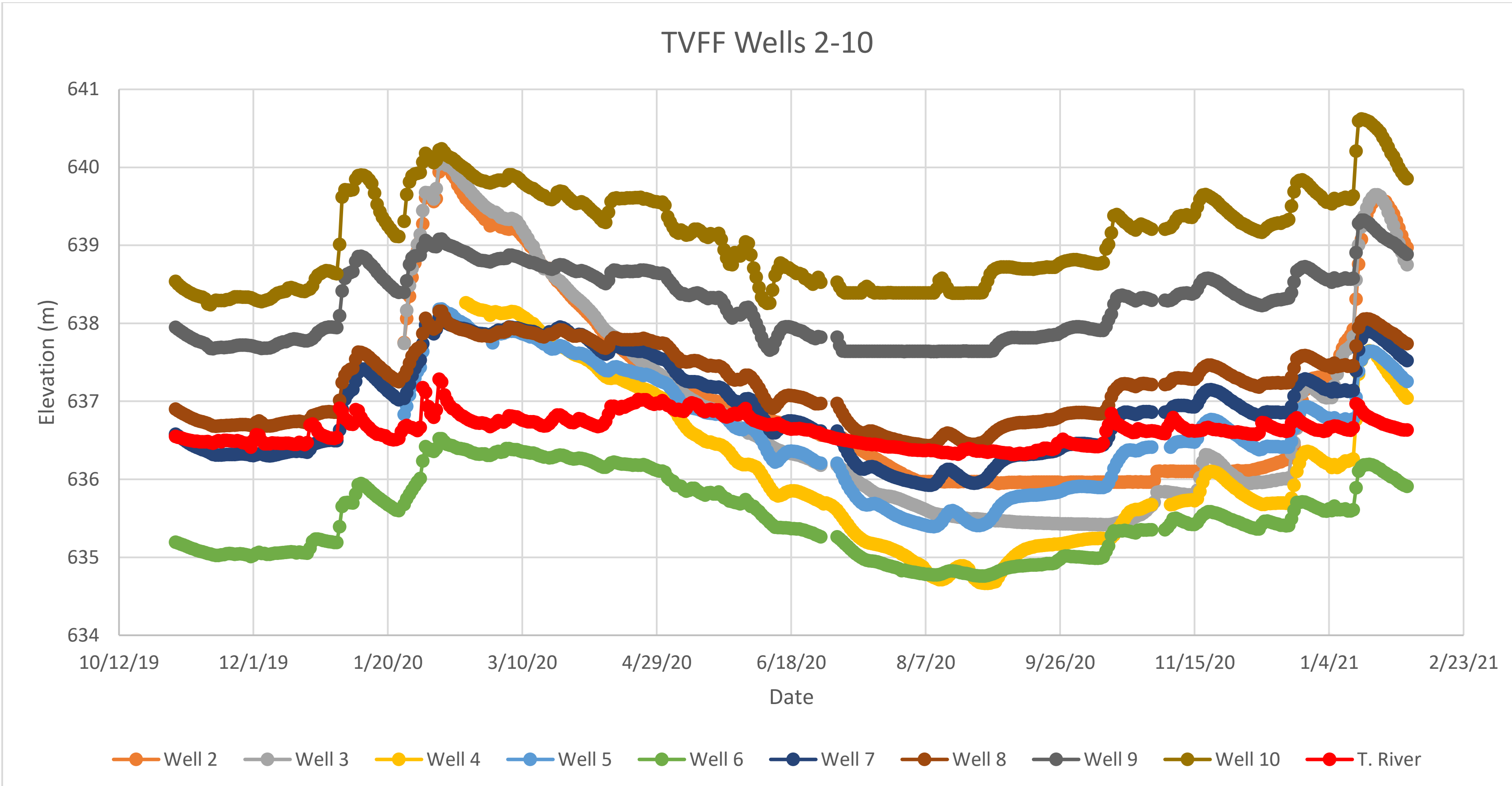


Figure 16. Groundwater elevation in wells 2-10 in TVFF.

Table 5. Stable isotope composition of δD/δH for all water samples collected.

δD												
DATE	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10	TR	Floodplain
11/14/18	-109.53		-105.82	-108.68	-108.42	-107.76	-106.07	-104.69	-102.58	-106.04	-107.08	
1/10/19	-107.27	-109.15	-107.51	-108.35	-107.98	-107.17	-106.32	-105.27	-106.50	-107.03	-106.69	
3/31/19	-106.47	-107.88	-108.51	-108.41	-107.72	-106.05						109.1
4/7/19	-107.50	-105.61	-109.09	-108.85	-108.57	-107.16	-108.71	-107.63	-107.70	-107.71	-108.97	
4/21/19	-107.87	-104.89	-109.62	-109.35	-108.85	-107.62	-108.69	-107.98	-107.63	-107.64	-110.34	
6/12/19	-106.65	-105.11	-108.90	-107.85	-107.55	-106.71	-106.77	-109.09	-107.29	-107.04	-108.87	
7/17/19	-106.59	-108.32	-108.50	-108.29	-106.95	-107.15	-106.58	-107.73			-108.47	
8/8/19	-107.27	-107.99	-108.82	-108.53	-107.06	-106.70	-106.50	-107.86			-107.27	
8/28/19	-106.88		-108.95	-108.37	-106.86	-106.14	-105.32	-107.20	-107.20	-105.33	-106.80	
10/3/19	-106.95		-108.59	-108.30	-105.71	-104.75	-104.70	-106.13	-105.47	-104.26	-105.82	
10/31/19	-107.16		-108.55	-107.40	-105.56	-104.72	-104.38	-100.18	-102.75	-103.84	-102.05	
12/3/19	-107.51		-108.32	-107.37	-104.87	-103.89	-103.62	-103.44	-103.73	-103.69	-103.27	
2/5/20	-109.12	-106.56	-105.60	-105.22	-103.08	-103.87	-103.32					
2/26/20	-107.30	-104.74	-104.89	-104.79	-103.39	-103.57	-103.52	-103.00	-102.85	-102.90	-103.46	
3/18/20	-107.86	-104.59	-105.14	-104.91	-103.74	-103.76	-103.60	-103.12	-103.21	-103.62		
5/7/20												-102.49
5/20/20	-106.98	-105.22	-105.16	-105.03	-103.76	-103.92	-102.99	-102.18	-102.16	-101.67		
6/1/20	-106.69	-105.62	-105.48	-104.74	-103.69	-103.90	-102.18	-100.79	-101.48	-100.99	-101.36	
8/26/20											-102.09	
9/1/20	-106.82		-106.40	-106.29	-103.30	-101.92	-100.78	-102.10	-101.99			
11/2/20	-107.26		-106.50	-104.27	-101.90	-100.91	-100.42	-99.70	-100.43		-98.81	
2/2/21	-107.23	-104.84	-102.58	-103.30	-101.30	-100.56		-100.63	-101.55	-101.55	-101.45	
3/18/21	-107.95	-105.72	-104.60	-104.31	-104.06	-103.19	-103.61	-102.38	-102.05	-102.11	-103.54	-105.31

Table 6. Stable isotope composition of $\delta^{18}O/\delta^{16}O$ for all water samples collected.

δ18O												
DATE	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10	TR	Floodplain
11/14/18	-14.55		-14.10	-14.47	-14.43	-14.35	-14.21	-14.15	-13.96	-14.30	-14.48	
1/10/19	-14.36	-14.71	-14.54	-14.44	-14.52	-14.42	-14.39	-14.29	-14.45	-14.47	-14.47	
3/31/19	-14.18	-14.34	-14.58	-14.50	-14.36	-14.19						-14.56
4/7/19	-14.37	-14.06	-14.70	-14.65	-14.64	-14.25	-14.66	-14.52	-14.68	-14.51	-14.75	
4/21/19	-14.39	-14.03	-14.77	-14.78	-14.71	-14.43	-14.67	-14.58	-14.50	-14.53	-15.04	
6/12/19	-14.28	-14.12	-14.73	-14.46	-14.54	-14.45	-14.47	-14.95	-14.38	-14.29	-14.87	
7/17/19	-14.07	-14.48	-14.50	-14.40	-14.24	-14.32	-14.17	-14.59			-14.69	
8/8/19	-14.25	-14.41	-14.54	-14.43	-14.22	-14.08	-14.16	-14.44			-14.41	
8/28/19	-14.20		-14.61	-14.44	-14.24	-14.05	-13.92	-14.43	-14.35	-13.93	-14.34	
10/3/19	-14.21		-14.58	-14.41	-13.96	-13.82	-13.85	-14.18	-14.05	-13.83	-14.36	
10/31/19	-14.27		-14.54	-14.24	-14.03	-13.96	-13.92	-13.63	-13.85	-13.96	-14.05	
12/3/19	-14.31		-14.50	-14.29	-14.08	-13.99	-13.99	-14.05	-14.00	-14.06	-14.24	
2/5/20	-14.51	-14.27	-14.23	-14.19	-13.94	-13.93	-14.05					
2/26/20	-14.31	-13.92	-14.16	-14.14	-13.95	-13.92	-14.03	-13.94	-13.90	-13.93	-14.08	
3/18/20	-14.41	-14.09	-14.32	-14.30	-14.15	-14.13	-14.17	-14.04	-14.08	-14.09		
5/7/20												-13.47
5/20/20	-14.25	-14.08	-14.24	-14.18	-14.03	-14.04	-13.96	-14.08	-14.13	-13.80		
6/1/20	-14.19	-14.15	-14.24	-14.11	-14.03	-14.04	-14.02	-13.87	-14.07	-13.66	-14.12	
8/26/20											-13.81	
9/1/20	-14.24		-14.37	-14.22	-13.85	-13.64	-13.44	-13.63	-13.72			
11/2/20	-14.17		-14.29	-13.87	-13.61	-13.52	-13.57	-13.55	-13.63	-13.66	-13.68	
2/2/21	-14.23	-13.94	-13.83	-13.84	-13.69	-13.60		-13.67	-13.81	-13.78	-13.96	
3/18/21	-14.46	-14.19	-14.29	-14.25	-14.21	-14.08	-14.21	-14.03	-13.98	-13.96	-14.33	

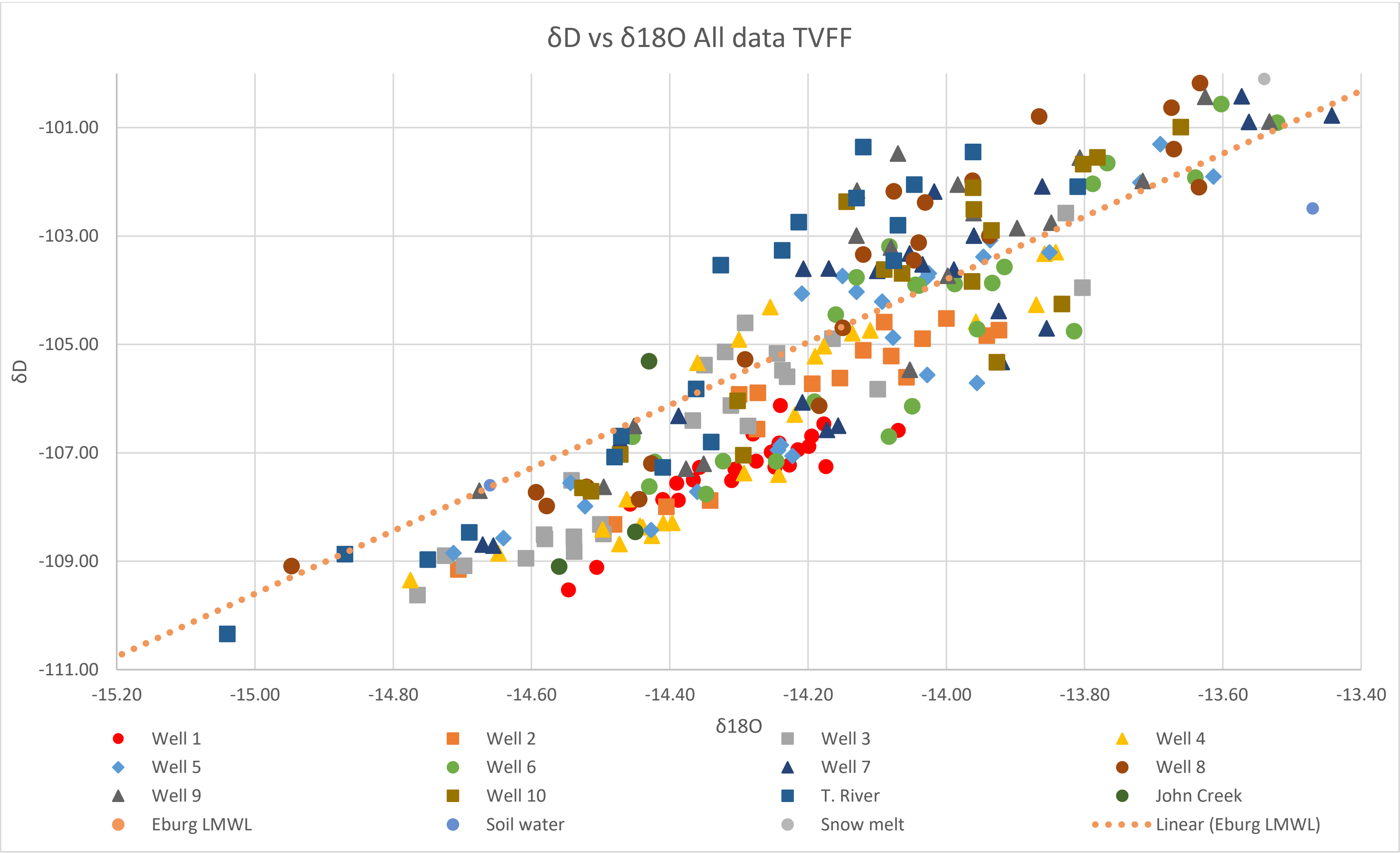


Figure 17. δD versus $\delta^{18}O$ plot for all water samples collected for TVFF.

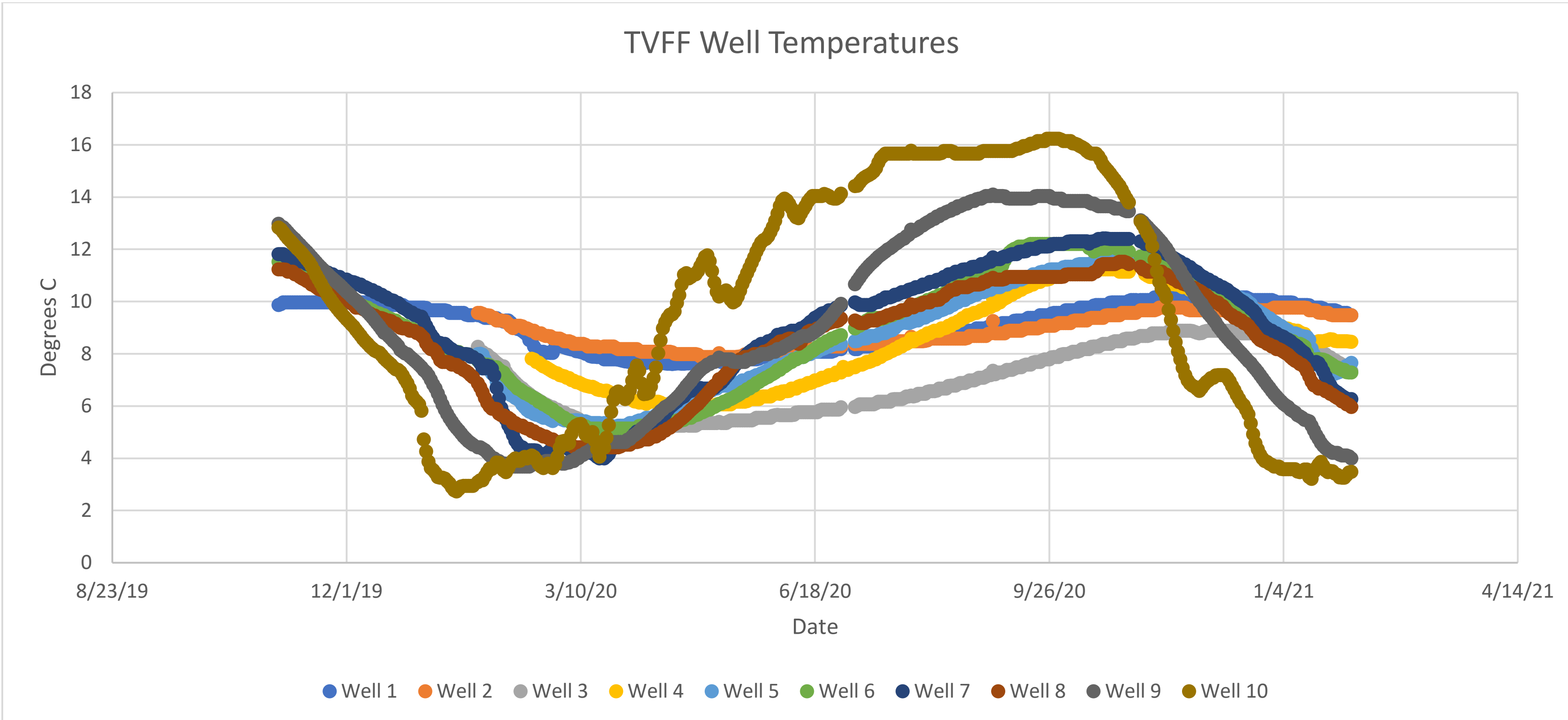


Figure 18. Daily average well temperature (Celsius) from pressure transducers.

CHAPTER IV

DISCUSSION

Groundwater has three distinct hydrologic periods. These periods include recharge, baseflow recession, and baseflow. Figure 19 shows groundwater elevation data for wells 2-10 with shading added to show when the daily minimum temperature was above freezing and when it was below freezing; Red Bridge data was adjusted to fit the stream gage at TVFF, as previously described in the methods section. All three hydrologic periods are shown in the 2019-2020 water year, recharge took place beginning at the end of December and peaking at the beginning of February. Winter 2019-2020 showed an abrupt shift from baseflow to recharge, whereas winter 2020-2021 had a more gradual rise in groundwater elevation followed by a rapid increase in elevation in January 2021. Groundwater recharge at TVFF takes place well before the peak of snowmelt and appears to be triggered by short warming spells in December through February. The groundwater recharge period is followed by groundwater recession, beginning in February and ending in June. This period begins well before streamflow starts to decline in May. Throughout this period groundwater in each of the wells decreases steadily in elevation. Specific precipitation events cause wells 4-10 to fluctuate but remain on a decreasing trend. Following groundwater recession, baseflow conditions exist from June until the beginning of October. During this period, the water levels in wells 4-10 fluctuate together and thus the shape and orientation of the groundwater table surface remains the same.

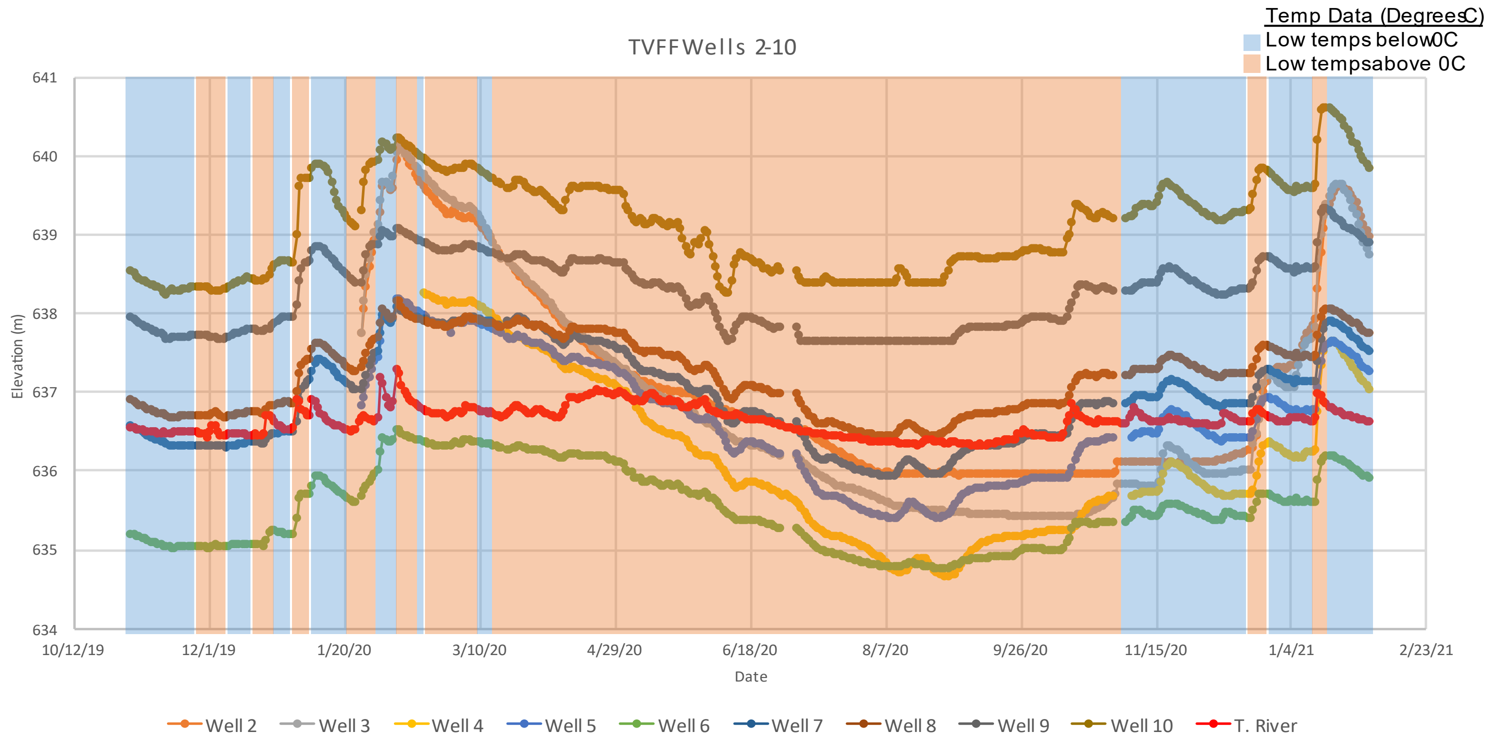


Figure 19. Groundwater elevation recorded by HOBOware pressure transducers from October 31, 2019 to February 2, 2021. Flat portions in Wells 2, 3, 9, and 10 data series' are dry periods in the wells. shaded regions showing (blue) days with low temperatures below zero degrees C, and (orange) low temperatures above zero degrees C.

