



# Upper Solomon River Subbasin

## 2010 Field Analysis Summary

May 16, 2011

Basin Management Team

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## **I. Introduction**

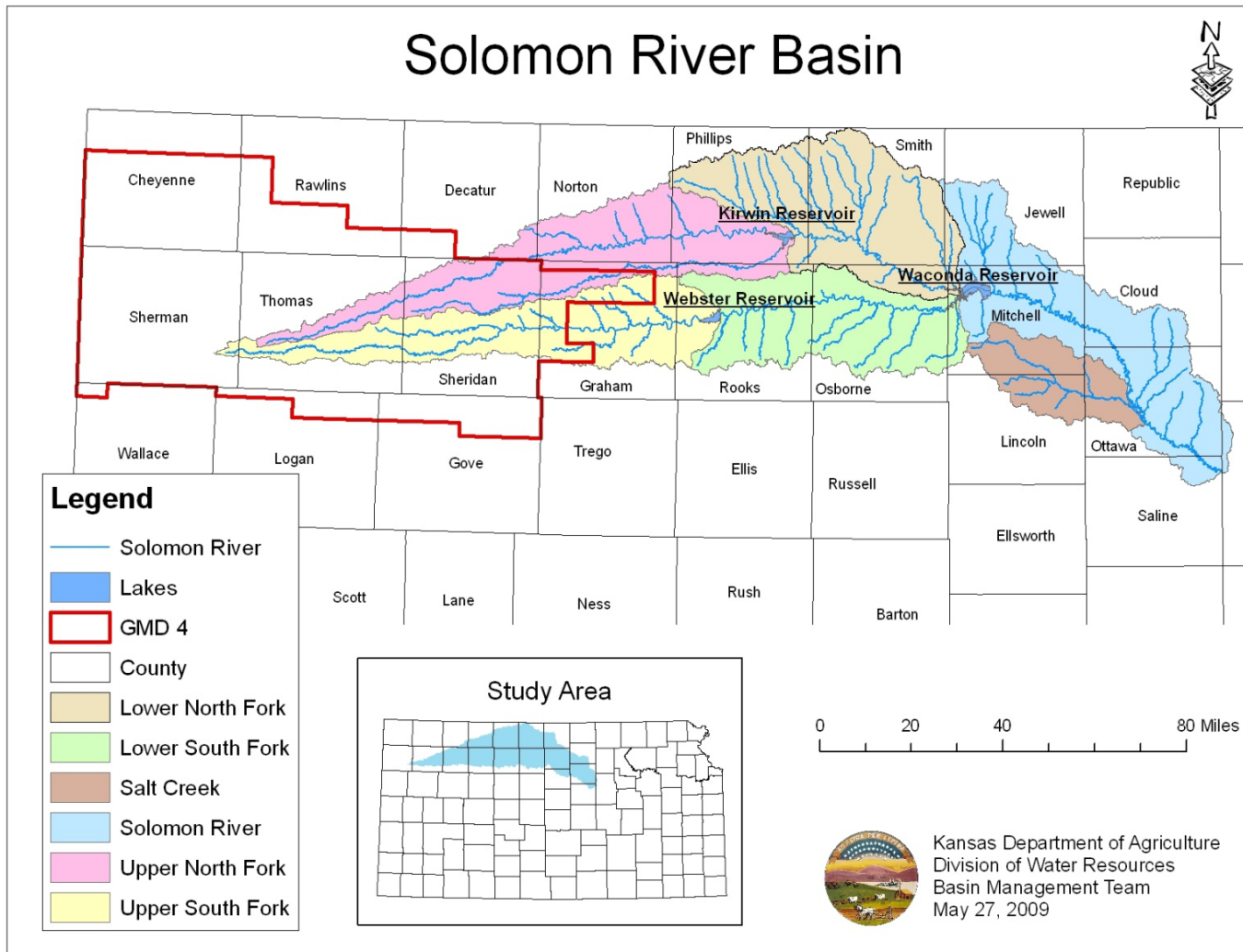
The Solomon River Basin is divided into three sections: Upper Forks, Lower Forks and Mainstem. This field summary will cover the Upper Forks section. The Upper Forks include both a North and South stem of the river. The Upper North Fork begins in Thomas County and continues through Sheridan, Decatur and Norton counties. It flows into Kirwin Reservoir in Phillips County. Bow Creek is a tributary to the North Fork and also flows into Kirwin Reservoir. The Upper South Fork headwaters are in Sherman County. It travels west to east through Thomas, Sheridan, Graham and Rooks Counties where it enters Webster Reservoir.

The Upper North Fork, Upper South Fork and Bow Creek headwaters all originate in the Northwest Kansas Groundwater Management District #4 (GMD 4). GMD 4 was formed on March 1, 1976 pursuant to the Groundwater Management District Act. More information about GMD 4 is available at their website, [www.gmd4.org](http://www.gmd4.org).

As mentioned above, Webster and Kirwin Reservoirs separate the Upper Forks from the Lower Forks. Both were constructed and are operated by the U.S. Department of the Interior, Bureau of Reclamation. Kirwin on the North Fork was completed in 1955 while Webster on the South Fork was finished in 1956. The reservoirs provide flood control and irrigation storage for the area.

The Upper Forks of the Solomon River flow mainly through the High Plains physiographic region. The topography is characterized by flat to gently rolling hills with narrow, shallow valleys. Sand, gravel and porous rock, called mortar bed, cover the region. The Smoky Hills physiographic region begins in Rooks County and continues eastward. The western edge of the Smoky Hills is characterized by steep chalk bluffs that can be found south of the Solomon River.

Figure 1 is a map of the entire Solomon basin.



**Figure 1: Solomon River Basin divided into subbasins**

## II. Precipitation

Precipitation in the Upper Solomon subbasin historically averages 21.5 inches based on 10 precipitation stations: Studley in Sheridan County, Densmore in Norton County, Lenora in Norton County, Norton in Norton County, Rexford in Thomas County, Damar in Rooks County, Hill City in Graham County, Hoxie in Sheridan County, Logan in Phillips County and Mingo in Thomas County. The chart in Figure 2 is based on averaged data from National Climatic Data Center (NCDC) weather stations. The highest precipitation total occurred in 1993 with 33.3 inches and the lowest annual precipitation was in 2002 with 10.9 inches. Precipitation was above average in 2009 at 25.0 inches but below 2008 precipitation amounts. Annual precipitation data for these NCDC stations is currently available through 2009.

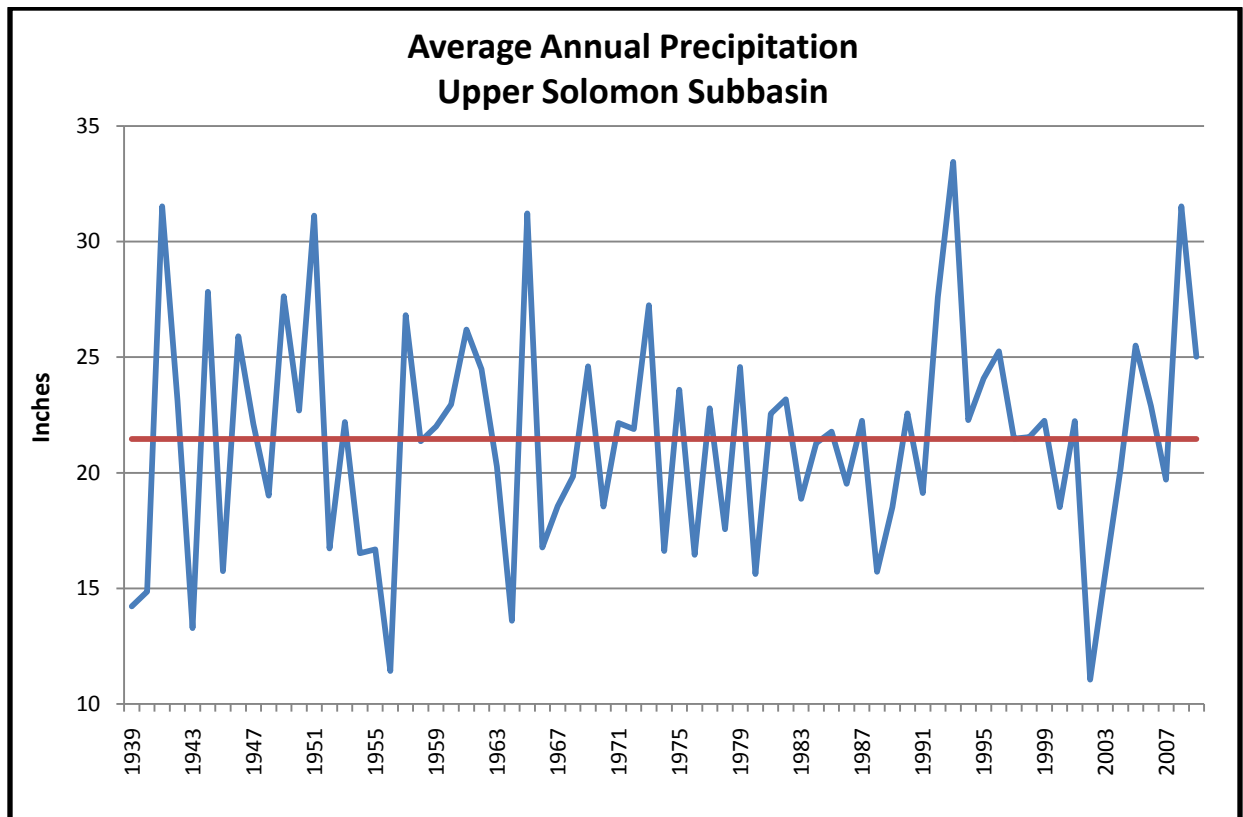
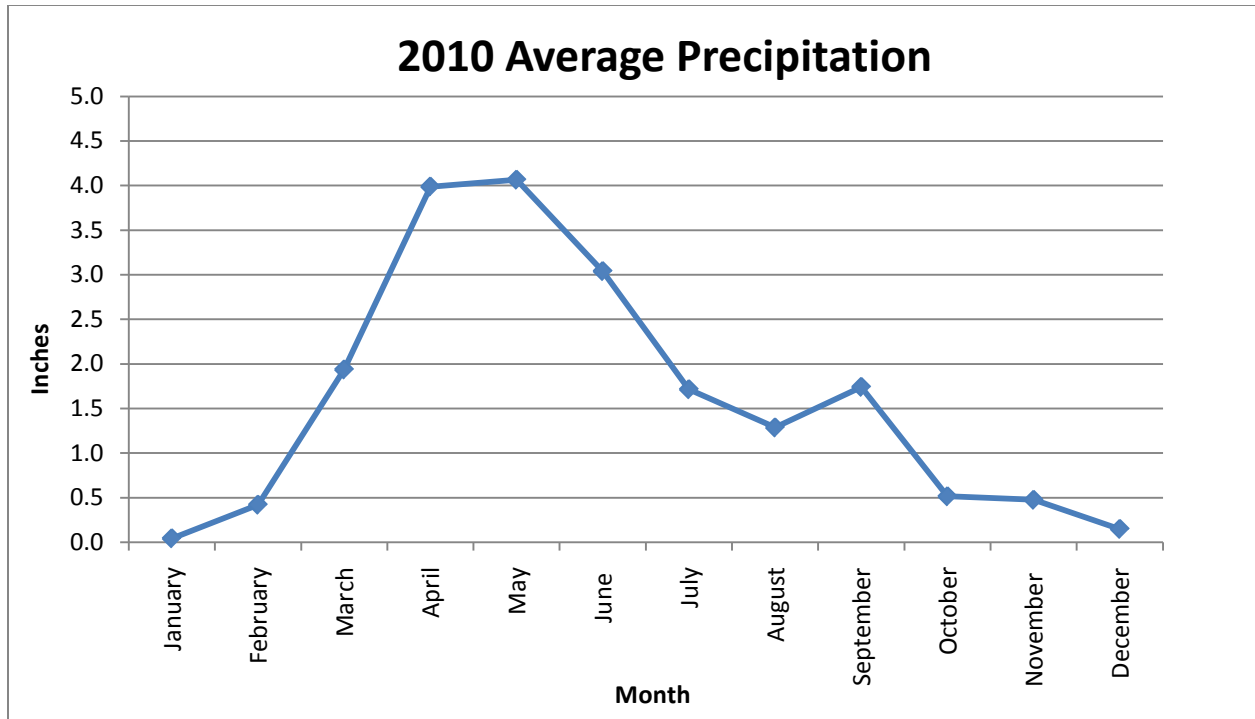


Figure 2: Upper Solomon Subbasin precipitation 1939-2009

Figure 3 shows provisional precipitation measurements for January 2010 to December 2010. The subbasin experienced a total of 19.4 inches of precipitation in 2010. This total is below the historic subbasin average of 21.5 inches. May had the most precipitation with 4.1 inches and January had the least with 0.04 inches.



**Figure 3: 2010 Monthly Average Precipitation**

### III. Surface Water

The Upper Solomon subbasin has three United States Geological Survey (USGS) streamflow gages. The Upper North Fork has a gage at Glade. It has been in operation since October 1, 1952. The Stockton gage is on Bow Creek which is a tributary to the North Fork Solomon River. It has been in service since November 20, 1950. The third gage is above Webster Reservoir on the Upper South Fork. It has been in operation the longest beginning January 8, 1945 (Figure 4).

