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Sedimentation of four reaches of the Mississippi and Illinois Rivers

NANI G. BHOWMIK, J. RODGER ADAMS & MISGANAW DEMISSIE
Illinois State Water Survey, 2204 Griffith Drive, Champaign, Illinois 61820, USA

Abstract The Illinois and Mississippi River basins are two of the largest river basins in the United States. Over the last 100 years or so, both of these river basins have been altered significantly by human activities. Extensive data on sediment input and deposition, including quality and characteristics of the sediment, were collected from a number of reaches of these rivers, analysed, and evaluated. Pool 19 along the Mississippi River has lost about 58% of its capacity to sedimentation and may lose about 67% of its capacity by the year 2050, when it will attain a dynamic equilibrium. Pool 21 along the Mississippi River has also been an accumulator of sediment. Peoria Lake along the Illinois River has lost about 68% of its original capacity, and in another 15 to 20 years it may become reminiscent of an incised river with shallow mudflats on both sides. On the other hand, Pool 26 along the Mississippi River has been a net exporter of sediment.

Sédimentation dans quatre sections droites des fleuves Mississippi et Illinois

Résumé Les bassins des fleuves Illinois et Mississippi sont deux des plus grands bassins fluviaux des Etats-Unis. Au cours des quelque 100 dernières années, ces deux bassins fluviaux ont été considérablement modifiés par les activités humaines. On a recueilli, analysé et évalué de nombreuses données relatives aux apports et au dépôt des sédiments, y compris la qualité et les caractéristiques de ces sédiments, a partir d'un certain nombre de sections droites de ces fleuves. Le lac 19 le long du fleuve Mississippi a perdu environ 58% de sa capacité à cause de la sédimentation et pourrait perdre environ 67% de sa capacité en l'an 2050 lorsqu'il atteindra un équilibre dynamique. Le lac 21 le long du fleuve Mississippi a, lui aussi, été accumulateur de sédiments. Le Lac Peoria le long du fleuve Illinois a perdu environ 68% de sa capacitée initiale, et dans 15 ou 20 ans il pourrait rappeler un fleuve incisé ayant des plages de vase peu profondes des deux côtés. Au contraire, le lac 26 le long du fleuve Mississippi s'est révélé être un net exportateur de sédiments.

INTRODUCTION

Sedimentation of the many backwater and bottomland lakes, side channels, and sloughs along the Mississippi and Illinois Rivers has been a chronic problem for many years. Construction of hydraulic structures has increased this problem, especially in and around the backwater areas. Sedimentation of the waterways has been instrumental in transforming some of the reaches of the river from a lake-like appearance (because of locks and dams) to a fairly narrow and incised river-like appearance. Many other reaches of the river may attain this fate in the next 30–50 years if no drastic measures are taken.

The Illinois River carries a greater sediment load than the Mississippi River. An evaluation of the sediment budget for the entire Illinois River valley has shown that about 20.6 million tonnes of sediment are deposited annually within this valley. Detailed information and data related to sediment movement and deposition were collected from Pool 19 along the Mississippi River and Peoria Lake along the Illinois River. Sediment transport data are also available from Pools 21 and 26 along the Mississippi River. Figure 1 shows the locations of these four sites along the Upper Mississippi River System (UMRS). This paper summarizes the sediment budgets for these four reaches of the UMRS.

SEDIMENT BUDGETS

Pool 19

Pool 19 along the Mississippi River is located at about River Mile 364.5 and is 74.5 km long. This is one of the oldest navigation pools on the Mississippi, and it also has one of the highest head differentials along the UMRS. Lock and Dam 19 located near Keokuk, Iowa, not only facilitates the navigation of barges with 2.75 m draft, but also is used as a hydroelectric power plant. The lock is located on the western shore of the river, and the gates are located across the remaining width of the river. These gates are normally utilized during high flows. This operation technique has been responsible for the high sedimentation rates of this pool just upstream of Lock and Dam 19. Figure 2 shows the sediment deposition pattern upstream of Lock and Dam 19 since 1891 (Bhowmik & Adams, 1986). It is quite obvious that more than 10 m of sediment has deposited at this location since 1891, and probably most of this deposition has occurred since 1913 when Lock and Dam 19 was constructed.