Unconfined Aquifer Volume

Wells 4-10 have all been placed within the unconfined aquifer in TVFF. This aquifer is met with a barrier in the form of the confining clay layer in the upper watershed zone. To determine the volume of this unconfined aquifer, the surface area was determined by Google Earth for the shaded rectangle in Figure 19, 53.4 acres (22-hectares). In this section, the English units, acre-ft, are used for volumes because this is the standard used by water managers in the U.S. The total volume of the saturated aquifer was calculated assuming that it is a triangular wedge with volume V=1/2Ah, where A = Area, h = maximum height of aquifer (at well 4). Two heights of the aquifer were used to determine the volume of the aquifer at maximum (recharge) storage and minimum (summer) storage. 7m for maximum and 3m for minimum storage heights. The aquifer is primarily comprised of unconsolidated river deposits such as gravel, boulders, and sand (determined by the well borings), so the porosity of each of these sediment sizes was assumed to be between 0.20 and 0.35 (Fetter, 2001). The aquifer volume at high flow (recharge) is 112-196 acre-ft of water, and the aquifer volume at low flow (baseflow) is 48-84 acre-ft of water. The difference between these values, 112.1 acre/ft is the amount of water that is recharged to the aquifer each year and released during the groundwater recession period. For each acre, this is 2.1 acre/ft of water. Importantly, this storage is only available in the lower 2/3 of the floodplain closer in proximity to the river. The floodplain above that is dominated by clay, which can hold water, but cannot transmit water on a time-scale fast enough to contribute to seasonal storage, and thus is not included as part of the seasonal storage.

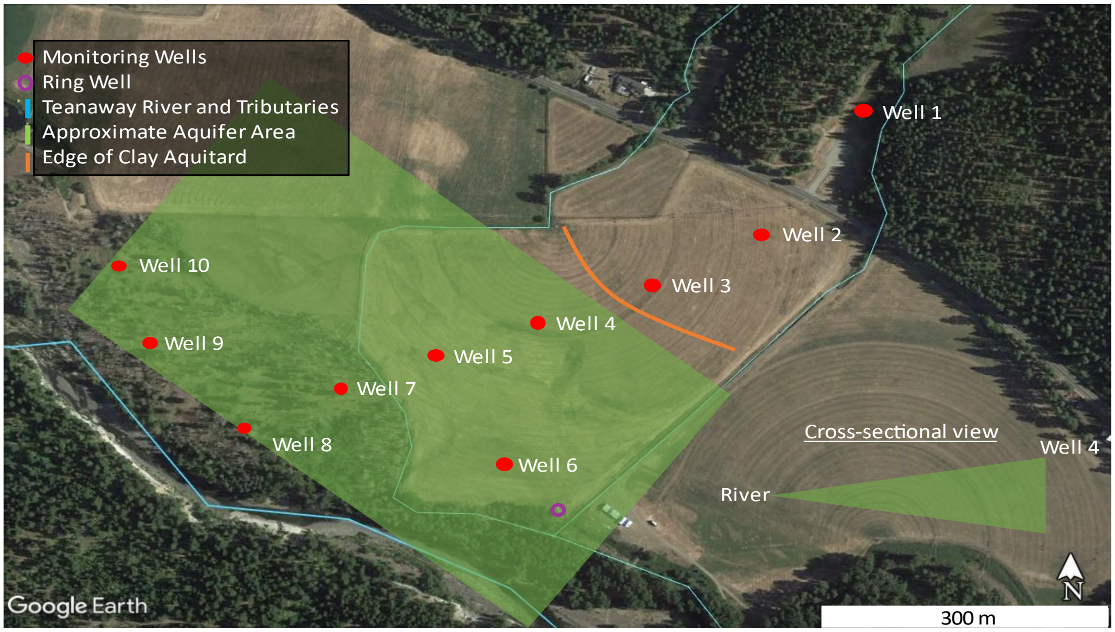


Figure 20. Rectangular area used to estimate unconfined aquifer volume (Google Earth Image). Volume determined by equation for volume of triangular prism.

Groundwater Recharge Events

To examine the response of the water level in the different wells to triggers such as recharge events, it is useful to compare their change in elevation from the time of the trigger. Figure 20 shows changes in groundwater elevation from the level on December 21, 2019. It indicates two distinct pulses of recharge for the winter of 2019-2020: One pulse after December 31, 2019, and one pulse that peaks on February 10, 2020.

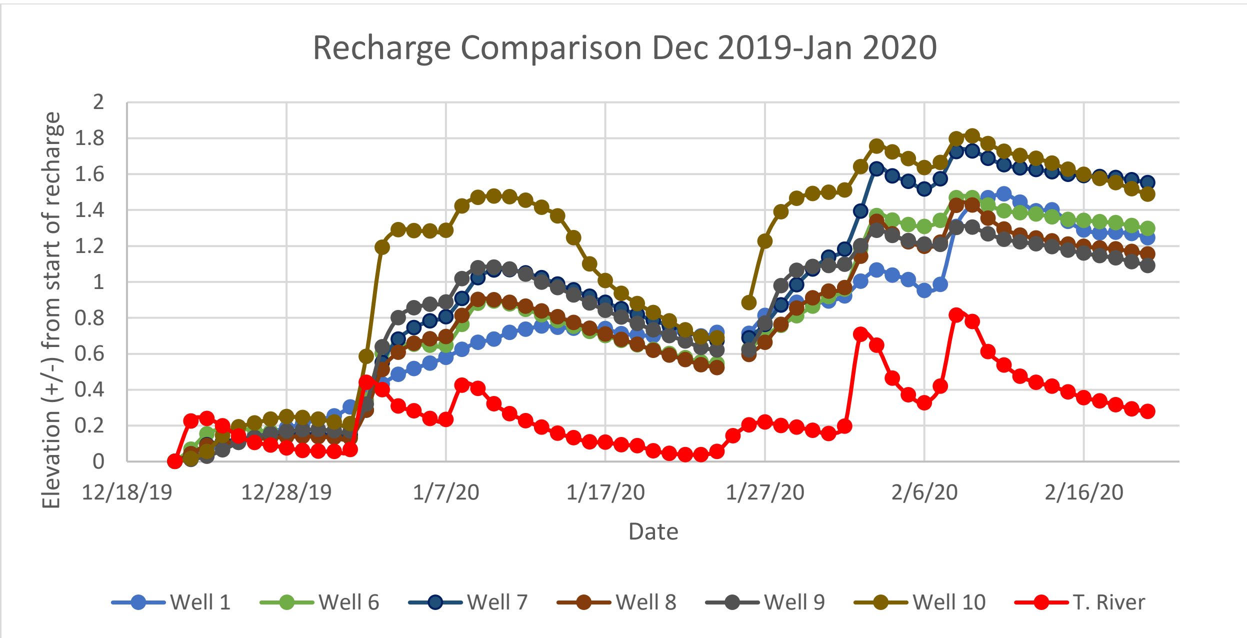


Figure 21. Groundwater elevation change for wells 1, and 6-10. Surface water elevation change for TVFF stream gage.

Wells 6-10 have patterns that reflect changes in the river, typically peaking one to two days after the river peak. Well 1, on the other hand, has the same broad pattern as the other wells, but does not have the same shorter-term fluctuations as the river. Well 1 also reaches its peak elevation on February 11, 2020 three days after the river reaches its peak. Well 10 shows the highest range in elevation of the wells reaching 1.8 meters of elevation change. Well 9 has the second highest change in elevation during the first pulse, but in the second pulse well 7 has the second highest change, suggesting that the sources of these water pulses are different. In the trough between the first and second pulse, the elevation of water in well 1 continues to steadily climb to its peak elevation, whereas the elevation decreases in all the other wells after the first pulse. Overall, this figure shows that well 10 is the most dynamic well, and that well 1 is the least influenced by the rivers and the upstream inputs that control groundwater levels in well 1. The different behavior of wells 1, 7 and 9 suggest that the first pulse is largely controlled by pressure from the Teanaway River whereas the second pulse has more influences from water pressure created by melt in the local hillslopes.

The second recharge event in the study period was during January 2021. Figure 21 shows the changes in water elevation after this event as well as high temperatures recorded in Cle Elum. Temperature controls the rate of snowmelt. High temperatures of 11.1ºC were recorded on January 15 and 17. Shortly after this warm spell, the river peaked, and the wells followed suit. Wells 2 and 3 have the highest range in elevation change. This is likely due to the fact that this water is in a narrow aquifer that is confined between the clay and the sandstone bedrock. The potentiometric surface of this aquifer can be raised with a relatively small amount of water given a change in hydraulic pressure due to snowmelt. Well 4 has a greater change in elevation during this recharge event than well 10, which had the greatest elevation change during the recharge in December 2019 – February 2020 (Figure 20). This is perhaps due to the greater inputs from the two tributaries that flow on either side of the property in 2021. Well 4 is not only receiving water from the Teanaway River, but it is also receiving significant input from the smaller streams.

Overall, there are three distinct hydraulic zones: Well 1, wells 2-3, and wells 4-10. Well 1 experiences the least amount of change during recharge. Wells 2-3, in the narrow aquifer confined between the clay and sandstone experience rapid change during recharge that peaks approximately 8 days after the river, and rapid decline during groundwater recession. Wells 4-10, in the unconfined alluvial aquifer, experience changes in water level that coincides more closely with the water elevation of the river, although there is a delay of up to 5 days in the peak elevation for the wells furthest from the river.

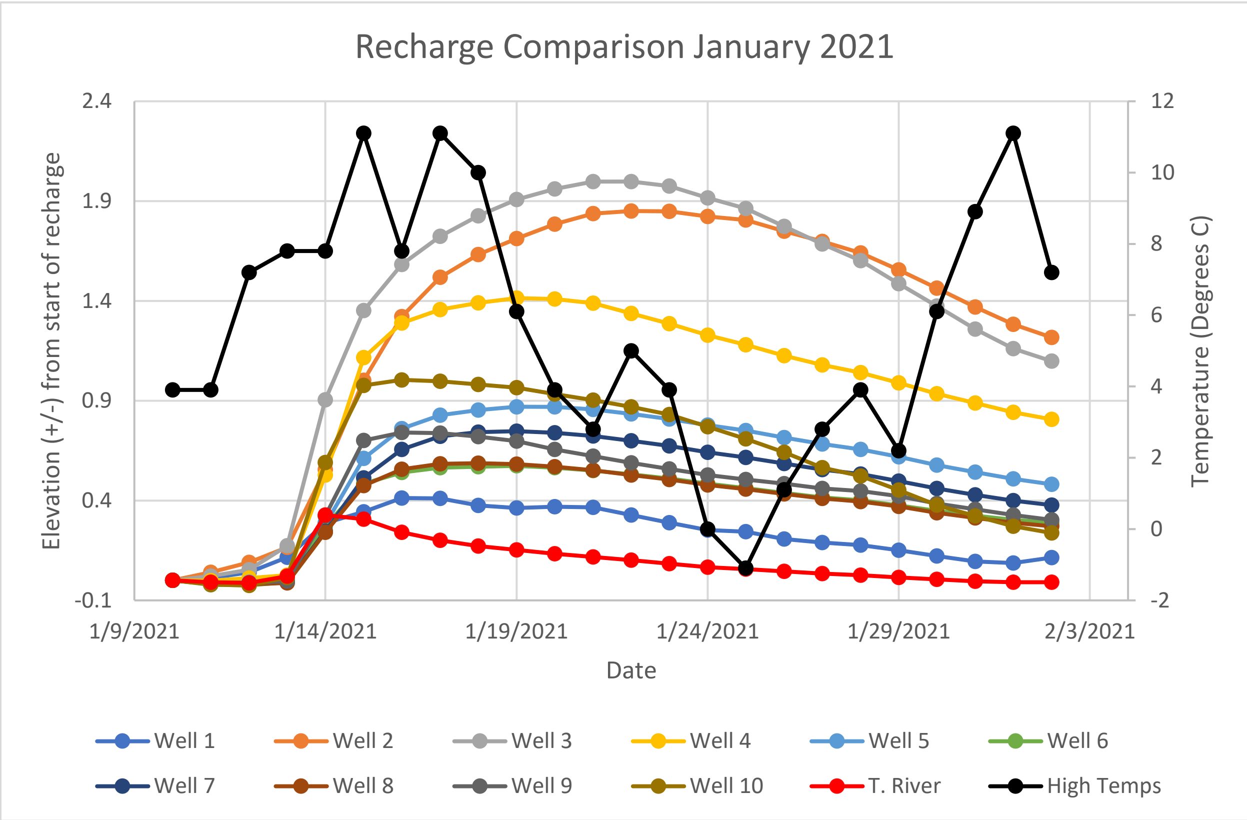


Figure 22. Groundwater elevation change for wells 1-10 and surface water elevation change for TVFF stream gage. High temperatures from Cle Elum weather station are included on the right Y-axis.

Influence of Pumping on Groundwater Elevations

During the groundwater recession of spring 2020, there are some distinct fluctuations, particularly in the well 10 elevations (Figure 18). Figure 23 compares groundwater elevation change in all wells and surface elevation of the Teanaway River from June 1, 2020 to June 20, 2020. In the summer months when the snowpack is depleted, groundwater within the Teanaway River Basin is supplied by baseflow. Figure 23 shows a steady decline in groundwater elevation from the beginning of June throughout the remainder of the month. Wells 1-3 form a linear decline, whereas the wells further down the floodplain, beyond the clay, have a downward excursion from this linear trend (trough). This water elevation trough is greatest in wells 10 and 9, which are closest to a series of ponds on the Northwest corner of the property, called Tom's ponds seen in Figure 22. The change in pressure appears to travel away from well 10 to well 4 over the course of about four days. Based on this behavior, we hypothesize that the drop in water elevation is likely due to pumping from Tom's ponds.

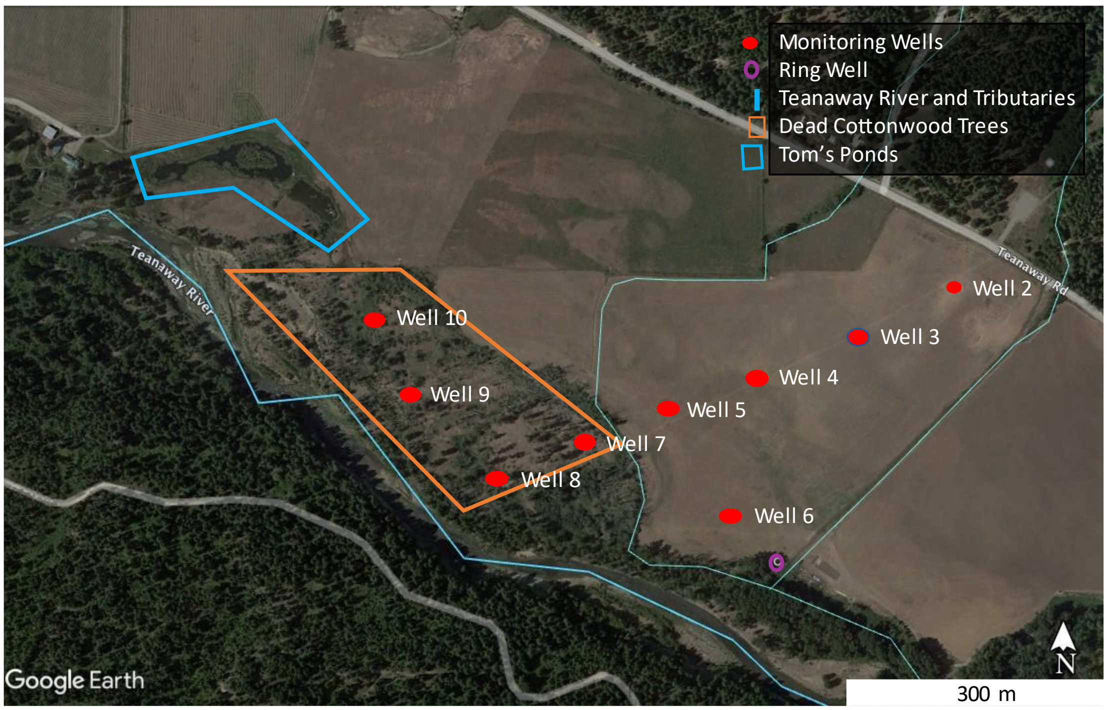


Figure 23. TVFF with Tom's ponds shown in blue.

In order to determine the pumping patterns from the ponds, I interviewed the upstream neighbor (Tom Conner, December 2021, personal communication). He pumps from the middle pond within a series (Figure 22) during the day and monitors the pond elevations as he pumps. He did not provide me with the exact pumping rate. If he notices the water levels of the ponds going down, then he will decrease the amount of water he pumps. The lowermost pond occasionally goes dry while he is irrigating his fields; however, the ponds higher in elevation do not go dry. Annually, he begins pumping from the ponds on May 1st, and he does three cuttings of alfalfa per year from the fields on his property per year. Pumping began in 1978. Originally, the ponds were pumped in conjunction with flood irrigation. A canal on the west side of the property was in place and used to flood irrigate the fields down gradient.

The example of a groundwater elevation "trough" shown in Figure 23 is likely due to a period of increased pumping and drawdown on Tom's ponds. The pumping severely reduces the groundwater level in well 10, which is directly downgradient of the ponds. This drawdown extends outward as far as well 4, approximately 500 m to the east, over the next 5 days.

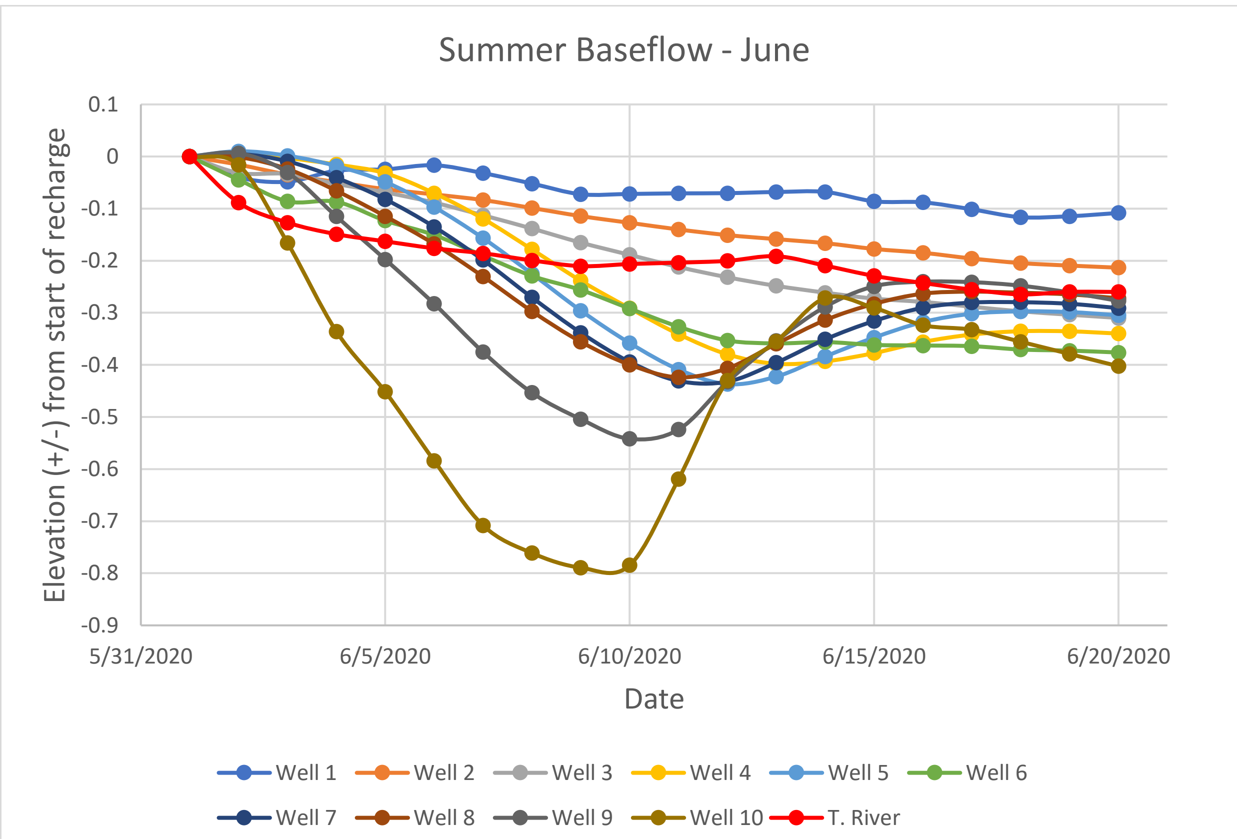
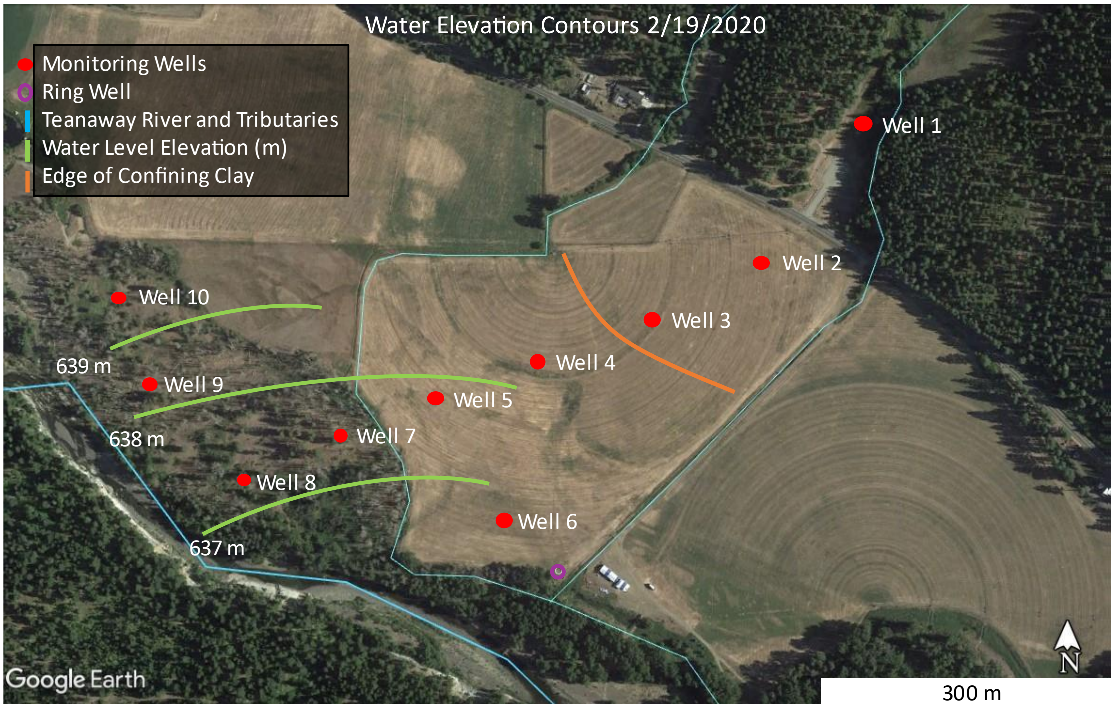
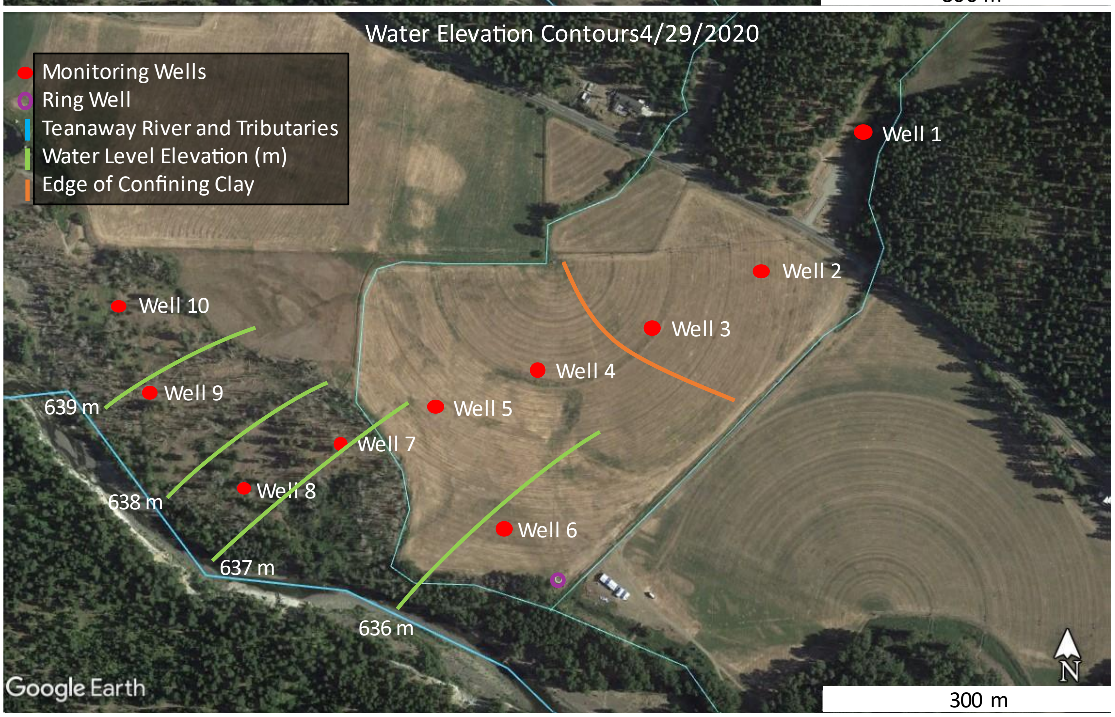


Figure 24. Groundwater elevation change in June. All wells set to zero for first point to show variability. This is a groundwater recession period.

