Yakima River Floodplain Mining Study – Interim Report

Pond Bathymetry and Sediment Particle Data

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II. Site Analysis and Recommendations

Site Analysis Overview: PIT BATHYMETRY, GEOMORPHIC RELATIONSHIPS, AND SEDIMENT PARTICLE DATA ANALYSIS AND INTERPRETATION OF SEDIMENT DISTRIBUTION FOR TEN GRAVEL MINES ALONG THE YAKIMA RIVER FLOODPLAIN

The following is a summary of the geomorphic setting, pit bathymetry and sediment particle data and analysis for the 10 specified mine sites examined along the Yakima River floodplain (Figure 1). Included is a description of the methods used for analysis, the general geomorphic and stratigraphic setting, pit bathymetry, sample locations, sediment in terms of the Unified Soil Classification System, grain size distribution, explanation of sediment deposition patterns with respect to flow regimes of the Yakima River, and recommendations for best management practices for floodplain sand and gravel mines of the Yakima River basin with respect to geologic and geomorphic conditions.

All of the mines studied have been developed in recent fluvial deposits of the Yakima River–comprised of unconsolidated to compact conglomerate as much as 25 m thick; and consisting of rounded clasts of quartzite, diorite, volcanic porphyries, basalt, micaceous quartzo-feldspathic sand matrix, and over bank sand, silt, and minor clay facies. Pits at the Selah, Parker, and WSDFW 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 Ma) (Walsh 1986; Schuster, 1994). Thorp sediments comprise the floor of the three above–mentioned pits, and consists of a conglomerate of coarse sand and gravel; moderately to highly weathered and poorly indurated stream terrace deposits; and includes a mainstream facies containing rounded to sub-rounded clasts of durable silicic to intermediate volcanic rocks (Waitt, 1979).

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

- The method of mining (e.g. shovel, excavator, or tower-dragline and whether or not the pit was wet or drained during mining) has an influence upon mine depth and sediment distribution within the mine site.
- Purpose for mining (e.g. interstate highway fill material vs. commercial aggregate source) may influence pit location, spatial extent and depth.
- Thickness of Holocene alluvial gravels in the mined reach and whether or not the alluvial gravels were mined down to the top of the Thorp Formation, which consist of gravel

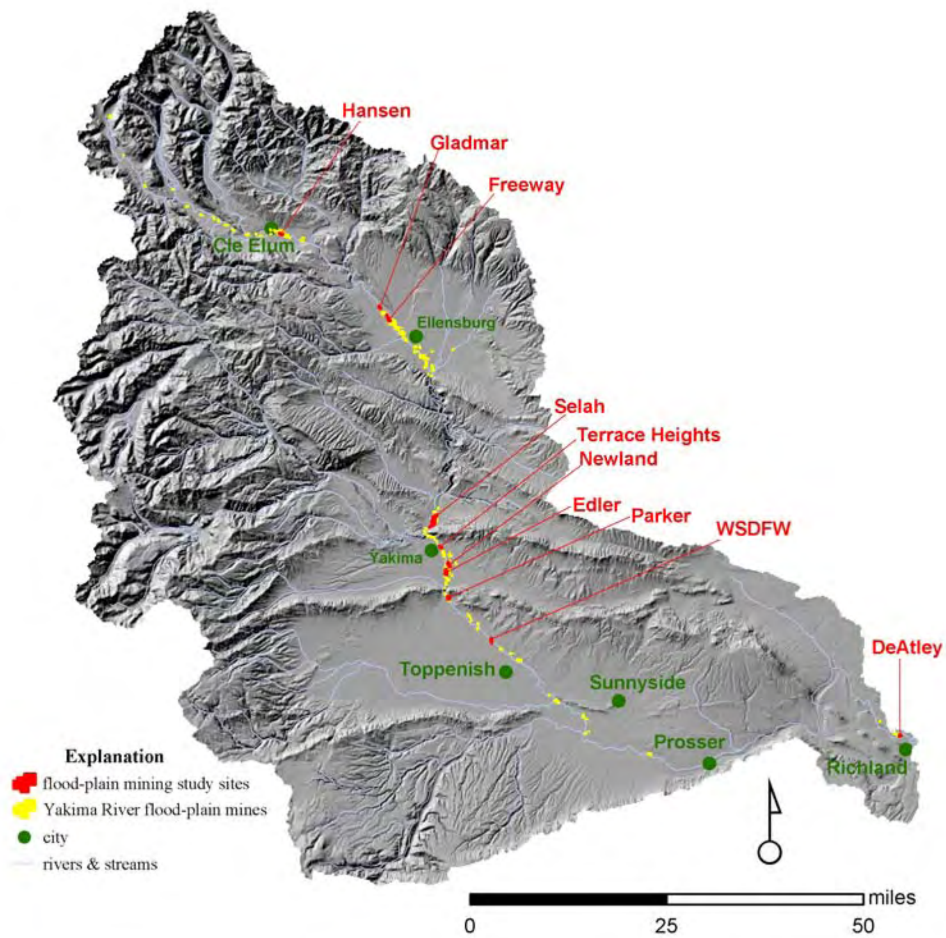

Figure 1. Map showing location of floodplain mine study sites within the Yakima River basin

embedded in a fine sand, silt and clay matrix with low hydraulic conductivity values as compared to the Holocene alluvial gravels of the Yakima River (Selah (Golder Associates, Inc., 1998), Parker (Norman and others, 1998), and WSDFW ponds).

- Initial proximity to the river channel, the amount of geomorphic work capable along the specific reach of the river as a function of reach-scale steam power potential (rates of channel migration and avulsion), upstream sediment availability, and man-made structures such as dikes and berms adjacent to the mine site (e.g. Stanford and others, 2002).
- Connectivity between the river and its floodplain aquifer in the vicinity of the mine pit (extensiveness of hyporheos zone along the mined reach)
- Post-mining history of the mine site, including whether or not the pit:
    - Is now permanently connected to the river via a natural or man-made ingress (avulsion) channel. If connected to the river, the location and size of connection with respect to river discharge and water velocity may impact sedimentation and water quality within the pit (Gladmar, Terrace Heights, Edler (south pond), and Parker).
    - Dikes are overtopped (but not breached) during subsequent 100-year flood events (e.g. 1996 Yakima River flood) impacts sediment distribution on pit floors, with dispersal of washed-in fines amongst coarser pit-floor gravels (Hansen and Freeway ponds).
    - Used as settling pond for fines derived from an adjacent gravel-mining operation (Newland).
    - Used as site for waste rock deposition (Parker).

Methods

Bathymetric Modeling and Geomorphic Analysis

Pond bathymetry measurements were collected for all of the study pits with the exception of the Terrace Heights pit (presently filled in after a river avulsion event into the pit in the 1970's) (Figure 1). Bathymetric measurements were made from a 10 ft long aluminum Sylvan John boat, powered by a Minn Kota Endura-40 electric boat motor (figure 2). Depth soundings were performed by one of two methods: (1) A 200 ft (60 m) Leitz plastic measuring tape, weighted with 2.95 lb (1.34 kg) of lead, was lowered over the side of the boat until it touched bottom. The water depth was measured on the tape at the tape-water interface (Hansen and Freeway ponds). (2) And by a Humminbird 300TX tri-beam Sonar that forms a continuous 90-degree area of uninterrupted bottom coverage, with measurement of water depth directly underneath the boat to an accuracy of ± 1 ft (0.3 m) (all other ponds). Periodic comparison between the Humminbird sonar and weighted-lead line insured data consistency. A hand-held Garmin GPS instrument was used to acquire a spatial geographic reference point (GPS waypoint) for each bathymetric measurement. Waypoints were collected in decimal degrees utilizing the World Geographic System Datum of 1984 (WGS84). Waypoint accuracy was generally 15 ± 5 ft (4.5 ± 1.5 m). Water depth, waypoint, and notes concerning pit geomorphology and sedimentology were recorded in a field notebook.

Pond bathymetry was modeled utilizing GIS (ESRI ArcInfo and ArcView) and contouring and 3D 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 (Appendix I). 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) as well as the Yakima River were digitized in ArcView utilizing 1996 Department of Natural Resources (DNR) digital orthophotos, which have a 3 ft (1 m) pixel resolution and a horizontal accuracy of ± 20 ft (6 m). The digitized perimeter of the Yakima River was approximated at bank-full width. Spatial data (longitude and latitude values) were exported from ArcView into Surfer. Data-point distribution maps (post maps), modeled contour maps, 3-dimensional surface maps, and geospatial grids were constructed from the spatial and depth data collected from each pond site. Artifacts generated in Surfer as a result of the spacing chosen for pond perimeter points caused undulating pit margins for the northern shorelines of the Freeway and Hansen – East ponds. In reality, these pit-margin walls are smoother than modeled. Pond-wall steepness may be underrepresented in the modeling for the WSDFW Ponds due to bathymetric sample spacing. The modeled bathymetric maps for each pond were exported into Joint Photographic Experts Group (JPEG) file format.

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 a GIS (ArcView), 1996 DNR digital orthophotos (3 ft (1 m) pixel resolution and ± 20 ft horizontal accuracy), and USGS 1:24,000-scale digital raster graphics (DRG) topographic maps.

Sediment Sampling

A total of 33 locations were sampled for sediment from 10 mine sites along the Yakima River floodplain (Figure 1). Sample stations were located using a hand-held Garmin GPS instrument. Sediment samples were extracted with a spade shovel over an area of about 1 ft^2 (930 cm^2) to a depth of about 4 in (9 cm), and were stored in drained fabric Olephin bags (figure 3). A person diving with scuba gear sampled subsurface sediments from the Hansen, Freeway, Newland, and WSDFW study ponds (Figure 4). The diver, and GPS survey team afloat in a small boat, also made visual observations of sediment attributes on pond floors. Where possible, bed-load of the active Yakima River channel was sampled or described, immediately up and down gradient of each mine site.

Eighteen samples, with grain size ranging from very fine silt (0.003 in (.075 mm)) to cobble (5.9 in (150 mm)) were submitted for sieve analysis to Geotechnical Testing Lab, Inc. of Olympia, WA (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 I). The range of particle sizes was estimated visually for the remaining 15 samples consisting mostly of large cobbles (>5.9 in or 150 mm) or of silt and clay (< 0.003 in or 0.075 mm). Sediment size is reported following the Unified Soil Classification System (USCS) (Table 1). 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 were also noted visually at other GPS stations throughout mine areas.

Table 1. Soil particle-size ranges

Component	Size Range		U. S. Standard Sieves Sizes
	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 " – 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	< 0.003	< 0.08	< No. 200
Clays	< 0.003	< 0.08	< No. 200

Figure 2. Bathymetric sampling and GPS location aided by use of small boat

Figure 3. Shovel and sample bag used to collect sediment samples

Figure 4. Diver-assisted sediment sampling and qualitative assessment of pond-bottom environment

<u>Hansen Ponds</u> (Cle Elum)

The Hansen ponds are located in the upper Yakima River basin (Figure 1). A meandering-to-slightly anastomosing channel, with a 1,500 to 2,000 ft (460 to 610 m) wide channel migration zone (CMZ) characterizes the river in the vicinity of the Hansen ponds. The Yakima River reach slope in the vicinity of the Hansen ponds is 0.0033 (approx. 17.4 ft drop in valley floor elevation for each mile downstream (3.3 m drop per km)). A potential avulsion point, situated on the outside of a meander bend, is located at the upstream (southwest) corner of the western pond. The Bonneville Power Administration and the Yakama Nation have proposed the breaching of the narrow dike at this potential avulsion point. The ponds are separated from the river by a rip-rap-reinforced dike, and are approximately 150 ft (45 m) from the river at the upstream end of the western pond, 60 to 100 ft (18 to 30 m) from the river at the junction of the two ponds, and 80 ft (24 m) from the river at the downstream end of the eastern pond (Figure 5).

The Hansen ponds are rectangular in plan-view, are shallow, 8 (2.4 m), and 9.5 ft (2.9 m) at the deepest for the western and eastern ponds respectively, and have fairly smooth and gently sloping bottoms (Figure 5). Both ponds have a simple bathymetric plan and are geomorphically non-complex. It is the authors' assumption that the Hansen ponds were mined to provide aggregate for Interstate-90 construction, which may explain their relative shallow depth, and fairly flat pond floors.

The Hansen-west pond has side margins that slope gently to a relatively flat pond floor. The average depth of the Hansen-west pond is 4.7 ft (1.4 m). The deepest portion of the pond is along the eastern margin, where two depressions reach approximately 6 and 8 ft (1.8 and 2.4 m) deep, respectively (Figures 6, 7, & 8).

The Hansen-east pond is slightly more bathymetrically "complex" than the Hansen-west pond (Figure 5). The east pond exhibits an asymmetry to its bathymetry, with the deeper sections situated along the northern side of the pond. In general, depths in the pond increase to the east, along the northern margin of the pond, reaching a maximum-measured depth of 9.5 ft (2.9 m) (Figures 9, 10, and 11). Side slopes are steeper along the northern and eastern margins of the pond. A low sill (-4 ft; -1.2 m) separates a small depression in the northwest corner of the pond from the main portion of the pond to the east. The southwest corner of the pond is characterized by shallow, gently sloping bathymetry. The average depth of the Hansen-east pond is 5.6 ft (1.7 m).

The floors of the Hansen East and West ponds consist of well-graded river gravel and cobbles ranging in size from 0.2 in to 5.5 in (5 mm to 140 mm) (some boulders up to12 in or 300 mm). As gravel mining excavated deeper into upward coarsening bar deposits, sediment becomes finer grained with increasing depth at both Hansen ponds. Sieve analysis of Hansen samples # 15, 1, 55, 62, 68, and # 71 (Figure 5) show that the larger clasts from the pit floors ranges in size from 7.8 in to 39.4 in (20 cm to 100 cm) (Table 2; Figure 12). Some of the finer-grained sediment found within both of the Hansen ponds may be 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. Located immediately upstream of the Hansen – West Pond, sample # 122 consists of 70.8% gravel and 29.1% sand (Figure 13). Immediately downstream from the Hansen – East Pond, # 121 consists of 85.1% gravel, 14.7% sand, and 0.3% silt, and clay (Figure 14).

Table 2. Hansen Ponds qualitative sediment particle data

Sediment Sample	Sediment Particle Size Range	Comments
Hansen West #15	100% @ 1.6 to 5.5 in (40 - 140 mm)	Coarse gravel and cobbles
Hansen West #1	25% @ 0.1 to 0.4 in (2.5 - 10 mm) + 75% @ 0.4 to 2 in (10 - 50 mm)	Fine to coarse gravel and cobbles with minor coarse sand
Hansen East #55	100% @ 1.6 to 5.5 in (40 - 140 mm)	Coarse gravel and cobbles
Hansen East # 62	100% @ 0.8 to 3.9 in (20 - 100 mm)	Coarse gravel and cobbles
Hansen East # 68	100% @ 0.4 to 3.5 in (10 - 90 mm)	Fine to coarse gravel and cobbles

Figure 5. Contoured bathymetric map of the Hansen Ponds – showing locations of sediment samples (GPS waypoint #) and proximity to the Yakima River

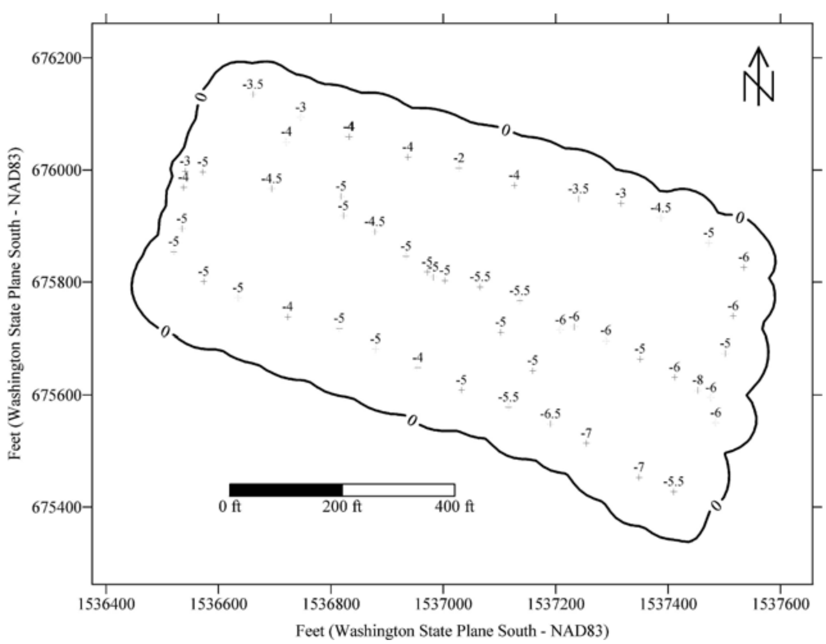

Figure 6. Post map showing data point locations and depths (ft) used to model pond bathymetry for the Hansen – West Pond

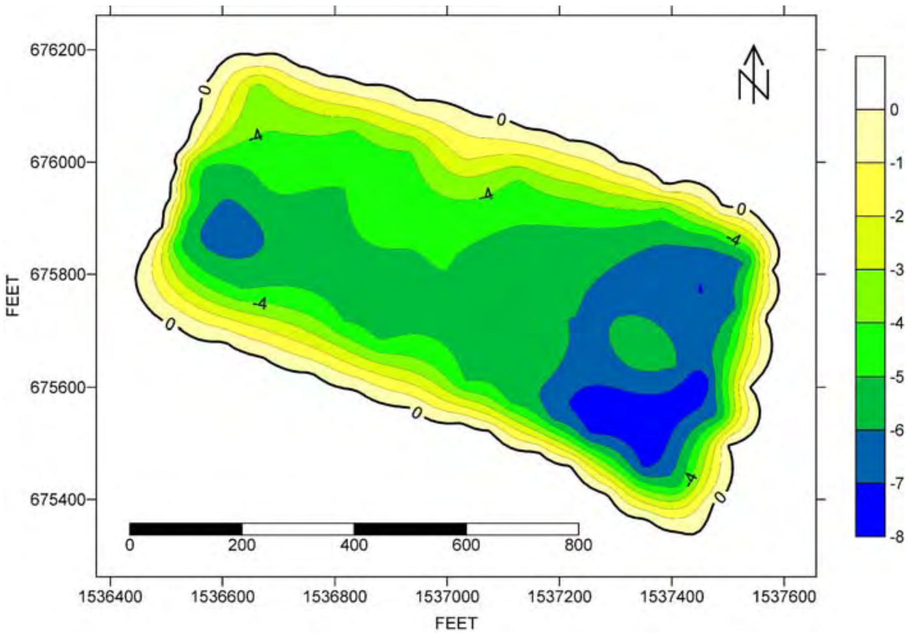

Figure 7. Contoured bathymetric map of the Hansen – West Pond (bathymetry in feet below 5/28/02 waterline)

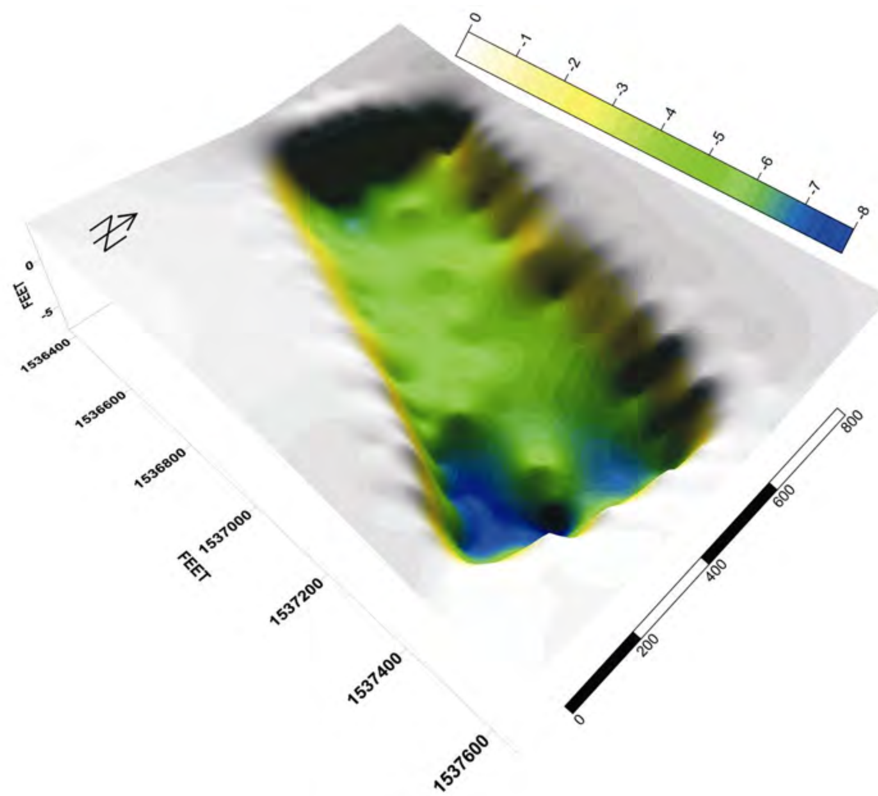

Figure 8. 3-D perspective bathymetric map of the Hansen – West Pond (bathymetry in feet below 5/28/02 waterline)

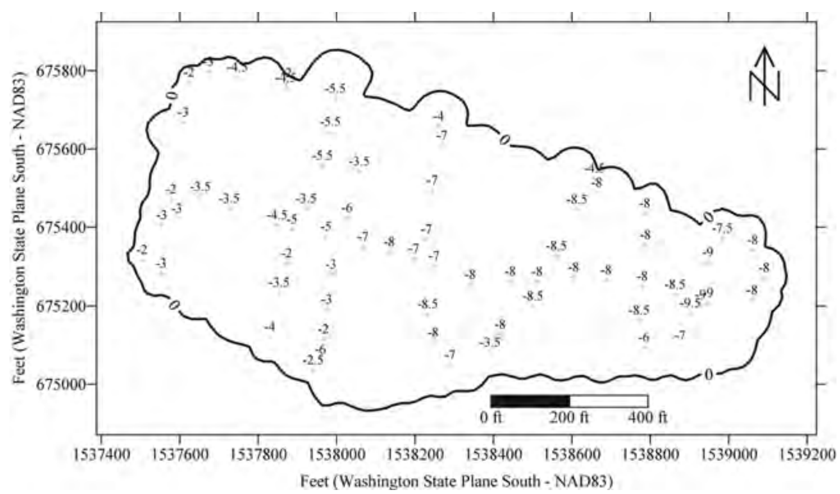

Figure 9. Post map showing data point locations and depths used to model pond bathymetry for the Hansen – East Pond

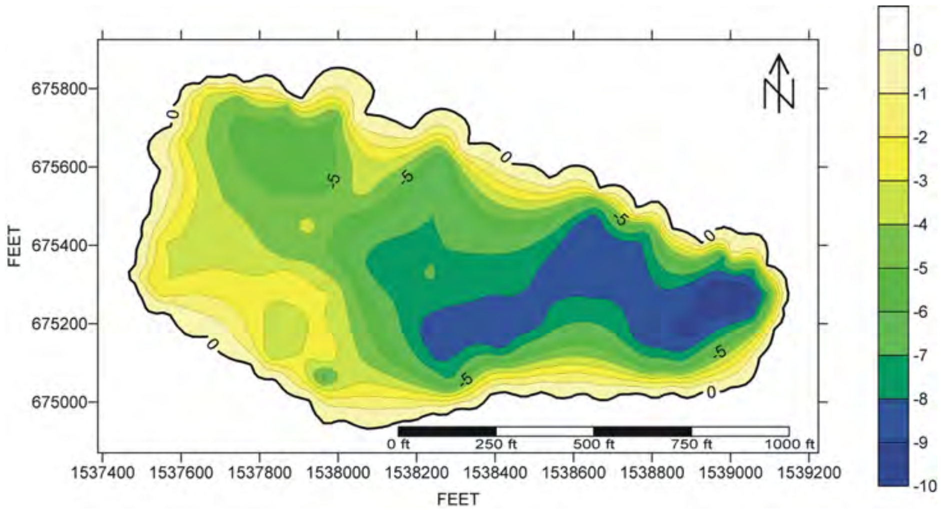

Figure 10. Contoured bathymetric map of the Hansen – East Pond
(bathymetry in feet below 5/28/02 waterline)

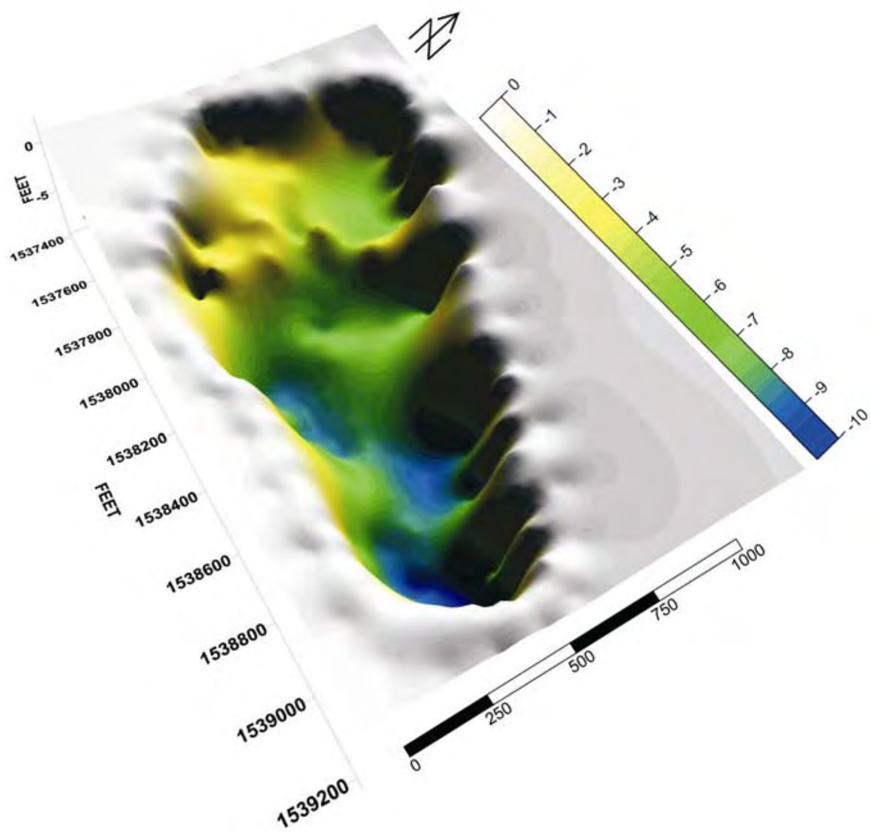

Figure 11. 3-D perspective bathymetric map of the Hansen – East Pond
(bathymetry in feet below 5/28/02 waterline)

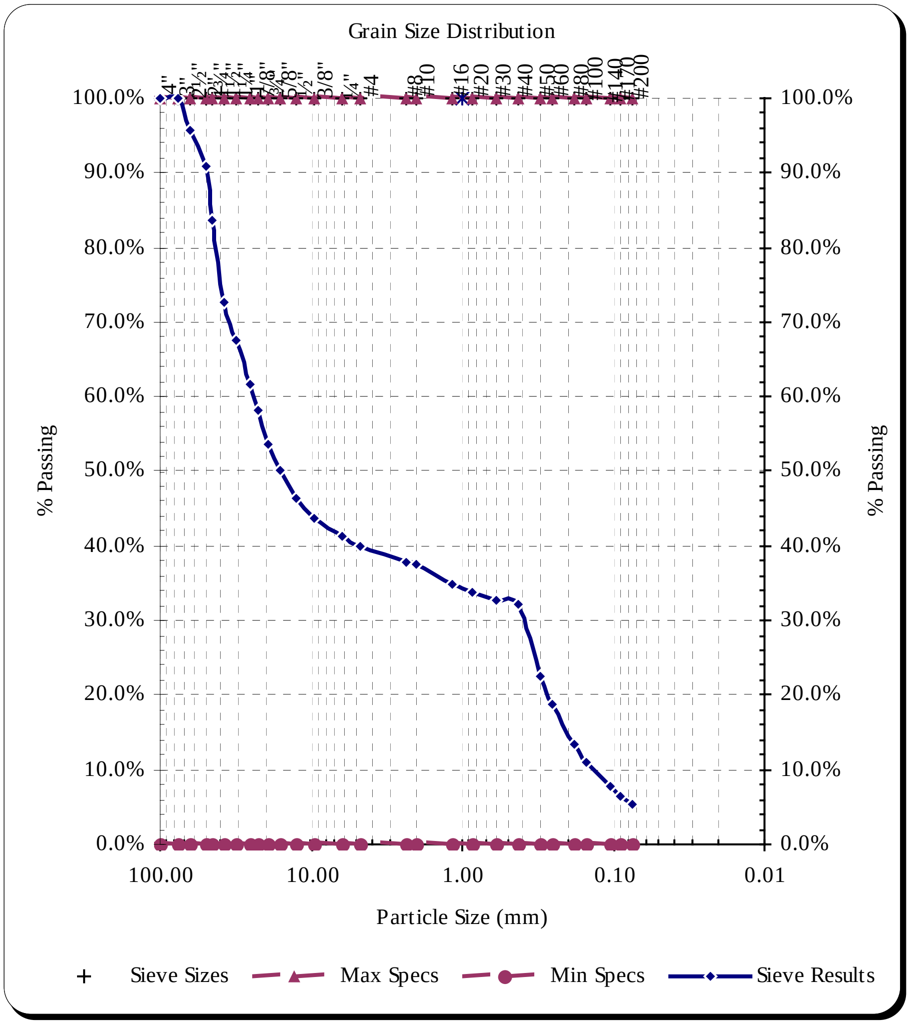

Figure 12. Grain size distribution plot for Hansen – East Pond sample #71

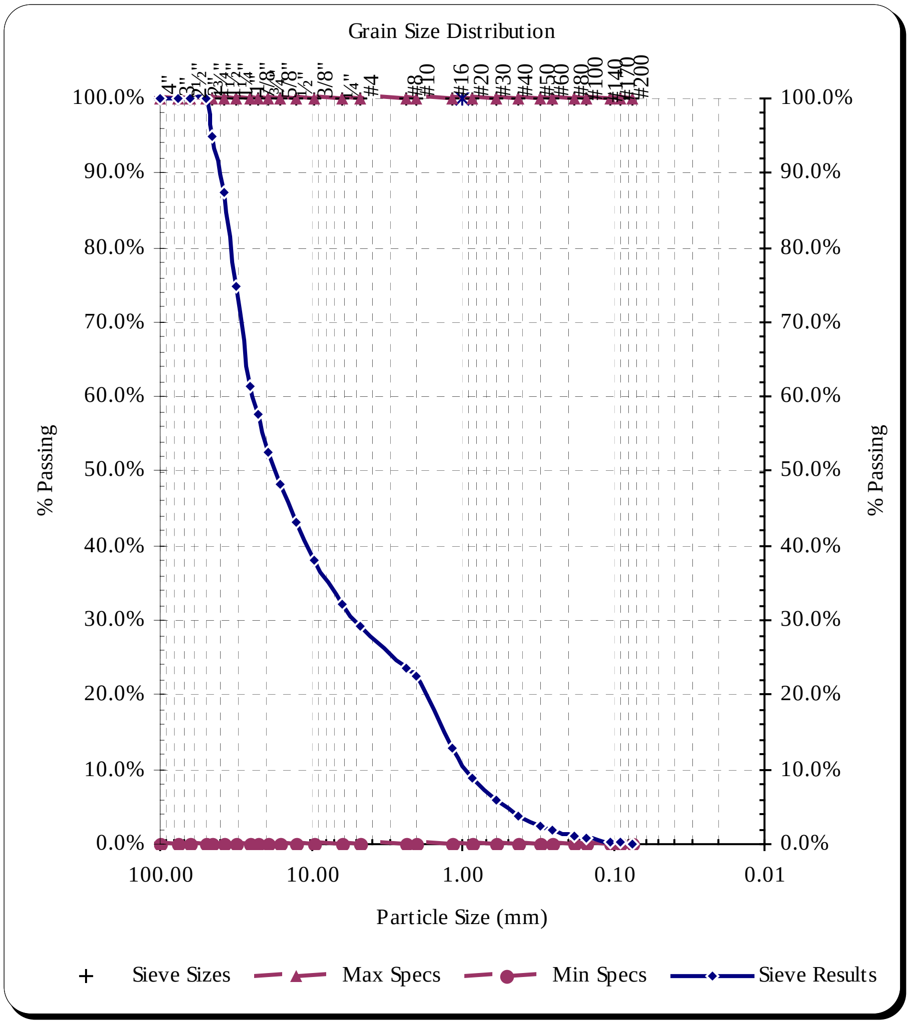

Figure 13. Grain size distribution plot for Hansen – upstream sediment sample # 122

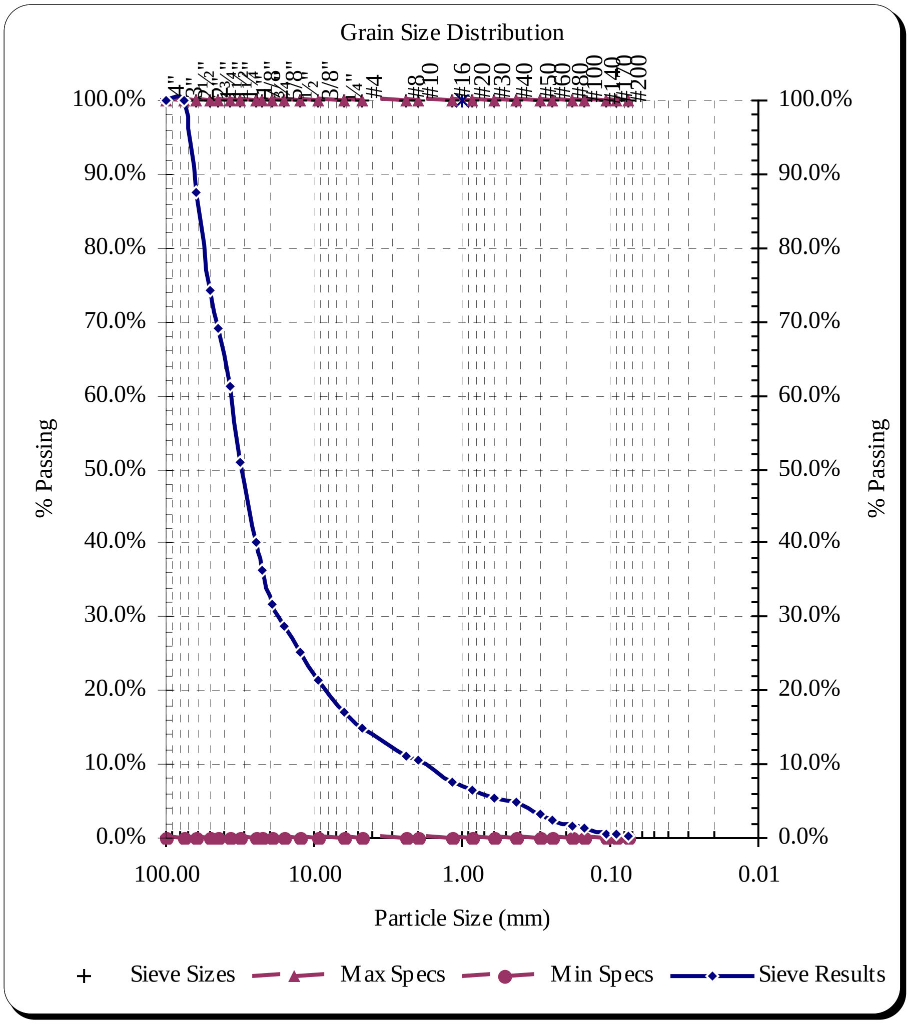

Figure 14. Grain size distribution plot for Hansen – downstream sediment sample # 121

Gladmar Pond (Thorp)

The Gladmar pond provides the opportunity to study a recently captured floodplain mine through which a significant percentage of the river's discharge flows during base flow conditions. The 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-year flood event of 1996, the Yakima River breached the narrow retaining dike, avulsing into the Gladmar pond. The 1996 avulsion event resulted in a partial cutoff of the meander, a shortening of the channel distance and an increase in channel slope for the portion of the flow passing through the Gladmar pond. If the riprap embankment at the point of avulsion were not in place, the entire Yakima River would likely be routed through the pond. The CMZ, for the Gladmar pond reach of the Yakima River, is 1400 to 1800 ft (425 to 550 m) wide and the channel gradient is 0.0037 (approx. 20-ft drop in valley floor elevation for each mile downstream (3.7 m drop per km)). One ingress channel brings river flow into the pond and two egress channels exit the pond and reconnect with the main-stem Yakima River approximately 2000 and 2300 ft (610 and 700 m) downstream for the southern and northern egress channels respectively (Figure 15).

