

**Changes in River Morphometry and Water Quality
for Proposed Changes in River- and Land-Use Practices
in the Minneapolis Stretch of the Mississippi River**

A Preliminary Assessment

by

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Introduction

As part of a long-range planning study underway for the City of Minneapolis and Minneapolis Park Board, BRW, Inc. is evaluating the potential changes that would result from termination of commercial navigation on the Mississippi River above Lock and Dam #1 and the subsequent relocation of industries in north Minneapolis that currently depend on barge traffic to ship and/or receive raw materials and products. This report provides a preliminary assessment of changes in the morphometry of the river channel that would occur if commercial navigation an* are am a navigation channel ceased in this stretch. Effects on river ecology an wa er qua i - i a ese c anges, as well as possible changes in stormwater management and land-use along the north Minneapolis corridor, could induce also are evaluated.

I. Effects on River Morphometry

Understanding of the work: physical river effects. The basis of this section of the report is that significant reduction in commercial traffic through the Mississippi River north of Lock and Dam Number 1 (LD 1) would result in the following actions by the US Army Corps of Engineers (ACE):

1. Cessation of lock operations at LDI and two sites upstream: Lower St. Anthony Falls (LSAF) and Upper St. Anthony Falls (USAF).
2. Cessation of dredging by the ACE in the reach north of LD 1.

Our goal here is to examine the general nature of the effect of these two actions on the river in the section from LDI to the Minneapolis city limit (hereafter the "study reach"). We will also examine the effects of other related actions the ACE might take concomitant with cessation of lock operations and dredging.

We want to stress from the outset that this is a very preliminary assessment, conducted in a short period and without any detailed physical or computational modeling. It is intended only as a guide to some of the possible effects that could result from changes in usage of the study reach. It is assumed throughout that any actual design decisions would be based on a well constrained, thorough study of the types of effects discussed here.

Background to the work. The present profile of water-surface elevation in the study reach is mainly determined by the presence of the three control structures listed above: LD1, USAF, and LSAF. Of these, LD 1 and USAF are both fixed-crest dams with limited capacity for water bypass - in other words, virtually all the water discharge that crosses them does so by flowing over the dam crest. LSAF, on the other hand, is equipped with a set of gates that allow water to flow through the structure. The level of water in the adjoining pools is manipulated by raising and lowering these gates.

Sediment in the study reach is predominantly sand sized. At present the ACE removes sediment from various points along the river bed to maintain a navigable channel in the river. Dredging occurs along most of the reach under consideration here, with the goal of maintaining a channel depth of at least 10.5 feet. Most of the dredged material (spoil) is provided to the City of

Minneapolis for use in construction and for sanding roads. A very small amount ($< 1\%$) is used for nourishment of beaches along the river and so is retained within the river system. Presumably some fraction of that sediment used for road sanding is returned to the river via runoff. Hence the dredging and sanding system functions as a short-range bypass for an unknown, though probably small, fraction of the dredged sediment.

Over the time scales of interest to us here, the steady state of a river such as the Mississippi is to transport through all the sediment that is supplied to it. The river will, unless interfered with, evolve its bed and banks in such a way as to accomplish this. Sediment supply can occur from upstream, from tributaries, from bank erosion, and from local runoff. Our goal here is to consider how changes in present river-management practices might change the way the river deals with its sediment load. The most obvious change is that, if the ACE ceases dredging operations, the sediment that would have been removed in this way will accumulate on the bed. This sedimentation will cause the river to increase its transport capacity until a configuration is reached in which the river can, on average, pass the entire load supplied to it through the study reach. Detailed prediction of this new configuration would require detailed numerical and physical modeling that is well beyond the scope of this initial assessment. However, the new configuration can be expected to involve some combination of higher velocity, shallower depth, greater slope, and greater width.

