MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

TO: Rick Henderson

FROM: Joe Victory, Susanne Biteman, Bob Versical, Keith Kidder, Eric Kimber

DATE: December 12, 2013

SUBJECT: Review of the Michigan State University (MSU) Memorandum Entitled "Preliminary Analysis of Fracking and Flows in Upper Manistee River", and Assessment of Available Area Hydrogeologic Data

Purpose

Michigan State University (MSU) conducted a preliminary analysis of discharge in headwater streams feeding the Upper Manistee and Au Sable River watersheds from 2011 through 2013 to examine the potential for water resource depletion associated with the completion of oil and gas wells via high volume hydraulic fracturing (HVHF).

MSU derived two primary conclusions:

1. *Index flow values used in the Michigan Department of Environmental Quality (MDEQ) Water Withdrawal Assessment Tool (WWAT) may be significantly overestimated.*
2. *Water withdrawals associated with hydraulic fracturing operations are likely to have significant impact to stream flows.*

Based on the conclusions presented by MSU, and based on continuing public concern regarding large volume water withdrawals (LVWWs) associated with HVHF well completions, the MDEQ Office of Oil, Gas, and Minerals (OOGM) conducted its own assessment of available data in the Upper Manistee River Watershed. This document provides an Executive Summary of the data assessment and conclusions drawn by the MDEQ OOGM.

Data Summary and Analysis

Between 2011 and 2012, four HVHF well completions have occurred in the Upper Manistee River Watershed (State Excelsior 1-13, State Excelsior 1-25, State Excelsior 2-25, and State Excelsior 3-25). Figure 1 provides an overview map of the Upper Manistee River Watershed, with surface locations depicted where groundwater withdrawals occurred for completion of the Excelsior wells and the locations of select MSU stream gauging stations. LVWW durations and volumes associated with the Excelsior HVHF well completions are summarized below:

<u>State Excelsior 1-13 Withdrawal (Permit Number 60360)</u>

- Water withdrawals began on 10/12/11 and concluded on 11/5/11.
- Total groundwater used: 5,860,777 gallons.
- Three water supply wells screened from approximately 207 to 229 feet below ground surface (bgs).

State Excelsior 1-25 Withdrawal (Permit Number 60389)

- Water withdrawals began between 11/5/11 and 11/7/11 and concluded on 11/21/11.
- Total groundwater used: 8,461,635 gallons.
- Three water supply wells with screen intervals ranging from 100 to 140 feet bgs.

State Excelsior 2-25 and 3-25 Withdrawal (Permit Numbers 60545 and 60546)

- Water withdrawals began between 10/6/12 and 10/9/12 and concluded on 10/30/12.
- Total groundwater used: 33,862,752 gallons.
- Six water supply wells with screen intervals ranging from 102 to 155 feet bgs.

MSU Data Summary

The MSU Hydrogeology Department conducted monitoring of discharge and stage data at 38 gauging stations in the headwater streams of the Upper Manistee River and Au Sable River Watersheds between 2011 and 2013. MSU focused its preliminary analysis on data derived from gauging stations in the Upper Manistee River Watershed based on their proximity to locations where HVHF occurred.

MSU Data In Relation to the WWAT

MSU's first primary conclusion indicates that the WWAT significantly overestimates index flows for the North Branch of the Manistee River, and Black Creek. Data obtained by MSU for monitoring points on the North Branch of the Little Manistee River and Black Creek indicated median low-flow discharge summer month values that were lower than the equivalent index flow values used in the MDEQ WWAT at the time. After review of this MSU data by the MDEQ Water Resources Division (WRD), the index flow of Black Creek has been lowered in the WWAT.

MSU Data In Relation to LVWW/HVHF

MSU's second primary conclusion asserted that a LVWW volume of 35 million gallons may cause a reduction in discharge of up to 1.8 cubic feet per second (cfs), thus causing headwater streams to go dry due to the relatively low observed base flows. The MDEQ OOGM notes that a value of 1.8 cfs of surface water discharge equates to approximately 35 million gallons over a 30-day time period.

MSU also asserts that stream discharge at monitoring point M9B on the North Branch of the Manistee River was likely reduced as a result of HVHF completion operations at the State Excelsior 1-13 location.

MDEQ OOGM Analysis of MSU Data

The MDEQ OOGM analyzed discharge and stage data from MSU monitoring points M9B through M9E, located in the Upper Manistee River Watershed, based on the locations of these gauging stations in relation to completed HVHF operations. Figures 2 through 4 represent discharge graphs for these gauging stations with an overlay of daily precipitation totals for the area and HVHF timeframes. Figures 5 through 7 provide normalized stream stage data with an overlay of daily precipitation totals for the area and HVHF timeframes. The data show event-based and seasonal fluctuations with increased base flow and stage at the downstream gauging stations as expected.

The State Excelsior 1-13 withdrawal is most appropriately compared to data obtained from gauging station 9B (at M-72), as it is the closest hydraulically downgradient gauging station. The State Excelsior 1-25, 2-25, and 3-25 withdrawals are most appropriately compared to data obtained from gauging station 9C (at Kniss Road), as it is the closest hydraulically downgradient gauging station. Figures 3 and 6 show no net decrease in discharge or stage across the duration of water withdrawals for the State Excelsior 1-13 completion and the State Excelsior 1-25 completion at downgradient gauging stations (9B and 9C, respectively). Figures 4 and 7 clearly show that the discharge and stage increase at hydraulically downgradient gauging stations 9C, 9D, and 9E during and following the water withdrawals for the State Excelsior 2-25 and 3-25. It is noteworthy that the low stage value recorded on October 25, 2011, at gauging station 9B occurred prior to the vast majority of water withdrawals for the State Excelsior 1-13 completion. Based on the on-site water storage volume, only approximately 15% of the 5,860,777 gallons of water used was withdrawn prior to the HVHF completion, which began on October 25, 2011.

MDEQ OOGM Analysis of Area Hydrogeologic Data

The MDEQ OOGM completed an assessment of additional available area hydrogeologic data to develop a broader conceptual understanding of the watershed. The OOGM reviewed numerous area residential water well logs, agricultural water well logs, as well as geologic and monitoring data obtained from pumping and observation wells utilized during the HVHF completions. Area well logs indicate the presence of an upper, unconfined aquifer composed of poorly graded sands with broad areas underlain by a clay aquitard; a lower semi-confined aquifer composed of well graded sands and gravels is present beneath the clay.

Figure 8 shows a generalized stratigraphic cross-section at the State Excelsior 1-13 well site. A shallow upper sand and gravel aquifer is present from surface to approximately 130 feet bgs, a clay layer is present from approximately 130 feet to 190 feet bgs, and a deep, semi-confined sand aquifer is present below the clay. Groundwater withdrawals for the State Excelsior 1-13 occurred from the deep sand aquifer at screened intervals from 207 to 229 feet bgs. The North Branch of the Little Manistee River is approximately 1900 feet to the west of the State Excelsior 1-13 well site.

