SIAM CASE STUDY: KANKAKEE RIVER BASIN, INDIANA AND ILLINOIS

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Abstract The Kankakee River extends from South Bend, Indiana to its confluence with the Illinois River near Wilmington, Illinois. The river has a 5,165 square mile drainage area and a length of about 150 miles, reduced from approximately 250 miles historically. The watershed once included the Grand Kankakee Marsh, a 400,000-acre freshwater wetland system. The process of channelizing streams and draining the landscape has had impacts on the hydrology, hydraulics, sedimentation, and ecology of the watershed and channel network. Increased sediment loads associated with channelization and changed land use are of particular concern.

Sediment data were compiled from multiple sources, and analyzed to give average annual values. The data varied in time periods measured, analysis methods used, types of data collected, and the variability of measured values over time. The estimates are reasonably consistent with the available data.

The Sediment Impact Analysis Methods (SIAM) model was used to rapidly evaluate alternatives for sediment management on a watershed basis, as well as the impacts of those alternatives on channel stability within the watershed and downstream sediment supply (Gibson, 2006). Once the model was set up, different management alternatives were compared and evaluated relatively quickly. SIAM provides the sponsors and stakeholders a scientific and defendable method of comparing alternatives for watershed sediment management. This work was performed using both Regional Sediment Management (RSM) Program and project funding.

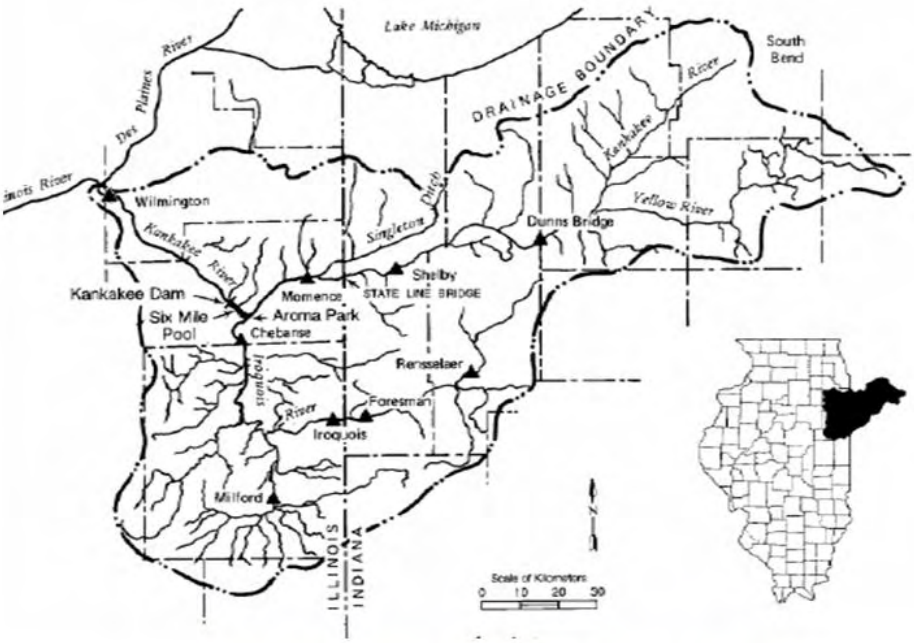
PROBLEM DEFINITION

Background of Kankakee River Basin The Kankakee River extends from South Bend, Indiana to its confluence with the Illinois River near Wilmington, Illinois (Figure 1). The river has a 5,165 square mile drainage area and a length of about 150 miles, reduced from approximately 250 miles historically. The watershed once included the Grand Kankakee Marsh, a 400,000-acre freshwater wetland system. The process of channelizing streams and draining the landscape has had impacts on the hydrology, hydraulics, sedimentation, and ecology of the watershed and channel network. Increased sediment loads associated with channelization and changed land use are of particular concern.

Sediment Concerns and Opportunites The Kankakee River basin has a history of sediment concerns. The upstream portion of the watershed in Indiana was channelized by 1918, while the mainstem of the river in Illinois was left in a largely natural alignment. Sites where concerns have been identified include the following:

- wetlands area downstream of state line (Illinois)
- areas of gravel and cobble substrate (Illinois)
- lower portion of the Yellow River (Indiana).

The lower portion of the Yellow River in Indiana has aggraded to the point where the elevation of the channel bed is above the adjacent floodplain and wetlands. The Yellow River drains an area of 435 square miles. Most of the Yellow River drainage area is overlain by sand size sediment.



Kankakee River Basin, Illinois and Indiana

Figure 1 Kankakee River Basin, Illinois and Indiana.

