Woodland Creek Pollution Load Reduction Study – Tanglewilde Retrofit Project

Data Review Summary

May 2011

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Thurston County Water Resources Division

Of

Thurston County Resource Stewardship Department

Woodland Creek Pollution Load Reduction Study

Tanglewilde Comprehensive Data Review – (2007 -2011)

Overview

This summary is a brief report on the monitoring data results obtained from all of the monitoring and recording devices and stations installed in the Tanglewilde neighborhood between 2007 and present. These monitoring devices and stations were installed as part of the Woodland Creek Pollution Load Reduction Study grant provided to Thurston County by the Washington Department of Ecology in 2009. The intent of the grant was to identify ways to reduce direct discharges to Woodland Creek from stormwater runoff and to construct the preferred design option. The reduction of surface stormwater runoff to Woodland Creek by infiltration was chosen as the most effective method to remove targeted pollutants from the stormwater. It was decided that the most cost effective way to treat the stormwater was through a series of retrofitted, pre-existing drywells. Retrofitting the drywells began in the summer of 2010 and was substantially completed by the fall of 2010. A series of groundwater wells and flow meters were installed as part of this study to help measure the pre and post-effectiveness of the project. The summary of results of the data collected to date is presented below. Charts of relevant data are attached in Appendix A.

Groundwater Well Data 2008-2011

Data collection began in 2008 after six monitoring wells were installed to begin measuring groundwater in the Tanglewilde neighborhood to initiate pre-construction monitoring of groundwater levels and to identify and sample subsurface soils. Five additional wells were installed in late 2008 and early 2009 as the final design of the infiltration system was completed. One well was not equipped with groundwater monitoring capability and was used for identification of subsurface materials for sampling and visual identification.

The groundwater is monitored monthly by manual sounding of each piezometer well to obtain the depth below ground surface of the dynamic water level. The results are then calculated to provide a water level elevation (NGVD '29) across the entire Tanglewilde study site.

Results: The datasets that Thurston County has collected since 2008 are summarized in the charts included in this discussion package. Generally, groundwater has fluctuated between approximately 2 to 4 feet. Some wells have shown very little water in them over the course of monitoring, or no groundwater at all (TWB-1 near Carpenter Road). The current 2011 water year has yielded highest groundwater levels to date. Higher groundwater levels are likely the result of overall higher groundwater trends throughout the region. It is also likely that the contribution made by the infiltration of surface water into the retrofitted drywells is feeding slightly higher groundwater levels. This would indicate the drywells are performing the function of diverting untreated runoff into the ground through the retrofitted drywells. Each drywell removes and infiltrates a significant amount of street runoff by

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filtering it into the ground. Infiltration rates vary between 90 inches per hour to 4 inches per hour (infiltration tests conducted summer 2010) for the rehabilitated drywells.

The groundwater is likely elevated because of the unusual rainfall patterns we have recorded in the 2010 and 2011 water years. These two water years can be characterized by higher than normal precipitation spread out over a longer period of the year. A typical wet season in Western Washington begins in late October and wanes by April. During the wet season, there are multiple large events that gradually charge the subsurface water levels to seasonal highs in March. Then we transition to a dry period at which time water levels return to predictable levels where they remain until the next wet season. In the 2010 and 2011 water years this pattern has not occurred. As you will see in more detail in the "Precipitation and Climate Fluctuations" Section, the wet seasons have been wetter and several months longer than our typical pattern. This has resulted in high surface flow and groundwater situations to develop in every part of Thurston County and persist even well into summer. On average, groundwater and streamflow levels in 2011 are 50 percent higher than normal.

Discussion of Stormwater System Flow Data (2007-2011)

In the case of the Tanglewilde project, Thurston County began recording stormwater outflows in 2008 to obtain pre-construction baseline readings of flow. The consolidated main outflow pipe near Woodland Creek (TWOF-1) was equipped in December 2007 with a Greyline Stingray Flowmeter. We captured a peak event in December 2007 and used this peak value (2100 GPM) to base our high flow assumptions upon. This storm event was determined to be a 50 to 75 year event in this location, so this was a reasonable assumption to set as a high level benchmark. But on January 9, 2009, we captured the 100 year storm event for this location; therefore, we selected this event as the new high flow threshold. Both of these events were positively correlated with a nearby precipitation data collection station the County operates approximately two miles south of Tanglewilde. Numerous other rainfall events were positively correlated to flow surges at the site. So a pattern was developed to predict flow based on precipitation. This pattern was not repeatable after 2009 because of a fundamental shift in the rainfall pattern and precipitation event cycles recorded from 2009 – 2011 (present). These changes are discussed in detail in the following section. We continue to see a consistent (but muted) correlation between rainfall, groundwater, and surface water, even in the current precipitation pattern.

There are two other flowmeters installed up gradient of the main outfall. There is one meter installed at Husky Way and Wildcat (TWOF-3) and another meter at Husky Way and School Street (TWOF-2). These flow meters record lower flow volumes than TWOF-1 because they are higher up in the system, but the pattern of storm surge peaks is generally very close to those observed in TWOF 1 (sharp rise, slow fall tail). TWOF-3 is located at an intersection where a continuous flow of water is present year round. The source of this water has never been positively determined but it is suspected to be a leaking municipal water supply source. It flows relatively constant throughout the year and is recorded as a low flow baseline reading of approximately 10 gallons per minute. Storm flows are also recorded in this meter station as peaks above this baseline flow and correlate positively with the other two meter stations.

We have determined that the flows recorded in the Tanglewilde stormwater system respond to many factors- not only rainfall. This is likely due to the fact that the stormwater system is not a tightly closed system and that there is inflow and exfiltration (outflow) into and out of the pipe network. The single most obvious piece of evidence for this condition is the fact that TWOF-3 records continuous flow year round as discussed earlier. This baseflow contributes to the overall output of the system and is incorporated into the total outflow recorded at TWOF-1, near Woodland Creek. In a typical weather pattern year, the main outfall dries out completely (zero flow) in early May. TWOF-3 never dries out and continuously flows at approximately 10 GPM, even in the dry months. Somewhere in the system this flow is lost into the ground in dry months and does not appear at the end of the pipe in TWOF-1 flow data.

Photo and video evidence shows areas in the stormwater system where cracks and openings in the pipes likely exchange water out of, or into, the pipe system. This evidence suggests groundwater can infiltrate and inject potentially significant amounts of water into the stormwater system through cracks and seams in the pipes. The opposite is also likely by reverse mechanisms, as the groundwater around the pipes rises and falls during seasonal fluctuations, water can flow in or out of the stormwater system. This evidence suggests that the total flow recorded is a combination of surface flow and groundwater flow (infiltration or exfiltration) over the course of the year.

The final piece of evidence of the connection between the groundwater and stormwater pipe flow is an increased in the lag time between the peak of the precipitation event and the peak of the flow spike in the flowmeter data. This indicates a buffering effect may be occurring due to subsurface flow paths through the soil. Unfortunately, the rainfall distribution has not followed past patterns closely, so this correlation is weak and cannot be definitively stated. For this observation to be definitively stated, one or more rapid, high-intensity rainfall events are necessary to quantify the lag times of the surge peaks.

Discussion of Precipitation (WY 2010 – WY 2011)

In the 2010 water year (Oct 2009 – October 2010) the rainfall patterns shifted dramatically, and we did not see typical large rainfall events (single events greater than 3.5 inches in a 24 hour period). Rather, we recorded multiple “moderate events” from October through June. We then observed the wet season beginning again in September and persisting throughout the winter and still maintaining in May 2011. This 2-year pattern has not been seen or recorded previously and it has made prediction and correlation between rainfall and ground/ surface water very difficult to determine. These unusual patterns have dramatically changed groundwater and surface flow characteristics of every location we monitor throughout Thurston County. This pattern of wetter and cooler weather provides an inconsistent pattern with which to develop direct correlation hypotheses. The characteristic peak events that we rely on as “tag events” normally occur in November through January. They range between 3 and 4 inches of precipitation over a 24 hour period and have a very distinct and predictable pattern that can be easily traced through a flow regime, even in groundwater. These are the events we have been looking for to definitively provide us with direct evidence of how the Tanglewilde stormwater system behaves post drywell rehabilitation. Our current pattern is scattered tag events less than 2 inches spaced irregularly throughout nine months with a brief reprieve in July and August. These events

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add up over the entire year and do not allow sufficient lowering of the groundwater table before the pattern begins again. As of May 12, 2011, we are currently at the average rainfall total for the entire water year (51 inches), with four months to go in the water year.

Summary

Increased surface flow into the drywells is likely to raise local groundwater levels because of the additional water flowing into the ground from the drywells. This in turn results in increased infiltration into the stormwater conveyance system through cracks and voids and is observed as higher flows (of groundwater entering the pipe) at TWOF-1 at the end of the pipe near Woodland Creek. The way to prove this theory is through water quality analysis and peak trace precipitation events. The current climate pattern is not allowing us to follow these trace events because they are not occurring in a predictable pattern.

There is undoubtedly a significant amount surface runoff being directed into the ground via the retrofitted drywells; this is directly observable on site during rain storms. We can compare pre-rehabilitation street flooding with post-rehabilitation conditions (no flooding) and we visually observe water infiltrating into the drywells.

The Tanglewilde stormwater system is not a closed, isolated network of pipes. There are older portions of the stormwater mainline along Husky Way that allows water to enter and exit the system through cracks and holes in the pipes comprising the stormwater system.

There is a direct correlation between the precipitation that falls on the pavement in the Tanglewilde neighborhood and the stormwater runoff recorded in the three flowmeters installed in the stormwater pipes. The relationship between precipitation and stormwater flow in the pipes is directly related. The current precipitation pattern has not, however, allowed this relationship to be definitively quantified. The rainfall events that we typically use (3- 4 inch trace events) to characterize correlations between rainfall, groundwater and surface flow have not occurred in the past two years. As a result, it is difficult to observe and record the working relationship between these three complex mechanisms and provide a direct cause and effect report at this time.

