SIAM and the Systems Approach to Watershed Sediment Management

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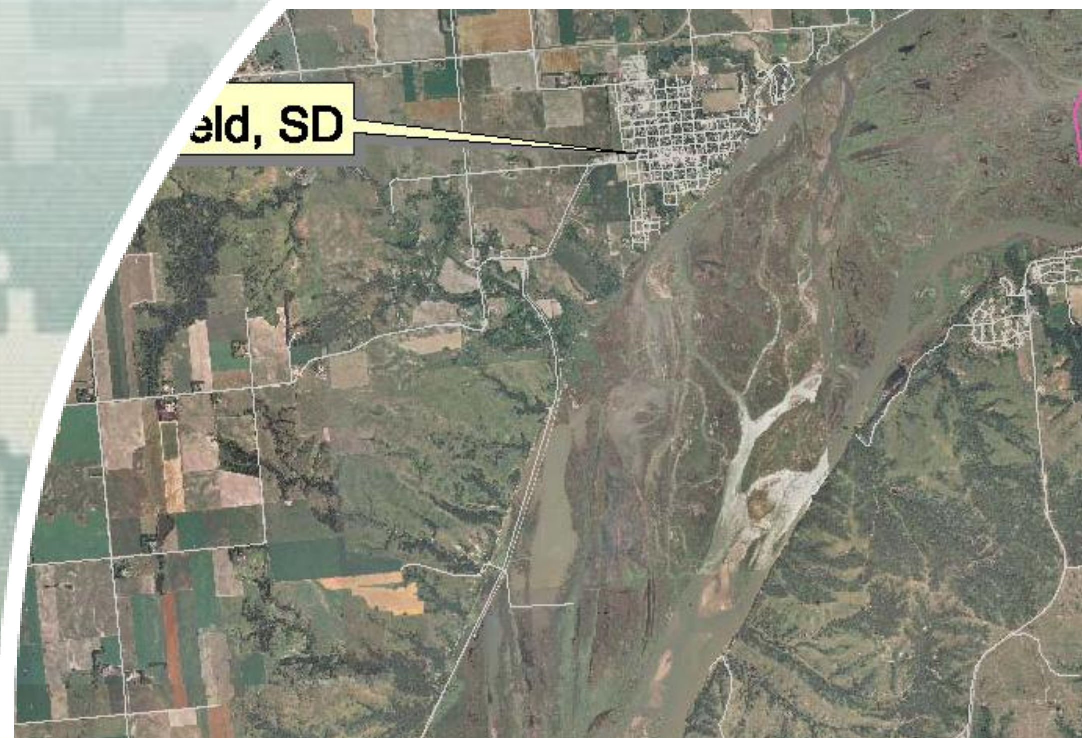

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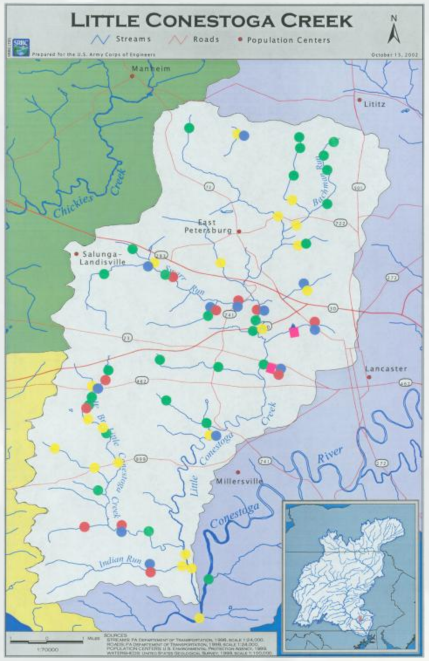
Topics

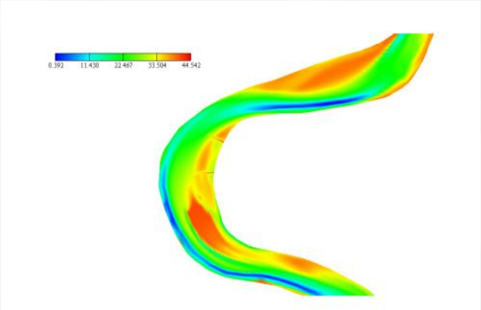
1. Geomorphic assessment and sediment budget
2. Sediment Impact Analysis Methods (SIAM) - used for sediment continuity analysis on a watershed basis

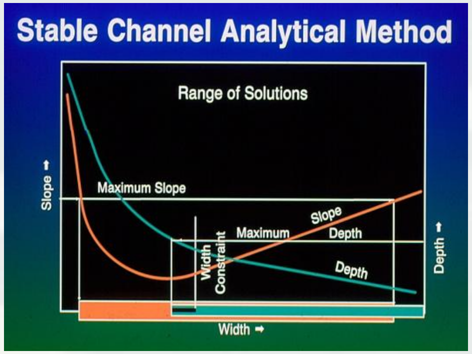
Topic 1 - Geomorphic Assessment

- Document the historical trends of the channel system
- Establish the current stability of the channel system and identification of the dominant processes and features within the system (i.e. sedimentation)
- Field and office analyses included
- Provides the foundation for projecting future trends with and without proposed project features
- Critical to the calibration of numerical models and the proper interpretation of numerical model results
- Provides rational basis for identification and design of effective alternatives to meet project goals

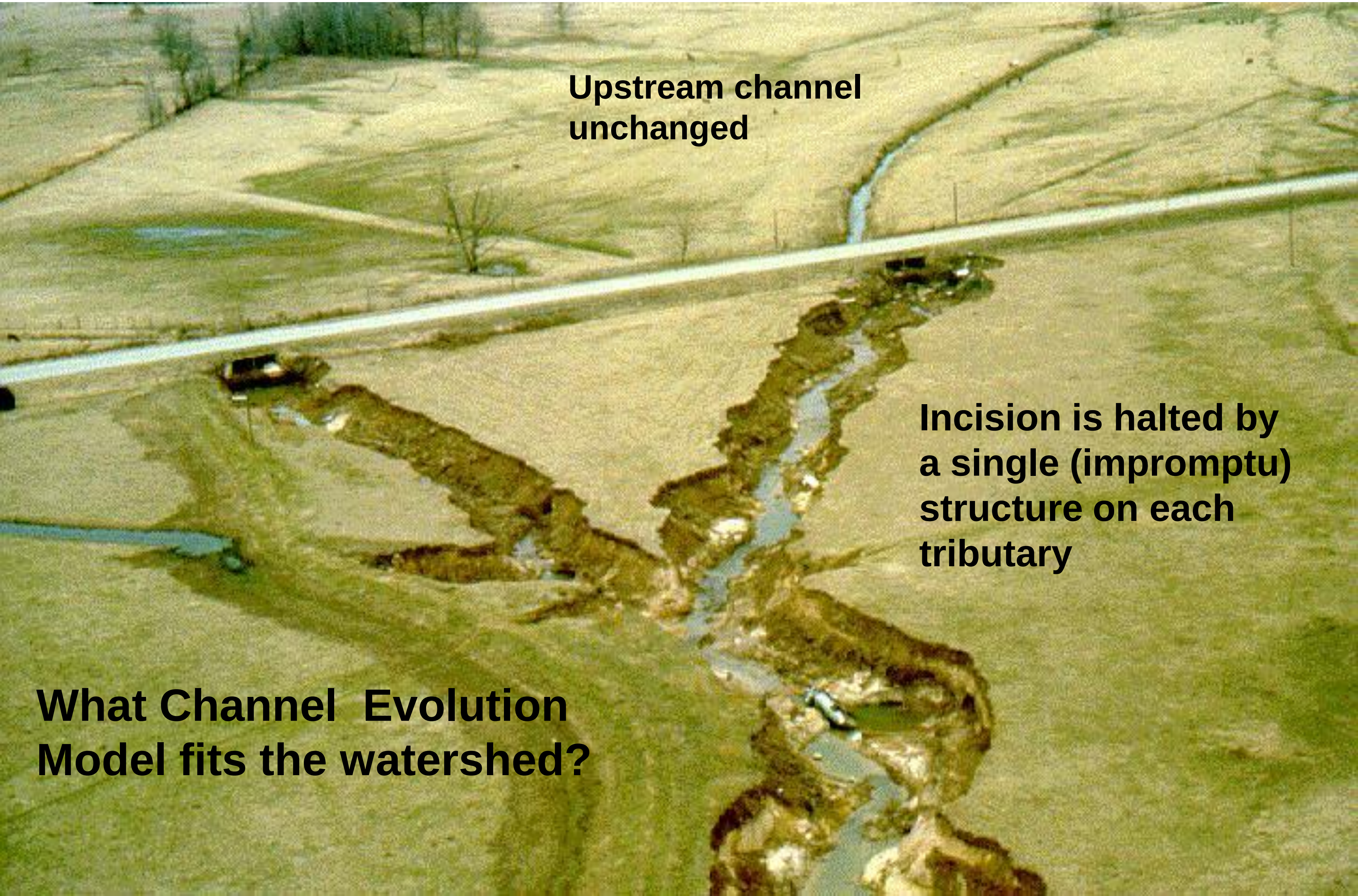
Systems Approach to Watershed Sediment Processes



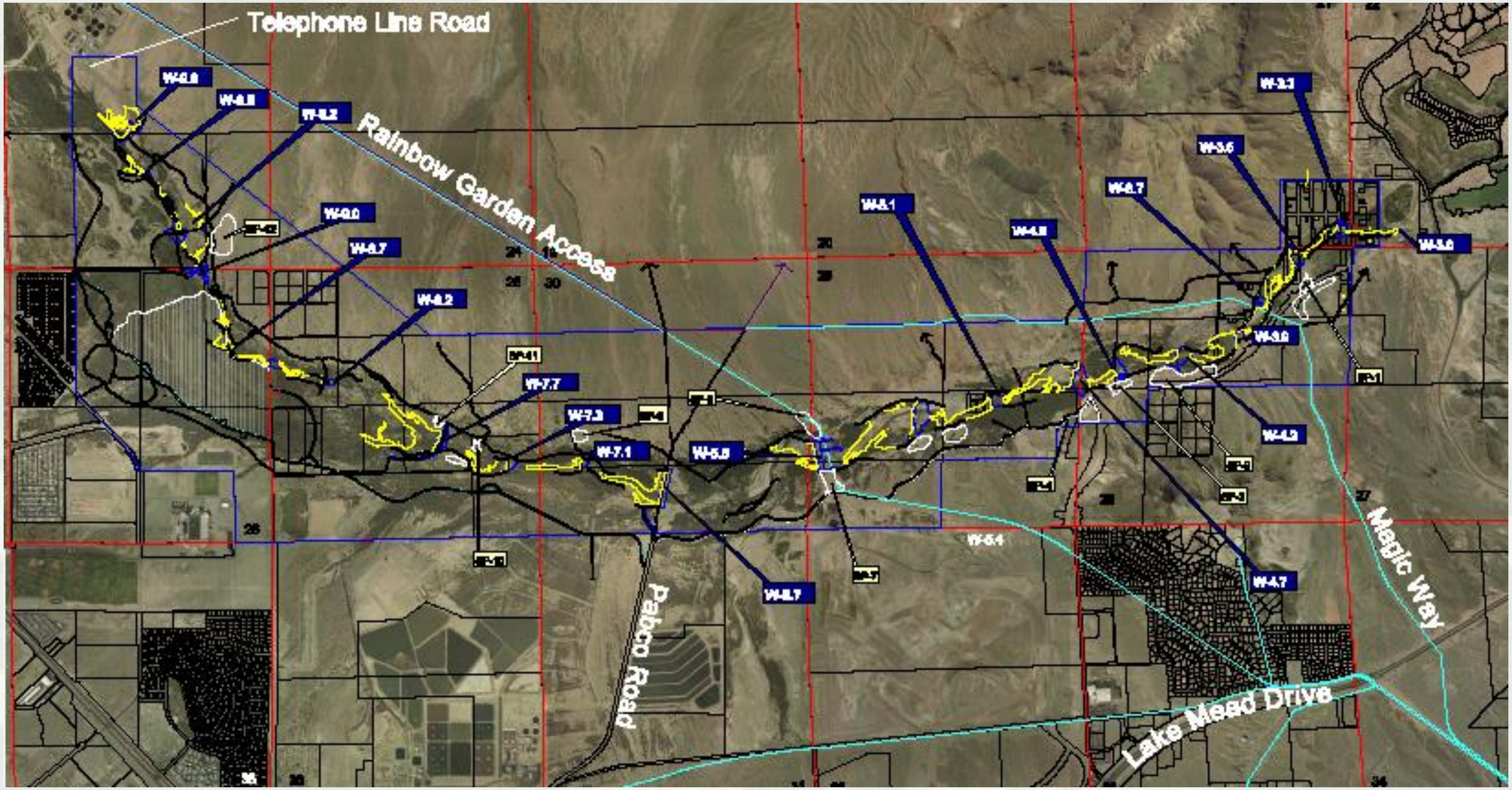




Upstream-Advancing Incision (Headcuts)