Seasonal Changes in Groundwater Flow Patterns

As previously stated, there are three distinct hydrologic periods that govern groundwater elevations: baseflow, recharge, and groundwater recession. The height and orientation of the water table is distinctly different during these periods. Figure 24 (A-C) shows water table contour maps for three dates, one at the end of recharge, one two months after the peak of recharge, and one towards the end of the baseflow period. At the end of recharge in February (Fig. 24-A) the groundwater elevation contours form a downstream-pointing “V” with the river, indicating that the Teanaway River is gaining during this period and groundwater is flowing approximately from north to south. At this time the unconfined aquifer has received input from local snow melt and tributaries to the north of the Teanaway River, which have ponded on the northern side of the study area. During groundwater recession in April (Fig 24-B) the water table contours are closer to perpendicular, indicating a transition from recharge to baseflow. During baseflow in November (Fig 24-C) the water table contours are roughly perpendicular to the river. Overall, this reach of the Teanaway River is neither gaining nor losing during this period and groundwater is flowing from northwest towards the southeast. However, water flows into and out of the unconfined aquifer as the stream meanders at angles to this groundwater flow direction.


Water Elevation Contours 2/19/2020
Monitoring Wells
Ring Well
Teanaway River and Tributaries
Water Level Elevation (m)
Edge of Confining Clay
Well 1
Well 2
Well 3
Well 4
Well 5
Well 6
Well 7
Well 8
Well 9
Well 10
639 m
638 m
637 m
Google Earth
300 m
N


Water Elevation Contours4/29/2020
Monitoring Wells
Ring Well
Teanaway River and Tributaries
Water Level Elevation (m)
Edge of Confining Clay
Well 1
Well 2
Well 3
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Well 5
Well 6
Well 7
Well 8
Well 9
Well 10
639 m
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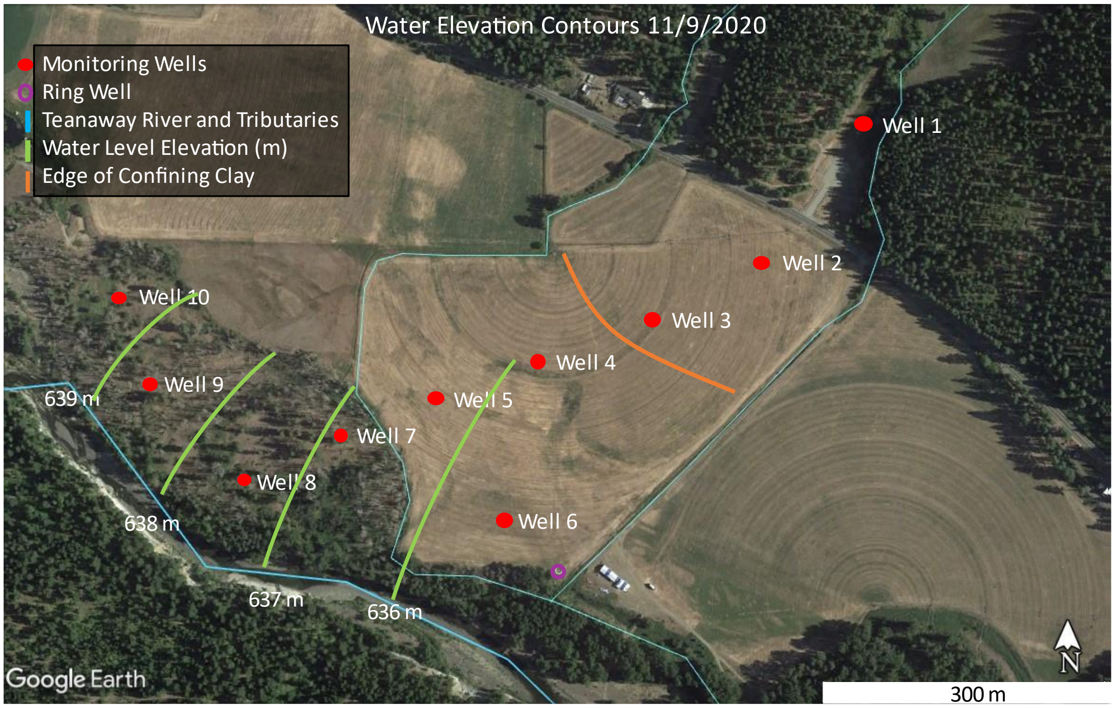


Figure 25. Groundwater elevation contours for February 2020 (A), April 2020 (B), November 2020 (C).

Evidence of River Water/Groundwater Interactions

Figure 25 is a δD-δ^{18}O plot of Teanaway River water samples and three groupings of wells: 1) wells 1-3 (blue), which are where the clay confining layer exists; 2) wells 4-6 (purple), which are located in a low area of the former hay field; and 3) wells 7-10 (red), located in the cottonwood forest. The groupings are combined with the river data in order to draw comparisons between the river and each group of wells. The Ellensburg LMWL was chosen as a reference instead of Cle Elum because the Cle Elum line fell far below the TVFF data.

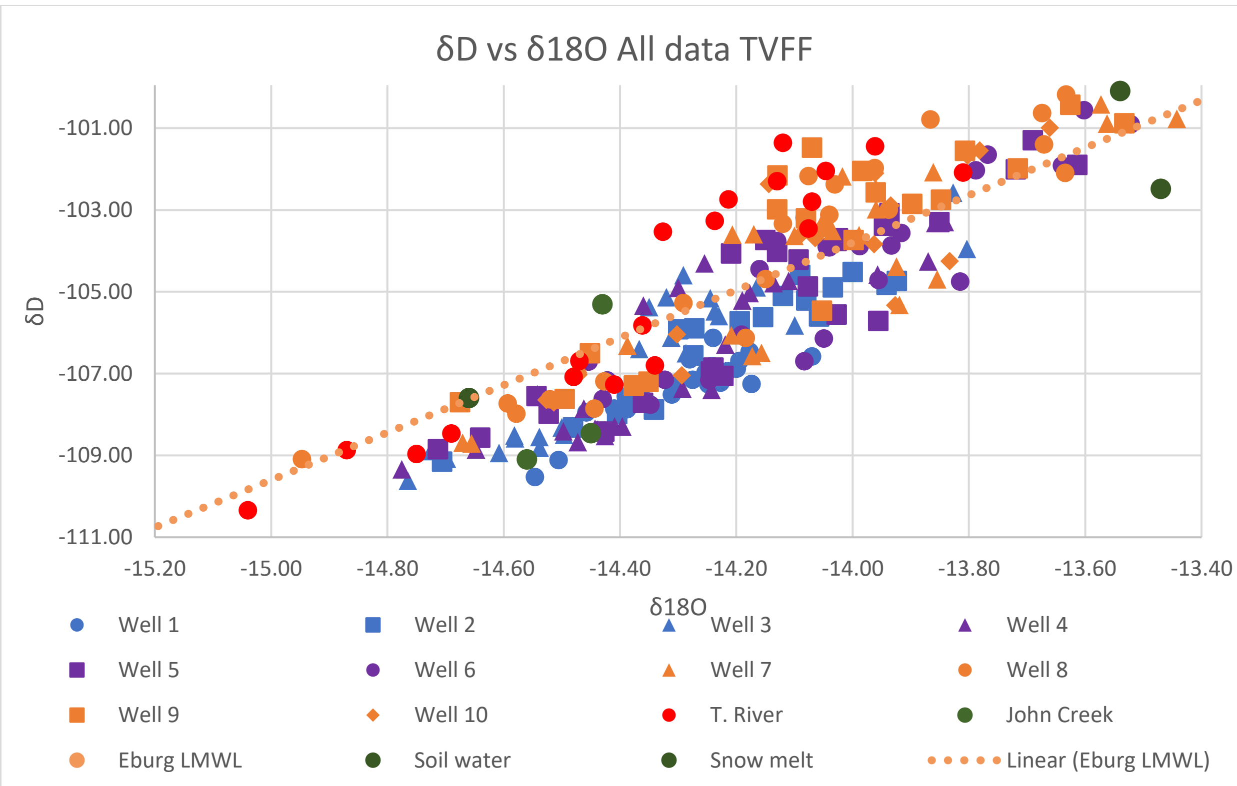
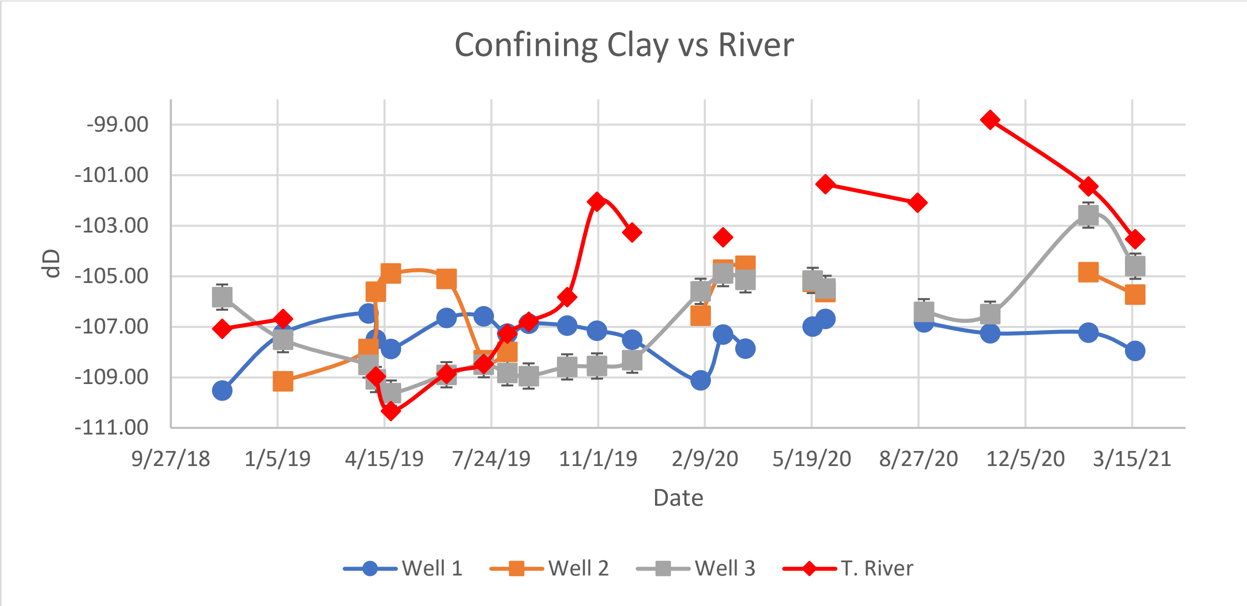


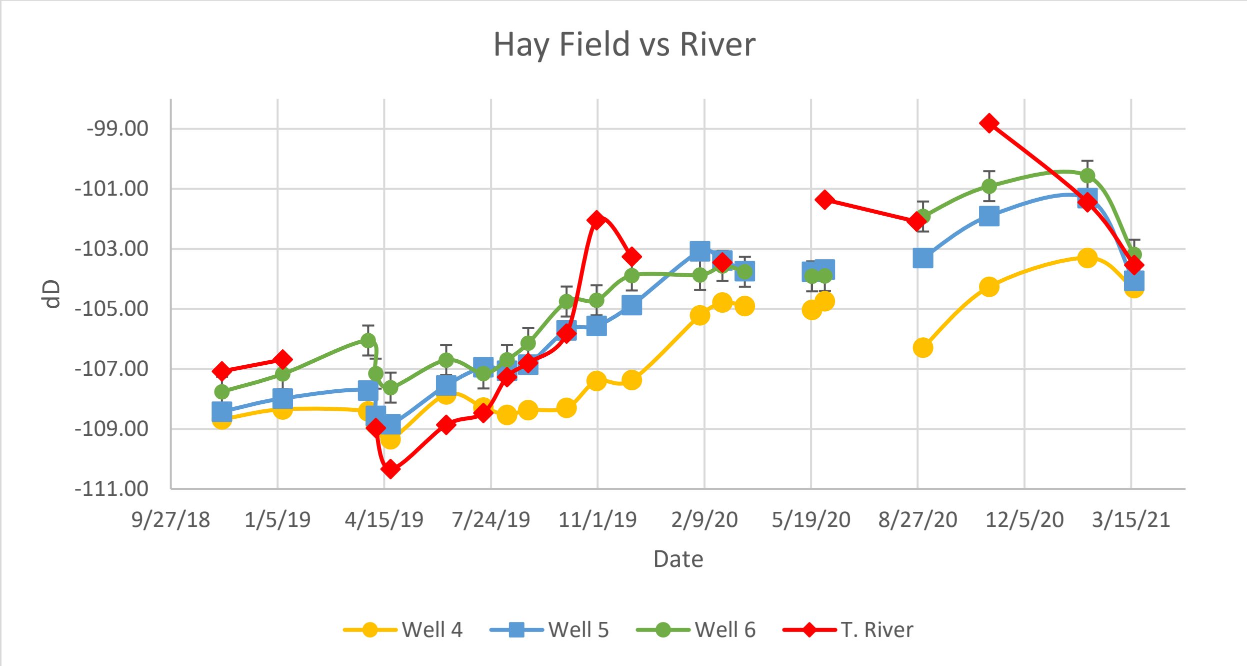
Figure 26. δD vs δ18O plotted with distinct well groups. Well 1-3 within the clay layer, wells 4, 5-6 perpendicular to the river, and wells 7-10 parallel to the river.

When comparing the time series data (Figure 26), each well grouping has a distinct manner of interaction with the river. Figure 26-A shows the clay-dominated wells have water that isotopically distinct from the river water, particularly from July 2019 to March 2021, when it is isotopically lighter. It does not appear that these wells respond to fluctuations in the river.

Figure 26-B shows wells 4-6 also contain water that is isotopically lighter than Teanaway River water, but they do appear to fluctuate with the river, possibly delayed by approximately two months. In November, 2020 the δD of the river water peaked at approximately -99 per mil, while wells 4-6 recorded their peaks in February, 2020. Figure 26-C shows that the cottonwood zone wells are the most isotopically similar to the Teanaway River. From February to mid-May of 2020, wells within this zone have a similar isotopic composition to the river, but in the summer their values are slightly heavier isotopically than the river, perhaps due to contributions from evaporated water from Tom's ponds. Another point of interest are the data gathered on November 11, 2020. The river has an isotopic value at -98.81‰. Well 3, at the edge of the clay, is much lighter at -106.5‰, compared to wells 8-9 which seem to be responding to the river at -99.7‰ and -100.4‰, respectively.

The overall picture presented by the isotope data is that the Teanaway River water freely moves into and out of the alluvial aquifer in the riparian forest region on a short timescale (days to weeks). Some of this water works its way into the alluvial aquifer below the field over the course of weeks to months and mixes with pre-existing groundwater that is derived from more local snowmelt and streams (John and Fred Creek). The groundwater in wells 1-3 is derived from these local sources. River water does not infiltrate into the clay-dominated region.


Confining Clay vs River
dD
-99.00
-101.00
-103.00
-105.00
-107.00
-109.00
-111.00
9/27/18
1/5/19
4/15/19
7/24/19
11/1/19
2/9/20
5/19/20
8/27/20
12/5/20
3/15/21
Date
Well 1
Well 2
Well 3
T. River


Hay Field vs River
dD
-99.00
-101.00
-103.00
-105.00
-107.00
-109.00
-111.00
9/27/18
1/5/19
4/15/19
7/24/19
11/1/19
2/9/20
5/19/20
8/27/20
12/5/20
3/15/21
Date
Well 4
Well 5
Well 6
T. River

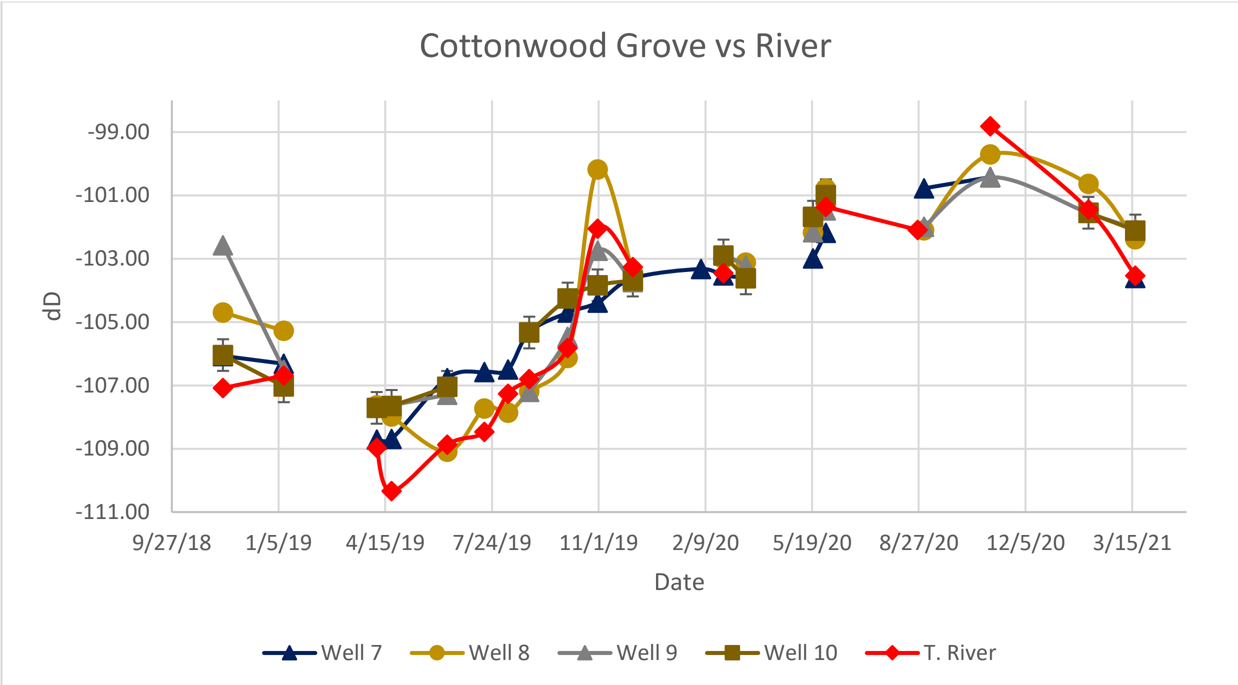


Figure 27. δD vs time plotted (A-C). Representative error bars (0.5 per mil) are included for one well on each figure.

Water Table and Cottonwood Roots

Examination of historical imagery and first-hand accounts indicate that the cottonwood forest on the TVFF property has been dying off over the past ~10 years. Current observations from the field include dead and decaying logs, shattered tree branches, and dead standing cottonwoods. Not many cottonwoods remain. Only a select few cottonwoods remain near John Creek in the center of the TVFF property. The only trees remaining within the area surrounding wells 9-10 are conifer and pine trees, which were sparse to begin with. A number of potential causes, such as disease or pest infestation have been considered for the die off, but no conclusive evidence has been found to support these as the main cause. The wells were emplaced on TVFF partly to determine the availability of groundwater to the cottonwood forest and explore the possibility that the die off is due to lack of sufficient water.

Cottonwood trees require shallow alluvial aquifers with water table depths consistently above 2m to persist throughout the year (Scott, 1999). Without a persistent water table within the roots of the cottonwood trees, the grove of trees is unable to mature. The cottonwood trees along the banks of the Teanaway River on the TVFF property have suffered from a lack of a consistent water table. Figure 27 (A-B) show the difference in the water table from spring recharge to early summer with triangles to represent the range of the roots of mature cottonwood trees. Figure 27-B features the water table depth during the period the upstream neighbor was pumping from his ponds in June. The water table continues to fall throughout the summer, so that the disconnect between the cottonwood roots and the water table would be even more exasperated.

During spring recharge, the water table is above the average level of mature cottonwood roots. The water table does not persist at this depth for long, and by June 1, 2020 the water table has already begun to lower to a depth below the cottonwood roots. This is a period of groundwater recession, so it is expected that the water table would be at an even lower level than shown on Figure 27 until the next recharge occurs.

These cross sections do not include wells 9-10; the cottonwood trees nearby to wells 9-10 are higher in elevation and are closer to Tom's ponds which have shown the most exaggerated decrease in water level due to pumping (Figure 23). This is also the area where the survival rate is the lowest. Thus, the cottonwood grove near wells 9-10 are even more disconnected with the water table during groundwater recession and baseflow. Overall, the cottonwood roots are absent of groundwater for 5-6 months of the year, depending on proximity to the upgradient ponds.