The Illinois River Basin Restoration Comprehensive Plan is a partnership opportunity. Addressing sediment as a misplaced resource is a major focus of the proposed interagency restoration program for the Illinois River Basin.

Need for Alternative Evaluation Different sediment management measures have been proposed for reducing sediment loads within the Kankakee Basin. SIAM was proposed as a screening level model for evaluating alternatives.

HYDRAULIC AND HYDROLOGIC DATA FOR SIAM MODEL

Rock Island District (USACE) supplied a HEC-RAS model of the entire Kankakee River mainstem, along with flow-duration information at various gages (Figure 2). The Rock Island project team came up with preliminary reach definitions, based on the locations of tributaries, dams and other break points (Figure 3). Example SIAM input is shown in Figure 4.

DEVELOPMENT OF SEDIMENT LOADS AND GRADATIONS

Sediment Data Sediment data have been compiled from multiple sources, and analyzed to give average annual values. The data used as the basis for these estimates varies in time periods measured, analysis methods used, types of data collected, and in the variability of measured values over time. The estimates are reasonably consistent with the available data.

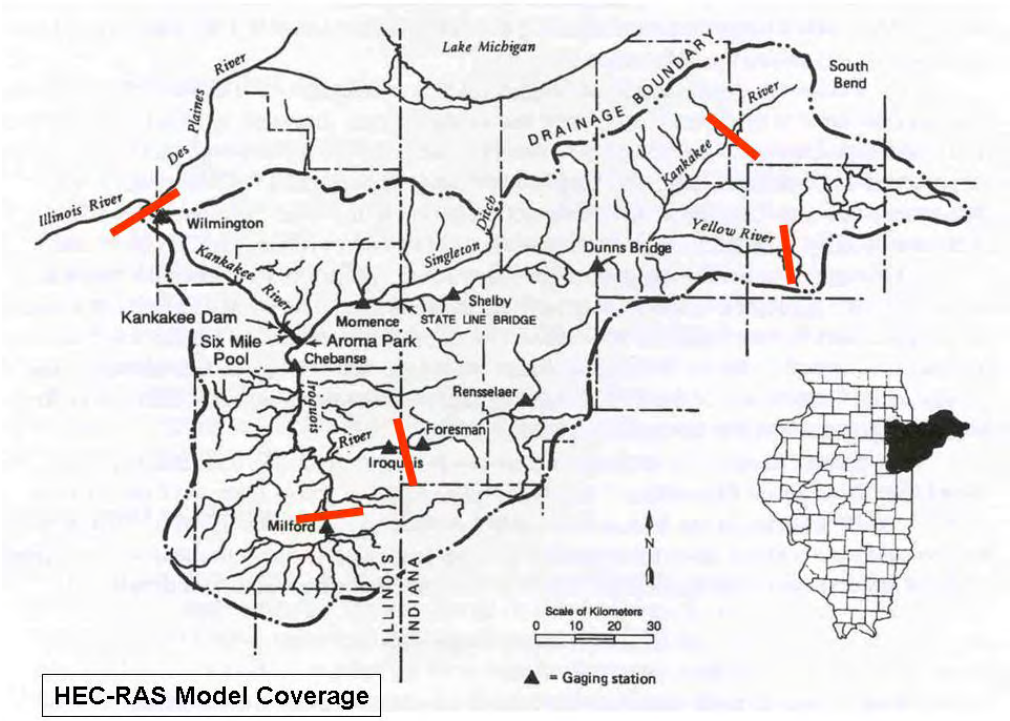


Figure 2 HEC-RAS Model Coverage.

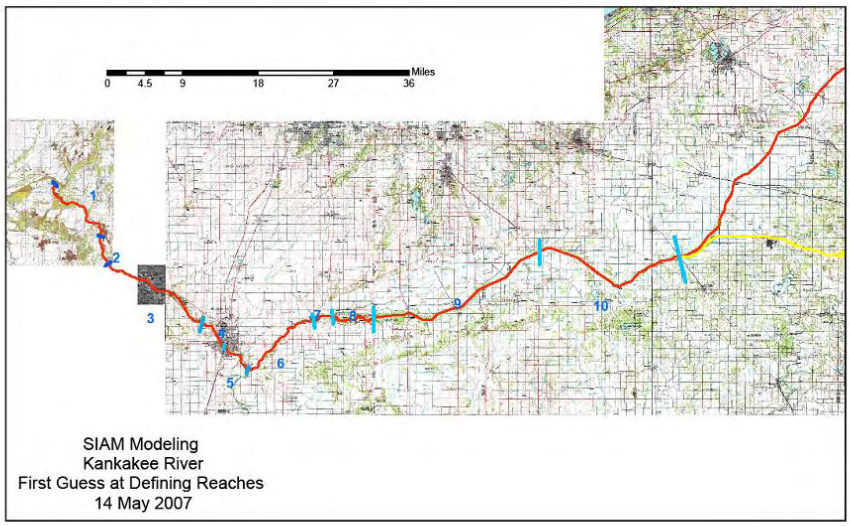


Figure 3. Trial Definition of SIAM Reaches.

