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Ohio Environmental Protection Agency
Division of Surface Water

Biological and Water Quality Study of the Licking River

And Selected Tributaries, 2008

Licking, Muskingum, Knox, and Fairfield Counties, Ohio

Licking River downstream from Newark, RM 28.6.

John R. Kasich, Governor
Mary Taylor, Lt. Governor
Scott J. Nally, Director

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SUMMARY

Ohio EPA has conducted three comprehensive Licking River watershed studies. In 1981, Licking River water quality was fair. Following substantial improvements at publicly owned wastewater treatment plants (WWTPs), conditions were very good in 1993. In 2008, Licking River water quality remained very good.

The 1972 Clean Water Act (CWA) required publicly owned WWTPs to adopt secondary treatment by 1988. By 1990, an associated federal construction grants program transitioned to each state offering alternative financing strategies. So, the 1990 grant program end marked a relevant time period. During the 1980's, Ohio EPA found many streams to be degraded. During the 1990's many of the same streams were significantly improved. The 1993 Ohio EPA Biological and Water Quality Study of the Licking River and Selected Tributaries (1995) was the first to document the basin wide scope of recovery attributable to WWTP upgrades.

It is more than a trivial truth to state that the Licking basin's very good water quality has been maintained only because direct efforts have been made to do so. US census statistics indicate the Licking watershed population has grown by 20% in the last two decades. Between Ohio EPA's 1993 and 2008 studies, basin wide municipal WWTP capacity has increased by 26%. Currently, the combined treatment capacity of all municipal WWTPs is 22.5 million gallons per day (MGD).

Successful planning, financing, construction and operation of municipal WWTPs are fundamental to our quality of life. Since 1993, four new municipal WWTPs have been built in the Licking basin. Three others were extensively upgraded. The additional 5.9 MGD of treatment capacity provided by these facilities is central to a sort of paradox. The ability to treat more wastewater more effectively also implies the alternative ability to more completely degrade the receiving stream.

Permitted stream waste loads are developed with reference to natural low flow conditions which statistically occur over seven consecutive days in a ten year period (Q7, 10). The Q7, 10 flow for the Licking River is 39.4 MGD. With WWTP expansion over the past 15 years, the potential amount of water in the River comprised by treated effluent during critical low flows has increased from 42% to 57%. Thus, perception of water quality is more meaningful when shifts of assimilative capacity are considered.

The very good water quality documented in 1993 occurred following a prior determination of impaired conditions. The status quo was unacceptable and corrective changes were necessary. Communities were motivated to avail themselves to federal grant money offered to obtain compliance with CWA requirements. These incentives were integral to the process which led to the laudable 1993 accomplishment.

Maintaining very good conditions has occurred under different circumstances. While compliance with CWA authorized permits has continued to exert influence, funding mechanisms have been more localized. The need to upgrade treatment capacity has been less tangible. The status quo was acceptable. Recognition that improvements

were nevertheless needed invoked different motivational factors from those felt previously.

Considering the Licking watershed population growth, the array of WWTP infrastructure challenges, and the increased proportion of effluent, continued achievement of very good water quality conditions in 2008 was remarkable.

Aquatic Life Use Attainment Status

Licking River

In 2008, full attainment of the WWH aquatic life use designation was observed at six of seven Licking River sample locations (IBI $\bar{x}$=48.3, MIwb $\bar{x}$=10.5, ICI $\bar{x}$=36.9, n=7). Partial attainment was documented downstream from Dillon Lake (RM 6.2, IBI=40, MIwb=10.5, ICI=22, Figure 1,Table 1). Overall, aquatic performance has remained very good since 1993 (IBI $\bar{x}$=46.3, MIwb $\bar{x}$=9.8, ICI $\bar{x}$=41.3, n=6) when Ohio EPA previously assessed the River. The reach downstream from Dillon Lake was also in partial attainment in 1993 (RM 5.5, IBI=46, MIwb=9.9, ICI=18, Table 17).

Ohio EPA evaluated Dillon Lake in 2008-2009 and in 1991-1992 (1994). Both surveys determined the highly eutrophic lake is prone to stratify with little dissolved oxygen (D.O.) available in a lower layer and a warm upper layer that is conducive to abundant algal growth. The earlier study and continuing anecdotal evidence indicate the recreational capacity of Dillon Lake is significantly reduced due to sedimentation and that this aggregation is beginning to impact the lake's flood prevention capacity.

The dam hypolimnetic discharge results in downstream oxygen depletion and degrades the reach with chronically toxic ammonia concentrations. The disruption in stream bedload transport and pollutant processing diminishes assimilative capacity, lowers water quality, and otherwise expected aquatic life is displaced. The lack of any remedial progress since these conditions were first documented is testament to the complexity of this challenge.

Including Dillon Lake and the impaired reach downstream from it, more than one third of the Licking River is impacted by excessive nutrient loading. The few other instances of Licking River basin water quality departure documented in 2008 are in total less consequential than the degraded condition of the mainstem (Table 2). Addressing this impairment should be prioritized accordingly.

Tributaries

Among 83 sample sites in the Licking watershed (excluding seven mainstem locations), aquatic communities at 73 locations (88%) achieved the relevant biocriteria. Performance at 40 sites (48%) was consistent with exceptional aquatic life use. In particular, nine of ten Rocky Fork sub-basin locations were inhabited by exceptional communities and conditions in the lower reach of Brushy Fork supported a fish assemblage with perfect integrity (IBI=60).

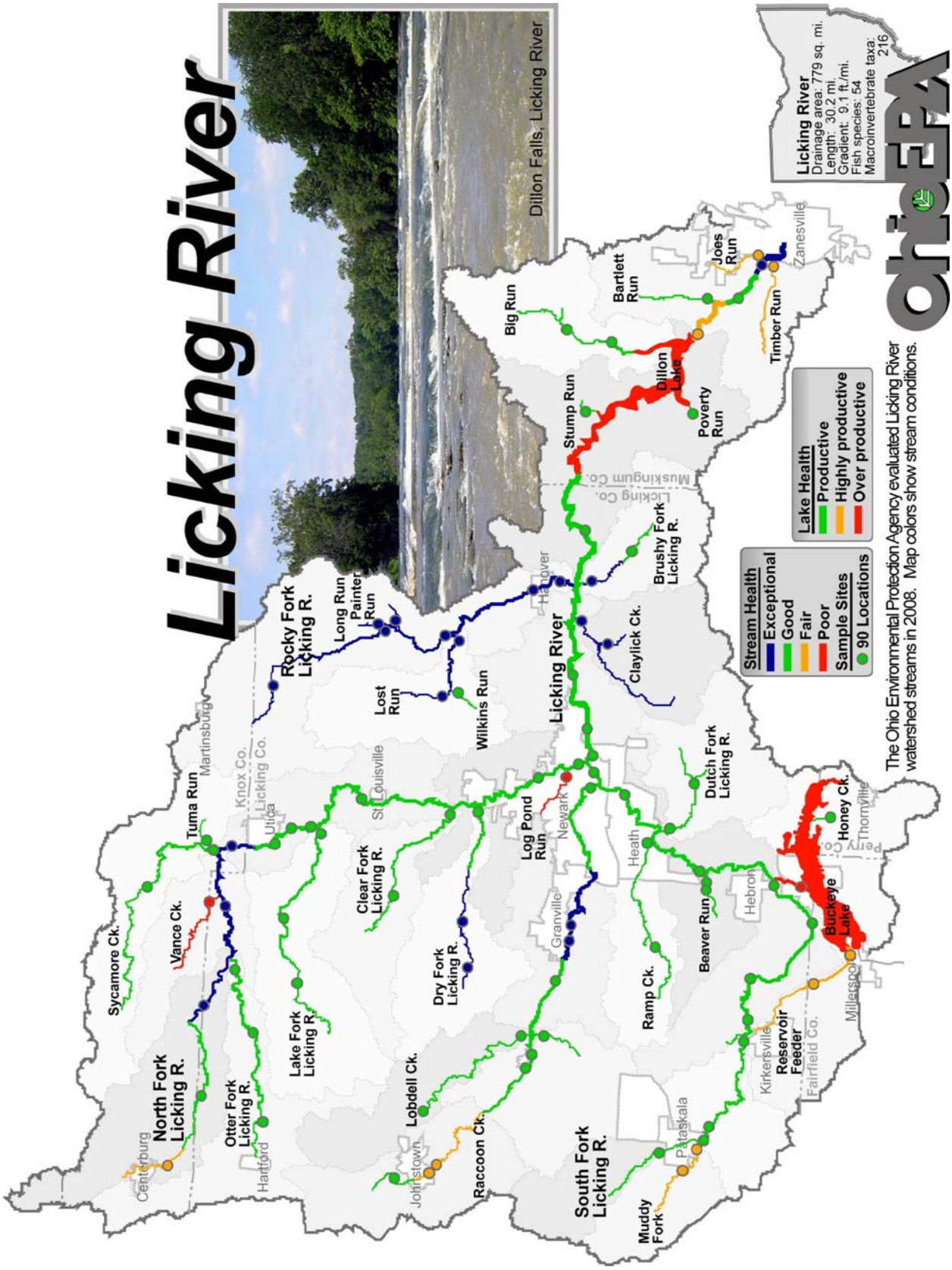

Figure 1. The Licking River basin showing 2008 stream conditions and sample sites.

The North Fork aquatic community reflected exceptional conditions at all but the most upstream location (IBI $\bar{x}$=50.6, MIwb $\bar{x}$=9.8, ICI $\bar{x}$=44.4, n=10). The macroinvertebrate assemblage at the most upstream site (RM 37.9, ICI=Fair) was influenced by an excess nutrient load associated with the Centerburg WWTP.

Vance Creek joins the North Fork upstream from Utica. A poor macroinvertebrate and marginally good fish community (IBI=36) were present at one Vance Creek site (RM 0.7). Intensive agricultural operations were the most plausible stressor related to this departure. Further investigation is warranted.

Log Pond Run was the only other North Fork tributary where biological performance did not attain the biocriterion. This highly modified urban waterway is diverted to a ditch and delivered to Raccoon Creek, instead. Much of what remains drains some of Newark's oldest neighborhoods. It is contained in concrete channels or conveyed underground before joining the North Fork in an industrial area. A poor assemblage of macroinvertebrates was contrasted by very good fish community performance (IBI=48). The hardened watershed offered little assimilative capacity and sporadic severe pollution was a suspected stress. Pioneer fish and those best suited to cold water matched the streams reduced conveyance. Removing trash from the waterway, increasing community stream awareness, and actions to slow and abate polluted runoff are suggested steps toward better water quality in Log Pond Run.

Joes Run drains some of Zanesville's older neighborhoods. Joes Run has better flow volume and more natural presence than was observed in Log Pond Run. These traits helped support an exceptional fish assemblage (IBI=56) but were just sufficient to maintain a fair assemblage of macroinvertebrates. Actions to improve urban stream conditions could improve Joes Run water quality.

Timber Run drains an urban Zanesville area adjacent to I-77. A fair fish community (IBI=36) was at odds with a good macroinvertebrate presence. Overall, the absence of expected species was consistent with exposures associated with wastewater treatment. Additional inquiry is likely to discern the relevant stressor.

Biocriterion departure was observed in Raccoon Creek at sample locations bracketing the Johnstown WWTP. At RM 23.9, a fair fish and a marginally good macroinvertebrate assemblage were less diverse than the community at the next upstream location. Pollution tolerant species were more numerous. The response and exposure values implicated inadequately treated livestock waste as the most likely stressor. Other bacteria sources could also be culpable.

At RM 23.7, downstream from the Johnstown WWTP, the fair macroinvertebrate assemblage was impaired by silty substrates and ample nutrient availability. A further invertebrate diversity decline and increased filamentous algal growth were attributed to overly enriched conditions. A good fish community (IBI=40) benefited from increased flow, as it was modestly richer and more abundant with pollution tolerant species.

Subpar sediment and erosion prevention practices were suspected at a barren development area upstream from this location.

Muddy Fork joins the South Fork upstream from the Pataskala WWTP. A fair macroinvertebrate community at both Muddy Fork sample locations was indicative of limited upstream summer flow combined with excess organic enrichment and unstable downstream substrates. Suburban and agricultural development in the Muddy Fork sub-basin has contributed to dewatering during low flow periods and rapid stream hydrograph peaks.

Buckeye Lake water level is regulated by two structures. Waste Weir Run conveys drainage from one of these outlets and previously received Buckeye Lake WWTP effluent. To keep the Lake at the preferred level, discharge to Waste Weir is minimized. The Buckeye Lake WWTP now discharges to the South Fork.

Macroinvertebrate community performance was poor and the fish assemblage was fair in Waste Weir Run. Anoxic conditions and channelized poor quality habitat precluded better biological response. Allowing more perennial flow through Waste Weir Run could improve stream conditions.

Comprehensive to the 779 mi^2 watershed, the amount of aquatic life use impairment in the 2008 Licking River study area tributaries was minimal and restricted to a small group of disparate incidences. Joes and Timber Runs in Zanesville and Log Pond Run in Newark were impaired by urban development. The North Fork was impacted downstream from the Centerburg WWTP. Vance Creek displayed attributes of intensive agricultural land use. Waste Weir Run reflects Buckeye Lake water quality and lacked flow. Short reaches of Raccoon Creek in Johnstown and of Muddy Creek in Pataskala were influenced by area land use and site specific factors.

Acknowledging that these instances of departure merit remedial attention, the relative absence of any more serious water quality perturbation is an important 2008 study conclusion. Overall, Licking River basin water quality is very good based on aquatic life use attainment status.

Table 1 Attainment status of the existing or ***recommended*** aquatic life uses for the Licking River basin, 2008. See Ohio WQS Table 24-1 (http://www.epa.ohio.gov/dsw/rules/3745_1.aspx#use%20designations) for beneficial use designations. Symbology and ecoregional biocriteria follow.

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
Licking River WWH -EOLP-						
30.1	51/ 10.1	34	FULL	94.0	527.0	Adj. CSO's, Dst. confluence
28.6	51/ 10.4	36	FULL	94.0	531.0	Ust. Newark WWTP, Ref. site
28.2/26.8	45/ 10.4	VG	FULL	96.0	537.0	Dst. Newark WWTP
18.8	51/ 9.9	VG	FULL	87.5	672.0	Toboso Rd., Blackhand area
Licking River WWH -WAP-						
5.8	40/ 10.7	22*	PARTIAL	75.0	742.0	Dst. Dillon Lake
3.6	49/ 11.6	34[ns]	FULL	92.5	753.0	Dillon Falls Rd., Ref. site
1.7	51/ 10.2	46	FULL	74.5	755.0	Dst. Burnham Foundry
North Fork WWH -EOLP-						
37.9	52	Fair*	PARTIAL	78.5	7.2	Dst. Centerburg WWTP
33.8	46	Good	FULL	75.5	16.8	Dutch Cross Rd.
28.9	54/ 10.4	50	FULL	80.5	23.0	Mink St.
23.9	55/ 10.1	Excpt.	FULL	82.0	64.0	Dst. Homer, Ref. site
18.8	52/ 10.2	-	(FULL)	88.5	113.0	Ust. Utica, Kirkpatrick Rd.
17.7	50/ 9.6	42	FULL	83.5	116.0	At Utica, US 62
17.1	51/ 9.2	48	FULL	81.5	117.0	Dst. Utica WWTP
15.5	49/ 10.1	42	FULL	82.5	119.0	Dst. Velvet Ice Cream
11.1	49/ 10.0	52	FULL	86.0	158.0	Ust. St. Louisville, SR 13
2.8	49/ 10.2	48	FULL	87.5	230.0	Water Works Rd.
0.1	48/ 9.1	42	FULL	61.0	241.0	Ohio St.
Otter Fork WWH -EOLP-						
9.3	44	Good	FULL	79.5	14.7	Dst. Hartford WWTP
4.1	44/ 9.3	38	FULL	81.5	26.0	Bennington Chapel Rd.
0.1	50/ 9.2	44	FULL	88.0	28.0	Lock Rd.
Vance Creek WWH -EOLP-						
0.7	36[ns]	Poor*	NON	73.5	9.8	Berger Rd.
Sycamore Creek WWH -EOLP-						
5.9	44	Excpt.	FULL	87.0	13.0	Weaver Rd.
0.1	54/ 9.8	32[ns]	FULL	87.0	30.0	Vance Rd.
Tuma Run WWH -EOLP-						
0.4	52	Good	FULL	83.5	7.6	SR 13
Lake Fork WWH -EOLP-						
7.9	52	42	FULL	66.5	17.8	US 62
4.8	44	42	FULL	64.0	24.0	Bruce Rd.
0.1	53/ 9.6	44	FULL	85.0	34.0	SR 13
Clear Fork WWH -EOLP-						
5.5	54	VG	FULL	84.0	12.1	From Dutch Lane Rd.
0.1	38 [ns]/ 8.0	48	FULL	84.5	22.0	SR 13
Dry Creek WWH -EOLP-						
7.6	54	VG	FULL	77.0	7.8	Dry Creek Rd.

Table 1 continued

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
Dry Creek WWH -EOLP-(continued)						
5.0	58	Excpt.	FULL	67.5	19.0	Dry Creek Rd.
0.4	42/ 8.5	44	FULL	57.0	24.0	SR 13
Log Pond Run WWH -EOLP-						
0.1	48	Poor*	NON	49.5	7.6	Riverside Dr.
South Fork WWH -ECBP-						
31.5	48	38	FULL	79.5	11.4	Cable Rd.
28.3	39/ 8.0	Good	FULL	76.5	30.0	Ust. Pataskala WWTP
27.6	45/ 9.4	32[ns]	FULL	73.5	32.0	Dst. Pataskala WWTP
South Fork WWH -EOLP-						
24.5	47/ 8.9	-	(FULL)	75.5	43.0	Ust. SW Licking WWTP
21.3	51/ 9.6	VG	FULL	67.0	51.0	Dst. SW Licking WWTP
19.1	52/ 9.5	36	FULL	73.5	55.0	US 40
15.3	48/ 8.8	46	FULL	69.5	64.0	Ust. Buckeye Lake WWTP
13.0	-	44	(FULL)	-	69.0	Dst. Buckeye Lake WWTP
8.8	44/ 8.4	38	FULL	63.5	133.0	Dst. Beaver Run, TR 308
1.8	48/ 9.3	44	FULL	80.0	183.0	Dst. Heath WWTP
0.3	46/ 8.2	44	FULL	59.5	288.0	S. Second St.
Muddy Fork WWH -ECBP-						
3.7	44	Fair*	PARTIAL	70.5	6.3	Columbia Rd.
0.1	52	Fair*	PARTIAL	68.0	14.1	Creek Rd.
Reservoir Feeder *MWH Recommended* -EOLP-						
1.9	30	-	(FULL)	41.0	14.8	SR 37
0.5	29/ 6.5	Fair	FULL	36.0	18.0	Millersport Rd.
Waste Weir Run *MWH Recommended* - EOLP -						
1.6	34 /-	Poor*	NON	41.0	NA	SR 79
Honey Creek *WWH Recommended* -EOLP-						
0.8	36[ns]	Good	FULL	59.5	6.6	Honey Ck. Rd.
Beaver Run WWH - EOLP -						
2.1	46	Good	FULL	66.5	5.0	Ust. Hebron WWTP
0.5	44	Good	FULL	51.5	7.4	Dst. Hebron WWTP
Ramp Creek WWH -EOLP-						
5.7	50	Good	FULL	74.0	4.9	Deeds Rd.
0.2	50	Good	FULL	57.0	16.7	SR 79
Dutch Fork WWH -EOLP-						
3.6	52	MG[ns]	FULL	67.5	10.4	SR 13
0.9	46/ 8.4	48	FULL	78.5	21.0	White Chapel Rd.
Raccoon Creek WWH -EOLP-						
26.2	48	Good	FULL	74.5	9.9	Ust. Johnstown, SR 37
23.9	34*	32[ns]	PARTIAL	69.0	12.4	Ust. Johnstown WWTP
23.7	40	24*	PARTIAL	78.0	12.4	Dst. Johnstown WWTP
15.4	49/ 8.6	42	FULL	79.5	37.0	Ust. Alexandria WWTP
15.1	48/ 8.7	34	FULL	78.5	37.0	Dst. Alexandria WWTP
11.7	49/ 8.5	-	(FULL)	60.0	78.0	CR 539

Table 1 continued

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
Raccoon Creek WWH -EOLP-(continued)						
9.2	51/ 8.9	52	FULL	72.0	82.0	Ust. Granville WWTP, SR 37
8.3	52/ 9.3	52	FULL	79.0	86.0	Dst. Granville WWTP
0.5	50/ 9.7	42	FULL	77.0	102.0	Wilson St.
Lobdell Creek WWH -EOLP-						
8.6	44	Good	FULL	51.5	8.3	Nichols Lane
0.2	56	VG	FULL	68.0	18.1	Raccoon Valley Rd.
Moots Run WWH -EOLP-						
0.6	48	Good	FULL	83.5	8.5	SR 161
Claylick Creek *EWH Recommended* - WAP-						
0.1	58/ 10.6	48	FULL	94.5	20.0	Brownsville Rd.
Little Claylick Creek WWH -WAP-						
0.2	58	VG	FULL	70.0	8.9	Colling Rd.
Rocky Fork EWH -EOLP-						
16.0/15.8	50/ 9.3[ns]	50	FULL	84.5	20.0	From Camp Ohio Rd.
Rocky Fork EWH -WAP-						
10.4/10.9	54/ 10.7	46	FULL	88.0	27.0	Rocky Fork Rd.
7.1/ 6.4	47[ns]/ 10.2	Excpt.	FULL	85.5	44.0	Hickman / Jobes Rd.
2.9	55/ 10.2	48	FULL	86.0	74.0	Wolford Rd.
1.3	56/ 10.1	Excpt.	FULL	91.5	78.0	Dst. Hanover WWTP, SR 16
Long Run *EWH Recommended* -WAP-						
0.5	52	46	FULL	86.5	5.8	Baker Rd.
Painter Run *EWH Recommended* -WAP-						
0.3	54	VG[ns]	FULL	84.5	6.2	SR 79
Lost Run WWH -WAP-						
4.1	52	54	FULL	74.0	11.9	Maharg Rd.
0.2	46/ 9.5	46	FULL	96.0	23.0	From Jobes Rd.
Wilkins Run WWH -WAP -						
0.2	50	Good	FULL	75.5	7.5	Wilkins Run Rd.
Brushy Fork WWH -WAP-						
3.1	46	VG	FULL	66.0	13.8	Stonepile Rd.
Brushy Fork *EWH Recommended* -WAP-						
0.1	60	Excpt.	FULL	68.5	18.0	From Brushy Fork Rd.
Stump Run WWH -WAP-						
1.6/ 1.0	50	Good	FULL	68.5	7.9	Shannon Valley Rd./ SR 146
Poverty Run WWH -WAP-						
1.5	48	Good	FULL	59.0	4.4	Pinecrest Rd.
Big Run WWH -WAP-						
5.1	42	Good	FULL	64.0	15.8	From Fawn Rd.
3.3	-	Excpt.	-	-		Creamery Rd.
Bartlett Run WWH -WAP-						
0.4	52	Good	FULL	52.0	9.0	SR 146
Joes Run WWH -WAP-						
0.1	56	Fair*	PARTIAL	56.0	8.6	Old Newark Rd.

Table 1 continued

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
Timber Run WWH -WAP-						
0.3	36*	Good	PARTIAL	54.0	11.7	Licking Rd., CR 414

***** Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
ns Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).
a The MIwb (Modified Index of well-being) is not applicable to headwater sites (<20mi^2). Boat critera *only* apply to all Licking River mainstem sites.
b Narrative evaluation used in lieu of ICI (Excpt=Exceptional; Good; MG=Marginally Good; Fair; Poor; VPoor=Very Poor).
(Full**)** Use attainment status based on one organism group is parenthetically expressed.

Narrative ranges, **WWH** and *MWH* biocriteria for the Licking basin study area ecoregions. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide. For WWH, the ranges of marginally good and nonsignificant departure are the same.

Headwater IBI	Wading IBI	Wading MIwb	Boat IBI	Boat MIwb	ICI	Narrative Evaluation
50-60	50-60	≥9.4	48-60	≥9.6	46-60	Exceptional
46-49	46-49	8.9-9.3	44-47	9.1-9.5	42-44	Very Good
Eastern Corn Belt Plains						
40-45	**40**-45	**8.3**-8.8	**42**-43	**8.5**-9.0	**36**-40	Good
36-39	36-39	7.8-8.2	38-41	8.0-8.4	32-34	Marginally Good
28-35	28-35	5.9-(*6.2*)-7.7	26-37	6.4-7.9	14-(*22*)-30	Fair
Erie-Ontario Lake Plain						
40-45	**38**-45	**7.9**-8.8	**40**-43	**8.7**-9.0	**34**-40	Good
36-39	34-38	7.4-7.8	36-39	8.2-8.6	30-32	Marginally Good
28-35	28-33	5.9-(*6.2*)-7.3	26-35	6.4-8.1	14-(*22*)-28	Fair
Western Allegheny Plateau						
44-45	**44**-45	**8.4**-8.8	**40**-43	**8.6**-9.0	**36**-40	Good
40-43	40-43	7.9-8.3	36-39	8.1-8.5	32-34	Marginally Good
28-39	28-39	5.9-7.8	26-35	6.4-8.0	14-(*22*)-30	Fair
18-(*24*)-27	18-(*24*)-27	4.5-5.8	16-25	5.0-6.3	8-12	Poor
12-17	12-17	0-4.4	12-15	0-4.9	≤6	Very Poor

Table 2 Licking River aquatic life use impairment signatures based on biological sampling conducted during July through October, 2008.

Location / RM	**Stressor** (Source)	**Exposure** (Cause)	**Response** (Evidence)
Licking River RM 5.8	Dillon dam	Ammonia Nutrients	ICI=22*
North Fork RM 37.9	Centerburg WWTP	Ammonia Nutrients	ICI=Fair*
Vance Creek RM 0.7	Agriculture	Ammonia Nutrients D.O.	ICI=Poor* IBI=36^{ns}
Log Pond Run RM 0.1	Urban Runoff Stormsewers	COD	ICI=Poor*
Muddy Fork RM 3.7	Agriculture Yard maintenance Land development	Organic enrichment D.O. Sedimentation	ICI= Fair*
Muddy Fork RM 0.1	Agriculture Yard maintenance Rural residences Land development	Organic enrichment Sedimentation	ICI= Fair*
Waste Weir Run RM 1.6	Buckeye Lake Flow regulation	Ammonia Nutrients	ICI=Poor*
Raccoon Creek RM 23.9	Rural residences Agriculture Land development	Ammonia Nutrients Sedimentation	IBI=34*
Raccoon Creek RM 23.7	Johnstown WWTP Rural residences Agriculture Land development	Ammonia Nutrients Sedimentation	ICI=24*
Joes Run RM 0.1	Urban runoff Storm sewers	Sedimentation	ICI=Fair*
Timber Run RM 0.3	Urban runoff Storm sewers Package plant	Nutrient enrichment	IBI=36*

Recreational Use Attainment Status

Ohio EPA's effort to characterize the risk of human illness associated with the recreational use of State waters has been an iterative process. The adoption of *E. coli* bacteria concentrations as surrogate indicators, sampling strategies, and attainment criteria have been in transition over the past several years. In 2008, nearly all Licking River basin sites were sampled during high flow conditions.

Samples obtained during high flows are useful for developing predictive models aimed at guiding remediation. However, storm runoff also transports soil borne bacteria. The combination of potentially pathogenic and less harmful bacteria usually yields cultures of *E. coli* in excess of recreational use criteria. So, expectation that State waters meet the criteria during high flows is questionable. Furthermore, recreation during high flow conditions is generally dangerous.

The elevated high flow concentrations and the presence of some likely bacteria sources resulted in nearly all of the Licking River basin being impaired for designated recreational uses. Exceptions occurred in the lower North Fork vicinity where abundant groundwater diluted surface flows and in the South Fork where treated WWTP effluent provided similar dilution benefits. Otherwise, all Raccoon Creek and all Rocky Fork locations included samples with bacteria values adequate to establish non-attainment.

Drinking Water Use Attainment Status

City of Newark Water Treatment Plant

The North Fork at the Newark WTP intake is designated for public water supply use. Full use attainment was determined consistent with Ohio Water Quality Standards (WQS) and Ohio EPA Division of Drinking Water use assessment protocols. In addition to Ohio EPA data, atrazine manufacturer Syngenta provided data relevant to Newark's drinking water use assessment.

Newark's treatment process, like most public WTP's, does not remove nitrates. Ohio EPA stream water column data and the Newark WTP finished water data were considered for this exposure assessment. Although the use was in full attainment, ambient summer nitrate concentrations were consistently detected. Winter values are likely to be higher during the dormant period of plant growth. Actions to reduce agricultural runoff and vigilance in sewage treatment can lower the related risk.

RECOMMENDATIONS

A water bodies beneficial uses are fundamental to Ohio's Water Quality Standards (WQS). Table 24-1 specifies waters within the Muskingum watershed and their ascribed uses (http://www.epa.ohio.gov/dsw/rules/3745_1.aspx#use%20designations). Attainment status of those uses and recommended changes are discussed within this document.

Subsequent to the 1993 Ohio EPA Biological and Water Quality Study of the Licking River and Selected Tributaries (1995) nearly all of the named streams in the study area were designated for warmwater habitat (WWH) aquatic life use. Since that study did not evaluate all of the affected streams, some of those designations lacked standard biological assessment support. Thirty-five streams were evaluated for aquatic life use status in 2008 compared to nine in 1993. As a result, this study confirms many existing aquatic life uses for the first time with appropriate biological data.

Honey Creek is presently not included in Ohio WQS Table 24-1. Despite having been historically modified, the stream's current fair habitat quality (QHEI=59.5) supported good biological community performance (IBI=36 and ICI=Good). Demonstrated attainment of WWH aquatic life use criteria confirms this use designation is appropriate for Honey Creek.

Waste Weir Run is presently designated for WWH aquatic life use in Ohio WQS Table 24-1. This designation occurred in concert with a 1984 water quality assessment specific to the performance of the Buckeye Lake WWTP. Since then, the WWTP relocated its discharge to outlet to the South Fork. The 1993 Ohio EPA study evaluated the WWTP influence on the South Fork but did not sample Waste Weir Run.

To develop WWTP permit requirements, it was necessary to designate an aquatic life use for Waste Weir Run. This assignment predated Ohio's 1990 adoption of tiered aquatic life uses. Pragmatically, Waste Weir Run was designated for WWH because it was the default aquatic life use designation.

Ohio incorporated alternative aquatic uses in acknowledgement that some waters exist outside the broad WWH category. Originally hand dug, the artificial Waste Weir Run was constructed to drain the canal reservoir, Buckeye Lake. Now, Waste Weir Run is a rock armored channel that receives little regulated flow. Its carefully maintained low gradient facilitates some permanent water retention, but overall habitat conditions are poor (QHEI=41). Biological index scores from all samples have never surpassed the poor to fair range. Thus, Waste Weir Run exemplifies the need for the modified warmwater habitat (MWH channel modification) aquatic life use designation.