Las Vegas Wash – Grade Control Plan

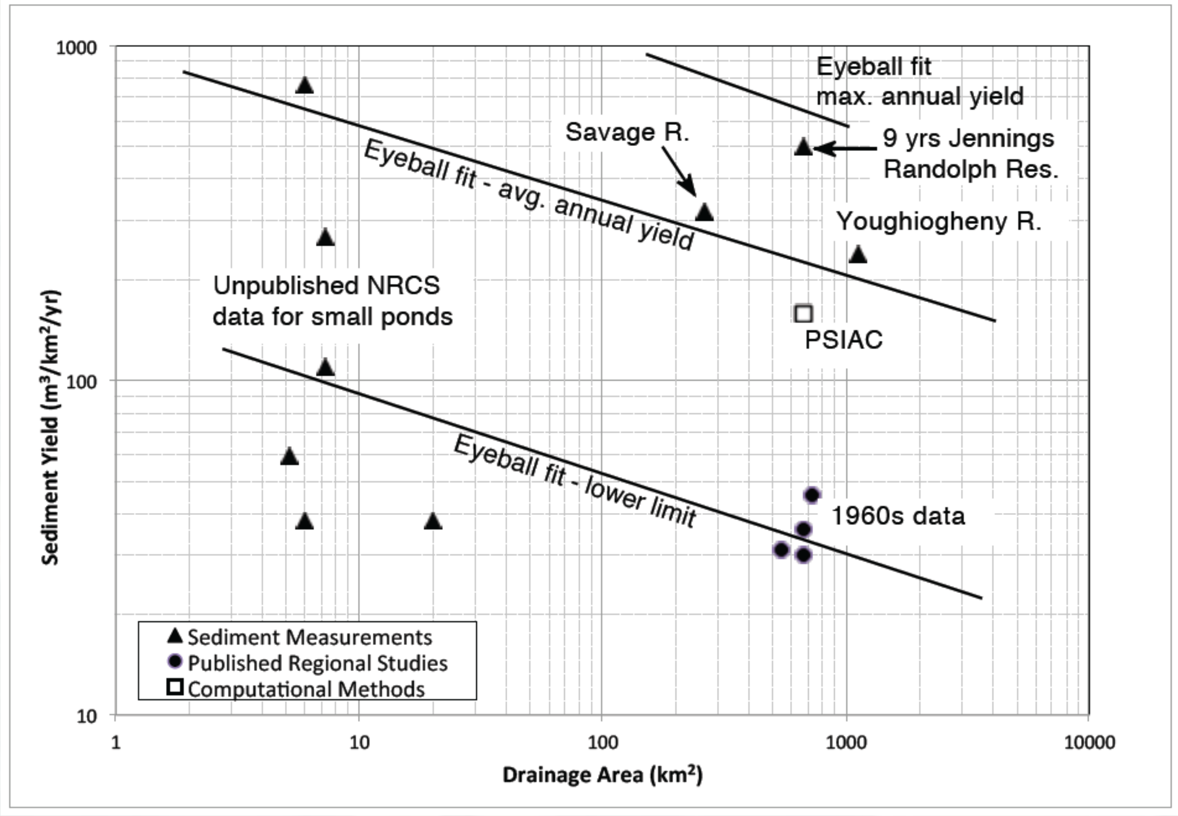


Effluent-dominated system –
Needs a different conceptual model
(note multiple grade control structures)

Sediment Budget

- Evaluate sediment sources and sinks
- Estimate loads and gradations
- Often difficult (but necessary) to reconcile all existing estimates and data
- Measured data provides validation but must be carefully reviewed (there are no perfect answers)

Discrepancies in Sediment Data



Importance of Geomorphic Assessment

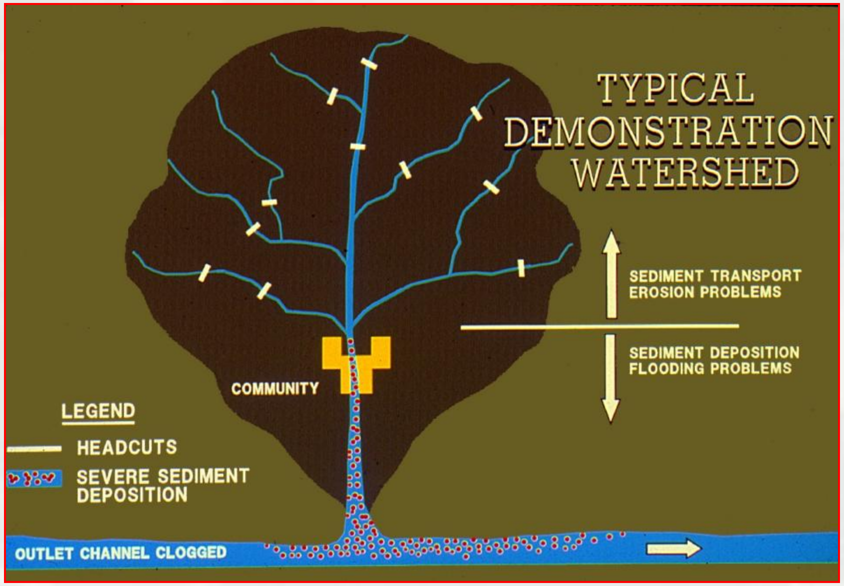
- An accurate understanding of sediment processes does not guarantee a good solution, but….
- A poor understanding of processes guarantees a bad solution.

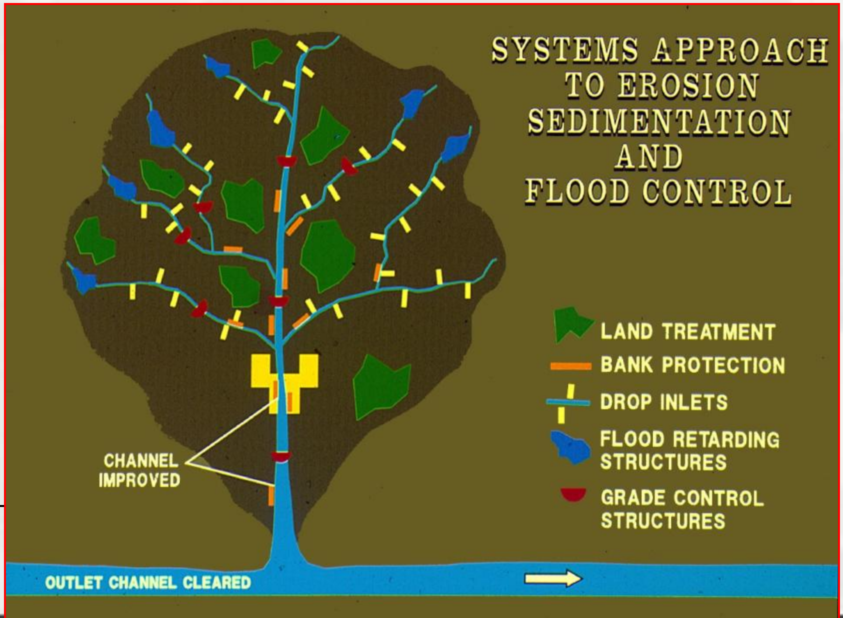
- Provides foundation for selection of objectives, attributes, alternatives, etc.

Watershed Restoration and Sediment Management

Needs:

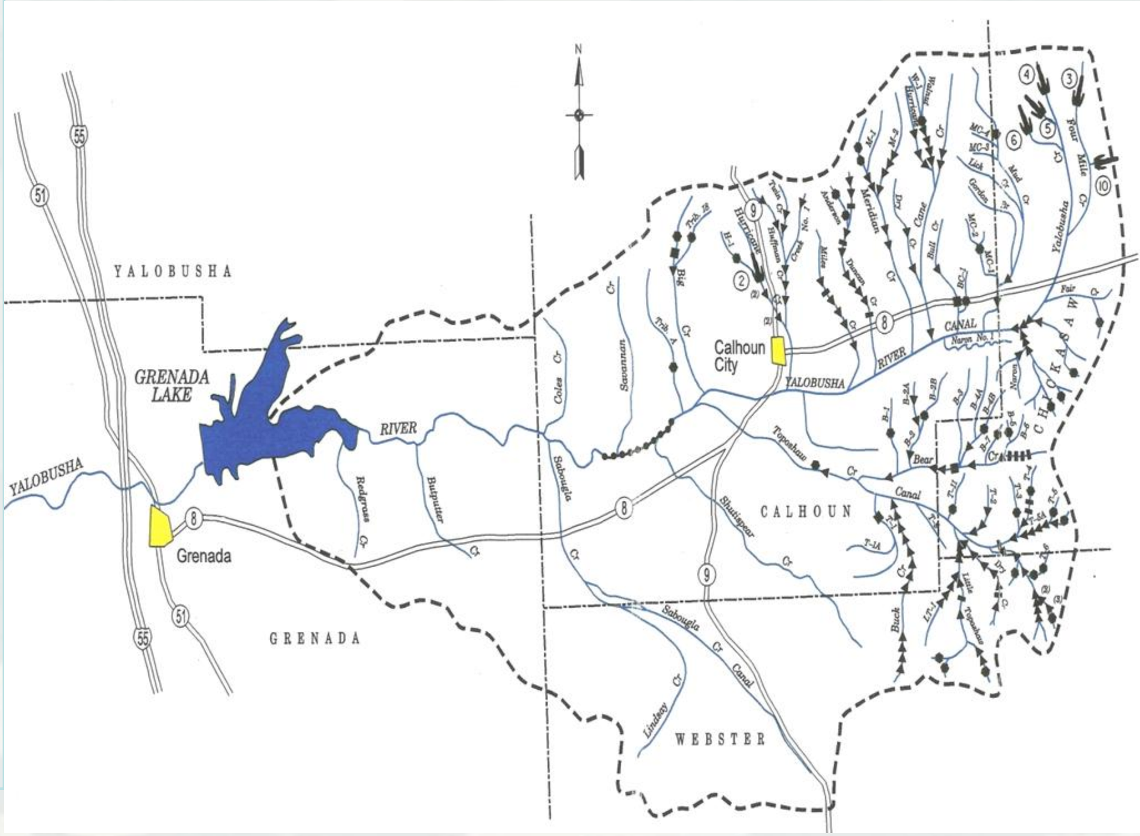
- **Evaluation of impacts on a watershed basis**
- **A tool appropriate for planning level alternative analysis**
- **Speedy and accurate evaluation of multiple alternatives**
- **Handle multiple sources of sediment (bank erosion, gullies, etc.)**
- **Evaluation long-term impacts on channel stability (equilibrium)**





Topic 2 - Sediment Impact Analysis Methods (SIAM)

- Initial development through ERDC/Colorado State University research effort on channel stability as part of Demonstration Erosion Control project. Originally conceived to assist with locating grade control structures.
- Original computer programming done by David Mooney (CSU PhD candidate, USBR).
- Incorporation into HEC-RAS through ERDC/HEC cooperative effort.



