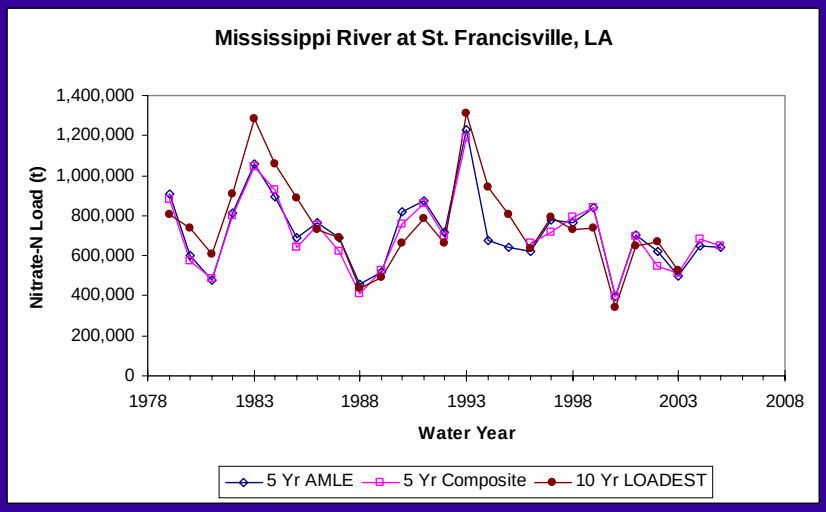
Subgroup 2
Characterization of nutrient sources, transport, and fate

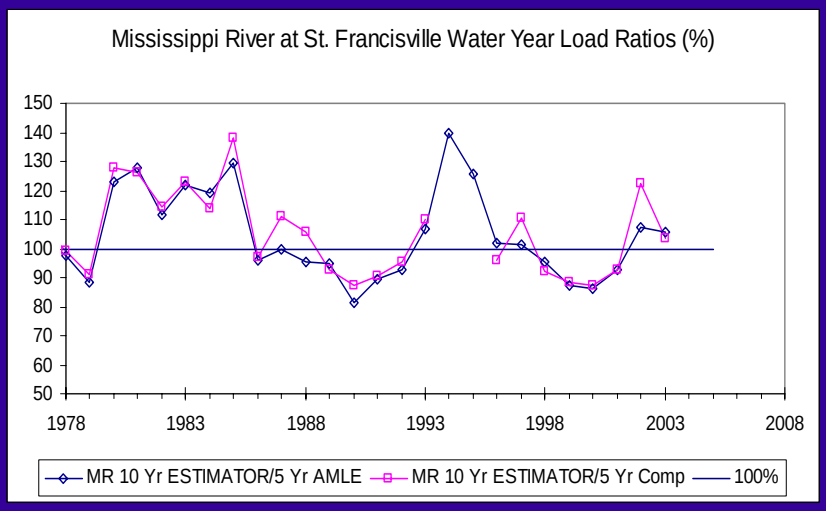
Participants:

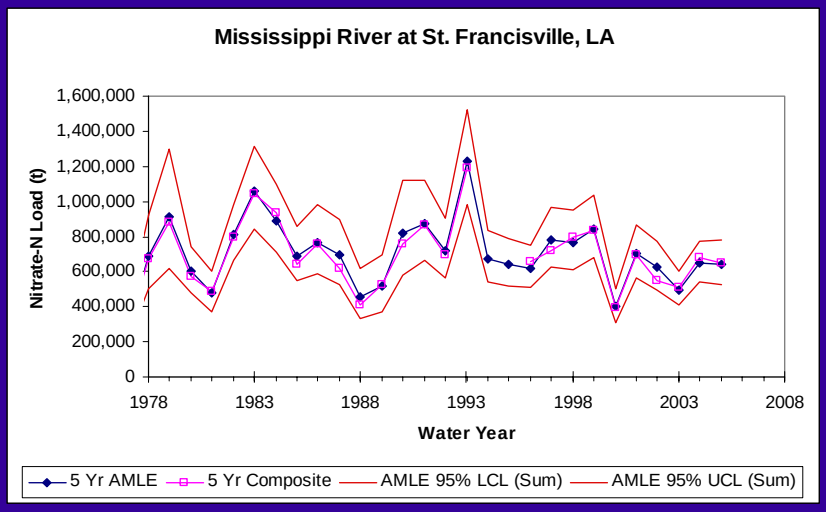
Judy Meyer, Mark David, Bob Howarth, Bill Crumpton, Richard Lowrance, Andrew Sharpley, Walt Boynton, Kyle Mankin, Ken Reckhow, Dave Wangsness (DFO)

