Facility-Wide Biological and Water Quality Study 2003 Ravenna Army Ammunition Plant

Part I - Streams
Part II - Ponds

FINAL

November 2005

Prepared for:

Ravenna Army Ammunition Plant
Ravenna, Ohio
Portage County

Prepared by:

U.S. Army Corps of Engineers Louisville District

with:
State of Ohio Environmental Protection Agency
Division of Surface Water
Lazarus Government Center
122 South Front Street
Columbus, Ohio 43215

Volume I

Table of Contents

PART I - STREAMS

PART II - PONDS

TITLE/DESCRIPTION **PAGE NO.**

List of Tables

PART I - STREAMS

PART II - PONDS

List of Figures

PART I - STREAMS

TITLE/DESCRIPTION **PAGE NO.**

List of Appendices

ACRONYMS

AOC	Area of Concern
AWS	Agricultural Water Supply
BRACO	Base Realignment and Closure Office
CWH	Cold water Habitat
DDD	1,1-Bis(4-chlorophenyl)-2,2-Dichloroethene
DDE	Dichlorodiphenyldichloroethylene
DDT	1,1,1-Trichlor-2,2-bis(4-chlophenyl)-ethan
EOLP	Erie-Ontario-Lake-Plain
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies)
ESLs	Ecological Screening Levels
EWH	Exceptional Warmwater Habitat
GOCO	Government-Owned, Contractor Operated
GPD	Gallons per Day
H/D	Hester-Dendy
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
IRP	Installation Restoration Program
IWS	Industrial Waste Supply
L-QHEI	Lake/lacustuary Qualitative Habitat Evaluation Index
LCG	Louisville Chemistry Guidance
LRW	Limited Resource Water
LPM	Liters per Minute
MEC	Munitions and Explosives of Concern
MEK	Methylethyl ketone
MIBK	Methyl isobutyl ketone
MIwb	Modified Index of Well-Being
MOA	Memorandum of Agreement
MWH	Modified Warmwater Habitat
NN	No Name
NPDES	National Pollution Discharge Elimination System
NWS	National Weather Service
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
OHARNG	Ohio Army National Guard
OMZA	Outside Mixing Zone Average Criteria
OSC	Army Operations Support Command
O-WQS	Ohio Water Quality Standards
PAH	Polyaromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCR	Primary Contact Recreation

PEC	Probable Effect Concentration
PETN	Pentaerythrioltetranitrate
PWS	Public Water Supply
QA	Quality Assurance
QC	Quality Control
QHEI	Qualitative Habitat Evaluation Index
RAI	Ravenna Arsenal, Inc.
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
RL	Reporting Limit
RVAAP	Ravenna Army Ammunition Plant
SCR	Secondary Contact Recreation
SFE	South Fork Eagle
SRVs	Sediment Reference Values
SSH	Seasonal Salmonid Habitat
SVOCs	Semi-volatile Organic Compounds
TAL	Target Analyte List
TEC	Threshold Effect Concentration
TNT	Trinitrotoluene
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
WQPSDs	Water Quality Permit Support Documents
WWH	Warm Water Habitat

NOTICE TO USERS

Ohio EPA incorporated biological criteria into the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) regulations in February 1990 (effective May 1990). These criteria consist of numeric values for the Index of Biotic Integrity (IBI) and the Modified Index of Well-Being (MIwb), both of which are based on fish assemblage data, and the Invertebrate Community Index (ICI), which is based on macroinvertebrate assemblage data. Criteria for each index are specified for each of Ohio's five ecoregions (as described by Omernik 1987), and are further organized by organism group, index, site type, and aquatic life use designation. These criteria, along with the existing chemical and whole effluent toxicity evaluation methods and criteria, figure prominently in the monitoring and assessment of Ohio's surface water resources.

The following documents support the use of biological criteria by outlining the rationale for using biological information, the methods by which the biocriteria were derived and calculated, the field methods by which sampling must be conducted, and the process for evaluating results:

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989c. Biological criteria for the protection of aquatic life: Volume III.. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Quality Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Since the publication of the preceding guidance documents, the following new publications by the Ohio EPA have become available. These publications should also be consulted as they represent the latest information and analyses used by the Ohio EPA to implement the biological criteria.

DeShon, J.D. 1995. Development and application of the invertebrate community index (ICI), pp. 217-243. in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio, pp. 109-144. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286, in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. 1995. Policy issues and management applications for biological criteria, pp. 327-344. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. The role of biological criteria in water quality monitoring, assessment, and regulation. Environmental Regulation in Ohio: How to Cope With the Regulatory Jungle. Inst. of Business Law, Santa Monica, CA. 54 pp.

These documents may be obtained by writing to:

Ohio EPA, Division of Surface Water
Ecological Assessment Section
4675 Homer Ohio Lane
Groveport, Ohio 43125
(614) 836-8777

Level II and Level III chemical-contaminant assessments were performed in accordance with specific State of Ohio Ecological Risk Assessment Guidance at the former Ravenna Army Ammunition Plant (RVAAP). Empirical chemical data from these assessments suggested impact to the surface water and bio-communities from prior activities conducted at the installation. As a result of this information, the RVAAP project team decided to conduct an installation-wide assessment in 2003 of the surface water, sediment and biological conditions existing at the facility. This type of assessment is conducted throughout numerous watersheds in the State of Ohio and follow rigorous Ohio EPA guidance and protocol. The results of the RVAAP study did not confirm the findings of the previous Level II and III studies. As such, this report is to be used as a significant piece in weight of evidence evaluations of the surface water, sediment and biological communities at the RVAAP. However, it does not replace area of concern (AOC) specific evaluations of the surface water and sediment that have already been conducted, nor does it preclude future AOC-specific studies of the surface water and sediment for evaluation of potential human-health impacts.

FOREWORD

What is a Biological and Water Quality Survey?

A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites.

Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (*e.g.,* NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1]), and are eventually incorporated into Water Quality Permit Support Documents (WQPSDs), State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the Ohio Water Resource Inventory (305[b] report). For this investigation and document, the US Army Corps of Engineers followed the protocols and procedures set forth by the State of Ohio explicitly with continuous oversight and guidance of the OEPA.

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators comprised of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach is outlined in Figure 1 and includes a hierarchical continuum from administrative to true environmental indicators. The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health,

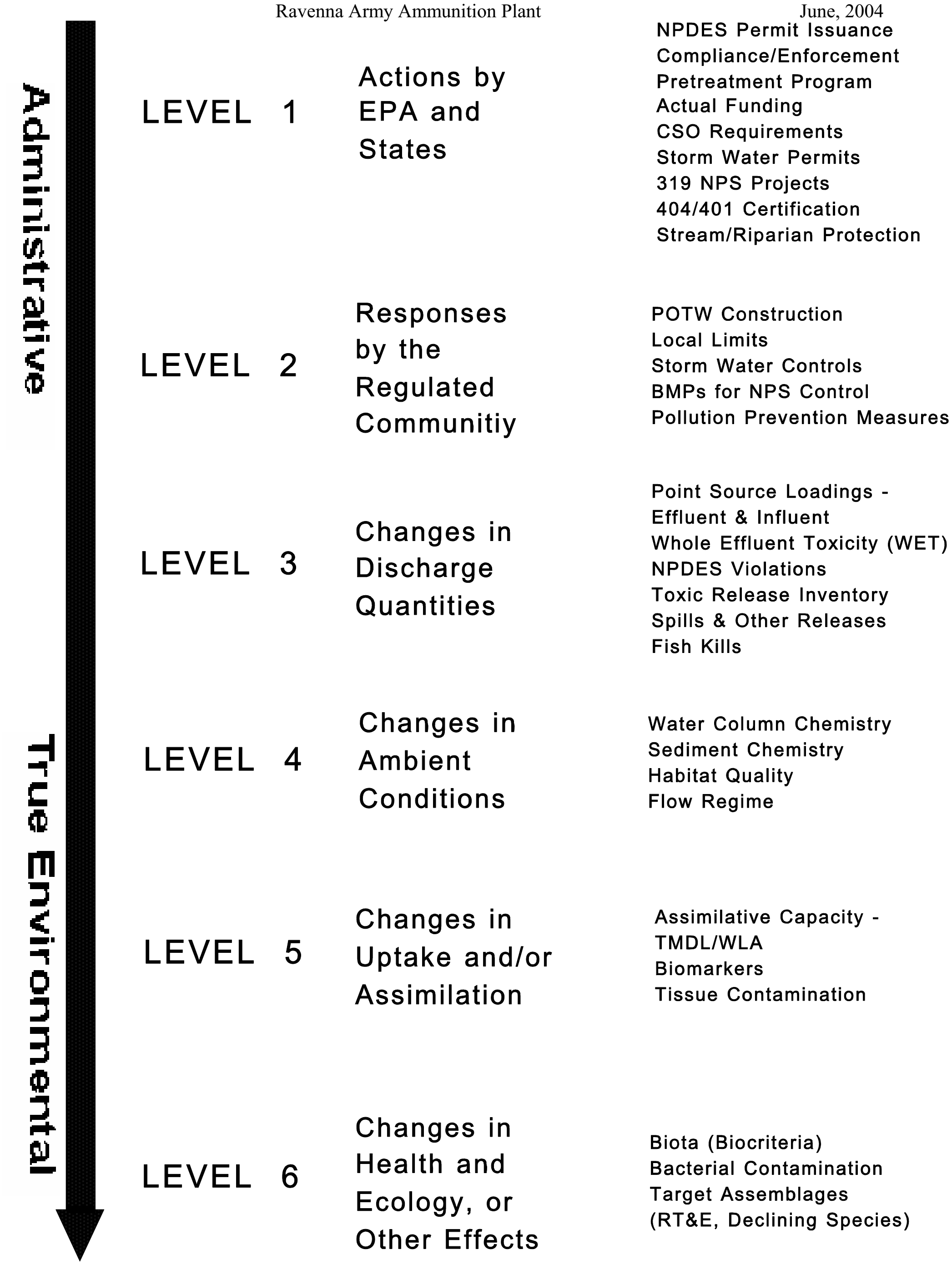

Figure 1. OEPA Tiered Approach

ecology, or other effects (ecological condition, pathogens). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental "results" (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. *Stressor* indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. *Exposure* indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. *Response* indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio's biological criteria. Other response indicators could include target assemblages, *i.e.,* rare, threatened, endangered http://midwest.fws.gov/endangered/lists/state-oh.html], special status, and declining species or bacterial levels which serve as surrogates for the recreational uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators *within* the roles which are most appropriate for each.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Ohio Water Resource Inventory (305[b] report), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Uses

The Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1) consist of designated uses and chemical, physical, and biological criteria designed to represent measurable properties of the environment that are consistent with the goals specified by each use designation. Use designations consist of two broad groups, aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in Ohio's rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protecting for aquatic life generally results in water quality suitable for all uses.

The five different aquatic life uses currently defined in the Ohio WQS are described as follows:

1) *Warmwater Habitat (WWH)* - this use designation defines the "typical" warmwater assemblage of aquatic organisms for Ohio rivers and streams; *this use represents the principal restoration target*

for the majority of water resource management efforts in Ohio.

2) *Exceptional Warmwater Habitat (EWH)* - this use designation is reserved for waters which support "unusual and exceptional" assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (*i.e.,* declining species); *this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.*

3) *Coldwater Habitat (CWH)* - this use is intended for waters which support assemblages of cold water organisms and/or those which are stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic "runs" of salmonids during the spring, summer, and/or fall.

4) *Modified Warmwater Habitat (MWH)* - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable *and where the activities have been sanctioned and permitted by state or federal law;* the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) *Limited Resource Water (LRW)* - this use applies to small streams (usually <3 mi.^{2} drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (*i.e.,* true ephemeral streams), or other irretrievably altered waterways.

Chemical, physical, and/or biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such the system of use designations employed in the Ohio WQS constitutes a "tiered" approach in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, temperature, and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use is simply having a water depth of at least one meter over an area of at least 100 square feet or where canoeing is a feasible activity. If a water body is too small and shallow to meet either criterion the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (*e.g.,* fecal coliforms, *E. coli)* and the criteria for each are specified in the Ohio WQS.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and

Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health and are detailed in other documents.

ACKNOWLEDGMENTS

The Corps of Engineers, Louisville District, would like to thank David Altfater and Mike Gray from the OEPA, for their invaluable assistance with the planning, execution, and assessment of this project.

EXECUTIVE SUMMARY

In 2003, a total of twenty-six stream sites were sampled within the Ravenna Army Ammunition Plant property. At each site, biological monitoring based on fish and macroinvertebrate community assessments were completed. The physical habitat of each site was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA. Two surface water samples from different collection dates during the summer were analyzed from each site for target analyte list metals, pesticides, PCBs, explosive compounds, semivolatile organic compounds, and several nutrient parameters. Sediment samples were collected by multi-incremental sampling at the co-located biological sampling sites. Sediments were analyzed for target analyte list metals, pesticides, PCBs, explosive compounds, percent solids, cyanide, ammonia, nitrate, phosphorus, and semivolatile organic compounds.

The collection of the aforementioned data provided: (1) aquatic life use attainment status of streams with regard to the Warmwater Habitat (WWH) or other applicable aquatic life use designation codified in the Ohio Water Quality Standards; (2) an assessment if chemical contamination within the streams is adversely affecting the biological communities; and, (3) an ecological assessment report summarizing the sediment, surface water, and aquatic biological results.

The recommended use designations for streams sampled within the Ravenna Army Ammunition Plant property are detailed inTable ES - 2. These recommendations will be included by the Ohio EPA in the next revision to the Ohio Water Quality Standards (Ohio Administrative Code 3745-1). South Fork Eagle Creek, Sand Creek, and Hinckley Creek currently have an aquatic life use designation of Warmwater Habitat. Based on this study's results, the Warmwater Habitat use should be retained for these three streams. Three unnamed tributaries to Sand Creek, one unnamed tributary to South Fork Eagle Creek, and one unnamed tributary to the West Branch Mahoning River (Table ES-2) are not listed in the Ohio WQS; however, based on the results of this study, they are recommended as Warmwater Habitat streams. An additional unnamed tributary to the West Branch Mahoning River (Table ES-2) is not listed in the Ohio WQS. Due to physical habitat limitations, the upper section is recommended as a Limited Resource Water. Further downstream, the waterbody is recommended as Warmwater Habitat based on improved habitat features and partial achievement of WWH biocriteria.

Surface water quality was generally good to excellent with very few exceedances of Ohio aquatic life water quality criteria. Sediment samples generally reflected non-contaminated conditions. Stream habitat was good at most sites. The intact riparian buffers around the streams contributed to the good habitat and absence of substantial silt deposits. Only in some of the Tributary to West Branch Mahoning River sites were low quality substrates and extensive embeddedness causes of biological impairment. The fish and macroinvertebrate communities met the Warmwater Habitat (WWH) biocriteria for all sampling locations in the Sand Creek, South Fork Eagle Creek, and Hinkley Creek basins (excluding one Hinkley Creek site). Chemical contamination of water and sediments was not observed at any of the stream sampling locations and was not the cause of biological use impairment. The mountain brook lamprey, an Ohio endangered species of fish, was collected at several locations. The caddisfly Psilotreta indecisa, state listed as threatened, was collected at several locations. In addition, the midge Neozavrelia, and the mayfly Plauditus cestus were collected for the first time in the state. The widespread presence of many coldwater and intolerant macroinvertebrate taxa reflect the undisturbed nature and good resource quality of many of the streams within the Ravenna Army Ammunition Plant property. Table ES - 1 provides an overview of biological, habitat, water, and sediment quality for each site sampled.

Table ES - 1 Biological community, water and sediment quality, habitat quality, and attainment status summary for stream sampling locations at the Ravenna Army Ammunition Plant property 2003

River Mile	Sample Location	Fish Community	Macroinvertebrate Community	Habitat	Water Quality	Sediment Quality	Use Designation[a]	Attainment Status [b]
Sand Creek								
7.0	S-1	Good	Exceptional	Good	Excellent	Excellent	WWH	FULL
5.9	S-2	Good	Exceptional	Excellent	Excellent	Excellent	WWH	FULL
4.5	S-4	Marg. Good	Very Good	Excellent	Excellent	Excellent	WWH	FULL
3.7	S-5	Good	Exceptional	Excellent	Excellent	Excellent	WWH	FULL
2.4	S-7	Marg. Good	Exceptional	Good	Excellent	Excellent	WWH	FULL
1.9	S-9	Good	Exceptional	Good	Excellent	Excellent	WWH	FULL
1.5	S-10	Marg. Good	Exceptional	Good	Excellent	Excellent	WWH	FULL
0.8	S-11	Marg. Good	Exceptional	Good	Excellent	Excellent	WWH	FULL
Tributary to Sand Creek (at RM 4.84)								
0.3	S-3	Very Good	Good	Good	Excellent	Good	WWH	FULL
Tributary to Sand Creek (at RM 3.25)								
0.1	S-6	Good	Good	Good	Excellent	Excellent	WWH	FULL
Tributary to Sand Creek (at RM 2.22)								
0.1	S-8	Very Good	Good	Good	Excellent	Excellent	WWH	FULL
South Fork Eagle Creek								
6.2	SFE-3	Good	Exceptional	Excellent	Excellent	Excellent	WWH	FULL
5.5	SFE-4	Very Good	Very Good	Excellent	Excellent	Excellent	WWH	FULL
3.8	Ref. Site	Marg. Good	Exceptional	Excellent	-	-	WWH	FULL
2.7	SFE-5	Good	Exceptional	Good	Excellent	Excellent	WWH	FULL
Tributary to South Fork Eagle Creek (at RM 6.34)								
1.2	SFE-1	Good	Marg. Good	Excellent	Excellent	Excellent	WWH	FULL
0.1	SFE-2	Very Good	Exceptional	Good	Excellent	Excellent	WWH	FULL

Hinkley Creek								
6.6	H-1	Good	Exceptional	Excellent	Excellent	Excellent	WWH	FULL
5.2	H-2	Marg. Good	Exceptional	Good	Excellent	Excellent	WWH	FULL
4.3	H-3	Fair	Exceptional	Good	Excellent	Excellent	WWH	PARTIAL
3.3	H-4	Marg. Good	Exceptional	Good	Excellent	Excellent	WWH	FULL

River Mile	Sample Location	Fish Community	Macroinvertebrate Community	Habitat	Water Quality	Sediment Quality	Use Designation[a]	Attainment Status[b]
Tributary to West Branch Mahoning River (at RM 0.01)								
4.1	NN3-1	Poor	Fair	Very Poor	Good	Good	LRW	FULL
3.5	NN3-2	Fair	Fair	Good	Good	Good	WWH	NON
2.5	NN3-3	Fair	Good	Fair	Good	Good	WWH	PARTIAL
2.1	NN3-4	Poor	Good	Good	Good	Good	WWH	NON
Tributary to West Branch Mahoning River (at RM 9.63,0.74)								
1.8	LL-4	Fair	Fair	Fair	Good	Good	WWH	NON

[a] WWH = Warmwater Habitat. LRW = Limited Resource Water.
[b] Attainment status is based on the quality of the fish and macroinvertebrate communities in relation to Ohio biocriteria.

Table ES - 2 Use designations for water bodies in West Branch Mahoning River and Eagle Creek drainage basins.

Water Body Segment	Use Designations												
		Aquatic Life Habitat						Water Supply			Recreation		
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR
South Fork Eagle Creek		+							*	*		+	
Unnamed Tributary to S.F. Eagle Creek (at RM 6.34)		Δ							Δ	Δ		Δ	
Sand Creek		+							*	*		+	
Unnamed Tributary to Sand Creek (at RM 2.22)		Δ							Δ	Δ		Δ	
Unnamed Tributary to Sand Creek (at RM 3.25)		Δ							Δ	Δ		Δ	
Unnamed Tributary to Sand Creek (at RM 4.84)		Δ							Δ	Δ		Δ	
Hinkley Creek		+							*	*		+	
Unnamed Tributary to W.Br. Mahoning River (at RM 0.01)													
Headwaters to RM 3.8							Δ		Δ	Δ			Δ
RM 3.8 to the mouth		Δ							Δ	Δ		Δ	
Trib. to Unnamed Tributary to W.Br. Mahoning River (at RM 9.63/0.74)		Δ							Δ	Δ		Δ	

SRW = state resource water; WWH = warmwater habitat; EWH = exceptional warmwater habitat; MWH = modified warmwater habitat; SSH = seasonal, salmonid habitat; CWH = coldwater habitat; LRW = limited resource water; PWS = public water supply; AWS = agricultural water supply; IWS = industrial water supply; BW = bathing water; PCR = primary contact recreation; SCR = secondary contact recreation.

* Designated use based on the 1978 water quality standards.

\+ Previously designated use (in 1978 water quality standards) verified by the findings of this report.

Δ New designated use based on findings of this report.

1 INTRODUCTION

1.1 Facility-Wide Description

The Ravenna Army Ammunition Plant (RVAAP) is located in northeastern Ohio within Portage and Trumbull counties, approximately 4.8 km (3 miles) east-northeast of the City of Ravenna and approximately 1.6 km (1 mile) northwest of the town of Newton Falls. The installation consists of 8668.3 ha (21,419 acres) contained in a 17.7 km (11 mile) long, 5.6 km (3.5 mile) wide tract bounded by State Route 5, the Michael J. Kirwan Reservoir, and the CSX System Railroad on the south; State Route 534 on the east; Garrettsville and Berry Roads on the west; and the CONRAIL Railroad on the north. The land use surrounding the installation is primarily rural with country-home residences. The installation is surrounded by several local communities: Windham, which borders on the installation to the north; Garrettsville, located 9.6 km (6 miles) to the northwest; Newton Falls, 1.6 km (1 mile) to the east; Charleston, bordering the southwest; and Wayland, 4.8 km (3 miles) to the southeast.

RVAAP was established on August 26, 1940 for the primary purpose of loading medium and large caliber artillery ammunition; bombs, mines; fuze and boosters; primers and percussion elements; and for the storage of finished ammunition components. Originally, the installation was divided into two separate units; one was designated as Portage Ordnance Depot with the primary mission of the depot's storage activity, and the other was designated as the Ravenna Ordnance Plant with the primary mission of the ammunition loading activities.

Over the years, the Defense Logistics Agency at RVAAP handled and stored strategic and critical materials for various government agencies, whereas RVAAP received, stored, maintained, transported, and demilitarized military ammunition and explosive items. RVAAP maintained the capabilities to load, assemble, and pack military ammunition; however, these operations are inactive. As part of the RVAAP mission, the inactive facilities were maintained in a standby status by keeping equipment in a condition to permit resumption of production within prescribed time limitations.

RVAAP is a Government-Owned, Contractor-Operated (GOCO) U.S. Army Operations Support Command (OSC) facility. Currently, RVAAP is an inactive facility maintained by a contractor caretaker, Tol-Test, Inc. of Toledo, Ohio. The Atlas Powder Company was the original GOCO manager of the Ravenna Ordnance Depot and operated the plant from 1940-1945; the government operated the Portage Ordnance Depot. The last production for World War II was in August 1945. The government assumed operations of both areas from 1945 to 1951 when Ravenna Arsenal Inc. (RAI), a subsidiary of the Firestone Tire and Rubber Co., Akron, Ohio, was contracted to operate the entire facility. In 1982, Physics International Co., a subsidiary of Rockcor Inc., purchased RAI from Firestone. Olin Corporation purchased Rockcor Inc. in June 1985. In December 1999 the Ohio Army National Guard (OHARNG) assumed administrative control over 16,164 acres at RVAAP. Transfer of an additional 3,774 acres to the National Guard took place in early 2002 bringing the total acreage to 19,938. The remaining 1,481 acres encompass the Areas of Concern (AOCs) and munitions storage areas and remain under control of the U.S. Army BRACO.

A brief overview of the history of RVAAP is provided in a chronological order to provide a summary of the site's history.

Date	Description of Activity/Facility Status
1940	10,117.5 ha (25,000 acres) purchased by the United States Government. Began construction of the plant.
Sept 1940	Operated by Atlas Powder Company.
Dec 1941 to Jan 1942	Facility completed and began operations. Primary mission was depot storage and ammunition loading. Divide installation into two separate units: Portage Ordnance Depot – depot storage of munitions and components; Ravenna Ordnance Plant – loading ammunition.
Aug 1943	Designated as the Ravenna Ordnance Center.
Nov 1945	Designated as Ravenna Arsenal.
1945	Turned over to Ordnance Department.
1945-1949	Silas Mason Co. operated the ammonium nitrate line for the production of ammonium nitrate fertilizer.
1950	Plant placed on standby status. Operations limited to renovation, demilitarization, and normal maintenance of equipment and stored ammunition and components.
Apr 1951	RAI contracted to run the facility. Subsidiary of Firestone Tire and Rubber Co.
Jul 1954	Plum Brook Ordnance Works of Sandusky, Ohio, and the Keystone Ordnance Works of Meadville, Pennsylvania, were made satellites of Ravenna.
Aug 1957	All at-plant production ended.
Oct 1957	The installation was placed on standby status.
Mar 1958	Plum Brook Ordnance Works ceased to be under the jurisdiction of Ravenna.
Jul 1959	Keystone Ordnance Works was transferred to General Services Administration.
Oct 1960	Began rehabilitation work to replace facilities in the ammonium nitrate line for the processing and explosive melt-out of bombs.

Date Description of Activity/Facility Status

Jan 1961	Operations began for the processing and explosive melt-out of bombs. Operation of this type was first in the ammunition industry.
Jul 1961	Plant again deactivated.
Nov 1961	Installation was divided into Ravenna Ordnance Plant and the industrial section. Entire facility was designated as the RVAAP.
May 1968	RVAAP reactivated in support of the Southeast Asian Conflict for loading, assembly, and packing munitions on three load lines and two component lines.
1971	Operations ceased at Load Lines 1,2,3, and 4.
Jun 1973 to Mar 1974	Deactivated major load lines and component line to demilitarization of the M7IA1 90 MM projectile.
Oct 1982	Physics International Company (a subsidiary of Rockcor Inc.) purchased Ravenna Arsenal Inc. from Firestone.
Jun 1985	Rockcor Inc. was purchased by Olin Corporation.
1992	The RVAAP mission was discontinued, placing the installation on the 'Inactive Maintained' status.
Mar 1993	Transfer of RVAAP from 'Inactive Maintained' to 'Inactive Modified-Caretaker' status.
Sept 1993	RVAAP was placed in 'Modified-caretaker' Status.
Sept 1993	Report of Excess determined the load lines and associated real estate as excess to the U.S. Army. The excess area includes approximately 2006.0 ha (4957 acres) and 362 buildings in Load Lines 1 through 12 (excluding 7 and 11), Area 4, and Area 8.
Oct 1993	Mason & Hanger-Silas Mason Co., Inc. took over as the installation's contractor modified caretaker.
Oct 1997	R&R International became the installation's contractor modified caretaker.

Date	Description of Activity/Facility Status
1998	Salvage and demolition operations commenced at RVAAP. Removal of the railroad ties and rails, copper wire, and excess metal for salvage was completed. Demolition of Load Lines 1, 2, and 12 commenced with complete or partial removal of transite (friable asbestos and concrete) siding and roofing.
Dec 1998	Administrative control of 16,164 acres of RVAAP was transferred to the Ohio Army National Guard for use in training and related activities.
Feb 2000	Tol-Test, Inc. replaced R&R International as contractor-modified caretaker.
Jan/Mar 2002	Administrative control of an additional 3,774 acres of RVAAP was transferred to the Ohio Army National Guard.
Feb 2003	Thermal Decomposition of Wet Storage Igloos.
May 2003	Thermal Decomposition of LL6
May 2003	Thermal Decomposition of LL9

Although currently inactive, RVAAP has historically handled hazardous wastes and operated several waste management units in support of its operations. Materials of potentially hazardous nature were stored, treated, deposited in landfills, or burned at the facility.

The industrial operations at RVAAP consisted of 12 load lines. Load Lines 1 through 4 were used to melt and load trinitrotoluene (TNT) and Composition B into munitions. The operations on the Load Lines 1 through 4 produced explosive dust, spills, and vapors that collected on the floors and walls of each building. Periodically, the floor and the walls would be hosed down with the water and steam cleaned. The liquid, containing TNT and Composition B constituents, would be collected in holding tanks, filtered, and pumped to one of the four settling ponds. Additionally liquids were swept from door ways. But sweeping water out of doorways was not a consistent practice among the load lines. Potential contaminants at Load Lines 1 through 4 include TNT and Composition B. Load Lines 5 through 11 were used to manufacture fuzes, primers, and boosters while Load Line 12 housed the ammonium nitrate plant. Potential contaminants in Lines 5 through 11 include, but are not limited to lead azide, lead styphnate, black powder, TNT, Composition B and Pentaerythrioltetranitrate (PETN). Load Line 12 was operated to produce ammonium nitrate for explosives and fertilizers. Any of the twelve Load Lines could have metals as potential contaminants due to the industrial nature of the processes.

Landfills at RVAAP were used to bury waste from industrial operations and sanitary sources. In addition, burial sites may also be located on-site based on historical information. Potential contaminants from these areas include, but are not limited to: explosive compounds, explosive wastes, mustard agent, metals, sodium chloride, and calcium chloride.

Settling and retention ponds at the facility collected wastewater from munitions wash down operations at various facilities. Potential contaminants associated with the settling and retention ponds include, but are not limited to, explosive compounds, aluminum chloride, metals, SVOCs, propellants, hexavalent chromium, and heavy metals.

RVAAP had several areas associated with the burning, demolition, and testing of various munitions. These burning grounds and demolition areas consisted of large areas of land or abandoned quarries for these activities. Potential contaminants at these sites include, but are not limited to, explosives [cyclonite [hexahydro-1,3,5-trinitro-1,3,5-triazine](RDX), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), Composition B, TNT, black powder], white phosphorous, antimony sulfide, lead azide, propellant, waste oils, heavy metals, sludge from load lines, various laboratory chemicals, and sanitary waste.

RVAAP has various industrial operations that have been identified as potential sources of contaminants. These operations include sewage treatment, wastewater treatment, vehicle maintenance, storage tanks, waste storage areas, equipment storage areas, furnaces, and evaporation units. Contaminants associated with these operations include, but are not limited to, explosives, lead azide, lead styphnate, metals, heavy metals, polychlorinated biphenyls (PCBs), waste oil, and petroleum.

1.2 Environmental Setting

1.2.1 Climatic Conditions

Daily weather for Ravenna Ohio can be retrieved for the accuweather web site: http://wwwa.accuweather.com/adcbin/public/local_index.asp?nav=home&thisZip=44266&partner=recordpub2

The general climate of the RVAAP area is continental and is characterized by moderately warm and humid summers, reasonably cold and cloudy winters, and wide variations in precipitation from year to year. The following climatological data were obtained from the National Weather Service Office (NWS 1995) at the Youngstown-Warren Regional Airport located in Trumbull County and are based on a 30-year average.

Total annual rainfall in the RVAAP area is approximately 93.25 cm (37.3 inches), with the highest monthly average occurring in July [10.2 cm (4.07 inches)] and the lowest monthly average occurring in February [5.0 cm (2.03 inches)]. Average annual snowfall totals approximately 140.5 cm (56.2 inches) with the highest monthly average occurring in January [32.2 cm (12.9 inches)]. It should be noted that due to the influence of lake-effect snowfall events associated with Lake Erie [located approximately 56.3 km (35 miles) to the northwest of RVAAP], snowfall totals vary widely throughout northeastern Ohio.

The average annual daily temperature in the RVAAP area is 48.3 ºF, with an average daily high temperature of 57.7 ºF and an average daily low temperature of 38.7 ºF. The record high temperature of 100 ºF occurred in July 1988, and the record low temperature of -22 ºF occurred in January 1994. The prevailing wind direction at RVAAP is from the southwest, with the highest average wind speed occurring in January [18.7 km (11.6 miles) per hour] and the lowest average wind speed occurring in August [11.9 km (7.4 miles) per hour].

Thunderstorms occur on approximately 35 days per year and are most abundant from April through August. The RVAAP area is susceptible to tornadoes; minor structural damage to several buildings on facility property occurred as the result of a tornado in 1985.

1.2.2 Geologic Setting

1.2.2.1 Unconsolidated Deposits

Two glacial advances during the Wisconsin Age of the Pleistocene Epoch resulted in the deposition of glacial till over the entire RVAAP installation. The first glacial advance deposited the Lavery Till over the facility. The Lavery Till consists mostly of clay and silt with a few cobbles and sporadic boulders. The second glacial advance deposited the Hiram Till over the eastern two-thirds of the facility only. The Hiram Till consists of 12% sand, 41% silt, and 47% illite and chlorite clay minerals, and ranges in depth from 1.5 to 4.6 m (5 to 15 feet) below ground surface (bgs). The Hiram Till overlies thin beds of sandy outwash material in the far northeastern corner of the facility. Field observations indicate that overall till thickness is less than 0.6 m (2 feet) in some areas of the RVAAP facility. The reduced till thickness may be due to natural erosion or construction grading operations and is not necessarily the result of deposition.

