MISSISSIPPI RIVER / ALLUVIAL AQUIFER INTERACTION AT SPECIFIC SITES IN NORTHWESTERN MISSISSIPPI

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INTRODUCTION

Purpose

In the fall of 1992, staff of the Office of Land and Water Resources began an investigation to determine the hydraulic connection or interaction between the Mississippi River and the Mississippi River Valley alluvial aquifer (MRVA) in the Yazoo Basin of northwestern Mississippi (the Delta). This can best be studied on a site-specific basis. Results of the study at six of these sites that were selected are presented in this paper.

Several questions regarding each site were asked. The first dealt with how far out into the Delta (away from the river) could the influence of the river be observed. The second question centered on the "ground-water divide" at each site. How far from the river is it located and how does it vary or migrate throughout each year? The next question was what determined the distance over which recharge from the Mississippi River extended? The obvious answer to this question lies in trying to understand the geology at each site.

Methods

A total of six sites have been studied. They are as follows: (1) northern Tunica County; (2) west central Coahoma County; (3) Rosedale, Mississippi; (4) southwestern Bolivar County at Scott, Mississippi; (5) Greenville, Mississippi; and (6) southwestern Washington County at Longwood, Mississippi. Each site consists of a number of alluvial wells that form lines or profiles extending eastward into the Delta that are generally perpendicular to the adjacent reach of the Mississippi River. On five of the profiles, water level measurements were collected on a monthly basis for each period of data collection, which is October through the following May. No measurements were collected during the irrigation season. Measurements for the Greenville profile were collected on a daily basis by continuous type recorders (pressure transducers). Transducers have also been installed in a few of the wells in other profiles, and these collect daily water levels as well. All water levels were then correlated to daily information on Mississippi River stages at selected gage sites.

In order to determine the geology in the area of each profile, drillers logs for water wells in each area were matched (where possible) with wells permitted by the Office of Land and Water Resources. These logs record the lithology through which the well was drilled. Cross-sections developed by the U.S. Army Corps of Engineers (COE) in its 1968 and 1979 reports on the geology of the Yazoo Basin (Kolb et al. 1968; Smith 1979) were also utilized.

Geology

The Mississippi River Valley alluvium was deposited by the Mississippi River during Holocene time as it migrated over an area now referred to as the Yazoo Basin within the Lower Mississippi Valley. The alluvium generally consists of a fining-upward sequence of gravel, coarse- to medium-grained sand, fine-grained sand, silt and clay. As the Mississippi River meandered over this area, abandoned channels remained where it shortened its course. In their early stages, these abandoned channels commonly formed oxbow lakes. Later, many became almost completely filled with very fine-grained sediments such as silts and clays. The thickness of these abandoned channels (sometimes referred to as "clay plugs") can average 70 to 90 feet, but some are known to be 100 feet or more in thickness (Kolb et al. 1968).

Acknowledgements

Credit is due to Mr. Ernest Boswell, who gave one of the authors the idea for this study during a conversation several years ago. Certainly without his encouragement and guidance, this project would never have been realized. A great deal of thanks is due to each person who has helped with the invaluable field work to collect water level measurements. Without them, this study would have been very difficult to pursue. Appreciation is due Mr. Bill Oakley and Mr. Kerry Arthur, both with the Jackson office of the United States Geological Survey, for the installation of six observation wells at three of these sites. Many thanks also go to Mr. Harold Bishop and Mr. Cliff Hornbeak for their help in making data collection from these wells so much easier. The authors express their gratitude to Mr. Jim Hoffmann, Mr. Steve Jennings and, once again, Mr. Ernest Boswell for the advice and assistance they each provided during the writing of this paper.

DATA AND RESULTS

Along each profile, observations of water levels indicate that the influence from the Mississippi River varies with the distance from the river. Even so, at some point away from the river on all the profiles, the effect becomes insignificant, apparently due to dampening by the tremendous amount of storage capacity in the alluvial aquifer (Boswell et al. 1968). In some instances, however, distance at which the influence of the river may be observed is sufficiently decreased, apparently due to the retarding effect of the clay plugs upon the river's recharge. If a clay plug is sufficiently thick, it may impede the recharge to the alluvial aquifer from the Mississippi River during high stages (wherein the head in the river is higher than that in the alluvial aquifer). Analysis of the data collected thus far demonstrates that along each profile, the interaction between the Mississippi River and the alluvial aquifer is different. This will be discussed in the following section and will include outlining what hydrographs developed for all the wells show and how they correlate to corresponding river hydrographs. There will also be a discussion regarding the geology at each site and how it apparently relates to the conclusions developed for each profile.

Tunica North Profile

Water Level and Mississippi River Data. This profile is located in northern Tunica County near the community of Commerce, Mississippi. Water level measurements along the Tunica North line began in the fall of 1994. It consisted originally of four wells (3 irrigation wells on the delta side of the levee and 1 casino well on the river side of the levee).

Well #	Approximate Distance from the MS River
T-1a	0.40 miles (casino well)
T-2	1.20 miles
T-3	3.10 miles
T-4	4.20 miles
T-1b	0.90 miles (casino well)

After a year of measurements, well T-1b was added to the profile as a check on well T-1a. The water levels in T-1a fluctuated to such a degree that there was a question in the confidence of the measurements. However, comparison of water levels through time in both of these wells showed that they were very similar. In addition, they both followed very closely the changes in the stages of the Mississippi River. Hydrographs developed for both wells show that the MRVA is in better connection with the Mississippi River at well T-1a than at well T-1b.

All water levels were correlated through specific time periods with river stages. The river stages during the 1994 – 1995 period of water level measurements are very similar to the 1995 – 1996 period of measurements. That is, the Mississippi River had fairly normal average stages through the fall, winter, and early spring months, with a significant rise in stage in May of each period. The recovery trends in the water levels for all the Tunica profile wells (especially wells T-2 through T-4) during this time are similar as well. Therefore, for these two periods, the influence of the Mississippi River can be observed as far out as well T-2 (Figure 1b). All water level elevations and river stage elevations are plotted on the same vertical scale. This shows very clearly that there is very little head difference between the river and the MRVA, particularly at well T-1a. This graph also shows that the water levels in wells T-3 and T-4 reflected very little to no influence from the river.

