GROUNDWATER WITHDRAWALS FROM THE MISSISSIPPI RIVER ALLUVIAL AQUIFER: A WEEKLY CASE STUDY OF INFLUENCING FACTORS

S. W. Neill and C. A. Giger
Yazoo Mississippi Delta Joint Water Management District
Stoneville, Mississippi

INTRODUCTION

The present course of the Mississippi River runs close to the eastern wall of its alluvial valley except between Memphis, Tennessee, and Vicksburg, Mississippi, where it swings westward in a great arc. This leaves 4.2 million acres of the Yazoo Mississippi Delta as the greatest of the eastern alluvial basins of the Mississippi (Harrison 1961). Beneath this 4.2 million acres lies the Mississippi River alluvial aquifer which ranges in thickness from about 80 feet to more than 200 feet and averages about 140 feet (Sumner and Wasson 1990). The aquifer consists of gravel and coarse sand and the alluvium grades upward from this coarse sand and gravel at the base, to fine sand, silt, and clay in the upper portion (Arthur 1994). Water from this aquifer is fresh in its entire area and is a hard, generally alkaline, calcium-bicarbonate type (Gandl 1982).

The broad expanse of fertile alluvial soils, the temperate climate, adequate rainfall, and easy access to the alluvial aquifer have helped make the Delta one of the better agricultural production areas for catfish, cotton, rice, and soybeans in the nation (Neill and Pennington 1995). In 1995, approximately 100,000 acres were in catfish production, 1.46 million acres in cotton, 290,000 acres of rice, and approximately 1.9 million acres in soybeans (Mississippi Ag Report January 1996). Of these primary production crops, rice and catfish are the two major consumers of water listed at 51% and 24%, respectively, in 1987. Water from the alluvial aquifer is of ideal quality for use in pond culture of catfish and the layer of clay overlying prevents contamination sometimes present in surface water, and the shallow depth at which it lies means that capital outlay and energy costs for pumping are relatively low (Pote et al. 1988). Of interest is a comment by F.T. Cooke, agricultural economist, that two factors that stimulated the development of the rice industry was the availability of large acreages of soil suited for rice and large quantities of available high quality water from the alluvial aquifer (Cooke and Caillavet 1993).

Mississippi Senate Bill 2778 empowered the Mississippi Department of Environmental Quality (MDEQ) to monitor groundwater resources in the state. This program is known as the Agricultural Chemical Groundwater Monitoring (AgChem) Program. A target list of 170 pesticides, metabolites, volatile organic compounds, metals, minerals, and other organics was established and the approach was patterned after criteria developed during the Environmental Protection Agency National Pesticide Survey. Water samples collected from fish culture and irrigation wells in the Delta, a region of high pesticide use, indicate low incidents of detection and extremely low levels of contaminants. The AgChem program has to date sampled a total of 138 agricultural wells screened in the Mississippi River alluvial aquifer from 8 of the 11 core Delta counties and has not detected current use pesticide compounds in 96 percent of those wells (Analytical Results and Activities of Mississippi Agricultural Chemical Groundwater Monitoring Program 1985).

This source of quality groundwater has given advantage to agricultural based industry in the Delta. The ability to irrigate inexpensively and easily has tended to even out the lows in crop production by the stabilization of crop yields. As a result, this has made the Mississippi River alluvial aquifer the most heavily pumped aquifer in the state. Current estimates are two billion gallons per day during the summer months for crop production (Arthur 1995). Concerns of over-drafting and depletion of this resource have been noted in several reports (Bryant 1993; Cooke et al. 1996; Long and Cleavenger 1987; and Pennington and Stiles 1994). Declines in the base flows of interior streams are thought to be the result of declining water levels in the aquifer (Bryant 1992). Monitoring of water levels in selected wells throughout the Delta was begun on a regular basis in 1981 with measurements taken in the spring and fall of each year.

A computer model was developed using this data to project the long-term results of various pumpage scenarios in 1983. This report warned of serious depletion of the aquifer if the high rates of pumpage continued by 2003 (Sumner and Wasson 1990). Recharge, from primarily the Mississippi River and rainfall, takes place during the winter and spring months when rivers and lakes are high and rainfall is frequent (Arthur 1995; Bryant 1992; Crawford 1991; Malone 1986; Sumner and Wasson 1990; Spencer and Ehret 1987). Recharge is reflected in measurements taken during the spring with discharge through pumpage and leakage to base flows in streams seen in fall measurements. However, these recharge events can be highly variable. Arthur (1995) cites rainfall data at Stoneville in Washington County ranging from 34.8 inches in 1981 to 68.1 inches in 1979. Mississippi River stage averages at Vicksburg ranged from 12.2 feet in 1988 to 32.9 feet in 1993 (Arthur 1995).

Additional sources of recharge to the Mississippi River alluvial aquifer are areas where the lower confining unit is absent or thin. At these points, the alluvial aquifer is in contact with Tertiary aquifers in the Cockfield Formation and Sparta Sand geologic units (Arthur 1994; Gandl 1982). Studies conducted by the Office of Land and Water Resources (OLWR) confirmed this hydraulic connection in 1994. OLWR noted significant differences in the geohydrology in the study areas and cautioned against application of assumptions of characteristics from one site to other sites without further study (Bryant 1995). The Cockfield and Sparta aquifers outcrop to the east of the alluvium plain and the sources of recharge to these aquifers are from rainfall in the outcrop areas and overlying aquifers (Gandl 1982).

In 1991, the U.S. Geological Survey (USGS) used radioisotope (trituim) dating techniques to assess the relative age of shallow groundwater in the Mississippi River alluvial aquifer. Tritium has been used as a hydrologic tracer since the 1950s and can be used to indicate the relative age of water (pre- or post- 1953). In this study, water samples from 34 shallow (less than 160 feet deep) wells were collected for tritium analyses in 13 Delta counties. Tritium concentrations of less than 1 picocurie per litre are considered to represent water with natural or background levels of tritium (pre-1953). Values greater are considered modern water (post-1953). Results indicated samples from 26 of the 34 wells (76 percent) were considered modern water (Slack and Oakley 1992).

Another variable to be reckoned with is the effect of barometric pressure. While this possibly has no effect on recharge or discharge within the aquifer, it could affect the analysis of collected data. Robinson (1939) sites the effects of barometric pressure on groundwater levels from wells in New Mexico and Iowa. Water level changes of as much as 0.5 ft were observed from wells in this study. The water level is inversely affected by barometric pressure, a low pressure causing a rise in water levels and a high pressure resulting in a decline in water levels. His report also states that during March and April 1938, changes in air-pressure were quite large and irregular. Hydrographs from these study wells indicate a rapid response to changes in barometric pressure.

The focus on recharge, discharge, quality, and age of water from the alluvial aquifer could aid in understanding the influence or lack of influence on the movement of water levels on both a short term and long term duration in the Mississippi River alluvial aquifer. Are the declines and recovery figures possibly masked due to outside events that slip by unnoticed?

PURPOSE AND SCOPE

Most of the conclusions about the changes in the water levels in the Mississippi River alluvial aquifer are based on data collected twice a year, spring and fall. As these conclusions could possibly be based upon inaccurate data due to variability in recharge or other factors as cited above, a study was initiated to monitor a number of wells in Washington County on a weekly basis to gather data indicative of the movement of water levels and the causative events.

MATERIALS AND METHODS

Wells were selected from the existing wells included in the semi-annual water level survey and their proximity to all weather roads (Appendix; Figure 1). This criteria is advantageous as it provides historical measurement data and the physical data of these wells and assures access on a regular basis. Washington County was selected due to distance from the permanent office site. The concept was to be able to measure all of these locations within a half day as the usual summer weather conditions tend to deteriorate in the afternoons in the Delta. Data gathered would be correlated with any influencing events as could be identified.

Ideally, this study would have begun with the spring water level survey, but at that time it was still more or less in the conceptual stage of development. The start date was the second week in June, Friday the 9th. Due to scheduling difficulties, the measurement day was moved to a Monday in the second week of July and adhered to except for four occasions, December 19th (due to rain on the 18th), Christmas Day, New Year's Day, and Ice Storm Day (February 5) when wells were measured on Tuesday. This study provides data on water level movement within a 7 day period for 35 weeks, June 9, 1995, through February 12, 1996.

Duplicate measurements were taken by hand utilizing a steel measuring tape of one hundred feet in length. The tape was chalked to indicate the distance from the measuring point to the level of the water in the well. These figures were recorded on field notes and entered into a database. These figures were then converted to mean sea level for comparison purposes to existing data and stream stage data. Visual influencing events such as rainfall, proximity well pumpage, stream stages, etc. were noted.