Recommending Waste Weir Run for MWH aquatic life use recognizes the reality that this water way has few features that render it capable of supporting an aquatic community consistent with WWH ecoregional expectations. These conditions have been perpetuated since the drainage was created. Assignment of the MWH use should

not be construed as a “downgrade,” as this use did not exist when the initial designation was made and no degradation has been evidenced since then.

The Reservoir Feeder is not currently listed in Ohio WQS Table 24-1. It was hand dug to route water from the South Fork into Buckeye Lake during the canal era. The South Fork diversion was discontinued with the demise of the canal. However, the Reservoir Feeder also cut off several smaller ditches in route to Buckeye Lake. By directing this flow away from the natural drainage pattern, the Reservoir Feeder became integral within the local network of agricultural drainage. Today, the Feeder is maintained by an ad hoc alliance of vested interests including governmental units and individual property owners. In effect, the area drained by the Reservoir Feeder varies with the persistence of this effort to defy the tendency of some small ditches to revert to former courses.

No longer used to convey the South Fork, the Feeder has ample channel capacity for present use. In places it seems like a wetland because typical flow is inadequate to perform sediment transport or facilitate riffle or pool development. Some reaches are flanked by mature trees and the channel appears as natural as it possibly could be. Other reaches are channelized in a classical manner. The most downstream part of the Reservoir Feeder is impounded by backwater from Buckeye Lake.

The fair performance of aquatic communities was consistent with these poor stream conditions (QHEI $\bar{x}$=39, n=2). Nothing about the Reservoir Feeder suggests any potential to resemble a natural stream capable of sustaining ecoregionally expected aquatic life. Therefore, it is appropriate to recommend that the Reservoir Feeder be designated for MWH (channel modification) aquatic life use.

Four streams currently designated WWH are recommended for exceptional warmwater habitat (EWH) aquatic life use designation. Long and Painter Runs have excellent habitat quality (QHEI=86.5 and QHEI=84.5, respectively). Previously evaluated in 1986 and 1999, exceptional 2008 biological performance established a trend of stable or improving water quality in these subbasins. The lower reach of Brushy Fork had good habitat quality (QHEI=68.5) and the lower reach of Claylick Creek had exceptional habitat quality (QHEI=94.5). While the fish communities at these four locations all met exceptional expectations, the fish community at Brushy Fork (RM 0.01) received a perfect IBI score of 60. This score demonstrates the exceptional integrity of the stream.

The remaining study area streams should retain existing aquatic life use designations. All study area streams should retain the existing recreational and water supply use designations.

Biological and Water Quality Study
of the Licking River
and Selected Tributaries
2008

Licking, Muskingum, Knox, and Fairfield Counties, Ohio

State of Ohio Environmental Protection Agency
Division Of Surface Water
Lazarus Government Center
P.O. Box 1049, Columbus, Ohio 43216-1049

INTRODUCTION

To determine the beneficial use attainment status of streams relevant to Ohio's Water Quality Standards (WQS), ambient biological, water column chemical, sediment, and bacteriological sampling was conducted in the Licking River basin from January to October 2008. This study area included the Licking River from its origin in Newark downstream to its mouth in Zanesville, both North and South Forks from their headwaters to their mainstem forming confluence, and sites on all tributaries with eight mi^2 or larger drainages. The study area encompassed the entire 779 mi^2 Licking River watershed, entailed 90 sample sites, and assessed performance of all National Pollution Discharge Elimination System (NPDES) permitted entities (Table 3 and Figure 2).

Specific objectives of this evaluation were to:

1) Monitor and assess the chemical, physical and biological integrity of the streams within the 2008 Licking River study area;

2) Characterize the consequences of various land uses on water quality within the Licking River watershed;

3) Evaluate the influence of eight large (Table 4) and other small wastewater treatment plants (WWTP's) within the Licking River watershed;

4) Evaluate the potential impacts from industrial (Burnham Metals) and commercial discharges, spills, nonpoint source pollution (NPS), and habitat alterations on the receiving streams; and

5) Determine the attainment status of the current designated beneficial uses and recommend changes where appropriate.

Assessment Units (AUs) based on 12 digit Hydrologic Unit Codes (HUC 12's) were adopted as a framework for sample site selection. Generally, three AU sample sites were desired to facilitate independent comprehensive assessment. The Licking River

was considered independently from the AUs through which it flows. As such, it is one of 23 Large River Assessment Units (LRAUs) in Ohio. Licking River sample sites were situated to bracket potential stressors and to achieve linear continuity.

With 29 HUC 12's (6 HUC 10's) in the Licking River HUC 8 basin (05040006), available sampling resources were balanced to achieve adequate AU assessment and to address other study objectives. Summary data tables relevant to individual AUs are presented based on aggregate HUC 10's. The aquatic life use attainment status of the Licking LRAU is followed by a summary of the attainment status determined for AU tributary streams. Further details are found in subsections following the accepted numerical sequence.

Study Area

The 30.2 mile long Licking River begins at the confluence of the North and South Forks in Newark. The Licking River drains most of Licking County and some of Knox, Fairfield, Perry, and Muskingum Counties (779 mi^2). This area has experienced some modest population growth, increasing by nearly 20%, in the past 20 years (Table 5).

The Licking River joins the Muskingum River in Zanesville. Dillon Lake, a flood control and recreational use impoundment operated by the U.S. Army Corps of Engineers (USACE) and the Ohio Department of Natural Resources (ODNR), is formed by a dam at RM 6.2. Usually, about ten miles of the River are impounded. In flood conditions, the pool can extend more than twenty miles upstream.

The Licking River basin spans three ecoregions (Omernick 1987). The Eastern Corn Belt Plains (ECBP) and the Erie-Ontario Lake Plain (EOLP) are glaciated with rolling topography, modest relief, and mostly agricultural land use. The Western Allegheny Plateau (WAP) is effectively unglaciated with rugged topography, hilly terrain and largely forested land use (Figure 2).

Most Licking River basin streams are designated for WWH aquatic life use. Rocky Fork and Dillon Lake are designated for EWH aquatic life use. The Licking River and lower reaches of the North and South Forks have Primary Contact Recreation Class A use designations. All other basin streams are designated for Primary Contact Recreation Class B use. A public water supply designation exists for the North Fork in the vicinity of the Newark WTP. All study area streams are listed as potential agricultural or industrial water supply sources.

Results

Attainment tables are presented in context with discussion of larger sub-basins. Most streams in the Licking River watershed exhibit very good water quality conditions. Stream habitat conditions were consistent with water quality and appeared to buoy aquatic performance in some reaches that otherwise would have been stressed by nutrient loading. The extraordinary habitat quality of the Licking River in the vicinity of the Newark WWTP was credited for this sort of important assimilative capacity boost. In

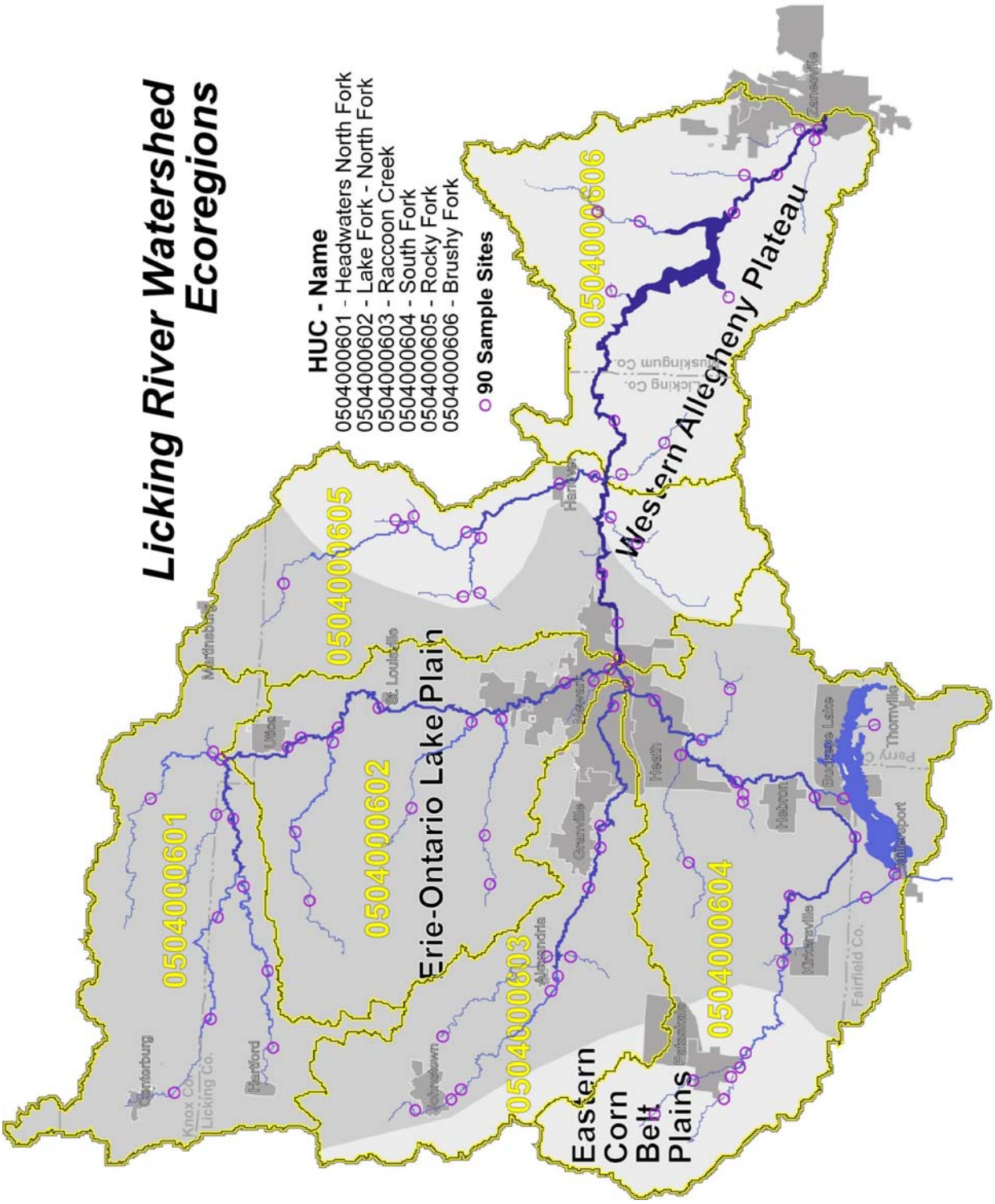

Figure 2 The Licking River watershed with ecoregion and HUC boundaries depicted.

Table 3 Sampling locations in the Licking River study area, 2008

RM	Stream	Location	Latitude	Longitude
30.1	Licking River	Dst. N./ S. Fork confluence	40.0508	-82.3897
28.6	Licking River	Ust. Newark WWTP	40.0524	-82.3645
28.55	Licking River	Newark WWTP Outfall	40.0526	-82.3625
26.8	Licking River	Dst. Newark WWTP	40.0591	-82.3386
18.8	Licking River	Toboso Rd.	40.0569	-82.2201
5.8	Licking River	Dst. Dillon Lake, Dst. dam	39.9912	-82.0815
3.6	Licking River	Dillon Falls Rd.	39.9707	-82.0565
2.0	Licking River	Burnham Foundry Discharge	39.9550	-82.0333
1.7	Licking River	Dst. Burnham Foundry	39.9545	-82.0292
37.91	North Fork Licking River	Dst. Centerburg WWTP	40.2891	-82.6904
33.8	North Fork Licking River	Dutch Cross Rd.	40.2720	-82.6390
28.9	North Fork Licking River	Mink St. / Douglas St.	40.2690	-82.5740
23.9	North Fork Licking River	Dst. Homer, TR 70	40.1428	-82.6936
17.7	North Fork Licking River	Ust. Utica WWTP	40.2298	-82.4553
16.3	North Fork Licking River	Dst. Utica WWTP	40.2180	-82.4415
15.5	North Fork Licking River	Ginger Hill Rd	40.2100	-82.4430
11.2	North Fork Licking River	Ust. St. Louisville, SR 13	40.1789	-82.4206
2.8	North Fork Licking River	Dst. Dam, at Water Works Rd.	40.0869	-82.4107
0.2	North Fork Licking River	Ohio St.	40.0539	-82.3922
9.28	Otter Fork Licking River	Crouse-Willison Rd	40.2400	-82.6600
4.13	Otter Fork Licking River	Bennington Chapel Rd.	40.2450	-82.5870
0.2	Otter Fork Licking River	Lock Rd.	40.2528	-82.5386
0.7	Vance Creek	Berger Rd.	40.2661	-82.4992
5.87	Sycamore Creek	Weaver Rd.	40.3050	-82.4880
0.1	Sycamore Creek	Tuma Run Rd.	40.2628	-82.4575
0.46	Tuma Run	SR 13	40.2690	-82.4500
10.86	Lake Fork Licking River	Shipley Rd.	40.2200	-82.5880
7.95	Lake Fork Licking River	US 62	40.2150	-82.5500
4.77	Lake Fork Licking River	Bruce Rd.	40.2250	-82.5060
0.05	Lake Fork Licking River	SR 13	40.2036	-82.4400
5.5	Clear Fork Licking River	From Dutch Lane Rd.	40.1640	-82.4960
0.13	Clear Fork Licking River	SR 13	40.1289	-82.4289
7.6	Dry Creek	Dry Ck. Rd.	40.1190	-82.5420
4.97	Dry Creek	Dry Ck. Rd.	40.1230	-82.5040
0.4	Dry Creek	SR 13	40.1147	-82.4286
0.1	Log Pond Run	Riverside Dr.	40.0640	-82.4000
31.5	South Fork Licking River	Cable Rd.	40.0244	-82.6889
28.3	South Fork Licking River	Key Blvd., U. Pataskala WWTP	39.9889	-82.6708
28.16	South Fork Licking River	Pataskala WWTP Outfall	39.9871	-82.6693
27.6	South Fork Licking River	Dst. Pataskala WWTP	39.9850	-82.6617
22.4	South Fork Licking River	Dam Pool, Outville Rd.	39.9636	-82.5986
21.65	South Fork Licking River	Dst WWTP's, Gale Rd	39.9627	-82.5797

Table 3 continued

RM	Stream	Location	Latitude	Longitude
21.57	South Fork Licking River	SW Licking WWTP Outfall	39.9623	-82.5860
19.1	South Fork Licking River	Dst. WWTP's, US 40	39.9592	-82.5508
15.3	South Fork Licking River	Ust. Buckeye Lake WWTP	39.9261	-82.5101
14.04	South Fork Licking River	Buckeye Lake WWTP Outfall	39.9364	-82.4944
13	South Fork Licking River	Dst. Buckeye Lake WWTP	39.9482	-82.4807
8.8	South Fork Licking River	Ridgely Tract Rd.	39.9886	-82.4753
2.2	South Fork Licking River	Heath WWTP Outfall	40.0340	-82.4138
1.8	South Fork Licking River	D. Heath WWTP, Hopewell Dr.	40.0375	-82.4131
0.35	South Fork Licking River	2nd St.	40.0507	-82.3968
3.7	Muddy Fork Licking River	Columbia Rd.	40.0110	-82.7170
0.1	Muddy Fork Licking River	Mill St., Dst. Pataskala WTP	39.9906	-82.6728
1.6	Waste Weir Run	Walnut Rd.	39.9275	-82.4883
4.25	Reservoir Feeder	Swamp Rd.	39.9450	-82.5710
0.5	Reservoir Feeder	Ust. Millersport WWTP	39.9070	-82.5340
0.32	Reservoir Feeder	Millersport WWTP Outfall	39.9060	-82.5320
0.3	Reservoir Feeder	Dst. Millersport WWTP	39.9075	-82.5347
0.8	Honey Creek	Honey Ck. Rd.	39.9170	-82.4340
2.05	Beaver Run	Canyon Rd, U. Hebron WWTP	39.9800	-82.5080
0.69	Beaver Run	Hebron WWTP Outfall	39.9846	-82.4856
0.45	Beaver Run	SR 79, Dst. Hebron WWTP	39.9860	-82.4790
3.63	Dutch Fork Licking River	SR 13	39.9950	-82.4050
0.9	Dutch Fork Licking River	TR 306, White Chapel Rd.	40.0020	-82.4410
5.73	Ramp Creek	Deeds Rd.	40.0090	-82.5360
0.2	Ramp Creek	Dst. Industries, SR 79	40.0186	-82.4503
26.2	Raccoon Creek	SR 37	40.1633	-82.6944
23.9	Raccoon Creek	Ust Johnstown WWTP	40.1428	-82.6936
23.7	Raccoon Creek	Dst. Johnstown WWTP	40.1408	-82.6919
15.9	Raccoon Creek	Ust. Alexandria WWTP	40.0850	-82.6150
15.12	Raccoon Creek	Dst. Alexandria WWTP, SR 37	40.0850	-82.6050
11.7	Raccoon Creek	CR 539A	40.0689	-82.5517
9.2	Raccoon Creek	Ust. Granville WWTP, SR 661	40.0622	-82.5208
9.04	Raccoon Creek	Granville WWTP Outfall	40.0620	-82.5180
7.86	Raccoon Creek	Dst. Granville WWTP, SR 37	40.0580	-82.5020
0.6	Raccoon Creek	Wilson St.	40.0533	-82.4117
0.55	Moots Run	Dst. SR 161	40.0764	-82.5933
0.2	Salt Run	Weaver Drive	40.0620	-82.5270
8.7	Lobdell Creek	Nicholas Lane	40.1478	-82.6517
0.2	Lobdell Creek	Raccoon Valley Rd.	40.0868	-82.5921
0.1	Claylick Creek	Brownsville Rd.	40.0580	-82.2880
0.17	Little Claylick Creek	TR 363, Colling Rd.	40.0450	-82.3060
15.77	Rocky Fork Licking River	Purity Rd.	40.2297	-82.3389
10.95	Rocky Fork Licking River	Camp Falling Rock, Access Rd.	40.1697	-82.2983
6.4	Rocky Fork Licking River	Ust. Lost Run, Jobes Rd.	40.1290	-82.2980

Table 3 continued

RM	Stream	Location	Latitude	Longitude
2.9	Rocky Fork Licking River	Wolford Rd.	40.0906	-82.2725
1.34	Rocky Fork Licking River	Marne Rd.	40.0725	-82.2595
0.5	Long Run	Baker Rd.	40.1725	-82.2922
0.3	Painter Run	SR 79	40.1589	-82.2931
4.1	Lost Run	Maharg Rd.	40.1444	-82.3428
0.2	Lost Run	From Jobes Rd.	40.1269	-82.3003
0.15	Wilkins Run	Wilkins Run Rd.	40.1290	-82.3400
3.14	Brushy Fork Licking River	Stonepile Rd.	40.0290	-82.2420
0.9	Brushy Fork Licking River	From Brushy Fork Rd.	40.0480	-82.2610
1.02	Stump Run	SR 146	40.0540	-82.1360
1.47	Poverty Run	Pinecrest Dr.	39.9930	-82.1370
5.1	Big Run	Fawn Dr.	40.0606	-82.0789
3.28	Big Run	Creamery Rd.	40.0390	-82.0860
0.44	Bartlett Run	SR 146	39.9840	-82.0530
0.2	Joes Run	Old Newark Rd.	39.9540	-82.0230
0.1	Timber Run	Licking Rd.	39.9472	-82.0264

Table 4 Design flows (MGD) of municipal WWTP's in the Licking study area, 1993 – 2008. Effluent sampling occurred in 2008 at those in ***bold, italics***.

WWTP	Design Flow 2008 / 1993		Discharge to	RM	Note
Newark	8.0	8.0	Licking River	28.55	Advanced functions
Centerburg	0.2	0.2	North Fork	38.08	Inadequate treatment
Utica	0.42	1.6	North Fork	17.14	Storm water challenged
Hartford	0.06	NA	Otter Fork Tributary	1.08	Began operation in 2006
Pataskala	1.1	0.8	South Fork	28.16	Storm water challenged
Kirkersville	0.1	0.1	South Fork	21.82	Adequate
SW Licking Com.	4.3	NA	South Fork	21.57	Began operation in 1994
Buckeye Lake	2.0	1.1	South Fork	14.04	Upgraded in 2008
Heath	1.75	1.75	South Fork	2.2	Inoperable sand filter
Millersport	0.3	0.3	Reservoir Feeder	0.32	Storm water challenged
Thornville	0.4	0.1	Honey Creek	2.55	Storm water challenged
Hebron	1.5	0.675	Beaver Run	0.69	Upgraded in 2006
Johnstown	1.2	0.75	Raccoon Creek	23.8	Upgraded in 2006
Alexandria	0.08	NA	Raccoon Creek	15.3	Began operation in 2005
Granville	0.9	1.2	Raccoon Creek	9.04	Adequate
Hanover	0.16	NA	Rocky Fork	1.65	Began operation in 2007

Table 5 Census data for selected counties in the Licking study area, 1980 - 2009.

	County Populations		
Year	**Licking**	**Knox**	**Muskingum**
1980	120,981	46,304	83,340
1990	128,300	47,473	82,068
2000	145,491	54,500	84,585
2009	158,488	59,637	84,884
Growth since 1990	30,188	12,164	2,816
Percent of 2009	19%	20%	3%

the Newark WWTP was credited for this sort of important assimilative capacity boost. In the historically channelized South Fork, habitat improvements attributed to natural attenuation appeared to offset concurrent increases in WWTP effluent loads.

Effectiveness of WWTP operations was specifically assessed at eight municipal facilities (Table 4, noted in bold, italics) and at the Burnham Corporation (Tables 11 and 12). Effluent samples from these entities were considered for permit compliance and possible relation to ambient water quality criteria exceedences (Table 6). No water quality impairment was attributed to any of the treatment works targeted by this sampling.

Inadequate treatment at the Centerburg WWTP was culpable for non attainment in the upper reach of the North Fork. The Village is following a compliance schedule to eliminate storm sewer overflow events and to implement facility upgrades. These actions are anticipated to alleviate the impairment documented in 2008.

Depressed D.O. concentrations occurred at six of the 91 chemical sampling locations (Table 6). Low D.O. availability and the associated nutrient enrichment exposure produced non-attainment in Vance Creek. Located in a rural area crossing the Knox – Licking County border, west from Utica, agricultural land use was the most apparent stressor. The low D.O. values recorded at five other Licking River basin locations were due to low stream flows, related reduced reaeration potential, and assimilative function overloads. The most upstream Lake and Muddy Fork locations became completely dry

Table 6 Exceedences and violations of aquatic life use criteria (OAC 3745-1) for chemical water quality parameters (mg/l) in the Licking River study area, June - August, 2008.

Stream	**RM**	**Parameter**	**Infraction**
Lake Fork	10.86	D.O. (2.80, 1.76)	Less than minimum criterion
Vance Creek	0.70	D.O. (3.80, 2.07)	Violation of minimum criterion
Lobdell Creek	0.20	D.O. (2.52, 1.50)	Less than minimum criterion
Reservoir Feeder	0.48	D.O. (3.15, 3.50)	Violation of minimum criterion
Muddy Fork	3.70	D.O. (3.67, 3.99)	Less than minimum criterion
Waste Weir Run	1.55	D.O. (1.38, 2.78)	Violation of minimum criterion

by late summer. Although the low Lake and Muddy Fork D.O. concentrations were less than the WWH minimum criterion (4.0 mg/l), the samples were obtained from separated pools in absence of interstitial flow and were thus technically outside the criteria's scope. Similarly, low D.O. presence was only detected in Lobdell Creek when it was devoid of surface flow. Subsurface flow frequently occurs where tributary streams meet the glacial outwash filled valley of a receiving stream. Low D.O. concentrations measured in the Reservoir Feeder and Waste Weir Run were due to algal respiration. These artificial channels at opposite ends of Buckeye Lake were also flow limited. The D.O. exposure was most stressful to the Waste Weir Run aquatic community which failed to achieve relevant biocriteria.

A subset of 11 "sentinel" sites was selected for more frequent water column chemical assessment. Whereas five chemical samples were typically obtained, June - August, 2008; the sentinel sites were sampled 12 to 15 times, January - September, 2008. Flow measurements and the additional chemical data from these locations facilitate modeling for load calculations and pollutant reduction strategies. The presence of organic constituents including volatile and semi-volatile compounds, PCBs and pesticides was evaluated at sentinel sites (Table 7). Generally, detected organic constituent concentrations were less than values which merit actionable concern.

Table 7 Water column organic chemical concentrations (µg/l) at selected Licking River study area sites, June 2008.

Stream	RM	acetochlor	atrazine	simazine	metalochlor	B2EHP[1]	3HCF[2]
Licking River	26.75	0.31	1.36	0.28	0.59	0.72	-
Licking River	18.87	0.29	1.22	0.22	0.57	1.00	-
Licking River	6.20	0.68	3.16	0.28	1.28	0.70	-
North Fork	17.70	0.35	2.19	0.33	0.80	0.90	-
North Fork	0.05	0.31	1.80	0.31	0.73	0.76	-
Raccoon Creek	11.70	0.22	0.84	0.22	0.44	0.92	-
Lobdell Creek	0.20	0.38	0.82	-	-	0.78	-
South Fork	22.40	0.52	1.07	-	0.29	1.74	-
South Fork	8.88	0.48	1.02	0.24	0.35	1.32	-
South Fork	0.35	0.32	1.05	0.25	0.41	0.74	0.55
Rocky Fork	1.20	-	0.42	-	-	0.91	-

1) bis(2-Ethylhexyl)phthalate: detected in all laboratory blanks, values are estimated.
2) 3-Hydroxycarbofuran: elevated recovery in quality control sample, value is estimated.

Stream sediments were analyzed for metals, organic contamination, and nutrients from 20 Licking River study area sites in 2008 (Tables 8, 9, and 10). Arsenic was detected in excess of the threshold effect concentration (TEC, MacDonald, et.al 2000) at nine locations. None of the detected values exceeded the probable effect concentration (PEC) and no impairment or other variables were correlated. The proximity of population centers with the nominal arsenic concentrations might be co-occurrences. Other metal concentrations were consistent with typical survey results.

Pentachlorophenol, an organochlorine compound most commonly used to preserve wood, was detected in sediment from Racoon Creek (RM 15.35) upstream from the Alexandria WWTP and from the South Fork (RM 21.24) downstream from the Southwest Licking Community Water and Sewer District WWTP. Telephone poles, guardrail posts and treated lumber used in bridge construction are plausible sources.

Table 8 Sediment metal concentrations (mg/kg dry weight) measured above screening guidance at selected Licking River study area sites, 2008. Sediment Reference Values (SRV) are Statewide (Hg, Pb) or ecoregional background concentrations (OEPA 2008). Results less than Threshold Effect Concentrations (TEC) are unlikely to be harmful (MacDonald, et.al 2000). No results exceeded the Probable Effect Concentration (PEC).

Stream/Guidance	RM	As	Cu	Hg[1]	Ni	Pb
SRV (EOLP)		25	32	0.12	33	47
TEC		9.8	31.6	--	22.7	35.8
Licking River	30.10			BRL		
Licking River	28.65	10.1	43.4	BRL		
Licking River	26.75			(0.026, RL=0.022)		
North Fork	2.82	10.0		BRL		
North Fork	0.05			BRL		
Raccoon Creek	15.35	14.9		(0.062, RL=0.042)	24.1	
Raccoon Creek	15.12	12.7		(0.037, RL=0.025)		
Raccoon Creek	9.18			(0.027, RL=0.024)		
Raccoon Creek	8.25			(0.031, RL=0.025)		
Raccoon Creek	0.54	12.9		BRL		
Moots Run	0.55	12.8		(0.031, RL=0.025)		
South Fork	22.38	11.0		(0.044, RL=0.035)		
South Fork	21.24	11.2		(0.033, RL=0.030)		
South Fork	19.10	11.2		BRL		
South Fork	15.75			BRL		
South Fork	12.96			(0.036, RL=0.029)		
South Fork	8.88			BRL		49.8
South Fork	1.80			BRL		
South Fork	0.35			not tested		
Rocky Fork	1.20			BRL.		

1) BRL: Below Reporting Limit; RL: Reporting Limit

Table 9 Sediment organic compound concentrations (mg/kg dry weight) measured above screening guidance at selected Licking River study area sites, 2008. Results less than Threshold Effect Concentrations (TEC) are unlikely to be harmful (MacDonald, et.al 2000). No results exceeded the Probable Effect Concentration (PEC).

Stream	RM	Organic compound	mg/kg	TEC
Raccoon Creek	15.35	Pentachlorophenol	1.72	NA
South Fork	21.24	Pentachlorophenol	1.02	NA
South Fork	8.88	Benz[a]antracene	0.74	0.11
		Benzo[a]pyrene	0.62	0.15
		Chrysene	0.69	0.17
		Fluoranthene	1.38	0.42
		Phenanthrene	0.98	0.20
		Pyrene	1.07	0.20
		Total PAH's	5.48	1.61
Licking River	28.65	PCB 1242	43.6	
		PCB 1254	163.0	
		PCB	47.7	
		Total PCB's	254.3	0.06
		Fluoranthene	0.91	0.42
		Phenanthrene	0.67	0.20
		Pyrene	0.70	0.20
		Total PAH's	2.28	1.61

The detected concentrations were not associated with any water quality issue.

A group of PAH's were detected in sediment at the Ridgley Tract South Fork (RM 8.88) location. As discussed in the Beaver Run – South Fork AU section, sediment degradation in this area was linked to minor aquatic community declines. The presence of detectable PAH's in rather small concentrations confirms the abundance of fine silty material necessary for sediment testing as much as the concentrations represent an item of interest. In this case, the contamination is less concerning than the quantity of sediment. Efforts to restore riparian vegetation and reduce stream bank erosion are prudent.

An array of PCB's and PAH's were among sediments in the Licking River (RM 28.65) reach downstream from Newark. An abandoned landfill nearby, a forgotten spill, or some historical industrial activity are suspect sources for this residual cocktail of detected compounds. Alternatively, the absence of detected compounds at 16 locations is another way of appreciating the quality of the Licking River study area. The

Table 10 Sediment Percent Total Organic Carbon (% T.O.C.) and Total Phosphorous (T-P) concentrations (mg/kg dry weight) at selected Licking River study area sites, 2008.

Stream	RM	%T.O.C.	T-P
Licking River	30.10	1.6	291
Licking River	28.65	1.9	198
Licking River	26.75	2.0	527
North Fork	2.82	1.8	304
North Fork	0.05	1.9	not tested
Raccoon Creek	15.35	1.9	485
Raccoon Creek	15.12	1.5	not tested
Raccoon Creek	9.18	1.2	not tested
Raccoon Creek	8.25	1.7	287
Raccoon Creek	0.54	1.6	47
Moots Run	0.55	1.7	317
South Fork	22.38	2.1	339
South Fork	21.24	1.6	not tested
South Fork	19.10	1.8	539
South Fork	15.75	1.4	474
South Fork	12.96	1.5	374
South Fork	8.88	1.9	198
South Fork	1.80	1.8	199
South Fork	0.35	1.7	not tested
Rocky Fork	1.20	0.8	200

sensitivity of these analytical tests often reveals traces of human activity decades in the past. The lack of detection at so many sites is a positive outcome.