The Mississippi River experienced higher than normal stages during the 1996 – 1997 period of measurements. This was especially true during March and April of 1997, when the river experienced near record-setting high stages. There is noticeably greater head in the river than the MRVA during these two months. As a result, all the wells in this line reflected influence from the Mississippi River, as shown in Figure 1c. Well T-1a obviously showed the most influence and Well T-4 showed the least amount of influence. Therefore, apparently only during high to very high stages on the Mississippi River can one observe recharge from the river as far away as well T-4 (approximately 4 miles from the river). Otherwise, the influence of recharge is apparently negligible at this distance.

Ground-Water Divide. Graphs showing a profile of the water level elevations for the river and all the wells were developed. These graphs indicate the approximate location of the "ground-water divide" along this line. Figure 1a shows how the divide shifts position through the 1994 – 1995 period. It apparently migrates between well T-2 and the Mississippi River, depending upon the stage in the river. When the head in the river is higher than that in the MRVA, the gradient slopes toward the southeast. When the head in the river is lower than that in the MRVA, the gradient reverses so that it is sloping back toward the river from well T-2. Therefore, the range of migration of the ground-water divide from the river along this line is probably less than two miles.

Geological Interpretation. The COE map of this area indicates that there is an abandoned channel that begins near well T-2 and extends in a direction perpendicular to the river along this profile out to and beyond well T-4. According to drillers logs along and near this line, the surficial clay thickness in the area around well T-1a ranges

from 18 to 10 feet. A drillers log for well T-2, which is located in the abandoned channel, reveals the surficial clay thickness is 40 feet. No other lithologic data could be obtained along the remainder of this profile. According to the COE map, however, there could be a sufficient thickness of clay to significantly diminish recharge from the Mississippi River along this line.

Profile C

Water Level and Mississippi River Data. The location of Profile C, which consists of four irrigation wells, is in west-central Coahoma County near the community of Farrell, Mississippi. Water level measurements along this line began in the fall of 1992. Well C-2 was added in January of 1995. Well C-1 has been converted to an observation well and houses a transducer that collects daily water levels.

Well #	Approximate Distance from the MS River
C-1	1.40 miles
C-2	3.50 miles
C-3	4.90 miles
C-4	5.50 miles

At the beginning of the 1992 – 1993 period of water level measurements along this profile, the Mississippi River was at relatively low stages. Then, starting in early November of 1992, the river experienced fairly high stages. These high stages were sustained for the most part through early May of 1993. Even so, the only water levels to be significantly influenced by the river were those in well C-1. The river stages during the 1993 – 1994 period remained fairly high through most of this time period. As in the previous period, even during the high stages, only the water levels in well C-1 were influenced by the Mississippi River. During the 1994 – 1995 and 1995 – 1996 periods, the Mississippi River stages were very similar to each other in that they were fairly low to average. Once again, the Mississippi River influenced only the water levels in well C-1. The 1996 – 1997 period began with the river at fairly low to average stages. In November of 1996, the river began rising; and in March and April of 1997, it reached near record high stages for those months. As usual, there was significant influence from the river on the water levels in well C-1. Similar influence was not observed in the other wells.

When a comparison is made of the individual recovery trend in each of the wells C-2, C-3, and C-4 for each of the periods of measurements (1992 – 1993 through 1995 – 1996), it is striking that the recovery trend for each well is basically the same throughout this time -- no matter what the river stages are. (The recovery trend for each well is unique.) That is, the 1992 – 1993 trend for C-3 is very similar to the 1993 – 1994 trend or the 1995 – 1996 trend. This is true for each period except for the 1996 – 1997 period. When the recovery trends from this period for the last two wells, C-3 and C-4, are compared with the trends of these same wells from the other periods, the slope of the 1996 – 1997 trend is steeper than that of the others. An example of this can be seen in Figure 2b, showing the 1995 – 1996 period, and Figure 2c, showing the 1996 – 1997 period. (These two graphs are different than those in figures 1b and 1c in that the wells are plotted on a second vertical scale that is much smaller than the scale for the river.) The trends for both wells in 2c become steeper, particularly in early March of 1997. This coincides with the river's rise. Apparently only at these high stages can the river's influence be observed as far away as well C-4, a distance of approximately 5 to 6 miles.

Ground-Water Divide. Graphs showing a profile of the water level elevations for the river and all the wells were developed. They indicate that the approximate location of the ground-water divide along this line is between the river and well C-1 as can be observed in Figure 2a. Therefore, the approximate range of migration is less than two miles.

Geological Interpretation. The only lithologic data available was along the western half of this profile. Based on this information, the surficial clay thickness ranges from 12 to 26 feet. The COE map shows abandoned channels to the south of this line and one at the eastern end of the line. The primary reason for the influence of only "high" river stages to influence the MRVA at wells C-3 and C-4 is probably due to the distance and the dampening effect because of the storage factor discussed earlier.

Rosedale Profile

Water Level and Mississippi River Data. As the name implies, this profile is located at Rosedale, Mississippi, and consists of six wells. Two are observation wells that are located on the river side of the levee on the grounds of Great River Road State Park and were drilled by the U. S. G. S. in early 1996. Both house transducers that collect water levels on a daily basis. The four irrigation wells are located on the delta side of the levee.