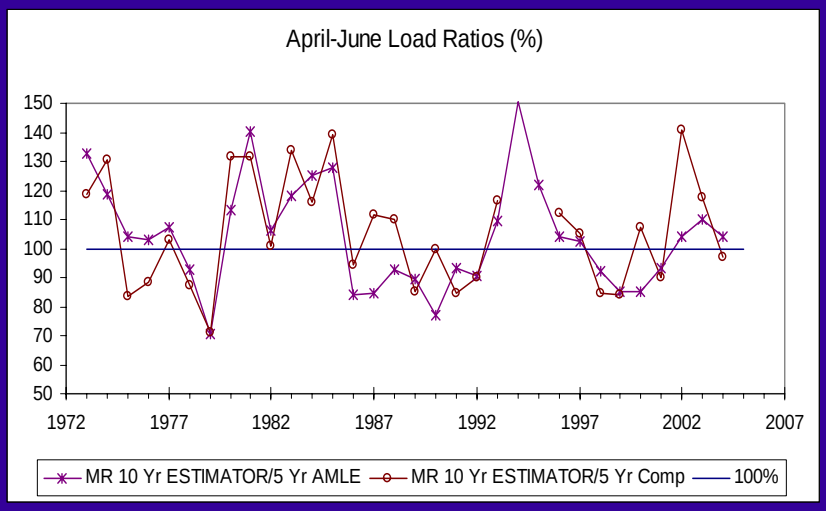
Topic 2A. i. Annual and seasonal fluxes of nutrients

- Fluxes recalculated since CENR Assessment
  - Calibration period
    - OLD Entire period
    - NEW 5 year moving windows
  - Regression model type
    - OLD “<“ concentrations = 0.5 detection limit
    - NEW LOADEST code with Maximum Likelihood Estimate and composite method
    - Includes time-squared term


Mississippi River at St. Francisville, LA
Nitrate-N Load (t)
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1978
1983
1988
1993
1998
2003
2008
Water Year
5 Yr AMLE
5 Yr Composite
10 Yr LOADEST


Mississippi River at St. Francisville Water Year Load Ratios (%)
150
140
130
120
110
100
90
80
70
60
50
1978
1983
1988
1993
1998
2003
2008
MR 10 Yr ESTIMATOR/5 Yr AMLE
MR 10 Yr ESTIMATOR/5 Yr Comp
100%


Mississippi River at St. Francisville, LA
Nitrate-N Load (t)
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1978
1983
1988
1993
1998
2003
2008
Water Year
5 Yr AMLE
5 Yr Composite
AMLE 95% LCL (Sum)
AMLE 95% UCL (Sum)


April-June Load Ratios (%)
150
140
130
120
110
100
90
80
70
60
50
1972
1977
1982
1987
1992
1997
2002
2007
MR 10 Yr ESTIMATOR/5 Yr AMLE
MR 10 Yr ESTIMATOR/5 Yr Comp
100%

2A. i. Fluxes
STREAMFLOW
(USGS Battaglin & Aulenbach)

- 1980 - 96 Average: 21,950 m^3/s
- 2001 - 2005 Average: 5.8% decrease
- 2001 - 2004 Average: 13.7 % decrease
- Five 5-year windows: 9.5 % decrease

2A. i. Fluxes: NUTRIENTS (USGS)

Time period	Total N	Nitrate	Total P	SRP	Silica (SiO_2)
1980-96	1.569 MMT	956,900 MT	136,700 MT	41,030 MT	4.530 MMT
2001- 05	20.5% decrease	13.3 % decrease	12.8 % increase	9.8 % decrease	15.8 % decrease
2001-04	26.5 % decrease	20.8 % decrease	4.7 % increase	12.8 % decrease	25.7 % decrease
Five 5 yr windows	18.8 % decrease	12.4 % decrease	6.2 % increase	7.1 % decrease	17.3 % decrease

