The Lower Olentangy River Watershed Lowhead Dams

Feasibility Study
CIP 650706
Franklin County, Ohio
December 22, 2005

Mr. Greg Barden, PE
Project Manager
City of Columbus
Department of Public Utilities
Division of Sewerage and Drainage
910 Dublin Road, 3rd Floor
Columbus, OH 43215-9053

Re: The Lower Olentangy River Watershed Lowhead Dams
Feasibility Study
CIP 650706
Franklin County, Ohio

Dear Mr. Barden:

Fuller, Mossbarger, Scott and May Engineers, Inc. (FMSM) is pleased to submit this FINAL Feasibility Study for the Lower Olentangy River Watershed Lowhead Dams in Franklin County, Ohio. This report summarizes our findings from the study and documents the processes utilized during the project. It also represents the invaluable input of project partners: the City of Columbus; the Friends of the Lower Olentangy Watershed; the Ohio Department of Natural Resources; and the Ohio Environmental Protection Agency.

If you have any questions, please feel free to contact us.

Sincerely,

FULLER, MOSSBARGER, SCOTT AND MAY ENGINEERS, INC.

Bryon F. Ringley, PE
Project Manager

/jfk

Enclosures: 1
The Lower Olentangy River Watershed Lowhead Dams

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CIP 650706
Franklin County, Ohio

This publication was financed in part or totally through a grant from the Ohio Environmental Protection Agency and the United States Environmental Protection Agency, under the provisions of Section 319(h) of the Clean Water Act.

Prepared for:
City of Columbus
Department of Public Utilities
Division of Sewerage and Drainage
Columbus, Ohio

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Executive Summary

The Ohio Environmental Protection Agency, under the provisions of Section 319(h) of the Clean Water Act, funded a feasibility study to look at the full removal and other potential alternatives to improve the water and habitat quality of the Olentangy River at five lowhead dam locations within the Greater Columbus, Ohio area. These five lowhead dams were constructed specifically as river crossings for gravity, sanitary sewers. Maintaining the sanitary sewer service integrity is of the utmost importance to the evaluation of full removal or any alternative presented.

The partners actively involved in the feasibility study include the City of Columbus; the Friends of the Lower Olentangy Watershed; Fuller, Mossbarger, Scott and May Engineers, Inc., the Ohio Department of Natural Resources, and the Ohio Environmental Protection Agency. Input from these partners was obtained during a Brainstorming Workshop where potential alternatives were listed, discussed and agreed upon for conceptual level development and evaluation. A second workshop was held with the project partners to gather a comprehensive list of evaluation criteria and to prioritize that list. The input from the staff of the various departments and sections of the partnering agencies lends credibility to the comprehensiveness and results of the study.

The following conceptual alternatives were developed, modeled and evaluated:

- Full dam removal, including several scenarios involving sanitary sewer relocation/realignment and potential pump stations;
- Grade control riffles on the downstream side of the dams;
- W-weir installations on the downstream side of the dams;
- Sluices through the dams;
- Narrowing the channel in the upstream pool area of the dams;
- Small diversion channels around the dams;
- Fish ladder structures on the dams;
- Boat portages around the dams; and
- Removal of the Antrim Lake levee and utilization of a stormwater pond near the Broad Meadows dam.

A hydrologic and hydraulic model (HEC-RAS) of the river reach containing the five dams was constructed to demonstrate the impacts of the dams on the river during a range of flood conditions from the 1-year event through the 500-year event. A typical dam, numerical flume model (HEC-RAS) was constructed based on the similar characteristics of the five dams. This model was used to predict the impacts of full removal, grade control riffles, sluices, and channel narrowing. A 1:50 scale model of a w-weir and lowhead dam was constructed in a tilting flume to demonstrate the impacts of the w-weir conceptual alternative.
Two evaluation criteria were given “make or break” status by the project partners during the Evaluation Criteria Workshop. Any alternative, to be considered feasible, had to 1) maintain the integrity of sanitary sewer service and 2) be able to be permitted. After those two criteria, hydraulics, biology/chemistry, recreation, safety, cost, aesthetics, reliability, timetable, public support and potential funding criteria were considered. The alternatives were differentiated by whether they positively, negatively or had no impact on the specific criteria.

Full removal is not considered feasible because of the sanitary sewer service integrity criterion. Relocation or realignment of the sanitary sewers introduces integrity issues associated with the pump stations that are required. The conceptual level costs of these alternatives, which do not include land acquisition costs and operation and maintenance costs, range from $7.5 million to remove only the Broad Meadows dam, to $44 million for the lowest cost option of removing the five dams. Zigzag Option 3, which removes the Union Cemetery and Dodridge dams, does not have the sewer service integrity issues caused by pump station installations. However, defining an alignment corridor in the highly developed area where the Franklin Main and Olentangy Scioto Interceptor Sewer (OSIS) are already located may be difficult. Maintaining the integrity of these existing sewers during construction would also be an issue. The conceptual level cost estimate for this option, excluding land acquisition costs is $7.4 million.

The future design and construction of the Olentangy Relief Tunnel (ORT) may provide opportunity to visit the Full Removal alternative in the future. As proposed, the ORT is not planned for any dry weather flows. Adding dry weather flows to the tunnel should be investigated to facilitate the Full Removal of the five lowhead dams. The preliminary design of the ORT is not planned until 2015 with construction complete in 2042. This is not a short-term solution, but should be investigated during the preliminary design phase of the ORT.

Grade control riffles and w-weirs are not considered feasible due to permitting issues associated with the National Flood Insurance Program (NFIP). These alternatives produce an increase in the base flood elevation at the dams of approximately one foot during the 100-year event.

Creating small diversion channels around the dams would require the diversion channels to cross over or under the sanitary sewers as they extend beyond the dams. These crossings would likely cause integrity issues with sanitary sewer service. For this reason, small diversion channels were also not considered feasible.

Sluices through the dams create unsafe hydraulic conditions on the upstream side of the dam. This safety issue, along with maintenance and constructability issues, renders this alternative not feasible.

Removal of the Antrim Lake levee and utilizing the stormwater pond offer no impacts to the dam locations. Further investigation is required to determine if benefits would be realized in flood storage.

Only three alternatives remain as feasible alternatives; Fish ladders, Boat portages, and Narrowing of the Channel. These conceptual alternatives have positive impacts in the areas of recreation, biology and hydraulics. Narrowing the channel upstream of the dams would be limited by the hydraulics and only offer some habitat benefits. The habitat benefits would likely not be sufficient to raise any use designation or index scores. The permitting required to enable filling in the floodway for this alternative may be prohibitive if the use designation or
index scores are not raised significantly. Fish ladders may enable fish species to migrate past the barriers posed by the dams; however, they would likely not populate the pool areas. The boat portages with associated signage would increase the safety for boaters and increase the use of the river as a water trail. Improved boat portages and fish ladder structures are alternatives that may be investigated further, designed and implemented without negative hydraulic impacts.
1. Introduction

1.1. Project Background

FLOW was formed in August of 1997 with a mission to increase public awareness of the extensive environmental, recreational and cultural resources of the Lower Olentangy River Watershed and to promote responsible policies and uses of the river. This organization drafted a watershed action plan based on water quality data collected by OEPA in 1999 and published in 2001. This plan, the Lower Olentangy Watershed Action Plan (2003), was endorsed by OEPA and ODNR in 2005. One of the nine priorities listed in the plan is restoration of the mainstem through dam removal or dam modifications.

To address the priority of dam removal or modification, FLOW prepared a Section 319(h) Nonpoint Source Program grant application for a project that included a feasibility study to improve the water quality and habitat of the impounded areas of the Olentangy River. (See Appendix A.) The grant application included a feasibility study on the five lowhead dams that harbor sanitary sewer lines to be completed by grant funds; removal of six lowhead dams in Delaware County to be completed with in-kind services; and a feasibility study on removing or altering the rock check dams installed by the Ohio Department of Transportation (ODOT) during the construction of OH SR 315 to be completed with in-kind services.

1.2. Project Purpose and Goals

The lowhead dams situated on the lower Olentangy River are viewed as a detriment to the quality of the river considering water quality, habitat quality and recreation factors. The Lower Olentangy Watershed Action Plan 2003 prepared by FLOW addressed the five lowhead dams that harbor sanitary sewer lines specifically in Table 13 of the Action Plan. A portion of that table is re-created in Table 1.1 on the following page.

An Ohio Environmental Protection Agency (OEPA) Section 319(h) Nonpoint Source Program Grant was obtained and used to fund the feasibility study on the five lowhead dams that harbor sanitary sewer lines. The study focuses on alternatives available to improve water quality while protecting the integrity of the sewer lines. Because of the presence of the sewer lines, full removal may not be considered feasible or desirable.
Table 1.1. Excerpt from the Lower Olentangy Watershed Action Plan 2003 Table 13

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<th>Objectives</th>
<th>Responsible Parties/ Partners</th>
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<th>Funding</th>
<th>Indicators of Success</th>
<th>Schedule</th>
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<td>Where dam removal is not feasible or desirable, investigate the means to modify structures to provide for fish ladders and boat chutes.</td>
<td>City of Columbus DOSD</td>
<td>$160,000 study needs completed.</td>
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<td>Increased diversity in fish and invertebrate species above and below impoundments.</td>
<td>2010 modifications complete.</td>
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“...The goal is to improve the QHEI scores to 60.0 and ICI scores to 36.0 to meet a WWH use designation; at the very minimum, the QHEI and ICI scores should meet the MWH use designation. A full-blown feasibility study is required for the lowhead dams within Franklin County portion of the Olentangy River…”

1.2.1. Project Partnerships

To accomplish the project as outlined in the grant application, several organizations would have to combine efforts and join as partners. FLOW, the City of Columbus, OEPA and ODNR have partnered together to work toward the success of the entire project.

The City of Columbus Department of Public Utilities agreed to administer the grant and is the designated subgrantee or sponsor of the project. The City solicited for proposals for the feasibility study on the five lowhead dams that harbor sewer lines, evaluated the proposals, and entered into contract with Fuller, Mossbarger, Scott and May Engineers, Inc. (FMSM) to conduct the study. The Division of Sewerage and Drainage, Sanitary Sewer Engineering Section assigned a project manager to oversee the project. City personnel have actively participated in the workshops and review of the feasibility study report, and provided existing water quality data and record plans.

FLOW developed the grant application and is named as the project representative. FLOW has actively participated in the workshops and is providing public outreach services. The public presentation of the draft report was hosted at FLOW's November 2005 monthly membership meeting. The organization provided mailings to their membership announcing the meeting.

OEPA is the grant provider and has been a significant source of the biological and chemical data and information for the project. Representatives from the Nonpoint Source Program...
have participated in the workshops and have reviewed the draft report and provided comments.

ODNR provided important information, and representatives participated in the workshops to brainstorm potential alternatives and develop criteria for evaluating the alternative concepts.

Each of the partners has a vested interest in the results of the study and has contributed in-kind services to add value to the total project.

1.2.2. Project Goals

With so many partners with a vested interest in this project, it is important to understand the goals that each organization hopes to accomplish with the completion of the feasibility study. These goals are not to be confused with the specific goals of the alternatives developed to address the five lowhead dam locations, which are further described in Section 4 Development of Alternatives and Evaluation Criteria.

FLOW is a non-profit citizen’s organization dedicated to protecting and promoting the beneficial use of the Olentangy River and its resources. The feasibility study should have this dedication as the primary goal throughout the process. As noted in Table 1.1, this feasibility study is one step toward completing an action item that is included in the Lower Olentangy Watershed Action Plan 2003. FLOW's definition of success for this study is a thorough investigation of alternatives, which includes examining, describing and projecting the ability of each of the proposed alternatives to achieve ecological and recreational benefits to the Olentangy River. Another important component to the organization is the comparison of the proposed cost of the alternatives to the effectiveness of achieving the ecological and recreational benefits.

The City of Columbus Department of Public Utilities also has an interest in defining the goals of this project. Not only is the City interested from the fact that they own and operate the sanitary sewers that are contained within the lowhead dams, but the Division of Sewerage and Drainage (DOSD) has initiated various programs and services under the umbrella title of Project Clean Rivers. The City believes that the entire community and aquatic wildlife will benefit from achieving clean water goals. The City desires to see alternatives available to improve water quality while protecting the integrity of the sanitary sewer lines. The determination of conceptual level costs is also important in the evaluation of the alternatives.

In funding this project through the Section 319(h) Nonpoint Source Program, OEPA also has a stake in defining the success of this project. Traditionally, 319(h) grants have been used for education, public participation and implementation type projects. This type of feasibility study does not include an implementation or construction phase. The benefits, however, are evident in the process of coordination between the partnering organizations, the development and evaluation of alternatives, and the public outreach. OEPA will be looking at the success of this project to determine if future projects of this nature should be funded under the Section 319(h) Program. Also as an outcome of this project, the process and alternatives should be applicable to other lowhead dam sites with similar constraints within Ohio and the nation.

It is a goal of this project to keep the partnering organizations and the public engaged in the process and outcome of the feasibility study. To consider the feasibility study comprehensive, it is imperative that the partnering organizations be actively involved in the
development and evaluation of the alternatives and the public also be given the opportunity to provide input. The partnering organizations – the City, FLOW, OEPA and ODNR – have played an active role during the Brainstorming Workshop and the Evaluation Criteria Workshop. The public presentation of the draft report and the comment period facilitated input from interested members of the public.

1.3. Project Timeline

The Section 319(h) Nonpoint Source Program grant application was submitted by FLOW on March 31, 2003, and endorsed by OEPA on December 5, 2003. The City of Columbus, Department of Public Utilities agreed to be the sponsoring organization and authorized the project on May 20, 2004. In-kind services on this project are being provided by the City of Columbus, FLOW, ODNR and OEPA.

The City awarded the Lower Olentangy River Watershed Lowhead Dams Study (CIP 650706) to FMSM and entered into an agreement on June 6, 2005 to conduct the feasibility study. In accordance with the terms of the grant, the project is to be completed by December 31, 2005.

The seven-month schedule is extremely aggressive for a project of this nature, especially considering the last two months are reserved for accepting public and partner comment, and finalizing the report. Figure 1.1 shows the timeline of phases, workshops, meetings and presentations demonstrates how critical the schedule is for this project.

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**Figure 1.1. Project Timeline**

The month of June and the first part of July were spent gathering and analyzing existing data. Record drawings of the five lowhead dams were obtained from the City. Additional record drawings were obtained from ODOT since modifications to the river channel and the Broad Meadows Lowhead dam were made during the construction of OH SR 315. Water chemistry data was obtained from OEPA’s 1999 Technical Support Document (TSD), the draft TSD currently being developed, and the City’s Wet Weather Management Plan.
Fish and mussel species data were also obtained from OEPA and City sources. QHEI, ICI and IBI score sheets were obtained from sources at OEPA and the City’s WWMP. Information on the sanitary sewer system and planned capital improvement projects was obtained from the City’s WWMP. Potential fish ladder configurations, in-stream structures, and other lowhead dam projects worldwide were researched from various sources. The City’s Floodplain Administrator obtained the current hydrologic and hydraulic model for the Olentangy River from the Federal Emergency Management Agency (FEMA) to be used for modeling the alternatives.

A Brainstorming Workshop was held on July 21, 2005, to develop a comprehensive list of potential alternatives to improve water quality, habitat quality and recreational improvements at the five lowhead dam sites. This half-day workshop was attended by representatives from the partnering entities. A copy of the minutes documenting the workshop is in Appendix B, and an overview of the workshop is presented in Section 4 Development of Alternatives and Evaluation Criteria.

The ideas that came out of the Brainstorming Workshop were further developed into conceptual alternatives in July and August. The existing hydrologic and hydraulic model was updated with current conditions to be used as a baseline to compare changes caused by the alternative concepts. The alternative concepts were added to the model and evaluated hydraulically during the months of September and into October.

An Evaluation Criteria Workshop was held with the partnering organizations on August 31, 2005. The purpose of this workshop was to develop a comprehensive list of the criteria by which the alternatives will be evaluated. The criteria were grouped and prioritized to aid in the evaluation process. A copy of the minutes documenting the workshop is in Appendix C, and an overview of the workshop is presented in Section 4 Development of Alternatives and Evaluation Criteria.

Preparation of the draft report began during the information gathering and analysis task. Fact sheets were generated for subjects such as water chemistry, aquatic life use attainment, sanitary sewers, habitat and QHEI, and fish and mussel species. These fact sheets were used in the Brainstorming Workshop and laid the groundwork for the existing conditions section of the draft report. As draft sections of the report were available, they were forwarded to the City for review and comment. A rough draft of the report was submitted to the City on October 14, 2005.

Before the report could be presented in a public forum, it required review by OEPA. Since the schedule is so compressed, OEPA agreed to have the draft report presented to them in a meeting on October 25, 2005, to facilitate their review during that meeting.

FLOW’s regularly scheduled, monthly meeting was set for November 2, 2005, at 7:30 PM at the Northwood High Building, 2231 North High Street, Columbus. Since FLOW is a partner in the project, has a date and location secured, and a meeting notice mailing developed, it was advantageous to coordinate for the public meeting. A meeting advertisement was placed in the Worthington and Clintonville Booster issues of the Suburban News Press (SNP) publication.

Public comment was received at the public meeting and for the period until November 28, 2005. The City forwarded any comments received to FMSM. Review comments were also received from the partnering organizations during this period.

The comments were reviewed and addressed to finalize the report during the first few weeks of December. Submittal of the final report to the City is targeted for mid December 2005.
2. Background on Lowhead Dams

2.1. Description and History

A lowhead dam, as defined by the Ohio Department of Natural Resource's (ODNR) Division of Water, Dam Safety Program, is a dam of low height (usually less than 15 feet) made of timber, stone, concrete and other structural material, that extends from bank to bank across a stream channel. The Olentangy River has more lowhead dams than any other stream in Franklin County, with 12 lowhead dams on its mainstem and a series of rock-check dams that have been installed in a channelized portion of the river between OH State Route (SR) 161 and Interstate 270. According to the Dam Safety Program, there are 20 regulated lowhead dams in Franklin County, three on the Scioto River, six on the Olentangy River, one on Little Darby Creek, one on Big Walnut Creek, four on Big Darby Creek and five on Alum Creek.