Well #	Approximate Distance from the MS River
R-1	0.20 miles (observation well)
R-2	0.90 miles (observation well)
R-3	2.30 miles
R-4	3.00 miles
R-5	4.90 miles
R-6	6.90 miles

Water level measurements along this profile began with the four irrigation wells in December of 1993. The Mississippi River had fairly high stages during the 1993 – 1994 period of measurements. The only well to reflect significant influence from the river upon its water levels was well R-3. The other wells showed very little or no influence from the river. The same is true for the 1994 – 1995 and 1995 – 1996 periods of measurements. The 1995 – 1996 period is shown in Figure 3b. The 1996 – 1997 period (Figure 3c) began with the Mississippi River at relatively low stages. Then, in November of 1996, the river began to rise. In March and April of 1997, near record stages for these two months were recorded. As a result, the river's influence extended out to not only well R-3, but also to well R-4. The water levels in the remaining wells reflected an insignificant amount of recharge from the river.

Data from the transducers in wells R-1 and R-2 show that the MRVA at both sites is in very good connection with the Mississippi River. Obviously, as R-1 is the closest to the river, the MRVA here has the best connection. Water level changes in well R-2, when correlated to the river and R-1, show a time lag compared with the changes in R-1.

The most significant influence from the river can be seen in wells R-1 and R-2. The river's influence on the MRVA at well R-3 and well R-4 diminishes, but is still fairly significant, especially during rises in the river such as occurred in March and April of 1997. However, beyond R-4 (approximately 3 miles), the influence from the Mississippi River is negligible.

Ground-Water Divide. Profile graphs of water level elevations for the river and the wells indicate that the probable location of the ground-water divide lies between well R-4 and the Mississippi River. When the head in the river is significantly higher than that in the MRVA, as shown in Figure 3a, the gradient is basically from west to east – that is from the river all the way out to well R-6. When the head in the river is significantly lower than that in the MRVA, the gradient shifts back toward the river beginning probably at the location of either well R-3 or R-4. The range of migration is up to approximately 3 miles away from the river.

Geological Interpretation. The COE map of this area shows a rather complex system of abandoned channels along and adjacent to this profile. The drillers log for well R-1 indicates no surficial clay at this site. However, the drillers log for well R-2 records as much as 80 feet of clay. A COE cross-section developed near and along this line shows several borings that penetrated clay plugs with thicknesses of as much as 90 feet. This complex system of abandoned channels containing thick units of clay certainly retards the recharge from the Mississippi River to the alluvium in this area.

Profile B

Water Level and Mississippi River Data. Profile B consists of an east-west line of wells that extends from the Mississippi River in southern Bolivar County across the entire delta to the foot of the bluff hills in Carroll County. However, for this project, only the western-most six wells along this line will be used. These six wells are all irrigation wells and are located near the communities of Scott and Choctaw, Mississippi. Water level measurements along this line began in the fall of 1992.

Well #	Approximate Distance from the MS River
B-1	0.90 miles
B-2	3.80 miles
B-3	6.60 miles
B-4	9.00 miles
B-5	10.80 miles
B-6	15.00 miles

Hydrographs developed for each well for each period of measurement indicate that the Mississippi River's influence can be observed as far away as well B-4. Hydrographs of well B-5 show similar recovery trends for each period of measurement, no matter how the river stages change through time. This can be seen in Figure 4b and 4c. When a similar comparison is made on well B-4, there is a difference between those periods during which the Mississippi River is at high stages and when it is at low stages. At each well progressively closer to the river, the difference in the recovery trends becomes greater. For those wells whose water levels reflect stage changes on the Mississippi River, the most striking difference is between the 1996 – 1997 period, when the river reached almost record stages, and the 1995 – 1996 period, when the river was at fairly low to average stages. Therefore, based on these hydrographs, the Mississippi River's influence may be observed as far as approximately 9 miles out into delta, especially during high stages.

Ground-Water Divide. Graphs showing profiles of the water level elevations indicate that the area in which the ground-water divide migrates is between well B-2 and the river (Figure 4a). When the head in the river is higher than that in the alluvial aquifer, the gradient slopes in a west to east direction. The approximate range of migration is 4 miles.

Geological Interpretation. Based on the COE map for this area and information obtained from drillers logs, there is no significant thickness of surficial clay along this profile. The COE map shows abandoned channels on both the north side and the south side of this line of wells as far out as well B-4, which is the last well that shows significant influence from the Mississippi River. The average surficial clay thickness along this line out to well B-4 is approximately 20 feet. The water levels in March and April of 1997 (measured from land surface) from wells B-1 to B-3 range from approximately 5 to 15 feet, respectively. Therefore, in this area the aquifer is under confined conditions. However, near well B-4, water levels are deeper, and, as a result, the aquifer is under water-table conditions. The confinement of the aquifer in this area is probably a major reason why a rise in the water levels out to well B-4 (9 miles from the Mississippi River) is observed so quickly after the river stages rise during this time.

Greenville Profile

Water Level and Mississippi River Data. This profile is located in the southern part of the City of Greenville, Mississippi. There are only three wells in this line, and they are all observation wells, each with a transducer that collects water levels on a daily basis.

Well #	Approximate Distance from the MS River
G-1	0.50 miles
G-2	0.90 miles
G-3	1.80 miles

Transducers were installed in G-2 and G-3 in December of 1994. G-1 was drilled by the USGS in early 1997, and a transducer was installed in it in May of that year.

Hydrographs developed from the transducer data clearly show that the MRVA at wells G-1 and G-2 is in excellent connection with the Mississippi River (Figure 5b). However, at well G-3 the influence from the river is diminished significantly.

Ground-Water Divide. The profile graph constructed for this line of wells shows that the area of migration of the ground-water divide lies between well G-2 and the river (Figure 5a). When the head in the Mississippi River is higher than that in the MRVA, the gradient slopes away from the river. When the head in the alluvial aquifer is higher than that in the river, the gradient is reversed -- back toward the river from well G-2. The range of migration in this area is apparently about 1 mile.

Geological Interpretation. The COE map indicates that there is an abandoned channel that trends in a northeast to southwest direction between wells G-2 and G-3. Information obtained from drillers logs show that the surficial clay thickness in the area between this abandoned channel and the river is about 15 to 20 feet. As the alluvium is only 75 to 100 thick along this profile, apparently the abandoned channel or clay plug is sufficiently thick to greatly impede recharge from the Mississippi River out to well G-3.