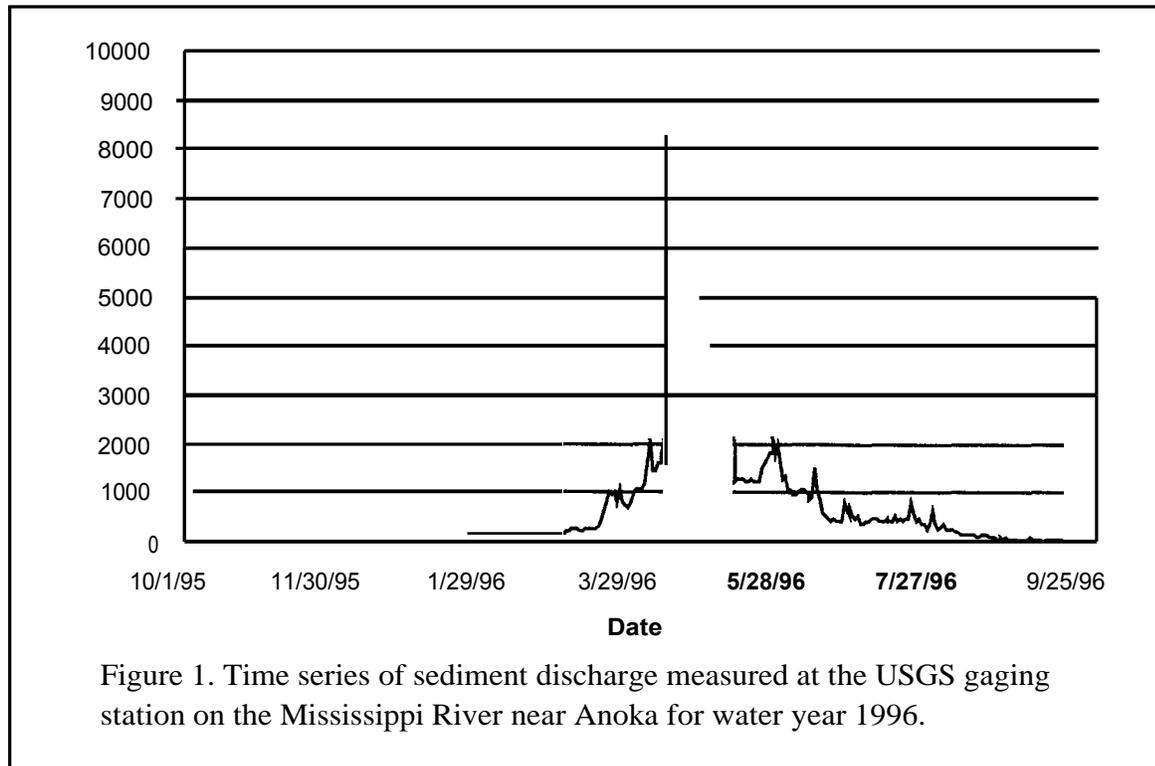
Sediment sources. The reach of river of interest to us here does not have significant tributary input. Bank erosion may be a source of sediment locally for short periods, but if it were a significant long-term source the river would show systematic increases in width. To the best of our knowledge this has not been observed in the study reach. We do not know how much sediment is supplied from local runoff, but considering that the landscape adjoining the study reach is heavily urbanized it seems unlikely that this is a significant source, except for (presumably minor) resupply of dredged sediment used by the city for road sanding. Hence we will base our reasoning on the premise that the major source of sediment to the reach in question is supply from upstream.

Direct physical effects. We turn first to the direct effects of the changes in river management envisioned above on the river. The most obvious of these is the cessation of dredging by the ACE. If this occurs, the material that was formerly dredged will have to be transported through the study reach by fluvial processes, and the river will adjust its geometry to accomplish this.

We begin by looking at the sediment budget for the study reach. We estimate the input sediment supply from the U. S. Geological Survey (USGS) gage station at Anoka, the nearest upstream station for which sediment discharge data are available. This station is located about 7 river miles upstream of the study reach. The record covers water years 1976-1996 and part of water year 1975. Suspended-sediment discharge at this station was recorded daily. A portion of this record is shown in Figure 1. Since only suspended sediment was recorded, the measured values underestimate the total load because they do not include material in transport very close to the bed. This so-called "bed load" is usually coarser than the sediment in suspension, and hence deposits more readily. It is difficult to say by how much the load is underestimated without more information. We note, however, that silt fractions of the suspended load reported by the USGS (42 % to 96 % during 1996 - 1997) are much higher than those of local bed

material, and of the material dredged by the ACE, both of which are mostly sand. This suggests that the gage measurements are indeed capturing only the finer part of the load.

With this important caveat, we find that the mean sediment discharge for the gaged period at this site is 737.8 tons per day.

