REIMAGINING OUR RIVERFRONT

January 22, 2018

Columbus Riverfront Concept

Columbus Redevelopment Commission

HITCHCOCK
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ACKNOWLEDGEMENTS

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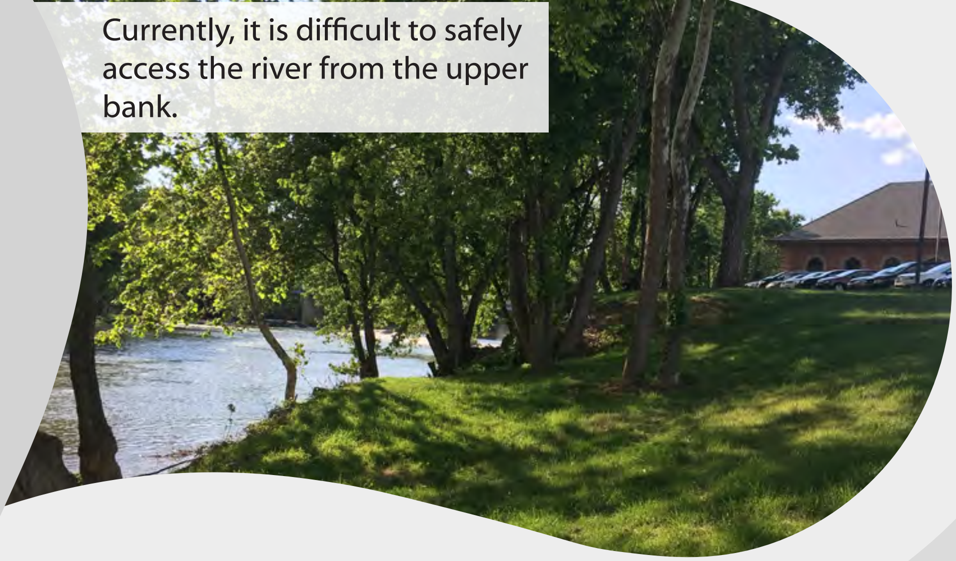
The iconic 2nd Street Bridge is the southern boundary of the project area.



Currently, it is difficult to safely access the river from the upper bank.

PROJECT TEAM

Rick Hitchcock | Hitchcock Design Group
Leadership, Strategy, Group Facilitation

Randy Royer | Hitchcock Design Group
Project Manager, Landscape Architect

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EXECUTIVE SUMMARY

Dear Commissioners:

Thanks to community leaders like you, Columbus, Indiana is the picture of economic stability, family-friendliness, and exceptional cultural treasures. Unlike downtowns in similarly-sized midwestern communities, Downtown Columbus is thriving. However, the riverfront, which defines the prominent western downtown gateway, has not been leveraged. Fortunately, you and other community leaders recognize the extraordinary potential of the downtown riverfront and have prioritized its improvement.

In early 2017, along with the Riverfront Steering Committee and the Riverfront Citizen's Committee, our team quickly confirmed your goal to **create and sustain an iconic riverfront experience that strengthens Columbus' distinctive brand and robust economy.** Last summer, we completed the Opportunity Analysis, and last fall, we explored alternative and preferred improvement concepts, both of which included extensive community interaction. This report summarizes the consensus, long-range Columbus Riverfront Vision and our near-term implementation recommendations.

Special Opportunity

Not only is the 19-acre study area at the literal intersection of SR 46 and the East Fork of the White River, it is at the figurative intersection of prominent community resources, dynamic marketplace characteristics, and demanding *stakeholder expectations*.

Resources: The river is the most prominent natural feature, and serves as the gateway to downtown Columbus where inbound traffic crosses the iconic Robert N. Stewart Bridge. An obsolete low-head dam creates an engaging visual and aural attraction, but compromises water quality and creates a dangerous impediment to navigation and fish passage. The 737-foot-long east bank, immediately south of Mill Race Park and the Columbus People Trail, is very steeply sloped and dotted with inferior quality trees. A local investor has converted the historic pump house, perched on top of the east bank, into a successful restaurant, offering exceptional views of the river and the west bank. The west bank is a remediated landfill that is overgrown with invasive vegetation. The on-going and massive SR 46 realignment and railroad grade separation project will significantly impact visitors' "front door" experience and the western and southern edges of the west bank property.

Marketplace: Columbus has a comparatively high growth and household formation rate, and its residents enjoy downtown, dining out, and outdoor activities – including walking, cycling, kayaking, swimming, and fishing. Columbus also has an exceptional tourism-driven economy that includes significant sports and nationally acclaimed cultural offerings. Remarkable for comparably-sized communities, Columbus has 9400 highly skilled workers downtown, within 5 minutes of the riverfront.

Stakeholder Expectations: Through extensive community outreach, we learned that the improvement of the riverfront is a very high community priority. Coincidentally, we also learned that attraction and retention of highly skilled talent is the business community's number one priority, and that an activated riverfront would give Columbus a distinct competitive advantage. All segments of the community agree about the need for increased connectivity to and along the river, and the need to create exceptional visitor experiences that perpetuate Columbus' outstanding brand. Finally, we clearly heard that the "Columbus Way" is to thoroughly examine promising opportunities, and when ready to implement, to design with distinction, and fund through public-private partnerships.

In addition to examining Columbus, we compared the Columbus Riverfront with dozens of downtown riverfronts across the country and created a set of best practices that are described in this report.

Strategy

Based on its prominent resources, dynamic marketplace, and demanding stakeholder expectations, Columbus leaders should execute an integrated 4-part strategy that features 3-Dimensional Connections, Compelling Attractions, Captivating Appearance, and Incremental Implementation to advance the community's riverfront goal.

3-D Connections: Construct a 3-dimensional (north/south, east/west, up/down) network of related connections including: east bank sidewalks that expand the People Trail along the river with connections north and south of the bridges; gateway features that clearly link the riverfront, downtown and Mill Race Park; west bank sidewalk loops that showcase views of the river and downtown; vehicular access and limited parking on the west bank for maintenance , emergencies , loading, and accommodation of less mobile patrons; and dam modification to accommodate in-stream watercraft passage.

Compelling Attractions: Construct a package of distinctive attractions that target young professionals and their families, which in turn are catalysts for related, nearby private sector investments. The principal attractions include: an in-river whitewater feature that appeals to a variety of audiences; a river-themed, inter-generational children's play space; and a high-amenity, east-bank riverwalk.

Captivating Appearance: Reaching beyond respectfulness of existing cultural community landmarks, construct the public riverfront features to be captivating icons of their own, giving special attention to: application of the "sinuosity" theme from Mill Race Park; an engaging "front door" gateway experience for motorists as they approach the river; the history of the river and its influence in Columbus; and the integration of the on-going community and neighborhood brand initiative.

Incremental Implementation: Create and sustain momentum by carefully synchronizing: big picture thinking coupled with systematic and incremental construction; design, engineering and concurrent permitting of the east bank and in-river improvements in 2018; construction of the first segment that features a publicly funded People Trail on the east bank; private sector fund raising for other high-profile, first segment, east bank amenities; aggressive pursuit of local, state, and federal grants for in-river improvements; and a longer-term fund-raising campaign for future west bank improvements.

Economic Impact

During construction, we estimate that the riverfront improvements will support almost 90 jobs, infuse $4.1 million into the local economy and create approximately $280,000 in state and local tax revenue. Following construction, we estimate that the same improvements will support almost 30 jobs, generate approximately $769,000 in recurring income, and generate approximately $103,000 in local and state tax revenue. In addition, we strongly believe that the new riverfront will serve as a land development and tourism catalyst generating over $1.5 million annually in new local tax revenue.

Action

Because of the complex and rigorous permitting process, escalating construction costs, and coincidental SR 46 realignment, we recommend that city leaders quickly endorse this plan as public policy, complete an $8.6 million public-private funding package, and commence the design, engineering and permitting process in early 2018, anticipating the start of segment one construction in 2019.

Now is the time to **create and sustain an iconic riverfront experience that strengthens Columbus' distinctive brand and robust economy!** On behalf of Market and Feasibility Advisors, S2O Design and Engineering, Christopher B. Burke Engineering, LLC, and Strand Associates, thank you for allowing our team to guide this fantastic and timely initiative.

Sincerely,

Hitchcock Design Group

Riverfront Plaza

OPPORTUNITY ANALYSIS
PROCESS

Opportunity Analysis → **Alternative Riverfront Concepts** → **Riverfront Concept Plan**

Opportunity Analysis	Alternative Riverfront Concepts	Riverfront Concept Plan
Resources	Strategy	Finalize Concept
Marketplace	Alternative Concepts	Priority Actions
Stakeholders	Hydraulic Testing	Riverfront Guidelines
Outreach	Market Impacts	Outreach
Analysis	Preferred Concept	Report
Memorandum	Implementation	
	Outreach	

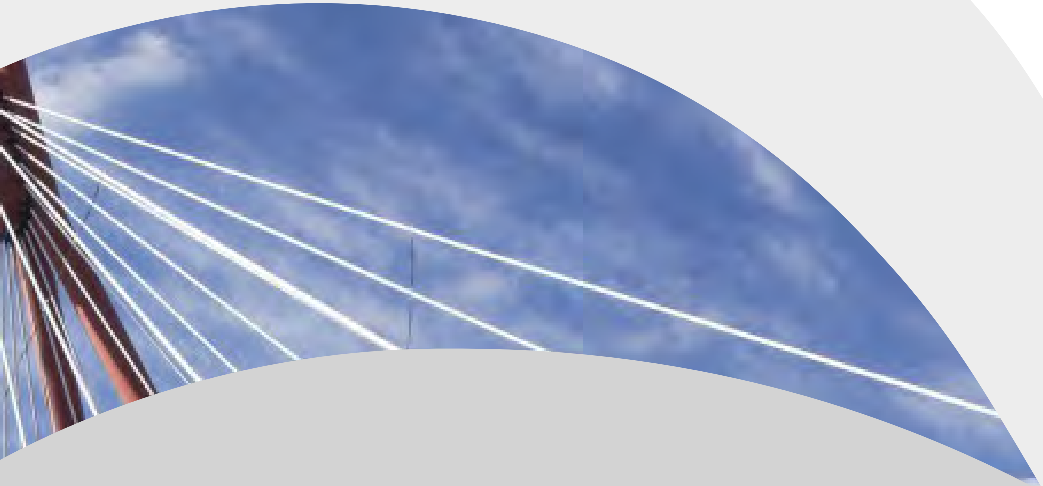
THE RIVERFRONT TODAY

GOAL:

To **create** and **sustain** an ICONIC RIVERFRONT experience that **STRENGTHENS** Columbus' distinctive brand and robust economy.

OPPORTUNITY ANALYSIS

OVERVIEW



In January of 2017, the Columbus Redevelopment Commission commissioned Hitchcock Design Group to lead a design team to improve the appearance, recreational function, environmental quality, and economic benefit of the East Fork of the White River. First, the team completed an Opportunity Analysis that examined area resources, the local and regional marketplace, and stakeholder behaviors and interests. Next, the team developed a Preferred Riverfront Concept that defined an integrated, market-supported strategy proposing operational and capital improvements.

The consultant team regularly met with the Columbus Redevelopment Commission and the Riverfront Steering and Citizens Committees, which consisted of elected officials, CRC board members, property and business owners, Redevelopment Commission staff, and residents. The team maintained a project website, conducted a community survey and confidential stakeholder interviews. The team also facilitated a public workshop and design charette prior to developing the alternative Riverfront concepts. To view the full Opportunity Analysis report, see Appendix D.

Community Open House
November 2017

■OPPORTUNITY ANALYSIS

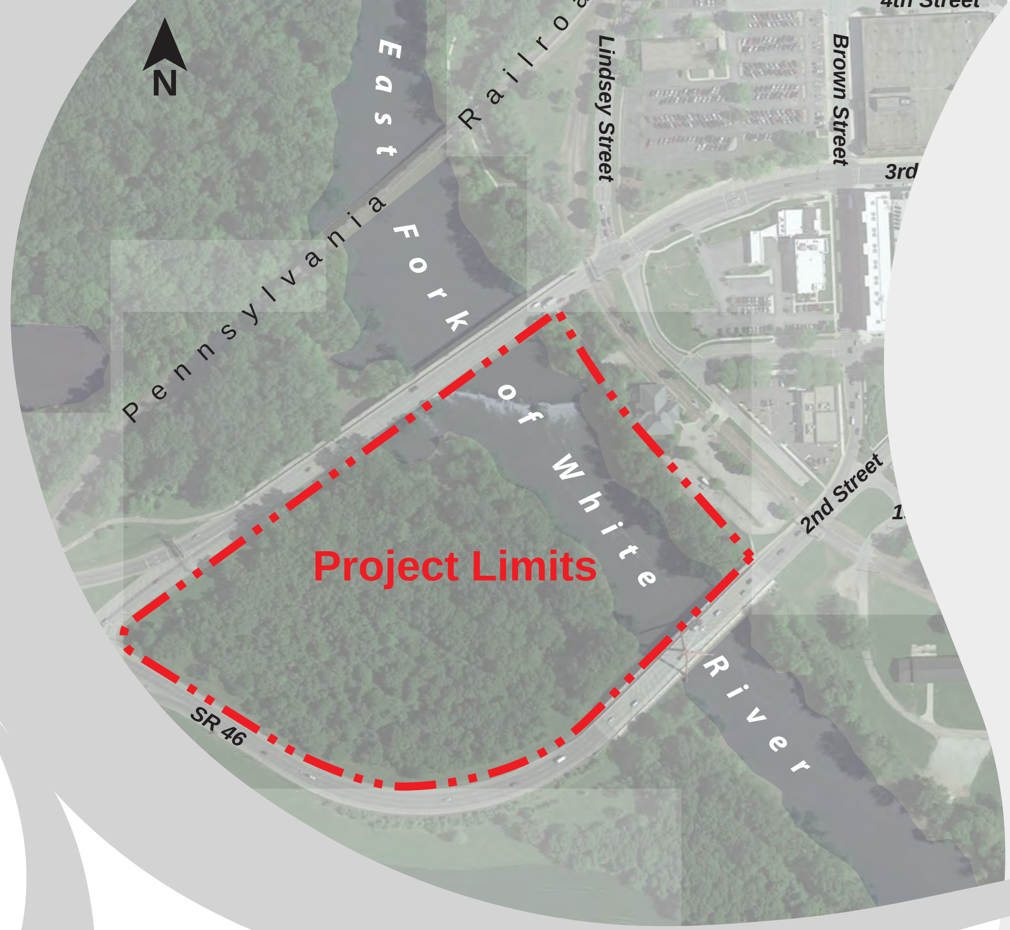
RESOURCES

The Riverfront study area is located along the East Fork of the White River, between the 2nd and 3rd Street bridges, and includes the east and west banks of the river. The 19.4 acre site is the first thing visitors see as they cross the iconic 2nd Street Bridge into Downtown Columbus.

Directly adjacent to the site is The Columbus Pump House. An integral part of Columbus' history, The Columbus Pump House is now a restaurant and brewery that overlooks the river. The low-head dam that spans the river just south of the 3rd Street Bridge once fed the historic Columbus Pump House, but is now obsolete and has become a safety and environmental hazard.

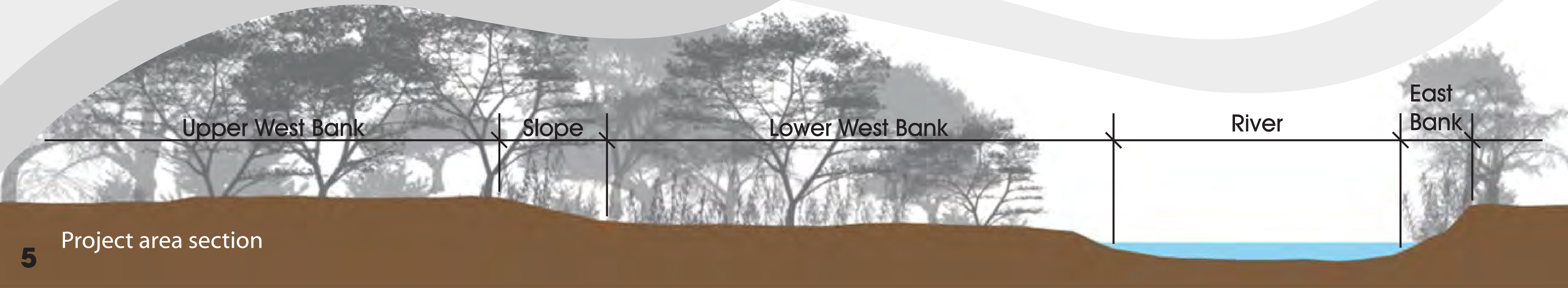
Directly north of the project site is Mill Race Park, designed by famed landscape architect Michael Van Valkenburgh. Mill Race Park hosts year-round events and is home to a section of the Columbus People Trail. The People Trail spans the river alongside the 3rd Street Bridge on the north side of the study area. There is also a branch of the trail that ends at Lafayette Street, but there is currently no connection on the south side of downtown between this branch of the trail and the trail through Mill Race Park.

In addition to Mill Race Park and the People Trail, there is a plethora of significant architecture, art, and entertainment in Downtown Columbus within a ten minute walk from the Riverfront.



TOPOGRAPHY

The east bank of the river is very steep, with a vertical drop of about 18 feet over a +/- 20' distance. The west bank has a vertical drop of about 21 feet, but over a much larger distance. The 10-year flood elevation is approximately 619' (NAVD88), and the 100-year flood elevation is approximately 622' (NAVD88).



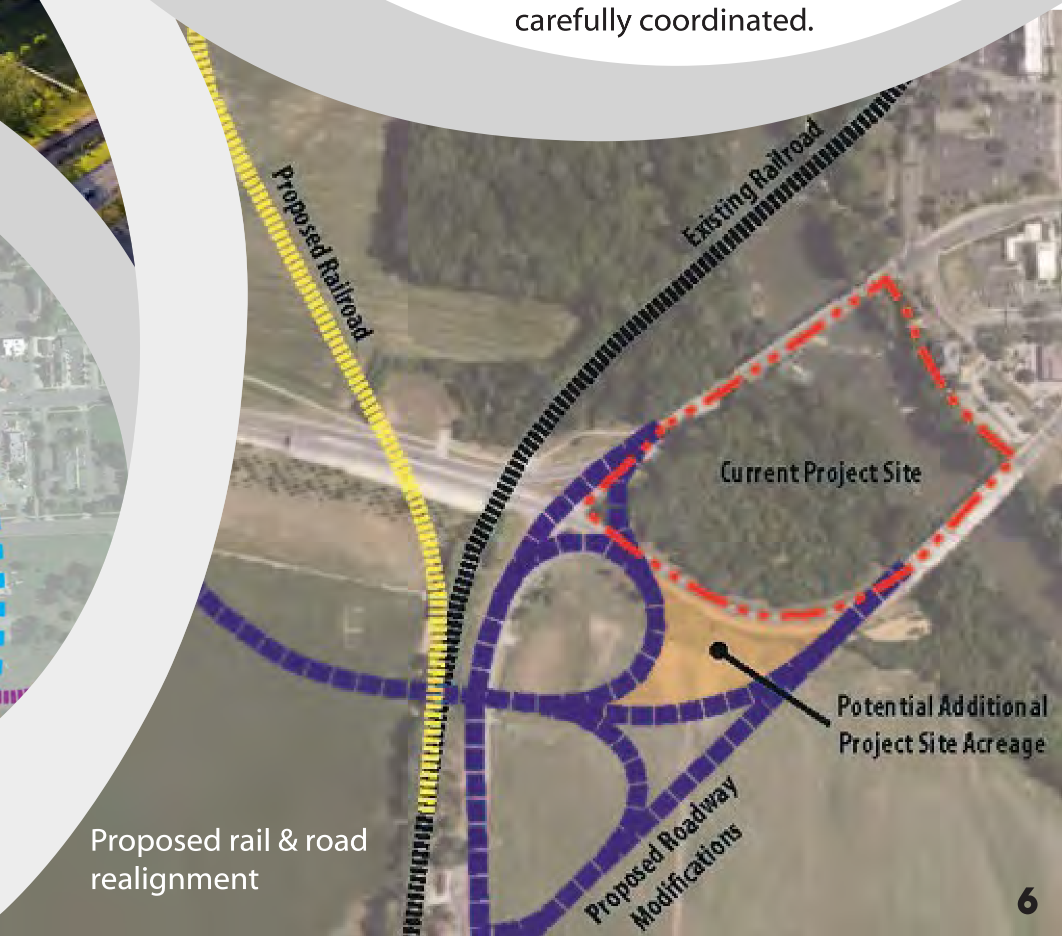
Project area section

Mill Race Park

PROPOSED RAILWAY REALIGNMENT

The Pennsylvania Railroad Bridge is north of the site, which carries between 4 and 20 trains along the western edge of downtown on a daily basis. Because of the increased train traffic and the hazard it poses to pedestrians, city leaders have initiated plans to reroute the railroad around downtown. The current concept reroutes the rail line west of the river. In addition, the February 2017 plan, prepared by American Structurepoint, suggests that SR 46 be elevated and reconfigured to eliminate the conflict between vehicles and trains. The concept also illustrates an interstate-type cloverleaf interchange that may affect the Riverfront in three significant ways. If constructed as conceptualized, the study area may expand southward to include the land directly east of the proposed cloverleaf, inbound vehicle speed may increase, making accessibility to the site challenging, and potential Riverfront and roadway improvements will need to be carefully coordinated.

Walking Distances

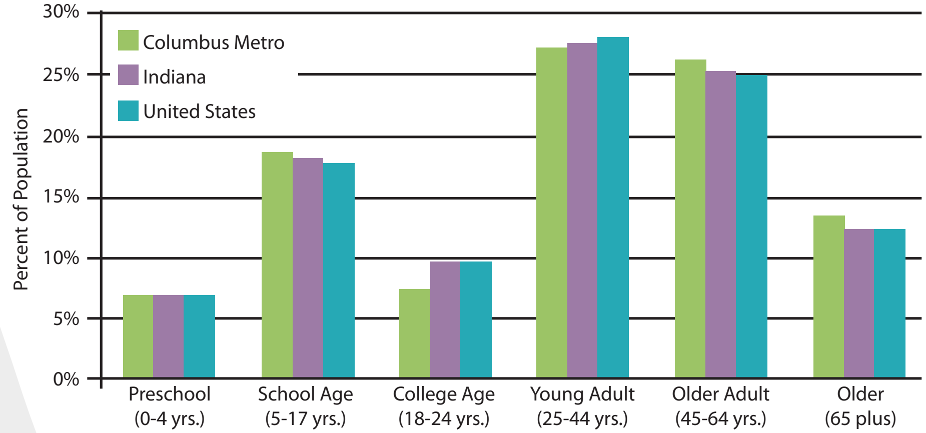


Proposed rail & road realignment

OPPORTUNITY ANALYSIS

MARKETPLACE

With a population of approximately 48,000, Columbus is a growing city with small town charm boasting exceptional history, art, and architecture. The market analysis considers area demographics, activities, and tourism. Comparable projects in other communities were also considered, suggesting best practices that are also appropriate for the Columbus Riverfront. For the full market analysis, see Appendix A.



Source: IBRC, using U.S. Census Bureau data

DEMOGRAPHICS

The population of Columbus is growing at a faster rate than the rest of the county, state, and country. Household size is also increasing, suggesting that there is a higher number of children. Columbus has a relatively young population, with an increasing age bracket of 18 and younger, which is different from similar sized communities throughout the country. The senior population is also growing, which is consistent with the national trend.

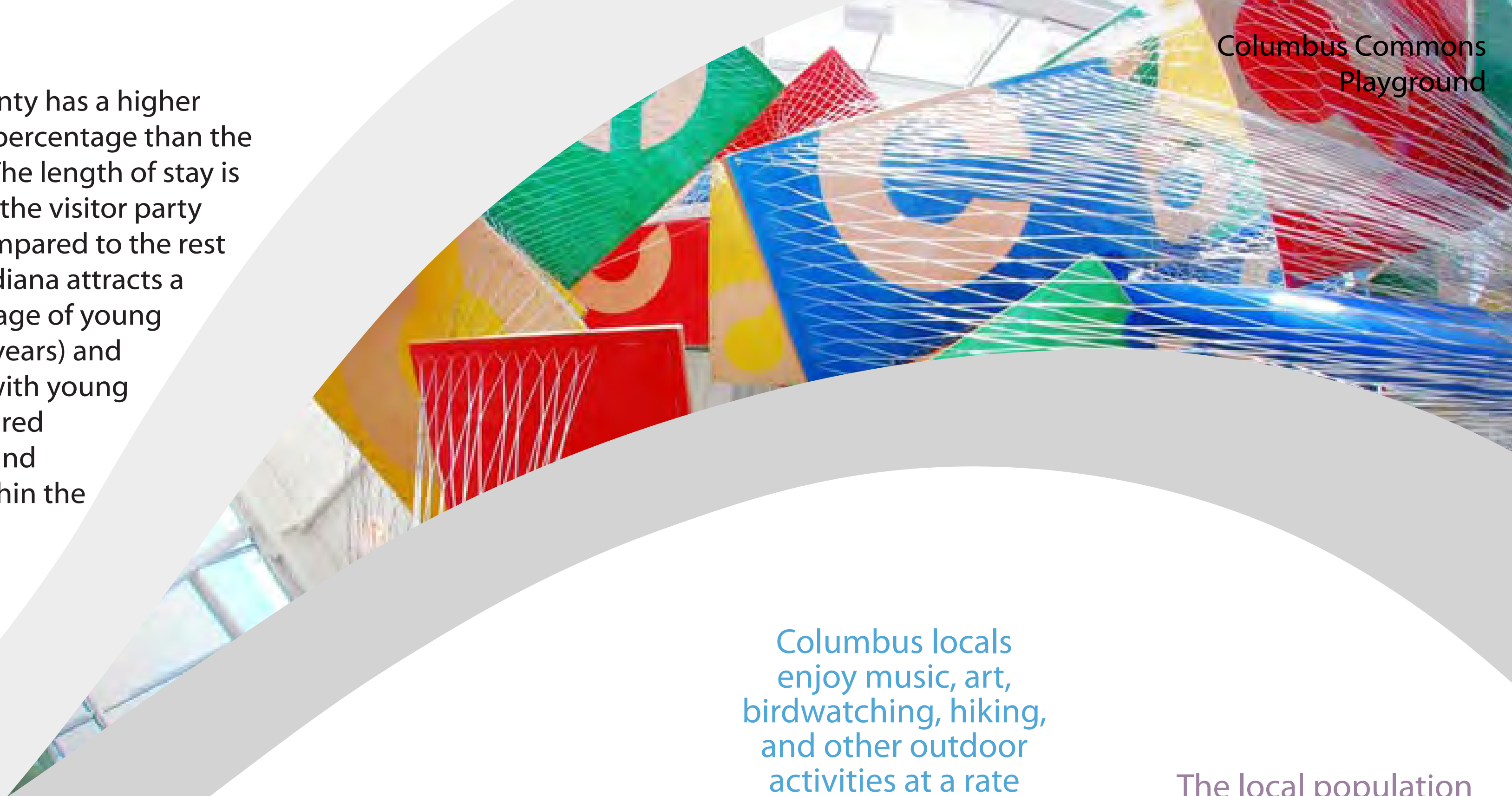
"Exhibit Columbus" sculpture

Cummins Headquarters

Architecture, sports, and dining top the major tourist attractions list in Columbus

TOURISM

Bartholomew County has a higher overnight visitor percentage than the rest of Indiana. The length of stay is also longer, and the visitor party size is larger compared to the rest of the state. Indiana attracts a higher percentage of young visitors (18-34 years) and more families with young children compared to other states and destinations within the country.



Columbus Commons Playground

Columbus population growth is faster than local, state, and even national averages

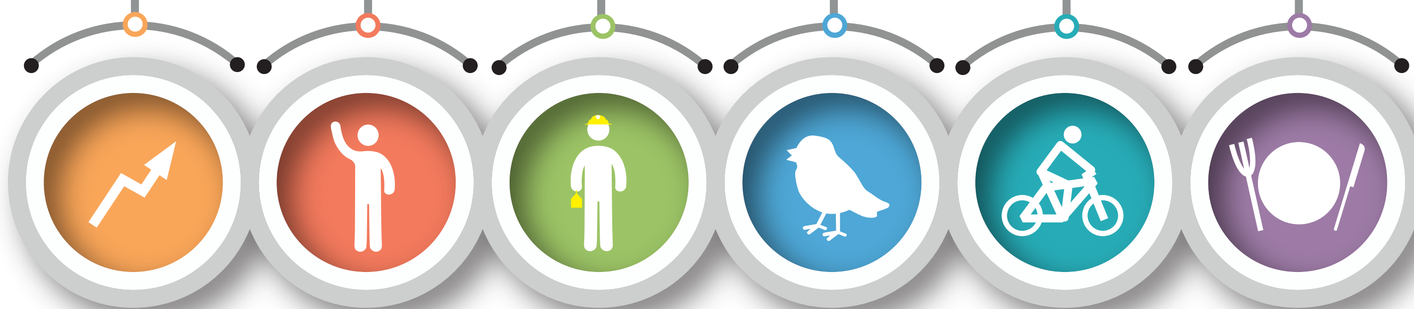
Columbus is relatively young with a median age of just 38.8 years old

9,400 People work within a 15-minute walk of the Riverfront

Columbus locals enjoy music, art, birdwatching, hiking, and other outdoor activities at a rate much higher than the national average

Jogging, walking, swimming, biking, and fishing top the list of local favorite activities

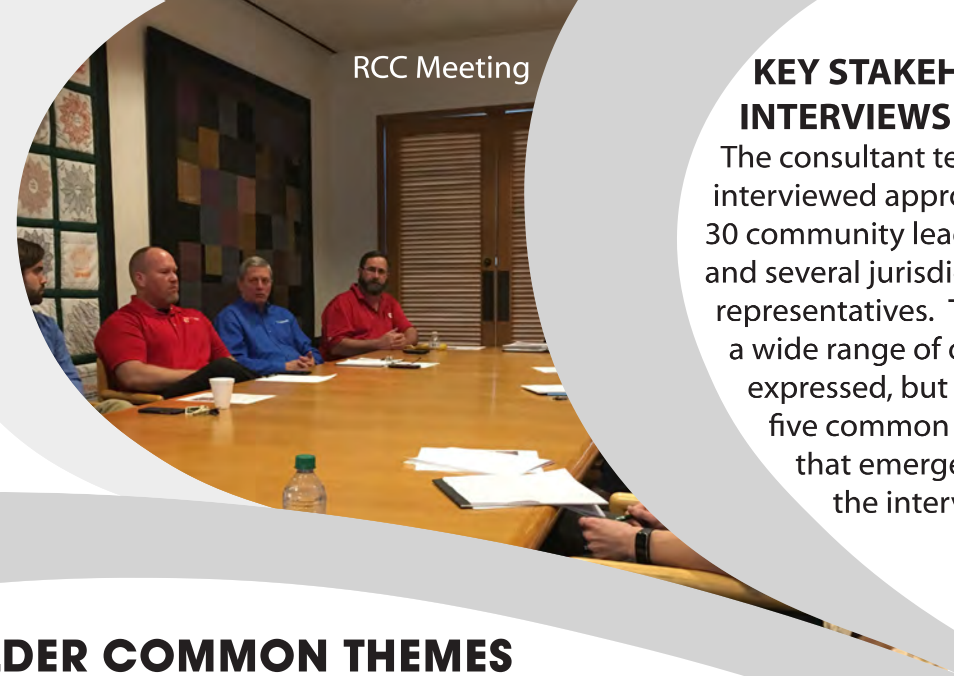
The local population dines out more frequently than the national average



■OPPORTUNITY ANALYSIS

STAKEHOLDERS

Columbus Riverfront stakeholders include government officials, property and business owners, and Columbus residents. In addition to ongoing guidance provided by the Riverfront Citizens Committee, the consultant team interviewed key stakeholders, facilitated a community workshop, and conducted a community survey to gather critical insight and brainstorm Riverfront improvement ideas.



RCC Meeting

KEY STAKEHOLDER INTERVIEWS

The consultant team interviewed approximately 30 community leaders and several jurisdictional representatives. There was a wide range of opinions expressed, but there were five common themes that emerged from the interviews.

STAKEHOLDER COMMON THEMES

IMPORTANCE

The Riverfront study area is important because it is an unfulfilled part of the gateway ("front door") experience and downtown.

TALENT

Talent attraction and retention is a major community priority. Activating the Riverfront to appeal to millenials and tourists is desirable.

THE COLUMBUS WAY

Do it right or don't do it at all. The emphasis on quality is unmistakable.

CONNECTIVITY

Three-dimensional (up/downstream, lateral and vertical) connectivity is important. Walking and cycling connections to the north, south, and west are a priority, as well as in-river connectivity.

HOSPITALITY

Hospitality is critically important. Every aspect of the Riverfront should create a positive and memorable experience for visitors and residents.

COMMON WORKSHOP THEMES

TRAIL
Overwhelmingly, the participants want to see multi-purpose trails that connect the study area to local trails and downtown.

KID ATTRACTIONS
Participants also expressed interest in distinctive, river-themed attractions that target children and families.

ENVIRONMENT
Participants want to see all improvements emphasize nature and the environment.

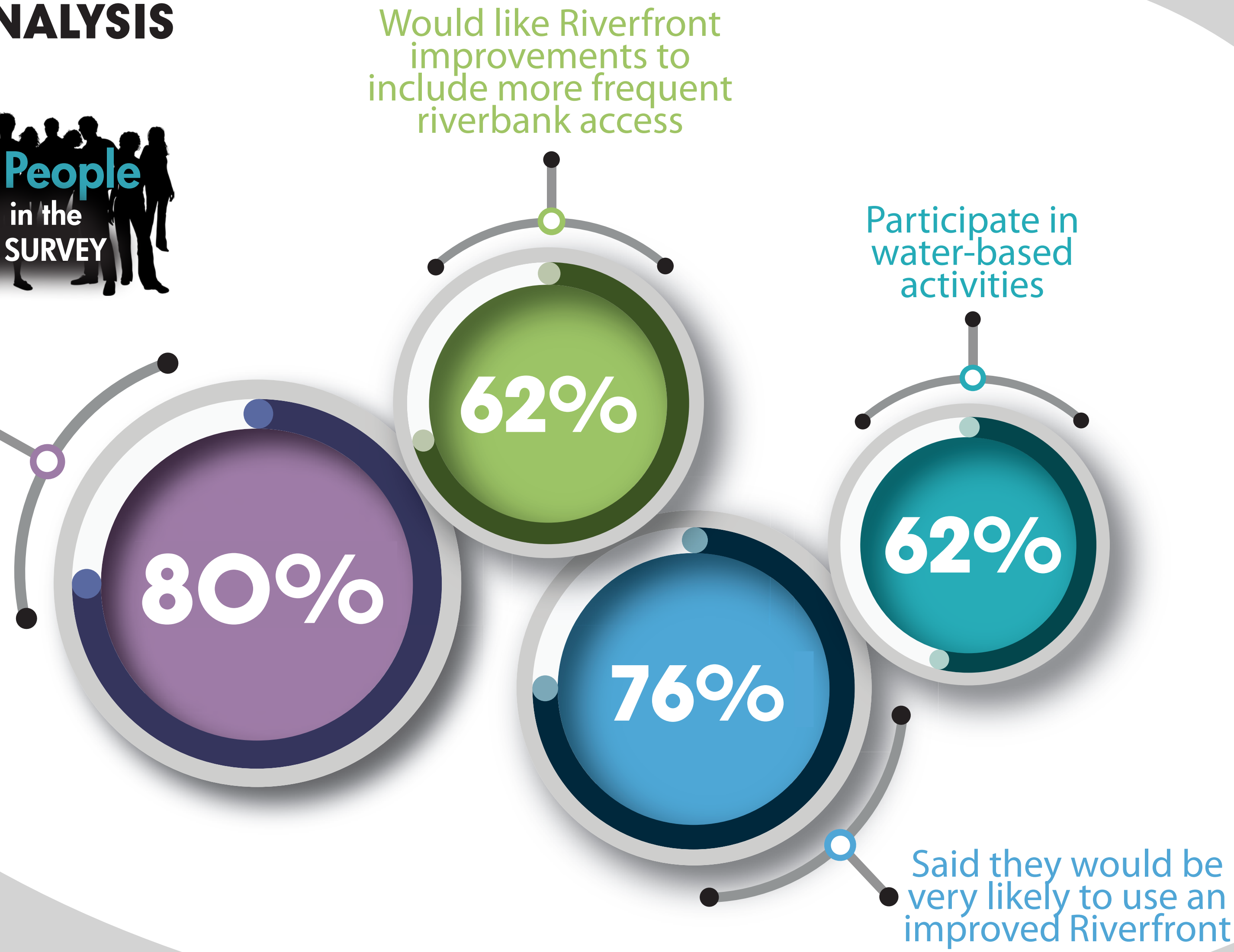
WHITEWATER
Participants expressed a noteworthy interest in a whitewater feature as a replacement for the existing dam.

NEW PARK
Participants saw the western portion of the study area as an opportunity for a unique park that is complementary to, but distinct from Mill Race Park.

OVERVIEW
The consultant team facilitated a public workshop on April 5, 2017 that was attended by approximately 70 energetic residents and others with a keen interest in the Riverfront. The team introduced the project and presented preliminary data about the study area resources and market. The team facilitated individual and interactive group exercises that identified some common interests and priorities of the participants when asked to describe the Riverfront in 2022.

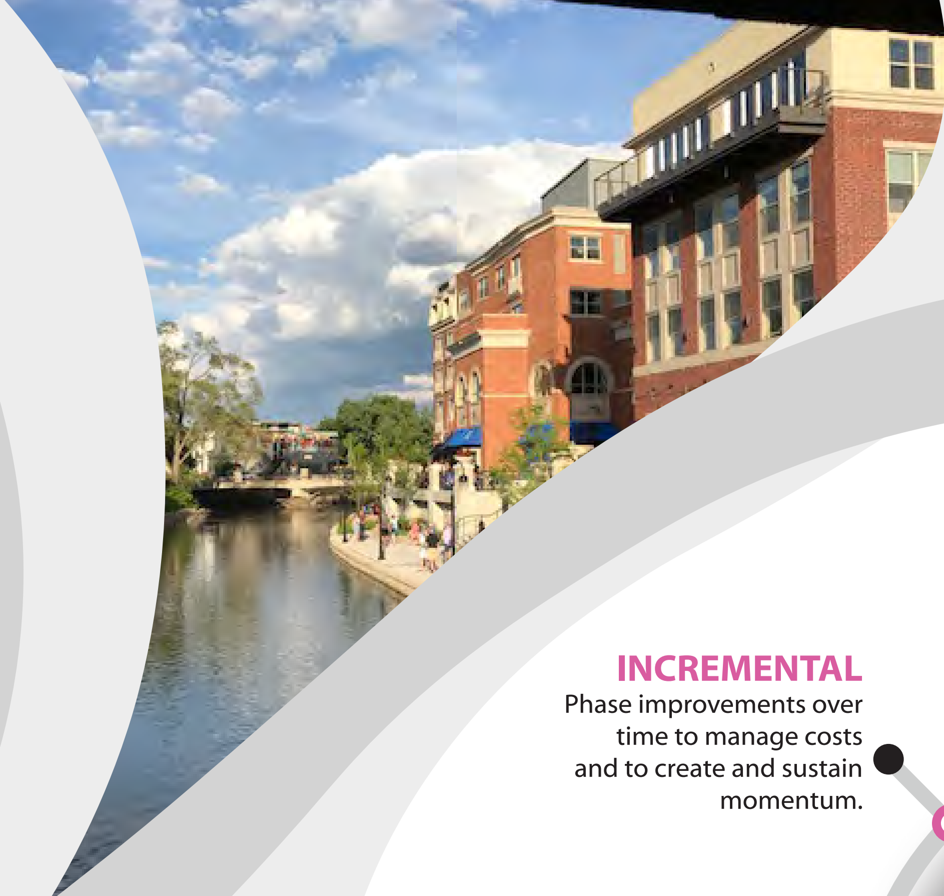
Community workshop

OPPORTUNITY ANALYSIS
COMMUNITY SURVEY



COMMUNITY SURVEY

Over 600 people participated in the community survey that was posted on the Columbus Riverfront website, which suggests an important level of stakeholder interest and statistically valid guidance. The design team carefully analyzed the survey results to create the strategy & alternative Riverfront concepts. The top three reasons respondents think the Riverfront should be improved are to provide more activities for residents, increase water-based recreation, and link downtown to the Riverfront.



OPPORTUNITY ANALYSIS
BEST PRACTICES

The common success factors found in dozens of comparable settings define the best practices that will likely be appropriate in Columbus.

BEST PRACTICES

MULTI-DIMENSIONAL
Construct improvements that target resident and visitor audiences and accommodate a variety of program requirements.

ATTRACTIVE
Create engaging, stimulating, and well-maintained improvements.

DISTINCTIVE
Differentiate the Columbus Riverfront from other riverfront destinations.

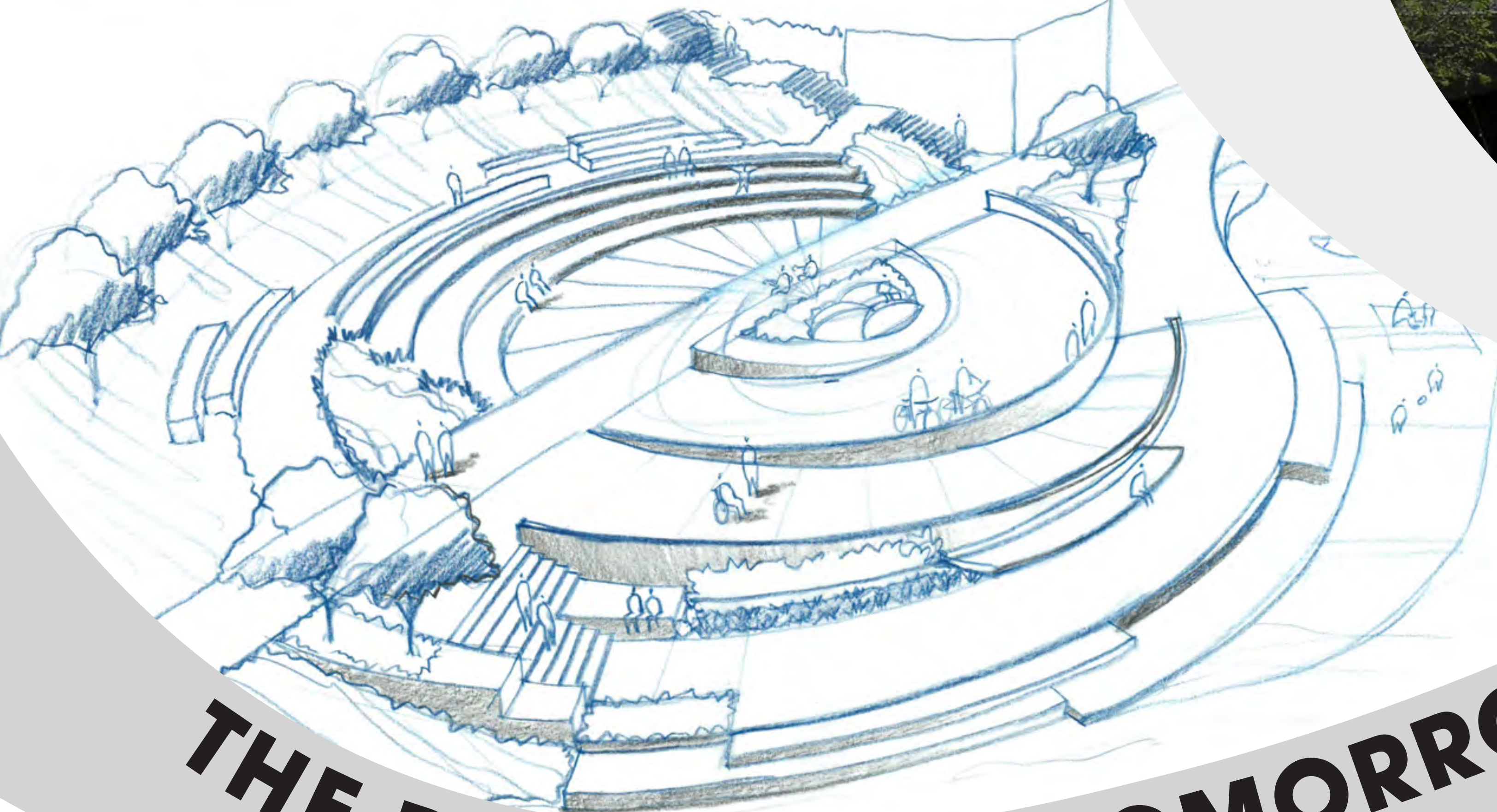
RESPECTFUL
Process and improvements should follow jurisdictional requirements, respect stakeholders, and support the community's rich cultural heritage.

BARRIER FREE
Provide access to the study area and its features for patrons with compromised mobility.

HEALTHY
Create a variety of active and passive, accessible, comfortable, clean, and safe experiences for all patrons.

SUSTAINABLE
Add environmental, economic, and cultural value for years to come.

INCREMENTAL
Phase improvements over time to manage costs and to create and sustain momentum.

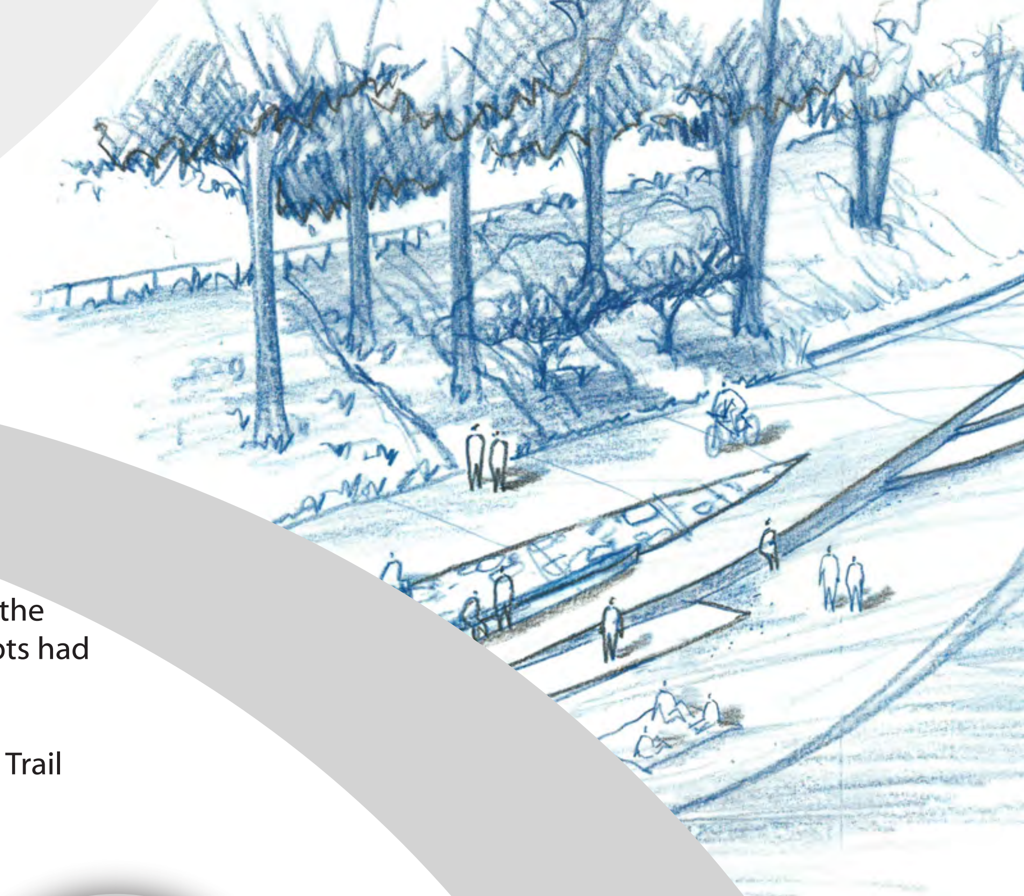


THE RIVERFRONT TOMORROW

STRATEGY

During the summer of 2017, the consultant team completed the Opportunity Analysis, which analyzed the resources, marketplace, and stakeholder expectations associated with the Riverfront. During the second phase of the engagement, the team has explored alternative improvement concepts, and based on its on-going interaction with the Riverfront Steering Committee and the Riverfront Citizen's Committee, the team has prepared a Preferred Riverfront Strategy and Vision Plan.

Based on the existing resources, marketplace, and stakeholder expectations, the consultant team recommends the following strategy to advance the community's riverfront goal. Each component should meet the four **objectives** and most, if not all the best practices.



CONCEPTS

The consultant team developed multiple solutions to accomplish the Riverfront goal and objectives. Both alternative Riverfront concepts had several common themes:

1. Accommodate the probable realignment of SR 46
2. A river walk on the east bank with a connection to the People Trail
3. Improved 3-dimensional connectivity
4. Nature-themed play space on the west bank
5. In-river improvements

STRATEGY

3-DIMENSIONAL CONNECTIONS

Construct a 3-dimensional network of related connections through...

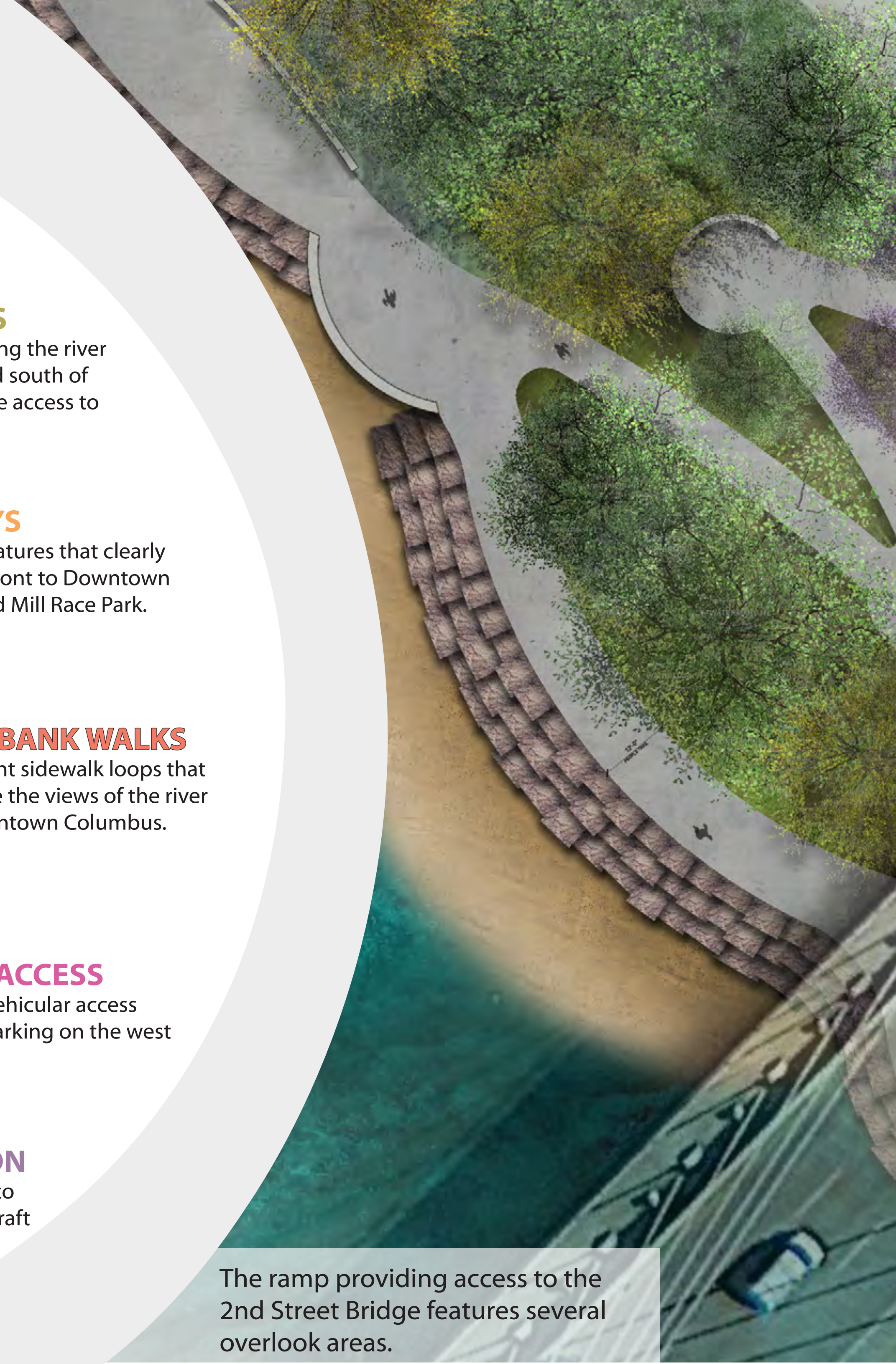
EAST BANK WALKS
Expand the People Trail along the river with connections north and south of the bridges with barrier-free access to street level.

GATEWAYS
Implement features that clearly link the riverfront to Downtown Columbus and Mill Race Park.

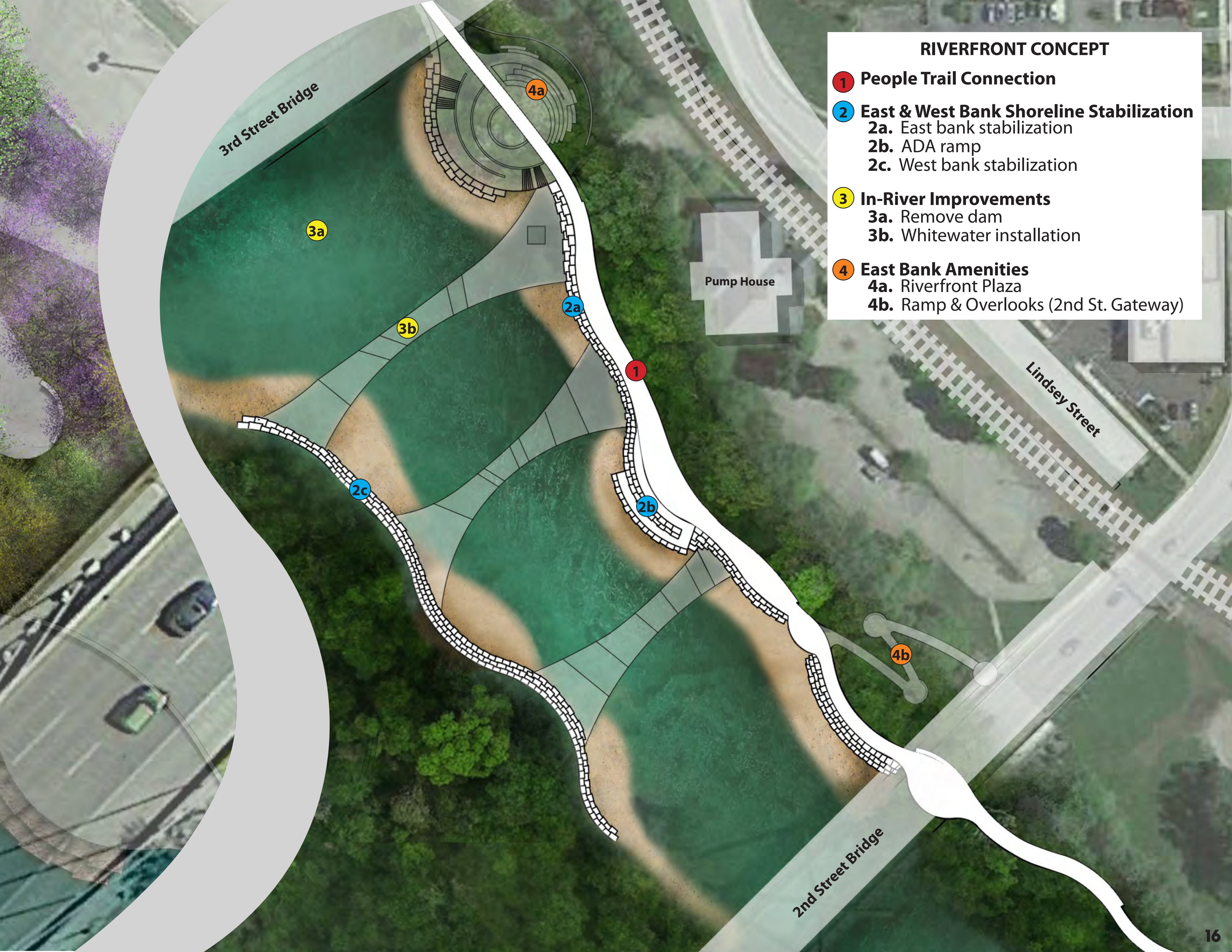
WEST BANK WALKS
Implement sidewalk loops that showcase the views of the river and Downtown Columbus.

VEHICLE ACCESS
Incorporate vehicular access and limited parking on the west bank.

DAM MODIFICATION
Remove the low-head dam to improve wildlife and watercraft passage.



The ramp providing access to the 2nd Street Bridge features several overlook areas.

