Appendix L

Return Flow Effects on Habitat in Underwood Creek and Menominee River

Return Flow Effects on Habitat in Underwood Creek and Menomonee River

TO: Waukesha Water Utility

FROM: CH2M HILL

DATE: January 23, 2010

The City of Waukesha is applying for a new Lake Michigan water supply that would require return flow. The return flow would come from the City of Waukesha wastewater treatment plant. This memorandum summarizes potential changes to the functional habitats in Underwood Creek and the Menomonee River that would result from return flow to Underwood Creek. This document expands on a previous study that evaluated the return flow effects on the geomorphic stability of Underwood Creek[1].

Executive Summary

Previous studies have determined that a return flow to Underwood Creek would not affect the geomorphic stability of the creek. This study evaluated the return flow influence on habitat and aquatic resources in Underwood Creek and the Menomonee River for locations downstream of the return flow discharge location. Information from representative areas indicates that:

- The habitat of dominant fish and macroinvertebrates could be improved with additional flow, especially in the rehabilitated segment of the creek and during periods when the creek flows are low (baseflow flow conditions).
- Underwood Creek often experiences extended periods when there is no flow in the creek because of ice or dry conditions when there is little precipitation. At those times, return flow would provide the greatest habitat improvement because periods of no flow could be eliminated.
- During baseflow and low flow periods, return flow would provide additional water depth to improve fish passage through the riffle and concrete parts of the creek, to deepen pools within the restored reach, and to provide more wetted perimeter habitat near the creek banks and overhanging vegetation.
- Return flow is expected to slightly increase shear stresses in the creek, which are insignificant to the geomorphic stability of the creek, but could improve the bottom substrate habitat by reducing embeddedness (fine sediment accumulation in coarse substrates) to support coarse (e.g., gravel) sediment habitat.

[1] Short Elliot Hendrickson, Inc. (SEH). 2009. "Underwood Creek Effluent Return Evaluation". Technical memorandum dated July 23, 2009,

- Most of the creek is concrete lined, but the areas that have already been rehabilitated or that will be rehabilitated in the future will benefit the most from additional flow.
- When creek flow is high (e.g., flow events greater than a 2-year flow), return flow is a small portion of the total creek flow. During these times, return flow is not expected to have a significant effect on the creek habitat.

Return flow influence on the larger Menomonee River is expected to benefit the habitat downstream of its confluence with Underwood Creek for the same reasons. Because the return flow will be a smaller percentage of the total river flow, it will improve fish passage, submerged habitat, and embeddedness to a lesser degree. When river flows are high, return flow is not expected to have a significant effect on river habitat because it will be a very small percentage of the total river flow.

Introduction

In support of the City of Waukesha's application for a Great Lakes drinking water supply, field data were collected and hydraulic models were used to assess the potential changes to habitat in Underwood Creek and the Menomonee River, for areas downstream of a future return flow. The location of the return flow discharge is anticipated to be in Waukesha County near the intersection of Underwood Creek and Bluemound Road. The distance from the creek at this location to its confluence with the Menomonee River (Figure 1) is roughly 2.6 miles and includes mostly concrete-lined channels (Figure 2) with a 2,400-foot section that was recently rehabilitated[2] (Figure 3). The downstream 4,400 feet of creek (immediately downstream of the rehabilitated reach) to the confluence with Menomonee River is mostly concrete-lined, with a short segment that has a concrete low-flow channel and vegetated floodplain (Figure 4) and a natural 300-foot segment at the end of the reach. That reach is expected to be rehabilitated in the future, but final design has not yet been completed.[3] Downstream of the creek confluence with the Menomonee River, the river is mostly an urban-natural channel with a natural bottom, vegetated riverbanks, and limited areas of concrete (Figure 5).

[2] Milwaukee Metropolitan Sewerage District (MMSD). 2008. "Watercourse: Underwood Creek Rehabilitation and Flood Management – Phase 1." Designed by Short Elliott Hendrickson, Inc.

[3] Short Elliot Hendrickson, Inc. (SEH). 2009. "Underwood Creek Effluent Return Evaluation". Technical memorandum dated July 23, 2009, page 2.

FIGURE 1
Underwood Creek and Menomonee River

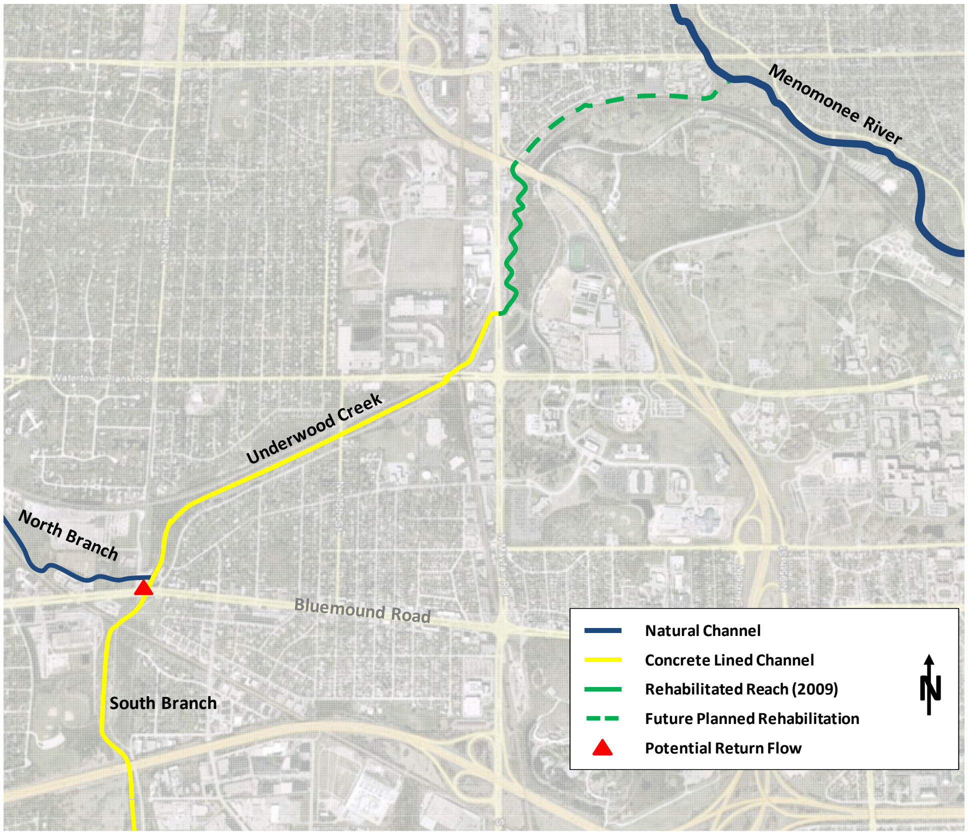


FIGURE 2
Concrete Lining in Underwood Creek

FIGURE 3
Rehabilitated Reach of Underwood Creek (during Construction)

FIGURE 4
Underwood Creek Concrete-Lined Low Flow Channel with Vegetated Floodplain

FIGURE 5
Menomonee River Downstream of Confluence with Underwood Creek (Looking Downstream)

Field Survey

A field survey was completed and included surveying cross sections at several locations in the creek and river, for low-flow portions of the cross section (i.e., the floodplain was not surveyed). The field survey conducted qualitative assessments of the existing aquatic habitat. The field survey was also completed to provide data on how additional flow could change the functional habitat (e.g., how additional flow could change the wetted perimeter, embeddedness, cross sectional flow area, flow depth, vegetation influence, etc).