Significant variability in pond bathymetry and water velocity regimes is evident in the Gladmar pond. The deepest portion of the pond is a triangular-shaped trough adjacent to, and in front of, the prograding delta at the head of the ingress channel, with measured depths of 12 ft (3.7 m). Two zones of high-velocity flow leading to the egress channels define deeper channels along the pond bottom, one along the western margin and the other across the center of the pond. The areas between the two channels and to the northeast of the northern egress channel are primarily shallow, low-energy benches, such as observed in the northeast corner of the pond. The average depth of the Gladmar pond is approximately 4 ft (1.2 m) (Figures 16, 17, and 18).

Because a portion of the Yakima River flows through the Gladmar 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 (Figure 15). Where the river enters the pond, bed load is aggrading to form a delta consisting of 0.8 to 7.9 in (2.0 to 20.0 cm) gravel and cobbles. The river's flow is bifurcated at the delta resulting in two streams, which flow to the south through the pond. One stream flows through the pond's central portion (northern egress channel), and the other flows along the south side of the pond (southern egress channel). Along the slope reach, or long axes, of these two diverging streams, the pit floor is being eroded and degraded. Typically consisting of sand and fine sediments, low energy depositional shelves are situated away from the pond's most energetic stream flow on the east and south shores of the pond. Accordingly, 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 19). Sample # 237, from a shallow shelf near the ponds south central shore, consists entirely of silt and clay (Table 3). Sample # 238, however, is well graded, and consists of 41.9% gravel, 53.5% sand, and 4.6 % silt and clay, and is typical of coarser sediment deposited proximal to higher velocity stream flow (Figure 20).

Table 3. Gladmar Pond qualitative sediment particle data

Sediment Sample	**Sediment Particle Size Range**
Gladmar - 237	100% silty clay

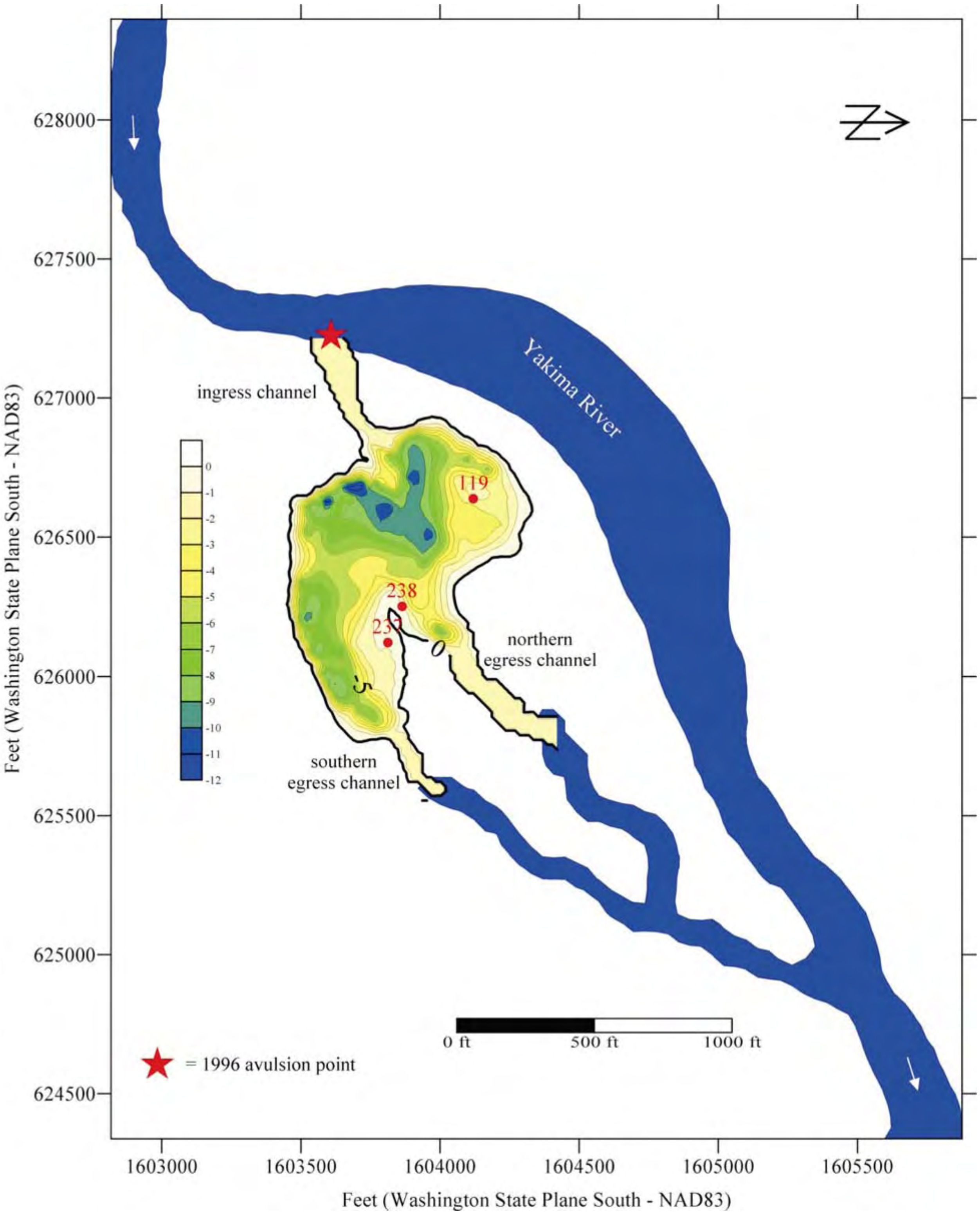

Figure 15. Contoured bathymetric map of the Gladmar Pond showing locations of sediment samples (GPS waypoint #) and proximity to the Yakima River

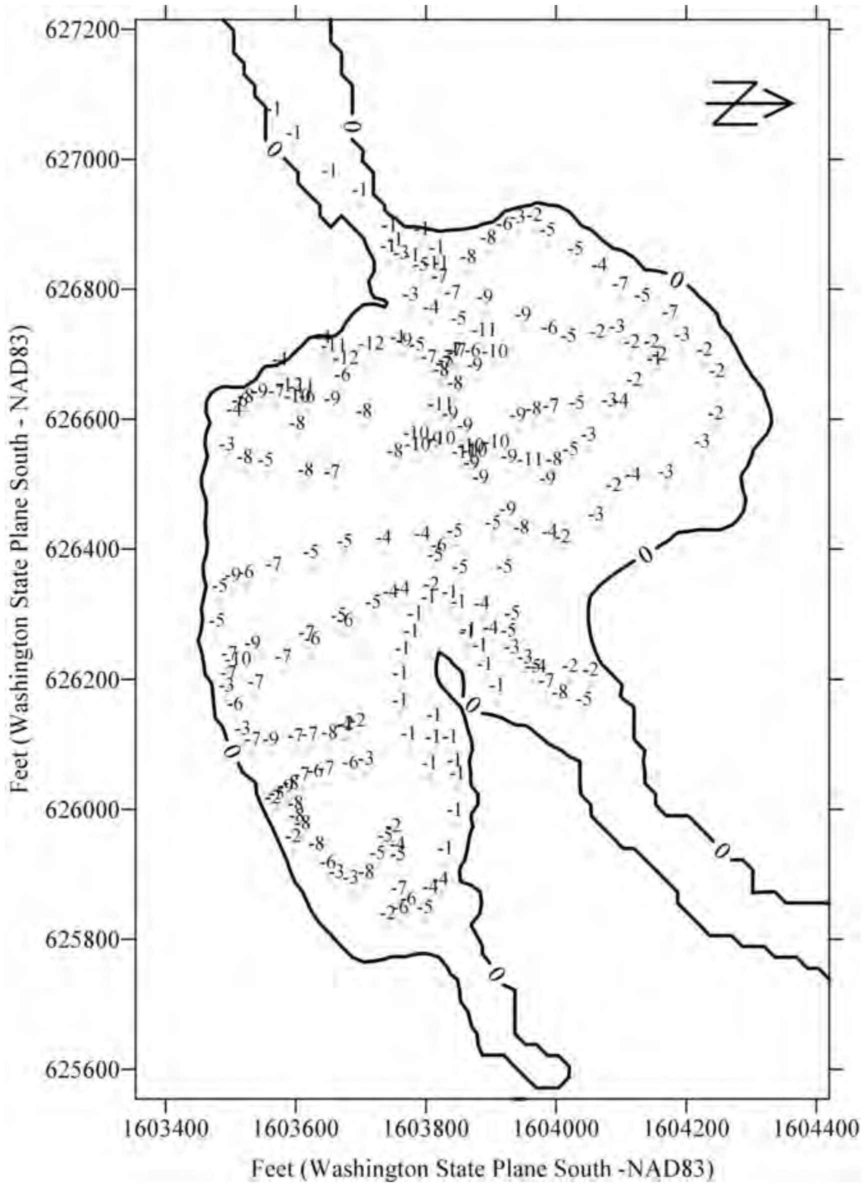

Figure 16. Post map showing data point locations and depths (ft) used to model pond bathymetry for the Gladmar Pond

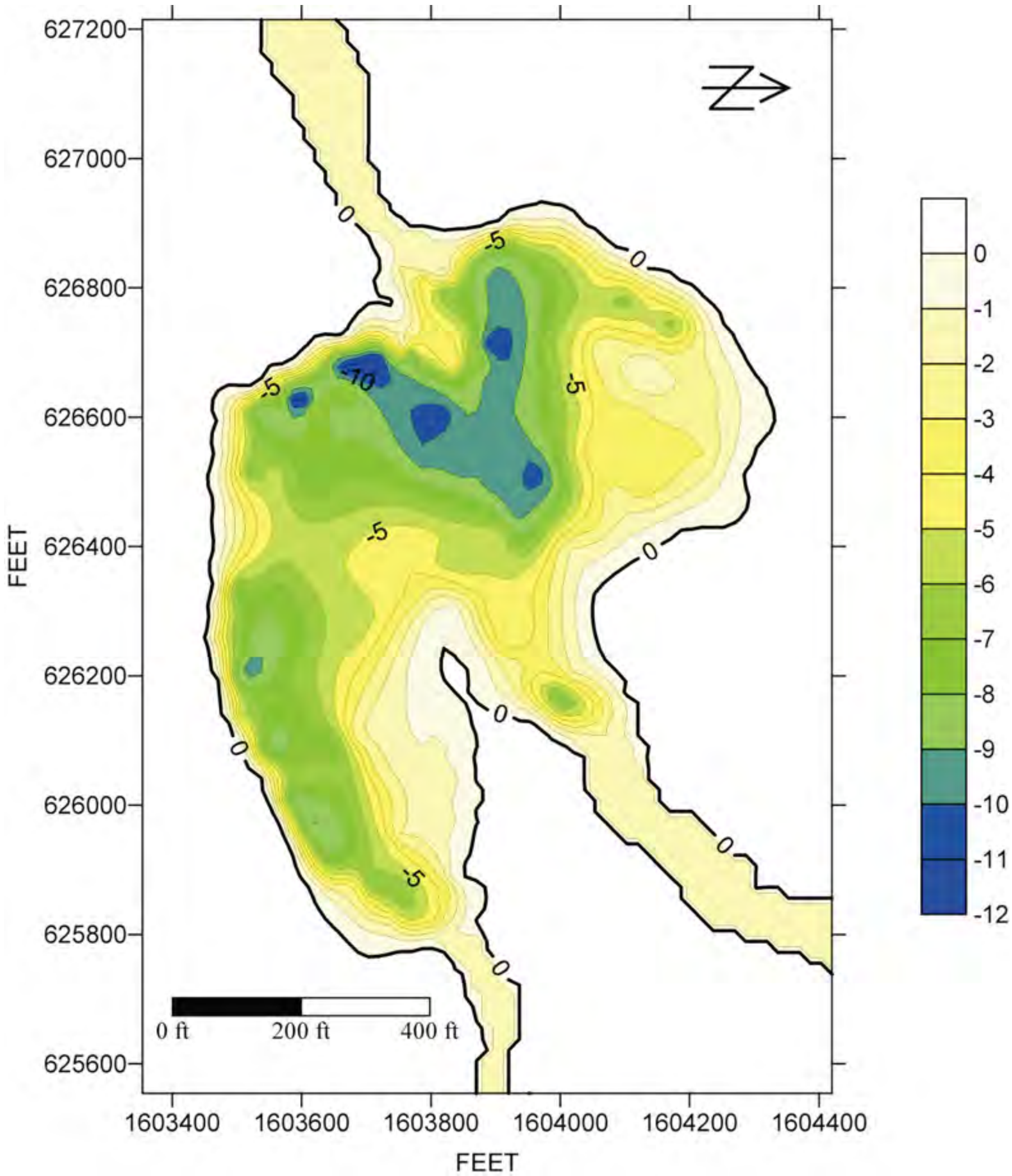

Figure 17. Contoured bathymetric map of the Gladmar Pit
(bathymetry in feet below 7/16/02 waterline)

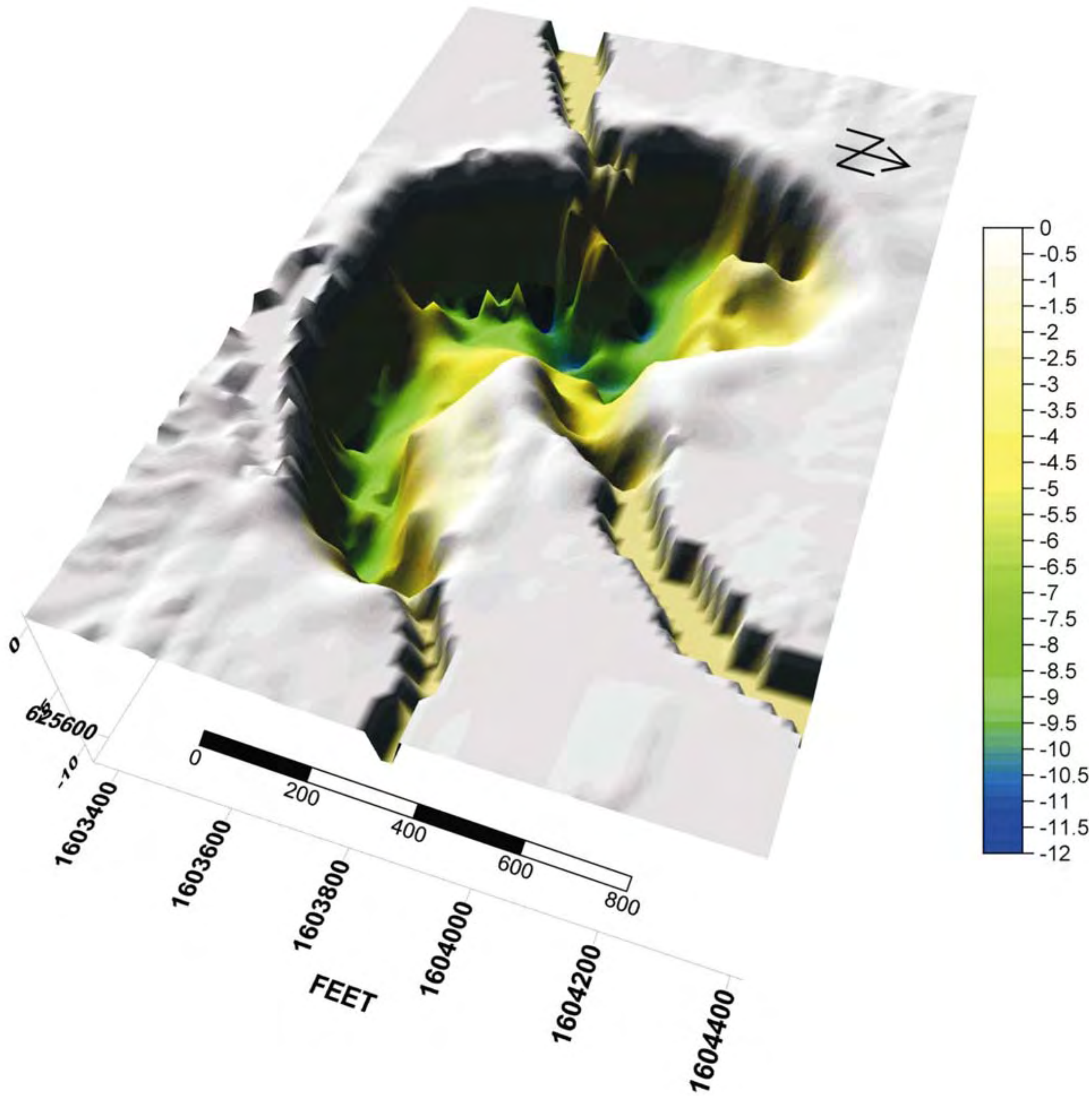

Figure 18. 3-D perspective bathymetric map of the Gladmar Pond
(bathymetry in feet below 7/16/02 waterline)

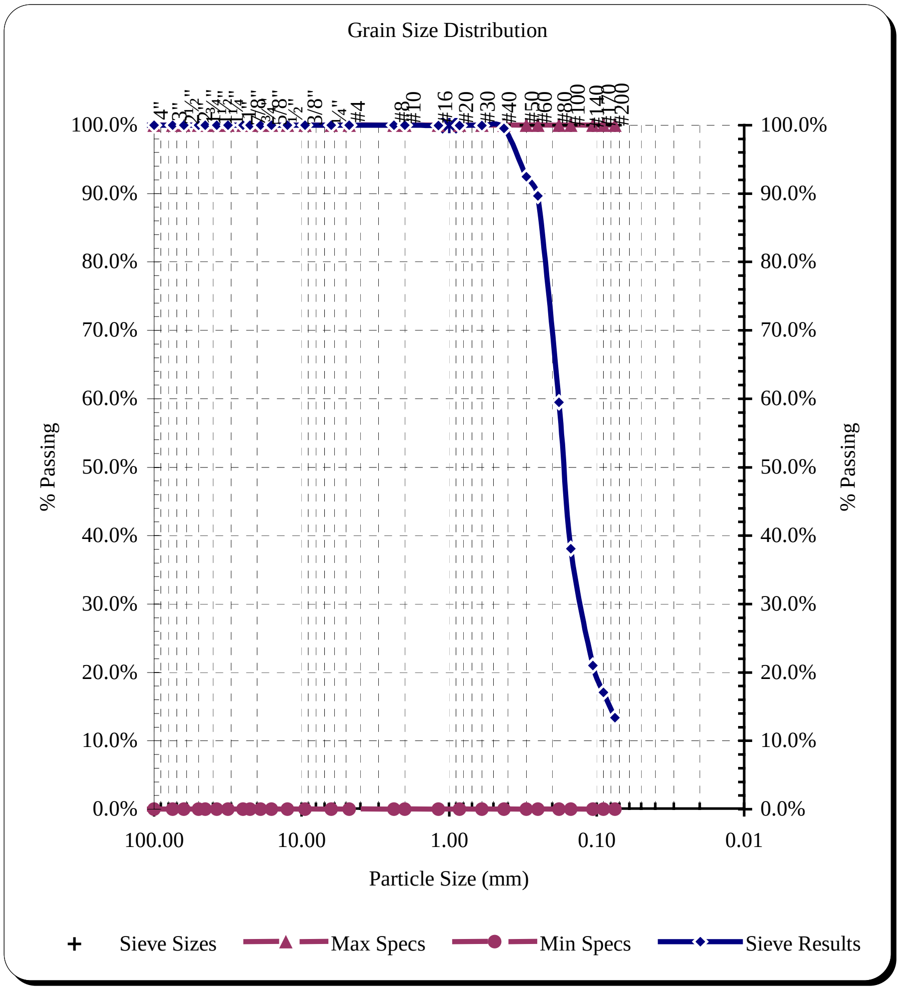

Figure 19. Grain size distribution plot for Gladmar sediment sample # 119

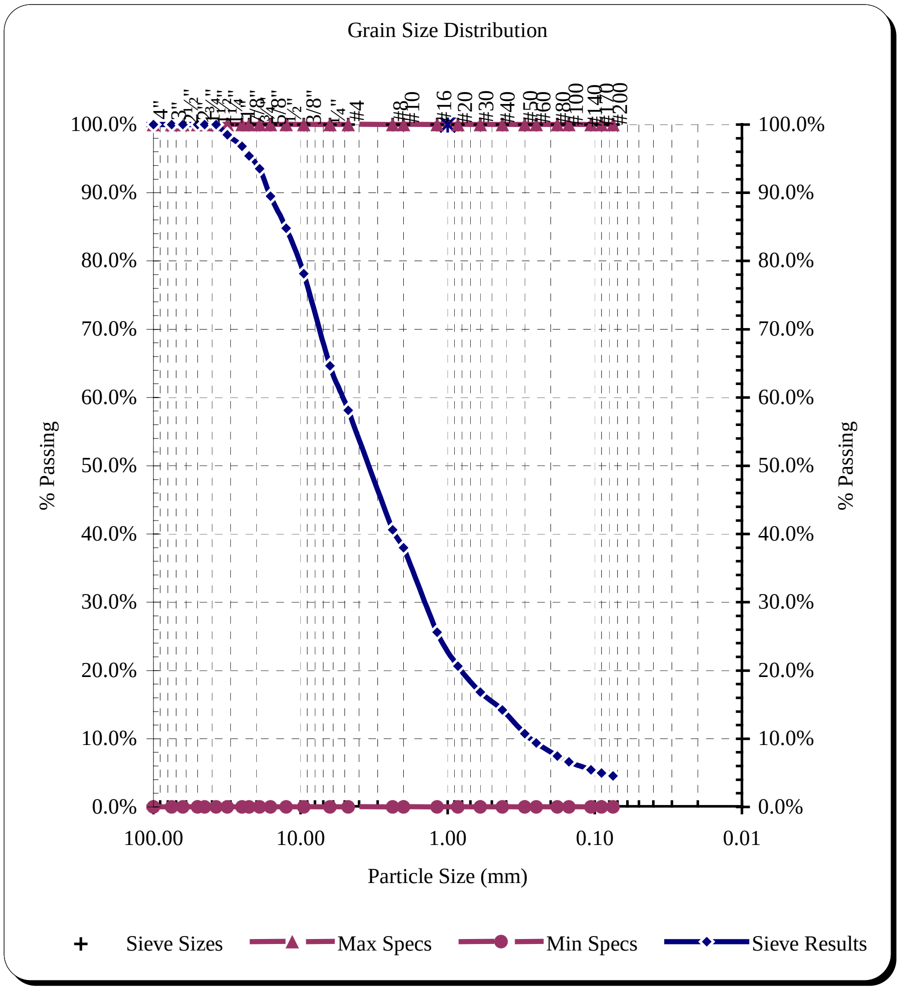

Figure 20. Grain size distribution plot for Gladmar sediment sample # 238

Freeway Ponds 3 & 4 (Ellensburg)

For this study, we characterized only the larger, downstream Freeway pond (pond 4?). In the vicinity of the Freeway ponds, the Yakima River is a confined meandering channel. Active channel migration and avulsion is somewhat retarded by the placement of Interstate-90 across the floodplain, effectively decreasing the area for floodplain migration in half. The CMZ in the vicinity of the Freeway ponds increases from approximately 600 ft (180 m) upstream of the ponds to 1500 ft (460 m) in width adjacent to the downstream pond. The average reach slope of the valley in the vicinity of the pond is 0.00294 (approx. 15.5-ft drop in valley floor elevation for each mile downstream (2.9 m drop per km)). Although not conclusive, there may have been overflow of the river into the lower pond during the 1996-100-year flood event. A potential avulsion point into the downstream pond exists along the far western portion of the pond (Figure 21). The downstream pond is separated from the river by a rip-rap-reinforced dike, and is approximately 550 ft (170 m) from the river at its northern end, 100 ft (30 m) from the river at its western margin, and 30 ft (9 m) from a side channel of the river at the outfall pipe across the riprap dike (Figure 21). Minor amounts of water were observed (5/29/02) entering the downstream pond via small surface streams connecting to the ponds to the northwest.

The bathymetry of the Freeway pond is relatively simple. The downstream Freeway pond is shallow, reaching a maximum measured depth of 8 ft in the southeast corner of the pond (Figure 22). There is a general downward slope from the northwest to the south and east from shallow, aggraded sediments infilling the pond during periods of high-flow on the Yakima River towards deeper areas along the southeastern margin of the pit (Figure 23). The location of the deeper-water areas may correspond to the direction of mining (from west to east), as material was "scooped" from the pond and used nearby as road aggregate during construction of Interstate-90. The scallops along the northeastern margin of the pond are artifacts of the bathymetric modeling and are not represented in the field (Figure 23 and 24). The northern-most portion of the pond is characterized by several shallow embayments. The average depth of the downstream Freeway pond is 4.2 ft (1.3 m).

Four sediment samples were collected from the downstream Freeway site (Figure 21). The grain size distribution of sediment at Freeway ranges from gravel and cobbles at the northwest corner of the pond to fine sand, silt, and clay progressively down gradient to the south and portions of the pond.

The northeast corner of the pond is an entry point for intermittent floodwaters from the Yakima River into the pond (Figure 21). South of the entry point (breeched dike) coarse gravel, cobbles, and boulders have been deposited to form a delta that is pro-grading south into the northwest portion of the pond. As floodwater enters the pond, stream energy is dissipated and finer sediment is progressively deposited down gradient from the floodwater's point of entry. Sediment samples # 136 and # 172 (Table 4) are composed of 100% silt and clay and # 159 consists of 72.3% silt and clay and 27.7% fine sand (Figure 25). These fine sediments, located at more deeply excavated portions of the pit floor may represent the top of the Thorp formation, or post-mining sedimentation during river overflow events. Sample # 200 is an in-stream sample, extracted from a downstream river bar (Figure 21). It consists of well-graded gravel (82.9%) with sand (16.8%0), and minor silt and clay (0.2%). Well-graded gravel and cobbles range from 0.2 to 5.9 in (4.75 to 150mm) in size. Sample #200 contrasts with the in-pit samples in that it has a much smaller percentage of fines.

Table 4. Freeway Pond 4 qualitative sediment particle data

Sediment Sample	Sediment Particle Size Range
Freeway - 136	100% silty clay
Freeway - 172	100% silty clay

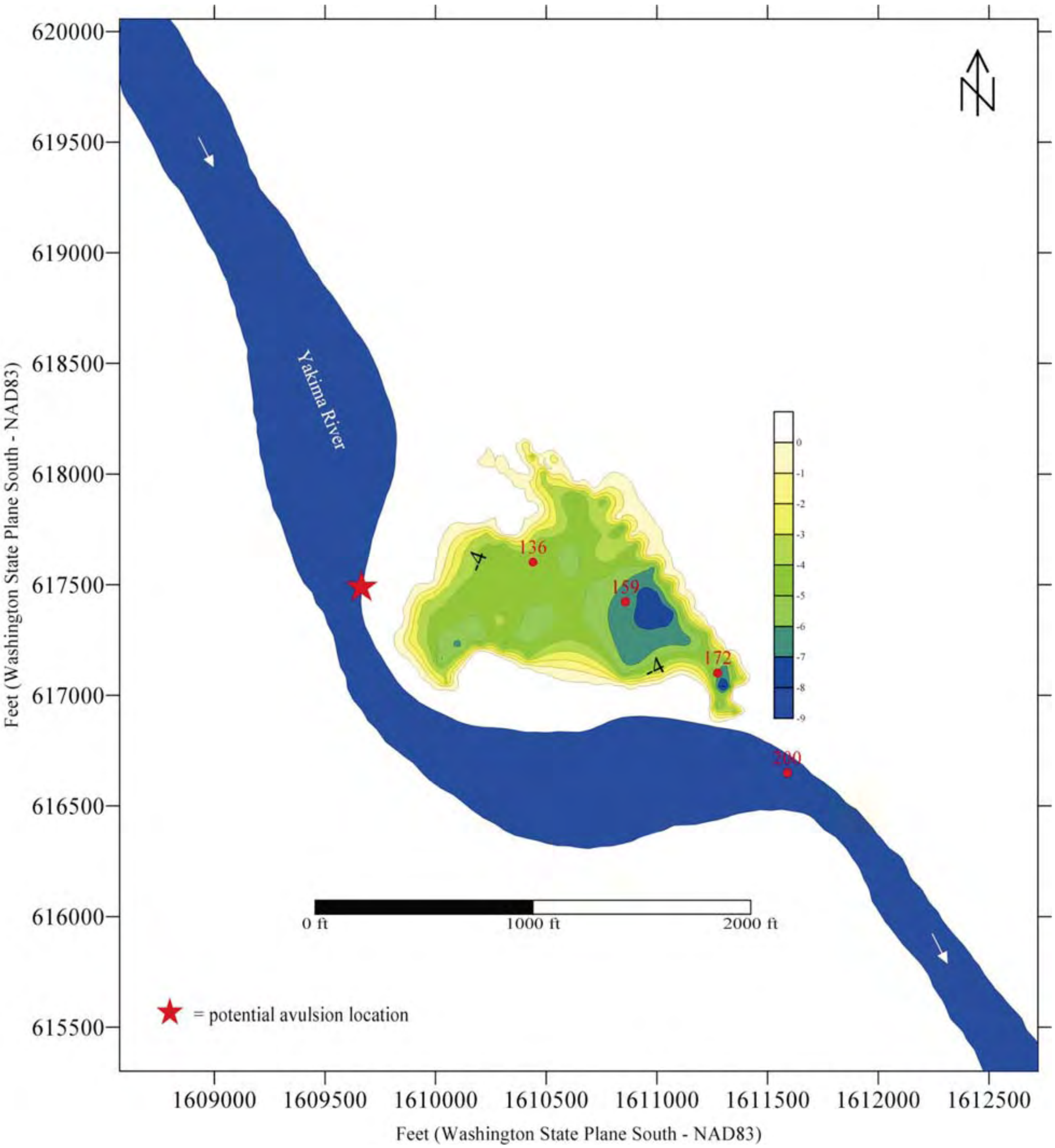

Figure 21. Contoured bathymetric map of Freeway Pond 4 showing locations of sediment samples (GPS waypoint #) and proximity to the Yakima River

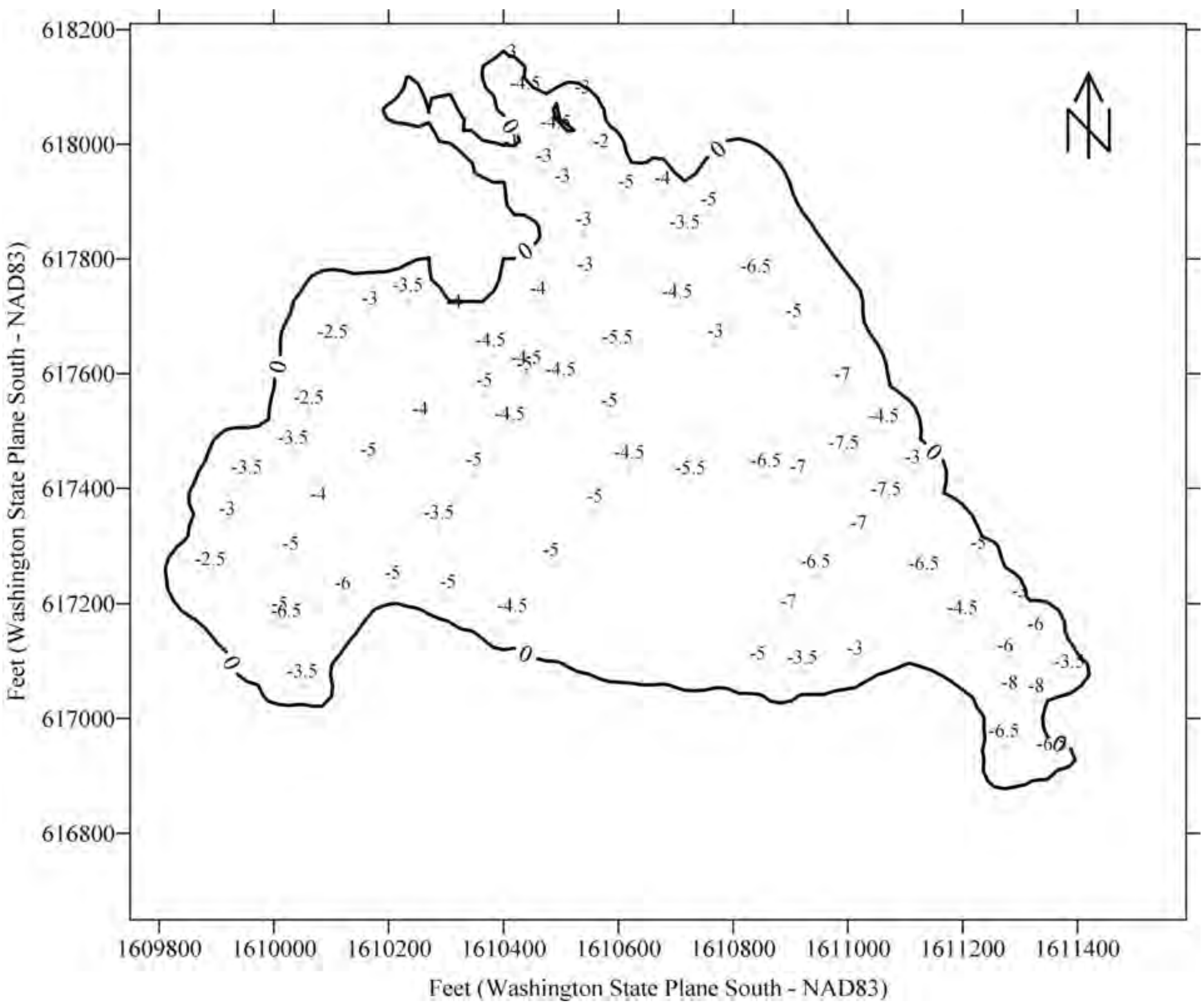

Figure 22. Post map showing data point locations and depths (ft) used to model pond bathymetry for Freeway Pond 4