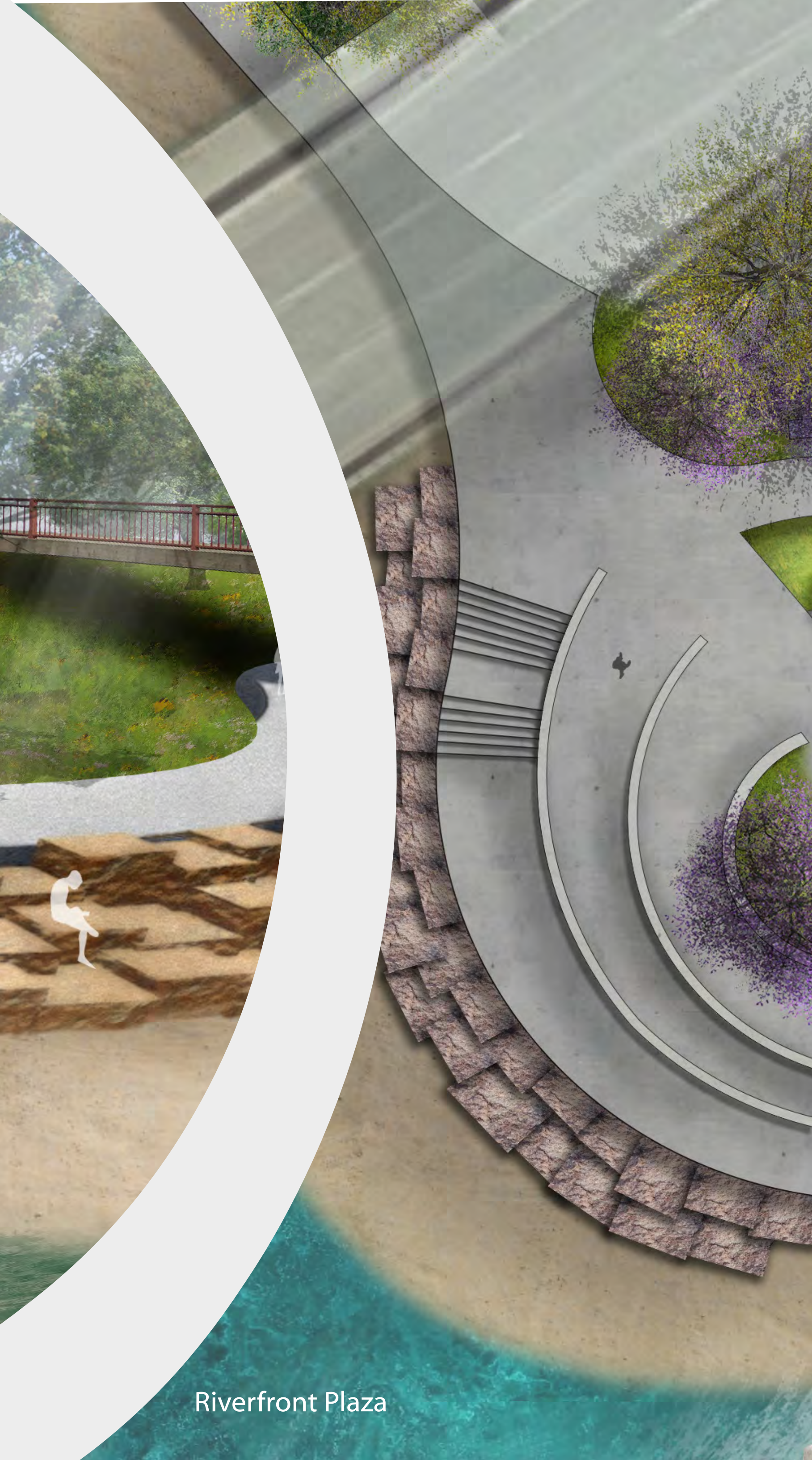


RIVERFRONT CONCEPT
1 People Trail Connection
2 East & West Bank Shoreline Stabilization
2a. East bank stabilization
2b. ADA ramp
2c. West bank stabilization
3 In-River Improvements
3a. Remove dam
3b. Whitewater installation
4 East Bank Amenities
4a. Riverfront Plaza
4b. Ramp & Overlooks (2nd St. Gateway)
3rd Street Bridge
Pump House
Lindsey Street
2nd Street Bridge
4a
3a
3b
2a
1
2c
2b
4b

■STRATEGY

3-DIMENSIONAL CONNECTIONS

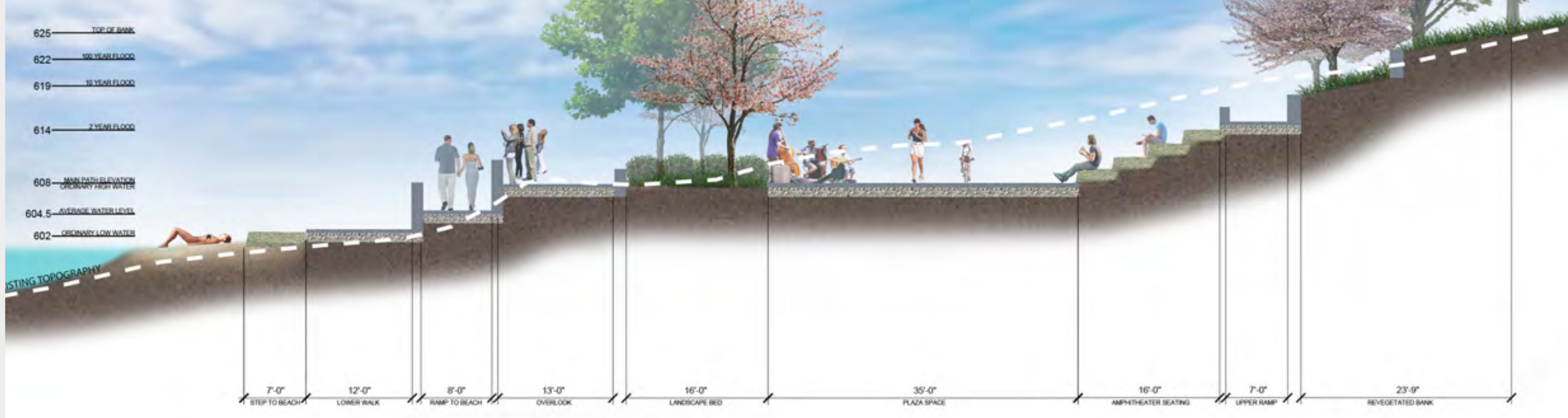
2nd Street Gateway



Riverfront Plaza

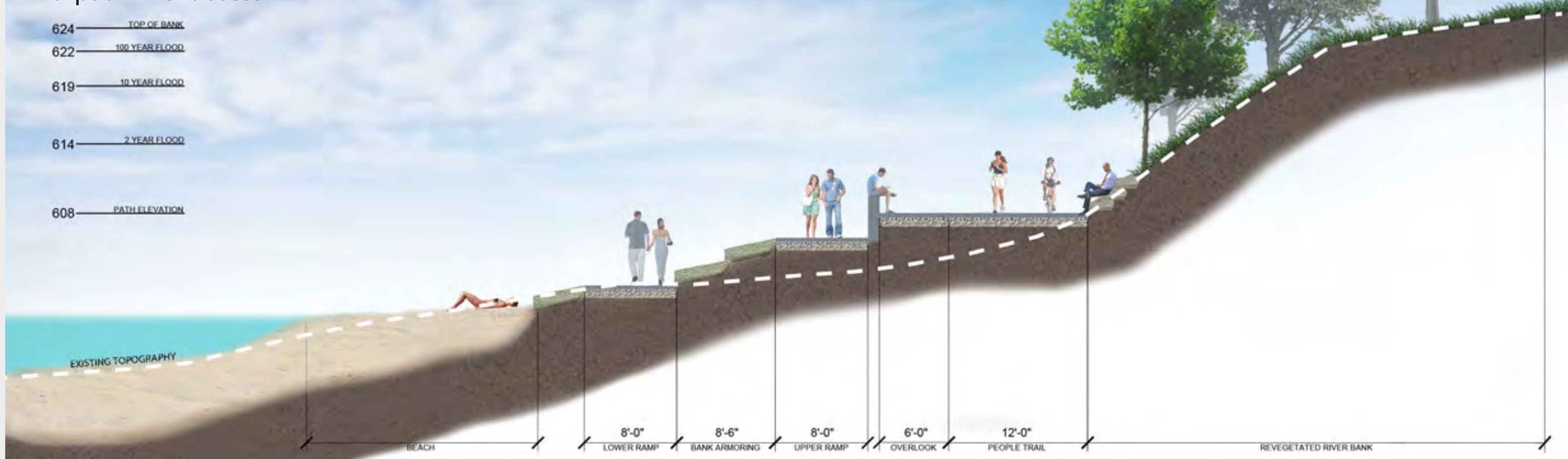
RIVERFRONT PLAZA (4a)

People Trail connection with
seating & river access.



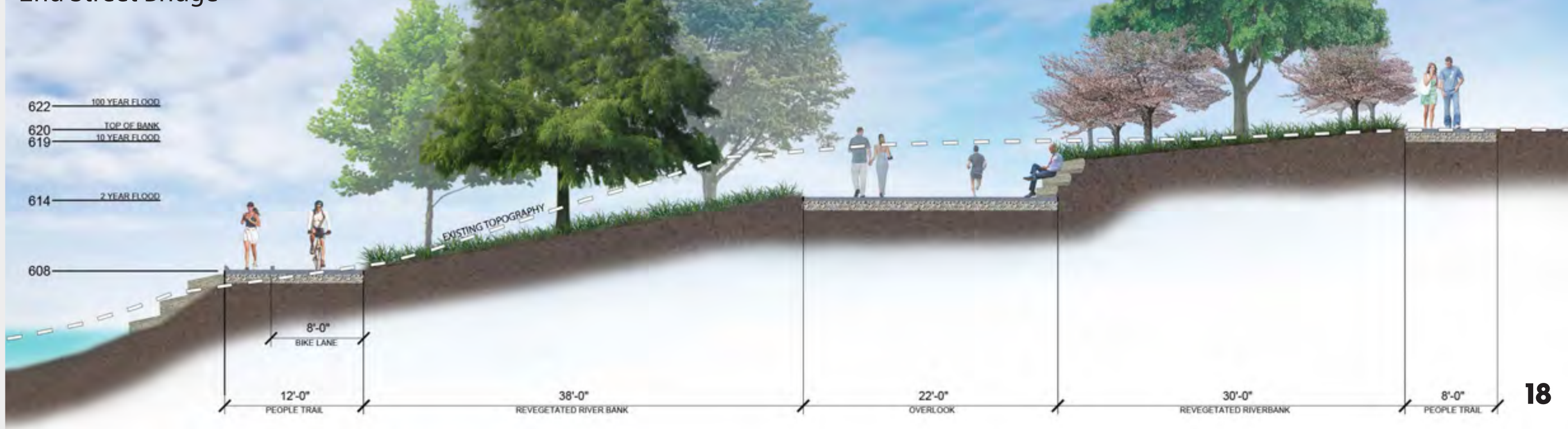
RIVER ACCESS (2b)

Mid-path river access



2nd STREET GATEWAY (4b)

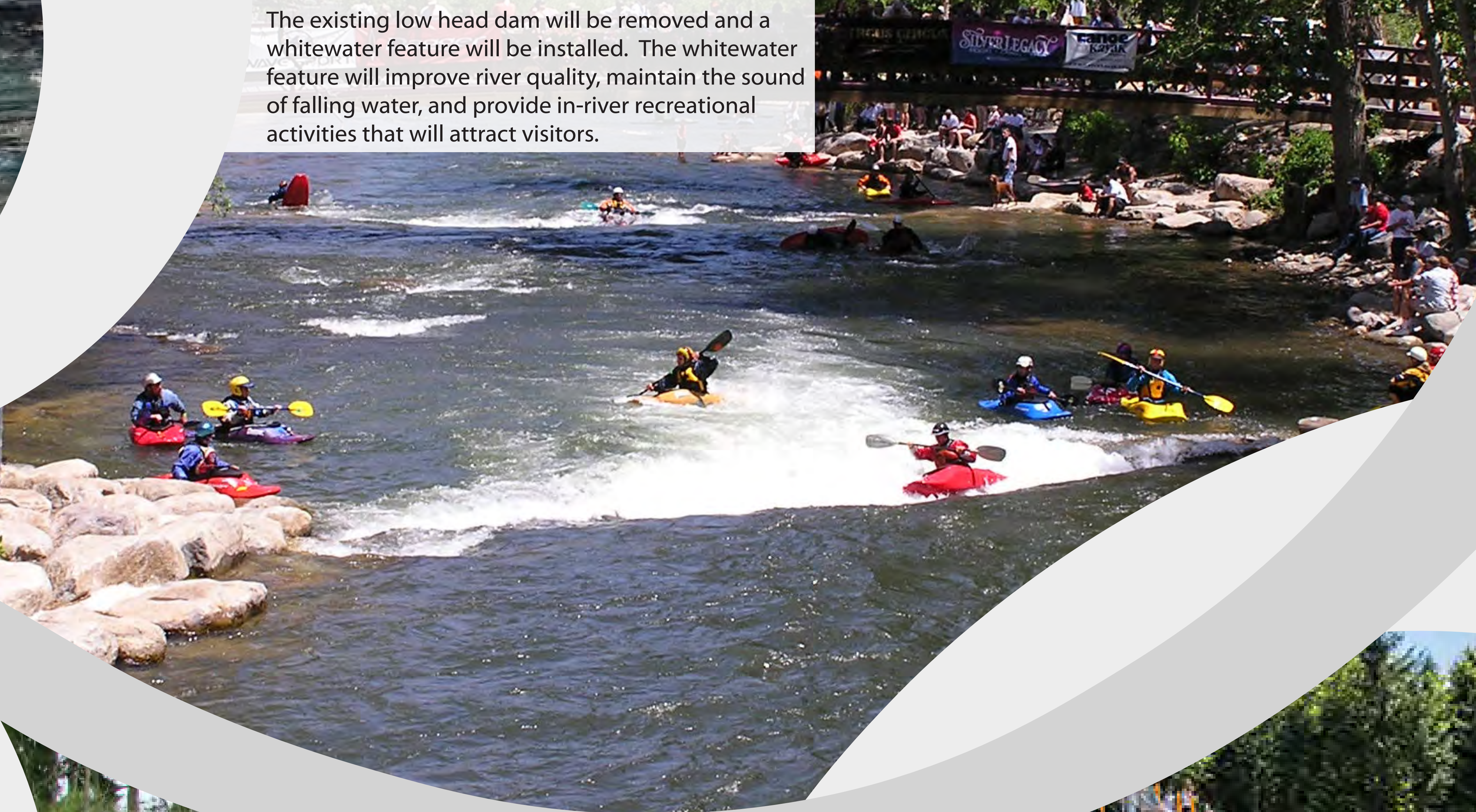
Connection from east riverbank to
2nd Street Bridge



The whitewater feature will provide in-river recreational opportunities such as kayaking.

COMPELLING ATTRACTIONS

- **Children's Play Space**
  - Nature-based play
  - Challenging & intergenerational
  - Accommodates parents
- **High Amenity River Walk**
  - Sculptural design
  - Overlooks & gathering space
  - Public art installations
- **White Water Feature**
  - Attractive sound
  - Built with natural materials
  - Improves water quality
- **Gateway to Columbus**
  - "Front Door" to Columbus
  - Transition from iconic SR 46 landscape
  - Southwest edge of west bank

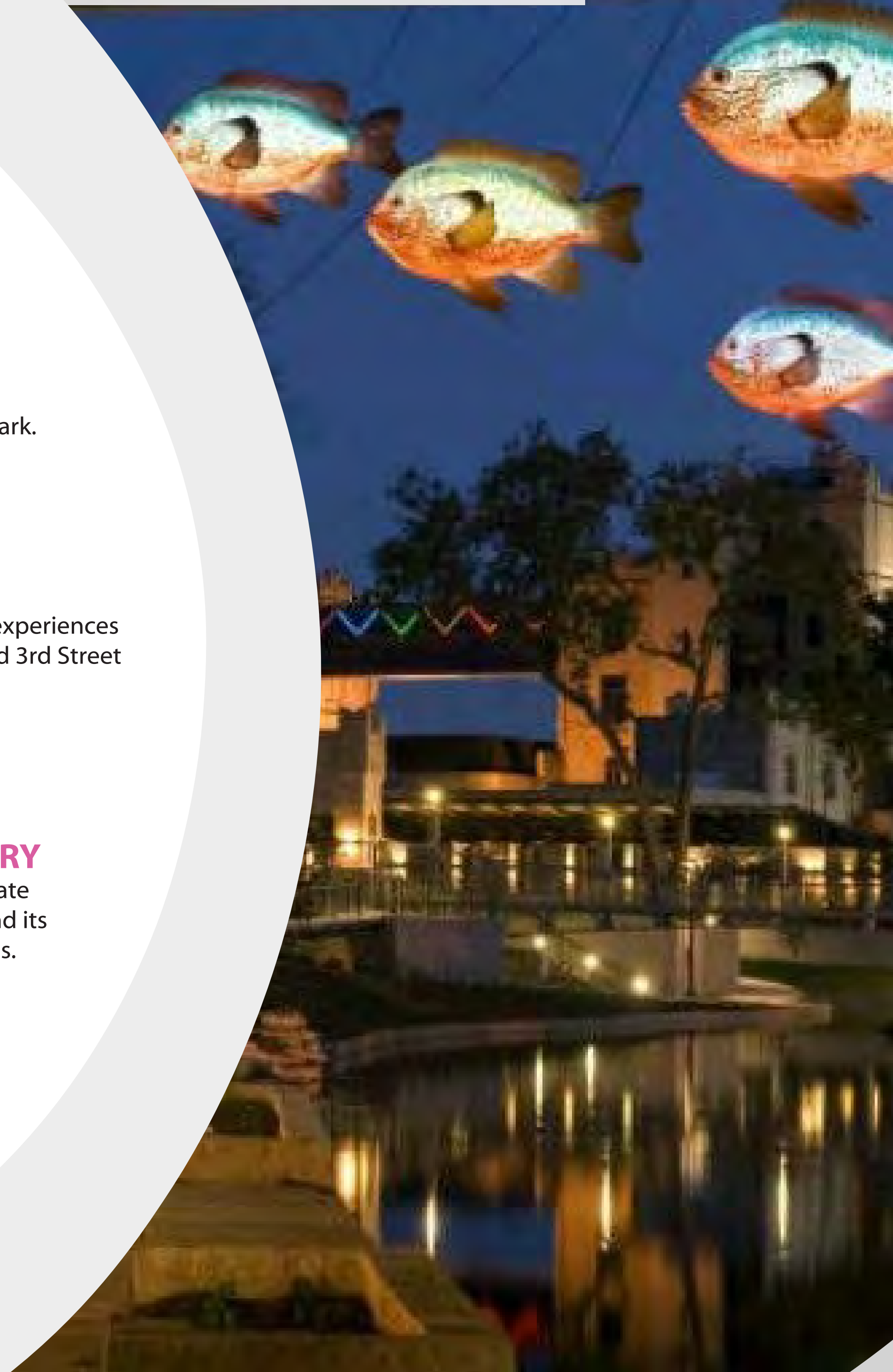


The existing low head dam will be removed and a whitewater feature will be installed. The whitewater feature will improve river quality, maintain the sound of falling water, and provide in-river recreational activities that will attract visitors.

The nature-based play feature will utilize the sloping terrain to engage children of all ages

STRATEGY
CAPTIVATING APPEARANCE

The underside of the 2nd and 3rd Street bridges offer an opportunity to create memorable gateways as visitors enter and exit the Riverfront.



RESPECTFULNESS
Construct the public features to be captivating while respecting the river.

SINUOSITY
Sinuous design that complements Mill Race Park.

GATEWAYS
Engaging gateway experiences beneath the 2nd and 3rd Street bridges.

THE RIVER'S STORY
Respect and commemorate the history of the river and its contribution to Columbus.

COMMUNITY
Incorporate Columbus' current branding strategy into the riverfront.

The mid-path river access ramp will provide a river overlook and barrier-free access to the river.

The Riverfront incorporates large, locally sourced limestone blocks that will be used for retaining walls and seating.

The expansive Riverfront plaza will feature seating and river access.

STRATEGY

INCREMENTAL IMPLEMENTATION

Create and sustain momentum through...

BIG PICTURE
Big picture thinking focused on incremental implementation.

PERMITTING
Concurrent permitting of the east bank and in-river improvements.

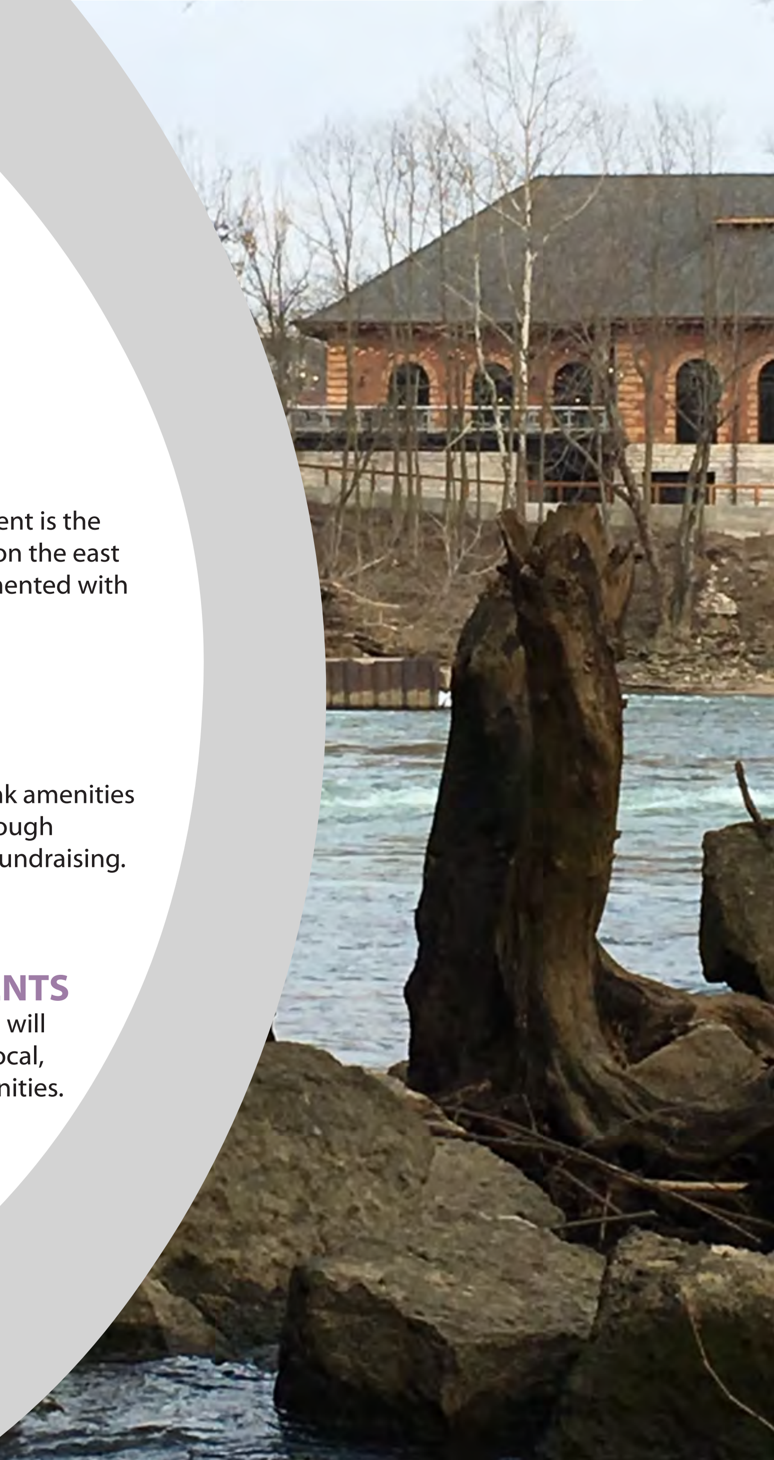
PEOPLE TRAIL
The first proposed segment is the People Trail connection on the east bank, potentially implemented with public funds

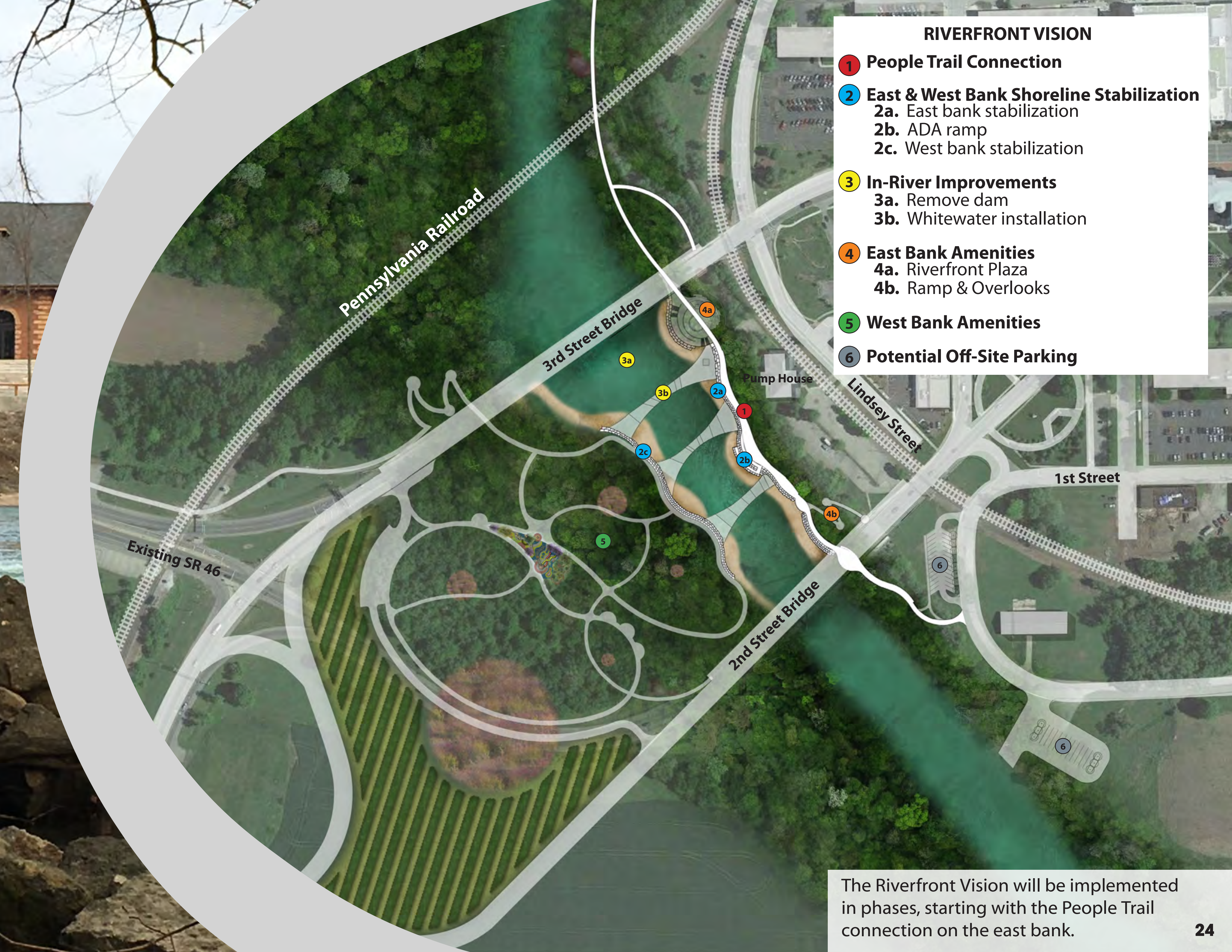
AMENITIES
Other proposed east bank amenities will be implemented through potential private sector fundraising.

IN-RIVER IMPROVEMENTS
Proposed in-river improvements will potentially be funded through local, state, and federal grant opportunities.

WEST BANK
Future west bank improvements will be implemented through long term fundraising.

The Columbus Pump House, located at the top of the east bank, is an integral part of the history of the river. It is now a restaurant and brewery.





The Riverfront Vision will be implemented in phases, starting with the People Trail connection on the east bank.

ECONOMIC IMPACT

For the full market analysis, see Appendix A

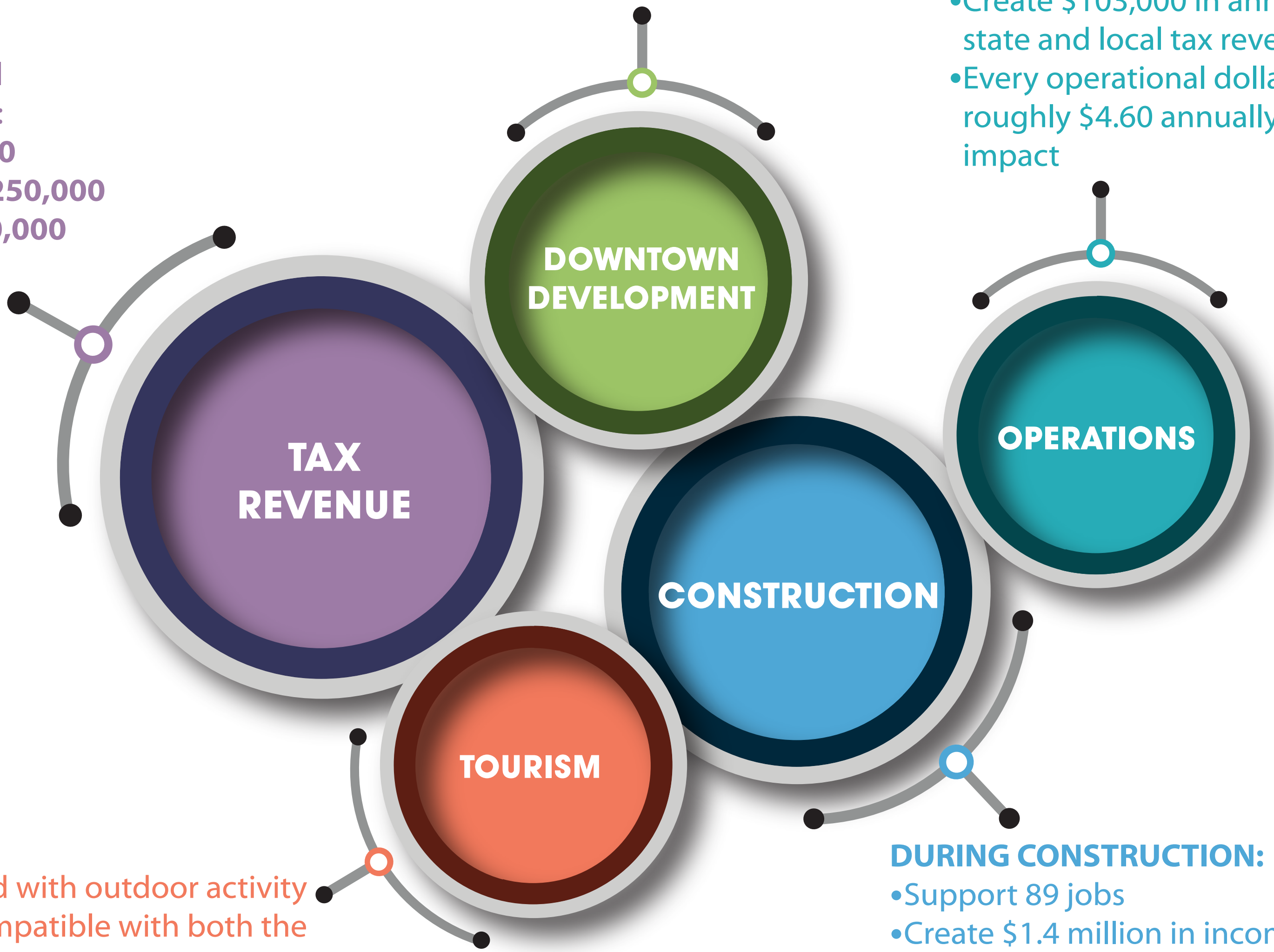
POST CONSTRUCTION OPERATIONS:

- Support 29 jobs
- Create $769,000 in annual recurring income
- Create $103,000 in annual recurring state and local tax revenue
- Every operational dollar returns roughly $4.60 annually in economic impact

Could trigger retail, restaurant, residential, and hotel construction.

Potential additional annual tax revenue:

- Sales tax: **$780,000**
- Innkeeper's tax: **$250,000**
- Property tax: **$490,000**

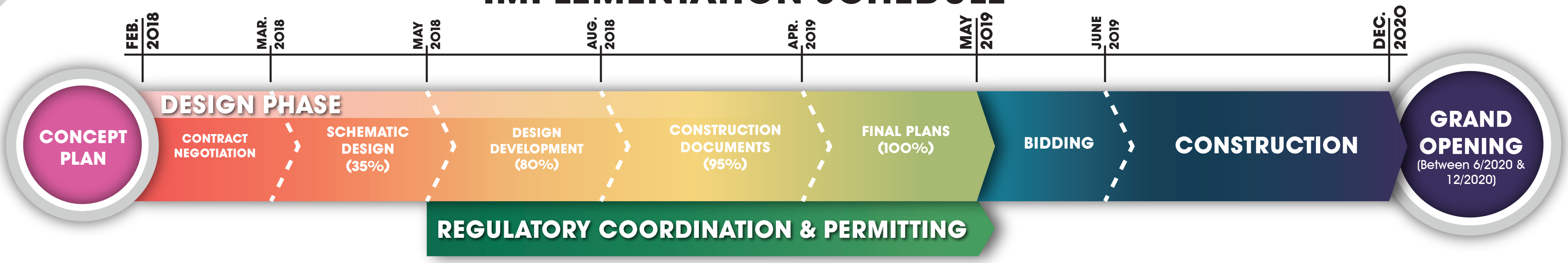


Diversified with outdoor activity experiences compatible with both the architectural and sports tournament markets. Potentially supported with proximate new hotel development focused more on the Columbus experience and less on the pass-through market.

DURING CONSTRUCTION:

- Support 89 jobs
- Create $1.4 million in income
- Create $280,000 in state and local tax revenue
- Every construction dollar returns roughly $1.80 in economic impact

IMPLEMENTATION SCHEDULE



REQUIRED PERMITS

CONSTRUCTION IN A FLOODWAY

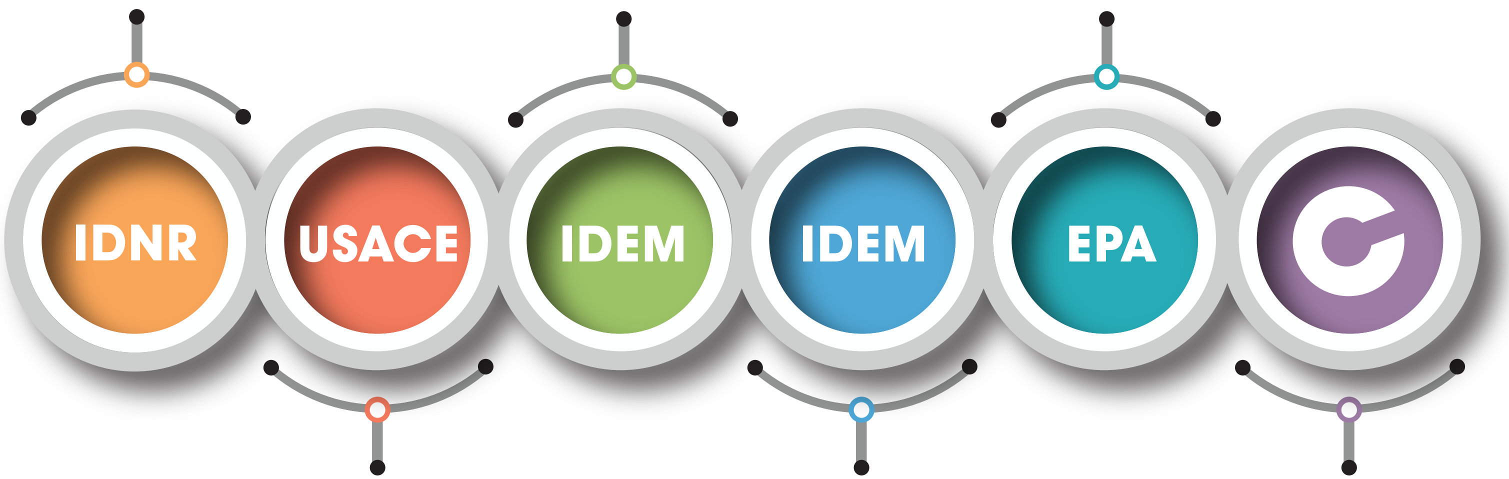
Because the suggested improvements will alter the cross sectional flow area, hydraulic computer modeling will be required to demonstrate the projected flow changes. Fish & Wildlife will need to approve changes to wildlife habitat including in-river and tree habitat. DNR will also be concerned with any tree removal within the floodplain.

WATER QUALITY CERTIFICATION

When a project is planned in Indiana that will impact a wetland, stream, river, lake, or other Water of the U.S., IDEM must issue a Section 401 Water Quality Certification.

EPA PERMITS

Because of the current restrictive covenants on the west bank due to the former landfill, EPA and IDEM will need to approve any improvements on that land, which may require a process to legally remove or modify the current restrictive covenants.



CLEAN WATER ACT SECTION 404

Section 404 of the Clean Water Act (CWA) establishes a program to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. If any federal funds are used, a Section 106 permit may also be required.

CONSTRUCTION/LAND DISTURBANCE

The requirements of the Construction Site Run-off general permit applies to all persons who are involved in construction activity (clearing, grading, excavation and other land-disturbing activities) that results in the disturbance of one acre or more of total land area.

LOCAL PERMITS

Standard local permits will be required per City of Columbus ordinances.

COST OPINION

The costs below include estimated design, permitting, and construction costs

AREA/PHASE	COST
People Trail Connection	$1,945,872
East & West Bank Shoreline Stabilization	$3,474,269
In-River Improvements	$2,369,054
Riverfront Amenities	$815,223
Totals	**$8,604,418**

GRANT OPPORTUNITIES

LOW HEAD DAM GRANTS

U.S. Fish and Wildlife National Fish Passage Program
DNR Lake and River Enhancement
USACOE Section 206 Aquatic Ecosystem Restoration Projects
Club Fostered Stewardship Grant
American Rivers

TRAIL/RECREATION/TOURISM GRANTS

Place Based Investment Fund
Recreational Trail Program
INDOT/Federal Funds for Local Projects
PeopleForBikes Community Grant Programs
Indiana Trail Fund
Cummins Foundation Architectural Program
NPS Community Assistance in Conservation & Outdoor Recreation Program
CreatINg Places

DESIGN GUIDELINES

Columbus Riverfront Design Guidelines

The purpose of the Columbus Riverfront Design Guidelines is to memorialize and document the design intent, considerations and materials suggested in the conceptual design phase of this project. These guidelines set the standards for future development along the riverfront and address the quality of materials, design style and functionality of the proposed improvements. This document will help ensure that future riverfront improvements will have a consistent aesthetic, replacement and maintenance requirements.

While these guidelines are intended to provide a unified design approach to the riverfront improvements, designs that vary from the information in the guidelines will be considered if judged to be in keeping with the overall intent of quality and functionality captured in this document.

SURFACES & PAVEMENT

The Columbus Riverfront is an extension of Mill Race Park and as such, should express the parks aesthetic wherever possible. The hardscape material palette and details should remain simple and modern in form. Following is a suggested palette of hardscape materials.

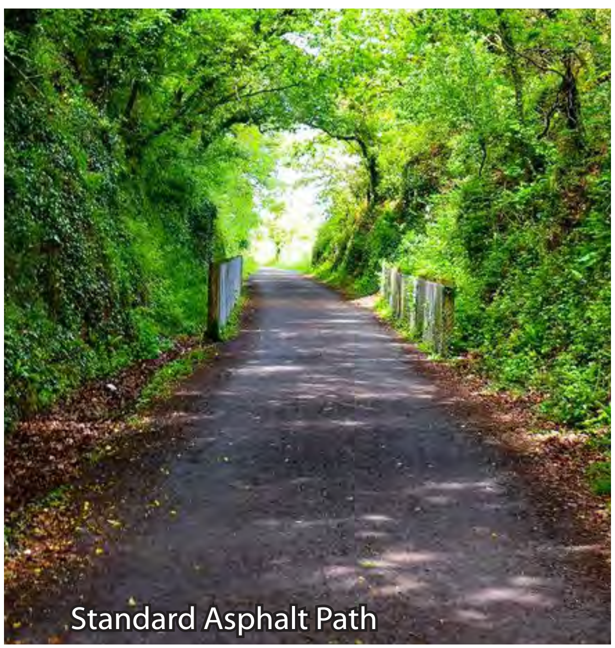
Concrete The pedestrian pavement material on the east river bank should be standard concrete with a medium broom finish perpendicular to the path of travel. The pedestrian pathways planned for the lower areas of the west bank improvements should also be be concrete.

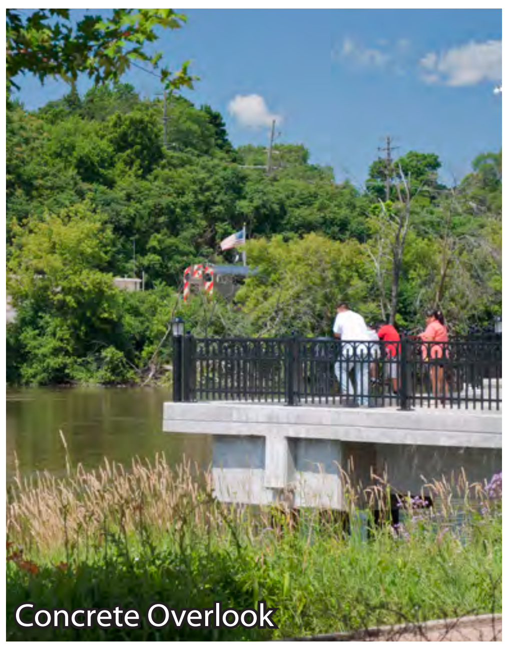
Asphalt Asphalt pavement should be used for the paths on the west bank that are on the high side of the site.


Mill Race Park


Standard Concrete Sidewalk


Standard Concrete Curb


Standard Asphalt Path


Concrete Overlook


Concrete Riverwalk

VERTICAL HARDSCAPE MATERIALS

Retaining Walls

Concrete Concrete retaining walls should match the concrete walls found in Mill Race Park, including finish and visible form connection holes.

Stone Stone retaining walls used to stabilize the toe of the slope along the east bank shall be made from blocks of Indiana Limestone. The blocks should be relatively uniform in shape, size and color. However; variation is allowable in order to incorporate interesting textures, pockets and details in the stone. Each block should be approximately 3-4'(L) x 18-24" (W) x 16-18" (H). Stone retaining walls should be dry laid. Care should be given in setting the stones to create seating opportunities along the river walk path.

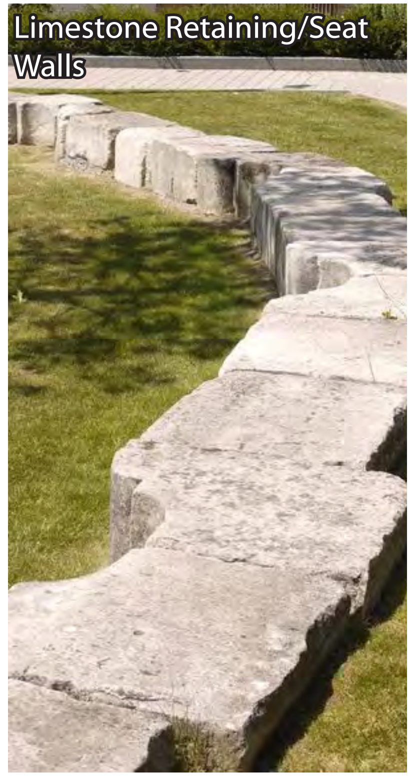
Riverbank Armoring

Stone Rectangular limestone blocks set irregularly along the rivers edge should be used to armor the bank. Each block should be approximately
3-4'(L) x 18-24" (W) x 16-18" (H).

In-River Improvements

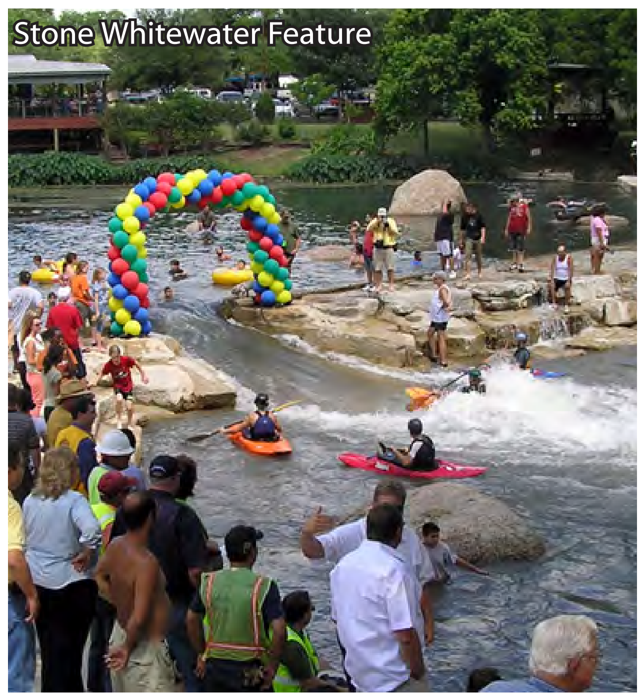
Stone The in-river white water improvements should incorporate native stone to appear as natural rock


Stone Whitewater Feature


Limestone Retaining/Seat Walls


Stone Bank Armoring


Stone Bank Armoring


Stone Whitewater Feature


Concrete Retaining Walls in Mill Race Park

SITE FURNISHINGS

Benches Wherever possible benches should be integrated into the concrete retaining walls.

Swings Swings should be constructed of durable, weather resistant materials

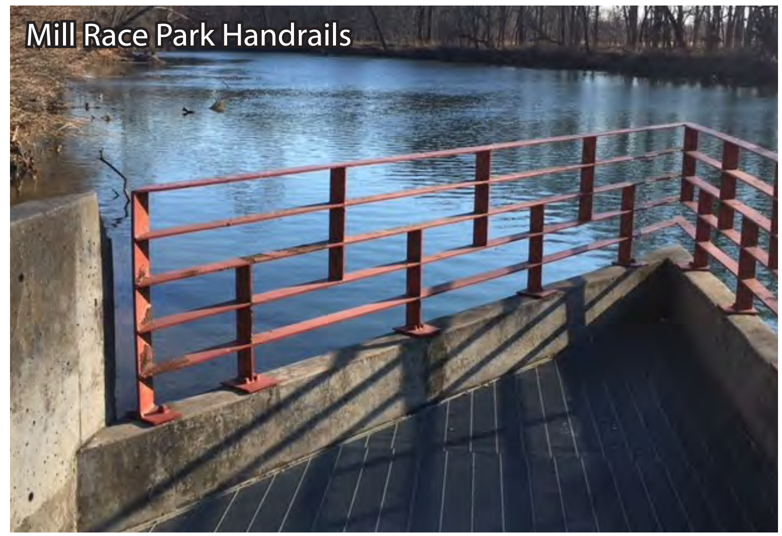
Waste Receptacles Waste receptacles to match those found in Mill Race Park.

Bike Racks All bike racks should match the Columbus "Dancing C" bike racks found throughout Columbus.

Handrails Any required handrails should match the style and design of the handrails found on the river overlook in Mill Race Park.


Swings


Swings


Mill Race Park Handrails


Mill Race Park Bench


Mill Race Park Bench


Standard Columbus Bike Rack


Mill Race Park Trash Can

SIGNAGE

Directional Signage Should match directional signage found in Mill Race Park.

Interpretive Signage Interpretive signage should be included near location of existing dam narrating the significance of the dam in Columbus' history. Signage should meet state requirements for historic signage.

Indiana Historical Signage

Mill Race Park Signage


Under Bridge Gateway Lighting Example

Lighting Lighting should be incorporated into the design of the Riverfront to light the path along the river. Special attention should be given to the lighting and gateway opportunities beneath the 2nd and 3rd Street Bridges.

Electrical Service Provide appropriate electrical service to the site to accommodate power needs for public gatherings and art installations.


Friendship Way Lighting


State Street Lighting


Mill Race Park Lighting

PLAYGROUND

Surfacing Resilient, child-friendly surfacing should be used. Multi-colored surfacing can be used to create visual interest.

Equipment Equipment should be nature-themed and inter-generational. It should create multi-level challenges for a range of ages and provide seating opportunities for parents. Equipment should also interact with the existing slope on the west bank.


Playground on Slope with Multi-colored Surfacing

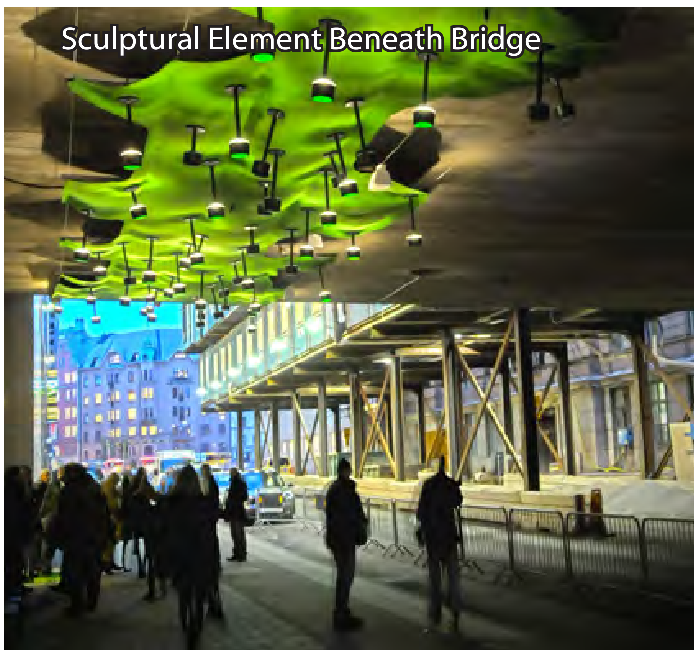

Slide on Slope


Nature-themed Playground Elements


Climbing wall on Slope

PUBLIC ART

Installations The Riverfront design itself is sculptural in form. Opportunities for additional public art are beneath the 2nd and 3rd Street Bridges and throughout the west bank.


Sculptural Element Beneath Bridge

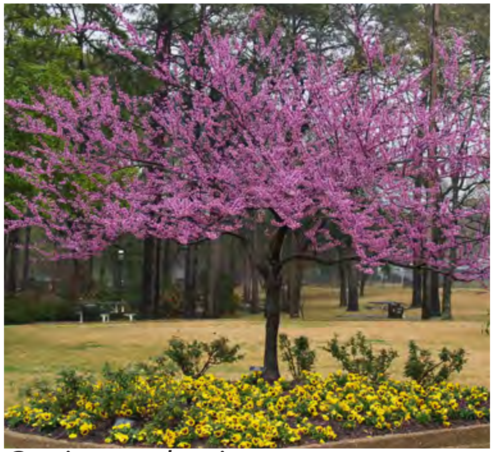

Sculptural Element Beneath Bridge


Nature-themed Public Art

■PLANTING

The plant palette for the Columbus Riverfront will be selected from species that are native to the ecoregion (Pre-Wisconsinan Drift Plains) and well suited for riverbanks and areas prone to flooding.

TREES


Cercis canadensis
Eastern Redbud


Cornus florida
Flowering Dogwood


Cornus racemosa
Grey Dogwood


Prunus americana
American Plum


Prunus Virginiana
Bitter-Berry

Liquidambar styraciflua
Sweetgum


Nyssa sylvatica
Black Gum


Quercus macrocarpa
Bur Oak

SHRUBS

Cephalanthus occidentalis
Buttonbush

Cornus stolonifera
Redosier Dogwood

Ilex verticillata
Winterberry Holly

Myrica pennsylvanica
Northern Bayberry

Physocarpus opulifolius
Ninebark

Rhus glabra
Smooth Sumac

Sambucus canadensis
American Black Elderberry

Viburnum dentatum
Arrowwood Viburnum

Viburnum trilobum
American Cranberrybush Viburnum

GRASSES & PERENNIALS


Carex stricta
Tussock Sedge


Carex vulpinoidea
Brown Fox Sedge


Juncus effuses
Soft Rush


Sorghastrum nutans
Indian Grass


Panicum virgatum
Switchgrass


Iris virginica
Blue Flag Iris


Iris cristata
Dwarf Crested Iris

Austin

Chicago

Indianapolis

Naperville

hitchcockdesigngroup.com

Planning
Landscape Architecture

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Columbus Riverfront Concept Appendix

TABLE OF CONTENTS

Appendix A
Market Study by Market & Feasibility Advisors, LLC

Market & Feasibility Advisors

Final Report

Riverfront Redevelopment
City of Columbus, Indiana

Submitted to:

Hitchcock Design Group

Submitted by:

Market & Feasibility Advisors, LLC

Thursday, December 21, 2017

MFA Project Number: 608

55 East Monroe Street, Suite 3800
Chicago IL 60603
312.212.4451 www.mfallc.com
Chicago Austin

Table of Contents

Opportunity Analysis

Demographics

Key Findings

- The population in Columbus is growing at higher level than the County, State and the US overall.
- The household size in increasing that is against the trend of smaller households, implying a higher number of families with children
- Young population with a median age of 38.8 in 2016
- The age bracket of age 18 and younger is growing which is against the trend of smaller communities in rural areas around the country
- The senior population (65+ years) is growing as well staying in line with the overall national trend.
- While the residential population is still small there is a large presence of a daytime working population (9,400) within a 15 minute walking time from the project site. Roughly 50% of the daytime working population with in 15 minute walking distance works in manufacturing.

Opportunities

- Family orientated activities – adventure playground, seasonal water feature, educational trails such as nature, and history trails
- Capturing the day time working population - lunch break or after work – making the site easy accessible, programming events and activities (fitness trail, fairs, markets, etc.)
- Engaging the senior population with exercise walking trails, bird watching and providing easy and secure access
- Younger population is attracted to non-conventional activities, this would open up opportunities such as mountain biking, bouldering, zip lining, kayaking, cameoing, river surfing and boarding and paintball for example. It would also help to achieve the goal to help retain and attract young talent and young downtown residents. This could also create a destination for those non-traditional activities that can draw additional participants/visitation to Columbus since there are - to our current knowledge - no comparable sites in the region that offers those kind of activities.
- Expand and connect the existing trail system to achieve and provide easy access

Activities

Key Findings

- The local population dines out often, the index shows a participation that is well above the national average
- Activities that have a participation at or above the national average are biking, boating canoeing/kayaking, fishing, swimming, walking for exercise, birdwatching and attending a country music performance.
- Activities with highest participation in numbers of the population are exercise walking, running/jogging. swimming, biking and fishing

Opportunities

- There is enough support and demand in the market place to support another restaurant along the riverfront. This can be done without competing directly with the existing brewery by choosing a different theme, cuisine or product.
- Based on participation preference there is demand for trails – running, maybe some cross country running, biking – including off road mountain biking and other trail related activities such as running/jogging and exercise walking
- While swimming in the river might not be advisable, access and interaction with the river should be taken in consideration

- Although lower in absolute numbers, participation in kayaking and canoeing are above the national average showing demand potential for this activity. Opportunities could be in a landing/launch some sort of white water features and a kayak and canoe rental business.

Tourism

Key Findings

- Bartholomew County has a higher overnight visitor percentage compared to the State of Indiana
- Visitors to Columbus engage in dining, shopping, attending sports events and outdoor recreation. In all four categories the participation is higher compared to the State of Indiana
- The length of stay and the visitor party size in Bartholomew County is longer/larger compared to the state of Indiana
- Indiana attracts a higher percentage of young visitors (18-34 years) and more families with young children compared to other states and destinations in the US

Opportunities

- With dining being the number one activity implies that there is demand for a restaurant development at the riverfront
- Outdoor recreation includes biking, hiking, adventure sports, nature/eco-travel, camping, visiting State and National parks. This creates opportunities for trails, ropes courses, and some non-traditional sports as mentioned before.
- Visitors staying longer in Bartholomew County compared to the State of Indiana, which creates demand for activities and entertainment.
- Visitors to Indiana are young and bring their children which implies a demand for family orientated activities – such as an adventure playground.

Issues

- Access – the site, especially across the river from downtown is secluded – a large median between a busy highway
- Landfill - if proven correct, the site is covered with a layer of (only) two feet of clay that cannot be penetrated thus limiting any structural development.
- Frequent flooding of the lower part of the site
- Disconnect between downtown and the riverfront
- Currently there is only a very small resident population in downtown.
- Most hotels are located along the interstate. With the potential expansion and improvement of the road system through the new railroad crossing visitors that are coming to the city will drive by the site on the way to and from their hotels.

Level of Development

MFA sees three level of development for this site:

Minimal – basic trails, on both sides that connect the existing trail system and don't require a lot maintenance that can be easily integrated into the City's Parks and Recreational department. This would mainly cater to the local population.

Medium – an adventure playground, a variety of trails, with varying difficulties, separating activities. Fitness trails, history trails, changing arts trails, cross country running, and mountain biking would be examples for that. This level would also include water access on both sides and a potential reuse of the dam parking and hospitality on the larger portion across the river from downtown. This still could be managed and maintained by the City's Parks and Recreational department. The target market for this level is the local population and parts of the tourism/sports tourism market.

High - this would require to bring in private operators. Taking all features of the medium level of development and adding for example a ropes course to the activity mix, (seasonal) concessions, an amphitheater, a new pedestrian bridge connecting both sides, adding white water channels to the rives at the dam location, creating a gateway for the downtown and the City of Columbus. This could have a regional draw and besides catering to the local population could increase day and overnight visitation.

