OFFICE OF THE GOVERNOR

207 STATE CAPITOL, SPRINGFIELD, ILLINOIS 62706

GEORGE H. RYAN
GOVERNOR

July 27, 1999

Gulf of Hypoxia Working Group
National Centers for Coastal Ocean Science
WS 13446 SSMC4
1305, East-West Highway
Silver Springs, MD 20910

Dear Members of the Hypoxia Working Group:

Scientists in a number of state agencies have reviewed the final, peer-reviewed reports of the Gulf of Mexico Hypoxia Assessment produced by the Committee on Environmental and Natural Resources of the Executive Office of the President for the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. I submit their comments (attachment) and request that this letter and the attached comments be appended to the reports, submitted to the Task Force, be made available on the Internet, and used in preparing the Integrated Assessment report. I understand that it was agreed at a February, 1999, meeting of the Hypoxia Working Group that review comments would be attached to the final reports.

In general, state scientists find that i) the framework for conducting the assessment is too narrowly focused, ii) there has been selective use of scientific data, iii) the reports do not present a clear cause-effect relationship between fertilizer use and hypoxia in the Gulf, and iv) the report includes many invalid assumptions and erroneous conclusions. Some of the technical reports also seem to be overly prescriptive in identifying policy solution to the issues addressed.

Nevertheless, scientists note key assessment findings, quoted here directly from the reports:

- *"The hypoxia in the Gulf of Mexico is assumed to be a result of excessive nutrient loading from the Mississippi River."*
- *"The economic assessment based on fisheries data, however, failed to detect effects attributable to hypoxia." and ".. The lack of measurable economic benefits from reduced hypoxia..."*

reasonable to conclude that reductions in nutrient loadings to the rivers will not improve compliance with the standards for these water quality variables."

- *"Consideration of how hypoxia and other stressors interact with all aspects of the Gulf ecosystem is essential **prior** to planning any restoration efforts."*

Scientists also note that i) the preferred nutrient reduction strategy (combined fertilizer reduction and wetland construction) is not the least-cost strategy, ii) the cost of implementing this preferred nutrient reduction strategy is $4.8 billion, and iii) the assessment does not address the probable negative impacts on the rich commercial and sports fisheries in the northern Gulf of a reduction in nutrient loads. Like most productive fisheries zones around the world, "The Fertile Fisheries Crescent" in the Gulf benefits from nutrients from runoff and/or upwelling. In the Yellow Sea and the Mediterranean Sea, fish catches have decreased markedly as the amount of nutrients brought down by the Yellow River and the River Nile have decreased. The failure to address this topic poses a significant bias in the assessment.

From a review of scientific literature, scientists also find that much data and information has not been used in the preparation of the reports. Drawing on the broader, scientific, peer-reviewed literature, scientists find that nutrient fluxes to the northern Gulf and productivity in the northern Gulf have decreased over the past 40-50 years. This finding invalidates the central assumption of the assessment that nutrient fluxed to the Gulf and productivity in the Gulf have doubled or tripled over the past 40-50 years, due mainly to fertilizer use.

In Illinois, we have implemented over the past several decades, and continue to implement, numerous regulatory and voluntary programs related to reducing the fluxes of nutrients and sediments from point and non-point sources (i.e., Sediment and Erosion and Control Program, Ecosystems programs, Conservation Practiced Program, Streambank Stabilization and Restoration Program). As a result of these programs, we have witnessed major improvements in water quality and ecological conditions. Unfortunately, the reports fail to characterize both the history of pollution and the many benefits of land management and pollution control.

Based on the above findings, resource managers conclude that the reports do not provide a sound basis for decision making. They do note that environmental impacts of nutrient loads in the Mississippi River Basin are currently being addressed under numerous existing regulatory programs (e.g., NPDES permits, state water quality standards etc), voluntary programs (Conservation Reserve Program, Conservation Reserve Enhancement Program, Wetlands Reserve Program, Environmental Quality Program etc). Through the development of criteria and standards for nitrogen and phosphorous, and implementation of total maximum daily loads. The State of Illinois is committed to implementing existing regulations and voluntary programs and will continue to participate in the development of new initiatives to improve the quality of our environment.

environment.

If the federal agencies wish to continue to address the issue of hypoxia in the Gulf of Mexico, state scientists suggest that a fresh start be made to framing and conducting a scientific assessment and setting a comprehensive research and monitoring program for the Mississippi River basin and Gulf coastal areas. Such programs should be based on holistic considerations of ecological hydrology and biogeochemistry, should involve in a decision-making mode representatives of key governments and organizations, and should have a more thorough and independent peer-review process.

Sincerely,

George H Ryan

GEORGE H. RYAN
Governor

GHR/IDNR/JDG/kac

cc: Brent Manning
Derek Winstanley

ATTACHMENT:

REVIEW COMMENTS ON THE SIX PEER-REVIEWED, FINAL, TECHNICAL REPORTS OF THE GULF OF MEXICO HYPOXIA ASSESSMENT PRODUCED BY THE COMMITTEE ON ENVIRONMENT AND NATURAL RESOURCES FOR THE MISSISSIPPI RIVER/GULF OF MEXICO WATERSHED NUTRIENT TASK FORCE.

Cleansing of the Mississippi River System

1. The assessment reports fail to draw on the full range of scientific data available in the scientific peer-reviewed literature.

Careful review and analysis of the six reports, and the scientific literature, lead us to reject the hypothesis that hypoxia in the northern Gulf of Mexico has accelerated in the last 50 years due to a doubling or tripling in the fluxes of nitrogen and phosphorous from the Mississippi River Basin (MRB), primarily from the use of inorganic fertilizer. By using the holistic methodology identified by the White House Committee on Environment and Natural Resources (CENR) in its own report on *"Setting a New Course for Coastal Ocean Science"*, we find that the fluxes of nitrogen and phosphorous from the MRB to the northern Gulf and the rate of primary productivity in the northern Gulf have declined over the past 50 years, even though the use of nitrogen and phosphorous fertilizer has increased. The failure to utilize the full spectrum of peer-reviewed scientific data has resulted in the development of invalid assumptions and hypotheses which are used as the basis for identification policy options.

2. The reports lack a credible, scientific, conceptual framework for addressing the causes and remedies of hypoxia.

The assessment is narrowly focused on dissolved nutrients and, even prior to the conduct of the assessment, the solution to the problem had been defined as a reduction in the load of dissolved nutrients carried by the Mississippi River. The structure and scope of the assessment is even inconsistent with the methodology identified by CENR in its own report on *"Setting a New Course for Coastal Ocean Science"*. This report, developed by consensus among federal science agencies, the university community, and natural resource managers, recommends a comprehensive, integrated, systems approach to address the complexities associated with the degradation of coastal ocean quality. This approach includes recognizing the heterogeneous and highly dynamic nature of coastal ecosystems and the need to address in a thorough manner freshwater, suspended solids, sediments, terrestrial organic matter, the loss of wetlands, pollution, and land-use changes, as well as dissolved nutrients. The failure to adopt an appropriate framework for the assessment contributes to the invalid nature of many of the key assumptions and hypotheses.

3. The assessment does not address the probable negative impacts on the rich commercial and sports fisheries in the northern Gulf of a reduction in nutrient loads.

Like most productive fisheries zones around the world, "The Fertile Fisheries Crescent" in the Gulf benefits from nutrients from runoff and/or upwelling. In the Yellow Sea and the Mediterranean Sea, fish catches have decreased markedly as the amount of nutrients brought down by the Yellow River and the River Nile have decreased. The failure to address the likely negative economic and ecological impacts of a further reduction in nutrient fluxes poses a significant bias in the assessment.

4. There is inadequate scientific understanding of hypoxia, biogeochemical cycling of nutrients, and ecosystem changes for developing sound response strategies and policies.

The inadequate understanding of the complex biogeochemistry of nitrogen and phosphorous cycling in the MRB and the complex issue of hypoxia and ecosystem changes in the Gulf is manifest in 15 pages of recommendations for further research. The limitations in the scientific understanding of these issues constrain the development of technically-sound response strategies and policies.

5. There is an absence of demonstrated significant benefits of nutrient control.

Report 6 finds that benefit cost analysis has a firm foundation in microeconomic theory and has the potential to rationalize policy making, and to assure that the outcomes of policy decisions are optimal. Cost effectiveness analysis is considered appropriate whenever it is impractical or impossible to consider the monetary value of the benefits provided by alternative policies. Report 6 uses cost effectiveness analysis. As stated in the assessment, any validity to the findings and recommendations contained in Report 6 rests on the assumption that measures to reduce nitrogen losses to the Gulf will ultimately prove beneficial. However, main findings of the assessment are that there is i) a *"lack of measurable benefits .... that might accrue from reduced hypoxia"*, and ii) states already are generally in compliance with related water-quality standards. Considering also the facts that iii) there is no statistically significant correlation between nutrient fluxes from the MRB to the northern Gulf and the mid-summer surface area of the hypoxic zone, and iv) the fluxes of nitrogen and phosphorous to the northern Gulf and the rate of primary productivity in the northern Gulf have decreased, the key assumption of the assessment - that measures to reduce nitrogen losses to the Gulf will ultimately prove beneficial - has not been demonstrated to be valid. The paucity of demonstrated significant benefits of nutrient control greatly diminishes the technical basis for proposing nutrient controls.

