Mora-Wagon Mound SWCD

Hydrogeology Project

Annual Progress Report

2018-2019

Please note that the contents of this report are proprietary to Zeigler Geologic Consulting, LLC, Western Geoinformatics, the Mora-Wagon Mound SWCD and the members of the High Plains Grasslands Alliance. If you wish to use any of the information in this report, please contact us for permission.

Zeigler Geologic Consulting, LLC
13170 Central Ave. SE, Suite B #137
Albuquerque, NM 87123
zeiglergeo@gmail.com; zeiglergeo.com
(505) 263.5448 (575) 207.7826

Kate Zeigler, Ph.D., CPG

Ethan Williams, B.S.

Brooklyn Armijo

WESTERN GEOINFORMATICS
415 Camino de la Tierra
Corrales, NM 87048
(406) 544.2133

Andrew Yuhas, M.S.

Contents

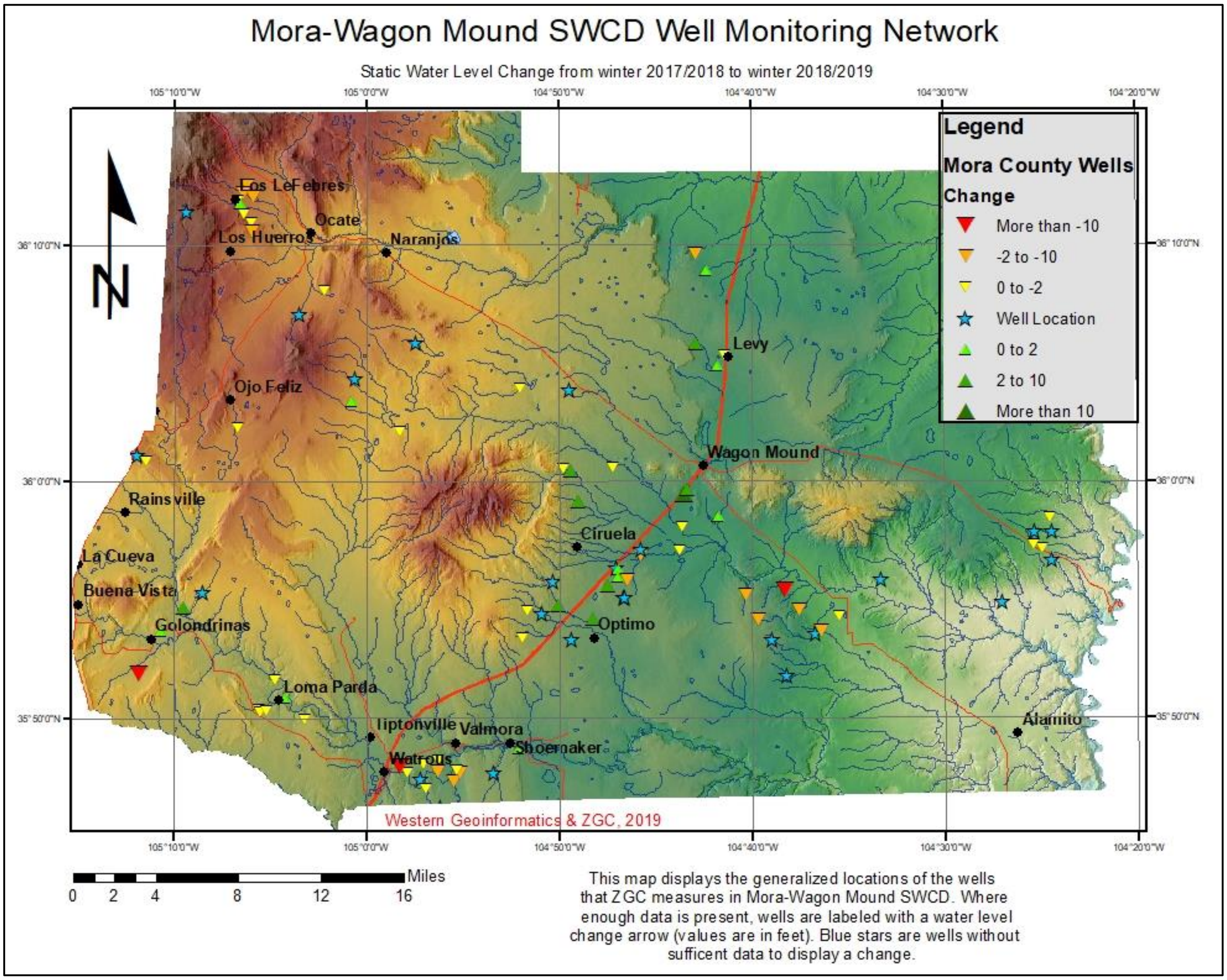
Introduction

This report is Zeigler Geologic Consulting, LLC's (ZGC) annual progress report for the Mora-Wagon Mound Hydrogeology Project, sponsored by the Mora-Wagon Mound Soil and Water Conservation District and the High Plains Grasslands Alliance. During the 2018-2019 fiscal year, ZGC measured static water level in 88 wells, continued revisions of maps around the Turkey Mountains, continued detailed mapping of the Mogote Hills-Wagon Mound and Ocate areas, and reviewed the data from eight data loggers. Here we describe the progress in each of these tasks. We also hosted a groundwater workshop in Ocate in early June to continue to provide information to the communities and producers served by this project. We would like to thank the Mora-Wagon Mound SWCD and the Soil and Water Conservation Commission for funding this project.

Static Water Level Measurements

In August and December of 2018 and January of 2019, depth to water was measured in 88 wells around the District to document maximum (August) and minimum (December) use water levels (Figure 1). We have continued to observed three discrete groupings of water levels in the District area, a shallow zone of water levels between 10' and 40', an intermediate zone between 150' and 300' and a deeper zone with water levels greater than 350'.

Of the 88 wells visited over the past fiscal year, 27 wells showed increases in water level, 52 showed decreases, the water level in one well remained unchanged, and two new wells were added. Six wells were not measured in the winter 18-19 season due to infrastructure issues or wells being dry. Compared to the previous year, where the majority of wells measured showed increasing water levels, this year showed the majority of wells exhibiting falling water levels.



Mora-Wagon Mound SWCD Well Monitoring Network

Static Water Level Change from winter 2017/2018 to winter 2018/2019

Western Geoinformatics & ZGC, 2019

This map displays the generalized locations of the wells that ZGC measures in Mora-Wagon Mound SWCD. Where enough data is present, wells are labeled with a water level change arrow (values are in feet). Blue stars are wells without sufficent data to display a change.

Figure 1. Location of wells and comparison of water levels from winter 17/18 to winter 18/19 where possible for wells in the Mora-Wagon Mound groundwater network.

Water Chemistry

Beginning in February 2015, approximately half a liter of water was collected from each of 25 wells and one spring for basic water chemistry analyses of major cations and anions as well as trace metals. Following initial sample collection, three of the wells had duplicate samples collected and analyzed for three subsequent years, two wells had duplicates collected and analyzed for two subsequent years and the spring had one duplicate sample analyzed. The analytical work was conducted by the New Mexico Bureau of Geology and Mineral Resources in Socorro. Major ion chemistry analyses include the cations calcium (Ca), sodium (Na), magnesium (Mg), and potassium (K), and the anions carbonate (CO_3), bicarbonate (HCO_3), sulfate (SO_4), and chloride (Cl). Trace metal analyses showed moderately elevated levels of iron, copper, and manganese in three wells, although no wells had concentrations of any of the 26 different trace metals tested for above drinking water standards (EPA method 200.8). We recommend Hem's (1985) *Study and Interpretation of the Chemical Characteristics of Natural Waters* for an in-depth review of groundwater chemistry. A Piper diagram (Figure 2) shows the concentrations of major cations and anions for all of the wells sampled to date.

Analyses of these 25 samples resulted in Ca, Mg, and Na as dominant cations and HCO_3, and SO_4 as dominant anions. Of these samples, 14 are of the Ca-(Mg)-HCO_3 water type, six are mixed cation-HCO_3 water type, five are Na-HCO_3, one is Na-SO_4 type and the remaining one is mixed cation-SO_4. The Ca-Mg-HCO_3 types correspond to wells completed through the Dakota Group and Quaternary alluvium. Ca-Mg-HCO_3 waters have been used as an indicator of shorter residence time of groundwater in aquifer systems, due to the lack of other cations and anions indicating too short of a time to dissolve minerals. Na-HCO_3 water types are assumed to indicate a longer residence time and these water types correspond to waters from the Graneros Shale and Greenhorn Limestone, which consist of black and gray shales, thin limestone beds and limey sandstone units. Ca-(Na)-SO_4 water types primarily reflect water from Graneros Shale and Greenhorn Limestone and correspond to the presence of local zones with higher concentrations of gypsum, a calcium sulfate.

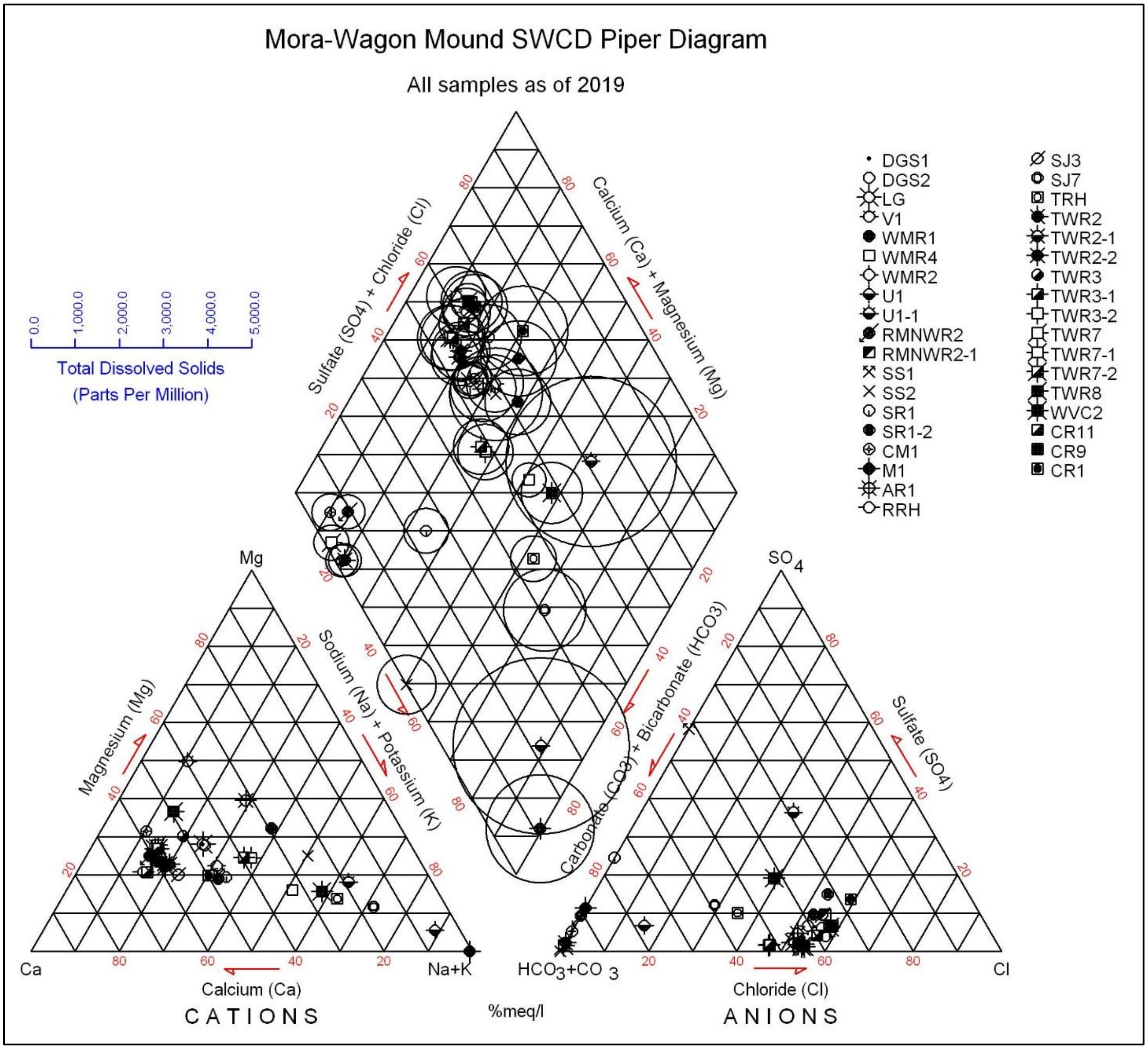


Figure 2. **Piper diagram for water chemistry samples collected from 2017 through January 2019 from Colfax County. Circles indicate total dissolved solids for each well – larger circles indicate higher TDS.**

Carbon-14 and Tritium Dates

One liter of water was collected from 10 wells and three springs for carbon-14 isotope analysis (Figure 3, Table 1); the samples were analyzed by Beta Analytic, Inc. in Miami, Florida. Groundwater age is related to the rate at which water migrates through the subsurface. It is important to remember that water molecules may enter and leave the system via cross-formational flow and that any given mass of groundwater will exchange water molecules with masses of water on all sides of it (Bethke and Johnson, 2008). Hence, a mass of water that entered the groundwater and had a single age associated with it will end up with many of those particles dispersed, rather than traveling entirely as a discrete package. A groundwater sample, therefore, is an average of the ages of all of the molecules of water contained in that sample (Bethke and Johnson, 2008). The distribution of these ages for each sample may include much older molecules and much younger molecules, and may be heavily skewed in one direction or the other. One complication for the ^{14}C method is that the oxidation of ancient organic matter or the dissolution of carbonates (e.g., limestone) will add ^{14}C-depleted carbon (also called "dead" carbon) into the groundwater (Bethke and Johnson, 2008). This process will create an erroneously old age and so ages of water extracted from systems that are suspected of including carbonate interactions should be corrected for this depleted carbon addition.

For this study, geochemical interactions with the host rocks in the Dakota Group or the shallow alluvial aquifers are unlikely to contribute significant amounts of "dead" carbon due to a lack of significant quantities of carbonate rocks. However, wells drawing water from the shale and limestone-dominated units above the Dakota Group, including the Graneros Shale, Greenhorn Limestone, and Niobrara Group, will probably have skewed age results due to the presence of limestone beds within these units.

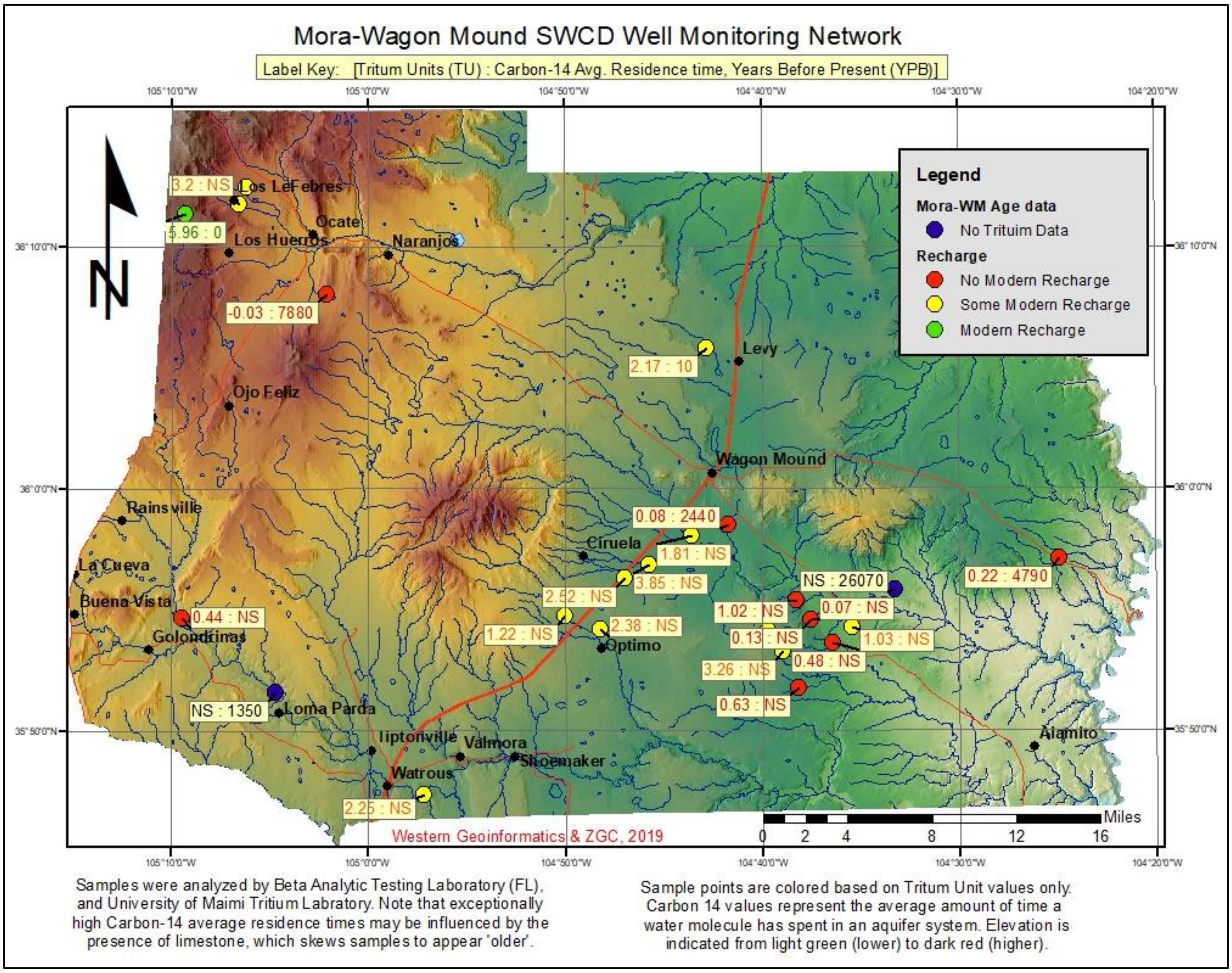
Twenty-six samples were analyzed by the Tritium Laboratory at the University of Miami. Tritium is a radioactive isotope that has a very short half-life of just 12.3 years. It is most commonly used to determine relative age of waters that are less than fifty years old (Clark and Fritz, 1997). Tritium is produced both as a natural byproduct of interaction of cosmic radiation with the stratosphere and comes into the water cycle by precipitation, but also was produced anthropogenically in large volumes during testing of thermonuclear bombs in the 1950s. The majority of the bomb-produced tritium has decreased significantly such that most modern dating is reflecting the natural tritium signal (Clark and Fritz, 1997). Generally, a tritium value (in tritium units or TU) less than 0.8 TU indicates pre-1952 or no modern recharge. Tritium values between 0.8 TU and 4.0 TU indicate a mixture of modern recharge and pre-1952 recharge and values between 5 TU and 15 TU indicate waters that are modern (5-10 years old).

Table 1: Tritium and 14-Carbon Results.