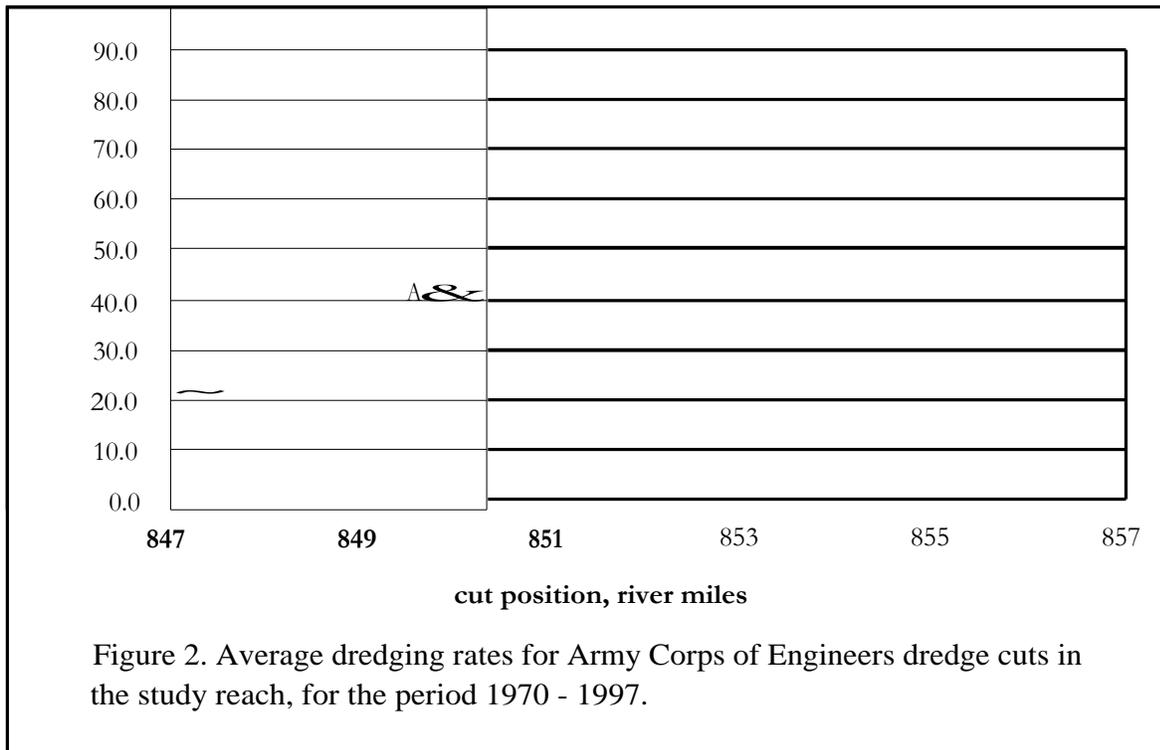


The next step is to compare this with the rate of sediment removal in the study reach by the ACE. There are four dredge cuts in the USAF pool, and eight cuts in Pool 1. These sites together account for most of the length of the study reach. The site locations and mean yearly dredge volumes, averaged over the period 1970-1997, are given in Figure 2. The total volume removed from the entire reach is the sum of the volumes removed from each dredge cut. Summing these, we arrive at a total average removal rate of 366.5 tons per day. Comparing this with the sediment supply estimated from the USGS gage data, we estimate that the ACE's dredging operations at present remove 50% of the sediment supplied to the reach from upstream.

These data suggest that cessation of dredging by the ACE would roughly double the amount of sediment passing through the study reach. Below, we will consider the effects of a doubling of sediment discharge on the river. However, we stress that there are potentially large errors in this estimate of the fractional increase in sediment discharge. As discussed above, the USGS gage sediment discharge is probably lower than the actual discharge. If this is the case, the fractional increase would be smaller than we have assumed, and the river response would be weaker than we have estimated. On the other hand, much of the material measured at the USGS gage is apparently substantially finer than what is being removed by the ACE from the study

reach. Some of this fine material is probably "wash load"-material that is too fine to have much of an effect on the river bed. The error from not excluding wash load is in the opposite sense, that is, it would tend to make the river response stronger than we have estimated.

With these caveats in mind, we will proceed using a doubling of sediment load as our baseline scenario. As mentioned above, the response of a river such as the Mississippi to an increase in sediment load is to adjust its geometry so as to be able to transport the load through. Typical responses could include increasing velocity, decreasing depth, increasing slope, and increasing width. Determination of how the response would be partitioned among these possibilities would require detailed computational and physical modeling that is well beyond the scope of this preliminary assessment. One can gain some insight, however, by asking how key variables would change assuming uniform response over the reach, for simplified scenarios in which as



many variables as possible are held constant. Estimates of fractional change in width, depth, velocity, and slope for two such scenarios are given in Table 1. In the first scenario, the total width is held constant; in the second, flow velocity. Given that the river flows in a gorge through the study reach, the constant-width scenario is closer to what would actually happen. The other scenario, which is more appropriate for laterally unconfined rivers, is included mainly to illustrate how sensitive depth and slope are to changes in width. In any case, we reiterate that the actual response would probably involve a combination of all the hydraulic variables, and that they can interact in quite complicated ways.

| Percent change in: | Variable held constant: | |
|----------------------|-------------------------|----------|
| | Total channel width | Velocity |
| total channel width | 0 % | +100% |
| flow depth | -13 % | -50% |
| <i>flow</i> velocity | +15% | 0 |
| river bed slope | +52% | +100% |

Table 1. Reach-averaged fractional changes in key river variables for two scenarios of river response to a doubling of sediment discharge: one in which the river adapts to increased total sediment transport without changing its width, and the other in which it adapts without changing its velocity (more correctly, its boundary shear stress).

We can get a rough idea of how quickly sedimentation would occur on average through the reach by determining the mean filling rate obtained by spreading the sediment that the ACE is presently removing over the area of the reach. Based on a total length of 9.9 miles and an average river width of 707 feet, the dredge volumes shown in Figure 2 give an average accumulation rate over the entire reach of 0.07 feet per year. The maximum dredge rate, above the Lowry Avenue Bridge, averaged over the length of the dredge cut, gives an average sedimentation rate of about 0.4 feet per year. Most of this yearly activity would probably take place during relatively short periods of high *flow*.