Annual average sediment loads were first estimated from data on loads and yields from the Indiana and Illinois portions of the river basin. Data on the relative percentages of fines (silts and clays) and sands (in the suspended load) were then used to refine these estimates. Particle size distribution data were used to estimate percentages in each size class. Some estimates were made for sources and sinks of sediment in the reaches studied.

Average Annual Loads Data for average annual sediment loads in the Kankakee River basin were located from the review of existing reports. These data are required to run the SIAM (Sediment Impacts Analysis Model) for existing conditions. For the current modeling work, data are required for the mainstem of the Kankakee River and major tributaries. Computed loads from different studies varied in time period covered, quantity of data, and the units of the final output. Fortunately, there is relatively good coverage of the basin, and good overlap of studies. The discussion below covers the data available, methods used to reduce data to average annual values, and the recommended results for average annual sediment loads.

Data Sources Although many reports were reviewed, data from three studies listed were used as primary sources: Demissie et al (2004), Holmes (1997), and Crawford and Mansue (1996). Two additional sources were used for corroboration: Bhowmik and Bogner (1981) and Demissie et al (1983). These gave data on suspended loads for water years 1979-1981 at Wilmington, Momence, Chebanse, and Iroquois.

Discussion of Data Available The data from these sources were compiled and compared. Key data are listed below.

Demissie et al (2004) gives a computed average annual sediment load for the Kankakee River at the mouth of 846,900 tons per year. The result is an average over a twenty-year period (1981-2000). This number is the only average annual value given for the basin, and has been used to normalize the data from other studies.

Holmes (1997) gives total sediment loads (in tons) for the study period of three years (1993-1995) for six gages, listed below. The last two gages (located in Indiana) overlap with the gages included in Crawford and Mansue (1996).

a. Kankakee River near Wilmingon, IL
b. Iroquois River near Chebanse, IL
c. Iroquois River at Iroquois, IL
d. Kankakee River at Momence, IL
e. Singleton Ditch at Schneider, IN
f. Kankakee River at Shelby, IN

Crawford and Mansue (1996) gives estimated mean annual suspended sediment yield (tons per square mile per year) for seven gages in the Kankakee River basin (the study covers the entire state of Indiana). The estimates are described as imprecise. The bulk of the data were collected from 1978-1982. The seven gages are listed below.

a. Kankakee River at Shelby, IN
b. Singleton Ditch at Schneider, IN
c. Yellow River at Plymouth, IN
d. Kankakee River at North Liberty, IN
e. Cobb Ditch near Kouts, IN
f. Iroquois River near Foresman, IN
g. Iroquois River at Rosebud, IN

Use of data from Demissie et al (2004) Demissie et al. (2004) gives the average annual suspended sediment load for the Kankakee River at the mouth (5165 square miles) for 20 years of record (1981-2000). To compute the average annual sediment load at Wilmington, it was necessary to estimate (and subtract) the average annual yield for the 15 square miles of contributing drainage area. Based on various estimates of yield for the lower Kankakee, an average annual value of 307 tons/mi2 was used. This gave an adjusted average annual value for the Kankakee River near Wilmington (5150 square miles) as 842,300 tons per year.

Use of data from the Holmes study (Holmes, 1997) The Holmes study measured sediment loads at multiple gages in the Kankakee River basin. The Wilmington gage was the most downstream gage, and the two most upstream gages were the Kankakee River at Shelby, Indiana and the Iroquois River at Iroquois, Illinois. Total sediment loads (tons) were published for each gage location for the measurement period, January 1993 through December 1995. Sediment loads were also computed for the contributing areas between gage locations. The data in the Holmes study were converted to average annual values in the following manner. For the Kankakee River near Wilmington, the Holmes study measured a sediment load of 2,010,000 tons for the three-year study period. The computed average annual sediment load for the Kankakee River near Wilmington is 842,300 tons/year (as computed above, from the data in Demissie et al). The ratio is 0.42. The rest of the loads in the Holmes study were multiplied by the same ratio (0.42) to convert them to annual average values.