The average annual streamflows over the period of records at Glade was 25.6 cfs, Bow Creek was 14.9 cfs, and above Webster was 53.5 cfs. During the 1990s, streamflow maintained higher annual averages with Glade at 38.63 cfs, Bow Creek at 16.84 cfs and above Webster at 55.30 cfs. Average annual streamflow declined during the 2000s with Glade at 13.8 cfs, Bow Creek at 10.9 cfs, and above Webster at 21.3 cfs (Figure 5). Flows also declined during the second half of 2010 (Figure 6).

# Upper Solomon Subbasin USGS Streamflow Gages

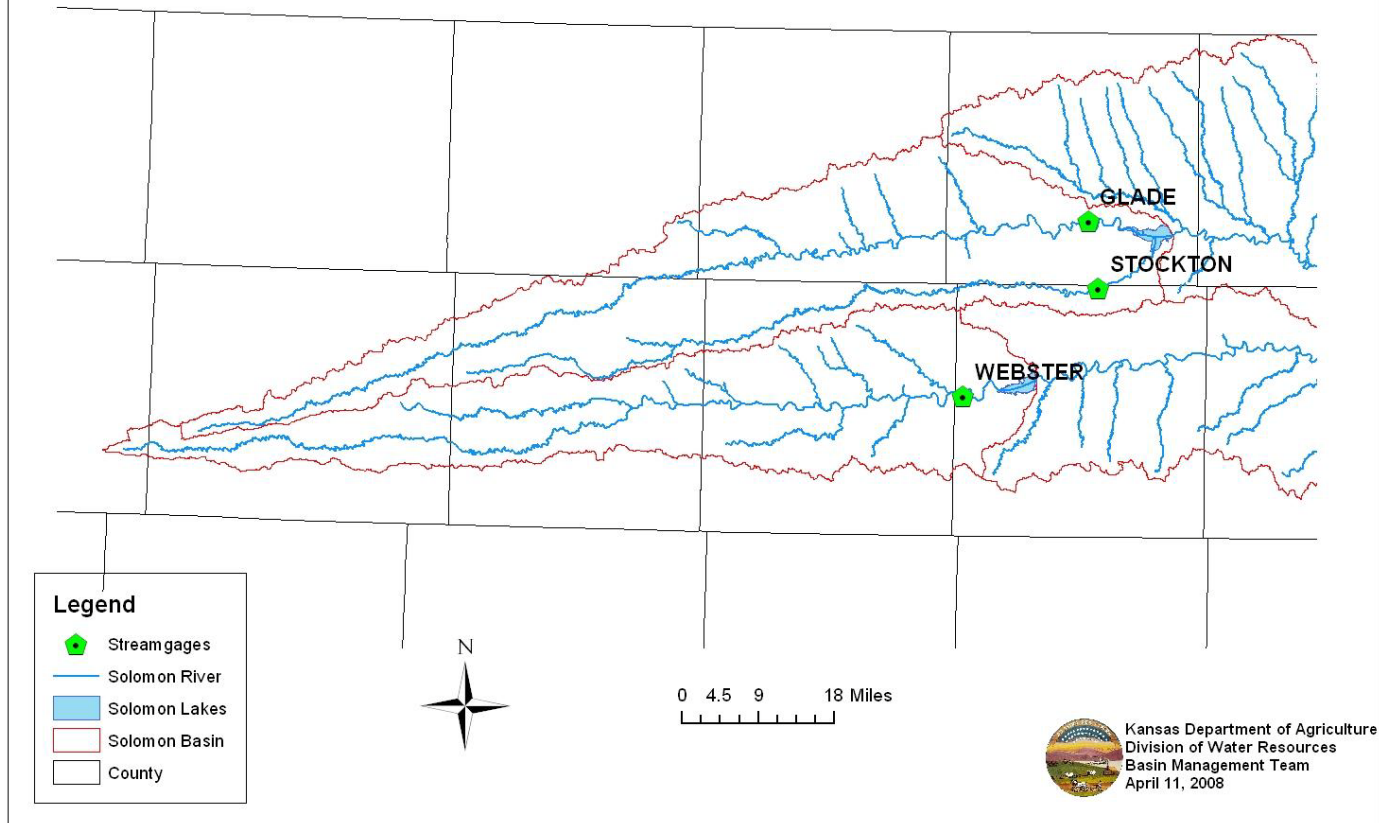


Figure 4: Upper Solomon Subbasin USGS Streamflow Gages

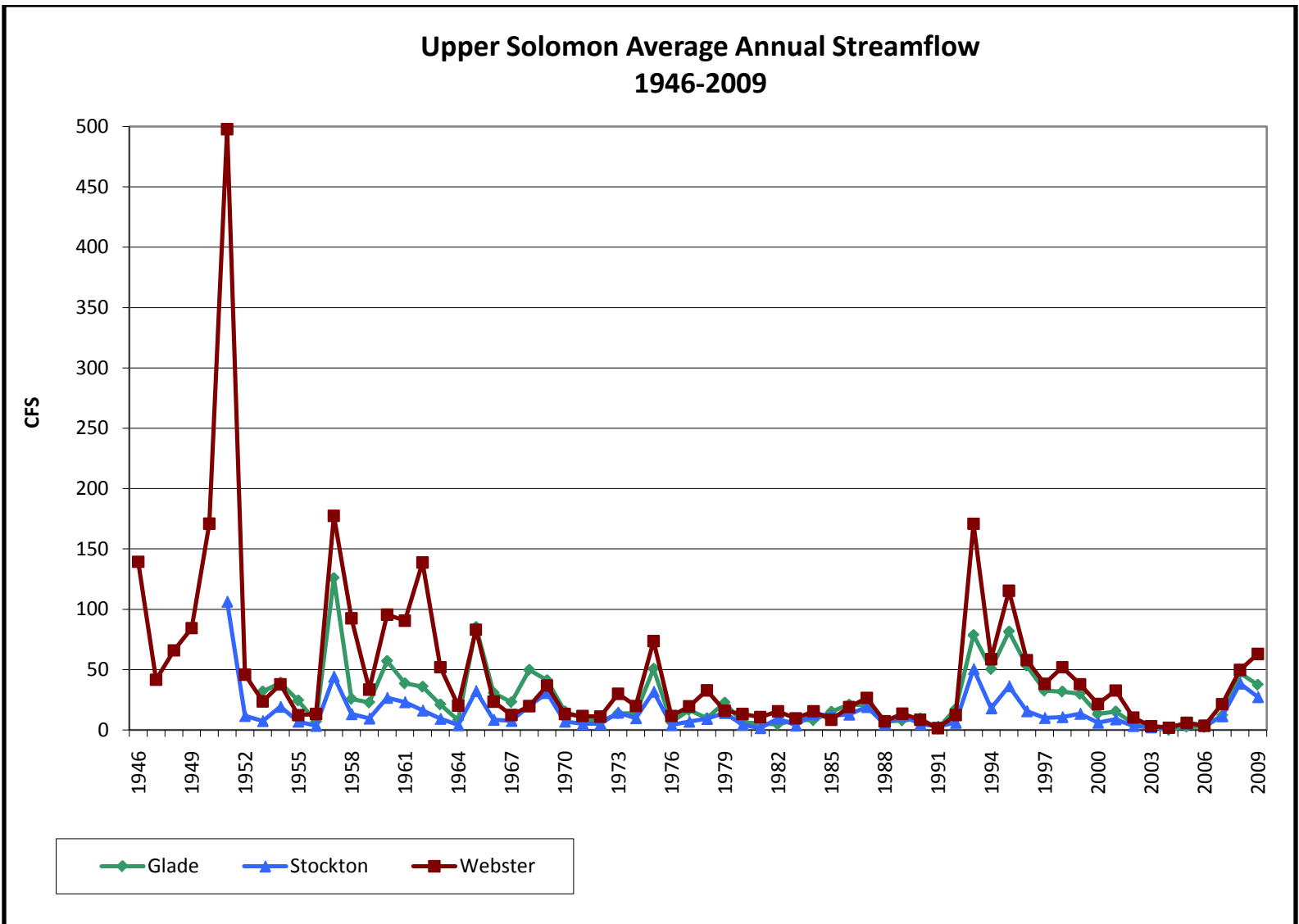


Figure 5: Average Annual Streamflow, 1946-2009



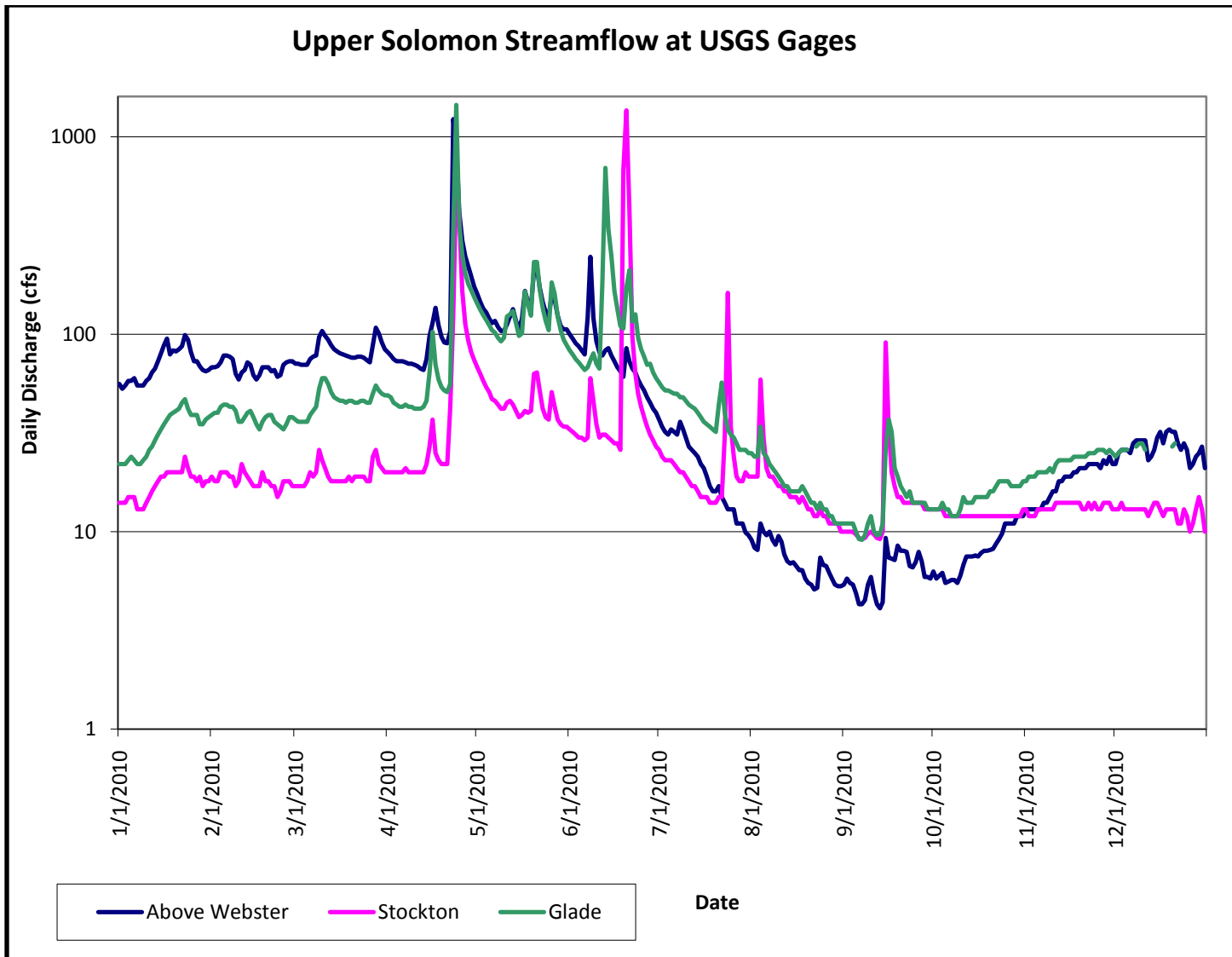


Figure 6: Daily Streamflow for 2010

## **IV. Groundwater**

The upper reaches of the Upper North and South Forks of the Solomon River subbasin overlie the Ogallala portion of the High Plains Aquifer (Figure 7). The Kansas Geological Survey (KGS) and the Kansas Department of Agriculture's Division of Water Resources (KDA-DWR) combine efforts to measure 110 groundwater levels in the Upper North and South Forks of the Solomon River subbasin annually. The monitoring wells were drilled in two aquifer systems, the Ogallala-High Plains and the alluvial aquifers and are plotted separately on the hydrologic charts (Figure 8 through Figure 19).

KDA-DWR collects additional water levels on a tri-annual basis in the winter, spring and fall. Only the winter measurements, taken in December, January or February, are used for the monitoring well water level charts, since those measurements are considered to be the least influenced by irrigation well pumping. Figure 8 to Figure 19 chart groundwater levels in all the monitoring wells (legal descriptions are available in the appendix) and also the five-year rolling averages. The y-axis is labeled as DBLS (feet). The DBLS stands for depth below land surface. The charts include all monitoring wells known to KDA-DWR with currently available data.

