NATURAL RESOURCES

YAKIMA RIVER FLOODPLAIN MINING IMPACT STUDY

by the
Yakima River
Floodplain Mining
Impact Study Team

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES
Open File Report 2004-8
June 2004

location map

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

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Initialisms

BOR, U.S. Bureau of Reclamation
BMP, best management practice
CCWF, Centennial Clean Water Fund
CMZ, channel migration zone
CWA, Clean Water Act
DOE, Washington State Department of Ecology
DOT, Washington State Department of Transportation
EIS, environmental impact study
ESA, Endangered Species Act
GMA, Growth Management Act
HPA, Hydraulic Project Approval
MRTF, Mineral Resources Task Force
SEPA, State Environmental Policy Act
SMA, Shoreline Management Act
SMP, Shoreline Master Program
RCW, Revised Code of Washington
WAC, Washington Administrative Code
WADNR, Washington State Department of Natural Resources
WDFW, Washington State Department of Fish and Wildlife
YRBWEP, Yakima River Basin Water Enhancement Project

Conversion factors

Acre x 0.40468 = hectare
Cubic foot per second x 1699.3 = liters per minute
Cubic yard x 0.7645 = cubic meter
Degrees Centigrade (Celsius) x 1.8 + 32 = degrees Fahrenheit
Inch x 25.4 = millimeter
Foot x 0.3048 = meter
Mile x 1.6093 = kilometer

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APPENDICES (Included on CD)

A. Quality Assurance Project Plan, Floodplain Mining Impact Study, Centennial Clean Water Fund Grant No. G0100193, 2002.

B. Mineral Resources Task Force Progress Report to the Planning Commission, Yakima County Planning Department, 2001.

C. The Effect of Anthropogenic Alterations to Lateral Connectivity on Seven Alluvial Floodplains within the Yakima River Basin, Washington, Central Washington University, 2002.

D. The Reaches Project: Ecological and Geomorphic Studies Supporting Normative Flows in the Yakima River Basin, Washington, University of Montana, 2002.

E. Yakima River Floodplain Mining Impact Study: Pond Bathymetry and Sediment Particle Data, interim draft report, Washington Department of Natural Resources, 2003.

F. Washington State Department of Natural Resources: GPS Waypoints.

G. Washington State Department of Natural Resources: Sediment Sample Sieve Lab Analysis.

H. Yakima River Floodplain Mining Impact Study: Thermal Investigation, Yakima County Planning Department and Washington State Department of Ecology, interim draft report, 2003.

I. Yakima County/ Washington State Department of Ecology: Temperature Data.

J. Yakima River Floodplain Mining Impact Study: Fish Assemblage, Washington State Department of Fish and Wildlife and Yakama Nation, interim draft report, 2003.

K. Washington State Department of Fish and Wildlife/Yakama Nation: Fish Assemblage Data.

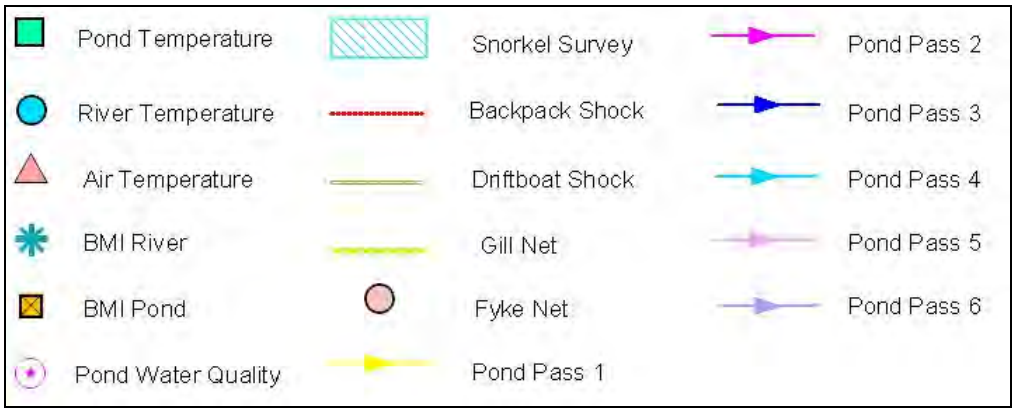
L. Yakima River Floodplain Mining Impact Study: Benthic Macroinvertebrate and Water Quality, Washington State Department of Ecology, Water Quality Program, interim draft Report, 2003.

M. Washington State Department of Ecology: Site Sample Information.

N. Final Biological Evaluation and Essential Fish Habitat Assessment for Hanson Ponds Restoration Project, for Yakama Klickitat Fisheries Project.

O. General proposal for a comprehensive sediment transport and geomorphic study of the Yakima Basin—Yakima and Kittitas Counties, Washington. U.S. Bureau of Reclamation draft proposal.

Master Explanation of Site Sample Maps



The symbols above are used in Chapters 5 through 14 on the aerial photos that show locations of sampling sites. Sampling methods and protocols are described in Chapter 4. BMI indicates benthic invertebrate and water quality sample sites. “Shock”, “backpack”, and “drift boat” indicate equipment to deliver small electroshocks to resident fish. “Pond Pass” and associated numbers (1–6) indicate the electroboat shock sampling of the shoreline in 8-minute intervals completed along the total shoreline of each pond sample site.

EXECUTIVE SUMMARY

YAKIMA RIVER FLOODPLAIN MINING IMPACT STUDY

The Yakima River system is the second largest subbasin in the Columbia River Basin (Figure ES1). The headwaters are in the Cascade Range (elevation ~8,000 feet), and the river joins the Columbia River at Richland (elevation ~300 feet). Precipitation ranges from about 140 inches in the headwaters to less than 10 inches at the mouth.

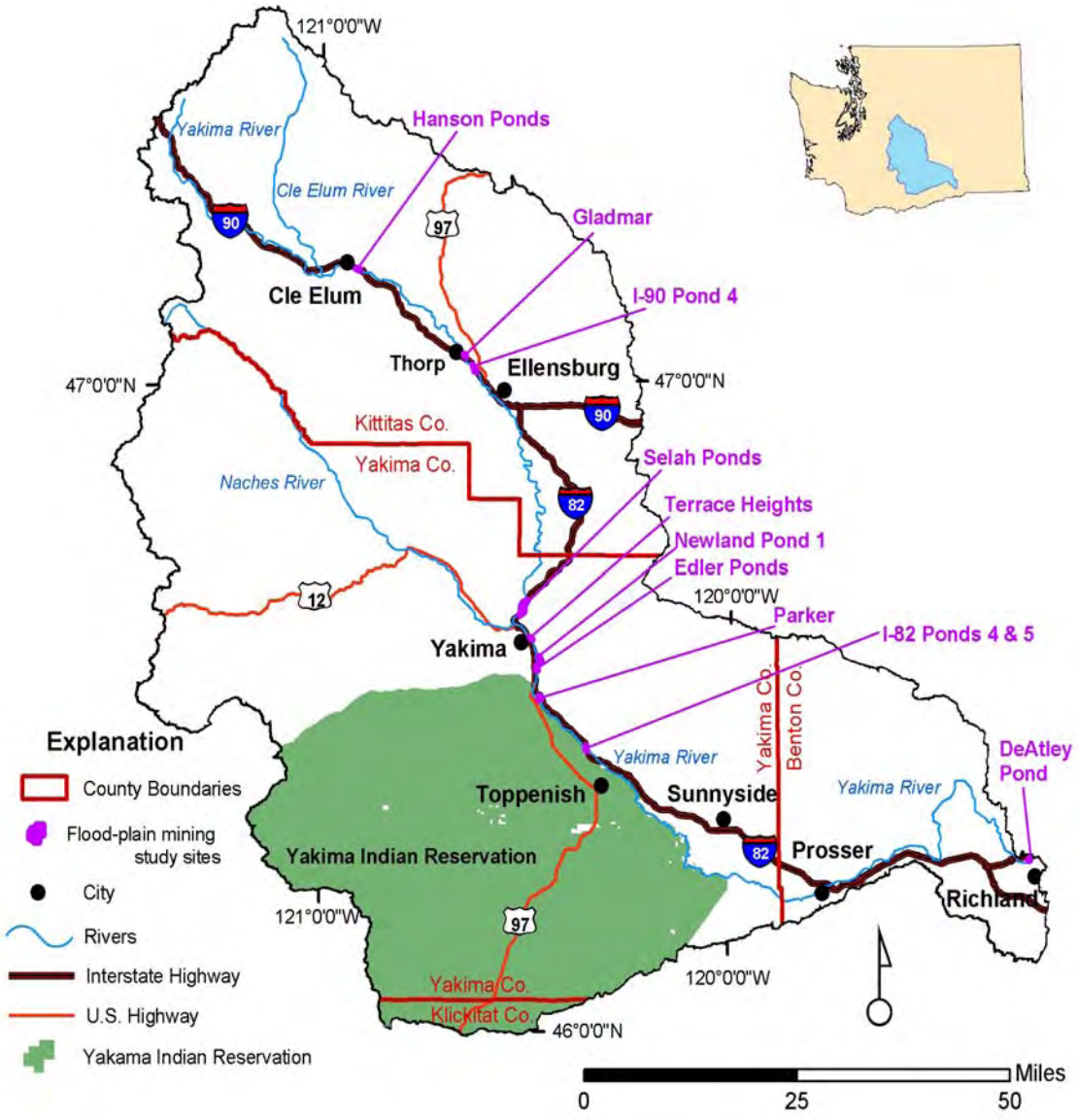


Figure ES1. The Yakima River Basin and location of study sites. Inset shows the location of the basin.

The Yakima River Basin is characterized by a longitudinal series of ground-water basins; the Yakima River flows generally southeast through a series of valleys and ridges to its confluence

with the Columbia River. Historically, winter and spring precipitation and spring snowmelt runoff would be “stored” in the sediments of the floodplains in these basins. On an annual basis, the upstream end of the basins were losing reaches; the accumulated water would return to the river above the constricting geological feature that divided a basin from its downstream neighbor. This ground-water resource added cool water to the river habitat in the summer and moderated winter water temperature. The shallow ground-water in channel gravels provided nutrients for salmon food organisms, while the multiple channels offered places for salmon to spawn and grow.

The river flow is managed, particularly for irrigation, by a system of dams. Keechelus, Kachess, Cle Elum, Rimrock, Clear, and Bumping reservoirs capture about a third (1.07 million acre-feet) of the basin-wide average runoff. (About 2 million acre-feet of basin runoff is not storable.) The dams have reduced the frequency, duration, and magnitude of the floods that formerly inundated the floodplains. Cooler ground water has been replaced by warm water flowing back from irrigation projects. Removing water from the river for irrigation can also raise the river water temperature. Structures built to “manage” the river have effectively reduced floodplain area, and flood flows are, in places, greater now than those recorded in the past. To make the Yakima's stream flow more uniform and to provide the water needed by irrigation districts in the lower river, water managers now release water from Keechelus, Kachess, and Cle Elum reservoirs until early September. “Flip flop” occurs when those dams are ramped down to accommodate spring chinook salmon spawning, and the Rimrock, Bumping, and Clear reservoirs provide the needed water.

Within the last 35 years, understanding of river ecology has increased. For example, to preserve fish populations, fish passage structures have been built at most low-head irrigation diversion dams. The Yakima River has good to excellent water quality upstream of Parker (Sunnyside) Dam; temperature standards are exceeded below Parker Dam during the summer when minimum target flows are in effect. In general, contamination is greater in lower reaches than in the upper basin.

For more than 100 years, numerous Yakima River floodplain mines have been a source of regionally significant construction aggregate. These mines have severely disrupted river channels and riparian communities. Depending on their location relative to the river and amount of flow, mine pits may be captured by the river, resulting in erosion, altered sediment transport regimes, and channel shifts that can damage highways and developments. Engineered structures that protect ponds and infrastructure also change river dynamics.

Other changes also occur with mining. Where mining removes riparian vegetation, disturbed ground provides places for invasive and non-native terrestrial plants to gain a toehold. New pond habitat created by mining expands the area available to exotic aquatic weeds and warm-water fish species. Mining also destroys the filtering capacity of vegetation and soil, making ground water susceptible to pollutants in mining process or waste-water from mining. Removal of riparian trees and shrubs that help moderate temperature changes can diminish the value of the reach to fisheries management.

Mining can also bring air pollution and noise, truck traffic, glare, and other unpleasant effects to nearby communities. Most mining impacts have been reduced by current “best management practices” that prescribe strategies to reduce or mitigate such negative impacts.

Fall chinook, coho, and steelhead (anadromous salmonids) runs are now at about 2 percent of their historic averages. Summer chinook and sockeye no longer have runs in this river. Recent increases in anadromous salmonids throughout the basin are attributed to favorable oceanic and climatic factors. Maintaining healthy fish stocks in the river basin is a major concern of the Yakama Nation and the Washington Department of Fish and Wildlife. Some ponds in the upper part of the river could be converted to spawning and or rearing habitat for resident and anadromous salmonids. However, ponds near the confluence with the Columbia River contain warm water and exotic fish that compete with or eat juvenile salmon. Furthermore, exotic fish are established in some ponds (by planned or illegal stocking), and some such populations are present in the river, probably because the ponds have temporarily been connected to the river during floods.

The demand for aggregate, however, continues. Washington’s Growth Management Act (GMA) requires that counties map and designate commercially significant mineral resources for the long term. Planning for mineral resources under the GMA requires careful mine site selection so as to protect the ecological health of the floodplain environment. Part of Yakima County’s response to the GMA was creation of a Mineral Resources Task Force (MRTF), whose report acknowledged that information about the impacts of floodplain mining can lead to being able to apply “best available science” to planning and permitting. Choosing criteria for responsible use of the floodplain gravel resource will be improved if there is good information about the effects of past and present mining.

Mine operators are required to reclaim mined areas. However, combined effects of mining on the Yakima River system have not been well-studied. Furthermore, the practice of restoring mine sites so as to improve floodplain function has not been a well-implemented reclamation goal. Determining how to include ponds in floodplain restoration, for example, depends on understanding how and when fish use mine ponds and what pond qualities are important to restoration. Resource managers and government officials recognized the importance of acquiring data that can guide actions capable of restoring river function, including ways to design potential mine sites and reclaim existing ponds. From this realization, the Floodplain Mining Impact Study was conceived. A partnership of the Yakama Nation, the Washington State Departments of Ecology, Natural Resources, and Fish and Wildlife and the Yakima County Planning Department was developed to address the need. A Centennial Clean Water Fund grant, matching funds from the Salmon Recovery Funding Board and the U.S. Bureau of Reclamation Yakima River Basin Water Enhancement Project, and assistance from Central Pre-Mix Concrete Co., Inc., provided the support for the study.

Regulatory Setting

Local governments approve mine siting and subsequent use of the site. Responsibilities for mines are divided among city and county governments and the Washington State Departments of Ecology (DOE) and Natural Resources (WADNR). Local government actions with regard to

mining are guided by the Growth Management Act (RCW 36.70A), the State Environmental Policy Act (RCW 43.21C), the Shoreline Management Act (RCW 90.58) as well as their respective Shoreline Master Programs, Critical Areas ordinances, comprehensive plans, and development regulations (zoning ordinances).

County actions with regard to aggregate resources are:

- Kittitas County has interim means for classifying and designating mineral resource lands; the county's planning department is directed to designate Commercial Mineral lands.
- Yakima County's Comprehensive Plan (Plan 2015) brings together tools to address surface mining and resources in the long and short term; the county assembled a Mineral Resources Task Force that has reviewed mineral resources inventories and suggested revised mapping criteria to review and adopt during the Plan 2015 update process. The County plans to adopt mapping criteria and implement land use and zoning concepts to protect mineral resource lands of long-term commercial significance.
- Benton County's Comprehensive Plan recognizes the importance of aggregate sources as well as the need to protect fishery resources. The plan focuses on identifying additional resource sites and protecting known sites through the Mineral Resources Protection Ordinance.

State government is involved in aggregate mining in these ways:

- DOE has oversight responsibilities in the Shoreline Management Act. This agency also regulates the amount of water pollution associated with aggregate mining by several kinds of permits that require best management practices to be used in wastewater treatment.
- The Surface Mine Reclamation Act (RCW 78.44.091), the purview of WADNR, requires that mine operators prepare and follow plans for thorough, effective reclamation (including creating wildlife habitat from mine ponds where possible). For mines in stream channels, the act requires evaluation of hydrologic conditions so as to minimize erosion and avulsion. WADNR recently facilitated a state-level committee report regarding to Substitute Senate Bill 5305 to address issues that complicate permitting processes.
- The Washington State Department of Fish and Wildlife (WDFW) and the Yakama Nation co-manage the coho, chinook, and resident trout populations for subsistence and recreation, including steelhead and bulltrout listed as "threatened" under the federal Endangered Species Act. WDFW requires Hydraulic Project Approvals for activities in the river environment below the ordinary high water line.

Because the many regulations and entities involved in permitting and regulating floodplain mining greatly complicate management and scientific data regarding the status of the riverine environment are generally lacking, this study builds the basis for a broad discussion of conditions and for coordinated development of policy and projects to address restoration of floodplain function.

Study Methods

Ten ponds representing a variety of characteristics were selected for intensive study (Figure ES1). Data collection began in April 2002 and continued through mid-November 2002. Efforts,

divided among the agencies, Yakima County, and the Yakama Nation, followed standard protocols. Study Team members calibrated equipment to assure uniformly high quality results.

Bathymetry of each pit pond was measured once during the study period. The Study Team used global positioning station equipment to record where depth measurements were made (by tape or sonar) from a small boat. These measurements enabled construction of bathymetric maps. Sediments collected from the pit and from the river nearby were qualitatively examined or sent to a laboratory for sieve analysis.

Water temperatures in the pond and river were measured at 2-hour intervals throughout a fairly uniform study period by equipment tethered to the bank or suspended in the pond. (The design of the data collection was similar to that under way by Central Pre-Mix Concrete Co., Inc.) Maximum and minimum water and air temperatures taken in the sites' riverine and riparian areas were analyzed for trends.

The Study Team sampled fish in the ponds and river reaches adjacent to the ponds, typically once at each site during the summer or fall. Backpack and driftboat electroshockers, shoreline live trap nets, and divers sampled 200 or more fish per river or pond site wherever possible. The number of species and the percentage of each species in each river or pond sample were tabulated.

Benthic macroinvertebrates were collected in replicate gravel-filled baskets placed in the ponds. The baskets remained in place for 6 weeks, and the insects collected were sent to a laboratory for identification. Benthic macroinvertebrates were collected in the river upstream and downstream each pond site using a standard kick-net method. The Study Team also measured water quality parameters, stream wetted width, stream velocity and gradient, macrophyte communities, and other variables at each site. Statistical analysis of the relations of the benthic community and the physical/chemical conditions led to conclusions regarding the biologic condition of the site.

Results of Sampling

Chapters 5 through 14 in this report provide, for each of the ten selected sites, details of:

- Pond area, depth, volume, and bottom sediment;
- Water temperatures in the ponds and river reaches adjacent to them, as well as differences among sampled sites;
- Fish assemblages in the ponds and river nearby; and
- The populations of benthic macroinvertebrates and differences among them, and aquatic and terrestrial plants.

A set of recommendations for actions (including monitoring) is presented at the end of each of these chapters.

Table ES1 summarizes the physical characteristics of the ponds selected for study. Table ES2 summarizes the salmonid presence in the river system. The number of salmonids declines from north to south, indicating the relative value to the fishery of the reaches.

Table ES1. Summary of physical characteristics of the selected pond study sites.

Pond Name	Area (acres)	Approx. Volume (yd^3)	Avg. Depth (ft)	Max. Depth (ft)	River Connec-tion?	In-Pond Sediment (general character)
Hanson Pond 1	15.8	49,000	4.7	~8	N	Fine to coarse gravel, cobbles
Hanson Pond 2	21.3	145,000	5.6	8.5	N	
Gladmar	21	102,000	~4	12	Y	Sand, silt; sandy gravel
I-90	40	96,000	4,2	8	N	Silt, clay; silt, fine sand
Selah 1		737,000	8.5	33	N	Fine to coarse gravel, cobbles, sand
Selah 2	150 (total)			25	N	
Selah 3		1,135,000	~9	30	N	
Terrace Heights					Y	Gravel (75%), sand (20%), silt (5%)
Newland Pond	8.2	153,000	12	31	N	Silty clay (slurry of fines from mining)
Edler Pond 1	12.4		7	19,18	N	
Edler Pond 2	6.3	216,000 (total)	7.6	17	N	
Edler Pond 3	1.9		11	17	Y	Gravel (75%), sand (22%), silt (~4%)
Parker 1-7	63	168,000	4	10	Y	Gravel (63%), sand (36%), clay (1%) (Thorp Fm)
I-82 Pond 4	19.3	584,000	19	25	N	Gravel (87%), sand (11%), silt (2%); Thorp Fm.
I-82 Pond 5	13.8	306,000	12	26	N	Gravel (77%), sand (13%), silt (10%)
DeAtley	18.2	78,000	4.2	15	N	Gravel (66%), sand (30%), silt, clay (2.5%)

Pond	Reach Gradient (ft/mi)	Channel Migration Zone Width (ft)			Distance from River (ft)			Potential or Actual Avulsion Point
		Above	Middle	Below	Upper	Middle	Lower	
Hanson Pond 1					150	60		Actual: Connected to river in 2004
Hanson Pond 2	17.4	1,500-2,000					80	
Gladmar	20	1,400-1,800				~100	~550	Actual: Avulsed in 1996
I-90	15.5	600		1,500	550	100	30	Potential: NW of W edge
Selah 1								Potential: Upstream of Pond 1
Selah 2	~15	1,800-2,300			150	160	75	
Selah 3								
Terrace Heights	~20	1,000	1,600		0			Actual: Avulsed in 1971
Newland Pond	17+	800-1,400		2,000	200	775	225	
Edler Pond 1				2,500				Actual: Connected to river at SE end, Pond 3
Edler Pond 2	12.5	1,400	1,000		800	250	0	
Edler Pond 3								
Parker 1-7	12.6	1,800	1,200		1,000		~100	Actual: Avulsed in 1996
I-82 Pond 4								Potential: N end, SW edge, Pond 4
I-82 Pond 5	13.2	3,700		2,800	100	100	450	
DeAtley	4.5	1,800	2,500		500	100	~100	Potential: SE end

Table ES2. Percentages of salmonids present in fish assemblages at the Yakima River mining pond study sites, by river reach, 2002. See Figure ES2 for reach location and extent. *O., Onchorhyncus.*

Reach	Pond Name	Pond sample (date)	River sample (date)	Comments
Upper	Hanson	No salmonids (7/24)	Rainbow or steelhead total 49% (9/5-6, 10/23)	Connected to the river in Feb, 2004
	Gladmar	Juvenile chinook ~25% (7/18, 19)	Chinook ~40%; mountain whitefish 22%; *O. mykiss* 14% (9/25, 10/16)	Pond assemblage has ~25% northern pikeminnow
	I-90	2 juvenile chinook (6/17, 18, 24)	Chinook and mountain whitefish total 53% (10/18, 11/6)	Pond samples was not connected to the river
Middle	Selah	No salmonids (6/13, 14)	*O. mykiss* 21% above the pond, fewer below. Chinook 6% (8/20, 10/11,18)	Pond is isolate from river and stocked with rainbow, large-mouth bass, and bluegills
	Terrace Heights	-----	Salmonids 20% at 4 of 8 sites. Overall chinook ~8%, *O. mykiss* ~5% (9/13,18,24)	Riverine environment, no pond
	Newland	No salmonids (Pond 1, 10/29,30; Pond 2, 5/30-31)	Salmonids ~5% (8/15,20)	River does not flood these ponds
	Edler	No salmonids (6/3,7-pre-breach); 7+% post-breach (7/2)	Chinook 5%, *O. mykiss* 3%, mountain whitefish 3% (8/14,27)	Lowest pond breached in July, 2002
Lower	Parker	Mountain whitefish 15+%, chinook 3%, coho 0.5% (7/10,11)	Juvenile coho and chinook ~5%; mountain whitefish ~27% (8/13,19)	Three ponds sampled; many competitor fish species
	I-82	No salmonids (5/24,25)	Mountain whitefish ~24%, Chinook + *O. mykiss* 2% (5/20, 8/21, 10/18, 11/6)	WDFW stocks Pond 4 with rainbow trout and Pond 5 with catfish. Warm water may limit salmonid use
	DeAtley	No salmonids (6/27)	No salmonids (8/13)	Limited to carp due to dewatering

Results of Data Analysis

Ecological analysis of the ponds showed that temperature and fish assemblages fell into three groupings: upper middle and lower river reaches (Table ES1, Figure ES2). In general, river and pond water temperatures were lower at the sites at higher elevation (upper reach). Large percentages of days exceeded the proposed seven-day average of the daily maximum temperature (7-DADMax) (16°C, higher than the current DOE standard) for spawning and rearing in the middle and lower reaches in summer and fall; somewhat fewer days exceeded the 7-DAD maximum temperature of 17.5°C in these two reaches. Fish in these three broad ecological reaches were considered in two groups: native (managed) salmonids, and exotic competitor or predator species. If connected, riparian zone gravel pit ponds in the upper reach have potential for providing high-quality native salmonid habitat; these species are already present in the river adjacent to the ponds. Fewer salmonids are present in the middle river reaches and present only in Edler Pond 3 (post-breach). The lower reach is poor late spring, summer, and early fall habitat or salmon rearing under current water management practices. The warmer water here favors the exotic competitors and predators, at least seasonally. These non-native fish species do not thrive in the cooler up-river sites.

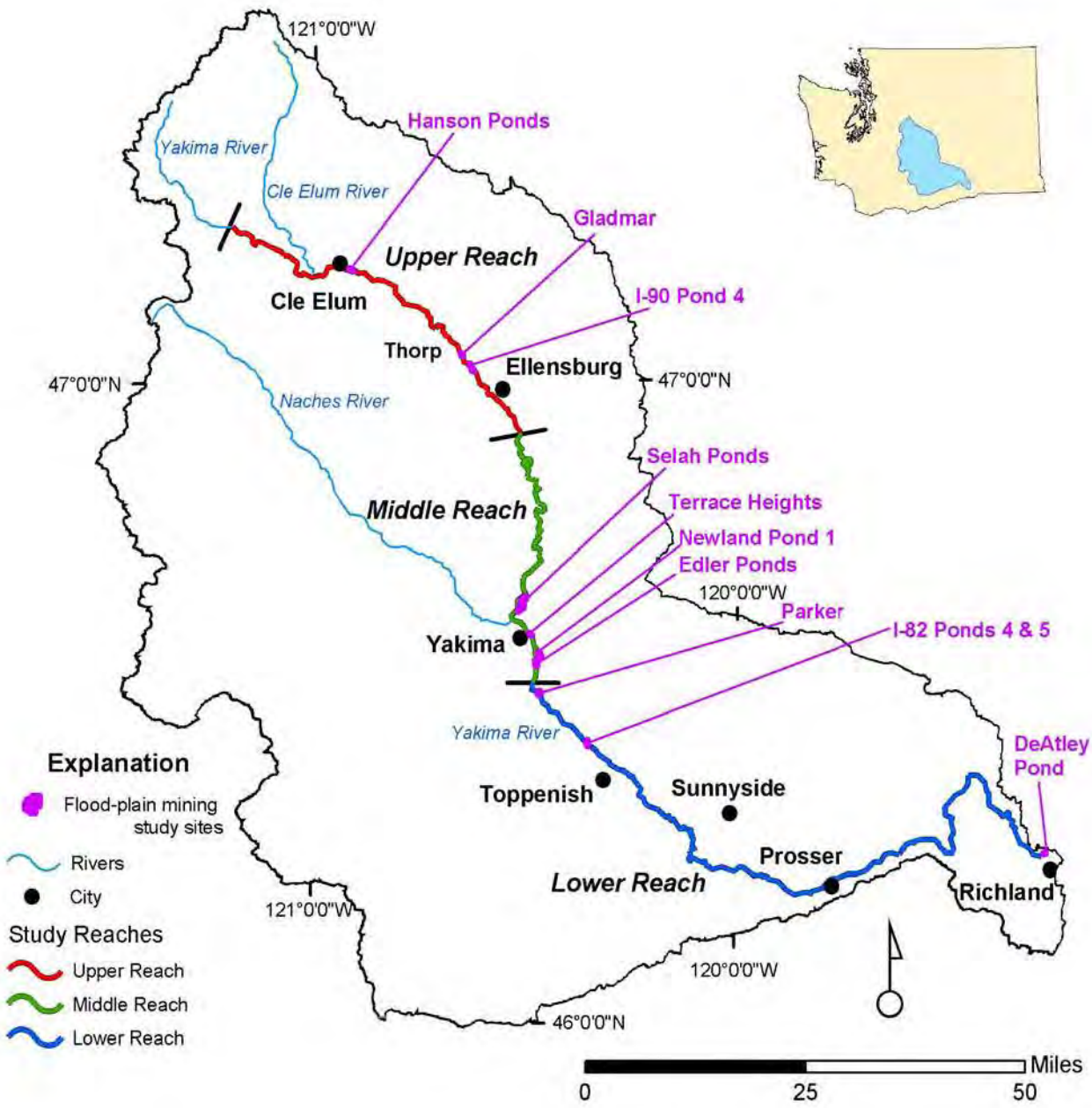


Figure ES2. Yakima River reaches and breaks as defined by study results.

Analysis of the benthic macroinvertebrates shows that, in general, the sampled sites above the studied ponds were in better biological condition than those below. The benthic macroinvertebrate communities are fairly similar at the sites within each reach, but there is an overall change in communities from upper to lower reaches, as determined with temperature and fish assemblages. Precisely what governs the "breaks" in community composition among reaches is not yet clearly understood, however, are linked with water quality, quantity, and geomorphic conditions.

It has become clear from the results of this study that geomorphic conditions at each site must be carefully considered when proposing to connect abandoned gravel pit ponds to the river to create new side channel habitat. The potential for uncontrolled avulsion at some sites is a challenge in the design of the connection, especially with regard to the area available for channel migration. Natural avulsion can cause damage to nearby property and infrastructure, particularly where the river captures a large, deep pond. However, this study shows that the upper reach ponds offer opportunities for developing high-quality salmonid habitat (if large northern pikeminnow populations are removed or can be managed). Central to success of pond reclamation for fish enhancement will be designing a connection to the river that minimizes areas of slow water and that will carry flow sufficient to add suitable sediment to the in-stream habitat being created. Ponds low in the river are sources of exotic competitor/predatory species leakage and are poor candidates for developing salmonid habitat under the current water management regime which causes the adjacent river reaches to be unsuitable for salmonid utilization a significant part of the year. Monitoring the benthic invertebrate community will track changes and assess the ecological health at connected sites.

Next Steps

Reclamation Concepts

The general goal of gravel pond reclamation is to restore river ecological function, where feasible. Decision-makers need to be aware of what fish use which part of the river at what times and what fishery benefits or detriments might accrue if the pond is reclaimed by connection to the river. Important to successful reclamation of floodplain mines for fisheries is a thorough understanding of the connections between river channels and floodplains. Washington's Surface Mine Reclamation Act requires reclamation of floodplain mines. Because the relation of river and floodplain is dynamic, detailed hydrologic (e.g., channel migration, historic flooding frequency and magnitude, discharge, sediment transport, avulsion history or potential, ground-water conditions, river-to-floodplain connections) and geomorphic (e.g., topography) data must be obtained to tailor technically and ecologically sound reclamation plans.

Restoration of riparian vegetation and shoreline biological communities is another vital component of reclamation. Challenges facing reclamation project proponents in the Yakima River Basin are that restoring riparian vegetation is difficult in the dry central Washington climate and that empirical data from successful (and failed) prior reclamation efforts, which could guide design and implementation, is very limited. Monitoring the establishment of riverine benthic macroinvertebrate communities is a useful method to assess the progress of reclamation efforts.

Conclusions and Future Efforts

The information gathered in this study provides a starting point, a baseline, for permit review, and land use and zoning considerations when designing "river reclamation" proposals for existing floodplain mine ponds/pits and for guiding site selection of future such mines. Information about sediment transport and geomorphology will enhance site selection, design, or reclamation/restoration activities and risk analyses for mining sites and should be heavily factored into the permit and policy review process. A draft proposal from the U.S. Bureau of

Reclamation's Technical Services Center describing a basin-wide sediment transport and geomorphic study sets out a path for completing a major part of the work needed to describe how flow might be managed to achieve optimal results in rehabilitating the floodplain. The Study Team, in collaboration with other organizations and agencies, is attempting to finalize the scope of the work and obtain funding for this work to proceed.

The goal of this study has been to find ways to balance sustaining a healthy river system with the need for continued production of aggregate. Based on study findings, the Study Team believes that alterations to the river system brought about by more than a century of mining suggest that the floodplains of the Yakima River are sensitive enough that alternatives to mining in the 100-year floodplain should be investigated. Future floodplain mine operations, if permitted, should be constrained by excavation design parameters that primarily reflect the application of best available reclamation science and secondarily consider the cost of the product mined. Natural or engineered avulsion may be the most cost-effective reclamation tactic at certain sites that can benefit habitat and minimize short-term and long-term flood hazards. Future research, planning, and permitting decisions concerning floodplain mining and restoration should be based on integration of all the technical results and recommendations in the study report and additional management considerations identified (Table ES3).

Table ES3. Matrix summary of site selection and decision issues. Reach limits are shown in Figure 156.

Management Issues	Upper Reach	Middle Reach	Lower Reach	General
Geomorphic Considerations	Degree and frequency of peak and long flow durations are limiting factors.	This gap-to-gap reach (below the Naches River confluence) has high sediment transport and deposition characteristics. Infill of shallow gravel pit ponds occurs at a preferable rate.	The channel migration zone is fairly expansive. Low seasonal flows must be addressed with regard to sediment transport capability.	Basin-wide sediment transport and geomorphology studies should be conducted. Channel migration studies at reach levels and assessments should be made. Project feasibility and design studies are needed.
Biological Considerations	Excellent river water quality and quantity and small populations of exotic species in the river suggest excellent potential for successful pond connection to river for salmonid habitat and production	Good water quality and quantity and small populations of exotic species suggest good potential for successful pond connection to river for salmonid habitat and production	Poor water quality and quantity and numerous predators and competitors in river suggest reduced potential for salmonid habitat.	Riparian conditions should be evaluated to determine impacts and mitigation and restoration needs. Seasonal water flow management by BOR and water demand by irrigation districts should be evaluated.
Social Considerations	The willingness of landowners to allow access to their land for restoration and/or to consider selling their property must be determined. Obtaining a funding source for changes is necessary. All assessments should be closely coordinated with other assessments and data-collection efforts.			

Due to the geomorphic uncertainties and dynamic nature of the Yakima River and its tributaries, the Study Team believes that, in an effort to determine appropriate overall management strategies for the suitability of specific future sites for floodplain gravel pits and/or related fisheries enhancement proposals in the Yakima River Basin, consideration should be given to the following five principles:

- Future mines should be sited outside the 100-year floodplain and, if at all possible, beyond the historic (100+ years) channel migration zone, as determined by aerial photograph and topographic map reconstructions. Data and observations within the Yakima River basin, as well as within other alluvial river systems of Washington State, show that natural avulsion into a mine pond is more likely to occur if a pond is situated within the 100-year floodplain and historic channel migration zone.

- At some point in the future (perhaps at geologic as opposed to human time scale), the river will avulse some part of a floodplain gravel mine pits. Avulsion may damage infrastructure (e.g., bridges, dikes, sewer outfall pipes). An effort should be made to reclaim the site such that when avulsion occurs, there is a maximum benefit for salmonid habitat as well as protection of upstream and lateral public infrastructure. Future ponds, if permitted by local and state government agencies to be developed in the floodplain or channel migration zone, should be designed for connection to the river (due to future natural avulsion events) without endangering infrastructure or encouraging avulsion. Future ponds constructed in these sensitive locations, as well as reclaimed existing ponds, should be designed and excavated to mimic river side channel morphology (length, width, depth, sinuosity) to accelerate conversion to river side channel fish and wildlife habitat when avulsion (natural or engineered) occurs in the future.

- Floodplain mining must not destroy intersections between the modern Yakima River channel and paleochannels where increased hyporheic ground-water flow to the river contributes a high concentration of dissolved oxygen. It is at such locations that salmonid populations congregate (J. Vacarro, U.S. Geological Survey, oral communication, 2003). A layer of gravel between the river and adjacent floodplain paleochannels should be left to increase hydraulic connectivity, protect ground-water resources, and benefit habitat for benthic macroinvertebrates.

- Ground-water flow into and out of mine ponds should be protected. Mining through the Holocene alluvium into underlying less permeable geologic units such as the Thorp or Ellensburg Formations should be prohibited by regulatory agencies because ground-water flow may be reduced. Ponds without ground-water inflow become stagnant warm-water habitat with low dissolved oxygen concentrations.

- Until additional mitigation options, standards, and protocols are in place to address large gravel ponds that pose an immediate avulsion risk to major infrastructures at a catastrophic scale, precautionary site protection measures should be considered.

A review of existing practices and regulatory and policy tools used to evaluate the suitability or risk of specific floodplain gravel pit proposals and related fisheries/habitat enhancement projects should consider the information in this report and the recommendations presented. Furthermore, improving the effectiveness of practice and regulatory and policy tools so as to eliminate or further reduce impacts to the river is important to the development of policy related to this study.

SUMMARY

YAKIMA RIVER FLOODPLAIN MINING IMPACT STUDY

The Yakima River system is the second largest subbasin in the Columbia River Basin (Figure S1). The headwaters are in the Cascade Range (elevation ~8,000 feet), and the river joins the Columbia River at Richland (elevation ~300 feet). Precipitation ranges from about 140 inches in the headwaters to less than 10 inches at the mouth. About half the basin is non-forested land, a quarter is forested, about one-fifth is agricultural land, and less than 1 percent is developed.

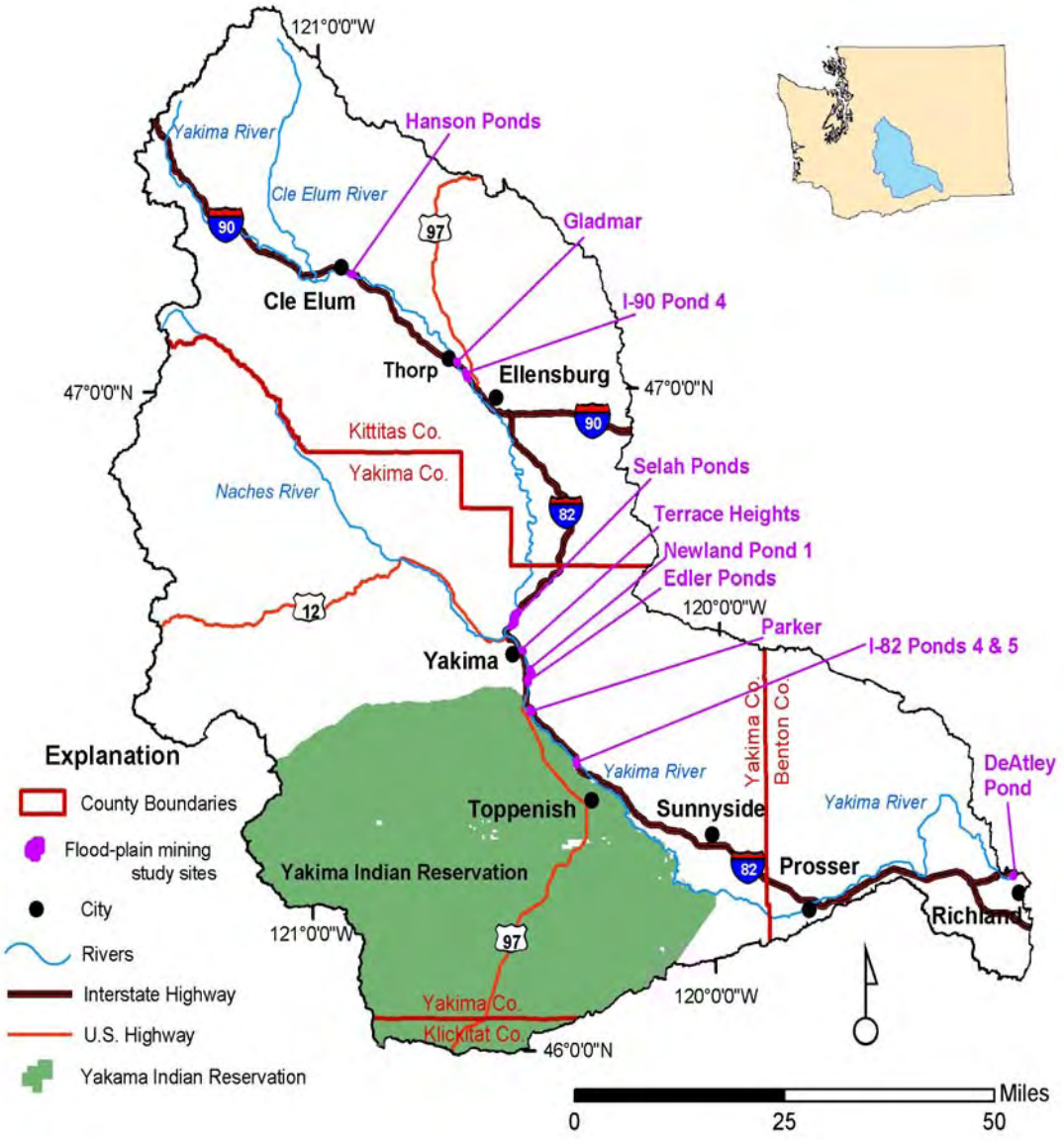


Figure S1. The Yakima River Basin and location of study sites. Inset shows the location of the basin.

The Yakima River Basin is characterized by a longitudinal series of ground-water basins. The river flows southeasterly through a series of valleys and ridges to its confluence with the Columbia River. Historically, winter and spring precipitation and spring snowmelt runoff would be “stored” in the sediments of the floodplains in these basins. On an annual basis, the upstream ends of the basins were losing reaches; the accumulated water would return to the river above the constricting geological feature that divided a basin from its downstream neighbor. This ground-water resource added cool water to the river habitat in the summer and moderated winter water temperature. The shallow ground-water in channel gravels provided nutrients for salmon food organisms, while the multiple channels offered places for salmon to spawn and grow.

The river flow is managed, particularly for irrigation, by a system of dams. Keechelus, Kachess, Cle Elum, Rimrock, Clear, and Bumping reservoirs capture about a third (1.07 million acre-feet) of the basin-wide average runoff. (About 2 million acre-feet of basin runoff is not storable.) The dams have reduced the frequency, duration, and magnitude of the floods that formerly inundated the floodplains. Cooler ground-water has been replaced by warm water flowing back from irrigation projects. Irrigation removes a great deal of water from the system and lowers river levels, a process that can also raise the river water temperature. As structures have been built to “manage” the river, the floodplain area that can receive flood water has been effectively reduced, and bank overflow flood elevations are, in places, greater than those recorded in the past.

Within the last 35 years, understanding of river ecology has increased. For example, to preserve fish populations, fish passage structures have been built at most low-head irrigation diversion dams. To make the Yakima's stream flow more uniform and provide the water needed by irrigation districts in the lower river, water managers now release water from Keechelus, Kachess, and Cle Elum reservoirs until early September. “Flip flop” occurs when those dams are ramped down to accommodate spring chinook salmon spawning, and the Rimrock, Bumping, and Clear reservoirs provide the needed water. Riverside development notwithstanding, the Yakima River has good to excellent water quality upstream of Parker (Sunnyside) Dam; temperature standards are exceeded in the lower river below Parker Dam during the summer after unregulated snowmelt runoff recedes and minimum target flow are in effect. Pesticides and herbicides enter the system from surface irrigation return flows; in general contamination is greater in lower reaches than in the upper basin.

For more than 100 years, numerous Yakima River floodplain mines have been a source of fairly high-quality, low-cost, accessible, “regionally significant” construction aggregate. These mines have severely disrupted river channels and riparian communities. Floodplain mine pits tend to fill with water and, depending on their location relative to the river and amount of flow, may be captured by the river, resulting in erosion, altered sediment transport regimes, and channel shifts that can damage highways and developments. Engineered structures constructed to protect ponds and infrastructure also change river dynamics.

Mining removes riparian vegetation, which has three basic negative consequences. The disturbed ground provides places for invasive and non-native terrestrial plant species to gain a toehold, and the new pond habitat created by mining expands the area available to exotic aquatic weeds. Additionally, mining destroys the filtering capacity of vegetation and soil and makes ground water susceptible to pollutants in mining process or waste water from mining. Finally, removal

of riparian trees and shrubs that help moderate temperature changes can diminish the value of the reach to fisheries management.

Mining can also bring air pollution and noise, truck traffic, glare, and other unpleasant effects to nearby communities. Most mining impacts can be reduced by current “best management practices” that prescribe strategies to reduce or mitigate such negative impacts.

Fall chinook, coho, and steelhead (anadromous salmonids) runs are now at about 2 percent of their historic averages. Summer chinook and sockeye no longer have runs in this river. However, within the last five years, anadromous salmonids have increased throughout the basin, partially because of favorable oceanic and climatic factors. Maintenance of healthy fish stocks in the river basin is a major concern of the co-managers, the Yakama Nation and the Washington Department of Fish and Wildlife. Some ponds in the upper part of the river could be converted to spawning and (or) rearing habitat for resident and anadromous salmonids. However, ponds near the confluence with the Columbia River contain warm water and exotic fish that compete with or eat juvenile salmon. Furthermore, exotic fish are established in some ponds (by planned or illegal stocking), and some such populations are present in the river, probably because the ponds have temporarily been connected to the river during floods.

The demand for aggregate, however, continues. Washington’s Growth Management Act (GMA) requires that counties map and designate commercially significant mineral resources for the long term. Part of Yakima County’s response to the GMA was creation of a Mineral Resources Task Force (MRTF), whose findings included acknowledgment that information about the impacts of floodplain mining can lead to being able to apply “best available science” to planning and permitting. Planning for mineral resources under the GMA requires careful mine site selection because the ecological health of the floodplain environment is at stake. Choosing criteria for responsible use of the floodplain gravel resource will be improved if there is good information about the effects of past and present mining.

However, combined effects of mining on the Yakima River system have not been well-studied. Determining how to include ponds in floodplain restoration, for example, depends on understanding how fish use mine ponds and what pond qualities are important to restoration. The need for information about mining impacts on aquatic and riparian ecology led to the decision to study the physical and biologic character of the ponds. Resource managers and government officials recognized the importance of acquiring data that can guide actions capable of restoring river function, including ways to design potential mine sites. From this realization, the Floodplain Mining Impact Study was conceived.

A partnership of the Yakama Nation, the Washington State Departments of Ecology, Natural Resources, and Fish and Wildlife and the Yakima County Planning Department was developed to address the need. A Centennial Clean Water Fund grant, matching funds from the Salmon Recovery Funding Board and the U.S. Bureau of Reclamation Yakima River Basin Water Enhancement Project, and assistance from Central Pre-Mix Concrete Co., Inc., provided the support for the study.

Regulatory Setting

Local governments approve mine siting and subsequent use of the site. A complex management and regulatory framework guides floodplain mining. Responsibilities for mines are divided among city and county governments and the State's Departments of Ecology and Natural Resources. Local government actions with regard to mining are guided by the Growth Management Act (RCW 36.70A), the State Environmental Policy Act (RCW 43.21C), the Shoreline Management Act (RCW 90.58) as well as their respective Shoreline Master Programs, Critical Areas ordinances, comprehensive plans, and development regulations (zoning ordinances).

The action of counties in the basin with regard to aggregate resources are:

- Kittitas County has interim means for classifying and designating mineral resource lands; the county's planning department is directed to designate Commercial Mineral lands.
- Yakima County's Comprehensive Plan (Plan 2015) brings together tools to address surface mining and resources in the long and short term; the County's Mineral Resources Task Force has reviewed mineral resources inventories and suggested revised mapping criteria to review and adopt during the Plan 2015 update process. The County plans to adopt mapping criteria and implement land use and zoning to protect mineral resource lands of long-term commercial significance.
- Benton County's Comprehensive Plan recognizes the importance of aggregate sources as well as the need to protect fishery resources. The plan focuses on identifying additional resource sites and protecting known sites through the Mineral Resources Protection Ordinance.

State government is involved in aggregate mining in these ways:

- The Washington State Department of Ecology has oversight responsibilities in the Shoreline Management Act. This agency also regulates the amount of water pollution associated with aggregate mining by several kinds of permits that require best management practices to be used in wastewater treatment.
- The Surface Mine Reclamation Act (RCW 78.44.091), the purview of the Washington State Department of Natural Resources (WADNR), requires that mine operators prepare and follow plans for thorough, effective reclamation (including creating wildlife habitat from mine ponds where possible). For mines in stream channels, the act requires evaluation of hydrologic conditions so as to minimize erosion and avulsion. WADNR recently facilitated a state-level committee report "Report to the Legislature—Findings and recommendations in response to Substitute Senate Bill 5305 regarding constructions aggregates" to address issues that complicate permitting processes.
- The Washington State Department of Fish and Wildlife (WDFW) and the Yakama Nation co-manage the coho, chinook, steelhead, and resident trout populations for subsistence and recreation, including species listed as "threatened" under the federal Endangered Species Act (steelhead and bulltrout). WDFW requires Hydraulic Project Approvals for activities in the river environment below the ordinary high water line.

The myriad regulations and entities involved in permitting and regulating Yakima River floodplain mining greatly complicate management. Further, scientific data regarding the status of the riverine environment are generally lacking. This study is building the basis for a broad discussion of conditions and for coordinated development of policy and projects to address restoration of floodplain function.

Study Methods

Ten ponds representing a variety of characteristics were selected for intensive study (Figure S1). Data collection began in earnest in April 2002 and continued through mid-November 2002. Efforts, divided among the agencies, Yakima County, and the Yakama Nation, followed standard protocols. Study Team members calibrated equipment to assure uniformly high quality results.

Bathymetry of each pit pond was measured once during the study period. The Study Team used global positioning station equipment to record the points at which depth measurements were made (by tape or sonar) from a small boat. These measurements enabled construction of bathymetric maps. Sediments collected from the pit and from the river nearby were qualitatively examined or sent to a laboratory for sieve analysis.

Water temperatures in the pond and river were measured at two-hour intervals throughout a fairly uniform study period by equipment tethered to the bank or suspended in the pond. (The design of the data collection was similar to that under way by Central Pre-Mix Concrete Co., Inc.) Maximum and minimum water and air temperatures taken in the sites' riverine and riparian areas were analyzed for trends, taking in to account missing or anomalous data caused by vandalism or amount of shading, among other factors.

The Study Team sampled fish in the ponds and river reaches adjacent to the ponds, generally once at each site during the summer or fall. Backpack and driftboat electroshockers, shoreline live trap nets, and divers sampled 200 or more fish per river or pond site wherever possible. The number of species and the percentage of each species in each river or pond sample were tabulated.

Benthic macroinvertebrates were collected in replicate gravel-filled baskets placed in the ponds. The baskets remained in place for six weeks, and the insects collected were bagged and sent to a laboratory for identification. Benthic macroinvertebrates in the river upstream and downstream each pond site were collected using a standard kick-net method. The Study Team also measured water-quality parameters, stream wetted width, stream velocity and gradient, and other variables at each site. Statistical analysis of the relations of the benthic community and the physical and chemical conditions led to conclusions regarding the biologic condition of the site.

Results of Sampling

Hanson Ponds

Pond Characteristics. Hanson Ponds 1 and 2 (Figure S1), on the north side of the Yakima River, were excavated during construction of Interstate 90 (I-90) in the late 1960s. In late May

2002, Pond 1 covered 15.8 acres and had a volume of about 49,000 cubic yards; Pond 2, adjacent on the downstream (east) side, covered 21.3 acres, and its volume was about 145,000 cubic yards. The ponds were separated from the river by a reinforced dike. The upstream end of Pond 1 was about 150 feet from the river; the downstream end of Pond 2 was about 80 feet from the river. The gradient (drop of the valley floor) in this 2-mile reach was about 17.4 feet/mile. The average depth of Pond 1 was 4.7 feet, and the greatest depth was about 8 feet, in the southeast corner. The bottom was fairly flat. Pond 2's average depth was 5.6 feet, and its greatest depth was 9.5 feet. The bottom, which was less regular than that of Pond 1, deepened to the north and east. The bottoms of both ponds were largely coarse gravel and cobbles; river bottom samples from sites up- and downstream of the ponds are somewhat finer. In February 2004, the ponds were connected to the river; flow re-enters the river about 4,500 feet below the ingress. The new configuration diverts about 10 percent of the river flow through the two ponds.

Thermal Characteristics. Water temperature was measured at three river sites and in Pond 2; air temperature was measured in a riparian area below Pond 2. The period of record was April 15 to November 14. Average monthly temperature contrasts among the river stations were ≤0.2°C. Temperatures were generally higher downstream, but the greatest increase occurred between the middle and downstream stations. Stronger air temperature gradients were recorded, and air temperature peaked (cold and warm) in advance of water temperature peaks. Water at the 2-foot depth in Pond 2 was warmest (~24°C) in July and was about 5°C in late October. Temperature trends at 6- and 10-foot depths generally paralleled that of the shallow water.

Fish Assemblage. Using standard protocols, 355 fish (seven species) were captured in Pond 2 on July 24. Nearly half that sample was northern pikeminnow; redside shiner and sucker made up about 18 percent each. River backpack electrofishing on September 5 and 6 and snorkeling on October 23 combined yielded 1,082 fish (nine species), of which mountain whitefish were most abundant (40.4%). Chinook salmon constituted 36.7 percent of the sample, and *Oncorhynchus mykiss* (resident rainbow trout and or juvenile anadromous steelhead) made up about 12 percent; neither of these species was found in the pond.

Benthic Macroinvertebrates, Water Quality, and Macrophytes. Water quality in Pond 2 was good in mid-September; the pond was not stratified. River water was cooler and had lower conductivity and pH values than the pond water, and water quality was similar at the two river sample sites. Benthic invertebrate communities differed at the sites, but this does not indicate that the upstream site was in better condition than the lower. Substrate was coarser at the upstream site, and water velocity was significantly greater at the lower site. Both variables can account for the difference in communities. Big-leaf pondweed (*Potamogeton amplifolius*) dominated the submersed plant community, and reed canary grass, *Phalaris arundinacea*, a non-native invasive plant, was present locally on the shore.

Gladmar Pond

Pond Characteristics. Gladmar Pond (Figure S1) was captured by the Yakima River during the flood of February 1996. River flow through the pond is maintained at 300 cubic feet/second or one-third of the total flow (whichever is less). The pond now covers about 21 acres. The volume of the pond and channels connecting it to the river in mid-July 2002 was about 102,000 cubic

yards, but the river is gradually filling the pond with sediment. River gradient here is about 20 feet/mile. The pond has one ingress channel and two egress channels. The pond's average depth is about 4 feet, but its depth varies considerably, and that in turn controls water velocity within the pond. The deepest part of the pond (max. 12 feet) is a Y-shaped area south of the delta that is being built where the river enters the pond. The pond bottom generally rises to the east, and flow maintains two shallow channels back to the river. The sediment on the bottom varies as well. Two of three samples from shallow areas on the north and east are fine sand to clay. The third sample, mostly gravel, is typical of sediment deposited where velocity is greater.

Thermal Characteristics. Three sites within the pond were sampled. The up- and downstream temperature monitoring instruments were placed in fairly deep water. The middle site, on the pond's east side, was subjected to direct sunlight and siltation; that instrument was moved to the west side in mid-September, and the record was not included in this report. Air temperature was recorded at a riparian site on the south outlet channel. The period of record was April 15 to November 14. Temperature differences between up- and downstream sites were small (avg. 0.6°C), and the temperature was higher downstream than upstream except in November. The maximum temperature was about 19°C.

Fish Assemblages. Electroshocking from a boat, fyke (live trap) nets and gill nets captured 414 fish (11 species) in the pond in mid-July and late September. Suckers, northern pikeminnow, and juvenile chinook each constituted about a quarter of the sample. Pikeminnow prefer the slower water portion of the pond. Nine species were found in the river samples taken by backpack electrofishing in late September and by snorkeling in late September and mid-October. Of the 1,190 fish taken by these techniques, chinook salmon made up nearly 40 percent of the sample; mountain whitefish (22%) and *O. mykiss* (14%) were other important species. Except for the northern pikeminnow in the pond, the river and pond had similar assemblages. No exotic species were taken here, suggesting that the changing habitat is no longer suitable for them. Prior to avulsion, non-native warm water species such as largemouth bass and pumpkinseed sunfish were present in the pond.

Benthic Macroinvertebrates, Water Quality, and Macrophytes. Gladmar Pond has good water quality. The composition of the macroinvertebrate populations differed slightly at the upstream and downstream sites, which could be accounted for by the wider wetted and bankfull widths at the upper site and the greater canopy cover at the lower. All submersed plants were native species. The flora was dominated by ribbon leaf pondweed (*Potamogeton epihydrus*). Reed canary grass was found on the shore.

I-90 Ponds

Pond Characteristics. The lowermost of the four ponds between I-90 and the Yakima River northwest of Ellensburg (Figure S1) was chosen for study. Pond 4 is separated from the river by a riprap-reinforced dike; this pond is about 500 feet from the river at the upstream end and 30 feet from a side channel at the downstream end. Surface water reaches the pond from the three smaller ponds upstream. Pond 4 covers about 40 acres and has a volume of about 96,000 cubic yards. The river gradient here is about 15.5 feet/mile. The pond's deepest point (8 feet) is near its southeast margin; its average depth is 4.2 feet. The pond bottom slopes gradually from the

northwest. Bottom sediments are gravel and cobble in the northwest and silty clay to the south and southeast. The coarse sediment (noted but not sampled) is likely a result of occasional flood flows entering the pond, whereas the fine sediment may represent lower flow velocity or the top of the Thorp Formation. A river bar sample taken downstream is, in contrast, nearly 83 percent gravel.

Thermal Characteristics. River temperatures were recorded at two sites upstream of the pond, one at about the middle of the pond complex, and one downstream. The air temperature instrument was placed in a riparian area near the upstream-most site. The period of record was April 15 to November 14. River temperature increased downstream; the largest increase was between the middle and downstream sites, and the greatest difference was recorded in October. The monthly maximum and minimum temperatures maintained the same relation through the period of record. Maximum temperatures exceeded 20°C only in mid-September. The pond temperature was monitored at two locations near the shore. The lower site was consistently a degree or two warmer; a temperature of nearly 30°C was recorded in mid-July.

Fish Assemblages. The pond sampling captured 874 fish (eight species) on June 17, 18, and 24, when the water was turbid. Pumpkinseed sunfish (43%) was the dominant species, but yellow perch made up 31 percent of the sample. Only two salmonids (juvenile coho salmon) were taken, suggesting that the river rarely floods into this pond. Northern pikeminnow are present (6.4%). Backpack electroshocking on October 15 and snorkeling in the river on October 18 and November 6 together captured 1,235 fish. Chinook and mountain whitefish together made up more than 53 percent of the combined samples; suckers, at 34 percent in the upstream sample and 14 percent downstream, were also numerous. The river assemblages were similar to those from upstream ponds

Benthic Macroinvertebrates, Water Quality, and Macrophytes. Pond 4 and the river had good water quality. The upstream benthic community differed slightly from that downstream. The average depth of the sampled reaches, their wetted widths, and gravel present could account for the differences. Pond 4 had a diverse native submersed flora, but curly leaf pondweed (*Potamogeton crispus*) was also present. Non-native invasive species, purple loosestrife (*Lythrum salicaria*) and reed canary grass, grew in patches on the shore.

Selah Ponds

Pond Characteristics. Three ponds at this large, mined area on the east side of Interstate Highway 82 (I-82) and west of the river were selected for study (Figure S1). A dike protects Ponds 1, 2, and 3 from the river, but some ground water seeps out of Pond 1 at its south end into a slough. The north end of the ponds is about 150 from the river; the downstream end of Pond 1 is only 75 feet from the river. Ponds 2 and 3 are connected; their combined volume is about 1,135,000 cubic yards. The volume of Pond 1 is about 727,000 cubic yards. The three ponds occupy about 150 acres. The gradient of the valley floor here is about 15 feet/mile. Ponds 2 and 3 average slightly more than 9 feet deep. They have fairly varied bathymetry, reflecting both the mining history and reclamation efforts. The deepest part of Pond 3 is more than 25 feet deep; its bottom slopes generally south. Pond 2 is deepest in the southwest, where it reaches 30 feet deep; its bottom slopes southwest. Ponds 2 and 3 are separated by a low sill and some small islands.

Pond 1, in contrast, is a rather deep, narrow feature that has three basins within it. The average depth is 8.5 feet, but depths of 33 feet were measured in the northern and middle parts of the pond, and the greatest depth recorded in the southern part of the pond is about 32 feet. The generally increasing pond depth from north to south reflects the dip of the top of the Thorp Formation, which is semi-consolidated and fairly fine grained (poorly permeable) here. A sample of the bottom of Pond 1 consisted of 75 percent fine to coarse gravel. In 1996 the Yakima River breached an upstream dike and flowed for 2 miles through the pond complex, from the area upstream of Pond 3 and out of Pond 1. The dike was subsequently rebuilt, the river has been returned to its former channel, and the ponds are now isolated from the river again.

Thermal Characteristics. River temperatures were recorded upstream of Pond 1 and adjacent to the pond. Shading was minimal here. Sites downstream were partially shaded. The air temperature was recorded along Pond 1. The pond temperatures were taken in the center of Pond 1 at depths of 2, 6, 12, 24, and about 32 feet. The period of record was April 15 to November 1. Although temperature differences among the river stations are inconsistent, from July to October the river was warmer at the downstream sites. The greatest differences were recorded in September and October. Pond 1 was stratified in the spring. The highest temperature at 2 feet was nearly 25°C in late August, but no temperatures on the stringer were recorded between late May and late August because the cable holding the instrument was cut by a boat.

Fish Assemblage. A drift boat electroshocker was used to sample the river above and below Pond 1 on August 20. Backpack electroshocking in two reaches above the river on October 17 captured fewer than 200 fish. The snorkel survey was made on October 11 below the south end slough. Combined results of all these techniques (649 fish; 13 species) show that suckers made up 41 percent of the assemblage. Chiselmouth and redside shiners were 16 percent and 12 percent of the samples, respectively; the redside shiners were particularly abundant in the slough areas. *O. mykiss* constituted 21 percent of the fish captured above the pond, but they were far less common elsewhere. Chinook composed 6 percent of the total river sample. The pond had large populations of yellow perch and pumpkinseed sunfish, and carp were fairly common. The pond is stocked by the private owner with rainbow trout, largemouth bass, and bluegill. Non-native fish made up less than 2 percent of the river fish assemblage, attesting to the isolation of the pond since the 1996 avulsion.

Benthic Macroinvertebrates, Water Quality, and Macrophytes. Pond water quality was marginal; the water was stratified, and the bottom had low dissolved oxygen concentrations. The pond surface had a higher pH than deeper water. Only a few benthic macroinvertebrate taxa were found. The benthic communities in the river samples were very similar, and gradient was the only variable that might explain the small difference. Water star grass (*Heteranthera dubia*) was growing vigorously at the pond. Several other native submersed species were present. Curly leafed pond weed (not native) was present but scarce. Purple loosestrife, reed canary grass, and yellow iris (*Iris pseudacorus*) were non-native invasive species noted on the shore.

Terrace Heights

Site Characteristics. The Terrace Heights site (Figure S1) was captured by the river in the 1970s and now resembles natural river habitat. Remnants of a dike that surrounded the mined area can

still be seen. The valley floor gradient between the Selah Ponds and this site is nearly 20 feet/mile. Sediment samples taken from the active channel above and below the site are more than 84 percent gravel. A sample from the formerly mined area is somewhat finer, perhaps because residual mine fines may be present or the river has less energy across this section of the site.

Thermal Characteristics. Temperature monitoring instruments were placed at the upstream end, middle, and downstream end of the mined site. Air temperature was measured at a site near the mid-point of the site. The period of record was April 15 to November 15. River temperature was consistently higher downstream than upstream, but the changes across the site were inconsistent. Maximum temperature downstream was about 22°C in mid-July. The daily maximum temperatures at the middle site were lower in midsummer, possibly because there is a spring-fed stream nearby.

Fish Assemblages. The main channel and several side channels were sampled. Nine sites above the former pit were sampled with the backpack electroshocker on September 13, 18, and 24; the drift boat was used below the pit area to sample about 2,000 m of channel on August 20. More than 1,100 fish were captured above the former pit, but only 108 were captured below the pit. Twelve species were found, with native minnows and suckers dominant, above the pit site. At four of eight sites sampled with the backpack gear, salmonids made up 20 percent of the assemblage. Overall, dace, redside shiner, and suckers together constituted 72 percent of the sample (16 species). Chinook and *O. mykiss* at nearly 8 percent and 5 percent, respectively, are more common than the remaining eleven species.

Benthic Macroinvertebrates, Water Quality, and Macrophytes. The macroinvertebrate samples show that the site conditions are essentially riverine throughout. The small differences between the communities up- and downstream of the former pit area could be attributed to differences in wetted width and canopy cover (both greater downstream). No macrophyte survey was made here.

Newland Pond

Pond characteristics. The Newland site is southeast of Yakima on the east side of the river (Figure S1). Newland Pond 1, the focus of this study, covers 8.2 acres and has a volume of about 153,000 cubic yards. Some small islands have been constructed for wildlife enhancement at the north end. The pond is separated from the river by a dike on its west side. The north end of Pond 1 is about 200 feet from the river, and the downstream end is about 225 feet away from the river. The valley floor slope here is slightly more than 17 feet/mile. Newland Pond 1 is elongate and has steep side walls. The average depth is about 12 feet. The pond is 31 feet deep in its north-central part. The bottom slopes fairly regularly to this deep area. The pond was being used as a settling pond during the investigation, and the water was turbid; slurry from adjacent mining enters the pond on its south end. As a result, the pond bottom is covered with silt and appears to be barren.

Thermal Characteristics. River temperatures were monitored at one site upstream and one site downstream of the pond area. The air temperature instrument was placed downstream of the

pond on the dike. The period of record was April 15 to November 14. The maximum water temperature was about 22°C in early July. After May the downstream temperatures were between 0.07°C and 0.3°C cooler than those upstream. The difference could be explained by the poor shading upstream or the distance of the pond from the river. Temperature was measured at 2, 6, 12, and 21.5 feet in the center of the pond. Apparently the lowest recorder was buried during the recording period. Water at the 2-foot depth was generally several degrees warmer early in the summer than deeper water; temperatures approaching 26°C were recorded in July. By September the temperatures from 2 to 12 feet were within a few degrees of each other.

Fish Assemblages. Samples were taken from Pond 1 and Pond 2. The turbid water in Pond 1 hampered the effectiveness of electroshocking, which was preformed on October 29 and 30. Nevertheless, sampling with the established protocol yielded 131 fish (six species) in Pond 1 and 766 fish (four species) in Pond 2. Pumpkinseed sunfish comprised about 40 percent of the fish community in both ponds. Yellow perch comprised 53 percent of the fish in Pond 2. The absence of northern pikeminnow and other native fish suggests that the river does not flood these ponds. Backpack electroshocking of a short upper reach on August 15 and drift boat electroshocking of about 6,000 feet of river on August 20 captured 353 fish (11 species). Of this total, redside shiner was the dominant species, but dace were far more abundant in the upstream sample. Salmonids (chinook and *O. mykiss*) comprised less than 5 percent of the total sample.

Benthic Macroinvertebrates, Water Quality, and Macrophytes. Because of the slurry in Pond 1, water quality was marginal. The benthic community there was not diverse. In the river there was little difference between upstream and downstream samples. Pond 1 supported a large population of water clover (*Marsilea* sp.), apparently rare along lake shores elsewhere. The non-native curly leaf pondweed was present in the diverse submersed flora. Dense patches of purple loosestrife grew on the pond shore.

Edler Ponds

Pond Characteristics. Three ponds on the west side of the Yakima River east of Union Gap were studied (Figure S1). Ponds 1 and 2 are not connected to the river, but when river level and associated ground-water level are high, surface water flows between the ponds. Pond 3 was breached at its southeast corner during a high flow event in June 2002. The area of the three ponds totals about 17 acres, and they have a combined volume of ~215,000 cubic yards. The valley floor gradient, at 12.5 feet/mile, is less than at upstream sites. Pond 1 consists of two basins; two islands rise on the sill between them. The northern of the two has a maximum measured depth of 19 feet; the southern basin is 18 feet deep. The average depth is about 7 feet. Sides slope smoothly to the deep spots. Pond 2 has a maximum measured depth of 17 feet; the deep part of the pond is along a central axis. The average depth is 7.6 feet. Shallow areas are present on the west and south sides. Like Pond 2, the maximum measured depth of Pond 3 is 17 feet. The pond has a large north basin and a smaller, slightly shallower southern basin. The average depth is 11 feet. The bottom of this pit is about 75 percent gravel with sand and minor silt or clay, typical of these three ponds.

Thermal Characteristics. Three monitoring instruments were placed in a small side channel on the east side of the ponds. All were within the reach from mid-Pond 1 to the lower part of Pond 2

and well shaded. The air temperature was recoded at a site just above the lower water temperature site. The period of record was April 14 to November 1. The differences in average temperature among the three sites follow no pattern; on average, the downstream water was cooler in July August, and September. However, downstream maximum summer temperatures at the lower site were warmer than at other sites. Pond temperatures were measured in Ponds 1 and 3, but the instruments were vandalized and the data set was too short to be useful.

Fish assemblage. All three ponds were sampled between June 3 and 7. Standard protocol was followed in Pond 1. The small lower ponds were sampled using only one fyke and one gill net, but standard boat electroshocking methods were used. Nine species (3,769 fish) were found in the ponds, but the species complex in each pond differed. Pumpkinseed sunfish dominated the assemblages in Ponds 2 and 3. Brown bullhead and pumpkinseed sunfish were the most abundant fish in Pond 1. No salmonids were found during the June sampling. The side channel was sampled above the ponds by backpack electroshocker on August 27; 586 fish (13 species) were captured. Roughly equal numbers of chiselmouth, carp, dace, pumpkinseed sunfish, and suckers were found; also present were chinook (5.6%) and *O. mykiss* (3%). The drift boat was used in the main channel, but only 51 fish (six species) were taken. About half that sample was suckers, but chinook (2%) and *O. mykiss* (~4%) were also recorded. Pond 3 was resampled in July (post-breach). Chinook now represented 7.2 percent of the assemblage, and chiselmouth and suckers were far more abundant, indicating that river species had moved into the breached pond. Pumpkinseed sunfish had declined to less than half their earlier numbers.

Benthic Macroinvertebrates, Water Quality, and Macrophytes. Pond 1 was the only pond sampled. Its water quality was poor, and the benthic community indicated disturbance. River water quality was similar at the sampled sites. The greater wetted and bankfull widths and substrate character of the upstream site may be responsible for the small differences in river benthic communities. The submersed flora was sparsely distributed. Some curly leaf pondweed was present. Purple loosestrife and reed canary grass were growing along all the shores; yellow iris was becoming established along Pond 1. An algal bloom was noted on September 5.

Parker Ponds

Pond Characteristics. The Parker site is 2 miles south of Union Gap, about 100 feet west of the Yakima River (Figure S1). I-82 is adjacent to the river on the east. Seven ponds here cover 63 acres and have a combined volume of about 168,000 cubic yards. Pond 7 was breached in the 1996 flood and Ponds 6-1 have seasonal connection from Pond 7 to the Pond 1 outlet. The valley floor gradient in this reach is about 12.6 feet/mile. These are the shallowest ponds among the study sites—the average pond depth is about 4 feet; the maximum measured depth is only 10 feet in Pond 2. Pond bottoms are fairly flat. Mining here was limited by a clay layer. The river avulsed the pond complex in 1996, entering and exiting Pond 7, with a slight amount of flow entering Ponds 6 through 1. A small outlet channel connects to the river. The coarsest sediment is being deposited at the north end of Pond 7. Some fine sediment is carried to lower ponds. The gravel and sand sample taken from the bottom of Pond 1 is Thorp Formation, which makes up the bottoms of Ponds 1 through 6.

Thermal Characteristics. The upstream river temperature monitoring site was in a side channel south of the main channel. The middle site was in Pond 2; it was not shaded, and the instrument experienced siltation. The downstream station was partly shaded, near the outlet. The air temperature instrument was placed near the upstream river station. The period of record was April 15 to November 1. Average monthly water temperature at the downstream site was consistently higher than at the upstream site. However, the differences between the site average temperatures varied because water at the middle site was, on average, warmer than at either other site in May, June, August, and November.

Fish Assemblages. Ponds 1, 2, and 5 (the isolated pond) were sampled on July 10 and 11 using only one fyke and one gill net each, but otherwise by standard procedures. The combined sample was 984 fish (13 species). Suckers made up 34 percent of the assemblages; pumpkinseed sunfish and mountain whitefish were also abundant, at 12.3 percent and 15.5 percent respectively. Salmonids (chinook, 3%; coho, 0.5%) were captured only in Ponds 1 and 2. The channel near the upstream temperature monitoring instrument was sampled by backpack electroshock gear on August 13. This gear was also used below the Pond 1 outlet. That small sample (39 fish, seven species) was dominated by dace; suckers, sculpins, and pumpkinseed sunfish were present in roughly equal numbers, and together they made up about 40 percent of the sample. On August 19, about 2,000 m below the Pond 7 outlet was sampled with the drift boat, and a section of the shore of Pond 7 was also sampled. About 4 percent of the pond sample was juvenile chinook and coho. In the river, suckers (~35%) were the dominant component, followed by mountain whitefish (~27%). Warm water, plentiful competitors, and large flow variations (downstream of Wapato Diversion Dam) appear to limit salmonid use of this site.

Benthic Macroinvertebrates, Water Quality, and Macrophytes. Pond water was of marginal quality and similar to that of the river above and below the ponds. The benthic community was in better condition upstream than downstream. *Glossosoma* was present only at the upper site; its absence at the lower site suggests habitat disturbance. The larger wetted width in the upper part of the reach may have influenced community differences. *Elodea* sp. was the most common submersed plant. *Nymphaea odorata* and curly leaf pondweed are non-native invasive species noted in the ponds. Purple loosestrife was present in scattered localities on the shore.

I-82 Ponds

Pond Characteristics. Ponds 4 and 5 were chosen for study at this site 7 miles south of Union Gap. Pond 4 covers 19.3 acres and has a volume of about 584,000 cubic yards. Pond 5 is 13.8 acres, and its approximate volume is 307,000 cubic yards. The river is actively meandering just west of the ponds. A dike system lies between the river and the ponds, but there are two potential avulsion points on Pond 4. Pond 5 is connected to a side channel of the river at its downstream end by subsurface flow through a rock-filled gabion core of the levee that was partially destroyed during the February 1996 flood event. Fish ingress and egress occur only during flood events when the levee core is overtopped. The gradient of this reach is about 13.2 feet/mile. Pond 4 is elongate and the deeper part is generally along the axis. The bottom is quite regular. The greatest recorded depth is 25 feet, and the average depth is almost 19 feet. The pond walls slope regularly, but fairly steeply. Pond 5 is also steep sided; the west side slopes somewhat more gently. The maximum measured depth is 26 feet, and the average is about 12 feet. An island on

the east side may have been constructed for wildlife. The bottom of Pond 4 is coarse gravel at the north end, but clay in the middle and Thorp Formation, gravel in a finer matrix, at the south end. The sediment sample taken from the base of the island in Pond 5 is gravel, probably younger than the Thorp.

Thermal Characteristics. The river water temperature monitoring sites were placed on a side channel and about 300 feet above and below the ponds and at a site near the south end of Pond 4. Air temperature was measured at the upstream site. The period of record was April 15 and November 1. This site differs from others in the study in that water was generally cooler downstream. The upstream instrument recorded temperatures as high as 24°C in July; maximum temperatures at the downstream site were about 8 degrees lower and constant during the summer, perhaps because there is shallow groundwater flow at that site. The magnitude of the differences between stations was about equal during the period of record. The pond temperatures were recorded at depths of 2, 6, 12, and 14 feet. The pond was stratified until mid-September. The maximum temperature at 6 feet was about 27°C in mid-July.

Fish Assemblages. WDFW stocks Pond 4 with rainbow and brown trout and channel catfish, but largemouth bass and other warm-water species are present and WDFW manages the pond as a "mixed species" fishery. Fish may move from Pond 4 to Pond 5 by way of a culvert. Only catfish are routinely stocked in Pond 5, which is managed for warm-water species. When sampled on May 24 and 25, yellow perch (30%), pumpkinseed sunfish (21%), bluegill (19%), and largemouth bass (16%) were the most abundant fish in the Pond 5 sample (14 species); Pond 4 was not sampled. Backpack electrofishing on May 20 and November 6, river drift boat electroshocking on August 21, and a snorkel survey on October 18 together captured/observed 1,016 fish. Chiselmouth were common above the site, but made up far less of the assemblage below. The same relation was seen for northern pikeminnow, but this species was less abundant overall. Redside shiner were common above and more abundant below the site. Mountain whitefish, at ~24 percent of the drift river boat sample, nearly equaled the number of shiner. Chinook and *O. mykiss* together made up only 2 percent of the river assemblage, probably limited by the warmth of the water.

Benthic Macroinvertebrates, Water Quality, and Macrophytes. Pond 4 had marginal water quality. The benthic community consisted of few, largely tolerant taxa. River water quality below the site was similar to that of the pond. The condition of the river above the site was better than below, possibly because the wetted width and velocity were greater there. A listed noxious weed, Eurasian milfoil (*Lyriophyllum spicatum*), dominated the submersed flora. Curly leaf pondweed was also present, but not as abundant. Purple loosestrife and reed canary grass were growing along the shore.

DeAtley Pond

Pond Characteristics. The lowest DeAtley pond near Richland (Figure S1) was selected for study. The surface area is 31.1 acres, and the approximate volume is 78,000 cubic yards. A dike separates the pond from the river, but the pond is only about 100 feet from the river; ground water enters the pond here at high flows. The gradient of this reach is low, about 4.5 feet/mile. The pond is shallow (avg. depth 4.2 feet), and its deepest point (15 feet) is near its southeastern

edge. The shallow northwest arm is connected to the main body of the pond only when river levels are high; otherwise it is a separate 5-foot deep pond. Sediment taken from the pond margin is about 63 percent gravel, coarser than the sediment along the river bank.

Thermal Characteristics. The water temperature instruments were placed in shaded areas, but all were affected by the fluctuations in river flow. The middle site, below Richland's sewer treatment outfall, and the lower site, below the pump outfall of the mining site, were repeatedly vandalized. Air temperature was measured at a site near the east side of the pond. The period of record was April 15 to November 1. Average river temperatures for April through July show that the river was warmest at the middle site; 36°C was reached there in early July there. Water temperatures were within a small range at all sites. The pond stringer was placed near the north shore, and temperatures were recorded at 2, 4, and 10 feet. The pond was stratified from late May through mid-September. The maximum temperature at 2 feet was slightly above 30°C in mid-July.

Fish Assemblages. Common carp were the only fish found in the pond. The small sample (19 fish; seven species) taken by drift river boat from the river on August 23 was strongly dominated by smallmouth bass; bluegill and channel catfish each made up 16 percent of the sample. No salmonids were found.

Benthic Macroinvertebrates, Water Quality, and Macrophytes. Water quality in the pond was poor; the pH was 9.5 and the total dissolved solids concentration was 189 mg/L. The benthic community had an above-average number of tolerant species. The upper part of the river reach here was in better condition than the area below the site. The average water velocity and gradient were higher at the upper site, whereas wetted width was greater at the lower site. Fast-water taxa were scarce at the lower site. The water was quite turbid when the baskets were retrieved. The native thin leaf pondweed (*Potamogeton foliosus*) dominated the submersed flora (four species). Apparently water clarity is normally good; plants were rooted at depths to 9 feet. No non-native species were found in the pond, but common reed (*Phragmites australis*), which has native and invasive varieties, was present. An algal bloom was noted on September 9.

Results of Data Analysis

Ecological analysis of the ponds showed that temperature and fish assemblages fell into three groupings: upper river reach (Hanson, Gladmar, and I-90 sites), middle reach (Selah Pond 1, Terrace Heights, Newland Pond 1, and Edler Ponds), and lower reach (Parker, I-82 Pond 5, and DeAtley pit) (Figure S2). In general, river and pond water temperatures were lower at the sites at higher elevation. Large percentages of days exceeded a seven-day average of the daily maximum temperature (7-DADMax) (16°C, higher than the current standard) in the middle and lower reaches in summer and fall; somewhat fewer days exceeded a 7-DAD maximum temperature of 17.5°C in these two reaches.

Fish in these three broad ecological reaches were considered in two groups: native (managed) salmonids, and exotic competitor or predator species. If connected, riparian zone gravel pit ponds in the upper reach have potential for providing high-quality native salmonid habitat; these species are already present in the river adjacent to the ponds. Fewer salmonids are present in the

middle river reaches and present only in Edler Pond 3 (post-breach). The lower reach is poor late spring, summer, and early fall habitat for salmon rearing under current water management practices. The warmer water here favors the exotic competitors and predators, at least seasonally. These non-native fish species do not thrive in the cooler up-river sites.

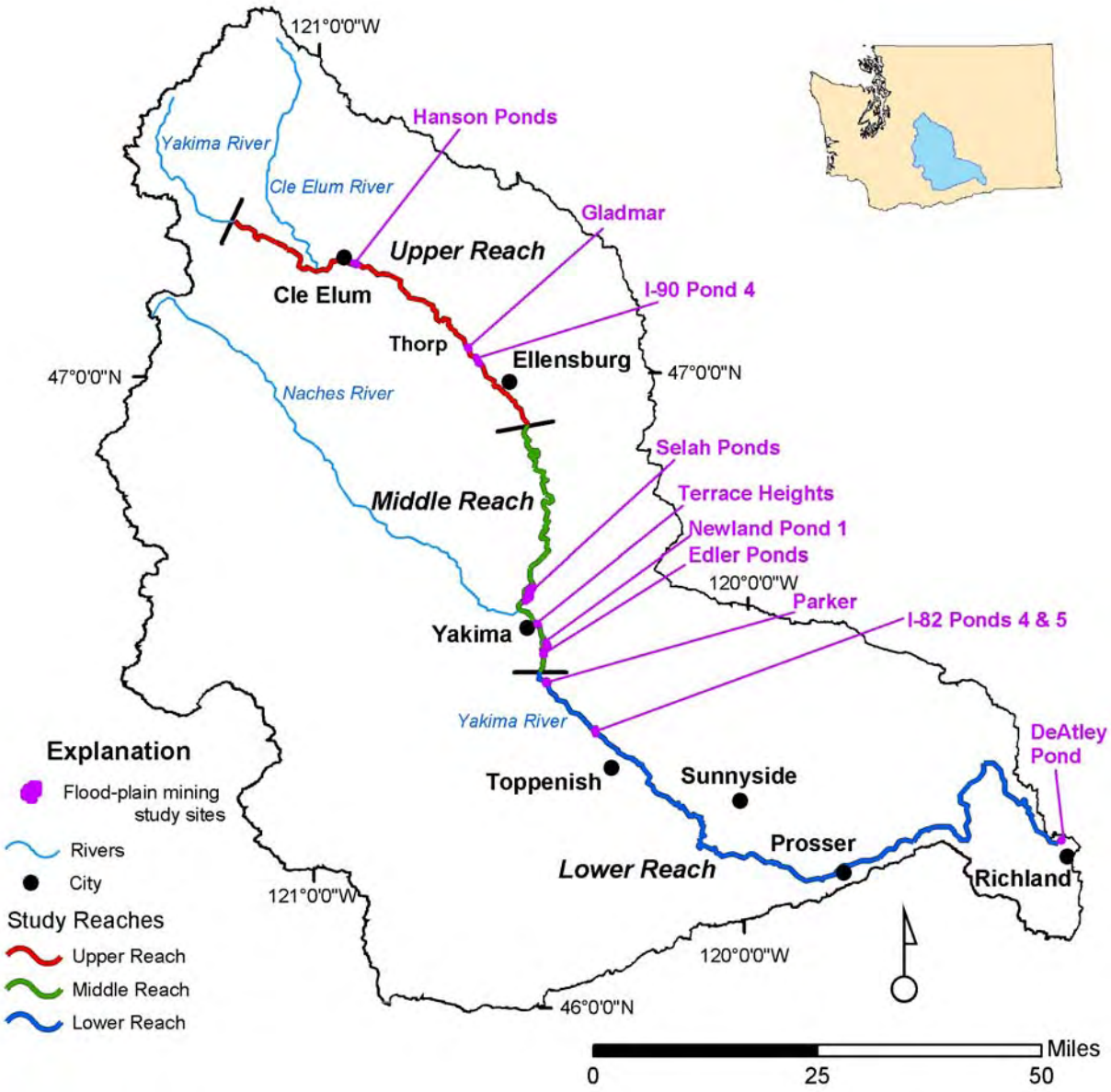


Figure S2. Yakima River reaches and breaks as defined by study results.

Analysis of the benthic macroinvertebrates shows that, in general, the sampled sites above the studied ponds were in better biological condition than those below. These communities are fairly similar at the sites within each reach, but there is an overall change in communities from upper to lower reaches. Precisely what governs the "breaks" in benthic macroinvertebrate community composition among reaches is not yet clearly understood, however, are linked with water quality, quantity, and geomorphic conditions.

Geomorphic conditions at each site must be carefully considered when proposing to connect abandoned gravel pit ponds to the river to create new side channel habitat. The potential for uncontrolled avulsion at some sites is a challenge in the design of the connection, especially with regard to the area available for channel migration. Natural avulsion can cause damage to nearby property and infrastructure, particularly where the river captures a large, deep pond. However, this study shows that the upper reach ponds offer opportunities for developing high-quality salmonid habitat (if large northern pikeminnow populations can be managed). Central to the success of reclaimed ponds for preferential fish habitat will be designing a connection to the river that minimizes areas of slow water and that will carry flow sufficient to add suitable sediment to the in-stream habitat being created.

Ponds low in the river are sources of exotic competitor/predatory species leakage and are poor candidates for developing salmonid habitat under the current water management regime which causes the adjacent river reaches to be unsuitable for salmonid utilization a significant part of the year. Monitoring the benthic invertebrate community will track changes and assess the ecological health at connected sites.

Next Steps

Reclamation Concepts

Important to successful reclamation of floodplain mines is a thorough understanding of the connections between river channels and floodplains. Washington's Surface Mine Reclamation Act requires reclamation of floodplain mines. Because the relation of river and floodplain is dynamic, detailed hydrologic (e.g., channel migration, historic flooding frequency and magnitude, discharge, sediment transport, avulsion history or potential, ground-water conditions, river and floodplain connection) and geomorphic (e.g., topography) data must be obtained to tailor technically and ecologically sound reclamation plans. Restoration of riparian vegetation and the shoreline biological communities is another vital component of reclamation. Monitoring the establishment of riverine benthic macroinvertebrate communities is a useful method to assess the progress of reclamation efforts.

The general goal of gravel pond reclamation is to restore river ecological function, where feasible. This in turn triggers the need to focus on the ways in which fish use (i.e., species and timing) the mined area and what benefits or detriments might accrue to the fishery if the pond is reclaimed by connection to the river. Challenges facing reclamation project proponents in the Yakima River Basin are that restoring riparian vegetation is difficult in the dry central Washington climate and that empirical data from successful (and failed) prior reclamation efforts, which could provide design and implementation guidance, is very limited.

Conclusions and Future Efforts

The information gathered in this study provides a starting point, a baseline, for permit review, land use and zoning considerations when designing "river reclamation" proposals for existing floodplain mine ponds/pits and for guiding site selection of future such mines. Information about

sediment transport and geomorphology will enhance site selection, design, or reclamation/restoration activities and risk analyses for mining sites and should be heavily factored into the permit and policy review process.

A draft proposal from the U.S. Bureau of Reclamation's Technical Services Center describing a basin-wide sediment transport and geomorphic study sets out a path for completing a major part of the work needed to describe how flow might be managed to achieve optimal results in rehabilitating the floodplain. That project will be central to site selection and risk analysis. The Study Team, in collaboration with other organizations and agencies, is attempting to finalize the scope of the work and obtain funding for this work to proceed.

The goal of this study is to find ways to balance sustaining a healthy river system with the need for continued production of aggregate. Based on related peer reviewed literature and the study findings, the Study Team believes that alterations to the river system brought about by more than a century of mining suggest that the floodplains of the Yakima River are sensitive enough that alternatives to mining in the 100-year floodplain should be investigated. Future floodplain mine operations, if permitted, should be constrained by excavation design parameters that primarily reflect the application of best available reclamation science and that with secondarily regard to the cost of the product mined. Natural or engineered avulsion may achieve the most cost-effective reclamation at certain sites that can benefit habitat and minimize short term and long term flood hazards.

Future research, planning, and permitting decisions concerning floodplain mining and restoration should be based on integration of all the technical results and recommendations in the study report and additional management considerations identified.

Due to the geomorphic uncertainties and dynamic nature of the Yakima River and its tributaries, the Study Team believes that, in an effort to determine appropriate overall management strategies for the suitability of specific future sites for floodplain gravel pits and/or related fisheries enhancement proposals in the Yakima River Basin, consideration should be given to the following five principles:

- Future mines should be sited outside the 100-year floodplain and, if at all possible, beyond the historic (100+ years) channel migration zone, as determined by aerial photograph and topographic map reconstructions. Data and observations within the Yakima River basin, as well as within other alluvial river systems of Washington State, show that natural avulsion into a mine pond is more likely to occur if a pond is situated within the 100-year floodplain and historic channel migration zone.

- At some point in the future (perhaps at geologic as opposed to human time scale), the river <u>will</u> avulse some part of a floodplain gravel mine pits. Avulsion may damage infrastructure (e.g., bridges, dikes, sewer outfall pipes). An effort should be made to reclaim the site such that when avulsion occurs, there is a maximum benefit for salmonid habitat as well as protection of upstream and lateral public infrastructure. Future ponds, if permitted by local and state government agencies to be developed in the floodplain or channel migration zone, should be designed for connection to the river (due to future natural avulsion events) without endangering infrastructure or

encouraging avulsion. Future ponds constructed in these sensitive locations, as well as reclaimed existing ponds, should be designed and excavated to mimic river side channel morphology (length, width, depth, sinuosity) to accelerate conversion to river side channel fish and wildlife habitat when avulsion (natural or engineered) occurs in the future.

- Floodplain mining must not destroy intersections between the modern Yakima River channel and paleochannels where increased hyporheic ground-water flow to the river contributes a high concentration of dissolved oxygen. It is at such locations that salmonid populations congregate (J. Vacarro, U.S. Geological Survey, oral communication, 2003). A layer of gravel between the river and adjacent floodplain paleochannels should be left to increase hydraulic connectivity, protect ground-water resources, and benefit habitat for benthic macroinvertebrates.

- Ground-water flow into and out of mine ponds should be protected. Mining through the Holocene alluvium into underlying less permeable geologic units such as the Thorp or Ellensburg Formations should be prohibited by regulatory agencies because ground-water flow may be reduced. Ponds without ground-water inflow become stagnant warm-water habitat with low dissolved oxygen concentrations.

- Until additional mitigation options, standards, and protocols are in place to address large gravel ponds that pose an immediate avulsion risk to major infrastructures at a catastrophic scale, precautionary site protection measures should be considered.

A review of existing practices and regulatory and policy tools used to evaluate the suitability or risk of specific floodplain gravel pit proposals and related fisheries/habitat enhancement projects should consider the information in this report and the recommendations presented. Furthermore, improving the effectiveness of practice and regulatory and policy tools so as to eliminate or further reduce impacts to the river is important to the development of policy related to this study.

Based on the research findings of this study, it appears entirely possible for a balance among mining and fishery interests to be achieved if appropriate regulatory policies are coordinated, developed, and implemented between local and state agencies and coordinated with industry. The Study Team suggests gravel mining companies may secure future access to aggregate, but in a more costly, environmentally sensitive manner if they want to mine in the channel migration zone or 100-year floodplain. These projects could be submitted as habitat reclamation projects or channel reconstruction/floodplain regrade work with the operational and reclamation design approved by all the regulatory agencies, including WDFW for the Hydraulic Project Approval. Less efficient, more costly excavation and reclamation requirements (e.g., creation of long, narrow, shallow, sinuous pits that mimic a river side channel) will increase the cost of those aggregate products, which pit operators will pass on to the public. This will “internalize” the environmental costs of gravel mining (“cost of doing business”), something that rarely occurred in the past. Mining and reclamation criteria might well be less stringent if alternative upland sites outside of the 100-year floodplain are developed in lieu of targeting the floodplain.

1. OVERVIEW OF FLOODPLAIN MINING IMPACT STUDY

Introduction

Sand and gravel mining in floodplains has been a common practice that provides fairly low-cost, high-quality aggregate with minimal processing. Current floodplain surface-mining practices in the Yakima River Basin involve the creation of pits that fill with water and become ponds or lakes that have various degrees of hydraulic connection to the Yakima River. The Yakima floodplain is now the most heavily mined area of this kind in the state. Proposals for additional Yakima River floodplain gravel pits in a time of Endangered Species Act restrictions and dwindling salmon and steelhead runs point to the need for improved understanding of the impacts of floodplain gravel mining on floodplain habitat that supports important native fisheries.

The effects of mining vary depending on how and where the pits are constructed (e.g., surface area, depth, geometric shape, distance from the channel migration zone), the degree of associated channelization (e.g., dikes, levees, bank barb), alterations to riparian communities, whether the pits have been stocked or become populated with hatchery or exotic fish, and if, or how frequently, the pits are connected to the river. Some avulsed or connected ponds can provide excellent habitat for native trout and salmon species that were historically abundant in the Yakima River system once they fill with sediment, provided that they retain flow adequate to support dynamic channel features and riparian communities. However, gravel ponds along the river's course may also become prime habitat for warm-water and competitor fish that can prey upon or out-compete native species. In addition, the presence of numerous gravel ponds may also contribute to higher water temperatures that can affect the metabolic rates of anadromous salmonids, increasing stress levels and death rates.

Statement of the Problem

Gravel mining in the Yakima River floodplain began at least a century ago, but it has been most intensive since the 1950s when state and interstate highways were being constructed. The Yakima River has approximately 140 active or abandoned floodplain gravel mines (Baker *et al*. 2003), including the state's single largest floodplain mine. Many "grandfathered" mines were not subject to a state-required reclamation plan and have been poorly reclaimed or abandoned. Collectively, these mines have severely altered floodplain function and river ecology.

Associated with floodplain mining are loss of riparian vegetation and suitable spawning substrate for anadromous fish, as well as reduction of active floodplain area and channel complexity through associated dikes and levees and subsequent avulsion events (pit capture). Additional effects of mining are lowered water tables, altered ground-water–surface-water interactions, and changes in water quality such as elevated temperature and pH. All these impacts are detrimental to coldwater fishes and the native ecology of the basin. The extent, scale, and duration of such alterations have been little studied. Therefore, a robust investigation into how floodplain mines individually and cumulatively impact the Yakima River ecosystem was warranted.

To mitigate loss of off-channel habitat for native fish habitat restoration, biologists have considered reconnecting the stream channel to abandoned floodplain gravel pits. However, uncertainty about which, when, and how fish utilize these pits has raised questions about floodplain management, especially in eastern Washington. Investigations of water temperature, geomorphology, and biological indicators, including fish and benthic macroinvertebrates, were the attributes used to determine baseline conditions at selected study sites.

From their regulatory standpoint, managers and elected officials are concerned about new floodplain mining proposals. Thus, another focus of the study was to gain a better understanding of how these mines affect the broader Yakima River ecosystem so that this knowledge can be used in the site selection process.

The Study Team determined the study sites on the basis of pit physical characteristics that could be quantified, such as connection to or isolation from the river, depth, distance from river, and relative location (elevation) in river reach in the Yakima Basin. Much of this information was unavailable at the time the project was conceived.

Identifying and quantifying factors that contributed to specific impacts formed a key impetus of this study. The Study Team recognized the need for identifying mitigation actions for impacts at existing and for future mines for incorporation as "best available science" in policy frameworks at various levels. From the analysis of the information, the development of recommendations and site selection parameters for enhancement of existing sites, as well as considerations for future sites can be started.

In a letter to the Salmon Recovery Funding Board Technical Panel dated December 4, 2000, Randall Doneen of the Washington State Department of Ecology Permit Assistance Center wrote:

> The focus of the study is to get a thorough understanding of how these gravel pits impact the river ecosystem. The integrated nature of this study will allow the results to be used in a variety of ways. Evaluation of how these gravel pits impact river temperatures could have direct implications for salmon survival in the Yakima Basin, as water temperature in the Lower Yakima Valley is a well known limiting factor. Lack of food source due to habitat loss for benthic macroinvertebrates is another aspect of the study that could have broad implications to salmon or other ecosystem functions. Predation and competition from native and exotic species in the gravel pits will be investigated…
>
> Floodplain mining is a classic example of growing human population demands and effects on the natural environment. It has been said that every person in the United States uses 12 cubic yards of aggregate a year. This sort of demand on a resource requires that natural resources be evaluated as to how they can be sustained while still protecting the values we as a society hold as important. An over simplification of the issue can be equated to salmon versus concrete; can the two coexist?

This letter acknowledged that the impacts of mining on salmonid species, their habitat, and river ecology were not well documented and that a science-based consensus among governments and

the aggregate mining industry has not yet emerged to guide decision-makers regarding the appropriateness of new floodplain mines or determining the use of mining “controlled” pit avulsion or other measures to enhance salmonid fisheries habitat. Products of this study, in addition to the partnership itself, will help provide science-based understandings of floodplain mining impacts.

Project History

The Floodplain Mining Impact Study represented a substantial collaborative effort by tribal, federal, state, and local governments. The study partners converged around an issue critical to the Yakima Valley, conceived the project, secured the grant and matching funds, and selected the sites. The resolve to overcome obstacles to this effort is in itself a product of the study, and the cooperative process could be a model for other watersheds.

The Yakama Nation, the Washington State Departments of Ecology (DOE), Natural Resources (WADNR), and Fish and Wildlife (WDFW), and the Yakima County Planning Department formed an unprecedented partnership to undertake a science-based study of the effects of floodplain mining on the Yakima River system. The study partners obtained a Centennial Clean Water Fund (CCWF) grant from DOE. Matching funds to fully fund the study were subsequently awarded by the IAC/Salmon Recovery Funding Board and the U.S. Bureau of Reclamation Yakima River Basin Water Enhancement Project (YRBWEP). In addition, Central Pre-Mix Concrete Co. provided extensive support and cooperation toward the completion of the study.

Contracting a project with three sources of funds to be shared by three State agencies, a local government, and a sovereign nation to accomplish a common purpose was challenging. The effort to resolve interagency issues in which to provide a high level of accountability for use of funds toward product delivery played out at the regional level and at agency headquarters in Olympia.

While the contracts were being developed, the study partners reviewed 30 mining sites and came to consensus on ten that represented desired conditions to be analyzed according to the study design.

From the time matching funds were secured in 2001, all partners scrambled to launch the project. However, working through contract details and resolving the issues surrounding selection of sites to be investigated took longer than anticipated. By the time contracts between WADNR and the study partners for CCWF funds were ready to sign, WADNR concluded that the timeframe for monitoring water quality, temperature, and fish assemblages in 2001 had been lost and that, in light of its budget for the 2002-03 biennium, WADNR could no longer take the lead for grant administration.

The Yakima County Planning Department then proposed extending the project into 2002 and taking on the lead agency responsibility for project administration. The study partners agreed that this approach would allow a more deliberate equipment acquisition and staffing effort to proceed prior to sampling and monitoring in 2002.

Study Team partners recognized that the project offered a rare chance to address floodplain mining impacts from a broad perspective. History has shown that the piecemeal approach could not deal with system-level problems. In recent decades, the legislature has given State agencies greater authority to regulate mining reclamation and to manage and protect natural resources. The Shoreline Management Act (SMA), State Environmental Policy Act (SEPA) and Growth Management Act (GMA) have provided local governments a clear role in siting and regulating floodplain mining and protecting natural resources, including fish and wildlife. With greater regulatory authority and industry cooperation, resource managers may conditionally allow mining, require reclamation, and authorize fisheries enhancement projects. Moreover, the floodplain mining study partners submitted that the study was critical, even required, to understand how these floodplain mines can be used or managed to enhance salmon habitat.

Project Objectives

The goal of the Floodplain Mining Impact Study was to identify impacts of sand and gravel mines on floodplain geomorphology and ecosystems throughout the Yakima River continuum (Appendix A). The study included the following areas of investigation at individual site locations:

- Documenting historic location and use of gravel pits;
- Studying fish assemblages in the gravel pits and in the river adjacent to the pits;
- Analyzing the control of upstream, downstream, and pit usage by benthic macroinvertebrates;
- Analyzing water temperature trends upstream and downstream of, and in gravel pits; and
- Recording geomorphology and bathymetry of gravel pits, including sediment sampling and analysis.

Ten floodplain mines were selected for comprehensive investigations of fish assemblages, benthic macroinvertebrate populations, water temperature, bathymetry, sediment, and geomorphology (Figure 1, Table 1). Sites were chosen to demonstrate a variety of characteristics of floodplain mines so that over time impacts can be identified with specific mine characteristics. The summary of results at a regional scale is described in Chapter 15 and recommendations to be used for analyzing and permitting existing and future floodplain mining is described in Chapter 16. The data from these investigations is being used to create a database that all study partners can use for further investigations and GIS mapping. The investigation results are also being used to develop (a) risk assessment approaches for future gravel mining operations and (b) a decision framework to identify management tools for existing pits.

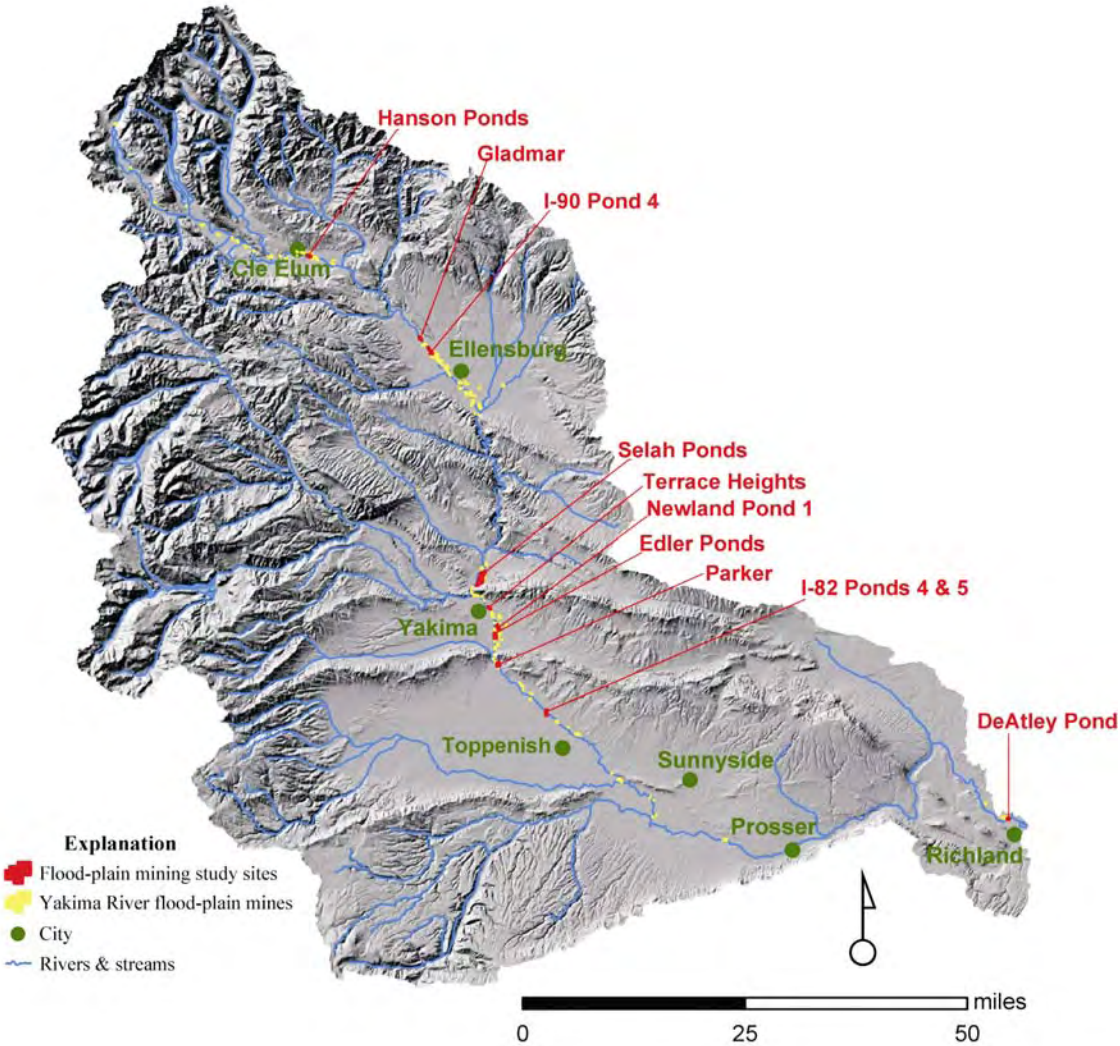


Figure 1. Location of study sites in the Yakima River Basin.