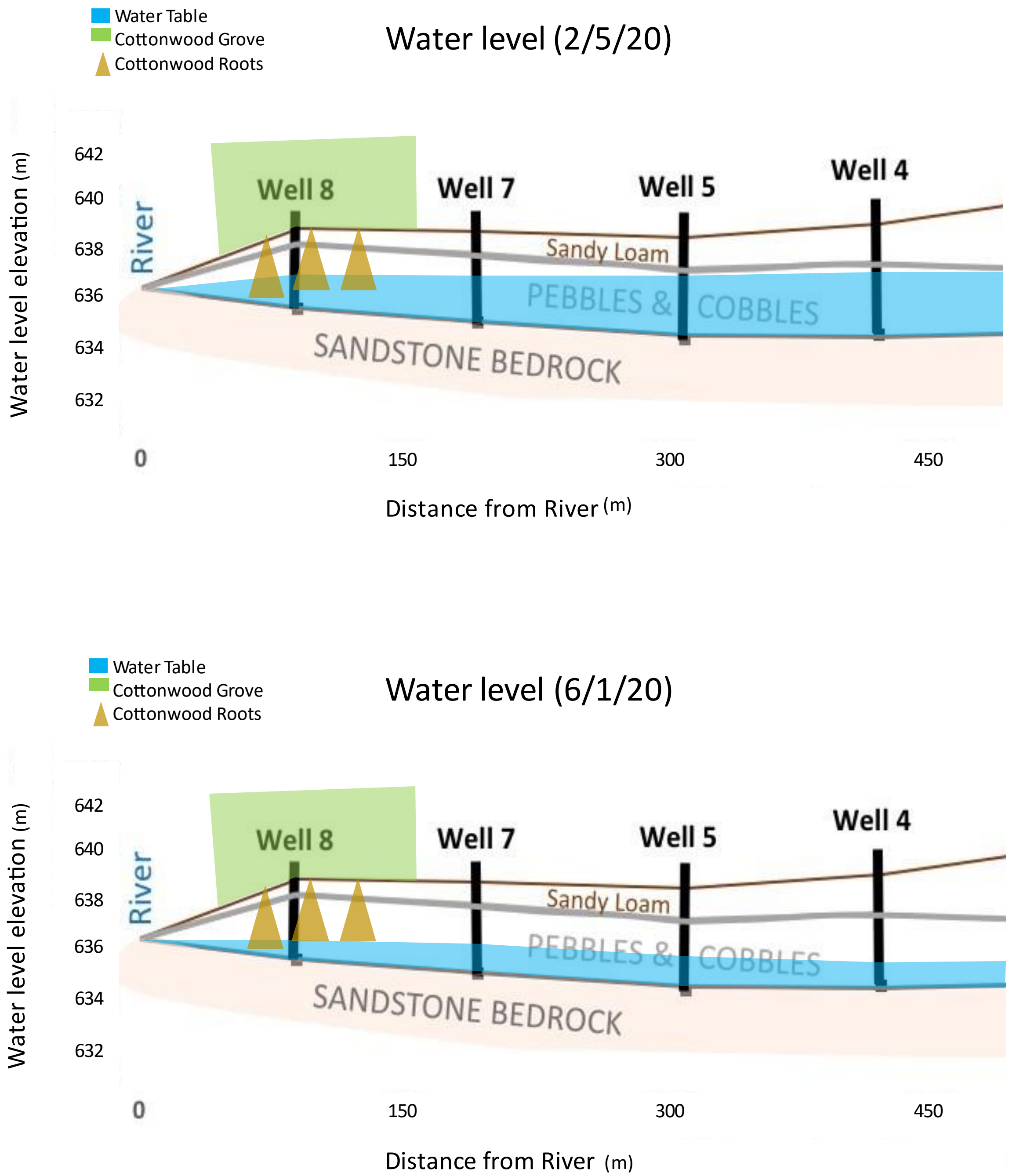


Figure 28. Cross-sections of unconfined alluvial aquifer featuring water table depth.

Two main factors are affecting this grove of cottonwood trees. First, the Teanaway River channel has been incised significantly, and has maintained its narrow course against the sandstone bedrock on the south side of the river. The incision results in less ponding of river water and an overall lower elevation of the river. With the majority of the recharge in the unconfined alluvial aquifer taking place over the course of two months, the water level within the unconfined aquifer is controlled by the river elevation for much of the year. Additionally, the roots and vegetation in the cottonwood grove have created stability for this part of the floodplain. This stopped allowing the river to create new channels within the floodplain, and forced it into its modern position against the Roslyn sandstone ridge to the south side of the channel.

The second factor influencing the mortality of the cottonwood trees is the change in irrigation practices. Flood irrigation from a canal on the north side of the property was the primary irrigation practice until 1978. Following 1978, flood irrigation remained in use during the spring while the canals were still in use, and pumping began taking place from the ponds upstream, and up-gradient of the TVFF property. The TVFF property had a pivot-irrigation system in use until shortly before the property was purchased by the WDFW in 2017. Perhaps the persistent use of irrigation allowed for the cottonwood grove to take root in the first place given the stream incision that had already occurred. Additionally, the irrigation ditch that constrains Fred Creek on the west side of the property limits the amount of water dispersing into the cottonwood forest near wells 8-10. The irrigation ditch is channelized so that it ends near well 7, where the mortality of the cottonwood trees is significantly less.

The combinaiton of these two factors, incising the channel, and the removal of artificial irrigation have caused the water table to drop below the cottonwood roots for an extended period of time. The removal of water from the roots of the cottonwoods for 5-6 months per year has lead to the rapid decline in thecottonwood forest.

Groundwater Temperature and Fish Habitat

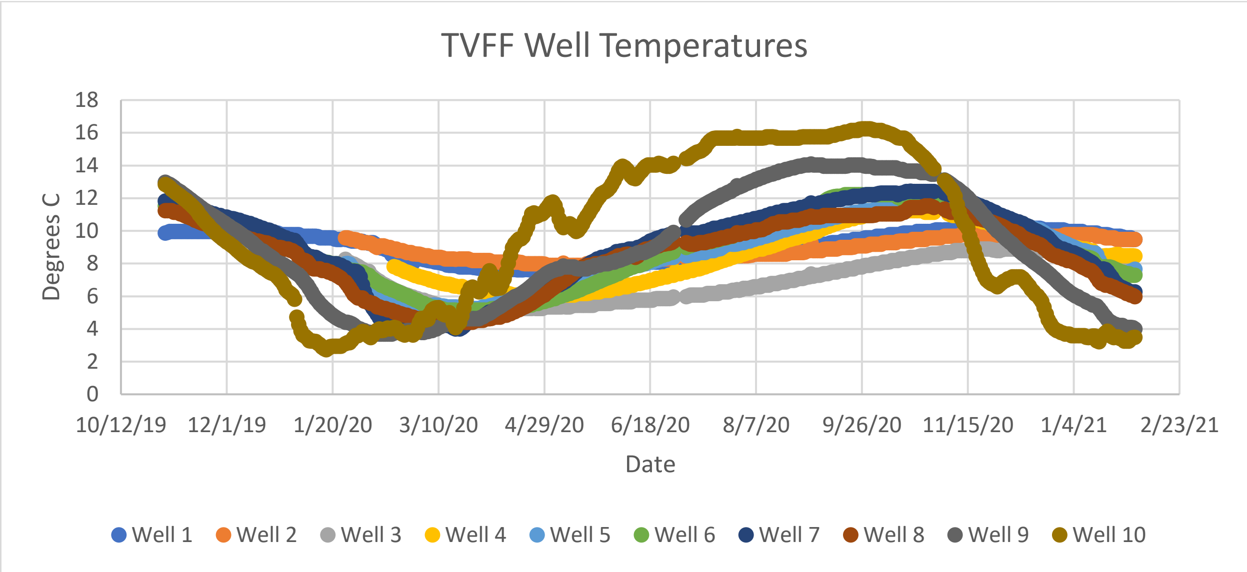


Figure 29. Water temperatures within wells.

Groundwater temperature plays an important role in maintaining fish habitat. In the summer months, groundwater is considerably colder than surface waters and groundwater inputs to streams tend to cool surface water temperatures where fish dwell and spawn. Climate change and removal of riparian vegetation that shade streams have the opposite effect, warming streams to dangerous levels. As a result, fish will seek out cooler regions of the stream where groundwater is entering.

The temperature data for TVFF wells show a gradation from well 10, which fluctuates the most with a maximum and minimum that roughly coincides with the air and stream temperatures to wells 1-4 which have a much more damped fluctuation and display a thermal lag of 2-3 months behind well 10.

Well 10 is also the furthest upstream of the wells, and temporarily goes dry during baseflow conditions. This well experiences rapid changes throughout times when there is little variance elsewhere. It is directly downgradient of the upstream neighbor's ponds and is likely fed partly by this surface water. In contrast, well 2 does not fluctuate much at all even though it goes dry for much of the groundwater recession period and baseflow period. This may be due to the fact that it is the deepest well. Wells 4-8, which are all within the unconfined alluvial aquifer, generally stay within a similar temperature range or 4-12ºC and are at a temperature of approximately 10ºC during the hottest part of the summer. If there were a means to direct this water to the stream at that time, it might improve its quality as fish habitat.

CHAPTER V

CONCLUSION

In this study, groundwater, surface-water, and soil water samples were collected over a 28-month period from Teanaway Valley Family Farm (TVFF) and a nearby site on the Teanaway River. These samples were analyzed for stable isotopes of hydrogen and oxygen (δD and $\delta^{18}O$). Additionally, over 15 months of groundwater elevation and temperature data were collected using pressure transducers in the ten wells at TVFF. These data were analyzed to address four general questions. These questions and the relevant findings are presented below.

Question 1: How does the elevation and direction of flow of the water table change seasonally? How long does the water table remain at high levels after spring recharge for TVFF?

The groundwater elevation data, combine with the river elevation data, was used to determine the specific timing and duration of the groundwater recharge, groundwater recession, and baseflow periods within the TVFF unconfined alluvial aquifer. Over the 15-month period, recharge was documented occuring twice: once in Jan-Feb in 2020, and again in Feb 2021. The 2020 recharge event in the unconfined alluvial aquifer in TVFF was characterized by two distinct "pulses", followed by a decline in groundwater elevation (groundwater recession) that took place from March 2020 to June 2020. After June 2020, groundwater elevations in the lower floodplain wells paralled each other and the river, indicating the baseflow period which persisted until snow began to accumulate in November. At this time, the unconfined alluvial aquifer gradually transitions to the next recharge period, with another recharge "pulse" in Feb 2021.

Similar to Yakima River Basin in its entirety, the Teanaway River basin is dependent upon snow melt for its groundwater recharge. The most significant change in groundwater elevations occurs during these “pulses” which occur after a series of days where the temperatures do not go below freezing. The peak of groundwater recharge occurred well ahead of the spring runoff peak, and groundwater levels transition quickly to the groundwater recession period. Overall, the water levels in TVFF did not persist long into the summer, and showed high variability allowing for potential transient storage. The water table contours created using the groundwater elevation data showed a transition from a ‘gaining’ stream during recharge to a neutral stream in the baseflow period.

Question 2: How do thick-clay sequences impact groundwater flow and storage potential?

The thick clay sequence was identified at the time of wel installation. Water levels in wells installed into the clay (wells 1-3) have a uniquely different trend, particularly during recharge and groundwater recession, than the wells in the cobble-rich alluvial aquifer. For example, when the river water elevation spiked December 2019 to February 2020, the wells within the confining clay only responded to local snow melt and water pressure from Fred and John Creeks.

This water in wells 1-3 appears to represent groundwater in a thin confined aquifer beneath or perhaps within the clay. It may contribute to the alluvial aquifer during recharge, but, based on the isotope data, the river and alluvial floodplain water does not infiltrate into this confined aquifer. The clay sequence serves to reduce the storage potential of the entire floodplain. Although the clay can and does hold water, it does not transmit it on a timescale that is useful to humans.

Question 3: What is the primary source of water for the shallow aquifer in TVFF, and how does the stream interact with the surrounding groundwater? How far does river water infiltrate into the alluvial aquifer and what are typical travel times?

Based on a comparison of groundwater and river water isotopic composition, groundwater was grouped into three distinct groups. Water from wells 1-3 are distinctly lighter than the river water samples. Isotopic fluctuations within these wells do not correlate with river water fluctuations and they appear to be derived from snowmelt from nearby hillslopes and Fred and John Creeks. Wells 1-3 are placed within the clay sequence, and are fed by one or more confined clay aquifers. Water from wells 4-6 share a similarity with the confining clay wells in that they contain water that is lighter than the river for much of the year. However, their seasonal fluctuations are similar to the river fluctuations although they are more attenuated and appear to have a several-month lag in some cases. These characteristics suggest that these groundwaters represent a mixture of more stagnant, locally derived groundwater and river water which has travelled for weeks to months into the alluvial aquifer. The final zone is the transect of wells parallel with the river, wells 7-10 (cottonwood forest). These wells have a similar isotopic composition to the Teanaway River throughout the year, fluctuating at the same time as the river. This water is most likely river water that is present within the unconfined alluvial aquifer and has travelled there in a matter of days. Overall, wells 1-3 are contain water that is distinct from the Teanaway River, wells 7-10 share a nearly identical isotopic composition to the river water and the interactions between river water and groundwater here are felt immediately within days to weeks, and wells 4-6 experience mixing between river water and water coming down from the confining clay zone. The interactions between wells 4-6 are also occurring with a delay of approximately 2-3 months.

Question 4: Can the cottonwood grove on the south side of the property, where trees have been dying over the past decade, be restored?

The water elevation data, particularly downward excursions in wells 4-10 during the irrigation season, suggest that pumping from upgradient ponds has a large impact on the groundwater levels in the cottonwood forest. When this is combined with the stream incision that occurred when this region was logged, it creates a situation where the cottonwood forest can not get water during the summer and early fall.

Cottonwood trees are widespread across river watersheds in semiarid environments all across the Northwestern United States, and their seedlings take root rapidly. The cottonwood trees were likely present within TR watershed before logging companies began moving in. After the channel was incised by log drives in the early 20th century, the cottonwood trees were able to persist with widespread irrigation water.

In the case of TVFF, irrigation was first accomplished by flooding fields using water from a canal at the base of the hills above the floodplain (next to the road). This artificially recharged the floodplain during the summer months. Irrigation water and spring runoff from the streams east and west of the property were constrained to man-made canals that channelize the streams not allowing for runoff to spread throughout the floodplain and enhance the water table. In addition, the irrigation source was moved from the canal along the road to ponds and ring wells on TVFF and neighboring properties after the canal was damaged in 1997. The cottonwood trees are largely dependent upon the irrigation water for a water table that is in contact with mature root systems due to the TR's unnatural incision into the stream bed. The cottonwood groves west of the property that still receive irrigation runoff are still alive, and the cottonwoods within the TVFF property that are still alive are at the end of the irrigation ditches on the south side of the property near wells 6 and 7. Standing water within these drainage ditches persists well into early June.

A solution to the channelization of the west creek would be to remove the irrigation ditch completely. This would allow water from spring recharge to spread across the floodplain instead of flooding surface and aquifer near wells 6 and 7. By increasing the surface area saturated by surface water in the high porosity, unconfined alluvial, there is a better likelihood of slowing the rate at which baseflow recession occurs. However, during the baseflow period, this recharged water will generally move to the east. To directly influence the most damaged zone of cottonwoods, water would have to be applied upgradient on the neighbor’s property.

Channel incision on the Teanaway River, however, remains an underlying problem and will require much more attention and work. Work has already begun upstream of the TVFF property with LWD emplacement in Teanaway. The net positive effects on LWD emplacements upstream may not be seen for a number of years. Similar restoration efforts at and below TVFF might also eventually restore sediment to the streambed.

Future Work/Recommendations

Stable isotope geochemistry and groundwater elevation analysis were useful tools for studying surface-water/groundwater interactions at Teanaway Valley Family Farm. Stable isotopes were particularly useful in identifying different origins of water whether it was upstream river water or water that slowly seeped through/around the confining clay aquifer. My study focused solely on groundwater within TVFF and the river water passing by the property. By expanding this study throughout the watershed, numerous sources of water could be differentiated and compared to the main stem Teanaway River composition. There are wells throughout Teanaway River watershed including wells on private property, and in publicly owned lands like the Indian Creek watershed. Establishing an isotopic record within the Teanaway River watershed could build a deeper understanding of water sources and surface-water/groundwater interactions for the entire watershed. In addition, isotopic analysis of precipitation could be used to establish a Local Meteoric Water Line (LMWL) would be useful for analyzing the amounts of local precipitation in different groundwaters and surface waters. Overall, building a stable isotope database for the Teanaway River watershed would provide useful for restoration projects concerned with groundwater inputs moving forward.

Groundwater elevations gave insight into the timing and duration of the three main hydrologic periods. Recharge in 2020 was characterized as having two “pulses” to high water elevations throughout the river and the unconfined alluvial aquifer. Following the pulses, there was a rapid transition to groundwater recession throughout the TVFF property. Wells 1-3, within the confining clay aquifer, saw a delayed reaction to these pulses or saw no reaction at all depending on proximity to floodplain. It is unclear how widespread these aquifer properties Determining the extent of clays within the watershed and replicating a spatial and temporal study of groundwater elevations in areas of interest moving forward would better constrain the amount of potential storage within floodplain aquifers and how quickly that water is released to the river.

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APPENDICES

Appendix A: Piezometer Installation and Well Development

The Indian Creek site was previously equipped with seven monitoring piezometers. Four of which have been recording water level data since 2014, and were installed by Ecology, WDFW and KCT. These four piezometers were established on two separate transects, an upstream transect (MP-3 and MP-4), and a downstream transect (MP-1 and MP-2) (Figure X). Both transects lie perpendicular to the stream. Nora Boylan, Oregon State University, installed the other three piezometers in October 2018. These piezometers were installed downstream of the transects to create a triangulation for groundwater flow. MP-6 was installed with the upstream grouping, and MP-5 and MP-7 were installed with the downstream grouping. In the spring of 2020, MP-7 presumably washed away.

To better determine the groundwater flow direction and aquifer storage of Indian Creek, two new wells were installed at the mouth of Indian Creek where it meets the North Fork Teanaway River. These new wells were installed by Central Washington University. The new wells (CWU-8 and CWU-9) were installed by hand-auger, and power-auger. ~Insert Auger Specifics~ … If resistance was met within three feet below ground surface, then the holes were side-stepped and augering resumed. This process repeated until water began filling the holes substantially. Total depth below ground for each well is 220cm and 207cm for CWU-8 and CWU-9, respectively. Table X shows well locations and depth.

295cm PVC pipes were placed in each hole. A foot-long section at the bottom of each pipe was drilled with holes to simulate a well screen, which allows water to flow freely from the aquifer into the pipe. The bottom of each pipe was capped to prevent sediment build-up at the base of the well.

Table 7. Well coordinates and depth measurements for newly installed wells.

Well Info				
	Lat	**Long**	**Depth below ground (cm)**	**Cap to ground (cm)**
CWU-8	47.29917	-120.85761	220	67
CWU-9	47.29960	-120.85761	207	73

All wells in Indian Creek were developed to ensure there was no build-up of sediment in the wells. There are several methods of well development, but for CWU-8 and CWU-9 wells the water and sediment mixture was extracted using a bailer. It is a repetitive process of bailing out water and allowing the well to refill with water and sediment until the water was clear, and not mixed with sediment. In addition to bailing out water, a mechanical pump was used to hasten the process of water and sediment removal. Water was then tested the following day using the bailer to ensure no sediment build-up had occurred.

Appendix B

Table B8. Daily average elevation (in meters) for wells at Teanaway Valley Family Farm.

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
11/2/2019	648.52					635.19	636.58	636.90	637.95	638.54
11/3/2019	648.53					635.18	636.56	636.88	637.92	638.50
11/4/2019	648.53					635.17	636.53	636.86	637.90	638.47
11/5/2019	648.53					635.16	636.51	636.84	637.88	638.45
11/6/2019	648.53					635.14	636.49	636.82	637.85	638.42
11/7/2019	648.53					635.13	636.46	636.80	637.83	638.40
11/8/2019	648.52					635.11	636.44	636.79	637.81	638.38
11/9/2019	648.52					635.10	636.42	636.77	637.79	638.37
11/10/2019	648.52					635.09	636.41	636.76	637.78	638.35
11/11/2019	648.52					635.08	636.39	636.75	637.76	638.34
11/12/2019	648.51					635.07	636.38	636.74	637.75	638.33
11/13/2019	648.51					635.06	636.37	636.73	637.74	638.31
11/14/2019	648.51					635.05	636.36	636.71	637.71	638.25
11/15/2019	648.51					635.04	636.34	636.70	637.68	638.24
11/16/2019	648.51					635.03	636.32	636.68	637.67	638.28
11/17/2019	648.50					635.03	636.31	636.68	637.69	638.30
11/18/2019	648.51					635.02	636.31	636.68	637.69	638.29
11/19/2019	648.51					635.03	636.31	636.69	637.69	638.29
11/20/2019	648.52					635.04	636.31	636.69	637.69	638.29
11/21/2019	648.51					635.05	636.32	636.69	637.69	638.30
11/22/2019	648.51					635.05	636.32	636.69	637.70	638.31
11/23/2019	648.50					635.04	636.32	636.69	637.70	638.32
11/24/2019	648.50					635.04	636.32	636.69	637.71	638.34
11/25/2019	648.50					635.04	636.32	636.70	637.72	638.34
11/26/2019	648.50					635.05	636.33	636.70	637.72	638.34
11/27/2019	648.51					635.04	636.32	636.70	637.72	638.34
11/28/2019	648.51					635.04	636.32	636.70	637.72	638.34

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
11/29/2019	648.51					635.03	636.32	636.70	637.72	638.34
11/30/2019	648.50					635.01	636.31	636.69	637.71	638.33
12/1/2019	648.49					635.02	636.30	636.70	637.71	638.31
12/2/2019	648.49					635.05	636.31	636.73	637.70	638.29
12/3/2019	648.48					635.07	636.32	636.75	637.69	638.28
12/4/2019	648.46					635.05	636.33	636.73	637.68	638.28
12/5/2019	648.47					635.05	636.31	636.69	637.68	638.29
12/6/2019	648.47					635.04	636.30	636.68	637.68	638.30
12/7/2019	648.48					635.04	636.30	636.68	637.68	638.31
12/8/2019	648.49					635.04	636.30	636.69	637.69	638.33
12/9/2019	648.50					635.05	636.31	636.69	637.71	638.36
12/10/2019	648.51					635.05	636.32	636.70	637.74	638.39
12/11/2019	648.52					635.06	636.33	636.71	637.75	638.40
12/12/2019	648.54					635.06	636.34	636.72	637.76	638.41
12/13/2019	648.56					635.06	636.34	636.73	637.77	638.41
12/14/2019	648.57					635.07	636.35	636.73	637.78	638.45
12/15/2019	648.59					635.07	636.36	636.74	637.79	638.46
12/16/2019	648.62					635.07	636.36	636.74	637.80	638.45
12/17/2019	648.64					635.06	636.36	636.74	637.80	638.43
12/18/2019	648.67					635.07	636.36	636.75	637.79	638.42
12/19/2019	648.70					635.06	636.36	636.74	637.78	638.41
12/20/2019	648.74					635.05	636.35	636.73	637.78	638.41
12/21/2019	648.77					635.05	636.35	636.73	637.78	638.43
12/22/2019	648.80					635.12	636.39	636.77	637.79	638.44
12/23/2019	648.83					635.21	636.44	636.82	637.81	638.48
12/24/2019	648.86					635.23	636.46	636.83	637.84	638.57
12/25/2019	648.89					635.23	636.47	636.84	637.88	638.62
12/26/2019	648.91					635.23	636.48	636.85	637.91	638.64
12/27/2019	648.93					635.22	636.49	636.86	637.93	638.66