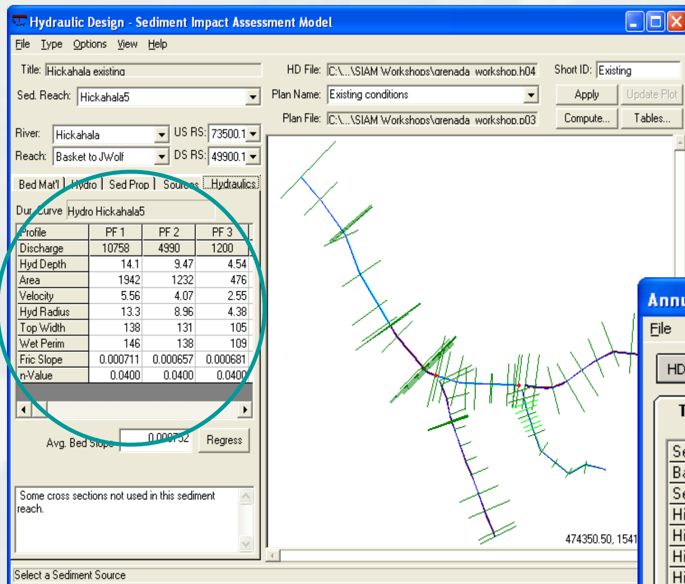
BUILDING STRONG®

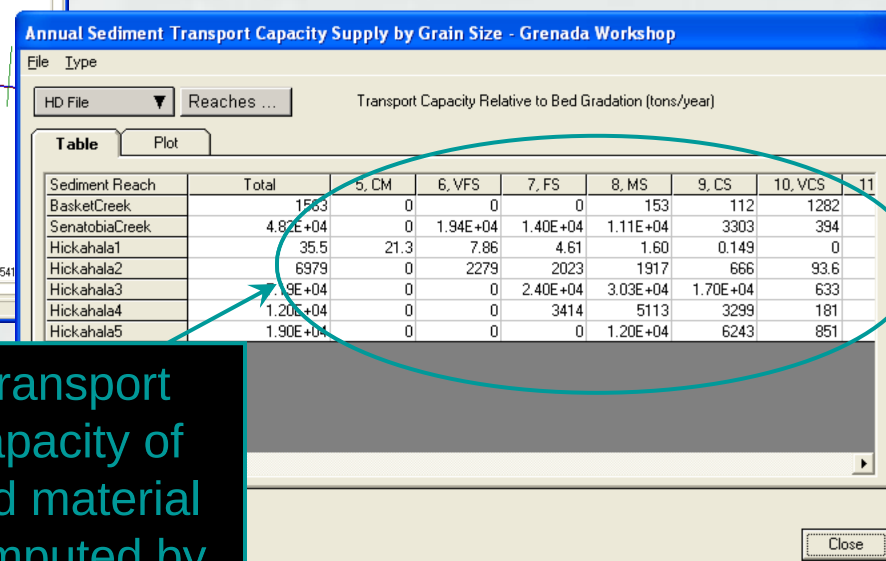
SIAM – the third generation of planning level sediment transport tools

- SIAM represents the 3rd generation of reconnaissance or planning level tools for evaluation of sediment continuity. Theoretical foundation is established; application is innovative.
- Sediment transport functions were included in Corps library software (first generation)
- SAM (Sediment Assessment Model) advanced this significantly, and added the capability of stable channel design
- SIAM incorporates this into HEC-RAS; adds the ability to evaluate an entire channel network; enables the user to add sediment sources and sinks; and routes the wash load in addition to the bed material load.
- Like SAM, SIAM fills a niche for planning level assessment.

Capabilities: SIAM is …….

A reach-based sediment continuity model. Uses reach averaged hydraulic parameters for sediment transport computations by grain size class.



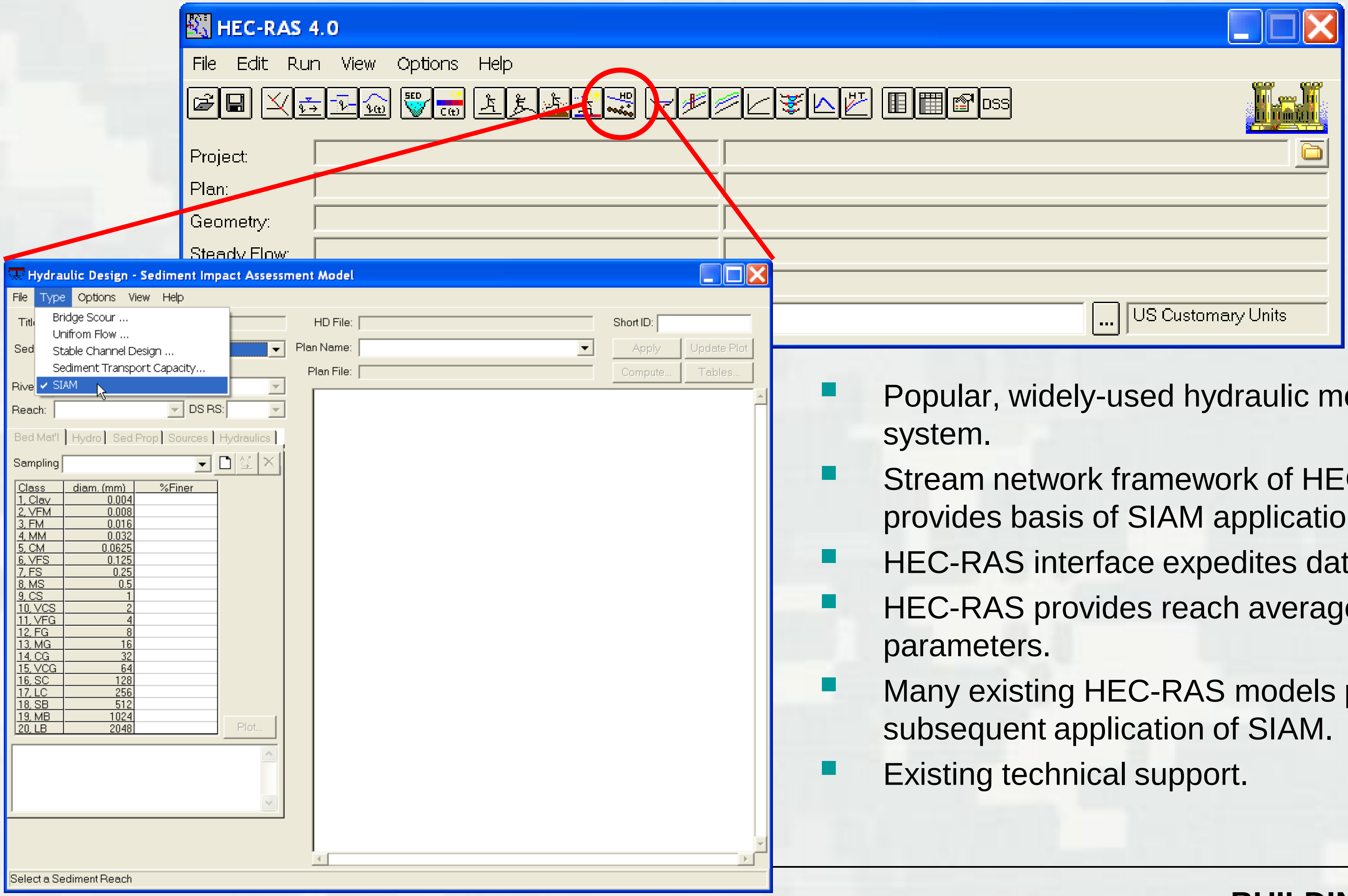


Reach averaged hydraulics from HEC-RAS results

Transport capacity of bed material computed by grain size class

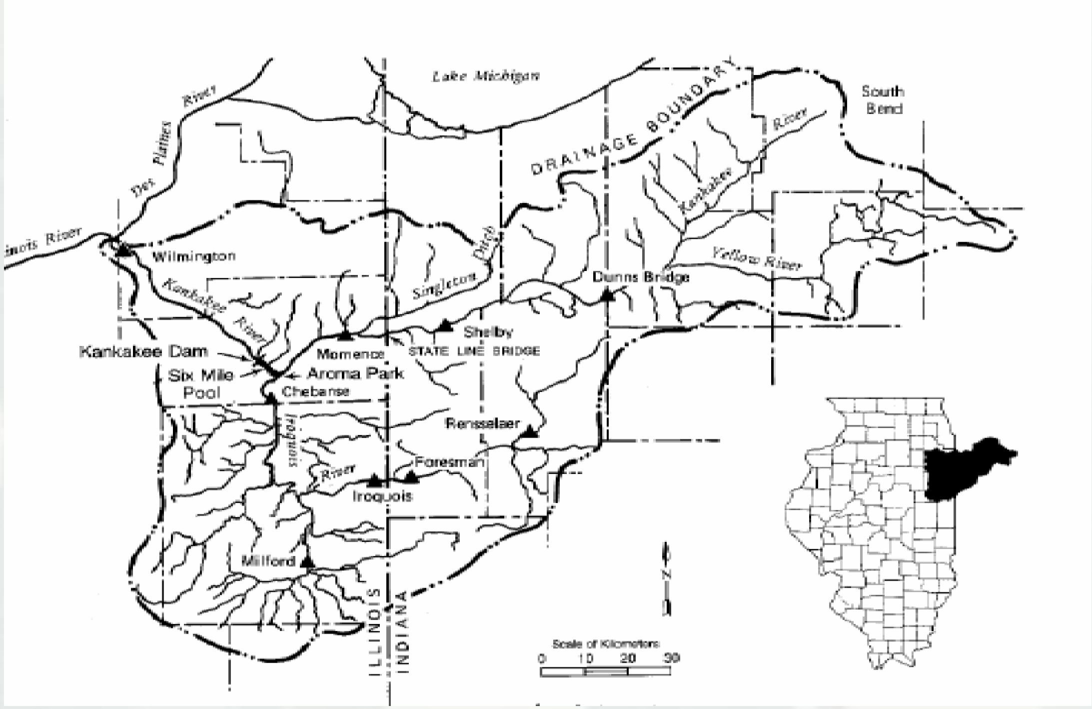
SIAM is incorporated in HEC-RAS

Hydraulic Design Module



- Popular, widely-used hydraulic modeling system.
- Stream network framework of HEC-RAS provides basis of SIAM application.
- HEC-RAS interface expedites data entry.
- HEC-RAS provides reach averaged hydraulic parameters.
- Many existing HEC-RAS models permit subsequent application of SIAM.
- Existing technical support.

Application of Sediment Impact Analysis Method (SIAM) in the Kankakee River Basin, Indiana and Illinois



Meg Jonas and Charles Little, ERDC Coastal & Hydraulics Laboratory
June 2010

Where?

- South Bend, Indiana to its confluence with the Des Plaines => Illinois River
- 5,165 square mile drainage area
  - 2,169 square miles in Illinois
  - 2,996 square miles in Indiana.
- Length of ~ 150 miles mainstem
  - Indiana portion channelized by 1918, Illinois mainstem left natural
  - Historic Indiana portion was Grand Kankakee Marsh, 400,000-acre freshwater marsh (625 sq miles). 3 to 5 miles wide, 1 to 4 feet water depth

Problem Definition

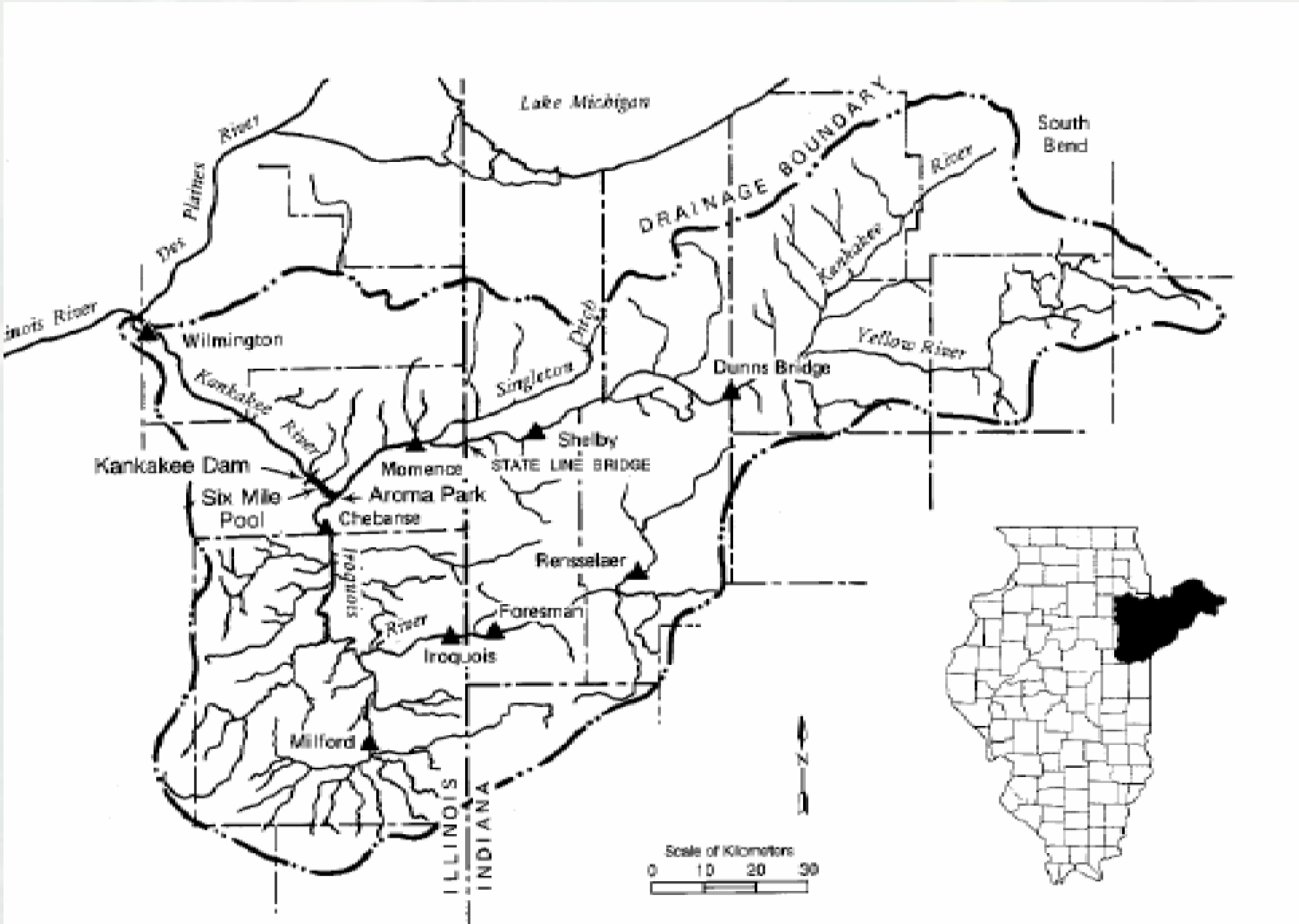
- Historic concerns over sedimentation
- Illinois:
  - ► Wetlands downstream of state line
  - ► Areas of gravel / cobble substrate
  - ► Side Channels
- Indiana:
  - ► Downstream portion of Yellow River (elevation of channel bed is above adjacent wetlands; water diversions into wetland are by gravity)


An overview of the Kankakee watershed
Watershed land use primarily agricultural

- **Most streams have been channelized**

- Kankakee 5165 sq miles
- Iroquois (silt & clay load) 2091 sq miles
- Yellow River (sand load) 435 sq mile

- The “sand belt” covers the Yellow River drainage basin



Kankakee River Basin, Illinois and Indiana

- Riffle area in lower part of Kankakee
- Excellent fishery
- Concerns about sand size sediment


Coarse Bed Material in Lower Kankakee River


Bar formation in Lower Kankakee

- Kankakee River near state line
- Illinois and Indiana

- **Yellow River – aggradation near mouth**
- **Channel bed here is above adjacent fields and wetland areas**

- Yellow River, perched channel
- Kankakee River FWA, IN

Water was originally pumped from the Yellow River (on the right) into The wetland on the left. Pumps were removed after Yellow River Aggraded. The wetland now receives water by gravity flow.