We stress that all the changes we have discussed are averages over the reach. The average values shown in Table 1 do not, for example, include the local effects of the dams on sedimentation. In reality, the river response would vary strongly from place to place--one can gain some sense of this by noting how variable the dredging rate is along the reach now (Fig. 2). It is likely that much of the sedimentation that would occur would be concentrated in a few areas, particularly upstream of the fixed-crest dams (USAF and LD 1). Local sedimentation might lead to formation of new sand bars. These would divert the *flow* locally, perhaps leading to local erosion of the bed or banks even though the reach as a whole would be undergoing deposition. Bars formed during floods might be exposed at lower flows, especially if less frequent adjustment of the gates at LSAF led to greater variability in pool elevation (see below). These bars might eventually become vegetated, stable islands.

Indirect effects. In the previous section we looked at the most obvious direct effect of changing the use of the upper river, sedimentation due to cessation of dredging by the ACE. We presented rough estimates of how this sedimentation might change the river hydraulic geometry, and how rapidly deposition might occur. Here we consider some possible indirect effects of the changes, either as a secondary result of sedimentation, or in addition to it.

Flooding. One of the classic side effects of sedimentation of river beds is to increase flood heights: at the simplest level, if the bed elevation rises, the water-surface elevation tends to rise as well. Sedimentation in the study reach in response to cessation of dredging by the ACE can thus be expected to raise flood levels in the study reach. It is difficult to estimate the magnitude of this effect without detailed study.

Effect on river beaches and banks. A general side effect of sedimentation in a river is a tendency for the channel to widen. Inasmuch as the reach of interest here is in a gorge, any widening associated with sedimentation is likely to be modest. Nonetheless, local widening could result in bank collapse in unstable areas, accelerating a phenomenon that occurs naturally in the river anyway. Widening could also result in local erosion of recreational river beaches. Both of these could enhance sedimentation in the channel. On the other hand, cessation of dredging may benefit the beaches, since there is probably some tendency for sediment to flow from the bank areas into the dredged channels. This lateral flow can deplete river beaches of sand.

We reiterate that it is very unlikely that sedimentation in response to cessation of dredging would occur uniformly over the width of the river. Apart from the uncertainty in the estimates presented in Table 1, local changes could be much larger than average values. As mentioned above, sedimentation might involve the growth of existing islands or formation of new bars in the channel. Bar formation could divert water laterally toward the bank, creating local beach or bank erosion. In-depth evaluation of this possibility is impossible without detailed study.

Other ACE activities. It is possible that, if it were not involved in day-to-day running of the lock system in the study reach, the ACE would scale back or eliminate its other activities in the area. Two of these are of particular interest: maintenance of pool water levels by adjustment of the gates at LSAF, and beach nourishment. At present, the ACE adjusts the gates at LSAF daily as part of its routine lock operation. Without the lock, ACE personnel might not be present on a daily basis to do this. Less frequent adjustment of the gates would lead to greater variability in pool elevation unless some sort of automated adjustment system were installed.

The beach nourishment program has been modest in scope and involves the use of a very small fraction of the sand dredged from the navigation channel for beach replenishment. Recent efforts have focused more on controlling vegetation than on actually adding sand to the beaches.

Sediment resuspension by barge traffic. There is some evidence that the wakes and propeller wash of barge tows can suspend significant amounts of bed sediment for periods of the order of a few hours. We do not know what role, if any, this mechanism plays in the total transport of sediment through the river; we doubt that it is significant. To the extent that it is, elimination of barge traffic in the reach might enhance the adjustments the river would make to its increased load. The resuspension also stirs the sediment and promotes mixing with the water. -

Lock decommissioning. It is not clear at this point what exactly would be done with the lock structures if the ACE decided to discontinue operation of the locks. However, at present the total transport of water and sediment through the locks during normal operations appears to be small. Hence we do not foresee any major physical changes in the river due to cessation of lock activity.

Changes in residence time. One effect of dams on rivers in general is to increase the residence time of water in the river system. Sedimentation behind the dam reduces the total volume

available for water in the upstream prism, and hence reduces the residence time. This is of significance primarily for water chemistry.

II. Effects on River Water Quality and Ecology

Current Water Quality Conditions

Data sources. In order to make projections concerning the effects of the proposed changes in land- and river-use practices on water quality in the stretch of the Mississippi River that flows through the City of Minneapolis, it is necessary first to consider current water quality conditions. The scope of this preliminary study precluded gathering of new data, and only limited time was available to search for existing data. The river has been monitored routinely by the Metropolitan Council Environmental Services (MCES) on a biweekly basis since 1976 at seven sites through the metro Twin Cities region. None of the monitoring sites is precisely within the -10 mile stretch of river in question, but one site is located at the downstream end of the stretch-at the Ford Motor Company hydroelectric plant across from Lock and Dam #1. Another MCES site is about 12 miles above the upstream end of the river stretch, in Anoka. The Minnesota Pollution Control Agency (MPCA) has had a water quality monitoring site at the Minneapolis water treatment plant in Fridley (near the upstream end of the stretch) since 1972. Its sampling frequency is monthly except in winter. The USGS has a sampling station in Fridley, just above the river stretch, where it has measured flow and water quality as part of its NASQUAN national monitoring network for over 25 years, but its sampling frequency for water quality also is low (at best bimonthly). We were successful in finding a detailed record of suspended solids measurements collected on a daily basis for over 20 years (1975-1996) at a site just north of the stretch; S. Kroening, USGS, Moundsview, MN, pers. comm., 1998).