Project Site

Market Area Demographics

Demographic Summary

Table 1.: Demographic Summary Market Area 2016		
Indicator	Market Area	
	City of Columbus	Bartholomew County
Population 2016	48,480	82,773
Households 2016	19,311	31,805
Families 2016	12,412	21,949
Average Household Size 2016	2.47	2.57
Owner Occupied Housing Units 2016	11,814	22,204
Renter Occupied Housing Units 2016	7,497	9,601
Median Age 2016	38.8	39.2
Population Age 21 and above 2016	35,172	60,008
Population Annual Growth 2016-2021	1.42%	1.27%
Households Annual Growth 2016-2021	1.33%	1.19%
Families Annual Growth 2016-2021	1.25%	1.09%
Owner HHs Annual Growth 2016-2021	1.38%	1.18%
Median Household Income Annual Growth 2016-2021	2.44%	2.52%
All Households with Children 2010	5,757	10,332
Median Household Income 2016	$52,070	$54,122
Average Household Income 2016	$71,451	$71,409
Per Capita Income 2016	$28,847	$27,699
Median Disposable Income 2016	$42,208	$44,129
Average Disposable Income 2016	$54,512	$54,814
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021, MFA		

Table 2.: Largest MSAs within 200 Miles				
Metropolitan Statistical Area (MSA)	Population			Distance (Miles)
	2010	2015	Change	
Bloomington, IN MSA	159,549	165,577	3.78%	36
Indianapolis-Carmel-Anderson, IN MSA	1,887,877	1,988,817	5.35%	46
Louisville/Jefferson County, KY-IN MSA	1,235,708	1,278,413	3.46%	72
Muncie, IN MSA	117,671	116,852	−0.70%	92
Cincinnati, OH-KY-IN MSA	2,114,580	2,157,719	2.04%	93
Terre Haute, IN MSA	172,425	171,019	−0.82%	97
Dayton, OH MSA	799,232	800,909	0.21%	130
Lexington-Fayette, KY MSA	472,099	500,535	6.02%	130
Fort Wayne, IN MSA	416,257	429,820	3.26%	158
Evansville, IN-KY MSA	311,552	315,693	1.33%	159
Champaign-Urbana, IL MSA	231,891	238,984	3.06%	169
South Bend-Mishawaka, IN-MI MSA	319,224	320,098	0.27%	188
Columbus, OH MSA	1,901,974	2,021,632	6.29%	189
Chicago-Naperville-Elgin, IL-IN-WI MSA	9,461,105	9,551,031	0.95%	229
Source: U.S. Bureau of the Census				

Table 3. Market Area Annual Growth Rate Comparison				
Indicator	**City**	**County**	**State**	**National**
Population Annual Growth 2016-2021	1.42%	1.27%	0.57%	0.84%
Households Annual Growth 2016-2021	1.33%	1.19%	0.55%	0.79%
Families Annual Growth 2016-2021	1.25%	1.09%	0.46%	0.72%
Owner HHs Annual Growth 2016-2021	1.38%	1.18%	0.55%	0.73%
Median Household Income Annual Growth 2016-2021	2.44%	2.52%	2.29%	1.89%
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021				

City of Columbus, Indiana

Demographics

Table 4.: City of Columbus, Indiana			
Year	**2010**	**2016**	**2021**
Population	44,066	48,480	52,014
Households	17,786	19,311	20,631
Families	11,505	12,412	13,208
Average Household Size	2.43	2.47	2.48
Age 7+	39,705	43,997	47,306
Age <18	11,103	11,615	12,437
Age 18+	32,963	36,863	39,579
Age 21+	31,409	35,172	37,801
Age 65+	6,352	7,943	9,369
Median Age	37.1	38.8	39.5
Age 7+ Percent of Total Population	90.1%	90.8%	90.9%
Age <18 Percent of Total Population	25.2%	24.0%	23.9%
Age 18+ Percent of Total Population	74.8%	76.0%	76.1%
Age 21+ Percent of Total Population	71.3%	72.5%	72.7%
Age 65+ Percent of Total Population	14.4%	16.4%	18.0%
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021, MFA			

Household Income

Table 5. City of Columbus, Indiana Household Income – Income Brackets						
Income Brackets	**Households Income**				**Disposable Income**	
	2016		**2021**		**2016**	
<$15,000 -$49,999	9,224	47.9%	8,510	41.2%	11,033	57.1%
$50,000 - $99,999	5,668	29.4%	6,564	31.8%	6,216	32.2%
$100,000>	4,419	22.9%	5,556	27.0%	2,063	10.7%
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021						

Table 6. City of Columbus, Indiana Household Income		
Year	**2016**	**2021**
Median Household Income	$52,070	$58,752
Average Household Income	$71,451	$78,602
Per Capita Income	$28,847	$31,547
Median Disposable Income	$42,208	
Average Disposable Income	$54,512	
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021		

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City of Columbus. Indiana

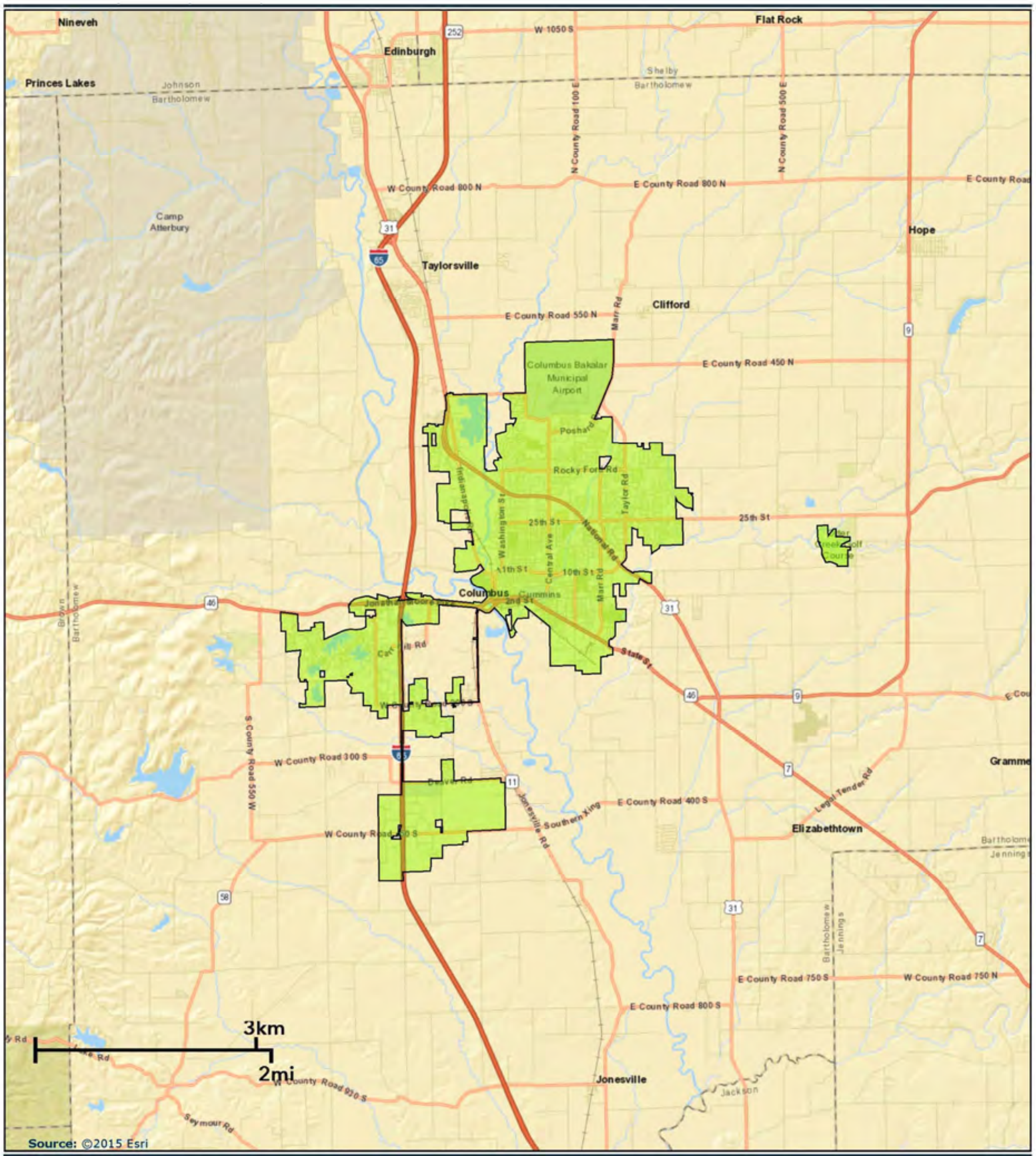

Table 7. Daytime Population By Walk Time from the Project Site			
Distance	**5 Minutes**	**10 Minutes**	**15 Minutes**
2016 Total Daytime Population	173	3,028	9,534
Workers	173	3,003	9,384
Residents	0	25	150
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021			

Recreational Budget Spending

Table 8.: City of Columbus, Indiana Recreational Annual Spending by Household			
Category	**Total**	**Average Amount Spent**	**Spending Potential Index**
Entertainment/Recreation Fees and Admissions	**$9,969,217**	**$516.25**	**90**
Tickets to Theatre/Operas/Concerts	$917,568	$47.52	90
Tickets to Movies/Museums/Parks	$1,135,401	$58.80	88
Admission to Sporting Events, excl.Trips	$971,343	$50.30	94
Fees for Participant Sports, excl.Trips	$1,576,487	$81.64	91
Fees for Recreational Lessons	$2,069,629	$107.17	87
Membership Fees for Social/Recreation/Civic Clubs	$3,298,789	$170.82	89
Source: 2013 and 2014 Consumer Expenditure Surveys, Bureau of Labor Statistics, MFA			

Consumer spending shows the amount spent on a variety of goods and services by households that reside in the area. Expenditures are shown by broad budget categories that are not mutually exclusive. Consumer spending does not equal business revenue. Total and Average Amount Spent per Household represent annual figures. The Spending Potential Index (SPI) represents the amount spent in the area relative to a national average of 100.

Restaurant Market Potential

Table 9.: City of Columbus, Indiana			
Consumer Behavior	**Adults/HH**	**Percent**	**MPI**
Went to fast food/drive-in restaurant in last 6 months	**33,579**	**91.1%**	**101**
Spent at fast food/drive-in last 6 months: <$11	1,541	4.2%	98
Spent in 6 months: $11-$20	2,882	7.8%	106
Spent in 6 months: $21-$40	4,448	12.1%	102
Spent in 6 months: $41-$50	2,875	7.8%	103
Spent in 6 months: $51-$100	6,206	16.8%	101
Spent in 6 months: $101-$200	4,700	12.7%	106
Spent in 6 months: $201+	4,698	12.7%	105
Went to family restaurant/steak house in last 6 months	**28,323**	**76.8%**	**103**
Spent in last 6 months: <$31	2,834	7.7%	108
Spent in 6 months: $31-50	3,103	8.4%	102
Spent in 6 months: $51-100	5,976	16.2%	107
Spent in 6 months: $101-200	4,600	12.5%	105
Spent in 6 months: $201-300	2,259	6.1%	113
Spent in 6 months: $301+	2,839	7.7%	105
Went to fine dining restaurant last month	**3,941**	**10.7%**	**95**
Spent in 6 months: <$51	692	1.9%	92
Spent in last 6 months: $51-$100	1,453	3.9%	107
Spent in 6 months: $101-$200	1,286	3.5%	94
Spent in 6 months: $201+	1,268	3.4%	87
Source: GfK MRI, MFA			

An MPI (Market Potential Index) measures the relative likelihood of the adults or households in the specified trade area to exhibit certain consumer behavior or purchasing patterns compared to the U.S. An MPI of 100 represents the U.S. average

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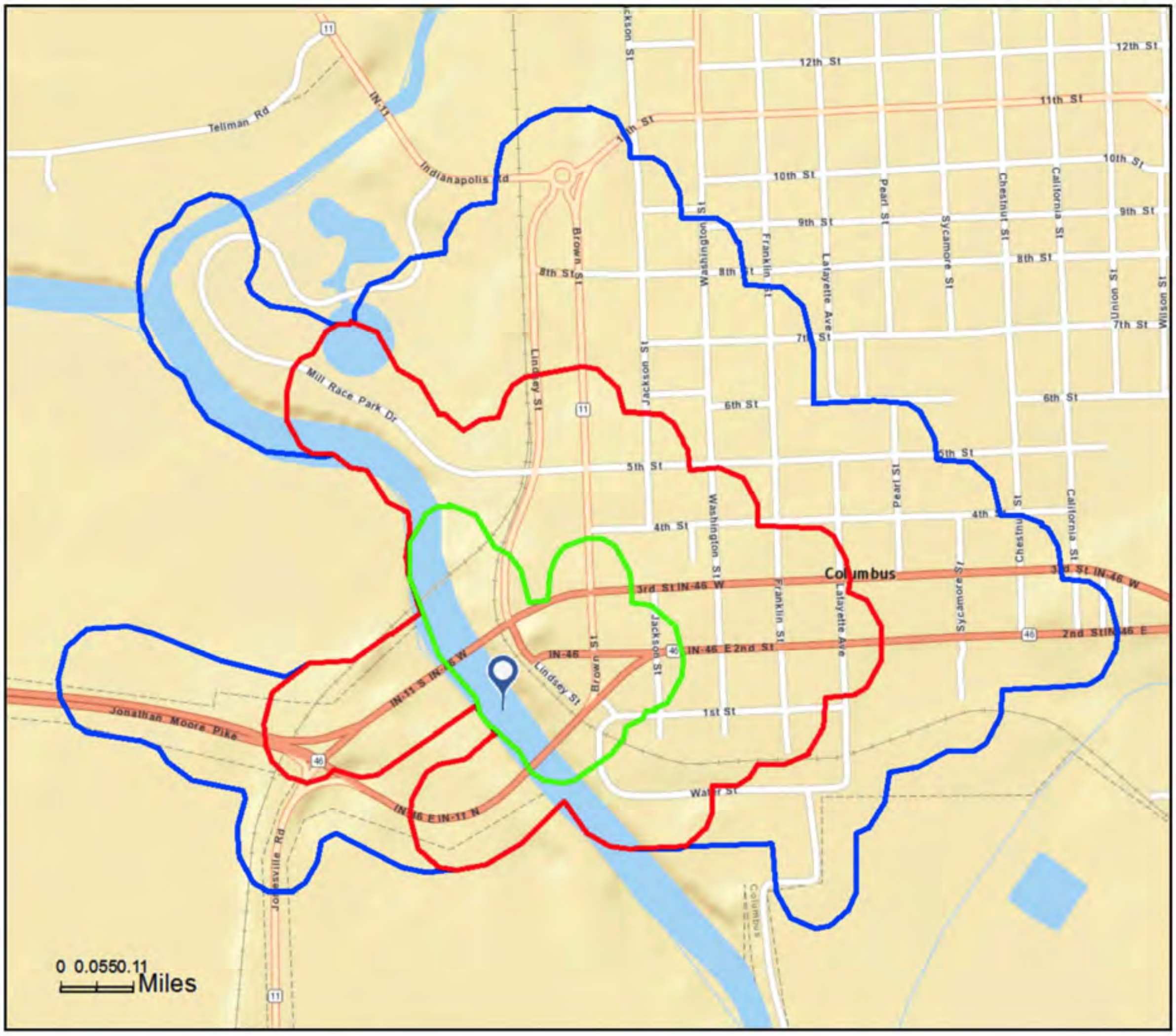
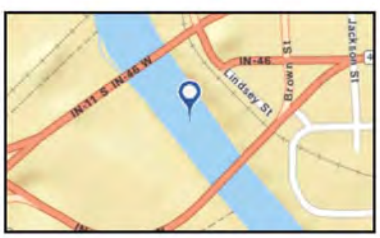
Site Map

148 Lindsey St, Columbus, Indiana, 47201
Walk Time: 5, 10, 15 minute radii

Prepared by Esri
Latitude: 39.19927
Longitude: -85.92569

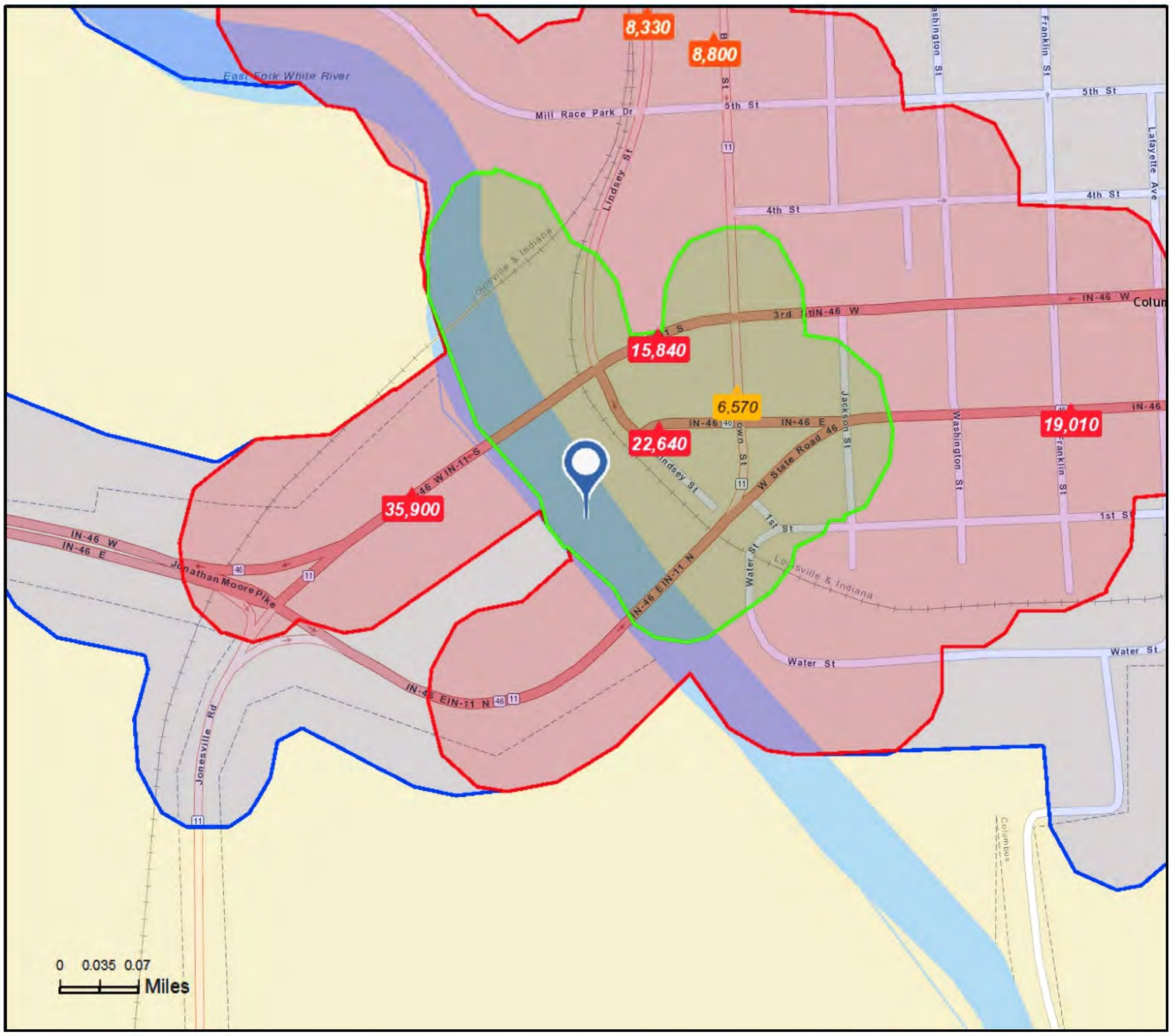


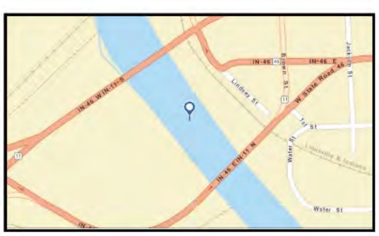


Traffic Count Map - Close Up

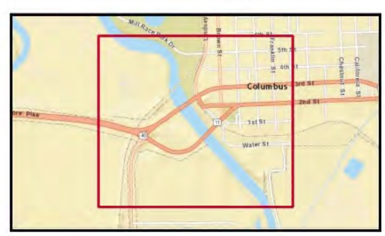
148 Lindsey St, Columbus, Indiana, 47201
Walk Time: 5, 10, 15 minute radii

Prepared by Esri
Latitude: 39.19927
Longitude: -85.92569





Average Daily Traffic Volume
- ▲ **Up to 6,000 vehicles per day**
- ▲ **6,001 - 15,000**
- ▲ **15,001 - 30,000**
- ▲ **30,001 - 50,000**
- ▲ **50,001 - 100,000**
- ▲ **More than 100,000 per day**



Bartholomew County, Indiana

Demographics

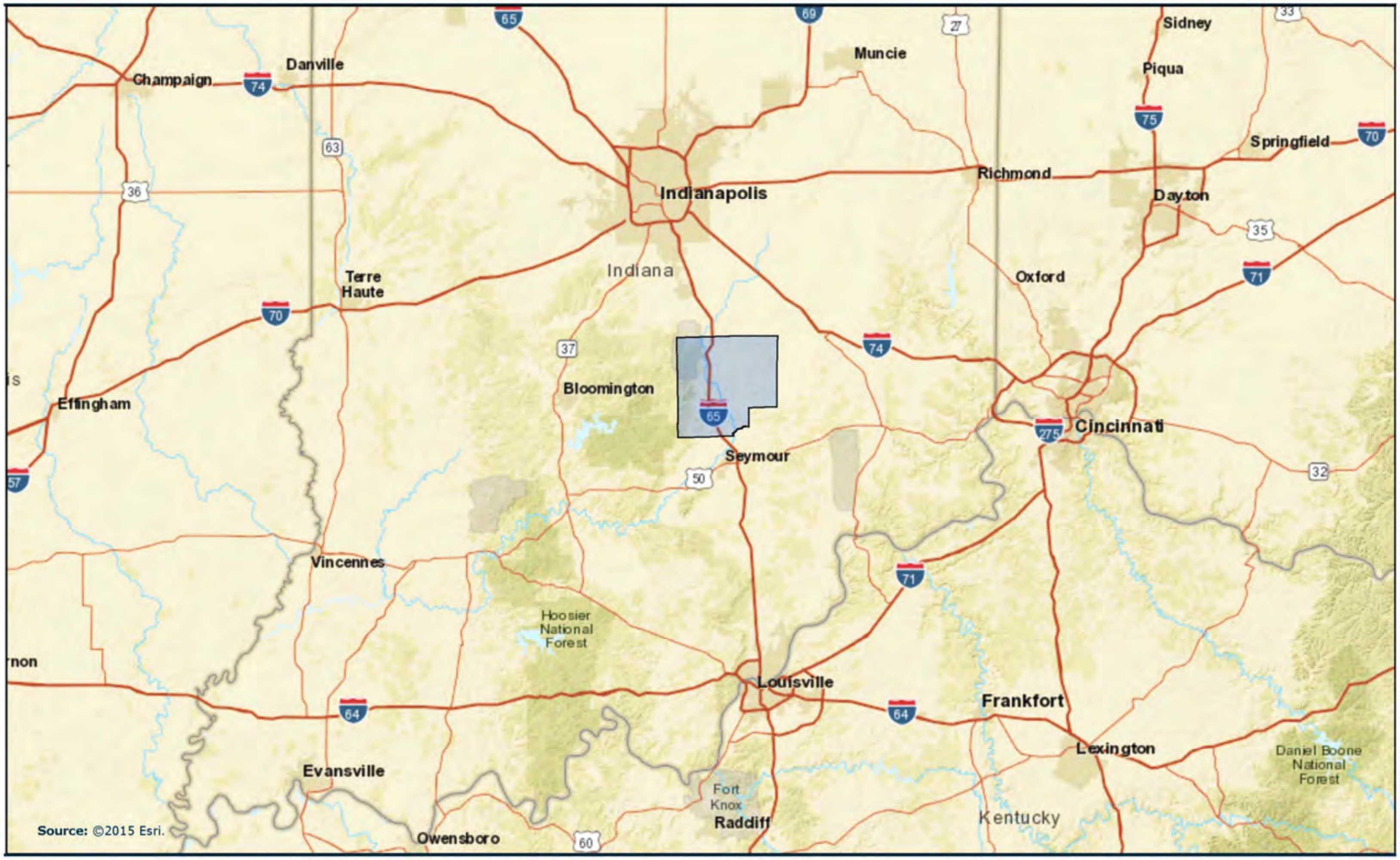
Table 10.: Bartholomew County, Indiana			
Year	**2010**	**2016**	**2021**
Population	76,794	82,773	88,156
Households	29,860	31,805	33,736
Families	20,788	21,949	23,176
Average Household Size	2.53	2.57	2.58
Age 7+	69,398	75,193	80,338
Age <18	19,360	19,823	21,007
Age 18+	57,434	62,950	67,149
Age 21+	54,715	60,008	64,097
Age 65+	10,731	13,183	15,761
Median Age	38.0	39.2	40.0
Age 7+ Percent of Total Population	90.4%	90.8%	91.1%
Age <18 Percent of Total Population	25.2%	23.9%	23.8%
Age 18+ Percent of Total Population	74.8%	76.1%	76.2%
Age 21+ Percent of Total Population	71.2%	72.5%	72.7%
Age 65+ Percent of Total Population	14.0%	15.9%	17.9%
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021, MFA			

Household Income

Table 11. Bartholomew County, Indiana Household Income – Income Brackets						
Income Brackets	**Households Income**				**Disposable Income**	
	2016		**2021**		**2016**	
<$15,000 -$49,999	14,374	45.1	12,798	37.9%	17,699	55.6%
$50,000 - $99,999	10,500	33.0%	12,158	36.0%	11,015	34.6%
$100,000>	6,931	21.8%	8,780	26.0%	3,091	9.8%
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021						

Table 12. Bartholomew County, Indiana Household Income		
Year	**2016**	**2021**
Median Household Income	$54,122	$61,284
Average Household Income	$71,409	$78,915
Per Capita Income	$27,699	$30,444
Median Disposable Income	$44,129	
Average Disposable Income	$54,814	
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021		

Bartholomew County, Indiana



Recreational Budget Spending

Table 13.: Bartholomew County, Indiana Recreational Annual Spending by Household			
Category	**Total**	**Average Amount Spent**	**Spending Potential Index**
Entertainment/Recreation Fees and Admissions	**$16,138,986**	**$507.44**	**88**
Tickets to Theatre/Operas/Concerts	$1,481,717	$46.59	88
Tickets to Movies/Museums/Parks	$1,829,891	$57.53	87
Admission to Sporting Events, excl.Trips	$1,581,560	$49.73	93
Fees for Participant Sports, excl.Trips	$2,559,998	$80.49	90
Fees for Recreational Lessons	$3,345,756	$105.20	85
Membership Fees for Social/Recreation/Civic Clubs	$5,340,064	$167.90	88
Source: 2013 and 2014 Consumer Expenditure Surveys, Bureau of Labor Statistics, MFA			

Consumer spending shows the amount spent on a variety of goods and services by households that reside in the area. Expenditures are shown by broad budget categories that are not mutually exclusive. Consumer spending does not equal business revenue. Total and Average Amount Spent per Household represent annual figures. The Spending Potential Index (SPI) represents the amount spent in the area relative to a national average of 100.

Restaurant Market Potential

Table 14.: Bartholomew County, Indiana			
Consumer Behavior	**Adults/HH**	**Percent**	**MPI**
Went to fast food/drive-in restaurant in last 6 months	**57,597**	**91.5%**	**102**
Spent at fast food/drive-in last 6 months: <$11	2,841	4.5%	105
Spent in 6 months: $11-$20	5,164	8.2%	111
Spent in 6 months: $21-$40	7,625	12.1%	103
Spent in 6 months: $41-$50	4,901	7.8%	103
Spent in 6 months: $51-$100	10,684	17.0%	102
Spent in 6 months: $101-$200	7,748	12.3%	102
Spent in 6 months: $201+	8,203	13.0%	107
Went to family restaurant/steak house in last 6 months	**48,308**	**76.7%**	**103**
Spent in last 6 months: <$31	4,996	7.9%	112
Spent in 6 months: $31-50	5,465	8.7%	105
Spent in 6 months: $51-100	9,937	15.8%	105
Spent in 6 months: $101-200	7,911	12.6%	105
Spent in 6 months: $201-300	3,857	6.1%	113
Spent in 6 months: $301+	4,569	7.3%	99
Went to fine dining restaurant last month	**6,217**	**9.9%**	**88**
Spent in 6 months: <$51	1,132	1.8%	88
Spent in last 6 months: $51-$100	2,296	3.6%	99
Spent in 6 months: $101-$200	2,052	3.3%	88
Spent in 6 months: $201+	1,869	3.0%	75
Source: GfK MRI, MFA			

An MPI (Market Potential Index) measures the relative likelihood of the adults or households in the specified trade area to exhibit certain consumer behavior or purchasing patterns compared to the U.S. An MPI of 100 represents the U.S. average

Sport & Leisure Activities

The Demand Potential by Propensity to Participate is based on the socio-economic characteristics of households in the market area and their tendencies to use various products and services. While this approach estimates sports activity participation, it also estimates potential event (e.g. competition, concert) attendance. However, it covers adults only – age 18 and above.

Table 15. Market Area Sport, Leisure & Entertainment Participation Potential for Selected Activities

Participation	Market Area					
	City of Columbus, Indiana			Bartholomew County, Indiana		
Sport Activities	**HH/Adults**	**Rate**	**MPI**	**HH/Adults**	**Rate**	**MPI**
Bicycling (road) in last 12 months	3,585	9.7%	98	6,111	9.7%	98
Boating (power) in last 12 months	2,138	5.8%	109	3,849	6.1%	115
Canoeing/kayaking in last 12 months	2,141	5.8%	104	3,732	5.9%	106
Fishing (fresh water) in last 12 months	5,343	14.5%	117	10,196	16.2%	131
Played Frisbee in last 12 months	1,566	4.2%	99	2,560	4.1%	95
Jogging/running in last 12 months	4,401	11.9%	90	6,984	11.1%	84
Swimming in last 12 months	5,587	15.2%	98	9,861	15.7%	101
Walking for exercise in last 12 months	10,087	27.4%	102	16,905	26.9%	100
Leisure/Entertainment Activities	**HH/Adults**	**Rate**	**MPI**	**HH/Adults**	**Rate**	**MPI**
Did birdwatching in last 12 months	1,645	4.5%	103	3,221	5.1%	118
Dined out in last 12 months	17,192	46.6%	104	29,422	46.7%	104
Went to a movie in last 6 months	21,489	58.3%	98	35,650	56.6%	95
Went to a movie: once a month	3,433	9.3%	92	5,370	8.5%	84
Attended classical music/opera performance/12 months	1,253	3.4%	81	1,975	3.1%	75
Attended country music performance in last 12 months	2,349	6.4%	113	4,180	6.6%	117
Attended rock music performance in last 12 months	3,667	9.9%	105	5,757	9.1%	96
Went to live theater in last 12 months	4,492	12.2%	94	7,366	11.7%	90

Source: GfK MRI, MFA

An MPI (Market Potential Index) measures the relative likelihood of the adults or households in the specified trade area to exhibit certain consumer behavior or purchasing patterns compared to the U.S. An MPI of 100 represents the U.S. average.

Sports Participation

This approach measures the number of individuals seven years of age or older who participated in each of a number of different sports in the previous year, based on a questionnaire.

The *National Sporting Goods Association* (NSGA) publishes annual surveys on sports participation in the United States. Participation rates for selected activities are available by region, age group (age 7+), frequency, gender and other variables. These rates have been applied to the market area demographics to estimate the demand potential for the development.

Participation Potential by Market Area

The first step is to apply the participation rates to the market area population. NSGA provides participation rates for age groups 7 years and older. The assumption is that at a younger age the shift between different sports activities is too great to capture any useful participation rates.

The following tables show the detailed participation potential (demand) in selected sports based on demographics and participation rates for several key sports/activities that could be part on a fully developed site

City of Columbus, Indiana

Table 16. City of Columbus 2016 Population by NSGA Age Group	
Total	**43,997**
7-11	3,343
12-17	3,791
18-24	3,949
25-34	6,317
35-44	6,310
45-54	6,335
55-64	6,009
65-74	4,330
75+	3,613
Sources: ESRI, NSGA, MFA	

Table 17. City of Columbus 2016 Participation by Sport/Activity		
Activity	**Participation Rate**	**Participation Number**
Bicycle Riding	15.0%	6,600
Boating (Motor/Power)	6.5%	2,860
Canoeing	3.7%	1,628
Exercise Walking	36.7%	16,147
Fishing (Fresh Water)	13.2%	5,808
In-line Roller Skating	2.2%	968
Kayaking	3.0%	1,320
Running/Jogging	15.5%	6,820
Skateboarding	1.7%	748
Swimming	15.1%	6,644
Sources: ESRI, NSGA, MFA		

The following two tables break participation down by age group. Fields marked green show which age group has the highest number of participants in each of the selected sports/activities

Table 18. City of Columbus Participation by Age Group										
Age Group	Bicycle Riding	Boating (Motor/Power)	Canoeing	Exercise Walking	Fishing (Fresh Water)	In-line Roller Skating	Kayaking	Running/ Jogging	Skateboarding	Swimming
7-11	16.0%	7.4%	8.5%	2.8%	7.9%	6.6%	7.4%	6.3%	22.4%	16.0%
12-17	12.4%	9.8%	11.8%	4.3%	10.7%	3.8%	10.8%	12.6%	27.3%	13.4%
18-24	9.6%	10.7%	11.4%	7.1%	8.2%	1.3%	11.6%	17.5%	16.8%	9.2%
25-34	13.2%	16.0%	19.8%	14.5%	16.1%	1.5%	18.6%	24.5%	17.5%	13.6%
35-44	14.9%	13.4%	17.9%	14.4%	15.4%	1.5%	16.9%	18.4%	10.9%	14.7%
45-54	13.5%	18.8%	15.6%	17.8%	17.8%	1.0%	17.3%	12.3%	3.6%	13.1%
55-64	12.0%	13.0%	11.3%	18.3%	13.1%	0.7%	11.5%	5.8%	1.5%	10.3%
65-74	6.1%	7.9%	3.3%	12.9%	7.4%	0.1%	4.8%	1.8%	0.0%	6.5%
75+	2.4%	3.0%	0.3%	7.8%	3.5%	0.1%	1.0%	0.8%	0.0%	3.0%
Sources: ESRI, NSGA, MFA										

Table 19. City of Columbus 2016 Participants by Age Group										
Age Group	Bicycle Riding	Boating (Motor/Power)	Canoeing	Exercise Walking	Fishing (Fresh Water)	In-line Roller Skating	Kayaking	Running/ Jogging	Skateboarding	Swimming
7-11	1,056	212	138	452	459	64	98	430	168	120
12-17	818	280	192	694	621	37	143	859	204	100
18-24	634	306	186	1,146	476	13	153	1,193	126	69
25-34	871	458	322	2,341	935	15	246	1,671	131	102
35-44	983	383	291	2,325	894	15	223	1,255	82	110
45-54	891	538	254	2,874	1,034	10	228	839	27	98
55-64	792	372	184	2,955	761	7	152	396	11	77
65-74	403	226	54	2,083	430	1	63	123	0	49
75+	158	86	5	1,259	203	1	13	55	0	22
Sources: ESRI, NSGA, MFA										

Frequent Participants

To estimate demand realistically, MFA estimated the number of participants with the highest participation percentage frequency for each selected sport. This shows estimates and includes participants

- who are likely to participate in a specific sport/activity over a longer period,
- who take part in competitions/events/tournaments,
- and are willing to travel longer distances to events.

Such participants represent the core market demand. The following tables show the detailed participation potential (demand) in selected sports by frequency of participation.

For the majority of team sports/activities frequent participation is defined as 50+ days of participation per year, occasional participation as 10-49 days per year and infrequent participation as 2-9 days per year

For the majority of individual sports/activities frequent participation is defined as 110+ days of participation per year, occasional participation as 25-109 days per year and infrequent participation as 6-24 days per year

Other factors that are influencing participation are cost and opportunity/accessibility. The table below shows participation by frequency and the number of participation days per year per participant – how many days a person devotes to a certain activity/sport per year

Table 20. City of Columbus Participation by Frequency and Annual Participation Days

Participation	Bicycle Riding	Boating (Motor/ Power)	Canoeing	Exercise Walking	Fishing (Fresh Water)	In-line Roller Skating	Kayaking	Running/ Jogging	Skate boarding	Swim ming
Frequent	7.6%	27.3%	18.7%	35.8%	37.1%	7.9%	18.7%	23.7%	16.3%	7.2%
Infrequent	52.2%	47.4%	57.8%	41.7%	38.1%	65.2%	43.7%	52.4%	48.0%	39.2%
Occasionally	40.1%	25.2%	23.6%	22.4%	24.8%	26.9%	37.5%	23.9%	35.7%	53.6%
Average # of Days per Participant	47	14	6	93	16	11	6	79	21	36
Median # of Days per Participant	30	10	5	75	10	10	3	50	12	20

Sources: ESRI, NSGA, MFA

For example – of all persons that participate in exercise walking, 35.8% participate frequently, 41.7% infrequent and 22.4% occasionally. On average an exercise walking participant goes out on the trails 93 times per year, the median number of participation is 75 days per year.

The following table applies the frequency rates to the participants and calculates an estimate of the total number of annual average and median participation days.

Table 21. City of Columbus 2016 Participants by Frequency and Annual Participation Days

Participation	Bicycle Riding	Boating (Motor/ Power)	Canoeing	Exercise Walking	Fishing (Fresh Water)	In-line Roller Skating	Kayak ing	Running/ Jogging	Skate boarding	Swimming
Frequent	502	781	304	5,781	2,155	76	247	1,616	122	478
Infrequent	3,445	1,356	941	6,733	2,213	631	577	3,573	359	2,604
Occasionally	2,646	721	384	3,617	1,440	260	495	1,630	267	3,561
Average # of Days of Participation	313,149	39,437	8,953	1,505,052	92,864	10,899	7,589	536,425	15,699	242,290
Median # of Days of Participation	197,987	28,598	8,139	1,211,017	58,076	9,679	3,960	340,977	8,975	132,871

Sources: ESRI, NSGA, MFA

Some activities are easier than others to do often, like basketball or exercise walking, while others require a special venue, like an ice rink or river for canoeing and kayaking. So, it's not surprising that exercise walkers or runners have a (relatively) high percentage of their participants who engage in the activity frequently. Many other activities like canoeing and kayaking, even bicycle riding have a higher percent of their participants who fall in the infrequent or occasional categories than the frequent one – most people simply don't live where it's easy to do so.

Another factor to look for in this data is what the average and median number of times people actually engage in the activities. For example, Exercise walkers average 93 outing a year and kayakers and canoers just 6. That means that being a frequent exercise walker means a lot more outs a year than being a frequent canoer or kayaker. The median number for canoers and kayakers is just 5. Median means half of all participants engage in the activity more than 5 times annually and half less. This means that mathematically, there are a lot of people who engage just once or twice a year if the average turns out to be 6 for all.

These points are relevant as we consider capacity needs. Clearly a trail system is at the top of the list, but the since demand for canoeing and kayaking is influenced by the availability of a great place to engage, then creating a great place in the Flatrock should boost demand and the numbers in the table that follows.

Bartholomew County, Indiana

MFA used the same approach to estimate demand that was used previously for the City of Columbus.

Table 22. Bartholomew County 2016 Population by NSGA Age Group	
Total	**75,193**
7-11	5,703
12-17	6,540
18-24	6,731
25-34	10,375
35-44	10,819
45-54	11,116
55-64	10,726
65-74	7,663
75+	5,520
Sources: ESRI, NSGA, MFA	

Table 23. Bartholomew County 2016 Participation by Sport/Activity		
Activity	**Participation Rate**	**Participation Number**
Bicycle Riding	15.0%	11,279
Boating (Motor/Power)	6.5%	4,888
Canoeing	3.7%	2,782
Exercise Walking	36.7%	27,596
Fishing (Fresh Water)	13.2%	9,925
In-line Roller Skating	2.2%	1,654
Kayaking	3.0%	2,256
Running/Jogging	15.5%	11,655
Skateboarding	1.7%	1,278
Swimming	15.1%	11,354
Sources: ESRI, NSGA, MFA		

Table 24. Bartholomew County Participation by Age Group										
Age Group	Bicycle Riding	Boating (Motor/Power)	Canoeing	Exercise Walking	Fishing (Fresh Water)	In-line Roller Skating	Kayaking	Running/ Jogging	Skateboarding	Swimming
7-11	16.0%	7.4%	8.5%	2.8%	7.9%	6.6%	7.4%	6.3%	22.4%	16.0%
12-17	12.4%	9.8%	11.8%	4.3%	10.7%	3.8%	10.8%	12.6%	27.3%	13.4%
18-24	9.6%	10.7%	11.4%	7.1%	8.2%	1.3%	11.6%	17.5%	16.8%	9.2%
25-34	13.2%	16.0%	19.8%	14.5%	16.1%	1.5%	18.6%	24.5%	17.5%	13.6%
35-44	14.9%	13.4%	17.9%	14.4%	15.4%	1.5%	16.9%	18.4%	10.9%	14.7%
45-54	13.5%	18.8%	15.6%	17.8%	17.8%	1.0%	17.3%	12.3%	3.6%	13.1%
55-64	12.0%	13.0%	11.3%	18.3%	13.1%	0.7%	11.5%	5.8%	1.5%	10.3%
65-74	6.1%	7.9%	3.3%	12.9%	7.4%	0.1%	4.8%	1.8%	0.0%	6.5%
75+	2.4%	3.0%	0.3%	7.8%	3.5%	0.1%	1.0%	0.8%	0.0%	3.0%
Sources: ESRI, NSGA, MFA										

Table 25. Bartholomew County 2016 Participants by Age Group										
Age Group	Bicycle Riding	Boating (Motor/Power)	Canoeing	Exercise Walking	Fishing (Fresh Water)	In-line Roller Skating	Kayaking	Running/ Jogging	Skateboarding	Swimming
7-11	1,805	362	236	773	784	96	167	734	286	1,817
12-17	1,399	479	328	1,187	1,062	91	244	1,469	349	1,521
18-24	1,083	523	317	1,959	814	190	262	2,040	215	1,045
25-34	1,489	782	551	4,001	1,598	352	420	2,855	224	1,544
35-44	1,681	655	498	3,974	1,529	280	381	2,145	139	1,669
45-54	1,523	919	434	4,912	1,767	294	390	1,434	46	1,487
55-64	1,353	635	314	5,050	1,300	217	259	676	19	1,169
65-74	688	386	92	3,560	734	99	108	210	0	738
75+	271	147	8	2,152	347	35	23	93	0	341
Sources: ESRI, NSGA, MFA										

Table 26. Bartholomew County Participation by Frequency and Annual Participation Days

Participation	Bicycle Riding	Boating (Motor/ Power)	Canoeing	Exercise Walking	Fishing (Fresh Water)	In-line Roller Skating	Kayaking	Running/ Jogging	Skate boarding	Swim ming
Frequent	7.6%	27.3%	18.7%	35.8%	37.1%	7.9%	18.7%	23.7%	16.3%	7.2%
Infrequent	52.2%	47.4%	57.8%	41.7%	38.1%	65.2%	43.7%	52.4%	48.0%	39.2%
Occasionally	40.1%	25.2%	23.6%	22.4%	24.8%	26.9%	37.5%	23.9%	35.7%	53.6%
Average # of Days per Participant	47	14	6	93	16	11	6	79	21	36
Median # of Days per Participant	30	10	5	75	10	10	3	50	12	20

Sources: ESRI, NSGA, MFA

Table 27. Bartholomew County 2016 Participants by Frequency and Annual Participation Days

Participation	Bicycle Riding	Boating (Motor/ Power)	Canoeing	Exercise Walking	Fishing (Fresh Water)	In-line Roller Skating	Kayak-ing	Running/ Jogging	Skate boarding	Swimming
Frequent	857	1,334	520	9,879	3,682	131	422	2,762	208	817
Infrequent	5,888	2,317	1,608	11,507	3,782	1,079	986	6,107	614	4,451
Occasionally	4,523	1,232	657	6,181	2,462	445	846	2,786	456	6,086
Average # of Days of Participation	535,186	67,399	15,302	2,572,207	158,708	18,627	12,971	916,776	26,831	414,086
Median # of Days of Participation	338,369	48,875	13,911	2,069,687	99,255	16,542	6,767	582,746	15,339	227,083

Sources: ESRI, NSGA, MFA

Extreme Sports (X-Sports) Introduction

During the course of this project the point was made several times that it should help to draw and retain young talent in the City of Columbus. Traditional (team) sports such as baseball, basketball and football are still in demand but participation didn't grow much over the last decade. This reflects a general shift away from the traditional team sports to individual sports. A lot of those individual activities and sports are summarized as extreme sports or X-Sports. The term "extreme" is a bit misleading, it rather describes non-traditional activities. Because those types of activities appeal to young adults – 35 years and younger – it is important to take them in consideration regarding one of the goals this project should help to achieve – to draw and retain young talent.

The activities that constitute extreme sports have been around for many decades. Southern California is generally considered the birthplace of the surf culture in the 1940's/early 1950's, BMX racing in the 1970's, and skateboarding. Australia gave us snowboarding and wakeboarding in the 1980s, although the Jacksonville, FL area also has some claim to wakeboarding.

But broadly speaking, the idea of extreme sports has been around for many years and includes rock and mountain climbing, bouldering and many other alpine activities (more recently mountain biking and BASE jumping). In typical team sports, players are governed by rules and play in teams on fields, diamonds, and courts. Extreme sports, in contrast, historically pit players against unpredictable environmental factors including weather and surface/terrain issues.

It could be argued that the rise and organization of extreme sports is due to the baby boom generation's emphasis on individuality -- from running and long distance cycling to BASE jumping. That generation and their children, who grew up in a media age, magnified and spread the popularity of these activities individually and called them sports through the 1980s and 1990s, culminating a series of competitive events like the 1978 Ironman competition, Hood River, Oregon's Gorge Games (aired on Fox Sports), X-Games and others that demonstrated that these activities and others like them could be harnessed as a group and antidote to traditional sports.

In the hands of ESPN/ABC Sports, the X-Games have accelerated the twice-yearly winter games beginning in 1997 and summer games in 1995 into a major sports event. So successful have these events been that starting in 2013 there will be 6 events across the world each year (creating more programming for the broadcast and cable networks). While ESPN/ABC, owned by Disney, is at the heart of corporate America, it has somehow kept a counter-cultural aura around these games.

2011 saw some slippage in viewership, but the 2012 Winter X Games proved more popular than ever. According to ESPN, *"Overall television rating across ESPN, ESPN2 and ABC was 0.8, representing an average of 903,000 homes, a 32 percent increase from the previous year."* The event saw massive double-digit growth across platforms such as television, smart phones apps, tablets, and online. Again, according to ESPN, *"The rating was boosted by the highest-rated and most-watched Winter X Games telecast ever on ESPN, a 1.4 on Sunday, Jan. 29." Still, for perspective, the NBA finals routinely have ratings of 10 and above.*

Despite the fact that that there are far more viewers watching on TV than in actual attendance, the X Games hosting communities still receive a significant a boost in tax revenue during the time of the event, not to mention the global exposure through TV and digital media broadcasts that help secure future visitation.

Other events, many televised, and with a broad array of sponsorships, have also prospered in the last decade - as measured by both viewership rating and number of sports participants across the country have continued to grow. This is supported by parks and recreation agencies creating thousands of skate parks and BMX facilities across the country. The popularity of snowboarding has overtaken centuries of skiing in some areas. Upscale ski resorts, seizing on its popularity, have permitted snowboarding on their slopes and have steadily increased its presence in recent years.

Are extreme sports a fad? A reasonable question a decade ago before they demonstrated their appeal, but doubt in the future of skateboarding and other sports is fading after more than 30 years of these activities. They draw a more youthful demographic than most team sports and participants with more of an independent performance ethic than in traditional sports.

With young, influential participants, action sports are a sought-after vehicle for marketers targeting American teens. As action sports have grown from niche to mainstream, participants have increasingly come from higher income homes, thus offering a larger spending potential for participation, events and retail.

X Sports appeal to men and women from the ages of 12-to-34. This age group is the prime participation age bracket, viewing audience for television, and a prime target for most advertisers.

Extreme and adventure sports are listed below – activities that could be a part of this project are marked in green:

Board Sports

- Bodyboarding
- Dirtsurfing
- Flowboarding
- Kitesurfing
- Longboarding
- Mountainboarding
- **River surfing**
- **River boarding**
- Sandboarding
- **Skateboarding**
- Skimboarding
- Skysurfing
- Snowboarding
- Snowskate
- Street luging
- Surfing
- **Wakeboarding**
- Windsurfing

Motor Sports

- Drifting
- GoKarts
- Karting
- Motocross
- Rallying
- Snocross
- Supercross

Water Sports

- Coasteering
- Free-diving
- Jet Skiing
- Scuba diving
- **Waterskiing**
- **Whitewater canoeing**
- **Whitewater kayaking**
- **Whitewater rafting**

Mountaineering

- **Bouldering**
- Canyoning
- Free solo climbing
- Ice climbing
- **Rock climbing**
- Skyrunning

Free Fall

- BASE jumping
- Bungee jumping
- Cliff diving
- Parachuting (skydiving)
- Wingsuit flying

Flying

- Air racing
- Gliding
- Hang gliding
- Paragliding
- Powered paragliding
- Speed flying

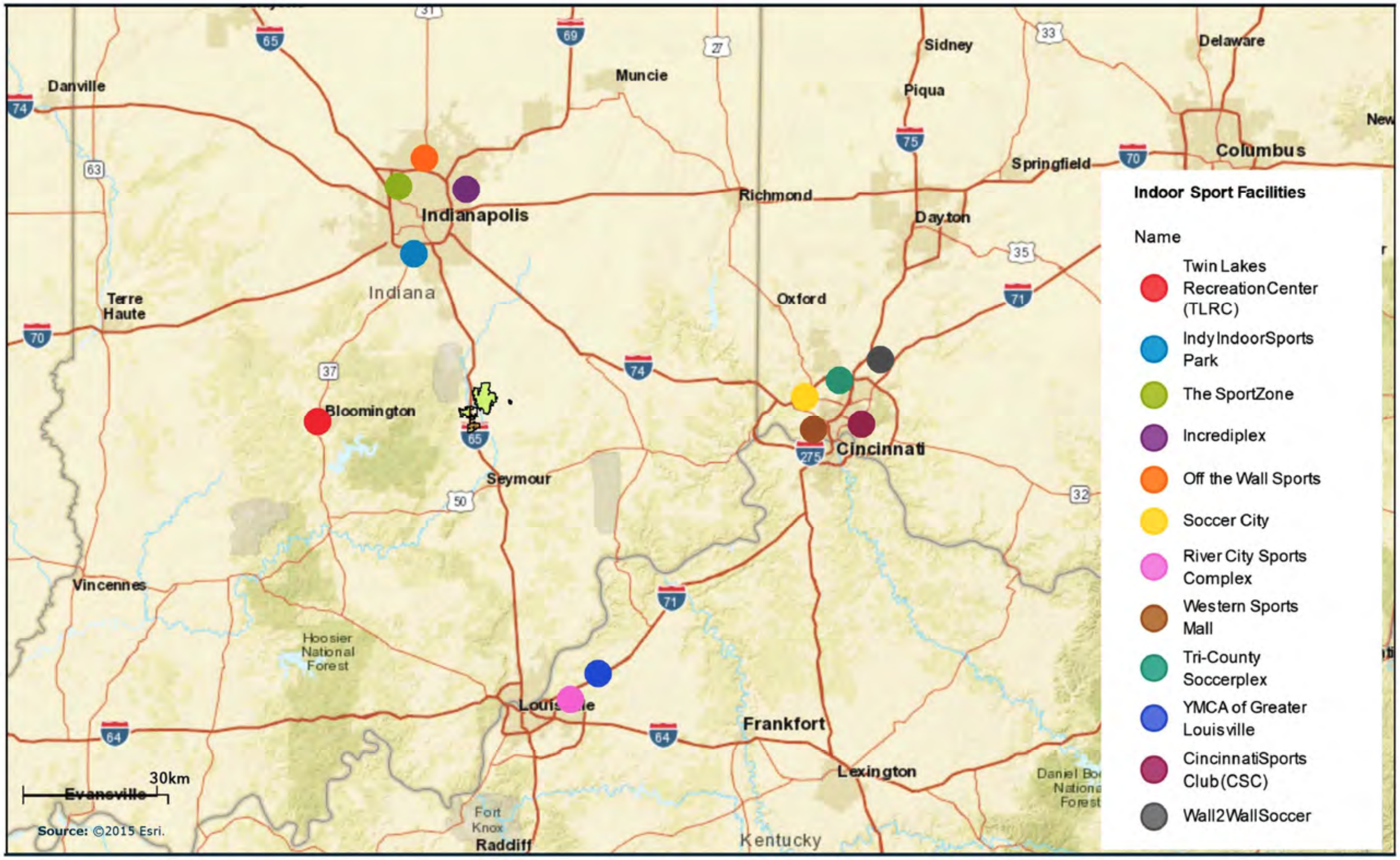
Other

- **BMX**
- Caving
- Extreme skiing
- Freestyle scootering
- Freestyle skiing
- Inline skating
- **Mountain biking**
- **Orienteering**
- **Paintball**
- Parkour
- Powerbocking
- Slacklining
- Stunt pogoing
- **Zip-lining**
- CycleCross

mfa

City of Columbus, Indiana

Regional Indoor Sport Facilities



Indiana Tourism

Summary

- **Volume:** In 2015, approximately 77 million person trips were taken in Indiana. Overnight or person-stays[1] accounted for 30 million, daytrips accounted for 47.2 million of the 77 million total.

- **Daytrips** reached 47.2 million in 2015, an increase of more than 6% from 2014. Daytrips are measured as anyone who has traveled more than 50 miles one way to visit an Indiana destination but has not stayed overnight. They include both out-of-state and in-state visitors.

- **Overnigh**t visits increased by 2.6% in 2015 to 30 million person-stays reaching pre-recession levels.

- **Travel Party Size**: The average travel party size for all Indiana visitor parties was 2.2.

- **Length of Stay**: The average length of trips all Indiana visitors was 1.9 days

- **Spending:** In 2015, the expenditure by visitors to Indiana was $11.5 billion. The average trip expenditure per person was $150 per visit.

- **Seasonality**: The summer (June - August) was the most popular season for travel to Indiana, with 32% of all visitors. Fall (September - November) followed with nearly 25% of the annual visitors. The Spring (March-May) season accounted for 23% of visitors and winter (December-February) saw 19% of visitors in 2015. June and August were the single largest month for travel to the state with 12% percent, followed by July and December (10%) and May and November (9%).

- **Origin:** The top states of origin of all domestic visitors to Indiana were:

- Indiana (46.7%)
- Ohio (11.1%)
- Michigan (10.0%)
- Illinois (6.7%)
- Additional from KY, GA, MO, TN, SC

There are a few but important tourism characteristics that stand out in Indiana that are significant to this project.

Activities
Based on National activity participation levels, Indiana is a destination for watching sports (tournament tourism) and for participating in outdoor activities/sports (biking, hiking, adventure sports, nature/eco-travel, camping, visiting State and National parks).

Compared to the U.S. index of participation levels in activities, watching sports is the leading activity that puts Indiana overnight leisure (ONL) visitors ahead of the visitor to a typical U.S. overnight leisure visitors destination'

- Watching Sports occurs in Indiana at 80% above the typical U.S. average.
- Parties that visit to watch sports spend more for at their trip destinations.

[1] "Person-Stays" represents the measure of the travel industry for which one person accounts for one trip regardless of trip length. "Person-Stays" is used to estimate travel volume. While "Person-Stays" does not capture the full impact of a person's travel, volume in "Person-Stays" is widely used in the industry. The estimated volume therefore allows comparison with other industry sources. "Person-Stays" includes Day- Trips of over 50 miles one-way and overnight trips.

- Sport watchers account for 13% of all leisure trip-expenditure in the state and have a 37% higher average party per trip spending over the State average spending level.
- Hiking and biking post the second highest participation level for Indiana ONL visitors, occurring at 75% above the average U.S. Leisure travel destination.

Particular Differences Bartholomew County vs. State of Indiana

- 83% of visitors have "some college" through grad degree – really high figure
- 82% of visitors stay in hotels – also unusually high also explains why only 8% are in town for VFR
- Only 8% state that Visiting Friends and Relatives (VFR) is the purpose of their visit (State of Indiana 42%)
- 57% of hotel guests first time visitors
- 50% of day visitors first time visitors (*Less re-visitation that a destination would typically hope for?)*

Demographics

Indiana attracts younger visitors - while the average U.S. destination are all losing share of 18-34 year-old ONL travelers, Indiana is increasing its share in this category. In all, 37% of Indiana's ONL are young (18-34) travelers. The U.S. on the whole has dropped share in this segment. Given Indiana's younger demography amongst ONL visitors, the State draws fewer retirees for leisure visits.

Indiana attracts visitors with children - more Indiana visitors have children in the household -- far more than the typical U.S. destination. Indiana visitors have young children. The State attracts substantially more visitors with kids 5 years or younger at home than the US average or any competitor state, and more visitors with children 6-12 living at home than the typical U.S. destination.

