MISI-ZIIBI: Living with the Great Rivers, Climate Adaptation Strategies in the Midwest River Basins

MISI-ZIIBI: Ojibwe Native-American name for the Mississippi River, meaning "Great River." The Mississippi River is the longest river in the USA, 4th longest in the world, and drains 31 states (41% of the US landmass) and potions of two Canadian Provinces. Together with the Missouri, Illinois and Ohio Rivers, the Mississippi River Basin has for centuries been a conduit for cultural and economic exchange throughout the North American continent and beyond globally. These rivers are also ecological treasures and the source of natural wealth for the Midwest – America's highly productive agricultural and industrial heartland.

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However, the Midwest is increasingly impacted by climate variability and weather extremes occurrences witnessed and clearly demonstrated by the 2011 floods and tornados, followed by the 2012 drought, and once again followed by the 2013 floods and tornados. Thus, climate variability and weather extremes across the Mississippi river basin cannot be ignored over the long-term and is a fact for which we need to plan. The data to date has indicated that extreme weather has a direct, and often negative, impact on the river's functioning and adjacent land-uses, and thus also the Mid-West's ecology, economies and communities. Increased climate variability may mean more frequent extreme weather throughout the Mid-West. More floods and droughts demand that stakeholders along the Mississippi and Missouri River system adapt at-risk communities, ecologies and economies to this uncertain future.

Thus, we propose that due to climate change there has been a fundamental change in the parameters or criteria for which we need to design – that there is a new design condition and that the current design strategies for the Midwest River Basins are pragmatically and conceptually inadequate to address this new design condition. This challenge which is occurring along the Mississippi, Missouri and Illinois Rivers, as in California's Central Valley, throughout Europe and Asia, and elsewhere – is one of design. The current design strategies address the river systems in a non-integrative manner and without an understanding of spatial differences based upon the hydraulic and morpho-dynamic nature of the river itself.

The premise of this research project is therefore to develop and test the concept of “fluvial zones” as the mechanism to create and promote sustainable, healthy river systems that enrich local communities, drive local economies, and provide key ecological services up and down the river system. These fluvial zones are broad-based proto-typological, multi-scaled planning areas that are defined by their unique hydraulic and morpho-dynamic nature in relationship to the adjacent urban and landscape ecologies. The spatial strategies developed for each of these fluvial zones are intended to be transferable and paradigmatic and ultimately, will become the components of a spatial mosaic for planning and design.

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RESEARCH METHODOLOGY: MULTI-DISCIPLINARY WITH LOCAL, NATIONAL, + INTERNATIONAL COLLABORATION

MISI-ZIIBI: Living with the Great Rivers is an on-going design research program into innovative, integrated design approaches for climate adaptation and sustainability along the Mississippi, Missouri and Illinois rivers in the Midwest that is being developed by way of an interdisciplinary workshop methodology supported with on-going testing, research and experimentation between workshops. The workshop methodology intends to foster a new dialogue about river management policy and design in relation to climate change and weather extremes, as well as the changing functioning of the river economically and ecologically and what this means for the adjacent communities. The work products from **MISI-ZIIBI** are meant to illuminate the wealth and challenges of water, and to serve as a tool to aid communities, stakeholders, and government officials as they develop ways to respond to the climate challenges of the Midwest.

The first workshop took place over a 5-day period in March, 2013 and focused on the confluence of the three rivers in the St. Louis region.[1] The purpose was to test the

Figure 1: The first MISI-ZIIBI multi-disciplinary workshop occurred in March 2013, bringing together Dutch and local experts for five days of presentations, site visits and design work sessions.

previously developed series of broad-based set of proto-typological, multi-scaled planning "fluvial zone" scenarios. The workshop approach brought together multiple disciplines of Dutch and American participants in an interactive design-based setting.[2] The participants sought input from local stakeholders and communities to ground the work in the specific realities and existing initiatives already at hand.