Yellow River Basin The estimated average annual yield for the Yellow River at Plymouth, Indiana (86 tons per square mile, from Crawford and Mansue, 1996) was used to compute an average annual suspended load for the entire basin (430 square miles) of 37,000 tons from watershed sources. An estimate of sediment load from streambank erosion (24,000 tons) was included because of the known presence of eroding banks. This material has a delivery ratio of 100% (USDA, SCS NEH, Chapter 6). Because of the importance of the Yellow River in the overall basin, further work in improving the accuracy and precision of the sediment figures would be very useful.

Impact of Geology and Surficial Materials on Sediment Yields The Yellow River drains sandy glacial outwash in the lower third of the drainage basin (below Plymouth), with the upper two-thirds (above Plymouth) draining soils with considerably more clay (USACE, 2006). The area of sandy glacial outwash covers the upper Kankakee down to Momence (Ivens et al, 1980, Figure 4). The suspended sediment yields from the northern lake and moraine area of Indiana tend to be much less than yields from other physiographic regions, so low values are expected in the Kankakee River basin in Indiana (Crawford and Mansue, 1996).

Overlap of data from Holmes (1994) and Crawford and Mansue (1996) The two studies overlap at two gages: the Kankakee River at Shelby, Indiana and the Singleton Ditch at Schneider, Indiana. Both values are given in the tables. At the two locations where the Indiana and Illinois USGS studies overlap, the yield values from the Illinois USGS study are 17-32% higher than the Indiana USGS values. The data from Crawford and Mansue (1996) are described as imprecise.

Bed load – estimated percentages of total load Information from studies throughout the basin is summarized below.

a. For the gaging stations at Wilmington, Momence, Chebanse, and Iroquois, the measured suspended sediment loads should be close approximations of the total sediment load. For the gages at Momence and Wilmington, this is because the river bed at both locations is rocky, and highly turbulent flows keep the sediment load in suspension at both of these stations (Bhowmik et al., 1980). At the Iroquois and Chebanse gages, the suspended load should be close to the total sediment load since the sediment transported in the Iroquois River is mainly silt and clay (Bhowmik et al., 1980).

b. The ISWS analysis at the State Line estimated that 1.7 percent of the suspended load or 1.6 percent of the total load is transported as bed load (Bhowmik et al, 1980).
c. Bhowmik et al (2004) estimated bed load percentage as 5 to 10 percent of total load (for the Stateline Bridge to the Kankakee Dam).
d. Sediment loads were not increased to account for bedload in this set of computations.

General procedure for estimating loads, yields, and gradations for existing conditions The following procedure was used:

a. The average annual suspended loads were estimated using the data and methods given above.
b. The percentages of sand and fines were estimated using available data from various sources. The loads were divided into sands and fines, and were compared along the basin for reasonable values. The yields were determined for sands and fines, as was the sand percent in the total load. These figures were compared with other available data.
c. Estimates of deposition were made for three locations (Yellow River above mouth, the Momence Wetlands, and the Six-Mile Pool).
d. Some data values were assumed to be fixed (the total average annual load at Wilmington is a good example). However, most data points could be modified within a range of reasonable values from the various data s sources. The determination of the best estimates for the sediment loads and gradations was an iterative procedure.
e. After the loads, yields, and fine-sand split seemed reasonable for the entire basin, the entire particle size distribution was assigned. The ratio of clay to silt was determined. The percent of sand in the different size classes was determined using appropriate sampled data. These percentages were entered into the spreadsheet to break the loads and yields down into individual size classes.

Estimates of Sediment Loads and Sources in the Kankakee Basin This analysis gives a “first cut” evaluation of where sediment comes from in the Kankakee River basin, and provides input for the SIAM model. Results are shown in Figures 5, 6, and 7.

Fine sediment load estimate The average annual load of fine sediment delivered to the Illinois River is 770,000 tons and comes from these sources:

a. Contributing area below the Iroquois River: 25%
b. Iroquois River: 52%
c. Upper Kankakee River: 23%

Sand load estimate The average annual load of sand delivered to the Illinois River is 77,000 tons and comes from these sources:

a. Contributing area below the Iroquois River: 8%
b. Iroquois River: 22%
c. Upper Kankakee excluding the Yellow River: 31%
d. Yellow River: 39%

Kankakee River - Percent of cobble and bedrock Ivens et al (1981) summarizes substrate data from biological sampling done in 1979. This data was taken for the seven biological sampling stations on the Kankakee mainstem. The percentage of bed material that is gravel, cobble and bedrock ranges from 0 to 80 percent of the substrate. This data is helpful in representing the portion of the substrate not included in collected bed material samples (e.g. bedrock and cobble).