Several of the monitoring wells have been measured since the early to mid-1960s. A number of wells were added to the monitoring network in the 1980s as well as in the 2000s after the Kansas State Water Plan targeted the Basin. Ongoing observation of water levels is critical to understanding the fluctuations that may occur over time. Historical records can provide a hydrologic outlook on the long-term sustainability or decline of an area.

Groundwater levels in the Ogallala-High Plains can be affected by climatic conditions and well pumping. After the irrigation season, water levels tend to recover rapidly, but may take up to six months or more to fully recover to static water level conditions. During drought conditions water levels may not fully recover before the next irrigation season begins. Positive long-term trends in water levels generally occur where recharge exceeds withdrawals from the aquifer. Declining trends in alluvial aquifer water levels may be a result of reduced discharge to streams from the Ogallala-High Plains aquifer as groundwater levels decline in this aquifer system.

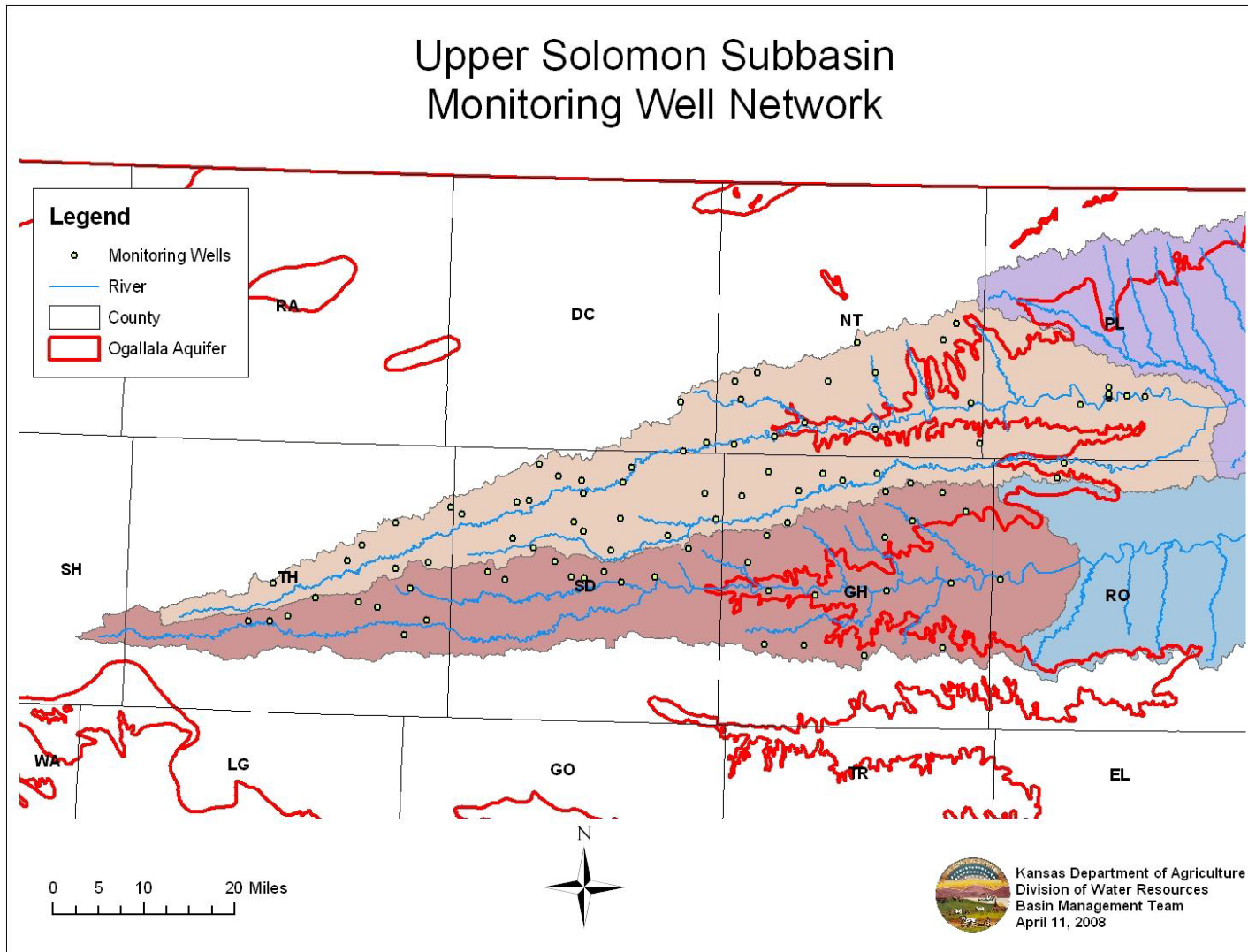
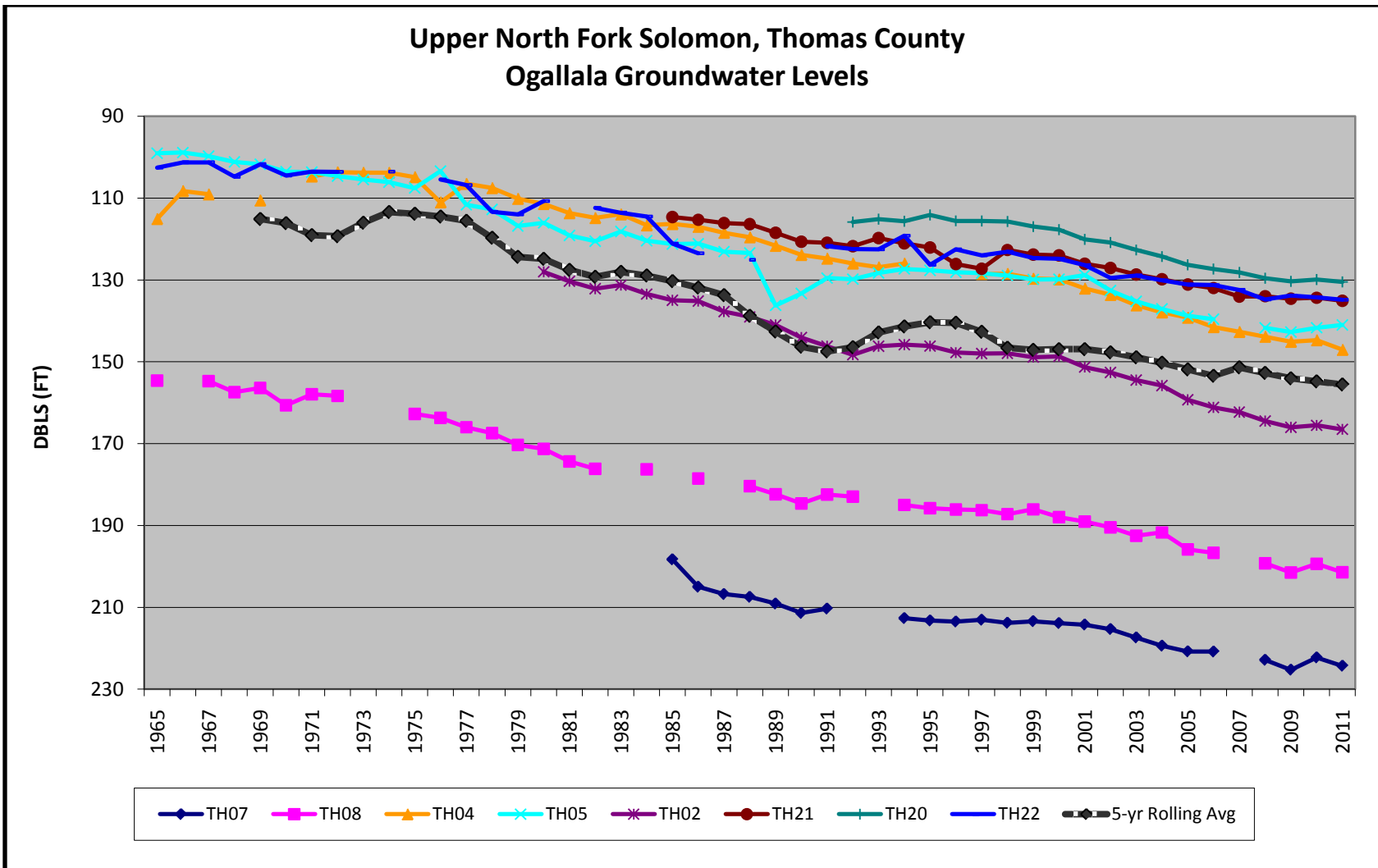
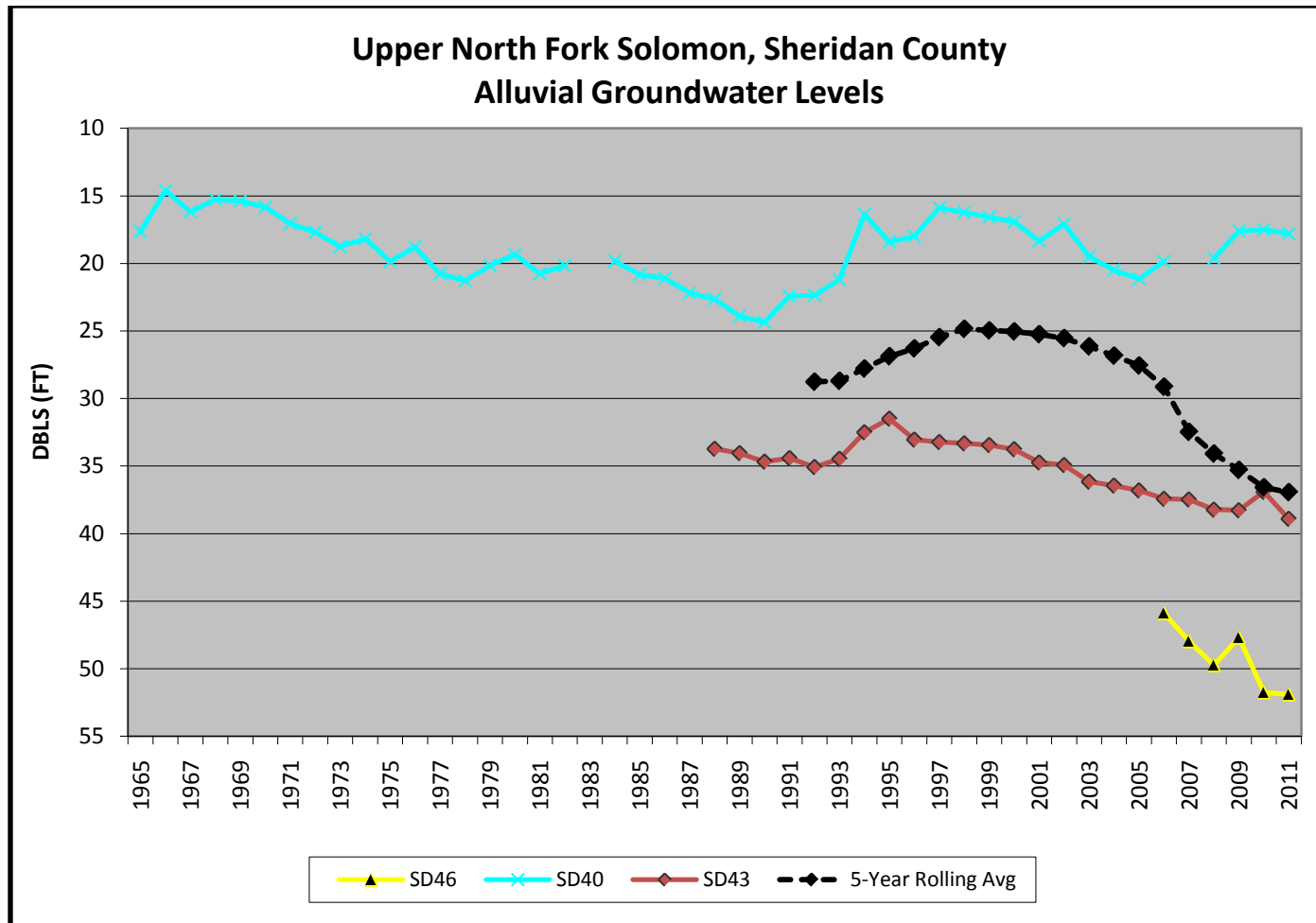