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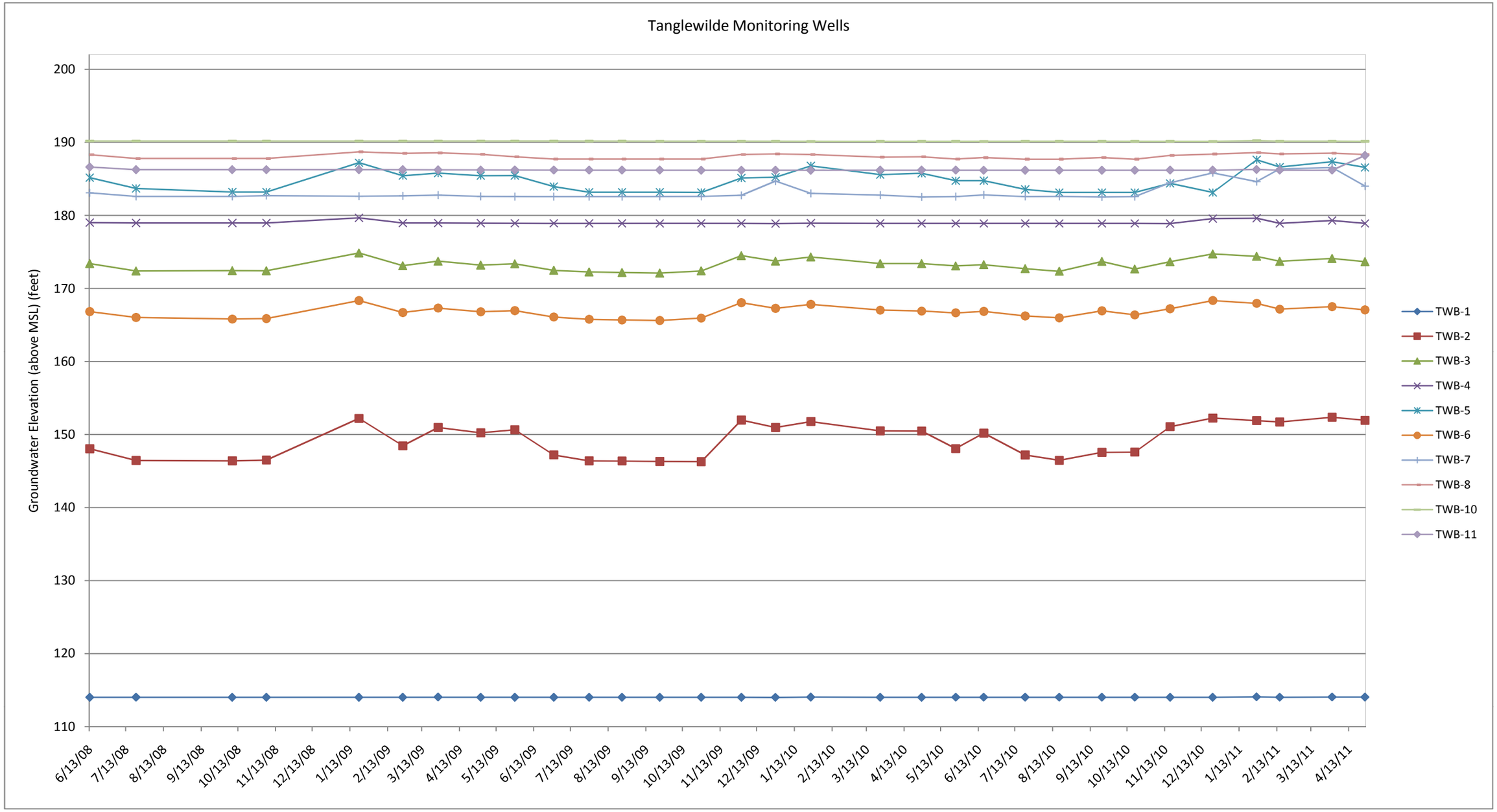
Map Features
Ground Water Wells2
Flow_monitoring
road
OWNER
City
County
Government
NO
Private
State
parcels
TW-1
TW-2
TW-3
TW-4
TW-5
TW-6
TW-7
TW-8
TW-9
TW-10
TW-11
MARTIN WAY E
HUSKY WAY SE
3RD WAY SE
4TH WAY SE
5TH CT SE
5TH WAY SE
6TH AVE SE
BRUNO LN SE
KINWOOD PARK LN SE
UNNAMED PVT DRWY
CARPENTER RD NE
CARPENTER RD SE
VILLANOVA ST NE
LOYOLA ST NE
GEORGETOWN DR NE
MERKEL WAY NE
12TH AVE NE
11TH AVE NE
HORNE ST NE
HENSLEY ST NE
KINGHAM ST SE
NEIL ST NE
3RD AVE SE
SCHOOL ST SE
3RD WAY SE
SAMURAI DR SE
CHOKER ST SE
BOBCAT DR SE
BOBCAT CT SE
RAM CT SE
THUNDERBIRD CT SE
SCHOOL CT SE
RANGER DR SE
LOGGER CT SE
LOGGER ST SE
WILDCAT ST SE
VIKING ST SE
WARRIOR ST SE
4TH CT SE
5TH CT SE
6TH AVE SE
BULLDOG ST SE
SEAHAWK ST SE
GLENALDA CT SE
KINWOOD RD SE
GLEN CT SE
GREEN CT SE
ALDEA CT SE
MALIBU CT SE
MALIBU DR SE
6TH AVE SE
OCLIGAR ST SE
ACORN CT SE
SCHOOL ST SE
THUNDERBIRD ST SE
TITAN CT SE
TITAN DR SE
TITUS CT SE
STEILACOOM RD SE
ROYAL OAKS DR SE
PAMELA DR SE
CHOKER CT SE
TROJAN CT SE

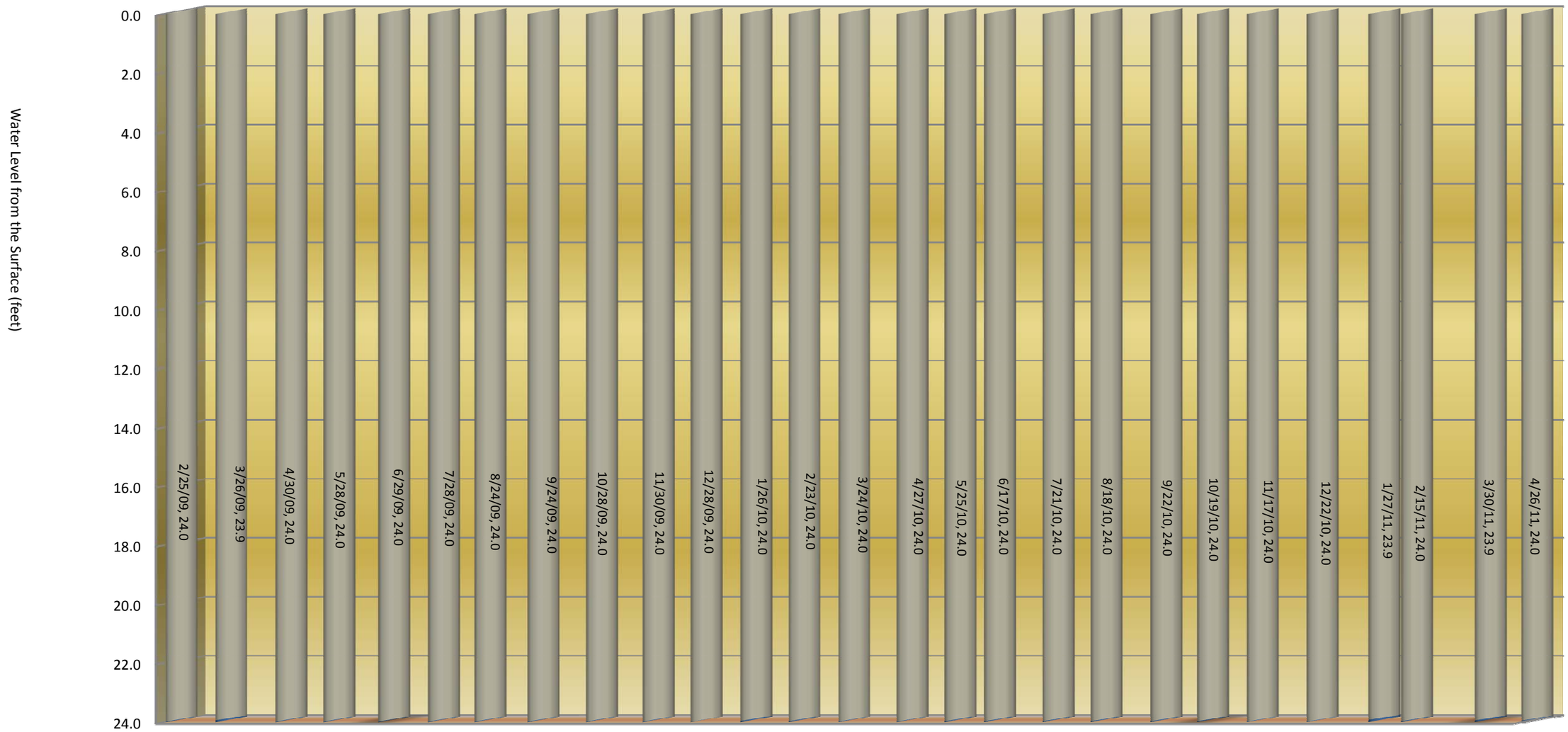
APPENDIX A – DATA CHARTS

- **Groundwater Charts**
- **Flowmeter Charts**
- **Precipitation Charts**

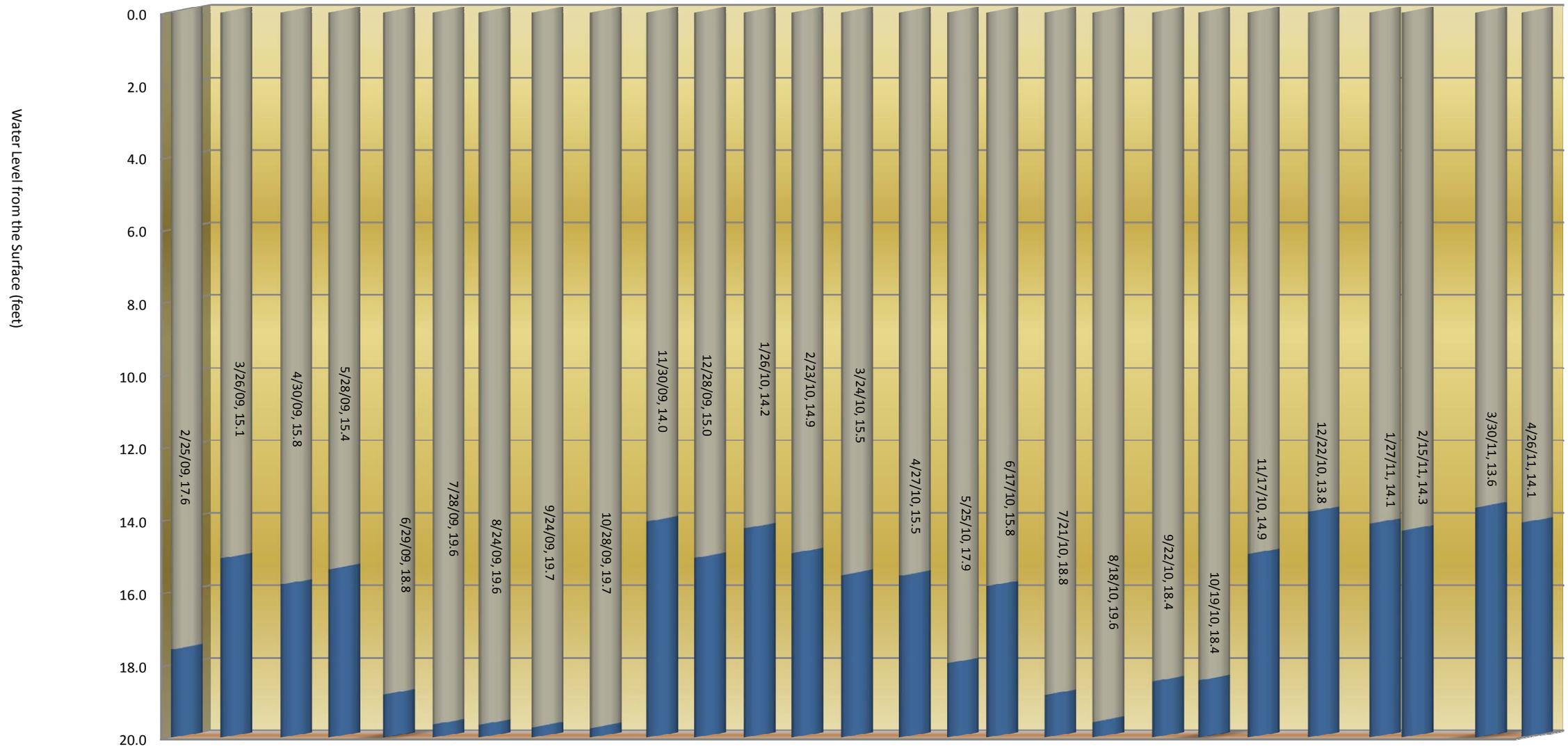
Groundwater Charts


Tanglewilde Monitoring Wells
Groundwater Elevation (above MSL) (feet)
200
190
180
170
160
150
140
130
120
110
6/13/08
7/13/08
8/13/08
9/13/08
10/13/08
11/13/08
12/13/08
1/13/09
2/13/09
3/13/09
4/13/09
5/13/09
6/13/09
7/13/09
8/13/09
9/13/09
10/13/09
11/13/09
12/13/09
1/13/10
2/13/10
3/13/10
4/13/10
5/13/10
6/13/10
7/13/10
8/13/10
9/13/10
10/13/10
11/13/10
12/13/10
1/13/11
2/13/11
3/13/11
4/13/11
TWB-1
TWB-2
TWB-3
TWB-4
TWB-5
TWB-6
TWB-7
TWB-8
TWB-10
TWB-11