Table 1. Site locations, by river kilometer (above the mouth) and General Land Office grid from south to north. Not all pond names are official.

Site	Pond Name	River Kilometer	Location	Comments
10	DeAtley Pond	4	T9N R28E, S23	Just upstream of Highway 240 bridge
9	I-82 Ponds 4 and 5	155	T11N R20E, S20	Public fishing access
8	Parker Ponds	170	T12N R19E, S20	Yakama Indian Reservation
7	Edler Ponds	177	T12N R19E, S5	North end of Valley Mall Boulevard
6	Newland Pond 1	180	T13N R19E, S33	Adjacent to State Route 24 east of the river
5	Terrace Heights	183	T13N R19E, S17	Avulsed in early 1970s
4	Selah Ponds	192	T14N R19E, S31	Large group of pits
3	I-90 Pond 4	255-257	T18N R18E, S29	Interstate 90 mile post 103
2	Gladmar	259	T18N R17E, S13	Avulsed in February 1996
1	Hanson Ponds	291	T20N R15E, S36	Near Cle Elum, connected to river in 2004

Roles, Responsibilities, and Goals of Study Partners

Yakima County Planning Department

Washington's Growth Management Act encourages local governments to plan for sustainable economic growth, which means that continuous economic development never exceeds the capacity of the land, environment, or community to sustain that growth (Lingley and Jazdzewski 1994). In order to achieve and balance planning goals, Yakima County must therefore map and designate mineral resources of long-term commercial significance. These resources must represent high-quality materials that have the lowest environmental, social, and economic costs. However, historic and current aggregate mining practices have heavily favored the economic and social costs over the environmental costs.

As a response to recommendations made by the Governor's Land Use Study Commission, the Washington State Legislature during its 1998 session asked WADNR to map gravel and bedrock resources that could be used for the construction of homes and infrastructure. The Study Commission sought this information to assess and protect mineral resources from urban development and other intensive land uses. The goal was to provide local governments data from which to implement better long-range planning strategies under the GMA (Lingley and Jazdzewski 1994).

In order to comply with the GMA, the Yakima County Board of Commissioners established a Mineral Resources Task Force (MRTF) in 1999 and appointed members, as called for under Plan 2015 (the Yakima County Comprehensive Plan). Members of the task force were chosen to represent various interests and concerns dealing with mineral resources issues. The MRTF met bimonthly from February through November of 2000 and again from February 2001 to winter of 2002.

In November 2001, the MRTF released a report of preliminary recommendations to the Yakima County Planning Commission (Appendix B). The MRTF is now awaiting the policy review and recommendations of the Floodplain Mining Impact Study in order to continue their work. This work includes completing a supplemental environmental impact statement, which will identify mineral resources of long-term commercial significance that meet the proposed site selection criteria (Table 2).

The recommendations and conclusions of this report will be subject to additional technical and public review and, as appropriate, incorporated as "best available science" in mineral resources planning and permitting in Yakima County. In addition, recommendations included in this report will identify potential habitat improvement considerations and strategies for existing and future floodplain mines that have the potential to provide benefits to native fish and wildlife, recreation, and sustainable community quality of life.

Table 2. Site selection and evaluation criteria of the Yakima County Mineral Resources Task Force (prepared in 2001).

Original	Proposed
1. Quality of the resource	1. Quality of the resource
2. Volume of the resource	2. Volume of the resource
3. Topographic characteristics of the site	3. Topographic characteristics of the site
4. Access suitability	4. Access suitability
5. Compatibility with land use patterns in the area	5. Compatibility with present and planned land use patterns in the area
6. Proximity to urban and rural settlement markets	6. Proximity to existing and planned markets
	7. Environmental sensitivity
	8. Cultural resources and aesthetics

Washington State Department of Ecology

DOE initiated the evaluation of ecological conditions near and in floodplain gravel mining operations along the Yakima River to determine if reconnecting pits to the main stem would alter instream communities and if gravel mining activity adjacent the river would have secondary effects on biotic community condition. Reconnecting old gravel pits can locally provide benefits by increasing the area of useful refuge for certain life stages of anadromous salmonids and increasin*g* availability of the aquatic invertebrate food source that supports the top end of the aquatic food chain.

Aquatic invertebrate communities are a superior means of evaluating physical and chemical changes in freshwater environments because of their sensitivity to a variety of stressors and their ability to reveal impacts on stream integrity that are not readily measured with a periodic water sampling strategy. The sample design and information collected at each pit site along the Yakima River made it possible to detect critical elements of the setting that can make instream biota susceptible to severe degradation from gravel mining activities. Alteration of stream temperature and certain water-quality parameters were considered the greatest risks posed by mining and were thoroughly characterized at each pit site.

The work conducted in this study was designed to establish a baseline for monitoring effectiveness of avulsion projects. In addition, the extensive data for benthic macroinvertebrates, fish, and temperature collected along most of the main stem Yakima River will be useful in evaluating the overall effectiveness of pollution control mechanisms currently in use in the Yakima Basin.

Washington State Department of Natural Resources

To help accomplish the study goal, WADNR defined and compared physical characteristics of the mine sites (i.e., connected or not connected to the river, deep or shallow, far from or close to the river). Use of global positioning systems (GPS) software and depth finder techniques produced accurate maps of the current bathymetry and morphology of selected floodplain mine

pits along the Yakima River. Particle-size measurements for bottom samples within each pond as well as in adjacent river reaches defined substrate character.

Washington State Department of Fish and Wildlife and the Yakama Nation

The WDFW and the Yakama Nation manage the Yakima River to protect and enhance salmon (chinook, coho), steelhead, and resident trout (cutthroat, rainbow, bull) populations for tribal subsistence and recreational fisheries. The co-managers were most concerned about effects that floodplain gravel mining may have on these native, actively managed salmonid species. Primary floodplain mining study interests and goals were (1) to determine how to protect and enhance salmonid habitat in Yakima Basin floodplain areas where gravel pit ponds already exist, and (2) to develop recommendations for the siting and designing of future floodplain gravel mines in order to protect juvenile salmonids and enhance opportunity for rapid conversion to riverine salmonid habitat after pit abandonment.

This study will assist future efforts in determining which existing pit ponds should be protected from river avulsion to prevent juvenile salmonid mortality resulting from contact with concentrations of non-native predatory fish species. WDFW and the Nation also sought to determine which abandoned gravel pits are suitable for connecting to the river to enhance salmonid habitat. In addition, these partners recognized that specific “best management practices” (or BMPs) need to be developed to (1) defend detrimental “predator ponds” from natural avulsion, and (2) connect beneficial “salmonid habit ponds” to the river. Technical recommendations developed from this study are intended to be forwarded decision makers and regulatory for policy review, consideration, adoption, and implementation in permits, plans, and regulations, especially for siting, designing, and permitting future floodplain mining.

Summary

The goal of the study was to provide an interdisciplinary review of the data collected and analysis performed in this effort. This report includes a consolidated, well-integrated set of individual site recommendations and regional ecologic characteristics that will help evaluate and, the Study Team hopes, better predict:

- River channel changes over time and the likelihood of avulsion triggered by mining or mitigation measures;
- Temperature and water quality changes to salmonid habitat as a result of mining in the floodplain;
- Ways to determine criteria for discerning whether, and under what conditions, it is appropriate to use fisheries enhancement projects to reclaim mining sites (e.g., reconnecting old ponds to the river); and
- What mitigation strategies are effective, and what impacts cannot be successfully remedied (or ameliorated).

Although the interim report by this Study Team identified draft recommendation and considerations for each of the study sites, this final report looks more closely at fish usage and also determines how to correlate that data with benthic macroinvertebrate data (food source), pit bathymetry, sediment composition, and water temperature. This information broadens an

evaluation of any gravel pit proposed as salmon habitat. This final report also discusses approaches and pathways to develop a decision framework to guide siting and management of future gravel mining operations.

In summary, this study was designed to help define, ultimately, what type of management is best for specific pits, as well as pits with similar geomorphic and ecologic characteristics in the Yakima River Basin. In addition, the Study Team hoped that specific recommendations for fish habitat restoration efforts could be identified and used to guide future restoration and enhancement efforts throughout the alluvial floodplains of the basin.

2. MANAGEMENT AND REGULATION OF FLOODPLAIN MINING

The Permit Process

Three regulatory agencies are involved in the permit process for proposed surface mines in Washington State: local government (county and/or city), the Washington State Department of Ecology (DOE), and the Washington State Department of Natural Resources (WADNR). Each agency plays a particular role in the permitting, operation, and reclamation process of surface mining within Washington.

Local Government

Local governments are given specific planning and regulatory responsibilities for surface mining by State statute (RCW) and administrative code (WAC):

- The Surface Mine Reclamation Act (RCW 78.44.091) requires formal approval of mine siting and any subsequent use of the mine site. WADNR has jurisdiction over approval of reclamation plans under the Act once a site is approved local jurisdiction and DOE.
- The State Environmental Policy Act (SEPA, RCW 43.21C) was enacted by the Legislature in 1970 to ensure that State and local governmental decision makers consider potential environmental impacts in their actions on projects and broad policy adoption and in non-project actions such as adoption of new plans, policies, or regulations. While the Surface Mining Reclamation Act has preeminence over reclamation plans, this reference to SEPA is important because it provides the authority under which local governments may intervene or alter a surface mine reclamation plan within a designated mining site.
- The Shoreline Management Act (SMA, RCW 90.58) was enacted by popular vote through referendum in 1972 to protect the uses of shorelines within Washington State. County and city governments are required to adopt Shoreline Master Programs (SMPs) to provide policies and regulations for land uses within shoreline jurisdictions. DOE approves the local SMPs and maintains a review and oversight role in the shoreline permit approval process.
- Comprehensive plans and development regulations provide the policies and implementation tools that frame land-use and zoning decisions, consistent with the 1990 Growth Management Act (GMA, RCW 36.70A). This legislation directs local governments to implement State goals, protect environmental resources, and balance competing interests in the uses of land. The GMA also specifically mandates county governments to designate and protect long-term commercially significant mineral resource sites for future use. The GMA is performance-oriented rather than prescriptive in order to give local governments planning under the GMA considerable flexibility in achieving compliance with the requirements of the Act.
- As a response from recommendations made by the Governor's Land Use Study Commission, the Washington State Legislature during its 1998 session asked WADNR to map gravel and bedrock resources that could be used for the construction of homes and infrastructure. The Study Commission sought this information to assess mineral

resources and protect them from urban development and other intensive land uses. The goal was to provide local governments data with which to implement better long-range planning strategies under the GMA (Lingley and Jazdzewski 1994).

The approach taken by local governments within the Yakima River Basin to review surface mining varies according to their adopted comprehensive plans and implementation tools, including local SEPA review requirements, zoning, subdivision, SMPs, and critical areas ordinances. A brief overview by county follows:

Kittitas County

The Board of Kittitas County Commissioners adopted interim measures for the classification and designation of mineral resource lands of long-term commercial significance in 1995 (Resolution 95-37). That resolution provides nine criteria for designating mineral resources sites, "whether active and closed or undiscovered meeting the criteria set forth shall also be classified as mineral resource lands of long term commercial significance. In addition, lands not currently active, but of a historical and economic value to the county, shall also be classified as such. On petition of the landowner, the Kittitas County Planning Department shall designate Commercial Mineral lands, if those lands meet the designation criteria."

The resolution further provides that the Planning Department's decision to designate a site may be appealed to the Kittitas County Board of Adjustment following public notice to landowners within 300 ft of the site. Designated sites are to be included on the comprehensive plan map (Kittitas County 1995).

Yakima County

Yakima County adopted its Shoreline Master Program in 1974. This policy and regulatory program, along with the 1975 County Zoning Ordinance and the 1995 Critical Areas Ordinance, provided primary guidance for floodplain surface mining until 1997, when the Board of Commissioners for Yakima County adopted a new Comprehensive Plan in compliance with the GMA. Plan 2015 incorporated the county's Shoreline Master Program policies and established new land-use and environmental protection goals and policies to address surface mining. An interim Mineral Resource Overlay Plan map designation was adopted in 1998 in anticipation of the designation work to be conducted by the Mineral Resources Task Force (MRTF).

The Mineral Resources section of Plan 2015 describes three basic goals: to identify and protect long term supplies of commercial aggregate sands, gravels, and rock; to recognize that the resource is nonrenewable and must be protected from incompatible uses; and to ensure that mineral resource site utilization is consistent with other Plan 2015 goals. Two objective benchmarks were set for further policy and regulatory work:

- Designation of sufficient existing sites and future areas to ensure a 50-year supply, and
- Maintenance of a ten-year supply of zoned Mineral Resources.

A MRTF was appointed in 2000 by the Board of Yakima County Commissioners to refine Plan 2015 criteria for designating mineral resource sites to meet near-term (1 to 10 years), mid-term (10 to 20 years) and long-term (20 to 50 years) community needs for the resource. Members selected to serve on the task force were chosen to represent various interests and concerns dealing with mineral resources issues. The MRTF met bimonthly from February through November of 2000 and from February to December 2001.

The MRTF report (Appendix B) addressed seven of the nine goals within five key categories that ere subject to comprehensive analysis:

Site Selection and Criteria

- Site Designation Options
- Site Mitigation
- Supply and Demand
- Incentives for Mineral Resources Use

The MRTF identified further research and recommendation considerations to complete prior to designation of new sites. In order to comprehensively review and propose land-use and zoning changes for 10-, 20-, and 50-year mineral resource lands, an environmental impact statement (EIS) is required. The County received a Growth Management Services GMA Update Grant in December 2003 to prepare the scope of work and to secure funding to complete the countywide mineral resources EIS.

The County's Zoning Ordinance, adopted in 2000, established a new performance standards-based Mining Zoning District for mining under an administrative site/operations permit when the site is within the plan-designated Mineral Resource Overlay, or for temporary mining when the site is not plan designated. The MRTF is scheduled to reconvene in 2004 to continue mineral resources work, incorporating the findings of this study. The zoning ordinance will also be reviewed for updates and changes.

Benton County

The following information has been excerpted from the Benton County Comprehensive Plan (Benton County 2003):

> The Benton County Comprehensive Plan refers to mineral resources as "aggregates," i.e., sand and gravel deposits and crushed quarry rock. These resources are second in importance to agricultural land as a "natural resource land" in Benton County.
>
> "Mineral resource lands" in Benton County are land areas with commercially viable mineral resource deposits. Mineral Resource lands are required to be protected under provisions of GMA. Mineral lands represent a particularly important local resource opportunity because the cost effectiveness of any particular project requiring such materials is greatly affected by the transport distance from its source to the project site. The presence of these resources in the county at scattered locations in every region is an economic benefit.

> The major use of aggregate resources is for urban and rural residential developments. Construction of both dwellings and road networks consumes substantial amounts of sand and gravel as well as quarried and crushed basalt.
>
> The importance of sand and gravel to the fishery resources of the Columbia River precludes the extensive use of this alluvial source for aggregate supplies. All of these general sites are producers of the kind of high grade sand and gravel that is needed for the manufacture of cement and cement products used in the construction industry.
>
> The principle [*sic*] considerations for the future use of mineral resources are: i) the identification of additional sites; and ii) providing the owners of known commercially viable sites the opportunity to apply the provisions of the County's Mineral Resources Protection Ordinance (Benton County Code 15.10.45) to the sites. Such protection can prevent the sites from having their future exploitation compromised by the location of incompatible land uses on adjacent lands.

Washington State Department of Ecology

In addition to the previously described regulatory review and oversight responsibilities assigned by the legislature to DOE for the Shoreline Management Act, DOE requires a permit to discharge wastewater into state waters (Johnson 1999). This authority is delegated to DOE by the federal Clean Water Act (CWA). The CWA ultimately provides the source of funds to DOE for this Floodplain Mining Impact Study under its Centennial Clean Water Fund.

DOE regulates the amount of water pollution generated by sand and gravel extraction activities through either a general or an individual sand and gravel permit. The sand and gravel general permit (most commonly used) is similar to an individual wastewater discharge permit; however, it is written for a group of facilities that are similar in processes and wastewater characteristics in order to save time and money on behalf of industry and DOE (Johnson 1999). The individual sand and gravel permit is required when a site-specific facility cannot readily meet the environmental standards required by the general permit.

The general permit provides permit coverage for discharges of process water, stormwater, and mine de-watering water associated with sand and gravel operations, rock quarries, and similar mining operations, including stockpiles (Johnson 1999). According to Johnson (1999), "the permit authorizes wastewater discharges to waters of the state of Washington subject to the permit conditions." The conditions of the general permit require that the permit holder apply best management practices (BMPs) toward wastewater treatment.

Washington State Department of Natural Resources

WADNR administers the Surface Mine Reclamation Act, a reclamation law that requires a permit for each mine that (1) results in more than 3 acres of disturbed ground or (2) has a high-wall that is both higher than 30 feet and steeper than 45 degrees (RCW 78.44; Chapter 332-18 [WAC]).

The Surface Mine Reclamation Act was amended in 1993 to assure that every mine in the state is thoroughly reclaimed. WADNR is responsible for ensuring that reclamation follows completion of surface mining. WADNR has exclusive authority to regulate mine reclamation and approve reclamation plans. (Metal mines and mills that meet the criteria defined in RCW 78.56 are regulated pursuant to the Metal Mining and Milling Act.)

Mine operations are specifically to be regulated by local governments or state and federal agencies exclusive of WADNR. Operations are all mine-related activities, exclusive of reclamation. Operations specifically include:

- The mining or extraction of rock, stone, gravel, sand, earth, and other minerals;
- Blasting, equipment maintenance, sorting, crushing, and loading; On-site mineral processing including asphalt or concrete batching, concrete recycling, and other aggregate recycling;
- Transporting minerals to and from the mine, on-site road maintenance, road maintenance for roads used extensively for surface mining activities, traffic safety, and traffic control; and
- Activities that affect noise generation, air quality, surface and ground-water quality, quantity, and flow, glare, pollution, traffic safety, and ground vibrations.

Local governments must formally approve mine siting and/or the subsequent use of the mine site (RCW 78.44.091) prior to receiving a reclamation permit. This "approval" process generally makes local jurisdictions lead agency, according to SEPA rules.

A high-quality reclamation plan is required for each mine, and periodic review and modifications are necessary. These plans specify the permit holder's methods for achieving the following reclamation goals (Norman 2000):

- Segmental reclamation;
- Preservation of the topsoil;
- Slope restoration such that high walls are rounded in plan and section for all mines;
- Stable slopes;
- Final topography that generally comprises sinuous contours, chutes and buttresses, spurs, and rolling mounds and hills, all of which blend with adjacent topography to a reasonable extent; and
- Effective revegetation with multi-species ground cover and trees.

RCW 78.44.091 states, "Where mining on floodplains or in river or stream channels is contemplated, a thoroughly documented hydrogeologic evaluation that will outline measures that would protect against or would mitigate avulsion and erosion as determined by the department [shall be included in the reclamation plan]."

Further, RCW 78.44.141 states:

> Where lakes, ponds, or swamps are created, the permit holder shall provide measures to establish a beneficial wetland by developing natural wildlife habitat and incorporating such measures as irregular shoreline configurations, sinuous bathymetry and shorelines, varied water depths, peninsulas, islands, and subaqueous areas less than 1.5 feet deep

> during summer low-water levels. Clay-bearing material placed below water level may be required to avoid creating sterile wetlands.

Washington State Department of Fish and Wildlife and the Yakama Nation

Washington State and the Yakama Nation have entered into a government-to-government agreement. Under its terms, the Department of Fish and Wildlife (WDFW) and the Yakama Nation co-manage the Yakima River to protect and enhance salmon (chinook, coho), steelhead, and resident trout (cutthroat, rainbow, bull) populations for tribal subsistence and recreational fisheries. WDFW also has responsibility for issuance of Hydraulic Project Approvals for activities within the riverine environment.

The Regulatory Dilemma

The regulatory dilemma surrounding this study includes poor communication, lack of scientific evidence, and decentralized regulation. (See Substitute Senate Bill 5305 Committee 2003.) The interim report by this Study Team (2003) identified problems resulting from the current regulatory process and suggested strategies to improve the process and its outcomes.

While all three agencies are responsible for specific aspects of proposed, current, and abandoned mine sites, historically, there has been a general lack of communication between regulatory agencies and local government. Each entity manages for specific attributes of individual mine sites, while the cumulative short-term and long-term cultural, physical, and biological dimensions may be overlooked. Differences in permit tracking and numbering systems, pit names, environmental criteria, documentation, and monitoring are only few of the problems that make permitting, regulation, and management of sand and gravel sites complicated and hard to manage. As Rachael Paschal (1999) has stated,

> Everyone and no one controls gravel mining. The existence of a large (and confusing) assortment of laws that do regulate industry—for example growth management planning, water quality, and surface reclamation permits—disguises the fact that no single agency is really in charge.

Another problem facing the health of the Yakima River has been the lack of scientific data in the decision-making process. Floodplain management and development has traditionally been difficult due to disagreements over mine siting, operations, and impacts to the river environment and use of management practices to mitigate adverse effects. Pressure from private landowners, public interest groups, the industry, and agencies has resulted in controversial, conflicting mine siting decisions and permit conditions by local government. The State's Shoreline and Growth Management Hearings Boards and the Court system have imposed solutions, but adversarial proceeding and settlement-based rulings have often 'muddied the waters' by creating winners and losers, a process that may not be in the best interest of the river environment or the parties to the proceedings.

In fact, the impetus for this study arose from the consensus of the study partners that a collaborative approach to identifying the science-based foundation for review and approval of

mining within or near the floodplain would be in the public interest. Whereas private landowners and businesses can be held be responsible for individual impacts, local government should function as a key regulator to protect and enhance existing floodplain habitats in partnership with state agencies.

Regulation of activities such as floodplain gravel mining have been generally addressed via Washington's GMA, Shoreline, and SEPA legislation, the State Surface Mining Reclamation Act, and the federal Clean Water Act. However, recent and on-going scientific studies conducted within the floodplains of the Yakima River Basin should provide a strong basis for future land-use decisions within the context of these laws (e.g., Stanford *et al.* 2002; Eitemiller *et al.* 2002).

Policy Issues and Concerns

Local government, state agencies, and the Yakama Nation have specific missions, goals, policies, and regulatory responsibilities to fulfill in the public interest, as defined by their respective enabling legislation or treaty. Assuming that each entity's approach to serving their interest is valid, the combination of jurisdictional, policy, and regulatory differences among them has not yielded satisfactory outcomes in terms of floodplain management and development.

The intergovernmental and tribal efforts by the Floodplain Mining Impact Study partnership takes a major step by using this research to build common understanding of the ecologic and geomorphic impacts of floodplain mining on the dynamics of the Yakima River system. The interim report (Yakima River Floodplain Mining Impact Study Team 2003) provided a foundation for this final phase of the study: an integrated discussion of the impacts, proposed policy considerations based on study research for guiding future collaboration, and proposed projects that could improve the health of the Yakima River Basin.

3. OVERVIEW OF THE YAKIMA RIVER BASIN AND FLOODPLAIN MINING

The Yakima River Basin (YRB) is a large subbasin of the Columbia River Basin and is located in south-central Washington (Figure 2). From its headwaters near the crest of the Cascade Range, the Yakima River flows 214 mi southeastward to its confluence with the Columbia River. Elevation ranges from approximately 8,000 ft in the Cascades to 315 ft at the Columbia River confluence. Climate varies significantly from the crest of the Cascade Mountains to the Columbia River; corresponding annual precipitation ranges from about 140 in. to less than 10 in. The Cascade and Eastern Cascade ecoregions make up 60% of the drainage basin area and supply 85% of the estimated annual unregulated flow (Berg 2001).

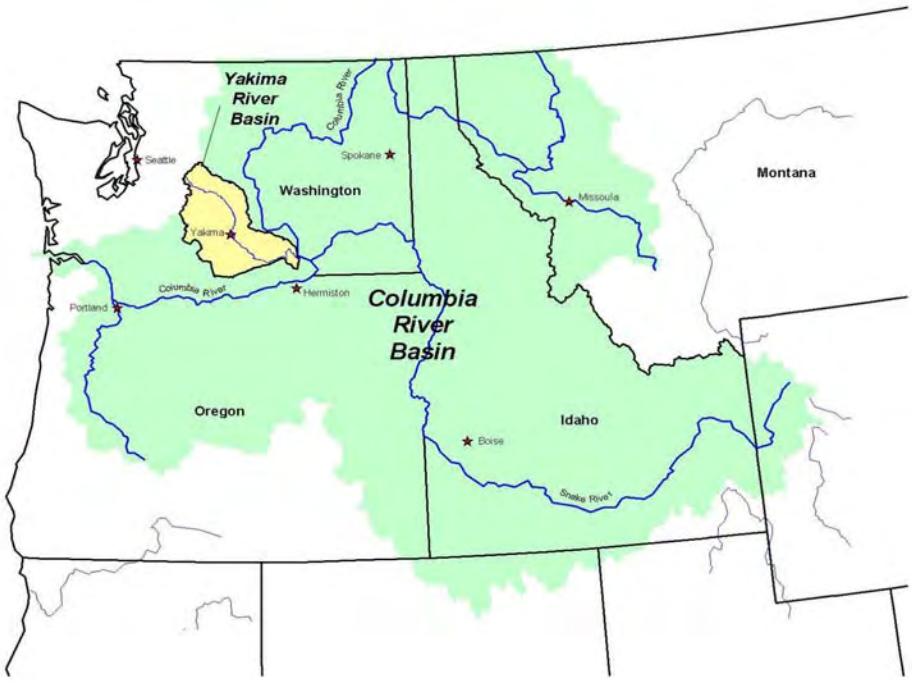


Figure 2. The Columbia River Basin and Yakima River Basin.

In both the Cascade and Columbia Plateau regions, late Pleistocene glacial activity and the network of tributary and main channel flow deposited large amounts of fluvial and lacustrine material in the valleys. This geologic template produced a series of ground-water basins separated by natural knick points (e.g., Selah and Union Gaps) and longer canyons (e.g., Yakima Canyon) (Kinnison and Sceva 1963). The Yakima River cuts through four large subbasins (Rosyln, Kittitas, Upper Yakima, and Lower Yakima). This geological setting influences the hydrologic cycle.

Historically, the hydrologic cycle in each basin was characterized by extensive exchange among the surface and hyporheic (or zone of shallow ground water made up of downwelling surface water) and ground-water zones (Kinnison and Sceva 1963; Ring and Watson 1999). This

exchange would have occurred mainly in the vast alluvial valleys and floodplains, which would have functioned as hydrologic buffers, distributing the energy of peak flows and moving cool, spring meltwater out onto the floodplains. This inundation would annually recharge the shallow, surficial aquifers, a process that would occur potentially well into summer due to extensive and long-lasting snowpack in the Cascades (Ring and Watson 1999).

Ground-water recharge of this nature provided a source and supply of ground water that would have maintained base flow and cooler thermal refugia as summer progressed and air temperatures increased, as well as maintaining higher winter temperatures that would prevent or reduce the risk of anchor ice (Ring and Watson 1999).

Reaches associated with alluvial floodplains have been shown to be centers of biological productivity and ecological diversity in gravel-bed rivers (Stanford and Ward 1988; Independent Scientific Group 1996). In the Yakima basin, bedrock constrictions between alluvial subbasins control the exchange of water between streams and the aquifer system. Under pre-development conditions, alluvial floodplains were connected to complex webs of braids and distributary channels. These large hydrological buffers spread and diminished peak flows, promoting infiltration of cold water into the underlying gravels. Side channels and sloughs provided a large area of edge habitat and a variety of thermal and velocity regimes. For salmon and steelhead, these side channel complexes increased productivity, carrying capacity, and life history diversity by providing suitable habitat for all freshwater life stages in close physical proximity.

At a large spatial scale, each of the Yakima subbasins is conceptualized as being a "downwelling" area (losing surface water to the hyporheic [zone of shallow ground water consisting of downwelling surface water] and ground-water systems) at the upstream end and an "upwelling" area (gaining surface water from the ground-water and hyporheic systems) at the downstream end (e.g., Standord *et al.* 2002; Stanford and Ward 1988). The hyporheic zone extended the functional width of the alluvial floodplain and hosted a microbe- and invertebrate-based food web that augmented the food base of the ecosystem. As snowmelt-generated runoff receded through the summer, cool ground-water discharge made up an increasing proportion of stream flow. Much of this ground water welled up from the gravel into complex channel networks, especially upstream of bedrock constrictions.

This upwelling is driven by the decreasing volume and depth of the sedimentary aquifers causing ground water to move back into the river, tributaries, and irrigation drains in the form of surface flow. Annual inundation and recharge also maintained the connectivity and flow of backwater, or spring brook habitats. These habitats are critical for successful completion of the life-history cycles of numerous fish species and other biota. Historic maps and photographs indicate that these types of habitats were much more abundant prior to anthropogenic alteration of the floodplain (archive, U.S. Bureau of Reclamation [BOR] Yakima Office; Morris Uebelacker, Central Washington Univ., oral communication, 2003).

Five distinct channel provinces are apparent along the altitudinal gradient from Cascade Range source to mouth: (1) high-gradient, largely constrained headwaters, (2) expansive anastomosed or braided alluvial floodplains, (3) constrained canyons, (4) meanders with expansive floodplains containing oxbows, and (5) a deltaic floodplain at the confluence with the Columbia River (Berg 2001).

Six storage reservoirs have been constructed in the Yakima Basin, including impoundment of five natural glacial lakes in the headwaters (see Figure 6): Keechelus Lake (157,800 acre-feet), Kachess Lake (239,000 acre-feet), Cle Elum Lake (436,900 acre-feet), Clear Lake (5,300 acre-feet), and Bumping Lake (33,700 acre-feet); Rimrock Reservoir (198,000 acre-feet) was not a natural lake prior to impoundment. Together they capture approximately one-third of the annual basin-wide runoff. Storage volume equals 1.07 million acre-feet, which leaves an average of 3.86 million-acre feet of unregulated runoff annually (System Operations Advisory Committee 1999; Berg 2001).

Historically, aquifer recharge would have occurred mainly in the winter and spring when evapotranspiration was low and precipitation was high. Irrigation system development has resulted in a reduction in the frequency, magnitude, and duration of floodplain inundation. Thus, recharge of cold, spring meltwater into the aquifer systems has been replaced by recharge of warmer water derived from irrigation later in the spring and summer. Because of regulation and withdrawals for irrigation, the Yakima River experiences periods of both dewatering and elevated flows relative to the historic discharge regime (Parker and Storey 1916; Vaccaro 1986; Yakima River Basin Conservation Advisory Group 1999; System Operations Advisory Committee 1999; USBOR 1999).

From late 1970 to the present, a new direction in resource management has emerged. Recognition of dramatic shifts in land-use practices and the accompanying decrease of fish and wildlife habitat drove this change. This recognition occurred at international, national, regional, landscape, and local scales and was related to an increasing ecological knowledge of how biophysical interactions were structured and functioned. Management strategies shifted. In the Yakima River Basin the change was manifest through radical shifts in the hydrograph ("flip flop") and the monumental efforts directed at fish passage through the historically transformed maze of connectivity.

The hydrograph of the upper Yakima River has been changed substantially by the "flip flop" river operation scheme. In practice, "flip flop" consists of releasing majority of the water needed by the lower basin irrigation districts (downstream of Union Gap) from the upper Yakima reservoirs until early September in order to facilitate spring chinook spawning in the upper basin. During this time, releases from Rimrock (and, to a much lesser degree, Bumping) are reduced. Then in early September, the pattern of releases is reversed: releases from Rimrock and Bumping provide all the water needed for the diversions at Wapato and Sunnyside Dam, and the upper Yakima releases are curtailed.

Detailed historic information on the anthropogenic alterations of critical floodplain reaches of the Yakima River Basin can be found in Eitemiller *et al.* (2002). Ecological and fluvial geomorphic analysis information supporting normative flows by Stanford *et al.* (2002) provides more information.

The Washington State Department of Ecology (DOE) has rated the Yakima River from the confluence with the Cle Elum River (river kilometer 481) to the mouth as having Class A, or "excellent" water quality (for detailed description, see Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A), whereas the American, Bumping, upper Naches,

and upper Yakima Rivers were classified as AA, or "exceptional". However, there are some specific water-quality parameters that do not conform to this classification. For example, 72 stream and river segments throughout the Yakima River Basin have been placed on the 303(d) list of threatened and impaired water bodies by DOE (candidate list for 1998, Federal Clean Water Act 1977). Of these segments, 83% were cited as exceeding temperature standards. Specifically, temperatures exceeded 21°C in the Yakima River and tributaries from the Columbia River confluence to the Cle Elum River and 16°C in the upper Yakima, American and Bumping Rivers.

Furthermore, standards set for DDT and DDT byproducts (including PCB's and other pesticides and herbicides) were exceeded in 15% of the listed reaches. Six of nine sites were located below the city of Yakima, and four of the nine were located in the Yakima River proper. In essence, longitudinal linkage within the river has led to a downstream increase in contamination.

Status of Anadromous Salmonids in the Yakima River Basin

Historical average runs of anadromous fish in the Yakima Basin were estimated at 200,000 spring chinook, 132,000 fall chinook, 110,000 coho, and 80,500 steelhead (Bonneville Power Administration [BPA] 1996). The recent ten-year annual average (1993-2002) adult returns of anadromous salmon to the Yakima River Basin are approximately 7,400 spring chinook, 2,200 fall chinook, 2,500 coho, and 1,600 steelhead (Figure 3). Historical average runs of approximately 68,000 summer chinook and 200,000 sockeye are now extirpated (BPA 1996). Counts of anadromous salmonids in the Yakima Basin have increased in recent years, as have counts throughout the Columbia River Basin. These increases are widely attributed to changes in ocean conditions and other favorable environmental factors experienced in recent years. A more detailed description of the status of anadromous fishery resources in the YRB can be found in Berg (2001).

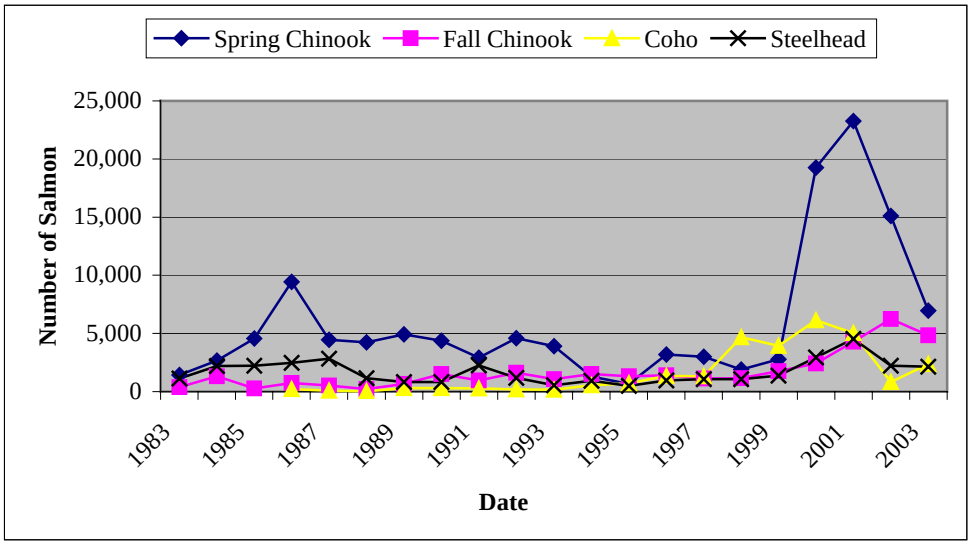


Figure 3. Yakima River adult salmon counts, 1983 to 2004, in the Yakima Subbasin.

Floodplain Mining in the Yakima River Basin

Sand and gravel mining occurs within alluvial deposits. Washington rivers generally have steep gradients and V-shaped cross sections in their upper reaches that facilitate headward erosion. Where the gradient of a river decreases and the valleys broaden, the water velocity decreases (hence, the "competency" of the river to transport sediments) and gravels, then sand, are deposited (Norman *et al.* 1998). Topographic constrictions such as Selah and Union Gaps are also sites of gravel deposition. Deposition rates are greatest at gradient intervals where lateral river movement compensates for aggradation.

Alluvial deposits are highly desired by sand and gravel companies because the deposits are generally well sorted and of high durability and quality. Another factor essential to alluvial mining is location. The highest cost of sand and gravel mining is in transportation; therefore, mine operators maintain that the aggregate mines must be near the product market.

The large alluvial floodplains of the Yakima River Basin have served as regional sources for aggregate for decades. Intensive floodplain mining has occurred throughout the main stem Yakima and Naches Rivers, primarily in response to roadway construction. While transportation projects still use the majority of sand and gravel resources, demand for aggregate resources for rural and urban development is steadily increasing.

Aggregate consists of sand, stone, and gravel that can be used in its natural state or crushed into smaller material. Sand and gravel resources provide construction aggregate for products including asphalt, concrete, road base and sub-base, drain rock, and other construction materials. Aggregate processing generally includes extraction, processing, crushing, screening, and washing.

Methods of aggregate extraction in the floodplain include dredging and digging. Dredging is the process of removing sediment from exposed gravel bars and ephemeral streambeds, as well as beneath the water table in areas such as lakes and rivers, using dredges or draglines. Dredging is no longer practiced in the Yakima River Basin. Digging consists of removing fairly loose or easily broken material via bulldozers, scrapers, and loaders. Digging procedures extract sediment from above (dry-pit) and below (wet-pit) the water table throughout the geomorphic floodplain.

Geomorphic Consequences of Floodplain Mining

Along the Yakima River and tributary streams, floodplain mining has transformed large areas of floodplain into hundreds of open-water ponds. Pits range in depth and size. Many inactive pits are steep-sided and lack irregular shorelines, offering little habitat for aquatic vegetation and wildlife. While recent efforts to enhance reclamation of active and proposed floodplain gravel pits include creation of irregular shorelines, gentle sloping banks, and shallow depths and the construction of small islands, these pond design features treat the reclaimed site as a static floodplain feature isolated from the river channel migration zone.

Pond water level generally mimics that of the local active channel. These ponds are commonly separated from the active channel by a narrow strip of land that in many places consist of dikes or levees. Engineered structures, such as dikes and levees, are designed to control flood events by

channeling the river. Such structures are commonly reinforced with riprap and are maintained to avoid the establishment of large riparian trees and riparian vegetation because they lack deep soils suitable for trees or are actively managed to prevent large vegetation from becoming established because of the potential threat to levee stability posed by tree root penetration.

Channelization by engineered structures can alter flow velocity and consequently modify the substrate, which can change benthic macroinvertebrate populations (Brookes 1988). Furthermore, when the thalweg is moved or deflected by dikes or levees, that realignment may have downstream effects on the banks and channel and can scour salmon spawning habitats (Norman *et al.* 1998). In addition, channelization has resulted in a substantial loss of lateral channel migration (channel complexity), a process that helps dissipate flood forces (Clark 2003). During high flood stages, flow energy is concentrated within the active channel, increasing the chance of avulsion as the river tries to diffuse its flow velocity and dump bed load (Kondolf 1994). Thus, during major floods, channel change can be highly unpredictable.

Floodplain mining generally involves the construction of dikes, levees, and/or placement of riprap along the adjacent channel to prevent the river from flooding or overtopping the mine site during high flows. Gravel pits adjacent to the active channel often are the path of least resistance during high flow (Kondolf 1994). Thus, gravel pits are especially vulnerable to capture during major flood events. Moreover, channelization features can be damaged when an adjacent pit is being de-watered for mining purposes (Norman *et al*. 1998). During floods, a large static head exists between the higher river water surface and that of the pit. The dikes and other structures are potentially further weakened by the head difference between the normally higher river level and the pond water level that is lowered by dewatering, increasing the risk of avulsion (particularly during high flows). Floods that overtop dikes can allow a river to rapidly head-cut through these structures as the flow drops from the river surface into the pit (Norman *et al*. 1998). However, bankfull discharge for long durations has the potential to do as much or more geomorphic work as a high-magnitude flood of short duration. Moreover, bankfull discharge occurs as a nearly annual event compared to the much longer return intervals of high-magnitude events. Frequent bankfull events can set the stage for large-scale geomorphic change by moderate- to high-magnitude floods of short duration.

One of the primary issues surrounding the existence of gravel ponds is pit capture, or avulsion. According to Kondolf (1997), pit capture is most likely when flowing through the pit offers the river a shorter course than the currently active channel. Avulsion events are typically associated with large-magnitude floods. Avulsion is characterized by a sudden change in the course of a river; the river breaks through a low point, such as meander neck or gravel pit (Norman *et al*. 1998). Changes in channel form that usually takes many years by the gradual shifting of the channel can be accomplished by one flood event (Dunne *et al*. 1976). Dunne *et al.* (1976) also noted, “the presence of many abandoned gravel pits in the floodplain increases the chances of future diversion because the river is capable of breaching any of the dikes surrounding the pits.” Kondolf (1997) stated that once a pit is captured, “the formerly off-channel pit is converted into an in-channel pit, and the effects of instream mining can be expected, notably propagation of incision (head-cut erosion) up and downstream of the pit.”

According to Dunne *et al.* (1976), when a pit is breached in an upstream then downstream occurrence, the river pours through the opening and into the slack water of the flooded pit, rapidly dropping its sediment load. As flooding continues the sediment accumulates, creating a causeway across the floor of the pit, and the river flows in a channel lined by levees across the top of the causeway embankment. Eventually the causeway will extend to the downstream end of the pit. Thereafter, the river will transport its sediment through the newly built channel across the pit, leaving a stagnant pond on each side of the levees of the newly formed channel. From this point on, a continuous new channel will extend from the original upstream point of avulsion to the downstream re-entry point and the newly-formed lateral levees are certain to be overtopped in the future.

Clark (2003) has determined that an overall decline in channel complexity in the Union Gap reach occurred from 1945 to 1971 as gravel pits were mined and captured by the river (Figure 4). This analysis was conducted using current channelization features (referred to as limits or zones) throughout all time periods. Subsequently, a rebound in channel complexity was observed; once the mining ceased, the pits filled and began to pass sediment (Figure 4). Individual zone responses varied, but all showed similar trends. This process has not been documented for other reaches of the Yakima River. However, the Union Gap reach is likely to have the fastest recovery rate from gravel pond avulsions of any of the other reaches due to the high volumes of sediment influx from the Naches subbasin (Table 3).

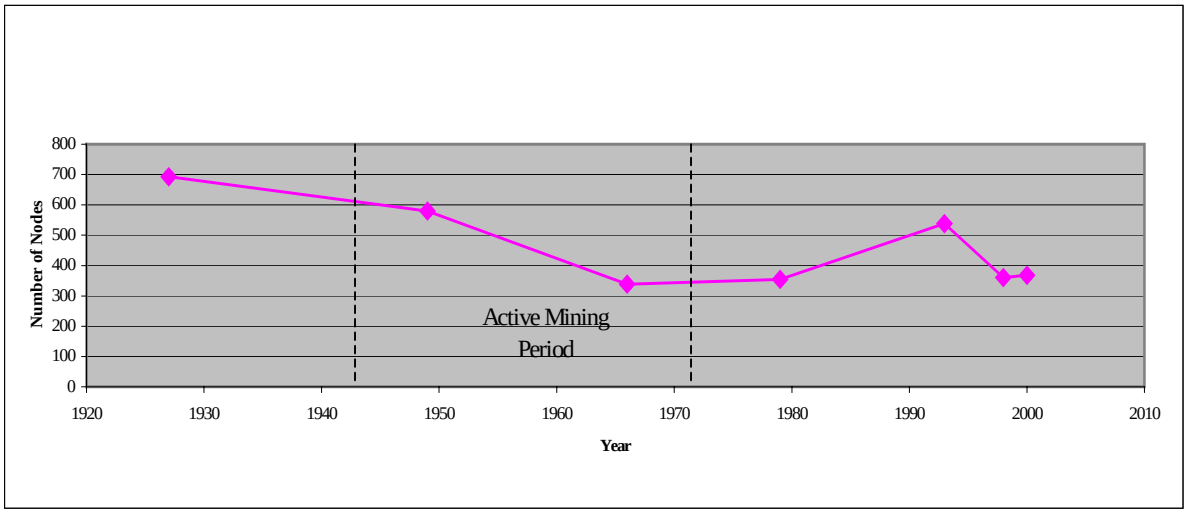


Figure 4. Nodal analysis of the Union Gap reach (total). The number of nodes equals the number of points of confluence or separation within the channel configuration of the Union Gap reach with in the active floodplain (channelized floodplain). The larger the number of nodes, the more complex the channel.

Table 3. A comparison of the total volume of sediment in each reach with a cut-volume associated with the 1999 channel position (from Stanford *et al.* 2002).

Reach	River Length (km)	Total Volume (m^3)	Normalized Volume (m^3/km)	Cut Volume (m^3)	Cut % of Total
Cle Elum	11.2	12,375,535	1,101,026	794,094	6.4
Kittitas	8.5	14,599,497	1,715,570	794,097	5.4
Naches	11.9	10,776.689	904,844	2,394,482	22.2
Union Gap	9.7	8,529,963	883,934	1,696,542	19.9
Wapato	41.4	60,116,120	1,450,679	NA	NA

According to Clark (2003):

> During the gravel-mining phase (from about 1945 to 1973), channel complexity decreased, especially during the peak of the mining activity, which occurred in the early 1960s through the early 1970s in conjunction with the construction of Interstate 82. The drop in channel complexity can be attributed primarily to channel simplification associated with mining and subsequent pit capture during high flow events. In addition, the presence and configuration of the channelization features themselves probably exaggerated the flow processes that influenced the pit captures during the active gravel-mining phase, but was not the primary factor in the decline in channel complexity, as seen in the increase in nodes in the Union Gap reach once the mining in the zones ceased (Figure 18). Moreover, the high flow events of the early and mid-1990s were especially critical to the mobilization and influx of sediments from the Naches River into the Union Gap reach, contributing to the increase in channel complexity from 1979 to 2000 [p. 49-50].
>
> The Union Gap reach is a highly dynamic floodplain. Due to frequent and favorable flow and sediment influxes, largely from the Naches River, these flood pulses have resulted in multiple gravel pit captures throughout the reach. However, these same processes have resulted in the self-reclamation of the Union Gap reach, as measured by nodal analysis. Though channel complexity is only one or many parameters that measure systems' responses to anthropogenic impacts, this research demonstrates that the fluvial geomorphic regime of the Union Gap reach has the power to reclaim itself in a highly effective manner under historic hydrologic conditions [p.73].

Impacts to Riparian Vegetation

Regulated flow, channelization, and land-use practices (e.g., mining, grazing, urban development) have severely impacted the riparian communities of the Yakima River Basin. Current floodplain mining operations involve stripping vegetation and topsoil (overburden), excavating commercial aggregate for processing, and pumping to evacuate infiltrating ground water as the deepening excavation intercepts the water table. This lowers the water table, resulting in a lack of viable seedbeds (for cottonwood recruitment) and enhanced opportunities for the establishment of noxious weeds. Loss of riparian cover also changes nutrient cycling and increases water temperature (due to loss of shading).

Impacts to Water Quality

The primary environmental effects of gravel extraction are related to physical disturbance of aquifer materials and exposing the aquifer's water to air by forming a pond or lake. For mines excavating above the water table, the potential water-quality problems are similar to those posed by storm-water disposal in any other environmentally sensitive area (Mead 1995).

Types of Wastewater: Process Water, Mine Dewatering Water, and Storm Water

The Sand and Gravel NPDES and State Waste Discharge General Permit (Fact Sheet) for Washington State (WSDOE 1999) provides a comprehensive discussion of the various types of wastewater associated with aggregate mining and processing. The general permit authorizes the discharge of three types of wastewater: mine process water, mine dewatering water, and storm water. (The information below is largely from this fact sheet.)

Process Water. Most floodplain mining facilities require the use of some water. Water used for extraction, processing, handling, and transporting the mined material is categorized as process water. Process water is primarily the result of dust control and washing and screening the aggregate. Less obvious sources of process water are concrete truck cleanup, application of an asphalt truck release agent, equipment maintenance, and spills or leaks from tanks and equipment. Facilities that include multiple phases of mining-related activities, from gravel removal through batch plant operations, generate the greatest volume of wastewater and have the most varied sources of potential water pollution.

Mine Dewatering Water. Some mining facilities also produce wastewater from mine dewatering, defined as removing any water that is impounded or that collects in the mine (pit) and is pumped, drained, or otherwise removed from the mine through the efforts of the mine operator. This term includes wet pit overflows caused solely by ground water that seeps into the mine or from direct precipitation into the mine.

Storm Water. Land development practices, including gravel mining, commonly change the quality and quantity of runoff, or storm water, produced by rainfall and snowmelt. Storm water can be a significant source of water at a mine facility and may become polluted by dissolving or eroding material it comes in contact with. Suspended solids typically travel with storm water. Pollutants, whether from urbanization, construction, or mining, can adversely affect water quality and habitat function of water they reach (WSDOE 2003).

Changes in Water Quality

Mining activities typically remove vegetation, soil, and overburden to expose the desired material. An immediate consequence of disturbing the land surface is that the mine area is more susceptible to erosion. Storm water can readily suspend exposed soil materials and transport suspended sediment to surface-water bodies. The resultant elevated turbidity in surface-water bodies can be harmful to aquatic life (WSDOE 1999; Mead 1995); fine sediment can be deposited on the natural sediment of the receiving water and degrade fish spawning areas and instream habitat for other

aquatic life. In some situations, suspended sediment can be associated with other common storm-water and process-water pollutants such as metals, nutrients, and pesticides.

Vegetation and soil protect ground water by providing filtration, chemical and physical reactions, and biological activity that generally remove pollutants before they can enter ground water. Loss of vegetation and soils can make underlying ground water vulnerable to water-quality impacts. Ground-water turbidity may be increased by physically disturbing the aquifer materials through mining, gravel washing, or erosion of disturbed areas. This turbid water can enter the saturated zone below the water table either by direct discharge into surface water created by breaching the water table or by infiltration into coarse materials exposed by mining operations (Mead 1995). Turbidity can have other undesirable effects (e.g., taste, staining, sedimentation), but it is regulated in public drinking water supplies primarily because it interferes with chlorine disinfection and provides organic precursors that may help form trihalomethanes (Driscoll 1986).

Industrial activities, such as mining and aggregate production, may cause or contribute to changes in water temperature. Storm-water heated on impervious surfaces and in exposed treatment and detention ponds may be discharged to streams that are already impaired due to high temperatures from a variety of human-related activities in the watershed (irrigation, land-use practices, etc.). Impervious surfaces (e.g., parking areas, roads, rooftops) also reduce recharge of ground water, a source of cool water contributions to stream flows.

Hydrologic Changes

Within the Yakima River basin, amount and timing of precipitation vary; some streams flow only during the wet winter and spring seasons or only during a runoff-producing rainstorm or snowmelt event. The hydrology of other streams has been altered by seasonal irrigation practices (WSDOE 2003); streams can also be impacted by urbanization (e.g., addition of impervious surfaces, cut and fill activities, compaction, mining) in their watersheds. Drainage patterns and the floodplain are altered.

As a consequence of these changes, stream channels may experience increased flooding and reduced base flows; natural riffles, pools, gravel bars, and other areas may be altered or destroyed. Increased channel erosion, loss of hydraulic complexity, degradation of habitat, and changes in the species present in receiving waters may follow as cumulative effects.

From a stream morphology standpoint, smaller flood events that approximate bankfull conditions and occur naturally every year or two (1.5- to 2-yr frequency) are the most influential discharges and most easily changed with added urban runoff. These smaller flood events shape the channel and are referred to as “effective flows” because over time they move the most sediment and transform the dimensions of a stream channel. When effective flows increase in size, duration, and frequency, channel morphology changes to accommodate the rise in erosive energy delivered to receiving streams on an annual basis (WSDOE 2003). Although specific data and studies for streams in eastern Washington are not currently available, research in other arid, semi-arid, and humid climatic settings has shown that this accommodation commonly takes place by widening and downcutting of the streambed, damaging habitats and potentially reducing biologic diversity.

Wastewater Discharge Characteristics

Wastewater discharge from floodplain mining operations can have high pH, suspended solids concentrations, turbidity, and temperature and may exhibit higher biochemical oxygen demand (BOD) values and contain higher concentrations of petroleum products (WSDOE 1999) than natural stream water. If mining-related pollution is not prevented with "best management practices", wastewater from floodplain mining operations can degrade water quality and aquatic ecosystems.

pH is the negative logarithm of the hydrogen ion concentration. A pH of 7 is defined as neutral, and large variations above or below this level are considered harmful to most aquatic life. The Water Quality Standards for Surface Waters require freshwater pH to be within the range of 6.5 to 8.5 units, with human-caused variation limited to less than 0.2 units for Class AA waters and 0.5 units for Class A waters. High pH (alkaline) wastewater is common near concrete batch plants due to the soluble cement constituents in washwater. pH values ranging as high as 12.5 units have been reported in Washington State water. In addition, acid materials such as hydrochloric acid are sometimes used as a pH treatment chemical or in cleaning operations. If acids are spilled or used improperly, surface waters could be contaminated, resulting in lethal and sublethal toxicity to fish and other aquatic life.

Total suspended solids (TSS) include organic and inorganic materials in wastewater. These materials (including cement, sand, and fine sediment) result from the washing and sorting of mined materials. Storm water can also contain high levels of TSS. These solids may settle out quickly or remain suspended for long periods of time. While suspended, "TSS increases the turbidity of the water, reduces light penetration and impairs the photosynthetic activity of aquatic plants, thereby contributing to oxygen depletion" (Johnson 1999). Large amount of TSS can kill fish and shellfish through abrasive injury or clogging of gills and respiratory passages and can blanket and destroy bottom aquatic habitat after falling out of suspension. Lethal effects on juvenile coho salmon in Washington State have been demonstrated at 488 milligrams/liter; reduced adult coho growth was documented at 1,400 to 1,600 mg/l (Stober *et al*. 1981 as cited in Lloyd 1987).

Water turbidity is an indirect measure of suspended solids and is related to the amount of suspended and colloidal matter in the water. (Turbidity is measured in nephelometric turbidity units, NTU). Turbidity is a common pollutant in surface- and ground-water discharges from sand and gravel mining operations. Reduced juvenile coho salmon growth at 25 NTU has been documented in Idaho (Sigler *et al.* 1984); reduced feeding was documented in juvenile coho at 10 to 60 NTU in British Columbia (Berg 1982; Berg and Northcote 1985). In drinking water, turbidity above 1 NTU indicates increased potential for the presence of other contaminants. Mining operations generally release highly turbid water into infiltration ponds. The Oregon Department of Environmental Quality studied a turbidity plume that extended more than a mile from a gravel mining operation through a highly permeable aquifer. The distance turbidity will be transported in ground water depends on the type and size of the particles causing the turbidity, the pore size of the aquifer medium, the ground-water flow velocity, and the ionic strength of the ground water (Mead 1995).

Total dissolved solids (TDS) are a gross measure of the amount of soluble pollutants in the wastewater. Although Washington State has not developed numeric surface water criteria for TDS, unnatural increases in TDS from industrial sources can be detrimental to freshwater aquatic life. Therefore, the permitted facilities that have the greatest risk of having elevated TDS (e.g., concrete and asphalt batch plants) are required to discharge process wastewater to water. The numeric ground-water quality criterion of 500 mg/l is intended to protect drinking water.

Iron and manganese are monitored in drinking water to avoid undesirable tastes and stains. These substances are commonly found in association with mined materials, but they are typically in their stable oxidized state and not readily soluble. Sand and gravel mining activities do not typically create conditions that would alter the solubility of iron and manganese. Low pH from an acid spill could potentially mobilize iron on manganese, resulting in ground-water contamination.

Oil and grease may pose a threat to aquatic organisms if they become part of the wastewater discharge. Oil and grease "includes thousands of organic compounds with varying physical and chemical properties" (Johnson 1999). In addition, "oil and grease exhibit an oxygen demand… [and] may adhere to fish gills or coat and destroy algae or other plankton" (Johnson 1999). Moreover, some types of oils are toxic to aquatic organisms at concentrations as low as 0.1 milligrams/liter.

Total petroleum hydrocarbons (TPH) and polynuclear aromatic hydrocarbons (PAH) are two other common measurements of petroleum concentrations in water. Salmonid embryos exposed to aqueous PAH concentrations of 1.0 ppb have demonstrated a twofold increase in mortality compared with unexposed embryos and a 10% reduction in growth during their first 6 months in salt water (Carls and Heintz 2000). The presence of an oil sheen on a floodplain mine pond or discharge plume is an obvious indication of TPH or PAH contamination.

Ambient air temperature and solar influences cause temperature fluctuations for process water, mine dewatering water, and storm water. Increased river temperatures can have lethal and sublethal affects on fish and other aquatic life. Surface-water discharges permitted under the General Permit must be monitored during July, August, and September, but ground-water discharge temperature is not. To date, in-stream temperature increases have not been directly linked to gravel mines permitted under the Sand and Gravel General Permit in Washington State, but discharge monitoring requirements for temperature will remain in effect.

Chloride and sulfate concentrations are regulated according to their independent effects on ground-water quality. Elevated chloride can affect the taste of drinking water, and elevated sulfate may have a laxative effect. To protect drinking water quality, the upper limit is 250 mg/l for both chloride and sulfate.

Exotic Fish

While some floodplain pits have the potential to provide habitat for successful spawning and juvenile salmonid rearing, the lower elevation reaches of certain warmer, eastside rivers, such as the Yakima River, are populated with non-native warm-water fish that prey on or compete with

juvenile salmonids year round. Most of the floodplain pits within the study area and throughout the Yakima River Basin contain some exotic fish species.

The Washington Department of Fish and Wildlife (WDFW) actively manages several Yakima Basin gravel ponds for warm-water or "mixed species" (warm-water and cold-water species) sport fisheries. These select ponds may be periodically stocked by WDFW with warm-water game fish and or "catchable size" hatchery trout. During the 1996 regular session, the Washington State Legislature unanimously passed Fourth Senate Substitute Bill 5159, which initiated a Warm Water Gamefish Enhancement Program within WDFW. The stated goal of the program is increased "opportunities to fish for and catch warm water game fish". The funding for the program currently comes from the basic freshwater and combination license fees and is intended to support the management and project goals of the program. One of these goals is to prevent Endangered Species Act and wild salmon conflicts. Consequently, program resources are directed to enhancement and management of warm-water game fish in ponds, lakes, and reservoirs isolated from anadromous fish-bearing rivers and creeks.

However, the presence of long-established, naturally producing, non-native warm-water species, particularly in the lower Yakima and Columbia River systems, represents a significant obstacle to recovery of fall chinook. For example, smallmouth bass have been present in the lower Yakima River since initial stocking in 1925. Recent WDFW studies have demonstrated that Yakima River bass predation on juvenile salmon is significant only for wild fall chinook salmon that rear and migrate through the lower Yakima River as sub-yearlings (Pearsons *et al.* 2003). Salmon species that migrate only as yearling (or older) smolts (e.g., spring chinook, steelhead, coho) are not significantly preyed on by bass or channel catfish.

Within the Yakima River Basin, three abandoned gravel ponds (McCabe, North Fio Rito and South Fio Rito in Kittitas County) have been periodically stocked by WDFW with selected warm-water gamefish species. In Yakima County, WDFW has periodically stocked nine gravel ponds (I-82 Ponds 1 to 7, Rotary, and Sarge Hubbard). No Yakima River floodplain ponds in Benton County have been stocked by WDFW with warm-water gamefish. Aside from these specific ponds managed by WDFW, the illegal stocking of warm-water species into other floodplain pit ponds (privately owned or public) presents a serious problem. WDFW does not intentionally release any exotic gamefish species into the Yakima River or any tributaries.

When pits are over-topped, but not breached (captured) by the river channel during floods, juvenile salmon can become stranded in the pits. These fish become disoriented by the stagnant condition of the pits and are easy prey to species such as largemouth bass (*Micropterus salmoides*). Largemouth bass in particular are highly skilled predators; they have highly developed visual, olfactory, and auditory senses, which allow them to successfully find prey during the night or in highly turbid waters.

Exotic Vegetation

Noxious weeds are non-native invasive plants that, once established, have the potential to degrade fish and wildlife habitat by out-competing native species. Removing gravel requires the stripping of mostly native vegetation and in many places intersects the water table, creating new aquatic

habitat. Thus, exposed soils and newly developed ponds and lakes invite the establishment and encroachment of noxious weeds.

Aquatic species reproduce from plant fragments that root and form new plants or can reproduce via seed dispersal. Once an infestation of an undesirable species occurs, control or elimination is very difficult. Many techniques used to manage aquatic noxious weeds are counterintuitive, aiding in the reproduction process of the plant and destroying remnant native habitat and biota. Several species of aquatic noxious weeds are abundant throughout the Yakima River Basin (Table 4).

Table 4. Freshwater aquatic noxious weeds (Washington State Department of Fish and Wildlife 1998).

Common Name	Scientific Name	Growth or Habitat
Eurasian watermilfoil	*Myriophyllum spicatum*	Submergent
Brazilian elodea	*Egeria densa*	Submergent
Parrot-feather	*Myriophyllum aquaticum*	Submergent
Hydrilla	*Hydrilla verticillata*	Submergent
Reed canarygrass	*Phalaris arundinacea*	Emergent/riparian/wetland
Giant hogweed	*Heracleum mantegazzianum*	Riparian/wetland
Japanese knotweed	*Polygonum cuspidatum*	Riparian/wetland
Indigo bush	*Amorpha fruiticopsa*	Riparian/wetland
Yellow nutsedge	*Cyperus esculentus*	Riparian/wetland
Salt cedar	*Tamarix* species	Riparian/wetland
Garden loosestrife	*Lysimachia vulgaris*	Riparian/wetland
Purple loosestrife	*L. salicaria* and *L. virginatum*	Emergent/riparian/wetland Wetland

Social Impacts of Floodplain Mining

Commonly identified social impacts related to floodplain mining include noise, blasting vibrations, glare, truck traffic hazards, diminished air quality, degradation of water quality and quantity, property damage (avulsion events), declines in native fishery, and aesthetic displeasure. Air and noise pollution commonly fall below infraction levels and are often more noticeable in pristine rural areas than in urban growth areas (Lingley and Jazdzewski 1994).

While implementing best management practices such as berms and noise reduction technology can dramatically reduce such impacts, the most important tool is proper designation of the site for mineral resources extraction and processing. Thus, when identifying and protecting mineral resource lands of long-term commercial significance, site selection criteria, such as the revised criteria listed in Table 2, must be utilized in the designation process. Counties and cities planning under the GMA must address and balance the multiple needs of environmental protection, resource conservation, and affordable housing and must promote a sustainable economy, including jobs related to mineral resources extraction, processing, and use.

4. METHODS

Pit Bathymetry and Sediment

Washington State Department of Natural Resources

Overview

This summary for the ten specified mine sites examined along the Yakima River floodplain includes a description of the methods used to collect and analyze the data for the general geomorphic and stratigraphic setting, pit bathymetry, sample locations, and sediment characteristics in terms of the Unified Soil Classification System.

All the mines studied were developed in recent (Holocene) fluvial deposits of the Yakima River, which comprise unconsolidated to compact conglomerate as much as 80 feet thick and consist of rounded clasts of quartzite, diorite, volcanic porphyries, and basalt in a micaceous quartzo-feldspathic sand matrix, as well as overbank sand and silt and minor clay facies. Pits at the Selah Ponds, Parker, and I-82 Ponds 4 and 5 sites have been excavated to the top of the Thorp Formation, which represents fluvial deposition within the ancestral Yakima River Basin from the Miocene to the Pliocene (≤ 5.2 to 1.6 million years ago) (Walsh 1986; Schuster 1994). Thorp sediments consist of a conglomerate of coarse sand and gravel and moderately to highly weathered and poorly indurated stream terrace deposits; the formation includes a mainstream facies containing rounded to subrounded clasts of durable silicic to intermediate volcanic rocks (Waitt 1979). The Thorp Formation has low hydraulic conductivity compared to younger gravels of the Yakima River.

The bathymetry, sediment distribution, and geomorphology of individual Yakima River floodplain surface mines are a function of several factors, including:

- The method of mining (e.g., shovel, excavator, or tower-dragline, and whether the pit was wet or drained during mining) influences mine depth and remnant sediment distribution within the mine site.
- The purpose of mining (e.g., interstate highway fill material or commercial aggregate source) may influence pit location, area, and depth.
- The thickness of Holocene alluvial gravels in the mined reach and whether the alluvial gravels were mined down to the top of the Thorp Formation can determine pit depth and shape. (Selah Ponds [Golder Associates, Inc. 1998], Parker [Norman *et al.* 1998], and I-82 Ponds 4 and 5 are floored by the Thorp.)
- The initial proximity of the mine to the river channel, the amount of geomorphic work possible along the specific reach of the river as a function of potential reach-scale stream power (rates of channel migration and avulsion), upstream sediment availability to the mined reach, and engineered structures such as dikes and berms adjacent to the mine site (e.g., Stanford *et al.* 2002) determine the sediment size deposited and mined and whether the reach is in equilibrium, aggrading, or eroding.
- The degree of connectivity between the river and its floodplain aquifer near the mine pit (extent of hyporheic zone along the mined reach) is important in determining the

chemistry and temperature of ground-water seepage into the mine site. This was not determined for this study.

- Post-mining history of the mine site, including whether the pit:
  - Is now permanently connected to the river via a natural (avulsion) or an artificial or engineered ingress channel. If connected to the river, the location and size of the connection with respect to river discharge and velocity may influence sedimentation and water quality within the pit (e.g., Gladmar, Terrace Heights, Edler [Pond 3], and Parker ponds).
  - Has dikes that are overtopped (but not breached) during 100-yr flood that will disperse washed-in fines and pit-floor gravel (e.g., Hanson and I-90 Pond 4).
  - Is used as a settling pond for fines derived from an adjacent gravel-mining operation (e.g., Newland Pond 1).
  - Is used as a site for waste rock deposition (e.g., Parker).

Appendix E contains the entire draft report "Pond Bathymetry and Sediment Particle Data."

Methods

Bathymetry

Pond bathymetry was measured at all the study pits except Terrace Heights (which was filled in after a river avulsion event into the pit in the 1970s). Bathymetric and sediment sample measurements were taken on a single day for each pond: Hanson Ponds, May 28, 2002; I-90 Ponds and Newland Pond 1, May 29, 2002; I-82 Ponds 4 and 5 and DeAtley Pond, May 30, 2002; Edler Ponds and Selah Pond 1, May 31, 2002; Gladmar Pond and Selah Pond 1, July 16, 2002; Selah Ponds 2 and 3, July 17, 2002; and the Parker Ponds, July 18, 2002. Measurements were made from a 10-ft-long aluminum Sylvan John boat powered by a Minn Kota Endura-40 electric boat motor (Figure 5 [All figures this section provided by WADNR]). Depth soundings were made by one of two methods:

(1) A 200-ft Leitz plastic measuring tape weighted with 2.95 lb of lead lowered over the side of the boat until it touched bottom. The water depth was recorded as the position of the tape–water interface (at Hanson Ponds 1 and 2 and I-90 Pond 4).

(2) A Humminbird 300TX tri-beam Sonar that forms a continuous 90-degree area arc of uninterrupted bottom coverage and measures water depth directly under the boat to an accuracy of ±1 ft (all other study sites).

Figure 5. Boat and electric motor used for measuring bathymetry and sediment sampling in the ponds.

Periodic comparison of the Humminbird sonar and weighted-lead line values insured data consistency. A hand-held Garmin Global Positioning System (GPS) instrument was used to acquire a spatial geographic reference point (GPS waypoint) for each bathymetric measurement. Waypoints were collected in decimal degrees using the World Geographic System Datum of 1984 (WGS84). Horizontal waypoint accuracy was generally 15 ± 5 ft. Water depth, waypoints, and notes concerning pit geomorphology were recorded in a field notebook. The number of depth soundings recorded for each pit depended upon its size and complexity, with a minimum of 133 soundings for Hanson Pond 1 and a maximum of 1,555 for Selah Ponds 2 and 3.

Pond bathymetry was modeled using geographic information system (GIS) software (ESRI ArcInfo® and ArcView®) and contouring and three-dimensional surface mapping software (Golden Software Surfer®). GPS waypoints, water-depth measurements, and notes were transferred into Microsoft Excel® spreadsheets upon return to the Division of Geology and Earth Resources (DGER) office. (See Appendix F.) All waypoints were projected from WGS84 into Washington State Plane South (FIPS Zone 4602) datum of 1983 in ArcInfo. The perimeters of individual ponds (shoreline–water interface) and the shore of the Yakima River (at approximate bankfull width) were digitized in ArcView utilizing 1996 Department of Natural Resources (WADNR) digital orthophotos, which have a 3-ft pixel resolution and a horizontal accuracy of ± 20 ft. The modeled bathymetric maps for each pond were exported into Joint Photographic Experts Group (JPEG) file format for insertion into this document.

Spatial data (longitude and latitude values) were exported from ArcView into Surfer. Data-point distribution maps (post maps), modeled contour maps, three-dimensional surface maps, and

geospatial grids were constructed from the spatial and depth data collected from each pond site. The geospatial grids were used in Surfer to determine the approximate surface area (acreage) as well as the net volume of aggregate extracted for each pond.

Three mathematical methods were also used to determine the volume: Trapezoidal Rule, Simpson's Rule, and Simpson's 3/8 Rule (Press *et al*. 1988). The difference in the volume calculations by the three different methods is a measure of the accuracy of the volume calculations. The net volume reported for this study is the average of the three values determined by the methods mentioned above.

Artifacts generated in Surfer as a result of the spacing chosen for pond perimeter points resulted in the undulating pit margins shown for the northern shorelines of I-90 Pond 4 and Hanson Pond 1. In reality, these pit-margin walls are smoother than modeled. In addition, pond-wall steepness may be underrepresented in the modeling for I-82 Ponds 4 and 5 due to the spacing of bathymetric measurements.

Geomorphic analysis for each pit site was conducted in the field as well as at the DGER lab. Lab analysis relied upon the measurement of horizontal and vertical distances with the aid of GIS (ArcView), 1996 WADNR digital orthophotos (3-ft pixel resolution and ± 20-ft horizontal accuracy), and U.S. Geological Survey 1:24,000-scale digital raster graphics (DRG) topographic maps.

Sediment Sampling

A total of 33 locations were sampled for sediment at the ten mine sites along the Yakima River floodplain. The position of sample stations was recorded using a hand-held Garmin GPS instrument. Sediment samples were extracted with a shovel over an area of about 1 ft^2 to a depth of about 4 in. and were stored in drained fabric Olephin® bags (Figure 6). A diver with scuba gear sampled sediments on the floors of Hanson Ponds, I-90 Pond 4, Newland Pond 1, and I-82 Ponds 4 and 5 (Figure 7). The diver and GPS survey team afloat in a small boat also made visual observations of sediment attributes on pond floors. At four sites, Hanson Ponds, I-90 Ponds, Terrace Heights, and DeAtley Pond, the bedload of the active Yakima River channel was sampled or described at sites immediately up and/or down gradient of each mine site. High river discharges and/or lack of exposed river sediments during the days of field work prevented sampling the river substrate at other mine sites.

Figure 6. Shovel and sample bag used to collect sediment samples.

Figure 7. Diver with pond-bottom sediment sample and sample bag.

Eighteen samples, with grain size ranging from very fine silt (0.003 in. [0.075 mm]) to cobble (5.9 in. [150 mm]), were submitted for sieve analysis to Geotechnical Testing Labs, Inc., of Olympia, Wash. Samples were not split, and sediment was sorted using one set of U.S. Standard

sieves. Sediment passing through sieves is reported as cumulative weight, percent retained and percent passing (Appendix G). The range of particle sizes was estimated visually for the remaining 15 samples; these consisted mostly of large cobbles (>5.9 in. [>150 mm]) or of silt and clay (< 0.003 in. [<0.075 mm]). Sediment size is reported following the Unified Soil Classification System (USCS) (Table 5). Two samples from the Terrace Heights site were passed through U.S. Standard sieves at the DGER lab to determine the gravel, sand, and fine fractions of Yakima River sediment. Obvious changes in grain size (e.g., silt to sand, sand to cobbles) were also noted visually at other GPS stations throughout mine areas.

Table 5. Unified Soil Classification System particle-size ranges.

Component	Size Range		U.S. Standard Sieve Sizes (For sediment retained on sieve)
	Inches	Millimeters	
Boulders	>11.8	>300	
Cobbles	2.9–11.8	75–19	
Gravel:			
Coarse	2.9–0.75	75–19	
Fine	0.75–0.19	19–4.8	3/4 in.–No. 4
Sand:			
Coarse	0.19–0.08	4.8–2.0	No. 4–No. 10
Medium	0.08–0.02	2.0–0.43	No. 10–No. 40
Fine	0.02–0.003	0.43–0.08	No. 40–No. 200
Fines:			
Silts and clays	<0.003	<0.08	<No. 200

Thermal Investigation

Yakima County Planning Department; Washington State Department of Ecology

Overview

Small increments of temperature change can have profound effects on biological and chemical systems. Consequently, there are many concerns related to the influences of solar-heated water in floodplain mine ponds on anadromous fish in the Yakima River Basin. Water temperatures above 23.89°C (75°F) may be fatal to salmonid species, and temperatures between 15.6°C and 23.89°C (60°F and 75°F) can increase their metabolic rates and stress levels. Because increasing river temperature with water leaving floodplain mines is a central question of the study, identifying how warm water leaving and if a pond changes the temperature of the adjacent river were primary objectives.

Water temperature data were collected in the Yakima River upstream of, adjacent to, downstream of, and within the ten selected floodplain mine sites. Plotting the measurements over time will determine if the mine is contributing to warming of river water.

River and pond temperature data collected from the East Selah and Newland sites (sites 4 and 6) by Central Pre-Mix Concrete Co., Inc. (Central Pre-Mix) personnel, as part of their independent

thermal transport investigation, were used to supplement the temperature investigation (David Brown and Associates 2001). Therefore, the additional site monitoring data included in this investigation utilized the data collection methodologies used by the Central Pre-Mix thermal transport study. Specifically, the data were collected at the same 2-hr intervals and were downloaded once around the middle of each month (~15th–17th). Appendix H contains the draft report on thermal transport at the Selah mine.

Data Quality Objectives

Numeric data were collected as part of the ambient and water temperature study. Onset Optic StowAway® Temp (StowAway) and Hobo® H8 Pro External Temperature (Ext) units were selected to take the temperature measurements (Figures 8 and 9 [All photos in this section provided by DOE personnel]). All StowAway data loggers were labeled and immersed in an ice water bath of a known temperature for 15 min to test the calibration of the instruments. All data loggers had an offload range greater than 0°C but less than 0.1°C.

Figure 8. Optic StowAway® Temp Unit

Figure 9. Hobo®H8 Pro Ext Temp Unit

Each StowAway logger was then programmed to take twelve temperature measurements daily (at 2-hr intervals). The Ext units were also launched to collect data every 2 hours to permit comparison of atmospheric and surface-water temperature trends. In addition to numerically reducing bias, placement and monitoring of data loggers were used to reduce bias.

Sampling Design

The location of the monitoring stations was critical to achieving representative measurements. In general, monitoring stations were located upstream of, adjacent to, downstream of, and in the selected floodplain mine site. Shading by riparian vegetation and flow depth and velocity were also considered during data logger placement. Similarities of shading patterns, depth, and flow were sought during placement of monitoring instruments.

The StowAway data loggers were placed in a housing of perforated polyvinyl chloride (PVC) pipe and deployed in the river/pit lakes (Figure 10). The multiple holes in the housings allowed water to flow through. Each pipe containing a logger was attached to a cable line above the tube so that the tube could be lowered into the river water column, but not enough deep enough to allow sediment accumulation within the tube, which could potentially insulate the data recorders

from the water flow. For pond temperature sampling, the loggers were suspended from a float device or tethered to the shore (Figure 11).

Figure 10. PVC logger housing (for river).

Figure 11. Vertical logger string for ponds.

The tube was deployed as close to the thalweg as possible and in water 2 to 3 ft deep; data loggers were tethered to the shore with a cable (Figure 12). Air temperature loggers were located in shaded places in the riparian zone of each site, not in direct sunlight (Figure 13).

Figure 12. Optic StowAway® in a shaded riparian area.

Figure 13. Hobo® Ext Unit at I-82 Ponds 4 and 5.

Many of the sites lacked riparian vegetation at the desired monitoring locations. While the logger units' housing protected them from direct exposure to sunlight, shading and siltation variables could not be accounted for.

Field Procedures

Most of the data loggers were deployed in early April and collected data from April 15 through November 1, 2002. Supplemental and replacement monitoring instruments were added throughout the duration of the field study. Theft and vandalism plagued sites 7, 9, and 10 (Edler Ponds, I-82 Ponds 4 and 5, and DeAtley), all of which are heavily used public access sites. Therefore, data collected from these sites is less reliable for review and site analysis purposes. Dates of voided data in the summary graphs reflect instrument replacement and or compromised instrument placement (e.g., removal from water or changes in site characteristics such as low or high flows that left the instrument high and dry).

Most sample sites were accessible from the shoreline, and some of the pit lake sites were accessed with a boat. The stations were checked and the data from the loggers was downloaded around the middle of every month. Collection sheets were used in the field for noting download date, time, and site observations.

The data loggers were downloaded using a Hobo® Optical Shuttle for the Optic StowAways® and a Hobo® Shuttle for the Ext Temp units. Data transfer time from the logger to the offload shuttle was approximately 5 to 20 sec. Data collected from Hobo® Optical Shuttle and Hobo® Shuttle was transferred to a computer at the Yakima County Planning Department, processed, and backed up on the network and on compact disks. Once the download process was completed, the data loggers were re-deployed.

Quality Control

Precision at specific monitoring station was maintained by using duplicate data loggers as checks. Additional data loggers were placed at and rotated throughout the monitoring stations to ensure dedicated data loggers were reaching desired data quality objectives (± 1°C).

Data Management and Review Procedures

Temperature data were downloaded in the field using the Optic Shuttle and Hobo Shuttle. The data on the shuttles was then transported back to the office computer and viewed with Onset software (Boxcar Pro 4.0®).

All data was saved to the network and backed up by Yakima County Technical Services Department on a daily basis. Once all data were downloaded and saved on the hard drive, it was imported into MicroSoft Excel for data analysis, editing, and graphing because the Boxcar Pro 4.0 software used to initially download and graph the temperature data has limited plot editing and statistical analysis properties. Data was then reviewed for quality, consistency, and completeness and incorporated into the cumulative data set.

Data from the replicate loggers was evaluated to determine if instruments were working correctly and to assure the precision of the measurements. Typically, temperature spikes were recorded during data retrieval when the temperature sensors were briefly removed from the water body. These temperature spikes were omitted from the finalized Excel spreadsheets, which were

composed of the daily 2-hr interval data points and daily and monthly minimum, maximum, and mean temperatures. (See Appendix I for temperature data graphs.) However, data collected by loggers that were out of water between downloads were included in the spreadsheets and graphs.

Fish Assemblages

Washington State Department of Fish and Wildlife; Yakama Nation

Overview

Fish populations were sampled between May and November 2002 at ten floodplain mining study sites in the Yakima River floodplain between Cle Elum and Richland. Each of the ten floodplain mine pond sites was sampled once, with the exception of Edler Pond 4, which was sampled pre- and post-breach (May and June 2002). In addition, I-82 Pond 3 was sampled, and fish entering and leaving the pond were trapped. In several places, samples were taken from multiple ponds at a study site. Ponds were sampled with a boat-mounted electroshocker, gill nets, and fyke (live trap) nets following a standard Washington State Department of Fish and Wildlife protocol (Bonar *et al*. 2000). River reaches adjacent to each pond were sampled by backpack electrofishing, drift boat electrofishing, and snorkeling. At some sites, identical techniques could not be used to sample river reaches below and above each pond because of variable water depths, flow (water velocity), and/or turbidity.

Species composition was estimated for each study site and compared between sites for both pond and river habitats. By using several of the aforementioned sampling techniques, gear sampling biases were minimized for select species or size groups. A total of 18,617 fish representing 24 species or genera was captured in the samples. Fifty-three percent (9,862) were sampled in ponds and 47% (8,755) in the Yakima River, including side channels and sloughs. The data from all river and pond samples shows that two exotic species, pumpkinseed sunfish (21%) and yellow perch (15%), followed by native sucker (10%), chinook salmon (8%), and mountain whitefish (8 %) were sampled most frequently. The Fish Assemblage Report is located in Appendix J.

Methods

Backpack and boat electroshocking gear, snorkeling gear, fyke nets, and gill nets were used to sample fish populations. (The standard sampling methods described below were altered at some of the sites because of adverse conditions. Deviations from standard methods are described for each site in the individual site chapters of this report.) The data tables referenced in the next sections of this report include details, such as length of river sample sections and percent species composition data for each sample method and site, that are summarized and briefly discussed in the text. Percent in the text refers to the number of fish of a given species divided by the total sample of all species of fish (species composition). Rather than inserting the data tables in the report text, detailed data and charts are presented in Excel workbooks in Appendix K.

Pond Sampling

The sampling methodology, briefly described here, is referred to as “standard protocol” throughout this report (Bonar *et al*. 2000). Pond fish populations were sampled using a boat

electroshocker, two fyke nets, and two gill nets. All three methods were used in each pond. Boat electrofishing was done after dark. The electrofishing unit consisted of a boat-mounted Smith-Root 5.0 GPP electroshocking unit that uses 120 Hz, pulsed DC current ranging from 4 to 6 amps. Fyke nets were constructed of a series of (1) several circular hoops 4 ft in diameter with a trap body 15 ft long made of 0.25-in.-mesh net material, (2) a center lead net (100 ft long x 4 ft deep) that diverts the fish toward the trap from shore, and (3) two wing nets (25 ft long and 4 ft deep) that form a "funnel" with the center lead net to guide fish into the trap body. Variable mesh monofilament gill nets were 150 ft in length and 8 ft deep with the following mesh sizes: 0.5 in.–25 ft, 0.75 in.–25 ft, 1 in.–50 ft, and 2 in.–50 ft.

Three people operated the electroshocking boat, two people in the bow who netted fish and a person who maneuvered the boat. Lake shoreline sections were shocked for a period of 600 sec (10 min) of actual "pedal-down" time; therefore the length of the lake shoreline sampled varied with shoreline complexity and boat speed. The boat was maneuvered along the shore, and fish were captured with dip nets. Normally, the entire perimeter of the pond was fished, or at least three randomly selected shoreline sections were shocked on larger ponds. At the end of each section, fish were identified, total length was measured (in mm), a sub-sample was weighed (in grams), and the fish were released in the middle of the pond to minimize the chance of capturing them a second time.

Two fyke nets and two gill nets were randomly set in each pond, generally on opposing ends of the pond. Both types of nets were deployed before the night electrofishing occurred and pulled and fish collected the following morning. Fyke nets were set with the center lead net tied to and deployed perpendicular to the shoreline; the wing nets were set at a 45-degree angle from the lead net (Figure 14 [All figures this section provided by WDFW]). Gill nets were set with the small mesh net panel tied to and deployed perpendicular to the shoreline extending out into deep water (Figure 15). A weight was attached to the outer end of the lead line and a buoy tied to the float line. As with boat electrofishing, fish live-trapped in the fyke nets were identified, total length measured, a sub-sample weighed, and the fish were released. Most fish sampled in the gill nets were injured or dead. However, any uninjured specimens were enumerated, measured, and released.

Figure 14. Fyke net deployment.

Figure 15. Gill net sampling.

River Sampling

River fish assemblage sampling was also done with three types of gear: drift boat electroshocker, backpack electroshocker, and dry suit/snorkeling gear. However, all three gear types were not used in each sample reach. Backpack electroshocking was the most frequently used method. Various sampling methods were utilized to compensate for “gear bias” and assure a representative sample of the fish community at each site. The effectiveness of each method varies for different fish species, size classes, and types of riverine habitat. Drift boat electrofishing can catch fish at greater depths, but it may miss some of the smaller species or individuals that backpack electrofishing gear might capture. Snorkeling was limited to the upper sections of the Yakima River because poor visibility made snorkeling difficult downstream of the Naches River confluence. Because water velocities and depths varied significantly, taking samples with identical gear types at each study site, as originally planned, was unachievable.

Drift boat electrofishing was conducted with a Smith-Root 5.0 GPP™ electrofishing unit producing pulsed DC current at approximately 4 amps. One person rowed the boat (Figure 16), and a second person netted fish from the bow of the boat. Sample reaches were 2,000 m in length. Drift boat electrofishing occurred during daylight hours; night shocking was judged to be too dangerous in most reaches because of high water velocity and woody debris in the river. Sampling was performed along the shoreline adjacent to the pond site for a minimum of 500 m above and below the site for a total of over 1,000 m. Fish were captured with a soft mesh dip net and placed in a live well until shocking was finished. At the end of each electrofishing reach, fish were processed and released in the same way as they were at the pond sites.

Backpack electrofishing was conducted during daylight hours using a battery-powered Smith-Root Type VII backpack electrofisher with a 28-cm aluminum ring anode and a 305-cm-long cable cathode (Figure 17). Power settings varied between 300 and 500 volts with the output frequency set to 30 Hz pulsed DC current, dependent on the conductivity of each site. Two sample reaches, each 200 m long (above the pond and below the pond), were sampled where possible, but river depth, high velocity flow, and muddy substrate resulted in some sample reaches being less than 200 m. In addition, some sample reaches were longer in order to meet the target collection of 200 fish per sample.

Figure 16. Drift boat electrofisher.

Figure 17. Backpack electrofish sampling.

Snorkel surveys were conducted only on the upper Yakima River reaches (sites 1–4) and at the I-82 Pond 5 site because of poor visibility in the middle and lower reaches of the river. Snorkeling these four sites was performed by a team of three surveyors in the water and one shoreline data recorder, if available (Figure 18). If the recorder was not present, snorkeling personnel recorded the data on PVC pipe arm cuffs and transferred it to data forms later. Each surveyor used a diver's mask, snorkel, and dry suit with wading boots to conduct surveys.

Although intentions were to sample two 200-m sections immediately above and below each pond with the same methods and collect a minimum of 200 fish, adverse conditions at many sites altered this plan. In most places, directly comparable samples were not collected above and below each pond. For example, water depth prevented backpack electrofishing at some sample sites, and turbidity prevented snorkel surveys in other areas. Only one lower river site (I-82 Pond 5) was surveyed with snorkel gear. An attempt was made to sample enough area so that representative habitat at each site was sampled. However, habitat characteristics differed between the paired (above pond/below pond) sites and likely affected the species composition. There is high confidence that in most places all fish species inhabiting each pond and river reach were found by using a variety of sampling techniques.

Particular care was taken while handling *Oncorhynchus mykiss* (juvenile anadromous steelhead and resident rainbow trout) so as to comply with the Endangered Species Act Section 10 "incidental take" permit for boat electroshocking and the Section 4(d) "scientific research limit" (on take prohibition) for other sampling techniques. During backpack electrofishing, fish were placed in 5-gal buckets after being netted, and bio-data was collected after every 25 m of sampling. The fish (Figure 19) were monitored closely during backpack and boat electrofish sampling for burn marks, vertebral damage, and mortality, and power settings were adjusted accordingly to prevent injury or death.

Figure 18. River snorkel sampling.

Figure 19. *Oncorhynchus mykiss* (juvenile anadromous steelhead/ resident rainbow trout, 10 cm).

Migration Trap Sampling

Two fish traps were placed in the outlet channel to record fish entering and leaving I-82 Pond 3, located 6 mi southeast of Union Gap on the WDFW Sunnyside Wildlife Area. Each wood frame,

wire mesh-covered (0.25-in.-mesh hardware cloth) trap was 4 ft long x 3 ft wide x 3 ft high with a cone-shaped entrance tapering from 16 in. to 7 in. diameter. Partitions of 0.25-in.-mesh hardware cloth and 2-in.-mesh chicken wire were built inside the traps to reduce predation on small fish, in the event that large predatory and small fish entered the trap at the same time. The traps were placed in the channel, attached to the bottom with steel fence posts and wire. Wood frame hardware cloth panels were placed in a "V" configuration on each side of the traps to divert fish into each trap. These panels blocked fish from moving in and out of the pond without entering the traps. One trap was placed with the entrance facing the pond, which captured fish migrating out of the pond, and the other was placed facing downstream to capture the fish migrating into the pond from the Yakima River.

All fish collected in the traps were identified, clipped (right or left ventral fin), the length measured, and a sub-sample was weighed. The first time a fish was sampled, it was returned to the water on the same side of the trap that it entered. When a fish was captured a second time, it was recorded again, received a second ventral fin clip, and was again released on the same side of the trap that it entered. The third time the fish was trapped (both ventral fins having been clipped), it was returned to the body of water it was trying to reach. That is, a fish entering the trap a third time from the lake that was attempting to move out of was released on the river side of the trap, and vice versa.

Data Analysis

Fish assemblage data were entered into Excel worksheets. Data collected at each of the ten study sites was compiled for each of three data sets: pond, Yakima River above the pond, and Yakima River below the pond. The Terrace Heights site is completely avulsed (no ponds present); consequently, no pond data was collected, but data was collected in the river at the approximate historic location of the pond. The number of fish by species sampled at each site with each sampling gear type was tabulated. Percent composition was determined by dividing the number of fish sampled for each species by the total number of fish sampled. Then an overall average species composition for all gear types for each pond and for all gear types in the river was calculated. Graphs and charts were prepared in Excel to illustrate the results.

The differences in percent composition between sampling methods in both the ponds and river are significant and demonstrate the challenge in determining true fish community species composition even when using several gear types. Because of the inability to use identical sampling techniques or multiple gear types in a number of areas above and below each pond, making statistical species composition comparisons between river reaches upstream and downstream of each pond site was not possible.

Table 6 is a list of fish species codes that were used to record data in the field and in the Excel data summaries. Rainbow/steelhead (*O. mykiss*) is referred to as *O. mykiss* in the text, and as "RB" in the tables. Most of the *O. mykiss* sampled were presumed to be juvenile resident rainbow trout, but these two life forms are indistinguishable in the field and some individuals, particularly in the Yakima River downstream of Roza Dam, may have been juvenile steelhead, the anadromous form.

Table 6. Fish species sampled during this project and species codes used.

Code	Common Name	Scientific Name	Code	Common Name	Scientific Name
BBH	Brown bullhead	*Ameiurus nebulosus*	MNS	Mountain sucker	*Catastomus platyrhynchus*
BC	Black crappie	*Pomoxis nigromaculatus*	NPM	Northern pikeminnow	*Ptychocheilus oregonensis*
BG	Bluegill	*Lepomis macrochirus*	PS	Pumpkinseed sunfish	*Lepomis gibbosus*
CC	Channel catfish	*Ictalurus punctatus*	RB	Rainbow trout (hatchery)	*Oncorhynchus mykiss*
CK	Chinook salmon	*Oncorhynchus tshawytscha*	RB	Rainbow trout (wild)	*Oncorhynchus mykiss*
CMO	Chiselmouth	*Acrocheilus alutaceus*	RS	Redside shiner	*Richardsonius balteatus*
CO	Coho salmon	*Oncorhynchus kisutch*	SK	Sucker (generic)	*Catostomus* sp.
COT	Sculpins (generic)	*Cottus* sp. or spp.	SMB	Smallmouth bass	*Micropterous dolomieui*
CP	Common carp	*Cyprinus carpio*	STB	Stickleback	*Gasterosteus aculeatus*
CT	Cutthroat trout	*Oncorhynchus clarki lewisi*	WBL	Western brook lamprey	*Lampetra richardsoni*
DAC	Dace (generic)	*Rhinichthys* sp. or spp.	WF	Mountain whitefish	*Prosopium williamsoni*
LMB	Largemouth bass	*Micropterus salmoides*	YP	Yellow perch	*Perca flavescens*
LND	Longnose dace	*Rhinichthys cataractae*			

Because of large sample sizes and the time required for the task, sucker, sculpin, and dace identified to species were infrequently recorded. When mountain suckers were sampled, they were recorded as MNS (mountain sucker); the other two species of sucker were recorded as SK (sucker - generic). Some dace were identified and recorded as a sub-sample of dace to species.

I-82 Pond 3 migration trap data was compiled in a table recording the date of initial capture, first recapture (one ventral fin clip), and second recapture (two ventral clips), by species. Graphs of daily in-migration and out-migration for yellow perch, pumpkinseed sunfish, and totals for all species were developed from the data (Appendix J, p. 23-24).

Benthic Macroinvertebrates and Water Quality

Washington State Department of Ecology

Overview

The role of the Department of Ecology (DOE) in this project was to use benthic macroinvertebrates as an indicator of overall reach or pond habitat quality and relate biological condition to its environment. The three key questions associated with this study are:

(1) What effects do gravel pits located adjacent to the Yakima River have on benthic communities, fish assemblages, temperature, and geomorphology?

The DOE approach to this question was to determine whether the benthic macroinvertebrate assemblages downstream from the gravel pits differ from assemblages upstream from the pits.

(2) What are the effects, design factors, and criteria associated with implementing connection or continued isolation of existing pits?

The DOE approach to this question is to (1) compare upstream/downstream replicate macroinvertebrate samples in the three avulsed sites and relate any differences in the downstream receiving waters to any physicochemical impacts, and (2) rank the benthic macroinvertebrate condition in the isolated pit ponds and relate the condition to pond water quality.

(3) What factors should be considered in siting, designing, permitting, and future use of new floodplain gravel pits?

The DOE approach to this question is to determine possible physicochemical impacts on (1) pond water quality and biological integrity, and (2) avulsed pit pond water quality and biological integrity in the historical pit location and receiving waters.

Methods

Sampling Design and Sites

Three replicate samples were collected at the same time from each gravel pit using gravel baskets filled with 2-in. rounded gravel obtained from a distributor in Tumwater, Wash. At each pit location, four replicates were collected at locations upstream and downstream of each pit, respectively (Appendix M). Thus, a total of eleven macroinvertebrate samples were collected from each gravel pit site. The upstream samples represented control locations. Future monitoring will able to determine what, if any, changes have occurred at the downstream river reach when the gravel pits are reconnected to the river.

Macroinvertebrate communities may indicate the type of pollutants (e.g., sedimentation) that are input to receiving water. Macroinvertebrate community composition, along with trophic state and macrophyte assessments, will rate each pit, in terms of productivity and biological integrity.

Biological expressions (biometrics) were calculated for each macroinvertebrate sample and were compared to others to detect changes that are related to chemical and physical alterations (Table 7). The relation between physical variables and the biotic community was further analyzed to determine which key variables in the riverine environment influence condition of aquatic life.

Table 7. Metrics used to describe benthic macroinvertebrate community condition.

Abbreviation	Full Name	Type of Metric	Description	Predicted Response to Human Disturbance
Taxa	Total richness	Richness	Sum presence of all taxa	Decrease
Ephem	Ephemeroptera richness	Richness	Sum presence of all Ephemeroptera	Decrease
Plecop	Plecoptera richness	Richness	Sum presence of all Plecoptera	Decrease
Trichop	Trichoptera richness	Richness	Sum presence of all Trichoptera	Decrease
EPT	EPT richness	Richness	Sum presence of all Ephemeroptera, Plecoptera, and Trichoptera	Decrease
Ephem	Percent Ephemeroptera	Composition	Sum counts of all Ephemeroptera and divide by the total sample count	Decrease
% Chiro	Percent Chironomidae	Composition	Sum counts of all Chironomidae and divide by the total sample abundance	Increase
% EPT	Percent EPT	Composition	Sum presence of Ephemeroptera, Plecoptera, and Trichoptera counts, and divide by the total sample count	Decrease
% Cling	Percent clingers	Trophic/Habit	Sum counts of all Clinger taxa and divide by the total sample count	Decrease
% Filt	Percent filterers	Trophic/Habit	Sum counts of all filterer taxa and divide by the total sample count	Variable
% Scrap	Percent scrapers	Trophic/Habit	Sum counts of all scraper taxa and divide by the total sample count	Variable
% Pred	Percent predators	Trophic/Habit	Sum counts of all predator taxa and divide by the total sample count	Decrease
Cling	Clinger richness	Trophic/Habit	Sum presence of all clinger taxa	Decrease
LL	Long-lived_richness	Trophic/Habit	Sum presence of all semi-voltine taxa	Decrease
Intol	Intolerant Richness	Tolerance	Sum presence of all intolerant taxa (Wisseman 1998)	Decrease
% Tol	Percent tolerant	Tolerance	Sum abundances of all tolerant taxa (Wisseman 1998), and divide by the total sample count	Increase
% Top 3	Percent top 3 taxa	Tolerance	Sum 3 most numerous taxa counts and divide by the total sample count	Increase
HBI	HBI	Tolerance	Multiply the number of individuals of each species by its assigned tolerance value, summing these products, and dividing by the total number of individuals. On a 0-10 scale, tolerance values range from intolerant (0) to tolerant (10). Tolerance values, modified from Hilsenhoff (1987), are from Wisseman (1998).	Increase

River Field Procedures

River field procedures for benthic macroinvertebrates conformed to standard DOE protocols (Plotnikoff and Wiseman 2001). A D-frame kicknet was used with a 500-micron mesh size. Because evaluation of the gravel pit influence on the mainstem river was confined to pit length,

the reach lengths upstream and downstream of the pit were approximately 10 to 15 wetted widths instead of the standard 40 widths for mid-order streams. Therefore, localized effects were measured. Sample locations varied in each reach, depending on where acceptable riffle habitat occurred. Physicochemical methods for river surveys are outlined in Table 8.

Benthic macroinvertebrate samples were stored in 80% ethanol and transported to Rhithron Associates Inc. for identification. The samples were sorted to a 500-count, and the lowest practical taxonomic effort was employed (Plotnikoff and Wiseman 2001).

Table 8. Methods for river and pond bioassessment and habitat surveys. Footnote numbers indicate methods used: from Plotnikoff and Wiseman (2001)[1], Rosenberg and Resh (1982)[2], Parsons (2001)[3], and Clesceri (1998)[4].

Parameter	Study Application	Method	Accuracy
River benthic macroinvertebrate collection	River	Replicated kicknet sampling[1]	NA
Canopy cover	River	Concave densiometer[1]	NA
Substrate grid counts	River	50-pt grid[1]	NA
Wetted and bankfull width	River	Laser range finder[1]	0.15 m
Gradient	River	Clinometer[1]	NA
Current velocity	River	Marsh-McBirney meter[1]	2%
Pond benthic macroinvertebrate collection	Pond	Artificial substrate sampling[2]	NA
Macrophyte survey	Pond	Qualitative survey[3]	NA
Dissolved oxygen	River and pond	Idiometric, with azide modification, 4500 OC[4]	0.1 mg/L
Temperature	River and pond	Alcohol thermometer or long-line thermistor 2500[4]	0.1 °C
Conductivity	River and pond	Electrode, 2510[4]	1 µmhos/cm
pH	River and pond	Glass electrode, 4500 H[4]	0.1 unit
Total Phosphate	Pond	Ascorbic acid method, 4500 PE[4]	1.39%
Ortho-Phosphate	Pond	Ascorbic acid method, 4500 PE[4]	1.39%
Total nitrogen (Kjeldahl)	Pond	Kjeldahl method, 4500 NB[4]	2.80%
Total Dissolved Solids	Pond	Total Dissolved Solids dried at 180 °C, 2540 C[4]	NA
Chlorophyll a	Pond	Flourometric, 10200[4]	NA

Pond Field Procedures

Pond field methods are outlined in Table 8. Together, the pond parameters comprise a Tier 2A Biological Assemblage Assessment (Gerritsen *et al.* 1998). Gravel baskets were used to collect benthic macroinvertebrates because the coarse sediments excluded the use of traditional grab samplers (e.g., Ponar grab sampler, Eckman dredge). The gravel baskets were filled with 5.3 L of 2-in. round gravel obtained from a gravel distributor near Tumwater, Wash. The baskets were deployed in the fourth week of July 2002. In order to avoid collecting invertebrates associated

with vascular plants, the baskets were placed just past (deeper than) the emergent macrophyte zone. In some ponds, floating macrophytes were present at all depths. In these places, the baskets were placed in pockets where the plants appeared to be absent. Approximately 6 weeks were allowed for colonization of the gravel baskets (Table 9). In September, all the baskets were retrieved with the aid of a 500-µm mesh dip-net. The baskets were temporarily stored in coolers with pond water. Later in the day, the macroinvertebrates were sorted out of the gravel, stored in 80% ethanol, and transported to Rhithron Associates inc. for identification. The samples were sorted to a 500-count, and the lowest practical taxonomic effort was employed (Plotnikoff and Wiseman 2001).

Table 9. Gravel basket deployment and retrieval dates.

Site	Deployed	Retrieved
DeAtley	07/25/2002	09/09/2002
I-82 Pond 5	07/25/2002	09/10/2002
Parker	07/25/2002	09/10/2002
Edler	07/26/2002	09/10/2002
Newland	07/26/2002	09/11/2002
Terrace Heights	07/26/2003	09/10/2002
Selah	07/24/2002	09/12/2002
I-90 Pond 4	07/26/2002	09/12/2002
Gladmar	07/26/2002	09/12/2002
Hanson	07/26/2002	09/12/2002

Water-quality and qualitative macrophyte surveys (Parsons 2001) were conducted in each pond on the day of gravel basket retrieval (Table 9). Temperature profiles were taken at approximately the deepest point in each pond at 0.5-m intervals. Dissolved oxygen, pH, and conductivity measurements were taken at 0.5 m from the surface and near the bottom of the profile. Orthophosphorus, Total Phosphorus, Total Kjeldahl Nitrogen, Total Dissolved Solids, and Chlorophyll a measurements were only taken at 0.5 m from the surface.

Data Quality Objectives

Benthic macroinvertebrate community characterizations were used to determine the influence gravel pits had on both adjacent stream and interior pit biota. Sampling must capture representative conditions at each sample site. Therefore, replicate samples were collected throughout each gravel pit site. Replicates were intended to measure the precision in field sampling and the variability associated with the natural “clumping” distribution in the macroinvertebrate communities. Double-nested freezer bags were used with internal and external labels in order to minimize sample desiccation and eliminate the possibility of mixing up sample identities. Standard sampling methods were used so the results from this study could be compared to other regional studies.

Macroinvertebrate laboratory data quality objectives cover the sorting, enumeration, and identification process. Precision of the sorting process was evaluated by resorting 20% of the original samples or having an independent technician examine the sorted residue for additional

organisms. Sorting efficiency was calculated by the sort count divided by the sort count plus the organisms overlooked. The sorting efficiency for this project was expected to be no less than 97%. No problems with enumeration and identification accuracy were expected. To control for possible mistakes, 10% of the original samples was exchanged among four professional taxonomists for verification and stardardization of identifications.

Data Analysis

Pond Water Quality

Temperature stratification was noted. Deleterious dissolved oxygen (<8 mg/L), temperature (>18°C), and pH (>8.5) conditions were noted and related to secchi depth, nutrient, Chlorophyll a, and Total Dissolved Solids values. These water-quality conditions are considered harmful to aquatic life.

Pond Biology

Invasive macrophyte presence was noted. Comments on macrophyte community structure and anomalies were also recorded. Different biometrics were calculated and used to rank pond biological health. (See Table 7, biometric explanations.) Biological condition was qualitatively related to water quality. Pond biological condition was also used as a benchmark to determine if the biological condition of the avulsed ponds changed to a condition more indicative of a riverine habitat.

River Physicochemical Variables

Temperature, dissolved oxygen, pH, and conductivity were correlated with elevation and river mile. Significant ($p<0.05$) upstream/downstream differences were noted. Histograms were constructed to compare the substrate distribution between each pair of reaches. Non-parametric Mann-Whitney U tests were run to determine if the gradient, canopy cover, average depth, average velocity, bottom velocity, wetted width, and bankfull widths were significantly different between reach pairs. The Mann-Whitney U tests the differences between two sets of samples, determining the probability that they belong to the same or different populations.

River Biology

In order to identify biologically similar reaches, all 80 river macroinvertebrate samples were clustered with a Bray-Curtis similarity measure and an average linkage metric. Cluster analysis is a technique that places similar entities, or samples, into groups, or clusters. The clusters are arranged in a hierarchical treelike structure called a dendrogram (Ludwig and Reynolds 1988). Macroinvertebrate samples that have a relatively similar species composition will appear in the same cluster. The Bray-Curtis similarity measure was used because it measures sample similarity based on common species presence, or overlap, weighted by species abundance. Species data in each sample were log (x+1) transformed. Cluster classes were compared to (1) orientation to the gravel pit (i.e., above or below), (2) elevation, and (3) river mile.