Sample ID	**Tritium (in TU*)**	**^{14}C Date (YBP*)**	**Age Interpretation**
Wells			
TWR 8	5.96	0	Modern
TWR 2	2.93	0	Modern
TWR 7	3.2	--	Mixed
SR 1	0.22	4,790	Pre-1952
RMNWR 2	--	1,350	Pre-1952?
CM	-0.03	7,880	Pre-1952
PR 8	0.03	21,630**	Pre-1952
PR 2	--	160	Modern?
WMR 3	0.08	2,440	Pre-1952
WMR 2	1.81	--	Mixed
WMR 4	3.85	--	Mixed
SS 1	2.17	10	Mixed
MLC 1	--	26,070**	Pre-1952?
TR 2	0.44	--	Pre-1952
RR house	0.13	--	Pre-1952
WVC 1	2.25	--	Mixed
AR 1	0.07	--	Pre-1952
CR 1	2.52	--	Mixed
CR 9	2.38	--	Mixed
CR 11	1.22	--	Mixed
SJ house	0.02	--	Pre-1952
SJ 1	0.89	--	Pre-1952
SJ 2	3.26	--	Mixed
SJ 3	0.63	--	Pre-1952
SJ 5	0.48	--	Pre-1952
SJ 6	1.03	--	Mixed
Springs			
SS	--	310	Mixed-Modern
DG	--	920	Pre-1952?
WM	2.12	820	Mixed

*TU = tritium units. YBP = Years before present.

**14-carbon results may be skewed by presence of “dead” carbon in limestone units.



Mora-Wagon Mound SWCD Well Monitoring Network

Label Key: [Tritum Units (TU) : Carbon-14 Avg. Residence time, Years Before Present (YPB)]

Western Geoinformatics & ZGC, 2019

Samples were analyzed by Beta Analytic Testing Laboratory (FL), and University of Maimi Tritium Labratory. Note that exceptionally high Carbon-14 average residence times may be influenced by the presence of limestone, which skews samples to appear 'older'.

Sample points are colored based on Tritum Unit values only. Carbon 14 values represent the average amount of time a water molecule has spent in an aquifer system. Elevation is indicated from light green (lower) to dark red (higher).

Figure 3. Tritium and ^{14}C data for the Mora-Wagon Mound project area.

Wells showing significant tritium levels and younger average residence times are all located close to drainages and have shallow water levels. Wells with little to no measurable tritium and older average residence times generally have deeper water levels and do not seem to be receiving significant modern recharge. Several of the 14-carbon results are presumably skewed by the presence of limestone in the rock units these wells are drawing water from.

Geologic Mapping and Cross Sections

We are continuing mapping and digitizing of the following 1:24,000 quadrangles: Wagon Mound, Mogote Hills, Optimo, Maxson Crater, Fort Union, Loma Parda, Ocate and Guadalupita. Bedrock outcrops include (in age order) the Permian Sangre de Cristo Formation and Glorieta Sandstone, Triassic Dockum Group, Jurassic Exeter (?Entrada) Sandstone and Morrison Formation, Cretaceous Dakota Sandstone, Graneros Shale, Greenhorn Limestone, and Carlile Shale, Miocene-Pliocene gravels (possibly relict Ogallala Formation) and Quaternary volcanic deposits, as well as Recent eolian sand and alluvial deposits (Figure 4).

Sangre de Cristo Formation deposits include very coarse-grained reddish-pink sandstone and pale purple conglomerate deposited as large-scale fans building off of the Ancestral Rocky Mountains. As those mountains were beginning to erode, sea level rose to flood much of the interior of New Mexico. The Glorieta Sandstone reflects beach deposits related to this interior seaway. The later part of the Permian and the Early to Middle Triassic portion of the rock record is missing in most of the project area, such that the Upper (=Late) Triassic Dockum Group redbeds sit atop the Glorieta Sandstone. These strata represent deposition in a complex landscape of rivers, fan systems and shallow marshy ponds. Above the Dockum Group are the yellow sandstones of the Exeter Sandstone, which is Middle Jurassic in age and was deposited as part of a large dune field that covered much of the Four Corners. The Exeter Sandstone is overlain by the Middle to Late-age Jurassic Morrison Formation, which includes green, purple, blue and pale red mudstone, gray limestone beds and pale gray sandstone lenses. As with the Dockum Group, the Morrison Formation was deposited by rivers, lakes and fan systems.

The earliest Cretaceous strata are not present in the project area, and the Upper Cretaceous Dakota Group sits above the Morrison Formation. Divided into three parts, the Dakota Group represents another episode where sea level rose enough to flood the interior of the continent. The Dakota Group was deposited in nearshore and beach environments and the overlying Graneros Shale, Greenhorn Limestone and Carlile Shale were formed as the seaway rose further such that eastern New Mexico was completely inundated. The record of deposition from the latest Cretaceous through the Oligocene is not present in the project area, aside from the Oligocene-age igneous intrusions that form the core of the Turkey Mountains. These rocks are not exposed, but are known from exploratory oil exploration drilling efforts in the 1980s. The

Miocene-Pliocene gravels that cap many of the mesa surfaces and occur as thin gravel beds on the surface of the landscape are probably relict Ogallala Formation deposits, representing the remnants of the large alluvial fans that formed off the newly-uplifted Rocky Mountains. These deposits are covered in places by the Quaternary basalt flows of the Ocate Volcanic Field and/or by modern alluvium and eolian sheet sands.

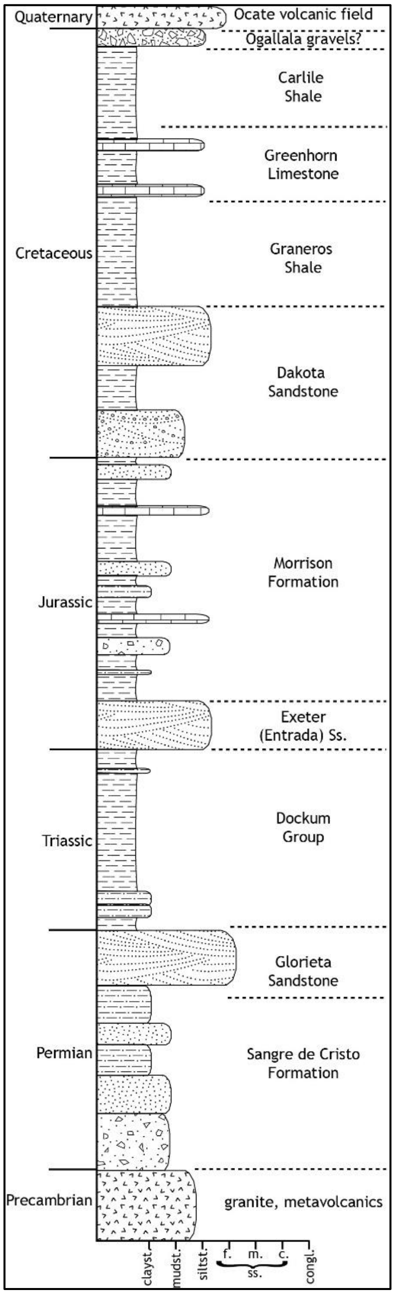


Figure 4. Schematic stratigraphic column showing the rock units in the project area.

Summary

As noted in previous progress reports, combined information from water chemistry, static water levels, well log data, and surface mapping demonstrate the complexity of the geology in the Mora-Wagon Mound District area. Zones of groundwater appear to occur at discrete depths over much of the District area: shallow (0 – 40’), intermediate (150-300’) and deep (>350’), which appear to correlate reasonably well to alluvial (shallow), the Dakota Sandstone (intermediate) and the Morrison Formation (deep). Additional structural complexities, such as the Ocate anticline and the Turkey Mountains, as well as paleotopography developed on the Morrison Formation, bring deeper and older rock units to the surface. Tritium isotopic data appear to indicate that there is some modern recharge reaching groundwater sources locally, but in many places, there is not volumetrically significant young water making its way into the aquifer systems.

Future work includes continued monitoring of static water level measurements to continue tracking rates of changes between minimum and maximum use seasons and on an annual basis. Continued geologic mapping and petroleum well log analyses will assist in developing a better picture of the complexities of the subsurface.

Appendices

Appendix I: Static Water Level Measurements

Individual well static water level measurements, corrected to land surface. *indicates measurement that is significantly different than previous or following measurements. For some wells, this is probably related to maintenance performed on the well that caused it to draw more water after the maintenance (e.g. LG #1). For wells where a measurement could not be obtained, "n/m" indicates "not measured".

ID	Date Measured	Depth to Water Below Land Surface (ft)
MLC #1	2/12/2015	72.54
	8/17/2015	72.55
	12/8/2015	73.20
	8/15/2016	73.20
	12/13/2016	74.90
	7/24/2017	74.56
	1/24/2018	75.09
	7/18/2018	74.90
	2/21/2019	76.13
MLC #2	1/19/2015	133.70
	8/18/2015	106.30
	12/8/2015	109.31
	8/15/2016	110.52
	12/13/2016	115.26
	7/24/2017	n/m
SR #1	1/19/2015	n/m
	8/18/2015	136.40
	12/8/2015	118.64
	8/15/2016	111.60
	12/12/2016	112.89
	7/24/2017	104.83
	12/18/2017	104.79
	7/17/2018	n/m
	12/10/2018	104.97

SR #3	1/19/2015	233.30
	8/18/2015	233.06
	12/8/2015	233.12
	8/15/2016	233.42
	12/12/2016	233.02
	7/24/2017	233.06
	12/18/2017	233.05
	7/17/2018	233.45
	12/10/2018	233.60
SR #4	7/24/2017	140.31
	7/17/2018	140.07
	12/10/2018	139.93
SR #5	1/19/2015	116.38
	8/18/2015	116.28
	12/8/2015	116.37
	8/15/2016	116.92
	12/12/2016	116.58
	7/24/2017	121.25
	12/18/2017	116.48
	7/17/2018	121.48
	12/10/2018	117.00
TWR #1	1/20/2015	87.06
	8/17/2015	86.19
	12/10/2015	85.41
	8/26/2016	85.72
	12/15/2016	86.54
	7/20/2017	86.39
	12/21/2017	85.18
	7/10/2018	86.16
	12/6/2018	86.45
TWR #2	1/20/2015	46.24
	5/21/2015	45.48
	8/17/2015	42.74
	12/10/2015	43.10
	8/26/2016	42.95
	12/15/2016	44.73
	7/20/2017	43.45
	1/23/2018	42.36

	7/10/2018	45.28
	12/11/2018	44.47
TWR #3	2/26/2016	40.43
	8/26/2016	40.49
	12/15/2016	40.62
	7/20/2017	41.16
	12/21/2017	39.86
	7/10/2018	41.07
	12/6/2018	41.34
TWR #4	2/26/2016	54.60
	8/26/2016	54.59
	12/15/2016	54.82
	7/20/2017	55.20
	12/21/2017	54.82
	7/10/2018	56.16
	12/6/2018	56.86
TWR #5	2/26/2016	41.43
	8/26/2016	41.03
	12/15/2016	42.63
	7/20/2017	41.62
	12/21/2017	39.62
	7/10/2018	43.65
	12/6/2018	42.64
TWR #7	2/26/216	41.64
	8/26/2016	39.92
	12/15/2016	42.47
	7/20/2017	44.10
	12/21/2017	42.26
	7/10/2018	41.73
	12/6/2018	41.76
TWR #8	8/26/2016	41.35
	12/15/2016	41.55
	12/21/2017	44.53
	2/22/2018	45.98
	7/10/2018	42.71
	12/6/2018	n/m
TWR #9	10/10/2017	132.16

	1/23/2018	129.42
	7/10/2018	134.33
	12/11/2018	135.15
RMNWR #1	2/8/2015	129.51
	8/19/2015	129.31
	12/9/2015	129.01
	8/16/2016	130.96
	12/14/2016	130.82
	7/21/2017	130.88
	12/20/2017	129.65
	7/9/2018	130.20
	12/5/2018	131.00
RMNWR #2	2/8/2015	28.40
	8/19/2015	27.81
	12/9/2015	29.00
	8/16/2016	29.09
	12/14/2016	30.57
	7/20/2017	30.96
	12/20/2017	30.75
	7/9/2018	31.63
	12/5/2018	31.55
RMNWR #3	2/8/2015	3.75
	8/19/2015	2.62
	12/9/2015	3.45
	8/16/2016	3.75
	12/14/2016	3.78
	7/20/2017	3.47
	12/20/2017	3.35
	7/9/2018	3.40
	12/5/2018	1.44
WMR #1	2/9/2015	38.10
	8/20/2015	44.60
	12/8/2015	32.86
	8/16/2016	28.91
	7/21/2017	28.71
	1/15/2018	23.61
	7/19/2018	26.50
	1/23/2019	27.43

WMR #2	2/9/2015	23.90
	8/20/2015	24.59
	12/8/2015	24.71
	8/16/2016	24.87
	12/12/2016	25.02
	7/12/2017	25.18
	12/22/2017	22.15
	7/18/2018	22.60
	12/6/2018	23.29
WMR #3	2/9/2015	46.82
	8/20/2015	46.62
	12/8/2015	46.26
	8/16/2016	46.47
	12/12/2016	46.60
	7/12/2017	46.68
	11/1/2017	46.06
	7/10/2018	46.96
	12/10/2018	45.45
WMR #4	12/12/2016	18.23
	7/12/2017	19.43
	12/22/2017	12.40
	7/18/2018	14.44
	12/6/2018	14.67
WMR #5	7/24/2017	48.93
	1/15/2018	40.48
	7/10/2018	42.27
	12/10/2018	41.12
DG #1	2/9/2015	174.83
	8/19/2015	174.86
	12/10/2015	175.00
	8/17/2016	175.21
	1/26/2017	174.15
	8/1/2017	175.55
	12/21/2017	175.53
	7/17/2018	175.69
	2/1/2019	175.85
S&S #1	2/10/2015	43.82
	8/18/2015	44.31

	12/9/2015	45.88
	8/15/2016	48.22
	12/12/2016	44.13
	7/12/2017	48.22
	12/18/2017	48.71
	7/10/2018	48.06
	12/6/2018	44.41
S&S #2	2/10/2015	24.52
	8/18/2015	25.87
	12/9/2015	24.20
	8/15/2016	60.05*
	12/12/2016	25.12
	7/12/2017	63.59*
	12/18/2017	25.35
	7/10/2018	97.19*
	12/6/2018	25.15
S&S #3	12/21/2016	47.04
	7/12/2017	47.73
	12/18/2017	46.87
	7/10/2018	46.86
	12/6/2018	47.43
C #1	2/12/2015	393.84
	8/17/2015	392.93
	12/10/2015	392.20
	8/16/2016	392.90
	12/14/2016	393.19
	7/20/2017	n/m
	2/22/2018	391.92
	7/21/2018	n/m
	12/12/2018	391.97
V #1	2/18/2015	261.37
	8/28/2015	263.19
	12/10/2015	263.11
	8/16/2016	263.24
	12/15/2016	263.68
	7/20/2017	265.22
	12/21/2017	263.60

U #1	5/20/2015	51.20
	8/18/2015	49.40
	12/11/2015	50.44
	8/17/2016	53.43
	12/12/2016	50.42
	7/12/2017	50.90
	12/18/2017	50.02
	7/17/2018	53.86
	12/6/2018	49.57
U #2	5/20/2015	27.23
	8/18/2015	27.03
	12/11/2015	23.96
	8/17/2016	30.56
	12/12/2016	28.37
	7/12/2017	44.19*
	12/18/2017	32.69
	7/17/2018	19.57
	12/6/2018	35.83
U #3	7/12/2017	45.07
	12/18/2017	44.20
	7/17/2018	161.34*
	12/6/2018	44.47
F #1	2/25/2016	23.97
	8/16/2016	24.08
	12/14/2016	24.12
	7/20/2017	24.58
	12/20/2017	23.66
	7/16/2018	24.12
	12/7/2018	23.77
F #2	2/25/2016	64.84
	8/16/2016	66.02
	12/14/2016	66.13
	7/20/2017	67.42
	12/20/2017	63.50
	7/16/2018	66.05
	12/7/2018	64.04
F #3	2/25/2016	38.65
	8/16/2016	38.52

	12/14/2016	38.49
	7/20/2017	38.80
	12/20/2017	38.36
	7/16/2018	40.87
	12/7/2018	39.51
LG	4/22/2016	54.98
	8/17/2016	162.35
	1/26/2017	162.36
	8/1/2017	171.09
	12/21/2017	157.62
	7/17/2018	161.34
	2/1/2019	159.95
CR #2	11/29/2016	12.91
	7/21/2017	14.68
	12/20/2017	12.29
	7/16/2018	12.65
	12/11/2018	11.96
CR #3	11/29/2016	32.16
	7/17/2018	30.48
	12/11/2018	29.71
CR #4	11/29/2016	94.57
	12/20/2017	92.78
	1/25/2019	92.64
CR #5	11/29/2016	24.14
	12/20/2017	16.46
	1/25/2019	20.93
CR #6	11/29/2016	40.69
	7/21/2017	107.52
	12/20/2017	106.80
	1/25/2019	n/m
CR #8	11/29/2016	61.08
	7/21/2017	92.09
	12/20/2017	56.56
	7/11/2018	85.74
	1/25/2019	50.83

CR #9	11/29/2016	98.38
	7/21/2017	112.04
	12/20/2017	n/m
	7/11/2018	100.88
	2/1/2019	92.80
CR #10	11/29/2016	211.14
	12/20/2017	n/m
	2/1/2019	215.15
CR #11	11/29/2016	80.68
	7/21/2017	82.39
	12/22/2017	80.68
	7/11/2018	76.84
	2/1/2019	72.50
CR #13	12/13/2016	n/m
	2/1/2019	290.05
CR #14	12/13/2016	244.80
	12/22/2017	244.20
	12/21/2018	244.51
CR #15	12/13/2016	250.00
	7/21/2017	261.17
	12/22/2017	249.88
	7/16/2018	253.22
	12/21/2018	250.24
RR domestic	12/12/2016	43.38
	12/20/2017	41.43
	7/9/2018	47.75
	12/5/2018	45.73
RR windmill	12/12/2016	38.18
	7/20/2017	37.60
	12/20/2017	35.19
	7/9/2018	36.56
	12/5/2018	35.49
AR #1	12/13/2016	59.23
	7/24/2017	59.25
	12/22/2017	43.19

	7/10/2018	44.13
	12/5/2018	44.36
AR #2	12/13/2016	75.57
	7/24/2017	70.25
	12/22/2017	46.65
	7/10/2018	49.51
	12/5/2018	50.24
TR #1	12/21/2016	145.87
	7/24/2017	124.99
	1/24/2018	123.43
	7/9/2018	139.36
	12/5/2018	n/m
	12/7/2018	n/m
TR #2	12/21/2016	37.50
	7/24/2017	147.06*
	1/24/2018	43.82
	7/9/2018	42.37
	12/5/2018	n/m
	12/7/2018	38.43
TR #3	12/21/2016	54.02
	7/24/2017	51.63
	1/24/2018	57.10
	7/9/2018	53.01
	12/5/2018	n/m
	12/7/2018	55.26
TR #4	12/21/2016	n/m
	7/24/2017	110.16
	2/22/2018	93.31
	7/9/2018	93.10
	12/5/2018	106.00
BW #1	12/21/2016	12.16*
	7/20/2017	93.83
	1/15/2018	95.69
	7/9/2018	93.86
	12/5/2018	95.79
BW #2	12/21/2016	74.65