By the Numbers

Table 28. Visitor Totals and Distribution

Jurisdiction	State of Indiana		Bartholomew County	
Total	77,000,000		4,110,000	
Overnight	47,200,000	61.3%	3,057,840	74.4%
Day	29,800,000	38.7%	1,052,160	25.6%

Sources: CERTEC Inc., Rockport Analytics, D. K. Shifflet & Associates,

Table 29. Trip Characteristics

Jurisdiction	State of Indiana	Bartholomew County
	Visitor Origin	
Indiana	46.7%	35.6%
Ohio	11.1%	12.9%
Michigan	10.0%	9.9%
Illinois	6.7%	12.9%
Average Travel Party Size	2.2	2.7
Average Length of Stay	1.9	2.3
	Visitor Activities	
Dining	24.0%	37.8%
Shopping	20.0%	32.2%
Attend Sports Event	8.0%	22.2%
Outdoor Recreation	5.4%	9.0%

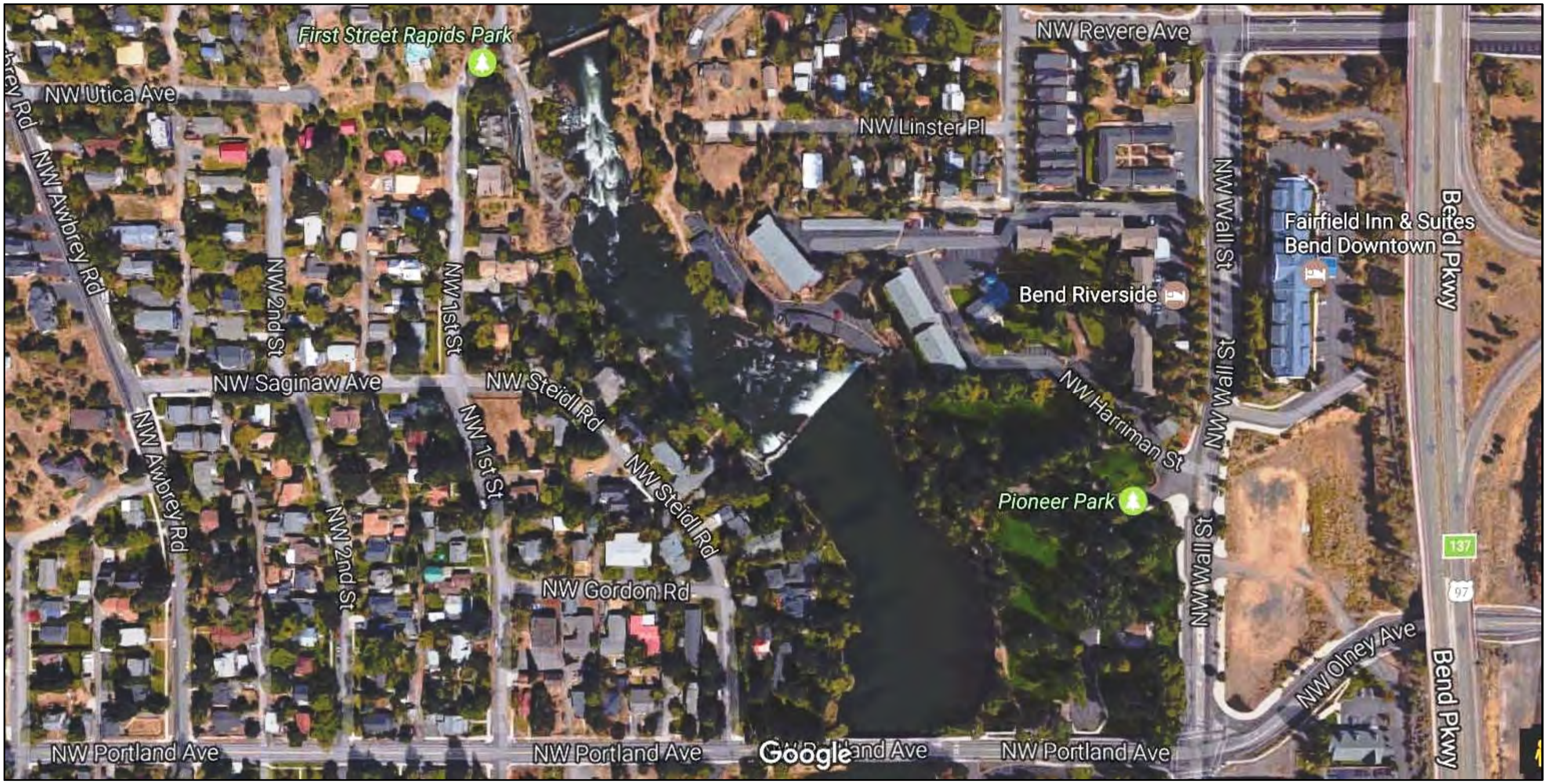
Sources: CERTEC Inc., Rockport Analytics, D. K. Shifflet & Associates,

Table 30. Visitor Spending and Distribution				
Jurisdiction	**State of Indiana**		**Bartholomew County**	
Total	**$11,529,000,000**		**$256,700,000**	
Lodging	$1,844,640,000	16.0%	$25,670,000	10.0%
Shopping	$2,421,090,000	21.0%	$84,711,000	33.0%
Entertainment	$2,075,220,000	18.0%	$35,938,000	14.0%
Transportation	$1,959,930,000	17.0%	$28,237,000	11.0%
Food & Beverage	$3,228,120,000	28.0%	$82,144,000	32.0%
Sources: CERTEC Inc., Rockport Analytics, D. K. Shifflet & Associates,				

Comparable Waterfront Developments

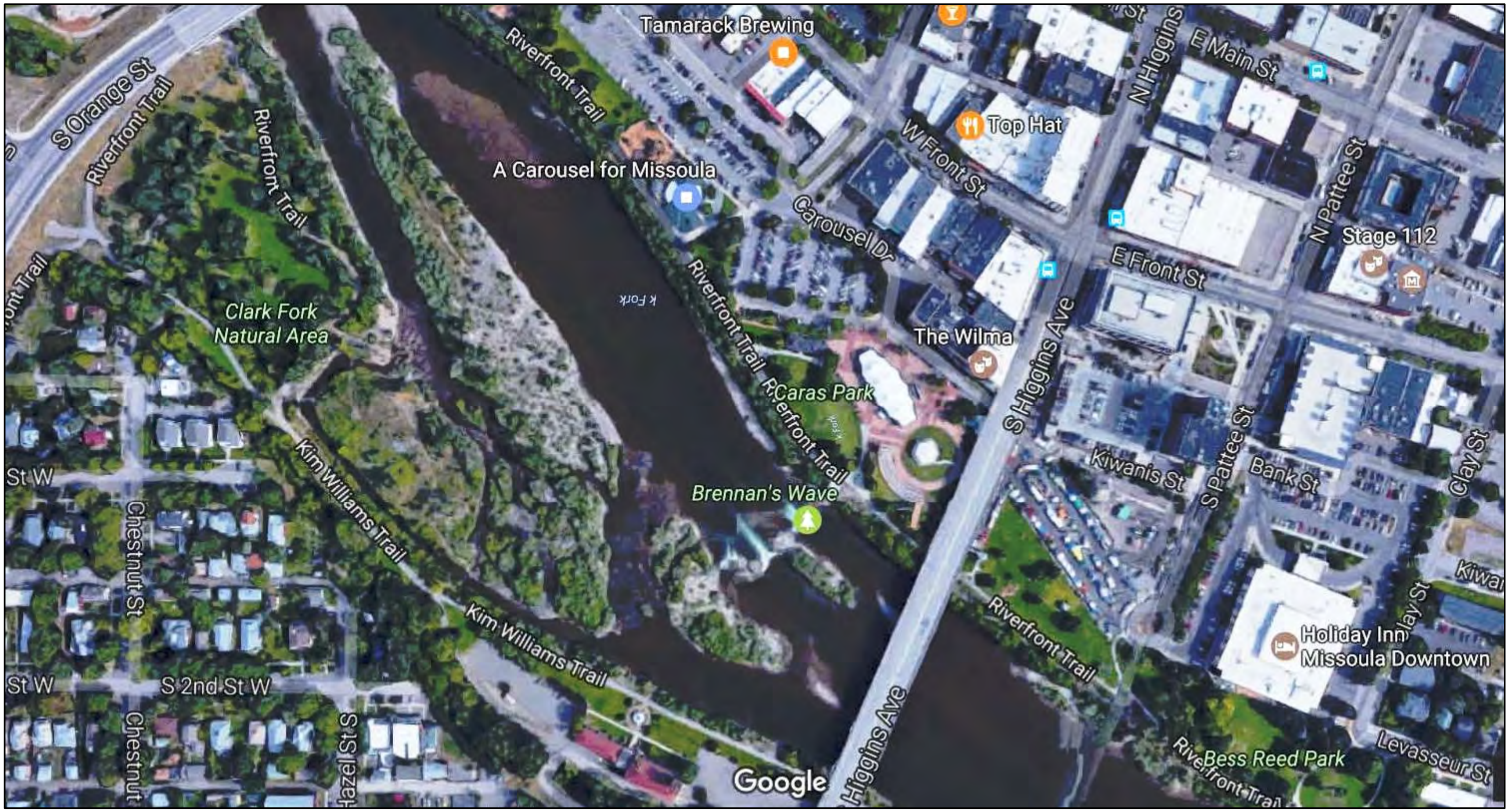
Downtown Columbus, GA

Downtown Bend, OR



Downtown Greenville, SC

Downtown Missoula, MT



Downtown Columbia, TN

Hotel Market Assessment

Hotel Market Overview

Columbus, Indiana Hotel Market

MFA obtained a list of hotels within 25 miles of the project site from Smith Travel Research (STR), a recognized leader in providing hotel and resort data in the U.S. Based on this dataset, 3,581 hotel rooms are currently available within 25 miles of the project site. These hotels are listed in the table below.

Table 31. Existing Hotels within 40 Miles

Property Name	Distance	Rooms	Chain Scale	Open Date
Hotel Indigo Columbus Architectural Center	0.3	85	Upper Upscale	Feb-08
Super 8 Columbus	1.6	57	Economy	Jul-84
Sleep Inn & Suites Columbus	1.7	72	Midscale	Jan-02
Clarion Hotel & Conference Center Columbus	1.7	253	Upper Midscale	Oct-63
Charwood Corporate Suites	1.8	72	Indep	Jun-96
Comfort Inn & Suites Columbus	1.9	75	Upper Midscale	Jun-65
Motel 6 Columbus	2.2	79	Economy	May-87
La Quinta Inns & Suites Columbus Edinburgh	2.2	78	Midscale	Jul-10
Days Inn Columbus	2.3	112	Economy	Jun-71
Courtyard Columbus Tipton Lakes	2.6	90	Upscale	Mar-98
Residence Inn Columbus	3	83	Upscale	May-09
Red Roof Inn Taylorsville	6.9	56	Economy	Sep-83
Comfort Inn Edinburgh	7.7	62	Upper Midscale	Jun-95
Hilton Garden Inn Columbus Edinburgh	7.9	125	Upscale	Jun-08
Holiday Inn Express & Suites Columbus Edinburgh	7.9	93	Upper Midscale	Jan-12
Hampton Inn Columbus Taylorsville Edinburgh	10.4	95	Upper Midscale	Jun-97
Best Western Edinburgh Columbus	11.9	57	Midscale	Jun-95
Abe Martin Lodge	16.3	160	Indep	Jun-32
Green Valley Lodge	16.7	31	Indep	Jun-81
Seasons Lodge	17	52	Indep	Jun-70
Comfort Inn Nashville	17.2	55	Upper Midscale	Aug-95
Fairfield Inn & Suites Seymour	17.2	73	Upper Midscale	Mar-09
Holiday Inn Express & Suites Seymour	17.3	85	Upper Midscale	Jun-07
Hampton Inn Seymour	17.3	70	Upper Midscale	Oct-98
Motel 6 Seymour North	17.3	61	Economy	May-00
Knights Inn Seymour	17.3	92	Economy	Jan-88
Quality Inn Seymour	17.4	67	Midscale	Jun-90
Economy Inn	17.4	48	Indep	Jul-97
Allstate Inn	17.4	46	Indep	N/A
Salt Creek Inn	17.5	66	Indep	Jun-88

Source: Smith Travel Research (STR),MFA

Table 32. Existing Hotels within 10 Miles continued				
Property Name	**Distance**	**Rooms**	**Chain Scale**	**Open Date**
Brown County Inn	17.5	99	Indep	Jun-74
Cornerstone Inn	17.5	38	Indep	May-93
Hidden Valley Inn	17.6	60	Indep	Mar-00
Artists Colony Inn	17.6	23	Indep	Jun-92
Travelodge Seymour	17.6	32	Economy	Aug-09
Econo Lodge Seymour	17.6	64	Economy	Jun-72
Hotel Nashville	17.6	45	Indep	Sep-89
Days Inn Seymour	17.6	60	Economy	Jun-74
Baymont Inn & Suites Franklin	19.9	68	Midscale	Jul-97
Motel 6 Franklin	20	50	Economy	May-94
Relax Inn	20	90	Indep	Jul-96
Quality Inn Franklin	20	45	Midscale	Nov-97
Tearman Motel	20.1	22	Indep	Jun-50
Comfort Inn North Vernon	20.2	60	Upper Midscale	Feb-99
Rasner Motel	23.5	40	Indep	Apr-56
Quality Inn & Suites Shelbyville	24.3	67	Midscale	Aug-88
Hampton Inn Suites Greensburg	24.3	113	Upper Midscale	Jul-08
Holiday Inn Express Greensburg	24.7	80	Upper Midscale	Mar-02
Hampton Inn Shelbyville	24.9	57	Upper Midscale	May-01
Wishing Well Motel	25	18	Indep	Jan-53
Source: Smith Travel Research (STR),MFA				

Table 33. Household Income Market Summary– By Income Brackets and Market Area for 2016				
Income Bracket	Market Area			
	City of Columbus, Indiana		City of Columbus, Indiana	
	Number	Percent	Number	Percent
<$15,000	2,235	11.6%	3,095	9.7%
$15,000 - $24,999	2,115	11.0%	3,097	9.7%
$25,000 - $34,999	2,155	11.2%	3,312	10.4%
$35,000 - $49,999	2,719	14.1%	4,870	15.3%
$50,000 - $74,999	3,571	18.5%	6,534	20.5%
$75,000 - $99,999	2,097	10.9%	3,966	12.5%
$100,000 - $149,999	2,753	14.3%	4,521	14.2%
$150,000 - $199,999	890	4.6%	1,309	4.1%
$200,000+	776	4.0%	1,101	3.5%
Median Household Income	**$52,070**		**$54,122**	
Average Household Income	**$71,451**		**$71,409**	
Per Capita Income	**$28,847**		**$27,699**	
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021, MFA				

Table 34. Population by Age Market Summary 2016				
Age Bracket	Market Area			
	City of Columbus, Indiana		City of Columbus, Indiana	
	Number	Percent	Number	Percent
0 - 4	3,191	6.6%	5,352	6.5%
5 - 9	3,258	6.7%	5,559	6.7%
10 - 14	3,300	6.8%	5,730	6.9%
15 - 19	2,976	6.1%	5,113	6.2%
20 - 24	2,840	5.9%	4,800	5.8%
25 - 34	6,317	13.0%	10,375	12.5%
35 - 44	6,310	13.0%	10,819	13.1%
45 - 54	6,335	13.1%	11,116	13.4%
55 - 64	6,009	12.4%	10,726	13.0%
65 - 74	4,330	8.9%	7,663	9.3%
75 - 84	2,464	5.1%	3,938	4.8%
85+	1,149	2.4%	1,582	1.9%
Source: U.S. Bureau of the Census, 2010 Census, ESRI BIS forecasts for 2016 and 2021, MFA				

Economic and Fiscal Impact Assessment

An impact analysis begins by identifying the economic activity, such as capital improvement projects, operational expenditures, expenditures on programs, or increased sales from a new initiative. Such activity is then assigned to the appropriate industry/economic sector.

The underlying economic rationale is that new expenditures in a region drive the demand for goods and services and lead to economic growth. The logic of the model is that any additional demand in any economic sector or institution triggers economic responses from other sectors and institutions through the linkages in an input-output matrix. This is often called the ripple effect, since it is similar to the cascade of waves that form when a stone is thrown into a lake.

The economic and fiscal impact of any project and its surrounding community is measured by deviation in economic activity (output), and the associated changes in jobs (employment), income (wages), and related tax revenues.

As a dollar flows through an economy, it touches various industries, some local and some non-local. The portion of a dollar spent locally turns over again. At each iteration, a portion of the economic activity spurs additional economic activity in the area, while some of the economic activity “leaks” to another area. The multipliers capture this iterative process until the whole dollar is “leaked”.

While the dollar “ripples” through the local economy, it has different effects in different economic sectors that are determined by a multiplier. A large impact area (such as a state) or an economically diverse area (such as an urban center) may have high multipliers because a greater portion of activity required to support the change in final demand would come from within the impact area’s boundaries. For a small impact area, a rural impact area a less diverse economy such as a single county or zip code, multipliers could be lower.

The impact model includes information for 536 different industries/economic sectors, generally at the three- or four-digit Standard Industrial Classification (SIC) level – called the NAICS codes. The multipliers are then selected based on the impact area’s geography and are applied to each industry sector present in the defined impact area to calculate impacts.

Regional input-output (I-O) multipliers systematically analyze economic impacts and account for inter-industry relationships within and between regions. These multipliers are unique to each industry sector and are geography based on the economic make-up of the locality. Thus, a construction project will have a greater local impact on an area that has a concentration of construction material suppliers, whereas a change to a banking policy will have a greater impact on an area with a concentration of financial institutions.

One-Time and Ongoing Impacts

There are two principal types of impacts: one-time impacts, such as those associated with a construction project, which end when the construction is completed, and ongoing impacts, which continue annually, such as those from the operation of a long-standing program, retailer, or other facility.

For example, the addition of new attractions, amenities, programs or facilities to Bartholomew County would have:

- a one-time effect during the construction phase, and
- on-going annual effects due to additional visitor spending, either onsite (concessions, souvenirs) or in adjacent restaurants, retail stores and/or hotels, as well as changes (increases) in the operational expenditures by the attractions to maintain and operate those new attractions or facilities

There are three types of impacts

Direct Impact
A direct impact is the change in sales, income, and jobs in those businesses or agencies that directly receive revenues from an operator/owner of an attraction. For example, the economic activity of the construction company building a new sports facility or parking deck would be a direct impact.

Indirect Impact
An indirect impact is the change in sales, income, and jobs in those businesses or agencies that supply the businesses or agencies receiving direct impacts. For example, if a steel fabrication plant in the impact area produces the steel that is sold to the construction company that builds sports facility or parking deck, the economic activity at the steel fabrication plant is an indirect impact.

Induced Impact
Induced impact measures ripple effects of wages in the local economy. As employees are paid by the businesses and agencies directly or indirectly impacted, there is an increase in household income, which is then spent, at least in part, in the impact area, which represents the induced impact.

The result of all of the three types of impacts above is the total economic impact -- the sum of direct, indirect, and induced impacts and are measured in changes to the economic activity (output), and the associated changes in jobs (employment), income (wages), and related federal, state and local tax revenues.

The model also allows to account for competition in the market place. If it is set to 100% local purchase, as it is in this case, it assumes that all expenditures are made within the impact area, given all economic sectors affected are present, thus eliminating competition and resulting in the highest possible impact. For example instead of purchasing concrete from a business in outside of Bartholomew County for a lower price, the concrete will be purchased from a business within the impact area despite a higher price.

This is an economic model, thus it does not measure social impacts of the new attractions and facilities such as the increase in quality of life through and becoming a more attractive county to live in. It also does not account for follow up investments that are likely to happen triggered by the increased visitation to the County.

Bartholomew County, Economic & Fiscal Impacts

MFA was tasked to assess the economic and fiscal impact of the construction and maintenance/operations of the new riverfront park in Columbus, Indiana in Bartholomew County.

The impact area is defined as Bartholomew County, Indiana

The model assumes that **all** spending is local given the economic sector in which the spending occurs is present in the defined impact area thus eliminating competition resulting in the maximum possible impact.

If an economic sector is not present in the impact area, the spending for this sector "leaks" out of the impact area and has no impact there.

Impact Assessment Results

East Bank & In-River Construction Impacts

Construction or capital improvement projects have one time impact; their impact ends when the projects are completed. Based on these assumptions, the estimated impacts of the construction of the East Bank & In-River features are shown in the following tables. These expenditures might occur over several years but were analyzed with 2015 impact multipliers.

Table 35.: Preliminary Construction Impacts			
Impact Type	**Employment**	**Income**	**Economic Activity**
Direct Effect	64	$2,997,900	$8,604,418
Indirect Effect	10	$475,503	$1,263,154
Induced Effect	10	$389,370	$1,255,877
Total Effect	**84**	**$3,862,774**	**$11,123,449**
Source: IMPLAN, MFA, BLS, Hitchcock Design Group			

Tax Revenues

The construction phase will also produce revenues for Local, State and Federal government agencies based on current taxing policy. The tax revenue from those projects estimates are as follows.

Table 36.: Preliminary Construction Impacts Estimated Tax Revenue	
Total State and Local Tax	$264,729
Total Federal Tax	$743,889
Source: IMPLAN, MFA, BLS, Hitchcock Design Group	

East Bank & In-River Attraction Annual Operational Impacts

The East Bank & In-River operations create several types of impacts on the local economy. Many of the operating expenses trickling through the local area economy in the form of expenses for goods and services, salaries, which are then spent by employees, sales and other tax payments that go to local governments, the following tables show these estimates economic impacts. The impacts are annually reoccurring through the ongoing maintenance and operational expenditures. These were analyzed with 2015 impact multipliers.

Table 37.: Preliminary Operational Impacts			
Impact Type	**Employment**	**Income**	**Economic Activity**
Direct Effect	4	$194,818	$633,088
Indirect Effect	1	$46,718	$125,712
Induced Effect	1	$27,290	$88,053
Total Effect	**6**	**$268,827**	**$846,853**
Source: IMPLAN, MFA, BLS, Hitchcock Design Group			

Tax Revenues

The East Bank & In-River Attraction's operational expenses also produced revenues for Local, State and Federal government agencies based on current taxing policy. The tax revenue estimates from operational expenses are as follows:

Table 38.: Preliminary Operational Impacts, Estimated Tax Revenue	
Total State and Local Tax	$20,860
Total Federal Tax	$51,987
Source: IMPLAN, MFA, BLS, Hitchcock Design Group	

East Bank & In-River Attraction Annual Visitor/Participant Impacts

Visitor/Participant impacts are "ongoing" annual impacts. To estimate the visitor/participant impact, MFA combined participation estimates for river/waterfront related activities, and spending per person estimates from ESRI, CERTEC, D.K. Shifflet & Associates, Rockport Analytics, U.S. Department of Commerce, International Trade Administration, and U.S. Office of Tourism Industries. These expenditures were analyzed with the currently available 2015 impact multipliers

Table 39.: Preliminary Visitor/Participant Impacts			
Impact Type	**Employment**	**Income**	**Economic Activity**
Direct Effect	21	$406,598	$887,530
Indirect Effect	1	$42,528	$143,432
Induced Effect	1	$50,565	$163,124
Total Effect	**23**	**$499,691**	**$1,194,086**
Source: IMPLAN, MFA, BLS, Hitchcock Design Group			

Tax Revenues

The visitor/participant expenses also produces revenues for Local, State and Federal government agencies based on current taxing policy. The tax revenue estimates are as follows:

Table 40.: Visitor/Participant Impacts, Estimated Tax Revenue	
Total State and Local Tax	$81,832
Total Federal Tax	$92,714
Source: IMPLAN, MFA, BLS, Hitchcock Design Group	

Summary

The following table summarizes the estimated impacts of the facility on the local economy.

Table 41.: Impact Summary				
Impact	**Employment**	**Income**	**Local & State Tax Revenue**	**Economic Activity**
One-Time Construction Impact	**84**	**$3,862,774**	**$264,729**	**$11,123,449**
Annual Reoccuring Operations Impact	6	$268,827	$20,860	$846,853
Annual Reoccuring Visitor Impact	23	$499,691	$81,832	$1,194,086
Annual Reoccuring Impacts Total	**29**	**$768,518**	**$102,692**	**$2,040,939**
Source: IMPLAN, MFA, BLS				

- It is estimated that every dollar in capital investment (construction) returns roughly $1.7 in economic impact (income, economic activity and local and state tax revenue)

- It is estimated that every dollar spend to maintain and keep the new Riverfront Park open (operations) returns $4.6 annually in in economic impact (income, economic activity and local and state tax revenue)

Riverfront Redevelopment – Potential Related Developments

The following describes potential scenarios of private developments and their fiscal impacts that could follow a successful redevelopment of the Columbus Riverfront in the downtown area on both sides of the river.

This scenario includes the following components:

- **Multi-Unit Residential Development**
- **Commercial Space Development**
- **Two New Hotels**

Table 42. Local Tax Rates	
Property Tax Rate	0.874%
Innkeeper's Tax (Bartholomew County)	5%
Sales Tax	7%
Sales Tax Breakdown	
Indiana	7%
Bartholomew County	0%
Columbus	0%

Multi-Unit Residential Development and Commercial Space

Assumptions:

- 150 Residential units
- 20,000 sq. ft. of commercial space
- Current Median List Price per sq. ft. in Columbus $108
- Estimated New Construction per sq. ft. $140 (national average is $125)
- Similar to The Cole: 173,307 total sq. ft., 146 Units, 9,000 sq. ft. Commercial

Table 43. Multi-Unit Residential Development					
Total	Units	Unit Size Sq. ft.	Price per Unit	Total	Tax Revenue
	150				Property Tax
1 Bedroom	80	850	$119,000	$9,520,000	$83,205
2 Bedroom	60	1,200	$168,000	$10,080,000	$88,099
Penthouse	10	1,800	$252,000	$2,520,000	$22,025
Total					**$193,329**

Table 44. Commercial Space Development				
	Total Size Sq. ft.			Tax Revenue
Commercial Space	20,000			Property Tax
Construction Cost	$2,800,000			$24,472
	Size Sq. ft.	Sales per Sq. ft.	Total Sales	Sales Tax
Restaurants/Bar/Cafe	10,000	$370	$3,700,000	$259,000
Neighborhood Retail	10,000	$250	$2,500,000	$175,000
Total				**$458,472**

Hotel Development

Assumptions:

- Two separate properties
- Midscale Type Hotel with F&B
- Extended Stay Type Hotel
- Cost per Room includes land costs
- Total of 180 rooms – replacement for the 199 rooms lost at the Clarion

Table 45. Assumptions Hotel Development	
Midscale Hotel with F&B	
# of Rooms	100
Cost per Room	$197,700
Total Cost	$19,770,000
Extended Stay Hotel	
# of Rooms	80
Cost per Room	$144,600
Total Cost	$11,568,000
Total Rooms	**180**
Total Room Nights	65,700
Occupancy Rate	65%
Room Nights Sold	42,705
ADR	$115
Room Revenue	$4,911,075

Table 46. Estimate Tax Revenues Hotel Development	
Sales Tax	$343,775
Hotel Occupancy Tax	$245,554
Property Tax	$273,894
Total	**$863,223**

Summary Scenario Tax Revenue Estimate

Table 47. Summary Estimate Tax Revenue Matrix				
Development/Tax	**Sales Tax**	**Hotel Occupancy Tax**	**Property Tax**	**Total**
Residential Development			$193,329	**$193,329**
Commercial Development	$434,000		$24,472	**$458,472**
Hotel Development	$343,775	$245,554	$273,894	**$863,223**
Total	**$777,775**	**$245,554**	**$491,695**	**$1,515,024**

Selected Definitions Related to Impact Assessments

Direct Impact
A direct impact is the change in sales, income, and jobs in those businesses or agencies that directly receive revenues from the agency or program. For example, the economic activity of the construction company building a parking deck would be a direct impact.

Indirect Impact
An indirect impact is the change in sales, income, and jobs in those businesses or agencies that supply the businesses or agencies receiving direct impacts. For example, if a steel fabrication plant in the impact area produces the steel that is sold to the construction company, the economic activity at the steel fabrication plant is an indirect impact.

Induced Impact
Induced impact measures ripple effects of wages in the local economy. As employees are paid by the businesses and agencies directly or indirectly impacted, there is an increase in household income, which is then spent, at least in part, in the impact area.

Output/Economic Activity
Output represents the value of industry production (gross domestic product -- GDP). These are annual production estimates for the year of the data set and are expressed in producer prices.

Employment
The number of jobs supported by a project. Aggregated job estimates are presented in the context of "full-time equivalent" positions. In the disaggregated data, partial jobs may be shown and could represent increased hours or labor productivity, depending on firm-by-firm staffing decisions.

Labor Income
Labor income includes all forms of employment income -- both employee compensation (wages and benefits) and proprietor income.

Taxes
Tax revenue contribution of the development, business or project to local, state and federal units of government. The analysis assumes current tax policy. However, results can vary depending on special incentives, programs, or rebates associated with the business or project being assessed.

Multiplier Effect
The "multiplier effect" is used to determine the impact of each dollar entering, impacting, and eventually leaving a defined economy (i.e. "dollar turnover"). This turnover results in increased production and expenditures, employment creation and attraction, and retention of new residents, businesses and investments. The "multiplier effect" is added to the final demand, which is the estimate of the level of spending in the local economy by the private or public sector.

Appendix

Impact Assessment Results 50% Leakage Scenario

Assumptions

- 50% of the construction and operations budget is spend outside of the impact area (Bartholomew County) accounting for competition in the marketplace.
- Visitor/Spectator impact remains the same – visitors will likely spend their money onsite or at adjacent restaurants and retailers in downtown.

East Bank & In-River Construction Impacts

Table 48.: Preliminary Construction Impacts			
Impact Type	**Employment**	**Income**	**Economic Activity**
Direct Effect	32	$1,498,950	$4,302,209
Indirect Effect	5	$237,752	$631,577
Induced Effect	5	$194,685	$627,938
Total Effect	**42**	**$1,931,387**	**$5,561,725**
Source: IMPLAN, MFA, BLS, Hitchcock Design Group			

Tax Revenues

Table 49.: Preliminary Construction Impacts Estimated Tax Revenue	
Total State and Local Tax	$132,365
Total Federal Tax	$371,945
Source: IMPLAN, MFA, BLS, Hitchcock Design Group	

East Bank & In-River Attraction Annual Operational Impacts

Table 50.: Preliminary Operational Impacts			
Impact Type	**Employment**	**Income**	**Economic Activity**
Direct Effect	2	$97,409	$316,544
Indirect Effect	1	$23,359	$62,856
Induced Effect	0	$13,645	$44,026
Total Effect	**3**	**$134,413**	**$423,427**
Source: IMPLAN, MFA, BLS, Hitchcock Design Group			

Tax Revenues

Table 51.: Preliminary Operational Impacts, Estimated Tax Revenue	
Total State and Local Tax	$10,431
Total Federal Tax	$25,992
Source: IMPLAN, MFA, BLS, Hitchcock Design Group	

East Bank & In-River Attraction Annual Visitor/Participant Impacts

Table 52.: Preliminary Visitor/Participant Impacts			
Impact Type	**Employment**	**Income**	**Economic Activity**
Direct Effect	21	$406,598	$887,530
Indirect Effect	1	$42,528	$143,432
Induced Effect	1	$50,565	$163,124
Total Effect	**23**	**$499,691**	**$1,194,086**
Source: IMPLAN, MFA, BLS, Hitchcock Design Group			

Tax Revenues

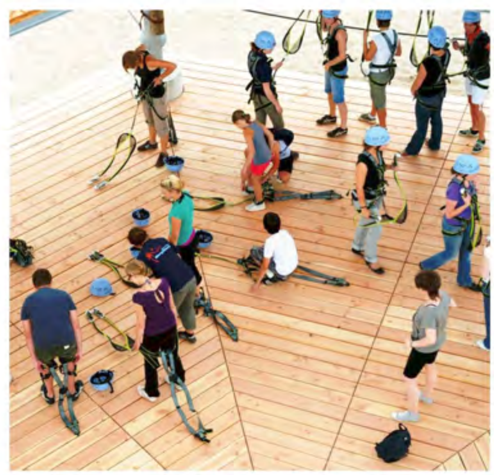
Table 53.: Visitor/Participant Impacts, Estimated Tax Revenue	
Total State and Local Tax	$81,832
Total Federal Tax	$92,714
Source: IMPLAN, MFA, BLS, Hitchcock Design Group	

Summary

The following table summarizes the estimated impacts of the facility on the local economy.

Table 54.: Impact Summary				
Impact	**Employment**	**Income**	**Local & State Tax Revenue**	**Economic Activity**
One-Time Construction Impact	**42**	**$1,931,387**	**$132,365**	**$5,561,725**
Annual Reoccuring Operations Impact	3	$134,413	$10,431	$423,427
Annual Reoccuring Visitor Impact	23	$499,691	$81,832	$1,194,086
Annual Reoccuring Impacts Total	**26**	**$634,104**	**$92,263**	**$1,617,513**
Source: IMPLAN, MFA, BLS				

Small Foot Print Ropes Course



Bouldering


evolv
evolv

General Limiting Conditions

Every reasonable effort has been made to ensure that the data contained in this study reflect the most accurate and timely information possible and they are believed to be reliable. This study is based on estimates, assumptions and other information developed by Market & Feasibility Advisors LLC from its independent research effort, general knowledge of the industry, and consultations with the Client and the Client's representatives. No responsibility is assumed for inaccuracies in reporting by the Client, the Client's agent, and representatives or any other data source used in preparing or presenting this study. No warranty or representation is made by Market & Feasibility Advisors LLC that any of the project values or results contained in this study will actually be achieved.

The fee Market & Feasibility Advisors LLC received for undertaking this project is in no way dependent upon the specific conclusions reached in this report. Market & Feasibility Advisors LLC has no financial interest in the project.

Possession of this study does not carry with it the right of publication thereof or to use the name of "Market & Feasibility Advisors LLC" in any manner. No abstracting, excerpting, or summarization of this study may be made. This study is not to be used in conjunction with any public or private offering of securities or other similar purpose where it may be relied upon to any degree by any person other than the client. This study may not be used for purposes other than that for which it is prepared. Exceptions to these restrictions may be permitted after obtaining prior written consent from Market & Feasibility Advisors LLC.

It is understood by MFA that the findings of this report are the proprietary property of the client and they will not be made available to any other organization or individual without the consent of the client.

Market & Feasibility Advisors LLC understands that the client may publish this report under the agreement that Market & Feasibility Advisors LLC and its contractors will be indemnified against any losses, claims, damages and liabilities under federal and state securities laws which may arise as a result of statements or omissions in public or private offerings of securities.

This study is qualified in its entirety by, and should be considered in light of, these limitations, conditions and considerations.

Appendix B
Hydraulic Analysis Summary by
Christopher B. Burke Engineering, LLC

To:	Randy Royer, ASLA – Hitchcock Design Group
From:	Heather Finfrock, PE, CFM – CBBEL
Subject:	Hydraulic Analysis Summary
Date:	January 8, 2018
Project Name:	Columbus Riverfront Redevelopment
Project No.:	17-0077

Christopher B. Burke Engineering, LLC (CBBEL) performed a hydraulic analysis of the East Fork White River near Columbus, Indiana to evaluate redevelopment of the riverfront area between SR 46 eastbound and westbound. This analysis included two-dimensional hydraulic modeling, one-dimensional hydraulic modeling, and a brief review of previous flood events and typical water surface elevations from nearby stream gages. This memorandum serves as a summary of this analysis.

Two-Dimensional Model

A two-dimensional model was selected for this analysis because of the complex flowpaths around the low-head dam near westbound SR 46 and an overland flowpath from Driftwood River to East Fork White River that is activated during large flooding events. In lower, more frequent events, the two-dimensional model more accurately depicts the flow in the vicinity of the dam due to the angle of the dam and its relationship to the westbound SR 46 bridge, which cannot be properly modeled with a one-dimensional model. In larger, less frequent events, the two-dimensional model better models the flow from the Driftwood River, over SR 46 and SR 11, which bypasses the riverfront area.

The full model begins approximately 3,700 feet downstream of the confluence with Haw Creek and extends upstream along the Driftwood River to immediately downstream of I-65 and along the Flatrock River to immediately downstream of the railroad between Indianapolis Road and Newsom Avenue. However, the area of interest is along the East Fork White River between approximately 2,000 feet downstream of the eastbound SR 46 bridge and extending upstream to the confluence with Driftwood and Flatrock Rivers.

Three geometric conditions were modeled, the existing condition with the low-head dam, a post-dam-removal condition, and a proposed condition that includes fill along the east bank of the river. There are several sources of existing condition geometric data included in the model. The main source of the two-dimensional geometry surface is the 2011 Bartholomew County Digital Elevation Model (DEM). The channel was updated with data from several bathymetric surveys completed in 2017. Channel data was estimated upstream of the confluence with Flatrock and Driftwood Rivers and downstream of the confluence with Haw Creek, as bathymetry was not collected in these areas. Bridge piers were added to the surface by estimating their widths from 2016 aerial photography. The low-head dam data was also collected during the bathymetric surveys. In the post-dam-removal condition, the existing condition geometry was modified to remove the dam and smooth the thalweg to estimate the movement of sediment behind the dam once it is removed. In the proposed condition, data from HDG was added along the east bank of East Fork White River between east and westbound SR 46.

Three flow conditions were considered – a bankfull condition, which was estimated by adjusting the flow along each stream until the channel was filled, a baseflow condition, which was estimated from the gages on Flatrock and East Fork White Rivers, and the 1% annual chance (100-Year) event from the Flood Insurance Studies (FIS) from each stream. For the bankfull condition, the impacts are primarily contained between the two SR 46 bridges. The existing condition, post-dam-removal condition, and proposed condition velocities are shown in **Figure 1**, **Figure 2**, and **Figure 3**, respectively.

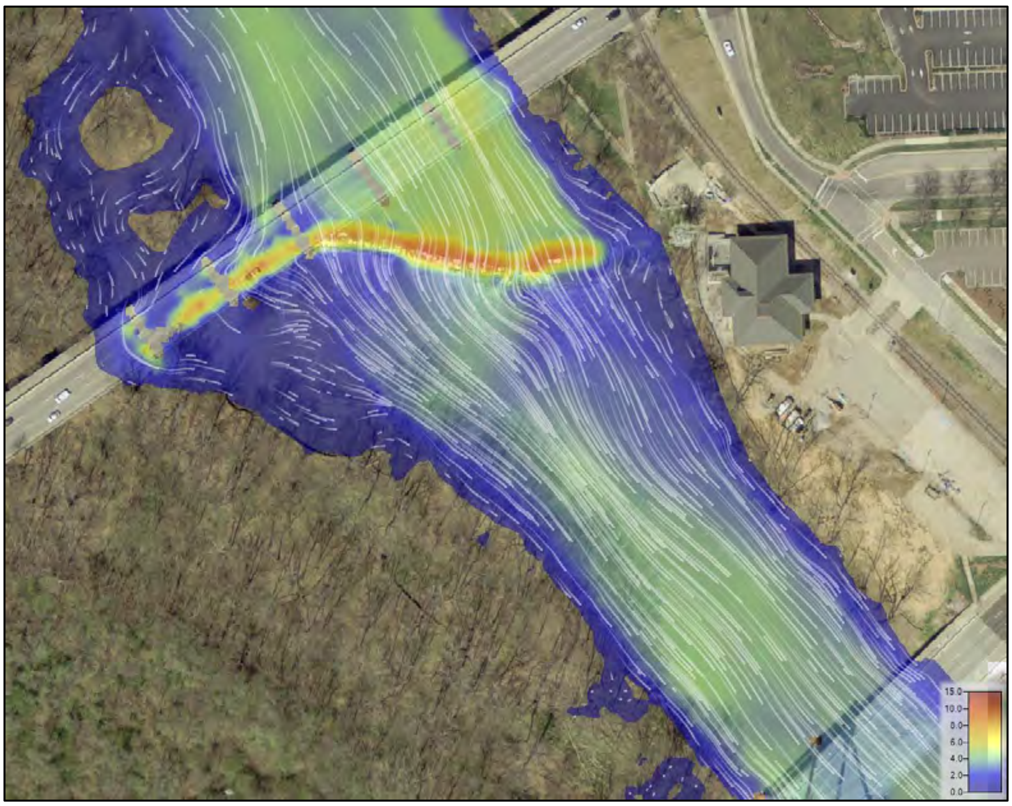


Figure 1: Existing Condition Bankfull Velocity

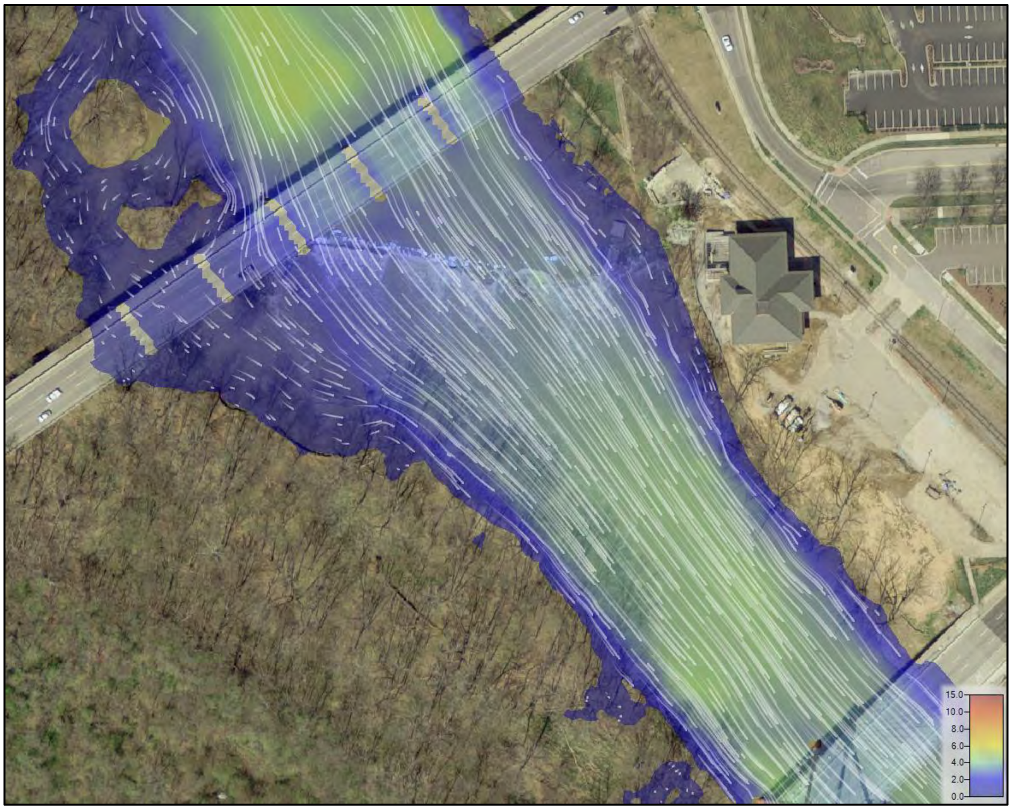


Figure 2: Post-Dam-Removal Condition Bankfull Velocity

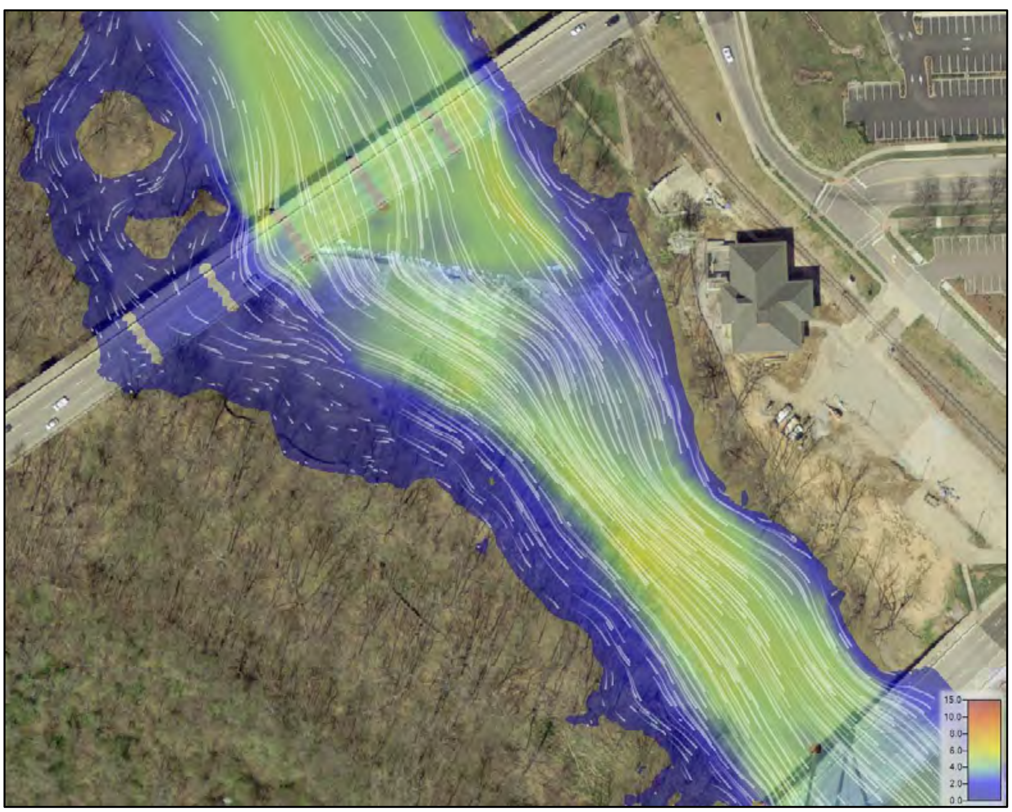


Figure 3: Proposed Condition Bankfull Velocity

A comparison of **Figure 1** and **Figure 2** shows that the velocities are reduced once the dam is removed and the flow direction is more one-dimensional, as expected. A comparison of **Figure 2** and **Figure 3** shows that the velocities are increased once flow is constricted by adding fill along the east bank. Bankfull water surface elevations at several locations are summarized in **Table 1**.

Table 1: Bankfull Water Surface Elevations

Location	Existing Condition (ft, NAVD)	Post-Dam-Removal Condition (ft, NAVD)	Proposed Condition (ft, NAVD)
At dam	604.93	604.57	604.64
Upstream of westbound SR 46	605.17	604.62	604.82

A baseflow condition was also modeled in the existing condition and post-dam-removal condition, primarily to determine the change in water surface elevations at the Mill Race Park. **Table 2** summarizes those elevations.

Table 2: Baseflow Water Surface Elevations

Location	Existing Condition (ft, NAVD)	Post-Dam-Removal Condition (ft, NAVD)
At dam	604.00	601.86
Upstream of westbound SR 46	604.17	601.90
At Mill Race Park	604.37	602.63

If the dam is removed and no grade control structures are constructed to maintain current water levels, modification of the intake structure near Mill Race Park is likely necessary due to the lowered water surface elevation. The water surface is approximately 50 feet narrower on the north bank, as shown in **Figure 4**.

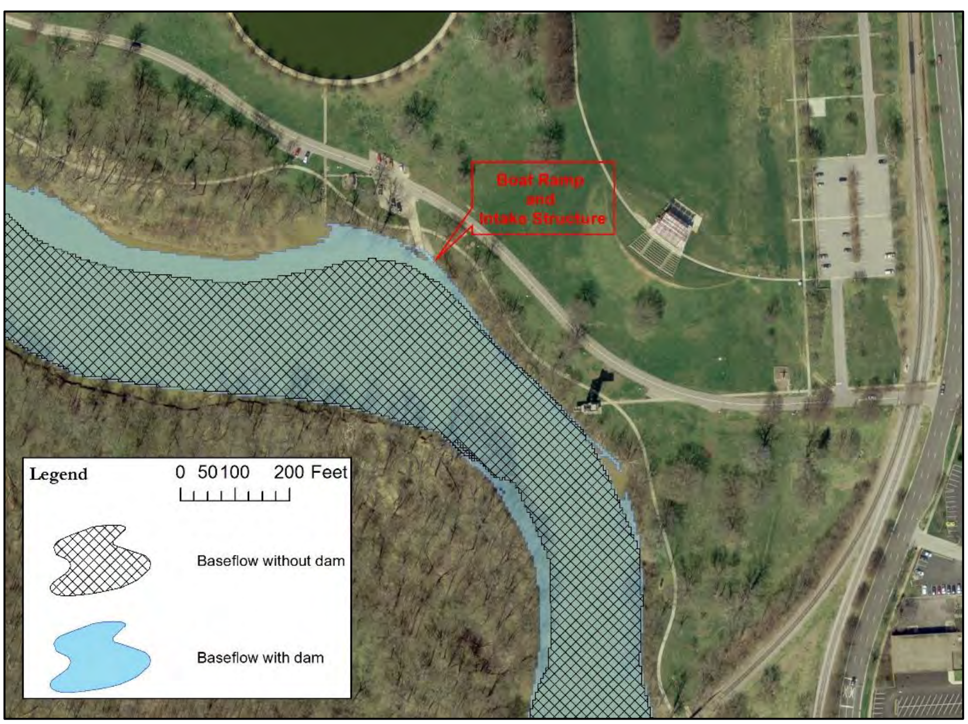


Figure 4: Baseflow Water Surface Comparison

In the 1% annual chance condition, the focus is no longer only on the riverfront site. This event is large enough to overtop SR 46 further west of the site and creates an alternative flow path that bypasses the site. The impacts caused by the project need to be considered in the bypass area also. There are minor changes to the velocity and direction of flow since the dam is significantly overtopped. The existing condition, post-dam-removal condition, and proposed condition velocities are shown in **Figure 5**, **Figure 6**, and **Figure 7**, respectively.

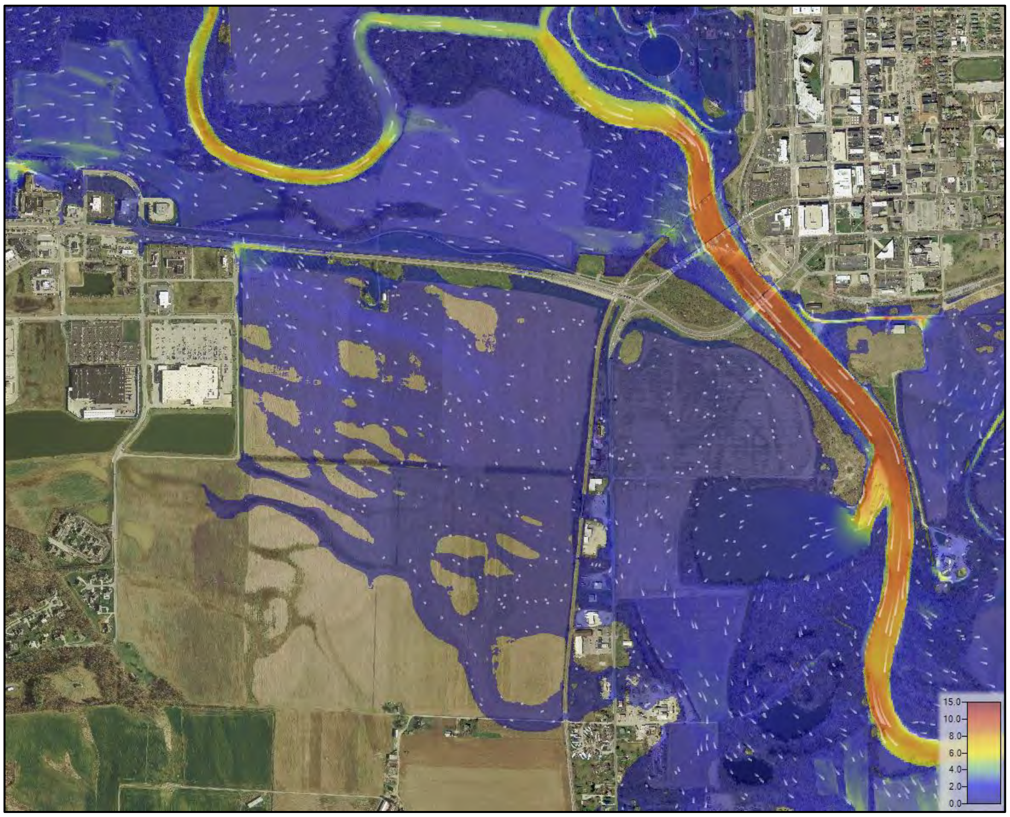


Figure 5: Existing Condition 1% Annual Chance Velocity

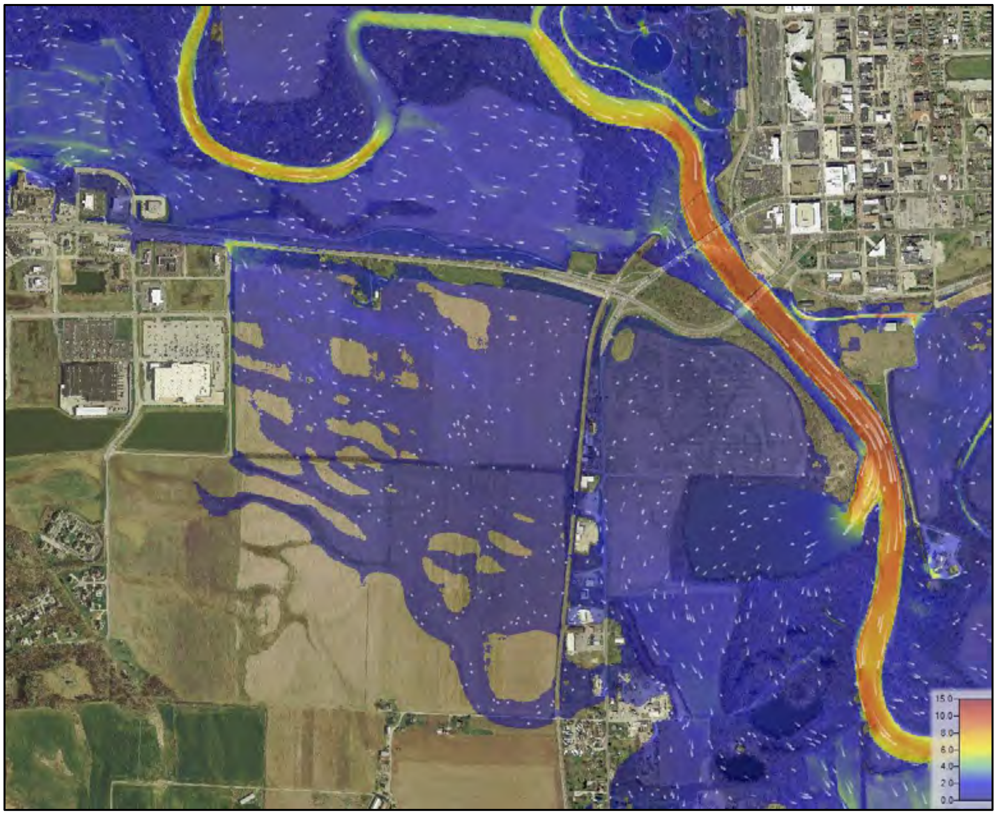


Figure 6: Post-Dam-Removal Condition 1% Annual Chance Velocity

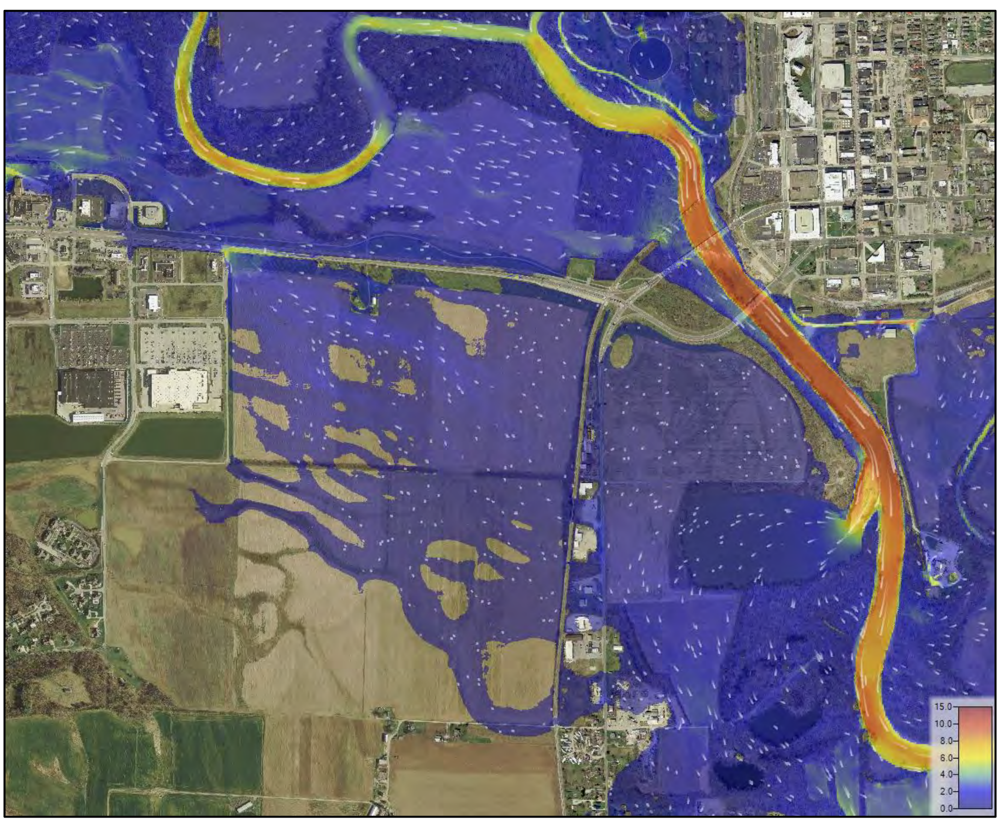


Figure 7: Proposed Condition 1% Annual Chance Velocity

A comparison of water surface elevations is also necessary, since permittablity is typically evaluated in fractions of a foot and may not be apparent at this scale. **Table 3** shows a comparison of elevations at key locations. The difference in water surface elevations are very small; the maximum difference of 0.06 feet between existing and proposed conditions is located at the dam.