Profile A

Water Level and Mississippi River Data. Profile A is located in the southern part of Washington County near the community of Longwood, Mississippi. This profile is similar to profile B in that it extends all the way across the delta - from the Mississippi River to the foot of the bluff hills in Holmes County. However, for this project, only the western-most 11 wells will be used. There are 3 observation wells (drilled by the USGS in early 1997) and 8 irrigation wells. Each of the observation wells houses a transducer that collects water levels on a daily basis.

Well #	Approximate Distance from the MS River
A-1	0.80 miles (observation well)
A-2	0.80 miles (observation well; about 20 to 30 feet from A-1)
A-3	0.90 miles
A-4	1.80 miles
A-5	2.50 miles (observation well)
A-6	2.60 miles
A-7	4.30 miles
A-8	4.90 miles
A-9	6.40 miles
A-10	9.80 miles
A-11	11.60 miles

Water level measurements along this profile began in the fall of 1992. Well A-4 was added in January of 1993, and well A-7 was added in the fall of 1993.

Hydrographs developed for each period of measurement indicate that influence from the Mississippi River can definitely be observed as far away as well A-9. When a comparison is made of the recovery trends in this well between the 1996 – 1997 period (high river stages) and the 1995 – 1996 period (fairly low to average stages), there is a significant increase in the rate of recovery when the Mississippi River stages are high. The same is true for all the wells between this site and the river, with each successive well having greater differences in their trends. Figures 6b and 6c show that at well A-10, the river's

influence may still be observed, but is greatly diminished. At well A-11 (12 miles), the trends for the 1996 – 1997 and 1995 – 1996 periods are very similar. This indicates that by this point, there is very little to no influence from the river. Based on this information, recharge from the Mississippi River can most certainly be observed between 6 and 7 miles out into the delta during periods of average river stages. At high stages, recharge may be observed as far as 10 miles from the river.

Hydrographs developed from transducer data on wells A-1 and A-2 illustrate an interesting fact. Well A-1 is screened at a depth of 160 to 170 feet in the MRVA. Well A-2 is screened at a depth of 80 to 90 feet. According to the hydrographs, the water levels in these two wells are nearly identical. Many ground-water scientists would assume that given this difference in the screened interval, there would be time-lag between the water level changes in each well. Apparently at this site, the alluvial aquifer has sufficient vertical continuity and is in such good connection with the river, that there is essentially no difference between water levels in the two wells.

Ground-Water Divide. Graphs, such as the one in Figure 6a, showing profiles of the water level elevations in the wells and stage elevations for the river indicate that the area in which the ground-water divide migrates is between well A-6 and the river. The approximate range of migration is 3 miles.

Geologic Interpretation. The COE map for this area shows two connecting abandoned channels in the area of profile A. These extend out as far as a point about half way between wells A-6 and A-7. Lithologic data from a COE cross-section through this area and from drillers logs indicate that the surficial clay thickness ranges from approximately 17 feet at well A-1 to about 35 feet at well A-7. One drillers log for a well near A-3 shows a surficial clay thickness of 65 feet. In the area of wells A-9 and A-10, the clay thickness is approximately 15 feet. Even so, there apparently is not a sufficient amount of clay to significantly impede recharge from the Mississippi River. The same confinement conditions that exist along profile B in March and April of 1997 are present along this profile during the same time period. Water levels (relative to land surface) range from 1 foot above ground surface in well A-1 to about 18 feet below ground surface near well A-7. The aquifer along this part of profile A is definitely under confined conditions. Near well A-8 and A-9, water levels range from 19 to 23 feet below ground surface. As the surficial clay thickness averages approximately 15 feet, the aquifer is under water-table conditions in this area. As in the case of profile B, the confinement of the aquifer here is probably a major factor influencing why a rise in the water levels out to well A-10 (12 miles from the Mississippi River) is observed so quickly, even though significantly diminished, after the river stages rise during this time.

CONCLUSIONS

The hydraulic connection or interaction between the Mississippi River and the alluvial aquifer varies greatly from site to site. Two of the major factors determining how well connected the aquifer is with the river are: (1) the presence (or absence) of an abandoned channel with a significant thickness of clay, and (2) whether or not the aquifer is under confined conditions. The Tunica, Rosedale, and Greenville profiles apparently show that when significant thicknesses of clay are present, the distance over which the river recharges the alluvial aquifer is tremendously reduced. However, where there apparently are no "clay plugs," but the aquifer is confined, this distance may be up to 9 or 10 miles away from the river, such as may be observed along profiles A and B.

Much more research needs to be conducted to better understand the Mississippi River Valley alluvial aquifer system. The geology is the determining factor as to why this aquifer is (or is not) influenced by the Mississippi River or an underlying aquifer system. Very little is known regarding the physical characteristics of the aquifer itself. Some of the questions that need to be answered are: How much gravel is present? What size are the gravels? Is there very fine-grained sand present immediately underlying the surficial clay? The presence of this type of sand, in conjunction with an overlying clay, can result in the aquifer acting as a confined system.