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
12/28/2019	648.95					635.21	636.50	636.86	637.95	638.67
12/29/2019	648.98					635.20	636.50	636.87	637.95	638.67
12/30/2019	649.00					635.20	636.50	636.87	637.95	638.66
12/31/2019	649.02					635.19	636.50	636.86	637.95	638.64
1/1/2020	649.07					635.19	636.50	636.86	637.95	638.64
1/2/2020	649.14					635.39	636.63	637.01	638.10	639.01
1/3/2020	649.20					635.65	636.90	637.24	638.41	639.62
1/4/2020	649.25					635.70	637.03	637.34	638.58	639.71
1/5/2020	649.28					635.70	637.09	637.39	638.63	639.71
1/6/2020	649.31					635.70	637.13	637.41	638.65	639.71
1/7/2020	649.35					635.70	637.15	637.42	638.66	639.71
1/8/2020	649.39					635.81	637.26	637.54	638.79	639.85
1/9/2020	649.43					635.93	637.37	637.63	638.86	639.90
1/10/2020	649.45					635.94	637.41	637.63	638.86	639.90
1/11/2020	649.49					635.93	637.42	637.61	638.85	639.90
1/12/2020	649.50					635.90	637.40	637.59	638.82	639.88
1/13/2020	649.52					635.87	637.37	637.56	638.77	639.84
1/14/2020	649.51					635.83	637.34	637.53	638.74	639.79
1/15/2020	649.51					635.80	637.30	637.50	638.70	639.67
1/16/2020	649.51					635.77	637.27	637.47	638.66	639.52
1/17/2020	649.51					635.75	637.23	637.44	638.62	639.43
1/18/2020	649.48					635.72	637.20	637.41	638.58	639.36
1/19/2020	649.47					635.70	637.17	637.38	638.54	639.30
1/20/2020	649.47					635.67	637.13	637.35	638.51	639.25
1/21/2020	649.48					635.65	637.10	637.32	638.48	639.21
1/22/2020	649.49					635.63	637.07	637.29	638.45	639.16
1/23/2020	649.47					635.61	637.04	637.27	638.41	639.12
1/24/2020	649.48					635.60	637.02	637.25	638.40	639.11
1/25/2020										

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
1/26/2020	649.48	637.75	637.74		636.83	635.68	637.04	637.32	638.40	639.31
1/27/2020	649.58	638.06	638.16		636.94	635.75	637.11	637.39	638.55	639.65
1/28/2020	649.64	638.35	638.48		637.08	635.81	637.22	637.49	638.75	639.81
1/29/2020	649.65	638.59	638.70		637.20	635.86	637.33	637.58	638.84	639.89
1/30/2020	649.65	638.77	638.87		637.30	635.92	637.42	637.64	638.86	639.92
1/31/2020	649.66	638.93	639.01		637.38	635.97	637.48	637.68	638.87	639.92
2/1/2020	649.69	639.06	639.14		637.44	636.01	637.53	637.70	638.87	639.94
2/2/2020	649.77	639.28	639.45		637.64	636.24	637.74	637.87	638.98	640.07
2/3/2020	649.83	639.61	639.68		637.92	636.42	637.98	638.07	639.06	640.18
2/4/2020	649.80	639.67	639.67		637.92	636.39	637.94	637.99	639.03	640.15
2/5/2020	649.78	639.63	639.65		637.89	636.37	637.91	637.95	639.01	640.11
2/6/2020	649.72	639.56	639.59		637.89	636.36	637.86	637.93	638.99	640.06
2/7/2020	649.75	639.60	639.73		637.94	636.39	637.92	637.95	638.98	640.09
2/8/2020	650.08	639.94	640.04		638.18	636.52	638.07	638.15	639.08	640.22
2/9/2020	650.20	640.19	640.14		638.18	636.52	638.08	638.16	639.08	640.24
2/10/2020	650.23	640.19	640.11		638.16	636.48	638.04	638.08	639.04	640.19
2/11/2020	650.26	640.06	640.03		638.12	636.45	638.00	638.02	639.01	640.15
2/12/2020	650.21	639.97	640.01		638.12	636.44	637.98	637.99	639.00	640.13
2/13/2020	650.16	639.90	639.98		638.10	636.43	637.97	637.97	638.99	640.11
2/14/2020	650.17	639.86	639.94		638.06	636.41	637.96	637.96	638.97	640.09
2/15/2020	650.10	639.78	639.88		638.04	636.40	637.95	637.94	638.95	640.05
2/16/2020	650.06	639.72	639.84		638.02	636.39	637.94	637.92	638.94	640.02
2/17/2020	650.04	639.66	639.80		638.00	636.39	637.93	637.92	638.92	640.00
2/18/2020	650.04	639.60	639.76	638.26	637.98	636.38	637.93	637.91	638.91	639.98
2/19/2020	650.04	639.57	639.72	638.24	637.94	636.36	637.92	637.90	638.89	639.94
2/20/2020	650.01	639.53	639.68	638.22	637.91	636.35	637.90	637.88	638.87	639.91
2/21/2020	649.99	639.49	639.64	638.20	637.89	636.34	637.89	637.87	638.85	639.89
2/22/2020	649.98	639.46	639.61	638.19	637.88	636.33	637.87	637.85	638.83	639.86
2/23/2020	649.97	639.42	639.57	638.17	637.87	636.32	637.86	637.84	638.81	639.84

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
2/24/2020	649.99	639.38	639.54	638.17	637.87	636.32	637.86	637.84	638.81	639.83
2/25/2020	649.97	639.33	639.50	638.16	637.87	636.33	637.86	637.84	638.80	639.82
2/26/2020	650.03	639.32	639.47	638.15	637.85	636.31	637.85	637.84	638.79	639.81
2/27/2020	650.18	639.25	639.45	638.10	637.85	636.31	637.85	637.83	638.79	639.80
2/28/2020	650.19	639.26	639.43	638.14	637.75	636.32	637.87	637.85	638.80	639.81
2/29/2020	650.21	639.30	639.42	638.15	637.87	636.35	637.89	637.87	638.82	639.82
3/1/2020	650.21	639.27	639.40	638.14	637.88	636.36	637.91	637.89	638.83	639.84
3/2/2020	650.16	639.24	639.36	638.13	637.87	636.35	637.91	637.89	638.83	639.84
3/3/2020	650.13	639.23	639.35	638.13	637.87	636.35	637.91	637.89	638.83	639.83
3/4/2020	650.11	639.21	639.34	638.13	637.89	636.39	637.93	637.90	638.84	639.85
3/5/2020	650.09	639.21	639.33	638.14	637.90	636.40	637.95	637.95	638.88	639.90
3/6/2020	650.09	639.22	639.34	638.15	637.90	636.39	637.95	637.94	638.88	639.91
3/7/2020	650.08	639.21	639.33	638.15	637.90	636.38	637.94	637.93	638.86	639.89
3/8/2020	650.07	639.19	639.31	638.14	637.89	636.38	637.94	637.93	638.86	639.87
3/9/2020	650.03	639.16	639.26	638.11	637.88	636.37	637.93	637.92	638.84	639.85
3/10/2020	650.01	639.12	639.20	638.09	637.86	636.36	637.92	637.90	638.83	639.81
3/11/2020	650.00	639.08	639.15	638.07	637.85	636.35	637.91	637.89	638.81	639.78
3/12/2020	649.99	639.04	639.09	638.04	637.84	636.34	637.90	637.88	638.79	639.76
3/13/2020	649.97	638.99	639.02	638.01	637.83	636.34	637.90	637.88	638.78	639.74
3/14/2020	650.00	638.96	638.99	638.00	637.82	636.34	637.89	637.87	638.78	639.73
3/15/2020	649.96	638.89	638.90	637.96	637.81	636.33	637.88	637.86	638.77	639.70
3/16/2020	649.93	638.82	638.82	637.92	637.78	636.31	637.86	637.85	638.75	639.67
3/17/2020	649.92	638.76	638.75	637.89	637.76	636.30	637.85	637.83	638.74	639.65
3/18/2020	649.94	638.70	638.70	637.86	637.74	636.28	637.83	637.83	638.73	639.64
3/19/2020										
3/20/2020	649.89	638.70	638.70	637.75	637.69	636.28	637.89	637.86	638.70	639.59
3/21/2020	649.87	638.64	638.64	637.72	637.67	636.28	637.88	637.86	638.69	639.59
3/22/2020	649.88	638.58	638.60	637.70	637.67	636.29	637.91	637.88	638.71	639.61
3/23/2020	649.88	638.54	638.56	637.70	637.69	636.30	637.93	637.90	638.74	639.68

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
3/24/2020	649.89	638.51	638.54	637.70	637.71	636.31	637.95	637.92	638.75	639.70
3/25/2020	649.87	638.47	638.51	637.69	637.70	636.31	637.94	637.91	638.75	639.69
3/26/2020	649.86	638.43	638.47	637.68	637.69	636.30	637.92	637.90	638.73	639.65
3/27/2020	649.85	638.39	638.43	637.65	637.66	636.28	637.89	637.87	638.71	639.62
3/28/2020	649.84	638.35	638.39	637.63	637.64	636.27	637.86	637.85	638.69	639.58
3/29/2020	649.84	638.31	638.36	637.61	637.62	636.26	637.84	637.84	638.67	639.55
3/30/2020	649.84	638.28	638.33	637.59	637.61	636.26	637.84	637.83	638.66	639.54
3/31/2020	649.83	638.25	638.30	637.58	637.62	636.27	637.86	637.84	638.67	639.54
4/1/2020	649.82	638.21	638.27	637.57	637.61	636.27	637.86	637.85	638.68	639.56
4/2/2020	649.81	638.18	638.24	637.56	637.60	636.26	637.84	637.83	638.66	639.54
4/3/2020	649.80	638.14	638.20	637.53	637.58	636.25	637.81	637.82	638.65	639.51
4/4/2020	649.80	638.11	638.17	637.51	637.56	636.24	637.78	637.80	638.63	639.47
4/5/2020	649.81	638.07	638.13	637.49	637.53	636.22	637.75	637.78	638.61	639.44
4/6/2020	649.81	638.03	638.09	637.46	637.51	636.21	637.72	637.76	638.60	639.41
4/7/2020	649.78	637.98	638.03	637.42	637.48	636.19	637.68	637.73	638.58	639.38
4/8/2020	649.76	637.93	637.99	637.38	637.44	636.17	637.65	637.71	638.55	639.34
4/9/2020	649.75	637.89	637.94	637.34	637.41	636.16	637.62	637.69	638.52	639.31
4/10/2020	649.76	637.85	637.91	637.32	637.39	636.16	637.61	637.68	638.51	639.30
4/11/2020	649.76	637.82	637.87	637.30	637.39	636.18	637.62	637.71	638.55	639.42
4/12/2020	649.75	637.79	637.85	637.29	637.42	636.21	637.68	637.78	638.65	639.56
4/13/2020	649.73	637.75	637.83	637.30	637.44	636.22	637.72	637.82	638.68	639.60
4/14/2020	649.72	637.72	637.80	637.30	637.44	636.21	637.72	637.81	638.68	639.61
4/15/2020	649.73	637.70	637.78	637.29	637.43	636.20	637.70	637.80	638.67	639.60
4/16/2020	649.72	637.67	637.75	637.28	637.42	636.20	637.68	637.79	638.66	639.60
4/17/2020	649.71	637.64	637.71	637.26	637.40	636.19	637.67	637.79	638.66	639.60
4/18/2020	649.73	637.61	637.68	637.25	637.40	636.19	637.67	637.79	638.67	639.61
4/19/2020	649.72	637.58	637.65	637.23	637.39	636.19	637.66	637.79	638.67	639.61
4/20/2020	649.70	637.55	637.61	637.21	637.37	636.18	637.65	637.79	638.67	639.61
4/21/2020	649.69	637.52	637.58	637.19	637.37	636.18	637.65	637.79	638.67	639.61

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
4/22/2020	649.68	637.48	637.55	637.18	637.36	636.18	637.64	637.79	638.67	639.61
4/23/2020	649.68	637.46	637.52	637.17	637.35	636.18	637.64	637.80	638.68	639.62
4/24/2020	649.59	637.41	637.48	637.16	637.33	636.19	637.65	637.81	638.68	639.59
4/25/2020	649.65	637.41	637.48	637.15	637.35	636.18	637.63	637.80	638.68	639.60
4/26/2020	649.67	637.39	637.45	637.14	637.33	636.16	637.62	637.78	638.67	639.59
4/27/2020	649.67	637.37	637.43	637.12	637.32	636.15	637.60	637.77	638.66	639.57
4/28/2020	649.66	637.35	637.40	637.10	637.30	636.13	637.59	637.76	638.65	639.56
4/29/2020	649.64	637.32	637.37	637.07	637.28	636.12	637.57	637.75	638.65	639.56
4/30/2020	649.66	637.31	637.35	637.06	637.26	636.11	637.55	637.74	638.64	639.55
5/1/2020	649.65	637.29	637.32	637.04	637.25	636.10	637.54	637.75	638.64	639.55
5/2/2020	649.63	637.27	637.30	637.02	637.24	636.09	637.53	637.74	638.63	639.52
5/3/2020	649.64	637.26	637.28	637.00	637.21	636.02	637.51	637.71	638.57	639.36
5/4/2020	649.61	637.23	637.25	636.96	637.18	635.99	637.47	637.67	638.53	639.30
5/5/2020	649.61	637.22	637.22	636.92	637.14	635.97	637.42	637.63	638.49	639.23
5/6/2020	649.61	637.20	637.19	636.87	637.09	635.92	637.37	637.59	638.44	639.18
5/7/2020	649.60	637.18	637.15	636.81	637.04	635.92	637.33	637.55	638.41	639.16
5/8/2020	649.53	637.14	637.12	636.75	636.97	635.91	637.30	637.51	638.38	639.20
5/9/2020	649.57	637.14	637.09	636.71	636.97	635.87	637.27	637.51	638.38	639.18
5/10/2020	649.60	637.13	637.07	636.66	636.94	635.85	637.26	637.50	638.36	639.13
5/11/2020	649.60	637.11	637.04	636.62	636.92	635.86	637.25	637.51	638.36	639.14
5/12/2020	649.60	637.10	637.02	636.60	636.92	635.89	637.25	637.52	638.37	639.16
5/13/2020	649.59	637.09	637.01	636.58	636.91	635.88	637.25	637.52	638.38	639.21
5/14/2020	649.57	637.07	636.98	636.56	636.90	635.85	637.25	637.52	638.39	639.21
5/15/2020	649.56	637.05	636.96	636.53	636.89	635.83	637.24	637.51	638.38	639.19
5/16/2020	649.55	637.04	636.94	636.51	636.87	635.81	637.22	637.48	638.36	639.16
5/17/2020	649.56	637.03	636.93	636.49	636.86	635.80	637.20	637.47	638.34	639.12
5/18/2020	649.56	637.02	636.92	636.48	636.85	635.83	637.19	637.45	638.32	639.10
5/19/2020	649.55	637.02	636.91	636.48	636.85	635.83	637.19	637.46	638.33	639.15
5/20/2020	649.53	637.01	636.90	636.46	636.84	635.81	637.18	637.45	638.33	639.14

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
5/21/2020	649.53	637.00	636.89	636.45	636.83	635.81	637.18	637.45	638.32	639.13
5/22/2020	649.53	636.99	636.87	636.45	636.84	635.84	637.18	637.45	638.33	639.15
5/23/2020	649.51	636.99	636.85	636.44	636.83	635.80	637.17	637.44	638.31	639.08
5/24/2020	649.50	636.99	636.83	636.42	636.81	635.77	637.15	637.41	638.25	638.94
5/25/2020	649.50	636.97	636.80	636.39	636.78	635.75	637.11	637.36	638.18	638.84
5/26/2020	649.50	636.97	636.77	636.35	636.74	635.72	637.06	637.32	638.11	638.76
5/27/2020	649.49	636.98	636.75	636.30	636.70	635.71	637.02	637.28	638.07	638.75
5/28/2020	649.48	636.96	636.72	636.26	636.67	635.70	637.00	637.27	638.10	638.91
5/29/2020	649.48	636.94	636.68	636.22	636.65	635.69	637.00	637.28	638.12	638.89
5/30/2020	649.48	636.93	636.66	636.20	636.64	635.68	636.99	637.27	638.11	638.86
5/31/2020	649.48	636.91	636.64	636.19	636.64	635.70	636.99	637.29	638.14	638.95
6/1/2020	649.47	636.89	636.63	636.19	636.66	635.74	637.03	637.34	638.20	639.04
6/2/2020	649.43	636.87	636.59	636.19	636.67	635.69	637.03	637.33	638.20	639.03
6/3/2020	649.42	636.85	636.59	636.18	636.66	635.65	637.02	637.31	638.17	638.88
6/4/2020	649.44	636.84	636.57	636.17	636.64	635.65	636.99	637.27	638.08	638.71
6/5/2020	649.44	636.83	636.56	636.15	636.61	635.62	636.95	637.22	638.00	638.59
6/6/2020	649.45	636.81	636.54	636.12	636.56	635.59	636.89	637.17	637.91	638.46
6/7/2020	649.43	636.80	636.51	636.07	636.50	635.55	636.83	637.10	637.82	638.34
6/8/2020	649.41	636.79	636.49	636.01	636.43	635.51	636.76	637.04	637.74	638.28
6/9/2020	649.39	636.77	636.46	635.95	636.36	635.48	636.69	636.98	637.69	638.25
6/10/2020	649.40	636.76	636.44	635.89	636.30	635.45	636.63	636.94	637.66	638.26
6/11/2020	649.40	636.75	636.41	635.85	636.25	635.41	636.60	636.91	637.67	638.42
6/12/2020	649.40	636.74	636.39	635.81	636.22	635.39	636.60	636.93	637.76	638.61
6/13/2020	649.40	636.73	636.38	635.79	636.24	635.38	636.63	636.98	637.84	638.69
6/14/2020	649.40	636.72	636.36	635.79	636.27	635.38	636.68	637.02	637.91	638.77
6/15/2020	649.38	636.71	636.35	635.81	636.31	635.38	636.71	637.05	637.95	638.75
6/16/2020	649.38	636.70	636.35	635.83	636.34	635.38	636.74	637.07	637.96	638.72
6/17/2020	649.37	636.69	636.34	635.84	636.36	635.38	636.75	637.08	637.96	638.71
6/18/2020	649.35	636.68	636.33	635.85	636.36	635.37	636.75	637.07	637.95	638.69

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
6/19/2020	649.35	636.68	636.32	635.85	636.36	635.37	636.75	637.07	637.94	638.66
6/20/2020	649.36	636.67	636.32	635.85	636.35	635.36	636.74	637.06	637.92	638.64
6/21/2020	649.35	636.67	636.31	635.84	636.34	635.36	636.73	637.06	637.91	638.64
6/22/2020	649.33	636.66	636.29	635.82	636.33	635.35	636.72	637.05	637.90	638.63
6/23/2020	649.32	636.65	636.28	635.81	636.32	635.35	636.71	637.04	637.88	638.58
6/24/2020	649.32	636.64	636.27	635.80	636.30	635.33	636.69	637.02	637.85	638.56
6/25/2020	649.31	636.63	636.25	635.78	636.28	635.32	636.67	637.00	637.84	638.53
6/26/2020	649.29	636.61	636.24	635.76	636.25	635.31	636.65	636.99	637.81	638.50
6/27/2020	649.29	636.60	636.22	635.74	636.23	635.29	636.63	636.97	637.80	638.54
6/28/2020	649.29	636.59	636.20	635.73	636.21	635.28	636.62	636.97	637.83	638.59
6/29/2020	649.28	636.57	636.18	635.71	636.21	635.26	636.62	636.97	637.82	638.53
6/30/2020				635.69						
7/1/2020				635.70						
7/2/2020				635.68						
7/3/2020				635.66						
7/4/2020				635.64						
7/5/2020	649.17	636.57	636.18	635.61	636.21	635.26	636.62	636.97	637.82	638.53
7/6/2020	649.17	636.55	636.16	635.56	636.14	635.24	636.55	636.91	637.72	638.46
7/7/2020	649.17	636.53	636.13	635.52	636.07	635.21	636.48	636.85	637.64	638.41
7/8/2020	649.16	636.51	636.10	635.47	635.99	635.17	636.41	636.79	637.64	638.39
7/9/2020	649.15	636.49	636.07	635.42	635.93	635.14	636.34	636.74	637.64	638.39
7/10/2020	649.15	636.46	636.04	635.38	635.87	635.11	636.28	636.70	637.64	638.39
7/11/2020	649.13	636.44	636.01	635.33	635.82	635.08	636.23	636.66	637.64	638.39
7/12/2020	649.13	636.42	635.99	635.29	635.78	635.05	636.19	636.63	637.64	638.39
7/13/2020	649.12	636.40	635.96	635.26	635.74	635.02	636.16	636.61	637.64	638.39
7/14/2020	649.12	636.38	635.94	635.24	635.70	635.00	636.13	636.60	637.64	638.39
7/15/2020	649.11	636.35	635.92	635.21	635.68	634.98	636.13	636.59	637.64	638.45
7/16/2020	649.10	636.33	635.90	635.20	635.67	634.96	636.14	636.61	637.64	638.47
7/17/2020	649.10	636.31	635.87	635.18	635.68	634.95	636.16	636.62	637.64	638.45