Figure 7: Upper Solomon Subbasin Monitoring Wells



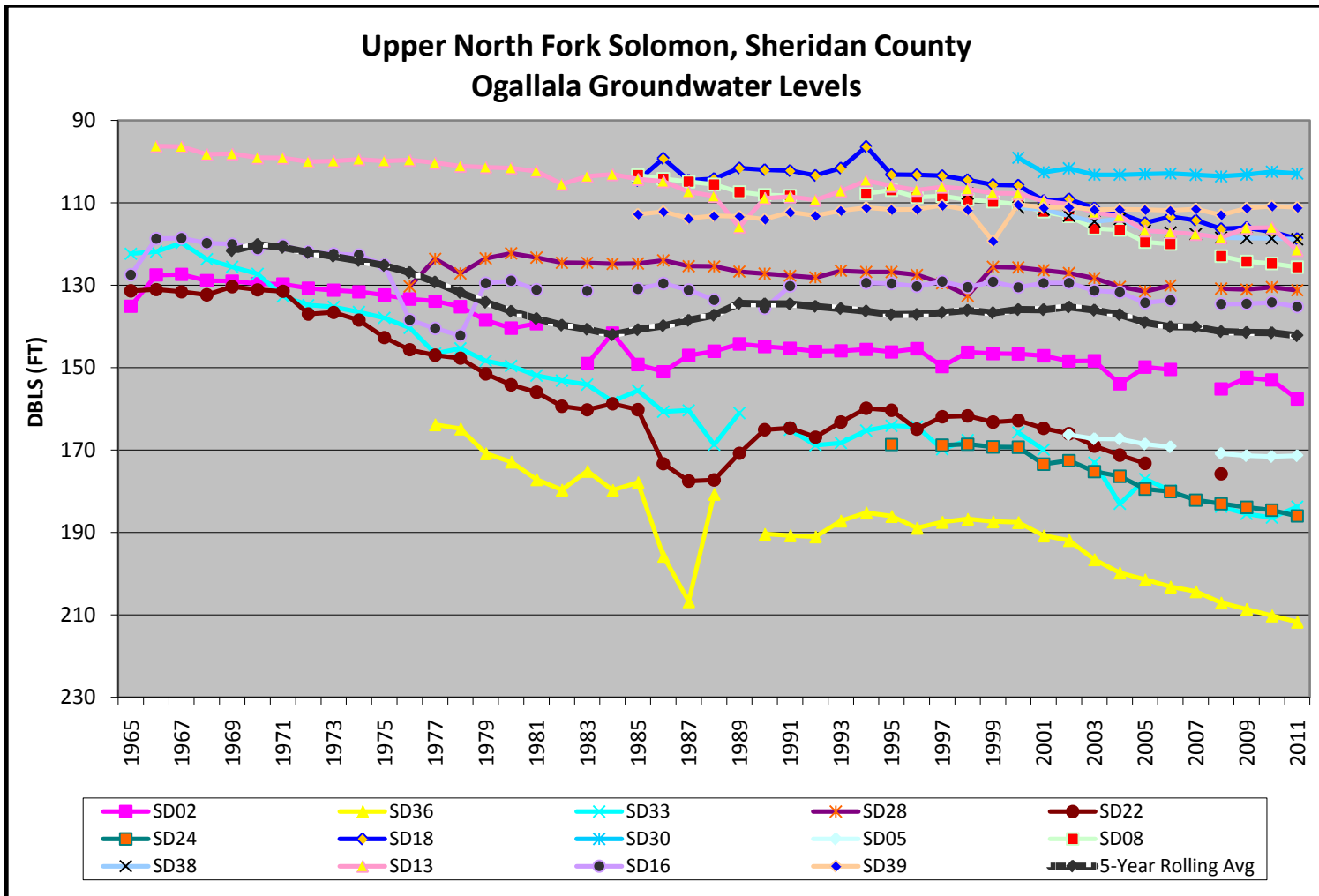
**Figure 8: Ogallala-High Plains monitoring well levels, Upper North Fork in Thomas County**

In the Upper North Fork of the Solomon River, the eight Ogallala-High Plains wells have decreased an average of 1.08 feet from 2010 to 2011 (Figure 8). All water levels decreased in 2011 except for TH05 (0.70 feet). There are a number of wells with historic data that show a net decline in water levels ranging from 14.65 feet (TH20) to 46.83 feet (TH08). The five-year rolling average shows a net decline in water levels of 40.45 feet since 1969.



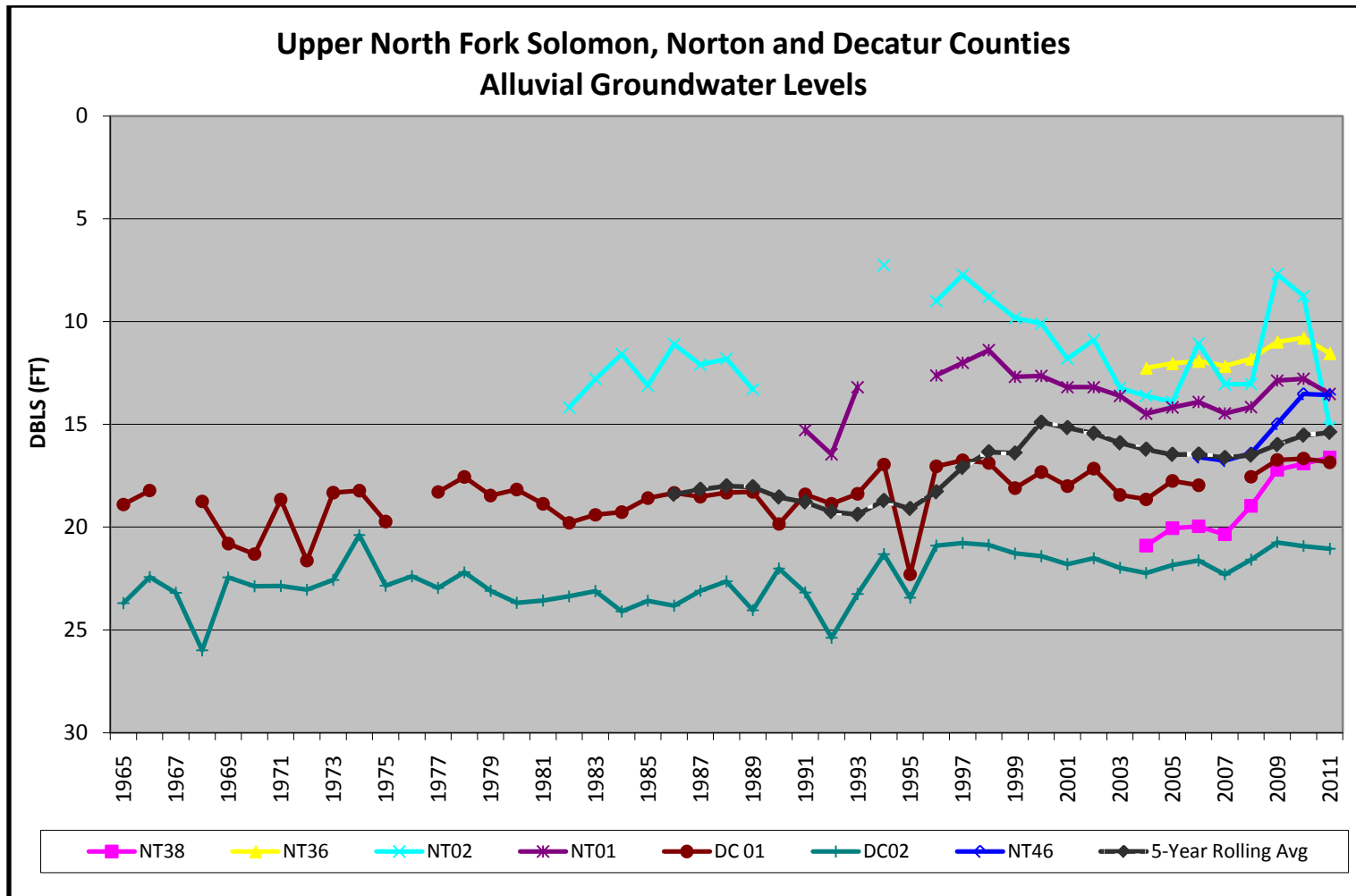
**Figure 9: Alluvial monitoring well levels, Upper North Fork in Sheridan County**

Wells located in Sheridan County on the Upper North Fork Solomon were drilled into the alluvial and Ogallala-High Plains aquifer. Figure 9 represents the three alluvial wells in Sheridan County. All three monitoring wells declined in 2011. SD46 declined 0.15 feet, SD40 declined 0.30 feet and SD43 declined 2.0 feet. SD40 has data dating back to 1965 and has shown a net decline of 0.15 feet, whereas SD43 that has only been measured since 1988 is showing a net decline of 5.18 feet in water levels. The five-year rolling average shows an increase in water levels during the mid-1990, then a declining trend in the last 10 years, which partly is attributed to the addition of SD46 in 2006.



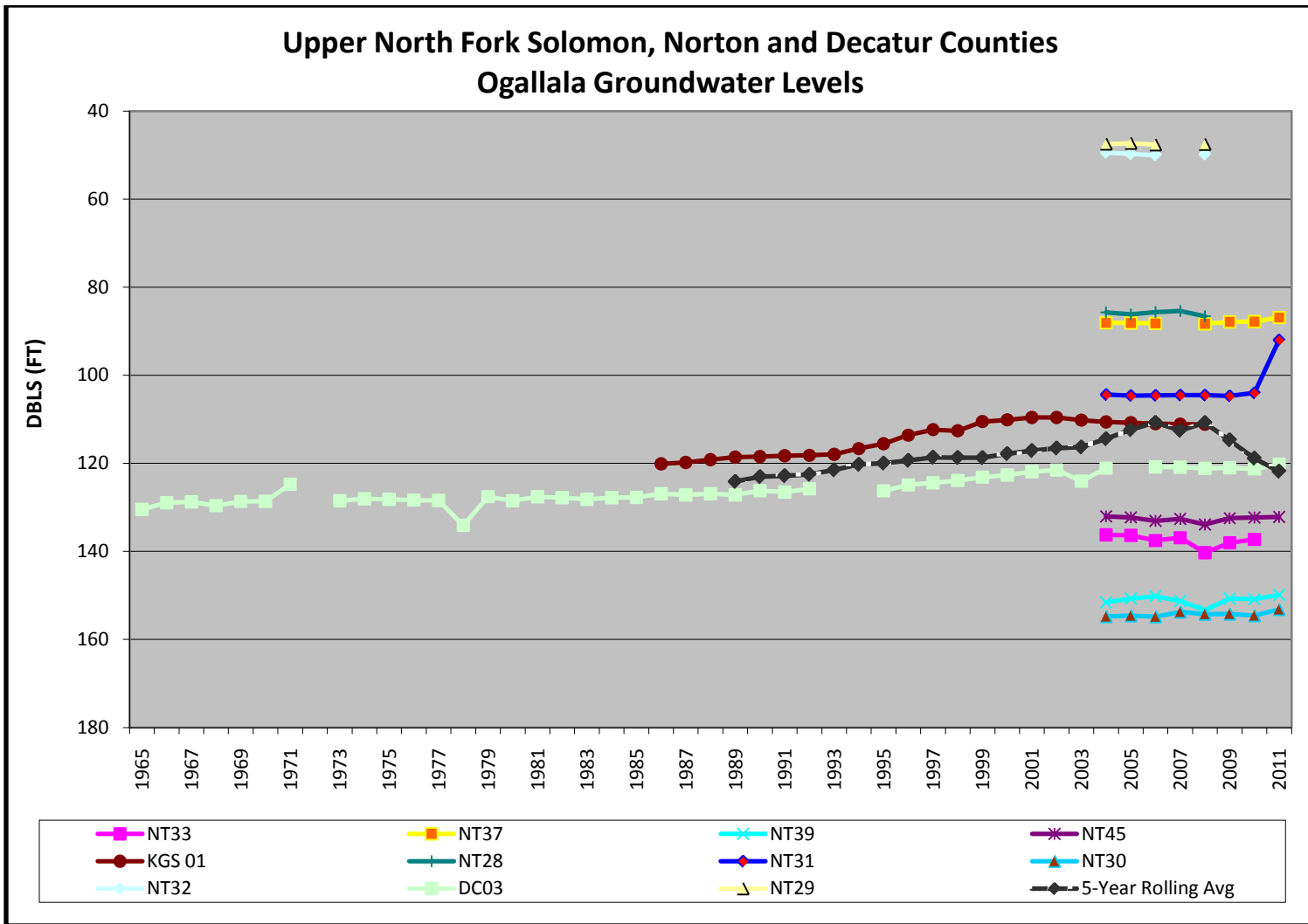
**Figure 10: Ogallala-High Plains wells in the Upper North Fork, Sheridan County.**

There are 14 wells monitored in the Ogallala-High Plains in the Upper North Fork, Sheridan County (Figure 10). From 2010 to 2011, on average these wells have declined 1.19 feet, with water levels ranging from a decline of 5.50 feet (SD13) to an increase of 2.66 feet (SD33). Monitoring of some of these wells started in 1965 and these wells have a net decline in the water table ranging from 7.75 feet (SD16) to 61.40 feet (SD33). The five-year rolling average shows an overall declining trend in water levels with a net decline of 20.64 feet.