Previously developed HEC-RAS hydraulic models of Underwood Creek[4] and the Menomonee River[5] were used in conjunction with the surveyed cross sections to evaluate the potential effect the addition of the return flow may have on the functional habitat within the creek and river. The functional habitat evaluation was completed with consideration for the dominant fish and macroinvertebrates identified for these water bodies (Attachment A).

Return Flow Effect on Underwood Creek Habitat

The rehabilitated parts of the creek provide greater functional habitat than the concrete lined parts because the bottom substrate is coarse grained sediments (gravel and cobbles); it provides various habitat features such as riffles, runs, pools, and glides; it meanders and includes other habitat features like rock boulders; the vegetation will overhang the channel once it is mature; and the creek will be reconnected with its floodplain. The concrete-lined creek provides less functional habitat because there is little or no vegetation providing cover; the water depth is

[4] Underwood Creek HEC-RAS Model. Underwood Creek Rehabilitation and Flood Management Project. Short Elliott Hendrickson Inc., 2009. Computer Model.

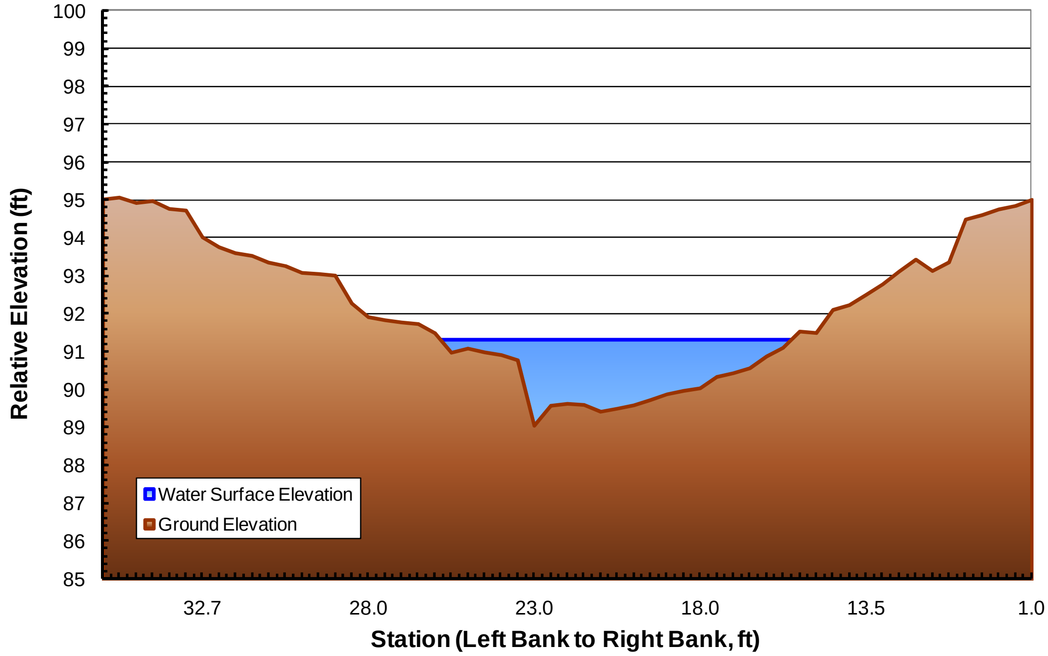
[5] Menomonee River HEC-RAS Model. Phase I Watercourse System Management Project. Milwaukee Metropolitan Sewerage District, 2001. Computer Model. Modified for newer HEC-RAS model v3.1.3.

very shallow and there are several drops that are barriers to fish passage during low flow periods; the bottom substrate does not support a functional benthic community; and the uniformity of the channel provides limited areas for fish to hold or seek refuge.

There are concrete-lined areas upstream and downstream of the rehabilitated reach, and its habitat resources are not fully used because there are barriers (concrete lining and drop structures) between it and the Menomonee River. However, because the downstream part of the creek is planned to be rehabilitated using similar design concepts, these areas of the creek are expected to provide functional habitat that is connected with the aquatic community in the river.

Two cross sections were surveyed in the rehabilitated portion of the creek, one at a pool (Figure 6) and one at a riffle-run (Figure 7). The cross sections were collected when the creek was very near its baseflow of 3 cubic feet per second (cfs), where the flow is well within main channel, and bottom substrate was readily visible. (The cross sections were surveyed using a relative benchmark elevation of 100 feet for each cross section.)

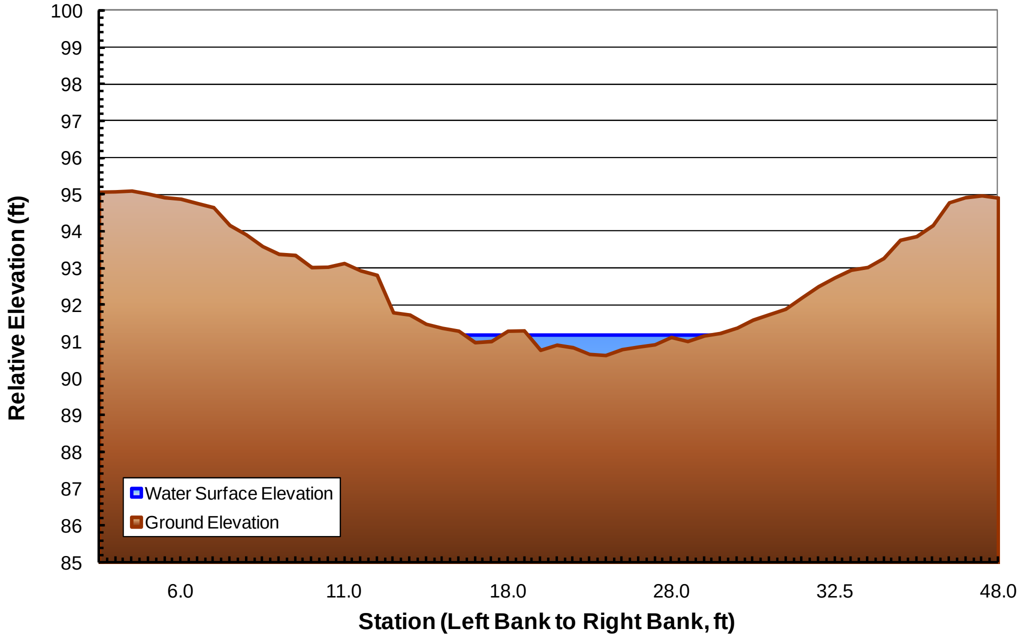
FIGURE 6
Baseflow at a Pool in the Underwood Creek Rehabilitated Reach



A hydraulic analysis was completed as part of the geomorphic stability analysis for a potential return flow of 20 cfs.[6] It estimated an increase in the water surface elevation between 0.15 to 0.80 foot in the existing and future rehabilitated reach during baseflow conditions. At two locations that coincide with this habitat evaluation, an increase in water surface elevation of 0.78 foot was estimated. Shown in Figures 8 and 9 are cross sections at the two locations that were surveyed as part of this study. These cross sections were used because they provide greater detail of the creek than do the cross sections used in the geomorphic hydraulic analysis.