In the central portion of the facility, oriented in a southwest–northeast direction, is located glacial outwash consisting of poorly sorted clay, till, gravel, and silty sand. Depths of unconsolidated sediments range from 30.5 to 61 m (100 to 200 feet) BGS.

1.2.2.2 Bedrock

The bedrock geology of RVAAP consists of Carboniferous Age sedimentary rocks that lie stratigraphically beneath the glacial deposits of the Lavery and Hiram tills. The oldest bedrock within the facility is the Cuyahoga Formation of the Mississippian Age. Three members comprise this formation: (1) the Orangeville Shale, (2) the Sharpsville Sandstone, and (3) the Meadville Shale. The Cuyahoga outcrops in the far northeastern corner of the facility and generally consists of blue-gray silty shale with interbedded sandstone. The regional dip of the Cuyahoga strata is between 1.5 to 3.0 m (5 to 10 feet) per mile to the south.

The remainder of the facility is underlain by bedrock associated with the Pottsville Formation of Pennsylvanian Age. The Pottsville Formation, which lies unconformably on an erosional surface of the Cuyahoga Formation, is divided into four members: (1) the Sharon, (2) the Connoquenessing Sandstone, (3) the Mercer, and (4) the Homewood Sandstone. The Sharon Member consists of two individual units: the Sharon Conglomerate and the Sharon Shale. The Sharon Conglomerate is a second cycle sedimentary rock, and pebbles are comprised of quartzite. The Sharon Conglomerate also has locally occurring thin shale lenses in the upper portion of the unit. Due to the differences in lithology between the Sharon Conglomerate and the underlying shales of the Cuyahoga Formation, the contact between the Pottsville and Cuyahoga Formations usually is quite distinct. The Sharon Shale overlies the Sharon Conglomerate and consists of sandy, gray-black, fissile shale with some plant fragments and thin flagstone beds. Sharon sandstones are exposed on the ground surface at Load Line 1 and the former Ramsdell Quarry.

The Connoquenessing Sandstone member of the Pottsville Formation unconformably overlies the Sharon Member and is a medium- to coarse-grained, gray-white sandstone with more feldspar and clay than the Sharon Conglomerate. Thin interbeds and partings of sandy shale also are common in the Connoquenessing. The Mercer member of Pottsville Formation overlies the Connoquenessing and consists of silty to carbonaceous shale with abundant thin, discontinuous sandstone lenses in the upper portion. Regionally, the Mercer also has been noted to contain interbeds of coal. The Homewood Member of the Pottsville Formation unconformably overlies the Mercer member and consists of coarse-grained crossbedded sandstones that contain discontinuous shale lenses.

The Connoquenessing, Mercer, and Homewood members are present only in the western half of the RVAAP facility. The Sharon Conglomerate unit is the upper bedrock surface in most of the eastern half. The regional dip of the Pottsville Formation strata is between 1.5 and 3.5 m (5 and 10 feet) per 1.6 km (1.0 mile) to the south.

1.2.3 Hydrologic Setting

1.2.3.1 Unconsolidated Sediments

The largest groundwater supplies within Portage County come from areas that underlie Franklin, Brimfield, and Suffield townships and Streetsboro, Shalersville, and Mantua townships, respectively. The unconsolidated units that consist of sand and gravel are favorably situated to receive recharge from surface streams and surface infiltration. These same areas are used as a source of drinking water for a good percentage of residents in the vicinity of RVAAP.

The water-bearing characteristics for the sand and gravel aquifers in the vicinity of the RVAAP installation are poorly documented. Wells that penetrate these aquifers can yield up to 6080 liters per minute (LPM) [1600 gallons per minute (GPM)]. However, yields from wells penetrating silty or clay till materials are significantly lower. In general, the Kent and Hiram tills are too thin and impermeable to produce useful quantities of water.

1.2.3.2 Bedrock

The most important bedrock sources of groundwater in the vicinity of the RVAAP facility are the sandstone/conglomerate members of the Pottsville Formation. These aquifers, together with two other deeper Mississippian/Devonian sandstone aquifers, represent the most important bedrock sources of groundwater in Northeastern Ohio.

The Sharon Conglomerate is the primary source of groundwater at RVAAP and maintains the most significant well yields of the Pottsville Formation members with hydraulic conductivity values of 19 to 7600 liters per day per meter (LPD/m) [5 to 2,000 gallons per day per foot (GPD/ft)]. Past studies of the Sharon Conglomerate indicate that the highest yields are associated with the true conglomerate phase (coarse-grained sandstone with abundant quartz pebbles) and with joints and fractures in the bedrock; however, there is no facility-specific information available regarding variations in aquifer properties due to these factors. Where present, the overlying Sharon Shale acts as a relatively impermeable confining layer for the Sharon Conglomerate. Several flowing artesian production wells have been noted at the facility.

The Connoquenessing Sandstone and the Homewood Sandstone are the remaining aquifers of the Pottsville Formation and exhibit hydraulic conductivities of 19 to 1140 LPD/m (5 to 300 GPD/ft) and 19 to 760 LPD/m (5 to 200 GPD/ft), respectively. Well yields in the Connoquenessing and Homewood sandstones, although lower than the Sharon Conglomerate, are high enough to provide significant quantities of water. Several wells at the RVAAP facility have penetrated both the Sharon Conglomerate and the Connoquenessing Sandstone and reportedly produced water from both units.

In general, hydraulic conductivities in the shales of the Sharon and Mercer members of the Pottsville Formation are low and result in insignificant groundwater yields. The primary porosity of the shales is likely secondary, owing to joints and fractures in the bedrock; however, there is no facility-specific information available regarding the occurrence of joints and fractures in these units.

1.2.3.3 Groundwater Utilization

All groundwater utilized at the RVAAP facility during past operations was obtained from on-site production wells, with the large majority of wells screened in the Sharon Conglomerate. Production wells scattered throughout the facility provided necessary sanitary and process water for RVAAP operations. All remaining process production wells were permanently abandoned in 1992. Currently, two groundwater production wells remain in operation. These wells, located in the central portion of the facility, provide sanitary water to the remaining site personnel. Additionally, a production well, not in operation, is located at the former site of Building T-5301.

Residential groundwater use in the surrounding area is similar to that for RVAAP, with the Sharon Conglomerate acting as the major producing aquifer in the area. Additionally, many local residents utilize the unconsolidated sand and gravel aquifer as their groundwater source. The Connoquenessing Sandstone and the Homewood Sandstone also provide limited groundwater resources, primarily near the western half of the RVAAP facility.

The *Ground Water Pollution Potential of Portage County* published by the Ohio Department of Natural Resources (1991) provides additional insight into the groundwater characteristics of the RVAAP area. This map indicates the relative vulnerability of groundwater in a specific area to contamination from surface sources. Intended primarily as a groundwater resource management and planning tool, the Ground Water Pollution Potential Map presents index values based on several hydrogeologic criteria including depth to water, hydraulic conductivity, topography, and others. Resulting index values range from a low pollution potential (zero) to a high pollution potential (200+).

Based on this mapping system, the majority of the RVAAP facility has a moderate pollution potential that ranges between 100 and 159, depending on location. In addition, three general hydrogeologic settings are defined for RVAAP and include: (1) glacial till overlying bedded sedimentary rock, (2) glacial till overlying sandstone, and (3) alluvium overlying bedded sedimentary rock. In general, the highest pollution potential values at RVAAP occur in the areas where alluvium overlies bedded sedimentary rock (index range of 140 to 159); however, these areas occur primarily in the northeast portion of the facility. The majority of RVAAP has pollution potential indices that range between 100 and 139.

1.2.3.4 Surface Water

The entire RVAAP facility is situated within the Ohio River Basin, with the West Branch of the Mahoning River representing the major surface stream in the area. The West Branch flows adjacent to the west end of the facility, generally in a north to south direction, before flowing into the M.J. Kirwan Reservoir, which is located to the south of State Route 5. The West Branch flows out of the reservoir along the southern facility boundary before joining the Mahoning River east of RVAAP.

The western and northern portions of the RVAAP facility display low hills and a dendritic surface drainage pattern. The eastern and southern portions are characterized by an undulating to moderately level surface, with less dissection of the surface drainage. The facility is marked with marshy areas and flowing and intermittent streams whose headwaters are located in the facility's hills. Three primary water courses drain RVAAP: (1) the South Fork of Eagle Creek, (2) Sand Creek, and (3) Hinkley Creek. All of these watercourses have many associated tributaries.

Sand Creek, with a drainage area of 36 km^2 (13.9 $miles^2$), flows generally in a northeast direction to its confluence with the South Fork of Eagle Creek. In turn, the South Fork of Eagle Creek then continues in a northerly direction for 4.3 km (2.7 miles) to its confluence with Eagle Creek. The drainage area of the South Fork of Eagle Creek is 67.8 km^2 (26.2 $miles^2$), including the area drained by Sand Creek. Hinkley Creek originates just southeast of the intersection between State Routes 88 and 303 to the north of the facility. Hinkley Creek, with a drainage area of 28.5 km^2 (11.0 $miles^2$), flows in a southerly direction through the installation to its confluence with the West Branch of the Mahoning River south of the facility.

Approximately 50 ponds are scattered throughout the installation. Many were built within natural drainage ways to function as settling ponds or basins for process effluent and runoff. Others are natural in origin, resulting from glacial action or beaver activity. All water bodies at RVAAP could support aquatic vegetation and biota. None of the ponds within the installation is used as a water supply source.

Storm water runoff is controlled primarily by natural drainage except in facility operations areas where an extensive storm sewer network helps to direct runoff to drainage ditches and settling ponds. In addition, the storm sewer system was one of the primary drainage mechanisms for process effluent during the period that production facilities were in operation.

1.2.3.5 Surface Water Utilization

Past and present surface water utilization at RVAAP generally was limited to use by wildlife and recreational users. Although some surface water may have been used intermittently for various facility operations, the vast majority of process water was provided by on-site groundwater production wells. There is no available documentation that indicates any past irrigation or other agricultural use of surface water sources on facility property. It is likely that some agricultural use of surface water was conducted in this area before facility construction due to the presence of homesteads and farms, with the assumption that surface water uses may have included livestock water sources at that time. On-site recreational surface water use was limited to managed fishing programs conducted in the past. Due to access limitations, fishing is not currently prevalent at RVAAP, however, based on the need and availability, catch and release fishing may be an option for facility managers. Based on conversations with site personnel, it is likely that some recreational trespasser use of surface water does occur on a limited basis, primarily for fishing.

The major surface water drainages at RVAAP all exit facility property and eventually flow into the Mahoning River to the east. Surface water from Sand Creek, which flows to the northeast across the facility, joins the South Fork of Eagle Creek, which flows to the east inside the northern property boundary. The South Fork of Eagle Creek continues to the east until it eventually discharges to the Mahoning River. It is possible that limited agricultural and recreational use of the South Fork of Eagle Creek does occur off of facility property, although no data are available to allow a more detailed study. Hinkley Creek, which enters the facility property from the north and flows to the south across the western portion of RVAAP, eventually discharges to the West Branch of the Mahoning River (and the West Branch Reservoir) south of State Route 5. It is doubtful that the Hinkley Creek is used for any agricultural purposes, although limited recreational use may occur.

1.2.4 Air Quality for Surrounding Area

The RVAAP facility is located in a rural area and has air quality that generally can be described as good. Currently, there are no significant airborne emissions from RVAAP due to its excess status. In addition, there is no operating air monitoring program in place at the facility at this time. There are no significant documented air pollution sources in close proximity to facility property that would affect air quality at RVAAP.

1.2.5 Site Use

Land use within the facility is restricted access industrial. At the present time, RVAAP is an excess status facility maintained by a contracted caretaker, TolTest, Inc. Site workers infrequently visit the AOCs for maintenance purposes, *e.g.*, mowing. The Ohio National Guard (OHARNG) also occupies parts of RVAAP and conducts training exercises. Personnel from OHARNG may occasionally travel through AOCs at RVAAP but generally restrict training to areas outside of AOCs. The land use immediately surrounding the facility is primarily rural. Approximately 55 percent of Portage County is either woodland or farmland (Portage County Soil and Water Conservation District Resources Inventory 1985: U.S. Census Bureau 1992). To the south of the facility is the Michael J. Kirwan Reservoir, which is used for recreational purposes. The reservoir is south of the site, across State Route 5. The reservoir is fed by the West Branch of the Mahoning River, which flows south along the western edge of the installation. Hinkley Creek flows south across the western portion of the facility and eventually flows into the West Branch of the Mahoning River. The major surface drainages at RVAAP-Sand Creek and South Fork Eagle Creek-exit the facility property and eventually flow east to the Mahoning River.

Residential groundwater use occurs outside the facility, with most of the residential wells tapping into either the Sharon Conglomerate or the surficial unconsolidated aquifer. Groundwater from on-site production wells was used during operations at the facility (USACE 1996); however, all but two production wells have been abandoned at the facility. These wells, located in the central portion of the facility, provide sanitary water to the facility. Additionally, a production well, not in operation, is located at the former site of Building T-5301. The Sharon Conglomerate is the major producing aquifer at the facility.

Currently surface water is primarily used by only wildlife. Based on conversations with site personnel, it is likely that some recreational trespasser use of the surface water occurs on a limited basis outside of the load lines, primarily associated with fishing. It is unlikely that any fishing occurs now or will in the future at load lines 2 and 3 since the drainage at the site are small and intermittent. There will be designated areas by OHARNG where surface water can be used for dust and fire suppression. These areas include: Erie Burning Grounds, WBG, LL1, 2, 4; Fuze/Booster Quarry, Upper/Lower Cobbs Pond, LL6 and NACA Test Area.

Future uses of RVAAP are currently being determined. Potential future uses include:

- Continued use of certain areas for training purposes by the OHARNG;
- Expanded training and occupancy by the OHARNG to encompass the entire facility (long term) >5 years; and
- Recreational use, *e.g.*, hunting, fishing, and hiking.

1.2.6 Ecological Setting

Available estimates indicate that approximately one-third of the RVAAP facility property meets the regulatory definition of a wetland, with the majority of the wetland areas located in the eastern portion of the facility (OHARNG, 1997). Wetland areas at RVAAP include seasonal wetlands, wet fields, and forested wetlands. Many of the wetland areas are the result of natural drainage or beaver activity; however, some wetland areas are associated with anthropogenic settling ponds and drainage areas. In the summer of 2000, the OHARNG constructed mitigation wetlands in the western part of RVAAP. There is a potential for chemical releases in wetland areas at RVAAP from past practices of process effluent discharging to settling ponds and the natural drainage of the area in the past.

The flora and fauna present at RVAAP are varied and widespread. A total of 18 plant communities have been identified on facility property, including marsh, swamp, and forest communities (USACE, April 2001).

A large number of animal species have been identified on facility property, including 26 species of mammals, 143 species of birds, and 41 species of fish. Two animal species identified at RVAAP are listed as Federal Candidate (Category 2) species: the Cerulean Warbler and the Henslow's Sparrow. Animal species listed as Ohio State Endangered (ODNR,2004 list) include the Northern Harrier, the Yellow-bellied Sapsucker and the Mountain Brook Lamprey. Species currently listed in Ohio can be found at ODNR, Division of Wildlife, http://www.ohiodnr.com/wildlife/resources/default.htm, and the Division of Natural Areas and Preserves, http://www.dnr.state.oh.us/dnap/heritage/heritage.html.

There is no documentation available to determine if any of the above animal or plant species have been affected by past facility operations. Future Installation Restoration Program (IRP) activities will require consideration of these species to ensure that detrimental effect on threatened or endangered RVAAP flora and fauna do not occur. There are no federal, state, or local parks or protected areas on RVAAP facility property.

1.3 Summary of Existing Site Data

To date, many of the potentially contaminated sites at RVAAP have been investigated to some degree. Some sites are currently being remediated for contaminants or explosive safety. The results of investigations can be found in the administrative record for RVAAP.

1.4 Current Study Objectives

Specific objectives of this evaluation were to:

1) Establish biological conditions in select streams of the Ravenna Army Ammunition Plant property by evaluating fish and macroinvertebrate communities, and assessing physical habitat conditions;

2) Measure and evaluate surface water and sediment chemical quality in select streams within the Ravenna Army Ammunition Plant property. General chemicals of concern included munitions and explosives of concern (MEC), semivolatile organic, and inorganic constituents;

3) Determine the aquatic life use attainment status of streams with regard to the Warmwater Habitat (WWH) or other applicable aquatic life use designation codified in the Ohio Water Quality Standards;

4) Determine if chemical contamination within the streams is adversely affecting the biological communities; and

5) Complete an ecological assessment report summarizing the sediment, surface water, and aquatic biological results.

2 History of Site Usage Associated with Surface Water Sites

The many activities and varied history of the sites at RVAAP could have contributed to contamination of surface water bodies within the installation. Similarly, impacts to habitat and other physical parameters, which can be just as detrimental to aquatic life as contamination, could have occurred during the active operations. This section describes many of the activities that occurred at RVAAP at the AOCs that could have an effect on the surface water either within the AOC or within the drainage area of the AOC. This discussion is not based on actual laboratory findings but the historical usage. This provides information that can be used to target chemicals to lessen the possibility that an analyte is overlooked in the investigation.

2.1 Hinkley Creek

The creek is described as a free flowing stream, which enters the Ravenna Army Ammunition Plant (RVAAP) just north of the Magazine Area located in the northwestern portion of the facility. The flow direction of Hinkley Creek is from the sampling locations specified as Hinkley Creek No. 1 (H-1) through Hinkley Creek No. 4 (H-4). See Appendix 1 for site map.

2.1.1 Section on H-1

The sample location noted as H-1 is at the intersection of Hinkley Creek and Magazine Road. It is located between Buildings 195 & 196 at the eastern portion of Magazine Area, where finished products were stored in buildings. No information is available as to the specific products that were stored in these magazines. If the products were stored in treated wire crates and boxes, pentachlorophenol (PCP) may have been released. PCP was the preservative of choice for treating wooden crates and other materials subject to dry rot or fungus during WWII and up through the Vietnam Era. The sampling location is up gradient from the Portage Ordnance Depot. The interval of Hinkley Creek sampled was upstream and downstream of Magazine Road. The initial Hinkley Creek sampling interval, H-1, may be considered as a background sampling point, since it is the most up-gradient for the creek.

2.1.2 Section on H-2

The second sample location, denoted as Hinkley Creek No. 2 (H-2), is at the intersection of Hinkley Creek and South Patrol Road. It is down gradient from the Portage Depot Area. The administration buildings, locomotive repair shops, sewage treatment plant, gas station, boiler house, living quarters and other similar activities are all up-gradient from the sampling interval. The highest potential for contamination would be from the locomotive repair shops and gas station. Their contribution would be hydrocarbons ranging from diesel fuel and gasoline to lubricating oils and greases. Solvents, such as carbon tetrachloride, chloroform, trichloroethylene, Stoddard Solvent containing toluene, xylenes and other degreasers may have been used in the repair and fueling operations.

Depending on the size of the boiler used, blow-down from the boiler operation may also contribute to surface water contamination if not routed to the sewer system. Typical 1940 boiler water treatments consisted of sodium and potassium sulfites for dissolved oxygen removal; magnesium oxide for silica treatment; and cyclohexylamine, morpholine and benzylamine for neutralizing acids such as carbonic acids in steam line condensates.

Block-B is side gradient (west) of Hinkley Creek. Drainage from the northern sectors from Block-B intersects a tributary to Hinkley Creek that enters the main stream between H1 and H2. Since B-Block is a finished product storage area, it is very unlikely that contamination from the activities conducted in this area would have entered from this tributary.

Several additional tributaries that issue from the western edge of Block-C may contribute runoff from the area periodically. This runoff from the Block-C storage may contain TNT and RDX stored in that area, although it is highly unlikely due to the care taken in the packaging and handling of these explosives.

2.1.3 Section on H-3

The third sample location, designated as Hinkley Creek No. 3 (H-3), is directly south of the runway used by NACA in its aircraft testing program. Considering the location of the actual aircraft test area to H-3, it most likely would have a greater impact on Hinkley Creek No. 4 (H-4) and will be covered in that section. Between the runway and sampling interval is Demolition Area #1, which was used for the demilitarization of fuze and fuze components. Some remedial and removal activity has recently been accomplished at Demolition Area #1. This interval is also down gradient from a main tributary that originates from the south end of Block C.

The highest probability for contamination entering Hinkley Creek at this location is runoff from the Demolition Area #1. Suspect compounds from products manufactured at RVAAP during WWII and from the incomplete combustion during the demilitarization process would be lead azide, mercury fulminate, tetryl, potassium nitrate and oxidized sulfur in the form of metal sulfites and sulfates, lead oxide, and mercuric oxide. Since demilitarization continued after WWII, other compounds that might be present are lead styphnate, a primary explosive, trinitroresorinol, and RDX from the lead cups integrated into more modern fuze systems. Oxidation of the metals components will have also occurred and may be found as iron, aluminum, and cadmium oxides. The cadmium would be from the plated booster cups and other fuze components.

Runoff from the Block-C storage may contain trinitrotoluene (TNT) and RDX stored in that area although it is highly unlikely due to the care taken in the packaging and handling of these compounds (See H-2). It was reported that annealing compounds were disposed of in C-Block Quarry. Common pre- and post treatment annealing compounds consist of degreasers such as detergents, phosphoric and citric acids, scouring agents commonly mixed with corncobs, as well as spent chromic acid. Contaminants carried from upstream should also be considered.

2.1.4 Section on H-4

The last sample location along Hinkley Creek's mainstem is at the fence line NPDES outfall directly west of landing strip utilized for the former NACA Test Area and intersecting South Perimeter Road. The sampling interval is up gradient from the outfall. A tributary entering Hinkley Creek downstream of sampling interval H-3 and upstream of H-4 interval emanates from Load Line # 8 (LL #8) used for the manufacture of booster components during WWII. The line was shutdown in 1945; all equipment was removed and never re-activated. Other facilities potentially impacting this run of Hinkley Creek include drainage from Fuze Lines 1 and 2, designated as Load Lines #5 & #6 (LL #5 & LL #6) to the previous mentioned tributary from LL # 8. Load Line #5 like LL #8 was shutdown in 1945; the equipment was removed and never reactivated. Several areas of Load Line #6 were modified and projects significantly different from the fuze loading operations in the 1940s era were conducted.

The potential contaminants contributed from LL #5 and LL #8 would be the primary explosive mercury fulminate, the components of black powder (potassium nitrate, sulfur, carbon) and the booster explosive tetryl. Marking inks, ethyl alcohol, lacquers, lacquer thinners [containing methyl ethyl ketone (MEK)], toluene, xylenes, isobutyl alcohol, methyl isobutyl ketone (MIBK), isopropyl alcohol, shellacs, Stoddard's solvent, and paints with organic and metallic pigments were used. At the booster lines, binders such as Gum Arabic were blended with the tetryl before the pellet manufacturing process.

The potential contamination from LL #6 for the 1941 to 1945 era of operation would be the same as that associated with LL #5 designated in the previous paragraph. Changes to LL #6 include the construction of a bunker outside Building 2F-12 used for shape charge testing; conversion of Building 2F-4 for the melt pour loading of 106 mm Recoilless Rifle projectiles; the construction of a warhead testing facility across the road from 2F-12 and the construction of a mine testing pond and an additional above ground test area to the southeast of Building 2F-3 [A General Layout, dated 1964 for the Open Test Range (Area) operated by Firestone Defense Research indicated that the open detonation area was used to test Pulsing Charges, fragmentation charges and 15 lb. High Explosive (HE) loads. Firestones contract was with the Picatinny Army Research and Development Command, Dover NJ. HE compound would include RDX, HMX, Composition B, and other explosive combinations. Residual contamination of Primary explosives from the detonators or primer mechanism would be minimal.]

Potential compound contributing to surface runoff from the bunker associated with 2F-12 would include the secondary explosives TNT, RDX, and Composition B. Contaminants carried from upstream should also be considered.

2.2 Sand Creek

The flow direction for Sand Creek is from the locations specified as S-1 through S-11. The creek is described as a free flowing. What appears to be the main stream enters the Ravenna Army Ammunition Plant just north of igloo storage area specified as Block-C and the North Perimeter Road. See Appendix 1 for site map.

2.2.1 Section on S-1

The first sample location, noted as Sand Creek No. 1(S-1), is at the intersection of the main stream of Sand Creek and Newton-Falls Road. A tributary to Sand Creek, which emanates from Block-D and passes adjacent to Building F-16, enters slightly north of the sampling interval. From operations that were conducted in this building, contaminated run-off may feed the aforementioned tributaries leading to main stream of Sand Creek. Some contaminants may also be expected from Block-C and the Block-C Quarry.

Potential compounds of concern from Block-C and the Block-C Quarry are reported in the section describing potential contamination to H-3. No contamination would be expected from the Block-C area, since it was utilized for finished products. However, disposal practices at Block-C Quarry have been documented and discussed in Section 2.1.3.

From 1951 to 1957, Building F-16 was used for the demilitarization of ammunition ranging from 37mm to 75mm, and components such as fuzes. Compounds that may have affected Sand Creek are nitrocellulose, 2,4-dinitrotoluene, dibutylphthalate, barium and potassium nitrate, graphite and diphenylamine (Diphenylamine is an Ultraviolet (UV) stabilizer commonly used in the M Series Gun propellants.) from M-1, M-2 and M-6 propellants; TNT, tetryl, Explosive D (ammonium picrate) and tetrytol (70 % tetryl, 30 % TNT). Seventy-five millimeter (75mm) smoke projectiles containing white phosphorus (WP) were handled at F-16. Also reported was the possible surveillance testing of signal flares that may have been conducted at Building F-16.

2.2.2 Section on S-2

The second sample location, designated as Sand Creek No. 2 (S-2), is also at the intersection of Sand Creek and Newton-Falls Road, approximately 0.9 miles directly east of S-1. The sampling interval is upstream and downstream of the road. The main stream runs from slightly east to the northeast of Load Line # 11 (LL #11), that was an artillery primer loading operation. Load Line #7 (LL #7) may also contribute contaminants from surface runoff.

Contamination potentially affecting this portion of the tributary to Sand Creek would include the compounds used in black powder and primer compounds. These would include potassium nitrate, sulfur, carbon, TNT, lead thiocyanate, antimony sulfide, and potassium chlorate. Solvents and lubricants used in the manufacturing processes conducted at LL #11 may also be found.

Potential contributions from LL # 7 resulting from the manufacturing process used during WWII would be analogous to LL #8, some of which is summarized in the descriptions provided for Hinkley Creek sampling interval H-4. There were at least two major modifications to operations at LL #7 after 1945. These included the manufacture of two specific rounds of 40mm ammunition, and a potential melt pour operation. A washout pink water treatment facility was also part of the operation.

Expected contamination from the 1940s operations would include tetryl. From 1969 to 1971, the M-406 and M-407A1 40mm rounds were produced at LL#7. Expected compounds from bulk handing operations would be RDX, TNT, polyisobutylene, and stearic acid. Also used in large quantities was the propellant M-9. Its composition is nitrocellulose, nitroglycerin, potassium nitrate, ethyl centralite and graphite. The smoke component in the training round M-407A1 is N,N-diethyl-4-(phenylazo)-benzenamine. No contamination from the primers or fuzes used would be expected because they are sealed systems and would enter the assembly process as completed components. Contaminants can also be expected from the up-gradient locations specified for the previous sampling intervals.

2.2.3 Section on S-3

The third location, denoted as Sand Creek No. 3 (S-3), is situated along a tributary to the main Sand Creek, and also intersects Newton-Falls Road approximately 0.56 miles directly east of the sample interval S-2. This sampling interval is north of Load Line # 9 (LL #9), which was used for the manufacture of detonator components for fuzes. Load Line #9, like LL#5 & LL#8, was shutdown in 1945; all equipment was removed and never re-activated. Runoff from LL#5, LL #7, LL#10 and LL #11 may also contribute to potential contamination of Sand Creek at this point. The wet storage igloos are located slightly to the northwest of this interval, but it is very unlikely that contamination would emanate from that area because of the handling practices of the compounds stored there. Handling protocol included: Primary explosives, such as lead azide, are stored and transported in drums containing water/alcohol mixtures. The azide is place in a cheesecloth mesh and suspended in the solution. The solution serves a two-fold purpose; 1) the solution keeps the bag of azide from impacting the sides of the shipping container during transport, and 2) the water/alcohol mixtures functions as an antifreeze during shipping and storage. The containers were stored in lead lined boxes (burms) in the igloos. The containers would be removed and transported to Load Line #9, where the amount needed for the day's production would be removed. Once the quantity was removed at the load line, the original container would be returned to the storage igloo.

Suspect compounds entering this watershed from WWII manufacturing at LL #9 would be lead azide, mercury fulminate, and tetryl. Gum Arabic, a solid binder, was blended with the tetryl before the pellet manufacturing process. The most common solvent expected is ethyl alcohol. The lead azide was suspended in cheesecloth in a water/alcohol mixture for safe transport. During storage, the mixture also functioned as an anti-freeze.

The potential contaminants contributed from LL #5 would be the primary explosive mercury fulminate, the components of black powder (potassium nitrate, sulfur, carbon) and the booster explosive tetryl. Marking inks, ethyl alcohol, lacquers, lacquer thinners [containing methyl ethyl ketone (MEK)], toluene, xylenes, isobutyl alcohol, methyl isobutyl ketone (MIBK), isopropyl alcohol, shellacs, Stoddard's solvent, and paints with organic and metallic pigments were used.

Since this tributary may extend back to Booster Line #2, the Fuze/Booster settling tanks may also contribute to the surface water from over flow. Potential contamination from LL #7 is described in the summary for Sand Creek #2.

Compounds that might be expected from LL #10, the percussion element manufacturing line, are TNT, pentaerythrite tetranitrate (PETN), potassium chlorate, antimony sulfide, and lead thiocyanate. Contaminants can also be expected from the up-gradient locations specified for the previous sampling intervals.

2.2.4 Section on S-4

The Sand Creek No. 4 (S-4) sample point is approximately 0.38 miles directly south of the southern edge of the Winklepeck Burning Grounds. The sampling interval was upstream and downstream of the George Road Bridge. The site also is slightly northeast-east of the Wet Storage Area. Again, no contributions from the Wet Storage Area are expected. The sampling interval is also situated downstream of Open Demolition Area 2.

Potential contamination would include those compounds from incomplete combustion in the Winklepeck burning ground area and or Open Demolition Area 2 (ODA2). These would include such compounds as TNT, RDX, HMX, 2,4 dinitrotoluene (2,4- DNT), nitrocellulose, dibutylphthalate, and diphenylamine (Diphenylamine is an Ultraviolet (UV) stabilizer commonly used in the M Series Gun propellants) from bulk disposal practices. Also found were fuze and primer components, which may have contained lead azide, mercury fulminate, TNT, antimony sulfide, PETN, and lead thiocyante. Other expected compounds would be the oxides from the combustion process, which include, but are not limited to lead, cadmium, barium and strontium. During the Remedial Investigation field work performed in the summer of 2002, smoldering (presumably from white phosphorus) was observed on the south bank of Sand Creek in an area identified as Rocket Ridge. The smoldering has not been observed since that time and the exact nature of this observation has not been verified. Additional contaminants can also be expected from the up-gradient locations specified for the previous sampling intervals.

2.2.5 Section on S-5

The Sand Creek No. 5 (S-5) sampling interval is along the northern boundary of the High Explosive Storage area, Area 5, at the location where Sand Creek intersects Wilcox-Wayland Road. The eastern most edge of the Winklepeck Burning Grounds is northwest of S-5. Contamination contributions would be expected from both areas.

Runoff from the High Explosive Storage area would be limited to and have some minimal impact on the S-5 location. Runoff from Winklepeck would be of greater importance. Potential contamination would include those compounds from incomplete combustion of explosives. These explosives would include such compounds as TNT, RDX, HMX, 2,4- DNT, nitrocellulose, dibutylphthalate, and diphenylamine from demilitarization burning practices. Fuze and primer components were also found, which may have contained lead azide, mercury fulminate, TNT, antimony sulfide, PETN, and lead thiocyante. Other expected compounds would be the oxides from the combustion process, which include but are not limited to: lead, cadmium, barium and strontium. Contaminants can also be expected from the up-gradient locations specified for the previous sampling intervals.