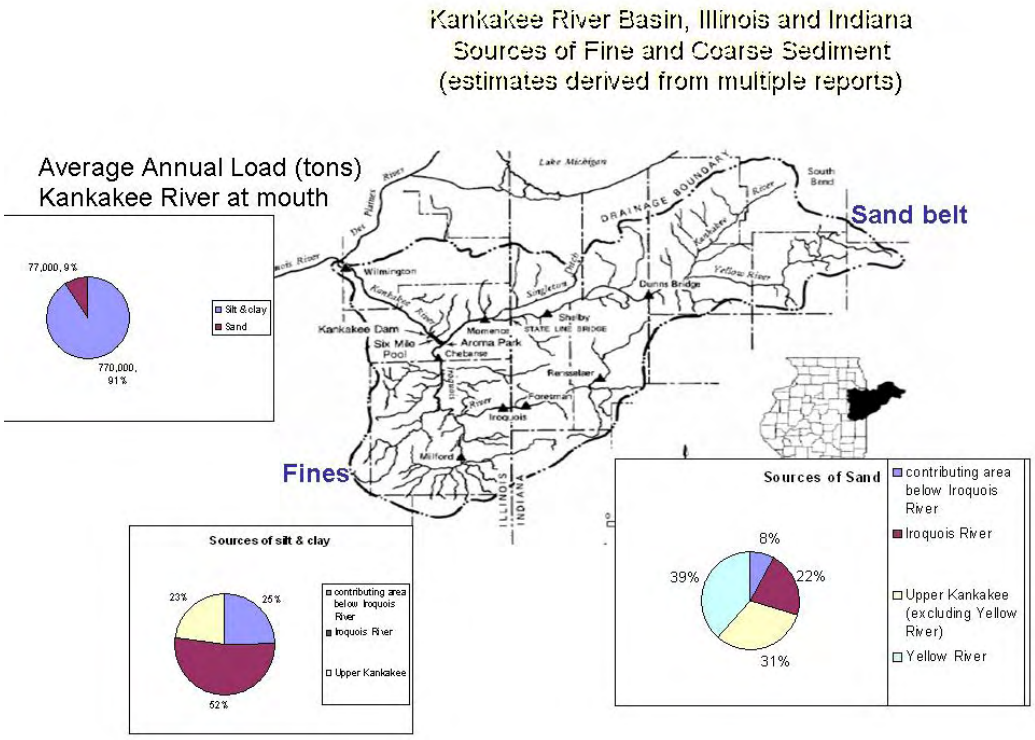


Figure 5 Sources of Fine and Course Sediment.

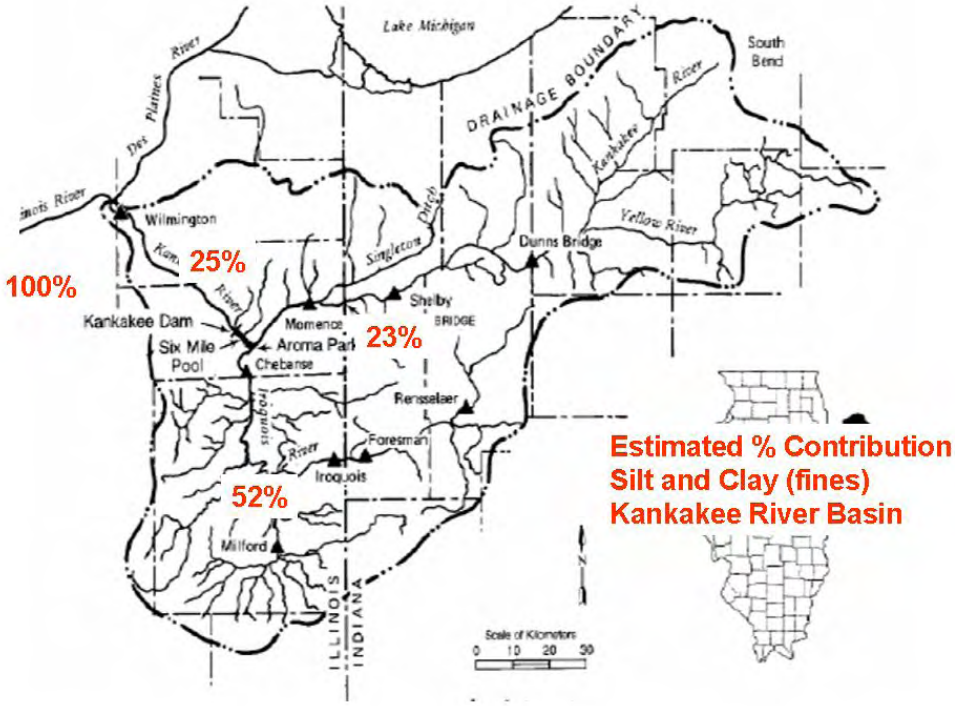


Figure 6 Contribution of Fine Sediment.