DISCUSSION

Several events are worth mentioning that had an effect at the initiation date and the duration of the study. One is the high stages of the Mississippi River. The River crested at 127.8 ft at Greenville, the second week of June. This was almost 28 ft higher than when the spring survey was taken the first week of April. River water was standing against the mainline levee, seep water was evident, and those wells close to the River indicated a definite hydraulic connection. One, N064, was free-flowing for over a month. The River fell to 89.9 ft on the Greenville gauge, the lowest recording for the study dates coinciding with the fall water level survey measurements taken the first week of October (Figure 8). All Mississippi River stage data are from the Greenville site.

Another event was the establishment of flood on fields in rice production. Several wells had been utilized prior to the spring survey to flush rice, and a standing flood of rice fields was generally established by the third week of May. Many of the study wells were being influenced by cones of depressions from those operating rice wells. Many had substantial fluctuations in level. But note the recovery and somewhat smooth line at the end of flood (Table 1; Figures 4 and 6).

A third event was the hot, dry summer and fall. A rainfall event the first week in July was the last run-off rainfall event Delta-wide until the third week of December. Rainfall was half of normal the next four months, while temperatures were above normal. Of 32 rainfall events at Stoneville over the next 122 days (July 7 through December 16), only 10 exceeded the daily evaporation rate. The irrigation season was extended for crop production into October when in normal years, it would have ended in early September. Actually, the lack of rainfall was a positive factor for this study as it filtered out the variability of rainfall in the study area.

In an effort to conform to publishing constraints, data is grouped by similar characteristics. The groupings are as follows: declining wells, static wells, and increasing wells.

Declining Wells

Eight wells demonstrated good hydraulic connection with the Mississippi River as indicated by Figures 2 and 3. These wells were in steady decline until the rainfall event of December 18 and 19, at which time over 4 inches were recorded at Stoneville. All but two wells reflected an increase, apparently due to this event either by barometric pressure or rainfall. Three of these eight wells increased, coinciding with a rise of approximately 10 ft by the Mississippi the second and third week of November (A119 and N064 are shown). The River again rose beginning the second week of January to a high of approximately 112 ft on the 7th of February. These same three wells also responded rather dramatically to this rise, increasing as much as 2.13 ft in a week (Table 1). It is also worth noting that seven of these wells were higher at the initial measurement in June, by as much as 12 ft, than they were when measured the first week of April during the spring portion of the semi-annual water level survey. Fluctuations during a seven day period in these wells were due to irrigations, either by the well or the cone of depression from another well, and were as much as 6 ft, and a somewhat steady decrease of 0.15 to 0.25 of a foot per week after the end of the irrigation season (Table 1). This discharge was probably back to the River or to lower elevations within the aquifer (leveling effect).

One well, O004, located on the bank of Deer Creek had a similar hydrograph as those close to the River (Figures 2 and 3). It experienced a steady rate of decline of about 0.2 of a foot per week after the irrigation season until leveling out the end of October. As Deer Creek is a perched stream, it is thought that this discharge is the result of the leveling effect as mentioned above. This well also responded positively, apparently to the low pressure and rainfall event in December, by increasing at a rate of approximately 0.1 of a foot a week (Table 1; Figure 3).

Static Wells

Seven wells exhibited a static trend at the cessation of the irrigation season (Figures 4 and 5). These wells moved both up and down from September with little loss or gain over time until the rainfall event in December. However, two of the wells recorded events related to work being done on the Upper Steele Bayou Project. This work was reflected on two separate occasions. One was illustrated by a decline of 0.7 of a foot at well N085 when the gates at Weir "E" were opened to draw down Silver Lake to allow a modification to the crest of the weir (Figure 5). Silver Lake fell 3 ft over 3 weeks and approximately 2 ft that last week which was the third week of November (Figure 8). The level in N085 fell the 0.7 ft the last week of November, approximately one week later. This decrease may have been masked by a rise in the Mississippi River, which probably keep the total decrease from being greater. Well N085 is approximately one mile west of Silver Lake (Figure 1). Two other wells later mentioned were also affected by this event.

The second event was recorded by a well, K005r, five miles to the North of N085, and located about a 0.25 mile southeast of the confluence of Main Canal and Granicus Bayou. Granicus empties into Silver Lake eventually six miles downstream. Dredging operations to Granicus and Main Canal were widening and deepening the channels to an elevation of 93 ft mean sea level. An earthen dam had been constructed across Granicus to enable dredging activities from both banks. This dam was removed the last week of November. The removal of the dam exposed the bottom of the dredged channel. K005r dropped 1.37 ft between the fourth week of November and the first week of December (Table 1). The stage recorder at Silver Lake recorded a 1.1 ft rise during this time frame, six miles downstream (Figure 8).

Two other wells of these five are located further south on the east side of Steele Bayou. Both of these wells appear to have a hydraulic connection with Steele Bayou. Well S001 is the northern well approximately a 0.25 mile east of Steele Bayou and S004 is located 4 miles further south and 1 mile east of Steele Bayou (Figure 1). Both wells responded to the rainfall event in December with an increase of 1.3 and 1.6 ft respectively over that week (Table 1; Figure 8). Stage data from Steele Bayou shows an increase in stage level of 1.5 ft during that period (Figure 8).

The last well, F117, showed a tendency to be static for two or three weeks and then decline about 0.1 of a foot. This well is located 200 yards north of the Bogue Phalia Cutoff, a man-made drainage diversion from the Bogue Phalia to the Sunflower River. At this location, the aquifer is exposed and the site of numerous springs. The intermittent decline of this well could be a reflection of discharge to the base flow of this stream. There was a slight (0.15) response to the December rainfall event (possible pressure) and then a return to the aforementioned trend (Table 1; Figure 5).

Wells N500 and N85 also indicated a hydraulic connection to the Mississippi River as indicated by their hydrographs. However, the distance from the River makes the graph not as pronounced as those defined as declining wells, as well as multiple operating during the production season.

Increasing Wells

The remaining wells have shown a continued rate of increase or upward movement (0.1 ft to 0.2 ft) since the irrigation season ended (Figures 6 and 7). All responded, seemingly, to the rainfall event in December ranging from 0.1 ft to 0.8 ft (Table 1). Two of these wells, N084 and N086, responded to the operations on the Upper Steele Bayou Project at Weir "E" (Figure 7). These wells fell 1.29 and 1.2 ft over a period of two weeks when Silver Lake was pulled down. Distance away from Silver Lake (Appendix; Figure 1) is reflected in the time the decrease in the wells occurred. This would indicate a hydraulic connection between these two wells and the Silver Lake/Granicus channel.

The data from Well M044 indicates that it was the last affected by the irrigation season with the lowest reading the second week in September when a nearby well was used to irrigate soybeans (Figure 7). This well has experienced an approximate recovery of about three ft since that time. The proximity to the Big Sunflower River has possibly influenced the recovery of this well.

Well G194 was at its lowest point the first week of August and recovered over six ft until the second week of January. It then began declining, dropping over two ft in the next four weeks (Table 1; Figure 7). Field notes pointed out new construction aqua-culture ponds to the north. Further investigation found that pond filling operations began the second week of January.

CONCLUSION

Due to extremely dry weather conditions mid-summer through fall, after the irrigation season, an interesting phenomenon developed in the Mississippi River alluvial aquifer. Data collected indicated a state of recharge and one of discharge. Wells at higher elevations (declining group, average elevation of 119.7 ft) discharged, either back into rivers and streams, or to lower elevations. Those wells grouped as static remained at the same level for a long period after the irrigation season until the December rainfall event. The average elevation of these wells was 113 ft. Interestingly, these wells were very close to the same level during this period as those levels recorded in the fall of 1994. The 1994 crop production season was wet and irrigation was not required nearly as much as the 1995 crop season. The group of increasing wells began recovery or recharge immediately at the cessation of irrigation and continue at press time. The average elevation of this group of wells is 110.2 ft.

Obviously, the low stages of the Mississippi River influenced many of those wells in the declining group, and most reached levels about two ft lower than those 1994 fall measurements. Seven of these eight wells serviced cotton. If an attempt was made to correlate aquifer movement by crop, these wells would have seemingly indicated cotton as the major user of water due to this draw down when, in fact, cotton irrigation was minimal in 1995. These wells averaged a 0.12 ft increase, apparently in response to the rainfall event in December, and ranged from -0.38 ft to 0.66 ft (Table 1; Figure 3). The Mississippi River had experienced a 5 ft drop during the previous two weeks and this is thought to result in the negative readings of two wells at this time.