Figure 9 shows a generalized stratigraphic cross-section at the State Excelsior 1-25, 2-25, and 3-25 well sites. A shallow sand and gravel aquifer is present from surface to approximately 80 feet bgs, a clay layer is present from approximately 80 to 100 feet bgs, and a deep, semi-confined sand aquifer is present below the clay. Groundwater withdrawals for the State Excelsior 1-25, 2-25, and 3-25 occurred from the deep sand aquifer at screened intervals from 100 to 155 feet bgs. The North Branch of the Little Manistee River is approximately 4900 feet to the west of the State Excelsior 1-25, 2-25, and 3-25 well sites.

At the State Excelsior 1-13 well site, pressure transducers were installed in deep, semi-confined monitoring well PW-MW-2 (screened interval 210-230 feet bgs) and shallow, unconfined monitoring well MW-1 (screened interval 8-13 feet bgs) to record depth to water prior to, during, and following hydraulic fracturing completions. This data was collected by Environmental Consulting and Technology Inc., subcontractor to Encana Oil and Gas (USA), Inc., and later provided to MDEQ OOGM.

Figures 10 and 11 show drawdown data at monitoring wells MW-PW-2 and MW-1 with an overlay of daily precipitation data for the area during HVHF operations at the Excelsior 1-13 well site. Water withdrawal intervals (shaded in yellow) and approximate withdrawal volumes are also presented on Figure 10. The maximum drawdown observed in the deep semi-confined aquifer at PW-MW-2 was 29.26 feet. The maximum drawdown observed in the shallow, unconfined aquifer at MW-1 was 0.26 feet. The shallow aquifer is affected by pumping; however, the shallow aquifer appears to be more influenced by precipitation than by pumping in the deep aquifer. The data reflects limited hydraulic communication between the shallow, unconfined aquifer and the deep semi-confined aquifer, as well as rapid recovery.

Recoveries of these wells show an overall net increase to the groundwater system during the course of HVHF operations at this location (Figure 11).

Figure 12 shows the water level elevation in the shallow aquifer (MW-1), elevation of the stream at gauging station 9B (at M-72), and daily precipitation data. Water withdrawal intervals (shaded in yellow) and approximate withdrawal volumes are also presented on Figure 12. This presentation of the data illustrates that precipitation is the primary driver to both the shallow water elevation and stream stage at gauging station 9B and that even after extended periods of pumping water from the deep aquifer both the shallow water level and the stream gauge are higher than they were prior to the pumping event.

Conclusions

Based on the review and assessment of available data for the Upper Manistee River Watershed, the MDEQ OOGM has concluded the following in relation to HVHF and potential water resource depletion:

- No relationship could be established between discharge/stage variations in headwater streams and water withdrawals associated with HVHF for the locations in question.
- Stream data fluctuations represent precipitation events and expected seasonal variations in discharge or stage. Additionally, many agricultural wells are located within the Upper Manistee River Watershed and the effects of these withdrawals on stream flow are unknown.
- Numerous residential water well withdrawals, and numerous other registered and unregistered agricultural water withdrawals occur on a continuing basis within the study area.
- Assertions that removal of 35.3 million gallons of water from the Black River Conservation Area pad over 1 month would “likely dry the stream out (or greatly reduce its flow) for some period of time” is premature. As of November 12, 2013, DEQ OOGM has not approved the water withdrawal because Encana has not yet submitted to the DEQ OOGM details about their water source, plan, and location of withdrawal as required in Supervisors Instruction 1-2011. Based on area well logs, multiple semi-confined aquifer sources are likely present in this area.
- Regionally expansive and prolific (highly transmissive) drift aquifers are present in the Upper Manistee River Watershed based on monitoring well recovery data collected at the State Excelsior 1-13 site and review of area well logs.
- Net increases in discharge, stage, and groundwater levels observed in the data during and after the Excelsior 1-13 HVHF well completion indicating that groundwater withdrawals did not cause a reduction in discharge. In fact, these increases indicate the availability of ample water resources to sustain the completed withdrawal.
- No net decrease to stream discharge and stage were observed in the data during and following the State Excelsior 1-25 HVHF well completion indicating that groundwater withdrawals did not cause a reduction in discharge.
- Net increases to stream discharge and stage were observed in the data during and following the Excelsior 2-25 and 3-25 HVHF well completion indicating that groundwater withdrawals did not cause reduction in discharge.

- Stream discharge data obtained by MSU may provide valuable information for assessing index flow values used in the WWAT where only limited data has been available to date. In this case, the surface water component of the WWAT now provides an even more conservative model for estimating potential stream depletions associated with groundwater withdrawals in the Upper Manistee River Watershed; however, MSU's analysis and data comparisons were limited to the surface water component of the MDEQ WWAT, and their overall conclusions appear to be based on the assumption that LVWWs associated with HVHF are derived directly from surface waters.

- The focus and conclusions drawn by MSU were based on limited interpretation of existing data. MSU also failed to acknowledge groundwater as the direct and primary source of water used in HVHF, and aquifer performance parameters (i.e. transmissivity and storativity) as governing components of the WWAT.

References

Hyndman, D. (2013, October 3). "Preliminary Analysis of Fracking and Flows in Upper Manistee River".

MSU Hydrogeology Department Stream Gauging Data for the Upper Manistee River Watershed.

Precipitation Data for Kalkaska County, Midwestern Regional Climate Center, Kalkaska 11 SE Station.

Attachments
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Figure 1. Locations of Large Volume Hydraulic Fracturing Completions, Proposed Locations, and Select Gauging Stations in Manistee River Watershed