Metrics describing richness, composition, trophic status, and tolerance attributes of the benthic macroinvertebrate community were used to describe macroinvertebrate samples. Non-parametric Mann-Whitney U tests were run on each metric with orientation to the gravel pit (i.e., above or below) as the treatment. Mann-Whitney U tests determine whether on not two sets of sample replicates are significantly different. Non-parametric pairwise correlations between the metrics, elevation, and river mile were also calculated.

Finally, in order to verify the relation between physicochemical variables and biological condition, Canonical Correspondence (CCA) axes were generated using the log (x+1) transformed species data matrix. CCA is an exploratory tool that can be useful when investigating the relation between biological species composition and physicochemical variables, such as elevation, benthic substrate, and water quality. Each CCA axis is defined by a relation between species and physicochemical variables. For example, a CCA axis may be positively related to mayflies and stoneflies, but negatively related to snails and midges. The relation between physicochemical variables and the axes are graphically defined on a bi-plot (CCA axis 1 and 2) by vectors originating from the origin. The location of each sample on the plot is based on the species that it contains. Thus, biological samples can be related to each other, based on their biological species composition and their physicochemical attributes at the same time. All physicochemical variables deemed to be relevant to biological condition from prior analyses were included in the CCA.

5. HANSON PONDS (Site 1)

Location and Site Information

The Hanson Pond complex is located south of Cle Elum and south of Interstate 90 (I-90) along the north shoreline of the main-stem Yakima River (Figure 20; see also Figure 31). The construction of I-90 resulted in extensive removal of gravel resources at this site. Two large ponds were excavated during that construction, and a third smaller pond was excavated later. Gravel was mined to a depth of about 10 ft below the average water surface elevation. When these pits were abandoned, ground water filled them. Ponds 1 and 2 are the focus of this study.

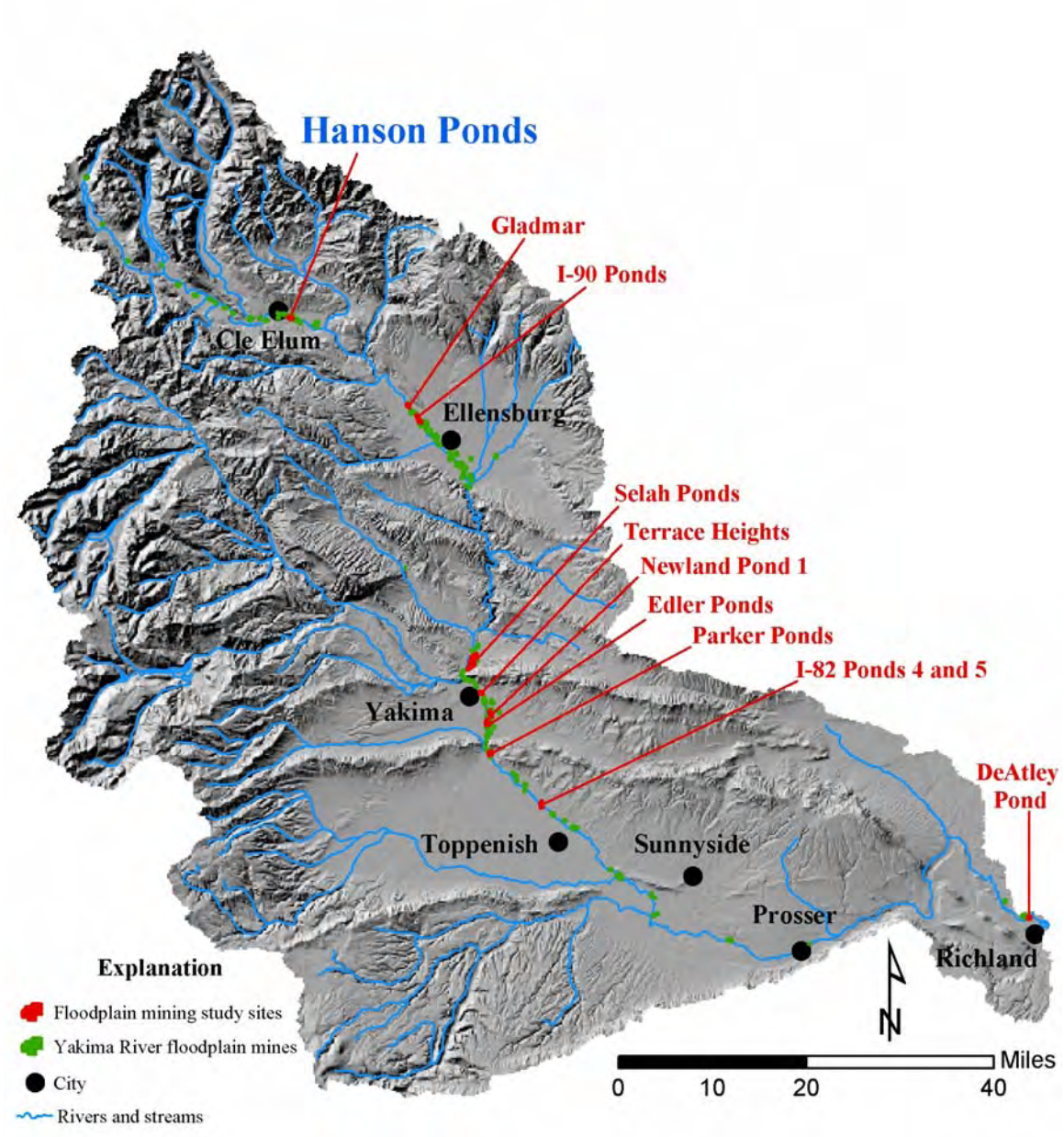


Figure 20. Location of Hanson Ponds (Site 1).

The meandering to slightly anastomosing river has a 1,500- to 2,000-ft-wide channel migration zone for an approximately 2-mi stretch of the river centered on the ponds. The Yakima River slope in this reach (from about a mile above to a mile below the site) is 0.0033, about a 17.4-ft drop in valley floor elevation for each mile downstream.

In 2002, Pond 1 covered 15.8 acres and had a volume of approximately 49,000 yd^3,. Pond 2 had an area of 21.3 acres and an approximate volume of 145,000 yd^3. The two gravel pits were separated from each other by a levee. The ponds were separated from the river by a rip-rap-reinforced dike (levee) and were about 150 ft from the river at the upstream end of Pond 1, 60 to 100 ft from the river at the junction of the two ponds, and 80 ft from the river at the downstream end of the Pond 2 (Figure 21). A potential avulsion point on the outside of a meander bend was at the upstream (southwest) corner of the Pond 1.

In fall of 2003, the Yakama Nation created a side channel through the Hanson Ponds. In February, 2004 the ponds were opened to the Yakima River. There is an armored grade control with an ingress notch. About 10% of the base flow passes through the ponds and returns to the river about 4,500 ft downstream via a wetland complex. The levee road has been ripped, seeded, and mulched, and large woody debris has been placed in the ponds. Other actions have been taken to create a productive lotic environment that adds to the juvenile rearing habitat for spring chinook, coho, summer steelhead, and resident trout; progress toward that goal is being monitored.

Pond Bathymetry and Sediment Sampling

In 2002, the rectangular Hanson Ponds were shallow. They had fairly smooth and gently sloping bottoms (Figure 21); both ponds had a simple bathymetric plan and were not geomorphically complex. The average depth of Hanson Pond 1was 4.7 ft. Along the eastern margin, two depressions reached approximately 6 and 8 ft deep, respectively (Figures 22, 23, and 24). The sides of the pond sloped gently.

Hanson Pond 2 was slightly more bathymetrically “complex” than Hanson Pond 1 (Figures 25, 26, and 27). The pond’s asymmetry had the deeper sections along the north side. In general, depths in the pond increased to the east, reaching a maximum measured depth of 9.5 ft (Figures 25, 26, and 27). Side slopes were steeper along the northern and eastern margins of the pond. A low sill at -4 ft separated a small depression in the northwest corner from the main east portion of the pond. The southwest corner of the pond was characterized by shallow, gently sloping bathymetry. The average depth of Hanson Pond 2 was 5.6 ft.

The bottom of Hanson Ponds 1 and 2 consisted of well-graded river gravel and cobbles ranging in size from 0.2 to 5.5 inches; some boulders were as large as about 40 inches. Because gravel mining excavated deeper into upward-coarsening bar deposits, sediment becomes finer with increasing depth in both ponds. Field observations and sieve analysis of Hanson samples 15, 1, 55, 62, 68, and 71 (Figure 21) show that the larger clasts from the pit floors range in size from 7.8 to 39.4 inches (Table 10; Figure 28). Some of the finer sediment in both ponds may have been due to overflow of the dike separating the ponds from the river during the 1996 flood event.

Sediment samples 122 and 121 were taken from the active Yakima River channel. The upstream sample, 122, consists of 70.8% gravel and 29.1% sand (Figure 29). Downstream sediment sample 121 obtained about 2,500 ft southeast of Pond 2 consists of 85.1% gravel, 14.7% sand, and 0.3% silt, and clay (Figure 30). Both are slightly less coarse than the pond samples.

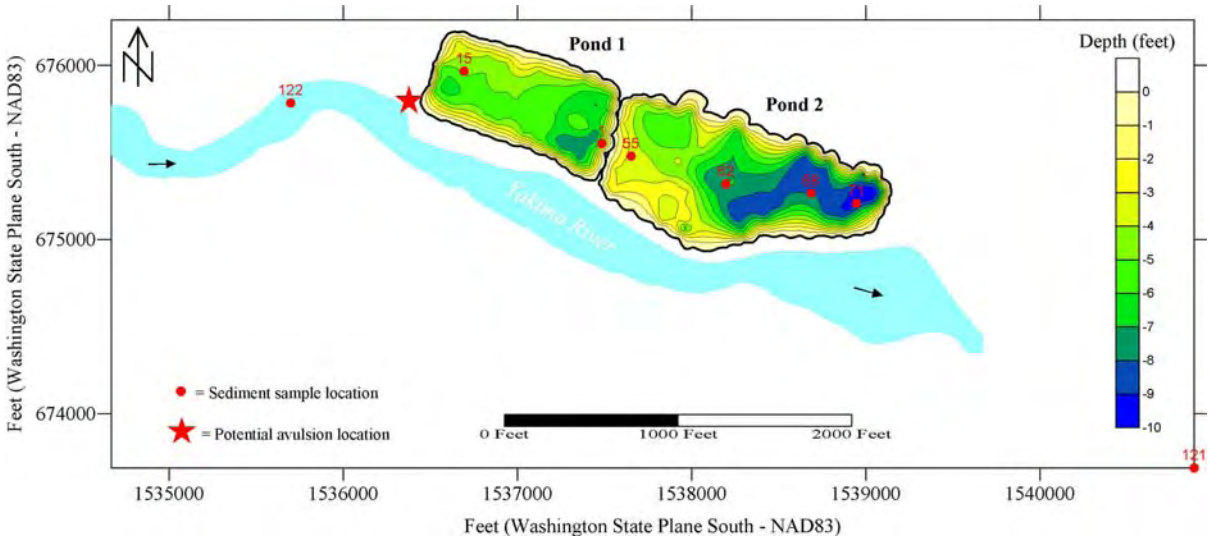


Figure 21. Contoured bathymetric map of the Hanson Ponds on May 28, 2002, showing locations of sediment samples (GPS waypoint number) and pond proximity to the Yakima River. Note the location of sediment sample 121 at the southeast corner of this figure; the river flows through that location.

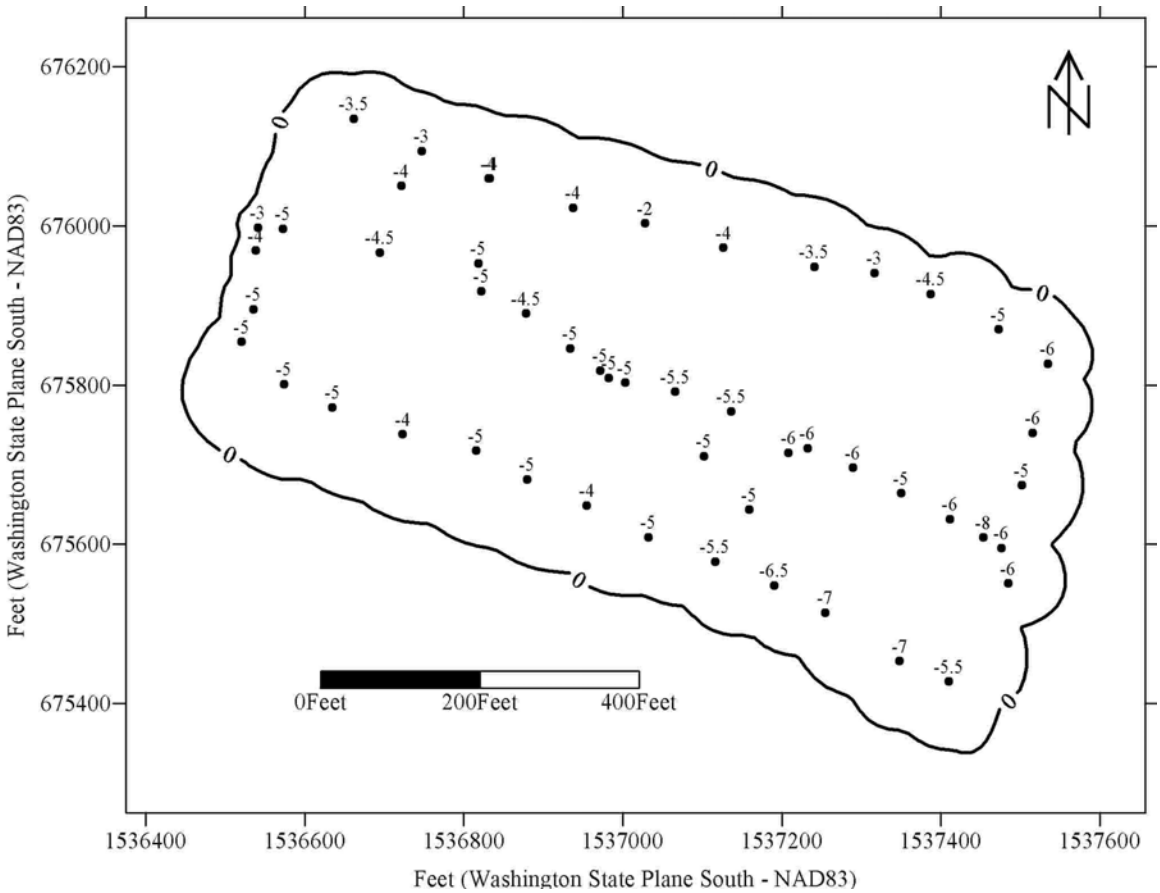


Figure 22. Data point locations and depths (in feet) used to model bathymetry for Hanson Pond 1, May 28, 2002.

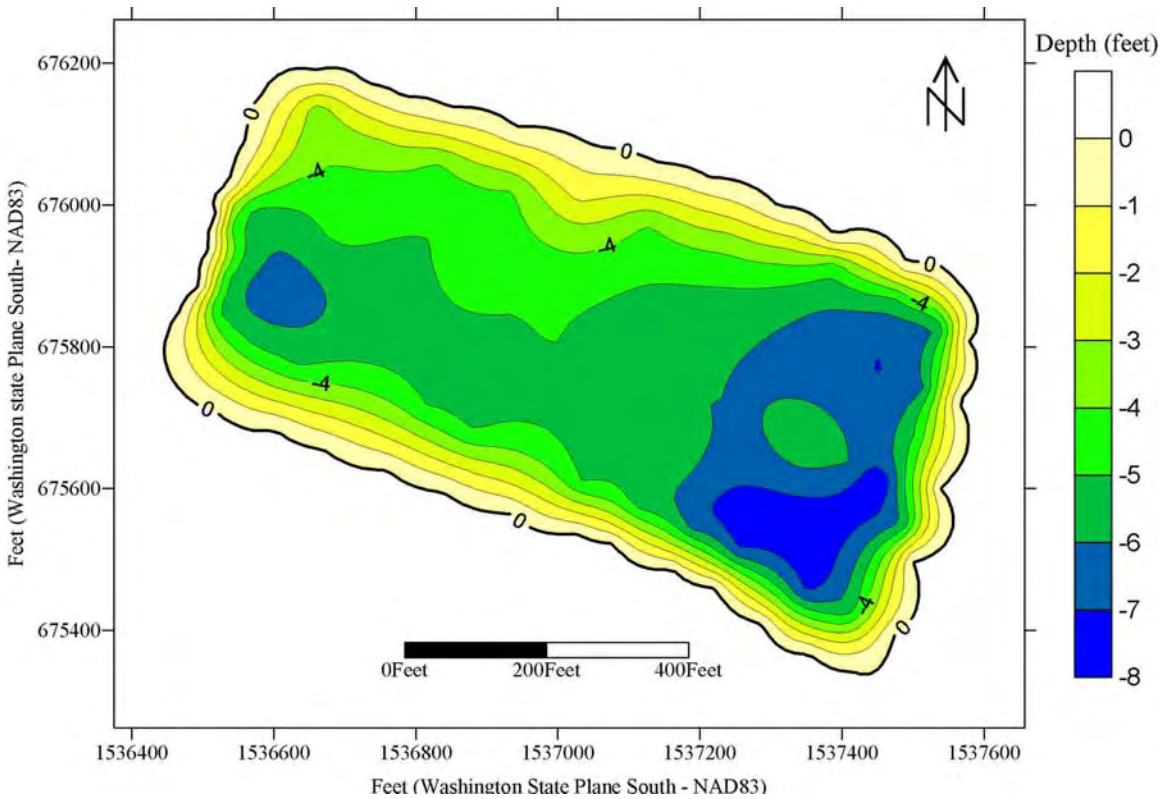


Figure 23. Contoured bathymetric map of Hanson Pond 1; bathymetry in feet below the May 28, 2002, water level.

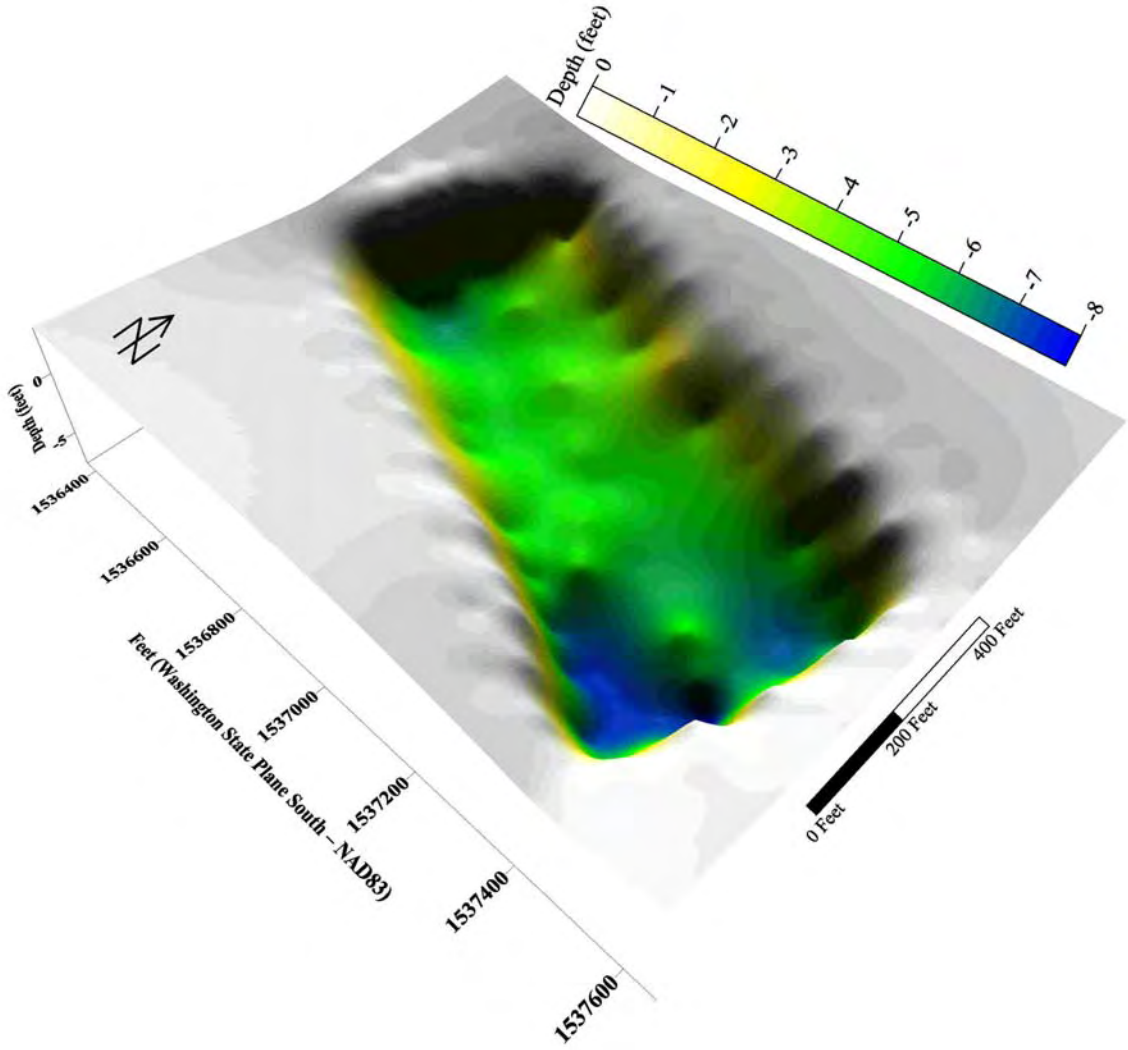


Figure 24. 3-D perspective bathymetric map of Hanson Pond 1; bathymetry in feet below the May 28, 2002, water level.

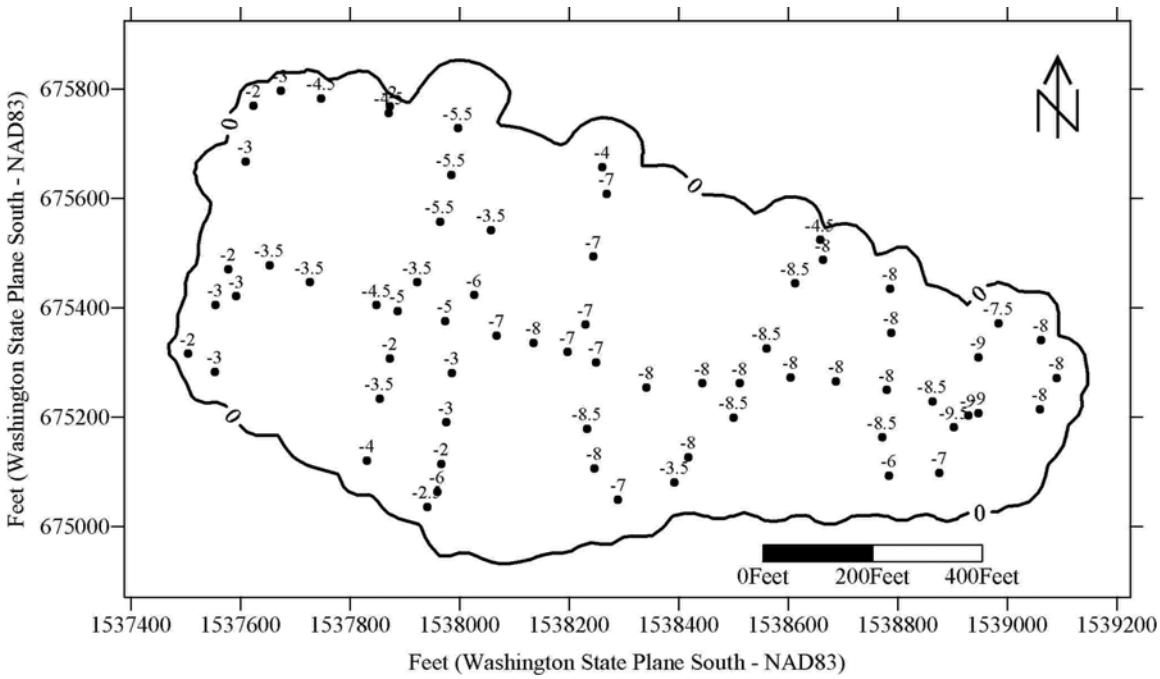


Figure 25. Data point locations and depths used to model pond bathymetry for Hanson Pond 2.

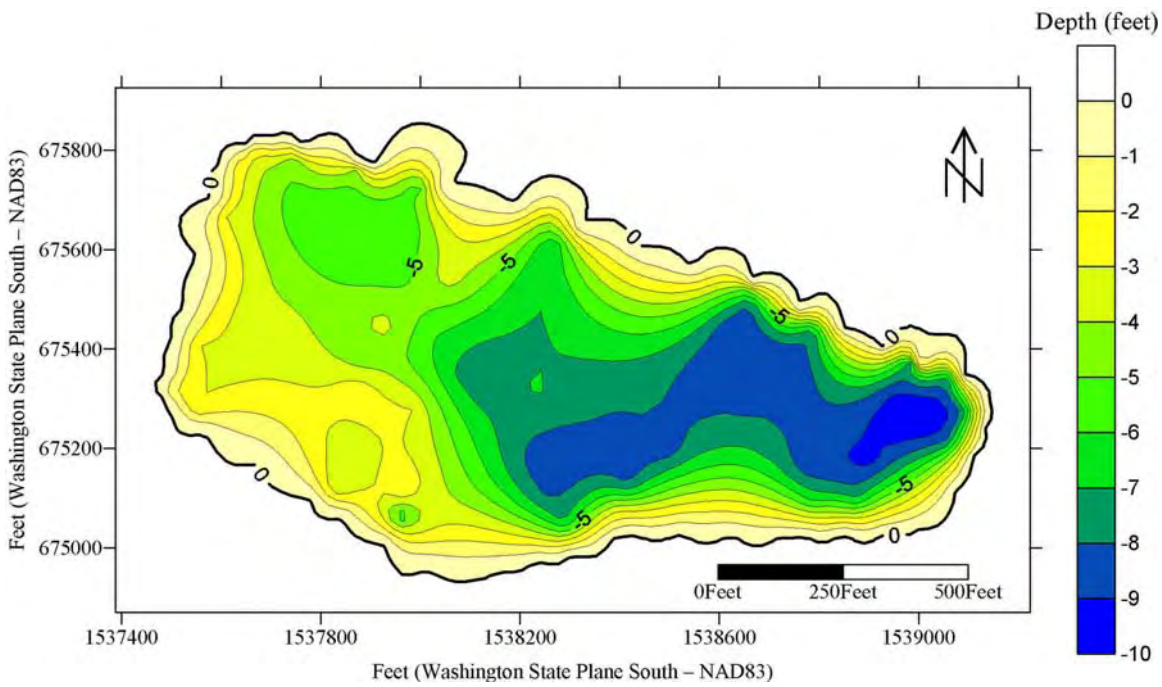


Figure 26. Contoured bathymetric map of Hanson Pond 2; bathymetry in feet below the May 28, 2002, water level.

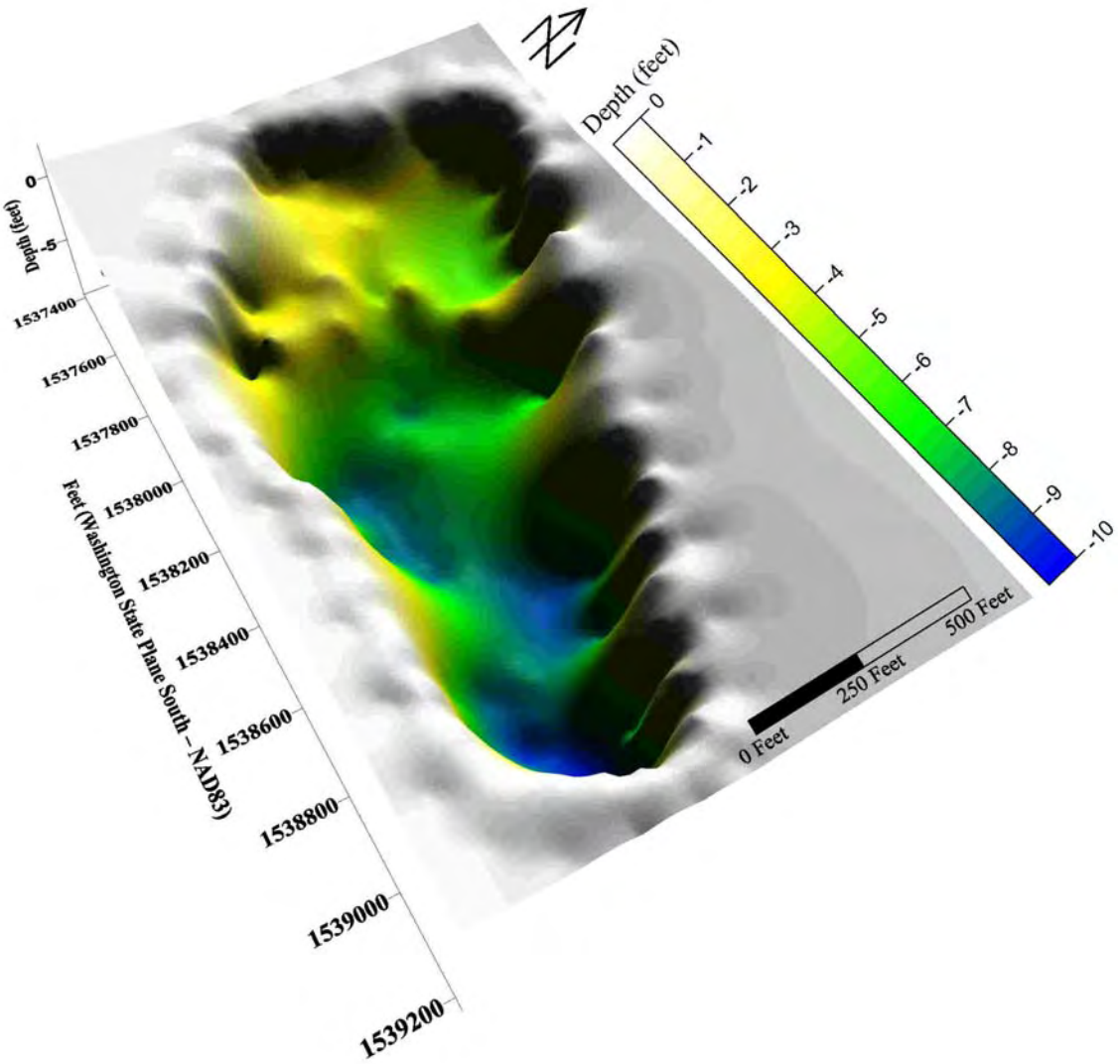


Figure 27. 3-D perspective bathymetric map of Hanson Pond 2; bathymetry in feet below the May 28, 2002, water level.

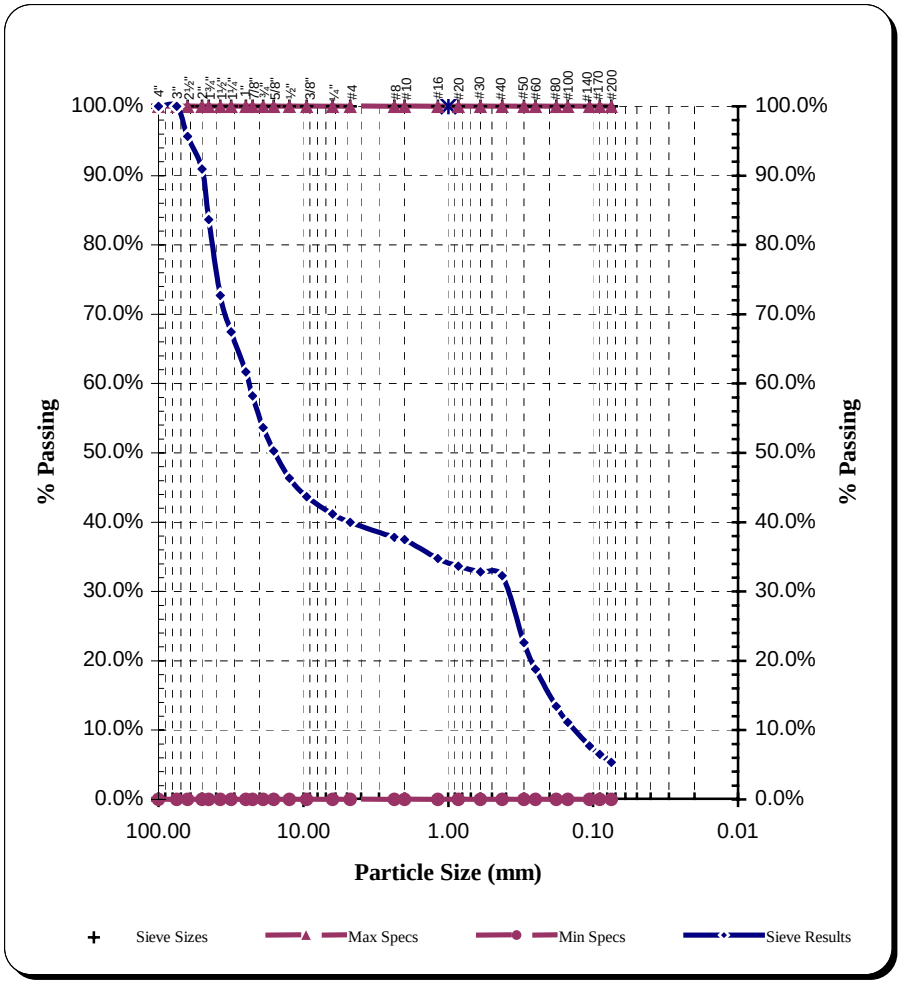


Figure 28. Grain-size distribution plot for Hanson Pond 1 sediment sample 71.

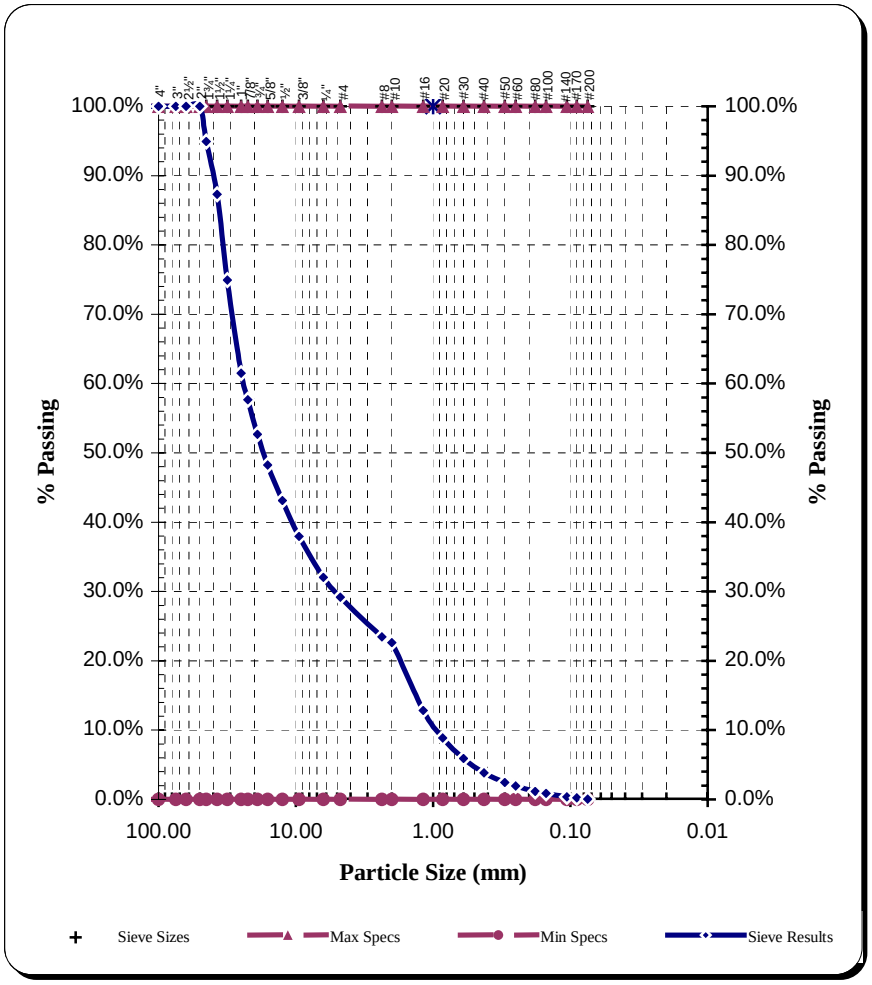


Figure 29. Grain-size distribution plot for Yakima River sample 122, upstream end of Hanson Pond 1.

Table 10. Qualitative sediment particle data for Hanson Ponds 1 and 2; see also Figures 28 to 30.

Sample No.	Particle Size Range	Comments
15, Pond 2	100% 1.6 to 5.5 in.	Coarse gravel and cobbles
1, Pond 2	25% 0.1 to 0.4 in ., 75% @ 0.4 to 2 in.	Fine to coarse gravel and cobbles with minor coarse sand
55, Pond 1	100% 1.6 to 5.5 in.	Coarse gravel and cobbles
62, Pond 1	100% 0.8 to 3.9 in.	Coarse gravel and cobbles
68, Pond 1	100% 0.4 to 3.5 in.	Fine to coarse gravel and cobbles
122, upstream	70.8% gravel, 29.1% sand	Gravel and sand
121, downstream	85.1% gravel, 14.7% sand, 0.3% silt and clay	Gravel and sand

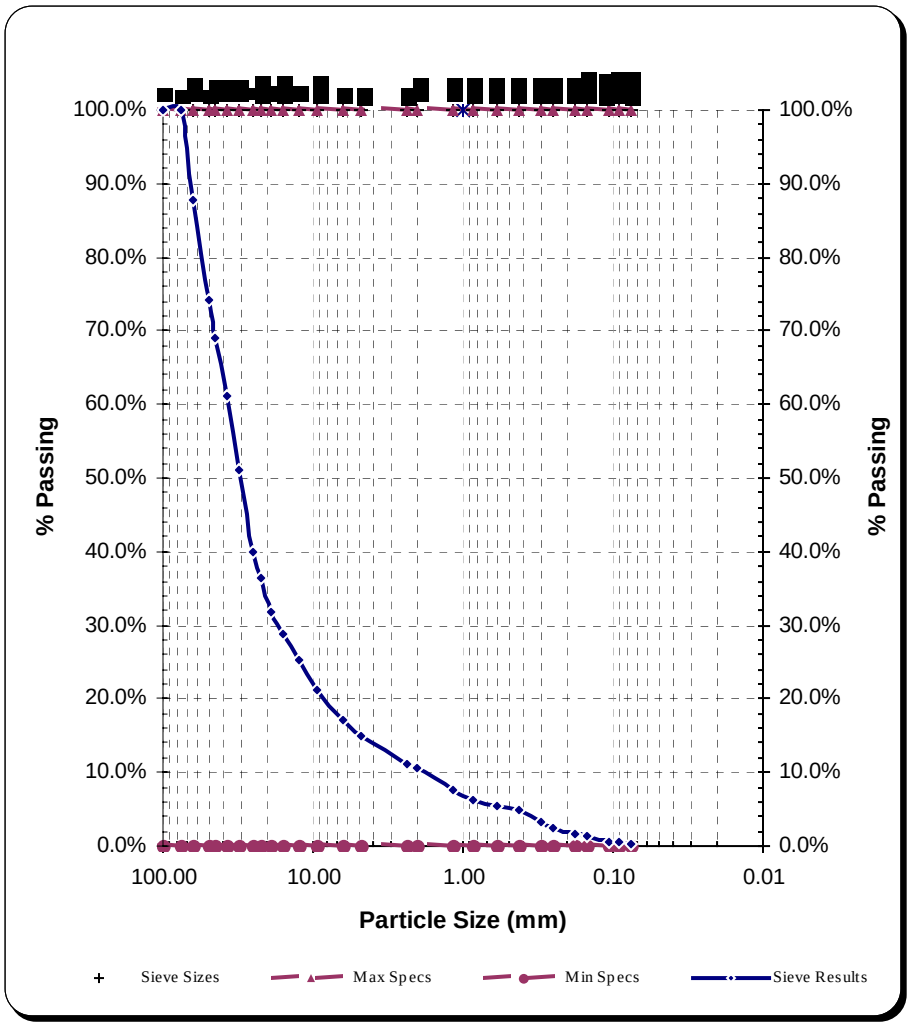


Figure 30. Grain-size distribution plot for Yakima River sample 121, downstream of Hanson Pond 2.

Site Sample Information

Sample site locations for the thermal investigation, fish assemblage, and benthic macroinvertebrate/ water-quality work for Hanson Ponds are shown in Figure 31. Standard sampling protocol is discussed in Chapter 4 (Methods). Individual site results are discussed per study component (to follow).

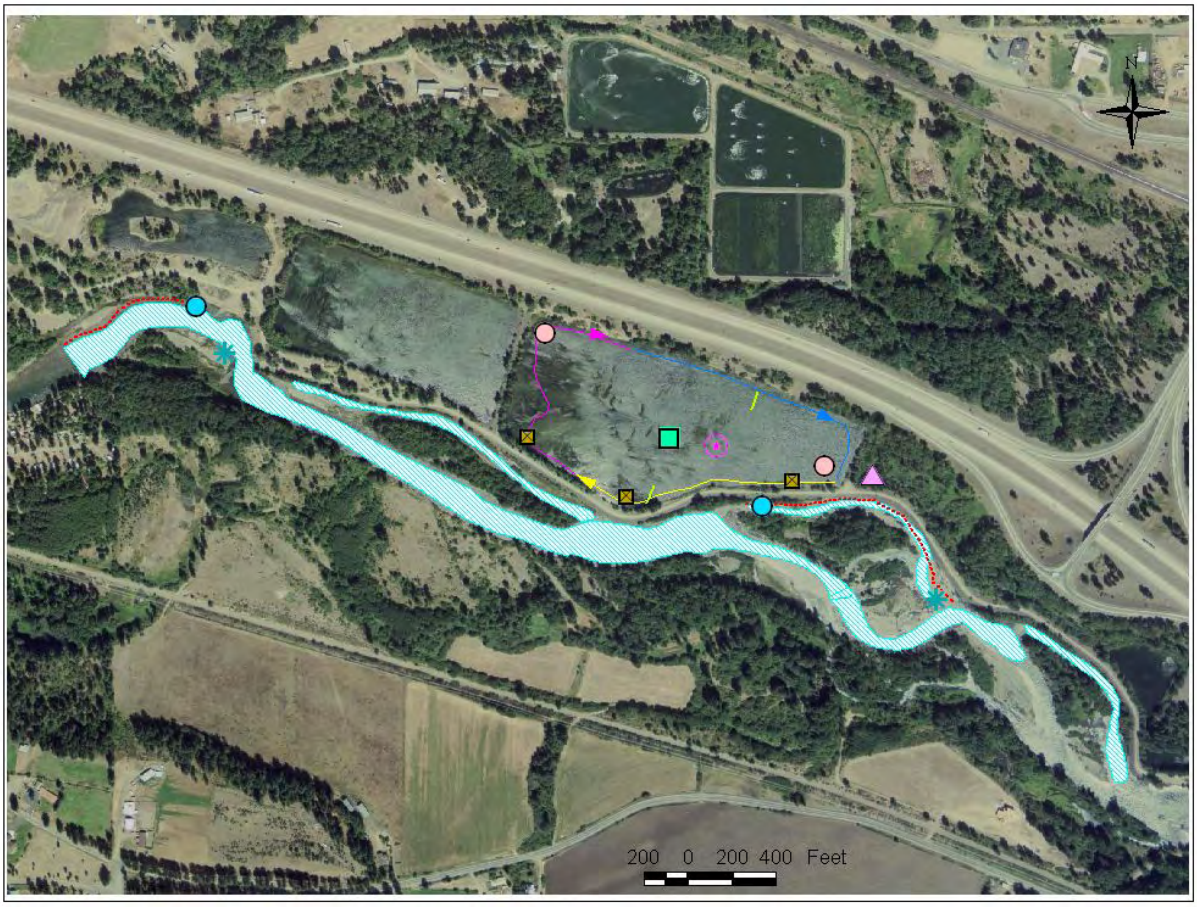


Figure 31. Thermal, fish assemblage, benthic macroinvertebrate, and water-quality sample sites for Hanson Ponds. The explanation of the symbols used to denote locations on this photograph is on p. xxii. (Photo source: Washington Department of Transportation, 2002)

Thermal Investigation

At the Hanson Ponds site, river temperature data were recorded at an upstream site, a middle site, and a downstream site (Figure 31). The upstream river instrument was tethered to a large tree, placed at a depth of approximately 2 ft, and partially shaded. The middle monitoring instrument was located in a small side channel at a depth of 2 ft and partially shaded. The downstream monitoring instrument was located below the ponds and the City of Cle Elum's sewage outfall pipe and directly below a small egress channel from a small pond to the Yakima River. Temperatures were also recorded near the center of Hanson Pond 2. The Ext unit (air temperature) was located in a riparian area directly below Pond 2 (Figure 31). The period of record is from April 15 to November 14, 2002.

River

Table 11 displays the averages of temperature measurements collected in the Yakima River during each month at the upstream, middle, and downstream sample sites. The table shows the

difference (dT) in average temperature among the sites. Because the comparisons are made to the downstream site, positive values indicate an increase in downstream temperature, while a negative value indicates a cooler temperature downstream.

Table 11. Average monthly river temperatures (in °C) and comparisons among sites at the Hanson Ponds.

Month	Upstream	Middle	Down-stream	dT Upstream/ Middle	dT Upstream/ Downstream	dT Middle/ Downstream
April	6.75	6.77	6.94	0.02	0.19	0.16
May	8.14	8.47	8.35	0.33	0.20	-0.12
June	9.67	9.68	9.80	0.01	0.12	0.11
July	12.00	12.03	12.13	0.03	0.13	0.10
August	14.28	14.30	14.38	0.02	0.09	0.07
September	14.89	14.91	14.99	0.02	0.10	0.08
October	10.50	10.48	10.61	-0.02	0.11	0.12
November	6.59	6.53	6.73	-0.06	0.14	0.20

Table 11 indicates that the average monthly river temperature contrasts were small and that in most months temperature increased downstream. Temperature data from April and November are for partial months. Comparisons using April data may be biased toward a higher average temperature because there is a general warming trend during this time of the year. For November, the opposite bias would be likely. In general, a greater increase occurred between the middle and downstream sites, accounting for the majority of the overall temperature increase between the upstream and downstream sites. Return flow from the sewer outfall may have contributed to this trend.

Figure 32 shows the relation among the upstream, middle, and downstream sites as reflected by the daily minimum and maximum air and water temperatures recorded at each site. The small spread of average monthly temperature differences shown in Table 11 is confirmed by the closely spaced data in this plot of daily minimum temperatures. As a result, it is difficult to visually determine temperature trends or distinguish among the sites. To assist interpretation of the data, the same data are presented in more detail as month by month plots over the period of record in Appendix I.

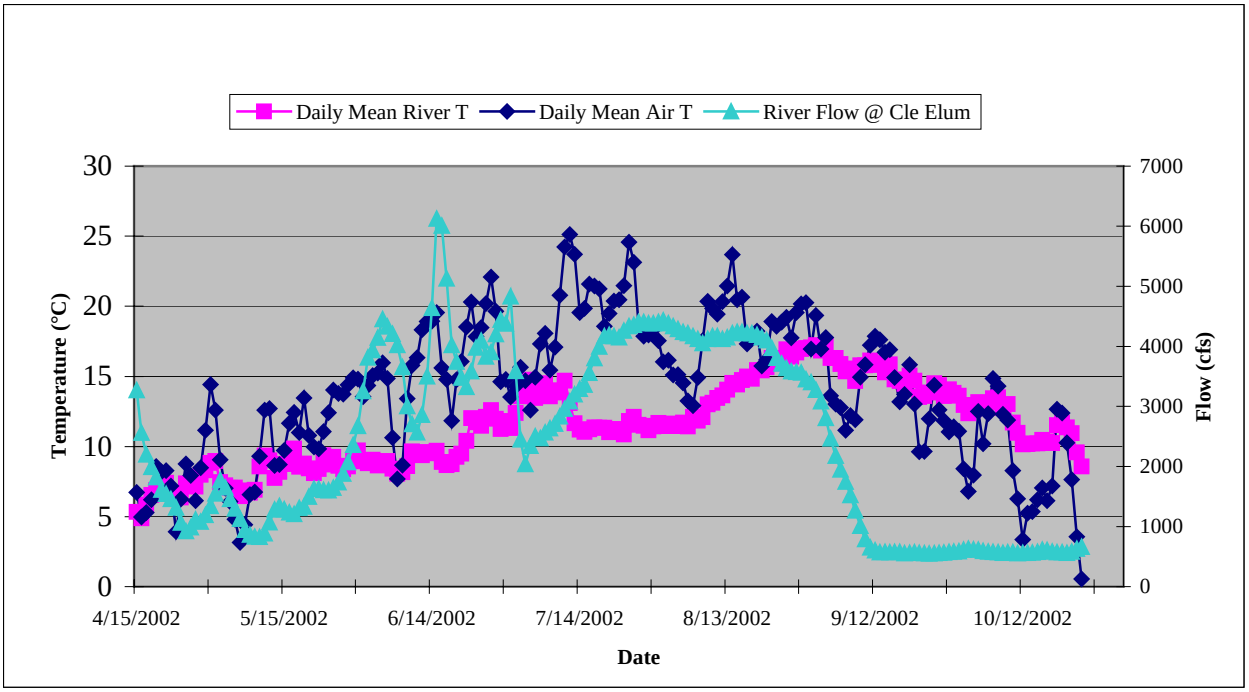


Figure 32. Yakima River minimum and maximum water and air temperatures and flow at Hanson Ponds.

Strong temperature gradients are present in the data, including the "flip flop" in early September, that could be due to releases from upstream regulating reservoirs or by changes in air temperature. Air temperature was measured at each site at the same frequency as river and pond temperatures.

Figure 33 adds the maximum daily air temperatures to the previous plot of minimum and maximum daily water temperatures. The plot suggests a correlation between air and river temperatures, although monthly divergences are apparent. Also apparent is the peaking of air temperature a month or more ahead of peak river temperatures and the cold weather that occurred in early November.

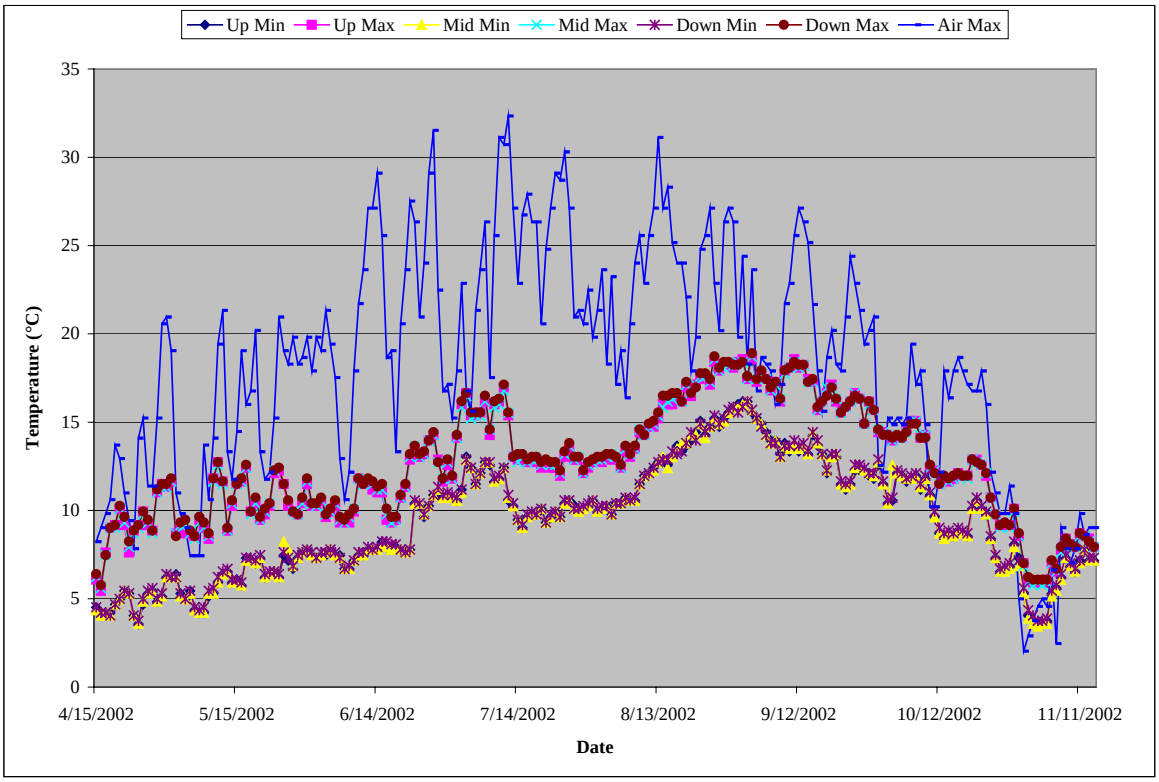


Figure 33. Yakima River minimum and maximum temperatures and daily air temperatures at the Hanson Ponds.

As a further investigation into the relation between air temperature and river temperature, some correlation coefficients were calculated. Table 12, the calculated relation between monthly minimum and maximum upstream river and air temperatures, shows that the best correlation between river and air temperature occurred early in the period of record and again late in the season. July and August temperatures had the poorest correlation. The July minimum, and to a lesser extent the maximum, correlation was apparently influenced by unusual data. In particular, there was an abrupt decrease in river temperatures in mid-July that altered the pattern of steadily rising temperatures that was established with the beginning of the period of record (Figure 33). The change in river temperature was not reflected in the pattern of air temperatures that up to mid-July was well correlated with the trend of river temperatures.

Table 12. Yakima River temperature (°C) correlation coefficients in 2002 at the Hanson Ponds.

Month	Minimum Daily	Maximum Daily
April	0.772	0.820
May	0.907	0.695
June	0.683	0.679
July	-0.425	-0.006
August	0.506	0.319
September	0.707	0.649
October	0.901	0.802
November	0.992	0.886

Pond

Figure 34 displays the daily minimum and maximum temperatures measured at depths of 2, 6, and 10 ft below the surface of Hanson Pond 2. The period of record was from April 15 to November 1, 2002.

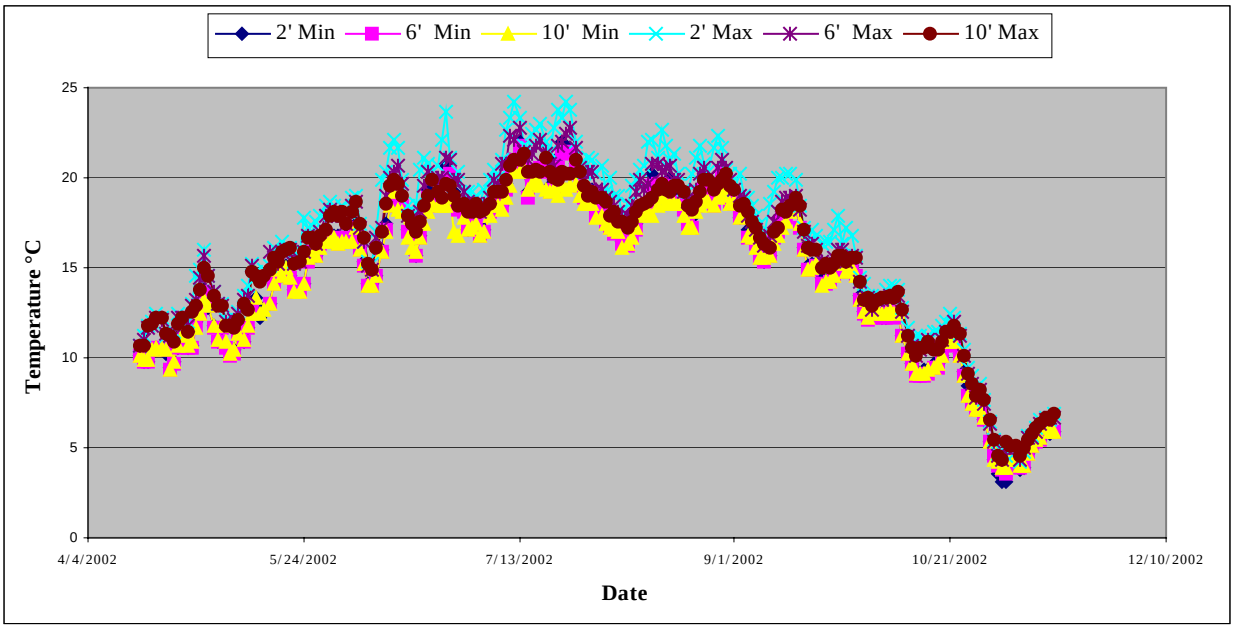


Figure 34. Minimum and maximum daily water temperatures in a vertical profile at Hanson Pond 2. See Figure 31 for sample site location.

This plot shows heating of the upper 2 ft of the water column; the maximum temperature curve for the 2-ft position consistently represents the highest maximum daily temperature. The heating was most pronounced during the early summer to early fall. Most of the temperature values occurred in a tight spread on a daily basis, and there are few differences between maximum and minimum temperatures or among the depths of measurement. However, in late June, as the

temperature at a depth of 10 ft approached 19°C, there was a tendency to diverge from the shallower measurements. This may reflect the cooling influence of ground-water recharge.

Fish Assemblage

For many years, WDFW has managed Hanson Ponds as a "put-and-take" fishery for rainbow trout. In February 2004 the Yakama Nation completed the process of connecting Ponds 1 and 2 to the Yakima River to provide salmonid habitat (Entrix, Inc. 2002). Consequently, hatchery rainbow trout were stocked for the last time in 2003.

Hanson Pond 2, the larger of the two ponds, was sampled for this study. Water clarity was excellent; the bottom of the pond was visible during all phases of fish assemblage data collection. Hanson Pond 2 was sampled on July 24, 2002, with the electroshocking boat, fyke nets, and gill nets following standard protocol. Theft of one fyke net required installation of a second fyke net set on July 25 after the initial survey. The river was sampled with backpack electroshocking gear September 5 and 6 and snorkel gear on October 23 both above and below the pond. A 300-m reach above and 225-m reach below the pond were backpack electrofished. Snorkel survey reaches were 400 m above and 500 m below the lower pond. The minimum target sample of 200 fish was achieved for all sample sets except the backpack electrofishing survey upstream of the pond.

Data collected in Hanson Pond 2 and the Yakima River above and below Hanson Ponds is presented in Appendix K, Tables 1-5. Species composition for this site is summarized in Table 13, and the dominant species are in bold type. In the text, sample size is denoted by (n = value).

Table 13. Percent composition (by species of fish) of the assemblage sampled at Hanson Pond 2 and the Yakima River adjacent to Hanson Ponds. The drift boat was not used at this site. See Table 6 for an explanation of species codes. The bold values indicate dominant species in the sample.

Species Code	Hanson Pond 2	River		
		Above	Below	Combined
BG	2.3			
CK		**42.0**	**32.7**	**36.7**
CO			0.8	0.5
COT		1.7	11.3	7.2
DAC			5.0	2.9
LMB	3.9			
NPM	**47.6**			
PS	9.0		0.3	0.2
*RB	2.0			
RB		8.4	**14.0**	**11.6**
RS	**17.2**		0.6	0.4
SK	**18.0**		0.3	0.2
WF		**47.8**	**34.8**	**40.4**
Total (%)	100.0	100.0	100.0	100.0
Sample Size	355	462	620	1082

A total of 355 fish of seven species were sampled (captured) in the pond on July 24. A predator, northern pikeminnow (48% of the total, all sampling methods combined), was the most frequently sampled fish (Figure 35), followed by sucker and redside shiner. Another predator, largemouth bass (Figure 36), was present, but they made up only 4% of the species assemblage.

Figure 35. Northern pikeminnow (54 cm), Hanson Pond 2.

Figure 36. Largemouth bass (33 cm), Hanson Pond 2.

Backpack electroshocking in river sample reaches on September 5 and 6 yielded 265 fish representing eight species. The most frequently sampled species with this gear were *Onchorhyncus mykiss* (resident rainbow trout and/or juvenile steelhead) and juvenile spring chinook salmon. Mountain whitefish (44%) and juvenile chinook (44%) were the most frequently observed fish during snorkel surveys on October 23 (816 fish sample). Combining all river sampling methods (nine species; n = 1,081), mountain whitefish were the most abundant species (40%), followed by chinook salmon (37%) and *O. mykiss* (12%). Only one exotic species, pumpkinseed sunfish (<1%), was sampled in the river below the pond. Even though northern pikeminnow were present in the pond, none were observed or captured in the river.

Because of the scarcity of native or exotic predatory/competitive species in the river, these ponds do not appear to be influencing species composition in this river reach. The spring chinook salmon, *O. mykiss*, and mountain whitefish dominance in the river adjacent to these ponds is consistent with the habitat and our expectations for this upper reach of the Yakima River. In 2002, no northern pikeminnow were sampled in the Yakima River adjacent to Hanson Ponds, which is somewhat surprising. The findings suggest that this pond serves as a reservoir for northern pikeminnow production, but that these fish cannot normally escape and enter the river. The February 1996 flood may have overtopped the dike and allowed access for northern pikeminnow and other species that are residing in this pond. Breaching and connecting the Hanson Ponds could release significant numbers of predatory sub-adult and adult northern pikeminnow into the river. The co-managers (WDFW and the Yakama Nation) are monitoring the northern pikeminnow population as part of their ongoing restoration project.

Benthic Macroinvertebrates, Water Quality, and Macrophytes

Benthic Macroinvertebrates and Water Quality

Hanson Pond 2 had good water quality and was not stratified on September 12, 2002, when it was sampled (Table 14, Figure 37; see also Table 15). The benthic macroinvertebrate community appeared to be in a condition typical of this lentic habitat. (See Table 7.)

Table 14. Pond water quality (Hanson Ponds). Temp, temperature; Cond, conductivity; DO, dissolved oxygen; chla, Chlorophyll a; secchi, depth of water clarity; OP, orthophosphorus; TDS, total dissolved solids; TN, total nitrogen; TP total phosphorus; NA, not analyzed.

Site	Depth (m)	Temp (°C)	pH (units)	Cond (µS/cm)	DO (mg/L)	chla (µg/L)	secchi (m)	OP (mg/L)	TDS (mg/L)	TN (mg/L)	TP (mg/L)
DeAtley	0.5	19.4	9.51	262	15.5	39.68	1	0.282	189.0	27.0	0.370
	3.5	14.2	7.4	280	0.9	NA	NA	NA	NA	NA	NA
I-82 Pond 5	0.5	20.5	8.47	119	8.6	3.63	2.9	0.013	88.0	26.6	0.740
	5	19.4	7.13	130	2.6	NA	NA	NA	NA	NA	NA
Parker	0.5	17.5	8.34	101	10.1	1.51	1.2	0.050	76.0	19.5	0.830
Edler	0.5	17.4	9.2	205	9.8	74.93	0.6	0.009	164.0	23.4	0.820
	4.3	16.5	7.7	221	1.3	NA	NA	NA	NA	NA	NA
Newland	0.5	20.4	7.77	120	8.1	4.70	0.2	0.018	126.0	10.8	0.580
	6.3	17.5	7.48	118	6.8	NA	NA	NA	NA	NA	NA
Terrace Heights	0.5	16	7.3	86	9.1	1.25	NA	0.021	78.0	21.9	0.470
Selah	0.5	20.8	8.61	171	8.5	1.54	3.5	0.019	54.0	65.6	0.400
	9	11	7.23	255	0.5	NA	NA	NA	NA	NA	NA
I-90 Pond 4	0.5	19.2	8.46	102	11.9	2.85	1.4	0.016	ND	51	0.17
	2	18.3	8.14	103	9.5	NA	NA	NA	NA	NA	NA
Gladmar	0.5	15.6	7.53	63	9.5	0.69	-99	0.014	ND	51	0.08
Hanson Pond 2	0.5	17.8	8.41	70	10.1	3.08	-99	0.021	2.0	50.25	0.07
	2	17.8	8.34	70	9.8	NA	NA	NA	NA	NA	NA

In the river, both sampled reaches were on the main stem. Water quality was similar in the upper and lower reaches (Table 16). At the macroinvertebrate sampling locations, the upper reach had significantly coarser substrate (Figure 38), and the lower reach had significantly faster water velocity (Table 17).

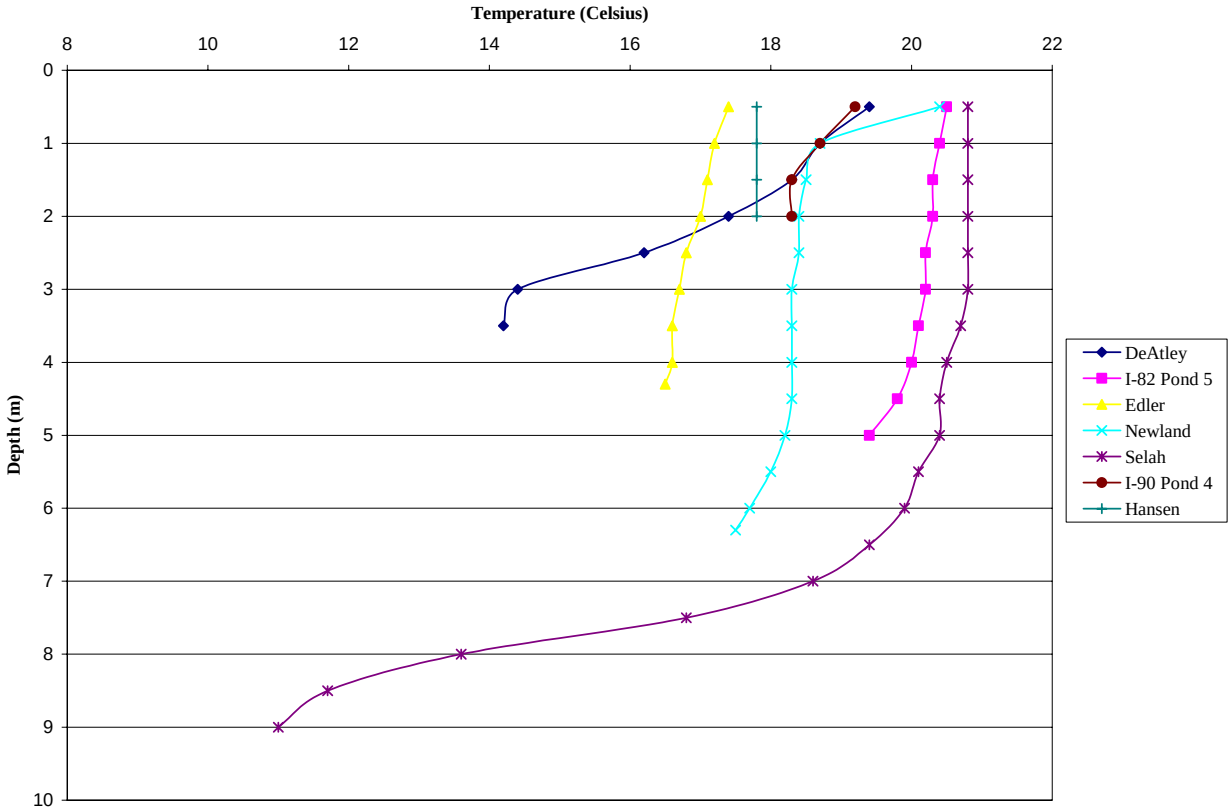


Figure 37. Temperature-depth profiles of each isolated pond.

Table 15. Selected biometrics for the ten pond sites, with scores ranked from best to worst. As environmental conditions deteriorate for macroinvertebrates, total richness should decrease, while the % top three taxa and the HBI scores should increase.

Site	HBI	Site	Total Richness	Site	% Top 3 taxa
Gladmar Pond	4.1	Terrace Heights Pond	38	Terrace Heights Pond	50
Terrace Heights Pond	5.7	Gladmar Pond	35	Gladmar Pond	54
Hansen Pond	6.0	I-90 Pond 4	23	I-82 Pond 5	62
Selah Pond	6.1	Parker Ponds	21	I-90 Pond 4	66
Edler Ponds	6.5	Edler Ponds	20	DeAtley Pond	66
I-90 Pond 4	7.1	DeAtley Pond	18	Hansen Pond	70
Newland Pond	7.4	Hansen Pond	16	Edler Ponds	79
DeAtley Pond	7.5	I-82 Pond 5	15	Parker Ponds	79
Parker Ponds	7.5	Newland Pond	10	Selah Pond	81
I-82 Pond 5	8.1	Selah Pond	8	Newland Pond	83

Table 16. Water quality at the river bioassessment sites. NA, not analyzed.

Site	Date (2002)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	pH (units)	Temperature (°C)
Downstream DeAtley	09/03	254	8.9	8.59	22.5
Upstream DeAtley	09/03	255	9.5	8.49	23.0
Downstream I-82 Pond	09/04	94	4.2	7.39	17.5
Upstream I-82 Pond 4	09/04	95	11.1	8.42	16.5
Downstream Parker	09/04	93	10.3	8.27	17.5
Upstream Parker	09/04	92	10.1	8.46	18.0
Downstream Edler	09/05	91	9.5	7.73	NA
Upstream Edler	09/05	91	10.3	7.87	14.2
Downstream Newland	09/17	89	10.6	8.28	16.2
Upstream Newland	09/17	88	9.6	7.33	17.0
Downstream Terrace	09/17	81	9.5	7.39	14.5
Upstream Terrace	09/16	81	10.0	7.79	17.0
Downstream Selah	09/16	136	11.7	8.94	17.0
Upstream Selah	09/17	130	12.2	9.05	16.5
Downstream I-90 Pond	09/18	60	10.1	7.32	16.1
Upstream I-90 Pond 5	09/18	60	9.8	7.11	15.0
Downstream Gladmar	09/18	60	10.2	7.63	13.0
Upstream Gladmar	09/18	57	10.2	7.49	13.8
Downstream Hanson	09/25	58	9.8	7.61	13.7
Upstream Hanson	09/25	58	9.9	7.88	15.1

Table 17. Physical traits that were significantly different (Mann-Whitney U, $p<0.05$) between river reach pairs above and below each gravel pit site. A "+" indicates a significant difference, and a "---" indicates an insignificant difference.

Pond Site	Average Depth	Bottom Velocity	Average Velocity	Canopy Cover	Gradient	Wetted Width	Bankfull Width
DeAtley	---	---	+	---	+	+	+
I-82 Pond 5	---	---	---	+	---	---	---
Parker	+	---	---	---	+	+	+
Edler	---	---	---	---	---	+	+
Newland	---	---	---	---	---	---	---
Terrace Heights	---	---	---	+	---	+	+
Selah	---	---	---	---	---	---	---
I-90 Pond 4	---	---	---	---	---	---	---
Gladmar	---	---	---	+	---	+	+
Hanson	---	---	+	---	---	---	---

Table 18. Metric expressions that were significantly different (Mann-Whitney U, p<0.05) between reaches upstream and downstream from the gravel pit site. In terms of biological quality,"+" indicates that the upstream reach had a "better" rank metric scores, "0" indicates that the upstream reach had a "worse" scores, and a "---" indicates that there was no significant difference between reach scores. See Table 7 for an explanation of column headings

	Taxa	Intol	Cling	Ephem	Plecop	Trichop	EPT	LL	% Cling	% Ephem	% EPT	% Pred	HBI	% Tol	% Chiro	% Filt	% Scrap	% Top 3
DeAtley	---	---	+	+	---	+	+	+	+	+	+	---	+	---	+	0	0	---
I-82 Pond 5	+	---	+	+	---	+	+	---	+	+	+	---	+	---	---	0	---	---
Parker	---		+	---	+	---	+	+	---	+	---	+	---	---	---	---	---	---
Edler	---	---	+	---	+	---	---	---	+	0	+	+	---	0	+	0	+	---
Newland	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Terrace Heights	---	---	---	+	---	---	---	---	---	+	---	---	---	---	0	---	+	---
I-90 Pond 4	---	---	---	---	---	---	---	+	---	---	---	---	---	---	---	---	---	---
Gladmar	---	---	---	+	0	---	---	---	0	---	---	---	---	---	---	+	---	---
Hanson	---	---	---	---	---	---	---	---	0	0	0	+	0	---	+	---	+	---
All Sites	---	---	+	+	---	---	---	---	---	---	---	---	---	---	---	---	---	---

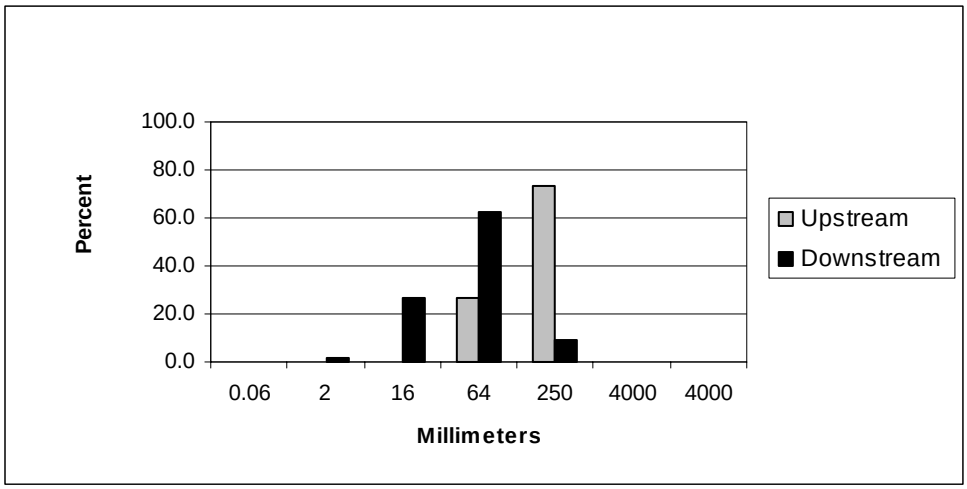


Figure 38. Average substrate composition of macroinvertebrate sampling locations at the Hanson Pond river reaches (4 grid locations per reach).

There were mixed biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Table 18). The cluster dendrogram (Figure 39), however, indicates that the reaches do have different macroinvertebrate community compositions. The exclusive presence of *Eukiefferiella* sp. and *Hydropsyche* sp. (Appendix M) in the lower reach contributed to this separation. The CCA plot also shows a separation of macroinvertebrate community composition between the two reaches (Figure 40). Differences in substrate appeared to be the simplest explanation for biological differences (Table 19).

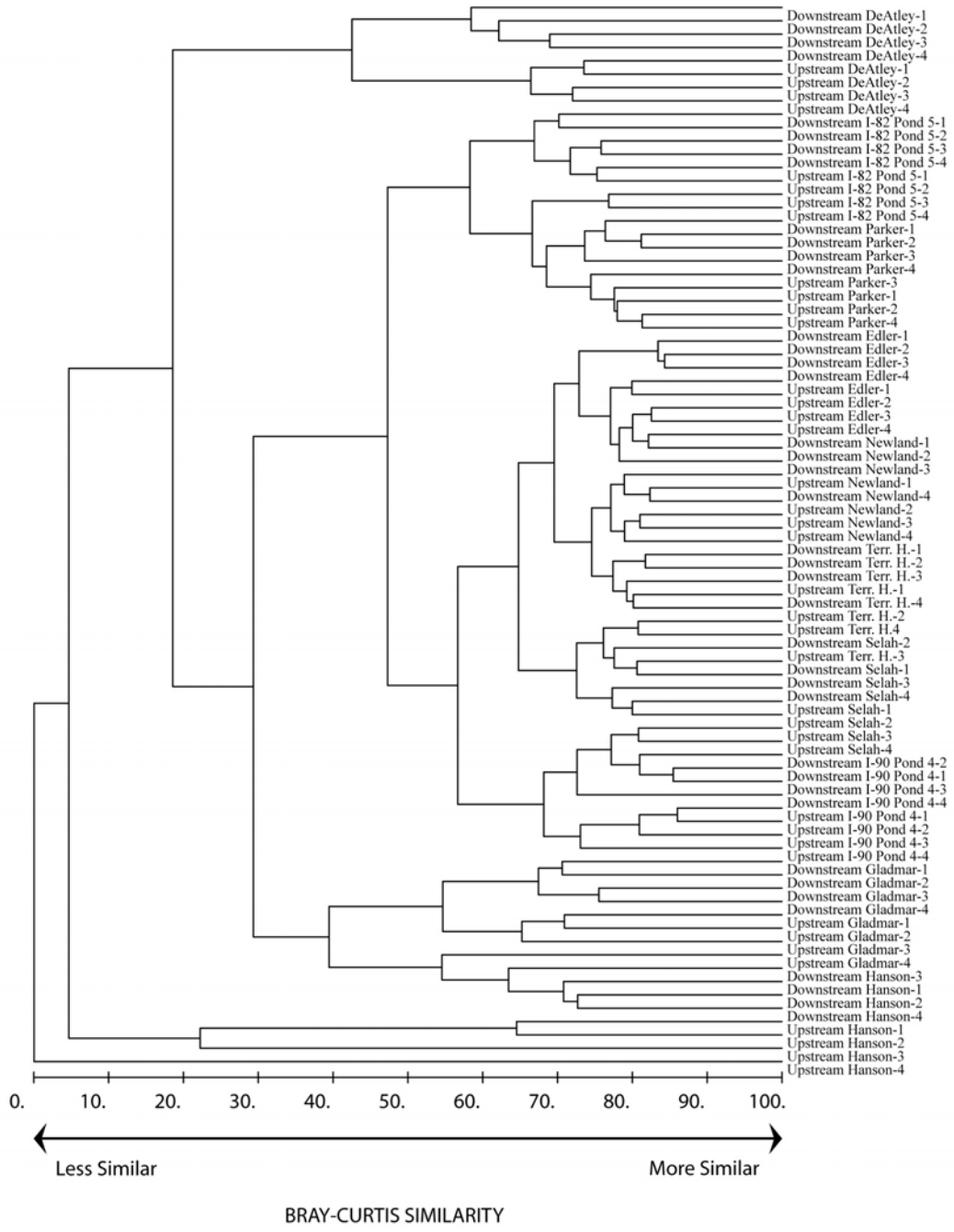


Figure 39. Cluster dendrogram of macroinvertebrate sample similarity. A Bray-Curtis similarity measure and an average linkage metric was used on log (x+1) transformed macroinvertebrate counts. The Bray-Curtis similarity scale represents percent species overlap, weighted by species abundance. Thus, the samples with the most similar species and abundances join at a higher percent

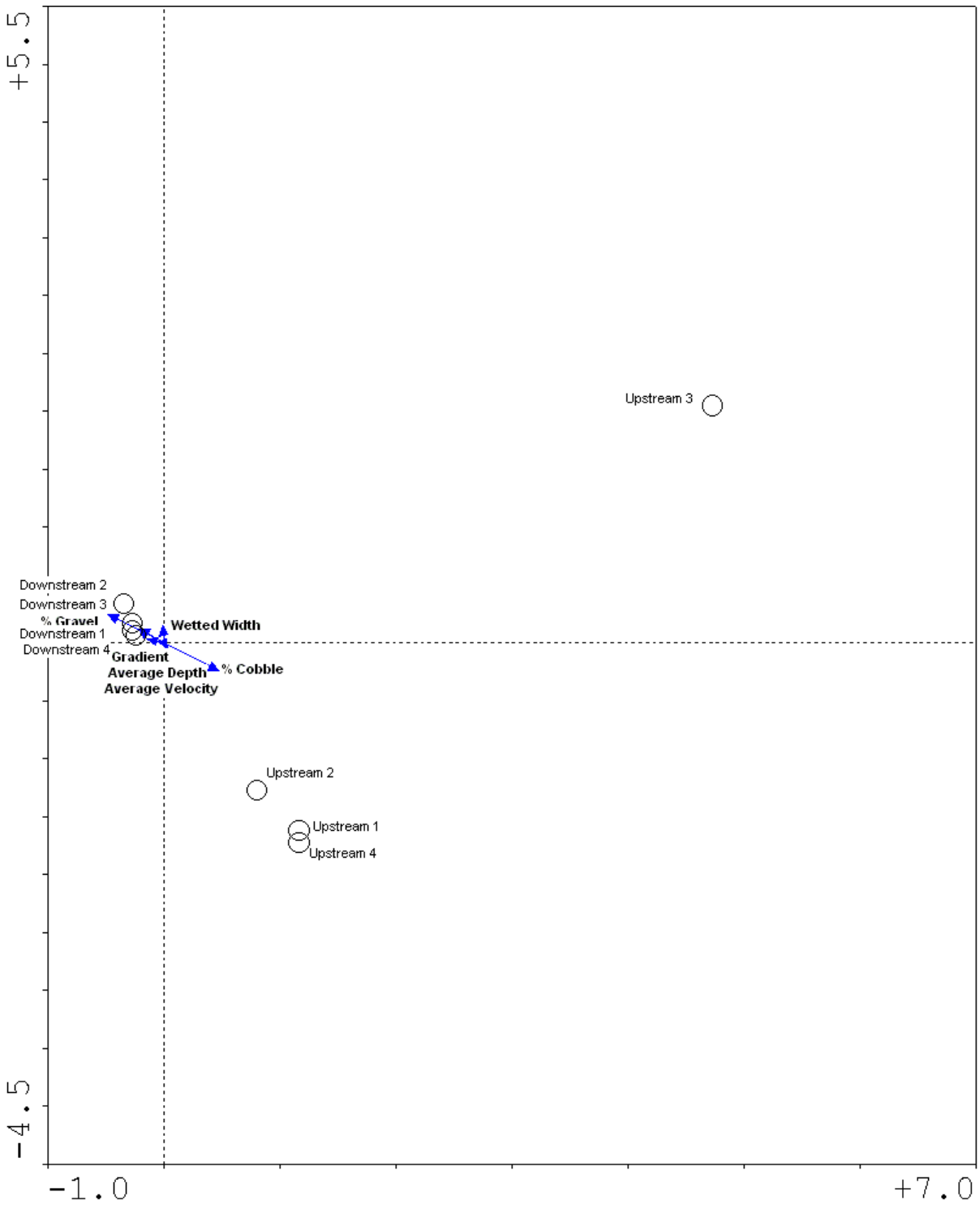


Figure 40. Canonical Correspondence bi-plot with Hanson Ponds benthic macro-invertebrate site distribution and major physicochemical explanatory vectors.

Table 19. Canonical correlations of physicochemical variables to ordination axes at the Hanson river sites. n.s., not significant at $p<0.05$

Variable	Axis 1 (x-axis)	Axis 2 (y-axis)
Wetted Width	.05	n.s.
Average Depth	-.02	n.s.
Average Velocity	-.32	n.s.
Gradient	-.23	n.s.
Cobble	.78	n.s.
Gravel	-.77	n.s.

Macrophyte Survey

Only Hanson Pond 2 was sampled. The macrophytes were sampled concurrently with the water quality sampling on September 9, 2002. The water was clear enough to see the bottom throughout the pond. The native plant big-leaf pondweed (*Potamogeton amplifolius*) dominated the submersed community. There were patches of bare gravel in shallow areas, and the northwest end of the pond appeared to be getting some nutrient input because there was a marked increase in algae in that area. Reed canarygrass (*Phalaris arundinacea*), a common non-native invasive species, was present along the shore where habitat was available.

Site 1 Comments and Recommendations

Hanson Ponds are fairly shallow ponds and have good ground-water–surface-water connectivity. The river at this site is excellent salmonid habitat. River and pond temperatures were the lowest recorded in this study and sample tests determined the water quality to be good.

Recommendations

The pond reconnection project under way by the Yakama Nation's Yakima–Klickitat Fisheries Project staff includes the following considerations:

- Monitoring of upstream and downstream geomorphic impacts (e.g., head-cutting, bank erosion, disruption of sediment supply, transport of sediment throughout the reach) so as to avoid threats to private property and other infrastructure.
- Comparison of benthic macroinvertebrate samples to reference sample sites (from this study) to assist in gaging habitat recovery.
- Determination of the range of flow that accelerates geomorphic and ecological recovery and maintenance of that flow.
- Photographic monitoring of riparian restoration to assure success.
- Adding large woody debris throughout the site where practical and economically feasible.
- Monitoring of the population of northern pikeminnow (salmon predators) and alteration of habitat if these fish become overabundant.
- Monitoring of summer water temperature to assess the fish assemblage in niche habitat.

6. GLADMAR (Site 2)

Location and Site Information

The Gladmar site (20.6 acres) is located a mile east of Thorp (Figure 41). Ground water filled this gravel pit when it was abandoned in the late 1960s. The Yakima River captured this pond during the February 1996 flood. The main channel of the Yakima River now flows directly through the pond and is gradually converting the pond into riverine habitat. After the 1996 flood, the levee was reconstructed, and an agreement was made among the Washington Department of Fish and Wildlife, Kittitas County Public Works, Cascade Irrigation District, and the Yakama Nation to maintain 300 cfs, or one-third of the flow, whichever is less, through the pond.

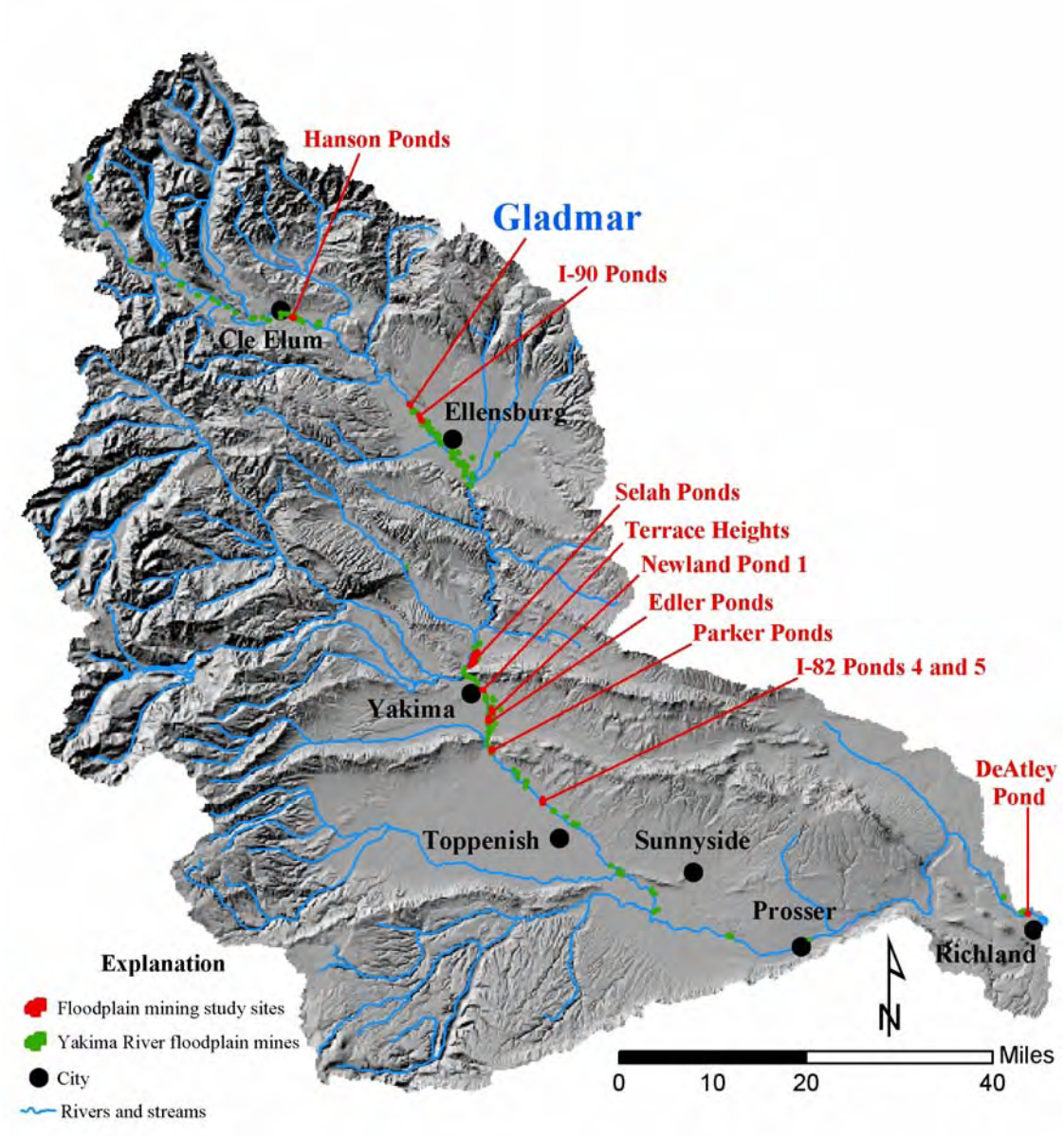


Figure 41. Gladmar site locator map (Site 2).

Pond Bathymetry and Sediment Sampling

Gladmar Pond is located on the inside of an active meander bend. Deposits mined at the pond represent a migrating point bar sequence. During the 100-yr flood of 1996, the Yakima River breached the narrow retaining dike, capturing Gladmar Pond and partially cutting off the meander, shortening and steepening the channel for the flow passing through the pond. The approximate volume of the pond, ingress, and egress channels was 102,000 yd^3 in the summer of 2002; the volume is decreasing as the river continues to deliver sediment via the ingress.

The channel migration zone for an approximately 2-mi stretch of the river centered on the Gladmar Pond reach of the Yakima River is 1,400 to 1,800 ft wide, and the channel gradient is 0.0037, or about a 20-ft drop in valley floor elevation for each mile downstream. One channel brings river flow into the pond, and two channels exit the pond and reconnect with the main-stem Yakima River about 2,000 and 2,300 ft downstream, respectively (Figure 42).

The average depth of Gladmar Pond is approximately 4 ft (Figures 43, 44, and 45). However, significant variability in pond bathymetry and water velocity regimes is evident in this pond. The deepest portion of the pond is a triangular 12-ft-deep trough in front of the prograding delta at the head of the ingress channel. Two zones of high-velocity flow (≥10 ft/sec) leading to the egress channels follow deeper troughs along the pond bottom, one along the western margin and the other across the center of the pond. The areas between the two toughs and northeast of the north egress channel are primarily benches in shallow, low-energy water, like that in the northeast corner of the pond.

Sediment particle-size distribution is a function of distance from the river's entry point into the pond as well as proximity to energetic stream flow through the pond to the south along the two deeper water toughs (Figure 42). Where the river enters the pond, bed load is aggrading to form a delta consisting of 0.8- to 7.9-in. gravel and cobbles. The flow bifurcates at the delta, and two streams flow south through the pond. One stream flows through the pond's central portion to the northern egress channel, and the other flows along the south side of the pond to the southern egress channel. Along the axes of these two streams, the pit bottom is being eroded. Typically consisting of sand and fine sediments, low-energy depositional shelves are situated on the east and south shores of the pond.

Sample 119, from the east side of the pond, is composed of poorly graded fine sand (86.6%) and lesser silt and clay (13.4%) (Figure 46). Sample 237, from a shallow shelf near the pond's south-central shore, consists entirely of silt and clay (Table 20). Sample 238, however, is well-graded and consists of 41.9% gravel, 53.5% sand, and 4.6 % silt and clay, typical of coarser sediment deposited close to faster stream flow (Figure 47).

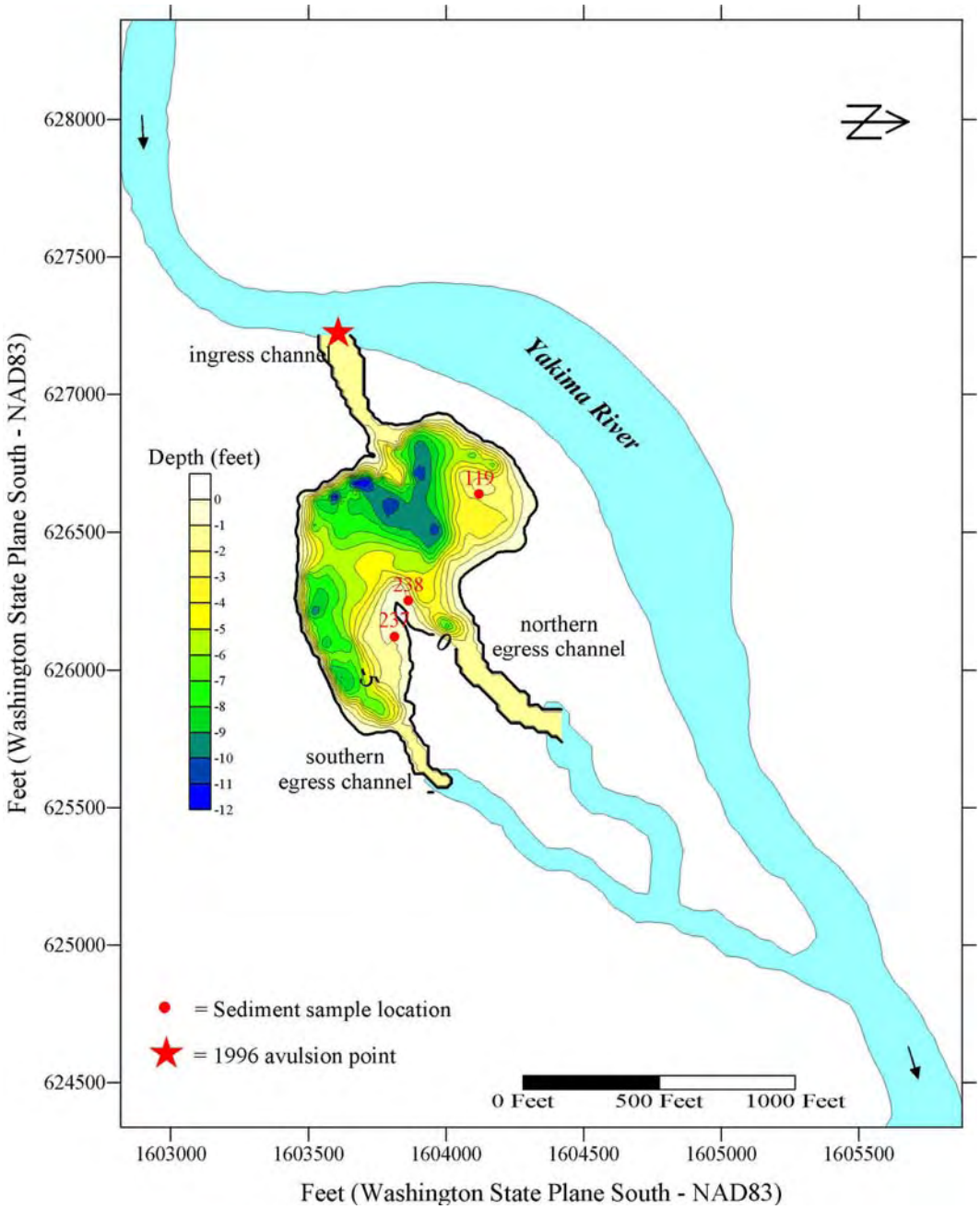


Figure 42. Contoured bathymetric map of Gladmar Pond showing locations of sediment samples (GPS waypoint number) and proximity to the Yakima River on July 16, 2002.

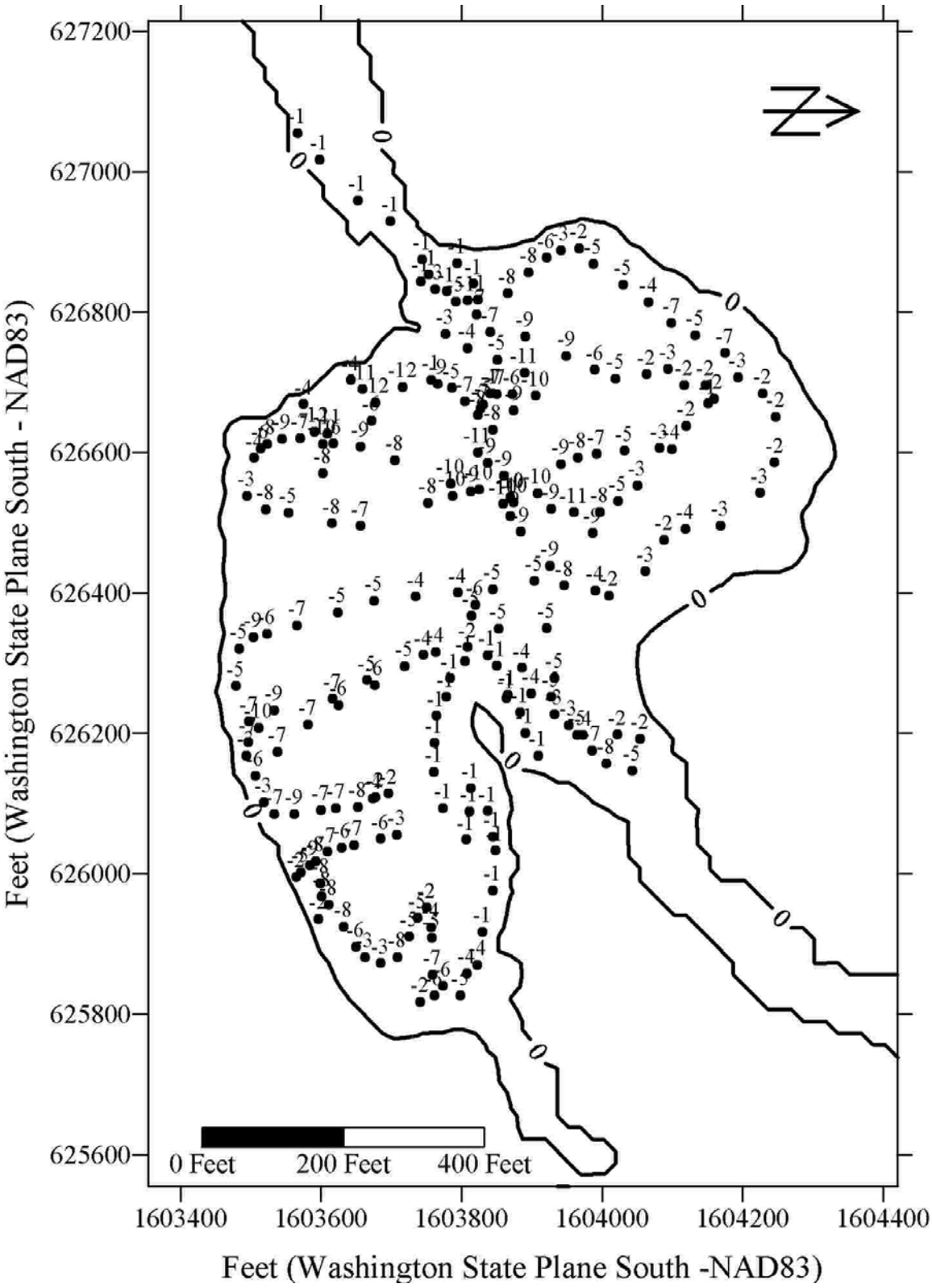


Figure 43. Data point locations and depths (in ft) used to model bathymetry of Gladmar Pond, July 16, 2002.

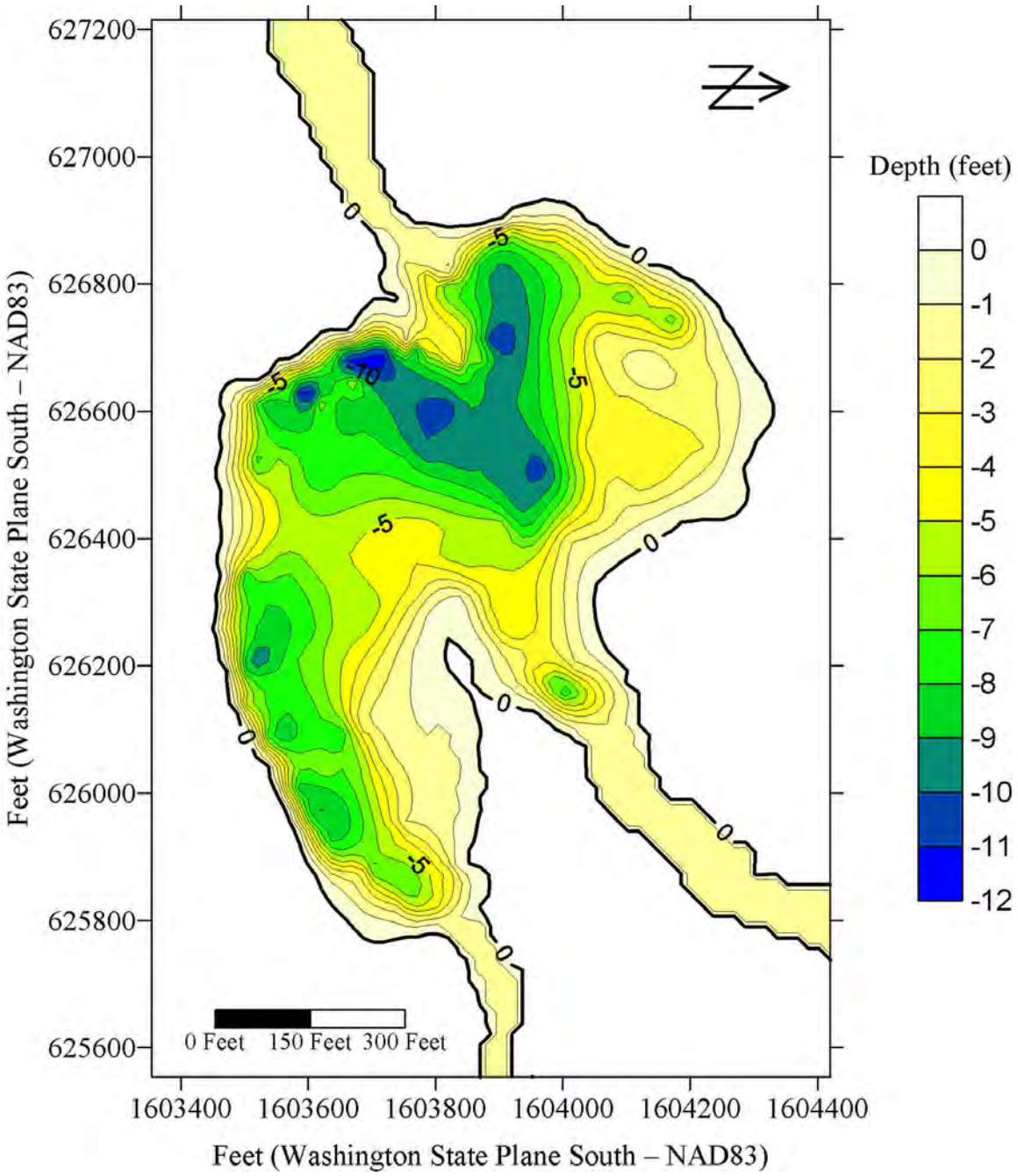


Figure 44. Contoured bathymetric map of Gladmar Pond; bathymetry in feet below the July 16, 2002, water level.