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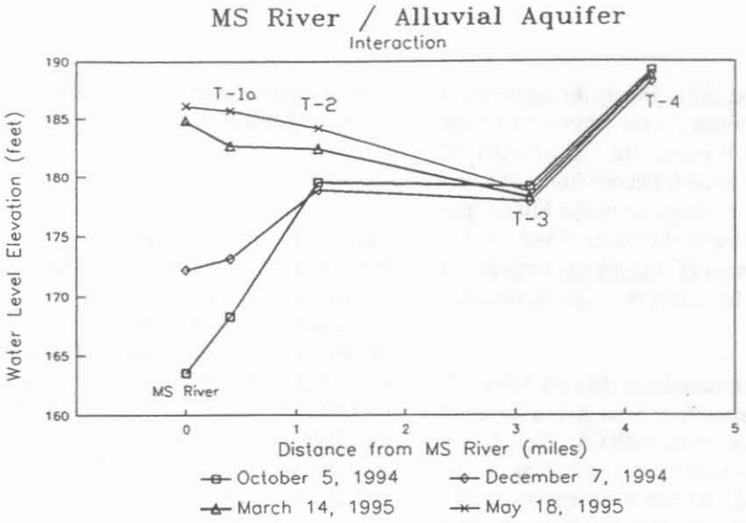

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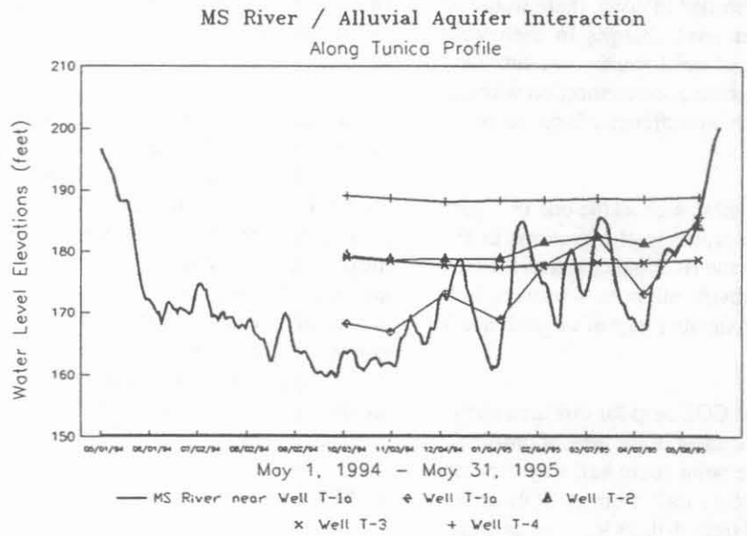

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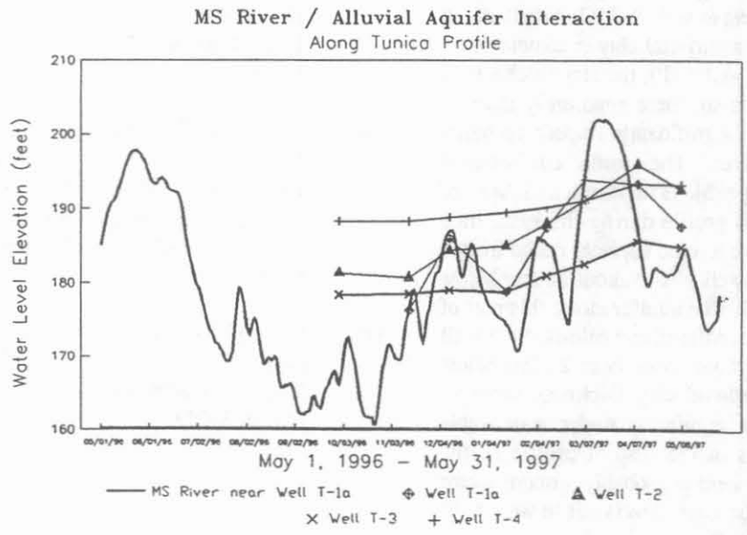

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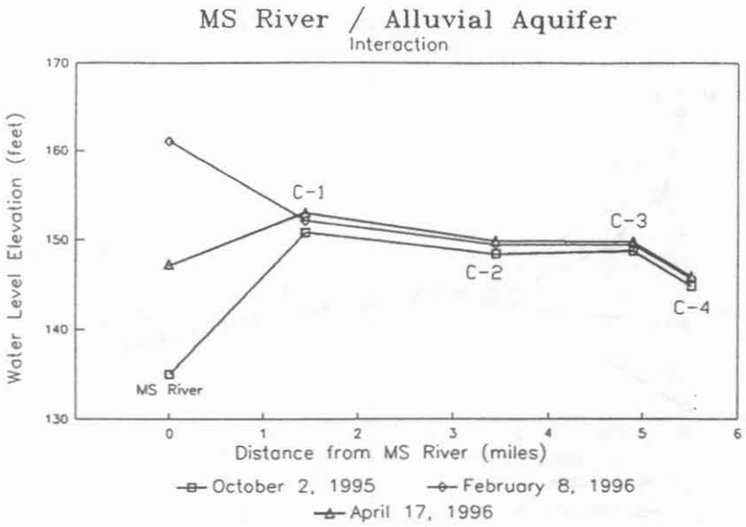

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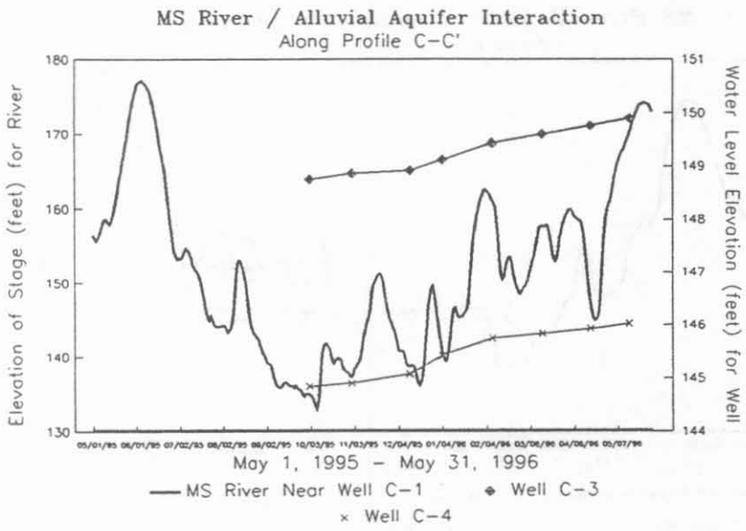