**Figure 11: Alluvial monitoring well levels, Upper North Fork in Norton and Decatur Counties**

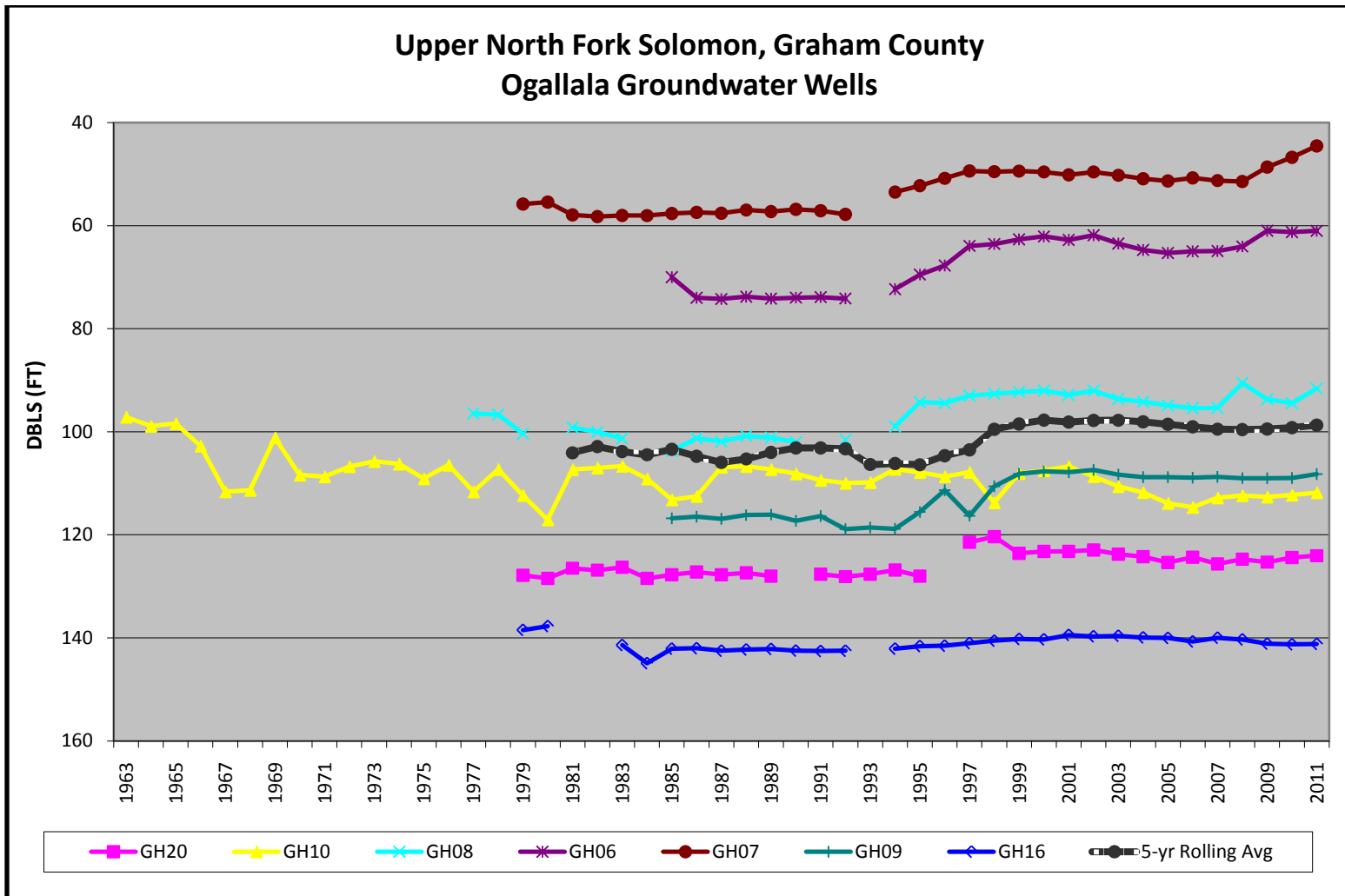
In Norton and Decatur Counties of the Upper North Fork Solomon, both alluvial and Ogallala-High Plains wells are measured. There are seven alluvial wells, five in Norton County and two in Decatur County (Figure 11). In 2011, the average change in water levels showed a decrease of 1.14 feet in these counties. The change in water levels ranged from an increase of 0.30 feet (NT38) to a decrease of 6.38 feet (NT02). DC01 and DC02 were first measured in 1965. Since 1965, the water table has increased 2.05 feet (DC01) and 2.65 feet (DC02). The five-year rolling average shows an increase since 2006.



**Figure 12: Ogallala-High Plains monitoring wells in the Upper North Fork, Norton and Decatur Counties.**

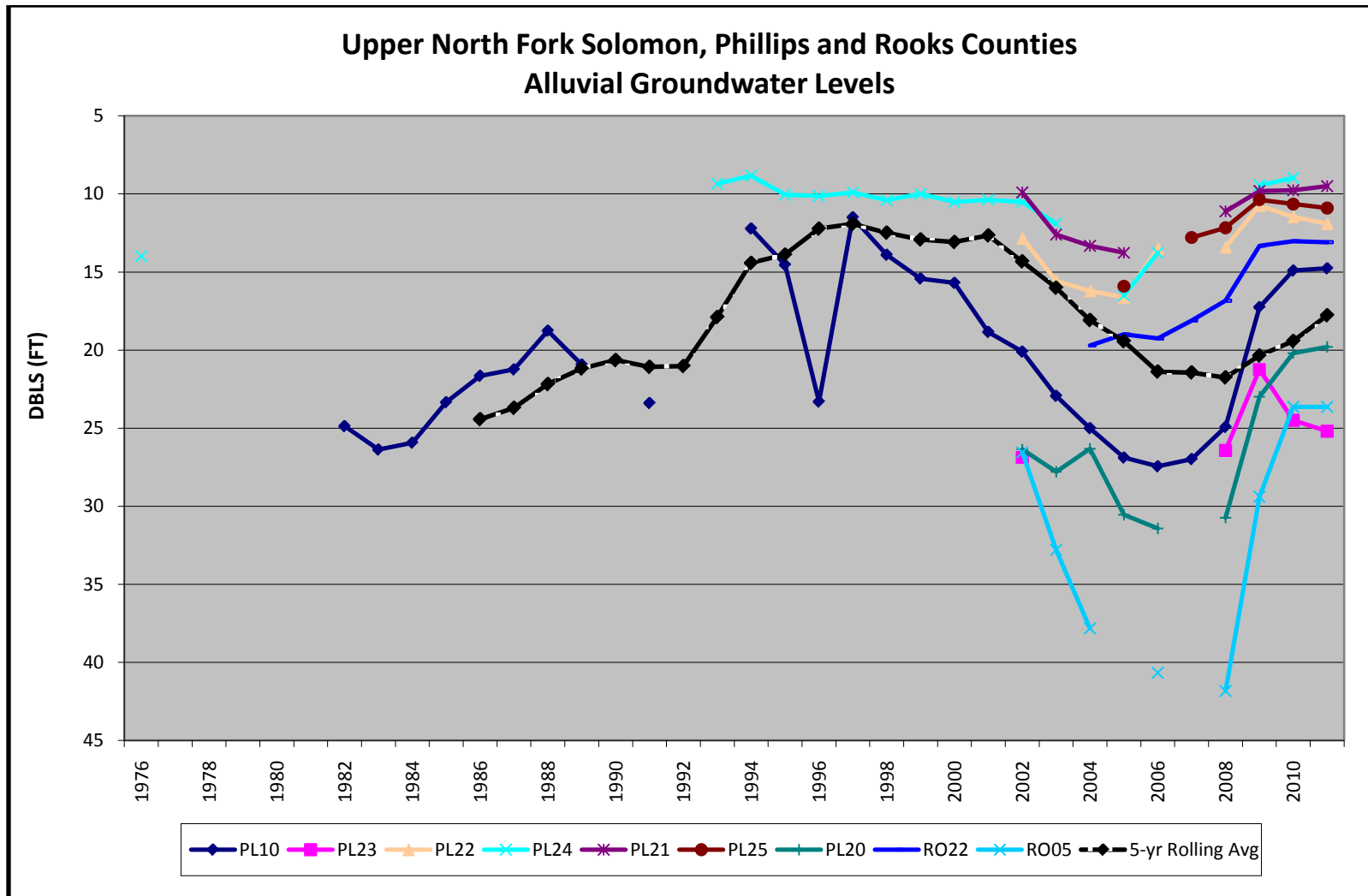
Only six of the 11 Ogallala-High Plains wells in Norton and Decatur Counties were measured in 2011. In Figure 12, the wells have shown an overall increase in water levels of 2.34 feet. The range in the water level changes are an increase of 11.98 feet (NT31) to an increase of 0.09 feet (NT45). DC03 has been measured since 1965 and shows a net increase in the water table of 10.25 feet. The five-year rolling average shows a net increase of 2.31 feet in the water table over time.





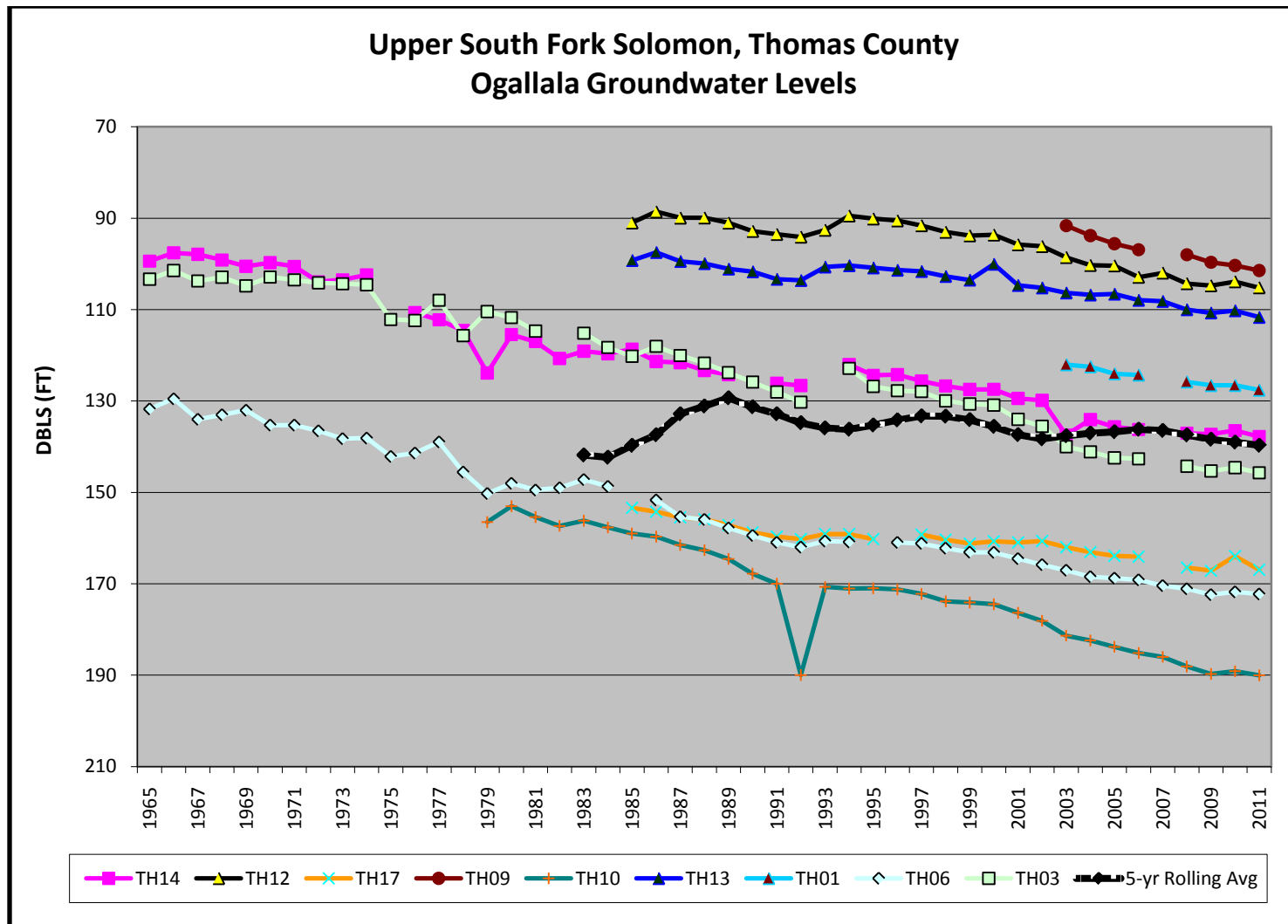
**Figure 13: Ogallala-High Plains monitoring well levels, Upper North Fork in Graham County**

There are seven monitoring wells in Graham County in the Upper North Fork Solomon (Figure 13) located in the Ogallala-High Plains aquifer. The average change in the water table in 2011 was an increase of 0.99 feet. The changes in the water table ranged from an increase of 2.83 feet (GH08) to an increase of 0.07 feet (GH16). GH10 has been measured since 1963 and shows a net decline in the water table of 14.68 feet, whereas GH07 measured since 1979 shows a net increase of 11.26 feet. The five-year rolling average shows fairly consistent water levels since 1998.