Even though Pool 19 is a riverine pool rather than an impounding reservoir, it still behaves like an impounding reservoir with regard to sedimentation rates over time, because of the operation techniques for the pool and its morphometric features. This is shown in Fig. 3, which illustrates the capacity of this pool at various time periods. As can be seen from this figure, the rate of capacity loss of the pool was about 1.3% per year from 1913 to 1928, which was the initial period after the construction of

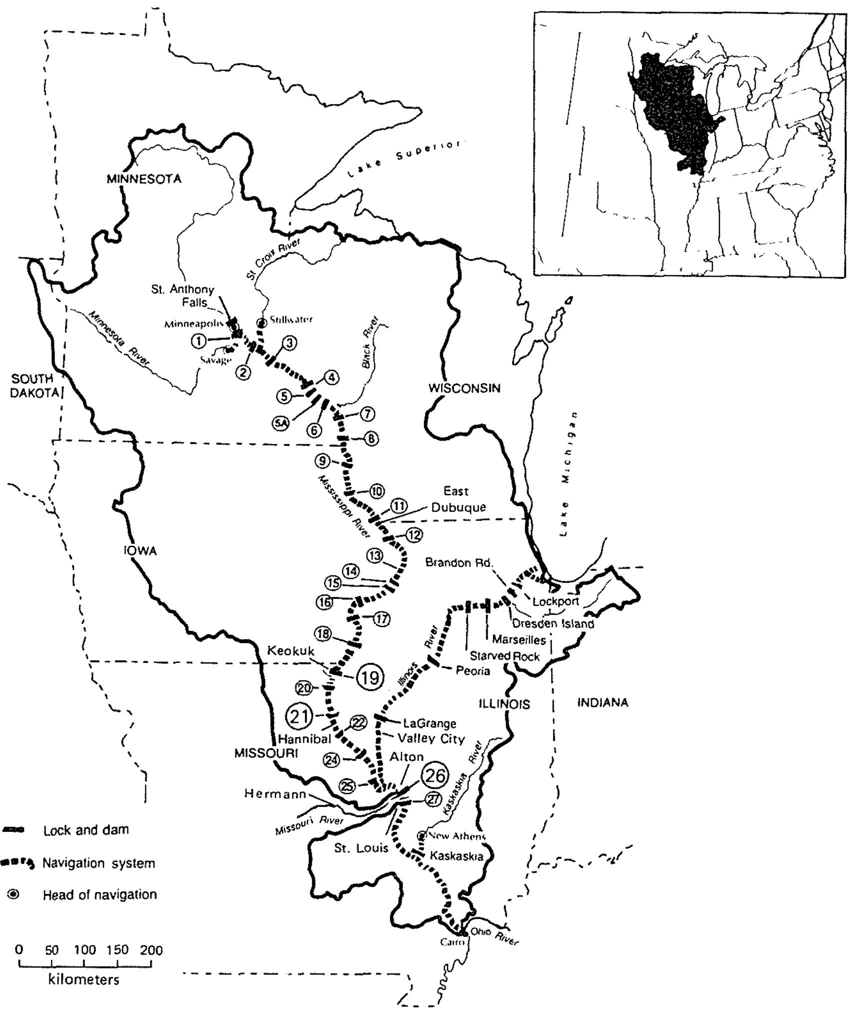

Fig. 1 The Upper Mississippi River System.

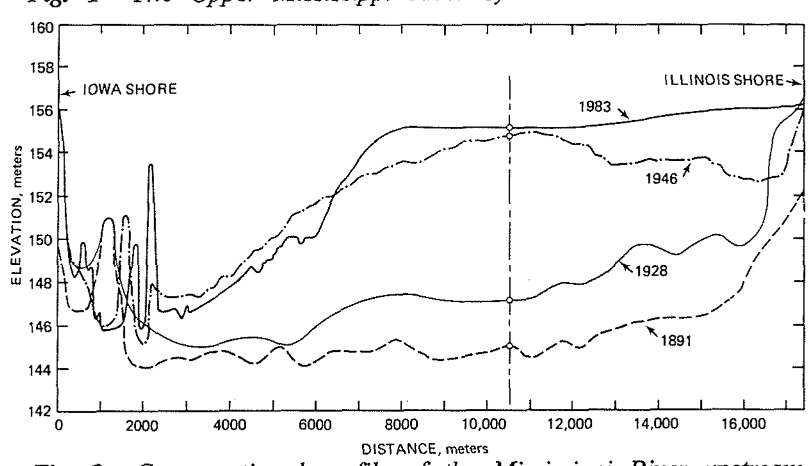

Fig. 2 Cross-sectional profile of the Mississippi River upstream of Lock and Dam 19.