Conversely, the group of increasing wells was located in rice and soybean production areas which had a high demand for irrigation. Draw down was as much as 16 ft in some of these wells, but the recovery has been steady. Possibly this is from a leveling effect whereby water within the aquifer moves from higher to lower elevations. Or could this be from underlying Cockfield and Sparta aquifer units? Earlier work showed pre-1953 water in 24 percent of the wells sampled, and two of those locations were in south central Washington County. These wells also indicated a high response to the December rainfall/pressure event [average increase of 0.50 ft, with a range of 0.24 ft to 0.72 ft (Table 1; Figures 6 and 7)].

The group of static wells had the highest response at the time of the rainfall event, increasing an average of 0.67 ft and with a range of 0.08 ft to 1.66 ft (Table 1; Figure 5). This was most unexpected and not readily understood. This response was measured the day following the two day event, and some of these wells were as much as a mile from interior streams. While this was a rainfall event totaling over four inches, conditions were such as that the net rise in interior streams was only >2 ft at Silver Lake, Steele Bayou, and the Big Sunflower (Figure 8). Earlier work cited responses to stream changes but noted flood stage plus seemed to be of significance. This was not the case with this event as, apparently, wells (17 of 20) positively responded.

The effect of rainfall could be significant; 15 wells are continuing to increase since the third week in December. Those wells that have decreased are known to have a good hydraulic connection to the Mississippi River, which declined until the third week of January. If rainfall is the causative agent to begin an upward trend, where are the contaminants expected to be attached to soil particles in rainfall run-off? Ninety-six percent of those wells sampled within the last two years indicated a "no detection" status, as previously reported.

Another possibility for the increases recorded during December might be an aquifer response to the rise in the Mississippi River during November (Figure 8) or the June rise. The fact that the increase affected 15 wells the same week at diverse locations would induce some skepticism. However, a rainfall event that affected some wells could mask the increase from the river rise. Further studies need to be made to separate these two methods of recharge, if possible.

Implications of this study indicate that there is considerable movement of the aquifer water level in survey wells within a seven day period, with a range of 0.0 to 8.37 ft in a positive or negative direction. Of 667 observations from the initiation date, 20 (three percent) reflected no movement (0.0 ft), 108 (sixteen percent) indicated movement between 0.0 ft and 0.05 ft, 71 (eleven percent) indicated movement between 0.06 ft and 0.09 ft, and 467 (seventy-one percent) at 0.1 ft or greater over a seven day period. Movement after October 1 contained 399 observations with a range from 0.0 ft to 2.13 ft, 17 (four percent) reflected no movement (0.0 ft), 90 (twenty-three percent) indicated movement between 0.0 ft and 0.05 ft, 62 (sixteen percent) indicated movement between 0.06 ft and 0.09 ft, and 230 (fifty-seven percent) at 0.1 ft or greater over a seven day period. Movement since the rainfall event the third week in December had 180 observations, 4 (two percent) reflected no movement (0.0 ft), 46 (twenty-six percent) indicated movement between 0.0 ft and 0.05 ft, 28 (sixteen percent) indicated movement between 0.06 ft and 0.09 ft, and 102 (fifty-seven percent) at 0.1 ft or greater over a seven day period.

Measurement levels are affected by pumpage from a nearby well or from a number of wells possibly as much as a mile away. The artificial raising or lowering of a stream level will affect a water level in a well as much as a mile away. The natural fluctuations of a stream will have an effect. Rainfall prior to a measuring date will affect the measurement in many cases, as will the change in barometric pressure. This study indicates that the analysis of data collected from the semi-annual water level survey of the Mississippi River alluvial aquifer involves many more factors than just the numbers recorded.

REFERENCES

Arthur, J. K. 1994. Thickness of the upper and lower confining units of the Mississippi River alluvial aquifer in northwestern Mississippi. U. S. Geological Survey Water-Resources Investigations Report 94-4172.

--------- 1995. Changes in the volume of water in the Mississippi River alluvial aquifer in the Delta, northwestern Mississippi, 1980-94. U. S. Geological Survey Water-Resources Investigations Report 95-4127.

Bryant, C. R. 1992. Interaction study of the Sunflower River and the Mississippi River Valley alluvial aquifer. In Proceedings of the Mississippi Water Resources Conference, April 14-15, 1992. Water Resources Research Institute: Mississippi State University, p.148-156.

--------- 1993. Water level changes in Delta aquifer. Mississippi Department of Environmental Quality, Environmental News. 13 (1):2.

--------- 1995. The tertiary-quaternary relation in Northwestern Mississippi. In Proceedings of the Mississippi Water Resources Conference, April 11-12, 1995. Water Resources Research Institute: Mississippi State University, p. 66-75.

Cooke, F. T. and D. F. Caillavet. 1993. Ricewater use in the Mississippi Delta. In Proceedings of the Mississippi Water Resources Conference, April 6-7, 1993. Water Resources Research Institute: Mississippi State University, p. 68-70.

Cooke, F. T., D. F. Caillavet, and J. C. Walker, III.1996.Rice water use and costs in the Mississippi Delta. MAFES Bulletin 1039. Mississippi Agricultural and Foresty Experiment Station: Mississippi State University.

Crawford, J. L. 1990. Potentiometric surface of the Mississippi River Valley alluvial aquifer, 1981-1989.In Proceedings of the Mississippi Water Resources Conference. Water Resources Research Institute: Mississippi State University, p. 147-151.

Gandl, L. A. 1982. Characterization of aquifers designated as potential drinking water sources in Mississippi. U. S. Geological Survey Water Resources Inveatigations Open-File Report 81-550.

Harrison, Robert W. 1961. Alluvial Empire. Vol.1. Little Rock: Pioneer Press.

Long, L. G., and C. E. Clevenger. 1987. The effect of the 1986 drought on streamflow in selected streams in Mississippi. In Proceedings of the Mississippi Water Resources Conference, March 25-26, 1987. Water Resources Research Institute: Mississippi State University, p. 38-40.

Malone, R. A. 1986. Results of a computer model of the Mississippi River alluvial aquifer. In Proceedings of the Mississippi Water Resources Conference, February 27-28, 1985. Water Resources Research Institute: Mississippi State University, p. 35-36.

Mississippi Ag Report. January 1996. Vol.96-02.

Mississippi Department of Environmental Quality. 1995 Analytical results and activities of Mississippi agricultural chemical groundwater monitoring program. Second Report MDEQ Office of Pollution Control: Jackson, MS

Neill, S. W. and D. A. Pennington. 1995. Water conservation practices and on-farm effects: a model farm. YMD Research Report 1. Yazoo Mississippi Delta Joint Water Management District: Stoneville, Mississippi.

Pennington, D. A. and C. M. Stiles. 1994. Use of regression analysis to evaluate water level changes in the Mississippi River alluvial aquifer. In Proceedings of the Mississippi Water Resources Conference, March 29, 1994. Water Resources Research Institute: Mississippi State University, p. 35-36.

Pote, J. W., C. L. Wax, and C. S. Tucker. 1988. Water in catfish production: sources, uses, and conservation. MAFES Special Bulletin 88-3. Mississippi Agricultural and Foresty Experiment Station: Mississippi State University.

Robinson, T. W. 1939. Earth-tides shown by fluctuations of water-levels in wells in New Mexico and Iowa. American Geophysical Union Transactions of 1939. National Research Council of the National Academy of Science: Washington, D.C. P. 656-666.

Slack, L. J. and W. T. Oakley. 1992. Tritium analyses of water in the Mississippi River alluvial aquifer in northwestern Mississippi, August 1991. U. S. Geological Survey Open-file Report 92-75.

Spencer, J. R. and K. S. Ehret. 1987. The effect of the 1986 drought on the Mississippi River alluvial aquifer. In Proceedings of the Mississippi Water Resources Conference, March 25-26, 1987. Water Resources Research Institute: Mississippi State University, p. 23-26.

Sumner, D. M. and B. E.Wasson. 1990. Geohydrology and simulated effects of large groundwater withdrawals on the Mississippi River alluvial aquifer in northwestern Mississippi. U. S. Geological Survey Water-Supply Paper 2292.

APPENDIX

Well Information

A109... Active irrigation well servicing cotton, approximately 9 miles north of Highway 82 and 4.5 miles east of the Mississippi River. This well was pumped twice during the month of July and the first week of August.

A119... Active irrigation well servicing cotton, approximately 12 miles NNW of Highway 82 and 3 miles east of the Mississippi River. This well is within sight of the mainline levee and 150 ft from Black Bayou. The well was not used during the production season. Black Bayou was a dry channel most of the fall until the third week in December.

