USEFULNESS OF DIVERSIONS

QUESTION 2

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ARE DIVERSIONS OF WATER AND SEDIMENT FROM THE MISSISSIPPI RIVER USEFUL TOOLS FOR BUILDING LAND IN THE MISSISSIPPI RIVER DELTA?

Sediment diversions are man made channels for delivering sediment laden river water to the coastal ecosystem. Diversions have been proposed for land building in the Mississippi River's lower delta plain. However, some have questioned the suitability of diversions, given projected sea level rise and subsidence rates as well as the catastrophic rate of land loss that Louisiana's coast is experiencing. Our analysis examined the question: can diversions build enough land to make a difference?

OUR ANALYSIS

We considered the land building capacity of a diversion to be the ability of deposited sediment to increase the elevation of a land or seabed surface. More specifically, we viewed the change of elevation in relation to what we called "sink" factors. These include factors such as rises in global sea level and local subsidence as well as sediment compaction. Sink factors can interact in many different ways, but their combined effect is always negative for land building. If this negative effect exceeds the supply of sediment, then land will not build. If the supply of sediment exceeds the negative effect of the sink factors, then land will build in varying degrees, depending on conditions on the ground. We considered several case studies as part of our analysis, including three kinds of diversions: flood control, land building, and freshwater.

KEY TERMS

- ***Global Sea Level Rise****, also known as eustatic sea level rise, is the expansion of the ocean's volume worldwide.*
- ***Subsidence*** *is the sinking of land. Louisiana's wetlands are subsiding at varying rates.*
- ***Relative Sea Level Rise*** *is a term that encompasses the effect of both global sea level rise and local subsidence rates.*

Case Study: Wax Lake Delta

The Wax Lake Outlet of the Atchafalaya River was completed by the U.S. Army Corps of Engineers in 1942 to relieve flood pressure downstream in Morgan City, Louisiana. A small delta at the outlet mouth emerged following the 1973 flood and has since grown rapidly at rates of 2 to 3 square kilometers per year to approximately 100 square kilometers in 2005. Measurements and model simulations show that this delta growth developed while local subsidence was occurring at rates of 5 millimeters per year and sea level rise was 2 millimeters per year. Model simulations indicated that this delta growth could continue to develop at combined rates of subsidence and sea level rise of up to 14 millimeters per year. This range of net subsidence plus sea level rise is characteristic of present and projected conditions for much of the delta region.

Case Study: Cubits Gap Subdelta

The Cubits Gap Subdelta, upstream from the Head of Passes, developed from a man made cut in the Mississippi River bank made in 1862. By 1868, the gap had widened to over 200 meters, and over the next two decades an extensive delta developed that had remarkable similarities to the Wax Lake Delta at the same age. The delta reached a maximum size of approximately 200 square kilometers by the 1940s, growing at rates of 2 to 3 square kilometers per year. Following the natural delta growth and decline cycle and impacted by high subsidence rates, the Cubits Gap Subdelta then began to decline and is now in an advanced state of deterioration.

Case Study: Caernarvon Diversion

The Caernarvon and David Pond Diversions are the two largest constructed freshwater diversions in Louisiana and are subject to strict flow regulation. The Caernarvon Diversion was designed to supply fresh water and optimize salinities for oyster cultivation; it was not designed to supply sediment and build land. The diversion began operation in 1992 and has discharged, on average, considerably less water than its maximum rated flow capacity of about 220 cubic meters per second. Land building in streamside marshes at Caernarvon has been able to keep up with local relative water level rise. Sediment capture is rapidly filling Big Mar, a lake that receives flow from Caernarvon, in which about 4 square kilometers of new land have emerged in the past five years.