Lowhead dams have historically been constructed across the United States for a variety of reasons. The most common reasons for dam construction include recreation, water supply, flood control, irrigation, water power, electricity production, navigation and utility crossings. Each of these reasons for dam construction is discussed in more detail below.

Recreation. Many dams were constructed for the creation of reservoirs, both small and large, which are used for recreational activities including fishing and boating. One of the reasons for construction of the 5th Avenue lowhead dam on the Olentangy River is documented for boating recreation.

Water Supply. The need for water for urban, domestic and industrial use was the impetus for the construction of many dams. About 60% of the domestic water and 80% of the industrial supply comes from surface water in rivers and streams (Heinz Center for Science, Economics and the Environment, 2002).

Flood Control. Flood control is a major function of large, multipurpose dams across the country, but especially in the East and Midwest. These dams are used to capture runoff and store it for a gradual release. Flood control is not limited to large dams, however, lowhead dams have been constructed for flood control purposes as well.

Irrigation. Irrigation diversions for agriculture are a common reason for the construction of lowhead dams in the plains and western states where rainfall is not consistent enough for crop production (Heinz Center for Science, Economics and the Environment, 2002).

Water Power. From the arrival of the first colonists through to the late 19th century, the mechanical power potential of lowhead dams was used to fuel rural economies. Some lowhead dams were built to power the early grist mills and sawmills and others were used to power factories like woolen mills.

Electricity Production. Lowhead hydroelectric dams were constructed to generate electricity for rural communities. Water is either passed through the structure of a dam to generate electricity or it may be diverted through canals or pipes to off-stream locations for energy generation (Heinz Center for Science, Economics and the Environment, 2002). Some dams were constructed to provide cooling water for power generating plants.
Utility Crossing. Progress has required public and private utilities to expand their service areas, sometimes requiring the crossing of rivers and streams. In some cases, utilities that depend on gravity like sanitary sewers, are physically constrained and not able to go over or under the stream or river. Lowhead dams are often constructed to house these utility corridors. The five lowhead dams on the Olentangy River between Dodridge Street and OH SR 161 were constructed for this purpose.

2.2. Impacts of Lowhead Dams

Lowhead dams are hydromodifications to the river system. Hydromodifications can cause significant changes in the system. These changes have ecological and recreational impacts that are significant.

2.2.1. Ecological Impacts

The Lower Olentangy Watershed Action Plan 2003, developed by FLOW and endorsed by OEPA and ODNR in 2005, includes information regarding the ecological impacts of lowhead dams. These impacts include the following:

- Conversion of reaches of the Olentangy River from a stream system characterized by riffles, pools and runs to a lake system with less habitat diversity and more uniform habitat characteristics. This reduction in the diversity of in-stream habitat has resulted in a reduction in biodiversity.

- Impediments to fish migrations.

- Degradations in the chemical quality of the river by increasing water temperature, decreasing dissolved oxygen reaeration and by trapping and decay of organic matter.

Other additional ecological impacts are listed in a 2003 position paper by the Mahoning River Consortium. These include the disruption of river geomorphology and the disruption of nutrient cycles. Lowhead dams reduce the currents that provide the energy for the dynamic geomorphology of free-flowing rivers. This results in a decrease in upstream scouring and a corresponding increase in downstream scouring. The stream also becomes more channelized due to the presence of the dams. Lowhead dams also alter the streambanks by limiting the dynamics of riverbank habitats and by encouraging the growth of non-riverine species along the shores of the pools. Lowhead dams also contribute to the disruption of nutrient cycles/food chains. The majority of food for river animals and organisms is imported in the form of detritus from the surrounding land. The lowhead dams serve as an impediment to the flow of this critical food source downstream (Mahoning River Consortium, 2003).

The storage of water and capture of sediment by dams causes changes downstream in the natural patterns of hydrologic variation and sediment transport. In a normal, un-dammed river, there are seasonal flows and variations in the hydrology of the river and the river deposits silt naturally along its banks. However in a dammed river, the seasonal flows are virtually eliminated and sediment builds up along the base of the river. Reduction in the magnitude of downstream peak flows commonly segregates the main channel from the floodplain, which results in the reduced ability of riparian species to establish and in the reduced access to floodplain habitats for fish. Long-term storage without the seasonal
release of floodwaters can also significantly alter downstream food webs and aquatic productivity.

This stream is controlled upstream by reservoirs and water plants. Seasonal variation is therefore a non-issue for the lowhead dams in Franklin County.

2.2.2. Recreational Impacts

Lowhead dams can create serious recreational hazards, especially to boaters. Lowhead dams are designed to allow water to flow over the top of the structure, usually along the entire width of the dam (National Association of State Boating Law Administrators, 2004). As the water flows over the dam, it falls into the downstream side of the dam and creates what is called a "hydraulic jump," also referred to as backwash. This hydraulic jump is a very powerful, re-circulating current that can trap and retain boaters and their boats (National Association of State Boating Law Administrators, 2004). The backwash, or upstream current, associated with the dam can extend many feet downstream and can easily pull a boater upstream into the turbulent area located just below the drop-off from the dam, where they are forced underwater. The boater is then pushed away from the dam underwater and when the boater surfaces, he or she can get drawn right back in toward the base of the dam, creating a vicious cycle. The boil line is the line that separates the current flowing downstream and the water rushing back upstream and is a dangerous location that is often difficult to see.

Lowhead dams pose the following list of dangers to boaters:

- Dams are difficult to spot from upstream and often are not marked by signs or buoys;
- Dam hydraulics are unpredictable;
- Dams can deceive even experienced boaters;
- The concrete walls at the side of the dam face block the exit route for individuals trying to escape;
- Areas immediately downstream also present risk as the water is flowing upstream; and
- Rescuing trapped individuals is dangerous and often unsuccessful.

Figure 2.1 illustrates the hydraulic backwash current that is so characteristic of lowhead dams (http://www.dnr.state.oh.us/watercraft/facts/dams.htm).
Lowhead dams can also create recreational opportunities that would not be possible without the impounded water. A natural flowing stream may be very shallow and only permit shallow running boats such as canoes or kayaks. A lowhead dam can create opportunities for larger or deeper running watercraft such as fishing boats, john boats or rowing crews.
3. Existing Conditions

3.1. Olentangy River / Franklin County to Dodridge Road Description

The study area for this feasibility analysis extends from OH SR 161 downstream to Dodridge Street in Franklin County. Starting at the upstream limits of the study area at OH SR 161, the river flows along the Olentangy Multi-Use Trail with public parkland on one or both sides until it flows down through the Ohio State University campus area. The river segments downstream of the study area flow through more urban areas and experience other water quality problems as it flows further into the Columbus metropolitan area toward its confluence with the Scioto River. It is in this lower stretch of the river where the effects of urbanization are clearly seen in the form of direct stream channelization, encroachment into the riparian corridor, or in some cases, removal of the riparian corridor, sedimentation and impoundments formed by another lowhead dam at 5th Avenue.

The Franklin County portion of the Olentangy River is vastly different from the Delaware County portion, which is still rural in nature although development is increasing. The Franklin County portion of the river is largely built-out and pollution in the form of surface runoff from extensive road and highway networks, overflows of sanitary and storm sewers, and urban runoff from parking lots, driveways, lawns, etc. is a major concern.

3.2. Sanitary Sewer Information

A main trunk sewer parallels the Olentangy River, providing service to the areas of Worthington, Riverlea and the north-central section of Columbus. This trunk sewer, referred to as the Olentangy Main Trunk Sewer (OMTS) and the Olentangy Main Interceptor, was constructed and placed into operation in the early 1970s. As constructed, the trunk sewer is 47,350 feet in length and ranges from 36” to 78” in diameter. A more detailed history of the Olentangy Interceptor Sewer is contained in the 1987 Phase One Report of the Olentangy Scioto Interceptor Sewer (OSIS) Tributary Study. An excerpt from this report is in Appendix D. A table of the associated flows at each dam location is in Appendix E.

In 1960 during the design phase, the envisioned tributary area of the Olentangy Main Trunk Sewer was 9,710 acres with a projected population of 61,990 people in 2000. In 1987, the population was found to be 70,168 and the dry weather tributary area was estimated at 18,104 acres (EMHT, 1987). This tributary area calculation was revised in 2004 to 14,626 acres, which includes 9,554 acres of served area and 5,072 acres of unserved area (City of Columbus, DOSD, 2005, WWMP Section 4).

The City installed two permanent flow monitors (OB4, in Antrim Park; and OB1, at OH SR 315 and Henderson Road) in manholes along the Olentangy Main and has been collecting flow velocity and depth data continuously since 1994. Current, non-archived data begins June 1, 1996. This flow monitoring data has been used to calibrate the hydraulic modeling of the sewer system performed by the city on an on-going basis. While there were no designed sewer relief (DSR) structures along the Olentangy Main since the elimination of the temporary pump station during the construction of the southern segment of the Olentangy Main and its discharge into the OSIS, sanitary sewer overflows were observed at manholes during extreme wet weather events in the mid-1990s. In 1997, the City raised manhole lids within corporate limits to elevations above the highest hydraulic grade line predicted for sewer segments north of Bethel Road in order to prevent sanitary sewer overflows.
Preliminary, in-house hydraulic calculation sheets prepared by the City in 2001 and updated as part of this study, based on the capacity study, were provided to and reviewed by FMSM. (See Appendix F for calculation sheets.) These calculation sheets provided information to determine if the hydraulics of the trunk sewer would support the conversion of the above ground crossings to inverted siphons (pipes that would cross under the riverbed) for the five lowhead dams. Based on initial draft findings, there is not enough available head within the trunk sewer at any of the dam locations to effectively convey flows and maintain a minimum of 3-feet per second velocity through siphons (City of Columbus, 2005 Columbus Sewer Capacity Calculations). The velocity of the flow is critical to prevent the rapid deposition of matter in the sewer and eventual clogging of the sewer line. The 2004 version of the Ten State Standards requires a minimum of 3-feet per second velocity in an inverted siphon.

On July 1, 2005, the City of Columbus submitted the Sanitary Sewer Overflow and Combined Sewer Overflow consent order required “Wet Weather Management Plan’ (WWMP). This plan consists of a capital improvements plan to address the sewer system overflows that occur during wet weather. As part of the WWMP planning process, the City evaluated all of its larger separate sanitary sewer lines (including the Olentangy Main Trunk Sewer) to determine whether they experienced hydraulic deficiencies. This evaluation was performed using a computer model, USEPA SWMM, which simulates flows in the sewer system for various wet weather scenarios.

Once the hydraulic deficiencies were identified using the computer model, the City developed a Large Scale System Strategy (LSSS) to eliminate the deficiencies. The LSSS proposed by the City includes two large diameter tunnels to provide relief to the hydraulically overloaded trunk sewers and interceptors. One of these tunnels, the Olentangy Relief Tunnel (ORT) is proposed to run on the west side of the Olentangy River. It will be utilized to convey excess wet weather flows from the hydraulically overloaded sewers and to provide storage of peak flow during wet weather prior to delivery to the wastewater treatment plants. The ORT will provide relief to the Olentangy Main Trunk Sewer at two points – one near Dodridge Street and the other further north within publicly owned parkland adjacent to the Olentangy. The tunnel will not be fully constructed and placed into service until the year 2042 (City of Columbus, DOSD, 2005, Volume 13, WWMP Appendix O). The WWMP evaluated the size and cost of the ORT assuming that it only received wet weather flows, which is the only time the existing sewers are hydraulically deficient.

In addition to the evaluation of the larger diameter sewer lines, the City evaluated twelve areas with more localized hydraulically deficient sewers where sanitary sewer overflows (SSOs) and sewer back-ups into homes occur during wet weather. An individual plan for mitigating these areas, referred to as Priority Areas, was developed. The Clintonville Priority Area plan includes a recommendation for a modification of the existing Broad Meadows Relief Sewer to optimize the amount of flow into the existing 30-inch pipe that conveys flow to the Olentangy Main Trunk Sewer. By completing this improvement, a sanitary sewer overflow location will be rendered inactive up through a 25-year, 6-hour rainfall event. The overflow location is to be abandoned once the ORT is built and improvements to the Clintonville Main Trunk Sewer are completed. The additional near-term wet weather flows conveyed to the OMTS were not specified in the WWMP. This recommended improvement can be completed now and the City has discussed incorporating this improvement with ongoing capital improvement plans in the area (City of Columbus, DOSD, 2005, Volume 15, WWMP Appendix S).
3.3. Dam Locations and Details

There are five lowhead dams included within the study area: State Route 161 Dam, Broad Meadows Dam, North Broadway Dam, Union Cemetery Dam and the Dodridge Street Dam. (See the overview map in Appendix G.) These dams provide sanitary sewer crossings for the Olentangy Main Trunk Sewer, or in the case of the Broad Meadows Dam, the Broad Meadows Relief Sewer. Information about each of these five dams is provided below. Additional photos are in Appendix H and record drawings are in Appendix I.

3.3.1. State Route 161 Dam

This dam is located along the Olentangy River at RM 9.4, adjacent to Antrim Park (Figure 3.1). The dam crest length is 205 feet with a crest height of 3.5 feet, as shown on the City’s record drawing. The OH SR 161 dam carries a 38” x 60” elliptical sewer line from the east subtrunk of the OMTS across the river to the connection with the trunk sewer. This sewer crossing was constructed in October 1959.

Figure 3.1. State Route 161 Lowhead Dam Map and Photo
3.3.2. **Broad Meadows Dam**

This dam is located along the Olentangy River at RM 8.5 and is surrounded by State of Ohio property (Figure 3.2). The dam crest length is 160 feet with a crest height of 5 feet upstream and 4 feet downstream, as illustrated on the City’s record drawing. The Broad Meadows dam carries a 29” x 45” elliptical sewer line from the Broad Meadows Relief Sewer across the river to its connection with the OMTS. Both the sanitary sewer crossing and the river channel were relocated during the construction of OH SR 315. This sewer crossing was constructed in June 1960.

![Broad Meadows Lowhead Dam Map and Photo](image)

*Figure 3.2. Broad Meadows Lowhead Dam Map and Photo*
3.3.3. North Broadway Dam

This dam is located at RM 5.1 and is bordered on the northwest and southeast sides by City of Columbus property (Figure 3.3). The dam crest length is 192 feet with a crest height of 6’ 7¼” upstream and 6’ 1¼” downstream, as shown on the City’s record drawing. This dam is classified as a Class II structure and is regulated by ODNR. The North Broadway dam carries three 42" diameter sewer segments of the OMTS across the river. This sewer crossing was constructed in May 1972.

Figure 3.3. North Broadway Lowhead Dam Map and Photo
3.3.4. Union Cemetery Dam

This dam is located along the Olentangy River at RM 4.4 (Figure 3.4). The intake for the Ohio State Olentangy River Wetland Research Park and a City bike path bridge are just upstream of the dam, and State of Ohio property is located on the west bank of the river near the dam. As indicated on the City’s record drawing, the dam crest length is 200 feet with a crest height of 6’ 4¾” upstream and 5’ 10¾” downstream. The Union Cemetery Dam carries two 48” diameter sewer segments of the OMTS across the river. This sewer crossing was constructed in May 1972.

Figure 3.4. Union Cemetery Lowhead Dam Map and Photo
3.3.5. Dodridge Street Dam

This dam is located at RM 4.0 on the Olentangy River with State of Ohio property on the west bank and a City bike path bridge located downstream of the dam (Figure 3.5). The dam crest length is 216 feet with a crest height of 11’ 9 2/3” upstream and 6’ 7¼” (plus 2 feet for scour) on the downstream side, as illustrated on the City’s record drawing. The Dodridge Street dam carries one 48” and two 42” diameter sewer segments of the OTMS across the river. This dam was constructed immediately downstream of an existing lowhead dam. The gap between the dams was filled with compacted fill and grouted cobblestones were placed on the surface. This sewer crossing was constructed in May 1972.

Figure 3.5. Dodridge Street Lowhead Dam Map and Photo
3.4. Status of Aquatic Life Use Attainment

Use attainment status refers to the degree to which environmental indicators are either above or below criteria which are specified by the Ohio Water Quality Standards (OEPA, 2001). The Ohio Water Quality Standards consist of designated uses and chemical, physical and biological criteria protective of those uses. Aquatic life use designations are assigned to specific waterbodies and the three aquatic life uses most commonly assigned to central Ohio streams and rivers are discussed below.

- Exceptional Warmwater Habitat (EWH) – This aquatic life use designation is reserved for waters which support “unusual and exceptional” assemblages of aquatic organisms that are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered or special status. This designation represents a protection goal for water resource management efforts for Ohio’s best water resources (Ohio Administrative Code (OAC) 3745-1).

- Warmwater Habitat (WWH) – This aquatic life use designation is characterized by the “typical” warmwater assemblage of aquatic organisms for Ohio rivers and streams and this use represents the principal restoration target for the majority of water resource management efforts in Ohio (Ohio Administrative Code 3745-1).

- Modified Warmwater Habitat (MWH) – This aquatic life use applies to streams and rivers which have been subjected to extensive, maintained and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable. These modifications are of a long-lasting duration (20 years or more) and may include the following: extensive stream channel modification activities permitted under Sections 401 and 404, extensive sedimentation resulting from abandoned mine land runoff and extensive permanent impoundment of free-flowing waters. The representative aquatic assemblages present in these waters are generally comprised of species which are tolerant to poor quality habitat and low dissolved oxygen concentrations, the presence of silt, and nutrient enrichment.

The attainment status of aquatic life uses is determined through biological community performance measures, which include the Index of Biotic Integrity (IBI) that measures the fish community characteristics, and the Invertebrate Community Index (ICI) that is based on macroinvertebrate characteristics.