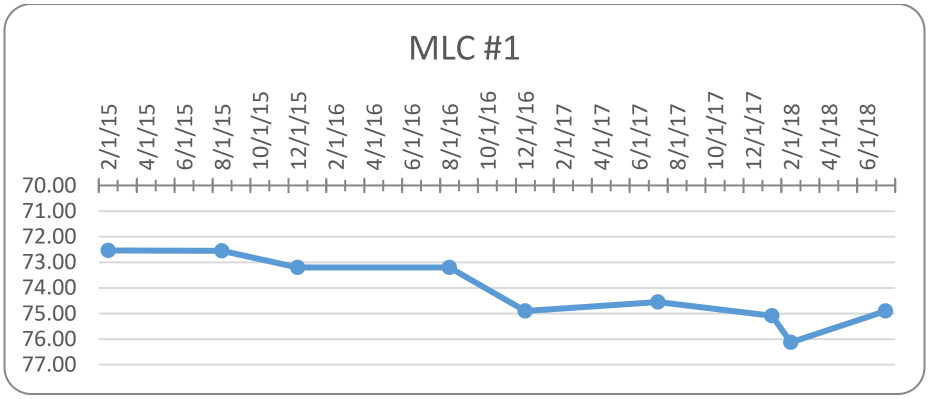
	1/15/2018	73.27
	7/9/2018	78.09
	12/7/2018	75.74
BW #3	12/21/2016	26.99
	7/20/2017	34.94
	1/15/2018	16.77
	7/9/2018	23.54
	12/7/2018	17.65
BW #4	12/21/2016	151.77
	7/20/2017	160.34
	1/15/2018	n/m
BW #5	12/21/2016	15.60
	1/15/2018	15.40
	7/9/2018	14.96
	12/7/2018	18.30
BW #7	7/9/2018	133.09
	12/5/2018	133.35
BK #1	1/26/2017	7.47
	7/20/2017	8.97
	12/20/2017	7.35
	7/9/2018	9.44
	12/5/2018	8.38
BK #2	1/26/2017	34.78
	7/20/2017	24.15
	12/20/2017	19.35
	7/9/2018	35.59
	12/5/2018	31.64
WVC #1	1/12/2017	18.15
	1/22/2018	n/m
	7/16/2018	11.76
	12/12/2018	107.64*
WVC #2	1/12/2017	147.49
	7/20/2017	151.69
	1/22/2018	151.88
	7/16/2018	101.97*

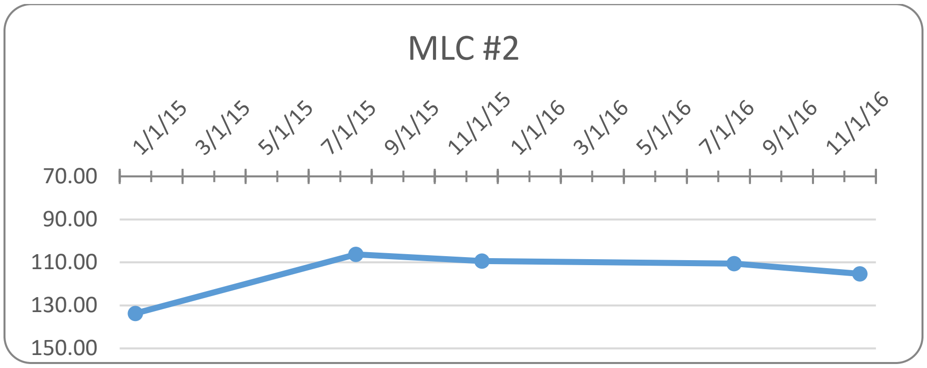
	12/12/2018	151.99
WV #2	1/12/2017	100.31
	7/20/2017	102.67
	1/22/2018	n/m
	12/12/2018	113.94
WV #5	1/22/2018	n/m
	7/16/2018	71.37
	12/12/2018	57.03
WV #8	1/12/2017	133.20
	1/22/2018	132.90
	7/16/2018	132.81
	12/12/2018	132.60
WV #9	1/12/2017	191.03
	7/20/2017	182.43
	1/22/2018	191.32
	7/16/2018	191.43
	12/12/2018	190.97
WV #12	1/12/2017	280.00*
	7/20/2017	278.97*
	1/22/2018	159.83
	7/16/2018	160.28
	12/12/2018	159.75
SJ #1	1/25/2017	35.49
	7/25/2017	37.94
	1/15/2018	28.17
	7/29/2018	36.65
	12/17/2018	37.08
SJ #2	1/25/2017	156.89
	7/25/2017	106.22
	1/2/2018	n/m
	7/15/2018	74.55*
	12/17/2018	217.03
SJ #3	1/25/2017	55.44
	7/25/2017	46.30
	1/15/2018	n/m

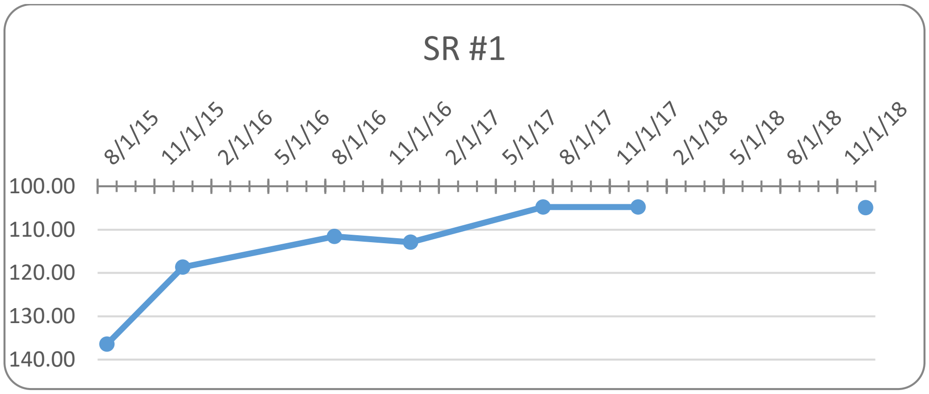
	7/12/2018	55.22
	12/18/2018	55.10
SJ #4	1/25/2017	50.04
	7/15/2018	46.30
	12/9/2018	44.74
SJ #5	1/25/2017	65.36
	7/25/2017	67.06
	1/2/2018	43.05
	7/15/2018	52.17
	12/9/2018	46.19
SJ #6	1/25/2016	17.33
	7/25/2017	18.21
	1/2/2018	14.08
	7/29/2018	16.00
	12/18/2018	15.94
SJ House	1/15/2018	211.59
	7/29/2018	215.55
	2/1/2019	246.35
OF #1	7/19/2017	67.04
	1/17/2018	49.23
	8/3/2018	n/m
	12/13/2018	50.82
OF #2	7/19/2017	11.53
	1/17/2018	8.29
	8/3/2018	8.70
	12/13/2018	8.54
OF #3	7/19/2017	94.52*
	1/17/2018	59.59
	8/3/2018	57.01
	12/13/2018	56.14
OF #4	7/19/2017	~ 46*
	1/17/2018	42.64
	8/3/2018	41.82
	12/13/2018	40.14

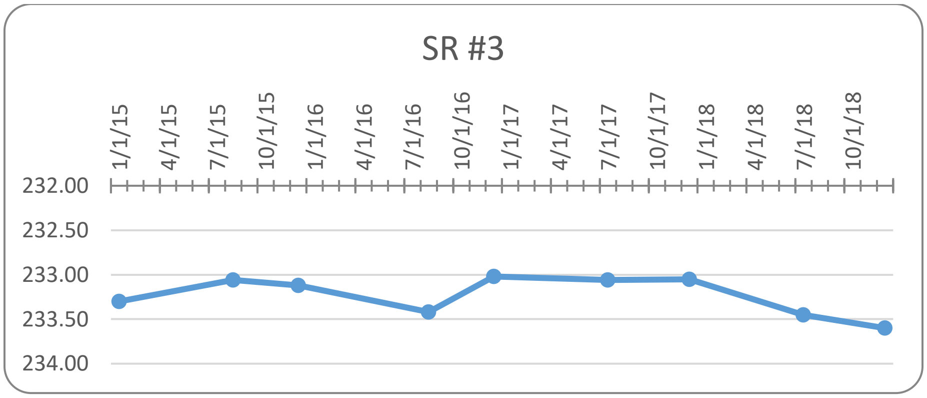
OF #5	7/19/2017	n/m
	1/17/2018	110.55
	8/3/2018	110.75
	12/13/2018	110.78
OF #6	7/19/2017	n/m
	1/17/2018	181.03
	8/3/2018	178.97
	12/13/2018	179.46
OF #7	7/19/2017	n/m
	1/17/2018	n/m
	8/3/2018	153.94
	12/13/2018	137.05
OF #9	7/19/2017	138.13
	1/17/2018	138.30
	8/3/2018	138.45
	12/13/2018	138.72
G #1	7/25/2017	9.35
	12/20/2017	11.64
	7/9/2018	13.88
	12/12/2018	10.14
M #1	7/25/2017	102.19
	12/18/2017	104.40
	7/18/2018	93.74
	12/10/2018	90.80
M #2	7/25/2017	99.61
	12/18/2017	97.84
	12/10/2018	90.80

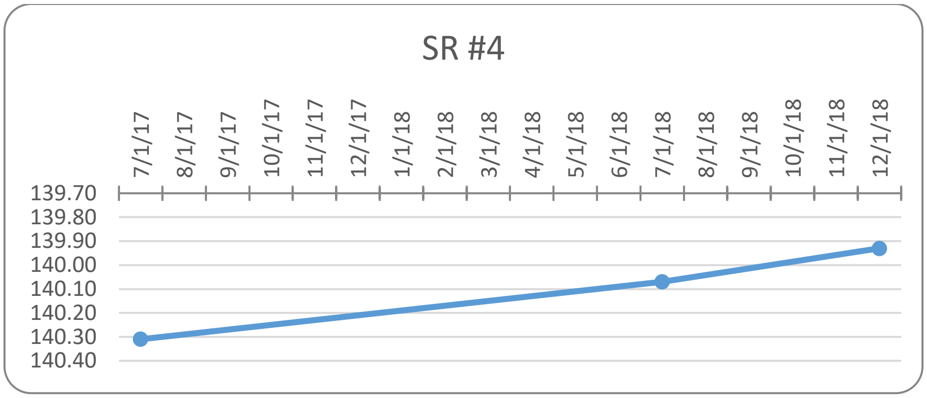
APPENDIX II: Hydrographs

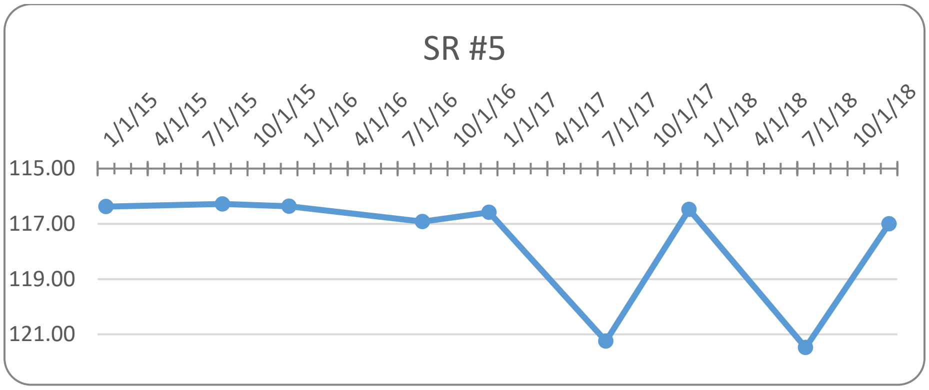


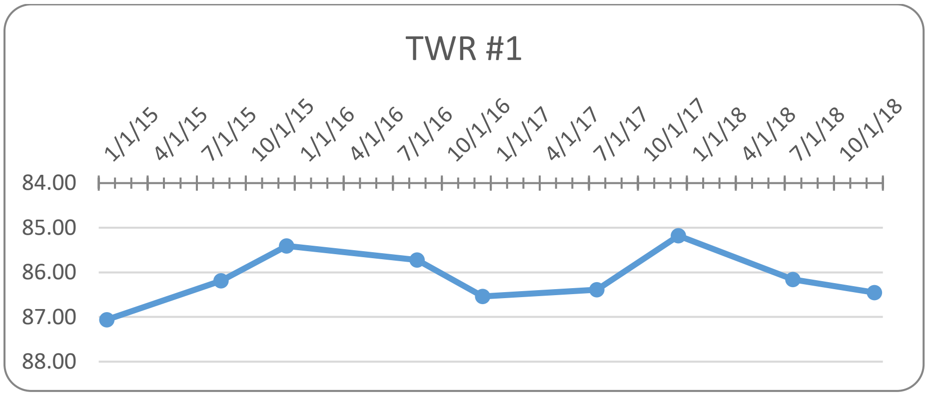


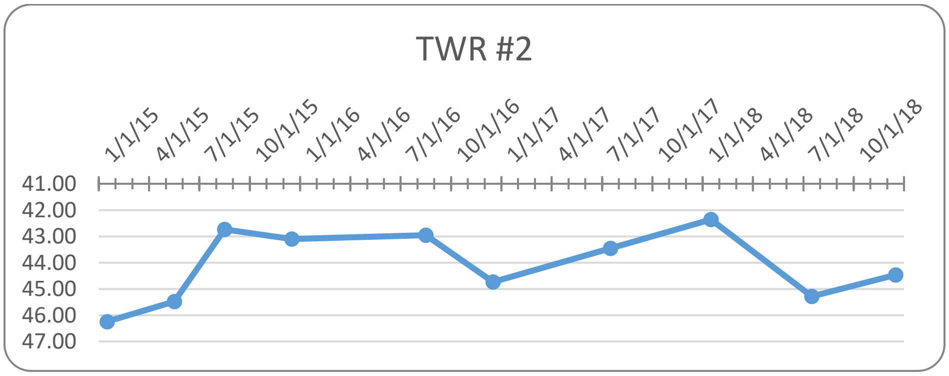


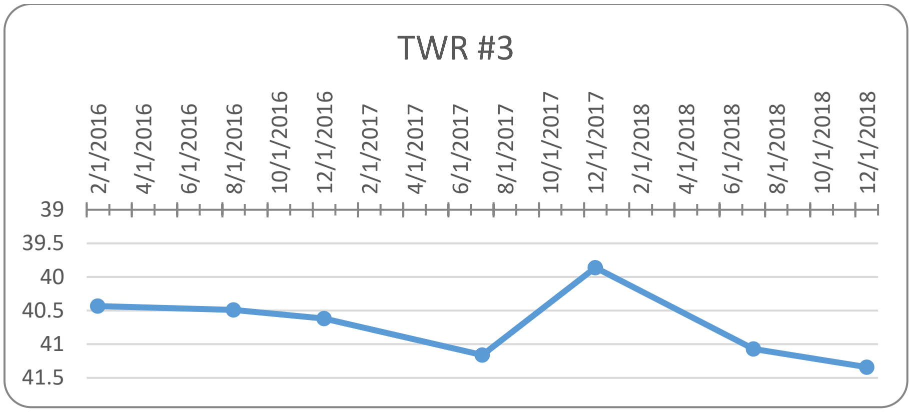


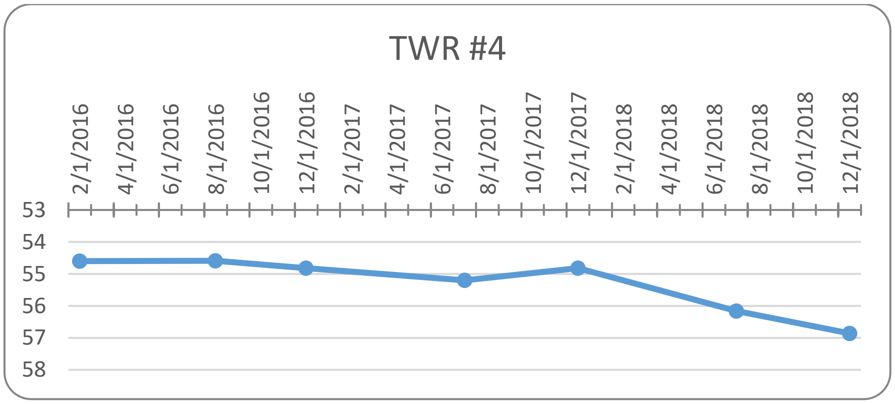

SR #4
7/1/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
1/1/18
2/1/18
3/1/18
4/1/18
5/1/18
6/1/18
7/1/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
139.70
139.80
139.90
140.00
140.10
140.20
140.30
140.40

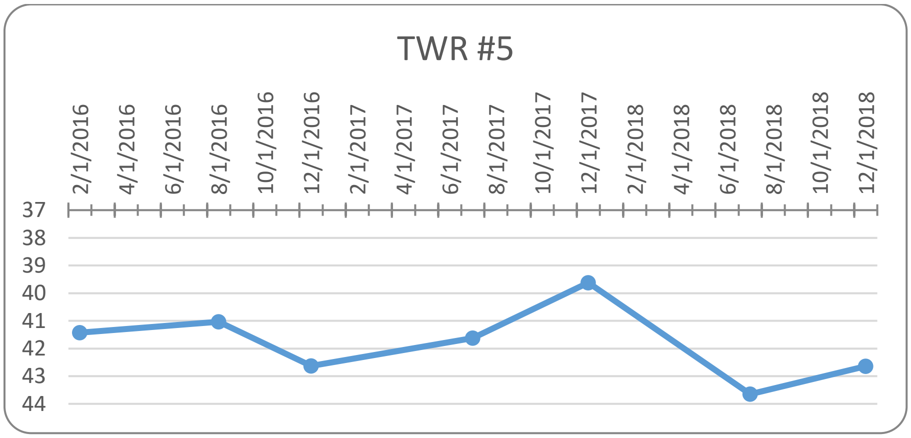

SR #5
1/1/15
4/1/15
7/1/15
10/1/15
1/1/16
4/1/16
7/1/16
10/1/16
1/1/17
4/1/17
7/1/17
10/1/17
1/1/18
4/1/18
7/1/18
10/1/18
115.00
117.00
119.00
121.00

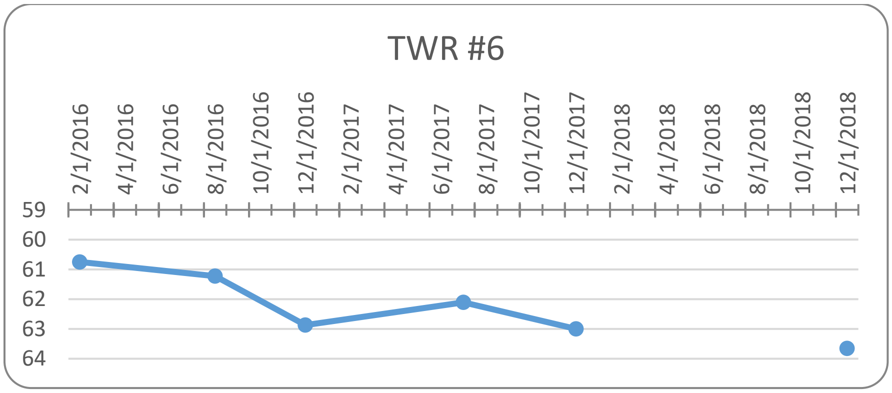

TWR #1
1/1/15
4/1/15
7/1/15
10/1/15
1/1/16
4/1/16
7/1/16
10/1/16
1/1/17
4/1/17
7/1/17
10/1/17
1/1/18
4/1/18
7/1/18
10/1/18
84.00
85.00
86.00
87.00
88.00

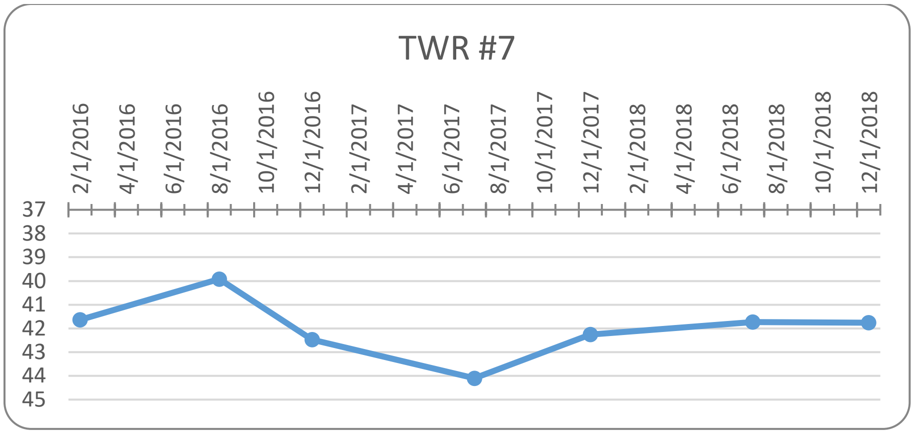

TWR #2
1/1/15
4/1/15
7/1/15
10/1/15
1/1/16
4/1/16
7/1/16
10/1/16
1/1/17
4/1/17
7/1/17
10/1/17
1/1/18
4/1/18
7/1/18
10/1/18
41.00
42.00
43.00
44.00
45.00
46.00
47.00