Figure 2. N. Branch Manistee River Discharge

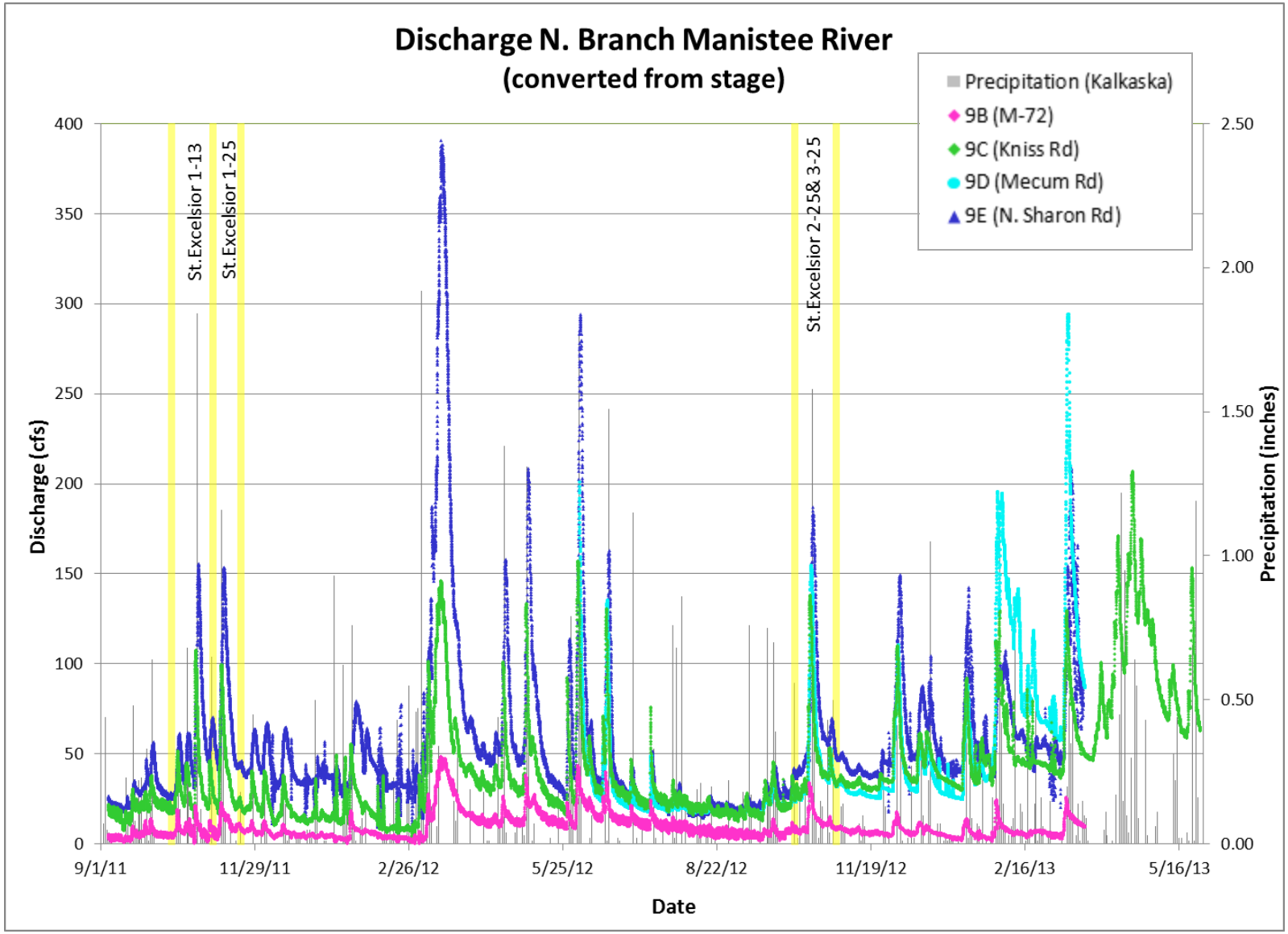
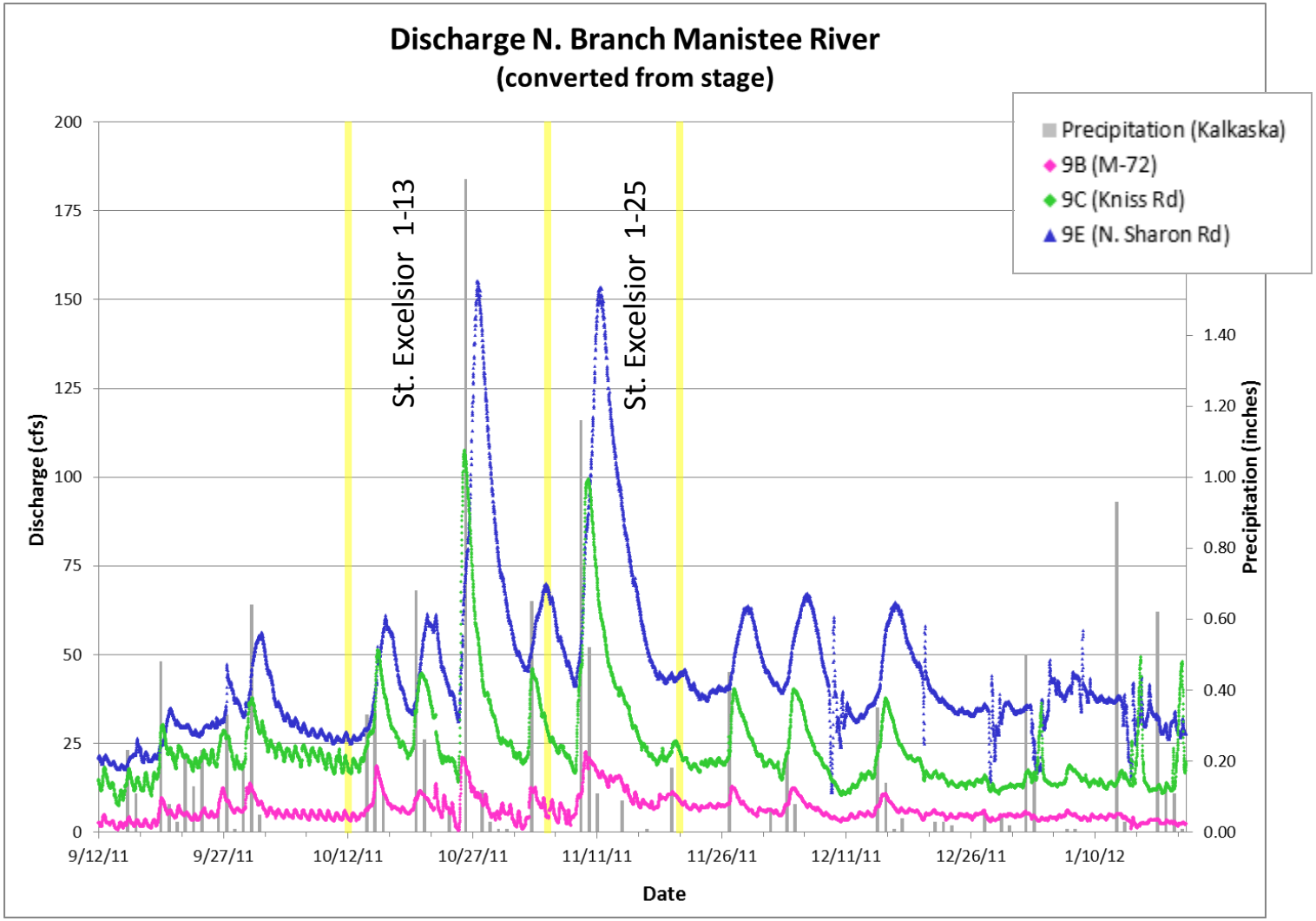