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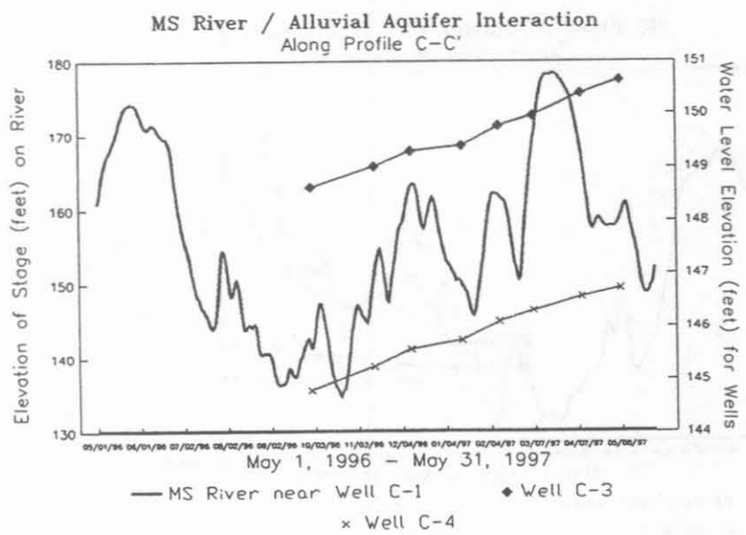

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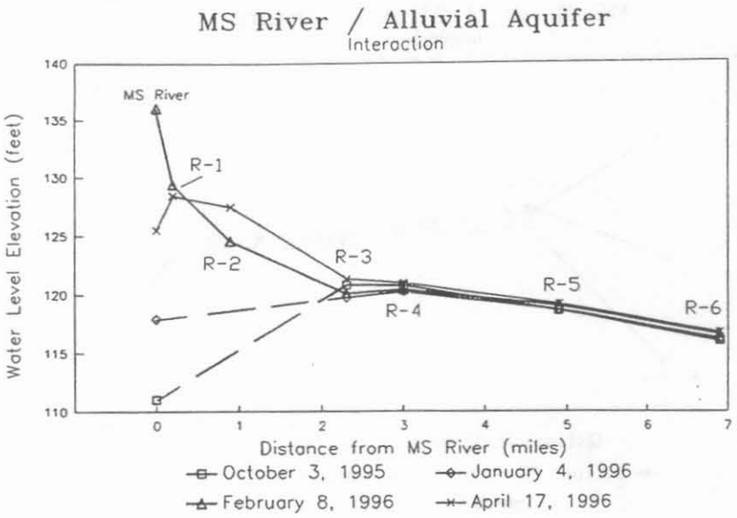

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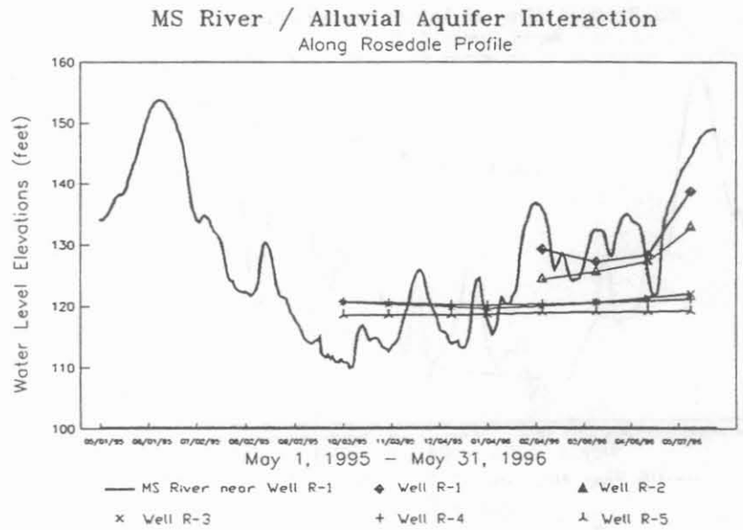

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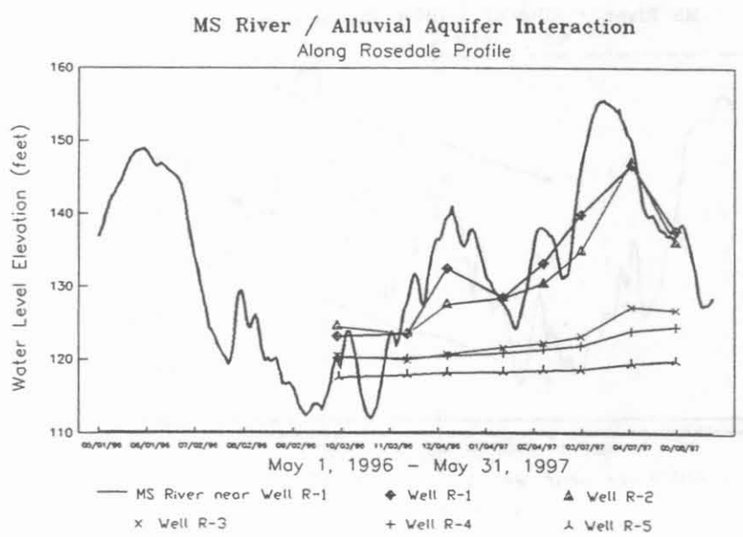