The workshop products were a series of scenario-based and scalable design strategies that investigated possible prototypes for integrated and sustainable models for land-use planning, flood-risk-protection, community and economic resilience, drought tolerance, ecological benefits and sustainable design developments along Midwest metropolitan river regions. **MISI-ZIIBI** asked groups to work at the St. Louis regional scale, in addition to various fluvial zones that included agricultural, suburban and urban typologies. An additional calculations specific group emerged during the workshop that devised the estimates for river discharge changes to underpin the fluvial zone scenarios. The graphic-based outputs of **MISI-ZIIBI** will aid the community, stakeholders and government officials as they develop ways to respond to the MISI-ZIIBI's climate challenges.[3]

AN INTEGRATIVE AND HOLISTIC DESIGN APPROACH:

A Balanced and Long-term Water-based Fluvial Morphology Approach

Fundamental to the MISI-ZIIBI workshop is that the Great Rivers are our local determinacy and our history; that the Great Rivers are our ecological bank; that the Great Rivers are our cultural bank; and, that the Great Rivers are our financial bank. However, the Great Rivers have been re-designed over time and are under stress. Most importantly and optimistically, the Great Rivers are our source of continued wealth…WATER.

It is anticipated that there will be continued change to weather patterns in the Midwest, which will alter how we live with and alongside our Great Rivers. Therefore, a new design condition is needed that will challenge our current assumptions about flood risk, drought and water supply; will require us to rethink how we use the river and adjacent lands; will require us to adapt; applies to both the entire river system as well as to our region; and, impacts the economies, ecologies and communities along the Great Rivers.

A proactive long-term integrative water-based approach needs to simultaneously improve the economy, ecology and quality of our cities and towns. This approach has been developed, studied and implemented by the Dutch throughout the world and can become applicable to other mid-western cities and towns along the Great Rivers. However, the approach needs to build upon the previous work and commitment of the community.

Climate Change Is Not Just Coastal: Weather Extremes & Why the Midwest and St. Louis Matter

We typically think extreme weather is just coastal - tropical storms, sea level rise, sinking lands, and saltwater intrusion. We hear from cities like New Orleans and New York - disasters like Katrina and Sandy are well known to all. Why is the Midwest relevant? The floods of 2011 that overtopped levees and the 2012 droughts that quickly followed demonstrated that extreme weather is not just a coastal issue.

Changes in climate and future fluctuations to come will mean changes in flood protection levels and will have the capacity to disrupt shipping and commerce along the working rivers. This will have a large impact on local, regional and

national economies. These changes in weather will modify how we live with and alongside our rivers. St. Louis' location at the confluence of three great rivers makes the region extremely relevant to the discussion of how climate driven changes in the rivers will affect communities. The fluvial zones in the St. Louis region are prototypical of Midwest zones - protected urban areas, leveed agricultural areas, and leveed areas for future development. The study of these areas and strategies for the new design condition will be applicable and transferable to other communities.

The Mississippi River Basin: Watershed Systems

The Mississippi River Basin is the largest river basin in the United States and the fourth largest in the world. It is made up of a series of diverse and important rivers, including its namesake as the main stem and a series of major tributaries, including the Missouri River -- the majority of the system's sediment -- and the Ohio River -- the majority of the system's volume. When measured by length as a combination of the lower Mississippi River (from St. Louis to the Gulf of Mexico), the Missouri River and the Jefferson River (the main tributary to the Missouri River), it becomes the fourth longest river in the world. The Mississippi river basin drains 31 states (41 % of the US landmass) and portions of 2 Canadian provinces.[4]

St. Louis Exists at the Confluence of Three Great Rivers: but the three great rivers are different

Not all rivers are the same and this is especially important to understand when the three rivers of the Mississippi, Missouri and Illinois converge just north of the City of St. Louis. For slope, the Missouri is the steepest at 1 foot per mile. This is very important because this steep slope contributes to why the Missouri is the main source of sediment. For length, the Missouri is slightly longer than the Mississippi at 2,341 miles. For discharge of water volume – calculated in the St. Louis region – the Mississippi is the largest at 205,000 cubic feet per second. This is important to note when understood in relation to what will be later defined in this paper as the "bottleneck or backwater effect." The Mississippi far and away accommodates the largest fleet of barge traffic with 80 metric tons per year. While the Missouri is the least of the three rivers, accommodating only 5 metric tons per year. In other words, only 10% of the entire barge traffic of the Mississippi River basin. This immediately begins to question the future sustainability of barge traffic along the Missouri River. And finally, as mentioned above in relation to its steep slope, the Missouri River far and away supplies the majority of the Mississippi River Basin's sediment load at 80 metric tons per year, measured as annual average in the St. Louis region. The Mississippi is a distant second at 20 metric tons per year and the Illinois at 5 million tons per year. Sediment load is incredibly important both locally and at the river basin scale when understood in relation to its importance as sediment supply of coastal wetland restoration strategies in the Louisiana delta along the Gulf of Mexico.