Three attainment status results are possible with respect to the assigned aquatic life use: full, partial or non-attainment. Full attainment means that all of the applicable indices meet the specified biocriteria. Partial attainment means that one or more of the applicable indices does not meet the biocriteria, and non-attainment means that none of the applicable indices meet the biocriteria or that one of the groups of organisms reflects poor or very poor performance (OEPA, 2001).

The 1999 TSD for the Olentangy River includes an aquatic life use attainment table for the mainstem of the Olentangy River. This table includes four sampling locations that fall within
the study area (OH SR 161 downstream to Dodridge Street) and their associated attainment status. That information is provided in Table 3.1.

### Table 3.1. Aquatic Life Use Attainment Status for Four Sites within the Study Area

<table>
<thead>
<tr>
<th>River Mile</th>
<th>IBI Score</th>
<th>ICI Score</th>
<th>Attainment Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.8</td>
<td>48</td>
<td>42</td>
<td>WWH – Full</td>
</tr>
<tr>
<td>6.8</td>
<td>50</td>
<td>44</td>
<td>WWH – Full</td>
</tr>
<tr>
<td>5.5</td>
<td>40</td>
<td>22</td>
<td>MWH – Full</td>
</tr>
<tr>
<td>3.9</td>
<td>49</td>
<td>26</td>
<td>WWH - Partial</td>
</tr>
</tbody>
</table>

*Table derived from 1999 Olentangy River TSD*

Updated information on aquatic life use attainment status will be provided in the upcoming 2003 TSD.

### 3.5. Water Chemistry

There are two components of water chemistry that will be discussed below: 1) physical / chemical; and 2) bacteria. The physical / chemical water quality of a stream includes parameters such as dissolved oxygen (DO), nutrient levels and measurements of organic compounds, heavy metals, and pesticides. Five parameters of physical / chemical water quality were assessed for this study using sampling data obtained from the OEPA and the WWMP: DO, total suspended solids (TSS), total phosphorus (TP), nitrate nitrogen and ammonia. The data obtained for these parameters within the study area indicate that the recent values are currently in attainment of the state standards. However, this is not the case with bacteria. The bacterial component of water quality was assessed separately and it was found that the bacterial levels were elevated above the standards, mostly during periods of wet weather with some dry weather samples of concern. Further details on each of the parameters are discussed below.

It is important to note here that it is difficult to assess the impact of the dams on water quality without data collected immediately upstream and downstream of the dams, data which does not currently exist. Past City of Columbus monitoring programs were designed to assess the impacts of combined sewer system outfalls. The purpose of the monitoring programs undertaken by the OEPA is typically to assess general water quality conditions within a given waterbody. The data collected through this type of monitoring provides an understanding of the general water quality for the Lower Olentangy River in this case, but is not specific to the impacts of the lowhead dams. Therefore, existing data on water quality has been collected and included here for general comment and interpretation.

Graphs were created to summarize the existing chemical water quality data for each parameter. These graphs can be found on the next several pages (Figure 3.6, Figure 3.7, Figure 3.8, Figure 3.9 and Figure 3.10). The locations of the lowhead dams and several of the largest tributaries are noted on the graphs. The values plotted are the mean concentrations measured during the indicated monitoring studies. Two of the data sets graphed in the figures are dry weather samples: the OEPA 1999 samples and the dry event samples from the Columbus WWMP. Inflows to this reach of the Olentangy during dry weather are small, so changes in water quality between the sampling locations are primarily the result of in-river processes. The other two data sets graphed in Figures 3.6 through 3.10 are predominantly wet weather samples (2003 OEPA and Columbus WWMP “All”). During
wet weather, river water quality includes pollutant loadings from storm sewers and tributary streams. Changes in water quality during wet weather events are more likely the result of varying pollutant inputs than from water quality modifications due to the dams.

The concentrations presented in the figures can be related back to the statewide water quality standards (where applicable) and proposed state-wide nutrient criteria for WWH, EWH, and MWH streams (OEPA, 1999) to assess whether they are in attainment of those standards/criteria. Each of the five parameters and their associated standards or criteria will be briefly discussed below. Because the Olentangy River downstream of I-270 is designated as WWH except for two segments that are designated as MWH, one of which is in the study area (Adena Brook (RM 5.9) to Dodridge Street Dam (RM 4.0)), the focus will be on those standards/criteria for WWH and MWH waters.

**Dissolved Oxygen.** According to the Statewide Water Quality Standards (OAC 3745-1-07), for WWH waters, the standard is an average of 5.0 mg/L for areas classified as outside mixing zones. A mixing zone is defined as an area of a waterbody contiguous to a treated or untreated wastewater discharge. For MWH waters, the standard is an average of 4.0 mg/L for areas outside mixing zones (OAC-3745-1-07 Table 7-1). The levels of DO documented in the study area indicate that in all instances, the concentrations of the sampled locations are better than the standard. These oxygen resources are sufficient to support WWH fish and macroinvertebrate assemblages (Figure 3.6).

![Figure 3.6. Olentangy River Dissolved Oxygen](image-url)
Total Suspended Solids (TSS). No applicable standards currently exist for total suspended solids; therefore, a comparison is not possible. However, because TSS is largely responsible for the aesthetics of the river (muddying, brown color, poor visibility, etc.) and because suspended solids often have other pollutants associated with them, lower TSS concentrations are favorable. With respect to the levels documented in the study area, they are relatively low, the majority of sampling points are plotted below 40 mg/L with the exception of the 2003 wet weather data from OEPA. TSS concentrations in urban runoff can often exceed 100 mg/L. The OEPA is currently developing a Total Maximum Daily Load (TMDL) for the Olentangy River. The TMDL may set forth target levels for total suspended solids. Sediments will be addressed in the substrate metric of the QHEI and the target score for that metric will be set at a 13 or 14 out of 20, and a TSS value of 44 mg/L. In light of that standard, the most recent sampling data (that done in conjunction with WWMP), indicates that the current TSS levels are below this target level (Figure 3.7).

![Figure 3.7. Olentangy River Total Suspended Solids](image)

Total Phosphorus (TP). Because the Statewide Water Quality Standards do not include a standard for TP, a proposed state-wide criteria for TP from a Technical Bulletin (MAS/1999-1-1) published by the OEPA will be used as a benchmark. This Technical Bulletin was based on a study undertaken as part of the overall OEPA Load Allocation Project. The main focus of the study was on the effects and interactions of residual nutrient concentrations and habitat and how these two are correlated with the relative health and well-being of aquatic communities (OEPA, 1999). Reference streams were used to document the ranges of nutrient concentrations during typical low-flow conditions. The effects of stream size, ecoregion and habitat were documented on these nutrient concentrations. This information was then used to determine whether the relative performance of fish and macroinvertebrate community assemblages were correlated with the nutrients and habitat variables. The
resulting proposed state-wide nutrient criteria are based on the aquatic use designation and on the size of the watershed. For small rivers (drainage area = 200 to 1000 square miles), such as the Olentangy River, the WWH criterion for TP is 0.17 mg/L, and for MWH waters, the criterion is 0.25 mg/L (OEPA, 1999).

With respect to the TP levels documented in the study area, there is a wide variation in attainment amongst the various samples. In terms of the most recent data, the dry weather samples from the WWMP appear to be in attainment of the proposed criterion indicated for the areas of WWH (0.17 mg/L) and MWH (0.25 mg/L) within the study area (just outside of the study area, upstream of the State Route 161 dam, there is a point that is non-attaining). In terms of the most recent wet weather samples, the two sampling points within the study area for the OEPA 2003 data were in exceedance of the WWH proposed criterion for TP. However, two out of the three sampling points for the WWMP All (which are primarily wet weather samples) obtained in 2004 were within the limits of the proposed criterion. As stated above, it is the dry weather events that provide a better idea of whether the water quality modifications can be traced back to dams (Figure 3.8).

As stated in the TSS discussion, the TMDL currently under development by the OEPA may set target levels for phosphorus at 0.16 mg/L. Given that target, the majority of the sampling data for the study area will be in exceedance.

![Figure 3.8. Olentangy River Total Phosphorous](image)
**Ammonia.** Ammonia concentrations are dependent upon the temperature and the pH of the water that is sampled. Therefore, the maximum value of 1.5 mg/L (water temperature = 25° C and a pH of 8.0) as cited in the WMMP (Volume 1, Section 4), derived from the Statewide Water Quality Standards is used as the benchmark. The values for ammonia obtained for the study area indicate that in all instances, the concentrations of the samples were well below the 1.5 mg/L maximum (Figure 3.9).

![Figure 3.9. Olentangy River Ammonia](image)

**Nitrate-Nitrogen.** Because the Statewide Water Quality Standards do not include a standard for nitrate-nitrogen, the proposed statewide criterion for nitrate-nitrogen as published in the Technical Bulletin referenced in the TP discussion is used as a benchmark. For small rivers (drainage area 200 to 1000 square miles), such as the Olentangy River, the WWH criterion for nitrate-nitrogen is 1.5 mg/L and for MWH waters, the criterion is 2.2 mg/L. The most recent levels of nitrate-nitrogen documented in the study area indicate that the majority of the sampling points are at or below the benchmark concentration for nitrate-nitrogen for both WWH and MWH waters (Figure 3.10).

![Figure 3.10. Olentangy River Nitrate-Nitrogen](image)
Figure 3.10. Olentangy River Nitrate

**Bacteria.** With respect to bacteria during dry weather, there were elevated bacteria concentrations that are of concern regarding Primary Contact recreational uses. Pertinent information regarding bacteria concentrations is found in the WWMP (Volume 1, Section 4). E. coli concentrations at the OH SR 161 zone were elevated several times during the sampling period completed during 2003-2004. The Henderson Road zone also experienced E. coli concentrations of concern during one documented sampling. E. coli concentrations of concern were documented at the Dodridge Street zone at several occasions and also at the 5th Avenue zone (City of Columbus, DOSD, 2005, Volume 1, WWMP Section 4).

3.6. Habitat and QHEI

Habitat was assessed for the Olentangy River in the study area primarily through evaluation of the Qualitative Habitat Evaluation Index (QHEI) scores provided. The QHEI is a physical habitat index that is designed to provide a quantified evaluation of the general macrohabitat, or large-scale habitat, characteristics that are important to fish communities. These macrohabitat characteristics are physical factors that affect fish communities and that are usually important to other aquatic life in addition to fish, for example, invertebrates.

The QHEI is composed of six metrics which have been found to be associated with stream fish communities:

- Substrate;
- Instream cover;
- Channel morphology;
• Riparian zone and bank erosion;
• Pool/glide and riffle-run quality; and
• Map gradient.

These metrics describe the attributes of the physical habitat that could potentially be important in explaining the presence, absence and composition of fish communities in a given stream (Rankin, 1989).

QHEI scores range from 0-100. QHEI scores less than 45 generally cannot support the assemblages associated with WWH. QHEI scores greater than 60 are generally conducive to supporting a warm water habitat (WWH) designation. QHEI scores greater than 75 commonly have habitat conditions which can support exceptional warm water habitat (EWH) (OEPA, 2001).

Previous studies and other applicable data were reviewed for QHEI scores relevant to the study area. This data was used to summarize and provide details as to the existing habitat conditions in the study area.

Habitat quality varies between the free-flowing and impounded areas of the study area. Free-flowing sections of the river have substrate features that have been predominantly characterized by boulder, cobble, gravel, sand and bedrock. Moderate amounts of instream cover were documented, provided by sources such as overhanging vegetation, deep pools and woody debris. Silt has been documented as being present in normal to moderate amounts in the free-flowing waters (OEPA, Division of Surface Water, 2005). In terms of channelization, the free-flowing sections of the Olentangy were found to show either no evidence of past channelization or in instances where channelization had occurred, the river appears to evidence recovery. Low to moderate amounts of sinuosity were commonly documented in the freely flowing portions of the river and the riffles, runs, pools and glides present provided not only microhabitat for various aquatic organisms, but also variations in flow regimes (OEPA, Division of Surface Water, 2005).

In stark contrast to the free-flowing areas of the Olentangy mainstem, the impounded areas were characterized by silt substrates, slow currents and homogeneous habitats comprised of long pools with occasional areas of woody debris and fallen logs (OEPA, Division of Surface Water, 2005). Low to no sinuosity was visible in these impounded sections with channel development being characterized as poor to fair.

The average QHEI score of the free-flowing portions of the lower Olentangy mainstream were 77.4, compared with an average score of only 44 in the impounded sections of the river (OEPA, Division of Surface Water, 2005). (Figure 3.11) As stated in the 2003 Technical Support Document Draft Report for the Olentangy River, “the presence of the dams within the lower reach dramatically affects the biological integrity of the system by impeding flow and reducing habitat quality to aquatic organisms."
Figure 3.12 illustrates the variation among scores between impounded and non-impounded sites.

As is evident from the data present above, there is a difference between QHEI scores at free-flowing sites versus those at impounded sites. However, an assessment into the individual metrics that make up the QHEI reveals that there are no clear trends as to what contributes to the differences between the scores in free-flowing and impounded sites. There is a combination of factors that make up each metric. Elements within one metric seem to offset negative elements within another metric as the total score is calculated. However, Metric 2 which assessed instream cover and Metric 3 which assesses channel morphology may offer some insights into what could be contributing to the lower scores at the impounded sites. Sparse instream cover was documented at the impounded sites as well as sites with lower scores. With respect to channel morphology, recent recovery or no recovery from channelization was also documented for the impounded sites, whereas the unimpounded sites evidenced a range from no channelization to recovering channelization. Individual metric scores for the sampled sites can be found in Appendix J.
3.7. Fish, Macroinvertebrates and Mussel Species

3.7.1. Fish

Fish can be one of the most sensitive indicators of the quality of the aquatic environment (Rankin, 1987). Changes in the relative abundance, species richness, composition and other characteristics are directly affected by the presence of water quality disturbances and by modifications to habitat. Factors which are responsible for the variations in fish communities include, among others, stream size, instream cover, stream morphology, flow, substrate and water quality (Rankin, 1987). Disturbances to the physical and/or chemical quality of a body of water can cause stress to fish species and these stressors will often determine which species are present or absent from an area.

One of the primary measures of overall fish community health and well-being is the Index of Biotic Integrity (IBI). The IBI incorporates 12 fish community metrics and these 12 are lumped into three broad categories: species richness and composition, trophic composition, and fish abundance and condition (Rankin, 1987). Some of the metrics will yield higher scores with increasing environmental quality, and others yield higher scores with increasing environmental degradation. The value of each metric is compared to the value expected at a reference site located in a similar geographic region with minimal human influence. The IBI score can range from 12-60.
Both fish species composition and IBI scores were assessed for the study area to aid in the determination of the quality of the aquatic environment. Information on both assessments is provided below.

3.7.1.1. Fish Species Composition and Species of Interest

Data on fish species found in the study area were obtained from the OEPA, FLOW Watershed Action Plan, and the City of Columbus WWMP. This information is summarized below.

There are two species of interest that have been caught in the reach of the Lower Olentangy under analysis. The River Redhorse (Figure 3.13) is a state special interest species that was caught at RM 3.9 (Dodridge Street) in 1999 and 2004. The Bluebreast Darter (Figure 3.14) is a threatened species that was caught at RM 7.8 (downstream of the Bull Moose Tributary) in 1999 and 2004. These two species are described in more detail below, including habitat requirements and threats.

**River Redhorses** are usually between 10 and 20 inches in length and prefer medium and large-sized rivers with moderate to strong currents and gravel or cobble substrates (Michigan Natural Features Inventory, 2005). This species of fish is most often associated with long, deep run habitats. The River Redhorse requires clear and unpolluted water and is intolerant of siltation and turbid conditions. The dams in the study area could be a potential separation barrier to spawning due to the fact that River Redhorses usually migrate upstream to medium sections of the river or to tributary streams to spawn (Michigan Natural Features Inventory, 2005). Habitat alteration, such as channelization, impoundments and siltation, are the major threats to this species.

![Figure 3.13. River Redhorse](image)

The **Bluebreast Darter** requires clean, medium to large-sized rivers with swift flow and high bottom velocities and a substrate composed of large rocks, rubble and coarse to fine gravel (Pennsylvania Department of Conservation and Natural Resources, 2005). The stones provide protection for the darter. The species is vulnerable to detrimental habitat changes. The Bluebreast Darter spawns in the summer and migrates from deeper water areas of a stream to selected riffles where their eggs are deposited behind large rocks. Due to the fact that the Bluebreast Darter is only three inches in length, additional design considerations may have to be made with respect to fish ladders or other structures for passage.
The most recent sampling data (2004) for the study area indicate that there is a wide mix of species with respect to tolerance and environmental disturbances. The species caught in the highest amounts ranged from moderately intolerant to highly intolerant on one side of the spectrum, to highly tolerant on the other. Species breakdowns for two specific locations are provided below.

Near the Dodridge Street dam (RM 3.9) at a free-flowing site, the assemblage of fish evidenced a wide range in pollution tolerance. The five species found in the greatest numbers at RM 3.9 were the following (listed in decreasing order) along with their associated pollution tolerance:

- Bluegill sunfish – Tolerant
- Longear sunfish – Moderately tolerant
- Black redhorse – Intolerant
- Logperch – Moderately tolerant
- Golden redhorse – Moderately tolerant.

Other species to note in higher numbers were the bluntnose minnow and the green sunfish, both highly tolerant to a wide variety of environmental disturbances, including water quality and habitat degradation. In addition to these tolerant species, two intolerant species were documented at Dodridge Street, the banded darter and the black redhorse.

At RM 7.8 in a free-flowing section of the river, downstream of the Bull Moose Tributary (located downstream of the Broad Meadows Dam), there is again a variety of tolerances evidenced in the fish species documented. The four species found in the greatest numbers were the following along with their associated pollution tolerance:

- Smallmouth bass – Moderately intolerant
- Sand shiner – Moderately intolerant
- Central stoneroller – Tolerant
- Bluegill sunfish – Tolerant.
The banded darter and the black redhorse, pollution intolerant species, were also documented at RM 7.8, as was the rare Bluebreast Darter.