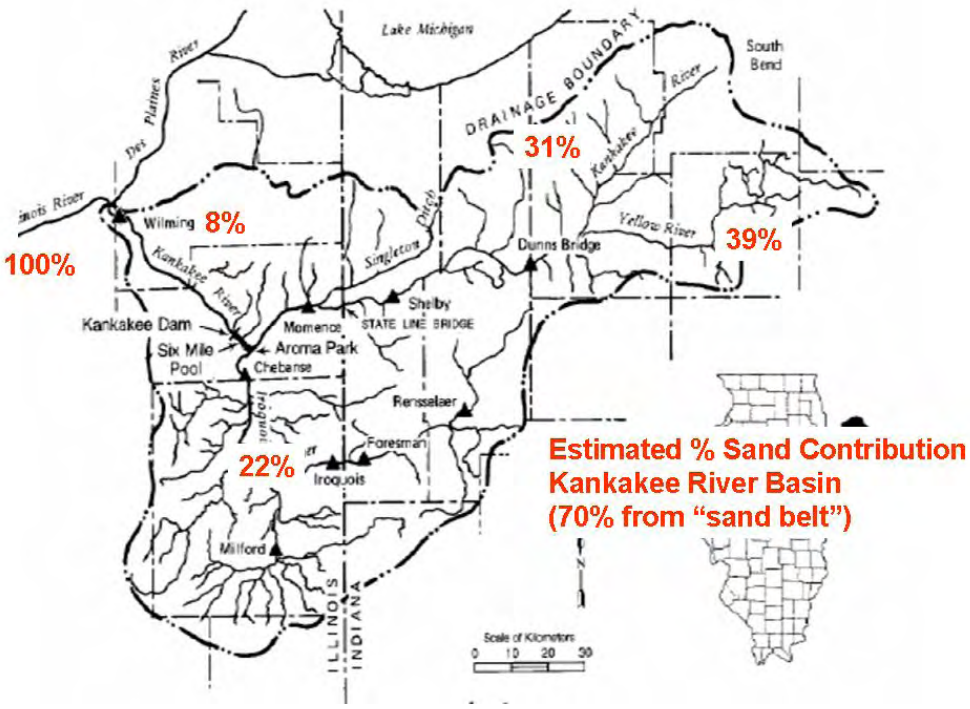


Figure 7 Contribution of Sand-Size Sediments.

SIAM MODELING OF ALTERNATIVES AND DISCUSSION OF RESULTS

Selected Alternatives for SIAM analysis The model was run for existing conditions and the following five alternatives. The final reaches are shown in Figure 8.

- Existing conditions
- Alternative 1: Remove bank erosion source from Yellow River
- Alternative 2: Reduce watershed source loads from Yellow River by 50 percent
- Alternative 3: Reduce watershed source loads from Iroquois River by 50 percent
- Alternative 4: Reduce watershed source loads from Kankakee River above state line by 50 percent
- Alternative 5: Simulate re-meandering of Kankakee River reach from state line through Shelby (SIAM reach M5) by increasing HEC-RAS channel lengths by a factor of 3.

Preliminary Results of SIAM modeling The preliminary results are shown in Figure 9.