Except for the above-mentioned suspended solids data, we were unable to locate any recent water quality data collected at sites along the stretch of river of concern in this report. To the best of our knowledge, there have been no recent studies of this river stretch conducted by students or faculty at the University of Minnesota or by state or local water management agencies. Similarly we were unable to find any data on physical and chemical characteristics of the bottom sediments in this stretch. It is possible that limited quantities of such data exist; our effort to find them was not exhaustive. However, a key member of the USGS team that has been studying the Mississippi River as part of a large-scale (national) river basin assessment program (NAWQA) indicated to us that the USGS team had not located any other historical data for this stretch of river.

General chemical conditions. Our analysis of current water quality conditions in the river stretch is based on inference from upstream and downstream monitoring data, on information from other sites in the drainage basin, and from personal observations. Within the limits of the information base described above, the chemical quality of the river water in this stretch generally appears to be good for a large river flowing through an urban area. Whereas in earlier decades of this century, dissolved oxygen levels were moderately to severely depleted through-

out the entire metro stretch of the river because of inputs of untreated or poorly treated sewage from numerous outfalls and small treatment plants (Johnson and Aasen, 1989), today, dissolved oxygen concentrations' are near saturation with respect to atmospheric oxygen, with which the river water equilibrates, throughout the stretch. Lack of dissolved oxygen led to severe odor problems, fish kills, and then an absence of fish communities in the 1920s. Today, odor problems do not occur, and a thriving fish community is thought to exist throughout the metro river stretch. Occasional taste problems are encountered by the Minneapolis water treatment plant, but these are associated with spring runoff events that bring in high loadings of natural organic matter from decomposing vegetation and soils in the drainage basin north of the metro area rather than from urban sources.

The river water is moderately colored with humic material. This is a natural situation; the humic matter consists of large, complicated organic acids derived from soils and the decomposition of woody vegetation in wetland areas that drain into the river above the Twin Cities metro area. The water also is hard (high in calcium and magnesium). This too is a natural situation and reflects the calcareous nature of many soils in the drainage basin and the contribution of water from underground limestone aquifers to the river's base flow. As a consequence of the river's hardness, Minneapolis and St. Paul, which use the river as a source of drinking water, treat it by softening processes before distributing it. Associated with the moderately high hardness is a high carbonate alkalinity, which is beneficial in buffering the pH of the water, and a slightly alkaline pH (typically in the range 7.0 to 8.3).

Nutrients and suspended solids. Concentrations of nutrient and suspended solids are low to moderate in the river as it flow through Minneapolis, especially in comparison to conditions downstream, i.e. below the confluence of the Mississippi River with the Minnesota River at Fort Snelling and the outfall of the Pig's Eye waste treatment plant below downtown St. Paul, which adds more than 200 million gallons per day of wastewater effluent to the river. For example, plots of the long-term data on total phosphorus (TP) concentrations in the river (Kroening, 1994) show that TP levels at Anoka and Fridley are not much higher than levels in the upper reaches (headwaters) of the river, which range from about 10 to 50 micrograms per liter ($\mu\text{g/L}$), depending on flow conditions. Phosphorus contributions from the St. Cloud wastewater treatment plant and possibly from agricultural runoff in the river basin between St. Cloud and the northern metro area probably account for the modestly higher TP levels at the north metro sampling sites. Mean annual concentrations at Lock and Dam #1 (MCES data) are no higher than the MCES data for Anoka, and in some years, the concentrations actually are lower at Lock and Dam #1. This suggests that Minneapolis is not a major contributor, at least of phosphorus, to the river. In contrast, TP concentrations typically are 100-200 pg/L at the first river sampling site below the confluence of the Minnesota River, and concentrations often rise above 200 pg/L (depending on flow) below the metro wastewater treatment [plant](#). TP levels in the Minnesota River are elevated (typically in the range 200-300 pg/L) as a result of agricultural drainage (land use in the Minnesota River Basin is over 90% agricultural) and inputs from several mid-sized wastewater treatment plant in the lower Minnesota River.