Table 3: 1% Annual Chance Water Surface Elevations

Location	Existing Condition (ft, NAVD)	Post-Dam-Removal Condition (ft, NAVD)	Proposed Condition (ft, NAVD)
At dam	619.42	619.43	619.48
Upstream of westbound SR 46	619.59	619.55	619.60
Upstream of eastbound SR 46	618.83	618.83	618.83
Downstream of SR 46 (bypass)	618.57	618.51	618.58
Railroad (bypass)	615.77	615.77	615.77

One Dimensional Model

To evaluate permittablity of the proposed kayak course, as well as the proposed fill along the east bank, a one-dimensional model was created. Three geometric conditions were modeled, the existing condition with the low-head dam, a proposed condition with east bank fill but without the kayak course, and a proposed condition with both the east bank fill and the kayak course. Bridge opening data was taken from the Flatrock River FIS model and the USGS East Fork White River model, while the top of road data was updated with the 2011 Bartholomew County DEM. Data for cross-sections and the low-head dam was taken from the two-dimensional model terrain surfaces.

Since the primary purpose of the one-dimensional model is to evaluate permittablity, only the 1% annual chance event was considered. A summary results table is attached for all three geometric conditions. When comparing the existing condition to the proposed condition without the kayak course, the maximum surcharge of 0.40 occurs on a parcel that is not owned by the City and will require a flood easement to be permittable. When comparing the existing condition to the proposed condition with the kayak course, the maximum surcharge of 0.71 occurs on a parcel that is not owned by the City and will require a flood easement to be permittable. A map showing the parcels with surcharges greater than 0.14 feet is attached. Both proposed conditions affect the same parcels; the kayak course increases that surcharge for most parcels.

Previous Flood Events

There is a stream gage along East Fork White River at the riverfront site that makes it possible to easily review past flooding events. The lower portion of the Riverfront site is subject to frequent flooding; it has flooded 10 times in the past 4 years. The higher portion of the site is less likely to flood; it has flooded less than 10 times in the past century. Once at flood stage, flood durations typically last 4 days or longer, depending on the severity of the storm. Specifically, at an elevation of 608 feet, NAVD88, the site can be expected to be under water more than 20 days annually.

Permitting Considerations

Several permits are needed for the riverfront redevelopment project. An Indiana Department of Natural Resources (IDNR) Construction in a Floodway permit is required for all construction inside a floodway for streams with drainage areas greater than 1 square mile. The East Fork White River watershed has a drainage area of approximately 1,700 square miles at this location. **Figure 8** shows the delineation of the floodway for this reach of East Fork White River. As long as the riverfront project includes the removal of the low-head dam or fill that is greater than 5% of the cross section of the floodplain, a hydraulic model will be required as part of the application. The current hydraulic modeling will need to be updated once a final design is selected and will need to show that the proposed condition does not create a water surface elevation increase greater than 0.14 feet off of city property during the 1% annual chance event, unless a flood easement can be obtained.

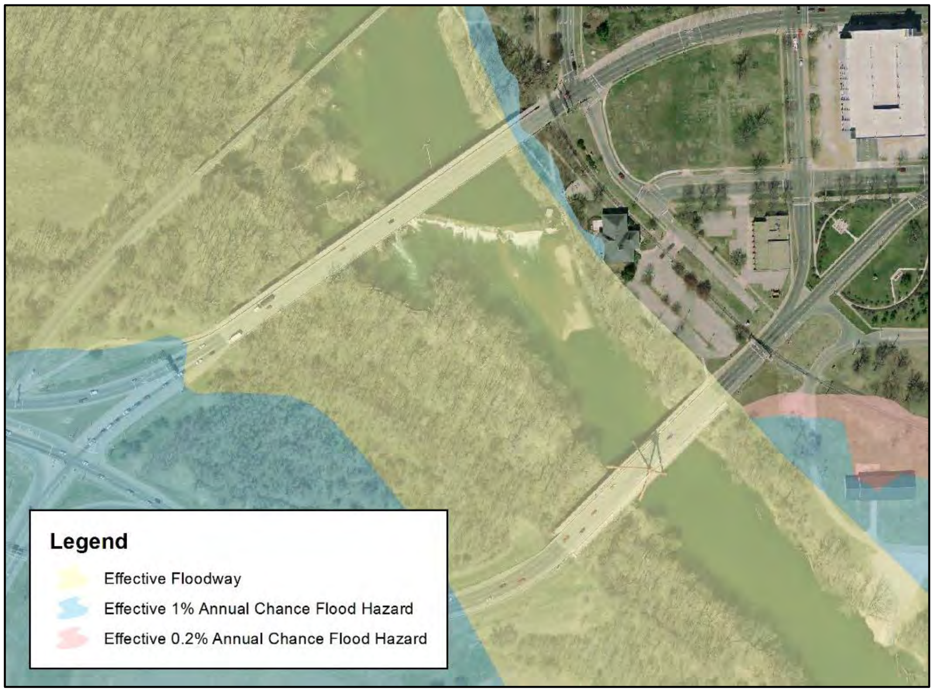


Figure 8: Effective Digital Flood Insurance Rate Map (DFIRM)

Since the project will include work below the ordinary high water mark, Section 401 and 404 permits are also required. Applications for these permits are submitted to the Indiana Department of Environmental Management (IDEM) and the United States Army Corps of Engineers (USACE), respectively.

HEC-RAS Profile: 100yr

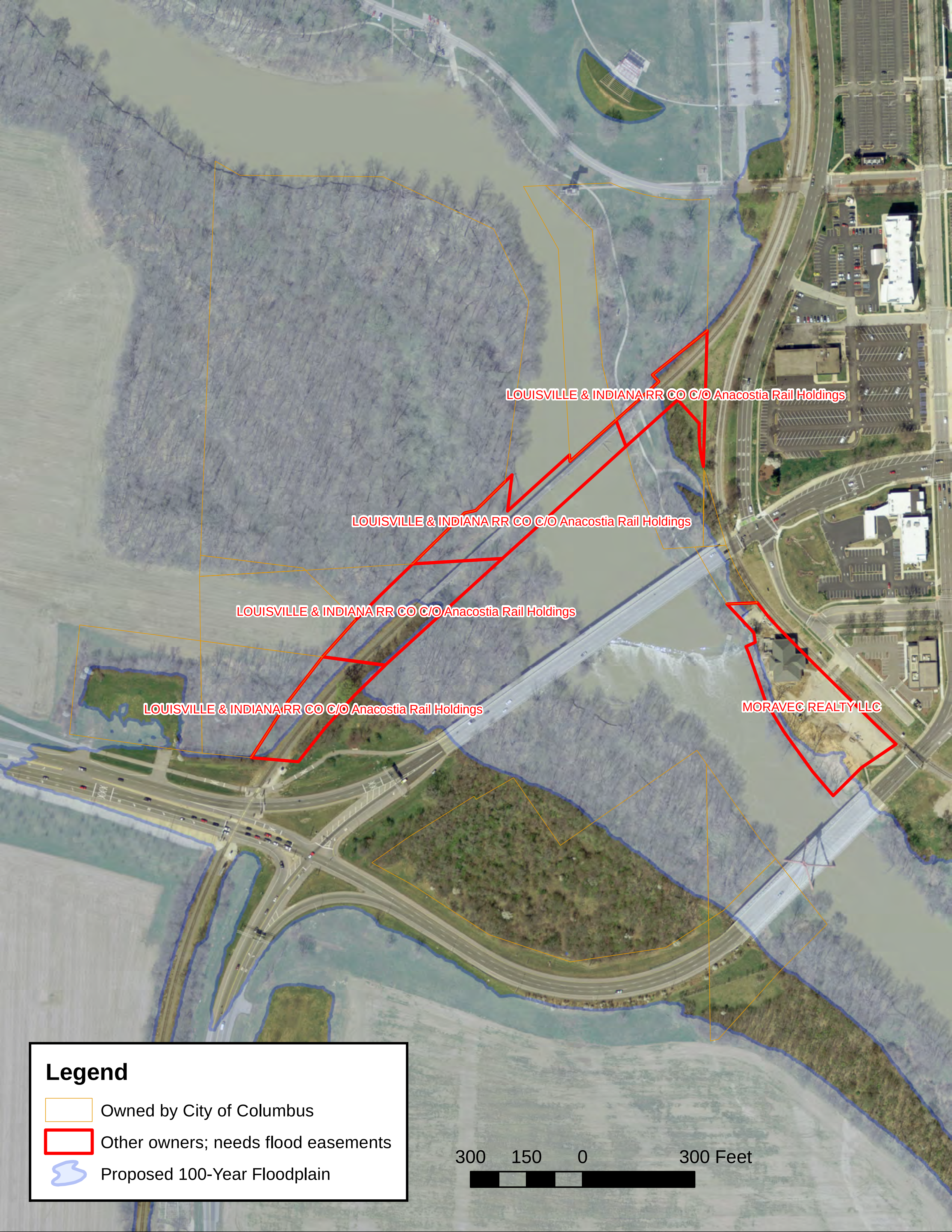
River	Reach	River Sta	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Bypass	Bypass	3694.208	Exist. Cond. 102317	12354.73	607.21	616.50		617.18	0.000573	7.41	1908.84	278.01	0.45
Bypass	Bypass	3694.208	PC - 102317	13070.17	607.21	616.49		617.25	0.000645	7.85	1905.53	277.91	0.47
Bypass	Bypass	3694.208	PC kayak 102317b	13057.54	607.21	616.49		617.24	0.000643	7.84	1905.58	277.91	0.47
Bypass	Bypass	3775.699 Railroad		Bridge									
Bypass	Bypass	3911.572	Exist. Cond. 102317	12354.73	609.19	617.48	613.28	617.68	0.001539	3.94	3722.63	4285.14	0.25
Bypass	Bypass	3911.572	PC - 102317	13070.17	609.19	617.59	613.44	617.81	0.001636	4.09	3782.15	4293.75	0.26
Bypass	Bypass	3911.572	PC kayak 102317b	13057.54	609.19	617.59	613.44	617.80	0.001634	4.09	3781.05	4293.58	0.26
Bypass	Bypass	5174.451	Exist. Cond. 102317	12354.73	612.28	618.31	614.99	618.33	0.000217	1.34	11060.43	3848.38	0.10
Bypass	Bypass	5174.451	PC - 102317	13070.17	612.28	618.44	615.03	618.47	0.000218	1.37	11436.76	3853.27	0.10
Bypass	Bypass	5174.451	PC kayak 102317b	13057.54	612.28	618.44	615.03	618.46	0.000218	1.37	11430.09	3853.20	0.10
Bypass	Bypass	5929.52	Exist. Cond. 102317	12354.73	613.61	618.61	616.84	618.65	0.000631	2.11	8357.71	4164.99	0.17
Bypass	Bypass	5929.52	PC - 102317	13070.17	613.61	618.75	616.85	618.78	0.000602	2.10	8775.87	4166.42	0.17
Bypass	Bypass	5929.52	PC kayak 102317b	13057.54	613.61	618.74	616.85	618.78	0.000602	2.10	8768.42	4166.40	0.17
Bypass	Bypass	7046.974	Exist. Cond. 102317	100.00	616.84	618.99	615.81	618.99	0.000000	0.02	4650.44	3893.87	0.00
Bypass	Bypass	7046.974	PC - 102317	100.00	616.84	619.10	615.81	619.10	0.000000	0.02	4962.15	3901.87	0.00
Bypass	Bypass	7046.974	PC kayak 102317b	100.00	616.84	619.10	615.81	619.10	0.000000	0.02	4956.51	3901.73	0.00
E Fk White River	Downstream	14482.36	Exist. Cond. 102317	78999.99	586.66	612.02	607.88	612.26	0.000615	6.29	43176.19	7512.77	0.26
E Fk White River	Downstream	14482.36	PC - 102317	78999.99	586.66	612.02	607.88	612.26	0.000615	6.29	43176.19	7512.77	0.26
E Fk White River	Downstream	14482.36	PC kayak 102317b	78999.99	586.66	612.02	607.88	612.26	0.000615	6.29	43176.19	7512.77	0.26
E Fk White River	Downstream	16472.65	Exist. Cond. 102317	78999.99	586.66	612.89		613.13	0.000441	5.57	45312.07	7999.16	0.22
E Fk White River	Downstream	16472.65	PC - 102317	78999.99	586.66	612.89		613.13	0.000441	5.57	45312.07	7999.16	0.22
E Fk White River	Downstream	16472.65	PC kayak 102317b	78999.99	586.66	612.89		613.13	0.000441	5.57	45312.07	7999.16	0.22
E Fk White River	Downstream	18834.63	Exist. Cond. 102317	78999.99	589.11	613.94		614.21	0.000652	6.26	39203.16	7552.46	0.27
E Fk White River	Downstream	18834.63	PC - 102317	78999.99	589.11	613.94		614.21	0.000652	6.26	39203.16	7552.46	0.27
E Fk White River	Downstream	18834.63	PC kayak 102317b	78999.99	589.11	613.94		614.21	0.000652	6.26	39203.16	7552.46	0.27
E Fk White River	Downstream	20916.99	Exist. Cond. 102317	78999.99	594.24	614.96	610.03	615.14	0.000472	5.26	45009.76	6915.90	0.22
E Fk White River	Downstream	20916.99	PC - 102317	78999.99	594.24	614.96	610.03	615.14	0.000472	5.26	45009.76	6915.90	0.22
E Fk White River	Downstream	20916.99	PC kayak 102317b	78999.99	594.24	614.96	610.03	615.14	0.000472	5.26	45009.76	6915.90	0.22
E Fk White River	E Fk White River	22840.12	Exist. Cond. 102317	66745.27	592.09	615.55	608.18	616.42	0.000659	8.06	12519.10	4400.99	0.35
E Fk White River	E Fk White River	22840.12	PC - 102317	66029.84	592.09	615.55	608.11	616.40	0.000644	7.97	12523.95	4401.31	0.35
E Fk White River	E Fk White River	22840.12	PC kayak 102317b	66042.45	592.09	615.55	608.12	616.40	0.000644	7.97	12523.95	4401.31	0.35
E Fk White River	E Fk White River	23995.08	Exist. Cond. 102317	66745.27	594.43	616.06	609.36	617.56	0.001046	10.00	7604.25	3006.19	0.44
E Fk White River	E Fk White River	23995.08	PC - 102317	66029.84	594.43	616.05	609.28	617.52	0.001026	9.90	7596.68	3005.93	0.44
E Fk White River	E Fk White River	23995.08	PC kayak 102317b	66042.45	594.43	616.05	609.29	617.52	0.001026	9.90	7596.91	3005.94	0.44
E Fk White River	E Fk White River	24621.73	Exist. Cond. 102317	66745.27	594.39	616.41	610.12	618.63	0.001229	12.46	7140.16	1967.20	0.50
E Fk White River	E Fk White River	24621.73	PC - 102317	66029.84	594.39	616.40	609.93	618.56	0.001205	12.29	7135.22	1967.00	0.49
E Fk White River	E Fk White River	24621.73	PC kayak 102317b	66042.45	594.39	616.40	609.93	618.57	0.001205	12.30	7135.43	1967.01	0.49
E Fk White River	E Fk White River	24695.09 SR 46 D/S		Bridge									
E Fk White River	E Fk White River	24788.9	Exist. Cond. 102317	66745.27	592.19	617.15	609.67	619.05	0.001001	11.56	7857.09	1243.54	0.45
E Fk White River	E Fk White River	24788.9	PC - 102317	66029.84	592.19	616.76	610.61	619.13	0.001322	13.02	7250.17	1206.05	0.52
E Fk White River	E Fk White River	24788.9	PC kayak 102317b	66042.45	592.19	616.76	610.66	619.13	0.001322	13.02	7250.44	1206.10	0.52
E Fk White River	E Fk White River	24895	Exist. Cond. 102317	66745.27	594.91	617.05	610.89	619.24	0.001229	12.42	7328.22	1218.93	0.50
E Fk White River	E Fk White River	24895	PC - 102317	66029.84	594.91	617.16	610.06	619.28	0.001184	12.20	7401.72	1242.56	0.49
E Fk White River	E Fk White River	24895	PC kayak 102317b	66042.45	596.00	617.15	610.81	619.28	0.001200	12.24	7380.79	1241.40	0.49
E Fk White River	E Fk White River	24905	Exist. Cond. 102317	66745.27	595.00	617.05	610.86	619.26	0.001224	12.46	7387.21	1223.35	0.50
E Fk White River	E Fk White River	24905	PC - 102317	66029.84	595.00	617.22	610.64	619.29	0.001149	12.08	7500.79	1239.98	0.48
E Fk White River	E Fk White River	24905	PC kayak 102317b	66042.45	597.00	617.07	611.32	619.33	0.001339	12.63	7222.16	1229.35	0.52
E Fk White River	E Fk White River	24920	Exist. Cond. 102317	66745.27	595.01	617.11	610.66	619.27	0.001179	12.34	7480.21	1211.33	0.49
E Fk White River	E Fk White River	24920	PC - 102317	66029.84	595.01	617.21	610.57	619.31	0.001152	12.19	7521.88	1221.05	0.48
E Fk White River	E Fk White River	24920	PC kayak 102317b	66042.45	598.50	616.82	612.20	619.46	0.001745	13.74	6797.14	1193.24	0.58
E Fk White River	E Fk White River	24930	Exist. Cond. 102317	66745.27	594.98	617.20	610.52	619.29	0.001138	12.14	7551.62	1208.46	0.48
E Fk White River	E Fk White River	24930	PC - 102317	66029.84	595.00	617.26	610.52	619.33	0.001131	12.08	7557.17	1215.93	0.48
E Fk White River	E Fk White River	24930	PC kayak 102317b	66042.45	596.00	617.50	610.60	619.53	0.001101	11.98	7653.00	1227.56	0.47
E Fk White River	E Fk White River	24946.33	Exist. Cond. 102317	66745.27	595.06	617.28	610.33	619.32	0.001093	11.98	7649.48	1199.56	0.47
E Fk White River	E Fk White River	24946.33	PC - 102317	66029.84	595.06	617.27	610.56	619.35	0.001136	12.12	7566.17	1203.21	0.48
E Fk White River	E Fk White River	24946.33	PC kayak 102317b	66042.45	595.06	617.53	610.56	619.55	0.001084	11.95	7699.88	1216.41	0.47
E Fk White River	E Fk White River	25012.47	Exist. Cond. 102317	66745.27	593.92	617.43	610.28	619.40	0.001086	11.82	7885.52	1072.38	0.46
E Fk White River	E Fk White River	25012.47	PC - 102317	66029.84	593.92	617.07	611.27	619.55	0.001339	13.42	7398.62	1040.27	0.52
E Fk White River	E Fk White River	25012.47	PC kayak 102317b	66042.45	593.92	617.34	611.31	619.74	0.001276	13.22	7538.18	1064.45	0.51
E Fk White River	E Fk White River	25115.85	Exist. Cond. 102317	66745.27	590.19	618.11	609.35	619.56	0.000724	10.15	9287.75	952.51	0.39
E Fk White River	E Fk White River	25115.85	PC - 102317	66029.84	590.19	618.28	609.96	619.78	0.000775	10.33	9090.35	958.62	0.40
E Fk White River	E Fk White River	25115.85	PC kayak 102317b	66042.45	590.19	618.50	609.95	619.96	0.000747	10.21	9216.71	971.83	0.39
E Fk White River	E Fk White River	25145	Exist. Cond. 102317	66745.27	590.16	618.31	609.08	619.59	0.000648	9.52	9665.70	952.07	0.37
E Fk White River	E Fk White River	25145	PC - 102317	66029.84	590.16	618.47	609.24	619.81	0.000655	9.78	9641.84	960.49	0.37
E Fk White River	E Fk White River	25145	PC kayak 102317b	66042.45	596.00	618.55	610.18	619.98	0.000754	10.17	9376.20	963.30	0.39
E Fk White River	E Fk White River	25155	Exist. Cond. 102317	66745.27	590.16	618.33	608.95	619.60	0.000626	9.46	9751.40	938.60	0.36
E Fk White River	E Fk White River	25155	PC - 102317	66029.84	590.16	618.54	609.04	619.82	0.000621	9.54	9786.61	946.79	0.36
E Fk White River	E Fk White River	25155	PC kayak 102317b	66042.45	598.50	618.44	611.43	620.03	0.000959	10.77	8903.12	943.11	0.44
E Fk White River	E Fk White River	25170	Exist. Cond. 102317	66745.27	590.44	618.43	608.75	619.61	0.000588	9.08	9853.71	932.82	0.35
E Fk White River	E Fk White River	25170	PC - 102317	66029.84	590.44	618.64	608.89	619.83	0.000586	9.17	9879.90	941.61	0.35
E Fk White River	E Fk White River	25170	PC kayak 102317b	66042.45	600.00	618.39	612.23	620.07	0.001122	11.02	8526.69	932.97	0.47
E Fk White River	E Fk White River	25180	Exist. Cond. 102317	66745.27	590.38	618.47	608.65	619.62	0.000571	8.94	9950.51	912.77	0.34
E Fk White River	E Fk White River	25180	PC - 102317	66029.84	590.38	618.67	608.78	619.84	0.000567	9.05	9994.84	923.93	0.34
E Fk White River	E Fk White River	25180	PC kayak 102317b	66042.45	596.00	618.89	609.69	620.12	0.000628	9.31	9821.35	959.95	0.36
E Fk White River	E Fk White River	25193.97	Exist. Cond. 102317	66745.27	590.56	618.54	608.39	619.63	0.000533	8.70	10187.88	883.80	0.33

HEC-RAS Profile: 100yr (Continued)

River	Reach	River Sta	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
E Fk White River	E Fk White River	25193.97	PC - 102317	66029.84	590.56	618.75	608.77	619.85	0.000544	8.80	10172.06	917.78	0.34
E Fk White River	E Fk White River	25193.97	PC kayak 102317b	66042.45	590.56	619.07	608.76	620.14	0.000516	8.65	10376.55	956.60	0.33
E Fk White River	E Fk White River	25260.43	Exist. Cond. 102317	66745.27	594.75	618.72	607.96	619.68	0.000462	8.22	11114.17	734.51	0.31
E Fk White River	E Fk White River	25260.43	PC - 102317	66029.84	591.57	619.12	608.13	619.91	0.000401	7.40	11271.60	744.59	0.29
E Fk White River	E Fk White River	25260.43	PC kayak 102317b	66042.45	591.57	619.43	608.14	620.20	0.000381	7.29	11477.12	751.83	0.28
E Fk White River	E Fk White River	25333.41	Exist. Cond. 102317	66745.27	595.94	618.91	608.64	619.73	0.000464	7.52	11324.14	798.81	0.30
E Fk White River	E Fk White River	25333.41	PC - 102317	66029.84	595.94	619.26	606.94	619.95	0.000325	6.92	12439.84	804.30	0.26
E Fk White River	E Fk White River	25333.41	PC kayak 102317b	66042.45	595.94	619.57	606.94	620.23	0.000310	6.82	12658.31	810.71	0.26
E Fk White River	E Fk White River	25361	Exist. Cond. 102317	66745.27	595.33	619.00	607.98	619.75	0.000387	7.15	11677.39	830.28	0.28
E Fk White River	E Fk White River	25361	PC - 102317	66029.84	595.33	619.30	606.90	619.96	0.000316	6.77	12440.77	835.60	0.26
E Fk White River	E Fk White River	25361	PC kayak 102317b	66042.45	595.33	619.60	606.89	620.25	0.000301	6.67	12667.03	841.00	0.25
E Fk White River	E Fk White River	25371	Exist. Cond. 102317	66745.27	595.69	619.02	607.85	619.75	0.000376	7.06	11862.02	840.50	0.28
E Fk White River	E Fk White River	25371	PC - 102317	66029.84	595.69	619.31	606.75	619.97	0.000310	6.73	12597.98	845.64	0.25
E Fk White River	E Fk White River	25371	PC kayak 102317b	66042.45	600.00	619.60	609.62	620.25	0.000382	6.59	11716.92	850.81	0.27
E Fk White River	E Fk White River	25386	Exist. Cond. 102317	66745.27	594.14	619.02	607.98	619.77	0.000386	7.15	11914.91	856.37	0.28
E Fk White River	E Fk White River	25386	PC - 102317	66029.84	594.14	619.33	606.74	619.98	0.000305	6.65	12742.68	863.04	0.25
E Fk White River	E Fk White River	25386	PC kayak 102317b	66042.45	601.50	619.58	610.82	620.27	0.000461	6.83	11172.32	868.18	0.30
E Fk White River	E Fk White River	25396	Exist. Cond. 102317	66745.27	593.80	619.08	607.83	619.78	0.000359	6.89	12225.03	869.97	0.27
E Fk White River	E Fk White River	25396	PC - 102317	66029.84	593.80	619.36	606.69	619.98	0.000292	6.52	12985.10	876.00	0.25
E Fk White River	E Fk White River	25396	PC kayak 102317b	66042.45	598.00	619.62	607.96	620.28	0.000331	6.75	12675.95	881.35	0.26
E Fk White River	E Fk White River	25400 Low-head Dam		Inl Struct									
E Fk White River	E Fk White River	25419.33	Exist. Cond. 102317	66745.27	594.75	619.38	606.82	619.95	0.000277	6.21	13344.52	915.37	0.24
E Fk White River	E Fk White River	25419.33	PC - 102317	66029.84	597.00	619.51	606.72	620.02	0.000251	5.92	13618.35	917.86	0.23
E Fk White River	E Fk White River	25419.33	PC kayak 102317b	66042.45	597.55	619.82	607.15	620.33	0.000252	5.92	13674.66	926.03	0.23
E Fk White River	E Fk White River	25502.81 SR 46 U/S		Bridge									
E Fk White River	E Fk White River	25590.99	Exist. Cond. 102317	66745.27	595.84	621.48	609.44	621.99	0.000264	5.91	13553.47	937.78	0.23
E Fk White River	E Fk White River	25590.99	PC - 102317	66029.84	595.84	621.65	609.38	622.14	0.000250	5.78	13706.18	942.87	0.23
E Fk White River	E Fk White River	25590.99	PC kayak 102317b	66042.45	595.84	621.65	609.34	622.14	0.000250	5.79	13704.20	942.81	0.23
E Fk White River	E Fk White River	25880.21	Exist. Cond. 102317	66745.27	595.95	621.47	609.15	622.12	0.000310	6.82	13330.24	1047.45	0.26
E Fk White River	E Fk White River	25880.21	PC - 102317	66029.84	595.95	621.64	609.08	622.27	0.000295	6.69	13464.26	1048.31	0.25
E Fk White River	E Fk White River	25880.21	PC kayak 102317b	66042.45	595.95	621.64	609.08	622.26	0.000295	6.69	13462.32	1048.30	0.25
E Fk White River	E Fk White River	25930.84 Railroad		Bridge									
E Fk White River	E Fk White River	26000.59	Exist. Cond. 102317	66745.27	594.16	622.24	613.35	622.85	0.000405	7.92	19739.56	1704.08	0.29
E Fk White River	E Fk White River	26000.59	PC - 102317	66029.84	594.16	622.38	613.22	622.96	0.000386	7.76	19937.99	1751.88	0.28
E Fk White River	E Fk White River	26000.59	PC kayak 102317b	66042.45	594.16	622.37	613.22	622.96	0.000386	7.76	19935.14	1751.74	0.28
E Fk White River	E Fk White River	26421		Lat Struct									
E Fk White River	E Fk White River	26421.79	Exist. Cond. 102317	66745.27	588.67	622.74	612.62	623.03	0.000219	5.91	29134.04	2602.28	0.21
E Fk White River	E Fk White River	26421.79	PC - 102317	66029.84	588.67	622.85	612.50	623.14	0.000209	5.79	29392.40	2603.13	0.21
E Fk White River	E Fk White River	26421.79	PC kayak 102317b	66042.45	588.67	622.85	612.50	623.14	0.000209	5.79	29388.80	2603.11	0.21
E Fk White River	Driftwood River	29149.01	Exist. Cond. 102317	45745.27	586.97	623.30	605.14	623.32	0.000042	1.47	51908.75	7323.46	0.05
E Fk White River	Driftwood River	29149.01	PC - 102317	45029.84	586.97	623.40	605.02	623.41	0.000040	1.43	52363.16	7324.38	0.05
E Fk White River	Driftwood River	29149.01	PC kayak 102317b	45042.46	586.97	623.39	605.01	623.41	0.000040	1.43	52357.18	7324.37	0.05
E Fk White River	Driftwood River	29294.42	Exist. Cond. 102317	46384.07	587.16	623.31	605.02	623.33	0.000052	1.62	47108.73	7055.20	0.05
E Fk White River	Driftwood River	29294.42	PC - 102317	45706.05	587.16	623.40	604.88	623.42	0.000050	1.58	47533.60	7055.95	0.05
E Fk White River	Driftwood River	29294.42	PC kayak 102317b	45718.00	587.16	623.40	604.88	623.42	0.000050	1.58	47527.71	7055.94	0.05
E Fk White River	Driftwood River	29945.09	Exist. Cond. 102317	49052.65	588.28	623.35		623.40	0.000106	2.47	37967.98	3731.61	0.08
E Fk White River	Driftwood River	29945.09	PC - 102317	48551.41	588.28	623.44		623.48	0.000101	2.42	38303.72	3732.27	0.08
E Fk White River	Driftwood River	29945.09	PC kayak 102317b	48560.17	588.28	623.44		623.48	0.000101	2.42	38299.16	3732.26	0.08
E Fk White River	Driftwood River	32717.47	Exist. Cond. 102317	51824.88	589.69	623.48		623.58	0.000105	4.02	35461.99	3417.20	0.14
E Fk White River	Driftwood River	32717.47	PC - 102317	51506.35	589.69	623.56		623.66	0.000101	3.96	35749.40	3417.37	0.14
E Fk White River	Driftwood River	32717.47	PC kayak 102317b	51511.94	589.69	623.56		623.66	0.000101	3.96	35745.65	3417.37	0.14
E Fk White River	Driftwood River	33000		Lat Struct									
E Fk White River	Driftwood River	34355.38	Exist. Cond. 102317	58000.00	591.66	623.62	613.97	624.00	0.000269	6.60	24473.27	4336.76	0.23
E Fk White River	Driftwood River	34355.38	PC - 102317	58000.00	591.66	623.70	613.97	624.07	0.000263	6.54	24775.76	4350.10	0.23
E Fk White River	Driftwood River	34355.38	PC kayak 102317b	58000.00	591.66	623.70	613.97	624.07	0.000263	6.54	24771.78	4350.02	0.23
E Fk White River	Driftwood River	36542.54	Exist. Cond. 102317	58000.00	592.63	624.23	617.46	624.45	0.000360	5.53	25293.61	3594.01	0.20
E Fk White River	Driftwood River	36542.54	PC - 102317	58000.00	592.63	624.29	617.46	624.51	0.000353	5.48	25480.71	3604.00	0.20
E Fk White River	Driftwood River	36542.54	PC kayak 102317b	58000.00	592.63	624.29	617.46	624.50	0.000353	5.48	25478.35	3603.93	0.20
E Fk White River	Driftwood River	38101.84	Exist. Cond. 102317	58000.00	595.03	624.49	618.88	625.01	0.000445	7.92	24772.56	3307.98	0.30
E Fk White River	Driftwood River	38101.84	PC - 102317	58000.00	595.03	624.55	618.88	625.06	0.000438	7.88	24917.20	3308.29	0.30
E Fk White River	Driftwood River	38101.84	PC kayak 102317b	58000.00	595.03	624.55	618.88	625.06	0.000438	7.88	24915.15	3308.29	0.30
E Fk White River	Driftwood River	40293.01	Exist. Cond. 102317	58000.00	596.26	625.51	615.65	625.71	0.000327	4.91	27454.67	2890.09	0.18
E Fk White River	Driftwood River	40293.01	PC - 102317	58000.00	596.26	625.55	615.65	625.75	0.000324	4.90	27543.13	2890.58	0.18
E Fk White River	Driftwood River	40293.01	PC kayak 102317b	58000.00	596.26	625.55	615.65	625.75	0.000324	4.90	27541.70	2890.58	0.18
Flatrock River	Flatrock River	1731.978	Exist. Cond. 102317	32500.00	588.25	623.27	609.72	623.34	0.000070	2.81	23624.03	6910.17	0.12
Flatrock River	Flatrock River	1731.978	PC - 102317	32500.00	588.25	623.37	609.75	623.44	0.000068	2.77	23941.24	6948.93	0.11
Flatrock River	Flatrock River	1731.978	PC kayak 102317b	32500.00	588.25	623.37	609.75	623.43	0.000068	2.78	23936.95	6948.65	0.11
Flatrock River	Flatrock River	1951.863 Indianapolis Rd.		Bridge									
Flatrock River	Flatrock River	2111.834	Exist. Cond. 102317	32500.00	588.63	623.36	612.73	623.68	0.000231	5.32	10908.13	6970.24	0.21
Flatrock River	Flatrock River	2111.834	PC - 102317	32500.00	588.62	623.46	612.72	623.77	0.000224	5.25	11135.98	7038.31	0.21
Flatrock River	Flatrock River	2111.834	PC kayak 102317b	32500.00	588.62	623.46	612.72	623.77	0.000224	5.26	11132.92	7037.43	0.21
Flatrock River	Flatrock River	5313.844	Exist. Cond. 102317	32500.00	592.91	624.08	614.26	624.80	0.000516	7.37	7211.88	7795.67	0.30
Flatrock River	Flatrock River	5313.844	PC - 102317	32500.00	592.91	624.15	614.26	624.86	0.000509	7.33	7257.57	7801.25	0.30

HEC-RAS Profile: 100yr (Continued)

River	Reach	River Sta	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Flatrock River	Flatrock River	5313.844	PC kayak 102317b	32500.00	592.91	624.15	614.26	624.86	0.000509	7.33	7256.97	7801.18	0.30


LOUISVILLE & INDIANA RR CO C/O Anacostia Rail Holdings
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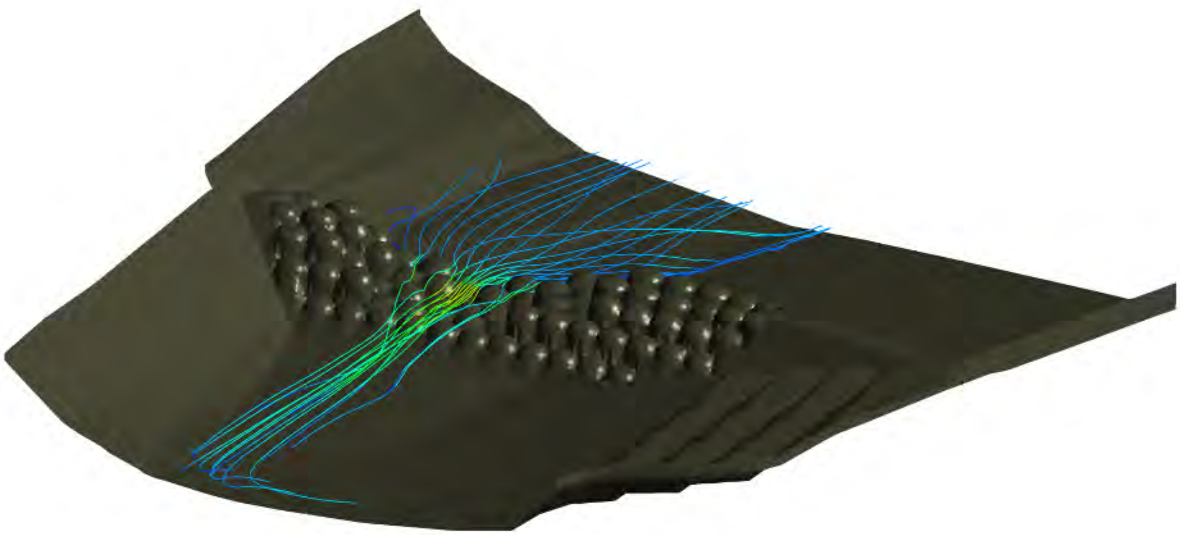
MORAVEC REALTY LLC
Legend
Owned by City of Columbus
Other owners; needs flood easements
Proposed 100-Year Floodplain
300 150 0 300 Feet

Appendix C

Computational Fluid Dynamics Study of Fish Passage and Aquatic Habitat for Redesigned Whitewater Structures by S2O Design & Engineering

Computational Fluid Dynamics Study of Fish Passage and Aquatic Habitat for Redesigned Whitewater Structures in Meadow Park

September 29th, 2015



REPORT PREPARED FOR:

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Contents

Abstract

The September 2013 flood on the North St. Vrain River in Lyons, CO, largely destroyed the Meadow Park Whitewater Park. Prior to the flood, Colorado Parks and Wildlife (CPW) had conducted several studies at this site to investigate the impacts of existing whitewater park structures on fish passage and aquatic habitat. These studies identified characteristics of whitewater park structures that may negatively affect fisheries and proposed ways to mitigate these impacts. Meadow Park is currently being redesigned as part of the Lyons flood recovery process and the study presented herein was undertaken to evaluate proposed design alternatives prior to construction in order to optimize the redesigned structures for both fish passage and recreation opportunities.

This study analyzed four prototype whitewater structure geometries that included distinct characteristics intended to improve fish passage opportunities and habitat at the Meadow Park Whitewater Park. These characteristics included low and high slope roughened structures, a fish notch structure, and an alternating terrace structure.

A 3D Computational Fluid Dynamics (CFD) model was developed to compare hydraulic parameters between redesigned structure geometries and pre-flood whitewater structure geometries. Of the four geometries analyzed, the structure containing a fish notch in the center chute consistently produced the most desirable hydraulic conditions for fish passage, aquatic habitat, and recreational use at Meadow Park. The study also found that these results may not be universal, whitewater structure geometry selection is highly dependent on local site conditions. Though this study identified the Fish Notch geometry as the preferred alternative, site specific conditions such as channel geometries, hydrology, and 3D hydrodynamics may produce differing results in larger rivers and other locations.

The study also evaluated the whitewater characteristics of the structures with regards to recreational value to in-stream users. The revised structure geometries for the Meadow Park Whitewater Park redesign were selected based on physical and ecological criteria identified by CPW and are intended to meet both the needs of the recreationists as well as provide for fish passage and improve aquatic habitat.

Introduction

Whitewater Parks (WWPs) have become popular recreational amenities in cities across the United States. WWPs provide access to outdoor recreation, promote public interest in rivers, and generate economic revenue through tourism and the associated benefits to nearby businesses. Colorado has more WWPs than any other state in the nation and leads the way in WWP development with all of the Country's leading design firms based in the State.

Riverine WWPs typically consist of in-stream structures designed to create a hydraulic jump by modifying channel geometries to constrict flows and create a steep chute into a larger, downstream pool. Previous studies have identified four major hydraulic factors within WWPs that could directly limit upstream fish passage, including: velocity, depth, total drop and turbulence (Fox, 2013). The first whitewater parks were simple efforts designed to create robust structures that formed recreationally appealing hydraulics. These early parks were largely successful in their objectives and many of these early parks have become renowned attractions that draw boaters from around the world. Early WWP designs, such as those seen in the first iteration of Meadow Park in Lyons, Colorado, were of a simple design constructed using large amounts of concrete grout to form smooth monolithic structures. The field of WWP design has recently expanded to include moveable systems, pneumatic systems, and a variety of shapes and layouts. Despite the advances in design and construction of WWPs, and despite the aforementioned studies, little to no effort has been undertaken by designers to evaluate and tailor WWP designs to address potential ecological impacts.

The increasing prevalence of WWPs and the rapid evolution of new whitewater park design concepts has created concerns about the ecological impact of WWPs. Specifically, Colorado Parks and Wildlife (CPW) is concerned about the potential impact of WWPs on aquatic habitat and fish passage. This concern has led to several studies that investigate the relationships between WWP structure geometries, associated hydraulic conditions, and fisheries impacts. These studies can inform the field of WWP design, thereby creating more ecologically sound WWPs while simultaneously meeting the objectives of communities and recreationalists.

The original Meadow Park WWP was constructed in 2003 and consisted of nine river-wide grouted boulder structures within a 0.35 mile reach of the South St. Vrain River in Lyons, Colorado. In the years following its construction, CPW conducted a series of studies to evaluate the WWPs impacts to fish passage and aquatic habitat. During the flood of 2013, the Meadow Park WWP was largely destroyed. Since then the Town of Lyons has been pursuing the redesign and eventual reconstruction of the WWP and has thereby created an ideal location to compare before-and-after data with regards to fish passage. This study, in conjunction with the previous studies, has informed the redesign effort by identifying preferred design alternatives for the proposed WWP features at Meadow Park.

The overarching goal of the redesigned Meadow Park WWP is to improve fish passage and aquatic habitat, particularly during low flow periods identified by CPW, while simultaneously enhancing river-based recreation during the annual high water season. This study will assist in reaching the stated goals for Meadow Park by analyzing results obtained from a 3D Computational Fluid Dynamics (CFD) model, which calculates hydraulic conditions associated with structure geometries. Four separate proposed WWP structure geometries were evaluated at four different flow rates and compared to modeled results obtained from the earlier studies performed at Meadow Park.

The redesign and eventual reconstruction of the Meadow Park WWP, combined with the results outlined in the pre-flood studies completed by CPW, provides an ideal experimental set-up to evaluate the effects of WWP structure geometries on fish passage and aquatic habitat. The effects of WWP structure geometries on hydraulic conditions and subsequently their impacts to fish passage and aquatic habitat are analyzed in this study. Moreover, a framework for conducting before and after comparisons of the pre-flood and redesigned Meadow Park WWP are outlined herein.

Literature Review

Historically, there has been limited information regarding the impacts of WWPs on fisheries and aquatic ecosystem health. In an effort to fill this gap, Colorado State University (CSU) and CPW have undertaken a multi-year study to determine the effects of WWPs on fish habitat quality, stream connectivity, fish populations and fish passage at the Meadow Park WWP. To date, three separate studies based on the pre-flood configuration of the Meadow Park WWP have been completed. These pre-flood studies provide historical data for future studies such as the one presented herein.

Constructed in 2003, the Meadow Park WWP consisted of nine separate river wide structures, representing a range of physical geometries and associated recreational experiences. Three of the structures, along with three control reach (CR) sites, were selected for the studies completed by CSU/CPW. The WWP sites were identified as WWP1, WWP2, and WWP3. The CSU/CPW study area is shown below in Figure 1 and Figure 2.

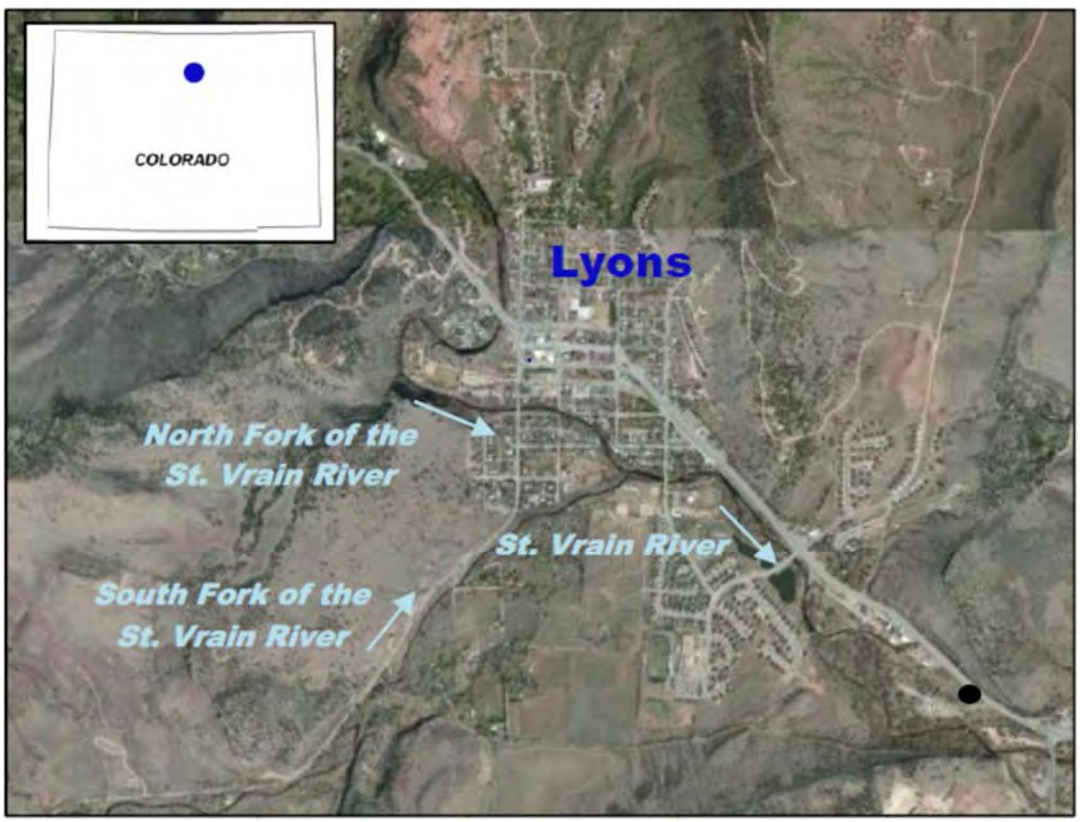


Figure 1: Study location, (Fox, 2013, p. 15).

Figure 2: Study Location, (Fox, 2013, p. 16)

The studies undertaken to date focus on altered hydraulic conditions at the WWP sites and rely on field data and 3D CFD modeling of the structures to assess impacts. A hydraulic dataset for the Meadow Park WWP was developed using FLOW-3D and this dataset was used to assess the effects of WWPs on fish passage (Fox, 2013) and habitat quality (Kolden, 2013). Stephens (2014) further used the results of the previous two studies to analyze the relationship between WWP hydraulics and fish passage. The selected control sites provided a baseline comparison for habitat and fish passage conditions.

Flow through a WWP structure is hydraulically complex and 3D modeling has the potential to be extremely useful in furthering our understanding of the effect of turbulence, vorticity and circulation on habitat quality (Kondratieff, 2013). The use of CFD modeling provides a powerful means of estimating the fine-scale hydrodynamic conditions through which fish passage must occur. Numerous studies have used CFD models to examine complex hydraulics related to fish passage and in-stream structures. Velocity, depth and turbulence have been used as variables to assess the hydraulic environment in the pre-flood studies. Vorticity and Turbulent Kinetic Energy (TKE) are measures of turbulence that influence fish movement. Vorticity is a pseudo vector representing the rotation rate of a small fluid element about its axis (Crowder DW, 2002). TKE is a measure of the increase in kinetic energy due to turbulent velocity fluctuations in the flow (Lacey RWJ, 2012); (Flow Science, 2009).

The study conducted by Brian Fox in 2013, *Eco-Hydraulic Evalution of Whitewater Parks as Fish Passage Barriers,* used a combination of fish movement monitoring and CFD modelling to assess if WWPs are barriers to upstream fish movement. CFD models provided detailed hydraulic conditions that were used to evaluate the flow field at all discharges over all modeled spatial and temporal fields.

Fox quantified fish movement across the Meadow Park WWP structures using Passive Integrated Transponder (PIT) telemetry system to track fish movement. Brown trout, rainbow trout, longnose sucker, and longnose dace were tagged and released for the study. Fixed PIT antennas were installed upstream and downstream of WWP structures along with the control sites to monitor fish movements. Raw PIT data were analyzed to determine if WWP structures posed a complete barrier to upstream movement for a given fish species or class size. Determination of partial barriers was completed by comparing raw movement counts for fishes known to make it upstream versus those that did not (Fox, 2013). This design measured successful passage across a structure, but did not quantify failed passage attempts, number of attempts, or behavior across the structure (Fox, 2013).

The commercially available software, FLOW-3D, was used to create 3D non-hydrostatic models of the each of the 3 WWP structures and three control sites. Six flow events (15, 30, 60, 100, 150 and 300 cfs) were modeled in FLOW-3D (Fox, 2013). 2D surfaces perpendicular to the flow were demarcated and the distribution of velocity values that described the range of potential flow conditions (Fox, 2013). The maximum, mean, 5^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentile velocities were calculated within each cross section and used to assess opportunities for fish passage. This method does not account for connectivity and flow paths between or within the each of the cross sections.

Fox found that rainbow and brown trout were able to complete upstream movement across all WWP structures at nearly all flows studied. Fish body length, which is positively correlated with swimming ability, did not correlate with fish passage success across all three structures. Fox found a positive relationship between fish size and passage at WWP2, however, a negative relationship between movement and size existed at WWP1 (large fish were less likely to move), and a positive, but weak, relationship at WWP3. Further regression model analyses revealed that individual site location, body length, and species are all significant effects in estimating upstream movement probability (Fox, 2013). Furthermore, the interaction of length and location indicated that fishes of different body lengths have different probabilities of moving across various WWP structures and control pools. The inconsistency between fish size and passage is shown in Figur*e* 3, below, where it is evident that the trend between size and probability of movement varies between structures. These results suggest that there are factors other than size that influence the probability of fish passage at whitewater park structures and highlights the need for further studies to investigate the impacts of structure geometry on fish passage.

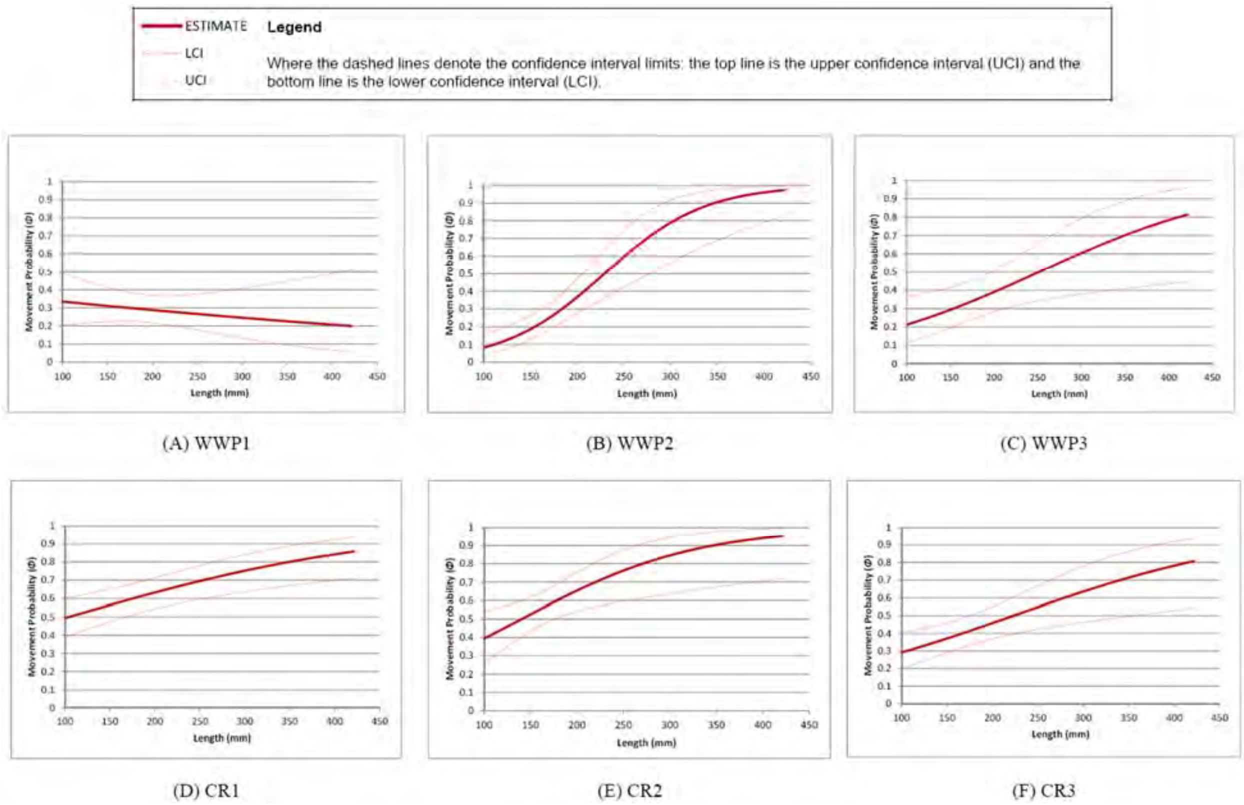


Figure 3: Effects of continuous variable body length on probability of upstream movement (Fox, 2013, p. 49).

Hydraulic modeling results were further used to evaluate and describe the flow velocity at each study site location. Flow velocity is a potential barrier to fish passage. Velocity can be either a burst swimming barrier, where the velocity exceeds a fish's maximum swimming speed, or an exhaustive swimming barrier, where a fish is unable to maintain positive ground over a given distance (Stephens, 2014).

The hydraulic modeling results, from Fox's report, show the range of velocities present at each WWP structures (Figure 4) and the Control Reaches (CR) (Figure 5). Fox (2013) further quantified velocities into 5th, 25th, 75th and 95th percentiles. For example, a flow classified at the 25th percentile indicates that 25% of the velocities sampled in the cross-section are less than or equal to the given velocity and the remaining 75% of the velocities sampled are greater than the given velocity.

The maximum velocities within the center chute of the WWP structures are significantly greater than those in the CR (Fox, 2013). The differences in velocities due to WWP structure geometries are seen below in Figure 4 and Figure 5. WWP1 is a short, steep drop, while WWP2 is a "wave" structure and consists of a longer, sloping chute with a confined outlet to the downstream plunge pool. WWP1 shows complex flow conditions due to the non-uniformity on the cross-sectional area. During low flows, the concentrated flow results in shallow depths, however the interstitial spacing may allow for potential passage routes. At WWP2 the entire flow area of the channel is restricted to the center chute at low discharges, however, there is only a very short section of the structure that contains high velocity magnitudes. WWP3 is also a "wave" structure, however, unlike WWP2, WWP3 has a maximum flow area constriction near the middle of the center chute and then expands laterally. This allows for reverse eddies to form on the sides of the jump of the plunge pool, possibly providing a by-pass around the high center velocities. These results highlight the influence of WWP structure geometry and design on velocity and fish passage.

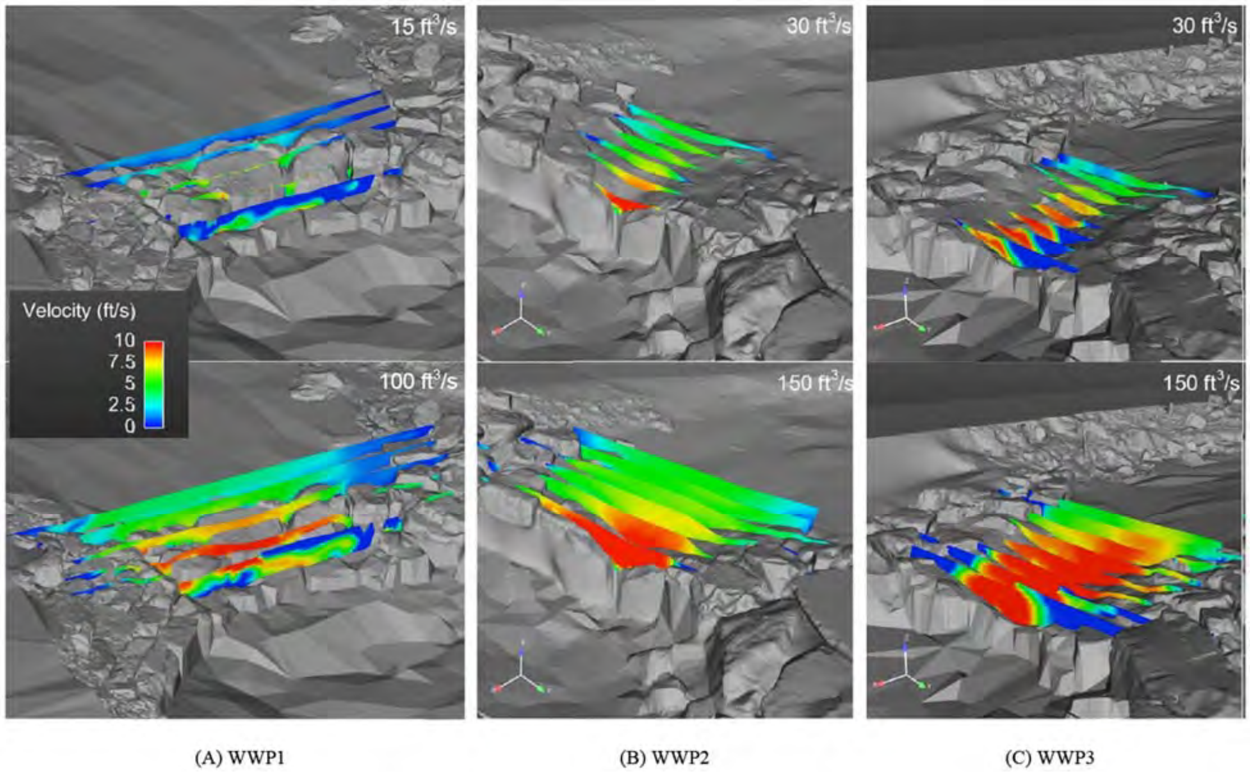


Figure 4: Cross sectional velocities for a low and high flow condition at (A) WWP1; (B) WWP2; (C) WWP3 (Fox, 2013, p. 52)

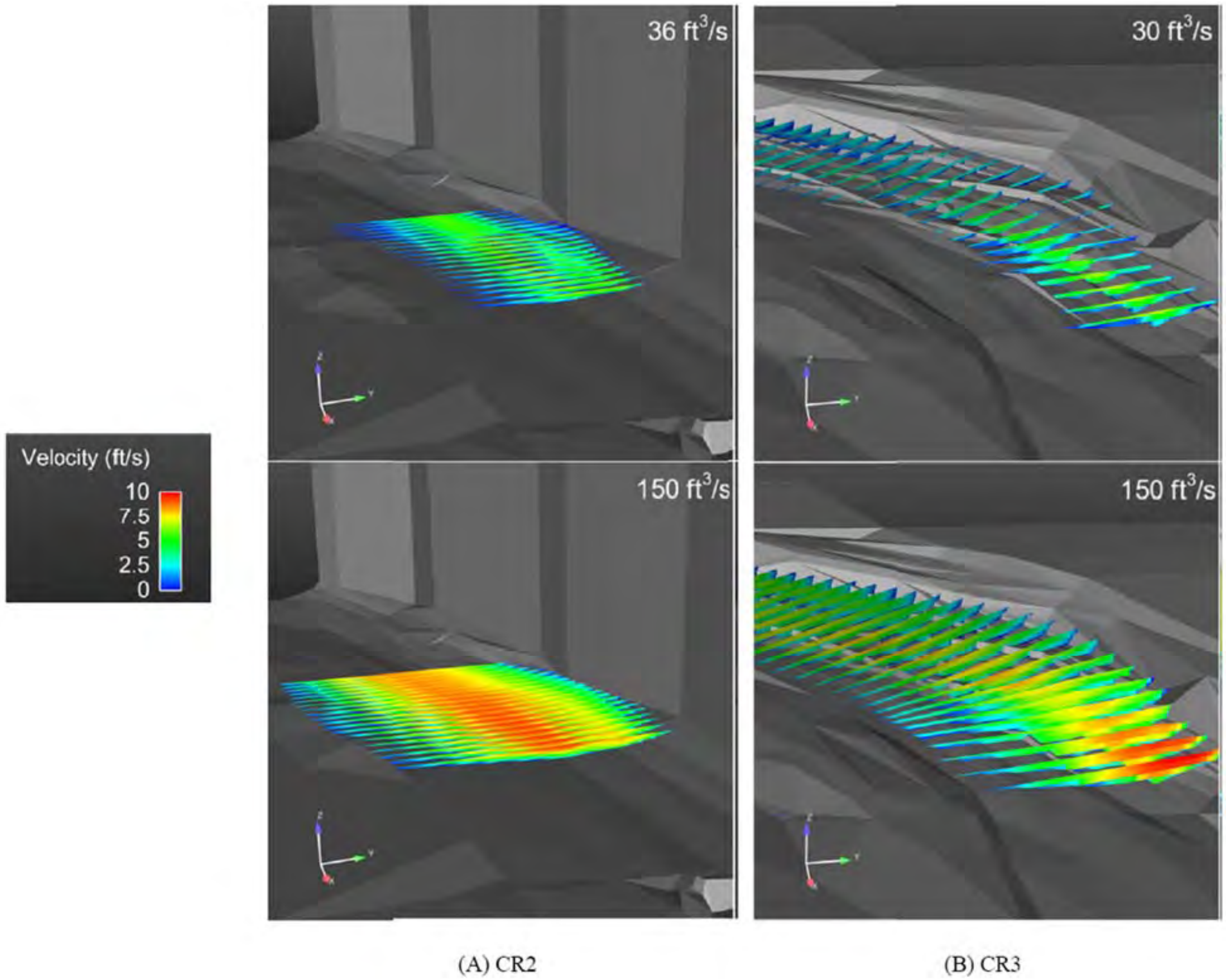


Figure 5: Cross-sectional velocities for a low and high flow condition at: (A) CR2 and (B) CR3 (Fox, 2013).