D176... Observation well located within the city limits of Greenville, approximately 2 miles south of Highway 82 and 3.5 miles from the Mississippi River.

F117... Active irrigation well servicing cotton, approximately 2.5 miles south of Highway 82 and 2 miles east of the Bogue Phalia, and 200 yards north of the Bogue Phalia Cutoff. This well was used twice in June and twice in August.

G194... Active irrigation well servicing soybeans, approximately 2 miles east of Highway 1 and 9 miles east of the Mississippi River. This well was not used during the production season.

J002... Standby irrigation well servicing cotton and soybeans, approximately 7 miles south of Highway 82 and 4 miles east of the Bogue Phalia. This well was not used during the production season.

K005r... Standby well servicing grain sorghum approximately 2 miles east of Highway 1 and 4.5 miles east of the Mississippi River. This well is also close to the confluence of Main Canal and Granny Baker Bayou and the scene of dredging activity during November through January. This well was not used during the production season.

M044... Active irrigation well servicing rice and soybeans approximately .5 mile north of Highway 12 and 200 yards from the Sunflower River. This well is 25 miles east of the Mississippi River. This well was utilized from June through September.

N022... Standby well servicing cotton approximately 4 miles west of Highway 1 and 1 mile south of Kentucky Bend in the Mississippi River.

N064... Active irrigation well servicing soybeans approximately 100 yards east of Highway 1 and 1 mile from the Mississippi River. This well was free-flowing during the month of June and the first week of July. It was used several times during the growing season.

N084... Active irrigation well servicing cotton approximately 100 ft south of Highway 12 and 5 miles from the Mississippi River. This well was used once the last week of July. Intense rice culture within one square mile of this well. This well is approximately 2 miles from Granny Baker Bayou where dredging activities took place during the fall.

N085... Active irrigation well servicing rice approximately 2 miles east of Highway 1 and 3 miles from the Mississippi River. This well operated during June and July. This well is just south of Whiskey chute and .5 mile from Silver Lake which was the sight of dredging activities during the fall.

N086... Active irrigation well servicing cotton approximately 100 ft south of Highway 12 and 4.5 miles from the Mississippi River. This well was used once the last week of July. Intense rice culture within one square mile of this well. This well is approximately 1.5 miles from Granny Baker Bayou where dredging activities took place during the fall.

N500... Active irrigation well servicing rice and soybeans approximately 1.5 miles east of Highway 1 and 2.5 miles from the Mississippi River. This well was utilized from June through September.

R001... Standby well servicing cotton approximately 5.5 miles west of Highway 1 and 4.5 miles from the Mississippi River. This well is on the northern bank of the south end of Lake Washington summer and fall.

R044... Private well approximately 6 miles west of Highway 1 and 1 mile east of the Mississippi River. This well is within sight of the mainline levee and in a pasture.

O004... Standby well servicing cotton approximately 200 ft west of Highway 61 and 14 miles from the Mississippi River. This well is on the west bank of Deer Creek at a farm headquarters and pecan orchard.

P088... Active irrigation well servicing cotton approximately 3 miles south of Highway 12 and 18 miles from the Mississippi River. This well was in an area of catfish and rice production in addition to cotton. It is on the south bank of Murphy Bayou about 6 miles west of the Sunflower River. This well was never operated.

S001... Active irrigation well servicing soybeans approximately 4 miles west of Highway 61 on the east bank of Steele Bayou about 12 miles from the Mississippi River. This well was not operated in 1995.

S004... Observation well on the east bank of Steele Bayou 1 mile east of Highway 1 and 10 miles east of the Mississippi River. Crops of cotton, soybeans, and rice were located in the proximity of this well.

Table 1. Table showing differences in feet over a seven day period from June 9 thru February 12 1995 - 1996. Missing data points reflect operation of well.

WEEK	A109	A119	D176	F117	G194	J002	K005r	M044	N022	N064	N084	N085	N086	N500	O004	P088	R001	R044	S001	S004
6/3	-0.07	0.23	-0.3				-1.28		1.4			-1.57	-7.79	-2.04			-0.09	1.93	-1.13	-0.74
6/4	-0.18	-0.98	-0.56		-1.03		-1.98	-0.22	0.56				0.85		-0.25	-0.29	-0.19	-1.99	-0.96	1.35
7/1	-0.29	-2.15	-0.32	-0.88	1.4	0.06	1.92	-0.56	-0.41		-2.26		-1.47		-1.44	0.32	0.2	-4.54	0.4	-0.14
7/2	0.05	-0.16	0.4	0.62	0.08	0.11	5.8	-0.35	-0.45	-0.72	4.45	1.03	4.01	2.09	0.69	0.04	0.12	-1.66	0.99	2.8
7/3	-0.24	-1.21	-0.39	-0.17	-2.11	-0.19	-8.37	-0.2	-0.76	-1.94	-5.77	-3.42	-5.15	-1.1	-0.12	-1.48	-0.02	-1.45	-1.46	-4.92
7/4	-2.44	-1.43	-0.26	-0.48	-0.98	0.02	2.72	-0.43	-0.51	4.06			1.71	-5.04	-0.23	-0.58	-0.45	-1.13	-1.76	1.52
7/5		-1.95	-0.46	0.24	-1.13	-0.25	-3.53	-0.51	-1.07				0.68	3.08	-0.37	-0.38	-0.48	-1.87	1.03	-0.61
8/1		-0.65	-0.32	-0.1	-0.25	0.05	8.66	-0.19	-0.64	-0.69	7.1	0.57	6.12	0.16	-0.22	0.48	0	-1.03	1.3	3.07
8/2	-0.7	-0.32	-0.35		1.31	0.65	0.7	-0.17	-0.44	0.1	-1.94	0.21	-0.75	-0.04	-0.16	0.94	-0.08	-0.46	0.01	-0.17
8/3	-0.46	-0.21	-0.35		0.54	0.1	-0.52		-0.18		-3.33	-0.83	-3.6		-0.24	0.27	-0.22	-0.14	-0.69	-0.52
8/4	-0.1	-0.84	-0.34	0.19	0.19	0.13	1.17		-0.59		5.62	1.04	4.59		-0.2	0.19	-0.11	-0.83	-0.75	-0.17
9/1	-0.17	-0.54	-0.26	0	0.45	0.02	0.09	0.17	-0.55	-0.44	0.27	-0.95	0.35	0.37	-0.2	0.1	-0.13	-0.87	-0.35	-0.44
9/2	-0.04	-0.46	-0.31	-0.02	0.64	-0.02	0.06	-0.62	-0.53	-3.33	0.23	-0.49	0.17	-0.84	-0.19	0.07	-0.15	-0.7	0.78	0.23
9/3	-0.24	-0.31	-0.16	-0.02	0.47	-0.02	0.04	0.35	-0.64	0.79	0.35	0.28	0.24	0.12	-0.15	0.15	-0.09	-0.65	0.42	0.03
9/4	-0.13	-0.18	-0.29	0.01	0.37	0.03	0.24	0.23		-0.53	0.28	-0.03	0.25	-0.14	-0.11	0.21	-0.12	-0.55	0.2	0.11
10/1	-0.04	-0.19	0.3	-0.05	0.41	0.09	-0.13	0.12		-0.31	0.18	-0.01	0.21	-0.18	-0.13	0.19	-0.05	-0.5	-0.07	-0.2
10/2	-0.47	-0.28	-0.6	-0.02	0.06	-0.09	-0.15	0.08	-0.54	-0.95	0.07	-0.14	-0.21	-0.26	-0.12	-0.19	-0.2	-0.59	-0.01	-0.07
10/3	0.22	-0.2	-0.2	-0.03	0.26	0.04	-0.05	0.1	-0.53	0.22	0.1	-0.01	0.36	-0.12	-0.12	0.39	-0.08	-0.45	-0.02	0.04
10/4	-0.11	-0.1	-0.27	0.1	0.22	0.07	0	0.15	-0.39	0	0.14	-0.05	0.09	-0.08	-0.09	0.15	-0.13	-0.43	-0.15	-0.09
10/5	-0.1	-0.12	-0.13	-0.11	0.07	0	-0.08	0.12	-0.32	-0.25	0.06	-0.05	0.05	-0.09	-0.06	0.11	-0.08	-0.41	-0.01	-0.06
11/1	-0.05	-0.02	-0.04	0	0.38	0	0.17	0.02	-0.38	-0.13	0.25	0.12	0.13	-0.03	0	0.16	0.01	-0.32	0.26	0.11
11/2	-0.07	-0.05	-0.1	-0.07	0.2	0	-0.01	0.17	-0.39	0.32	0.07	0.03	0.15	0	-0.03	0.07	-0.05	-0.3	0.07	0.01
11/3	-0.11	0.21	-0.16	0	0	0	-0.09	0.19	-0.26	0.75	-0.73	-0.16	-0.58	0.01	-0.07	0.06	-0.15	-0.23	-0.09	-0.11
11/4	0	0.46	-0.09	-0.01	0.36	0.05	0.07	0.17	-0.06	0.73	-0.56	0.15	-0.62	0.17	0.01	0.13	0.02	0.32	0.15	0.03
12/1	-0.18	-0.4	-0.19	-0.03	-0.16	-0.01	-1.37	0.14	-0.13	-0.02	0.37	-0.7	0.34	-0.09	-0.11	0	-0.16	-0.34	-0.35	-0.17
12/2	0.02	-0.03	-0.1	0.02	-0.04	-0.07	0.94	0.06	-0.18	-0.5	0.43	0.38	0.37	0.01	-0.02	0.06	-0.05	-0.21	0.32	0.23
12/3	0.31	0.66	0.44	0.15	0.51	0.08	0.6	0.37	-0.19	-0.38	0.72	0.6	0.68	0.26	0.09	0.24	0.22	-0.18	1.36	1.66
12/4	0.16	-0.06	0.06	-0.08	-0.02	0.03	0	-0.08	-0.22	-0.06	0.17	-0.12	0.26	-0.1	0.01	-0.08	-0.08	-0.11	-0.16	-0.34
1/1	0.14	0.6	0.19	-0.05	0.47	0.05	0.27	0.25	-0.1	0.86	0.4	0.32	0.35	0.28	0.09	0.11	0.08	0.05	0.22	0.13
1/2	0.03	-0.25	0.04	-0.01	-0.07	-0.07	0.08	-0.04	-0.15	-0.26	0.01	0.04	-0.02	-0.04	-0.01	-0.02	-0.09	-0.22	0.43	0.51
1/3	0.03	0.02	0.1	-0.04	-1.32	0.04	0.01	0.1	-0.1	0.31	0.29	0.03	0.29	0.17	0.09	0.09	0.06	-0.11	0.05	-0.19
1/4	0.07	0.06	-0.07	-0.02	-0.42	0.03	0.03	0.15	-0.04	0.27	0.05	0.13	0.04	0.11	0.07	0.1	0	-0.02	0.04	-0.23
1/5	0.12	1.24	0.16	0.03	0	0.07	0.22	0.24	0.14	1.43	0.33	0.37	0.37	0.4	0.11	0.17	0.1	0.42	0.38	0.61
2/1	0.15	2.07	0.16	-0.06	-0.34	0.03	-0.12	-0.04	0.29	2.13	0.03	0.12	0.02	0.49	0.03	0.02	-0.07	1.17	-0.03	-0.24
2/2	-0.03	-0.12	0	0.01	-0.02	0	0.03	0.07	0.32	1.15	0.03	0.21	0.06	0.52	0.03	-0.01	-0.02	1.06	-0.06	-0.21