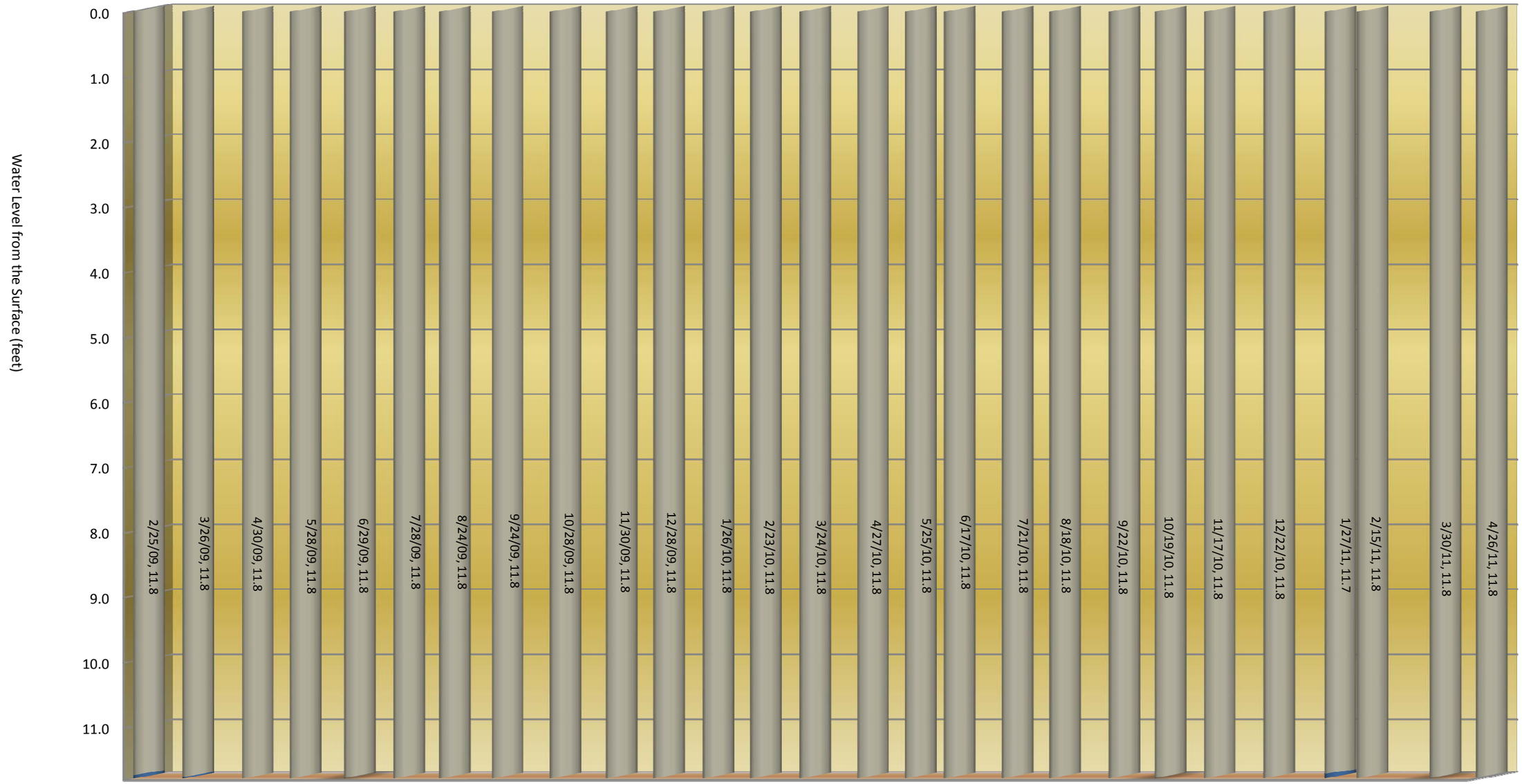
Tanglewilde Well TWB-1 (Husky Way near Carpenter Rd). Well depth is 24 feet. Manual water level readings, from ground level to water surface.



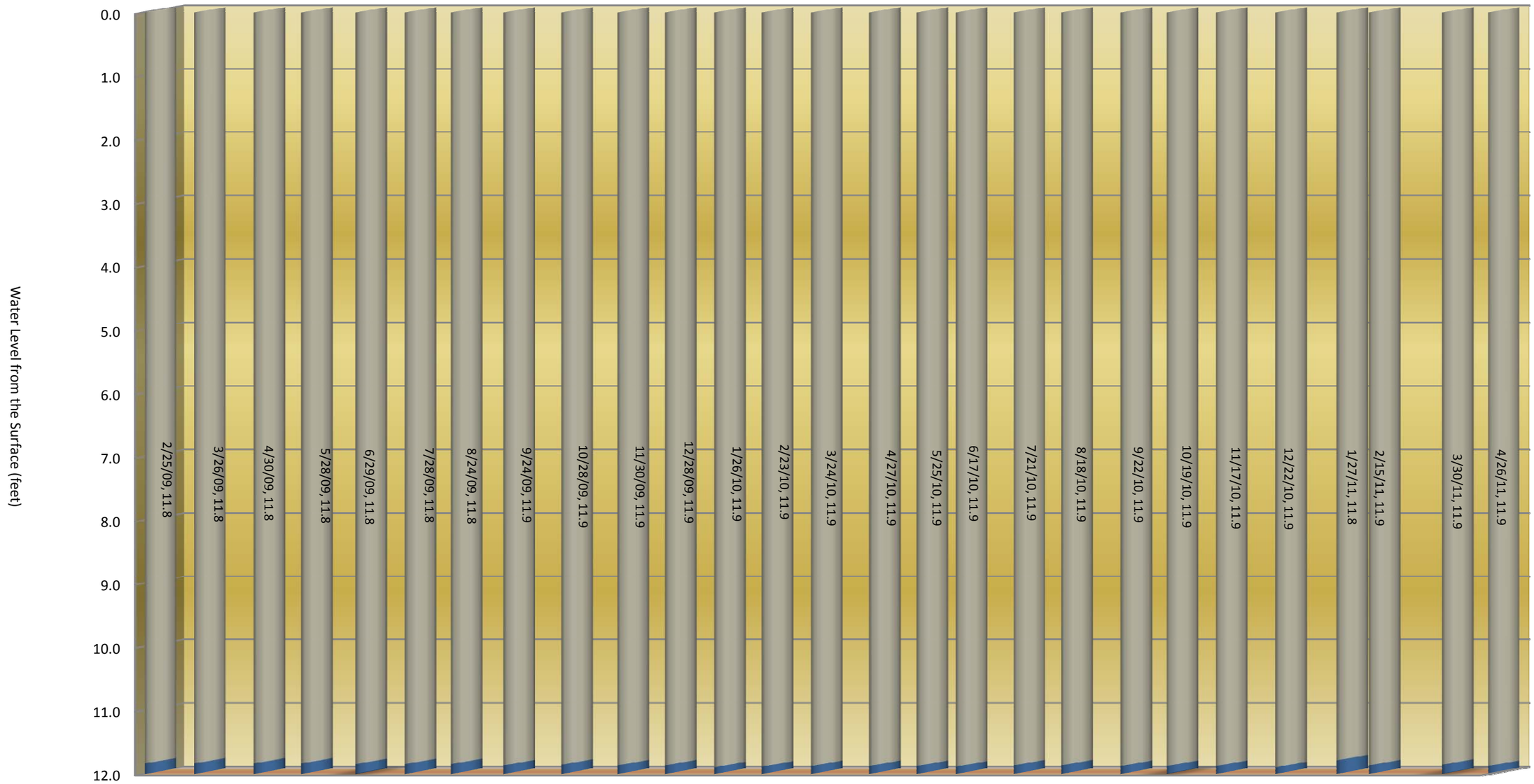
Tanglewilde Well TWB-2 (Husky Way Kinwood St). Well depth is 20 feet. Manual water level readings, from ground level to water surface.



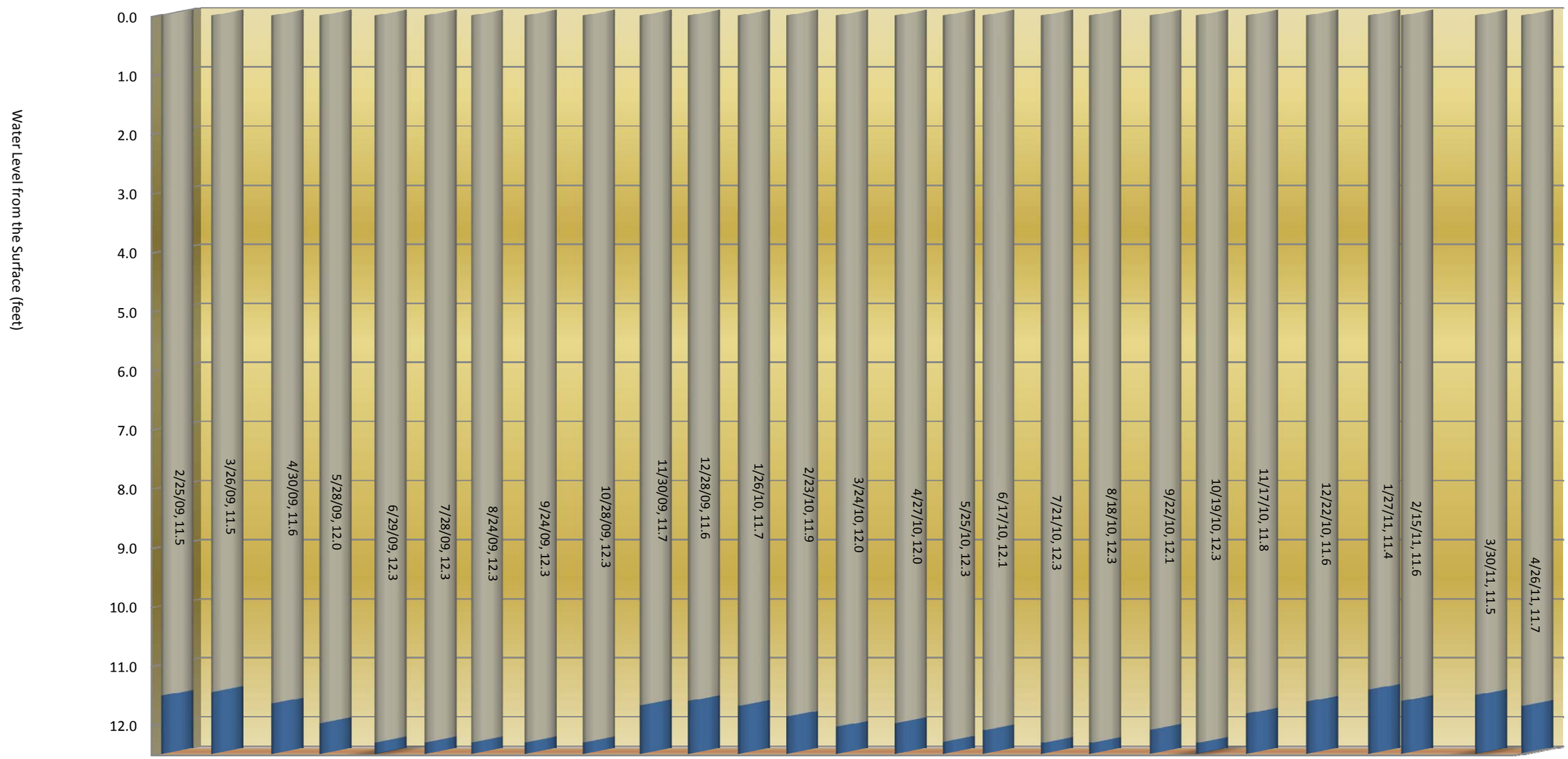
Tanglewilde Well TWB-11 (315 Ranger Dr SE). Well depth is 11.8 feet. Manual water level readings, from ground level to water surface.