Figure 3. N. Branch Manistee River Discharge

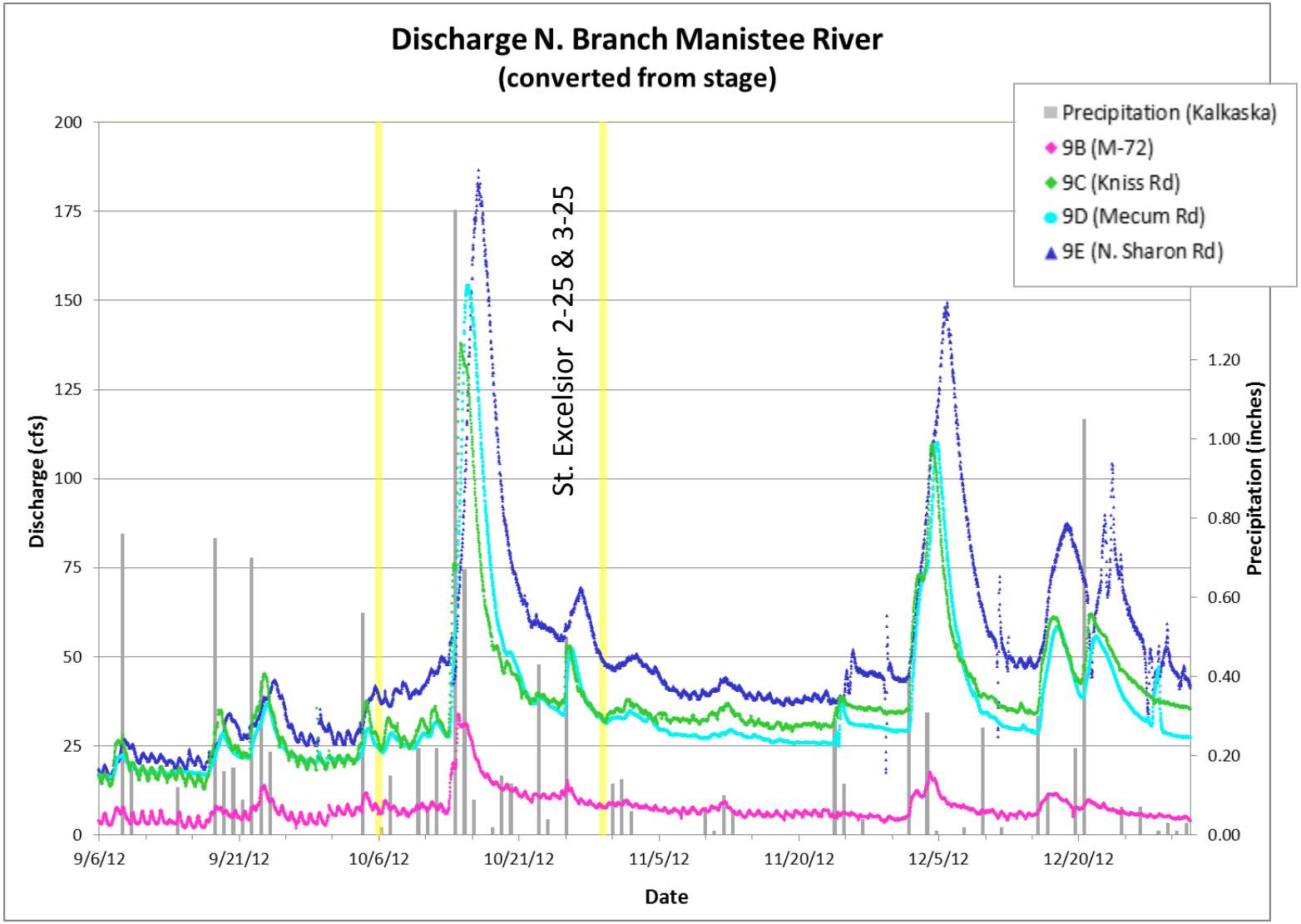
St. Excelsior 1-13 and St. Excelsior 1-25 Completions



1-13: Water withdrawn: 10/12/11 to 11/5/11; Max Rate: 540 gpm; Total withdrawn: 5,860,777 gal; Average rate: 177 gpm
1-25: Water withdrawn: 11/5/11 to 11/21/11; Max Rate: 595 gpm; Total withdrawn: 8,461,635 gal; Average rate: 345 gpm

Figure 4. N. Branch Manistee River Discharge

St. Excelsior 2-25 and St. Excelsior 3-25 Completions



Water withdrawn: 10/6/12 to 10/30/12; Max Rate: 1300 gpm; Total withdrawn: 33,862,752 gal; Average rate: 940 gpm