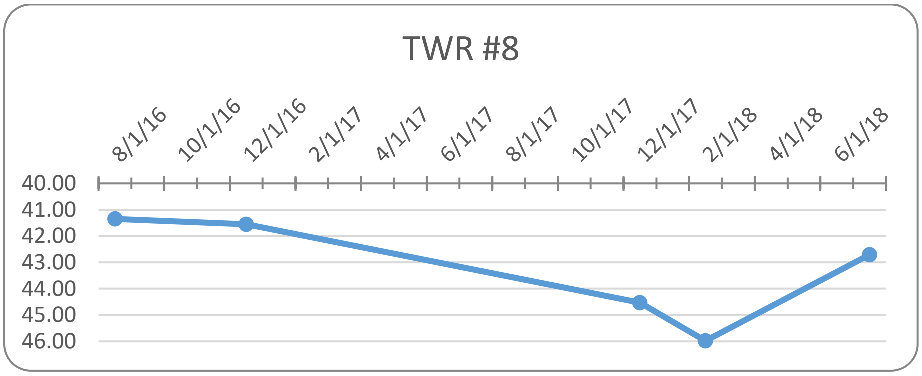

TWR #3
2/1/2016
4/1/2016
6/1/2016
8/1/2016
10/1/2016
12/1/2016
2/1/2017
4/1/2017
6/1/2017
8/1/2017
10/1/2017
12/1/2017
2/1/2018
4/1/2018
6/1/2018
8/1/2018
10/1/2018
12/1/2018
39
39.5
40
40.5
41
41.5

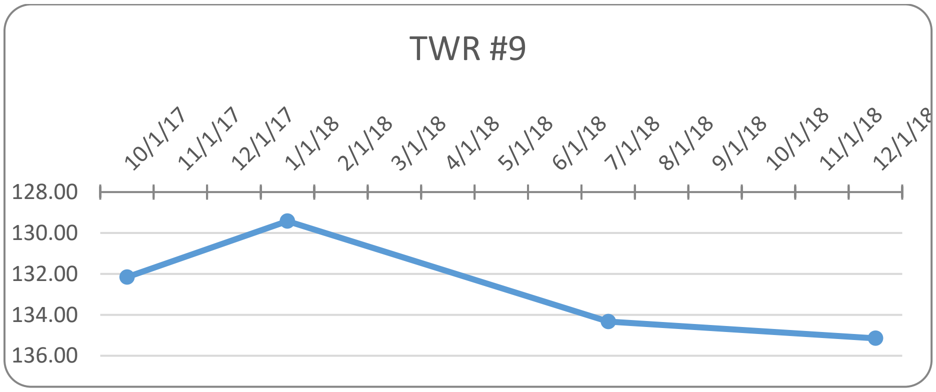

TWR #4
2/1/2016
4/1/2016
6/1/2016
8/1/2016
10/1/2016
12/1/2016
2/1/2017
4/1/2017
6/1/2017
8/1/2017
10/1/2017
12/1/2017
2/1/2018
4/1/2018
6/1/2018
8/1/2018
10/1/2018
12/1/2018
53
54
55
56
57
58

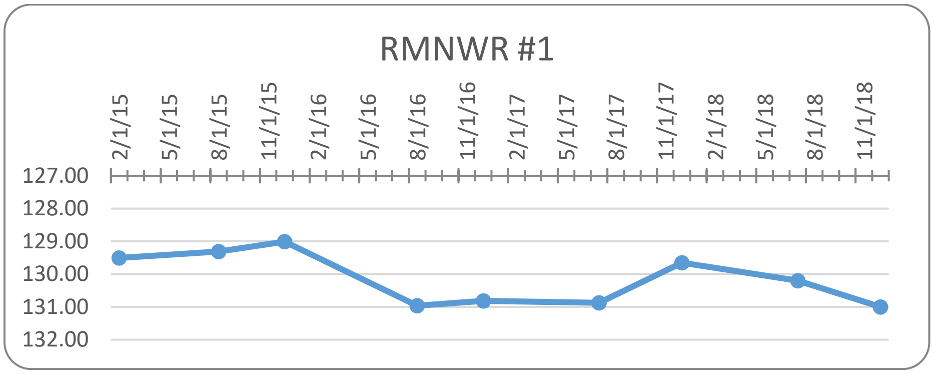

TWR #5
2/1/2016
4/1/2016
6/1/2016
8/1/2016
10/1/2016
12/1/2016
2/1/2017
4/1/2017
6/1/2017
8/1/2017
10/1/2017
12/1/2017
2/1/2018
4/1/2018
6/1/2018
8/1/2018
10/1/2018
12/1/2018
37
38
39
40
41
42
43
44

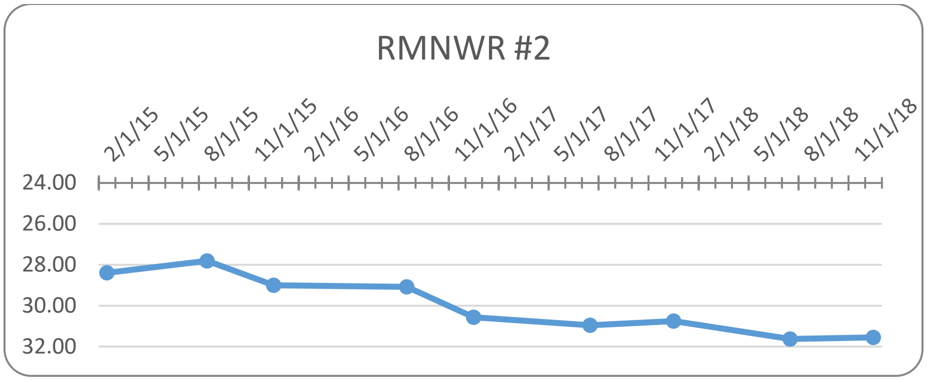

TWR #6
2/1/2016
4/1/2016
6/1/2016
8/1/2016
10/1/2016
12/1/2016
2/1/2017
4/1/2017
6/1/2017
8/1/2017
10/1/2017
12/1/2017
2/1/2018
4/1/2018
6/1/2018
8/1/2018
10/1/2018
12/1/2018
59
60
61
62
63
64

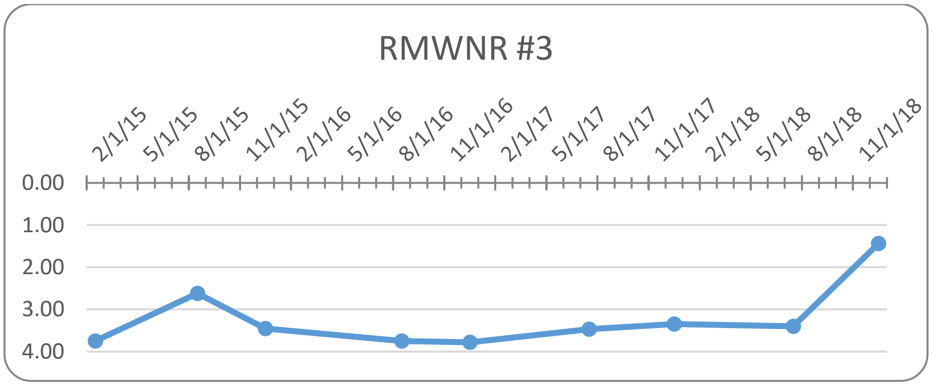

TWR #7
2/1/2016
4/1/2016
6/1/2016
8/1/2016
10/1/2016
12/1/2016
2/1/2017
4/1/2017
6/1/2017
8/1/2017
10/1/2017
12/1/2017
2/1/2018
4/1/2018
6/1/2018
8/1/2018
10/1/2018
12/1/2018
37
38
39
40
41
42
43
44
45

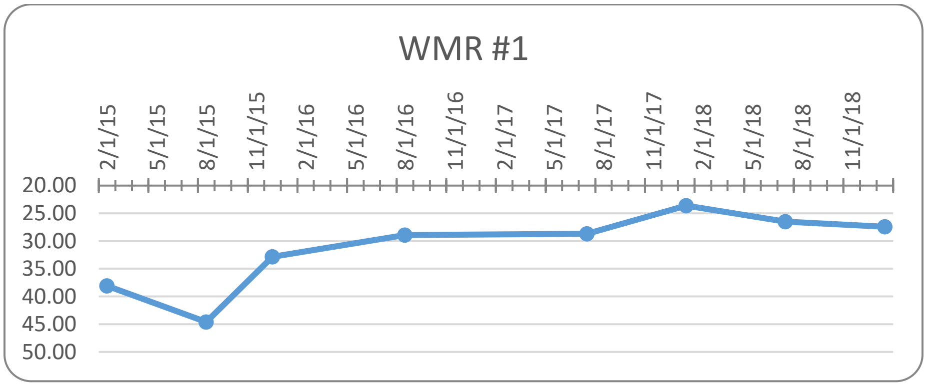

TWR #8
8/1/16
10/1/16
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
40.00
41.00
42.00
43.00
44.00
45.00
46.00

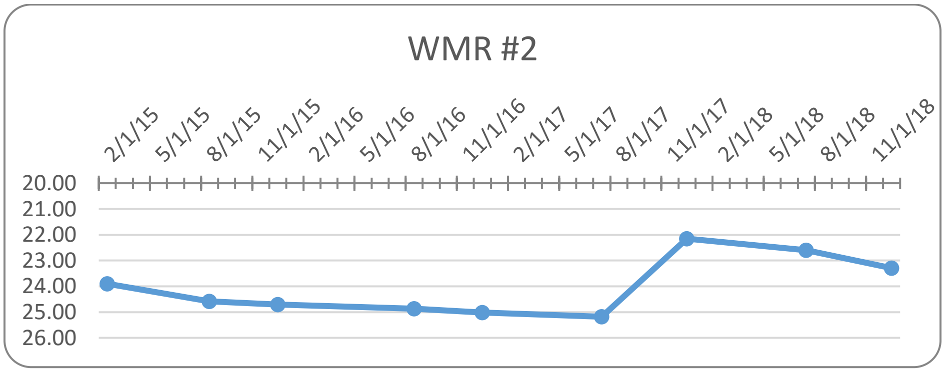

TWR #9
10/1/17
11/1/17
12/1/17
1/1/18
2/1/18
3/1/18
4/1/18
5/1/18
6/1/18
7/1/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
128.00
130.00
132.00
134.00
136.00

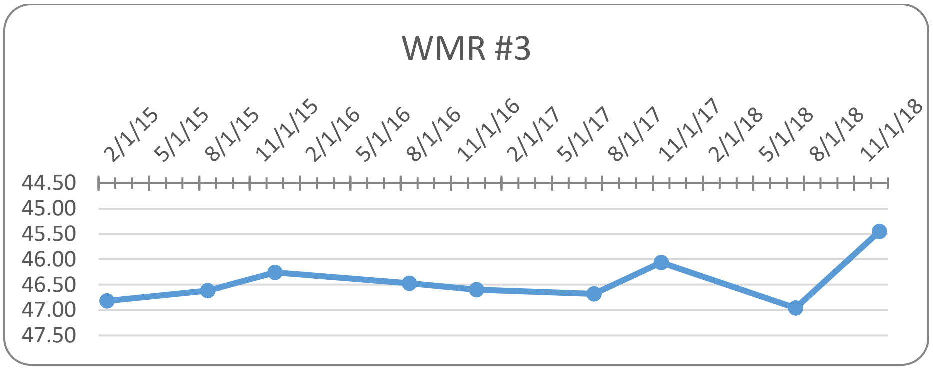

RMNWR #1
2/1/15
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
127.00
128.00
129.00
130.00
131.00
132.00

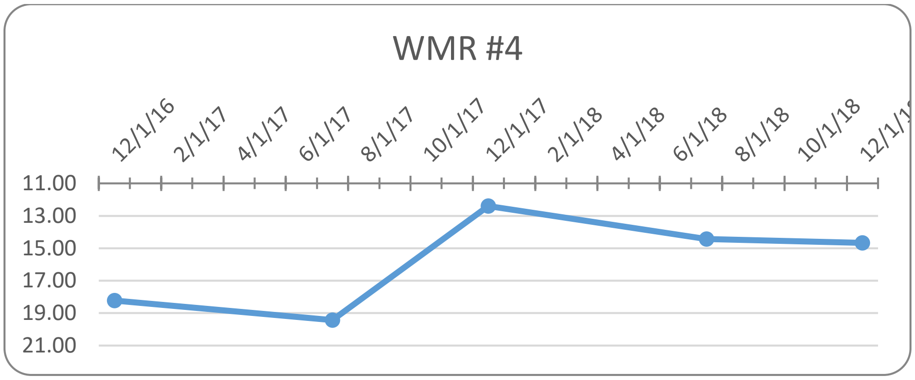

RMNWR #2
2/1/15
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
24.00
26.00
28.00
30.00
32.00

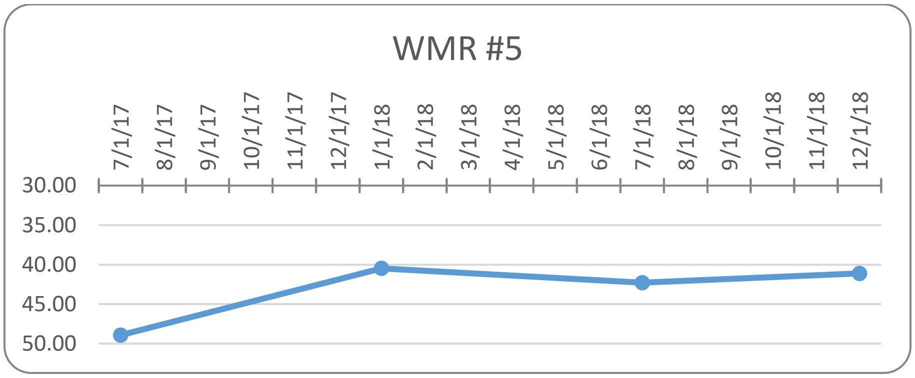

RMWNR #3
2/1/15
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
0.00
1.00
2.00
3.00
4.00

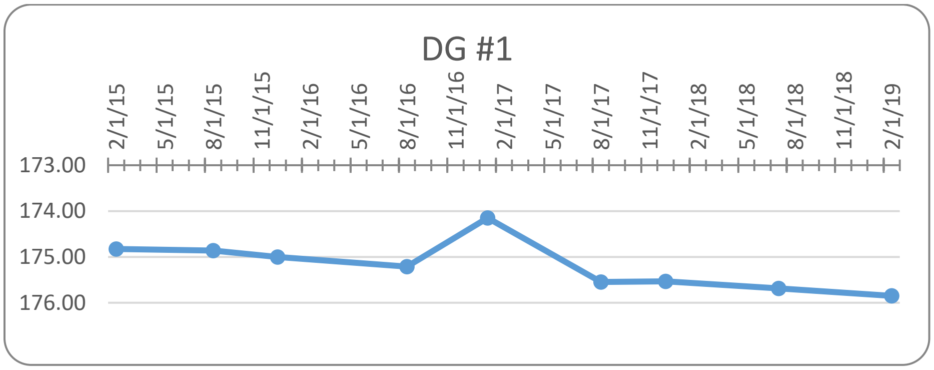

WMR #1
2/1/15
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
20.00
25.00
30.00
35.00
40.00
45.00
50.00

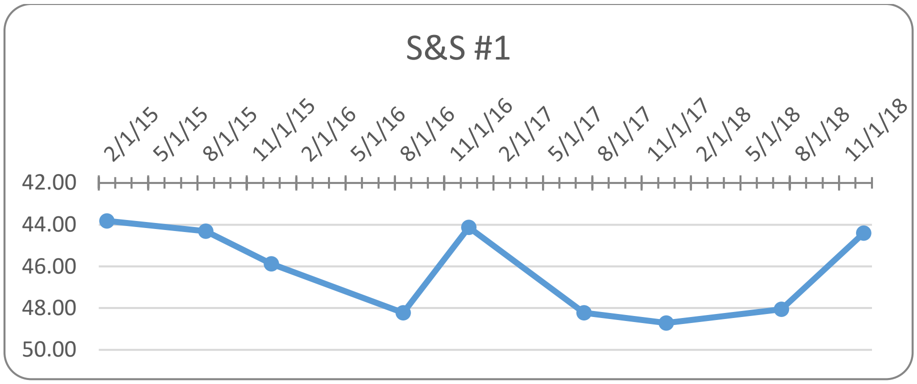

WMR #2
2/1/15
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
20.00
21.00
22.00
23.00
24.00
25.00
26.00

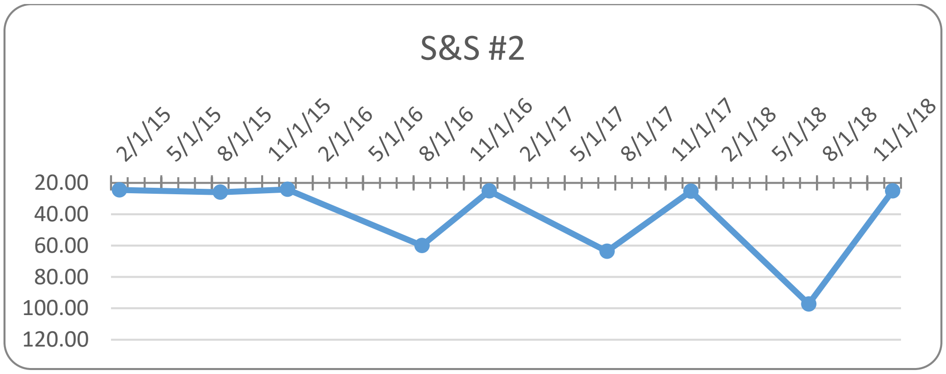

WMR #3
2/1/15
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
44.50
45.00
45.50
46.00
46.50
47.00
47.50

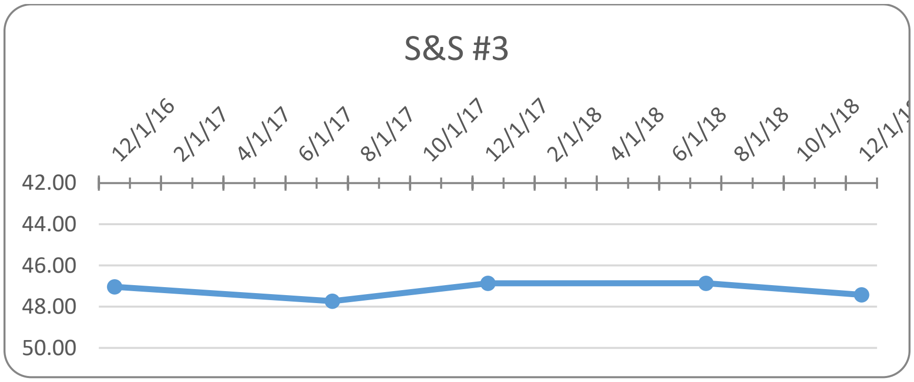

WMR #4
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/1
11.00
13.00
15.00
17.00
19.00
21.00