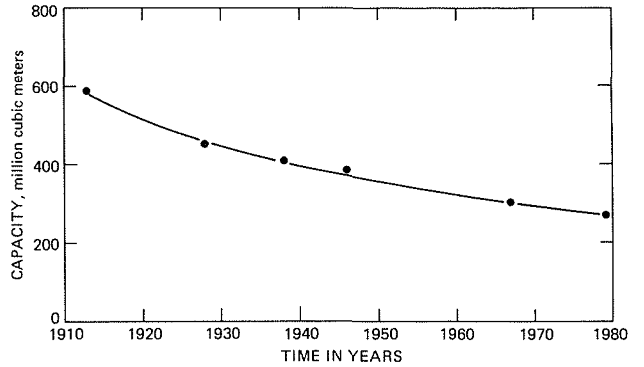

Fig. 3 Capacity loss of Pool 19 since 1913.

Lock and Dam 19. Since then the capacity loss rate has decreased, attaining a value of about 0.58% per year from 1946 to 1979. It should be noted that this pool has been accumulating most of the sediment within its lower reaches.

Table 1 shows the sediment budget for this pool. This analysis indicates that the pool has been accumulating sediment at the rate of about 3.3 million tonnes per year. The surface area of this pool is 12 330 ha.

Table 1 *Sediment budget for Pool 19*

Location	*Drainage area (km^2)*	*Discharge (m^3 s^{-1})*	*Sediment load (t $year^{-1}$)*
At Lock and Dam 18	*294 200*	*1 688*	*10 800 000*
Henderson Creek	*1 550*	*11*	*310 000*
Skunk River	*11 200*	*66*	*2 550 000*
Ungauged area	*1 250*	*9*	*300 000*
At Lock and Dam 19	*308 200*	*1 774*	*10 690 000*
Net deposition			*3 270 000*

Table 1 also indicates that even though Skunk River (located between Lock and Dam 18 and Lock and Dam 19) contributes only about 3.6% of the total drainage area upstream of Lock and Dam 19, it delivers about 18% of the total sediment load to this pool.

Long-term data also have shown that the 2 m depth contour lines upstream of Lock and Dam 19 have been migrating laterally at the rate of about 1.2 m per year. It is suspected that a 2–3 km reach of the river upstream of Lock and Dam 19, especially near the eastern part of the river, will soon convert into a wetland with very shallow water depths (Bhowmik *et al.*, 1986).

Pool 21

Pool 21 is also located along the Mississippi River, at River Mile 324.8. This pool is 29.5 km long and has a surface area of about 2565 ha. The sediment budget for this pool is shown in Table 2.

Table 2 *Sediment budget for Pool 21*

Location	*Drainage area (km^2)*	*Discharge (m^3 s^{-1})*	*Sediment load (t $year^{-1}$)*
At Lock and Dam 20	*347 610*	*1 924*	*18 930 000*
Bear Creek	*900*	*6*	*292 000*
Wyaconda River	*1 190*	*7*	*400 000*
At Lock and Dam 21	*349 700*	*1 937*	*18 950 000*
Net deposition			*672 000*

This budget for Pool 21 was prepared on the basis of available data and those published by Keon *et al.*, (1986). This pool is also accumulating sediment, at the rate of 672 000 t $year^{-1}$.

Pool 26

Pool 26 on the Mississippi is located near Alton, Illinois. Lock and Dam 26 is located about 24.4 km below the confluence of the Illinois and Mississippi Rivers. The annual sediment transport from the Illinois River to the Mississippi River is estimated to be 6.3 million tonnes. Pool 26 extends about 62 km along the Mississippi River and 129 km along the Illinois River. The total surface area of this pool is 4920 ha. Table 3 shows the average annual sediment budget for this pool. This budget shows that Pool 26 is a net exporter of sediment on an annual basis.

PEORIA LAKE

Peoria Lake, located along the Illinois River at RM 162, extends for about 38 km. This is the remnant of one of the bottomland lakes that was formed by the retreat of the much larger glacial river that once occupied the Illinois River valley. The present-day flow of the Illinois River is much too small to transport the sediment delivered by its tributaries. At the same time, the lower Illinois River also has a fairly flat gradient, which exaggerates the sedimentation problems. Moreover, around 1939, the Peoria Lock and Dam was constructed to increase the low flow depths for navigational purposes, which again increased the sediment deposition at this location.