Yellow River
Sand belt

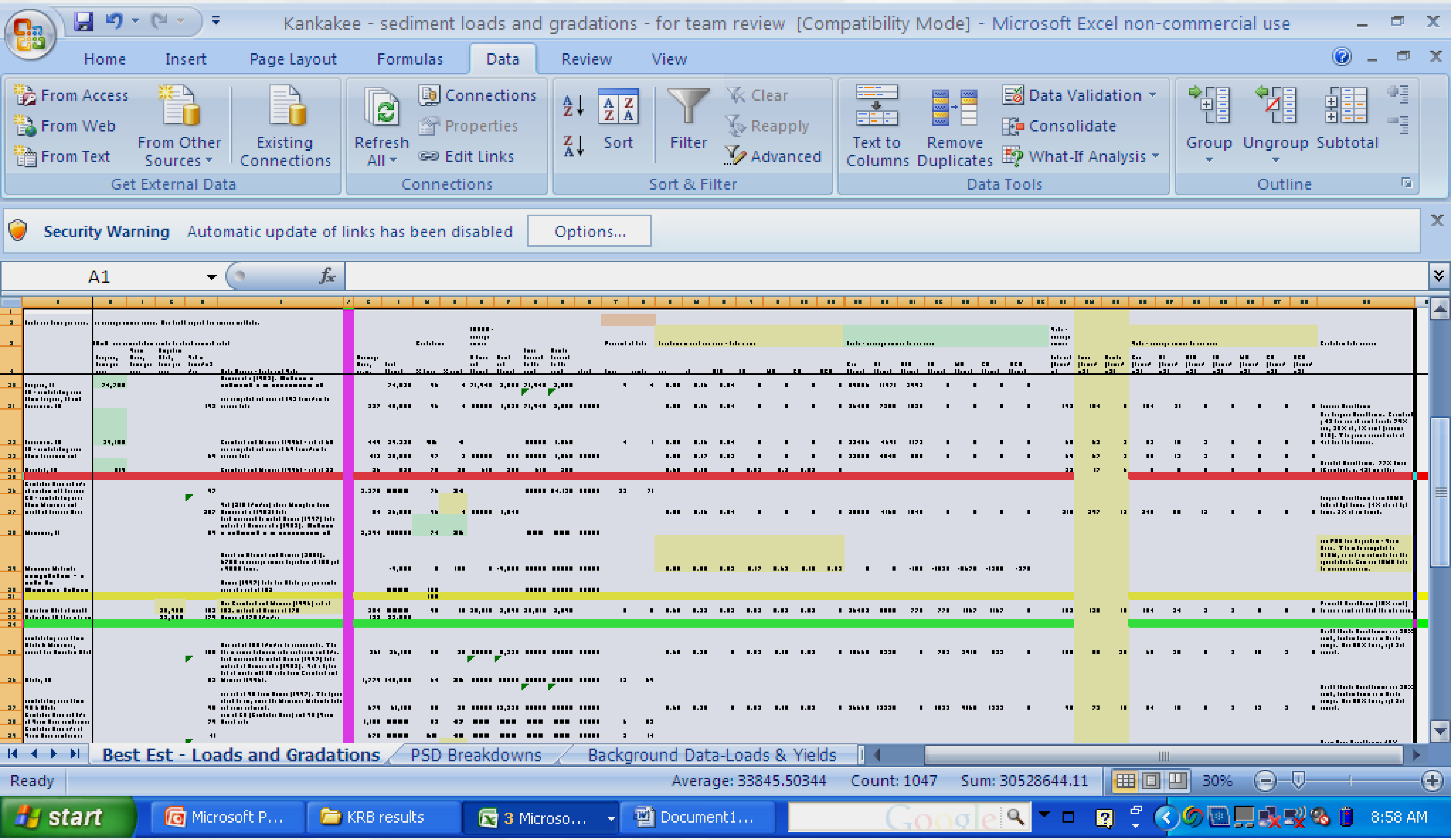
- Closeup of eroding bank
- Sand contribution from eroding banks
- Yellow River


Coarse Bed Material in Lower Kankakee River

Sediment Budget

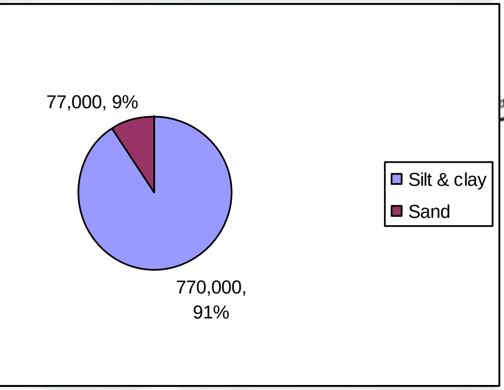
- Estimates of average annual sediment loads and gradations needed for the SIAM model
- Historic data and reports were evaluated and reconciled to develop estimates

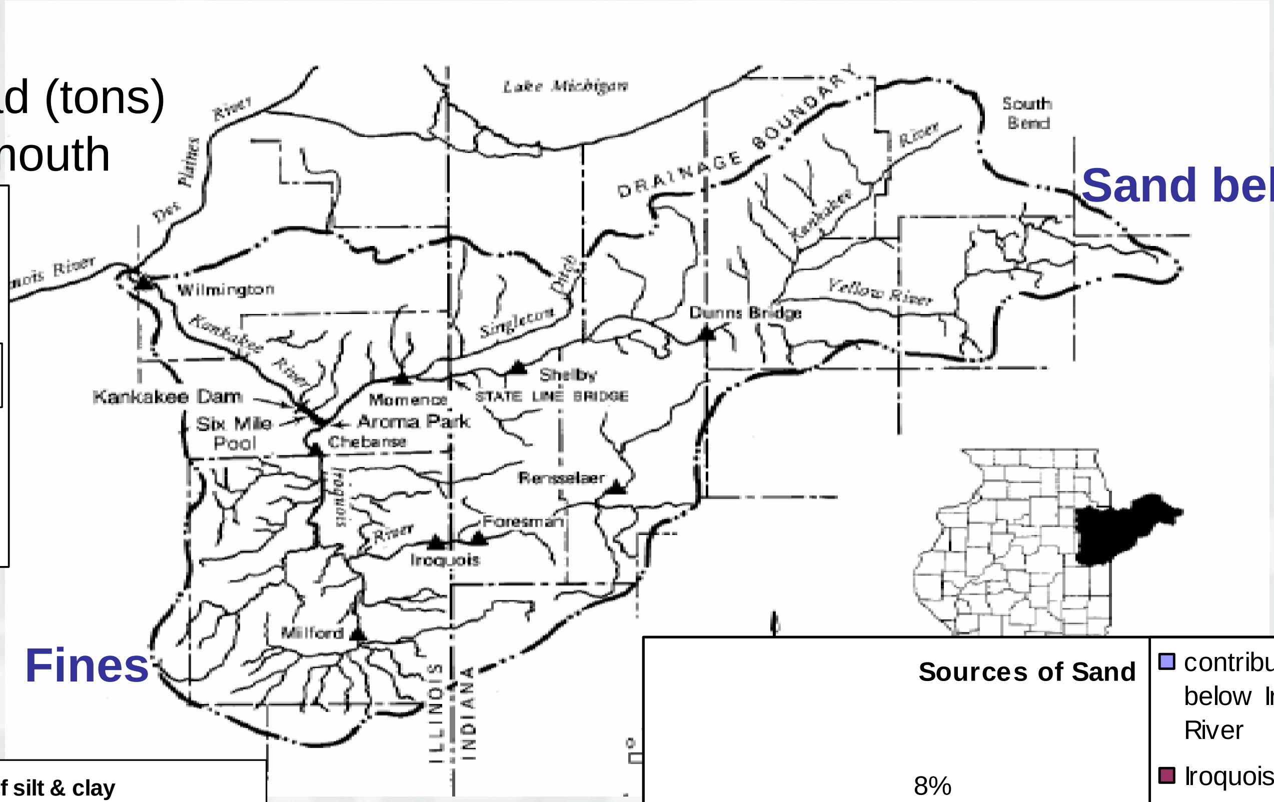
Sediment Load Data – Kankakee Basin Reconciled from13 Basin-Specific Reports

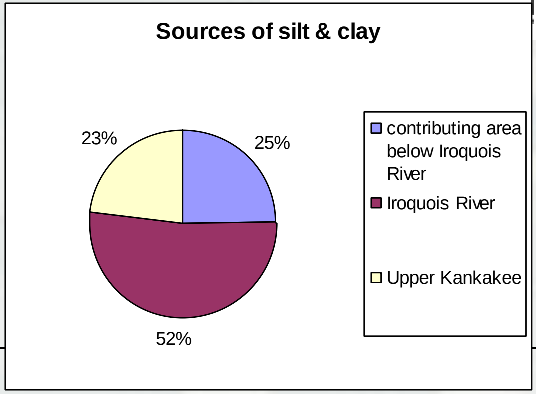


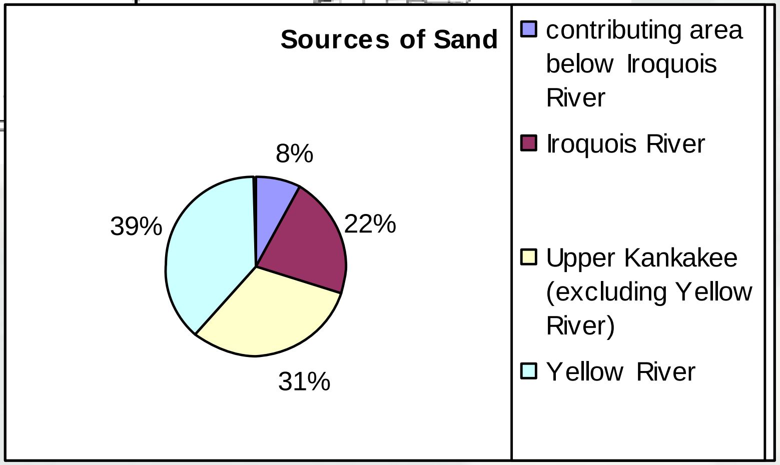
Kankakee River Basin, Illinois and Indiana Sources of Fine and Coarse Sediment (estimates derived from multiple reports)