3.7.1.2. IBI Scores

IBI scores from the most recent sampling efforts were obtained from the OEPA, as were data from past sampling efforts. The 1999 TSD for the Olentangy River includes an assessment of the fish community. The IBI scores for four sites within the study area from that assessment along with more recent data are included in Table 3.2 and are illustrated in Figure 3.15. One important observation to make about the data is that it does not include enough data points to conclude whether or not there is a significant difference between IBI scores at impounded sites versus free-flowing sites. To achieve WWH use designation, IBI scores should be at least 42.

Table 3.2. IBI Scores

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<td>32</td>
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</table>

*Indicates that three scores were averaged from the same year

Figure 3.15. IBI Graph
3.7.2. Macroinvertebrates

Aquatic macroinvertebrates are animals lacking backbones that are large enough to be seen by the naked eye and include such organisms as crayfish, mussels, snails, clams, and aquatic worms. They are useful as indicators of environmental quality due to several factors, including that they react quickly to environmental changes. In streams of high water quality and suitable habitat conditions, a well-balanced macroinvertebrate community will likely be found and these organisms will predominantly be pollution sensitive (Rankin, 1987). When environmental quality has been degraded, the sensitive species decline and tolerant organisms dominate. Primary examples of pollution sensitive insects are called the EPT taxa: Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies).

3.7.2.1. Invertebrate Community Index (ICI)

The Invertebrate Community Index (ICI) is used to assess the macroinvertebrate community, using primarily insects and their larvae, as an indicator of environmental quality. The ICI consists of 10 community metrics which are scored by comparing a stream community to a reference site. The ICI scores can range from 0 to 60. To achieve WWH use designation, the ICI score should be at least 36.

Before discussing ICI scores any further, an important caveat must be stated. The ICI scores can be highly impacted by impoundments due to the fact that macroinvertebrate data is much more diverse in free-flowing areas (Dennis Mishne, OEPA, personal communication). In contrast, diversity is very low in impoundments, yielding ICI scores that are low. With that understanding in place, the data from recent sampling efforts as well as from the 1999 TSD can be assessed. Figure 3.16 provides a graphical illustration of the data.

![ICI Graph](image-url)
The 1999 TSD includes an assessment of the macroinvertebrate community and the pertinent information from that assessment as it applies to the study area (between State Route 161 and Dodridge Street) is included. The assessment documented two sites between RM 11.6 and Adena Brook (RM 5.9) that were considered to have met EWH status, meaning macroinvertebrate communities were characterized as very good and were comprised of many EPT taxa (OEPA, 2001).

In contrast, at a site at RM 5.5 which is impounded by the North Broadway dam and considered to be only achieving MWH status, there is no visible flow and the stream bottom was comprised of silt and detritus. As a result, the ICI score was a 22 and the diversity of the macroinvertebrates was much lower than what was documented at the free-flowing sites upstream (OEPA, 2001).

3.7.2.2. Mussels

Mussels are a group of benthic macroinvertebrates that are considered to be a pollution-intolerant species. Thus, their presence in a stream can serve as an indicator of good to excellent water quality conditions and to the contrary, their absence can serve as an indicator of poor water quality and the presence of negative factors (FLOW, 2005). Members of FLOW completed mussel surveys on the Olentangy River between Kenny Park to the north and from the North Broadway bridge to the south in 1998, 1999 and 2000. These surveys indicate the presence of “a diverse, abundant mussel biota of at least 14 living species” in this reach of the river (FLOW, 2005). Two state special interest species were also documented in this stretch of the river: the Round Pigtoe and the Wavy-lined Lampshell (Figure 3.17). The Round Pigtoe is sensitive to pollution, siltation, habitat perturbations, inundation and loss of habitat (NatureServe, 2005). Dams and other impoundments are considered to be separation barriers for this species. The Wavy-lined Lampshell is found in and near riffles with good current and because of this habitat requirement; they are often the first to be affected by disturbance (Michigan Natural Resources Inventory, 2005). They are also sensitive to river impoundments, siltation and channel disturbance.

A freshwater mussel survey was also undertaken as part of the receiving waters characterization report that is included in the WWMP. Three sites on the Olentangy River were sampled as part of the survey: Fifth Avenue, Mount Air and Dodridge Street. The survey results indicated that the Dodridge Street site had the least diverse mussel community with six species collected (City of Columbus, DOSD, 2005, Appendix F). One of those species was the Elktoe, an Ohio Special Concern Species.
A study was conducted in Wisconsin on the potential ecosystem response to dam removals. This study involved a post-removal survey of mussels within the impoundment and downstream following the removal of the Rockdale dam on the Koshkonong River (Doyle and Stanley, 2005). The results of this survey concluded that within the former reservoir, mortality rates of mussels following dam removal were 95% due to dehydration and exposure (Doyle and Stanley, 2005). The absence of mussels in the newly formed channel from the time of dam removal strongly stresses the slow recovery of mussels when compared to the recovery rates of fish and macroinvertebrates (Doyle and Stanley, 2005). Of all the ecosystem components, mussel communities in midwestern streams were impacted most severely by dam removal and did not become established within the downstream channel within three years after the removal. Because mussel reproduction and colonization are dependent on fish, at a minimum, mussel recovery requires the geomorphic adjustments necessary for fish recovery, as well as those needed for the mussels themselves. Recent studies have suggested that mussels do recover following catastrophic disturbances, but recovery may be on the order of decades (Doyle and Stanley, 2005).

3.8. Recreational Use

The Olentangy River is currently used by boaters, waders and fisherman, although there are dangers present due to the lowhead dams. Hydraulic jumps and eddy currents are created on the downstream side of the dams; however, the dams also provide an artificial pool which allows for canoeing to occur (FLOW, 2003). Increasing recreational safety and decreasing impediments for boaters, waders and fisherman is a primary goal of FLOW. Action items for increasing recreation safety presented in the FLOW Watershed Action Plan include the installation of permanent boat chutes through the lowhead dams and installation of in-stream and bridge signage alerting boaters of lowhead dams and the location of chutes and portage routes (FLOW, 2003).
4. Development of Alternatives and Evaluation Criteria

4.1. Alternatives Brainstorming Workshop

In order to capitalize on the wealth of knowledge and experience of the project partners, a Brainstorming Workshop was held to generate a comprehensive list of potential alternatives that might improve water quality, habitat and recreational uses of the Lower Olentangy River impacted by the five lowhead dams. A copy of the workshop agenda and minutes are in Appendix B. Staff from the following organizations participated in the workshop:

- City of Columbus DOSD Sewer System Engineering Section;
- City of Columbus DOSD Stormwater Management Section;
- City of Columbus Recreation and Parks Department;
- Ohio Environmental Protection Agency, Division of Surface Water, Nonpoint Source Section;
- Ohio Department of Natural Resources, Division of Natural Areas & Preserves;
- Ohio Department of Natural Resources, Division of Wildlife;
- Ohio Department of Natural Resources, Division of Soil and Water Conservation;
- Friends of the Lower Olentangy Watershed; and
- Fuller, Mossbarger, Scott and May Engineers, Inc.

At the beginning of the workshop, background information compiled for different facets of the project was shared with the group. Detailed information on the location and configuration of each dam was presented. Fact Sheets on subjects that would give the participants a snapshot of the current conditions of the river and corridor within the study area were prepared, distributed and reviewed. These Fact Sheets covered sanitary sewers, water chemistry, habitat and QHEI, status of aquatic life use attainment, and fish and mussel species. Two Fact Sheets were also prepared on fish ladders and W-weirs for participants who were not familiar with these types of structures. The Fact Sheets and project location maps are in Appendix K.

The group discussed the problems experienced in portions of the Olentangy River impacted by the lowhead dams and listed some overall goals that should be realized upon implementation of an alternative improvement concept. Problems identified were as follows:

- Impairments to the stream preclude segments from attaining warm water habitat designations;
- Fish passage inhibited;
- Boat passage inhibited;
• Current appearance of the dams impacts the stream’s ability to achieve scenic river designation;

• Safety issues;

• Potential sewer line integrity compromise issues; and

• The Lower Olentangy Watershed Action Plan issues, including ICI and QHEI scores.

As a whole, the group determined that the recommended alternative(s) resulting from this feasibility study should be in accordance with the following project goals:

• Address issues outlined in FLOW’s Lower Olentangy Watershed Action Plan (which includes some of the goals listed below);

• Stream segment moves closer to meeting warm water habitat use designation;

• Increase safety at lowhead dam sites;

• Cost-effective, justifiable and affordable sewer alternative;

• Minimize increases to flood water surface elevations (no impact to structures within the 100-year flood plain)

• Improve habitat (for non-game and game species);

• Improve aesthetics; and

• Incorporate natural stream profile in riffle pool format as much as possible.

Other goals were added to this listing through various discussions during the weeks following the brainstorming workshop. These additions include:

• Improve recreational value for boating, canoeing and kayaking; fishing; wading; and birding;

• No impact to sanitary sewer service or operation;

• Ensure access for sewer maintenance needs; and

• Re-establish connection to the floodplain and/or increase access to the floodplain.

An overview of the improvement alternatives discussed in FMSM’s feasibility study proposal was presented. The three concepts included were full removal of lowhead dams (diversion of existing sanitary sewers), W-weirs and fish passages.

During the next portion of the workshop, participants were encouraged to express all ideas for water quality, fish passage and recreational use improvements for consideration. No
judgment or critique of the ideas was allowed, although clarification questions were allowed to be asked. A lively exchange ensued and a list of possible alternatives was generated. Similar ideas were grouped, and advocates pressed their cases for the participants to consider their ideas. Each participant was given ten sticky dots and was directed to place the dots next to the ideas they thought should be developed into an alternative concept to be further evaluated. Each participant could place no more than three sticky dots on any one idea.

Results of this exercise produced the following list [bracketed number indicates total number of dots received]:

1) [18] Grade Control Riffle/[11] Rock Ramps (also known as Boulder Fields and Newberry Riffles) – these two ideas were combined following voting;

2) [12] Remove Antrim Lake levee or construct box culverts to Lake (to provide available flood plain, but maintain trails);

   [11] Narrow Channel (where sections have been artificially widened in the past);

4) [9] Full Lowhead Dam Removal;

5) [7] Remove “Zigzags” in Sewer Alignment in the 3 downstream dams;

6) [6] Sluice Under Dams;

7) [2] Broad Meadows Storm Pond (to utilize for flood control);

8) [1] Small Diversions Around Dams
   [1] Fish Passages
   [1] Boat Passages; and

9) [-] Aerial Sewer Crossings
   [-] Do Nothing
   [-] Porous Dams.

The information gained during the brainstorming workshop was used to finalize the scope of alternatives and level of detail to be developed and evaluated within the project budget. FMSM and the City agreed that the following conceptual alternatives would be analyzed at the various lowhead dam locations as listed in Table 4.1. A description of each of these conceptual alternatives is provided in Section 5 of this report.
Table 4.1. Alternative Concepts for the Lower Olentangy Lowhead Dams Project

<table>
<thead>
<tr>
<th>SR 161 Dam</th>
<th>Broad Meadows Dam</th>
<th>North Broadway Dam</th>
<th>Union Cemetery Dam</th>
<th>Dodridge Street Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Control Riffles</td>
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<td>W-weirs</td>
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<td>Remove Portion of Antrim Lake Levee</td>
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<tr>
<td>Utilize Storm Pond</td>
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<tr>
<td>Full Removal</td>
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<sup>a</sup> Providing sluices under the dams may not be applicable at each location depending on site conditions. Applicable locations will be determined.

<sup>b</sup> Narrowing the channel may not be applicable at each location depending on site conditions.

<sup>c</sup> Fish ladders will be described in the text and by a typical design. Issues at each location will be listed.

<sup>d</sup> Boat portages at each location will be described in the text and by a typical sketch. Issues at each location will be listed.

4.2. Evaluation Criteria Workshop

A separate workshop was held to identify and prioritize criteria by which the lowhead dam improvement alternatives should be evaluated as part of this feasibility study. A copy of the agenda and minutes are in Appendix C. Staff from the following groups participated in the workshop:

- City of Columbus DOSD Sewer System Engineering Section;
- City of Columbus Recreation and Parks Department;
- Ohio Environmental Protection Agency, Division of Surface Water, Nonpoint Source Section;
- Ohio Environmental Protection Agency, Division of Surface Water, TMDL Coordination Section;
- Ohio Department of Natural Resources, Division of Natural Areas & Preserves, Scenic Rivers;
• Ohio Department of Natural Resources, Division of Wildlife;
• Friends of the Lower Olentangy Watershed; and
• Fuller, Mossbarger, Scott and May Engineers, Inc.

The workshop began with a project status update, details on the hydraulic modeling undertaken and a discussion on the conceptual alternatives that were identified. The goals developed during the brainstorming workshop were reviewed and discussed in detail. Following the goals discussion, workshop participants were divided into groups to develop the criteria needed to judge the effectiveness of the alternative concepts in meeting the goals listed in Section 1. Each group recorded criteria on Post-It™ notes. Notes from each group were presented and placed on the wall. The group then organized the criteria into the similar categories as follows:

### Recreation
- Usability
  - Improved portages/remove the need for portages
  - Access to river
  - Stable banks
  - Sediment (mud) trap elimination

### Safety
- River Hydraulics

### Aesthetics
- Scenic river designation
- Overall appearance

### River Hydraulics
- Instream channel stability
- Sediment/bed load transport
- Access to floodplain
- Increase average flow velocity
- Impacts to floodplain
- Natural stream profile
- Fish passage/migration
- Maintenance
- Increase Width/Depth ratio (per Brian Belcher, consider target reference entrenchment ratio)

### Biology / Chemistry
- QHEI increased by either score or percent increase
- Increased IBI
- Increased ICI
- Increase abundance and diversity of mussels
- Dissolved Oxygen

### Cost
- Cost

### Constructability

### Reliability

### Time Table
Sewer Issues

Structural Integrity (including bridges)
Operation and Maintenance (O&M) Issues

Public Support

Permit Requirements

Funding

After a robust discussion of the evaluation criteria, it was determined that both the sewer issues (structural integrity and ensuring proper operation and maintenance) and permit requirements are “make or break” criteria. If an alternative could not protect the integrity and allow for proper operation and maintenance of the sewer system and/or could not be granted permits, it is automatically considered “not feasible” and disqualified from further consideration.

The consensus of the group indicated that the criteria with the highest priority after the “make or break” criteria are as follow:

1) River Hydraulics;
2) Biology / Chemistry;
3) Recreation (including public support and safety); and
4) Cost benefit ratio.

It was noted that public support for a recommended feasible alternative will be based on a variety of criteria, including recreation, safety and aesthetics. Opportunities for funding an improvement project will be directly proportional to the public support garnered for the project.

4.3. Benefit of Conducting Workshops

Given the wide range of interests of this 319 Grant project partners; the City of Columbus, FLOW, ODNR and OEPA, the brainstorming and evaluation workshops provided a platform for individual messages from each organization to be stated, discussed and understood by the participants. This valuable forum brought additional ideas and concepts to the table for thought-provoking consideration. This type of interaction will prove invaluable as the parties associated with this study move through securing the necessary funding to design and implement feasible solutions, both in the Olentangy River Watershed and other streams within the state of Ohio.
5. Conceptual Alternatives

5.1. Full Dam Removal

To facilitate the full removal of the dam structures and return the Olentangy River to its natural profile, more than just the destruction and removal of the structures is needed. The sanitary sewers that are contained within the dam structure itself need to be relocated. There are several different options for relocating or realigning the sewer lines and they are outlined below.

The first option is to construct siphons under the Olentangy River at each crossing in order to abandon the sanitary sewer lines that are housed within the lowhead dams and demolish the dams. Preliminary hydraulic analyses were previously conducted by the Division of Sewerage and Drainage to determine the potential for siphons. These analyses, presented in Appendix F, indicate that existing dry weather flows experienced within the sewer lines and the physical elevations of the existing sewers (upstream and downstream invert elevations) would not allow for hydraulic conditions necessary for the installation of siphons. The lack of necessary hydraulic conditions renders this option not feasible; therefore, it has been withdrawn from further consideration.

Another option to consider for full lowhead dam removal is to abandon the existing sanitary lines presently located within the dams and to install replacement lines under the Olentangy River. The construction of a pump station is needed at the downstream side of the new sewer line to lift sewage flows back to the connecting pipe elevation. Challenges faced when implementing this option include the following:

a. Given the wide variation in dry weather and wet weather flow rates and possible surcharge conditions within the Olentangy Main Trunk Sewer, sizing each pump station to operate under all flow conditions will be challenging. Additionally, flow rates within the OMTS and the Broad Meadows Relief Sewer may change drastically over time (increasing or decreasing), depending on the implementation of the City’s Wet Weather Management Plan Large Scale System Solutions and Priority Area recommendations.

b. Storage basins to capture and hold peak wet weather flows may be required as a temporary measure to prevent sanitary sewer overflows and water-in-basement occurrences prior to the construction of the proposed Olentangy Relief Tunnel (ORT). In order to properly size such facilities, an application of the City’s sewer collection system capacity study model (beyond the scope of this feasibility study) will need to be undertaken. Given the footprint of the required storage basin(s), adequate available land may simply not exist within the developed area near the stream corridor to accommodate such a facility.

c. During discussions with DOSD staff, another method to construct sanitary sewer river crossings was identified which includes constructing a pump station on the upstream side of the lowhead dam and installing a force main under the river using horizontal directional drilling technology or open cut.

d. Easements will be needed for construction operations, insertion pits, manholes, sanitary sewer installation, pump station and storage basin locations. Easement
acquisition can be a lengthy and expensive process and can be delayed indefinitely if there is local opposition to the project.

e. The constructability of a tunneled sewer at the Broad Meadows location is questionable given the close proximity to State Route 315.

f. Additional costs for back-up generators will be incurred at all pump stations to ensure that power failures do not result in sewer back-ups that may cause upstream sanitary sewer overflow or water-in-basement occurrences.

g. The City’s sewer system is predominately gravity based, with few pump stations in operation today. By introducing additional pump stations into the collection system, the City will be significantly increasing the risk of failure of the system which may result in sanitary sewer overflows and/or water-in-basement occurrences. Pump station failures can be caused by a multitude of scenarios and such a failure could introduce unintended consequences to the Olentangy River and businesses/residents upstream of the pump station.