Similarly, suspended solids concentrations in the Minneapolis stretch of the Mississippi River are moderate compared with the Minnesota River and the Mississippi River below its con-

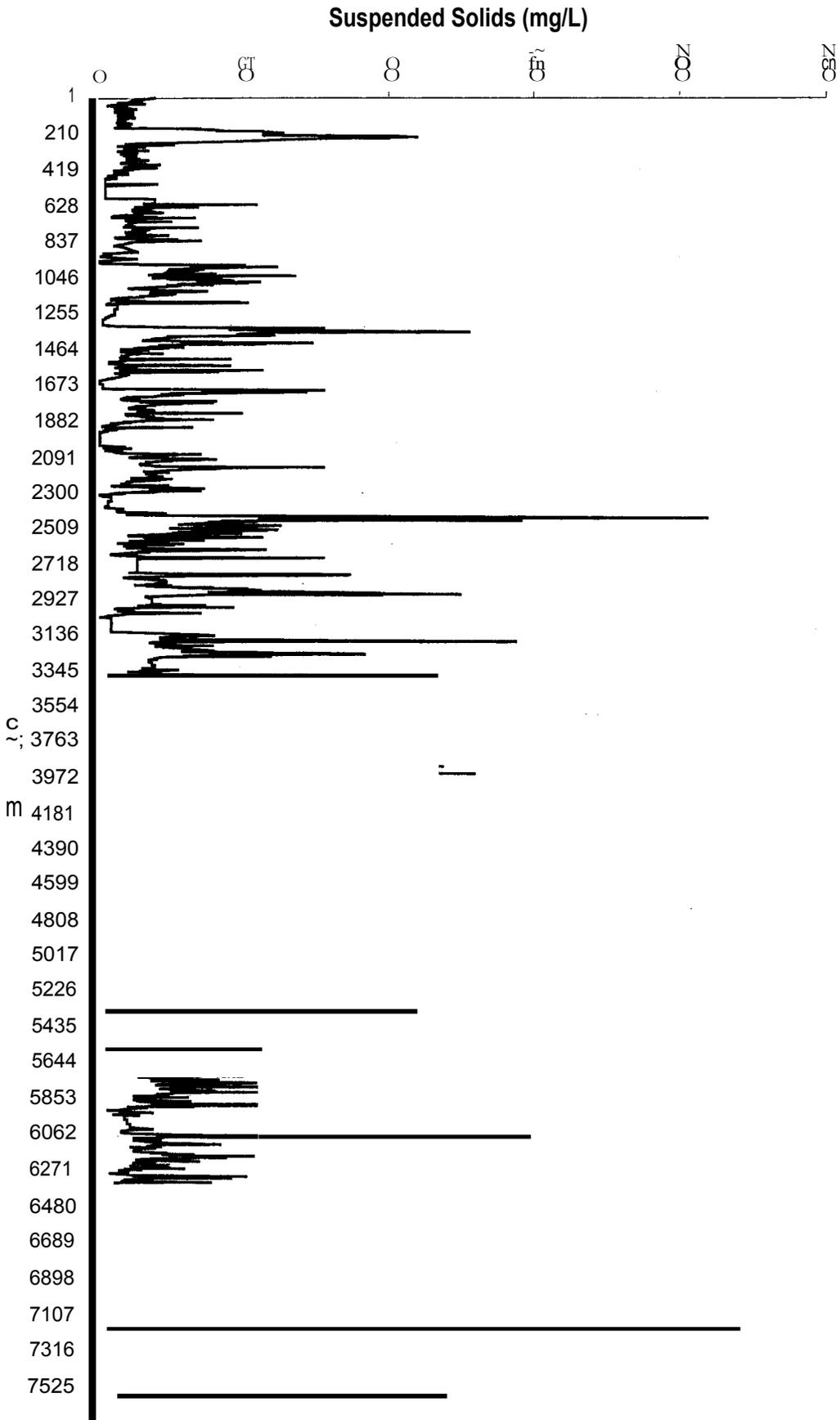


Figure 3. Suspended solids in Mississippi River near Anoka, 1975 (day 7713 = Sept. 30, 1996)

fluence with the Minnesota River. The grand mean for the 20+ years of suspended solids measurements at the sampling site north of Minneapolis is 19.3 milligrams per liter (mg/L) (Figure 3), but there are strong seasonal variations, with highest values occurring each year during late winter and early spring (the snow-melt, high runoff period). In contrast, typical concentrations of suspended solids in the Minnesota River are in the range of several hundred mg/L. Depending on relative flows of the Minnesota and Mississippi Rivers, concentrations in the latter river downstream of its confluence with the former also can be greater than 100 mg/L. Nonetheless, the combination of moderate levels of organic color and suspended solids in the Minneapolis stretch of the river severely limits light penetration in the water. Because the river is fairly deep (partly because of dredging to maintain the 10 ft deep navigation channel), there is not sufficient light penetration to the bottom to allow the development of rooted plants in this stretch of river; high water flow velocities also may hinder the establishment of aquatic plant communities along the river channel.