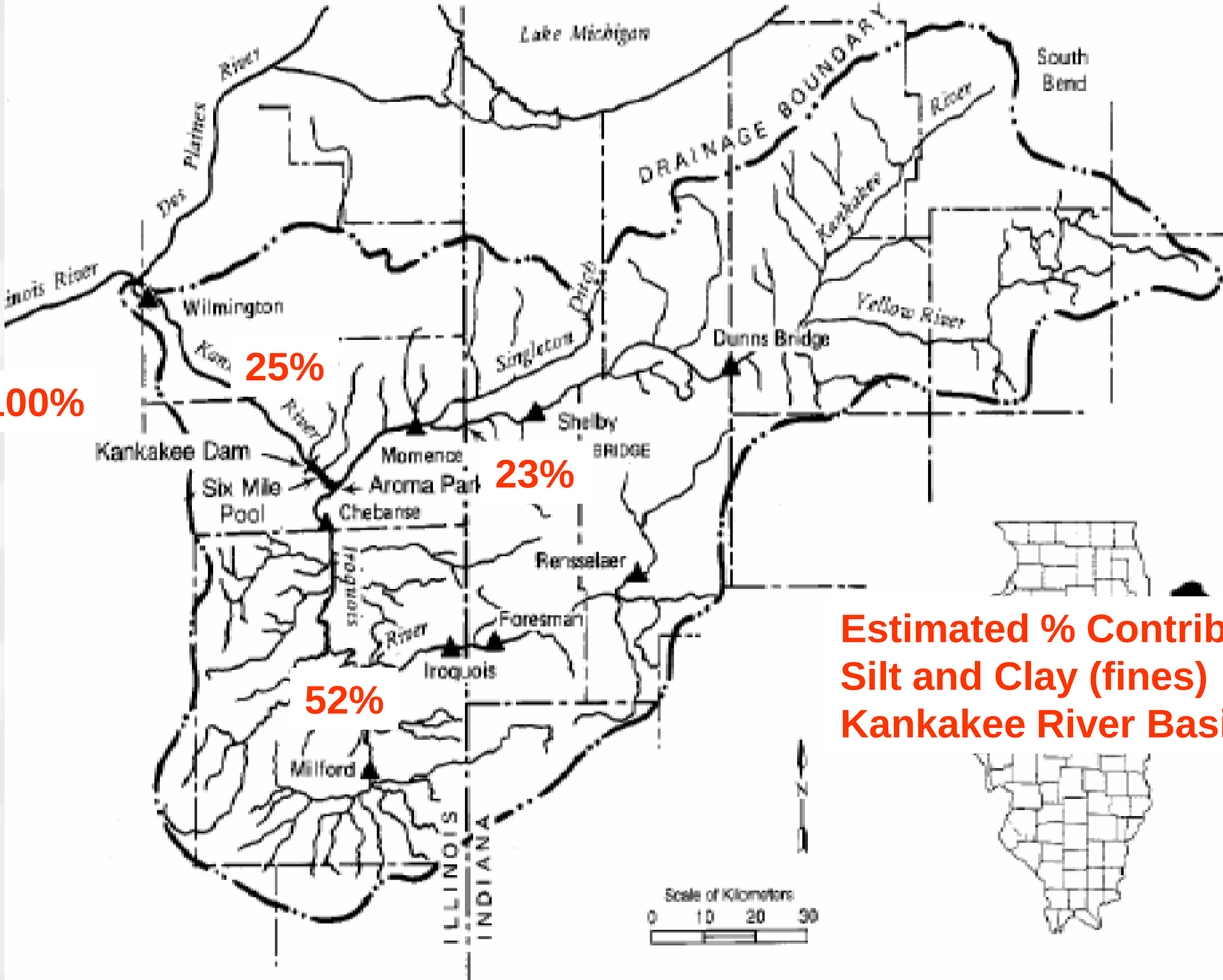
Average Annual Load (tons)
Kankakee River at mouth





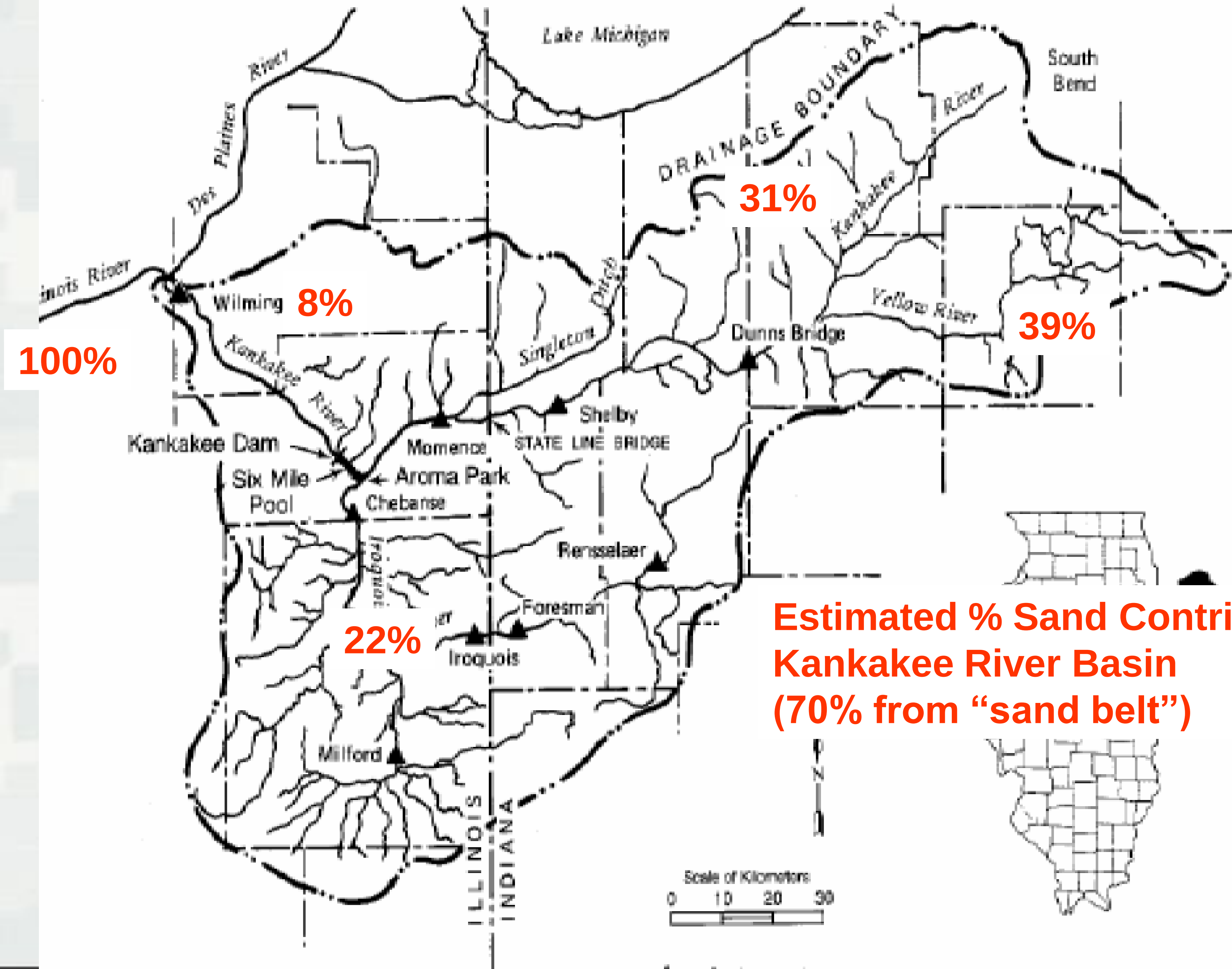




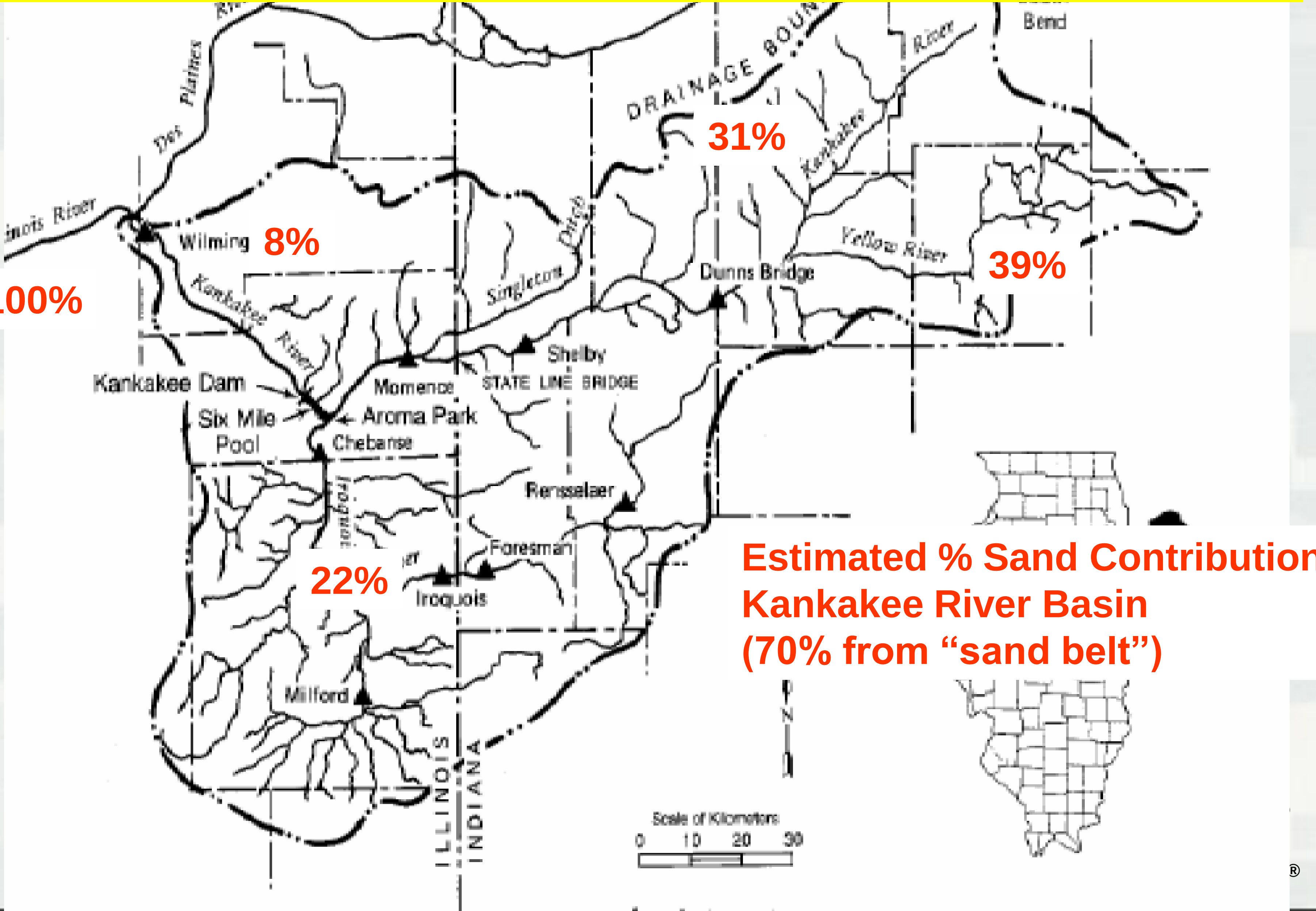


Estimated % Contribution
Silt and Clay (fines)
Kankakee River Basin

Estimated % Sand Contribution Kankakee River Basin (70% from "sand belt")



If a project goal is to decrease the amount of sand that gets to the lower Kankakee, what alternatives should be considered?