There has been vigorous debate as to whether the introduction of fresh water by Caernarvon made the nearby marsh more susceptible to marsh tearing during Hurricane Katrina. Some scientists claim that the fresh water weakened the marsh soils and made them more vulnerable to storm related effects. Other scientists disagree. Excessive nutrients, lack of sediments, and low salinity due to freshwater conditions may have all contributed to Katrina induced marsh tearing. Most scientists who have studied the diversion believe, however, that to improve land building, Caernarvon should introduce more sediment per unit of water diverted. This could be done by diverting water during periods when sediment concentrations in the river are high or by enhancing the concentration of sediments in diverted water. Pumping dredged sediment into the diversion stream would increase this concentration, as would constructing a berm in the river bottom to direct more of the bedload into diverted water.

Case Study: West Bay Diversion

The West Bay Diversion near Head of Passes was designed to build land. New land appeared in 2011 following a historic flood, nearly a decade after the project's construction, although extensive underwater deposits had been forming since the diversion was opened in 2004. However, the combined effects of local subsidence and rising sea level are particularly significant in this portion of the Bird's Foot Delta and may impair the long term stability of the new land built. Despite the success of new land formation at West Bay, it is currently slated for closure.

WHAT THE SCIENCE SAYS

Sediment diversions can build extensive land in open bays and other areas throughout the coast, taking into account present and projected levels of sea level rise and local subsidence. In order to achieve this outcome, however, sufficient water and sediment must be provided to allow wetland elevation to keep up with sea level rise. If the wetlands can achieve and maintain this elevation, it is possible to envision a long term future for Louisiana's coast.

Photo By: Yuki Kokubo, www.yukikokubo.com

It takes between 50 and 75 years to develop small deltas, which peak in size at about 200 square kilometers. Crevasse splay deposits, which were historically important for forming and maintaining the natural levee of the Mississippi River Delta, developed over shorter timescales of 20 to 30 years, creating deposits on the order of 15 to 20 square kilometers. The speed with which these landforms grow depends on how the system retains sediment. In Wax Lake, West Bay, and probably Cubits Gap, sediment retention rates are/were on the order of 25 to 50 percent. These rates could be increased by sending the sediment where it is most likely to build land, such as wetlands and enclosed basins that are not exposed to open water. For example, a recent study indicates that sediment retention in Lake Pontchartrain, which has fewer open boundaries to the ocean than Wax Lake or Cubits Gap, was near 100 percent following the 2011 flood and operation of the Bonnet Carré Spillway. The retention rates influencing crevasse splay deposits are not known with any confidence but are likely to be of similar order, or higher, if the flow is directed to enclosed swamps or basins.

IMPLICATIONS FOR POLICY MAKERS

If properly designed and operated, sediment diversions are capable of building substantial land from river sediment. Historical patterns of land growth and loss also suggest that with continued subsidence and sea level rise, sediment supply must be maintained in order to sustain the land that is formed. To be effective, diversions must be much larger than Caernarvon and Davis Pond, and they must deliver more sediment, both fine and coarse, than these two freshwater diversions. Future diversions should approximate the size of the many natural diversions that occurred along the Mississippi River's distributary channels as well as the Bonnet Carré Spillway, which regularly flowed at rates of 5,000 to 10,000 cubic meters per second.

Optimizing diversions' design, location, and operation for sediment capture will increase land building capacity. Data collected in specific reaches of the Mississippi River have shown a 50-fold increase above average in coarser grained sediment when the river's flow is two to three times above average. If sediment retention rates can be increased by careful selection and engineering of the basins into which diversions flow, the time required for building land can be decreased.

- Large diversions need not function every year to be effective land builders. The Bonnet Carré Spillway has been opened about once a decade, and elevations in the spillway between U.S. 61 and Lake Pontchartrain have risen as high as 2 meters, far outstripping subsidence and sea level rise.

- A pulsed diversion is one option for maximizing sediment capture. Using this approach, the diversion is operated at low to no discharge most of the year, reserving its additional pulsing capacity for those weeks of the year when river levels are high and the water contains significantly more sediment.

- Climate projections indicate that if no aggressive restoration action is taken, most coastal wetlands will disappear. A program of very large diversions will be necessary to offset this projected wetland loss.