2A. i. Fluxes: SPRING April, May, June (USGS)

Time period	Stream flow	Total N	Nitrate	Total P
1980-96	30,090 m^3/s	588,120 MT	377,250 MT	44,700 MT
2001- 05	14.2 % decrease	18.9 % decrease	11.6 % decrease	10.9 % increase
2001-04	17.0 % decrease	25.8 % decrease	18.2 % decrease	4.3% decrease
Six 5 yr windows	10.7 % decrease	16.3 % decrease	8.6 % decrease	12.4 % increase

2A. i. Fluxes: Proportions from Upper Mississippi and Ohio (USGS)

	Stream flow	Total N	Nitrate	Total P
1980-96 Upper Miss	19 %	39 %	43 %	27 %
1980-96 Ohio	38 %	33 %	35 %	28 %
2001-05 Upper Miss	18 %	39 %	49 %	26 %
2001-05 Ohio	43 %	41 %	41 %	38 %

2A.i. Fluxes: Tile drainage

- Decreased subsurface flow and decreased N loss at wider tile spacing, but the effect varies. Reductions in nitrate export are primarily due to reductions in the volume of flow rather than reductions in nitrate concentration. Drain flows and N loss can be affected by both drain spacing and depth.
- Simulation studies predict increased surface runoff when higher water tables are maintained using controlled drainage.
- There is limited research addressing the extent and density of agricultural drainage in the US Corn Belt. More recent estimates of the extent of drained agricultural land have been developed based on land use and soil class/characteristics. Neither the previous surveys nor the newer GIS based approaches provide information on drainage intensity.
- Additional research needed on: effects of drainage depth, spacing, intensity on N transformations and exports in soils; extent, pattern and intensity of agricultural drainage.

2A.i. Fluxes: Needs

- Fewer monitoring sites today than during first assessment. Need information on location of eliminated monitoring sites because we want to comment on impacts of site loss on estimates and on ability to detect changes in response to altered management practices.
- Need further work on annual and seasonal flux patterns WITHIN the basin.

Topic 2 A ii Mass Balance

- New calculations show NANI (net anthropogenic nitrogen inputs) has increased since 1950s. Some components of earlier calculations shown to be unimportant or unable to be estimated (e.g., net soil mineralization, denitrification).
  - NANI = inputs (deposition, fertilizer, and fixation) minus outputs (crop harvest, net transfer in feed and food)
- Increased yields and steady fertilization rates resulted in a NANI decline ~ 10% 1997 - 2005 cf. 1987 - 1996 (greater decline in IA, IL, IN)
- NANI linked to river N flux with 2 - 5 year lag.
- P mass balance for IL showed inputs = outputs with large soil P pool, only a small fraction of which is lost to streams

Topic 2 A ii Mass Balance: Point Source Nutrient Mass Loadings to the Mississippi River Basin Report

- Recent estimates based on 1999 and 2004 data (cf. 1993, 1996 in CENR)

Kg/day	2005 - 2006 assessment	Recent/CENR
Total N	578,681	72 %
Total P	97,840	59 %
BOD	690,863	N/A

Topic 2 A ii -- Mass balance : Manure

- Manure as a nutrient source needs to be addressed in this review. Estimates that compare manure and fertilizer as sources of N & P vary widely, and there appears to be very limited information on application rates and timing of manure and fertilizer at the watershed scale.
- In IA manure N is 50% fertilizer N and 13% of total N inputs; manure P is 86% of fertilizer P and 45% total P inputs to state.
- Information on manure application rates from other states would be useful.
- Manure management an issue for Subgroup 3?

Topic 2 A iii Nutrient transport and transformation in streams and rivers

- Small streams account for a large fraction of in-stream N removal in river networks.
- In-stream N removal is a small fraction of N exported from tile-drained agricultural watersheds.
- Denitrification in small streams is a significant loss during warm, low flow months, improving water quality; however most N is exported to the Gulf Jan - June, and denitrification removes an insignificant % during this time.
- Enhancing N and P removal by 50% during low flows would reduce export by < 2%; enhancing removal by 25% during high flows would increase removal by 20 - 24%.
- Effectiveness of N removal via denitrification increases with water retention time. Denitrification in IL reservoirs reduced N export by 58%.