2.2.6 Section on S-6

Location S-6 is situated on an unnamed tributary to Sand Creek at Winklepeck Road near the mouth of the tributary. The S-6 sampling location is along the northeastern boundary of the High Explosive Storage area, Area 5, east of the Winklepeck Burning Grounds and directly south of the finished ammunition storage area designated as Area 1-A. No contamination contribution is expected from the finished product storage area Area 1-A.

2.2.7 Section on S-7

Sand Creek No. 7 (S-7) is down gradient from a tributary along the south side of the high explosive storage area, Area 5, that extends through the north end of the Fuze and Booster Storage area, Area 4, to Load Line #9 and the Wet Storage Area. No contribution is expected from the Fuze and Booster Storage of finished products, the Wet Storage igloos or any potential compound that may enter from LL #9 as described in Sand Creek S-3.

Tributaries emanating back to Block-D, Block-E and Storage Areas A-1 and A-1-A all enter the mainstem of Sand Creek up-gradient of this sampling interval. These areas are all finished product storage and would not influence the contamination in S-7. The major influence to S-7 would be from the up-gradient locations along the main channel of Sand Creek.

2.2.8 Section on S-8

Sand Creek No. 8 (S-8) is located along a tributary to Sand Creek slightly down gradient from S-7. Features feeding this location are Upper and Lower Cobbs Ponds which in turn have drainages from Load Lines 3 and 12 and the Atlas Scrap Yard. The sampling interval is adjacent to the Sand Creek Sewage Treatment Plant. Contamination emanating from both load lines and the Atlas Scrap Yard through both Upper and Lower Cobb's Ponds is expected.

The nature of the expected contamination from LLs #3 and #12 includes, but is not limited to 1,3,5-

trinitrobenzene, TNT, 2,4-DNT, 2,6-DNT, 2-amino-4,6-DNT, 4-amino-2,6-DNT from the melt pour operations and the natural degradation of TNT. Expected also from the propellants M-1, M-2, M-5 and M-6 used in loading is nitrocellulose, nitroglycerin, nitroguanidine, barium nitrate, potassium nitrate, dibutyphthalate, and diphenylamine. The compounds and elements of black powder, potassium nitrate, sulfur and carbon and their oxides may also be present.

2.2.9 Section on S-9

Sand Creek No. 9 (S-9) is directly south of the ammunition holding area A-2, to the east of the 1-A ammunition storage area, and the sampling interval is upstream and downstream of Windam/Paris Road. No compounds of concern are expected from the A-2 holding area at this location. The major influence to S-9 would be from the up-gradient locations along Sand Creek, particularly those from LLs #3 and #12.

2.2.10 Section on S-10

Sand Creek No. 10 (S-10) is east of the southern end of the inert storage area, Area 2, and straddles a spur of the railroad bed in this area. A tributary emanating from Load Lines #1 and #2 could also contribute to this sampling interval. This interval is similar to the previous Sand Creek location sampled, and no compounds of concern are expected from Area 2 at this location. Potential contamination from LLs #1 and #2 has been covered in S-8 & 9 summaries.

2.2.11 Section on S-11

S-11 is along Smalley Road slightly to the northeast of the Smokeless Powder Storage area, Area 3, and at the northeastern edge of the ammunition holding area, Area 2. It is up gradient from the entrance of Sand Creek into the South Fork Eagle Creek. This location would be solely influenced from the up-gradient locations along the whole path of Sand Creek.

2.3 South Fork Eagle Creek

The South Fork of Eagle Creek is situated generally along the north boundary of the facility from approximately north of Block-D to north of Area 3. Flow direction is from SFE-1 through SFE-5. See Appendix 1 for site map.

2.3.1 Section on SFE -1

Sampling site SFE -1 is located on an unnamed tributary to South Fork Eagle Creek near where the South Fork enters RVAAP property. Site SFE-1 is directly north of the Block-D storage area and down-gradient of Building F-15. A major explosion occurred in the northern most section of D-Block in 1943 during a boxcar unloading operation that was transferring M-41 fragmentation bombs, and M-110 nose fuze. Damage extended as far as 2100 feet to other existing structures. The exact nature of the compounds in these munitions is not known, but TNT, RDX and other high explosives were the most likely constituents.

Building F-15 may also feed side tributaries to SFE-1. From 1951 to 1957, Building F-15 was used for the demilitarization of ammunition ranging from 37mm to 75mm, and components, such as fuzes. Compounds that may have affected SFE - 1 include, but are not limited to nitrocellulose, 2,4-DNT, dibutylphthalate, barium and potassium nitrate, graphite and diphenylamine from M-1, M-2 and M-6 propellants, TNT, tetryl, Explosive D (ammonium picrate) and tetrytol (70 % Tetryl, 30 % TNT).

2.3.2 Section on SFE's 2, 3, & 4

Unnamed tributary to South Fork Eagle Creek site SFE-2, and South Fork Eagle Creek sites 3 and 4 (SFE-3, & 4) would be influenced by runoff from Block-E and Areas 1 and 1-A, which are all finish product storage areas. No contamination would be expected to emanate from these areas considering the nature of the operations conducted. These locations would be solely influenced from the up-gradient location SFE-1 and any tributaries flowing up-gradient into South Fork Eagle Creek.

2.3.3 Section on SFE – 5

South Fork Eagle Creek-5 is down-gradient of the entrance of Sand Creek into SFE Creek. The major contribution for SFE #5 would come from all the up-gradient influences of South Fork Creek and Sand Creek. Consideration should be given to any off site contribution(s) from runoff emanating from other local operations.

2.4 Unnamed Tributary to W. Br. Mahoning River (@RM 0.01)

The unnamed tributary to the West Branch Mahoning River (confluence at RM 0.01) was identified in the workplan as No Name Stream No. 3 (NN#3). Sampling locations were identified as NN#3-1 to NN#3-4. Flow direction is from NN3#-1 located downstream of the Erie Burning Ground Pond through NN3#-4 located at State Route 534. The main impacts on the NN#3 main stream is from the Erie Burning Grounds and Load Line #1. No other areas from the main production at Ravenna Army Ammunition Plant affect this particular stream. Operations that are part of the Ohio National Guard's activities may contribute to the stream. These will not be discussed or presented in this report. See Appendix 1 for site map.

2.4.1 Section on NN#3-1

The sampling location designated as No Name Stream #3 – 1 (NN#3-1) is down-gradient of the former Erie Burning Grounds and is situated at Smalley Road. Contaminants would be similar to those described above for S-4, which received drainage from the Winklepeck Burning Grounds.

2.4.2 Section on NN#3-2

The sampling interval for No Name Stream #3 – 2 (NN#3-2) was relocated during the field investigation and is located where NN#3 flows from Portage County into Trumbull County. Expected contamination for this location would be predominantly from the up-gradient main stream emanating from NN#3-1.

2.4.3 Section on NN#3-3

No Name Stream #3 – 3 is upstream and downstream of the Bailey bridge on the Ohio Army National Guard Training facility. Considering the location of this sampling interval, potential contamination would emanate from Load Line #1 and any compounds entering the main stream up-gradient from this location. Load Line #1 contributions would be Composition B, TNT and the propellant M1 consisting of the compounds NC, 2, 4 DNT, DBP, and diphenylamine.

2.4.4 Section on NN#3-4

No Name Stream #3 – 4 (NN#3-4) is situated upstream and downstream of State Route 534, just east of the Ohio Army National Guard training facility. All contamination found in this portion of the stream would be from up-gradient sources feeding the main streams of NN#3-1 through NN#3-3.

2.5 Unnamed Tributary to W. Br. Mahoning River (@ RM 9.63, 0.74)

The unnamed tributary to the West Branch Mahoning River (confluence at RM 9.63,0.74) was identified in the workplan as Load Line #4 Stream. Load Line #4 stream sampling interval was down-gradient from Load Line #4 Pond (LL#4 Pond). A stream arm feeding the LL #4 pond continues upstream to the fuze and booster storage igloos, Area 4. This arm is also in the proximity of RVAAP # 48 (Anchor Test Area), which will undergo initial investigation in Fall, 2004. See Appendix 1 for site map.

No contamination is expected from the fuze and booster storage igloo area, Area 4, since finish sealed fuze and fuze components were staged for other operations or stored prior to shipment to other load, pack and assemble facilities. The activities conducted at these locations are not conducive to processes that one would expect major contamination.

The majority of the potential contamination is expected from Load Line #4. Expected contamination would be similar to that described for Kelly's Pond, which drains approximately the south half of Load Line #2. RVAAP # 48 will undergo investigation in Fall, 2004, so little is known as to its potential for contributing to the contamination of LL#4 Pond.

3 METHODS

All physical, chemical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a), Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c), The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995) for aquatic habitat assessment, Ohio EPA Sediment Sampling Guide and Methodologies (Ohio EPA 2001, Louisville Chemistry Guidelines, Version 5 (USACE 2002), and the Facility-Wide Sampling and Analysis Plan for Environmental Investigations at the RVAAP, Ravenna, Ohio (USACE 2001). Sampling locations are listed in Appendix 2.

3.1 Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 7-15). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the Index of Biotic Integrity (IBI) and modified Index of Well-Being (MIwb), indices measuring the response of the fish community, and the Invertebrate Community Index (ICI), which indicates the response of the macroinvertebrate community. The MIwb was not applicable in evaluating streams of the RVAAP because all sites were at or less than 20 square miles drainage. Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fail to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment Tables constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (*i.e.,* full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and a sampling location description.

3.2 Habitat Assessment

Physical habitat for streams was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score, which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of stream segments around the state have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently typify habitat conditions which have the ability to support exceptional warmwater faunas.

3.3 Sediment Sampling/ Assessment

The RVAAP stream sampling locations were sampled once for sediment during 17 – 25 June 2003. To obtain a representative measure of chemical contamination within the sediment, multi-incremental sampling was performed at each co-located biological sampling site. At each stream sample site, the entire sampling reach (120 - 210 m) was walked from downstream to upstream, with equal volume sediment sub-samples taken randomly at 30 to 50 locations. Each of these sub-samples was then composited together to provide an average sediment sample for each biological sampling site. Sediment field sub-samples were collected with two tools; a two-ounce plastic scoop for the cobble/gravel bottom streams in the South Fork Eagle Creek and Sand Creek basins; and a steel, nickel-plated step probe with a 13" slot and inside diameter of 7/8-inch for all other stream samples. At the hard bottom streams, the plastic scoop was used to collect 2 ounces of the upper 1-2 inches of silty-sandy sediment present. Where the step probe was utilized, individual field sub-samples were collected from the upper 4 – 6 inches of the stream bottom of the more silty, clayey sediment. The sediment collected was placed in doubled plastic baggies, sealed, and placed on ice in a cooler for transport to the sample preparation building on site. All sampling equipment was decontaminated between stream sample sites according to the Ravenna Facility-Wide Sampling and Analysis Plan.

The overall goal of the sediment collection was to collect sufficient material over the sample area (stream or pond) to account for both compositional and distributional heterogeneity. Much more sediment sample material was collected than could be practically forwarded to the laboratory. Thus processing was done of the field collected sample to provide a smaller but representative sample of material for shipment to a laboratory. The type of material collected determined the type of processing required. For the silty/clayey sediments (muck) collected from the ponds and several streams, the entire sample was mixed and laid out and 30 small spoon samples taken randomly across the mix to fill each of the analytical sample jars. For the silty sandy sediment incremental samples from the South Fork Eagle Creek and Sand Creek basins, the entire sample was initially sieved through a #10 size sieve. All materials larger than the #10 sieve size were discarded. The remaining material was mixed, laid out and 30 small spoon samples taken randomly across the mix to fill each of the analytical sample jars. The sample processing described provided a more representative and uniform set of samples for the laboratories to analyze. Once sediment samples were processed, the jars were placed on ice (to maintain 4^{o}C) in a cooler, and shipped to USACE contract labs. Quality control (QC) and quality assurance (QA) samples were collected as directed by the LCG and the QA samples were submitted to a secondary USACE contract lab. Sediment data is reported on a dry weight basis.

Sediment evaluations were conducted using guidelines established in MacDonald *et al.* (2000), sediment reference values for inorganic chemicals (Ohio EPA 2003), USEPA Region 5 Ecological Screening Levels - ESLs (2003), and published literature.

3.4 Surface Water Sampling/ Assessment

Surface water grab samples were collected from the upper 12 inches of stream water and sampled directly into appropriate containers. The RVAAP stream sampling locations were sampled twice with the initial samples collected during17 – 25 June 2003. The second round of stream samples were collected during 15 – 18 September 2003. These water sampling periods coincided with the fish collection passes and when the macroinvertebrate samplers were set and retrieved. The initial surface water sampling was concurrent with the sole sediment sampling event. Collected surface water samples were preserved using appropriate methods, as outlined in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 1991), and the Louisville Chemistry Guidelines (LCG) Version 5 (USACE 2002), and shipped to the USACE contract laboratory. Additionally, chemical analyses of the surface water conformed to the RVAAP Facility-Wide Sampling and Analysis Plan for Environmental Investigations at the RVAAP, Ravenna, Ohio (USACE 2001). Quality control (QC) and quality assurance (QA) samples were collected as directed by the LCG and with the QA samples submitted to a USACE contract laboratory different from the primary lab. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions, or published literature.

3.5 Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from the natural habitats at 23 RVAAP stream sites. The artificial substrate collection provided quantitative data and consisted of a composite sample of five modified Hester-Dendy (H/D) multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multihabitat composite sample was also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (e.g., riffle, run, pool, margin). At 8 of the RVAAP stream sites with small drainage basins, qualitative samples were collected when the H/D samplers were initially set in case the sites went dry later in the season. Detailed discussion of macroinvertebrate field and laboratory procedures is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b). Due to extremely high flow conditions in all of the RVAAP streams during the initial artificial substrate sets (July), all stream sites with initial H/Ds had to be reset. Original H/D sets were either completely buried in bottom sediments, washed downstream from there original set, or completely lost. All stream H/Ds were reset from 4-8 August, 2003 and retrieved 15-19 September, 2003. Ohio EPA Macroinvertebrate Field Sheets were filled out for each sampling site, noting physical stream characteristics and predominant organisms by habitat type.

3.6 Fish Community Assessment

Fish were sampled twice at each stream site using pulsed DC electrofishing methods; the long-line wading method was used at stream sites. Sampling distances at stream locations varied between 120m and 210m. Fish were processed in the field, and included identifying each individual to species, counting, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989b).

3.7 Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr *et al.* 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data; we are referring to the process for evaluating biological integrity and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. There have been criticisms of misapplying the metaphor of ecosystem "health" compared to human patient "health" (Suter, 1993). Here we are referring to the process for identifying biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

4 SAND CREEK AND TRIBUTARIES

4.1 SUMMARY

A total of 7.5 miles of Sand Creek were assessed in 2003. Based on the performance of the biological communities, the entire 7.5 miles of Sand Creek were in full attainment of the Warmwater Habitat aquatic life use (Table 4-1). None of the chemicals measured in the surface water of Sand Creek exceeded criteria protective of the Warmwater Habitat aquatic life use. Aside from one chemical, all organic parameters tested (explosives, semivolatiles, pesticides, and PCBs) in the water were reported as non-detect. Nutrients, metals and dissolved solids were at low levels in Sand Creek surface water, and were largely reflective of the undeveloped condition of the watershed. Some SVOCs were detected in sediment collected from all locations in Sand Creek. However, the concentrations were either below screening levels or when marginally above screening levels, the concentrations were estimated values. Metals in sediments were below Ohio sediment reference values and organic compounds were either non-detect or at low levels. Stream physical habitat conditions were good to excellent. QHEI scores for Sand Creek averaged 75.2, demonstrating the potential to support WWH biological communities. Mountain brook lamprey, a state endangered fish, and the caddisfly Psilotreta indecisa, a state threatened insect, were collected from Sand Creek. Based on sampling results from Sand Creek, no biological impairment associated with chemical contaminants was observed. Fish communities in Sand Creek were assessed by the Ohio DNR during 1999 and 1993. Results of those collections were generally comparable to the 2003 results, with a majority of sites attaining the Warmwater Habitat biocriterion.

Three unnamed tributaries to Sand Creek were assessed in 2003. Biological results indicate that these three unnamed tributaries were in full attainment of the Warmwater Habitat aquatic life use (Table 4-1). Surface water and sediment conditions in the three unnamed tributaries were reflective of good water resource quality, and physical habitat demonstrated the potential to achieve the Warmwater Habitat use. Based on sampling results from three unnamed tributaries to Sand Creek, no biological impairment associated with chemical contaminants was observed. Fish communities were assessed at two of the three unnamed tributaries previously during 1999 and 1993. Biological performance was comparable between the three years in the tributaries sampled.

Sampling during 2003 confirmed the appropriateness of the Warmwater Habitat aquatic life use designation for Sand Creek. Presently, Sand Creek is listed as Warmwater Habitat in the Ohio Water Quality Standards (WQS). Based on the 2003 sampling results, Tributary to Sand Creek @ RM 4.84, Tributary to Sand Creek @ RM 3.25, and Tributary to Sand Creek @ RM 2.22 are recommended for listing as Warmwater Habitat streams in the Ohio WQS.

Table 4-1 Attainment status of the aquatic life use for Sand Creek and tributaries based on biological sampling conducted during June - September 2003.

RIVER MILE Fish/Invert.	Sample Location	IBI	ICI	QHEI	Attainment Status	Site Location
Ecoregion - *Erie Ontario Lake Plain (EOLP)*						
Sand Creek *- WWH Use Designation (Existing)*						
7.0/ 7.0	S-1	41	54	74.0	FULL	Background site
5.9/ 5.9	S-2	40	54	78.5	FULL	Dst. West Fuze/Booster Load Lines
4.5/ 4.5	S-4	37[ns]	44	75.5	FULL	Dst. Demolition Area #2
3.7/ 3.7	S-5	44	50	85.5	FULL	Dst. Winklepeck Burning Ground
2.4/ 2.4	S-7	36[ns]	54	70.0	FULL	Dst. Central Burn Pits
1.9/ 1.9	S-9	43	46	71.5	FULL	Dst. Paris-Windham Dump
1.5/ 1.5	S-10	39[ns]	46	74.5	FULL	Dst. LLs # 1 and 2
0.8/ 0.8	S-11	36[ns]	50	72.0	FULL	Lower end of Sand Creek drainage
Tributary to Sand Creek *(at RM 4.84) - WWH Use Designation (Recommended)*						
0.3/ 0.3	S-3	48	38	68.0	FULL	Dst. East Fuze/Booster Load Lines
Tributary to Sand Creek *(at RM 3.25) - WWH Use Designation (Recommended)*						
0.1/ 0.1	S-6	45	40	74.5	FULL	Dst. North Winklepeck Landfill
Tributary to Sand Creek *(at RM 2.22) - WWH Use Designation (Recommended)*						
0.1/ 0.1	S-8	48	26*	61.0	FULL**	Dst. Lower Cobbs Pond

Ecoregion Biocriteria: Erie Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[a]
IBI-Headwater	40	50	24
ICI	34	46	22

[a] Modified Warmwater Habitat for channel modified areas.
* Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
[ns] Nonsignificant departure from ecoregion biocriterion (≤4 IBI and ICI units).
** The macroinvertebrate community did not attain the WWH criterion based on an ICI score of 26; however with a drainage area less than 1mi^2 , a Primary Headwater Habitat (PHWH) use is most appropriate. The macroinvertebrate community achieves a Class 3 PHWH rating, and there appears to be no impairment.

4.2 Surface Water Quality

Chemical analyses were conducted on surface water samples collected in June and September, 2003 from eight locations in Sand Creek and three unnamed tributaries to Sand Creek (Appendix 2, Appendix 3 Tables 1 and 2). Surface water samples were analyzed for target analyte list metals, pesticides, PCBs, explosive compounds, semivolatile organic compounds, and several nutrient parameters. Parameters which were in exceedence of Ohio WQS criteria are reported in Table 4-2.

4.2.1 Sand Creek

For all eight of the Sand Creek sampling locations, there were no exceedences of the Ohio WQS aquatic life maximum or average water quality criteria. None of the chemicals measured in this study exceeded criteria protective of the Warmwater Habitat aquatic life use. Concentrations of all but one [bis(2-ethylhexyl) phthalate] of the organic parameters tested (explosives, semivolatiles, pesticides, and PCBs) were reported as non-detect. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] In addition, metals concentrations were very low, with many of the results less than lab detection limits. Parameters with measurable concentrations were below applicable Ohio WQS aquatic life criteria. All ammonia-N measurements were less than lab detection limits (0.10 mg/l), and nitrate-N values were measured at low concentrations, with all values less than Ohio least impacted reference conditions (below Erie Ontario Lake Plain ecoregion 75th percentile value). Low nutrient and dissolved solids levels in Sand Creek were largely reflective of the undeveloped condition of the watershed.

4.2.2 Unnamed Tributaries to Sand Creek

Similar surface water chemical conditions observed in Sand Creek were also recorded for three unnamed tributaries to Sand Creek. None of the chemical measurements exceeded Ohio WQS aquatic life maximum or average criteria (Table 4-2). None of the chemical concentrations exceeded criteria protective of the Warmwater Habitat aquatic life use. Concentrations of all but one [bis(2-ethylhexyl) phthalate] of the organic parameters tested (explosives, semivolatiles, pesticides, and PCBs) were reported as non-detect. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] In addition, metals concentrations were very low, with many of the results less than lab detection limits. All ammonia-N measurements were less than lab detection limits (0.10 mg/l), and nitrate-N values were measured at low concentrations, with all values less than Ohio least impacted reference conditions (below the Erie Ontario Lake Plain ecoregion 75th percentile reference value).

4.3 Sediment Chemistry

Sediment samples were collected at eight locations in Sand Creek and three unnamed tributaries to Sand Creek during June, 2003. Samples were analyzed for semivolatile organic compounds, pesticides, PCBs, target analyte list metals, explosive compounds, percent solids, cyanide, ammonia, nitrate, and phosphorus. Specific chemical parameters tested and results are listed in Appendix 3 Tables 1 and 2.

Sediment data were evaluated using guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald *et.al*. 2000), and USEPA Region 5, RCRA Appendix IX compounds - Ecological Screening Levels (ESLs) (USEPA 2003). The consensus-based sediment guidelines define two levels of ecotoxic effects. A *Threshold Effect Concentration* (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A *Probable Effect Concentration* (PEC) indicates a level above which harmful effects are likely to be observed. Ecological screening levels (ESLs) are initial screening levels used by USEPA to evaluate RCRA site constituents. In addition, sediment reference values (SRVs) for metals (Ohio EPA 2003) are presented in Table 4-3 for comparison to the Sand Creek watershed results.

4.3.1 Sand Creek

All metals tested in sediments were below Ohio sediment reference values (Ohio EPA 2003) - levels established from chemical results collected at biological reference sites. All tested explosive compounds, pesticides, PCBs, and most semivolatile organic compounds were not detected in sediment samples collected from Sand Creek. The few detected semivolatile compounds were measured at low levels; i.e., the concentrations were either below screening levels , or when marginally above screening levels, the concentrations were estimated values. Di-n-butyl phthalate was detected (estimated concentration) at four of eight Sand Creek sediment sites; however, all values were below ESLs. Phthalates are potential lab contaminants. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] Ammonia and total phosphorus levels were measured in all Sand Creek sediment samples below screening guidelines (Persaud et. al. 1993).

Total cyanide was measured at three Sand Creek sampling locations (RMs 5.9, 4.5, and 3.7) above ESL levels. Cyanide as measured and reported as total cyanides in sediments can include hydrogen cyanide (HCN), cyanide anion (CN^-), simple cyanides, and metallo- and organo-cyanide complexes. HCN and CN^- are grouped as free cyanides and are the most toxic forms of cyanide and the forms of concern. Most complexed cyanides are relatively nontoxic and total cyanide determinations are not very useful measures of either water or sediment quality. Factors that affect the release or dissociation of free cyanides from complexed cyanide forms include pH, redox potential, photodecomposition of the complex and release of free cyanide, relative strength of the metallo- and organo-cyanide complexes, and possible presence of bacteria responsible for degradation of ferrocyanide complexes. In sediments, the cyanide in the free form present in the pore water is more relatable to toxicity to benthic organisms than the total cyanide measured in the solid phase. However, given the above factors, it is difficult to predict or model the dissociation and release of the free toxic forms of cyanide to the pore water from the less toxic total cyanide form associated with and normally measured in the solid phase sediments (Wisconsin DNR 2003). Free cyanides as HCN, in general, are not very persistent in the environment due to their volatility, have low adsorption to sediment particles, high water solubility, and do not substantially bioaccumulate. Moreover, there are no reports of cyanide biomagnification or cycling in living organisms, probably owing to its rapid detoxification. Cyanide seldom persists in surface waters and soils owing to complexation or sedimentation, microbial metabolism, and loss from volatilization. Cyanides do not seem to persist in aquatic environments (Eisler 1991).

4.3.2 Unnamed Tributaries to Sand Creek

Some SVOCs were detected in sediment samples collected from two of the unnamed tributaries to Sand Creek (@ RMs 3.25 and 2.22). However, the concentrations were either below screening levels, or when marginally above screening levels, the concentrations were estimated values. All of the metals measured were below Ohio reference values, and all explosive compounds, pesticides, PCBs, and nearly all semivolatile compounds were not detected in the sediment. Any detected semivolatile compounds were measured at very low levels and below ecologically harmful effects guidelines.

The unnamed tributary to Sand Creek at confluence point river mile 4.84 was sampled near the mouth at Old Newton Falls Road. Eight PAH compounds were measured above TEC levels, and two PAH compounds were measured above ESL guidelines. These levels suggest a minor potential for adverse influences on the biological stream communities of the unnamed tributary; however, both fish and macroinvertebrate results indicated full attainment of the Warmwater Habitat biological criteria.

Ammonia and total phosphorus levels were measured in all three Sand Creek tributary sediment samples below screening guidelines (Persaud et. al. 1993).

4.4 Physical Habitat For Aquatic Life

Physical habitat was evaluated in Sand Creek and tributaries at each fish sampling location. Qualitative Habitat Evaluation Index (QHEI) scores are detailed in Table 4-4.

4.4.1 Sand Creek

All eight Sand Creek sites evaluated in this survey revealed very good to excellent stream habitats. QHEI scores for Sand Creek sites ranged between 70.0 and 85.5, with an average score of 75.2. These scores demonstrate the potential to support WWH biological communities. Sand was a predominating bottom substrate at nearly all of the sampling sites, with gravel and cobble prevalent at half of the locations. Sandstone bedrock, along with sand, predominated at RM 4.5 (George Rd.), while muck, along with sand, predominated at RM 2.4 (upstream WWTP tributary). The stream channel was natural within the study area and was represented by pool, run, and riffle areas, with minor amounts of glide habitat. Instream channel development was good, and surrounding land use was largely forest and shrub. Of the eight sites sampled in Sand Creek, one site (RM 2.4) was partially impounded by a beaver dam.

4.4.2 Tributary to Sand Creek (at RM 4.84)

One site was sampled in an unnamed tributary to Sand Creek which receives runoff from the east fuze and booster load lines area. The sampling site was typical for the lower 0.3 miles of the tributary. This study documented good stream habitat, represented by a QHEI score of 68.0. Although this stream has a small drainage area (0.5 sq. mi.) and high gradient (91 ft/mi.), pool, run, and riffle areas were well represented in the sampling zone. Gravel and bedrock predominated bottom substrates, maximum pool depth ranged between 70 and 100 cm, riffles were comprised of cobble and boulders, and the riparian corridor was comprised of trees and shrubs.

4.4.3 Tributary to Sand Creek (at RM 3.25)

One site was sampled in an unnamed tributary to Sand Creek which receives runoff from the Winklepeck landfill area (landfill north of Winklepeck Burning Ground) as well as a portion of the burning grounds. The sampling site occurred in the lower 0.2 miles of stream. This study documented good stream habitat, represented by a QHEI score of 74.5. Pool, run, and riffle areas were well represented in a natural channel stream. Gravel predominated bottom substrates, maximum pool depth was 60 cm, riffles were comprised largely of cobble and gravel, and the riparian corridor was comprised of trees.

4.4.4 Tributary to Sand Creek (at RM 2.22)

One site was sampled in an unnamed tributary to Sand Creek which receives drainage from the Upper and Lower Cobbs Ponds. The sampling site occurred in the lower 0.2 miles of stream, within 0.1 miles downstream from Lower Cobbs Pond. This study documented good stream habitat, represented by a QHEI score of 61.0. Pool, run, and riffle areas were well represented in a natural channel stream; however, pool depths were shallow with a maximum depth of 22 cm. Gravel and cobble predominated bottom substrates, riffles were comprised largely of cobble, boulders, and gravel, and the riparian corridor was comprised of trees, shrubs, and old fields.

4.5 Fish Community Assessment

Fish communities were assessed at 11 locations in the Sand Creek watershed (Table 4-5, Appendix 4 Table 1). Eight sites were located on Sand Creek, and one site was located on each of three tributaries to Sand Creek.

4.5.1 Sand Creek

Fish communities ranged from marginally good to good in Sand Creek. IBI scores ranged between 36 and 44. These IBI values achieved the ecoregional biocriterion established for Warmwater Habitat (WWH) streams and rivers in Ohio (Table 4-5). Mountain brook lamprey, an Ohio Endangered Species, were collected in Sand Creek at the lower three sampling locations (RMs 1.9, 1.5, and 0.8). Based on the fish community results from the eight Sand Creek sites, no biological impairment associated with chemical contaminants was observed.

Fish communities were sampled by the Ohio DNR during the summers of 1993 and 1999 at a number of locations in Sand Creek. IBI results from 2003, 1999, and 1993 were graphed longitudinally to evaluate the differences and similarities between years (Figure 4-1). Direct comparisons between the 2003 sampling event and those conducted by the Ohio DNR should be viewed with some caution. IBI calculations for all years of data were based on Ohio EPA methodology, calibrated to the electrofishing wading method. However, most of the 1993 and 1999 fish data were collected using seines, or a combination of seines and electrofishing. Overall, fish biological diversity scores were similar between sampling years at co-located sites. Three of the sampling locations (RMs 3.6, 2.2, and 0.8) reported IBI scores below the Warmwater Habitat biocriterion during either 1993 or 1999. The predominance of shallow bedrock at RM 2.2 (downstream Sand Creek Tributary @RM 2.22) could have been a primary factor in the lower score during 1993. Yearly summer flow variability can have a substantial influence on stream biota in bedrock bottom stream segments. The reason for the lower scores at RMs 3.6 and 0.8 are unknown.

4.5.2 Tributary to Sand Creek (at RM 4.84)

The fish community was assessed at RM 0.3. The IBI score was in the very good range, with a value of 48. The IBI score achieved the ecoregional biocriterion established for Warmwater Habitat streams. Impairment of the fish community was not observed at this site. Past collections of the fish community at RM 0.3 occurred in 1993 and 1999. IBI scores from 1993 and 1999 were 46 and 50, respectively. Results were comparable from all three sampling years, and were reflective of very good to exceptional fish community quality.

4.5.3 Tributary to Sand Creek (at RM 3.25)

The fish community was assessed at RM 0.1. The IBI score was in the good range, with a value of 45. The IBI score achieved the ecoregional biocriterion established for Warmwater Habitat streams. Impairment of the fish community was not observed at this site.

Past collections of the fish community at RM 0.1 occurred in 1993 and 1999. IBI scores from 1993 and 1999 were 40 and 46, respectively. Results were comparable from all three sampling years, and were reflective of good to very good fish community quality.

4.5.4 Tributary to Sand Creek (at RM 2.22)

The fish community was assessed at RM 0.1. The IBI score was in the very good range, with a value of 48. The IBI score achieved the ecoregional biocriterion established for Warmwater Habitat streams. Impairment of the fish community was not observed at this site.

4.6 Macroinvertebrate Community Assessment

Macroinvertebrate communities were assessed using artificial substrates supplemented with a qualitative multihabitat composite natural substrate sample at 11 locations in the Sand Creek watershed (Table 4-6, Appendix 4 Table 4). Eight sites were located on Sand Creek, and one site was located on each of three tributaries to Sand Creek. At the most upstream site (RM 7.0) and the three tributary sites, an additional qualitative sample was collected when the artificial substrate samplers were deployed in June.

4.6.1 Sand Creek

Macroinvertebrate communities were very good to exceptional in Sand Creek. ICI scores ranged between 44 and 54. These ICI values achieved the ecoregional biocriterion established for the designated Warmwater Habitat (WWH) use, as well as meeting the Exceptional Warmwater Habitat (EWH) criterion (Table 4-6). The caddisfly Psilotreta indecisa, which is state listed as threatened, was collected from the three most upstream Sand Creek sites. The midge genus Neozavrelia was collected for the first time in the state from the Sand Creek sites at river miles 5.9 and 4.5. The mayfly, Plauditus cestus, was collected for the first time in Ohio from Sand Creek at river mile 1.5. A Cold Water Habitat (CWH) use designation may be appropriate for Sand Creek from RMs 7.0-3.7 based on the number of macroinvertebrates on the Ohio EPA coldwater taxa list collected from these sites. The macroinvertebrate community results from the eight Sand Creek sites indicated no biological impairment.