[6] Short Elliot Hendrickson, Inc. (SEH). 2009. "Underwood Creek Effluent Return Evaluation". Technical memorandum dated July 23, 2009, page 1 and Attachment 3.

FIGURE 7
Baseflow at a Riffle-run in the Underwood Creek Rehabilitated Reach



During baseflow periods, the return flow also increases the average velocity, cross sectional flow area, shear stress, and the wetted perimeter in the creek. These increases will have a negligible effect on the hydraulic and geomorphic conditions in the creek[8], but the increase in flow is expected to benefit the habitat within the creek during baseflow periods by reducing the extent to which fine sediments fill the coarse sediment substrate (embeddedness), providing deeper pools and riffles for more functional fish passage, and providing more wetted perimeter to support a greater benthic community.

To supplement the hydraulic analysis completed as part of the geomorphic stability analysis, additional hydraulic modeling was completed for return flows of 11.6 and 30 cfs. The 11.6 cfs flow was chosen because it represents the existing average day water demand. The 30-cfs flow was chosen as an upper boundary for analysis because the return flow management plan is based on a maximum return flow less than 30 cfs. As expected, the lower return flow has less of an increase in cross sectional flow area, shear stress, and wetted perimeter compared to 20-cfs return flow and the 30-cfs return flow has more. Table 1 summarizes the modeling output for the surveyed cross sections during baseflow periods. Similar to the 20 cfs results, the model results are applied to the surveyed cross sections.

[8] Short Elliot Hendrickson, Inc. (SEH). 2009. "Underwood Creek Effluent Return Evaluation". Technical memorandum dated July 23, 2009, page 1.

FIGURE 8
Underwood Creek Water Surface Elevation with 20-cfs Return Flow (23-cfs total flow) at Pool

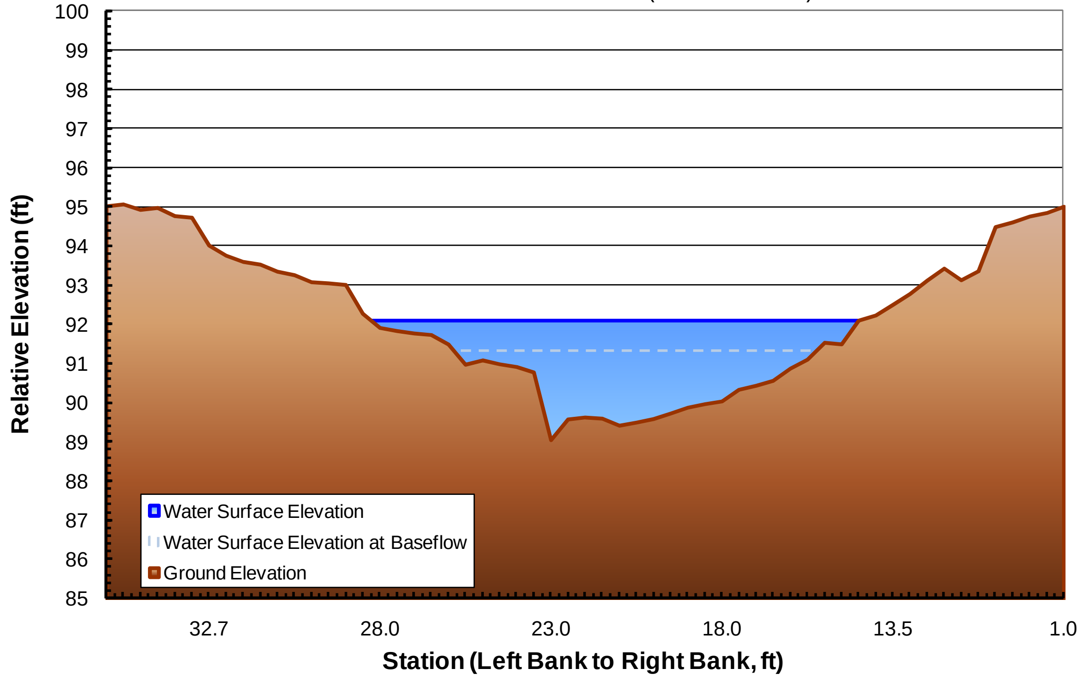


FIGURE 9
Underwood Creek Water Surface Elevation with 20-cfs Return Flow (23-cfs Total Flow) at Riffle-run

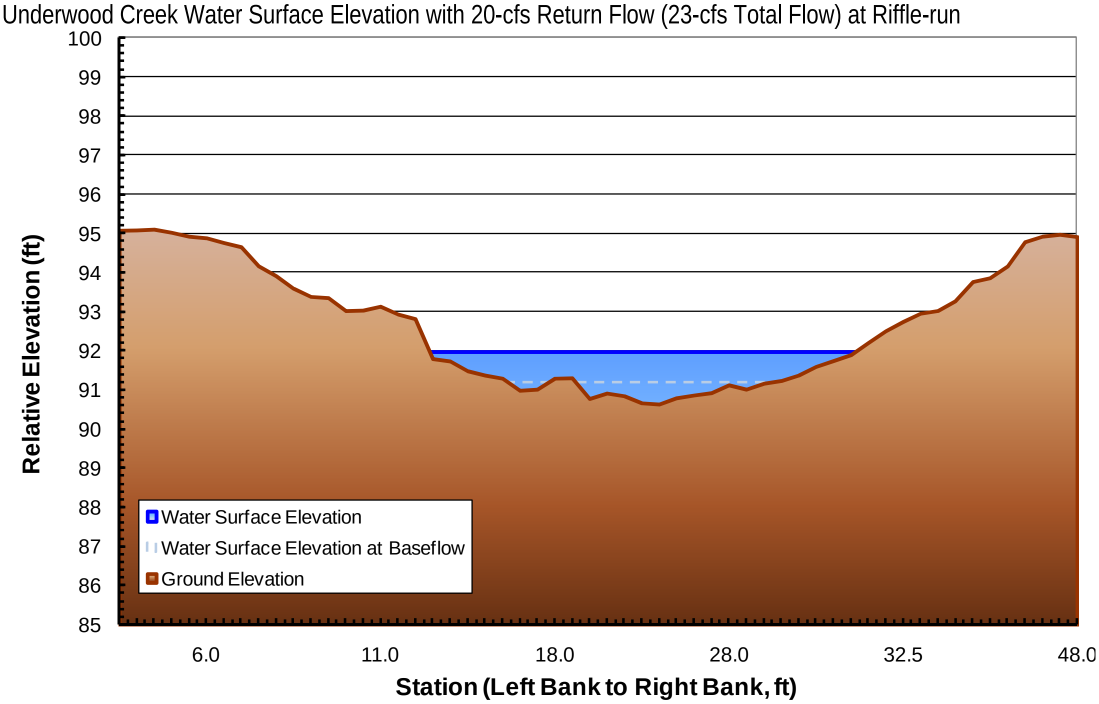


TABLE 1
Underwood Creek Summary Output for Surveyed Cross Sections During Baseflow with Varying Return Flow

		Baseflow with Return Flow of		
	Baseflow	**11.6 cfs**	**20 cfs**	**30 cfs**
Average velocity (ft/sec)	0.85	1.11	1.32	1.51
Channel shear stress (lb/ft^2)	0.05	0.08	0.11	0.13
Flow area (ft^2)	3.51	13.13	17.43	21.84
Wetted perimeter (ft)	Riffle-run: 11.6 Pool: 12.6	Riffle-run: 18.6 Pool: 15.8	Riffle-run: 19.7 Pool: 16.3	Riffle-run: 20.2 Pool: 18.0

Note: Model results assuming Phases I and II of the channel rehabilitation are complete and the channel vegetated. Wetted perimeter calculated from surveyed cross sections.