6. Some key findings are valid.

In spite of the generally unsatisfactory framework and invalid conclusions of the reports, there are many individual findings, conclusions, and recommendations contained in the reports with which we concur. It is interesting to note that any number of these items by themselves invalidate the overall hypothesis of the reports that hypoxia in the northern Gulf of Mexico has accelerated in the last 50 years due to a doubling or tripling in the fluxes of nitrogen and phosphorous from the MRB, primarily from the use of inorganic fertilizer. In particular, we note the following findings, conclusions, and recommendations, as quoted directly from the reports:

i) "The hypoxia in the Gulf of Mexico is ***assumed [our emphasis]*** *to be a result of excessive nutrient loading from the Mississippi River."*

ii) *"We did find tantalizing bits and pieces of data pointing to differences and responses with hypoxia related effects but could not isolate confounding factors that could also produce similar responses."*

iii) *"Results presented in this report are from an ongoing research program and should be considered preliminary and provisional in nature." "Some issues just cannot be resolved adequately without further data analyses, more data collection, or improved and different modeling efforts."*

iv) " A total ecosystem approach to the problem will be the only successful one. Consideration of how hypoxia and other stressors interact with all aspects of the Gulf ecosystem is essential ***prior [our emphasis]*** *to planning any restoration efforts."*

v) *"Land-use characteristics are of secondary importance to climatic factors."*

vi) *"The economic assessment based on fisheries data, however, failed to detect effects attributable to hypoxia."*

vii) *"Overall, the above analysis indicates that rivers in the MRB generally meet ambient water quality standards for substances affected by nutrient loadings and concentrations (i.e., dissolved oxygen, pH, nitrate, and un-ionized ammonia). On this basis, it is reasonable to conclude that reductions in nutrient loadings to the rivers will not improve compliance with the standards for these water quality variables."*

viii) *"There is not yet a complete understanding of the physical, chemical and biological processes that influence water quality responses in the northern Gulf of Mexico."*

ix) "Direct, quantitative information about the severity and extent of hypoxia is lacking."

x) *"The extent to which producers across the Mississippi River Basin are currently over-fertilizing is unknown."*

xi) *"The relative contribution of offshore sources of nutrients from upwelled waters of the continental slope is unknown."*

*xii) "... these early conclusions [*of an early version of a large-scale simulation model being developed] *should not be used as the basis for policy and management decisions."*

xiii) *"The principal reason for this model limitation is that field measurements are not available to characterize temporal variability at the shelfwide spatial scale." "The results indicated that although the model represented the overall mean state of the system reasonably well, it explained an average of only 40% of the spatial variability among individual model segments."*

xiv) "Because of nutrient retention and loss mechanisms that vary in importance as a function of spatial and temporal scales, it is particularly difficult to predict downstream loads that will result from management changes in the upper part of the drainage basin." "The degree of nutrient limitation needed to affect substantial temporal and spatial diminishment in the hypoxic zone cannot yet be determined from the existing models."

xv) "A comprehensive research plan is needed as a focus for efforts at assessing both ecological and economic effects of hypoxia in the northern Gulf of Mexico."

xvi) "The extent to which producers across the Mississippi River Basin are currently over-fertilizing is unknown."

xvii) Most of the increase in oxygen stress (as indicated by the A-E index) occurred **prior to** the 1940s, and hence, cannot be attributed to the increased use of inorganic nitrogen fertilizer, which occurred after World War II.

xviii) Oxygen stress has decreased in some parts of the northern Gulf in the last 40-50 years.

7. There are major inconsistencies in the relationship between fertilizer increase and increases in nitrate concentration.

Findings in the report show that there are major inconsistencies in the hypothesized universal relationship between increased nitrogen fertilizer use and increased nitrate concentration and load in the MRB. For example:

i) Nitrate concentration in the Ohio River remains low and has not increased over the past 45 years, despite the fact that the more than a million tons of nitrogen fertilizer are used in the Ohio River Basin each year, some 50 percent of all cropland in Ohio and Indiana is drained, the flux of nitrogen from the Ohio River is about 500,000 metric tons per year - about one third of the nitrogen discharged into the Gulf by the MRB and about the same as the entire Mississippi River basin above the Missouri River. No explanation is offered for this apparent lack of response of the Ohio River to these farming conditions, which the assessment blames for a doubling or tripling of nitrate concentration in the MRB. Nitrate concentrations in the Arkansas River was about 60 percent higher at the start of the century than in 1980-1996. This decline in nitrate concentration has occurred as the application of inorganic fertilizer has increased.

ii) There was no increase in nitrate concentration in the Mississippi River at St.Francisville from the 1950s to early 1970s, as the application of nitrogen fertilizer in the USA increased fourfold from about 2 to 8 million tons (Report 1, Figure 42). The diagram in Report 3 shows nitrate concentration at St.Francisville to be no higher in 1974 than it was in 1954. No explanation is offered for this lack of correlation between nitrate concentration in the Lower Mississippi River and the doubling of fertilizer use.

iii) Conversely, scientific literature indicates that nitrate concentration at St.Francisville increased sharply from 84.2ug at/l in 1975-80 to 119.9 ug at/l in 1981-87 - an increase of about 40 percent. However, over the same period U.S. nitrogen fertilizer use remained essentially constant: 10.29 million short tons N/yr in 1975-80 and 10.75 million short tons N/yr in 1981-87. No explanation is offered for this sharp increase in Lower Mississippi River nitrate concentration in association with the lack of an increase in the use of fertilizer.

iv) The highest concentrations of total nitrogen in watersheds in the USA are found in the Lower Colorado and the Souris-Red-Rainy [flowing from northern Minnesota and North Dakota to Hudson Bay] regions. Both are outside the MRB. Total nitrogen concentrations in these regions are about 50 percent higher than in the Upper Mississippi River and Missouri River resource regions. Concentrations of total phosphorous in the Lower Colorado are also about 70 percent higher than in the Upper Mississippi and Missouri resource regions. No explanation is given for the high concentrations of nitrogen and phosphorous in these non-agriculturally-dominated basins. It is concluded in Report 4 that *"In reality, the watersheds with the greatest nitrate loadings (Lower Minnesota, Blue Earth, and La Sueur) are not those with the greatest applied amounts of manure and fertilizer N...."*

These inconsistencies invalidate the central hypotheses that increased nitrogen inputs, especially nitrogen fertilizer, have increased nitrogen concentration and loads, and that the highest concentrations of nitrogen in streams and rivers occur in tile-drained/heavy fertilized/corn-soybean regions of the MRB.

8. A wealth of historical data demonstrates that nitrogen concentrations and/or fluxes of nitrogen in the Mississippi and Illinois Rivers have not discernable increased over those of a century ago.

Claims of increased concentrations and fluxes of nitrogen down the Mississippi River are scientifically-unsupportable as they are based upon incomplete considerations of nitrogen chemistry.

For example, while there are problems with intercomparison of chemical data derived from different methodologies and practices over time. Nevertheless, high-quality data on the concentration of total nitrogen in the Upper Mississippi River at the end of the 19th Century and start of the 20th Century indicate that, unlike today, nitrate was a minor component. Organic nitrogen plus ammonia concentration was reported to be about 4-6 times higher than the nitrate plus nitrite concentration [note: data on all forms of nitrogen are included in, for example, the Leighton (1907) report cited by Report 3, but Report 3 chooses only to include the nitrate data]. Applying a 4:1 ratio of organic nitrogen plus ammonia to nitrate plus nitrite at St. Francisville for 1905-06 (nitrate = 0.56 mg/l - Report 3, Table 3-4), it can be concluded that the concentration of total nitrogen in the Lower Mississippi River almost one hundred years ago would have been about 2.8 mg/l. Applying this same ratio of organic nitrogen plus ammonia to nitrate plus nitrite ratio for St.Francisville for 1955-65 (nitrate = 0.65 mg/l - Report 3, Table 3-4), it can be demonstrated that the concentration of total nitrogen in the Lower Mississippi River some 40 years ago would have been about 3.25 mg/l. These figures compare with a mean concentration of total nitrogen at St. Francisville of 2.26 mg/l for the period 1980-1996 (Report 3, Table 3.1), and less than 2.0 mg/l in the most recent years.

These estimates of total nitrogen concentration at St. Francisville in 1905-1906 and 1955-65 are probably conservative estimates, as will be demonstrated below. There are two reasons for concluding that these are probably conservative estimates. First, it is probable that the flux of organic material, including organic nitrogen, in the MRB reached a peak in the 1920-1960 period, associated with huge amounts of human and industrial waste, mineralization of organic nitrogen, release of organic nitrogen, loss of lush aquatic biota, erosion, and other activities not dealt with in the reports. Thus, the mean concentration of nitrate at St. Francisville in mid-century - 0.65 mg/l - probably represented a smaller fraction of the total nitrogen than the 20-25 percent measured in the Upper Mississippi River at the start of the century. Secondly, using the data in Report 3, the current (1980-1996) ratio of organic nitrogen plus ammonia to nitrate plus nitrite at Grafton is 1:2. The St. Francisville ratio is 2:3. These data indicate that the Lower Mississippi River is today relatively more organic-nitrogen rich than the Upper Mississippi River. If we make the reasonable assumption that the Lower Mississippi River was also more organic-nitrogen rich than the Upper Mississippi River earlier in the century, then it can be estimated that the concentration of total nitrogen in the Lower Mississippi River at the start of the Century was higher than 2.8 mg/l and in the 1950s-1960s higher than 3.25 mg/l, compared with the 1980-1996 value of 2.26 mg/L. The above two factors combined probably resulted in a concentration of total nitrogen at St. Francisville in mid-century about 4.0 mg/l, or higher.