Sediment Impact Analysis Methods (SIAM)

- **General information on model background and capabilities**

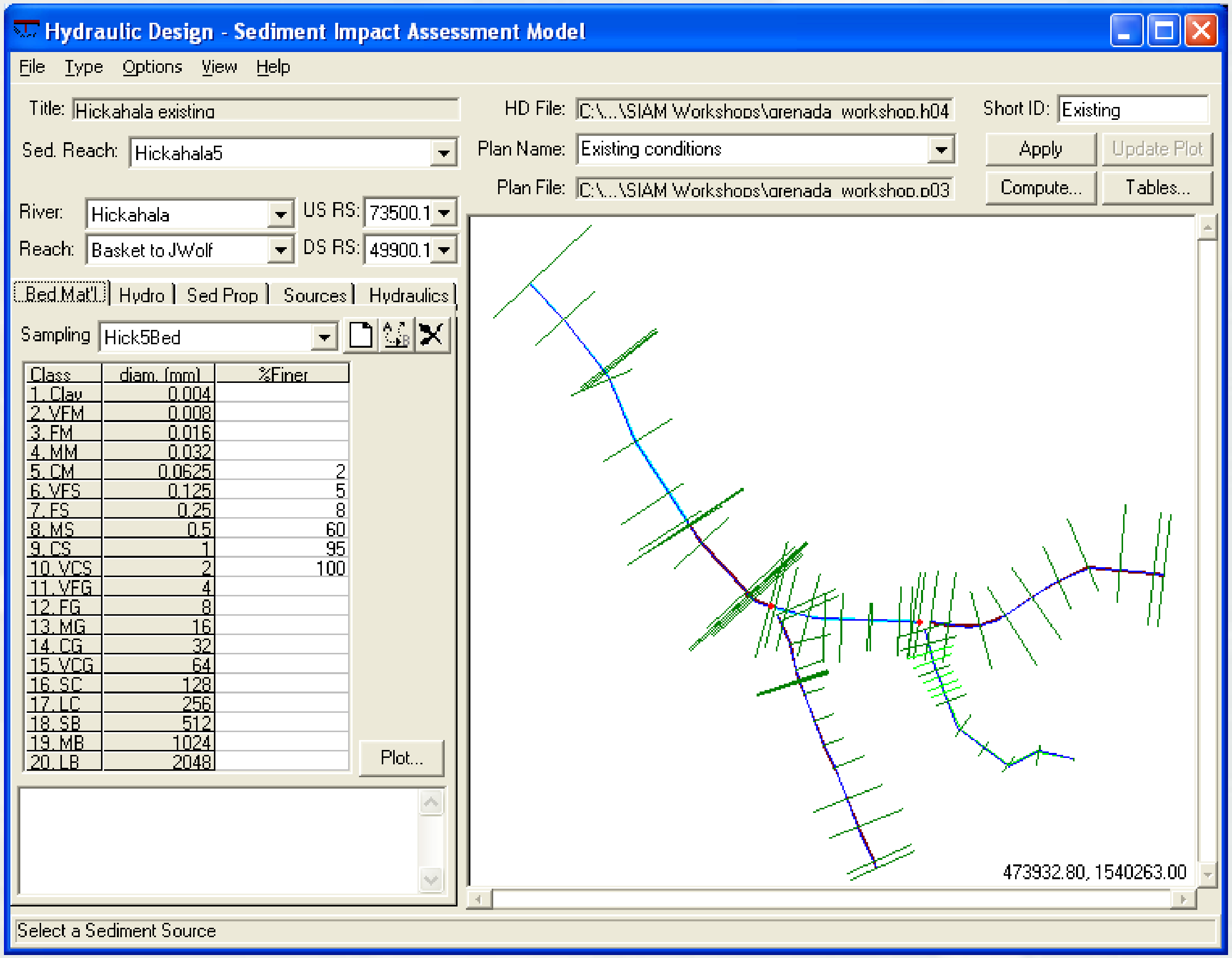
SIAM Highlights/Capabilities

- Reach-based sediment accounting
  - sediment transport parameters
- Long-term channel stability
  - grain size class.
  - Compares transport capacity with bed material supply
  - Net sediment balance for reach
- Distinguishes bed material load and wash load
  - User defined wash material threshold
  - Allows bed and wash material to interchange
- Easily manipulated to customize sediment loading.
- TIMELY ASSESSMENT OF ALTERNATIVES

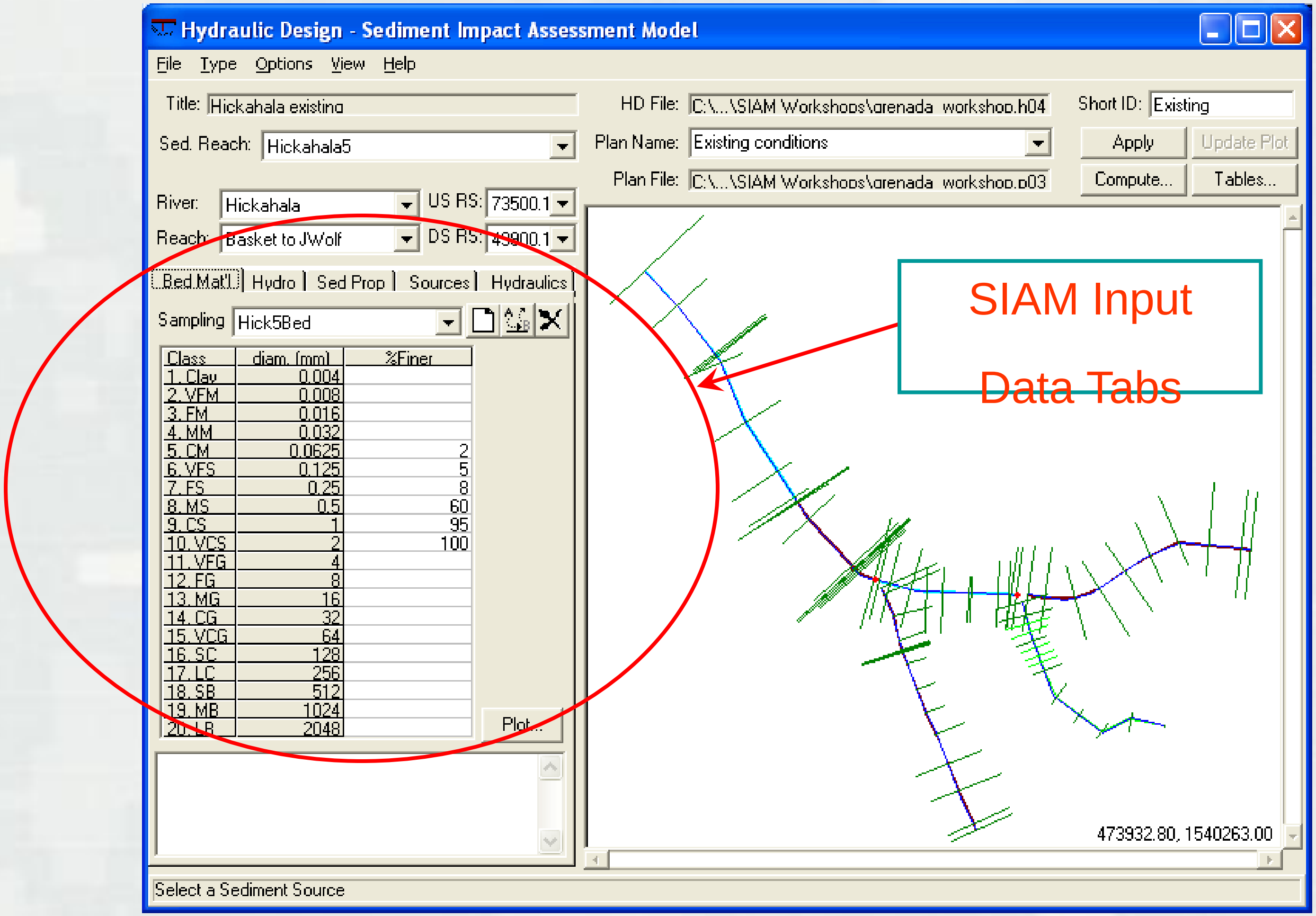
SIAM Highlights/Capabilities

- Sensitivity analyses
- Particle tracking by sediment size
- sediment sources and sinks. all inputs to the sediment load – not just watershed yield.
- Bridges gap between watershed sediment yield / in-channel sediment transport models
- New combination of applications
  - Underlying theory is proven.
  - extends sediment processes evaluation
- Technical support for decision-making

HEC-RAS/SIAM Interface

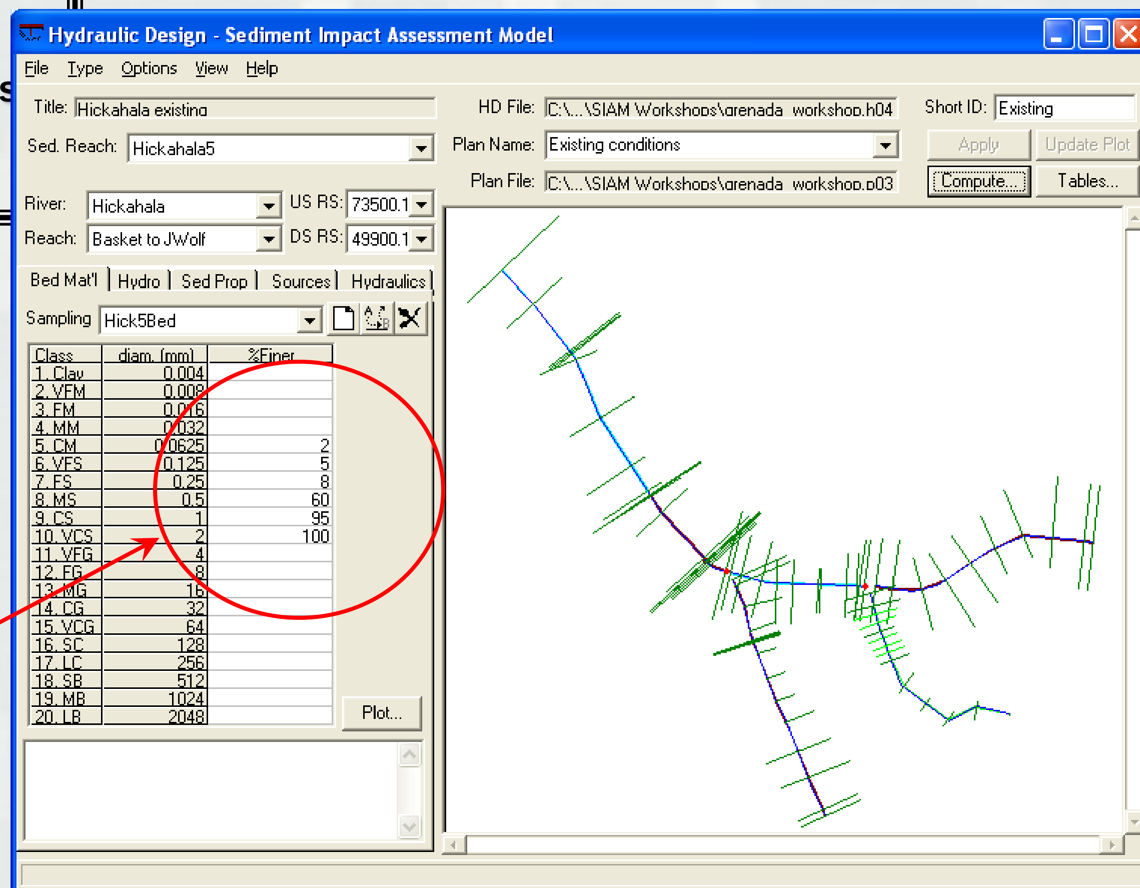


HEC-RAS/SIAM Interface



SIAM Input Data

- Bed material gradation
- **Hydrology/flow duration**
- **Sediment properties**
- **Sediment sources/loadings**
- **Hydraulics**

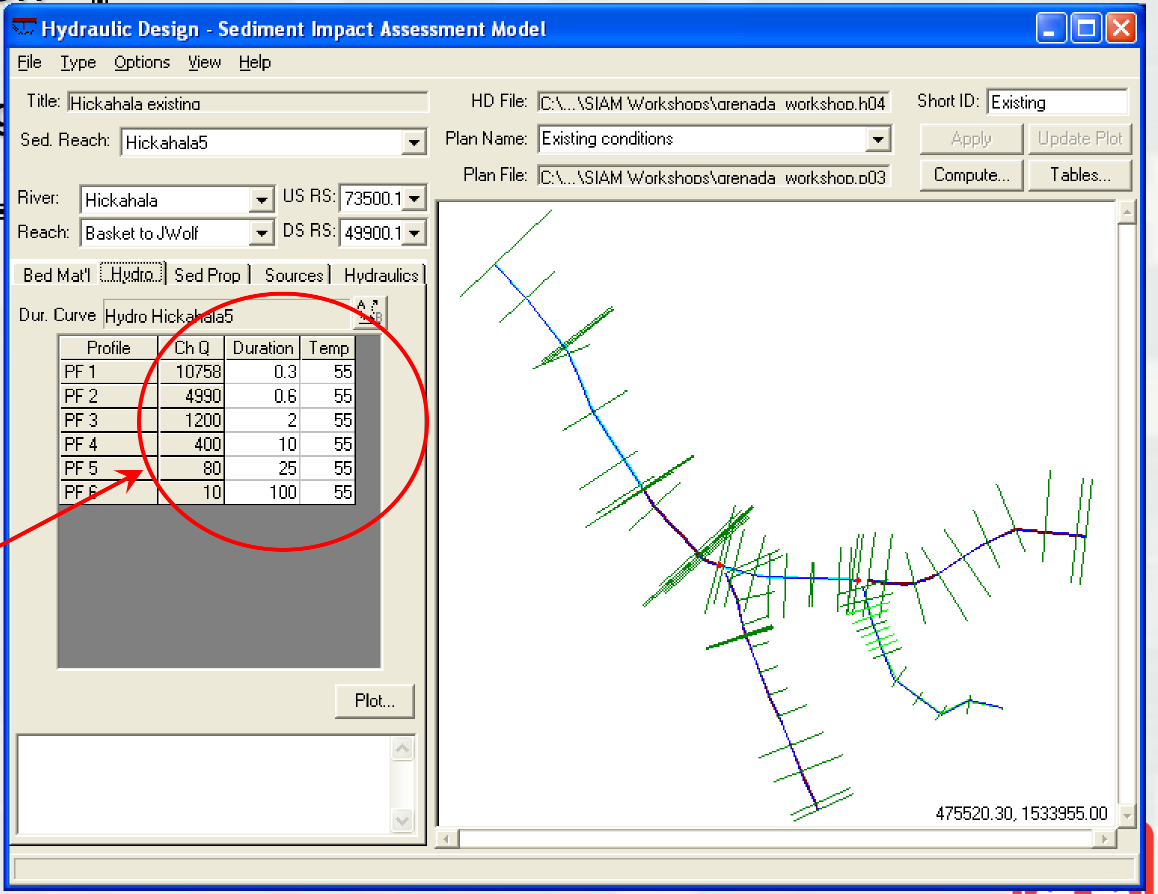


Class	diam. (mm)	%Finer
1. Clay	0.004	
2. VFM	0.008	
3. FM	0.016	
4. MM	0.032	
5. CM	0.0625	2
6. VFS	0.125	5
7. FS	0.25	8
8. MS	0.5	60
9. CS	1	95
10. VCS	2	100
11. VFG	4	
12. FG	8	
13. MG	16	
14. CG	32	
15. VCG	64	
16. SC	128	
17. LC	256	
18. SB	512	
19. MB	1024	
20. LB	2048	