Figure 3c

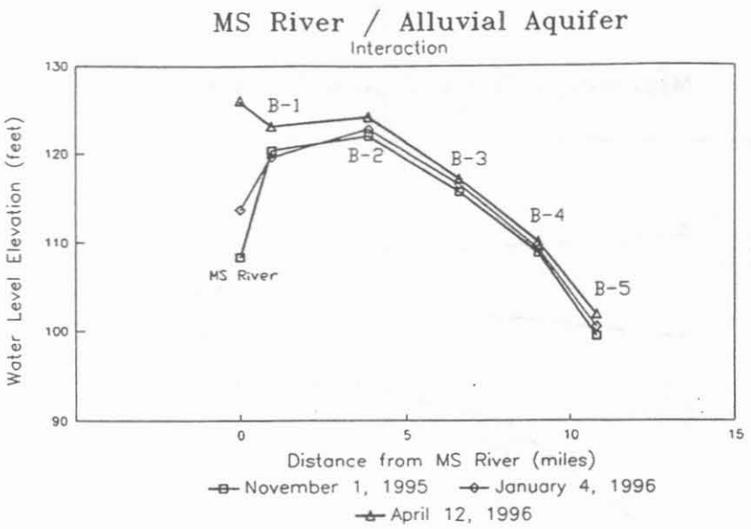
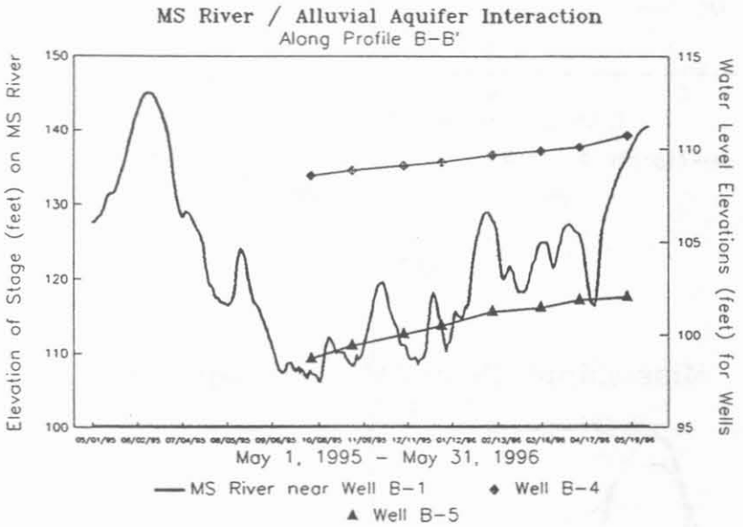


Figure 4a



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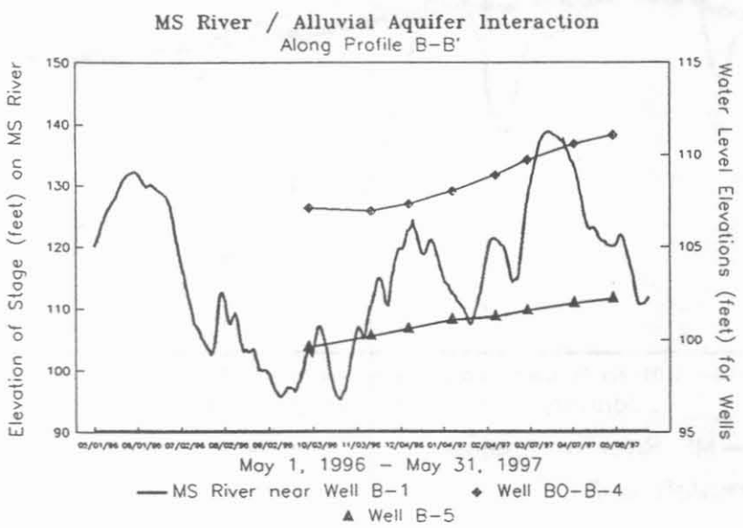