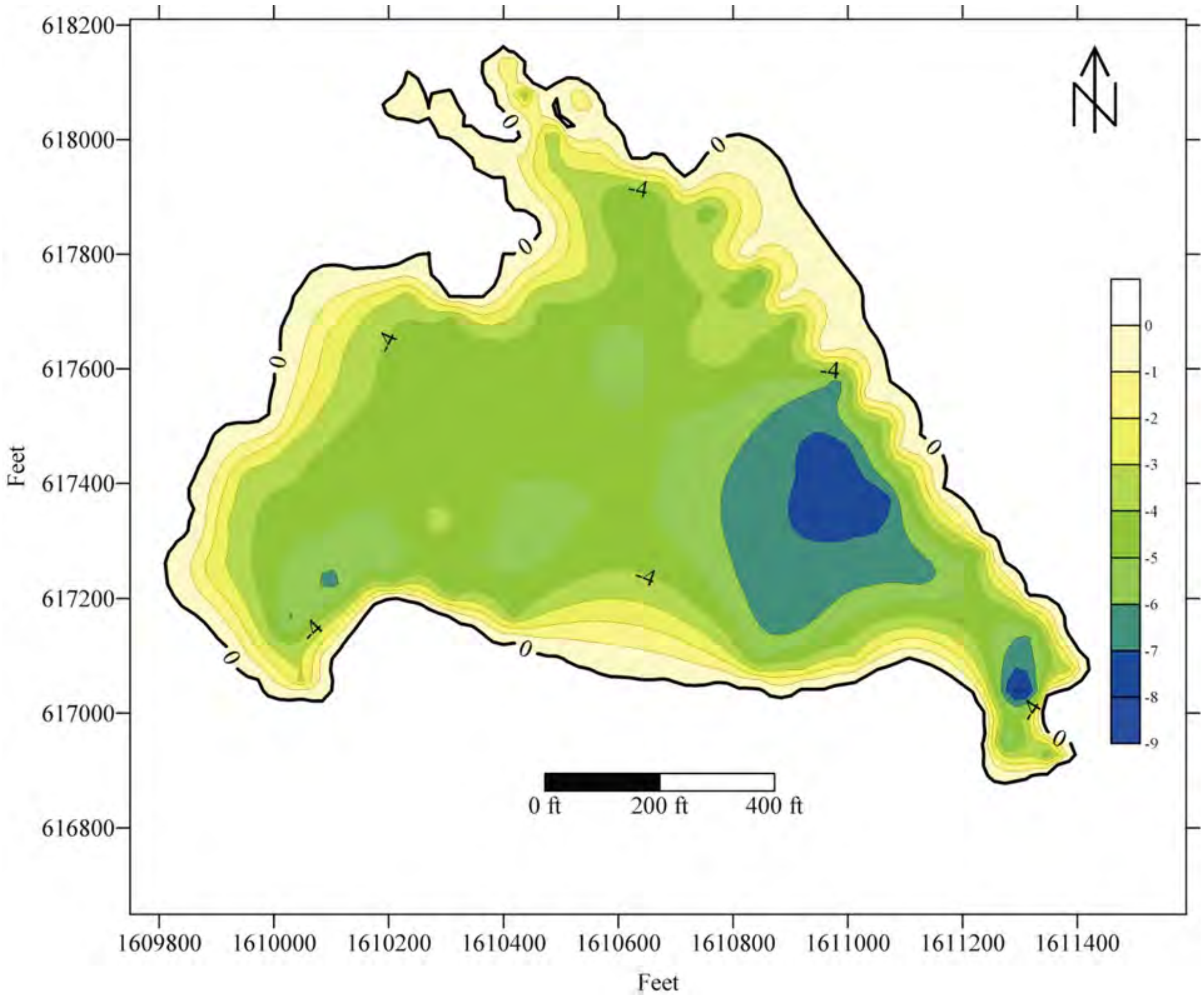

Figure 23. Contoured bathymetric map of the Freeway Pond #4
(bathymetry in feet below 5/29/02 waterline)

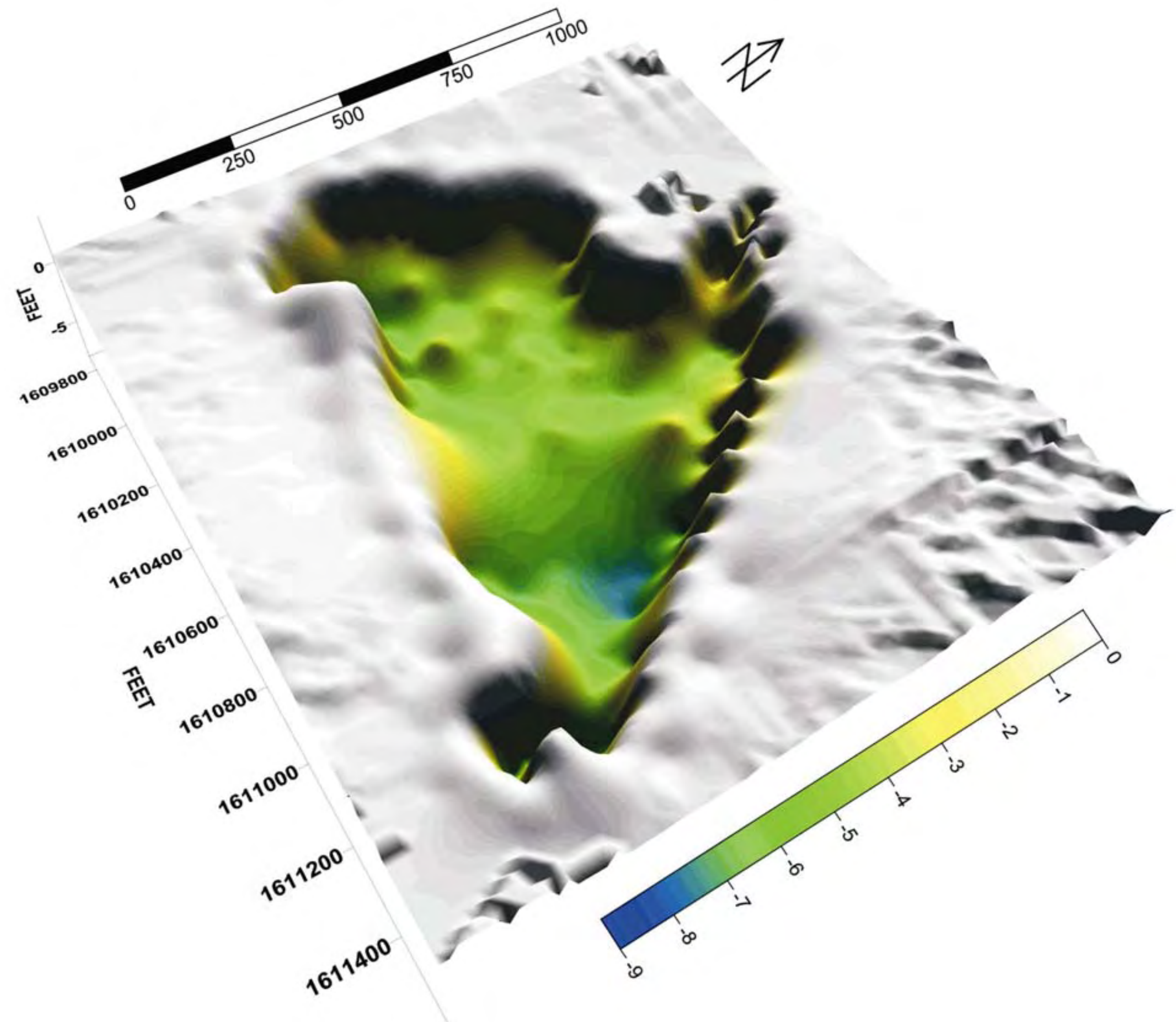

Figure 24. 3-D perspective bathymetric map for the Freeway #4 Pond (bathymetry in feet below 5/29/02 waterline)

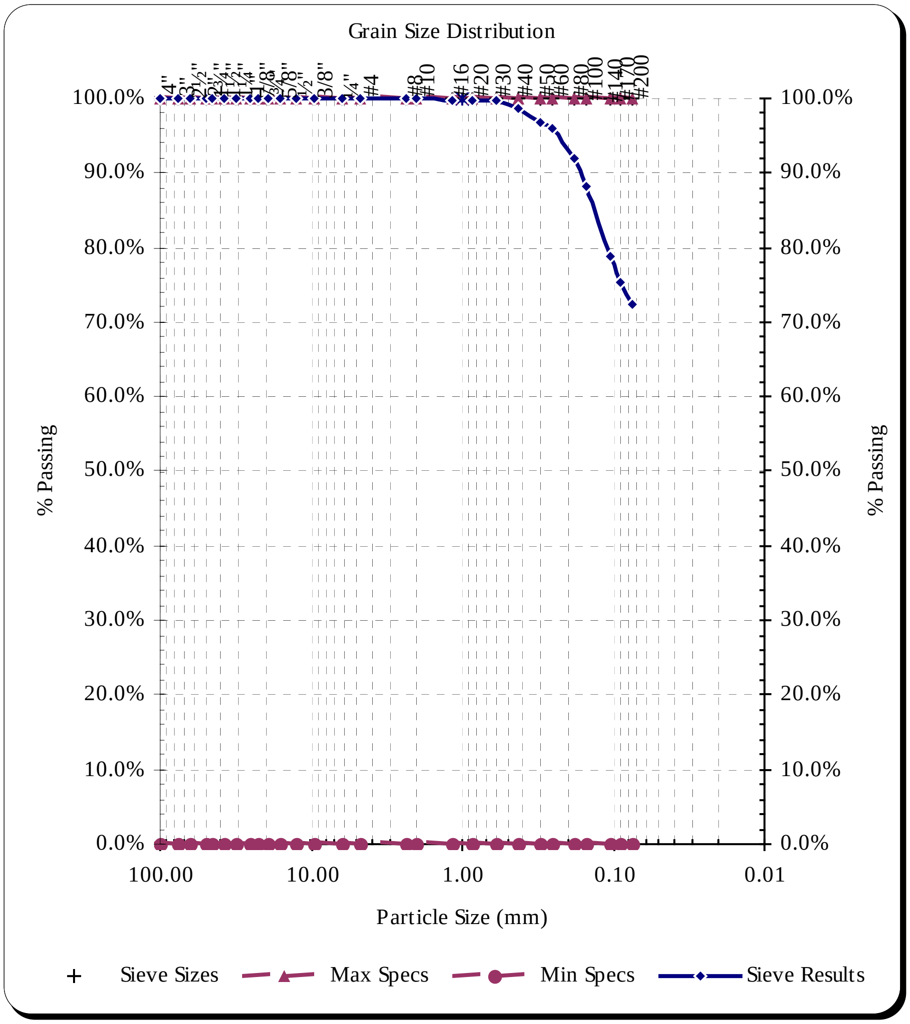

Figure 25. Grain size distribution plot for the Freeway #4 Pond sediment sample #159

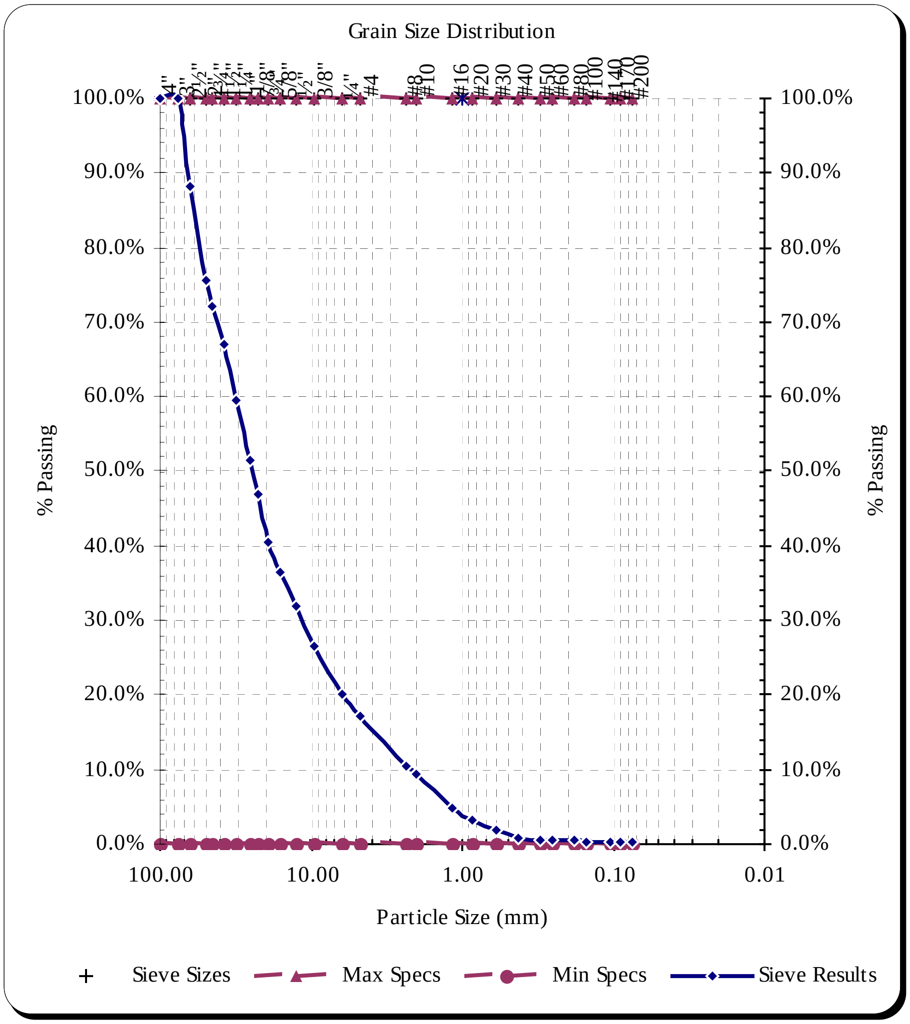

Figure 26. Grain size distribution plot for the Freeway #4 Pond – downstream sediment sample #200

<u>Selah Ponds</u> (Selah)

The Selah ponds are located in the Selah Valley, a structural depression between Umtanum Ridge (Yakima River Canyon) to the north and Yakima Ridge (Selah water gap) to the south, which is immediately upstream of the confluence of the Naches River with the Yakima River, marking the termination of the Upper Yakima Basin just south of Yakima Ridge (Figure 1). The river in the vicinity of the Selah ponds is a meandering channel pinned between two water gaps on either side. In the vicinity of the ponds, the CMZ is 1,800 to 2,300 ft (550 to 700 m) and the valley slope is 0.0028 (approx. 14.8-ft drop in valley floor elevation for each mile downstream (2.8 m drop per km)). A dike restricts movement of the river into the ponds (to the east). Presently, the river is approximately 150 ft (45 m) from the ponds on the upstream (north) end, 160 ft (50 m) at the mid-point of the pond complex and 75 ft (25 m) from the river at the downstream (south) end of the pond complex (Figure 27).

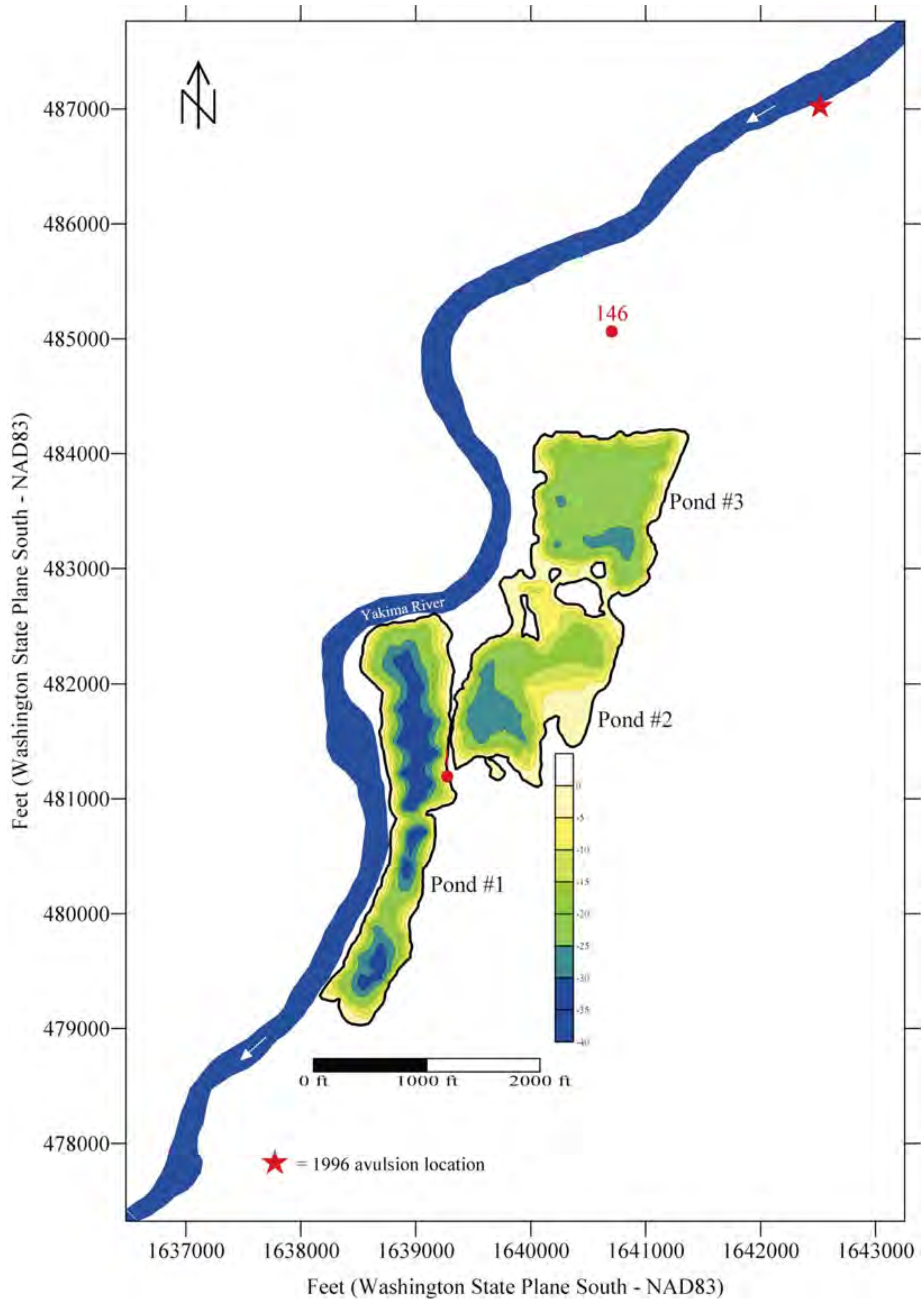

Figure 27. Contoured bathymetric map of the Selah Ponds showing locations of sediment samples (GPS waypoint #) and proximity to the Yakima River

For this study we measured the bathymetry of the upstream (North Selah Ponds 2 and 3 – now connected) and downstream (South Selah Pond 1) ponds (Figure 27). At the time of our measurements, the mined area to the north (pond 4) of the north pond was still dry. During the 1996 100-year flood event, the Yakima River avulsed into the northern most portion of the Selah mine complex (pond 4), abandoning some 8,000 ft (2,440 m) of channel, it exited at the southern end of the south pond. Norman and others (1998) report that this avulsion event produced approximately 6 to 8 ft (1.8 to 2.4 m) of incision immediately upstream of the point of avulsion accompanied by local upstream knick point migration. It was estimated that at least 300,000 yd^3 (230,000 m^3) of gravel was scoured from the riverbed and deposited as a layer at least 6 ft (1.8 m) thick in the excavated pits over a 33-acre (13 hectare) area (Norman and others, 1998). Golder Associates (1998) calculated the long-term sediment for the Yakima River through the Selah reach to be on the order of 100,000 tons/year. Subsequent to the avulsion event, the dikes were rebuilt and the river forced back into its old channel. Presently, there is no river flow into the Selah pits.

In general, the bathymetric data collected for the north and south Selah ponds (Figure 27) supports the findings by Golder Associates (1998) that the deepest portions of the ponds correlates with a lithologic change that appears to represent the geologic contact between the 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 deeper depth of mining (pond depth) in the south pond as compared to the north pond.

The Selah north pond has a varied bathymetry, reflecting in part its mining history as well as post-mining efforts to enhance wildlife habitat within and adjacent to the pond (Figure 28). The pond is separated into two deep flat-floored basins, a north (pond 3), and south (pond 2) basin, with the maximum measured depths of 26 ft (7.9 m) and 30 ft (9.1 m) in the north and south basins respectively (Figure 28). These depths may represent the approximate depth of Holocene alluvium above the Thorp Formation. Numerous small wildlife-enhancement islands exist along the margins of the northern portion of the north pond; however, due to their small size, they were not modeled in the bathymetric maps for the north Selah pond. The intervening shallow area, or sill between the two deep basins likely represents the margin between two areas of mining. This shallow-water area also contains islands. The south basin of the Selah north pond is not as large as the north basin, although it is slightly deeper. The southeastern portion of the southern basin has been used as a mine slurry deposition area, resulting in the progradation of a fine-grained delta along the eastern margin of the southern basin (Figure 29 and 30). The average depth of the Selah north pond is 9.1 ft (2.8 m).

The Selah south pond, with an average depth of 8.5 ft (2.6 m), is a long arcuate trench with steep-sided walls and a relatively flat bottom that is at about 30 ft (9 m) in depth. Several low sills partition the pond into three basins, with the maximum measured depth of 35 ft (10.6 m) (Figure 31, 32, and 33). The depth of the Selah south pond may indicate the approximate top elevation of the Thorp Formation. The Selah south pond lacks the bathymetric complexities found in the Selah north pond (Figure 33).

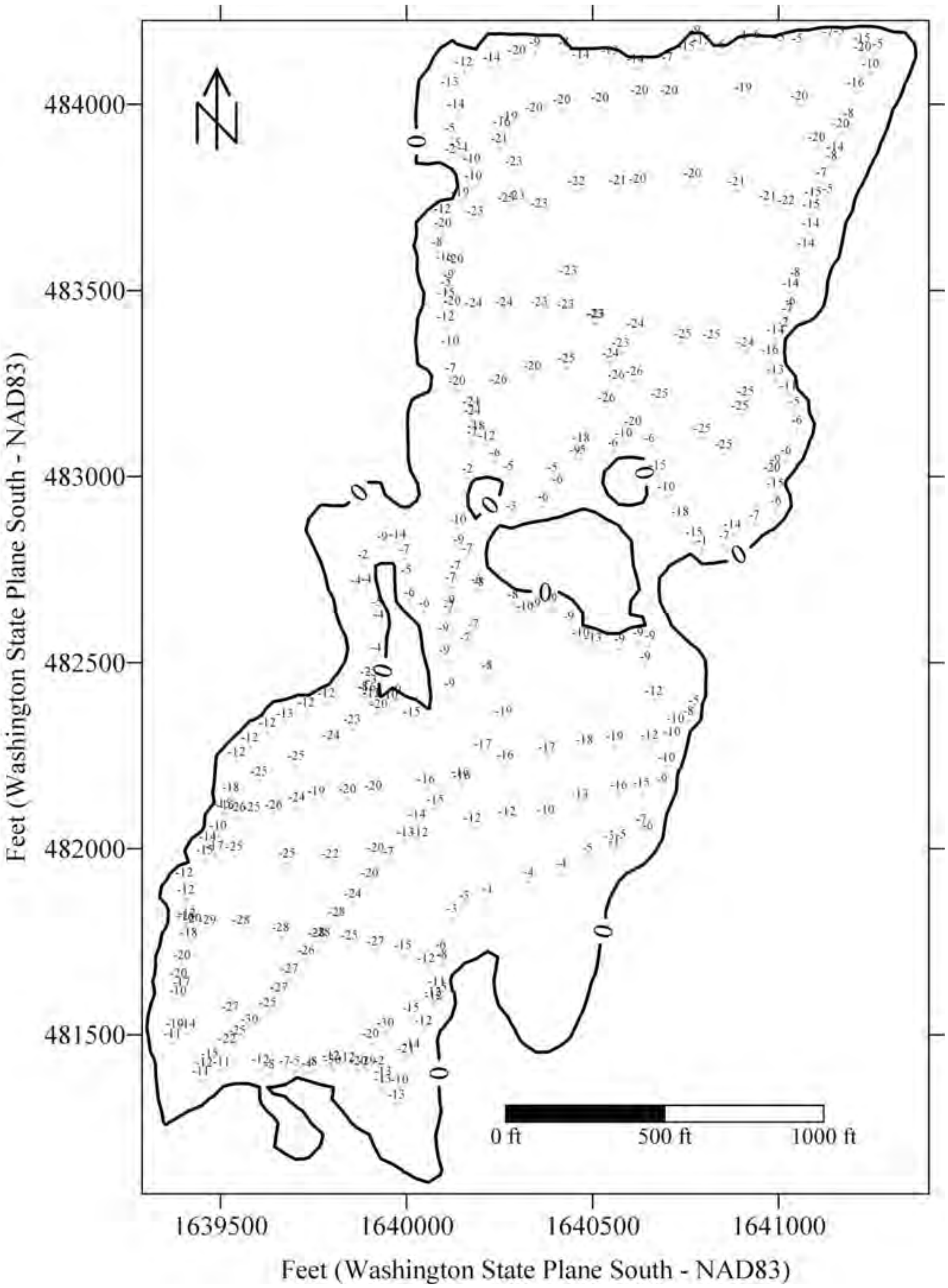

Figure 28. Post map showing data point locations and depths (ft) used to model pond bathymetry for the Selah North Pond (ponds II & III)

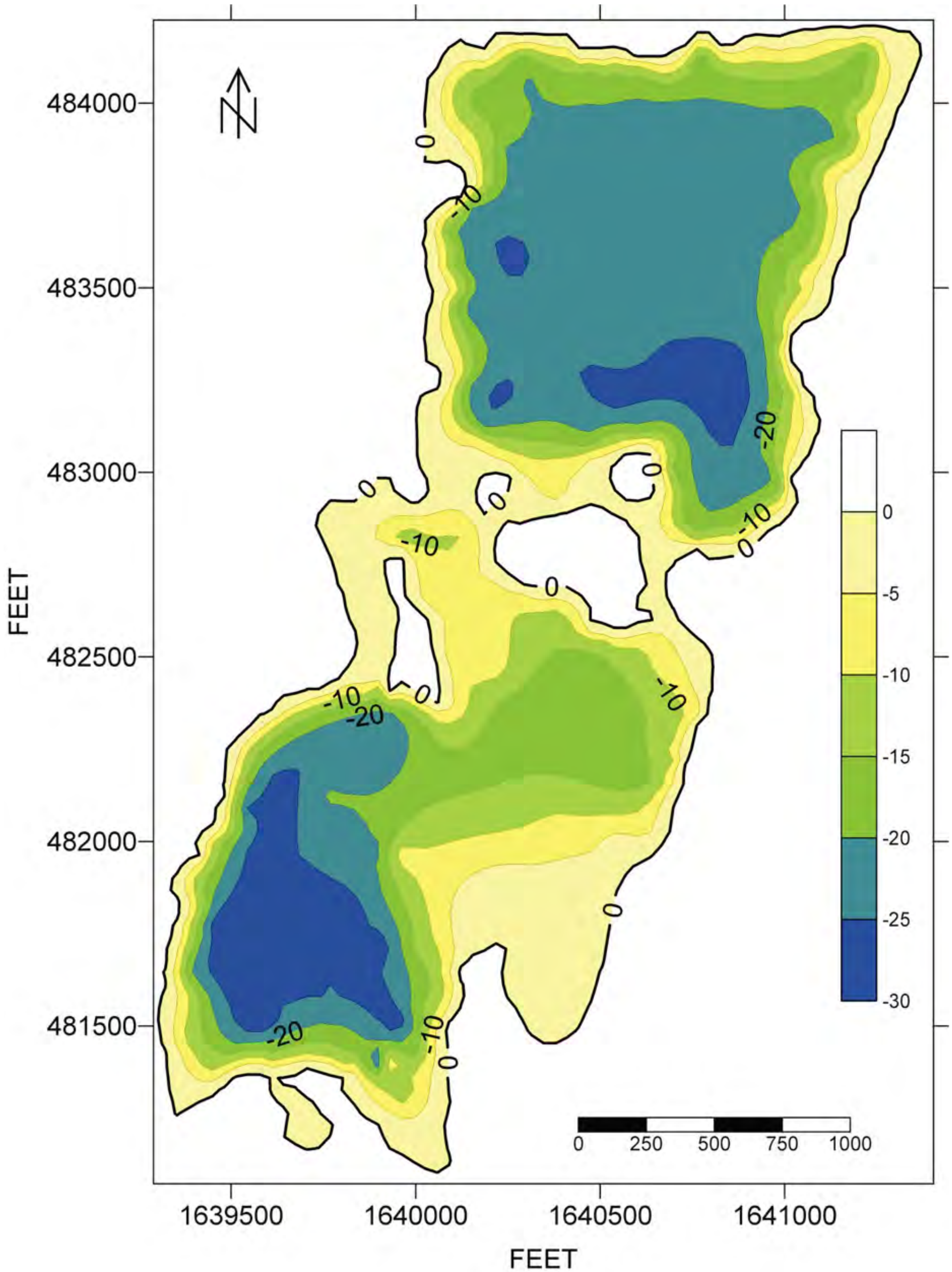

Figure 29. Contoured bathymetric map of the Selah – North Pond (ponds II & III)
(bathymetry in feet below 7/17/02 waterline)

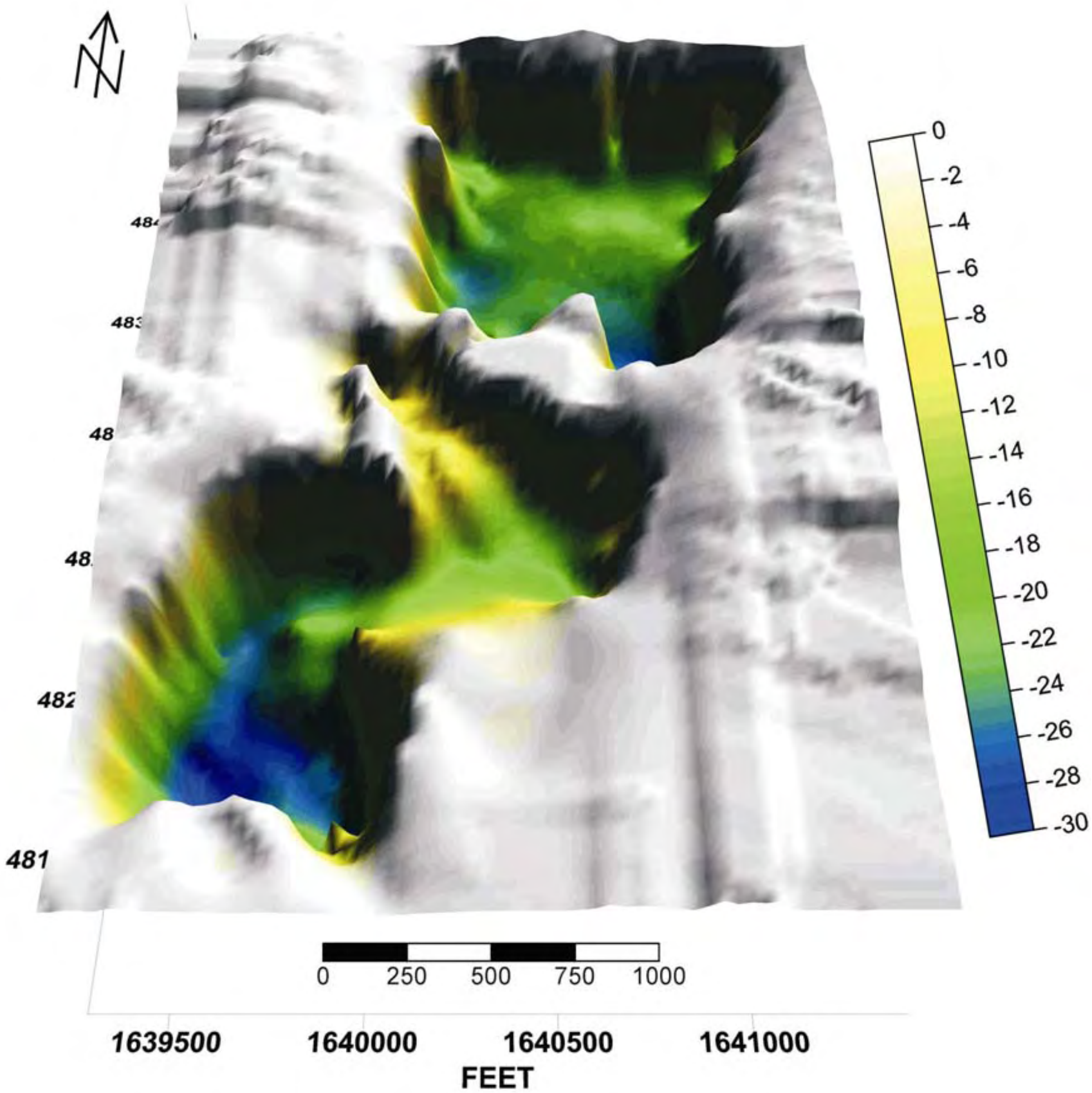

Figure 30. 3-D perspective bathymetric map of the Selah – North Pond (ponds II & III) (bathymetry in feet below 7/17/02 waterline)