LICKING RIVER, BRUSHY FORK AND MUSKINGUM COUNTY TRIBUTARIES

Chemical water quality sampling in the Licking River, Brushy Fork and Muskingum Co. tributaries showed no violations of chemical water quality standards. Biological indicators also revealed little impairment with all sites showing at least partial attainment. The only site on the Licking River in partial attainment was directly downstream from the Dillon Lake dam and impoundment. Dillon Lake dam is a hypolimnetic release dam. Fish community scores attained WWH standards while macroinvertebrate community scores did not (Table 17). Macroinvertebrate community performance is often degraded by hypolimnetic discharge (Table 18). Nutrient enrichment and chronic ammonia concentrations were in evidence downstream from Dillon Lake (Figure 3) and likely the cause of the invertebrate non-attainment.

The other sites in partial attainment were found on Joes Run and Timber Run. Both are small tributaries in the Zanesville area (Table 19). Widely varying flow (due to hardening of the drainage area from development) has initiated changes to the stream bed and banks causing erosion and embedded substrates sufficient to inhibit the Joes Run macroinvertebrate community. Nutrient enrichment influenced the Timber Run macroinvertebrate community (Table 20).

Bacteriological sampling in this area revealed several areas that do not attain current recreational use criteria (Table 13). Sources include animal agriculture and manure management in addition to home sewage treatment systems. The majority of the Licking River mainstem (and Dillon Lake) is designated Class A recreational use. Only 2 sites in this commonly paddled reach failed to attain recreational uses.

Trend analysis showed close similarities between most 2008 chemical results compared with those found in 1993. D.O. values typified this result (Figure 3).

Sediment sampling and analysis revealed little in the way of contamination (other than insignificant elevated concentrations of metals) at six of the seven sites on the Licking River mainstem and Timber Run. Only the site at RM 28.65 on the Licking River showed contamination from PAHs and PCBs (Table 9). However, the contamination from these materials was minor and had no effect on biological attainment in this area. The source(s) of these organic contaminants could possibly be the old Newark landfill or from a minor historical spill. However, the specific source may never be known for certain and the amounts of these materials found in the sediments are not causing noticeable impairment.

City of Newark WWTP

The WWTP is located at 1003 East Main Street and discharges to the Licking River at RM 28.55. Design flow is 8.0 MGD. Treatment plant processes and/or equipment include: bar screens, grit and scum removal, flow equalization, primary settling, activated sludge aeration, biological nitrification and BOD removal, biological phosphorus removal, secondary clarification and ultraviolet disinfection. Sludge is

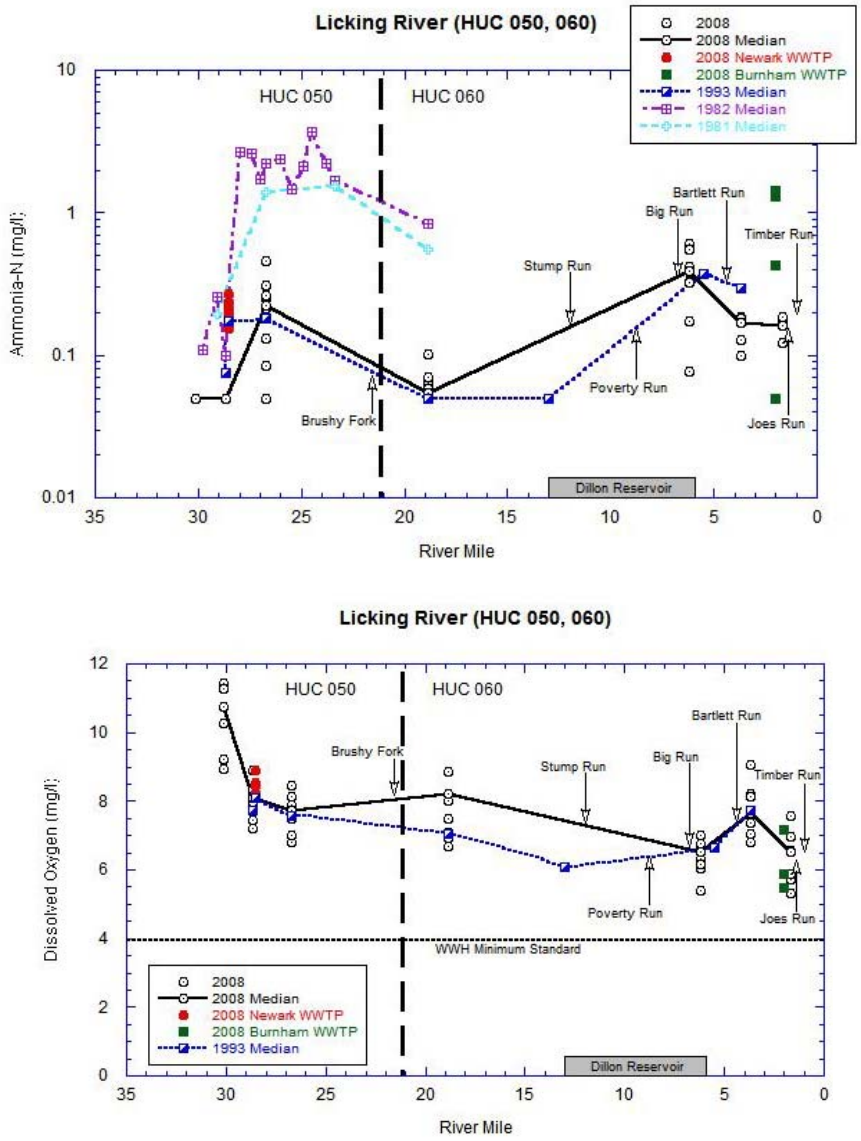

Figure 3 Longitudinal summary of median concentrations of ammonia-N and D.O. in the Licking River, 1981 – 2008.

processed by gravity belt thickening, followed by anaerobic digestion and belt filter presses. Dewatered sludge is currently disposed of at a solid waste landfill.

The City of Newark's collection system includes both combined sanitary and storm sewers and separate sanitary sewers. The combined sewer overflows (CSOs) in the combined collection system may discharge wastewater to the North Fork Licking River, the South Fork Licking River, Raccoon Creek, and the Licking River during periods of wet weather. In addition the treatment plant has two bypasses which may discharge during wet weather; one which bypasses raw sewage and the second which bypasses settled sewage. To minimize inflow and infiltration into the sanitary sewer collection

system the city is implementing a CSO Long Term Control Plan (LTCP) which includes construction of a high-rate treatment facility adjacent to the WWTP.

The wastewater discharge permit contains an extensive compliance schedule for improvements. There have been very few instances of noncompliance at this WWTP in recent history.

Newark City Landfill
This old, inactive landfill is located on Watson Rd., 0.5 miles east from Blue Jay Rd. in Newark and discharges to an unnamed tributary which confluences with the Licking River at approximately RM 29.6. The wastewater discharge permit compliance schedule for this landfill requires the city to develop and implement a plan that will account for any wastewater discharges from the landfill.

Burnham Corporation
Burnham Corporation is a foundry that manufactures gray and ductile iron castings, including manifolds, boilers, and radiators, using various casting and molding techniques. The process operations at Burnham are classified under the Standard Industrial Classification (SIC) Code 3321, "Gray Iron Foundries." The Federal Effluent Guidelines found in Metal Molding and Casting Point Source Category (40 CFR 464) apply to the process wastewaters generated at this facility. The 2008 NPDES permit renewal application indicates that Burnham manufacturers 400,000 pounds (200 tons) per day. This rate of production is the same that was used to develop limits for the previous permit renewal. Water is supplied to the Burnham Foundry from the City of Zanesville, wells operated by the company and an intake on the Licking River. The river water intake is used for cooling purposes and then discharged through outfall 002. City water is used for sanitary purposes such as restrooms, showers, and drinking water, and discharged at outfall 003.

Table 11 shows the external discharges or outfalls, the types of plant operations associated with each outfall, the treatment systems used to treat the wastewater generated by each source, and the average amount of wastewater discharged through each outfall. All of the outfalls discharge directly to the Licking River. The average flow for each outfall was obtained from the NPDES permit renewal application.

The process wastewaters from the Burnham facility flow into an influent wet well prior to discharge into the equalization (EQ) tank. Oil is skimmed from the EQ tank and then a polymer and caustic chemicals are added to the wastewater to promote coagulation. The wastewater flows into a clarifier from the EQ tank where solids are settled out. The solids are sent to sludge storage, and then to a filter press prior to transport to an appropriate landfill. The wastewater from the clarifier is adjusted for pH before being discharged to the Licking River through outfall 005.

Monitoring data reported by Burnham Foundry since January 2004 shows that most of the violations have been associated with outfall 005. The majority of the total phenolics violations were reported in 2004 and 2005 while the total suspended solids violations

Table 11 Summary of Burnham Corporation Outfalls to the Licking River.

Type of Wastewater	Treatment System	Discharge Point	Average Discharge (MGD)
Outfall 001			
Air compressor cooling	Sedimentation	Licking River	0.383
Airset cooler classifier			
Roof areas			
Heat exchanger water			
Other cooling water			
Outfall 002			
Cupola control panel, furnace, and cooling	Sedimentation	Licking River	0.338
Roof area			
Outfall 003			
Sanitary wastewater	Sedimentation, disinfection	Licking River	0.003
Outfall 004			
Air compressor cooling/cistern overflow	None	Licking River	0.079
Outfall 005			
BMP tanks 1, 2, & 3 drains	Sedimentation, Pressure filtration, Coagulation	Licking River	0.035
Coke bin drainage			
Sludge press filtrate			
Pressure test benches			
Scrap pad drain			
Slag quench tank overflow			

were more scattered throughout the five-year period. Table 12 presents a summary of violations

Polk Scrap Metal

Polk Scrap Metal is a typical scrap metal recycling operation that has been in business since the 1950s. Historically, stormwater runoff has carried pollutants such as metals into Timber Run. Construction of stormwater retention structures was completed in July, 2009 in an attempt to eliminate discharge of metals-contaminated water off site.

This series of storm water retention structures was constructed to capture contaminants from surface water runoff. The two ponds were designed to handle flows of 1,185 gallons per minute allowing for adequate settling time and volume. Both ponds have a working depth of 9.5 feet. If 9.5 feet is reached in the first pond, water flows through a 12 inch pipe into the second pond. If a depth of 10.5 feet is reached in the second pond, the water exits via an emergency spillway. The first and second ponds have side slopes of 20 feet with a 2:1 ratio. The bottoms of Pond 1 and Pond 2 measure 79.5 feet by 22 feet and 64 feet by 22 feet respectively and will remain wet. Clean pond water

Table 12 Violations of NPDES permit limits for Burnham Corporation from January 2004 until December 2008.

Parameter	Type of Violation	Frequency of Violations
Outfall 003		
Fecal coliform bacteria		1
Total suspended solids	Concentration	4
pH	Minimum	1
Outfall 005		
pH	Minimum	29*
pH	Maximum	13*
Total phenolics	Concentration	9
Total phenolics	Loading	12
*The pH limit excursions at outfall 005 technically may not be violations depending upon the length of time the excursion occurred.		

confirmed by required analysis may be sprayed on facility roadways for dust control. Each pond liner is comprised of 1.5 feet of re-compacted clay. Each pond will receive periodical cleaning via removal of settled materials with the solids disposed at an approved landfill.

The ponds now receive all storm water that comes in contact with active areas of the facility. Stormwater that does not contact areas of industrial activity is routed off site using diversion ditches. Additionally, best management practices have been adopted for the scrap operations at Polk to minimize movement of contaminants into the ponds.

Dillon Lake

Dillon Lake is a 1,560 acre flood control impoundment formed by the construction of a dam on the Licking River. There are 27 miles of shoreline. The USACE completed the dam in 1961. Maximum depth is about 24 feet. Normal summer pool elevation is 737 feet above sea level.

While Dillon Lake is within the Western Allegheny Plateau ecoregion the majority of the watershed contributing to Dillon Lake is within the Eastern Corn Belt Plains and the Erie-Ontario Lake Plain. The watershed above the dam is 748 mi^2. The large watershed size to lake volume results in rapid water movement through the reservoir. On an average annual basis the water in the lake is replaced every 9.7 days.

During the summer season the lake stratifies into distinct layers of different water quality. In general the upper layer is warm and oxygen rich while lower layer is much cooler and there is little oxygen to support fish below about 14 feet. This stratification was broken down by weather conditions in the latter part of August 2008.

Ohio EPA has implemented a sampling strategy that focuses on evaluating the water quality conditions present in the epilimnion of lakes. The sampling target consists of an

Table 13 Licking River, Brushy Fork and Muskingum Co. tributaries recreational use attainment status, May 1-October 31, 2008. All values are expressed as *E. coli* colony forming units per 100 ml of water (cfu/100ml).

RM	N	gm$\bar{x}$	Max.	STATUS	Location
Licking River *PCR Class A*					
30.10	6	103	290	FULL	Dst. North / South Fork confluence
28.65	6	96	480	FULL	Ust. Newark WWTP
26.75	11	260	32000	NON	Stadden Rd.
18.87	8	59	140	FULL	Toboso Rd.
6.20	8	19	260	FULL	Dst Dillon Lake
3.68	7	141	1300	NON	Dillon Falls Rd.
1.70	7	92	260	FULL	Dst Burnham Corporation
Brushy Fork *PCR Class B*					
3.14	5	599	730	NON	Stonepile Rd.
0.9	5	263	580	NON	Ust. Licking River confluence
Stump Run *PCR Class B*					
1.02	5	471	1300	NON	SR 146
Poverty Run *PCR Class B*					
1.47	4	50	130	FULL	Pinecrest Rd.
Big Run *PCR Class B*					
5.1	5	771	1700	NON	Fawn Dr.
3.28	5	515	940	NON	Creamery Rd.
Bartlett Run *PCR Class B*					
0.44	5	548	5800	NON	SR 146
Joes Run *PCR Class B*					
0.2	5	730	9300	NON	Old Newark Rd.
Timber Run *PCR Class B*					
0.1	5	191	470	NON	Licking Rd.

PCR Criteria	gm$\bar{x}$	Max.
Class A	<126	≤298
Class B	<161	≤523

even distribution of a total of ten sampling events divided over a two-year period and collected during the summer months. Key water quality parameters sampled include total phosphorus, total nitrogen, chlorophyll a, secchi depth, ammonia, D.O., pH, total dissolved solids, and various metals such as lead, mercury, and copper.

Sampling was conducted at a station designated L1 in the deepest part of the lake immediately adjacent to the dam. Field measurements of temperature, conductivity, dissolved oxygen and pH were measured in a vertical profile. Clarity was measured with a secchi disc from the surface. Samples for laboratory analysis were collected at one half meter below the surface and one half meter above the bottom. Sediment was collected at L1. Samples were collected for *E.coli* analysis at the L1 station and the beach.

Field measurements were made and water samples were collected for laboratory analysis thirteen times in 2008. One sediment sample was collected. *E. coli* samples for recreation use attainment were collected seven times at the primary sampling location and seven times at the beach in 2008.

Dillon Lake is impaired for the proposed lake habitat aquatic life use due to exceedances of the chlorophyll-a, total nitrogen and D.O. proposed targets. The methodology for assessing the Lake Habitat aquatic life use was described in the 2010 Ohio EPA Integrated Water Quality Monitoring and Assessment Report. Results are presented in Table 14. All base Lake Habitat aquatic life use metal parameters meet their targets (Table 15). The primary contact recreation use *E. coli* standard is met at both L1 and beach locations (Table 16).

Table 14 Dillon Lake proposed Lake Habitat aquatic life use assessment, 2008.

Parameter (Target[1])	**Chlorophyll-a** ($50^{th}\%_{tile}$<6.2 ug/l)	**Total Phosphorus** ($50^{th}\%_{tile}$<14 ug/l)	**Total Nitrogen** ($50^{th}\%_{tile}$<350 ug/l)	**Ammonia** (mg/l, temp. dependent)	**D.O.**[2] 6.0 mg/l OMZA 5.0 mg/l OMZM	**pH** 6.5 s.u.-9.0 s.u.	**TDS** (mg/l)	**Secchi depth** (Transparent to 2.16 m)
5/22/2008	2.2	142	625	0.111	meets	meets	262	0.42
6/3/2008	62.9	195	1180	<	meets	meets	274	0.66
6/10/2008	42.4	134	3920	<	meets	meets	252	0.64
6/16/2008	72.3	136	2020	0.146	meets	meets	280	0.58
6/18/2008	32.4	129	2180	0.091	meets	meets	280	0.53
6/26/2008	56.6	140	2140	<	meets	meets	276	0.84
7/14/2008	89.1	129	1320	<	meets	meets	242	0.75
7/23/2008	48	113	620	<	meets	meets	256	0.81
8/5/2008	47	91	510	<	exceeds	meets	284	0.86
8/12/2008	75	119	600	0.095	exceeds	meets	316	0.88
8/15/2008	19.6	138	390	0.107	exceeds	meets	342	-
8/21/2008	4.2	123	620	0.217	-	meets	354	2.26
8/27/2008	15.3	171	800	0.177	exceeds	meets	374	0.88
$50^{th}\%_{tile}$	47	134	800	-	-	-		0.78
status	***impaired***	***watch***	***watch***	***meets***	***impaired***	***meets***	***meets***	***watch***

1 Proposed Lake Habitat aquatic life use chlorophyll-a, nutrient, and Secchi depth targets have not been enacted into the Ohio WQS. Proposed Lake Habitat aquatic life use D.O. and pH targets replicate values applicable to lakes currently designated within the Ohio WQS.

2 For D.O., OMZM means outside mixing zone minimum and OMZA means outside mixing zone minimum twenty-four-hour average. The D.O. targets apply in the epilimnion of stratified lakes and throughout the water column in unstratified lakes.

Sediment nutrient and metals results were compared with other results from other lake sediment data from the same ecoregions. Ammonia is elevated relative to lakes in the Erie-Ontario Lake Plain and slightly elevated relative to lakes within the Eastern Corn Belt Plains. All other results are non-elevated.

Table 15 Dillon Lake water column metals concentrations (ug/l), 2008. Values are assessed in reference to the proposed Lake Habitat aquatic life use targets.

Date	Arsenic	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
5/22/2008	<	<	<	<	<	2.3	<
6/3/2008	2.3	<	<	<	<	2.5	<
6/10/2008	3.2	<	2.2	5.3	3.5	5.5	15
6/18/2008	2.8	<	<	2.3	<	2.5	<
6/26/2008	2.6	<	<	<	<	2.6	<
7/14/2008	2.2	<	<	<	<	<	<
7/23/2008	2.5	<	<	<	<	<	<
8/5/2008	3.9	<	<	<	<	2.4	<
8/12/2008	4.9	<	<	<	<	2.4	<
8/15/2008	4.9	<	<	<	<	2.2	<
8/21/2008	5.1	<	<	<	<	2.3	<
8/27/2008	6.1	<	<	<	<	2.8	<
status	***meets***	***meets***	***meets***	***meets***	***meets***	***meets***	***meets***

Table 16 Dillon Lake recreational use attainment status, May 1-October 31, 2008. All values are expressed as *E. coli* colony forming units per 100 ml of water (cfu/100ml).

Date	L1	Beach
5/22/2008	<	
6/18/2008		230
6/26/2008		
7/14/2008	10	690
7/23/2008	<10	<10
8/5/2008	<10	10
8/12/2008	<10	<10
8/15/2008		
8/21/2008	<10	<10
8/27/2008	<10	<10
Geometric mean	**5**	**16**
status	***meets***	***meets***

Recreational Use Criteria	gm$\bar{x}$	Max.
PCR Class A and Bathing waters	<126	≤298

HUC 05040006 9001 Licking River Large River Assessment Unit

Formed by the confluence of the North and South Forks, the Licking River is 30.2 miles long. Beginning at Dillon dam (RM 6.2), Dillon Lake is capable of extending upstream to RM 28.8, a few tenths above the Newark WWTP. Under normal summer flow, slack water conditions are present at RM 16.2. Essentially, one third or more of the Licking River is more accurately Dillon Lake.

In 2008, Ohio EPA evaluated Licking River water quality upstream from Dillon Lake at four locations and downstream at three locations. The most upstream site (RM 30.1) was in proximity to Newark CSO's and storm sewers. The next two sites (RMs 28.6 – 28.2) bracketed the Newark WWTP, while the other upstream site (RM 18.8) was downstream from the Blackhand gorge in the Toboso area.

Stream habitat conditions in the upper reach were extraordinary (QHEI $\bar{x}$=92.9). Outwash cobbles and mixed aggregates provide generous interstitial voids for macroinvertebrate colonization. Strong base flows spread over washed riffles, constricted in swift runs and stilled in scoured pools offered, in multiple combinations with snags of woody debris and boulders, a plethora of highly functional cover. The riparian corridor was surprisingly intact. Few Ohio metropolitan streams are flanked by so much wooded property.

Biological community performance in the upper reach was exceptional to very good (IBI $\bar{x}$=49.5, MIwb $\bar{x}$=10.2, ICI $\bar{x}$=VG). The nutrient pulse downstream from the Newark WWTP was evident but both fish and macroinvertebrates were more responsive to gravel outwash substrates and flows. Macroinvertebrate diversity increased with drainage area. Intolerant and piscivorous fish species were limited or modestly abundant at all upper reach sites. Pollution sensitive redhorse species predominated this area.

Ammonia-N was routinely detected downstream from the Newark WWTP ($\bar{x}$=0.24 mg/l, n=10) but went undetected upstream (n=10). Ambient nutrient concentrations more than doubled downstream from the facility (NO_2+NO_3-N $\bar{x}$=2.1 mg/l, TP $\bar{x}$=1.2 mg/l). Effluent samples confirmed the WWTP discharge contains extremely high nutrient concentrations (NO_2+NO_3-N $\bar{x}$=16.1 mg/l, TP $\bar{x}$=22.2 mg/l, n=5). The fact that aquatic life use attainment was compatible with this load can best be attributed to the assimilative capacity of the outstanding habitat.

Downstream from Dillon dam (RM 5.8), the 2008 macroinvertebrate community continued to underperform as documented in 1993 (OEPA 1995). This symptom of water quality degradation has been unmitigated for more than 15 years.

The assessment of conditions downstream from Dillon dam provided in the previous report remains cogent and applicable today. Pollution sensitive EPT macroinvertebrate taxa were reduced to half (8) the number present at upstream locations (16.3, n=4). With 11 and 16 EPT taxa at the next consecutive downstream sites, the Licking River never fully recovers from Dillon Lake water quality degradation. Total

macroinvertebrate taxa richness mimics the same trend. At the four upstream smaller drainage locations, an average of 66.3 aquatic invertebrate types were present compared to an average of 51 taxa at the three downstream sites. Tolerant midges were numerous at downstream sites but total invertebrate abundance was noticeably lower.

The fish community mirrored the macroinvertebrate declines. The exceptional upstream performance was reduced to just meeting the WWH IBI criterion downstream from Dillon dam. Redhorse abundance scored low in both dam influenced samples. Simple lithophils require clean well washed substrates to spawn over. These fish were well represented and scored highly upstream from the dam. Downstream fish assemblages scored low or moderate for this metric. Instead, fish community scores in the lower reach were improved by more piscivorous species including stocked saugeye and white x striped bass hybrids. These and some large flathead and channel catfish bolstered both IBI and MIwb scores at the downstream sites. The additional presence of some unique species (mooneye, warmouth sunfish, slenderhead darter, gravel and bigeye chubs), most likely migrating from the Muskingum River, further improved downstream fish diversity. Incidentally, in addition to those fish, both smallmouth and river redhorse, smallmouth buffalo, bowfin and longnose gar were present downstream from Dillon dam but not upstream.

Ammonia-N was detected in all downstream water column samples. The macroinvertebrate community is most sensitive to this chronic toxicity (NH_3-N $\bar{x}$=0.42 mg/l, n=8 at RM 6.1; NH_3-N $\bar{x}$=0.15 mg/l, n=5 at RM 3.6; NH_3-N $\bar{x}$=0.16 mg/l, n=5 at RM 1.7). Water temperature downstream from Dillon dam is higher than anywhere else in the Licking River basin. At the four upstream sites water temperature averaged 20.7°C. At the three downstream sites water temperature averaged 24.3°C. Downstream from Dillon dam, and at the most downstream sample site, average D.O. concentrations were just 6.5 mg/l. The 7.8 mg/l average D.O. concentration at the middle site was a local response to Dillon Falls reaeration. Total phosphorus concentrations (0.2 mg/l, n=18) were also elevated at the three downstream sites.

HUC 05040006 0601 Brushy Fork Assessment Unit

The most forested (77%) subbasin (18.3mi^2) in the 2008 Licking River watershed, Brushy Fork (4% row crop, 15% pasture) was also notable for having a fish community that achieved a perfect IBI score (60 at RM 0.1). Two Brushy Fork locations were evaluated in 2008. Water column chemistry results were generally normal. Ammonia-N was just above detection in three of five upstream samples ($\bar{x}$=0.05 mg/l) and was not detected downstream. Nutrient parameter concentrations at both sites were among the lowest in the study area. Other parameters were also unremarkable.

Both sites appeared unstable with raw eroded banks, open sunlight reaches and remarkable deeply scoured pools. Good stream habitat quality scores (QHEI $\bar{x}$=67.3) reflected substrate movement and the need for more riparian canopy. These conditions

Table 17 Licking River aquatic life use attainment status, 1981-2008. Symbology and ecoregional biocriteria follow.

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
HUC 05040006 9001 Licking Large River Assessment Unit (Downstream from the North and South Fork confluence to the Muskingum Large River Assessment Unit, excluding all tributaries)						
2008		**Licking River** WWH -EOLP-				
30.1	51/ 10.1	34	FULL	94.0	527.0	Adj. CSO's, Dst. confluence
28.6	51/ 10.4	36	FULL	94.0	531.0	Ust. Newark WWTP, Ref. site
28.2/26.8	45/ 10.4	VG	FULL	96.0	537.0	Dst. Newark WWTP
18.8	51/ 9.9	VG	FULL	87.5	672.0	Toboso Rd., Blackhand area
		Licking River WWH -WAP-				
5.8	40/ 10.7	22*	PARTIAL	75.0	742.0	Dst. Dillon Lake
3.6	49/ 11.6	34[ns]	FULL	92.5	753.0	Dillon Falls Rd., Ref. site
1.7	51/ 10.2	46	FULL	74.5	755.0	Dst. Burnham Foundry
1993		**Licking River** WWH -EOLP-				
28.6	50/ 9.9	40	FULL	79.5	531.0	Ust. Newark WWTP, Ref. site
26.8	49/ 10.0	46	FULL	76.0	537.0	Dst. Newark WWTP
18.8	46/ 9.8	52	FULL	75.5	672.0	Toboso Rd., Blackhand Area
13.3/14.8	39[ns]/9.4	54	FULL	50.0	691.0	Dillon Wildlife Area
		Licking River WWH -WAP-				
5.5	46/ 9.7	18*	PARTIAL	72.5	742.0	Dst. Dillon Lake
3.4	48/ 9.9	38	FULL	76.5	753.0	Dillon Falls Rd., Ref. site
1988		**Licking River** WWH -EOLP-				
26.8	-	42	(FULL)	-	537.0	Dst. Newark WWTP
3.6	40/ 9.1	34[ns]	FULL	83.0	753.0	Dillon Falls Rd., Ref. site
1985		**Licking River** WWH -EOLP-				
28.1	38[ns]/ 10.0	-	(FULL)	58.0	531.0	Dst. Newark WWTP
26.4	40/ 9.4	-	(FULL)	-	537.0	Dst. Newark WWTP
13.4	32*/8.3[ns]	-	(FULL)	-	691.0	Dillon Wildlife Area
1981		**Licking River** WWH -EOLP-				
30.1/28.6	33*/ 7.1*	32[ns]	PARTIAL	-	527.0	Ust. Newark WWTP
27.5/26.8	29*/ 7.0*	40	PARTIAL	-	531.0	Dst. Newark WWTP
24.8/23.3	29*/ 7.2*	42	PARTIAL	-	544.0	Ust. Claylick Ck.
20.0/18.9	24*/ 6.4*	46	NON	-	672.0	Toboso Rd., Blackhand Area
16.1	27*/ 6.4*	-	(NON)	-	682.0	Dillon Wildlife Area
11.0	25*/ 5.4*	-	(NON)	-	692.0	Dillon Lake

***** Significant departure from ecoregion biocriterion; poor and very poor results are underlined.

ns Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).

a The MIwb (Modified Index of well-being) is not applicable to headwater sites (<20mi^2). Boat critera *only* apply to all Licking Large River Assessment Unit sites.

b Narrative evaluation used in lieu of ICI (Excpt=Exceptional; Good; MG=Marginally Good; Fair; Poor; VPoor=Very Poor).

(Full**)** Use attainment status based on one organism group is parenthetically expressed.

Narrative ranges and **WWH** biocriteria for Ohio ecoregions. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide. For WWH, the ranges of marginally good and nonsignificant departure are the same.

Boat IBI	Boat MIwb	ICI	Narrative Evaluation
48-60	≥9.6	46-60	Exceptional
44-47	9.1-9.5	42-44	Very Good
Erie-Ontario Lake Plain			
40-43	**8.7**-9.0	**34**-40	Good
36-39	8.2-8.6	30-32	Marginally Good
26-35	6.4-8.1	14-28	Fair
Western Allegheny Plateau			
40-43	**8.6**-9.0	**36**-40	Good
36-39	8.1-8.5	32-34	Marginally Good
26-35	6.4-8.0	14-30	Fair
16-25	5.0-6.3	8-12	Poor
12-15	0-4.9	≤6	Very Poor

Table 18 Licking River aquatic life use impairment signatures based on biological sampling conducted during July through October, 2008.

Location / RM	**Stressor** (Source)	**Exposure** (Cause)	**Response** (Evidence)
HUC 05040006 9001 Licking Large River Assessment Unit (Downstream from the North and South Fork confluence to the Muskingum Large River Assessment Unit, excluding all tributaries)			
Dst. Dillon Lake RM 5.8	Dillon dam	Ammonia Nutrients	ICI=22*

probably limited the upstream aquatic community to very good status. The downstream fish and macroinvertebrate assemblages were exceptional.

One of ten *E. coli* concentrations was less than the PCR class B criterion (*E. coli*<161 cfu/100ml). Upstream, (geometric mean=599 cfu/100ml, abbreviated hereafter as gm$\bar{x}$) and downstream (gm$\bar{x}$=263 cfu/100ml) geometric mean *E. coli* concentrations were above the criterion. Unlike the also well forested Rocky Fork basin with erratic bacteria values, samples from Brushy Fork sites were consistently elevated. Rocky Fork is influenced by multiple groundwater sources whereas Brushy Fork riffle function appeared threatened by limited flow. No pathogen stress sources were specifically evident.

HUC 05040006 0602 Big Run Assessment Unit

Big Run (25.1 mi^2) drains a hilly, unglaciated area (11% row crop, 29% pasture, forest 53%) between Zanesville, Dresden, and Dillon Lake. The lower 2.5 miles of Big Run are impounded by Dillon dam.

In 2008, Big Run was evaluated at two locations. Wetland aspects were influential at both sites. Water chemistry results included modestly elevated TSS and nutrient concentrations. Low ammonia-N concentrations were detected in seven of ten samples. D.O. values were typical for WWH streams.