St. Louis Metropolitan Statistical Area: the 79th Largest Global Economy

St. Louis is typically understood as an urbanized "rust belt city" along the Mississippi River, the "Gateway to the West." However, like other Midwestern cities, and arguably the most explicit of all Midwestern cities, the City of St. Louis exists within a much larger and broader regional context, otherwise known as the Metropolitan Statistical Area. This specific scale was the scale of understanding for the MISI-ZIIBI workshop.[5]

However, together with the Mississippi, Missouri, Illinois, and Ohio Rivers, the basin has been a conduit for cultural and economic exchange throughout the

North American continent and beyond. The port system of South Louisiana - in the river's delta – is one of the largest ports in the world and the inland port of metropolitan St. Louis is a large, multi-modal network at the heart of America's commercial traffic, handling over 32 million tons of freight each year, including grain, coal, petroleum products, scrap metals, aggregates, and chemicals. The St. Louis port is the northern-most lock and ice-free port on the Mississippi, the second largest inland port by trip-ton miles and the third largest by tonnage. In the Upper Mississippi River Basin, the 78 counties that border the main waterways contain 5% of the nation's population totaling 13.4 million.

These rivers are ecological treasures, with the Mississippi river alone containing 241 species of fish, 292 species of birds, 57 mammals, 45 reptiles and untold numbers of invertebrates using the river. In particular, the Mississippi river remains a key economic resource: over 92% of US agricultural exports are produced in the Mississippi River Basin.