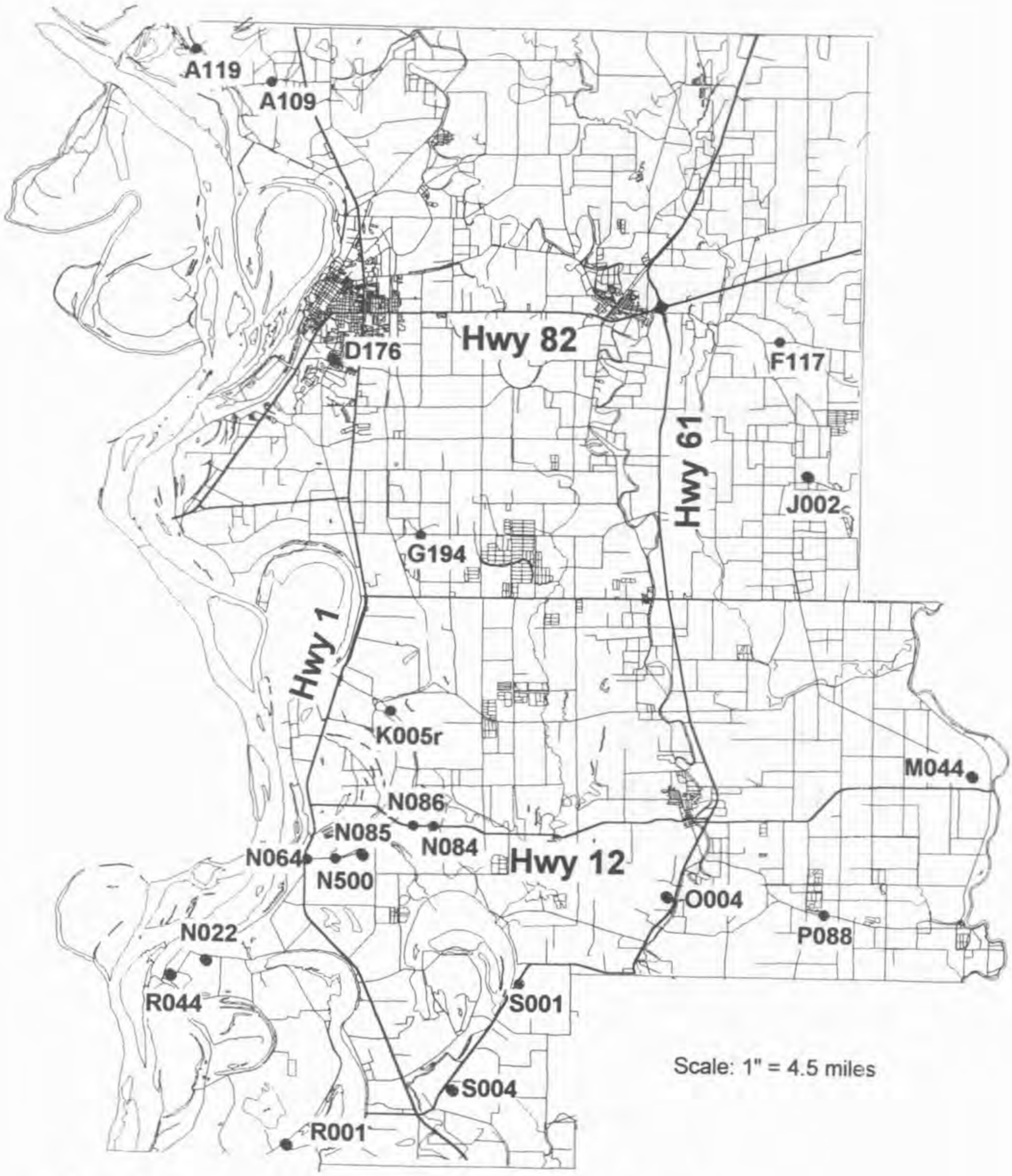

Figure 1. Location of Study Wells in Washington County

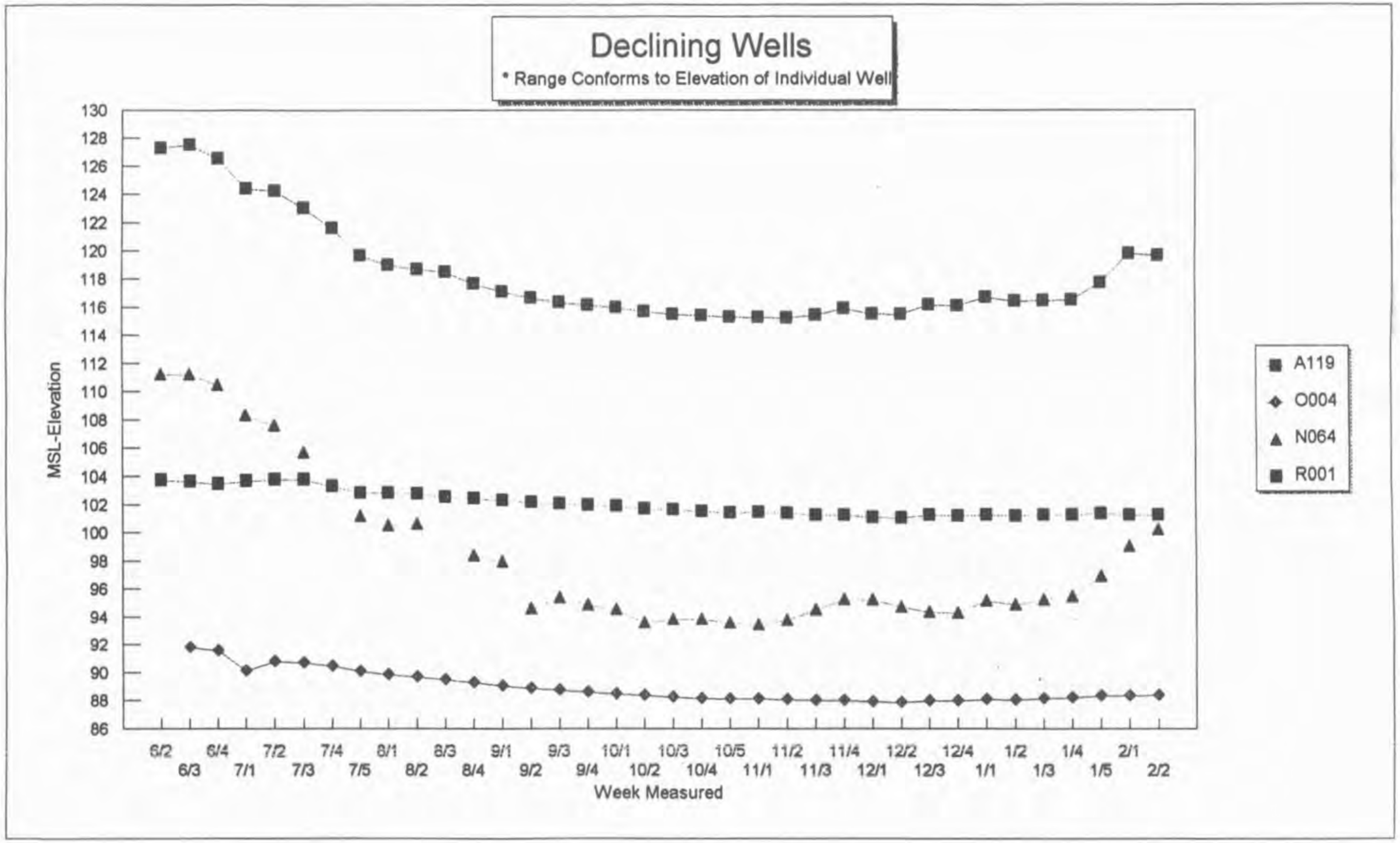

Figure 2. Graph of Declining Study Wells