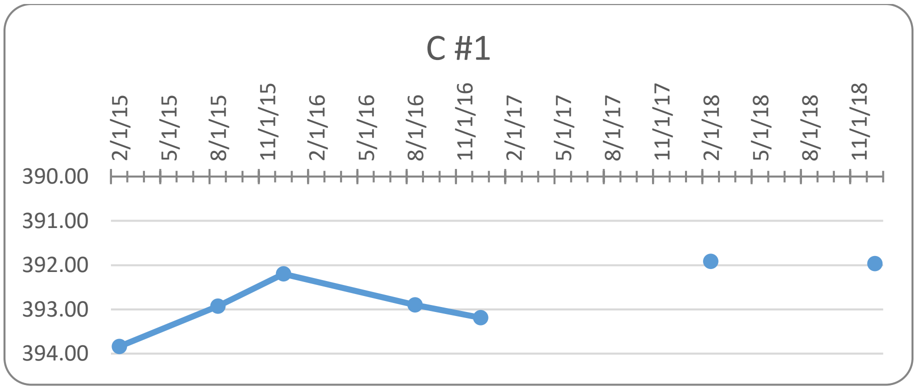

WMR #5
7/1/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
1/1/18
2/1/18
3/1/18
4/1/18
5/1/18
6/1/18
7/1/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
30.00
35.00
40.00
45.00
50.00

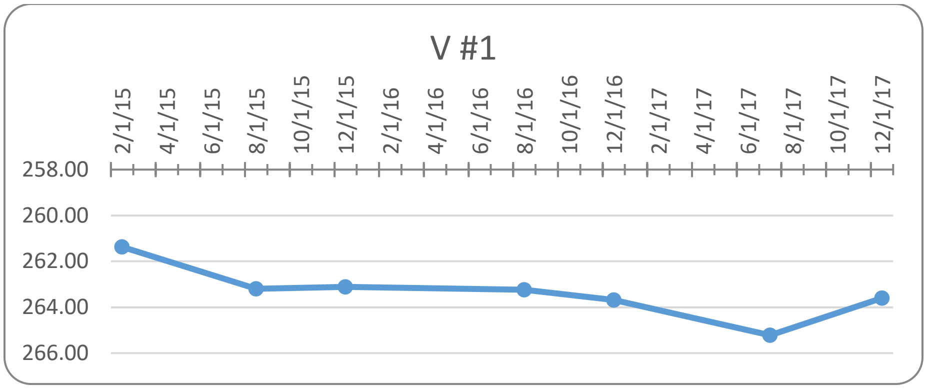

DG #1
2/1/15
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
2/1/19
173.00
174.00
175.00
176.00

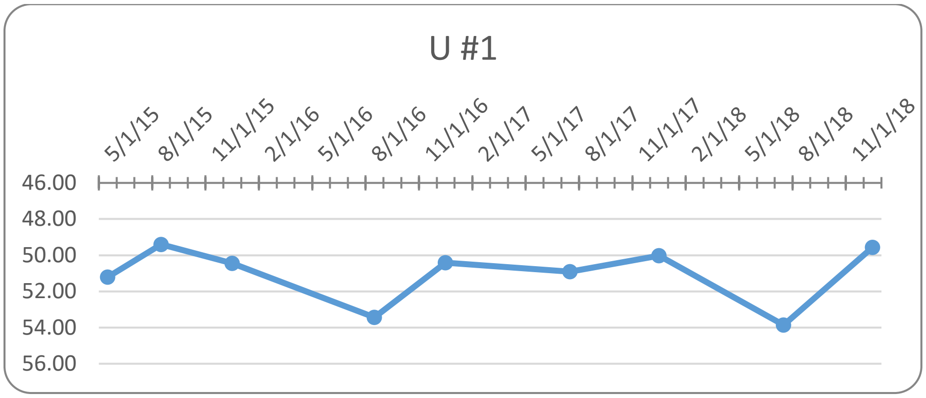

S&S #1
2/1/15
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
42.00
44.00
46.00
48.00
50.00

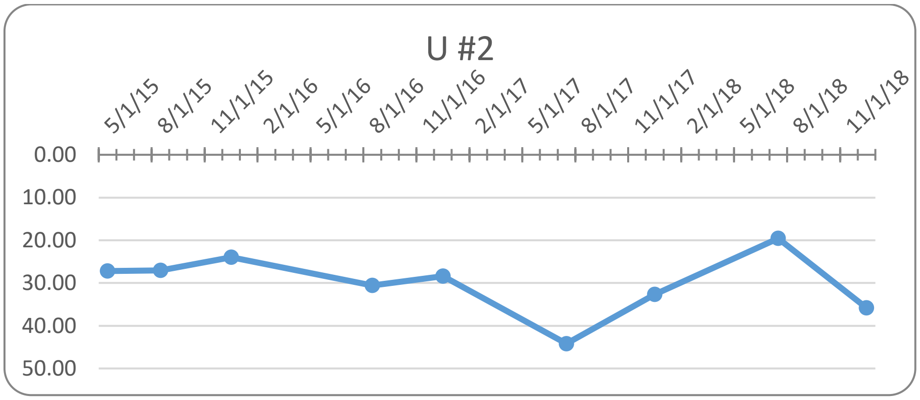

S&S #2
2/1/15
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
20.00
40.00
60.00
80.00
100.00
120.00

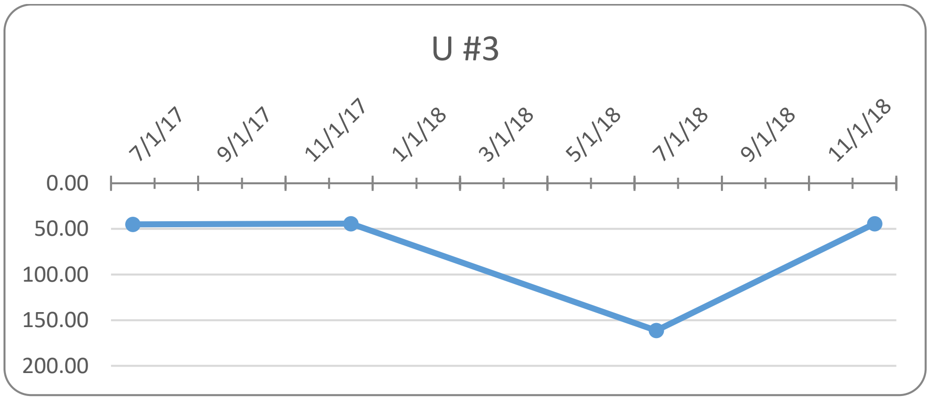

S&S #3
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/1
42.00
44.00
46.00
48.00
50.00

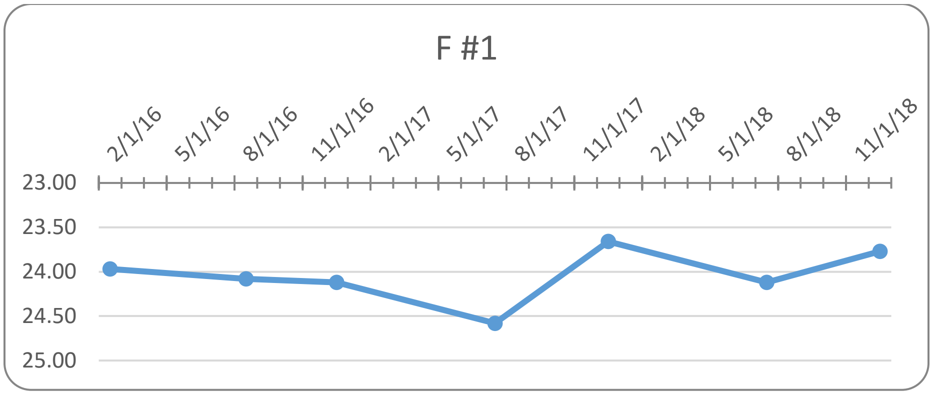

C #1
2/1/15
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
390.00
391.00
392.00
393.00
394.00

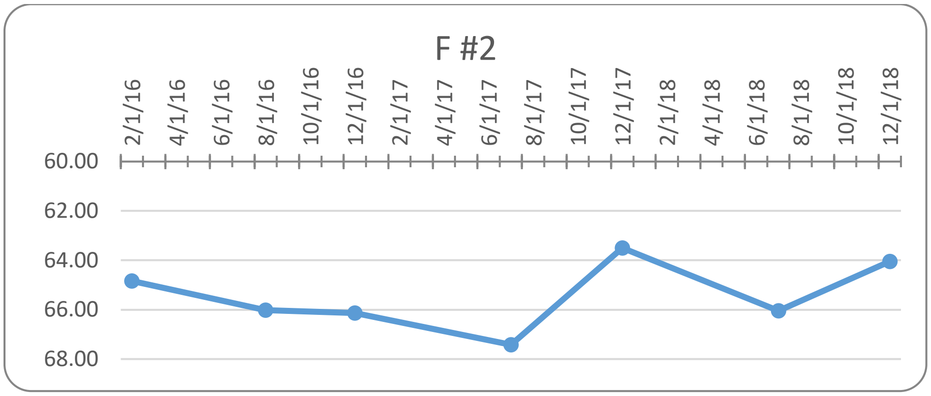

V #1
2/1/15
4/1/15
6/1/15
8/1/15
10/1/15
12/1/15
2/1/16
4/1/16
6/1/16
8/1/16
10/1/16
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
258.00
260.00
262.00
264.00
266.00

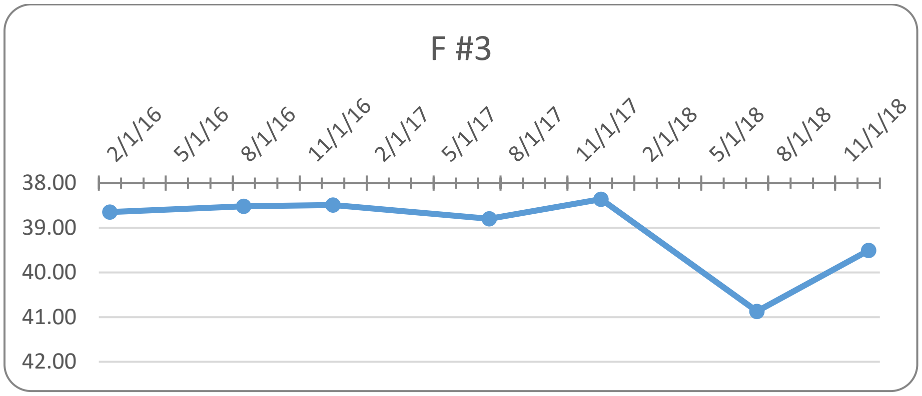

U #1
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
46.00
48.00
50.00
52.00
54.00
56.00

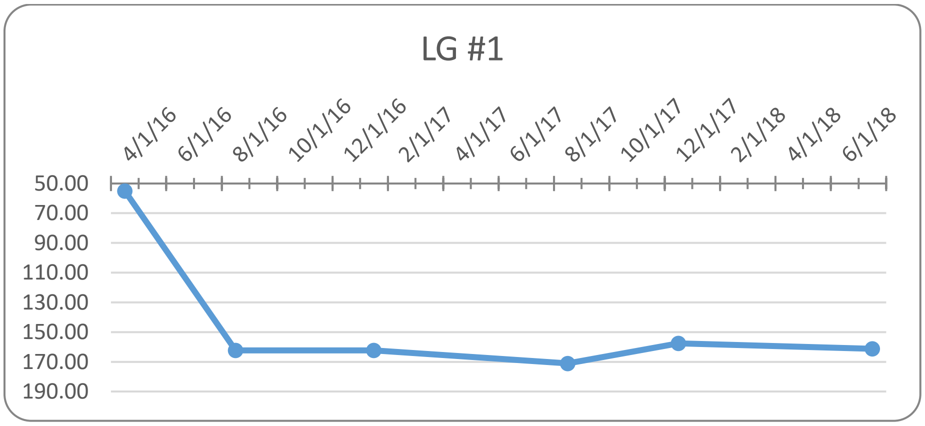

U #2
5/1/15
8/1/15
11/1/15
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
0.00
10.00
20.00
30.00
40.00
50.00

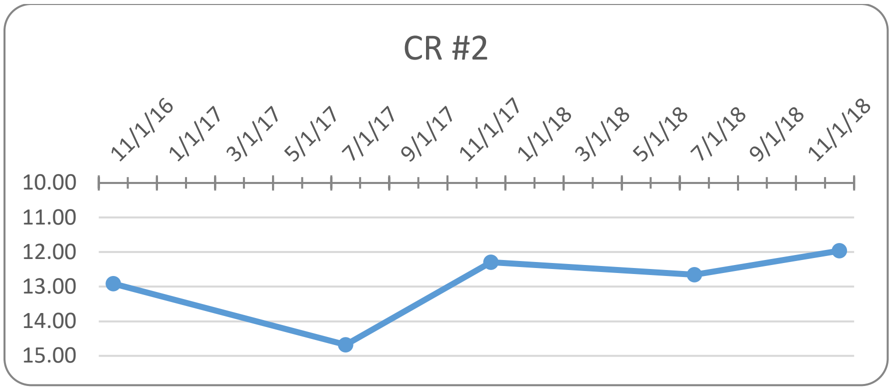

U #3
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
50.00
100.00
150.00
200.00

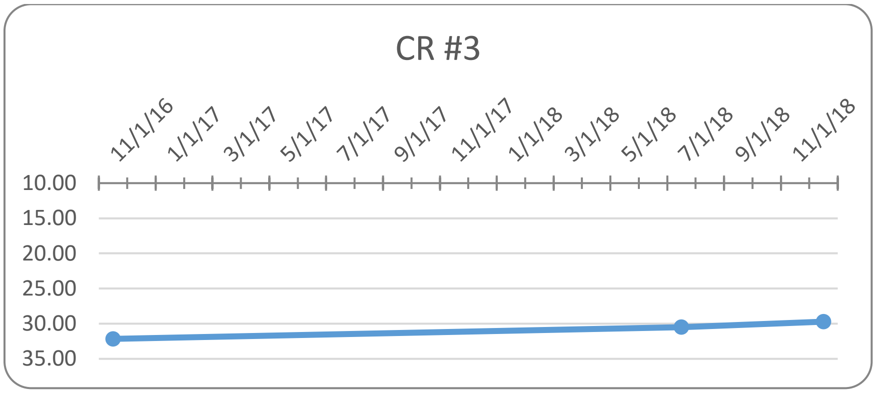

F #1
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
23.00
23.50
24.00
24.50
25.00

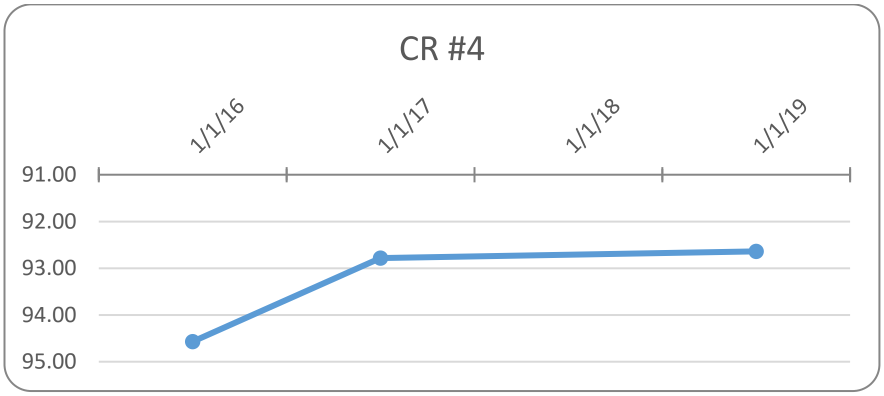

F #2
2/1/16
4/1/16
6/1/16
8/1/16
10/1/16
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/18
60.00
62.00
64.00
66.00
68.00

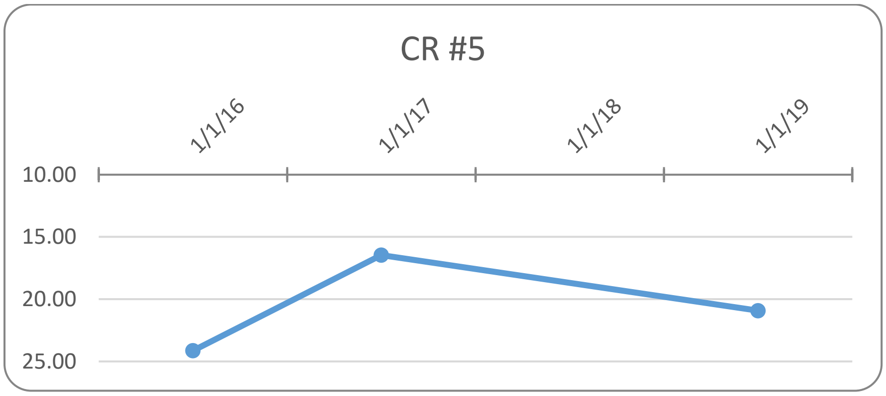

F #3
2/1/16
5/1/16
8/1/16
11/1/16
2/1/17
5/1/17
8/1/17
11/1/17
2/1/18
5/1/18
8/1/18
11/1/18
38.00
39.00
40.00
41.00
42.00

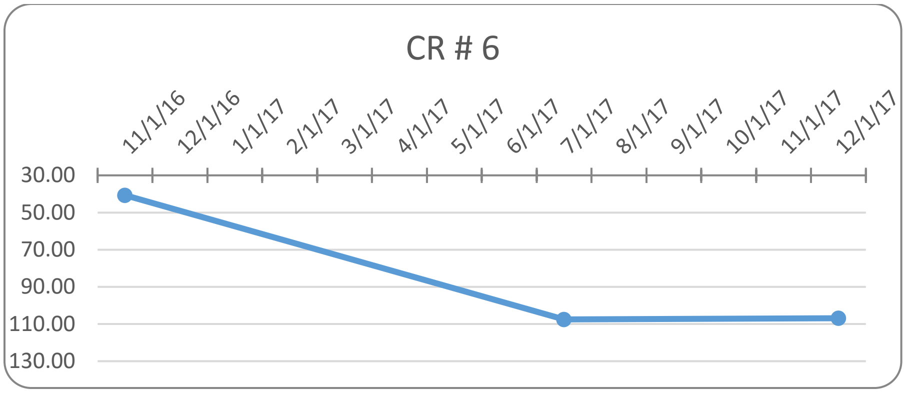

LG #1
4/1/16
6/1/16
8/1/16
10/1/16
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
50.00
70.00
90.00
110.00
130.00
150.00
170.00
190.00

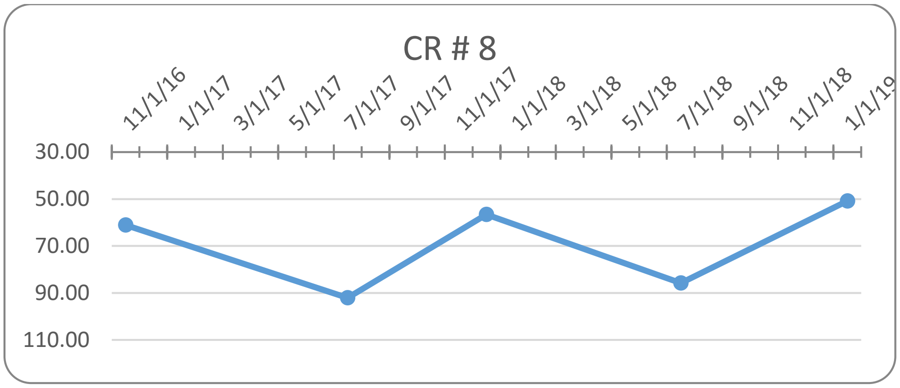

CR #2
11/1/16
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
10.00
11.00
12.00
13.00
14.00
15.00