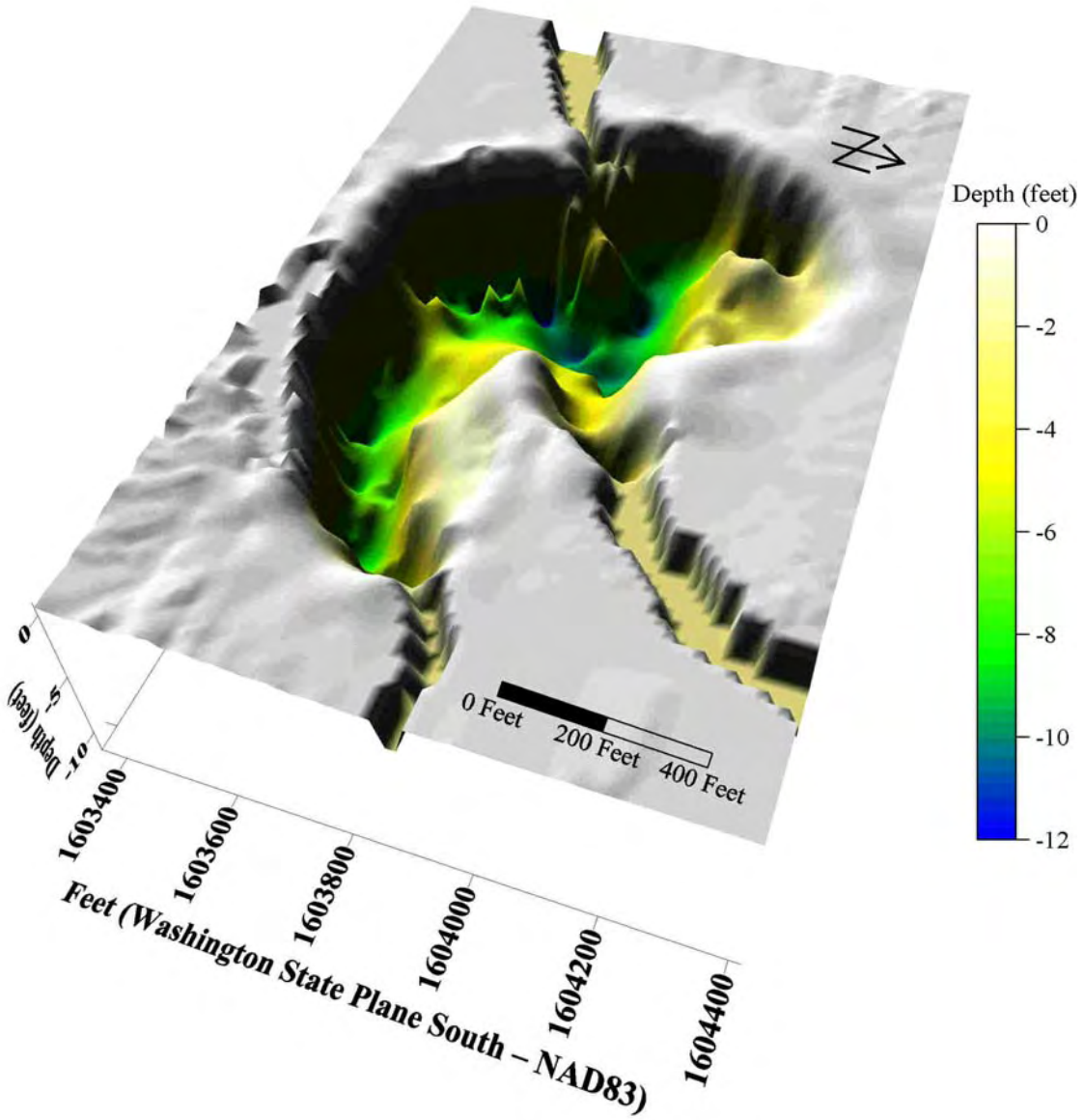


Figure 45. 3-D perspective bathymetric map of Gladmar Pond; bathymetry in feet below the July 16, 2002, water level.

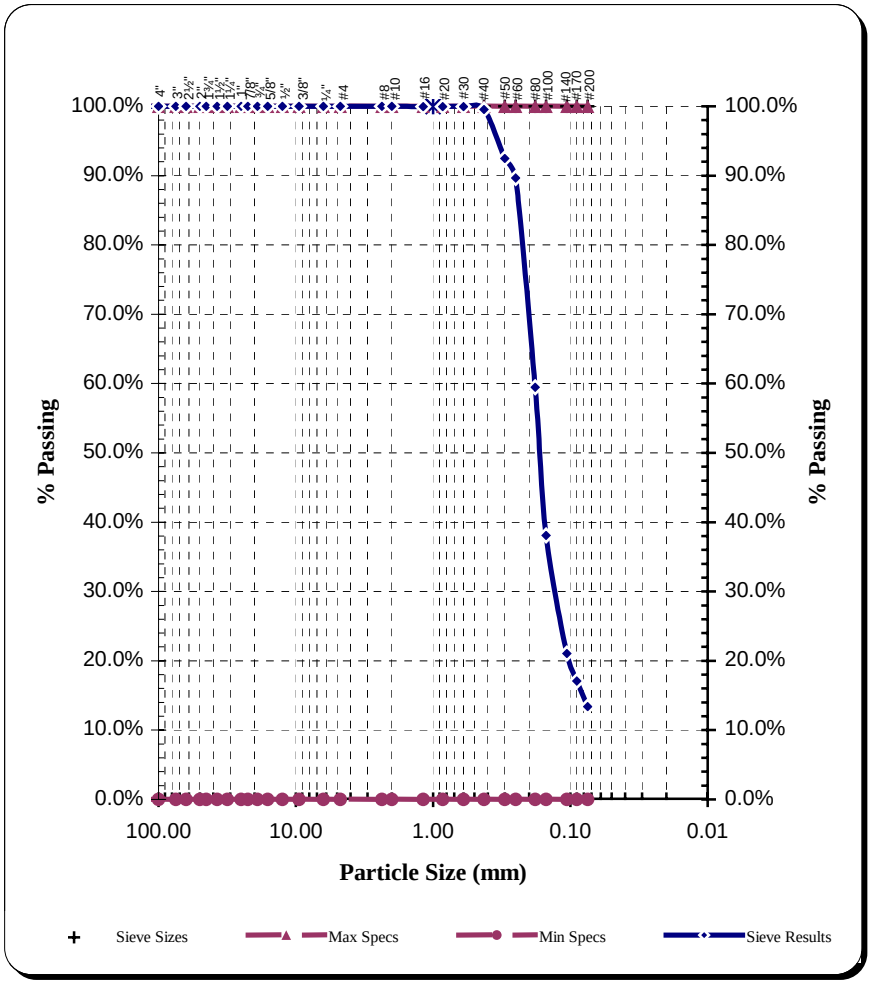


Figure 46. Grain-size distribution plot for sample 119, Gladmar Pond.

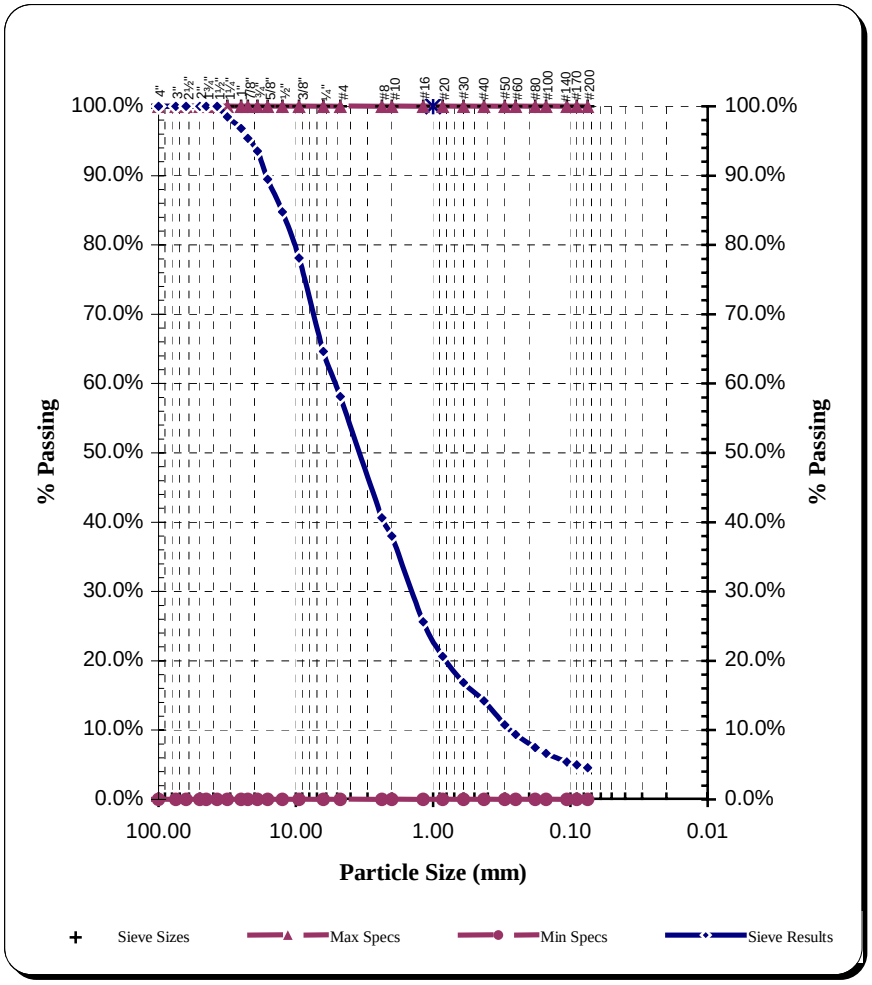


Figure 47. Grain-size distribution plot for sample 238, Gladmar Pond.

Table 20. Qualitative sediment particle data for Gladmar Pond; see also Figures 46 and 47.

Particle Size Range	Comments
86.6% 0.02 to 0.003 in., 13.4% <0.003 in.	Fine sand, silt and clay
100% < 0.003 in	Silty clay
41.9% 2.9 to 0.19 in., 53.5% 0.19 to 0.003 in., 4.6% <0.003 in.	Graded gravel to silt and clay

Site Sample Information

Sample site locations for the thermal investigation, fish assemblage, and benthic macroinvertebrate/water-quality work for Gladmar Pond are shown in Figure 48. Standard sampling protocol is discussed in Chapter 4 (Methods). Individual site results are discussed per study component in the next sections.

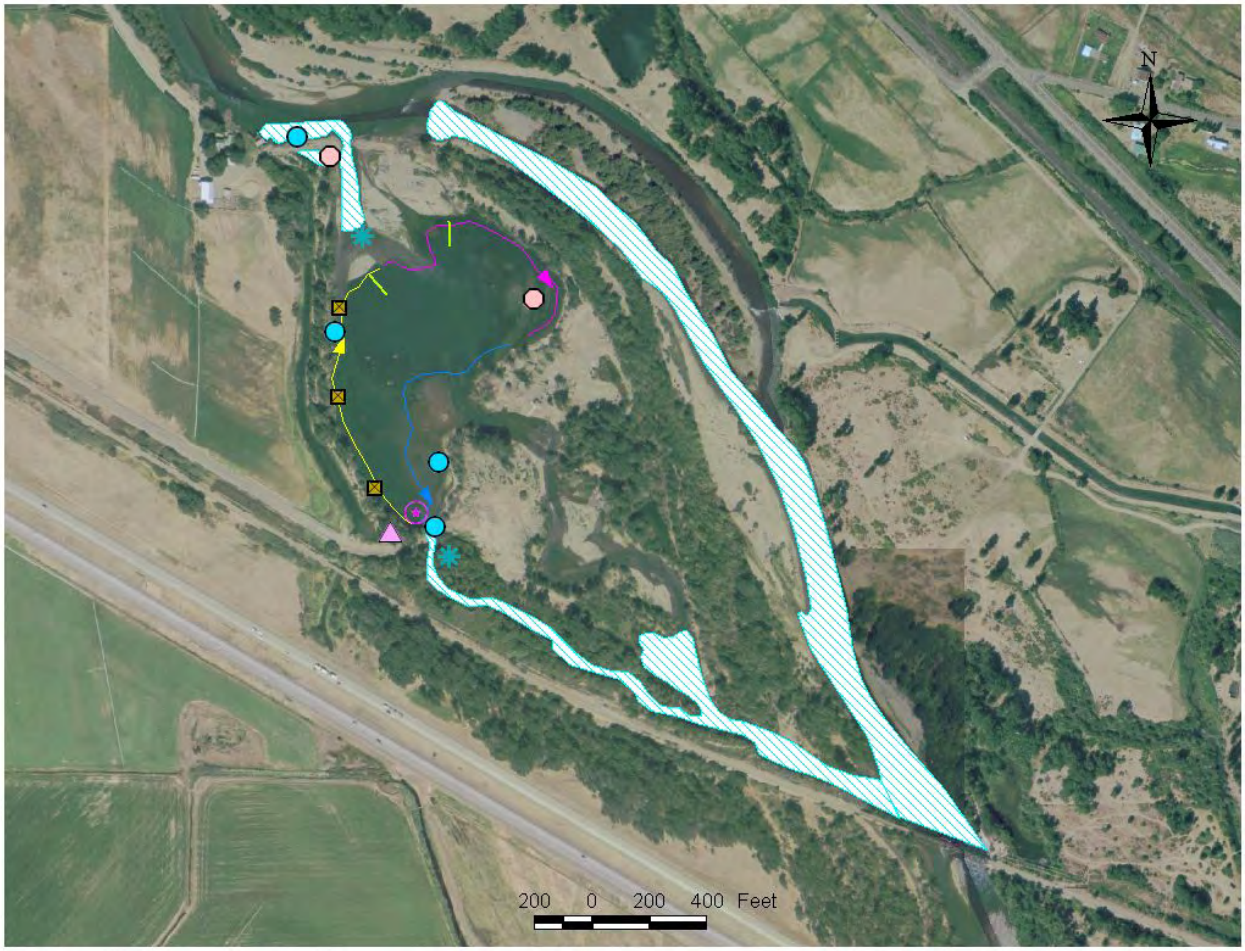


Figure 48. Thermal, fish assemblage, benthic macroinvertebrate, and water-quality sample site locations for Gladmar Pond. The explanation of the symbols used to denote locations on this photograph is on p. xxii. (Photo source: Washington Department of Transportation, 2002)

Thermal Investigation

Temperature was monitored upstream of, in the middle, and at the downstream portion of the breached pond shoreline (Figure 48). The upstream monitoring equipment was attached to a large rip-rap dike in fairly deep, swift water; the middle monitoring station was located off the east bank of the former pit site and was exposed to direct sunlight, siltation, and lack of surface water in the mid-summer months. The recording unit was consequently moved to the west bank in mid-September. The downstream monitoring instrument was located in fairly deep water and was shaded in the morning. The Ext unit (air) was located in a riparian area in the downstream portion of the site (Figure 48). Temperature data were recorded from April 15 to November 14, 2002.

River

Table 21 lists the monthly averages of all temperature measurements collected in the Yakima River at the upstream and downstream sites. Data from a middle site have been omitted due to

erratic results probably related to variations in water depth at the site. The table also shows the difference in average temperature between the upstream sample site and the downstream site. Comparisons are made downstream. Thus, a positive value indicates an increase in downstream temperature, whereas a negative value indicates a cooler temperature downstream. The average monthly temperature contrasts are small, but temperature increases downstream.

Table 21. Average monthly Yakima River temperatures (in °C) and comparisons at Gladmar.

Month	Upstream	Downstream	dT Upstream/ Downstream
April	7.24	7.31	0.07
May	8.95	9.07	0.12
June	10.98	11.10	0.11
July	13.59	13.77	0.19
August	15.05	15.12	0.07
September	15.31	15.34	0.03
October	10.02	10.03	0.00
November	5.65	5.56	-0.09

Figure 49 shows the daily minimum and maximum temperatures recorded at the upstream and downstream sites. The plot indicates that there is a small but persistent increase in the temperature of the river downstream. This increase is reflected in both the daily minimum and maximum temperatures. (More detail is given in the monthly time series plots of daily minimum and maximum temperatures in Appendix I.)

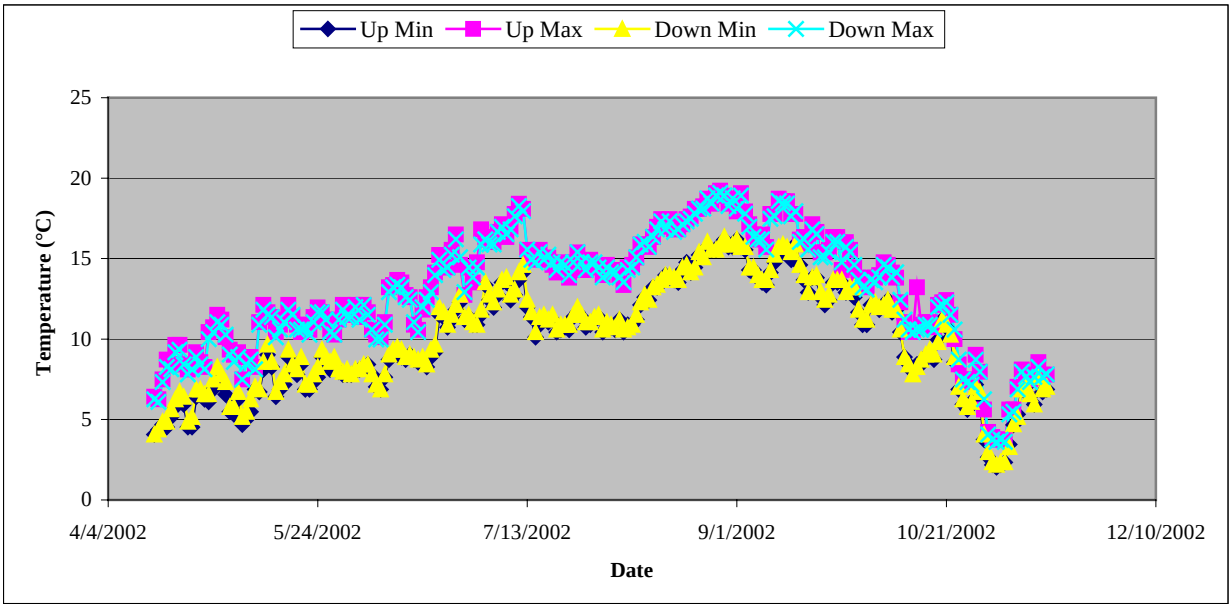


Figure 49. Yakima River minimum and maximum temperatures at the Gladmar site.

Fish Assemblage

Gladmar was sampled by electroshocking boat, fyke nets, and gill nets following the standard protocols on July 18-19, 2002. The river was sampled with backpack electroshocking gear on September 25 only above the pond (250-m reach) and was surveyed with snorkeling gear above (300-m reach) on September 25 and below (300-m reach) the pond on October 16. The water was too deep for wading and prevented backpack shocking below the pond. The water was very clear, and visibility during sampling was excellent.

Appendix K, Tables 6-9 display data collected at Gladmar and in the Yakima River above and below the naturally avulsed pond. A summary of species composition is presented in Table 22.

Eleven species (n = 414) were found in the pond. A composite sample of all three sample gear types shows that suckers (28%) were slightly more plentiful than northern pikeminnow (25%) and were followed by juvenile chinook (23%). Other salmonids (rainbow and cutthroat trout; whitefish) were present but less abundant in the pond than in the adjacent river reaches. The significant presence of northern pikeminnow, even though this pond is avulsed, is clear evidence that the remaining low-velocity areas on each side of the river flow that now bisects the pond is preferred pikeminnow rearing habitat. Most northern pikeminnow were observed at the interface between moving and still water.

The presence of chinook salmon (Figure 50) and mountain whitefish (Figure 51) in the river above and below the Gladmar site is consistent with our expectations for this reach and similar to the species complex near Hanson Ponds. Seven species (n = 113) were sampled with backpack electrofishing gear, and the same seven species (n = 1,077) were observed while snorkeling. A total of 1,190 fish representing nine species was sampled in the river. Combining results of all river sampling methods, chinook (39%), whitefish (22%), and *Onchorhynchus mykiss* (14%) were most the most abundant fish. Northern pikeminnow (8.5%) were the only interspecific salmonid predators sampled in the river.

Figure 50. A 9 cm juvenile spring chinook salmon, Gladmar.

Figure 51. Mountain whitefish (33 cm), Gladmar.

The data does not suggest that Gladmar Pond is influencing species composition in the river. The only exotic species observed in the pond was common carp, at very low relative density (0.2%), and no carp were sampled in the river. Two other native species, chiselmouth and coho salmon, were observed in the pond, but not during river sampling, although they are undoubtedly there. Cutthroat trout was the only species observed in the river (0.2%) that was not observed in the pond.

Prior to avulsion, Gladmar Pond was stocked by WDFW annually with rainbow trout and supported several exotic species, including largemouth bass and pumpkinseed sunfish. Post-avulsion, the spiny-ray species are absent, and the habitat is gradually becoming more suitable for Yakima River salmonids. None of the exotic species that would have entered the river when Gladmar was captured by the river in 1996 were found in the river above or below the pond, indicating that river habitat in this reach is not favored by exotic warm-water species.

Table 22. Percent composition of fish sampled in 2002 at Gladmar Pond and the Yakima River adjacent to the pond. See Table 6 for definitions of the species code. The bold values indicate dominant species in the samples. The drift boat was not used on these reaches.

Species	Gladmar Pond (7/18-19)	River		
		Above (9/25)	Below (9/25)	Combined
CK	**22.7**	**25.1**	**48.5**	**39.2**
CMO	0.2			
CO	5.6			
COT	1.4	7.2		2.9
CP	0.2			
CT		0.2	0.1	0.2
DAC	0.2	1.5		0.6
NPM	**24.9**	**20.3**	0.7	8.5
RB	2.7	**17.9**	**10.8**	**13.6**
RS	6.3	0.6	8.7	5.5
SK	**28.0**	12.4	4.5	7.6
WF	7.7	14.8	**26.8**	**22.0**
Total %	100.0	100.0	100.0	100.0
Sample size	414	474	716	1190

Benthic Macroinvertebrates, Water Quality, and Macrophytes

Benthic Macroinvertebrates and Water Quality

Water quality in the flow exiting the Gladmar pond was good (tabulation below; see Table 14 for definition of column headings*)*. The benthic macroinvertebrate community in the pond appeared to be in a condition more similar to that of the mainstem Yakima River than to isolated ponds (Appendix L, Table 14).

Depth (m)	Temp (°C)	pH (units)	Cond (µS/cm)	DO (mg/L)	chla (µg/L)	secchi (m)	OP (mg/L)	TDS (mg/L)	TN (mg/L)	TP (mg/L)
0.5	15.6	7.53	63	9.5	0.69	-99	0.014	ND	51	0.08

In the river, water quality was similar between the upper and lower reach (see tabulation below and Table 15). At the macroinvertebrate sampling locations, the upper reach had significantly wider wetted and bankfull widths (Table 23), and the lower reach had significantly more canopy cover (Table 17).

Site	Date (2002)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	pH (units)	Temperature (°C)
Downstream Gladmar	09/18	60	10.2	7.63	13.0
Upstream Gladmar	09/18	57	10.2	7.49	13.8

There were mixed biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Tables 17 and 18). The cluster dendrogram, however, indicates that the reaches did have slightly different biological compositions (Figure 39). The CCA plot also shows a slight separation of macroinvertebrate community compositions between the two reaches (Figure 52).

The lower reach had intolerant macroinvertebrates, which indicates good water quality. However, the exclusive presence of *Simulium* spp., filter feeders, in the lower reach, illustrates the presence of lentic water immediately upstream. *Simulium* species. feed on suspended organic particles and are commonly dominant in lake outlets or ponds. Differences in wetted width appeared to explain the physicochemical variations in biological differences, but this may be an artifact of sampling locations (Table 23).

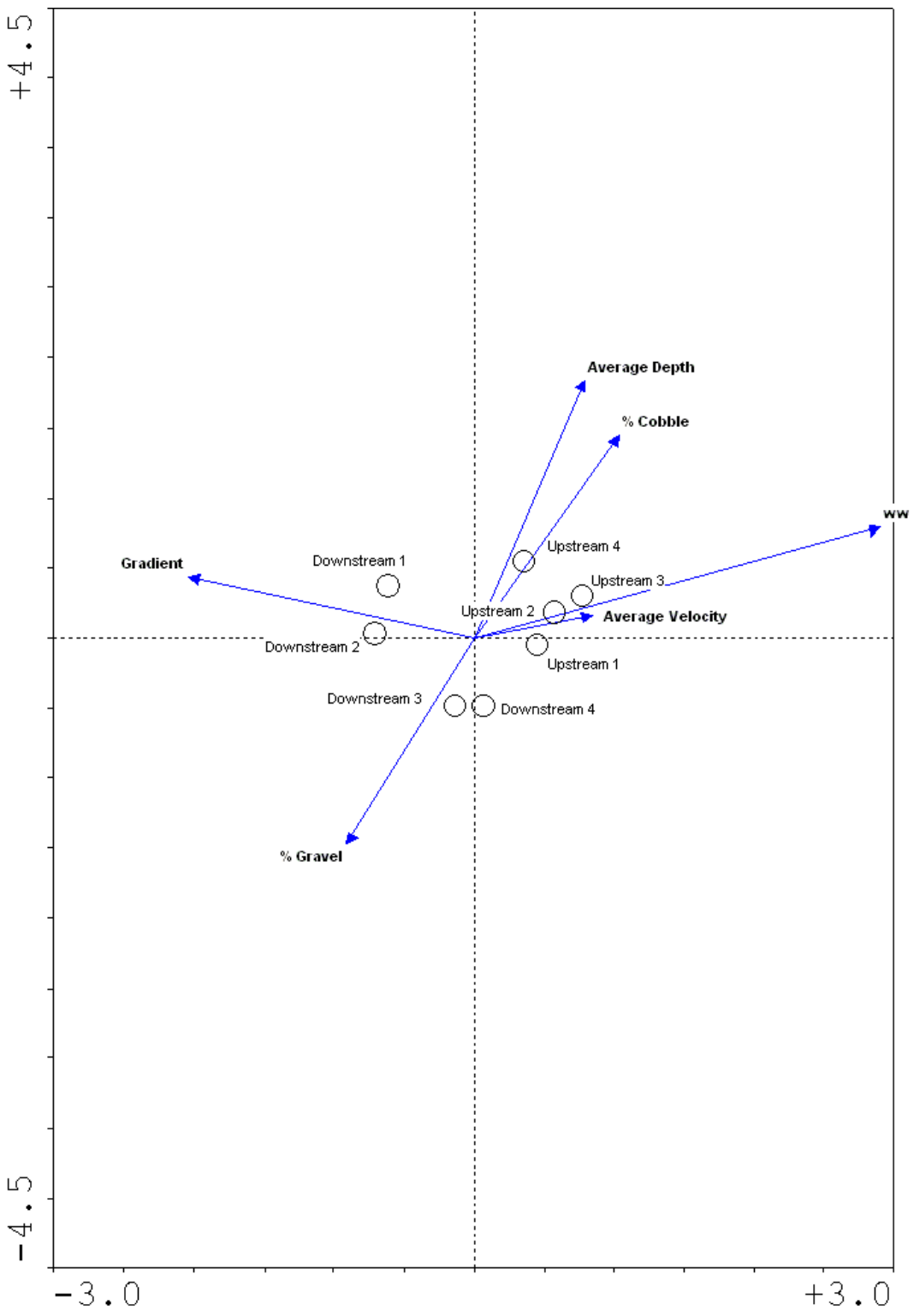


Figure 52. Canonical Correspondence bi-plot showing Gladmar benthic macroinvertebrate site distribution and major physicochemical explanatory vectors.

Table 23. Canonical correlations of physiocochemical variables of ordination axes at Gladmar river sites. n.s., not significant at $p<0.05$.

Variable	Axis 1 (x-axis)	Axis 2 (y-axis)
Wetted Width	0.86	.35
Average Depth	n.s.	.81
Average Velocity	0.25	.07
Gradient	n.s.	.20
Cobble	n.s.	.64
Gravel	n.s.	-.65

Macrophyte Survey

This pond is joined to the Yakima River and had a current flowing through it. Because the team did not launch a boat, we identified only plant species growing close to shore. All the submersed plants were native, the dominant being ribbon leaf pondweed (*Potamogeton epihydrus*), which appeared to also be plentiful in the flowing water away from shore. Reed canarygrass (*Phalaris arundinacea*), a common non-native invasive species, was present along the shore.

Site 2 Comments and Recommendations

The Gladmar site avulsed in 1996. The water quality is good, and flow through the site is adequate for salmonids. Further, the benthic macroinvertebrate community in the pond appeared to be in a condition more similar to that of the mainstem Yakima River than to isolated ponds in this reach.

Fishery concerns include fairly high populations of northern pikeminnow in the slack water perimeter of the former pond site. However, exotic predator/competitor species, including largemouth bass and pumpkinseed sunfish, were absent. Chinook salmon, rainbow trout, and whitefish were present in good numbers (compared to the adjacent river study reach), especially near the thalweg, demonstrating that the river water quality at this site is conducive to providing excellent salmonid habitat. River temperatures were similar to those at the Hanson Pond site.

The results of sampling this pond after avulsion illustrate the short-term response of fish species after avulsion of a gravel pit pond in the upper reaches of the Yakima Basin. As the avulsion process continues, the Gladmar site is expected to become more riverine (lotic) and less pond-like (lentic). This should result in a shift toward improved salmonid habitat and a reduction in preferred habitat (deeper, slower water) for northern pikeminnow, suckers, and carp.

Recommendations

Recommendations for Gladmar include:

- Continue monitoring fish assemblages and benthic macroinvertebrate communities.
- Continue to track sediment transport and river and pond geomorphology.

- Pair monitoring research, particularly water temperature, with the Hanson Ponds reclamation project.
- Ensure adequate flow is diverted through the site in order to promote sediment deposition with which to regrade and reclaim the site. Given effective flow, sediment will be transported into and reworked within and below the site, providing preferential habitat for salmonids.

7. I-90 PONDS (Site 3)

Location and Site Information

Several ponds are located between the river and Interstate 90 (I-90) approximately 7 mi northwest of Ellensburg (Figure 53). They are fairly shallow and cover 43.6 acres. The southernmost pond, Pond 4, was the focus of this study. Pond 4 (39.9 acres) has a volume of about 96,000 yd^3.

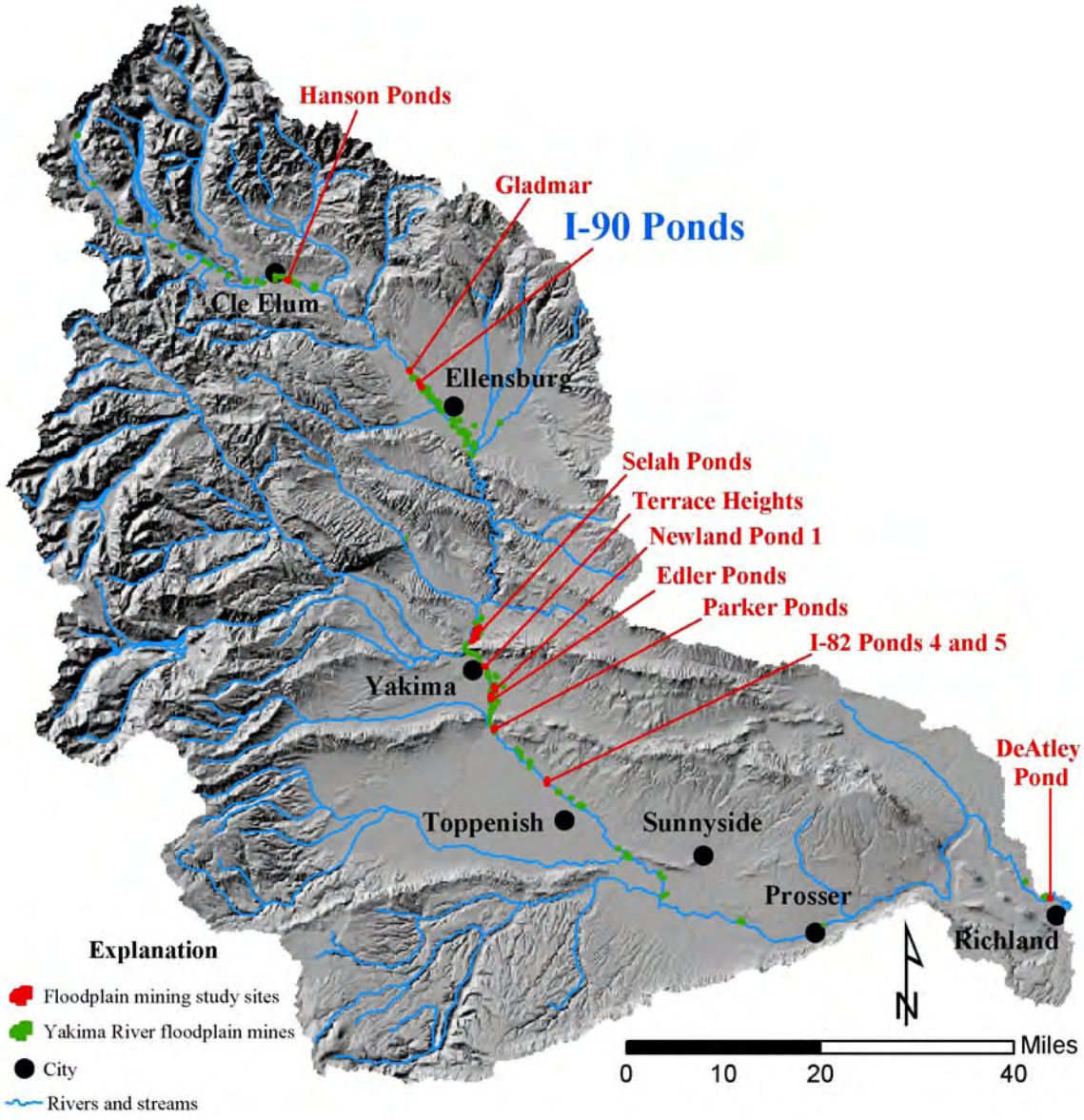


Figure 53. Location of I-90 Ponds (Site 3).

Pond Bathymetry and Sediment Sampling

The Yakima River near Pond 4 has a confined meandering channel. Active channel migration and avulsion have been somewhat retarded by the placement of I-90 across the floodplain, which effectively halved the area for migration. The channel migration zone near Pond 4 increases from approximately 600 ft wide in the mile upstream of the pond to 1,500 ft wide adjacent to the downstream end of the pond. The average reach slope of the valley near the ponds is 0.00294, or about a 15.5-ft drop in elevation for each mile downstream.

Pond 4 is separated from the river by a rip-rap reinforced dike and is approximately 550 ft from the river at its northern end, 100 ft at its western margin, and 30 ft from a side channel of the river at the outfall pipe across the dike (Figure 54). The river may have overflowed into the pond during the 1996 100-yr-flood event, although it did not avulse it. Along the far western portion of the pond is a potential avulsion point (Figure 54) where, during very high flood discharges, the river could overtop the dike. On May 29, 2002, minor amounts of water were observed entering Pond 4 via small surface streams connecting this pond to the up-gradient ponds; this water is not associated with overtopping of the dike by the river or imminent avulsion, but is normal down-gradient movement of water within the semi-connected I-90 Ponds system.

The bathymetry of Pond 4 is simple. It is shallow (avg 4.2 ft); it reaches a maximum measured depth of 8 ft in the southeast corner (Figure 55). The northernmost portion of the pond is characterized by several shallow embayments. There is a general downward slope of the pond bottom from the northwest to the south and east. The location of the deeper areas may reflect mining from west to east as material was “scooped” from the pond and used nearby as road aggregate during construction of I-90. The scallops along the northeastern margin of the pond are artifacts of the bathymetric modeling (Figures 56 and 57).

As noted, the northeast corner of the pond is a potential entry point for occasional floodwaters from the Yakima River (Figure 54). South of the potential entry point, coarse gravel, cobbles, and boulders have been deposited to form a delta that is prograding south into the northwest portion of the pond. As floodwater enters the pond, stream energy is dissipated, and visual inspection of the pond floor by a diver indicates that finer sediment is deposited progressively downgradient from the potential point of entry. Sediment samples 136 and 172 (Table 24) are composed of 100% silt and clay, and 159 consists of 72.3% silt and clay and 27.7% fine sand (Figure 58). These fine sediments, which appear to be ubiquitous across the pond bottom, may represent the top of the Thorp Formation or post-mining sedimentation during river overflow events. In-stream sample 200 collected from a downstream river bar (Figure 59) consists of well-graded cobbles and gravel (82.9%), sand (16.8%), and minor silt and clay (0.2%). Gravel and cobbles range from 0.2 to 5.9 in. in diameter. Sample 200 contrasts with the in-pit samples in that it has a much smaller percentage of fines.

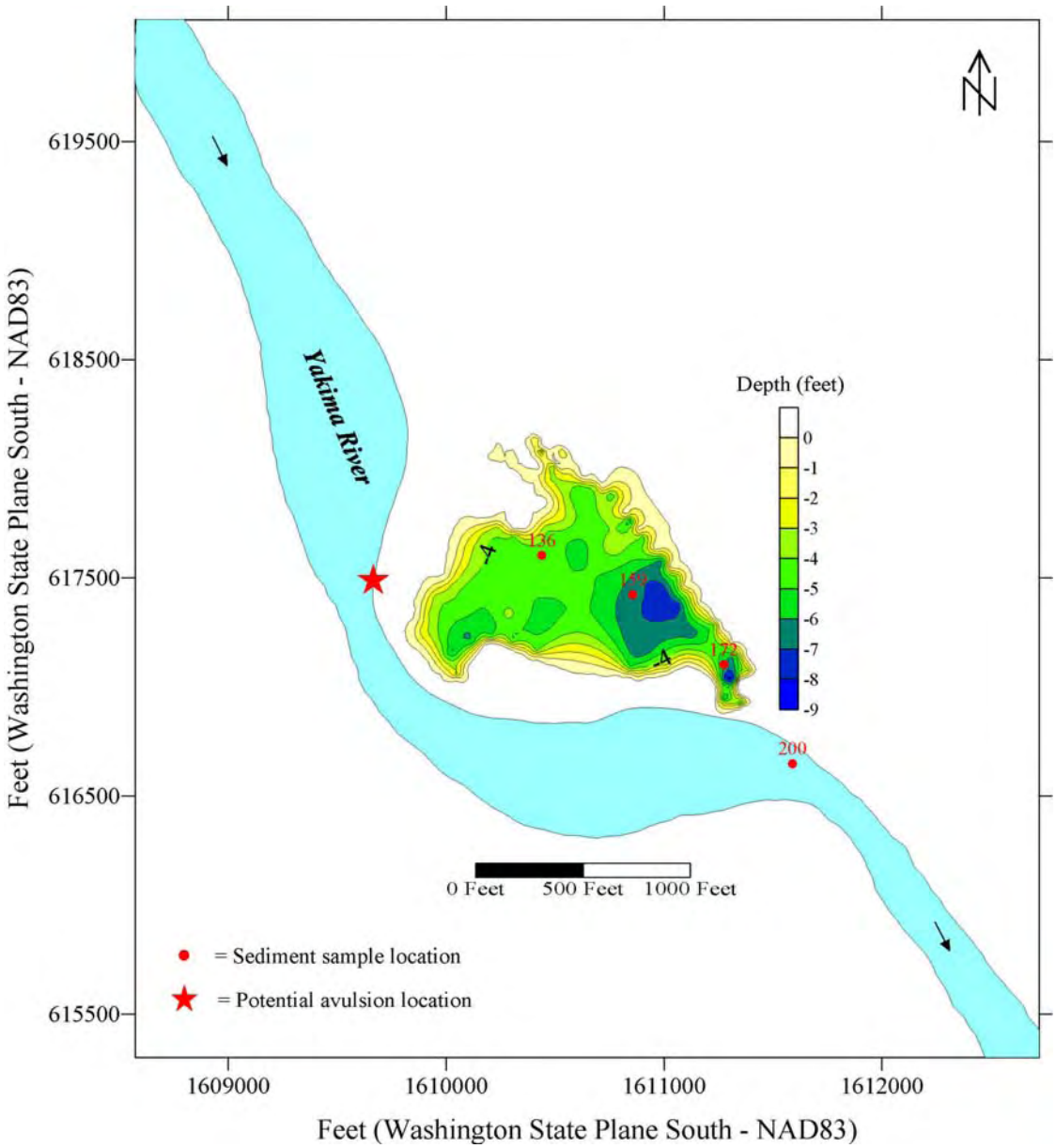


Figure 54. Contoured bathymetric map of I-90 Pond 4 showing locations of sediment samples (GPS waypoint number) and proximity to the Yakima River.

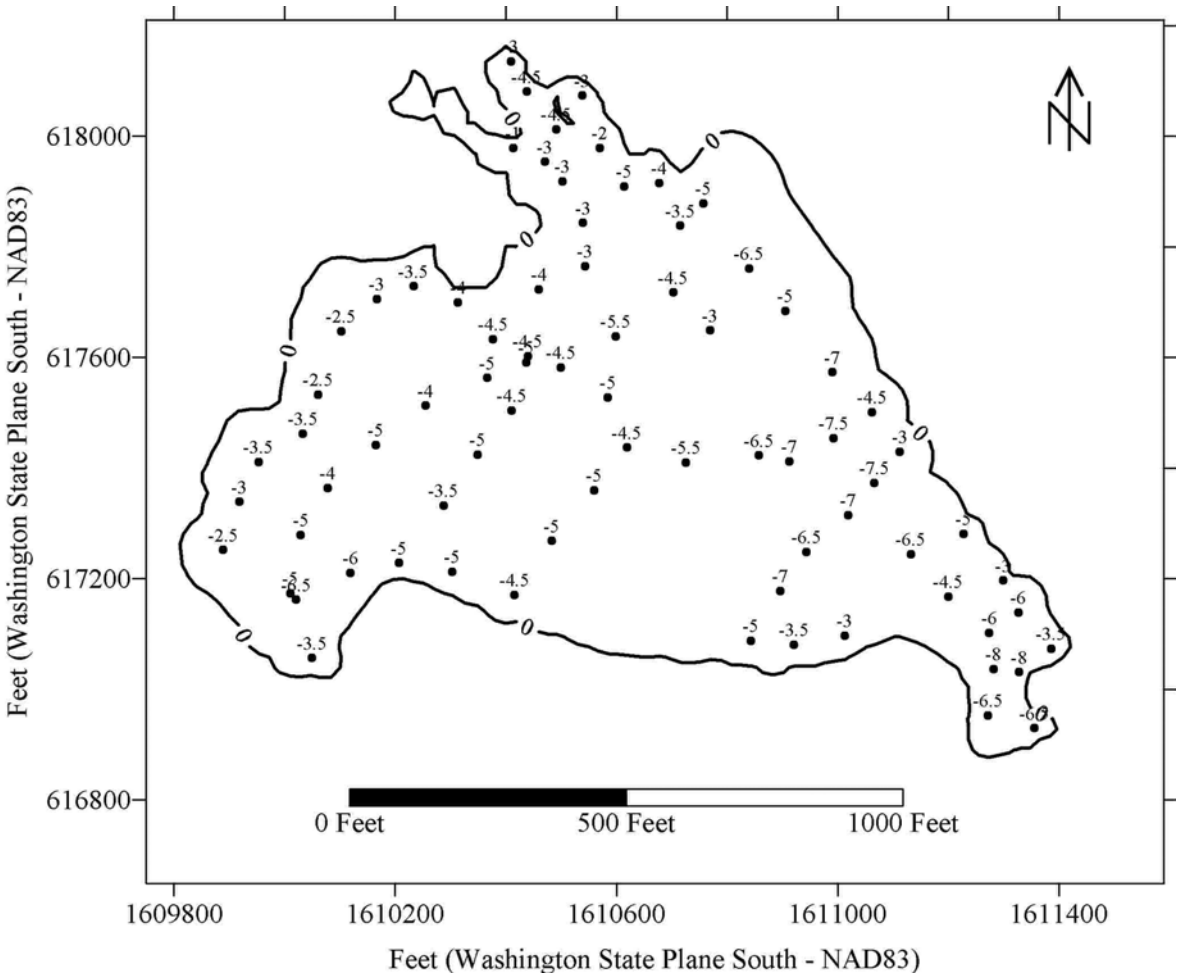


Figure 55. Post map showing data point locations and depths (in ft) used to model pond bathymetry for I-90 Pond 4, May 29, 2002.

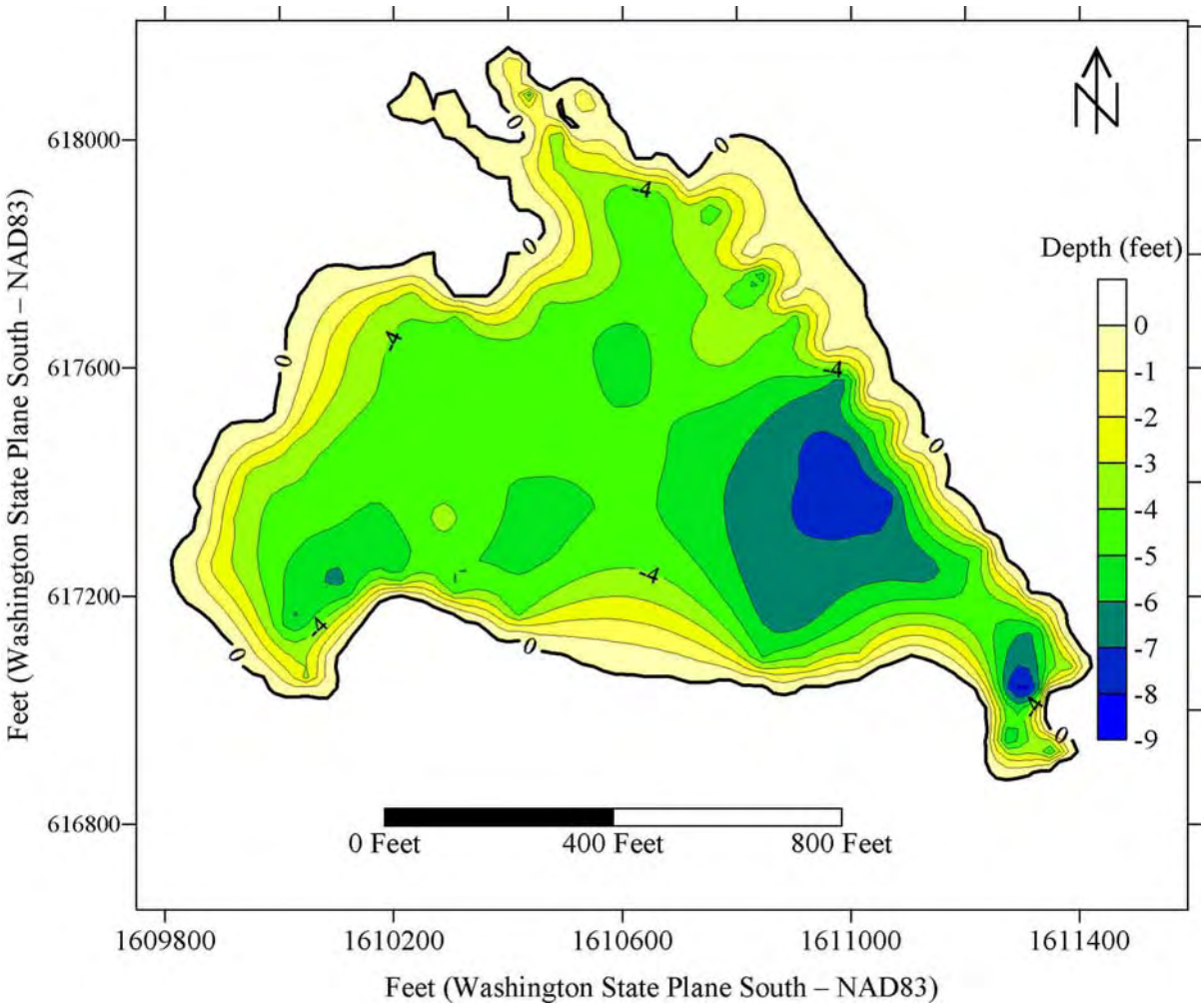


Figure 56. Contoured bathymetric map of I-90 Pond 4; bathymetry in feet below the water level on May 29, 2002.

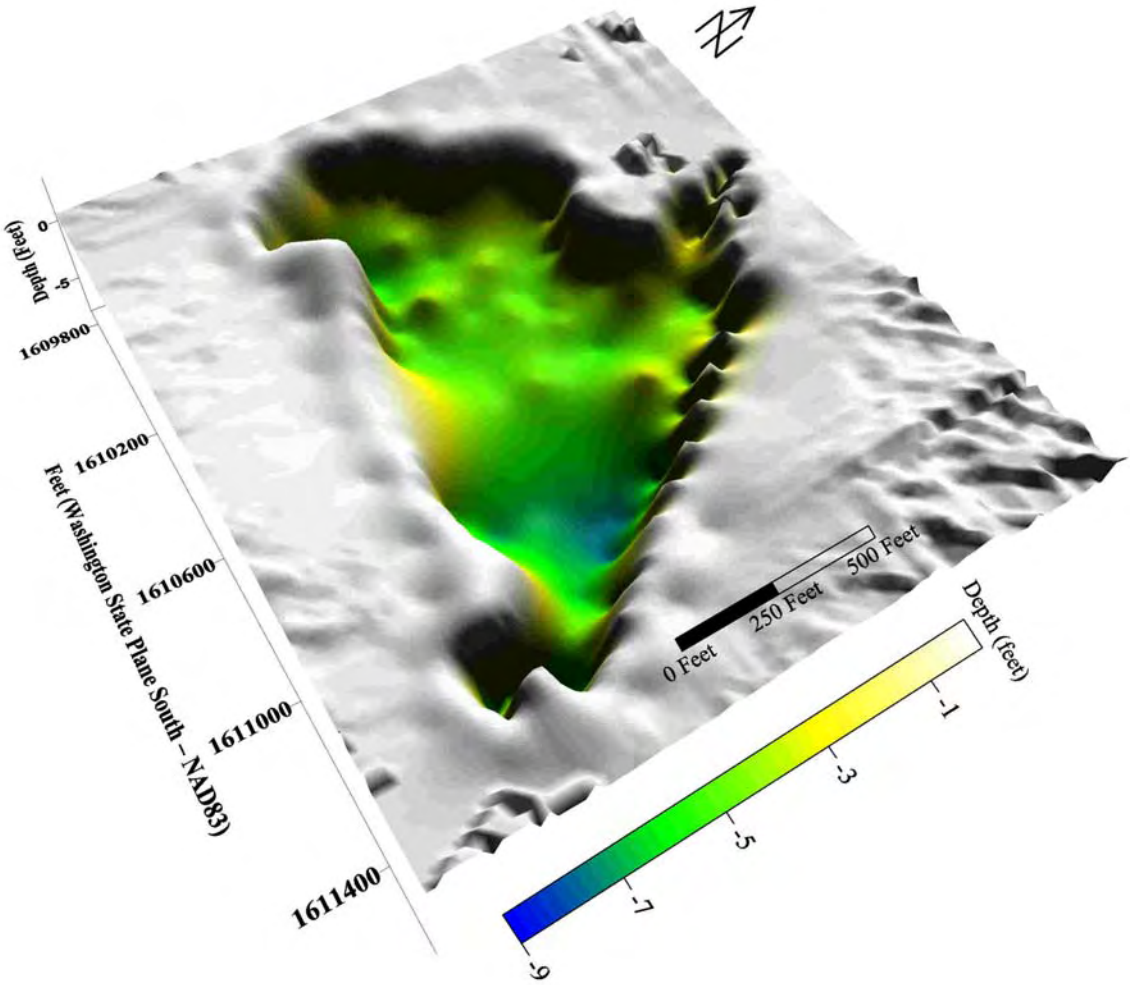


Figure 57. 3-D perspective bathymetric map for I-90 Pond 4; bathymetry in feet below the water level on May 29, 2002.

Table 24. Qualitative sediment particle data for I-90 Pond 4; see also Figures 58 and 59.

Sample No.	Particle Size Range	Comments
136	100% <0.003 in.	Silt and clay
159	27.7% 0.02 to 0.003 in., 72.3% < 0.003 in.	Fine sand, silt and clay
172	100% <0.003 in.	Silt and clay
200	82.9% 11.8 to 0.19 in., 16.8% 0.19 to 0.003 in., 0.2% <0.003 in.	Cobbles and Gravel with minor sand, silt and clays

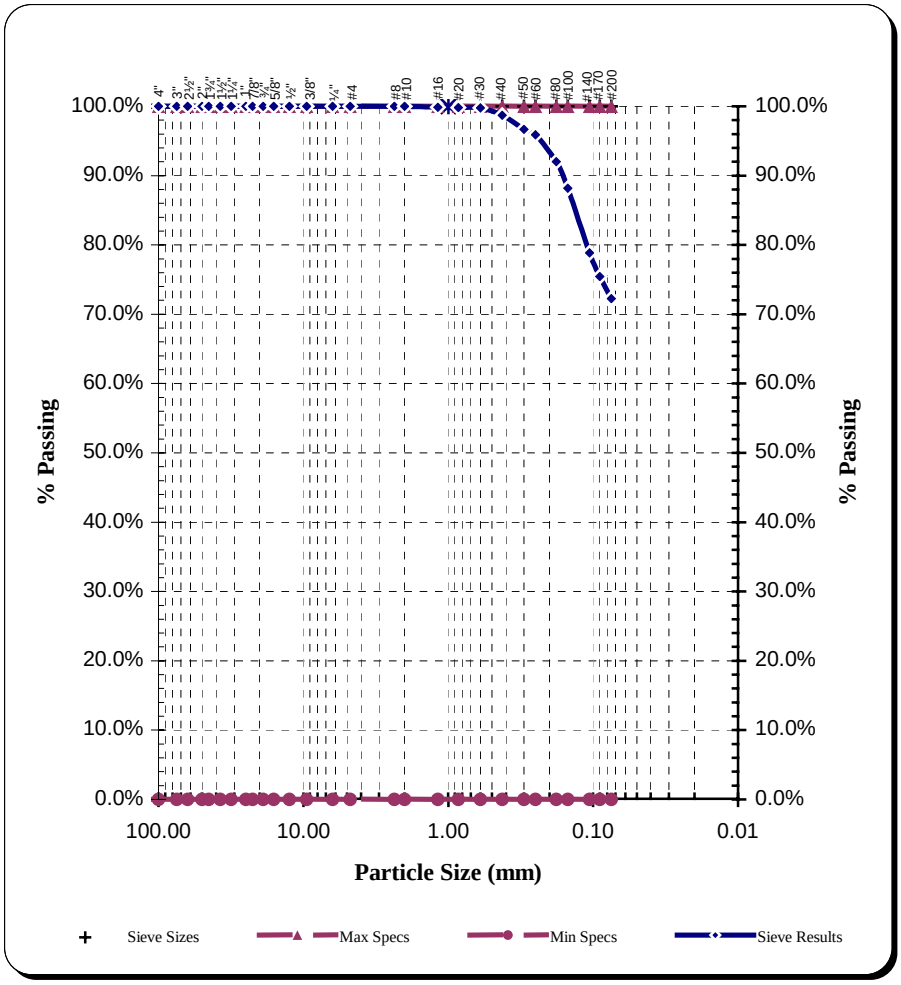


Figure 58. Grain-size distribution plot for sample 159, I-90 Pond 4 sediment.

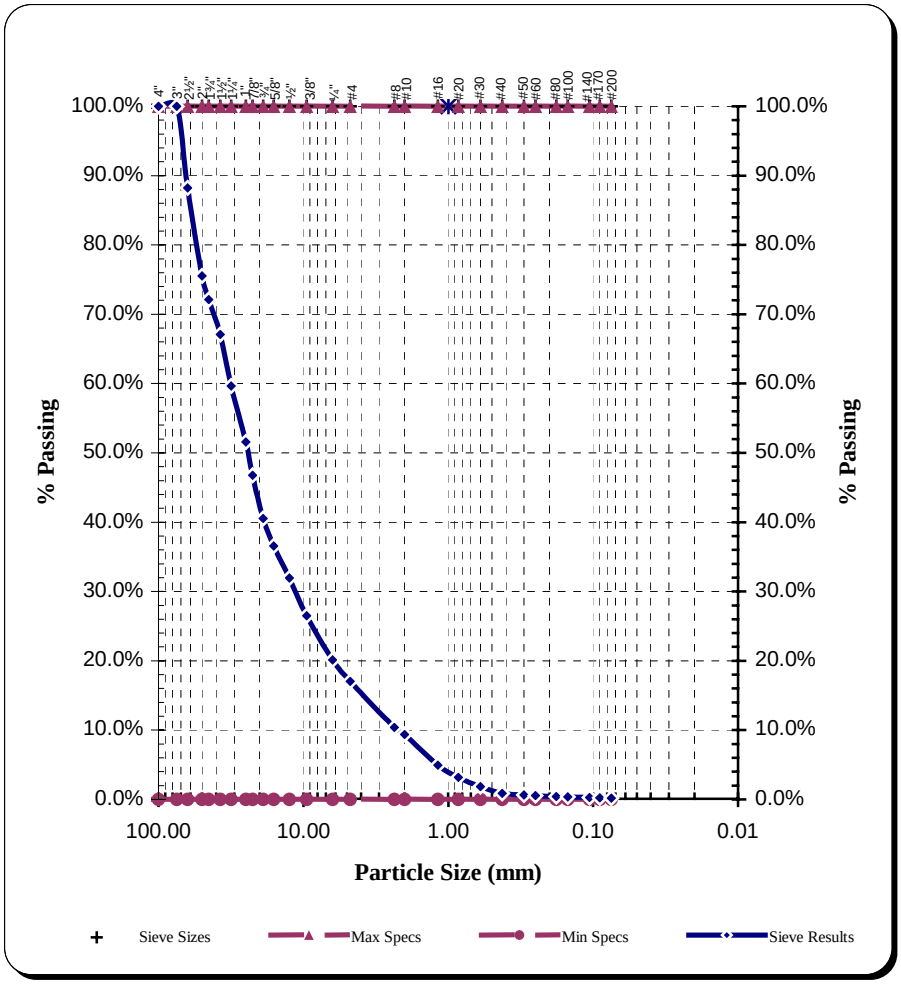


Figure 59. Grain-size distribution plot for the Yakima River sediment sample 200, downstream of I-90 Pond 4.

Site Sample Information

Sample site locations for the thermal investigation, fish assemblage, and benthic macroinvertebrate, and water-quality work for I-90 Ponds are shown in Figure 60. Standard sampling protocol is discussed in Chapter 4 (Methods). Individual site results are discussed per study component below.

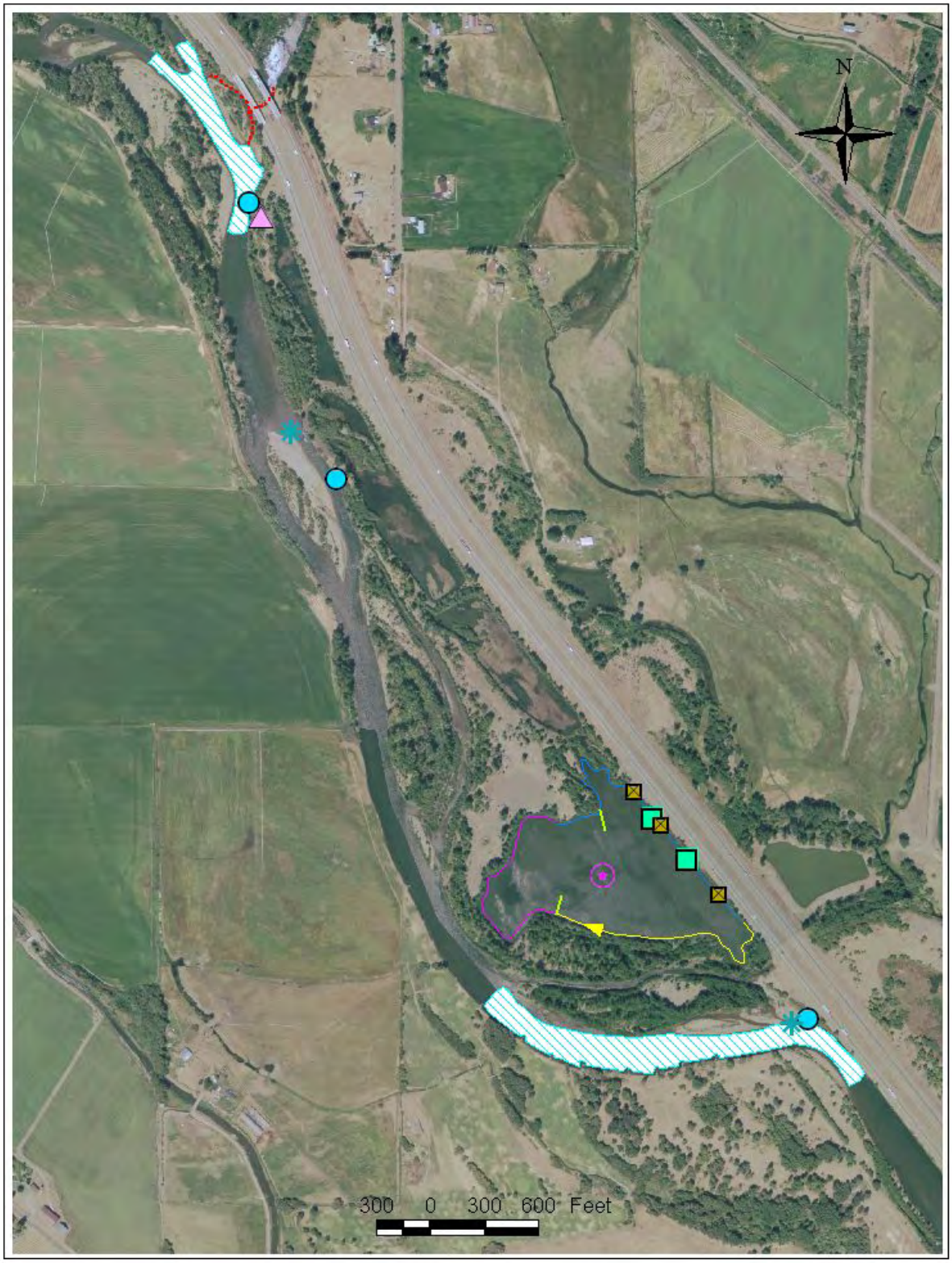


Figure 60. Thermal, fish assemblage, benthic macroinvertebrate, and water-quality sample site locations for I-90 Pond 4. The explanation of the symbols used to denote locations on this photograph is on p. xxii. (Photo source: Washington Department of Transportation, 2002)

Thermal Investigation

At the I-90 Ponds site, river temperature data were recorded at an upstream site, a middle site, and a downstream site (Figure 60). Both the upstream and middle river temperature monitoring instruments were located upstream of Pond 4, but the middle station was central to the pond complex. The downstream instrument was located directly below Pond 4, in 2 to 3 ft of water. The upstream and downstream locations were partially shaded, and the instruments were also placed in approximately 2 to 3 ft of water.

In addition, two monitoring instruments were tethered to the pond shoreline and placed in 2 to 3 ft of water (pond water levels fluctuated with river level) on the west bank of the pond (nearest to the freeway) in early June. The Ext (air) unit was located in the riparian area near the upstream river monitoring location (Figure 60). Temperatures were recorded at the Ext and river monitoring locations from April 15 to November 14, 2002.

River

Table 25 shows the averages of the temperature data recorded each month and the changes (dT) in average temperature between the upstream and middle sample sites, between the upstream and downstream sites, and between the middle and downstream sites. Positive numbers represent an increase in temperature in the downstream direction, whereas negative values represent cooler downstream temperatures. The table documents a consistent and perhaps significant increase in temperature downstream. The greatest temperature increases occurred between the middle and downstream sites, with more than a 1°C increase in October.

Table 25. Average monthly Yakima River temperatures (in °C) at I-90 Pond 4.

Month	Upstream	Middle	Down-stream	dT Upstream/-Middle	dT Upstream/ Downstream	dT Middle/ Downstream
April	7.36	7.36	7.71	0.00	0.35	0.35
May	8.99	9.03	9.37	0.04	0.38	0.34
June	11.00	11.03	11.31	0.02	0.30	0.28
July	13.66	13.68	14.05	0.02	0.39	0.37
August	15.05	15.06	15.28	0.02	0.24	0.22
September	15.28	15.29	15.69	0.01	0.41	0.40
October	10.07	10.22	11.24	0.15	1.17	1.02
November	5.65	5.75	6.54	0.10	0.90	0.79

Figure 61 displays the river daily minimum and maximum temperatures with time and suggests little difference among the maximum temperatures at the various measurement sites early in the period of record. However, during the mid-summer and fall, the river temperature notably increased downstream. The minimum temperatures appeared to retain the same relation throughout the year, although the downstream minimum temperatures were slightly higher than at the other two sites.

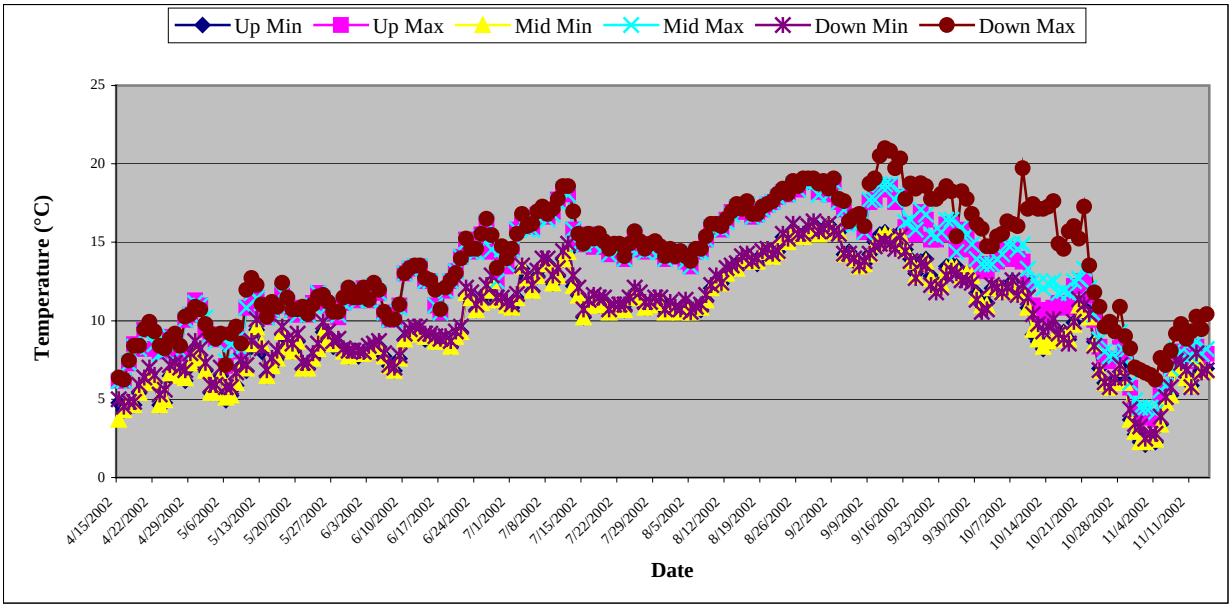


Figure 61. Daily Yakima River minimum and maximum temperatures at I-90 Pond 4.

Pond

Figure 62 displays the minimum and maximum daily temperature gradient measured along the west bank of Pond 4. Note that the maximum temperature approached 30° C in mid-July.

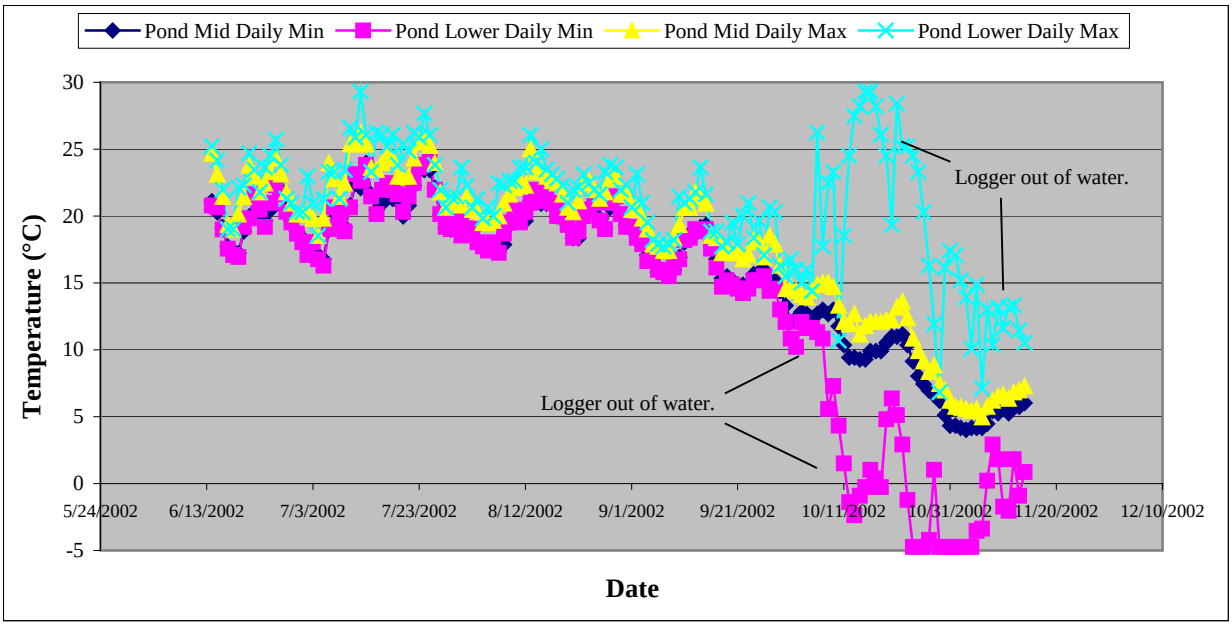


Figure 62. Daily minimum and maximum temperatures at ~3-ft depth, west bank, I-90 Pond 4.

Fish Assemblage

I-90 Pond 4 was sampled with the electroshocking boat, fyke nets, and gill nets following the standard protocol on June 17 and 18, 2002. The sampled river reach above the pond was upriver of the series of small ponds that drain into the largest I-90 Pond. The sample site below the pond was closest to the easternmost point of the pond. The reach above the pond (225 m) was sampled with backpack electroshocking on October 15 and snorkeling gear (200 m) on October 8 and November 11. The section below the pond was too deep to use backpack electrofishing equipment, so a 400-m reach was surveyed by snorkeling. Minimum sample sizes of 200 fish were exceeded in all reaches. Water in the pond was turbid (poor visibility) and may have affected sampling efficiency during boat electroshocking, but the river was clear during sampling.

Appendix K, Tables 10-13 display data collected in I-90 Pond 4 and in the Yakima River above and below the pond. A summary of species composition for this site is presented in Table 25.

Eight species (n = 874) were collected from Pond 4. Pumpkinseed sunfish (43%) (Figure 63) were most abundant, followed by yellow perch (31%) (Figure 64), but neither species was observed in the adjacent river samples. Northern pikeminnow and carp were collected, but composed only 6% and 1% of the pond sample, respectively. Two juvenile coho salmon were sampled, but no chinook or *Onchorhynchus mykiss* were found, which suggests that the pond is connected to the river infrequently and for short duration during flood events.

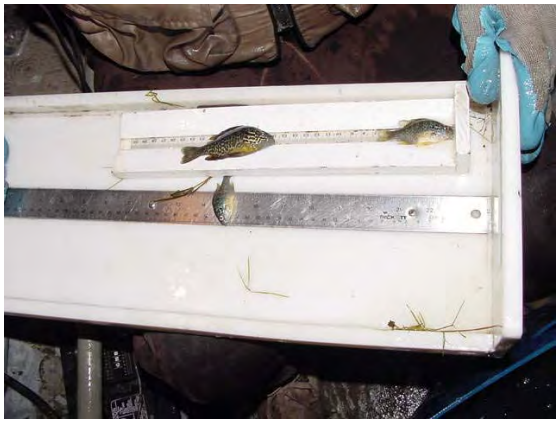


Figure 63. Pumpkinseed sunfish (7-10 cm), I-90 Pond 4.

Figure 64. Yellow perch (36 cm), I-90 Pond 4.

Nine species were sampled in the river (n = 340) with backpack electroshocking gear and six species (n = 895) during snorkel surveys. Backpacking electroshocking showed that salmonids, including chinook, *O. mykiss*, and mountain whitefish, in that order, dominated the river sample above the pond. However, suckers and whitefish were the most abundant species upstream on the basis of snorkeling observations; snirkeling was a more effective sampling method in deeper water where adult suckers and whitefish were primarily located. During snorkel surveys downstream of the pond, chinook (40%), whitefish (29%), and suckers (14%), in that order, were the most abundant species observed. Considering all river samples combined, whitefish (32%),

suckers (27%), chinook (22%), and *O. mykiss* (8%) were the most abundant species (Table 26). Northern pikeminnow (3%) was the only non-salmonid predator sampled in the Yakima River at this site.

Table 26. Percent composition of fish sampled in I-90 Pond 4 and the Yakima River adjacent to I-90 Pond 4. The bold values indicate dominant species. The drift boat was not used at this site. See Table 6 for species codes.

Species	I-90 Pond	River		
		Above	Below	Combined
CK		**12.1**	**40.2**	21.9
CMO	0.8			
CO	0.2	0.4		0.2
COT		**10.2**		6.6
CP	1.3			
DAC		2.6		1.7
NPM	6.4	0.9	5.8	2.6
PS	**42.9**			
RB		6.6	**11.0**	8.1
RS	**15.0**	0.5		0.3
SK	2.6	**34.0**	**14.0**	**27.0**
WF		**32.8**	**29.0**	**31.5**
YP	**30.8**			
Total	100.0	100.0	100.0	100.0
Sample Size	874	807	428	1235

Although the species assemblage in the pond was markedly different from that at Hanson and Gladmar, the species composition in the river adjacent to these ponds was similar to those at the two upriver sites. If this pond is allowed to naturally avulse or is breached, a number of exotic species will enter the river, but the species present are not important predators and the river habitat in this upper part of the Yakima Basin is not conducive to establishing a community of exotic spiny-ray species. These ponds could provide valuable salmonid habitat if connected to the river in a manner that minimizes slackwater areas preferred by northern pikeminnow. The salmonid predators are currently at low abundance in the pond and river, but breaching has the potential to increase their abundance, as at Gladmar.

Benthic Macroinvertebrates, Water Quality, and Macrophytes

Benthic Macroinvertebrates and Water Quality

I-90 Pond 4 had good water quality and was not stratified at the time of sampling (September 18; see tabulation below and Table 14). The benthic macroinvertebrate community appeared to be in a condition typical of this pond habitat (Appendix L, Table 17).

Depth (m)	Temp (°C)	pH (units)	Cond (µS/cm)	DO (mg/L)	chla (µg/L)	secchi (m)	OP (mg/L)	TDS (mg/L)	TN (mg/L)	TP (mg/L)
0.5	19.2	8.46	102	11.9	2.85	1.4	0.016	ND	51	0.17
2	18.3	8.14	103	9.5	NA	NA	NA	NA	NA	NA

In the river, water quality was similar at the upper and lower reaches (tabulation below). Reach characteristics and sediment composition were also similar between them, with no statistical differences (Appendix L, Table 1).

Site	Date (2002)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	pH (units)	Temperature (°C)
Downstream I-90 Pond 4	09/18	60	10.1	7.32	16.1
Upstream I-90 Pond 4	09/18	60	9.8	7.11	15.0

There was very little difference in biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Table 17). The cluster dendrogram (Figure 39), however, indicates that the reaches did have different biological compositions. The CCA plot also shows a weak separation of macroinvertebrate community composition between the two reaches (Figure 65). The predominance of the chironomids *Cricotopus* and *Eukiefferiella* and the oligochaete family Lumbriculidae in the lower reach contributed to the separation. Differences in average depth, wetted width, and gravel appeared to be the most important physicochemical variables, in terms of explaining site biological differences (Table 27; Appendix L).

Macrophyte Survey

On September 12, 2002, I-90 Pond 4 hosted a diverse community of mostly native submersed plants, the exception being curly leaf pondweed (*Potamogeton crispus*), which was not abundant. The shoreline had scattered patches of two invasive non-native species, purple loosestrife (*Lythrum salicaria*) and reed canarygrass (*Phalaris arundinacea*). There was also a coating of algae on the pond bottom in many areas.

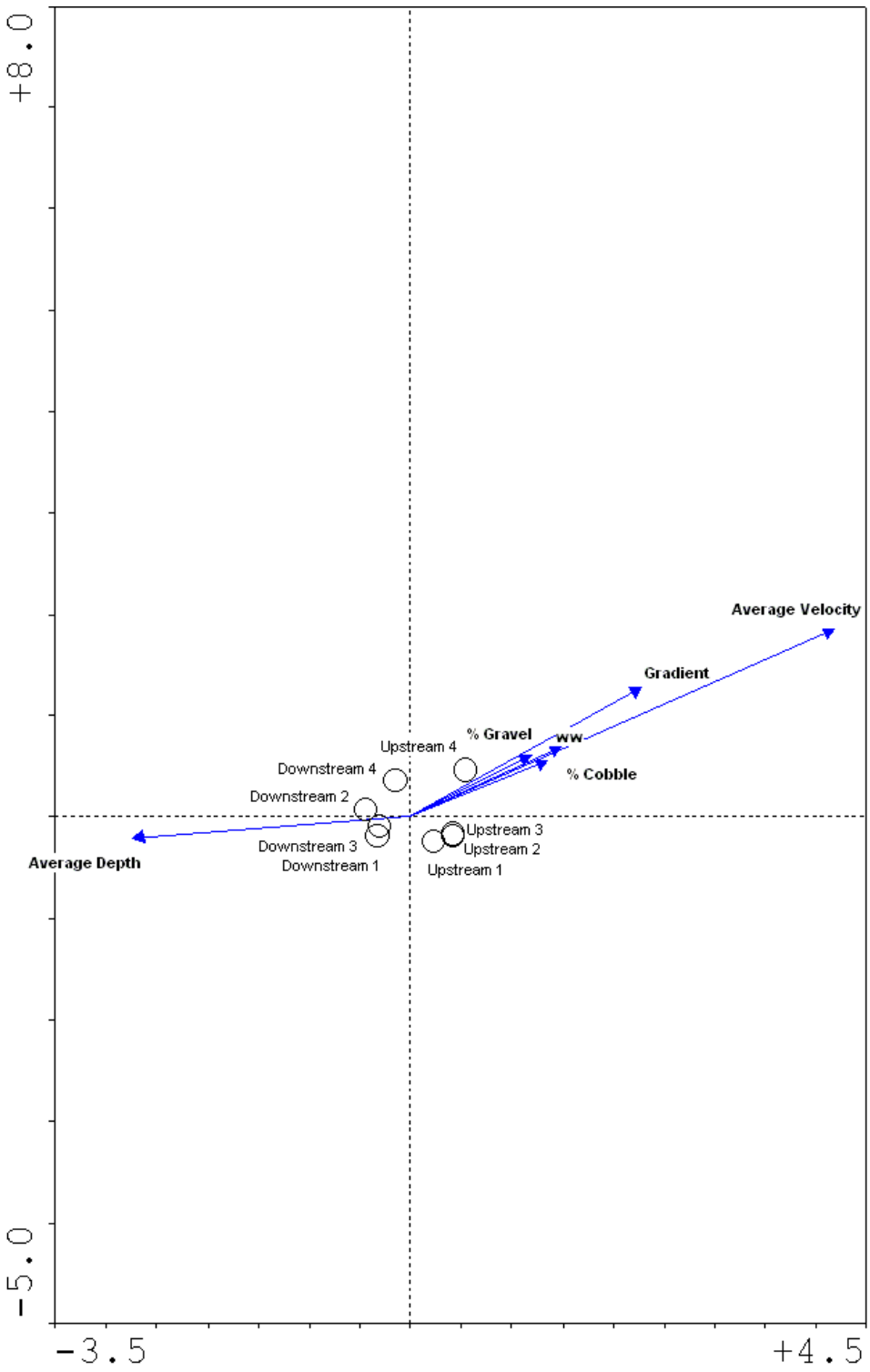


Figure 65. Canonical Correspondence bi-plot with I-90 Pond 4 benthic macroinvertebrate site distribution and major physicochemical explanatory vectors.

Table 27. Canonical correlations of physicochemical variables to ordination axes at the I-90 Pond river sites. n.s., not significant at $p<0.05$.

Variable	Axis 1 (x-axis)	Axis 2 (y-axis)
Wetted Width	.27	.19
Average Depth	-.52	-.06
Average Velocity	n.s.	.50
Gradient	n.s.	.35
Cobble	n.s.	.15
Gravel	.22	.17

Site 3 Comments and Recommendations

The I-90 Ponds are fairly shallow and subject to overflow events that have contributed sediment to the upper portion of Pond 4. Thermal conditions were optimal for anadromous salmonids, and water quality was good. Pumpkinseed sunfish, yellow perch, northern pikeminnow, and carp were collected in Pond 4. In addition, two juvenile coho salmon were sampled, suggesting connectivity between the Yakima River and the pond during seasonal high flow events. The river at this site is excellent salmonid habitat; therefore a properly designed and implemented reconnection with the Yakima River should increase salmonid habitat and production.

Recommendations

Because I-90 Ponds have considerable potential for reclamation and reconnection to the mainstem Yakima River, considerations include:

- Continue to monitor pond and upstream and downstream geomorphic changes such as head-cutting, bank erosion, and temporary alterations in sediment supply and transport throughout the adjacent river reach while the ponds capture sediment and the pond bottom regrades. Potential impacts of reconnection to the I-90 embankment and upstream bridges will need to be researched.
- Control or reduce the abundance of resident warm-water and predator species in the I-90 Ponds prior to connection to the river. Time the project so that fish removal can occur in the spring, summer, or fall with open-water conditions (no ice).
- Add gravel to the pond periphery to avoid creation of habitat for northern pikeminnow. Investigate suitable aggregate volumes, size, and sources.
- Control noxious weeds on site and revegetate with native species.
- Determine a range of flow that accelerates geomorphic and ecological recovery and maintain that flow. Evaluate the effects of any reconnection and site reclamation by monitoring pond and stream temperature, benthic macroinvertebrate assemblages, erosion, sediment transport/deposition rates and characteristics, and water quality.

8. SELAH PONDS (Site 4)

Location and Site Information

The Selah Ponds are on the east side of Interstate 82 near Selah, north of Yakima (Figure 66). Early large-scale mining at the east Selah site can be seen in 1947 aerial photographs (Figure 67). At 340 acres (150 acres composed of gravel ponds), Selah Ponds represents the largest floodplain mine site in the State of Washington. Ponds 1 through 3 were the focus of this study.

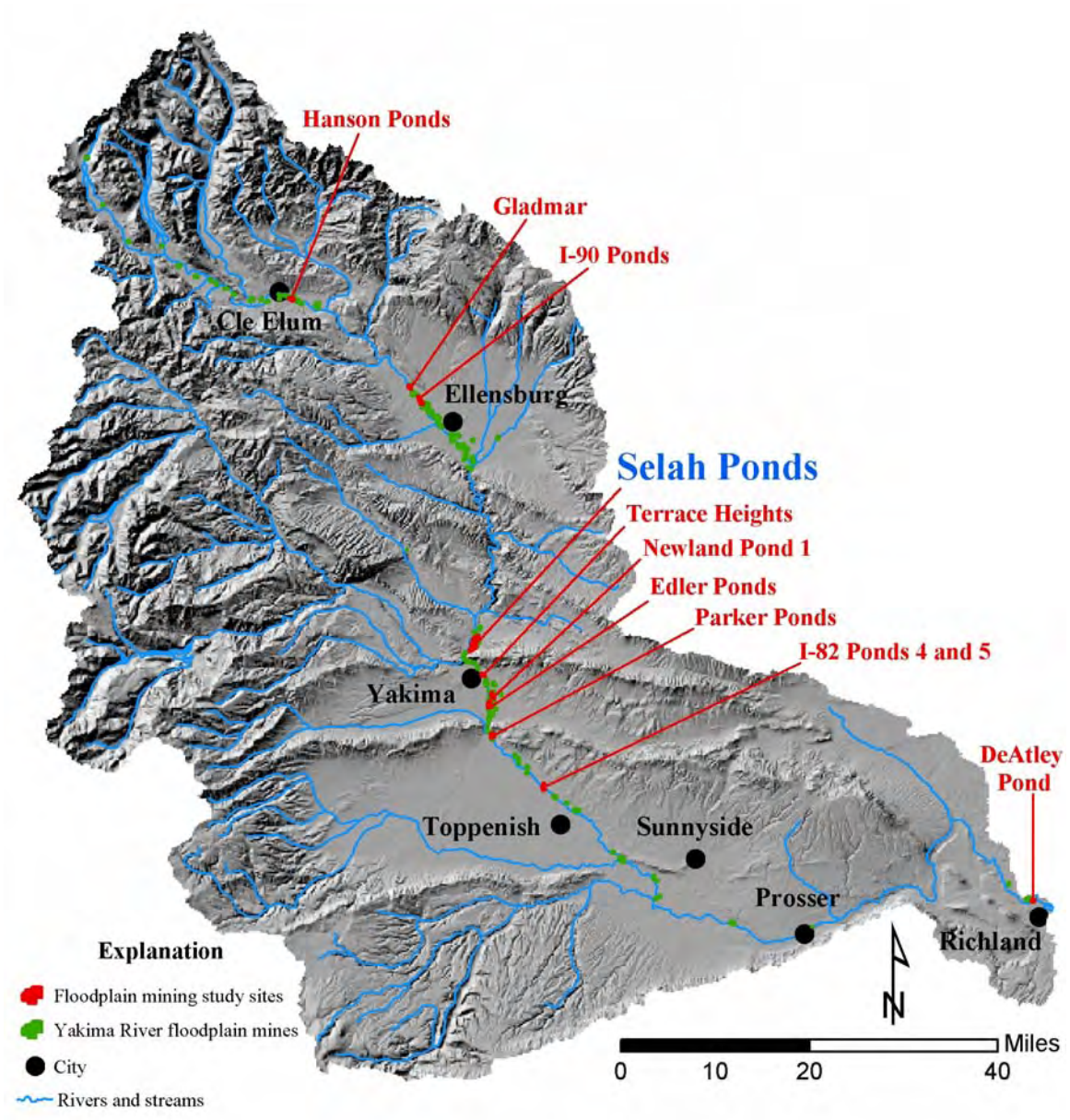


Figure 66. Location of Selah Ponds (Site 4).

Figure 67. East Selah, mining activity in 1947 (Washington Department of Transportation photo).

Selah Ponds were captured during the spring 1996 floods. When the upstream dike was breached, the entire Yakima River flow entered the gravel pits between river miles 118 and 120 and exited the site at the downstream end. The estimated volume of the Selah Ponds is 727,000 yd^3 for Pond 1 and 1,135,000 yd^3 for Ponds 2 and 3 collectively, totaling about 1,862,000 yd^3.

A 1984 report by CH2MHill explored the possibility of turning what is now the Selah Lakes site into attenuation reservoirs for relief retaining of water during high flows. After the 1996 avulsion event, WADNR required Central Pre-Mix Concrete Co., Inc. (CPM) to study the potential for future avulsions, as well as to characterize the hydrologic and geomorphological aspects of the site (see David Brown and Associates 2002). As a result of the information assembled in those studies, and more importantly, in response to Condition 13 of the July 24, 1999, WADNR permit to allow CPM to re-open the Selah gravel mine, hydraulic and thermal interactions between the ponds and the river were identified and a thermal investigation of the Selah ponds was required. (See Chapter 173-201A WAC of the water-quality standards for surface waters of the State of Washington).

Pond Bathymetry and Sediment Sampling

The river in the Selah Ponds reach meanders between two water gaps: the Yakima River Canyon, where the river cuts through Umtanum Ridge to the north of the ponds, and Selah gap a short distance downstream of the ponds where the river cuts through Yakima Ridge. A dike on the west side of the ponds now restricts movement of the river into the ponds. The river is about 150 ft from the ponds on the upstream (north) end, 160 ft at the mid-point of the pond complex, and 75 ft from the river at the downstream end of the complex (Figure 67). Pond 1 is separated from Ponds 2 and 3 by a dike that serves as an access road. At the time of the field investigation (mid-July), Ponds 2 and 3 were connected via shallow sills. In the vicinity of the ponds, the channel migration zone is 1,800 to 2,300 ft wide, and the valley slope for about a mile above to about a mile below the site is 0.0028 (approx. a 14.8-ft drop in valley floor elevation for each mile downstream). Golder and Associates (1998) calculated the long-term sediment transport for the Yakima River through the Selah reach, between the two water gaps, to be roughly 100,000 tons/yr.

During the 1996 100-yr flood event, the Yakima River avulsed into Pond 4 (north of Pond 3; Figure 68), abandoning some 8,000 ft of channel; it exited at the southern end of Pond 1. Norman *et al.* (1998) reported that this avulsion event produced approximately 6 to 8 ft of incision immediately upstream of the point of avulsion and was accompanied by local upstream knick point migration. An estimated minimum 300,000 yd^3 of gravel was scoured from the riverbed and deposited as a layer at least 6 ft thick in the excavated pits over a 33-acre area (Norman *et al*. 1998). This amount of transported sediment is estimated to be on the order of six times the average annual long-term amount reported by Golder and Associates. Subsequent to the avulsion event, the dikes were rebuilt and the river forced back into its old channel. There is now no river flow into the Selah Ponds.

For this study WADNR team members measured the bathymetry of Selah Ponds 1, 2, and 3 (Figure 68). In late May, Selah Pond 4, the mined area to the north of Pond 3, was still dry due to ongoing mining operations. In general, the bathymetric data collected for Selah Ponds 1, 2, and 3 (Figure 68) supports the findings of Golder and Associates (1998): the deepest portions of the ponds are at a lithologic change that appears to represent the geologic contact between Holocene alluvial gravels and the underlying Thorp Formation, which varies from clayey silt and sandy clay to sandstone and siltstone. The southward dip on this contact is reflected in the greater depth of mining (thus pond depth) in Pond 1 as compared to Pond 3.

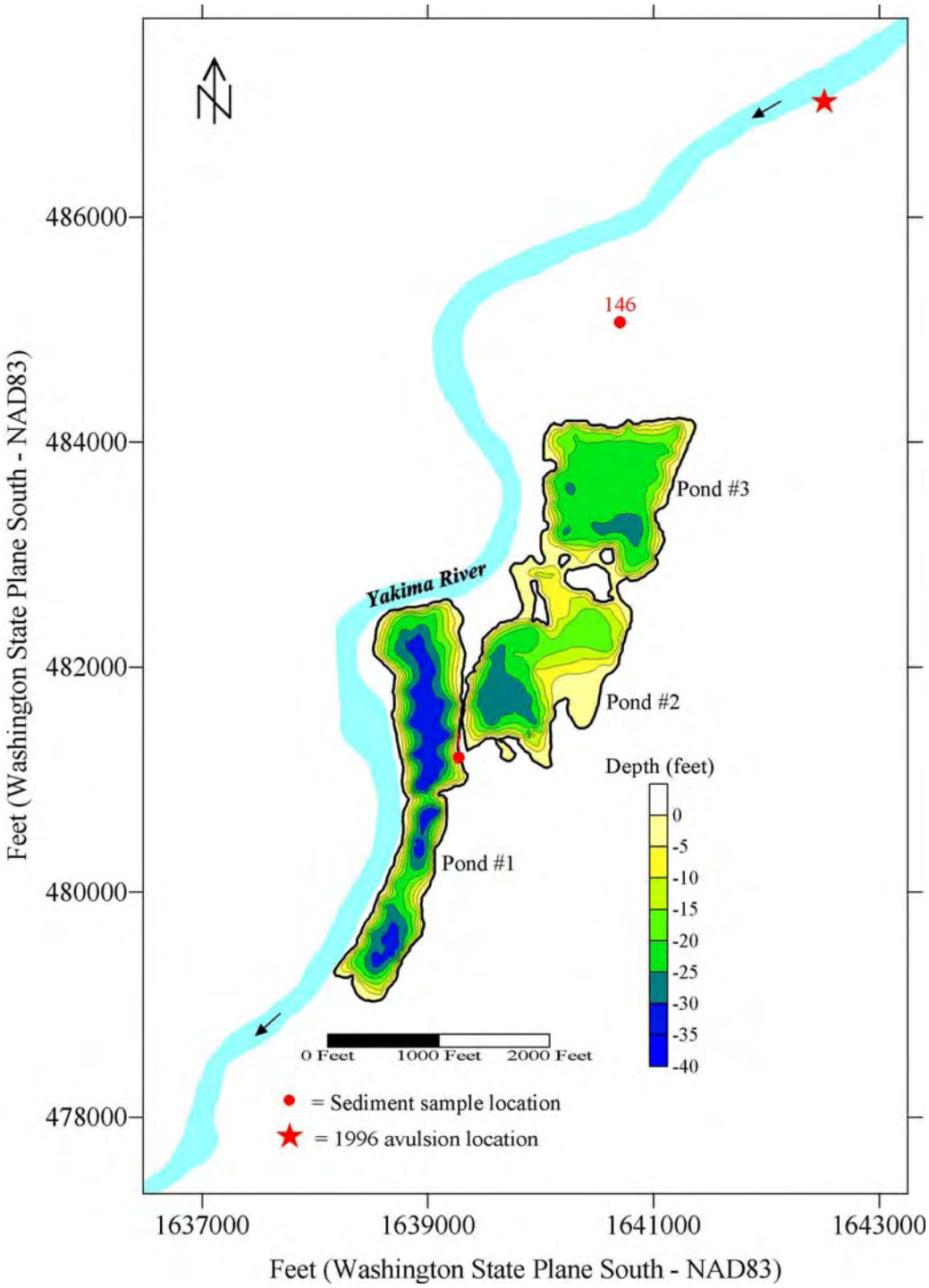


Figure 68. Contoured bathymetric map of the Selah Ponds showing locations of sediment samples (GPS waypoint numbers) and proximity to the Yakima River, July 17, 2002.

Selah Ponds 2 and 3 have varied bathymetry (Figures 69, 70 and 71), reflecting in part their mining history as well as post-mining efforts to enhance wildlife habitat within and adjacent to the pond. The combined average depth of these ponds is 9.1 ft. The flat-bottomed basins of Ponds 2 (north) and 3 (south) have maximum measured depths of 30 ft and 26 ft respectively (Figure 69). These depths may represent the approximate thickness of Holocene alluvium above the Thorp Formation. Numerous very small wildlife-enhancement islands along the margins of the northern portion of Pond 3 were not modeled in the bathymetric maps for this pond. The shallow area, or sill, between the two deep basins likely represents the margin between two areas of mining. This shallow area also contains islands. The southeastern portion of Pond 2 has been used as a mine slurry deposition area, resulting in the progradation of a fine delta along part of the eastern margin (Figures 70 and 71).

Selah Pond 1, with an average depth of 8.5 ft, is a long arcuate trench with steep-sided walls and a fairly flat bottom that is at about 30 ft in depth. Several low sills partition the pond into three basins. The maximum measured basin depth is 35 ft (Figures 72, 73, and 74). The depth of Selah Pond 1 may also indicate the approximate elevation of the top of the Thorp Formation. The pond has no surface inlet or outlet, but subsurface water from the pond seeps into a slough that enters the river near the south end of the property.

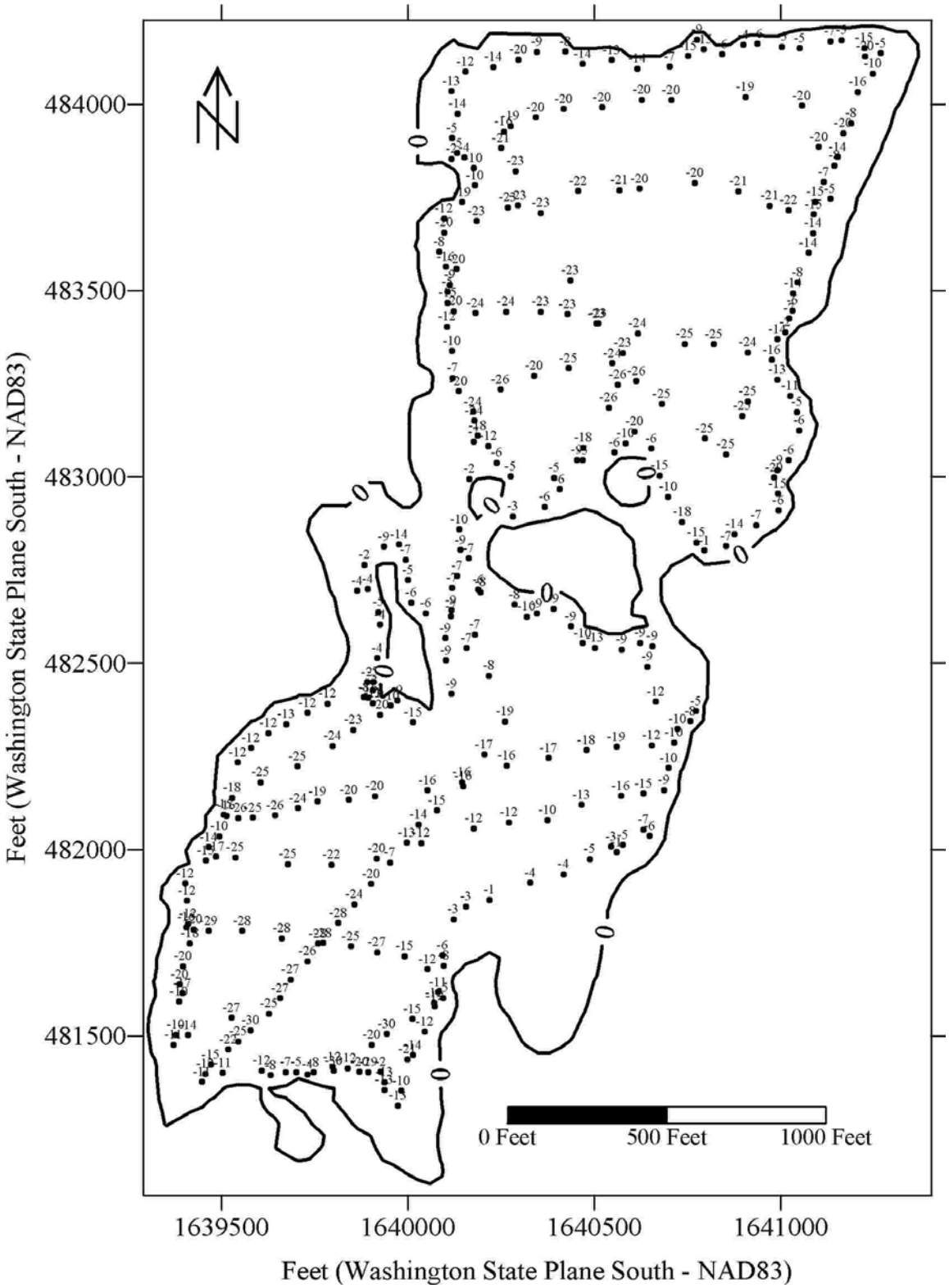


Figure 69. Post map showing data point locations and depths (in feet) on July 17, 2002, used to model pond bathymetry of Selah Ponds 2 and 3.

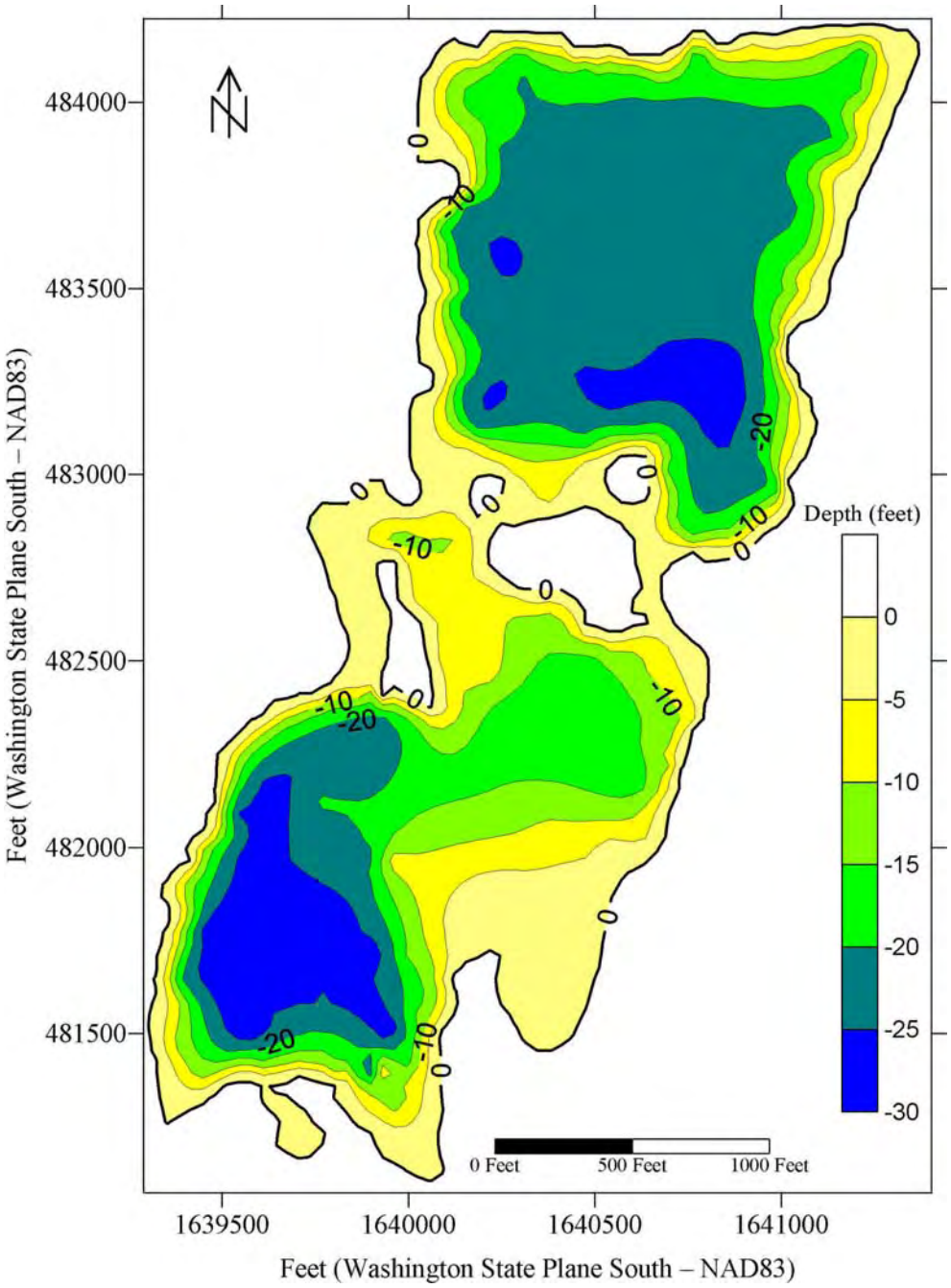


Figure 70. Contoured bathymetric map of Selah Ponds 2 and 3; bathymetry in feet below the water level on July 17, 2002.

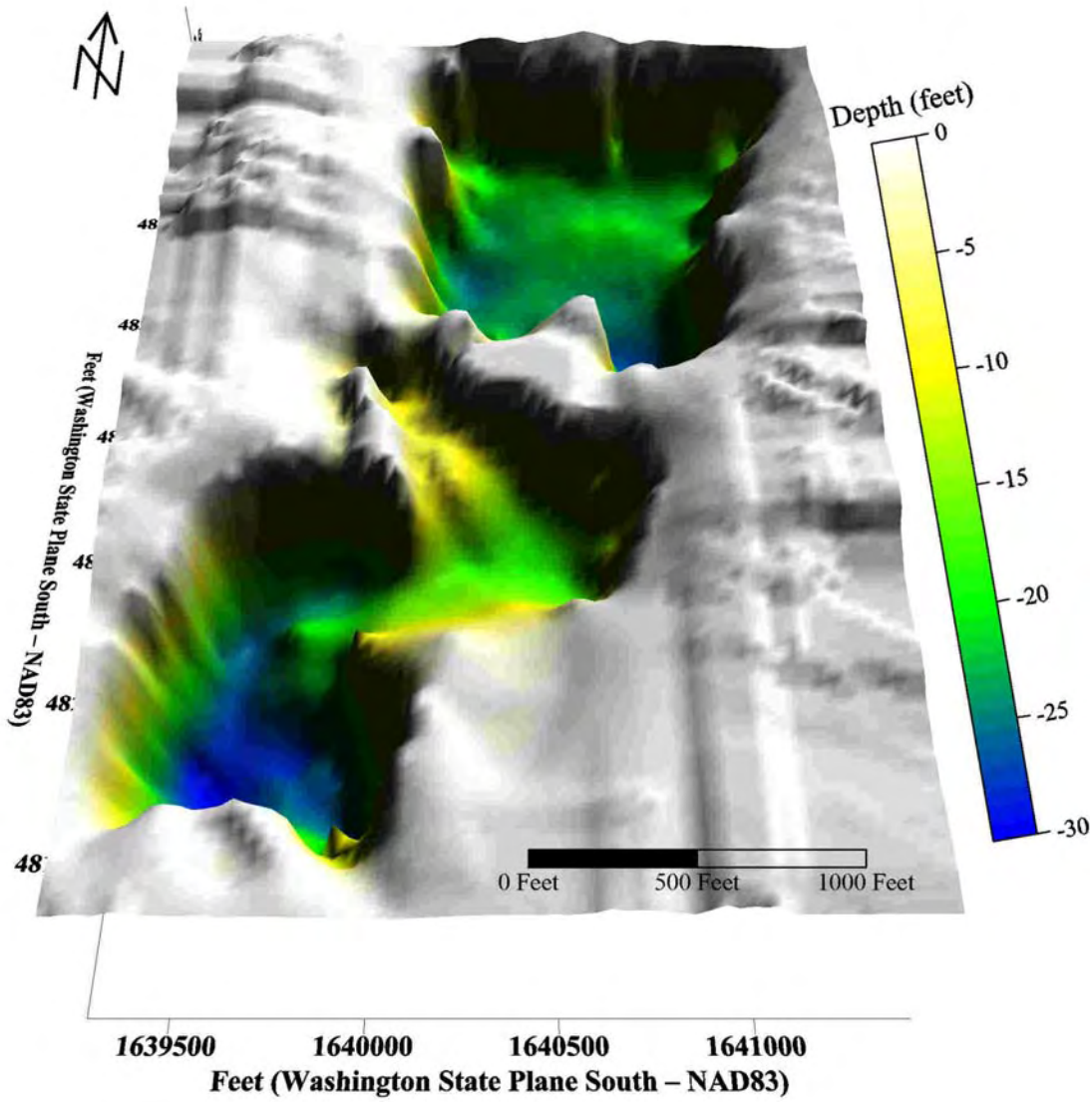


Figure 71. 3-D perspective bathymetric map of Selah Ponds 2 and 3; bathymetry in feet below the water level on July 17, 2002.