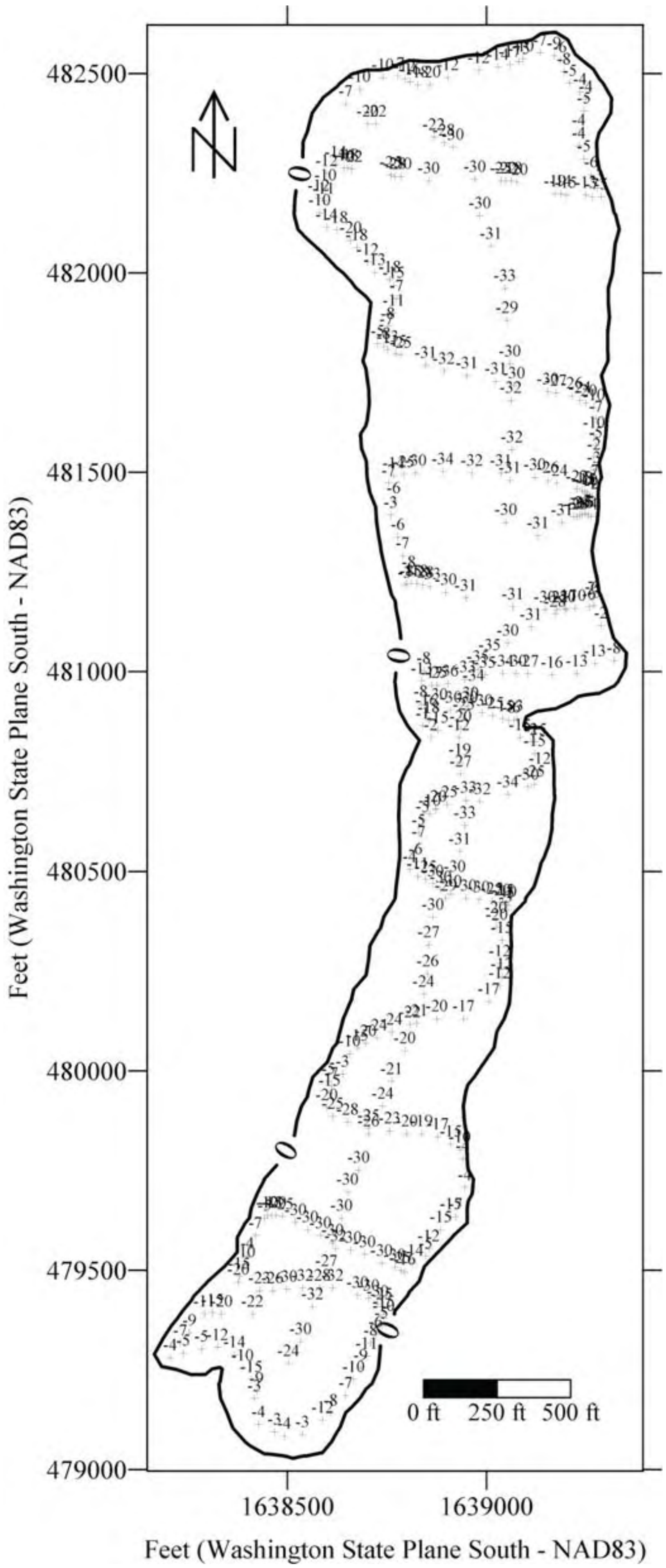

Figure 31. Post map showing data point locations and depths (ft) used to model pond bathymetry for the Selah South Pond (pond I)

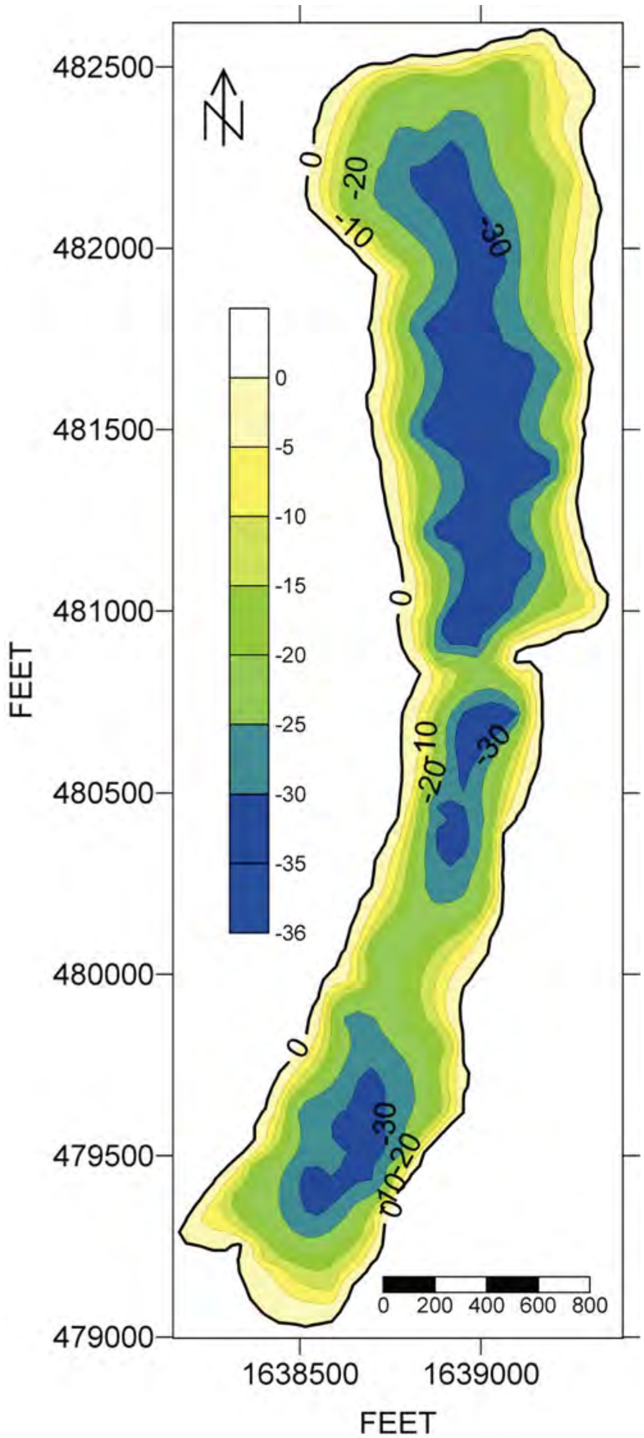

Figure 32. Contoured bathymetric map of the Selah – South Pond (pond I)
(bathymetry in feet below 7/16/02 waterline)

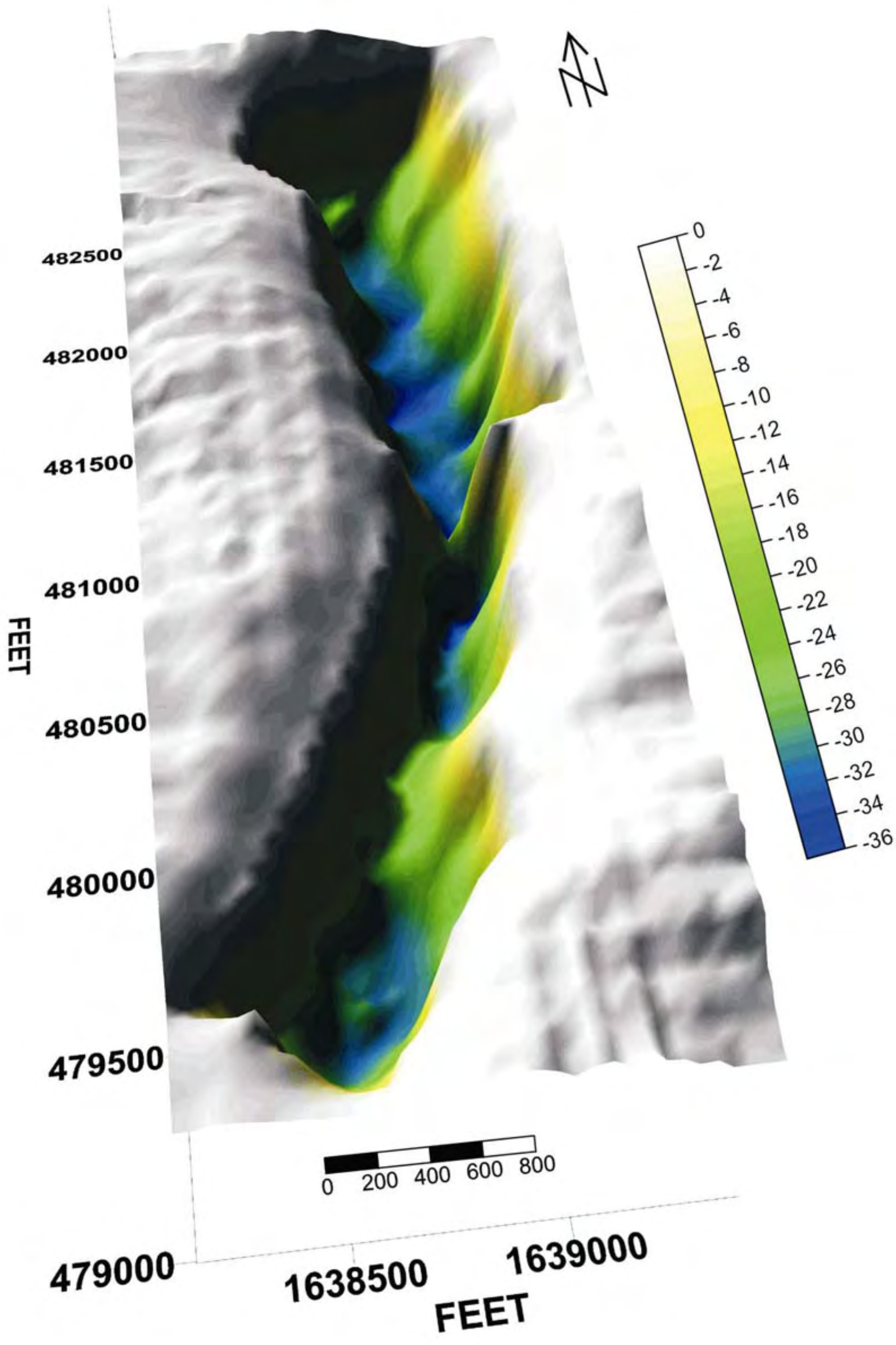

Figure 33. 3-D perspective map of the Selah – South Pond (pond I)
(bathymetry in feet below 7/16/02 waterline)

Recently deposited river gravel has been mined down to older semi-consolidated sediments of the Thorp Formation. At Selah, the Thorp Formation comprises the floors of all mine pits. Thorp sediments typically consist of well-graded or poorly sorted gravel embedded in a matrix of fine sand, silt, and clay. Sediment sample # 146, for example, from the drained north pit (Selah Pond IV) (Figure 27), has a grain size distribution of 63.6% gravel, 32.0% fine sand, and 4.5% silt and clay (Figure 34).

Sediment sample #1, from the east shore of the long pond (southwest side of the Selah site), represents more recently deposited Yakima River sediment (Table 5), containing a significantly smaller percentage of fines than samples (e.g. sample # 146) retrieved from the underlying Thorp Formation.

Table 5. Selah Ponds qualitative sediment particle data

Sediment Sample	Sediment Particle Size Range	Comments
Selah - 1	10% @ 0.001 to 0.02 in (0.25 - 0.5 mm) + 15 % @ 0.02 to 0.39 in (0.5 - 10mm) + 75% @ 0.39 to 2.4 in (10 - 60 mm)	Fine to coarse gravel and cobbles with minor coarse sand

At Selah, the Thorp Formation has a high silt and clay content. As a result, sediments composing the pit floors have a low hydraulic conductivity and; therefore, little upwelling of ground water to the pond floors is expected. This is evident at the drained north pit where the rate of ground water discharge into the pit is low.

<u>Terrace Heights Pits</u> (Yakima)

The Yakima River avulsed through the retaining dike and into the Terrace Height gravel mine in the early 1970s. The mine has had the river flowing through it for about 30 years, and at the time of this report is nearly completely filled-in with sediment (Figure 35). 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 is presently an anastomosing channel. Channel complexity appears to increase at the mine site with a concomitant increase in CMZ width from approximately 1000 ft (300 m) upstream to 1600 ft (490 m) adjacent to, and decreasing to near 0 ft (0 m) downstream of the mine at the first bridge crossing. The Terrace Heights reach valley slope of 0.00375 (approx. 19.8-ft drop in valley floor elevation for each mile downstream (3.7 m drop per km)) is an increase from the upstream Selah site. This increase in valley-reach gradient may be the result of channel changes due to an increase in sediment and/or discharge at the Naches River confluence.

Three sediment samples were taken at Terrace heights (Figure 35). 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 6). 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 was extracted from an upstream gravel bar, and is representative of the modern alluvium within the Yakima River channel, as well as that filling in the Terrace Heights mine site

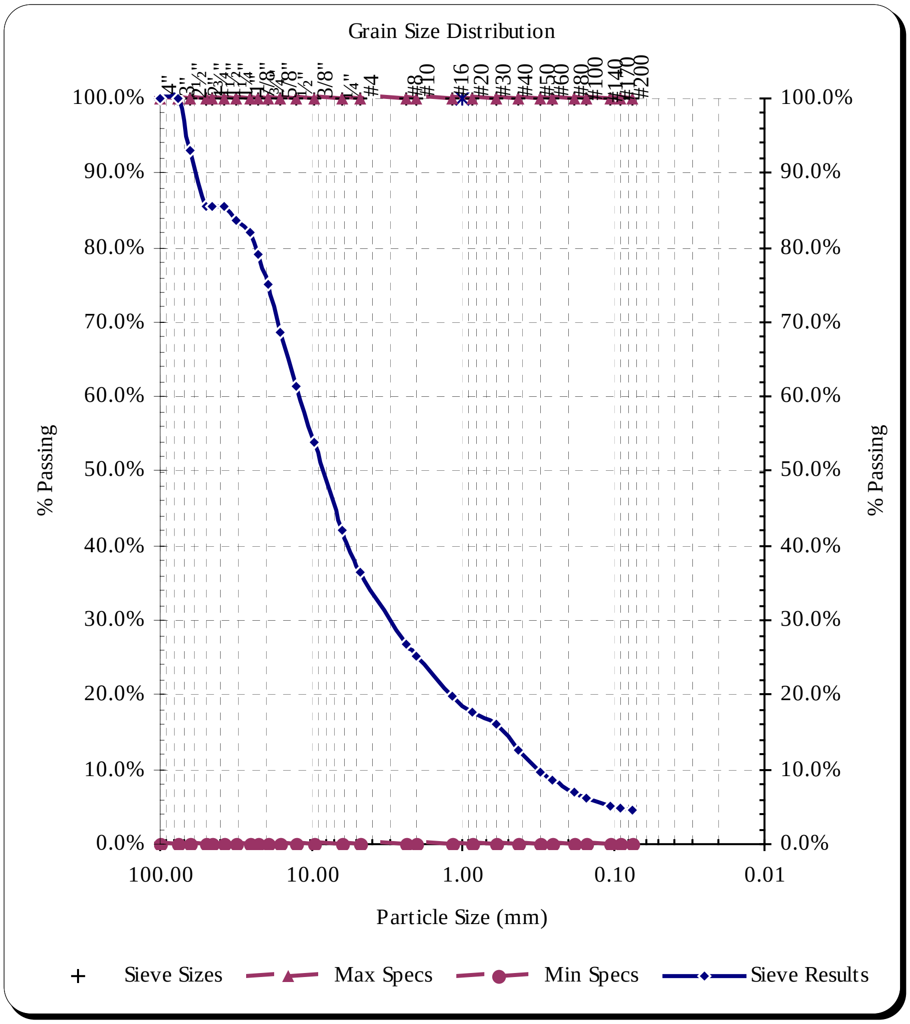

Figure 34. Grain size distribution plot for the Selah Ponds sediment sample # 146 – a sample of the Thorp Formation from the drained floor of Selah Pond IV (see Figure 27)

(Figure 36). Sediment upstream of the old pit (sample #437) is poorly graded and consists of 90.2% gravel, 9.2% sand, and 0.6% silt, and clay (Figure 36). Gravel size ranges from 0.19 in (4.8 mm) to a cobble size of 3.15 in (80mm). Active channel sediment was also sampled immediately downstream of the mine site (sample #23) (Figure 35; Table 6). The downstream sample (sample # 23) is composed of a coarser 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 as compared to samples #437 and #23 may be due to residual fines from the mining operation and a slightly lower energy regime as the river flows across the mine site as compared to upstream and downstream of the mine.

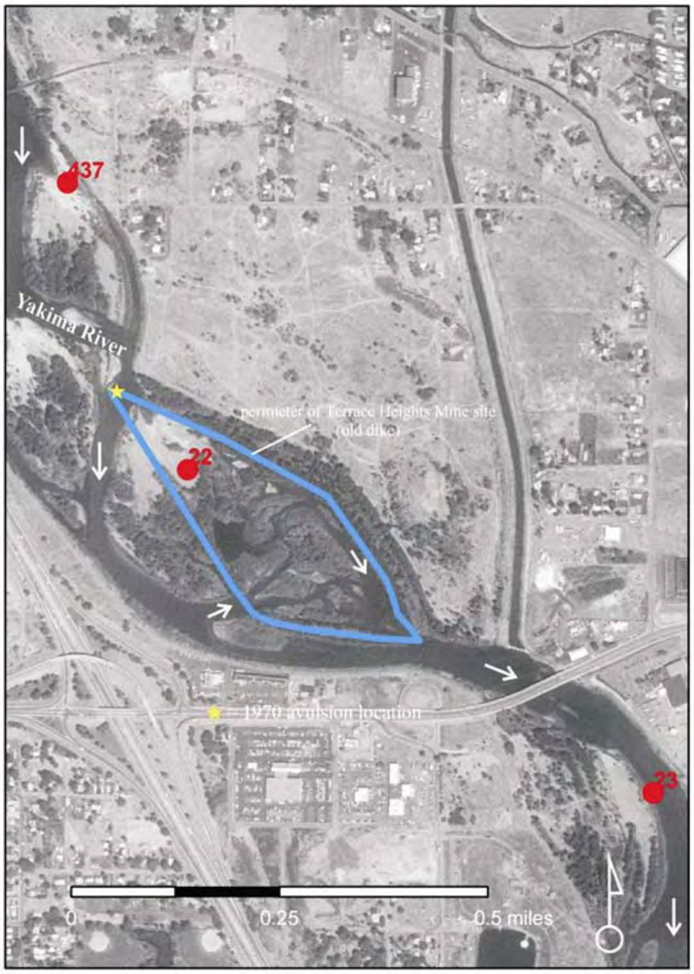

Figure 35. Digital orthophoto of the Terrace Heights Mine site showing sediment sample locations (GPS waypoint #) and former dike margin

Table 6. Terrace Heights Mine qualitative sediment particle data

Sediment Sample	Sediment Particle Size Range	Comments
#22	5% @ 0.001 to 0.003 in (0.025 to 0.08 mm) + 20% @ 0.003 to 0.19 in (0.08 to 4.8 mm) + 75% @ 0.19 to 2.9 in (4.8 to 75 mm)	Fine to coarse gravel with minor coarse sand and silt
#23	1% @ 0.001 to 0.003 in (0.025 to 0.08 mm) +14% @ 0.003 to 0.19 in (0.08 to 4.8 mm) + 85% @ 0.19 to 2.9 in (4.8 to 75 mm)	Fine to coarse grave with minor coarse sand and silt

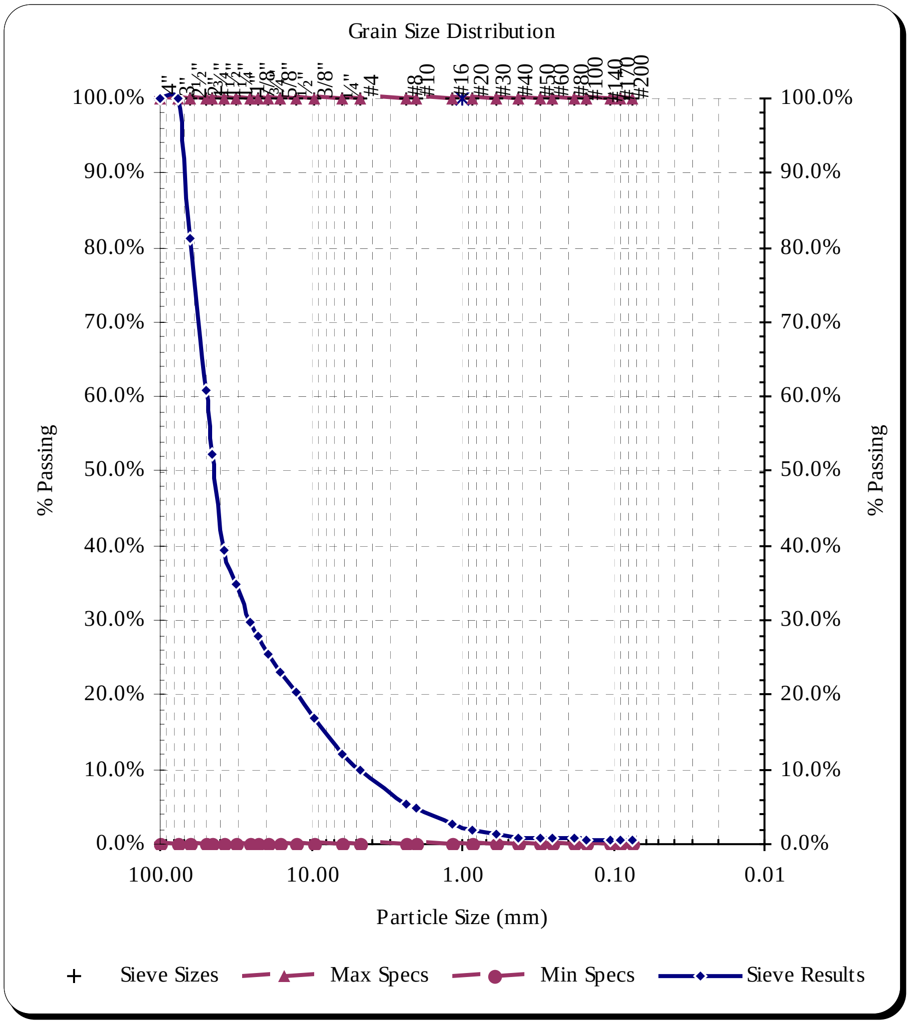

Figure 36. Grain size distribution plot for Terrace Heights upstream sediment sample # 437

<u>Newland Pit</u> (Yakima)

The Newland Pit is an example of a closed system, not currently in connection with the Yakima River (Figure 37). 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 pit is approximately 200 ft (60 m), the western-most point (pit midpoint) is 775 ft (235 m), and the southern (downstream) end is 225 ft (70 m) from the river, respectively. The Newland reach of the Yakima River is an area of historic channel migration through avulsion events (as visible upon comparison of 1953 and 1985 USGS 1:24,000-scale topographic maps); however, extensive diking and embankment armouring have reduced the present mobility of the river through this reach. The CMZ in the Newland reach is 800 to 1,400 ft (240 to 425 m) wide, increasing downstream to approximately 2,000 ft (600 m). The Newland reach valley slope is 0.00325 (approx. 17.2-ft drop in valley floor elevation for each mile downstream (3.25 m drop per km)).

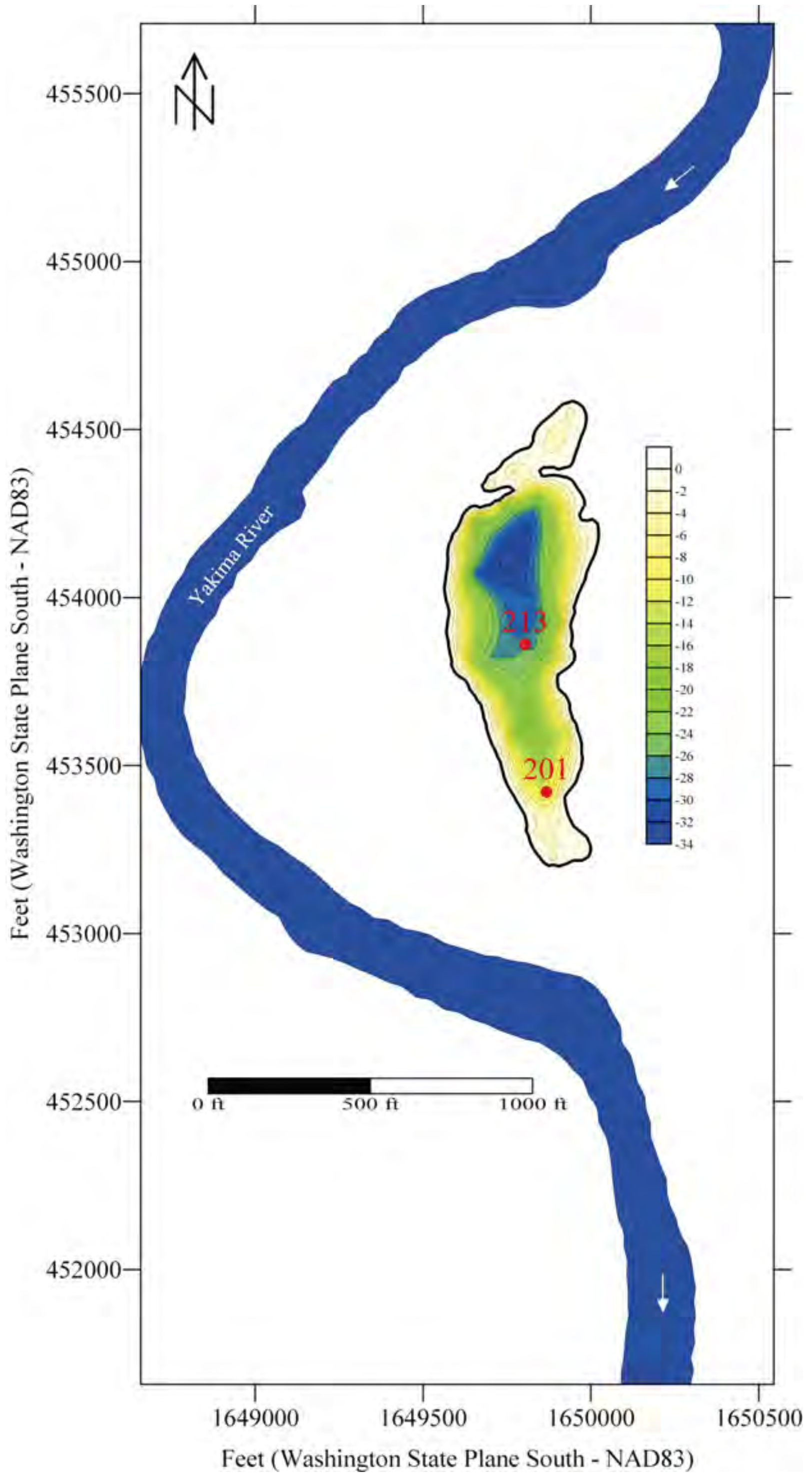

Figure 37. Contoured bathymetric map of the Newland Pond showing location of sediment sample (GPS waypoint #) and proximity to the Yakima River

The Newland pit has steep sidewalls, a northward slopping bottom, and is fairly deep, culminating in a depression in the north-central portion of the pit with a maximum measured depth of 30 (9 m) feet (Figure 38, 39 and 40). The northern and southern-most portion of the pit

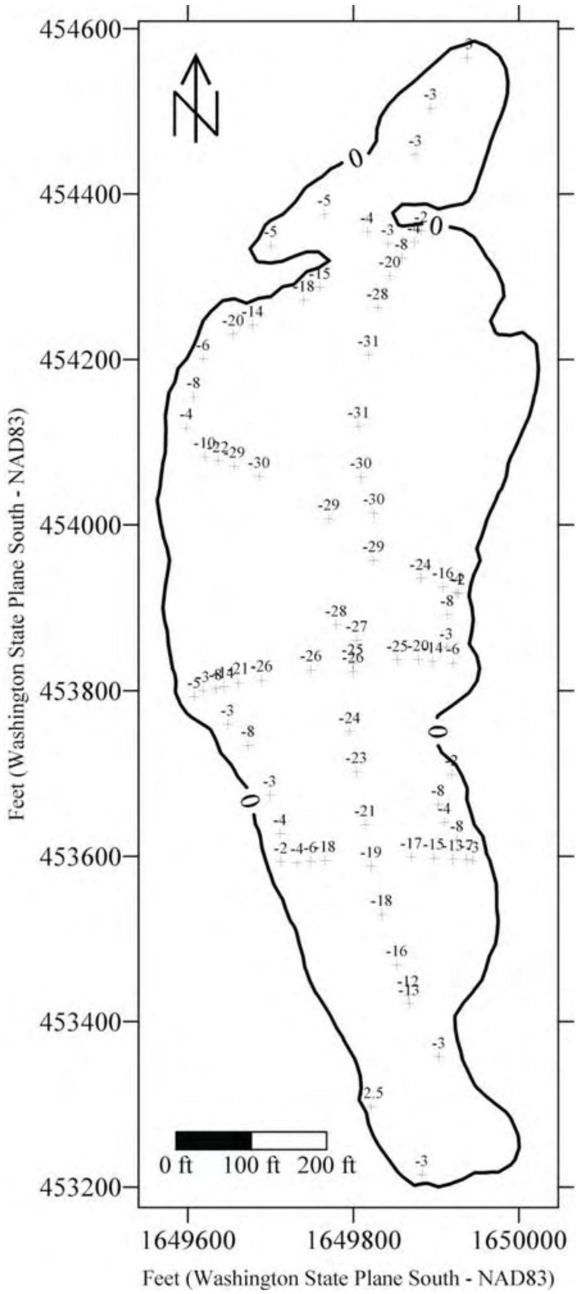

Figure 38. Post map showing data point locations and depths (ft) used to model pond bathymetry for the Newland Pond

are gently sloping and shallow, with the southern portion of the pond receiving sediment input in the form of a silt-clay slurry from adjacent mining operations. This has resulted in the northward progradation of a delta into the pit from the southern end (Figure 40). Several small wildlife-enhancement islands are present in the shallow northern extension of the pond. The average depth of the Newland pit is 11.9 ft (3.6 m).

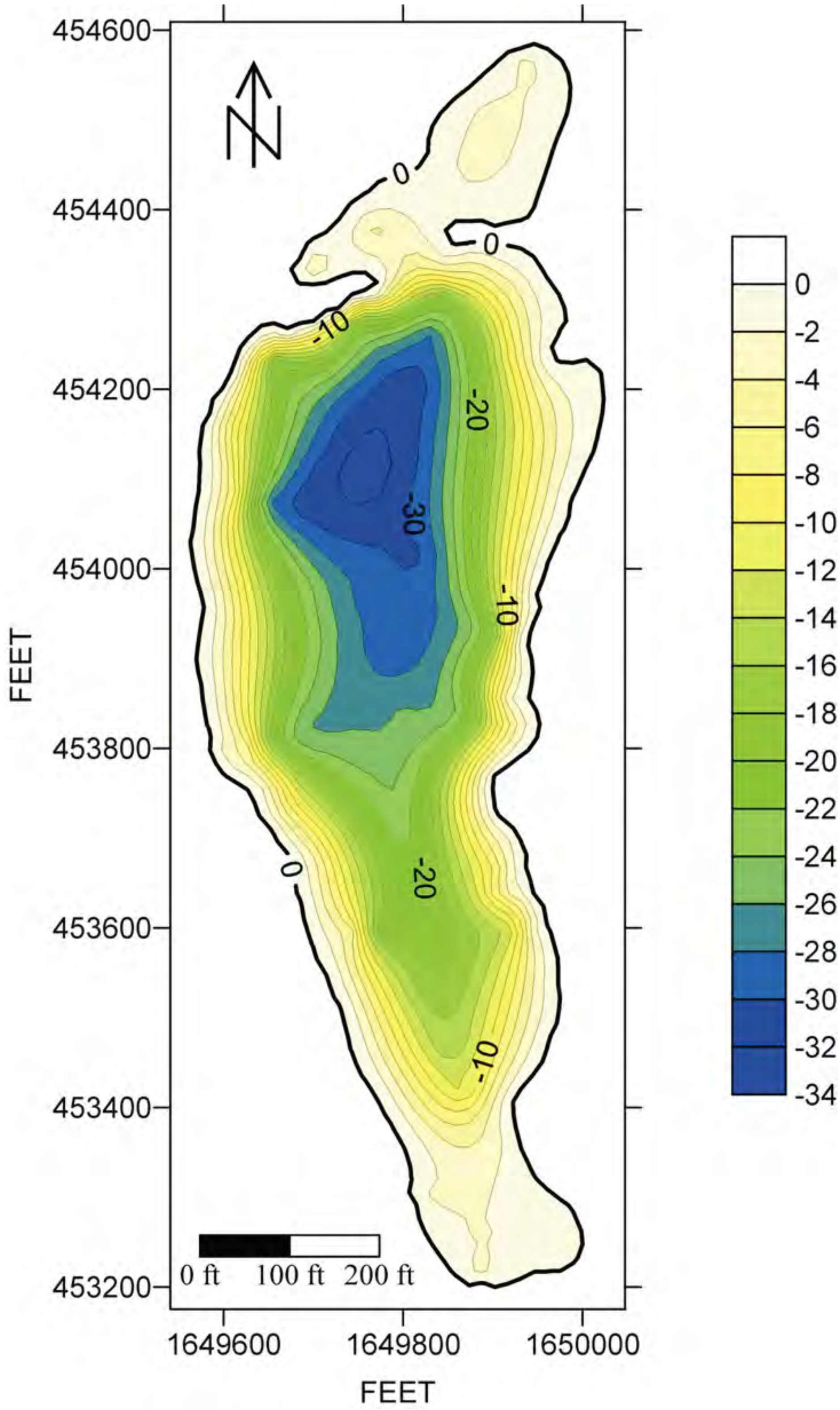

Figure 39. Contoured bathymetric map of the Newland Pond
(bathymetry in feet below 5/29/02 waterline)

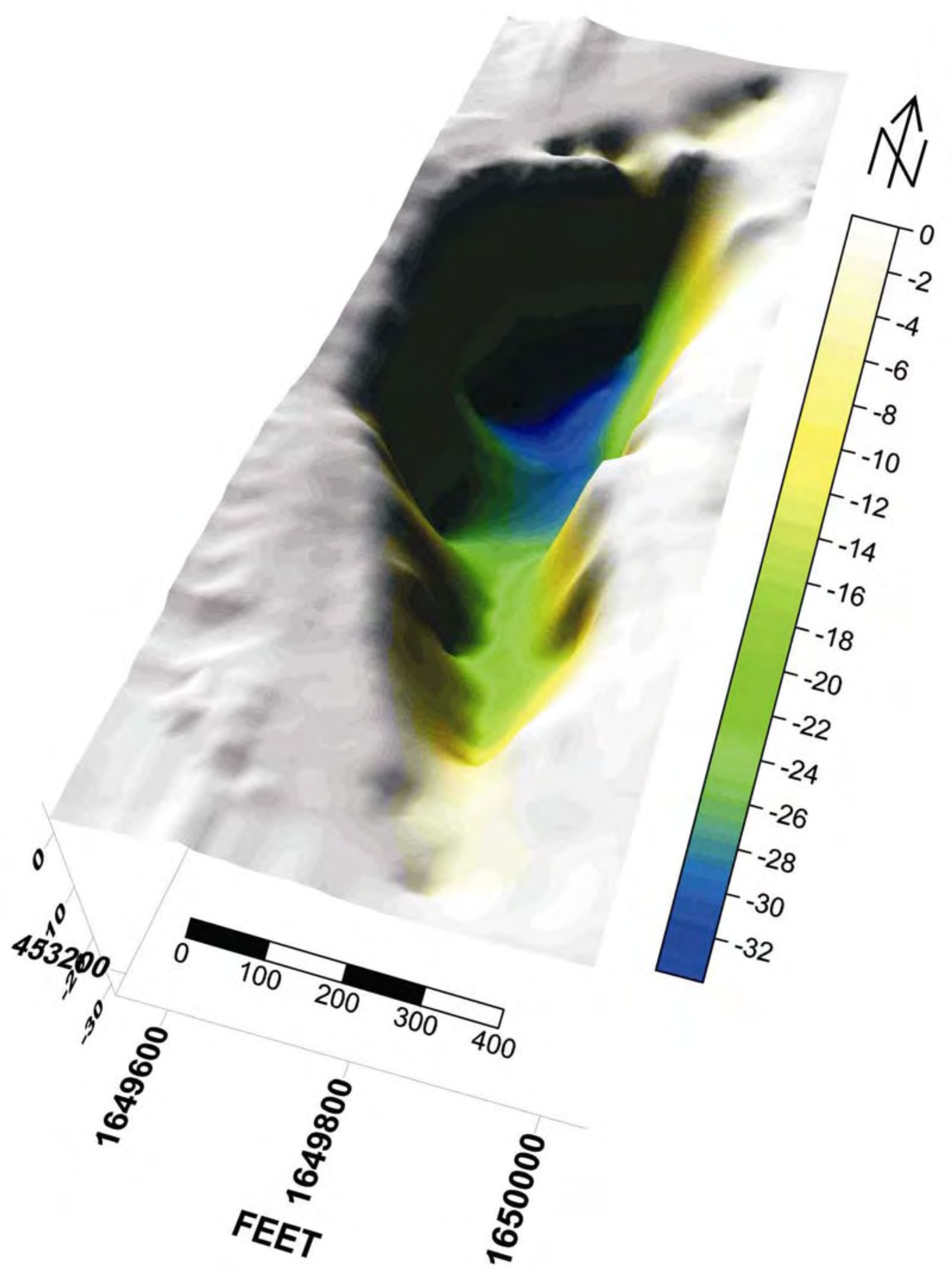

Figure 40. 3-D perspective map of the Newland Pond
(bathymetry in feet below 5/29/02 waterline)

The Newland pit has recently been used as a settling pond for fines derived from an adjacent active gravel mining operation. At the time of this study the pond floor was blanketed with thick clay slurry. One sample, # 201, was collected from the southern end of the pond, near to the location where fine sediment is being washed into the pond from adjacent mining activity. Qualitative assessment of sample # 201 indicates that the pit floor in this location is comprised of 100% silty clay (particle sizes < 0.003 in (< 0.08 mm)) (Table 7). An attempt was made to obtain an additional sample from the deeper portion of the pond (Figure 37) at location # 213; however, the existence of thick clay slurry along the basal 5 to 10 ft (1.5 to 3 m) of the water column prevented sample recovery. It is assumed that the bottom sediments at location # 213 are similar to those sampled at location # 201. (Note that the silt and clay sediment on the deeper floor (>15 ft (5 m)) was void of macroscopic plant life).