Figure 5. N. Branch Manistee River Normalized Stage

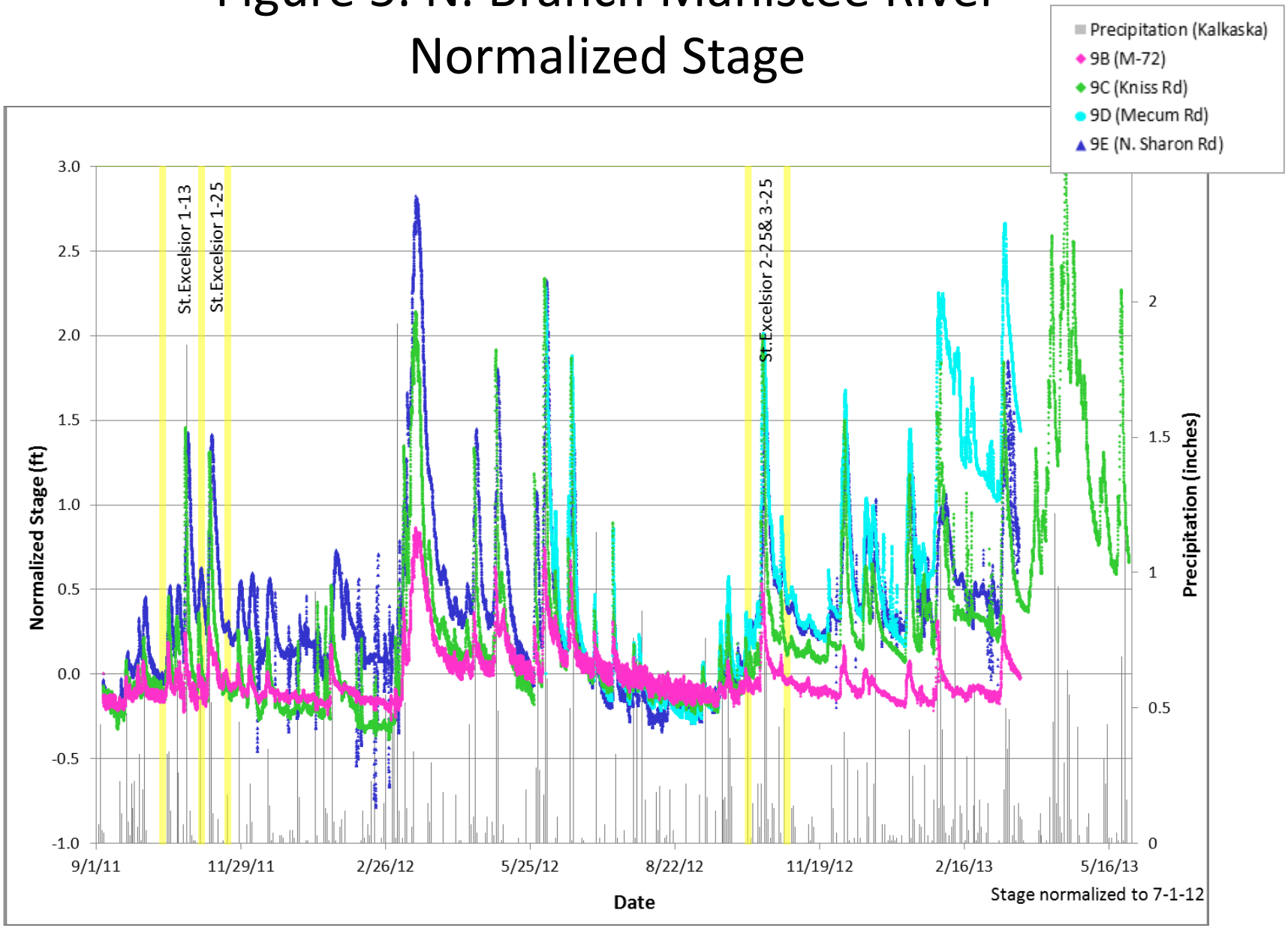
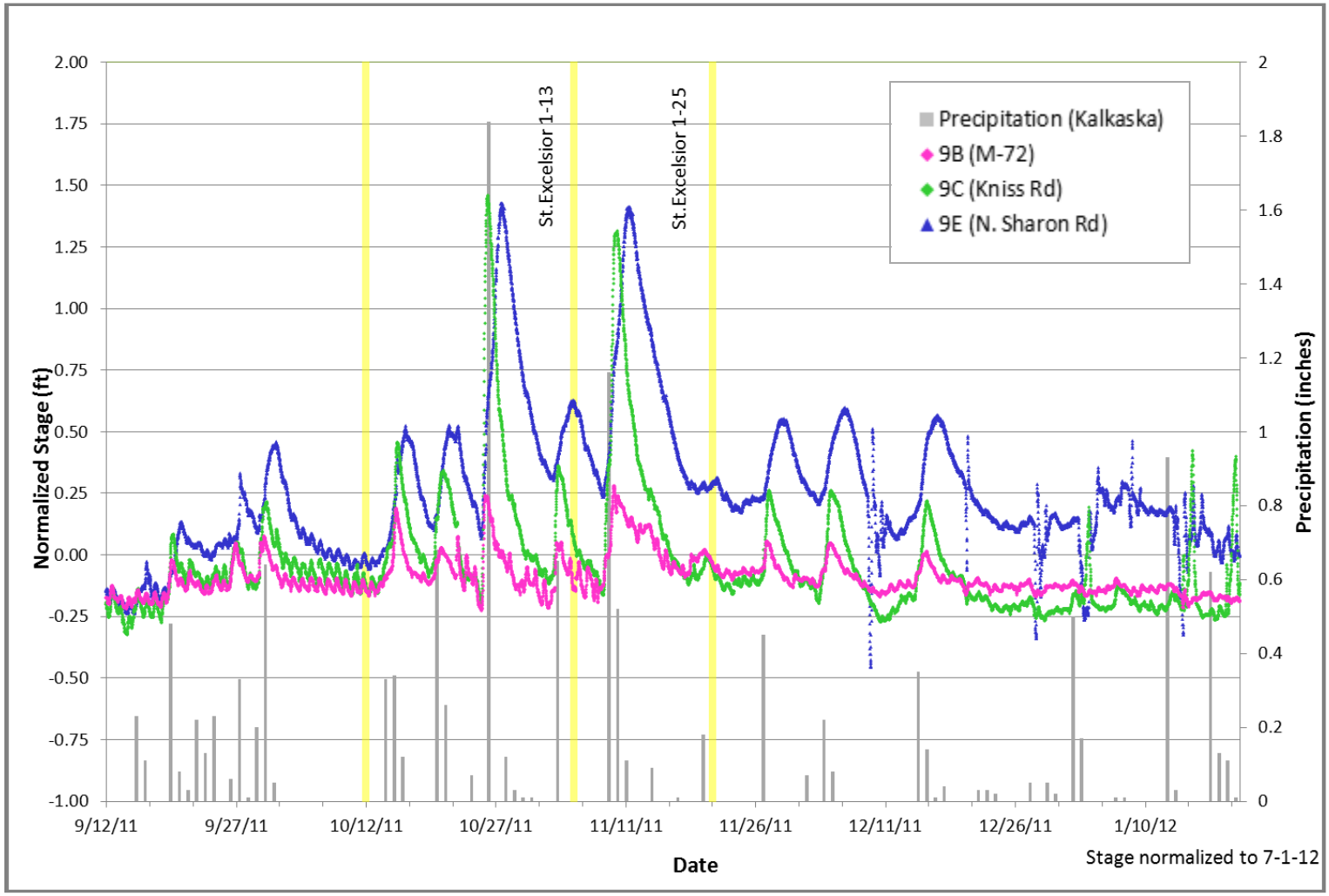


Figure 6. N. Branch Manistee River Normalized Stage

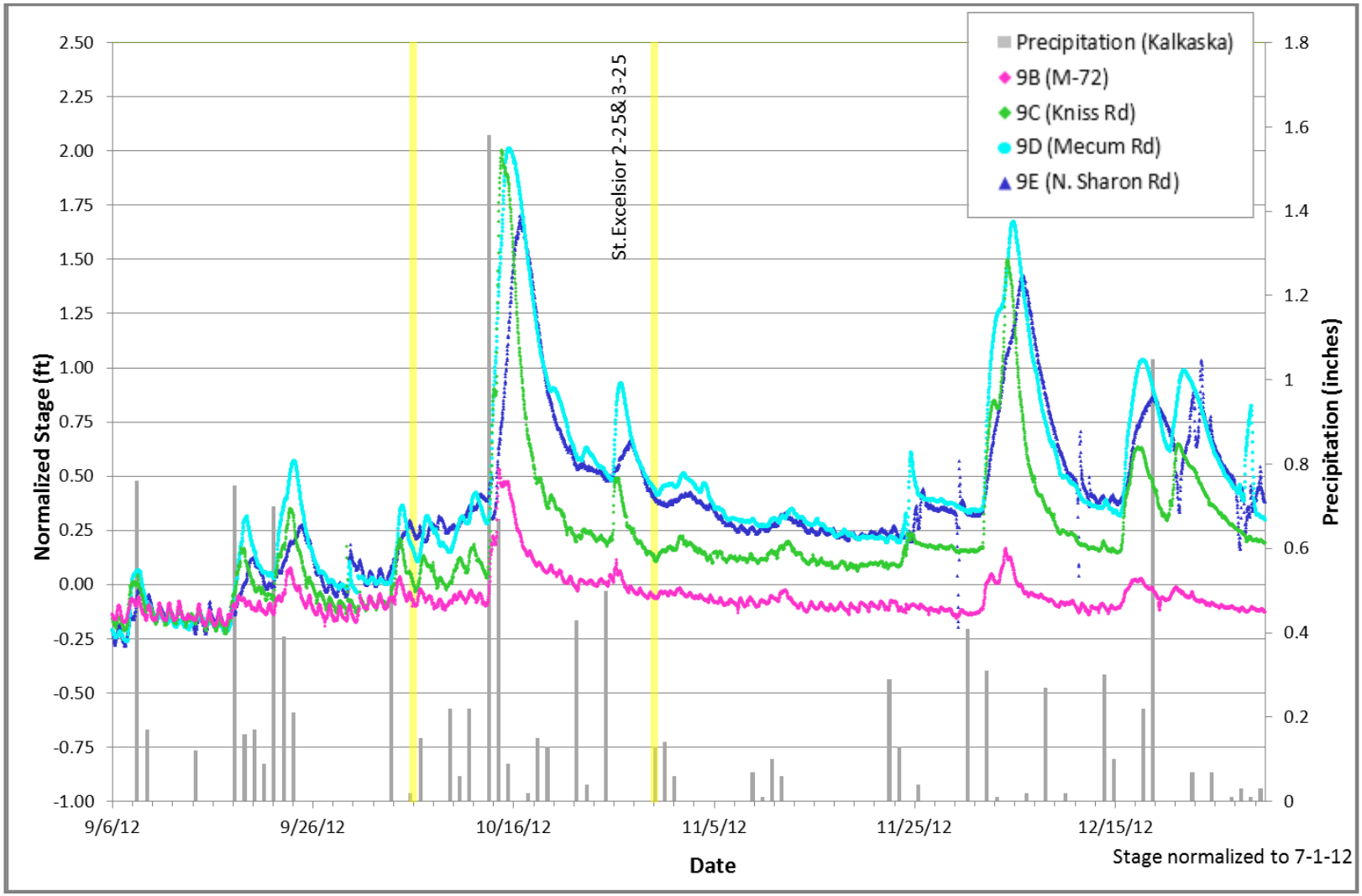
St. Excelsior 1-13 and St. Excelsior 1-25 Completions