4.6.2 Tributary to Sand Creek (at RM 4.84)

The macroinvertebrate community was assessed at RM 0.3. The ICI score was in the good range, with a value of 38. The ICI score achieved the ecoregional biocriterion established for Warmwater Habitat streams. Based on the number of coldwater macroinvertebrate taxa collected in both the June qualitative sample and the September artificial substrate and qualitative samples, a CWH use designation may be appropriate. Impairment of the macroinvertebrate community was not observed at this site.

.

4.6.3 Tributary to Sand Creek (at RM 3.25)

The macroinvertebrate community was assessed at RM 0.1. The ICI score was in the good range, with a value of 40. The ICI score achieved the ecoregional biocriterion established for Warmwater Habitat streams. Based on the number of coldwater macroinvertebrate taxa collected in the June qualitative sample, a CWH use designation may be appropriate. Impairment of the macroinvertebrate community was not observed at this site.

4.6.4 Tributary to Sand Creek (at RM 2.22)

The macroinvertebrate community was assessed at RM 0.1. The ICI score was in the fair range, with a value of 26. The ICI score did not achieve the ecoregional biocriterion established for Warmwater Habitat streams. Although the ICI score indicated potential impairment, the scoring criteria and WWH use may not be appropriate for this site. With a drainage area less than 1mi^2, Ohio EPA's proposed Primary Headwater Habitat classification is appropriate. Using scoring criteria established for this use, this site achieves Class III PHWH, which indicates no impairment.

Table 4-2 Exceedances of Ohio Water Quality Standards aquatic life criteria (OAC 3745-1) for chemical/physical parameters from Sand Creek and three unnamed tributaries in the Sand Creek study area during 2003.

River Mile	Parameter (value)
Sand Creek	
7.0	None
5.9	None
4.5	None
3.7	None
2.4	None
1.9	None
1.5	None
0.8	None
Tributary to Sand Creek (RM 4.84)	
0.3	None
Tributary to Sand Creek (RM 3.25)	
0.1	None
Tributary to Sand Creek (RM 2.22)	
0.1	None

Table 4-3 Chemical parameters measured above screening levels (metals) or detected (organics) in sediment samples collected from Sand Creek and tributaries, June, 2003. Contamination levels were determined for parameters using either consensus-based sediment quality guidelines (MacDonald et.al. 2000) or ecological screening levels (ESLs) for RCRA appendix IX constituents (USEPA 2003). Sediment reference values (SRVs) are listed in the Ohio EPA Ecological Risk Assessment Guidance (2003).

	SAND CREEK SEDIMENT							
Parameter	**RM 7.0**	**RM 5.9**	**RM 4.5**	**RM 3.7**	**RM 3.7 Duplicate**	**RM 3.7 QA Split**	**RM 2.4**	**SRVs**
Arsenic (mg/kg)	7.1	5.3	5.6	5.5	4.8	4.8	12.3^{T}	25
Nickel (mg/kg)	6.3	4.8	6.2	5.4	4.8	4.4	12.7	33
Benzo(a)anthracene (ug/kg)	<410	<420	<370	<410	$140J^{T}$	<390	<430	-
Anthracene (ug/kg)	<410	<420	<370	<410	<410	<390	<430	-
Benzo(a)pyrene (ug/kg)	<410	<420	<370	<410	120J	<390	<430	-
Benzo(g,h,i)perylene (ug/kg)	<410	<420	<370	<410	60J	<390	<430	-
Benzo(k)fluoranthene (ug/kg)	<410	<420	<370	<410	86J	<390	<430	-
di-n-Butyl Phthalate (ug/kg)	400J	54J	340J	430J	230J	<390	120J	-
Fluoranthene (ug/kg)	<410	<420	<370	<410	100J	<390	<430	-
Indeno(1,2,3-c,d)pyrene (ug/kg)	<410	<420	<370	<410	60J	<390	<430	-
Pyrene (ug/kg)	<410	<420	<370	<410	120J	<390	<430	-
Chrysene (ug/kg)	<410	<420	<370	<410	120J	<390	<430	-
Cyanide (mg/kg)	<0.19	1.3^{E}	0.75^{E}	1.2^{E}	1.2^{E}	<1.2	<0.19	-
Phenanthrene (ug/kg)	<410	<420	<370	<410	<410	<390	<430	-

	SAND CREEK and TRIBUTARIES SEDIMENT						
Parameter	**RM 1.9**	**RM 1.5**	**RM 0.8**	**Trib. @ RM 4.84**	**Trib. @ RM 3.25**	**Trib. @ RM 2.22**	**SRVs**
Arsenic (mg/kg)	4.5	4.3	4.8	6.2	4.8	12.6[T]	25
Nickel (mg/kg)	5.3	4.1	4.7	12	4.4	24.2[T]	33
Benzo(a)anthracene (ug/kg)	<400	<430	<410	590[T]	<410	<420	-
Anthracene (ug/kg)	<400	<430	<410	120J[T]	<410	<420	-
Benzo(a)pyrene (ug/kg)	<400	<430	<410	590[T]	<410	<420	-
Benzo(g,h,i)perylene (ug/kg)	<400	<430	<410	340J[E]	<410	<420	-
Benzo(k)fluoranthene (ug/kg)	<400	<430	<410	500[E]	<410	<420	-
di-n-Butyl Phthalate (ug/kg)	<400	<430	79	180J	<410	<420	-
Fluoranthene (ug/kg)	<400	<430	<410	1000[T]	<410	<420	-
Indeno(1,2,3-c,d)pyrene (ug/kg)	<400	<430	<410	330J[T]	<410	<420	-
Pyrene (ug/kg)	<400	<430	<410	950[T]	<410	<420	-
Chrysene (ug/kg)	<400	<430	<410	590[T]	<410	<420	-
Cyanide (mg/kg)	<0.18	<0.19	<0.18	<0.19	<0.18	<0.19	-
Phenanthrene (ug/kg)	<400	<430	<410	480[T]	<410	<420	-

J - The analyte was positively identified, but the quantization was below the reporting limit (RL).
[T] - Above Threshold Effect Concentration (below which harmful effects are unlikely to occur; MacDonald et.al. 2000).
[P] - Above Probable Effect Concentration (above which harmful effects are likely to occur; MacDonald et.al. 2000).
[E] - Above Ecological Screening Level (USEPA 2003).

Table 4-4 – QHEI (Sand Creek)

Table 4-4. Qualitative Habitat Evaluation Index (QHEI) scores for Sand Creek and tributaries, 2003.

Key QHEI Components

			WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence														
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total H.I. MWH Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(18-044) Sand Creek																																		
Year: 2003																																		
7.0	74.0	26.32	■	■		■	■	■		■	■	■	8			◆	◆		2				●					●	●	●		4	0.33	0.78
5.9	78.5	26.32	■	■		■		■		■	■	■	7			◆			1									●				1	0.25	0.38
4.5	75.5	66.67	■	■		■	■	■		■	■	■	8			◆			1									●				1	0.22	0.33
3.7	85.5	27.03	■	■		■	■	■		■	■	■	8			◆			1									●				1	0.22	0.33
2.4	70.0	14.49	■			■		■			■		4		◆	◆	◆		3		●							●	●	●		4	0.80	1.60
1.9	71.5	14.49	■			■	■	■	■		■	■	7				◆		1										●			1	0.25	0.38
1.5	74.5	7.41	■	■		■		■			■		5			◆	◆		2					●				●	●	●		4	0.50	1.17
0.8	72.0	7.41	■	■		■	■	■			■		6			◆			1									●	●	●		3	0.29	0.71
(18-071) Trib. to Sand Creek (RM 3.25)																																		
Year: 2003																																		
0.1	74.5	29.41	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22
(18-074) Trib. to Sand Creek (RM (2.22)																																		
Year: 2003																																		
0.1	61.0	50.00	■	■			■	■				■	5				◆	◆	2		●			●				●	●	●		5	0.50	1.33
(18-075) Trib. to Sand Creek (RM (4.84)																																		
Year: 2003																																		
0.3	68.0	90.91	■	■		■	■	■		■	■	■	8				◆		1									●				1	0.22	0.33

Table 4-5. Fish community summaries based on pulsed DC electrofishing sampling conducted in Sand Creek and tributaries from June and September, 2003. Sampling by Ohio DNR during 1999 and 1993 is also included. Relative numbers are per 0.3 km of stream length. Ohio DNR sampling was conducted using either electrofishing gear, seining, or a combination of both.

Stream/ River Mile	Station Location	Mean Number of Species	Total Number Species	Mean Relative Number	QHEI	Mean Index of Biotic Integrity	Narrative Evaluation
Sand Creek (2003)							
7.0	S-1	13.0	15	643	74.0	41	Good
5.9	S-2	13.0	15	490	78.5	40	Good
4.5	S-4	11.5	13	671	75.5	37^{ns}	Marginally Good
3.7	S-5	15.0	18	851	85.5	44	Good
2.4	S-7	12.5	15	195	70.0	36^{ns}	Marginally Good
1.9	S-9	15.5	19	347	71.5	43	Good
1.5	S-10	16.0	19	419	74.5	39^{ns}	Marginally Good
0.8	S-11	18.0	22	256	72.0	36^{ns}	Marginally Good
Tributary to Sand Creek (at RM 4.84) (2003)							
0.3	S-3	7.5	8	591	68.0	48	Very Good
Tributary to Sand Creek (at RM 3.25) (2003)							
0.1	S-6	9.0	10	573	74.5	45	Good
Tributary to Sand Creek (at RM 2.22) (2003)							
0.1	S-8	8.0	9	141	61.0	48	Very Good
Sand Creek (1999)							
7.0	-	11	11	362	-	40	Good
6.2	-	14	14	442	-	42	Good
5.9	-	10	10	704	-	42	Good
4.5	-	12	12	742	-	40	Good
3.6	-	13	13	500	-	44	Good
3.2	-	10	10	504	-	38^{ns}	Marginally Good
2.3	-	15	15	998	-	38^{ns}	Marginally Good
2.2	-	15	15	108	-	42	Good
1.9	-	14	14	782	-	42	Good
0.9	-	17	17	778	-	40	Good
0.8	-	13	13	542	-	34*	Fair
0.1	-	12	12	700	-	40	Good
Tributary to Sand Creek (at RM 4.84) (1999)							
0.3	-	7	7	418	-	50	Exceptional

Stream/ River Mile	Station Location	Mean Number of Species	Total Number Species	Mean Relative Number	QHEI	Mean Index of Biotic Integrity	Narrative Evaluation
Tributary to Sand Creek (at RM 3.25) (1999)							
0.1	-	11	11	174	-	46	Very Good
Sand Creek (1993)							
7.0	-	10	10	520	-	38[ns]	Marginally Good
6.3	-	12	12	308	-	36[ns]	Marginally Good
5.9	-	13	13	830	-	42	Good
4.5	-	12	12	467	-	42	Good
3.6	-	13	13	496	-	34*	Fair
3.3	-	12	12	558	-	36[ns]	Marginally Good
2.3	-	19	19	328	-	38[ns]	Marginally Good
2.1	-	12	12	178	-	32*	Fair
1.9	-	15	15	1142	-	44	Good
1.6	-	20	20	652	-	44	Good
0.8	-	26	26	1158	-	38[ns]	Marginally Good
Tributary to Sand Creek (at RM 4.84) (1993)							
0.3	-	8	8	292	-	46	Very Good
Tributary to Sand Creek (at RM 3.25) (1993)							
0.1	-	9	9	415	-	40	Good

Ecoregion Biocriteria: Erie-Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	**WWH**	**EWH**	**MWH[a]**
IBI-Headwater	40	50	24

[a]Modified Warmwater Habitat for channel modified areas.
* Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
[ns] Nonsignificant departure from ecoregion biocriterion (≤4 IBI units).

Figure 4-1. Longitudinal profile of IBI results for 2003, 1999, and 1993 by river mile in Sand Creek. The shaded area represents the non-significant departure range for the IBI biocriterion.

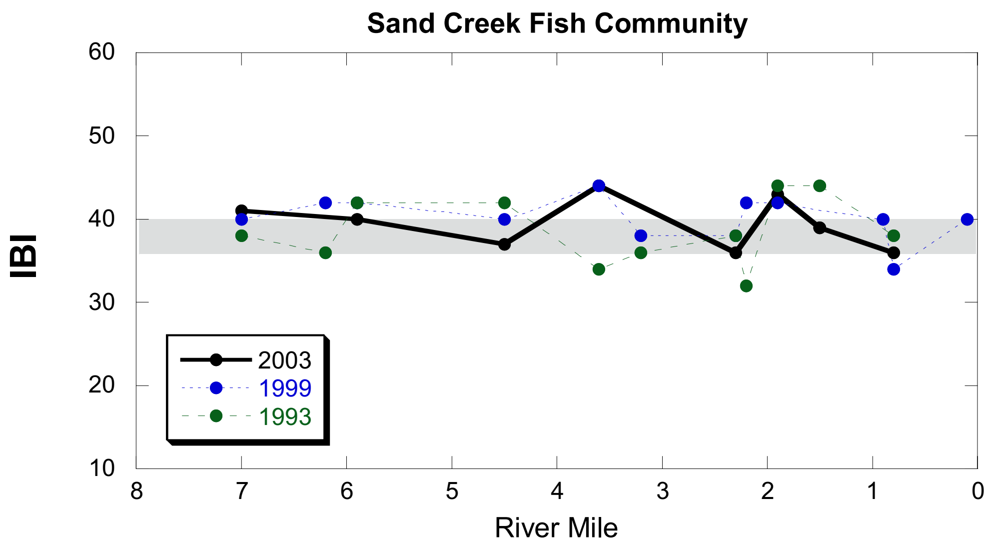

Table 4-6. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in Sand Creek and tributaries, 2003.

Stream/ River Mile	Station Location	Density No./ft^2	Total Taxa	Quant-itative Taxa	Qual-itative Taxa	Qual-itative EPT[a]	ICI	Narrative Evaluation
Sand Creek (2003)								
7.0	S-1	330	67	38	48	14	54	Exceptional
5.9	S-2	385	75	39	61	23	54	Exceptional
4.5	S-4	247	56	32	36	18	44	Very Good
3.7	S-5	873	62	36	39	17	50	Exceptional
2.4	S-7	489	58	32	40	15	54	Exceptional
1.9	S-9	627	62	43	35	14	46	Exceptional
1.5	S-10	995	52	35	37	15	46	Exceptional
0.8	S-11	500	57	44	24	7	50	Exceptional
***Tributary to Sand Creek** (atRM 4.84)*								
0.3	S-3	298	46	34	17	7	38	Good
***Tributary to Sand Creek** (at RM 3.25)*								
0.1	S-6	253	35	26	17	3	40	Good
***Tributary to Sand Creek** (at RM 2.22)*								
0.1	S-8	506	43	36	17	5	26*	Fair/Good**

Ecoregion Biocriteria: Erie-Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[b]
ICI	34	46	22

[a] EPT= total Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness, a measure of pollution sensitive organisms.
[b] Modified Warmwater Habitat for channel modified areas.
* Significant departure from ecoregional biocriterion (>4 ICI units); poor and very poor results are underlined.
** Fair evaluation based on the ICI score, good evaluation based on comparison to headwater habitat guidelines.

5 SOUTH FORK EAGLE CREEK AND TRIBUTARY

5.1 SUMMARY

A total of 4.1 miles of South Fork Eagle Creek were assessed in 2003. Based on the performance of the biological communities, the entire 4.1 miles of the South Fork Eagle Creek were in full attainment of the Warmwater Habitat aquatic life use (Table 5-1). None of the chemicals measured in the surface water of South Fork Eagle Creek exceeded criteria protective of the Warmwater Habitat aquatic life use. Aside from two chemicals, all organic parameters tested (explosives, semivolatiles, pesticides, and PCBs) in the water were reported as not detected. Nutrients, metals and dissolved solids were at low levels in South Fork Eagle Creek surface water. Some SVOCs were detected in sediment collected from all locations in South Fork Eagle Creek. However, the concentrations were either below screening levels or, when marginally above screening levels, the concentrations were estimated values. Metals in sediments were below Ohio sediment reference values and organic compounds were either not-detected or at low levels. Stream physical habitat conditions were good to excellent. QHEI scores for South Fork Eagle Creek averaged 76.9 demonstrating the potential to support WWH biological communities. Mountain brook lamprey, a state endangered fish, were collected from South Fork Eagle Creek. Based on sampling results from South Fork Eagle Creek, no biological impairment associated with chemical contaminants was observed. Fish communities in South Fork Eagle Creek were assessed by the Ohio DNR during 1999 and 1993. Results of those collections were generally comparable to the 2003 results, with all but the site at RM 6.3 (1993) attaining the Warmwater Habitat biocriterion.

One tributary to South Fork Eagle Creek was assessed at two locations in 2003. The biological communities at both sites were in full attainment of the Warmwater Habitat aquatic life use (Table 5-1). Surface water conditions were reflective of good water resource quality, with only three field measurements of pH below the range of the Ohio water quality criterion (6.5-9.0). Sediment sampling results reflected non-contaminated conditions. Metals in sediments were below Ohio reference values and organic compounds were either not detected or at low levels. The physical habitat demonstrated the potential to achieve the warmwater habitat use based on good to excellent QHEI scores. Based on sampling results from the two sampling locations on the tributary to South Fork Eagle Creek, no biological impairment associated with chemical contaminants was observed. A caddisfly state listed as threatened, Psilotreta indecisa, was collected at the RM 1.2 site. Fish communities were assessed at two locations during 1993 by ODNR. Biological performance was comparable at the upstream sampling location but the downstream site was evaluated as fair indicative of non-attainment of the WWH use.

Sampling during 2003 confirmed the appropriateness of the Warmwater Habitat aquatic life use designation for South Fork Eagle Creek. Presently, South Fork Eagle Creek is listed as Warmwater Habitat in the Ohio Water Quality Standards (WQS). Based on the 2003 sampling results, the tributary to South Fork Eagle Creek at RM 6.34 is recommended for listing as a Warmwater Habitat stream in the Ohio WQS.

Table 5-1. Attainment status of the aquatic life use for South Fork Eagle Creek and one tributary based on biological sampling conducted during June - September, 2003.

RIVER MILE Fish/Invert.	Sample Location	IBI	ICI	QHEI	Attainment Status	Site Location
Ecoregion - Erie Ontario Lake Plain (EOLP)						
South Fork Eagle Creek - *WWH Use Designation*						
6.2/ 6.2	SFE-3	40	48	82.0	FULL	Background site
5.5/ 5.5	SFE-4	46	42	83.5	FULL	Dst. Boy Scout Pond
3.8/ 3.8	Ref. Site	39[ns]	46	75.5	FULL	Historical Ohio EPA reference site
2.7/ 2.7	SFE-5	44	52	66.5	FULL	Lower end of drainage from RVAAP
Tributary to S. Fork Eagle Creek (at RM 6.34) - *WWH Use Designation (Recommended)*						
1.2	SFE-1	43	32[ns]	76.0	FULL	Background site
0.1	SFE-2	48	46	59.5	FULL	Near mouth

Ecoregion Biocriteria: Erie Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[a]
IBI-Headwater	40	50	24
ICI	34	46	22

[a] Modified Warmwater Habitat for channel modified areas.
*Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
[ns] Nonsignificant departure from ecoregion biocriterion (≤4 IBI and ICI units).

5.2 Surface Water Quality

Chemical analyses were conducted on surface water samples collected in June and September, 2003, from three locations in the South Fork Eagle Creek and at two locations in an unnamed tributary to the South Fork Eagle Creek (Appendix 2, Appendix 3 Tables 3 and 4). Surface water samples were analyzed for target analytes list metals, pesticides, PCBs, explosive compounds, semivolatile organic compounds, and several nutrient parameters. Parameters which were in exceedance or outside of the range of Ohio WQS criteria are reported in Table 5-2.

5.2.1 South Fork Eagle Creek

For all three of the South Fork Eagle Creek sampling locations, there were no Exceedances of the Ohio WQS aquatic life maximum or average water quality criteria. None of the chemicals measured in this study exceeded criteria protective of the Warmwater Habitat aquatic life use. Concentrations of all but two [bis(2-ethylhexyl) phthalate, and 4,4-DDD] of the organic parameters tested (explosives, semivolatiles, pesticides, and PCBs) were reported as not detected. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] In addition, metals concentrations were very low, with many of the results less than lab detection limits. Parameters with measurable concentrations were below applicable Ohio WQS aquatic life criteria. Most ammonia-N measurements were less than lab detection limits (0.10 mg/l), and of the samples with measurable concentrations, values were substantially below the water quality criterion. Nitrate-N values were measured at low concentrations, with all values less than Ohio least impacted reference conditions (below Erie Ontario Lake Plain ecoregion 75^{th} percentile value). Overall, nutrients and metals levels were low in the South Fork Eagle Creek, and organic chemical compounds were nearly all non-detect.

5.2.2 Tributary to S.F. Eagle Creek (RM 6.34)

Surface water chemical conditions observed in South Fork Eagle Creek were similarly recorded for the unnamed tributary to South Fork Eagle Creek. Aside from three field measurements of pH, none of the other chemical analyses exceeded (or were outside the range of) Ohio WQS aquatic life maximum or average water quality criteria. None of the chemical concentrations (excluding the three lower pH values) exceeded criteria protective of the Warmwater Habitat aquatic life use. Concentrations of all but two [bis(2-ethylhexyl) phthalate, acenaphthene] of the organic parameters tested (explosives, semivolatiles, pesticides, and PCBs) were reported as not detected. These two organic chemicals with values above lab detection limits (3 total samples) were substantially below water quality criteria. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] In addition, metals concentrations were very low, with many of the results less than lab detection limits. All ammonia-N measurements were less than lab detection limits (0.10 mg/l), and nitrate-N values were measured at low concentrations, with all values less than Ohio least impacted reference conditions (below the Erie Ontario Lake Plain ecoregion 75^{th} percentile reference value).

5.3 Sediment Chemistry

Sediment samples were collected at three locations in South Fork Eagle Creek and from two locations in an unnamed tributary to South Fork Eagle Creek during June, 2003. Samples were analyzed for semivolatile organic compounds, pesticides, PCBs, target analyte list metals, explosive compounds, percent solids, cyanide, ammonia, nitrate, and phosphorus. Specific chemical parameters tested and results are listed in Appendix 3 Table 3.

Sediment data were evaluated using guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald et.al. 2000), and USEPA Region 5, RCRA Appendix IX compounds - Ecological Screening Levels (ESLs) (USEPA 2003). The consensus-based sediment guidelines define two levels of ecotoxic effects. A Threshold Effect Concentration (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A Probable Effect Concentration (PEC) indicates a level above which harmful effects are likely to be observed. Ecological screening levels (ESLs) are initial screening levels used by USEPA to evaluate RCRA site constituents. In addition, sediment reference values (SRVs) for metals (Ohio EPA 2003) are presented in Appendix 3 Table 3 for comparison to the South Fork Eagle Creek watershed results.

5.3.1 South Fork Eagle Creek

Some SVOCs were detected in sediment collected from all three locations in the South Fork Eagle Creek. However, the concentrations were either below screening levels, or when marginally above screening levels, the concentrations were estimated values. All metals tested in sediments were below Ohio reference values (Ohio EPA 2003) and below TEC levels (Table 5-3). All tested explosive compounds, pesticides, PCBs, and most semivolatile organic compounds were not detected in sediment samples collected from South Fork Eagle Creek. The few detected semivolatile compounds were measured at low levels. Di-n-butyl phthalate and bis(2-ethylhexyl) phthalate were detected (estimated concentration) at one of three South Fork Eagle Creek sediment sites; however, these values were below ESLs. Phthalates are potential lab contaminants. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] Ammonia and total phosphorus levels were measured in all South Fork Eagle Creek sediment samples below screening guidelines (Persaud et. al. 1993).

5.3.2 Tributary to S.F. Eagle Creek (RM 6.34)

Some SVOCs were detected in sediment samples collected from two sites in an unnamed tributary to South Fork Eagle Creek (confluence at RM 6.34). However, the concentrations were either below screening levels, or when marginally above screening levels, the concentrations were estimated values. All of the metals measured were below Ohio reference values, and all explosive compounds, pesticides, PCBs, and nearly all semivolatile compounds were below lab detectable limits in the sediment. Any detected semivolatile compounds were measured at very low levels and below ecologically harmful effects guidelines.

5.4 Physical Habitat For Aquatic Life

Physical habitat was evaluated in South Fork Eagle Creek and one tributary at each fish sampling location. Qualitative Habitat Evaluation Index (QHEI) scores are detailed in Table 5-4.

5.4.1 South Fork Eagle Creek

All four South Fork Eagle Creek biological sampling sites evaluated in this survey revealed good to excellent stream habitats. QHEI scores for South Fork Eagle Creek sites ranged between 66.5 and 83.5, with an average score of 76.9. These scores demonstrated the potential to support WWH biological communities. Physical habitat conditions of the upper two sites (RMs 6.2 and 5.5) varied in comparison with the lower two sites (RMs 3.8 and 2.7). Sandstone bedrock, cobble, and boulders predominated at the upper sites (RMs 6.2 and 5.5), while sand and small gravel predominated at the lower sites (RMs 3.8 and 2.7). The stream channel was natural within the study area and was represented by pool, run, and riffle areas, with minor amounts of glide habitat. Instream channel development was good, and surrounding land use was forest and shrub. The lowest QHEI score was recorded at RM 2.7, and the lower score resulted from a complete dominance by soft sand substrates causing extensive embeddedness of the stream bottom, both in pool and riffle/run areas.

5.4.2 Tributary to South Fork Eagle Creek (at RM 6.34)

Two sites were sampled in an unnamed tributary which flows into South Fork Eagle Creek at RM 6.34 (where South Fork enters RVAAP property). The unnamed tributary flows from west to east along the northern edge of the RVAAP property. These two sites represented background reference conditions. Distinct differences were noted between the two sites sampled in the unnamed tributary to the S. F. Eagle Creek. Natural channel features, high quality substrate conditions (low to no silt or embeddedness), pool, run, and riffle complexes were common to both sampling locations. However, the upper site was predominated by cobble and gravel substrates while the lower site was nearly all sandstone bedrock. Overall stream habitat was good to very good as represented by QHEI scores of 59.5 (RM 0.1) and 76.0 (RM 1.2).

5.5 Fish Community Assessment

Fish communities were assessed at six locations in the South Fork Eagle Creek watershed (excluding Sand Creek sites). Four sites were located on South Fork Eagle Creek, and two sites were located on an unnamed tributary to the South Fork Eagle Creek. Appendix 4 Table 1.

5.5.1 South Fork Eagle Creek

Fish communities were marginally good to very good in the South Fork Eagle Creek. IBI scores ranged between 39 and 46. These IBI values achieved the ecoregional biocriterion established for Warmwater Habitat (WWH) streams and rivers in Ohio (Table 5-5). Mountain brook lamprey, an Ohio Endangered Species, were collected in the South Fork Eagle Creek at the lower two sampling locations (RMs 3.8 and 2.7). Based on the fish community results from the four South Fork Eagle Creek sites, no biological impairment associated with chemical contaminants was observed.

Fish communities were sampled by the Ohio DNR during the summers of 1993 and 1999 at a number of locations in the South Fork Eagle Creek as well as by Ohio EPA at one site (RM 3.9) during 1999. IBI results from 2003, 1999, and 1993 were graphed longitudinally to evaluate the differences and similarities between years (Figure 5-1). Direct comparisons between the 2003 sampling event and those conducted by the Ohio DNR should be viewed with some caution. IBI calculations for all years of data were based on Ohio EPA methodology, calibrated to the electrofishing wading method. However, most of the 1993 and 1999 fish data were collected using seines, or a combination of seines and electrofishing. Overall, fish biological diversity scores were similar between sampling years at co-located sites. One of the sampling locations (RM 6.3) reported an IBI score below the Warmwater Habitat biocriterion during 1993. The reason for the lower score at RM 6.3 during 1993 is unknown.

5.5.2 Tributary to South Fork Eagle Creek (at RM 6.34)

The fish community was assessed at RMs 0.1 and 1.2. The IBI scores were in the good to very good range, with values of 43 and 48. The IBI scores achieved the ecoregional biocriterion established for Warmwater Habitat streams. Impairment of the fish community was not observed at these two sites.

Past collections of the fish community at RMs 0.3 and 1.1 occurred in 1993. IBI scores from 1993 at RMs 0.3 and 1.1 were 32 and 42, respectively. Results from sampling at RM 1.1 were comparable between 1993 and 2003, and were reflective of good fish community quality. The fish community at RM 0.3 was substantially lower in biological quality during 1993 (IBI = 32) versus 2003 (IBI = 48 at RM 0.1). The predominance of shallow bedrock at RM 0.3 could have been a primary factor in the lower score during 1993.

5.6 Macroinvertebrate Community Assessment

Macroinvertebrate communities were assessed using artificial substrates supplemented with a qualitative multihabitat composite natural substrate sample at six locations in the South Fork Eagle Creek watershed (Table 5-6, Appendix 4 Table 4). Four sites were located on South Fork Eagle Creek, and two sites were located on a tributary to South Fork Eagle Creek.

5.6.1 South Fork Eagle Creek

Macroinvertebrate communities were very good to exceptional in South Fork Eagle Creek. ICI scores ranged between 42 and 52. These ICI values achieved the ecoregional biocriterion established for the listed Warmwater Habitat (WWH) use, in addition to meeting the Exceptional Warmwater Habitat (EWH) criteria (Table 5-6) at all but the RM 5.5 site which was a nonsignificant departure from the EWH criterion. A Cold Water Habitat use designation may be appropriate for the upstream portion of South Fork Eagle Creek based on the number of macroinvertebrates on the Ohio EPA coldwater taxa list collected from the RMs 6.2 and 5.5 sites. The macroinvertebrate community results from the four South Fork Eagle Creek sites indicated no biological impairment.

5.6.2 Tributary to South Fork Eagle Creek (at RM 6.34)

The macroinvertebrate community was assessed at RMs 1.2 and 0.1. The ICI scores were 32 and 46, respectively, which range from marginally good to exceptional. The ICI scores achieved the ecoregional biocriterion established for Warmwater Habitat streams. The caddisfly Psilotreta indecisa, which is state listed as threatened, was collected at the RM 1.2 site. Impairment of the macroinvertebrate community was not observed at these sites.

Table 5-2. Exceedances of Ohio Water Quality Standards aquatic life criteria (OAC 3745-1) for chemical/physical parameters from the South Fork Eagle Creek and one unnamed tributary to the S. F. Eagle Creek during 2003.

River Mile	Parameter (value)
South Fork Eagle Creek	
6.2	None
5.5	None
2.7	None
Tributary to S.F. Eagle Creek (RM 6.34)	
1.2	pH (6.4*, 5.54*)
0.1	pH (6.39*)

* Exceedance (or outside of range) of aquatic life Outside Mixing Zone Average Criteria (OMZA).

Table 5-3. Chemical parameters measured above screening levels (metals) or detected (organics) in sediment samples collected from the South Fork Eagle Creek and tributary, June, 2003. Contamination levels were determined for parameters using either consensus-based sediment quality guidelines (MacDonald et.al. 2000) or ecological screening levels for RCRA appendix IX constituents (USEPA 2003). Sediment reference values (SRVs) are listed in the Ohio EPA Ecological Risk Assessment Guidance (2003).

	SOUTH FORK EAGLE CREEK/ TRIB. SEDIMENT							
Parameter	**RM 6.2**	**RM 5.5**	**RM 2.7**	**Trib. RM 1.2**	**Trib. RM 1.2 Duplicate**	**Trib. RM 1.2 QA Split**	**Trib. RM 0.1**	**SRVs**
Arsenic (mg/kg)	4.1	4.3	4.7	6.7	10.4^{T}	5.8	10.1^{T}	25
Benzo(a)anthracene (ug/kg)	<420	<420	<410	<410	$87J^{T}$	<430	<420	-
Benzo(b)fluoranthene	<420	<420	<410	<410	67J	<430	<420	-
Benzo(a)pyrene (ug/kg)	<420	<420	<410	<410	65J	<430	<420	-
di-n-Butyl Phthalate (ug/kg)	<420	100J	<410	53J	270J	<430	<420	-
Fluoranthene (ug/kg)	<420	<420	<410	<410	110J	<430	<420	-
Pyrene (ug/kg)	<420	<420	<410	<410	99J	<430	<420	-
Chrysene (ug/kg)	<420	<420	<410	<410	78J	<430	<420	-
bis(2-ethylhexyl) phthalate (ug/kg)	51J	<420	<410	<410	<410	<430	<420	-
Cyanide (mg/kg)	<0.18	<0.18	<0.18	<0.18	1.2^{E}	<0.66	<0.19	-

J - The analyte was positively identified, but the quantization was below the reporting limit (RL).
^{T} - Above Threshold Effect Concentration (below which harmful effects are unlikely to occur; MacDonald et.al. 2000).
^{P} - Above Probable Effect Concentration (above which harmful effects are likely to occur; MacDonald et.al. 2000).
^{E} - Above Ecological Screening Level (USEPA 2003).