- Large diversions should be located as far inland within deltaic basins as possible. This would take advantage of higher upstream river stages that have power to deliver sediment, and lead to a greater capture of sediment and restoration of coastal forested wetlands that are rapidly degrading.

- Building a series of very large diversions in the next decade would be a defense against rising energy costs because diversions like the Bonnet Carré Spillway can operate for more than a century with few energy subsidies following construction.

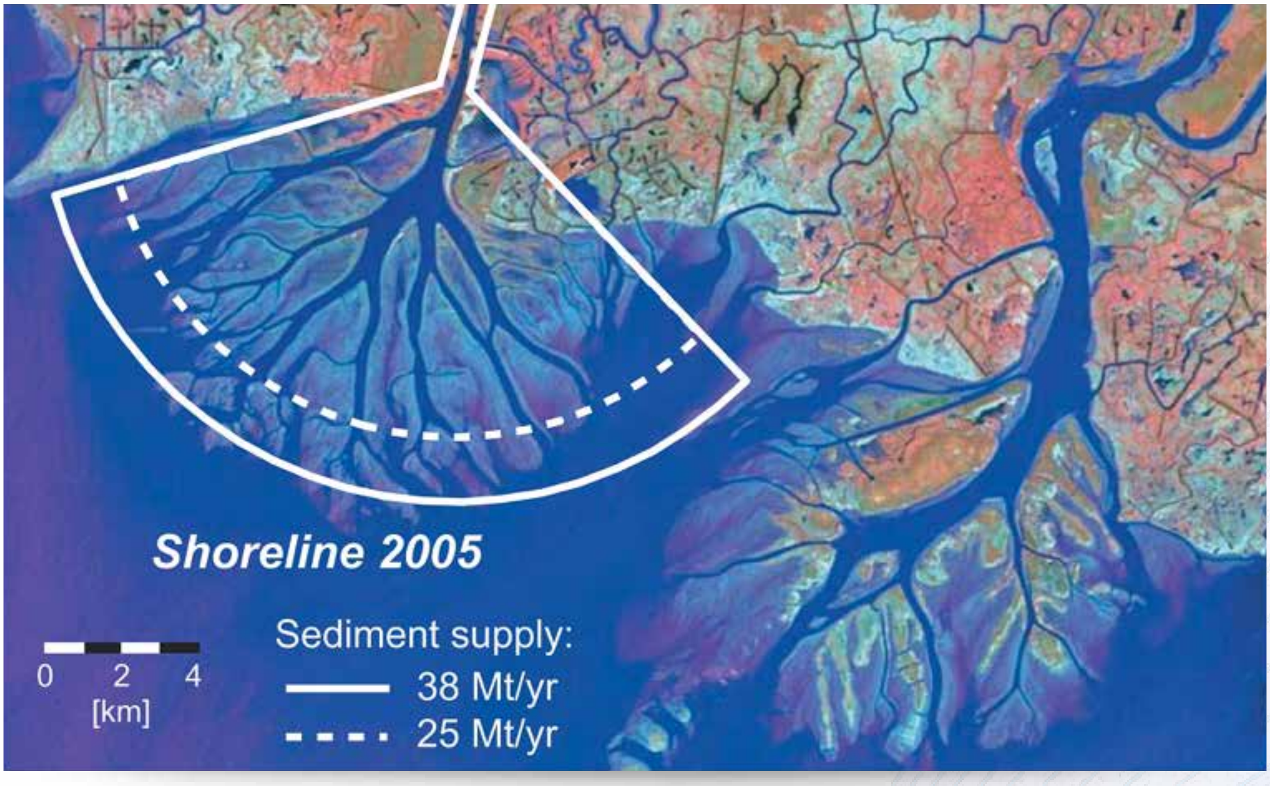

Figure 1: Wax Lake and Atchafalaya River Deltas from Kim et. al 2009 (Landsat Image). Reproduced/modified by permission of American Geophysical Union.