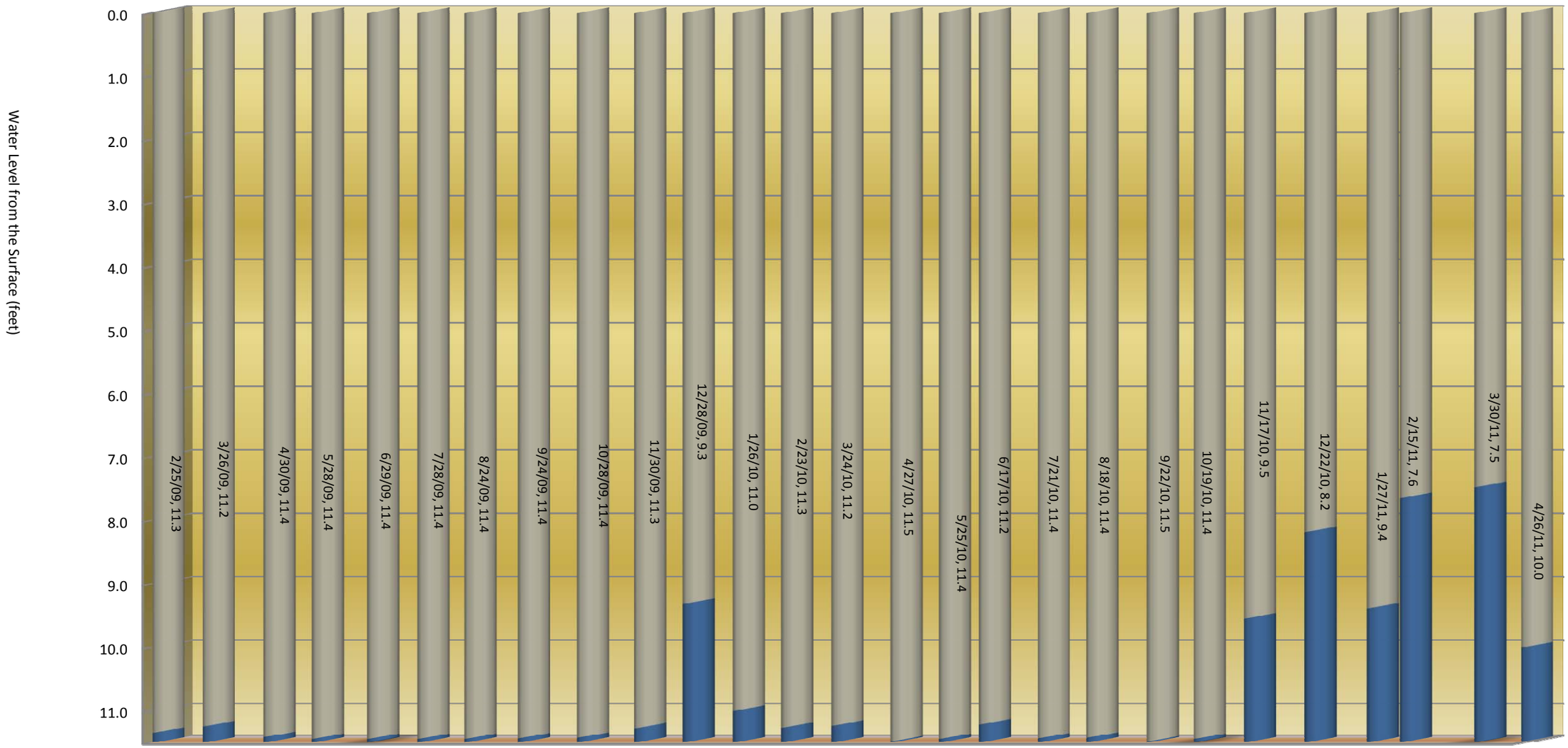
Tanglewilde Well TWB-10 (Choker Ct & Bobcat Dr SE). Well depth is 11.8 feet. Manual water level readings, from ground level to water surface.



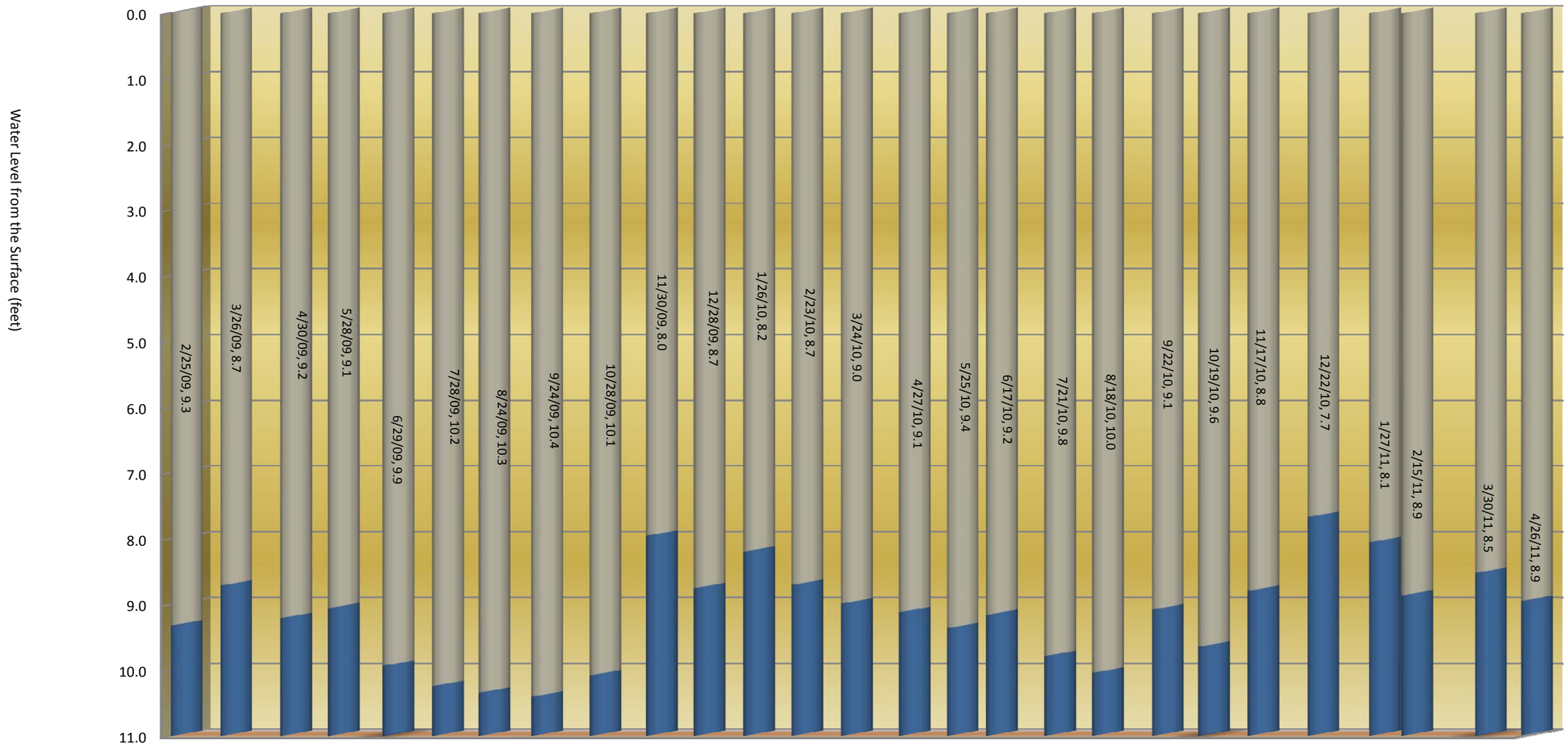
Tanglewilde Well TWB-8 (455 Bulldog St SE & 4th Way SE). Well depth is 12.5 feet. Manual water level readings, from ground level to water surface.



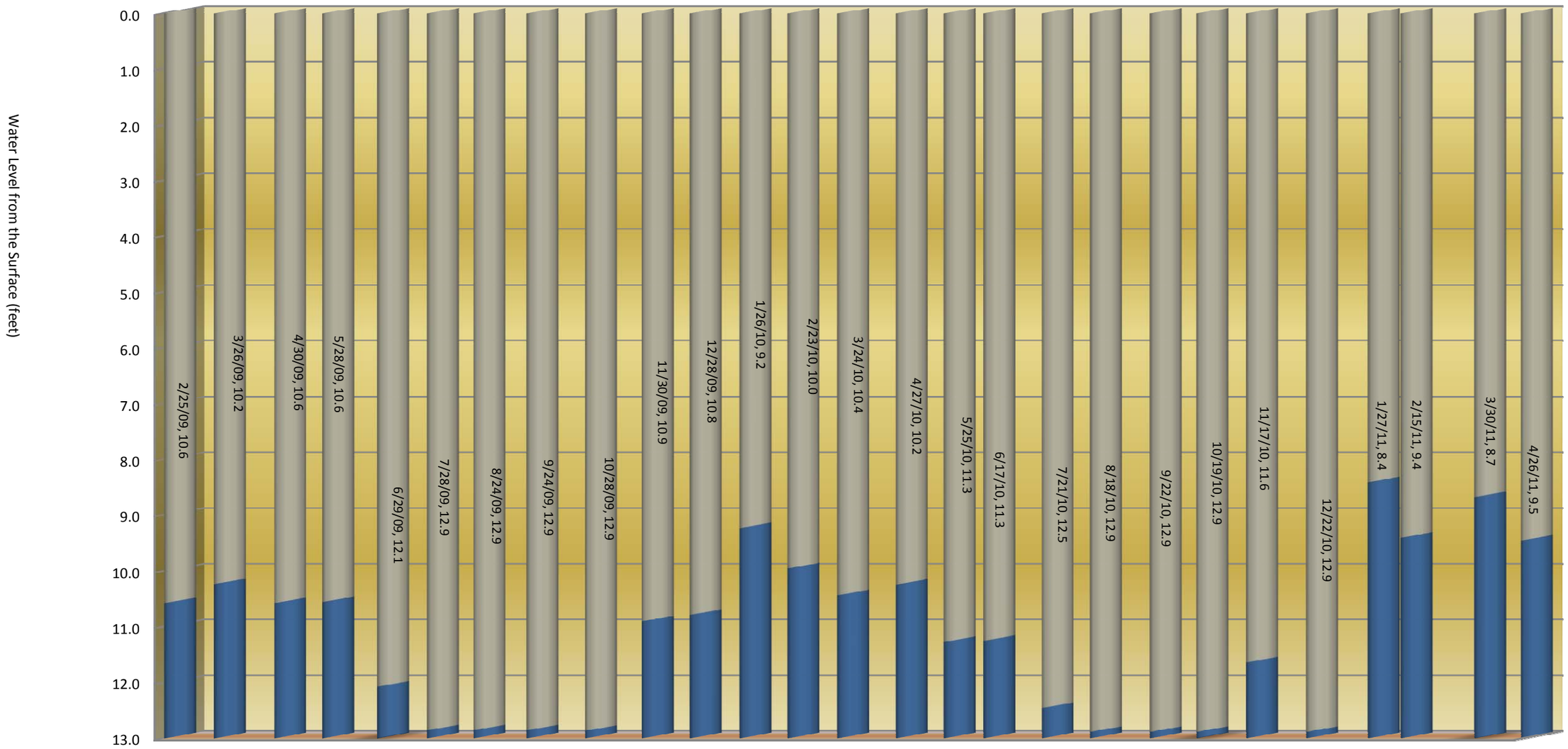
Tanglewilde Well TWB-7 (454 Cougar St SE). Well depth is 11.5 feet. Manual water level readings, from ground level to water surface.



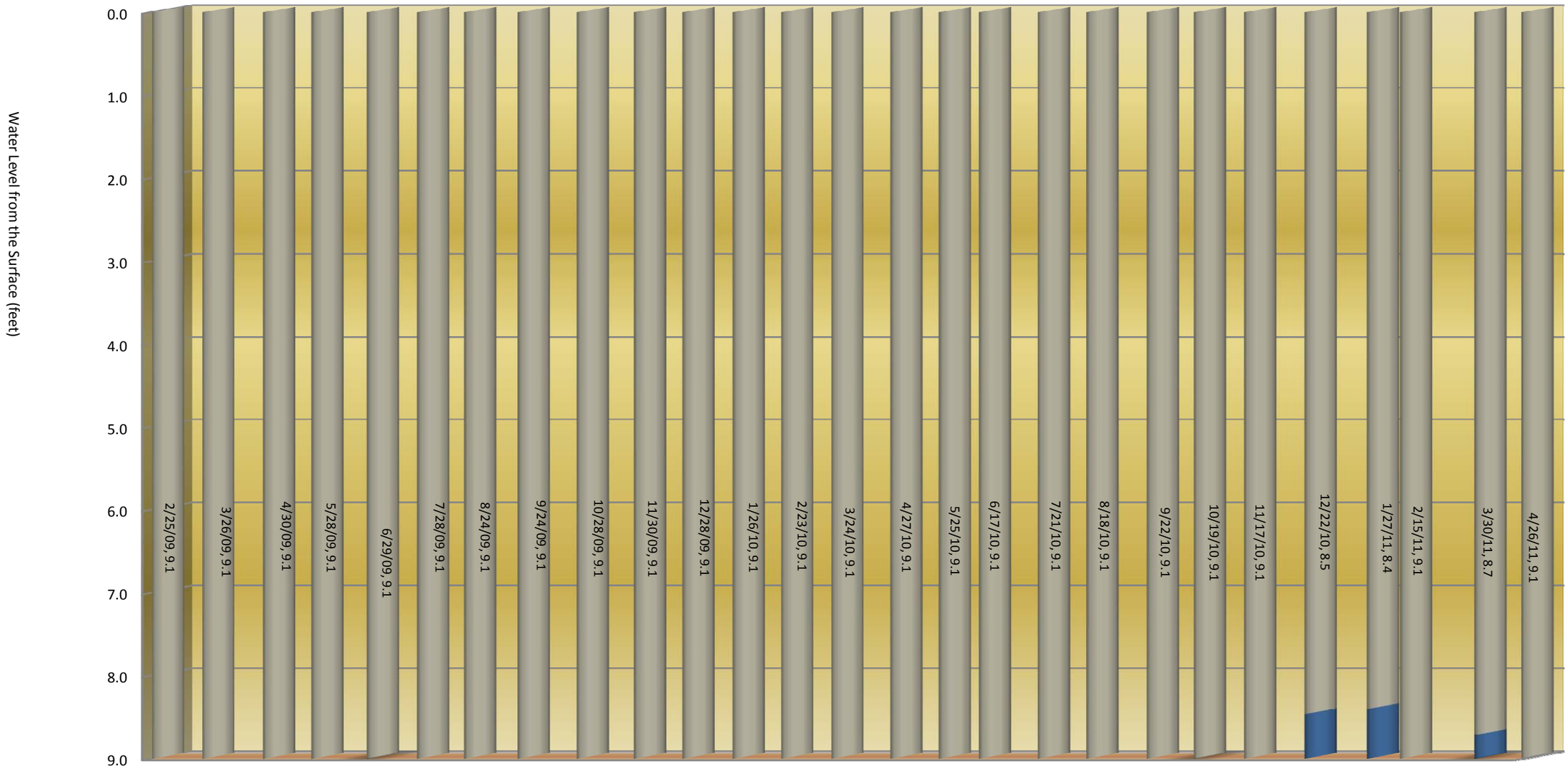
Tanglewilde Well TWB-6 (Tanglewood Park @ Husky Way SE & Wildcat St SE) Well depth is 11 feet. Manual water level readings, from ground level to water surface.