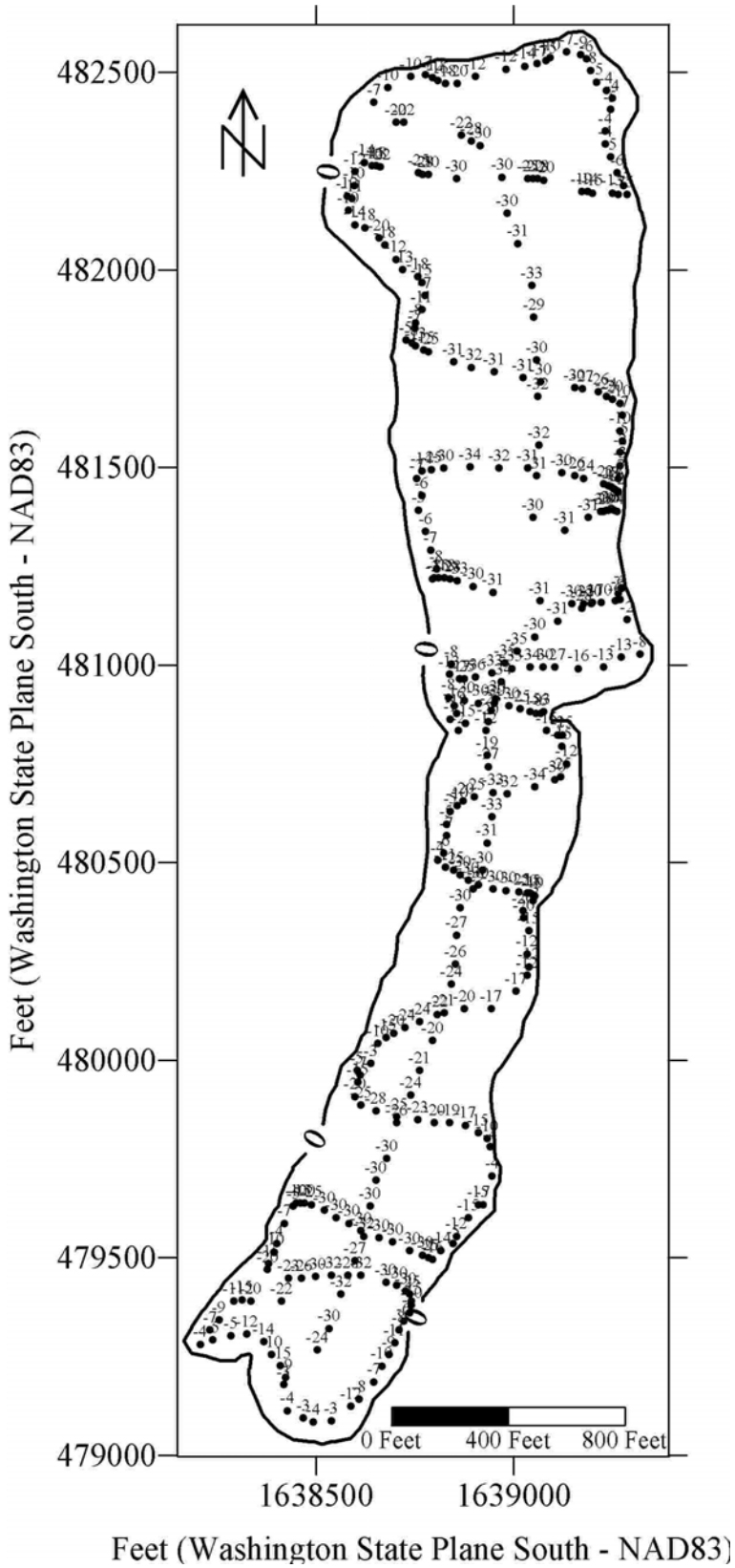


Figure 72. Post map showing data point locations and depths (ft) used to model pond bathymetry for Selah Pond 1, July 16, 2002.

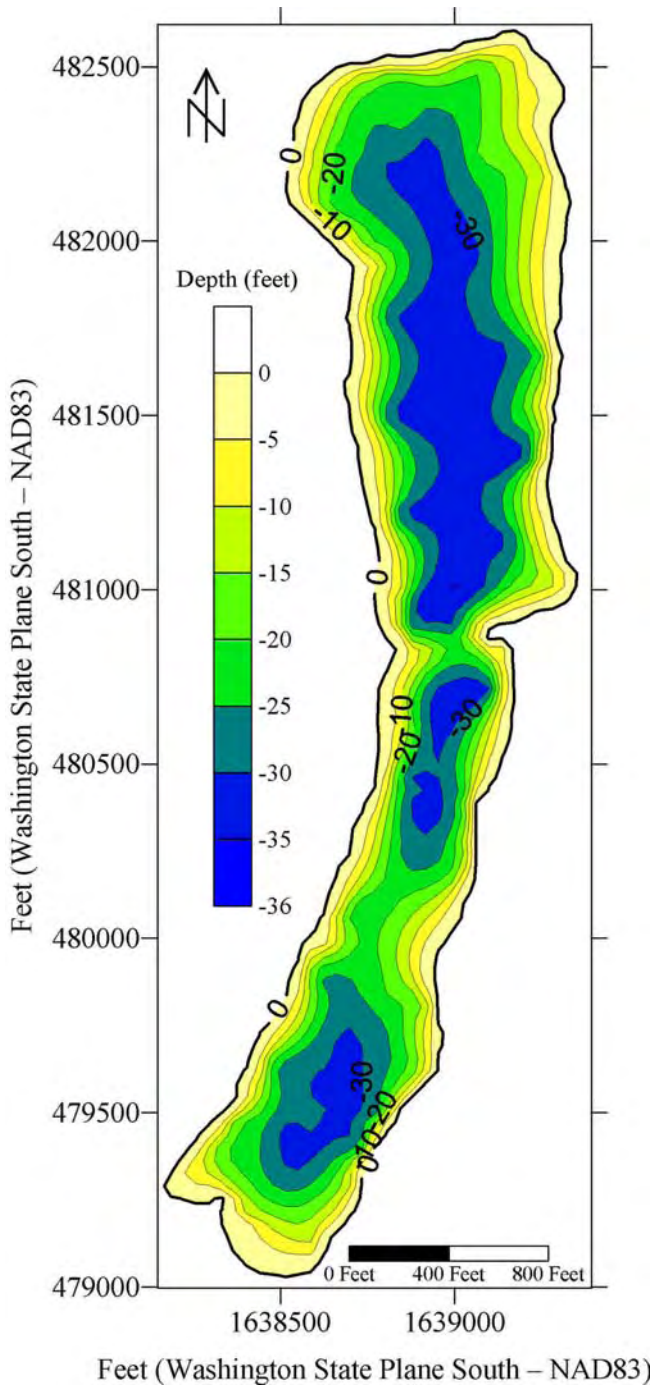


Figure 73. Contoured bathymetric map of Selah Pond 1; bathymetry in feet below the July 16, 2002, water level.

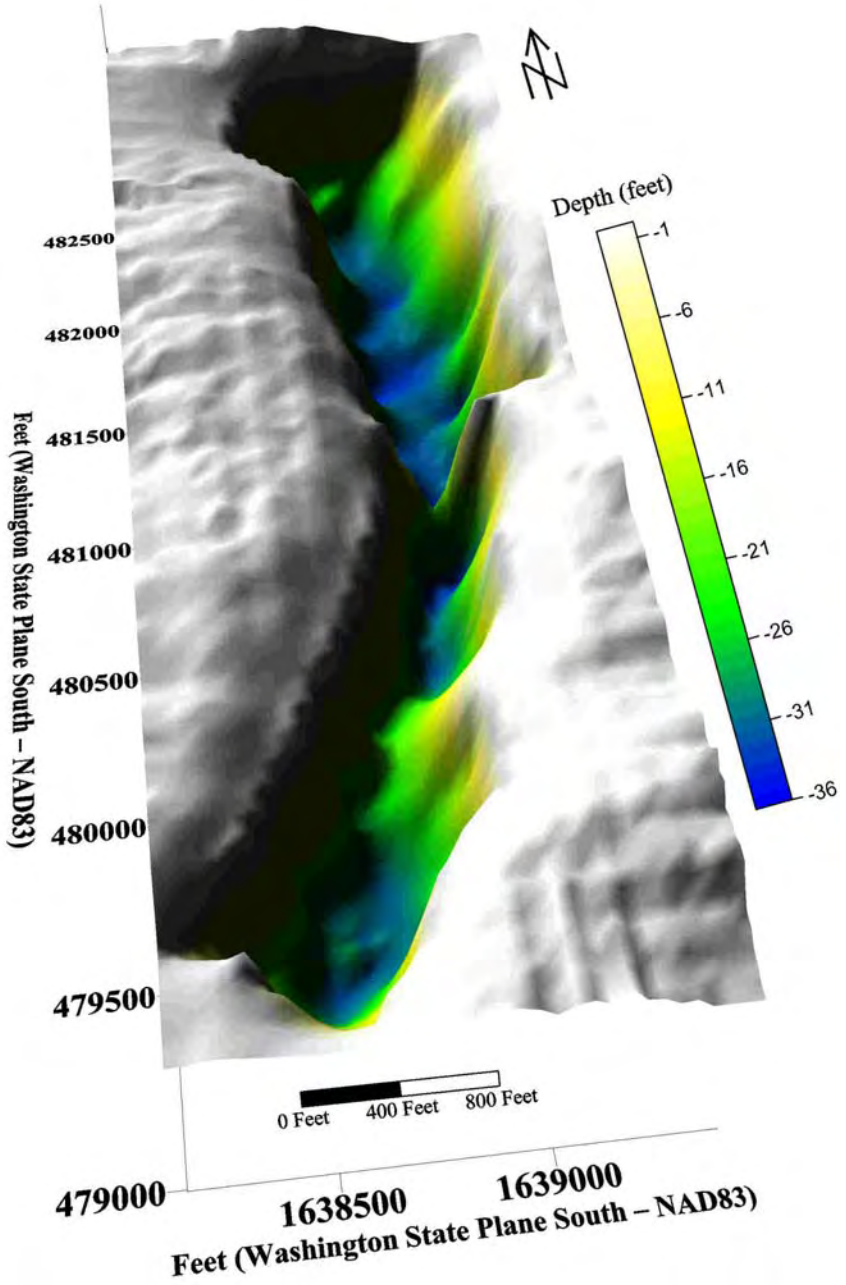


Figure 74. 3-D perspective map of Selah Pond 1; bathymetry in feet below the July 16, 2002 water level.

Recently deposited river gravel has been mined down to older semi-consolidated sediments of the Thorp Formation that typically consists of well-graded or poorly sorted gravel in a matrix of fine sand, silt, and clay. Thorp sediment sample146, for example, from the drained north pit (Selah Pond 4; Figure 75, Table 28) is 63.6% gravel, 32.0% fine sand, and 4.5% silt and clay.

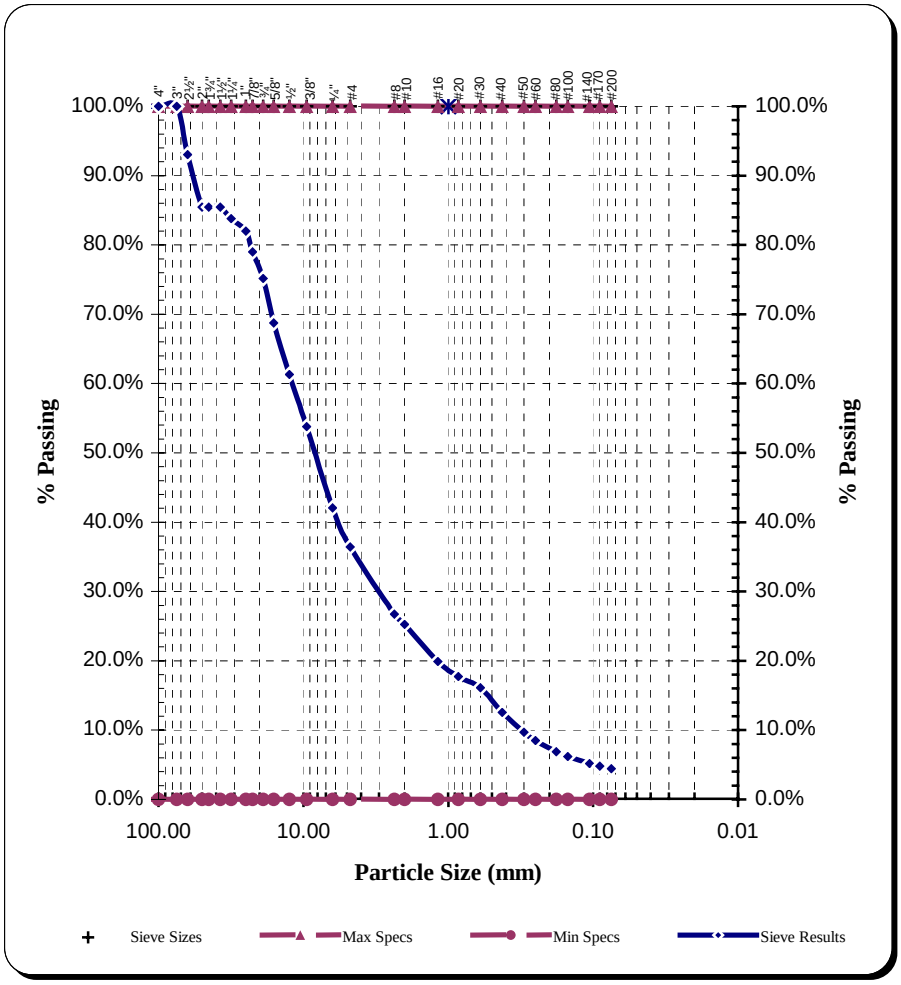


Figure 75. Grain-size distribution plot for Selah Pond 4 sediment sample 146, Thorp Formation from the drained pond bottom (see Figure 68).

Sediment sample 1, from the east shore of Selah Pond 1, is considerably coarser than Thorp sediment sample 146; sample 1 represents more recently deposited Yakima River sediment (Table 28; Figure 68). It contains a significantly smaller percentage of fines than samples retrieved from the underlying Thorp Formation (e.g., sample 146). At Selah, the high silt and clay content of the Thorp Formation retards upwelling of ground water to the pond bottoms. Consequently, at Selah Pond 4 the rate of ground-water recharge into the excavated pit is very low.

Table 28. Qualitative sediment particle data for Selah Ponds; see also Figure 75.

Sample No.	Particle Size Range	Comments
1	75% 2.4 to 0.39 in., 15% 0.39 to 0.19 in., 10% 0.19 to 0.08 in.	Fine to coarse gravel with minor coarse sand
146	63.6% 2.9 to 0.19 in., 32% 0.02 to 0.003 in., 4.5% <0.003 in.	Fine to coarse gravel with find sand and silt and clay

Site Sample Information

Sample site locations for the thermal investigation, fish assemblage, and benthic macroinvertebrate/water quality work for Selah Ponds are shown in Figure 76. Standard sampling protocol is discussed in Chapter 4 (Methods). Individual site results are discussed per study component below.

Figure 76. Thermal, fish assemblage, benthic macroinvertebrate, and water-quality sample site locations for Selah Pond 1. The explanation of symbols used to denote locations on this photograph is on p. xxii. 100A, French Drain station. (Photo source: Washington Department of Transportation, 2002)

Thermal Investigation

All river and pond data was collected by Central Pre-Mix Concrete Co., Inc., as part of their thermal investigation of East Selah Ponds. The upstream and middle monitoring instruments were located upstream of and adjacent to Pond 1 at a depth of 3 to 5 ft off the riprap dike on the east bank of the river; shading was minimal. Downstream instrument locations were partially shaded and under approximately 2 to 3 ft of flow. The French Drain station (100A) was also incorporated into the dataset (Figures 76 and 77). Sample sites are labeled with the Central Pre-Mix station numbers, which indicate the distinction between left bank (L) and right bank (R) locations, and the number correlates with upstream to downstream locations, with 2L located at the most upstream location and 100A at the downstream end. The mine is located on the left bank of the river, and only left bank stations were used in this study. A vertical stringer with recorders at depths of 2, 6, 12, 24, and 32.2 ft was placed the center of Pond 1.The Ext (air) unit was located in the riparian area near the lower eastern portion of Pond 1 (Figure 76). Temperature data for the Ext and river monitoring locations were recorded from April 15 to November 1, 2002. Pond temperature data were not collected from late May through early September due to incompatibility with pond usage as a water skiing recreational site.

River

Table 29 contains the averages of all river temperature data measurements each month at the upstream, middle, and downstream sites. Table 29 shows the difference (dT) in average temperatures between the successive upstream sample site and the next downstream site. A positive value indicates an increase in downstream temperature, whereas a negative value indicates a lower temperature downstream.

Table 29. Average monthly Yakima River temperatures (in °C) at Selah Ponds. See Figure 76 for location of 2L, 5L, 6L, 8L, and 100A

Month	2L	5L	6L	8L	100A
May	11.85	11.96	11.54	11.99	11.83
June	13.48	13.52	13.08	13.51	13.48
July	16.85	16.88	16.43	16.92	17.17
August	15.82	16.88	16.39	16.88	17.04
September	14.28	16.21	15.79	16.36	19.86
October	9.50	10.30	9.90	10.35	14.42

Table 30 indicates that the average monthly temperature contrasts were inconsistent. Between many stations, monthly temperature increases occurred, while in other months cooling occurred. However, Table 30 shows a general increase in temperature downstream, especially during the summer and early fall.

Table 30. Change (dT) in average monthly river temperatures (in °C) among sites at Selah Ponds.

Month	dT 2L/5L	dT 5L/6L	dT 6L/8L	dT 8L/100A	dT 2L/100A
April	0.05	-0.39	1.81	-2.14	-0.67
May	0.11	-0.42	0.45	-0.17	-0.02
June	0.04	-0.44	0.43	-0.03	0.00
July	0.02	-0.44	0.49	0.24	0.31
August	1.05	-0.48	0.48	0.16	1.21
September	1.93	-0.42	0.57	3.51	5.58
October	0.80	-0.41	0.45	4.07	4.91

Figure 77 shows the daily minimum and maximum temperatures for the five river sites. The plot illustrates the slight but persistent increase in downstream temperature. For the most part, slight separation among the data is indicated until early in the fall. At that time, the sites farther downstream recorded large temperature increases in both minimum and maximum daily temperatures.

Also of interest on Figure 77 is the difference between the daily maximum and daily minimum temperature at each monitoring station beginning with “flip flop” in September. Prior to “flip flop”, the difference between these two measurements was fairly small at all stations. Abruptly, and coinciding with “flip flop”, the spread between the daily maximum and minimum increased substantially. It is unlikely that this occurrence was due to a change in river depth at the monitoring sites as it would seem likely that maximum and minimum temperatures would have been equally affected. Also occurring at this time was the upward drift of station 100A minimum temperatures that in a short period exceeded the maximum temperatures at the other monitoring stations. Similarly, the station 100A maximum temperatures were detached from their former close relations with the other monitoring stations. Then, in late October, river temperatures resumed their pre-“flip flop” relations. At this time, river flows increased from about 500 cfs to about 1,000 cfs, still substantially below the pre-“flip flop” flow.

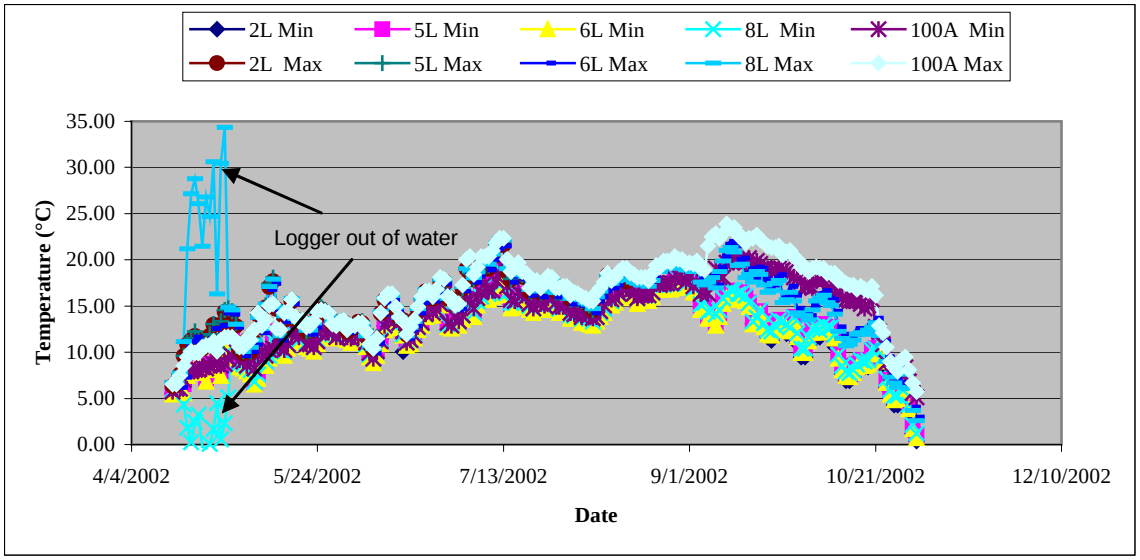


Figure 77. Daily Yakima River minimum and maximum temperatures at Selah.

Pond

Most of the late spring and summer data were lost from the vertical profile samplers (Figure 78). Stratification of the pond was evident in the spring. Convergence of the data in early September was interpreted to indicate pond turnover.

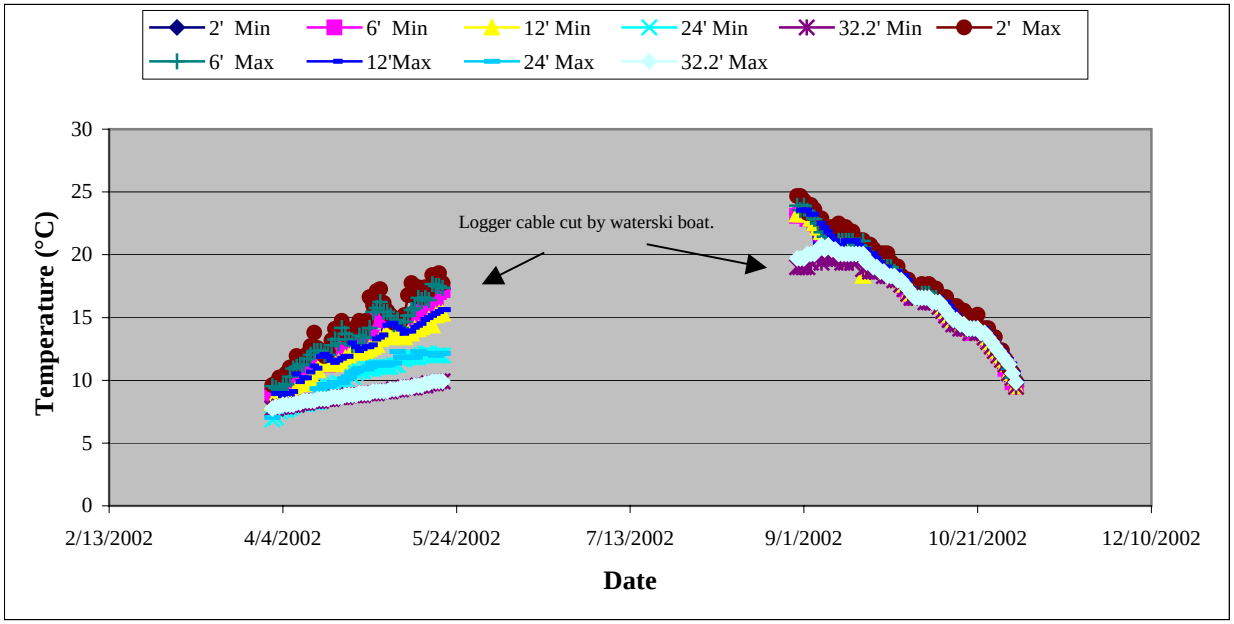


Figure 78. Daily minimum and maximum water temperatures for Selah Pond 1.

Fish Assemblage

Selah Pond 1 was sampled July 13 and 14, 2002, with the electroshocking boat, fyke nets, and gill nets following the standard protocol. In addition, approximately 2,000 m of river was sampled on August 20 above and below the pond with a drift boat-mounted electroshocker. A 275-m reach above the pond was sampled on October 17 with backpack shocker, and a 300-m reach below the downstream "seep slough" was sampled with snorkel gear on October 10. There were less than the desired 200 minimum fish sampled with the backpack shocker. Detailed data is presented in Appendix K, Tables 14-17 for Selah Pond 1 and the river reaches adjacent to the pond. A summary of species composition at this site is presented in Table 31.

Yellow perch (51%) and pumpkinseed sunfish (23%) dominated the Selah Pond 1 fish assemblage (n = 803). Twelve species were sampled, some in very low numbers, including several hatchery rainbow trout that were stocked by the pond owner. Carp comprised nearly 10% of the sample, and two species of warm-water game fish stocked by the pond owner, largemouth bass (6%) and bluegill (4.5%), were present in significant numbers.

Table 31. Percent composition of fish sampled at Selah Pond 1 and the Yakima River adjacent to Selah Pond 1. The bold values indicate dominant species. See Table 6 for the explanation of species codes.

Species	Selah Pond 1	River			
		Above	Below	Drift Boat	Summary
BBH	0.9				
BC	1.0				
BG	4.5				
CC	0.1				
CK		11.0	4.0	5.1	6.0
CMO	0.1		1.5	**32.3**	**16.0**
COT		**18.4**	0.5		4.0
CP	9.6		1.5		0.5
DAC		**16.9**		0.6	3.9
LMB	6.0		1.0	0.3	0.5
NPM	1.4	6.6	**10.0**	2.9	5.9
PS	**22.9**			0.3	0.2
*RB	0.5				
RB		**20.6**	4.0		5.5
RS		2.9	**11.0**	**15.7**	**11.6**
SK	2.7	**21.3**	**58.0**	**38.0**	**40.7**
STB		2.2			0.5
WF			8.5	4.8	4.9
YP	50.3				
Total	100.0	100.0	100.0	100.0	100.0
Sample Size	803	136	200	313	649

In the river, eight species (n = 136) were collected with backpack shocking gear, nine species (n = 313) with the drift boat electroshocker, and 10 species (n = 200) observed during snorkel surveys below the pond. Suckers and *Onchorhyncus mykiss* were most frequently sampled above the ponds, and redside shiner was most frequently sampled below the ponds. Sloughs below the ponds had so many redside shiners that counts were difficult and may have been skewed during snorkel surveys.

Backpack electroshocking above the ponds revealed that *O. mykiss* (21%) were surprisingly abundant and that juvenile spring chinook (11%) were present. Few chinook or *O. mykiss* were observed below the pond, indicating a preference for upriver habitat. Northern pikeminnow were present in both the pond and river, but they made up a relatively small percentage of the species composition. Several largemouth bass, pumpkinseed sunfish, and common carp were found in the river. This site was the farthest upriver location where largemouth bass, a salmonid predator, were found in the river.

Combining all river sampling methods, the most frequently sampled fish were suckers (41%), chiselmouth (16%), and redside shiners (12%), followed by *O. mykiss* (6%), northern pikeminnow (6%), and chinook salmon (6%).

Native river species were not present, or were at very low abundance, in Selah Pond 1. No chinook, sculpins, dace, or wild *O. mykiss* were captured following the standard protocol. Instead, exotic warm-water species and a few hatchery rainbow trout stocked by the private owner accounted for virtually the entire fish community. The few chiselmouth (0.1%) and northern pikeminnow (1.4%) probably were entrained by, and trapped during the 1996 flood, but it appears that chinook salmon and wild rainbow trout were not “stocked” by the flood in sufficient numbers to show up during sampling six years later. Conversely, all non-native species (largemouth bass, pumpkinseed, common carp) combined only comprised 1.2% of the river fish assemblage. The absence of a surface outlet and high, maintained dikes have generally kept the pond and river isolated, with the exception of the temporary avulsion in 1996.

Benthic Macroinvertebrates, Water Quality, and Macrophytes

Benthic Macroinvertebrates and Water Quality

Selah Pond 1 had marginal water quality and was stratified at the time of sampling (Table 14, Figure 37; tabulation below). There were low dissolved oxygen conditions at the bottom of the pond, and the surface was relatively alkaline. The benthic macroinvertebrate community in the pond had fairly few taxa and was dominated numerically by a subset of those taxa (Appendix L, Table 3).

Depth (m)	Temp (°C)	pH (units)	Cond (µS/cm)	DO (mg/L)	chla (µg/L)	secchi (m)	OP (mg/L)	TDS (mg/L)	TN (mg/L)	TP (mg/L)
0.5	20.8	8.61	171	8.5	1.54	3.5	0.019	54.0	65.6	0.400
9	11	7.23	255	0.5	NA	NA	NA	NA	NA	NA

In the river, water quality was similar in the upstream and downstream reaches (tabulation below and Table 16). There were no statistical differences in measured channel characteristics and sediment composition appeared to be similar (Table 17; Appendix L).

Site	Date (2002)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	pH (units)	Temperature (°C)
Downstream Selah	09/16	136	11.7	8.94	17.0
Upstream Selah	09/17	130	12.2	9.05	16.5

There was little difference in biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Table 17). The cluster dendrogram did not show a difference between reach samples (Figure 39). The CCA plot shows a slight separation of macroinvertebrate community composition between the two reaches (Figure 79). Only gradient could be interpreted as having a relationship with site faunal distribution (Table 32).

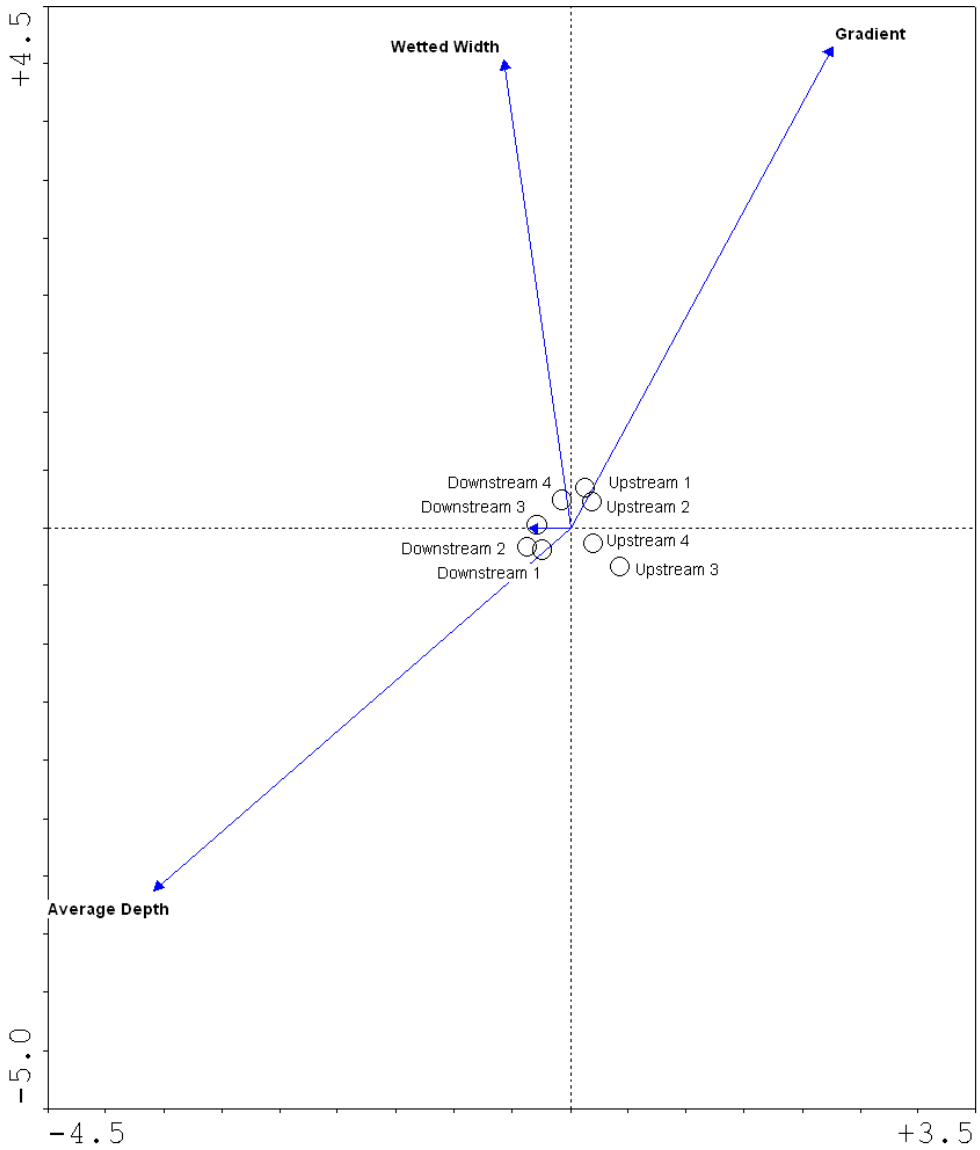


Figure 79. Canonical Correspondence bi-plot with the Selah Yakima River benthic macroinvertebrate site distribution and major physicochemical explanatory vectors.

Table 32. Canonical correlations of physicochemical variables to ordination axes at the Yakima River sites at the Selah Ponds. n.s., not significant at p<0.05

Variable	Axis 1 (x-axis)	Axis 2 (y-axis)
Wetted Width	-.09	.75
Average Depth	n.s.	-.58
Average Velocity	n.s.	n.s.
Gradient	.36	.77
Cobble	n.s.	n.s.
Gravel	n.s.	n.s.

Macrophyte Survey

On September 12, Selah Pit 1 was dominated by an unusually prolific population of the native plant water star grass (*Heteranthera dubia*). Several other submersed species were also present in the clear water of this pond. All were native except curly leaf pondweed (*Potamogeton crispus*), which was in very low abundance. The shoreline hosted three invasive non-native species, purple loosestrife (*Lythrum salicaria*), yellow iris (*Iris pseudacorus*), and reed canarygrass (*Phalaris arundinacea*).

Site 4 Comments and Recommendations

The Selah Ponds have marginal water quality for salmonids, low hydraulic connectivity with the river due to the depth of the mining activity (down to the Thorp Formation), and the pond fish assemblages are dominated by warm-water predator species. There is a steady increase of river temperature downstream among the study sites.

River habitat is suitable for salmonids, but it is not of the excellent quality observed at upriver sites because of low and fluctuating flows downstream of Roza Dam, lack of channel complexity and succession of riparian communities, and higher maximum water temperatures.

Recommendations

The property is privately owned, and the owner wants to maintain the site for private recreation. However, any future reclamation that includes reconnection to the river must consider the potential effects of the large area and depth of the ponds because mobilization and deposition of sediment into Pond 4 could result in impacts to the river upstream and downstream in the form of headcutting and lateral erosion even greater than those during the 1996 flood event.

9. TERRACE HEIGHTS (Site 5)

Location and Site Information

The Terrace Heights pit site, located a short distance upstream of the Yakima Avenue–Terrace Heights Bridge on the north side of the river in Yakima (Figure 80), was avulsed in the early 1970s. Thirty years later, the pit site resembles the natural Yakima River habitat; there is little or no evidence that a 30-acre pit ever existed, as shown in a 1998 aerial photo (Figure 81).

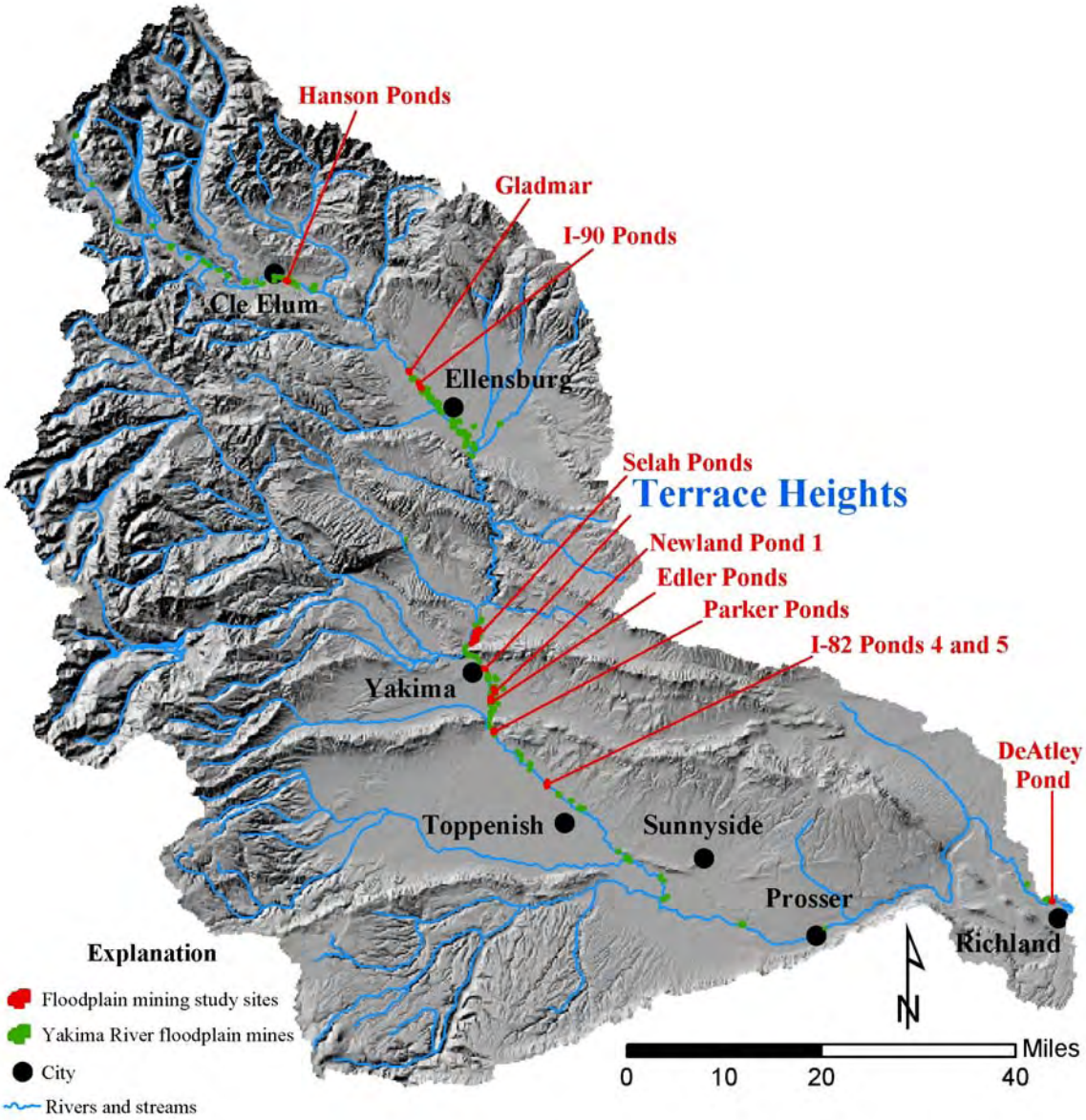


Figure 80. Location of Terrace Heights (Site 5).

Figure 81. The Terrace Heights pit site in 1998. Dashed red line shows location of former pit dikes. (Photo source: Washington Department of Transportation).

Pond Bathymetry and Sediment Sampling

As noted above, the Yakima River avulsed through the retaining dike and into the Terrace Heights gravel mine in the early 1970s. The river has flowed through the mined area for about 30 years, and in 2004 the area was nearly completely filled with sediment (see Figure 84 [2002]; compare Figure 82 [1993]). Remnants of the dike surrounding the mine site are still visible in aerial photographs. The Terrace Heights mine is an example of a naturally reclaimed floodplain mine, where fluvial and ecologic function has been restored to near pre-mining conditions. The Yakima River in the vicinity of the Terrace Heights Mine site has an anastomosing channel. Channel complexity appears to increase at the mine site with a concomitant increase in channel migration zone (CMZ) width from approximately 1,000 ft upstream to 1,600 ft adjacent to the first bridge crossing; the CMZ decreases to near 0 ft downstream, at the Terrace Heights Road bridge. The Terrace Heights valley slope for the reach from about a mile above to about a mile below the site is 0.00375 (approx. 19.8 ft drop in valley floor elevation for each mile downstream). This is greater than the reach slope for the upstream Selah Ponds reach. This increase may be the result of a steepening of the Yakima River channel slope immediately downstream of the Naches River confluence due to deposition of sediments and/or an increase in discharge with the addition of the Naches discharge to the Yakima.

Three sediment samples were taken at the Terrace Heights site at the locations shown in Figure 82. The in-mine sample, sample 22, is poorly sorted or well graded and consists of 75% gravel, 20% sand, and 5% silt and clay (Table 33). With the pit's capture of a channel of the river system, incision and headward erosion have mobilized and again deposited stockpile gravels and coarse river bar deposits into the pit. Sample 437 is from an upstream gravel bar and is representative of the modern alluvium in the Yakima River channel, as well as that filling in the Terrace Heights mine site. This sample is poorly graded and consists of 90.2% gravel, 9.2% sand, and 0.6% silt and clay (Figure 83). Sample 23 is active channel sediment taken immediately downstream of the mine site; it is composed of a coarse bed load of 85% gravel, 14% sand, and 1% silt and clay.

Although one sample from within the mine site itself is not conclusive, the slightly finer grain size of sample 22 in comparison to samples 437 and 23 may be due to residual fines from the mining operation and a slightly lower energy regime where the river flows across the mine site as compared to upstream and downstream of the mine.

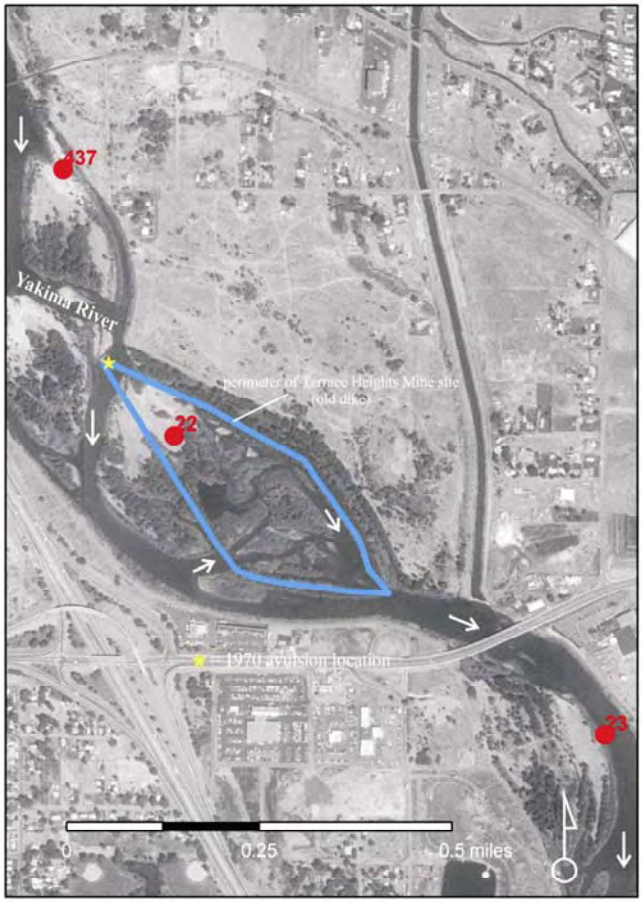


Figure 82. A 1993 Washington State Department of Natural Resources digital orthophoto of the Terrace Heights mine site, showing sediment sample locations (GPS waypoint numbers) and former dike margin. Scale bar is 0.5 mi long

Table 33. Qualitative sediment particle data for Terrace Heights mine site; see also Figure 83.

Sample No.	Particle Size Range	Comments
22	75% 2.9 to 0.19 in., 20% 0.19 to 0.08 in., 5% <0.003 in.	Fine to coarse gravel with minor coarse sand and silt and clay
23	85% 2.9 to 0.19 in., 14% 0.19 to 0.003 in., 1% <0.003 in	Fine to coarse gravel with minor coarse sand and silt
437	90.2% 2.9 to 0.19 in., 9.2% 0.19 to 0.003 in., 0.6% <0.003 in.	Gravel with lesser amounts of sand and minor silt and clay

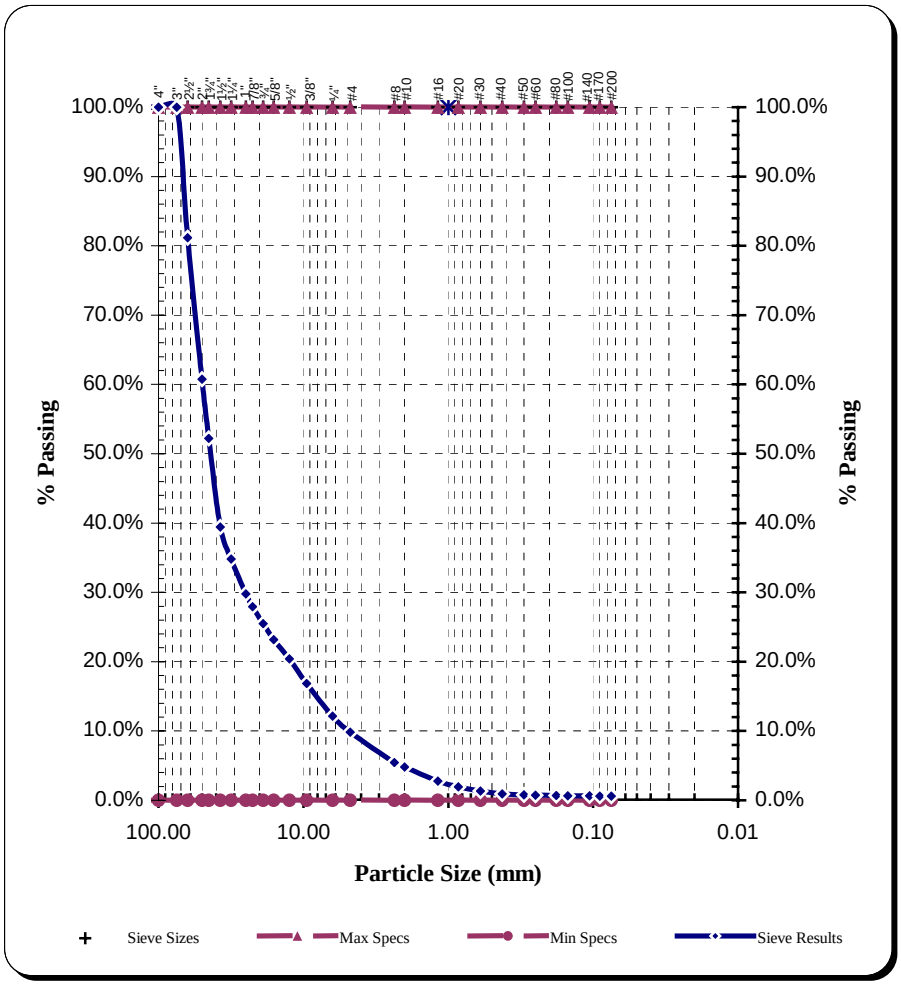


Figure 83. Grain-size distribution plot for sample 437 upstream of the Terrace Heights site.

Site Sample Information

Sample site locations for the thermal investigation, fish assemblage, and benthic macroinvertebrate and water-quality work for the Terrace Heights site are shown in Figure 84. Standard sampling protocol is discussed in Chapter 4 (Methods). Individual site results are discussed per study component below.

Figure 84. Thermal, fish assemblage, benthic macroinvertebrate, and water-quality sample site locations for the Terrace Heights site. The explanation of the symbols used to denote locations on this photograph is on p. xxii. (Photo source: Washington Department of Transportation, 2002)

Thermal Investigation

The Terrace Heights site is an avulsed, filled pit site. Temperature data were recorded here beginning April 15 and ending November 14, 2002. Data were obtained at an upstream site, a middle site, and a downstream site in the Yakima River. All monitoring locations were within the former pit area.

Table 34 shows the averages of the temperatures recorded each month and the changes in average temperature between the upstream and middle sample sites, the upstream and downstream sites, and the middle and downstream sites. Positive numbers represent an increase in temperature in the downstream direction, whereas negative values represent lower downstream temperatures.

Table 34. Average monthly river temperatures (°C) and comparisons (dT) between sample locations at the Terrace Heights site.

Month	Upstream	Middle	Down-stream	dT Upstream/ Middle	dT Upstream/ Downstream	dT Middle/ Downstream
April	8.22	8.50	8.71	0.28	0.49	0.21
May	10.39	10.61	10.54	0.22	0.15	-0.07
June	13.00	12.26	13.13	-0.74	0.13	0.87
July	17.20	16.50	17.42	-0.70	0.22	0.92
August	17.55	18.05	17.83	0.50	0.28	-0.22
September	16.07	16.70	16.43	0.62	0.36	-0.27
October	10.90	11.60	11.61	0.70	0.71	0.01
November	5.27	6.75	6.39	1.48	1.12	-0.36

Table 34 indicates a generally small increase in temperature downstream among the sample sites; there was a slight tendency for a greater temperature increase between the upstream and middle sites. The increase was not consistent and varied in timing of occurrence between the sample sites. “Flip flop” may have had an influence on temperatures at the Terrace Heights site and potentially farther down the Yakima River in September and October due to the release of cold water from Rimrock Reservoir.

Figure 85 shows the minimum daily and maximum daily temperatures at the Terrace Heights site. The plot suggests little difference among the maximum temperatures at the various measurement sites early in the period of record. However, during the mid-summer the maximum river temperatures at the upstream and downstream sites notably increased, while the middle site lower temperatures may reflect its location directly below a spring-fed brook and/or insulation of the instrument by siltation after higher flows receded periodically throughout the irrigation season. The minimum temperatures appeared to retain the same relations throughout the year. The downstream minimum temperatures were slightly higher than at the other two sites.

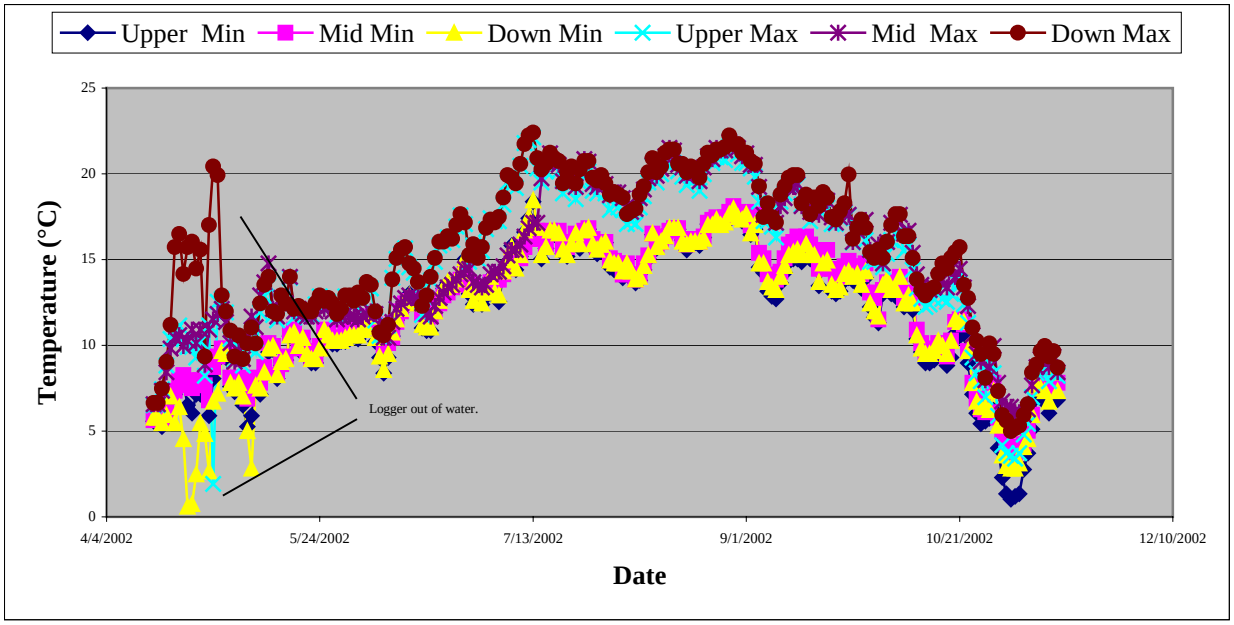


Figure 85. Daily minimum and maximum Yakima River temperatures at Terrace Heights.

Fish Assemblage

The pond sampling protocol was not followed at this site because there is no "still water" pond to sample. The location of sampling reaches was based on historical data regarding the boundaries of the former pond. The main channel of the Yakima River flows around the west side of the site; many side channels and sloughs characterize the riverine habitat within the old pit site. The main river channel and a number of side channels were sampled. Nine sites (1,156 m) were sampled with a backpack electroshocker on September 13, 18, and 24, 2002, and approximately 2,000 m was sampled with the drift boat electroshocker on August 20. Only the reach above the old pit site was surveyed with backpack electrofishing gear, and the only sampling method used below the former pond site was the drift boat electroshocker. A minimum desired sample size of 200 fish was not obtained with the drift boat survey, but that number was far exceeded with the backpack electrofisher.

Appendix K, Tables 18-20 display detailed fish assemblage data for Terrace Heights, Yakima River and side channels. A summary of species composition at this site is presented in Table 35.

A total of 1,115 fish was captured with backpack electroshocking gear, and 108 fish were sampled with the drift boat electroshocker. Twelve species were sampled. Native minnows, predominantly dace and suckers, dominated the species assemblage. Salmonids (chinook, coho, *Onchorhyncus mykiss*, and mountain whitefish) collectively ranged from 0% to 24% of the species composition sampled with backpack electrofishing gear, depending on specific sample reach.

Table 35. Percent composition of fish sampled in riverine habitat at the Terrace Heights site. The drift boat was not used below this site. Bolded values indicate dominant species. See Table 6 for an explanation of the species codes.

Species	Avulsed Terrace Heights	River		
		Above	Drift Boat	Summary
CK	5.7	**10.0**	**11.1**	**7.8**
CMO	1.7	3.1	**11.1**	3.0
CO		0.7		0.2
COT	2.4	3.3	0.9	2.6
CP			0.9	0.1
DAC	**42.0**	**52.9**		**42.3**
LMB	0.5			0.2
LND		2.9		1.1
MNS		0.4	1.9	0.3
NPM	4.7	3.1	4.6	4.1
PS	0.6			0.3
RB	3.0	8.4	1.9	4.9
RS	**22.1**	5.1	8.3	**14.6**
SK	**16.2**	**8.9**	**31.5**	**14.9**
WBL	1.2	0.2		0.7
WF		0.9	27.8	2.8
Total (%)	100.0	100.0	100.0	100.0
Sample Size	665	450	108	1223

At four of the nine sites sampled with the backpack electroshocker, salmonids constituted more than 20% of the fish community. More salmonids (41%), predominantly whitefish (28%), were present in the relatively small sample collected with the drift boat electrofisher. Although more species were present at this site compared to the upriver sites, dace, suckers and salmonids comprised more than 90% of the total population. Northern pikeminnow was the most abundant non-salmonid predator (4%). The only other predatory species sampled was one largemouth bass. Several western brook lamprey were captured.

Combining data for all river sampling methods (Table 35), the most frequently sampled species were dace (42%), redside shiner (15%), and sucker (15%); less frequently sampled species included chinook (8%) and *O. mykiss* (5%). The results reflect the expected species assemblage in the middle reach of the Yakima River where ponds avulse and complex braided channel habitat is created.

Benthic Macroinvertebrates, Water Quality, and Macrophytes

Benthic Macroinvertebrates and Water Quality

The historic Terrace Heights pond is now a side channel. At the time of sampling, the side channel had water quality similar to that of the upstream and downstream main channel (tabulation below, Tables 14 and 16). The benthic macroinvertebrate community in the side channel appeared to be in a condition more similar to that of the mainstem Yakima River than to isolated ponds (Appendix L, Tables 3, 14, and 15).

Depth (m)	Temp (°C)	pH (units)	Cond (µS/cm)	DO (mg/L)	chla (µg/L)	secchi (m)	OP (mg/L)	TDS (mg/L)	TN (mg/L)	TP (mg/L)
0.5	16	7.3	86	9.1	1.25	NA	0.021	78.0	21.9	0.470

In the river (lower tabulation), the lower reach was warmer; however, it was sampled on a different day. Other physicochemical differences between the reaches were canopy cover (more downstream), wetted width (larger downstream), and bankfull width (larger downstream).

Site	Date (2002)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	pH (units)	Temperature (°C)
Downstream Terrace Heights	09/17	81	9.5	7.39	14.5
Upstream Terrace Heights	09/16	81	10.0	7.79	17.0

There was very little difference in biometric results between reaches, indicating that the upstream control reach was not necessarily in better biological condition than the lower reach (Tables 17 and 18).The cluster dendrogram did not show a difference between reach samples (Figure 39). The CCA plot shows a slight separation of macroinvertebrate community composition between the two reaches (Figure 86). The exclusive presence of *Epeorus* sp. in the upper reach contributed to the separation (Appendix M). *Epeorus* sp. is a scraper and was probably capitalizing on the fairly open canopy of the upper reach. The average depth and wetted width appeared to be related to the slight divergence in biological condition between reaches (Table 36).

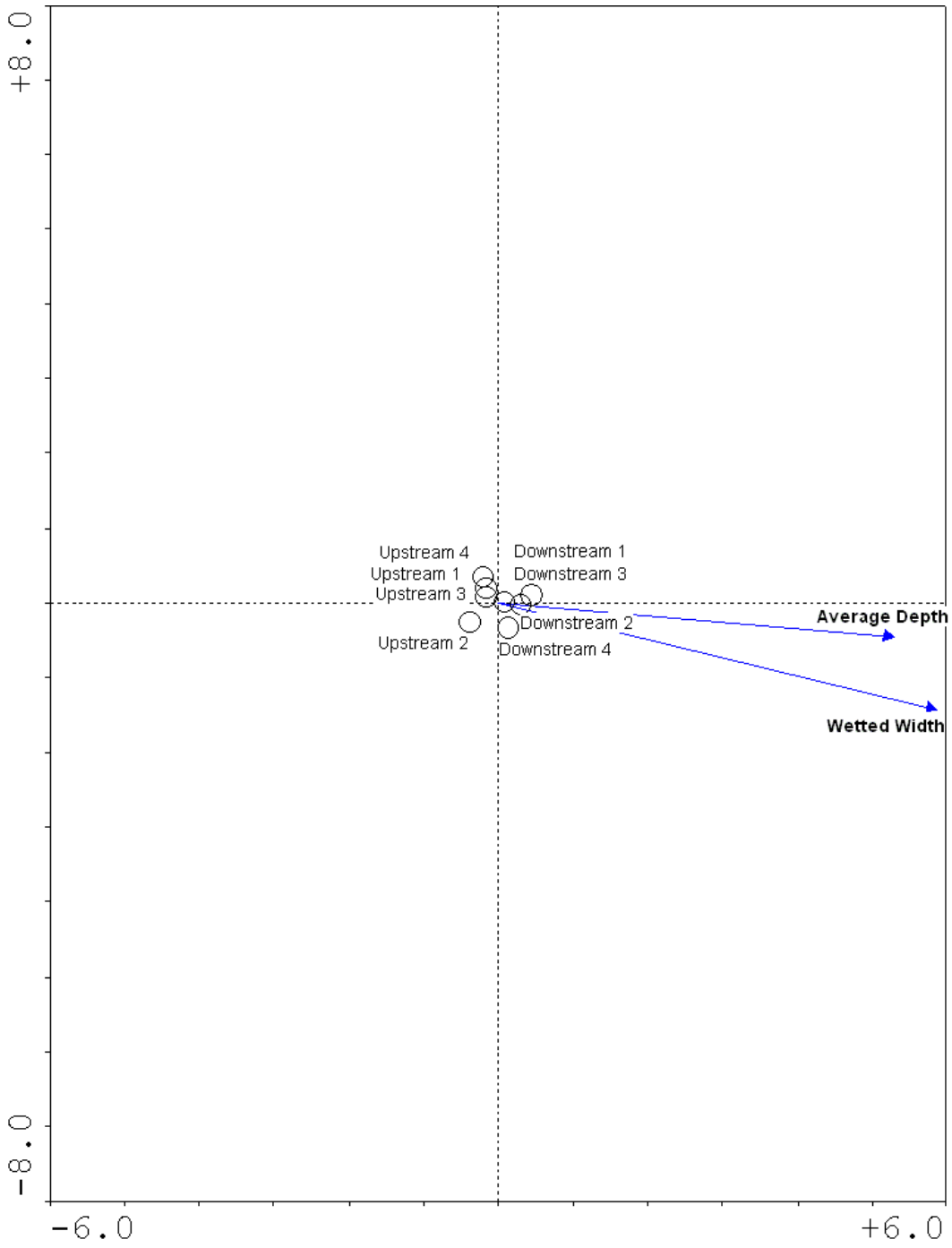


Figure 86. Canonical Correspondence bi-plot with the Terrace Heights river benthic macroinvertebrate site distribution and major physicochemical explanatory vectors.

Table 36. Canonical correlations of physicochemical variable to ordination axes at the Terrace Heights river sites. n.s., not significant at $p<0.05$

Variable	Axis 1 (x-axis)	Axis 2 (y-axis)
Wetted Width	.79	n.s.
Average Depth	.72	n.s.
Average Velocity	n.s.	n.s.
Gradient	n.s.	n.s.
Cobble	n.s.	n.s.
Gravel	n.s.	n.s.

Macrophyte Survey

Site 5 was not surveyed because the original gravel pit area did not resemble a pond. Rather, it resembled a riverine side channel. The macrophytes surveys were designed for pond and lake habitat.

Site 5 Comments and Recommendations

The Terrace Heights site represents the nearly natural conditions that an avulsed pit can achieve over time. In about 30 years, sediment deposition, grading, and cottonwood recruitment have stabilized the reach. Water quality in the former pit area is similar to that in the main-stem Yakima River, and thermal impacts are not an issue. This reach serves as salmonid rearing habitat, and it may be more important as winter rearing habitat than our summer/fall data reflect. Large populations of competing native fish and a small number of northern pikeminnow may have some impact on salmonid growth and survival. Overall, however, this site provides good spawning, and rearing habitat for anadromous salmonids.

Recommendations

Recommendations for the Terrace Heights site are as follows:

- Use the Terrace Heights site channel morphology and complexity data as a “river habitat conversion” goal for similar avulsed sides (e.g., Hanson, Gladmar, Parker).
- Monitor anadromous salmonid use of the site year-round for spawning and rearing.
- Monitor water temperature and benthic macroinvertebrate communities in conjunction with fish studies.

10. NEWLAND POND 1 (Site 6)

Location and Site Information

Newland Pit Ponds, owned by Central Pre-Mix Concrete Co., Inc. (CPM), are east of the City of Yakima on the east bank of the Yakima River, downriver from State Route 24 (Figure 87; see also Figure 93). This mining site has been active for more than 50 years. Pond 1 was used as a settling pond during mining activity in Pond 2 (adjacent) in 2002; that use resulted in the turbid water shown in Figure 88. Of the three main and two small ponds at the site, this study focused on Newland Pond 1, which covers 8.2 acres and has a mined volume of about 153,000 yd^3.

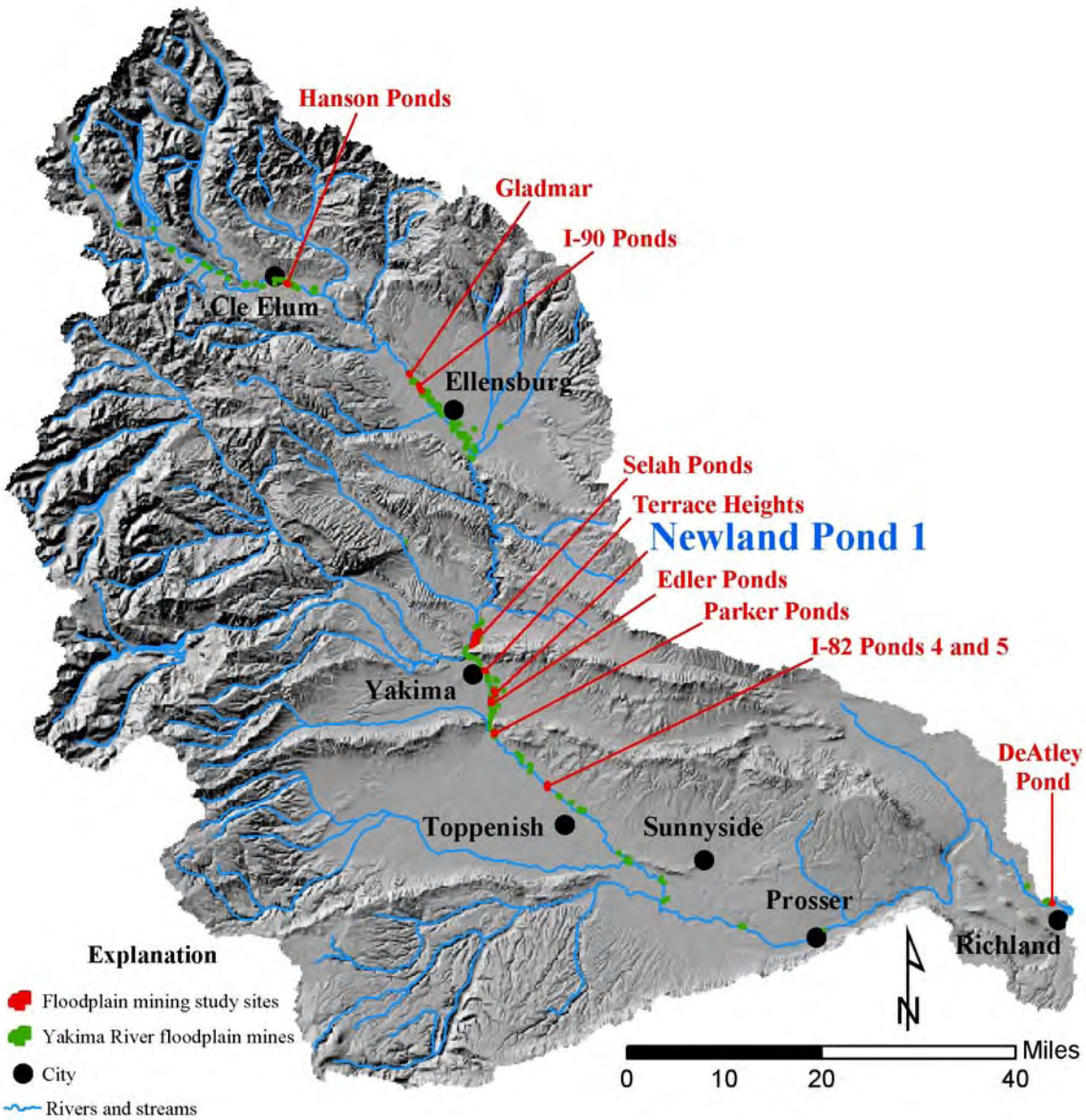


Figure 87. Location of Newland Pond (Site 6).

Figure 88. Turbid water in Newland Pond 1. (Photo source: Washington Department of Fish and Wildlife, Oct. 30, 2002)

Pond Bathymetry and Sediment Sampling

Newland Pond 1 is a closed system, not currently in connection with the Yakima River (Figure 89). A dike exists along the entire west-margin of the pond, and no likely near-term avulsion points were identified. Currently, the north end of the pond is approximately 200 ft, the western-most point (pit midpoint) is 775 ft, and the southern (downstream) end is 225 ft from the river. The Newland reach of the Yakima River is an area of historic channel migration through avulsion events (compare the 1953 and 1985 U.S. Geological Survey 1:24,000-scale topographic maps); however, extensive diking and embankment armoring have reduced the mobility of the river through this reach. The channel migration zone in the Newland reach is 800 to 1,400 ft wide, increasing downstream to approximately 2,000 ft. The Newland reach valley slope from about a mile upstream to a mile downstream of the site is 0.00325 (an approximate 17.2-ft drop in valley floor elevation for each mile downstream).

The average depth of Newland Pond 1 is 11.9 ft. This pond has steep sidewalls and a northward-sloping bottom. The depression in the north-central portion of the pond has a maximum measured depth of 30 ft (Figures 90, 91, and 92). The northern and southernmost portions of the pond bottom slope gently and are shallow.

The southern portion of the pond was receiving sediment input in the form of a silt-clay slurry from adjacent mining operations during the study period. This has resulted in the northward

progradation of a delta into the pond from the southern end (Figure 90). Several small wildlife-enhancement islands are present in the shallow northern extension of the pond.

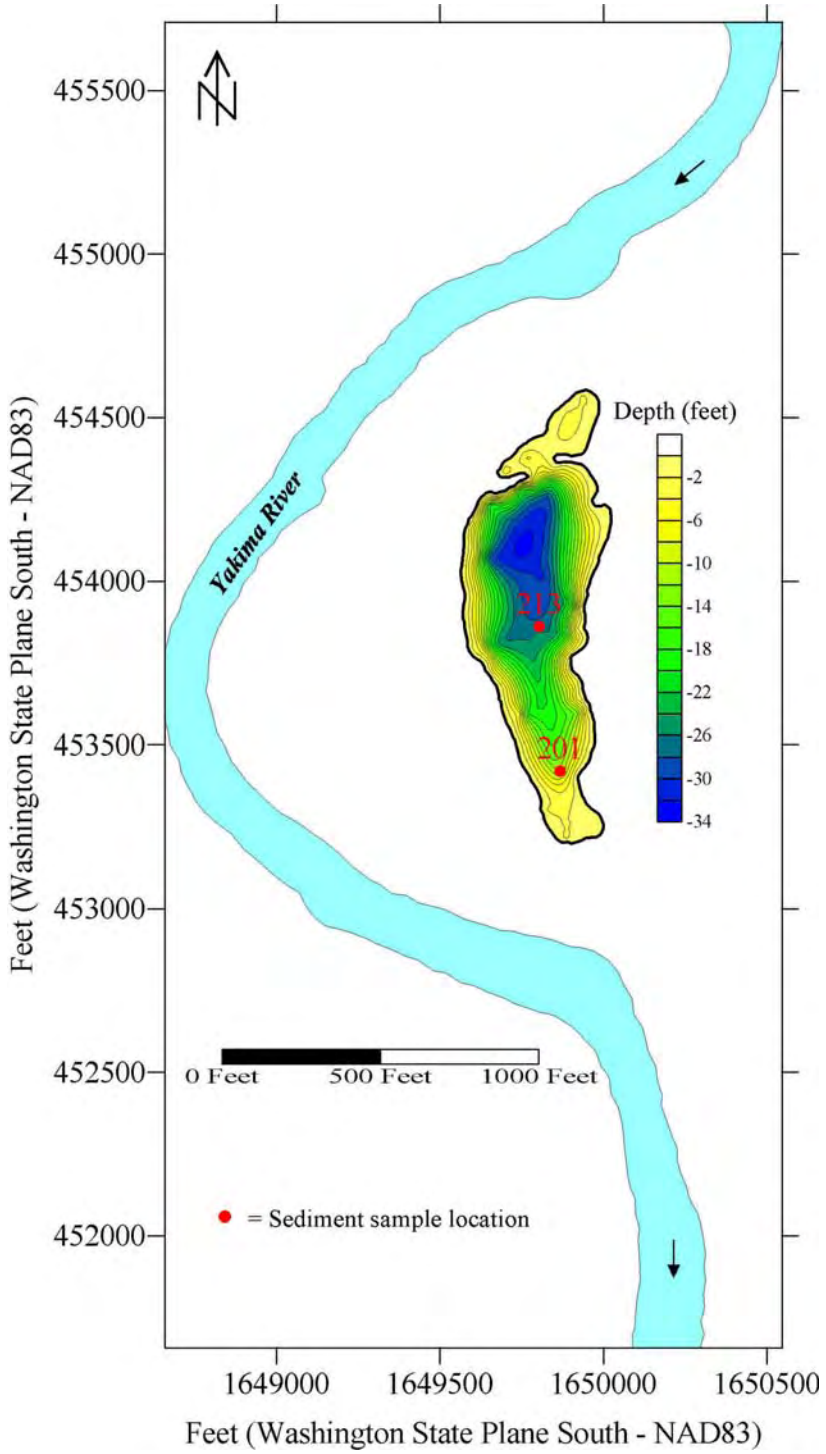


Figure 89. Contoured bathymetric map of Newland Pond 1 showing location of the sediment samples (GPS waypoint number) and proximity to the Yakima River.

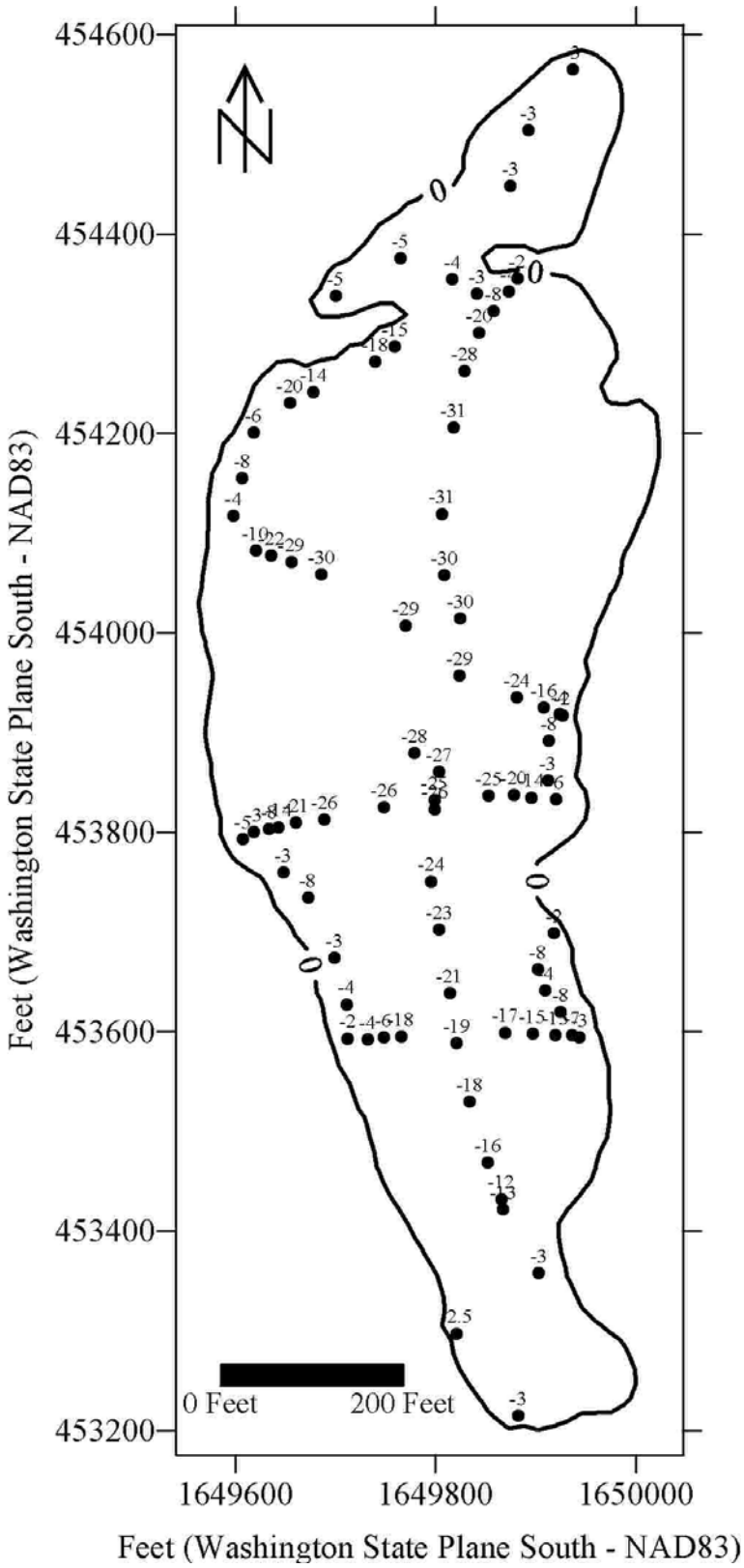


Figure 90. Post map showing data point locations and depths (in feet) used to model bathymetry for Newland Pond 1, May 29, 2002.

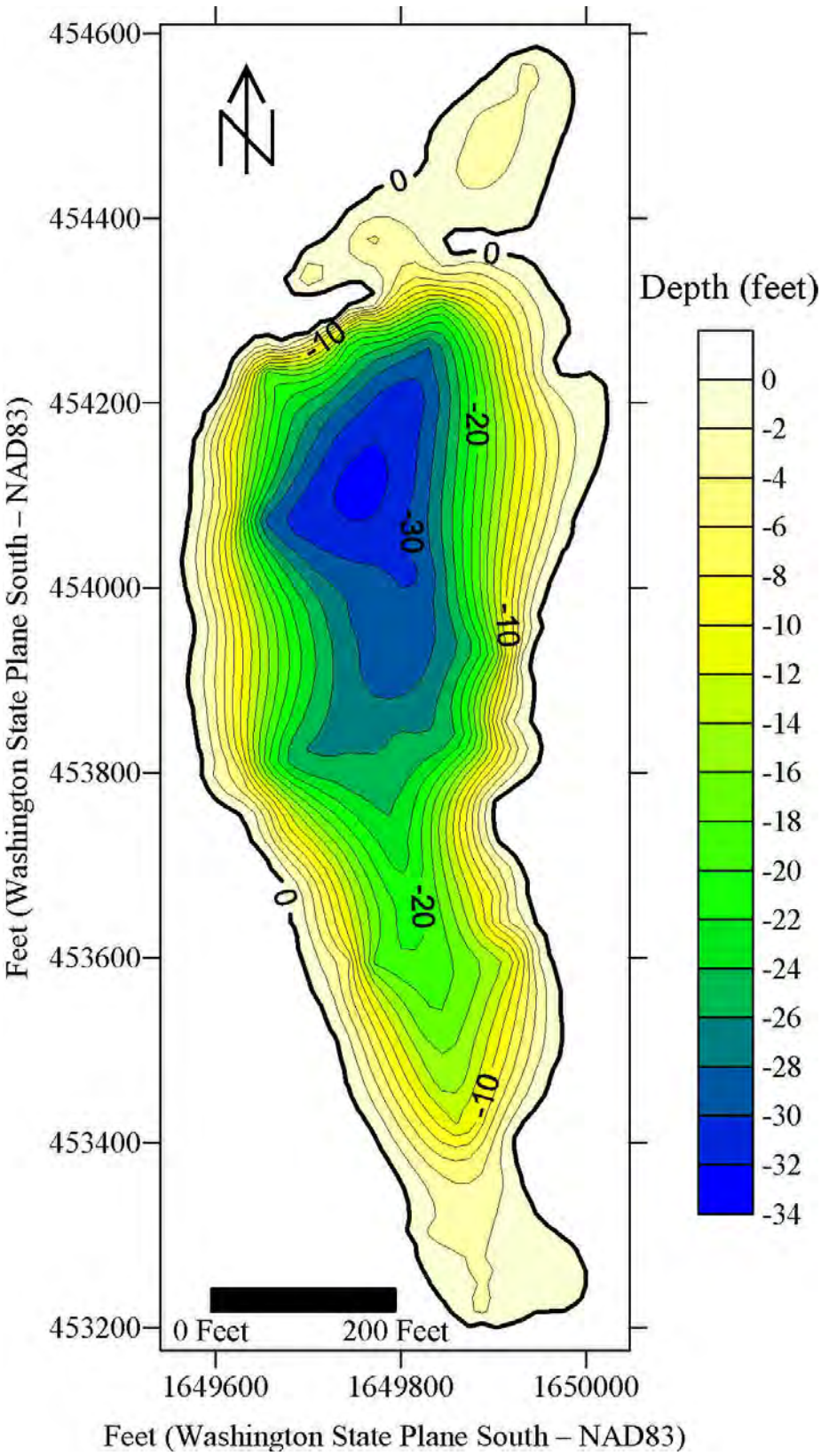


Figure 91. Contoured bathymetric map of Newland Pond 1; bathymetry in feet below the May 29, 2002, water level.

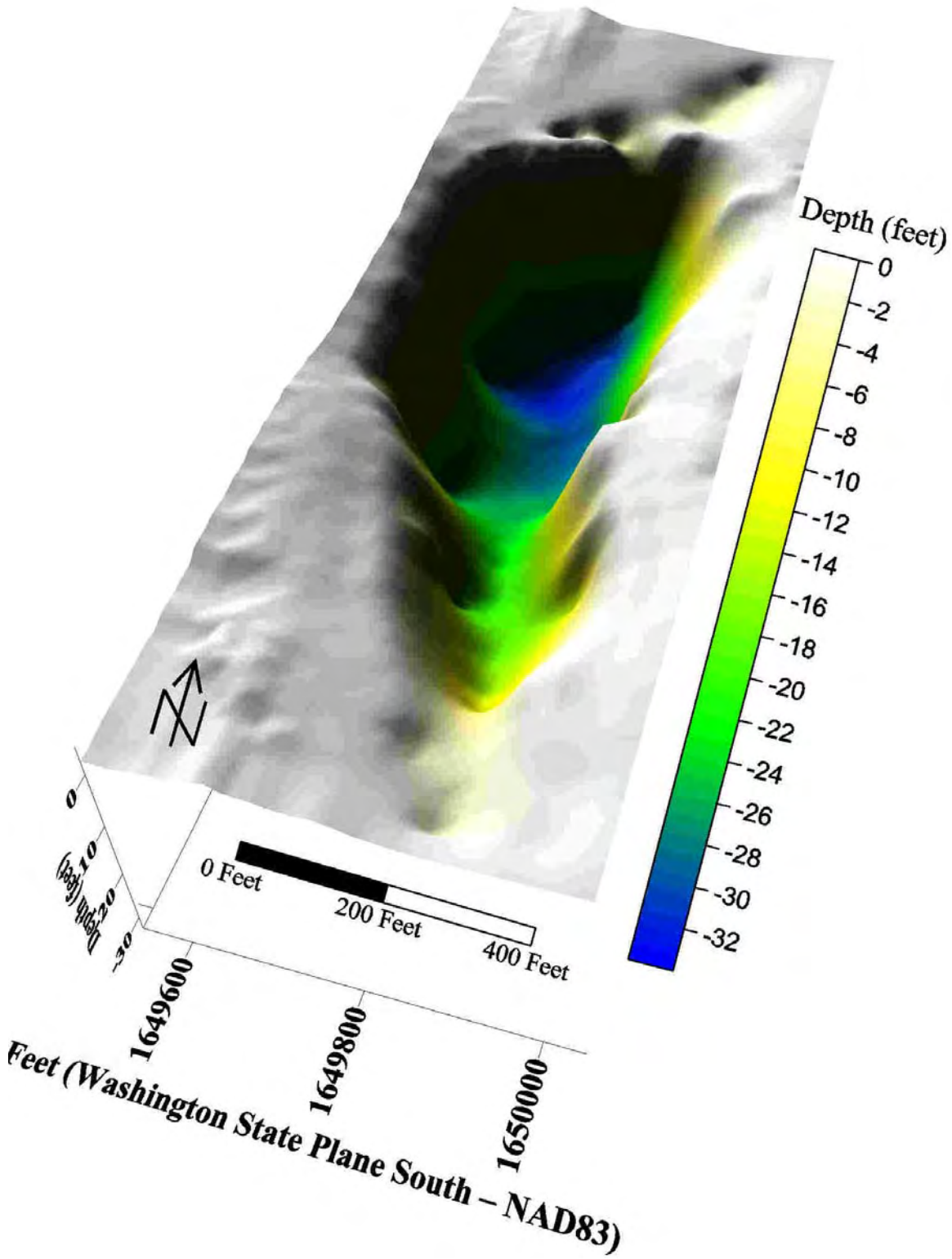


Figure 92. 3-D perspective map of Newland Pond 1; bathymetry in feet below the May 29, 2002, water level.

At the time of sediment sampling, on May 29, 2002, the pond bottom was blanketed with a thick clay slurry. Sample 201 was collected from the southern end of the pond, near where fine sediment was being washed in from adjacent mining activity. Qualitative assessment of sample 201 indicates that the pit bottom in this location is entirely silty clay (particle sizes <0.003 in., Table 37). An attempt was made to obtain an additional sample from the deeper portion of the pond (Figure 89) at location 213; however, the thick clay slurry in the basal 5 to 10 ft of the water column prevented sample recovery. The bottom sediments at location 213 are probably similar to those sampled at location 201. In contrast to every other pit sampled, the silt and clay sediment on the deeper part (>15 ft) of Newland Pond 1 was void of visible macroscopic plant life, probably because the influx of fine sediment from ongoing mining activity was reducing available light for photosynthesis at water depths greater than 15 ft.

Table 37. Qualitative sediment particle-size data for Newland Pond 1.

Sample No.	Particle Size Range	Comments
201	100% @ <0.003 in.	100% silty clay derived from fines washed into pond from adjacent mining operation
213	No sample	Thick colloidal clay slurry in lower portion of water column prevented sample recovery.

Site Sample Information

Sample site locations for the thermal investigation, fish assemblage, and benthic macroinvertebrate and water-quality work for the Newland Ponds site are shown in Figure 93. Standard sampling protocol is discussed in Chapter 4 (Methods). Individual site results are discussed per study component below.

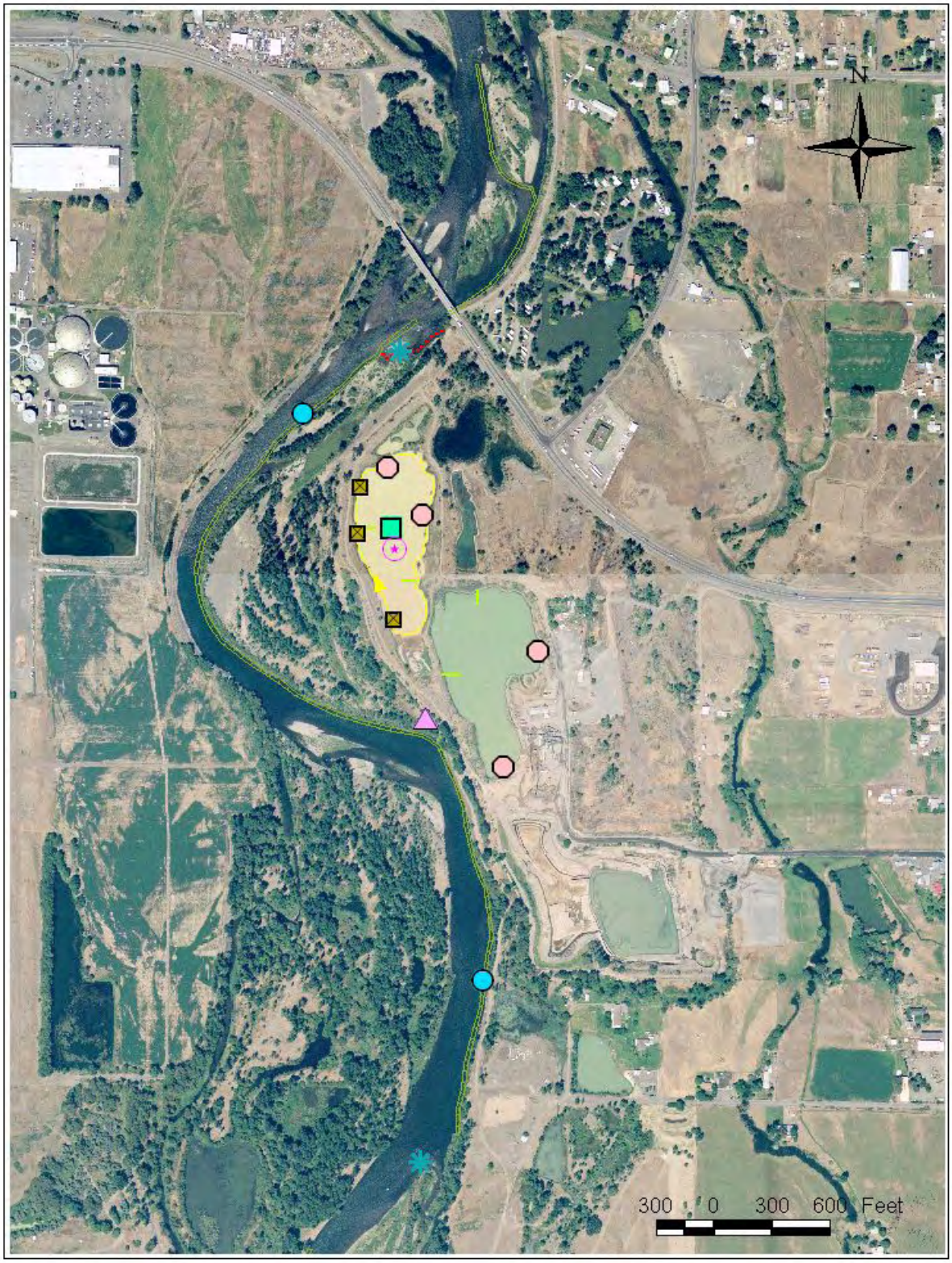


Figure 93. Thermal, fish assemblage, benthic macroinvertebrate, and water-quality sample site locations for the Newland Ponds site. Explanation of location symbols is on p. xxii. (Photo source: DOT, 2002)

Thermal Investigation

River and pond temperature data was monitored and collected by CPM personnel. The upstream and downstream monitoring instruments were tethered to the riprap dike on the east bank of the Yakima River; these were placed at water depths of about 3 ft, and shading was minimal (Figure 93). The Pond 1 vertical stringer was located in the center of Pond 1; recorders were at depths of 2, 6, 12, and 21.5 ft. Analysis of data from the deepest pond monitoring instrument determined that the data were affected by silt from the adjacent gravel washing operation. The Ext (air) unit was located in the riparian area below Pond 1 on the dike (Figure 93). Temperature data for the Ext and river monitoring locations were recorded from April 15 to November 1, 2002.

River

Table 38 shows the average of the temperatures recorded each month and the change (dT) in average temperature between the upstream and downstream sample sites. Positive numbers represent an increase in temperature in the downstream direction, whereas negative values represent lower downstream temperatures. Table 38 indicates that there was little change in the river temperature at this site. In general, there was a small decrease in temperature downstream among the sample sites. The decrease was not consistent and varied by month.

Table 38. Average monthly Yakima River temperatures (in °C) at the Newland Ponds site.

Month	Upstream	Downstream	dT Upstream/ Downstream
April	8.17	8.38	0.20
May	10.55	10.57	0.02
June	13.13	13.02	-0.11
July	17.32	17.02	-0.30
August	17.46	17.29	-0.17
September	16.18	16.09	-0.09
October	11.06	10.99	-0.07

Figure 94 illustrates the daily minimum and maximum temperatures in the river at the site. The upstream daily minimum and maximum temperatures were higher than the downstream temperatures. This could be related to the locations selected for the temperature recorders and the distance of the pond from the river.

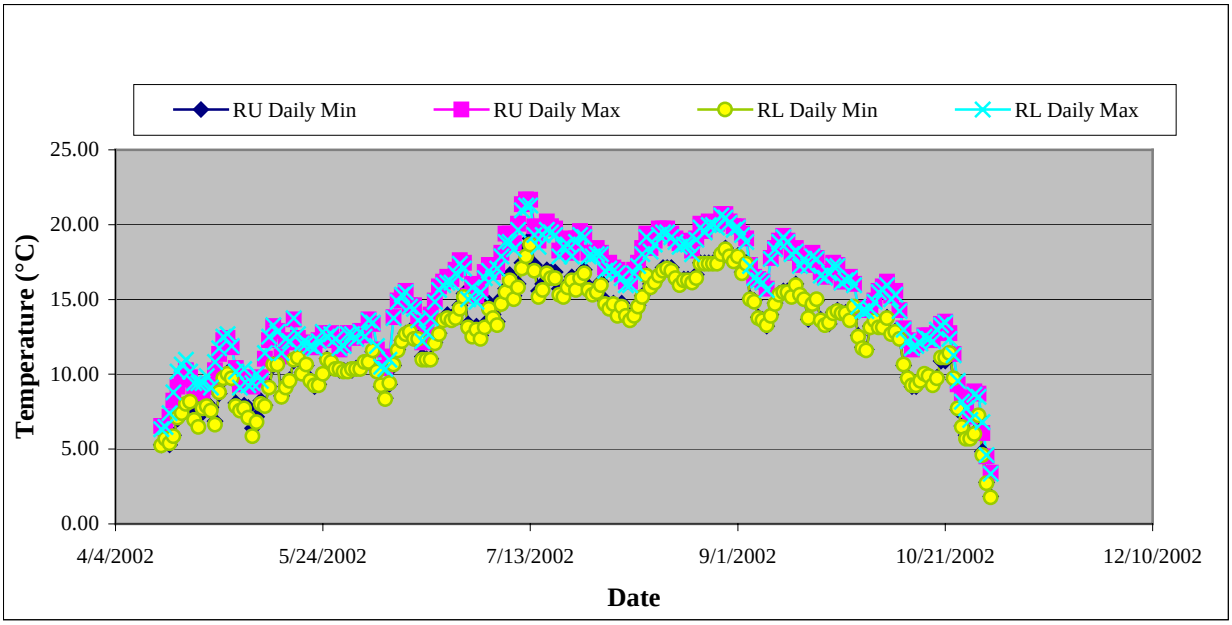


Figure 94. Yakima River daily minimum and maximum temperatures at the Newland Pond site. RU, RM, RL, upper middle, and lower river sites, respectively; see Figure 93.

Pond

Figure 95 shows minimum and maximum temperatures recorded in a vertical profile in Newland Pond. Early in the year, water at the 2-ft depth was notably warmer than at the other depths. However, by summer, most temperatures were within a small range. The pond was being used as a settling pond during this time; sediment was apparently burying the deepest temperature recorder and preventing the pond from stratifying.

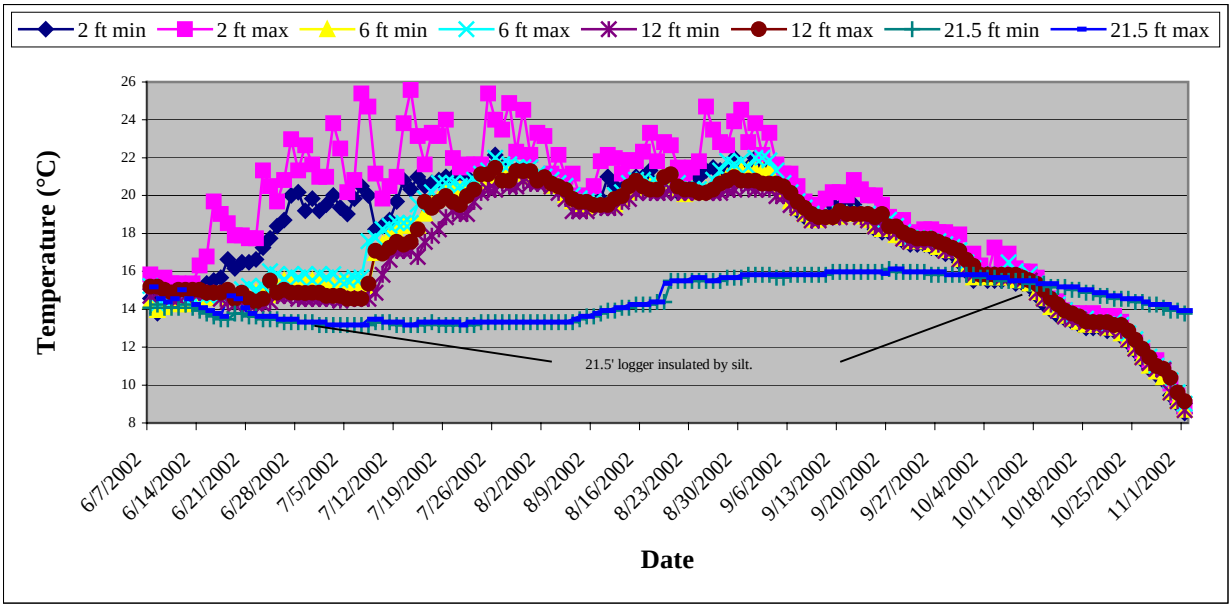


Figure 95. Daily minimum and maximum temperatures for Newland Pond 1.

Fish Assemblage

The northernmost pond (upper, or Pond 1), which was serving as a gravel washing settling pond, and the pond immediately south from the settling pond (lower, or Pond 2) were sampled on October 29 and 30 and May 30 and 31, respectively. Both ponds were sampled with the electroshocking boat, fyke nets, and gill nets following the standard protocol. Because the water clarity was poor in the settling pond, electrofish sampling efficiency was very low. Figure 96 shows a largemouth bass stunned by the electroshocking boat and the low water clarity; only the upper portion of the fish is seen. A 100-m reach of the river above Pond 1 was sampled on August 15 with the backpack electroshocker above the pond A long river reach A long river reach beginning 2,000 m upstream of Pond 1 and extending 2,000 m downstream of Pond 2 was surveyed with the drift boat electrofisher on August 20 . Fish sample sizes in the river were lower than the 200 fish target because of high flows from peak summer irrigation deliveries.

Figure 96. A 40-cm largemouth bass captured in Newland Pond 1. (Photo source: Washington State Department of Fish and Wildlife, Oct. 30, 2002)

Appendix K, Tables 21-23 present detailed fish species assemblage data for the two Newland ponds and the Yakima River adjacent to these ponds. A summary of species composition at this site is presented in Table 39.

Samples of 766 fish (four species) in Newland Pond 2 and 131 fish (six species) in Newland Pond 1 were collected. The low sample size in the gravel wash settling pond was the result of poor boat electroshocking efficiency due to extreme turbidity and/or low fish abundance resulting from the high level of total suspended solids. Pumpkinseed sunfish (53% Pond 2; 40% Pond 1) dominated the fish community in both ponds. Yellow perch (41%) were the second most frequently sampled species in Pond 2; largemouth bass (31%) were the second most frequently sampled species in Pond 1. No northern pikeminnow or other native minnows were found in these ponds, unlike many of the other ponds surveyed. Likely, this is an indication that fish have not had access to these ponds from the river during flood events.

Table 39. Percent composition of fish sampled at two Newland Ponds and the Yakima River adjacent to the Newland Ponds site. The river was not sampled by backpack electroshocker below the ponds. The bolded values indicate dominant species. See Table 6 for an explanation of species codes.

Species	Newland Pond 1	Newland Pond 2	River		
			Above	Drift Boat	Summary
BBH	1.5				
BC	**22.1**				
CK			2.7	3.6	3.4
CMO				**16.2**	**12.7**
COT			**28.0**	0.7	6.5
CP	0.8				
DAC			**65.3**		13.9
LMB	**31.3**	5.7			
MNS				2.5	2.0
NPM				4.0	3.1
PS	**40.5**	**40.7**			
RB			1.3	1.1	1.1
RS				**49.3**	**38.8**
SK				**21.6**	**17.0**
WBL			2.7		0.6
WF				1.1	0.8
YP	3.8	**53.5**			
Total (%)	100.0	100.0	100.0	100.0	100.0
Sample Size	131	766	75	278	353

Seventy-five fish were sampled in the river with backpack electroshocking gear. Only five species were collected: dace (65%), cottids (28%), chinook (3%), western brook lamprey (3%) and *Onchorhynchus mykiss* (1%). Combining data for all river sampling methods, redside shiner (39%), sucker (17%), dace (14%), and chiselmouth (13%) were the most frequently sampled species adjacent to the Newland Ponds site.

Benthic Macroinvertebrates, Water Quality, and Macrophytes

Benthic Macroinvertebrates and Water Quality

The Newland Pond 1 had marginal water quality, particularly high TDS, and a low secchi depth (see tabulation below and Table 14). The benthic macroinvertebrate community in the pond had few taxa and was dominated numerically by a subset of those taxa (Appendix L, Table 3).

Depth (m)	Temp (°C)	pH (units)	Cond (µS/cm)	DO (mg/L)	chla (µg/L)	secchi (m)	OP (mg/L)	TDS (mg/L)	TN (mg/L)	TP (mg/L)
0.5	20.4	7.77	120	8.1	4.70	0.2	0.018	126.0	10.8	0.580
6.3	17.5	7.48	118	6.8	NA	NA	NA	NA	NA	NA

In the river, the lower reach had less dissolved oxygen and was less alkaline than the upper reach (lower tabulation below and Table 16). Channel morphology and sediment composition were similar between reaches (no statistical differences).

River Site	Date (2002)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	pH (units)	Temperature (°C)
Downstream Newland	09/17	89	10.6	8.28	16.2
Upstream Newland	09/17/2002	88	9.6	7.33	17.0

There were no statistical differences in biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Table 18). The cluster dendrogram did not show a strong difference between reach samples (Figure 39). The CCA plot also did not show a clear pattern of macroinvertebrate community composition difference between the two reaches (Figure 97).

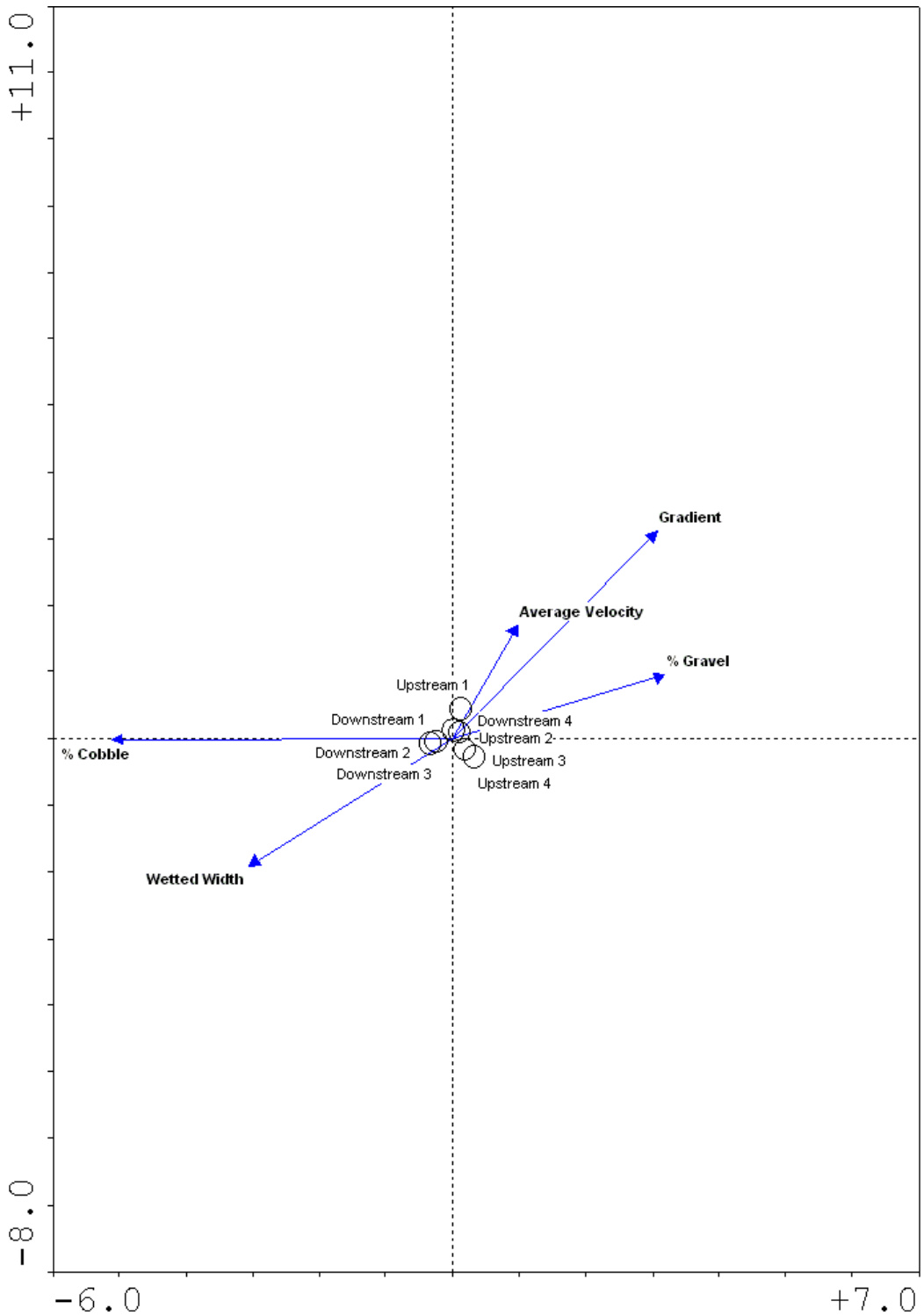


Figure 97. Canonical Correspondence bi-plot with the Newland river benthic macroinvertebrate site distribution and major physicochemical explanatory vectors.