Table 7. Newland Pond qualitative sediment particle data

Sediment Sample	**Sediment Particle Size Range**	**Comments**
Newland - 201	100% @ <0.003 in (<0.08 mm)	100% silty clay derived from fines washed into pond from adjacent mining operation
Newland - 213	No sample recovered	thick colloidal clay slurry in lower portion of water column prevented sample recovery.

<u>Edler Ponds</u> (Union Gap)

In the vicinity of the Edler ponds, the Yakima River has a meandering-to-anastomosing plan form, with a variable CMZ of approximately 1,400 ft (425 m) upstream of the ponds, decreasing to approximately 1,100 ft (335 m) adjacent to the ponds, and then increasing to approximately 2,500 ft (760 m) downstream of the ponds. Dikes on either side of the river limit the CMZ adjacent to the pits. The average Edler reach valley slope is 0.00237 (approx. 12.5-ft drop in valley floor elevation for each mile downstream (2.37 m drop per km)). This decrease in valley slope from the Terrace Heights and Newland reaches may be the result of one or more factors, including: (1) a lower slope due to aggradation of sediments upstream of (behind) Union Gap, or (2) active subsidence of the southern Yakima Valley, resulting in channel aggradation and a decrease in channel slope (which is manifested in an increase in meander wavelength and the formation of an anastomosing channel upstream of Union Gap) at the downstream end of the zone of subsidence (Edler ponds reach) (Schumm and others, 1987). Upstream of the zone of subsidence, channel slopes would be expected to increase slightly (as seen as the Newland and Terrace Heights sites).

At the time of our field measurements, the Edler ponds were interconnected during periods of high water via a culvert between the North and Central ponds and a low pass between the Central and South ponds. None of the ponds were connected to the river. In June of 2002, the South Edler pond was connected to the river on the downstream (southeast) end (Figure 41). Breaching of the narrow strip of land separating the South Edler Pond from the Yakima River accelerated bank erosion on the north side of the breach. River flow into the pond formed a large

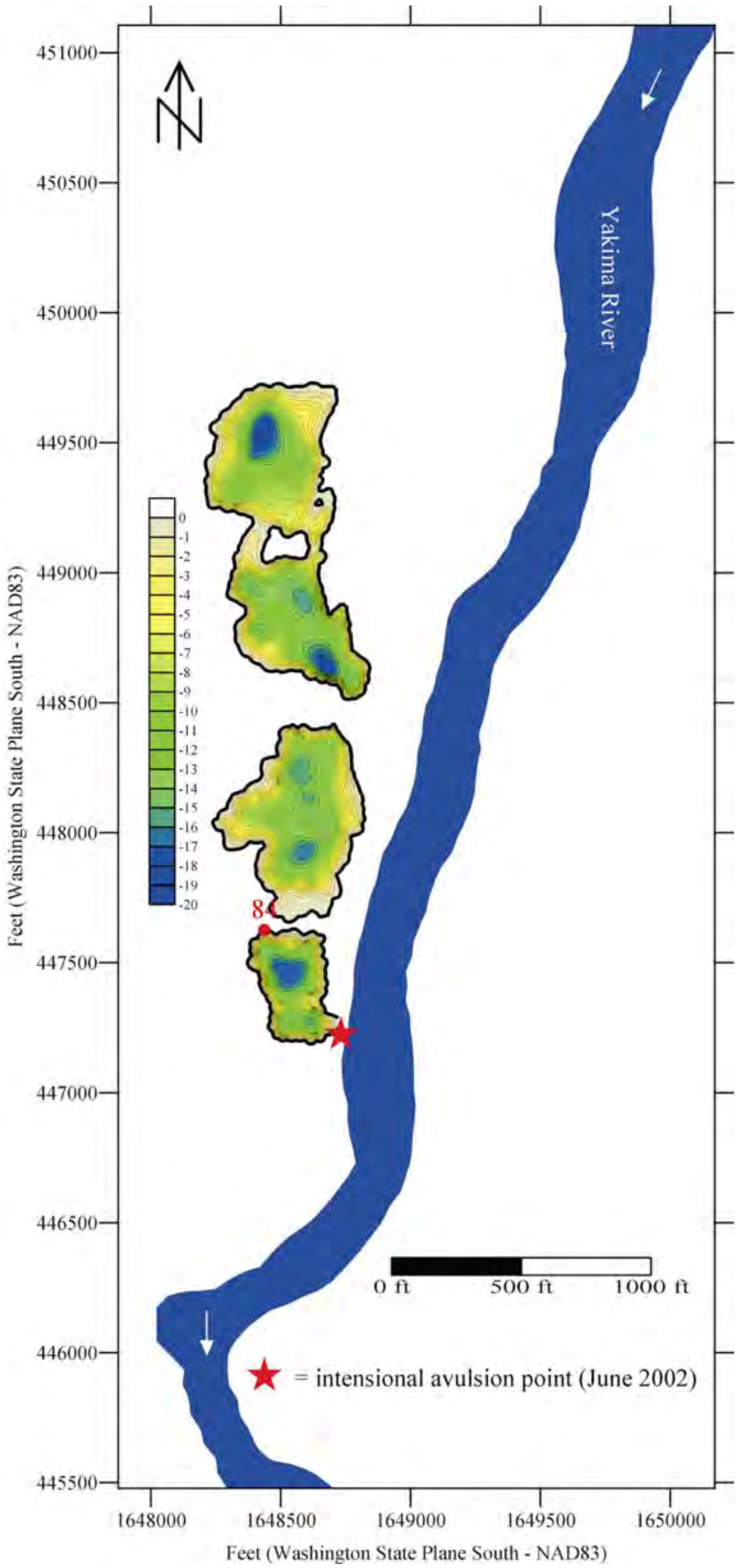

Figure 41. Contoured bathymetric map of the Edler Ponds showing the location of sediment sample (GPS waypoint #) and proximity to the Yakima River

recirculating eddy in the southern portion of the pond, which may result in the deposition of a coarser-grained delta at the point of breaching along with deposition of finer-grained sediments in the lower-energy northern portion of the pond. Continued bank erosion both up-and-downstream of the breach will likely continue.

The North Edler pond is essentially two basins connected by two shallow channels, which were likely dug for the purpose of connecting the two pits. A small island separates the two connecting channels. The maximum measured depth is 19 ft (5.8 m) and 18 ft (5.5 m) for the north and south basins, respectively (Figure 42). In general, the walls of the pond drop quickly towards the deeper basins (Figure 43). The southern basin of the north pond has several small basins separated by broad-shallow sills (Figure 44). The average depth of the North Edler pond is approximately 7.3 ft (2.2 m).

The Central Edler pond is somewhat oval in plan view, with a deeper-central axis running the north-south length of the pond (Figure 45). The maximum measured depth of the pond, 16 ft (4.9 m), was measured in several localities along the central axis of the pond. Shallower benches are located along the western embayment, southern, and southeastern shores (Figures 46 and 47). The average depth of the Central Edler pond is approximately 7.6 ft (2.3 m), which is quite similar to the North Edler pond.

Prior to breaching of the southeast pit margin in June of 2002, the bathymetry of the South Edler pond was characterized by pond-wall slopes of fairly consistent gradient, and a pond floor that reaches a maximum measured depth of 17 ft (5.2 m) (Figure 48). The pond floor is divided into a north and south depression, separated by a sill at approximately 11 ft (3.4 m) (Figures 49 and 50). The average depth of the South Edler pond is approximately 11.1 ft (3.4 m).

Sediment sample # 84 was taken from the north edge of the South Edler pond. This sample, of recent river bar deposits, consists of poorly graded gravel (74.4%), with sand (21.8%), and minor silt and clay (3.8%), and is typical of the particle size distribution, which comprises the floors of North, Central and South Edler ponds (Figure 51). Because we have this baseline of bathymetric and sedimentologic data for the south Edler pond prior to the June 2002 intentional breaching event, it may be worth resurveying this pond in the future to determine how river flow entering on the downstream end of the pond is affecting sediment distribution and bathymetry.

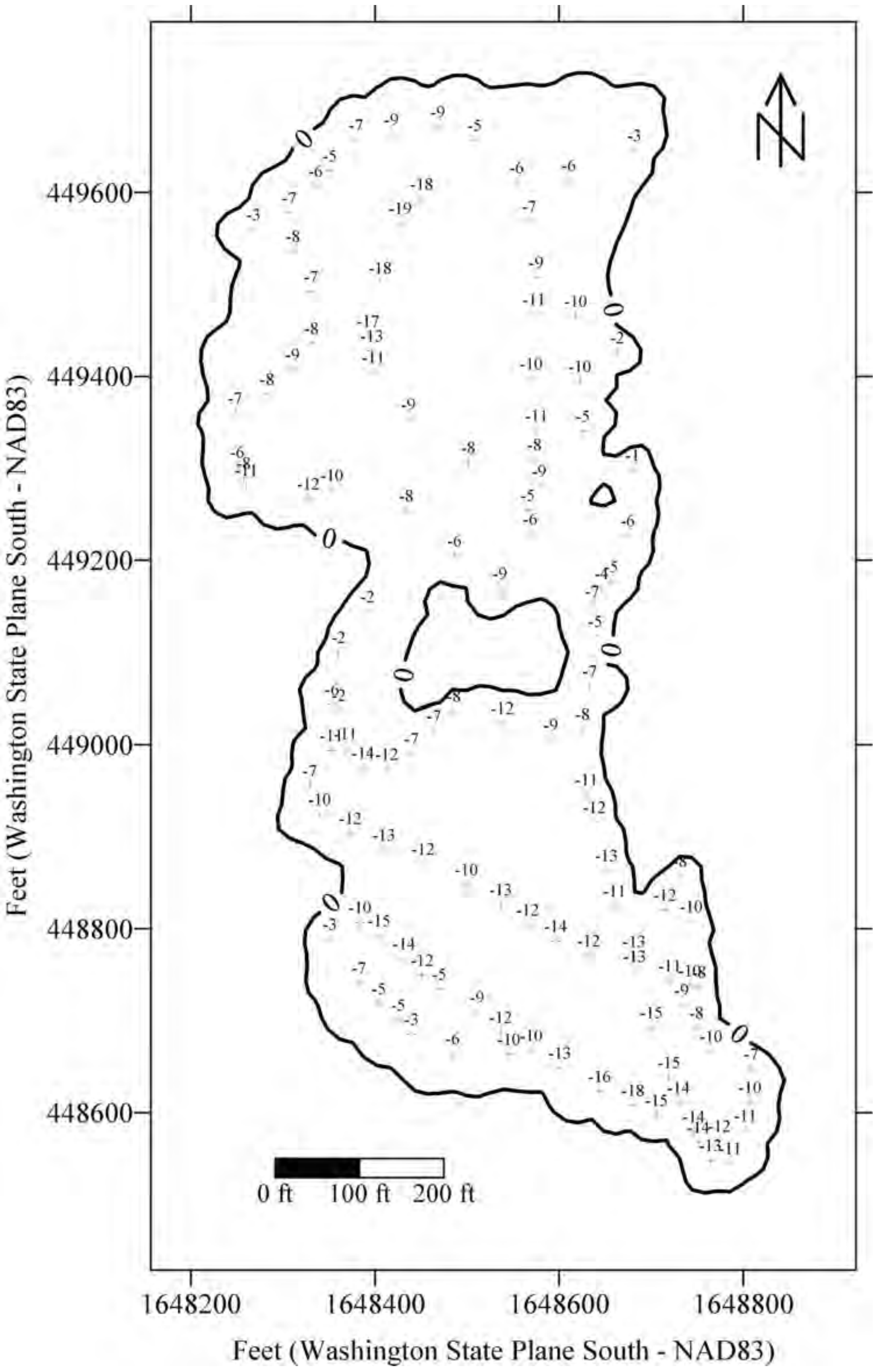

Figure 42. Post map showing data point locations and depths (ft) used to model pond bathymetry for the Edler – North Pond

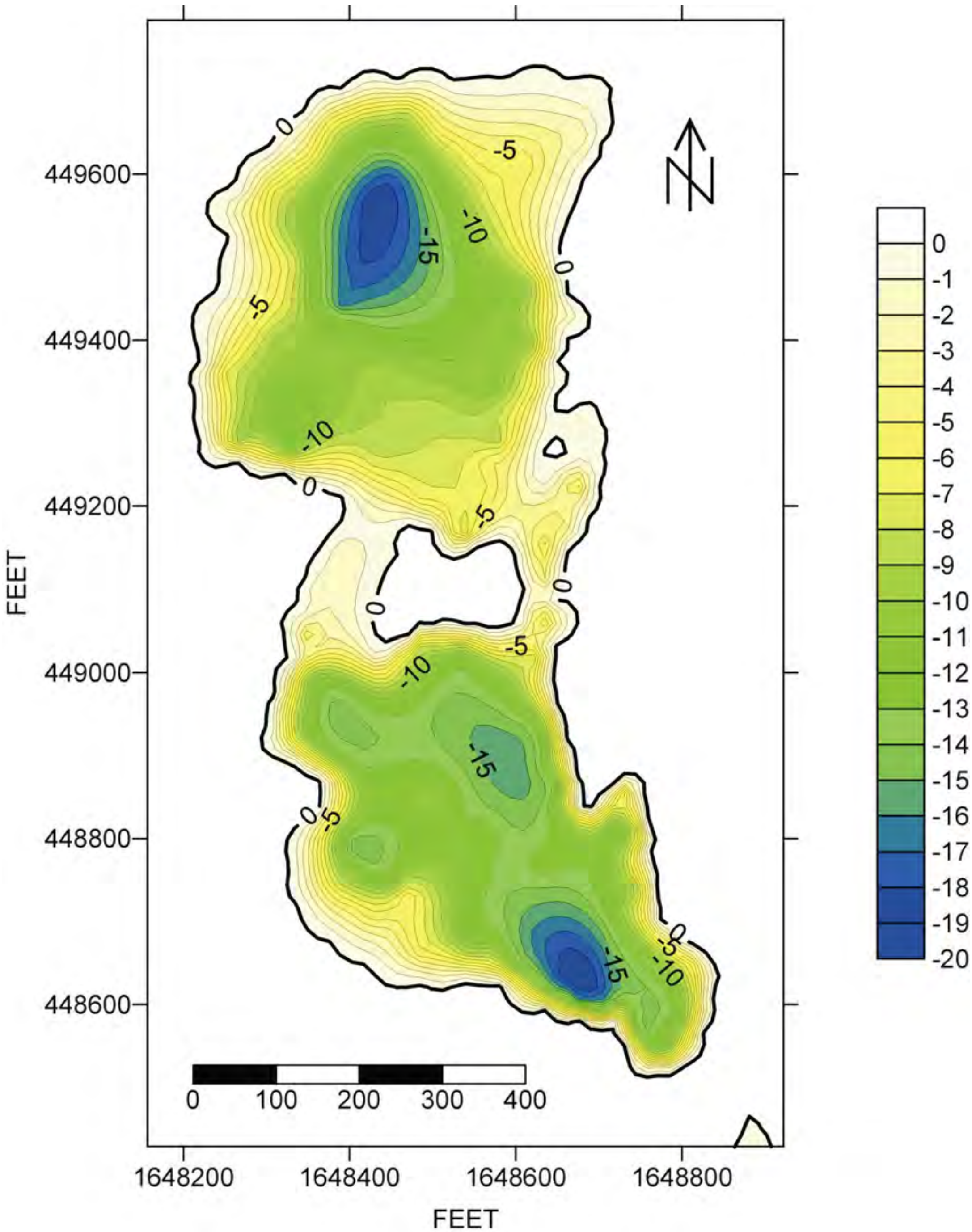

Figure 43. Contoured bathymetric map of the Edler – North Pond (bathymetry in feet below the 5/31/02 waterline)

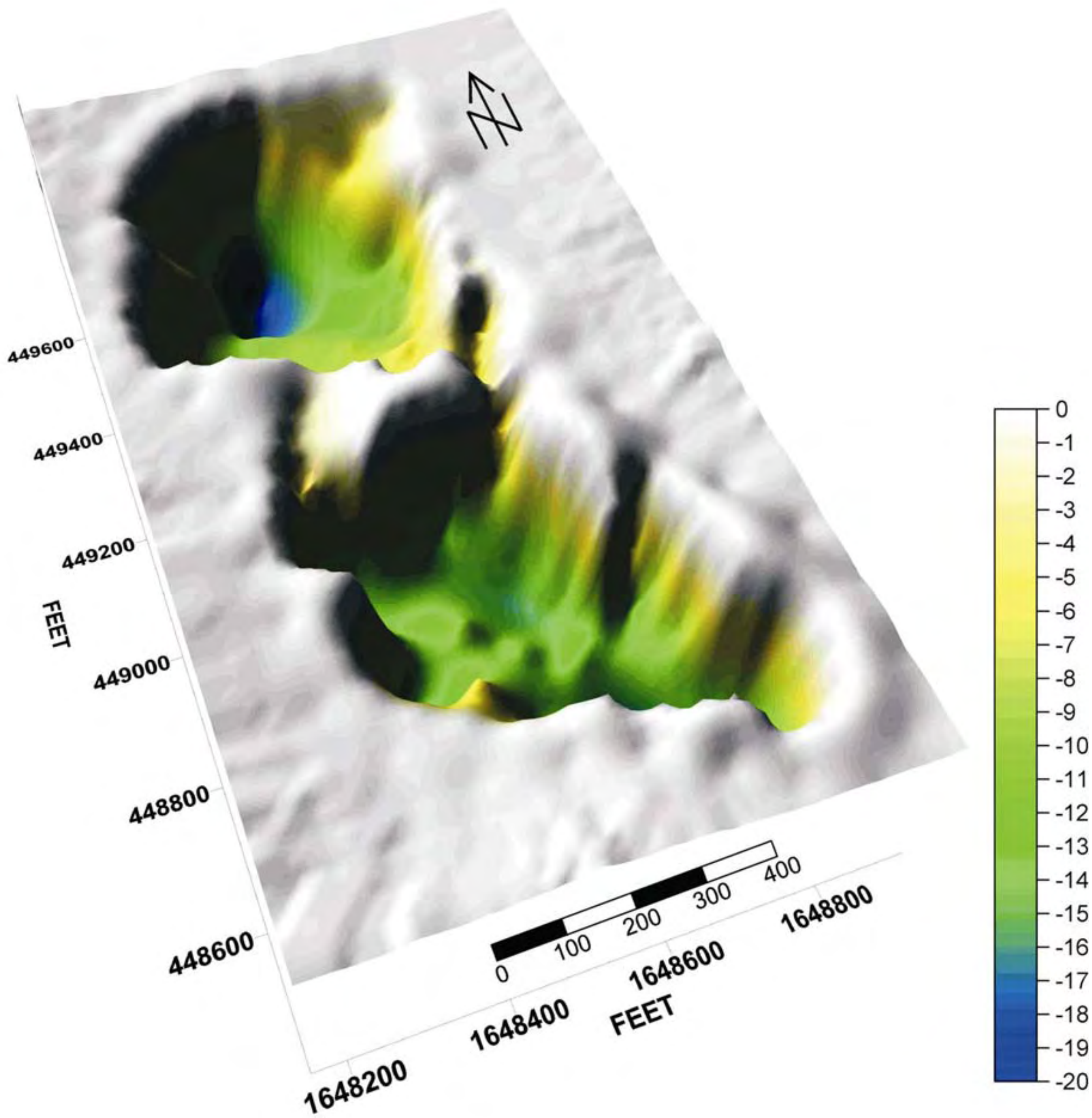

Figure 44. 3-D perspective map of the Edler – North Pond
(bathymetry in feet below the 5/31/02 waterline)

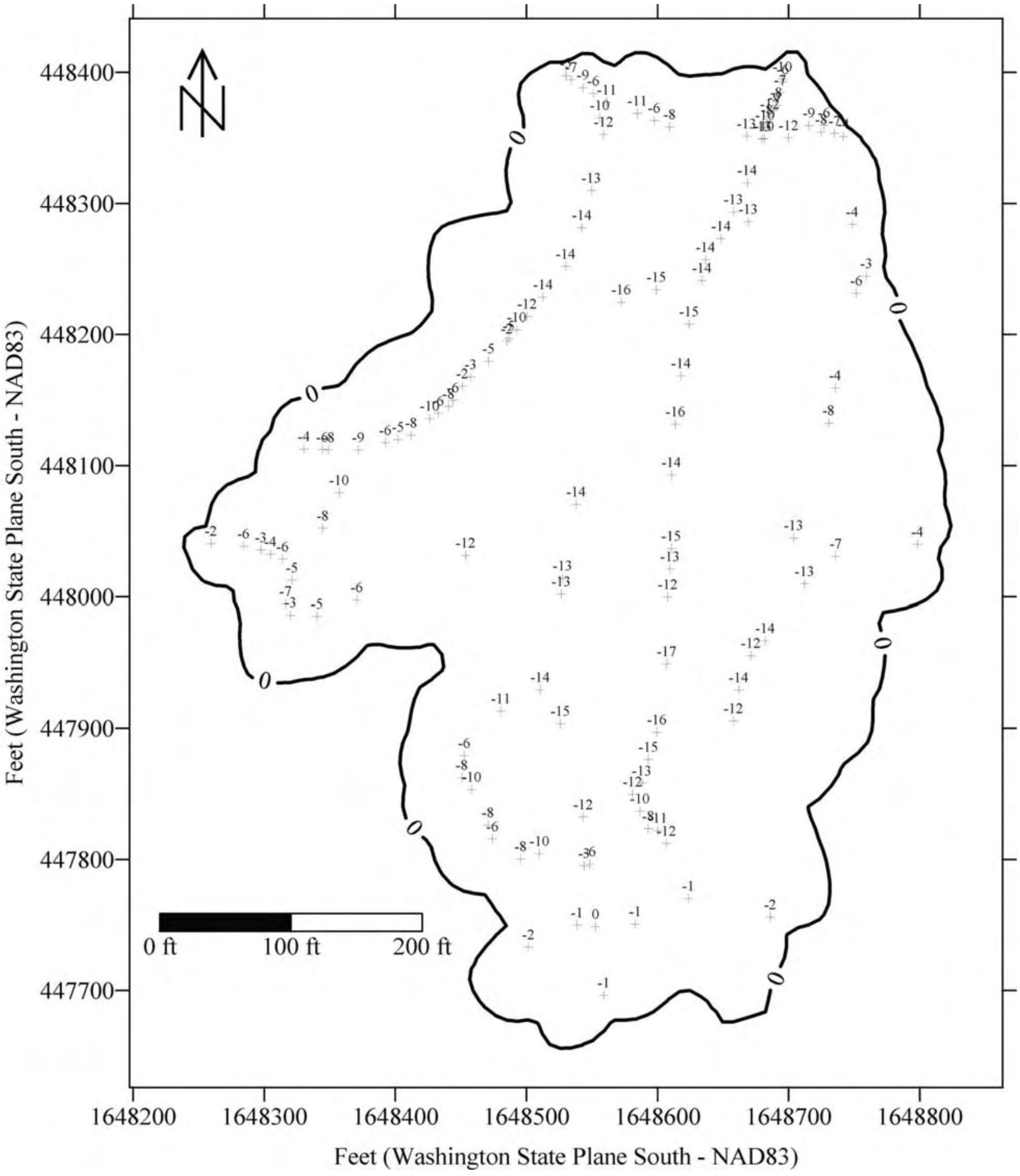

Figure 45. Post map showing data point locations and depths (ft) used to model pond bathymetry for the Edler – Central Pond

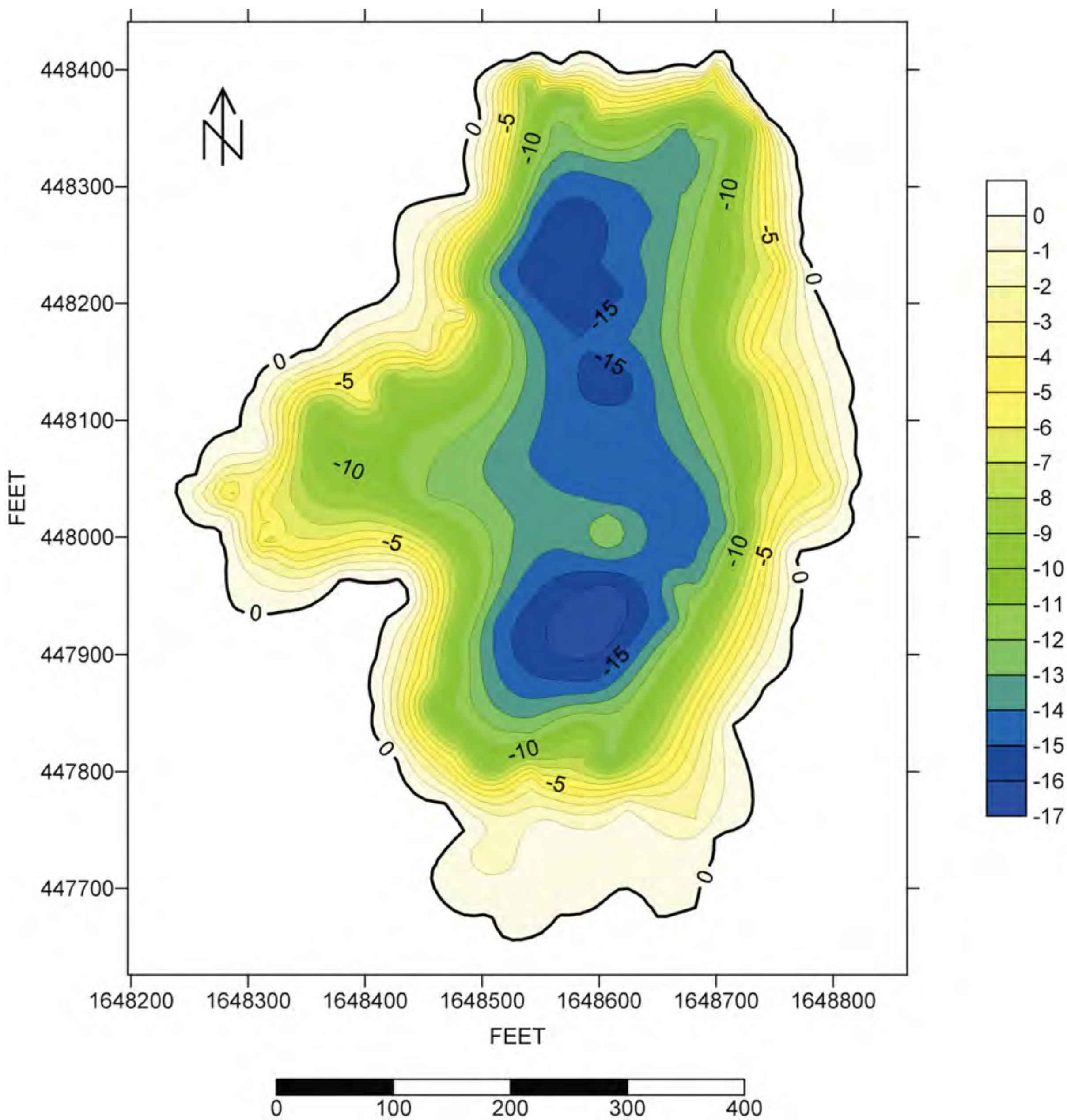

Figure 46. Contoured bathymetric map of the Edler – Central Pond
(bathymetry in feet below 5/31/02 waterline)

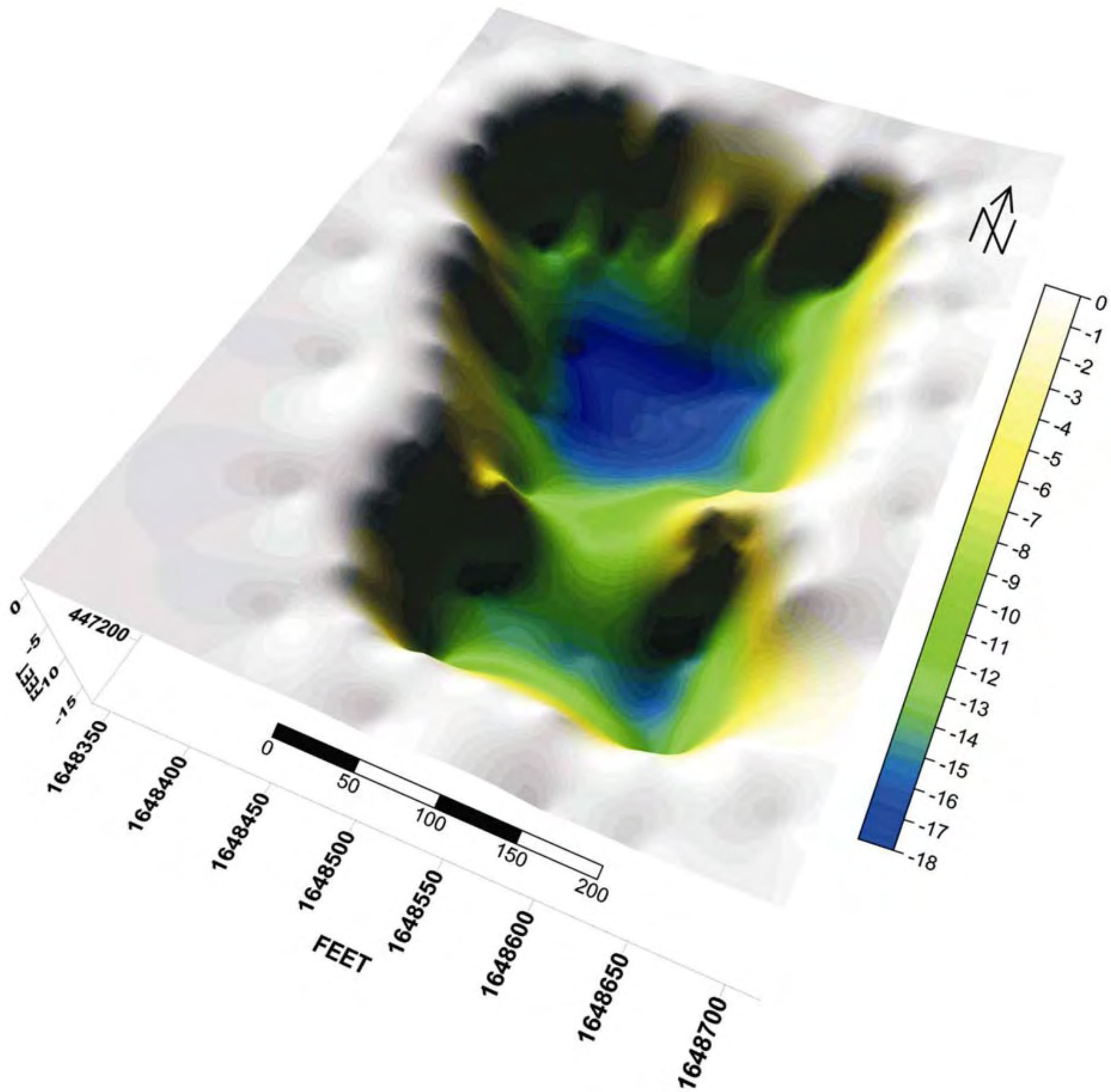

Figure 47. 3-D perspective bathymetric map for the Edler – Central Pond (bathymetry in feet below 5/31/02 waterline)