5.2. Realignment of Olentangy Main Trunk Sewer Lowhead Dams (Remove “Zigzag” in 3 Downstream Dams)

Three options were considered when developing an alternative to remove the “zigzag” or to realign the Olentangy Main Trunk Sewer between the North Broadway and Dodridge Street dams to minimize the number of river crossings, thus the number of lowhead dams. Each of these options includes the reconstruction of the Olentangy Main Trunk Sewer on one side of the river and abandoning the existing sanitary sewer river crossings. The options are described in detail below.

5.2.1. Option 1. Abandon / Remove North Broadway, Union Cemetery and Dodridge Street Dams

In order to remove the three dams, the Olentangy Main would be realigned from the western (upstream) end of the North Broadway dam to the eastern (downstream) end of the Dodridge Street Dam (Figure 5.1). Challenges faced when implementing this option include:

a. The river would have to be crossed at least once, involving both microtunneling and the construction of a pump station with emergency back-up power capabilities and peak wet weather storage facilities.

b. Detailed design of the realignment would require complex hydraulic modeling to ensure proper dry weather operation and wet weather peaking factors are incorporated into the design of the sewer lines and pump station.

c. Given the proximity of the Olentangy Scioto Interceptor Sewer (OSIS) and the Franklin Main to the downstream end of the Dodge Street Dam, constructability and hydraulic operation of the pump station may negate this option.

d. Right-of-Way and easement acquisition along the Olentangy River corridor may be difficult to complete in this developed and populated corridor of Columbus.

e. Depending on the negotiated alignment of the proposed sewer line, a new river crossing may be required in order to maintain the Tulane Relief Sewer which
carries flow from the OSIS to the OMTS. This relief sewer is located on the river’s east bank between the Union Cemetery and North Broadway dams.

f. Requires the removal of the existing dam upstream of the Dodridge Street sewer dam. Any alternative that requires removal of Dodridge Street dam also will require removal of the existing upstream dam.

Figure 5.1. Abandon / Remove North Broadway, Union Cemetery and Dodridge Dams
5.2.2. **Option 2. Abandon / Remove North Broadway and Union Cemetery Dams**

In order to remove the these two dams, the Olentangy Main would be realigned from the western (upstream) end of the North Broadway dam to the western (downstream) end of the Union Cemetery dam (Figure 5.2). Challenges faced when implementing this option include:

a. Right-of-Way and easement acquisition along the Olentangy River corridor may be difficult to complete in this developed and populated corridor of Columbus. In addition, much of the construction would occur through the Union Cemetery, maybe necessitating the need for portions of the sewer to be constructed in tunnel.

b. A new river crossing may be required in order to maintain the Tulane Relief Sewer, which carries flow from the OSIS to the OMTS. This 54-inch diameter relief sewer is located on the river’s east bank between the Union Cemetery and the North Broadway dams. For this feasibility study, it is assumed that the flows in this sewer will have to be pumped across the river. However, an application of the City’s sewer system hydraulic modeling could be undertaken (outside the scope of this study) to determine if this sewer could be redesigned and relieved to another point in the sewer system.

c. Detailed design of the realignment and new river crossing would require complex hydraulic modeling to ensure proper dry weather operation and wet weather peaking factors are incorporated into the design of the sewer lines.

**Figure 5.2. Abandon / Remove North Broadway and Union Cemetery Dams**
5.2.3. Option 3. Abandon / Remove Union Cemetery and Dodridge Street Dams

In order to remove the Union Cemetery and Dodridge Street dams, the Olentangy Main would be realigned from the eastern (upstream) end of the Union Cemetery dam to the eastern (downstream) end of the Dodridge Street dam (Figure 5.3). Challenges faced when implementing this option include:

a. Right-of-Way and easement acquisition along the Olentangy River corridor may be difficult to complete in this developed and populated corridor of Columbus.

b. Much of the construction would occur near the riparian corridor close to residential housing, the OSIS and the Franklin Main, raising constructability concerns.

Figure 5.3. Abandon / Remove Union Cemetery and Dodridge Street Dams
5.3. Grade Control Riffles

Grade control riffles are installed to maintain a desired streambed elevation. These riffles are used to either raise the stream invert in order to reverse past channel incision, or to maintain the channel invert at a current elevation in order to prevent future channel incision (Stormwatercenter, 2005). Grade control practices create what is referred to as a “hardpoint” along the channel, which prevents the streambed from degrading below the top elevation of the structure (Stormwatercenter, 2005). Grade control structures can be designed with rocks, boulders or other materials. A grade control riffle is a constructed riffle comprised of rock that has been placed in a similar configuration as a natural riffle. (A riffle is an area of the stream with fast currents and shallow depth.) A grade control riffle would be constructed on the downstream side of each lowhead dam using rocks and boulders as part of this alternative as illustrated in Figure 5.4. The Midtown Dam Rapids (Figure 5.5) is an example of a stream that has had grade control riffles installed.

Figure 5.4. Grade Control Riffles Diagram
W-weirs are structures used to maintain or enhance river stability and can be constructed using rocks available on-site in many cases. They are designed to create in-stream cover and diversity of velocity and depths, creating more usable area across the width of a channel (Rosgen, 1996). W-weirs serve a multitude of objectives in addition to the enhancement of river stability (Rosgen, 2001):

- Stabilize stream banks by reducing shear stress;
- Provide grade control on streambeds;
- Maintain the width/depth ratio in existing and reconstructed streams;
- Enhance fish habitat by maximizing holding, feeding and spawning areas;
- Provide recreational boating;
- Facilitate irrigation diversions;
- Reduce center pier and foundation scour;
- Increase sediment transport at bridge locations;
- Be compatible with natural channel design; and
- Be visually acceptable to the public.
The shape of the w-weir is where the structure gets its name. The weir is shaped like a “W” when looking in a downstream direction. Figure 5.6 illustrates a plan view of a w-weir. Both sides of a w-weir are vanes directed from the bankfull bank upstream toward the bed with similar departure angles of 20-30 degrees. The crest of the weir rises in the downstream direction to the center of the bankfull channel. This creates two thalwegs in the stream approximately ¼ of the channel width from both banks.

When placed in a stream, the weirs are used to control channel bed elevation and width-to-depth ratio. W-weirs promote bank stability by reducing grades and directing flow to the center of the channel. The application of these weirs provides wide, shallow channels. W-weirs can also be used to enhance fish habitat in that they can maximize usable holding, feeding and spawning areas. The two thalweg locations and pools created by W-weirs are ideal feeding locations. Spawning habitats are created in the tail-out of pools due to the upwelling currents. Figure 5.7 shows a before and after rendering of a W-weir application at the sewer crossing at Broad Meadows.

Figure 5.6. W-weir Diagrams
Figure 5.7. Before and After Rendering of W-weir Application at the Sewer Crossing at Broad Meadows
5.5. Narrowing of Channel

This alternative would focus on narrowing the river upstream of the dams in places where it has widened and may be unstable. Fill would be placed alongside one or both banks of the channel in the form of dirt and other natural materials suitable for fill. Alternating the sides of the fill would begin to add some sinuosity back into the stream channel. A 401 permit would need to be obtained from the U.S. Army Corps of Engineers (USACE) for the filling. Vegetative plantings would also be placed along the constructed stream banks to enhance the riparian corridor. The fill will cause the channel to become more stable and not continue to expand out into the floodplain. The narrowing of the channel would also allow the velocities in the pool to increase, allowing the sediment transport capabilities to improve. Figure 5.8 illustrates where the placement of fill will occur within the channel.

Figure 5.8. Narrowing of Channel Diagram
5.6. Sluice Under Dam

This alternative would consist of constructing several pipes through the base of each dam to lower the surface elevation behind the dam to a more natural stream profile (Figure 5.9). These pipes would be placed underneath the existing sewer pipes and would conduct water from the upstream side of the dam to the downstream side. During low flow conditions, it is possible that no water would be flowing over the dams. The pipes through the dams may even allow fish to migrate upstream.

Figure 5.9. Sluice Under Dam Diagram
5.7. Fish Ladders

Fish ladders, also known as fishways or fish passes, are structures placed on or around man-made structures such as weirs or dams. A fish ladder, as defined by the Biotech Dictionary, is “a series of descending weirs which carry water around a dam or waterfall to facilitate the upstream migration of fish.” Fish can leap through the partitions or pools that separate the steps that make up the ladder, because each pool is slightly higher than the one before it. The water rushing from one pool to the next simulates the flow of a natural river (Encarta, 2005). The velocity of the water flowing over the ladder must be great enough to attract the fish to the ladder, but not too great that it washes the fish back downstream. There are five primary types of fish ladders:

**Rock-Ramp Fish Ladder.** This type of fish ladder uses large rocks and timbers to create a natural structure. Pools and small flats are created from the natural material. This fish ladder is most applicable for short barriers.

**Pool and Weir Fishway.** This type of fishway is comprised of a series of small dams and pools of regular length that are used to create a long, sloping channel for fish to move upstream. Fish jump from box to box to travel around a structure in the stream.

**Vertical Slot Fish Passage.** This is similar to a pool and weir fishway except that it allows fish to swim through narrow slots near the channel wall. This allows movement upstream but does not require fish to jump from box to box. One advantage to this fishway is that it handles seasonal fluctuations in water levels rather well.

**Denali Fishway.** This type of fish ladder uses a series of symmetrical, closely spaced baffles to redirect the flow of water. Denil fishways are typically not built with resting areas although pools can be included if desired. These fishways can be built with switchbacks to minimize the space needed for construction.

**Fish Elevator.** Also known as a fish lift, this carries fish over particularly tall barriers. Fish swim into a collection area at the base of an obstruction and when a mass of fish accumulates, they are nudged into a hopper. The hopper carries the fish into a flume which empties into the river above the barrier.

The type of fish ladder most likely to be implemented as part of this alternative is the rock-ramp fish ladder. One rock-ramp fish ladder would be constructed at each of the lowhead dams to provide passage for the fish. Figure 5.10 provides a general illustration of the concept. Figure 5.11 shows a fish ladder over a dam in Massachuttes.
5.8. Small Diversion Channel

A diversion channel is a channel constructed to convey stream flow around an in-stream obstacle such as a dam. This alternative would consist of the construction of a small, permanent diversion channel parallel to the river at each dam to provide passage for fish whose passage is inhibited by the dams. The diversion channel would begin just upstream of the dam and would continue, parallel to the river to some distance below the dam where it would then converge with the river. The channel would need to be very shallow as it crosses the sewer line, or may need to be piped under the sewer before daylighting back to an open diversion channel. Because of the sewer acting as a barrier, boat passage is probably not possible, but fish passage may be possible. Figure 5.12 provides an illustration of the diversion channel. Figure 5.13 shows an example of a diversion channel from Austria.
Figure 5.12. Small Diversion Channel Diagram
Figure 5.13. Small Diversion Channel in Austria

5.9. Boat Portage

A boat portage (Figure 5.14) is an access point to the river where boats can be put in and be pulled out of the water. A portage is placed along the river at points where there is an obstacle to the water route, such as a dam. A boat portage would be constructed at each of the dam locations. A trail would be constructed between the upstream portages at the dams to the portages just downstream of the dams. This alternative would not impact the dam or the river segment upstream or downstream of the dam. This alternative could be used in conjunction with other alternatives.
5.10. **Removal of a Portion of the Antrim Lake Levee and Utilization of the Storm Pond near Broad Meadows**

This alternative would focus on the removal of a portion of the Antrim Lake levee in order to provide access to the floodplain and storage of floodwaters. In removing the levee, detailed calculations and assessments would be undertaken as to the effects on the stream profile both upstream and downstream of the location of the levee. This alternative would not result in any in-stream habitat benefits or water quality benefits. It would solely provide floodplain connection and storage.

There is an existing stormwater pond located alongside the river near the Broad Meadows Dam. This pond could also be used to divert and store floodwaters along that section of the river.

These alternatives do not impact the dams themselves. These alternatives may be used in addition to the other alternatives to provide the additional benefit of increased flood storage.
6. Hydraulics

6.1. Introduction

Velocity patterns, water surface elevations and sediment transport properties vary throughout the highly urbanized and impacted project reach. The flow is influenced, or controlled, by many factors, including bed and form resistance in mild reaches upstream and downstream of lowhead dams (Leliavsky), sediment deposits, bends, bridges and lowhead dams. The sudden expansion at the base of the lowhead dams at normal flows causes the formation of a hydraulic jump and severe turbulence (Henderson). The energy dissipated in the hydraulic jump occurs over a relatively short distance (less than one channel width); whereas the energy dissipated in a naturally formed river occurs over a much longer distance via pool and riffle distances on the order of two to five widths (Leopold et al). Downstream controls can change the behaviour of the lowhead dams, causing them to flow freely or as sills (Henderson). This chapter of the report contains discussion of the hydraulics of lowhead dams and the hydraulic ramifications associated with modifications to a lowhead dam for purposes of river restoration.

Many researchers have shown that in stable rivers of comparable size and bed resistance to the Olentangy, pools and riffles develop along the longitudinal profile and deeps and shallows alternate along the flow path (Leopold et al). Formation of pools and riffles is also related to the meander pattern (Leopold). Pools have been observed in scour holes created by debris and near the apex of meander bends with or without debris (Leopold et al) and riffles tend to occur in straight parts of the river between bends (Leopold et al). Straightened rivers and rivers bounded by levees or artificial valley fills have had failures due to erosion. Aerial photographs of rivers taken after floods along the Mississippi and other rivers that have been straightened show erosion and channel evolution patterns developing. Channel evolution has been studied by Lane, Rosgen and others. Rivers controlled by bridge openings, dams, levees and/or widening have been observed evolving into a meandering channel with pools and riffles. The sediment forming the developing riffles in an evolving river pattern comes from bed and bank erosion in the upstream reach (Hey). The earth moves the flow of water and sediment through the reach by shifting its surface form in an unpredictable but recognizable way. Rosgen and others have shown a relationship to channel slope and sinuosity in naturally formed rivers. Erosion problems that undermine banks occur in response to engineering controls that alter the channel slope either by changing its course or bedform (Parola et al).

Before a discussion of hydraulic impacts of lowhead dams on the Olentangy, a discussion of discharge records and flood frequency analysis is provided to quantify flow magnitudes possible in the project area and to determine design flows for this report.

6.2. Gage Analysis

According to information available from FLOW, the average stream flow in the Olentangy River is 360 cfs\(^1\), low flow is 19 cfs and high flow is 1,000 cfs. Variability in the flows is impacted by various upstream facilities, such as the Delaware Dam, water supply intakes for Delco Water and wastewater treatment plants. To understand flow variability in the Olentangy, an analysis of flood data available from USGS is presented herein\(^2\). A record of

\[\text{1 cfs} = \text{cubic feet per second}\]

thirty-five years of annual peak flow values (1956-2002) and 10,352 daily mean flow values (1955-1984) were used to develop flood frequency values for this report.

6.2.1. Flood Frequency Analysis

The computer program RIVERMorph\(^3\) was used to store and evaluate a thirty-five-year record of existing, annual peak flow records and to perform flood frequency analyses. Results of two types of frequency analysis, an empirical best-fit method and the log-pearson type III method, were used to calculate design flows. The flood frequency model used is a combination of the two methods. The model, along with values used in a 1977 flood study (FEMA) is plotted against the data available at a nearby gage in Figure 6.1.

Regression of the logarithms of discharge versus probability yielded a correlation coefficient \(r^2\) of 0.971, which indicates a good fit, meaning over 97% of the variability of the data in Figure 6.1 can be explained by a best-fit line. The log-pearson type III method also yielded a good fit by visual comparison with the data. The empirical method fits the data very well for probabilities less than 30% (or return intervals greater than 3.33 years). The analytical method fits the data better for probabilities greater than 30%. A conservative approach for flood forecasting is to use a combination of the two models, the empirical method for high flows (probabilities < 30%) and the analytical method for low flows (probabilities < 30%). The composite model is shown as a solid line in Figure 6.1.

\(^3\) The Reference Reach approach to natural channel design is a popular method for analyzing the stream’s optimal potential and for restoring impacted reaches. In 1999, FMSM engineers developed computer algorithms for processing the data used in this approach, simplifying the calculations. Later, RIVERMorph\(^3\), LLC was formed to develop and distribute this new tool, useful to a wide range of ecosystem restoration professionals. RIVERMorph\(^3\) has become the standard in stream restoration assessment, monitoring and design software, with sales throughout the United States and other parts of the world.
6.2.2. Mean Daily Flow Model

The probabilities of occurrence of ranked mean daily flows are shown in Figure 6.2.

Flows of interest were read from Figure 6.1 and Figure 6.2. Typical design probabilities used in engineering analyses are tabulated in Table 6.1.

**Table 6.1. Design Flows**

<table>
<thead>
<tr>
<th>Probability (%)</th>
<th>Return Interval (yr)</th>
<th>Discharge (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>95*</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>50*</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>30*</td>
<td>325</td>
<td></td>
</tr>
<tr>
<td>10*</td>
<td>1,300</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>1</td>
<td>2,700</td>
</tr>
<tr>
<td>80</td>
<td>1.25</td>
<td>4,600</td>
</tr>
<tr>
<td>66.7</td>
<td>1.5</td>
<td>5,300</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
<td>6,000</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>7,700</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>9,900</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>12,700</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>13,800</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>17,700</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>22,800</td>
</tr>
<tr>
<td>0.5</td>
<td>200</td>
<td>29,200</td>
</tr>
<tr>
<td>0.2</td>
<td>500</td>
<td>40,700</td>
</tr>
</tbody>
</table>

* Based on the mean daily series, other values are based on the annual peak series.
6.2.3. Hydraulic Geometry

RIVERMorph was also used to store and analyze specific measurements at this gage to create plots of width, mean depth, cross sectional area and velocity versus discharge. Models of hydraulic geometry were created from this data (Figure 6.3, Figure 6.4, Figure 6.5 and Figure 6.6).