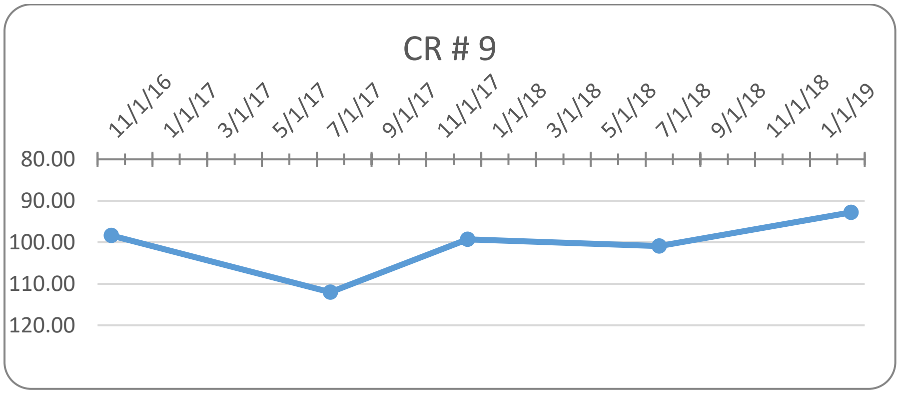

CR #3
11/1/16
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
10.00
15.00
20.00
25.00
30.00
35.00

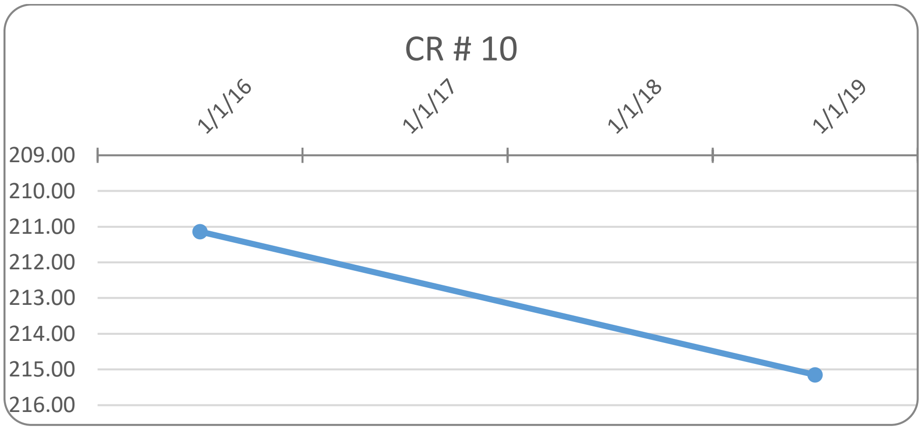

CR #4
1/1/16
1/1/17
1/1/18
1/1/19
91.00
92.00
93.00
94.00
95.00

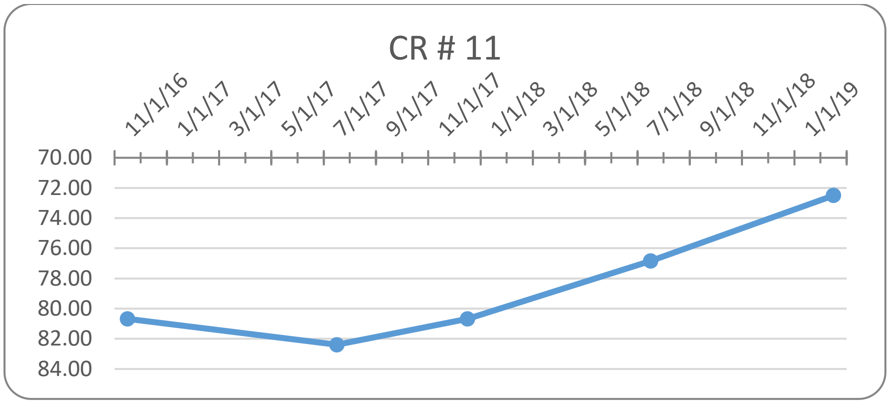

CR #5
1/1/16
1/1/17
1/1/18
1/1/19
10.00
15.00
20.00
25.00

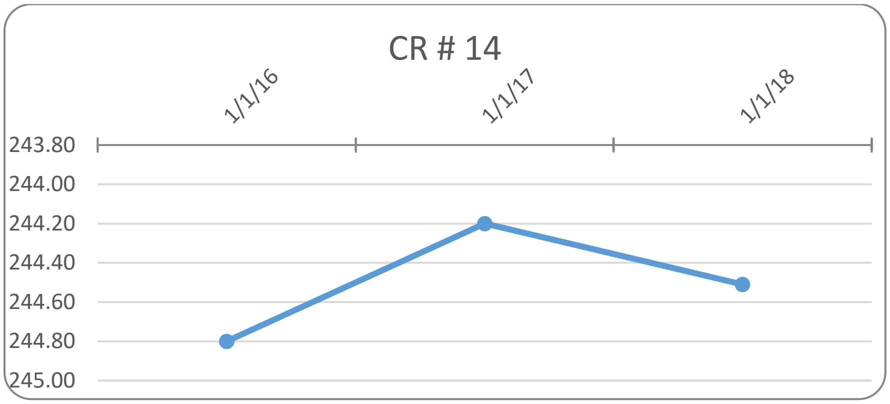

CR # 6
11/1/16
12/1/16
1/1/17
2/1/17
3/1/17
4/1/17
5/1/17
6/1/17
7/1/17
8/1/17
9/1/17
10/1/17
11/1/17
12/1/17
30.00
50.00
70.00
90.00
110.00
130.00

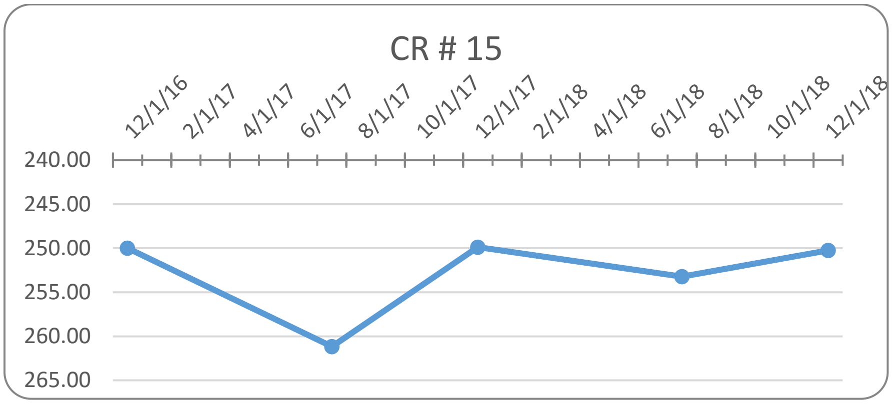

CR # 8
11/1/16
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
1/1/19
30.00
50.00
70.00
90.00
110.00

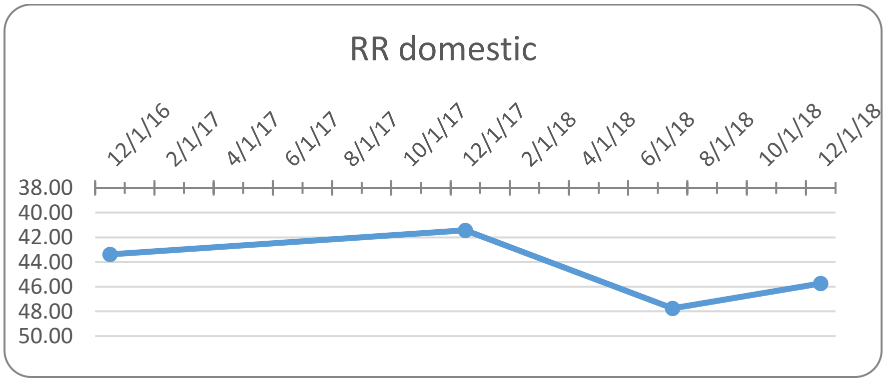

CR # 9
11/1/16
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
1/1/19
80.00
90.00
100.00
110.00
120.00

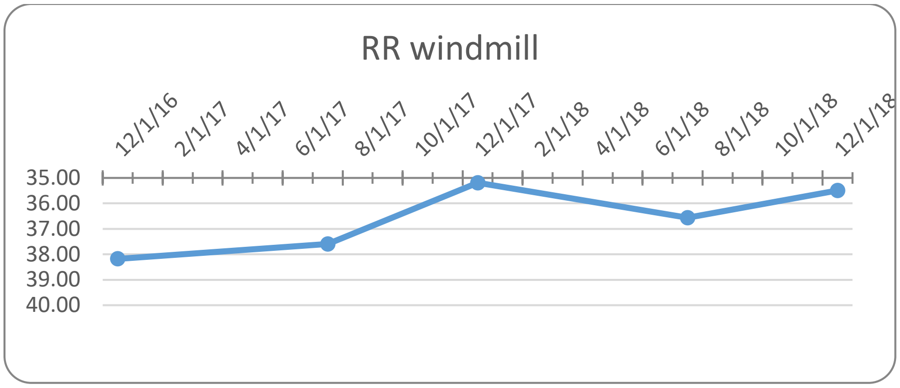

CR # 10
1/1/16
1/1/17
1/1/18
1/1/19
209.00
210.00
211.00
212.00
213.00
214.00
215.00
216.00

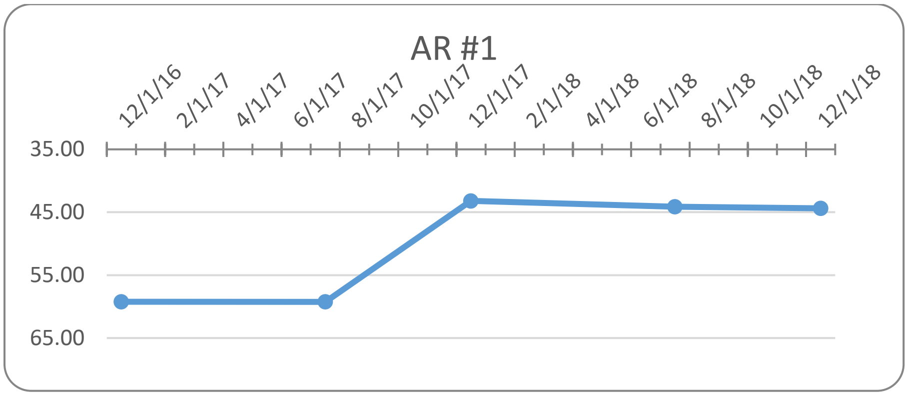

CR # 11

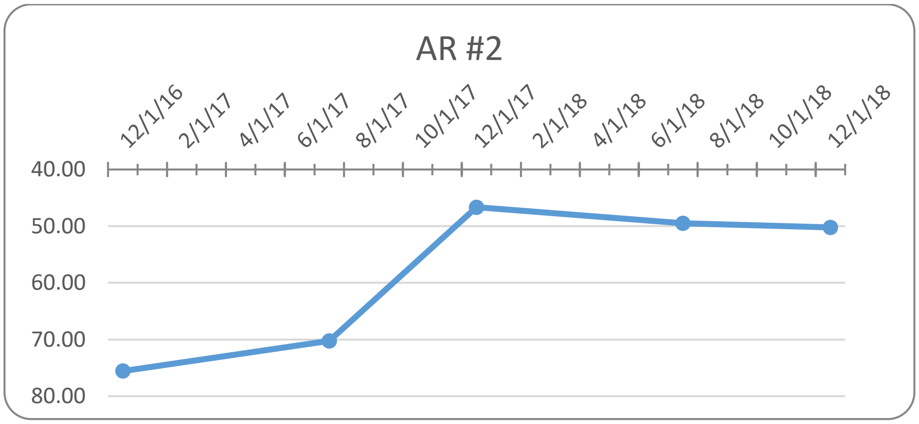

CR # 14

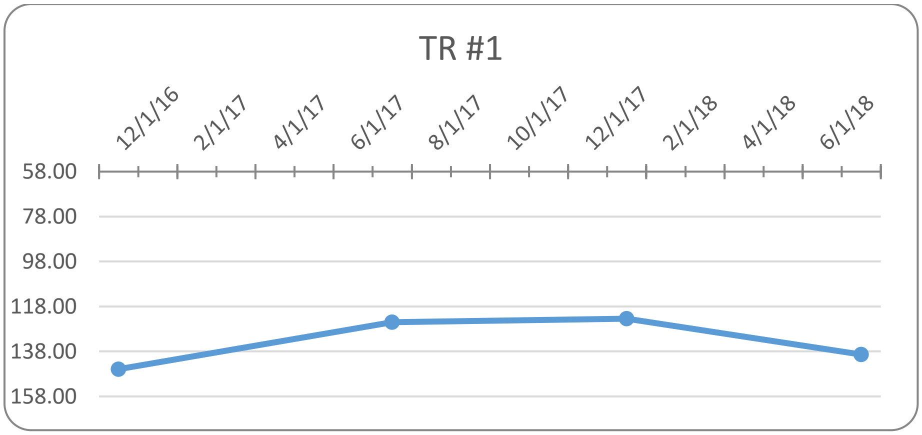

CR # 15

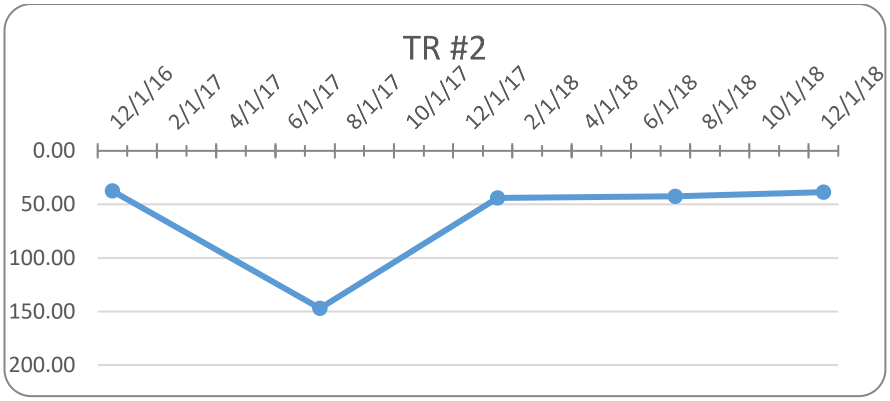

RR domestic

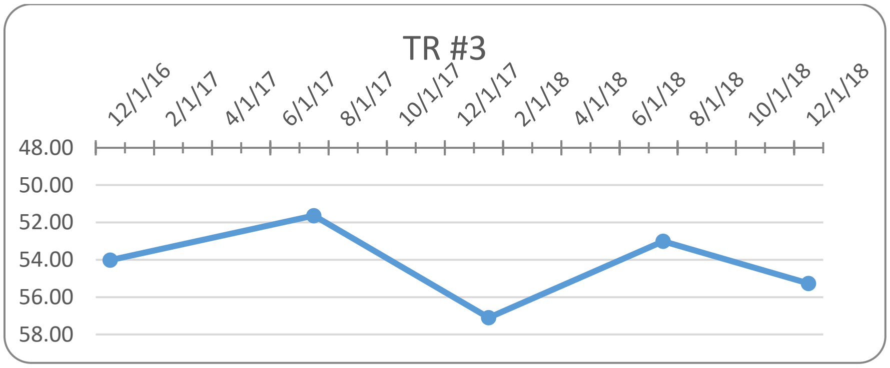

RR windmill
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/18
35.00
36.00
37.00
38.00
39.00
40.00

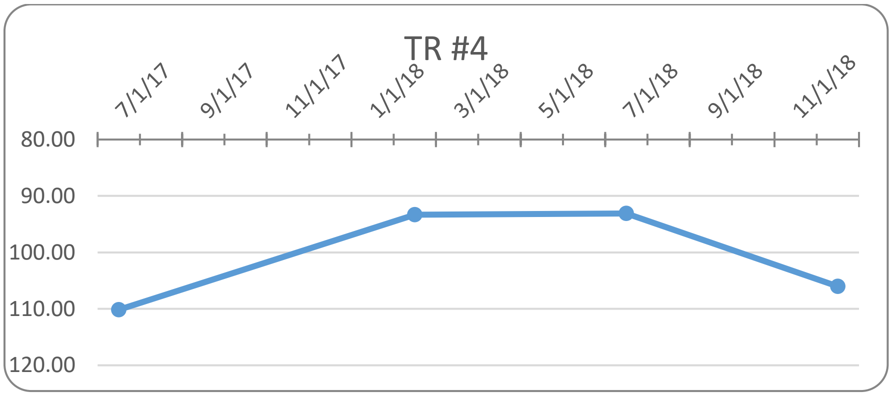

AR #1
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/18
35.00
45.00
55.00
65.00

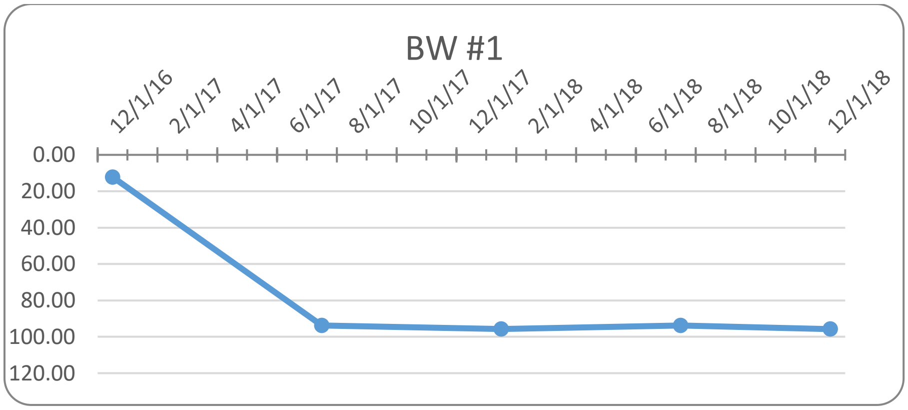

AR #2
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/18
40.00
50.00
60.00
70.00
80.00

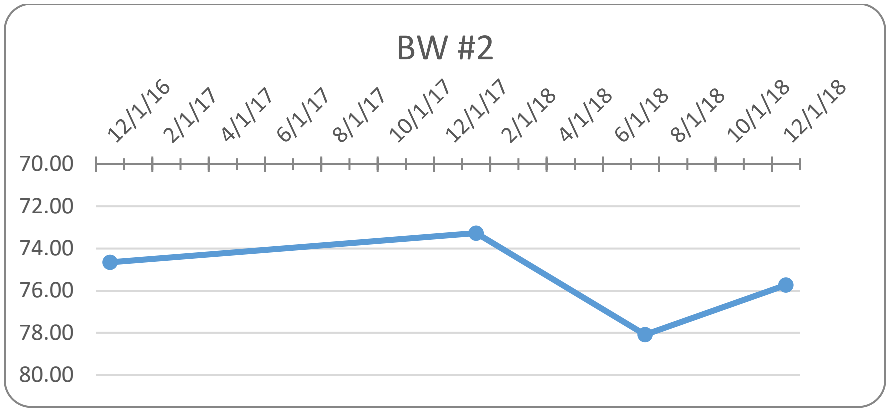

TR #1
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
58.00
78.00
98.00
118.00
138.00
158.00