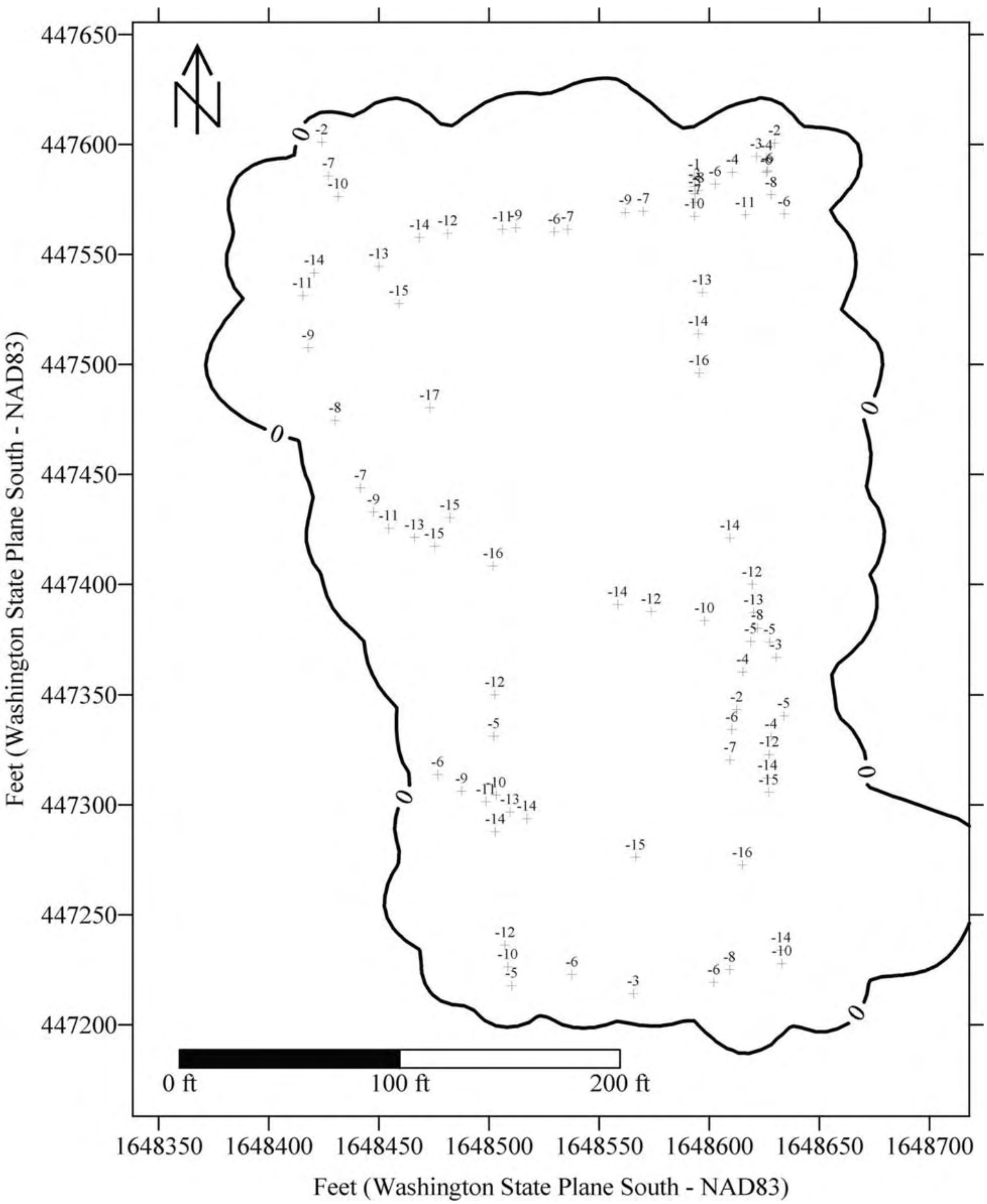

Figure 48. Post map showing data point locations and depths (ft) used to model pond bathymetry for the Edler – South Pond prior to breaching in June of 2002

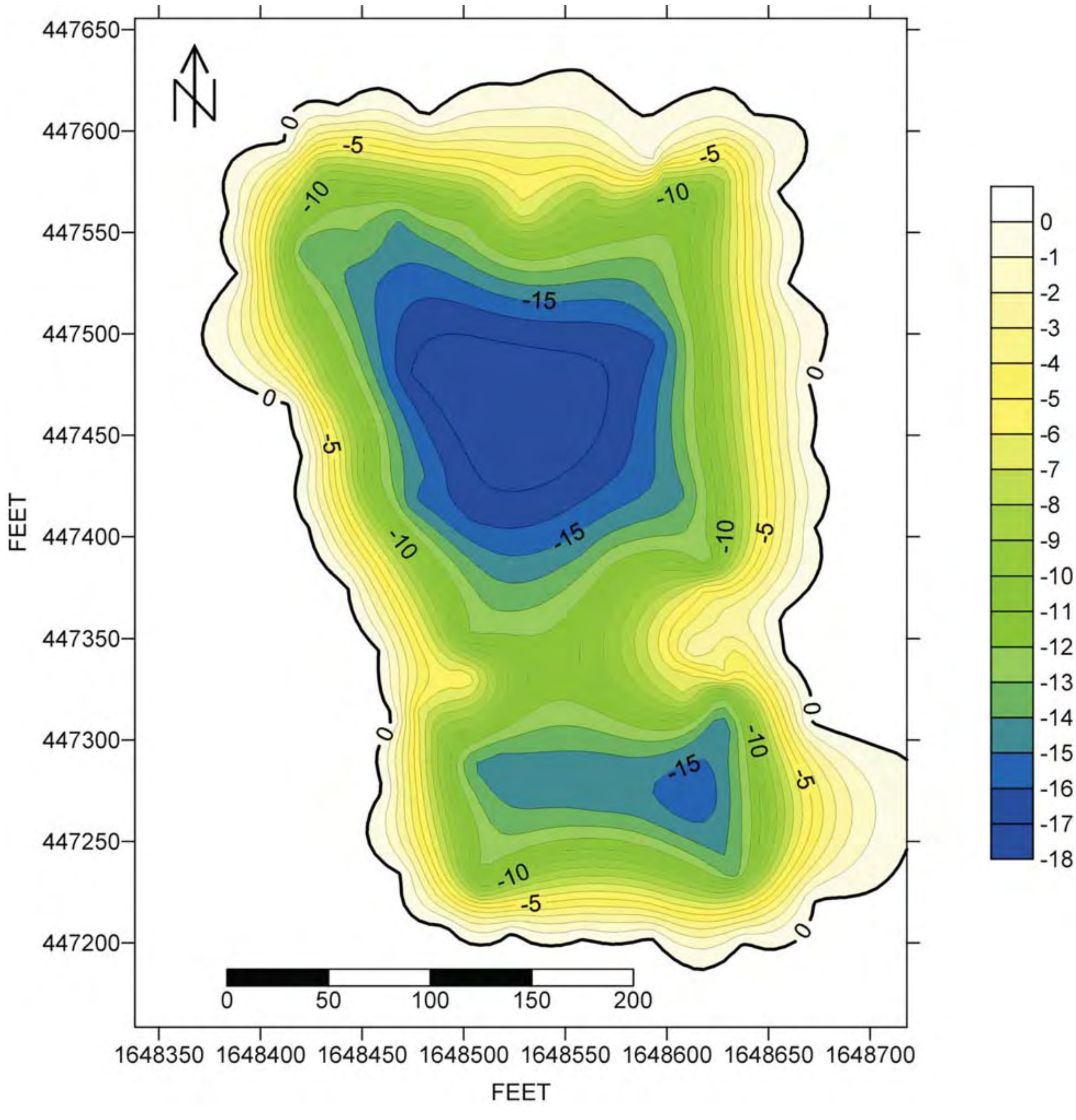

Figure 49. Contoured bathymetric map of the Edler – South Pond prior to breaching of the pit in June 2002 (bathymetry in feet below 5/31/02 waterline)

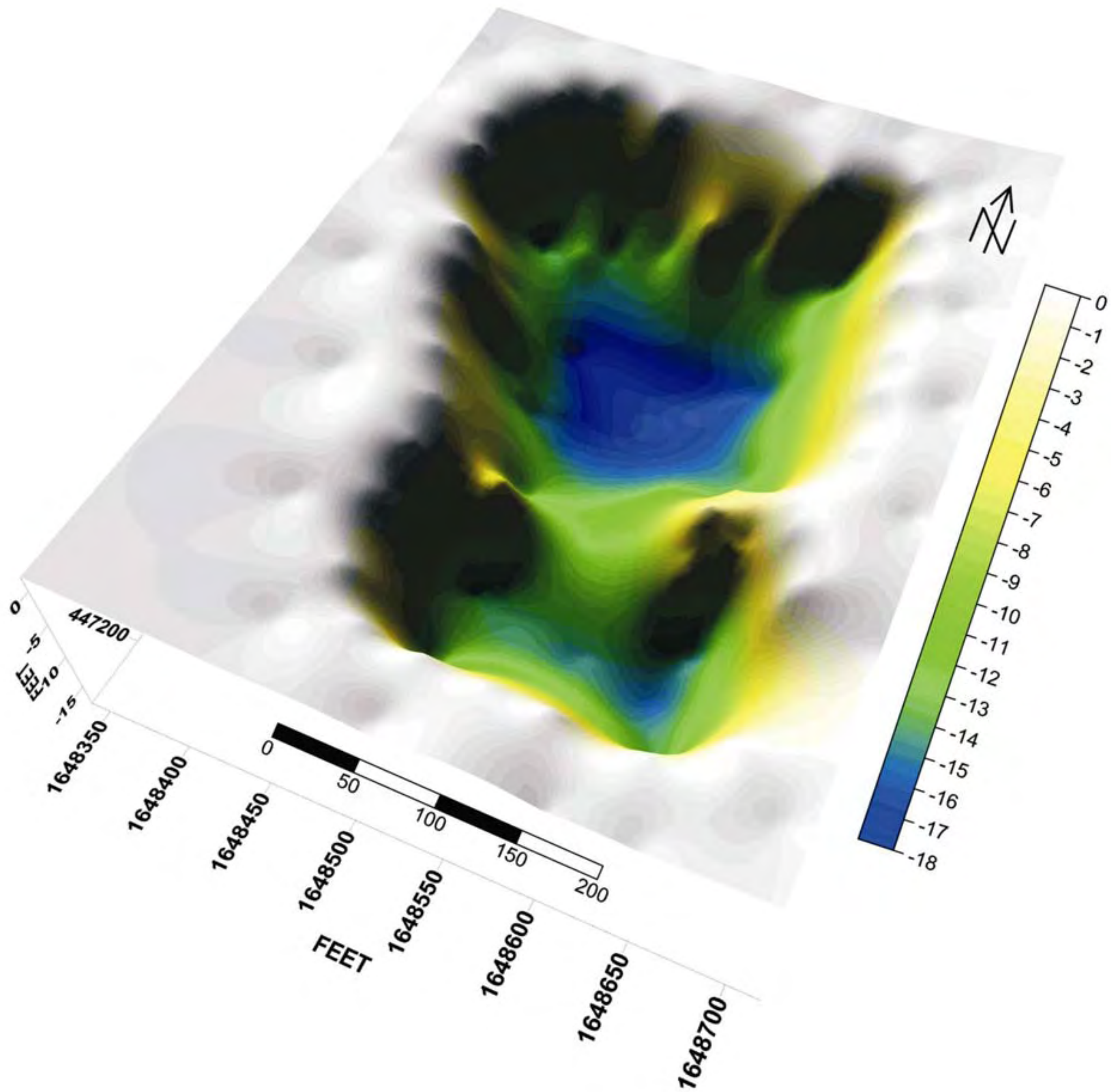

Figure 50. 3-D perspective bathymetric map of the Edler – South Pond prior to breaching of the pond in June 2002 (bathymetry in feet below 5/31/02 waterline)

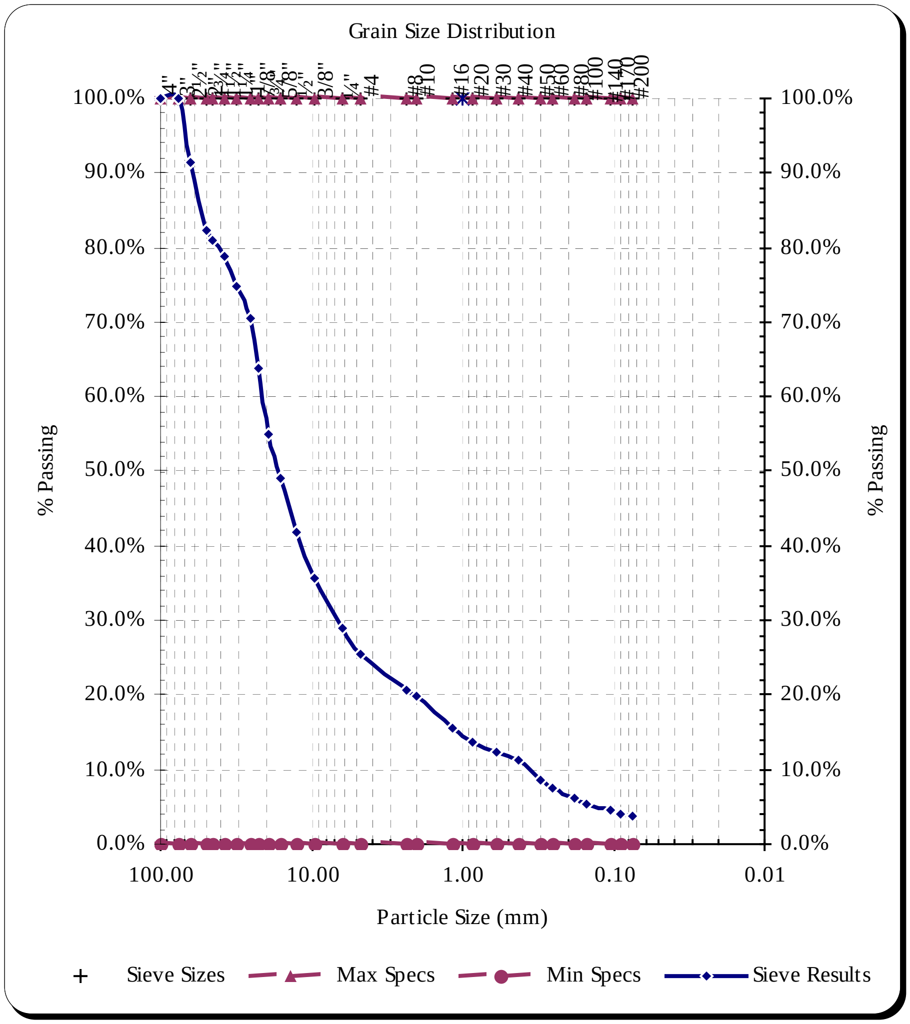

Figure 51. Grain size distribution plot for the Edler Ponds
(collected from margin of the Edler – South Pond)

<u>Parker Pits</u> (Parker)

The Parker site is located just downstream of Union Gap, along the inside of a large meander bend that is now confined to the east by Interstate-82. The mine site represents point bar accretion behind a migrating meander. The river avulsed into the Parker complex during the 1996-100 year flood event (Norman and others, 1998) (Figure 52). Prior to the 1996 avulsion event, the river was effectively confined between the eastern-diked margin of the pit complex and Interstate-82. Prior to 1996, the CMZ width adjacent to the mine site was essentially non-existent. After the 1996 avulsion event, the CMZ adjacent to the mine site has expanded to include the seven ponds of the Parker mine site. Just downstream of Union Gap the CMZ is 1,800 ft (550 m) wide, decreasing to 1,200 ft (365 m) in width at the upstream end of the complex, and decreasing slightly further to approximately 1,000 ft (300 m) downstream of the

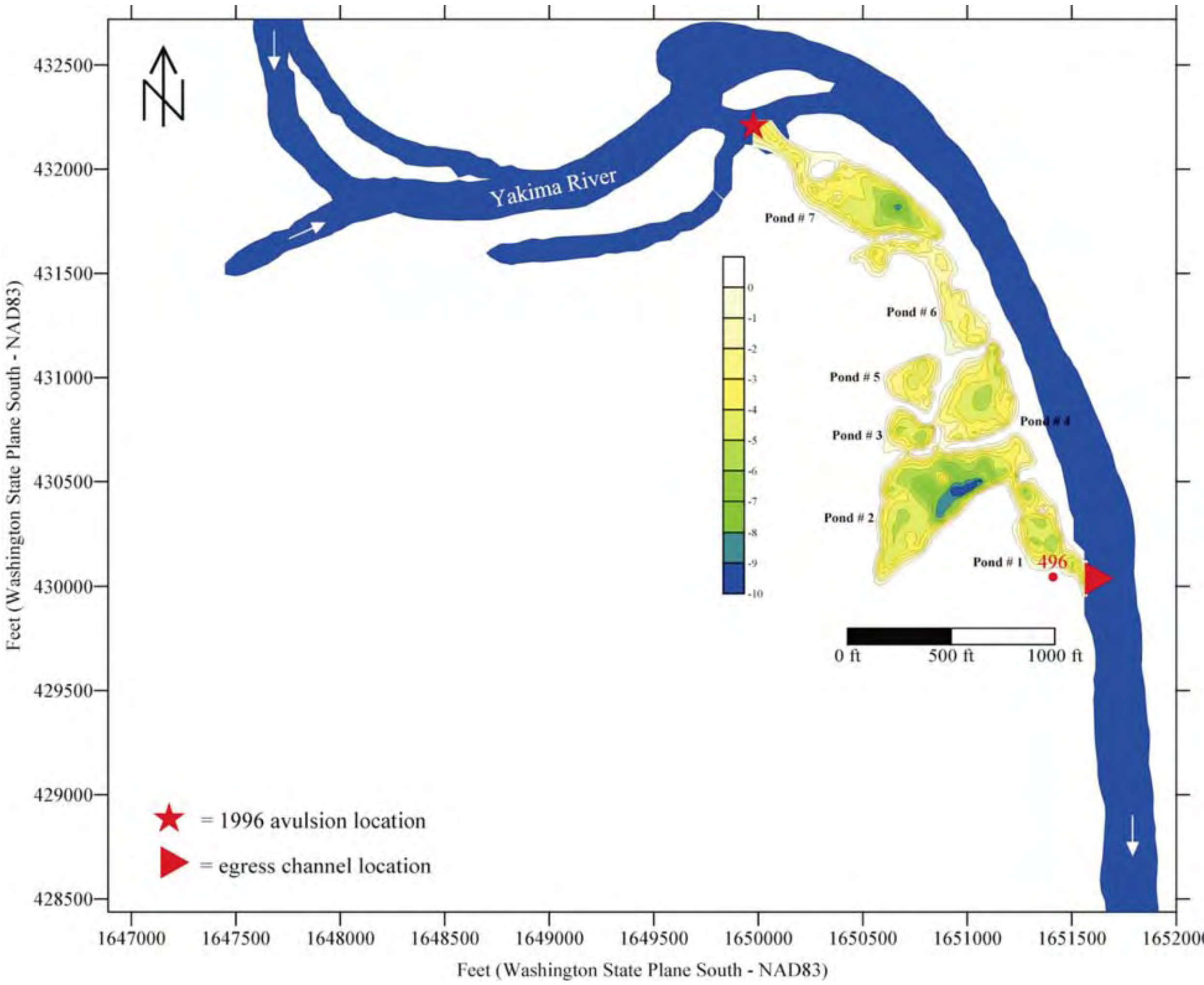

Figure 52. Contoured bathymetric map of the Parker Ponds complex showing location of sediment sample (GPS waypoint #) and proximity to the Yakima River

complex. The Parker complex valley reach slope is 0.00238 (approx. 12.6-ft drop in valley floor elevation for each mile downstream (2.38 m drop per km)).

At the Parker site, 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 in the Parker complex was shallow, approximately 10-ft (3 m) thick, and was limited by the presence of a thick clay layer underlying the extractable sand and gravel in the area (Norman and others, 1998) (Figure 53). The complex consists of seven shallow flat-floored interconnected ponds (Figure 52). The northern most 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 (2.5 to 13.0 cm)) is pro-grading southward into the pond (Figures 54 and 55). Downstream, in the central and south portions of pond 6, 2.0 to 23.5 in (5.0 to 60.0 cm) of fine sand and silt have been deposited over the top of the Thorp Formation. The maximum measured depth in the Parker complex is 8 ft (2.4 m), located along

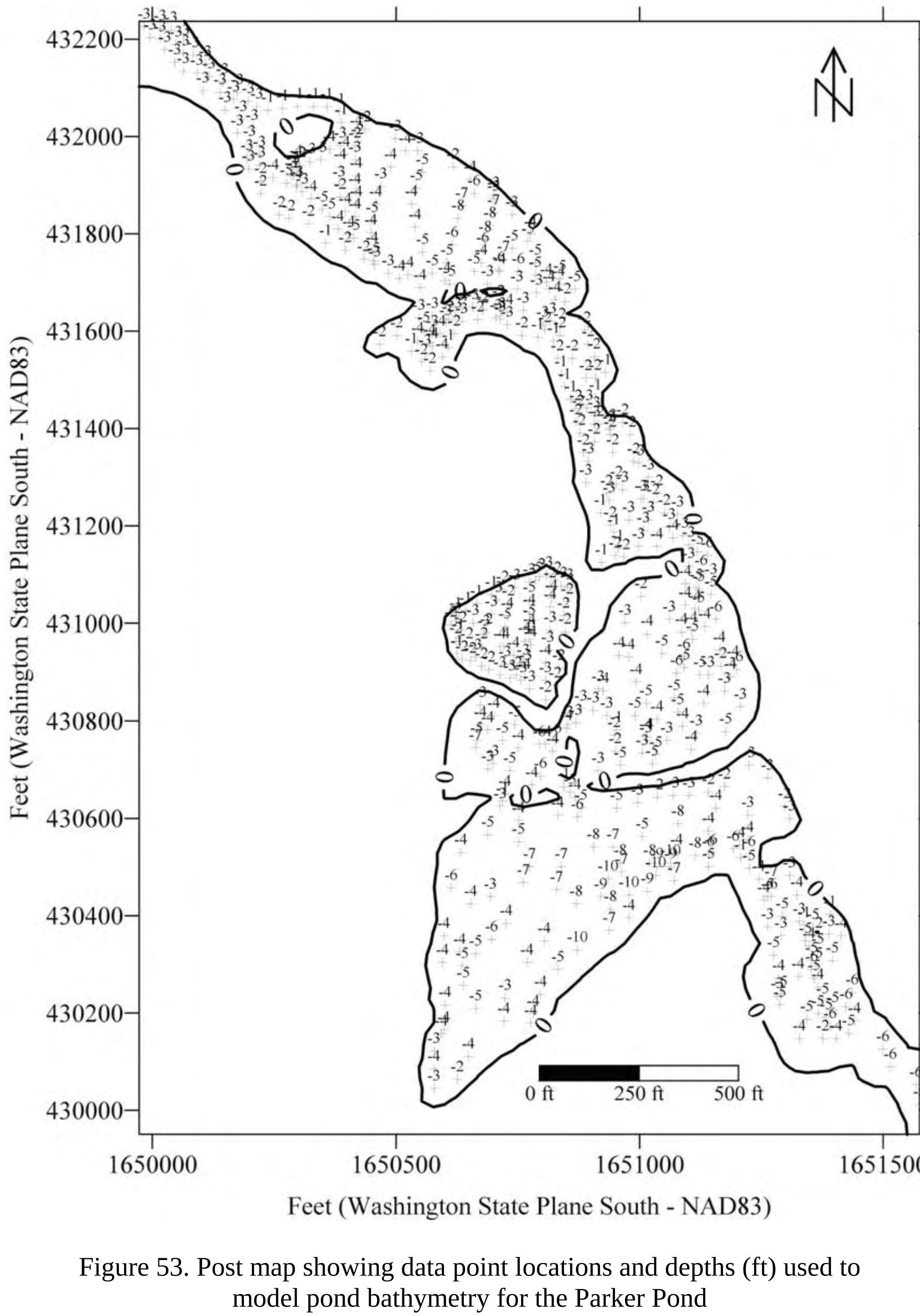

Figure 53. Post map showing data point locations and depths (ft) used to model pond bathymetry for the Parker Pond

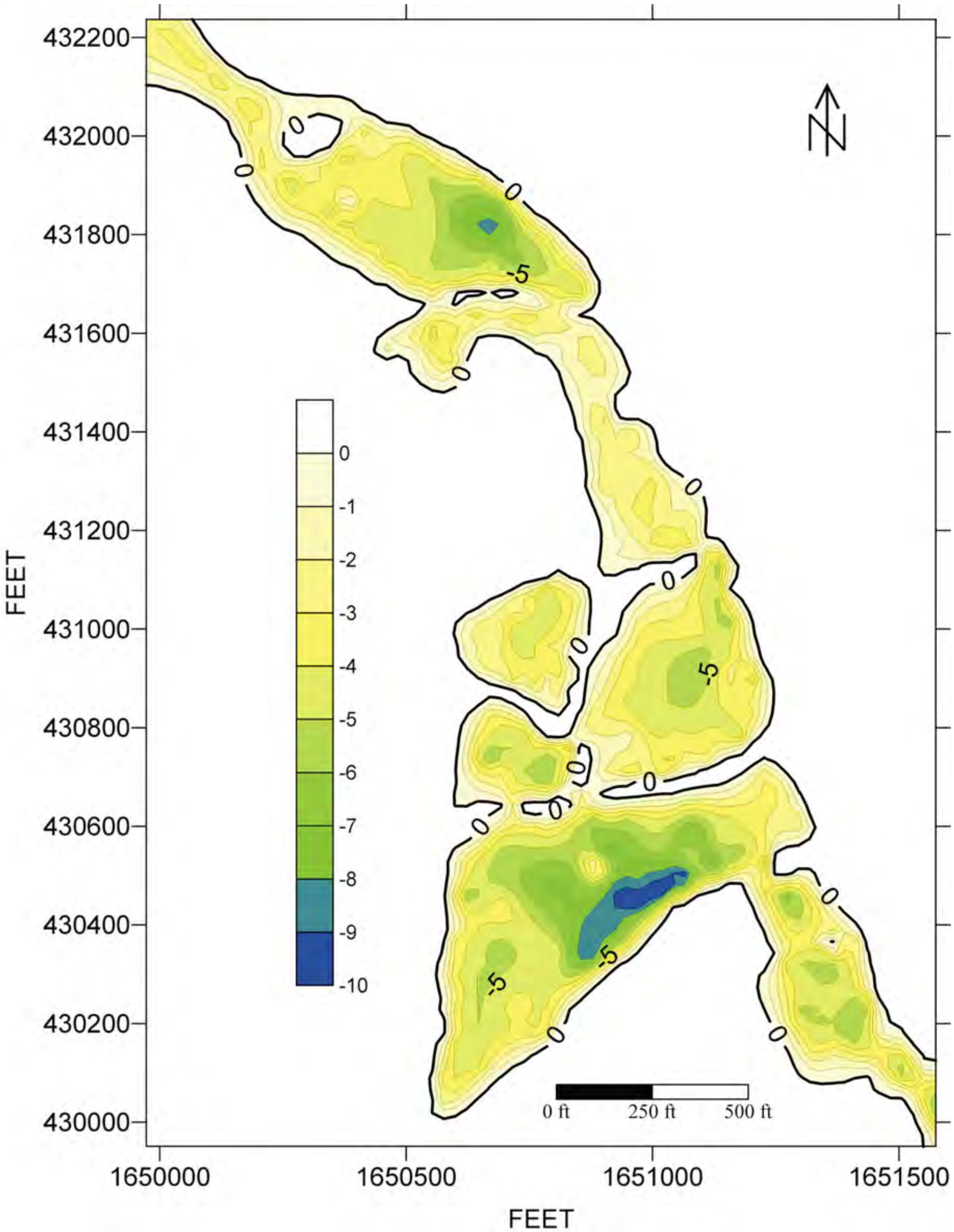

Figure 54. Contoured bathymetric map of the Parker Pond complex
(bathymetry in feet below 7/18/02 waterline)

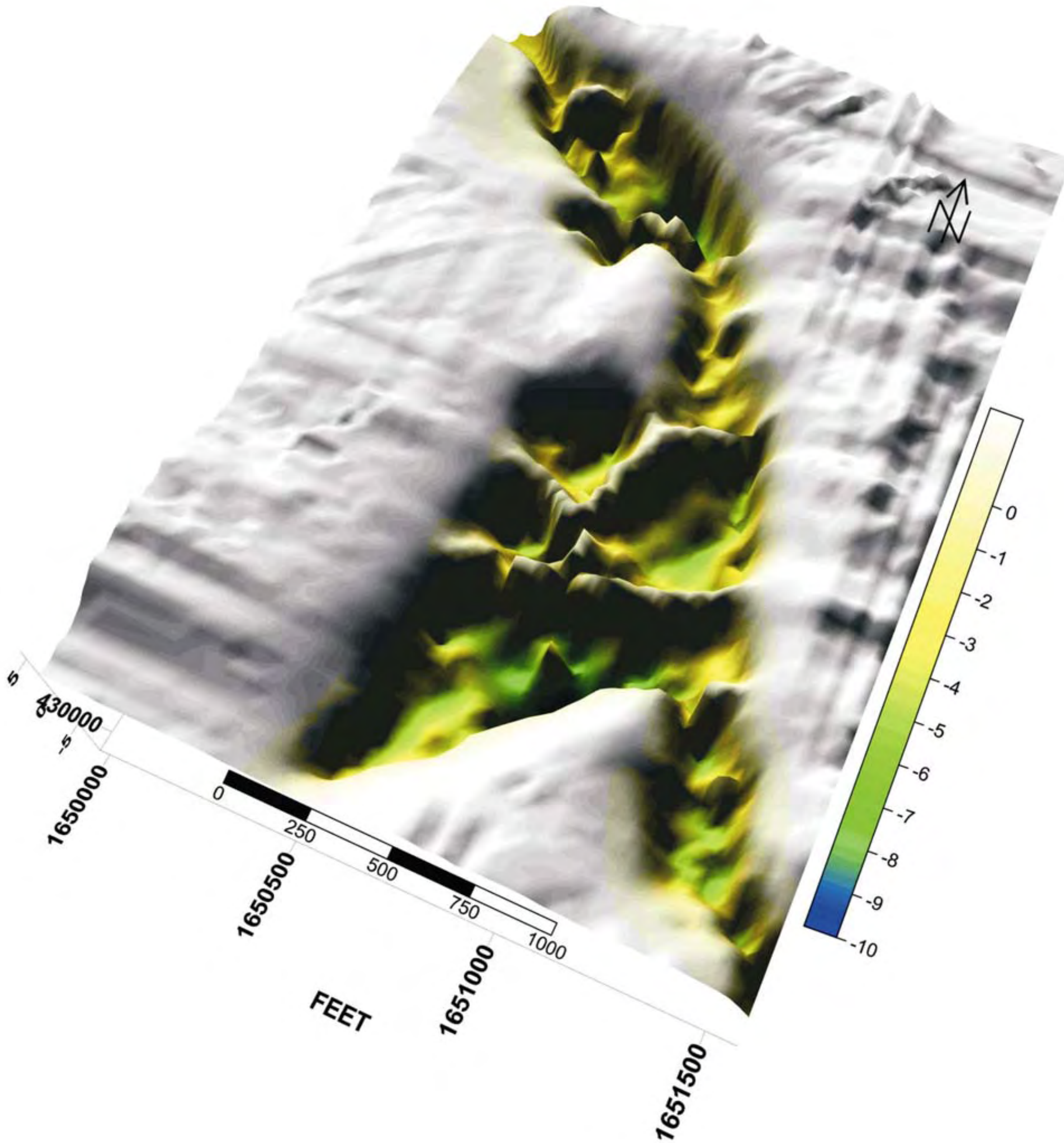

Figure 55. 3-D perspective map of the Parker Ponds complex
(bathymetry in feet below 7/18/02 waterline)

the southern margin of pond 2. The average depth of the entire Parker complex is 3 ft (1 m), making this the shallowest of the mine sites in the study.

Down gradient of pond 7, a network of six poorly connected ponds was examined (Figure 52). Because connecting channels between these ponds are shallow and narrow, the velocity and volume of surface water flowing between pits are low. As a result, the rate of sediment delivery to the pond network is low. Sediment sample # 496 was taken from Thorp Formation at the shores of the south-most pond (pond 1, Figure 52). 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 exposed on all the pit floors south of pond 7 (Figure 56). Only during river flood events have new fine sand, silt, and clay been deposited discontinuously onto pit floors, predominantly at the upstream end of the pond complex. At Parker, aquatic plants grow profusely in fine sand, silt, and clay sediments; and in locations of stagnant water abundant organic matter decomposes during warmer seasons producing eutrofied conditions.

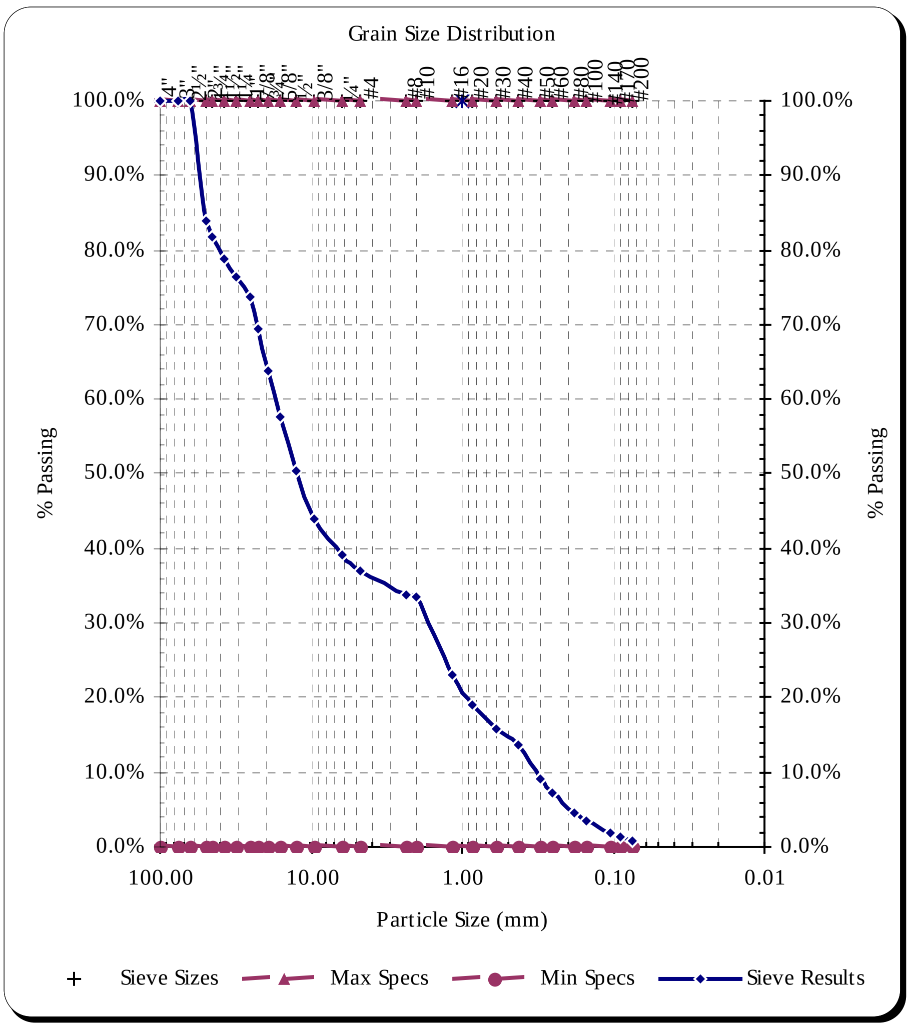

Figure 56. Grain size distribution plot for southern portion of Parker Ponds complex sediment sample # 496

<u>WSDFW Ponds</u> (Buena)

In the vicinity of the WSDFW ponds the Yakima River is an actively meandering channel. The ponds are diked along their western margin and abut up against Interstate-82 to the east. The South WSDFW pond is connected to a side channel of the Yakima River via an egress channel that exits the pond from the southwest corner (Figure 57). The width of the CMZ decreases from approximately 3,700 ft (1,130 m) upstream to approximately 2,800 ft (850 m) downstream of the ponds, respectively. The CMZ in the vicinity of the WSDFW ponds is the widest of those measured in association with the mine sites of this study. The ponds are approximately 100 ft (30 m) from the river at the upstream end of the north pond, 100 ft (30 m) from the river at the junction of the two ponds and 450 ft (140 m) from the side channel of the Yakima River from the downstream end of the south pond (via the egress channel). Two potential avulsion sites were identified during geomorphic reconnaissance mapping, at the northwest and southwest corners of the north pond, respectively (Figure 57). The valley reach slope adjacent to the WSDFW ponds is 0.0025 (approx. 13.2 ft-drop in valley floor elevation for each mile downstream (2.5 m drop per km)).