1 **Table 5-4. QHEI (SF Eagle Creek)**

Table 5-4. Qualitative Habitat Evaluation Index (QHEI) scores for South Fork Eagle Creek and tributary, 2003.

Key QHEI Components			WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence														
River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes	Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total H.I. MWH Attributes	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(18-043) South Fork Eagle Creek																																		
Year: 2003																																		
6.2	82.0	23.81	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22
5.5	83.5	15.63	■	■		■	■	■	■	■	■	■	9			◆			1													0	0.20	0.20
3.8	75.5	14.29	■	■		■	■	■			■		6			◆			1		●		●					●	●	●		5	0.29	1.00
2.7	66.5	5.62	■			■	■	■			■		5						0					●				●	●	●		4	0.17	0.83
(18-082) Trib. to S. Fk. Eagle Creek (RM 6.34)																																		
Year: 2003																																		
1.2	76.0	41.67	■	■		■	■	■		■	■	■	8						0									●				1	0.11	0.22
0.1	59.5	50.00	■		■	■			■	■	■	■	7			◆	◆		2					●								1	0.38	0.50

Table 5-5. Fish community summaries based on pulsed DC electrofishing sampling conducted in South Fork Eagle Creek and tributary from June and September, 2003. Ohio DNR results are presented from 1999 and 1993, along with one site sampled by Ohio EPA in 1999 (RM 3.9). Relative numbers are per 0.3 km of stream length. Ohio DNR sampling was conducted using either electrofishing gear, seining, or a combination of both.

Stream/ River Mile	Station Location	Mean Number of Species	Total Number Species	Mean Relative Number	QHEI	Mean Index of Biotic Integrity	Narrative Evaluation
South Fork Eagle Creek (2003)							
6.2	SFE-3	11.0	12	660	82.0	40	Good
5.5	SFE-4	16.0	18	520	83.5	46	Very Good
3.8	Ref. Site	16.5	21	226	75.5	39[ns]	Marginally Good
2.7	SFE-5	19.0	20	243	66.5	44	Good
Tributary to South Fork Eagle Creek (at RM 6.34) (2003)							
1.2	SFE-1	8.5	10	454	76.0	43	Good
0.1	SFE-2	11.5	13	641	59.5	48	Very Good
South Fork Eagle Creek (1999)							
6.3	-	14	14	888	-	38[ns]	Marginally Good
5.5	-	18	23	425	-	40	Good
5.2	-	15	15	804	-	44	Good
3.9	-	16	16	156	76.5	40	Good
3.8	-	22	22	1026	-	40	Good
2.7	-	15	20	1082	-	38[ns]	Marginally Good
South Fork Eagle Creek (1993)							
6.3	-	10	10	802	-	34*	Fair
5.5	-	21	21	912	-	38[ns]	Marginally Good
5.2	-	20	20	472	-	48	Very Good
3.8	-	25	25	682	-	48	Very Good
2.7	-	22	22	310	-	44	Good
Tributary to South Fork Eagle Creek (at RM 6.34) (1993)							
1.1	-	10	10	600	-	42	Good
0.3	-	9	9	334	-	32*	Fair

Ecoregion Biocriteria: Erie-Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[a]
IBI-Headwater	40	50	24

[a] Modified Warmwater Habitat for channel modified areas.
* Significant departure from ecoregion biocriterion; poor and very poor results are underlined.
[ns] Nonsignificant departure from ecoregion biocriterion (≤4 IBI units).

Figure 5-1. Longitudinal profile of IBI results for 2003, 1999, and 1993 by river mile in SF Eagle Creek. The shaded area represents the non-significant departure range for the IBI biocriterion.

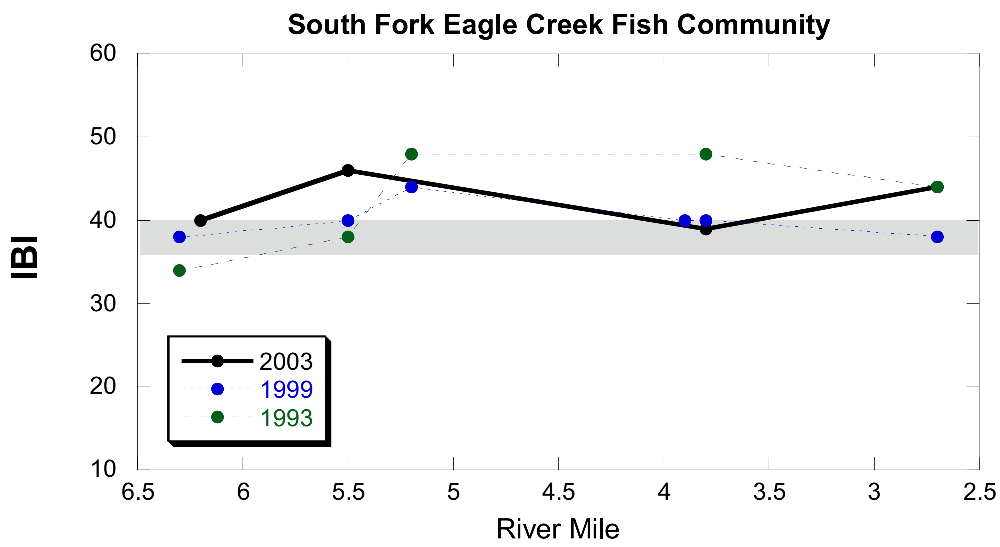

Table 5-6. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in South Fork Eagle Creek and one tributary, 2003.

Stream/ River Mile	Station Location	Density No./ft^2	Total Taxa	Quant-itative Taxa	Qual-itative Taxa	Qual-itative EPT[a]	ICI	Narrative Evaluation
South Fork Eagle Creek (2003)								
6.2	SFE-3	529	59	43	30	16	48	Exceptional
5.5	SFE-4	575	62	43	30	8	42	Very Good
3.8	SFE-Ref	1225	76	45	52	17	46	Exceptional
2.7	SFE-5	798	51	45	22	10	52	Exceptional
Tributary to South Fork Eagle Creek (at RM 6.34)								
1.2	SFE-1	147	38	25	19	10	32[ns]	Marginally Good
0.1	SFE-2	201	42	34	14	7	46	Exceptional

Ecoregion Biocriteria: Erie-Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[b]
ICI	34	46	22

[a] EPT= total Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness, a measure of pollution sensitive organisms.
[b] Modified Warmwater Habitat for channel modified areas.
[ns] Nonsignificant departure from ecoregion biocriterion for WWH (≤4 ICI units).
* Significant departure from ecoregional biocriterion (>4 ICI units); poor and very poor results are underlined.

6 HINKLEY CREEK

6.1 SUMMARY

A total of 4.3 miles of Hinkley Creek were assessed in 2003. Based on the performance of the biological communities, three of the four sampling locations were in full attainment of the Warmwater Habitat aquatic life use (Table 6-1). Only two field measurements of pH were below the WQS criteria range (6.5-9.0) protective of the Warmwater Habitat aquatic life use. Aside from three chemicals, which were at levels below water quality criteria, all organic parameters tested (explosives, semivolatiles, pesticides, and PCBs) in the water were reported as not detected. Nutrients, metals and dissolved solids were at low levels in Hinkley Creek surface water, and were largely reflective of the undeveloped condition of the watershed. Some SVOCs were detected in sediment collected from all four locations in Hinkley Creek. However, the concentrations were either below screening levels, or when marginally above screening levels, the concentrations were estimated values. Metals in sediments were below Ohio sediment reference values and organic compounds were either not detected or at low levels. Stream physical habitat conditions were good to excellent. QHEI scores for Hinkley Creek averaged 74.4 demonstrating the potential to support WWH biological communities. Although the fish community assessment at RM 4.3 documented a fair community and non-attainment of the WWH criterion, the IBI score of 35 was only one point below non-significant departure from the biocriterion. The macroinvertebrate community at all sites met both the WWH and EWH biocriteria. Based on sampling results from Hinkley Creek, no biological impairment associated with chemical contaminants was observed. Fish communities in Hinkley Creek were assessed by the Ohio DNR during 1999 and 1993. Results of those collections ranged from poor at RM 3.3 (1999 and 1993) and RM 6.3 (1999) to good at most other locations.

Sampling during 2003 confirmed the appropriateness of the Warmwater Habitat aquatic life use designation for Hinkley Creek. Presently, Hinkley Creek is listed as Warmwater Habitat in the Ohio Water Quality Standards (WQS).

Table 6-1. Attainment status of the aquatic life use for Hinkley Creek based on biological sampling conducted during June - September, 2003.

RIVER MILE Fish/Invert.	Sample Location	IBI	ICI	QHEI	Attainment Status	Site Location
						Ecoregion - *Erie Ontario Lake Plain (EOLP)*
Hinkley Creek - *WWH Use Designation*						
6.6/ 6.6	H-1	44	48	86.5	FULL	Background site
5.2/ 5.2	H-2	38[ns]	56	71.0	FULL	South Patrol Road
4.3/ 4.3	H-3	35*	52	72.0	PARTIAL	Adj. NACA and Demolition #1
3.3/ 3.3	H-4	37[ns]	50	68.0	FULL	Lower end of Hinkley Cr. drainage

Ecoregion Biocriteria: Erie Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[a]
IBI-Headwater	40	50	24
ICI	34	46	22

[a] Modified Warmwater Habitat for channel modified areas.
* Significant departure from ecoregion biocriterion (> 4 IBI and ICI units); poor and very poor results are underlined.
[ns] Nonsignificant departure from ecoregion biocriterion (≤4 IBI and ICI units).

6.2 Surface Water Quality

Chemical analyses were conducted on surface water samples collected in June and September, 2003 from four locations in Hinkley Creek (Appendix 2, Appendix 3 Tables 5 and 6). Surface water samples were analyzed for target analyte list metals, pesticides, PCBs, explosive compounds, semivolatile organic compounds, and several nutrient parameters. Parameters which were in exceedance or outside of the range of Ohio WQS criteria are reported in Table 6-2.

6.2.1 Hinkley Creek

Aside from two field measurements of pH, none of the other chemical analyses exceeded (or were outside the range of) Ohio WQS aquatic life maximum or average water quality criteria. None of the chemical concentrations (excluding the two lower pH values) exceeded criteria protective of the Warmwater Habitat aquatic life use. Concentrations of all but three [bis(2-ethylhexyl) phthalate, di-n-butyl phthalate, m-nitrotoluene] of the organic parameters tested (explosives, semivolatiles, pesticides, and PCBs) were reported as not detected. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] These three parameters with measurable concentrations were below the water quality criteria, and all measurable levels were reported as estimated concentrations. Metals concentrations were very low, with many of the results less than lab detection limits. All ammonia-N measurements were less than lab detection limits (0.10 mg/l), and nitrate-N values were measured at low concentrations, with all values less than Ohio least impacted reference conditions (below the Erie Ontario Lake Plain ecoregion 75th percentile reference value). Total cyanide measurements were all less than the lab detection limit (0.01 mg/l). Overall, nutrients and metals levels were low in Hinkley Creek, and organic chemical compounds were nearly all not detected.

6.3 Sediment Chemistry

Sediment samples were collected at four locations in Hinkley Creek during June, 2003. Samples were analyzed for semivolatile organic compounds, pesticides, PCBs, target analyte list metals, explosive compounds, percent solids, cyanide, ammonia, nitrate, and phosphorus. Specific chemical parameters tested and results are listed in Appendix 3 Table 5.

Sediment data were evaluated using guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald et.al. 2000), and USEPA Region 5, RCRA Appendix IX compounds - Ecological Screening Levels (ESLs) (USEPA 2003). The consensus-based sediment guidelines define two levels of ecotoxic effects. A Threshold Effect Concentration (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A Probable Effect Concentration (PEC) indicates a level above which harmful effects are likely to be observed. Ecological screening levels (ESLs) are initial screening levels used by USEPA to evaluate RCRA site constituents. In addition, sediment reference values (SRVs) for metals (Ohio EPA 2003) are presented in Appendix 3 Table 5 for comparison to Hinkley Creek results.

6.3.1 Hinkley Creek

Sediment collected from all four locations in Hinkley Creek were not contaminated (Table 6-3). All metals tested in sediments were below Ohio reference values (Ohio EPA 2003) and below TEC levels. All tested explosive compounds, PCBs, and most pesticides and semivolatile organic compounds were not detected in sediment samples collected from Hinkley Creek. The few detected semivolatile compounds and pesticides were measured at low levels, with all concentrations below TEC or ESL guidelines. Ammonia and total phosphorus levels were measured in all Hinkley Creek sediment samples below screening guidelines (Persaud et. al. 1993).

6.4 Physical Habitat For Aquatic Life

Physical habitat was evaluated in Hinkley Creek at each fish sampling location. Qualitative Habitat Evaluation Index (QHEI) scores are detailed in Table 6-4.

6.4.1 Hinkley Creek

All four Hinkley Creek biological sampling sites evaluated in this survey revealed good to excellent stream habitats. QHEI scores for Hinkley Creek sites ranged between 68.0 and 86.5, with an average score of 74.4. These scores demonstrated the potential to support WWH biological communities. Substrate conditions of the most upstream site (RM 6.6) varied in comparison with the lower three sites (RMs 5.2, 4.3, and 3.3). Cobble and gravel predominated at the upper site (H1), while sand, silt, muck, and small gravel predominated at the lower three sites (H2, H3, H4). The stream channel was natural within the study area and was represented by pool, run, and riffle areas, with minor amounts of glide habitat. Instream channel development was good, and surrounding land use was forest and shrub. Beaver activity was noted at RMs 5.2 and 3.3, with several small beaver dams within the sampling zone.

6.5 Fish Community Assessment

Fish communities were assessed at four locations in Hinkley Creek. Each location was sampled twice during the 2003 sampling season. Appendix 4 Table 1.

6.5.1 Hinkley Creek

Fish communities were fair to good in Hinkley Creek. IBI scores ranged between 35 and 44. Three of the four IBI values achieved the ecoregional biocriterion established for Warmwater Habitat (WWH) streams and rivers in Ohio (Table 6-5). Sampling at RM 4.3 (H3 - adjacent NACA and demolition area #1) documented a fair fish community, with an IBI score of 35 (one point below the nonsignificant departure range of the biocriterion). The IBI score of 35 is the mean value of two separate sampling events. The first fish sampling event resulted in an IBI score of 34, and the second sampling event resulted in an IBI score of 36. Results were very similar; however, a greater number of darter fish species were recorded during the second sampling pass, leading to a higher metric score and thus a higher IBI value for the second pass. No substantial differences in the fish communities were observed between Hinkley Creek sites at RMs 5.2, 4.3, and 3.3. Based on the fish community results from the four Hinkley

Creek sites, no biological impairment associated with chemical contaminants was observed. Fish communities were sampled by the Ohio DNR during the summers of 1993 and 1999 at a number of locations in Hinkley Creek. IBI results from 2003, 1999, and 1993 were graphed longitudinally to evaluate the differences and similarities between years (Figure 6-1). Direct comparisons between the 2003 sampling event and those conducted by the Ohio DNR should be viewed with some caution. IBI calculations for all years of data were based on Ohio EPA methodology, calibrated to the electrofishing wading method. However, most of the 1993 and 1999 fish data were collected using seines, or a combination of seines and electrofishing. Overall, fish biological diversity scores were similar between sampling years at RM 5.2. Sampling results at co-located sites at RMs 6.6 and 3.3 were substantially lower during the 1999 and 1993 sampling. Of particular note was the poor fish community results reported for Hinkley Creek at RM 3.3 during the 1999 and 1993 sampling effort; both values were below the Warmwater Habitat IBI biocriterion. The low fish diversity reported at RM 3.3 during 1993 and 1999 appeared associated with impaired surface water quality; however, chemical data were not collected and there is no substantiation of this conclusion.

6.6 Macroinvertebrate Community Assessment

Macroinvertebrate communities were assessed using artificial substrates supplemented with a qualitative multihabitat composite natural substrate sample at four locations in Hinkley Creek (Table 6-6, Appendix 4 Table 4).

The macroinvertebrate communities were all exceptional in Hinkley Creek. ICI scores ranged between 48 and 56. These ICI values achieved the ecoregional biocriterion established for the designated Warmwater Habitat (WWH) use, in addition to meeting the Exceptional Warmwater Habitat (EWH) criteria (Table 6-6). A qualitative sample collected in June at RM 6.6 had 8 coldwater macroinvertebrate taxa. The macroinvertebrate community results from the four Hinkley Creek sites indicated no biological impairment.

Table 6-2. Exceedances of Ohio Water Quality Standards aquatic life criteria (OAC 3745-1) for chemical/physical parameters from Hinkley Creek during 2003.

River Mile	Parameter (value)
Hinkley Creek	
6.6	pH (5.35*)
5.2	pH (6.1*)
4.3	None
3.3	None

* Exceedances (or outside of range) of aquatic life Outside Mixing Zone Average Criteria (OMZA).

Table 6-3. Chemical parameters measured above screening levels (metals) or detected (organics) in sediment samples collected from Hinkley Creek, June, 2003. Contamination levels were determined for parameters using either consensus-based sediment quality guidelines (MacDonald et.al. 2000) or ecological screening levels for RCRA appendix IX constituents (USEPA 2003). Sediment reference values (SRVs) are listed in the Ohio EPA Ecological Risk Assessment Guidance (2003).

	HINKLEY CREEK SEDIMENT						
Parameter	**RM 6.6**	**RM 5.2**	**RM 5.2 Duplicate**	**RM 5.2 QA Split**	**RM 4.3**	**RM 3.3**	**SRVs**
Benzo(a)anthracene (ug/kg)	<420	73J	<420	<440	<410	<490	-
Benzo(a)pyrene (ug/kg)	<420	58J	<420	<440	<410	<490	-
Benzo(b)fluoranthene	<420	62J	<420	<440	<410	<490	-
Chrysene (ug/kg)	<420	68J	<420	<440	<410	<490	-
Fluoranthene (ug/kg)	<420	120J	<420	<440	<410	<490	-
Pyrene (ug/kg)	<420	120J	<420	<440	<410	<490	-
di-n-Butyl Phthalate (ug/kg)	500	<410	430	<440	280J	<490	-
bis(2-ethylhexyl) phthalate (ug/kg)	<420	<410	60J	<440	<410	<490	-
4,4-DDD (ug/kg)	0.28J	<2.1	<2.1	<2.2	<2.1	<2.5	-
4,4-DDE (ug/kg)	0.3J	<2.1	<2.1	<2.2	<2.1	<2.5	-
Cyanide (mg/kg)	<0.18	<0.17	<0.18	<0.66	<0.19	1.8 [E]	-

J - The analyte was positively identified, but the quantization was below the reporting limit (RL).
[T] - Above Threshold Effect Concentration (below which harmful effects are unlikely to occur; MacDonald et.al. 2000).
[P] - Above Probable Effect Concentration (above which harmful effects are likely to occur; MacDonald et.al. 2000).
[E] - Above Ecological Screening Level (USEPA 2003).

1 **Table 6-4. QHEI (Hinkley Creek)**

Table 6-4. Qualitative Habitat Evaluation Index (QHEI) scores for Hinkley Creek, 2003.

Key QHEI Components

River Mile	QHEI	Gradient (ft/mile)	WWH Attributes: No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes	MWH Attributes, High Influence: Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total H.I. MWH Attributes	MWH Attributes, Moderate Influence: Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(18-052) Hinkley Creek																																		
Year: 2003																																		
6.6	86.5	20.00	■	■	■	■	■	■	■	■	■	■	10						0													0	0.09	0.09
5.2	71.0	20.83	■			■		■			■	■	5		♦	♦			2		●			●				●	●	●		5	0.50	1.33
4.3	72.0	12.82	■	■		■	■	■			■		6						0		●		●					●	●	●		5	0.14	0.86
3.3	68.0	19.23	■				■	■			■		4		♦				1		●			●				●	●	●		5	0.40	1.40

Table 6-5. Fish community summaries based on pulsed DC electrofishing sampling conducted in Hinkley Creek from June and September, 2003, and by Ohio DNR, 1993 and 1999. Relative numbers are per 0.3 km of stream length. Ohio DNR sampling was conducted using either electrofishing gear, seining, or a combination of both.

Stream/ River Mile	Station Location	Mean Number of Species	Total Number Species	Mean Relative Number	QHEI	Mean Index of Biotic Integrity	Narrative Evaluation
Hinkley Creek (2003)							
6.6	H-1	14.5	17	629	86.5	44	Good
5.2	H-2	16.5	21	378	71.0	38^{ns}	Marginally Good
4.3	H-3	15.5	19	271	72.0	35*	Fair
3.3	H-4	18.5	24	438	68.0	37^{ns}	Marginally Good
Hinkley Creek (1999)							
6.6	-	10	10	48	-	36	Marginally Good
6.3	-	8	8	80	-	26*	Poor
6.1	-	15	15	292	-	40	Good
5.2	-	20	20	1004	-	42	Good
3.3	-	10.5	12	225	-	26*	Poor
Hinkley Creek (1993)							
6.6	-	10	10	130	-	32*	Fair
6.1	-	14	14	380	-	44	Good
5.2	-	22	22	856	-	42	Good
3.3	-	7	7	222	-	24*	Poor

Ecoregion Biocriteria: Erie-Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[a]
IBI-Headwater	40	50	24

[a] Modified Warmwater Habitat for channel modified areas.
* Significant departure from ecoregion biocriterion (> 4 IBI units); poor and very poor results are underlined.
[ns] Nonsignificant departure from ecoregion biocriterion (≤4 IBI units).

Figure 6-1. Longitudinal profile of IBI results for 2003, 1999, and 1993 by river mile in Hinkley Creek. The shaded area represents the non-significant departure range for the IBI biocriterion.

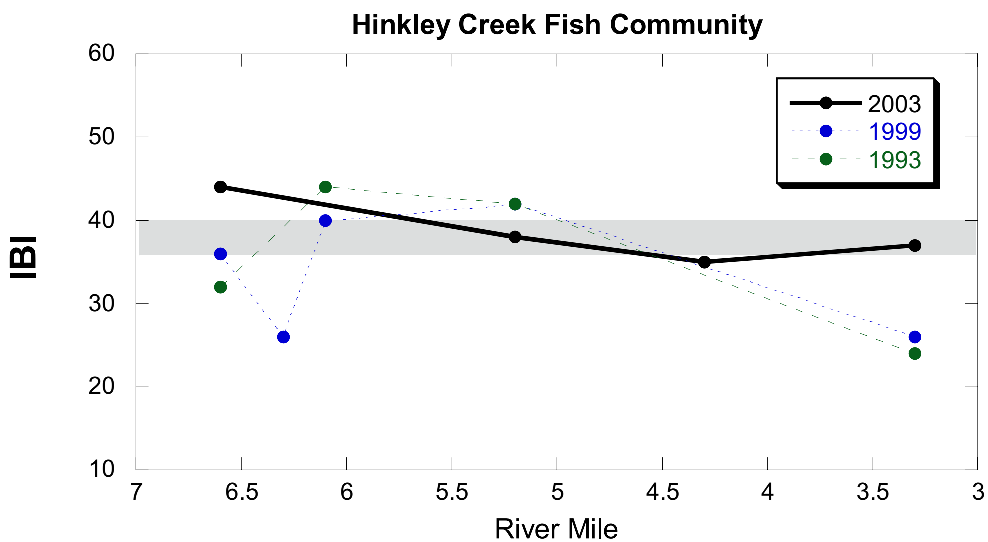

Table 6-6. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in Hinkley Creek, 2003.

Stream/ River Mile	Station Location	Density No./ft^2	Total Taxa	Quant-itative Taxa	Qual-itative Taxa	Qual-itative EPT[a]	ICI	Narrative Evaluation
Hinkley Creek (2003)								
6.6	H-1	637	57	37	34	13	48	Exceptional
5.2	H-2	1034	77	48	47	17	56	Exceptional
4.3	H-3	1145	75	62	25	7	52	Exceptional
3.3	H-4	565	82	52	46	12	50	Exceptional

Ecoregion Biocriteria: Erie-Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[b]
ICI	34	46	22

[a] EPT= total Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness, a measure of pollution sensitive organisms.
[b] Modified Warmwater Habitat for channel modified areas.
* Significant departure from ecoregional biocriterion (>4 ICI units); poor and very poor results are underlined.

7 WEST BRANCH MAHONING RIVER TRIBUTARIES

7.1 SUMMARY

A total of 2.6 miles of a tributary to the West Branch Mahoning River at RM 0.01 and one site on a another West Branch Mahoning River tributary at RM 9.63/0.74 were assessed in 2003. Based on the performance of the biological communities, only the site at RM 4.1 of the tributary at RM 0.01 was in attainment of the recommended Limited Resource Water (LRW) use. All other sites were in partial or non-attainment of the recommended WWH use (Table 7-1).

From surface water sampling on the West Branch Mahoning River tributary at RM 0.01, four field pH measurements were the only chemical analyses which exceeded the Ohio WQS criteria . Water quality was considered good with some minor nutrient enrichment noted. Aside from two chemicals, all organic parameters tested (explosives, semivolatiles, pesticides, and PCBs) in the water were reported as not detected. Metals and dissolved solids were at low levels with the exception of iron for which there is no aquatic life water quality criterion. For nutrients, ammonia was detected at all sites at levels below the applicable water quality criterion and phosphorous was slightly elevated. Sediment from the most upstream sampling location had slightly elevated levels of PAH compounds though at levels still protective of the LRW use. Metals in sediments were below Ohio sediment reference values from all sites with only arsenic above the TEC level at the RMs 3.5 and 2.5 sampling locations. No organic compounds were detected from the three downstream sites which further reflected non-contaminated conditions. Stream physical habitat conditions ranged from very poor at RM 4.1 with a QHEI of 25 to good at RM 2.1. The upstream site (RM 4.1) had bottom substrates predominated by muck, no instream cover, very shallow pool depths, and no riffles. The very poor habitat is not capable of supporting a WWH community. A Limited Resource Water (LRW) use is appropriate for the tributary from its headwaters to RM 3.8. QHEI scores for the three downstream sites averaged 61.5, demonstrating the potential to support WWH biological communities. Based on sampling results, impairment of the biological communities in the West Branch Mahoning River tributary at RM 0.01 appeared to be related to reduced habitat quality and not sediment or surface water chemical contamination. Very shallow pool depths at RM 3.5, lack of riffles and low quality substrates at RM 2.5, and low quality substrates and extensive embeddedness at RM 2.1 were overriding factors reducing biological diversity, even though total QHEI scores were representative of warmwater habitat conditions.

Sampling during 2003 is the basis for recommending LRW as the proposed use designation for the tributary from the headwaters to RM 3.8. Downstream from RM 3.8, WWH is recommended as the aquatic life use. Because of the shallow water depths and ephemeral condition of the LRW section of the tributary to the West Branch Mahoning River at RM 0.01, the Secondary Contact Recreation use is appropriate and recommended.

Surface water sampling from the West Branch Mahoning River tributary at RM 9.63/0.74, indicated that all tested parameters (metals, nutrients, explosives, semivolatiles, pesticides, and PCBs) were below detection limits or Ohio WQS criteria with the exception of bis(2-ethyl hexyl) phthalate, a common lab contaminant. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.]

Sediment collected at the RM 1.8 sampling location reflected non-contaminated conditions with metals below Ohio reference values and no organic compounds were detected. Based on the performance of the biological communities at the RM 1.8 sampling location, the tributary is in non-attainment of the recommended WWH use. The physical habitat was marginal for WWH conditions with a QHEI score of 50.5. Based on sampling results, non-attainment of the WWH use by the biological community was related to habitat issues and not sediment or surface water chemical contamination.

Sampling during 2003 is the basis for recommending WWH as the proposed use designation for the tributary to West Branch Mahoning River at RM 9.63/0.74.

Table 7-1. Attainment status of the aquatic life use for two West Branch Mahoning River tributaries based on biological sampling conducted during June - September, 2003.

RIVER MILE Fish/Invert.	Sample Location	IBI	ICI[a]	QHEI	Attainment Status	Site Location
			Ecoregion - *Erie Ontario Lake Plain (EOLP)*			
Tributary to West Br. Mahoning River at RM 0.01 - *LRW Use Designation (Recommended)*						
4.1	NN3-1	21	F	25.0	FULL	Dst. Erie Burning Ground
Tributary to West Br. Mahoning River at RM 0.01 - *WWH Use Designation (Recommended)*						
3.5	NN3-2	30*	F*	65.0	NON	Dst. Erie Burn. Gr./ Ust. LL1
2.5	NN3-3	30*	34	51.0	PARTIAL	Active OHARNG area/ beaver dam
2.1	NN3-4	25*	40	68.5	NON	Stream exits from RVAAP property
Tributary to West Br. Mahoning River at RM 9.63/0.74 - *WWH Use Designation (Recommended)*						
1.8	LL-4	30*	F*	50.5	NON	Dst. Load Line 4 pond

Ecoregion Biocriteria: Erie Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[b]	LRW
IBI-Headwater	40	50	24	18
ICI	34	46	22	8

[a] Narrative evaluation used in lieu of ICI score (E- excellent, G - good, F- fair, P-poor, VP- very poor). Sampling sites with narrative evaluations lacked adequate flow and water depth to quantitatively assess with Hester/Dendy samplers. Only qualitative samples of the natural substrates were collected.

[b] Modified Warmwater Habitat for channel modified areas.

* Significant departure from ecoregion biocriterion (>4 IBI and ICI units); poor and very poor results are underlined.

[ns] Nonsignificant departure from ecoregion biocriterion ($\leq$4 IBI and ICI units).

7.2 Surface Water Quality

Chemical analyses were conducted on surface water samples collected in June and September, 2003 from four locations in the West Branch Mahoning River unnamed tributary at RM 0.01 and from one location in the West Branch Mahoning River unnamed tributary at RM 9.63, 0.74 (Appendix 2, Appendix 3 Tables 7 and 8). Surface water samples were analyzed for target analyte list metals, pesticides, PCBs, explosive compounds, semivolatile organic compounds, and several nutrient parameters. Parameters which were in exceedance or outside of the range of Ohio WQS criteria are reported in Table 7-2.

7.2.1 West Branch Mahoning River Tributary at RM 0.01

Aside from four field measurements of pH, none of the other chemical analyses exceeded (or were outside the range of) Ohio WQS aquatic life maximum or average water quality criteria. None of the chemical concentrations (excluding the two lower pH values) exceeded criteria protective of the Warmwater Habitat aquatic life use or the Limited Resource Water use. Concentrations of all but two [bis(2-ethylhexyl) phthalate, 4,4-DDD] of the organic parameters tested (explosives, semivolatiles, pesticides, and PCBs) were reported as not detected. These two parameters with measurable concentrations (two total measurements) were reported at estimated levels. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] Most metals concentrations were very low, with many of the results less than lab detection limits. Elevated levels of total iron were measured in the two most upstream sampling locations (RMs 4.1 and 3.5), with high values of 5,310 ug/l and 5,580 ug/l, respectively. No aquatic life WQS criterion exist for total iron; however, these values far exceeded the least impacted ecoregion reference concentrations. Ammonia-N was measured in detectable amounts at each sample location, but values were less than the Ohio WQS criterion. Nitrate-N values were measured at low concentrations, with all values less than Ohio least impacted reference conditions (below the Erie Ontario Lake Plain ecoregion 75th percentile reference value). Total cyanide measurements were all less than the lab detection limit (0.01 mg/l). Total phosphorus levels were slightly elevated during the June sampling, with all values above the least impacted reference conditions (above the Erie Ontario Lake Plain ecoregion 75th percentile reference value: 0.11 mg/l). Phosphorus concentrations were below reference levels during the September sampling, at all sites except the most upstream station (RM 4.1). Chemical water quality in the West Branch Mahoning River tributary (at RM 0.01) was considered good; however, minor nutrient enrichment was noted.