Figure 6.3. Width Versus Discharge ($r^2 = 0.647$)

Figure 6.4. Mean Depth versus Discharge ($r^2 = 0.871$)
Figure 6.5. Cross Sectional Area versus Discharge \( (r^2 = 0.946) \)

Figure 6.6. Velocity versus Discharge \( (r^2 = 0.878) \)
6.3. Lowhead Dam Hydraulics

According to ODNR’s Dam Safety Program, “a lowhead dam is a dam of low height, usually less than fifteen feet, made of timber, stone, concrete and other structural material, or some combination thereof, that extends from bank to bank across a stream channel. A lowhead dam may also be referred to as a channel dam.” Photographs of five such dams in the Olentangy are shown in Figure 6.7.

The general shape of the five dams is similar. The Dodridge Street dam closely resembles the U.S. Army Corps of Engineers’ standard spillway (Henderson) on the downstream side of the sewers, having an ogee shape, with a flip-bucket energy dissipating shape at the base (boulders have later been added). The other dams have an elliptical or parabolic spillway face. All of the structures have an apron made of grouted riprap or concrete on the downstream side to prevent bed scour.

The lowhead dams encase sanitary sewers on the upstream side of the spillway, creating a short, flat approach section to the spillway.

Some general properties, i.e. geometry, of the dams are summarized in Table 6.2.
Table 6.2. Olentangy Lowhead Dam Geometry

<table>
<thead>
<tr>
<th>Location</th>
<th>$L_w$</th>
<th>$\alpha$</th>
<th>$L_1$</th>
<th>$L_2$</th>
<th>$L_3$</th>
<th>$W$</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Rt. 161</td>
<td>205</td>
<td>85</td>
<td>4.8</td>
<td>3.0</td>
<td>7.9</td>
<td>7.3</td>
</tr>
<tr>
<td>Broad Meadows</td>
<td>160</td>
<td>45</td>
<td>2.5</td>
<td>4.5</td>
<td>9.0</td>
<td>4.0</td>
</tr>
<tr>
<td>N. Broadway</td>
<td>192</td>
<td>85</td>
<td>12.3</td>
<td>6.5</td>
<td>10.0</td>
<td>6.1</td>
</tr>
<tr>
<td>Union Cemetery</td>
<td>200</td>
<td>85</td>
<td>8.4</td>
<td>6.2</td>
<td>10.0</td>
<td>5.9</td>
</tr>
<tr>
<td>Dodridge St.</td>
<td>216</td>
<td>90</td>
<td>12.9</td>
<td>12.5</td>
<td>20.6</td>
<td>10.8</td>
</tr>
</tbody>
</table>

Where: $L_w =$ weir length across channel (ft);  
$\alpha =$ angle relative to river (degrees); and  
$L_1$, $L_2$, $L_3$, and $W$ are defined in Figure 6.8.

![Figure 6.8. The Typical Olentangy Lowhead Dam](image)

Where: $L_1 =$ length of approach (ft);  
$L_2 =$ length of hydraulic jump (ft);  
$L_3 =$ length of energy dissipation field (ft);  
$Z =$ elevation differential between the downstream bed and the upstream water surface (ft);  
$y_c =$ critical depth (ft);  
$W =$ elevation differential between mean sediment surface and top of lowhead dam at time of construction (ft); and  
$H =$ head, or elevation differential between the top of the lowhead dam and the water surface in the upstream pool (ft).

The photographs in Figure 6.7 indicate that the reaches upstream of the dams have mild profiles and that flow resembles flow over a broad-crested weir with boundary layer.
corrections for growth along the weir length and sides. Discharge over the spillway face is likely to have little amounts of air entrainment and the flow is approximately hydrostatic in pressure distribution at the top of the weir. Flow passes through critical depth a short distance upstream of the overflow, and according to Henderson the discharge is determined from the upstream head \( H \) by:

\[
q = \frac{2}{3} H \left( \frac{2}{3} gH \right)^{\frac{1}{2}}
\]  

Eqn. 6.1

Where: \( q \) = discharge per unit width (cfs/ft); and

\( g \) = the acceleration of gravity.

With weir lengths \( L_1 \) in Table 6.2, resistance effects across the weir surface become appreciable and the flow is based on the brink depth instead of the critical depth:

\[
y_b = 0.715 y_c
\]  

Eqn. 6.2

Where: \( y_b \) = brink depth (ft);

\( y_c \) = critical depth (ft); (Henderson).

Flow measurement based on the brink depth is

\[
q = \frac{y_b}{0.715} \sqrt{\frac{g y_b}{0.715}} = 1.65 y_b \sqrt{g y_b}
\]  

Eqn. 6.3

When the water surface on the downstream side of the hydraulic jump, along length \( L_3 \), is greater than about 0.8\( H \) the weir becomes submerged and the flow is affected by downstream conditions and the above equations are no longer valid (Henderson).

Rating curves for the five dams were calculated using Eqn. 6.3 and the geometry listed in Table 6.2, the results are shown in Figure 6.9.

As expected, the dams have similar hydraulics because they have similar geometry. Figure 6.9 indicates that the Broad Meadows dam creates higher water surfaces than the others for a given discharge value. This is because of its shorter weir length across the river. The rating curves ignore submergence and downstream controls and are therefore valid only for frequent discharge values.
6.4. Fluvial Hydraulics

The performance and stability of the Olentangy River through the study reach is not only dependant on the variability in flow over time, but also the discharge of sediment delivered from the upstream watershed. The river flows through glacial outwash deposits over limestone and shale bedrock (Sanders) and the bed materials primarily consist of sands and gravels. Gravel from the riverbed is visible in the top-left photograph in Figure 6.7. Sediment load data published by FLOW for the same USGS gauging station that the design discharge data were collected are shown below in Figure 6.10, which shows that for flows ranging from 2,460 to 5,200 cfs, the total sediment load ranged from 3,990 to 12,100 tons/day.
6.5. Modeling

One tool used to evaluate the various alternatives that may involve structural modifications of the lowhead dams is a hydraulic model of the reach. The portion of the Olentangy River in Franklin County was modeled by the USACE in 1977 to prepare the initial Flood Insurance Study for the county. The 1977 model has not been superseded in subsequent Flood Insurance Study reports for this portion of the Olentangy River. The 1977 model was used in part to establish a baseline condition for the portion of the river included in this study, as further described below.

6.5.1. Methodology

The 1977 hydraulic model was based on the results of HEC-2 calculations. HEC-2 was a program developed by the USACE’s Hydrologic Engineering Center (HEC) to estimate water surface profiles in open channels.

The 1977 HEC-2 model was used as the starting point to establish an existing or baseline condition for the Olentangy River in the project area, defined for evaluation purposes to extend from the 3rd Avenue bridge (downstream limit) to approximately 1 mile upstream of the State Route 161 bridge (upstream limit). (See the Overview Map in Appendix G.) The 1977 HEC-2 model was updated for this evaluation by converting it to a HEC-RAS (River Analysis System) model, which allows for more accurate hydraulic modeling of structures such as lowhead dams. The model conversion process is described in the following paragraphs.

The model was reviewed for applicability to the hydraulic evaluations required for the lowhead dams project. The review indicated that within the project area the 1977 model did not include the bridge at John Herrick Drive, or the Broad Meadows and State Route 161 lowhead dams. In addition, it was reported that changes in the development of the floodplain since 1977 were not reflected in the model. The missing lowhead dam structures and potentially differing floodplain characteristics were addressed when the 1977 HEC-2 model was converted/updated to a HEC-RAS model. Based on the review, it was determined that with some modifications the model could be used as the basis for an existing condition HEC-RAS model of the project area.

6.5.2. Model Conversion and Verification

The input file of the 1977 USACE HEC-2 model was imported into the HEC-RAS computer program, and a conversion process was implemented whereby the “card” type data fields from HEC-2 were translated into geometry and flow files within HEC-RAS. Manning’s roughness or “n” values for the channel and over banks were reviewed and modified during the conversion process to reflect HEC-RAS preferences and recent “n” values. Due to computational differences in the two programs, geometric bridge data (i.e. low chord and bridge deck elevations, pier size and location) from the 1977 HEC-2 model required modification to be evaluated properly in HEC-RAS. In addition, low flow and high flow computational methods around each bridge also had to be verified for proper usage upon model conversion. Other modeling parameters, such as expansion and contraction coefficients at cross sections immediately upstream and downstream of bridges, were also reviewed and modified as necessary to follow HEC-RAS program suggested guidelines. Finally, the Antrim Park levee located between the State Route 161 and Broad Meadows lowhead dams was not modeled as a true levee in the HEC-2 model but simply coded into
the cross section geometry allowing for split flow to occur. This error was corrected in the converted HEC-RAS model by using the available levee feature in HEC-RAS.

As was mentioned previously, the HEC-RAS program allows more variations in modeling approach for such structures as lowhead dams which was unavailable with the HEC-2 program. The lowhead dams included in the 1977 HEC-2 model (North Broadway, Union Cemetery and Dodridge Street dams) were represented by one cross section at each dam location, and the crest of the dam was modeled as the “bottom” of the cross section. HEC-RAS allows the user to model structures such as lowhead dams as an inline weir, allowing for various weir shapes to be evaluated (e.g. broad-crested and ogee) and the consideration of submergence and its influence on weir discharge over the dam during hydraulic calculations.

For this project, each lowhead dam was modeled as an ogee weir based on the geometry obtained from available design drawings. The converted geometry file was also modified in HEC-RAS to include the missing State Route 161 and Broad Meadows lowhead dams. HEC-RAS requires four cross sections in the immediate vicinity of an inline weir structure for proper evaluation in the model. Therefore, supplemental cross sections upstream and downstream of each lowhead dam were determined from available topographic mapping and input into the HEC-RAS model.

The flows used in the 1977 USACE HEC-2 model were retained for the converted HEC-RAS model for the purpose of initial model verification and comparison following conversion. The following return intervals were included in the model: 1, 2, 5, 10, 20, 50, 100, 200 and 500-year events. For the purposes of the lowhead dam alternatives analysis, the flows were modified and more frequent return interval storm events were added to the model. The modified flows were obtained from a flow frequency analysis of the Worthington USGS gage just upstream of the project area (refer to Section 5.2.1 for further discussion).

Following model conversion and modified flow input, the water surface profile results from the HEC-RAS model were compared to the 1977 HEC-2 model. Considering the modifications and revisions needed during the conversion process, the converted HEC-RAS model results appear to agree reasonably well with the output from the original HEC-2 model. The results indicate that a majority of the water surface profiles are within 1.0 foot between HEC-2 and HEC-RAS models along the project area study reach. Based on review of the model results, it appears that the converted HEC-RAS model approximates a reasonable existing or “baseline” condition for further evaluation of lowhead dam removal or modification alternatives in the project area. Water surface profiles computed by the HEC-RAS model in the study reach are shown in Figure 6.11 indicates that the lowhead dams control the water surface elevations in the Olentangy for lower flow rates. An evaluation of the amount of control provided for all flows was performed by removing all of the dams from the existing conditions model and then comparing the results for these two cases.

Figure 6.12 and Figure 6.13 show that the lowhead dams significantly influence the water surface elevations for the 1-year flow but that the influence is diminished and nearly negligible for the 500-year flow.
Figure 6.11. Water Surface Profiles – Existing Conditions
Figure 6.12. 1-Year Water Surface Profiles in Study Reach with and without Lowhead Dams
(Solid blue line is existing conditions, triangles is without dams.)
Figure 6.13. 500-Year Water Surface Profiles in Study Reach with and without Lowhead Dams
(Solid line is existing conditions, triangles is without dams.)
6.5.3. Numerical Flume Analysis

Based on the updated existing conditions HEC-RAS model, a “typical” section of the Olentangy River with a typical lowhead dam was coded into a separate HEC-RAS model so that various modifications could be examined qualitatively at a single structure.

Figure 6.14. Perspective Plot of Numerical Flume (HEC-RAS) with Typical Dam

Figure 6.14 depicts the model developed to evaluate the alternatives. This model consists of seven rectangular cross sections and one lowhead dam modeled as an ogee-shaped spillway. Flow rates, roughness values, dam geometry, cross-section widths and depths, and channel slope was taken from the existing conditions HEC-RAS model discussed above.

6.5.3.1. Full Dam Removal

The first dam modification option evaluated with the numerical flume was full dam removal. Figure 6.15 shows how the 1-year flood elevations change upstream of a typical dam if it is removed. As expected, the water surface in the vicinity of a removed dam is a function of the channel geometry and the pool upstream of the dam is lowered to normal flow depth, a decrease on the order of 4 to 5 feet. Velocities upstream of the dam increase from approximately 1.5 fps (feet per second) to approximately 3.5 fps. The model also shows increasing values of channel shear stress, power and Froude number after the dam is removed, indicated a more efficient condition for sediment transport, i.e. increasing “flushing” strength.
6.5.3.2. Constructed Riffle

Another alternative evaluated with the numerical flume was a constructed riffle on the downstream side of the lowhead dam. The riffle was modeled by modifying the geometry of the channel bed downstream of the dam. Several riffle configurations were modeled by varying the slope of the constructed riffle. A relatively steep riffle is shown in Figure 6.16 along with the resulting water surface profiles compared to existing conditions. Figure 6.16 indicates that a riffle will increase the water surface elevations upstream of the dam and along the riffle compared to existing conditions.

Figure 6.15. Impacts of Full Dam Removal on the 1-Year Flood

Figure 6.16. Impacts of a Constructed Riffle on the 1-Year and 500-Year Floods
6.5.3.3. W-weirs

A W-Weir is a boulder structure constructed within the channel bed used for grade control and bank protection in river restoration projects. A schematic is shown below in Figure 6.17.

The idea here is to place one or more W-weirs on the downstream side of a given lowhead dam to “drown-out” the dam in such a way as to create a more natural appearing river while providing a means for fish migration. In the above figure, points B and D would be adjacent to the downstream face of the dam.

Modeling the impacts associated with placing W-weirs in the Olentangy is a difficult task. Flow through these types of structures is three-dimensional in nature and the HEC-RAS model is incapable of handling these complex hydraulics. Therefore a more qualitative and experimental approach was taken to evaluate the impacts. A 1:50 scale model of a W-Weir and typical lowhead dam was constructed and placed in a tilting flume at the University of Kentucky. The model dam was subjected to various flows with and without the W-Weir attached to the downstream end. The model indicated that for small flows, i.e. low depths across the dam, no backwater was created by the W-Weir. However, for higher flows water surface increases were observed upstream of the dam when the W-Weir was in place. The results of this simple experiment indicate that placing this type of structure on the downstream side of a lowhead dam in the Olentangy River can potentially create water surface rises on the same order as that of a constructed riffle at high flows.
6.5.3.4. Channel Narrowing

Because the pools upstream of the lowhead dams are created by backwater and some of these areas have been widened, a restoration approach concerning placing fill in the active channel was evaluated to examine the impacts on flood elevations.

Figure 6.18 shows a cross section of the model run for the limiting case of fill placed in the upstream pool of the numerical flume. In this case the water surface at low flow (1-year) has been narrowed by 18-feet on both banks for a total of 36-feet. The original rectangular model representing “existing conditions” is shown with a heavy, magenta line. It was observed that placing any additional fill began to steadily increase the water surface for higher flow rates, thus the amount of fill indicated in Figure 6.18 was the upper limit of channel narrowing that could occur prior to creating adverse flooding impacts. The impact of channel filling on average streamwise velocities is shown in Figure 6.19.

Figure 6.19 indicates that channel narrowing has a beneficial impact on frequent flows by increasing the velocities in the pools upstream of a dam. In this figure the dam is located at 500 ft. on the bottom axis and the solid line shows velocities for the narrowed channel relative to the dashed line for the existing channel. In this case the mean velocity of the upstream pool was increased by approximately 1 fps. Velocity increases ranged from 1 to 2 fps for all flows investigated.
6.5.3.5. Sluice Under Dams

Another alternative evaluated with the numerical flume was the installation of sluices, or conduits, through the lowhead dam below the elevation of the sanitary sewers. The idea behind this option is to provide a method to lower the pools and increase low-flow velocities upstream of the dams. Several combinations of conduit sizing and spacing were evaluated. One case is shown below in Figure 6.20, where fifteen 30" diameter conduits were placed through the lowhead dam.
Figure 6.20 shows the upper limit of the amount of conduits that can be placed through the dam and compares this case to existing conditions for the 1-year flow. Figure 6.20 indicates that for the 1-year flow, water surfaces in the pool are lowered by approximately one foot. Velocities in the pool at this flow are increased by approximately 0.5 feet per second. Interestingly, the effect of the conduits is diminished for high flows such that the water surface and velocity changes for the 500-year flow are negligible. The effect of sedimentation on this alternative was not evaluated with this model. At very low flows all of the discharge is carried through the conduits and the lowhead dam protrudes through the water surface.

6.5.3.6. Diversions / Fish Passages / Boat Passages

Diversions, fish passages or fish ladders and boat passages are all small channels constructed around the edges of a lowhead dam to allow for aquatic organisms and humans to migrate from downstream to upstream of a dam at low flows. Construction of these types of improvements will not significantly change the hydraulics of the lowhead dam or impact water surface elevations or velocities in the upstream pool.