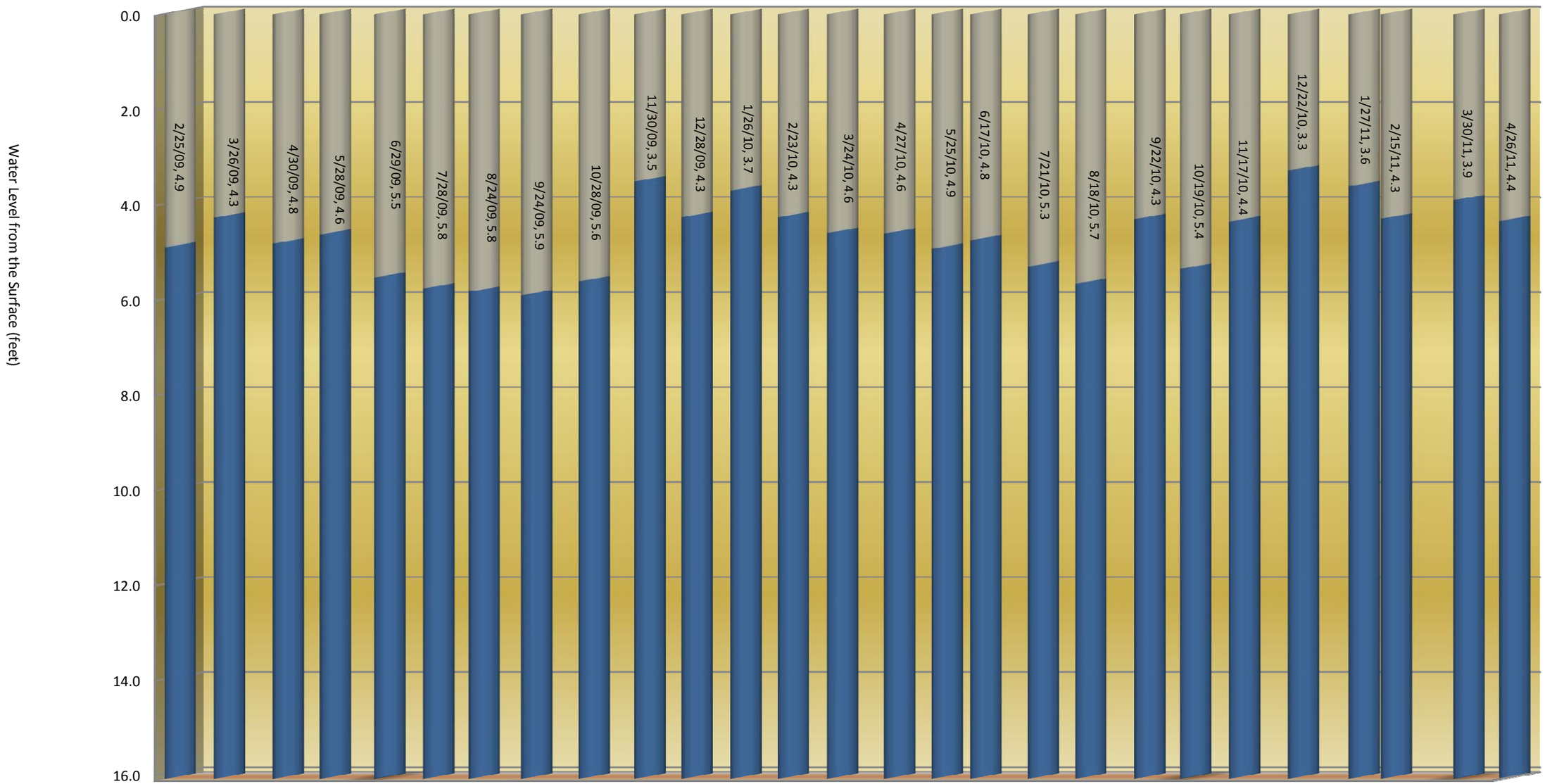
Tanglewilde Well TWB-5 (404 Choker St SE & Husky Way SE). Well depth is 13 feet. Manual water level readings, from ground level to water surface.



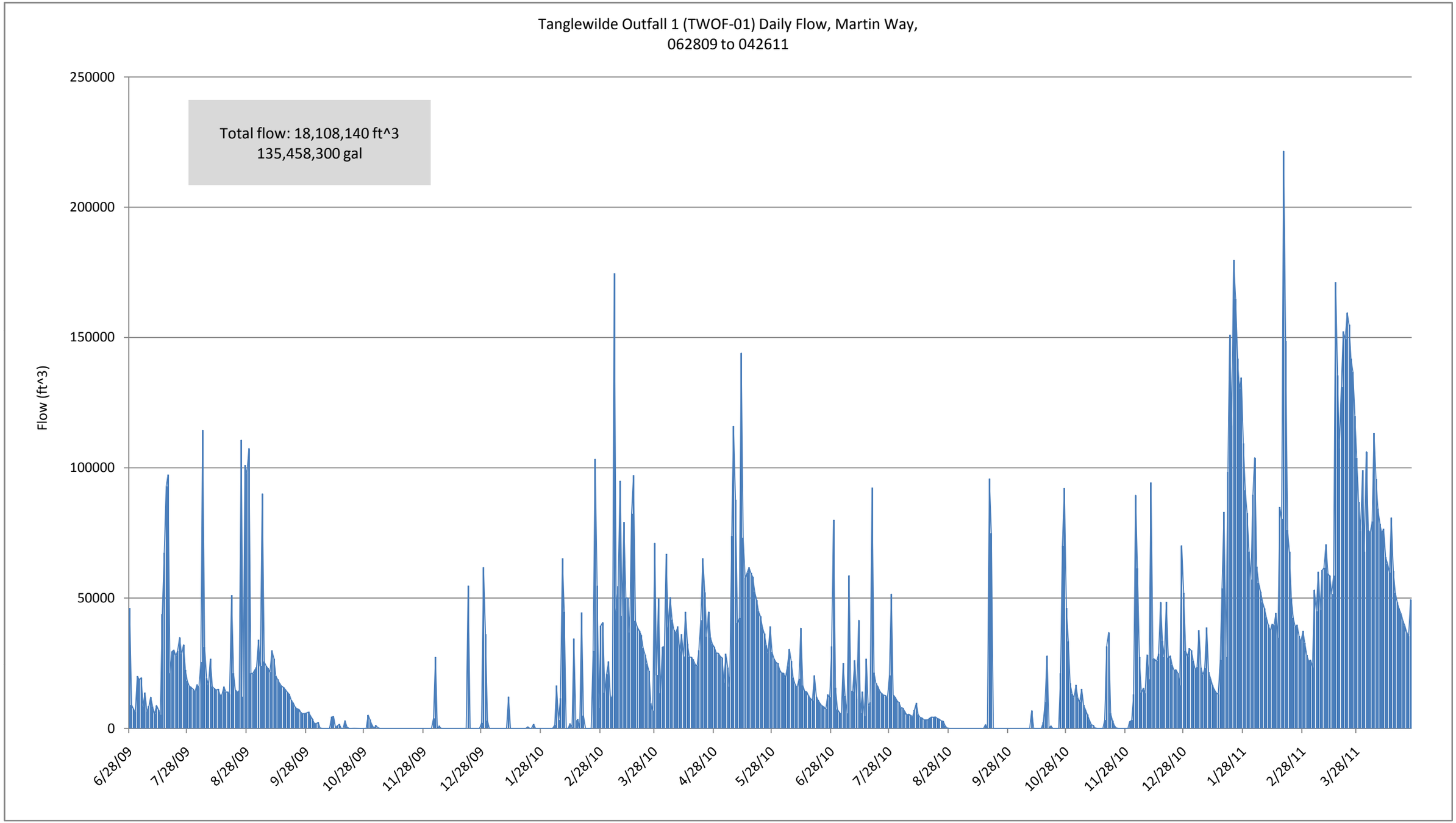
Tanglewilde Well TWB-4 (7653 Husky Way & Ram Ct SE). Well depth is 9 feet. Manual water level readings, from ground level to water surface.



Tanglewilde Well TWB-3 (7309 Husky Way SE & Logger St SE). Well depth is 16 feet. Manual water level readings, from ground level to water surface.



Flowmeter Charts


Tanglewilde Outfall 1 (TWOF-01) Daily Flow, Martin Way,
062809 to 042611
Total flow: 18,108,140 ft^3
135,458,300 gal
Flow (ft^3)
250000
200000
150000
100000
50000
0
6/28/09
7/28/09
8/28/09
9/28/09
10/28/09
11/28/09
12/28/09
1/28/10
2/28/10
3/28/10
4/28/10
5/28/10
6/28/10
7/28/10
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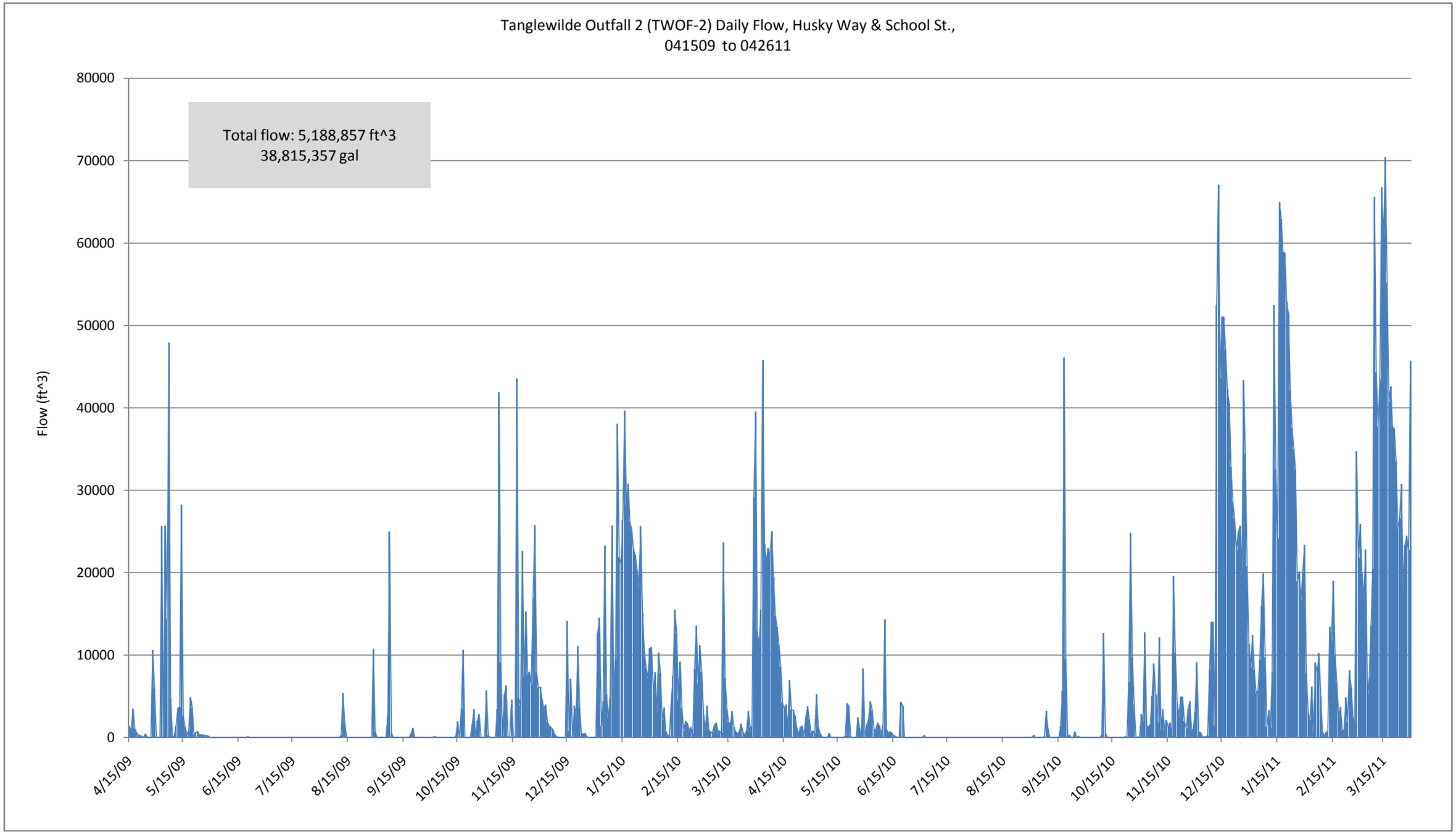
1/28/11
2/28/11
3/28/11