Enter percent finer of average bed material gradation for reach

SIAM Input Data

- **Bed material gradation**
- Hydrology/flow duration
- **Sediment properties**
- **Sediment sources/loading**
- **Hydraulics**



Enter duration in days for each HEC-RAS profile

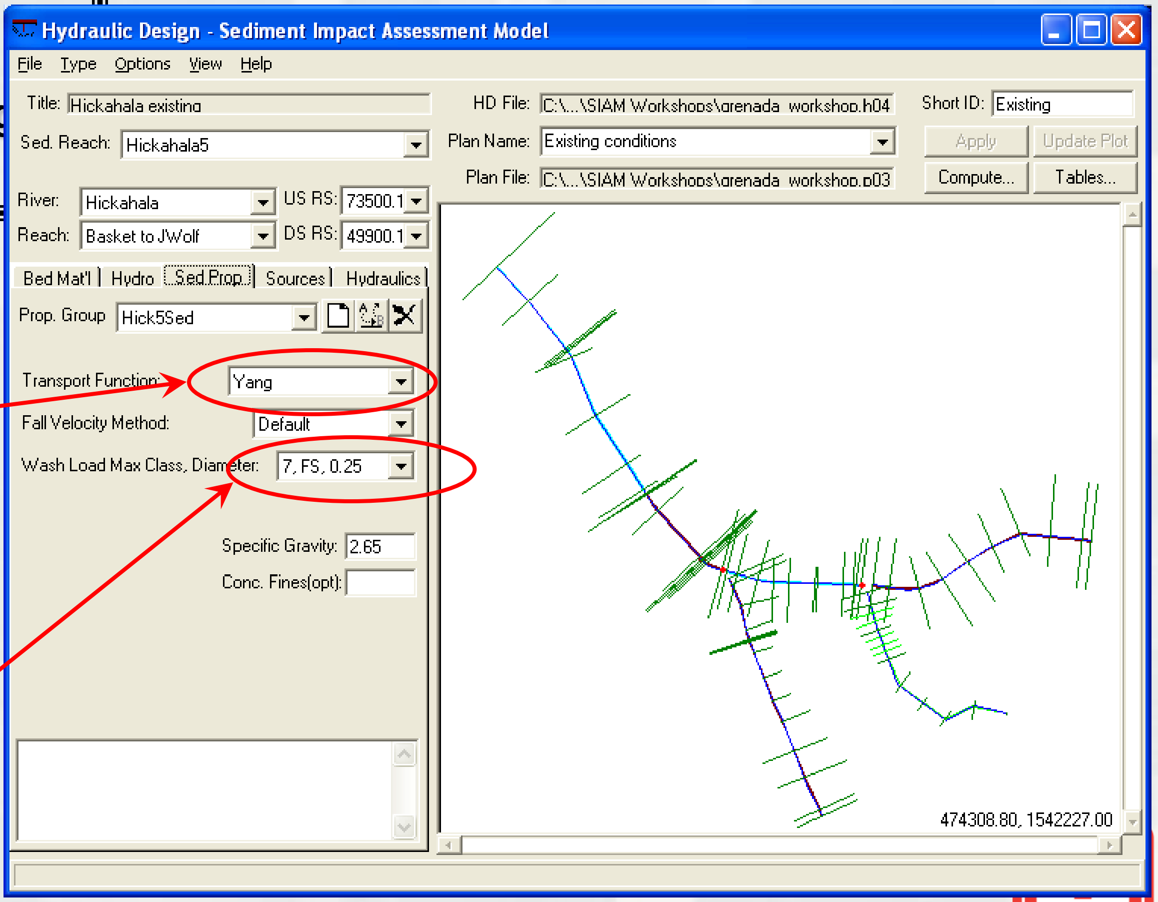
SIAM Input Data

- Bed material gradation
- Hydrology/flow duration
- Sediment properties
- Sediment sources/loading
- Hydraulics

Sediment transport functions available:

Ackers-White, Engelund-Hansen, Laursen-Copeland, Meyer-Peter Muller, Toffaleti, Yang

Wash load threshold diameter

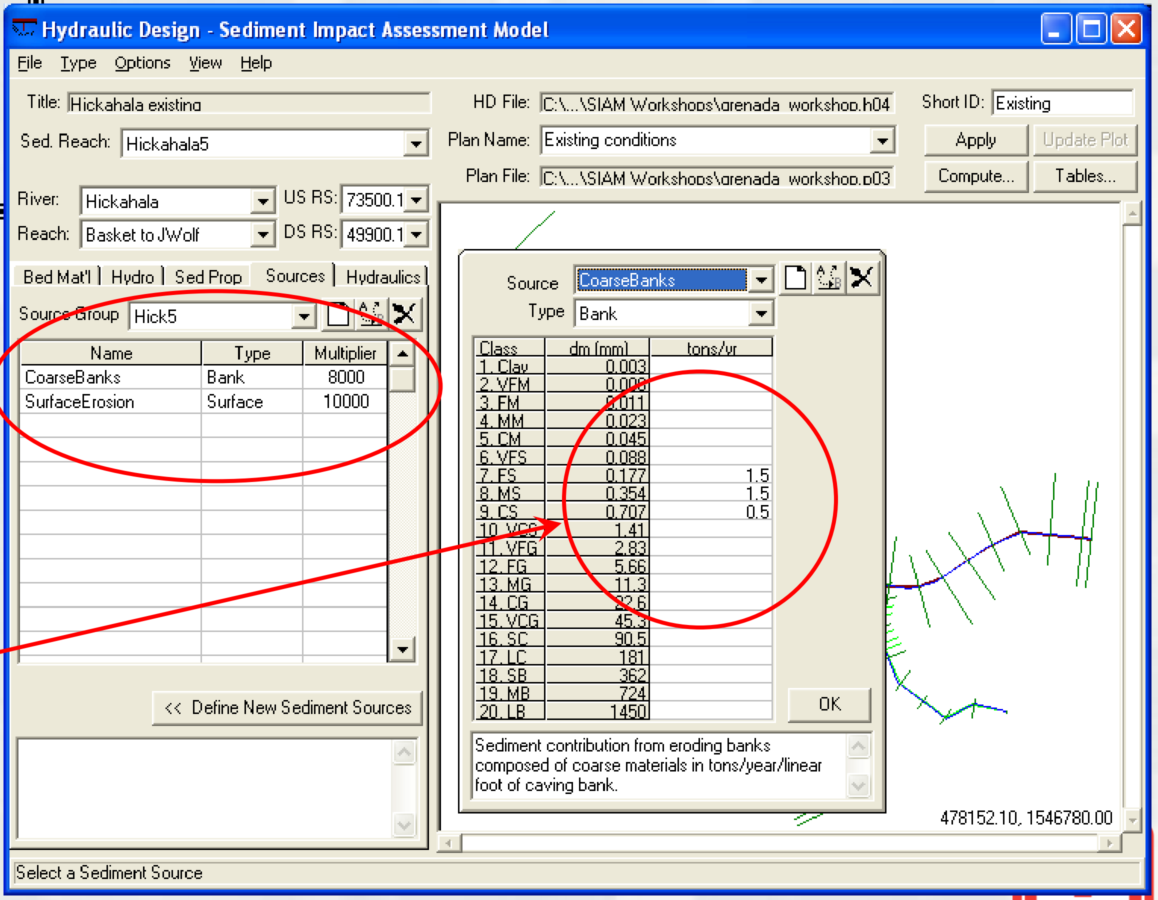


SIAM Input Data

- **Bed material gradation**
- **Hydrology/flow duration**
- **Sediment properties**
- Sediment sources/loadings
- **Hydraulics**