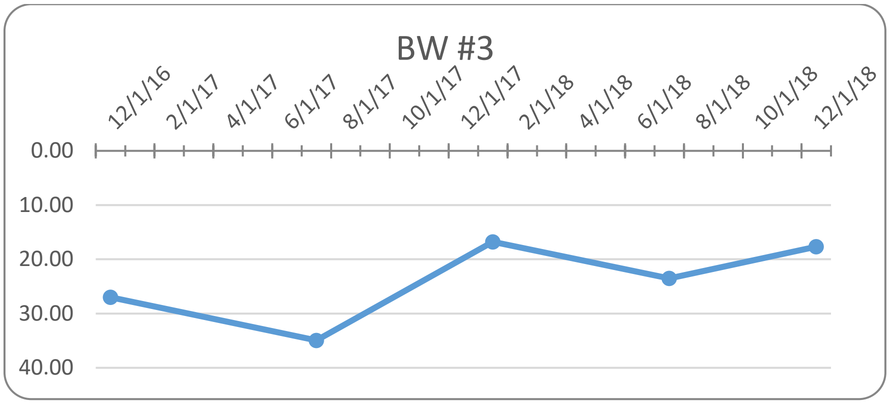

TR #2
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/18
0.00
50.00
100.00
150.00
200.00

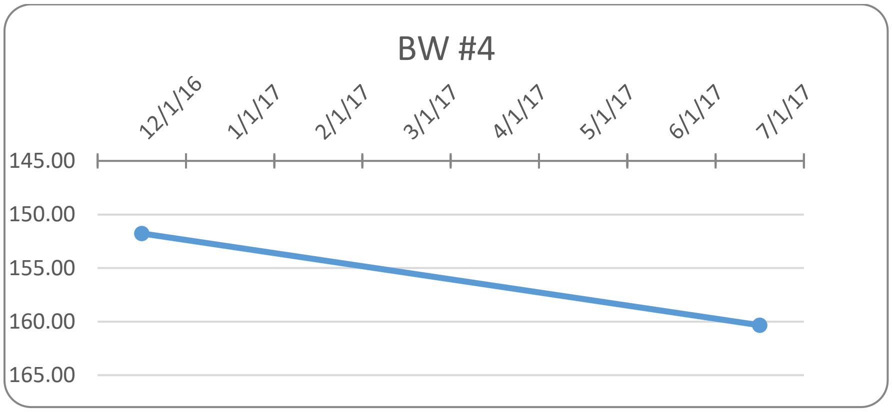

TR #3
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/18
48.00
50.00
52.00
54.00
56.00
58.00

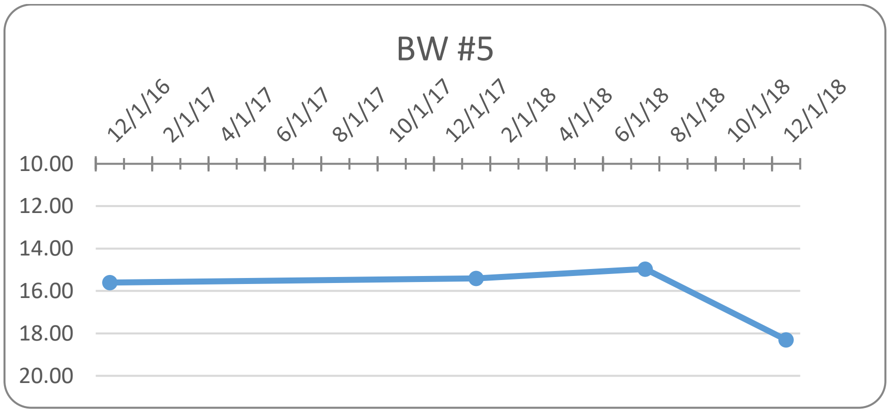

TR #4
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
80.00
90.00
100.00
110.00
120.00

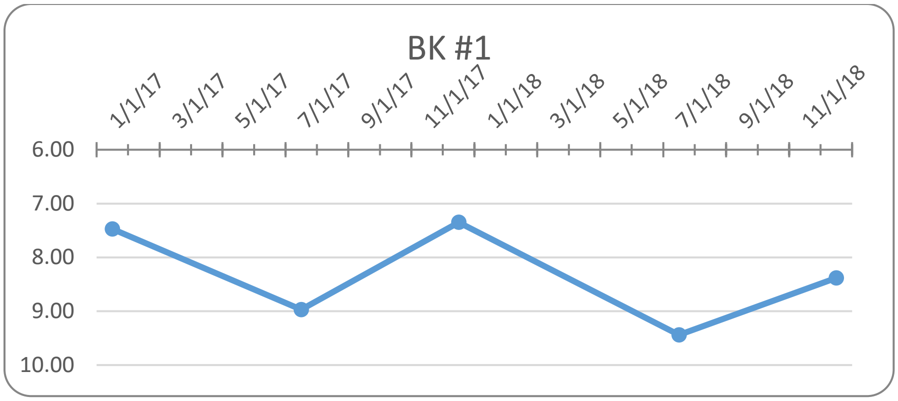

BW #1
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/18
0.00
20.00
40.00
60.00
80.00
100.00
120.00

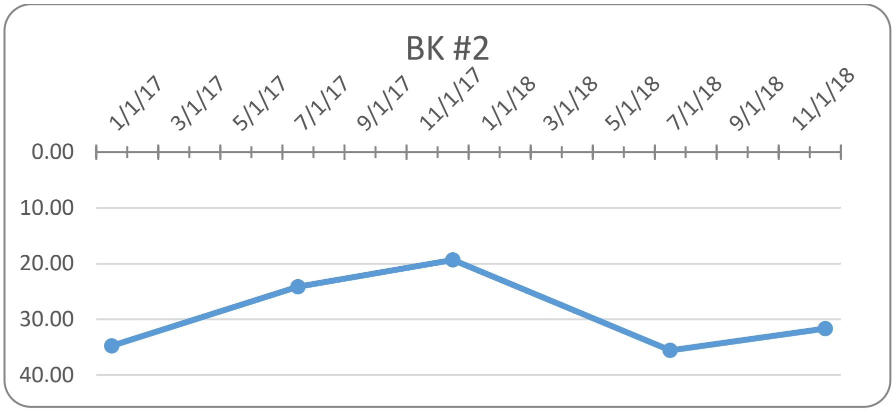

BW #2
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/18
70.00
72.00
74.00
76.00
78.00
80.00

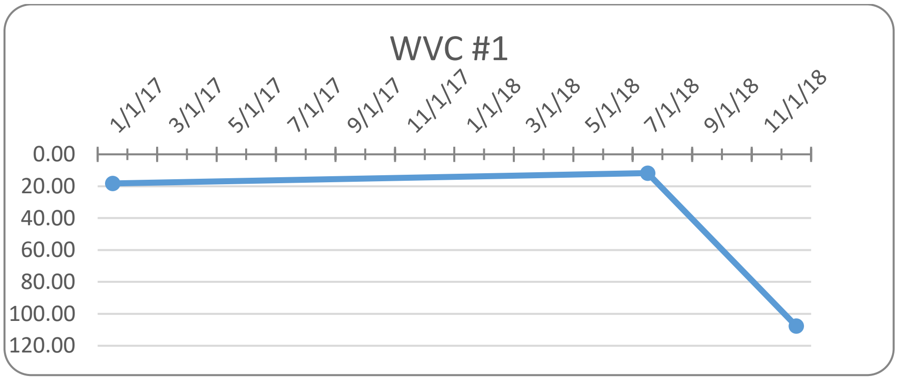

BW #3
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/18
0.00
10.00
20.00
30.00
40.00

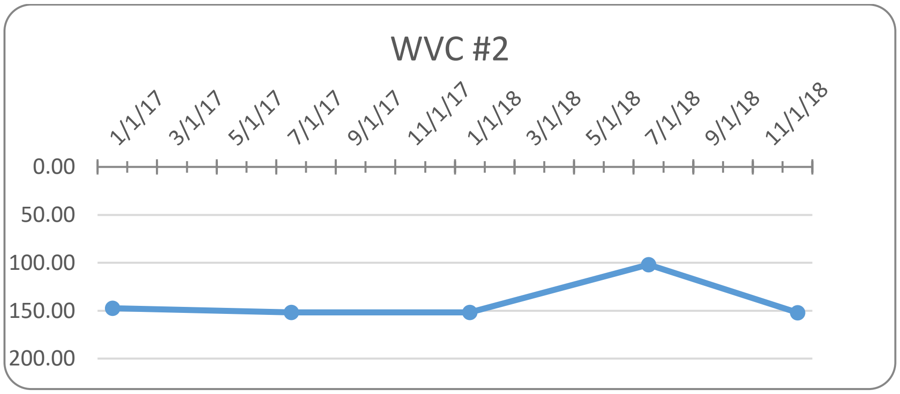

BW #4
12/1/16
1/1/17
2/1/17
3/1/17
4/1/17
5/1/17
6/1/17
7/1/17
145.00
150.00
155.00
160.00
165.00

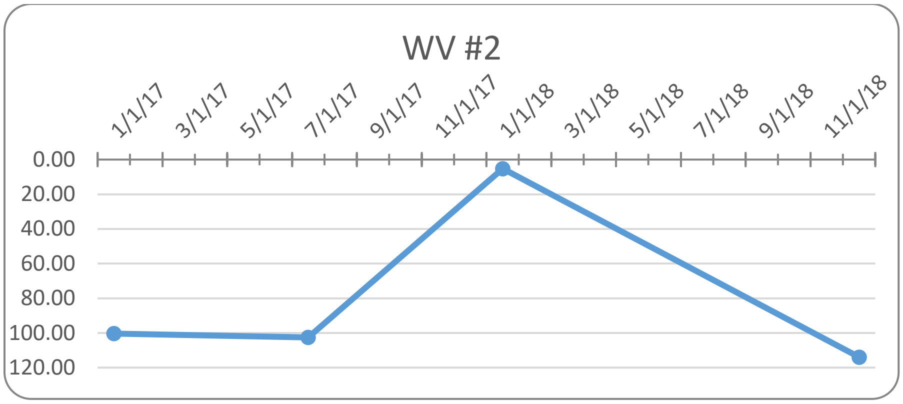

BW #5
12/1/16
2/1/17
4/1/17
6/1/17
8/1/17
10/1/17
12/1/17
2/1/18
4/1/18
6/1/18
8/1/18
10/1/18
12/1/18
10.00
12.00
14.00
16.00
18.00
20.00

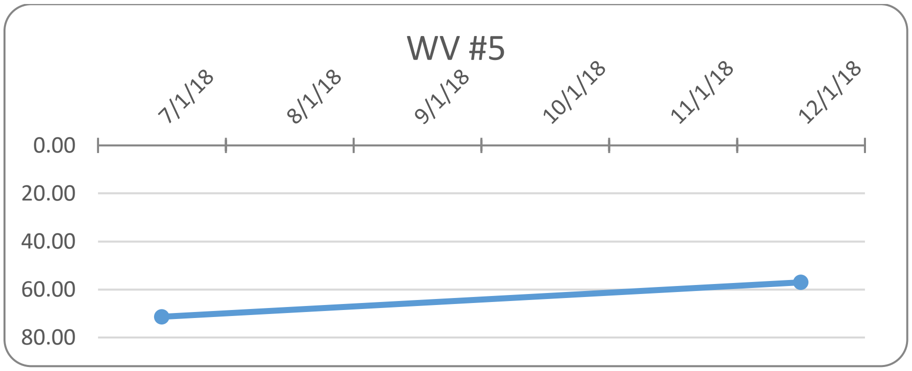

BK #1
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
6.00
7.00
8.00
9.00
10.00

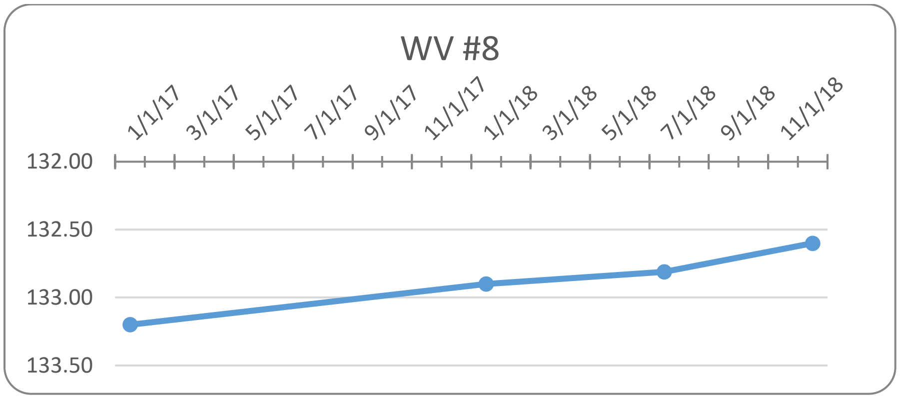

BK #2
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
10.00
20.00
30.00
40.00

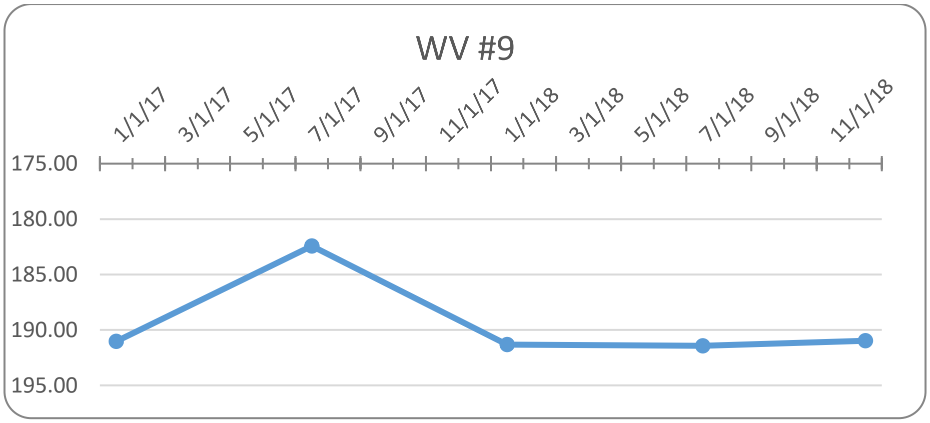

WVC #1
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
20.00
40.00
60.00
80.00
100.00
120.00

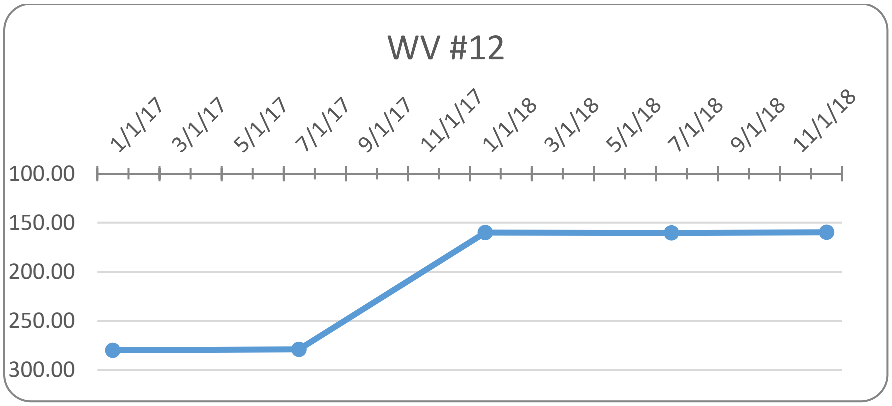

WVC #2
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
50.00
100.00
150.00
200.00

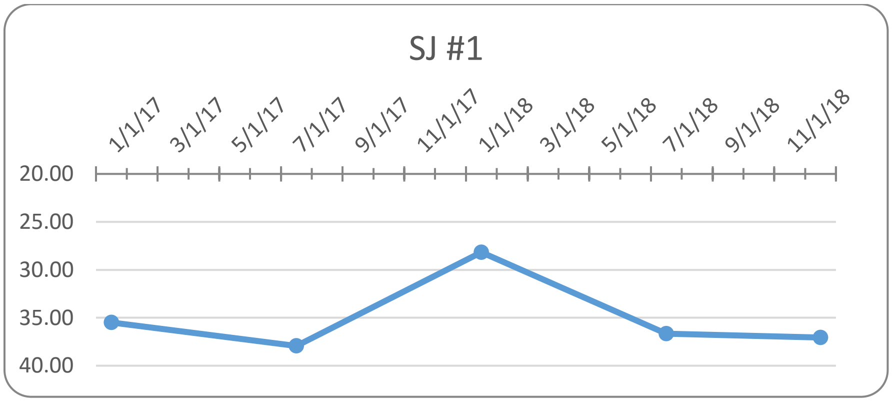

WV #2
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
20.00
40.00
60.00
80.00
100.00
120.00

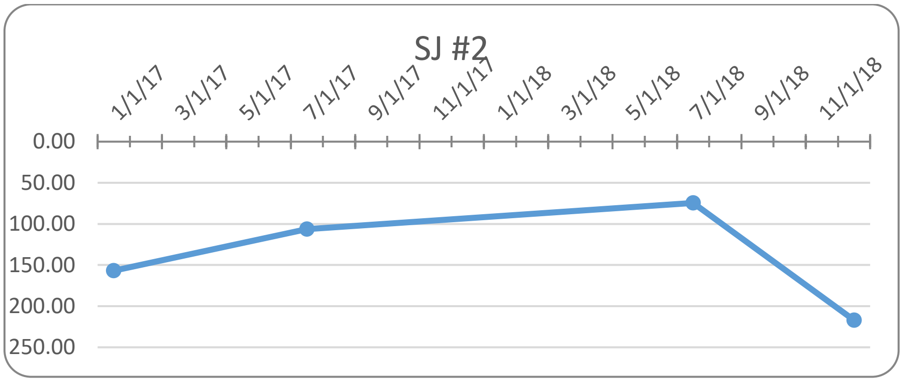

WV #5
7/1/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
0.00
20.00
40.00
60.00
80.00

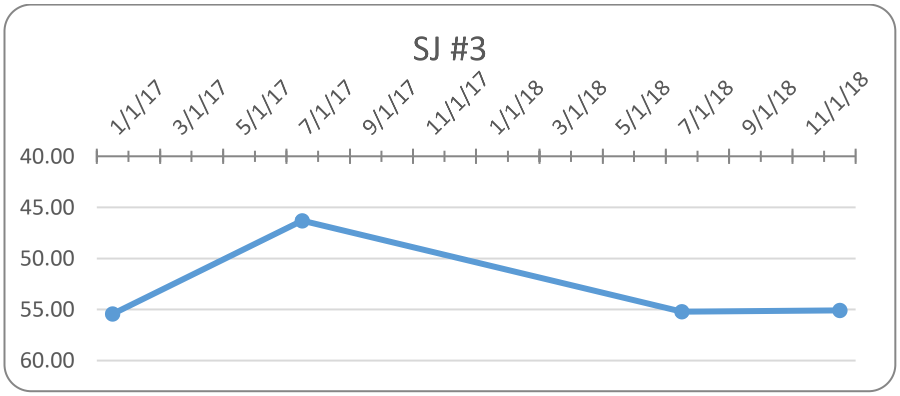

WV #8
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
132.00
132.50
133.00
133.50