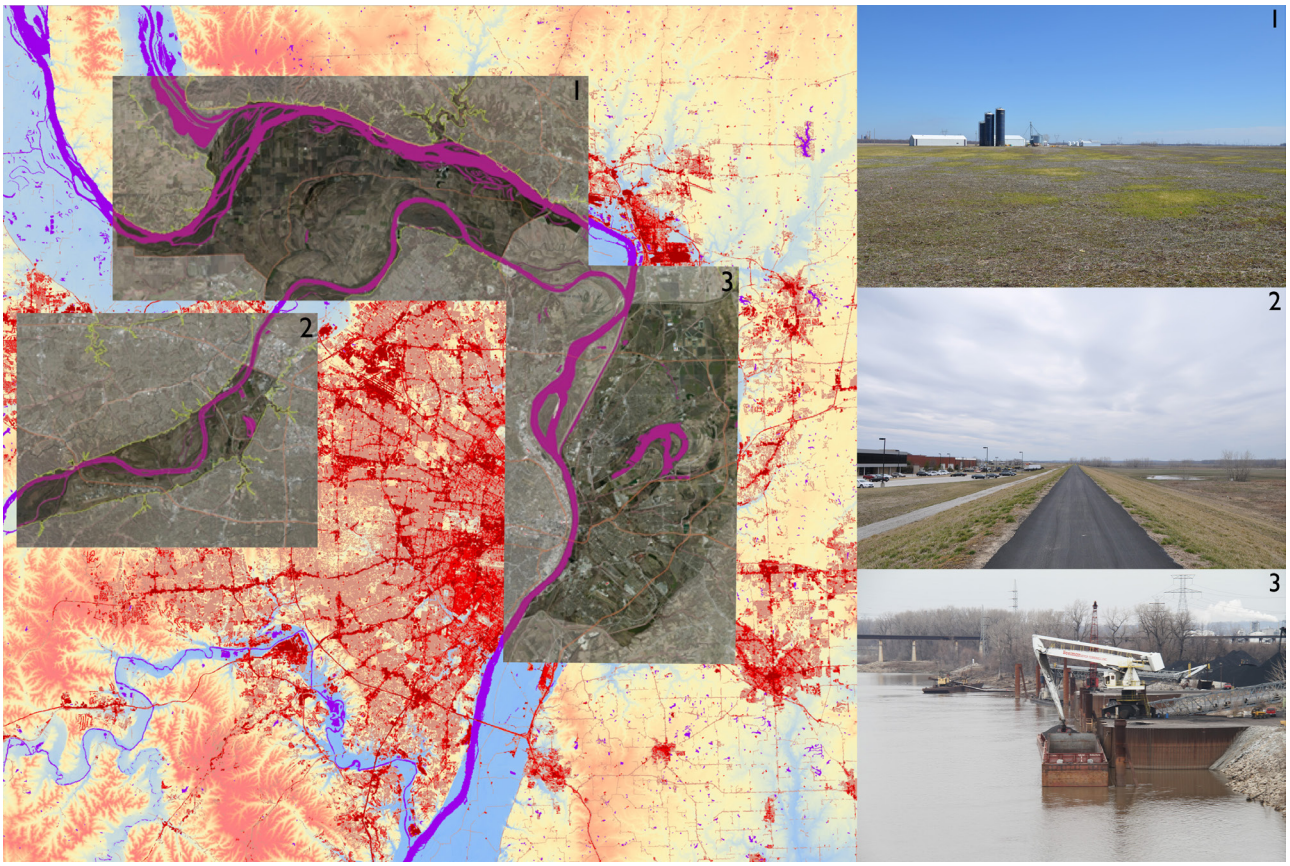

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Figure 2: The three fluvial zones (1-agriculture, 2-suburban, 3-urban), overlaid on a St. Louis regional map indicating land cover (red), topography (yellow-orange) and floodplains (blue).

THE NEW DESIGN CONDITION & SPATIAL SCENARIO'S: CLIMATE CHANGE AND FLUVIAL ZONES

The NEW DESIGN CONDITION based upon National Oceanic and Atmospheric Administration (NOAA) Climate expectations (01/2013) was that extreme weather would result in increased flood levels and lower drought levels. The changes in extreme precipitation events (greater than 1 inch/day) for the year 2050 may be: for a high scenario +40% days and for a low scenario +10% days. Using the low scenario as a conservative starting point, river discharges will increase 10% or more during floods. Meaning flood water levels at St. Louis can be anticipated to rise 3-8 feet, and low stage water levels will drop -3-5 feet, with

uncertainty whether these numbers may potentially double in the year 2100. Therefore, according to these new estimates, a “100 year flood” now becomes a “40 year flood” and a “500 year flood” now becomes a “200 year flood.”

When the above estimates are weighed in relation to the local conditions of the developed St. Louis river region, certain characteristics emerge that can be considered quite alarming. After the last sets of locks and dams of the upper Mississippi River, and just south of the confluence of the three great rivers, and just north of St. Louis city, a narrowing of the Mississippi channel causes a “bottleneck” and potentially disastrous “backwater” effect. Contrary to intuition, modifications to the river system have a downstream as well as upstream effect. The backwater effect is an unexpected—often unanticipated—effect of narrowing of the river bed by flood protection measures or urbanized areas.

With an understanding of the new estimates and the defining of the bottleneck and backwater effect, the provocative new design condition proposal stated: “We need to stop calling floods “100 year” or “500 year” events. Because ‘100 year’ events seem to happen much more frequently. And many people do not really understand the definition of a ‘100 year flood.’ Rather, what if we calculate probabilities based on something people can relate to, like the chances a flood occurring during a 30-year mortgage, or one’s lifetime!”

In other words, probabilities will indeed change in the future. A ‘100 year flood’ means a flood has a 1% chance of occurring in any year. If we calculate the chance of a home in the 100 year flood zone flooding over the life of a 30 year mortgage, it turns out there is 26% chance such a flood will occur. For a home in the 500 year floodplain there is a 6% chance of flooding. When re-calculated based on NOAA’s above climate change expectations of a 10% increase in river discharges, a previously 100 year flood increases in frequency to a 40 year flood. There is now a 53% chance of a home in the 100 year (now 40 year) flood zone flooding, and a 26% chance of a home in the 500 year (now 200 year) flood zone flooding.

And these statistics become even more alarming when these numbers are quantified in terms of the consequences of flooding and/or catastrophic levee breach. Taking the American Bottom Metro East Sanitary District in Illinois (a 500 year flood protection level just east of St. Louis) as an example, the direct damages would be $7 billion USD and loss of life. The indirect damages would be loss of business profits (agriculture, navigation, small businesses, etc.), pollution (the spreading of toxins and debris both locally and downstream), and the questioning of whether the protection level is economically optimal, especially when weighed based on the 2050 climate change estimates.