The WSDFW ponds were mined to provide aggregate for construction of the adjacent Interstate-82. The bathymetry of the North pond consists of long relatively flat-floored pit (Figure 58). The maximum measured depth for the North WSDFW pond is 25 ft (8 m). The margins of the pond are relatively steep (in general steeper than those modeled), as evidenced by the quick descent of the sidewalls of the pond where sampling tracks (Figure 58) came close to the pond margins (Figure 59). The broad slope along the western side of the pond is likely and artifact of the modeling process and design of the bathymetric survey. In reality, the western wall of the pond probably drops off more steeply (Figure 60). The average depth for the North WSDFW pond is 18.6 ft (5.7 m), making this the study pond with greatest average depth.

The South WSDFW pond, like its twin to the north, is rectangular in plan view, has fairly steep side margins (which are not well modeled due to bathymetric survey design), and has a broad relatively flat-floored bottom (Figure 61). The maximum measured depth is 26 ft (7.9 m). A small island (wildlife-enhancement?) island is located off the eastern margin of the pond, creating a prominent shallow-water bulge westward into the pond (Figure 62). The northwest and southwest corners of the pond are shallow shelves, with the egress channel exiting from the southwest corner (Figure 63). The average depth of the South WSDFW pond is approximately 12.2 ft (3.7 m).

At the WSDFW Ponds, recently deposited river gravel (25 ft (7.5 m) thick) has been mined from the North and South WSDFW ponds down to top of the older semi-consolidated sediments of the Thorp Formation. The Thorp Formation at the WSDFW site consists of well-graded gravel embedded in a matrix of sand, silt, and clay, and largely comprises the floors of the north and south WSDFW ponds.

The grain size distribution of sediment in the pond ranges from coarse gravel and cobbles at the north end of the north pond to fine sand and largely silt and clay progressively down gradient to the south and southeast portions of the pit.

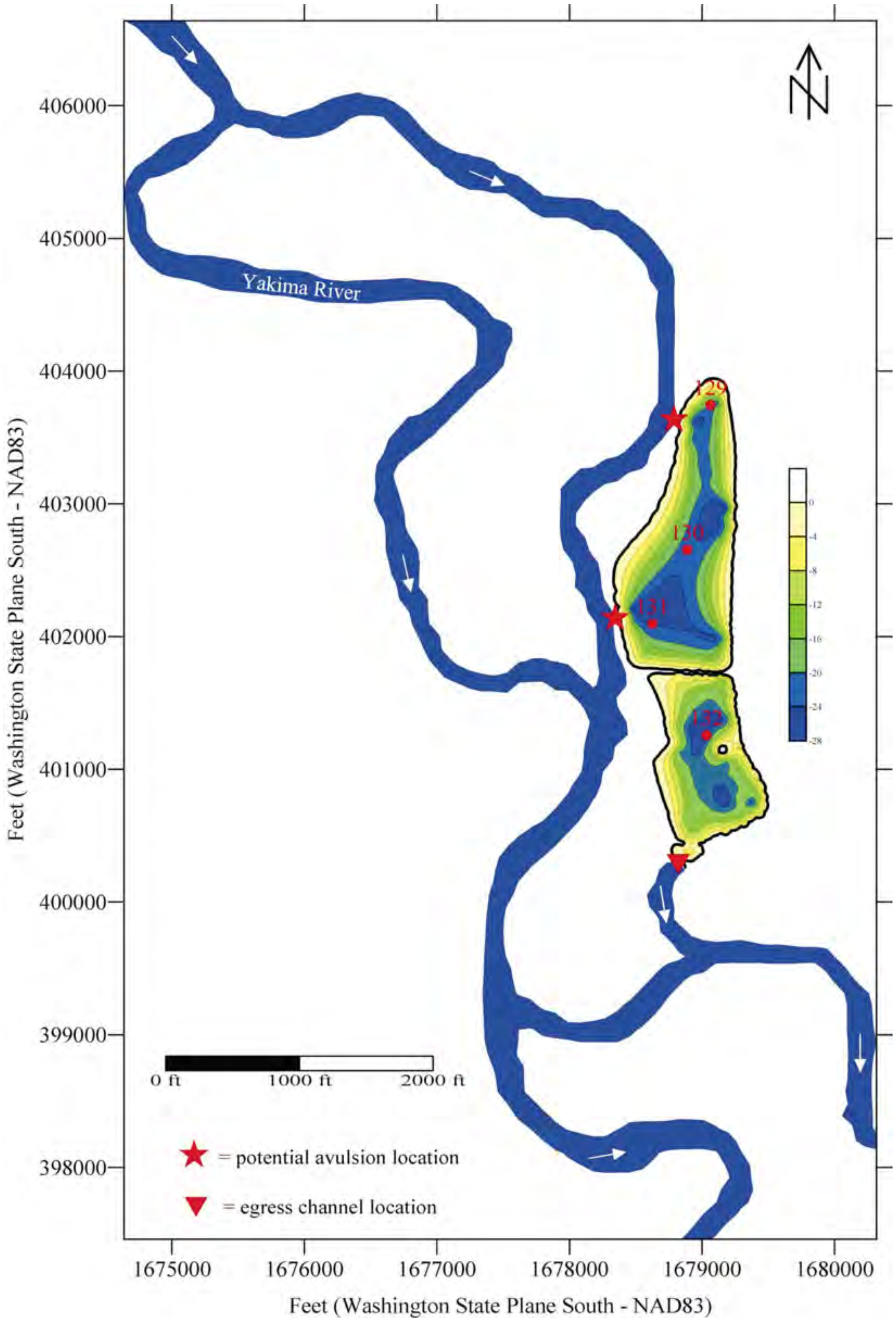

Figure 57. Contoured bathymetric map of the WSDFW Ponds showing locations of sediment samples (GPS waypoint #) and proximity to the Yakima River

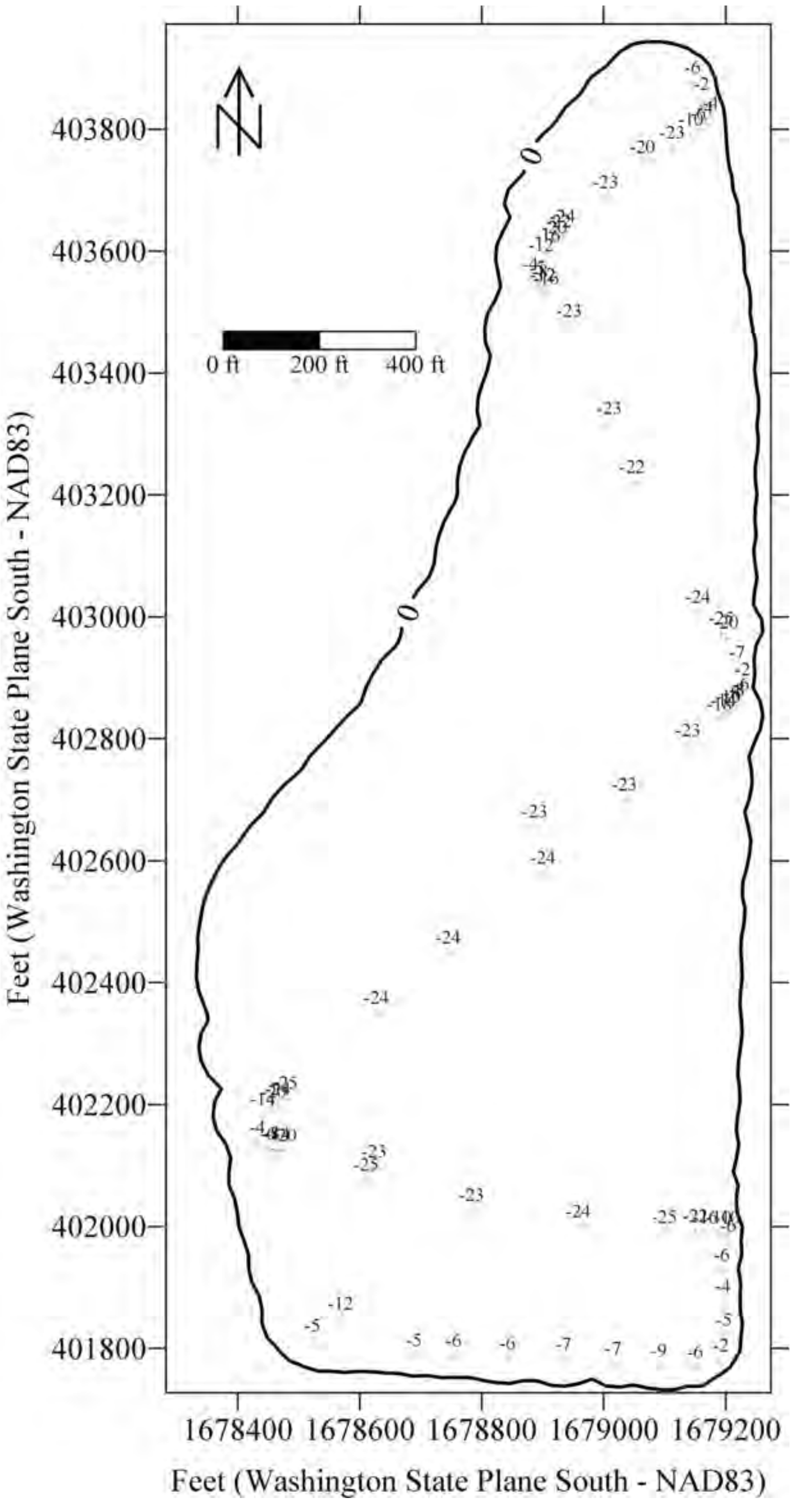

Figure 58. Post map showing data point locations and depths (ft) used to model pond bathymetry for the WSDFW – North Pond

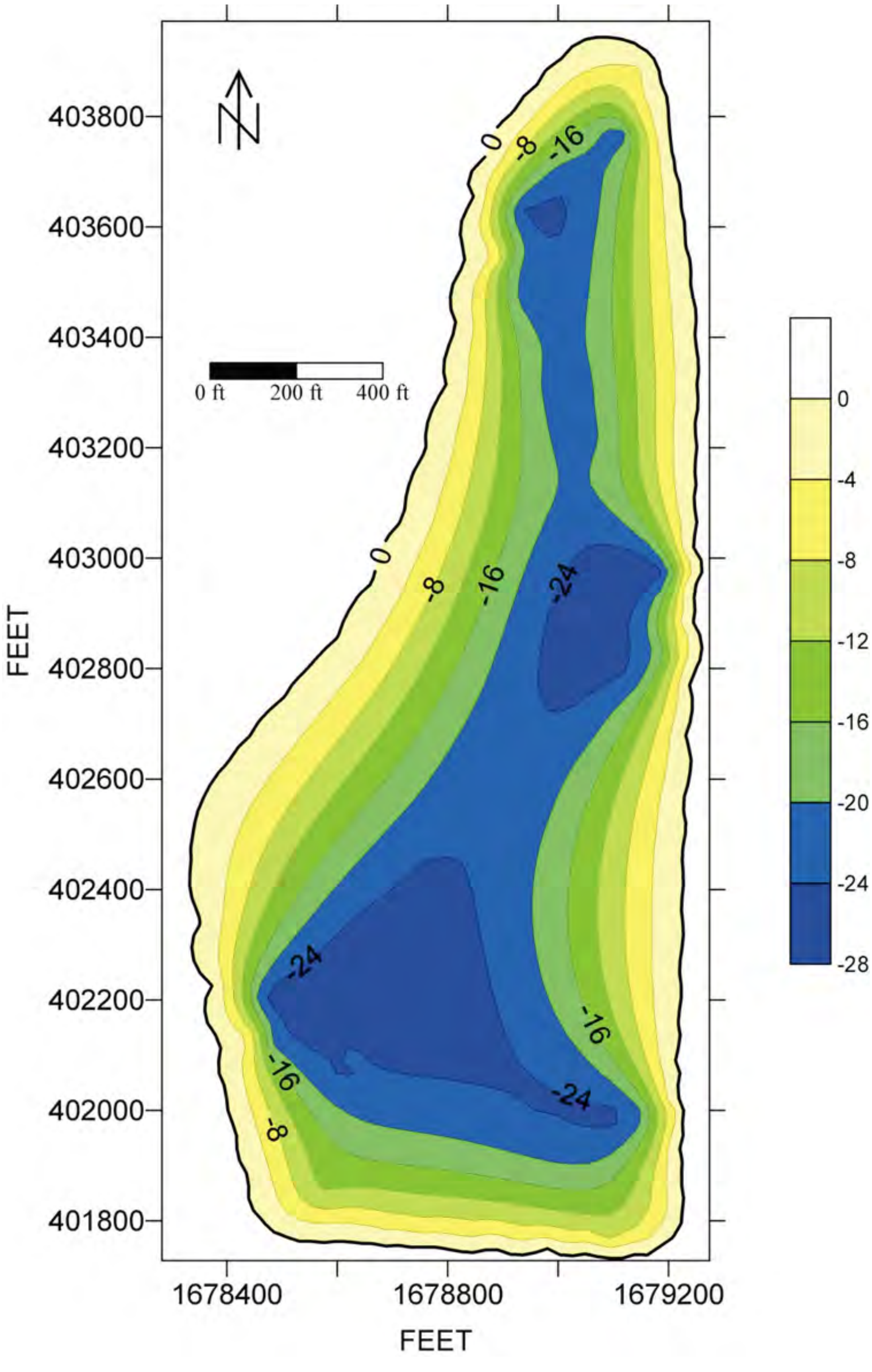

Figure 59. Contoured bathymetric map of the WSDFW – North Pond
(bathymetry in feet below 5/30/02 waterline)

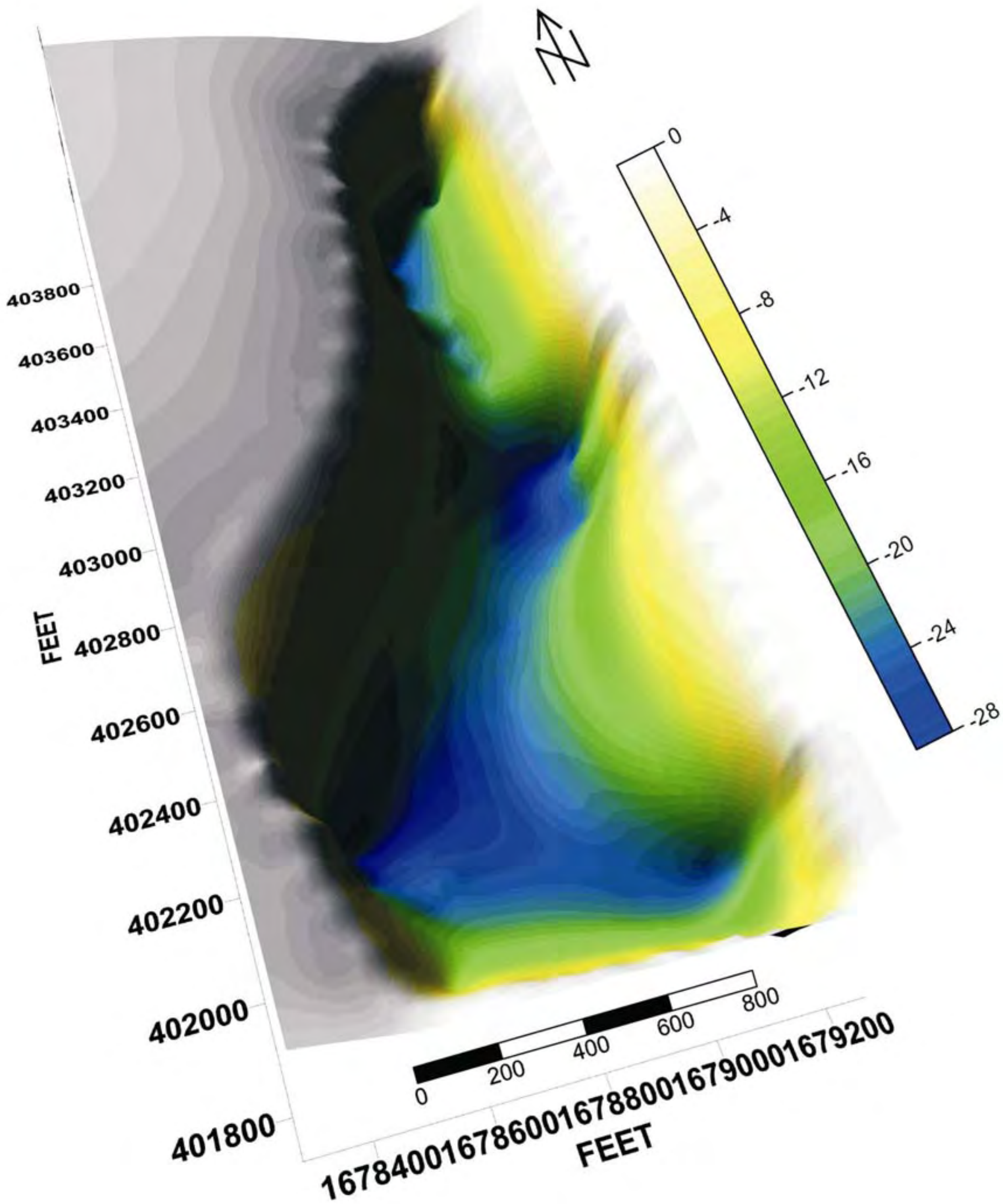

Figure 60. 3-D perspective map of the WSDFW – North Pond
(bathymetry in feet below 5/30/02 waterline)

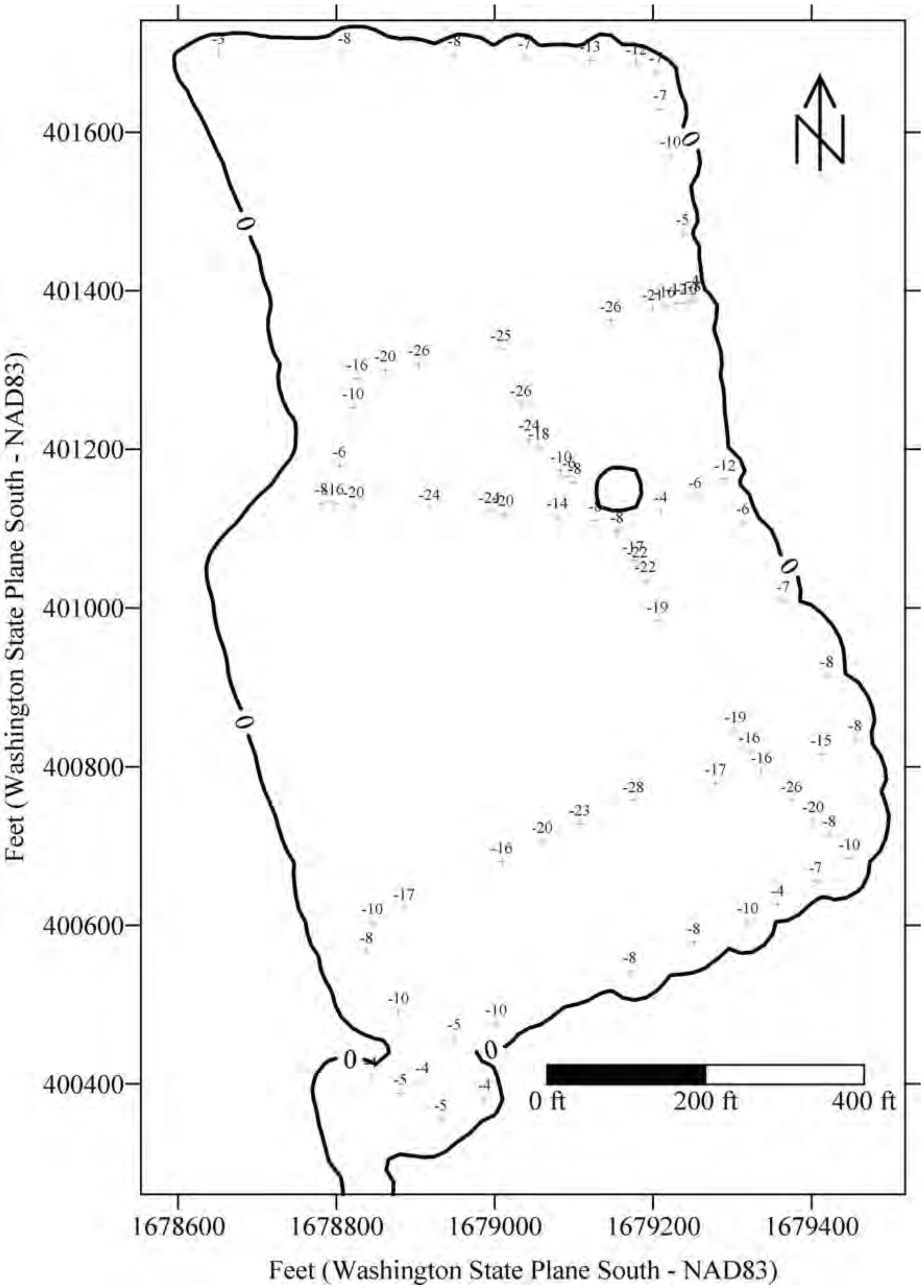

Figure 61. Post map showing data locations and depths (ft) used to model pond bathymetry for the WSDFW – South Pond

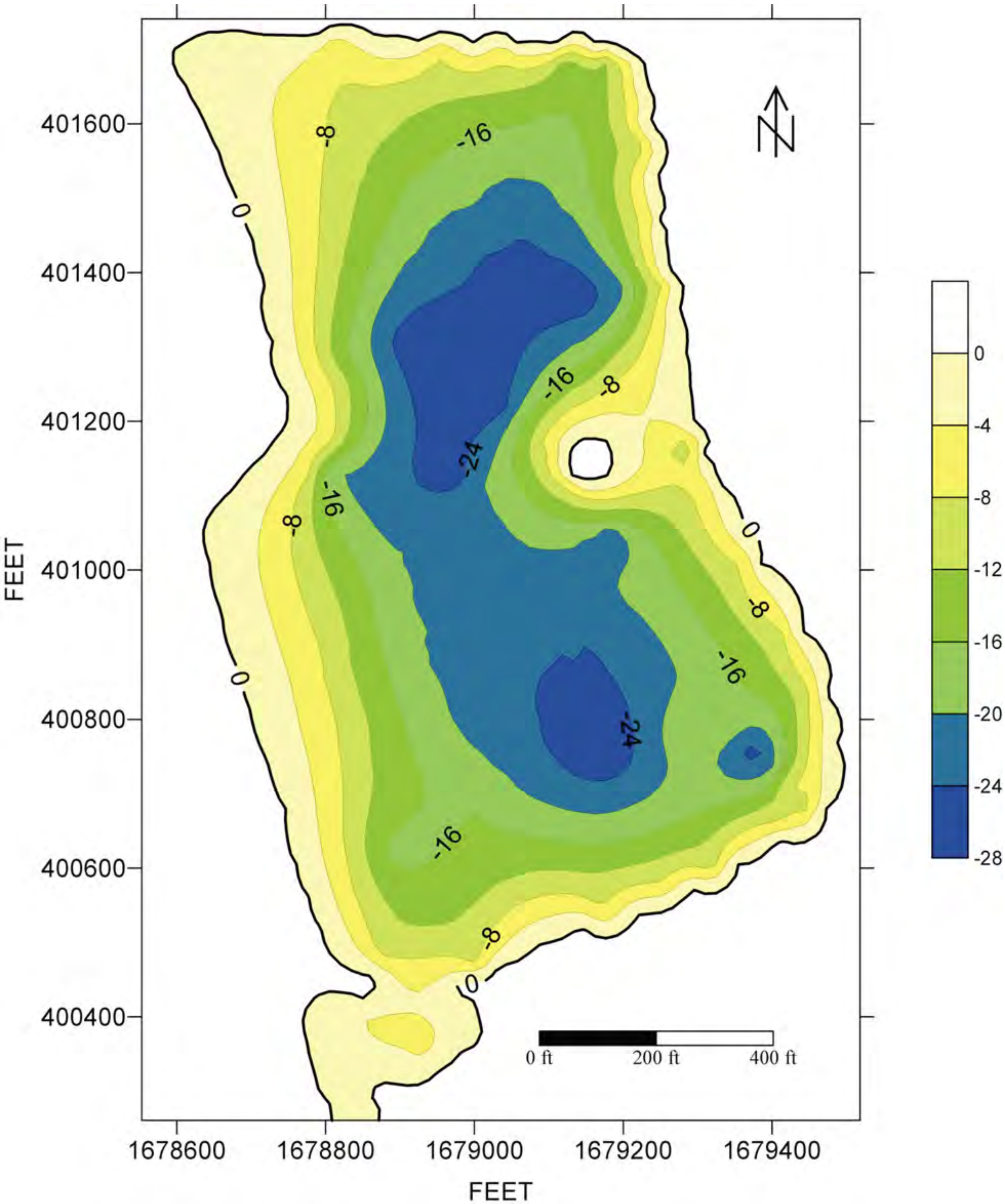

Figure 62. Contoured bathymetric map of the WSDFW – South Pond
(bathymetry in feet below 5/30/02 waterline)

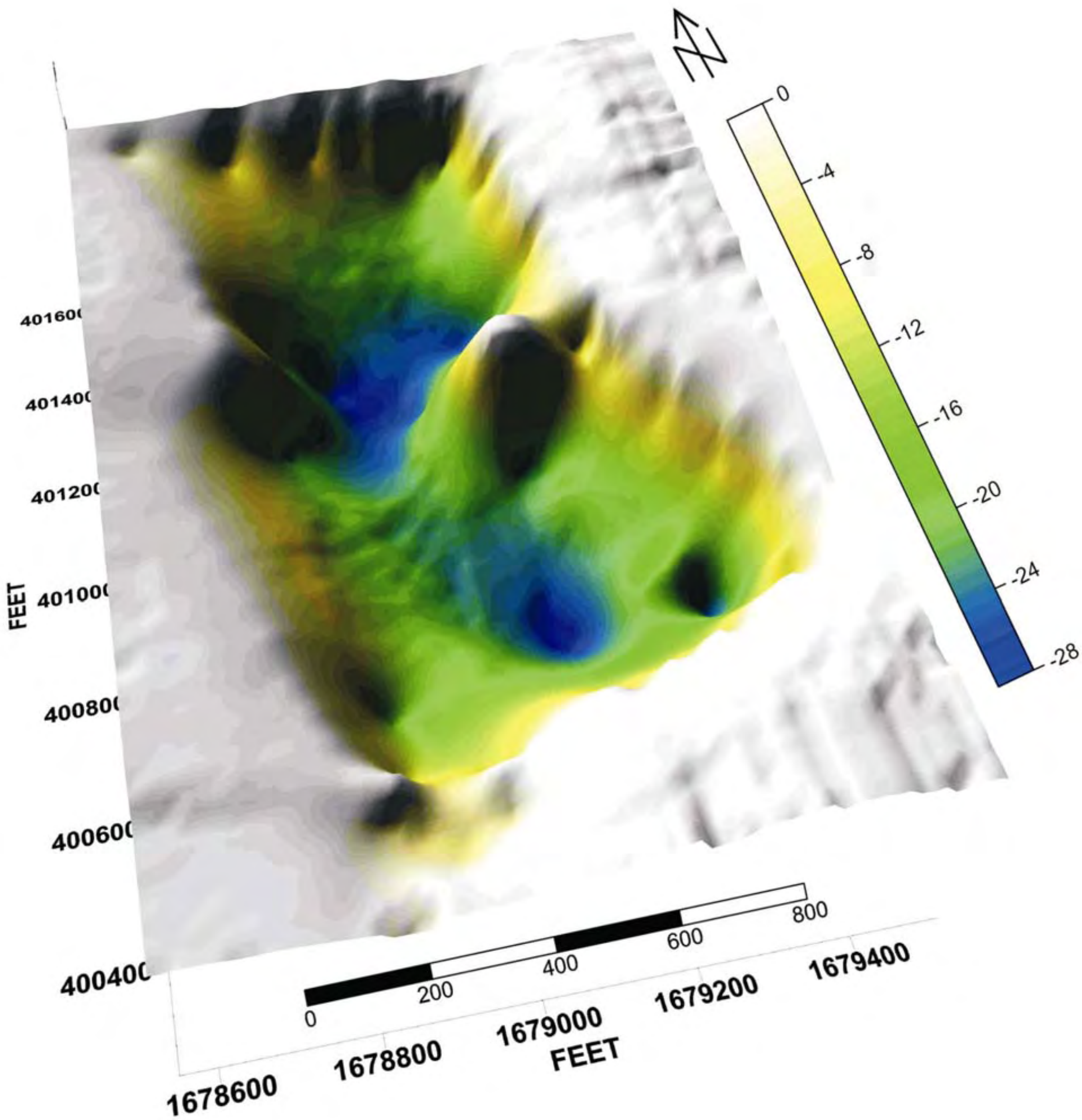

Figure 63. 3-D perspective bathymetric map of the WSDFW – South Pond
(bathymetry in feet below 5/30/02 waterline)

Sample # 129 consists of poorly graded gravel (86.6%), sand (11.2%), and silt and clay (2.2%) at the north end of the north pond (Figure 64). This sample represents the base of more recent riverbed load deposited over the top of Thorp sediments. Sample # 130 at the center and more deeply excavated portion of the north pond is comprised of 100% silty clay (Table 8). And sample # 131, at the south most part of the pond, is typical of the silt and clay-rich Thorp Formation containing variable amounts of suspended gravel and cobbles (Figure 65).

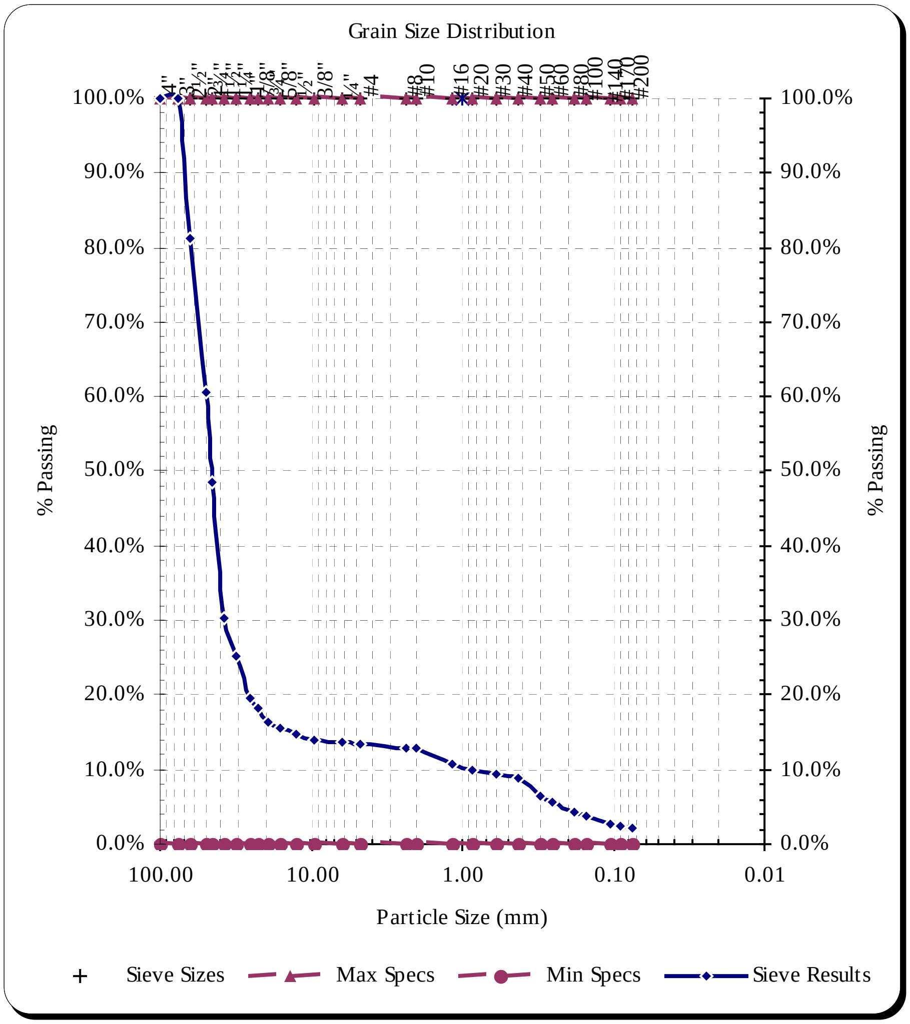

Figure 64. Grain size distribution plot for WSDFW – North sediment sample # 129

Table 8. WSDFW – North Pond qualitative sediment particle data

Sediment Sample	Sediment Particle Size Range
DFW West - 130	100% silty clay

Sample # 132, from the east central portion of the south pond, was extracted from the base of a 23 ft (7.0 m) thick deposit of river gravel near a steep-sloped island comprised of river gravel with sand. This sample is 77.2% gravel, 13.4% sand, and 9.4% silt and clay, and represents a remaining veneer of coarser river bar sediment deposited over Thorp Formation (Figure 66).