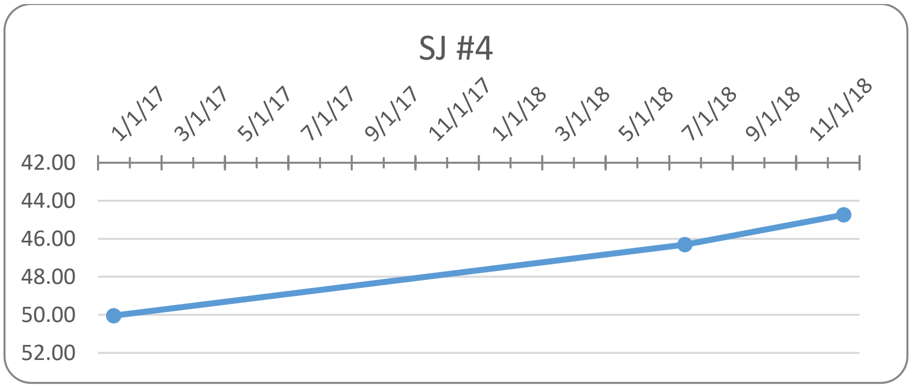

WV #9
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
175.00
180.00
185.00
190.00
195.00

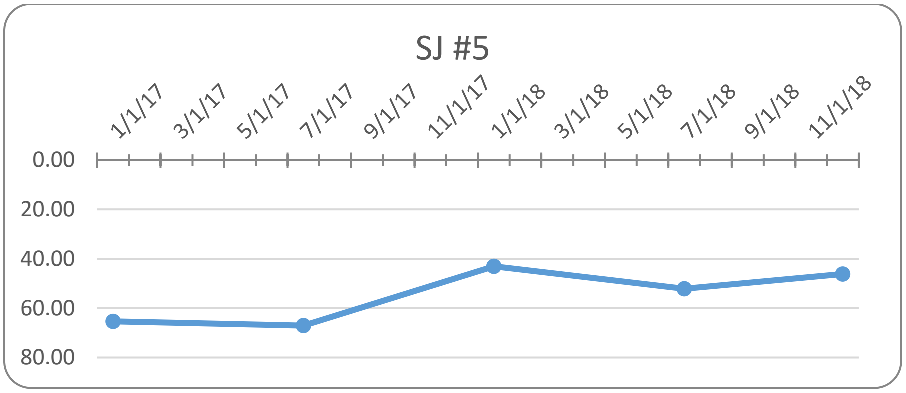

WV #12
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
100.00
150.00
200.00
250.00
300.00

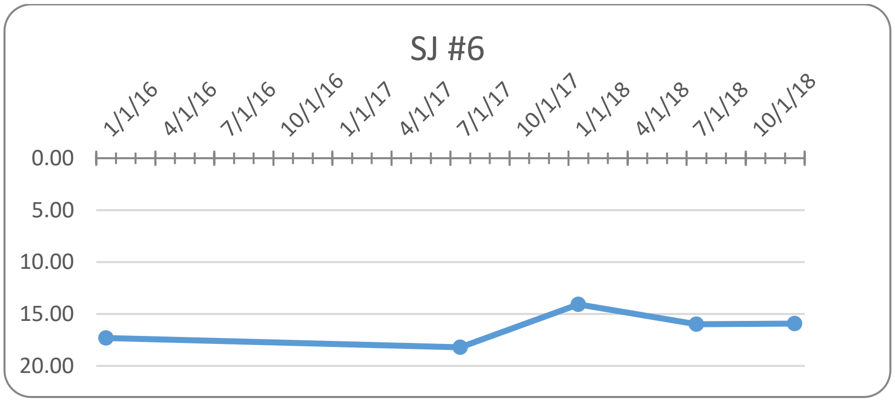

SJ #1
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
20.00
25.00
30.00
35.00
40.00

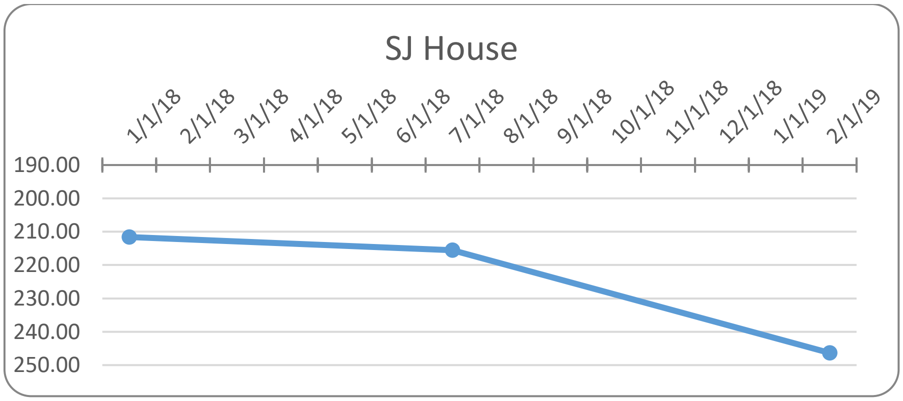

SJ #2
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
50.00
100.00
150.00
200.00
250.00

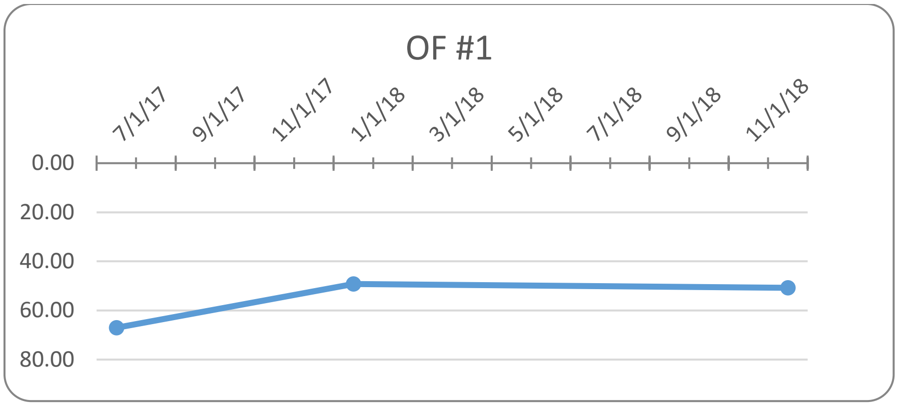

SJ #3
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
40.00
45.00
50.00
55.00
60.00

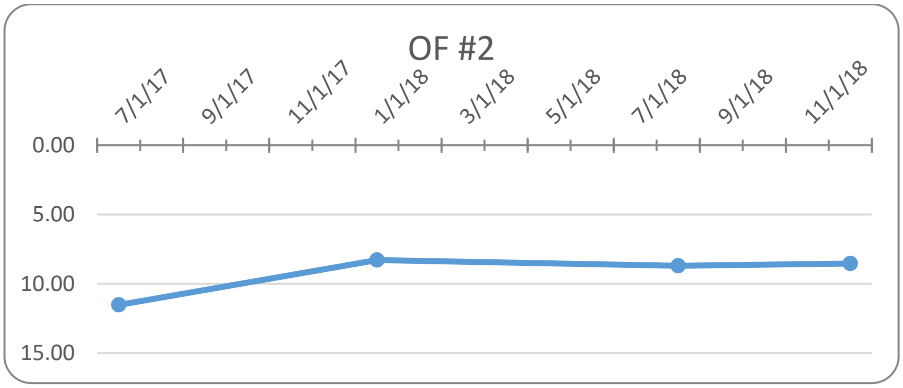

SJ #4
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
42.00
44.00
46.00
48.00
50.00
52.00

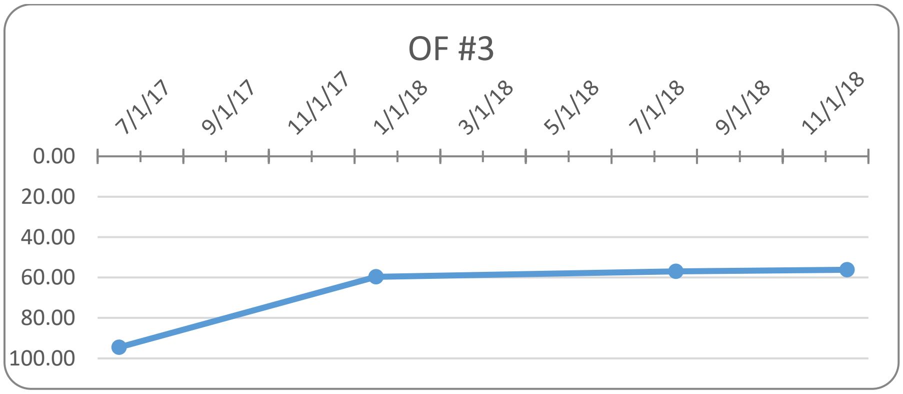

SJ #5
1/1/17
3/1/17
5/1/17
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
20.00
40.00
60.00
80.00

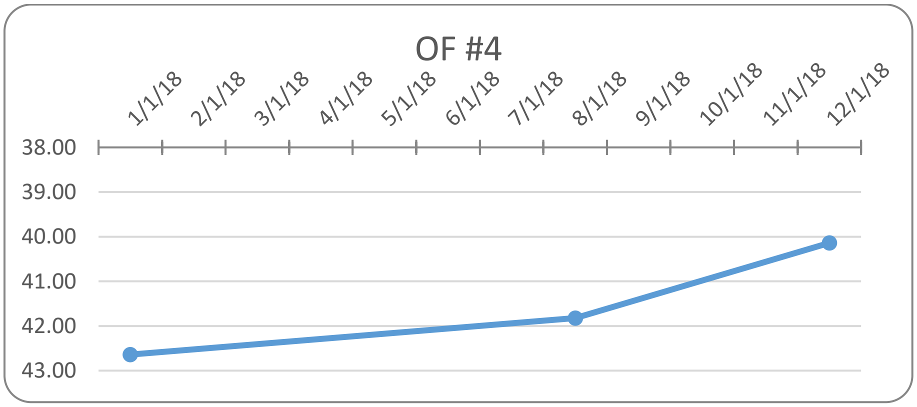

SJ #6
1/1/16
4/1/16
7/1/16
10/1/16
1/1/17
4/1/17
7/1/17
10/1/17
1/1/18
4/1/18
7/1/18
10/1/18
0.00
5.00
10.00
15.00
20.00

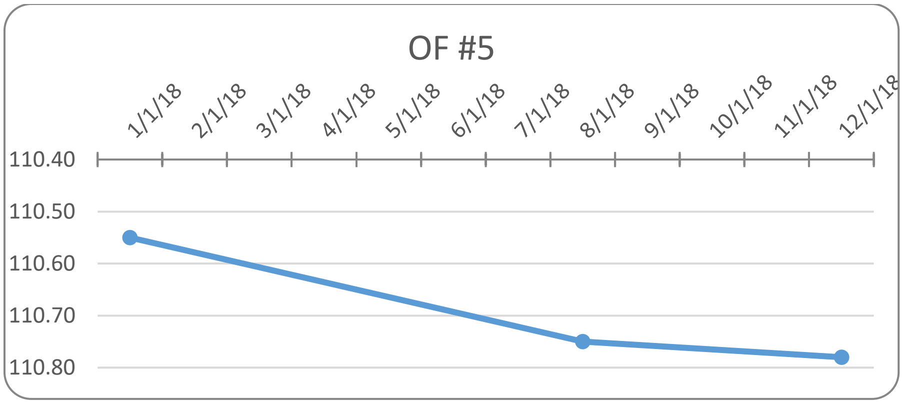

SJ House
1/1/18
2/1/18
3/1/18
4/1/18
5/1/18
6/1/18
7/1/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
1/1/19
2/1/19
190.00
200.00
210.00
220.00
230.00
240.00
250.00

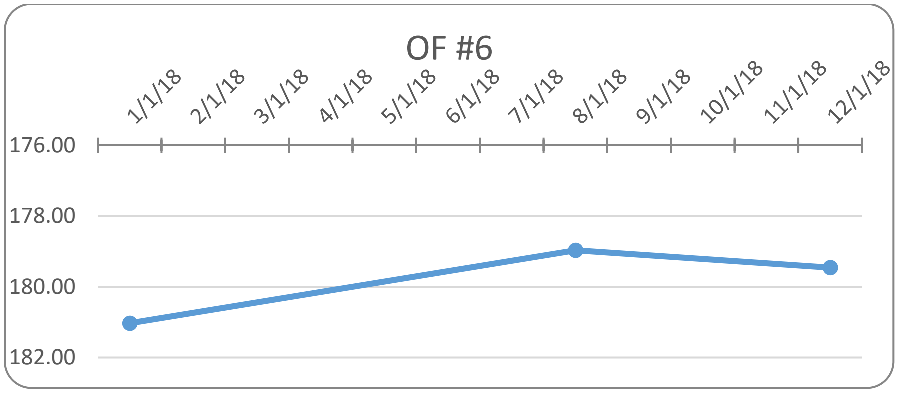

OF #1
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
20.00
40.00
60.00
80.00

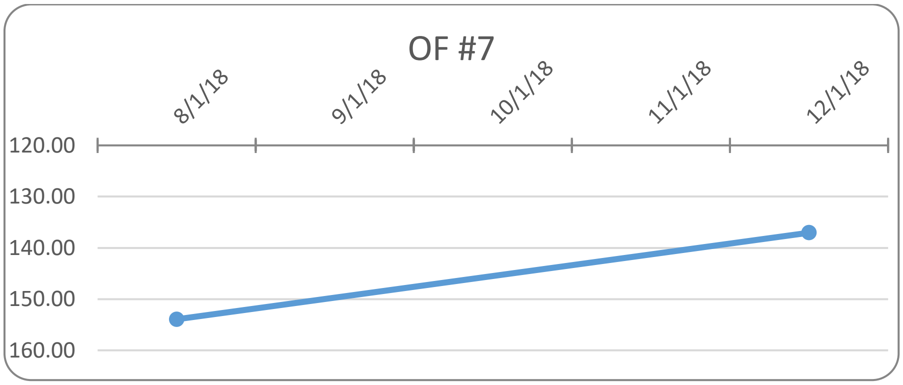

OF #2
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
5.00
10.00
15.00

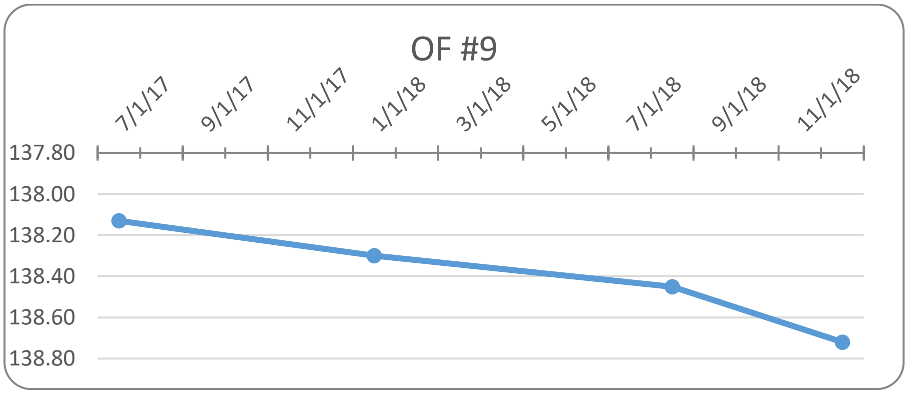

OF #3
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
20.00
40.00
60.00
80.00
100.00

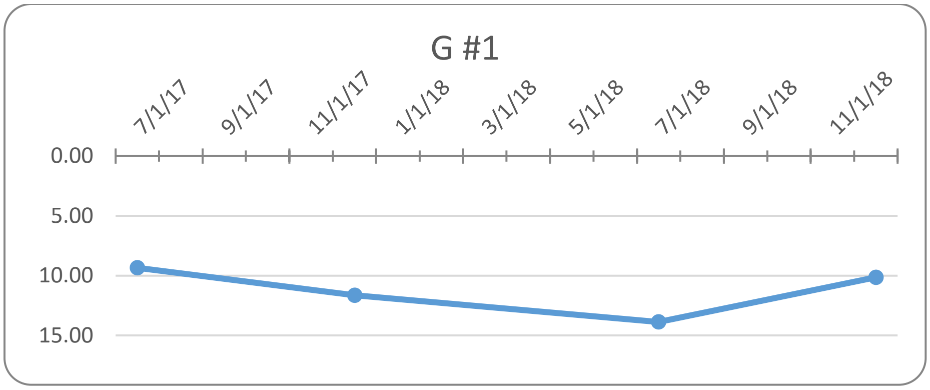

OF #4
1/1/18
2/1/18
3/1/18
4/1/18
5/1/18
6/1/18
7/1/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
38.00
39.00
40.00
41.00
42.00
43.00

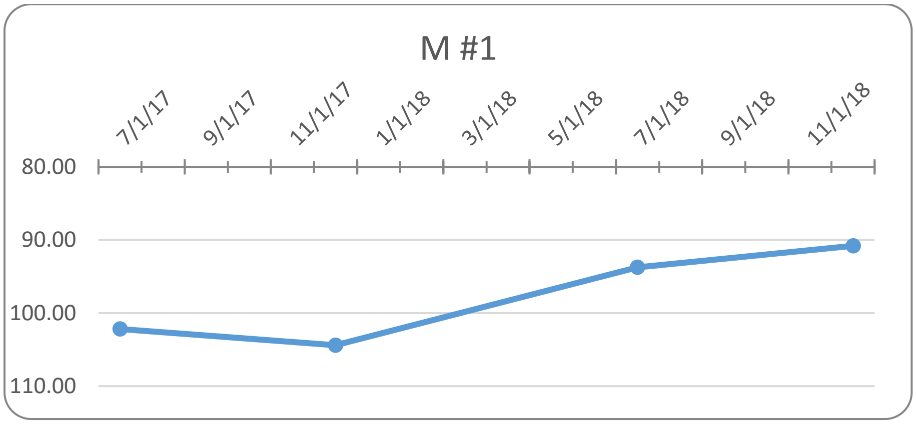

OF #5
1/1/18
2/1/18
3/1/18
4/1/18
5/1/18
6/1/18
7/1/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
110.40
110.50
110.60
110.70
110.80

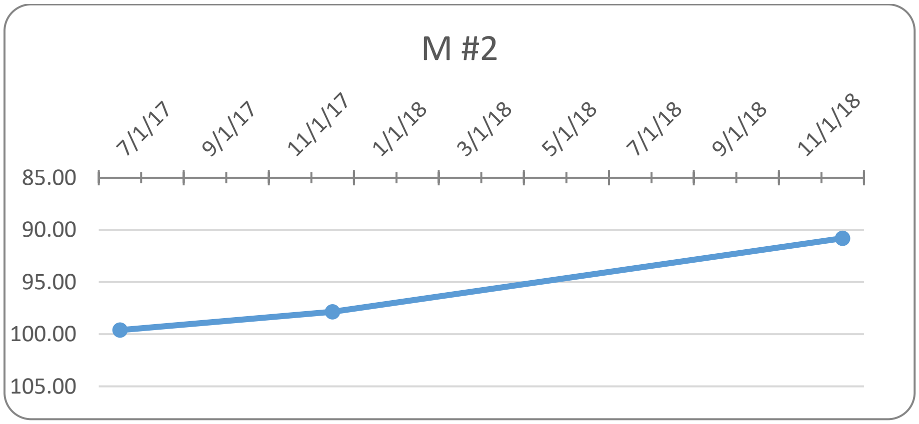

OF #6
1/1/18
2/1/18
3/1/18
4/1/18
5/1/18
6/1/18
7/1/18
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
176.00
178.00
180.00
182.00


OF #7
8/1/18
9/1/18
10/1/18
11/1/18
12/1/18
120.00
130.00
140.00
150.00
160.00


OF #9
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
137.80
138.00
138.20
138.40
138.60
138.80


G #1
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
0.00
5.00
10.00
15.00


M #1
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
80.00
90.00
100.00
110.00


M #2
7/1/17
9/1/17
11/1/17
1/1/18
3/1/18
5/1/18
7/1/18
9/1/18
11/1/18
85.00
90.00
95.00
100.00
105.00