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
7/18/2020	649.08	636.29	635.85	635.17	635.69	634.95	636.16	636.62	637.64	638.40
7/19/2020	649.07	636.27	635.82	635.17	635.69	634.95	636.16	636.61	637.64	638.39
7/20/2020	649.06	636.25	635.81	635.16	635.68	634.94	636.14	636.59	637.64	638.39
7/21/2020	649.05	636.23	635.80	635.15	635.66	634.93	636.12	636.58	637.64	638.39
7/22/2020	649.06	636.21	635.79	635.14	635.64	634.92	636.10	636.56	637.64	638.39
7/23/2020	649.13	636.19	635.79	635.13	635.62	634.91	636.08	636.55	637.64	638.39
7/24/2020	649.12	636.17	635.78	635.12	635.60	634.90	636.06	636.54	637.64	638.39
7/25/2020	649.10	636.15	635.78	635.11	635.58	634.89	636.05	636.53	637.64	638.39
7/26/2020	649.08	636.13	635.77	635.10	635.56	634.88	636.03	636.52	637.64	638.39
7/27/2020	649.05	636.11	635.76	635.08	635.54	634.87	636.02	636.51	637.64	638.39
7/28/2020	649.05	636.10	635.75	635.07	635.52	634.86	636.01	636.50	637.64	638.39
7/29/2020	648.96	636.08	635.74	635.04	635.51	634.83	636.00	636.48	637.64	638.39
7/30/2020	648.99	636.05	635.72	635.03	635.49	634.83	635.99	636.48	637.64	638.39
7/31/2020	648.98	636.04	635.71	635.01	635.48	634.83	635.98	636.48	637.64	638.39
8/1/2020	648.96	636.02	635.69	634.98	635.47	634.82	635.97	636.47	637.64	638.39
8/2/2020	648.93	636.01	635.68	634.95	635.46	634.81	635.96	636.46	637.64	638.39
8/3/2020	648.93	635.99	635.67	634.93	635.45	634.81	635.96	636.46	637.64	638.39
8/4/2020	648.93	635.98	635.65	634.92	635.44	634.80	635.95	636.45	637.64	638.39
8/5/2020	648.93	635.97	635.64	634.90	635.43	634.79	635.94	636.44	637.64	638.39
8/6/2020	648.92	635.97	635.62	634.88	635.42	634.79	635.93	636.44	637.64	638.39
8/7/2020	648.92	635.97	635.61	634.83	635.41	634.78	635.93	636.43	637.64	638.39
8/8/2020	648.89	635.97	635.59	634.78	635.40	634.78	635.92	636.43	637.64	638.39
8/9/2020	648.84	635.97	635.58	634.76	635.40	634.78	635.92	636.43	637.64	638.39
8/10/2020	648.81	635.97	635.56	634.74	635.39	634.78	635.93	636.44	637.64	638.39
8/11/2020	648.78	635.97	635.55	634.73	635.40	634.78	635.96	636.47	637.64	638.44
8/12/2020	648.76	635.97	635.55	634.71	635.42	634.78	636.01	636.50	637.64	638.55
8/13/2020	648.73	635.97	635.55	634.71	635.46	634.79	636.06	636.55	637.64	638.58
8/14/2020	648.71	635.97	635.54	634.72	635.51	634.80	636.11	636.58	637.64	638.52
8/15/2020	648.69	635.97	635.54	634.74	635.56	634.82	636.13	636.59	637.64	638.46

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
8/16/2020	648.67	635.97	635.53	634.78	635.59	634.83	636.13	636.59	637.64	638.40
8/17/2020	648.65	635.97	635.53	634.82	635.60	634.83	636.11	636.57	637.64	638.39
8/18/2020	648.63	635.97	635.52	634.86	635.58	634.82	636.08	636.54	637.64	638.38
8/19/2020	648.62	635.97	635.52	634.88	635.56	634.81	636.05	636.52	637.64	638.38
8/20/2020	648.60	635.97	635.51	634.89	635.53	634.80	636.02	636.50	637.64	638.39
8/21/2020	648.58	635.97	635.51	634.89	635.50	634.79	636.00	636.48	637.64	638.39
8/22/2020	648.57	635.97	635.50	634.88	635.47	634.79	635.98	636.46	637.64	638.39
8/23/2020	648.55	635.97	635.50	634.85	635.45	634.78	635.96	636.46	637.64	638.39
8/24/2020	648.54	635.97	635.49	634.78	635.43	634.78	635.95	636.45	637.64	638.39
8/25/2020	648.52	635.97	635.49	634.73	635.42	634.77	635.95	636.45	637.64	638.39
8/26/2020	648.51	635.97	635.49	634.70	635.41	634.76	635.95	636.45	637.64	638.39
8/27/2020	648.50	635.97	635.49	634.68	635.41	634.76	635.96	636.46	637.64	638.39
8/28/2020	648.49	635.97	635.49	634.67	635.42	634.76	635.98	636.47	637.64	638.39
8/29/2020	648.47	635.97	635.48	634.67	635.43	634.76	636.00	636.49	637.64	638.46
8/30/2020	648.46	635.97	635.48	634.67	635.45	634.77	636.03	636.52	637.64	638.54
8/31/2020	648.44	635.97	635.48	634.67	635.48	634.78	636.07	636.55	637.64	638.63
9/1/2020	648.43	635.97	635.47	634.68	635.52	634.79	636.12	636.58	637.65	638.68
9/2/2020	648.41	635.96	635.47	634.69	635.58	634.80	636.15	636.61	637.70	638.70
9/3/2020	648.38	635.94	635.47	634.75	635.63	634.82	636.20	636.64	637.74	638.72
9/4/2020	648.37	635.95	635.47	634.81	635.67	634.83	636.23	636.66	637.77	638.72
9/5/2020	648.36	635.95	635.47	634.86	635.70	634.85	636.25	636.68	637.79	638.72
9/6/2020	648.35	635.96	635.46	634.91	635.73	634.86	636.27	636.69	637.80	638.72
9/7/2020	648.34	635.96	635.46	634.94	635.75	634.87	636.29	636.70	637.81	638.72
9/8/2020	648.33	635.96	635.46	634.98	635.76	634.87	636.30	636.71	637.82	638.72
9/9/2020	648.32	635.96	635.45	635.01	635.77	634.88	636.30	636.72	637.82	638.71
9/10/2020	648.31	635.96	635.45	635.04	635.78	634.89	636.31	636.72	637.82	638.71
9/11/2020	648.31	635.96	635.45	635.07	635.78	634.89	636.31	636.73	637.82	638.70
9/12/2020	648.30	635.96	635.45	635.09	635.79	634.89	636.31	636.73	637.81	638.70
9/13/2020	648.30	635.96	635.45	635.10	635.79	634.89	636.32	636.73	637.81	638.70

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
9/14/2020	648.30	635.96	635.45	635.12	635.79	634.90	636.32	636.73	637.81	638.70
9/15/2020	648.30	635.96	635.44	635.13	635.80	634.90	636.32	636.74	637.81	638.70
9/16/2020	648.29	635.96	635.44	635.13	635.80	634.90	636.32	636.74	637.81	638.70
9/17/2020	648.29	635.96	635.44	635.14	635.80	634.90	636.33	636.74	637.82	638.70
9/18/2020	648.29	635.96	635.44	635.15	635.80	634.90	636.33	636.74	637.82	638.71
9/19/2020	648.29	635.96	635.44	635.15	635.80	634.90	636.33	636.75	637.83	638.71
9/20/2020	648.28	635.96	635.44	635.15	635.81	634.91	636.34	636.75	637.83	638.71
9/21/2020	648.28	635.96	635.44	635.16	635.82	634.92	636.35	636.76	637.84	638.72
9/22/2020	648.27	635.96	635.43	635.16	635.82	634.92	636.35	636.76	637.85	638.72
9/23/2020	648.27	635.96	635.43	635.16	635.82	634.92	636.35	636.77	637.85	638.72
9/24/2020	648.26	635.96	635.43	635.17	635.83	634.93	636.36	636.77	637.85	638.72
9/25/2020	648.26	635.96	635.43	635.17	635.83	634.96	636.37	636.79	637.86	638.75
9/26/2020	648.26	635.96	635.43	635.17	635.85	634.98	636.39	636.81	637.88	638.77
9/27/2020	648.27	635.95	635.43	635.18	635.86	635.01	636.42	636.83	637.90	638.79
9/28/2020	648.27	635.96	635.43	635.18	635.88	635.02	636.43	636.84	637.92	638.80
9/29/2020	648.27	635.96	635.43	635.19	635.89	635.02	636.44	636.85	637.93	638.81
9/30/2020	648.28	635.96	635.43	635.20	635.90	635.01	636.45	636.85	637.94	638.81
10/1/2020	648.28	635.96	635.43	635.20	635.90	635.01	636.45	636.85	637.95	638.82
10/2/2020	648.28	635.96	635.43	635.21	635.91	635.01	636.46	636.86	637.96	638.82
10/3/2020	648.28	635.96	635.43	635.22	635.91	635.00	636.46	636.86	637.96	638.81
10/4/2020	648.28	635.96	635.43	635.22	635.91	635.00	636.46	636.86	637.95	638.80
10/5/2020	648.27	635.96	635.42	635.23	635.91	635.00	636.46	636.86	637.95	638.80
10/6/2020	648.26	635.96	635.42	635.23	635.91	634.99	636.46	636.85	637.94	638.79
10/7/2020	648.26	635.96	635.42	635.24	635.91	634.99	636.45	636.85	637.93	638.78
10/8/2020	648.25	635.96	635.42	635.24	635.90	634.99	636.45	636.85	637.93	638.77
10/9/2020	648.24	635.96	635.42	635.24	635.90	634.99	636.44	636.84	637.92	638.77
10/10/2020	648.24	635.96	635.42	635.24	635.90	634.99	636.44	636.84	637.91	638.76
10/11/2020	648.23	635.96	635.42	635.24	635.89	634.99	636.44	636.84	637.91	638.76
10/12/2020	648.22	635.97	635.42	635.24	635.90	635.00	636.44	636.85	637.91	638.78

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
10/13/2020	648.22	635.96	635.42	635.24	635.91	635.08	636.48	636.89	637.96	638.95
10/14/2020	648.24	635.96	635.42	635.24	635.95	635.15	636.54	636.95	638.05	639.01
10/15/2020	648.26	635.97	635.42	635.25	636.03	635.28	636.65	637.06	638.12	639.16
10/16/2020	648.28	635.96	635.43	635.28	636.14	635.34	636.73	637.13	638.25	639.38
10/17/2020	648.31	635.96	635.44	635.33	636.21	635.33	636.78	637.17	638.33	639.39
10/18/2020	648.34	635.96	635.45	635.38	636.27	635.34	636.82	637.21	638.35	639.37
10/19/2020	648.35	635.96	635.45	635.44	636.32	635.34	636.85	637.22	638.36	639.33
10/20/2020	648.37	635.97	635.46	635.50	636.35	635.34	636.86	637.23	638.35	639.30
10/21/2020	648.37	635.97	635.47	635.55	636.37	635.34	636.86	637.22	638.34	639.27
10/22/2020	648.38	635.97	635.48	635.58	636.38	635.33	636.85	637.21	638.33	639.24
10/23/2020	648.37	635.97	635.50	635.60	636.37	635.32	636.84	637.20	638.31	639.21
10/24/2020	648.37	635.97	635.52	635.61	636.37	635.31	636.83	637.19	638.29	639.20
10/25/2020	648.39	635.97	635.54	635.61	636.37	635.35	636.84	637.21	638.30	639.25
10/26/2020	648.39	635.97	635.55	635.62	636.39	635.35	636.86	637.23	638.33	639.27
10/27/2020	648.41	635.96	635.57	635.63	636.40	635.35	636.87	637.23	638.33	639.26
10/28/2020	648.42	635.96	635.60	635.65	636.41	635.35	636.87	637.22	638.32	639.24
10/29/2020	648.43	635.97	635.64	635.67	636.41	635.35	636.87	637.22	638.31	639.23
10/30/2020	648.43	635.96	635.66	635.67	636.41	635.35	636.86	637.21	638.30	639.21
10/31/2020	648.45	635.98	635.71							
11/1/2020	648.56	636.10	635.83							
11/2/2020	648.55	636.10	635.84							
11/3/2020										
11/4/2020	648.55	636.10	635.84			635.35	636.86	637.21	638.30	639.21
11/5/2020	648.55	636.10	635.84			635.39	636.87	637.22	638.29	639.22
11/6/2020	648.56	636.10	635.83	635.67	636.41	635.43	636.89	637.25	638.30	639.23
11/7/2020	648.57	636.10	635.83	635.68	636.45	635.49	636.93	637.29	638.31	639.26
11/8/2020	648.58	636.10	635.82	635.70	636.47	635.50	636.94	637.30	638.35	639.33
11/9/2020	648.57	636.10	635.82	635.71	636.48	635.49	636.95	637.30	638.37	639.37
11/10/2020	648.56	636.10	635.81	635.72	636.49	635.47	636.95	637.30	638.38	639.38

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
11/11/2020	648.56	636.10	635.81	635.73	636.49	635.46	636.95	637.30	638.39	639.38
11/12/2020	648.55	636.10	635.80	635.73	636.49	635.44	636.94	637.29	638.39	639.39
11/13/2020	648.55	636.10	635.80	635.73	636.48	635.43	636.93	637.29	638.38	639.36
11/14/2020	648.57	636.10	635.80	635.73	636.48	635.42	636.93	637.28	638.38	639.36
11/15/2020	648.57	636.10	635.79	635.72	636.48	635.42	636.93	637.28	638.39	639.40
11/16/2020	648.60	636.10	635.86	635.75	636.53	635.45	636.96	637.32	638.44	639.49
11/17/2020	648.63	636.10	636.02	635.84	636.61	635.50	637.03	637.38	638.51	639.59
11/18/2020	648.68	636.10	636.22	635.96	636.68	635.54	637.09	637.42	638.56	639.65
11/19/2020	648.72	636.10	636.31	636.05	636.73	635.57	637.12	637.45	638.57	639.65
11/20/2020	648.76	636.10	636.31	636.09	636.75	635.58	637.15	637.46	638.58	639.64
11/21/2020	648.78	636.10	636.29	636.10	636.77	635.58	637.15	637.46	638.57	639.61
11/22/2020	648.79	636.10	636.27	636.10	636.76	635.57	637.14	637.45	638.55	639.59
11/23/2020	648.81	636.10	636.26	636.09	636.75	635.57	637.13	637.44	638.54	639.57
11/24/2020	648.82	636.10	636.23	636.07	636.74	635.56	637.12	637.43	638.52	639.54
11/25/2020	648.82	636.10	636.19	636.04	636.71	635.54	637.10	637.41	638.50	639.50
11/26/2020	648.81	636.10	636.16	636.01	636.69	635.53	637.08	637.39	638.47	639.47
11/27/2020	648.80	636.10	636.11	635.98	636.66	635.51	637.05	637.37	638.45	639.44
11/28/2020	648.78	636.10	636.08	635.94	636.63	635.49	637.02	637.35	638.42	639.41
11/29/2020	648.78	636.10	636.06	635.92	636.61	635.48	637.00	637.33	638.40	639.38
11/30/2020	648.76	636.10	636.03	635.89	636.58	635.46	636.98	637.31	638.38	639.35
12/1/2020	648.76	636.11	636.01	635.87	636.56	635.46	636.96	637.29	638.36	639.32
12/2/2020	648.74	636.11	635.97	635.83	636.53	635.44	636.93	637.28	638.33	639.29
12/3/2020	648.72	636.11	635.96	635.81	636.50	635.42	636.91	637.26	638.32	639.27
12/4/2020	648.72	636.11	635.95	635.79	636.48	635.41	636.89	637.24	638.30	639.26
12/5/2020	648.71	636.11	635.95	635.76	636.45	635.40	636.87	637.23	638.28	639.24
12/6/2020	648.72	636.11	635.95	635.74	636.43	635.38	636.85	637.21	638.27	639.22
12/7/2020	648.74	636.12	635.96	635.73	636.41	635.37	636.84	637.20	638.26	639.20
12/8/2020	648.76	636.13	635.96	635.71	636.39	635.36	636.82	637.19	638.25	639.19
12/9/2020	648.78	636.14	635.96	635.69	636.38	635.36	636.81	637.18	638.24	639.17

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
12/10/2020	648.81	636.15	635.96	635.68	636.39	635.43	636.84	637.21	638.23	639.17
12/11/2020	648.83	636.16	635.96	635.68	636.41	635.46	636.86	637.23	638.24	639.19
12/12/2020	648.86	636.17	635.97	635.69	636.42	635.47	636.86	637.23	638.26	639.23
12/13/2020	648.88	636.18	635.97	635.69	636.42	635.45	636.86	637.23	638.27	639.26
12/14/2020	648.90	636.19	635.98	635.69	636.42	635.44	636.86	637.24	638.29	639.27
12/15/2020	648.92	636.20	635.99	635.69	636.42	635.43	636.86	637.24	638.30	639.28
12/16/2020	648.94	636.22	636.00	635.70	636.42	635.42	636.86	637.24	638.30	639.29
12/17/2020	648.96	636.22	636.00	635.70	636.41	635.41	636.85	637.23	638.30	639.28
12/18/2020	648.98	636.24	636.01	635.70	636.42	635.41	636.86	637.24	638.31	639.30
12/19/2020	649.00	636.25	636.01	635.69	636.41	635.40	636.85	637.24	638.32	639.31
12/20/2020	649.02	636.27	636.02	635.69	636.41	635.41	636.86	637.24	638.33	639.33
12/21/2020	649.07	636.30	636.34	635.76	636.49	635.49	636.93	637.31	638.39	639.50
12/22/2020	649.19	636.44	636.47	635.92	636.65	635.60	637.07	637.43	638.53	639.69
12/23/2020	649.32	636.69	636.66	636.10	636.80	635.71	637.20	637.55	638.67	639.81
12/24/2020	649.35	636.84	636.90	636.21	636.86	635.70	637.24	637.56	638.69	639.83
12/25/2020	649.41	637.01	637.11	636.30	636.91	635.71	637.27	637.58	638.72	639.84
12/26/2020	649.45	637.15	637.20	636.35	636.93	635.71	637.29	637.59	638.73	639.82
12/27/2020	649.46	637.23	637.23	636.36	636.93	635.69	637.28	637.58	638.72	639.79
12/28/2020	649.47	637.27	637.20	636.35	636.91	635.68	637.27	637.56	638.70	639.75
12/29/2020	649.47	637.29	637.18	636.33	636.90	635.66	637.25	637.55	638.67	639.72
12/30/2020	649.46	637.30	637.14	636.30	636.88	635.64	637.23	637.53	638.65	639.68
12/31/2020	649.47	637.31	637.11	636.28	636.86	635.63	637.21	637.51	638.62	639.66
1/1/2021	649.45	637.30	637.08	636.25	636.83	635.61	637.18	637.48	638.60	639.63
1/2/2021	649.45	637.29	637.06	636.22	636.80	635.60	637.16	637.47	638.58	639.58
1/3/2021	649.46	637.30	637.05	636.20	636.79	635.59	637.15	637.46	638.56	639.55
1/4/2021	649.45	637.33	637.05	636.19	636.78	635.62	637.15	637.46	638.56	639.55
1/5/2021	649.46	637.34	637.05	636.15	636.75	635.60	637.12	637.43	638.53	639.53
1/6/2021	649.52	637.45	637.20	636.19	636.79	635.66	637.17	637.49	638.58	639.60
1/7/2021	649.53	637.50	637.35	636.15	636.74	635.61	637.12	637.45	638.54	639.57

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
1/8/2021	649.52	637.59	637.50	636.17	636.75	635.61	637.13	637.45	638.56	639.58
1/9/2021	649.54	637.68	637.59	636.20	636.76	635.61	637.14	637.46	638.57	639.60
1/10/2021	649.55	637.76	637.65	636.23	636.77	635.62	637.15	637.47	638.58	639.62
1/11/2021	649.56	637.80	637.67	636.23	636.76	635.60	637.13	637.45	638.57	639.60
1/12/2021	649.59	637.85	637.71	636.25	636.76	635.59	637.13	637.45	638.57	639.59
1/13/2021	649.67	637.92	637.82	636.26	636.77	635.61	637.14	637.46	638.58	639.63
1/14/2021	649.84	638.31	638.56	636.76	637.05	635.89	637.39	637.71	638.91	640.21
1/15/2021	649.89	638.76	639.00	637.35	637.38	636.10	637.66	637.94	639.28	640.59
1/16/2021	649.96	639.08	639.23	637.52	637.53	636.16	637.80	638.03	639.32	640.62
1/17/2021	649.96	639.28	639.37	637.59	637.60	636.18	637.87	638.05	639.32	640.61
1/18/2021	649.93	639.39	639.48	637.62	637.63	636.19	637.89	638.06	639.30	640.60
1/19/2021	649.91	639.47	639.56	637.65	637.64	636.19	637.89	638.05	639.28	640.58
1/20/2021	649.92	639.54	639.61	637.64	637.64	636.18	637.89	638.04	639.24	640.55
1/21/2021	649.92	639.59	639.65	637.62	637.63	636.17	637.87	638.02	639.21	640.52
1/22/2021	649.88	639.61	639.65	637.57	637.61	636.15	637.85	638.00	639.17	640.49
1/23/2021	649.84	639.61	639.63	637.52	637.58	636.13	637.82	637.97	639.14	640.45
1/24/2021	649.80	639.58	639.57	637.46	637.55	636.10	637.79	637.95	639.11	640.39
1/25/2021	649.79	639.56	639.51	637.42	637.52	636.08	637.76	637.93	639.09	640.33
1/26/2021	649.76	639.51	639.43	637.36	637.49	636.06	637.73	637.90	639.07	640.26
1/27/2021	649.74	639.45	639.34	637.31	637.46	636.03	637.70	637.88	639.04	640.18
1/28/2021	649.73	639.40	639.25	637.27	637.43	636.02	637.68	637.86	639.03	640.14
1/29/2021	649.70	639.31	639.14	637.22	637.39	636.00	637.64	637.84	639.00	640.07
1/30/2021	649.67	639.22	639.03	637.17	637.35	635.97	637.61	637.81	638.97	639.99
1/31/2021	649.65	639.13	638.91	637.12	637.32	635.94	637.58	637.78	638.94	639.94
2/1/2021	649.64	639.04	638.81	637.08	637.28	635.92	637.55	637.76	638.91	639.89
2/2/2021	649.66	638.97	638.75	637.04	637.25	635.91	637.52	637.74	638.89	639.85

Table B9. Daily average temperature (in C) for wells at the Teanaway Valley Family Farm.