The only stream access between the impoundment and the upstream sample location, Creamery Rd. is built on a substantial dike, with gauntlet like guardrails extending on both berms for hundreds of yards. Moving fish sampling equipment safely and efficiently to the stream was not possible here. An exceptional macroinvertebrate community was indicative of biological attainment at this site.

Good aquatic diversity upstream was not limited by an overwhelming silt bedload. A good habitat score (QHEI=64.0) was inconsistent with first impressions. Good flow volume appears to have ameliorated perceived influences of heavy sedimentation and limited cover quality.

All bacteria samples were above the PCR class B criterion (*E. coli*<161 cfu/100ml). Geometric mean *E. coli* concentrations upstream (771 cfu/100ml) and downstream (515 cfu/100ml) generally followed this decreasing trend between individual samples. Livestock with unrestricted stream access were a likely source of bacterial contamination.

HUC 05040006 0603 Dillon Lake - Licking River Assessment Unit

The unglaciated Dillon Lake – Licking River AU includes two small tributaries which join the River from opposite banks. Among the larger AU's in the watershed (47.1 mi^2), it is second in forest cover amount (65%), and second to last in agricultural land use (9% row crop, 18% pasture).

Stump Run 2008 water quality can be summarized as good. No ammonia-N was detected. Nutrient parameter concentrations were low. D.O. concentrations were ample for aquatic life. The fish community achieved an exceptional IBI score (50). The macroinvertebrate assemblage merited a good rating. Stream habitat was consistent with this performance (QHEI=68.5).

All five bacteria samples and the geometric mean *E. coli* concentration (471 cfu/100ml) were above the PCR class B criterion (*E. coli*<161 cfu/100ml).

Poverty Run had good chemical, biological *and* bacteriological water quality. Four of four Poverty Run bacteria samples ($gm\bar{x}$=50 cfu/100ml) were less than the PCR class B criterion. These characteristics separate Poverty Run from most other 2008 study area streams.

HUC 05040006 0604 Timber Run - Licking River Assessment Unit

The Timber Run – Licking River AU includes parts of Zanesville and a commercial area near an I-70 interchange (28% developed). This most downstream Licking basin AU

(37.3 mi^2) includes natural (40% woods) and some agricultural land use (9% row crop, 24% pasture).

In 2008, three different streams were sampled at one location each. Bartlett Run attained the WWH biocriteria. A fair macroinvertebrate community in Joe's Run contrasted with an exceptional fish assemblage. And, a fair Timber Run fish community was at odds with a good assemblage of macroinvertebrates. The latter two streams were in partial attainment of the designated WWH aquatic life use.

Fair habitat quality was present at each location (QHEI $\bar{x}$=54.0). All streams had been historically modified, contained refuse and unnecessary fill material, and appeared stressed by excessive storm water flow. Grime like silt embedded riffles and instream cover was limited.

Bartlett Run water column chemistry results were normal. Ammonia-N was not detected. Concentrations of nutrient constituents were low. D.O. concentrations and water temperature were stable. Five of five bacteria samples (gm$\bar{x}$=548 cfu/100ml) were above the PCR class B criterion.

Joes Run chemical monitoring detected ammonia-N twice and very low nutrient concentrations. Chloride exposure was moderate ($\bar{x}$=55 mg/l, n=5). Five of five bacteria samples (gm$\bar{x}$=730 cfu/100ml) were above the PCR class B criterion

The fair Joes Run macroinvertebrate assemblage had low taxa richness (28) and few pollution sensitive EPT taxa (6). The low abundance was notable. Joes Run macroinvertebrate diversity was the second lowest in the 2008 Licking River study area. Aggressive high storm flows and poor quality substrate were deemed most limiting. An exceptional fish community (IBI=56) benefited from the immediacy of the Licking River. Lack of riffle dependent darter species kept this community from scoring higher.

The Joes Run fish community included large numbers of minnows that presumably move back and forth to the Licking River. To be clear, there were riffles and some woody debris that prevented fish from freely moving between the sampled reach and the receiving stream. However, the profusion of small fish was more than Joes Run could independently support and produced a high IBI score.

The Joes Run fish community was not as exceptional as its index score. Two fantail and 27 johnny darters comprised the riffle obligate species. Both are adapted to smaller streams and johnny darters are somewhat tolerant of degraded substrate. The absence of other darters is consistent with the low macroinvertebrate richness. Other fish species were represented by one or two individuals. Their ability to live in the lower reach of Joes Run suggests water quality in normal flows is acceptable. The poor quality substrates and excessive scouring flows are nevertheless limiting.

Timber Run chemical parameters implicate a source of high chlorides ($\bar{x}$=103 mg/l, n=5), high sodium ($\bar{x}$=58 mg/l, n=5) and high TKN ($\bar{x}$=0.7 mg/l, n=5). Three of five

bacteria samples (gm$\bar{x}$=191 cfu/100ml) were above the PCR class B criterion. The lack of elevated pathogens with the high chlorides and TKN is consistent with wastewater treatment. Sodium is symptomatic of water conditioning and treatment. The sampling location near industrial and commercial operations not far from I-77 bids inquiry of other possible contributory leachate or road salt like agents.

The fair Timber Run fish assemblage (IBI=36) was modestly abundant and amply populated by pioneering, omnivorous species. Proximity to the Licking River may have buoyed good minnow numbers but the presence of a sand darter was unexpected. The absence of redhorse species, rosyface shiner and logperch, found at other AU streams, influenced the subpar score. The macroinvertebrate community was comprised by a similar mix of tolerant taxa (11) off set by sufficient sensitive taxa (9) to effect a good evaluation. In concert, the response and exposure indicators confirm a local source of stress is present and should be remediated.

Table 19 Brushy Fork and Muskingum Co. tributaries aquatic life use attainment status, 2008. Symbology and ecoregional biocriteria follow.

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
HUC 05040006 0601 Brushy Fork - Licking River Assessment Unit (Brushy Fork)						
	2008	**Brushy Fork** WWH -WAP-				
3.1	46	VG	FULL	66.0	13.8	Stonepile Rd.
		Brushy Fork *EWH Recommended* -WAP-				
0.1	60	Excpt.	FULL	68.5	18.0	From Brushy Fork Rd.
HUC 05040006 0602 Big Run Assessment Unit (Big Run)						
	2008	**Big Run** WWH -WAP-				
5.1	42	Good	FULL	64.0	15.8	From Fawn Rd.
3.3	-	Excpt.	-	-		Creamery Rd.
HUC 05040006 0603 Dillon Lake - Licking River Assessment Unit (Licking River tributaries, dst. from Rocky Fork to ust. Dillon dam)						
	2008	**Stump Run** WWH -WAP-				
1.6/ 1.0	50	Good	FULL	68.5	7.9	Shannon Valley Rd./ SR 146
		Poverty Run WWH -WAP-				
1.5	48	Good	FULL	59.0	4.4	Pinecrest Rd.
HUC 05040006 0604 Timber Run - Licking River Assessment Unit (Licking River tributaries, dst. from Dillon dam)						
	2008	**Bartlett Run** WWH -WAP-				
0.1	52	Good	FULL	52.0	9.0	SR 146
		Joes Run WWH -WAP-				
0.1	56	Fair*	PARTIAL	56.0	8.6	Old Newark Rd.
		Timber Run WWH -WAP-				
0.3	36*	Good	PARTIAL	54.0	11.7	Licking Rd., CR 414

***** Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
ns Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).
a The MIwb (Modified Index of well-being) is not applicable to headwater sites (<20mi^2). Boat critera *only* apply to all Licking Large River Assessment Unit sites.
b Narrative evaluation used in lieu of ICI (Excpt=Exceptional; Good; MG=Marginally Good; Fair; Poor; VPoor=Very Poor).
(Full**)** Use attainment status based on one organism group is parenthetically expressed.

Narrative ranges and **WWH** biocriteria for the Western Allegheny Plateau ecoregion. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide. For WWH, the ranges of marginally good and nonsignificant departure are the same.

Headwater IBI	Wading IBI	Wading MIwb	ICI	Narrative Evaluation
50-60	50-60	≥9.4	46-60	Exceptional
46-49	46-49	8.9-9.3	42-44	Very Good
Western Allegheny Plateau				
44-45	**44**-45	**8.4**-8.8	**36**-40	Good
40-43	40-43	7.9-8.3	32-34	Marginally Good
28-39	28-39	5.9-7.8	14-30	Fair
18-27	18-27	4.5-5.8	8-12	Poor
12-17	12-17	0-4.4	≤6	Very Poor

Table 20 Muskingum Co. tributaries aquatic life use impairment signatures based on biological sampling conducted during July through October, 2008.

Location / RM	**Stressor** (Source)	**Exposure** (Cause)	**Response** (Evidence)
HUC 05040006 0604 Timber Run - Licking River Assessment Unit (Licking River tributaries, dst. from Dillon dam)			
Joes Run RM 0.1	Urban runoff Storm sewers	Sedimentation	ICI=Fair*
Timber Run RM 0.3	Urban runoff Storm sewers Package plant	Nutrient enrichment	IBI=36*

NORTH FORK

The North Fork watershed exhibited few violations of water quality criteria. The mainstem of the North Fork showed absolutely no violations nor did most of the tributary streams other than the upper portions of Lake Fork and Vance Creek (Table 6). Depressed D.O. concentrations were found at sites on each of these streams. Both streams exhibited nutrient enrichment with consistently elevated ammonia, total phosphorus and nitrate concentrations. This load promoted large growths of filamentous algae and fostered low D.O. measurements. Violations of the WWH minimum D.O. criterion likely contributed to the lack of biological attainment in Vance Creek at Berger Rd. (RM 7.0). Tributary streams such as Dry Creek and Clear Fork showed a significant and important groundwater component to flow as noted by consistent, low stream temperatures. This is especially evident near the mouths of these streams.

Very few areas of the North Fork subwatershed exhibited partial or non-attainment of biological water quality criteria. Two of those that did, failed to show any violations of chemical water quality criteria but did exhibit elevated concentrations of certain parameters. The uppermost site on North Fork revealed a fair community of macroinvertebrates with an exceptional fish community (Table 22). Elevated concentrations of nutrients and ammonia instream were the likely causes of partial biological attainment. The source of these constituents was the Village of Centerburg WWTP (Table 23).

Log Pond Run did not exhibit biological attainment for macroinvertebrates and barely met the WWH criterion for fish (Table 22). Consistently elevated concentrations of nitrates, organic nitrogen (TKN), chloride, and dissolved solids were indicators of chronic diffuse sources of pollutants plaguing this urbanized stream. This, in addition to fair habitat contributed to the poor invertebrate community and a threatened (but attaining) fish community. Consistently cool water temperatures served to partially ameliorate some stressors, especially with regard to the fish community diversity as cool water species were evident in the collection.

Recreational uses in the North Fork watershed typically did not attain promulgated PCR standards. None of the Class B mainstem or tributary streams upstream of Utica managed to attain recreational uses as defined by the geometric mean *E. coli* standard (Table 21). Fortunately, all of the Class A sites downstream of Utica attained the recreational use. However, 8 of 11 Class B tributary sites failed to attain the recreational use (Table 21). A variety of causes and sources contribute to this non-attainment and include the Centerburg WWTP, animal agriculture including manure management, and home sewage treatment systems. In smaller Class B streams that attained the recreational use (Clear Fork, Dry Creek), groundwater dilution was significant in ameliorating bacterial contamination from upstream areas.

Historical water chemistry values in North Fork showed few differences when compared with current data for most chemical parameters. For example, median dissolved oxygen concentrations were nearly identical with those observed in 1993. However,

ammonia-N, TKN, and total phosphorus concentrations generally decreased downstream of the Utica WWTP when compared with 1982 and 1993 results. This is best exemplified by the graph of total phosphorus (Figure 4).

Sediment samples taken at two sites on the North Fork revealed several analytes in concentrations greater than threshold or low effect levels (Table 8). However, macroinvertebrate and fish community data revealed full attainment of water quality standards and indicated no effect from these materials.

Village of Centerburg WWTP

The treatment works is located at the Daily Street extension in Centerburg and discharges to an unnamed tributary at RM 0.63 southeast of Centerburg. This unnamed tributary flows into the North Fork Licking River at RM 38.08. The WWTP design flow is 0.2 MGD. Treatment processes and equipment include: screening, grit removal, imhoff tank settling, fixed media treatment via a trickling filter, solids reaeration, clarification, chlorination and dechlorination. Sludge is disposed of at a solid waste landfill.

Wet weather infiltration / inflow (I&I) of water into the separate sanitary collection system results in periodic, sanitary sewer overflows (SSOs) from a manhole located at W. Houck and Willis Streets in the village and therefore permit compliance suffers during wet weather events. The wastewater discharge permit contains a compliance schedule requiring WWTP upgrade and elimination of SSO events. The village is making steady progress toward full compliance.

Village of Utica WWTP

The treatment works is located at 418 Blacksnake Rd. and discharges to the North Fork Licking River at RM 17.14. The WWTP design flow is 0.423 MGD. Treatment processes and equipment include: screening, oxidation ditch aeration, clarification, chlorination and dechlorination. Sludge is land applied at agronomic rates on Ohio EPA authorized sites.

Wet weather I&I into the village's separate sanitary collection system results in periodic SSOs from the detention basin and WWTP bypass. A flow detention basin is available to capture wet weather flows exceeding the WWTP capacity. The village has inspected and improved its sanitary sewer collection system to minimize I&I but has been unable thus far to completely eliminate SSO events. Compliance has been generally good at this WWTP in recent years but is problematic during wet weather events. Planned capital improvements to the WWTP are designed to eliminate SSO events as required in its wastewater discharge permit compliance schedule.

Velvet Ice Cream

This facility is located at State Route 13, south of Utica, and discharges to the North Fork Licking River at RM 15.95. The facility discharges noncontact cooling water from equipment used in its ice cream manufacturing process. Process wastewater from the

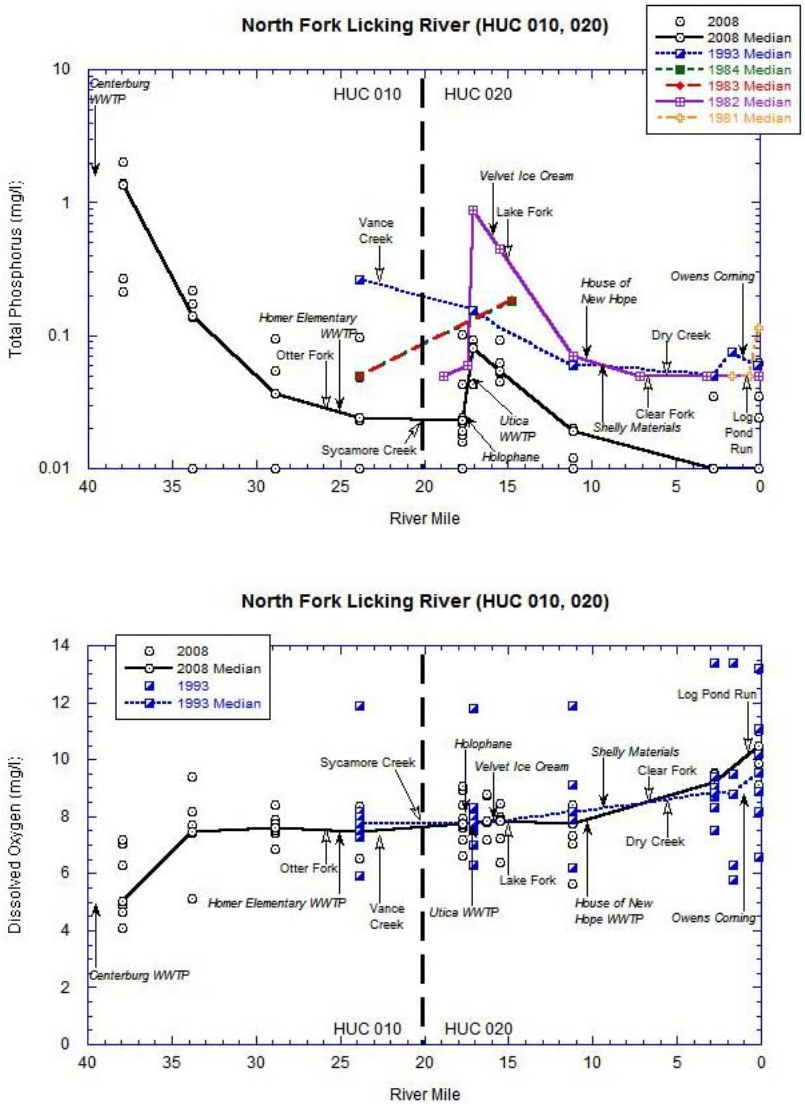

Figure 4 Longitudinal summary of median concentrations of total phosphorus and D.O. in the North Fork, 1981-2008.

ice cream manufacturing process is treated by an on-site ridge and furrow (land) treatment system and does not directly discharge to the river.

Owens Corning, Newark

Owens Corning operates a landfill located north of Manning Street in Newark. The landfill has two storm water sedimentation ponds which discharge to an unnamed tributary which confluences with the North Fork Licking River at RM 0.85. Discharge from the sedimentation ponds is authorized through a stormwater discharge permit. Process wastewater from this facility is discharged into the City of Newark sanitary sewer collection system for treatment at the Newark WWTP.

Village of Hartford WWTP
This WWTP is located at Hartford Fairgrounds north of the village and discharges to an unnamed tributary to Otter Fork at RM 1.08 (confluence with Otter Fork at RM 9.68). The plant and new sanitary sewer collection system was placed into service in June, 2006. The WWTP design flow is 0.06 MGD. The treatment processes and/or equipment include: screening, flow equalization, extended aeration, clarification and ultraviolet disinfection. Sludge is disposed at a solid waste landfill.

Compliance at this WWTP has been good with the exception of the dates encompassing the annual county fair when wastewater volume and pollutant load dramatically increase. Adjustments are ongoing as necessary to provide compliance during the annual fair.

Ohio Fresh Eggs
Ohio Fresh Eggs (FKA Buckeye Egg Farm) is an enormous, integrated chicken egg production facility with associated facilities located throughout Ohio. Buckeye Egg Farm had a history of environmental compliance problems and in March, 2001 a Consent Order was issued to the company and its operators. The terms of the order required that Buckeye Egg Farm renovate thirty-five old commercial layer buildings and fifteen commercial pullet barns at its Croton, Ohio location while prohibiting discharge of the storm water from all of the Croton area facilities. The Consent Order also required the submittal of Concentrated Animal Feeding Operation (CAFO) NPDES permit applications for all of the Croton and northwest Ohio locations. The terms of the Consent Order have carried over to the new owner, Ohio Fresh Eggs LLC.

Ohio Fresh Eggs submitted CAFO NPDES applications to Ohio EPA for all of its facilities in September, 2003. The permit applications stated there would be no direct surface water discharge. While the permits were drafted and public noticed in 2005, they were never issued due to ongoing litigation between Ohio Fresh Eggs and the Ohio Department of Agriculture.

In 2007 and 2008, Ohio Fresh Eggs management met with representatives of the Division of Surface Water (DSW) to discuss stormwater issues at the Croton facilities. The prohibition to discharge stormwater at Ohio Fresh Eggs caused problems containing and controlling the large amounts of stormwater generated there. Although Ohio Fresh Eggs uses center pivot systems to irrigate cropland with the stormwater (an egg wash water), the Croton facilities were still burdened with excessive amounts of stormwater during prolonged wet weather. Thus, Ohio Fresh Eggs was forced to resort to expensive solutions to manage the stormwater, including trucking the excess to the Johnstown WWTP for treatment. It should also be noted that the fields on which the stormwater has been land applied are extremely high in phosphorus and should not be used for future land application of stormwater or egg wash water.

In August and October of 2008, the law firm Bricker & Eckler LLP submitted revised NPDES applications for several of the Croton facilities on behalf of Ohio Fresh Eggs. The facilities for which new applications were received are Croton layer facilities 1, 3,

Table 21 North Fork recreational use attainment status, May 1-October 15, 2008. All values are expressed as *E. Coli* colony forming units per 100 ml of water (cfu/100ml).

RM	N	$gm\bar{x}$	Max.	STATUS	Location
North Fork *PCR Class B*					
37.91	7	1185	2300	NON	Dst. Centerburg WWTP
33.80	7	330	560	NON	Dutch Cross Rd.
28.90	7	365	620	NON	Mink / Douglas St.
23.90	7	220	530	NON	TR 70
17.70	9	100	590	FULL	US 62
PCR Class A					
16.30	7	117	640	FULL	Dst. Utica WWTP
15.50	7	117	1100	FULL	Ginger Hill Rd.
11.20	7	80	1700	FULL	Ust. St. Louisville
2.80	7	88	870	FULL	Waterworks Rd.
0.20	9	81	680	FULL	Ohio St.
Otter Fork *PCR Class B*					
9.28	5	393	970	NON	Crouse-Willison Rd.
4.13	5	470	730	NON	Bennington Chapel Rd.
0.20	5	338	570	NON	Lock Rd.
Sycamore Creek *PCR Class B*					
5.87	5	450	750	NON	Weaver Rd.
0.10	4	433	710	NON	Tuma Run Rd.
Tuma Run *PCR Class B*					
0.46	5	846	1200	NON	SR 13
Vance Creek *PCR Class B*					
0.70	5	386	2200	NON	Berger Rd.
Lake Fork *PCR Class B*					
10.86	5	1530	4200	NON	Shipley Rd.
7.95	5	642	5400	NON	US 62
4.77	5	261	2100	NON	Bruce Rd.
0.05	5	414	2000	NON	SR 13
Clear Fork *PCR Class B*					
5.50	5	200	830	NON	Agape Retreat Center Driveway
0.13	5	56	100	FULL	SR 13
Dry Creek *PCR Class B*					
7.60	5	263	710	NON	Dry Creek Rd.
4.97	5	207	430	NON	Dry Creek Rd.
0.40	5	73	150	FULL	SR 13
Log Pond Run *PCR Class B*					
0.10	4	375	660	NON	Riverside Dr.

PCR Criteria	$gm\bar{x}$	Max.
Class A	<126	≤298
Class B	<161	≤523

and 4 and Croton pullet facilities 1 and 2. The applications requested a direct discharge of stormwater and provided an antidegradation analysis as required. Ohio EPA examined these applications along with sampling data collected from the stormwater ponds at the Croton sites between November, 2007 and August, 2008. Discussion and evaluation of the application is ongoing.

Ohio Fresh Eggs has recently made many improvements to the Croton facilities. The conversion of the manure handling facilities to belt battery systems (which convey manure out of the production buildings to separate storage and handling areas) has significantly decreased the volume of pollutants which formerly entered the stormwater ponds via previous manure management methods.

HUC 05040006 0101 Otter Fork Licking River Assessment Unit

Located in the northwest part of the Licking River watershed, the Otter Fork drains a 28.3 mi^2 area encompassing the Village of Hartford, the area west from Centerburg, and north from Johnstown. Agricultural land use (69% row crop, 8% pasture) is prevalent across the generally flat glaciated terrain. Forested areas (16%) are limited to a few scattered woodlots and the more rolling valley topography flanking some small streams. Most headwater reaches are managed as agricultural drains. Upstream from Hartford (RM 11.5), Otter Fork is channelized and maintained as a joint county ditch.

Very good stream habitat conditions (QHEI $\bar{x}$=83) at three 2008 sampling stations supported very good biological performance (IBI $\bar{x}$=46, MIwb $\bar{x}$=9.3, ICI $\bar{x}$=41). Water column chemical concentrations were typical for an agricultural area. Detection of some ammonia-N at Bennington Chapel Rd. ($\bar{x}$=0.06 mg/l, n=5) and routine concentrations of nitrite+nitrate-N ($\bar{x}$=1.3 mg/l, n=15) and total phosphorus ($\bar{x}$=0.1 mg/l, n=15) at all sites was likely due to livestock waste polluted runoff.

Among 15 bacteria samples at three sites, only one concentration was less than the criterion (*E. coli*<161 cfu/100ml). Geometric mean values (*E. coli* gm$\bar{x}$=393 cfu/100ml at RM 9.3, *E. coli* gm$\bar{x}$=470 cfu/100ml at RM 4.1, and *E. coli* gm$\bar{x}$=338 cfu/100ml at RM 0.2) were more than double the criterion at all locations. Livestock and faulty home sewage systems were probable sources.

Between 1999 and 2001, Ohio EPA evaluated streams in the Otter Fork and Raccoon Creek sub-basins following instances of spills reported at Ohio Fresh Eggs (FKA Buckeye Egg Farm). Despite documenting some rather severe fish kills, affected biological communities usually recovered within three to six months. Strong ground water flow seemed to ameliorate the negative impacts.

HUC 05040006 0102 Headwaters North Fork Licking River Assessment Unit

East from and adjacent to Otter Fork, the headwaters of the North Fork AU drains a 33 mi^2 watershed terminating at the Otter Fork confluence. The glaciated area has slightly more rolling topography than that of the Otter Fork sub-basin. While still principally comprised by agricultural land use (60% row crop, 12% pasture), the area has witnessed recent increases in rural residential development. Centerburg is the largest

community in the AU. Woodlots (20%) are primarily associated with stream corridors or poorly drained tracts.

The Centerburg WWTP discharges to an unnamed tributary which joins the North Fork at RM 38.08. In 2008, three locations were sampled downstream from this tributary. Although very good habitat qualities (QHEI $\bar{x}$=78) were evident across the reach, the macroinvertebrate community downstream from the unnamed tributary failed to achieve the biocriterion (ICI=Fair at RM 37.9).

A nutrient enrichment signature was apparent at RM 37.9. The numerically low abundance of macroinvertebrate taxa included dense populations of pollution tolerant midges and aquatic worms. EPT taxa were notably limited. The fish community responded to the nutrient pulse with high individual abundance. Half of the community was comprised by pollution tolerant species. Even so, good species richness including several pollution sensitive minnows and darters produced an exceptional fish community score (IBI=52).

Elevated ammonia-N ($\bar{x}$=0.15 mg/l), nitrite+nitrate-N ($\bar{x}$=8.7 mg/l) and total phosphorus ($\bar{x}$=1.1 mg/l) concentrations were detected in all water column samples (n=5) at RM 37.9. Implication of the Centerburg facility as the source was also evident in August as natural flow diminished and concentrations of chemical parameters associated with treated well water were especially apparent (iron, chlorides, and TDS).

Concentrations of *E. coli* ranged from 690 cfu/100ml to 2300 cfu/100ml in seven samples at RM 37.9. The geometric mean value (*E. coli* gm$\bar{x}$=1,185 cfu/100ml) was an order of magnitude above the criterion (*E. coli*<161 cfu/100ml) and was the third highest value anywhere in the 2008 study area.

Geometric mean *E. coli* concentrations also exceeded the criterion at the other two sites in the AU. In fact, all 21 bacteria samples from the AU exceeded the PCR class B trigger. In addition to the Centerburg WWTP, poorly treated home sewage and livestock waste polluted runoff were other sources of bacteria.

HUC 05040006 0103 Sycamore Creek Assessment Unit

Sycamore Creek joins the North Fork upstream from Utica. The 30.7 mi^2 watershed drains a rolling glaciated agricultural area (61% row crop, 13% pasture). Wooded places (19%) exist adjacent to stream margins and as isolated stands. A small crossroads community, Brandon is the only development in the AU.

Sycamore Creek AU water quality was evaluated at three locations in 2008. Stream habitat conditions were very good at all sites (QHEI $\bar{x}$=86). Biological performance was consistent with habitat. Good to exceptional fish and macroinvertebrate communities inhabited the area.

Water chemistry results were typical for the agricultural area. Some detectable ammonia-N ($\bar{x}$=0.06 mg/l, n=15) and modest nitrite+nitrate-N concentrations ($\bar{x}$=0.9

mg/l, n=15) suggested livestock waste polluted runoff and inadequately treated home sewage were contributing to stream loadings. Likewise, all *E. coli* samples from the AU exceeded the relevant criterion. This further implicated common bacteria sources.

HUC 05040006 0104 Vance Creek - North Fork Licking River Assessment Unit

The Vance Creek – North Fork AU covers an 18.9 mi^2 area downstream from Otter Fork and upstream from Sycamore Creek. Similar to other adjacent AUs, it is a rolling glaciated agricultural area (61% row crop, 15% pasture) where forest presence is limited to stream corridors and discrete woodlots (19%). The small village of Homer is situated along the North Fork within the AU.

Sampling occurred at two sites in 2008. A North Fork site (RM 23.9) was downstream from Homer and upstream from the Vance Creek confluence. Very good habitat quality (QHEI=82) and exceptional biological performance (IBI=55, MIwb=10.1, ICI=Exceptional) were recorded at this location.

Vance Creek was evaluated at Berger Rd. (RM 0.7). Good habitat conditions (QHEI=73.5) were insufficient to buffer the aquatic community from an unknown source of perturbation. The poor macroinvertebrate assemblage was comprised by few EPT taxa and low taxa richness. Pollution tolerant taxa were most numerous. A high density of low D.O. tolerant pouch snails and abundant aquatic plant growth were symptomatic of enrichment.

The marginally good fish community (IBI=36) was also influenced by low D.O. stress and enrichment. Pioneering fish are adept at recolonizing streams following periods of desiccation or where fish may have otherwise been eliminated. Pollution tolerant, pioneering fish comprised 68% and 57% respectively, of the modestly abundant assemblage. Lithophilic species prefer clean, silt free substrates with ample interstitial voids. The reduced presence of these fish in Vance Creek further suggested impaired conditions.

Five water column samples were obtained from Vance Creek (RM 0.7) in 2008. D.O. concentrations in two samples (3.80 mg/l on Aug. 11, 2.07 mg/l on Aug. 25) were less than the WWH minimum criterion (4.0 mg/l). Collectively, the average D.O. concentration (4.95 mg/l) was also less than the WWH average criterion (5.0 mg/l). The first two samples contained elevated nitrite+nitrate-N concentrations ($\overline{x}$=3.2 mg/l, n=2). Later, the last three samples included elevated ammonia-N concentrations ($\overline{x}$=0.20 mg/l, n=3). Similarly, early samples included high *E. coli* concentrations (790 cfu/100ml on June 23, 2200 cfu/100ml on July 14) while later samples nearly met the PCR class B criterion (*E. coli*<161 cfu/100ml).

Taken together, biological, chemical, and bacteriological sampling suggests livestock manure may routinely be washing into the stream. However, other enrichment sources are also plausible and further investigation is recommended.

Geometric mean *E. coli* concentrations at both Vance Creek – North Fork AU sample sites failed to achieve the recommended PCR class B criterion.

HUC 05040006 0201 Lake Fork Licking River Assessment Unit

The Lake Fork joins the North Fork downstream from Utica. Topography in this 35.1 mi^2 sub-basin is somewhat more rolling than that of the upstream AU's. Land use includes more forest (29%) and a little less agriculture (55% row crop, 11% pasture). A glacial kettle lake exists near the mouth of Lake Fork. There are no developed communities in the watershed.