While the claims of increasing-with-time nitrogen concentrations in the Mississippi River are scientifically unsupportable, analyses of historical conditions in the Illinois River further invalidate key hypotheses in the assessment.

For example, Report 3 shows that in recent years the yield of total nitrogen from the Illinois River has been greater than the yield from any other river in MRB. That this relatively high rate of loss of nitrogen is mostly delivered during the dormant season is represented as an unnatural phenomenon caused mainly by the increased use of chemical nitrogen fertilizer -- Illinois farmland has come to be fertilized so heavily that nitrate is leaking out of the soils during the dormant season into receiving waters. Thus, the Illinois River basin, and to a lesser degree other basins like it, are driving the increase in nitrogen flux -- principally through the development of an unnatural peak in nitrate concentration. However, claims that vast losses of nitrogen fertilizer are leaking into the Illinois River and driving the flux of nitrogen in the MRB are based on non-causal correlation which is asserted to be causal. This erroneous cause-and-effect relationship between flux of nitrogen and nitrogen fertilizer has been developed by selectively ignoring relevant areas of ecological hydrology, historical observations and historic data, and chemical data which disprove the relationship and, furthermore, show that relatively high rates of nitrogen flux are natural for Illinois.

The first omission is the fact that watershed studies in undisturbed forested and prairie watersheds show that nitrate concentrations are naturally highest in streams and rivers during the dormant season. Secondly, the soils of the Illinois cornbelt are naturally among the most nitrogen-rich soils of the MRB. As such, they naturally undergo the highest natural rate of natural soil nitrogen mineralization into naturally leachable nitrogen, especially nitrate. Thus the dormant season stream water nitrogen peak is expected to be naturally quite pronounced for the Illinois River basin. The third omission of hydrological fact is the reason why the Illinois River basin would naturally have even a greater flux of nitrogen than other high soil nitrogen basins. This is because most high nitrogen soil regions of the Mississippi basin do not experience their peak flows during the naturally high nitrate dormant season. And those that do have several-fold to order-of-magnitude lower flow rates (in runoff/acre) than in the Illinois River basin. In summary, while the dormant season nitrogen peak is taken as proof of over fertilization of farmland, ecological hydrology tells us that the dormant season nitrogen and nitrate peak is a natural phenomenon. And, whereas it is also asserted that the relatively high flux of Illinois River nitrogen is the unnatural result of over fertilization of farmland, ecological hydrology tells us that it is to be naturally expected.

We can now look at historic data to scientifically test the understanding of ecological hydrology. The Illinois River has been said to be "the most studied river in the world." In this regard, significant turn-of-the-century data and observations of the Illinois River basin were made under the direction of S.A. Forbes of the Illinois State Laboratory of Natural History and Professor Palmer of the University of Illinois - the first Chief of the Illinois State Water Survey. We see from these data that half a century prior to the beginning of the era of chemical nitrogen fertilizer the Illinois River had a huge nitrogen and nitrate peak during the dormant season. We see that as the river drained more and more land, it picked up more and more nitrogen. It should be noted that the peak nitrogen loadings are significant underestimates as, "At times when the dam is very deeply submerged, there is also considerable flow over the banks and through the bottoms around the dam, so that for the short period of extremely high water, the flows thus calculated are undoubtedly much below the truth."

Regarding the role of seasonal changes in concentration driving the depicted flux of Illinois River nitrogen, Palmer noted that: "The enormous quantities of nitrates found in the water at Averyville and Kampsville during March and April, the freshlet season, are in the main derived from the leaching of surface soils. The decrease at the coming of warmer weather and lower water, in May and June, results from the partial exhaustion of the supply of nitrates in the soil, and from the assimilation of nitrates by the [aquatic] vegetation..." The Illinois Natural History Survey came to a similar conclusion with its research. To quote the summary of 1894-1899 Illinois River water quality data reported by the Illinois Natural History Survey, "The coincidence of the spring plankton maximum and the decline of nitrogenous matters in the river water has its parallel in the decline of nitrates in soil waters with the pulse of spring vegetation. In both cases the decline in nitrogenous matters seems to be due to the utilization of growing vegetation, by chlorophyll-bearing organisms."

These early Illinois River researchers recognized that great amounts of nitrogen from runoff from the naturally nitrogen-rich soils of the watershed supported the lush biota of the Illinois River. Other than during times of the dormant season peak flow, "The Illinois is a river of relatively insignificant volume. Its natural low-water discharge is less than that of the Rock River....." Naturally, it is a river "filled with bayous, ponds, and swamps." The backwaters of the Illinois invariably stunned first time visitors with the tropical-like lush denseness of its aquatic vegetation. Aquatic vegetation with a carbon:nitrogen ratio of 5:15 is, on average, even more nitrogen-rich than legumes and, thus, requires massive inputs of nitrogen to support such massive and lush growth. During the high water periods, Illinois River water would flush out these backwaters carrying with them voluminous amounts of unmeasured nitrogen-rich plant and animal debris. The open river water also had much plant life in the form of plankton. For example, in the warm months, when the open river water was not mixed by wind and waves, the water was naturally coated with a green scum of algae. Also, at the start of the century, some 300,000 tons of plankton per year were discharged from the Illinois River. At a carbon:nitrogen ratio of 6:1, this means the flux of planktonic nitrogen alone discharged by the Illinois River was about 50,000 tons per year. Around the turn-of-the century the fish catch was millions of pounds annually. The plankton, other forms of lush vegetation, and the fish and animal populations contained large amounts of nitrogen. As with aquatic vegetation, these plankton are even more nitrogen rich than legumes. Regarding nitrates and other forms of dissolved nitrogen (organic, ammonium and nitrite), the authors of the early reports considered nitrates and other forms of dissolved nitrogen measured in the river as residual; described as the "... **unutilized** [author's emphasis] portion of the nitrogenous plant food immediately available." It is also recognized in these early reports that the large quantities of organic matter "... are destined to become [biologically] available." It was also recognized that "Its burden of silt thus adds to the source of fertility of the main stream and the reservoir backwaters at the time of flood." The quantity of nitrogen-containing silts was not
determined. Regarding the relative organic richness of the Illinois and Mississippi Rivers, the authors note that tests show that the amount of oxygen consumed in the Mississippi River water was even higher than that consumed in Illinois River water. Contrary to the present perception, the Illinois River basin is one where huge fluxes of nitrogen are natural.

These early researchers also recognized that nitrate is "the final product of decay." The formation of nitrate requires appreciable oxygen, not only for the decomposition of the organic carbon but also for the organic nitrogen itself (4.57 grams of oxygen for every gram of organic nitrogen).

In regard to shift in the nitrogen chemistry of the Illinois River itself, the flux of organic-rich materials and nutrients into the Illinois River increased rapidly in the first decades of the century and was accompanied by the river becoming hypoxic. In 1914-1920 the river received untreated domestic and industrial wastes having a population equivalent of between 4.2 and 6.2 million. The sediments were described as "the sludge of a septic tank." The river as far downstream as Beardstown was practically anaerobic and benthic organisms had been virtually terminated by pollution. The suppression of the seasonal nitrate peak in both the Mississippi and Illinois Rivers correlates to the time when both rivers were used literally as open sewers for massive amounts of human, animal, and industrial oxygen-consuming wastes. The rise in nitrates corresponds to the time of the environmental success story of the cleaning up of MRB streams and rivers. Nevertheless, the hypoxia reports do not recognize that this well-known environmental success story also results in changes in Mississippi River water chemistry of the type observed (i.e., an increase in nitrate concentration), thereby invalidating the assessment's conclusion about chemical nitrogen fertilizer being the dominant cause of these changes.

As will be discussed below, the construction of locks, dams, and levees in the first half century further complicated the hydrology and ecology of the river and these constructions and barge traffic continue to influence water quality today, and may very well also contribute to the observed changes observed.

Domestic sewage and industrial wastes were not the only sources of organic pollution, however; studies in Cincinnati concluded that the oxygen demand of storm water was equal to about 60 percent of the oxygen demand of sewage effluent.

From 1939 to 1969, the average amount of Lake Michigan water diverted into the Illinois River was decreased by more than 50 percent to 3,237 cfs. The reduced flow undoubtedly contributed to an increase in pollutant concentrations. In the Upper Illinois River, total nitrogen concentration in the early 1970s was about 9.2 mg/l and yet at this time the Illinois River was described as "a relatively clean stream"! Dissolved oxygen at Peoria was lower in the 1960s than the 1970s and we can reasonably assume that pollution was worse' in the 1960s than the 1970s. In 1960 the municipal and industrial organic waste discharge into the Illinois river was still about 2,300,000 population equivalent. Ecological conditions along the Illinois River reached a low point in the 1960s.