When creek flow is high during large storms (e.g., 2-year flow events and larger), the return flow is a very small part of the creek flow and is not expected to have a significant effect on the creek habitat. For example, a 20-cfs return flow is only 1.5 to 2.0 percent of the 2-year flow (for locations in the creek downstream of the potential return flow location)[9] and 0.29 to 0.76 percent of the 100-year flow. For a 30-cfs flow, it is only 2.2 to 3.0 percent of the 2-year creek flow and 0.44 to 1.1 percent of the 100-year flow. This results in very little or no change to the calculated average velocity, shear stress, flow area, or wetted perimeter with 30 cfs return flow for a 2-, 5- and 100-year creek flow (Table 2).

TABLE 2
Underwood Creek Summary Output for Surveyed Cross Sections during High Flow Periods with Varying Return Flow

	2-year Creek Flow	2-year Creek Flow plus 30 cfs Return Flow	5-year Creek Flow	5-year Creek Flow plus 30 cfs Return Flow	100-year Creek Flow	100-year Creek Flow plus 30 cfs Return Flow
Average velocity (ft/sec)	5.32	5.38	6.61	6.66	7.20	7.21
Channel shear stress (lb/ft^2)	0.97	0.99	1.38	1.39	1.54	1.54
Flow area (ft^2)	321.2	327.7	502.7	507.9	678.0	685.6
Wetted perimeter (ft)	118.1	118.4	133.3	133.8	163.1	164.7

Note: The 30 cfs flow was chosen as an upper boundary for analysis because the return flow management plan is based on a maximum return flow less than 30 cfs. Model results assuming Phases I and II of the channel rehabilitation are complete and the channel vegetated.

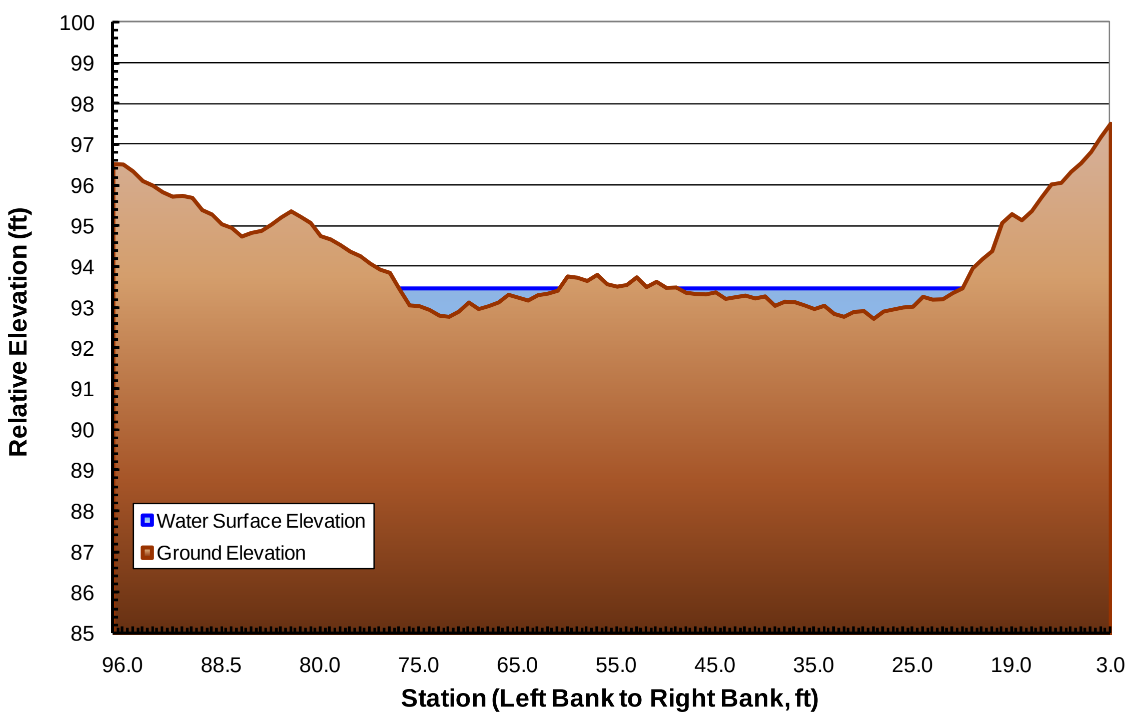
Dominant fish and macroinvertebrates, and associated preferred habitats were identified for these areas (Attachment A). Based on that analysis and the results above, the habitats for the dominant species would most benefit from a return flow during periods of low flow, such as baseflow conditions, and it would be expected that the fish and benthic communities would also improve because of the improvements to the functional habitat. Underwood Creek often experiences extended periods when there is no flow in the creek due to ice or dry conditions with little precipitation. During such times, return flow would provide the greatest habitat improvement because the periods with no flow would be eliminated.

[9] Underwood Creek HEC-RAS Model. Underwood Creek Rehabilitation and Flood Management Project. Short Elliott Hendrickson Inc., 2009. Computer Model.

Return Flow Effect on Menomonee River Habitat

The Menomonee River is much larger than Underwood Creek, when comparing watershed size, average annual flows, and cross sectional areas of the river and creek, and therefore the addition of return flow will have a less significant effect on the habitat within the river. To estimate the potential changes in habitat, a cross section was surveyed at a riffle on the river immediately downstream of the confluence with the creek. The location was chosen because it was very near a location within the hydraulic model (river mile 8.37), which was used to predict changes in the river hydraulics that would influence habitat changes. The base flow rate of about 8 cfs was estimated from low flow periods of average daily flow at the USGS gauge (#04087120). Figure 10 shows the surveyed cross section during baseflow, including exposed substrate in the center of the cross section that is not functional for fish or macroinvertebrates.