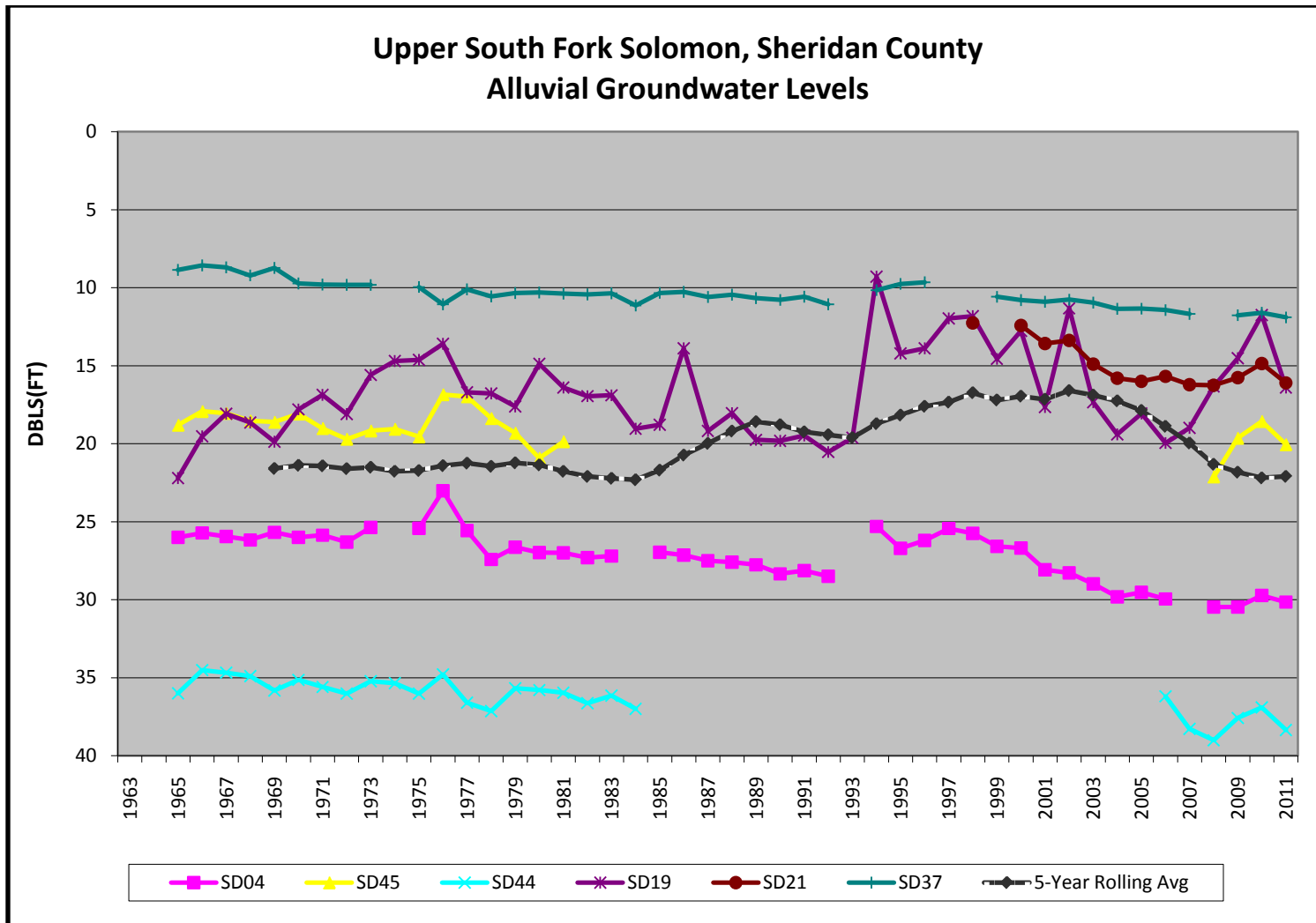
**Figure 14: Alluvial monitoring well levels, Upper North Fork in Phillips and Rooks Counties**

In Phillips and Rooks Counties, there are nine alluvial wells monitored in the Upper North Fork Solomon (Figure 14). The average change in water levels from 2010 to 2011 shows a decline of 0.08 feet. The change in the water levels ranged from a decline of 0.70 feet (PL23) to an increase of 0.39 feet (PL20). The five-year rolling average shows an increasing or stable water table until 2001 when it started to decline. The five-year rolling average increased in 2011 (1.65 feet).



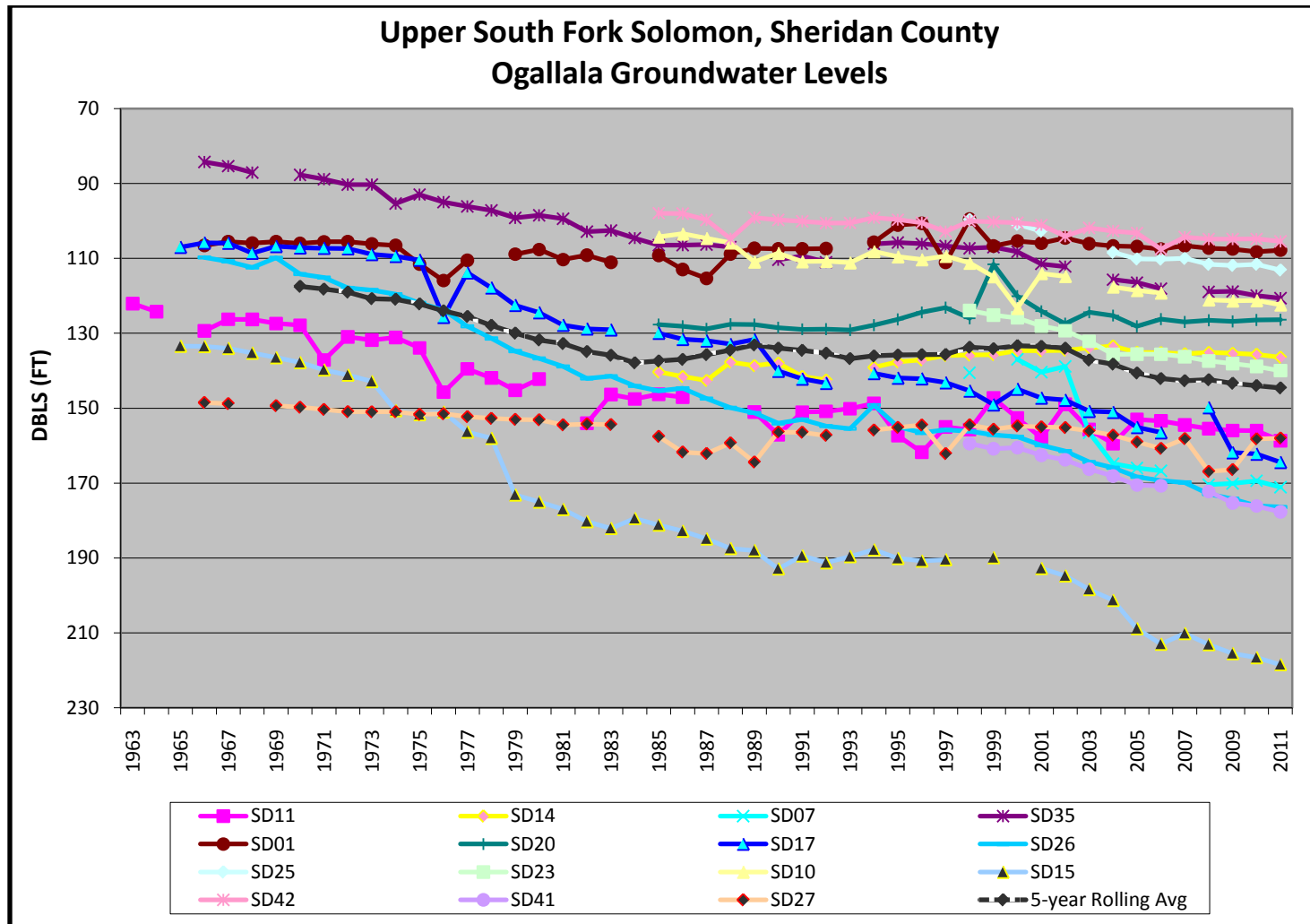
**Figure 15: Ogallala-High Plains monitoring well levels, Upper South Fork in Thomas County**

The Upper South Fork Solomon in Thomas County has nine Ogallala-High Plains wells monitored. The average change in the water table is a decline of 1.30 feet, ranging from a decline of 0.47 feet (TH06) to a decline of 3.02 feet (TH17) from 2010 to 2011. Two wells, TH06 and TH03, have been measured since 1965. TH06 has a net decline of 40.53 feet since 1965 and TH03 has a net decline of 42.36 feet. The five-year rolling average shows a general decline from the late 1980s to present.



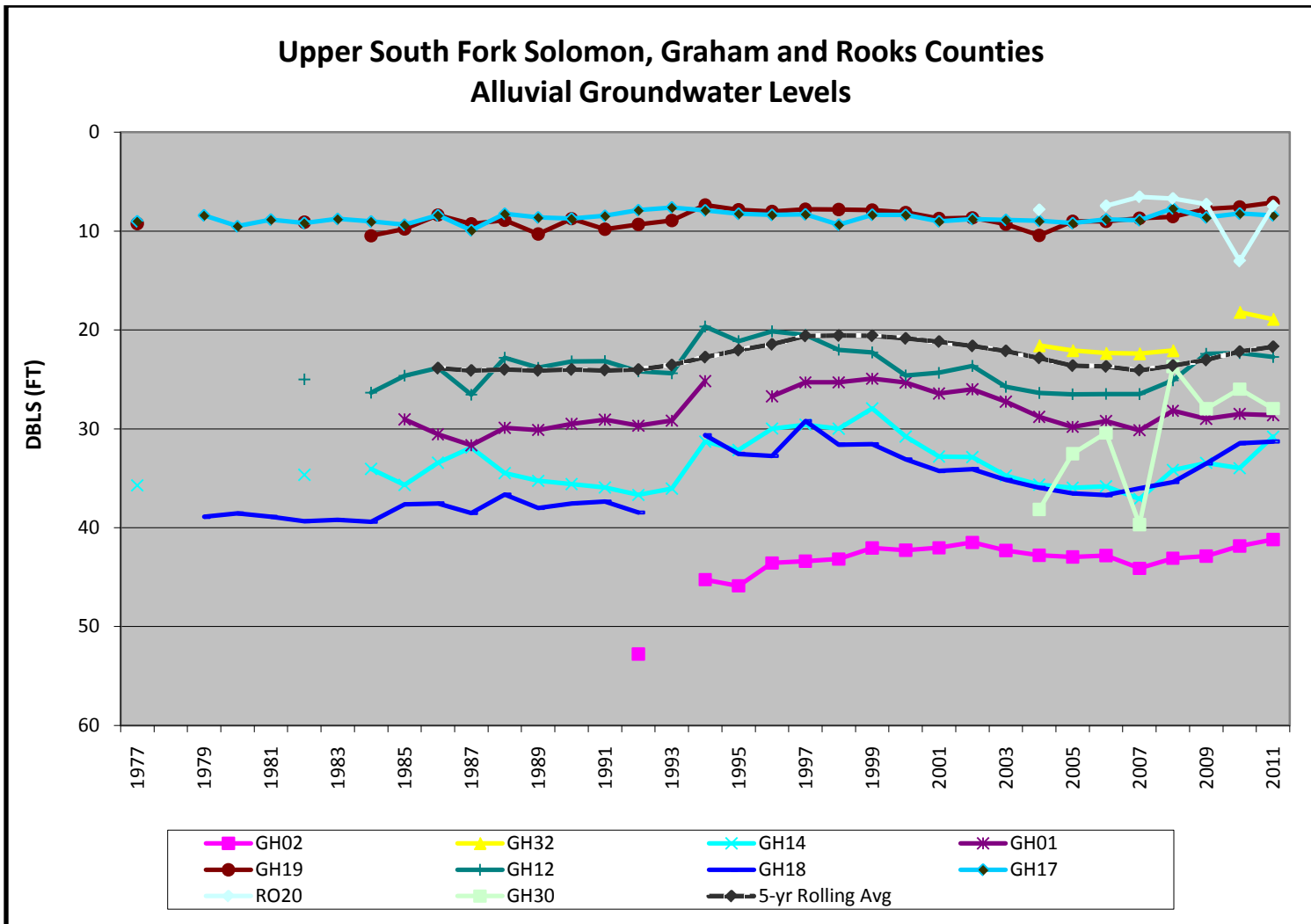
**Figure 16: Alluvial monitoring well levels in the Upper South Fork Solomon, Sheridan County**

There are six alluvial monitoring wells in the Upper South Fork Solomon in Sheridan County (Figure 16). From 2010 to 2011, the change in the water table ranged from a decline of 0.30 feet (SD37) to 4.65 feet (SD19) for an average decline of 1.91 feet. There are a number of wells with historical data dating back to 1965. SD19 over time has a net increase of 5.8 feet, whereas SD04 declined a net of 4.15 feet. The 5-year rolling average had a slight increase in 2011.