Since then, water quality has improved. Waste-treatment facilities were built in the 1960s and 1970s, dissolved oxygen in the river increased dramatically, and ecological conditions improved. Decreased nitrogen inputs and rising values of dissolved oxygen in the Illinois River have been accompanied, as would be expected, by increasing nitrate concentration and declining organic nitrogen, ammonia, and total nitrogen concentrations. In the Upper Illinois River, total nitrogen concentration in the mid-1990s had decreased to 5.5-6.0mg/L. In the lower Illinois River, total nitrogen concentration in 1993-1998 was about 4.8 mg/L There has been a steady decrease in mean Kjeldahl nitrogen concentration in Illinois rivers and streams from about 1.65 mg/l in 1981 to about 1.1 mg/l in the mid-1990s.

Furthermore, we also know from scientific literature that parts of the Upper Mississippi River were oxygen deficient and periodically hypoxic earlier in the century and that the river was very organic rich - more organic rich than the Illinois River! In the 1920's and 1930s, some benthic organisms were literally wiped out from the whole of the upper Mississippi River by pollution and sediment. By 1944 the measured oxygen consumed in the Upper Mississippi River water averaged 25 ppm! At high-water (spring) average Kjeldahl nitrogen was 5.5 ppm. Near Cairo, Kjeldahl nitrogen in the Mississippi River at high water was 9.0-10.0 ppm.

In 1960, the discharge of municipal and industrial organic waste discharged into the Upper Mississippi River Basin was 6,030,000 population equivalent. The total potential strength of agricultural wastes from cattle, calves, hogs and pigs was about 3.2 times the total potential strength of organic wastes from the entire human population and from all industry in the basin. At St. Louis, an estimated 300 tons of ground garbage was dumped into the river daily in 1957 and raw sewage discharged continued until 1970.

The Twin Cities Metropolitan Wastewater Treatment Plant was upgraded from primary to secondary treatment only in 1978 and water quality downstream of the Twin Cities improved by the early 1980s. In the last two decades, the untreated waste discharged into the Upper Mississippi River Basin has decreased dramatically. However, the organic-rich sediments and sludge from previously untreated wastes remain in the river.

In the USA, the number of horses, sheep, and mules is today less than one third the approximately 60 million during the period 1920-1940. The much higher number of horses, mules and sheep earlier in the century must have had a large, but neglected, impact on nutrient fluxes.

In a USGS report on the Upper Mississippi River, concentrations of total nitrogen in the Upper Mississippi River is shown to have decreased dramatically from 1991 through 1997: just before the junction with the Ohio River, concentration of total nitrogen in the Mississippi River declined from about 6.0 mg/L to 2.0-3.0mg/L - a 50 per cent or more decrease. Total nitrogen concentration and load in most Upper Mississippi River waters is unchanged since the 1970s, when records started.

The low nitrate values in mid-century at St.Francisville reported in Reports 1 and 3 are consistent with an organic-rich and oxygen-depleted system. No measured values for organic nitrogen are presented in the assessment reports for this period, but from what is known of the Illinois and Upper Mississippi Rivers, it can be concluded that there were vast quantities of organic nitrogen and ammonia in the Lower Mississippi River. Thus, it is indeed reasonable to estimate that the concentration of total nitrogen in the Lower Mississippi River in mid-Century was 4.0 mg/l, or higher. At the start of the century, we know that organic nitrogen plus ammonia formed about 75 percent of total nitrogen in the Mississippi River. In 1994-1996, organic nitrogen formed only about 30 percent of total nitrogen in the Lower Mississippi River (Report 3). We are indeed witnessing a major cleansing of an organic-rich system.

Consistent with a decreasing load of organic material and an increased availability of dissolved oxygen in the MRB since mid-century, the concentration of nitrate has increased in the Lower Mississippi River, as it has in the Illinois River. Another unaddressed factor contributing to the increase in nitrate concentration is the loss of much of the rich, tropical-like biota observed at the start of the century, which converted massive amounts of dissolved nitrogen into particulate organic nitrogen. By focusing on the input of dissolved inorganic nutrients and on fertilizer use, the federal assessment has failed to characterize the complex evolution of water quality and the cleanup that has occurred in recent decades.

Perhaps the reason why we have not observed an increase in nitrate concentration in the Ohio River is that the Ohio River was never an organic-rich and oxygen-deficient river to the extent of the Illinois and Upper Mississippi Rivers, and nitrification/denitrification could always proceed readily.

An important diagram in the assessment is Figure 3.4A in Report 3. There are, as with most time series, different ways of interpreting data. Report 3 concludes that the average annual nitrate concentration at St.Francisville has more than doubled since the 1954-60 period. Figure 3.4A also shows that nitrate concentration in the early 1970s was no higher than in the mid-1950s - about 1.0 mg/l, and that there was no trend in the average annual nitrate concentration from about 1977 to 1996 - the average for this period is slightly less than 1.4mg/l. This gives an increase in nitrate in the Lower Mississippi of only about 0.4 mg/l, or about 40 percent.

Report 3 finds that the flux of freshwater in the MRB has increased by about 30 percent from the 1950s-1960s to the 1970s-1980s and that this increase in river flow is partly responsible for the increase in nitrate flux to the Gulf. A recently released USGS report on the Upper Mississippi River shows an increasing trend in flood elevations at St. Louis since the 1850s, and identifies increasing rainfall as one of the main causes. Scientific literature recognizes that variations in concentration attributable to streamflow must be removed to clearly detect any temporal trends in constituent concentration. However, no attempt is made in the assessment reports to quantify the effects on nitrate concentrations in the Lower Mississippi River or on Gulf hypoxia of increasing floods in the Upper Mississippi River since the mid-19th Century, and the increase in the flux of freshwater into the Gulf since mid-20th Century. The scientific literature finds that in about 75 percent of stations in the MRB, there was no significant trends in flow-adjusted total nitrogen load from 1974 to 1994.

Report 3 notes that there were changes in the analytical method of measuring nitrate concentration in rivers in the 1970s. For the Mississippi River at St. Louis and the Ohio River at Grand Chain, the change from the phenoldisulphonic method to the cadmium reduction, automated method occurred around1973, the same time that nitrate concentration was increasing at St.
Francisville (Goolsby, personal communication). Report 3 concludes that the lack of an increase in nitrate concentration in the Ohio River is evidence that the change in analytical method did not impact the historical time series and that the increase in nitrate concentration at St. Francisville is

real, and due mainly to fertilizer use. However, as noted elsewhere in these comments, the lack of an increase in nitrate concentration in the Ohio River is itself inconsistent with the hypothesis that tile drainage and fertilizer application caused an increase in nitrate concentrations in rivers in the MRB.

In an evaluation of methods used from 1965 to 1982 to determine inorganic constituents in water sample, the literature finds no significant difference in concentrations using the phenoldisulphonic and calorimetric, cadmium reduction, automated methods. However, only 5 intercomparisons were reported when the test samples were greater than 2.0 mg/L - typical values in the Midwest. In 4 of these intercomparisons, the cadmium reduction method yielded higher concentrations than the phenoldisulphonic method by an average of 2.54 mg/L (+8.6; +0.7; +0.1; +0.75 mg/L). Thus, it can not be concluded with confidence that the change in analytical methods did not result in an artificial increase in nitrate concentration of 0.4 mg/L in the Lower Mississippi River in the 1970s.

In reviewing the USGS records for the station on the Ohio River at Grand Chain, IL, it is apparent that there are discontinuities in the record since the 1950s, there have been numerous changes in field methods, differences in reporting, and methods of preserving samples were unknown. Combined with the changes in analytical methods identified above, it is difficult to have
confidence in the homogeneity of the time series for nitrate concentration.

With these concerns for the homogeneity of the Grand Chain record, we are also even more concerned about the homogeneity of the St. Francisville record Report 3 does acknowledge that prior to 1967, daily samples were composited at 10-day to 30-day intervals. In 1967, compositing was discontinued and analysis was on discrete samples. However, Report 3 does not address the significance of this and other change in analytical and field procedures on the homogeneity of the long-term record.

At this time, based on the data and analyses presented in the reports, we do not find convincing evidence for a doubling or tripling of nitrogen concentration in the lower Mississippi River. Even the most obvious of facts which detract the chemical nitrogen fertilizer hypothesis are ignored. The many errors in the assessment are not random; they all err on the side of overestimating the effect of chemical nitrogen fertilizer on MRB water chemistry. Since this is the literal dictionary definition of bias, we can only conclude, sadly, that the assessment is biased to support the nitrogen fertilizer hypothesis.

9. The important role of suspended sediment in nutrient fluxes has not been quantified.

Suspended sediments brought down to the Gulf from states such as Illinois result from sheet, rill, gully, and streambank erosion of rich organic soils and the suspended sediments contain much nitrogen, phosphorous, and silica. The assessment makes no attempt to quantify the flux of these nutrients into the Gulf and their impact on primary productivity and hypoxia.

Data in the scientific literature and on USGS home page indicate that the sediment flux into the Gulf has decreased by about 70 percent since 1700 and by more than 50 percent since the 1950s. Report 1 also recognizes that *"The decrease in suspended sediments has happened mostly since 1950 ....."* The scientific literature also finds that, even during this contemporary period of reduced sediment flux, about 40-45 percent of the nitrogen delivered by the Mississippi River is in the form of particulates. The implications of this huge reduction in sediment transport and associated nutrient fluxes to the Gulf are profound and have been largely ignored in the assessment.