Topic 2 A iii Nutrient transport and transformation in streams and rivers

- Less information on denitrification in large rivers. Recent data from Upper Mississippi shows 5-15% of N input to the river is denitrified. More effective routing of waters to backwaters could enhance this removal.
- Where denitrification occurs on the landscape influences its contribution to greenhouse gases. N_2O is < 6% of denitrification gas emissions in aquatic systems; the fraction is much higher in soils (highly variable; commonly 30-40 %).
- There does not appear to be much net exchange (sorption/desorption) of P in the river system, but desorption occurs as the plume becomes more salty (approximately 10% of the load on the time scale of hours to days); the remainder can desorb from the sediments on the time scale of years. Hence P is released over a 1-2 year period on the shelf and, therefore, it is more important to consider annual loads for P.

Topic 2 A iii Nutrient removal & transformation in wetlands & riparian zones

- Riparian zones not effective for nutrient removal in tile-drained fields
- Switchgrass and switchgrass/woody plant buffers remove significant fractions of N and P (Lee et al. 2000, 2003)
- Elevated soil organic matter (SOM) and microbial biomass in herbaceous riparian buffers resulting in higher infiltration rates and denitrification rates 4X that in cropped fields.
- MART report: ~332,000 acres in riparian buffers in Mississippi River basin in 2002-2005
- Coastal wetlands: More to come …

Topic 2 A iii Nutrient removal & transformation in wetlands & riparian zones

- Recent research showing emergent marshes provide significant potential for removal of nitrate and particulate phosphorous. They can be effective at reducing nutrient loads associated with agricultural drainage.
- There are opportunities for wetland restoration throughout the Cornbelt with potential to intercept tile flow. Nitrate removal rates ~ 1000 kg N ha^{-1} yr^{-1}.
- MART report: ~785,000 acres in wetland creation, enhancement and restoration in MRB 2002 - 2005
- Overlap with subgroup 3.

Topic 2 A -- Overlaps with Subgroup 3: Fertilizer application and cropping systems

- It is beyond the scope of the HAP review to discuss all research relevant to changing SOC in Corn Belt soils. Inclusion of alfalfa in a rotation is very effective at building SOC, but effects of tillage are not clear.
- Possibility of further reductions in SOM in fields if fertilizer levels are reduced; however, calculations are based on mass balances, and small inaccuracies in estimates would result in different conclusions. High fertilizer inputs lead to SOM increases; 0 inputs lead to decreases; evidence from several studies suggests little change in SOM with N fertilizer applied in range of 90 - 180 kg N ha^{-1} yr^{-1} (142 kg N ha^{-1} yr^{-1} applied in IA in 2005).
- Changes in fertilizer rates within the range of those optimum for corn production are unlikely to lead to long-term SOC and SON declines.
- Impacts of changing timing of fertilizer application (e.g., Last Spring Nitrate Test) handled by Subgroup 3?
- Impacts of cropping system changes handled by Subgroup 3?
- Nutrient management plans handled by Subgroup 3?

Topic 2B i Predicting nutrient delivery to the Gulf

- Uncertainty in the prediction of N and P delivery is clearly important in the assessment of management actions.
- SPARROW provides a prediction error term. Uncertainty analysis is likely to be incomplete for the other models.
- Sensitivity analysis can be done, but a complete uncertainty analysis (that includes all parameters, parameter covariances, and model error) is probably not feasible.
- More to come …

Topic 2B ii Route nutrients from sources & account for transport processes in basin & delta

- Several models have the capability to route nutrients in stream channels in the basin and yield predictions of nutrient delivery to the Gulf: SWAT, HSPF, SPARROW, Donner's model, and Howarth's model (?). Prediction of in-stream nutrient loss is important (given the overall length of in-stream travel); in-stream nutrient loss is likely due primarily to denitrification and sediment deposition of phosphorus.
- Process descriptions in mechanistic (e.g., SWAT) models permit application of the model outside the calibration bounds (extrapolation). Statistical models (e.g., SPARROW) are used most confidently within the bounds of calibration (interpolation). Important applications of these models to assess management actions will involve extrapolation. It will be useful to compare the equations and calibration approaches for routing and delivery in each of the models to assess the degree of mechanism and empiricism.
- More to come …