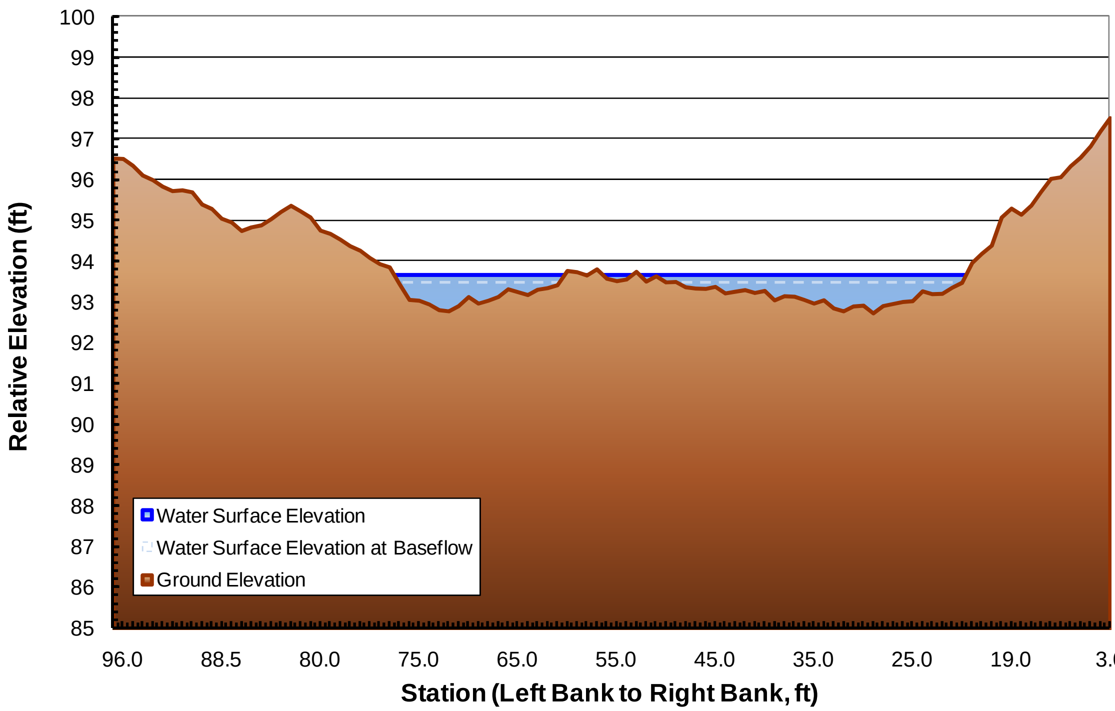
FIGURE 10
Baseflow at Surveyed Riffle Cross Section in the Menomonee River



A HEC-RAS hydraulic analysis was completed during this study for a potential return flow of 20 cfs, which predicted a slight increase in the water surface elevation of 0.17 foot under baseflow conditions (Figure 11). There is exposed substrate at that location, and the increased cross sectional flow area provided by the return flow provides greater functional area for fish and macroinvertebrates.

The return flow in the river is expected to also have a negligible effect on the hydraulic and geomorphic conditions in the river, the same conclusion reached for the creek. The return flow is estimated to slightly increase the average velocity, shear stress and the wetted perimeter in the river. The return flow is estimated to have a greater increase in cross sectional flow area, where the area would increase by 60 percent for a 20-cfs return flow. These increases are expected have a benefit to the river habitat, similar to the benefits within the creek.

FIGURE 11
Menomonee River Water Surface Elevation with 20-cfs Return Flow (28 cfs Total Flow)



The return flow could benefit the river by reducing the opportunity for fine sediments to fill the coarse sediment substrate (embeddedness), providing deeper pools and riffles for more functional fish passage, and providing more wetted perimeter to support a greater benthic community. The river has a better functioning aquatic community than the creek (Attachment A), where the return flow could have a greater benefit to the river aquatic community.

Hydraulic modeling was completed for a return flow of 11.6, 20, and 30 cfs. As expected, the lower return flow has less of an increase in cross sectional flow area, shear stress and wetted perimeter compared to the larger return flow. Table 3 summarizes the modeling output for the surveyed cross section during baseflow periods.

TABLE 3
Menomonee River Summary Output for Surveyed Cross Section During Baseflow with Varying Return Flow

		Baseflow with Return Flow of		
	Baseflow	11.6 cfs	20 cfs	30 cfs
Average velocity (ft/sec)	0.5	1.0	1.14	1.27
Channel shear stress (lb/ft^2)	0.01	0.05	0.06	0.07
Flow area (ft^2)	15.1	19.2	24.3	30.0
Wetted perimeter (ft)	43.8	48.8	50.8	53.9

Note: Wetted perimeter calculated from surveyed cross sections.

When the river flow is high during large storms (e.g., 2-year flow events and larger), the return flow is a very small portion of the river flow. As with the creek, return flow during these times is not expected to have a significant effect on the river habitat. For example, a 20-cfs return flow is only 0.30 to 0.59 percent of the 2-year flow (for locations in the river downstream of the potential return flow location)[10] and 0.11 to 0.21 percent of the 100-year flow. For a 30-cfs return flow, it is only 0.45 to 0.88 percent of the 2-year river flow and 0.16 to 0.32 percent of the 100-year flow. This results in very little or no change to the calculated average velocity, shear stress, flow area, or wetted perimeter with 30-cfs return flow for a 2-, 5- and 100-year river flow (Table 4).

TABLE 4
Menomonee River Summary Output for Surveyed Cross Section during High Flow Periods with Varying Return Flow

	2-year River Flow	2-year River Flow plus 30 cfs Return Flow	5-year River Flow	5-year River Flow plus 30 cfs Return Flow	100-year River Flow	100-year River Flow plus 30 cfs Return Flow
Average velocity (ft/sec)	6.86	6.88	7.14	7.14	6.70	6.69
Channel Shear Stress (lb/ft^2)	0.85	0.85	0.85	0.85	0.66	0.66
Flow Area (ft^2)	790.2	800.5	1,579.1	1,593.3	3,670.1	3,684.7
Wetted Perimeter (ft)	260.9	270.3	481.4	481.7	531.7	532.0

Note: The 30 cfs flow was chosen as an upper boundary for analysis because the return flow management plan is based on a maximum return flow less than 30 cfs.

Dominant fish and macroinvertebrates and associated preferred habitats were identified for these areas (Attachment A). Based on that analysis and the results above, the habitats for the dominant species would most benefit from a return flow during periods of low flow. It would be expected that the fish and benthic communities would also improve because of the improvements to the functional habitat.

10 Menomonee River HEC-RAS Model. Phase I Watercourse System Management Project. Milwaukee Metropolitan Sewerage District, 2001. Computer Model. Modified for newer HEC-RAS model v3.1.3.

Attachment A
Desktop Fisheries Analysis Assessment for Underwood Creek Return Flow

Desktop Fisheries Analysis Assessment for Underwood Creek Return Flow

PREPARED FOR: Waukesha Water Utility

PREPARED BY: CH2M HILL

DATE: January 23, 2010

This memorandum reviews historical fisheries and macroinvertebrate data collected from Underwood Creek and the Menomonee River both upstream of and near the confluence of the Creek. The object of this review is to present an overview of historical fish community structure and selected habitat preferences in areas where return flow from the City of Waukesha could occur. This review summarizes biological information within the Menomonee River watershed that could offer comparisons to Underwood Creek now or in a future restored condition. Summary benthic macroinvertebrate and habitat information is also presented to give a broader perspective of Underwood Creek's biological and physical nature.

Physical Description

The physical nature of Underwood Creek from the potential return flow location to about Highway 100 (Mayfair Road) is predominantly a trapezoidal concrete channel with little habitat for fish. The relatively smooth concrete channel does provide some limited substrate for benthic macroinvertebrates and algae colonization. There is very little overhead tree or shrub cover.

A total of approximately 2,400 feet of the concrete stream channel in Underwood Creek from about Highway 100 downstream to about the Chicago, Milwaukee, St. Paul and Pacific Railroad Bridge (Highway 45 overpass) was removed in 2009 and rehabilitated to a meandering stream channel with numerous pools/riffles. The bottom substrate material is largely cobble and boulders with some large to medium gravel.