1-13: Water withdrawn: 10/12/11 to 11/5/11; Max Rate: 540 gpm; Total withdrawn: 5,860,777 gal; Average rate: 177 gpm
1-25: Water withdrawn: 11/5/11 to 11/21/11; Max Rate: 595 gpm; Total withdrawn: 8,461,635 gal; Average rate: 345 gpm

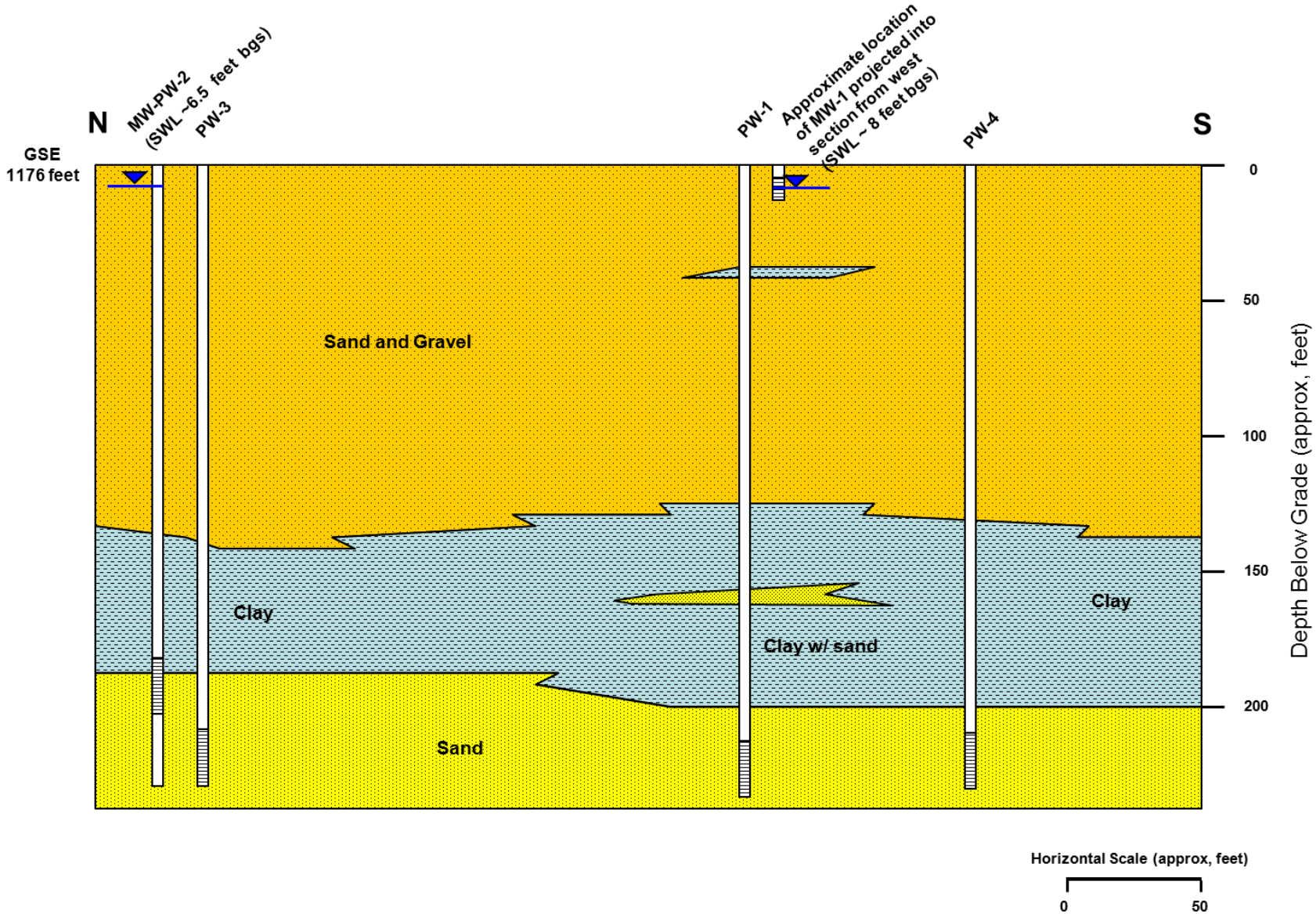
Figure 7. N. Branch Manistee River Normalized Stage

St. Excelsior 2-25 and St. Excelsior 3-25 Completions



Water withdrawn: 10/6/12 to 10/30/12; Max Rate: 1300 gpm; Total withdrawn: 33,862,752 gal; Average rate: 940 gpm