6.5.3.7. Removal of Antrim Lake Levee

The final option analyzed was the impact of removing the levee around Antrim Lake to provide the Olentangy increased floodplain access. For this option the HEC-RAS model of the existing river was used to evaluate the changes. Three cross sections are located in the vicinity of the Antrim Lake Levee and these cross sections were modified to reflect removal of the levee down to the elevation of the surrounding floodplain. Results of the analysis indicate that no influence on water surface elevations or other hydraulic properties is realized by removing the levee due to backwater generated from downstream controls. An unsteady state model would be required to accurately predict the benefits.

6.6. Summary

Several hydraulic models were used to analyze the existing river and various dam modification alternatives. The modeling results indicate that none of the alternatives (i.e. constructed riffles or W-weirs) are capable of “drowning out” the dams without adversely impacting floodplain elevations for high flows. Constructed riffles and W-weirs would be expected to increase the 100-year flood elevation on the order of 1-foot throughout the project reach. Sluices or conduits through the dam are capable of increasing pool velocities and decreasing pool depths but the number and size of conduits required to achieve beneficial results could lead to structural instabilities in the dams and pose hazardous conditions to boaters and swimmers in the vicinity of the dams. Diversions channels and/or fish passages (ladders) do not influence the hydraulics of the river. Removal of the Antrim Lake levee does not appear to influence the hydraulics of the river.

Of the alternatives analyzed, channel narrowing in the impounded areas appears to have the greatest benefits relating to hydraulics associated with ecological enhancements. Channel narrowing has the potential of increasing the mean velocity in the pools, decreasing the width/depth ratio, increasing sediment transport potential, and can be performed without significantly impacting flood elevations.
7. Alternative Evaluation

Each of the alternatives included in Table 4.1 was assessed using the evaluation criteria that were developed by the group of project partners during the Evaluation Criteria Workshop. Instead of assessing each dam individually, the matrix was streamlined to include all of the alternatives available for consideration. The evaluation was then undertaken on a general basis, assuming that the five dams would be considered uniformly with respect to the alternatives (however, not all of the alternatives were applicable to all five dams).

Each of the alternatives was evaluated as to whether it would:

a. Yield a positive impact on the criteria;

b. Yield a negative impact on the criteria; or

c. Have no impact on the criteria.

If a positive impact would be generated, a plus (+) sign was indicated in the matrix (Figure 7.1). If a negative impact would be generated, a minus (-) sign was indicated in the matrix, and if no impact would be generated on a particular criterion, a zero (0) was indicated in the matrix.

Two of the criteria discussed during the workshop were considered “make or break” criteria. The group concurred that these two criteria must be met before an alternative could even be considered. These were Sewer Service Integrity and Permitting. The group realized that first and foremost, sanitary sewer service had to be maintained to customers in an efficient and environmentally conscience manner.

The group also stated that construction of an alternative had to be able to be permitted by the appropriate agencies. Of particular concern is being able to obtain a Conditional Letter of Map Revision (CLOMR) if any alternative causes a rise in the Base Flood Elevation (BFE). The National Flood Insurance Program (NFIP) regulates construction within the regulatory floodplain and floodway.

44CFR 60.3(d)(3):  [In the regulatory floodway, communities must] Prohibit encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway unless it has been demonstrated through hydraulic and hydrologic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge.

The remaining ten overall evaluation criteria were subdivided into specific points. The alternatives were each assessed through the use of a question associated with each criterion. These questions are listed below.

River Hydraulics

- Instream Channel Stability – Will the alternative provide a stable channel in the areas of the dams and immediately upstream and downstream of the dams?
• Sediment/Bed Load Transport – Will the alternative improve the ability of the river to transport the bed load associated with the Olentangy River?

• Access to Floodplain – Will the alternative maintain or improve the river’s access to its floodplain?

• Increase Average Flow Velocity – Will the alternative result in increasing the average flow velocity in the impounded area behind the dam?

• Impacts to Floodplain – Will the alternative impact the base flood elevation (BFE) as currently provided by FEMA’s Flood Insurance Study?

• Natural Stream Profile – Will the alternative cause the stream profile to more closely resemble the natural stream profile if the dams were not present?

• Fish Passage/Migration – Can the alternative provide for fish passage or migration past the dam impediments?

• Maintenance – Will the alternative require periodic maintenance or cause any maintenance issues?

• Decrease Width/Depth Ratio – Will the alternative decrease the width/depth ratio?

**Biology / Chemistry**

• Increase QHEI – Can the alternative improve conditions measured in the following six metrics; substrate, instream cover, channel morphology, riparian zone and bank erosion, pool/glide and riffle/run quality, and map gradient, to allow for an increase in the Qualitative Habitat Evaluation Index scores?

• Increase IBI – Can the alternative improve the fish community habitat and diversity to allow for an increase in the IBI scores?

• Increase ICI – Can the alternative improve macroinvertebrate habitat and diversity to allow for an increase in the ICI scores within the impounded areas?

• Increase Number and Diversity of Mussels – Can the alternative lead to an increase in the number and diversity of mussel species present?

• Increase Dissolved Oxygen – Can the alternative lead to an increase in the dissolved oxygen levels in the impounded areas?

**Recreation**

• Usability – Can the alternative improve the usability of the river for recreational purposes?

• Improved Portages – Can the alternative improve or remove the need for portages?
• Access to River – Does the alternative improve access to the river?

• Stable Banks – Can the alternative lead to more stable banks associated with recreational uses such as fishing, birding, wading, or portaging?

• Sediment Trap Elimination – Can the alternative reduce some of the existing sediment trapping behind the dams?

Safety

• Hydraulics – Can the alternative reduce or help to avoid the dangerous hydraulic jump that is created by lowhead dams or other dangerous hydraulic conditions?

Aesthetics

• Scenic River Designation – Can the alternative help move the river closer toward Scenic River Designation?

• Overall Appearance – Can the alternative improve the overall appearance of the river?

Reliability

• Reliability – Has this alternative worked at other locations?

Time-Table

• Time-Table – Can the alternative be constructed in the near future or is it dependent on other capital projects that are projected many years from now?

Public Support

• Public Support – Will public support be easy to garner from the population that may utilize the river for recreational purposes?

Funding

• Funding Opportunities – Will the funding sources for the alternative be limited by the magnitude of dollars needed or by other factors?

Cost/Benefit

• Cost – Conceptual level cost estimates.
<table>
<thead>
<tr>
<th>Low Head Dam Alternatives</th>
<th>Full Cost Alternatives</th>
<th>Hydraulics</th>
<th>Biology / Chemistry</th>
<th>Recreation</th>
<th>Safety</th>
<th>Cost</th>
<th>Aesthetics</th>
<th>Reliability</th>
<th>Time Table</th>
<th>Public Support</th>
<th>Funding</th>
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* Yields a positive impact on the criterion
* Yields a negative impact on the criterion
* No impact on the criterion
* Water level changes lead to increased reliability of the dam (rather than decreased)
* May have issues associated with pump systems
* May have issues associated with construction/sediment

Figure 7.1. Lowhead Dam Alternatives Evaluation Matrix
7.1. Full Removal

Full removal of the dams affords the best opportunity for the river to maintain its natural profile, allow the existing pool areas to recover habitat (thus potentially increasing QHEI, ICI and IBI scores), facilitate the migration of fish and mussel species upstream, and allow recreational boating without portages.

These benefits are offset by the high costs and the sewer service integrity issues including potential concerns of overflows associated with the relocation and/or realignment of the sanitary sewers and necessary pump stations, and the availability of adequate construction corridors parallel to the river. The sanitary sewer modifications require large pump stations, which are costly to construct and operate. Pump stations also introduce a location for potential sanitary sewer overflows. These overflows would not be designed overflows, but equipment failure and wet weather conditions increase the probability of such an occurrence. The community and its citizens may not be willing to take that risk. For these reasons, this alternative is not feasible.

Opportunity may exist to examine the full removal options in the future. During the preliminary design of the Olentangy Relief Tunnel, adding dry weather flows to the tunnel to allow redirection of the flow from the dams should be explored by the City.

7.2. Grade Control Riffles

Because grade control riffles cause an increase in the water surface elevation (WSE) of approximately one foot during the 100-year event, this alternative would be very difficult to get approved through FEMA and the surrounding communities. This increase would result in a rise in the base flood elevations (BFE) of the floodplain in these segments of the river. The increased floodplain limits have not been mapped, but the impacts to structures, roadways and property are expected to be significant. For these reasons, this alternative is not feasible.

7.3. W-weirs

W-weirs also cause an increase in the WSE during the 100-year event similar to the impacts of the grade control riffles. The impacts of this rise are expected to be significant. For this reason, the alternative is not feasible.

7.4. Channel Narrowing

Narrowing the channel in the pool areas is limited by the impacts caused to the 100-year floodplain and BFE. From the hydraulic analyses, it was determined that the channel could be narrowed up to 15 feet on each bank without significantly raising the water surface elevations during the 100-year event.

This alternative increases the mean velocities through the pool sections by approximately 1 foot per second, which increases the bed load carrying capacity. By designing the narrowing using natural channel design techniques, some sinuosity could be reintroduced into the river. The pool will still exist behind the dams, so only small increases in QHEI scores could be expected.
Fish ladders would be required to facilitate the migration of fish upstream, and boat portages would also be required to facilitate recreational boating.

The permitting issues for placing fill in the regulated floodway would be significant for small increases in QHEI scores. Further discussion with the regulating agencies would be required to work through these issues.

7.5. Sluice Under the Dams

Constructing a sluice under the dam may remove the dangerous hydraulics on the downstream face of the dam during low flow, but it introduces dangerous hydraulics on the upstream side of the dam. The sluices may cause a suction force that would trap a person underwater against the upstream face of the dam. The pipes through the dam may also be a maintenance problem if debris collects over the opening of the pipes. The safety and maintenance issues make this alternative not feasible.

7.6. Diversion Channels

Diversion channels around the dams would afford excellent benefits to boat passage and fish migration if the barrier of the sewer did not exist on both sides of the dams. To construct a diversion channel around the dam, the channel would have to go over or under the existing sewer line that extends upstream and downstream of the dam. In either case, at least one joint of the sewer would be exposed, increasing the possibility of infiltration and/or exfiltration. Construction under the sewer introduces a number of construcability concerns and safety issues as well. These issues are considered sanitary sewer service integrity concerns and the alternative is therefore considered not feasible.

The sewer line would impede boat passage and a portage would still be required. Fish passage may be possible, but a fish ladder would afford the same benefit at a much lower cost.

7.7. Fish Ladders

For fish to migrate upstream, they need to cross the sewer line. A fish ladder structure at one edge of the dam would not impact the hydraulics of the flow of the 100-year event. The structure would not cause any improvement in the habitat of the pool areas, but may increase the number and diversity if fish species in upstream areas.

This alternative could be used in conjunction with other alternatives such as narrowing the channel in the pool areas and the construction of boat portages. One challenge in the design of the fish ladder structures is increasing the depth in the approach length of the top of the dam. The shallow approach lengths on the top of the dams range from 2.5 feet to almost 13 feet.

7.8. Boat Portages

Boat portages provide recreational benefit for little cost. The alternative has no impact on the hydraulics, biology/chemistry or aesthetics of the river. Warning signs should be placed near the dams to warn boaters of the potential hazard of the lowhead dams.
7.9. Antrim Lake Levee Removal (and Utilization of Storm Ponds near Broad Meadows)

Removal of the levee between the Olentangy River and the Antrim Lake may offer some flood storage benefits during flood events, but it has no hydraulic benefits at the dam locations. To correctly determine the flood storage benefits, an unsteady state model would need to be created and evaluated. The same holds true for any modifications to the stormwater ponds near Broad Meadows Boulevard.
8. Alternative Costs

The following section states the conceptual level estimate of probable costs for the developed alternatives. The costs were figured with a contingency factor of 50% on average. The cost estimating utilized the methods developed in Appendix U of the Wet Weather Management Plan when applicable.

8.1. Full Dam Removal

The full dam removal alternative entails the costs of removing the dam structure, providing stream restoration upstream and downstream, and providing for the relocation or realignment of the sanitary sewer lines. These costs include restoration.

8.1.1. Dam Removal and Stream Restoration Costs

Based on a similar dam removal project currently being undertaken in Englewood, Ohio, on the Stillwater River, the removal and restoration costs are: (Olentangy dams are 2/3 the height.)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>$1,082,000</td>
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<tr>
<td>Engineering/Construction Monitoring (15%)</td>
<td>162,000</td>
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<tr>
<td>Subtotal</td>
<td>$1,244,000</td>
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<tr>
<td>Contingency (50%)</td>
<td>622,000</td>
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<tr>
<td>Total per Lowhead Dam Location</td>
<td>$1,866,000</td>
</tr>
</tbody>
</table>

8.1.2. Sanitary Sewer Relocation and/or Realignment Costs

Any alternative for removal of one or more of the lowhead dams in this study would require modification of the Olentangy Main Trunk and tributary sewers. Since the gravity, sanitary sewer crossings were the reason for the construction of the lowhead dams, the sewer crossings would need to be eliminated or modified to allow for the full removal of the dams. The potential options for sewer modifications and full dam removal are explored in this section.

The conceptual statements of probable costs for the following improvements were developed using the methodology set forth in the City of Columbus’ CIP 650360 and CIP 650690 Wet Weather Management Plan (WWMP), Appendix U.

Sanitary sewer pipe unit cost estimates were obtained from the WWMP Exhibit U.3.10 for Relief Sewer Urban Installation costs.

Pump station capital cost estimates were generated using the pump station capital costing equation developed for the WWMP as follows:

\[ \text{Cost ($millions)} = 0.3515 \times Q(\text{cfs})^{0.726} \]  
(Eqn. 8.1)

(Brown and Caldwell, 2005)

Conceptual estimates presented below include a 30% markup to reflect design and construction management services. A 50% cost contingency is included and may be used
for providing peak wet weather storage. Costs associated with land acquisition are not included.

Pump Station capacity requirements were based on information provided by DOSD and presented in Appendix E. It is important to note that the sizing of the pump stations will need to be based on an analysis of flow monitoring data and hydraulic capacity modeling results. Costs to provide off-line storage for extraneous peak wet weather flows to maintain the operational functionality of the pump station are not included in this conceptual capital costing exercise. In addition, annualized operation and maintenance costs are not included below.

Construction Cost Indices for 2005 cost indexing was obtained from Engineering News Record, October 10, 2005.

8.1.2.1. Relocate Sewers Under the River at Current Locations

An option to consider for full lowhead dam removal is to abandon the existing sanitary lines presently located within the dams and microtunnel to install replacement lines under the Olentangy River. The construction of a pump station is needed at the downstream side of the new sewer line to lift sewage flows back to the connecting pipe elevation.

Conceptual level preliminary costs have been calculated for horizontally drilling and installing replacement lines crossing beneath the Olentangy River and pump stations to lift flows to existing sewer appurtenances associated with this option and these costs are provided on the following pages.

These costs were calculated using a simplified method and assuming a 400 lineal feet length of realigned sewer section.

State Route 161

Piping Costs: 48-inch diameter sewer

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanitary Sewer capital costs (WWMP Exhibit U.3.10)</td>
<td>$ 1,003 x 400 = $ 401,200</td>
</tr>
<tr>
<td>Sewer design, construction management</td>
<td>$ 401,200 x 30% = 120,360</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$ 521,560</td>
</tr>
<tr>
<td>50% Contingency</td>
<td>$ 521,560 x 50% = $ 260,780</td>
</tr>
<tr>
<td>Estimated pipe cost (without land acquisition)</td>
<td>$ 782,340</td>
</tr>
</tbody>
</table>

Pump Station Costs: sized at 11 mgd (17 cfs)

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Station Capital Costs 0.3515 x (17)0.726 =</td>
<td>$ 2,749,000</td>
</tr>
<tr>
<td>Pump station design, construction management</td>
<td>$ 2,749,000 x 30% = 824,700</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$ 3,573,700</td>
</tr>
<tr>
<td>50% Contingency</td>
<td>$ 3,573,700 x 50% = 1,786,850</td>
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<tr>
<td>Estimated pump station cost (without land acquisition)</td>
<td>$ 5,360,550</td>
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Dam Removal

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
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<tbody>
<tr>
<td>Dam Removal</td>
<td>$ 1,866,000</td>
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</table>

Estimate for Full Removal of State Route 161 Dam approximately $8,009,000
Broad Meadows (Questionable Constructability)

Piping Costs: 36-inch diameter sewer

- Sewer capital costs (WWMP Exhibit U.3.10) $ 935 x 400 = $ 374,000
- Sewer design, construction management $ 374,000 x 30% = 112,200
- Subtotal $ 486,200
- 50% Contingency $ 486,200 x 50% = 243,100
- Estimated pipe cost (without land acquisition) $ 729,300

Pump Station sized at 10 mgd (15 cfs)

- Capital Costs 0.3515 x (15)^0.726 = $ 2,511,000
- Pump station design, construction management $ 2,511,000 x 30% = 753,300
- Subtotal $ 3,264,300
- 50% Contingency $ 3,264,000 x 50% = 1,632,150
- Estimated pump station cost (without land acquisition) $ 4,896,450

Dam Removal $ 1,866,000

Estimate for Full Removal of Broad Meadows Dam approximately $ 7,491,750

North Broadway

Piping Costs 78-inch diameter sewer

- Pipe capital costs (WWMP Exhibit U.3.10) $ 1,173 x 400 = $ 469,200
- Pipe design, construction management $ 469,200 x 30% = 140,760
- Subtotal $ 609,960
- 50% Contingency $609,960 x 50% = $304,980
- Estimated pipe cost (without land acquisition) $ 914,940

Pump Station sized at 59 mgd (92 cfs)

- Pump Station Capital Costs 0.3515 x (92)^0.726 = $ 9,368,000
- Pump station design, construction management $ 9,368,000 x 30% = 2,810,400
- Subtotal $ 12,178,400
- 50% Contingency $12,178,400 x 50% = 6,089,200
- Estimated pump station cost (without land acquisition) $ 18,267,600

Dam Removal (each) $ 1,866,000

Estimate for Full Removal of North Broadway dam approximately $ 21,049,000
Union Cemetery and Dodridge Street (each)

Piping Costs 78-inch diameter sewer

Pipe capital costs (WWMP Exhibit U.3.10) $ 1,173 x 400 = $ 469,200
Pipe design, construction management $ 469,200 x 30% = 140,760
Subtotal $ 609,960
50% Contingency $609,960 x 50% = $ 304,980
Estimated pipe cost (without land acquisition) $ 914,940

Pump Station sized at 82 mgd (127 cfs)

Pump Station Capital Costs 0.3515 x (127)0.726 = $ 11,838,000
Pump station design, construction management $ 11,838,000 x 30% = 3,551,400
Subtotal $ 15,389,400
50% Contingency $ 15,389,400 x 50% = 7,694,700
Estimated pump station cost (without land acquisition) $ 23,084,100

Dam Removal (each) $ 1,866,000

Estimate for Full Removal of Union Cemetery and Dodridge Street dams (each) approximately $ 25,865,000

The conceptual level statement of probable cost (without land acquisition or annualized O&M costs) for full removal of 5 lowhead dams approximately $ 88,000,000
8.1.2.2. Remove the Zigzags between North Broadway and Dodridge

The options for which costs have been developed are described in Section 5 - Conceptual Alternatives.