From the downstream end of the rehabilitated channel to roughly 300 feet upstream of the confluence with the Menomonee River the stream channel is also a trapezoidal concrete channel with several drop structures. Little fish habitat exists in this portion of Underwood Creek. The drop structures preclude movement of fish to the restored area under normal baseflow. A future Phase 2 channel restoration plan includes removing most of the remaining concrete all the way to the Menomonee River.

The last 300 feet of Underwood Creek before the confluence with the Menomonee River has natural substrate. Several pools and riffles are present along with large amounts of woody debris. The stream bottom is largely cobble, with varying amounts of sand, gravel, and silt.

Available Data Review

Inquiries were made to various organizations to determine data already available for Underwood Creek and the Menomonee River. Inquiries were made with the Milwaukee

Metropolitan Sewerage District, the Southeastern Wisconsin Regional Planning Commission (SEWRPC), and the Wisconsin Department of Natural Resources. These three organizations, and local academic institutions in conjunction with the United States Geological Service (USGS), have been collaborating in data-sharing efforts as part of the Regional Water Quality Management Plan Update efforts lead by SEWRPC. The data have been compiled into an overall database. Relevant portions of this database were made available to conduct this review.

Fisheries

The USGS obtained the most recent fisheries data for lower Underwood Creek and the Menomonee River near Underwood Creek in 2004 and 2007. Data collected by the USGS were from both concrete-lined and natural channel segments at the downstream end of Underwood Creek. The results of these two stream surveys identified about 20 species of fish. Table 1 lists the 14 most abundant species collected, along with their preferred habitat characteristics. Underwood Creek sampling found 12 species. The consolidated information in Table 1 is from information collected from several sources (see Attachment A-1). These species are common in other subwatersheds in the Menomonee River Basin.

TABLE 1
Summary of Preferred Habitat Characteristics for Dominant Fish Species in the Menomonee River Watershed

Dominant Fish Species	Found in Underwood 2004 or 2007	Preferred Current Velocity Range	Stream Gradient	General Habitat Characteristics	Dominant Substrate Preference
Pearl dace	X			Pools	Sand/gravel
Creek chub	X	< 0.98 ft/sec	3-23 m/km	Pools	Sand/gravel
White sucker	X	1.31 ft/sec	Wide range	Wide range	Gravel/sand
Long nose dace	X	> 1.48 ft/sec	1.9-18.7 m/km	Riffles	Gravel/rubble
Blunt nose minnow	X			Wide range	Gravel/sand
Black nose dace	X	0.49–1.48 ft/sec	11.4–23.3 m/km	Rocky runs and pools	Gravel/sand
Central stoneroller	X			Rocky riffles, runs, and pools	Gravel/sand/rubble
Common shiner	X			Rocky pools near riffles	Hard bottom/gravel/sand/rubble
Fathead minnow	X			Muddy pools	Sand/rubble/gravel
Largemouth bass	X	> 0.33 ft/sec			Vegetated areas, sand/gravel/mud
Green sunfish	X	< 0.33ft/sec	0.2–5.7 m/km	50% pools	Vegetated cover
Johnny darter				Pools	Sand/mud
Bluegill	X	< 0.33ft/sec	≤ 0.5 m/km	60% pool areas	Submerged vegetation/ logs/brush
Central mud minnow				Quiet areas	Soft mud bottom/dense vegetation

ft/sec = feet per second m/km = meters per kilometer

The following assessment of water quality/habitat quality is based on fish community structure as expressed in the Index of Biotic Integrity (IBI). The IBI, derived from 2004 and 2007 data (Thomas et al. 2007), is a multi-metric index that uses information on fish species richness and composition, number and abundance of indicator species, trophic organization and function, reproductive behavior, fish abundance, and condition of individual fish to assess the health and well being of a water body. The index is composed of several metrics (measurement endpoints, such as catch per unit effort), which are then summed into a final value (Index Value). That value is then compared to a standard value that reflects a stream condition with little human influence. The IBI scores in Table 1 are based on a rating system of warmwater streams in Wisconsin (Lyons 1992).

The index of biotic integrity rating suggests that there are variations year to year and factors limiting the fishery in the lower part of Underwood Creek and the Menomonee River near the creek. The concrete-lined segments of Underwood Creek are considered habitat limiting.

TABLE 2
Fish IBI Assessment Results

Location	Year of Survey	IBI Score	Biotic Integrity Rating
Menomonee River at Menomonee Falls, WI	2004	30	Fair
Menomonee River at Menomonee Falls, WI	2007	15	Very Poor
Underwood Creek at Wauwatosa, WI [a]	2004	10	Very Poor
Underwood Creek at Wauwatosa, WI [a]	2007	37	Fair
Menomonee River at Wauwatosa, WI	2004	12	Very Poor
Menomonee River at Wauwatosa, WI	2007	40	Fair

Legend: 100–65 excellent, 64–50 good, 49–30 fair, 29–20 poor, 19–0 very poor

[a] Sample location included areas of concrete-lined channel.

Source: USGS 2004 and 2007 data

Benthic Macroinvertebrates

Benthic macroinvertebrates are small aquatic organisms that are often used to assess stream health. Table 2 presents benthic macroinvertebrate data collected by the USGS in 2007, which were developed into an index to assess relative quality. Aquatic worms and midges were the dominant groups collected in the lower Underwood Creek. Likewise, the Menomonee River sample location far upstream of the confluence with Underwood Creek in Menomonee Falls was also dominated by midges, but a few mayflies were present, which represent a more sensitive group. The Menomonee River sample location downstream of the confluence was dominated by mayflies, caddisflies, and riffle beetles. Table 3 presents consolidated benthic macroinvertebrate information from selected stations in 2007.

General Habitat Information

The part of Underwood Creek that is not concrete lined at the confluence with the Menomonee River generally is a pool with two well-defined riffle areas. The substrate material is composed largely of gravel, with some sand and silt. No formal measurement of

TABLE 3
Consolidated Benthic Macroinvertebrate Information from Selected Stations in 2007

Location	Number of Species	HBI-10	HBI Rating
Menomonee River at Menomonee Falls, WI	24	4.77	Good
Underwood Creek at Wauwatosa, WI [a]	21	6.66	Fairly Poor
Menomonee River at Wauwatosa, WI	22	5.85	Fair

Legend: HBI/HBI-10: < 3.50, excellent; 3.51–4.50, very good; 4.51–5.50, good; 5.51–6.50, fair; 6.51–7.50, fairly poor; 7.51–8.50, poor; 8.51–10.00, very poor

[a] Sample location included areas of concrete-lined channel.

Source: Hilsenhoff 1987 and 1998

embeddedness was conducted during a field visit, but qualitatively it appeared that the bottom substrate is roughly 25 percent or more embedded. Depth of pool areas was less than 2 feet. The Menomonee River just downstream of the confluence with Underwood Creek exhibited a large riffle area, with some exposure of cobble and coarse gravel. The pool area downstream of the riffle was roughly 2 feet deep with a cobble bottom. Embeddedness was 25 percent or more.