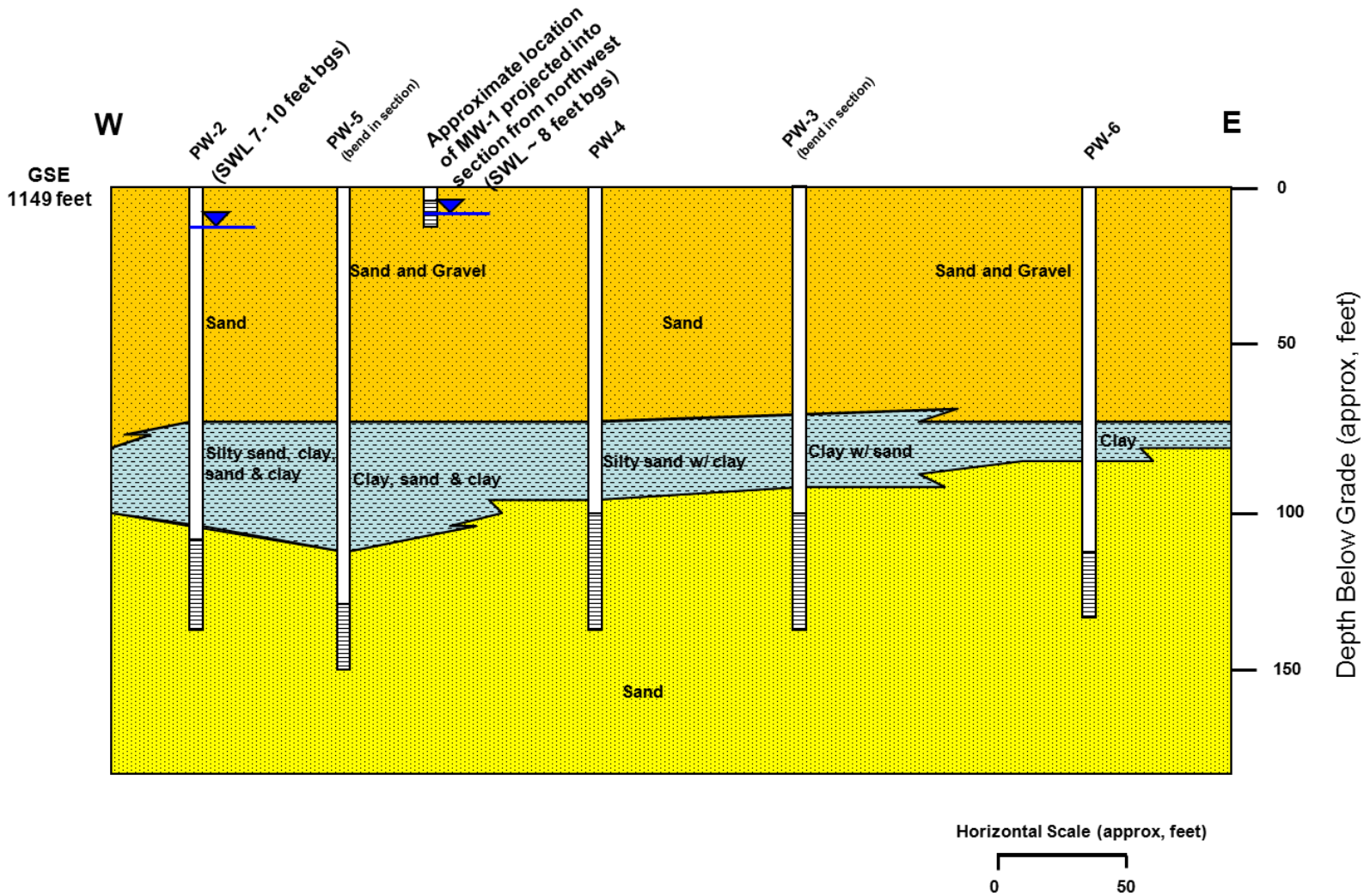
Figure 8. Generalized Stratigraphic Section – St. Excelsior 1-13



* North Branch of the Little Manistee River Located ~1,900 feet West, Gauging Station 9B located ~3,500 feet South.

Figure 9. Generalized Stratigraphic Section

St. Excelsior 1-25, St. Excelsior 2-25, and St. Excelsior 3-25



* North Branch of the Little Manistee River Located ~4,900 feet West, Gauging Station 9C located ~8,900 feet South.

Figure 10. St. Excelsior 1-13 Completion Drawdown

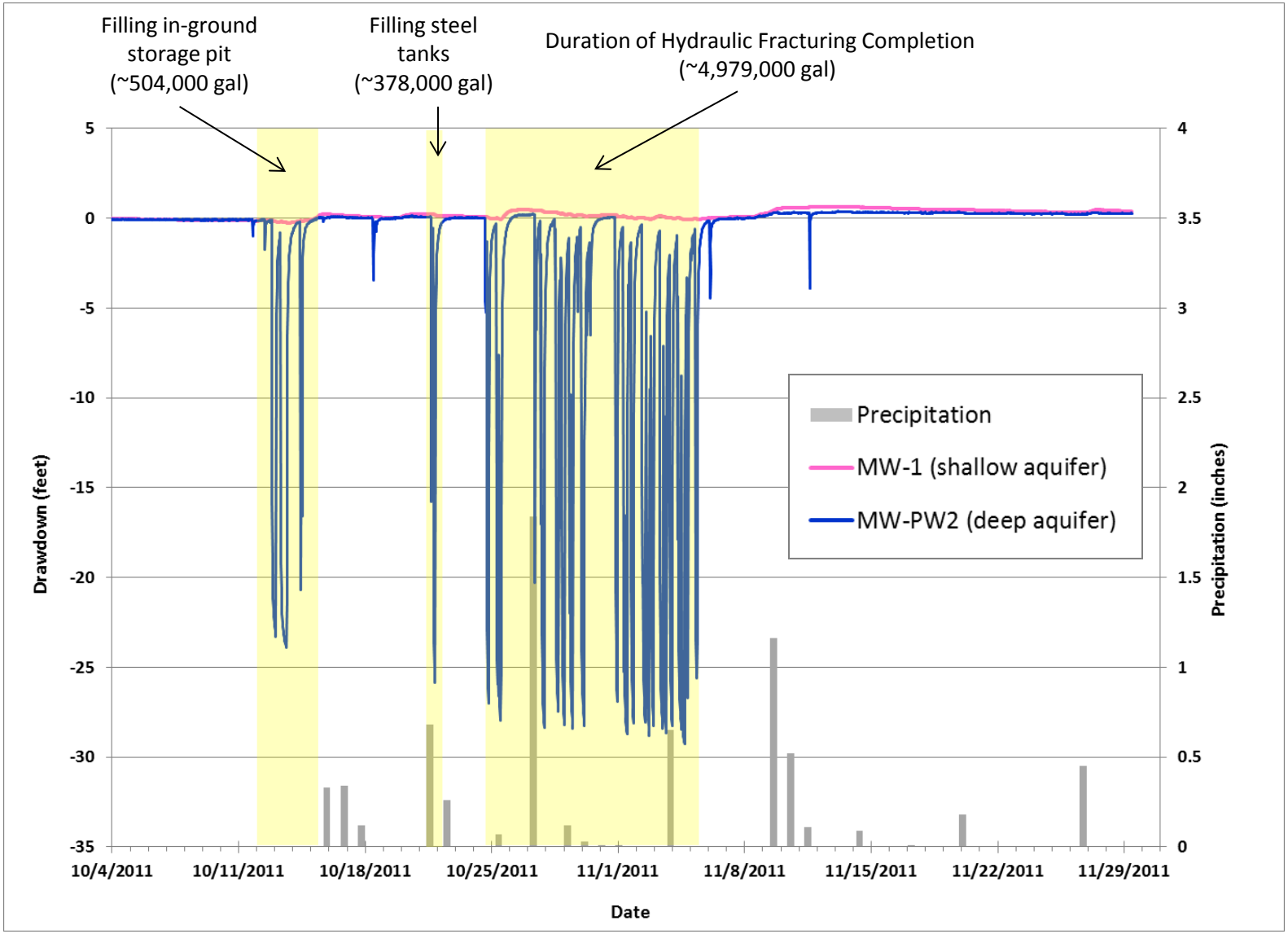


Figure 11. St. Excelsior 1-13 Completion Drawdown (Detail Scale)