CLIMATE ADAPTATION – “FROM WORKING RIVERS…TO RIVERS THAT WORK”

The new design condition was then applied to various “Fluvial Zones” and a number of spatial design climate adaptation scenarios were developed. Fluvial Zones are prototypical of the upper Midwest. They are agricultural, suburban and urban. The fluvial zones are within both free-flowing and pooled (dammed) river conditions. It is extremely important to emphasize that fluvial zones are not floodplains per se. Fluvial zones are a multi-functioning diverse set of land-use zones defined by landscape features and levee protected areas along rivers that need to be considered holistically and sustainably when understood in relation to the above-mentioned climate change estimations.

The **MISI-ZIIBI** workshop 3 fluvial zones were: 1) Agricultural Land Use and Pooled Mississippi River, from the confluence of the Illinois and Mississippi Rivers south to

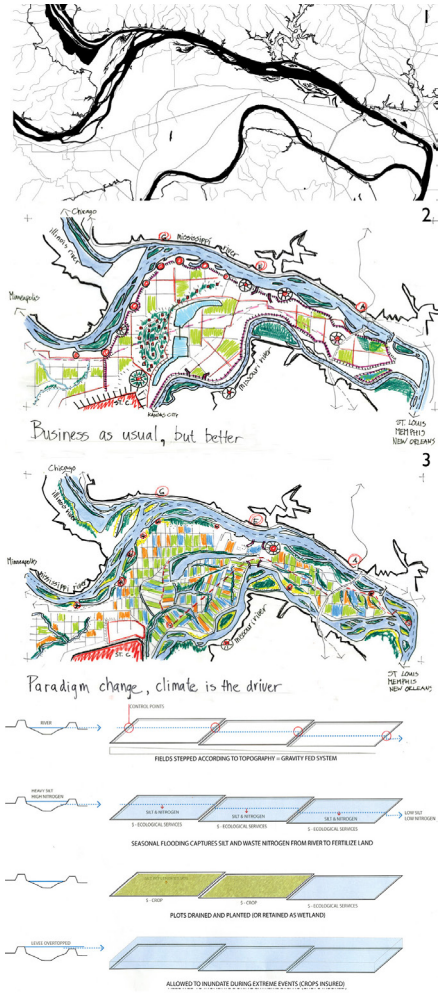


Figure 3: Fluvial Zone 1 (agriculture) Scenarios: 1-Do nothing different…business as usual, 2-Business as usual…but better, 3-Paradigm change…climate is the driver; sketches proposing gravity-fed rotating crops that take advantage of flood pulses, sediments and nutrients.

Alton and Melvin Price Locks and Dam; 2) Levee-protected suburban development and free-flow Missouri River, west to east from Howell Island State Wildlife Area to Interstate 70; and, 3) Levee-protected existing urbanized area and free-flow Mississippi River, north to south from the Mississippi/Missouri Rivers confluence to Interstate 270/55. It was the charge of each Fluvial Zone group, after site visits and initial analyses and group impressions, to define the challenges and the potentials of each fluvial zone, and use these to propose multiple design-based scenarios, ranging from do nothing business as usual to radical paradigm shifts in land use.