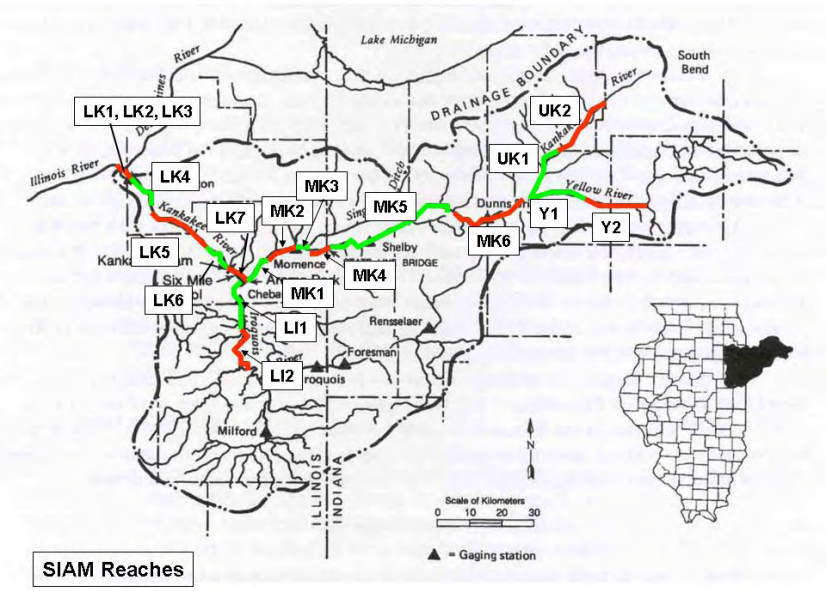


Figure 8 SIAM Reaches.

Kankakee – Preliminary SIAM Results

SIAM - **PRELIMINARY RESULTS** - Local Balance and Total Load in tons/year

Reach	Existing local bal	Existing total	Alt 1 local bal	Alt 1 total	Alt2 local bal	Alt2 total	Alt3 local bal	Alt3 total	Alt4 local bal	Alt4 total	Alt5 local bal	Alt5 total
LK1	0	947,000	0	943,000	0	931,000	0	738,000	0	895,000	0	947,000
LK2	-4,508	1,077,000	-4,508	1,073,000	-4,508	1,061,000	-4,508	868,000	-4,508	1,025,000	-4,508	1,077,000
LK3	0	917,000	0	914,000	0	901,000	0	708,000	0	866,000	0	917,000
LK4	-124,000	922,000	-124,000	918,000	-124,000	906,000	-124,000	712,000	-124,000	870,000	-124,000	922,000
LK5	0	715,000	0	711,000	0	699,000	0	506,000	0	663,000	0	715,000
LK6	0	683,000	0	679,000	0	667,000	0	473,000	0	631,000	0	683,000
LK7	69,300	643,600	69,300	639,600	69,300	627,600	69,300	434,600	69,300	591,600	69,300	643,600
MK1	-12,500	295,300	-12,500	292,300	-12,500	279,300	-12,500	295,300	-12,500	244,300	-12,500	295,300
MK2	0	217,000	0	213,000	0	201,000	0	217,000	0	165,000	0	217,000
MK3	-21,100	174,500	-21,100	170,500	-21,100	158,500	-21,100	174,500	-21,100	122,400	-21,100	174,500
MK4	2,081	146,400	2,081	142,400	2,081	130,400	2,081	146,400	2,081	94,600	-16,700	146,400
MK5	-6,859	128,800	-6,859	125,800	-6,859	113,100	-6,859	128,800	-8,998	77,200	9,204	109,986
MK6	33,000	91,600	33,000	88,000	33,000	75,600	33,000	91,600	30,900	52,900	35,700	88,912
UK1	2,974	22,033	2,974	22,033	2,974	22,033	2,974	22,033	124	12,423	2,978	22,029
UK2	2,413	5,987	2,413	5,987	2,413	5,987	2,413	5,987	1,153	3,047	2,413	5,987
LI1	-18,900	439,600	-18,900	439,600	-18,900	439,600	-18,900	229,600	-18,900	439,600	-18,900	439,600
LI2	-1,765	240,765	-1,765	240,765	-1,765	240,765	-1,765	121,765	-1,765	240,765	-1,765	240,765
Y1	19,800	72,100	-569	68,500	18,000	56,200	19,800	72,100	18,000	56,200	19,800	72,100
Y2	-30,900	55,900	-30,900	55,900	-31,600	44,200	-30,900	55,900	-31,600	44,200	-30,900	55,900

degradational or less sediment

aggradational or more sediment

Total load computed for downstream end of reach
Total load is mostly (but not all) fines.

Alt 1 - Yellow River bank erosion reduced by 100% (sand)
Alt 2 - Yellow River watershed yield reduced by 50%
Alt 3: Iroquois River watershed source loads reduced by 50 percent
Alt 4: Kankakee River (above state line) watershed source loads reduced by 50%
Alt 5: Re-meandering of Kankakee River reach from state line through Shelby (SIAM reach M5)

Figure 9 Preliminary SIAM Results for Existing Conditions and Five Alternatives.

General Discussion of Results Since the bed material in the Kankakee River coarsens downstream (unusual in a watershed), any reduction in wash load from an upstream source persists downstream to the Illinois River. In reaches with a sand bed, any reduction in incoming sand load is compensated for by additional transport of material from the channel bed. This will shift the local sediment balance towards degradation. However, in the short term, the impacts of reducing bed material load are local, and do not persist significantly downstream.