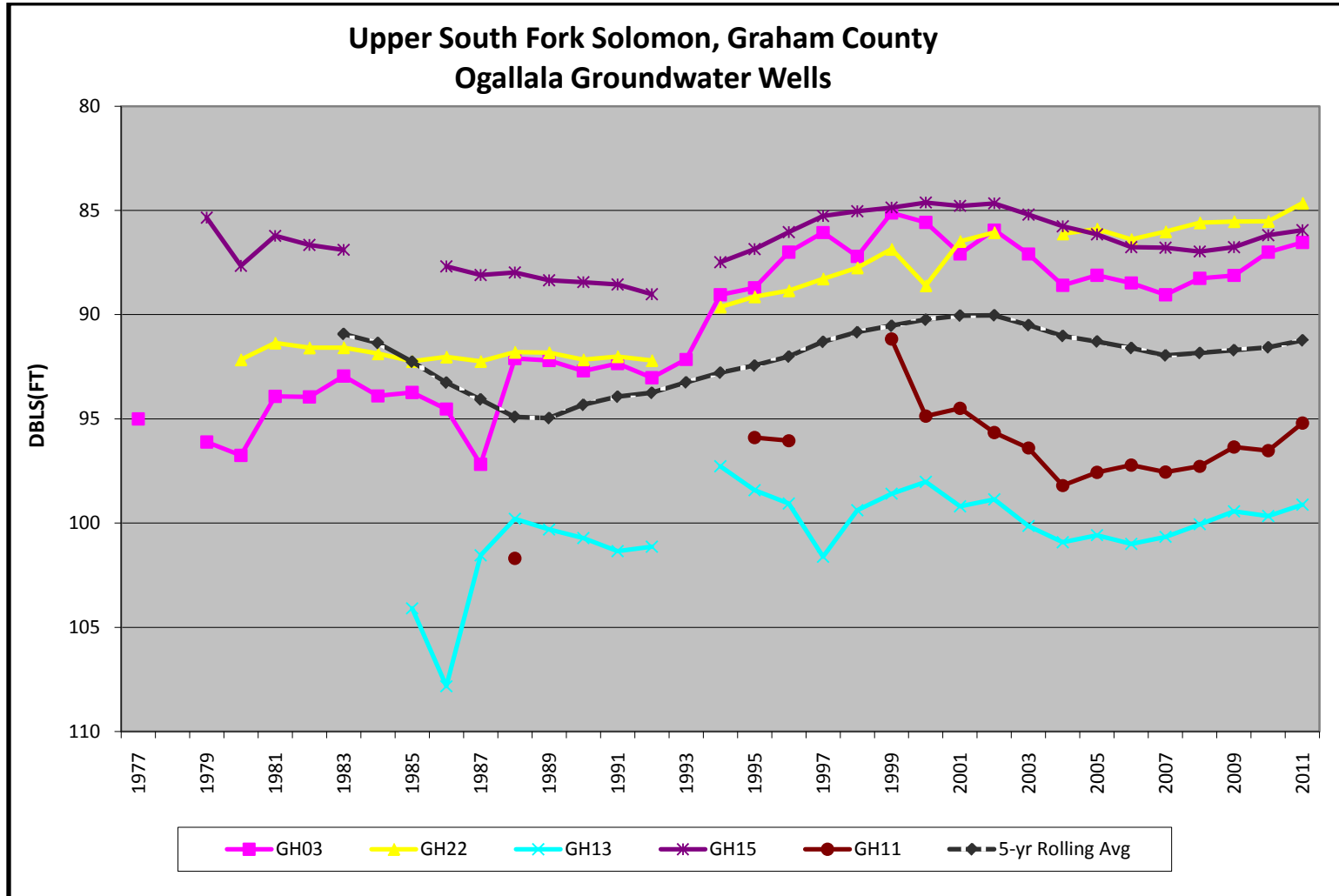
**Figure 17: Ogallala-High Plains monitoring well levels, Upper South Fork in Sheridan County**

Fifteen Ogallala-High Plains monitoring wells are located in the Upper South Fork in Sheridan County (Figure 17). The Ogallala-High Plains wells have measurements dating back to 1965 as do the alluvial wells. The average change in the water table for these wells is a decline of 1.04 feet in 2011. The change in the water levels ranged from a decline of 2.72 feet (SD11) to an increase of 0.45 feet (SD01). Since 1963, SD11 has a net decline of 36.62 feet while SD27 has had a net decline of 9.52 feet. The five-year rolling average reflects this declining trend and continued to decline in 2011 (0.62 feet).



**Figure 18: Alluvial monitoring well levels, Upper South Fork in Graham and Rooks Counties**

Figure 18 shows the 10 alluvial monitoring wells located in the Upper South Fork in Graham and Rooks counties. From 2010 to 2011, the average change in the alluvial water levels is an increase of 0.67 feet. The change in the water levels ranged from a decrease of 1.97 feet (GH30) to an increase of 5.57 feet (RO20). GH14 has been measured since 1977 and has had a net increase of 4.93 feet. The five-year rolling average shows a generally stable water table but increasing in 2011.



**Figure 19: Ogallala-High Plains monitoring well levels, Upper South Fork in Graham County**

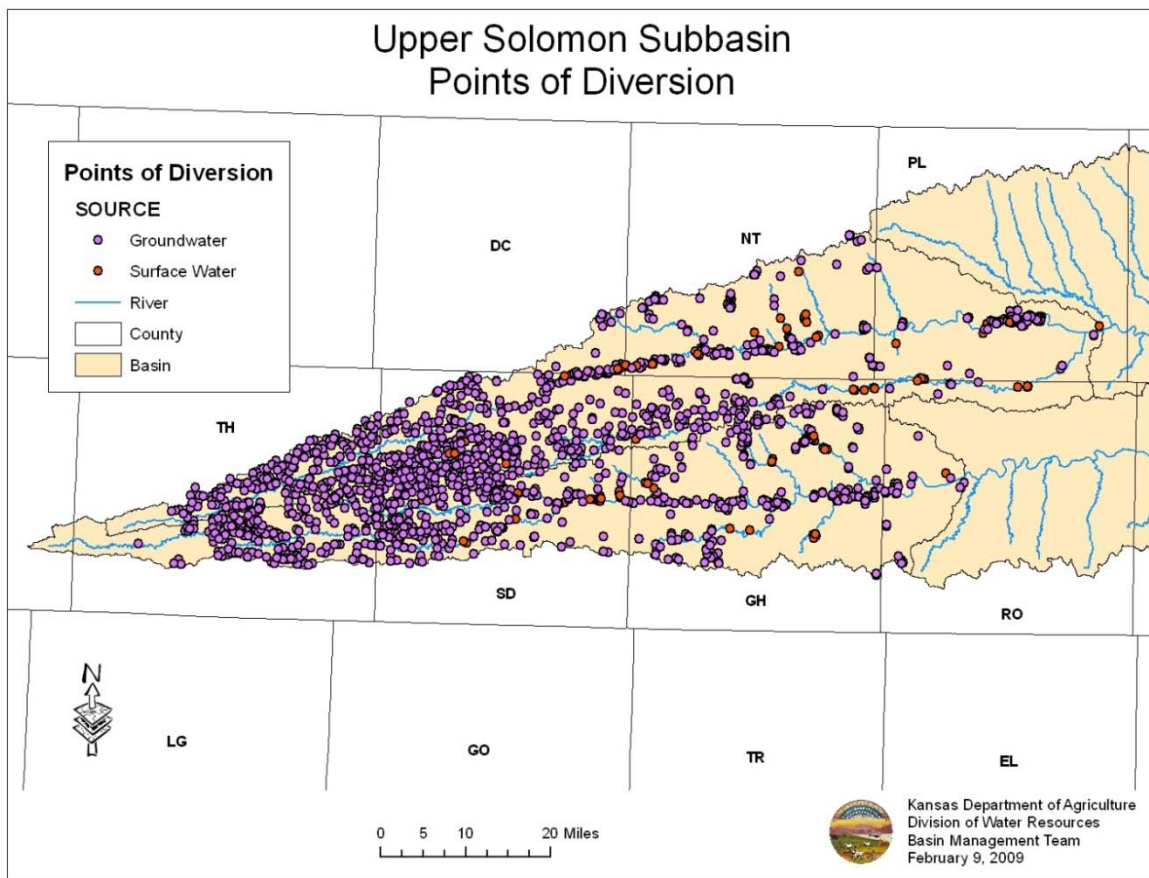
Five Ogallala-High Plains monitoring wells are located in the Upper South Fork in Graham County (Figure 19). The average change in the water levels for the Ogallala-High Plains wells was an increase of 0.69 feet in 2011 and ranged from an increase of 0.24 feet (GH15) to an increase of 1.33 feet (GH11). Data for this area dates back to 1977. Since 1977, GH03 increased a net of 8.46 feet whereas GH15 has had a net decline of 0.60 feet. The five-year rolling average saw another increase in 2011 (0.34 feet).

## V. Water Use

The Upper Solomon subbasin has 1,184 water rights with an authorized quantity of 261,297 acre-feet per year. About 98 percent of the water rights in the subbasin are appropriated (Table 1). The following map shows both the surface water and groundwater points of diversion for the Upper subbasin (Figure 20). More than one point of diversion can be associated with one water right.

**Table 1: Water Rights in the Upper Solomon Subbasin**

Type	Source	Number of Rights	Authorized Quantity
Vested	Surface Water	4	559
Appropriated	Surface Water	16	897
Vested	Groundwater	19	1,000
Appropriated	Groundwater	1145	258,841



**Figure 20: Upper Solomon Subbasin Points of Diversion**

The water use ranges from 169,999 acre-feet in 2003 to 59,656 acre-feet in 1993. The average water use for the subbasin from 1989-2009 was 122,381 acre-feet. Water use in 2009, the most recent year for which complete records are available, was 90,528 acre-feet, which is down from 2008 and below the historical average (Figure 21).