Macrophyte Survey

The water at Newland Pit site was very turbid at the time of the plant inventory (September 11) because the site was being actively used as a washing pond. There was a large population of the water clover *Marsilea* in shallow water along most of the shoreline. This plant is typically found in wetlands, and while it is not uncommon in central Washington, it had not been observed before on a lakeshore. The submersed plant community was diverse; among pondweed species was the non-native curly leaf pondweed (*Potamogeton crispus*). The invasive plant purple loosestrife (*Lythrum salicaria*) was scattered in locally dense patches along the shore.

Site 6 Comments and Recommendations

Newland Pond 1 is a closed pond system that is more than 30 ft deep. An armored dike along the entire west margin of the pond reduces the lateral channel migration potential throughout this reach. No likely near-term avulsion points were identified. Water quality was poor because the site was used as a settling pond from June to August 2002. At the time of the sediment and particle data study in May, the pond bottom was blanketed with thick clay slurry. Few benthic macroinvertebrate taxa were sampled, and the community was dominated by a subset of those taxa.

Water in the lower river reach here had less dissolved oxygen and was less alkaline than that in the upper reach. There are no statistical differences in the channel morphology or substrate composition between the sampled reaches. The river was generally slightly cooler below the ponds than above.

Pumpkinseed sunfish dominated the fish community in both ponds. River habitat is suitable for salmonids, but it is of poorer quality than that at upriver sites. This reach of river serves as winter rearing habitat for salmonids and may be more important to salmonids than our sampling indicates because no sampling was conducted in the winter.

Recommendations

Given the size and depth of the Newland Ponds and their proximity to the State Route 24 Bridge, if they are to be reclaimed for the benefit of anadromous salmonids, the following actions must be considered:

- Research the size range and volume of appropriate material required to fill this pond to a level that would enhance fish usage and contribute to the geomorphic recovery of the site.
- Conduct a comprehensive cost-benefit analysis for this reach to determine the feasibility and the priority ranking of gravel pond reclamation of this site compared to others, given the impacts to roads and facilities infrastructure that would need to be mitigated.

11. EDLER PONDS (Site 7)

Location and Site Characteristics

Edler Ponds, located east from the City of Union Gap (immediately south of the City of Yakima) off Valley Mall Boulevard, are a complex of three small pit ponds along the west bank of the Yakima River (Figure 98; see Figure 110). These ponds formed when pits filled with ground water after mining in the early 1990s (northern basin of Pond 1) and late 1990s to 2000 (southern basin of Pond 1 and Ponds 2 and 3). The south half of the site is within about 200 ft of the river. All three ponds, covering a total of about 17 acres, were studied for this project.

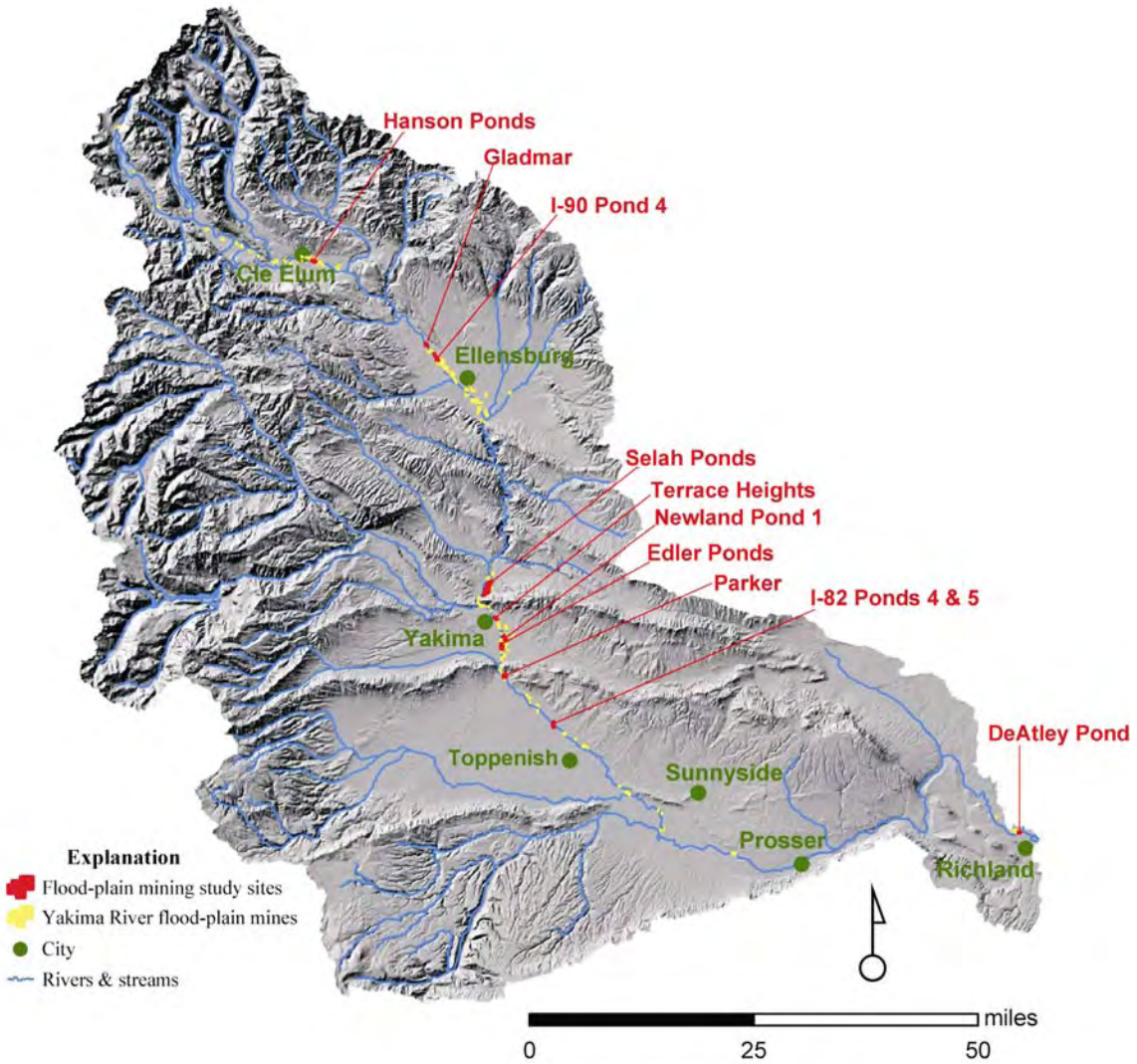


Figure 98. Location of Edler Ponds (Site 7) south of Yakima.

Pond Bathymetry and Sediment Sampling

Near the Edler Ponds, the Yakima River has a meandering to anastomosing form. The width of the channel migration zone (CMZ) is approximately 1,400 ft upstream of the ponds, about 1,100 ft adjacent to the ponds, but about 2,500 ft downstream. Dikes on either side of the river limit the CMZ width adjacent to the ponds. The average Edler reach valley slope for a reach extending from about a mile upstream to a mile downstream of this site is 0.00237, or about a 12.5-ft drop in valley floor elevation for each mile downstream. This is less than at the Terrace Heights and Newland Pond sites. The decrease in slope in this reach may be the result of aggradation of sediments upstream of (behind) Union Gap or active subsidence of the southern Yakima Valley (Waitt 1979), both of which would increase meander wavelength and precipitate the formation of an anastomosing channel upstream of Union Gap, at the downstream end of the zone of subsidence (Edler Ponds reach) (Schumm *et al*. 1987).

At the time of our field measurements (late May 2002), during periods of high water levels, flow could pass between Edler Ponds 1 and 2 through a culvert and between Ponds 2 and 3 through a low pass. None of the ponds were connected to the river. In June 2002, the southernmost end of Pond 3 was “naturally” breached and thus connected to the river (Figure 99). After breaching of the narrow strip of land separating Edler Pond 3 from the Yakima River, bank erosion on the north side of the breach was rapid (greater than 1 ft per day for several weeks).

Edler Pond 1 is essentially two basins connected by two shallow channels, which were dug to connect the two pits. A small island separates the channels. The average depth is approximately 7.3 ft. The maximum measured depths are 19 ft and 18 ft for the north and south basins, respectively (Figure 100). In general, the walls of the pond slope steeply toward the deep parts of the basins (Figure 101). A low sill separates the relatively shallow north end of the southern basin from the deepest part at the south end (Figure 102).

Edler Pond 2 is roughly oval in plan view. The average depth of Edler Pond 2 is approximately 7.6 ft. It has a deep central north-south axis running the length of the pond (Figures 103 and 104). The pond is at least 16 ft deep in several places along that axis. Shallower benches are located along the western embayment and southern and southeastern shores (Figures 103, 104, and 105).

Edler Pond 3 consists of two basins separated by a sill at about -11 ft. The north basin is deeper; its maximum measured depth is 17 ft (Figures 106 and 107). The average depth of the pond is about 11 ft. The pond walls slope quite consistently (Figures 107 and 108).

Sediment sample 84 was taken from the north edge of Edler Pond 3. This sample, of alluvial deposits, consists of poorly graded gravel (74.4%) with sand (21.8%) and minor silt and clay (3.8%). On the basis of visual field inspection, sediment sample 84 appears to be typical of the particle-size distribution on the bottoms of all three Edler ponds (Figure 109).

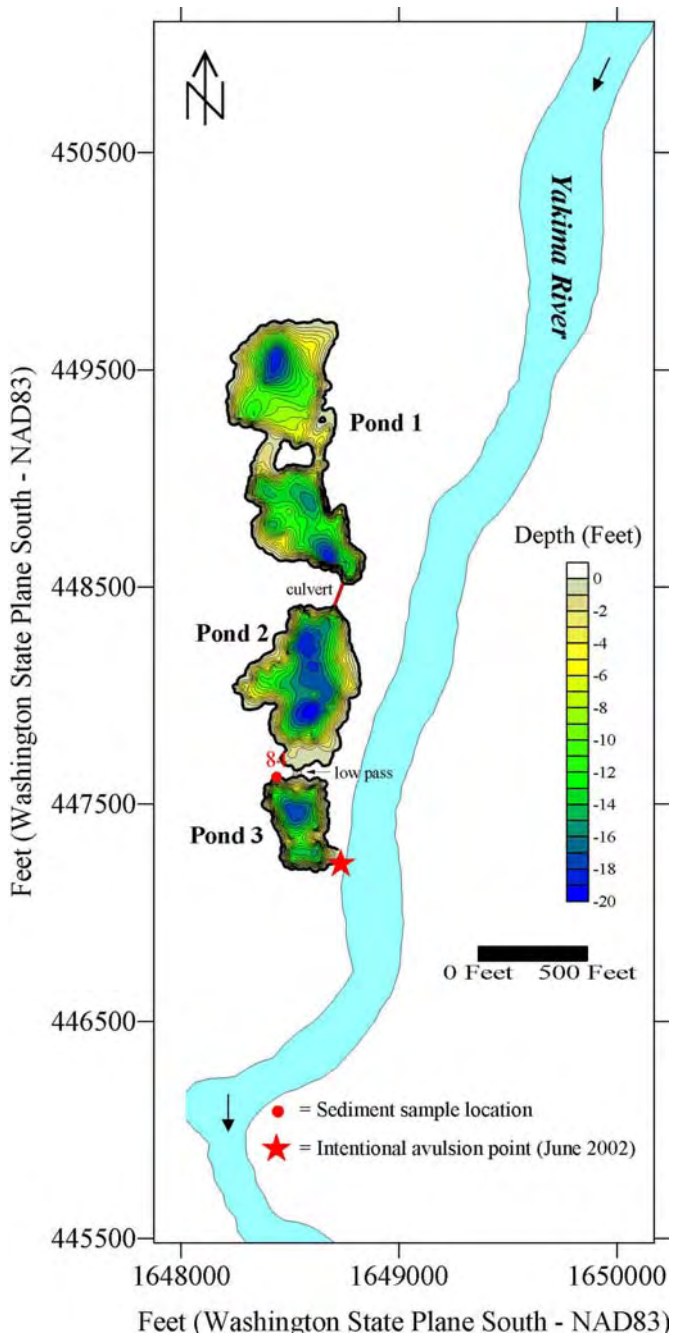


Figure 99. Contoured bathymetric map of the Edler Ponds showing the location of sediment sample (GPS waypoint number) and proximity to the Yakima River.

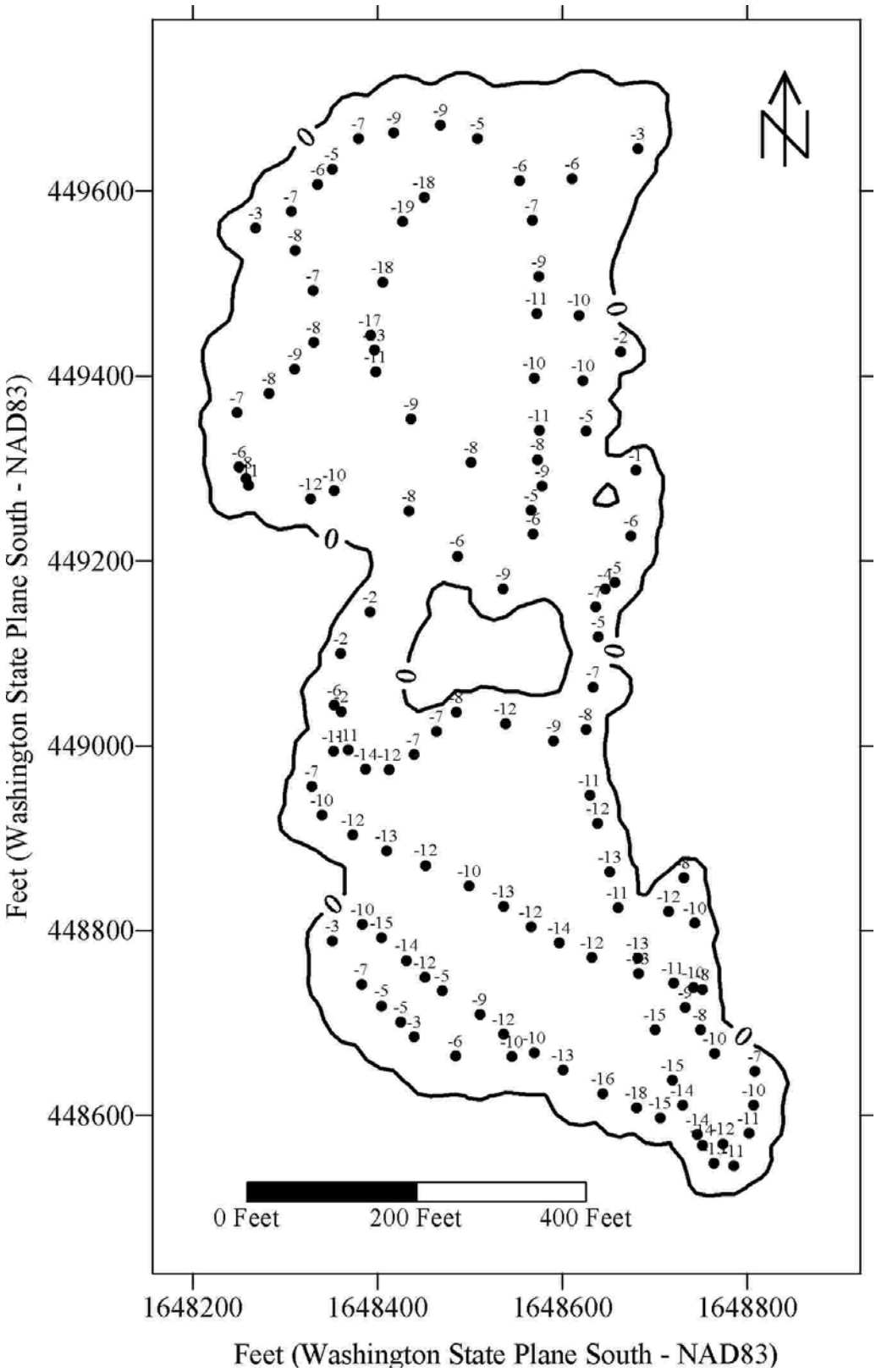


Figure 100. Post map showing data point locations and depths (in feet) used to model pond bathymetry for Edler Pond 1, May 31, 2002.

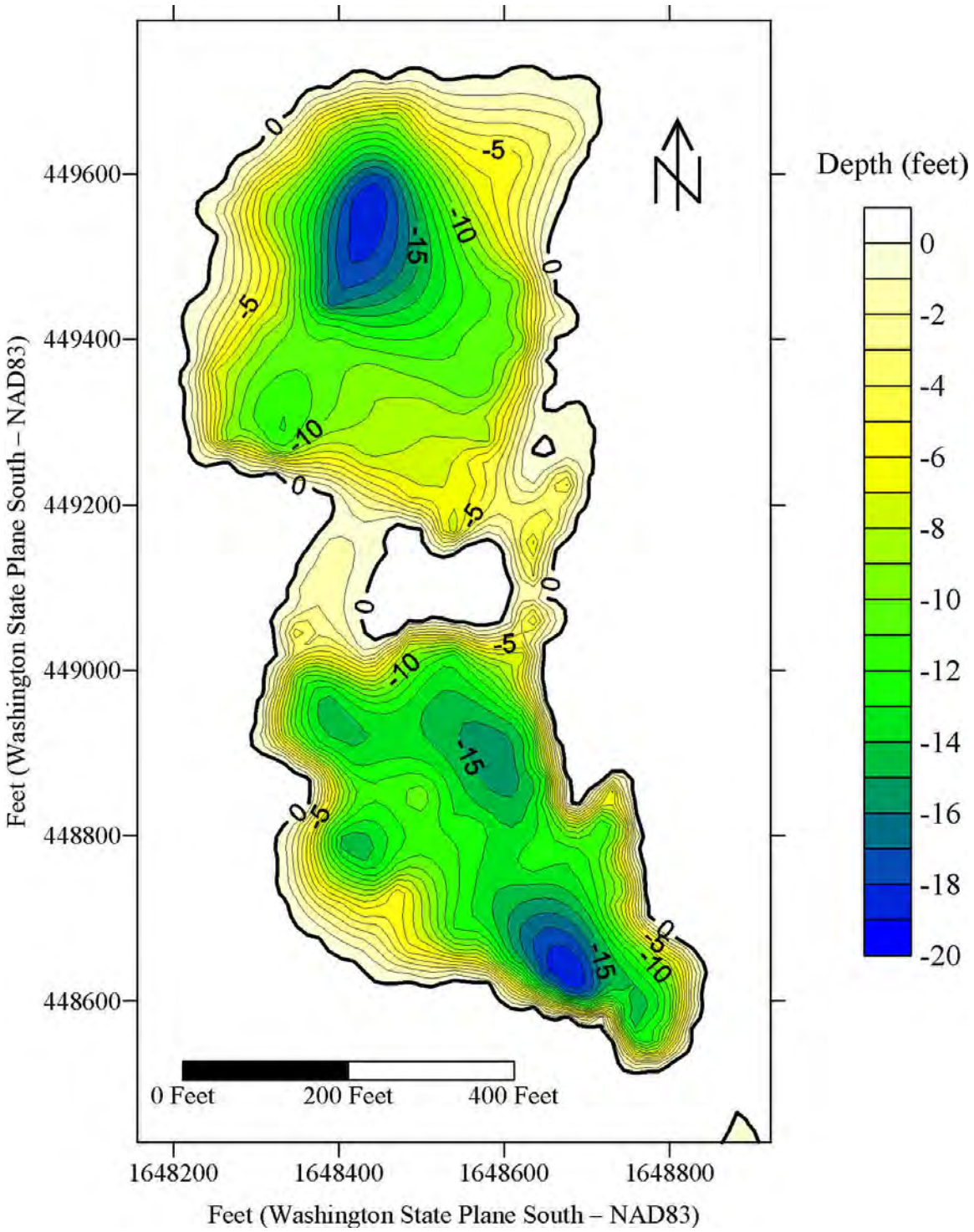


Figure 101. Contoured bathymetric map of Edler Pond 1; bathymetry in feet below the May 31, 2002, water level.

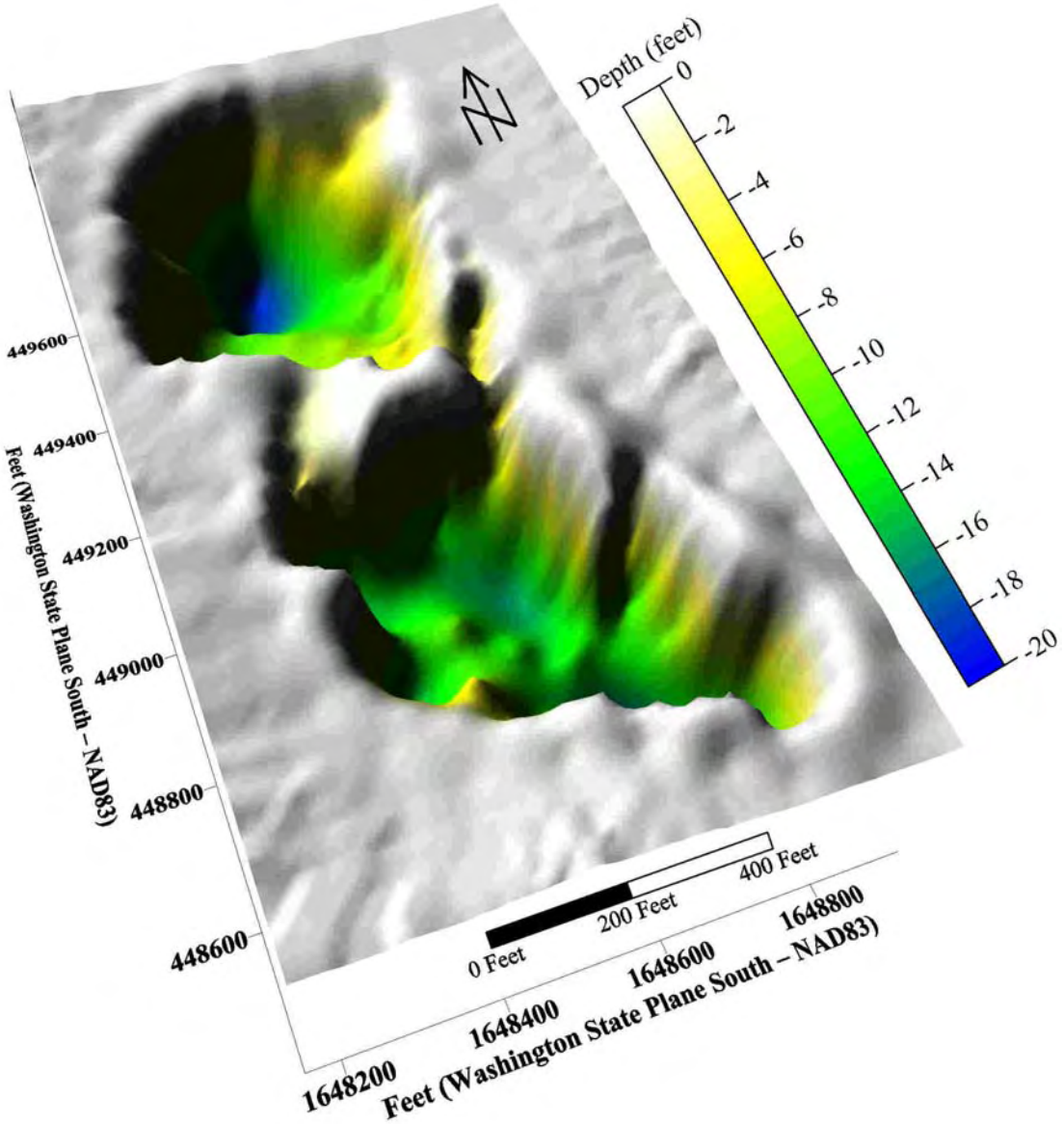


Figure 102. 3-D perspective map of Edler Pond 1; bathymetry in feet below the May 31, 2002, water level.

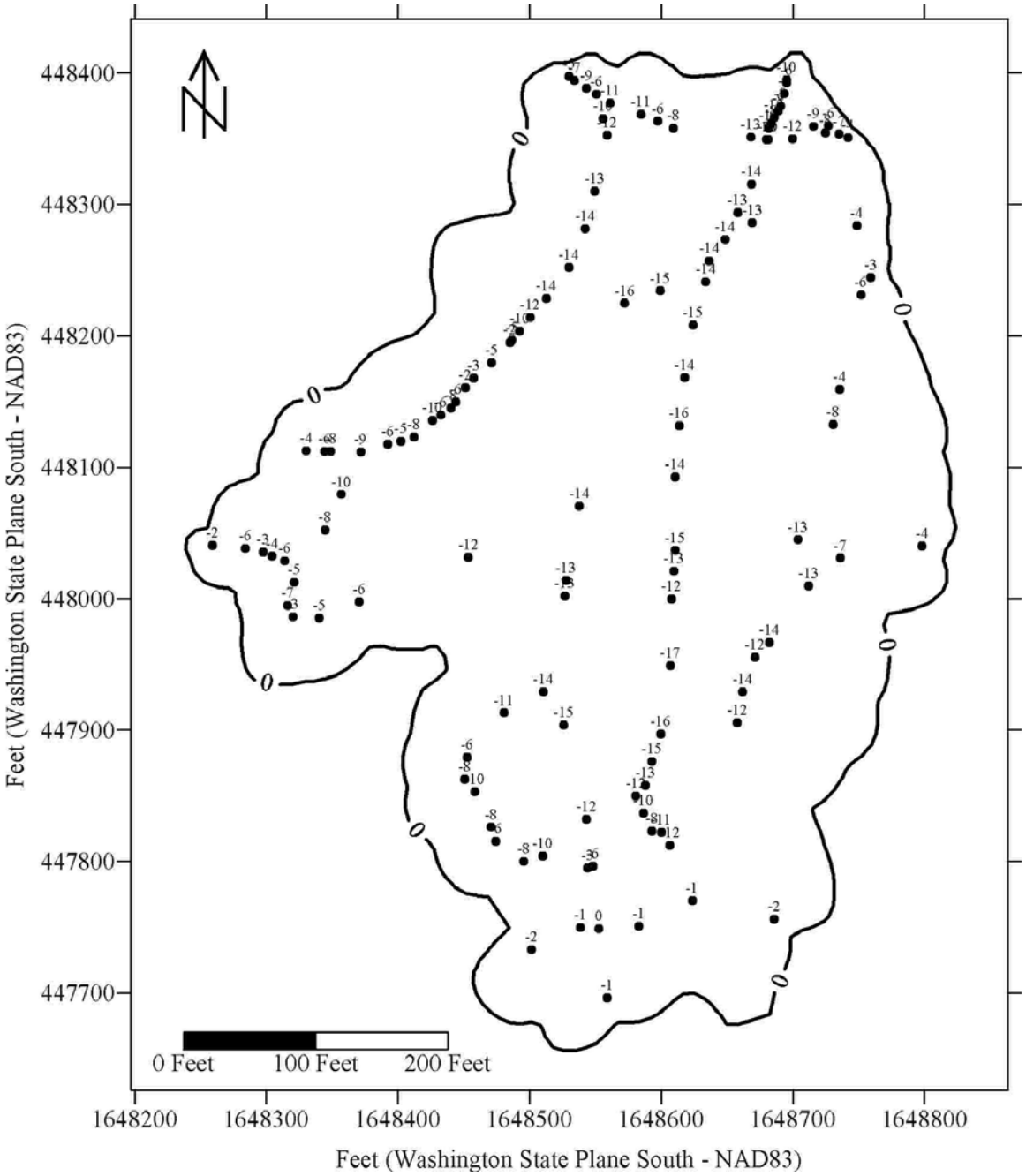


Figure 103. Post map showing data point locations and depths (in feet) used to model pond bathymetry for Edler Pond 2, May 31, 2002.

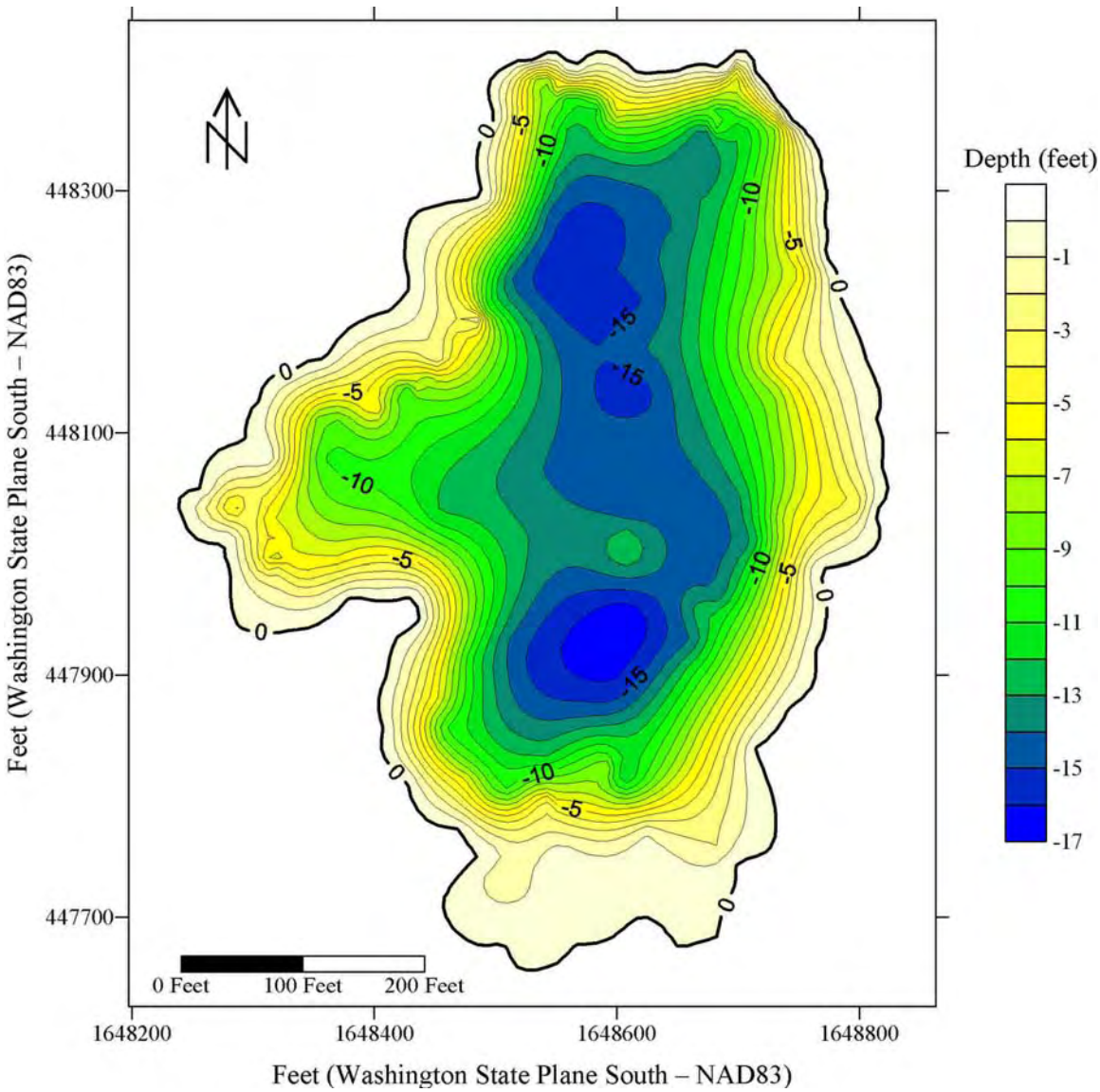


Figure 104. Contoured bathymetric map of Edler Pond 2; bathymetry in feet below the May 31, 2002, water level.

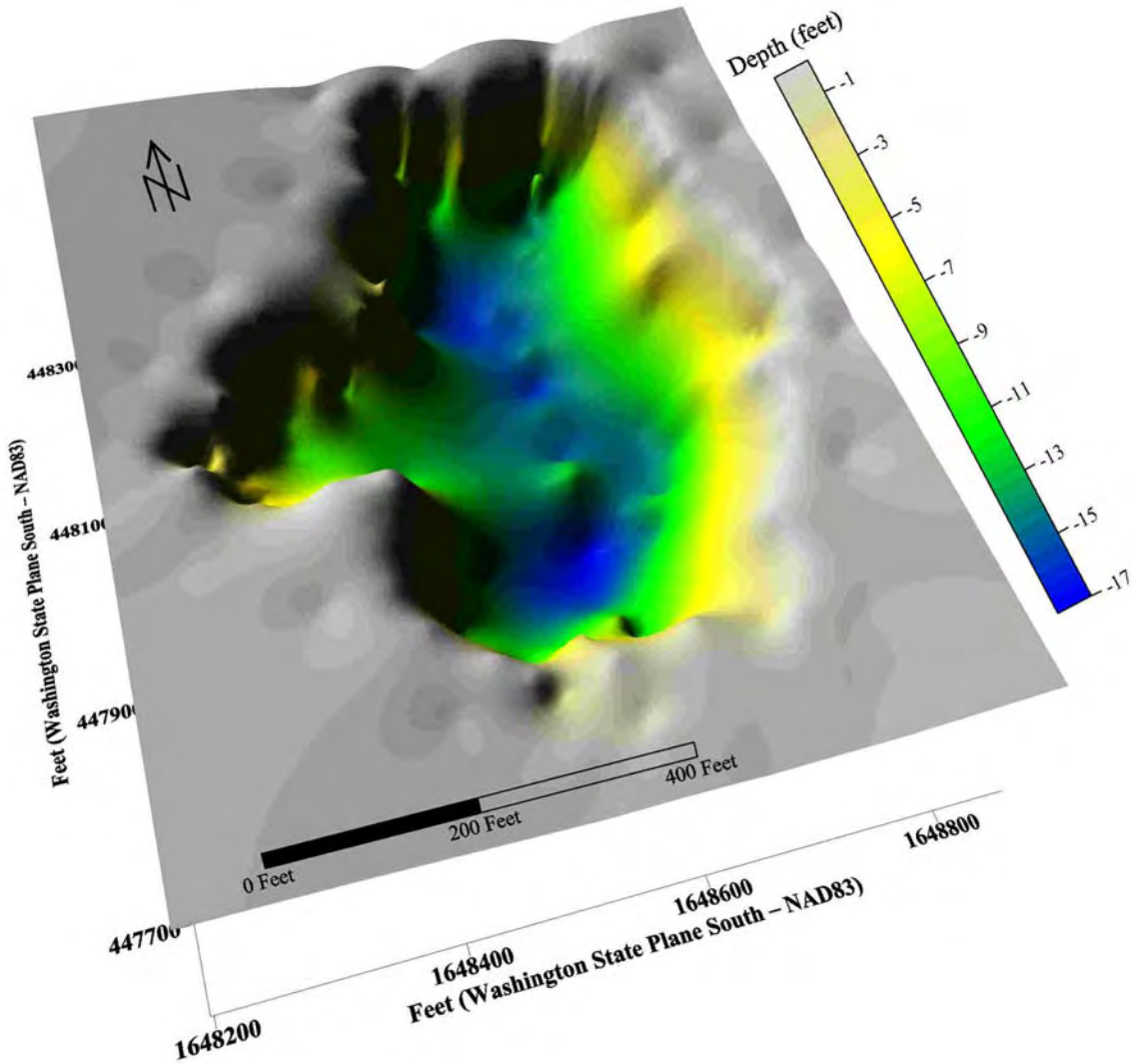


Figure 105. 3-D perspective bathymetric map for Edler Pond 2; bathymetry in feet below the May 31, 2002, water level.

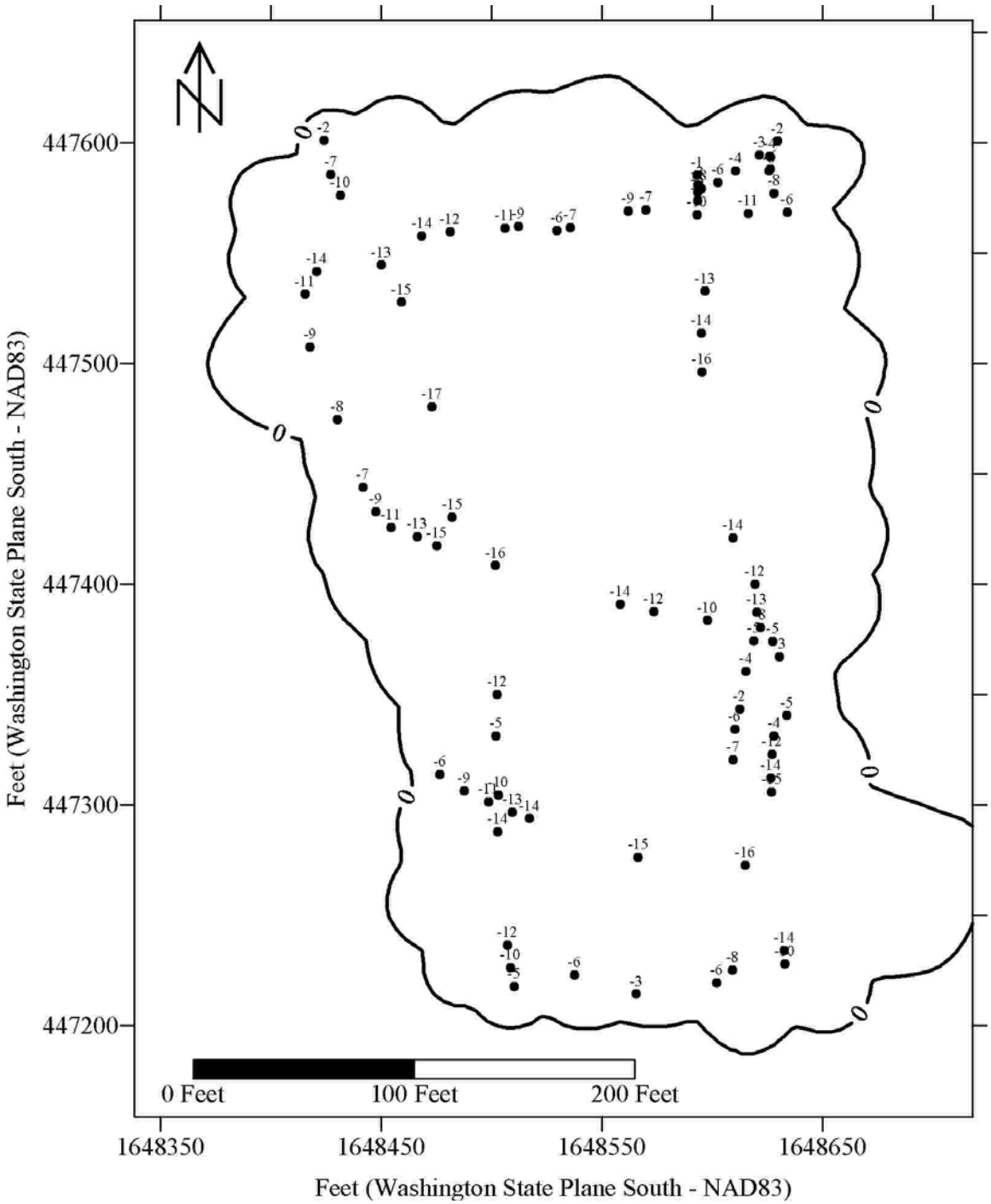


Figure 106. Post map showing data point locations and depths (in feet) used to model pond bathymetry for Edler Pond 3, May 31, 2002.

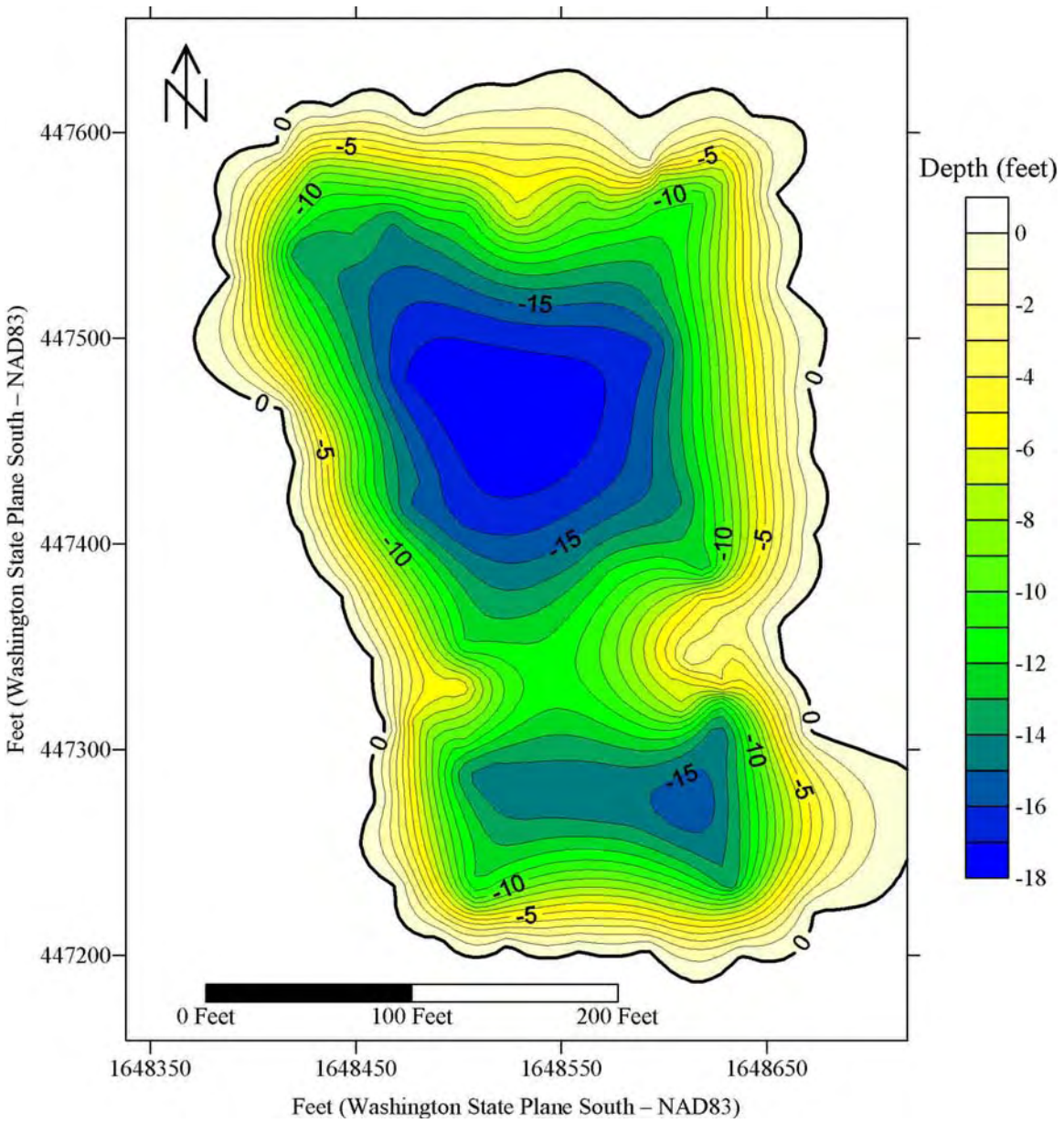


Figure 107. Contoured bathymetric map of Edler Pond 3; bathymetry in feet below the May 71, 2002, water level.

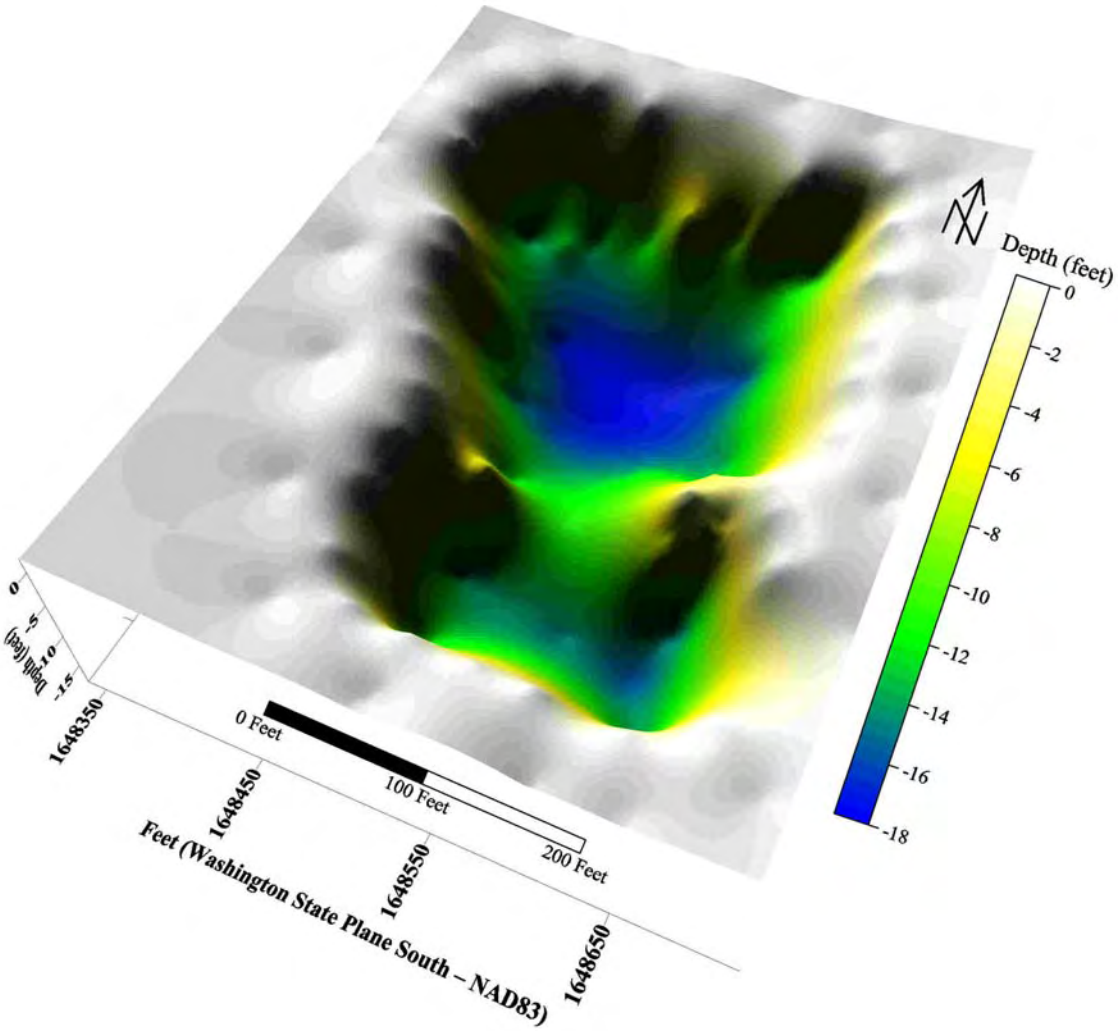


Figure 108. 3-D perspective bathymetric map of Edler Pond 3; bathymetry in feet below the May 31, 2002, water level.

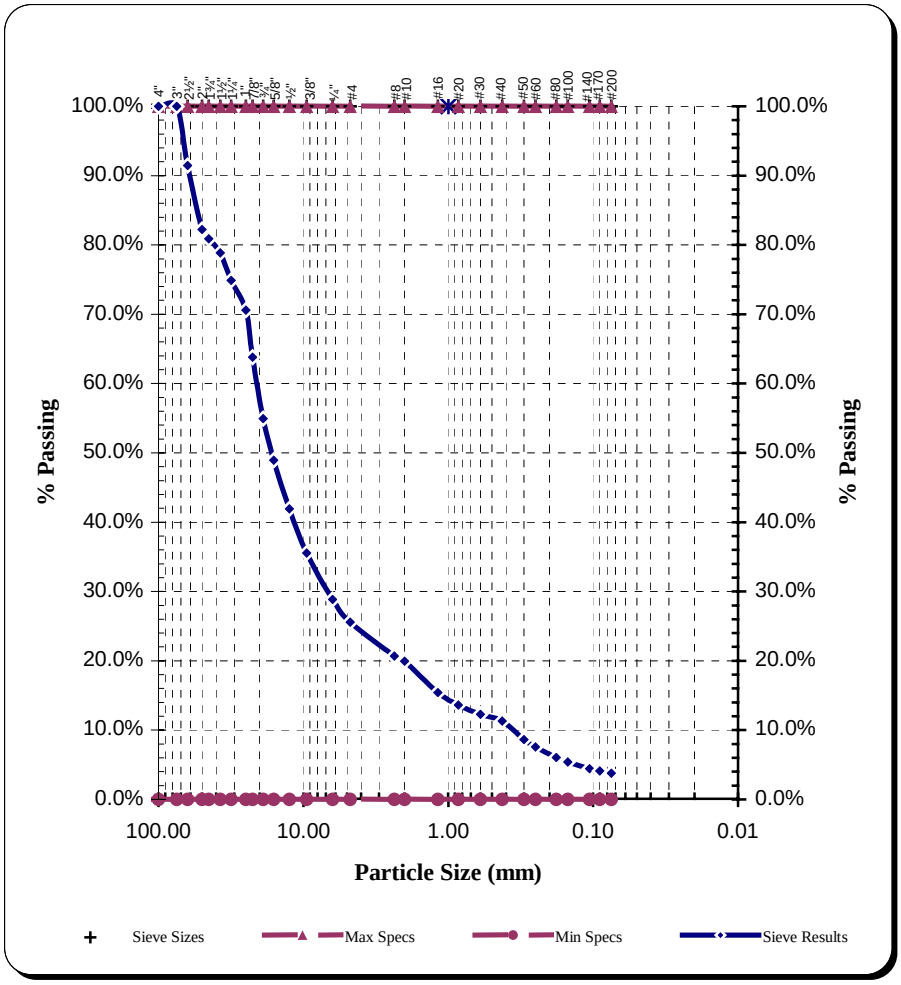


Figure 109. Grain-size distribution plot for sample 84 from the north margin of Edler Pond 3.

Site Sample Information

Sample site locations for the thermal investigation, fish assemblage, and benthic macroinvertebrate and water-quality work for Edler Ponds are shown in Figure 110. Standard sampling protocol is discussed in Chapter 4 (Methods). Site results are discussed per study component below (to follow).

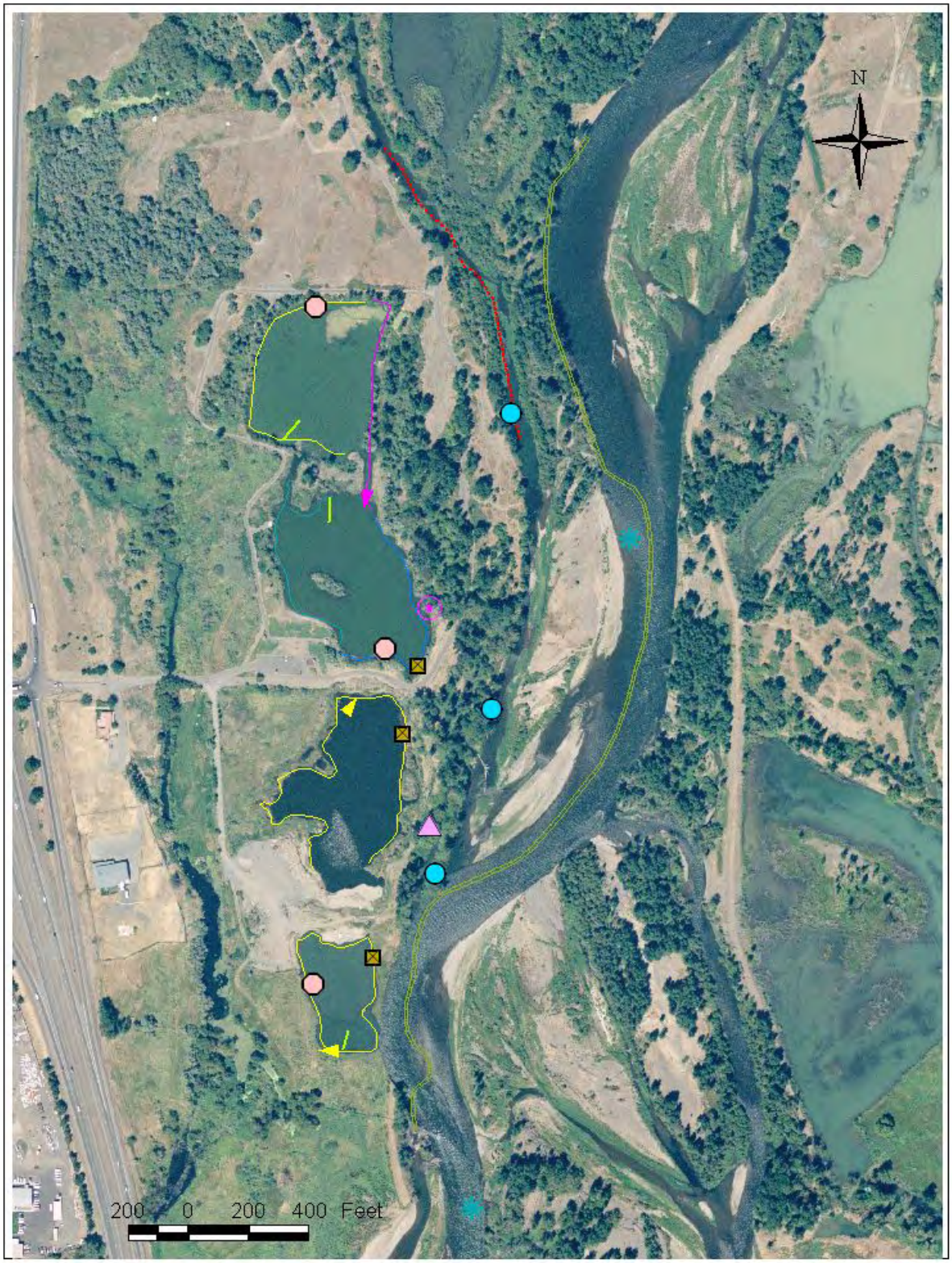


Figure 110. Thermal, fish assemblage, benthic macroinvertebrate, and water-quality sample site locations for Edler Ponds. The explanation of location symbols is on p. xxii. (Photo source: DOT, 2002)

Thermal Investigation

The upstream, middle, and downstream temperature monitoring instruments were located on the west bank of the river in a small side channel adjacent to the site. All these instruments were tethered to the shore, were subject to riparian shading, and were placed in approximately 2 to 3 ft of surface flow. Vertical stringers were placed in Ponds 1 and 3, but they were lost to vandalism during the 4th of July weekend. The pond dataset was not sufficient to incorporate into this report. The Ext (air) unit was located in the riparian area near the lower eastern portion of Pond 2 (Figure 110). Temperatures at the Ext monitoring location were recorded from April 15 to October 14, 2002. At the river monitoring stations, variable periods of record among the monitoring stations were also caused by vandalism. Data were collected from May 9 to November 13 at the upper station, from April 15 to November 13 at the middle station, and from May 15 to October 13 at the lower station.

River

Table 40 shows the averages of the temperatures recorded each month and the change (dT) in average temperature between the upstream and middle sample sites, between the upstream and downstream sites, and between the middle and downstream sites. Positive numbers represent an increase in temperature downstream, whereas negative values represent lower downstream temperatures. The results in Table 40 indicate a generally inconsistent pattern of higher and lower temperatures among the sample sites; small increases and decreases are evident and vary month by month.

Table 40. Average monthly Yakima River temperatures at Edler Ponds.

Month	Upstream	Middle	Downstream	dT Upstream/ Middle	dT Upsteam/ Downstream	dT Middle/ Downstream
April	No data	8.73	No data	No data	No data	No data
May	11.53	11.46	11.63	-0.07	0.10	0.17
June	13.21	13.24	13.30	0.03	0.09	0.06
July	18.09	17.78	17.22	-0.31	-0.87	-0.56
August	18.14	17.83	17.46	-0.31	-0.68	-0.37
September	16.52	16.46	16.20	-0.05	-0.32	-0.27
October	11.99	12.73	13.25	0.75	1.27	0.52
November	6.79	8.60	No data	1.81	No data	No data

The plot of maximum and minimum daily river temperatures shows the variation in heating and cooling among the Edler Ponds sample sites (Figure 111). During the summer, the downstream maximum temperatures stand out as significantly higher than at the other sites.

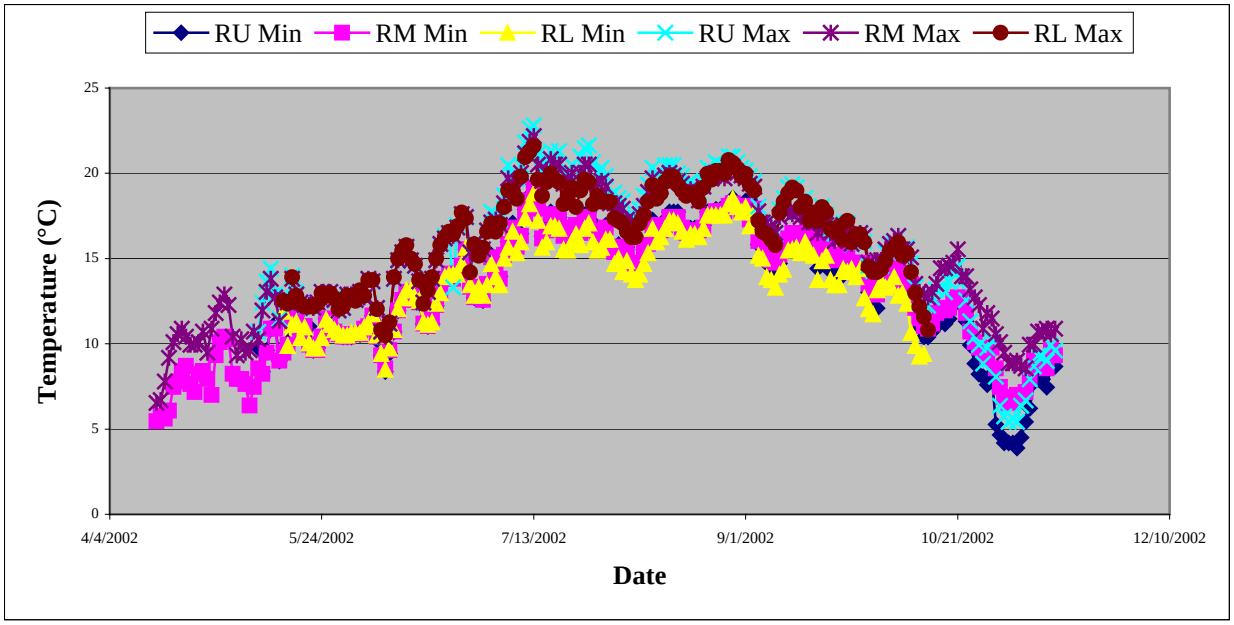


Figure 111. Yakima River daily minimum and maximum temperatures for Edler Ponds. RU, RM, RL, upper, middle, and lower sites, respectively.

Fish Assemblage

Standard protocol was followed on the north pond, Pond 1. However, because of their small size, the lower two ponds (Ponds 2 and 3) were each sampled with only one fyke net and one gill net, but boat electroshocking followed standard protocol. A 400-m river reach, best described as a slough, was shocked above the Pond 1 with the backpack electroshocker on August 27, 2002. Because of high velocity and depth, river sampling was limited to using the drift boat-mounted electroshocker on August 14. A total of approximately 2,000 m of river extending from above Pond 1 to below Pond 3 was surveyed (Figure 110).

Pond 3 was breached by the river in late June during a sustained high flow period (Figure 112) after the initial sampling was completed. Consequently, the Study Team sampled the pond a second time to determine if the fish species assemblage changed within a month after the initial stages of avulsion.

Figure 112. Edler Pond 3 on July 2, 2002, after it was breached by the Yakima River. View to the southeast. Note the circular eddy created by the breach.

Detailed fish assemblage data for the three ponds and the river adjacent to the ponds is presented in Appendix K, Table 24. A summary of species composition is presented in Table 41. The drift boat electrofishing sample did not attain the target sample size of 200 fish, so that information does not appear in the table.

The species assemblage on June 3 was markedly different in each pond. A total of 10 species (n = 3,769) was found in the combined three-pond complex, but not all species inhabited each pond. Pumpkinseed sunfish comprised 73% and 68% of the sample in Pond 3 and Pond 2, respectively. Brown bullhead (45%) and pumpkinseed sunfish (42%) were the dominant species in Pond 1, where more than 2,200 fish were captured. Although present in these pit ponds, northern pikeminnow (0.5%) and largemouth bass (0.3%) were rare. No salmonids were found in these ponds prior to Pond 3 avulsion.

A sample of 207 fish representing 10 species was collected in Pond 3 on July 2 with the boat electroshocker after sustained bankfull flow captured the pond in June. The abundance of two river species had increased dramatically: chiselmouth from 5% to 29% of the sample, and suckers from 7.5% to 25%. However, pumpkinseed sunfish abundance had declined precipitously, from 73% to 21%, indicating they migrated out of the pond into the river. Conversely, migration of juvenile spring chinook into the pond increased their abundance from 0% before breach to 7% of the sample in the span of one month.

Table 41. Percent composition of fish sampled in June at Edler Ponds and the Yakima River adjacent to this site. Bold type indicates dominant species. The river was sampled by electrofishing only above the ponds. See Table 6 for an explanation of species codes.

Species	Edler Ponds June 3-7	Edler Pond 3 July 2	River		
			Above (Aug. 27)	Drift Boat (Aug. 14)	Summary
BBH	**29.7**				
BG			0.2		0.2
CK		7.2	5.6	2.0	5.3
CMO	1.3	**29.0**	**16.9**		**15.5**
COT			1.1		1.0
CP	0.3	3.9	**14.4**		13.2
DAC		0.5	**16.7**		**15.3**
LMB	0.3	4.3	9.7		8.9
LND				2.0	0.2
NPM	0.5	4.3	1.1		1.0
PS	**53.6**	**20.8**	**14.6**		**13.4**
RB			3.0	3.9	3.1
RS	0.1	1.9	1.4	2.0	1.5
SK	1.9	**25.1**	**14.3**	**51.0**	**17.3**
STB		2.9			
WBL			1.1		1.0
WF				**39.2**	3.2
YP	**12.4**				
Total	100.0	100.0	100.0	100.0	100.0
Sample Size	3769	207	586	51	619

In the river, 51 fish (six species) were sampled with the drift boat electrofisher on August 14. That sample included 51% suckers and 39% whitefish; chinook (2%) and O*nchorhynchus mykiss* (4%) were also present. A collection of 568 fish captured with backpack electrofishing gear in the slough and the river above the ponds included 13 species, none of which dominated the fish community. Chiselmouth, carp, dace, sucker, *O. mykiss*, and chinook salmon were among the diverse community sampled in the slough and river. A composite sample of all gear types shows the most frequently sampled species above and below the Edler Ponds were sucker (17%), chiselmouth (16%), dace (15%), pumpkinseed sunfish (13%), and common carp (13%). Largemouth bass, primarily inhabiting the river slough, were a larger percentage (9%) of this river assemblage than at any of the upriver study sites.

Benthic Macroinvertebrates, Water Quality, and Macrophytes

Benthic Macroinvertebrates and Water Quality

Edler Pond 1 had poor water quality (tabulation below and Table 14). There were low dissolved oxygen conditions at the bottom of the pond, and the surface was relatively alkaline. Edler Pond 1 also had fairly high orthophosphorus, chlorophyll a, and TDS values and a low secchi depth. The benthic macroinvertebrate community in the pond was dominated by few taxa, indicating disturbance (Appendix L, Table 3).

Depth (m)	Temp (°C)	pH (units)	Cond (µS/cm)	DO (mg/L)	chla (µg/L)	secchi (m)	OP (mg/L)	TDS (mg/L)	TN (mg/L)	TP (mg/L)
0.5	17.4	9.2	205	9.8	74.93	0.6	0.009	164.0	23.4	0.820
4.3	16.5	7.7	221	1.3	NA	NA	NA	NA	NA	NA

In the river, water quality was similar in the upstream and downstream reaches (tabulation below and Table 16). The upper reach had a larger wetted and bankfull width than the lower reach.

Site	Date (2002)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	pH (units)	Temperature (°C)
Downstream Edler	09/05	91	9.5	7.73	NA
Upstream Edler	09/05	91	10.3	7.87	14.2

There were mixed biometric results between reaches, indicating that the upper (control) reach was not necessarily in better biological condition than the lower reach (Table 18). The cluster dendrogram did not show a difference between reach samples (Figure 39). The CCA plot shows a slight separation of macroinvertebrate community composition between the two reaches (Figure 113); wetted width, gradient, and cobble could be interpreted being related to the faunal distribution (Table 42).

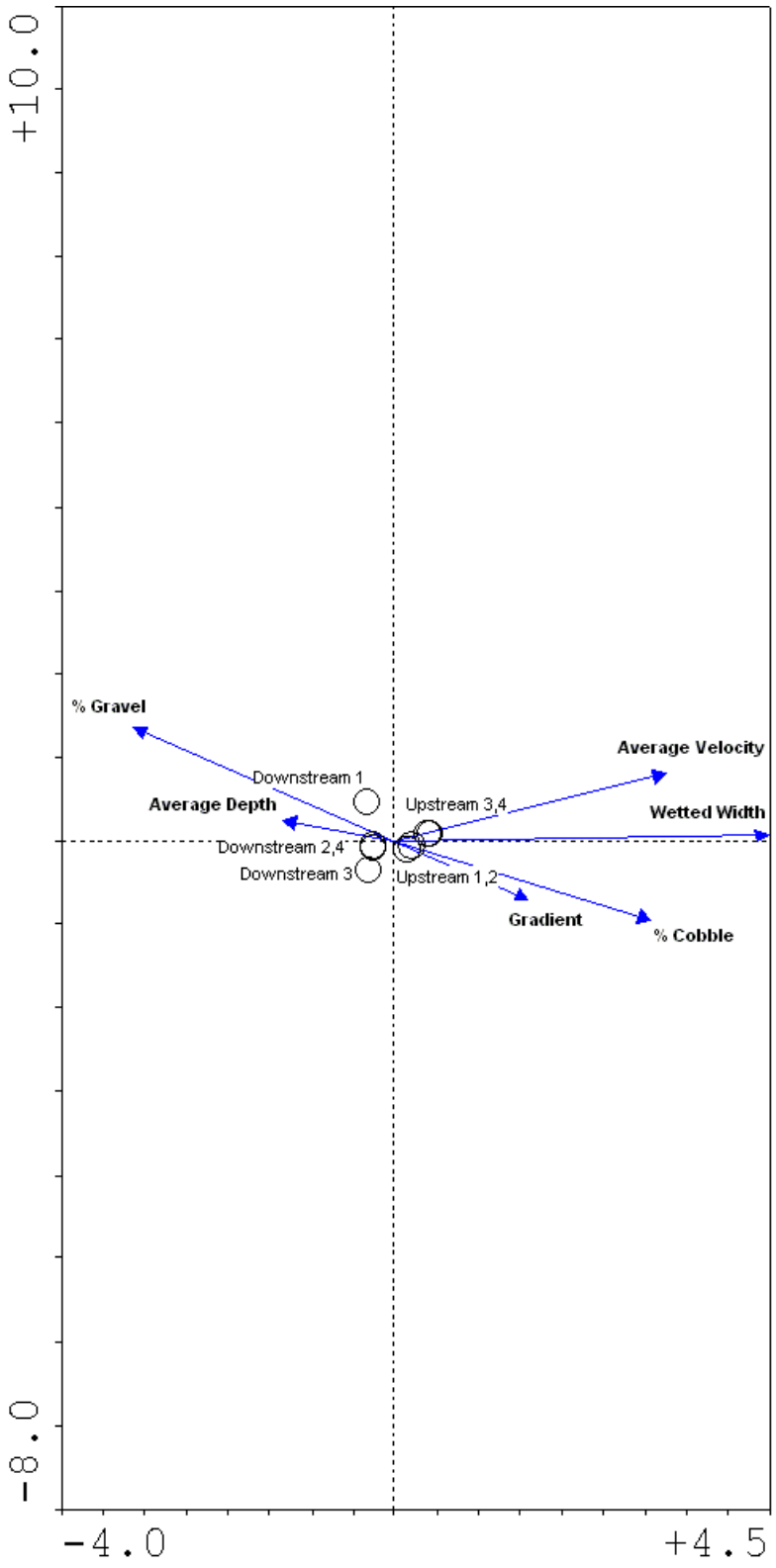


Figure 113. Canonical Correspondence bi-plot with the Edler river benthic macro-invertebrate site distribution and major physicochemical explanatory vectors.

Table 42. Canonical correlations of physicochemical variables to ordination at the Edler river sampling sites. n.s., not significant at $p<0.05$

Variable	Axis 1 (x-axis)	Axis 2 (y-axis)
Wetted Width	.99	n.s.
Average Depth	n.s.	.07
Average Velocity	n.s.	.25
Gradient	.35	-.22
Cobble	.67	-.31
Gravel	n.s.	.42

Macrophyte Survey

The Edler Ponds were experiencing an algae bloom at the time of the aquatic plant inventory on September 10, so visibility through the water was limited. The submersed plant community was fairly sparse, especially in the southern pond. One non-native submersed plant, curly leaf pondweed (*Potamogeton crispus*), was present, though it was not dominant. The invasive non-native yellow iris (*Iris pseudacorus*) was just becoming established in the north pond. Purple loosestrife (*Lythrum salicaria*) and reed canarygrass (*Phalaris arundinacia*) lined the shores of all three ponds.

Site 7 Comments and Recommendations

The Edler Ponds are located in a fairly restricted, high-energy portion of the lower Union Gap floodplain due to dikes on both sides of the river. Therefore, the ponds are prone to avulsion. The June 2002 flood eroded through the narrow strip of land separating the south end of Edler Pond 3 from the Yakima River, thus breaching the pond (Figure 112). Visits to the ponds later in summer showed that the north bank of the breached area was eroding more quickly than the south. Bank erosion both up and downstream of the breach will likely continue.

Edler Pond 1, the only pond in which water-quality samples were taken, had poor water quality. The benthic macroinvertebrate community contained only a few taxa, indicating habitat and water quality disturbance. Brown bullhead and pumpkinseed sunfish were the dominant species in Pond 1. Although present, northern pikeminnow and largemouth bass were not abundant. No salmonids were found in these ponds prior to breaching, but chinook were found in Pond 3 a month after the breach. River habitat is suitable for salmonids, but it does not have the excellent quality found at upriver sites. This reach of river is believed to be suitable winter rearing habitat because of increased channel complexity, abundance of large woody debris, and appropriate water quality for salmonids.

Due to difficulty in sampling this section of river, there is no conclusive evidence to determine that the breaching of the lower Edler Pond site has impacted the fish species complex in the river. However, pumpkinseed sunfish (PS) constituted 13% of the combined river sample after the avulsion, while at the same time PS abundance in the pond had declined precipitously. The avulsion of Edler Pond 3 may provide salmonid rearing habitat. However, the pond may also

serve as a reservoir for predatory northern pikeminnow and largemouth bass unless river flow or water exchange from eddying is maintained through these ponds and the conversion from pond to river habitat continues.

Recommendations

Recommendations for the Edler Ponds site are:

- Re-sample Pond 3 seasonally to monitor salmonid use of the pond as off-channel habitat. Measure species assemblages over time to determine if there is a concurrent decrease in warm-water predatory/competitor species and increase in salmonids.
- Document changes to water temperature in Pond 3 that accompany changes in habitat following this connection to the river.
- Identify and analyze potential effects of connecting Pond 3 to Ponds 1 and 2 as a means of enlarging habitat area for salmonids and, in particular, the possibility that expanding the channel migration zone in this manner would reduce flood damage to local infrastructure.
- Encourage the City of Union Gap to rezone the pond area to prohibit future commercial development adjacent to and upstream and downstream of the ponds.
- Encourage the Yakima Greenway Foundation to limit infrastructure improvements to Pond 1; control “unimproved” access and recreation at the lower ponds.
- Allow the river to “naturally” rework the site below Pond 1.

12. PARKER PONDS (Site 8)

Location and Site Information

The Parker ponds are located approximately 2 mi south of the Union Gap (south of the City of Yakima), along the inside of a large meander bend that is now confined to the east by Interstate 82 and adjacent to the west bank of the Yakima River (Figure 114; see Figure 120). The northern end of this large pond complex, totaling 63 acres and averaging 3 ft deep, was partially avulsed during the February 1996 flood. The total volume of the Parker ponds is about 168,000 yd^3.

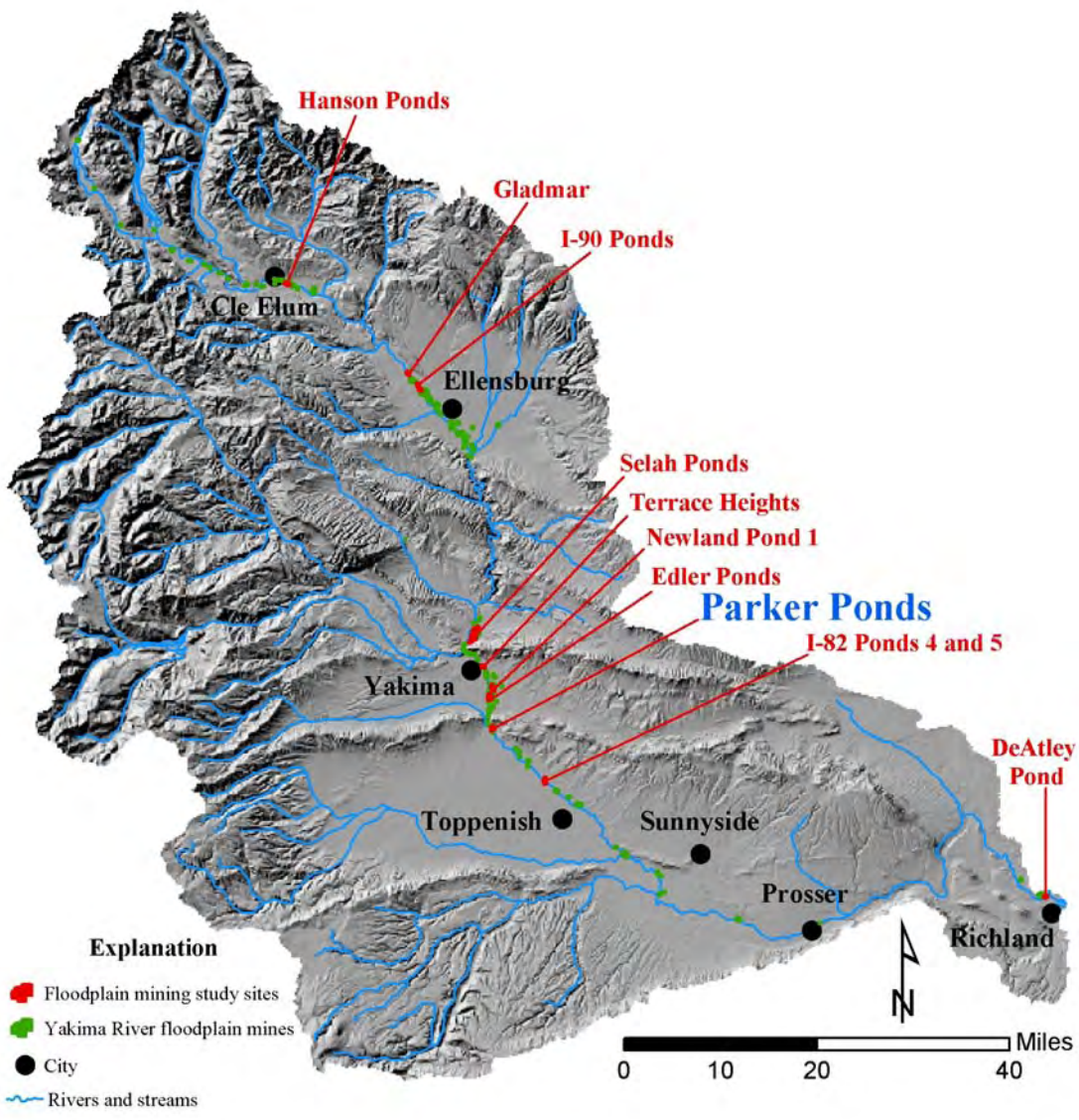


Figure 114. Location of Parker Ponds (Site 8).

Pond Bathymetry and Sediment Sampling

Material mined at the Parker site has been point bar deposits behind a migrating meander. The river avulsed into the Parker complex during the 1996 100-yr flood event (Norman *et al.* 1998)(Figure 115). Prior to the avulsion, the river was effectively confined between the eastern diked margin of the pond complex and Interstate Highway 82, and there was little or no channel migration zone (CMZ) adjacent to the. Since the avulsion, the CMZ has expanded to include the seven ponds of the Parker mine site. Just downstream of Union Gap, the CMZ is 1,800 ft wide, decreasing to 1,200 ft at the upstream end of the complex and to approximately 1,000 ft downstream of the complex. The Parker site valley reach slope is 0.00238, or about a 12.6-ft drop in valley floor elevation for each mile downstream.

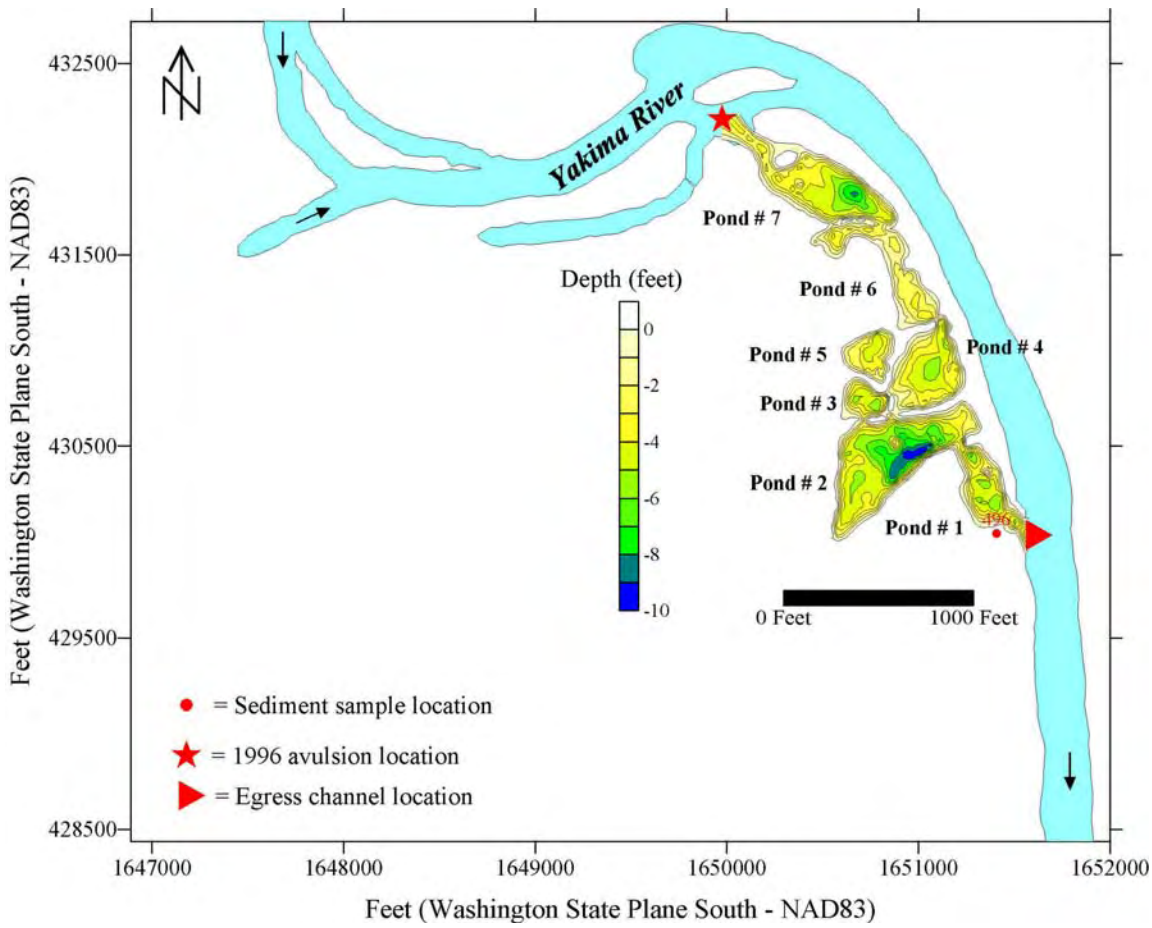


Figure 115. Contoured bathymetric map of the Parker Ponds showing location of sediment sample (GPS waypoint number) and proximity to the Yakima River (July 18, 2002).

At Parker, recent Yakima River sand and gravel deposits have been mined down to older semi-consolidated sediments of the Thorp Formation. The total depth of mining at Parker was approximately 10 ft and was limited by the presence of a thick Thorp Formation clay layer underlying the extractable sand and gravel in the area (Norman *et al*. 1998).

The complex consists of seven shallow flat-bottomed interconnected ponds (Figures 116 and 117). The northernmost pond (Pond 7) is open to the Yakima River and is filling with river sediment. Immediately down-gradient of the nick point, where a portion of the river flows into Pond 7, a gravel delta (grain-size range 1.0 to 5.1 in.) is prograding southward into the pond (Figure 118). Downstream, in the central and south portions of Pond 6, 2.0 to 23.5 in. of fine sand and silt have been deposited on the Thorp Formation. The maximum measured depth in the Parker Ponds complex is 8 ft along the southern margin of Pond 2. The average depth of the entire Parker complex is 3 ft, the shallowest average depth of all the study sites. Downgradient of Pond 7, a network of six poorly connected ponds was examined (Figure 114).

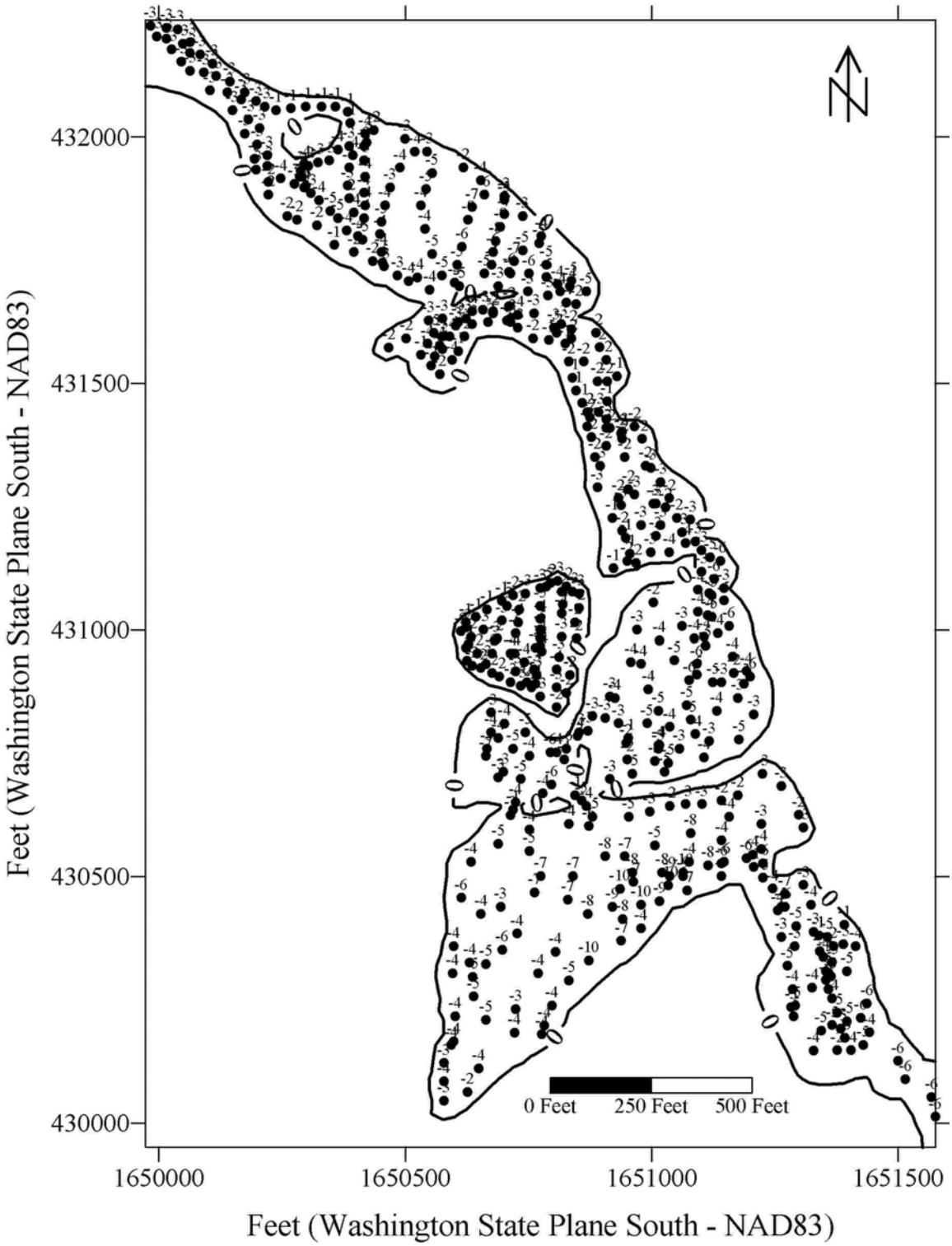


Figure 116. Post map showing data point locations and depths (in feet below the July 18, 2002, water level) used to model pond bathymetry for the Parker Ponds.

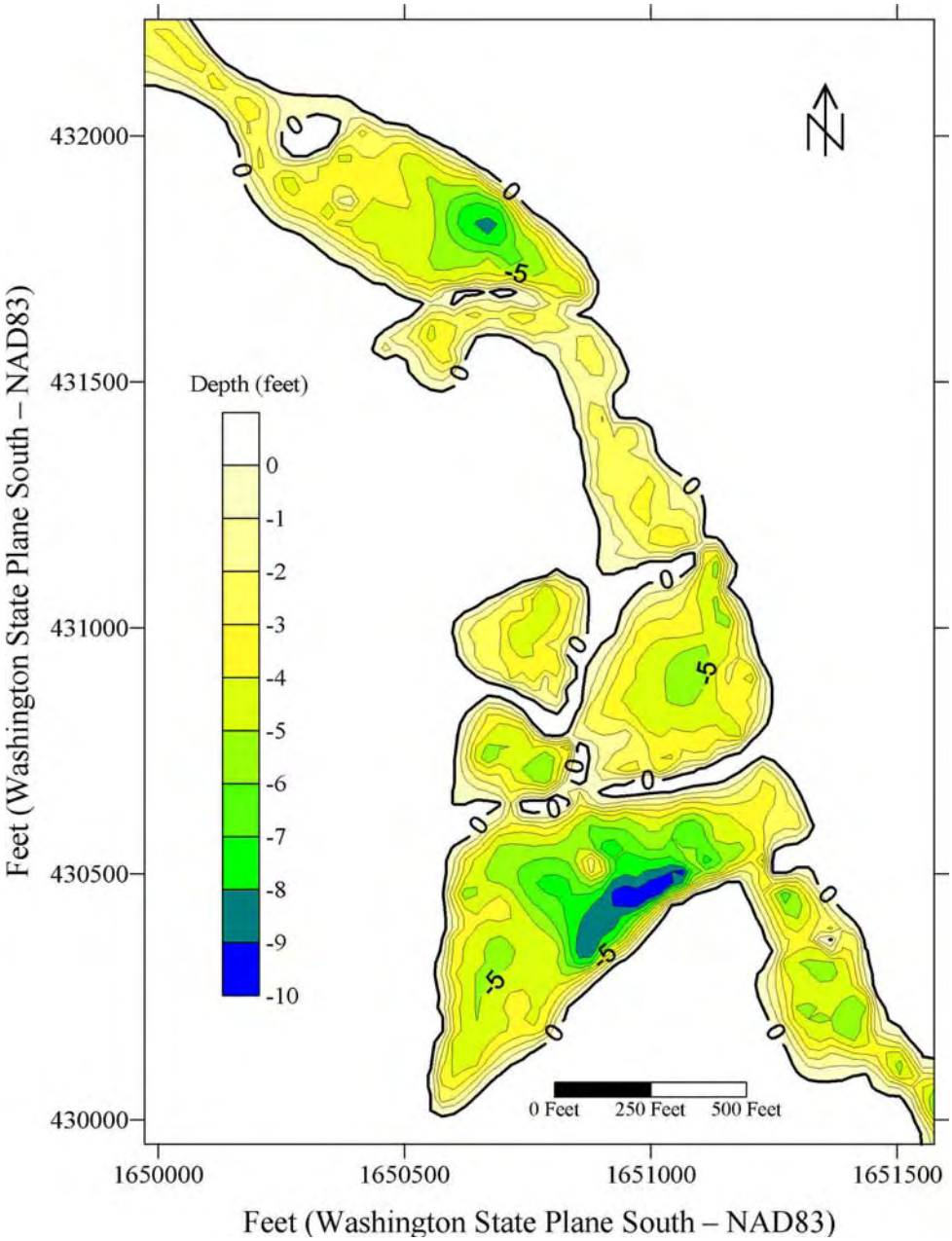


Figure 117. Contoured bathymetric map of the Parker Ponds; bathymetry in feet below the July 18, 2002, water level.

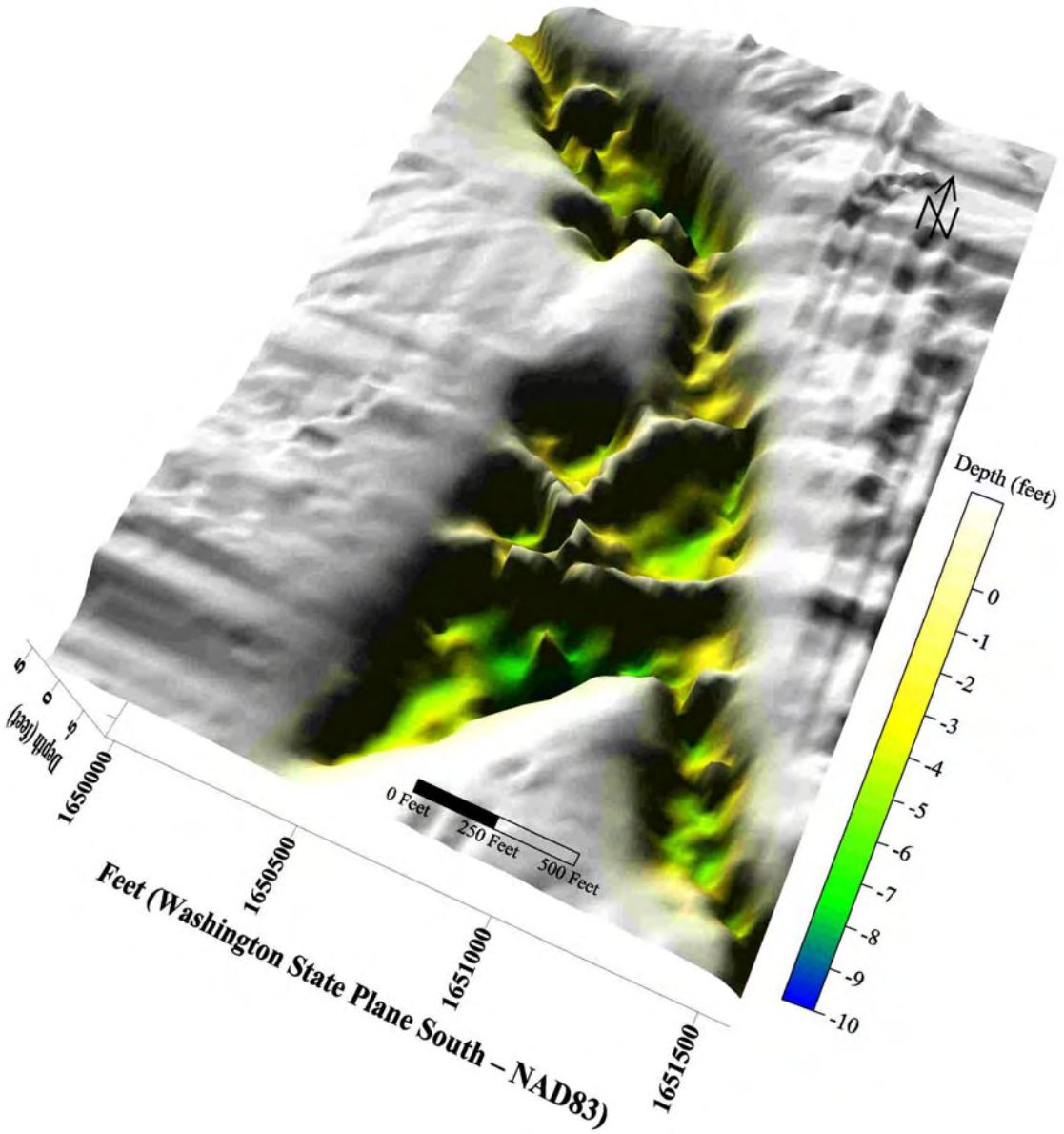


Figure 118. 3-D perspective map of the Parker Ponds; bathymetry in feet below the July 18, 2002, water level.

Because connecting channels between these ponds are shallow and narrow, the velocity and volume of surface water flowing between ponds are low. As a result, the rate of sediment delivery to the pond network is low. Only during river flood events have new sand, silt, and clay been deposited discontinuously at the upstream end of the pond network. Sample 496 was taken from Thorp Formation sediments at the south shore of Pond 1 (Figure 114). This sample consists of poorly graded gravel (63.0%), sand (36.19%), and minor silt and clay (0.8%) and is typical of the native Thorp sediment that composes the pit floors south of Pond 7 (Figure 119).

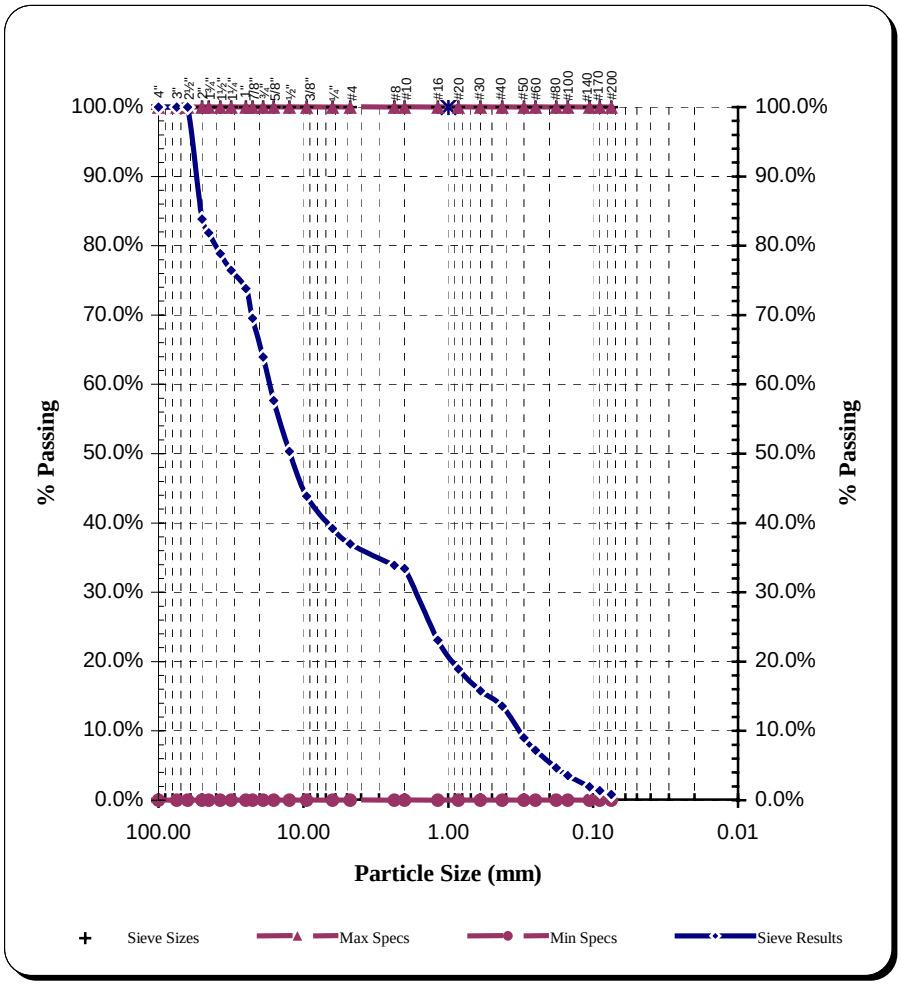


Figure 119. Grain-size distribution plot for sediment sample 496, south end of Parker Pond 1.

Site Sample Information

Sample site locations for the thermal investigation, fish assemblage, and benthic macroinvertebrate and water-quality work for Parker Ponds are shown in Figure 120. Standard sampling protocol is discussed in Chapter 4 (Methods). Individual site results are discussed per study component below.

Figure 120. Thermal, fish assemblage, benthic macroinvertebrate, and water-quality sample locations for the Parker Ponds. The explanation of location symbols is on p. xxii. (Photo source: DOT, 2002).

Thermal Investigation

Parker is an avulsed pit site in which multiple ponds are connected to the Yakima River (Figure 120). The upstream river temperature monitoring instrument was tethered to a vegetated dike along the northwest portion of the site (along a relatively large side channel). The middle monitoring instrument was placed in one of the central ponds, Pond 2, in approximately 2 to 3 ft of water. This station was exposed to direct sunlight and experienced periods of siltation and exposure to the air. The downstream station was located near the mouth of the lowest pond, near its outlet to the Yakima River. The downstream location was partially shaded, and the instrument was situated under 3 ft of water. The Ext (air) unit was located in the riparian area near the upper portion of the site near the upstream monitoring station (Figure 120). Temperature data for the Ext and the upstream and middle river monitoring locations were recorded from April 15 to November 13, 2002. The middle temperature monitoring instrument was exposed to the air from May 15 to May 27, as shown on Figure 121. Those data were removed from the calculations for Table 43.Temperature data at the downstream monitoring were collected from April 20 to November 13, 2002.

River

Table 43 shows the averages of the temperature data recorded each month and the change (dT) in average temperature between the upstream and middle sample sites; between the upstream and downstream sites; and between the middle and downstream sites. Positive numbers represent an increase in temperature in the downstream direction, whereas negative values represent cooler downstream temperatures. Table 43 indicates a substantial increase in temperature downstream between the upper and middle sample sites. The increase from the middle sample site to the downstream site is not consistent and also varies monthly.

Table 43. Average monthly Yakima River temperatures (in °C) and differences (dT) at Parker Ponds.

Month	Upstream	Middle	Downstream	dT Upstream/ Middle	dT Upstream/ Downstream	dT Middle/ Downstream
April	8.76	9.62	9.73	0.86	0.98	0.11
May	11.02	13.22	11.38	2.20	0.36	-1.84
June	13.42	13.74	13.54	0.32	0.12	-0.20
July	17.60	19.27	19.36	1.68	1.77	0.09
August	17.68	19.10	19.02	1.42	1.34	-0.08
September	16.21	17.06	17.31	0.85	1.10	0.26
October	10.93	11.62	11.93	0.69	1.00	0.31
November	5.45	6.06	5.58	0.61	0.12	-0.49

Figure 121 shows the daily minimum and maximum temperatures recorded at the three river sample sites. The plot demonstrates the increase in temperature downstream across the site. In particular, the temperature increase between the upstream and middle sites is evident in both the minimum and maximum temperature data.

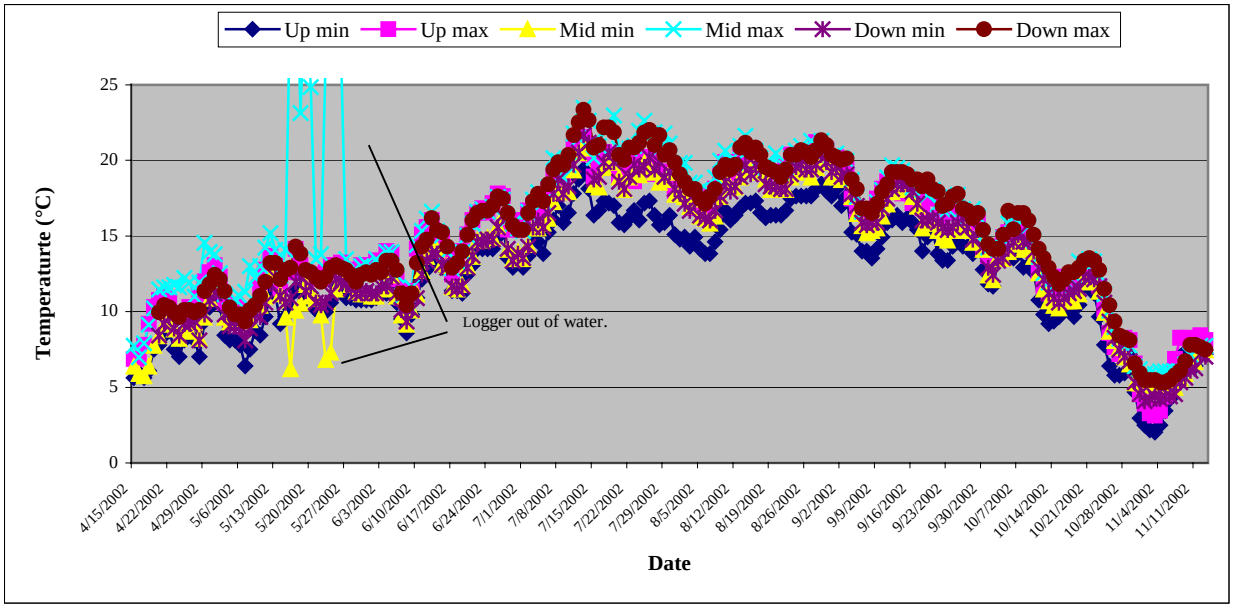


Figure 121. Daily minimum and maximum temperatures for the Yakima River at Parker Ponds.

Fish Assemblage

Prior to sampling, the avulsed pond (Pond 7; Figure 115) was selected for evaluation. However, there was no access to this pond with the pond electrofishing boat. Instead, Ponds 1, 2, and 5 were sampled following pond protocols. Pond 5 is isolated from the other two ponds and the river. Pond 1 and Pond 2 are connected by a channel, and Pond 1 has an outlet to the river. The river sample site above the pond complex was a side channel of the Yakima River that flowed through avulsed Pond 7. The downriver sample reach was located downstream of the Pond 1 outlet channel.

Pond 5 (Figure 122) was sampled , on July 10 and 11 using standard lake protocol, except that only one fyke and one gill net were deployed. Ponds 1 and 2 were also sampled with only one gill net and one fyke net total (combined) on the same dates, to stay within standard lake protocol of three sections shocked, two fyke, and two gill net samples. A 250-m river reach was sampled with backpack electrofishing gear on August 13 above the pond complex, but the sample size did not meet our goal of 200 fish. A total of approximately 2,000 m extending from above Pond 7 downstream to the Parker Bridge was sampled with the drift boat electroshocker on August 19. This sampling effort included fishing along the right bank inside avulsed Pond 7. Detailed information on the data collected in the ponds and river is in Appendix K, Tables 28-30.

Figure 122. View of Parker Pond 5 toward the Rattlesnake Hills (northeast) on July 10, 2002, during fish assemblage sampling (Photo source: Washington State Department of Fish and Wildlife).

Table 44 presents a summary of species composition at this site. A total of 984 fish representing 14 species were collected from the three ponds. Sucker (35%), whitefish (15.5%), pumpkinseed sunfish (12%), and redside shiner (11%) were the most frequently sampled species. Northern pikeminnow (7%) and largemouth bass (2.5%) were present in these ponds. A few chinook (3%) and coho salmon (0.5%) but no *Onchorhynchus mykiss* were sampled. Salmonids were found only in Ponds 1 and 2, which are connected to the river.

Backpack electroshocking in the river produced seven species (39 fish), including dace (44%), sculpins (15%), sucker (13%), and pumpkinseed sunfish (13%), which composed most of this small sample. Chinook and *O. mykiss* were sampled in small numbers. Drift boat shocking resulted in a sample of 210 fish (11 species). Sucker (36%), whitefish (27%), redside shiner (12%), and chiselmouth (12%) were most frequently sampled, but juvenile chinook (4%) and *O. mykiss* (1%) were also collected. In a composite of all sampling methods used in the river (12 species; n = 249), suckers were the most abundant (32%), followed by whitefish (23%), chiselmouth (10%), and redside shiner (10%). Chinook salmon and *O. mykiss* are present at 4% and 2%, respectively. Northern pikeminnow (4%) and largemouth bass (1%) were present, but at relatively low abundance.