Summary

The fish community in Underwood Creek was limited to 12 of the 20 species found at 3 sampling locations within the Menomonee River watershed. The dominant species in lower Underwood Creek and the Menomonee River near the creek are considered tolerant of local environmental conditions, as indicated by the IBI. The benthic macroinvertebrate community structure in Underwood Creek was restricted in community structure and indicated habitat limiting factors, as suggested by the Hilsenhoff Biotic Index.

The concrete-lined parts of Underwood Creek and the many drop structures continue to impede fish passage. The rehabilitated channel that is isolated from the Menomonee River has habitat features that fish and macroinvertebrates would use once the Phase 2 concrete channel removal restores stream connectivity.

General habitat characteristics and dominant substrate preferences were identified for the dominant fish species in Underwood Creek and Menomonee River near the creek. Habitat conditions in Underwood Creek are limiting for the fish and benthic communities; however, if the habitat were to be improved by providing more or higher quality habitat, it would be expected that the fish and benthic communities would also improve.

References

Hilsenhoff, W. L. 1987. “An Improved Biotic Index of Organic Stream Pollution.” *Great Lakes Entomologist.* v. 20, no. 1, pp. 31–40.

Hilsenhoff, W. L. 1998. A Modification of the Biotic Index of Organic Stream Pollution to Remedy Problems and Permit Its Use Throughout the Year.” *Great Lakes Entomologist.* v. 31, no. 1, pp. 1–12.

Lyons, John. 1992. *Using the Index of Biotic Integrity (IBI) to Measure Environmental Quality in Warmwater Streams of Wisconsin.* St. Paul, Minn., U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station, 48 p.

Thomas, J. C., M. A. Lutz, et al. 2007. *Water-Quality Characteristics for Selected Sites within the Milwaukee Metropolitan Sewerage District Planning Area, Wisconsin, February 2004–September 2005.* U.S. Geological Survey Scientific Investigations Report 2007–5084, 187 p.

Attachment A-1

Literature Review of Habitat Preferences for Dominant Fish Species near Underwood Creek

ATTACHMENT A-1

Literature Review of Habitat Preferences for Dominant Fish Species near Underwood Creek

Main sources of information were Froese and Pauly (2009), Becker (1983), Stuber et al. (1982a, 1982b, 1982c), McMahon (1982), Twomey et al. (1984), Edwards et al. (1983), and Trial et al. (1983).

Pearl Dace

Adults inhabit pools of creeks and small rivers, also ponds and lakes. Encountered in clear to slightly turbid water most frequently at depths less than 0.5 m (Becker 1983). Usually occurs over sand or gravel, most often in streams < 3m wide (Becker 1983). Feeds on copepods, cladocerans, chironomids, beetles, filamentous algae, and *Chara* (Scott and Crossman, 1973).

Creek Chub

Inhabits rocky and sandy pools of headwaters, creeks and small rivers (Page and Burr 1991). Mostly found in tiny, intermittent streams. Young feed on small aquatic invertebrates. Adults consume small fish, crayfish, and other large invertebrates (Etnier and Starnes 1993). One of the most common fishes in eastern North America.

Optimum habitat is small, clear, cool streams with moderate to high gradient, gravel substrate, well defined riffles, and pools with abundant cover and abundant food (Trautman 1957; Monshenko and Gee 1973; Hocutt and Stauffer 1975). Creek chubs are found in streams with gradients of 3 to 23 m/km with their greatest abundance in gradients of 7 to 13.4 m/km (Monshenko and Gee 1973; Hocutt and Stauffer 1975). They are most abundant in small streams 0.5 to 7 m in width (Hocutt and Stauffer 1975) and less than 1 m in average depth (Barber and Minckley 1971).

Most abundant in streams with alternating pools and riffle-run areas (Trautman 1957; Minckley 1963; Monshenko and Gee 1973). Rubble substrate in riffles, abundant aquatic vegetation (Hynes 1970), and abundant streambank vegetation (Monshenko and Gee 1973; Cummins 1974) are conditions associated with high production of food types consumed by creek chubs. Adults generally occur in streams with an average velocity of less than 60 cm/sec (Minckley 1963; Monshenko and Gee 1973). Most abundant in stream sections of deep runs and pools with surface velocities ≤ 30 cm/sec (Monshenko and Gee 1973). Fry are found along the edges of pools with surface velocities ≤ 10 cm/sec (Clark 1943; Minckley 1963; Copes 1978).

White Sucker

Inhabits a wide range of habitats, from rocky pools and riffles of headwaters to large lakes. Usually occurs in small, clear, cool creeks and small to medium rivers. Moves to shallower water near sunrise and sunset to feed. Fry (1.2 cm) feed on plankton and other small invertebrates; bottom feeding commences upon reaching a length of 1.6 to 1.8 cm. Prey for birds, fishes, lamprey, and mammals (Scott and Crossman 1973).

Stream populations of white sucker reach maximum abundance in low to moderate stream gradients of 2.8 to 7.8 m/km (Hocutt and Stauffer 1975). Inhabit primarily pools and areas of slow to moderate velocity (about 40 cm/sec). Water movement is important to suckers, and they are generally absent when flow is less than 10 cm/sec (Minckley 1963).

Longnose Dace

Inhabit rubble and gravel riffles (sometimes runs and pools) of fast creeks and small to medium rivers. Young up to 4 months are pelagic (Scott and Crossman 1973). Form schools (Scott and Crossman 1973). Feed on mayflies, blackflies, and midges (Scott and Crossman 1973). Spawn over pits in loose gravel substrate (Bartnik 1970).

Most abundant in swift flowing, steep gradient, headwater streams of large river systems (Kuehn 1949; Reed 1959; Reed and Moulton 1973). Probably live in streams with a gradient from 1.9 to 18.7 m/km (Kuehne 1962). All age groups occur in very shallow water, usually < 0.3 m deep (Gee and Northcote 1963) and rarely > 1 m deep (Sigler and Miller 1963). Overhead cover and shelter from the current is required during all seasons (Bartnik 1973). Usually collected in streams with current velocities > 45 cm/sec (Gee and Northcote 1963).

Bluntnose Minnow

Occurs almost anywhere in its range but most common in clear rocky streams (Robins et al. 1991; Etnier and Starnes 1993). Found most often over sand and gravel substrates (Becker 1983). Often associated with submerged vegetation (Becker 1983). Feeds on algae, detritus, entomostraca, and immature insects, especially midge larvae and pupae (Etnier and Starnes 1993).

Blacknose Dace

Inhabits rocky runs and pools of headwaters, creeks and small rivers (Page and Burr 1991; Etnier and Starnes 1993). Feeds on aquatic insects; also on diatoms and other algae. Blacknose dace spawn on substrates of sand, gravel, and cobble.

Prefers swift streams (Traver 1929; Harlan and Speaker 1951; Scarola 1973). Greatest densities of blacknose dace adults occur when surface velocities are between 15 and 45 cm/sec (Gibbons and Gee 1972). Common at gradients of 11.4 and 23.3 m/km, but almost entirely absent at 67.2 m/km (Burton and Odum 1945). Low gradients (, 5 m/km) are also avoided (Trautman 1957; Gibbons and Gee 1972).

Central Stoneroller

Inhabits rocky riffles, runs, and pools of headwaters, creeks and small to large rivers (Page and Burr 1991; Etnier and Starnes 1993). Generally found in riffle and pool sections of streams over rubble, gravel, and sand (Becker 1983). Subadults and adults feed on detritus, filamentous algae, and diatoms, and occasionally on small aquatic insects; young on rotifers and microcrustacea (Etnier and Starnes 1993).