Date	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
11/2/2019	9.87					11.53	11.82	11.24	12.98	12.84
11/3/2019	9.91					11.44	11.82	11.24	12.89	12.76
11/4/2019	9.96					11.43	11.82	11.24	12.84	12.65
11/5/2019	9.97					11.36	11.74	11.23	12.76	12.53
11/6/2019	9.97					11.33	11.72	11.14	12.65	12.42
11/7/2019	9.97					11.27	11.72	11.14	12.55	12.33
11/8/2019	9.97					11.24	11.63	11.14	12.47	12.23
11/9/2019	9.97					11.15	11.63	11.05	12.38	12.13
11/10/2019	9.97					11.13	11.62	11.02	12.28	12.03
11/11/2019	9.97					11.04	11.54	10.94	12.18	11.93
11/12/2019	9.97					11.00	11.53	10.88	12.09	11.83
11/13/2019	9.97					10.94	11.50	10.85	11.99	11.72
11/14/2019	9.97					10.89	11.43	10.78	11.90	11.61
11/15/2019	9.97					10.85	11.43	10.75	11.80	11.50
11/16/2019	9.97					10.77	11.34	10.66	11.70	11.35
11/17/2019	9.97					10.75	11.33	10.62	11.60	11.19
11/18/2019	9.97					10.66	11.28	10.55	11.50	11.01
11/19/2019	9.97					10.65	11.24	10.48	11.40	10.85
11/20/2019	9.97					10.56	11.24	10.46	11.31	10.69
11/21/2019	9.97					10.55	11.16	10.43	11.22	10.53
11/22/2019	9.97					10.46	11.14	10.36	11.14	10.39
11/23/2019	9.97					10.45	11.11	10.36	11.04	10.23
11/24/2019	9.97					10.36	11.04	10.34	10.96	10.10
11/25/2019	9.97					10.36	11.04	10.27	10.87	9.97
11/26/2019	9.97					10.28	10.98	10.26	10.80	9.84
11/27/2019	9.97					10.26	10.94	10.22	10.72	9.73

11/28/2019	9.97					10.22	10.94	10.17	10.64	9.62
11/29/2019	9.97					10.16	10.85	10.16	10.55	9.52
11/30/2019	9.97					10.16	10.85	10.12	10.46	9.42
12/1/2019	9.97					10.08	10.85	10.06	10.38	9.32
12/2/2019	9.97					10.06	10.79	10.00	10.30	9.23
12/3/2019	9.97					10.03	10.75	9.94	10.20	9.13
12/4/2019	9.98					9.94	10.75	9.87	10.11	9.04
12/5/2019	9.97					9.97	10.71	9.77	10.04	8.92
12/6/2019	9.97					9.89	10.65	9.77	9.96	8.81
12/7/2019	9.97					9.87	10.65	9.77	9.86	8.69
12/8/2019	9.97					9.83	10.56	9.71	9.77	8.58
12/9/2019	9.97					9.77	10.55	9.67	9.68	8.47
12/10/2019	9.97					9.77	10.51	9.59	9.59	8.38
12/11/2019	9.97					9.68	10.46	9.55	9.49	8.28
12/12/2019	9.97					9.67	10.44	9.48	9.38	8.20
12/13/2019	9.93					9.60	10.36	9.46	9.27	8.12
12/14/2019	9.87					9.57	10.35	9.40	9.16	8.08
12/15/2019	9.87					9.55	10.27	9.37	9.05	8.04
12/16/2019	9.87					9.47	10.26	9.37	8.93	7.95
12/17/2019	9.87					9.47	10.18	9.33	8.81	7.84
12/18/2019	9.87					9.38	10.16	9.28	8.76	7.74
12/19/2019	9.87					9.37	10.08	9.27	8.67	7.66
12/20/2019	9.87					9.33	10.06	9.25	8.58	7.58
12/21/2019	9.87					9.27	10.03	9.18	8.48	7.49
12/22/2019	9.87					9.27	9.97	9.15	8.40	7.41
12/23/2019	9.87					9.19	9.95	9.06	8.30	7.38
12/24/2019	9.87					9.15	9.86	8.99	8.15	7.31
12/25/2019	9.87					9.08	9.77	8.98	8.08	7.17
12/26/2019	9.81					9.08	9.72	8.98	8.01	7.01
12/27/2019	9.77					9.00	9.67	8.97	7.98	6.87

12/28/2019	9.77					8.98	9.59	8.88	7.90	6.67
12/29/2019	9.77					8.96	9.57	8.88	7.82	6.40
12/30/2019	9.77					8.88	9.48	8.88	7.75	6.26
12/31/2019	9.77					8.88	9.47	8.80	7.66	6.16
1/1/2020	9.77					8.83	9.42	8.78	7.58	6.06
1/2/2020	9.77					8.76	9.42	8.69	7.48	5.81
1/3/2020	9.77					8.68	9.26	8.61	7.38	4.73
1/4/2020	9.76					8.55	9.08	8.40	7.29	4.27
1/5/2020	9.67					8.40	8.90	8.27	7.17	3.87
1/6/2020	9.67					8.30	8.74	8.18	7.01	3.63
1/7/2020	9.67					8.26	8.62	8.18	6.83	3.54
1/8/2020	9.67					8.09	8.50	8.10	6.68	3.43
1/9/2020	9.67					8.04	8.40	7.94	6.48	3.28
1/10/2020	9.67					8.10	8.42	7.75	6.27	3.26
1/11/2020	9.67					8.13	8.38	7.68	6.05	3.26
1/12/2020	9.67					8.13	8.38	7.68	5.86	3.22
1/13/2020	9.64					8.13	8.30	7.68	5.69	3.12
1/14/2020	9.57					8.12	8.22	7.66	5.53	3.03
1/15/2020	9.57					8.10	8.16	7.58	5.40	2.89
1/16/2020	9.57					8.08	8.09	7.58	5.27	2.78
1/17/2020	9.57					8.08	8.07	7.58	5.16	2.73
1/18/2020	9.57					8.07	8.05	7.48	5.06	2.82
1/19/2020	9.57					8.00	8.00	7.47	4.94	2.92
1/20/2020	9.57					7.98	7.98	7.38	4.84	2.94
1/21/2020	9.50					7.98	7.98	7.34	4.74	2.94
1/22/2020	9.47					7.98	7.98	7.27	4.66	2.94
1/23/2020	9.47					7.89	7.89	7.18	4.59	2.94
1/24/2020	9.47					7.88	7.88	7.11	4.52	2.95
1/25/2020										
1/26/2020	9.47	9.57	8.27		7.99	7.74	7.76	6.87	4.42	3.09

1/27/2020	9.47	9.57	8.11		8.00	7.67	7.64	6.72	4.42	3.16
1/28/2020	9.42	9.53	8.07		7.96	7.61	7.44	6.52	4.37	3.16
1/29/2020	9.37	9.47	7.99		7.77	7.58	7.44	6.31	4.31	3.31
1/30/2020	9.37	9.47	7.96		7.56	7.58	7.54	6.12	4.22	3.47
1/31/2020	9.37	9.46	7.88		7.40	7.56	7.52	5.99	4.12	3.60
2/1/2020	9.37	9.37	7.82		7.25	7.49	7.43	5.90	4.03	3.59
2/2/2020	9.37	9.37	7.73		7.19	7.48	7.18	5.89	4.00	3.66
2/3/2020	9.36	9.28	7.65		6.95	7.48	6.69	5.89	3.91	3.84
2/4/2020	9.28	9.27	7.58		6.91	7.40	6.29	5.71	3.89	3.82
2/5/2020	9.27	9.27	7.50		6.83	7.33	5.94	5.65	3.79	3.67
2/6/2020	9.23	9.25	7.52		6.75	7.29	5.70	5.64	3.81	3.54
2/7/2020	9.27	9.24	7.31		6.60	7.14	5.49	5.55	3.79	3.47
2/8/2020	9.27	9.16	7.17		6.49	7.05	5.27	5.55	3.79	3.62
2/9/2020	9.19	9.06	7.09		6.42	6.95	5.11	5.48	3.75	3.79
2/10/2020	9.08	8.98	7.00		6.38	6.85	4.89	5.35	3.68	3.91
2/11/2020	9.05	9.06	6.91		6.31	6.77	4.68	5.35	3.68	4.00
2/12/2020	8.95	9.08	6.82		6.27	6.67	4.54	5.29	3.68	3.90
2/13/2020	8.93	9.08	6.73		6.18	6.63	4.42	5.24	3.68	3.91
2/14/2020	8.87	9.05	6.68		6.05	6.57	4.42	5.24	3.68	4.00
2/15/2020	8.80	8.98	6.59		5.96	6.51	4.34	5.16	3.68	4.05
2/16/2020	8.73	8.98	6.52		5.85	6.47	4.31	5.14	3.68	4.00
2/17/2020	8.53	8.93	6.46		5.78	6.41	4.31	5.12	3.68	4.06
2/18/2020	8.48	8.88	6.38	7.81	5.75	6.37	4.31	5.04	3.74	4.10
2/19/2020	8.28	8.88	6.33	7.77	5.70	6.30	4.31	5.04	3.79	4.06
2/20/2020	8.15	8.79	6.27	7.69	5.66	6.27	4.30	4.94	3.79	3.93
2/21/2020	8.09	8.78	6.22	7.66	5.65	6.17	4.21	4.93	3.79	3.78
2/22/2020	8.08	8.78	6.17	7.59	5.59	6.15	4.17	4.89	3.79	3.68
2/23/2020	8.07	8.72	6.11	7.52	5.54	6.06	4.10	4.83	3.86	3.62
2/24/2020	8.04	8.68	6.06	7.48	5.55	6.03	4.12	4.83	3.89	3.68
2/25/2020	8.04	8.68	6.02	7.43	5.52	5.96	4.22	4.78	3.89	3.79

2/26/2020	8.03	8.67	5.97	7.38	5.47	5.90	4.31	4.73	3.89	3.72
2/27/2020	8.04	8.59	5.95	7.32	5.43	5.86	4.32	4.73	3.89	3.63
2/28/2020	8.24	8.59	5.87	7.27	5.67	5.77	4.42	4.66	3.89	3.75
2/29/2020	8.34	8.58	5.86	7.25	5.72	5.73	4.51	4.62	3.89	4.07
3/1/2020	8.29	8.58	5.79	7.19	5.54	5.65	4.62	4.62	3.82	4.39
3/2/2020	8.27	8.54	5.76	7.16	5.48	5.59	4.62	4.60	3.79	4.64
3/3/2020	8.25	8.48	5.75	7.13	5.45	5.55	4.56	4.52	3.79	4.66
3/4/2020	8.22	8.48	5.68	7.08	5.46	5.47	4.43	4.53	3.83	4.55
3/5/2020	8.19	8.48	5.66	7.07	5.45	5.45	4.34	4.52	3.84	4.57
3/6/2020	8.16	8.44	5.63	6.99	5.45	5.35	4.31	4.51	3.89	4.92
3/7/2020	8.16	8.38	5.58	6.97	5.45	5.35	4.31	4.43	3.90	5.16
3/8/2020	8.11	8.38	5.55	6.91	5.46	5.32	4.31	4.42	4.00	5.24
3/9/2020	8.09	8.38	5.50	6.90	5.45	5.24	4.33	4.42	4.01	5.29
3/10/2020	8.07	8.38	5.44	6.86	5.44	5.24	4.40	4.42	4.10	5.31
3/11/2020	8.05	8.38	5.40	6.82	5.40	5.24	4.32	4.42	4.13	5.16
3/12/2020	8.00	8.34	5.36	6.78	5.41	5.22	4.31	4.42	4.21	4.91
3/13/2020	7.98	8.28	5.34	6.76	5.39	5.14	4.24	4.42	4.25	4.85
3/14/2020	7.91	8.28	5.30	6.74	5.35	5.14	4.21	4.42	4.31	4.96
3/15/2020	7.88	8.28	5.25	6.74	5.35	5.14	4.21	4.42	4.37	5.00
3/16/2020	7.88	8.28	5.26	6.69	5.35	5.14	4.13	4.42	4.42	4.67
3/17/2020	7.88	8.28	5.27	6.64	5.35	5.14	4.05	4.42	4.46	4.36
3/18/2020	7.88	8.26	5.24	6.61	5.35	5.14	4.00	4.42	4.52	4.07
3/19/2020										
3/20/2020	7.78	8.28	5.22	6.58	5.35	5.14	4.00	4.42	4.53	4.41
3/21/2020	7.79	8.28	5.14	6.59	5.35	5.14	4.07	4.42	4.62	4.79
3/22/2020	7.79	8.28	5.15	6.55	5.27	5.14	4.17	4.42	4.62	5.27
3/23/2020	7.79	8.28	5.15	6.48	5.24	5.14	4.32	4.42	4.62	5.78
3/24/2020	7.78	8.28	5.14	6.42	5.22	5.14	4.43	4.42	4.62	6.23
3/25/2020	7.78	8.22	5.14	6.42	5.19	5.14	4.52	4.42	4.62	6.51
3/26/2020	7.78	8.18	5.14	6.39	5.24	5.14	4.62	4.42	4.62	6.56

3/27/2020	7.76	8.18	5.14	6.37	5.24	5.14	4.62	4.46	4.62	6.40
3/28/2020	7.73	8.18	5.14	6.37	5.24	5.14	4.62	4.52	4.62	6.37
3/29/2020	7.71	8.18	5.14	6.37	5.24	5.14	4.62	4.52	4.62	6.27
3/30/2020	7.70	8.18	5.14	6.35	5.29	5.14	4.66	4.52	4.71	6.37
3/31/2020	7.69	8.18	5.14	6.27	5.35	5.14	4.74	4.52	4.73	6.60
4/1/2020	7.68	8.18	5.14	6.25	5.35	5.14	4.83	4.62	4.83	6.97
4/2/2020	7.66	8.18	5.15	6.17	5.35	5.14	4.93	4.62	4.89	7.31
4/3/2020	7.66	8.18	5.14	6.17	5.41	5.15	5.02	4.62	4.96	7.55
4/4/2020	7.68	8.11	5.14	6.13	5.45	5.23	5.04	4.64	5.04	7.35
4/5/2020	7.66	8.08	5.13	6.13	5.45	5.24	5.04	4.73	5.13	6.86
4/6/2020	7.67	8.08	5.13	6.15	5.50	5.24	5.04	4.73	5.20	6.45
4/7/2020	7.66	8.08	5.14	6.09	5.55	5.24	5.04	4.73	5.29	6.47
4/8/2020	7.67	8.08	5.14	6.17	5.55	5.24	5.04	4.73	5.37	6.51
4/9/2020	7.67	8.08	5.14	6.17	5.55	5.24	5.04	4.79	5.45	6.75
4/10/2020	7.66	8.08	5.14	6.17	5.57	5.24	5.10	4.83	5.55	7.07
4/11/2020	7.65	8.08	5.14	6.17	5.65	5.24	5.17	4.83	5.62	7.47
4/12/2020	7.66	8.08	5.15	6.17	5.65	5.24	5.28	4.92	5.70	8.03
4/13/2020	7.66	8.08	5.14	6.13	5.65	5.26	5.40	4.94	5.80	8.52
4/14/2020	7.64	8.08	5.14	6.06	5.65	5.34	5.54	5.03	5.88	8.97
4/15/2020	7.63	8.08	5.15	6.06	5.72	5.35	5.70	5.05	5.96	9.21
4/16/2020	7.62	8.08	5.17	6.06	5.76	5.35	5.84	5.14	6.01	9.38
4/17/2020	7.61	8.08	5.23	6.06	5.78	5.35	5.95	5.17	6.06	9.50
4/18/2020	7.61	8.06	5.24	6.06	5.86	5.35	6.04	5.24	6.15	9.51
4/19/2020	7.62	8.00	5.24	6.06	5.88	5.35	6.11	5.31	6.23	9.63
4/20/2020	7.63	7.98	5.24	6.06	5.96	5.45	6.18	5.36	6.32	9.95
4/21/2020	7.63	7.98	5.24	6.06	5.97	5.45	6.27	5.45	6.42	10.25
4/22/2020	7.62	7.98	5.24	6.06	6.06	5.45	6.33	5.52	6.53	10.65
4/23/2020	7.61	7.98	5.24	6.06	6.06	5.47	6.37	5.59	6.63	11.03
4/24/2020	7.63	7.99	5.29	6.03	6.17	5.57	6.47	5.67	6.76	11.09
4/25/2020	7.63	7.98	5.24	5.96	6.17	5.55	6.55	5.76	6.86	10.89

4/26/2020	7.67	7.98	5.24	5.96	6.26	5.55	6.58	5.85	6.96	10.94
4/27/2020	7.81	7.98	5.24	5.96	6.27	5.65	6.67	5.93	7.08	11.03
4/28/2020	7.88	7.98	5.25	5.96	6.36	5.65	6.67	6.00	7.18	11.04
4/29/2020	7.87	7.97	5.31	5.96	6.37	5.68	6.69	6.08	7.28	11.17
4/30/2020	7.69	7.90	5.35	5.96	6.42	5.76	6.69	6.18	7.38	11.36
5/1/2020	7.77	7.88	5.35	5.96	6.47	5.76	6.67	6.28	7.45	11.52
5/2/2020	7.72	7.88	5.35	5.96	6.49	5.80	6.67	6.38	7.51	11.71
5/3/2020	7.72	7.88	5.35	5.97	6.57	5.86	6.67	6.48	7.58	11.77
5/4/2020	7.78	7.88	5.35	5.96	6.57	5.86	6.67	6.58	7.61	11.54
5/5/2020	7.78	7.88	5.35	5.96	6.60	5.95	6.67	6.68	7.68	11.17
5/6/2020	7.73	7.88	5.35	5.99	6.67	5.96	6.69	6.77	7.68	10.73
5/7/2020	7.78	7.88	5.35	6.06	6.67	6.02	6.77	6.85	7.75	10.37
5/8/2020	7.84	8.03	5.39	6.07	6.80	6.09	6.84	7.02	7.86	10.19
5/9/2020	7.68	7.88	5.35	6.06	6.77	6.10	6.90	7.03	7.78	10.36
5/10/2020	7.74	7.88	5.35	6.06	6.77	6.17	7.01	7.14	7.78	10.38
5/11/2020	7.78	7.88	5.35	6.06	6.77	6.17	7.11	7.23	7.78	10.42
5/12/2020	7.78	7.88	5.40	6.06	6.77	6.24	7.22	7.34	7.78	10.34
5/13/2020	7.78	7.88	5.45	6.06	6.78	6.27	7.34	7.45	7.78	10.07
5/14/2020	7.78	7.88	5.45	6.13	6.87	6.31	7.46	7.56	7.70	9.97
5/15/2020	7.78	7.88	5.45	6.16	6.88	6.37	7.57	7.65	7.68	10.02
5/16/2020	7.78	7.88	5.45	6.17	6.88	6.41	7.67	7.69	7.68	10.19
5/17/2020	7.78	7.90	5.45	6.17	6.91	6.47	7.74	7.78	7.68	10.42
5/18/2020	7.78	7.92	5.45	6.17	6.98	6.53	7.82	7.78	7.68	10.67
5/19/2020	7.78	7.98	5.45	6.17	6.98	6.57	7.90	7.87	7.68	10.88
5/20/2020	7.78	7.98	5.45	6.19	7.01	6.65	7.98	7.88	7.77	11.08
5/21/2020	7.78	7.98	5.45	6.27	7.08	6.67	8.07	7.88	7.78	11.29
5/22/2020	7.78	7.98	5.45	6.27	7.08	6.75	8.13	7.93	7.80	11.49
5/23/2020	7.78	7.98	5.49	6.27	7.13	6.79	8.19	7.98	7.88	11.70
5/24/2020	7.78	7.98	5.55	6.27	7.18	6.88	8.28	7.98	7.88	11.91
5/25/2020	7.81	7.98	5.55	6.27	7.18	6.92	8.29	7.98	7.92	12.10

5/26/2020	7.86	7.98	5.55	6.35	7.25	6.98	8.38	7.99	7.98	12.26
5/27/2020	7.88	7.98	5.55	6.37	7.28	7.03	8.38	8.08	7.98	12.35
5/28/2020	7.88	7.98	5.55	6.37	7.33	7.08	8.40	8.08	7.98	12.40
5/29/2020	7.88	7.98	5.55	6.37	7.38	7.12	8.48	8.14	7.98	12.50
5/30/2020	7.88	8.02	5.55	6.37	7.38	7.18	8.48	8.18	8.04	12.67
5/31/2020	7.88	8.08	5.63	6.44	7.48	7.22	8.55	8.25	8.08	12.86
6/1/2020	7.88	8.08	5.65	6.47	7.48	7.28	8.58	8.33	8.08	13.08
6/2/2020	7.93	8.11	5.66	6.51	7.58	7.37	8.73	8.39	8.18	13.37
6/3/2020	7.88	8.08	5.65	6.47	7.58	7.39	8.68	8.47	8.18	13.66
6/4/2020	7.88	8.08	5.65	6.55	7.58	7.48	8.77	8.48	8.22	13.86
6/5/2020	7.97	8.08	5.65	6.57	7.64	7.52	8.78	8.48	8.28	13.94
6/6/2020	7.98	8.08	5.65	6.57	7.68	7.58	8.78	8.55	8.32	13.87
6/7/2020	7.98	8.08	5.65	6.58	7.70	7.66	8.83	8.58	8.38	13.74
6/8/2020	7.98	8.11	5.65	6.67	7.78	7.69	8.88	8.58	8.43	13.57
6/9/2020	7.98	8.17	5.67	6.67	7.78	7.78	8.88	8.51	8.48	13.35
6/10/2020	7.98	8.18	5.75	6.67	7.79	7.78	8.88	8.43	8.54	13.22
6/11/2020	7.98	8.18	5.76	6.75	7.88	7.85	8.90	8.38	8.58	13.19
6/12/2020	7.98	8.18	5.76	6.77	7.88	7.88	8.98	8.45	8.65	13.37
6/13/2020	7.98	8.18	5.76	6.77	7.88	7.88	8.98	8.60	8.68	13.52
6/14/2020	7.98	8.18	5.76	6.82	7.93	7.97	9.06	8.74	8.68	13.66
6/15/2020	8.00	8.18	5.76	6.88	7.98	7.98	9.13	8.84	8.68	13.83
6/16/2020	8.07	8.18	5.76	6.88	7.98	8.07	9.22	8.88	8.73	13.95
6/17/2020	8.08	8.18	5.76	6.91	8.05	8.11	9.28	8.88	8.78	14.04
6/18/2020	8.08	8.18	5.76	6.98	8.08	8.18	9.37	8.90	8.85	14.04
6/19/2020	8.08	8.18	5.76	6.98	8.08	8.26	9.42	8.98	8.91	14.04
6/20/2020	8.08	8.19	5.83	7.01	8.17	8.29	9.47	8.98	8.98	14.04
6/21/2020	8.08	8.19	5.86	7.08	8.18	8.38	9.54	9.05	9.07	14.04
6/22/2020	8.08	8.25	5.86	7.08	8.21	8.40	9.57	9.08	9.16	14.12
6/23/2020	8.08	8.28	5.86	7.11	8.28	8.48	9.59	9.16	9.26	14.09
6/24/2020	8.08	8.28	5.86	7.18	8.28	8.49	9.67	9.18	9.36	14.04

6/25/2020	8.08	8.28	5.86	7.18	8.33	8.58	9.67	9.21	9.46	13.96
6/26/2020	8.11	8.28	5.86	7.19	8.38	8.58	9.70	9.24	9.58	13.94
6/27/2020	8.18	8.28	5.86	7.28	8.38	8.65	9.77	9.24	9.70	13.94
6/28/2020	8.18	8.28	5.86	7.28	8.38	8.68	9.77	9.27	9.80	14.00
6/29/2020	8.18	8.28	5.96	7.28	8.38	8.71	9.86	9.35	9.91	14.13
6/30/2020				7.49						
7/1/2020				7.38						
7/2/2020				7.38						
7/3/2020				7.45						
7/4/2020				7.49						
7/5/2020	8.18	8.37	5.96	7.48	8.48	8.98	9.97	9.27	10.67	14.42
7/6/2020	8.18	8.38	6.01	7.55	8.50	9.07	9.92	9.23	10.79	14.44
7/7/2020	8.24	8.38	6.06	7.58	8.58	9.08	9.87	9.18	10.92	14.56
7/8/2020	8.28	8.38	6.06	7.58	8.58	9.18	9.87	9.18	11.06	14.67
7/9/2020	8.28	8.38	6.06	7.64	8.58	9.21	9.87	9.18	11.17	14.74
7/10/2020	8.28	8.38	6.06	7.68	8.59	9.27	9.87	9.22	11.27	14.80
7/11/2020	8.28	8.38	6.06	7.68	8.68	9.32	9.87	9.27	11.36	14.85
7/12/2020	8.28	8.38	6.06	7.72	8.68	9.37	9.87	9.27	11.46	14.90
7/13/2020	8.28	8.38	6.06	7.78	8.68	9.37	9.94	9.27	11.54	14.99
7/14/2020	8.28	8.38	6.11	7.78	8.68	9.37	9.97	9.27	11.63	15.10
7/15/2020	8.28	8.38	6.17	7.87	8.74	9.37	9.98	9.34	11.71	15.31
7/16/2020	8.31	8.38	6.17	7.88	8.78	9.32	10.06	9.37	11.78	15.48
7/17/2020	8.38	8.38	6.17	7.95	8.78	9.37	10.07	9.37	11.85	15.57
7/18/2020	8.38	8.38	6.17	7.98	8.79	9.37	10.16	9.43	11.92	15.66
7/19/2020	8.38	8.38	6.17	8.03	8.88	9.42	10.16	9.47	11.99	15.66
7/20/2020	8.38	8.41	6.17	8.08	8.88	9.47	10.16	9.47	12.04	15.66
7/21/2020	8.38	8.48	6.26	8.12	8.91	9.47	10.20	9.53	12.11	15.66
7/22/2020	8.38	8.48	6.27	8.18	8.98	9.55	10.26	9.57	12.18	15.66
7/23/2020	8.38	8.48	6.27	8.19	9.08	9.57	10.26	9.57	12.23	15.66
7/24/2020	8.39	8.48	6.27	8.28	9.17	9.57	10.31	9.61	12.30	15.66