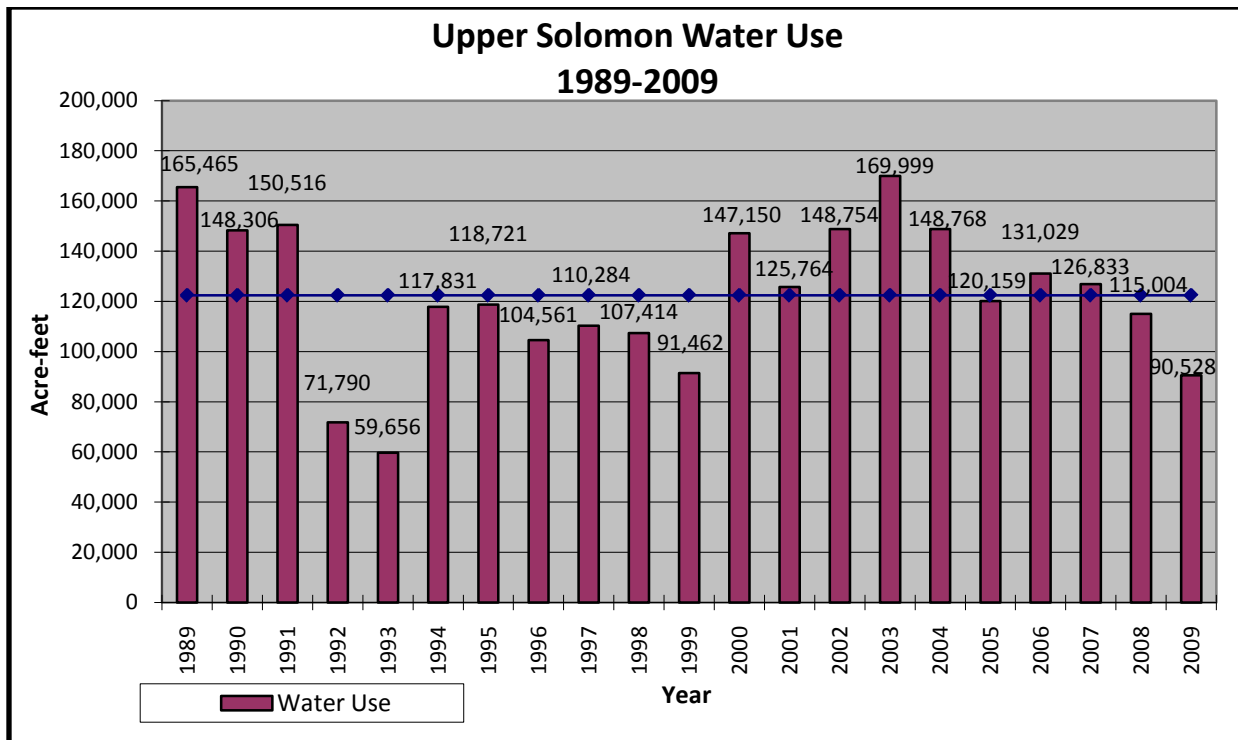


Figure 21: Ground and Surface Water use by year

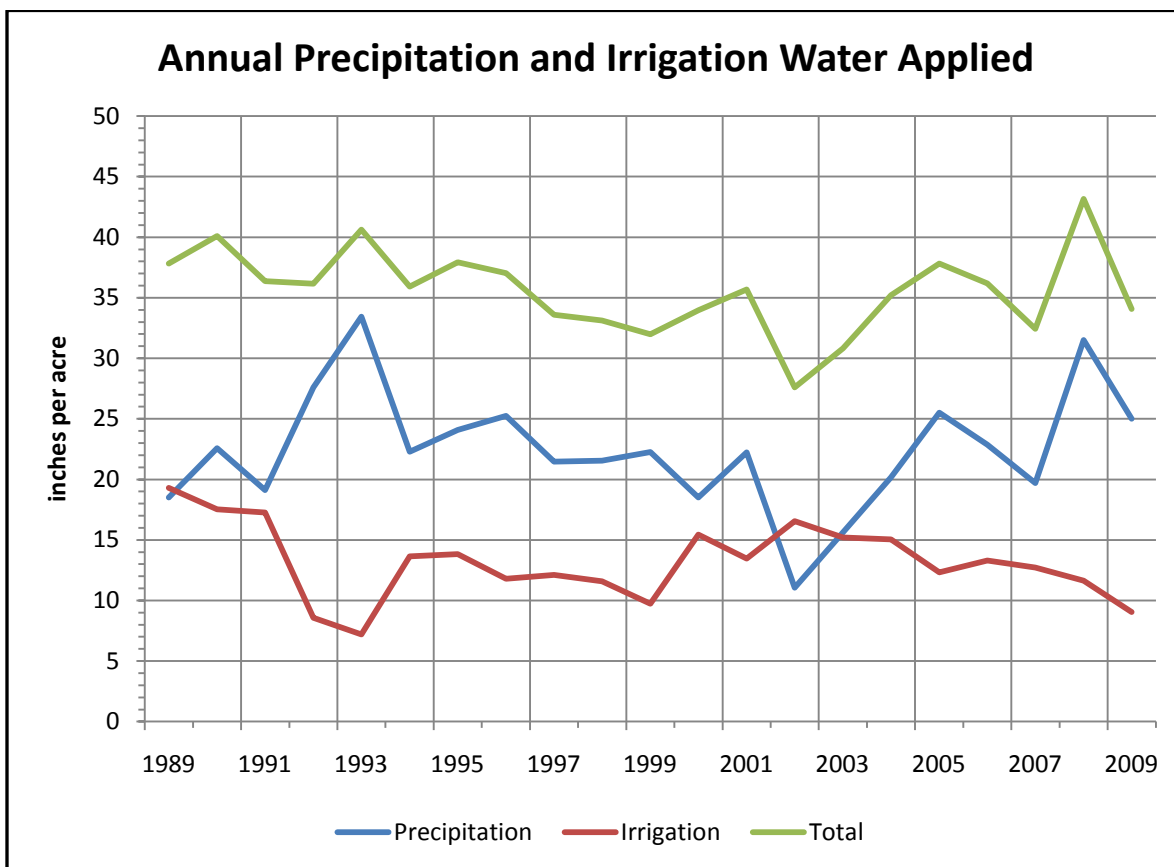


Figure 22: Annual Precipitation and Irrigation (inches per acre) 1989-2009

Irrigation pumping is the number of inches applied to an acre for that year. As more precipitation falls, irrigation pumping declines (Figure 22). Since 1989, the Upper Solomon subbasin averaged 22.4 inches in precipitation and 13.2 inches irrigation pumping. In 2009, the subbasin received 25.02 inches in precipitation and pumped 9.0 inches. Irrigation season precipitation averages 16.8 inches which is nearly five inches below the annual average (Figure 23).

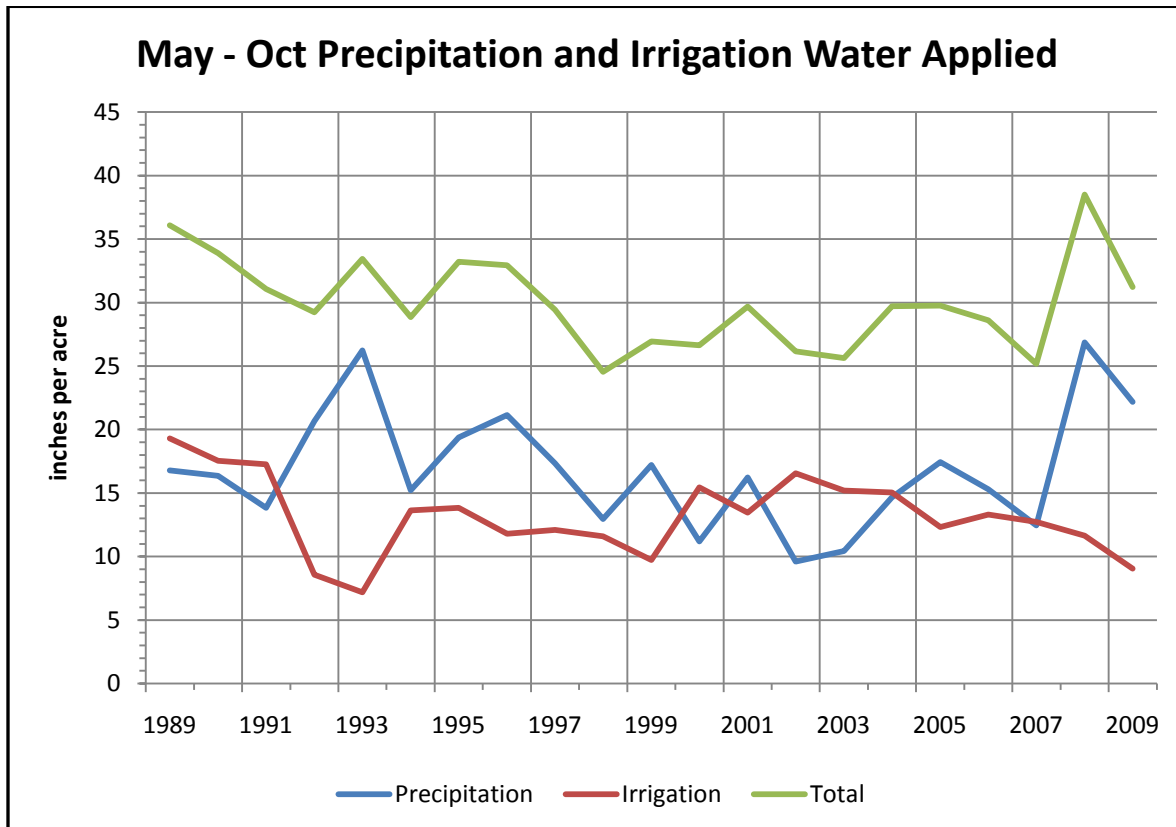


Figure 23: May - October Precipitation and Irrigation (inches per acre) 1989-2009

## VI. Conclusions

Many of the Ogallala-High Plains water levels had declines in 2011. More wells that are alluvial experienced an increase in water levels for 2011 than Ogallala-High Plains wells. The streamflows started high in 2010, but declined in the latter part of the year. Water use in 2009 was below 2008 levels and below the average for the subbasin. It is important to continue to increase our understanding of the impacts of pumping, how fast the system recovers after recharge events, and other characteristics of the hydrologic system in order to evaluate the long-term effects of water usage on this subbasin, protect property rights, and ensure the benefits of these water resources to future generations.

## VII. Appendix

Monitoring Well ID	Legal Description	Subbasin
DC03	05S 26W 05 NESESE	High Plains
GH03	09 24W 22 NWNENE	High Plains
GH04	06S 22W 19 SWSWSW	High Plains
GH05	06S 22W 16 SESWSW	High Plains
GH06	06 23W 17 SWSWNE	High Plains
GH07	06 23W 13 NWNWNW	High Plains
GH08	06 24W 28 NWNENW	High Plains
GH09	06 24W 14 NENENE	High Plains
GH10	06 25W 28 SWNWSW	High Plains
GH11	06S 21W 19 SWSESW 02	High Plains
GH13	07 25W 33 SESESE	High Plains
GH15	07 25W 24 NWNWNW	High Plains
GH16	06 25W 12 SWSWSW	High Plains
GH20	07 24W 08 SWNWNE	High Plains
GH22	09 25W 14 SESESE	High Plains
KGS01	04S 25W 13 SWSWSW	High Plains
NT28	03S 23W 34 NESESE	High Plains
NT29	04S 22W 18 SWNWSW	High Plains
NT30	03S 22W 20 SESESE	High Plains
NT31	03S 21W 29 SESWSW	High Plains
NT32	03S 21W 21 NENESE	High Plains
NT33	05S 21W 25 NESESW	High Plains
NT37	04S 25W 34 SWSESW	High Plains
NT39	04S 25W 28 NWNENE	High Plains
NT45	04S 23W 19 SESENE	High Plains
SD01	09 27W 12 SWSWSW	High Plains
SD02	07 28W 36 NENWNE	High Plains
SD05	07 27W 07 NE	High Plains
SD07	09 28W 15 SWNWNE	High Plains
SD08	07 29W 05 NWNWNW	High Plains
SD10	09 29W 03 NENENE	High Plains
SD11	09 30W 35 NWNWNW	High Plains
SD13	06 29W 24 NENWNW	High Plains
SD14	09 26W 22 NWNWNW	High Plains
SD15	08 30W 11 SWNWSW	High Plains
SD16	06 29W 10 SENWSW	High Plains
SD17	08 30W 30 NENWSW	High Plains
SD18	07 30W 08 SWSWNW	High Plains
SD20	08 27W 35 SWNWNW	High Plains
SD22	07 28W 21 NENWNW	High Plains
SD23	08 28W 17 NWNESE	High Plains
SD24	07 28W 08 SESWSW	High Plains
SD25	08 28W 16 NENESW	High Plains
SD26	08 30W 13 SENENE	High Plains
SD27	07 26W 28 SWNENW	High Plains
SD28	07 26W 19 NWNWSW	High Plains

SD30	07 26W 12 NWSSENW	High Plains
SD33	07 29W 30 NENWNE	High Plains
SD34	06 26W 26 SWNWNW	High Plains
SD35	09 29W 17 NWNENW	High Plains
SD36	07 29W 27 SWSWSW	High Plains
SD38	06 28W 21 NWSWSE	High Plains
SD39	06 27W 05 SWNWNW	High Plains
SD41	08 29W 01 NWSESE	High Plains
SD42	08 28W 11 SENENE	High Plains
TH01	08 32W 32 SENENE	High Plains
TH02	08 31W 03 SWSESE	High Plains
TH03	08 31W 20 SWSESE	High Plains
TH04	08 32W 12 SENWSW	High Plains
TH05	08 32W 07 NWNENE	High Plains
TH06	08 33W 34 NWNWSW	High Plains
TH07	08 34W 29 SWSWSW	High Plains
TH08	08 34W 23 SWNWSE	High Plains
TH09	09 31W 10 NWSESE	High Plains
TH10	09 34W 12 NESENE	High Plains
TH12	09 31W 17 SWSWSW	High Plains
TH13	09 32W 03 NENENE	High Plains
TH14	09 32W 27 NWSWSE	High Plains
TH17	09 34W 17 NENWNE	High Plains
TH18	09 34W 11 SWSWSW	High Plains
TH19	09 35W 32 SENENE	High Plains
TH20	07 32W 13 SENWSE	High Plains
TH21	07 32W 33 NWSWNW	High Plains
TH22	07 31W 01 SESWNE	High Plains
DC01	05 26W 33 SESWSW 1	Upper North Fork
DC02	05 26W 26 SESENE 1	Upper North Fork
NT01	05 04W 14 NWSESW 1	Upper North Fork
NT02	05 22W 18 SWSWSE 1	Upper North Fork
NT36	05S 24W 20 SWSWSW	Upper North Fork
NT38	05S 25W 28 SESWSW	Upper North Fork
NT46	04S 21W 35 SESESW	Upper North Fork
PL10	04 19W 35 SESESE	Upper North Fork
PL20	04S 18W 28 NWNWNW	Upper North Fork
PL21	04S 18W 28 SWSWNW	Upper North Fork
PL22	04S 18W 28 SWSWSW	Upper North Fork
PL23	04S 18W 33 NWSWNE	Upper North Fork
PL24	04S 18W 34 NENENE	Upper North Fork
PL25	04S 17W 30 SWSWSW	Upper North Fork
RO05	06S 19W 05 SENENW	Upper North Fork
RO22	06S 19W 17 NWNWNW	Upper North Fork
SD40	06 27W 08 SESWNE 1	Upper North Fork
SD43	06 27W 19 NESESW 1	Upper North Fork
SD46	06S 28W 28 SWSENE	Upper North Fork
GH01	08 25W 24 NWNENW 1	Upper South Fork

GH02	09 23W 26 NWNENE	Upper South Fork
GH12	08 21W 17 NENWNW 1	Upper South Fork
GH14	08 24W 23 NESWSW 1	Upper South Fork
GH17	07 22W 10 NWNWSW	Upper South Fork
GH18	07 22W 19 NWNWNW	Upper South Fork
GH19	08 22W 18 SWSESW 1	Upper South Fork
GH30	06S 21W 33 SESESE	Upper South Fork
GH32	09S 21W 19 NENENW	Upper South Fork
RO20	08S 20W 07 NESESE	Upper South Fork
SD04	09 28W 04 NWSWSW 1	Upper South Fork
SD19	08 26W 14 SENENE 1	Upper South Fork
SD21	08 27W 18 SENENE	Upper South Fork
SD37	08 27W 11 SESWSE 1	Upper South Fork
SD44	08S 26W 16 SWSWSE	Upper South Fork
SD45	08S 27W33 NWNWSE	Upper South Fork