Common Shiner

Adults inhabit rocky pools near riffles in clear, cool creeks and small to medium rivers. Sometimes occurs in lakes in northern part of range. Oviparous (Breder and Rosen 1966), nest spawners (Coker et al. 2001). Hybridization between *Luxilus cornutus* and *L. chrysocephalus* occurs frequently in areas where the ranges of the two species overlap.

Typically occurs in small and medium-sized streams with clear, cool water, moderate current; and unvegetated gravel to rubble (Lee et al. 1980). These minnows frequent pools in streams more often than rapids (Adams and Hankinson 1928). They congregate in pools immediately below cascades, but not in deadwater or long pools, which are common at stream mouths. When the pH drops below 5.8, reproduction ceases and the population disappears (Harvey 1980).

Fathead Minnow

Inhabits muddy pools of headwaters, creeks and small rivers (Welcomme 1988). Also found in ponds and lakes (Etnier and Starnes 1993). Tolerates unsuitable conditions (e.g., turbid, hot, poorly oxygenated, intermittent streams) (Welcomme 1988). Feeds on detritus and algae (Etnier and Starnes 1993). Introductions consequently caused the spread of the enteric red-mouth disease throughout northern Europe which infected wild and cultured trouts and eels (Welcomme 1988). Maintained a relatively high metabolic rate and level of activity under hypoxic conditions (Klinger et al. 1982). Individuals that survived the hypoxic conditions during winter had rapid growth rates after ice-off (Held and Peterka 1974).

Largemouth Bass

Inhabits clear, vegetated lakes, ponds, swamps. Also in backwaters and pools of creeks and rivers (Page and Burr 1991). Prefers quiet, clear water and over-grown banks. Adults feed on fishes, crayfish and frogs; young feed on crustaceans, insects and small fishes. Sometimes cannibalistic. Does not feed during spawning, or when the water temperature is below 5°C and above 37°C (Billard 1997).

Adult largemouth bass are most abundant in areas with vegetation (Jenkins et al. 1952); availability (Saiki and Tash 1979) and in areas of low current velocity, based on catch data (Hardin and Bovee 1978). Increased water levels in reservoirs may reduce prey availability due to increased cover for prey species. Stable to decreased water levels concentrate prey, which increased feeding and growth rates of adult bass (Heman et al. 1969). Thus, stable to slightly negative midsummer fluctuations (0 to 3m) are considered optimal for adult largemouth bass.

Optimal spawning substrate is gravel (Newell 1969; Robinson 1961), but other substrates such as vegetation, roots, sand, and mud are suitable (Harlan and Speaker 1956; Mraz and Cooper 1957; Marz et al. 1961). Silty, mucky bottoms are unsuitable (Robinson 1961). Water velocities as low as 40 cm/sec may result in mortality of embryos (Dudley 1969), Hardin and Bovee (1978) reported that velocities >10 cm/sec were avoided by the species Largemouth bass spawn at depths ranging from 0.15 m to 7.5 m. Optimal current velocities fro fry are 4 cm/sec (Hardin and Bovee 1978), and fry cannot tolerate current velocities > 27 cm/sec.

Green Sunfish

Inhabits quiet pools and backwaters of sluggish streams; lakes and ponds. Often near vegetation (Page and Burr 1991; Welcomme 1988). Juveniles feed on immature insects and microcrustaceans (Welcomme 1988).

Optimal riverine habitat consists of at least 50 percent pool area. Species abundance is positively correlated with percent vegetation cover (Moyle and Nichols 1973). Have been found at a wide range of gradients, varying from 0.2 to 5.7 m/km (Cross 1954; Funk 1975a). Most abundant at lower (≤ 2 m/km) gradients (Trautman 1957; Funk 1975b). Prefers small to medium-sized (< 30 m width) streams (Trautman 1957; Cross 1967; Moyle and Nichols 1973).

High species abundance is positively correlated with moderate (25 to 100 JTU) turbidities (Trautman 1957; Cross 1967; Moyle and Nichols 1973), although the species occurs in both clear and turbid water (Jenkins and Finnell 1957). Dissolved oxygen requirements are presumably similar to those of the bluegill sunfish. Thus, optimal dissolved oxygen levels are > 5 mg/l (Petit 1973), and lethal levels are ≤ 1.5 mg/l (Moore 1942). Optimal pH range is from 6.5 to 85. (Stroud 1967), mortality may occur at levels ≤ 4.0 or ≥ 10.35 (Trama 1954; Calabrese 1969; Ultsch 1978).

Based on catch data, preferred current velocities are ≤ 10 cm/sec, but adults will tolerate velocities up to 25 cm/sec (Kallemyn and Novotny 1977; Hardin and Bovee 1978). Optimal current velocities for fry are ≤ 5 cm/sec, and fry avoid areas with velocities exceeding 8 cm/sec (Kallemyn and Novotny 1977; Hardin and Bovee 1978).

Johnny Darter

Occurs in sandy and muddy, sometimes rocky, pools of headwaters, creeks; small to medium rivers; and sandy shores of lakes (Page and Burr 1991; Welcomme 1988). Also found in streams (Welcomme 1988). Adults feed on midge larvae, mayfly nymphs, caddis larvae, and microcrustaceans; young on entomostracans and tiny midge larvae (Welcomme 1988). Eggs are found clustered on underside of stone and guarded by males (Page 1983).

Bluegill

Found frequently in lakes, ponds, reservoirs and sluggish streams (Page and Burr 1991; Welcomme 1988). Lives preferably in deep weed beds (Page and Burr 1991). Active mainly during dusk and dawn. Adults feed upon snails, small crayfish, insects, worms and small minnows (Page and Burr 1991). Young feed on crustaceans, insects and worms (Page and Burr 1991; Welcomme 1988).

In riverine habitats, bluegills are mostly restricted to areas of low velocity (Hubbs and Lagler 1958). Hardin and Bovee (1978) developed probability curves showing that adults prefer current velocities < 10 cm/sec but will tolerate up to 45 cm/sec. Abundance has been correlated to a high percentage (60%) pool area and negatively correlated to a high percent riffle/run area (Moyle and Nichols 1973). Optimal stream gradient (≤ 0.5 m/km) is based on the preference for low gradient, lentic-type waters (Trautman 1957).

Uses cover in riverine habitats is in the form of submerged vegetation or logs and brush, especially juveniles and small adults (Moyle and Nichols 1973; Scott and Crossman 1973). However, an excessive abundance of vegetation can inhibit utilization of prey by bluegills.

Optimal temperatures for fry are 25 to 32°C (Hardin and Bovee 1978). Optimal current velocities are < 5 cm/sec; fry are not found in areas with velocities greater than about 7.5 cm/sec (Kallemyn and Novotny 1977; Hardin and Bovee 1978).

Central Mudminnow

Occurs in quiet areas of streams, sloughs, swamps and other wetlands over soft mud bottom and debris (Page and Burr 1991, Welcomme 1988). Often found in dense vegetation. Tolerates drought, low oxygen levels and extremes water temperature (Page and Burr 1991). Feeds on aquatic insects, amphipods, isopods, and snails (Welcomme 1988).

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