Tanglewilde Outfall 2 (TWOF-2) Daily Flow, Husky Way & School St.,
041509 to 042611
Total flow: 5,188,857 ft^3
38,815,357 gal
Flow (ft^3)
80000
70000
60000
50000
40000
30000
20000
10000
0
4/15/09
5/15/09
6/15/09
7/15/09
8/15/09
9/15/09
10/15/09
11/15/09
12/15/09
1/15/10
2/15/10
3/15/10
4/15/10
5/15/10
6/15/10
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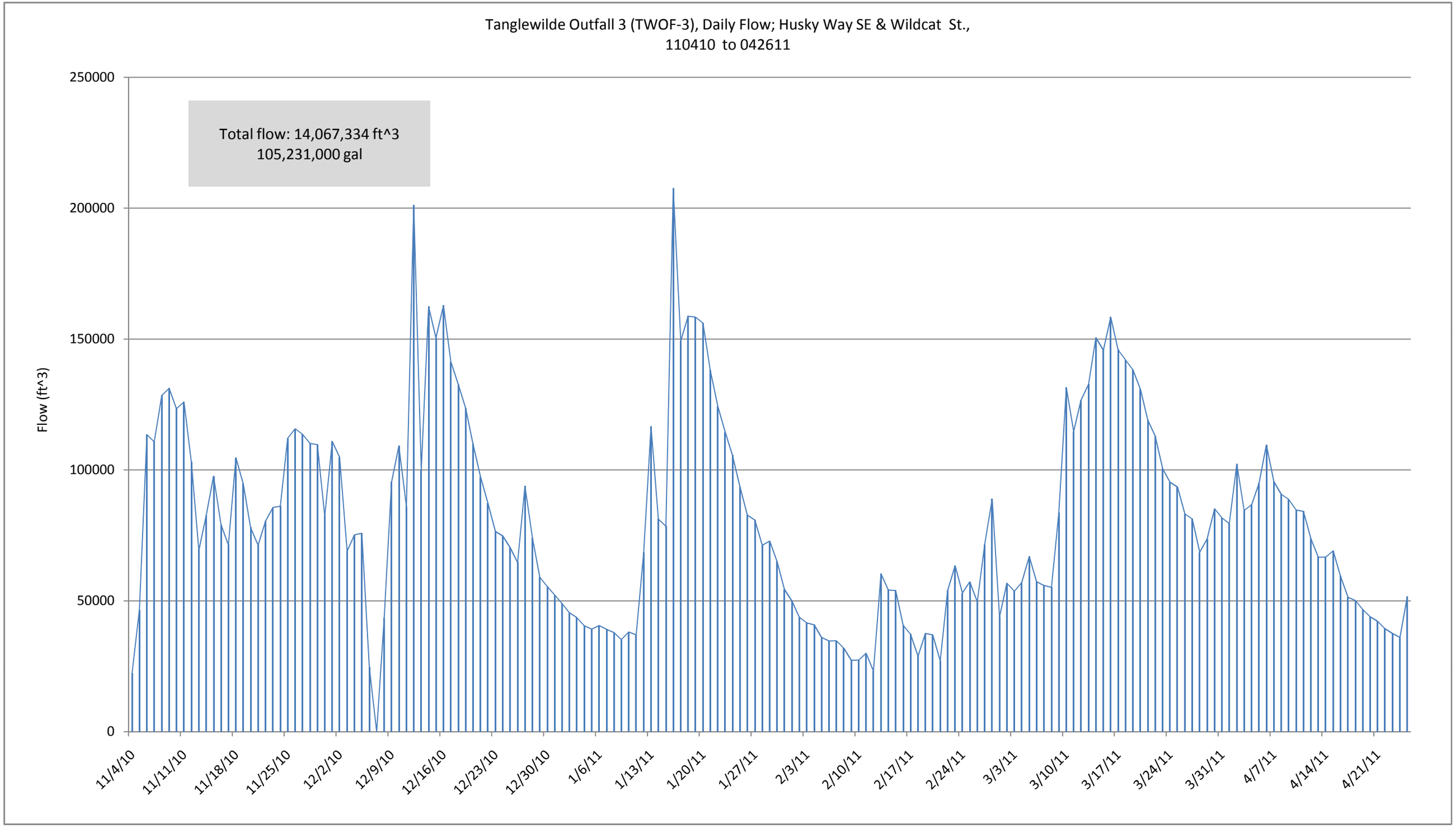
1/15/11
2/15/11
3/15/11


Tanglewilde Outfall 3 (TWOF-3), Daily Flow; Husky Way SE & Wildcat St.,
110410 to 042611
Total flow: 14,067,334 ft^3
105,231,000 gal
Flow (ft^3)
250000
200000
150000
100000
50000
0
11/4/10
11/11/10
11/18/10
11/25/10
12/2/10
12/9/10
12/16/10
12/23/10
12/30/10
1/6/11
1/13/11
1/20/11
1/27/11
2/3/11
2/10/11
2/17/11
2/24/11
3/3/11
3/10/11
3/17/11
3/24/11
3/31/11
4/7/11
4/14/11
4/21/11

Precipitation Charts

18u--Lacey Fire Dist. 3 Fire Station_Rain

Water Year: 2006

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
01		0.04	0.06	0.05	0.03	0.01	0.39	0.00	0.77	0.00	0.00	0.00
02		0.40	0.25	0.15	0.30	0.00	0.02	0.00	0.24	0.00	0.00	0.00
03		0.01	0.01	0.01	0.03	0.18	0.04	0.00	0.00	0.00	0.00	0.00
04		0.00	0.19	0.05	0.00	0.02	0.00	0.00	0.43	0.00	0.00	0.00
05		0.00	0.22	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00
06		0.00	0.30	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07		0.01	0.17	0.99	0.02	0.05	0.00	0.19	0.00	0.00	0.00	0.00
08		0.02	0.00	0.24	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
09		0.00	0.01	0.08	0.00	0.00	0.01	0.00	0.05	0.00	0.08	0.00
10		0.17	0.34	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11		0.05	0.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12		0.00	0.24	0.08	0.00	0.00	0.01	0.00	0.06	0.04	0.00	0.00
13		0.00	0.47	0.02	0.11	0.00	0.26	0.00	0.01	0.00	0.00	0.00
14	0.00	0.03	0.34	0.31	0.33	0.00	0.24	0.00	0.10	0.00	0.00	0.00
15	0.46	0.17	0.01	0.02	0.19	0.00	0.25	0.00	0.01	0.00	0.00	0.00
16	0.97	0.78	0.10	0.00	0.31	0.00	0.09	0.00	0.06	0.00	0.00	0.03
17	0.51	0.76	0.01	0.01	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.01
18	0.00	0.85	0.00	0.24	0.12	0.22	0.00	0.00	0.00	0.00	0.00	0.22
19	0.28	0.83	0.09	0.08	0.01	0.24	0.00	0.01	0.00	0.00	0.00	0.06
20	3.85	0.63	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.07
21	0.31	0.03	0.07	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.00
22	0.30	0.00	0.00	0.07	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00
23	0.02	0.30	0.03	0.38	0.01	0.02	0.00	0.38	0.00	0.00	0.00	0.00
24	0.00	0.01	0.53	0.05	0.01	0.35	0.00	0.27	0.00	0.00	0.00	0.00
25	0.00	0.80	0.07	0.01	0.16	0.26	0.00	0.20	0.00	0.00	0.00	0.00
26	0.00	0.04	0.00	0.06	0.08	0.19	0.00	0.03	0.00	0.00	0.00	0.00
27	0.00	0.00	0.30	0.00	0.15	0.11	0.00	0.13	0.00	0.00	0.00	0.00
28	0.07	1.12	0.08	0.64	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
29	0.00	0.13	0.00	1.02		0.00	0.14	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.70		0.06	0.00	0.00	0.00	0.03	0.00	0.00
31	0.00		0.22	0.17		0.00		0.09		0.00	0.00	
Total	**6.77**	**7.18**	**4.33**	**5.57**	**2.05**	**2.05**	**1.72**	**1.80**	**1.73**	**0.07**	**0.08**	**0.39**

Total Rainfall for Water Year 2006: 33.74

Precipitation is measured with a tipping bucket rain gauge. Ice and snow accumulations in the rain gauge are not measured until they melt.

Precipitation from snow is not measured accurately

Notes:

Thurston County Fairgrounds

Thurston County Water Resources Unit

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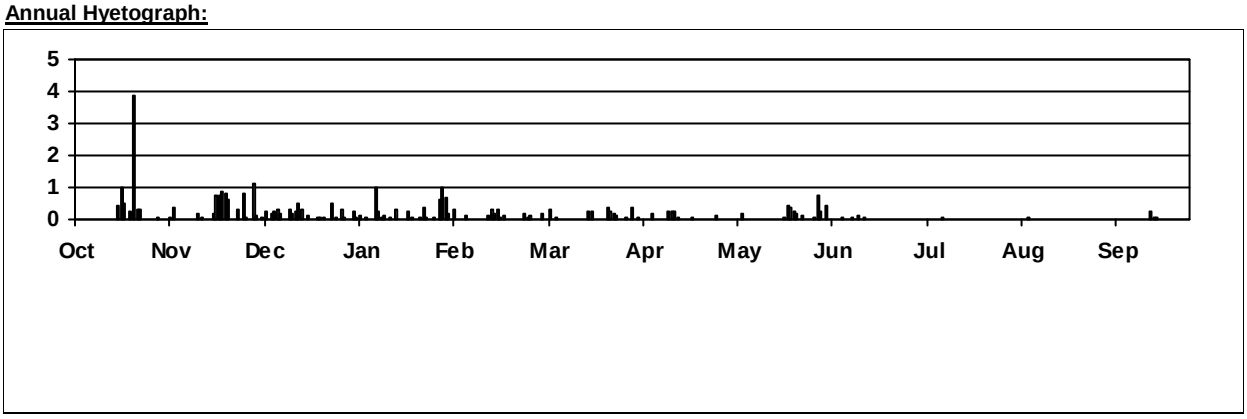