The flux of dissolved phosphorous into the Gulf by the MRB has not increased since the early 1970s when records started. Given the strong positive correlation between the flux of phosphorous and sediment flux and the large decrease in sediment flux over the historical time period, the flux of phosphorous into the Gulf must have decreased substantially during the 20th Century. Report 3 states that *"...sediment discharge from the Mississippi River basin to the Gulf of Mexico has decreased by more than 50 percent (Meade and Parker, 1985)"* and one can *".. hypothesize that the flux of P to the Gulf was considerably higher prior to the completion of the Missouri River reservoirs in the 1950s than it is today."* However, the decrease in the sediment nitrogen load and its significance for changes in total nitrogen load are not quantified. Current loading of total phosphorous in the Lower Mississippi River is 136,000 metric tons per year, but the greater than halving of the sediment load to the Gulf represents an estimated decrease of about 325,000 metric tons of particulate phosphorous per year. Thus, there has been a remarkable net decrease in total phosphorous flux to the Gulf since the 19th Century.

Similarly, it can be calculated that the flux of nitrogen in suspended sediments has decreased by almost 400,000 metric tons per year this century. This is a conservative estimate that does not include any bedload or detritus nitrogen. The scientific literature reports that the loss of particulate organic nitrogen, mainly from farmland, declined from 5.0 million metric tons in 1930, to 4.0 million metric tons in 1947, to 3.0 million metric tons in 1969.

By omitting data and making erroneous assumptions (Report 1 states clearly that *"The flux of nitrogen has also increased over the last three decades (Figure 36)."* However, Figure 36 is taken from Turner and Rabalais (1991) which states that *"... **we assumed [our emphasis] that** there has been a 100% increase in loading (Figure 6)."* This key assumption, which in Report 1 is reported as a fact, rather than an assumption, is invalid. Report 1 states that *"Long-term changes in organic nitrogen flux cannot be documented because that component has been measured only since 1972 (Goolsby et al. 1999)."* In Report 3, Goolsby et al. include organic data from the 1960s, but in a personal correspondence, Goolsby retracted the data prior to 1972. Thus, the assessment does not include any organic data prior to 1972. All the calculations of increases in phytoplankton productivity rates based on Turner and Rabalais' *"assumed"* doubling of nitrogen loading, and the hypoxia index used in Report 2 based on this assumption, are erroneous.

From the total nitrogen data presented above, it is apparent that the assessment has erroneously concluded that the concentration and flux of nitrogen has doubled or tripled over the last 50 years, coincident with the increased use of nitrogen fertilizer. If the nitrogen loading had doubled or tripled in the last 50 years, total nitrogen concentration at St.Francisville would today be about 9.0mg/l, rather than less than 2.0 mg/l.

10. The evolution of agriculture and its impacts on nutrient fluxes has been largely ignored.

While it is true that little water-quality data exist for MRB sites from the start of the century to about 1970, the assessment is deficient in not providing a fuller understanding of all the complex changes that have occurred in the MRB this century. An explanation of the complex changes in inputs, storages, releases, and fates of nitrogen, phosphorous, and silica. A more thorough identification and discussion of biogeochemical cycles would have provided a more thorough and comprehensive analytical framework for the assessment.

For example, a more thorough and comprehensive assessment of the scientific literature indicates that the loss of nitrogen from U.S. croplands has been decreasing from the first half of the century to the second half in spite of increased use of nitrogen fertilizer after WW II. Contrary to the assertions of the reports, the scientific soils literature shows that the largest source of N loss from croplands to surface waters is from soil erosion. In this regard, the scientific literature reports, as mentioned above, that the loss of such particulate organic nitrogen declined from 5.0 million metric tons in 1930, to 4.0 million metric tons in 1947, to 3.0 million metric tons in 1969. This reduction is expected to continue due to continually improving soil conservation practices and land-retirement programs. Similarly, soils literature indicates agricultural practices have reduced the soil nitrogen in US soils by some 1.75 billion tons. Whereas chemical nitrogen fertilizer is typically applied only once or twice per year, the mineralization of organic soil nitrogen to mineral forms proceeds year-round. Not surprisingly, this results in highest nitrogen concentrations in natural runoff being highest during the dormant season. Thus, with the decreasing store of mineralizable soil nitrogen, it should not be surprising to see that the leaching of soluble nitrogen from US croplands is reported to have decreased from 4.0 million metric tons in 1930, to 3.0 million metric tons in 1947, to 2.0 million metric tons in 1969. This trend should also continue. That the scientific literature shows loss of soil nitrogen from agricultural lands of about 1.75 billion tons, compared to total nitrogen fertilizer application of several hundred million tons, points to the failure of analysts to acknowledge the huge amounts of nutrients that are cycled in plants and soils and the huge amounts of nutrients that have been removed by cultivation.

These omissions have resulted in a large bias in estimating the human impact on the nitrogen cycle - globally and in Illinois. Reports 3 and 5 show that today some 6.5 million tons mineralized soil nitrogen are input to the MRB each year. Knowing that some 50 percent of the organic nitrogen is lost within the first 50 years of cultivation, and assuming the same mineralization rate (a conservative estimate as the lost soil nitrogen would have a higher mineralization rate than the more refractory residual), it can be readily calculated that earlier in the century the amount of mineralized soil nitrogen must have been at least 13.0 million tons per year. Unfortunately, the assessment does not attempt to address the historical evolution of these and other activities related to the nitrogen, oxygen, and carbon cycles.

11. The large flux of organic carbon into the Gulf has been unduly discounted.

The flux of organic carbon into the Gulf is summarily dismissed in the assessment as an unimportant factor. It is dismissed principally on the statement that carbon brought down the Mississippi River (plus the additional quantities emanating from the vast Gulf wetlands) is localized close to the shore and is unimportant to the near continental shelf where hypoxia occurs. This assertion is demonstrably not true.

For example, floods, such as the 1993 are considered to be very important to the delivery of dissolved nutrients needed to increase hypoxia. Satellite imagery of the 1993 flood (from a publication cited in the assessment) shows that suspended sediment is carried to the outer continental shelf and beyond. Indeed, analysis of Gulf sediments show that this has been the case for floods over the last several thousand years: suspended sediment from the Mississippi, especially during floods, is important in waters up to 5,000 feet deep.

Another example of bias is in the carbon isotope studies generated by the hypoxia program which are used to support the above summary dismissal. These isotope analyses seem to assume that the carbon isotope signature in Mississippi River basin suspended sediment is that of forested soils. However, the main soil types of the basin have been developed under grasslands. The carbon isotope signature of grassland soil more resembles that of marine carbon than forest soil carbon. Today, as in the recent geologic past, the main source of soil erosion in the basin is from prairie soils. This and other errors add up to grossly underestimate the importance of Mississippi River basin organic carbon to the Gulf. Today more than 10 million metric tons per year of organic carbon (dissolved and particulate) are brought down the Mississippi into the Gulf. Furthermore, the decline in Mississippi sediment loading to the Gulf has caused an estimated decline of 6.7 million metric tons per year of organic carbon to the Gulf. To put this value in perspective, the estimated total primary production of organic carbon (122 gC/m2-yr) in the hypoxic zone (18,000 km2) is on the order of 2.0 million metric tons per year.

12. Primary productivity in the Gulf has decreased, not increased.

In evaluating changes in primary productivity in the northern Gulf, the assessment ignores 1950s data on primary productivity produced by the National Science Foundation, the National Research Council, and the Scripps Institute of Oceanography performed over a multi-year period during what the hypoxia program considers the background period - the 1950s. The rate of primary productivity on the continental shelf around the Mississippi River delta was >183 gC/m2/yr, with a mean value estimated to be 365 gC/m2/yr. According to the assessment reports, and consistent with literature, the rate of primary productivity on the continental shelf and in the hypoxic zone is 122 gC/m2/yr. These data clearly demonstrate that primary productivity in the hypoxic area has decreased . The decrease in primary productivity in the Gulf is consistent with a decrease in the flux of total nitrogen, total phosphorous, and organic carbon since mid-Century.

The assessment, through the application of spurious and false assumptions, concludes that primary productivity in the hypoxic area has increased about fivefold from about 25 gC/m2/yr in the 1950s. However, it is inconceivable that a natural, *"pre-pollution"* primary productivity rate of only 25 gC/m2/yr could sustain the most productive fishery in the USA - the "Fertile Fisheries Crescent". Such a low rate of primary productivity is typically found in the biologically depauparate areas of the world's oceans - the "biological deserts" of the sea.

13.The importance of surface runoff has been unduly downplayed.

The reports overemphasize tile drainage and downplays surface runoff. Table 2.3 in Report 3 shows that over most of the MRB annual runoff is about 20-60 cms per year. Surface runoff, its organic and inorganic contents, and its ability to transport atmospheric deposition of nitrogen need to be better characterized.