Fluvial Zone 1

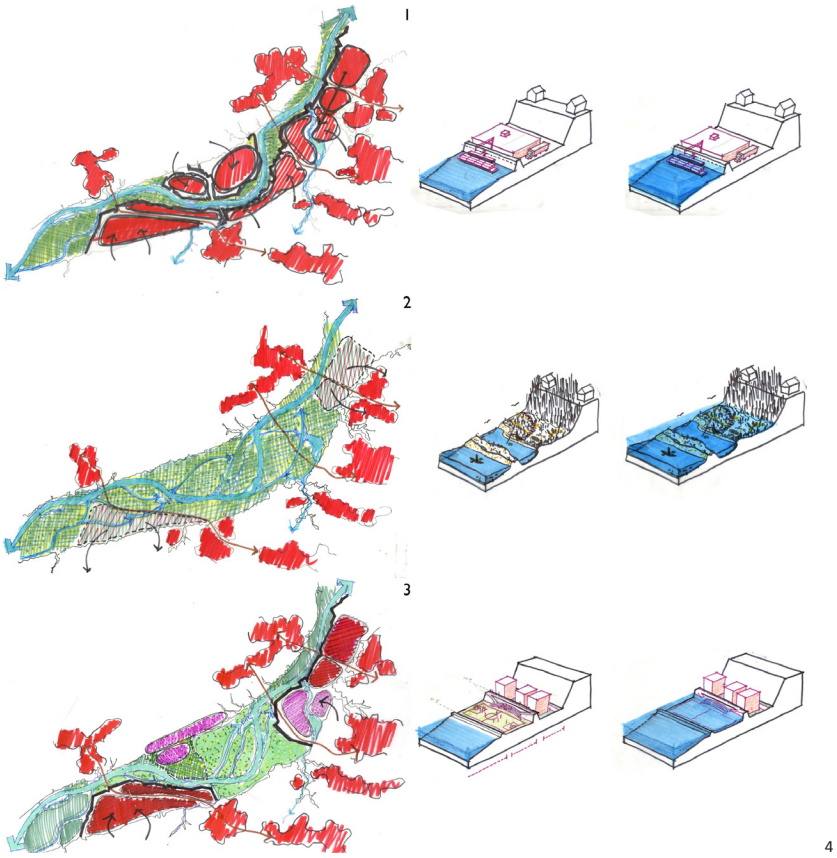
Challenges include: agriculture (droughts, floods, nutrient loads, mono-cultures); ecology (native and migratory species); development (future other than agriculture); flood protection (risks and levels); local vs. global (export of crops); navigation (future capacities of Mississippi and Missouri Rivers).

Potentials include: the utilization of existing topography and levees and the development of innovative agriculture and nutrient capture techniques. The fluvial zone has areas of higher ground and varying levels of protection in the zone. Different uses are able to naturally align with these different levels - trends extrapolated from nearby development allow it to continue onto higher ground. Land that frequently floods can still be utilized efficiently for agriculture using innovative farming techniques. At present low-value and water-thirsty commodity crops such as corn and soybean are grown in the region and then exported to other parts of the country or abroad. There is little access to fresh fruit and vegetable crops, and must be imported from afar. There is an opportunity to diversify markets, increase resiliency of the crops, and perhaps even create new high-value exports through innovative agriculture. A gravity-fed system would take advantage of the flood-pulse, and use the opportunity to recapture run-off nutrients, thereby converting a former problem into a resource.

Scenarios are: 1) Status Quo, Do Nothing Different; 2) Business As Usual, But Better; and, 3) Paradigm Shift, Climate Is the Driver. For Scenario 1, the opportunities include: robust mono-culture based agricultural production, increased conservation area, developable land and recreation. The challenges include: more frequent high water, subsidence, water pollution, questionable agricultural security, the protection of existing developed lands, Missouri river water competing uses and the status of a comprehensive ecological health plan. For Scenario 2, the opportunities include: flood pulse, increased conservation area, recreation, agricultural diversity and utilization of climate variabilities. The challenges include: spatial quality and levee improvements required if increased development. For Scenario 3, the opportunities include: a new local food source, diversified agricultural economy, recreational economy, ecological health and safety, flood pulse and economic risk management. The challenges include: major crop shifts to the existing history of farming and large up-front costs.

Fluvial Zone 2

Challenges include: “backwater effect” (due to development that creates bottlenecks locally and downstream at St. Louis due to reduced river profile cross-section for discharge); Missouri River sediment transport (“the big muddy” supplies 75% of the Mississippi River Basin’s sediment load); Missouri River access (little visual/literal connections); development pressures impact risk profile (population increases, commercial and industrial “big-box” typology); flood protection (risk and levels); navigation (only 10% of barge traffic); recreation (hunting, fishing,



ecology); stormwater management (large parking lots, impervious surfaces, limited storage); and, water treatment (3 major plants in study area).

Potentials include: Missouri river as an urban, ecological and landscape development opportunity adaptable to high and low water levels; long-term demographic trends of continued increasing populations; improved and multi-functional levees; river by-passes and islands; innovative agriculture and aquaculture; sustainable/controlled sediment mining to benefit river maintenance and minimize impacts on rive ecologies; hydro-power technologies; and, floodable/temporary programs/elevated developments.