The burst swimming abilities of fish species coupled with the velocities generated by the WWP structures can influence the upstream mobility of fishes at Meadow Park. Castro-Santos (2013) suggests that brown trout have greater burst swimming abilities (up to 25 body lengths/s) than previously found by Peake (1997) (10 body lengths/second). Based on this study, a burst swimming barrier was assessed by considering the maximum velocity at each cross-section. The maximum velocities are considered the limiting condition burst swimming barrier.

The velocities calculated by the hydraulic models were typically less than calculated burst velocities, further suggesting that there are other factors that may explain the lack of correlation between fish size and passage at the studied WWP structures. While the study showed that cross-sectional velocity for burst swimming conditions shows large differences between CR and WWPs in the magnitude of velocity that must be overcome however, the velocities found in the WWP structures are likely not burst swimming barriers to salmonids despite flow velocities greater than 10 ft/s within each of the WWP structures (Fox, 2013). Figure 6, below, illustrates the velocity distributions through the WWP structures and the control reaches.

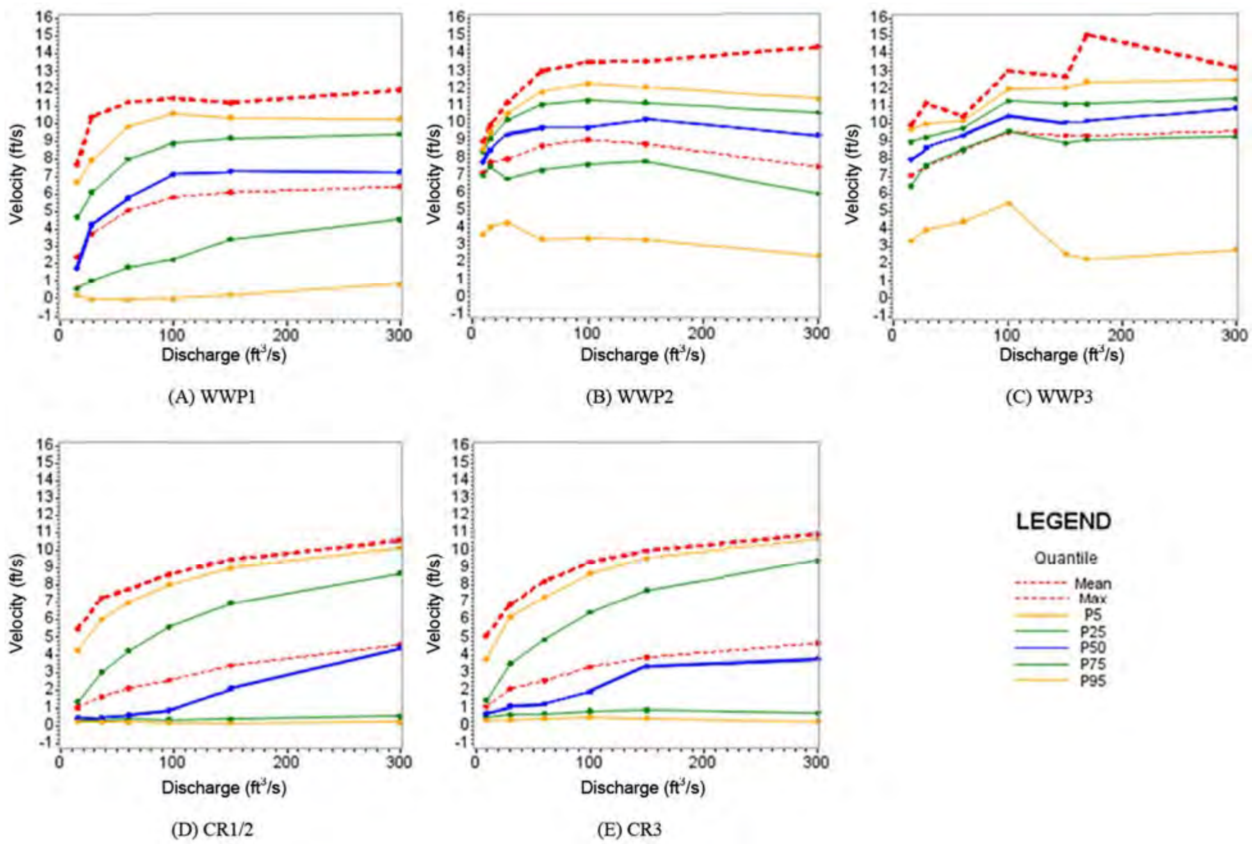


Figure 6: Limiting magnitudes of velocity within the zone of passage to assess burst swimming barriers (Fox, 2013, p. 57).

Successful movement was observed within WWP sites where fish were able to overcome velocities ranging from 8 ft/s in the 25th percentile to 12 ft/s in the 95th percentile (Fox, 2013). The control sites maintained lower velocities within 25-50% of the cross-sectional area, but the maximum flow velocities were nearly as high as those in the WWP sites.

Rainbow and brown trout were successfully able to pass each WWP structure, suggesting that the WWP does not represent a complete barrier to upstream movement (Fox, 2013). Results pertaining to native fish were less conclusive due to the relatively small sample sizes utilized in the study conducted by Fox. However, successful passage of longnose dace was observed at two of the three WWP structures studied and successful passage of longnose suckers was observed at all three of the WWP structures studied. Other potential causes for reduced fish movement include: an exhaustive swimming barrier, reduced flow depth, total hydraulic drop, turbulence, habitat quality, fish behavior, and/or differences in survival between WWP and CR sites.

Modeling results indicated that an exhaustive swimming barrier is unlikely. While all three structures show zones of high-flow velocities, these are generally limited to the downstream point of the center chute. Lower velocities can be observed at locations close to the outlet and along the channel margins, providing favorable conditions for the remainder of the passageway (Fox, 2013). Despite the higher velocities at the WWP sites, there was not a significant trend between passage and body length (Fox, 2013).

In the Discussion Section of Fox's study he recommends certain guidelines for the design of WWP structures, which include: structures that maintain short, high-velocity zones should be passable for species of similar swimming abilities; the presence of lower velocity routes around high velocity zones and roughness elements on the lateral margins of the channel also may improve fish passage success by reducing and magnitude of a potential velocity challenge.

A study conducted by Eleanor Kolden, *Modeling in a Three-Dimensional World: Whitewater Park Hydraulics and Their Impact on Aquatic Habitat in Colorado* (2013), described and compared fish habitat quality in the Meadow Park WWP and Control Reaches using 3D CFD modeling and traditional 2D habitat suitability criteria. Kolden (2013) modeled the same reaches along the North St. Vrain River as described in the study by Fox (2013). Using 3D CFD models, hydraulic conditions at each of the three WWP structures studied by Fox were modeled by Kolden and the calcualted hydraulic parmeters were used as inputs for the 2D habitat suitibility indeces.

Habitat sutabitlity models typically relate 2D hydraulic variables of depth and depth averaged velocity to habitat suitibility indices for specific species and lifestages. However, the 2D simplification of hydraulic conditions ignores the effects of vertical velocity components and gradients in the water column (Crowder DW, 2002), a factor that is of key importance at WWP structures due to the complexity of the associated hydraulic conditions. Furthermore, there is limited information on the correlations between ecological functions and 3D hydrodynamics, including turbulence, vorticity and circulation (Pasternack, 2008). Kolden (2013) modeled a range of discharges using FLOW-3D that are intended to represent the range of flows that occur over a typical year in the South St Vrain. The coresponding results for velocities, depths, vorticities and TKE are presented in the discussion and provide comparisons to the results of this study.

Habitat suitibility analyses were performed for brown and rainbow trout, longnose dace, and longnose sucker. These analyses predicted substantially higher habitat quality in WWPs as compared to natural reaches for both adult brown and rainbow trout, however, instream surveys completed by CPW showed higher fish biomass per volume in natural pools (Kolden, 2013). The discrepancy between these results indicates the need for additional studies, as well as the need to include other possible variables, such as competition, predation, food availablity, water quality and recreational use.

Kolden (2013) further investigated the differences between the 2D and 3D vorticity and TKE. In the 2D rendering, vorticity in and around the eddy was almost completely damped out, indicating that the vorticity in that area was not in the horizontal plane. Similarly, at the center jet, the 2D rendering did not show the large area of higher vorticity downstream of the jet, despite the clear presence of churning and boils from field surveys (Kolden, 2013). These differences indicate the advantages of 3D modeling to relate vorticity and TKE within WWP structures to fish habitat.

Kolden's (2013) report suggested possible connections between modeled hydraulic conditions and biomass. TKE, 2D voriticity, and 3D vorticity measurements were all higher in the WWP pools, while the biomass was lowest in the WWP pools. 3D modeling was shown to be important in this study for determining velocity distribution in the water column and vorticity. Due to the geometries of the WWP structures studied, the velocities tended to be highest near the bottom of the water column and slower near the surface, the opposite of what is generally observed. This can have implications on fish movement, as some species are adapted to swimming near the bottom where the velocities tend to be slower. This study highlights the need for further information on the impact of TKE and vorticity on fish behavior.

Timothy Stephens completed a study, *Effects of Whitewater Parks on Fish Passage: A Spatially Explicit Hydraulic Analysis* (2014), which combined observed fish movement data and 3D hydraulic modeling results to examine the physical processes that may limit the upstream movement of trout at the Meadow Park WWP. The methods used provide a continuous and spatially explicit description of velocity, depth, voticity and TKE along potential fish swimming pathways within the flow field. Using the results from the 3D modeling described above, Stephens (2014) identified a relationship between velocity, depth, vorticity and TKE on the suppression of movement of upstream migrating fish through statistical analysis of movement data from PIT-tagged studies at the Meadow Park WWP.

Stephans (2014) found that both the magnitude and distribution of TKE and vorticity varied substantially among WWP structures and discharges, as shown below in Figure 7, Figure 8, and Figure 9 (Stephens, 2014).

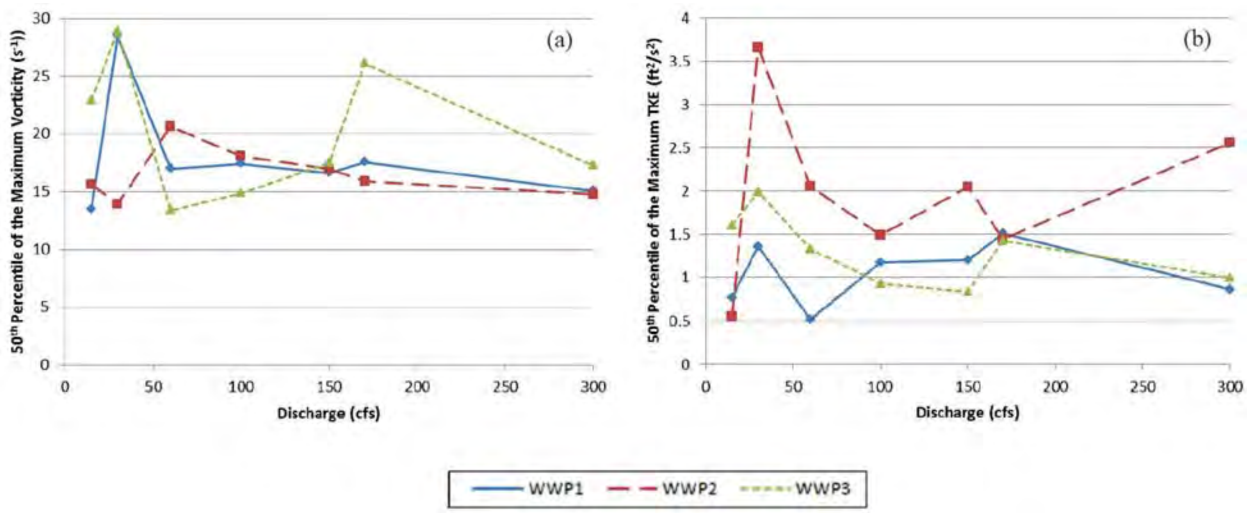


Figure 7: 50th percentile of (a) maximum vorticity and (b) maximum TKE along a flow path for each WWP structure and discharge (Stephens, 2014, p. 32)

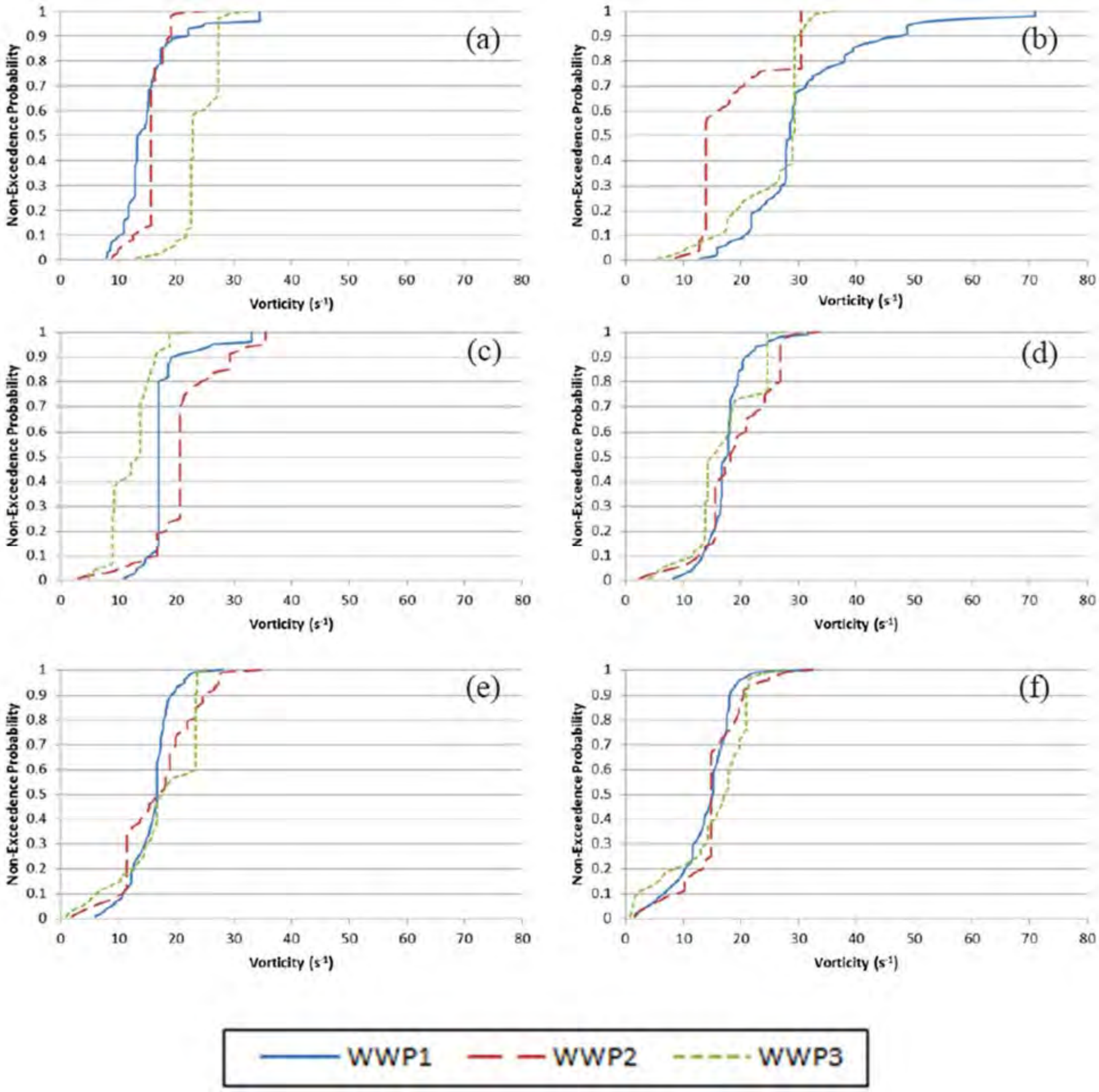


Figure 8: Non-exceedence probabilities for maximum vorticity along flow paths at each WWP structure for: (a) 15 cfs, (b) 30 cfs, (c) 60 cfs, (d) 100 cfs, (e) 150 cfs, and (f) 300 cfs (Stephens, 2014, p. 33)

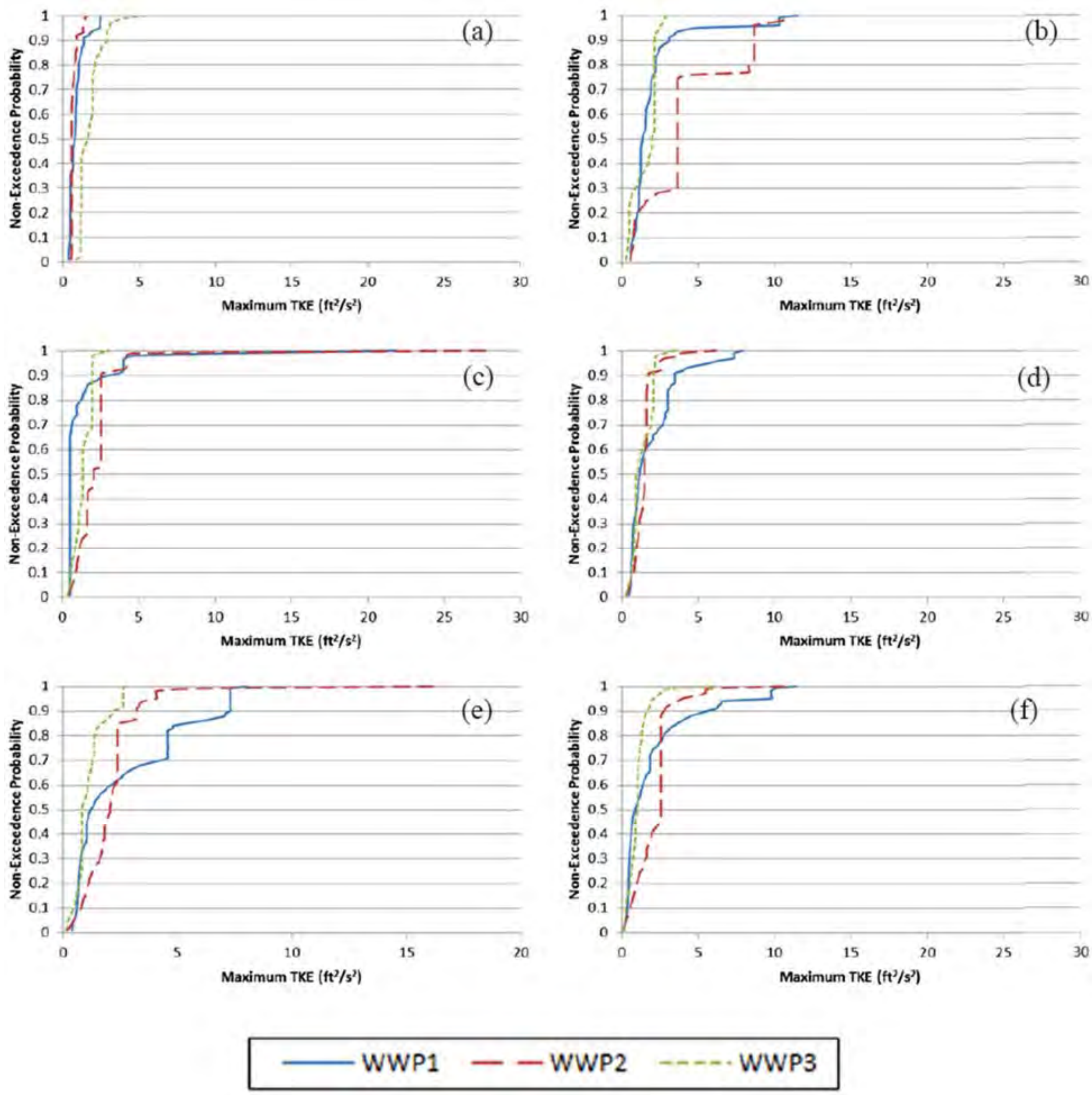


Figure 9: Non-exceedence probabilities for the maximum TKE along flow paths at each WWP structure for: (a) 15 cfs, (b) 30 cfs, (c) 60 cfs, (d) 100 cfs, (e) 150 cfs, and (f) 300 cfs (Stephens, 2014, p. 34)

Stephens (2014) also found that velocity, depth, and body length all have a signficant influence on passage success. Depth was the primary limiting factor at WWP1, while both velocity and depth have signficant influences at WWP2 and WWP3. Regression analysis demonstrated the influence of the combined variables of maximum velocity (25 BL/s) and minimum depth across all WWP structures. These results may be applied broadly across other WWPs, however, additional investigations of WWPs of various sizes and hydrologic regimes should be investigated (Stephens, 2014). This demonstrates the importance of considering depth and velocity jointly when evaluating barriers to upstream passage (Stephens, 2014).

The significance of velocity as an influence on fish passage differs from Fox's study which did not find velocity to have a clear effect on passage success. This contradiction may be attributed to the difference in scales over which velocities were calculated. Fox (2013) calculated cross sectional velocity quantiles within the chute of the WWP, not accounting for discontinuities in acceptable velocities along the movement path (Stephens, 2014). This indicates that secondary pathways can be designed that allow for fish passageway.

All three studies demonstrate a clear need for better understanding of how design-specific features and small scale hydraulics affect fish passage and behavior and provide insight into ways that WWPs can be designed to improve fish passage and aquatic habitat. The following study utilized the results of these studies to create an experiment that evaluated varying designs with the intent of maximizing fish passage and fish habitat through the use of metrics identified in these studies.

Methods

Study Site

The North St. Vrain River begins as snowmelt, in the Front Range of the Colorado Rockies, along the east side of the Continental Divide. It descends rapidly through high alpine glacial valleys and entrenched bedrock canyons to an elevation of 5,374 ft at its confluence within the South St. Vrain River. The Meadow Park WWP is located within the Town of Lyon, CO, approximately 0.5 miles upstream from the confluence of the North and South St. Vrain Rivers. The existing channel morphology of the 0.35 mile Meadow Park WWP reach is primarily single-thread with alternating step/pool bed sequences created from the construction of nine separate whitewater structures. Bed slopes within this reach typically range from 1 to 1.5 percent, with locally steeper slopes observed within the WWP structures. The valley floor is flanked by large sandstone escarpments on both sides, which impose geologic controls on the river channel, thereby limiting its ability to meander.

This study focused modeling efforts on a single WWP structure, described as WWP3 in the previous CPW studies. This study compared hydraulic conditions calculated for four different proposed geometries at the WWP3 structure, which currently exists at the Meadow Park WWP.

Hydrology

The hydrology of the North St. Vrain River is primarily snowmelt dominated. However, high intensity convective thunderstorms, typically occurring in mid to late summer, can generate extreme flood events such as those seen in 2013.

The hydrology for the study was developed based on direction provided by CPW and a separate analysis of stream gage data on the North St. Vrain River, post 1965, following the construction of the Button Rock Dam. Average mean daily flow rates for the North St. Vrain River were calculated using 33 years of stream gaging records on the St. Vrain River and four years of data measured on the South St. Vrain River (Figure 10). A percent reduction factor was calculated using years where gaging records overlapped between the South St. Vrain and the main stem. This reduction factor was then multiplied by the flows measured in the main stem on years where no flows were measured in the North St. Vrain to calculate flows.

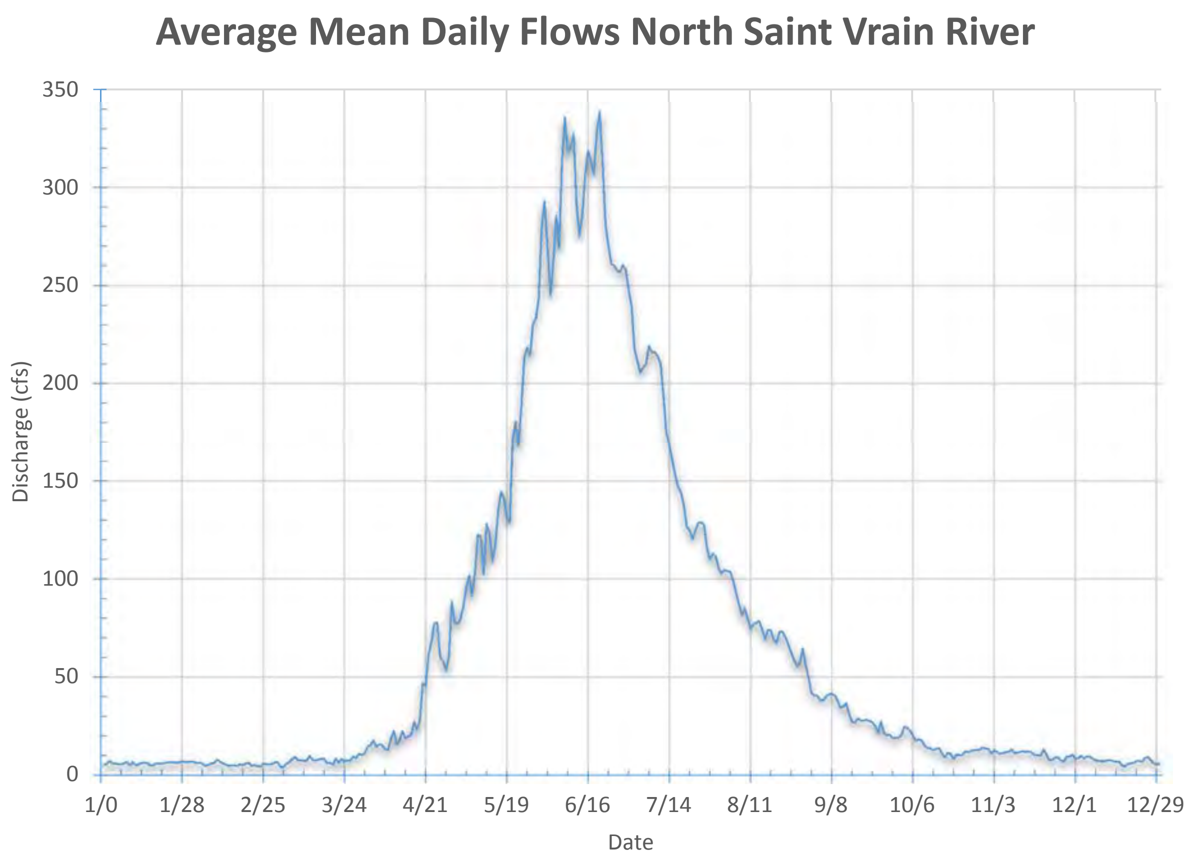


Figure 10: Hydrograph showing the calculated average of mean daily flows for the North St. Vrain River, following the construction of Button Rock Dam.

Based on the calculated average of mean daily flows for the North St. Vrain, four different flow rates were selected for this study. These flows included: base flows, spawning flows, recreational flows and peak flows (Table 1).

Table 1: Study Flow Rates

	Base Flows	Spawning Flows	Recreational Flows	Bank Full Flows
Time Period	Oct 15-Nov 15	April 1-April 30	June 1 - June 30	2 Yr Flow
Average Flow (cfs)	11.8	32.5	289.9	NA
Maximum Flow (cfs)	14.2	77.6	338.5	NA
Minimum Flow (cfs)	8.2	11.1	244.7	NA
Study Flow (cfs)	10.0	30.0	300.0	600.0

Base Flows

Discussions with CPW revealed that October 15th-November 15th is a critical time period for fish passage in the St. Vrain River system. Using the calculated average of mean daily flows for the North St. Vrain

River, the average flow for this period was determined to be 11.8 cfs while the minimum and maximum flows for the period were determined to be 8.2 cfs and 14.2 cfs respectively. A second time period between January 1st and March 31st was also evaluated. This period shows even lower flows than the October 15th through November 15th window. The average, minimum, and maximum flows calculated during this period were 6.4 cfs, 4.1 cfs, and 10.8 cfs respectively. Given the variability of low flows in the North St. Vrain between October and March a Base Flow of 10 cfs was proposed for the CFD modeling study.

Spawning Flows

CPW also specified the period between April 1st and April 30th as a second critical window for spawning in the North St. Vrain. Using the calculated average of mean daily flows the average, minimum, and maximum flows for this period were determined to be 32.5 cfs, 11.1 cfs, and 77.6 cfs respectively. Based on this analysis a Spawning Flow of 30 cfs was proposed for this study.

Recreational Flows

Recreational flows were also identified in this study to determine the effects of various fish passage treatments on the anticipated recreational opportunities to occur at the modeled drop structure. The period between June 1st and June 30th was identified as a critical window for recreation in Meadow Park. Using the average of mean daily flows, an average flow of 290 cfs was calculated for this period. The minimum and maximum flows for the same period were calculated as 245 cfs and 339 cfs respectively. Based on this analysis a Recreational Flow of 300 cfs was proposed for this study.

Bank Full Flows

Bank full flows are also proposed for this study to evaluate the hydraulic conditions generated by the structures during high probability flood events where the river accesses its primary floodplain. For this analysis, the 2 year recurrence interval was proposed as the flow in which the river stage exceeds its banks. Using a similar methodology to the calculation of the average of mean daily flows, peak flow data were obtained for the main stem of the St. Vrain River in Lyons then reduced by a calculated percentage of flow as determined from stream flows measured in the South St. Vrain River. Using the Weibull plotting position formula these corrected peak flow data were then used to obtain the probability of occurrence and recurrence interval. This analysis yielded a flow of 608 cfs for a 2 year recurrence interval. Based on this analysis a Bank Full flow of 600 cfs was proposed for the CFD model.

Experimental Setup

Four different prototype geometric configurations were developed for the proposed WWP3 structure redesign. The four identified flow rates were modeled within the prototype structures to characterize associated hydraulic conditions and their implications to fish passage, aquatic habitat, and recreation. Structure geometries varied to include the range of cross sectional differences, longitudinal slopes, wing configurations and boulder edges shown in Table 2. Structure geometries were developed in AutoCAD Civil3D as Triangular Irregular Networks (TIN), for export to ANSYS CFX. The prototype geometries studied are listed below:

Roughened Ramp 16%

The Roughened Ramp 16% (RR16) geometry has a 16.6% (6H:1V) low flow ramp slope, symmetrical wing elevations, staggered boulder edges along the margins, and boulder roughness elements intended to simulate a recessed grout line relative to the top of boulder (Figure 11 and Figure 12). This design was used to investigate the effect of surface roughness on modeled hydraulic conditions.

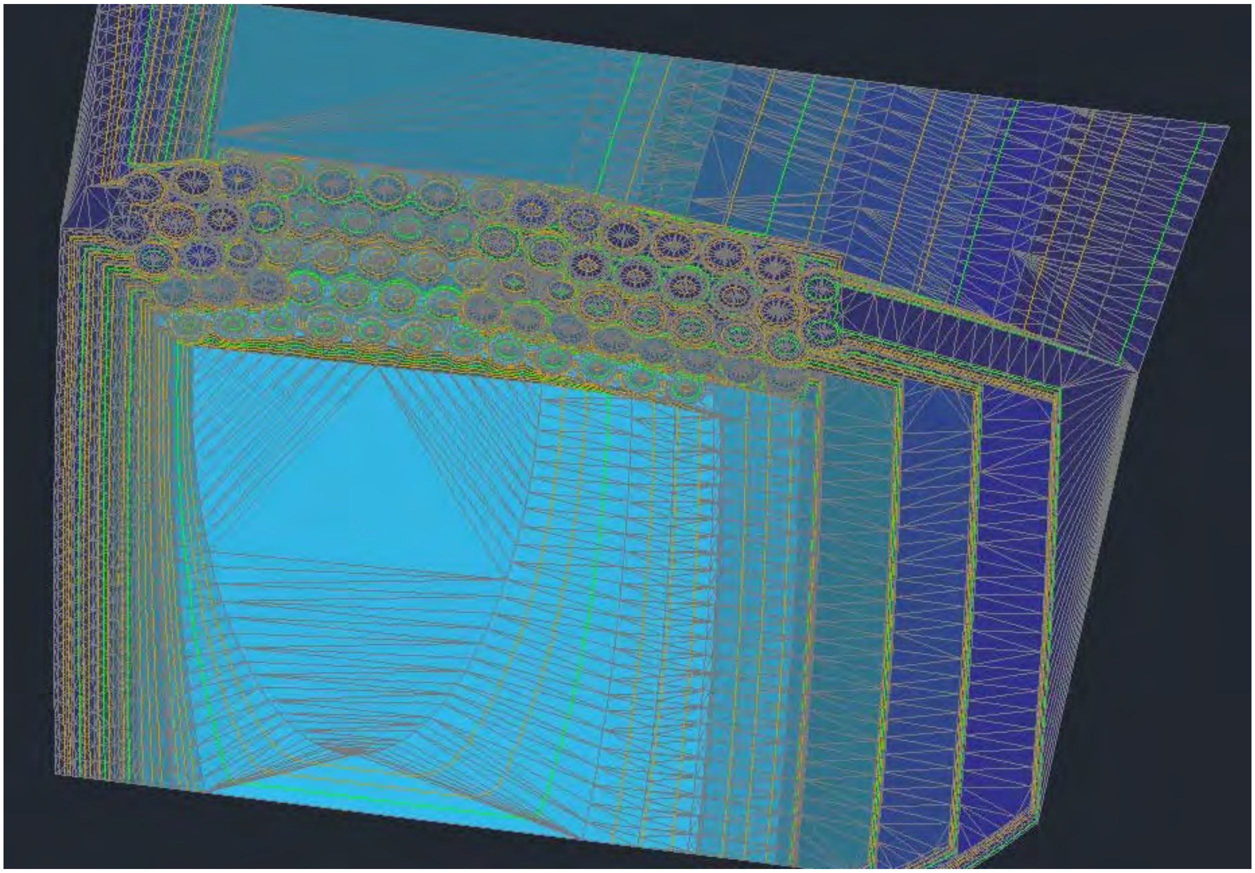


Figure 11: Planview of the Roughened Ramp 16% geometry

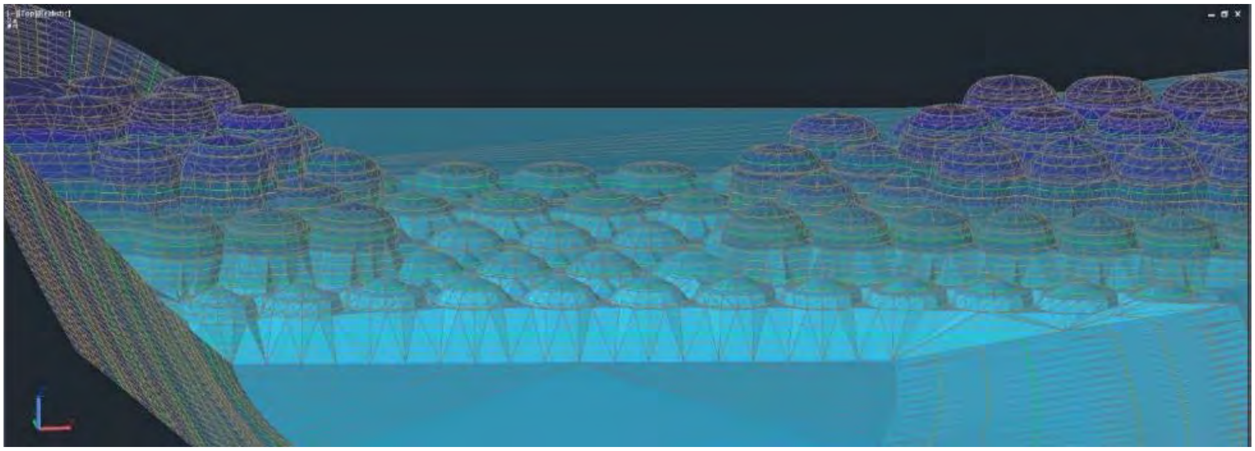


Figure 12: Looking upstream through the throat of the Roughened Ramp 16% geometry.

Roughened Ramp 12%

The Roughened Ramp 12% (RR12) geometry has a 12.5% (8H:1V) low flow ramp slope, symmetrical wing elevations, staggered boulder edges along the margins, and boulder roughness elements (Figure 13 and Figure 14). This design allowed for the investigation of the effect of reduced bed slopes on modeled hydraulic conditions.

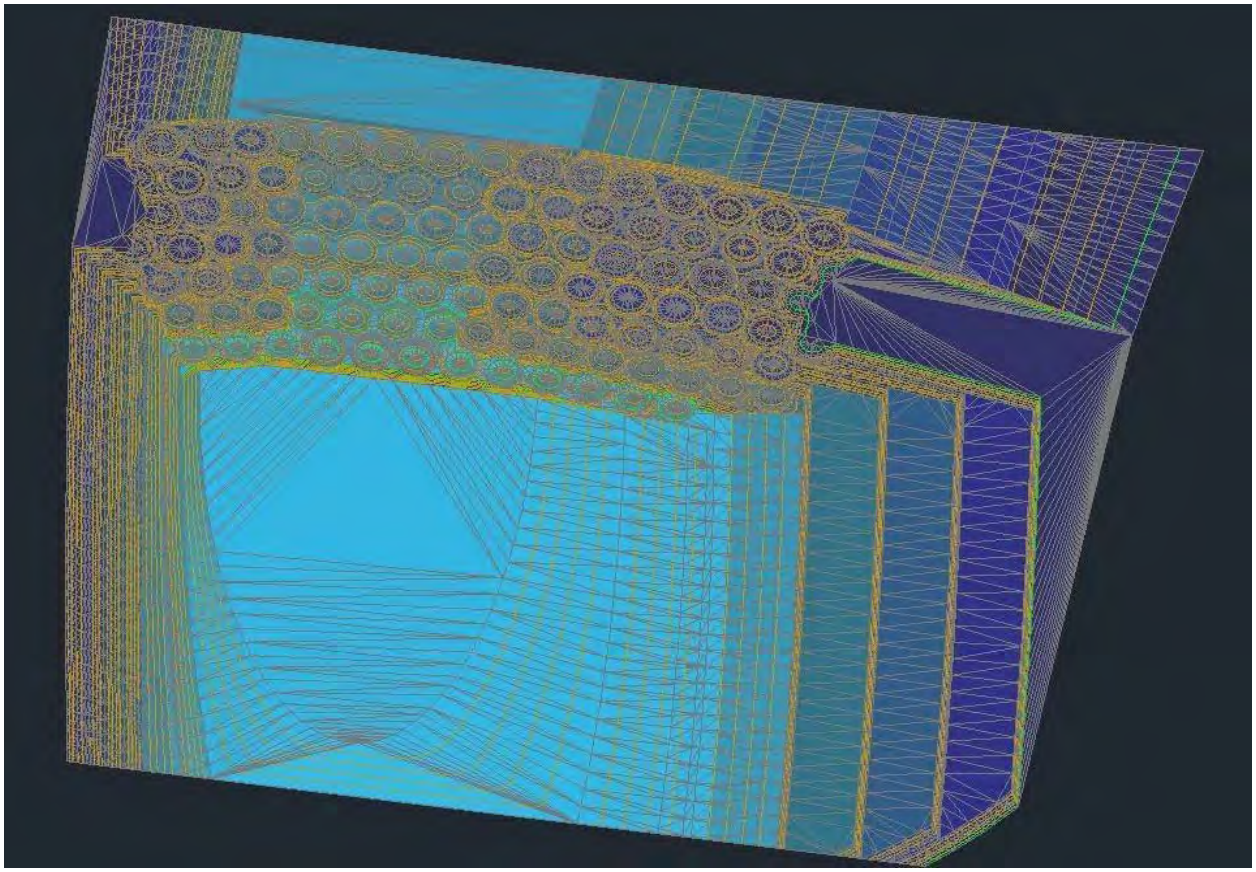


Figure 13 Planview of the Roughened Ramp 12% geometry.

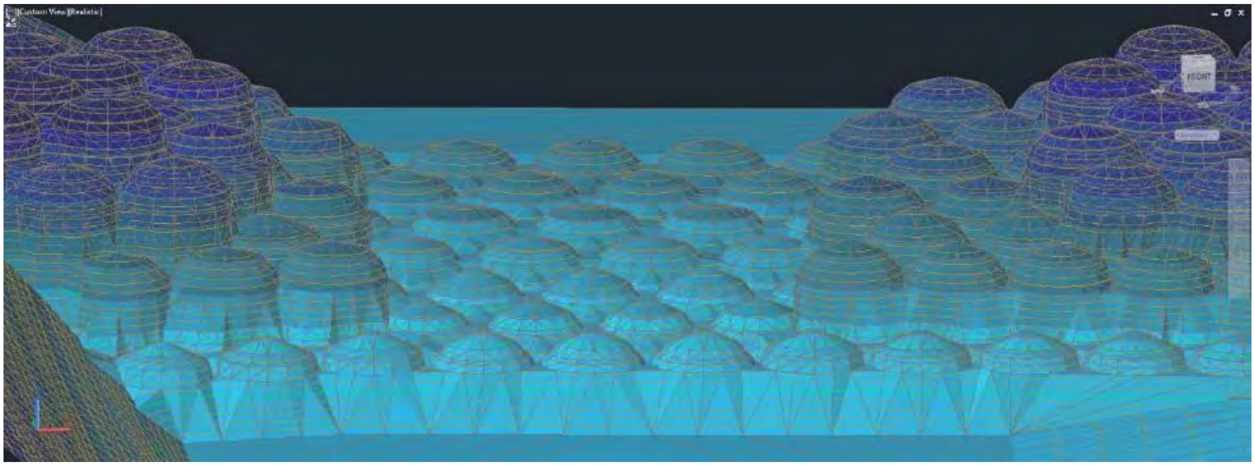


Figure 14: Looking upstream through the throat of the Roughened Ramp 12% geometry.

Alternating Terrace

The Alternating Terrace (AT) geometry has a 16.6% (6H:1V) low flow ramp slope, alternating staggered wing elevations, staggered boulder edges along the margins, and boulder roughness elements (Figure 15 and Figure 16). This geometry was investigated to determine how alternating terrace depths affect small scale hydrodynamics.

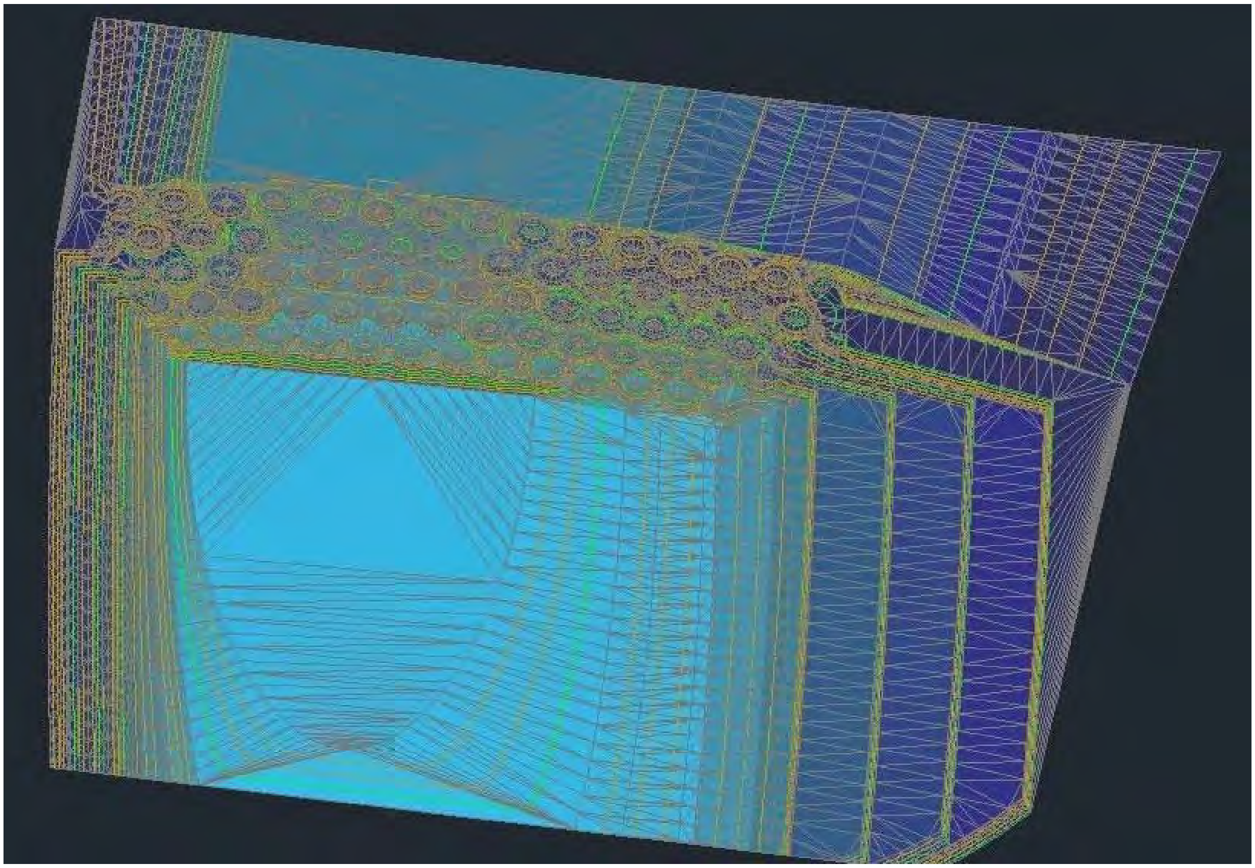


Figure 15: Planview of the Alternating Terrace geometry.

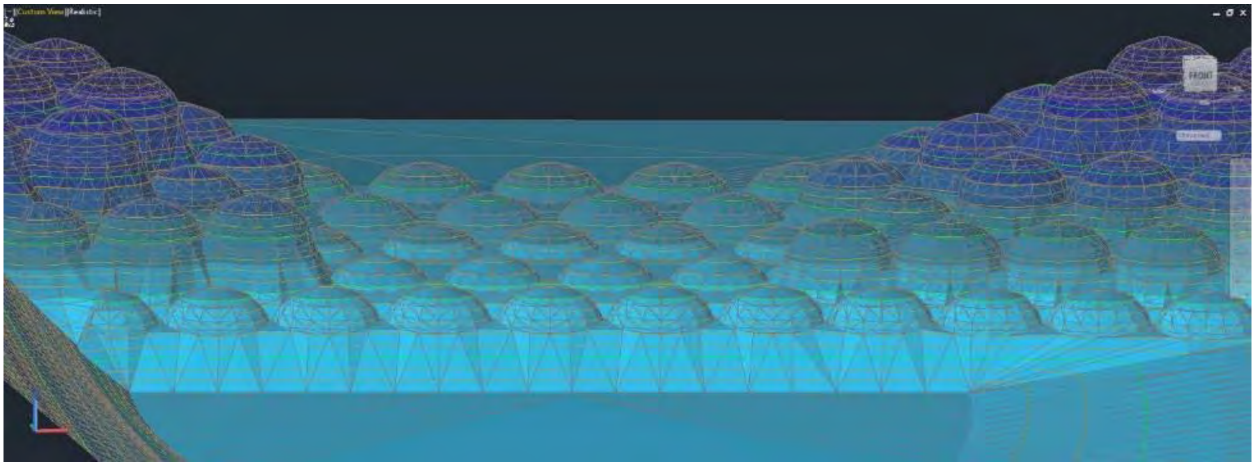


Figure 16: Looking upstream through the throat of the Alternating Terrace geometry.

Fish Notch

The Fish Notch (FN) geometry has a central notch 5.5% (18H:1V), a 16.6% (6H:1V) low flow ramp slope, symmetrical wing elevations, staggered boulder edges along the margins, and boulder roughness elements (Figure 17 and Figure 18). This geometry was investigated to see how a low slope centered notch effect hydraulic conditions, particularly at lower flows.

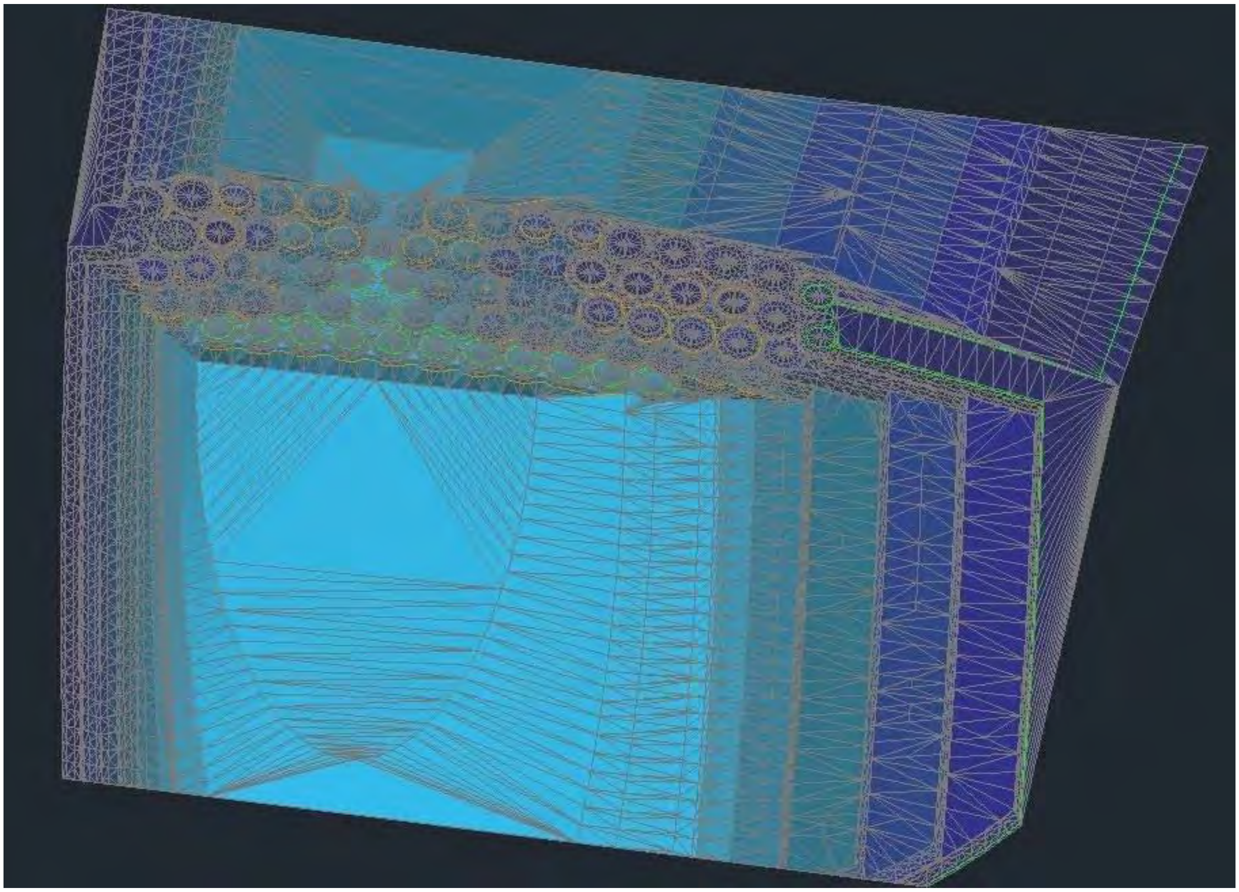


Figure 17: Planview of the Fish Notch geometry.

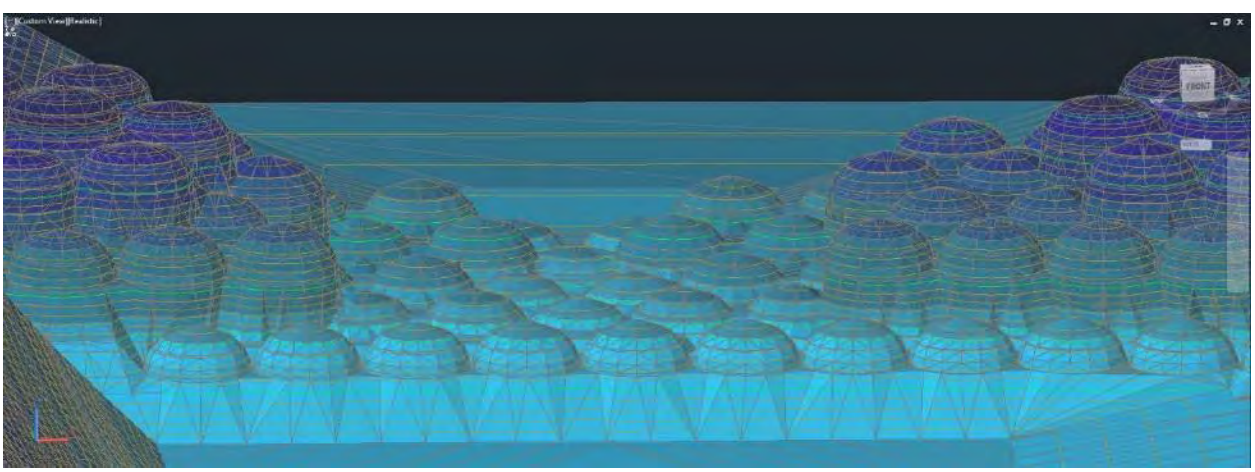


Figure 18: Looking upstream through the throat of the Fish Notch geometry.

Table 2: Four geometry types studied to evaluate associated hydraulic conditions and their potential Implications to fish passage and aquatic habitat.

Geometry Name	Ramp Slope	Wing Elevation	Boulder Edge
Roughened Ramp 16%, RR16	16.6% (6H:1V) Low Flow Ramp Slope	Symmetrical Wing Elevations	Staggered
Roughened Ramp 12%, RR12	12.5% (8H:1V) Low Flow Ramp Slope	Symmetrical Wing Elevations	Staggered
Alternating Terrace, AT	16.6% (6H:1V) Low Flow Ramp Slope	Alternating Staggered Wing Elevations	Staggered
Recessed Fish Notch, FN	5.5% (18H:1V) Fish Notch Ramp Slope, 16.6% (6H:1V) Low Flow Ramp Slope	Symmetrical Wing Elevations	Staggered

Modeling

Terrain Modeling

Survey data were collected by a professionally licensed surveyor, sufficient to describe the existing (post flood) topography and bathymetry of the Meadow Park WWP. These data included spot elevations with descriptions, breaklines, and channel cross sections. AutoCAD Civil 3D 2014 was used to generate a Triangular Irregular Network (TIN) from the survey data for the purpose of creating a baseline Digital Terrain Model (DTM) of the project site. The DTM was created in the Colorado State Plane Coordinate System, US foot (COHP-NF). The vertical datum of the DTM is the North American Vertical Datum of 1988 (NAVD 88).