Figure 4 shows a plan form view of Peoria Lake (Demissie & Bhowmik, 1987). Peoria Lake has two distinct areas, Upper and Lower Peoria Lake. The Tenmile Creek delta constricted the flow of the Illinois River near River Mile 166.4 and has forced Upper Peoria Lake to behave more or less like a retention basin for the whole lake. Sediment deposition patterns in Upper and Lower Peoria Lake attest to the different depositional patterns.

Table 3 *Sediment budget for Pool 26*

Location	*Drainage area (km^2)*	*Discharge ($m^3\ s^{-1}$)*	*Sediment load ($t\ year^{-1}$)*
At Lock and Dam 25	*367 900*	*2 250*	*20 540 000*
Cuivre River	*2 340*	*18*	*630 000*
Illinois River	*67 400*	*615*	*6 349 000*
Ungauged area	*6 560*	*50*	*1 800 000*
Lock and Dam 26	*444 200*	*2 930*	*30 840 000*
Net scour			*1 521 000*

Figure 5 shows cross-sectional profiles of the river at River Miles 175 and 164, respectively (Fig.4). River Mile 175 is located in Upper Peoria Lake, and RM 164 is located in Lower Peoria Lake. Even though significant sediment deposition has occurred at both locations, the rate of filling at RM 175 in Upper Peoria Lake is much higher than that at RM 164 in Lower Peoria Lake. Cross-sectional profiles for the years 1903, 1965, 1976 and 1985 are shown in this illustration.

Since 1903, Peoria Lake has lost about 68% of its original capacity. The capacity loss of Peoria Lake at various time periods is shown in Table 4. Upper Peoria Lake has lost about 72% of its 1903 capacity, compared to a capacity loss about 51% in Lower Peoria Lake. In 1903, the average depth in Upper Peoria Lake was about 2.3 m, compared to a depth of 0.6 m in 1985. On the other hand, Lower Peoria Lake had an average depth of 3.0 m in 1903, compared to a 1985 average depth of 1.6 m. Therefore, it is obvious that the construction near RM 166.4 (Fig. 4) has been instrumental in forcing Upper Peoria Lake to absorb a larger percentage of sediment load than Lower Peoria Lake. However, as Upper Peoria Lake gradually fills up with sediment and attains a dynamic equilbrium, Lower Peoria Lake will start to fill up with sediment at a much higher rate and will soon attain the appearance of an incised river flanked by broad, wide, and extremely shallow wetlands. This is essentially the fate that awaits many bottomland lakes with similar hydrologic and morphometric features.

A sediment budget of Peoria Lake (Demissie & Bhowmik, 1985) has shown that about 60% of the sediment being deposited within this lake environment is contributed by the main stem of the Illinois River, and the other 40% is contributed by the local tributaries. Of this 40%, about 2-3% is contributed by the erosion of the lake shore.