7/25/2020	8.47	8.48	6.27	8.28	9.18	9.65	10.36	9.67	12.37	15.66
7/26/2020	8.48	8.48	6.32	8.37	9.21	9.67	10.36	9.67	12.41	15.66
7/27/2020	8.48	8.48	6.37	8.38	9.19	9.67	10.38	9.68	12.50	15.66
7/28/2020	8.48	8.48	6.37	8.43	9.18	9.77	10.46	9.77	12.55	15.66
7/29/2020	8.57	8.65	6.40	8.57	9.20	9.78	10.47	9.89	12.76	15.78
7/30/2020	8.48	8.48	6.37	8.48	9.24	9.80	10.49	9.78	12.69	15.66
7/31/2020	8.48	8.48	6.39	8.58	9.27	9.87	10.55	9.87	12.74	15.66
8/1/2020	8.55	8.48	6.47	8.58	9.27	9.87	10.55	9.87	12.79	15.66
8/2/2020	8.58	8.48	6.47	8.62	9.34	9.94	10.58	9.87	12.88	15.66
8/3/2020	8.58	8.48	6.47	8.68	9.37	9.97	10.65	9.94	12.91	15.66
8/4/2020	8.58	8.49	6.47	8.69	9.38	9.97	10.65	9.97	12.98	15.66
8/5/2020	8.58	8.52	6.55	8.78	9.47	10.06	10.67	9.97	13.04	15.66
8/6/2020	8.58	8.57	6.57	8.78	9.47	10.06	10.75	9.97	13.08	15.66
8/7/2020	8.59	8.58	6.57	8.84	9.53	10.11	10.75	10.06	13.15	15.66
8/8/2020	8.68	8.58	6.57	8.88	9.57	10.16	10.75	10.06	13.17	15.66
8/9/2020	8.68	8.58	6.59	8.88	9.57	10.16	10.83	10.06	13.25	15.66
8/10/2020	8.68	8.58	6.67	8.88	9.67	10.25	10.85	10.07	13.27	15.66
8/11/2020	8.68	8.58	6.67	8.97	9.67	10.26	10.85	10.16	13.35	15.69
8/12/2020	8.68	8.58	6.67	8.98	9.70	10.30	10.94	10.20	13.37	15.76
8/13/2020	8.68	8.58	6.67	9.00	9.77	10.36	10.95	10.30	13.42	15.76
8/14/2020	8.75	8.58	6.77	9.08	9.77	10.37	11.04	10.36	13.46	15.76
8/15/2020	8.78	8.58	6.77	9.08	9.83	10.46	11.04	10.44	13.48	15.76
8/16/2020	8.78	8.58	6.77	9.17	9.87	10.48	11.08	10.46	13.56	15.73
8/17/2020	8.78	8.58	6.77	9.18	9.96	10.55	11.14	10.46	13.56	15.66
8/18/2020	8.78	8.58	6.84	9.24	9.97	10.60	11.14	10.55	13.65	15.66
8/19/2020	8.78	8.58	6.88	9.27	10.04	10.65	11.14	10.55	13.65	15.66
8/20/2020	8.86	8.58	6.88	9.36	10.06	10.66	11.23	10.55	13.70	15.66
8/21/2020	8.88	8.58	6.88	9.39	10.06	10.74	11.24	10.55	13.75	15.66
8/22/2020	8.88	8.60	6.93	9.47	10.14	10.75	11.24	10.55	13.75	15.66
8/23/2020	8.88	8.68	6.98	9.47	10.16	10.76	11.24	10.59	13.81	15.66

8/24/2020	8.88	8.68	6.98	9.52	10.20	10.85	11.32	10.65	13.85	15.66
8/25/2020	8.89	8.68	6.98	9.57	10.26	10.85	11.33	10.65	13.85	15.66
8/26/2020	8.97	8.68	7.03	9.57	10.26	10.88	11.33	10.65	13.92	15.66
8/27/2020	8.98	8.68	7.08	9.61	10.33	10.94	11.35	10.65	13.94	15.66
8/28/2020	8.98	8.68	7.08	9.67	10.36	10.94	11.43	10.68	13.94	15.73
8/29/2020	8.98	8.68	7.08	9.67	10.36	10.99	11.43	10.75	13.99	15.76
8/30/2020	8.98	8.68	7.13	9.75	10.40	11.04	11.46	10.75	14.04	15.76
8/31/2020	9.03	8.76	7.18	9.77	10.46	11.04	11.53	10.83	14.04	15.76
9/1/2020	9.08	8.78	7.18	9.79	10.46	11.12	11.53	10.85	14.04	15.76
9/2/2020	9.12	9.25	7.35	10.14	10.66	11.18	11.69	10.91	14.10	15.76
9/3/2020	9.08	8.78	7.22	9.87	10.55	11.18	11.63	10.85	14.04	15.76
9/4/2020	9.08	8.78	7.28	9.95	10.55	11.24	11.63	10.85	14.04	15.76
9/5/2020	9.10	8.78	7.28	9.97	10.55	11.30	11.63	10.85	14.04	15.76
9/6/2020	9.18	8.78	7.28	10.06	10.62	11.38	11.70	10.85	14.04	15.76
9/7/2020	9.18	8.78	7.33	10.11	10.65	11.57	11.72	10.87	14.03	15.76
9/8/2020	9.18	8.86	7.38	10.16	10.65	11.77	11.72	10.94	13.95	15.76
9/9/2020	9.18	8.88	7.38	10.24	10.71	11.88	11.78	10.94	13.94	15.76
9/10/2020	9.18	8.88	7.38	10.26	10.75	11.96	11.82	10.94	13.94	15.76
9/11/2020	9.27	8.88	7.43	10.36	10.75	12.01	11.82	10.94	13.94	15.81
9/12/2020	9.27	8.88	7.48	10.36	10.82	12.05	11.82	10.94	13.94	15.86
9/13/2020	9.27	8.88	7.48	10.44	10.85	12.10	11.91	10.94	13.94	15.86
9/14/2020	9.27	8.88	7.48	10.46	10.85	12.11	11.92	10.94	13.94	15.90
9/15/2020	9.27	8.92	7.56	10.52	10.89	12.11	11.92	10.94	13.94	15.95
9/16/2020	9.32	8.98	7.58	10.55	10.94	12.11	11.92	10.94	13.94	15.95
9/17/2020	9.37	8.98	7.58	10.58	10.94	12.16	12.00	10.94	13.94	15.98
9/18/2020	9.37	8.98	7.58	10.65	10.98	12.21	12.01	10.94	13.95	16.05
9/19/2020	9.37	8.98	7.66	10.65	11.04	12.21	12.01	10.94	13.97	16.05
9/20/2020	9.37	8.98	7.68	10.72	11.04	12.21	12.01	10.94	14.03	16.08
9/21/2020	9.39	8.98	7.68	10.75	11.04	12.21	12.07	10.94	14.04	16.14
9/22/2020	9.47	9.01	7.68	10.75	11.12	12.21	12.11	10.94	14.04	16.14

9/23/2020	9.47	9.08	7.75	10.81	11.14	12.21	12.11	10.94	14.04	16.14
9/24/2020	9.47	9.08	7.78	10.85	11.14	12.21	12.11	10.94	14.04	16.15
9/25/2020	9.47	9.08	7.78	10.85	11.14	12.21	12.11	10.94	14.04	16.23
9/26/2020	9.47	9.08	7.78	10.87	11.22	12.21	12.12	10.94	14.04	16.24
9/27/2020	9.55	9.08	7.87	10.94	11.24	12.17	12.19	10.94	13.98	16.24
9/28/2020	9.57	9.08	7.88	10.94	11.24	12.21	12.21	10.94	13.94	16.24
9/29/2020	9.57	9.13	7.88	10.94	11.24	12.21	12.21	10.94	13.94	16.24
9/30/2020	9.57	9.18	7.88	11.01	11.24	12.21	12.21	10.94	13.94	16.24
10/1/2020	9.57	9.18	7.96	11.04	11.24	12.21	12.21	10.94	13.94	16.21
10/2/2020	9.58	9.18	7.98	11.04	11.31	12.21	12.21	10.96	13.85	16.14
10/3/2020	9.67	9.18	7.98	11.04	11.33	12.21	12.24	11.03	13.85	16.14
10/4/2020	9.67	9.18	7.98	11.11	11.33	12.21	12.30	11.04	13.85	16.14
10/5/2020	9.67	9.18	8.03	11.14	11.33	12.21	12.30	11.04	13.85	16.14
10/6/2020	9.67	9.25	8.08	11.14	11.33	12.21	12.30	11.04	13.85	16.06
10/7/2020	9.67	9.27	8.08	11.14	11.34	12.21	12.30	11.04	13.85	16.05
10/8/2020	9.68	9.27	8.08	11.14	11.42	12.21	12.30	11.04	13.85	16.01
10/9/2020	9.77	9.27	8.11	11.16	11.43	12.21	12.30	11.04	13.85	15.95
10/10/2020	9.77	9.27	8.18	11.23	11.43	12.21	12.30	11.04	13.85	15.91
10/11/2020	9.77	9.27	8.18	11.24	11.43	12.21	12.30	11.04	13.85	15.85
10/12/2020	9.77	9.28	8.18	11.24	11.43	12.16	12.30	11.04	13.85	15.76
10/13/2020	9.77	9.35	8.18	11.24	11.43	12.05	12.22	11.04	13.79	15.70
10/14/2020	9.77	9.37	8.27	11.24	11.46	12.02	12.30	11.04	13.75	15.66
10/15/2020	9.84	9.37	8.28	11.24	11.53	11.92	12.30	11.12	13.75	15.66
10/16/2020	9.87	9.37	8.28	11.24	11.53	11.96	12.34	11.14	13.69	15.66
10/17/2020	9.87	9.37	8.28	11.24	11.53	12.01	12.40	11.26	13.65	15.57
10/18/2020	9.87	9.37	8.34	11.24	11.56	12.01	12.40	11.40	13.65	15.41
10/19/2020	9.87	9.38	8.38	11.24	11.63	12.01	12.42	11.43	13.65	15.23
10/20/2020	9.87	9.47	8.38	11.24	11.64	12.01	12.41	11.43	13.65	15.11
10/21/2020	9.87	9.47	8.38	11.24	11.72	12.01	12.41	11.43	13.65	15.01
10/22/2020	9.96	9.47	8.38	11.24	11.72	12.06	12.40	11.43	13.65	14.91

10/23/2020	9.97	9.47	8.44	11.24	11.72	12.10	12.40	11.43	13.62	14.78
10/24/2020	9.97	9.47	8.48	11.24	11.72	12.08	12.40	11.43	13.56	14.66
10/25/2020	9.97	9.47	8.48	11.22	11.72	12.01	12.40	11.48	13.56	14.55
10/26/2020	9.97	9.47	8.48	11.14	11.75	12.01	12.40	11.53	13.56	14.43
10/27/2020	9.97	9.56	8.48	11.14	11.82	12.01	12.40	11.53	13.56	14.27
10/28/2020	9.97	9.57	8.56	11.14	11.82	12.01	12.40	11.53	13.49	14.10
10/29/2020	9.97	9.57	8.58	11.14	11.82	11.94	12.40	11.49	13.46	13.94
10/30/2020	10.02	9.57	8.58	11.14	11.82	11.92	12.40	11.43	13.46	13.79
10/31/2020	10.06	9.57	8.58							
11/1/2020	10.06	9.57	8.58							
11/2/2020	10.06	9.57	8.62							
11/3/2020										
11/4/2020	10.06	9.67	8.68			11.73	12.30	11.33	13.12	13.06
11/5/2020	10.06	9.67	8.68			11.72	12.28	11.24	13.04	12.92
11/6/2020	10.06	9.67	8.68	11.04	11.72	11.63	12.21	11.21	12.95	12.75
11/7/2020	10.06	9.67	8.68	10.99	11.72	11.58	12.21	11.14	12.86	12.60
11/8/2020	10.06	9.67	8.71	10.94	11.72	11.53	12.17	11.14	12.76	12.44
11/9/2020	10.08	9.67	8.78	10.94	11.72	11.48	12.11	11.14	12.67	12.11
11/10/2020	10.15	9.67	8.78	10.94	11.72	11.43	12.09	11.14	12.57	11.60
11/11/2020	10.16	9.70	8.78	10.87	11.69	11.43	12.01	11.14	12.48	11.15
11/12/2020	10.16	9.77	8.78	10.85	11.63	11.36	12.01	11.14	12.38	10.75
11/13/2020	10.16	9.77	8.78	10.85	11.63	11.33	11.92	11.14	12.27	10.49
11/14/2020	10.16	9.77	8.78	10.83	11.63	11.29	11.91	11.04	12.16	10.36
11/15/2020	10.16	9.77	8.78	10.75	11.58	11.24	11.82	11.03	12.04	10.16
11/16/2020	10.16	9.77	8.85	10.75	11.53	11.19	11.78	10.94	11.89	9.68
11/17/2020	10.16	9.77	8.88	10.75	11.53	11.14	11.72	10.94	11.73	9.30
11/18/2020	10.16	9.77	8.88	10.67	11.46	11.11	11.68	10.86	11.62	8.87
11/19/2020	10.16	9.77	8.88	10.65	11.41	11.04	11.63	10.82	11.49	8.44
11/20/2020	10.16	9.77	8.88	10.65	11.33	10.98	11.56	10.75	11.33	8.09
11/21/2020	10.16	9.77	8.88	10.61	11.27	10.94	11.53	10.75	11.20	7.79

11/22/2020	10.16	9.77	8.88	10.55	11.23	10.85	11.44	10.68	11.02	7.47
11/23/2020	10.16	9.77	8.88	10.55	11.15	10.81	11.42	10.65	10.88	7.19
11/24/2020	10.16	9.69	8.88	10.53	11.13	10.75	11.34	10.65	10.72	6.99
11/25/2020	10.16	9.67	8.88	10.46	11.04	10.70	11.32	10.55	10.55	6.86
11/26/2020	10.16	9.67	8.87	10.46	11.02	10.65	11.24	10.55	10.42	6.77
11/27/2020	10.16	9.67	8.84	10.43	10.94	10.59	11.18	10.51	10.27	6.74
11/28/2020	10.16	9.67	8.80	10.36	10.90	10.55	11.13	10.46	10.13	6.65
11/29/2020	10.16	9.67	8.78	10.36	10.85	10.48	11.04	10.42	10.01	6.58
11/30/2020	10.16	9.67	8.79	10.34	10.82	10.46	10.98	10.36	9.91	6.69
12/1/2020	10.16	9.67	8.85	10.26	10.75	10.36	10.93	10.29	9.77	6.81
12/2/2020	10.16	9.67	8.88	10.26	10.75	10.34	10.85	10.24	9.65	6.91
12/3/2020	10.16	9.67	8.88	10.23	10.68	10.26	10.85	10.15	9.52	6.98
12/4/2020	10.16	9.67	8.88	10.16	10.65	10.24	10.75	10.06	9.42	7.07
12/5/2020	10.16	9.67	8.88	10.16	10.63	10.16	10.74	10.02	9.30	7.08
12/6/2020	10.16	9.67	8.88	10.15	10.56	10.15	10.66	9.97	9.19	7.17
12/7/2020	10.16	9.67	8.88	10.06	10.55	10.06	10.63	9.96	9.06	7.18
12/8/2020	10.16	9.67	8.88	10.06	10.55	10.03	10.55	9.87	8.94	7.18
12/9/2020	10.16	9.67	8.88	10.06	10.53	9.97	10.55	9.82	8.82	7.18
12/10/2020	10.16	9.67	8.88	9.99	10.44	9.87	10.50	9.72	8.71	7.18
12/11/2020	10.16	9.67	8.88	9.97	10.36	9.79	10.45	9.60	8.60	7.08
12/12/2020	10.16	9.67	8.88	9.97	10.30	9.77	10.36	9.53	8.51	6.94
12/13/2020	10.16	9.67	8.88	9.91	10.26	9.68	10.31	9.47	8.40	6.77
12/14/2020	10.16	9.71	8.88	9.87	10.25	9.67	10.25	9.38	8.32	6.62
12/15/2020	10.16	9.73	8.88	9.87	10.17	9.59	10.16	9.37	8.21	6.43
12/16/2020	10.16	9.75	8.84	9.80	10.16	9.57	10.08	9.28	8.11	6.28
12/17/2020	10.16	9.76	8.79	9.77	10.11	9.53	10.03	9.27	8.02	6.12
12/18/2020	10.16	9.77	8.78	9.77	10.06	9.47	9.97	9.18	7.92	6.03
12/19/2020	10.16	9.77	8.78	9.73	10.06	9.45	9.89	9.16	7.82	5.86
12/20/2020	10.12	9.77	8.78	9.67	9.98	9.37	9.83	9.08	7.72	5.69
12/21/2020	10.06	9.77	8.78	9.64	9.91	9.32	9.74	8.95	7.64	5.33

12/22/2020	10.06	9.76	8.78	9.58	9.77	9.27	9.66	8.85	7.52	4.92
12/23/2020	10.06	9.72	8.78	9.57	9.68	9.22	9.56	8.72	7.42	4.57
12/24/2020	10.06	9.67	8.78	9.57	9.66	9.12	9.41	8.61	7.31	4.34
12/25/2020	10.06	9.67	8.78	9.53	9.58	9.03	9.27	8.53	7.18	4.14
12/26/2020	10.06	9.67	8.78	9.42	9.54	8.96	9.14	8.48	7.06	4.00
12/27/2020	10.06	9.67	8.78	9.27	9.47	8.88	9.03	8.45	6.93	3.89
12/28/2020	10.06	9.67	8.78	9.18	9.40	8.83	8.97	8.38	6.81	3.86
12/29/2020	10.06	9.67	8.78	9.18	9.36	8.78	8.89	8.36	6.70	3.79
12/30/2020	10.06	9.72	8.77	9.17	9.28	8.78	8.88	8.28	6.58	3.74
12/31/2020	10.02	9.77	8.68	9.11	9.23	8.69	8.80	8.28	6.46	3.68
1/1/2021	9.97	9.77	8.68	9.08	9.17	8.68	8.78	8.18	6.37	3.68
1/2/2021	9.97	9.77	8.68	9.08	9.10	8.68	8.72	8.18	6.27	3.68
1/3/2021	9.97	9.77	8.68	9.06	9.07	8.68	8.68	8.14	6.18	3.59
1/4/2021	9.97	9.77	8.68	9.01	8.99	8.60	8.65	8.08	6.09	3.58
1/5/2021	9.97	9.77	8.68	8.98	8.94	8.58	8.58	8.02	6.02	3.58
1/6/2021	9.97	9.77	8.68	8.97	8.88	8.55	8.54	7.97	5.96	3.58
1/7/2021	9.97	9.77	8.64	8.88	8.81	8.48	8.48	7.88	5.87	3.58
1/8/2021	9.96	9.77	8.58	8.90	8.78	8.48	8.39	7.80	5.81	3.58
1/9/2021	9.88	9.77	8.58	8.88	8.78	8.41	8.34	7.73	5.75	3.58
1/10/2021	9.87	9.77	8.58	8.88	8.75	8.38	8.26	7.68	5.65	3.49
1/11/2021	9.87	9.77	8.58	8.83	8.68	8.38	8.18	7.60	5.61	3.47
1/12/2021	9.87	9.77	8.58	8.78	8.68	8.33	8.10	7.57	5.55	3.51
1/13/2021	9.87	9.77	8.58	8.77	8.65	8.28	8.03	7.48	5.47	3.57
1/14/2021	9.87	9.75	8.52	8.63	8.65	8.06	7.88	7.33	5.45	3.57
1/15/2021	9.86	9.67	8.38	8.45	8.54	7.74	7.60	7.14	5.41	3.28
1/16/2021	9.78	9.67	8.33	8.39	8.20	7.75	7.58	6.93	5.25	3.21
1/17/2021	9.77	9.67	8.28	8.40	7.96	7.78	7.65	6.79	5.07	3.48
1/18/2021	9.77	9.66	8.19	8.45	7.72	7.79	7.68	6.76	4.89	3.63
1/19/2021	9.77	9.57	8.14	8.48	7.59	7.80	7.64	6.67	4.75	3.76
1/20/2021	9.77	9.57	8.08	8.48	7.47	7.79	7.51	6.67	4.59	3.87

1/21/2021	9.73	9.57	8.01	8.48	7.37	7.78	7.33	6.65	4.47	3.72
1/22/2021	9.67	9.57	7.98	8.50	7.31	7.75	7.14	6.57	4.39	3.53
1/23/2021	9.67	9.57	7.89	8.52	7.24	7.69	6.96	6.56	4.31	3.47
1/24/2021	9.67	9.50	7.86	8.56	7.22	7.63	6.80	6.47	4.27	3.51
1/25/2021	9.67	9.47	7.79	8.55	7.21	7.57	6.65	6.43	4.21	3.51
1/26/2021	9.67	9.47	7.76	8.49	7.24	7.51	6.58	6.37	4.21	3.41
1/27/2021	9.63	9.47	7.68	8.48	7.27	7.48	6.52	6.31	4.21	3.36
1/28/2021	9.57	9.47	7.65	8.48	7.31	7.42	6.45	6.27	4.14	3.26
1/29/2021	9.57	9.47	7.58	8.48	7.39	7.38	6.39	6.18	4.10	3.26
1/30/2021	9.57	9.47	7.53	8.48	7.48	7.38	6.33	6.16	4.10	3.26
1/31/2021	9.56	9.47	7.47	8.48	7.54	7.29	6.27	6.06	4.10	3.36
2/1/2021	9.47	9.47	7.38	8.47	7.59	7.28	6.27	6.05	4.07	3.46
2/2/2021	9.47	9.47	7.34	8.46	7.65	7.28	6.27	5.96	4.00	3.48