Table 44. Percent composition of fish sampled at three Parker Ponds and the Yakima River adjacent to this site. The number of fish captured above the ponds was not adequate for reporting here. The bold values indicate dominant species. See Table 6 for an explanation of species codes.

Species	Parker Ponds	River		
		Below	Drift Boat	Summary
BBH	6.0			
CK	2.8	2.6	3.8	3.6
CMO	6.1		**12.4**	**10.4**
CO	0.5			
COT	0.1	15.4	0.5	2.8
CP	0.9			
DAC	0.2	**43.6**	1.0	7.6
LMB	2.5	5.1	0.5	1.2
MNS			0.5	0.4
NPM	6.6		4.8	4.0
PS	**12.3**	12.8		2.0
RB		7.7	1.4	2.4
S	11.3		**12.4**	**10.4**
SK	**34.9**	**12.8**	**35.7**	**32.1**
WF	**15.5**		**27.1**	**22.9**
YP	0.2			
Total	100.0	100.0	100.0	100.0
Sample Size	984	39	210	249

Although largemouth bass and northern pikeminnow did not appear to be present in numbers that would threaten chinook salmon and *O. mykiss* survival, few salmon and trout were present. Mountain whitefish were the only abundant salmonid. Native competitors, such as redside shiner, dace, and sucker, may have a competitive advantage in this reach of the river. High water temperatures, extreme flow fluctuations downstream of Wapato Diversion Dam (about a mile upstream), and other factors may be limiting salmon and trout production in this reach of the Yakima River, which is generally considered the downstream limit for salmonid rearing during the summer by the Yakama Nation and WDFW.

Benthic Macroinvertebrates, Water Quality, and Macrophytes

Benthic Macroinvertebrates and Water Quality

The Parker ponds had marginal water quality at the outlet, and conditions were similar to those in the adjacent mainstem (see tabulations below and Tables 14 and 16).

Pond 5 Depth (m)	Temp (°C)	pH (units)	Cond (µS/cm)	DO (mg/L)	chla (µg/L)	secchi (m)	OP (mg/L)	TDS (mg/L)	TN (mg/L)	TP (mg/L)
0.5	17.5	8.34	101	10.1	1.51	1.2	0.050	76.0	19.5	0.830

The benthic macroinvertebrate community in the pond had a low taxa richness, similar to that of other isolated ponds, and was dominated numerically by a subset of those taxa (Appendix L, Table 3).

River Site	Date	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	pH (units)	Temperature (°C)
Downstream Parker	09/04/2002	93	10.3	8.27	17.5
Upstream Parker	09/04/2002	92	10.1	8.46	18.0

In the river, water quality was similar in the upstream and downstream reaches. There were differences in wetted and bankfull widths (greater in the lower), gradient (greater in the upper), and average depth (greater in the upper; Table 17).

The biometric results indicate that upstream reach was in a better biological condition than the downstream reach (Table 18). The cluster dendrogram also shows a difference between reaches (Figure 39). The CCA plot showed a slight separation of macroinvertebrate community composition between the two reaches (Figure 123). An illustration of the biological differences between reaches is the near-exclusive presence of *Glossosoma* sp. in the upper reach. *Glossosoma* sp. can live in marginal water quality, but the genus drops out with increasing disturbance. Wetted width, cobble, and gravel could be interpreted as having a relationship with distribution of benthics at this site (Table 45).

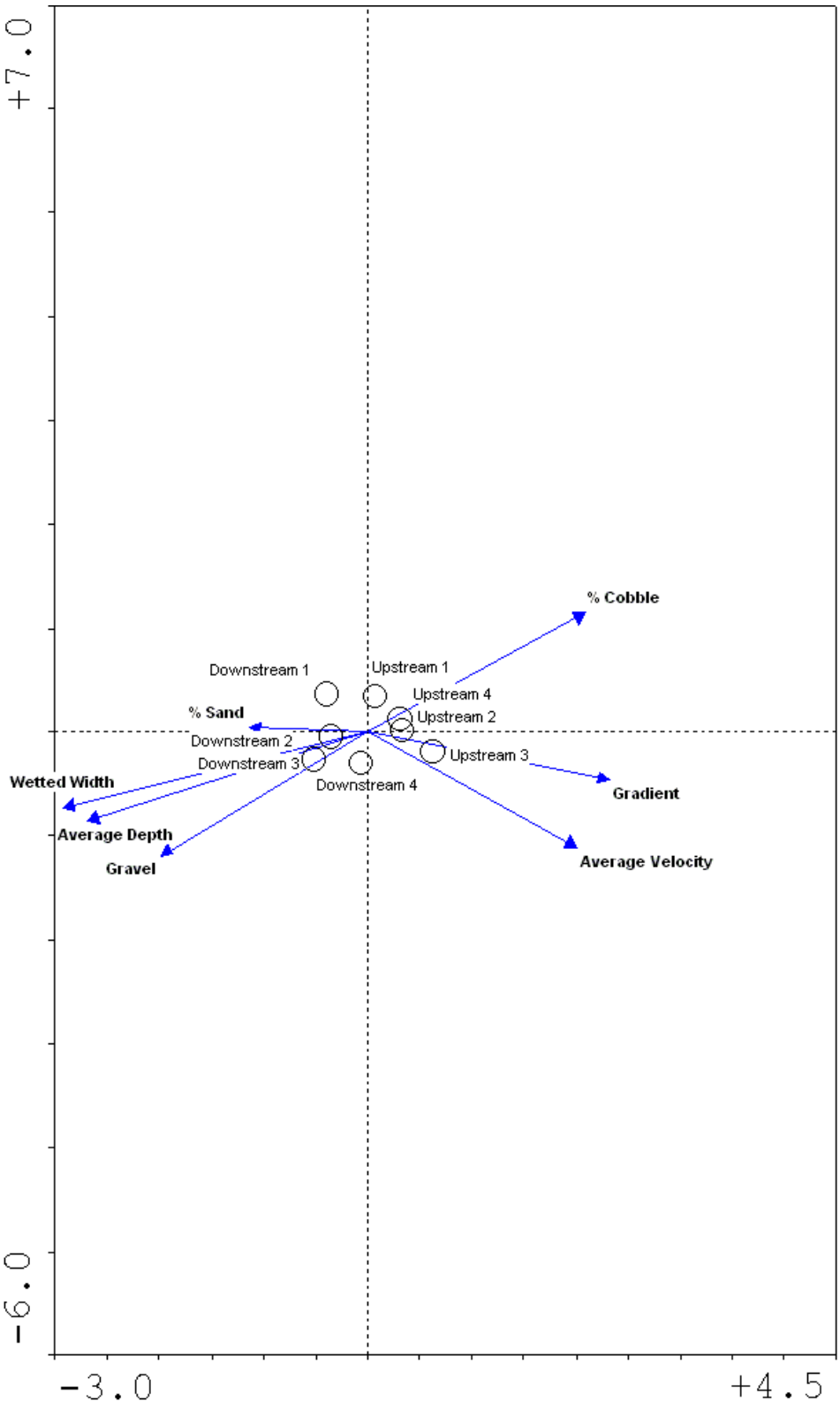


Figure 123. Canonical Correspondence bi-plot with the Parker river benthic macroinvertebrate site distribution and major physicochemical explanatory vectors.

Table 45. Canonical correlations of physicochemical variables to ordination axes at the Parker river sites. n.s., not significant at $p<0.05$

Variable	Axis 1 (x-axis)	Axis 2 (y-axis)
Wetted Width	-.88	-.35
Average Depth	n.s.	-.41
Average Velocity	n.s.	-.53
Gradient	n.s.	-.21
Cobble	.62	.53
Gravel	-0.59	-.55

Macrophyte Survey

On September 10, the dominant submersed plant in the Parker Ponds included in this study was a native waterweed (*Elodea* sp). There was a non-native water lily (*Nymphaea odorata*) in small patches. This water lily can become quite dense in shallow, quiet water with soft sediment, as in some of the other ponds in this gravel mining area. Another non-native submersed plant, curly leaf pondweed (*Potamogeton crispus*), was also present, though not abundant. Scattered patches of the invasive shoreline plant purple loosestrife (*Lythrum salicaria*) were also present along the ponds and river.

Site 8 Comments and Recommendations

Parker Ponds are connected to the main stem Yakima River upstream (Pond 7) and downstream (Ponds 1 and 2), are shallow, and have marginal water quality. The benthic macroinvertebrate community of the site was similar to that at other pond sites in this reach. Largemouth bass and northern pikeminnow were not abundant, and a few salmon and trout were present.

Because the existing inlet/outlet channels that connect Pond 7 to the river are shallow and narrow, the surface flow through this pond is relatively low. As a result, geomorphic work occurring in Pond 7 is minimal at this time. A future flood event could enlarge the river connections to Pond 7 and increase sediment transport. The Pond 1 outlet channel allows infiltrating ground or surface water to flow back to the river, but no geomorphic work is occurring in Ponds 1 to 6 because there is no direct river inflow. Water temperatures in Ponds 1 to 6 are elevated relative to the upstream Edler and Newland sites, possibly because of the reduction of river flow below Wapato Diversion Dam, which is a short distance upstream of the Parker Ponds. Aquatic plants grow profusely in fine sand, silt, and clay sediments in Ponds 1 to 6. In places abundant organic matter decomposes in stagnant water during warm seasons, producing eutrophic conditions. Moreover, the low permeability of the Thorp Formation, to the pits have been excavated, has resulted in poor ground-water infiltration.

Fish habitat in this reach of the river is less than ideal for salmonids and will remain so under current water management scenarios. However, this section of the river serves as a migration corridor for salmonids and may have more benefit than the Study Team has documented as over-

winter rearing habitat. In time, high-magnitude/long-duration flood events are likely to rework the site, promoting natural ‘healing’.

Recommendations

Recommendation considerations for Parker include the following:

- Control noxious weeds along the river and in the ponds.
- Re-establish native shading vegetation such as black cottonwood, willows, and red osier dogwood on the banks.
- Remove waste and dumped materials from adjacent ponds and processing areas.
- Monitor geomorphology, water temperature, fish assemblage, and benthic macroinvertebrate status and conditions with regard to salmonid habitat requirements.
- Divert as much as river flow as is environmentally and economically feasible into Pond 7 to increase sediment deposition to convert the pond into side channel habitat for fish and wildlife habitat.
- Investigate an engineered means of isolating Ponds 1to 6 from the river because, due to lack of river inflow and the eutrophic conditions of these ponds, current habitat conditions favor warm-water fish that can out-compete or prey on anadromous salmonids that migrate into the pond network through the Pond 1 outlet channel. There is no beneficial habitat for salmonids in these ponds under current river management and pond physical configurations.

13. I-82 PONDS 4 and 5 (Site 9)

Location and Site Information

I-82 Ponds 4 and 5 are approximately 7 mi south of Union Gap (Figure 124). The Washington Department of Fish and Wildlife owns this site and has managed the ponds for public fishing since 1981. Pond 4, the northern of the two ponds, covers 19.3 acres and has an approximate volume of 584,000 yd^3. Pond 5 has a surface area of 13.8 acres and an approximate volume of 307,000 yd^3.

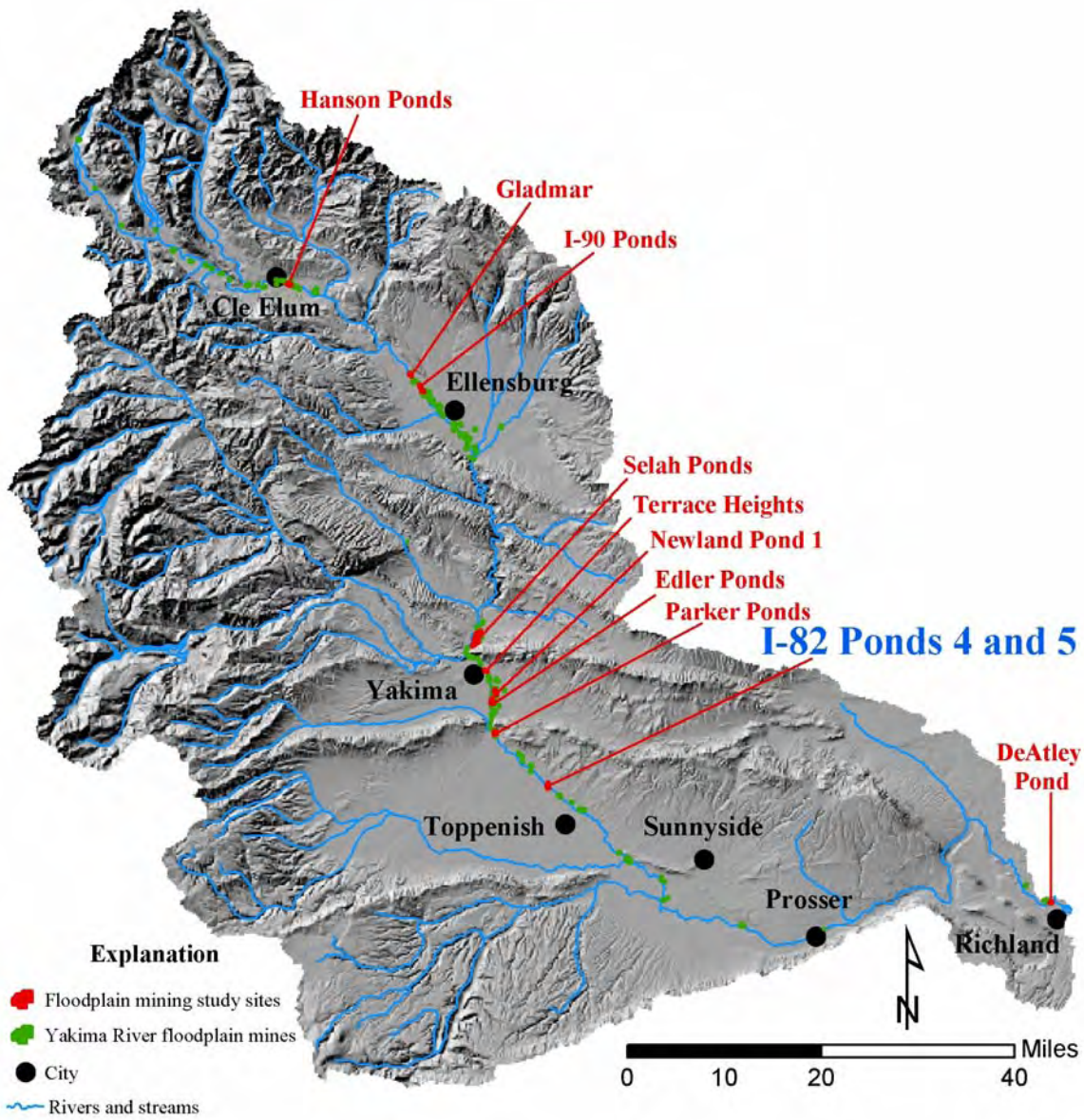


Figure 124. Location of I-82 Ponds 4 and 5 (Site 9).

Pond Bathymetry and Sediment Sampling

The Yakima River near the I-82 ponds has an actively meandering channel. The width of the channel migration zone decreases from about 3,700 ft upstream to about 2,800 ft downstream of the ponds, widest of those measured in association with the mine sites of this study. The ponds are approximately 100 ft from the river at the upstream end of Pond 4, 100 ft from the river at the junction of the two ponds, and 450 ft from the side channel of the Yakima River at the downstream end of Pond 5 (via the egress channel). The ponds are diked along their western margin and abut Interstate Highway 82 to the east. The valley reach slope in the reach from about a mile above to a mile below I-82 Ponds 4 and 5 is 0.0025, or about 13.2 ft drop in valley floor elevation for each mile downstream.

Pond 5 is connected to a side channel of the Yakima River from its southwest corner (Figure 124). Two potential avulsion sites were identified during geomorphic reconnaissance mapping, at the northwest and southwest corners of the north pond (Figure 125).

Pond 4 is long and fairly flat-bottomed (Figure 126); its maximum measured depth is 25 ft. The average depth is 18.6 ft, the greatest average depth of ponds in this study. The margins of the pond are quite steep (in general, steeper than those modeled), as evidenced by the sharp descent of the sidewalls where sampling tracks came close to the pond margins (Figures 126, 127, and 128). The broad slope along the western side of the pond is likely an artifact of the modeling process and design of the bathymetric survey.

Pond 5 is rectangular in plan view, has fairly steep side margins (which are not well modeled due to bathymetric survey design), and has a relatively flat bottom (Figure 129). The average depth of Pond 5 is approximately 12.2 ft; the maximum measured depth is 26 ft. A small island off the eastern margin of the pond creates a prominent shallow-water bulge westward into the pond (Figure 130). The northwest and southwest corners of the pond are shallow shelves. The egress channel exits at the southwest corner (Figures 125, 130, and 131).

I-82 Ponds 4 and 5 were mined to provide aggregate for construction of the adjacent Interstate Highway 82. At this site, recently deposited (Holocene) river gravel (25 ft thick) has been mined down to top of the older semi-consolidated sediments of the Thorp Formation. The Thorp Formation here consists of well-graded gravel in a matrix of sand, silt, and clay. It is the pond bottom over most of the ponds' area. The grain-size distribution of the Thorp Formation sediment in the ponds ranges from coarse gravel and cobbles at the north end of Pond 4 to fine sand and largely silt and clay progressively down-gradient in the south and southeast portions of the Pond 4.

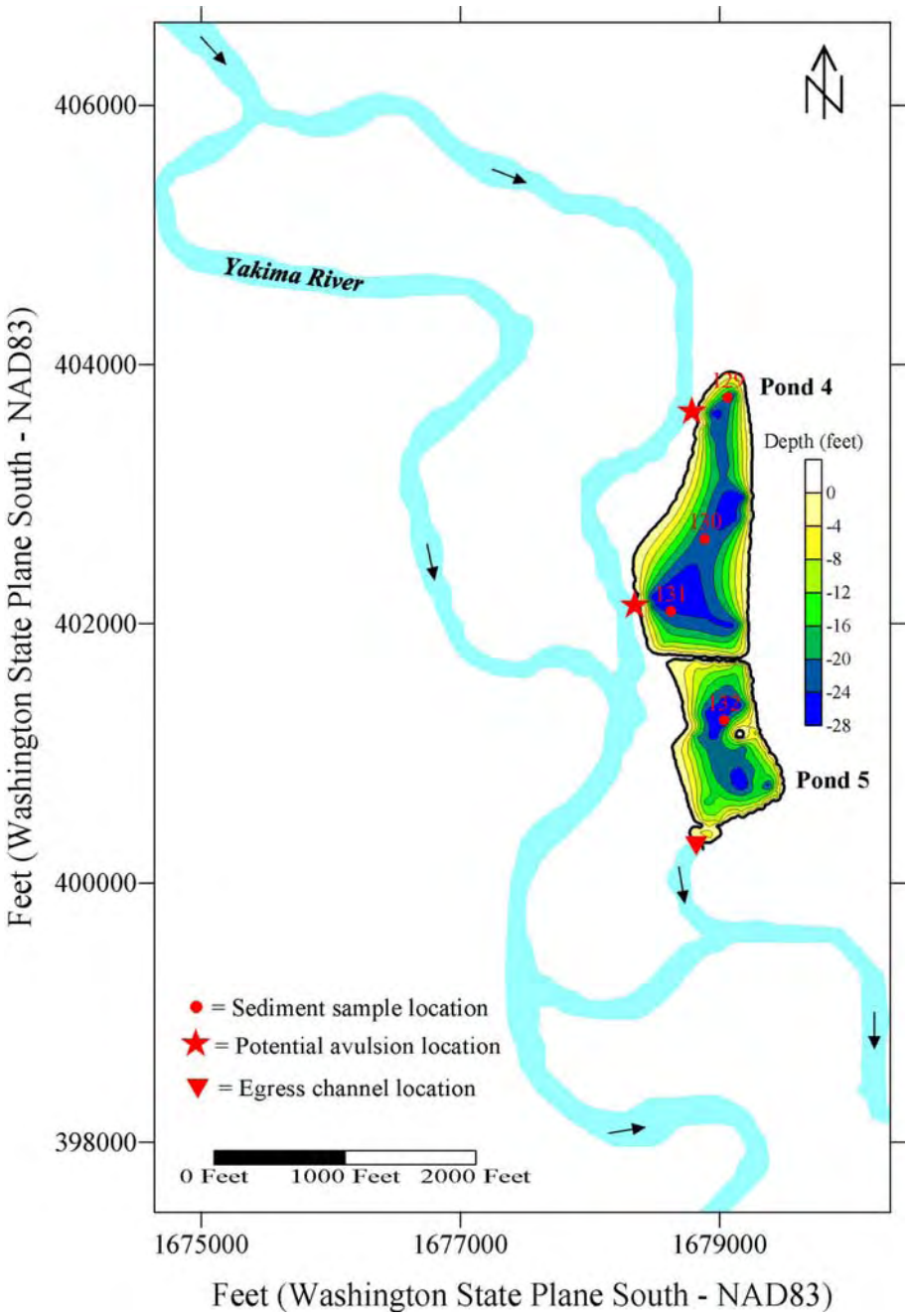


Figure 125. Contoured bathymetric map of the I-82 Ponds showing locations of sediment samples (GPS waypoint numbers) and proximity to the Yakima River.

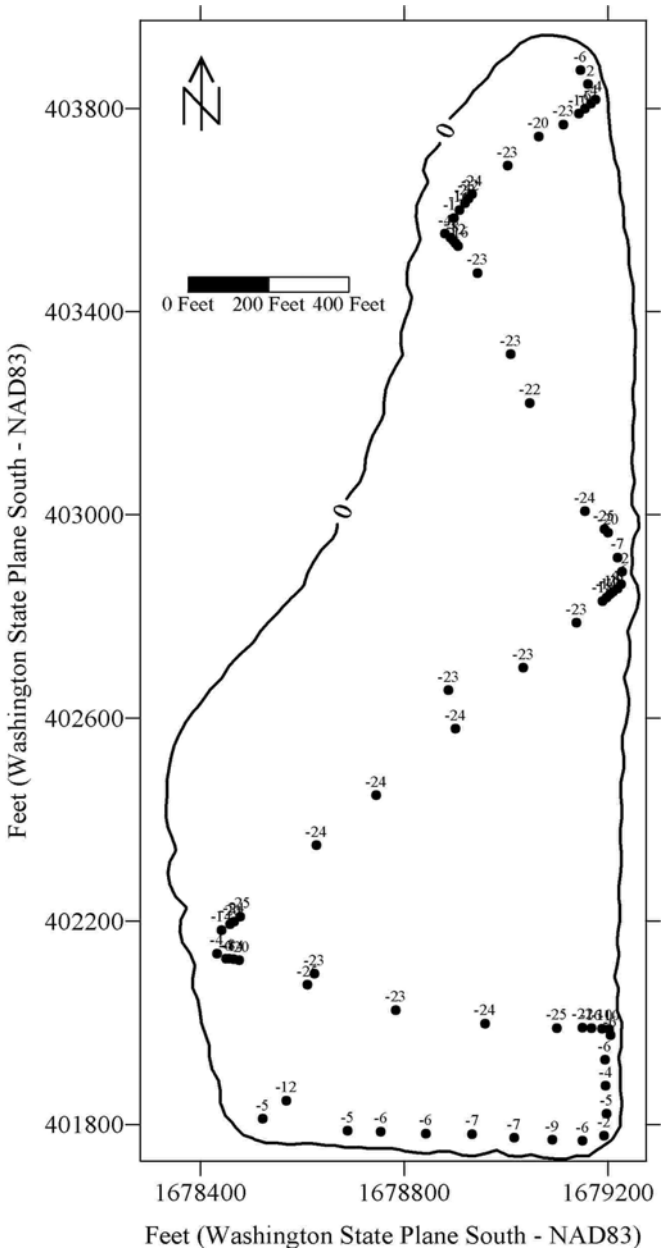


Figure 126. Post map showing data point locations and depths (in feet) used to model bathymetry for I-82 Pond 4.

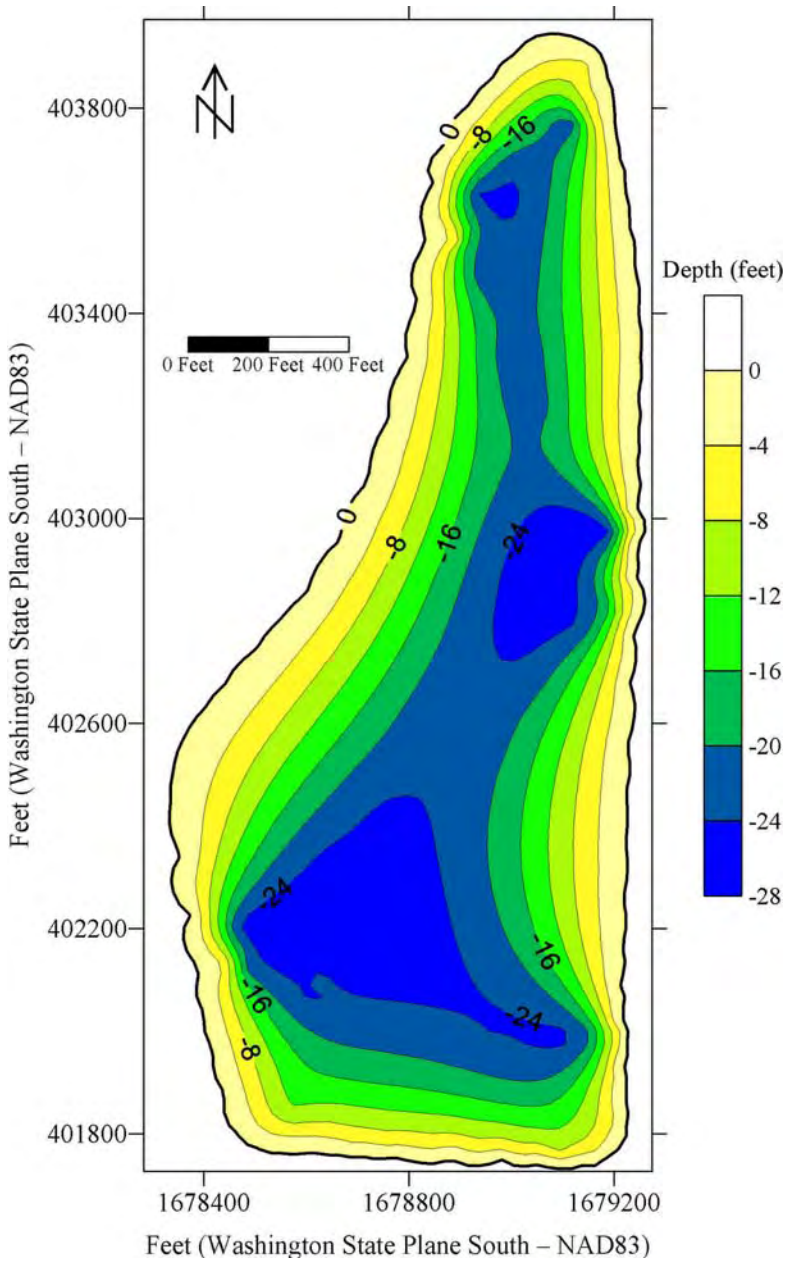


Figure 127. Contoured bathymetric map of I-82 Pond 4; bathymetry in feet below the May 30, 2002, water level.

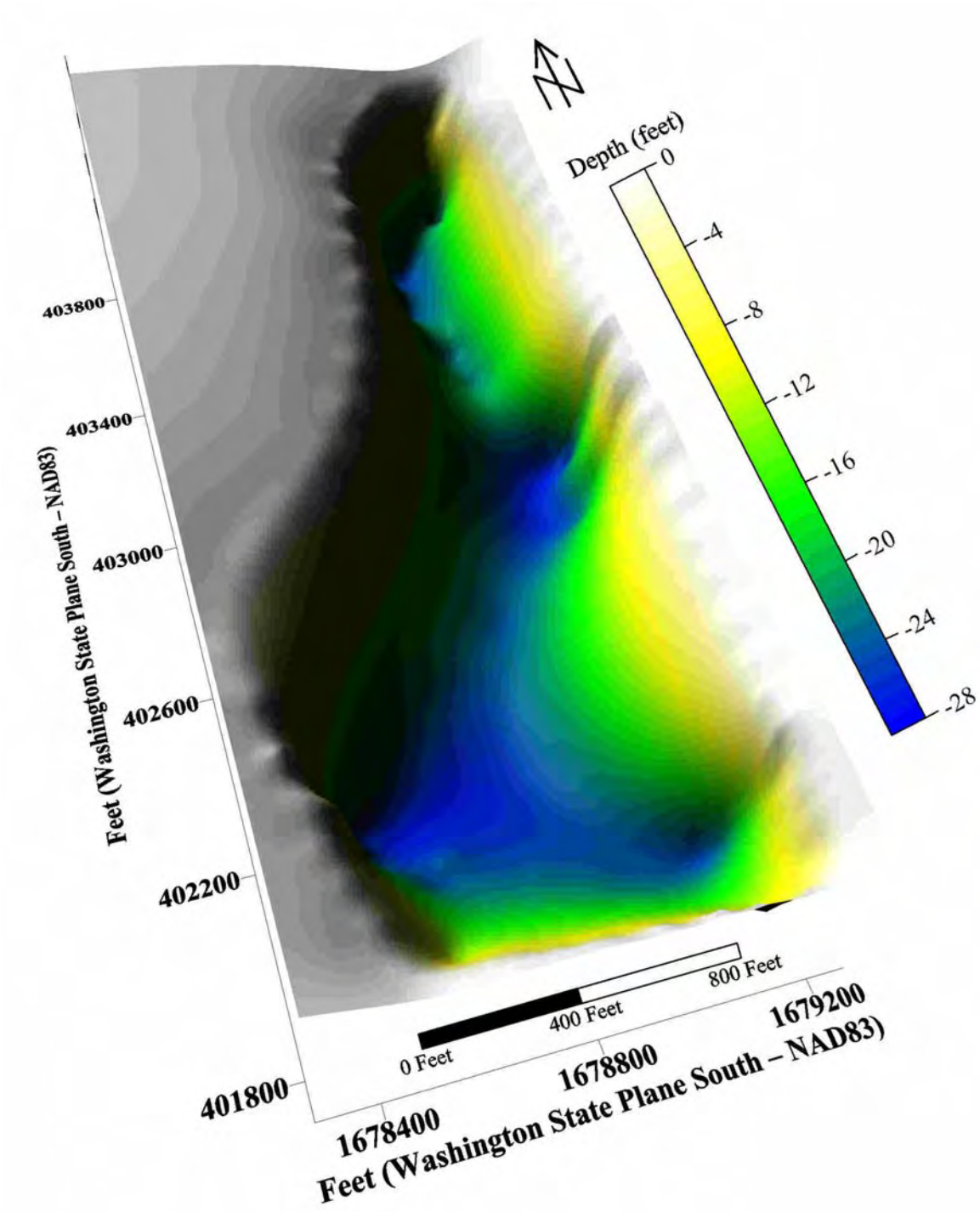


Figure 128. 3-D perspective map of I-82 Pond 4; bathymetry in feet below the May 30, 2002, water level.

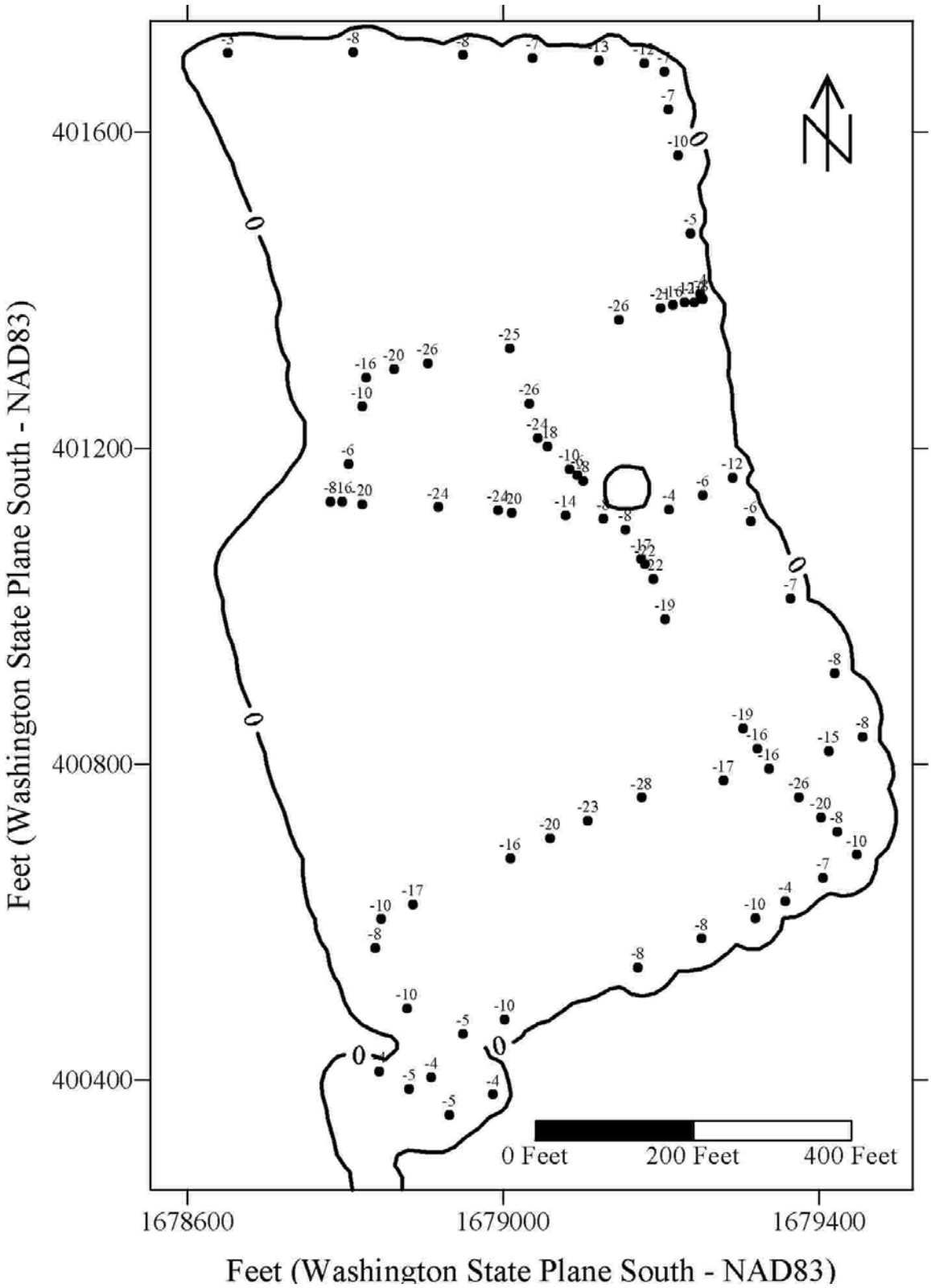


Figure 129. Post map with data locations and depths (in feet) used to model bathymetry for I-82 Pond 5.

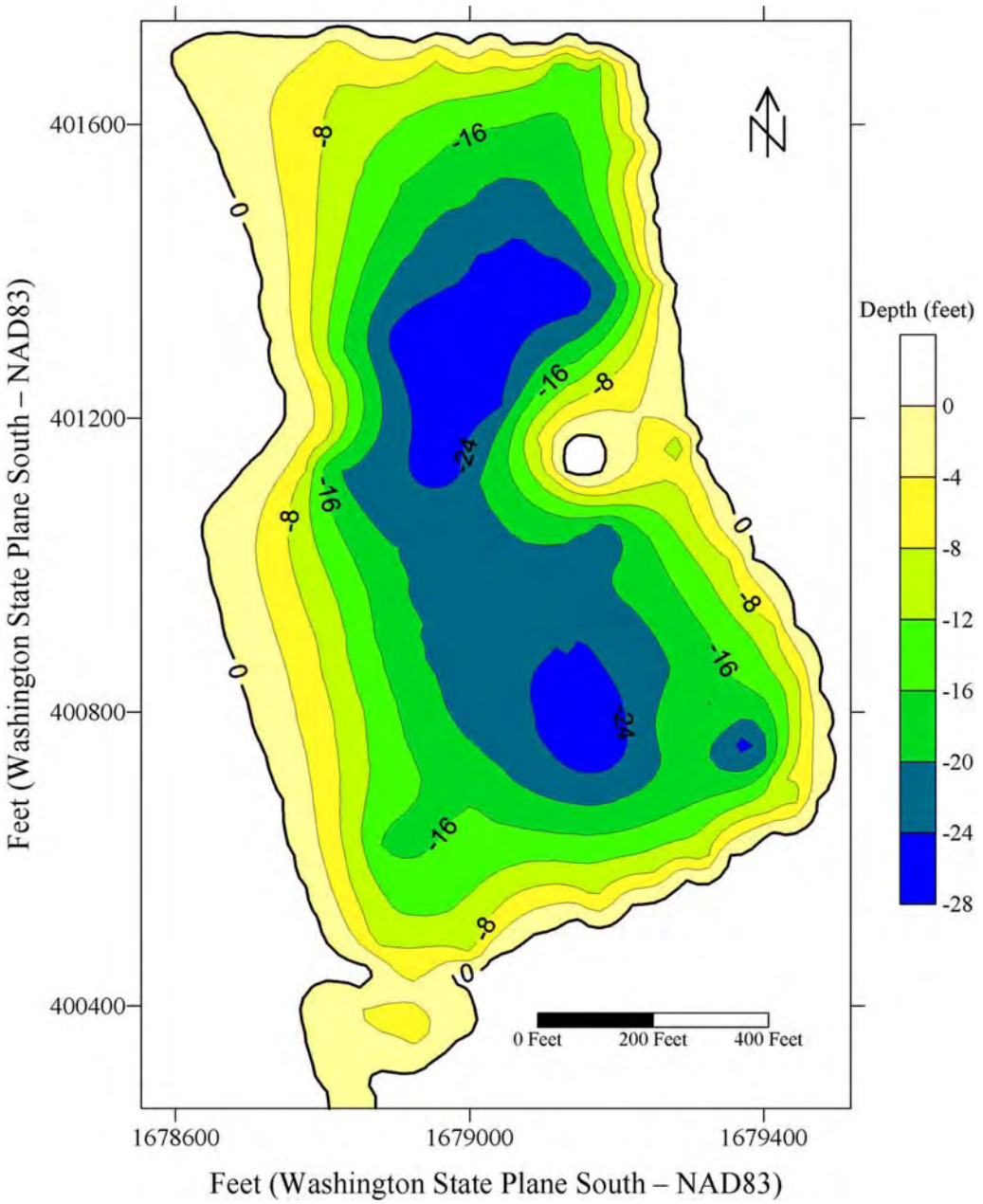


Figure 130. Contoured bathymetric map of I-82 Pond 5; bathymetry in feet below the May 20, 2002, water level.

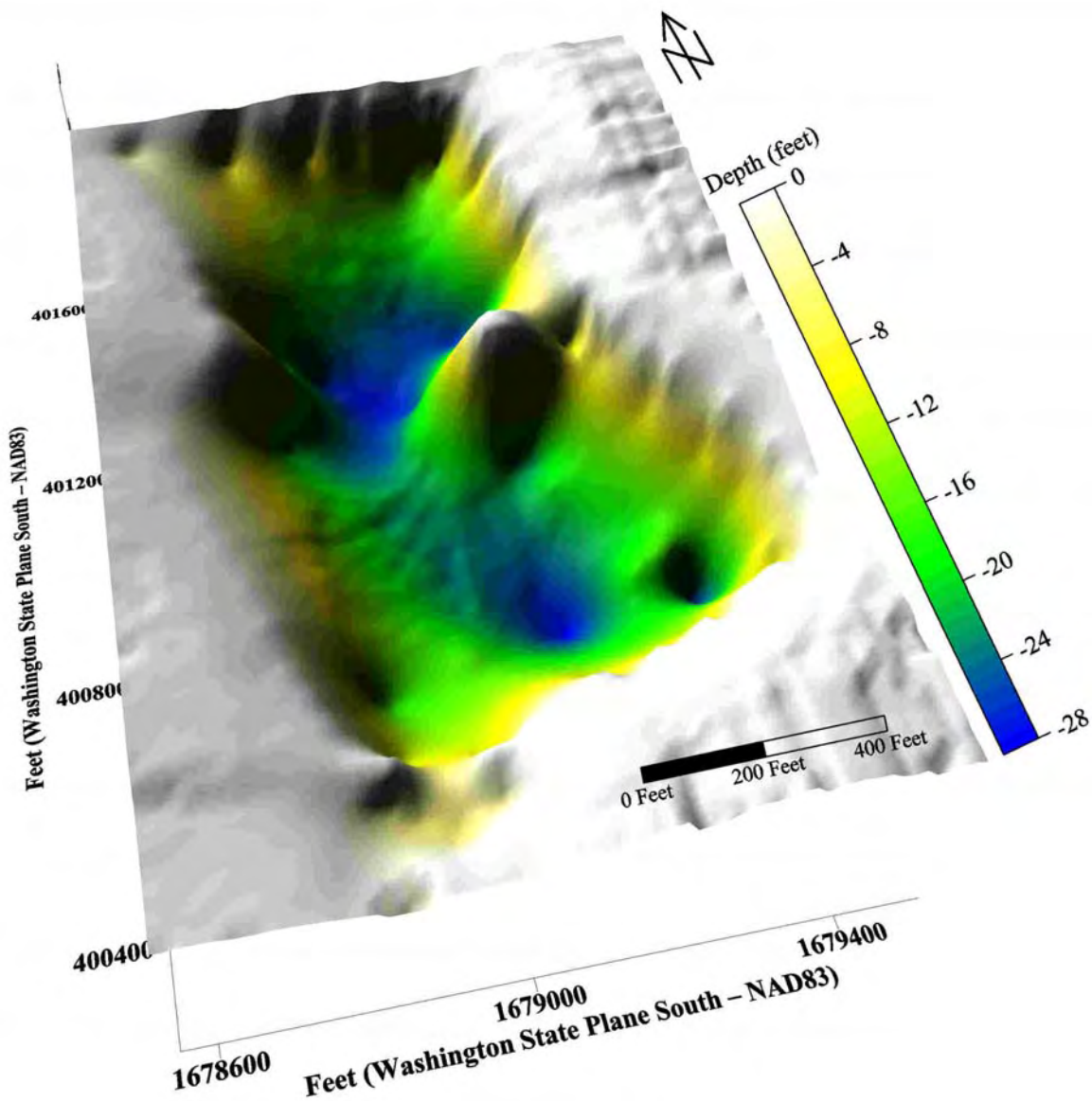


Figure 131. 3-D perspective bathymetric map of I-82 Pond 5; bathymetry in feet below the May 30, 2002, water level.

Sample 129 from the north end of Pond 4 consists of poorly graded gravel (86.6%), sand (11.2%), and silt and clay (2.2%) (Figure 132). This sample represents more recent river bedload deposited on the underlying Thorp sediments. Sample 130 from the center and more deeply excavated portion of I-82 Pond 4 is composed of 100% silty clay (Table 46). Sample 131, from the southernmost part of I-82 Pond 4, is typical of the Thorp Formation containing varied amounts of sporadically distributed gavel and cobble clasts sporadically distributed in a silt and clay matrix (matrix-supported conglomerate) (Figure 133)

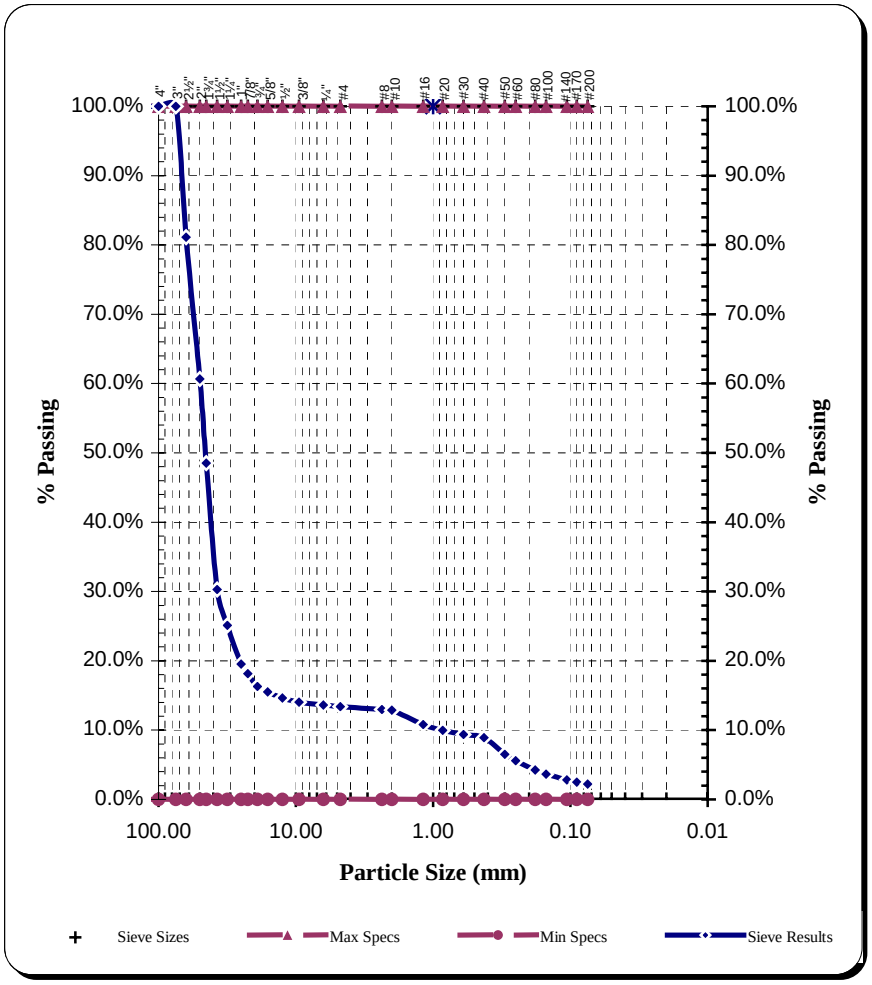


Figure 132. Grain-size distribution plot for sample 129, I-82 Pond 4.

Table 46. Qualitative sediment particle data for I-82 Pond 4; see also Figures 132, 133, and 134.

Sample No.	Particle Size Range	Comments
129	86.6% 2.9 to 0.19 in., 11.2% 0.19 to 0.003 in., 2.2% <0.003 in.	Poorly graded gravel with lesser sand and minor silt and clay
130	100% <0.003 in.	Silty clay
131	57.1% 2.9 to 0.19 in, 4.5% 0.19 to 0.003 in., 38.4% <0.003 in.	Gravel in a matrix of silt and clay
132	77.2% 2.9 to 0.19 in., 13.4% 0.19 to 0.003 in., 9.4% <0.003 in.	Gravel with lesser amounts of sand, silt and clay

Sample 132, from east-central Pond 5, was extracted from the base of a 23 ft thick stratigraphically intact (residual) deposit of river gravel near a steep-sloped island. This sample is 77.2% gravel, 13.4% sand, and 9.4% silt and clay and is thought to be representative of the stratigraphically younger veneer of coarse river bar sediment deposited over the Thorp Formation and was mined to make the I-82 Ponds 4 and 5 (Figure 134).

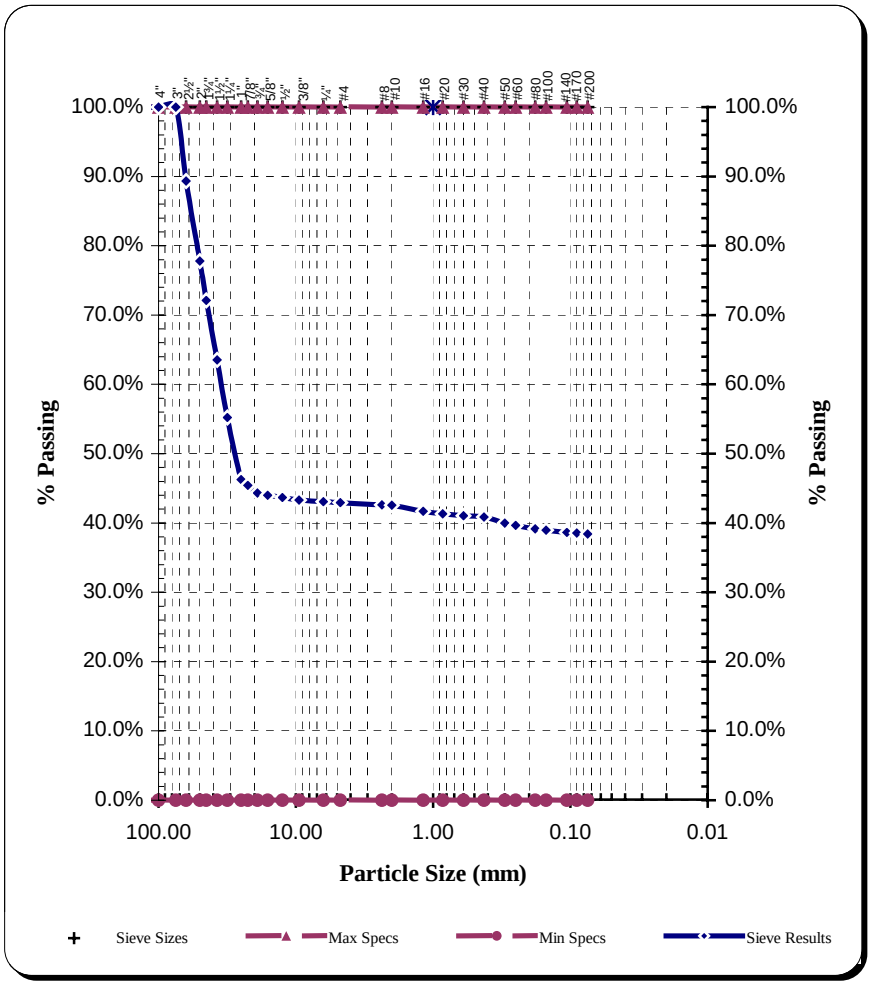


Figure 133. Grain-size distribution plot for sample 131, I-82 Pond 4.

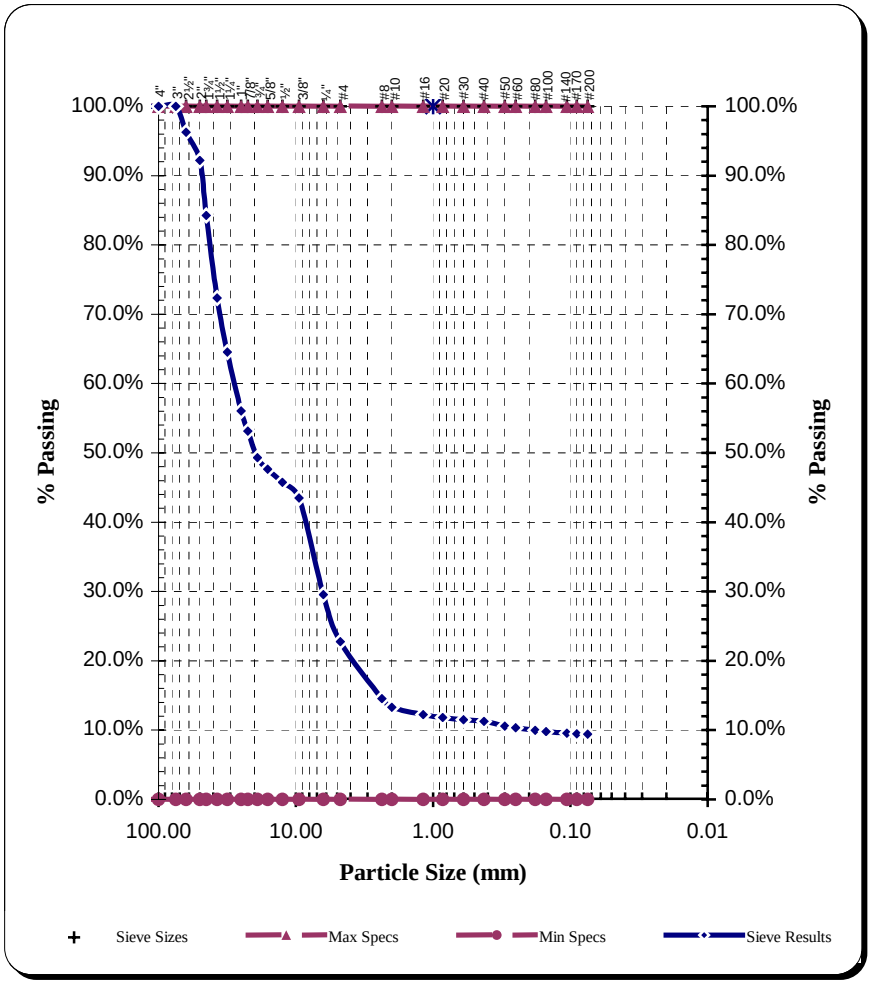


Figure 134. Grain-size distribution plot for sample 132, I-82 Pond 5.

Site Sample Information

Sample site locations for the thermal investigation, fish assemblage, and benthic macroinvertebrate and water-quality work for I-82 Ponds are shown in Figure 135. Standard sampling protocol is discussed in Chapter 4 (Methods). Individual site results are discussed per study component below.

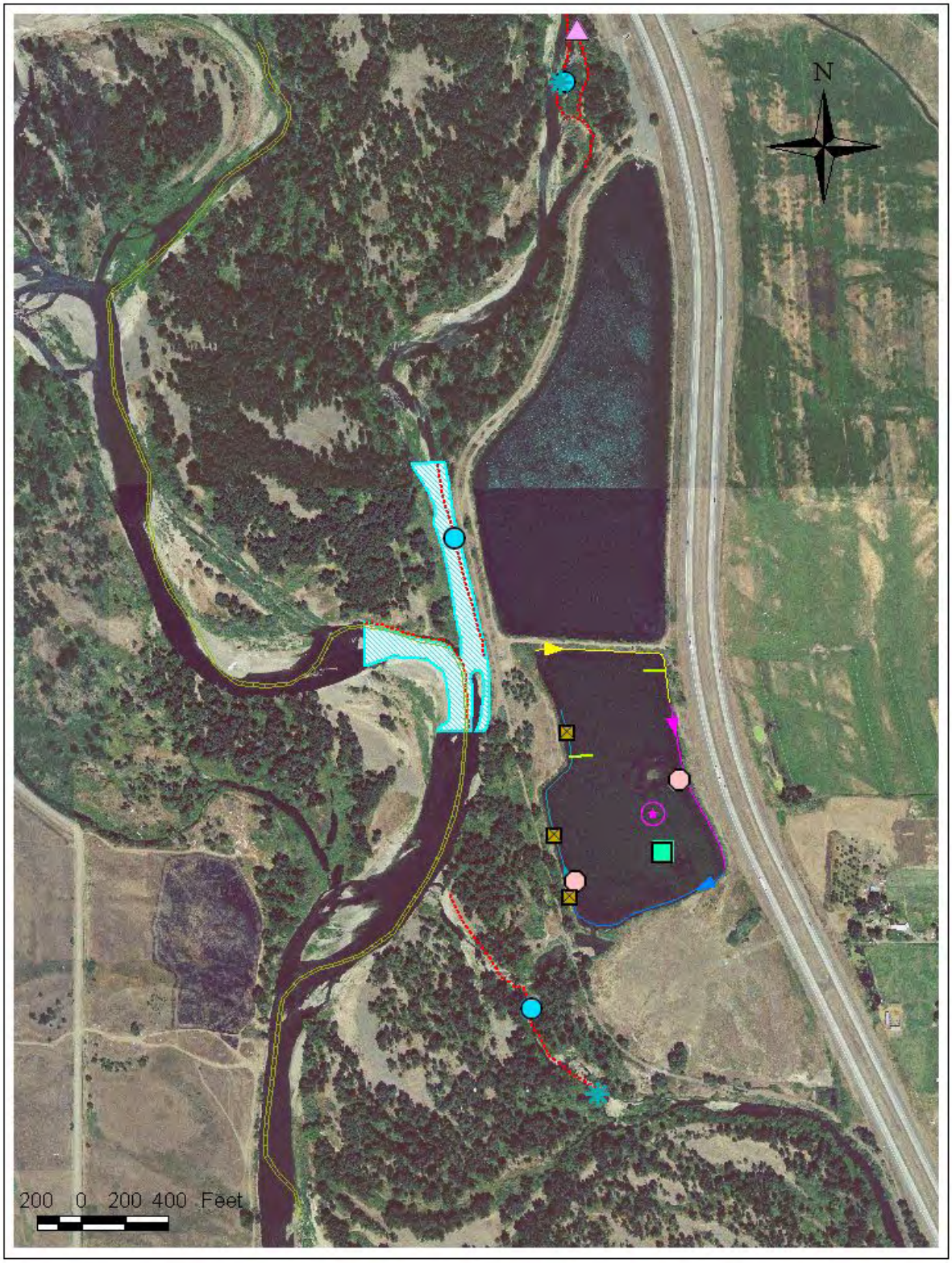


Figure 135. Thermal, fish assemblage, benthic macroinvertebrate, and water-quality sample site locations for the I-82 Ponds. Explanation of location symbols is on p. xxii. (Photo source: DOT, 2002)

Thermal Investigation

The upstream, middle, and downstream monitoring locations were on the west bank of the river on smaller side channels adjacent to the site (Figure 135). All monitoring instruments were tethered to the shore, were subject to riparian shading, and were placed in approximately 2 to 3 ft of surface flow. The downstream monitoring station was located on a side channel that is connected a secondary side channel at the upstream end of Pond 5 during the spring and early summer and maintained interstitial flow to the bed throughout mid-summer and fall (Figure 135). The vertical stringer placed in Pond 5 collected temperature data at 2, 6, 10, and 14 ft depths. The Ext (air) unit was located in the riparian area near the upstream river station of the site (Figure 135). Temperature data for the Ext and river monitoring instruments were recorded from April 15 to November 1, 2002. Pond data was collected from June 27 to November 1, 2002.

River

Table 47 shows the monthly averages of all temperature measurements collected in the Yakima River during each month at the I-82 Ponds upstream site, middle site, and downstream sites. The table shows the difference (dT) in average temperatures between the upstream and middle sites; between the upstream and downstream sites; and between the middle and downstream sites. Because the comparisons are made downstream, positive values indicate an increase in downstream temperature, whereas a negative value indicates a lower temperature downstream.

Table 47. Average monthly Yakima River temperatures (in °C) and differences (dT) among samples sites at I-82 Ponds 4 and 5.

Month	Upstream	Middle	Downstream	dT Upstream/ Middle	dT Upstream/ Downstream	dT Middle/ Downstream
April	9.34	No Data	8.83	No Data	-0.51	No Data
May	11.77	12.41	12.11	0.63	0.33	-0.30
June	14.10	13.94	14.22	-0.15	0.13	0.28
July	20.45	18.53	16.70	-1.92	-3.75	-1.83
August	18.91	17.65	16.46	-1.26	-2.44	-1.19
September	16.98	16.65	16.47	-0.33	-0.51	-0.18
October	11.53	12.20	12.30	0.67	0.78	0.10
November	5.87	5.68	5.61	-0.19	-0.26	-0.07

Table 47 shows that this site is the only one in this study at which, during the study period, water was cooler at the downstream site than the upstream site. The temperature gradient was also substantially greater across Site 9 than any of the other sites. The temperature changes appear to have been evenly distributed between the upstream and middle sites and between middle and downstream sites.

Figure 136 shows the minimum and maximum daily river temperatures at the site. Water at the upstream site was warmer than at the other two sites during much of the period of record. The downstream site had little variation between daily minimum and maximum temperatures. This

was likely due to cold shallow ground-water infiltration to the river along this reach.

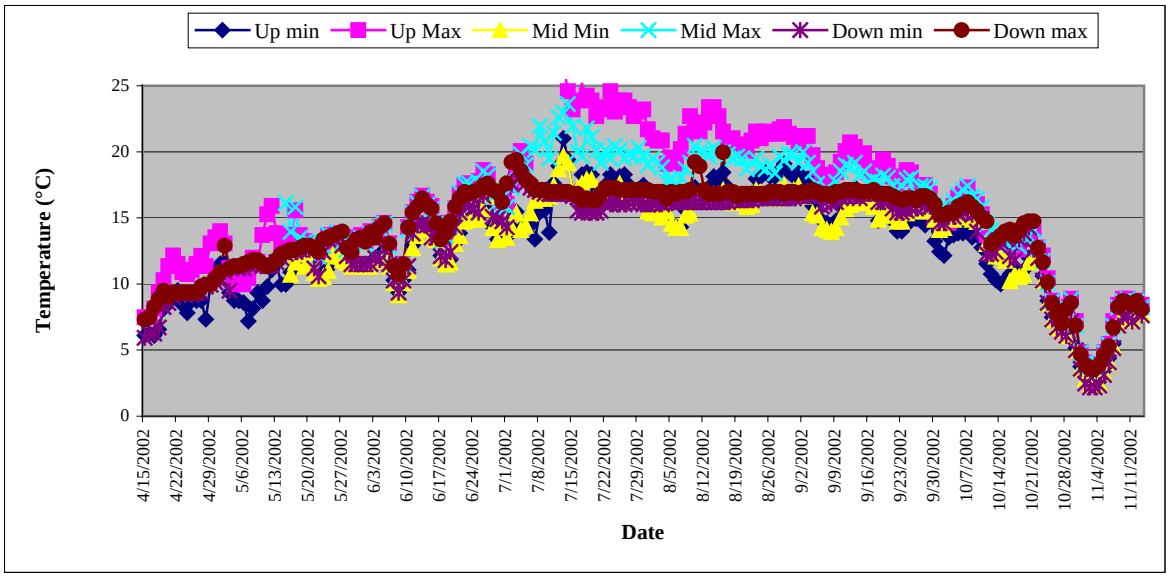


Figure 136. Yakima River daily minimum and maximum temperatures near I-82 Pond 5.

Pond

Figure 137 shows daily minimum and maximum temperatures recorded by the vertical stringer in Pond 5. Temperature stratification was noted in summer; turnover occurred in early September.

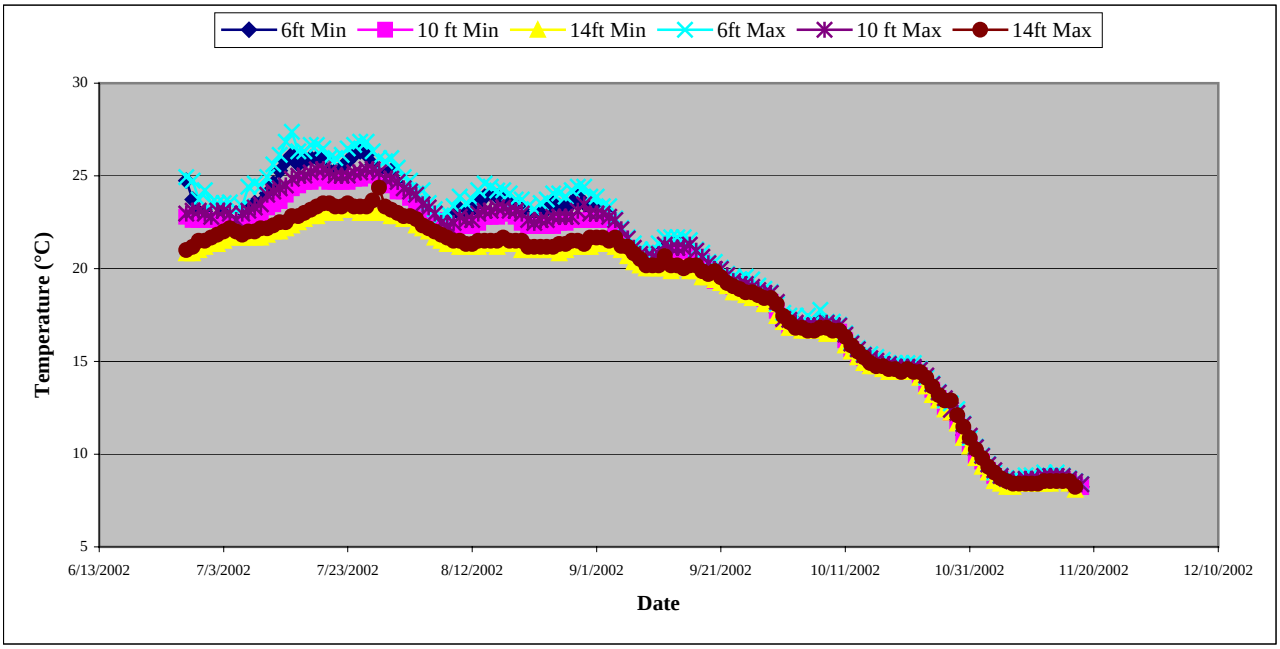


Figure 137. Daily minimum and maximum water temperatures by depth in I-82 Pond 5.

Fish Assemblage

Pond 4 drains into Pond 5 through twin culvert pipes that penetrate the dike separating the two ponds. Catchable (9-11 in. total length) hatchery rainbow trout (Figure 138) are stocked in Pond 4, and a few may move into Pond 5 through the culvert. Channel catfish (Figure 139) have been stocked in both ponds.

Figure 138. A hatchery rainbow trout (23 cm) planted by WDFW.

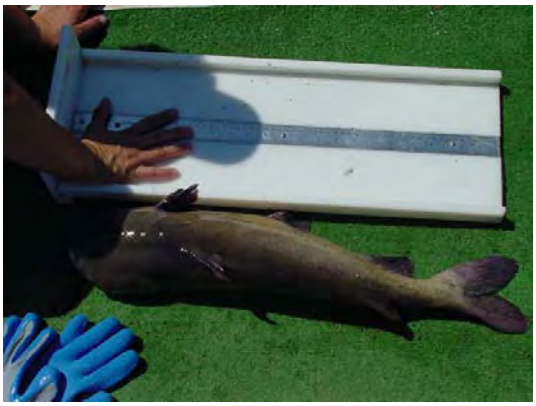


Figure 139. Channel catfish (67 cm) captured during fish assemblage collection.

Pond 5 was sampled with the electroshocking boat, fyke nets, and gill nets on May 24 and 25 following the standard protocol. River reaches totaling 650 m adjacent and downstream of Pond 5 were sampled with the backpack electroshocker on May 20 and September 12. A 225-m reach upstream of Pond 4 was surveyed on November 6. A snorkel survey was conducted on October 18 adjacent to Ponds 4 and 5 (400-m reach). A total of approximately 2,000 m of river was sampled with the drift boat-mounted electroshocker on August 21 (Figure 134). Water velocity was high and visibility was poor during the snorkel survey. Appendix K, Tables 31-35 present detailed fish assemblage data for I-82 Pond 5 and the Yakima River above and below this pond. Table 48 summarizes species composition at this site.

A total of 359 fish representing 14 species was collected in Pond 5. Yellow perch (30%), pumpkinseed sunfish (21%), bluegill (19%), and largemouth bass (16%) were the most frequently sampled species. Except for a small number of hatchery rainbow, no salmonids were sampled in this pond. Although not sampled effectively by the methods used, channel catfish (1%) were part of the species assemblage. This pond has a higher percentage of exotic species popular with anglers (largemouth bass, black crappie, bluegill, and channel catfish) than the other sampled ponds. WDFW's management objective is to produce a high-quality warm-water fishery in Pond 5.

Table 48. Percent composition of fish sampled at I-82 Pond 5 and the Yakima River adjacent to this site. “below” includes backpack electroshocking (May 20, Sept. 12, 2002) and snorkel survey (Oct. 18, 2002). The bold values indicate dominant species. See Table 6 for explanation of species codes.

Species	Pond 5	River			
		Above	Below	Drift Boat	Summary
BBH	0.3				
BC	3.3				
BG	**19.2**				
CC	0.8				
CK		10.2	0.1		1.5
CMO	2.8	**41.6**	10.2	**19.0**	**15.4**
COT		0.7		1.0	0.2
CP	3.1				
DAC		6.6	**29.7**	**18.1**	**25.4**
LMB	**15.9**		1.4		1.1
MNS			0.1		0.1
NPM	0.6	**22.6**	5.2	6.7	7.7
PS	**21.2**	0.7	0.3		0.3
*RB	0.3				
RB		0.7			0.1
RS	0.3	**13.9**	**43.2**	24.8	**37.3**
SK	1.9	2.2	9.3	6.7	8.1
WF				**23.8**	2.5
STB			0.5		0.4
YP	**30.4**	0.7			0.1
Total	100.0	100.0	100.0	100.0	100.0
Sample Size	359	137	774	105	1016

The backpack electrofishing sample in the river produced 393 fish representing nine species. Native resident fish, including chiselmouth, sucker, dace, whitefish, redside shiner, and northern pikeminnow, were present, but percent composition varied widely among sample sites and no species dominated. Although whitefish were important in the species assemblage, few chinook and *O. mykiss* were sampled. An exotic predator, largemouth bass, and competitor, pumpkinseed sunfish, were sampled in the river in relatively small numbers. Drift boat electrofisher sampling produced 105 fish (seven species), including almost equal proportions of whitefish (24%), redside shiner (25%), chiselmouth (19%), and dace (18%). Redside shiners accounted for 78% of the 381 fish observed during the snorkel survey; they were followed by dace (20%).

On the basis of all river sampling techniques combined (Table 48), redside shiner (37%), dace (25%), and chiselmouth (15%) were most frequently sampled in this reach of the river. Salmonid predators northern pikeminnow (8%) and largemouth bass (1%) were present, as well as the exotic species, pumpkinseed sunfish and yellow perch (<1% each). Yellow perch were rarely sampled in the river; they prefer still water (pond) habitat and would be expected to move downriver and seek preferred habitat if they move into the river from a pond. Only a small

number of chinook (1.5%) and *O. mykiss* (0.1%) were sampled. The sample reach adjacent to Pond 5 was the lowest site in the Yakima R. where salmon and *O. mykiss* were found.

High summer water temperatures, low flow, and rapid flow fluctuations downstream of Sunnyside Diversion Dam are limiting salmon and trout production in this reach of the Yakima River. Except for whitefish, salmonids were present here in much smaller numbers than sample sites above Parker, which was expected.

I-82 Pond 3 Ingress/Egress Trap and Standard Protocol Sampling

The Study Team placed traps in the outlet of I-82 Pond 3 to assess the possible interaction of pond and riverine species where there is a flowing surface connection between a gravel pit pond and the river. (The team found no suitable outlet trap site at the 10 primary study sites.) This pond, about a mile from I-82 Pond 5 (Site 9), was chosen because of easy access and the ease with which it could be monitored. Fish were trapped from May 30 to November 21, 2002.

Out-migration Trap

The out-migration trap, which captured fish leaving the pond (moving into the river), caught mostly yellow perch and pumpkinseed sunfish (Figure 140). Most yellow perch migrated out of the pond from May until mid-June, soon after the trap was placed in the outlet channel. Few yellow perch were found to be moving out of the pond later in the study. Pumpkinseed sunfish began moving out in late summer and early fall; peak movement was in mid-October. The team captured 187 yellow perch and 268 pumpkinseed sunfish in the out-migration trap (Table 49). Only two fin-clipped yellow perch were recaptured (1 ventral fin clip) compared to 32 recaptured pumpkinseed sunfish. We also captured 21 largemouth bass (none recaptured), a small number of bluegill, chiselmouth, common carp, dace, northern pikeminnow, and one brown bullhead.

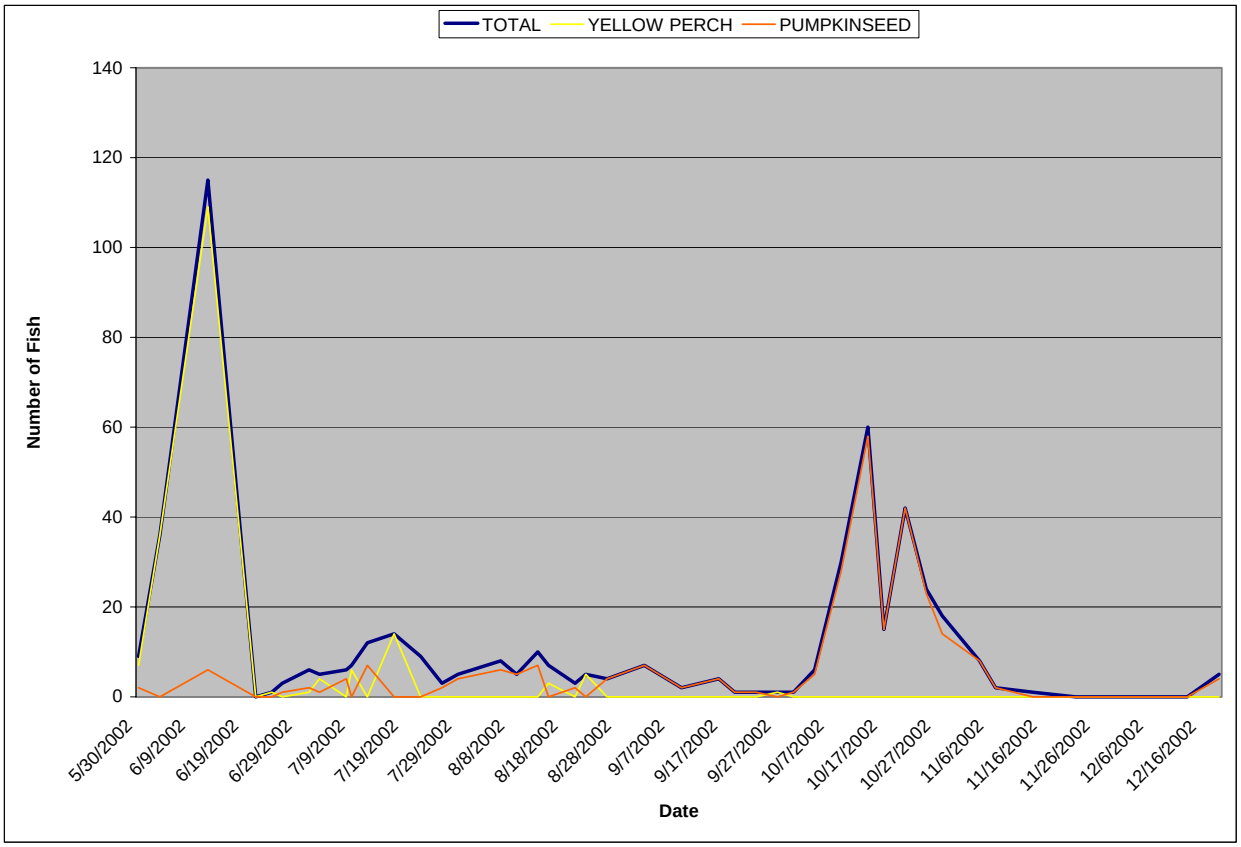


Figure 140. I-82 Pond 3 daily fish out-migration.

Table 49. I-82 Pond 3 ingress/egress trap data summary. See Table 6 for explanation of species codes.

Out-migration (Number of fish)												
	BBH	BG	CMO	CP	DAC	LMB	NPM	PS	YP	RS	SK	Total
Fish entering trap	1	5	5	4	4	21	5	264	187			496
Recaptures					1			32	2			35
In-migration (Number of fish)												
Fish entering trap	5	5	5	32	3	5	42	34	494	3	1	629
Recaptures	1		1	9			4	5	116			136
Out-migration (Percentage)												
Fish entering trap	0	1	1	1	1	4	4	52	38			99
In-migration (Percentage)												
Fish entering trap	1	1	1	5		1	7	5	79			100

In-Migration Trap

Yellow perch were the most abundant fish that entered the in-migration trap; 494 perch, 34 pumpkinseed sunfish, 32 carp, and 42 northern pikeminnow were captured (Table 49). Many fin-clipped perch (116) were recaptured. Figure 141 shows fish movement over time into the trap. Common carp and northern pikeminnow showed up sporadically throughout the study period. In-

migrating yellow perch were abundant from early July to mid-August. In addition, many yellow perch left the pond (were trapped in the out-migration trap) and returned in a short time period (approximately 45 days). Brown bullhead, bluegill, chiselmouth, dace, largemouth bass, redside shiners, and one sucker were also captured in the in-migration trap.

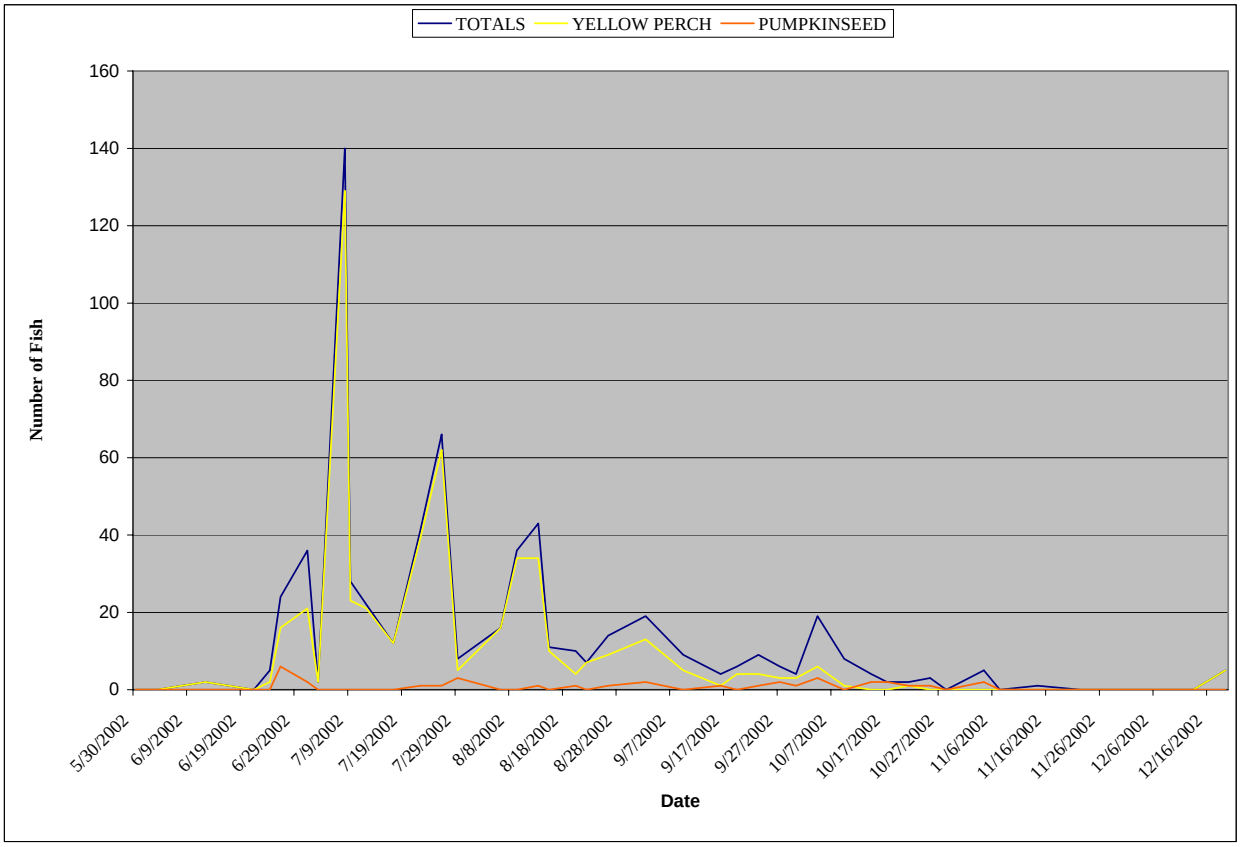


Figure 141. I-82 Pond 3 daily in-migration.

Yellow perch and pumpkinseed sunfish entering and leaving Pond 3 may have been making back-and-forth migrations between the beaver-dammed slough area on the river side of I-82 and the pond, as opposed to actually migrating into and out of the main river channel, which is a considerable distance from the highway.

We also used the standard pond protocol to sample I-82 Pond 3 to determine species composition for comparison with trap data. We collected 892 fish representing 10 species (Table 50). Yellow perch (60%) and pumpkinseed sunfish (28%) were the most abundant species, which explains why they were most frequently found in the outlet traps. The only salmonid in the pond sample were hatchery brown trout (2%); these are periodically stocked by WDFW. Northern pikeminnow (1%) and largemouth bass (3%) were also present. Trap data indicates the both species are migrating in both directions. The species composition in the pond is very similar to the trap data, which would be expected if most species are equally likely to migrate.

Table 50. Number and percent composition of fish sampled in I-82 Pond 3.

Species	Electro-shock	Fyke nets	Gill nets	Total	% Composition
Bluegill	9	--	--	9	1.0
Brown trout	14	3	--	17	1.9
Channel catfish	0	6	--	6	0.7
Chiselmouth	13	9	--	22	2.5
Common carp	4	--	--	4	<0.01
Largemouth bass	24	1	--	25	2.8
Northern pikeminnow	6	4	--	10	1.1
Pumpkinseed sunfish	241	6	--	247	27.7
Sucker (generic)	4	17	--	21	2.4
Yellow perch	434	89	8	531	59.5
Total	749	135	8	892	100

Benthic Macroinvertebrates, Water Quality, and Macrophytes

I-82 Pond 4 had marginal water quality and low dissolved oxygen at the bottom (tabulation below, Table 14). The benthic macroinvertebrate community in the pond had relatively few taxa, and many of those were tolerant (Appendix L, Table 3).

Depth (m)	Temp (°C)	pH (units)	Cond (uS/cm)	DO (mg/L)	chla (µg/L)	secchi (m)	OP (mg/L)	TDS (mg/L)	TN (mg/L)	TP (mg/L)
0.5	20.5	8.47	119	8.6	3.63	2.9	0.013	88.0	26.6	0.740
5	19.4	7.13	130	2.6	NA	NA	NA	NA	NA	NA

The downstream river reach had a much lower dissolved oxygen concentration and a less alkaline pH than the upstream reach (tabulation below, Table 16). These conditions in the downstream reach resembled the water quality at the bottom of Pond 4. Canopy cover was greater in the downstream reach (see Table 17).

Site	Date (2002)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	pH (units)	Temperature (°C)
Downstream I-82 Pond 4	09/04	94	4.2	7.39	17.5
Upstream I-82 Pond 4	09/04	95	11.1	8.42	16.5

The biometric results indicate that the upstream control reach was in a better biological condition than the lower reach (Table 18). The cluster dendrogram did not show a clear difference in species similarity (Figure 39). The CCA plot showed a slight separation of macroinvertebrate community compositions between the two reaches (Figure 142). The absence of the otherwise ubiquitous *Baetis tricaudatus* (Appendix L*)* in the lower reach also suggests that the lower reach is biologically impaired. Wetted width, average velocity, and gradient could be interpreted as having a relationship with site fauna distribution (Table 51). Extreme low flow observed in this side channel could have caused biological impairment.

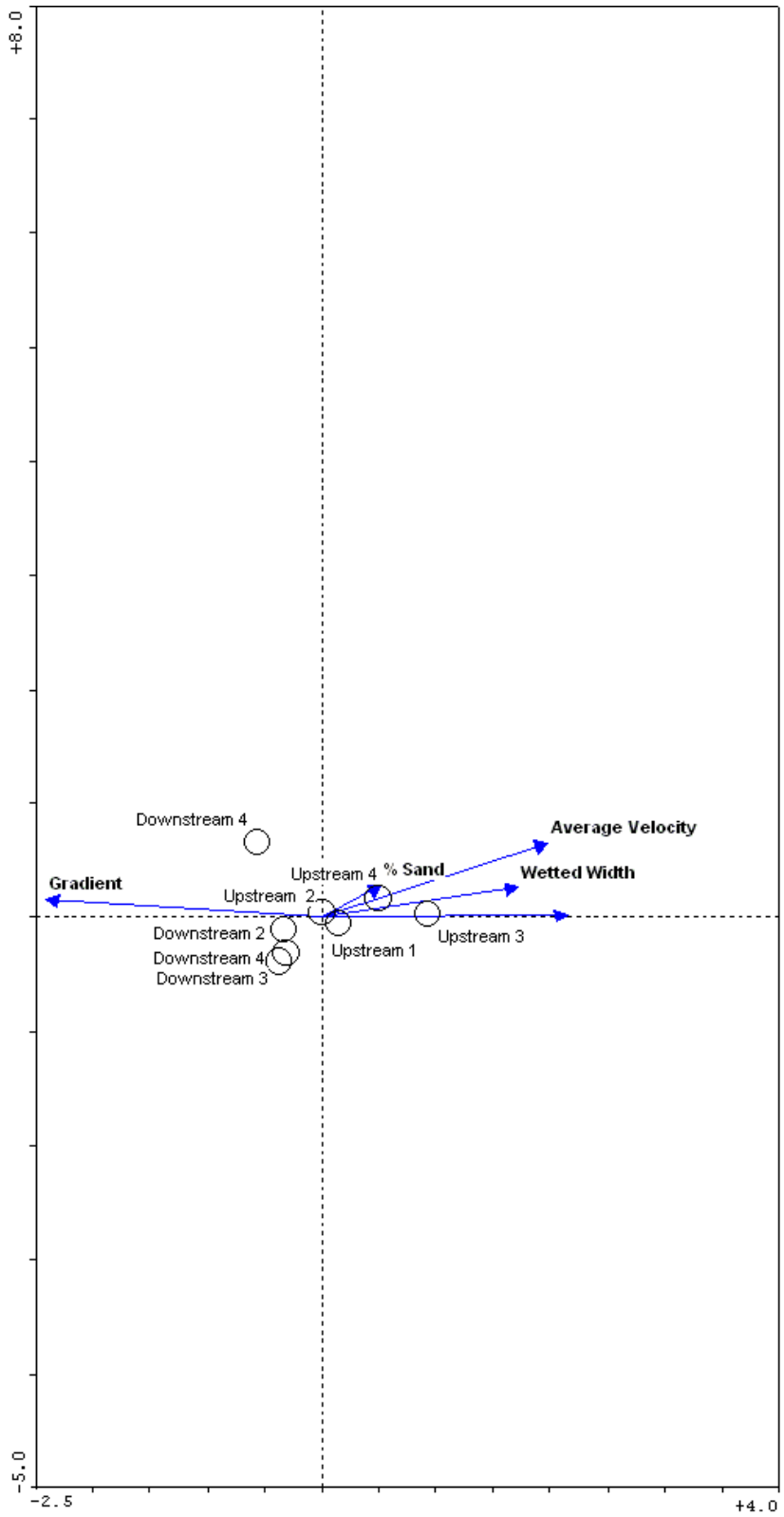


Figure 142. Canonical Correspondence bi-plot with the I-82 Pond 4 river benthic macroinvertebrate site distribution and major physicochemical explanatory vectors.

Table 51. Canonical correlations of physicochemical variable to ordination axes at the I-82 Pond 5 river sites. n.s., not significant at p=<0.05

Variable	Axis 1 (x-axis)	Axis 2 (y-axis)
Wetted Width	0.63	0.15
Average Depth	n.s.	n.s.
Average Velocity	0.63	n.s.
Gradient	-0.88	n.s.
Cobble	n.s.	n.s.
Gravel	n.s.	n.s.

Macrophyte Survey

On September 10, the submersed plant community of I-82 Pond 5 was dominated by Eurasian milfoil (*Myriophyllum spicatum*), a listed noxious weed. Another non-native submersed plant, curly leaf pondweed (*Potamogeton crispus*) was also present, though not abundant. Two invasive non-native plants were also found along the shore: purple loosestrife (*Lythrum salicaria*) and reed canarygrass (*Phalaris arundinacea*). If this pond were reconnected to the Yakima River, it would act as a source of additional Eurasian milfoil to the river.

Site 9 Comments and Recommendations

I-82 Ponds 4 and 5 are managed by WDFW as a productive warm-water fishery. These two ponds have the greatest average depth of all the study sites, marginal water quality, and tolerant benthic invertebrate taxa.

The lower reach of the river here has lower dissolved oxygen concentrations and is less alkaline than the upper; water quality in the downstream site resembles that of the bottom of Pond 4. Moreover, in August (the month prior to flip flop), average monthly river temperatures were 5°C greater at I-82 Ponds than the river at Hanson Ponds. Few salmonids were sampled, and this reach is poor summer/fall rearing habitat; there may, however, be some winter-rearing potential. The Yakima River has a wide channel migration zone throughout the Wapato reach. If the ponds were to be captured at the potential avulsion points or reconnected, the habitat area gained would be minimal and the negative impacts to freeway and irrigation infrastructure could be long lasting and costly.

Recommendation

I-82 Ponds 4 and 5 should continue to be managed for recreational warm-water fishing.

14. DeATLEY POND (Site 10)

Location and Site Information

The DeAtley pit ponds, owned by Acme Materials/Inland Asphalt, Inc., are just upstream of the State Route 240 Bridge in Richland (Figure 143; see also Figure 151). The lowest DeAtley Pond was selected for study. It has a surface area of about 17 acres and a volume of about 78,000 yd^3.

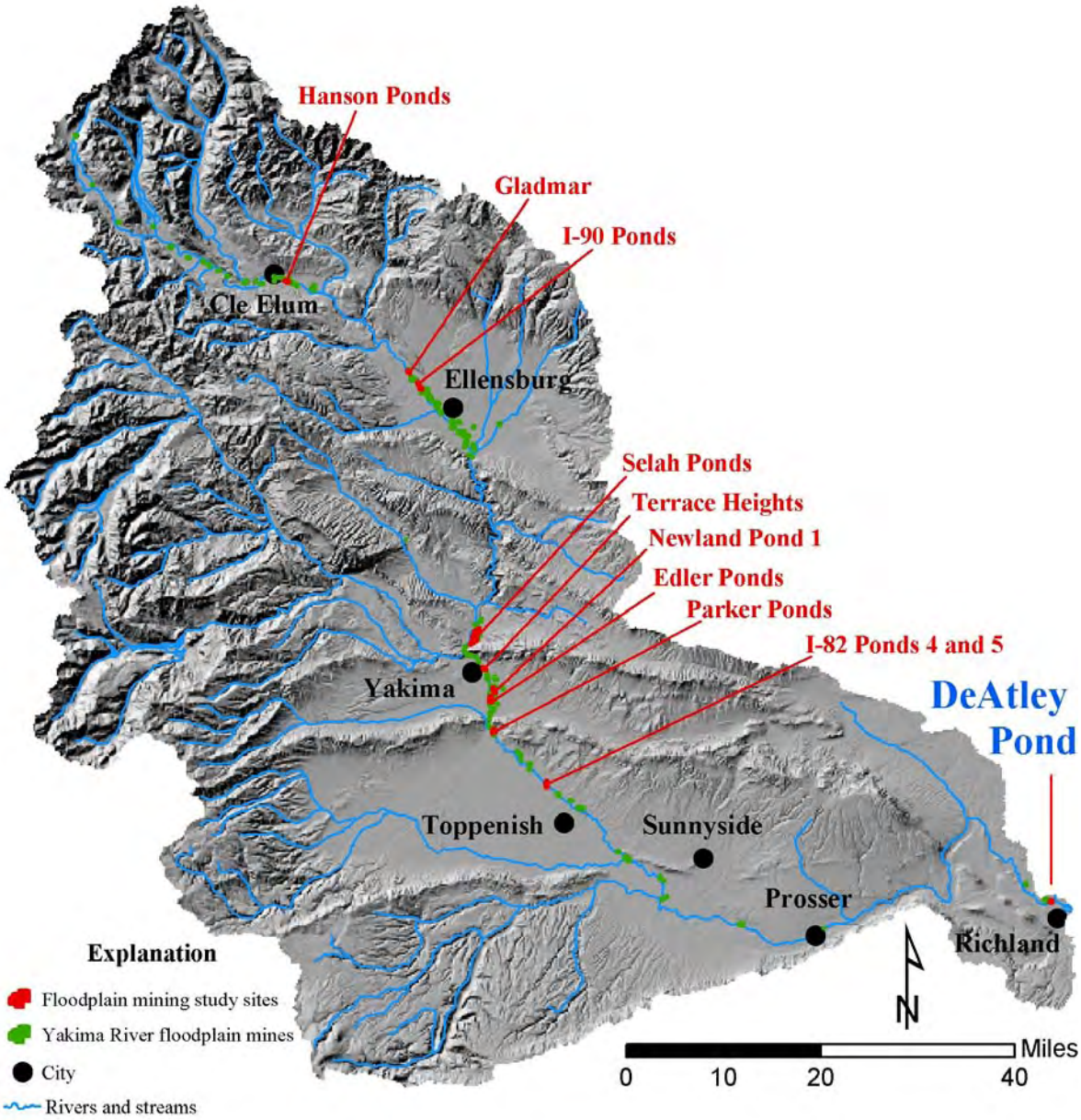


Figure 143. Location of DeAtley Pond (Site 10).

Pond Bathymetry and Sediment Sampling

The DeAtley Pond sand and gravel operation is mining a Holocene point bar sequence along the transition from an inside to an outside meander bend of the lowermost portion of the Yakima River (Figure 144). A dike along the entire length of the pond separates the pond from the river; however, a potential avulsion point exists along the southeast margin of the pond, where the cut bank of a meander bend is against the dike.

Upstream of the pond the channel migration zone is approximately 1,800 ft wide, increasing to 2,500 ft adjacent to the mine. Downstream of the mine the river is constricted by dikes protecting the mine and adjacent railroad bridge. The upstream end of the mine (southwest corner) is approximately 500 ft from a side channel of the river, whereas the downstream end of the mine (southeast corner) is 100 ft or less from the river. The river valley slope along the DeAtley reach, approximately one mile above the mine site to one mile below, is 0.00085, or about a 4.5 ft drop in valley floor elevation for each mile downstream. This is the lowest value of all the studied sites and expected for a site at the bottom of the drainage basin.

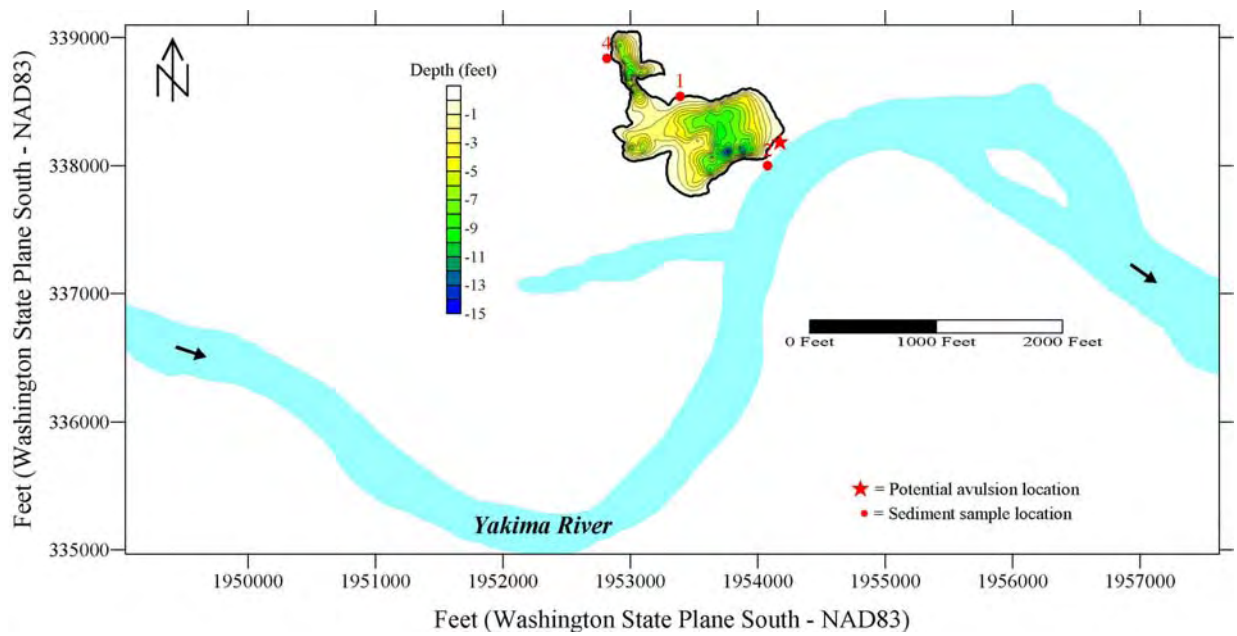


Figure 144. Contoured bathymetric map of the DeAtley Pond showing locations of sediment samples, potential avulsion sites, and proximity to the Yakima River.

DeAtley Pond is fairly shallow throughout. The average depth is 4.2 ft; the exception is an I-shaped depression in the eastern third of the pond that has a maximum measured depth of 15 ft along the southeastern margin (Figures 145 and 146); it is adjacent to a water-extraction pump.

When the bathymetry was measured on May 30, 2002, the river level was higher than that of the pond. Ground water was entering the pond from the dike area on the south side of the pond. Under these conditions the northwestern arm of the pond is connected to the main pond body (Figure 147). In the summer when river level is lower, the arm is an isolated 5 ft deep pond.

Three sediment samples were taken at the DeAtley site (Table 52). Sample 2 was extracted from the active channel of the Yakima River where it impinges on the dike separating the river from the southeast margin of the pond. This sample is of sediment from the outer bank of a river meander and consists of silty gravel with sand (Figure 148). The well-graded gravel fraction from the Yakima River ranges in size from 0.18 in. to 1.6 in.

Sediment samples 1 and 4 from the pond have a gravel fraction ranging from 0.18 in. to 1.2 in. Pond sample 4 is well-graded gravel (63.4%) with sand (32.1%) and silty clay (4.5%)(Figure 149), and sample 1 is poorly graded gravel (69.2%) with sand (29.5%), and silt and clay (1.2%)(Figure 150). This is less sand and silt than in sediment from the active river channel. Channel sediment may be finer due to the effects of hydraulic ponding of the lower Yakima River as it enters the McNary Pool (Columbia River) at Richland.

Table 52. Qualitative sediment particle data for DeAtley Pond; see also Figures 148, 149, and 150.

Sample No.	Particle Size Range	Comments
1	69.2% 2.9 to 0.75 in., 29.5% 0.19 to 0.003 in., 1.2% <0.003 in.	Poorly graded gravel with sand and minor silt and clay
2	60%, 2.9 to 0.19 in., 26.7% 0.19 to 0.003 in., 13.3 % <0.003 in.	Gavel with sand and silt
4	63.4% 2.9 to 0.19 in., 32.1% 0.19 to 0.003 in., 4.5% <0.003 in.	Well-graded gravel and sand with minor silt and clay

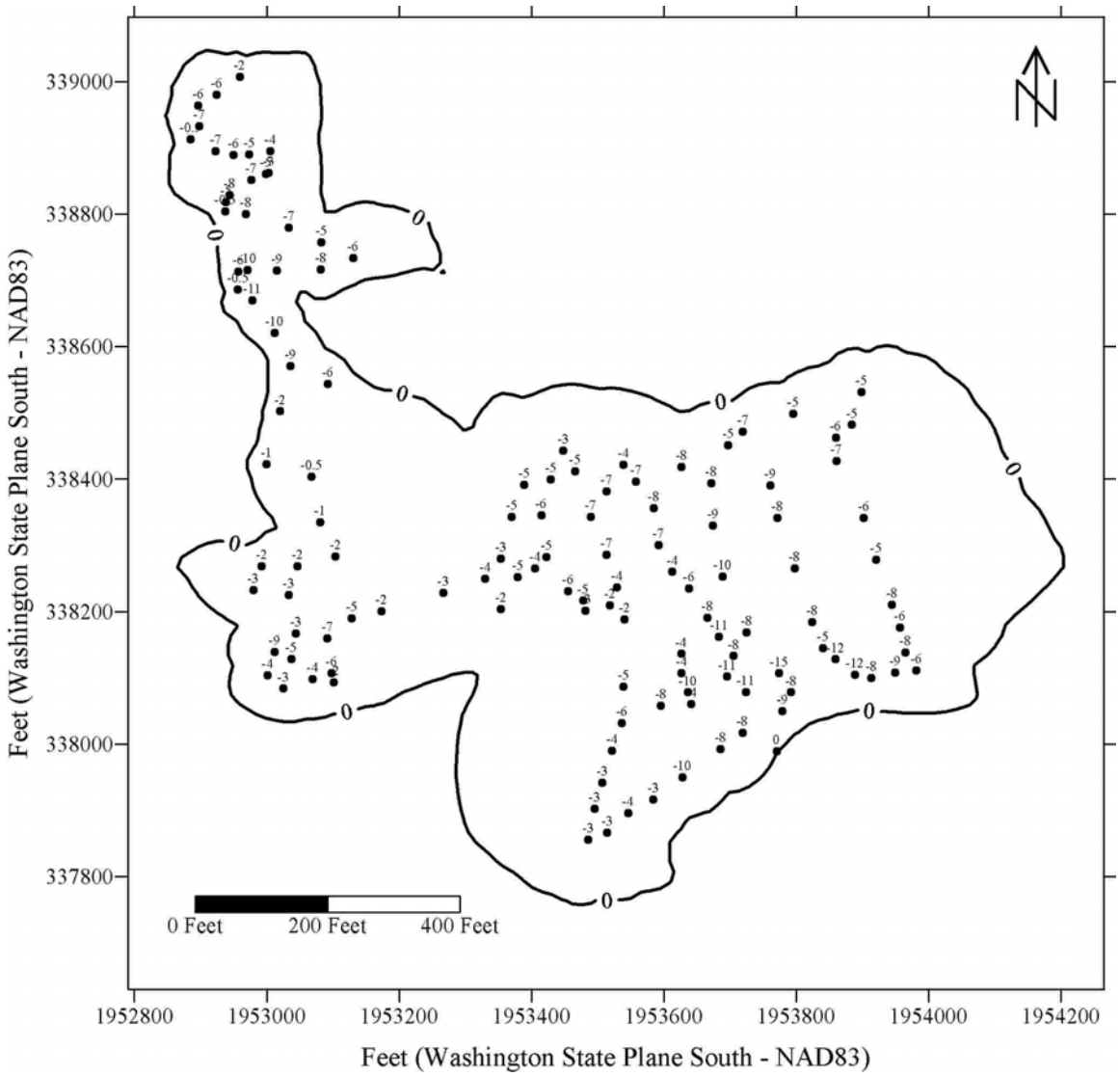


Figure 145. Post map showing data point locations and depths (in feet) used to model pond bathymetry for DeAtley Pond, May 30, 2002.

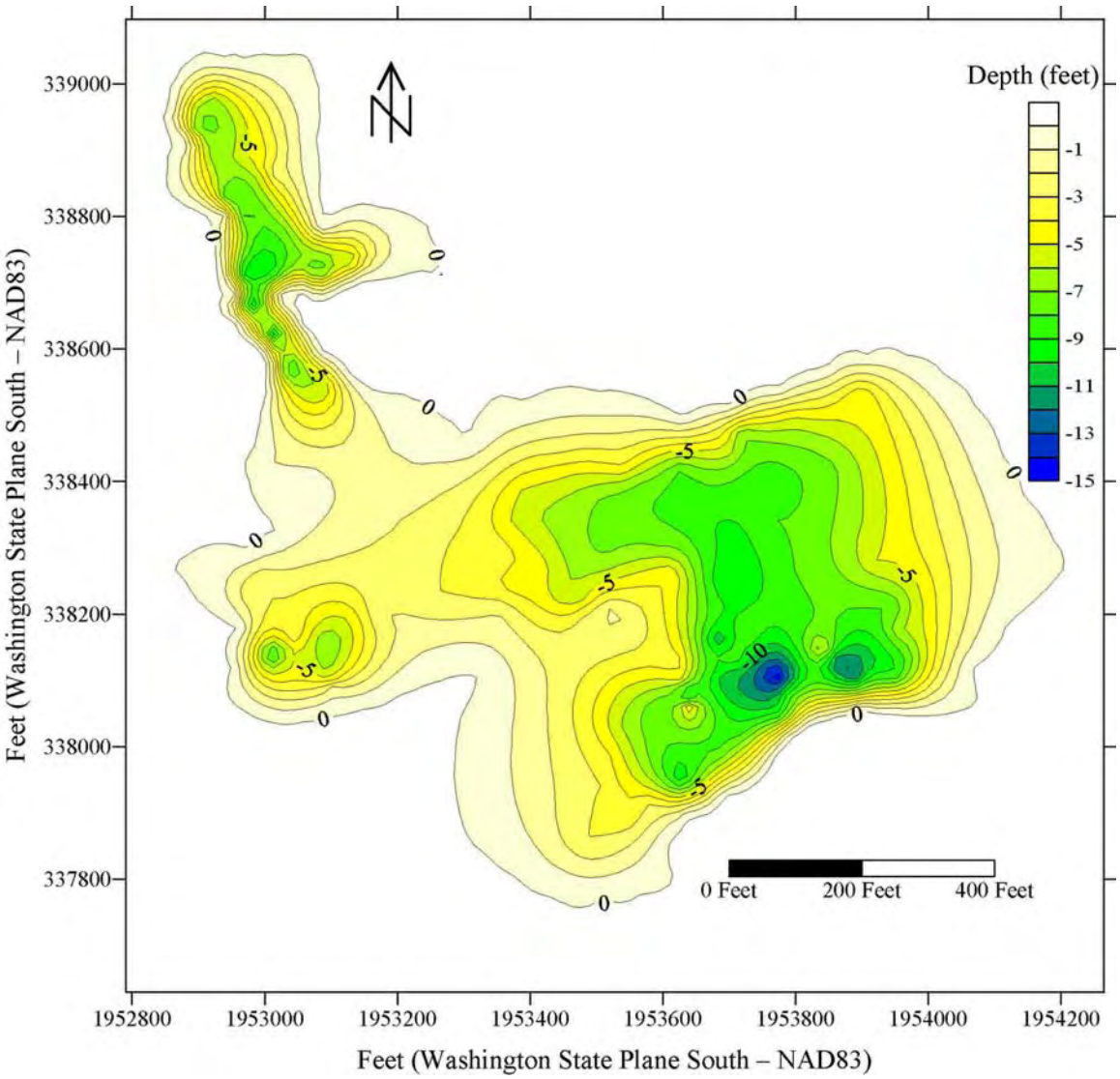


Figure 146. Contoured bathymetric map of DeAtley Pond; bathymetry in feet below the May 30, 2002, water level.