14. Input-output mass balance calculations are flawed.

i) No source is identified in the input-output tables in Report 3 or Report 5 for almost 40 percent of the total nitrogen in the Mississippi River - organic nitrogen! Despite this major omission, the tables that account for inputs and outputs of nitrogen are, remarkably, balanced! Report 4 also fails to address this form of nitrogen. Report 5 shows that wetlands increase the flux of organic nitrogen. Report 6 does not address the control of organic nitrogen, or how the fact that organic nitrogen constitutes almost 40 percent of total nitrogen affects the effectiveness of controlling fertilizer use to reduce nitrogen-loss by 20 percent. The failure to address the sources of almost 40 percent of total nitrogen is a major omission in the assessment.

ii) In the Executive Summary of Report 3 it states that municipal and point sources contribute about 11 percent of the total nitrogen flux to the Gulf. In Table 6.1 it shows that municipal and industrial point sources contribute 287,000 tons, or 18 percent.

iii) The Executive Summary of Report 3 concludes that inputs of nitrogen from atmospheric deposition "*are small relative to other nitrogen inputs to most of the Mississippi-Atchafalaya River basin.*" However, in the Lower Mississippi atmospheric deposition is equivalent to over 40 percent of fertilizer nitrogen, and in Upper Ohio it is more than 50 percent. In the Illinois River basin, total nitrogen deposition from the atmosphere is about1,000 $kg/km^2/yr$, which is about 50 percent of the average annual total nitrogen yield for the basin. For the entire MRB, atmospheric deposition can account for all the nitrogen load in the Mississippi and Atchafalaya Rivers. We conclude that the Executive Summary unduly downplays the significance of nitrogen inputs other than fertilizer.

Overall, the reports establish little credible scientific basis for developing precise input-output tables, conducting detailed mass-balance studies, and determining source contributions to the nitrogen and phosphorous loads in the Lower Mississippi. As an example, a change in the assumed mineralization rate of 0.5 percent can account for all the nitrogen in the Lower Mississippi River.

15. There is no significant relationship between nitrogen flux from the Mississippi River and the size of the hypoxic zone

Report 1 finds that the maps of mid-summer extent of hypoxia *"provide a benchmark for year-to-year comparisons......"* In view of the alleged central importance of the nitrogen flux down the Mississippi River, we plotted a scatter diagram to examine the relationship between nitrogen flux and the mid-summer areal extent of hypoxia over the past several decades. The diagram shows that there is no statistically significant correlation between the two variables. Report 1 finds that from 1985 to 1993 there was a correlation coefficient of 0.934 for the mid-summer hypoxic area and the mean Mississippi River discharge for the proceeding year, but that this relationship fails to hold for the additional years 1994-1998. Report 1 concludes that a comparison of mid-summer area versus discharge is not *"entirely"* satisfactory, and proceed to talk about carbon burial. Thus, neither freshwater discharge nor nitrogen flux produces a "satisfactory" correlation with the mid-summer surface extent of the hypoxic zone.

16. The dynamics of the coastal zone and continental shelf have been ignored and/or unduly discounted.

The entire coastal zone is highly dynamic and scientific literature shows, for example, vast upwellings of deep-water marine muds are extruded upward at rates in excess of 300 feet per 20 years. These extruded muds form islands which erode at the mouth of the Mississippi River and these muds take on a deep-water marine faunal characteristic because of this process. In turn, large quantities of marine carbon and preserved marine microfossils are dispersed into the nearby coastal shelf from which the Gulf program samples its sediment. The authors of the assessment reports do not consider these and other potentially important geomorphic and geological conditions and changes.

17. The importance of freshwater fluxes and stratification has been unduly discounted.

The reports acknowledge the necessary role of freshwater stratification in hypoxia formation, but fail to quantify the role of changes in the patterns and quantities of freshwater flux on changes in the location and magnitude of hypoxia. For example, the Atchafalaya River was a bayou last century - small enough to be crossed by foot bridge and shallow enough for cattle to wade across. Thus, it is likely that there was little stratification and little hypoxia in the central and western parts of the hypoxic zone last century when the discharge of freshwater by the Atchafalaya River was small. Today, the discharge of freshwater by the Atchafalaya into the central hypoxic area is equivalent to about the discharge of the Ohio River into the Mississippi River and about 4 times the discharge of the River Nile into the Mediterranean Sea. Also, the Atchafalaya River discharges its water into much shallower coastal water than does the Mississippi River from its Southwest Passage and this factor needs to be considered. Failure to attempt to quantify the importance of changes in freshwater fluxes biases the assessment to other variables, especially nutrient fluxes.

18. Sediments in the river plumes carry nutrients far out to sea.

The statement in Report 1 that sediments do not accumulate in the Atchafalaya River plume is untrue. The scientific literature demonstrates clearly that sediment builds up on the continental shelf from the Atchafalaya plume and has been doing so at an accelerated rate as the Atchafalaya's sediment load has been progressively filling up the formerly ~1,000 square mile Grand Lake through which it flows. In fact, the US Corps of Engineers has a major project to remove large amounts of deposited Atchafalaya River sediment after the Atchafalaya River sediment load achieved essentially complete breakthrough to the Gulf with the 1993 flood. A major goal of the engineering work is also to diminish the forceful stream jet ejection of the over 100 million cubic yards per year Atchafalaya River mud stream directly out into the Gulf. Further, if the sediments in the Atchafalaya River plume do not accumulate on the continental shelf, they must be transported out of the region. Using the same logic, it must be assumed that the nitrogen and phosphorous in the Atchafalaya plume also do not reside in the hypoxic zone and are transported out. In Report 1 it states that *"Since the 1700s humans have altered the morphology and flow of the Mississippi River so that now 30% is diverted to the Atchafalaya that also captures the flow of the Red River."* Humans have, in fact, contained the natural changes that were occurring. It is well known that, in the absence of human intervention, the Atchafalaya River would by now have captured the entire Mississippi River and New Orleans would be on a backwater swampy bayou rather than the mightiest river of the nation. Humans have thus also contained the large increase in hypoxia that would have occurred had the Atchafalaya River fully captured the Mississippi River.

The reversal of the Atchafalaya River to bayou status is probably the single most effective strategy that could be implemented to reduce hypoxia in the central and western parts of the current hypoxic zone and rebuild wetlands in Louisiana. The assessment does not address this.

19. Nitrogen dynamics in the coastal zone have not been addressed comprehensively.

Another reflection of the failure to adequately adopt biogeochemical cycling as the framework for the assessment is the failure in Reports 1, 2, 3, and 4 to adequately address nitrogen losses and nitrogen fixation in the coastal areas and the northern Gulf. These reports largely take the amount of nitrogen, phosphorous, and silica measured in the rivers to represent the nutrient fluxes into the Gulf; little accounting is done of nutrient losses in the estuaries, bays, and wetlands and on the continental shelf.

However, it is fortunate that Report 5 does provide some insights into the magnitude of these losses: *"Figure 3.28 illustrates significant reductions in nitrate concentrations from the River to the nearshore Gulf."* Transects show up to almost 100 percent reduction in near-shore nitrate concentrations in the spring and fall and up to 90 percent reductions in summer. Some of this is probably due to mixing, but a large part is probably a loss due to denitrification and assimilation.

On page 70 it is acknowledged that up to 50 percent of nitrate and nitrite in river estuaries can undergo denitrification and that denitrification takes place in *"coastal wetlands and practically all shallow inshore waters"*. It is well documented in the scientific literature by experts such as Professor James Galloway that some of the highest rates of denitrification in the world occur in the shallow continental shelves. Professor Robert Howarth concludes that, on average, only 25 percent of human-controlled inputs of nitrogen to a region are exported to the ocean in riverine flow; the majority (50 percent or more) is probably denitrified in wetlands, streams, and rivers. Data in Report 3 show that in the MRB, only about 8 percent of all the identified nitrogen inputs is exported to the ocean. This percentage would be considerably less if sources of organic nitrogen (37 percent of the total nitrogen in the Mississippi River) had been identified.

There is no detailed dynamic analysis in the reports on source attribution to identify from the ~21.0 million metric tons of nitrogen inputs those that contribute to the 1.5 million tons of nitrogen flux in the lower Mississippi River, i.e., ~7 percent (or less, if sources of organic nitrogen were identified) of nitrogen inputs. If we assume that all sources contribute equally to the flux of nitrogen, then all the nitrogen fertilizer inputs (~30 percent of total) contribute ~30 percent of the outputs, i.e., ~470,000 tons of nitrogen. Reducing nitrogen loss in the Lower Mississippi by 20 percent, or ~310,000 tons, would require a reduction of fertilizer loss of ~65 percent. Report 6 concludes that a reduction in fertilizer loss of 45 percent will produce a 20 percent reduction in nitrogen loss.

Furthermore, Report 5 finds that the deltaic plain of the Mississippi River delta has some 2,800,000 hectares of wetlands and shallow coastal waters. If, according to Report 5, removing 50,000 metric tons of nitrogen per year could be achieved by 500,000 hectares, then it can be calculated that the MRB deltaic plains, coastal wetlands, estuaries, and coastal waters must already be removing some 300,000 to 400,000 tons of nitrogen. Report 5 also finds that *"It is likely that significant denitrification is currently occurring in the Gulf of Mexico hypoxic zone."* However, failure to adequately account for denitrification and other nitrogen losses in the assessment has resulted in large overestimates of the role of nutrients in processes on the continental shelf and to gross errors in estimating the efficacy of reductions in nutrient loads in the upper MRB on nutrient delivery to the hypoxic zone.