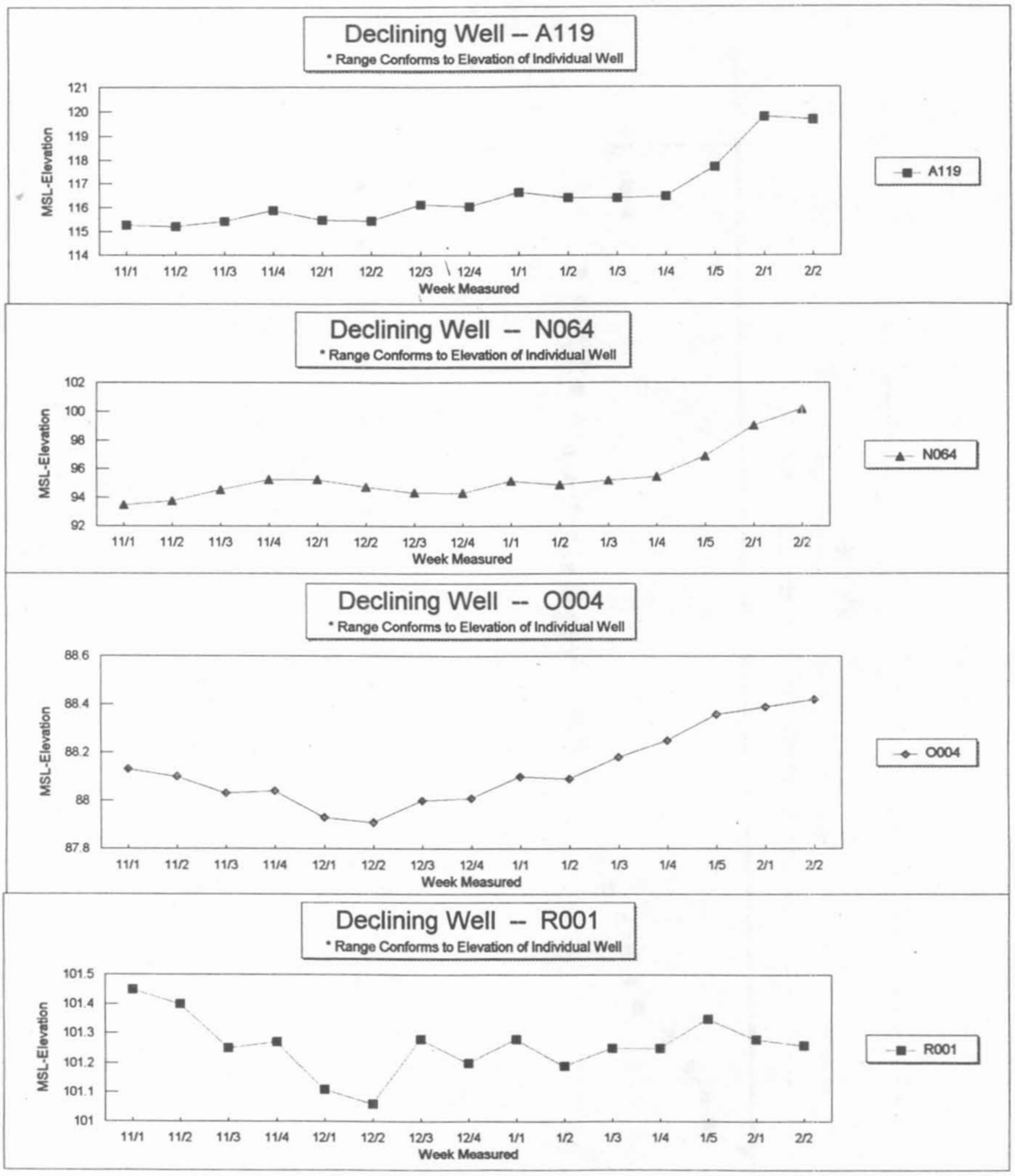

Figure 3. Graphs of Individual Declining Study Wells

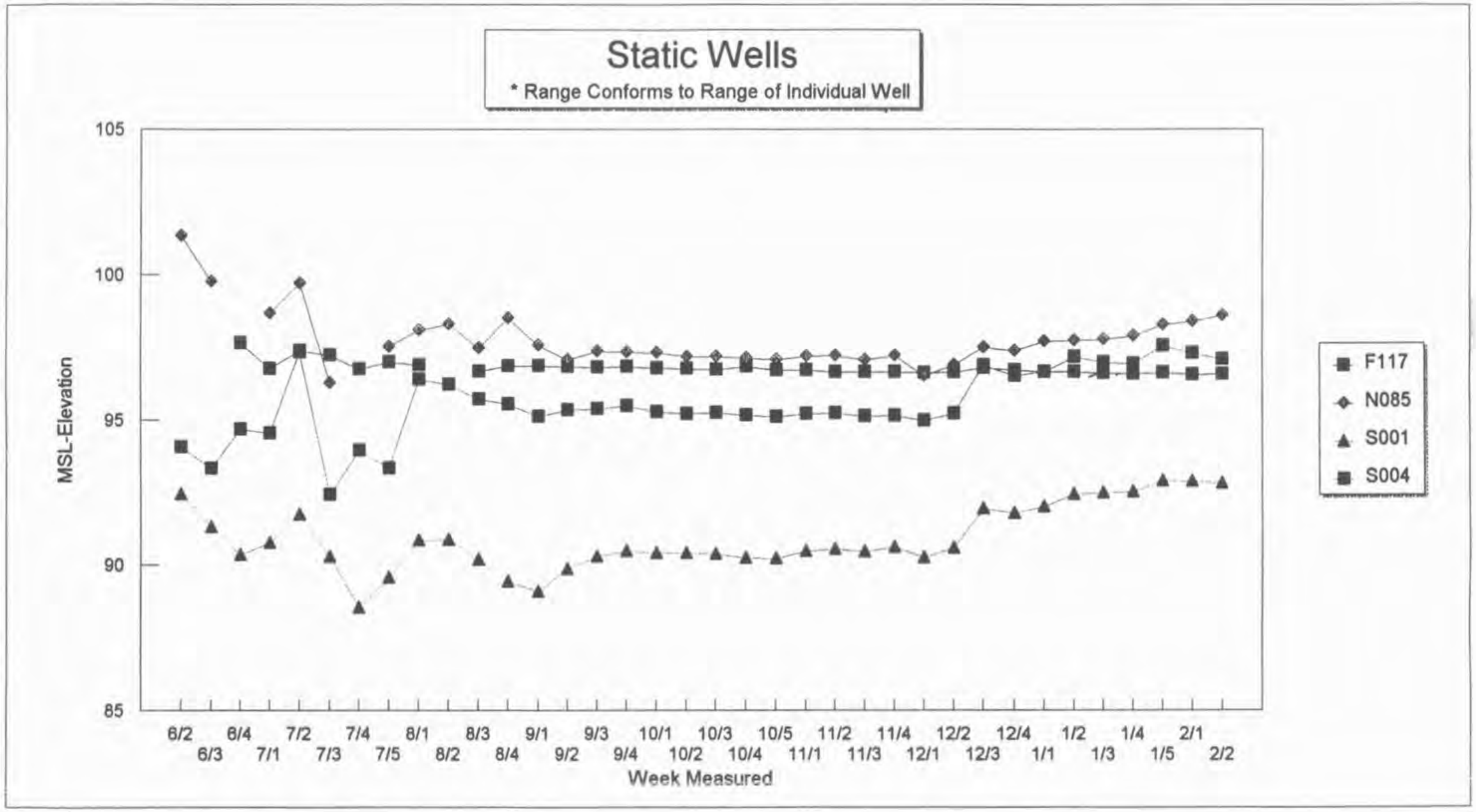

Figure 4. Graph of Static Study Wells