Scenarios are: 1) Urban Flood Plain; 2) Flood Plain Sponge; and, 3) Multi-functional Flood Plain. For Scenario 1, opportunities include: investment, multi-use development, jobs/money generators and new functions and destinations. The challenges include: impact of development on room for water, increased risk with high levees or improved flood protection required, ecological degradation and increased "back-water effect." For Scenario 2, opportunities include: resiliency to weather extremes, reduction of "back-water" effect, expanded habitat and wildlife, and outdoor recreation and hunting. The challenges include: voluntary buyouts of property, relocation of development, and navigation cutoff. For Scenario 3, opportunities include: cultural value, optimization of temporal uses, room for the river and new jobs. The challenges include: living with risk, up-front costs and competing jurisdictional interests.

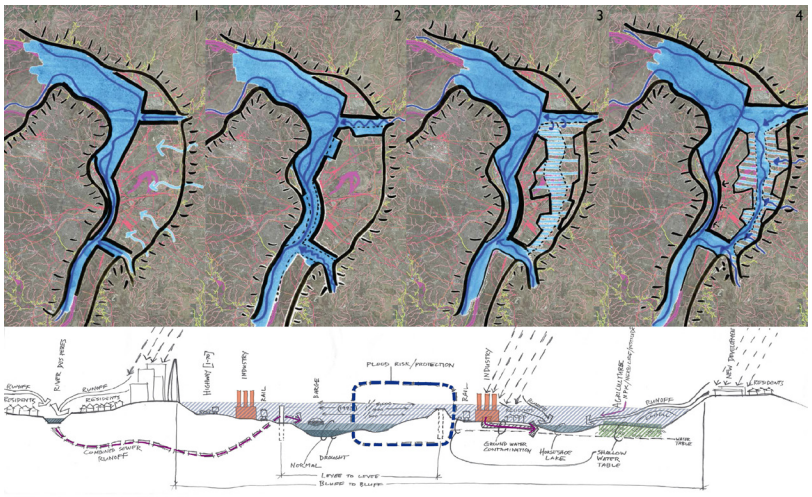
Fluvial Zone 3

Challenges include: regional bottleneck of Mississippi River; large population protected by an "all or nothing" single-line levee system; historically important

Figure 4: Fluvial Zone 2 (suburban) Scenarios: 1-Urban flood plain, 2-Flood plain sponge, 3-Multi-functional flood plain; axonometrics of high and low water river-edged conditions for each scenario.

communities and the site of Mississippian cultures and UNESCO Cahokia Mounds site; heavy industry uses: steel, chemical and petrochemical; spatial, social and economic fragmentation; drought and flooding; contamination; and, the "Big If" – a social, financial and industrial catastrophe on the horizon.

Potentials include: increased safety from flooding and contamination, opportunities for new waterfront developments, hydraulic relief locally, regionally and nationally (mitigate the bottleneck and backwater effect), improvements to local ecology, connecting communities; and, enhancements to port operations along the river.



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Scenarios are: 1) Business As Usual, but Better; 2) Set Back; 3) Managed and Staged Flood; 4) Blue Green By-Pass. For Scenario 1, opportunities include: safety within local area is ensured, contamination is contained within reinforced levee, and least expensive. The challenges include: the river is constricted, still an "all or nothing" approach, zero redundancy, developed with East St. Louis' back to the river – does not add qualities of life to the area. For Scenario 2, opportunities include: addresses bottleneck by expanding floodway, relieves larger system, contains majority of contaminants, increases protection to local levee district, and opportunity for new waterfront and industry on Illinois side. The challenges include: located in an historic area – must be sensitive to historic settlement patterns, industrial remediation along river, and expensive. For Scenario 3, opportunities include: significant hydraulic relief for the entire system to have impacts on a national scale, protection of industry and containment of contaminants, bulk of the population protected by a new levee, and water remediation. The challenges include: expensive to build and maintain the levees, impacts majority of the agricultural community, and some need for temporary inundation of agricultural lands. For Scenario 4, opportunities include: hydraulic relief that functions on the national scale, major improvements to the local ecology, which will have positive impacts on the local area as well as the regional area, strengthens navigation while limiting uncertain flood stages, and new port development opportunities along the river. The challenges include: modifies land use from agricultural to ecological, infrastructural blockages, high up-front costs and time.