12/14/2009 3:03:05 PM by Howard Hama (360)-480-8359

18u--Lacey Fire Dist. 3 Fire Station_Rain

Water Year: 2007

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
01	0.00	0.00	0.00	0.08	0.00	0.02	0.03	0.10	0.00	0.00	0.00	0.00
02	0.00	0.89	0.00	1.13	0.00	0.21	0.04	0.36	0.00	0.00	0.00	0.00
03	0.00	0.74	0.00	0.18	0.20	0.02	0.00	0.15	0.00	0.00	0.00	0.03
04	0.00	1.19	0.04	0.07	0.03	0.00	0.00	0.01	0.05	0.00	0.00	0.36
05	0.00	1.08	0.01	1.49	0.00	0.02	0.00	0.00	0.06	0.00	0.00	0.00
06	0.13	3.88	0.01	0.12	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07	0.00	1.09	0.00	1.70	0.15	0.29	0.35	0.00	0.00	0.00	0.00	0.00
08	0.03	0.26	0.02	0.00	0.01	0.16	0.18	0.00	0.00	0.00	0.00	0.00
09	0.00	0.24	0.12	0.22	0.12	0.00	0.26	0.00	0.21	0.00	0.00	0.00
10	0.00	0.99	0.22	0.16	0.09	0.72	0.18	0.00	0.02	0.00	0.00	0.00
11	0.00	0.25	0.79	0.01	0.04	1.23	0.01	0.00	0.00	0.00	0.00	0.00
12	0.00	1.04	0.32	0.00	0.00	0.16	0.03	0.00	0.00	0.00	0.00	0.00
13	0.00	0.24	0.82	0.00	0.03	0.03	0.09	0.00	0.00	0.00	0.00	0.00
14	0.01	0.00	1.57	0.00	0.23	0.01	0.07	0.00	0.00	0.00	0.00	0.00
15	0.58	0.54	0.27	0.00	0.26	0.01	0.00	0.00	0.01	0.00	0.00	0.00
16	0.08	0.00	0.00	0.16	0.06	0.00	0.03	0.00	0.00	0.00	0.00	0.12
17	0.00	0.00	0.00	0.07	0.11	0.21	0.04	0.00	0.04	0.47	0.01	0.18
18	0.15	0.00	0.00	0.08	0.07	0.05	0.01	0.01	0.00	0.23	0.17	0.00
19	0.10	0.45	0.00	0.16	0.98	0.23	0.00	0.15	0.00	0.05	0.12	0.00
20	0.00	0.48	0.39	0.01	0.71	0.21	0.00	0.38	0.00	0.19	0.17	0.09
21	0.00	0.70	0.62	0.00	0.04	0.00	0.16	0.00	0.00	0.11	0.14	0.01
22	0.00	0.49	0.01	0.00	0.03	0.09	0.01	0.03	0.00	0.23	0.00	0.00
23	0.00	0.92	0.71	0.01	0.05	0.37	0.00	0.00	0.01	0.01	0.00	0.00
24	0.01	0.24	0.89	0.00	0.26	1.34	0.08	0.00	0.24	0.00	0.00	0.00
25	0.00	0.01	0.01	0.02	0.13	0.01	0.01	0.00	0.03	0.00	0.03	0.01
26	0.00	0.53	1.22	0.00	0.04	0.19	0.01	0.00	0.00	0.00	0.00	0.01
27	0.00	0.02	0.40	0.00	0.32	0.14	0.02	0.00	0.00	0.00	0.00	0.08
28	0.00	0.00	0.00	0.01	0.19	0.00	0.00	0.00	0.06	0.00	0.00	0.08
29	0.02	0.29	0.01	0.00		0.00	0.00	0.00	0.38	0.00	0.00	0.01
30	0.00	0.19	0.00	0.00		0.05	0.15	0.00	0.11	0.00	0.00	0.67
31	0.00		0.00	0.01		0.14		0.00		0.03	0.00	
Total	**1.11**	**16.75**	**8.45**	**5.69**	**4.19**	**5.91**	**1.76**	**1.19**	**1.22**	**1.32**	**0.64**	**1.65**

Total Rainfall for Water Year 2007: 49.88

Precipitation is measured with a tipping bucket rain gauge. Ice and snow accumulations in the rain gauge are not measured until they melt.

Precipitation from snow is not measured accurately

Notes:

Thurston County Fairgrounds

Thurston County Water Resources Unit

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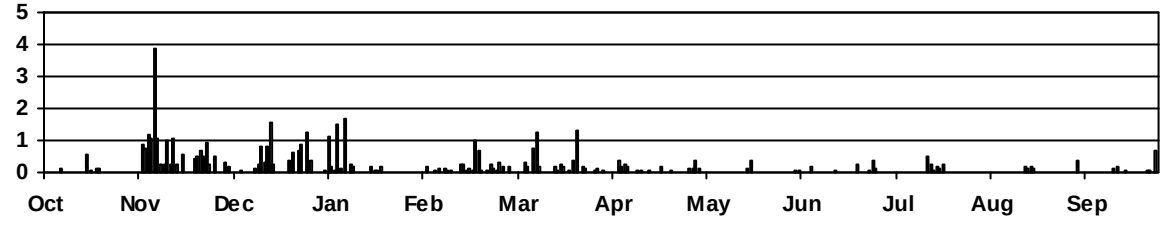

12/14/2009 3:04:26 PM by Howard Hama (360)-480-8359

18u--Lacey Fire Dist. 3 Fire Station_Rain

Water Year: 2008

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
01	0.20	0.00	0.41	0.00	0.38	0.18	0.00	0.00	0.00	0.00	0.06	0.00
02	0.97	0.00	1.68	0.24	0.12	0.00	0.00	0.00	0.07	0.00	0.00	0.00
03	0.28	0.00	3.46	0.26	0.01	0.17	0.00	0.17	0.43	0.10	0.00	0.00
04	0.01	0.00	0.36	0.20	0.02	0.00	0.12	0.00	0.00	0.01	0.00	0.00
05	0.00	0.00	0.00	0.63	0.46	0.00	0.04	0.00	0.16	0.03	0.00	0.00
06	0.01	0.00	0.06	0.12	0.61	0.00	0.17	0.00	0.37	0.00	0.00	0.00
07	0.24	0.06	0.00	0.02	0.68	0.04	0.14	0.00	0.00	0.00	0.00	0.00
08	0.00	0.00	0.00	0.48	0.73	0.01	0.08	0.00	0.00	0.00	0.00	0.00
09	0.00	0.18	0.08	0.28	0.05	0.00	0.01	0.00	0.17	0.00	0.09	0.00
10	0.13	0.34	0.01	0.95	0.20	0.14	0.00	0.03	0.04	0.00	0.00	0.00
11	0.00	0.12	0.00	0.17	0.00	0.25	0.00	0.01	0.00	0.00	0.00	0.00
12	0.03	0.78	0.01	0.29	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.05	0.04	0.01	0.00	1.00	0.02	0.05	0.00	0.00	0.00	0.00
14	0.00	0.07	0.02	0.33	0.00	0.18	0.08	0.00	0.00	0.00	0.00	0.00
15	0.10	0.79	0.38	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.00	0.00
16	0.18	0.27	0.02	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
17	0.16	0.54	0.19	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00
18	0.28	0.00	0.57	0.00	0.00	0.02	0.07	0.00	0.00	0.00	0.05	0.00
19	1.06	0.04	0.97	0.04	0.01	0.05	0.39	0.01	0.00	0.00	0.28	0.00
20	0.77	0.00	0.01	0.05	0.00	0.17	0.02	0.28	0.00	0.00	0.67	0.14
21	0.05	0.00	0.00	0.00	0.00	0.12	0.04	0.00	0.00	0.00	0.11	0.00
22	0.01	0.01	0.34	0.00	0.03	0.00	0.06	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.72	0.00	0.00	0.72	0.14	0.01	0.00	0.00	0.00	0.00
24	0.01	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.05
25	0.00	0.00	0.33	0.00	0.02	0.24	0.00	0.01	0.00	0.00	0.00	0.14
26	0.00	0.34	0.02	0.23	0.00	0.38	0.00	0.00	0.00	0.00	0.12	0.01
27	0.00	0.00	0.33	0.01	0.01	0.08	0.07	0.00	0.00	0.00	0.14	0.00
28	0.00	0.29	0.34	0.12	0.02	0.28	0.21	0.00	0.00	0.00	0.00	0.00
29	0.01	0.24	0.16	0.51	0.24	0.04	0.05	0.00	0.00	0.09	0.00	0.00
30	0.00	0.00	0.26	0.31		0.01	0.00	0.00	0.00	0.01	0.00	0.00
31	0.00		0.01	0.62		0.05		0.00		0.10	0.00	
Total	**4.50**	**4.12**	**10.83**	**5.87**	**3.63**	**4.23**	**1.73**	**0.57**	**1.24**	**0.34**	**1.93**	**0.34**

Total Rainfall for Water Year 2008: 39.33

Precipitation is measured with a tipping bucket rain gauge. Ice and snow accumulations in the rain gauge are not measured until they melt.

Precipitation from snow is not measured accurately

Notes:

Thurston County Fairgrounds, then moved to Lacey Fire District 3 Fire Station on Franz St. SE

Thurston County Water Resources Unit

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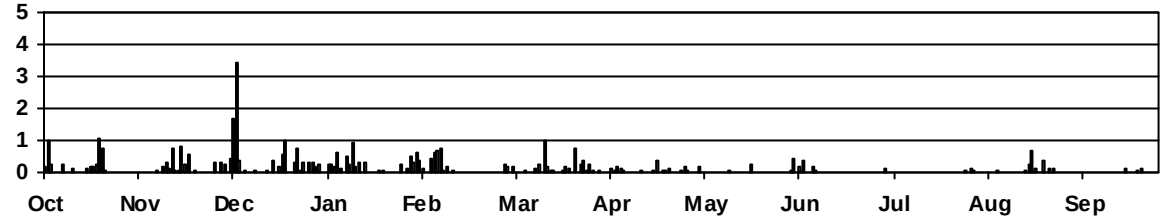

12/14/2009 3:37:52 PM by Howard Hama (360)-480-8359

18u--Lacey Fire Dist. 3 Fire Station_Rain

Water Year: 2009

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
01	0.00	0.10	0.22	0.73	0.00	0.32	0.45	0.00	0.00	0.00	0.00	0.05
02	0.13	0.32	0.07	0.21	0.00	0.17	0.02	0.76	0.00	0.00	0.00	0.00
03	0.72	0.51	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.03
04	0.23	0.50	0.00	0.59	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00
05	0.15	0.06	0.01	0.33	0.00	0.21	0.00	0.44	0.00	0.00	0.00	0.19
06	0.63	2.37	0.00	1.25	0.08	0.01	0.00	1.16	0.07	0.02	0.00	1.17
07	0.13	1.12	0.25	4.47	0.00	0.16	0.00	0.24	0.00	0.16	0.00	0.30
08	0.00	0.16	0.00	0.33	0.01	0.08	0.00	0.00	0.00	0.00	0.00	0.00
09	0.46	0.02	0.04	0.00	0.00	0.12	0.06	0.00	0.00	0.00	0.02	0.01
10	0.00	0.07	0.03	0.30	0.03	0.00	0.17	0.02	0.00	0.00	0.09	0.00
11	0.00	1.16	0.00	0.06	0.42	0.00	0.06	0.10	0.00	0.00	0.22	0.00
12	0.00	1.80	0.53	0.02	0.00	0.00	1.10	0.29	0.00	0.23	0.54	0.00
13	0.03	0.00	0.12	0.00	0.00	0.00	0.45	0.82	0.00	0.00	0.12	0.00
14	0.00	0.00	0.00	0.00	0.01	0.80	0.00	0.09	0.00	0.00	0.00	0.00
15	0.07	0.00	0.01	0.00	0.10	0.72	0.00	0.00	0.00	0.00	0.00	0.00
16	0.02	0.00	0.00	0.00	0.00	0.78	0.07	0.00	0.00	0.00	0.00	0.01
17	0.05	0.01	0.02	0.00	0.00	0.74	0.27	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.29	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.13	0.14	0.00	0.00	0.33
20	0.44	0.33	0.00	0.01	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.18	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	0.00	0.06	0.07	0.00	0.14	0.08	0.00	0.00	0.00	0.00	0.04	0.00
23	0.03	0.00	0.03	0.00	0.19	0.27	0.12	0.00	0.00	0.00	0.00	0.00
24	0.00	0.01	1.24	0.09	0.54	0.03	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.02	0.34	0.11	0.38	0.14	0.03	0.00	0.00	0.00	0.04	0.00
26	0.00	0.00	0.46	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.57	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.02	0.27	0.00	0.00	0.82	0.70	0.00	0.00	0.00	0.01	0.11
29	0.00	0.00	0.54	0.00		0.00	0.20	0.00	0.00	0.00	0.90	0.05
30	0.00	0.00	0.19	0.00		0.00	0.00	0.00	0.00	0.00	0.01	0.00
31	0.47		0.22	0.02		0.19		0.00		0.00	0.00	
Total	**3.56**	**8.82**	**5.24**	**8.79**	**1.98**	**6.07**	**3.70**	**5.08**	**0.21**	**0.41**	**2.00**	**2.25**

Total Rainfall for Water Year 2009: 48.11

Notes:

Precipitation is measured with a tipping bucket rain gauge. Ice and snow accumulations in the rain gauge are not measured until they melt.