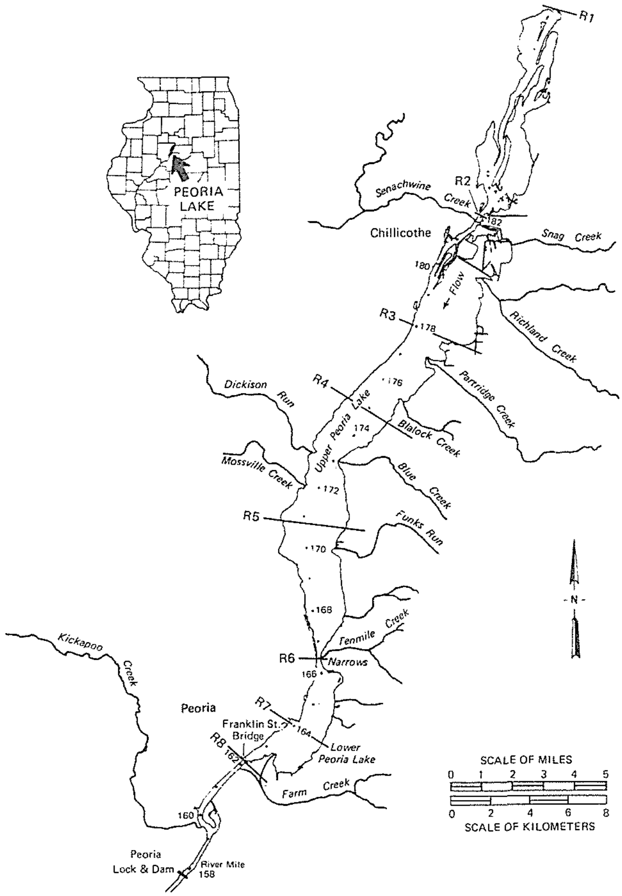

Fig. 4 Plan view of Peoria Lake.

Table 4 Volume of Peoria Lake at different times at 134.2 m a.m.s.l.

Year	Volume in Upper Peoria Lake ($m^3 \times 10^3$)	Volume in Lower Peoria Lake ($m^3 \times 10^3$)	Peoria Lake (Upper plus Lower) ($m^3 \times 10^3$)
1903	118 368	29 592	147 960
1965	68 062	21 824	89 886
1976	52 033	17 755	69 788
1985	32 675	14 549	47 224

REMARKS

These large river systems have been modified because of human activity both within the main body of the river and within its drainage basin. Recent data have shown trends towards increased sediment deposition within both the river environment and its valley. This trend of increased sediment deposition may transform many reaches of these rivers from a lacustrine-type environment (because of locks and dams) to a riverine environment with an incised stream flowing somewhere close to the original thalweg of the river.

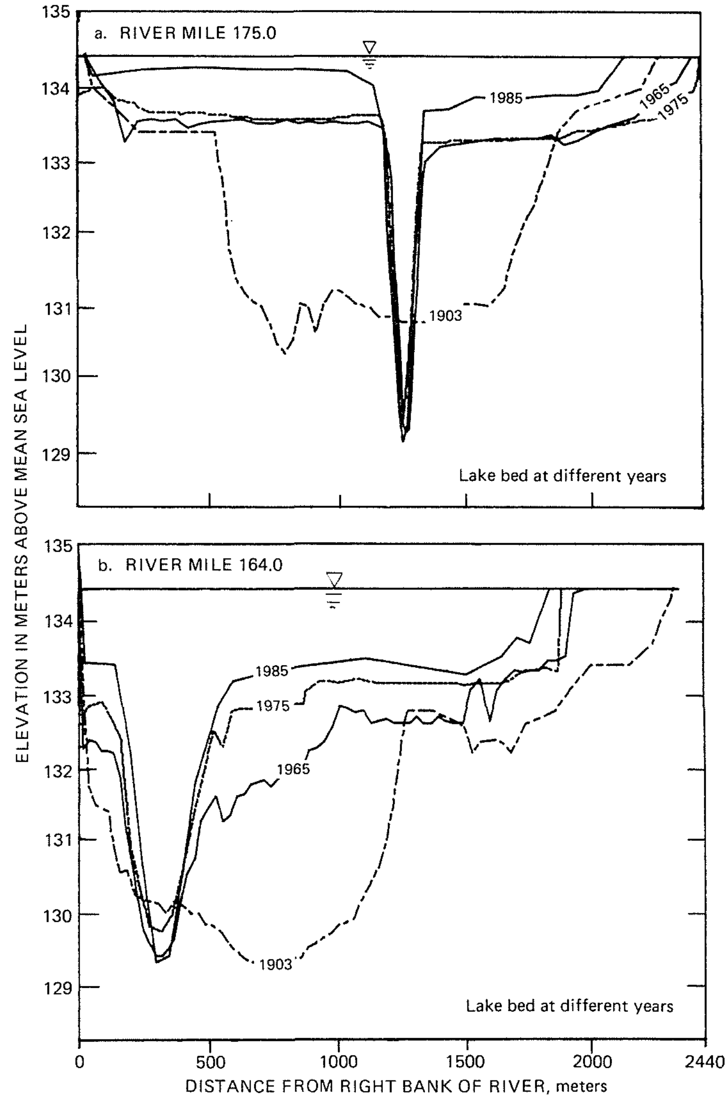

Fig. 5 Cross-sectional profiles of Peoria Lake at RM 164 and 175.

Sediment budgets from four pools along the Upper Mississippi River System show that three of the pools are accumulating sediment, and that only one has been a net exporter of sediment.

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