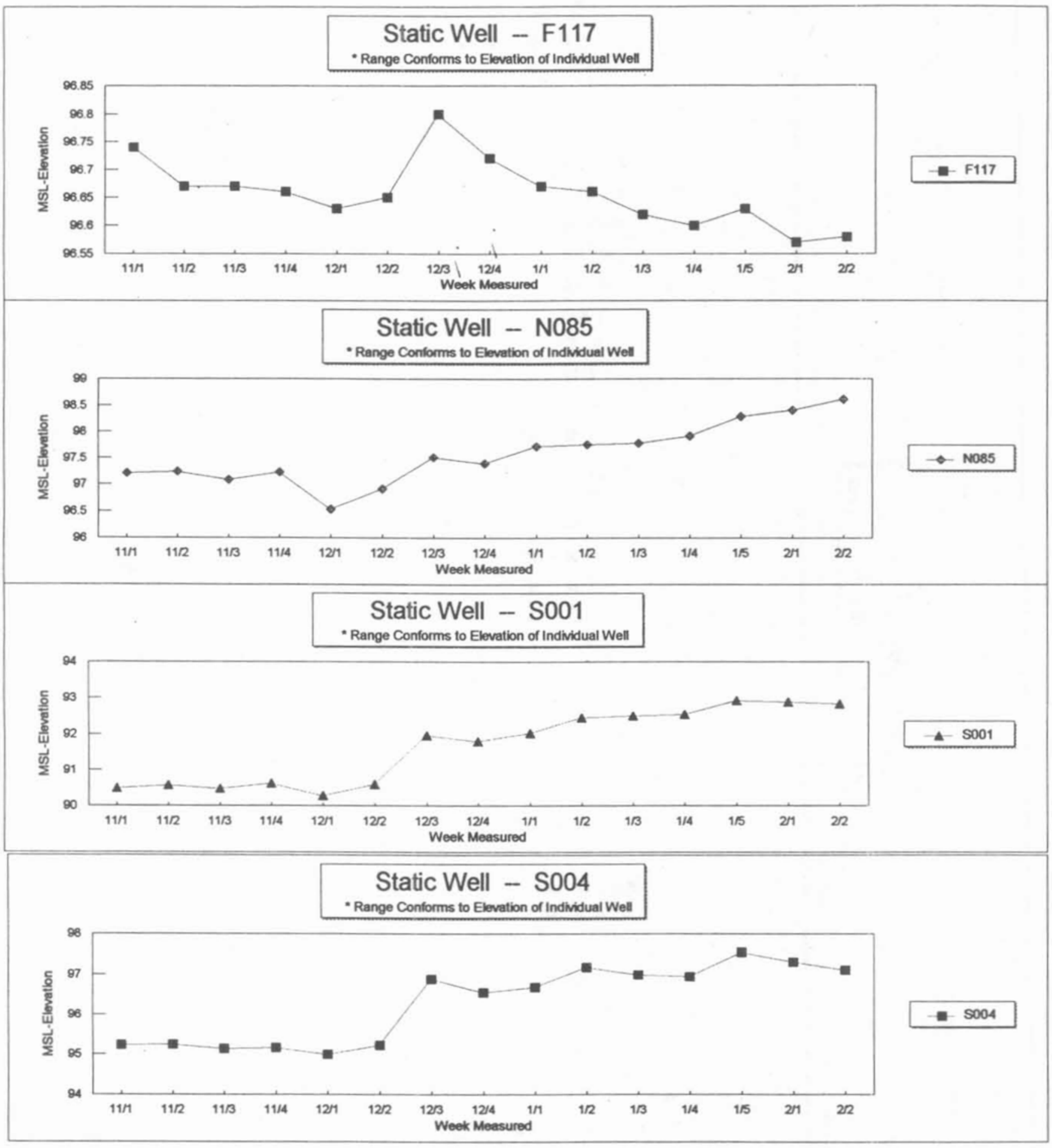

Figure 5. Graphs of Individual Static Study Wells

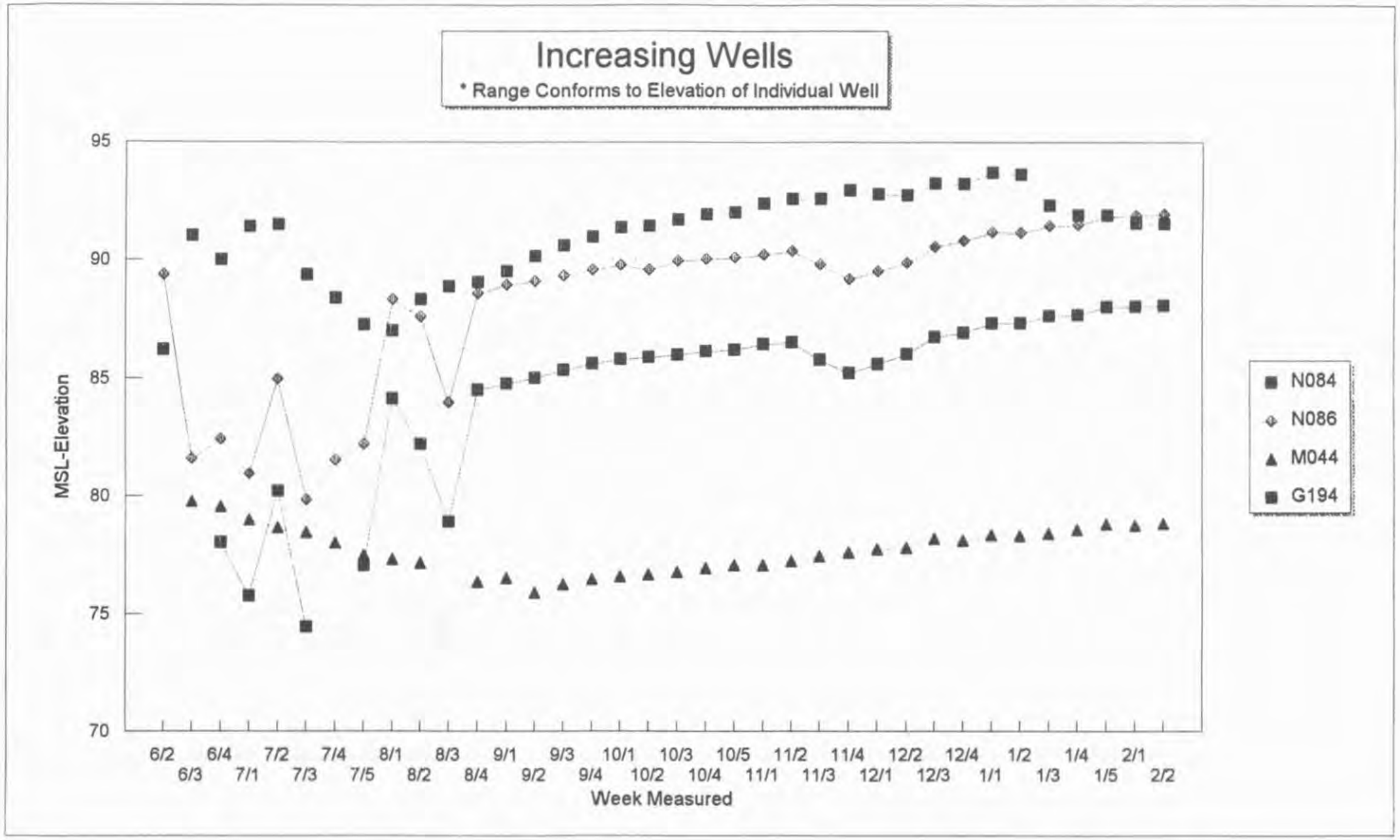

Figure 6. Graph of Increasing Study Wells