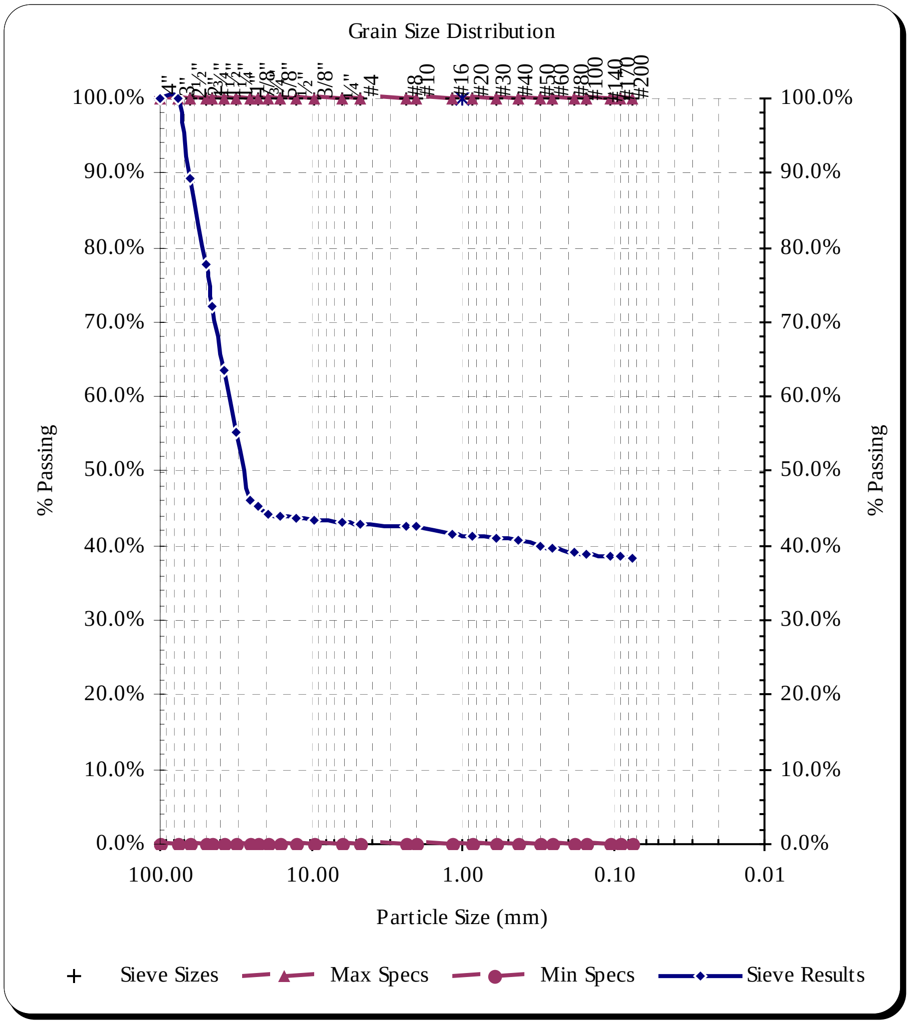

Figure 65. Grain size distribution plot for the WSDFW – North Pond sediment sample # 131

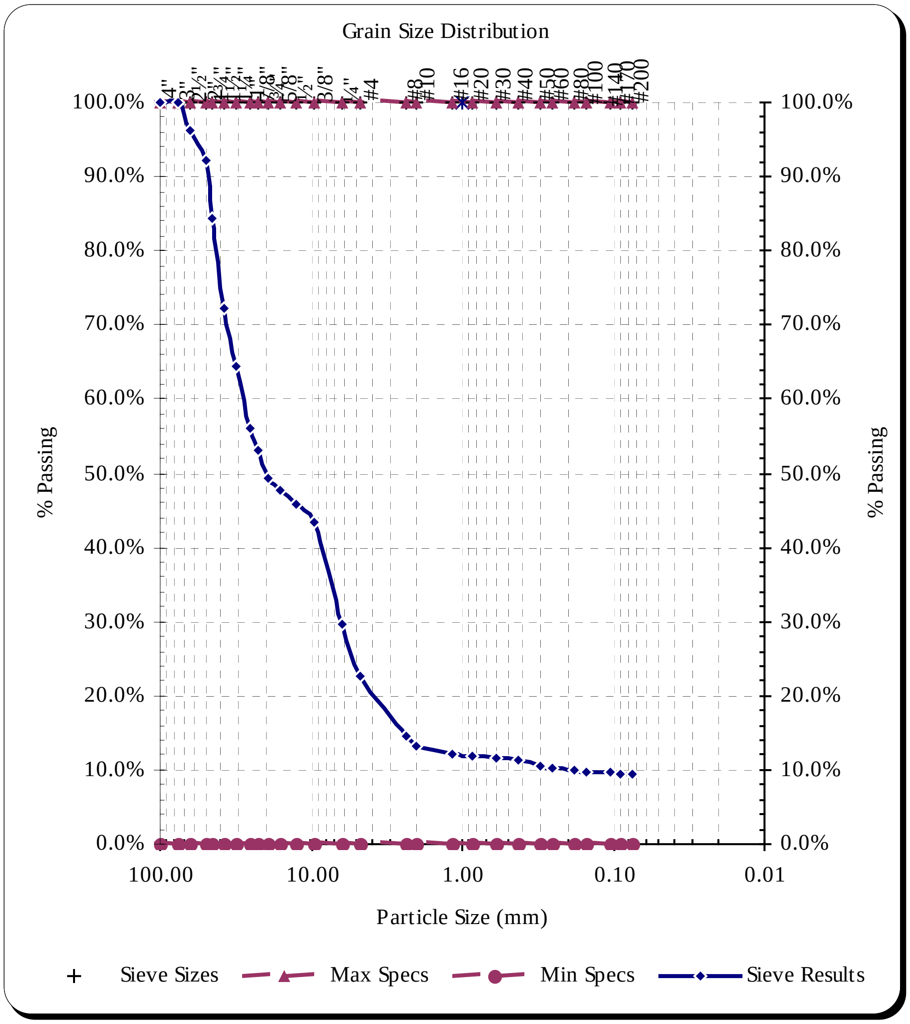

Figure 66. Grain size distribution plot for WSDFW – South Pond sediment sample # 132

<u>DeAtley Pit</u> (Richland)

The DeAtley pit, an active sand and gravel mine, is being mined in a Holocene point bar sequence located along the transition from an inside-to-outside meander bend of the lowermost portion of the Yakima River. A dike separates the pond from the River along the entire length of the pond; however, a potential avulsion point exists along the southeast margin of the pond, where the cutbank of a meander bend is up against the dike (Figure 67). Upstream of the pond the CMZ is approximately 1,800 ft (550 m) wide, increasing to 2,500 ft (760 m) 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 (150 m) from a side channel of the river, while the downstream end of the mine (southeast corner) is 100 ft (30 m) or less from the river. The river valley slope along the DeAtley reach, 0.00085 (approx. 4.5 ft-drop in valley

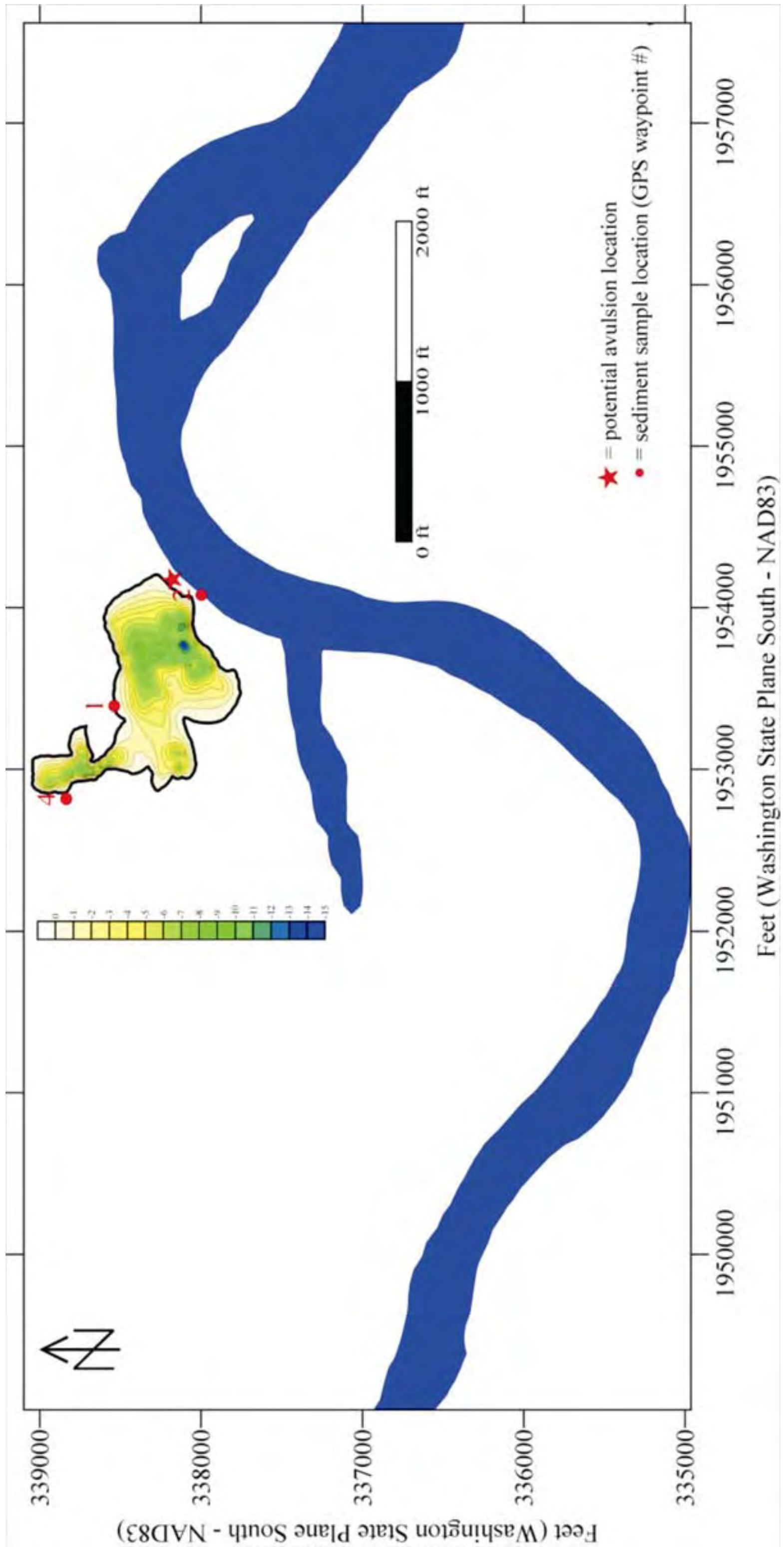

Figure 67. Contoured bathymetric map of the DeAtley Pond showing locations of sediment samples, potential avulsion sites, and proximity to the Yakima River

floor elevation for each mile downstream (0.85 m drop per km)), is the lowest of all the studied sites, which is expected for a site at the bottom of the drainage basin.

The DeAtley pond is characterized by fairly shallow depths throughout, with the exception of an “I”-shaped depression located in the eastern-third of the pond, which culminates in a small depression with a maximum measured depth of 15 ft (4.6 m) along the southeastern margin of the pond (Figure 68 and 69). This deeper area is adjacent to a water-extraction pump. A broad shallow sill separates the main pond from the northwestern arm. The northwestern arm of the DeAtley pond is only connected to the main pond during periods of higher river flow, and thus elevated groundwater elevations (Figure 70). During summer months, the northwest are becomes a disconnected isolated pool of approximately 5 ft (1.5 m) deep. The average depth of the DeAtley pond is 4.2 ft (1.3 m).

Three samples were taken at the DeAtley site. Sediment Sample # 2 was extracted from the active channel of the Yakima River, and is located immediately below the dike separating the river from the southeast margin of the DeAtley pond. The sample is of sediment from the outer bank of a river meander and consists of silty (13.5%) gravel (60%) with sand (60%) (Figure 71). The well-graded gravel fraction from the Yakima River ranges in size from 0.18 to 1.6 in (4.75 to 40mm).

Sediment samples taken from the pit typically have a gravel fraction ranging from 0.18 to 1.2 in (4.75 to 30mm), and have less sand and silt than sediment from the active river channel. Sediment from the active river channel may be finer-grained due to the effects of hydraulic ponding of the lower Yakima River as it enters the McNary Pool (Columbia River) at Richland. For example, pit sample # 4 is well-graded gravel (63.4%) with sand (32.1%), and silty clay (4.5%) (Figure 72), and sample #1 is poorly graded gravel (69.2%) with sand (29.5%), and silt and clay (1.2%) (Figure 73). (Note: ground water was observed seeping into the pond from a dike situated on the south margin of the pond (~50 gpm) on 5/30/02, indicating that at the time of observation the level of the river was higher than the water surface of the pond.

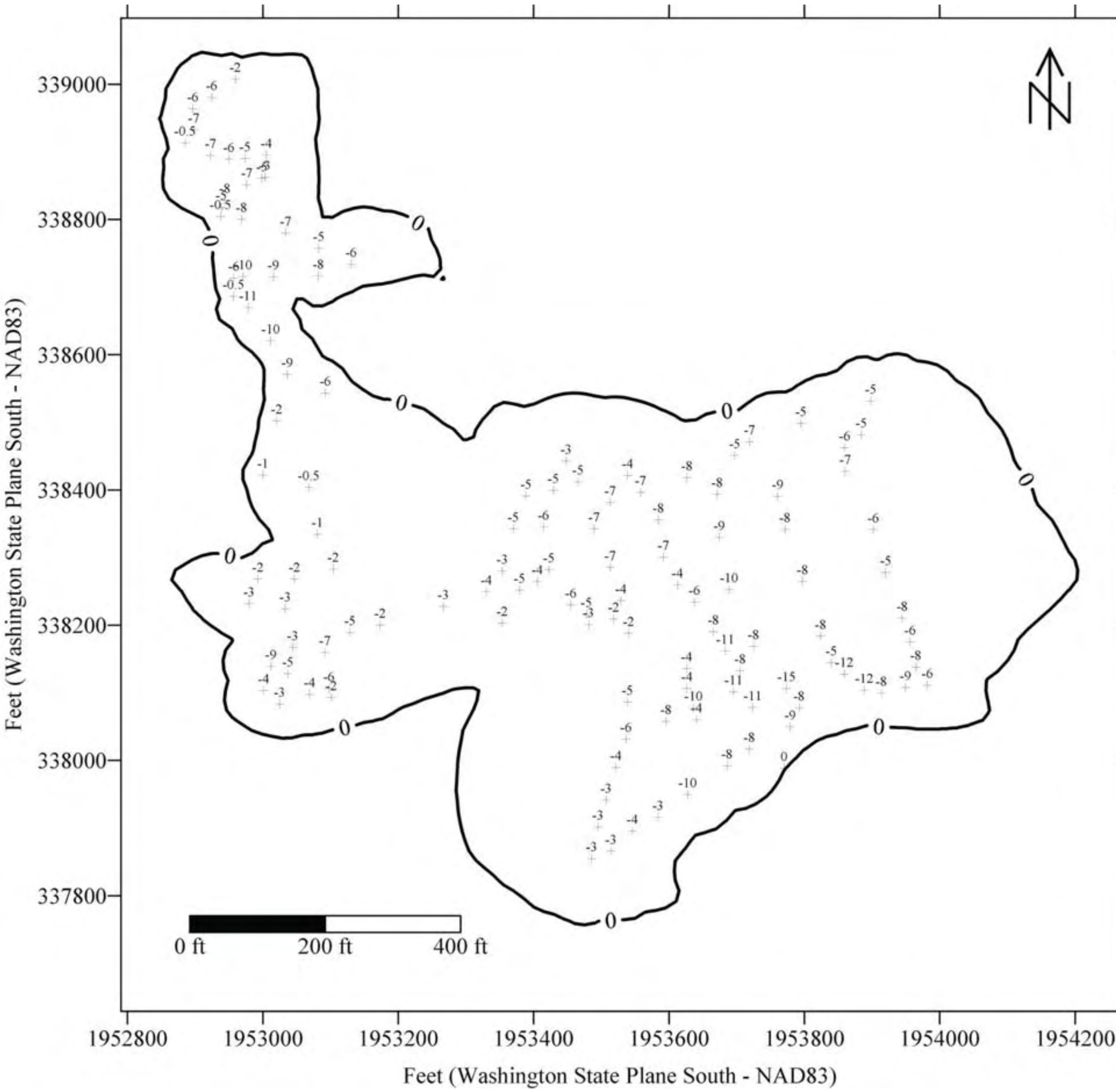

Figure 68. Post map showing data point locations and depths (ft) used to model pond bathymetry for the DeAtley Pond

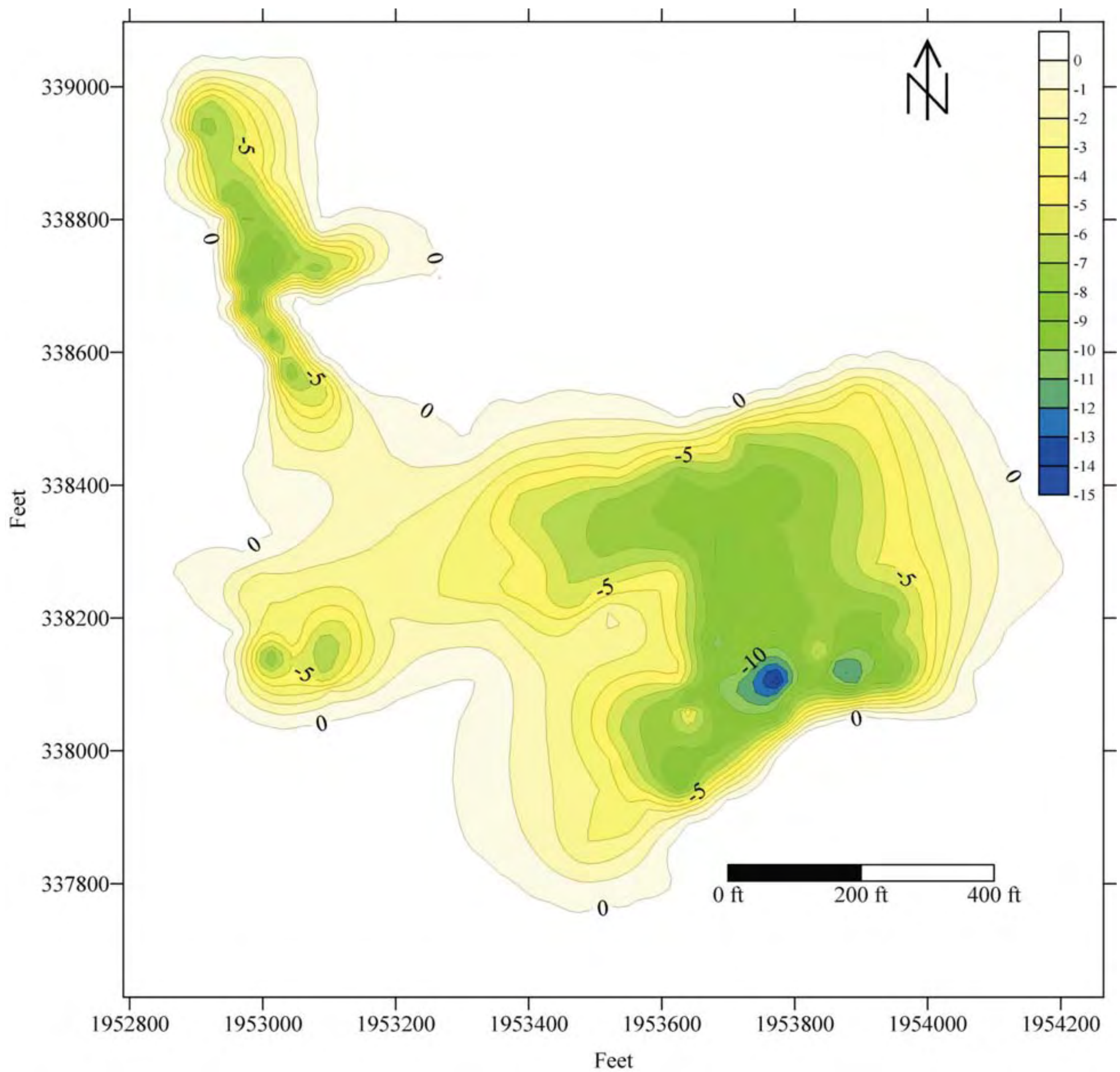

Figure 69. Contoured bathymetric map of the DeAtley Pond
(bathymetry in feet below 5/30/02 waterline)

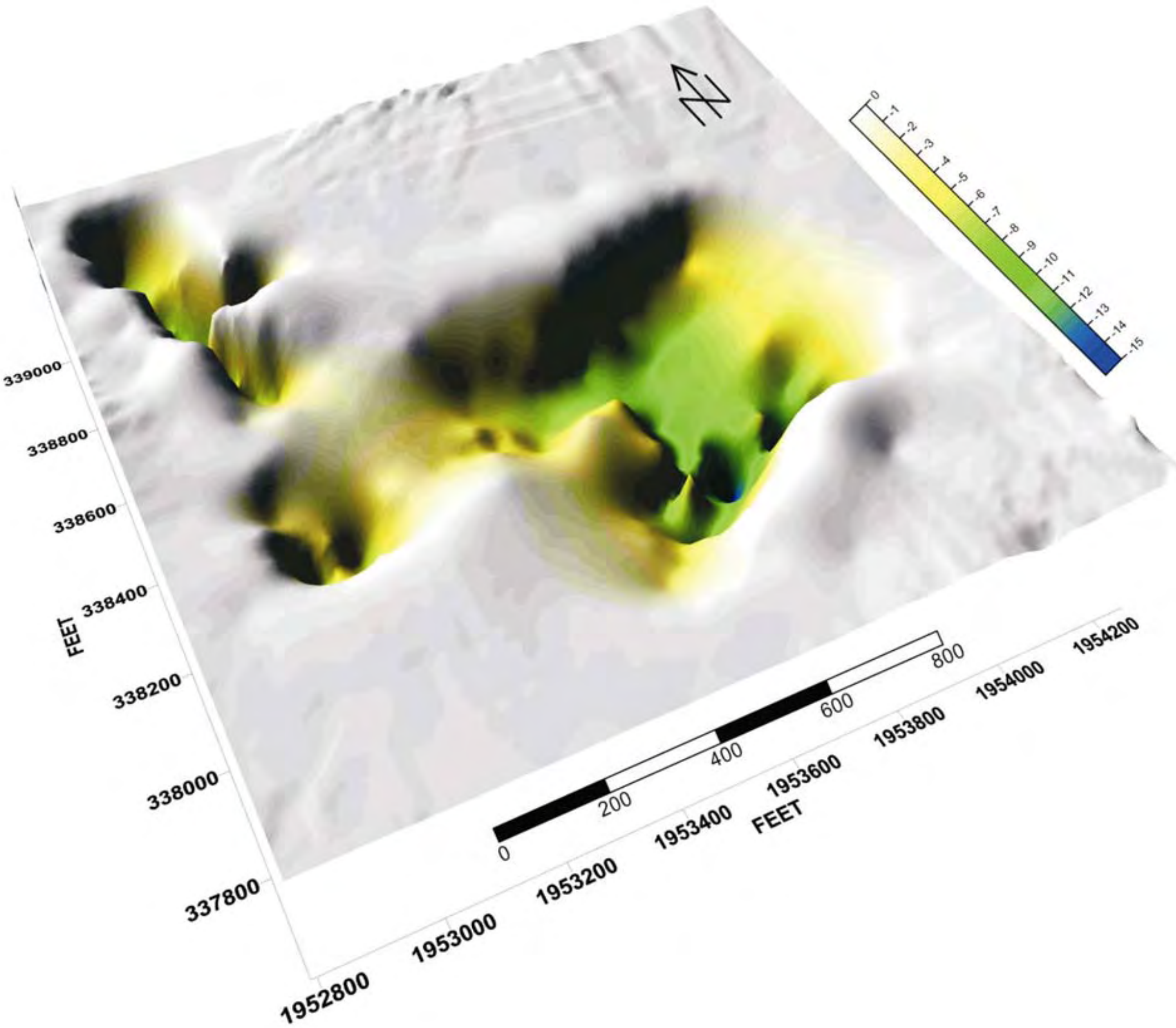

Figure 70. 3-D perspective bathymetric map for the DeAtley Pond
(bathymetry in feet below 5/30/02 waterline)

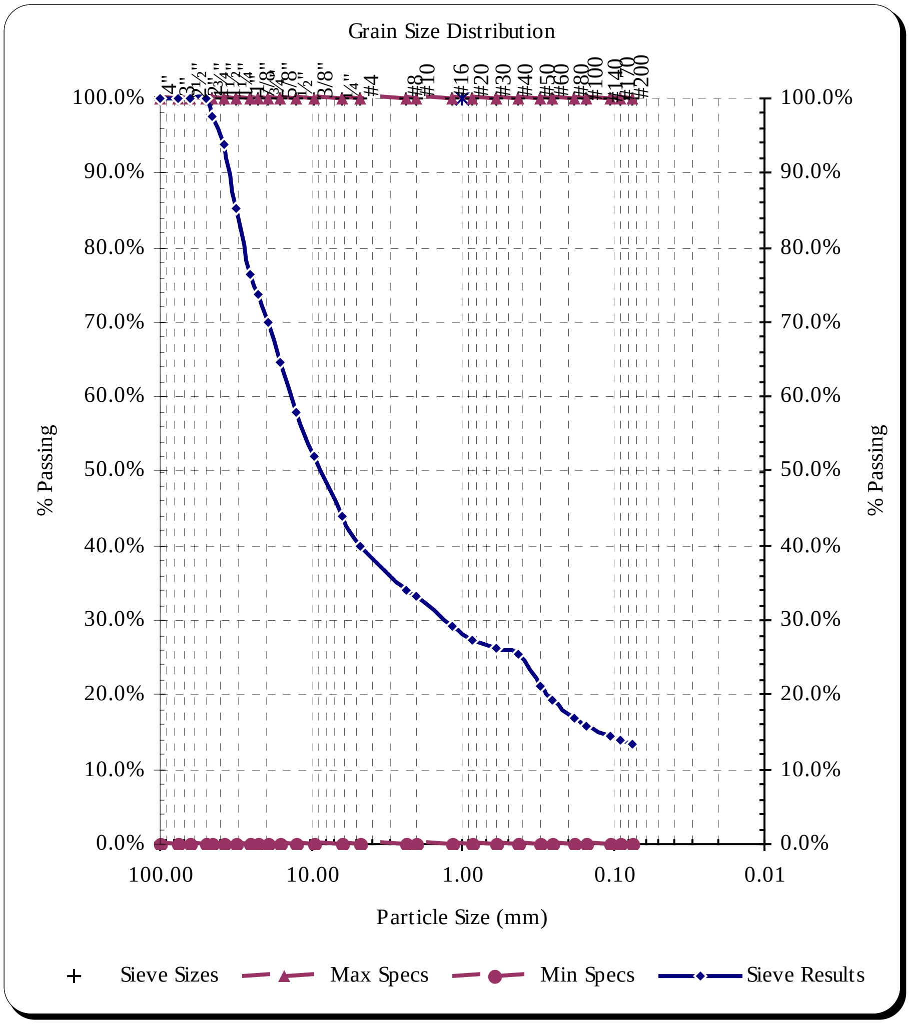

Figure 71. Grain size distribution plot for Yakima River sample # 2 (from adjacent to the DeAtley Pond)

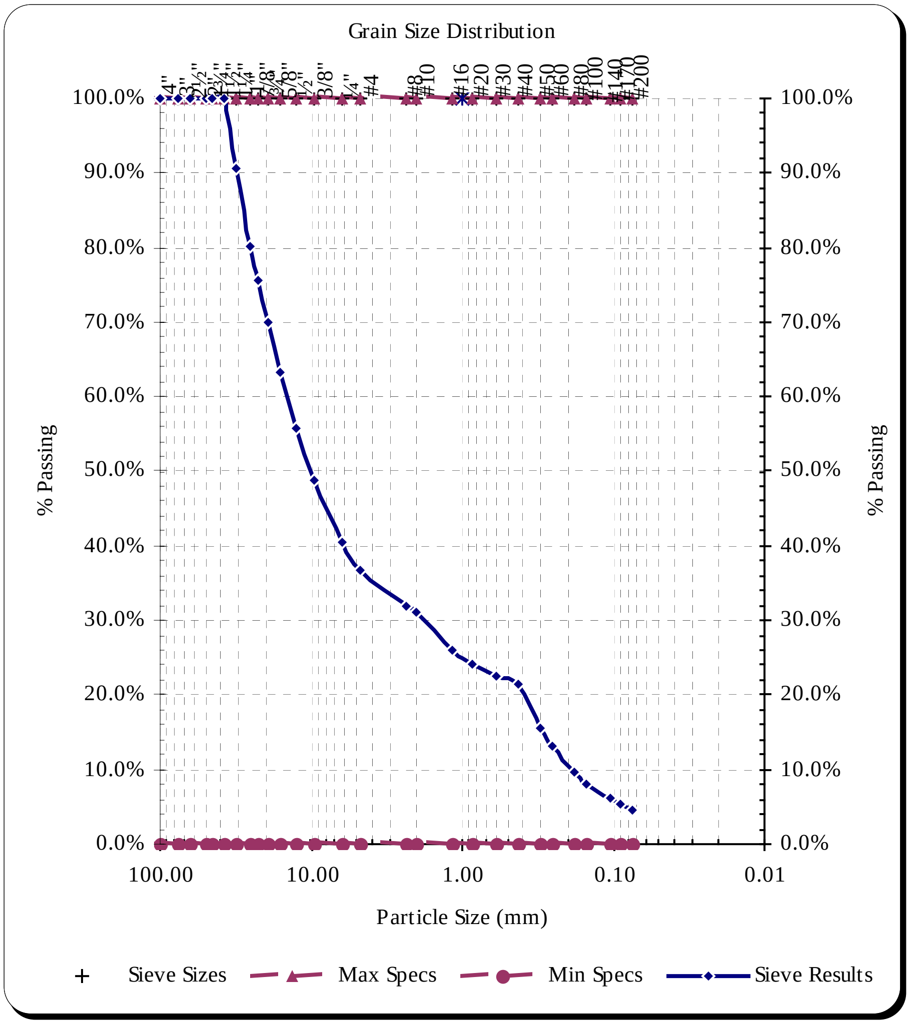

Figure 72. Grain size distribution plot for DeAtley sediment sample # 4

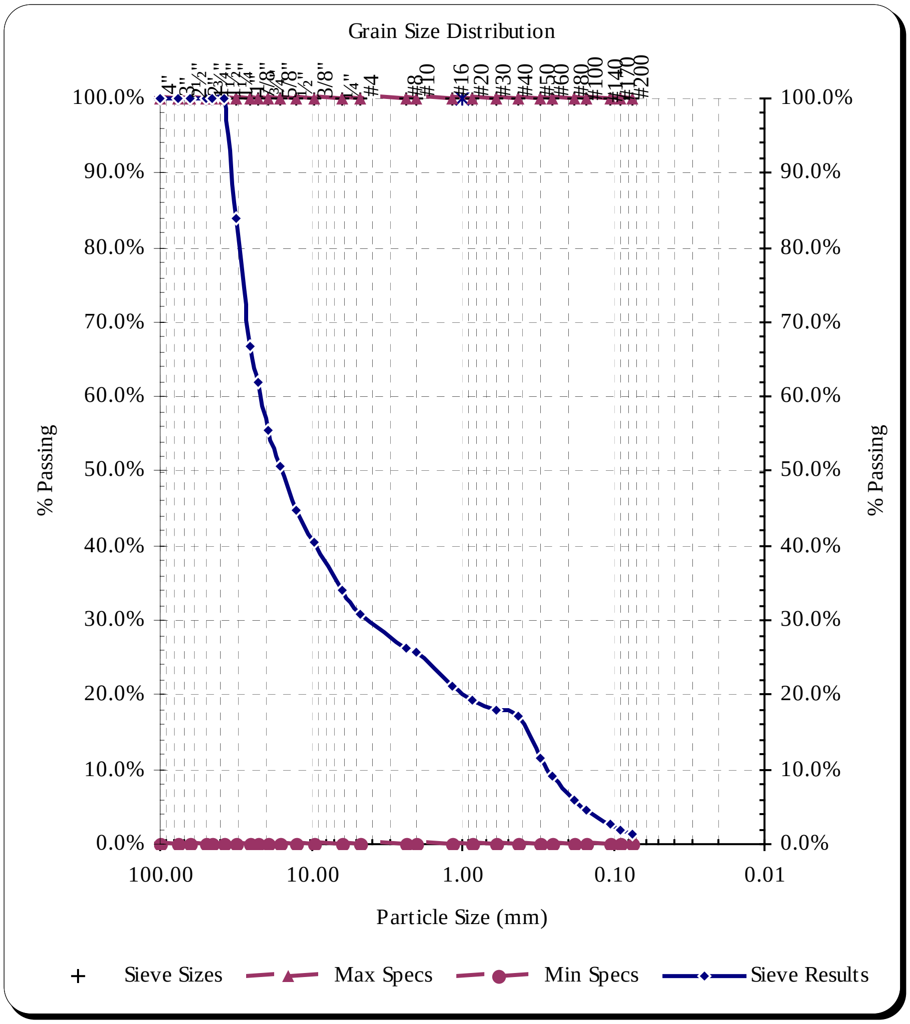

Figure 73. Grain size distribution plot for DeAtley sediment sample # 1

Comprehensive Analysis and Recommendations (draft)

Planning for Future Mine Site: Considerations

If the intended outcome from this study is to slow down the degradation of salmonid habitat along the Yakima River, the following items should be considered:

- If at all possible, future mine sites should be sited beyond the 100-year flood plain, and if at all possible beyond the historic (100+ year) channel migration zone, as determined by aerial photograph and topographic map reconstructions.

- All future mining in the floodplain of the Yakima River should be done with the understanding, that at some point in the future, the river will avulse into the pit. This has ramifications for the potential effects of floodplain mine avulsion by the Yakima River with respect to cultural entities (e.g. bridges, dikes, sewer outfall pipes, etc.).

- If a future mine is sited within the active historic channel migration zone then:
    - The size, depth, and proximity to river should be considered, as well as long-term plan for the site (Norman and others, 1998). With the understanding that the river will avulse into the pit at some point, 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.

    - An awareness of the spatial location and geometry of abandoned channels (paleochannels) within the floodplain of the Yakima River is critical in order to understand shallow groundwater flow. Intersections between the modern Yakima River channel and paleochannels results in areas of increased groundwater flow to the river. It is at such locations that salmonid populations congregate (J. Vacarro, U.S.G.S., personal communication, 2003). Floodplain mining has the potential to disconnect these groundwater flow paths (paleochannels) from the modern river.

    - A layer of gravel should be left to increase connectivity between the river and adjacent floodplain paleochannels.

    - Mining completely through the Holocene alluvium into underlying impermeable geologic units such as the Thorp and/or Ellensburg Formations should be discouraged because groundwater flow into and out of the ponds may be reduced in such situations.

    - Future ponds should be designed for connection to the river (due to future natural avulsion events).

    - Ponds should be designed to mimic, as much as possible, the natural fluvial system.

    - The depth of the extractable layer should be considered. Is the ecological cost worth the societal benefit of shallow, yet spatially extensive, floodplain mines?

<u>Future Mine Site Considerations:</u>

<u>Preexisting Mine Sites Where Avulsion Is Being Considered:</u>

- Avulsion events into 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 man-made structures (dikes, abutments, etc.). Terrace Heights mine site is a good example of this. It has taken ± 30 years to reach a point where channel habitat (including riparian vegetation) has been restored to a quasi-natural state.

- The amount of discharge from the river into the pits, during summer base-flow, may impact salmonid habitat. Too little water entering the pits from the river may result in increased temperatures, and at places like the Parker complex, oxygen-poor conditions at the lower-end ponds.

- Extent and connectivity of the mine site to the hyporheos zone will impact water quality and temperature in ponds.

- The underlying geology of the mine site is critical for several reasons:
    - If Holocene alluvial veneer is thick then there is a high likelihood of high hydrologic connectivity between the river and adjacent mine site, including the upwelling of cool groundwater into the mine site.
    - If alluvial veneer is thin (such as at Parker) and underlain by impermeable units (such as the Thorp or Ellensburg Formations) then there may be very little ground water upwelling into the mine site.

- Depth of mine is important. Upstream incision may occur after forced avulsion event (Norman and others, 1998)

- Detailed reach-scale studies should be performed to determine the following factors:

    - Available sediment load upstream of planned avulsion point.
    - Amount of available sediment from erosive banks and bars available upstream of avulsion point.
    - Ability of bank-full discharge to transport available sediment (potential stream power of reach).
    - Volume of the mine, gradient of potential knickpoint, and potential implications to cultural features in upstream reach.
    - Is the reach where mine is to be avulsed characterized by upwelling groundwater flow paths? It is believed reaches having upwelling groundwater flow paths will be beneficial to salmonids. If upwelling of groundwater cannot be determined, perhaps the mine site should be reconsidered as a candidate for forced avulsion.
    - Estimate from sediment flux studies as to how long it will take to aggrade pit under normal flow regimes.

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