Three locations were sampled in 2008. Good habitat conditions at the two upstream sites (QHEI $\bar{x}$=65) reflected the more intensive surrounding agricultural land use compared to very good stream habitat at the most downstream site (QHEI=85). Biological communities mirrored the habitat with very good performance upstream (IBI $\bar{x}$ =48, MIwb=9.4, ICI $\bar{x}$=42) compared to exceptional scores downstream (IBI=53, MIwb=9.6, ICI=44).

In May 2008, land applied manure via tile drainage entered the headwater reaches of this AU causing a fish kill. A sample site downstream from the spill area (Shipley Rd., RM 10.9) was included in the study plan. Chemical sampling began here on June 23. By July this 4.5 mi^2 upper Lake Fork reach became intermittent. Although a small pool remained near the bridge permitting further chemical analysis, the stream became completely dry by late summer.

Aquatic communities are adapted for survival in intermittent streams. Ohio's bioassessment protocols provide for evaluating partially desiccated reaches. The extent of Lake Fork water loss at RM 10.9 precluded aquatic life use assessment in 2008.

Chemical data from four Lake Fork sites was obtained. As the summer progressed, the Shipley Rd. bridge pool within a cattle pasture became anoxic and bacteria laden. Concurrently at downstream locations which also became intermittent, D.O. concentrations remained similar to values in other similar area streams. Livestock waste appeared to influence all locations.

Ammonia-N was detected in all five samples at Bruce Rd. ($\bar{x}$=0.17 mg/l). Among 15 samples at the three lower sites, three *E. coli* concentrations were less than the PCR class B criterion (*E. coli*<161 cfu/100ml). Geometric mean values of *E. coli* (642 cfu/100ml at RM 7.9, 261 cfu/100ml at RM 4.8, and 414 cfu/100ml at RM 0.1) exceeded the PCR class B at these locations.

The absence of an appreciable volume of water at Shipley Rd. (RM 10.9) suggests chemical and bacteriological sampling results have little bearing on conditions outside the limited confines of the bridge pool.

HUC 05040006 0202 Clear Fork Licking River Assessment Unit

The 22.1 mi^2 Clear Fork AU joins the North Fork in Vanatta near Newark. Compared to upstream AU's, agricultural land use (40% row crop, 18% pasture) is limited in this rugged, hilly area where forest cover (38%) is more extensive. Higher gradients provide more stream energy. The Clear Fork ($\bar{x}$=31.3 ft/mi) demonstrates this by transporting large amounts of outwash gravel.

The fish community was influenced by unstable substrates especially evident near the North Fork confluence. Where hillside streams meet the lower gradient floodplain of a receiving stream, water may flow through a porous floodway rather than over it. The North Fork flows over and through an area of gravel outwash deposited on top of valley train aggregates downstream from Utica. Clear Fork's lower reach traverses this outwash in route to the North Fork. The elevated outwash fan delivers the interstitial flow of both streams to the surface water at Vanatta (Dove 1960, 63).

As water moves through the gravel lens, its temperature cools and remains fairly constant absent the affects of sunlight. Water temperatures at Clear Fork RM 0.1 ($\bar{x}$ =13.9°C, n=5) averaged a degree colder than anywhere else in the study area and was much colder than recorded upstream ($\bar{x}$=18.6°C at RM 5.5, n=5). Sand incorporated in the gravel lenses is particularly effective at filtering water. Water in the aptly named Clear Fork is well polished before meeting the North Fork.

During high flows, the loose, saturated substrates are especially prone to travel. The temporary nature of riffles in the lower Clear Fork reach preempted some species use. Stream bed instability here was balanced by deeper pools, good cover and sufficient flow. A marginally good to good fish assemblage (IBI=38^{ns}, MIwb=8.0) together with an exceptional macroinvertebrate score (ICI=48) were consistent with expectations. Biological performance upstream was very good (IBI=54, ICI=VG). Habitat at both sites averaged a very good QHEI score ($\bar{x}$=84).

Sand filtration coupled with increased flow reduced water column *E. coli* concentrations at RM 0.1. Upstream at RM 5.5, *E. coli* concentrations ranged between 70 cfu/100ml and 830 cfu/100ml (n=5). The geometric mean of 200 cfu/100ml here was among the lower values for similar size study area streams (12.1 mi^2) but still above the PCR class B criterion (*E. coli*<161 cfu/100ml). After filtration and dilution, all *E. coli* concentrations at RM 0.1 were 100 cfu/100ml or less (n=5). The geometric mean concentration (*E. coli*=56 cfu/100ml) here and at an adjacent Dry Fork location were the only places in the North Fork watershed where the PCR class B criterion was achieved.

No ammonia-N or total phosphorus was detected in 10 Clear Fork samples. Nitrite+nitrate-N concentrations averaged 1.3 mg/l (RM 5.5) and 1.8 mg/l (RM 0.1).

HUC 05040006 0203 Dog Hollow Run - North Fork Licking River Assessment Unit

Beginning downstream from Sycamore Creek and ending upstream from Clear Fork, the Dog Hollow Run – North Fork AU covers 24.6 mi^2 of hilly glaciated terrain. The towns of Utica and St. Louisville are included in its developed area (10%). Compared to

other North Fork AU's, this area is more forested (42%) and offers less agricultural land use (30% row crop, 18% pasture).

Five sites on the North Fork bracketed Utica's WWTP and Velvet Ice Cream in 2008. Stream habitats were very good in this reach. QHEI scores ($\bar{x}$=84) were above 80 at all sites. Very good to exceptional aquatic communities were present at all locations (IBI $\bar{x}$ =50, MIwb=9.8, ICI $\bar{x}$=46). No influences were evident from either facility.

Water column chemical parameter values were very good. Aggregately, ammonia-N was detected once (0.13 mg/l) in 22 samples. Nitrite+nitrate-N concentrations averaged 0.8 mg/l (range 0.1 mg/l - 2.1 mg/l). Total phosphorus concentrations were low ($\bar{x}$=0.05 mg/l, range 0.01 mg/l - 0.10 mg/l).

The pattern of a storm tracking over the Lake Fork sub-basin appears in the bacterial data on July 14. While North Fork bacteria values were elevated upstream from the Lake Fork confluence (*E. coli*=590 cfu/100ml at RM 17.7, *E. coli*=640 cfu/100ml at RM 17.1), downstream concentrations nearly doubled (*E. coli*=1100 cfu/100ml at RM 15.5, *E. coli*=1700 cfu/100ml at RM 11.1). Lake Fork runoff *E. coli* concentrations averaged 2600 cfu/100ml among four sites on the same day.

Aside from this storm date, other North Fork *E. coli* concentrations were generally low. Thirty *E. coli* concentrations were cultured from four 2008 AU locations (gm$\bar{x}$=102 cfu/100ml). Geometric mean values at each site (*E. coli*=100 cfu/100ml at RM 17.7, *E. coli*=117 cfu/100ml at RM 17.1, *E. coli*=117 cfu/100ml at RM 15.5, and *E. coli*=80 cfu/100ml at RM 11.1) were less than the PCR class B criterion (*E. coli*<161 cfu/100ml). Achievement of this criterion was most attributable to the filtering action of and additional dilution water contributed by glacial outwash substrates.

HUC 05040006 0204 Dry Creek Assessment Unit

Draining 24.6 mi^2, just over half of Dry Creek's land use is agricultural (30% row crop, 26% pasture) while 38% is forested. Like Clear Fork, Dry Creek's lower reach flows over and through a deep aggregate filled valley where significant subsurface flow disguises its actual volume of water.

Investigation of the Dry Creek AU occurred at three locations in 2008. Upstream (RM 7.6), water temperature averaged 18.1°C, (n=5). Centrally (RM 5.0), temperatures declined ($\bar{x}$=17.7°C, n=5), despite the lack of riparian canopy in between. Downstream (RM 0.4), water temperatures were cold ($\bar{x}$=14.6°C, n=5). No Ammonia-N was detected in any sample (n=15). Nitrite+nitrate-N concentrations were low. Low total phosphorus concentrations were detected in three samples (n=15).

As with Clear Creek, dilution and sand filtering effectively reduced *E. coli* concentrations downstream (gm$\bar{x}$=73 cfu/100ml, n=5 at RM 0.4). Upstream bacteria concentrations were above the PCR class B criterion (*E. coli*<161 cfu/100ml) in eight of ten samples (gm$\bar{x}$=263 cfu/100ml at RM 7.6, gm$\bar{x}$=207 cfu/100ml at RM 5.0). Pastured livestock were the most probable source of upstream bacteria.

Dry Creek habitat conditions were good (QHEI $\bar{x}$=67). Encroachment on the stream margin and laminar undifferentiated currents were factors limiting better habitat scores. Very good to exceptional biological performance was recorded at Dry Creek sites (IBI $\bar{x}$ =51, MIwb=8.5, ICI=VG - Exceptional). Loose, easily moved substrates at RM 0.4 prevented habitation by some riffle obligate fish species.

HUC 05040006 0205 Log Pond Run - North Fork Licking River Assessment Unit

The Log Pond Run North Fork AU (23.0 mi^2) includes Log Pond Run and the North Fork between its confluences with the Clear and South Forks. It is among the more developed (31%) AU's in the Licking River watershed. To alleviate flood damage in older neighborhoods drained by Log Pond Run, the USACE built a 1.2 mile long diversion channel to redirect flow from the less developed (9% row crop, 24% pasture, and 36% forest) upper part of the Log Pond Run sub basin.

Today, a ditch runs due south from Goose Pond Rd. to Granville Rd. where it meets a modified Sharon Run before joining an improved reach of Raccoon Creek on the south side of SR 16. The natural Log Pond headwaters (9.6 mi^2) and other western tributaries are diverted into the ditch. Three traffic bridges, two large drop structures and 30 acres of property were part of the $1.03 million flood control project (USACE 1967).

The much shortened Log Pond Run (1.3 mi^2) begins behind the 21st Street retail area (WalMart and Meijers stores), flows through many blocks of neighborhood backyards, and is confined in walls and culverts before snaking through an industrial area to join the North Fork near SR 16.

In 2008, Log Pond Run was sampled in the industrial area at RM 0.1. Fair habitat quality (QHEI=49.5) reflected the stream's modified heritage, ample amount of stream bed smothering fine silt, and shallow limited riffle conditions. The very good fish assemblage (IBI=48) was comprised by modest numbers of tolerant (82%) and pioneering (62%) species. The presence of species with preference for perennial, cold water ($\bar{x}$=16.8°C, n=5) implied ground water contributed to stream flow.

The poor macroinvertebrate community had reduced EPT taxa, had limited total taxa abundance, and overall low numbers of aquatic invertebrates. The presence of four cold water taxa was at odds with the otherwise depauperate assemblage but consistent with the ground water signature also expressed by fish species.

Taken together, the prevalence of pioneering fish and absence of expected macroinvertebrate taxa implied a response to episodic toxicity. Both assemblages had limited diversity despite being buoyed by ground water influences. Additionally, dead aquatic animals were noted by both sampling teams.

Water column chemical parameters included elevated conductivity, higher chloride, TDS, and sodium concentrations, and an unusually elevated COD concentration.

Ammonia-N was not detected. Nitrite+nitrate-N concentrations were comparatively high ($\bar{x}$=2.5 mg/l, n=5).

Among different exposure values, the single COD spike was most similar to the sporadic biological response. Considering the variability of upstream possible stressor sources, designation of additional exposures as cause for the biological impairment is reasonable. Generally, the chemical parameters were symptomatic of sump and water softener drainage.

Concentrations of bacteria were above the PCR class B criterion (*E. coli*<161 cfu/100ml) in three of four samples. The geometric mean E. coli concentration at RM 0.1 (gm$\bar{x}$=375 cfu/100ml) also implied an elevated exposure risk.

The North Fork site at RM 2.8 is downstream from two low head dams. The upper dam pool is used for Newark's drinking water intake. The lower dam's purpose is questionable. Both may trap some sediment but plenty of aggregate appears to still be transported. At RM 2.8, deep pools have been carved in outwash cobbles. High banks have been aggressively eroded. Large swaths of gravels flank the stream as it switches sides from left to right and back.

Energy dissipated by the dam pool is restored downstream and the North Fork exerts this force to carry sediment. Strong flow, deep runs, and large submerged trees provide very good stream habitat (QHEI=87.5) at RM 2.8. Aquatic communities responded with exceptional performance (IBI=49, MIwb=10.2, ICI=48).

The most downstream sample location on the North Fork (RM 0.1) was in a wide, modified, flat flowing channel. The area is maintained as part of the USACE Newark flood control project. A good habitat score (QHEI=61) resulted from the combination of well washed, clean gravel and cobble substrates, deeper functional pool areas, and adequate cover despite the effort to manage for homogenous, laminar flow. Biological assemblages achieved very good index scores (IBI=48, MIwb=9.1, ICI=42).

In 2008, ammonia-N was not detected in 12 summer water column samples collected at the two downstream North Fork locations. Nitrite+nitrate-N and total phosphorus concentrations were low or not detected. A modest increase in chloride concentrations between the two sample locations may be due to the Log Pond Run load.

The previously discussed July 14 storm resulted in high *E. coli* concentrations at both locations (870 cfu/100ml at RM 2.8, 680 cfu/100ml at RM 0.1). Otherwise, *E. coli* concentrations in 11 of 16 samples were below PCR class A criterion (*E. coli*<126 cfu/100ml). Geometric mean concentrations were less than the threshold at both sites (gm$\bar{x}$=88 cfu/100ml at RM 2.8, gm$\bar{x}$=87 cfu/100ml at RM 0.1).

Table 22 North Fork aquatic life use attainment status, 1993-2008. Symbology and ecoregional biocriteria follow.

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
HUC 05040006 0101 Otter Fork Licking River Assessment Unit (Otter Fork)						
	2008	**Otter Fork** WWH -EOLP-				
9.3	44	Good	FULL	79.5	14.7	Dst. Hartford WWTP
4.1	44/ 9.3	38	FULL	81.5	26.0	Bennington Chapel Rd.
0.1	50/ 9.2	44	FULL	88.0	28.0	Lock Rd.
	2001	**Otter Fork** WWH -EOLP-				
15.6	46	-	(FULL)	48.0	5.4	School Lane Rd.
13.9	36[ns]	-	(FULL)	50.5	6.4	From Croton Rd.
12.0	38[ns]	MG[ns]	FULL	45.0	8.0	From Croton Rd.
11.9	34*	Fair*	NON	41.5	8.7	From Croton Rd.
10.3	34*	MG[ns]	PARTIAL	52.5	11.1	Mitchell Rd.
7.7	46/ 9.0	MG[ns]	FULL	73.0	22.5	Dutch Cross Rd.
5.5	50/ 9.3	-	(FULL)	79.5	26.0	Drury Rd.
3.9	46/ 9.8	-	(FULL)	79.5	28.1	SR 657
		Bowl Run MWH -EOLP-				
2.3	34	-	(FULL)	50.5	2.2	Parsons Rd.
0.6	36	-	(FULL)	58.5	2.9	Appleton Rd.
	2000	**Otter Fork** WWH -EOLP-				
18.1	26*	MG[ns]	PARTIAL	42.0	3.4	Ust. US 36
15.6	44	MG[ns]	FULL	49.0	5.4	School Lane Rd.
13.9	42	MG[ns]	FULL	43.0	6.4	From Clover Valley Rd.
12.7	46	MG[ns]	FULL	50.0	7.7	Ust. Croton Rd.
12.0	39[ns]	MG[ns]	PARTIAL	49.5	8.0	From Croton Rd.
11.9	32*	Fair*	NON	45.5	8.7	From Croton Rd.
10.3	33*	Fair*	NON	65.0	11.1	Mitchell Rd.
7.7	37[ns]/ 7.2*	MG[ns]	PARTIAL	75.0	22.5	Dutch Cross Rd.
5.5	42/ 7.9	MG[ns]	FULL	80.0	26.0	Drury Rd.
3.9	40/ 9.1	MG[ns]	FULL	81.5	28.1	SR 657
1.8	50/ 8.8	Good	FULL	77.5	29.7	From Bennington Chapel Rd.
		Bowl Run MWH -EOLP-				
2.3	29	Poor*	PARTIAL	36.5	2.2	Parsons Rd.
0.6	26	Fair	FULL	-	2.9	Appleton Rd.
	1998	**Otter Fork** WWH -EOLP-				
15.6	45	Fair*	PARTIAL	38.0	5.4	School Lane Rd.
7.7	46/ 9.2	Good	FULL	81.5	22.5	Dutch Cross Rd.
3.9	42/ 8.9	Good	FULL	80.0	28.1	SR 657
		Bowl Run MWH -EOLP-				
0.6	40	MG	FULL	67.5	2.9	Appleton Rd.

Table 22 continued

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
HUC 05040006 0102 Headwaters North Fork Licking River Assessment Unit (North Fork, ust. from Otter Fork)						
	2008	**North Fork** WWH -EOLP-				
37.9	52	Fair*	PARTIAL	78.5	7.2	Dst. Centerburg WWTP
33.8	46	Good	FULL	75.5	16.8	Dutch Cross Rd.
28.9	54/ 10.4	50	FULL	80.5	23.0	Mink St.
	1999	**North Fork** WWH -EOLP-				
38.2	46	24*	PARTIAL		6.2	Croton Rd.
HUC 05040006 0103 Sycamore Creek Assessment Unit (Sycamore Creek)						
	2008	**Sycamore Creek** WWH -EOLP-				
5.9	44	Excpt.	FULL	87.0	13.0	Weaver Rd.
0.1	54/ 9.8	32[ns]	FULL	87.0	30.0	Vance Rd.
		Tuma Run WWH -EOLP-				
0.4	52	Good	FULL	83.5	7.6	SR 13
	1993	**Sycamore Creek** WWH -EOLP-				
0.1	48/ 8.9	Good	FULL	80.0	30.0	Vance Rd.
HUC 05040006 0104 Vance Creek - North Fork Licking River Assessment Unit (Vance Creek and North Fork, dst. from Otter Fork to ust. Sycamore Creek)						
	2008	**North Fork** WWH -EOLP-				
23.9	55/ 10.1	Excpt.	FULL	82.0	64.0	Dst. Homer, Ref. site
		Vance Creek WWH -EOLP-				
0.7	36[ns]	Poor*	NON	73.5	9.8	Berger Rd.
	1999	**North Fork** WWH -EOLP-				
23.9	52/ 9.6	50	FULL		64.0	Dst. Homer, Ref. site
	1993	**Vance Creek** WWH -EOLP-				
0.7	48	Good	FULL	59.5	9.8	Berger Rd.
HUC 05040006 0201 Lake Fork Licking River Assessment Unit (Lake Fork)						
RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
	2008	**Lake Fork** WWH -EOLP-				
7.9	52	42	FULL	66.5	17.8	US 62
4.8	44	42	FULL	64.0	24.0	Bruce Rd.
0.1	53/ 9.6	44	FULL	85.0	34.0	SR 13
	1999	**Lake Fork** WWH -EOLP-				
0.1	44/ 9.2	-	(FULL)		34.0	SR 13
HUC 05040006 0202 Clear Fork Licking River Assessment Unit (Clear Fork Licking River)						
	2008	**Clear Fork** WWH -EOLP-				
5.5	54	VG	FULL	84.0	12.1	From Dutch Lane Rd.
0.1	38[ns]/ 8.0	48	FULL	84.5	22.0	SR 13

Table 22 continued

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
HUC 05040006 0203 Dog Hollow Run - North Fork Licking River Assessment Unit (North Fork, dst. from Sycamore Creek to ust. Clear Fork)						
	2008	**North Fork** WWH -EOLP-				
18.8	52/ 10.2	-	(FULL)	88.5	113.0	Ust. Utica, Kirkpatrick Rd.
17.7	50/ 9.6	42	FULL	83.5	116.0	At Utica, US 62
17.1	51/ 9.2	48	FULL	81.5	117.0	Dst. Utica WWTP
15.5	49/ 10.1	42	FULL	82.5	119.0	Dst. Velvet Ice Cream
11.1	49/ 10.0	52	FULL	86.0	158.0	Ust. St. Louisville, SR 13
	1999	**North Fork** WWH -EOLP-				
11.5	52/ 9.7	44	FULL	-	162.0	Ust. St. Louisville, SR 13
HUC 05040006 0204 Dry Creek Assessment Unit (Dry Creek)						
	2008	**Dry Creek** WWH -EOLP-				
7.6	54	VG	FULL	77.0	7.8	Dry Creek Rd.
5.0	58	Excpt.	FULL	67.5	19.0	Dry Creek Rd.
0.4	42/ 8.5	44	FULL	57.0	24.0	SR 13
HUC 05040006 0205 Log Pond Run - North Fork Licking River Assessment Unit (North Fork, dst. from Clear Fork)						
	2008	**North Fork** WWH -EOLP-				
2.8	49/ 10.2	48	FULL	87.5	230.0	Water Works Rd.
0.1	48/ 9.1	42	FULL	61.0	241.0	Ohio St.
		Log Pond Run WWH -EOLP-				
0.1	48	Poor*	NON	49.5	7.6	Riverside Dr.
HUC 05040006 0205 Log Pond Run - North Fork Licking River Assessment Unit (North Fork, dst. from Clear Fork)						
	1999	**North Fork** WWH -EOLP-				
4.4	46/ 8.8	40	FULL	-	225.0	Ust. Newark WTP
	1993	**North Fork** WWH -EOLP-				
2.5/ 2.8	51/ 10.9	44	FULL	82.5	230.0	Water Works Rd.
0.2	46/ 9.4	Fair*	PARTIAL	60.0	241.0	Ohio St.
	1985	**North Fork** WWH -EOLP-				
0.9	52/ 9.5	-	(FULL)	-	231.0	Everett Park
	1982	**North Fork** WWH -EOLP-				
2.4/ 2.8	41/ 9.3	42	FULL	77.0	230.0	Water Works Rd.
	1981	**North Fork** WWH -EOLP-				
2.0	39[ns]/ 8.6[ns]	-	(FULL)	-	230.0	Manning St.
0.7/ 0.2	31*/ 7.7*	38	PARTIAL	-	239.0	Ohio St.

***** Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
ns Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).
a The MIwb (Modified Index of well-being) is not applicable to headwater sites (<20mi^2). Boat critera *only* apply to all Licking Large River Assessment Unit sites.
b Narrative evaluation used in lieu of ICI (Excpt=Exceptional; Good; MG=Marginally Good; Fair; Poor; VPoor=Very Poor).
(Full**)** Use attainment status based on one organism group is parenthetically expressed.

Narrative ranges and **WWH** biocriteria for the Erie-Ontario Lake Plain ecoregion. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide. For WWH, the ranges of marginally good and nonsignificant departure are the same.

Headwater IBI	Wading IBI	Wading MIwb	ICI	Narrative Evaluation
50-60	50-60	≥9.4	46-60	Exceptional
46-49	46-49	8.9-9.3	42-44	Very Good
Erie-Ontario Lake Plain				
40-45	**38**-45	**7.9**-8.8	**34**-40	Good
36-39	34-38	7.4-7.8	30-32	Marginally Good
28-35	28-33	5.9-7.3	14-28	Fair
18-27	18-27	4.5-5.8	8-12	Poor
12-17	12-17	0-4.4	≤6	Very Poor

Table 23 North Fork aquatic life use impairment signatures based on biological sampling conducted during July through October, 2008.

Location / RM	**Stressor** (Source)	**Exposure** (Cause)	**Response** (Evidence)
HUC 05040006 0102 Headwaters North Fork Licking River Assessment Unit (North Fork, ust. from Otter Fork)			
North Fork RM 37.9	Centerburg WWTP	Ammonia Nutrients	ICI=Fair*
HUC 05040006 0104 Vance Creek - North Fork Licking River Assessment Unit (Vance Creek and North Fork, dst. from Otter Fork to ust. Sycamore Creek)			
Vance Creek RM 0.7	Agriculture	Ammonia Nutrients D.O.	ICI=Poor* IBI=36^{ns}
HUC 05040006 0205 Log Pond Run - North Fork Licking River Assessment Unit (North Fork, dst. from Clear Fork)			
Log Pond Run RM 0.1	Urban Runoff Stormsewers	COD	ICI=Poor*

RACCOON CREEK

There were no violations of chemical water quality standards found in the Raccoon Creek watershed. Interstitial flow noted at the mouth of Lobdell Creek triggered depressed D.O. concentrations; however this type of situation is not technically a violation of water quality standards since it can be a typical (and natural) summertime occurrence during dry spells. Dry weather essentially lowers the water table and the stream disappears into the sand and gravel until rains arrive and the water table rises again.

Two sites on the upper portion of Raccoon Creek were the only sites that did not attain biological water quality standards. These sites were in partial attainment, but each partially attained based on differing criteria. The site at RM 23.90 (upstream Johnstown WWTP discharge) did not attain the appropriate fish community criteria. The site at RM 23.70 (downstream Johnstown WWTP discharge) did not attain due to issues in the invertebrate community (Table 25). Chemical analysis of these areas failed to specifically indicate why there was only partial attainment in the biology. Increased concentrations of total phosphorus, TKN, and nitrate+nitrite downstream of the Johnstown WWTP at RM 23.70 (Figure 5) may be part of the problem at RM 23.70 along with agricultural or rural/urban development factors (Table 26). Similar factors seem to be causing non-attainment at the upstream location (without the nutrient influence from the WWTP).

Bacteriological sampling for *E. coli* revealed non-attainment of geometric mean primary contact recreational standards for nearly all stream segments in the watershed (Table 24). Salt Run was the only stream in full attainment of the recreational use. Causes and sources of non-attainment include chronic bacterial pollution from a wide variety of sources including agricultural business, combined sewer overflows, stormwater runoff, and rural home sewage treatment systems.

Trends in water chemistry were difficult to evaluate based on spotty historical data, but generally indicated similar or better (e.g., lower concentrations of nutrients) chemical water quality in 2008 when compared with past years (Figure 5).

Sediment samples obtained from six locations in the Raccoon Creek watershed revealed minor amounts of contamination from one organic chemical (pentachlorophenol) and a few metals (Tables 8 and 9). Biological communities were unaffected by the presence of these materials and fully attained biological criteria.

Village of Johnstown WWTP

The wastewater treatment works is located at 470 West Jersey Street and discharges to Raccoon Creek at RM 23.78. The WWTP was upgraded in 2005-2006 with a new design flow of 1.2 MGD. Treatment processes and equipment include: screening, grit removal with a sequencing batch reactor followed by ultraviolet disinfection. Sludge is land applied at agronomic rates on Ohio EPA authorized sites. Compliance at this facility has been very good since the new plant was placed into service.

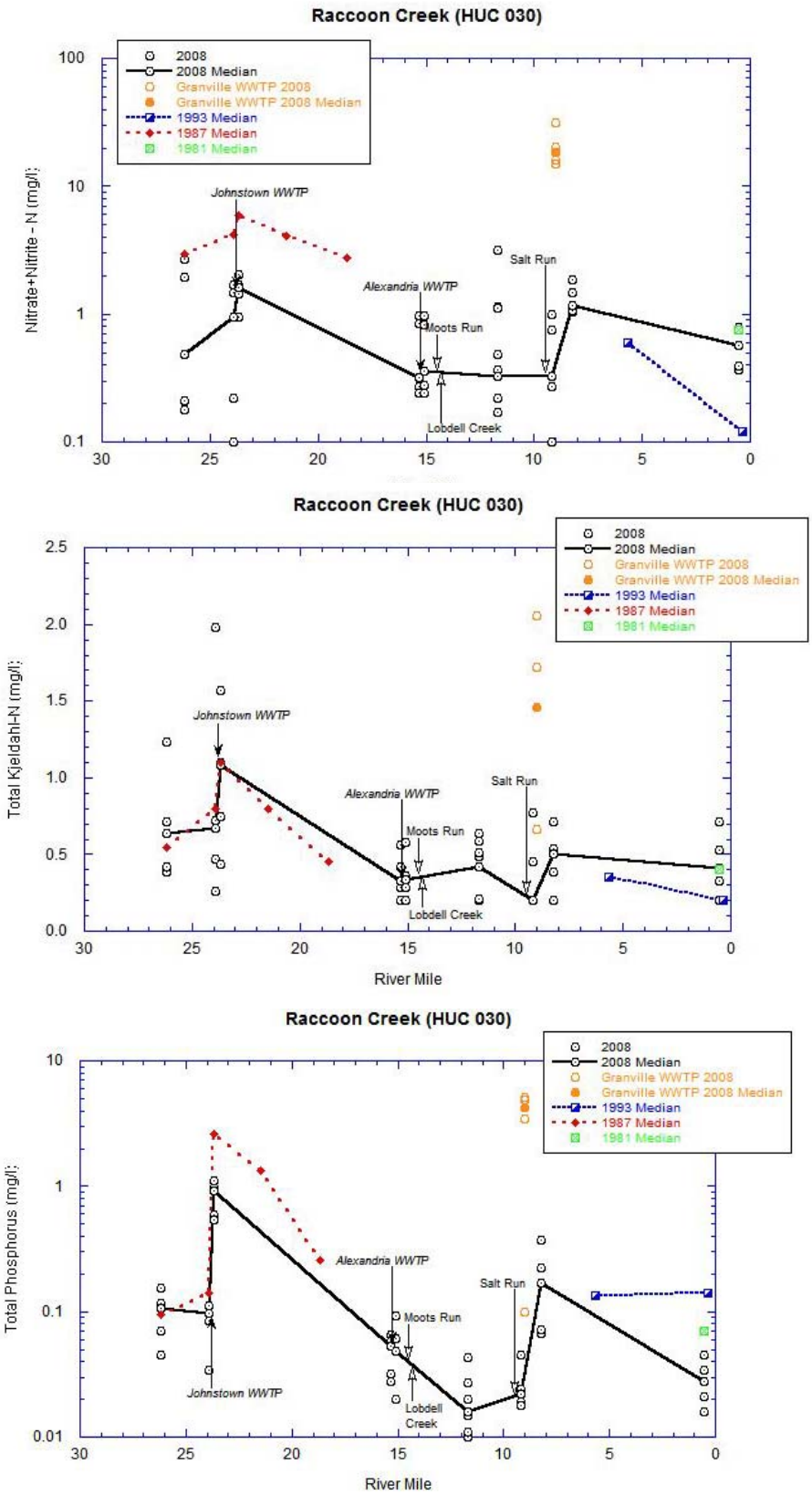

Figure 5 Longitudinal summary of median concentrations of nitrite+nitrate-N, TKN, and total phosphorus in Raccoon Creek, 2008.

Table 24 Raccoon Creek recreational use attainment status, May 1-October 15, 2008. All values are expressed as *E. coli* colony forming units per 100 ml of water (cfu/100ml).

RM	N	gm$\bar{x}$	Max.	STATUS	Location
Raccoon Creek *PCR Class B*					
26.20	7	1362	9900	NON	SR 37
23.90	7	1194	4600	NON	Ust Johnstown WWTP
23.70	7	1016	4000	NON	Mink St.
15.30	7	477	850	NON	Ust Alexandria WWTP
15.12	7	488	1400	NON	SR 37
11.70	9	523	3200	NON	CR 539A
9.20	7	479	1800	NON	SR 661
7.86	7	684	3100	NON	SR 16
0.60	7	437	790	NON	Wilson St.
Moots Run *PCR Class B*					
0.55	5	190	810	NON	SR 161
Salt Run *PCR Class B*					
0.20	5	128	1100	FULL	Weaver Dr.
Lobdell Creek *PCR Class B*					
8.70	5	194	650	NON	Nicholas Ln.
0.20	8	550	1700	NON	Raccoon Valley Rd.