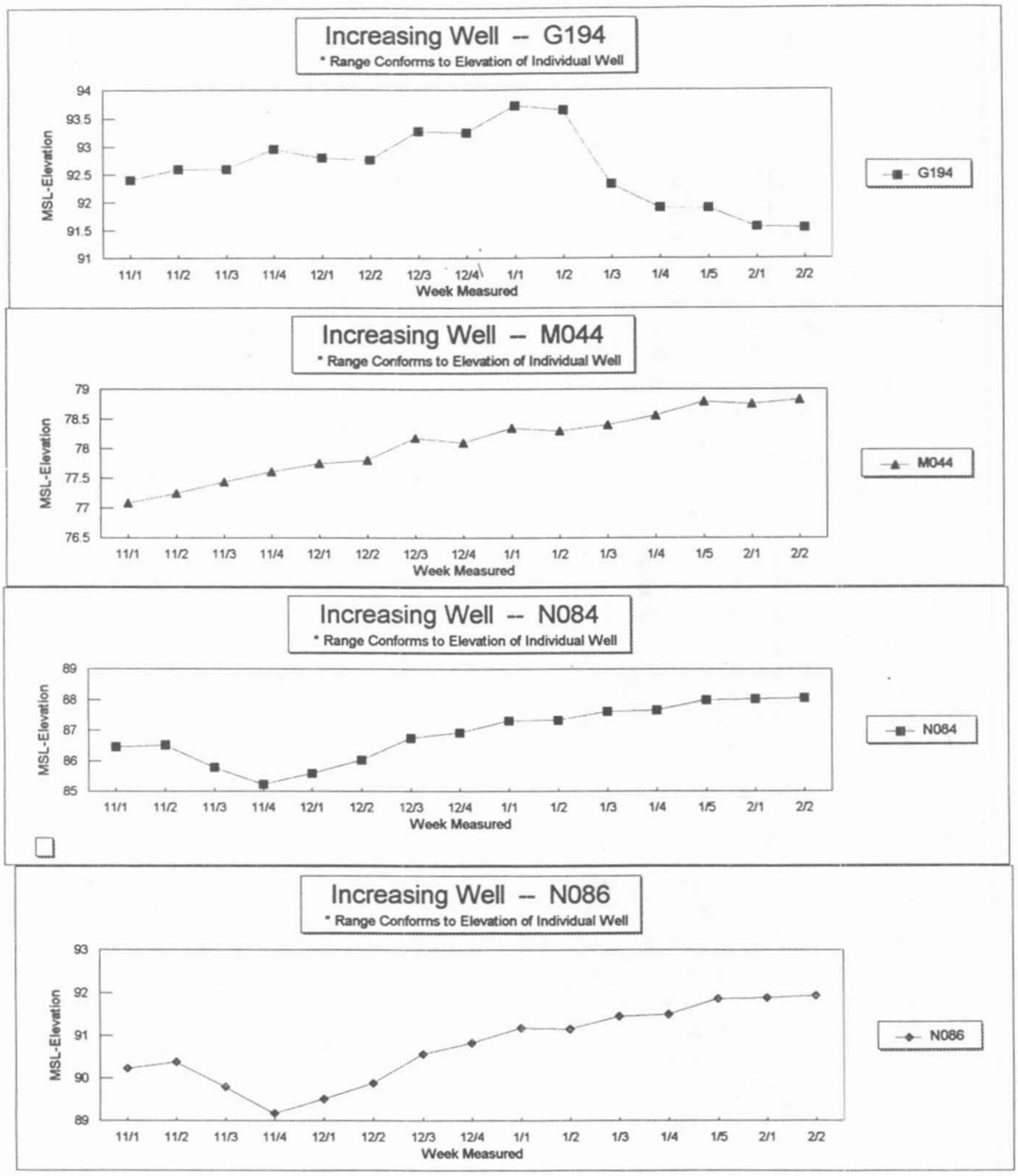

Figure 7. Graphs of Individual Increasing Study Wells

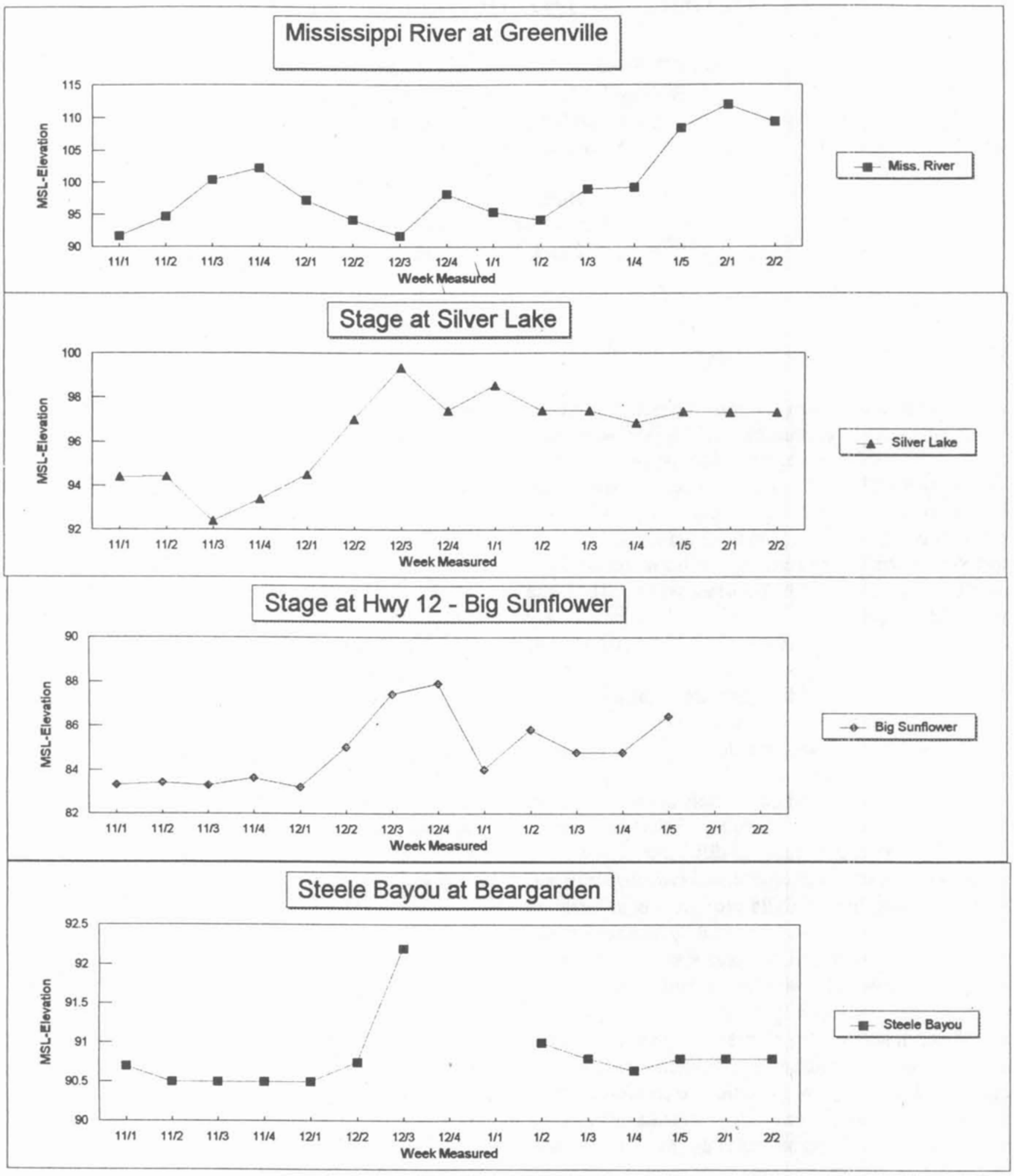

Figure 8. Graphs of Different Stream/River Stages