For the three model application periods in Report 4, the influx of freshwater into the hypoxic zone was 50 percent greater from the Atchafalaya River than from the Mississippi River. The nutrient loads from the Atchafalaya River into the hypoxic zone were also higher than from the Mississippi River. In the Mississippi River, the load of organic nitrogen was about 27 percent of the total nitrogen load. The load of organic nitrogen in the Atchafalaya River was about 48 percent of the total nitrogen load. Report 1 fails to adequately address the great importance of hydrodynamics and biogeochemistry in the Atchafalaya and Red Rivers and in the coastal zone on nutrient fluxes to the Gulf. Report 3 does not identify the sources of organic nitrogen.

20. 1993 Mississippi River flood waters moved towards Florida, not into the hypoxic zone.

Much has been made by the lead author of Report 1 on the major influence of the impact of the Mississippi River floods in the summer of 1993 in enlarging the hypoxic zone and perhaps being a cause of the sustained large hypoxic area in subsequent years. However, as with the assertion that Mississippi River suspended sediment is not transported out to the continental shelf, Report 1, while citing Walker (1994), fails to acknowledge that Walker includes a satellite photograph taken in August 1993 which shows that the plume of the Mississippi River flowed eastwards towards Florida, ultimately joined the Gulf Stream, and then flowed northward along the eastern seaboard of the USA. In the main, the freshwater, the dissolved nutrients, and the sediments from the Mississippi River flowed away from the hypoxic zone and, therefore, could not have influenced the hypoxic area, either in 1993 or subsequent years.

21. Natural hypoxia has been ignored.

In the same vein as the preceding comment, Reports 1 states that *"The largest zone of oxygen-depleted coastal waters in the United States, and the entire western Atlantic Ocean, is in the northern Gulf of Mexico on the Louisiana/Texas continental shelf."* Nevertheless, the lead author of Report 1 is fully aware that the lead author of Report 2 is the lead author of a 1995 scientific peer-reviewed article on global hypoxia that shows clearly that naturally hypoxic conditions extend all the way from the Canadian border down to Chile. The introduction states that *"Hypoxic and anoxic basins are well known features of the world's ocean...."* Many parts of the world's oceans in shallow coastal waters and in remote parts of deep oceans are naturally hypoxic, and have been throughout geological history. In Report 2, the lead author refers to his 1985 paper to state that *"Many coastal ecosystems throughout the world suffer from eutrophication and hypoxia."*

We conclude that the purpose of such an omission of facts on natural hypoxia in the authors' possession can only be to mislead readers into believing that hypoxia on the scale seen in the Gulf is necessarily a vast and unnatural, man-made phenomenon. The failure to address natural hypoxia formation adds to the bias of the assessment.

22. A strong seasonal peak in nitrate concentration is not a recent phenomenon caused by fertilizer application.

Report 1 finds that *"There was no pronounced seasonal peak in nitrate concentration prior to 1960, whereas there was a spring peak from 1975 to 1985."* The implication of this assertion is consistent with the conclusion asserted earlier by program scientists that a dormant-season nitrate peak is unnatural and represents unnatural nitrogen saturation of the landscape by chemical nitrogen fertilizer. However, the data shown in Report 1, Figure 38, clearly indicate that the concentration of nitrate at St.Francisville in 1905-1906 in March was twice as high as in October. In 1955-1959 the spring peak in nitrate concentration was less than twice as high as the October minimum. The data for many stations in Illinois and the mainstem Mississippi River in the early 1900s show that there was a very pronounced seasonal cycle of nitrate concentration, with a clear peak in spring and a minimum in the fall. Clearly, the spring peak a century ago could not have been due to the application of inorganic fertilizer, which increased rapidly only after World War II. The spring peak and fall minimum are consistent with the nitrogen trends seen in undisturbed prairie and forested watersheds which invariably show that nitrate concentrations peak during the dormant season. The failure to identify the natural and historical spring peak in nitrate concentration is another example of the bias in the assessment towards fertilizer use. What is unnatural is the lack of the pronounced seasonal cycle in the 1930s and 1950s and an objective and competent assessment would note so.

23. Fertilizer loads in major rivers are much higher in other parts of the world.

The reports make comparisons with human-modified hypoxic areas in other parts of the world. It should be noted, however, that according to the peer-reviewed scientific literature, the fertilizer load in river basins such as the Danube, Meuse, Rhine, Po, Rhone, Thames, and Vistula are 2-5 times greater than in the Mississippi River basin. The failure to address these higher fertilizer loads leads the reader to implicitly assume, erroneously, that the fertilizer loads in the MRB are similar to those in heavily polluted rivers of the world.

24. The externalities of wetlands are not adequately addressed.

Wetlands are proposed as a major strategy for reducing nitrate concentrations and loads in rivers and streams. The scientific literature also provides evidence that wetlands can also mobilize and release toxic organic chemicals, metals, and methane. Report 4 discusses briefly the release of nitrous oxide from wetlands, but it does not discuss the release of another powerful greenhouse gas - methane. Thus "externalities" associated with wetlands are not well discussed in the reports, even though the reports themselves are geared to addressing the externalities of farming and other activities. Furthermore, Report 4 does show that many wetlands are sources of organic nitrogen. Report 4 does also state that "... *a Louisiana swamp forest acted primarily as a transformer* *system, removing inorganic forms of nitrogen and serving as a net source of organic nitrogen, phosphate, and organic phosphorous."* Also, wetland vegetation is typically very nitrogen rich: even more nitrogen rich than legumes. When flushed during periods of high water, natural wetlands export large amounts of nitrogen-rich particulate organic matter. However, there appears to be little consideration of such particulate organic nitrogen export from mature wetlands, which is most profound during periods of high flow. Overall, a more thorough analysis of the externalities associated with wetlands would be appropriate.

25. Limiting nutrients are not well identified.

Report 1 identifies that hypoxia is due primarily to excess fluxes of nitrogen and phosphorous down the MRB, both of which can be limiting nutrients, but Reports 4-6 address only nitrogen control. Clearer definition of nutrient limitation is needed.

26. The concentration of phosphorous is higher in the Atchafalaya River than in the Mississippi River.

The concentration of total phosphorous in the Atchafalaya River is shown to be 30 percent higher than in the Mississippi River. Given the fact that about two thirds of the water in the Atchafalaya River is diverted from the Mississippi River, then the concentration of total phosphorous in the Red River, other tributaries of the Atchafalaya Rive, and the Atchafalaya River itself must be about twice that of the Mississippi River. These variations in the sources of phosphorous need to be addressed in any deliberations on phosphorous control.

27. Economic analysis questioned.

It is concluded in Report 6 that fertilizer restrictions are more cost-effective than a fertilizer tax. This seems to be a patent misapplication of the concept of cost-effectiveness. It is widely held by economists that a price signal (such as a tax) is more efficient than a quantity restriction (such as fertilizer limits).

28. Feedlot runoff analysis does not make sense.

Report 5 finds that *"A 20% decrease in feedlot runoff could result in a decrease of 5.3 million metric tons/year* [of nitrogen loss] *to streams and rivers in the Basin."* In view of the fact that Report 3 finds that a reasonable assumption is that most of the nitrogen that leaves a farm field does reach the Gulf, then it can be concluded that a 20 percent reduction in feedlot runoff would more than totally eliminate all nitrogen flux in the Mississippi River, which is about 1,568,000 tons per year. This finding is absurd!

29. Input-output ratios show that controlling atmospheric deposition and manure use is more effective than controlling fertilizer.

Report 3 shows scatter plots of relations between total nitrogen yield and nitrogen inputs. It is evident from these diagrams that controlling atmospheric deposition of nitrate and the use of manure is the most effective way of controlling nitrogen yield: the input-output ratio is about 1.0:2.0. For nitrogen fertilizer, the input-output ratio is about 1.0:0.3. This factor of seven difference in inputs and yields should be incorporated in the economic analysis.

30. There are many inconsistencies within and among the reports. For example:

i) Report 1 finds that there is i) *"... a close coupling between river-borne nutrients, net productivity, vertical carbon flux and hypoxia..."*, and ii) *"... no simple description of the couplings between nutrient delivery, carbon production in surface waters and delivery and recycling in bottom waters."* Report 4 finds *"...large uncertainties in the magnitudes of these responses for a given nutrient loading reduction. These uncertainties are due to lack of information on controlling physical, chemical, and biological processes, and to natural variability in hydrometeorological conditions in the northern Gulf of Mexico."*

ii) Report 4 finds that *"The mean percentage loss of TN was estimated to be ~35-40% in small tributaries and ~20% in mainstem rivers."* These figures indicate that only about 50 percent of total nitrogen originating in small tributaries is retained in the mainstem river channels. If we also allow for i) at least 40 percent denitrification in the coastal wetlands and shallow coastal waters (Report 5), and ii) the fact that less than one half of the MRB waters remain in the hypoxic zone for an extended period of time, then only about 15 percent - 275,000 tons - of total nitrogen in the MRB resides in the hypoxic zone for some time.