From Exhibit U.3.10 of the WWMP, sanitary sewer pipe unit costs of a similar relief sewer (an installation from an upstream manhole to some downstream manhole with no lateral tie-ins) in an urban environment can be estimated at $1,139 per lineal foot for 72-inch diameter pipe. Using a straight line extension of costs presented, installation of 78-inch diameter pipe in this environment would be $1,173 per lineal foot. Additionally, the costs associated with tunneling a 54-inch diameter pipe (Tulane Relief Sewer) can be interpolated to be $3,450 per lineal foot.

The conceptual level preliminary cost estimates are presented as follows:

Option 1 (Section 5.2.1 Figure 5.1)

Sewer Capital Cost

Pipeline costs (WWMP Exhibit U.3.10 – assume straight line interpolation for 78 inch pipe is $1,173 per lineal foot) for approximately 4,300 LF

$1,173 x 4,300 = $5,043,900

Design and construction management $5,043,900 x 30% = __1,513,170

Subtotal, 78-inch diameter $6,557,070

50% Contingency $6,557,070 x 50% = __3,278,535

78-inch pipe estimated cost (without land acquisition) $9,835,605

Pump Station sized at 82 mgd (127 cfs)

Pump Station Capital Costs 0.3515 x (127)^0.726 = $11,838,000

Pump station design, construction management $11,838,000 x 30% = __3,551,000

Subtotal $15,389,000

50% Contingency $15,389,000 x 50% = __7,695,000

Estimated pump station cost (without land acquisition) $23,084,000

Dam Removal (3)

$5,598,000

Option 1 conceptual level statement of probable cost (without land acquisition or annualized O&M costs) approximately $38,518,000
Option 2 (Section 5.2.2 Figure 5.2)

Sewer Capital Cost
Pipeline costs (WWMP Exhibit U.3.10 – assume straight line interpolation for 78 inch pipe is $1,173 per lineal foot) for approximately 3,550 LF

78-inch diameter
Pipeline costs $ 1,173 x 3,550 = $ 4,164,150
Design and construction management $ 4,164,150 x 30% = 1,249,245
Subtotal, 78-inch diameter $ 5,413,395
50% Contingency $ 5,413,395 x 50% = 2,706,698
78-inch pipe estimated cost (without land acquisition) $ 8,120,093

54-inch diameter
Pipeline costs $ 1,037 x 900 = 933,300
Design and construction management $ 933,300 x 30% = 279,900
Subtotal, 54-inch diameter $ 1,213,290
50% Contingency $ 1,213,290 x 50% = 606,645
54-inch pipe estimated cost (without land acquisition) $ 1,819,936
Estimated sewer cost (without land acquisition) $ 9,940,028

Pump Station sized at 31 mgd (48 cfs)
Pump Station Capital Costs 0.3515 x (48)^0.726 = $ 5,841,000
Pump station design, construction management $ 5,841,000 x 30% = 1,752,000
Subtotal $ 7,593,000
50% Contingency $ 7,593,000 x 50% = 3,797,000
Estimated pump station cost (without land acquisition) $ 11,390,000

Dam Removal (2)
$ 3,732,000

Option 2 conceptual level statement of probable cost
(without land acquisition or annualized O&M costs) approximately $ 25,062,000
Option 3 (Section 5.2.3 Figure 5.3)

Pipe Costs (not including land acquisition or contingency) for approximately 2,400 LF of open cut 78” is $3,700,000.

Sewer Capital Cost

Pipeline costs (WWMP Exhibit U.3.10 – assume straight line interpolation for 78 inch pipe is $1,173 per lineal foot) for approximately 2,400 LF

$ 1,173 x 2,400 = $ 2,815,200

Design and construction management

$ 2,815,200 x 30% = 844,560

Subtotal, 78-inch diameter

$ 3,659,760

50% Contingency

$ 3,659,700 x 50% = 1,829,880

78-inch pipe estimated cost (without land acquisition) $ 5,489,640

Dam Removal

$ 1,866,000

Option 3 conceptual level statement of probable cost (without land acquisition or annualized O&M costs) approximately $ 7,356,000

8.1.3. Least Cost Full Removal Alternative

The conceptual level cost estimates for removing all five dams using the river crossing/pump station configuration and considering the incorporation of zigzag realignment options are summarized in Table 8.1.

Table 8.1. Full Removal and Zigzag Options Cost Comparison

<table>
<thead>
<tr>
<th>Lowhead Dam</th>
<th>Full Removal ($M)</th>
<th>Full Removal Utilizing Option 1 ($M)</th>
<th>Full Removal Utilizing Option 2 ($M)</th>
<th>Full Removal Utilizing Option 3 ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Route 161</td>
<td>8.009</td>
<td>8.009</td>
<td>8.009</td>
<td>8.009</td>
</tr>
<tr>
<td>Broad Meadows</td>
<td>7.471</td>
<td>7.471</td>
<td>7.471</td>
<td>7.471</td>
</tr>
<tr>
<td>North Broadway</td>
<td>21.049</td>
<td>38.518</td>
<td>25.062</td>
<td>21.049</td>
</tr>
<tr>
<td>Union Cemetery</td>
<td>25.865</td>
<td>25.865</td>
<td>7.356</td>
<td></td>
</tr>
<tr>
<td>Dodridge Street</td>
<td>25.865</td>
<td>25.865</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated Cost ($millions)</td>
<td>88.259</td>
<td>53.998</td>
<td>66.407</td>
<td>43.885</td>
</tr>
</tbody>
</table>

As indicated in the above table, the least cost full removal alternative (considering only the costs outlined in section 8.1 consists of the following:

- Utilizing the removal of the State Route 161, Broad Meadows, and North Broadway lowhead dams and installing sanitary sewer crossings under the Olentangy River and constructing pump stations downstream in order to lift flows back up into the Olentangy Main Sewer East Subtrunk and the Broad Meadows Relief Sewer, and the Olentangy Main Trunk Sewer.

\[d\] Costs do not include land acquisition, storage facilities, or hydraulic modeling costs to verify/size pump stations and peak flow storage basins.
• The Union Cemetery and Dodridge Street dams would be removed and the Olentangy Main would be realigned from the eastern (upstream) end of the Union Cemetery dam to the eastern (downstream) end of the Dodridge Street dam.

This full removal alternative is estimated at a conceptual level to cost $44,000,000.

8.2. Grade Control Riffles

The riffles are comprised of graded rip-rap to emulate the natural bed material of the river. Construction would be comprised of placing the graded rip-rap at the base of the dam at a thickness equal to the crest of the dam tapering down at a constant slope to the channel bed some distance from the base of the dam. It is assumed this distance is approximately 750 feet, and the average depth is 2 feet.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructed Riffle (5000 cubic yards of graded rip-rap)</td>
<td>$75,000</td>
</tr>
<tr>
<td>Design and Construction Management (30%)</td>
<td>$22,500</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$97,500</td>
</tr>
<tr>
<td>Contingency (50%)</td>
<td>$48,750</td>
</tr>
<tr>
<td>Total per Lowhead Dam Location</td>
<td><strong>$146,250</strong></td>
</tr>
</tbody>
</table>

8.3. W-weirs

W-weirs are constructed from boulders similar to ODOT Class A rock. A typical w-weir installation on a river section such as the Olentangy near these lowhead dams would be approximately $30,000.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>W-Weir Installation</td>
<td>$30,000</td>
</tr>
<tr>
<td>Design and Construction Management (30%)</td>
<td>$9,000</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$39,000</td>
</tr>
<tr>
<td>Contingency (50%)</td>
<td>$19,500</td>
</tr>
<tr>
<td>Total per Lowhead Dam Location</td>
<td><strong>$58,500</strong></td>
</tr>
</tbody>
</table>

8.4. Channel Narrowing

Narrowing of the channel upstream of the lowhead dam locations is limited by the hydraulics to approximately 15 feet on each side. The narrowing would be extended the entire length of the pool for each dam location. The amount of fill required is estimated as follows:

$$15' \times 4' \times 2 = 120 \text{ ft}^2$$

$$120 \text{ ft}^2 \times 1 = 120 \text{ ft}^3 / 27 = 4.5 \text{ yd}^3$$

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.R. 161 5200LF (pool) X 4.5 yd$^3$</td>
<td>$468,000</td>
</tr>
<tr>
<td>Design and Construction Management (30%)</td>
<td>$140,400</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$608,400</td>
</tr>
</tbody>
</table>
Contingency    304,200
Total          $ 912,600

**Broad Meadows**

4800LF (pool) X 4.5 yd³ = 21,600 yd³ @ $20/yd³ $ 432,000
Design and Construction Management (30%)    129,600
Subtotal                                    $ 561,600
Contingency                                 280,800
Total                                       $ 842,400

**North Broadway**

7000LF (pool) X 4.5 yd³ = 31,500 yd³ @ $20/yd³ $ 630,000
Design and Construction Management (30%)    189,000
Subtotal                                    $ 819,000
Contingency                                 409,500
Total                                       $ 1,228,500

**Union Cemetery**

3400LF (pool) X 4.5 yd³ = 15,300 yd³ @ $20/yd³ $ 306,000
Design and Construction Management (30%)    91,800
Subtotal                                    $ 397,800
Contingency                                 198,900
Total                                       $ 596,700

**Dodridge Street**

2300LF (pool) X 4.5 yd³ = 10,350 yd³ @ $20/yd³ $ 207,000
Design and Construction Management (30%)    62,100
Subtotal                                    $ 269,100
Contingency                                 134,550
Total                                       $ 403,650

8.5. **Sluice Under Dams**

Construction of the pipes through the base of the dam could be accomplished by methods similar to horizontal directional drilling through the concrete dam structure beneath the sanitary sewer lines at a cost of $600/foot.

Assume 15 pipes X 25.5 feet (length) = 382.5 @ $ 750 $ 286,875
Design and Construction Management (30%)    86,063
Subtotal                                    $ 372,938
Contingency (50%) 186,469
Total per Lowhead Dam Location $ 559,407

8.6. Diversion Channels

Diversion channels can be estimated at a cost of $ 500 per linear foot of channel.

Assume 500 LF channel length @ $500/LF $ 250,000
Design and Construction Management (30%) 75,000
Subtotal $ 325,000
Contingency (50%) 162,500
Total per Lowhead Dam Location $ 487,500

8.7. Fish Ladders

Fish Ladders can also be estimated at a cost of $ 500 per linear foot.

Assume 20 LF fish ladder @ $500/LF $ 10,000
Design and Construction Management (30%) 3,000
Subtotal $ 13,000
Contingency (50%) 6,500
Total per Lowhead Dam Location $ 19,500

8.8. Antrim Lake Levee Removal

The removal of the levee between the Olentangy River and the Antrim Lake would be excavation and replacement of the multi-use trail. The levee is approximately 5 feet tall with a 20 feet wide top width for a total length of 2000 LF.

300 ft² X 2000 ft = 600,000 ft³ / 27 = 22,222 yd³ @ $20/yd³ $ 450,000
Design and Construction Management (30%) 135,000
Subtotal $ 585,000
Contingency (50%) 292,500
Total $ 877,500

8.9. Boat Portages

The cost for constructing boat portages and the trails associated with the portages are minimal and can be considered insignificant to the cost of the other alternatives.
9. Public Meeting and Comments

The draft report was presented to the general public on Wednesday, November 2, 2005. The presentation was given during the regularly scheduled monthly meeting of FLOW at the Northwood High Building, 2231 North High Street, Columbus, Ohio, at 7:30 PM. Approximately forty people were in attendance at the meeting. The sign-in sheets are in Appendix L.

The draft report was made available for download on the FMSM website on October 31, 2005. A link to that site was also placed on the City’s website. An e-mail account and link was also placed on the FMSM website for any comments regarding the draft report. Comments from the public and project partners were requested to be submitted on or before November 28, 2005.

Only four comments were received via e-mail,, which are in Appendix M. There was one request for a hard copy of the report. OEPA responded that they had no significant comments. Mr. Mike Steinmetz commented on recreational issues and the desire to see a whitewater park constructed along the Olentangy River. Ms. Erin Miller commented about the importance of exploring the option of adding dry weather flows to the Olentagy Relief Tunnel (ORT) during the design process to allow the full removal of the lowhead dams.

A response was sent to Mr. Steinmetz (included in Appendix M) clarifying the issues that may exist with the design of a whitewater park. The modeling for the grade control riffles and the w-weir concepts would be applicable to the whitewater park concept. The diversion channel issues would also be applicable.

A phone conversation with Ms. Miller addressed her comments regarding the ORT design. The recommendation to look at that option during the preliminary design of the ORT is included in the evaluation and conclusion sections of the final report.

The City of Columbus provided comments during review and presentation of the draft report. Those comments were addressed accordingly.
10. Conclusions

The purpose of the Lower Olentangy River Watershed Lowhead Dams Feasibility Study was to develop concepts that may improve water quality while protecting the integrity of the sanitary sewer service provided by the sewer lines within the dams. Improving water quality has a broad meaning in this context. It encompasses improving the:

- Hydraulics of the Dams and the River;
- Biology, Chemistry, and Habitat;
- Recreational Potential;
- Safety; and
- Aesthetics.

As a result of the Brainstorming Workshop, a comprehensive list of potential alternatives was discussed, and the ones that seemed to have the most potential were developed into conceptual alternatives. These alternatives were modeled and evaluated hydraulically. The results of the hydraulic analyses rendered several of the alternatives not feasible. These included Grade Control Riffles and W-weirs because they raised the water surface elevations during the 100-year event, and Sluices Under the Dams because of the unsafe hydraulics on the upstream side of the dam.

The conceptual alternatives were then evaluated for the other evaluation criteria that were discussed and prioritized during the Evaluation Criteria Workshop. The two conceptual alternatives presented for their flood storage capabilities, Removal of the Antrim Lake Levee and Utilization of the Storm Ponds near Broad Meadows, offered no other benefits to the segments of the river near the dam locations. These concepts could be modeled in more detail using an unsteady state model to determine the benefits for flood storage separately.

The Full Removal alternative affords the highest potential for improving the river hydraulics, biology, chemistry and habitat, recreational boating, safety and aesthetics. This alternative, however, requires the relocation and/or realignment of the sanitary sewer lines. Several options were discussed and costs were developed. The costs ranged from $7.5 million for the dam removal and associated sewer relocation at Broad Meadows to $44 million for the removal of the five lowhead dams and the associated relocation and realignment of the sanitary sewers. The capital construction costs, operation and maintenance costs associated with the pump stations, and the increased potential for sanitary sewers overflows associated with pump stations currently make this option not feasible.

The future design and construction of the Olentangy Relief Tunnel (ORT) may provide opportunity to visit the Full Removal alternative in the future. As proposed, the ORT is not planned for any dry weather flows. Adding dry weather flows to the tunnel should be investigated to facilitate the Full Removal of the five lowhead dams. The preliminary design of the ORT is not planned until 2015 with construction complete in 2042. This is not a short-term solution, but should be investigated during the preliminary design phase of the ORT.
The remaining conceptual alternatives are Narrowing the Channels, Diversion Channels, Fish Ladders and Boat Passages.

Diversion Channels afford no additional benefits that are not accomplished by Fish Ladders. The barrier of the sewer lines remain on both ends of the dams. Diversion Channels would require the exposing of one or more pipe joints, which would increase the potential for infiltration and/or exfiltration. For these reasons Diversion Channels are considered not feasible, and Fish Ladders are recommended over Diversion Channels.

Narrowing the Channel upstream of the dams may increase the quality of the habitat in some metrics in the upstream pools. Increasing the mean velocities and possibly adding some sinuosity back to the channel could improve habitat scores for some metrics in the total QHEI score. The improvements would be limited by the fact that the pool would still remain and the narrowing would be limited by the hydraulics needed to not raise the water surface elevations at the 100-year event. The conceptual level costs for this alternative ranges from $400,000 to $1,200,000. It is recommended that funding for these options be explored through grant opportunities and the mitigation clearinghouse on OEPA’s website. Permitting issues may prove to be prohibitive.

Fish Ladders offer a means for fish migration upstream of the barriers caused by the dams. The Fish Ladder structures cause no adverse impacts hydraulically, and they offer no improvements hydraulically. This option may be used in conjunction with the Narrowing the Channel alternative and included in the search for funding opportunities.

Boat Portages should be constructed before or along with the Fish Ladders and Narrow the Channel alternatives. Warning signs should be placed upstream of the dams for the protection of of the recreational boaters. A simple portage and trail system from the upstream portage point to the portage below the dams could be constructed on lands that are publicly owned and adjacent to most of the dams.
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Henderson

Hey

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