7.2.2 West Branch Mahoning River Tributary at RM 9.63,0.74

Water quality results were documented from one location on this unnamed tributary to the West Branch Mahoning River. One parameter, bis(2-ethylhexyl) phthalate, exceeded the Ohio WQS aquatic life average water quality criterion, with an estimated value of 9.8 ug/l. Phthalates are typical lab contaminants, and two phthalate parameters were noted as present in the associated method blank from the September water samples. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] All other tested parameters (metals, nutrients, explosives, semivolatiles, pesticides, and PCBs) were reported as non-detect, or at low concentrations, and below water quality criteria. The September sampling pass recorded the presence of HMX (1.4 ug/l) and RDX (11 ug/l) in the water column. Both values were below Ohio water quality criteria. Nitrate-N and total phosphorus values were measured at low concentrations, with values at or less than Ohio least impacted reference conditions (below the EOLP ecoregion 75th percentile reference value). Total cyanide measurements were less than the lab detection limit (0.01 mg/l). Chemical water quality in the West Branch Mahoning River tributary (at RM 9.63,0.74) was considered good.

7.3 Sediment Chemistry

Chemical analyses were conducted on sediment samples collected in June, 2003, from four locations in the West Branch Mahoning River unnamed tributary at RM 0.01 and from one location in the West Branch Mahoning River unnamed tributary at RM 9.63, 0.74. Samples were analyzed for semivolatile organic compounds, pesticides, PCBs, target analyte list metals, explosive compounds, percent solids, cyanide, ammonia, nitrate, and phosphorus. Specific chemical parameters tested and results are listed in Table 7-3 and Appendix.3 Table 7

Sediment data were evaluated using guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald et.al. 2000), and USEPA Region 5, RCRA Appendix IX compounds - Ecological Screening Levels (ESLs) (USEPA 2003). The consensus-based sediment guidelines define two levels of ecotoxic effects. A Threshold Effect Concentration (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A Probable Effect Concentration (PEC) indicates a level above which harmful effects are likely to be observed. Ecological screening levels (ESLs) are initial screening levels used by USEPA to evaluate RCRA site constituents. In addition, sediment reference values (SRVs) for metals (Ohio EPA 2003) are presented in Appendix 4Table 7 for comparison to West Branch Mahoning River tributary results.

7.3.1 West Branch Mahoning River Tributary at RM 0.01

The West Branch Mahoning River tributary (at RM 0.01) was sampled at four locations. At the most upstream sampling location (RM 4.1, NN3-1), five PAH compounds were measured above TEC levels, and one PAH compound was measured above ESL guidelines. These levels of PAH chemicals, although slightly elevated, are protective of biological communities representative of the Limited Resource Water aquatic life use recommended for this area. Sediment collected at the downstream Warmwater Habitat sites (RMs 3.5 - 2.1) reflected non-contaminated conditions, with all tested explosive compounds, PCBs, pesticides, and semivolatile organic compounds not detected. All metals tested in sediments were below Ohio reference values (Ohio EPA 2003) and only arsenic from two locations (RMs 3.5 and 2.5) was measured above the TEC level. Ammonia and phosphorus levels in sediment at all locations were below screening guidelines ((Persaud et. al. 1993).

7.3.2 West Branch Mahoning River Tributary at RM 9.63,0.74

The West Branch Mahoning River tributary draining the load line four area was sampled at one location, downstream from the load line four pond. Sediment collected from this location reflected non-contaminated conditions. All metals tested in sediments were below Ohio reference values (Ohio EPA

2003) and below TEC and ESL levels. All tested explosive compounds, PCBs, pesticides and semivolatile organic compounds were not detected in the sediment sample. Ammonia and total phosphorus levels were measured in the sediment below screening guidelines (Persaud et. al. 1993).

7.4 Physical Habitat For Aquatic Life

Physical habitat was evaluated in the West Branch Mahoning River tributaries at each fish sampling location. Qualitative Habitat Evaluation Index (QHEI) scores are detailed in Table 7-4.

7.4.1 West Branch Mahoning River Tributary at RM 0.01

Distinct physical habitat differences were observed between the four sites evaluated. QHEI scores ranged between 25.0 and 68.5. The most upstream site, at RM 4.1 (Smalley Road), had very poor habitat as evidenced by the low QHEI score of 25.0. Bottom substrates were dominated by muck, resulting in extensive embeddedness. Instream cover was nearly absent, no riffles were present, and the maximum pool depth during the second fish pass was 3 centimeters. The best feature observed at this location was the wide riparian zone, comprised of forest and wetland. During a normal summer flow year, this location would likely go ephemeral (excluding the bridge effect pool).

WWH conditions existed at RM 3.5, which had a QHEI score of 65.0. Substrate quality was good, represented primarily by cobble and gravel. Instream cover was marginally abundant and the riparian zone was wide and comprised of forest cover. However, the riffle areas, although abundant, were very shallow. Additionally, the maximum pool depth was 22 cm, limiting the pool habitats available to fish. The good QHEI score resulted from good quality substrates, an excellent riparian zone, natural stream channel, and moderate stream gradient.

Marginal WWH conditions existed at RM 2.5, which had a QHEI score of 51.0. A beaver dam impounded this section of stream, resulting in 100 percent pool habitat for the sampling zone. Sand and detritus predominated the bottom substrates, the stream channel appeared to be recovering from past modification, and instream cover was sparse. The lack of riffles, lower quality substrates, and only fair channel development contributed to the fair QHEI score.

Improved WWH conditions were noted at RM 2.1, with a QHEI score of 68.5. Sand and muck predominated the bottom substrates. The stream channel was natural within the study area and was represented by pool, run, and riffle areas. Instream channel development was good, and surrounding land use was forest and shrub. Overall habitat conditions scored good; however, substantive negative attributes included a predominance of muck substrates and extensive/moderate substrate embeddedness.

7.4.2 West Branch Mahoning River Tributary at RM 9.63,0.74

The West Branch Mahoning River tributary draining the load line four area was sampled at one location, downstream from the load line four pond at RM 1.8. Marginal WWH conditions existed at RM 1.8, which had a QHEI score of 50.5. A beaver dam impounded the lower section of stream, resulting in mostly pool habitat for the sampling zone. Silt predominated the bottom substrates, the stream channel appeared to be natural, and instream cover was sparse. Although riffles were present, their shallow depth, along with lower quality substrates and only fair channel development, contributed to the fair QHEI score.

7.5 Fish Community Assessment

Fish communities were sampled in June and September, 2003, from four locations in the West Branch Mahoning River unnamed tributary (at RM 0.01) and from one location in the West Branch Mahoning River unnamed tributary (at RM 9.63, 0.74).Table 7-5 and Appendix 4 Table 1.

7.5.1 West Branch Mahoning River Tributary at RM 0.01

Fish communities were very poor to fair in the West Branch Mahoning River tributary (at RM0.01), with IBI scores between 21 and 30. The most upstream site, at RM 4.1, although only of poor quality, achieved the recommended Limited Resource Water aquatic life use designation with a mean IBI score of 21. This site was represented by three fish species during the June sampling (central mudminnow, grass pickerel, and golden shiner). These species are typically associated with wetland areas and streams with low gradients. The emphemeral nature of this section of stream was evidenced by the lack of fish during the September sampling, when the stream was nearly devoid of water (maximum depth of 3 cm).

Sampling at the next two downstream sites (RMs 3.5 and 2.5) documented a fair fish community, with both sites scoring an IBI of 30. These two sites did not achieve the ecoregional Warmwater Habitat biocriterion. Limiting factors to fish diversity at RM 3.5 primarily included shallow water conditions in pool and riffle areas. The lack of riffle and run habitat, along with soft bottom substrates (excessive embeddedness), were limiting factors to fish diversity at RM 2.5. As was observed at RM 4.1, wetland associated fish species were common at these two sampling locations.

At the most downstream sampling location (RM 2.1 - State Route 534 - exiting military base), poor fish results were recorded, as evidenced by an IBI score of 25. This site did not achieve the Warmwater Habitat biocriterion. Improved physical habitat conditions were documented at RM 2.1, in comparison to upstream sampling locations (higher QHEI score, greater stream flows, pool/riffle/run habitats). However, a predominance of soft bottom substrates and high embeddedness appeared as limiting conditions to the fish community. Sediment and surface water sampling results suggested good water quality conditions, with levels reflective of reference quality.

7.5.2 West Branch Mahoning River Tributary at RM 9.63, 0.74

The fish community sampled at RM 1.8 in the load line four tributary to the West Branch Mahoning River represented fair biological conditions, with an IBI score of 30. This site did not achieve the Warmwater Habitat biocriterion. Factors limiting fish diversity included a beaver dam impoundment, predominance of soft bottom substrates, and shallow riffle depth. Sediment and surface water sampling results suggested good water quality conditions, with levels reflective of reference quality.

Macroinvertebrate Community Assessment

Macroinvertebrate communities were assessed using artificial substrates supplemented with a qualitative multihabitat composite natural substrate or only a qualitative natural substrate sample at 5 locations in the two West Branch Mahoning River tributaries. The results are summarized in Table 7-6, and detailed in Appendix 4 Table 4). Four sites were located on the tributary to West Branch Mahoning River at RM 0.01. One site was located on the tributary to West Branch Mahoning River at RM 9.63/0.74.

7.6.1 Tributary to West Branch Mahoning River at RM 0.01

Based on artificial substrate sample results from RMs 2.5 and 2.1, the macroinvertebrate communities were evaluated as good. ICI scores were 34 and 40, respectively. These ICI values achieved the ecoregional biocriterion established for the recommended Warmwater Habitat (WWH) use and indicated no biological impairment. The sites at RMs 4.1 and 3.5 had small drainage areas and were sampled using only qualitative multihabitat composite samples. Samples were collected in both June and September. The site at RM 4.1 was a channelized drainage ditch with only muck substrates for habitat and a drainage area of only 0.6 mi^{2}. The ditch drained a wetland area. The macroinvertebrates from both samples were typical wetland fauna consisting of primarily Hemiptera (true bugs), Coleoptera (beetles) and the crayfish Procambarus acutus, a common wetland species. Based on a narrative evaluation of fair for the macroinvertebrate community, the site is in attainment of the recommended Limited Resource Water (LRW) use. The site at RM 3.5 had a natural stream channel but the small drainage area limited upstream flow which reduced the function of the riffle habitat. The macroinvertebrate community was evaluated as fair which did not attain the recommended WWH use.

7.6.2 Tributary to West Branch Mahoning River at RM 9.63/0.74

The macroinvertebrate community was assessed at RM 1.80. Qualitative multihabitat composite samples were collected in both June and September. The site was downstream from the load line #4 pond. The macroinvertebrate community was pond-like in character, with the scud Hyalella azteca, Odonata (dragonflies and damselflies), Coleoptera (beetles), and Mollusca (clams and snails) predominant. The site was evaluated as fair which did not attain the recommended WWH use.

Table 7-2. Exceedances of Ohio Water Quality Standards aquatic life criteria (OAC 3745-1) for chemical/physical parameters from two unnamed tributaries to the West Branch Mahoning River during 2003.

River Mile	Parameter (value)
W.B. Mahoning River Tributary at RM 0.01	
4.1	pH (6.1*)
3.5	pH (6.44*)
2.5	pH (5.82*)
2.1	pH (5.24*)
W.B. Mahoning River Tributary at RM 9.63/0.74	
1.8	bis(2-ethylhexyl) phthalate (9.8J*)

* Exceedances (or outside of range) of aquatic life Outside Mixing Zone Average Criteria (OMZA).

Table 7-3. Chemical parameters measured above screening levels (metals) or detected (organics) in sediment samples collected from two West Branch Mahoning River tributaries, June, 2003. Contamination levels were determined for parameters using either consensus-based sediment quality guidelines (MacDonald et.al. 2000) or ecological screening levels for RCRA appendix IX constituents (USEPA 2003). Sediment reference values (SRVs) are listed in the Ohio EPA Ecological Risk Assessment Guidance (2003).

	WEST BRANCH MAHONING RIVER TRIBUTARIES SEDIMENT					
	Tributary @ RM 0.01				**Trib.@ 9.63.0/74**	
Parameter	**RM 4.1**	**RM 3.5**	**RM 2.5**	**RM 2.1**	**RM 1.8**	**SRVs**
Arsenic (mg/kg)	4.7	13.7^{T}	16.2^{T}	8.2	4	25
Benzo(a)anthracene (ug/kg)	330J^{T}	<420	<450	<500	<510	-
Benzo(a)pyrene (ug/kg)	270J^{T}	<420	<450	<500	<510	-
Benzo(b)fluoranthene (ug/kg)	350J	<420	<450	<500	<510	-
Benzo(g,h,i)perylene (ug/kg)	180J^{E}	<420	<450	<500	<510	-
Benzo(k)fluoranthene (ug/kg)	160J	<420	<450	<500	<510	-
Chrysene (ug/kg)	310J^{T}	<420	<440	<420	<450	-
Fluoranthene (ug/kg)	500J^{T}	<420	<440	<420	<440	-
Indeno(1,2,3-c,d)pyrene (ug/kg)	160J	<420	<440	<420	<440	-
Phenanthrene (ug/kg)	140J	<420	<440	<420	<440	-
Pyrene (ug/kg)	390J^{T}	<420	<440	<420	<440	-

J - The analyte was positively identified, but the quantization was below the reporting limit (RL).
^{T} - Above Threshold Effect Concentration (below which harmful effects are unlikely to occur; MacDonald et.al. 2000).
^{P} - Above Probable Effect Concentration (above which harmful effects are likely to occur; MacDonald et.al. 2000).
^{E} - Above Ecological Screening Level (USEPA 2003).

Table 7-4. QHEI (WB Mahoning tributaries)

Table 7-4. Qualitative Habitat Evaluation Index (QHEI) scores for West Branch Mahoning River tributaries, 2003.

Key
QHEI
Components

WWH Attributes

River Mile	QHEI	Gradient (ft/mile)	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Substrates	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max Depth > 40 cm	Low-Normal Riffle Embeddedness	Total WWH Attributes
(18-069) Trib. to W. Br. Mahoning R. (RM 0.01)													
Year: 2003													
4.1	25.0	7.69											0
3.5	65.0	14.71	■	■				■				■	4
2.5	51.0	17.86									■		1
2.1	68.5	15.87	■			■	■	■			■		5
(18-083) Trib to W. Br. Mahoning R (RM 9.63/0.74)													
Year: 2003													
1.8	50.5	20.00	■								■		2

MWH Attributes

River Mile	High Influence: Channelized or No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40 cm (WD, HW)	Total H.I. MWH Attributes	Moderate Influence: Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent and Poor Pools	No Fast Current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Total M.I. MWH Attributes	(MWH H.I.+1)/(WWH+1) Ratio	(MWH M.I.+1)/(WWH+1) Ratio
(18-069) Trib. to W. Br. Mahoning R. (RM 0.01)																					
Year: 2003																					
4.1	◆	◆	◆	◆	◆	5		●			●		●		●	●		●	6	6.00	*.**
3.5			◆	◆	◆	3					●				●	●			3	0.80	1.40
2.5			◆	◆		2	●	●			●				●	●		●	6	1.50	4.50
2.1		◆				1		●							●	●	●		4	0.33	1.00
(18-083) Trib to W. Br. Mahoning R (RM 9.63/0.74)																					
Year: 2003																					
1.8		◆	◆	◆		3		●			●				●	●	●	●	6	1.33	3.33

Table 7-5. Fish community summaries based on pulsed DC electrofishing sampling conducted in two West Branch Mahoning River tributaries from June and September, 2003. Relative numbers are per 0.3 km of stream length.

Stream/ River Mile	Station Location	Mean Number of Species	Total Number Species	Mean Relative Number	QHEI	Mean Index of Biotic Integrity	Narrative Evaluation
Tributary to West Br. Mahoning River @ RM 0.01 (2003)							
4.1	NN3-1	1.5	3	47	25.0	21	Poor
3.5	NN3-2	5.5	7	33	65.0	30*	Fair
2.5	NN3-3	7.5	9	107	51.0	30*	Fair
2.1	NN3-4	5.5	6	99	68.5	25*	Poor
Tributary to West Br. Mahoning River @ RM 9.63/0.74 (2003)							
1.8	LL-4	5.0	6	79	50.5	30*	Fair

Ecoregion Biocriteria: Erie-Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[a]	LRW
IBI-Headwater	40	50	24	18

[a] Modified Warmwater Habitat for channel modified areas.
* Significant departure from ecoregion biocriterion (>4 IBI units); poor and very poor results are underlined.

Table 7-6. Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in West Branch Mahoning River tributaries, 2003.

Stream/ River Mile	Station Location	Density No./ft^2	Total Taxa	Quant-itative Taxa	Qual-itative Taxa	Qual-itative EPT[a]	ICI	Narrative Evaluation
Tributary to Mahoning River at RM0.01 (2003)								
4.1	NN3-1	-	-	-	16/21	0/5	F	Fair
3.5	NN3-2	-	-	-	23/31	5/4	F*	Fair
2.5	NN3-3	395	64	47	28	2	34	Good
2.1	NN3-4	620	42	37	13	4	40	Good
Tributary to Mahoning River at RM 9.63/0.74 (2003)								
1.8	LL4	-	-	-	30/17	3/1	F*	Fair

Ecoregion Biocriteria: Erie-Ontario Lake Plain (EOLP)
(Ohio Administrative Code 3745-1-07, Table 7-15)

INDEX	WWH	EWH	MWH[b]
ICI	34	46	22

[a] EPT= total Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa richness, a measure of pollution sensitive organisms.
[b] Modified Warmwater Habitat for channel modified areas.
* Significant departure from ecoregional biocriterion (≤4 ICI units or narrative equivalent established for the designated or recommended aquatic life use); poor and very poor results are underlined.

8 Conclusions and Recommendations

8.1 Summary

The 2003 facility-wide surface water sampling and assessment study was a holistic examination of the streams within the boundaries of RVAAP that could potentially be impacted chemically or physically by the activities of the former ammunition plant. Twenty-six stream sites were sampled in order to assess each stream that moves across the property and at points along the stream where areas of former activity could have contributed to contamination or degradation of the surface water and sediment or the physical habitat.

The facility-wide surface water sampling and assessment effort revealed that in general, surface water quality in the streams was good to excellent with few exceedances of Ohio Water Quality Standards criteria. Some SVOCs were detected in sediment samples. However, the concentrations were either below screening levels, or when marginally above screening levels, the concentrations were estimated values. Intact riparian buffers around the streams contributed to good habitat and absence of substantial silt deposits. Only in some of the Tributary to West Branch Mahoning River sites was low quality substrates and extensive embeddedness a cause of biological impairment. The fish and macroinvertebrate communities attained the Warmwater Habitat biocriteria for all but five stream sampling locations. Chemical contamination of the water and sediments was not observed at any of the stream sampling locations and was not the cause of biological use impairment.

8.2 Conclusions

The streams in RVAAP are mostly undisturbed and are a good quality resource for aquatic biota. The 2003 study was performed during a period of greater than normal rainfall. This occurrence allowed biotic and chemical sampling to occur with good water flow at the stream sites. This also should have allowed for movement of contamination along drainage paths from the areas of concern to the streams if this potential existed. Based on both surface water sampling runs chemicals were detected, but they were below water quality criteria. The second round of surface water sampling performed 15-18 September, was conducted after a significant flooding event in late July, which should have allowed the release of site contaminants if they were in the drainage pathways Sediment samples, all collected 17-25 June, were also found to be free of site related contamination. Although a significant flood event occurred between the first and second rounds of surface water sampling, flow conditions during the collection of samples was similar between the two rounds. The physical change in stream habitats associated with the flooding event included scoured banks, shifts in riffle and run substrates, and numerous dislodged trees. The severity of the flood was evidenced by major erosion at several culvert and bridge crossings. Biologically, no obvious difference was observed in the fish community before and after the flood event.

8.3 Recommendations

Evidence suggests that additional remedial investigation effort, on an installation wide basis, of the streams included in this report is not warranted. However, this does not preclude investigating surface water and sediment on individual AOC basis as required by the Ohio EPA. Contamination is not currently present in the surface water. Some SVOCs were detected in sediment, however, the concentrations were either below screening levels, or when marginally above screening levels, the concentrations were estimated values. Monitoring of stream biology did not indicate impaired conditions associated with chemical contaminants. Biological monitoring incorporates influences from both low and high flow events, conditions that were experienced during this surface water study. Because aquatic stream organisms complete their life cycles in the water body, they are continuous monitors of environmental quality, both chemical and physical. As remedial actions are undertaken as necessary for each associated area of concern, plans must be made to ensure that those actions will not impact the streams or create drainage pathways that would allow contaminant loading into the stream system. During and following remedial actions, special attention should be paid to the impact on the stream system, which may include use of physical barriers, scheduled sampling of surface water or sediment runoff, and special attention or restoration of riparian zone vegetation.

Care should be taken by the future landowners and users to minimize impacts to the stream systems in their activities.

Biological and Water Quality Study of Ravenna Army Ammunition Plant

Part II - Ponds

November 14, 2005

EXECUTIVE SUMMARY

In 2003, eleven ponds were sampled within the Ravenna Army Ammunition Plant (RVAAP) property. Four of the ponds were considered representative of reference conditions. At each pond, two surface water samples from different collection dates during the summer were analyzed for target analyte list metals, pesticides, PCBs, explosive compounds, semivolatile organic compounds, and several nutrient parameters. Sediment samples were collected from each pond by incremental sampling randomly across the entire waterbody. Sediments were analyzed for target analyte list metals, pesticides, PCBs, explosive compounds, percent solids, cyanide, ammonia, nitrate, phosphorus, and semivolatile organic compounds. Macroinvertebrate community assessments were completed at all eleven ponds. Fish community assessments were completed at eight ponds - three ponds (Administration, Erie Burning Ground, Snow) were not sampled for fish due to shallow water depths. Physical habitat was evaluated only at the eight ponds which were sampled for fish. Pond habitat was evaluated using the Lake/Lacustuary (Lentic) Qualitative Habitat Evaluation Index (QHEI) developed by Ohio EPA. Although biological criteria are not applicable to pond or lake waterbodies, chemical Water Quality Standards (WQS) criteria identified for the Warmwater Habitat (WWH) aquatic life use designation apply to all eleven ponds evaluated at the RVAAP.

Reference Ponds/Wetlands

Boy Scout Pond

Chemical water quality values did not exceed WQS criteria, and sediment levels were below ecological benchmarks. Boy Scout Pond had higher quality habitat than other ponds. The fish and macroinvertebrate communities had low similarity to the other reference sites as well as the potentially contaminated sites, which can be attributed to its substantially different habitat and riverine hydrology.

Snow Pond

Snow Pond was selected as a wetland to define reference conditions at RVAAP. Surface water quality in Snow Pond, although slightly exceeding several chronic WQS criteria, did not appear to be sufficient to impact the biological community. Sediment levels were below ecological benchmarks. The activity trap sampling results indicated a typical macroinvertebrate, amphibian, and fish wetland fauna. The fish community was not sampled using electrofishing equipment due to shallow water depth.

Franks Pond

Surface water quality in Franks Pond, although slightly exceeding several chronic WQS criteria, did not appear to impact the biological community. Sediment levels were below ecological benchmarks. Fair habitat quality was noted, and the fish community was similar to Trouts Pond, a reference waterbody. There was sufficient vegetative cover along the shoreline to support a moderately diverse macroinvertebrate community and an abundance of green frog tadpoles.

Trout Pond

Surface water quality in Trout Pond, although slightly exceeding several chronic WQS criteria, did not appear to impact the biological community. Sediment levels were below ecological benchmarks. Habitat quality was fair in Trout Pond, and the fish community was similar to Franks pond, a reference waterbody. Greater shoreline water depth (compared to Franks Pond) appeared to limit the diversity and abundance of free-swimming macroinvertebrates collected in activity traps.

Non-Reference Ponds/ Wetlands

Erie Burning Ground Pond/Wetland

Surface water quality in Erie Burning Ground, although slightly exceeding several chronic WQS criteria, did not appear to impact the biological community. Water quality conditions were comparable to reference ponds. Based on sediment sampling results, moderate contamination was evident in Erie Burning Ground. Particularly noteworthy were elevated levels of several explosive compounds in the sediment. Macroinvertebrate communities in Erie Burning Ground were substantially different from the reference wetland Snow Pond, which may be the result of the different plant communities and the soft anoxic sediments at the Erie Burning Ground, as well as potential sediment contamination. The fish community was not sampled due to shallow water depth.

Administration Pond

Chemical water quality values did not exceed WQS criteria, and sediment levels were below ecological benchmarks. Two explosive compounds were detected in the surface water, but levels were below Ohio WQS criteria. The macroinvertebrate community in the Administration Pond did not differ significantly from Snow Pond, a reference wetland. The fish community was not sampled due to shallow water depth.

Upper Cobbs Pond

Surface water and sediment quality in Upper Cobbs Pond was of sufficient quality to not adversely impact the biological community. One explosive compound was detected in the surface water of Upper Cobbs Pond, but the measurement was below the WQS criterion. Habitat quality was considered poor, influenced by reduced aquatic macrophyte diversity. The poor habitat appeared to reduce the free-swimming macroinvertebrate community diversity in activity trap samples. Fish community results were strongly similar to reference pond conditions.

Lower Cobbs Pond

Surface water quality in Lower Cobbs Pond, although slightly exceeding several chronic WQS criteria, did not appear to impact the biological community. Although most chemical compounds in the sediment were below ecological benchmarks, chromium was measured above the *Probable Effect Concentration*. Habitat quality was considered poor, influenced by reduced aquatic macrophyte diversity. The poor habitat appeared to reduce the free-swimming macroinvertebrate community diversity in activity trap samples. Fish community results were strongly similar to reference pond conditions.

Load Line Four Pond

Surface water and sediment quality in Load Line 4 Pond was of sufficient quality to not adversely impact the biological community. Habitat quality was considered fair. The macroinvertebrate fauna did not differ significantly from reference conditions. Fish community results were strongly similar to reference pond conditions.

Fuze/Booster Pond

Surface water quality in Fuze/Booster Pond, although slightly exceeding several chronic WQS criteria, did not appear to impact the biological community. Sediment sampling results indicated moderate contamination, with lead and zinc measured above the *Probable Effect Concentration*. Habitat was evaluated as fair, although aquatic vegetation was sparse along much of the shoreline. Based on artificial substrate sample results, the macroinvertebrate community was similar to reference conditions. Macroinvertebrate abundance and diversity, as measured through activity trap sampling, was reduced in Fuze/Booster Pond due to sparse shoreline vegetative cover. Fish community results were strongly similar to reference pond conditions.

Kellys Pond

Kellys Pond exhibited the highest concentration and most numerous detections of explosive compounds in the surface water. However, none of the measured explosive parameters exceeded OhioWQS aquatic life criteria. Several metal parameters exceeded chronic water quality criteria; however, these did not appear to be of sufficient concentration to impair the biological community. Kellys Pond sediment sampling results indicated moderate contamination. Three metal parameters and six PAH compounds were reported at levels above the *Threshold Effect Concentration*. Five PAH compounds exceeded the *Probable Effect Concentration*. Explosive compounds were not detected in the sediment. Habitat quality was very poor, as evidenced by a lack of aquatic vegetation, a soft, mucky bottom, and no cover. The artificial substrate results were relatively similar to reference conditions. The activity trap sample results were not similar to reference conditions. As a potential cause of macroinvertebrate community impairment, it is impossible to discern very poor habitat impacts from potential chemical contamination impacts. The fish community of Kellys Pond was dissimilar from all reference ponds (as well as all other ponds sampled). The fish community was dominated by pollution tolerant fathead minnows.

As a result of data gaps identified in the 2003 assessment effort, additional work was performed during the summer of 2004 as well as December 2004 . This work included additional sampling and analysis of surface water and sediments as well as plant and animal tissue. On completion, the information collected during this work will be be submitted as an addendum to this document.

9 INTRODUCTION

Specific objectives of this evaluation were to:

1) Establish biological conditions in select ponds of the Ravenna Army Ammunition Plant property by evaluating fish and macroinvertebrate communities, and assessing physical habitat conditions.

2) Measure and evaluate surface water and sediment chemical quality in select ponds within the Ravenna Army Ammunition Plant property. General chemicals of concern included MEC, semivolatile organic and inorganic constituents.

3) Determine if chemical contamination within the ponds is adversely affecting the biological communities, and

4) Complete an ecological assessment report summarizing the sediment, surface water, and aquatic biological results.

10 HISTORY OF SITE USAGE ASSOCIATED WITH SURFACE WATER SITES

10.1 Boy Scout Pond

This 3.4-acre pond, part of Wadsworth Glen is the result of an old concrete dam across Eagle Creek just west of Wadsworth Road. Waterfowl and beaver use is supported.

10.2 Snow Road Pond

This pond was created by a beaver dam across a small tributary of South Fork Eagle Creek. It supports panfish and bass, and provides good waterfowl habitat.

10.3 Frank's Pond

Frank's pond is not stocked and contains three wood duck boxes.

10.4 Reference Pond No. 2 (RT 80 Trout Pond)

Pond No. 2 is an impoundment located along Hinckley Creek. Considering the location of this pond, it is considered as a background impoundment feeding the main-stem. It is fed principally by streams emanating from off the facility, with a minor component from the far northwest end of Block C. No information is available as to the specific products that were stored in Block-C. If the products stored were treated wire crates and boxes, one could expect to find pentachlorophenol (PCP). PCP was the preservative of choice for treating wood crates and other materials subject to fungus and rot during the WWII and up through the Vietnam Era. The sampling location is up gradient from the former Portage Ordnance Depot administration area situated south east of the intersection of Route 80 and Newton Falls Road. No other compounds of concern are reported.

10.5 Erie Burning Ground Pond

This 35-acre AOC was used to thermally treat munitions by open burning on the ground surface. Bulk, obsolete, off-spec propellants, conventional explosives, rags, and large explosive-contaminated items were treated at this location. The ash residue from the burns was left at the AOC. Waste constituents of concern at this location include RDX, TNT, and heavy metals.

10.6 Administration Pond

The Administration Pond is situated east of and down gradient of both the former pesticide storage facility and the former facility laundry. Additionally, there are tributaries from Load Lines 5, 6, and 10 that drain into the Administration Pond.

No information is available as to the pesticide formulations that were used, but it must be assumed that they were applied as recommended. The potential contaminants contributed from LL #5 and #6 would be the primary explosive mercury fulminate, and the components of black powder which are potassium nitrate, sulfur, and carbon. Compounds that might be expected from LL #10, the percussion element manufacturing line, are TNT, pentaerythrite tetranitrate (PETN), potassium chlorate, antimony sulfide, and lead thiocyanate. Marking inks, dyes, wood preservatives, ethyl alcohol, lacquers, lacquer thinners (containing methyl ethyl ketone (MEK), toluene, xylenes, isobutyl alcohol, methyl isobutyl ketone (MIBK), isopropyl alcohol, shellacs, and Stoddard solvent) and paints with organic and metallic pigments, were used.

Common detergents from the laundry most likely contained phosphate which would be present in the form of ortho-phosphate. Phosphate would support the growth of algae.

In addition to the afore-specified compounds, other expected contamination from the primary lines is discussed in sections covering portions of Hinckley, Sand Creek and the Fuze and Booster Ponds.

10.7 Upper and Lower Cobbs Pond

Features feeding Sand Creek location are Upper and Lower Cobbs Ponds which in turn have drainages from Load Lines 3 and 12 and the Atlas Scrap Yard. The Lower Cobbs Pond is adjacent to the Sand Creek Sewage Treatment Plant (Stream Sample section S-8). Contamination emanating from both load lines and the Atlas Scrap Yard through both Upper and Lower Cobb's Ponds is expected. The nature of the expected contamination from LL #3 and #12 is 1,3,5-trinitrobenzene, TNT, 2,4-DNT, 2,6-DNT, 2-amino-4,6-DNT, 4-amin-2,6-DNT from the melt pour operations and the natural degradation of TNT. Expected also from the propellants M-1, M-2, M-5 and M-6 use in loading is nitrocellulose, nitroglycerin, nitroguanidine, Barium nitrate, potassium nitrate, dibutyphthalate, and diphenylamine. The compounds and elements of black powder, potassium nitrate, sulfur and carbon and their oxides may also be present.

10.8 Load Line 4 Pond

A stream arm feeding the LL #4 pond continues upstream to the fuze and booster storage igloos, Area 4. This arm is also in the proximity of RVAAP # 48, which is the Anchor Test Area scheduled for investigation in October, 2004. No contamination is expected from the fuze and booster storage igloo area, Area 4, since finished, sealed fuze and fuze components were staged for other operations or stored prior to shipment to other load, assemble and pack facilities. The activities conducted at these locations are not conducive to processes that one would expect major contamination. The majority of the potential contamination is expected from Load Line #4. Expected contamination would be similar to that described for Kelly's Pond, which drains the approximate south half of Load Line #2.