PCR Criteria	gm$\bar{x}$	Max.
Class A	<126	≤298
Class B	<161	≤523

Village of Johnstown WTP

The water treatment plant is located at 395 West Jersey Street in Johnstown and discharges to an unnamed tributary which confluences with Raccoon Creek at RM 23.10. Construction on this upgraded plant was completed in 1995. The ground water treatment process uses lime softening technology. Wastewater supernatant from the process is discharged to the stream. Wastewater discharge permit compliance has been very good.

Village of Alexandria WWTP

The Alexandria WWTP is located 550 feet southeast of the intersection of Granville Street and State Route 37. The treatment works discharges into Raccoon Creek at approximately RM 25.30. The plant and new sanitary sewer collection system were placed into service in 2005. The treatment processes and equipment include: screening, flow equalization, extended aeration, secondary clarification, fixed media clarification, sand filtration, post aeration and ultraviolet disinfection. Sludge is hauled to another WWTP for disposal. Wastewater discharge permit compliance has been very good.

Village of Granville WWTP
The treatment works is located at 456 Main Street and discharges into Raccoon Creek at RM 11.50. The WWTP design flow is 1.2 million gallons per day. The treatment processes and equipment include: screening, activated sludge extended aeration, clarification, chlorination, dechlorination, and post aeration. Sludge is land applied at agronomic rates on Ohio EPA authorized sites.
The village plans to replace the chlorination/dechlorination disinfection system with an ultraviolet light disinfection system in the near future. Disinfection system improvements will improve compliance at this facility.

Village of Granville WTP
The water treatment plant is located at 456 South Main Street in Granville and discharges to Raccoon Creek at RM 9.68. The ground water treatment process uses lime softening technology. Wastewater supernatant from the process is discharged to the stream. Wastewater discharge permit compliance has been very good.

Owens Corning, Granville
The WWTP is located at 2790 Columbus Rd. in Granville and discharges to an unnamed tributary (RM 0.55) which confluences with Raccoon Creek at RM 11.25. The WWTP design flow is 0.150 MGD. Treatment processes include: screening, flow equalization, aeration, sedimentation, and ultraviolet light disinfection followed by effluent polishing. Wastewater discharge permit compliance has been very good.

HUC 05040006 0301 Headwaters Raccoon Creek Assessment Unit
Located on the western edge, in the central part of the Licking River watershed, the 27.0 mi^2 Headwaters Raccoon Creek AU includes Johnstown and the largely agricultural area nearby (53% row crop, 19% pasture). Most small tributaries are maintained for agricultural drainage in this generally flat, glaciated area with few wooded places (18%). The AU's downstream terminus includes an unnamed stream which joins Raccoon Creek upstream from the Duncan Plains Rd. crossing (RM 18.93).

The Johnstown WWTP outfall is at RM 23.78 on Raccoon Creek. In 2008, two locations were sampled upstream from the facility and another was situated immediately downstream. Slow, rather monotonous flow conditions with under developed riffle, run, and pool sequences detracted from generally good (QHEI $\bar{x}$=74) habitat attributes throughout the reach. Sediments were silty and more embedded downstream from the WWTP.

Variable aquatic community scores were registered at the three Raccoon Creek sites in the AU. Good scores (IBI=48, ICI=Good) at SR 37 (RM 26.2) were generated by a mainly insectivorous (69%) fish community with modest species richness (14) and numerical abundance (Rel.No.–tol./0.3Km=242). The assemblage included few omnivores (15%), few pollution tolerant fish (30%), and limited pioneers (24%). The likewise moderately diverse macroinvertebrate community was predominated by midges and other typical taxa. Nine pollution sensitive EPT taxa were noted at SR 37.

Upstream from the Johnstown WWTP (RM 23.9), a fair fish community (IBI=32*) complimented a marginally good macroinvertebrate community (ICI=32^{ns}). Fewer species (11) and fewer individual fish (Rel.No.–tol./0.3Km=198) were collected here. Fewer insectivores (53%) were among the more omnivorous (24%), pollution tolerant (46%), and pioneer (56%) oriented assemblage. Aquatic invertebrates were less diverse. The community included seven EPT taxa and low D.O. tolerant red midges.

Downstream from the Johnstown WWTP (RM 23.7), an improved fish community (IBI=40) was incongruent with an additional decline registered by the fair scoring macroinvertebrates (ICI=24*). A modest gain in fish diversity (17 species, Rel.No.–tol./0.3Km=372) was fundamental to the better index score, though the trophic composition continued to decline (insectivores=24%, omnivores=34%). The proportions of pollution tolerant (47%) and pioneer fish (44%) were similar.

Profuse filamentous algal growth and patchy, heavy deposition of fines deterred macroinvertebrate community performance at RM 23.7. The further overall loss of a few taxa, a small abundance decline, and only four EPT taxa produced the low ICI score. Lower densities of clinging mayflies (*Stenonema*) and net-spinning caddisflies (Hydropsychidae) and similar subtle shifts in the macroinvertebrate assemblage were attributed to nutrient enrichment and the presence of organic flocculants.

Water column chemical evaluation provided further clues for interpretation. Dissolved oxygen concentrations hovered near the WWH average criterion (5.0 mg/l) in half of the AU samples (10 of 20 >4.0 mg/l <6.0 mg/l). Mean D.O. concentrations were lowest upstream from the WWTP (D.O. $\overline{x}$=6.5 mg/l at RM 26.2, D.O. $\overline{x}$=5.8 mg/l at RM 23.9, and D.O. $\overline{x}$=6.2 mg/l at RM 23.7). Chemical oxygen demand (COD) followed the same pattern (COD $\overline{x}$=18 mg/l at RM 26.2, COD $\overline{x}$=25 mg/l at RM 23.9, and COD $\overline{x}$=23 mg/l at RM 23.7). Ammonia-N spikes were detected in about half of the AU samples (7 of 15).

Nutrient parameters and TDS concentrations were corroborated by the macroinvertebrate response. These exposures increased the most downstream from the WWTP (NO_2+ NO_3-N $\overline{x}$=1.1 mg/l, TP $\overline{x}$=0.1 mg/l, and TDS $\overline{x}$=403 mg/l at RM 26.2, NO_2+ NO_3-N $\overline{x}$=0.9 mg/l, TP $\overline{x}$=0.1 mg/l, and TDS $\overline{x}$=387 mg/l at RM 23.9, and NO_2+ NO_3-N $\overline{x}$=1.5 mg/l, TP $\overline{x}$=0.8 mg/l, and TDS $\overline{x}$=493 mg/l at RM 23.7).

This puzzle is further complicated by flow additions which occur between each sample location. In addition to flow from the WWTP, drainage area increases between the upstream sites by 2.5 mi^2 after the confluences of tributaries draining both rural and residential settings.

High bacteria concentrations were common to all AU samples. *E. coli* concentrations in 21 samples ranged between 390 cfu/100ml and 9900 cfu/100ml. Geometric mean values (1,362 cfu/100ml at RM 26.2, 1,194 cfu/100ml at RM 23.9, and 1,016 cfu/100ml at RM 23.7) grossly exceeded the PCR class B criterion (*E. coli*<161 cfu/100ml) at all locations. No other 2008 study area AU rivaled this area for the level of risk associated with bacterial exposure.

The gross concentrations of bacteria in all AU samples primarily implicate runoff polluted with livestock waste. Some inadequately treated residential sewage and runoff may also contribute to this violation. The low D.O., COD and ammonia-N spikes, symptomatic of the bacteria pollution, are especially harmful to fish. Normally, fish communities respond to drainage increases with increased diversity. However, the drainage increase between the upstream locations in this AU appears to be coupled with additional pollutants. The prevalence of pioneering and pollution tolerant fish combined with a decline in diversity suggest sporadic or chronic toxicity affects the middle site. The decline in macroinvertebrate performance and presence of red midges was consistent with this interpretation.

Dilution provided by the Johnstown WWTP helped the fish community respond with anticipated better diversity. But the nutrient influence evident in the macroinvertebrate assemblage also checked the fish community as demonstrated by the further decline in trophic status. The abundance of omnivorous fish downstream from the WWTP was characteristic of the foraging challenges presented by degraded substrates and algal growth. The algal growth was likely spurred on by enrichment evident in chemical parameters.

Sedimentation at the downstream locations was influenced by residential and commercial development adjacent to Raccoon Creek near SR 62. Fill placed in flood zones, acres of bare, uncultivated earth, and minimal sediment and erosion prevention practices were observed in this vicinity.

HUC 05040006 0302 Lobdell Creek Assessment Unit

Lobdell Creek joins Raccoon Creek downstream from Alexandria. The 19 mi^2 sub-basin encroaches on the eastern sides of Johnstown and Alexandria. Most of the rolling, glaciated area is cultivated for agriculture (51% row crop, 18% pasture). Forested areas (26%) are primarily adjacent to waterways, in a few small wood lots, or preserved as a park.

Two Lobdell Creek locations were sampled in 2008. Good habitat qualities (QHEI $\bar{x}$ =60) across the reach were noted. Good upstream biological performance improved to very good at the downstream site.

Chemical analysis of water samples provided results characteristic of an agricultural area. Low concentrations of ammonia-N, nutrients, and low D.O. were recorded occasionally. The downstream location was sampled once in February and twice in March. Extremely high metal concentrations in February (T-Fe=62,500 μg/l, T-Al=28,400 μg/l) were replicated at lower but still atypical concentrations in March. These high values were repeated at downstream Raccoon Creek locations. The data yields an impression that a spill or unusual discharge occurred in Lobdell Creek during the 2007 – 2008 winter.

Concentrations of bacteria exceeded the PCR class B criterion (*E. coli*<161 cfu/100ml) in 10 of 13 AU samples. The geometric mean values were above the threshold at both locations (194 cfu/100ml at RM 8.6, 550 cfu/100ml at RM 0. 2).

HUC 05040006 0303 Moots Run - Raccoon Creek Assessment Unit

The new SR 161 latitudinally bisects the 25.7 mi^2 Moots Run - Raccoon Creek AU. This sub-unit begins downstream from the Headwaters Raccoon Creek AU and ends at the Lobdell Creek confluence. SR 310 longitudinally trisects the western third of the AU. Alexandria is situated in the eastern third.

The rural spirit of the area (53% row crop, 13% pasture, 28% forest) is likely to change in the future. With two SR 161 highway interchanges, the AU is easily accessed from Columbus or Newark. The hilly, glaciated terrain will appeal to country home development and the SR 161 corridor is sure to attract business interests.

Three sites were sampled in 2008. Two Raccoon Creek locations bracketed the Alexandria WWTP. Another sample location was situated downstream from SR 161 on Moots Run. Very good stream habitat was common to all locations (QHEI $\bar{x}$=81). Good or very good aquatic community performance was recorded at all three sites. Water column chemical concentrations were universally very good.

Only three of 19 AU *E. coli* concentrations were below the PCR class B criterion (*E. coli*<161 cfu/100ml). Geometric mean concentrations (477 cfu/100ml, 488 cfu/100ml, and 190 cfu/100ml) were above the threshold at all sites. The Alexandria WWTP had no influence on Raccoon Creek. A large proportion of the bacterial contamination in this AU originates upstream in the Johnstown area.

HUC 05040006 0304 Salt Run - Raccoon Creek Assessment Unit

The Village of Granville is centrally located in the 30.9 mi^2 Salt Run-Raccoon Creek AU. This much developed (28%) AU spans Raccoon Creek between the Lobdell Creek and South Fork confluences. Newark occupies the AU's lower reach. Although glaciated, the area nevertheless includes some rather rugged hills. These steeper areas are forested (42%). Agriculture is limited in the AU (13% row crop, 18% pasture).

Salt Run, a small tributary to Raccoon Creek at RM 9.55 was assessed for water column chemical and bacteria concentrations, only. Ammonia-N was not detected, nutrient parameter concentrations were low, and other water chemistry values were very good in five Salt Run samples at Weaver Drive (RM 0.2). This was the only location in the Raccoon Creek watershed where the geometric mean *E. coli* concentration (128 cfu/100ml, n=5) achieved the PCR class B criterion (*E. coli*<161 cfu/100ml).

Four Raccoon Creek locations were evaluated in this AU. The Granville WWTP outfall was bracketed in the middle of the sites. Habitat conditions were good in the reach (QHEI $\bar{x}$=72). Performance of the biological community was very good or exceptional at all locations (IBI $\bar{x}$=51, MIwb $\bar{x}$=9.1, ICI $\bar{x}$=49). Chemical constituents in the water

column were normal. Although some ammonia-N and nutrients were present, chemical water quality was generally good in 23 Raccoon Creek samples.

Two of 30 Raccoon Creek bacteria evaluations returned values less than the relevant concentration limit. Five samples were in excess of 1,000 cfu/100ml. Eleven more samples were in excess of 500 cfu/100ml. Geometric mean *E. coli* concentrations at the four Raccoon Creek sample sites (523 cfu/100ml, 479 cfu/100ml, 684 cfu/100ml, and 437 cfu/100ml) were all well above the PCR class B criterion (*E. coli*<161 fu/100ml).

Water column chemistry reflected the presence of the Granville WWTP with some increases in downstream nitrite+nitrate-N and total phosphorus concentrations. Aside from an ability to relate a potential stressor with exposure and response data, no impact from the Granville WWTP was observed in 2008.

The amount of bacterial contamination in Raccoon Creek implicates multiple sources. The load from Johnstown with additional contribution from agricultural and rural residential sources enters this AU at unacceptable concentrations. Livestock sources upstream from Granville increase the pathogen load. Runoff and storm sewers in the Village of Granville and Newark deliver even more bacteria to the stream. Finally, Raccoon Creek supplies a large bacterial load to the South Fork of the Licking River.

Table 25 Raccoon Creek aquatic life use attainment status, 1987-2008. Symbology and ecoregional biocriteria follow.

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
HUC 05040006 0301 Headwaters Raccoon Creek Assessment Unit (Raccoon Creek, ust. from [RM 18.93] Duncan Plains Rd.)						
	2008	**Raccoon Creek** WWH -EOLP-				
26.2	48	Good	FULL	74.5	9.9	Ust. Johnstown, SR 37
23.9	34*	32[ns]	PARTIAL	69.0	12.4	Ust. Johnstown WWTP
23.7	40	24*	PARTIAL	78.0	12.4	Dst. Johnstown WWTP
	2001	**Raccoon Creek** WWH -EOLP-				
28.2	28*	Poor*	NON	43.0	4.5	Clover Valley Rd.
26.2	40	MG[ns]	FULL	79.0	9.9	Ust. Johnstown, SR 37
24.0	40	-	(FULL)	79.0	11.2	Ust. Johnstown WWTP
21.5	36[ns]	-	(FULL)	73.0	16.5	Caswell Rd.
19.7	46	-	(FULL)	80.5	20.4	SR 310
	2000	**Raccoon Creek** WWH -EOLP-				
28.2	27*	Poor*	NON	39.5	4.5	Clover Valley Rd.
26.2	41	Fair*	PARTIAL	73.0	9.9	Ust. Johnstown, SR 37
24.0	41	Fair*	PARTIAL	73.0	11.2	Ust. Johnstown WWTP
21.5	38[ns]	Fair*	PARTIAL	60.5	16.5	Caswell Rd.
19.7	42	Fair*	PARTIAL	85.5	20.4	SR 310
	1999	**Raccoon Creek** WWH -EOLP-				
28.2	40	Poor*	NON	37.5	4.5	Clover Valley Rd.
26.2	36[ns]	Poor*	NON	51.0	9.9	Ust. Johnstown, SR 37

Table 27 continued

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
1999		**Raccoon Creek** WWH -EOLP--(continued)				
24.0	18*	24*	NON	64.5	11.2	Ust. Johnstown WWTP
21.5	30*	Fair*	NON	68.0	16.5	Caswell Rd.
1998		**Raccoon Creek** WWH -EOLP-				
26.2	46	Good	FULL	78.5	9.9	Ust. Johnstown, SR 37
1987		**Raccoon Creek** WWH -EOLP-				
26.2	46	20*	PARTIAL	82.0	9.9	Ust. Johnstown, SR 37
24.0	43	38	FULL	82.5	12.4	Ust. Johnstown WWTP
23.7	45	10*	NON	53.0	12.4	Dst. Johnstown WWTP
21.5	43	40	FULL	68.0	16.5	Caswell Rd.
HUC 05040006 0302 Lobdell Creek Assessment Unit (Lobdell Creek)						
2008		**Lobdell Creek** WWH -EOLP-				
8.6	44	Good	FULL	51.5	8.3	Nichols Lane
0.2	56	VG	FULL	68.0	18.1	Raccoon Valley Rd.
2001		**Lobdell Creek** MWH -EOLP-				
13.0	32	Fair*	PARTIAL	45.0	3.7	Woodhaven Rd.
11.0	30	Fair*	PARTIAL	37.5	5.0	Jacob White Rd.
		Lobdell Creek WWH -EOLP-				
8.6	41	MG[ns]	FULL	70.0	7.5	Nichols Lane
2001		**Lobdell Creek** WWH -EOLP-				
7.0	46	Fair*	PARTIAL	75.0	9.8	Castle Rd.
4.7	50	-	(FULL)	60.5	14.2	Sadie Thomas Rd.
2.6	54	-	(FULL)	79.5	15.7	Mounts Rd.
1.6	48	-	(FULL)	74.0	16.7	Lobdell Rd.
2000		**Lobdell Creek** MWH -EOLP-				
13.0	17*	Poor*	NON	48.0	3.7	Woodhaven Rd.
11.0	28	Poor*	NON	48.5	5.0	Jacob White Rd.
		Lobdell Creek WWH -EOLP-				
8.6	39[ns]	Fair*	PARTIAL	73.5	7.5	Nichols Lane
7.0	40	Fair*	PARTIAL	79.0	9.8	Castle Rd.
4.7	52	MG[ns]	FULL	64.0	14.2	Sadie Thomas Rd.
2.6	49	Good	FULL	49.5	15.7	Mounts Rd.
1.6	49	Good	FULL	74.5	16.7	Lobdell Rd.
1999		**Lobdell Creek** MWH -EOLP-				
12.0	12*	Poor*	NON	40.0	5.0	Woodhaven Rd.
		Lobdell Creek WWH -EOLP-				
8.3/ 9.3	14*	Poor*	NON	63.0	8.3	From Nichols Lane
6.7	24*	Fair*	NON	72.0	9.8	Castle Rd.
4.6	dry	Fair*	(NON)	63.5	14.2	Sadie Thomas Rd.
2.6	54	Fair*	PARTIAL	75.0	15.7	Mounts Rd.
1.6	48	VG	FULL	70.0	16.7	Lobdell Rd.
1998		**Lobdell Creek** MWH -EOLP-				
12.0	29	Poor	NON	36.5	5.0	Woodhaven Rd.

Table 27 continued

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
	1993	**Lobdell Creek** WWH -EOLP-				
1.6	40	-	(FULL)	51.5	16.7	Lobdell Rd.
0.2	48	-	(FULL)	70.5	18.1	Raccoon Valley Rd.
HUC 05040006 0303 Moots Run - Raccoon Creek Assessment Unit						
(Raccoon Creek, dst. from [RM 18.93] Duncan Plains Rd. to ust. from Lobdell Creek)						
	2008	**Raccoon Creek** WWH -EOLP-				
15.4	49/ 8.6	42	FULL	79.5	37.0	Ust. Alexandria WWTP
15.1	48/ 8.7	34	FULL	78.5	37.0	Dst. Alexandria WWTP
		Moots Run WWH -EOLP-				
0.6	48	Good	FULL	83.5	8.5	SR 161
	2001	**Raccoon Creek** WWH -EOLP-				
16.9	49/ 8.9	Good		75.5	27.0	Jersey Mill Rd.
	1999	**Raccoon Creek** WWH -EOLP-				
16.9/18.6	52/ 9.6	VG	FULL	66.0	27.0	Jersey Mill/ Duncan Plains Rd.
	1987	**Raccoon Creek** WWH -EOLP-				
18.6	45/ 8.6	38	FULL	76.0	27.0	CR 33
HUC 05040006 0304 Salt Run - Raccoon Creek Assessment Unit						
(Raccoon Creek, dst. from Lobdell Creek)						
	2008	**Raccoon Creek** WWH -EOLP-				
11.7	49/ 8.5	-	(FULL)	60.0	78.0	CR 539
9.2	51/ 8.9	52	FULL	72.0	82.0	Ust. Granville WWTP, SR 37
8.3	52/ 9.3	52	FULL	79.0	86.0	Dst. Granville WWTP
0.5	50/ 9.7	42	FULL	77.0	102.0	Wilson St.
	1993	**Raccoon Creek** WWH -EOLP-				
5.6	43/ 10.0	46	FULL	77.5	94.0	Cherry Valley Rd.
0.2	50/ 10.2	MG[ns]	FULL	65.0	103.7	Wilson St.

***** Significant departure from ecoregion biocriterion; poor and very poor results are underlined.

ns Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).

a The MIwb (Modified Index of well-being) is not applicable to headwater sites (<20mi^2). Boat critera *only* apply to all Licking Large River Assessment Unit sites.

b Narrative evaluation used in lieu of ICI (Excpt=Exceptional; Good; MG=Marginally Good; Fair; Poor; VPoor=Very Poor).

(Full**)** Use attainment status based on one organism group is parenthetically expressed.

Narrative ranges and **WWH** biocriteria for the Erie-Ontario Lake Plain ecoregion. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide. For WWH, the ranges of marginally good and nonsignificant departure are the same.

Headwater IBI	Wading IBI	Wading MIwb	ICI	Narrative Evaluation
50-60	50-60	≥9.4	46-60	Exceptional
46-49	46-49	8.9-9.3	42-44	Very Good
Erie-Ontario Lake Plain				
40-45	**38**-45	**7.9**-8.8	**34**-40	Good
36-39	34-38	7.4-7.8	30-32	Marginally Good
28-35	28-33	5.9-7.3	14-28	Fair
18-27	18-27	4.5-5.8	8-12	Poor
12-17	12-17	0-4.4	≤6	Very Poor

Table 26 Raccoon Creek aquatic life use impairment signatures based on biological sampling conducted during July through October, 2008.

HUC 05040006 0301 Headwaters Raccoon Creek Assessment Unit (Raccoon Creek, ust. from [RM 18.93] Duncan Plains Rd.)			
Location / RM	**Stressor** (Source)	**Exposure** (Cause)	**Response** (Evidence)
Raccoon Creek RM 23.9	Rural residences Agriculture Land development	Ammonia Nutrients Sedimentation	IBI=34*
Raccoon Creek RM 23.7	Johnstown WWTP Rural residences Agriculture Land development	Ammonia Nutrients Sedimentation	ICI=24*

SOUTH FORK (EXCLUDING RACCOON CREEK)

Chemical water quality sampling in the South Fork watershed revealed very few violations of water quality standards. Only two streams showed violations of D.O. minimum criteria; Muddy Fork at RM 3.70 and Waste Weir Run at RM 1.55 (Table 6). Biological attainment status in both of these streams was either partial or not attaining the WWH biological criteria.

Specifically, Muddy Fork macroinvertebrate communities were only in fair condition (fish were in attainment) resulting in only partial attainment at both Muddy Fork sites (Table 28). At RM 3.70, this appeared to be due to several issues, including D.O. violations along with organic enrichment evidenced by elevated COD concentrations. The site at RM 0.08 was likely affected by organic enrichment as well (3 of 5 COD values exceeding median background), although dissolved oxygen concentrations were above minimum standards (Table 29).

Waste Weir Run is a small stream which receives most of its flow from the dam overflow of Buckeye Lake. There were violations of minimum D.O. criteria found instream in addition to biological non-attainment due to the chronic presence of ammonia and general nutrient enrichment. Discharges from impoundments are typically problematic to stream biota directly downstream from the release point. Water from Waste Weir Run or other outlets from Buckeye Lake did not seem to negatively impact South Fork.

Bacteriological sampling revealed chronic problems with bacterial contamination in the form of *E. coli*. Neither of the two Class A sites on South Fork attained the recreational use standard. Most of the Class B sections were also in non-attainment with the exception of four sites (Table 27). Both Class C sites met the criteria associated with recreational use. Sources of bacteria include mainly wet weather sources including sanitary and combined sewer overflows at many of the wastewater treatment facilities (see discussions below) in addition to runoff from agricultural sources, urban and rural stormwater, and home sewage treatment systems.

Trend analysis revealed mixed results. Parameters such as D.O. (along with others) evaluated in 2008 were generally very similar to historical values (Figure 6). Ammonia-N concentrations decreased downstream from municipal WWTPs in 2008 when compared with historical data. This was indicative of improved treatment at most of the WWTPs in the South Fork watershed although some still have compliance issues (discussed below). Total phosphorus concentrations between RM 20 and RM 15 revealed large increases in 2008 compared with historical data possibly indicative of increased loadings from both Kirkersville WWTP and Southwest Licking Community Water and Sewer District WWTP or other sources, possibly agricultural.

Sediment samples obtained from eight locations in the South Fork watershed revealed minor amounts of contamination from a few PAHs and metals (Tables 8 and 9). Biological communities were unaffected by the presence of these materials and in full attainment of aquatic life use criteria.

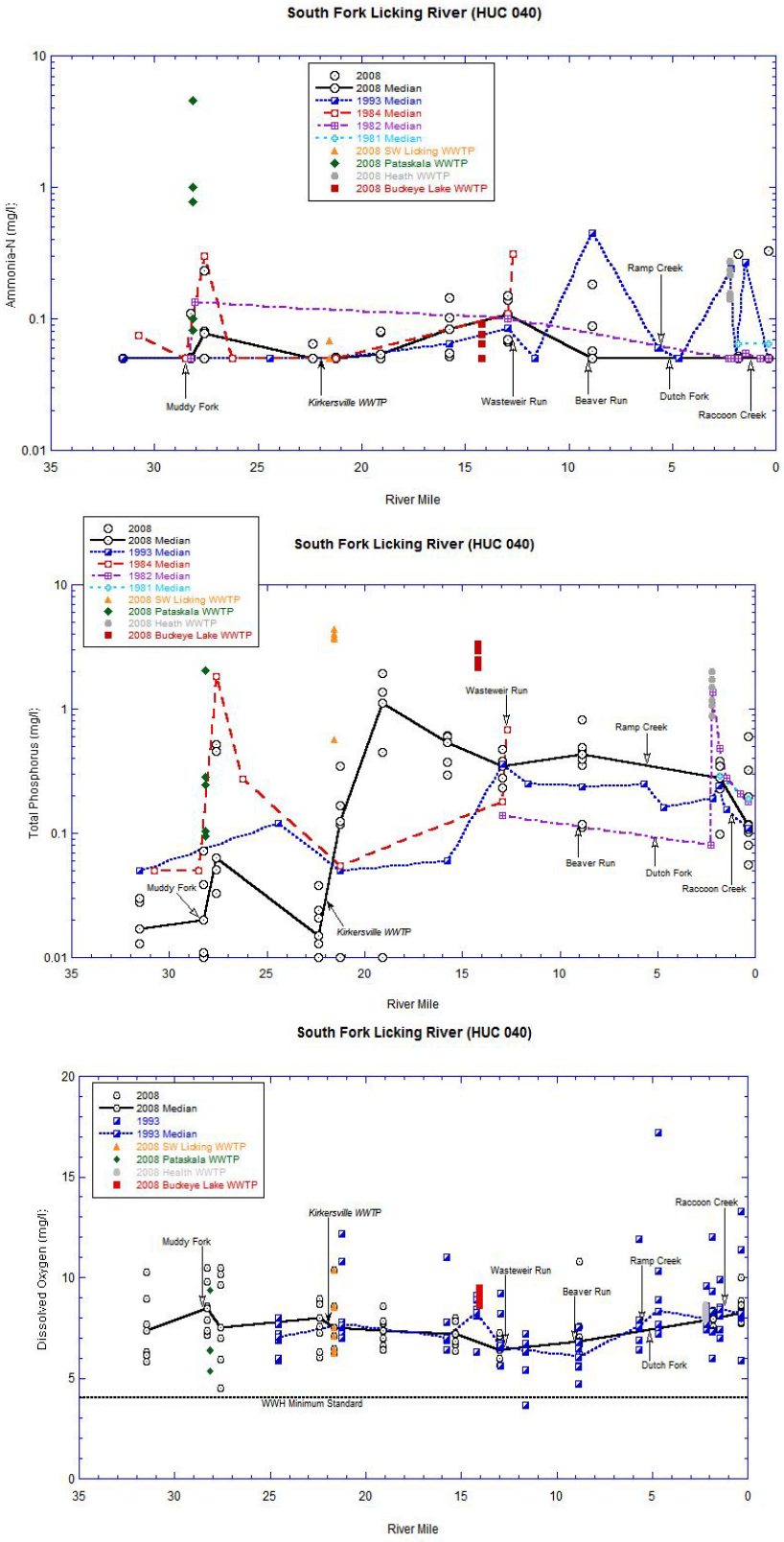

Figure 6 Longitudinal summary of median concentrations of ammonia-N, total phosphorus, and D.O. in the South Fork, 2008.

Table 27 South Fork recreational use attainment status, May 1-October 15, 2008. All values are expressed as E. Coli colony forming units per 100 ml of water (cfu/100ml).

RM	N	$gm\bar{x}$	Max.	STATUS	Location
South Fork *PCR Class B*					
31.5	7	586	2100	NON	Cable Rd
28.3	7	290	2900	NON	Key Blvd.
27.6	7	143	490	FULL	Dst Pataskala
22.4	9	63	220	FULL	Outville Rd.
21.6	7	202	630	NON	Ust Gale Rd.
19.1	7	596	12000	NON	US 40
15.3	7	288	760	NON	SR 79 / 360
13.0	7	204	360	NON	SR 79
8.8	9	332	2500	NON	Ridgely Tract
PCR Class A					
1.8	7	239	25000	NON	Hopewell Dr.
0.3	8	239	25000	NON	2nd St.
Muddy Fork *PCR Class B*					
3.7	5	69	120	FULL	Columbia Rd .
0.1	5	319	1200	NON	Mill St.
Wasteweir Run *PCR Class B*					
1.60	5	180	1300	NON	Walnut St.
Honey Creek *PCR Class B*					
0.80	5	628	6700	NON	Honey Creek Rd.
Beaver Run *PCR Class B*					
2.05	5	1172	3400	NON	Canyon Rd.
0.45	5	492	2400	NON	SR 79
Dutch Fork *PCR Class B*					
3.63	5	1020	20000	NON	SR 13
0.90	5	255	390	NON	White Chapel Rd.
Ramp Creek *PCR Class B*					
5.73	5	117	490	FULL	Deeds Rd.
0.20	5	264	19000	NON	SR 79
Reservoir Feeder *PCR Class C*					
0.50	5	116	840	FULL	SR 37
0.30	5	161	190	FULL	Dst Millersport WWTP

PCR Criteria	$gm\bar{x}$	Max.
Class A	<126	≤298
Class B	<161	≤523
Class C	<260	≤940

Village of Pataskala WWTP
The treatment works is located at 388 Shawnee Loop Street and discharges to the South Fork Licking River at RM 28.16. The WWTP design flow is 1.1 MGD. The treatment process and/or equipment include: screening, oxidation ditch/extended aeration, clarification, ultraviolet disinfection followed by cascade aeration. Two lagoons are available but currently are not used in the treatment processes at this facility. Sludge is currently disposed in a landfill but land application may resume in the future.