Precipitation from snow is not measured accurately

Thurston County Water Resources Unit

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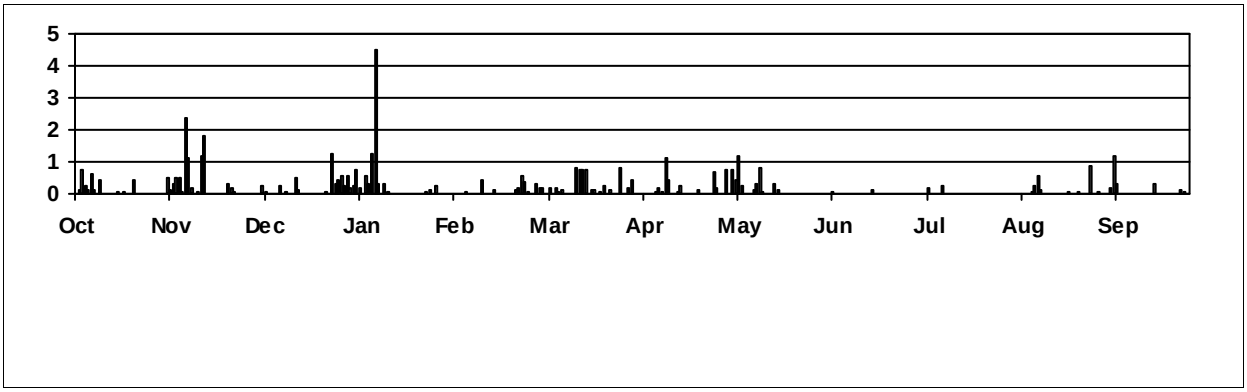

12/14/2009 3:39:00 PM by Howard Hama (360)-480-8359

18u--Lacey Fire Dist. 3 Fire Station_Rain

Water Year: 2010

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
01	0.10	0.00	0.00	0.57	0.22	0.00	0.10	0.00	0.26	0.30	0.00	0.00
02	0.01	0.00	0.00	0.24	0.01	0.11	1.23	0.33	0.57	0.14	0.00	0.00
03	0.00	0.00	0.00	0.00	0.32	0.02	0.32	0.27	0.02	0.00	0.00	0.00
04	0.00	0.00	0.01	0.74	0.11	0.01	0.05	0.06	0.21	0.00	0.00	0.00
05	0.00	0.53	0.00	0.10	0.02	0.00	0.06	0.03	0.00	0.00	0.00	0.00
06	0.00	1.48	0.00	0.14	0.08	0.00	0.06	0.00	0.26	0.00	0.00	0.21
07	0.00	0.82	0.00	0.10	0.02	0.03	0.15	0.00	0.00	0.00	0.08	0.25
08	0.00	0.08	0.00	0.84	0.00	0.02	0.09	0.00	0.12	0.00	0.00	0.60
09	0.00	0.54	0.00	0.00	0.00	0.04	0.04	0.01	0.28	0.00	0.00	0.02
10	0.00	0.47	0.00	0.09	0.28	0.00	0.00	0.28	0.11	0.00	0.00	0.01
11	0.00	0.06	0.00	0.88	0.30	0.70	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.08	0.00	0.38	0.69	0.78	0.02	0.00	0.00	0.00	0.00	0.00
13	0.17	0.35	0.01	0.23	0.36	0.08	0.02	0.00	0.00	0.00	0.00	0.00
14	0.49	0.00	0.25	0.37	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.07	0.13	0.13	0.57	0.19	0.01	0.08	0.00	0.07	0.00	0.00	0.64
16	0.66	1.52	0.19	0.10	0.18	0.14	0.00	0.00	0.00	0.00	0.00	1.00
17	1.14	0.80	0.02	0.30	0.00	0.02	0.25	0.05	0.00	0.00	0.00	1.72
18	0.01	0.19	0.04	0.02	0.00	0.00	0.00	0.21	0.33	0.00	0.00	1.02
19	0.00	1.10	0.57	0.00	0.00	0.00	0.03	0.68	0.77	0.00	0.00	0.22
20	0.00	0.37	0.22	0.04	0.00	0.00	0.04	0.44	0.01	0.00	0.00	0.17
21	0.17	0.34	0.52	0.01	0.00	0.17	0.07	0.07	0.00	0.00	0.00	0.00
22	0.01	0.39	0.00	0.00	0.00	0.01	0.00	0.10	0.00	0.00	0.00	0.00
23	0.80	0.16	0.00	0.00	0.40	0.00	0.06	0.05	0.00	0.00	0.00	0.16
24	0.00	0.05	0.00	0.50	0.52	0.00	0.09	0.00	0.00	0.00	0.00	0.00
25	0.05	0.10	0.00	0.05	0.05	0.56	0.00	0.61	0.00	0.00	0.00	0.00
26	0.71	1.26	0.00	0.00	0.46	0.05	0.27	0.19	0.00	0.00	0.00	0.28
27	0.00	0.01	0.01	0.01	0.22	0.00	0.22	0.07	0.00	0.00	0.00	0.02
28	0.13	0.00	0.00	0.00	0.01	0.82	0.20	0.91	0.00	0.00	0.00	0.00
29	0.11	0.00	0.05	0.09		1.34	0.00	0.03	0.00	0.00	0.00	0.00
30	0.39	0.00	0.02	0.25		0.54	0.02	0.19	0.00	0.00	0.00	0.00
31	0.32		0.41	0.01		0.03		0.27		0.00	0.38	
Total	**5.34**	**10.83**	**2.45**	**6.63**	**4.64**	**5.48**	**3.47**	**4.85**	**3.01**	**0.44**	**0.46**	**6.32**

Total Rainfall for Water Year 2010: 53.92

Notes:

Precipitation is measured with a tipping bucket rain gauge. Ice and snow accumulations in the rain gauge are not measured until they melt.

Precipitation from snow is not measured accurately

Thurston County Water Resources Unit

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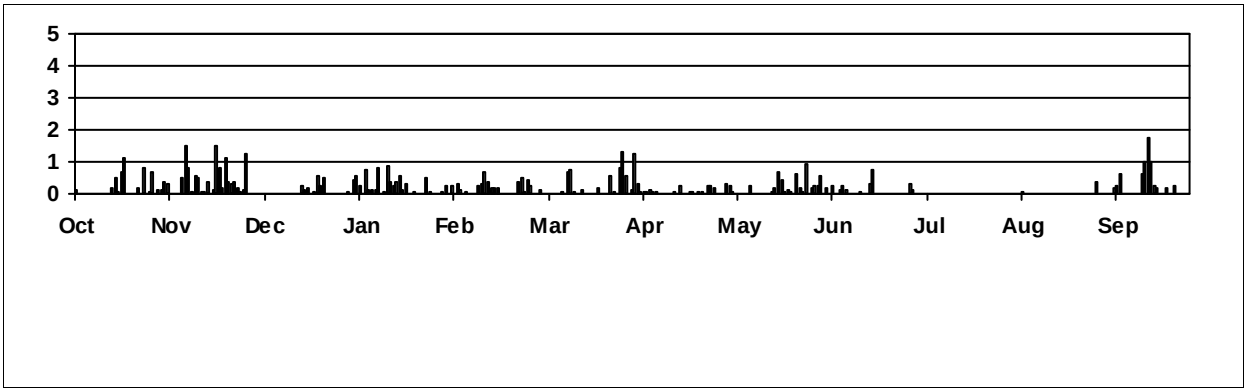
Annual Hyetograph:



11/01/2010 12:11:13 PM by Howard Hama (360)-480-8359

18u--Lacey Fire Dist. 3 Fire Station_Rain

Water Year: 2011

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
01	0.00	1.90	0.01	0.00	0.00	0.40	0.54	0.00				
02	0.00	0.00	0.04	0.00	0.00	0.31	0.05	0.08				
03	0.00	0.00	0.00	0.00	0.00	0.30	0.05	0.00				
04	0.00	0.00	0.00	0.00	0.19	0.29	0.36	0.00				
05	0.00	0.16	0.00	0.28	0.03	0.01	0.54	0.11				
06	0.00	0.62	0.01	0.23	0.21	0.00	0.47					
07	0.00	0.22	0.45	0.32	0.07	0.00	0.00					
08	0.21	0.09	0.81	0.00	0.00	0.20	0.00					
09	0.91	0.52	0.96	0.04	0.00	1.84	0.00					
10	0.64	0.01	0.06	0.01	0.00	1.02	0.25					
11	0.00	0.18	1.43	0.00	0.00	0.01	0.07					
12	0.00	0.01	1.84	1.41	0.60	0.42	0.00					
13	0.00	0.04	0.37	1.37	0.44	0.47	0.13					
14	0.02	0.08	0.71	0.44	0.65	0.65	0.49					
15	0.00	0.13	0.32	0.89	0.13	0.69	0.21					
16	0.00	0.00	0.02	1.18	0.15	0.40	0.06					
17	0.00	1.15	0.01	0.03	0.02	0.01	0.00					
18	0.00	0.60	0.35	0.04	0.08	0.05	0.00					
19	0.00	0.10	0.13	0.00	0.00	0.00	0.00					
20	0.00	0.02	0.03	0.02	0.00	0.04	0.00					
21	0.01	0.03	0.02	0.13	0.09	0.09	0.00					
22	0.11	0.01	0.00	0.00	0.08	0.00	0.00					
23	0.45	0.00	0.21	0.10	0.31	0.00	0.00					
24	1.66	0.00	0.13	0.19	0.14	0.21	0.21					
25	1.15	0.34	0.18	0.00	0.28	0.15	0.67					
26	0.38	0.47	0.63	0.00	0.00	0.11	0.19					
27	0.00	0.00	0.75	0.01	0.99	0.28	0.68					
28	0.10	0.02	0.05	0.07	0.96	0.30	0.07					
29	0.01	0.17	0.02	0.23		0.38	0.00					
30	0.41	0.54	0.00	0.13		0.60	0.00					
31	0.11		0.00	0.00		0.20						
Total	**6.17**	**7.41**	**9.54**	**7.12**	**5.42**	**9.43**	**5.04**	**0.19**				

Total Rainfall for Water Year 2011: 50.32

Notes:

Precipitation is measured with a tipping bucket rain gauge. Ice and snow accumulations in the rain gauge are not measured until they melt.

Precipitation from snow is not measured accurately

Thurston County Water Resources Unit

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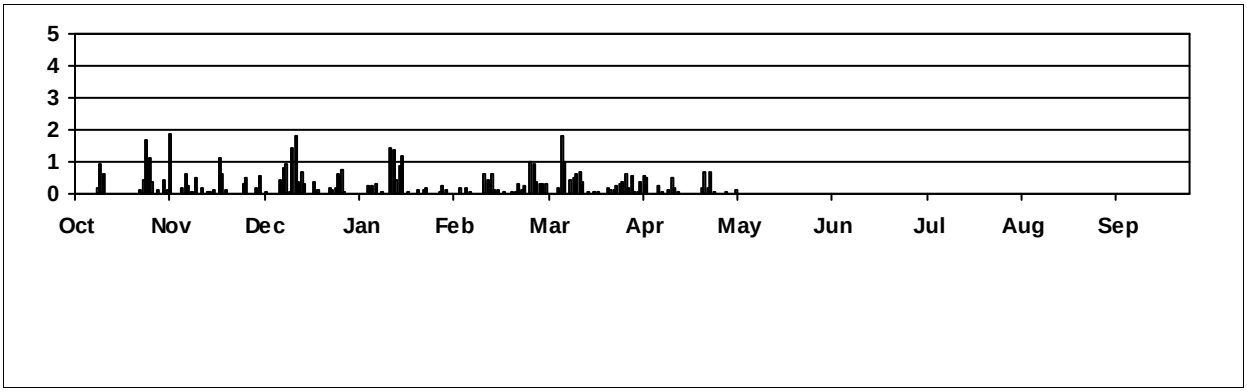
Annual Hyetograph:



05/09/2011 7:02:18 AM by Howard Hama (360)-480-8359