Heavy metals and organic contaminants. We are not aware of any information on organic contaminants such as PCBs and pesticides in the Minneapolis stretch of the river. Unpublished data obtained by the USGS for the stretch of river immediately to the north show that a variety of organic contaminants, including volatile industrial solvents and agricultural chemicals, are present at detectable levels, but concentrations are not high enough to cause concerns about use of the water for drinking purposes or to have significant ecological impacts. Consumption advisories have been issued by the Minnesota Pollution Control Agency and Department of Health for some fish species caught in the metro stretch of the Mississippi River because of elevated tissue levels of PCBs. The origin of the PCBs is uncertain, and whether the problem occurs in the Minneapolis stretch of the river also is uncertain. Because the fish sampling that led to the consumption advisory was done more than ten years ago, it also is not certain whether the problem still persists.

No recent data are available on heavy metal levels in this river stretch.' We can speculate, however, that levels of common industrial metals such as zinc, copper, lead, nickel, chromium, iron, and aluminum, may be elevated somewhat above background levels because of industrial activities along the river corridor in north Minneapolis and because of loadings from urban stormwater runoff. (Urban runoff generally has elevated concentrations of such metals compared with concentrations in rural runoff). However, because such local inputs would be diluted to a significant extent by river flow from upstream sources, it is likely that metal levels in the river still would be low, probably below ambient water quality standards.

Bottom sediments. Although no data are available on the chemical composition of bed sediments in the Minneapolis stretch of the Mississippi River, we can make some inferences from the finding that the sediment dredged from the river bottom to maintain the navigation channel

¹Limited data are available on heavy metal concentrations in the river for a site near the University of Minnesota campus from a study during the 1970s by Professors S.J Eisenreich and M.R. Hoffmann, but because the data are so old and so much has happened that could affect metal levels, they are not considered to be reliable indicators of current conditions.

is mostly sand rather than finer grained silts and clays. Because natural organic matter, organic contaminants and heavy metals are associated with fine grained rather than coarse grained particles, it is likely that the bed sediments in this river stretch have a low organic content and relatively low levels of organic and metal contamination. It is possible, of course, that some local areas may be exceptions to this statement. For example, harbor areas protected from the high flow rates of the main channel and areas downstream of stormwater outfalls, if they are protected from scour by the presence of a sand bar, may have fine-grained, organic-rich sediments with elevated levels of contaminants.

Stormwater inflows. As mentioned above, several stormwater outfalls are located within the river stretch. During rain events they bring low-quality stormwater discharges into the river. Although data are lacking on the chemical composition of these discharges, numerous data are available for other sites in the Twin Cities area. There is little reason to expect that stormwater from residential and commercial areas in the north Minneapolis corridor would be different from that in other twin Cities urban areas. In general, such stormwater is characterized by moderately high concentrations of nutrients (nitrogen and phosphorus), high suspended solids, elevated levels of some heavy metals, bacteria, and organic carbon (e.g. Wilson, 1993). For large rain events with much runoff, these discharges have a detrimental impact on chemical water quality in the river, even though there is substantial dilution of the runoff by the river flow. However, because the travel time of water through the 10-mile river stretch is less than a day, these impacts are of short duration. The quality of stormwater runoff from industrial areas in the river corridor north of St. Anthony Falls is uncertain and bears further analysis. It is possible that concentrations of heavy metal and organic contaminants in runoff from this area are substantially higher than concentrations in the commercial and residential areas of the corridor. Further investigation is underway to determine whether runoff studies have been conducted on outfalls in the industrial area.

River ecology. From an ecological perspective, current conditions in the river stretch must be considered rather poor, especially in the stretch above St Anthony Falls, where riparian vegetation is very limited. In addition, the lack of a flood plain and the deep channel tend to make the river as it flows through most of Minneapolis essentially into a water conduit that is depauperate in biological diversity and productivity. As mentioned above, there is little if any aquatic macrophyte growth within the river channel. Combined with the lack or paucity of riparian vegetation, this implies that there is a limited input of fresh organic matter to support a diverse aquatic food web.

Projected Changes in Water Quality following Cessation of Navigation

Projected changes in controlling factors. If commercial navigation ceases above Lock and Dam 1, the following changes are expected to occur. First, the river channel will fill in (for maintenance over time the 10-ft navigation channel will fill in (for s, see section of this report on river geomorphology)). Second, businesses in north Minneapolis that depend in whole or part on barge traffic for movement of raw materials or products will close and move elsewhere. As a result, a significant stretch of the land corridor

now used for heavy industry on the west bank of the river in north Minneapolis is likely to be redeveloped for light industrial, commercial, and even residential and park use. Third, as part of land redevelopment on both sides of the river, stormwater that now drains directly into the river is likely to be diverted through created wetlands retention/detention ponds, or other treatment devices. Fourth, the river banks north of St. Anthony Falls are likely to be converted increasingly into more natural-looking park land with a much greater amount of riparian vegetation than currently exists. It should be noted that the second, third, and fourth changes are not wholly dependent on the cessation of commercial navigation, but the loss of barge traffic at least would accelerate these changes.