Wastewater discharge permit compliance has not been good at this WWTP during wet weather events. Wet weather I&I of water into the separate sanitary collection system results in periodic, sanitary sewer overflows from the oxidation ditch. The village has inspected and improved its sanitary sewer collection system to minimize I&I but has been unable thus far to eliminate SSO events. The wastewater discharge permit contains a schedule requiring improvements necessary to eliminate SSO events and to provide for consistent compliance with the NPDES permit.

Village of Pataskala WTP
This water treatment plant was placed into service early in 2007. It is located at the NE Corner of Refugee and Watkins Rd.s southeast of Pataskala and discharges to the South Fork Licking River at RM 25.70.

The ground water treatment processes consist of iron removal filters and ion-exchange water softening. Iron filter backwash wastewater is routed to sand filter beds to remove suspended solids before discharge to the river. Water softening wastewater is routed to a waste detention tank where the TDS concentration may be diluted, if necessary, prior to discharge. Wastewater discharge permit compliance in 2007 and 2008 was poor as this new plant was placed online and operational troubles were encountered. Permit compliance has improved in 2009 as these problems were resolved.

Village of Kirkersville WWTP
The treatment works is located along the north side of US Route 40 on the east side of Kirkersville and discharges to the South Fork Licking River at RM 21.82. The WWTP design flow is 0.1 MGD. Treatment processes and equipment include: screening, flow equalization, extended aeration, secondary clarification, fixed media clarification, sand filtration followed by ultraviolet disinfection. Sludge is disposed at a solid waste landfill. Wastewater discharge permit compliance has been good.

Southwest Licking Community Water and Sewer District WWTP
The WWTP is located at 8720 Gale Rd. east of Kirkersville and discharges to the South Fork Licking River at RM 21.48. The WWTP design flow is 4.3 MGD. Influent wastewater is routed to and divided between two treatment trains: an oxidation ditch (designated as the “old plant”) which was constructed in 1994; and an extended aeration reactor (the “new plant”) which was a part of an upgrade completed in 2004. Treatment processes and/or equipment include: mechanical screening, extended aeration (new plant), oxidation ditch (old plant), secondary clarification, post aeration;

and ultraviolet disinfection. Sludge is land applied to Ohio EPA authorized sites at agronomic rates.

Wet weather I&I of water into the district's separate sanitary collection system results in periodic SSOs at various locations. The district has been aggressively working to eliminate SSO events by improving its collection system. Even though SSO events continue to be an issue in the collection system; wastewater discharge permit compliance has been very good at this WWTP.

Licking County Commissioners Buckeye Lake Sewer District #1 WWTP
The treatment works is located at 458 Hilton Rd. in the Village of Buckeye Lake and discharges to the South Fork of the Licking River at RM 14.20. The WWTP design flow is 2.0 MGD. Treatment processes and equipment include: flow retention basins, bar screening, comminution, primary settling, oxidation ditch aeration, secondary clarification and ultraviolet disinfection. Sludge may be land applied on Ohio EPA authorized sites at agronomic rates or disposed at a solid waste landfill.

The collection system employs both gravity and small diameter septic tank effluent pump (STEP) systems to convey sanitary sewage to the treatment plant. While this collection system is classified as a separate system, there has been a great deal of I&I into the system particularly during wet weather periods. Detention basin overflows had frequently occurred in the past to Wasteweir Run, a tributary of South Fork. In 2005 the sewer district signed a Consent Decree with USEPA requiring WWTP and sanitary sewer collection system upgrades to eliminate overflow events. In 2008 the upgraded WWTP was placed into service. Improvement of the sanitary sewer collection system is continuing to reduce I&I into the system. Wastewater discharge permit compliance for the upgraded WWTP has been very good.

Village of Hebron WWTP
The treatment works is located at 3261 Hebron Rd. SE north of Hebron and discharges to Beaver Run which confluences with South Fork Licking River at RM 9.03. The WWTP design flow is 1.5 MGD. Treatment processes and equipment include: screening, grit and scum removal, flow equalization, primary clarification, activated sludge extended aeration, secondary clarification, sand filtration, and ultraviolet disinfection followed by post aeration. Sludge may be land applied on Ohio EPA authorized sites at agronomic rates, disposed of at a solid waste landfill, or hauled to another permitted facility. Effluent quality and permit compliance improved greatly in late 2006 when the upgraded WWTP was placed into service. But, continued sporadic effluent violations remain a problem under scrutiny by Ohio EPA and the village.

City of Heath WWTP
The treatment works is located at 719 Lickingview Drive and discharges to the South Fork at RM 2.20. The WWTP design flow is 1.75 MGD. Treatment processes and equipment include: a bar screen, grit removal, activated sludge extended aeration, secondary clarification, scum removal, post aeration, chlorination and dechlorination. A sand filter exists at the WWTP but the filter is out of service and in need of repair.

Sludge is land applied at agronomic rates on Ohio EPA authorized sites. Wastewater discharge permit compliance at this facility has been somewhat inconsistent and routinely scrutinized by Ohio EPA.

Village of Thornville WWTP
The treatment works is located at 100 Thompson Drive and discharges to an unnamed tributary at RM 0.10 which subsequently flows into Honey Creek at RM 2.55. Treatment processes and equipment include motorized auger screening, flow equalization, liquid chemical precipitant feed, extended aeration, settling, rapid sand filtration, and UV disinfection. Sludge is processed through a plate press with polymer addition and stored on site dry.

Thornville had problems complying with their NPDES permit in 2008 particularly during precipitation events where I&I into the collection system hydraulically overloaded the plant causing permit violations. Typically, the WWTP is underloaded with dry weather discharge well under the design flow of 0.4 MGD. Compliance has improved through 2009. The village is also studying I&I problems with the goal of significantly decreasing wet weather flow to the plant.

Village of Millersport WWTP
The WWTP is located at the northern edge of Millersport just east of Millersport Rd. and discharges to the Reservoir Feeder at RM 0.32. The WWTP design flow is 0.302 MGD. The plant was initially constructed in the early 1960s and was upgraded to its current configuration in 1987. Influent wastewater flows through a bar screen to an oxidation ditch fitted with propeller mixers and air diffusers. It is then routed through intra-channel clarifiers integral to the oxidation ditch and then to a settling tank prior to disinfection with ultraviolet radiation. Filter press dewatered sludge is disposed at a sanitary landfill.

Wet weather I&I of stormwater into the village's separate sanitary collection system results in periodic overflow from manholes or lift stations. The village has been aggressively working to eliminate SSO events by relining and repairing sewers and the future installation of a flow equalization basin to handle increased flows during precipitation events.

HUC 05040006 0401 Muddy Fork Licking River Assessment Unit
The smallest AU in the Licking River watershed is located in the far south west part of the 2008 study area. The Muddy Fork (14.1 mi^2) includes part of the Village of Pataskala and the developing area (10%) west from it. As the greater Columbus area expands, agricultural land use (56% row crop, 15% pasture) is lessoning. The generally flat, glaciated AU is in the ECBP ecoregion. Most headwater streams are channelized and managed for agricultural drainage. Woodlots (19%) exist on poorly drained soils and in narrow corridors flanking larger streams.

Limited flow and indistinct separation between riffles, runs, or pools were countered by good substrate variety and multiple cover components so that both Muddy Fork sample sites achieved good QHEI scores ($\bar{x}$=69). Aquatic assemblages responded differently

to contrasting habitat attributes. Principally, a very good fish community (IBI $\bar{x}$=48) resided in Muddy Fork in 2008. A fair macroinvertebrate community failed to achieve the biocriterion at both Muddy Fork locations.

Although both Muddy Fork macroinvertebrate assemblages achieved fair evaluations, each earned the grade via different low metric scores. The upstream moderately diverse community lacked pollution sensitive taxa and was predominated by low D.O. tolerant red midges. The downstream less diverse community included low abundances of pollution sensitive organisms and notably more black fly larvae (*Simulium spp.*).

Two of five water column samples at the upstream Muddy Fork site (RM 3.7) had D.O. concentrations (3.99 mg/l, 3.67 mg/l) below the WWH minimum criterion (4.0 mg/l). The average D.O. concentration ($\bar{x}$=5.57 mg/l) fell close to the WWH average criterion (5.0 mg/l), too. Oxygen demand was elevated at both locations as eight of ten COD sample values were greater than the ecoregion WWH median (11.5 mg/l, OEPA 1999). Average COD concentrations at both sites (18 mg/l, 20 mg/l) were above the ECBP WWH $75^{th}\%_{tile}$ (17.0 mg/l).

Chloride concentrations were high at both Muddy Fork sites ($\bar{x}$=66.2 mg/l at RM 3.7, $\bar{x}$ =61.5 mg/l at RM 0.1, ECBP WWH $50^{th}\%_{tile}$=20.0 mg/l, $75^{th}\%_{tile}$=80.5 mg/l). Sodium concentrations at both locations were elevated compared to other study area streams. The mean RM 0.1 TDS concentration (480 mg/l) exceeded the ecoregion WWH $75^{th}\%_{tile}$ (443 mg/l). Conductivity jumped between sites ($\bar{x}$=605 µS/cm at RM 3.7, $\bar{x}$=822 µS/cm at RM 0.1, ECBP WWH $90^{th}\%_{tile}$=803 µS/cm). Other parameters also registered significant increases between sampling locations. Alkalinity nearly doubled, calcium and hardness increased by a third, and strontium concentrations more than tripled.

Muddy Fork's dissimilar chemical mixtures were replicated by the bacteriological results. Upstream, *E. coli* concentrations (gm$\bar{x}$=69 cfu/100ml at RM 3.7) were among the lowest recorded in the 2008 Licking River study area. Downstream, *E. coli* concentrations (gm$\bar{x}$=319 cfu/100ml at RM 0.1) were almost twice the PCR class B criterion (*E. coli*<161 fu/100ml).

Low flow combined with organic enrichment characteristic of the upstream drained wetland heritage was responsible for the biocriteria departure at RM 3.7. Flow was noticeably increased at RM 0.1. Together, the response and exposure variables indicate additional stressors exist between sample locations. The presence of many groundwater constituents in water column samples suggests a spring fed tributary joins Muddy Fork or that another source was discharging to Muddy Fork or that both possibilities were factors.

From 6.3 mi^2 to 14.1 mi^2, drainage area doubled between Muddy Fork sampling sites. Among several tributaries joining Muddy Fork in this reach, none are particularly unique. Yet, any one of them could convey the majority of the difference in downstream bacteria

load. Possible pathogen sources include inadequately treated sewage and runoff from residential areas or livestock manure.

The macroinvertebrate biocriteria departure at RM 0.1 was likely influenced by increased exposure concentrations but habitat conditions were deemed to be a greater factor. Evidence of high scouring flows leaving steep eroded banks and continually redistributing stream bed aggregate was considered sufficient to perpetually disturb macroinvertebrate colonization. In other places, sediment had smothered marginal cover and degraded macroinvertebrate habitat. The reach immediate to the bridge displayed instability associated with an undersized conveyance.

Agricultural tile drainage and municipal storm sewers quickly convey surface water to streams. Increasing development sponsors increased drainage which in turn increases peak flows. Scoured stream reaches are unstable. Their temporary condition, lack of well defined riffle, run and pool sequences, and disruptive sediment deposition can challenge sensitive taxa.

Muddy Fork at RM 0.1 has experienced aggressive stream flows. The macroinvertebrate assemblage was sensitive to the extreme events. The fish community was less disturbed in part because the nearby confluence with the South Fork provided a refuge and a recolonization reservoir. While this exceptional community was diverse, it included modest numbers of pollution sensitive fish, lacked some darter species present at nearby sites, and had fewer simple lithophils. These modest diversions supported the conclusion that habitat more than chemical exposures were fundamental to the invertebrate response.

HUC 05040006 0402 Headwaters South Fork Licking River Assessment Unit

The 15.4 mi^2 South Fork watershed upstream from the Muddy Fork confluence includes the principal part of Pataskala and extends north where new development within the SR 161 corridor will bring future land use changes. Currently, 12% of the AU is comprised by residential or commercial type property. Agriculture (42% row crop, 19% pasture) is likely to decline as the Columbus metro area grows. Forested lots in this gently rolling glaciated sub-basin are allied with more rugged places or more poorly drained spots.

Biological performance at the single sample site was good (IBI=48, ICI=38). Stream habitat earned a very good QHEI score (79.5). Water column chemical parameters were consistent with good quality. Nutrients were low or not detected.

The amount of waterborne bacteria was high (*E. coli* gm$\bar{x}$=586 cfu/100ml). All samples at Cable Rd. (RM 31.5) exceeded the PCR class B criterion (*E. coli*<161 cfu/100ml). Among seven cultures, *E. coli* concentrations ranged from 220 cfu/100ml to 2,100 cfu/100ml. A mix of rural residential and agricultural sources were present in the AU.

HUC 05040006 0403 Buckeye Lake Assessment Unit

The Buckeye Lake AU (27.1 mi^2) includes the lake and the tributaries which drain to it. Honey Creek (6.7 mi^2) is the largest of these streams. Several small towns are situated

in or on the AU divide. Buckeye Lake, Harbor Hills, Fairfield Beach, Millersport, and Thornville, along with the Lake itself, occupy 20% of the area. Nearly two-thirds of the AU land use is agricultural (49% row crop, 13% pasture) and 17% is wooded. Trees are present in some odd parcel areas and along some small streams in the mostly flat, glaciated locale.

Honey Creek was sampled at RM 0.8, upstream from the Buckeye Lake backwater. The modified stream had fair habitat quality (QHEI=59.5). Biological performance was good (IBI=36, ICI=Good). Nutrient concentrations were high in five samples at this site (NO_2+ NO_3-N $\bar{x}$=3.1 mg/l, TP $\bar{x}$=0.1 mg/l).

Concentrations of *E. coli* ranged from 270 cfu/100ml to 6,700 cfu/100ml. The geometric mean bacteria value (*E. coli* gm$\bar{x}$=628 cfu/100ml) exceeded the PCR class B criterion (*E. coli*<161 cfu/100ml). Plausible residential and agricultural sources exist upstream.

Buckeye Lake was assessed for the proposed Lake Habitat aquatic life use consistent with Ohio's Inland Lake Monitoring program. Buckeye Lake is impaired based on a median chlorophyll-a concentration (76.4 µg/l) greater than the recommended median criterion (14.0 µg/l) and a high percentage (70%) of average D.O. criterion excursions in the lake epilimnion. Median total nitrogen (1075 µg/l), total phosphorus(34 µg/l), and Secchi depth values all exceeded the proposed median corresponding criterion (total nitrogen<930 µg/l, total phosphorus<67.5 µg/l) and resulted in the lake being considered "Watch" status for all three.

Cyanobacteria called blue-green algae can produce microcystin toxins. In June 2009, ODNR reported a microcystin toxin concentration (10.0 ppb) from Fairfield Beach at half the World Health Organization recreational guidance criteria (20.0 ppb). Samples were also obtained from Brooks (1.4 ppb) and Crystal Beaches (0.7 ppb). After the initial spike at Fairfield Beach, weekly summer samples from all three locations returned results hovering near 1.5 ppb (n=32). Ohio EPA sampled Buckeye Lake weekly at the same sites in 2010. Lower microcystins were typical (0.5 ppb, n=43).

Ohio EPA also evaluated Buckeye Lake in 1994, 1993, 1992, and in five other previous field years. All prior studies determined the shallow impoundment to be over productive, prone to D.O. concentration extremes, and a source of organic loading to the South Fork. The most recent secchi depths are 25% less than were recorded in the 1990's. Efforts to prevent nutrient input to Buckeye Lake are strongly encouraged.

HUC 05040006 0404 Buckeye Lake Reservoir Feeder Assessment Unit

Agriculture (61% row crop, 13% pasture) is the principal land use in the Reservoir Feeder AU. Interstate 70 crosses the upper third of the sub-basin. It and the two small towns of Kirkersville and Millersport comprise 11% of the watershed. Only 15% of the flat glaciated area remains forested.

Historically, Buckeye Lake was a reservoir used to supply water to the Ohio Canal. The Reservoir Feeder, a hand dug channel, once routed water from the South Fork to

Buckeye Lake. The Reservoir Feeder AU boundary (17.2 mi^2) is defined by the enhanced drainage system which diverts a natural drainage tendency away from the South Fork and channels the flow to Buckeye Lake.

The Reservoir Feeder drains a small area relative to its channel capacity. Consequently, the low gradient, over wide ditch does not effectively transport bed load and the channel is filling with sediment. Functionally, the ditch is like a linear wetland rather than a riffle pool sequenced stream. Maintenance near roadways or by individual landowners has been piecemeal. Otherwise, parts of the Reservoir Feeder have been allowed to recover naturally for 100 years. Indeed, large cottonwood and other mature trees flank both banks along much of its course. The diked elevated channel contains abundant woody debris and aquatic vegetation.

The 2008 study included two Feeder sample sites. Encountering the atypical stream, each sample team moved the planned upstream location to suit their discipline constraints. The macroinvertebrates were evaluated in a shallow flow limited reach among a thick growth of aquatic vegetation. The fish community was assessed further downstream in a locally maintained glide surrounded by corn fields. Chemical water column samples were obtained just upstream from the Millersport WWTP discharge (RM 0.32).

This scattershot reaction affirms the asymptotic conditions pertinent to the Feeder. Ohio EPA routinely samples ditches, cutoff diversions, and many stream abstractions. The Reservoir Feeder is unique. On paper it appears to flow into Buckeye Lake. Sometimes, some of the Feeder flow is received by the lake. Most of the time it does not appear to have any flow. Some of the flow finds its former natural course and ends up in the South Fork. The extensive tile drainage system adds another element of guesswork to understanding flow patterns.

Flow or drainage area is an important consideration in appreciating biological performance. On paper it might seem that the Feeder drains 17 - 18 mi^2. Depending on how flow is managed through the Pigeon Swamp Petition Ditch the total Reservoir Feeder AU area plausibly could outlet to Buckeye Lake. Most often, the area north from I-70 flows via the Petition Ditch to the South Fork.

The site downstream from the Millersport WWTP is impounded by Buckeye Lake. Dimensionally it seems like a river. The tree lined banks include habitat features less common in backwaters. Tree root wads, boulders and emergent vegetation provide cover opportunities. Some substrate and depth heterogeneity are present. These river like features contrast with the sites headwater drainage area.

Recognizing the unique Reservoir Feeder characteristics, biological performance was consistent with the habitat. The upstream fish assemblage was comprised by 12 species. A third (34%) were tolerant to pollution, half were omnivorous, but only a quarter (21%) were pioneering types. Larger percentages of pioneers imply instability. The substrates were not conducive to more insectivores or sensitive species. A fourth

of the fish were gizzard shad. These and logperch darter were likely Buckeye Lake emigrates.

The downstream fish community was typical of a lake. It included nine logperch darter, 741 gizzard shad, 47 saugeye, 34 white x striped hybrid bass, 26 yellow perch, 144 bluegill, 29 black or white crappie, and 16 largemouth bass. The absence of redhorse or other suckers and lack of minnows made for poor scores for those and the simple lithophil metrics.

The macroinvertebrate community performed similarly. The EPT taxa numbers were low and tolerant taxa were numerous. Both assemblages appeared consistent with the wetland or lake environments where they resided.

Two upstream bacteria samples all but failed to generate cultures (*E. coli* gm$\bar{x}$=20 cfu/100ml). Two others resulted in a geometric mean (*E. coli* gm$\bar{x}$=116 cfu/100ml) less than the PCR class B criterion (*E. coli*<161 cfu/100ml). Downstream *E. coli* bacteria concentrations were all less than 200 cfu/100ml but the geometric mean (*E. coli* gm$\bar{x}$ =161 cfu/100ml) exceeded the criterion.

At the upstream site, two of five D.O. concentrations were less than a 4.0 mg/l minimum criterion. Both sites returned one just detectable ammonia-N concentration. Nitrite+nitrate-N concentrations were erratic. Two upstream and four downstream concentrations were elevated. The early upstream spike abated and subsequent values were less than or at detection. The downstream concentrations were high but correlation with any stressor is diluted by lake conditions. In summary, the upstream chemistry appeared modestly enriched and the downstream conditions were very enriched.

HUC 05040006 0405 Kirkersville - South Fork Licking River Assessment Unit

A rapidly growing area (15% developed), the Kirkersville – South Fork AU encompasses the Pataskala and Etna vicinities (17.2 mi^2) beginning downstream from the Muddy and South Fork confluence and ending at the Kirkersville South Fork dam. Crossed by US 40 and I-70 in the south and SR 16 to the north, the generally flat, glaciated AU is easy to access. Its agricultural heritage (46% row crop, 16% pasture, forest 23%) is being exchanged for rural residences. In 2008, two upstream sample locations bracketed the Pataskala WWTP and a third downstream sample site was within the pool created by the Kirkersville dam.

Ammonia-N was detected in four of five samples downstream from the Pataskala WWTP. The highest ambient sample concentration (0.23 mg/l) was obtained just before collecting a facility effluent sample with a high ammonia-N concentration (4.53 mg/l). Nitrite+nitrate-N concentrations were low ($\bar{x}$=0.3 mg/l, n=17). Total phosphorus concentrations tended to be low through the reach ($\bar{x}$=0.22 mg/l). Collectively, ammonia and nutrient concentrations were regarded as possible downstream loading concerns and less likely as reach specific stressors.

Good to very good habitat quality was observed across the reach in 2008 (QHEI $\bar{x}$ =75.1) and in 1993 (QHEI $\bar{x}$=76.8). The persistence of similar attributes over a 15 year period suggested some of the extreme flow stress at the lower Muddy Fork site was abated by downstream stability. Even so, aquatic community performance declined slightly in this reach between the two surveys. Very good 1993 communities (IBI $\bar{x}$ =47.3, MIwb $\bar{x}$=9.4, ICI $\bar{x}$=36, n=3) declined to good community performance in 2008 (IBI $\bar{x}$=43.7, MIwb $\bar{x}$=8.8, n=3, ICI=good, n=2). The decline resulted from the absence of one or two species in all samples. Pollution sensitive minnow species were absent or less abundant in 2008.

This decline is an opportunity to consider pertinent factors in this AU and the Bell Run – South Fork AU immediately downstream. Population growth, new home development, and increased effluent flow affect both AUs. With increasing stressors, habitat conditions have remained the same and biological assemblages have declined in the upstream AU. Downstream, biological assemblages have improved with habitat gains despite additional loading.

The diminishing margin of assimilative capacity in the Kirkersville – South Fork AU can be affected in a variety of ways. Proactive measures to buffer storm water flash flows, conservation practices to retard soil erosion, and increasing the width of riparian corridor can make a significant difference. Aerial photography reveals several places where encroachment on the stream margin facilitates soil runoff, bank erosion and contributes to stream instability. Enhancement of the stream assimilative capacity through improvement of the riparian corridor is encouraged.

The effluent domination of this reach by the Pataskala WWTP was most apparent in the bacteriological sampling. Upstream, all *E. coli* sample concentrations exceeded the PCR class B criterion (*E. coli*<161 cfu/100ml). Most samples and the geometric mean *E. coli* values at both sites downstream from the facility were less than the criterion. (*E. coli* gm$\bar{x}$=143 cfu/100ml at RM 27.6 and *E. coli* gm$\bar{x}$=63 cfu/100ml at RM 27.6).

HUC 05040006 0406 Bell Run - South Fork Licking River Assessment Unit

Commencing on the South Fork at the Kirkersville dam and ending downstream from the confluence with Waste Weir Run, the Bell Run – South Fork AU (26.0 mi^2) drains some of the flattest, glaciated topography in the Licking River watershed. Bisected by US 40 and split again by I 70, the area appears more developed than it is (55% row crop, 15% pasture, forest 16%). Numerous rural residences, the Village of Buckeye Lake, and the small towns of Outville and Luray comprise the developed fraction (14%).

Four 2008 sample sites were located downstream from the Village of Kirkersville WWTP, downstream from the Southwest Licking Community WWTP at US 40, and two sites bracketed the South Fork Buckeye Lake WWTP discharge. Ammonia, nutrients and parameters associated with treated effluent were present in all water column samples. The highest average concentrations were measured at the US 40 site (NO_2+ NO_3-N $\bar{x}$=7.8 mg/l, TP $\bar{x}$=1.0 mg/l, and TDS $\bar{x}$=914 mg/l, RM 19.1). Elevated ambient chloride concentrations correlated with effluent sample values. Average chloride

sample content ($\bar{x}$=299 mg/l) was highest at RM 19.1. The low gradient of this reach is most noticeable downstream from the Buckeye Lake WWTP. Average D.O. concentrations declined here ($\bar{x}$=6.4 mg/l, RM 13.0) and ammonia-N was detected in all samples ($\bar{x}$=0.11 mg/l).

Stream habitat quality has continued to improve in this historically modified reach. In 1993, fair habitat conditions (QHEI $\bar{x}$=55.2) were associated with good to very good aquatic community performance. Fifteen years of natural attenuation have contributed to the same numerical increase in the average habitat score (QHEI $\bar{x}$=70.0). Commensurate gains in biological index scores were indicative of very good to exceptional aquatic assemblages. These gains have occurred at the same time effluent volume has also increased. In both surveys, modest nutrient enrichment and other effluent constituents could have easily overwhelmed water quality expectations.

Normally the last process before discharge to a receiving stream, most WWTPs are required to disinfect effluent. Consequently, effluent dominated streams convey proportionately less bacteria than would be present absent the addition of artificial flow. Compared to other Licking River basin streams, the South Fork conveys the most effluent and proportionately the least amount of bacteria.

Nevertheless, geometric mean *E. coli* concentrations were still greater than the PCR class B criterion (*E. coli*<161 cfu/100ml) at all sites. Individual sample values under the threshold were obtained on three occasions downstream from the Kirkersville WWTP and twice each at locations bracketing the Buckeye Lake facility.

Waste Weir Run was created to convey excess water from Buckeye Lake in the canal era. Prior to 1992, the Buckeye Lake WWTP discharged to Waste Weir Run. Chemical and bacteriological sampling in Waste Weir Run occurred at one location within a few hundred yards downstream from the Buckeye Lake outlet structure. Absent any apparent source of bacteria, it was puzzling that three *E. coli* concentrations exceeded the PCR class B criterion as did the geometric mean value (gm$\bar{x}$=180 cfu/100ml at RM 1.6)

Effects of Buckeye Lake algal respiration were evident in Waste Weir Run water column samples. Chronologically, the first two samples differed from the later three. Initial D.O. concentrations were consistent with WWH expectations. Later summer values were well below aquatic life requirements ($\bar{x}$=4.8 mg/l, n=5). Anoxic conditions were apparent as the summer progressed (ammonia-N $\bar{x}$=0.13 mg/l, n=5). All organic nitrogen (TKN $\bar{x}$ =0.76 mg/l, n=5) and oxygen demand (COD $\bar{x}$=26 mg/l, n=5) concentrations were elevated.

Waste Weir Run was evaluated in 1984 at two sites bracketing the Buckeye Lake WWTP. Overall, biological performance was poor. Since the 1984 evaluation the WWTP outfall was moved to discharge to the South Fork. No assessment of Waste Weir Run occurred in subsequent surveys until 2008.

The existence of an additional Buckeye Lake outlet structure complicates biological index score calculation based on drainage area. By design, higher flows are released from the Sellers Point structure. Both outlets have control mechanisms that could be used to appreciably change lake water level. The Waste Weir outlet is designed to rapidly release water below normal lake levels as needed in an emergency. Under lower summer influent flow conditions, lake discharge from both structures is minimized.

The construction of Waste Weir Run was accomplished so that some water remains in the channel even if no flow is contributed by Buckeye Lake. It is a rock lined trapezoidal low gradient ditch which offers poor habitat quality (QHEI=41) to aquatic communities. In 1984 it contained an array of lake type fish. In 2008, 16 Waste Weir fish species could be described the same way. A few less tolerant types and the singular instance of capturing a mudminnow helped the 2008 community into the fair IBI score range. The poor macroinvertebrate community will improve when Buckeye Lake water quality conditions improve. Allowing some water to perennially flow through the channel will help stabilize habitat conditions.

HUC 05040006 0407 Ramp Creek Assessment Unit

Ramp Creek drains (16.8 mi^2) the rolling mixed land use area south from Granville, north from Hebron, and east from SR 16; with a South Fork confluence in Heath (12% developed, 32% row crop, 26% pasture, and 29% forest). Sampling in 2008 occurred upstream at Deeds Rd. (RM 5.7) and downstream at SR 79 (RM 0.2).

Good habitat conditions in the rural upstream reaches transitioned to fair quality in the more urban lower reach. Exceptional fish and good macroinvertebrate communities inhabited each site. Water column chemical sampling results were normal at both locations. Nutrient parameters and constituents of concern mentioned in regard to other AUs were detected at concentrations which can be characterized as background levels.

Bacteria sampling results were also better than or typical for the area. The upstream geometric mean *E. coli* concentration (117 cfu/100ml) was less than the PCR class B criterion (*E. coli*<161 cfu/100ml). The downstream geometric mean *E. coli* concentration (264 cfu/100ml) would have achieved the criterion except that a rather spurious sample (19000 cfu/100ml) skewed the central tendency. This sample is at odds with other bacteria collected on the same date. The possibility of localized runoff is suggested because the only instance of ammonia-N (0.08 mg/l) detected in the basin was a co-occurrence.

In 1993 four sample locations between RM 2.0 and the South Fork confluence were assessed to discover whether the industrial /commercial area along lower Ramp Creek was a source of reported spills. A petroleum impact was documented at one location where macroinvertebrate performance was poor. Otherwise, exposures were low and biological response in the reach was good. The past record of spills and the spurious 2008 bacteria sample could be construed to imply occasional pulses of pollutants emanate from the industrial /commercial park. Good housekeeping is encouraged to reduce these non-trivial events.

HUC 05040006 0408 Dutch Fork Licking River Assessment Unit

Dutch Fork drains a 21.8 mi^2 area comprised by 36% row crop, 23% pasture, and 31% forest land uses. Overall, biological performance and habitat conditions at both 2008 sample locations were very good. Water chemistry suggested a source(s) of modest amounts of nitrogenous waste was present upstream from SR 13. This load was assimilated a mile and a half downstream at White Chapel Rd. Geometric mean *E. coli* values followed the same pattern although concentrations at both sites exceeded the PCR class B criterion (*E. coli*<161 cfu/100ml).

HUC 05040006 0409 Beaver Run - South Fork Licking River Assessment Unit

Almost a third (30%) of the Beaver Run – South Fork AU is within the developed Hebron and Heath areas (32% row crop, 13% pasture, and 23% forest). Beginning downstream from Waste Weir Run, this area includes the lower South Fork and Beaver Creek. WWTP stress previously limited biological response in the area.