10.9 Fuze and Booster Pond

The Fuze and Booster Quarry's were initially used for the disposal or demilitarization of components, out of specification fuzes and other materials associated with the fuze and booster line operations. Drainage from these ponds flows into Hinckley Creek between sampling intervals H-3 and H-4. Compounds from products manufactured at RVAAP during WWII, and from the incomplete combustion during the demilitarization process would be lead azide, mercury fulminate, tetryl, potassium nitrate and oxidized sulfur in the form of metal sulfites and sulfates, lead oxide, and mercuric oxide. Since demilitarization of products continued after WWII, other compounds that might be present are lead styphnate and RDX from the lead cups integrated into more modern fuze systems. Oxidation of the metals components will have also occurred and may be found as iron, aluminum, and cadmium oxides. The cadmium would be from the plated booster cups and other fuze components. Other potential contaminants would be the components of black powder, potassium nitrate, sulfur, carbon and the booster explosive tetryl. Marking inks, ethyl alcohol, lacquers, lacquer thinners (containing methyl ethyl ketone (MEK), toluene, xylenes, isobutyl alcohol, methyl isobutyl ketone (MIBK), isopropyl alcohol), shellacs, and Stoddard's solvent, and paints with organic and metallic pigments, were used. At the booster lines, binders such as Gum Arabic were blended with the tetryl before the pellet manufacturing process. Additional information can be located in the sections covering Hinckley Creek sampling intervals H-3 and H-4.

10.10 Kelly's Pond

Kelly's pond is southeast of Load Line #2. The pond is directly south of a series of inert product warehouses presently used to store the M-1 Abram's Tank by the Ohio National Guard.

Explosive compounds that might be expected from LL #2 potentially impacting Kelly's Pond would be TNT, RDX, Comp B, and M1 Propellant, which is composed of NC, 2,4 DNT, DBP, and Diphenylamine.

Other materials used in support of the processes at LL #2 are marking inks, ethyl alcohol, lacquers, lacquer thinners containing methyl ethyl ketone (MEK), toluene, xylenes, isobutyl alcohol, methyl isobutyl ketone (MIBK), isopropyl alcohol (IPA), shellacs, Stoddard's solvent, and paints with organic and metallic pigments. Metallic pigments would include but are not limited to barium, lead and cadmium salts, and oxides of chromium. Lubricants and other hydrocarbons may also be expected. Since there were no metal working processes at LL #2, no cutting lubricants would be expected.

11 METHODS

All physical, chemical, and biological field, laboratory, data processing, and data analysis methodologies and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio Environmental Protection Agency 1989a), Biological Criteria for the Protection of Aquatic Life, Volumes I-III (Ohio Environmental Protection Agency 1987a, 1987b, 1989b, 1989c), The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application (Rankin 1989, 1995) for aquatic habitat assessment, Methods of Assessing Habitat in Lake Erie Shoreline Waters Using the Qualitative Habitat Evaluation Index (QHEI) Approach (Ohio EPA 2002a), Ohio EPA Sediment Sampling Guide and Methodologies (Ohio EPA 2001), Amphibian Index of Biotic Integrity (AmphIBI) for Wetlands (Ohio EPA 2002b), Louisville Chemistry Guidelines, Version 5 (USACE 2002), and the Facility-Wide Sampling and Analysis Plan for Environmental Investigations at the RVAAP, Ravenna, Ohio (USACE 2001). Sampling locations are listed in Table 11-1. Reference ponds used in this evaluation included Boy Scout Pond, Franks Pond, Trout Pond, and Snow Pond. Ponds evaluated as potential repositories of contamination included Upper Cobbs Pond, Lower Cobbs Pond, Fuze/Booster Pond, Load Line 4 Pond, Kellys Pond, Administration Pond, and Erie Burning Ground Pond. Fish communities were not evaluated in Snow Pond, Administration Pond, and Erie Burning Ground Pond due to shallow water depths. In addition, these ponds were more comparable to wetland conditions and were evaluated biologically using wetland techniques.

11.1 Habitat Assessment

Physical habitat for ponds was evaluated using the Lake Erie shoreline Qualitative Habitat Evaluation Index (L-QHEI) developed by the Ohio EPA (2002a). Various attributes of the habitat were scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of cover types, shoreline morphology, extent and quality of riparian vegetation, and aquatic vegetation quality are habitat characteristics used to determine the L-QHEI score. Lake Erie shoreline/lacustuary areas generally can have L-QHEI scores between 0 and 100. Draft scoring guidelines for the L-QHEI include excellent (>80), good (80-60), fair (59-45), poor (44-30), and very poor (<30). These guidelines were used to assess physical habitat conditions at eight ponds evaluated as part of this study.

11.2 Sediment Sampling / Assessment

The RVAAP pond sampling locations were sampled once for sediment during 18 – 24 June 2003. To obtain a representative measure of chemical contamination within the pond sediment, incremental sampling was performed randomly across the entire pond bottom to provide an average level of sediment quality. At each pond, equal volume sediment sub-samples were taken randomly at 30 to 50 locations across the entire pond. Each of these sub-samples was then mixed together to provide an average sediment sample for the pond. Sediment field sub-samples were collected with two tools; a steel, nickel-plated step probe with a 13” slot and inside diameter of 7/8-inch for areas where access by wading could be done; and an Ekman dredge at locations where a boat was required. Only the step probe was used at the Fuze and Booster Quarry Pond because the finer grained sediment in this former quarry was found only from around the perimeter. From 30 to 50 individual field sub-samples were collected in doubled plastic baggies as a two-person crew traversed an entire pond. Where the step probe was utilized, individual field sub-samples were collected from the upper 0- 6 inches of the pond bottom of the generally more silty, clayey sediment. The Ekman dredge collected sediment from the upper 0-3 inches of bottom material. Once the total incremental sediment sample was collected, it was placed on ice in a cooler for transport to the sample preparation building on site. All sampling equipment was decontaminated between pond locations according to the Ravenna Facility-Wide Sampling and Analysis Plan.

The overall goal of the sediment collection was to collect sufficient material from the pond to account for both compositional and distributional heterogeneity. Much more sediment sample material was collected than could be practically forwarded to the laboratory. Thus processing was done of the field collected sample to provide a smaller but representative sample of material for shipment to a laboratory. The entire sample was mixed and laid out and 30 small spoon samples taken randomly across the mix to fill each of the analytical sample jars. The sample processing described provided a more representative and uniform set of samples for the laboratories to analyze. Once sediment samples were processed, the jars were placed on ice (to maintain 4^{o}C) in a cooler, and shipped to USACE contract labs. Quality control (QC) and quality assurance (QA) samples were collected as directed by the LCG and the QA samples were submitted to a secondary USACE contract lab. Sediment data is reported on a dry weight basis. With dedicated sampling equipment, minimal IDW was created. Liquids and solids from equipment decontamination were included with IDW generated during the concurrent assessment of DLA Storage areas.

Sediment evaluations were conducted using guidelines established in MacDonald *et al.* (2000), sediment reference values for inorganic chemicals (Ohio EPA 2003), USEPA Region 5 Ecological Screening Levels - ESLs (2003), and published literature.

11.3 Surface Water Sampling / Assessment

Surface water grab samples were collected from the upper 12 inches of pond water and sampled directly into appropriate containers. The RVAAP pond sampling locations were sampled twice, with the exception of Kelly's Pond, with the initial samples collected during17 – 25 June 2003. The second round of pond water samples were collected during 4 – 6 August 2003. These water sampling periods coincided with the fish collection passes and when the macroinvertebrate samplers were set and retrieved. The initial surface water sampling was concurrent with the sole sediment sampling event. Based on the aforementioned sampling, a data gap was uncovered at Kelly's Pond that required additional information that was collected in July and December of 2004. The third and fourth sampling events at Kelly's Pond will be appended to this report in 2005. Collected surface water samples were preserved using appropriate methods, as outlined in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 1989a), and the Louisville Chemistry Guidelines (LCG) Version 5 (USACE 2002), and shipped to the USACE contract laboratory. Additionally, chemical analyses of the surface water conformed to the RVAAP Facility-Wide Sampling and Analysis Plan for Environmental Investigations at the RVAAP, Ravenna, Ohio (USACE 2001). Quality control (QC) and quality assurance (QA) samples were collected as directed by the LCG with the QA samples submitted to a USACE contract laboratory different from the primary lab. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards (WQS) criteria, reference conditions, or published literature.

11.4 Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from the natural habitats at 11 RVAAP pond and wetland sites. Artificial substrate sampling was comparable to the effort used for stream sampling. The H/Ds were placed, one per pond or wetland, near the shoreline and allowed to colonize for a six week period (June 18 - August 6, 2003). Qualitative collections of macroinvertebrates were made concurrently with the retrieval of artificial substrate samplers at each wetland or pond. Qualitative sampling involved the collection of macroinvertebrates from all available pond and wetland habitat features using triangular ring frame dipnets and manual picking of substrates with field forceps. The goal was to compile a comprehensive species/taxa inventory of macroinvertebrates at the site. There was no attempt to make an absolute quantification of organism densities although observed predominant populations were noted. A minimum of thirty minutes was spent collecting the qualitative sample. The qualitative field collection and laboratory analysis of these samples followed the standardized Ohio EPA procedures (Ohio EPA 1989c). Ohio EPA Macroinvertebrate Field Sheets were filled out for each sampling site, noting physical pond characteristics and predominant organisms.

An additional tool to assess macroinvertebrate communities in ponds and wetlands was the use of funnel traps (Ohio EPA 2002b). Funnel traps were constructed of aluminum window screen cylinders with fiberglass window screen funnels at each end. The funnel traps are similar in design to minnow traps. The cylinder is 18" long and 8" in diameter. The base of the funnel is 8" in diameter and attached to each end of the cylinder so that the funnel directs inward. The funnel has an opening 1.75" in diameter which serves as the means of entry into the trap. Laboratory analysis of the funnel trap macroinvertebrate samples followed the standardized Ohio EPA procedures (Ohio EPA 1989c).

Ten funnel traps were installed in each pond and wetland studied. Prior to installing the first funnel trap, the perimeter of the area where standing water was present in the wetland/pond was measured. The total perimeter length was divided by 10 and the ten funnel traps were installed uniformly around the perimeter of the pond/ wetland at 10% of the total perimeter distance. The funnel traps were installed on the bottom at a location deep enough to submerge the trap. The traps were left in the wetland/pond for twenty-four hours in order to ensure unbiased sampling for animals with diurnal and nocturnal activity patterns. The traps are designed to collect any amphibians, fish, or macroinvertebrates that swim or crawl into the funnel openings.

Upon retrieval, the traps were emptied by everting the funnel and shaking the contents into a white sorting pan. Organisms that could be readily identified in the field were counted and recorded in the field logbook and released. The remaining organisms were transferred to a 1 liter plastic bottle and preserved with 70% ethanol. The contents of each trap were kept in separate bottles for individual analysis in the laboratory. Salamanders were identified using keys in Pfingsten and Downs (1989c). Frogs and tadpoles were identified using keys in Walker (1946). Macroinvertebrates were identified using procedures outlined in Ohio EPA (1989c).

11.5 Fish Community Assessment

Fish were sampled twice at each pond site using pulsed DC boat electrofishing methods. Boat electrofishing in ponds included sampling distances of between 250m and 500m along the perimeter of the pond. Sampling distances in ponds varied due to size constraints of several of the ponds. Fish were processed in the field, and included identifying each individual to species, weighing, counting, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989c).

11.6 Similarity Assessment

Similarity indices were calculated using fish and macroinvertebrate sampling results for the wetlands and ponds sampled in 2003 at the RVAAP. The methodology is discussed in Ohio EPA guidance documents (Ohio EPA 1989b).

The computation formula is: $C = \frac{2 \times W}{a + b}$

where: W is the number of species common to both sites
a is the number of species at one site
b is the number of species at the other site

Similarity indices were also calculated using abundance and biomass data where appropriate. The prominence of each species in the sample was calculated by multiplying the relative number of each species in the sample by the square root of its frequency in the sample, where the sum of all species frequencies in the sample equal 1.0. The sum of the prominence values for all the species within a sample were used as the value for a or b as appropriate in the similarity calculation. Since the value for W may be different for each site when prominence values are used in the paired comparison, the lower of the two W values was used.

12 RESULTS

12.1 Surface Water Quality

Chemical analyses were conducted on surface water samples collected in June and August, 2003 from eleven ponds at RVAAP (Appendix 2, Appendix 3 Tables 11 and 12). Surface water samples were analyzed for target analyte list metals, pesticides, PCBs, explosive compounds, semivolatile organic compounds, and several nutrient parameters. Parameters which were in exceedance of Ohio WQS criteria are reported in Table 12-1.

Table 12-1. Exceedances of Ohio Water Quality Standards aquatic life criteria (OAC 3745-1) for chemical/physical parameters measured in reference and study ponds at the Ravenna Army Ammunition Plant study area during 2003. Metals are reported in ug/l, dissolved oxygen in mg/l, and pH in S.U.

Waterbody	Parameters	Value	
		June	August
Franks Pond	pH	6.3*	6.3*
	Lead	3.9*	2.6*
Trout Pond	pH		6.1*
	Lead	2.4*	2.6*
	Copper		3.2*
Boy Scout Pond	None		
Snow Pond	Dissolved Oxygen	3.28**	
	Lead	5.3*	2.6*
	Silver	3.1*	
Fuze/Booster Pond	pH	6.34*	6.04*
	Lead	5.8*	
	Zinc		83.1*
Upper Cobbs Pond	pH		6.3*
	Lead		2.2*
Lower Cobbs Pond	pH		6.27*
	Lead		2.9*
Kellys Pond	Lead		4.4*
	Copper		7.0*
Administration Pond	None		
Load Line 4 Pond	pH		6.2*
	Lead		2.9*
Load Line 4 Pond	Duplicate	None	
	QA Split	None	
Erie Burning Ground Pond	pH		6.3*
	Dissolved Oxygen	3.29**	
	Copper	7.4*	
	Lead	15.2*	

* Exceedances (or outside of range) of aquatic life Outside Mixing Zone Average Criteria (OMZA).
** Exceedances of aquatic life Outside Mixing Zone Minimum.

12.2 Sediment Chemistry

Sediment samples were collected at ten ponds during June, 2003 and one pond during October, 2003. In 2004 two additional sampling events (July and December) occurred at Kelly's Pond to address data gaps assessed from respective 2003 sample events. The 2004 data from Kellys Pond will be addressed under separate cover appended to this report in 2005. Samples were analyzed for semivolatile organic compounds, pesticides, PCBs, target analyte list metals, explosive compounds, percent solids, cyanide, ammonia, nitrate, and phosphorus. Specific chemical parameters measured above screening levels for metals or detected for organics at the reference ponds are reported in Table 12-2. Specific chemical parameters measured above screening levels for metals or detected for organics at the non-reference ponds are reported in Table 12-3. Contamination levels were determined for parameters using either consensus-based sediment quality guidelines (MacDonald et.al. 2000) or ecological screening levels for RCRA appendix IX constituents (USEPA 2003).

Table 12-2. Reference Ponds - Chemical parameters measured above screening levels (metals) or detected (organics) in sediment samples collected June, 2003, along with sediment reference values (SRVs) for metals.

	REFERENCE PONDS				
Parameter	Franks Pond	Trout Pond	Boy Scout Pond	Snow Road Pond	**SRVs[a]**
Arsenic (mg/kg)	5.8	10.2 [T]	9.4	3.8	25
Bis (2-ethylhexyl) phthalate (ug/kg)	150J	<690	<710	<640	*NA*
di-n-Butyl Phthalate (ug/kg)	450J	490J	<710	<640	*NA*

[a] - Sediment Reference Values (SRVs) are listed in the Ohio EPA Ecological Risk Assessment Guidance (2003).
J - The analyte was positively identified, but the quantization was below the reporting limit (RL).
[T] - Above Threshold Effect Concentration (below which harmful effects are unlikely to occur; MacDonald et.al. 2000).
[P] - Above Probable Effect Concentration (above which harmful effects are likely to occur; MacDonald et.al. 2000).
[E] - Above Ecological Screening Level (USEPA 2003).
NA - Not Available

Table 12-3. Non-Reference Ponds - Chemical parameters measured above screening levels (metals) or detected (organics) in sediment samples collected June, 2003, along with sediment reference values (SRVs) for metals. Erie Burning Ground samples were collected during October 2003. (Shaded areas represent exceedance of the SRV)

	NON-REFERENCE PONDS								
Parameter	Fuze/ Booster Pond	Upper Cobbs Pond	Lower Cobbs Pond	Kellys Pond	Admin-istration Pond	Load Line 4 Pond	Load Line 4 Pond (Duplicate)	Erie Burning Ground Pond	SRVs[b]
Antimony (mg/kg)	3.5	1	1.3	9.5	0.53	0.98	<2	97.2J	1.3
Arsenic (mg/kg)	7.9	6.5	10.2[T]	7.8	11.1[T]	9.5	12.6[T]	8.6	25
Beryllium (mg/kg)	0.55	0.48	0.83	0.96	0.7	0.62	0.75	1.1	0.80
Cadmium (mg/kg)	1.3[T]	0.6	1.2[T]	0.79	0.085	0.62	0.74	4.9[T]	0.79
Chromium (mg/kg)	20.1	18.6	121[P]	36.2	20	15.3	18.9	49.4[T]	29
Copper (mg/kg)	57.9[T]	23	120[T]	87.5[T]	20.2	19.2	23.5	603[P]	32
Lead (mg/kg)	177[P]	17.8	34.2	80.5[T]	32.3	18	24	401[P]	47
Mercury (mg/kg)	<0.067	0.048	0.1	0.083	0.051	0.043	0.062	0.31 J[T]	0.12
Nickel (mg/kg)	20.5	14.4	24.6[T]	30.3[T]	21	20.5	23.9[T]	52.8[P]	33
Selenium (mg/kg)	<0.96	1.1	1.6	2.1	1.3	1.5	1.6	<2.6	1.7
Silver (mg/kg)	0.19	1.1[E]	1.5[E]	0.099 [U]	<0.064	<0.32	<0.44	1.3[E]	0.43
Zinc (mg/kg)	632[P]	153[T]	259[T]	331[T]	77.4	172[T]	196[T]	1,370J[P]	160
Anthracene (ug/kg)	<530	<1000	<1300	245J[T]	<700	<970	<1300	<810	NA
Benzo(a)anthracene (ug/kg)	<530	<1000	<1300	1250[P]	<700	<970	<1,300	130 J[T]	NA
Benzo(a)pyrene (ug/kg)	<530	<1000	<1300	1400[T]	<700	<970	<1,300	140 J	NA
Benzo(b)fluoranthene (ug/kg)	<530	<1000	<1300	2300	<700	<970	<1,300	250 J	NA
Benzo(g,h,i)perylene (ug/kg)	<530	<1000	<1300	1200[E]	<700	<970	<1,300	150 J	NA

	NON-REFERENCE PONDS								
Parameter	Fuze/ Booster Pond	Upper Cobbs Pond	Lower Cobbs Pond	Kellys Pond	Admin-istration Pond	Load Line 4 Pond	Load Line 4 Pond (Duplicate)	Erie Burning Ground Pond	SRVs[b]
Benzo(k)fluoranthene (ug/kg)	<530	<1000	<1300	730J[E]	<700	<970	<1300	<810	NA
Benzyl Butyl Phthalate (ug/kg)	<530	160J	<1300	<1100	<700	<970	<1300	<810	NA
Carbazole (ug/kg)	<530	<1000	<1300	365J	<700	<970	<1300	<810	NA
Chrysene (ug/kg)	<530	<1000	<1300	1550[P]	<700	<970	<1,300	170 J[T]	NA
Dibenz(a,h)anthracene (ug/kg)	<530	<1000	<1300	135J[T]	<700	<970	<1300	<810	NA
Fluoranthene (ug/kg)	63J	<1000	<1300	3050[P]	<700	<970	<1,300	250 J	NA
Indeno(1,2,3-c,d)pyrene (ug/kg)	<530	<1000	<1300	1045[E]	<700	<970	<1,300	130 J	NA
Phenanthrene (ug/kg)	<530	<1000	<1300	1250[P]	<700	<970	<1,300	210 J[T]	NA
Pyrene (ug/kg)	<530	<1000	<1300	2300[P]	<700	<970	<1,300	180 J	NA
bis(2-ethylhexyl) phthalate (ug/kg)	<530	840J[E]	<1300	145J	<700	<970	<1,300	96 J	NA
di-n-Butyl Phthalate (ug/kg)	420J	2700[E]	1035J	2250[E]	<700	1,800[E]	<1,300	290 J	NA
4,4-DDD (ug/kg)	0.9J	<5.0	<6.3	15P[T]	<3.5	<4.9	<6.3	<4.1	NA
4,4-DDE (ug/kg)	1.3J	<5.0	<6.3	<5.4	<3.5	<4.9	<6.3	1.8J	NA
4,4-DDT (ug/kg)	3P	<5.0	<6.3	<5.4	<3.5	<4.9	<6.3	<4.1	NA
Aroclor 1260 (ug/kg)	20J	<100	<130	<110	<70	<97	<130	<81	NA
2,4-Dinitrotoluene (ug/kg)	<100	<100	<100	<100	<100	<100	<100	300 J[E]	NA
2-Methylnapthalene ((ug/kg)	<530	<1000	<1300	<1100	<700	<970	<1300	120 J[E]	NA
2,4,6-Trinitrotoluene[a] (ug/kg)	<100	<100	<100	<100	<100	<100	<100	21,000	NA
2-Amino-2,6-Dinitrotoluene[a] (ug/kg)	<100	<100	<100	<100	<100	<100	<100	8,300	NA

	NON-REFERENCE PONDS								
Parameter	Fuze/ Booster Pond	Upper Cobbs Pond	Lower Cobbs Pond	Kellys Pond	Admin-istration Pond	Load Line 4 Pond	Load Line 4 Pond (Duplicate)	Erie Burning Ground Pond	SRVs[b]
4-Amino-2,6-Dinitrotoluene[a] (ug/kg)	<100	<100	<100	<100	<100	<100	<100	15,000	NA
Endrin. (ug/kg)	<2.6	<5.0	<6.3	<5.4	<3.5	<4.9	<6.3	7.2 J[E]	NA

.

[a] - Screening benchmarks are not available for this compound.

[b] - Sediment Reference Values (SRVs) are listed in the Ohio EPA Ecological Risk Assessment Guidance (2003).

J - The analyte was positively identified, but the quantization was below the reporting limit (RL).

[T] - Above Threshold Effect Concentration (below which harmful effects are unlikely to occur; MacDonald et.al. 2000).

[P] - Above Probable Effect Concentration (above which harmful effects are likely to occur; MacDonald et.al. 2000).

[E] - Above Ecological Screening Level (USEPA 2003).

NA - Not Available

12.3 Physical Habitat for Aquatic Life

Physical habitat was evaluated in each pond electrofished during 2003. Table 12-4 summarizes the metric results for the reference ponds and Table 12-5 summarizes the metric results for the non-reference ponds.

Table 12-4. Reference Ponds - Lake/Lacustuary Qualitative Habitat Evaluation Index (L-QHEI) scores and scoring metrics for evaluating physical habitat quality of eight ponds at the Ravenna Army Ammunition Plant, 2003.

Ponds	Scoring Metrics					L-QHEI[a]	Habitat Narrative Quality[b]
	Substrate	Cover	Shoreline Morphology	Riparian	Aquatic Vegetation		
Franks Pond	6	12	19.5	9.5	11	58	Fair
Trout Pond	4	16	20	9.5	7	56.5	Fair
Boy Scout Pond	11	20	20	9.5	6	66.5	Good

[a] Lake Erie shoreline Qualitative Habitat Evaluation Index (L-QHEI) developed by the Ohio EPA (2002a).
[b] - Draft L-QHEI scoring guidelines include excellent (>80), good (80-60), fair (59-45), poor (44-30) and very poor (<30).

Table 12-5. Non-Reference Ponds - Lake/Lacustuary Qualitative Habitat Evaluation Index (L-QHEI) scores and scoring metrics for evaluating physical habitat quality of eight ponds at the Ravenna Army Ammunition Plant, 2003.

Ponds	Scoring Metrics					L-QHEI[a]	Habitat Narrative Quality[b]
	Substrate	Cover	Shoreline Morphology	Riparian	Aquatic Vegetation		
Fuze/Booster	16	13	14	7.5	4	54.5	Fair
Upper Cobbs	5	11	20	7	0	43	Poor
Lower Cobbs	2	15	17.5	8	0	42.5	Poor
Kellys	0.5	2	11.5	6.5	0	20.5	Very Poor
Load Line 4	3.5	11	20	9	3	46.5	Fair

[a] - Lake Erie shoreline Qualitative Habitat Evaluation Index (L-QHEI) developed by the Ohio EPA (2002a).
[b] - Draft L-QHEI scoring guidelines include excellent (>80), good (80-60), fair (59-45), poor (44-30) and very poor (<30).

12.4 Fish Community Assessment

Fish communities were assessed at eight ponds within the RVAAP property (Appendix 1 , 2 and Appendix 4 Table 2). Based on the results of the fish community assessment, a comparison was made between individual ponds for similarities in fish abundance and fish biomass. These results are reported in Table 12-6 and Table 12-7. A summary of the fish community statistics are reported below in Table 12-8. In addition, the number of largemouth bass was also documented in the eight ponds. The results are reported in Table 12-9.

Table 12-6. Community Similarity Index based of fish abundance at the Ravenna Army Ammunition Plant ponds, 2003. Ponds with identical composition have a value of 1.0. Ponds with no similarity have a value of 0. Shaded areas (≥.65) indicate strong resemblances.

Pond	Boy Scout [R]	Fuze/ Booster	Trout [R]	Lower Cobbs	Upper Cobbs	Franks [R]	Load Line 4	Kellys
Boy Scout [R]	-							
Fuze/Booster	.413	-						
Trout [R]	.378	.870	-					
Lower Cobbs	.597	.766	.670	-				
Upper Cobbs	.469	.928	.826	.822	-			
Franks [R]	.558	.701	.600	.925	.780	-		
Load Line 4	.776	.632	.766	.514	.643	.371	-	
Kellys	0	0	0	0	0	0	0	-

[R] - reference pond.
- = Pond cannot be compared to itself
Blank Cell = comparison already made within table

Table 12-7. Community Similarity Index based on fish biomass at the Ravenna Army Ammunition Plant ponds, 2003. Ponds with identical composition have a value of 1.0. Ponds with no similarity have a value of 0. Shaded areas (≥.65) indicate strong resemblances.

Pond	Boy Scout [R]	Fuze/ Booster	Trout [R]	Lower Cobbs	Upper Cobbs	Franks [R]	Load Line 4	Kellys
Boy Scout [R]	-							
Fuze/Booster	.058	-						
Trout [R]	.048	.758	-					
Lower Cobbs	.778	.766	.838	-				
Upper Cobbs	.051	.785	.889	.877	-			
Franks [R]	.059	.938	.797	.813	.832	-		
Load Line 4	.927	.630	.954	.841	.868	.680	-	
Kellys	0	0	0	0	0	0	0	-

[R] - reference pond.
- = Pond cannot be compared to itself
Blank Cell = comparison already made within table

Table 12-8. Fish community summaries based on pulsed DC electrofishing sampling conducted in eight ponds at Ravenna Army Ammunition Plant from June and August, 2003.

Pond	Mean Number of Species	Total Number Species	Mean Relative Number	Mean Relative Weight	Percent Highly Pollution Tolerant	L-QHEI[a]	Mean Modified Index of Well-being[b]
Reference Ponds							
Franks	6.0	8	174	22.9	14	58.0	6.3
Trout	4.0	5	263	30.2	2	56.5	6.2
Boy Scout	7.0	8	410	31.1	59	66.5	5.5
Other Ponds							
Upper Cobbs	6.5	8	222	33.8	7	43.0	6.6
Lower Cobbs	8.0	11	173	38.0	10	42.5	6.8
Fuze/Booster	3.0	3	254	22.9	0	54.5	6.1
Kellys	2.5	3	1648	17.4	99	20.5	2.8
Load Line 4	4.0	5	324	32.3	3	46.5	5.9

[a] - Lake Erie shoreline Qualitative Habitat Evaluation Index (L-QHEI) developed by the Ohio EPA (2002a).
[b] - The Mean Modified Index of Well-being (MIwb) measures the response of the fish community to habitat and pollution influences. Four factors are measured to arrive at the MIwb. These factors include number of individual fish, biomass, and the Shannon diversity index (H) based on both numbers and weight.

Table 12-9. Largemouth bass results from eight ponds at the Ravenna Army Ammunition Plant sampled using pulsed DC electrofishing during June and August, 2003. Relative numbers and weight are per 1.0 km.

Ponds	Mean Relative Number	Mean Relative Weight (kg)	Mean Fish Weight (grams)
REFERENCE PONDS			
Franks	68	14.42	212
Trout	88	18.27	207
Boy Scout	10	1.17	113
Ponds	**Mean Relative Number**	**Mean Relative Weight (kg)**	**Mean Fish Weight (grams)**
NON-REFERENCE PONDS			
Upper Cobbs	49	19.21	392
Lower Cobbs	45	19.53	434
Fuze/Booster	56	9.34	167
Load Line 4	39	16.05	405
Kellys	0	0	0

12.5 Macroinvertebrate Community Assessment

The biological community in uncontaminated reference sites was compared to the community in potentially contaminated sites to assess potential impacts. Macroinvertebrate communities were assessed at eight ponds and three wetlands within the RVAAP property (Appendix 1 and 2, Appendix 5 Tables 2,3 and 4)

Similarity index values based on the presence of macroinvertebrate taxa in the Hester Dendy artificial substrate/qualitative samples are presented in Table 12-10. Similarity index values based on abundance of macroinvertebrates in funnel trap samples are presented in Table 12-11. Similarity index values based on the presence of macroinvertebrate species are presented in Table 12-12. Average similarity values in relation to all other sites are presented in Table 12-13.

Table 12-10. Community Similarity Index based on macroinvertebrate species from the Hester Dendy artificial substrate and qualitative samples at the Ravenna Army Ammunition Plant ponds, 2003. Ponds with identical composition have a value of 1.0. Ponds with no similarity have a value of 0. Shaded areas (≥.65) indicate strong resemblances.

Pond	Franks [R]	Trout [R]	Snow [R]	Admin.	Upper Cobbs	Lower Cobbs	Boy Scout [R]	Load Line4	Kellys	Fuze/ Booster	Erie Burn.
Franks [R]	---										
Trout [R]	.427	---									
Snow [R]	.475	.457	---								
Administration	.496	.4	.729	---							
Upper Cobbs	.569	.427	.508	.478	---						
Lower Cobbs	.442	.537	.505	.509	.611	---					
Boy Scout [R]	.424	.395	.452	.382	.444	.522	---				
Load Line4	.495	.568	.547	.571	.574	.638	.469	---			
Kellys	.482	.314	.364	.404	.386	.395	.325	.39	---		
Fuze/Booster	.447	.5	.436	.354	.471	.462	.268	.476	.364	---	
Erie Burning	.366	.483	.391	.366	.31	.375	.265	.343	.308	.296	---

[R] - reference pond/wetland
- = Pond cannot be compared to itself
Blank Cell = comparison already made within table

Table 12-11. Community Similarity Index based on macroinvertebrate species from the funnel trap samples at the Ravenna Army Ammunition Plant ponds, 2003. Ponds with identical composition have a value of 1.0. Ponds with no similarity have a value of 0. Shaded areas ($\geq$.65) indicate strong resemblances.

Pond	Franks [R]	Trout [R]	Snow [R]	Admin.	Upper Cobbs	Lower Cobbs	Boy Scout [R]	Load Line 4	Kellys	Fuze/ Booster	Erie Burn.
Franks [R]	---										
Trout [R]	.50	---									
Snow [R]	.50	.393	---								
Administration	.513	.364	.561	---							
Upper Cobbs	.561	.311	.51	.507	---						
Lower Cobbs	.419	.32	.364	.421	.691	---					
Boy Scout [R]	.34	.244	.386	.388	.522	.51	---				
Load Line4	.508	.431	.478	.468	.739	.59	.462	---			
Kellys	.364	.279	.508	.406	.292	.264	.364	.407	---		
Fuze/Booster	.267	.485	.286	.203	.211	.326	.235	.364	.222	---	
Erie Burning	.38	.388	.482	.602	.333	.338	.353	.462	.486	.20	---

[R] - reference pond /wetland
- = Pond cannot be compared to itself
Blank Cell = comparison already made within table

Table 12-12. Community Similarity Index based on abundance of macroinvertebrate species from the funnel trap samples at the Ravenna Army Ammunition Plant ponds, 2003. Ponds with identical composition have a value of 1.0. Ponds with no similarity have a value of 0. Shaded areas (≥.65) indicate strong resemblances.