Projected changes in the river. Changes in the character and quality of the river that the above landscape changes likely would produce can be divided into five main categories: (i) physical changes in the river bed and channel (geomorphological changes); (ii) changes in the chemical composition of the river water during dry weather; (iii) changes in the chemical quality of the river water during runoff events; (iv) changes in the physical and chemical character of bed sediments and (v) long-term biological/ecological changes. Changes in river morphology are described in a separate section. Projected changes in the last four categories are summarized below.

- The chemical composition of the river water during dry weather should be unaffected by changes in navigation and land use in the adjacent Minneapolis land corridor.
- The chemical quality of the river in the Minneapolis stretch should improve at least marginally during wet weather conditions (during periods of stormwater runoff). In particular, concentrations of nutrients (N and P), oxygen-demanding organic matter, heavy metals, inorganic suspended solids, and bacteria should be lower. It is uncertain whether these improvements would appear to be significant to human users of the river stretch or whether they would have significant effects on water quality and river ecology during dry weather conditions.
- Biological conditions in the river that depend strongly on river morphometry could be affected significantly by the end of maintenance dredging. This includes the possible development of riparian shrubs and grasses along the river bank, beds of (rooted) submersed aquatic macrophytes in shallow zones, and emergent macrophytes (e.g. cat tails) along some parts of the river edge. These changes likely would lead to the development of more diverse communities of benthic organisms and fish associated with the macrophyte beds.
- Biological conditions in the river related to suspended plankton (algae and bacteria) should not be affected significantly by any of the proposed changes.
- To the extent that contaminated sediments exist in the river stretch under current conditions (which is not well understood), they should be exported downstream or covered by cleaner sediments as the river channel adjusts to a new and shallower morphology after dredging stops and controls are instituted to eliminate or minimize local sources of contamination (from industrial sites along the river corridor in north Minneapolis and stormwater runoff from residential and commercial areas of Minneapolis).
- Changes in river morphology also would tend to increase the mean particle size of bed sediments, but without further studies and analysis it is not possible to say whether this would have significant effects on sediment chemistry.

The basis for the projected changes can be explained by describing the main factors controlling the chemical and biological water quality of the Minneapolis stretch of the river. First, it should be noted that the gross chemical composition of the river, including the major ions, pH, natural organic matter, and suspended load, is controlled primarily by upstream sources. The river has a large drainage basin upstream of Minneapolis, and the river has flowed more than 300 miles from its source by the time it reaches the relatively short Minneapolis stretch. No significant tributaries enter the river in the Minneapolis stretch. Consequently, the chemical composition of the water reflects upstream sources much more than sources within the Minneapolis stretch. During dry weather, concentrations of nutrients (nitrogen and phosphorus) and various pollutants, including bacteria, oxygen-demanding organic matter, trace organic pollutants (pesticides, industrial chemicals), and trace metals also are controlled largely by upstream inputs.

During wet weather, local stormwater runoff can bring significant quantities of common pollutants (e.g. suspended solids, nutrients, bacteria, oxygen-demanding organic matter) into the river stretch. Although data are lacking on the quantitative significance of this pollution, it is likely that the effects at least are measurable. However, it also is likely that the effects are very short-lived because of the short hydraulic residence time of the river stretch. In fact, the residence time is too short for local loadings of nutrients to express themselves in terms of increased phytoplankton growth and higher chlorophyll concentrations within the river stretch. The common pollutants listed above also arise from urban stormwater that flows into the river above the Minneapolis stretch. In addition, agricultural stormwater runoff from areas further to the north and west probably contribute nutrients, suspended solids and organic matter to the Minneapolis stretch during wet weather. Without more detailed studies, it is not possible to quantify the relative importance of near-upstream lands versus land contiguous to the Minneapolis river stretch as sources of the common pollutants mentioned above.

During wet weather, industries on the west side of the river in north Minneapolis and the power plant on the east side of the river could be important sources of sediment and water contaminated with specific chemical pollutants such as PAHs, organic solvents and heavy metals, for which there may not be important sources upstream. Redevelopment of the industrial corridor on the west side of the river would eliminate most of this potential source of contaminants.

Biological conditions in the river depend not only on chemical conditions but also on physical habitat. Indeed, many biological/ecological conditions depend more on physical habitat than on water chemistry (so long as toxic conditions are absent and chemical conditions are within a broad range in which organisms can live). This is especially so for nonplanktonic communities, such as rooted macrophytes, and the organisms that depend on such communities. In contrast, suspended bacteria and phytoplankton depend primarily on water chemistry conditions, which are controlled primarily by upstream sources rather than local inputs, as explained above.

Finally, to the extent that contaminated sediments in the river bottom are result of local sources of pollution (this is somewhat speculative), these should dissipate or be covered with cleaner sediments as the river channel adjusts to a new steady state morphometry in the absence of maintenance dredging. The basis for concluding that the mean particle size of bottom sediments

may increase slightly in the absence of dredging is based on the conclusion (see section on river morphometry) that the average water velocity will increase slightly as the channel adjusts to its new shape. Because the ability to maintain particles in suspension increases with velocity of flow, on average the particles that reach the bottom of the future channel would be slightly larger than under current conditions.

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