Boundary Conditions Modeling

A one-dimensional (1D) steady flow model of the Meadow Park WWP was created using the publically available HEC-RAS flood modeling software created by the US Army Corps of Engineers. This model was used to characterize existing and proposed 1D hydraulic conditions within the reach. The existing conditions model describes streamflow in the downstream direction, along a defined channel alignment. Channel cross sections were cut perpendicular to the alignment, sampling the DTM at locations of interest along the reach. Hydraulic roughness coefficients (Manning's n) were assigned to the model based on observed conditions and standard tables presented in the HEC-RAS User's Manual.

Two separate flow paths were identified at an island just upstream of the WWP3 structure. A split flow model was developed to better characterize flows in this sub-reach. Within the HEC-RAS model options, flow optimization was performed to iteratively determine the portion of the total discharge to be assigned to each flow path. Using the split flow optimization, HEC-RAS creates a water surface profile based on the initial trial flows. Using results from the computed profile, new flows are calculated at the junctions and the profiles are subsequently recalculated. This process continued until the calculated and assumed flows matched within a given tolerance (Brunner, 2002). Downstream of the confluence of these two separate flow paths, the model returned to a single thread geometry.

A proposed conditions model was created based on modifications to the existing conditions model, sufficient to describe proposed geometric changes to the channel, banks, and whitewater structures as well as hydraulic roughness coefficients. This model was then used to develop and analyze hydraulic conditions resulting from the proposed changes to the Meadow Park WWP and to assign boundary conditions for the 3D CFD modeling.

Three-Dimensional CFD Modeling

Each of the four whitewater structure geometries described above were developed as geometric inputs into four separate 3D CFD models. Modeling was completed using ANSYS CFX, a 3D Computational Fluid Dynamics simulations software.

The individual CFD model geometries were created in the ANSYS WorkBench geometry editor by importing and subtracting each unique boulder geometry from the associated riverbed geometry (Figure 19).

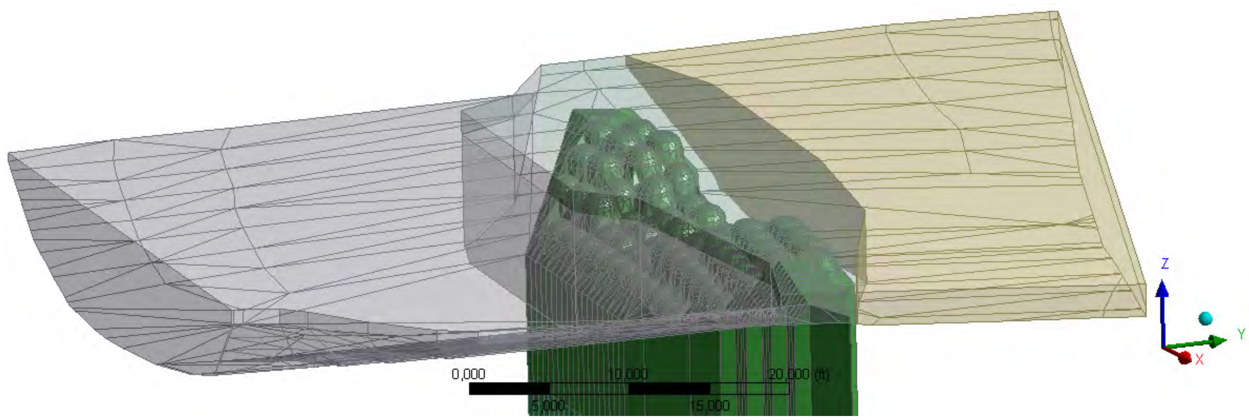


Figure 19: Geometry created by subtracting boulders (green color) from riverbed geometry (gray color).

Consecutive meshing was performed using ANSYS Meshing toolbox (Figure 20). A tetrahedral cell geometry with typical element sizes of 0.25 ft (min size), 0.5 ft and 1 ft (max size) were used.

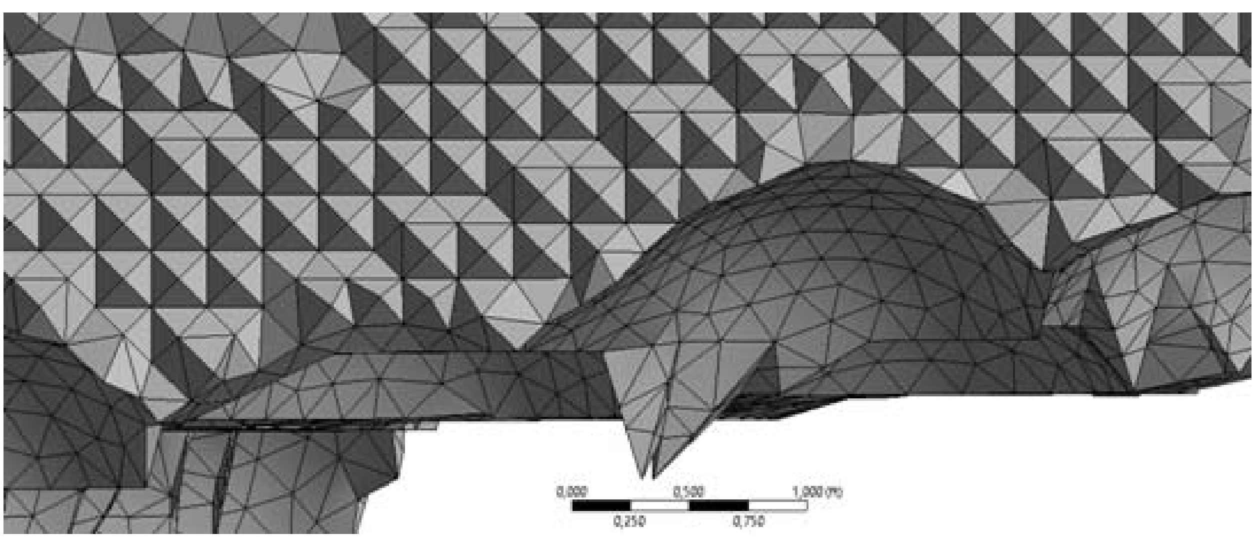


Figure 20: Minimum mesh element size (0.25 ft).

The number of elements varied according to each of the four structure geometries and flow rates studied. Between 2 million and 3 million elements were used for smaller flows, while larger elements were used for higher flows. Element spacing also increased with elevation and distance from the physical structure, necessary to reduce the total number of computational nodes, thereby improving model stability and reducing computational requirements (Figure 21).

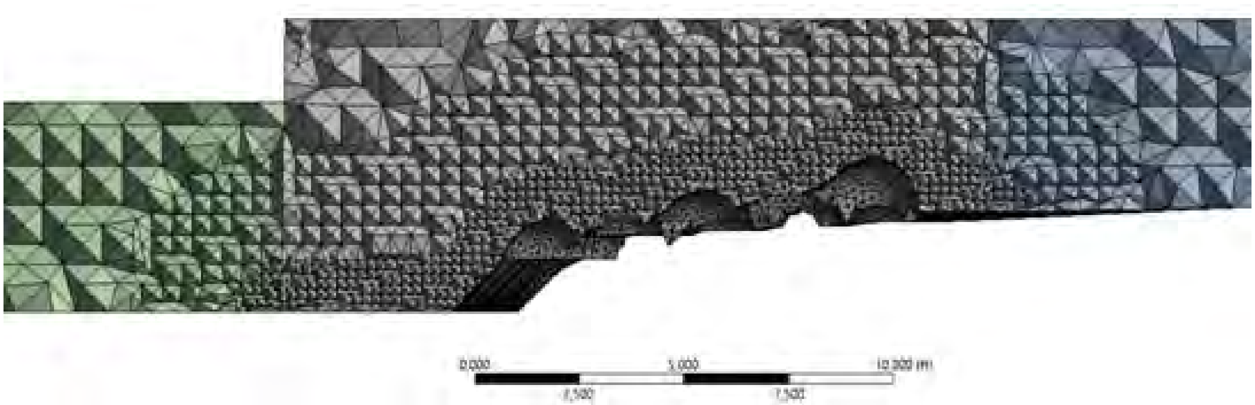


Figure 21: Maximum mesh size element (1 ft), medium size element (0.5 ft) and minimum mesh element size (0.25 ft).

The following settings for the CFX Solver (ANSYS) were used: a homogeneous model (2 phase - water and air) with a standard Free Surface Model; turbulence was modeled using a standard k-epsilon model with a standard wall function.

The upstream and downstream boundary conditions were developed based on the outputs from the 1-D HEC-RAS model for given cross section (Figure 22). The water intake boundary condition was defined using the given flow rates. The outlet boundary condition was defined as pressure outlet with a specified water surface elevation. The channel bottom was set up as a solid surface with assigned roughness elements.

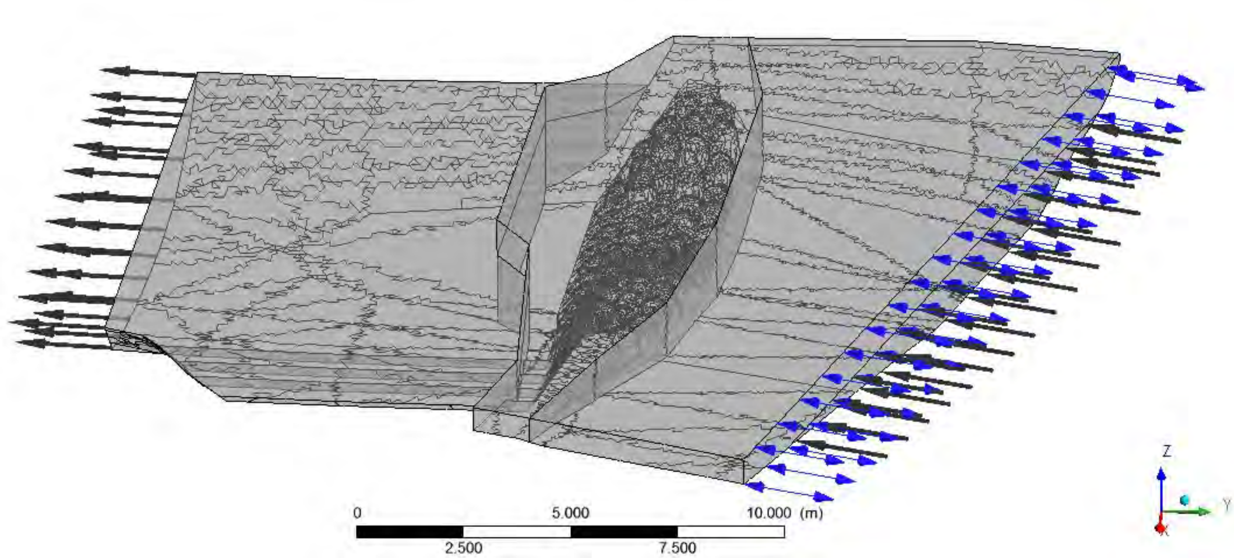


Figure 22: Boundary conditions; black arrow right - water intake (flow rate), blue arrow right - air intake, black arrow left – outlet.

Convergence controls were limited to a maximum of 1000 iterations and monitored with the stabilization of flow rate within the computational domain (Figure 23).

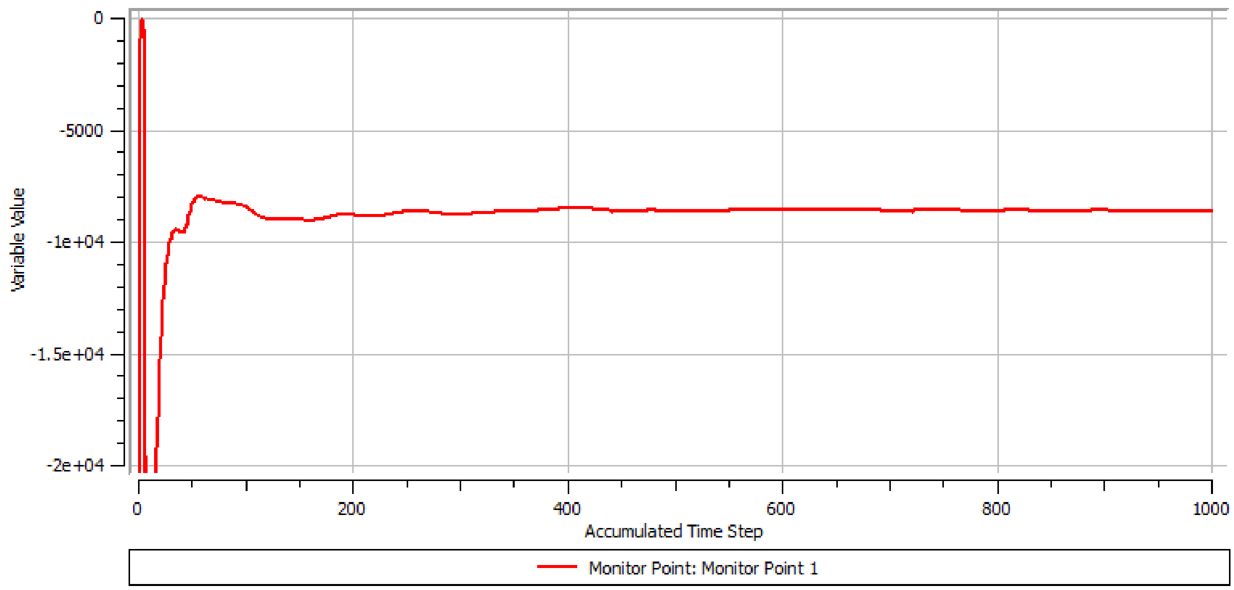


Figure 23: Monitoring of stabilization of flow rate.

Results

Results describing the hydraulic conditions calculated for each of the structure geometries and flow rates are outlined in the following sections. Numerical outputs for cross-sectional velocities, depths, vorticity, and TKE are presented below and include maximum, mean, 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} quantile values. Graphical results are presented for the 5^{th}, 25^{th}, and 50^{th} quantiles of velocity and the 50^{th}, 75^{th}, and 95^{th} quantiles of depth to highlight specific metrics of importance to the study.

The geometries of the WWP structures studied create unique hydraulic conditions as compared to the natural pool/riffle sequences found in the St. Vrain River. The distribution of flows over a whitewater structure affects the availability of fish passage routes and the predominant mechanisms by which passage is limited. During low flows, slower more shallow water is typically concentrated in the center portion of the ramp while at higher flows, deeper more rapid water spreads out laterally over the entire structure. Because fish seek the most energy efficient pathway for passage, it stands to reason that at high flows fish will seek out pathways in the lower velocity zones near the margins of the channel, while at lower flows fish are forced into fewer flow pathways with sufficient depth for passage. In this way fish passage can be depth limited at low flows whereas at high flows it may be velocity limited. For this reason, it is assumed that the 5^{th} quantile for velocity, TKE, and vorticity during higher flows is the threshold that must be crossed by the fish to complete a successful passage through the structure.

At low flows, when water is concentrated in the center portion of the ramp, the total number of continuous passage routes is reduced as lower velocity zones along the channel bottom and margins become depth limited. For this reason, it is assumed that fish passing upstream must navigate zones of higher relative velocity due to the reduced number of continuous passage routes. Based on this assumption, results from the 50^{th} quantile of velocity, TKE, and vorticity are considered to act as thresholds for fish passage at lower flows.

Depth

Depth measurements were determined for all four of the whitewater structures at each specified flow rate using the 3D CFD models described above. 2D cross sections were cut along the longitudinal profile at 1 foot increments from the upstream subcritical pool, through the super critical structure throat, and downstream into the subcritical pool (stations 93.2-58.2). Along these cross sections, 2D depths were sampled at every tenth of a foot across the wetted channel.

Statistical analyses were performed on these data to describe the maximum depth sampled at each cross section, mean depth sampled at each cross section, 5^{th} percentile (95% of the flow depths sampled greater than the given value), 25^{th} percentile (75% of the flow depths sampled greater than the given value), 50^{th} percentile (50% of the flow depths sampled greater than the given value), 75^{th} percentile (25% of the flow depths sampled greater than the given value), and the 95^{th} percentile (5% of the flow depths sampled greater than the given value).

Similar to the methodology described in the study by Fox (2013), it was assumed that a fish passing upstream over the whitewater structure must pass through each cross section. This allowed for the most difficult hydraulic conditions faced by an individual fish to be identified by classifying the limiting depths to passage within each cross section, despite not knowing the exact pathway to be followed by a given fish. Table 3 describes the limiting depths for each structure geometry at each flow rate based on the minimum value of maximum depths sampled for the maximum, mean, 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} quantiles, calculated from the 2D cross sections sampled along the longitudinal profile.

Table 3: Describes the minimum value of maximum depths sampled for the maximum, mean, 5th, 25th, 50th, 75th, and 95th quantiles for each structure geometry at each flow rate.

Geometry Type	Flow, Q	Max Depth	Mean Depth	5th PCTL	25th PCTL	50th PCTL	75th PCTL	95th PCTL
	ft^3/s	ft	ft	ft	ft	ft	ft	ft
Fish Notch	10	0.8	0.3	0.0	0.1	0.2	0.6	0.7
Roughened Ramp 12%	10	0.4	0.2	0.0	0.1	0.1	0.2	0.3
Roughened Ramp 16%	10	0.5	0.2	0.0	0.1	0.1	0.3	0.5
Alternating Terrace	10	0.5	0.2	0.0	0.1	0.1	0.3	0.5
Fish Notch	30	1.1	0.5	0.0	0.1	0.3	0.7	1.1
Roughened Ramp 12%	30	0.7	0.4	0.0	0.3	0.4	0.5	0.6
Roughened Ramp 16%	30	0.7	0.4	0.0	0.3	0.4	0.5	0.7
Alternating Terrace	30	0.8	0.4	0.0	0.2	0.4	0.6	0.8
Fish Notch	300	2.7	1.0	0.0	0.2	0.5	1.9	2.5
Roughened Ramp 12%	300	2.6	0.7	0.0	0.1	0.2	0.9	2.4
Roughened Ramp 16%	300	2.9	0.8	0.0	0.1	0.2	1.0	2.5
Alternating Terrace	300	2.5	0.9	0.0	0.1	0.3	1.6	2.2
Fish Notch	600	3.9	1.2	0.2	0.4	0.6	1.4	3.6
Roughened Ramp 12%	600	3.7	1.2	0.1	0.3	0.5	1.3	3.4
Roughened Ramp 16%	600	3.8	1.1	0.2	0.4	0.6	1.5	3.5
Alternating Terrace	600	3.7	1.3	0.2	0.4	0.7	1.6	3.4

Limiting depths for the 25th, 50th, 75th, and 95th quantiles are shown graphically below in Figure 24. At the 25th and 50th quantiles, we do not see much difference between measured depth values across the range of structure geometries and flowrates. However, at the 75th and 95th quantiles we see that the Fish Notch geometry produces greater limiting depths as compared to the other structure geometries studied, particularly during critical base and fish flows. Moreover, because the critical depth threshold of 0.6 ft, utilized by Stephens (2014), is surpassed in both the 75th and 95th quantiles at both 10 and 30 cfs, as compared to the three other structure geometries, which only exceed the 0.6 ft threshold in the 95th quantile for the same flows, we can see that a significantly greater portion of the flow area is available for passage within the Fish Notch geometry during these critical low flow periods.

At 300 cfs no structure geometry achieves the limiting depth condition of 0.6 ft prior to the 75th quantile however, the magnitude of limiting depth produced by the Fish Notch geometry is significantly greater than the other geometries studied at this flow rate. At 600 cfs we see three of the four geometries studied produce limiting depths equal to or greater than 0.6 ft, within 50% of the cross sectional area sampled. Because these threshold depths are generated by the Fish Notch within both a greater portion of the cross sectional area sampled as well as during the lower flow periods studied, this geometry type appears to produce the most favorable limiting depth conditions for all structure geometries studied.

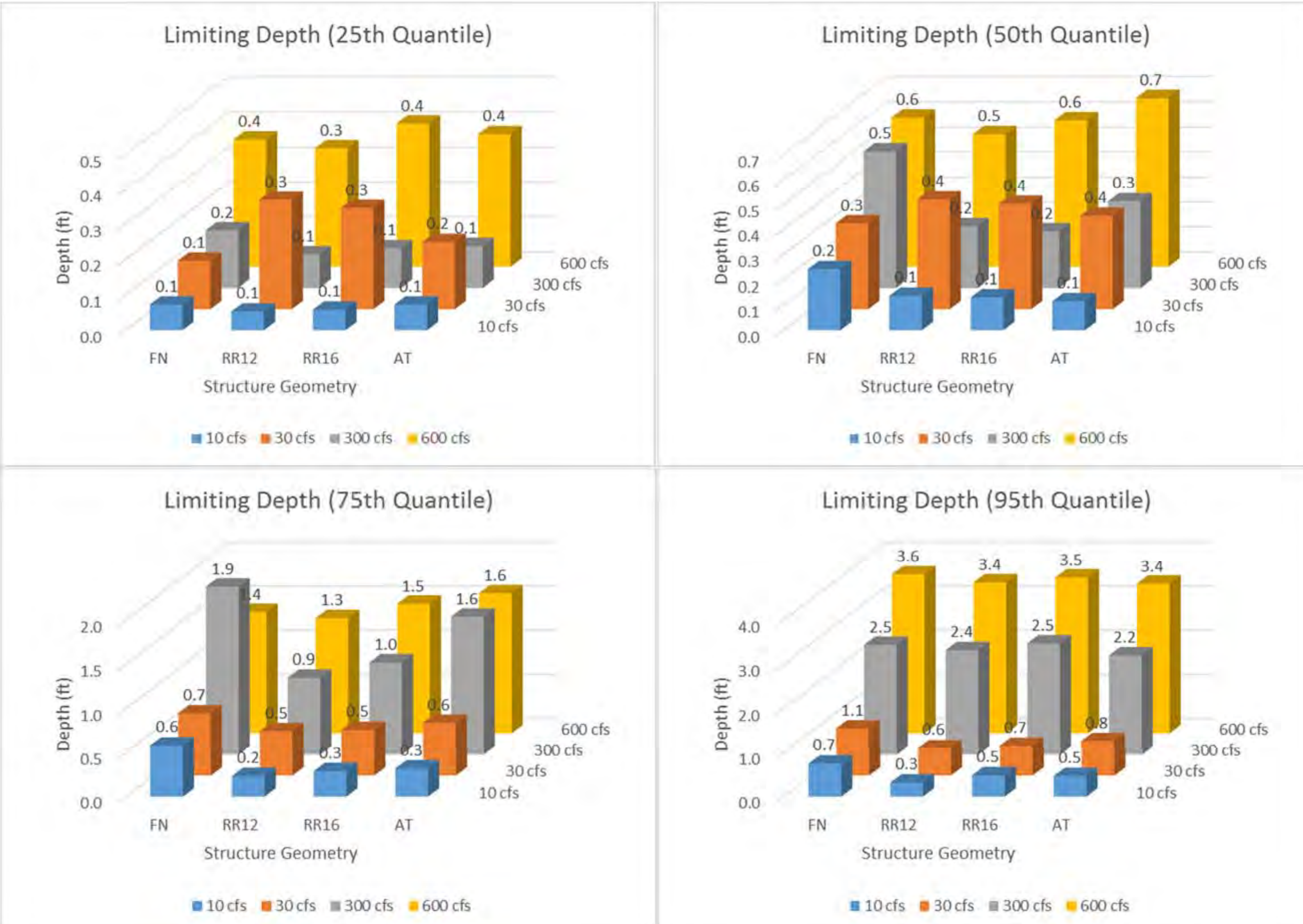


Figure 24: 25th, 50th, 75th, and 95th quantiles of limiting depth

Velocity

Cross sectional velocities were also sampled at each of the four whitewater structures geometries at each specified flow rate. Using the same cross sections cut along the longitudinal profile, velocity values were sampled at each computational node within the 2D plane. Statistical analyses were performed on these data to describe the maximum, mean, 5th, 25th, 50th, 75th, and 95th quantile velocities.

In the same way as limiting depth, it was assumed that the cross sections containing the greatest values of velocity would act as limiting velocities to upstream fish passage. Table 4 describes the limiting velocities for each structure geometry at each flow rate based on the maximum velocities sampled for the maximum, mean, 5th, 25th, 50th, 75th, and 95th quantiles.

Table 4: Describes the maximum velocities sampled for the maximum, mean, 5th, 25th, 50th, 75th, and 95th quantiles for each structure geometry at each flow rate.

Geometry Type	Flow, Q	Max Velocity	Mean Velocity	5th PCTL	25th PCTL	50th PCTL	75th PCTL	95th PCTL
	ft^3/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s
Fish Notch	10	5.2	3.6	2.1	2.9	3.8	4.2	5.0
Roughened Ramp 12%	10	5.9	4.6	3.1	3.9	4.8	5.4	5.7
Roughened Ramp 16%	10	6.4	4.3	2.8	3.8	4.5	4.9	5.9
Alternating Terrace	10	5.6	4.3	3.1	3.9	4.4	4.9	5.4
Fish Notch	30	6.9	4.6	2.8	3.9	4.9	5.7	6.7
Roughened Ramp 12%	30	8.2	5.7	3.0	5.1	6.4	7.4	7.9
Roughened Ramp 16%	30	8.3	6.2	5.4	5.9	6.3	7.4	8.1
Alternating Terrace	30	7.3	5.8	4.7	5.4	5.8	6.7	7.0
Fish Notch	300	13.4	8.1	2.0	5.7	10.4	11.2	12.3
Roughened Ramp 12%	300	14.7	7.1	1.9	3.7	7.3	12.1	13.1
Roughened Ramp 16%	300	14.8	8.7	2.2	6.6	10.4	11.6	12.7
Alternating Terrace	300	14.9	8.1	2.0	5.8	9.8	11.9	13.3
Fish Notch	600	13.5	7.8	1.6	5.2	8.7	10.6	11.8
Roughened Ramp 12%	600	13.2	7.6	1.9	4.9	8.3	11.0	12.0
Roughened Ramp 16%	600	12.7	8.3	1.7	6.4	9.1	10.9	11.9
Alternating Terrace	600	13.2	7.1	1.5	4.4	8.1	10.4	11.7

The results shown in Table 4 have been distilled to look at the limiting velocities for the 5th, 25th, 50th, and 75th quantiles (Figure 25). At the lower more critical fish passage flows of 10 and 30 cfs, the Fish Notch geometry produces the least limiting velocities of 2.1 ft/s and 2.8 ft/s respectively in the 50th quantile. At higher more recreationally desirable flows, when the fish have increased passage options, it can be seen that fairly uniformly low flow velocities are seen across all geometries at the Recreational Flows while the Alternating Terrace and Fish Notch geometries show the lowest velocities at Bankfull Flow levels. Because the Fish Notch geometry creates the lowest limiting velocities during the low flow periods while not producing significant differences during high flow periods, this geometry type appears to produce the most favorable hydraulic conditions for both fish passage and recreation in the structure.

Figure 25: 5th, 25th, 50th, and 75th quantiles of limiting velocity.

3D Vorticity

Without direct knowledge of the mechanisms through which vorticity within the structure ramp impacts fish passage, this parameter was analyzed in a similar manner to velocity to look for trends between prototype structure geometries and flows. Using the same 2D cross sections sampled at 1 foot increments along a longitudinal profile, 3D vorticity was sampled at each computational node. Statistical analyses were performed to describe the maximum, mean, 5th, 25th, 50th, 75th, and 95th quantiles of sampled vorticities, within each cross section. Table 5 describes the limiting 3D vorticities for each structure geometry at each flow rate based on the maximum 3D vorticity sampled for the maximum, mean, 5th, 25th, 50th, 75th, and 95th quantiles.

Table 5: Describes the maximum 3D vorticity sampled for the maximum, mean, 5th, 25th, 50th, 75th, and 95th quantiles for each structure geometry at each flow rate.

Geometry Type	Flow, Q	Max Vorticity	Mean Vorticity	5th PCTL	25th PCTL	50th PCTL	75th PCTL	95th PCTL
	ft^3/s	1/s	1/s	1/s	1/s	1/s	1/s	1/s
Fish Notch	10	11.6	5.6	1.5	3.2	5.5	7.7	10.4
Roughened Ramp 12%	10	16.5	5.4	3.2	4.4	5.3	7.1	9.1
Roughened Ramp 16%	10	19.5	6.8	4.4	6.0	6.8	9.2	13.3
Alternating Terrace	10	16.8	6.8	1.9	4.2	7.1	9.8	13.2
Fish Notch	30	19.0	5.3	1.6	3.1	4.3	7.3	12.2
Roughened Ramp 12%	30	22.8	6.7	3.1	4.3	6.4	8.7	13.1
Roughened Ramp 16%	30	16.5	6.5	3.1	4.2	6.0	9.8	13.0
Alternating Terrace	30	19.7	5.4	2.9	4.0	5.4	7.1	13.9
Fish Notch	300	30.3	6.9	0.7	2.7	5.9	11.2	17.5
Roughened Ramp 12%	300	60.8	8.4	1.5	5.1	8.3	11.3	17.8
Roughened Ramp 16%	300	44.6	9.7	1.7	5.1	8.2	13.2	23.0
Alternating Terrace	300	30.6	7.9	1.3	3.8	7.2	11.6	16.8
Fish Notch	600	35.0	9.1	0.9	4.5	8.3	12.7	20.5
Roughened Ramp 12%	600	38.7	9.0	0.6	4.1	7.9	12.7	21.6
Roughened Ramp 16%	600	37.1	10.3	0.9	4.7	9.4	14.9	23.1
Alternating Terrace	600	32.5	8.1	0.8	3.7	7.3	11.7	19.3

At Base Flows the Fish Notch geometry produced the lowest limiting 3D vorticities in the 5th and 25th quantiles, while the Roughened Ramp 12% geometry produced the lowest limiting 3D vorticities in the 50th and 75th quantiles (Figure 26). At Fish Flows the Fish Notch geometry produced the lowest limiting 3D vorticities at the 5th, 25th, 50th, and 75th quantiles. At recreation Flows the Fish Notch Geometry once again produced the lowest limiting 3D vorticities at the 5th, 25th, 50th, and 75th quantiles. At Bank Full Flows the Roughened Ramp 12% geometry produced the lowest limiting 3D vorticities in the 5th quantile while the Alternating Terrace geometry produced the lowest limiting 3D vorticities in the 25th, 50th, and 75th quantile.

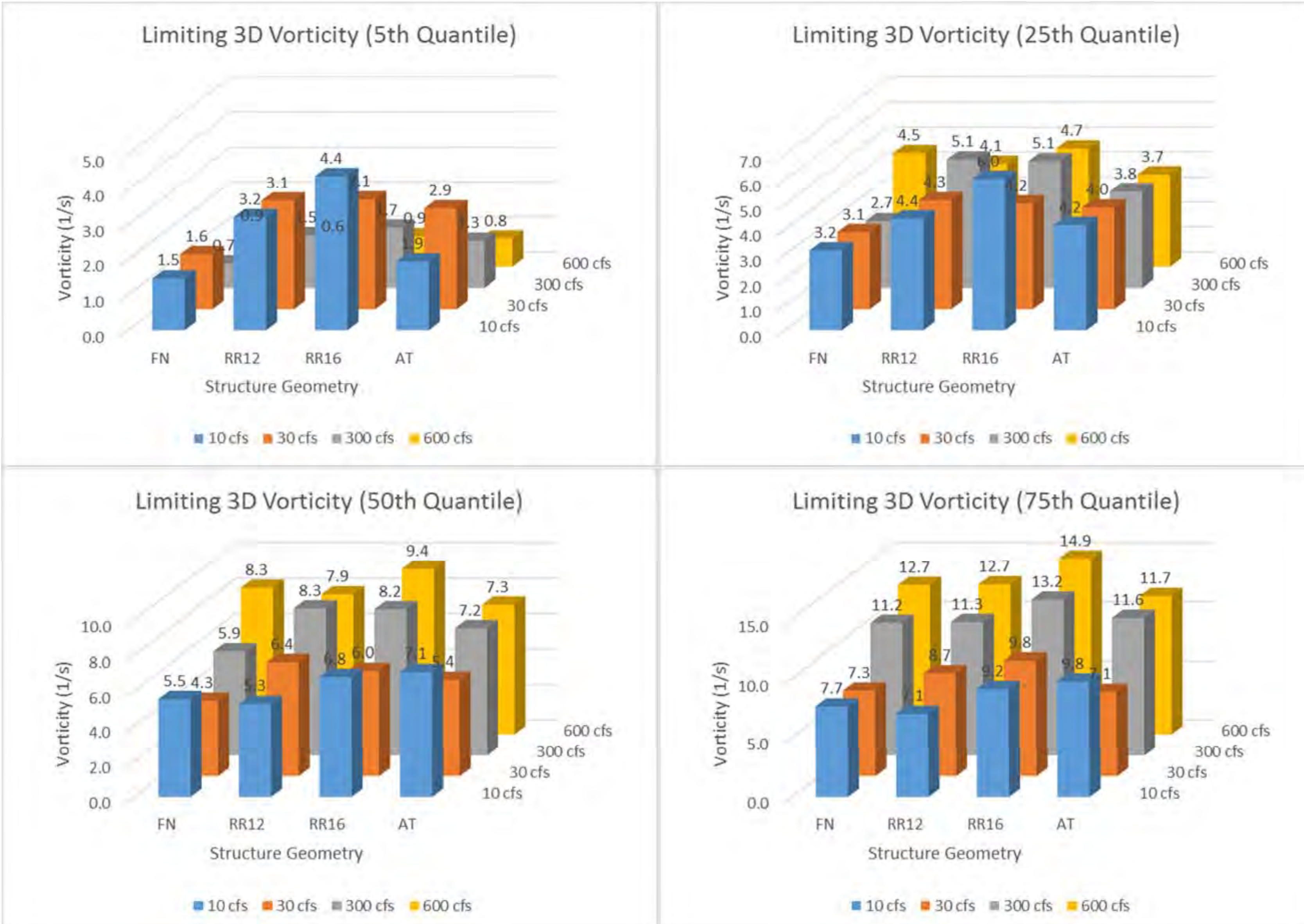


Figure 26: 5th, 25th, 50th, and 75th quantiles of limiting 3D vorticity.

TKE

Turbulent Kinetic Energy (TKE) was also analyzed using 2D cross sectional data, in order to describe limiting TKEs to upstream fish passage. Using the same 2D cross sections located at 1 foot increments along a longitudinal profile, TKE was sampled at each computational node. Statistical analyses were also performed to describe the maximum TKE sampled for the maximum, mean, 5th, 25th, 50th, 75th, and 95th quantiles, within each cross section (Table 6)

Table 6: Describes the maximum TKE sampled for the maximum, mean, 5th, 25th, 50th, 75th, and 95th quantiles for each structure geometry at each flow rate.

Geometry Type	Flow, Q	Max TKE	Mean Velocity	5th PCTL	25th PCTL	50th PCTL	75th PCTL	95th PCTL
	ft^3/s	ft^2/s^2	ft^2/s^2	ft^2/s^2	ft^2/s^2	ft^2/s^2	ft^2/s^2	ft^2/s^2
Fish Notch	10	0.9	0.3	0.0	0.1	0.3	0.5	0.7
Roughened Ramp 12%	10	1.5	0.5	0.1	0.2	0.5	0.8	1.2
Roughened Ramp 16%	10	1.7	0.4	0.1	0.2	0.4	0.6	1.2
Alternating Terrace	10	1.3	0.5	0.1	0.2	0.5	0.7	1.0
Fish Notch	30	1.4	0.3	0.1	0.1	0.2	0.4	0.9
Roughened Ramp 12%	30	2.0	0.4	0.1	0.1	0.3	0.5	1.2
Roughened Ramp 16%	30	2.6	0.5	0.1	0.2	0.3	0.7	1.6
Alternating Terrace	30	1.8	0.5	0.1	0.2	0.3	0.7	1.4
Fish Notch	300	5.3	0.5	0.0	0.1	0.2	0.5	2.7
Roughened Ramp 12%	300	7.3	0.5	0.0	0.1	0.3	0.6	1.9
Roughened Ramp 16%	300	6.2	0.5	0.0	0.1	0.2	0.5	2.2
Alternating Terrace	300	7.7	0.4	0.0	0.1	0.2	0.4	2.5
Fish Notch	600	5.6	0.7	0.0	0.1	0.4	1.0	2.8
Roughened Ramp 12%	600	6.9	0.6	0.0	0.1	0.3	0.7	2.2
Roughened Ramp 16%	600	5.9	0.8	0.0	0.1	0.4	1.1	2.9
Alternating Terrace	600	7.0	0.6	0.0	0.1	0.4	0.9	2.6

At recreational and bankfull flows, all geometries show relatively low TKE values, with RR12 being the lowest at both flows. The Fish Notch resulted in the lowest 5th percentile values of TKE at base flows and fish flows. At base flows and fish flows, TKE is lowest at the Fish Notch geometry. The 50% TKE is very similar across all geometries at recreational lows, and lowest at RR12 during bankfull flows. TKE is consistently lowest at the Fish Notch during the lower flows across all quantiles. At higher flows there is a not a single geometry that produces consistently lower values than the others, but there TKE do not differ significantly between the structures.

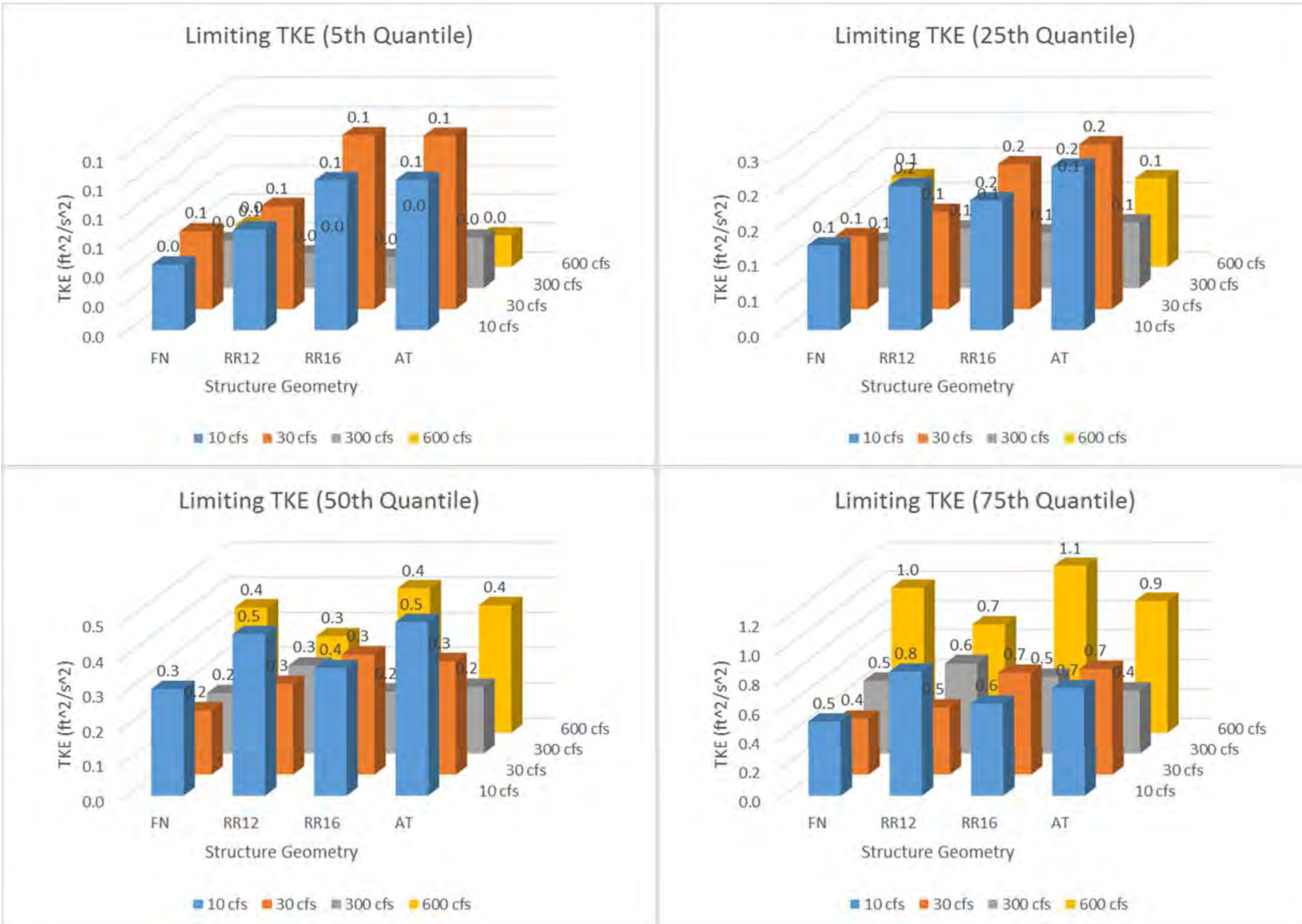


Figure 27: 5th, 25th, 50th, and 75th quantiles of limiting TKE.

Discussion

For the purposes of identifying the structure geometries that produce the least limiting hydraulic conditions as well as relating hydraulic conditions between this study and previous studies, internal comparisons between results from this study and external comparisons between results from different studies were both performed. Internal comparisons include evaluations of the limiting hydraulic conditions, and depths as well as a combination approach intended to identify potential opportunities for fish passage within each studied structure geometry at each identified flow rate. External comparisons were also made to assess of limiting velocities, structure geometries and pool turbulence to results presented in the previous studies at Meadow Park.

Limiting Hydraulic Conditions

A comparison of the results for the 95th quantiles for each hydraulic parameter sampled is shown below in Table 7. For the purposes of describing the limiting conditions for each structure geometry and flow rate, it was assumed that the 95th quantile represented a statistically significant portion of the sampled cross sectional area. The maximum values were not chosen for comparison, as they may represent more extreme observations and as such, are less representative of the sampled data sets.

Table 7: Comparison of the 95th quantiles of limiting velocities, depths, vorticities and TKE.

Geometry Type	Flow, Q	Limiting Velocity	Limiting Depth	Limiting Vorticity	Limiting TKE
	ft^3/s	ft/s	ft	s^{-1}	ft^2/s^2
Fish Notch	10	5.0	0.7	10.4	0.7
Roughened Ramp 12%	10	5.7	0.3	9.1	1.2
Roughened Ramp 16%	10	5.9	0.5	13.3	1.2
Alternating Terrace	10	5.4	0.5	13.2	1.0
Fish Notch	30	6.7	1.1	12.2	0.9
Roughened Ramp 12%	30	7.9	0.6	13.1	1.2
Roughened Ramp 16%	30	8.1	0.7	13.0	1.6
Alternating Terrace	30	7.0	0.8	13.9	1.4
Fish Notch	300	12.3	2.5	17.5	2.7
Roughened Ramp 12%	300	13.1	2.4	17.8	1.9
Roughened Ramp 16%	300	12.7	2.5	23.0	2.2
Alternating Terrace	300	13.3	2.2	16.8	2.5
Fish Notch	600	11.8	3.6	20.5	2.8
Roughened Ramp 12%	600	12.0	3.4	21.6	2.2
Roughened Ramp 16%	600	11.9	3.5	23.1	2.9
Alternating Terrace	600	11.7	3.4	19.3	2.6

As shown in Table 7, the Fish Notch geometry consistently produces the lowest limiting velocities, vorticities and TKEs along with the greatest limiting depths for all scenarios at 10 and 30 cfs, other than the vorticity observation at 10 cfs, where the Roughened Ramp 12% produces a lower limiting vorticity value. As flows increase to recreationally desirable levels, between 300 and 600 cfs, it can be seen that the Fish Notch geometry no longer produces the lowest limiting conditions for all hydraulic parameters measured and generally produces very comparable limiting values of velocity, depth, vorticity, and TKE between all structure geometries studied.

These results demonstrate the ability of the Fish Notch geometry to produce the least limiting hydraulic conditions during the more critical lower flow periods, while producing very similar hydraulic conditions during recreationally important flows. These results suggest that when each hydraulic parameter is analyzed independently, the Fish Notch geometry appears to produce the most conducive hydraulic conditions for fish passage at lower flows while simultaneously producing very similar hydraulic conditions at higher flows.

Limiting Depth

Stephens used a minimum value of 0.6 ft to define a depth limiting fish passage barrier, and any location along a flow path where the water column was less than 0.6 ft was defined as such. Without direct knowledge of fish body depths, 0.6 ft provides an average minimum depth criterion across the range of suggested values and fish size (Hotchkiss and Frei, 2007).

The results of this study, shown in Table 7, demonstrate how the more traditional ramp geometries, such as the Roughened Ramp 12%, Roughened Ramp 16% and Alternating Terrace, can create limiting depths for fish passage, particularly during critical low flow periods. Of the four geometry types studied only the Fish Notch generates limiting depths greater than 0.6 ft at 10 cfs, suggesting that this geometry type would not limit passage as a function of depth. As flows increase to 30 cfs, all four structure geometries create depths equal to or greater than 0.6 ft no longer creating a depth limiting scenario for fish passage.

Comparison of Limiting Velocities

Limiting velocities were compared between the Fish Notch geometry and the pre-flood geometries presented by Fox (2013). The Fish Notch geometry was selected for comparison because it consistently produced the lowest limiting conditions of the four geometry types studied and was selected as the preferred geometry for the structure redesigns at Meadow Park.

A comparison of the maximum velocity, mean velocity, 5th, 25th, 50th, 75th, and 95th velocity quantiles, shown in Table 8, demonstrates the Fish Notch geometry's ability to produce significantly lower velocity values when compared to pre-flood geometries, WWP2 and WWP3, at both 10 and 30 cfs. When compared to the WWP1 geometry, the Fish Notch geometry produces lower maximum velocities as well as 75th, and 95th velocity quantiles at both 10 and 30 cfs. However, as flows increase to 300 cfs, the Fish Notch geometry produces very similar velocities to all pre-flood structure geometries, suggesting that at recreationally desirable levels, the Fish Notch geometry is capable of producing equivalent and even superior recreational opportunities.

Table 8: Comparison of velocity results for pre-flood geometries and proposed Fish Notch geometry at WWP3.

Geometry Type	Flow, Q	Max Velocity	Mean Velocity	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile
	ft^3/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s
Fish Notch	10	5.2	3.6	2.1	2.9	3.8	4.2	5.0
Fox WWP1	15	7.6	2.4	0.1	0.5	1.7	4.6	6.6
Fox WWP2	15	9.7	7.7	4.0	7.4	8.3	9.0	9.3
Fox WWP3	15	9.8	7.0	3.3	6.4	7.9	8.8	9.6
Fish Notch	30	6.9	4.6	2.8	3.9	4.9	5.7	6.7
Fox WWP1	30	10.3	3.7	0.0	1.0	4.3	6.1	7.9
Fox WWP2	30	11.0	7.8	4.3	6.7	9.2	10.0	10.4
Fox WWP3	30	11.1	7.4	3.9	7.5	8.5	9.0	9.9
Fish Notch	300	13.4	8.1	2.0	5.7	10.4	11.2	12.3
Fox WWP1	300	11.8	6.4	0.8	4.5	7.2	9.3	10.1
Fox WWP2	300	14.2	7.5	2.3	5.9	9.2	10.5	11.3
Fox WWP3	300	13.1	9.4	2.7	9.1	10.8	11.3	12.4

Combination of Limiting Depth and Velocity

Stephens (2014) describes a method to evaluate fish passage opportunities at a given WWP structure based on a combination of limiting depth and velocity. A similar approach has been taken within this study to evaluate passage opportunities at WWP3 for all four prototype structure geometries, albeit without performing the calculations explicitly along streamlines.

For this analysis a ratio of the limiting velocity to maximum burst speed was developed for each structure geometry at each flow rate. The 95^{th} quantile describing both depth and velocity was assumed to conservatively represent limiting hydraulic conditions for this analysis. The maximum burst speeds were calculated based on the burst swimming abilities of 25 body lengths/s described by Castro-Santos (2013) and further validated by Stephens (2014). All calculated ratios of limiting velocity to maximum burst speed greater than 1.00 were assumed to produce velocity limiting conditions for fishes of a given size class and are represented in Table 9 with a by a red shaded cell. A secondary depth limiting condition of calculated depths less than 0.6 ft was then superimposed on top of the calculated ratios to further define fish passage limitations. Depth limited values are described by the value within the cell being crossed out. Both yellow and green shaded cells, without crossed out values, represent opportunities for passage of fishes of the indicated size class. Yellow shaded cells contain calculated ratio values between 0.99 and 0.50, while green shaded cells contain calculated ratio values less than 0.49.

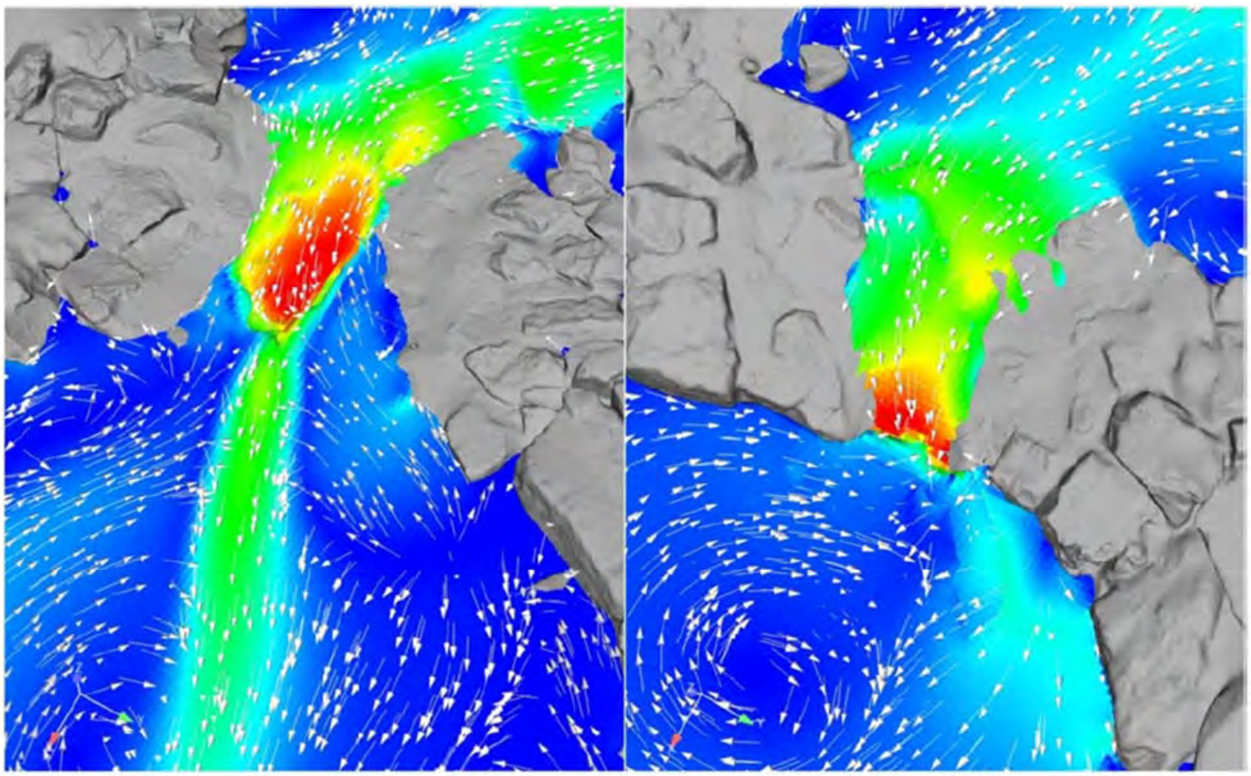
The results of this analysis, shown in Table 9, demonstrate the Fish Notch geometries ability to produce the lowest ratios of limiting velocity to maximum burst speed during the critical fish passage periods. Although all four geometries do not produce velocity limiting conditions for fish larger than 75 mm at 10 cfs, when the depth limiting condition is superimposed, we see that only the Fish Notch geometry will allow for passage of fishes 75 mm and greater, due to depth limiting conditions.

Table 9: Ratio of limiting velocity to maximum burst speed along with superimposed depth limiting condition.

		Fish Body Length (mm)												
		50	75	100	125	150	175	200	225	250	275	300	325	350
Base Flow (10 cfs)	Fish Notch	1.22	0.81	0.61	0.49	0.41	0.35	0.30	0.27	0.24	0.22	0.20	0.19	0.17
	Roughened Ramp 12%	~~1.38~~	~~0.92~~	~~0.69~~	~~0.55~~	~~0.46~~	~~0.39~~	~~0.34~~	~~0.31~~	~~0.28~~	~~0.25~~	~~0.23~~	~~0.21~~	~~0.20~~
	Roughened Ramp 16%	~~1.43~~	~~0.95~~	~~0.71~~	~~0.57~~	~~0.48~~	~~0.41~~	~~0.36~~	~~0.32~~	~~0.29~~	~~0.26~~	~~0.24~~	~~0.22~~	~~0.20~~
	Alternating Terrace	~~1.31~~	~~0.87~~	~~0.66~~	~~0.52~~	~~0.44~~	~~0.37~~	~~0.33~~	~~0.29~~	~~0.26~~	~~0.24~~	~~0.22~~	~~0.20~~	~~0.19~~
Fish Flow (30 cfs)	Fish Notch	1.63	1.09	0.81	0.65	0.54	0.47	0.41	0.36	0.33	0.30	0.27	0.25	0.23
	Roughened Ramp 12%	1.92	1.28	0.96	0.77	0.64	0.55	0.48	0.43	0.38	0.35	0.32	0.30	0.27
	Roughened Ramp 16%	1.98	1.32	0.99	0.79	0.66	0.56	0.49	0.44	0.40	0.36	0.33	0.30	0.28
	Alternating Terrace	1.70	1.14	0.85	0.68	0.57	0.49	0.43	0.38	0.34	0.31	0.28	0.26	0.24
Recreation Flow (300 cfs)	Fish Notch	3.01	2.01	1.50	1.20	1.00	0.86	0.75	0.67	0.60	0.55	0.50	0.46	0.43
	Roughened Ramp 12%	3.19	2.13	1.60	1.28	1.06	0.91	0.80	0.71	0.64	0.58	0.53	0.49	0.46
	Roughened Ramp 16%	3.10	2.07	1.55	1.24	1.03	0.89	0.78	0.69	0.62	0.56	0.52	0.48	0.44
	Alternating Terrace	3.24	2.16	1.62	1.29	1.08	0.92	0.81	0.72	0.65	0.59	0.54	0.50	0.46
Bankfull Flow (600 cfs)	Fish Notch	2.89	1.93	1.44	1.16	0.96	0.83	0.72	0.64	0.58	0.53	0.48	0.44	0.41
	Roughened Ramp 12%	2.93	1.96	1.47	1.17	0.98	0.84	0.73	0.65	0.59	0.53	0.49	0.45	0.42
	Roughened Ramp 16%	2.90	1.93	1.45	1.16	0.97	0.83	0.73	0.64	0.58	0.53	0.48	0.45	0.41
	Alternating Terrace	2.85	1.90	1.42	1.14	0.95	0.81	0.71	0.63	0.57	0.52	0.47	0.44	0.41

Structure Geometries

All three previous studies have noted that a highly constricted outlets at the exit of the structure could limit potential fish passage routes by forcing fish to pass through the highest velocity and most turbulent sections of the flow field. However, no specific hydraulic parameters were used to describe this effect. Fox stated that “a fish moving upstream through WWP2 is required to pass through the highly-turbulent jump because of the constricted outlet flow area; while within WWP3 fishes may bypass the highest turbulent zones through the lateral eddies. The effects of turbulence within WWP1 are less clear because potential movement pathways are less defined, and turbulence effects will be largely dependent on the specific location a fish attempts to move upstream” (Figure 28).



(A) WWP3 (B) WWP2

Figure 28: (A) Modeling results for WWP3 indicates reverse flow around the high-velocity turbulent zones on lateral margins of the hydraulic jump; and (B) modeling results for WWP2 indicate highly-constricted outlet flow area limits potential passage routes through the highest velocity and turbulent sections of the flow field (Fox, 2013, p. 69).

Figure 29 and Figure 30, shown below, demonstrate how the redesigned structures at Meadow Park can minimize this affect by altering the geometry of the structure to allow for backwatering of the ramp at critical fish passage flows. Furthermore, the inclusion of roughness elements on the structure bed and edges along with hydraulically designed structure geometries, allows for the structure to drive flows through critical depth during periods of flow when whitewater recreation is occurring in the reach, while simultaneously limiting flow choking at lower flows when fish passage needs are more critical.

A comparison of these figures demonstrates the ability of the Fish Notch geometry, relative to the other geometries analyzed, to create the lowest velocity zones through the throat and along the lateral margins of the structures during both the 10 and 30 cfs simulations. It is assumed that these reduced margin and terrace velocities along with the more focused turbulent zone at the structure exit will result in increased pathways and subsequent increased passage success.