Fair biological performance was documented in the lower South Fork in 1981 (IBI $\bar{x}$=33, MIwb $\bar{x}$=7.4, ICI $\bar{x}$=31). The Buckeye Lake, Hebron, and Heath WWTPs were required to improve effluent quality. In 1993, biological performance was very good to exceptional (IBI $\bar{x}$=51, MIwb $\bar{x}$=10.0, ICI $\bar{x}$=42). The facility upgrades all occurred within a few years prior to the 1993 assessment. Very good habitat quality (QHEI $\bar{x}$=76.0) further bolstered the health of aquatic communities in 1993.

Between 1993 and 2008, Buckeye Lake and Hebron increased their facility design outflow capacities to just less than double their former capacity (1.78 MGD to 3.5 MGD). Heath's 1.75 MGD WWTP is essentially the same as operated in 1993 with expected issues associated with age. In 2008, aquatic community performance declined (IBI $\bar{x}$ =46, MIwb $\bar{x}$=8.6, ICI $\bar{x}$=42), but still reflected acceptable water quality conditions. Habitat quality also declined to good (QHEI $\bar{x}$=67.7).

Water column sample results reveal a trend of nutrient assimilation through the reach. Starting upstream from the Buckeye Lake WWTP (RM 15.8), high total phosphorus concentrations ($\bar{x}$=0.48 mg/l) were influenced by additional flow from the Hebron and Heath WWTPs and from Raccoon Creek. Total phosphorus concentrations averaged 0.20 mg/l at the most downstream South Fork site (RM 0.4). The same trend was apparent in nitrite+nitrate-N concentrations ($\bar{x}$=5.0 mg/l at RM 15.8 and $\bar{x}$=1.1 mg/l at RM 0.4). Ammonia-N was detected at each location once or twice amongst the five or more samples at each ambient site. All detections were at low concentrations but still add to the cumulative stress through the reach. Likewise, COD concentrations through the reach were occasionally moderately elevated and overall represented oxygen demands that were persistently and potentially stressful.

The 2008 habitat quality decline was most evident in the upper part of the reach. Stream substrates in the Ridgley Tract area (RM 8.9) have become more homogenous and appeared embedded with limited differentiation among gravels. Substrates across the reach in 1993 had more heterogeneity and included an abundance of coarse aggregates intermixed with gravels. Little riparian corridor is present in the reach

upstream from Beaver Run. The increased WWTP nutrient load, ample sun light, and fewer substrate interstitial voids have been factors in subtle fish community shifts. The decline to good water quality at Ridgley Tract indicates the assimilative capacity of this reach is becoming challenged.

Two Beaver Run locations bracketing the Hebron WWTP were sampled in 2008. Upstream water chemistry results were normal with some indications of low flow oxygen demand. Beaver Run provides minimal dilution to Hebron's effluent. Downstream nutrient concentrations closely mirrored outfall ratios. Both sites had good aquatic community performance. Half (54%) of the more diverse upstream fish assemblage were tolerant of lower water quality. A less abundant downstream fish assemblage was better balanced by insectivores (72%). Facultative EPT macroinvertebrate taxa were abundant upstream while more tolerant taxa were present downstream.

E. coli concentrations were erratic and geometric mean values were skewed by stormwater runoff. At both downstream South Fork sites (RM 1.8 and RM 0.4) the same very high *E. coli* concentration (25,000 cfu/100ml) on June 26, 2008 produced the same geometric mean value ($gm\bar{x}$=239 cfu/100ml) at each site. The Heath WWTP effluent sample on that date (980 cfu/100ml) suggested the plant was overwhelmed by I&I. Ten of 16 *E. coli* concentrations from the downstream locations were above PCR class A criterion (*E. coli*<126 cfu/100ml). Eight of nine bacteria samples and the geometric mean concentration exceeded the PCR class B criterion (*E. coli*<161 cfu/100ml) at the Ridgley Tract site (RM 8.9).

Excluding Raccoon Creek, the highest bacteria concentrations in the South Fork were cultured from the upstream Beaver Run site ($gm\bar{x}$=1172 cfu/100ml, RM 13.0). All five samples from this location and three of five from the downstream site ($gm\bar{x}$=492 cfu/100ml, RM 8.9) were more abundant than the PCR class B criterion.

Table 28 South Fork aquatic life use attainment status, 1981-2008. Symbology and ecoregional biocriteria follow.

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
HUC 05040006 0401 Muddy Fork Licking River Assessment Unit (Muddy Fork)						
	2008	**Muddy Fork** WWH -ECBP-				
3.7	44	Fair*	PARTIAL	70.5	6.3	Columbia Rd.
0.1	52	Fair*	PARTIAL	68.0	14.1	Creek Rd.
HUC 05040006 0402 Headwaters South Fork Licking River Assessment Unit (South Fork, ust. from Muddy Fork)						
	2008	**South Fork** WWH -ECBP-				
31.5	48	38	FULL	79.5	11.4	Cable Rd.
	1993	**South Fork** WWH -ECBP-				
31.5	47	Good	FULL	60.0	11.4	Cable Rd.
	1984	**South Fork** WWH -ECBP-				
31.5	36[ns]	40	FULL	64.0	11.4	Cable Rd.

Table 30 continued

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
	1984	**South Fork** WWH -ECBP- (continued)				
28.5	42	30*	PARTIAL	70.0	15.8	Ust. Pataskala WWTP
	HUC 05040006 0403 Buckeye Lake Assessment Unit (Buckeye Lake and tributaries)					
	2008	**Honey Creek *WWH Recommended*** -EOLP-				
0.8	36[ns]	Good	FULL	59.5	6.6	Honey Ck. Rd.
	HUC 05040006 0404 Buckeye Lake Reservoir Feeder Assessment Unit (Reservoir Feeder)					
	2008	**Reservoir Feeder *MWH Recommended*** -EOLP-				
1.9	30	-	(FULL)	41.0	14.8	SR 37
0.5	29/ 6.5	Fair	FULL	36.0	18.0	Millersport Rd.
	1999	**Reservoir Feeder** -EOLP-				
0.4	36/ 8.4	2	(NON)	-	18.0	Millersport Rd.
	1984	**Reservoir Feeder** -EOLP-				
0.5	26/ 7.2	Fair	FULL	-	18.0	Millersport Rd.
	HUC 05040006 0405 Kirkersville - South Fork Licking River Assessment Unit (South Fork, dst. from Muddy Fork to ust. Reservoir Feeder)					
	2008	**South Fork** WWH -ECBP-				
28.3	39/ 8.0	Good	FULL	76.5	30.0	Ust. Pataskala WWTP
27.6	45/ 9.4	32[ns]	FULL	73.5	32.0	Dst. Pataskala WWTP
		South Fork WWH -EOLP-				
24.5	47/ 8.9	-	(FULL)	75.5	43.0	Ust. SW Licking WWTP
	1993	**South Fork** WWH -ECBP-				
28.3	47/ 9.4	32[ns]	FULL	64.5	30.0	Ust. Pataskala WWTP
27.6	49/ 9.6	36	FULL	83.0	32.0	Dst. Pataskala WWTP
24.5	46/ 9.1	40	FULL	83.0	43.0	York Rd.
	1984	**South Fork** WWH -ECBP-				
27.6	37[ns]/ 9.9	42	FULL	69.0	32.0	Dst. Pataskala WWTP
26.2	36[ns]/ 8.2	-	(FULL)	68.0	38.0	Ust. Jordan Manor WWTP
	HUC 05040006 0406 Bell Run - South Fork Licking River Assessment Unit (South Fork, dst. from Reservoir Feeder to dst. Waste Weir Run)					
	2008	**South Fork** WWH - EOLP -				
21.3	51/ 9.6	VG	FULL	67.0	51.0	Dst. SW Licking WWTP
19.1	52/ 9.5	36	FULL	73.5	55.0	US 40
15.3	48/ 8.8	46	FULL	69.5	64.0	Ust. Buckeye Lake WWTP
13.0	-	44	(FULL)	-	69.0	Dst. Buckeye Lake WWTP
		Waste Weir Run *MWH Recommended* - EOLP -				
1.6	34 /-	Poor*	NON	41.0	NA	SR 79
	1993	**South Fork** WWH - EOLP -				
21.3	52/ 9.6	Good	FULL	67.0	51.0	Gale Rd.
15.3	49/ 8.6	50	FULL	59.5	64.0	Ust. Buckeye Lake WWTP
13.1	37[ns]/ 8.9	34	FULL	39.0	69.0	Dst. Buckeye Lake WWTP
	1984	**South Fork** WWH -ECBP-				
21.5	47/ 10.1	-	(FULL)	-	58.0	Dst. Jordan Manor WWTP

Table 30 continued

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
	1984	**South Fork** WWH -ECBP-(continued)				
21.3	44/ 10.2	42	FULL	-	51.0	Gale Rd.
13.1	39[ns]/ 9.0	22*	PARTIAL	42.0	69.0	Ust. Waste Weir Run
		Waste Weir Run *MWH Recommended*- EOLP -				
0.7	26	Fair*	NON	-	NA	Ust. Buckeye Lake WWTP
0.4	24	Poor*	NON	-	NA	Dst. Buckeye Lake WWTP
		HUC 05040006 0407 Ramp Creek Assessment Unit (Ramp Creek)				
	2008	**Ramp Creek** WWH -EOLP-				
5.7	50	Good	FULL	74.0	4.9	Deeds Rd.
0.2	50	Good	FULL	57.0	16.7	SR 79
	1993	**Ramp Creek** WWH -EOLP-				
2.0	53	42	FULL	80.5	14.3	Heath Boundary Rd.
1.4	53	42	FULL	76.5	16.0	Dst. Koper Co.
0.7	51	Poor*	NON	66.5	16.7	Dst. Kaiser Aluminum
0.1	55	52	FULL	75.5	17.1	SR 79
		HUC 05040006 0408 Dutch Fork Licking River Assessment Unit (Dutch Fork)				
	2008	**Dutch Fork** WWH -EOLP-				
3.6	52	MG[ns]	FULL	67.5	10.4	SR 13
0.9	46/ 8.4	48	FULL	78.5	21.0	White Chapel Rd.
		HUC 05040006 0409 Beaver Run - South Fork Licking River Assessment Unit (South Fork, dst. from Waste Weir Run)				
	2008	**South Fork** WWH - EOLP -				
8.8	44/ 8.4	38	FULL	63.5	133.0	Dst. Beaver Run, TR 308
1.8	48/ 9.3	44	FULL	80.0	183.0	Dst. Heath WWTP
0.3	46/ 8.2	44	FULL	59.5	288.0	S. Second St.
	2008	**Beaver Run** WWH - EOLP -				
2.1	46	Good	FULL	66.5	5.0	Ust. Hebron WWTP
0.5	44	Good	FULL	51.5	7.4	Dst. Hebron WWTP
	1993	**South Fork** WWH - EOLP -				
9.4	51/ 9.9	42	FULL	76.5	120.0	Ust. Beaver Run
8.8	51/ 9.8	42	FULL	75.0	133.0	Dst. Beaver Run, TR 308
4.3	49/ 9.6	44	FULL	85.5	178.0	Ust. Heath WWTP
1.7	52/ 10.2	46	FULL	82.5	183.0	Dst. Heath WWTP
0.5	52/ 10.3	36	FULL	60.5	288.0	S. Second St.
	1981	**South Fork** WWH - EOLP -				
7.2	31*/ 7.4*	-	(NON)	-	134.0	From Reinhart Dr.
5.6	-	38[ns]	(FULL)	-	176.0	Ust. Heath WWTP
2.1	33*	-	(NON)	-	183.0	Dst. Heath WWTP
0.9/ 0.4	35*	24*	NON	-	288.0	S. Second St.

***** Significant departure from ecoregion biocriterion; poor and very poor results are underlined.

ns Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).

a The MIwb (Modified Index of well-being) is not applicable to headwater sites (<20mi^2). Boat critera *only* apply to all Licking Large River Assessment Unit sites.

b Narrative evaluation used in lieu of ICI (Excpt=Exceptional; Good; MG=Marginally Good; Fair; Poor; VPoor=Very Poor).

(Full**)** Use attainment status based on one organism group is parenthetically expressed.

Narrative ranges, **WWH** and (*MWH)* biocriteria for the Eastern Corn Belt Plains and Erie-Ontario Lake Plain ecoregions. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide. For WWH, the ranges of marginally good and nonsignificant departure are the same.

Headwater IBI	Wading IBI	Wading MIwb	ICI	Narrative Evaluation
50-60	50-60	≥9.4	46-60	Exceptional
46-49	46-49	8.9-9.3	42-44	Very Good
		Eastern Corn Belt Plains		
40-45	**40**-45	**8.3**-8.8	**36**-40	Good
36-39	36-39	7.8-8.2	32-34	Marginally Good
28-35	28-35	5.9-(*6.2*)-7.7	14-(*22*)-30	Fair
		Erie-Ontario Lake Plain		
40-45	**38**-45	**7.9**-8.8	**34**-40	Good
36-39	34-38	7.4-7.8	30-32	Marginally Good
28-35	28-33	5.9-(*6.2*)-7.3	14-28	Fair
18-(*24*)-27	18-(*24*)-27	4.5-5.8	8-12	Poor
12-17	12-17	0-4.4	≤6	Very Poor

Table 29 South Fork aquatic life use impairment signatures based on biological sampling conducted during July through October, 2008.

Location / RM	**Stressor** (Source)	**Exposure** (Cause)	**Response** (Evidence)
HUC 05040006 0401 Muddy Fork Licking River Assessment Unit (Muddy Fork)			
Muddy Fork RM 3.7	Agriculture Yard maintenance Land development	Organic enrichment D.O. Sedimentation	ICI= Fair*
Muddy Fork RM 0.1	Agriculture Yard maintenance Rural residences Land development	Organic enrichment Sedimentation	ICI= Fair*
HUC 05040006 0406 Bell Run - South Fork Licking River Assessment Unit (South Fork, dst. from Reservoir Feeder to dst. Waste Weir Run)			
Waste Weir Run RM 1.6	Buckeye Lake Flow regulation	Ammonia Nutrients	ICI=Poor*

ROCKY FORK

There were no violations of biological or chemical water quality criteria in the Rocky Fork watershed. Biological attainment was full at each location assessed (Table 31). Conversely, examination of bacteriological data in the Rocky Fork watershed revealed complete non-attainment of the recreational use geometric mean criteria for all streams assessed in the survey (Table 30). Causes and sources of bacterial contamination are mostly diffuse. However, some small WWTPs may also be contributing to the situation. Several small manufactured home communities located on Wilkins Run in addition to the Camp Ohio facility and the newer Hanover WWTP may all be chronic contributors.

Historical data for this basin was somewhat limited. Comparisons of 2008 data with available historical information showed little change except for decreased concentrations of total phosphorus (Figure 7).

Sediment samples were obtained from a site (RM 1.2) downstream from Marne Rd. on Rocky Fork. No concentrations were detected above ecoregional background (Table 9). Biological communities were in full attainment of the EWH criteria and so unaffected by sediments (Table 33).

Village of Hanover WWTP

The WWTP is located on Marne Rd. south of the village and discharges into Rocky Fork at RM 1.65. This new plant and sanitary sewer collection system was placed into service in September, 2007 and has a design flow of 0.160 MGD. Treatment processes and equipment include: screening, Kruger double oxidation ditch aeration followed by ultraviolet disinfection. Sludge is managed by hauling it to another facility.

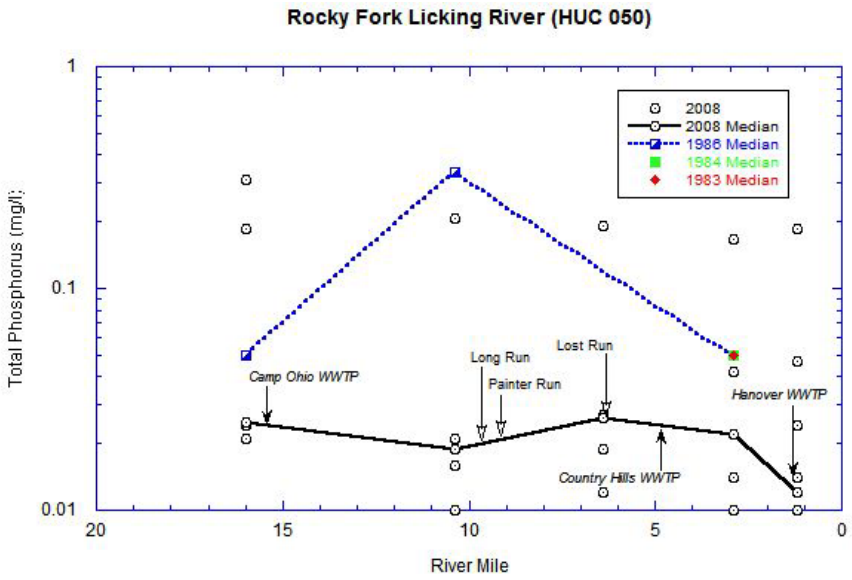

Figure 7 Longitudinal summary of median total phosphorus concentrations in the Rocky Fork, 1983 - 2008.

Table 30 Rocky Fork recreational use attainment status, May 1-October 15, 2008. All values are expressed as *E. Coli* colony forming units per 100 ml of water (cfu/100ml).

RM	N	gm$\bar{x}$	Max.	STATUS	Location
Rocky Fork *PCR Class B*					
16.00	7	1030	38000	NON	Camp Ohio Rd.
10.40	7	409	25000	NON	Rocky Fork Rd.
6.40	7	500	24000	NON	Jobes Rd.
2.91	7	354	23000	NON	Wolford Rd.
1.20	7	257	21000	NON	Marne Rd.
Claylick Creek *PCR Class B*					
0.10	5	478	9200	NON	Brownsville Rd.
Little Claylick Creek *PCR Class B*					
0.17	5	917	10000	NON	Colling Rd.
Long Run *PCR Class B*					
0.50	5	891	11000	NON	Baker Rd.
Painter Run *PCR Class B*					
0.30	5	565	7300	NON	SR 79 (south crossing)
Lost Run *PCR Class B*					
4.10	5	1100	11000	NON	Maharg Rd.
0.20	5	1027	17000	NON	adj. Jobes Rd.
Wilkins Run *PCR Class B*					
0.15	5	824	28000	NON	Wilkins Run Rd.

PCR Criteria	gm$\bar{x}$	Max.
Class A	<126	≤298
Class B	<161	≤523

Village of Hanover WWTP

The WWTP is located on Marne Rd. south of the village and discharges into Rocky Fork at RM 1.65. This new plant and sanitary sewer collection system was placed into service in September, 2007 and has a design flow of 0.160 MGD. Treatment processes and equipment include: screening, Kruger double oxidation ditch aeration followed by ultraviolet disinfection. Sludge is managed by hauling it to another facility.

WWTP operational problems led to wastewater discharge permit noncompliance which has not yet been entirely resolved. The village is working with Ohio EPA towards consistent compliance with their NPDES permit.

HUC 05040006 0501 Claylick Creek Assessment Unit

Claylick Creek (20.8 mi^2) joins the Licking River at RM 23.3, opposite and upstream from the Rocky Fork confluence (RM 21.7). This rugged, hilly AU is mostly forested (61%) with some pasture (28%) and row crop fields (6%) interspersed in flatter places.
In 2008, Claylick Creek AU water quality was assessed at two locations. Very good stream habitat (QHEI $\bar{x}$=82) supported exceptional biological communities. Water column chemical analysis returned results typical for similar rural waterways. Runoff

captured in a June sample displayed spikes of ammonia, nutrient and TSS concentrations. Several metal values were also elevated in the high flow sample.

Concentrations of *E. coli* were especially increased by runoff (9,200 cfu/100ml and 10,000 cfu/100ml). All routine bacteria samples exceeded the PCR class B criterion (*E. coli*<161 fu/100ml). Consequently, *E. coli* geometric mean concentrations were above the threshold at both sites (gm$\bar{x}$=478 cfu/100ml and gm$\bar{x}$=917 cfu/100ml).

HUC 05040006 0502 Lost Run Assessment Unit

Geologically, Lost Run (16% row crop, 30% pasture, forest 49%) is situated between the Wisconsinan and Illinoian terminal moraines. Glacial outwash contributes a large volume of flow to Wilkins Run (7.5 mi^2), a Lost Run (23.0 mi^2) tributary. Today, a fish farm on Wilkins Run benefits from the abundant water source.

The influences of a dairy farm, fish farm and 2 mobile home parks were evident in Wilkins Run water chemistry data obtained from a sample location near the Lost Run confluence. Ammonia-N ($\bar{x}$=0.14 mg/l, n=5) and nitrite+nitrate-N concentrations ($\bar{x}$=2.3 mg/l, n=5) were detected and elevated in every sample. Nitrite concentrations were odd ($\bar{x}$=0.6 mg/l, n=5), as this was the only location in the Rocky Fork drainage where nitrites were detected in normal flows.

Considering the flow volume, the source(s) of this nitrogenous load are grossly excessive. With very good habitat conditions (QHEI=75.5), fish community performance was exceptional (IBI=50) despite the exposure concentrations. Cold water temperature ($\bar{x}$=15.5°C, n=5) likely ameliorated the stress.

The Wilkins Run macroinvertebrate community achieved a good rating. The strong flow appeared at odds with an excessive amount of silt deposited in every little marginal area and slack water spot. While EPT taxa abundance was sufficient for WWH expectations, the community displayed symptoms of moderate nutrient enrichment. The strong flow over rather loose outwash gravel also challenged colonization.

Sampling in 2008 on Lost Run bracketed Wilkins Run. Upstream Lost Run water column chemistry was normal. Downstream nitrite+nitrate-N concentrations ($\bar{x}$=1.5 mg/l, n=5) remained elevated, consistent with the reduction of upstream ammonia-N. Ammonia-N was detected in one downstream sample (0.06 mg/l).

Exceptional biological performance (IBI=52, ICI=54) upstream was supported by very good habitat quality (QHEI=74.0). Downstream habitat conditions were extraordinary (QHEI=96.0). The exceptional macroinvertebrate assemblage (ICI=46) represented the better substrate variety and outstanding riffles with many different flow conditions. Even so, the index score declined downstream from Wilkins Run.

The downstream Lost Run fish community IBI score also declined to very good (IBI=46) with an exceptional MIwb value (9.5). No smallmouth bass or rock bass were present at this location. Recognizing this absence, additional sampling was conducted to ensure

an adequate variety of cover types were assessed. Although present, redhorse were numerically much fewer than were documented upstream. Small rainbow trout were collected here and at the Wilkins Run site.

The good aquatic invertebrate community in Wilkins Run was the only instance in the entire 2008 Rocky Fork sub basin where biological performance was less than exceptional. Although biological performance at all AU sites attained the WWH criteria, the declines downstream from Wilkins Run and the character of the Wilkins Run biological assemblages are disconcerting, especially in view of the tremendous flows. Further investigation is warranted to confirm potential stressors are benign.

Lost and Wilkins Run *E. coli* concentrations were grossly high on June 26, 2008 as stormwater created higher flow conditions. The bacteria concentrations at all Rocky Fork sample sites on that date stand out as the highest anywhere in the Licking River basin. The Wilkins Run sample was the third highest in the 2008 study (*E. coli*=28,000 cfu/100ml). All AU bacteria values were above the PCR class B criterion (*E. coli*<161 fu/100ml). Geometric mean *E. coli* concentrations were: gm$\bar{x}$=1100 cfu/100ml at the upstream Lost Run site, gm$\bar{x}$=1027 cfu/100ml at the downstream Lost Run site, and gm$\bar{x}$=824 cfu/100ml at the Wilkins Run location.

HUC 05040006 0503 Rocky Fork Licking River Assessment Unit

At 55.5 mi^2 the Rocky Fork is the largest AU in the Licking River watershed. It covers the area around and south from Martinsburg and includes the small communities of Purity, Rocky Fork, Hickman, and Hanover. The area (23% row crop, 20% pasture, forest 50%) was lightly sculpted by Illinoian glacial action and includes a small unglaciated central region of rock outcrops.

In 2008, five Rocky Fork sample locations were spaced from Camp Ohio Rd. (RM 16.0) to downstream from the Hanover WWTP (RM 1.2). Long and Painter Runs were each assessed at one site upstream from the respective Rocky Fork confluences. Water column chemical sampling on June 26 returned information about storm runoff. Nutrients, TSS and most metal concentrations were well above normal exposure thresholds. These high flow samples were the only occasions where ammonia-N was detected in Rocky Fork. Ammonia-N was never detected in Long or Painter Runs.

Otherwise, nitrite+nitrate-N concentrations were routinely detected at a chronic one milligram per liter rough average at all sites. This perpetual nutrient load is confounding where the natural presence would not have suggested it. With regard to this background, the discharge from the Hanover WWTP was unnoticeable. Other chemical parameter concentrations downstream from the facility were similar to upstream values. No exposure signature was evident from the entity.

Rocky Fork, Long Run and Painter Run all exhibited excellent stream habitat conditions (QHEI $\bar{x}$=86.4). Biological performance was consistently exceptional at all locations (IBI $\bar{x}$=52.6, MIwb $\bar{x}$=10.1, ICI $\bar{x}$=48). The universally high index scores, rich community

composition and robust abundance distinguish the Rocky Fork as one of Ohio's most biologically intact watersheds.

Rocky Fork was also distinguished for the highest single sample *E. coli* concentration (38,000 cfu/100ml) in the 2008 Licking River study area. This sample and others obtained during the June 26 runoff period are extreme to the point of challenging explanation. Furthermore, over the course of the summer no pattern is apparent in the bacteria data aside from this off the chart event. When considered from upstream to downstream, values at one location do not predict any trend at the next.

The intent of determining *E. coli* concentrations is to infer human health risk from recreation in the sampled stream. With two youth camps and several Hanover Parks along Rocky Fork there is ample recreational stream use. It is inherent that efforts be made in the watershed to preclude livestock waste and inadequately treated sewage from these streams.

Table 31 Rocky Fork aquatic life use attainment status, 1983-2008. Symbology and ecoregional biocriteria follow.

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
HUC 05040006 0501 Claylick Creek Assessment Unit (Claylick Creek)						
	2008	**Claylick Creek *EWH Recommended*** - WAP-				
0.1	58/ 10.6	48	FULL	94.5	20.0	Brownsville Rd.
		Little Claylick Creek WWH -WAP-				
0.2	58	VG	FULL	70.0	8.9	Colling Rd.
HUC 05040006 0502 Lost Run Assessment Unit (Lost Run)						
	2008	**Lost Run** WWH -WAP-				
4.1	52	54	FULL	74.0	11.9	Maharg Rd.
0.2	46/ 9.5	46	FULL	96.0	23.0	From Jobes Rd.
		Wilkins Run WWH -WAP -				
0.2	50	Good	FULL	75.5	7.5	Wilkins Run Rd.
	1999	**Lost Run** WWH -WAP-				
4.1	52	52	FULL	-	11.9	Maharg Rd.
0.2	53/ 9.9	48	FULL	-	23.0	From Jobes Rd.
	1986	**Lost Run** WWH -WAP-				
4.1	44	52	FULL	-	11.9	Maharg Rd.
0.3	48/ 9.0	50	FULL	-	23.0	From Jobes Rd.
HUC 05040006 0503 Rocky Fork Licking River Assessment Unit (Rocky Fork)						
	2008	**Rocky Fork** EWH -EOLP-				
16.0/15.8	50/ 9.3[ns]	50	FULL	84.5	20.0	From Camp Ohio Rd.
10.4/10.9	54/ 10.7	46	FULL	88.0	27.0	Rocky Fork Rd.
7.1/ 6.4	47[ns]/ 10.2	Excpt.	FULL	85.5	44.0	Hickman / Jobes Rd.
2.9	55/ 10.2	48	FULL	86.0	74.0	Wolford Rd.
1.3	56/ 10.1	Excpt.	FULL	91.5	78.0	Dst. Hanover WWTP, SR 16

Table 33 continued

RM	IBI / MIwb[a]	ICI[b]	STATUS	QHEI	MI[2]	Location
		Long Run *EWH Recommended* -WAP-				
0.5	52	46	FULL	86.5	5.8	Baker Rd.
		Painter Run *EWH Recommended* -WAP-				
0.3	54	VG[ns]	FULL	84.5	6.2	SR 79
1999		**Rocky Fork** EWH -EOLP-				
16.0/16.3	48[ns]	40*	PARTIAL	-	20.0	From Camp Ohio Rd.
		Rocky Fork EWH -WAP-				
2.0/ 2.8	53/ 9.8	48	FULL	-	76.0	High St./ Wolford Rd.
HUC 05040006 0503 Rocky Fork Licking River Assessment Unit (Rocky Fork)						
1999		**Long Run *EWH Recommended*** -WAP-				
0.4	53	42[ns]	FULL	-	5.8	Baker Rd.
		Painter Run *EWH Recommended* -WAP-				
0.3	48[ns]	44[ns]	FULL	-	6.2	SR 79
1986		**Rocky Fork** EWH -EOLP-				
16.0	44*	48	PARTIAL	-	20.0	From Camp Ohio Rd.
		Rocky Fork EWH -WAP-				
10.4	47[ns]/ 8.9[ns]	-	(FULL)	-	27.0	Rocky Fork Rd.
2.0	53/ 9.6	52	FULL	-	76.0	High St.
		Long Run *EWH Recommended* -WAP-				
0.4	53	28*	PARTIAL	-	5.8	Baker Rd.
		Painter Run *EWH Recommended* -WAP-				
0.3	47[ns]	40*	PARTIAL	-	6.2	SR 79
1983		**Rocky Fork** EWH -WAP-				
2.1/ 3.0	51/ 9.4	44[ns]	FULL	-	76.0	High St./ Wolford Rd.

***** Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
ns Nonsignificant departure from biocriterion (≤4 IBI or ICI units; ≤0.5 MIwb units).
a The MIwb (Modified Index of well-being) is not applicable to headwater sites (<20mi^2). Boat critera *only* apply to all Licking Large River Assessment Unit sites.
b Narrative evaluation used in lieu of ICI (E=Exceptional; Good; MG=Marginally Good; Fair; Poor; VPoor=Very Poor).
(Full**)** Use attainment status based on one organism group is parenthetically expressed.

Narrative ranges and **WWH** biocriteria for the Erie-Ontario Lake Plain and Western Allegheny Plateau ecoregions. Exceptional (EWH biocriteria), very good (EWH nonsignificant departure), poor and very poor evaluations are common statewide. For WWH, the ranges of marginally good and nonsignificant departure are the same.

Headwater IBI	Wading IBI	Wading MIwb	ICI	Narrative Evaluation
50-60	50-60	≥9.4	46-60	Exceptional
46-49	46-49	8.9-9.3	42-44	Very Good
Erie-Ontario Lake Plain				
40-45	**38**-45	**7.9**-8.8	**34**-40	Good
36-39	34-38	7.4-7.8	30-32	Marginally Good
28-35	28-33	5.9-7.3	14-28	Fair
Western Allegheny Plateau				
44-45	**44**-45	**8.4**-8.8	**36**-40	Good
40-43	40-43	7.9-8.3	32-34	Marginally Good
28-39	28-39	5.9-7.8	14-30	Fair
18-27	18-27	4.5-5.8	8-12	Poor
12-17	12-17	0-4.4	≤6	Very Poor

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