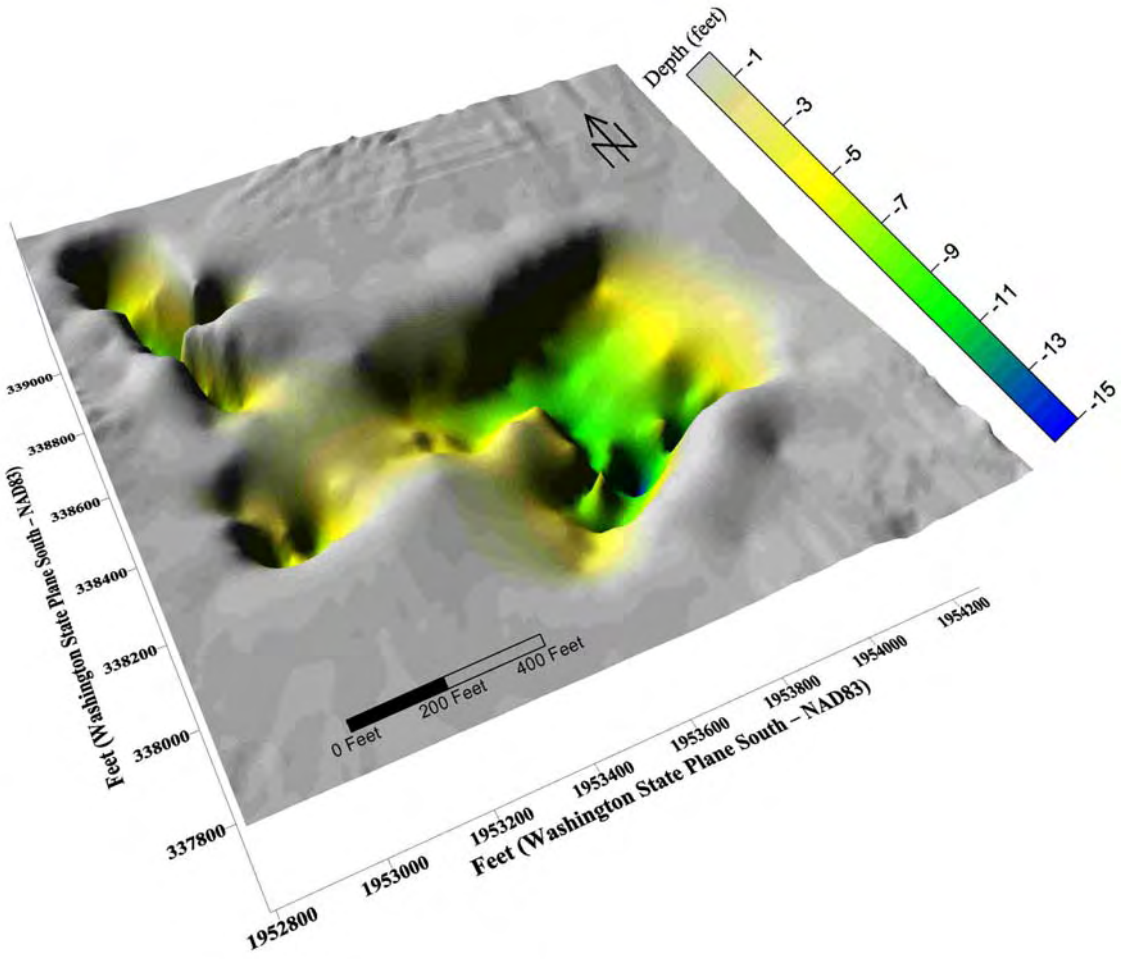


Figure 147. 3-D perspective bathymetric map for DeAtley Pond; bathymetry in feet below the May 30, 2002, water level.

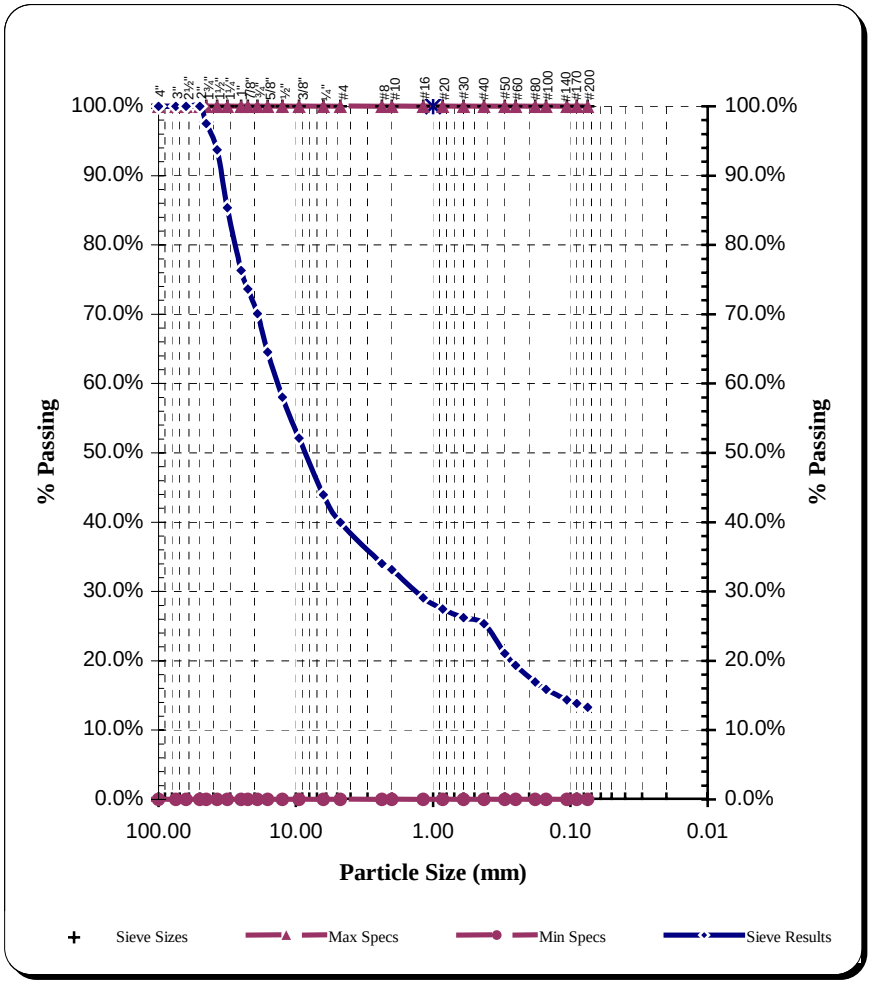


Figure 148. Grain-size distribution plot for Yakima River sample 2, adjacent to DeAtley Pond.

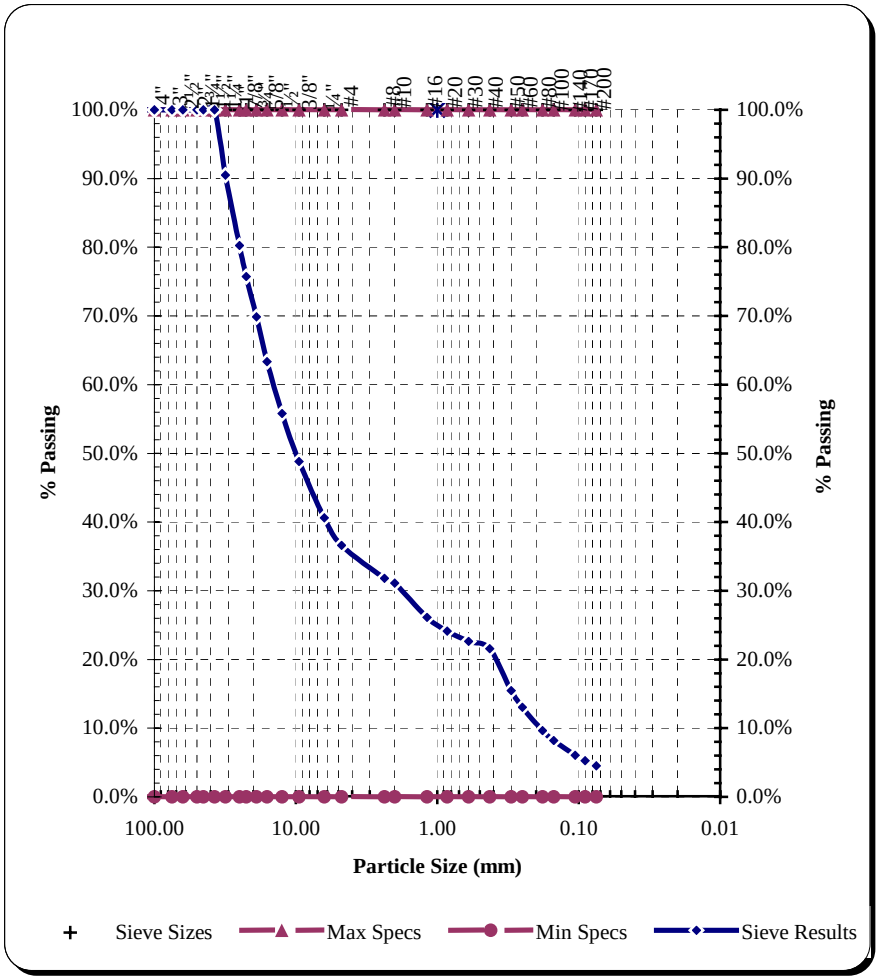


Figure 149. Grain-size distribution plot for sample 4, DeAtley Pond.

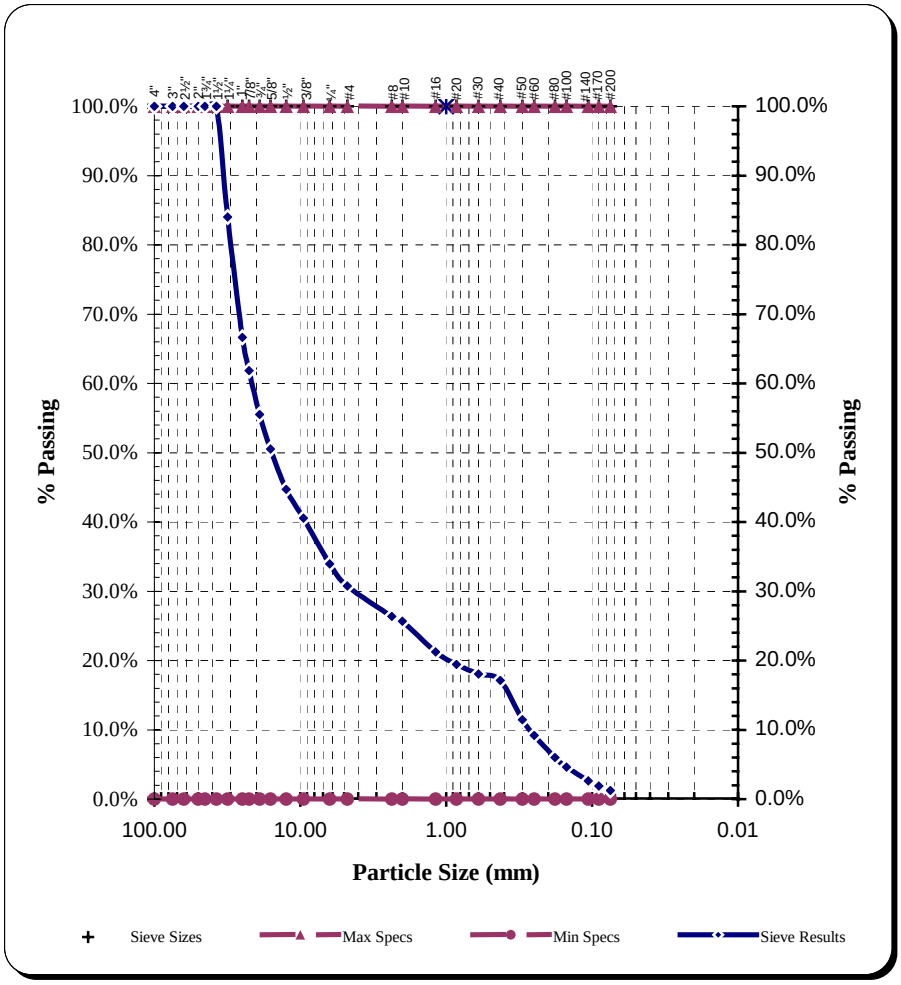


Figure 150. Grain-size distribution plot for sample 1, DeAtley Pond.

Site Sample Information

Sample site locations for the thermal investigation, fish assemblage, and benthic macroinvertebrate and water-quality work for DeAtley Pond are shown in Figure 151. Standard sampling protocol is discussed in Chapter 4 (Methods). Individual site results are discussed per study component below.

Figure 151. Thermal, fish assemblage, benthic macroinvertebrate, and water-quality sample site locations for DeAtley Pond. The explanation for the site location symbols on this photo are on p. xxii. (Photo source: Washington Department of Transportation, 2002)

Thermal Investigation

The upstream, middle, and downstream monitoring instruments were tethered to the shore, were subject to riparian shading, and were placed under approximately 2 to 3 ft of surface flow. Flow fluctuated dramatically throughout the period of record, and vandals damaged the middle and downstream monitoring instruments on numerous occasions. The upstream monitoring instrument was not vandalized, but it was out of water during a period of low flow in the fall. The middle instrument was situated below the City of Richland's sewer treatment outfall, and the lower monitoring instrument was placed below the pump outfall of the active mining site (Figure 151). Pond temperature was recorded on a vertical stringer at depths of 2, 6, and 10 ft. The Ext (air) unit was located in the riparian area near the lower eastern portion of the Pond (Figure 151). Temperature data for the Ext, pond, and river monitoring locations were recorded from April 15 to November 1, 2002.

River

Table 53 shows the averages of the temperatures recorded during various periods of record and the change (dT) in average temperatures between the upstream and middle sample sites, between the upstream and downstream sites, and between the middle and downstream sites. Positive numbers represent an increase in temperature in the downstream direction, whereas negative values represent cooler downstream temperatures. The collection of river temperature data in the vicinity of the DeAtley Pit was severely hampered by vandalism and fluctuating river levels, which intermittently exposed the instruments (see Figure 152). This resulted in independently varied lengths of record for each monitoring device, depending on when the vandalism or exposure took place.

Table 53. Average monthly river temperatures (in °C) at DeAtley Pond.

Month	Upstream	Middle	Downstream	dT Upstream/ Middle	dT Upstream/ Downstream	dT Middle/ Downstream
April 16-30	12.29	11.72	12.34	-0.56	0.05	0.61
May 16-31	16.61	17.92	16.68	1.31	.07	-1.24
June 1-13	15.83	No data	15.84	No data	.01	
June 14-30	19.47	19.34	No data	-.13	No data	No data
July	No data	No data	No data	No data	No data	No data
August 1-12	24.36	22.34	No data	-2.02	No data	No data
August 13-31	23.54	22.99	23.80	-.55	.26	.81
September 1-19	20.10	20.14	20.58	.04	.48	.44
September 20-30	No data	16.99	17.95	No data	No data	.96
October 1-15	No data	14.49	15.38	No data	No data	.89
October 16-31	10.23	10.24	10.83	.01	.60	.59
November 1-14	6.35	6.36	6.71	.01	.35	.34

Table 53 was prepared so as to maximize the available data and is broken into segments of less than a month, unlike similar data tables for other pits included in this study. The table includes only calculations based on 10 consecutive days of overlapping data. Table 53 indicates an erratic and inconsistent temperature distribution. Some of the temperature gradients are the largest recorded in this study and are due to extreme temperature increases and decreases as shown in the calculated differences (dT) among the three sample sites. It is possible that the temperature extremes reflect bias caused by decisions regarding which data were interpreted to have been affected by vandalism or exposure and their subsequent inclusion or exclusion in calculations. In general, there is a marked increase in temperature between the middle and downstream sample sites and a smaller increase between the upstream and downstream sample sites.

The Figure 152 time series plot shows the minimum daily and maximum daily river temperatures at the site. The plot suggests little consistent difference among the maximum temperatures at the various measurement sites early in the period of record. During the mid-summer period the downstream sample site was offline, and during the early and late period of record, the middle

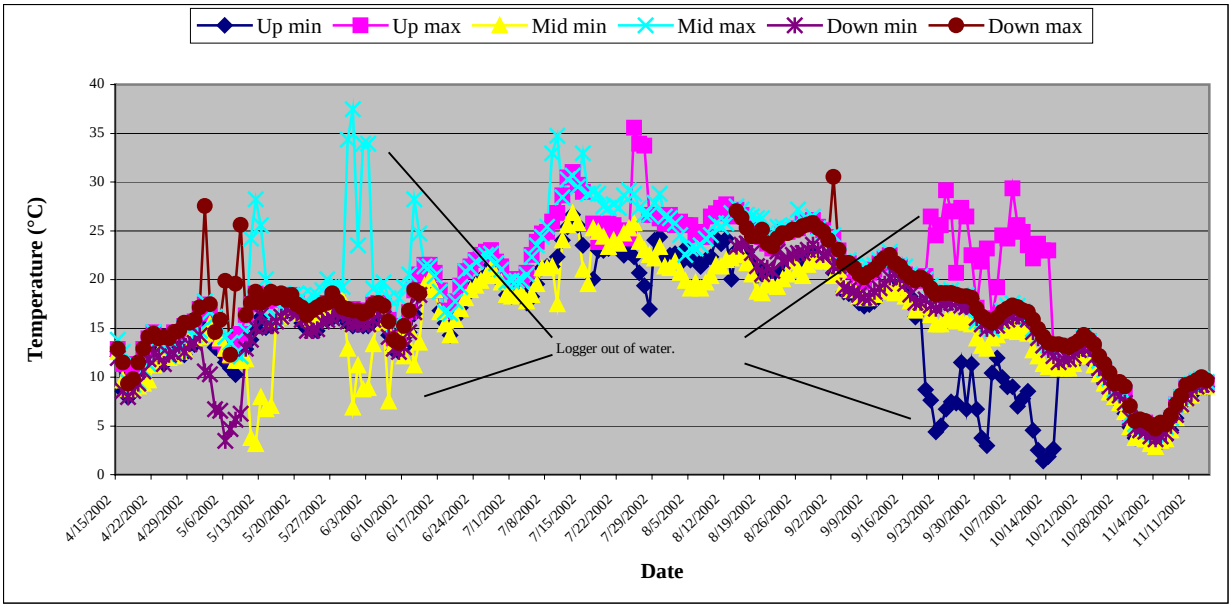


Figure 152. River daily minimum and maximum temperatures at DeAtley Pond.

recorder was out of the water. It appears that through the summer the middle site instrument recorded slightly higher river temperatures than the instrument at the upstream site.

Pond

Figure 153 displays a vertical profile of daily minimum and maximum temperatures in DeAtley Pond. Stratification occurs during the summer, and turnover occurred in mid-September.

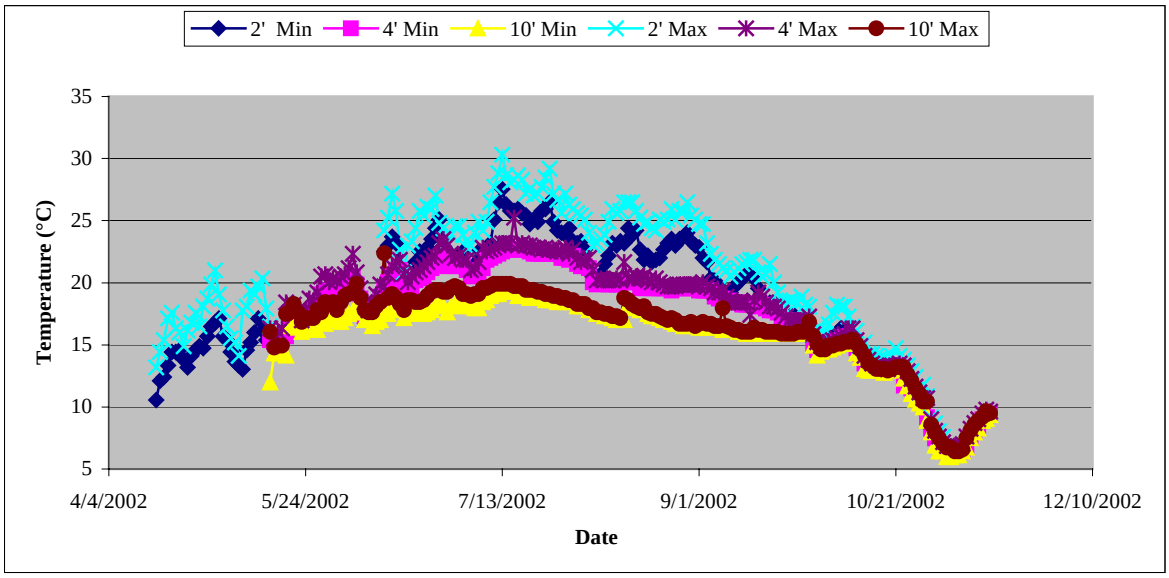


Figure 153. Daily minimum and maximum water temperatures, by depth, for DeAtley Pond.

Fish Assemblage

The pond selected for study covers 17 surface acres, and the standard pond sampling protocol was employed. Only the drift boat electrofisher was used in the river, on August 23. The river depth and soft silt bottom made sampling with a backpack electroshocker ineffective, and the turbidly precluded snorkeling.

Common carp were the only fish sampled in DeAtley Pond on June 27 (Figure 155, Table 54). The pond was partially dewatered by mining operations in early May 2002, which explains why no other species were found. Nineteen fish (seven species) including smallmouth bass (48%), bluegill (16%), and channel catfish (16%) were sampled in the river on August 23 (Appendix K, Table 37). Although the sample size was small, other WDFW sampling has shown that smallmouth bass and channel catfish, both predators on salmonids, are abundant throughout the lower Yakima River and prey heavily on juvenile fall chinook salmon (Pearsons *et al*. 2003; Fritts *et al*. 2001a, 2001b). No juvenile salmonids were captured in the river at Richland during the drift boat electroshocking in late August, as expected. Spring chinook, fall chinook, coho, and steelhead smolts (*Oncorhynchus mykiss*) would have been present in late winter and spring during their downstream migration to the Columbia River.

Figure 151. A common carp (74 cm) captured during river sampling in a large slough adjacent to DeAtley Pond (Photo source: WDFW, June 29, 2002).

Table 54. Percent composition of fish sampled at DeAtley Pond and the Yakima River adjacent to this site. The bold values indicate dominant species. See Table 6 for explanation of species codes. The river was not sampled by backpack electrofishing or snorkeling due to river conditions.

Species	DeAtley Pond	River	
		Drift Boat	Summary
BBH		5.3	5.3
BG		**15.8**	**15.8**
CC		**15.8**	**15.8**
CP	**100.0**	5.3	5.3
NPM		5.3	5.3
PS		5.3	5.3
SMB		**47.4**	**47.4**
Total	100.0	100	100
Sample Size	308	19	19

Benthic Macroinvertebrates, Water Quality, and Macrophytes

The DeAtley Pond had poor water quality and was stratified at the time of sampling (tabulation below, Table 14,figure 37). There were low dissolved oxygen conditions at the bottom of the pond and supersaturated, alkaline conditions near the surface. The pond water also had relatively high chlorophyll a and TDS concentrations, resulting in a low secchi depth value. The benthic macroinvertebrate community in the pond had an average number of taxa, although there was an above-average number of tolerant taxa, resulting in a low HBI score (Appendix L, Table 3).

Depth (m)	Temp (°C)	pH (units)	Cond (µS/cm)	DO (mg/L)	chla (µg/L)	secchi (m)	OP (mg/L)	TDS (mg/L)	TN (mg/L)	TP (mg/L)
0.5	19.4	9.51	262	15.5	39.68	1	0.282	189.0	27.0	0.370
3.5	14.2	7.4	280	0.9	NA	NA	NA	NA	NA	NA

In the river, water quality was generally similar in the upstream and downstream reaches (tabulation below, Table 16). Water in the lower reach had less dissolved oxygen and was less alkaline than the upper reach. This might be attributed to effluent discharge from the City of Richland's regional sewage treatment plant to the river between the upper and lower water-quality sampling sites. Differences between the reaches were wetted and bankfull widths (greater downstream), gradient (greater upstream), and average velocity (greater upstream).

Site	Date (2002)	Conductivity (µS/cm)	Dissolved oxygen (mg/L)	pH (units)	Temperature (°C)
Downstream DeAtley	09/03	254	8.9	8.59	22.5
Upstream DeAtley	09/03	255	9.5	8.49	23.0

The biometric results indicate that upper (control) reach was in a better biological condition than the lower reach (Table 18). The cluster dendrogram also showed a difference in species similarity (Figure 39). The CCA plot showed a slight separation of macroinvertebrate community composition between the two reaches (Figure 155). Wetted width, average velocity, and gradient appeared to account for site faunal distribution, even though they were not significantly correlated with axis 1 (Figure 155, Table 55). The lower reach was backed up by the Columbia River and lacked many fast-water taxa, such as *Cheumatopsyche* sp. and *Hydropsyche* sp. (Appendix L).

Table 55. Canonical correlations of physicochemical variables to ordination axes at the DeAtley river sites. n.s., not significant at $p<0.05$

Variable	Axis 1 (x-axis)	Axis 2 (y-axis)
Wetted Width	n.s.	-0.02
Average Depth	n.s.	-0.23
Average Velocity	n.s.	0.01
Gradient	n.s.	-0.02
Cobble	n.s.	-0.64
Gravel	n.s.	0.56

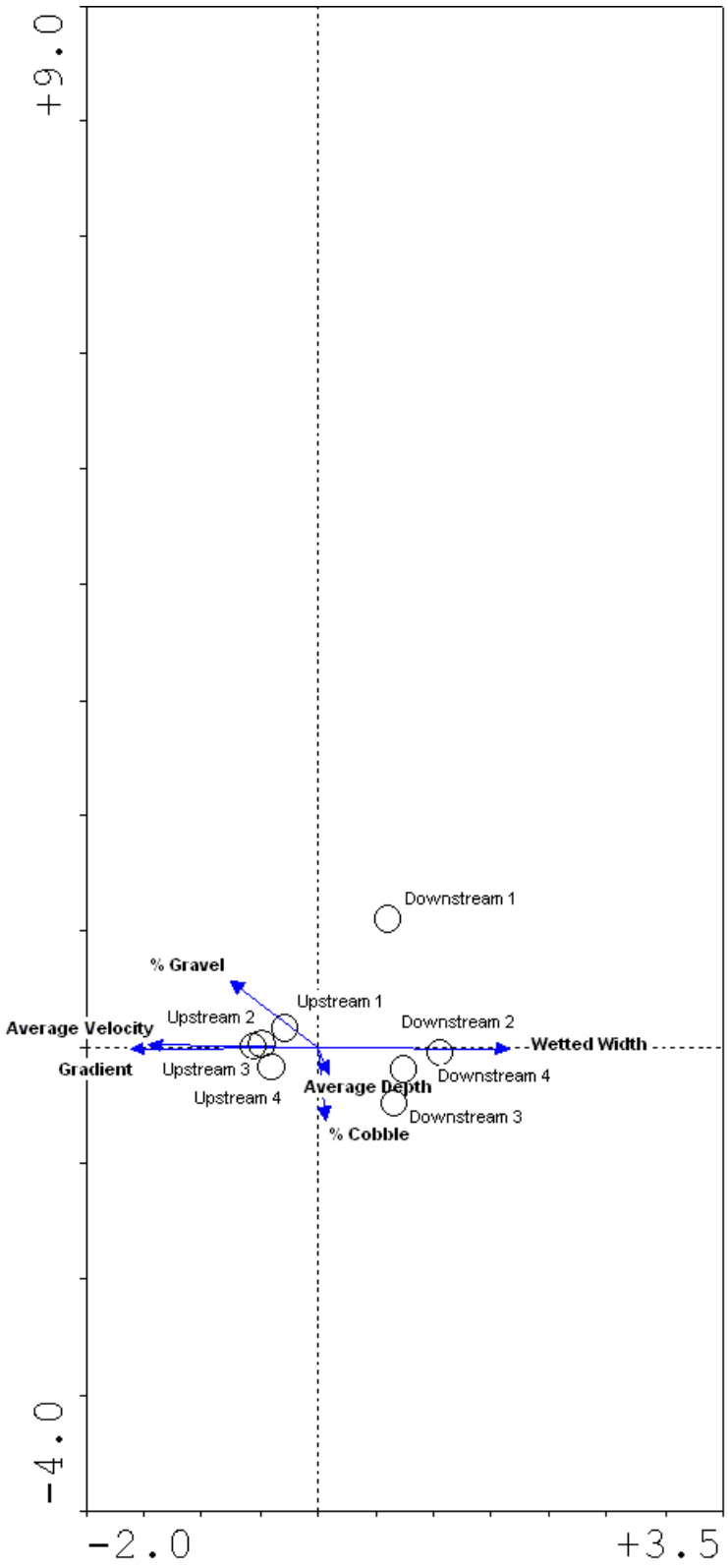


Figure 155. Canonical Correspondence bi-plot with the DeAtley river benthic macro-invertebrate site distribution and major physicochemical explanatory vectors.

Macrophyte Survey

On the day of aquatic plant sampling the visibility in DeAtley Pond was impaired by an algae bloom. The submersed plant community grew to a depth greater than 9 ft, suggesting that normally water clarity is not as bad. No invasive non-native species of concern were identified in the pond, with the possible exception of common reed (*Phragmites australis*), an emergent grass with both native and invasive varieties. Four submersed species were identified, a relatively low number. The dominant submersed plant was a native thin-leaf pondweed (*Potamogeton foliosus*).

Site 10 Comments and Recommendations

DeAtley Pond currently offers little habitat for native species. Reclamation opportunities are minimal and would not likely include any form of surface reconnection to the Yakima River. River and pond temperatures were the highest recorded in this study. Thermal impacts in the lower Yakima River Basin are already a concern to fishery managers. The water quality of the pond was poor. An above-average number of tolerant benthic invertebrate taxa were found in the pond. Active mining is disturbing surrounding ground, but noxious terrestrial and aquatic weeds were fairly minimal. Due to frequent pumping of the pond during processing, poor water quality, and thermal impacts, the only fish in the pond were common carp, which are tolerant of such conditions. In this reach, the Yakima River is populated with fish predators (smallmouth bass and channel catfish), making it an inhospitable environment for anadromous salmonids.

The elevation of the bed Yakima River is at times substantially higher than the pond. Minor breaches of the levee have occurred throughout the operation of the pit. Avulsion could threaten local infrastructure (including railroad bridges, the SR 240 Bridge, and the sewage treatment facility) and release an invasive reed species. Connection of the pond to the river would likely raise the local water table.

Recommendations

Reclamation of the DeAtley Pond as fish habitat by reconnecting it to the Yakima River is not recommended. Engineered solutions to maintain continued isolation should be sought.

15. ECOLOGICAL ANALYSIS OF THE YAKIMA RIVER BASIN

During the site analysis phase of the study, the Study Team found trends in the temperature and ecologic data suggesting similarities among sites grouped in the respective upper, middle, and lower geographic regions, or reaches, of the Yakima River (Figure 156). This longitudinal trends identified in this chapter should be considered in future policy revisions, permitting, project design, implementation and monitoring particular to the character of these reaches.

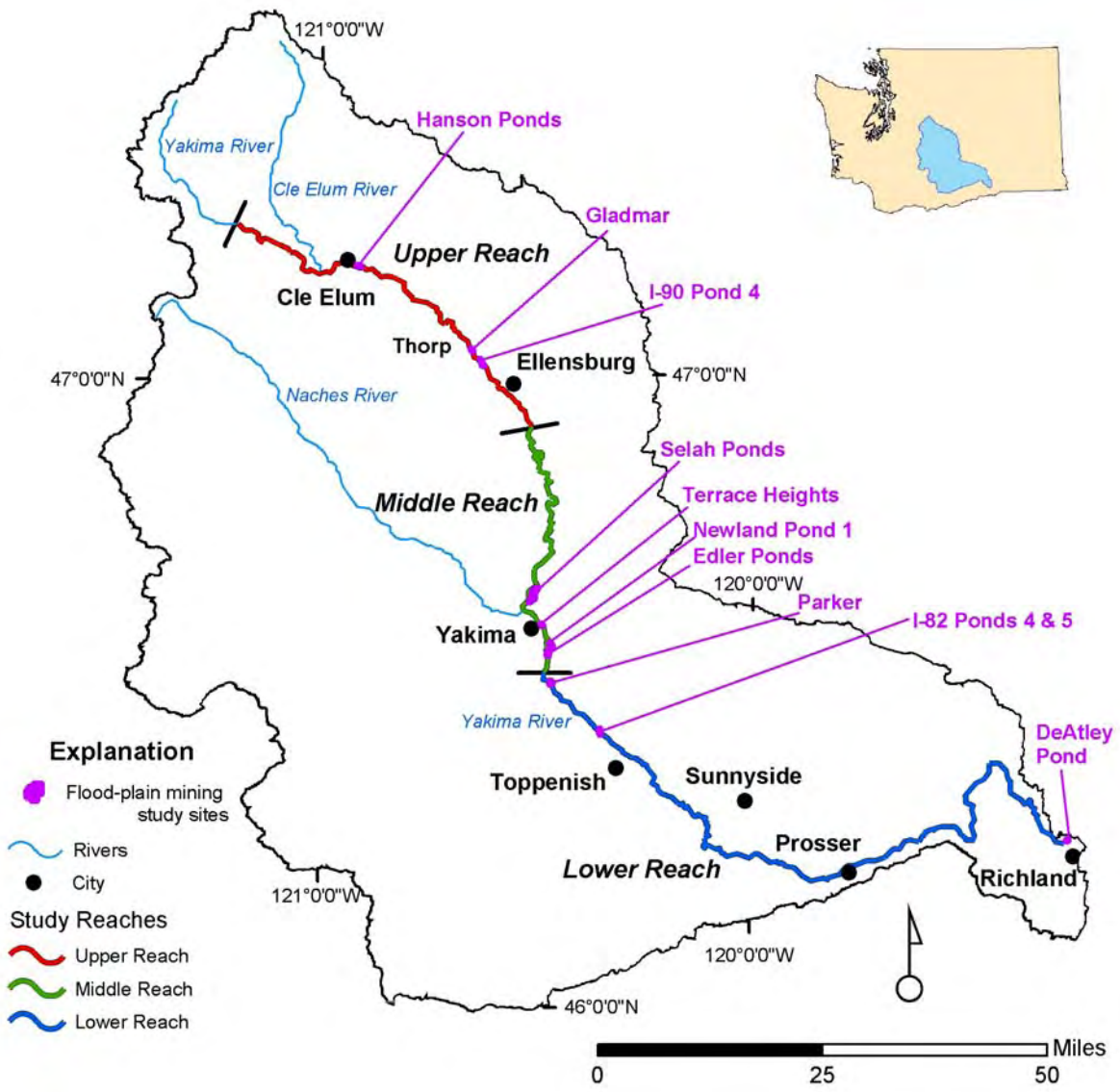


Figure 156. Reaches and floodplain mining study sites in the Yakima River Basin. Fishery managers believe the ecological or reach boundaries are defined by major water diversions that significantly reduce flow and introduce unnatural flow fluctuations, resulting in higher summer water temperatures that influence habitat and biological communities. The “upper reach” extends upstream from Cle Elum to the Yakima Canyon, the “middle reach” extends from Selah to Union Gap, and the “lower reach” extends downstream from Parker to the Richland.

Discussion of Thermal Investigation Results

Yakima River

Within the study area, three distinct site groupings were identified by temperature ranges in the Yakima River: (1) the "upper reach", containing sites 1 to 3 (Hanson Ponds, Gladmar, and I-90 Pond 4, (2) the "middle reach", containing sites 4 to 7 (Selah Ponds, Terrace Heights, Newland, and Edler Ponds), and (3) the "lower reach", containing sites 8 to 10 (Parker Ponds, I-82 Ponds 4 and 5, and DeAtley Pond) (Figure 157). The grouping was made on the basis of the period of temperature data collection, mid-April to mid-November 2002.

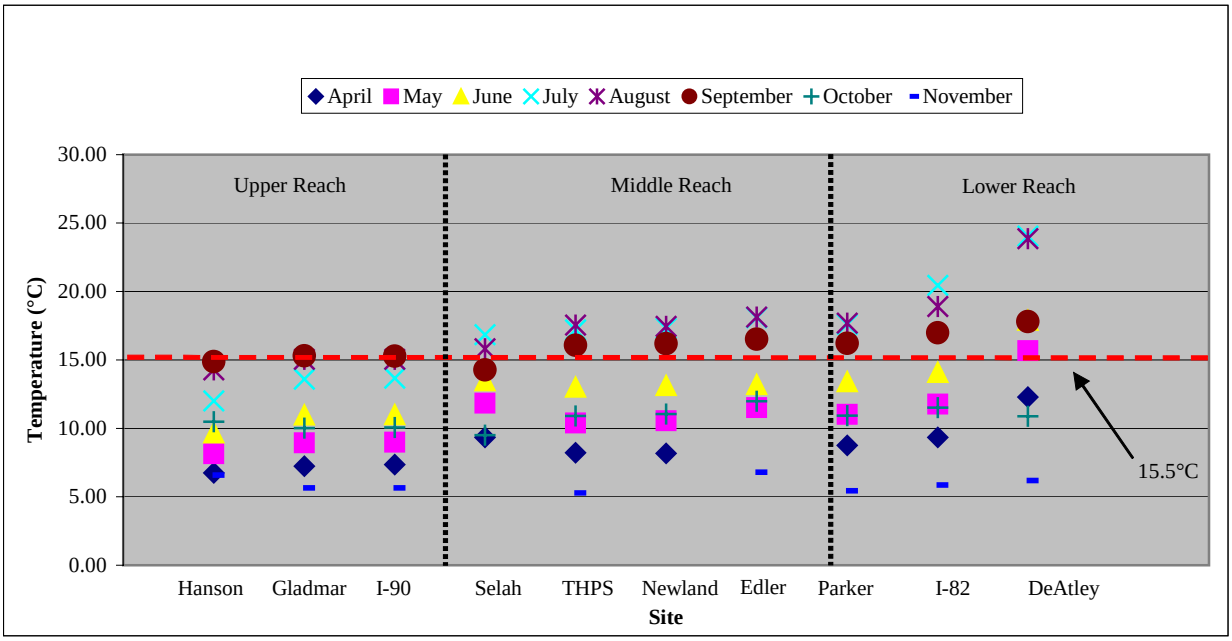


Figure 157. Average monthly Yakima River temperatures for the river site monitoring locations. THPS, Terrace Heights pond site.

Among variables directly measured in this study, average daily river temperatures seem to correlate to air temperature and flow, as observed in the time series graphs (see site chapters). Further, it appears that the relations may change depending on the season. Figure 158 shows the daily average flow at U.S. Geological Survey (USGS) gaging stations located nearest the sample sites.

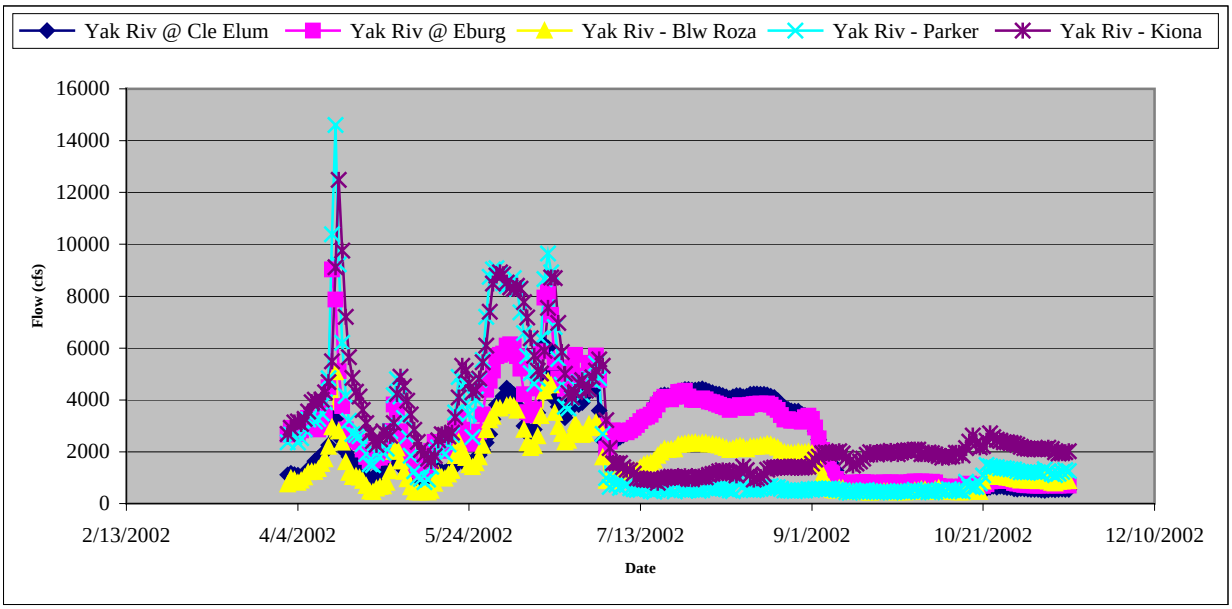


Figure 158. Daily average flow of the Yakima River during the thermal sampling period (U.S. Geological Survey data, 2002).

Two notable events are apparent in Figure 158. The first occurred from July 1 through July 3, when river flow abruptly decreased from nearly 5,000 cfs to about 2,000 cfs. The second event began on September 1, the date of “flip flop”, as river flows decreased over a 10-day period from about 4,000 cfs to about 500 cfs. Flow in the upper reach is controlled by Keechelus, Kachess, and Cle Elum reservoirs; flow in the lower reach is controlled by flows from the upper reach, plus flows released from Rimrock, Bumping, and Clear reservoirs.

Figure 159 illustrates the apparent relation among average daily river temperature, air temperature, and river flow in 2002. Average daily river temperatures presented are the average of the daily temperatures recorded by the upstream, downstream, and middle temperature monitoring locations at Hanson Ponds. Air temperature is the average daily temperature at the site. River flow is the daily mean measurement at the Cle Elum USGS gage station located near the Hanson Pond site. Data from the USGS gage station is real time streamflow that is relayed to the Survey’s District office through the Geostationary Operational Environmental Satellite (GOES) data-collection system. Data is transmitted from each station at intervals of either 3 or 4 hours and loaded onto the District's computer system.

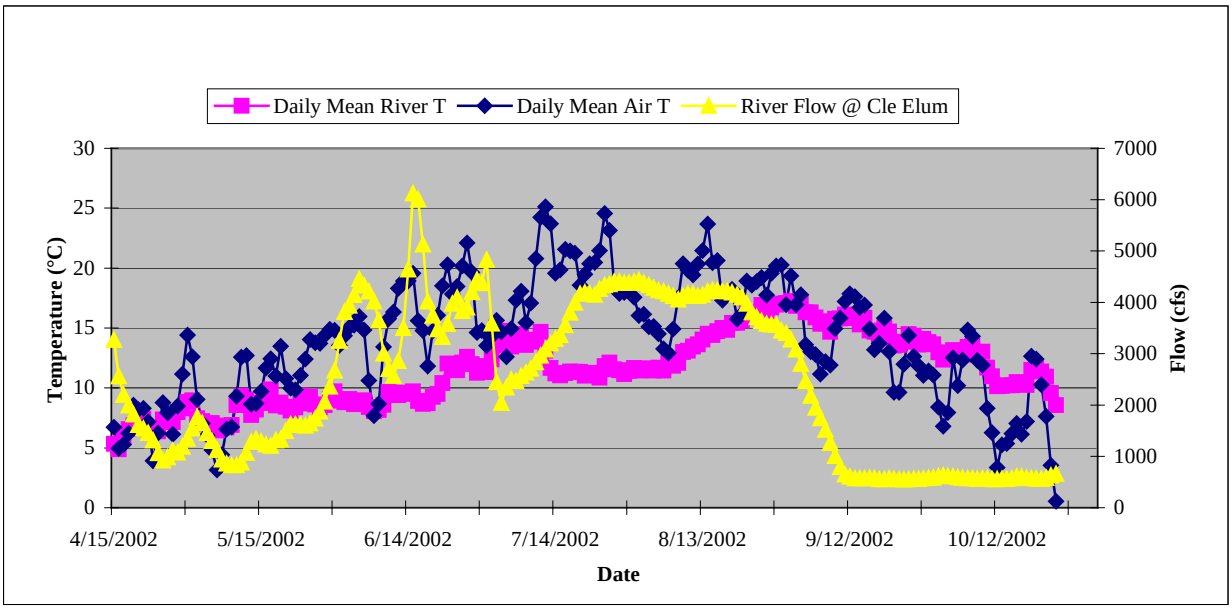


Figure 159. Relation between daily mean air and water temperatures and flow at the Hanson Pond site (U.S. Geological Survey data, 2002).

From April to mid-June, river temperatures were closely correlated to small changes in air temperature, as illustrated on May 6 and June 7, among other dates (Figure 159). River temperature at this time did not appear to be closely related to flow. Then, on July 1, with a drop in river flow, river temperature increased abruptly, and a simultaneous drop in air temperature did not affect river temperature as it had previously. Later short-term temperature changes were not correlated to river temperature, as seen in the air temperature increase on July 12 and the drop on August 6. This pattern held until "flip flop".

During the first two weeks of September, the period of "flip flop", when flows are halted from the reservoirs that feed the upper reaches of the Yakima River, river flows steadily decreased; air temperature and water temperature again appeared to be closely correlated, with decreasing air temperatures linked to decreasing water temperatures. By mid-September, river flows were nearly constant at about 500 cfs, while river temperature and air temperature continued to exhibit minor fluctuations in parallel. This may be explained in part by the fact that, in general, the smaller the water body, the more it is influenced by meteorological impacts including incoming solar radiation and long-wave radiation from nearby objects, among other variables.

The pulses of increased flow were observed to propagate downstream in the time series plots for each site for which there was a nearby gaging station. Major flow changes, such as the July 1 event and "flip flop", traveled from the uppermost site in the study, Hanson Pond, to the lowest site, DeAtley Pit, over a period of two days. At each site, observations similar to those at the Hanson Pond site could be made of the relations among river flow, river temperature, and air temperature, although flow conditions were modified by various diversions along the river. However, whether the apparent seasonal relations among flow and river and air temperatures are more than empirical observations can not be determined from this study, as there are additional

confounding variables that may be unique to each site; these would include the depth, shading, siltation, and other site-specific attributes that must be considered in further detail.

Upper Reach Sites (Cle Elum to Yakima Canyon)

In the upper reach, September was the warmest month (post "flip flop"), and April and May were the coolest. The highest average water temperatures were recorded between April and September, and in June and October average temperatures were very similar.

In this reach, the recorded average daily Yakima River temperatures did not exceed ~15.5°C, a value that falls just below the temperature range (15.6° to 23.9°C) known to increase stress and metabolic rates in anadromous salmonids. (Temperatures higher than 23.89°C are generally fatal to salmonids in any water body and at all life stages.)

The proposed new Washington State water-quality standard for temperature is a seven-day average of the daily maximum temperatures (7-DADMax). The not-to-exceed value for the Yakima River, from mouth to the Cle Elum River, is 17.5°C (WAC 173-201A, as amended July 1, 2003).

Middle Reach Sites (Selah to Union Gap)

The average monthly river temperature in the middle reach of the Yakima River (adjacent to the Selah Ponds, Terrace Heights, Newland Pond, and Edler Ponds [and Parker Ponds]) exceeded 15.6°C during July, August, and September. Overall, however, average monthly temperatures during the study period did not exceed ~18°C, which falls within the lower part of the temperature range that affects salmonids by increasing stress and metabolic rates. In the middle reach, the river temperatures were highest in July and August, and the river near Edler Ponds experienced the highest average temperatures of the study sites (Figure 157). At the Selah Ponds, the average daily temperature during September was lower than at the other nine sites.

Lower Reach Sites (Parker to Richland)

In the lower reach, the average monthly river temperature at both I-82 Ponds 4 and 5 and DeAtley Pond exceeded 15.6°C during July, August, and September; temperatures at both sites exceeded 20°C during July (Figure 157). During May and June, the average monthly river temperature exceeded 15.6°C at the DeAtley Pond site, and monthly average river temperatures from April through August were higher at the DeAtley site than at all other sites. Note again that the Washington State water-quality standards are based on daily maximum temperatures.

Ponds

A key observation is the apparent relation between the time of "flip flop" and the time of pond de-stratification (for the ponds deep enough to be thermally stratified). De-stratification in thermally stratified ponds appeared to follow "flip flop" by a few days at most.

Average monthly temperature data from the vertical stringers placed in ponds are shown in Figures 160 and 161. These temperatures are displayed for shallow (2 ft) and deeper (10 to 14 ft) recorder positions at four ponds (Hanson Pond 2, Selah Pond 1, Newland Pond 1, and I-82 Pond 5). At a depth of 2 ft, the highest temperatures were in June, July, and August, and they still exceeded 15.6°C May through September. At the deeper monitoring locations, average monthly temperatures exceeded 15°C July through September, reaching a high of ~24°C at Selah in August and 22.58°C at I-82 Pond 5 in July. Hanson Pond (in the upper reach) did not experience as high an average, but the temperature still exceeded 18°C May through September at the 10-ft depth; this lower temperature is believed to be a result of ground-water infiltration (Figure 161).

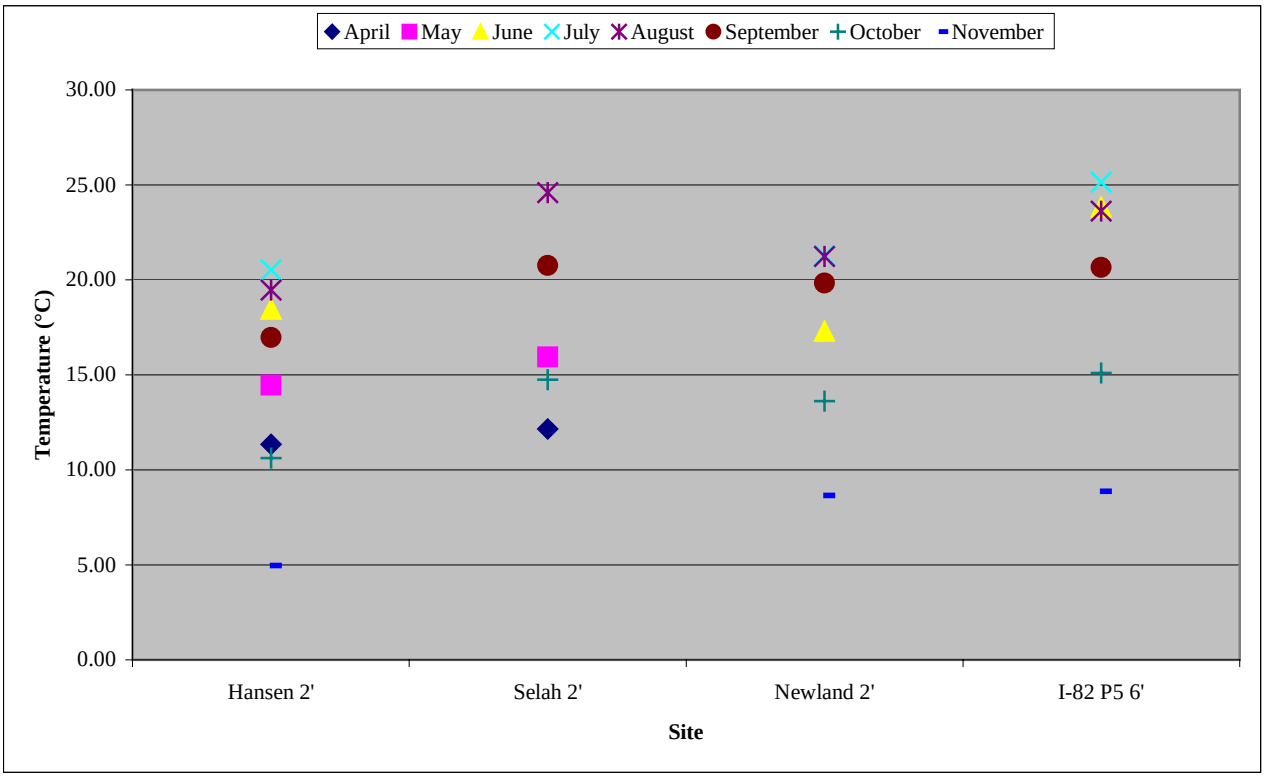


Figure 160. Average monthly water temperatures at 2-ft depths at Hanson Pond 2 (upper reach), Selah Pond 1 and Newland Pond (middle reach), and I-82 Pond 5 (lower reach).

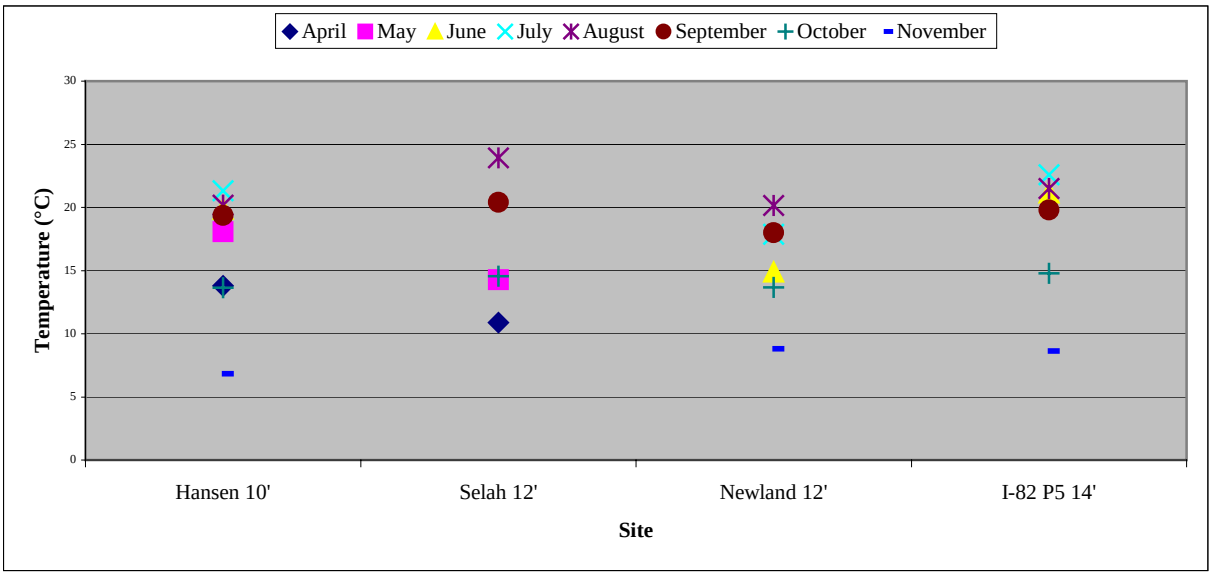


Figure 161. Average monthly temperatures at 10- to 14-ft depths at Hanson Pond 2 (upper reach), Selah Pond 1 and Newland Pond 1 (middle reach), and I-82 Pond 5 (lower reach).

The proposed new Washington State water-quality standards for temperature is a seven-day average of the daily maximum temperatures (7-DADMax). The not-to-exceed value for the Yakima River, from its mouth to the Cle Elum River, is 17.5^{o}C (WAC 173-201A, as amended July 1, 2003). The standards also state that when the Washington State Department of Ecology determines that the above standard is not protective of spawning and rearing in a specific water body, the 7-DADMax is 13°C during spawning and fry emergence for salmon and trout. (For further information, see the back of Appendix I.)

Table 56 shows the percentage of 7-DADMax measurements that exceeded 16°C (higher than the current standard [13°C]) in each reach. The correlation between river temperature and month (which generally determines the amount of incoming solar radiation) is evident in July and August; 7-DADMax percentages for 16°C then approach 100% in the middle and lower reaches. The middle and lower reaches began to exceed that criterion as early as April, while the upper reach remained below the criterion until July. Table 56 shows that the lower reach exceeded the 16°C temperature criterion earlier and more frequently than the middle reach. The middle reach exhibited the same character when compared to the upper reach. Spawning for salmonids and trout usually occurs from September into November in various parts of the Yakima basin. (Not all species found in the river spawn in the main stem, and steelhead and resident rainbow and cutthroat spawn in March through May.)

Table 56. Percentage of 7-DADMax temperatures that exceed 16°C; bold numerals are percentages above 50%.

Month	Upper Reach (%)	Middle Reach (%)	Lower Reach (%)
April	0	2	8
May	0	6	50
June	0	40	48
July	23	**99**	**100**
August	**63**	**97**	**100**
September	**78**	**84**	**98**
October	12	19	16
November	0	0	0

Table 57 shows the percentage of 7-DADMax measurements that exceeded 17.5°C for each of the three reaches. As in Table 56, the relation between river temperature and month is evident; high percentages of days exceeded the maximum temperature during July and August in the middle and lower reaches. However, the middle reach had a higher percentage of exceedances than the lower reach. This is likely due to the lack of data at the DeAtley site during midsummer. The lower reach began to exceed the criterion as early as April, whereas the middle reach was below the criterion until June and the upper reach remained below the criterion until July.

Table 57. Percentage of 7-DADMax temperatures that exceed 17.5° C; bold numerals are percentages above 50%.

Month	Upper Reach (%)	Middle Reach (%)	Lower Reach (%)
April	0	0	4
May	0	0	35
June	0	17	17
July	2	**82**	19
August	34	**78**	**54**
September	43	**63**	47
October	1	10	0
November	0	0	0

Basin Analysis Using Proposed Temperature Criteria

In 2002, spring, summer and fall water temperatures in the Yakima River and associated ponds increased from the upper to lower reaches. Water temperatures were lowest in November. At all sites, water temperature in the river decreased dramatically from September to October and again from October to November. For the rest of the year (April to October), temperatures between reaches and individual sites varied during the rest of the year as a result of flow regulation,

ground-water influences, irrigation diversions, different shading characteristics, channel geomorphology and other climatic variables.

Discussion of Fish Assemblages

Yakima River aquatic/riparian habitat and water quality differ significantly among the three major reaches: upper reach (Cle Elum to Yakima River Canyon), middle reach (Selah to Union Gap), and lower reach (Union Gap to Richland/river mouth) (Figure 156). The real or potential impacts of floodplain gravel pit mining are discussed within this longitudinal habitat context. Fish assemblages at the river sites within each major reach were broadly similar. Therefore, data from individual ponds were combined for the purpose of drawing broad inferences about gravel mining impacts within each major river reach. For this discussion, fish species have also been grouped into two broad categories to facilitate discussion of gravel mining impacts on fish assemblage: native or managed salmonid species, and salmonid predators/competitors.

Managed Salmonids

Chinook salmon, coho salmon, and steelhead trout (*Onchorhynchus mykiss*) were the only anadromous salmonids sampled. The only anadromous "species" (actually, "race") not sampled was fall chinook, which inhabits the lower Yakima River. Juvenile fall chinook were not present at Site 10 (DeAtley Pit) in late August when river sampling was conducted. Numerous *O. mykiss* were sampled in the upper river; most of them were presumed to be resident rainbow trout because few (5-10%) Yakima Basin steelhead migrate upstream of Roza Dam. (Juvenile resident rainbow trout and anadromous steelhead are indistinguishable from each other.) Mountain whitefish, sampled frequently during this study, are a resident native salmonid that in some river reaches are more abundant than chinook and *O. mykiss*, but they are not actively managed by WDFW other than by limits on daily harvest.

Salmonid Predators/Competitors

Many non-native cool- or warm-water fish species have been stocked into ponds and lakes in the Yakima Basin and, in some places, introduced intentionally or accidentally into the Yakima River. Species such as smallmouth bass, largemouth bass, pumpkinseed sunfish, and yellow perch are referred to here as "exotics". Most of these exotic species have inherently high reproductive potential, regardless of where they live. Even when not intentionally stocked (legally or illegally) to produce recreational fishing opportunity, these species often find a way to populate lakes, ponds, and streams. The only study pond intentionally stocked by WDFW with exotic species is I-82 Pond 5. Exotic species in the other study ponds were illegally introduced, entered ponds from the river, or perhaps entered ponds as eggs or juveniles through subsurface hyporheic flow. Some exotic species are native salmonid predators, others are competitors, and some are neither predators nor competitors.

Sampling methods used during this study allowed the capture or observation of 24 fish species or genera (generic dace, sculpins, suckers), 9 exotic and 15 native species. All non-salmonid species were grouped into three ecological trophic (food chain or web) groups based on potential interactions with native salmonids. Table 58 lists all species as either "exotic" or "native" and

Table 58. Exotic and native non-salmonid fish species captured during 2002 and presumed interspecific trophic relation to juvenile salmonids.

Exotic Species	Salmonid Predator	Salmonid Competitor	Opportunistic Feeder
Black crappie	**X**	**X**	
Bluegill		**X**	
Brown bullhead		**X**	**X**
Channel catfish	**X**		
Common carp		**X**	**X**
Largemouth bass	**X**		
Pumpkinseed sunfish		**X**	
Smallmouth bass	**X**		
Yellow perch		**X**	**X**
Native Species	Salmonid Predator	Salmonid Competitor	Opportunistic Feeder
Chiselmouth			**X**
Dace		**X**	
Mountain whitefish		**X**	
Northern pikeminnow	**X**	**X**	
Rainbow trout (hatchery)		**X**	**X**
Redside shiner		**X**	
Sculpin			**X**
Stickleback			**X**
Suckers			**X**
Western brook lamprey			**X**

then further classifies them as salmonid predators, competitors, or opportunistic feeders. Salmonid predators include species that selectively feed on salmonids if given the opportunity.

Although salmonids sometimes prey on each other, in this analysis salmonids were not classified as predators. Salmonids and their competitors compete for food and living space when co-existing in the same habitat. Opportunistic species feed on a variety of food sources and do not selectively prey on salmonids. Opportunistic species may prey on salmonids or be competitive in the food chain, but they are not strong predators or competitors.

Some species may fit in multiple categories if they exhibit both characteristics or if their feeding/rearing behavior changes with life stage. For example, yellow perch may be mainly competitors during early life stages, but this species can prey on salmonids if the appropriate conditions exist (e.g., adult yellow perch in a pond connected to the river preying on chinook salmon fry). Generally, the magnitude of negative interactions on juvenile salmonids follows a continuum from the greatest impacts from predatory species to the least impacts from opportunistic feeders. Species that have large populations have greater potential for predation/competition with salmonids.

Basin Analysis of Managed Salmonids

The Washington State Department of Fish and Wildlife and Yakama Nation manage the Yakima River to protect and enhance salmon (chinook and coho), steelhead, and resident trout (cutthroat, rainbow, and bull trout) populations for tribal subsistence and recreational fisheries.

Appendix K, Tables 38-40 display percent composition for managed salmonids at each site sampled (pond and river). Percent composition data for trout and salmon were plotted to compare study sites and to illustrate the contribution of trout and salmon to the total fish species assemblage at each sample site (Appendix K, Figures 5-7). These figures illustrate the differences and similarities in managed salmonid populations among sites sampled during this project. As expected, percent composition of managed salmonids decreases downstream from the upper to middle to lower river reaches, in both the river and connected ponds (avulsed or with surface outlet). Avulsed ponds in the upper and middle reaches had percent salmonid compositions similar to those in the adjacent river (Gladmar, Terrace Heights, lower Edler Pond after avulsion). Parker Pond 1 is not avulsed like Gladmar or lower Edler Pond, but the surface outlet allowed ingress of salmonids (3.3%) to about half the level observed in the river at Parker (6.0%). Appendix K, Figure 7 also illustrates the steep decline in managed salmonid abundance in the lower river from Union Gap to the mouth, concurrent with the decline in summer water quality suitable for salmonids.

Upper Reach (Cle Elum to Yakima River Canyon)

Data points for Hanson, Gladmar, and I-90 Pond 4 study sites are plotted (Appendix K, Figure 5) on the basis of chart data presented in Appendix K, Table 38. As expected, Hanson, Gladmar and I-90 Pond 4 river data shows consistently high levels of trout/salmon making up the assemblage, ranging from about 30% to 50%. Gladmar, an avulsed pond, is supporting salmonids at a level approximately equivalent to the river downstream at I-90 Pond 4.

As expected, I-90 Pond 4 currently has no value as native salmonid habitat because it does not have a surface outlet and is not avulsed. On the other hand, the Gladmar site, naturally breached in 1996, is gradually becoming high-quality river habitat suited to salmonid rearing. Hanson Ponds 1 and 2 were re-engineered and breached by the Yakama Nation in February 2004 and will provide off-channel habitat for managed salmonids. The I-90 ponds and other gravel pit ponds within the upper river reach have the highest potential to produce managed salmonids (juvenile rearing initially, spawning eventually) if connected to the river. Predatory northern pikeminow are a concern, but breaching can be designed to minimize the slower, deep “velocity interface” habitat preferred by adult pikeminnow for ambush feeding on salmonids.

Middle Reach (Selah to Union Gap)

The middle Yakima River fish assemblage samples have lower percentages of managed salmonids than the upper reach. Three of the four pond sites did not contain managed salmonids during sampling. Edler Pond 3, surveyed after a spring 2002 flood event and partial avulsion, contained managed salmonids at levels comparable to the adjacent river. The Terrace Heights site, which avulsed in the early 1970s, is riverine habitat and supports salmonids at a level equal

to or higher than the river sample reaches adjacent to the upstream Selah Pond 1 site. The other three pond sites have no inlets or outlets and very little surface-water interaction with the Yakima River, only when the river is at or near flood stage. (Sata for Selah Pond 1, Terrace Heights, Newland Pit Ponds, and Edler Ponds sites is tabulated in Appendix K, Table 39 and plotted in Appendix K, Figure 6.)

Lower Reach (Union Gap to Richland)

Collections of fish in this lower reach of the Yakima River had the lowest proportion of salmonids. Continuing the trend noted for upriver sites, Parker site, the site farthest upriver in the lower Yakima habitat zone, held the highest proportion of salmonids in this reach. The root cause of low managed salmonid abundance in the lower Yakima River is the poor quality of rearing habitat that is characterized by high summer water temperature and low flow and/or extreme flow fluctuations (frequency, magnitude) resulting from irrigation management, not interspecies competition from non-salmonids rearing in gravel pit ponds. (Data for Parker, I-82 Pond 5, and DeAtley Pit study sites is summarized in Appendix K, Table 40 and plotted in Appendix K, Figure 7.)

Basin Analysis of Salmonid Predators/Competitors

Percent composition of all exotic fish predators and competitors and native northern pikeminnow were graphed to illustrate the potential impact of these predators/competitors on salmonids at the study sample sites (Appendix K, Tables 41-43, Figures 8, 9, and10). Exotic species known to prey on native salmonids that were present in the study samples are channel catfish, black crappie, smallmouth bass, and largemouth bass (Table 58). Habitat where the species assemblage includes a high percentage of predators/competitors is less productive salmon habitat than where predator abundance is low. Appendix K, Figures 8, 9, and 10 also illustrate the potential for seeding the mainstem Yakima River with exotic fish species where ponds are naturally avulsed, inundated by flood water, or breached. On the basis of data collected at I-82 Pond 3, pumpkinseed sunfish and, to a lesser extent, northern pikeminnow and largemouth bass may be moving into the river from ponds where there is passage through a surface outlet. Obviously, when Gladmar, Selah Pond 1, or any ponds supporting exotic species are naturally avulsed, the fish in those ponds enter the river. Pumpkinseed sunfish were found in the vicinity of several ponds, indicating that gravel pit ponds may be seeding the river with this species.

Upper Reach (Cle Elum to Yakima Canyon)

Native northern pikeminnow were the primary salmonid predator at the Hanson Pond site and the avulsed Gladmar site. Exotic yellow perch and pumpkinseed made up 74% of the sample at I-90 Pond 4. Exotic fish predators/competitors were an important part of the pond species assemblages, but they generally were not frequently sampled in this reach of the river. (Percent composition data for the Hanson, Gladmar, and I-90 Pond 4 study sites is plotted in Appendix K, Figure 8, taken from data presented in Appendix K, Table 41.)

Middle Reach (Selah to Union Gap)

River sites have few exotic predators/competitors, and the Terrace Heights site is a good example of the species complex that would be expected in this middle reach of the Yakima River where a pond is fully avulsed and the river has completely "reclaimed" the pond site. Although there is likely some fish predation on salmonids, this site provides good salmon and trout habitat (Appendix K, Figure 6). The river sampling reach above the Edler Ponds was a slough that lies between the main river channel and Edler Pond 1. This slough supported the only significant number of exotic predators/competitors in the middle reach sample sites. (Data for Selah Pond 1, Terrace Heights, Newland Pond 1, and Edler Ponds sites is tabulated in Appendix K, Table 42 and plotted in Appendix K, Figure 9.)

Lower Reach (Union Gap to Richland)

The Parker Ponds, which are partially avulsed, and the adjacent river sampling reaches have the lowest proportion of native and exotic predators/ competitors (28.5%) in the lower Yakima River Basin. This was not unexpected because it is located at the upstream boundary of the lower river reach in the "transition zone" with the middle river area. Native competitors and/or opportunistic feeders dominated the assemblages in Parker Ponds 1, 2, and 5 (not avulsed), which reduced the relative abundance of salmonid predators. The site farthest downriver, DeAtley, has 100% exotic competitors (common carp), and the river, at least in August, was populated exclusively with native and exotic predator/competitors. (Data for Parker, I-82 Pond 5, and DeAtley Pit study sites is summarized in Appendix K, Table 43 and plotted in Appendix K, Figure 10.)

Conclusions

A grand total of 18,617 fish representing 24 species/genera (Appendix K, Table 44) were collected (or observed while snorkeling) and identified during the study. Fifty-three percent of the fish (9,862) were sampled in ponds and 47% in the Yakima River (8,755), including side channels and sloughs. Two exotic species, pumpkinseed sunfish (21%) and yellow perch (15%), followed by sucker (10%), chinook salmon (8%), and whitefish (8 %), were sampled most frequently.

Pond and river species assemblages differed significantly from upriver to downriver sample sites. Salmonids (whitefish, *O. mykiss*, and juvenile chinook salmon) contributed most to the species composition in the colder upper reaches of the Yakima River. Fewer species were present in the upriver pit ponds and adjacent river sampling reaches. Species diversity increased in the middle Yakima River reach from Selah to the Parker Ponds, but fewer resident and anadromous salmonids were present compared to the upper river above the Yakima River Canyon. Species diversity in ponds was high in the middle and lower river sample sites, except for DeAtley.

As expected, higher percentages of exotic species were sampled in the ponds in the lower Yakima Basin downstream of Union Gap than elsewhere in the basin. Summer water temperature, total suspended solids, and turbidity increased in the river below Union Gap, providing increasingly productive habitat for exotic and native predator/competitor species and

increasingly unproductive habitat for salmonids. However, exotic predator/competitor species and native northern pikeminnow did not make up more than 10% of the river fish assemblage, except at the Edler Ponds (37%) and DeAtley (100%) sites. Smallmouth bass were present in large numbers in the DeAtley river reach and not seen at any other site.

On the basis of data from the sampling efforts, similar species compositions were present above and below each pond site, but there were large differences in fish assemblages among upper, middle, and lower river sites. Complete numbers of fish sampled at each site, by method, location and percent composition, are presented in Appendix K, Table 45. As expected, more river fish species were found in ponds that have avulsed and that flood during high-water periods than in ponds that are isolated and not inundated by flood events. Ponds that have little or no surface-water connection to the river supported more exotic fish than those that are connected to the river. Ponds in the upper and middle river reaches (upstream from Union Gap) that are not directly connected to the river are considerably warmer than the river and provide ideal habitat for warm-water exotic species.

Discussion of Benthic Macroinvertebrates and Water Quality

Of the ten ponds studied, DeAtley, Edler, and Selah Ponds appeared to be the most eutrophic. The poor water quality noted in DeAtley and Edler Ponds coincided with cyanobacteria blooms and relative paucity of submersed macrophytes. Among the three avulsed sites, Gladmar and Terrace Heights had physicochemical and biological attributes similar to side channels, while Parker retained attributes more similar to the isolated ponds.

River water quality and benthic macroinvertebrate distribution were strongly correlated with elevation and river mile. Even though elevation and river mile coincide, the two variables have different ecological meanings. (See Table 59.) Elevation is a component of natural variability, and river mile accounts for largely anthropogenic variability. Cluster analysis results indicated that river benthic macroinvertebrates varied longitudinally along the river (i.e., river mile and/or elevation).

Table 59. Non-parametric correlation among river water-quality parameters, elevation, and river mile. Spearman's Rho is a correlation coefficient that ranges from -1 (perfect negative rank correlation) to +1 (perfect positive rank correlation); a Rho of 0 indicates no correlative relation between variables. Thus, this table shows that conductivity is less well correlated to elevation and river mile than it is to pH. The 2-tailed significance values refer to the probability of committing a Type 1 error, or concluding that a significant correlation exists when it does not. For example, a significance value of 0.002 has a 0.2% chance of committing a Type 1 error.

Parameters	Spearman's Rho	Significance (2-tailed)
Elevation – Temperature	-0.53	0.002
Elevation – Conductivity	-0.73	0.000
River mile – Temperature	-0.53	0.002
River mile – Conductivity	-0.73	0.000
Conductivity – pH	0.52	0.001
Conductivity –Temperature	0.51	0.002
Dissolved oxygen – pH	0.33	0.044

The macroinvertebrates also clustered strongly on site (i.e., above or below the pit), nesting in the overarching trend of longitudinal variability. Site clustering strongly suggests that some difference(s) in local setting was contributing to biological variation. When CCA (Canonical Correspondence bi-plots) was run with all 20 river sites (80 samples), river mile and elevation were again the most strongly correlated to site distribution, with channel width and water velocity also being important (Appendices L and M). The cluster analysis indicated that many of the downstream reaches had different biological community compositions relative to their upstream (above) controls.

What physicochemical variable(s) are responsible for the differences? All reach pairs, except at Newland, had at least a slight clustering of samples by reach in the CCA plots. Since the clustering was so slight, the variability could have been due to differences in stream setting. Alternatively, we could also expect differences caused by the presence of an avulsed pit between the reaches to occur. Gladmar and Terrace Heights had mixed biometric results, whereas Parker clearly had a higher quality biological condition above the avulsed pond.

In conclusion, relative to the upstream sites, pond water quality appeared to be more susceptible to eutrophication in the middle and lower Yakima valley. The benthic macroinvertebrate communities in these areas also showed signs of eutrophication stress, with relatively high HBI scores, and river temperature and conductivity increased downstream (Appendix L). In addition, every biometric indicated that biological condition worsens from upstream to downstream (Appendix L). This may be due to increased degradation in water quality or to other physical degradation such as fine sediments in riffle substrate. In general, river macroinvertebrate communities were fairly similar at (1) Hanson and Gladmar, (2) I-90, Selah, Terrace Heights, Newland, and Edler, and (3) Parker, I-82, and DeAtley (Figure 38). This supports the idea of longitudinal change in biological composition, but it also indicates that there are certain break points of habitat quality. These break points may be the result of a complex gradient that includes natural and anthropogenic factors (Cuffney *et al.* 1996).

Potential of the Studied Mine Sites for Fish Habitat—Management Considerations

Geomorphic Considerations

Pond location in the basin dictates to a large degree the water and air temperature and the fish and benthic invertebrate assemblages, indeed, habitat quality. However, the pond bathymetry, configuration, and location with regard to the river and the character of the river influence habitat quality and place some constraints on restoration actions. Moreover, land ownership, owner's intentions, zoning, and the location of highways and development should be thoroughly considered in management planning.

The primary geomorphic issues that must be considered in habitat restoration are

- Potential for natural avulsion (including the area available for natural channel migration) and consequences of avulsion,

- Amount, suitability, and location of sediment that can be transported into connected ponds at expected flows (including therefore gradient and hydrology), and
- Potential for channel changes to adversely affect local infrastructure.

A review of the conclusions and recommendations that accompany the texts for the 10 study sites shows that several geomorphic aspects of the sites created by mining require serious consideration. The text below is a condensation of the pond/river issues for each site. Table 60, which follows this discussion, summarizes issues to be considered.

Site 1 – Hanson Ponds. These ponds were connected to the river in February 2004. Flow through the ponds is controlled by rock grade drop structures to prevent uncontrolled avulsion and head-cutting erosion that may threaten nearby private property and infrastructure. The rate of conversion from pond to river side channel habitat will depend on the amount of sediment available for transport into the ponds under the flow range determined by the elevation of grade structures. Large woody debris has been placed in the ponds to improve juvenile salmonid rearing habitat and to provide escape cover from bird and fish predators in the near-term until the river has time to "rework" the site. Northern pikeminnow were not removed from the ponds before connection to the river because winter ice cover precluded capture using the boat electroshocker.

Site 2 – Gladmar. This site avulsed in 1996. As adjustment to the river hydrology continues, the site is potentially vulnerable to flood flows. The relation of available sediment to flow will determine the rate of recovery to desired salmonid habitat.

Site 3 – I-90 Ponds. Although they are not now connected to the river, sediment is carried into these shallow ponds during high-flow events. If reconnection is considered, the potential effect of channel shift on the highway and nearby bridges and the sediment/flow regime will have to be studied.

Site 4 - Selah Ponds. This site has poor river channel complexity due to 1996 avulsion and mining activity that included the construction of armored levees. These large ponds are privately owned, and the owner wishes to keep them for private recreation.

Site 5 – Terrace Heights. Avulsion 30 years ago has created near-optimal pre-mining habitat for salmonids at this site. Few traces of earlier ponds remain. The channel complexity and restored riparian vegetation provide a goal or "future desired outcome" for designing other pond-to-river reclamation projects.

Site 6 – Newland Pond. This large, deep pond is protected from the river by dikes and armored embankments that reduce the area available for channel migration. The site is used to collect mine slurry. Restoration of the habitat would have to be based on study of the availability of transported river sediment to "rework" the site in a reasonable time period and potential effects of reconnection on land ownership, zoning, and nearby highways.

Site 7 – Edler Ponds. The presence of dikes on both sides of the river here makes the ponds susceptible to avulsion; a flood in 2002 breached the downstream end of the lower pond and has

accelerated local bank erosion. Connecting the ponds to the river at the upstream end could enlarge the area available to attenuate floods and reduce flood damage.

Site 8 – Parker Ponds. The Yakima River now flows through these shallow ponds. The present flow is relatively low, which means that sediment transport and conversion to river side channel habitat will occur slowly, barring a major flood. The fairly impermeable Thorp Formation is the bottom of these ponds and permits little ground-water inflow. The ponds and adjacent areas also contain mining and other waste. Economics may well determine if connecting and filling the ponds is a better restoration tactic than isolating the ponds. Natural floods may convert this area to suitable habitat over time.

Site 9 – I-82 Ponds. Avulsion or reconnection of these deep ponds may result in damage to the highway and adjacent irrigation diversion and fish screen structures. WDFW intends to continue to manage Ponds 4 and 5 as lake fisheries for mixed or warm-water species and does not want the ponds connected to the river.

Site 10 – DeAtley Pond. This fairly shallow pond is pumped during mining operations, and its water level fluctuates as a result. The river level at this site is higher than pond water level, and there is significant potential for avulsion. Erosion following avulsion could threaten the water-treatment plant upstream and developments and bridges nearby.

Biological Considerations

Ponds in the upper and middle reaches of the Yakima River are best suited for breaching and connecting to the river because the river provides suitable salmonid habitat. Ponds in these reaches generally have fewer exotic predators/competitors than ponds lower in the system. However, presence of the exotics should not be an obstacle to breaching because the cold-water habitat should prevent warm-water species from becoming established.

A concern in the upper and middle reach, however, is the native northern pikeminnow, which can survive and reproduce in cold water, particularly in slower, deeper habitat that may result from breaching or natural avulsion. Reducing large northern pikeminnow populations before ponds are breached using mechanical removal methods or a chemical piscicide is probably warranted. Furthermore, breaching of ponds should be designed and implemented so as to rapidly convert the pond into viable river habitat for salmonids. Large areas of still or slow-moving water or inlet/outlet channels that significantly restrict river flow through the pond may result in increased water temperature and favor northern pikeminnow and exotic predators, thereby constituting a chronic death trap for salmonids.

Under current water management scenarios, lower reaches of the river provide marginal to poor habitat for salmon and trout during the summer. Gravel pit ponds downstream of Sunnyside Dam should not be considered for breaching and should be defended from natural avulsion to prevent creating a chronic source of salmonid predator/competitor “leakage” into the river. Leakage is of particular concern because juvenile anadromous salmonids overwinter in the lower river habitat (potentially entering breached ponds where abundant predators could cause high mortality) and migrate during the spring downstream to the Columbia River.

Impacts of future actions, such as avulsing currently disconnected ponds, or further reclamation of new ponds can be investigated by comparing the macroinvertebrate community condition with that of the samples collected for this survey.

Social Considerations

Social considerations generally apply to the whole basin. They center on land ownership as that affects the potential to change land use or configuration. Making any changes of this sort depends on obtaining funding. To optimize any assessment, data collection and other efforts should be collaborative with any other on-going such work. This basin wide analysis should provide baseline data for consideration of future floodplain mining proposals and enhancement or reclamation of existing sites within the respective "reaches" of the Yakima River (Figure 156).

Table 60. Matrix summary of site selection and decision issues. Reach limits are shown in Figure 156.

Management Issues	Upper Reach	Middle Reach	Lower Reach	General
Geomorphic Considerations	Degree and frequency of peak and long flow durations are limiting factors.	The gap-to-gap reach (below the Naches River confluence to Union Gap) has high sediment transport and deposition characteris-tics. Infill of shallow gravel ponds occurs at a preferable rate.	The channel migration zone is fairly expansive. Low seasonal flows must be addressed with regard to sediment transport capability.	Basin-wide sediment transport and geomorphology studies should be conducted. Channel migration studies at reach levels and assessments should be made. Project feasibility and design studies are needed.
Biological Considerations	Excellent river water quality and quantity and small populations of exotic species in the river suggest excellent potential for successful pond connection to river for salmonid habitat and production	Good water quality and quantity and small populations of exotic species suggest good potential for successful pond connection to river for salmonid habitat and production	Poor water quality and quantity and numerous predators in the river lower potential for suitable salmonid habitat.	Riparian conditions should be evaluated to determine impacts and mitigation and restoration needs. Seasonal water flow management by BOR and water demand by irrigation districts should be evaluated.
Social Considerations	The willingness of landowners to allow access to their land for restoration and/or to consider selling their property must be determined. Obtaining a funding source is necessary. All assessments should be closely coordinated with other assessments and data-collection efforts.			

16. RECLAMATION CONCEPTS AND RECOMMENDATIONS

Kondolf (1997) wrote, "A river channel and floodplain are dynamic features that constitute a single hydrologic and geomorphic unit characterized by frequent transfers of water and sediment between two components." Kondolf (1997) also mentioned that the basis for many environmental problems in river management today is human failure to acknowledge and understand connections between river channels and floodplains. Short-term decisions create long-term and often irreversible problems.

The integrity of healthy stream ecosystems within the Yakima River Basin has been compromised by some land-use activities, particularly flow regulation and channelization. These activities have, however, facilitated floodplain pit mining in and near the active channels of the Yakima River. Effects on floodplain habitat associated with this mining are significant and include loss of channel complexity, destruction of riparian zones, avulsion events, threats to ground-water quality, increased water temperatures, fish predation, and surface-water quality issues (e.g., lower levels of dissolved oxygen, changes in pH, increased loads of suspended sediments). All these impacts have been examined in this study.

Two primary questions related to floodplain mining are at the heart of this study:

- Where should future sand and gravel extraction sites be located, and how should their effects be mitigated?
- What can be done with existing pit sites to benefit native resident and anadromous salmonid species and other native biological communities?

Guidance for managing ecological impacts of floodplain mines is available in reclamation standards and in some of the results of this study.

Recommendations for Future Aggregate Resource Sites

Bedrock Resource Sites

WADNR geologists have identified, mapped, and quantified mineral resources in the Yakima and Toppenish 1:100,000 quadrangles (Dunn 2001; Weberling *et al*. 2001). These maps can guide selection of lands of long-term commercial significance for the needs of Yakima County. Mineral resources mapped by the WADNR are subject to four criteria (Weberling *et al.* 2001):

1. The strength and durability of the rock meet the Washington State Department of Transportation's minimum specifications for asphalt-treated base, a rock product used to construct some lower layers of asphalt roads.
2. The area of the deposit exposed at the surface exceeds 160 acres and measures at least 1,500 ft across the minimum dimension of the deposit, or the reserves exceed 10 million yd^3. The thickness of the sand and gravel or bedrock deposit appears to be in excess of 25 ft.
3. The 'stripping ratio' (ratio of overburden to gravel or bedrock) is less than one to three (1:3).
4. A few exceptions were included where unusually thick deposits or resources of special local importance were present.

The Yakima River Basin is rich in bedrock quarry resources. The two rock units that contain large volumes of high-quality bedrock are the Tieton Andesite and the Columbia River Basalt Group. The average commercial bedrock quarry in the basin is permitted to a depth of 83 ft, covers 23 acres, and has one foot of overburden (Weberling *et al.* 2001). Because these extrusive-rock resources are abundant and typically have fewer environmental impacts associated with mining them than floodplain sites, they may be more resource sensible economical in the long term.

Sand and Gravel Resource Sites

The Study Team believes that, in an effort to determine appropriate overall management strategies for existing pits, as well as the suitability of specific future sites for floodplain gravel pits and/or related fisheries enhancement proposals in the Yakima River Basin, consideration should be given to the following four overarching concepts:

- Future mines should be sited outside the 100-yr floodplain and, if at all possible, beyond the historic (100+ years) channel migration zone, as determined by aerial photograph and topographic map reconstructions. Data and observations within the Yakima River basin, as well as within other alluvial river systems of Washington State, show that natural avulsion into a mine pond is more likely to occur if a pond is situated within the 100-yr floodplain and historic channel migration zone.

- At some point in the future (perhaps at geologic as opposed to human time scale), the river <u>will</u> avulse some part of a floodplain gravel mine pits. Avulsion may damage infrastructure (e.g., bridges, dikes, sewer outfall pipes). An effort should be made to reclaim the site such that when avulsion occurs, there is a maximum benefit for salmonid habitat as well as protection of upstream and lateral public infrastructure. Future ponds, if permitted by local and state government agencies to be developed in the floodplain or channel migration zone, should be designed for connection to the river (due to future natural avulsion events) without endangering infrastructure or encouraging avulsion. Future ponds constructed in these sensitive locations should be designed and excavated to mimic river side channel morphology (length, width, depth, sinuosity) to accelerate conversion to river side channel fish and wildlife habitat when avulsion (natural or engineered) occurs in the future.

- Floodplain mining must not destroy intersections between the modern Yakima River channel and paleochannels where increased hyporheic ground-water flow to the river contributes a high concentration of dissolved oxygen. It is at such locations that salmonid populations congregate (J. Vacarro, U.S. Geological Survey, oral communication, 2003). A layer of gravel between the river and adjacent floodplain paleochannels should be left to increase hydraulic connectivity, protect ground-water resources, and benefit habitat for benthic macroinvertebrates.

- Ground-water flow into and out of mine ponds should be protected. Mining through the Holocene alluvium into underlying less permeable geologic units such as the Thorp or Ellensburg Formations should be prohibited by regulatory agencies because ground-water flow may be reduced. Ponds without ground-water inflow become stagnant warm-water habitat with low dissolved oxygen concentrations.

A review of existing practices and regulatory and policy tools used to evaluate the suitability or risk of specific floodplain gravel pit proposals and related fisheries/habitat enhancement projects should consider the information in this report and the recommendations presented. Furthermore, improving the effectiveness of practice and regulatory and policy tools so as to eliminate or further reduce impacts to the river is important to the development of policy related to this study.

Site Character

When considering reclamation of proposed future floodplain mines subject to the Surface Mine Reclamation Act (RCW 78.44), mine plan and site characteristics may trigger the need for information not typically developed by mining proponents. Proposed mining locations that require more detailed pre-development planning include: a proposed mine within a 100-yr floodplain; a site in a river stream channel and the 100-yr floodplain, and; and a proposed mine that will be deeper than the deepest part of the active channel. Norman *et al.* (1998) noted that information that may be required in the planning phase for these sites includes:

- A topographic map of the existing conditions and surrounding lands at a 2-ft contour interval and appropriate scale, which may require surveying the property;
- Maps and cross sections that show depths and locations of all bodies of water, the stream profile, and the measured elevation from a permanent station such as a nearby bridge, that elevation referenced to mean sea level;
- A geomorphic analysis that identifies historic channels and channel migration trends on the basis of examinations of all available data, such as historic aerial photographs and maps, and that considers geological and artificial controls on the channel, such as armored banks, dikes, bridges, dams, and other mine sites;
- A detailed chronology and description of historical precipitation, flooding, discharge, and sediment transport, including description of sediment sizes in and adjacent to the proposed mine site and information about any prior known ice-damming events;
- Maps of vegetation and analysis of its role in flood and erosion control, as well as a description of the relation between the sediment distribution and riparian communities, especially as that applies to bank erosion and avulsion;
- An analysis of avulsion or stream capture potential, including the consequences of stream capture, such as channel incision and scouring of a stream channel that is significantly wider and deeper than the pre-exiting river channel;
- An analysis of avulsion to consider potential damage to neighboring properties, fish and wildlife habitat, bridges, and rights-of-way and to evaluate the effects of existing or proposed dikes and levees and their long-term maintenance;
- Data on the length of time expected for refilling ponds with sediment;
- Evaluation of the hyporheic zone for potential effects on ground water and benthic macroinvertebrates;
- Identification of cold-water return areas to the main stem from upwelling or laterally from abandoned channels;
- Thorough description, with appropriate maps and engineering drawings, of all proposed mitigation measures to address impacts to fish and wildlife and their habitat of avulsion and stream capture, river morphology, and structures;
- Data from monitoring temperature of ground water, surface water, and air before, during, and after mining;

- A geohydrologic analysis that addresses channel stability, magnitude and frequency of the 5-, 10-, 25-, and 100-yr floods, channel and floodplain hyraulics near the proposed mine site, and any previous stream capture events;
- Identification and evaluation of losing reaches or downwelling areas; and
- Evaluation of the effects of dewatering during mining on local springs and brooks.

Reclamation Standards for the State of Washington

Long-term reclamation objectives for sand and gravel mines include returning pits to a "stable, usable condition and [producing] an area that blends with its surroundings" (Norman and Lingley 1992). Minimum allowable reclamation standards for these mines in Washington State are defined in the Surface Mine Reclamation Act (Chapter 78.44 RCW).

According to Norman *et al*. (1997), four strategies generally can be used in surface mine reclamation, and some mines may use all four of these strategies:

- Post-mining reclamation—reclamation only after all resource have been depleted from the entire mine;
- Interim reclamation—temporary reclamation to stabilize disturbed areas;
- Concurrent (progressive or continuous) reclamation—reclamation as minerals are removed; overburden and soil are immediately replaced; and
- Segmental reclamation—reclamation following depletion of minerals in a sector of the mine.

Segmental reclamation has economic advantages over the other processes because it costs less, less material is removed, and it establishes final slope angles during the excavation process instead of as a separate process. The Washington Legislature has recognized segmental reclamation as the strategy of choice and adopted it in 1971 as part of the Surface Mine Reclamation Act (Norman and Lingley 1992). However, all the above strategies assume that the site will remain stable over a long period of time. Traditional reclamation strategies may not be fully applicable in a dynamic area such as a floodplain. For that reason, Norman and Lingley (1992) noted "a good operating and reclamation plan should be simple, practical, and easy to implement" and "the plan should be flexible and take into account the potential for unanticipated changes ..."

In general, an acceptable reclamation plan describes in detail:

- The ground-water hydrology and how the site will be mined (wet or dry);
- Existing topography;
- Subsequent use of the land, appropriate for the location of the mine;
- Sequence of stripping, storing, and replacing topsoil on mined segments;
- Designated overburden storage areas beyond the limit of mining but positioned for the shortest possible downhill transport during reclamation;
- Location of waste rock piles and how they will be reclaimed and stabilized;
- Final grades and shapes of the pit walls and floor to incorporate sinuous contours and effective drainage;
- Permanent drainage and water-control systems;

- The schedule of planting to assure survival of new vegetation;
- Specifications for ground-cover plants to minimize erosion and establish conditions that will increase the survival rates of trees;
- Specifications and schedules for planting trees to make use of conditions established by a healthy ground cover;
- Locations of trees planted to stabilize the site and generate a new humic layer; and
- Other information pertaining to the permit and required by statute.

Mine site managers and senior equipment operators must be familiar with the reclamation plan in order to ensure its proper implementation. However, reclamation design and implementation practices as they pertain to Washington's Surface Mine Reclamation Act have been subject to a wide spectrum of interpretation and implementation success. Effective reclamation plans in eastern Washington are harder to design and implement because of the dry climate and high summer temperatures that characterize the region.

Reclamation of Existing Floodplain Mine Ponds

Biological Considerations

Even though habitat near floodplain mining may have been significantly altered, a well-planned site with the appropriate reclamation strategy has the potential to enhance off-channel habitat. Exposed water surfaces can be especially attractive to waterfowl and riparian organisms under the right conditions. Exotic fish and plant species often out-compete native biotic communities and therefore must be accounted for, and precautions must be taken to avoid the temptation of solving complex problems with quick solutions. Analysis of fish assemblages and benthic macroinvertebrate communities by reach can provide important guidance during pond reclamation analysis and development of specific reclamation recommendations.

When considering the reclamation of existing gravel ponds that may have not been reclaimed under the Surface Mine Reclamation Act, biological issues must be explored. Questions that should be addressed include:

- For what fish and wildlife species is reclamation intended?
- What is the location of the pond(s) in relation to the active channel(s)?
- Is the pond too deep or too shallow for salmonid habitat?
- Is the slope/gradient of the pond(s) too steep to sustain a healthy littoral zone?
- Is the pond connected to drains or other surface-water features?
- Is there ample shade from native riparian vegetation, or can trees be planted and successfully maintained?
- Is the pond stocked or utilized by exotic predator fish species?
- Are there, or will there be water-quality issues?
- How will reclamation affect channel morphology and sediment transport processes?
- Could the strategic removal/percolation of dikes/levees improve existing conditions?
- Can the river be reconnected to the pond at more than one entrance upstream and downstream?
- Is the pond at immediate or short-term risk for capture by the active channel? What are channel migration rates?

Byrant (1988) found that the design of artificial ponds for successful coho salmon rearing habitat should include adequate water quality, supply, and access throughout the year (particularly through the winter) via perennial flow of surface water into the pond. Ideally, that flow would be provided by constructing an upstream inlet from the stream to the pond and a downstream outlet from the pond to the stream. The average depth of the access corridors (inlet and outlet) should be greater than 2 m, and the corridor margins would be planted with native riparian vegetation to provide shade and cover.

While Bryant's study had successful results, that research was performed in western Washington, where the climate and hydrology are more suitable for reclaiming ponds as fish habitat than in the eastern part of the state. Furthermore, the target species (coho salmon) can easily adapt to various types of spawning and rearing habitat; thus, other anadromous fish with specific habitat needs may not be able to utilize such an engineered site.

Another important feature of reclaimed off-channel habitat for productive fish habitat is the littoral zone within the pond. Littoral zones, the gentle slopes of ponds that allow enough sunlight to support diverse near-shore aquatic plant communities, should be less than 1 m deep (Rumble 1988).

Floodplain Pits as Salmon Habitat

All river-dwelling salmonids (resident or anadromous) in the Yakima River and other river systems require cool flowing water, shelter, and suitable food sources to thrive in off-channel habitat. The various species of Yakima River salmonids have requirements during their life stages that differ enough that optimal conditions for one species are not necessarily optimal for another. Any pond connected to the river is likely to have or can attract competitor or predatory fish whose presence will limit salmonid utilization. Consequently, the planning process for both reclamation and siting future mines includes evaluating physical and biological variables.

Norman *et al.* (1997) have suggested the following questions regarding selecting sites for creating off-channel habitat for salmon:

- Is the section of river or stream near a site used in any way by salmon, such as for spawning, travel to spawning areas, or for rearing fry?
- Will the depth of excavation be shallow enough to provide salmonid spawning habitat, but deep enough to provide cold-water rearing habitat?
- Will the final substrate of the excavation be suitable for the habitat desired?
- Is there sufficient water circulation to provide oxygen and keep the pond cool?
- Can an outlet channel to the river be placed where it can be easily found by migrating fish?

These questions identify general considerations for off-channel habitat design. Because of inherent characteristics of floodplains, other questions need to be asked regarding a proposed action:

- What types of habitat are lacking in that reach of the river and the river basin as a whole?

- What are the constraints to reclamation implementation (e.g., ownership, risk/liability, funding, permitting, and monitoring and management problems)?
- How does the reclamation plan contribute to cumulative river processes and function?
- Will the action enhance or limit channel complexity?
- How will adjacent and future land uses affect the site? Will there be public or private access?
- Will the site be allowed to evolve under "normative" flooding and subsequent channel change?

Before attempting to model Yakima River Basin reclamation projects, it is important to identify what types of fish habitat are lacking throughout the basin and for which species reclamation is intended. Preferred spawning and or rearing habitat for Yakima River managed salmonid species (including spring chinook, fall chinook, coho, steelhead, rainbow trout, cutthroat trout, and bull trout) can be highly variable. Furthermore, the Yakima River Basin has greater water quality and quantity problems than western Washington, along with a notable warm-water fish problem in the lower river ecological reach under the current water management regime. Thus, applying the western Washington selection and reclamation process in the Yakima River Basin would not necessarily yield positive results.

Creating Channel Complexity

Connection of gravel pit ponds to rivers or avulsion of some shallow, small existing mine sites may be beneficial to salmonid habitat by increasing channel complexity, especially in reaches of the river where natural channel complexity has been compromised by encroachment of engineered structures (e.g., dikes, abutments) (Norman *et al.* 1998). The Terrace Heights mine site is a good example of unplanned avulsion leading to habitat creation. However, it has taken about 30 years for channel habitat (including riparian vegetation) to reach to a quasi-natural state (Clark 2003).

The extent and connectivity of the mine site to the hyporheic zone will affect water quality (Norman 1998) and temperature in ponds, and thus the viability of salmon habitat. The underlying geology of the mine site generally determines this connectivity. A deep mine can adversely influence hyporheic ground-water flow to adjacent stream channels (Norman *et al*. 1998). For example, if the Holocene alluvial layer is thick, there is an increased likelihood of high hydrologic connectivity between the river and adjacent mine site, including the upwelling of cool ground water with high dissolved oxygen concentrations into the mine site. On the other hand, if thin alluvial deposits (such as at the Parker site) are underlain by impermeable units (such as the Thorp or Ellensburg Formations), there may be little ground-water upwelling into the mine site, or the upwelling of deeper ground water that does occur has low concentrations of dissolved oxygen because of the low permeability. Therefore, it is essential to understand the distribution of the gravel at the site so as to avoid compromising connectivity during reclamation.

Mine depth influences the amount of upstream river incision that occurs after a natural or engineered avulsion event, and thus the alluvial material that may be carried in to the pond and replace substrate. Detailed reach-scale flow regime studies will be thus important to planned

avulsion. Factors that should determine whether a site is a good candidate for connection to the river include:

- The geologic character of the sediment/rock underlying the alluvial gravels of economic interest. Basalt, clay, and gravels in clay matrix make undesirable substrate for a mined pond floor because of the reduced potential for ground-water flow into the pond.
- The available in-channel sediment load upstream of the planned avulsion point.
- The amount of sediment in erodible banks and bars available upstream of the avulsion point.
- The ability of bank-full discharge to transport available sediment (potential stream power of reach [Stanford *et al*. 2002]).
- The depth of the mine as it affects the gradient of a potential knickpoint, and potential effects of headward erosion on cultural features in upstream reach.
- The length of time needed, on the basis of sediment flux studies, to aggrade (fill in) the mine pond under the normal river flow regime.

Particularly important to fish habitat is the amount of flow into the connected or avulsed pit, especially during summer low-flow periods. Too little water entering the pits from the river may result in high water temperatures and, in places, oxygen-poor conditions at the lower end ponds (such as the Parker site). Therefore, two other factors need to be closely examined:

- The historic flow regime at the site.
- The location of upwelling ground-water flow paths. If no such ground water is present, the mine site may be a poor candidate for forced avulsion if sufficient surface flow is not assured.

Any planned pit-to-river connection must be coupled with monitoring of the site before and after the connection is made to evaluate effectiveness.

Summary and Next Steps

A decision framework to identify beneficial overall management strategies for existing or future pits should be based on the integration of the technical results and recommendations and the policy components identified in this final report. Further analysis of fish assemblages and benthic macroinvertebrate communities in priority river reaches identified by Stanford *et al.* (2002) may provide important guidance in regional pond reclamation considerations and recommendations for the Basin. In addition, the depth, shading, flow, and other site-specific attributes of each site should be considered when investigating the sediment transport and geomorphology of the reaches of the upper and middle Yakima River Basin. The complexity of the floodplain condition and ecology suggests that management will be refined over time as information is acquired. For example, the impacts of future actions at existing ponds, such as connecting currently disconnected ponds or reclamation of new ponds, can be investigated by comparing the sequential macroinvertebrate community conditions with the community samples collected for this study, and from that, timing or magnitude of actions may be altered.

The study team identified two categories of work remaining to refine planning for reclamation and for selecting future mine sites:

- Develop a list of additional potential reclamation and fisheries enhancement projects for future funding (beneficial sites not researched during this study).
- Devise risk assessment approaches for evaluating future gravel mining operations (e.g., permits) and related fisheries enhancement proposals.

The most beneficial and appropriate way to address these two categories of work is to complete a basin-wide study of sediment transport and geomorphology. A sediment budget is a key component in understanding both short- and long-term impacts of removing alluvial sediment for use as aggregate resources and for habitat (side channel) creation, as well as for knowing which existing pond sites are suitable for reclamation, given the current and likely future hydrograph conditions.

A draft proposal for necessary work has been completed by Hilldale (2004) of the Bureau of Reclamation Technical Services Center in Denver, Colo. The Floodplain Mining Impact Study Team is working in collaboration with various organizations and agencies to finalize the scope of work and secure funding for the completion of this work (see Appendix O).

Guiding the sediment transport and geomorphology study proposal is the conclusion from experience that reclamation projects are often under-studied and over-engineered, contributing to higher financial and environmental costs of many projects. Therefore, future studies may conclude that under suitable hydrogeomorphic circumstances, allowing “normative” river processes to perform the majority of the work will be both financially efficient and beneficial to the floodplain ecosystems. The sediment transport and geomorphology study would supply the basic information to identify the most beneficial and cost-effective sites to reclaim.

Based on the research findings of this study, it appears entirely possible for a balance among mining and fishery interests to be achieved if appropriate regulatory policies are coordinated, developed, and implemented between local and state regulatory agencies and coordinated with industry. The Study Team suggests gravel mining companies may secure future access to aggregate, but in a more costly, environmentally sensitive manner if they want to mine in the channel migration zone or 100-yr floodplain. These projects could be submitted as habitat reclamation projects or channel reconstruction/floodplain regrade work with the operational and reclamation design approved by all the regulatory agencies, including WDFW for the Hydraulic Project Approval. Less efficient, more costly excavation and reclamation requirements (e.g., creation of long, narrow, shallow, sinuous pits that mimic a river side channel) will increase the cost of those aggregate products, which pit operators will pass on to the public. This will “internalize” the environmental costs of gravel mining (“cost of doing business”), something that rarely occurred in the past. Mining and reclamation criteria might well be less stringent if alternative upland sites outside of the 100-yr floodplain are developed in lieu of targeting the floodplain.

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