Figure 4c

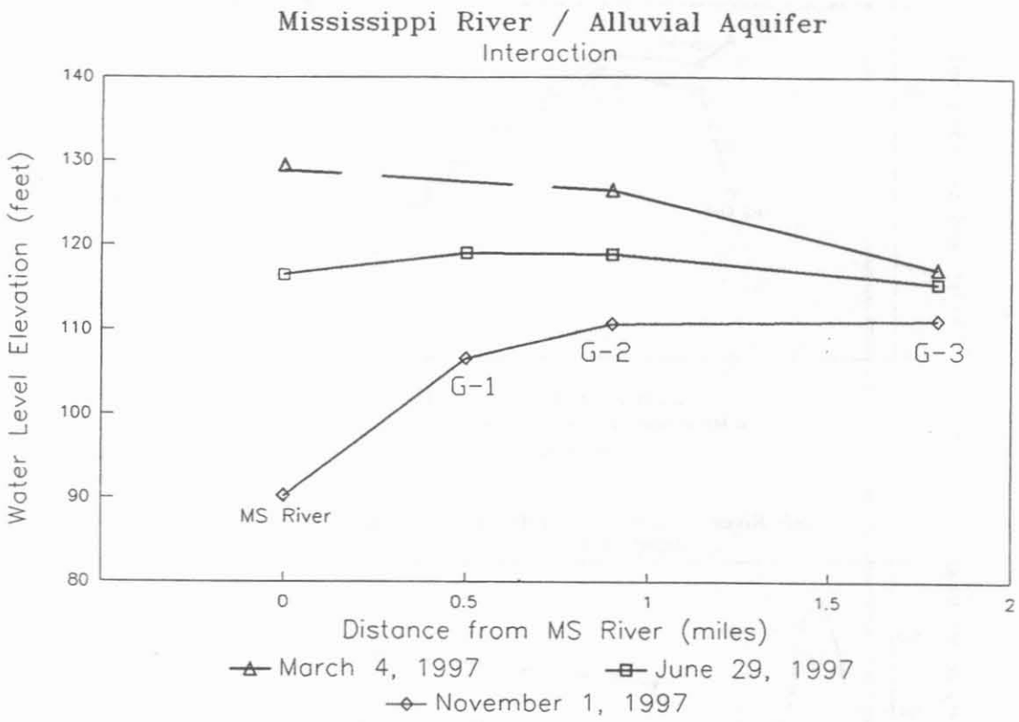

Figure 5a

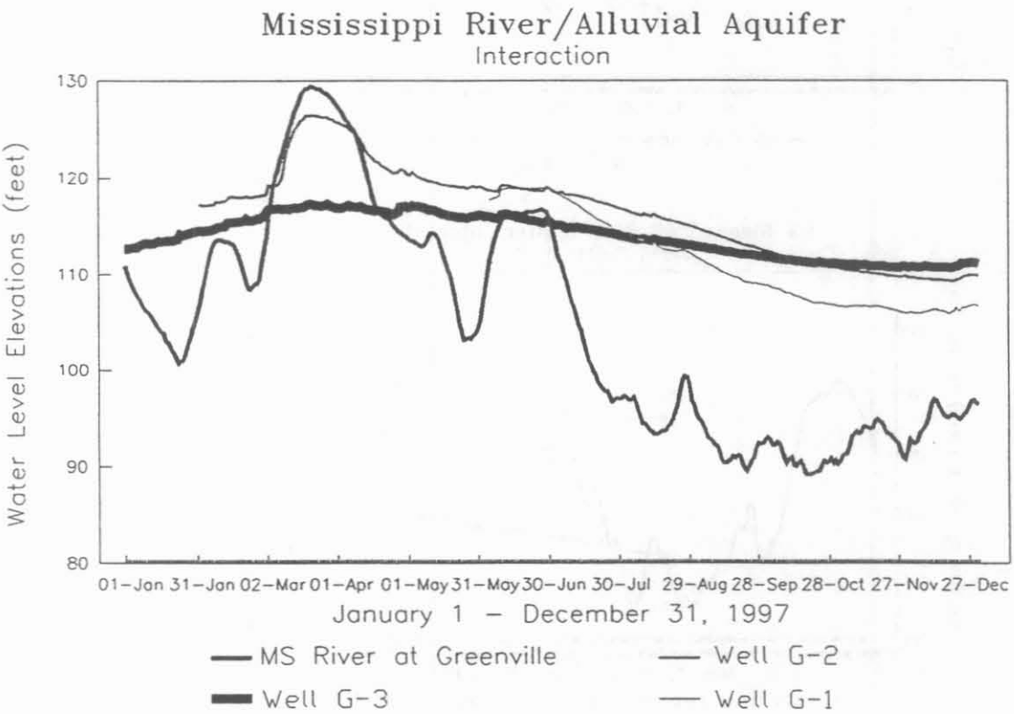

Figure 5b

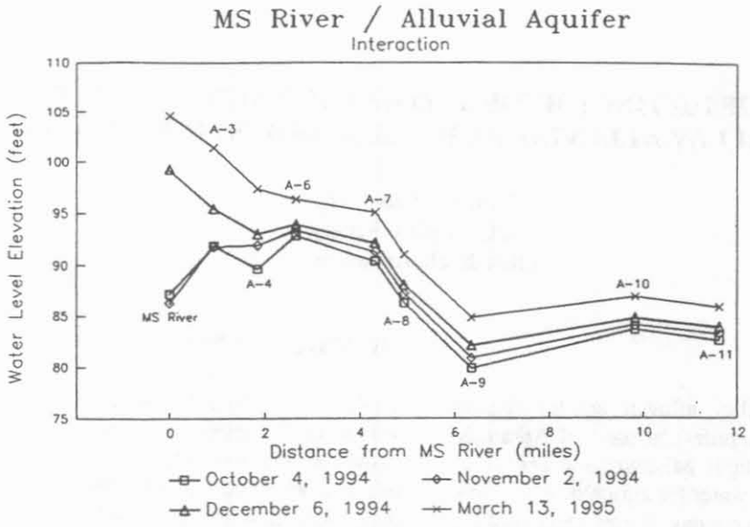

Figure 6a

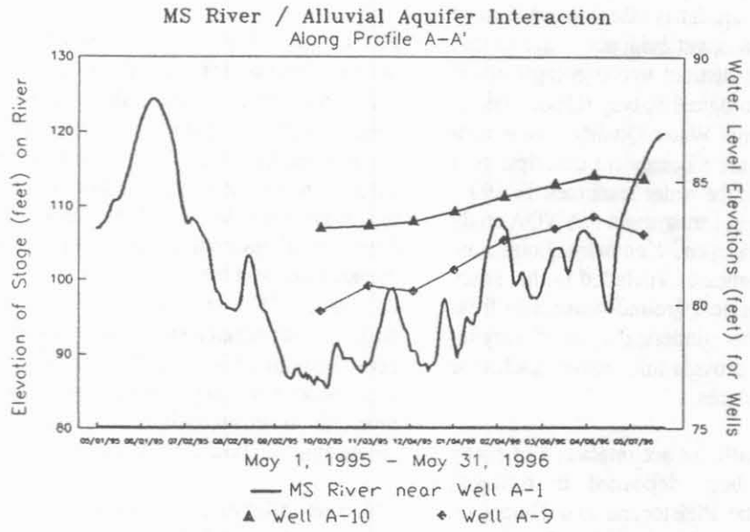

Figure 6b

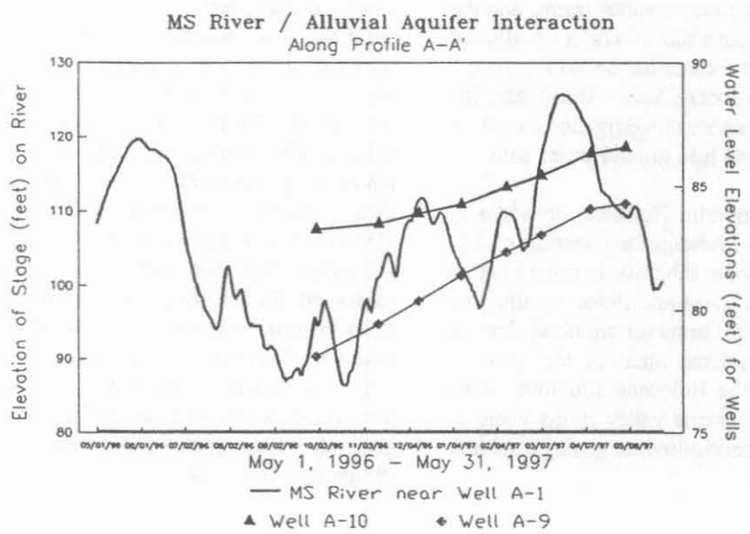

Figure 6c