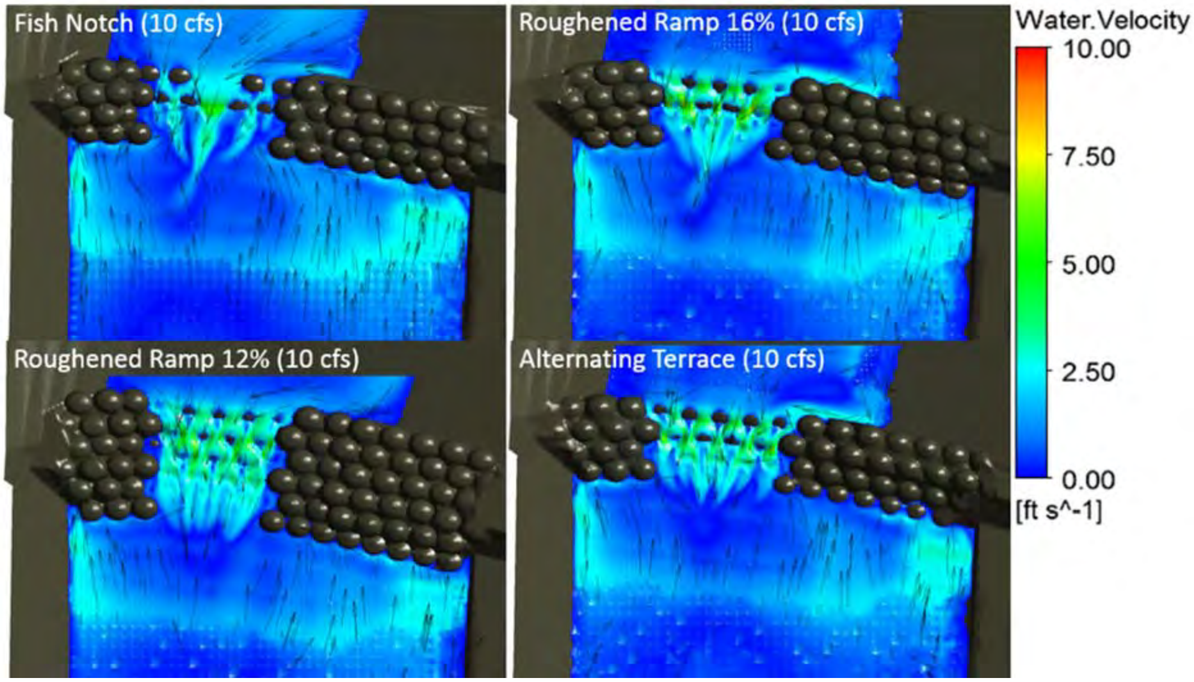


Figure 29: Turbulent high velocity zones at 10 cfs along the lateral margins of revised study geometries.

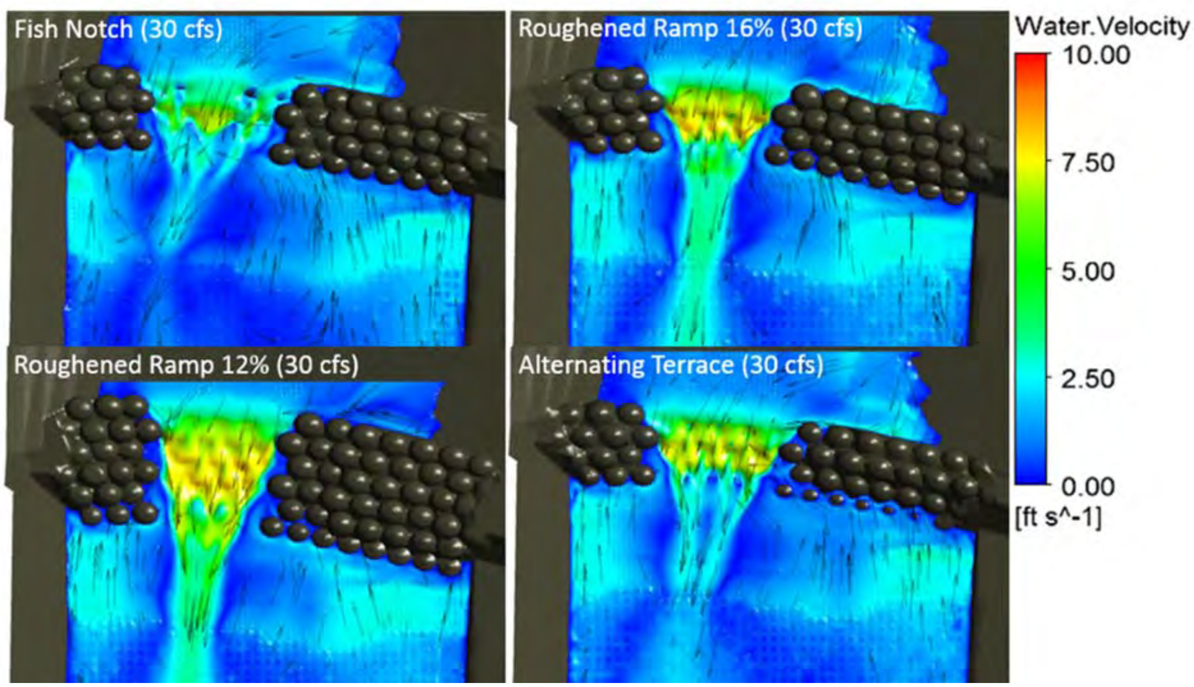


Figure 30: Turbulent high velocity zones at 30 cfs along the lateral margins of revised study geometries.

Pool Turbulence

Kolden compared modeled aquatic habitat quality to field measurements of fish biomass to examine the applicability of 3D modeling to assess habitat suitability. The primary zones of interest studied by Kolden were the scour pools, downstream of the whitewater structures. Maximum depth, vorticity and TKE were averaged across all four pool cross-sections and compared to the results reported by Kolden (2013) for both WWP pools and natural pools. Results presented by Kolden were averaged across the pools of all three whitewater structure geometries studied, while our results are presented as averages for each individual study geometry. Kolden compared hydraulic variables at WWP pools and natural pools for Low (15 cfs) Medium (150 cfs) and High flow rates (300 cfs). Because our study did not analyze flows at 150 cfs, results are only presented for the Low and High flows described by Kolden. Hydraulic conditions created by flows at 10 and 15 cfs are assumed to be similar thereby allowing for a comparison of the Base flows calculated in this study and the Low flows analyzed by Kolden.

TKE

Average maximum pool TKE results for all structure geometries modeled were lower than the WWP values reported by Kolden (2013) at both Low and High flows (Table 10). At Low flows, Kolden reported 2.0 and 0.3 ft^2/s^2 for the average of the WWP pools and the Natural Pools, respectively. At High Flows, Kolden reported 5.5 and 2.3 ft^2/s^2 for the average of the WWP pools and the Natural Pools, respectively. Of the four geometries modeled in this study, RR12 resulted in the lowest TKE values at base flows, while both the RR16 and Alternating Terrace geometries resulted in the lowest TKE values at recreational flows. In all cases the Fish Notch geometry produced significantly lower TKE values when compared to WWP pool values presented by Kolden (2013).

Table 10: Average maximum pool TKE (ft^2/s^2).

	Kolden (2013)		**S2o (2015)**			
	WWP	Natural	Fish Notch	Roughened Ramp 12%	Roughened Ramp 16%	Alternating Terrace
Low (10-15 cfs)	2.0	0.3	0.8	0.7	0.8	0.8
High (300 cfs)	5.5	2.3	1.9	2.9	1.6	1.6

Depth

All modeled structure geometries resulted in shallower pool depths than those reported by Kolden (2013) for the WWP pools (Table 11). All four geometries modeled in this study resulted in very similar depths (within 0.1 ft) at base flows, with the Fish Notch having the greatest depth. At Low flows, Kolden reported the natural pool as having the shallowest depth, at 2.0 ft, while the average WWP pool had a depth of 4.9 ft. At High Flows, the redesigned structure geometry pools produced significantly lower depths than those reported by Kolden (2013) for the WWP pools.

Table 11: Average maximum pool depths (ft).

	Kolden (2013)		**S2o (2015)**			
	WWP	Natural	Fish Notch	Roughened Ramp 12%	Roughened Ramp 16%	Alternating Terrace
Low (10-15 cfs)	4.9	2.0	3.1	3.1	3.0	3.0
High (300 cfs)	6.9	3.6	4.4	4.4	4.4	4.3

Vorticity

Average maximum 3D pool vorticity for the revised structure geometries was also much lower than those reported by Kolden (2013) (Table 12). At Low flows, Kolden found maximum vorticities of 9.3/s and 4.5/s in the WWP and natural pools, respectively. At High flows, Kolden found maximum vorticities of 17.7 /s and 8.3 /s in the WWP and natural pools, respectively. The Alternating Terrace geometry resulted in the lowest maximum vorticities for both Base and Recreational Flows. The Fish Notch geometry also produced significantly lower average pool 3D vorticity values when compared to both the WWP and natural pools studied by Kolden (2013).

Table 12: Maximum 3D pool vorticity (/s).

	Kolden (2013)		**S2o (2015)**			
	WWP	Natural	Fish Notch	Roughened Ramp 12%	Roughened Ramp 16%	Alternating Terrace
Low (10-15 cfs)	9.3	4.5	3.3	2.8	3.2	2.7
High (300 cfs)	17.7	8.3	7.6	8.0	7.6	6.9

Overall, all four proposed geometries resulted in lower average maximum TKE and vorticity values at both base flows and recreational flows as compared to the pre-flood structures presented in Kolden's 2013 study. The proposed geometries also had lower depths when compared to Kolden's WWP results. These results suggest that alterations to structure geometries can successfully reduce pool turbulence and subsequently improve aquatic habitat in WWP pools.

Recreation

The modeling of recreation at a whitewater structure can be subjective and is generally based on associating quantitative measurements and qualitative visual assessments of the modeled hydraulic jump to existing WWP features of a known character. Specific parameters used in this study to assess the recreational quality of the four geometry types modeled include:

- Depth over the structure;
- Shape of the wave surface;
- Eddy function and velocity; and
- Overall character of hydraulic jump.

Depth over Structure

The depth of flow over the structure is one of the most critical factors to downstream recreational use of a WWP. Though freestyle kayakers will typically have a higher standard for use for a WWP, often requiring waves and holes of substantial size and power, slalom boaters and tubers will often use WWPs at much lower flows. It is feasible that these downstream users could potentially use the park at flows as low as 30 cfs, which would only require adequate depth to float over a structure without coming into physical contact with it. Similar to upstream fish passage, the limiting cross section for downstream recreational use will contain the minimum value of maximum depths observed. As presented above, the limiting depth in the Fish Notch geometry, at 30 cfs, is 1.1 ft, whereas the other three geometries produce significantly lower values of limiting depths. Figure 31, below, shows how the Fish Notch geometry provides a deeper flow path through the low flow notch, which is anticipated to increase the duration of potential downstream use of the WWP.

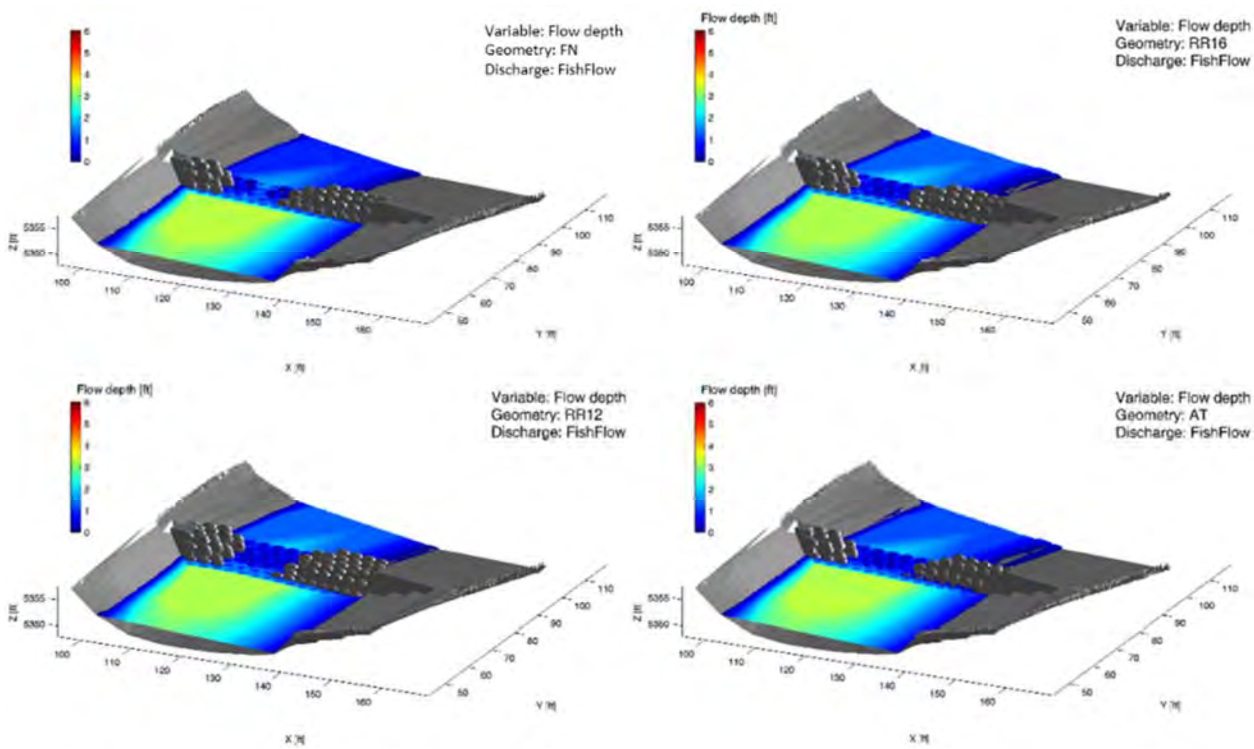


Figure 31: Water depths over the structure throat during Fish Flows (30 cfs).

Shape of Wave Surface

The overall shape of the wave surface is one of the most critical factors for freestyle use of a whitewater structure. For this study, the shape of the wave surface was generally broken into three defining factors including: formation and height of a pile; symmetry of the wave trough; and abruptness of the transition between supercritical and subcritical flows at the hydraulic jump.

Freestyle use of the Meadow Park WWP will largely hinge on the availability to adequate flows in the North St. Vrain River. Using the Recreational Flows (300 cfs) as a general measure of the necessary flow to create good recreation, Figure 32 below, shows that the Fish Notch geometry creates the greatest modeled height of the pile as well as uniformity of pile shape. The increased pile height also translates to lower velocities within the pile, suggesting a more desirable hydraulic conditions for freestyle kayaking.

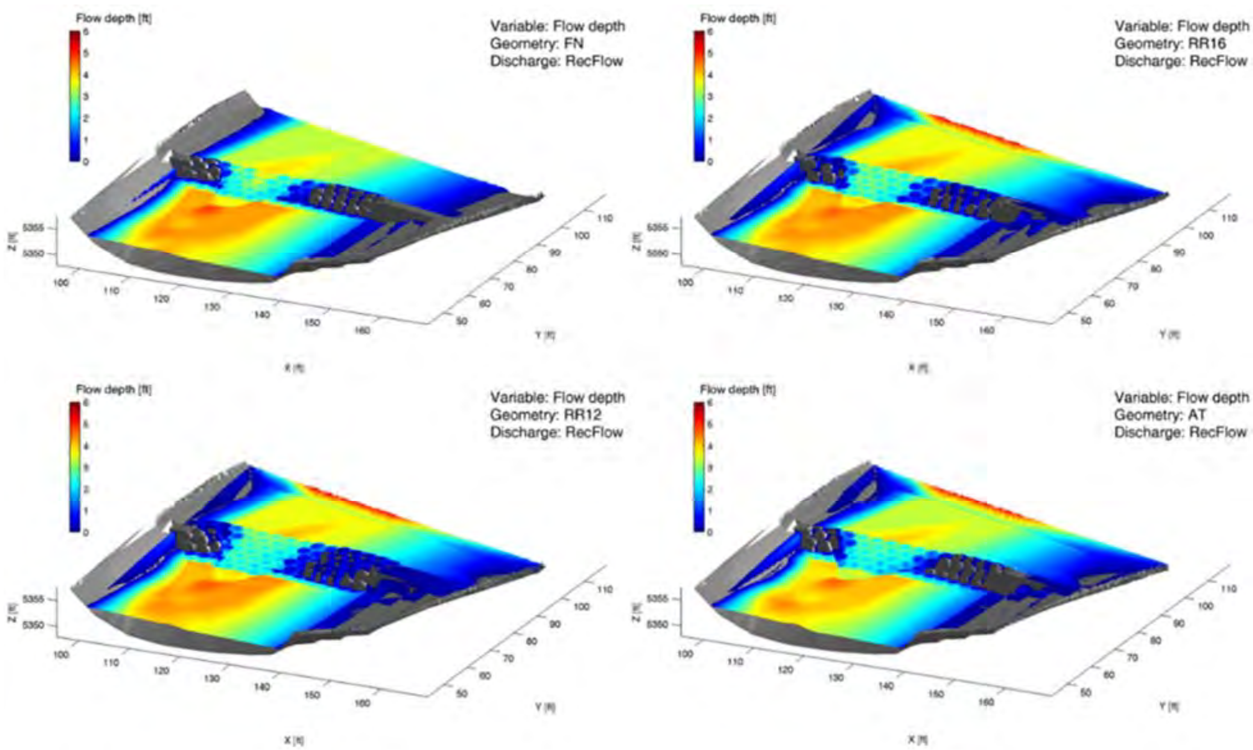


Figure 32: Water depths over the structure throat during Rec Flows (300 cfs).

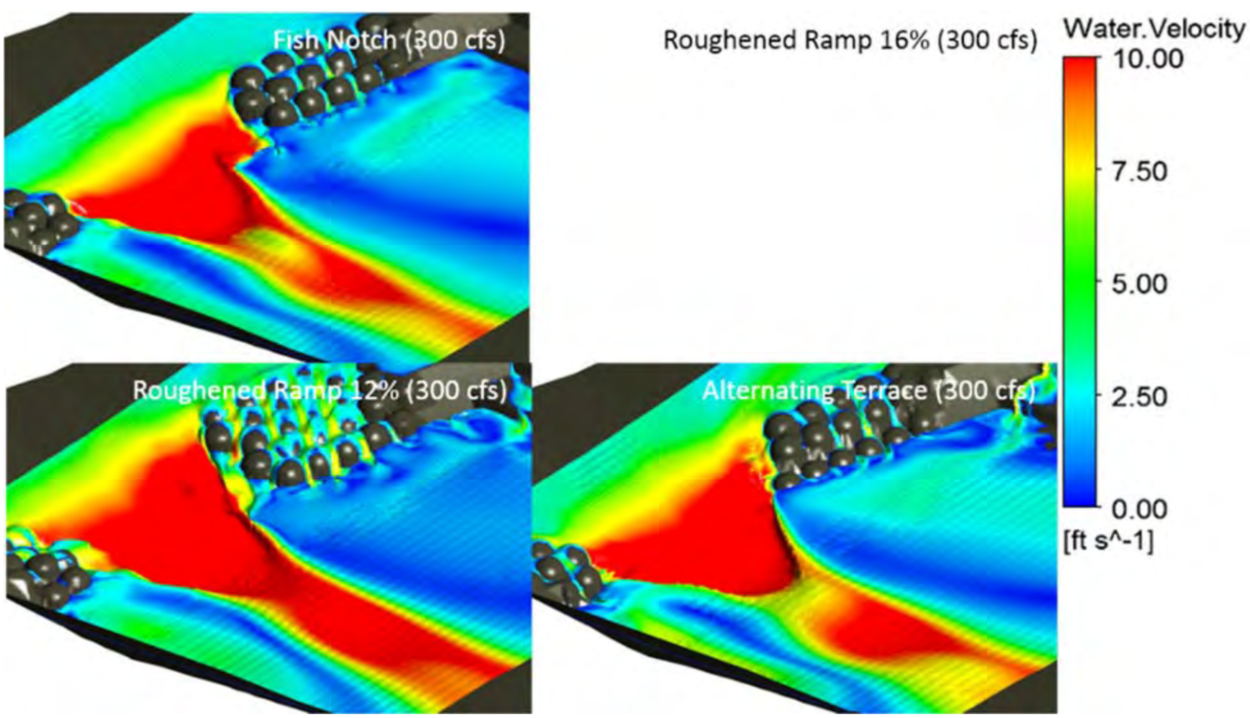


Figure 33: Isometric view of wave troughs and associated velocities for the four structure geometries studied.

The Fish Notch geometry also appears to create the most symmetrical wave trough (Figure 33). At 300 cfs, all four geometries create relatively smooth transitions between supercritical and subcritical flows, though the Alternating Terrace geometry creates the most abrupt transition along the left edge of the wave. It can also be seen that the lower bed slopes of the Roughened Ramp 12% do not generate the desired pile or wave shape as compared to the other geometry types studied. The Fish Notch geometry appears to create the most attractive wave shape from a qualitative standpoint.

Eddy Function

Park and play freestyle kayaking requires both the formation of desirable wave shapes and the creation of feeder eddies to allow for continued use of the feature without having to exit ones kayak to return to the wave. Eddies should provide adequate recirculation to attain back to the wave without generating excessive velocities, which can result in reduced function by pulling freestyle uses toward the feature while waiting their turn in line. It should also be noted that eddy velocities can be too low as well. In this scenario excess sedimentation can occur in the pools outside the primary jet, limiting the functional use of the waves. Figure 34 shows the eddy circulation patterns, at 300 cfs, for all four geometries studied. It can be seen that the Alternating Terrace geometry produces the greatest eddy velocities along both the left and right banks of the pools. Furthermore, the Fish Notch geometry appear to produce the greatest amount of pool surface area at relatively low velocities where freestyle users can wait their turn in line, without generating excessively low velocities such as the Roughened Ramp 12% geometry, which could result in increased sedimentation in the pool.

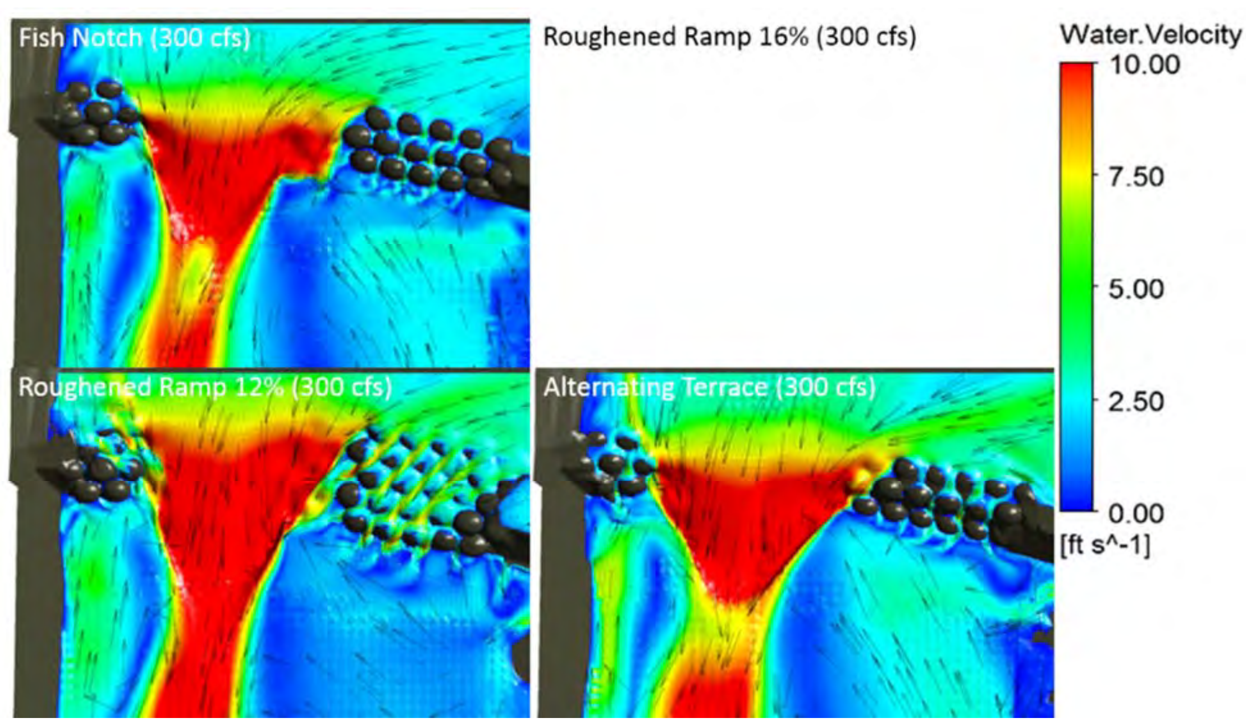


Figure 34: Planview of the modeled hydraulic jumps and velocity vectors at each studied geometry type studied.

Character of Hydraulic Jump

The character of a hydraulic jump in this study is generally defined as a combination of the magnitude and direction of the velocity vectors produced within the wave and pile. Traditional analyses of hydraulic jumps in rectangular channels produces a general classification of hydraulic jumps as a function of Froude Numbers, as shown in Figure 35.

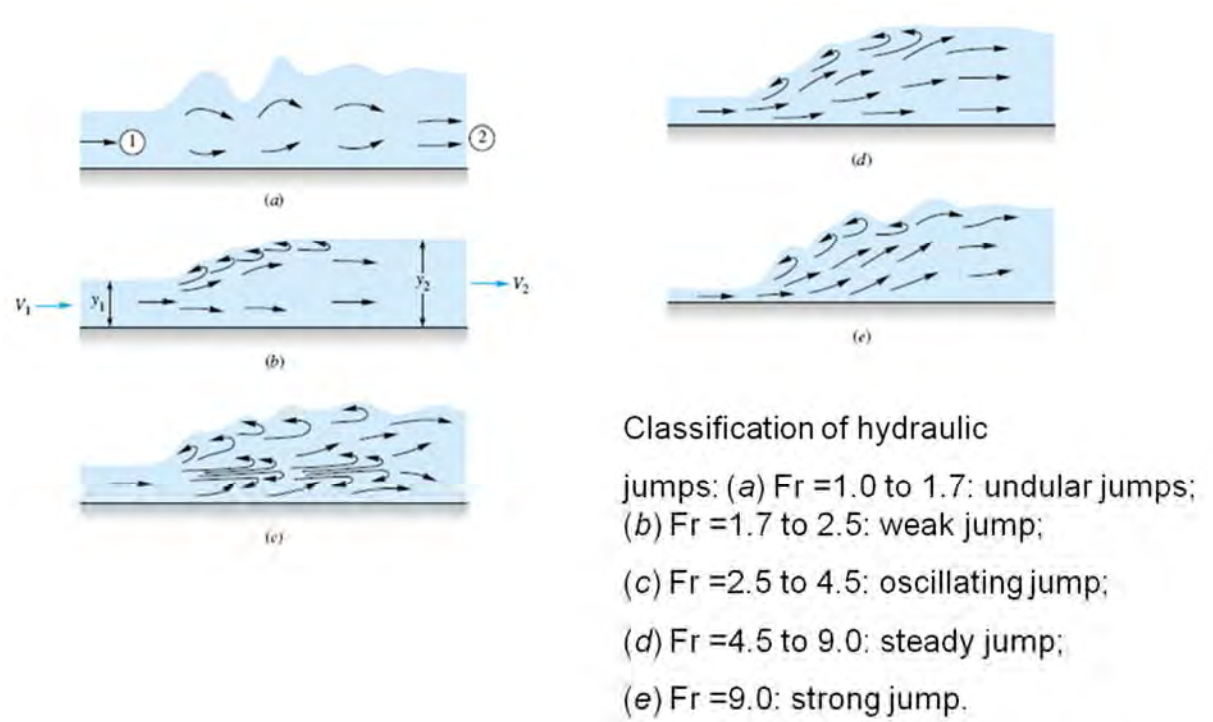


Figure 35: Traditional classification of hydraulic jumps in a rectangular channel (optimist4u.blogspot.com, 2015).

For recreational applications, a wave resembling a weak or oscillating hydraulic jump is typically preferable, though a direct comparison of hydraulic jumps occurring in natural channels versus rectangular flumes is not always advisable. Weaker hydraulic jumps such as those formed in an oscillating jump are not generally preferable as they do not effectively dissipated their energy in the primary jump and form apparent wave trains downstream in the pool, which often does not produce desirable recreational features and can lead to excessive downstream erosion. On the other end of the spectrum, both steady and strong hydraulic jumps can be overly retentive resulting in potentially dangerous waves that do not allow for sufficient egress from the wave. Working within this general framework for hydraulic jumps, Figure 36 shows that the Alternating Terrace and Fish Notch geometries appear to produce hydraulic jumps of appropriate character, while the Roughened Ramp 12% and Roughened Ramp 16% geometries appear to produce more defined wave trains with extended zones of downstream energy dissipation. All hydraulic jumps appear to be safe and do not suggest that they will produce dangerous conditions at Bank Full flows, the greatest flow rates modeled.

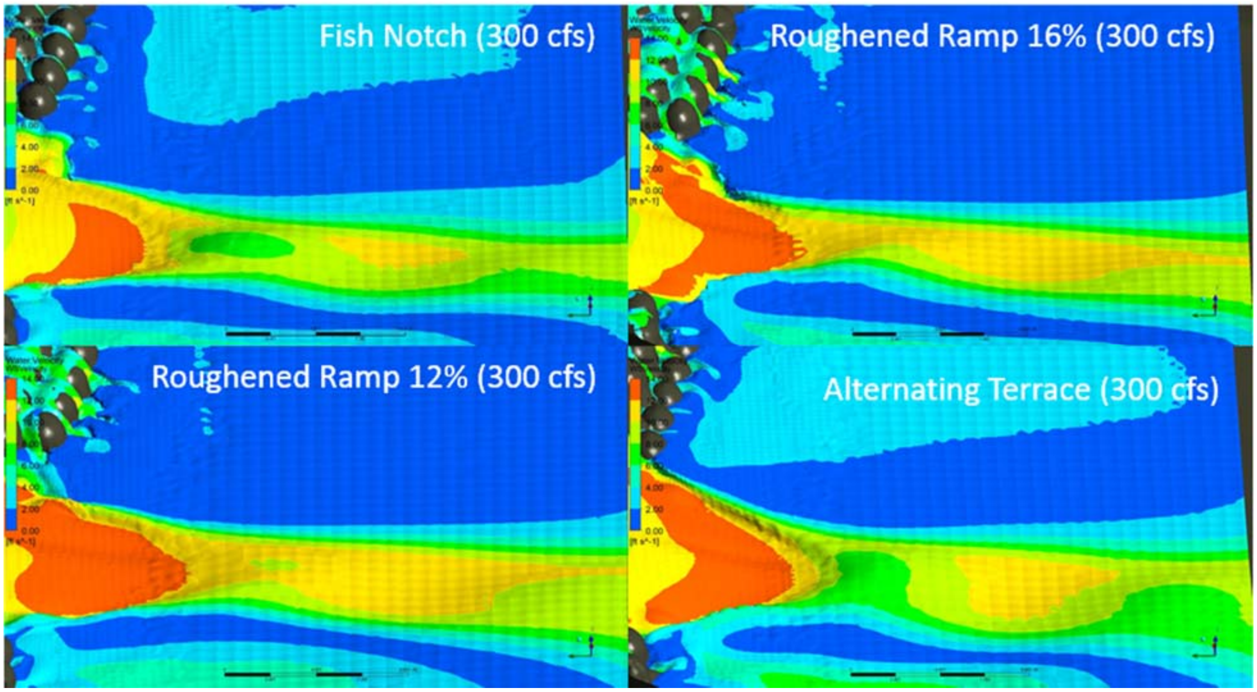


Figure 36: View of the modeled hydraulic jumps and pools occurring at each studied geometry type.

Conclusion

The redesign effort along with the previous pre-flood studies completed by CPW at Meadow Park, provided the ideal study setting to analyze the effects of different WWP structure geometries on hydraulic conditions that can effect fish passage and aquatic habitat. In total, four structure geometries were analyzed for the redesign effort and 3D CFD modeling was used to assess differences in associated hydraulic conditions.

The Meadow Park WWP has been the site of three prior studies, two of which analyzed fish passage over WWP structures and one that looked at aquatic habitat in the downstream pools of the pre-flood structures. This study has been conducted to analyze the effects of new structure geometries on hydraulic conditions for the proposed reconstruction of the Meadow Park WWP in 2015. Four separate structure geometries were modeled at the WWP3 site. The results were used to characterize the effects of structure geometry on hydraulic conditions and subsequently fish passage limitations and downstream aquatic habitat. The structures were evaluated over a range of flows that were determined to be representative of the typical flow variation seen during the course of a year and were identified as critical to fish passage and recreation. Hydraulic conditions created by each different structure geometry were compared to one another to identify which geometries created the least limiting hydraulic conditions and subsequently the preferred structure designs for the proposed Meadow Park WWP reconstruction. Hydraulic conditions calculated for the preferred design approaches were then compared to results presented in previous studies to better understand the implications of the revised geometries on fish passage and habitat.

The results of this study suggest that changing WWP structure geometries can significantly affect calculated hydraulic conditions and subsequently improve fish passage and aquatic habitat without compromising recreational opportunities. Though all revised structure geometries created hydraulic conditions, at 10 cfs, which suggests they may act as fish passage barriers to fishes less than 75 mm, the Fish Notch geometry is the only structure studied that does not create a depth limiting condition during this critical low flow period. Of the four geometries analyzed, the Fish Notch consistently resulted in the lowest velocities, vorticities and TKE at 10 and 30 cfs. At recreationally desirable flows, the Fish Notch produced very comparable limiting velocity, depth, TKE, and 3D vorticity values. The revised structure geometries also drastically reduce calculated turbulence in the scour pools downstream of the WWP structures when compared to the pre-flood geometries analyzed by Kolden (2013). These results further demonstrate the ability of the revised design approaches, particularly the Fish Notch geometry, to meet both the needs of the recreationists as well as to facilitate fish passage and aquatic habitat.

When hydraulic conditions generated by the Fish Notch geometry are compared to results from previous studies, the differences suggest that this is not only the best structure geometry of the four analyzed, but that the fish notch treatment option, when designed correctly, can greatly improve fish passage opportunities within similar WWPs elsewhere. However, because of the complexity of 3D flows over whitewater structures, the fish notch may not be applicable to significantly higher volume rivers. The other treatment options evaluated in this study, including the use of roughened edges along the lateral margins, varying ramp slopes, non-symmetrical wing terraces, and recessed notches, may provide additional fish passage treatment options for bypass channel solutions in larger river settings.

This study provides a framework for conducting before and after comparisons of the pre-flood and redesigned Meadow Park WWP. The redesign and eventual reconstruction of the Meadow Park WWP, combined with the results outlined in the pre-flood studies completed by CPW, provides an ideal experimental set-up to evaluate the effects of WWP structure geometries on fish passage and aquatic habitat. It is anticipated that future studies of Meadow Park, following its reconstruction in 2015, will be used to further assess the success of design and analytical methodologies outlined herein.

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Appendix D
Columbus Riverfront Opportunity Analysis by
Hitchcock Design Group

Memorandum

Date: May 24, 2017
To: Heather Pope
Columbus Redevelopment Commission

From: Hitchcock Design Group

RE: **Columbus Riverfront Opportunity Analysis**

Acknowledgements

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Summary

This Opportunity Analysis concludes the first of our three-phased study of the Columbus Riverfront between the 2nd and 3rd Street Bridges. It includes a review of important study area **resources, marketplace, and stakeholder expectations**. It also summarizes promising riverfront opportunities that we will explore in greater detail in the upcoming Alternative Riverfront Concepts phase.

Introduction

The **Columbus Redevelopment Commission** is leading an initiative to improve the appearance, recreational function, environmental quality, and economic benefit of the East Fork of the White River between the 2nd and 3rd Street bridges (see project map below).

On behalf of the city, the Redevelopment Commission has engaged a team of planning, design, engineering, and market economic professionals led by Hitchcock Design Group to create a compelling riverfront concept that improves access to and along the river, and creates dynamic public places consistent with the city's rich cultural history.

As an integral part of the project, the team will consider modifications of the low-head dam to improve river water quality, safety, and navigation. The Redevelopment Commission expects the concept to be finished in September and introduced to the community during a series of public workshops and meetings.

After an initial kickoff meeting with City of Columbus officials, the consultant team reviewed and analyzed existing data such as demographic studies, current land uses, market trends, and historical data to evaluate the existing conditions within the study area. The consultant team also reviewed several studies to gather up-to-date information about the natural and hydrological characteristics of the study area. Simultaneously, the team launched a project website and conducted a Community Survey (see **Appendix A**) that provided valuable primary data that will be used in the upcoming Alternative Riverfront Concepts phase.

The consultant team also conducted key stakeholder interviews and hosted a Community Workshop at Cal Brand Meeting Hall on April 5-6, 2017. During the Community Workshop, the consultant team provided an overview of the study area and its surroundings. The participants represented a broad cross section of the community and included business owners, residents, property owners, and elected officials. HDG asked stakeholders to share their thoughts, concerns, and ideas regarding the Riverfront and its potential, and encouraged stakeholders to keep up to date on the project through the website.

In the next phase, the Alternative Riverfront Concept, the consultant team will explore promising opportunities in greater detail to reach consensus on an overall strategy, the most promising improvements, and preliminary implementation recommendations.

Figure 1. Project Map

Riverfront Today

Resources

The resource analysis considers the regional context, natural and cultural resources, land use and structures, infrastructure, and financial resources.

Regional Context

With a population of approximately 48,000, Columbus is a growing city with small town charm boasting a plethora of history, art, and architecture. With its close proximity to I-65, Columbus is easily accessible and is within 100 miles of several major cities, including Indianapolis, Louisville, and Cincinnati. Located in Bartholomew County, the study area is nestled between the 2nd and 3rd Street Bridges that carry the inbound and outbound traffic to and from Downtown Columbus. Though it is not easily accessible, the site is within a half mile walk from the heart of downtown. The 19.4 acre site includes the east and west banks of the East Fork of the White River, as well as the river itself, between the 2nd and 3rd Street Bridges. The study area is just south of Mill Race Park, an 85-acre riverfront park designed by Michael Van Valkenburgh in conjunction with Stanley Saitowitz. Despite the expansive stretch of the White River and its watershed, there are few improved urban riverfronts near Columbus.

Natural Resources

The most dominant natural resource is the East Fork of the White River that flows through the project site. The Flatrock and Driftwood Rivers converge north of the site to feed the East Fork of the White River. Due to its location within floodway and floodplain, the site is structurally undeveloped except for the low-head dam. The site has limited accessibility due to steep slopes and thick vegetation. There are no jurisdictional wetlands within the project area.

Soil erosion is a problem along the east and west bank of the site. River current and spillway orientation continue to contribute to the erosion on the site.

Typical tree species found along the banks of the East Fork of the White River include silver maple, boxelder, sycamore (American planetree), cottonwood, green ash, elms, and sandbar willows. A large portion of the green ash trees have been killed by the emerald ash borer. There are very few shrubs due to the dense tree canopy. Herbaceous plants found on the forest floor include Virginia wild rye, reed canary grass, stinging nettle, and great ragweed. See “Waters of the U.S. Determination Report” in **Appendix B**.

The portion of the river that runs through the study area is considered to be one of the best smallmouth bass fisheries in the state. Other fish species found in the river include channel catfish, sunfish, bluegill, and more. A variety of wildlife inhabits the banks of the river, including wood ducks, kingfishers, spotted sandpipers, great horned owls, muskrats, groundhogs, an occasional blue heron, and fox squirrels.

Cultural Resources

The Riverfront is rich in cultural history, and has been an integral part of Columbus since the early 1800s. In 1821, a commercial ferry began carrying people across the river. The Columbus Bridge Company was incorporated in 1847, and constructed a bridge across the river that was completed in 1849. The expanding population of Columbus eventually led to the construction of two bridges, each carrying traffic in or out of downtown. These two bridges are the northern and southern boundaries of the study area. The most architecturally notable of these bridges is the Robert N. Stewart Bridge (formerly known as the 2nd Street Bridge), completed in 1999. Constructed as a part of the Front Door Project, the “legs” of the Robert N. Stewart Bridge frame the view of the Bartholomew County Courthouse as motorists approach downtown. The original Pump House was completed in 1871, and was constructed to provide a consistent water supply to the city. The original low-head dam that spans the river was constructed around 1890 to provide consistent water availability to Columbus after several significant buildings were destroyed by fire because lack of water pressure prevented fire fighters from extinguishing the flames in a timely manner. The dam remains, but it is no longer used for its originally intended purpose of providing water and water pressure to Columbus.

The City of Columbus has several historically and architecturally significant features throughout the community. The riverfront is close to many of those features, including Mill Race Park, the Bartholomew County Courthouse, The Commons, and many others within a half mile walking radius.

Due to the number of nearby archaeological sites, parts of the study area may be of archaeological significance. Butler, Fairman, and Seufert Civil Engineers, who performed the Historic Resource Inventory for the study area, recommend that the southernmost portion of the west bank undergo a

Phase 1a archaeological field reconnaissance before any improvements are constructed (see **Appendix C**).

Topography
The east bank of the river is very steep, with a height change of about 18 feet over a +/- 20' distance. The west bank has a height change of about 21 feet, but over a much larger area. The 10-year flood elevation is approximately 619' (NAVD88), and the 100-year flood elevation is approximately 622' (NAVD88).

Size
The total study area is approximately 19.4 acres
East Bank: 1 acre
West Bank: 13.4 acres
River: 5 acres
Length of riverfront within study area: 737 feet

Hydraulics & Hydrology
The East Fork of the White River has a watershed encompassing 1,700 square miles in ten counties. The contributing watershed is primarily agricultural in land use, and is typically not prone to flash flooding. When it does reach flood stage, flood durations typically last four days or longer, depending on the severity of the storm. During average flow conditions, the water surface increases 3-4 feet upstream of the dam. Downstream of the dam, flow moves in all directions, particularly near the west bank where an eddy forms. In large flood events, the dam is unlikely to impact flows. The lower portion of the riverfront site is subject to frequent flooding; it has flooded 10 times in the past four years. The upper portion of the site is less likely to flood; it has flooded less than ten times in the past century.

Based on fixed monitoring stations maintained by the Indiana Department of Environmental Management (IDEM), it appears the chemical and physical status of the East Fork of the White River at the riverfront site are of good condition. Few exceedances of water quality benchmarks have been observed and habitat evaluations have been favorable.

The low-head dam that spans the project site was originally constructed to increase the water pressure to the city and power grist mills. Despite its historical contributions to the City of Columbus, the dam is now obsolete. Low-head dams have many negative impacts on water quality, including disruption of water flow, sediment flow, and passage of fish and other species. They also impede river-based recreation and create a dangerous drowning hazard. The combination of reversed currents, dangerous rotating objects underwater, hard surfaces, large hydraulic forces, and low buoyancy created by low-head dams are a deadly combination. Between the years of 1960 and 2014, 287 low-head dam fatalities have been reported in the United States, as well as 71 injuries and 235 incidents. The Department of Natural Resources inspected the dam in 2007 , at which time they determined that it is no longer useful, in poor condition, and should be removed (see **Appendix D**).

In addition to the dangers present to river users, the dam has also caused a breech in the river on the west bank. Because this area is a capped landfill, there is the potential for pollutants to leech into the river if the water continues to erode the western bank.

The possible modification or removal of the low-head dam at the riverfront site provides both opportunities and challenges. Clear benefits of low head dam modification or removal include returned natural river flow, reconnected habitat for aquatic species, improved water quality, and increased river safety. The challenges consist of preparing for the release of the sediment to minimize turbidity and impacts from potential contaminants that have accumulated behind the dam. In addition, regardless of what modifications may be considered or if the low-head dam is removed, there will inevitably be changes in the river morphology that will impact the channel shape and sinuosity, consequently requiring regulatory agency construction permits. IDEM and the U.S. Army Corps of Engineers (USACE) will regulate both temporary and permanent impacts below the ordinary high water elevation. IDEM will also want to know the potential impacts to water quality, plant life, and animal species that exist. A permit will also be required by the Indiana Department of Natural Resources (IDNR) for any fill placed in the floodway.

The consultant team is collecting survey data and working on a two-dimensional hydraulic model of the river that will serve as a baseline condition against which, we will compare various improvement concepts.

Streets & Railways
The study area is encompassed on three sides with roadways and bridges. The northern boundary of the study area is the 3rd Street Bridge, which carries traffic westward out of downtown. The southern boundary of the study area is the 2nd Street Bridge, which carries traffic eastward into downtown. The west/southwest boundary is where these two roadways converge at the SR 11 and SR 46 intersection. The property east of the study area is privately owned and currently used as a restaurant. Motorists are challenged to find Upland Brewery via Lindsey Street, which runs roughly north and south, but dead ends before it reaches 2nd Street.

The Pennsylvania Railroad Bridge is north of the site, which carries 4 and 20 trains through downtown on a daily basis. Because of the increased train traffic and the hazard it poses to pedestrians, city leaders have initiated plans to reroute the railroad around downtown. The most current concept would reroute the rail line west of the river. In addition, the February 2017 plan prepared by American Structurepoint suggests that SR 46 be elevated and reconfigured to eliminate the conflict between vehicles and trains. The concept also suggests an interstate-type cloverleaf interchange that may affect the Riverfront in three significant ways. If constructed as conceptualized, the study area may expand southward to include the land directly east of the proposed cloverleaf, vehicle speed may increase, making accessibility to the site challenging, and potential Riverfront and roadway improvements will need to be carefully coordinated.

The Columbus Thoroughfare Plan suggests a very long term goal to move SR 46 completely out of town.

Pedestrian Paths
The Columbus People Trail currently circulates along the river north of the study area through Mill Race Park. The path spans the river alongside the 3rd Street Bridge, on the north edge of the study area. There is a branch of the People Trail that ends at Lafayette Street behind the jail, but there is currently no connection on the south side of downtown between this branch of the trail and the trail through Mill Race Park. There is a section of the People Trail along SR 46 between I-65 and the river. The study area has the potential to be a connection point between these three trails.

Parking & Access
There is currently no parking or vehicular access serving the site. However, there are approximately 1,100 public parking spaces located within a ten-minute walking radius of the study area. Upland Brewing Company at the Pump House has approximately 65 parking spaces that are reserved for patrons, and according to the owner, the lot is frequently at capacity. Accessibility to the site, on both the east and west bank, is challenged, but there is a small, well-used foot path on the east bank leading down to the sandbar. There is currently no American Disabilities Act compliant pedestrian access to the site.

Exposure and Appearance

Community leaders consider the study area to be part of a larger "Front Door" visitor experience, and because of its location between two major bridges, the study area is very visible to both inbound and outbound motorists. With approximately 18,000 cars moving inbound and 17,000 cars moving outbound from Downtown Columbus, daily, the study area has thousands of onlookers. Even though it is not easily accessible, 42% of people responding to the Riverfront survey said they have been to the study area on foot. Another 34% said they were familiar with the area because they drive past it.

According to the survey results, the appearance of the study area has room for improvement. Only 11% of those surveyed said that they were highly satisfied with the overall attractiveness of the site, while the remaining percentage was split almost evenly between "somewhat satisfied" and "not satisfied."

Hazardous Waste/Landfill

The old city landfill is located on the west bank of the river within the study area. The site operated as a landfill from 1938-1966, and was designated a National Priority List (NPL) site in 1986. Remediation of the site began in 1993 and included leachate seep inspections, groundwater monitoring and use restrictions, and placement of a clean soil cover over the site. Remediation was completed in 1994, and five-year monitoring reports have been completed by IDEM in 1999, 2005, 2010, and 2014. The site was declared "site-wide ready for reuse" in 2012, and was deleted from the NPL in 2014. No additional hazardous materials investigations appear to be necessary at this time. See "Hazardous Waste Site Inventory" in **Appendix E** for more in depth information.

The site is still protected by Institutional Controls in the form of two Environmental Restrictive Covenants:

1993 Declaration of Restrictions
- There is to be no interference with improvements on the site related to remedial actions
- Groundwater exposure and use at the site is prohibited for any use other than for approved remedial actions.
- The site cannot be used for any other purpose, including agriculture, recreational, residential, commercial, or industrial, including any movement of soil or construction of structures related to the above uses, unless such construction is approved, in writing, by IDEM and USEPA.

2010 ERC (between City of Columbus, Cummins Inc, IDEM, and USEPA)
- Same as 1993 ERC summary above
- The security fence at the site cannot be removed
- Emergency repairs to sewers located within the site are permitted under certain conditions (as listed in the ERC)

Soils

Most the study area is located within floodway. Because of frequent flooding, the site is dominated by alluvial soils from years of sediment deposition. The existing low-head dam has also impacted the soils within the site. The dam has increased backwater, affected sediment transport, and changed the geophysical conditions of the East Fork of the White River. The dam also causes more frequent flooding and increased soil deposition within the study area.

Utilities

The study area is served by city-owned water and wastewater utilities and franchise-owned electric, data and communications services.

Marketplace

The market analysis considers area demographics, activities and tourism. We also considered comparable projects in other communities, which suggest best practices that may be appropriate in Columbus.

Demographics

The population in Columbus is growing at a faster rate than the rest of the county, state, and country, and household size is increasing, implying a higher number of children. Columbus has a relatively young population, with a median age of 38.8 in 2016, and the age bracket of 18 and younger is growing, which is different from other similar sized communities throughout the country. The senior population is also growing, consistent with the national trend. The residential population of 48,480 is relatively small, but there are 9400 people working during the day within a 15-minute walking radius from the project site.

Activities

The local population dines out at a rate that is well above the national average. Residents also participate in biking, boating, canoeing/kayaking, fishing, swimming, walking for exercise, birdwatching, and attending musical performances at a rate that is much higher than the national average. The highest participation levels are walking, running/jogging, swimming, biking, and fishing.

Tourism

Columbus is a genuine visitor attraction for the state of Indiana. Data shows that people come from out of state to visit Columbus for many reasons, including athletic tournaments, architecture, business, and more. Brown County and other surrounding outdoor attractions are also a popular destination for a large group of visitors. While Brown County visitors are heading in the opposite direction of Columbus, it puts them within close proximity to Columbus. Bartholomew County has a higher overnight visitor percentage compared to the rest of Indiana, and the length of stay and the visitor party size in Bartholomew County is longer/larger compared to the rest of the state. Visitors to Columbus engage in dining, shopping, sporting events, and outdoor recreation, and the participation in those four categories is higher than the rest of the state. Indiana attracts a higher percentage of young visitors (18-34 years) and more families with young children compared to other states and destinations within the country.

Best Practices

The common success factors found in comparable settings define the best practices that will likely be appropriate in Columbus. The consultant team considered their own portfolios of riverfront projects and Market and Feasibility Advisors also consider several other riverfronts. Our research suggests that when completed, the Columbus Riverfront should be multi-dimensional, attractive, distinctive, respectful, barrier-free, healthy, sustainable and incremental.

Multi-dimensional
We should consider improvements that target resident and visitor audiences and accommodate a variety of program requirements to provide a high return on investment for all project investors.

Attractive
We should create engaging, stimulating and well-maintained improvements that support and help define this gateway to downtown.

Distinctive
We should differentiate the riverfront from other local and area destinations.

Respectful
The process and the improvements should follow jurisdictional requirements, respect the riverfront stakeholders and support the community's rich cultural heritage.

Barrier-free
While challenging, we should provide access to the study area and its features for patrons with compromised mobility, and we should provide all patrons with barrier-free access to the river.

Healthy
We should create a variety of active and passive, accessible, comfortable, clean and safe experiences for all patrons.

Sustainable
We should create improvements that add environmental, economic and cultural value for years to come.

Incremental
We should phase the improvements over time to manage costs and to create and sustain momentum.

Stakeholder Expectations

Columbus Riverfront Stakeholders include government officials, property and business owners, and residents. In addition to on-going guidance provided by the Riverfront Citizens Committee, the consultant team interviewed key stakeholders, facilitated a community workshop, and conducted a community survey to gather critical insight and brainstorm riverfront improvement ideas.

Key Stakeholder Interviews
The consultant team interviewed approximately 30 community leaders and several jurisdictional representatives. As anticipated, we received a wide range of opinion, but there were five common themes that emerged from the interviews:

Importance
Even though Columbus has Mill Race Park and its many natural and man-made amenities, the riverfront study area is important because it is an unfulfilled part of the gateway ("front door") experience and downtown. And of course, the study area features very engaging, moving river water in a setting that offers a wide variety of perspectives and engagement opportunities.

Connectivity
Interviewees stressed the importance of 3-dimensional (up/downstream, lateral and vertical) connectivity, and they stressed walking and cycling connections, north, south and west as the highest priorities. However, many interviewees expressed interest in canoeing or kayaking, and many expressed the need for some on-site parking to accommodate a variety of loading, maintenance, family and mobility-challenged interests.

Activity
Talent attraction and retention is a major community priority, so anything that we can do to activate engaging, in-or-near-river experiences that appeal to millennials and families is very desirable. Active recreation also appeals to tourists.

Hospitality
Hospitality is critically important. Every aspect of the riverfront, from convenience to comfort to safety to appearance should create a positive and memorable experience for visitors and residents.

The Columbus Way
Some communities want to "go big or go home." Columbus seems to want it "done right or not at all." The emphasis on quality (loosely defined as durable design distinction) is unmistakable.

Community Workshop
The consultant team facilitated a public workshop on April 5, 2017 that was attended by approximately 70 energetic residents and others with a keen interest in the riverfront. The team introduced the project and presented preliminary data about the study area resources and market. The team facilitated individual and interactive group exercises that identified some common interests and priorities of the participants when asked to describe the riverfront in 2022.

Trail
Overwhelmingly, the participants want to see multi-purpose trails that connect the study area to local trails and downtown.

Whitewater
Participants expressed a noteworthy interest in a whitewater park as a replacement for the existing dam.

Kid attractions
Participants also expressed interest in distinctive, river-themed attractions that target children and families.

New park
Participants saw the western portion of the study area as an opportunity for a unique park offering that is complementary to, but distinct from Mill Race Park.

Natural environment
Participants want to see all improvements emphasize nature and the environment.

Community Survey
Over 600 people took the survey that was posted on the Columbus Riverfront website, which suggests both an important level of interest and statistically valid guidance. Please see **Appendix A** for complete results, which are summarized as follows:

Approximately 75% of the respondents are "familiar" or "very familiar" with the study area because of their daily travels across the bridges or because they have visited The Pump House. Respondents are least satisfied with noise level, maintenance, safety and river access.

More than half of the respondents consider the study area to be part of downtown, and 58% of the respondents visit downtown, weekly or daily for dining, arts/entertainment or to work.

Respondents are physically active. More than half of the respondents visit Mill Race Park multiple times per year to walk, run, cycle, stroll along the river or simply relax. In fact, 70% of the respondents walk, run or cycle, often, in their neighborhoods or along one of the existing trails in Columbus, and 63% participate in water-based activities.

The top 3 reasons why respondents think that the riverfront should be improved are to provide more activities for residents, increase water-based recreation and link downtown to the river. Respondents top 3 improvement suggestions were better, more frequent river access, more trails and bicycle facilities and a whitewater course.

Approximately 77% of the survey respondents indicated that they would very likely use the river if it were improved.

Riverfront Tomorrow

Goal

The long-term goal of the Columbus Redevelopment Commission for the riverfront study area is to:

Create and sustain an iconic riverfront experience that strengthens Columbus' distinctive brand and robust economy.

Objectives

Superbly **connect** the riverfront to other local and regional destinations.

Attract residents, daytime workers and regional visitors with a distinctive package of river-oriented public improvements, and over time, additional private sector investment.

Build and maintain beautiful and environmentally respectful riverfront improvements that **complement** Columbus' rich cultural tradition.

Upon completion of the Columbus Riverfront plan incrementally **phase** the project to create and sustain momentum.

Promising Opportunities

On April 6, the consultant team brainstormed opportunities to accomplish the riverfront goal and objectives, then discussed the most promising opportunities with the Riverfront Steering Committee. The concepts, which focused on primarily on connections and attractions such as:

- All concepts illustrated improved 3-dimensional connectivity and featured modification or removal of the dam.
- Some concepts illustrated a riverwalk on the east bank as both a connection and an attraction. Some concepts emphasized a simpler trail connection on the east bank and a more modest trail along the west bank.
- All concepts illustrated some level of river-themed play on gentler slopes of the west bank. Some concepts illustrated more elaborate river-themed play opportunity on the west bank downstream of the remodeled dam.
- Some concepts packed the river and west bank with active recreation attractions.

- All concepts accommodate the probable, but unscheduled realignment of SR 46 and recognize the importance of the gateway experience and the challenges of west bank access, both now and in the future.

- One concept featured a berm on the landfill site that is a gateway feature, look-out, and backdrop for westbank activities.

- Challenges that require special attention during the next phase include:
  - The future realignment of SR 46, as currently conceptualized, may cause increased motorist speeds where we desire lower speeds and a tricky left-in/out of the west bank property.
  - The street network east of the study area complicates the lateral connectivity to downtown.
  - Construction restrictions on the capped landfill will complicate some desired improvements.

Strategy

Based on the existing resources, marketplace and stakeholder expectations, the consultant team recommends the following strategy to advance the community's riverfront goal. Each component should meet the four objectives and most, if not all the best practices (multi-dimensional, attractive, distinctive, respectful, barrier-free, healthy, sustainable, incremental).

Connect

Construct a 3 dimensional network of related connections.

- vehicular access and limited parking on the west bank for maintenance, emergencies, loading, and accommodation of less mobile patrons
- sidewalks that expand the People Trail along the river with connections north and south of the bridges
- sidewalks that provide river access from the top of the banks
- sidewalks that clearly link the riverfront and downtown, providing convenient access to nearby public and privately owned destinations
- dam modification that allows in-stream watercraft passage

Attract

Construct several distinctive public features that target young professionals and families, which in turn, are catalysts for related, nearby private sector investments.

- whitewater course that appeals to a variety of experience levels
- river-themed children's play space
- high-amenity riverwalk (spacious, and sculptural with attention to surfaces, fixtures, furnishings, lighting, public art and landscaping) with node(s) that accommodate small groups and overlooks with great river views
- the western/southern edge of the west bank property should get special attention as part of a beautiful Columbus "front door" downtown gateway

Complement

Reaching beyond "respectfulness," design and construct the public features to be captivating, giving special attention to:

- the gateway experience
- the river and its story in Columbus

- the community and neighborhood brand strategy

Phase
Develop a phase-able approach to the riverfront improvements.