Figure 5: Fluvial Zone 3 (urban) Scenarios:
1- Business as usual, 2-Set back, 3-Managed and staged floods, 4-Blue-green bypass; "bluff to bluff" section through St. Louis, Missouri, Mississippi River, East St. Louis and the American Bottom, Illinois, indicating multiple challenges faced by fluvial zone 3.

CONCLUSION

It is fully understood that there is a need to continue these discussions and research to assist in ensuring our collective long-term future is resilient and

prosperous. The above fluvial zone scenarios are not meant to be prescriptive. But they are the beginnings of a long-term approach, a continuing of the conversation and the development of a robust research agenda including the following:

1. Validate the discharge and water level data, flood and drought impacts and establish future hydrological design conditions based upon climate change / extreme weather scenarios;
2. Evaluate options for risk management for flood and drought control, spatial planning, contaminants, and disaster management;
3. Develop a more integrated vision for land-use and multi-layered and functional infrastructure;
4. Create new (sustainable) economic generators;
5. Continue building community capacity to foster dialogue around these issues;
6. Build a multi-disciplinary international "think tank" dedicated to the research and practice of long-term integrative water-based planning.
7. Develop follow-up workshops with strategic partners focusing on specific valuations.
8. Develop a climate adaptation performance model for a holistic research framework to understand fluvial zones along rivers.

REFERENCES:

1. The Royal Netherlands Embassy, Washington D.C. cosponsored the workshop with the Sam Fox School of Design & Visual Arts at Washington University in St. Louis. The March 2013 workshop was hosted by Washington University in St. Louis. It was co-organized by Dale Morris of the Royal Netherlands Embassy and John Hoal and Derek Hoeferlin of Washington University in St. Louis. See *http://issuu.com/derek.hoeferlin/docs/misi-ziibi_final_report_issuu* for workshop report, participants, acknowledgments and credits.
2. **MISI-ZIIBI** is a continuation of existing interactions between communities in the United States in partnership with the Royal Netherlands Embassy in Washington D.C. to reconsider issues around river environments. **MISI-ZIIBI** brought Dutch experts that have worked directly on The Netherlands' *"Room for the River"* program to work with local and regional conterparts, building on the significant work that has been and is occurring in the St. Louis region, while adding an additional factor. But is not a comprehensive approach and could not have been fully researched since the workshop took place over the course of only a weekend.
3. Two follow-up workshops in September 2013 and February 2014 collaborated with Earth Economics, a Tacoma, Washington based organization promoting the economic benefits for ecosystem services in floodplain regions. The September 2013 workshop worked with Earth Economics and the US Army Corps of Engineers to apply ecosystem service valuation metrics for each of the fluvial zones scenarios that were developed in the prior March 2013 workshop. The February 2014 workshop worked with Earth Economics at the Nature Serve Bio-Diversity Without Boundaries conference held in New Orleans, Louisiana. We used our scenario-based methodology to study a fluvial zone along the Mississippi River just outside of New Orleans.
4. Mississippi River Basin statistics according to the United States Geological Survey.
5. Important statistics for the St. Louis MSA include: 2.8 million residents (19th largest MSA in USA); 2 states (Illinois, Missouri); 7,889 square miles; 16 counties (Bond, Calhoun, Clinton, Franklin, Jefferson, Jersey, Lincoln, Macoupin, Madison, Monroe, St. Claire, St. Charles, St. Louis, St. Louis City, Warren, Washington); 3 major rivers (Illinois, Mississippi, Missouri); 2 major tributaries (Kaskaskia, Meramec); 2 Mississippi watershed sub-basins (Missouri, Upper-Mississippi); 2 US Army Corps of Engineers Districts (Kansas City, St. Louis); 5 Interstate highways; 16 Rail lines; 2nd largest inland port by trip-ton miles; last set of Mississippi river locks and dams; major variations of land use including agriculture, health care, bio-tech, industrial, institutional, suburban, urban, exurban and recreational land uses; 9 Fortune 500 companies; and, its 2011 Gross Metropolitan Product (GMP) was $133 billion USD (21st highest in USA -- or making it the 79th largest global economy if compared with countries). Sources: East-West Gateway Council of Governments, Fortune 500, Port of St. Louis, US Census, Wall Street Journal.