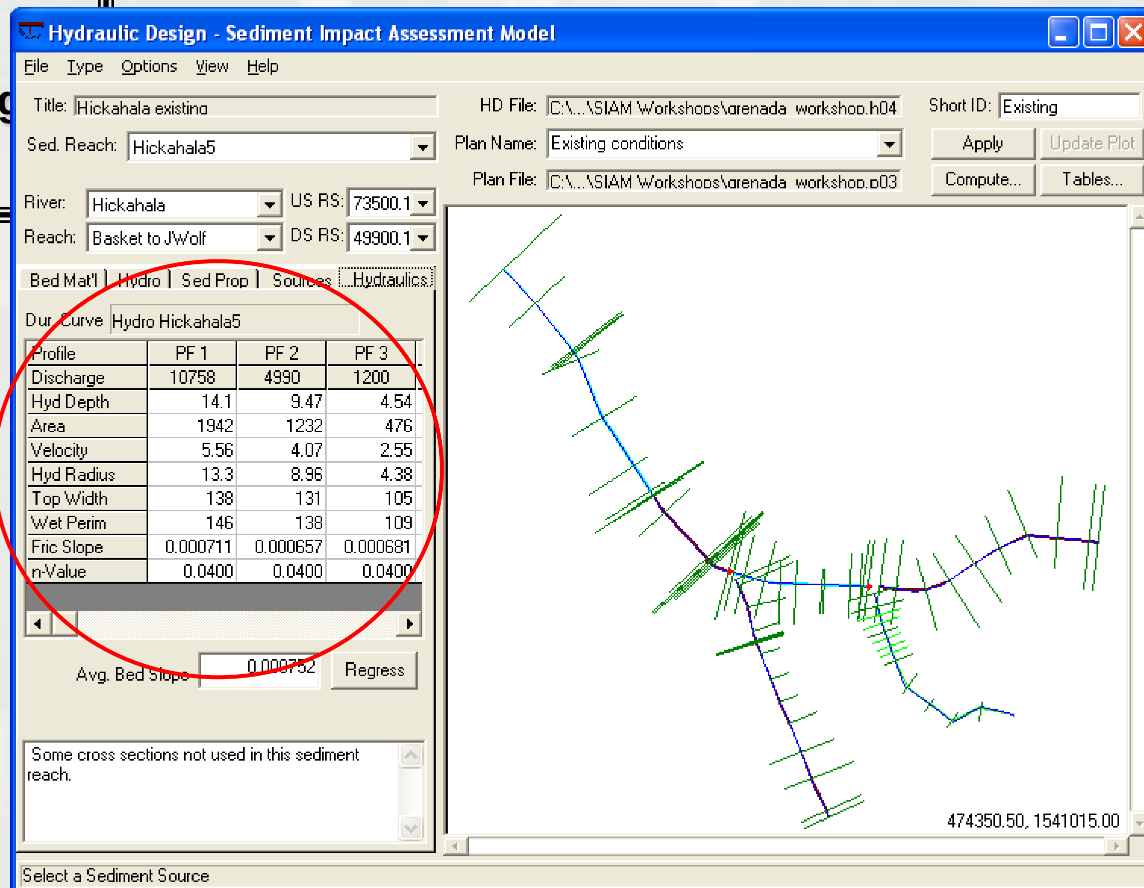
Sediment source loads for reach

Rate and distribution of sediment source



SIAM Input Data

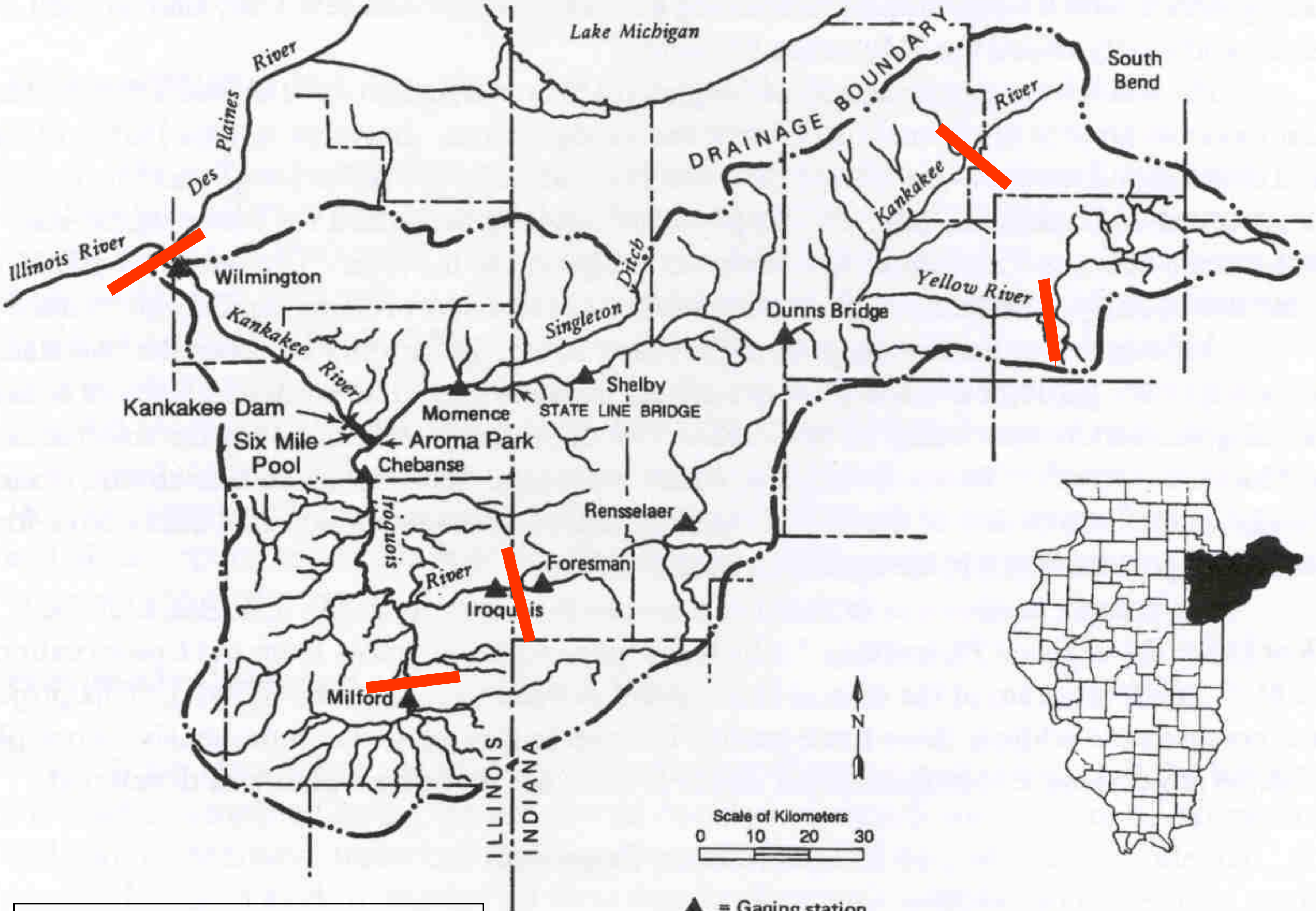
- Bed material gradation
- Hydrology/flow duration
- Sediment properties
- Sediment sources/loading
- Hydraulics



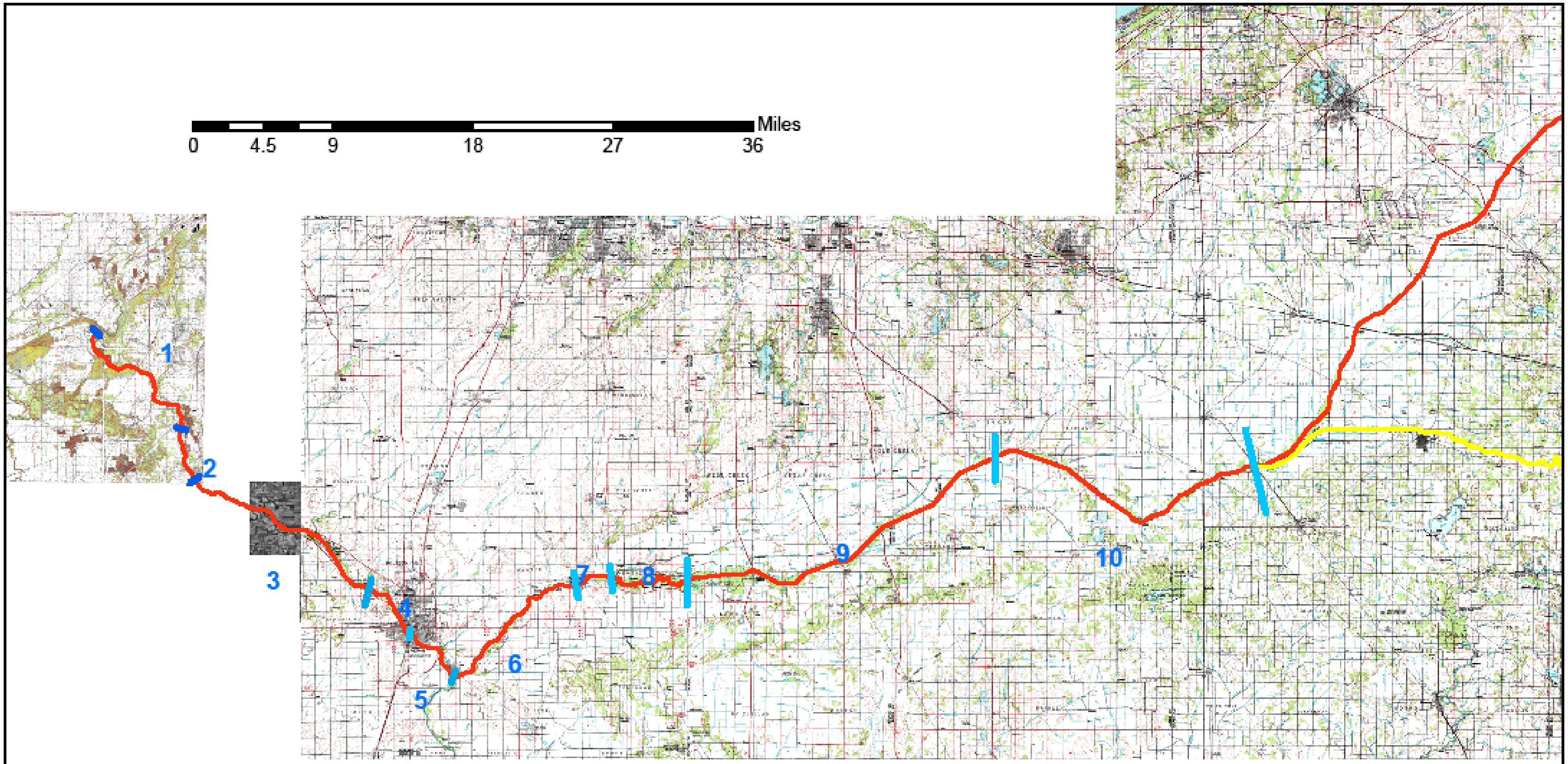
Reach averaged hydraulics from HEC-RAS results

SIAM

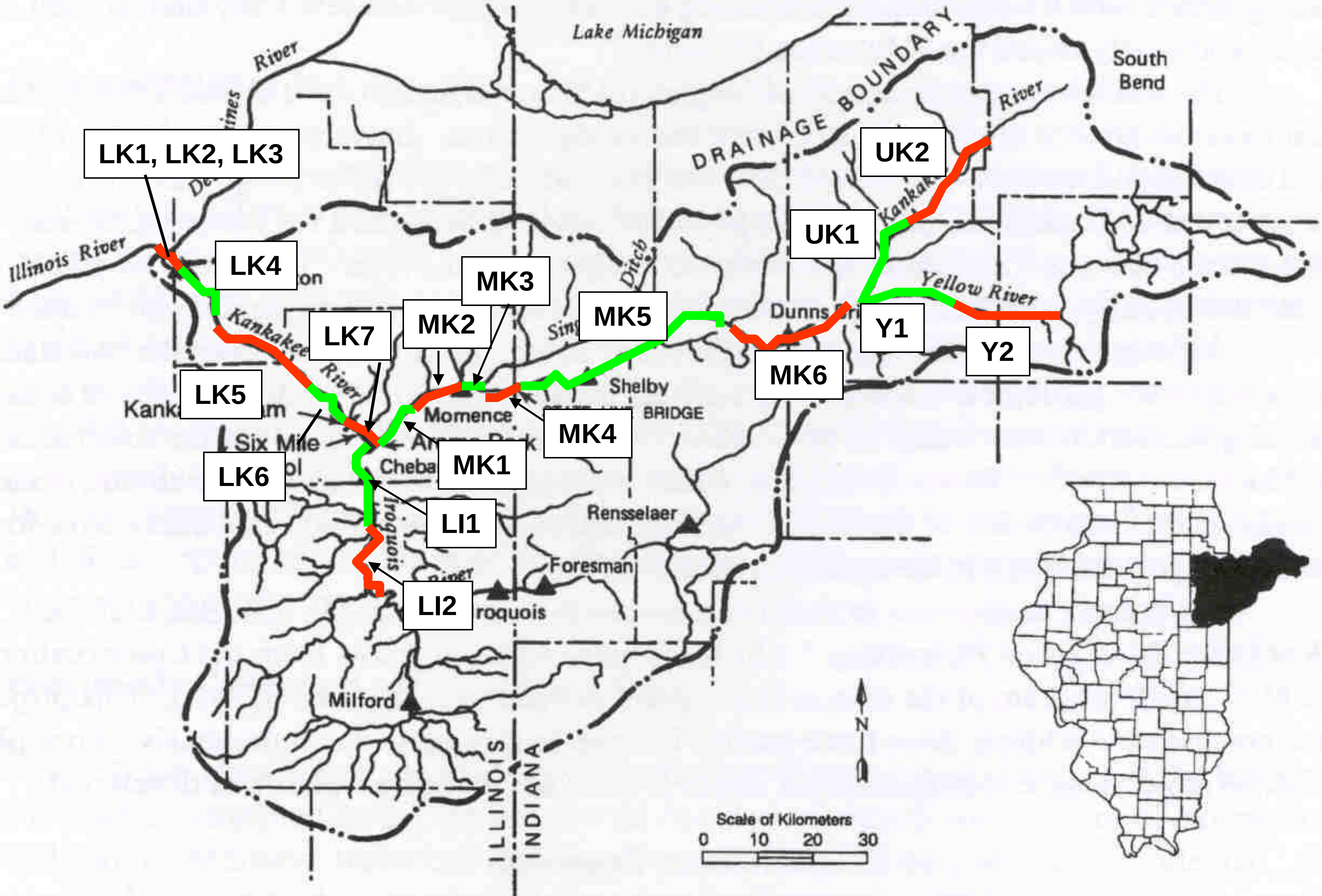
- **Application on the Kankakee River Basin**
- **HEC-RAS and flow-duration information supplied by Rock Island District**



HEC-RAS Model Coverage



SIAM Modeling
Kankakee River
First Guess at Defining Reaches
14 May 2007



SIAM Reaches

Kankakee River Basin
SIAM Runs

Existing Conditions and 5 Alternatives

- Existing conditions
- Alt1: Remove bank erosion source from Yellow River
- Alt2: Reduce watershed source loads from Yellow River by 50 percent
- Alt3: Reduce watershed source loads from Iroquois River by 50 percent
- Alt4: Reduce watershed source loads from Kankakee River above state line by 50 percent
- Alt5: 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.

Kankakee – Preliminary SIAM Results

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

	Existing		Alt 1		Alt2		Alt3		Alt4		Alt5	
Reach	local bal	total	local bal	total	local bal	total	local bal	total	local bal	total	local bal	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)

Discussion of SIAM Results
General Observations

Since the Kankakee bed material 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.

Discussion of SIAM Results

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.

Note: Bank erosion contribution is an estimate.

Discussion of SIAM Results

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.

Discussion of SIAM Results

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.

Note: The magnitude and gradation of the annual average sediment load from the Iroquois River are established with a high degree of confidence.

Discussion of SIAM Results

Alternative 4: Kankakee River, above Indiana state line – watershed yields reduced by 50%

- 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.

Discussion of SIAM Results

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.

Notes: This was an initial evaluation to see how this alternative operated with a basic flattening of bed slope. The impacts of a revised cross section were not evaluated.

General Discussion

- SIAM provides an accurate overview of sediment processes and linkages at a watershed scale
- The model can provide value by quickly assessing impacts. For instance, the sand loads in the Kankakee River appear to be relatively insensitive to changes in the bank erosion contribution from the Yellow River.
- 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.


Questions?