Pond	Franks[R]	Trout[R]	Snow[R]	Admin	Upper Cobbs	Lower Cobbs	Boy Scout[R]	Load Line 4	Kellys	Fuze/ Booster	Erie Burn.
Franks[R]	---										
Trout[R]	.254	---									
Snow[R]	.886	.188	---								
Administration	.361	.065	.392	---							
Upper Cobbs	.090	.077	.062	.094	---						
Lower Cobbs	.225	.236	.104	.128	.480	---					
Boy Scout[R]	.206	.300	.164	.142	.330	.751	---				
Load Line4	.723	.311	.166	.177	.095	.268	.266	---			
Kellys	.252	.146	.897	.350	.041	.203	.156	.403	---		
Fuze/Booster	.066	.637	.136	.016	.017	.016	.036	.095	.026	---	
Erie Burning	.613	.207	.772	.422	.080	.188	.137	.593	.666	.052	---

[R] - reference pond/wetland
- = Pond cannot be compared to itself
Blank Cell = comparison already made within table

Table 12-13. Average Community Similarity Index for a site compared to all other sites using funnel trap taxa, abundance data and Hester Dendy artificial substrate/ qualitative samples at the Ravenna Army Ammunition Plant ponds, 2003.

Pond	Average Similarity Based on Funnel Trap Abundance Data	Average Similarity Based on Funnel Trap Macroinvertebrate Species	Average Similarity Based on Artificial Substrate/Qualitative Sample Macroinvertebrate Species
Franks	.368	.435	.462
Trout	.242	.372	.451
Snow	.377	.447	.486
Administration	.215	.443	.470
Upper Cobbs	.137	.468	.477
Lower Cobbs	.260	.424	.500
Boy Scout	.249	.380	.395
Load Line4	.310	.491	.507
Kellys	.314	.359	.373
Fuze/Booster	.110	.280	.407
Erie Burning	.373	.402	.350

13 DISCUSSION

13.1 Surface Water Quality

Of the eleven ponds sampled during the 2003 survey, Boy Scout Pond and Administration Pond were the only waterbodies which did not have exceedances of the Ohio Water Quality Standards (WQS)WWH aquatic life maximum or average water quality criteria. For most parameters tested, there were no obvious differences between reference ponds and ponds which were potential repositories of contamination. Exceedances of lead, copper, and pH WQS criteria were documented at reference ponds as well as other ponds evaluated. The most numerous WQS criteria exceedances occurred for lead (nine ponds), followed by pH (seven ponds), and copper (3 ponds). Exceedances of lead and copper criteria were largely driven by the very low hardness conditions recorded at nine of the eleven ponds evaluated. These two parameters have adjustable water quality criteria based on hardness levels - lower hardness lowers the criteria. Lead and copper levels were comparable between most pond locations. However, because of higher hardness values in Boy Scout Pond and Administration Pond, lead and copper did not exceed WQS criteria. The average hardness value of the very low hardness ponds was 46 mg/l, compared to the average hardness of 121 mg/l for Boy Scout and Administration ponds. Although pH measurements at seven of the ponds were below the minimum WQS criterion of 6.5 S.U., none of the values measured were below 6.0 S.U. Dissolved oxygen exceedances of the minimum WQS criterion were noted in Snow Pond and Erie Burning Ground Pond. These two ponds were shallow, with extensive plant growth. Large swings in diurnal dissolved oxygen would be expected in these types of conditions. Aside from the above listed parameters, silver exceeded the WWH average water quality criterion in Snow Pond and zinc exceeded the WWH average criterion in Fuze/Booster Pond.

Concentrations of PCBs, pesticides, and total cyanide were reported as non-detect in all eleven ponds. Semivolatile compounds, excluding various phthalates, were also reported as non-detect in all eleven ponds. The phthalate compounds reported at measurable levels were below applicable Ohio WQS aquatic life criteria. Phthalates are typical lab contaminants. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] Nine of the eleven ponds did not have detectable levels of ammonia-N. Of the two ponds with detectable ammonia-N, Administration Pond reported one value of 0.18 mg/l. Ammonia-N values in the Erie Burning Ground Pond were 0.30 mg/l and 0.42 mg/l. All of the reported ammonia-N concentrations were below the applicable WQS aquatic life criterion. A review of the nitrate levels in the RVAAP ponds with other Ohio lakes/ponds designated as mesotrophic, indicated comparable levels. Comparison of nitrate levels of RVAAP reference ponds (excluding Boy Scout Pond) to other RVAAP ponds indicated about a 50% increase; however, overall nitrate levels were still low. Macrophytes (generally desirable) were abundant in most ponds, while filamentous algae and single cell algae were not abundant (also a good thing). Total phosphorus levels measured in all ponds suggest eutrophic to hyper-eutrophic nutrient conditions (Ohio EPA 1996). Of the ponds evaluated, Erie Burning Ground Pond had the highest average total phosphorus concentration (0.58 mg/l) versus an average T-P of 0.15 mg/l for all other ponds. Eutrophic or hypereutrophic conditions do not imply impaired water quality, but a state of production. Phosphorus is typically the limiting nutrient in pond/lake systems. Although an aquatic life water quality criterion for iron does not exist in the Ohio Water Quality Standards, elevated iron levels were noted in Franks Pond (2420 ug/l and 4710 ug/l), Snow Pond (2870 ug/l and 3530 ug/l), and Erie Burning Ground Pond (3760 ug/l and 8520 ug/l).

Fourteen explosive compounds were tested in the eleven ponds evaluated. Explosive compounds were reported as non detected in the reference ponds, or in Fuze/Booster Pond, Load Line 4 Pond, or Erie Burning Ground Pond. Other ponds where explosive compounds were detected are reported in Table 13-1.

Table 13-1. Areas where explosives were detected at the Ravenna Army Ammunition Plant during two rounds of surface water sampling, 2003. ND = not detected.

Waterbody	Explosive Compound	Concentrations (ug/l)	
Upper Cobbs Pond	4-amino-2,6-dinitrotoluene	0.24	ND<0.2 ug/L
Lower Cobbs Pond	4-amino-2,6-dinitrotoluene	0.29	ND<0.2 ug/L
Administration Pond	HMX	0.48	1.8
	RDX	0.9	ND<0.5 ug/L
Kelly's Pond	2,4,6-trinitrotoluene	1.1	ND<0.2 ug/L
	4-amino-2,6-dinitrotoluene	5.7	0.53
	2-amino-4,6-dinitrotoluene	1.8	0.32
	HMX	1.6	0.18
	RDX	12.0	5.6

Based on the two water sampling events at each pond during this study, Kellys Pond exhibited the highest concentration and most numerous detections of explosive compounds. However, none of the measured explosive parameters exceeded Ohio WQS aquatic life criteria.

13.2 Sediment Chemistry

Sediment data were evaluated using guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald *et.al*. 2000), and USEPA Region 5, RCRA Appendix IX compounds - Ecological Screening Levels (ESLs) (USEPA 2003). The consensus-based sediment guidelines define two levels of ecotoxic effects. A *Threshold Effect Concentration* (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A *Probable Effect Concentration* (PEC) indicates a level above which harmful effects are likely to be observed. Ecological screening levels (ESLs) are initial screening levels used by USEPA to evaluate RCRA site constituents. In addition, sediment reference values (SRVs) for metals (Ohio EPA 2003) are presented in Table 12-3 for comparison to the pond results.

Sediment results from the four identified reference ponds sampled during this study are presented in Table 12-2, Appendix 1 and Appendix 2. Sediment collected from all four reference ponds reflected non-contaminated conditions. Arsenic was measured in Trout Pond sediment above the TEC; however, this value, along with arsenic measurements at all the other reference ponds were below the Ohio sediment reference values for rivers and streams (Ohio EPA 2003). In fact, all metals tested in the reference ponds were below Ohio sediment reference values (Ohio EPA 2003); these levels were established from chemical results collected at biological reference sites. Only two organic chemical parameters were above detectable levels (both phthalates), and these measurements were below benchmark screening levels. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] All tested explosive compounds, pesticides, PCBs, and nearly all semivolatile organic compounds were not detected in sediment samples collected from the reference ponds. Ammonia and total phosphorus sediment levels were measured in all reference ponds below screening guidelines (Persaud et. al. 1993).

Three ponds which are potential repositories of contamination (Upper Cobbs, Load Line 4, Administration) reflected non-contaminated sediment conditions, and chemical concentrations were comparable to the reference ponds. Metals measured from these ponds were near or below Ohio sediment reference values. Explosive compounds, pesticides, and PCBs were all reported as non-detect in the sediment. Of the semivolatile organic compounds tested, only three phthalate chemicals were measured above lab detection limits. [Page 5-2 of RAGS Part A 1989 confirms phthalate esters as common lab contaminants.] As noted earlier, phthalates are potential lab contaminants. Ammonia and total phosphorus sediment levels in Upper Cobbs, Load Line 4, and Administration ponds were measured below screening guidelines (Persaud et. al. 1993).

Sediment collected from Lower Cobbs Pond reflected slightly contaminated conditions. Three metal parameters (cadmium, copper, zinc) were reported at levels above the TEC (and above the SRVs). In addition, chromium (121 mg/kg) was measured above the PEC, a level above which harmful effects potentially could occur to aquatic biota. Aside from several elevated metals and one phthalate compound, all other metals, explosive compounds, PCBs, pesticides, and semivolatile compounds were low or reported as non-detect. Ammonia and total phosphorus sediment levels were measured below screening guidelines.

Fuze/Booster Pond sediment sampling results indicated moderate contamination. Two metal parameters (cadmium, copper) were reported at levels above the TEC (and above the SRVs). In addition, lead (177 mg/kg) and zinc (632 mg/kg) were measured above the PEC. DDT metabolites (4,4-DDD; 4,4-DDE; and 4,4-DDT), di-n-butyl phthalate, fluoranthene, and aroclor 1260 were the only organic parameters detected in Fuze/Booster pond; however, levels were below screening levels. Explosive compounds were not detected in the sediment, and ammonia-N and total phosphorus levels were below screening guidelines.

Kellys Pond sediment sampling results indicated moderate contamination. Three metal parameters (copper, lead, and zinc) were reported at levels above the TEC (and above the SRVs). Eleven PAH compounds were measured above ecotox screening levels, with five of the PAH compounds exceeding the PEC level. The concentration of all detected PAHs combined equaled 16,820 ug/kg, a value between the TEC and PEC screening levels. Explosive compounds were not detected in the sediment, and ammonia-N and total phosphorus levels were below screening guidelines.

Erie Burning Ground Pond sediment collections were conducted during October, 2003. Six multi-incremental samples were collected - three in the southern section and three in the northern section. The highest values for each parameter tested were used for screening comparisons. Based on sediment sampling results, moderate contamination was evident in Erie Burning Ground Pond. Three metal parameters (chromium, mercury, and silver) were reported at levels above the TEC/ESL (and above the SRVs). Antimony was highly elevated in the Erie Burning Ground Pond sediment, with a maximum concentration of 97.2 mg/kg (compared to the SRV of 1.3 mg/kg). Four metal parameters (copper: 603 mg/kg, lead: 401 mg/kg, nickel: 52.8 mg/kg, and zinc: 1370 mg/kg) exceeded PEC levels, suggesting probable effects on aquatic biota. Four PAH compounds were measured above TEC or ESL levels.

Of particular note was the measurement of explosive compounds in the sediment. Of the 11 ponds sampled at the RVAAP, only Erie Burning Ground Pond had any detectable explosive compounds. The compounds detected and the corresponding concentrations are reported in Table 13-2.

Table 13-2. Area where explosives were detected at the Ravenna Army Ammunition Plant during sediment sampling in 2003

Waterbody	Explosive Compound*	Maximum Concentrations (ug/kg)
Erie Burning Ground Pond	2,4,6-trinitrotoluene	21,000
	2-amino-4,6-dinitrotoluene	8,300
	4-amino-2,6-dinitrotoluene	8,300

* Sediment screening values are not available for these three explosive compounds.

Total cyanide was tested in the sediment from all eleven ponds, and all results were reported as non-detect.

13.3 Physical Habitat for Aquatic Life

A Lake/Lacustuary (Lentic) Qualitative Habitat Evaluation Index (QHEI) field sheet was filled out for each pond, using guidance in the *Methods of Assessing Habitat in Lake Erie Shoreline Waters Using the Qualitative Habitat Evaluation Index (QHEI) Approach* (Ohio EPA 2002a). Each habitat field sheet is listed in Appendix 6

Habitat quality for the eight ponds evaluated generally separated out by ponds identified as reference ponds and ponds with potential repositories of contamination. The three reference ponds (Franks, Trout, and Boy Scout ponds) revealed fair to good habitat. L-QHEI scores for the reference ponds ranged between 56.5 and 66.5, with an average score of 60.3. Reference ponds generally scored better in the aquatic vegetation metric (quality and amount of vegetation) and cover metric than the other ponds. The highest quality pond habitat occurred in Boy Scout Pond, which was influenced by a variety of bottom substrates, good cover, and numerous types of aquatic vegetation. Boy Scout Pond was also significantly different from all other ponds because it has the largest watershed, and sandstone cliffs are common along one side of the pond.

Four ponds with potential repositories of contamination (Fuze/Booster, Upper Cobbs, Lower Cobbs, and

Load Line 4 ponds) revealed fair to poor habitat quality. L-QHEI scores for these four ponds ranged from 42.5 to 54.5, with an average score of 46.6. All four ponds had abundant aquatic vegetation; however, scoring for this metric was low due to excessive amounts of undesirable species or low amounts of preferred species. Load Line 4, Upper Cobbs, and Lower Cobbs ponds had comparable bottom substrates predominated by muck. Fuze/Booster Pond - an old quarry area - was predominated by cobble and sand substrates.

Physical habitat conditions in Kellys Pond were of very poor quality. The L-QHEI score for Kellys Pond was 20.5, the lowest score of all the ponds evaluated. Metric scoring was very low for substrate quality, in-pond cover, and aquatic vegetation. Sampling during 2003 documented a complete absence of submerged aquatic vegetation. A contributing factor to the lack of aquatic vegetation and poor substrate quality was the presence of grass carp in Kellys Pond.

13.4 Fish Community Assessment

It was not possible to determine impairment of the fish community contained in the eight ponds assessed based on IBI scoring metrics as used in streams since the metrics are not applicable to pond biota and conditions. Community Similarity Index values were calculated based on fish relative abundance and relative biomass (Tables 12-10, 12-11, 12-12, and 12-13). Relative abundance and biomass for each pond were calculated based on a sampling distance of 1.0 km. Ponds sampled during this study had sampling distances of between 250 m and 500 m. Community similarity was used to evaluate the degree of faunal similarity between each pond. Ponds by pond comparisons were made resulting in the construction of the two similarity matrices (Table 12-6 and 12-7). Using this method, ponds with identical composition would have a value of 1.0 and those with no similarity at all would have a value of 0. Comparisons with values of 0.65 or greater were regarded as having strong resemblances, a criterion used previously by Hanson (1955), Beckett (1978), and Ohio EPA (1981).

Fish abundance similarity index values revealed a strong resemblance between the reference ponds Franks Pond and Trout Pond, and Lower Cobbs Pond, Upper Cobbs Pond, and Fuze/Booster Pond. Load Line 4 Pond was similar to the reference Boy Scout Pond and Trout Pond. Stronger similarities were observed based on fish biomass between all of the ponds except Boy Scout Pond and Kellys Pond. As noted in Table 13-1, the Kellys Pond fish community was not similar to any other RVAAP pond, with similarity scores of zero for both abundance and biomass. Kellys Pond was represented by fathead minnow, channel catfish, and grass carp, and these species were not collected in any other of the RVAAP ponds. Boy Scout Pond was generally dissimilar to all other ponds sampled (except Load Line 4 Pond and Lower Cobbs Pond). Boy Scout Pond is a mix between a ponded waterbody and a flowing stream. Habitat conditions were characterized by a narrow impounded channel, a deep channel along sandstone cliffs on one side, a large amount of submerged woody debris, and the largest watershed of any of the RVAAP ponds sampled. These conditions contributed to the uniqueness of Boy Scout Pond, compared with the other ponds sampled, and appeared to be a large factor in the composition of the fish community. While other ponds were characteristically pond-like (shallow, muck bottoms, with little submerged woody debris), Boy Scout Pond was characteristic of an impounded stream channel. The high abundance and biomass of white suckers collected in Boy Scout Pond was driving the lower similarity scores with other ponds. Overall results of the similarity index revealed that Kellys Pond was distinctly different from all other RVAAP ponds. Strong similarities were noted between two of the reference ponds, and four of the ponds considered potential repositories of contamination (Upper Cobbs, Lower Cobbs, Fuze/Booster, Load Line 4).

A number of components of the fish community are presented in Table 12-8. The Modified Index of Well-being (MIwb) was calculated for each pond sample. The MIwb is an index which measures the response of the fish community to habitat and pollution influences. The MIwb incorporates four measures of fish communities: numbers of individuals, biomass, and the Shannon diversity index (H) based on numbers and weight. In addition, the index was modified from its original form by excluding any of 13 highly tolerant species, exotics, and hybrids from the numbers and biomass components. However, the tolerant and exotic species are included in the two Shannon index calculations (Ohio EPA 1987b). An evaluation of the MIwb for pond sites revealed little difference between reference sites and 4of 5 potential repositories of contamination ponds. The one pond substantially different from all reference ponds was Kellys Pond, which had an average MIwb score of 2.8. Other factors separating Kellys Pond from all other ponds included a high percentage of highly pollution tolerant fish (99 percent), and the lack of largemouth bass (Table 12-9). Fish sampling results for eight ponds sampled at RVAAP indicated little difference between reference ponds and other ponds with potential contamination issues, excluding Kellys Pond. Kellys Pond revealed a biologically dissimilar fish community dominated by pollution tolerant fathead minnows.

13.5 Macroinvertebrate Community Assessment

It was not possible to determine impairment of the macroinvertebrate community based on ICI scoring metrics as used in streams since the metrics are not applicable to pond biota and conditions. The biological community in uncontaminated reference sites was compared to the community in potentially contaminated sites to assess potential impacts. Comparability metrics are not standardized but valid and as such metrics criteria are ratios with favorability in the direction of > 0.05. End point comparisons of biological metrics among reference ponds at times do not exceed favorability of being > 0.05. Therefore, it is noteworthy that not all four reference ponds have to be indicative of favorability when comparison is made to a study pond on specific measurement endpoints. Macroinvertebrate communities were assessed at eight ponds and three wetlands within the RVAAP property (Appendix 1, Appendix 2 and Appendix 4 Table 4). Franks pond, Trout pond, and Boy Scout pond were considered reference ponds. The reference pond communities were compared to the communities in the potentially contaminated sites, Upper and Lower Cobbs, Fuze/Booster, Load Line 4, and Kellys pond. Snow pond was sampled as a reference wetland while Administration Pond and Erie Burning Ground Pond were potentially contaminated wetlands. The wetland sites lacked deep water and did not support large populations of insectivorous fish. Fish populations can have a large impact on the abundance and species composition of macroinvertebrate communities in ponds and wetlands (Ohio EPA unpublished data). Comparisons between ponds and wetlands may yield dissimilar results for reasons independent of potential contamination issues.

Community Similarity Index values were calculated for the macroinvertebrate species in the funnel trap samples and the Hester Dendy artificial substrate/qualitative samples. In addition, Similarity Index values were calculated for the funnel trap samples based on the abundance of the macroinvertebrate taxa. The funnel traps were effective in sampling the macroinvertebrates that were actively swimming and crawling about the pond. The artificial substrate samplers sampled the sedentary macroinvertebrates that associated with bottom substrates. Together the two sampling methods were effective in sampling the entire macroinvertebrate community.

Similarity index values based on abundance of macroinvertebrates in funnel trap samples were highly variable (Table 12-11). Values ranged from a low of 0.016, meaning almost no similarity to a high of 0.897, which is highly similar. Franks Pond showed similarity to Snow Pond, a reference wetland, and to the Load Line 4 Pond. Franks Pond was dissimilar to the potentially contaminated sites, Upper Cobbs, Lower Cobbs, Kellys, and Fuze/Booster ponds, but it was also dissimilar to the other reference ponds. The variability of community similarity within the reference ponds is nearly as great as compared to the potentially contaminated sites. The Snow Pond reference wetland was highly similar to the Erie Burning Ground wetland and Kellys Pond (which lacked insectivorous fish). The other paired sites which were highly similar included: Lower Cobb and Boy Scout ponds, and Kellys Pond and the Erie Burning Ground Pond. The variability of the funnel trap abundance data is caused by the high degree of dominance within a sample by relatively few macroinvertebrate taxa. Two sites may have only a few very abundant taxa in common, but due to their relative importance in the similarity index calculation, the sites are highly similar. It is difficult to make generalizations about the similarity of reference to potentially contaminated sites due to the dominance of a few macroinvertebrate taxa in the funnel trap samples.

Similarity index values based on the presence of macroinvertebrate species at a site were not as variable as the abundance data (Table 12-13). The only sites which were highly similar to each other were Upper Cobbs to Lower Cobbs ponds, and Upper Cobbs Pond to Load Line 4 Pond. Franks Pond similarity to the other reference pond, Trout Pond, was somewhat higher than its similarity to the potentially contaminated ponds, Lower Cobbs, Kellys, and Fuze/Booster. Kellys Pond was substantially different from all other ponds in the absence of aquatic plants due to the presence of grass carp. With the significant habitat differences it was not possible to attribute macroinvertebrate faunal differences from the reference condition to potential contamination. The macroinvertebrate community of the Fuze/Booster Pond was significantly different from Franks Pond but habitat differences in bottom substrates and an absence of shoreline plant cover may be responsible. The absence of plant cover makes the macroinvertebrate community susceptible to fish predation. The Boy Scout Pond had low similarity to the other reference sites as well as the potentially contaminated sites which can be attributed to its substantially different habitat and riverine hydrology. The similarity of the reference wetland, Snow Pond, to Administration Pond and the Erie Burning Ground Pond was not outside the range of similarity between reference ponds.

Similarity index values based on the presence of macroinvertebrate taxa in the artificial substrate/qualitative samples was the least variable of the data sets. The artificial substrate samplers tend to be colonized by relatively sedentary macroinvertebrates that are not actively swimming in the water column making them less susceptible to fish predation. This may reduce impacts from fish populations and site habitat differences as they relate to fish predation on the macroinvertebrate community. The only site comparison which was highly similar was Snow Pond to Administration Pond. Snow Pond was substantially different from Erie Burning Ground which may be the result of the different plant communities and the soft anoxic sediments at the Erie Burning Ground Pond in addition to potential sediment contamination.

The average similarity of a site in relation to all other sites may be a useful tool to examine site differences (Table 12-10 and 12-13). Using the average similarity of the Hester Dendy/qualitative sample data, Kellys Pond, Fuze/Booster Pond and Boy Scout Pond were the most dissimilar to all other sites. Habitat differences related to these sites has been discussed earlier. Macroinvertebrate community differences between reference ponds and potentially contaminated ponds are most likely related to habitat. In the wetlands, habitat differences between Snow Pond and Erie Burning Ground Pond may be responsible for some differences in the macroinvertebrate communities, but sediment sampling chemical results do not eliminate contamination as a potential contributor.

14 CONCLUSION

Table 14-1 - Correlation between Chemistry and Biological Parameters

	Surface Water Chemistry Exceedances	**Sediment Chemistry Exceedances**	**Physical Habitat Quality**	**Fish Community**	**Fish Biomass**	**Macro-Invertebrate Community Index**	**Macro-Invertebrate Species Comparability**	**Macro-Invertebrate Abundance**	**Funnel Trap Taxa**
Reference Ponds									
Franks Pond	pH, Pb	None	Fair						
Trout Pond	pH, Pb, Cu	None	Fair						
Boy Scout Pond	None	None	Good						
Snow Pond	O_2, Pb, Ag	None	-	-	-	-	-	+	+
Non-Reference Ponds									
Fuze/Booster Pond	pH, Pb, Zn	Sb, Cu, Cd, Pb, Zn	Fair	++	++	-	-	-	-
Upper Cobb Pond	pH, Pb	Ag, Zn	Poor	++	+	-	-	-	+
Lower Cobb Pond	pH, Pb	Be, Cu, Pb, Zn	Poor	++	++	-	-	+	+
Kellys Pond	Pb, Cu	Sb, Be, Cr, Cu, Pb, Zn	Very Poor	-	-	-	-	-	+
Administration Pond	None	None	-	-	-	-	-	-	+
Load Line 4 Pond	pH, Pb	Zn	Fair	+	++	-	-	+	+
Erie Burning Ground Pond	pH, O_2, Pb, Cu	Cd, Cr, Cu, Pb, Hg, Ni, Ag, Zn	-	-	-	-	-	-	+

\- Comparability absent
\+ - Comparability to 1 reference pond.
++ - Comparability to 2 reference ponds.
\- = Pond cannot be compared to itself
Blank Cell = comparison already made within table

Boy Scout Pond, Snow Pond, Franks Pond, and Trout Pond were used as reference ponds for evaluating biological conditions and surface water quality at seven potentially contaminated ponds at RVAAP. In addition, surface water and sediment quality were evaluated using criteria or benchmark levels. Based on these lines of evidence, it is concluded that Administration Pond, Upper Cobbs Pond, and Load Line Four Pond are not currently affected by activities that occurred at RVAAP when it is was in operation. Biological conditions at these three ponds were comparable to reference ponds, sediment chemical levels were below benchmark levels, and surface water quality was consistent with reference conditions and/or below water quality criteria.

Biological communities in Lower Cobbs Pond and Fuze/Booster Pond were not affected by chemical exposures from past activities at RVAAP. Fish communities from these two ponds were strongly similar to reference ponds. Poor quality vegetative cover in both ponds influenced macroinvertebrate results. Surface water quality was consistent with reference conditions and/or below water quality criteria. Although sediment quality (lead, zinc, or chromium) from both ponds suggest the potential for a negative impact, aquatic biological results confirmed conditions comparable to reference ponds.

Two waterbodies, Erie Burning Ground Pond and Kellys Pond, had biological communities substantially different from reference conditions. For both ponds, direct correlation between biological conditions and chemical exposures from past activities at RVAAP is inconclusive. For example, macroinvertebrate communities (fish were not sampled) in Erie Burning Ground Pond were substantially different from the reference wetland Snow Pond, which may be the result of the different plant communities and the soft anoxic sediments at Erie Burning Ground Pond, as well as potential sediment contamination from explosive compounds and metals. Additionally, as a potential cause of macroinvertebrate community impairment at Kellys Pond, it is impossible to discern very poor habitat impacts from potential chemical contamination impacts. The fish community of Kellys Pond was dissimilar from all reference ponds (as well as all other ponds sampled). The fish community was dominated by pollution tolerant fathead minnows. A contributing factor to the lack of aquatic vegetation and poor substrate quality was the presence of grass carp in Kellys Pond.

14.1 Recommendation

In order to validate the poor scoring of Kellys Pond additional sampling was completed in July and December of 2004. The additional work focused on the presence of grass carp, additional sediment and water samples in Kellys Pond, as well as upstream and downstream from the pond at stream sites. This report will be appended to include information collected at Kelly's pond during July and December 2004.

15 REFERENCES

Beckett, D.C. 1978. Ordination of macroinvertebrate communities in a multi-stressed river system, pp. 748-770. In Energy and Environmental Stress in Aquatic Systems, J.H. Thorpe and J. W. Gibbons (eds.). DOE Symp. Ser. (CONF-771114).

DeShon, J.D. 1995. Development and application of Ohio EPA's invertebrate community index (ICI), in W.S. Davis and T. Simon (eds.). Biological assessment and criteria: tools for risk-based planning and decision making. CRC Press/Lewis Publishers, Ann Arbor.

Eisler, Ronald. 1991. Cyanide Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review- U.S. Fish Wildl. Serv., Biol. Rep. 85(1.23). 55 pp.

Fausch, D.O., Karr, J.R. and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Trans. Amer. Fish. Soc. 113:39-55.

Hanson, H.C. 1955. Characteristics of the Stripa comato-Bouteloua gracilis- Toutelona curtipendula association of northern Colorado. Ecology, 36: 221-280.

Karr, J. R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications 1(1): 66-84.

Karr, J.R., K.D. Fausch, P.L. Angermier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Ill. Nat. Hist. Surv. Spec. Publ. 5. 28 pp.

MacDonald, D., C. Ingersoll, and T. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxical.: Vol.39, 20-31.

Miner R. and D. Borton. 1991. Considerations in the development and implementation of biocriteria, Water Quality Standards for the 21st Century, U.S. EPA, Offc. Science and Technology, Washington, D.C., 115.

Ohio Environmental Protection Agency. 2003. Ecological risk assessment guidance manual. Feb. 2003. Division of Emergency and Remedial Response, Columbus, Ohio.

___ 2002a. Methods of assessing habitat in Lake Erie shoreline waters using the Qualitative Habitat Evaluation Index (QHEI) approach. Twinsburg, Ohio.

___ 2002b. Amphibian Index of Biotic Integrity (AmphIBI) for wetlands. Wetland Ecology Group. Div. of Surface Water. Columbus, Ohio.

___ 2001. Sediment sampling guide and methodologies, 2nd edition. Nov. 2001. Division of Surface Water, Columbus, Ohio.

___ 1996. Ohio Water Resource Inventory. Vol. 3: Ohio's public lakes, ponds, and reservoirs. Tech. Bulletin MAS/1997-10-2. Div. of Surface Water. Columbus, Ohio.

___ 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

___ 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

___ 1989a. Ohio EPA manual of surveillance methods and quality assurance practices, updated edition. Division of Environmental Services, Columbus, Ohio.

___ 1989b. Addendum to biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Planning and Assessment, Surface Water Section, Columbus, Ohio.

___ 1989c. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Planning and Assessment, Columbus, Ohio.

___ 1981. Fish community status in the Scioto River, 1979. Tech. Report OEPA 81/3. Division of Surveillance and Standards, Columbus, Ohio.

OHARNG 1997 (see reference on page 16)

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Ann. Assoc. Amer. Geogr. 77(1): 118-125.

Persaud D., J. Jaagumagi, and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Toronto. 24 pp.

Pfingsten, R.A. and F.L. Downs. 1989. Salamanders of Ohio. Bulletin of the Ohio Biological Survey. Vol. 7, No. 2. Columbus, Ohio.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus, Ohio.

Suter, G.W., II. 1993. A critique of ecosystem health concepts and indexes. Environmental Toxicology and Chemistry, 12: 1533-1539.

USACE 2002 (see reference on page 31)

USACE 2001 (see reference on page 31)

USACE 2001 (see reference on page 16)

USACE 1996 (see reference on page 15)

United States Environmental Protection Agency. 1996. Ecotox thresholds. Office of Solid Waste and Emergency Response. EPA 540/F-95/038. January 1996.

United States Environmental Protection Agency. 2003. Region 5, final technical approach for developing ecological screening levels for RCRA Appendix IX constituents and other significant contaminants of ecological concern. August, 2003.

Walker, C.F. 1946. The amphibians of Ohio, part 1. The frogs and toads. Ohio State Museum Science Bulletin Vol. 1, No. 3. Columbus, Ohio.

Whittier, T.R., D.P. Larsen, R.M. Hughes, C.M. Rohm, A.L. Gallant, and J.M. Omernik. 1987. The Ohio stream regionalization project: a compendium of results. EPA/600/3-87/025. 66 pp.

Wisconsin Department of Natural Resources. 2003. Consensus-based sediment quality guidelines, recommendations for use & application, interim guidance developed by the contaminated sediment standing team, December 2003. WT-732

Yoder, C.O. 1989. The development and use of biological criteria for Ohio surface waters. U.S. EPA, Criteria and Standards Div., Water Quality Stds. 21st Century, 1989: 139-146.

Yoder, C. O. 1991. Answering some concerns about biological criteria based on experiences in Ohio, in G. H. Flock (ed.) Water quality standards for the 21st century. Proceedings of a National Conference, U. S. EPA, Office of Water, Washington, D.C.

Yoder, C.O. 1995. Policy issues and management applications of biological criteria, in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor.

Yoder, C.O. and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multi-metric data, in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor.

OHARNG. 1999. Fish surveys of the streams, ponds, and beaver swamps of the Ravenna Training and Logistics Site (Ohio National Guard). Produced by the ODNR, Div. of Natural Areas and Preserves. 38 pp.

Species and Plant Communities Inventory (1993), Ravenna Army Ammunition Plant, Ohio Department of Natural Resources Division of Natural Areas and Preserves in cooperation with The Nature Conservancy, Ohio Chapter.