SIAM is not a movable-bed model. The terms "aggradation" and "degradation" do not refer to bed changes, but to the tendency to aggrade or degrade based on local bed material balance and sediment continuity. Long-term morphological adjustments (over years or decades) will cause the results to change.

Results for Alternative 1 - Yellow River bank erosion reduced by 100% Alternative 1 reduces the estimated bank erosion contribution in the lower Yellow River reach (Y1) to zero. This is all sand, and mostly bed material. The reduction in wash load (4,000 tons) persists all the way downstream to the Illinois River. The reduction in bed material load contributed by the banks (20,000 tons approx) is immediately compensated for by increased transport from the bed. This results in a major reduction in aggradation in this reach. No impacts on bed material are seen downstream. (The contribution from bank erosion contribution is estimated.)

Results for Alternative 2 - Yellow River watershed yield reduced by 50% Alternative 2 reduces the Yellow River watershed yield, which is almost entirely wash load. The 16,000 tons reduction in wash load persists all the way to the Illinois River. The small reduction in bed material load (in reaches Y1 and Y2) changes the local balance by almost 2,000 tons in each reach. (Y1 becomes more degradational; Y2 becomes less aggradational.) There is no change in local balance downstream.

Results for Alternative 3 - Iroquois River watershed yields reduced by 50% Alternative 3 reduces the Iroquois River watershed yield, which is entirely wash load. This reduction in wash load (over 100,000 tons) persists all the way to the downstream to the Illinois River. Since this sediment is not bed material in any reach, there is no impact on local balance (aggradation or degradation) anywhere in the channel network. (The magnitude and gradation of the annual average sediment load from the Iroquois River are established with a high degree of confidence.)

Results for Alternative 4 - watershed yields reduced by 50% for the Kankakee River above the Indiana State Line Alterative 4 reduces the Kankakee River watershed yield in Indiana (reaches MK5-6, UK1-2, and Y1-2). This is almost entirely wash load. The reduction in wash load contribution (50,000 tons approx) persists downstream to the Illinois River. The reductions in bed material load (1,000 to 2,000 tons per reach) result in less aggradation (or increased degradation) in reaches MK5-6, UK1-2, and Y1-2. No impact in local balance is computed for reaches downstream.

Results for Alternative 5 - Re-meandering of the Kankakee River above the Indiana State Line Alterative 5 simulates a re-meandered reach in MK5 (above the Indiana state line through Shelby). The reach lengths in HEC-RAS were increased by a factor of 3. The reduced channel slope caused reduced velocities, reduced sediment transport capacity, and increased stages. This alternative had no significant impact on the wash load, and no significant impact on the wash load downstream. This alternative reduced the bed material sediment transport capacity in MK5 significantly, and changed the local balance in the reach from degradational to aggradational (a net change of approx 15,000 tons). The reach upstream (MK6), which was already aggradational, would be slightly more aggradational from the increased backwater from MK5 downstream. A major impact of this alternative is felt at the next reach downstream (MK4). Since less bed material load is delivered to MK4, the sediment balance shifts toward

degradation. This impact does not persist downstream. (This was a preliminary evaluation to see how this alternative operated with a basic flattening of bed slope. The impacts of a modified cross section were not evaluated.)

SUMMARY AND CONCLUSIONS

The SIAM model was demonstrated successfully on a relatively large watershed (5200 square miles). The model was run for existing conditions and five alternatives. The work was conducted collaboratively with Rock Island District. The district supplied the HEC-RAS models and the hydrologic data that served as the foundation for the SIAM model. Additional information was gained from the extensive reports produced by the Illinois State Water Survey, a field investigation, and a detailed evaluation of the existing data on sediment loads and gradations. SIAM provided an accurate overview of sediment processes and linkages at a watershed scale.

The model was able to assess the impacts of various alternatives. For instance, in the near term, the sand loads in the Kankakee River appear to be relatively insensitive to changes in the bank erosion contribution from the Yellow River. Long-term morphological adjustments (over years or decades) will cause the results to change.

Further work could include items such as the following:

- Evaluation of additional alternatives (Rock Island proposed 30 alternatives)
- Address the time element of sediment reduction
- Address changes in equilibrium slope and sediment delivery (morphologic changes)
- Improve estimates of sediment sources for both existing conditions and alternatives. (The Yellow River basin is of particular interest.)
- Extend the model to address Yellow River basin (existing conditions and alternatives) in more detail.

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