Report 5, on the other hand, finds that *"A reasonable assumption is that most of the nitrogen that leaves a farm field does reach the Gulf as Goolsby et al. (1999) point out that there appears to be little in-stream loss of nitrogen once it reaches the streams and rivers. Reducing 1 million metric tons of nitrogen in a wetland conceivably causes a reduction of 1 million metric tons of nitrogen at the Gulf."* The estimated percentage nitrogen contributions in Report 3 assumes that there are no instream losses of nitrogen between the outflow point of each large basin and the Gulf of Mexico. If the data in Report 4 or other estimates of instream losses had been used, different contributions would have been calculated.

Report 6 finds that a reduction of fertilizer use of 45 percent will produce a nitrogen-loss reduction of 20 percent - 1,027,000 metric tons - from agriculture within the MRB. *"The strategy that comes closest to the least-cost solution is the 45% fertilizer restriction."* The cost of this strategy is $2.9 billion. The cost of the preferred strategy for reducing nitrogen-loss by 20 percent is the combined strategy of reducing nitrogen fertilizer use by 20 percent and reconstructing 5 million acres of wetlands. The cost of this strategy is $4.8 billion for a nitrogen-loss reduction of 882,000 metric tons. Nevertheless, the Concluding Observations and the Executive Summary of report 6 find that the fertilizer/wetlands combined strategy is the *"most cost effective in meeting a 20% nitrogen loss reduction goal."* ! The effectiveness of a nitrogen-loss reduction of 1,027,000 tons from agriculture on nitrogen fluxes in the Lower Mississippi River will likely vary, according to which assumption one accepts, from 1,027,00 to about 500,000 million metric tons per year- a 30-60 percent reduction from a total nitrogen-loss in the Lower Mississippi of about 1.6 million tons per year. The reduction in nitrogen loading in the hypoxic zone could be much smaller. Fertilizer use constitutes about 30 percent of all the recognized nitrogen inputs to the MRB. If reducing nitrogen fertilizer use by 45 percent results in a reduction in nitrogen flux in the Lower Mississippi River by 30-60 percent, then presumably a 45 percent reduction of nitrogen inputs from the other 70 percent of sources would, as a first approximation, result in a reduction in nitrogen-loss in the Lower Mississippi River of 75-150 percent - a calculation that clearly does not make sense.

Report 4 appears to evaluate water-quality responses in the Gulf to a reduction in nutrient loading of 20-30 percent - a 20-30 percent reduction in nutrient loading in the lower Mississippi and Atchafalaya, not a 20-30 percent nitrogen loss reduction of 20-30 percent from agriculture in the upper watersheds. Report 4 concludes correctly that *"...it is not possible to even predict that the same percentage reductions will occur in river loads of nitrogen from diffuse sources for a given percentage reduction in inputs of nitrogen to the basin."*

The bottom line is that the reports do not present consistent and credible analyses of i) source attribution, i.e., identification of the contributions of inputs of nitrogen from different sources in the MRB to nitrogen loadings in the hypoxic zone, and ii) the effectiveness of reducing nitrogen inputs from different sources in the MRB on nitrogen loadings in the hypoxic zone.

iii) Two following two conclusions in Report 1 are contradictory: i) *"An effect likely to occur in the offshore region as a result of increased flow through the Atchafalaya delta is an increase in stratification west of Atchafalaya bay and further westward into Texas."* is inconsistent with ii) *"Thus, long-term effects in the offshore ecosystem are likely as a result of changes in constituents, primarily nitrogen as nitrate, and not the amount of freshwater discharge or alterations in delivery."* Report 1 acknowledges the essential role of freshwater fluxes in establishing the necessary stratified conditions for hypoxia formation: *"Freshwater discharge dictates, along with seasonal atmospheric warming, a strong seasonal pycnocline that is necessary for the development and maintenance of hypoxia."* It is inconceivable that the influx of freshwater equivalent to the flow of the Ohio River directly into the middle of today's hypoxic zone has not been a major, if not the major, influence on the occurrence of hypoxia.

iv) In the Executive Summary of Report 3 it states that 10 percent of the phosphorous flux to the Gulf is estimated to come from municipal and industrial point sources and 31 percent from fertilizer. In Table 5.13 it shows that 59,000 metric tons per year come from point source discharge, i.e., about 43 percent of phosphorous discharged to the Gulf. Using this figure, the contribution from fertilizer use is greatly reduced.

v) The USMP model used for Report 6 determines that tillage practices and crop rotations are not important factors for achieving N-loss, and, therefore, Report 6 focuses on *"reducing nitrogen fertilizer use."* Such a finding on the lack of importance of crop rotations is not consistent with the scientific literature and it thus brings into question the validity of the model. Report 5 finds that *"Nitrate concentrations in subsurface drainage water are related to cropping systems." "Alternative cropping systems that contain perennial crops would greatly reduce nitrate losses."* Report 5 does agree that *"Tillage methods appear to have little influence on nitrate loss from agricultural fields."*

31. The use of much unpublished data reduces credibility.

There is much use of unpublished data, especially in Report 1. It is impossible to comment on the credibility of unpublished data.

32. Some of the Executive Summaries do not provide balanced summaries of key findings and conclusions. For example:

i) The Executive Summary of Report 1 states that *"The best current knowledge is that the outflows of the Mississippi and Atchafalaya Rivers dominate the nutrient loads to the continental shelf where hypoxia is likely to develop."* Such a conclusion is inconsistent with the statement in Report 1 that *"The relative contribution of offshore sources of nutrients from upwelled waters of the continental slope is unknown."* The latter finding should have been incorporated in the Executive Summary in place of the scientifically unsupportable first statement. A recent scientific article also documents upwelling and associated nutrient enrichment and phytoplankton blooms in the southern Gulf of Mexico, which could serve as a source for nutrient enrichment along the northern Gulf coast.

ii) Report 6 finds that *"The strategy that comes closest to the least-cost solution is the 45% fertilizer restriction."* The cost of this strategy is \$2.9 billion. The cost of the preferred strategy for reducing nitrogen-loss by 20 percent is the combined strategy of reducing nitrogen fertilizer use by 20 percent and reconstructing 5 million acres of wetlands. The cost of this strategy is \$4.8 billion. Nevertheless, the Executive Summary finds that the fertilizer/wetlands combined strategy is the *"most cost effective in meeting a 20% nitrogen loss reduction goal."* ! No estimates of cost are included in the Executive Summary.

33. Peer review

With all these problems, we are surprised that the reports have passed successfully through the peer-review process. The existence of major problems indicate that the peer-review process has not been rigorous.

SUMMARY

The reports includes many invalid assumptions and erroneous conclusions, and there has been selective use of scientific data.

Fluxes of total nitrogen and total phosphorous from the MRB to the northern Gulf have decreased since mid-century. Consistent with the reduced fluxes of nutrients, the rate of primary productivity in the northern Gulf has also decreased.

These findings invalidate the central hypothesis of the assessment that the fluxes of nitrogen and phosphorous and the rate of primary productivity have doubled or tripled since mid-century. They also invalidate the crystal-ball gazing in Report 3 that *"... increases in nutrient flux will continue."*

Changes in the forms of nutrients and nutrient fluxes can only be understood from a scientific perspective when all the components of the nutrient cycles and other related biogeochemical cycles - especially carbon and oxygen - are addressed simultaneously and in a historical, evolutionary context. The hypoxia assessment fails to do this. The assessment reports represent a teflon-like river - a "one-way street" - which focus on how MRB nitrate-nitrogen may influence the carbon and oxygen cycles of the Gulf, but they neglect how the carbon and oxygen cycles of the MRB have influenced the flux and form of nitrogen transported to the Gulf. Many factors that influence nutrient loads have been ignored.

The role of fertilizers, atmospheric deposition, manure, mineralization of organic nitrogen, release of organic nitrogen, tile drainage, and other factors influencing the nitrogen cycle in the MRB must be evaluated in the context of major chemical, biological, and physical changes in the MRB and the Gulf. The assessment fails to do this.

The reports do not present a clear cause-effect relationship between fertilizer use, high nutrient yields, nutrient fluxes, and hypoxia in the Gulf.

Nitrate is the final product of the oxidation of nitrogenous matters. From a scientific perspective, an increase in nitrate represents a cleansing of the system from a low-oxygen, organic-rich system dominated by dissolved and particulate organic nitrogen and ammonia to a more oxidized system dominated by nitrate.

The hypoxic zone and its surrounding coastal area are undergoing perhaps the most massive environmental changes of their kind in the world. Namely, a swampy backwater bayou has transformed itself into the largest river capture in the world. This new river, the Atchafalaya, now discharges four times more freshwater than the River Nile directly into the heart of the hypoxic zone along with over 100 million cubic yards of fertile mud per year. Conversely, the concomitant loss of this water and sediment from the mainstem of the Mississippi has been accompanied by the largest loss of coastal wetlands in the world. The occurrence of and changes in northern Gulf hypoxia must also be re-evaluated in the context of these massive and rapid changes occurring in the northern Gulf itself.

To paraphrase former-Senator Everett Dirksen of Illinois, a billion here, a billion there, and yet another billion over there, and pretty soon we are talking about significant money. The same is true with the federal assessment of Gulf hypoxia. The piling up of selective omissions and misrepresentations of the importance of natural fluxes and biogeochemical cycles of nitrogen, phosphorus and carbon to the Gulf rapidly add up to gross overestimation of the effect of fertilizer additions. These errors are not random; they all work in one direction. Such consistency in direction of errors is the dictionary definition of bias.

The peer-review process has not been rigorous.