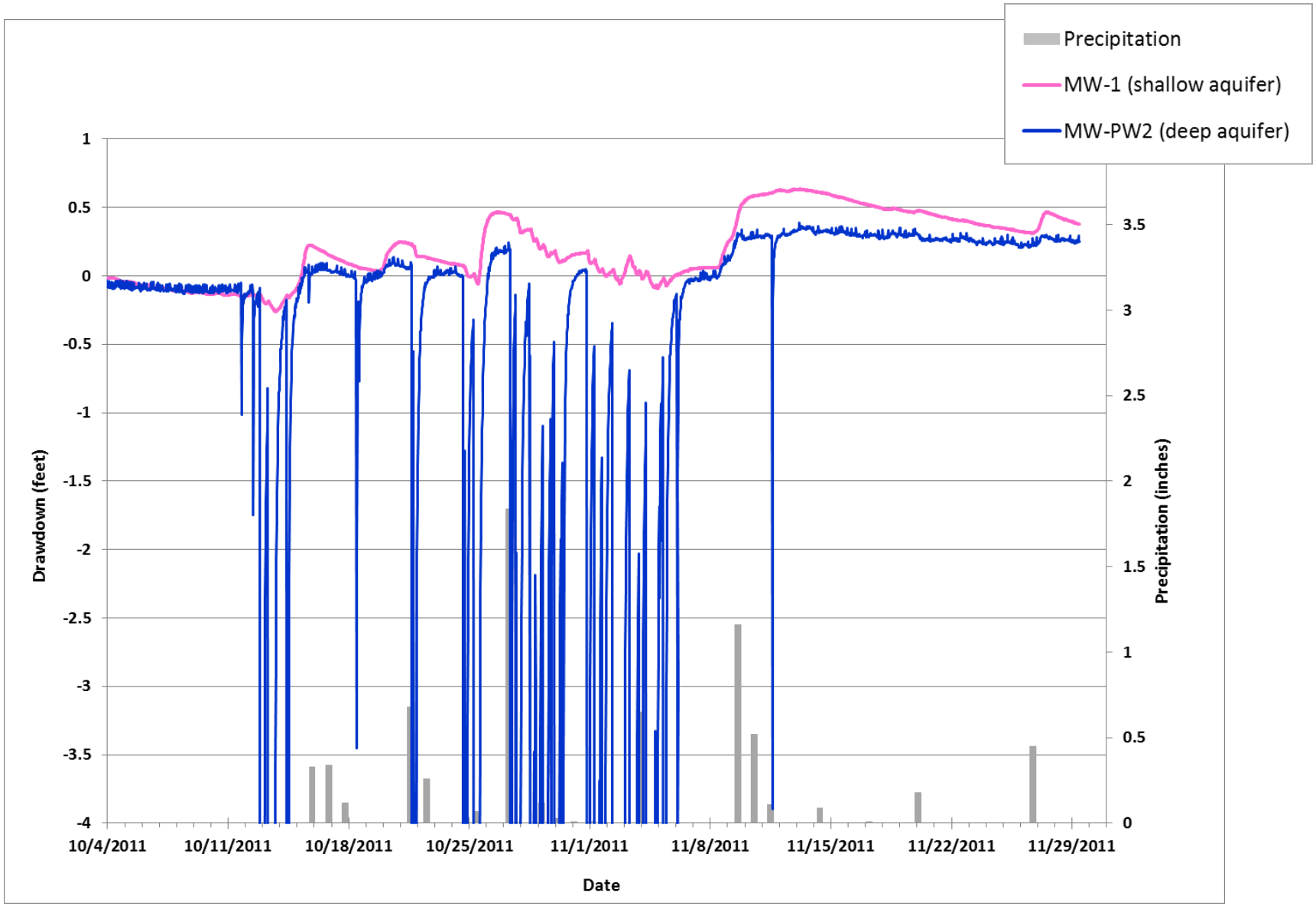
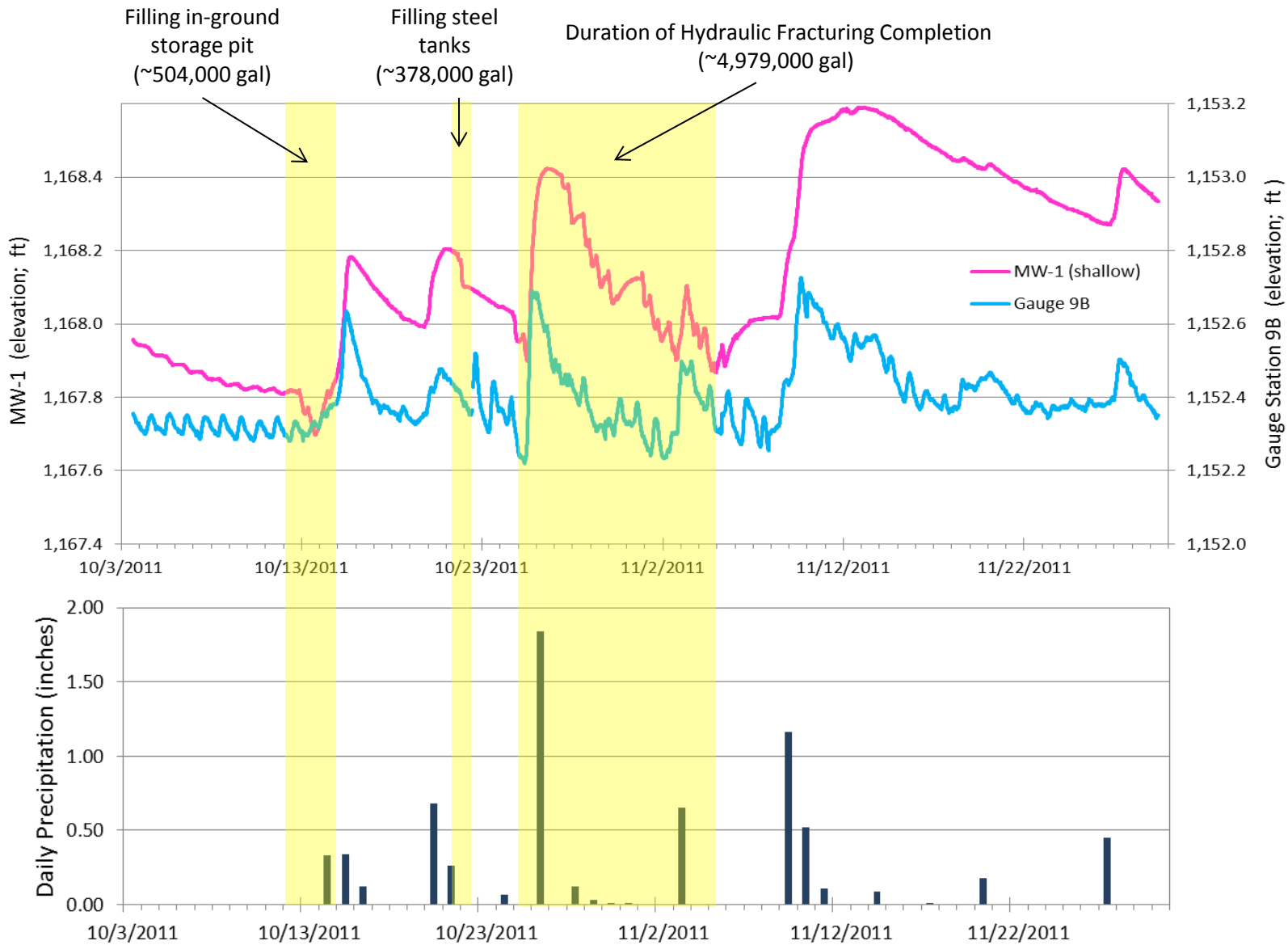


Figure 12. St. Excelsior 1-13 Completion Drawdown with Station 9B Elevation and Precipitation



Water withdrawn intervals shown by yellow shading.